Brave New World: Exploring the Non-academic Career Pathways of Women Astronomy PhD Graduates

by

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Declaration of Authorship

I, Amanda Nadia Manypeney, declare that this thesis titled, ‘Brave New World: Exploring the Non-academic Career Pathways of Women Astronomy PhD Graduates’ and the work presented in it are my own. I confirm that:

- the thesis comprises only their original work towards the Doctor of Philosophy except where indicated in the preface;
- due acknowledgement has been made in the text to all other material used; and
- the thesis is fewer than the maximum word limit in length, exclusive of tables, maps, bibliographies and appendices or that the thesis is 77,000 words as approved by the Research Higher Degrees Committee.

Signed: 

Date:
“Whereas if [s]he had the smallest sense, [s]he’d understand that [her] punishment is really a reward. [S]he’s being sent to an island. That’s to say, [s]he’s being sent to a place where [s]he’ll meet the most interesting set of men and women to be found anywhere in the world. All the people who, for one reason or another, have got too self-consciously individual to fit into community life. All the people who aren’t satisfied with orthodoxy, who’ve got independent ideas of their own.” (p. 199)
Abstract

Policies designed to retain women in science, technology, engineering and maths (STEM) tend to focus on the idea of the leaky pipeline, a model for retaining women by minimising the structural barriers that force them to leave. Retention during doctoral candidature and early career is seen as necessary for increasing women’s participation at higher levels within the sciences, and to create management and institutional equity and change. Problematically, however, this policy approach, and its focus on structural problems within the sciences, fails to consider the complexity of women’s lives, and minimises the levels of agency attributed to decision-making processes, particularly in relation to leaving their field of study. The expectation that, having attained a PhD in the sciences, women will automatically wish to stay in the academic STEM pipeline is limiting. Current doctoral programs fail to adequately recognise the importance of non-academic career pathways as legitimate career options outside the academy.

This thesis addresses one of the fundamental assumptions about PhD education and policy; that women who undertake a PhD want to pursue academic careers and that non-academic careers are potentially a second choice. Through a case study of women who have engaged in doctoral research in Australia, this thesis argues that measures put in place by gender equity policies tend to benefit those who are directly employed in academic research, while ignoring the female graduates who move out of academia. By focusing resources only on retaining women in postgraduate programs, institutions are in fact restricting women’s science careers by limiting training opportunities and providing inadequate information on non-academic career choice, which in turn creates a perceived stigma about leaving the academy.

By applying a feminist lens to a qualitative sociological study, this thesis examines the experiences of PhD educated women astronomers as they narrate their pathways into and out of academia. It sheds a particular light on transitional experiences and demonstrates the importance of agency in work-related decisions and the complex factors that influence women’s career choice. This thesis concludes that moving beyond a linear understanding of the pathways of women in STEM, towards an understanding of how women navigate complex labour market pathways outside the expected academic norm, will enable the development of better policy and programs to support women interested in the STEM fields.
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Chapter 1

Women in Science: Not Just a Historical Problem

Caroline Herschel was fortunate to be born into a family of astronomers and thus evaded many of the limitations that were placed on her gender during her lifetime. She was a talented astrophysicist, not an observational astronomer like her brother, William. Caroline worked with William’s telescope observations to make significant discoveries, such as the second companion of the Andromeda galaxy and eight comets including the periodic comet 35P/Herschel-Rigollet, that bears her name. These discoveries led George III to provide her with an annual salary of 50 Pounds to continue working in the position of William’s assistant, though not as an astronomer in her own right (International Astronomical Union, 2009). Caroline later published the Catalogue of Stars in 1798 (International Astronomical Union, 2009), which was a considerable undertaking that used her brother’s observations (and her own when he was otherwise engaged) that she calculated against other star catalogues to make a correct, definitive astronomical catalogue. It was Caroline Herschel’s success and subsequent awards that enabled her, with Mary Sommerville, to become the first women to gain honorary membership to the Royal Astronomical Society (RAS) in 1835. This membership was largely symbolic as female members still had none of the rights as male members concerning decision-making and publication. Even though Herschel was a ground-breaking woman astrophysicist, she was never able to escape from under her brother’s shadow.

Current biographic literature considers Caroline Herschel as an accomplished astronomer in her own right, yet after all her success her RAS obituary reduces her achievements to that of a clerk.

There, from the first commencement of his astronomical pursuits, her attendance on both his daily labours and nightly watches was put into requisition;
and was found to be so useful, that...he being then occupied with his views of the heavens and other researches...she performed the whole of the arduous and important duties of his astronomical assistant...not only reading clocks and noting down all observations from dictation as an amanuensis, but subsequently executing the whole of the extensive and laborious numerical calculations to render them available to science as well as a multitude of others relative to the various objects of theoretical and experimental inquiry in which, during his long and active career, he at any time engaged. (Royal Astronomical Society, 1848, p. 64)

Through professional memberships, the RAS was able to exclude talented women by trapping them into lower status occupations, such as clerk or later, at the dawn of computing as a ‘calculator’. This trivialisation of women’s scientific work and the over-recognition of their male counterparts, labelled as the ‘Matthew and Matilda effect’ (Rossiter, 1993), values men’s contributions more than women’s of the same calibre and reinforces the systemic advantage that is still a significant issue in astronomy today. Caroline Herschel’s accomplishments are now well documented in popular science literature, and she is held as an unrecognised exemplar for women and a role model for young girls interested in astronomy. The number of women in scientific fields has grown significantly since the nineteenth century and the days of Caroline Herschel. Scientific disciplines still suffer from a cultural hangover where the generation of scientific knowledge is still highly gendered to benefit men and masculine ways of working. These structural barriers effectively limit women’s involvement in the sciences and serve as a filtering mechanism that makes it difficult for women to advance to senior levels within the sciences.

1.1 What is the Problem?

Although women’s positions within the astronomical sciences have progressed since the days of Hershel, astronomy workplaces are still highly gendered, and women experience these institutions differently from their male counterparts. This interdisciplinary study provides a sociological perspective on this problem that draws from the gender studies, labour market, and higher education fields to explore current decision-making factors that women apply in career choice post-PhD. The research primarily uses feminist standpoint theory (Harding, 2004) that is supported by further feminist theorising of gendered workplaces (Acker, 2006, 2012), and technologies (Wajcman, 1991). These conceptual tools are applied to typological narratives drawn from interview data, which explores the experiences that shape women’s views of themselves, astronomy, higher education, employment, and examines links to their careers post-degree.
This research addresses one of the fundamental assumptions about PhD education and policy; the assumption that women who undertake a PhD want to pursue academic careers. This assumption leads Australian policy for women in STEM education to focus on the leaky pipeline (Berryman, 1983), a model for retaining women by minimising the structural barriers that force them to leave. Retention is thought to ultimately increase women’s participation at higher levels within the sciences to create management and institutional equity and change. Problematically, however, this policy approach, and the focus on structural problems within the sciences, fails to take into account the complexity of women’s lives and minimises the levels of agency attributed to decision-making processes, particularly in relation to leaving their field of study. The expectation that, having attained a PhD in the sciences, women will automatically wish to stay in the pipeline is limiting, and PhD programs fail to adequately recognise the importance of non-academic career pathways as legitimate career options outside the academy. As such, measures put in place by gender equity policies benefit those who are directly employed in academic research, while the majority of women PhD graduates who move out of academia are largely ignored. I argue that by focusing resources on retaining women in postgraduate programs, institutions are restraining women’s science careers by limiting training opportunities and providing inadequate information on outside career choice.

This study examines the experience of PhD educated women astronomers and traces their education and work narratives through their PhD, transitional experiences, and into their current non-academic research careers. More importantly, it challenges the idea that women who do astronomy PhDs intend to become academics and wish to be retained in the pipeline. By interviewing women who have left astronomy, I demonstrate the importance of agency in these decisions and the complex factors that influence career choice. This thesis argues that it is time to move beyond a linear pipeline understanding of women in STEM careers to a non-linear understanding that better fits the current neo-liberal labour market. By understanding how women choose career pathways outside the expected academic norm, the study enables a better understanding of how women with astronomy PhDs experience the labour market. It asks the key questions; Where do women go after they complete their astronomy PhD and how did they get there? How do women account for their career transition and frame these experiences? In addition to exploring career pathways, I will consider gendered factors within astronomy and how women navigate the transitional stages between deciding to leave the field and leaving.
1.2 Women in Science

The discussion of how to get more women into science is not new. In 1965, Rossi, asked “Women in Science: Why so few?” and suggested that both educational and societal changes were necessary if more women were to choose to engage with and remain active in science. She noted that “work must be less dominant than it is in the lives of men for it to be more dominant in the lives of women.” (p. 1199). Since then, scholarship on women in STEM (Science, Technology, Engineering, and Mathematics) has focused on engaging women in STEM education and changing the culture within the sciences to better accommodate the needs of women. The status and number of women in scientific fields has been closely monitored and has been the subject of government, professional association, and institutional reporting. These reports provide extensive quantitative data on the recruitment, retention, and career development of women within discipline-specific scientific fields.

Subsequently, reporting has shown that while certain disciplines, such as the biological sciences, have experienced a significant influx of women, other fields have not experienced an increase in the same proportions. This ongoing problem of the recruitment and retention of women in mathematics led to one of the most over-used metaphors in women in STEM fields, the leaky pipeline (Berryman, 1983). Originally developed to account for significant losses of women and minorities from advanced science degrees, the leaky pipeline metaphor sought to identify areas of attrition and understand how this could be prevented. By viewing the educational process as a pipeline that both men and women pass through, a number of women (and other minority) specific filters and leaks lead to women leaving the sciences and explains their small numbers continuing to advanced degrees. This relatively simple linear metaphor was attractive to women in STEM programs and research because it provided a static framework to identify points of ‘leakage’ that could be changed and adapted for the greater retention of women (and possibly other minority groups).

The identification of problems experienced by women in STEM fields has also provided a body of survey and case study literature that demonstrates that women are at a structural disadvantage and often become stuck in the lower levels of scientific career development (Etzkowitz, Kemelgor, & Uzzi, 2000; Ceci & Williams, 2011; Fox, 2010). These barriers make women more prone to leaving their field of expertise and thus ‘leak’ from the scientific pipeline. Although some issues are science-specific, the majority of inequality practices are universal and overlap with broader women’s labour market and organisational management scholarship (Acker, 2006, 2012). Recently, the Australian government has started the SAGE Pilot (Australian Academy of Science, 2015), based on the UK Athena SWAN Charter (Equality Challenge Unit Athena Swan Charter, 2015), which has been in place for over a decade. Here, women-specific retention measures, such as training, support,
and changes in work conditions aim to retain more women within the scientific (academic research) pipeline so that they reach senior levels and help rectify the gender imbalance across all disciplines. Though these initiatives are sorely needed within the sciences, there is limited scope for them to influence the larger scientific field.

As illustrated by Caroline Herschel’s story, women’s scientific contributions have long been under-recognised or, as science is often conducted in teams, attributed to others. The historical undermining of women’s achievements, combined with legislative restrictions on women’s employment, limited how women were able to influence development of the sciences. Though her strong objectivity test, Harding (2004) notes the way science is conducted is fundamentally flawed as its process includes the bias and values of the society in which scientific research is undertaken. These biases include government funding priorities, the measurement of institutional metrics, and attribution of success, as well as the personal biases that scientists themselves bring into the workplace. This has left a cultural hangover, or as Harding (1991) calls it “science as usual” (p. 54) where the scientific method favours traditionally masculine approaches and behaviours. This process has also entrenched the idea of a gender-neutral meritocracy, where the most qualified, hardworking, and talented person becomes the most successful. In reality, this is not the case as complex factors advantage men over women and other minority groups (Castilla, 2008; Castilla & Benard, 2010). By fuelling the implicit belief in objectivity and meritocracy, the onus of success falls on the individual and their ‘merit’ which does not include important structural and cultural factors that influence opportunity. The idea that those who ‘leaked’ were possibly not worthy, is subtly perpetuated in the leaky pipeline method of retention, and the subsequent dismissal of women who leave.

This does not mean that retentive and leaky pipeline-based initiatives are not valuable or essential, they are. But the myopic focus on retaining women within the sciences places an implicit expectation for women to ‘persist’ and does not adequately account for agency and personal preferences. By focusing on only internal pipeline or structural issues, there remains an enormous knowledge gap about career navigation, personal choice, labour markets, and other factors that are more complex than structural pipeline issues.

1Until 1966 Australian women were required to give up their government jobs after marriage (The Australian Government, 2015).
1.3 Astronomy as a Case Study

Physics is one of the key problem areas where women are under-represented at an advanced postgraduate level. There is, however, an exception as astronomy (or astrophysics),\(^2\) a sub-field of physics, consistently attracts significantly higher numbers of women at the PhD level (Barthelemy, Grunert, & Henderson, 2013; Cesarsky & Walker, 2010; Ivie, 2014; Ivie & White, 2015). To date, there has been no definitive research as to why more women choose astronomy over other areas of physics, though smaller pilot studies, such as Barthelemy et al. (2013), have begun to consider the phenomenon and found that both a ‘love’ of the subject and availability of financial resources greatly influence women’s decisions to study astronomy.

In the US, the physics postgraduate cohort has remained relatively steady at around 20 percent women whereas astronomy has between 34-40 percent women which is a significantly higher level of engagement (Barthelemy et al., 2013; US National Science Foundation, 2014b; Barthelemy, McCormick, & Henderson, 2015a). In Australia, figures are marginally lower where 33.3 percent of the PhD cohort are women, and the cohort size is much smaller (Australian Academy of Science’s National Committee for Astronomy, 2015). The relatively successful engagement and retention of women in postgraduate astronomy studies, however, does not directly translate into academic employment where 18.7 percent of ongoing (or permanent, tenured positions) and 21.8 percent of fixed-term positions are held by women (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 5). The ‘loss’ of women from relatively strong postgraduate levels to a significant minority regarding employment, especially in senior positions, means that women have less input into the higher level management of the discipline and the subsequent shaping of research and funding priorities. The implementation of two versions of the Athena SWAN Charter, in both the Pleiades Awards (Astronomical Society of Australia Women in Astronomy Chapter, 2014)\(^3\) to the SAGE Pilot (Australian Academy of Science, 2015)\(^4\) means that Australian astronomy departments are in the unique position of having two versions of the same initiative that encourage change from both grass-roots and senior management levels. Because of this, establishing gender equity policy and practice has become a priority in the field.

The under-representation of women in astronomy is complicated by the fact that, although there is some progress in relation to the retention of women at a postgraduate level, it is only a very small field worldwide. Astronomy PhD graduates develop skills to become

\(^2\)For this study I will refer to the field as astronomy, which is the observation and study of astronomical phenomena. Astrophysics, a sub-section of astronomy that refers to theoretical mathematical calculations is automatically included in this definition for simplicity.

\(^3\)which is a departmental/school-based initiative, or bottom up.

\(^4\)which is institutional wide or top down.
research astronomers, which is a highly competitive job in a niche area. In 2008, it was estimated that there were approximately 10,000 professional astronomers worldwide, and each year 200 short-term postdoctoral positions and 80 permanent positions were listed worldwide (Forbes, 2008). These figures are now out of date, and there has been more funding and job creation, but the problem remains. Astrid, one of the established astronomers interviewed in this study, estimates the at there are “20,000 [astronomy] people in the whole world. Well, it’s a very small community. Maybe, it’s 50,000”. When considering the number of astronomy PhD graduates versus the number of jobs in astronomy worldwide, it is evident that there is not enough room in the field to retain women astronomers at the levels required to make substantive change within a short period.

It is this point that makes the leaky pipeline view of scientific retention potentially harmful to women. By focusing on how to keep women ‘in’ the pipeline, the pipeline view ignores the current labour market and the fact that most PhD graduates, regardless of their gender, will not work in astronomy in the long term due to the scarcity of positions. The pipeline also assumes that graduates will become academics, which in itself imposes a level of conformity on the expectations of women in science. The imposed limitation on PhD graduate careers goes against the grain of both feminist ideas of social change as well as the goal of the exploratory sciences, of which astronomy is the most well known in the public sphere. By focusing inward on the small percentage of women who stay in academic research, the pipeline effectively discounts women who leave the academic pipeline as ‘leaked’ or ‘unknown’ and devalues the choices of women who make these decisions.

In the tradition of feminist research (Smith, 1974; Harding, 1991; Haraway, 1988), and to some extent the exploratory nature of the astronomical sciences, this thesis demonstrates that the complexity of women’s career pathways post-PhD is dependent on a variety of factors, only some of which are identified by structural limitations experienced by women in STEM’s leaky pipeline. By reducing women’s non-academic employment decisions to ‘leakage’ the pipeline view suggests that women’s experiences in the field are wasted. In reality, their expertise is redistributed into equally valuable areas of the labour market outside academic research. Until recently, it has been relatively difficult to track university PhD alumni and, as such, detailed work on career pathways beyond academia is subsequently underdeveloped. Using public data such as social networks, social media, alumni sites, and professional networking sites, it is now possible to obtain accurate career exit information of PhD graduates to answer a major question in the sciences: What happens to women who ‘leak’ out of the pipeline post-PhD? Now, instead of being uncountable, or listed in survey data as ‘unknown’ (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 10), non-academic career pathways can be examined.
Due to its relatively small cohort and strong social and professional networks, Australian astronomy is a well-situated case study. Through qualitative interviews, this thesis considers the experiences of women PhD graduates who have completed Australian doctorates in astronomy who are now working in non-academic fields and asks; what influenced them to leave astronomy research, how did they describe this transition, and what type of work were they engaged in at the time of interviewing? By understanding standpoints of this previously hidden group, the thesis contributes to the understanding of the complexity of women’s lives during doctoral education and examines factors, both structural and agentic, that actively contribute to women leaving their field of academic research, and where they later choose to employ their expertise.

1.4 Purpose

This thesis argues that while conditions for women within the sciences are constantly improving, current models that focus on the retention of women and the removal of structural barriers do not reflect women’s current needs. When equity policies and programs focus on the leaky pipeline (Berryman, 1983) model of retaining women, they fail to acknowledge the complexities of women’s lives and the decision-making processes that lead to career choices beyond the academic sphere. By using Australian astronomy as a case study, the thesis demonstrates that women’s perspectives of their post-PhD career choices vary depending not only on identified structural barriers but also personal motivation, experiences within the PhD program, and the intersection of other aspects of their lives over which they assert agency in their decision to ‘leak’ from the academic pipeline. By viewing doctoral education only as a conduit towards professorship, doctoral programs and supporting policies are not providing the support and preparation that women astronomers need to thrive and transition into other areas of the workforce. By focusing only on gender as the primary marker of retention, as part of the larger push for greater participation of women in STEM fields, there is a failure to acknowledge intersectional aspects that also influence women’s lives (Crenshaw, 1991). This thesis also considers the intersectional effects of gender, social class, and mental health, or well-being, in relation to women in careers beyond astronomy.

The main questions asked by this research are:

- How do the experiences of women during their astronomy PhD influence future career pathways outside academic research?
- Where are women employed outside academic astronomy? What do they gain from these positions?
• What does the transitional process look like and how does this correspond to university training?

• How can we understand women’s career pathways post-PhD from an agentic perspective?

By examining these aspects through the lens of the higher education experience, gender, and labour markets this thesis captures the current state of women’s career decision making and, more importantly, illustrates the need for scholarship to move outside the pipeline model to provide women the best possible opportunities concerning employment post-PhD.

1.4.1 Project Significance

This thesis provides a new analysis of research women’s scientific careers that considers more than the potential leaks in the leaky pipeline. Instead, women in this study are considered to be fully-developed scientists who can navigate structural barriers, assert agency and choose whether to conform or not to the desired model of retention in the sciences. That is not to say that gendered barriers do not exist, but rather that decision making processes, personal preferences, and underlying academic labour market conditions all play a part in deciding whether women will pursue academic positions or instead leave the field of their PhD. The thesis argues that by representing academic research careers as the ideal way to retain women, we are restraining them and failing to provide the information that they need to make weighted, agentic decisions about their careers post-PhD. This is particularly relevant because of the small number of positions within the field of astronomy and the current state of the academic job market, where positions are increasingly becoming precarious short-term contracts or casual work that replace tenured academic jobs. Here, I assert that women do not ‘leak’ from the pipeline but re-distribute their labour to other areas of equal value.

Furthermore, this research contributes to the important, developing field of ‘alternative’ academic careers which demonstrates that PhD graduates do not need to work in academic research to be successful. In reality, alternative or non-academic careers are the mainstream option for PhD graduates, and labelling them as alternative is perhaps intentionally misleading. This thesis provides an account of the transitional stages that women experience when deciding to leave academic research astronomy after their doctoral studies. By connecting education, motivation, and experience to career outcomes, I assert that employment decisions, while sometimes gendered, reflect complex life decisions, attachment to people and places, and other intersectional elements that restructure priorities
post PhD. Limiting the career trajectory expectations of doctoral students toward academic careers undervalues the PhD as a qualification and the achievements of those who have attained one.

As an emancipatory feminist project (Hesse-Biber, 2010), the inclusion of women’s stories, or narratives works twofold; by revealing the standpoints of women who have completed Australian PhDs in astronomy, and as an emancipatory and normalising exercise to break the stigma of leaving the academic sphere for other careers. Here, I demonstrate that non-academic careers are valued and that through active discussion and breaking the silence that surrounds leaving the academic profession, a greater knowledge of transitional processes and outcomes may significantly improve the experiences of current and future students.

By using feminist standpoint theory (Harding, 2004) and thematic narrative analysis (Riessman, 2005) to create motivational and leaving typologies, I have analysed women’s experiences and identified connections between PhD motivation, post-graduate experiences, and career outcomes outside the academy. This information contributes to knowledge on multiple levels. Firstly, it traces previously unknown career outcomes of women with astronomy PhDs who work in ‘industry’ and exposes possible pathway data for non-academic employment. More importantly, it captures women’s experiences in Australian astronomy PhDs and the process of career transition from their standpoint, providing valuable feedback on the culture of Australian academy and beyond.

In the next chapter, I will examine literature related to women in astronomy and the subsequent technological and organisational development of the field in Australia. I will further introduce the theoretical frameworks outlined in this chapter and examine recent work in the field of women in astronomy and the exploration of non-academic workplaces. Through these theories, I will trace the historical development of astronomy and outline where the field is currently situated in the area of women’s equity and development.

1.5 Conceptualising Women in Scientific Labour

This research uses multiple frameworks that fall under a number of disciplinary categories yet are united by a feminist perspective. The development of Australian astronomy, which will be explored later in this chapter and the literature review, has led to a distinct culture that is both situated within the broader world astronomical context, yet focused on a small, relatively insular community that is geographically isolated. Instead of focusing on how women fit into astronomy, I have chosen feminist standpoint theory (Harding, 2004) to elevate women’s experiences of astronomy as a primary way of understanding
what it means to be an astronomy doctoral student in Australia and what it means to move from that field into a post-astronomy career pathway. Current labour market conditions and precarious employment lend weight to Acker’s (2006, 2012) assertion that work organisations are gendered, which sets this work apart from other current education focused scholarship in the field (Barthelemy, 2014; Barthelemy et al., 2013; Barthelemy, Van Dusen, & Henderson, 2015; Barthelemy, McCormick, & Henderson, 2015a; McCormick, Barthelemy, & Henderson, 2014; Danielsson & Linder, 2009; Danielsson, 2012; Pettersson, 2016; Gonsalves, Danielsson, & Pettersson, 2016). By focusing on the Australian PhD as a place of work, as many interviewees described it, instead of only a place of education I can better explore how workplace factors influence women’s decisions to stay in or leave the field. Constructing PhD higher education institutions as workplaces, better reflects the PhD apprenticeship model employed in Australia where, through work experience and meeting academic performance requirements, students are (in theory) transformed into early career researchers.

Feminist standpoint theory (Harding, 2004) argues that the construction of knowledge is socially situated and seeks to re-position the construction of knowledge, and view it from the perspective of women. It is through “studying up” (Harding, 1991, p. 132), or linking political struggle and oppression, to the larger androcentric system of the generation of knowledge, that feminist standpoint theory transforms perspectives into standpoints that reflect how knowledge is both experienced and socially situated within higher systems. It is through the engagement with standpoints of women astronomers, and post-astronomers, that I am able to explore and uncover the gendered state of Australian astronomy, the gendered disciplinary conventions that are imposed upon women who participate in doctoral studies, and how they structure their future career pathways.

The standpoint theory approach is complemented by other feminist theories of work and technology. As a technologically advanced discipline, astronomy has a long history of excluding women from the use and development of technology. To better understand how women interact with technologies involved in astronomical research, I consider Wajcman’s (1991) theories of gendered technologies. Like Harding’s (1991) assertion that the production of knowledge is socially situated, Wajcman observes that although technology is a gender-neutral object or tool, the culture surrounding it is highly gendered. Here, masculinity is closely linked to the development and use of machinery and technology, which makes women’s relationships in diverse and highly technical fields such as astronomy more complex. In combination with Acker’s (2006, 2012) gendered workplace theory, this study utilises the interaction of these frameworks to understand how women position themselves in a highly technical scientific work field and beyond. This study has also included a number of further intersectional factors (Crenshaw, 1991) such as social class, and mental health. Due to the relative homogeneity of the Australian astronomy cohort, this research
purposefully excludes race as an intersectional factor even though Acker’s (2006) inequality regimes links gender, race, and social class. The mechanics behind these interactions and further exploration of these theoretical frameworks will be further explained in both this chapter and in Chapter Two.

1.6 Feminist Standpoint Theory

Feminist standpoint theory was developed to,

see “beneath” and “behind” the dominant sexist and androcentric ideologies that shaped everyone’s lives to the relations between, on one hand, the actualities of women’s everyday lives, and on the other hand, the conceptual practices of powerful social institutions, especially in relation to research disciplines. (Harding, 2004, p. 6)

Developed in the 1970s and 1980s, feminist standpoint theory, like Marxism (Marx, 1867), shifted the focus from the dominant class to the proletariat, or in this case women, and elevated their experiences as a way of accounting for the generation of knowledge. A multidisciplinary theory that was developed in the philosophy of political and natural science, and the sociology of knowledge (Harding, 2004, p. 9), feminist standpoint theory sought to understand the experiences of women and the generation of knowledge from a standpoint other than the traditional androcentric doctrine of the sciences. This view differs from feminist empiricism, which seeks to fill in the gendered gaps of scientific knowledge using established method (Harding, 1986, p. 33-34). Feminist empiricism is the preferred method employed by historians in relation to women in science. Smith (1974), observes that feminist standpoint theory goes beyond understanding what is “left out, overlooked, or by making sociological issues of the relevances of the world of women. That merely extends the authority of the existing sociological procedures and makes of a womens sociology an addendum”(p. 6). Here, she asserted that using the traditional sociological practices employed by the men who shaped the discipline was inadequate for accurately understanding the experiences of women.

Smith (1974) also observes that “the only way of knowing a socially constructed world is knowing it from within”(p. 11), thus feminist standpoint theory situates itself within the knowledge base that it is trying to understand. In this study, it is the social, political, and personal struggles of women within the discipline of Australian astronomy and, how individually and as a group, they navigate these factors that produce knowledge. The establishment of a standpoint is, however, more than a collection of views and perspectives. What Harding (1991) refers to as “studying up” (p. 132) is a focus that begins with
the accounting of women’s experiences and the generation of knowledge. This knowledge is then examined through social and political theory to better understand how practices came to be, how inequalities are enforced, and what new insights can be gained from women’s standpoints. This method differs from the ‘top-down’ model that Smith describes in relation to the sociological perspective where women’s experiences are analysed through an already established methodological framework that will likely produce certain predetermined results. Harding (2004) observes that “the more value-neutral a conceptual framework appears, the more likely it is to advance the hegemonous interests of dominant groups, and the less likely it is to be able to detect important actualities of social relations” (p. 6). This is relevant for both social and scientific disciplines. For example, the study of astronomy, as a sub-discipline of physics, is generally perceived as being value-neutral due to its strong use of mathematical theory and ‘objective’ observations of astronomical phenomena. In this thesis, I demonstrate that the development and generation of astronomical knowledge is socially situated and that women’s contributions have historically been, and are still, undermined by the structure of the discipline. Furthermore, the implicit expectations of career trajectories within the field along with intersectional factors such as social class and mental health, are contributing to the already established difficulties of women within the field.

Although they are elite scientists, women in astronomy are still considered an oppressed group who work within the confines of an androcentric discipline and thus share a standpoint or “situated knowledge” (Haraway, 1988). The concept of situated knowledges will be discussed further below. There is, however, a long-established history of innovative, non-conformist women in the field who have struggled for equality. The women who were interviewed for this study reveal their experiences, successes, and struggles, and by participating in this research, continue their objective of improving the experiences of women within the discipline, especially in relation to career outcomes.

Over the last decade, reflexive astronomers, who have not been the subject of many sociological studies, have been proactive in filling the knowledge void of their experiences within the discipline. Fohlmeister and Helling (2012; 2014) for example, conducted surveys of European astronomers to provide a quantitative snapshot of women’s career experiences. This snapshot, which also contains quotes from free-text responses, indicates that there is discrimination within the discipline. This survey uses quantitative data supplemented by qualitative data from free-text responses from the survey to report and extrapolate how women experience astronomy. Together with statistical reports from the American Institute of Physics (American Institute of Physics, 2017) and the Astronomical Society of Australia (Astronomical Society of Australia, 2015) astronomers are trying, in their empirical disciplinary language, to create an awareness of issues that affect women in the field. This method, as used by astronomers, does not necessarily constitute a standpoint
because this limited level of quantitative empiricism falls short of the critical insights and engagement with the extended social, political and philosophical theory which is instrumental in transforming a perspective or view into a standpoint. It is at this juncture feminist theory and science must combine. As Harding (1991) explains,

feminist theory about science must be seen as inside the process of science, where it can help scientists explain the social conditions in both scientific institutions and the surrounding society that tend to encourage empirically more adequate beliefs; identify background assumptions that tend distort the results of research; conceptualize and design research in ways that avoid powerful cultural biases; interpret and select data to produce the most reliable evidence for and against hypotheses. (p. 74)

The formation of a standpoint, which is “something for which oppressed groups must struggle, something that requires both science and politics” has the potentiality to “turn an oppressive feature of the group’s condition into a source of critical insight about how the dominant society thinks and is structured” (Harding, 2004 p. 7-8). It envisaged that once a standpoint is identified this articulation of women’s experiences within the sciences can bring about change.

1.6.1 Strong Objectivity in the Production of Science

Feminist standpoint theory seeks to examine science from the perspective of women, who have traditionally been excluded from the production of knowledge. Through this lens, it is possible to better understand the social circumstances under which ‘objective’ scientific knowledge is generated. In order to examine whether science is objective, Harding (1991) coined the term “strong objectivity” (p. 138). This idea challenges the traditional assumption of the objectivity in science, debunking the idea that rational scientific method can remove bias contributed by scientists and societal influences. Harding argues that,

Important causes of scientist’s everyday activities and experiences are found far distant from the laboratory or field site in the economy, government policy, Supreme Court decisions, child-rearing practices, religious beliefs and other social relations (p. 94).

In other words, the generation of scientific knowledge is conducted within a larger social and political framework that shapes the scientific process and subsequent outcomes. By examining ‘objective’ science through the lens of strong objectivity, feminist standpoint theory asserts that even our best scientific beliefs “are socially situated, but they also
require a critical evaluation to determine which social situations tend to generate the most objective knowledge claims” (Harding, 1991, p. 142). This extension of scientific objectivity is important when viewing science in ‘pure’, or mathematically complex, disciplines such as physics and by extension astrophysics and astronomy. Harding argues that the practice of conducting science is fundamentally flawed due to its narrow focus on specific research problems without accounting for the society in which values are shaped. Acknowledging such bias, does not, however, necessarily devalue knowledge, but rather adds an extra layer to its complexity that must also be considered when accounting for its generation in a social and historical context.

Combined with women’s standpoints, strong objectivity allows us to critically evaluate scientific progress in a way that establishes exactly where it is socially situated. Here, social policies that shape women’s experience have traditionally limited their roles in the production of knowledge. Key examples examined in this chapter are the women of the Astrographic Catalogue and Ruby Payne-Scott. These women were subject to a number of exclusionary policies such as the Australian Public Service Act 1901 (The Australian Government, 2015) and further limitations imposed on their pay and work conditions. Without understanding the long-term effects that these policies have had on the shaping of Australian astronomy, an account of the modern astronomy workplace would be incomplete.

1.6.2 Situated Knowledges and Partial Perspectives

Haraway’s (1988) most noted contribution to feminist standpoint theory was to create “a doctrine of embodied objectivity that accommodates paradoxical and critical feminist science projects: Feminist objectivity means quite simply situated knowledges.” (p. 581). Haraway argues that knowledge can be seen from the partial perspective of the participant, and it is within that perspective that it is situated. What Haraway calls the ‘god trick’ of ‘seeing everything from nowhere” (p. 181), masks the concept of an objective scientific perspective as a myth. For Haraway, the tension between the subjective and objective is key to understanding the generation of scientific and technical knowledge, raising the key question of how much is knowledge generation influenced by the community from which it is created?

Haraway (1988) further argues “[that] situated knowledges are about communities and not isolated individuals. The only way to a larger vision is to be somewhere in particular” (p. 590). In this study ‘somewhere in particular’ is the combination of standpoints of a situated community of current and former astronomers. By analysing this data from my own standpoint, as a sociologist and as someone who has worked within the astronomical
community for a number of years, I am able to consider nuanced partial perspectives of what it is like to be located within the field of Australian astronomy. By ‘studying up’ this research reveals previously hidden experiences of women in astronomy and employment beyond. The empirical analysis chapters of this thesis (Chapters 4-8) explore the implicit expectation that women who get PhDs, in astronomy at least, will stay in the field and not ‘leak’ from the over-referenced leaky pipeline. This assumption is at odds with their experiences as a minority in the field, where they have already chosen an unconventional pathway through maths and physics into astronomy. Consequently, women are then expected to conform to disciplinary roles as researchers with aspirations towards a professorship. This is unreasonable as they have already eschewed other gendered expectations by conducting their research to obtain a PhD and now perhaps have different goals.

It is through the complex mechanisms of feminist standpoint theory, strong objectivity and situated knowledges that I can best examine the historical, social and political contexts of the development of Australian astronomy as it relates to the current experiences of women within the discipline. By elevating women’s standpoints, how they experience everyday lives, and the narratives that they tell themselves about their place within the discipline and society, I have developed insight into the decision-making practices of these unconventional women and their response to the gendered factors that influence their lives and employment decisions.

1.7 Astrophysics: Women’s work

Historical factors have greatly influenced the development of modern astronomy and the roles of women in the workplace. By viewing contributions through the lens of strong objectivity (Harding, 1991, p.138), I can trace the connection between social factors, the generation of astronomical knowledge, and the impact thereof. Rather than constructing women’s astronomical histories from historical documents, I focus on turning points in Australian astronomy, societal factors, and women’s roles therein.

The example of Caroline Herschel, as told earlier in this chapter, is that of a woman who excelled in her family business. Although she did not gain the recognition that she deserved and was always overshadowed by her brother, William, she was acknowledged by the Royal Astronomical Society for contributing to the field. Historically, Herschel’s time of lone, or small groups of astronomers that worked in relative isolation, was quickly coming to a close in favour of a more technologically advanced, industrialised method that has reshaped astronomy into its current form. It is at this late stage that Australian

\footnote{For a more detailed explanation of my situatedness see Chapter Three.}
astronomy and the lesser mapped Southern Field\textsuperscript{6} starts to become more researched and better documented.

The history of conventional (non-indigenous\textsuperscript{7}) astronomy in Australia is relatively short and follows the tradition of European astronomy. Here, the same methods, values, and professional bodies were essentially transplanted from Europe onto Australian soil. European style observatories were built in capital cities, and early Australian astronomers were subject to the same restrictions and memberships as their European and North American counterparts.

One of the major organisations for astronomers, both past and present, is the Royal Astronomical Society (RAS), which from Australia’s early colonial settlement linked Australian State observatories with Britain which ensured participation in the comprehensive survey resulting in the Astrographic Catalogue (Stevenson, 2014). Membership of the RAS was closed to women from its inception in 1820 until the first women’s full membership in 1916, though Caroline Hershel received honorary membership in 1835 (Royal Astronomical Society, 2016). This professional association ensured that only full members were able to publish astronomical research, and those without, such as women, were excluded from making significant contributions to the field. These exclusionary policies, which shape astronomical knowledge highlight the importance of analysis through the lens of strong objectivity (Harding, 1991). By elevating the more developed Eurocentric Northern Fields, and by excluding women and other minorities, the RAS consequently restricted its research interests in favour of its social agenda. Such exclusionary policies are harmful because they effectively erase women’s research contributions, or at least relegate them to an obscure historical footnote, and their knowledge is lost to the field. Fortunately, scientific historians such as Freitag (2010), and Stevenson (2014; 2015; 2016) have been able to trace women’s research and acknowledge the accomplishments of women astronomers. Although this historical documentation does not rectify the damage caused by gendered policies, the addition of women to comprehensive databases demonstrates that women have made a substantive contribution to the field of astronomy, which may, in turn, influence others to join the field.

\textsuperscript{6}The astronomical sky is divided into two hemispheres. The Northern Hemisphere, where conventional western astronomy originates, has been observed and thoroughly mapped by European astronomers and, as such, most of the discipline is Northern Field centric. The Southern Hemisphere, or Southern Field, has been less thoroughly researched by Europeans and does not have the same amount of historical data available. Still, to date, most astronomy is situated in the Northern Field.

\textsuperscript{7}Indigenous or Aboriginal astronomy is beyond the scope of this project. Over the last decade, there has been significant interest in linking traditional Aboriginal knowledge with European astronomy.(Clarke, 2007; Fuller, 2014; Hamacher, 2013; Norris & Hamacher, 2011) This has resulted in a large body of information and educational programs and online. Up to date information can be found at http://wwwaboriginalastronomy.com.au
1.7.1 The Industrialisation of Astronomy and the Astrographic Catalogue

Instead of conducting research with singular or small groups of astronomers at minor observatories, “By the late 1800s major observatories were starting to resemble industrial factories” (Lankford & Slavings, 1990, p. 59). This new arrangement led to the decline of small team astronomy, like Caroline and William Herschel a decade earlier. Single object research\(^8\) morphed into large-scale research through which astronomers could survey and photograph large sections of sky with astrographic plates. This enabled the observation of much larger amounts of astronomical data (Kass-Simon, 1993). Such technological advancements enabled astronomers to study star’s spectra, or light, and meant that astronomers could now study not only an object’s astronomical position but also its physical composition. This new technology led to the emergence of a new sub-discipline; astrophysics (Kass-Simon, 1993). Here, astrophysical calculations were essentially like what Caroline Herschel had done earlier, yet with an added layer of spectral analysis. Now high outputs of data needed to be calculated and analysed effectively. The industrialisation of astronomy created an excess of low-level analytical positions in what Lankford and Slavings (1990) termed “knowledge factories” (p. 59), which in turn needed affordable workers. As technology for data collection and analysis has improved, modern astronomy continues to have a high demand for lower-level workers to undertake data cleaning and reduction. This task now falls to junior astronomers or university students.

The change from Herschel era astronomers to large, organised teams provided both work opportunities and subsequent restrictions for women in the field. Stevenson (2016) in her doctoral thesis, traces the largely undocumented women who worked as low-level workers on the Astrographic Catalogue. These women, who held titles such as “assistant computers” or “star measurers” and other variations, were paid only 54 percent of that of their male peers (p. 222). Stevenson notes that even though women performed to the same level as men, they were restricted by their gender and not assigned work based on skill and merit. Strictly hierarchical, this early industrialisation of astronomy employed men in active instrumentation research and limited women to passive, low-level astrophysics. The active exclusion of women in relation to technology access and development is what Wajcman (1991) focuses on in her work on gendered technologies and their close relation to masculine culture. These theories on technology development and usage will be explored later in Chapter Two in relation to modern astronomy technologies.

Within the technical sciences, astronomy was not the only area where women were employed to do pioneering work that was ultimately redistributed towards men. This is now

\(^8\)Where observations concentrate on one phenomenon or small area of the sky.
explained by gender queuing theory, where low-status fields that employ women gain status, effectively forcing women out and enabling males to establish and retain dominance (Reskin & Roos, 1990). This also occurred in the closely related field of computing, where women, initially employed as “lady computers” to undertake low-level coding became displaced by highly professionalised structures that were later dominated by men (Ensmenger, 2013). Unlike computing, astronomy and astrophysics still attracts a relatively healthy number of women at a postgraduate level, though at senior levels numbers are lacking.

1.7.2 Gender and Astronomy in Australia

Australia’s contribution to the Astrographic Catalogue (AC) was significant, and consequently bolstered the numbers of Australian astronomers. Stevenson (2014, 2016) notes that Australia, commissioned by the RAS in 1893, undertook 18 percent of the AC survey from Australian State-run observatories in Adelaide, Sydney, Melbourne, and Perth. For such a small outpost country, this was a high percentage of data collection which consisted of mapping the little-known Southern Field. The survey employed 61 women (from the years 1891 to 1922) who were subject to European work restrictions and policy. Here, the commissioning bureaux of the AC, based in Paris, prescribed workplace conditions for all contributing sites worldwide. Perhaps the most obtrusive condition set by the bureaux was the segregation of male and female workers in order to prevent male staff from being “distracted” by their female colleagues (Stevenson & Lomb, 2015, p. 5). This practice set an alarming precedent for further workplace culture and the hierarchy of male-dominance in the field was firmly established. Women were held responsible for being ‘distracting’ and the onus was not placed on men to exert self-discipline or control. This was not limited to astronomy and was common work practice in other male-dominated professions, and is one of the key contributors to gender inequality in the modern workplaces.

Observational equipment was considered the exclusive domain of men, possibly due to segregation, and women were discouraged from working at night due to the isolated and poorly lit locations of the observatories (Brück, 2009). These centrally located AC policies meant that women working on the AC catalogue were effectively unable to conduct astronomy at night or talk to their male co-workers. Such restrictions were not practical, especially at minor observatories, where removed from direct oversight of the Bureaux, small acts of resistance occurred. Stevenson (2014; 2016) found, through telescope logs, that Mary Emma Greayer and Charlotte Emily Ffjorde-Peel, both actively observed the stars with telescopes, at night, encouraged by, and interacting with, their male colleagues. Much like Herschel who worked with her brother, Greayer and Ffjorde-Peel were supported by male colleagues who recognised them as innovative women in the field. Although at the

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9 Which is Southern Hemisphere-specific.
time women were very restricted, these small acts of resistance helped shape Australian astronomy. Here, the circumvention of impractical policies was made possible due to the distance from European oversight.

1.7.2.1 Federation: The Dawn of Large-Scale Bureaucracy

Australian Federation took place in 1901, in the midst of ongoing observations for the Astrographic Catalogue (AC), which went from 1893 to 1922 (Stevenson, 2014; 2016). The formation of a Federal government meant that while States kept their autonomy, the country was subject to new legislation that would affect women’s work until 1966. It is unclear from the literature exactly how this Federal legislation interacted with individual State legislation and is beyond the scope of this thesis. What is relevant, is that upon federation, astronomers and their assistants became subject to the Australian Public Service Act 1901 (The Australian Government, 2015), which dictated that women, once married, must resign from a government job. The subsequent intellectual loss, especially for the AC, was significant. Mary Emma Greayer lost her position after marriage. After her mandatory resignation, her employer wrote to the NSW Government astronomer “praising her as ‘a veritable Caroline Herschel’ and bemoaning that, after Greayer’s departure, the work of measuring standard stars for the AC ‘stalled’ for a number of years” (Todd 1899b in Stevenson, 2014. p. 6). It is unclear exactly how many women were lost from Australian science and government positions because of this legislation, which was finally amended in 1966. Nevertheless, the loss of women within the field still has a significant impact on the number of senior women present in Australian astronomy today. No story reflects this more than that of Ruby Payne-Scott, one of the world’s first radio astronomers and an influential figure in Australian astronomy.

1.7.2.2 Acts of Resistance: Ruby Payne-Scott

Australian astronomer Ruby Payne-Scott is widely regarded as the first female radio astronomer10 (Dyer, 2000; CSIRO Staff Association, 2012; Goss & Hooker, 2012). Educated at the University of Sydney, she graduated with honours in physics and mathematics and was the third female physics graduate in the university’s history (CSIRO Staff Association, 2012). During World War II, Payne-Scott obtained a position at the government’s CSIR (currently the CSIRO) from 1941 until 1950 where she worked in the radio physics

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10 The CSIRO recently named one of their computer servers ‘Ruby’ in honour of her contribution. Usually, they would use surnames of prominent scientists, but Payne-Scott included an incompatible character that the system would not allow, so they settled for Ruby. This has ironically set her apart from other computer servers.
division. Her work there led to significant discoveries in solar radio astronomy for which she is recognised worldwide.

While Payne-Scott is known for her ground-breaking scientific work, the more compelling aspects of her story come from her acts of resistance against workplace inequalities and government policy. Had Payne-Scott followed the rules, her scientific breakthroughs in radio astronomy would never have eventuated. Considered somewhat of a folk hero at CSIRO, official government documents (National Archives of Australia, 2009) represent her as a curmudgeonly figure who was a member of the communist party. While stories differ, what is clear from Payne-Scott’s actions is that she was a pragmatic scientist, whose belief in collaborative science and equity overrode the social and institutional structures that sought to suppress her.

Payne-Scott’s position as a permanent full-time scientist with the Australian government allowed her more agency than the ‘lady computers’ employed at the AC twenty years earlier. Not only was she highly educated as a scientist able to speak the lexicon of other predominantly male scientists, but her contributions were highly valued by the government. This granted her more leverage and leeway than women before her. Her ongoing challenge of women’s stereotypes, interest in equity, and skill as a scientist made her an Australian Security Intelligence Organisation (ASIO) ‘person of interest’. She possessed revolutionary attitudes towards trade unionism, a belief in international scientific cooperation, and was a member of the communist party (CSIRO Staff Association, 2012). Payne-Scott personally had a reputation for being “feisty, self-confident and immensely capable” (Goss & Hooker, 2012) and as such actively challenged the inequality that surrounded her.

Payne-Scott’s activism resisted barriers at all strata of institutional and governmental policy. This ranged from everyday workplace dress codes, as she liked to wear shorts in the workplace (Dyer, 2000), to active opposition regarding the cut of wartime pay rates that ended equal pay for men and women. Under the proposed change, women were set to receive only 75 percent of their previous pay, but due to significant activism against this unpopular policy, the pay cut was largely avoided. Ultimately:

> Women employed during the war won a reprieve from the pay cut (provided they continued to work in the same division doing the same work) the reduced rate applied to all new women employees or those transferring to new positions at CSIRO. (CSIRO Staff Association, 2012)

While Payne-Scott, certainly represented the pioneering ideal of astronomy, perhaps one of her greatest achievements was in managing to circumvent the Public Service Act (Australian Government, 1901) for so long after marriage. That Payne-Scott successfully hid
her marriage for six years, while working at the CSIRO and being the subject of an ASIO file is a testament to her ingenuity. Like Greayer and Fjorde-Peel of the astrographic catalogue, it is highly likely that Payne-Scott’s co-workers were aware of her situation and assisted her in her bid to maintain her position. This deception indicates that although public policy called for her resignation, these restrictions were not necessarily in line with the social values of scientists at the CSIRO. In 1950, upon calls for her demotion to casual worker and her subsequent resignation, Payne-Scott was unrepentant and told the CSIR that

> Personally, I feel no legal or moral obligation to have taken any other action than I have in making my marriage known...the present procedure with regard to married women seems to go far beyond the simple statement in the Act...[it] is ridiculous and can lead to ridiculous results.

(National Archives of Australia, 2009)

Payne-Scott later became a mother and a teacher, never again actively contributing to the field of advanced scientific research that she had pioneered.

The Public Service Act was amended in 1966, which meant that women were not forced to resign from their jobs upon marriage. Though there was an influx of women in the field in the 1970s because of the women’s movement and anti-discrimination laws (Bhathal, 2001), the hangover from previous workplace and educational policies still affects women today. Many senior women in Australian science are the same trailblazers who initially navigated the androcentric world of science and technology and persevered through discriminatory workplace practices. This gives women, who still have contact with the original pioneers or their students/mentees, a strong connection to the original women who occupied senior level Australian science. Women currently make up only 20 percent of Australian astronomers (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 10) with less in senior management positions. This means that until relatively recently women have had little input in shaping science as “key members of the community...[to] set the research agenda, receive and spend a substantial fraction of the research income” (Australian Academy of Science’s National Committee for Astronomy, 2005, p. 10). Now, as women become more senior, they are able to make greater contributions to shaping the discipline and its sub-fields.

Historically, Australian astronomy has been dominated by European policies and practices that have excluded women from employment and access to technologies. By framing the historical development of Australian astronomy from the standpoint of women such as Payne-Scott, and the women of the Astrographic Catalogue, it becomes clear how damaging relatively recent policies have been regarding the participation of women.
1.8 Thesis Structure

The structure of this thesis is conventional and consists of nine chapters. The first four chapters situate the study within the multiple literatures, theoretical, and methodological frameworks, while the latter focuses on interviewee narratives that describe complex experiences pre, during, and post-PhD that have shaped career pathways. This temporally structured narrative, from the standpoint of women astronomers, uncovers previously hidden information in relation to women’s PhD experiences, how they assert agency to navigate structural barriers, and other life factors during their degrees and beyond.

1.8.1 Introductory, Theory, and Contextual Chapters

This introductory chapter situates the thesis within the field of feminist sociological research and examines the gendered nature of women and scientific work. By utilising a historical narrative of the gendered development of Australian astronomy with specific examples of women’s stories, who were pioneers in the field of astrophysics, it illustrates how restrictive policies have undermined women’s contributions to the field and how these factors are still present in modern astronomical research. These descriptive historical accounts position women astronomers as intelligent and unconventional, both traits that are essential to further arguments about women’s career pathways post PhD. It also further demonstrates that women’s relationship to the field of astronomy is complex and that by using feminist standpoint theory (Harding, 2004) as an epistemological tool we can flip the view of women in science from a study of gendered barriers, to the experience of women doing science and agentic decisions that influence their lives.

Chapter Two, Women in Astronomy: Building on Unequal Foundations, asserts that the current framework for Australian gender policy, which revolves around the leaky pipeline (Berryman, 1983) is flawed and that other feminist theories of work and technology (Acker, 2006; Wajcman, 1991) illustrate a complex problem that cannot be fixed by minor structural changes. While current literature accounts for women’s experiences in astronomy in an educational and retentive context, there is very little scholarly research on what happens to women after they leave their doctoral programs and work outside academic research.

Chapter Three, Constructing the Study: Methods and Data, details two methods of data collection. Firstly, it considers methods, strategies, and ethics employed to construct a database of public career exit data of approximately two hundred astronomy PhD graduates from five Australian universities over the course of a decade (2005-2015). Secondly, it details interview sampling strategies, interview and transcription protocols for three
interviewee groups: established astronomers (n=5) (Group A), recent graduates (n=22) (Group B), and current students (n=5) (Group C). Lastly, the chapter introduces additional analytical strategies and asserts that by using thematic narrative analysis (Riessman, 2005) combined with feminist theory, interviewee data can be temporally organised, and arranged into functional groupings and typologies that can best assert the standpoint (Harding, 2004) of women.

1.8.2 Empirical Analysis Chapters

The analysis stage of this thesis builds a narrative structure that follows women’s experiences through their doctoral education and into non-academic employment. Chapter five transitions from literature that frames the Australian PhD into narrative accounts from interviewees that contextualise the educational experiences of interviewees. Here, the PhD environment is considered a workplace where learning occurs. This is largely due to the perspectives of interviewees, who although technically students, undertook their PhDs in Australian universities which use a three to four-year apprenticeship model where interviewees were paid a scholarship stipend. This separation between work and education is essential when contextualising the choices of women and provides new insight into how PhD programs perform from the perspective of participants.

Chapter Four, PhD Experiences: In the ‘Pipeline’, overlaps with pipeline research on structural barriers and presents a nuanced astronomy interpretation that examines doctoral candidate experiences in relation to potential career choices. Here, I argue that there is a connection between supervisory relationships, workplace culture (including sexual harassment), and networking opportunities that directly influences work types pursued outside academia.

Chapter Five, Entering Academia: Narratives and Motivation, frames Australian PhD process, educational filters and the recruitment of doctoral candidates through a combination of literature analysis and personal narratives. This chapter asserts that there are three motivational narratives of doctoral students; the accidental PhD, who are retained from undergraduate/master’s degrees; the adventure PhD, who are experience seekers; and the research career PhD, who are the archetypal PhD student who wishes to become an academic post-degree. By accounting for the skills and motivation students bring into their doctoral studies, the chapter shows that not all PhD students entering the program wish to become academic researchers post-PhD. This illustrates that the key assumption made by gender equity retention programs, that women wish to stay, is not necessarily correct.
Chapter Six, *Stigma and a Lack of Information about Leaving* examines the idea of ‘leaving stigma’ associated with choosing a post-astronomy career pathway outside the expected academic norm. This chapter explores perceptions of stigma at multiple levels; the established astronomers, and the recent graduates and current students. Here, perceptions differ, and students report a sense of ‘failure’ about their decision to leave the field of astronomy. In addition to this, there is a lack of information about the type of careers that lie outside the academy, which also contributes to a stigma cycle that is perpetuated at multiple levels in astronomy and the academy.

Chapter Seven, *Leaving the Academy: Three Typologies*, establishes typologies of leaving that consider agency, opportunity, exit strategies, personal choice, their relation to motivation, and formative experiences during the PhD. These typologies have been developed to account for the three main leaving narratives; determined Leavers, who have made an active decision during their doctoral studies to leave the field; involuntary leavers, who through factors related to their PhD, are excluded from progressing; and flexible Leavers that re-evaluate their career goals during the course of their studies and act accordingly. Each of these groups exhibits decision-making strategies that temporally vary which impact how effectively women look for work outside the academy and establish support networks. This section also considers intersectional factors such as mental health.

Chapter Eight, *Accounts of Post-astronomy Careers*, accounts for exit data from two sources; the preliminary survey of five universities as discussed in Chapter Three, and nuanced interviewee data regarding their post-astronomy jobs. Here, I demonstrate that locating astronomers post-PhD is not necessarily difficult, but time-consuming and that career pathways are largely location centred and relatively evenly distributed between government, industry and university employers. Divided into three major career types; astronomy satellite careers, technical careers, and people oriented careers, this chapter provides accounts of how career transitions were achieved and what different jobs entail. Moreover, it fills the gap in scholarly literature regarding post-PhD pathways and how these are achieved. The latter part of the chapter focuses on ‘intangible’ benefits of employment and what post-astronomers’ value in their new work environments.

Chapter Nine, *Conclusion: Brave New World*, is the final chapter of this thesis that draws together the main findings of this research. Firstly, it takes a holistic view of this research and explains its function to link how women enter, experience, and leave astronomy. In addition, this research provides a map of new post-astronomy fields that have attracted PhD educated women astronomers. The second research finding positions the PhD into a workplace context and asserts that by doing so, it may ease the career transition of graduates and potentially create a better relationship between the academy and industry. The third research finding explores the notion of a perpetuated stigma cycle experienced by
doctoral students regarding their decisions to leave the field of astronomy. The final finding links women’s career patterns to finding one, their experiences and brings new insights into potential careers for women. In addition, I explore the limitations of this research and identify future avenues of research that have been identified during this study.
Chapter 2

Women in Astronomy: Building on Unequal Foundations

This chapter examines the development of women in STEM programs in relation to the leaky pipeline (Berryman, 1983) and its adoption from an educational metaphor into a way of accounting for the lack of senior-level women in STEM workplaces. To better understand how women experience the astronomy workplace, feminist theories of gendered technologies (Wajcman, 1991) and gendered workplaces (Acker, 2006, 2012) are explored in relation to the development of the modern astronomy workplace. While the discipline of astronomy is largely included in more general in women in STEM literature, this chapter considers astronomy and physics specific literature to further contextualise this study and provide a more nuanced understanding modern astronomy workplaces. As such, scholarly literature on gendered behaviours, discriminatory practices, and the industry of non-academic career pathways are explored to identify the knowledge gaps that frame this thesis.

2.1 How Leaky is the Pipeline?

Perhaps the most over-used metaphor to describe in women in STEM is that of the leaky pipeline. This relatively simple metaphor has been adopted by Australia and the United States as the cornerstone of women in STEM policies and initiatives. However, it has not been so enthusiastically adopted by parts of Europe (Husu, 2001), partly due to the simplistic nature of the metaphor and its fundamental flaw; that it does not account for the complexity of women’s lives. The mainstream adoption of the leaky pipeline by women in STEM literature has been widely criticised (Allen & Castleman, 2001; Bennett, 2011; Blickenstaff, 2006; Husu, 2001), yet persists and has developed into a short-hand to describe the lack of representation of women in scientific fields. In this context, the simple
linear representation and description of structural barriers becomes a powerful tool to educate people about women’s disadvantage within the sciences. Its usage is now similar to the ‘glass ceiling’ and ‘chilly climate’ metaphors which are widely used to describe women’s work environments and difficulties in career progression.

Originally conceived in a report by Berryman in 1983, the leaky pipeline accounted for the attrition of women and other minority groups such as “Blacks, Hispanics and American Indians” in advanced mathematics and science degrees. Ideally, minorities would “persist through the [educational] pipeline and field choice” (p. 39) to attain an advanced postgraduate degree. This failure to recruit and retain women and other minority groups needed,

Interventions that aid retention in the educational process [that] should therefore increase the representation of these groups among quantitative PhDs...

Policy makers can try to increase the group’s share of the initial mathematical/scientific talent pool by more than any increase in its attrition from it, or try to reduce the group’s attrition from the pool by more than any decrease in its share of the initial pool. (p. 5-6)

Berryman’s educational pipeline ideally recruits and retains a large number of girls from secondary school level and, through the removal of structural barriers and the repair of leakage points, this greater flow of minority students will then translate into a larger number of women and minorities in advanced postgraduate degrees. Berryman’s initial metaphor considers educational theory and engagement strategies that encourage women to work within the already structured scientific pipeline. The subsequent identification of attrition points and the pragmatic approach to increasing the number of minorities in STEM fields has been significant in the development of women in STEM programs over the last forty years, which have focused on removing structural barriers that have made it harder for women to ‘persist’ in the field. Bennett (2011) asserts that the leaky pipeline model

has acted as a means to focus policy intervention on certain stages of education and on organisational practices. It has also provided a concise way to unite different theoretical concerns, incorporating literature on the influence of sex-based stereotypes on education and labour market choices, and theories of women’s labour market activity and experience. (p. 151)

This unification of policy and theory has been the key strength of the leaky pipeline, which created a multidisciplinary focus on the experiences of women within the sciences and how
they navigate traditionally masculine STEM fields. Work in this area has identified the
gendered link between technology, its use and development in the workplace (Wajcman,
1991; Pettersson, 2011; Gonsalves et al., 2016), and phenomena such as impostor syndrome
(Clance & Imes, 1978) and the unfair distribution of gendered tasks within the workplace
(Acker, 2012). These workplace theories will be addressed below and more specifically
in relation to astronomy. Without the unifying focus of the leaky pipeline in science
education, many of these areas may have remained separate.

Despite its influence, however, the leaky pipeline can be seen to have two major flaws.
Firstly, it assumes that women conform to the shape of the pipeline and largely assimilate
into the masculine culture of science in order to progress. This perpetuates the problem
identified by Harding’s strong objectivity (1991), where the fundamental underpinning of
science is already highly biased. To change small aspects within a profession or discipline
in order to retain and promote women does nothing to fix the underlying problem with
how science is conducted, funded and rewarded. Allen and Castleman (2001), succinctly
identify the leaky pipeline’s main flaw as,

its failure to acknowledge the complexities of male advantage, gender power
and gendered nature of organisational dynamics, for its implicit incorporation
of a simple human capital approach to labour markets and for ignoring of
systemic and cultural discrimination. (p. 156)

Here, the human capital approach to flood the field with women with the view that there
will eventually be change is unrealistic. In addition to describing women’s education,
the metaphor “has [now] become the commonly accepted paradigm describing the attri-
tion of women along their career path in science.” (Bell, O’Halloran, Saw, & Zhao, 2009,
p. 33). The transition from an educational to career model is problematic and represents
a conformist viewpoint. Here, “women successful in traditionally masculine fields often
assimilate or are assimilated into masculine codes of honour” (Schiebinger, 1999, p. 77).
This assimilation is at odds with the Baltimore Charter, an astronomy-specific voluntary
code, that asserts women should not have to be clones of men to participate in astronomy
research (Albert et al., 1993). The goal to transform and promote women into competi-
tive senior scientists strongly favours the position that women should persist within the
sciences and that ‘leaking’ is an undesirable outcome. This imposes strong expectations
on women to stay and the implication of failure if they leak from the pipeline. Schiebinger
(1999) notes that pipeline scholarship focuses on why women leave science and that the
pipeline “does not account for successful women who, after achieving professional posi-
tions, choose to leave” (p. 62). It is my position that this expectation, and the stigma
associated with leaving, is not necessarily helping women within the field but discouraging
further non-conformist behaviour. PhD educated women may desire work in an interdisciplinary or hybrid position which is less highly gendered or try a different field altogether. By expecting women to conform to the pipeline it assumes that agency and motivation play a minimal part in decision-making and stigmatises women who fail to conform as ‘leaked’ when perhaps the term, as Marshall (2008) asserts, is indeed “escape”.

The second issue with the leaky pipeline is that it assumes that women are automatically motivated to continue along the pipeline when the barriers and filters are removed (Blickenstaff, 2006). This movement does not account for variations in motivation, agency, and the complexity of women’s lives after master’s level education. Until this point, due to the structured nature of education, the engagement, retention, and forward movement of girls and women benefit from initiatives along this linear pathway. It is the extension of the leaky pipeline into complex areas such as post-PhD careers where it becomes problematic. Though identified barriers, filters and leakage points are still present, other factors contribute to women leaving their PhD field that cannot be explained by women in a static pipeline scenario. Allen and Castleman (2001) argue that a completed PhD is both a collective and individual endeavour and “that both the distribution of postgraduate qualifications and the ways they are used for employment decisions are part of an integrated (and gendered) context, and not different stages and a neutral process that is employed by...pipeline arguments” (p. 154). The achievement of a PhD has many moving parts where women rely on large numbers of university staff, both academic and professional, complex interactions with members of their discipline, their personal support network and other responsibilities and setbacks that come with adult life. The assumption that minor structural changes to the pipeline are enough to increase women’s participation and promotion post-PhD is as false and limiting as the assumption that the only reason women pursue a PhD to become qualified to be an academic. This is not necessarily the case and employment post-PhD relies on a number of factors such as the labour market, particularly employment stability which is slowly becoming more precarious with the increase of casualisation at universities (Connell, 2013; Davies & Bansel, 2007; Standing, 2011; Vosko, 2010), personal work preferences, connection to people and places, and other factors such as health and responsibilities. These factors are not necessarily ‘leaking’ but reflect a re-prioritisation and redistribution of expertise into other areas. By dismissing agentic decisions based on factors that are not necessarily related to the pipeline, it undermines and devalues the decisions of women who choose to leave.

2.1.1 Pipeline Based Programs

It has been clearly established by feminist scholars that gender inequality is ingrained in the fundamental operating principles of science (Harding, 1986, 1991, 2004), and according
to Allen and Castleman (2011),

...the pipeline argument is still offered as an excuse for inaction or invoked to deny systemic gender discrimination...The danger of pipeline arguments is that they are often accepted, partly because they appeal to a simple common sense and partly because they reduce the discomfort of having to acknowledge gender inequalities and the need for further change. (p. 163)

By tinkering at the edges of work conditions, and not performing a dramatic overhaul of STEM disciplines, voluntary programs that benefit women and minorities do not significantly challenge the status quo and are generally more accepted within organisations. Though their effects are limited, and progress is relatively slow, voluntary programs can eventually make limited positive change to women’s work conditions.

During this research, both the Australian Academy of Sciences and the Astronomical Society of Australia have both launched versions of the British Athena SWAN Charter, which works on the pipeline principle of retaining women by improving participation and work conditions in the sciences (Equality Challenge Unit Athena Swan Charter, 2015). The Australian Academy of Science’s SAGE Pilot (Australian Academy of Science, 2015) is a voluntary nationwide program for scientific institutions which includes universities and government science bodies, such as the CSIRO. It aims to emulate its parent program, the Athena SWAN Charter, by increasing departmental and senior-level engagement in the process of improving gender equity, in panels for women’s promotion and review, the implementation of data collection structures, and the development of mentoring systems, leadership training, and maternity leave processes that target and benefit women (Munir et al., 2013, pp. 10-33). These are of benefit to women already employed within participating STEM organisations.

The implementation of the Australian SAGE Pilot has created new jobs such as administrative support positions and a number of women-only academic positions in maths and engineering fields to increase women’s faculty numbers (Metherell, 2016; Melbourne School of Engineering, 2018). The top-down equity hiring strategy aims to make long-term changes within the sciences by increasing women’s employment and targeted support to encourage retention and promotion. This pro-active strategic approach in addressing the shortage of women in maths and engineering is important but the long-term effect of these targeted hires is yet to be determined and it remains to be seen whether a significant cultural change will occur as a result. Much like creating gender-specific professional awards, however, there is a danger that overtly targeting a minority demographic may, in the eyes of their majority co-workers, devalue women’s accomplishments as they may be perceived as a shortcut that bypasses traditional meritocratic processes (Cadwalader, Herbers, &
This may, in turn, make the integration of staff employed by this method more difficult.

The Astronomical Society of Australia’s Pleiades Awards (Astronomical Society of Australia Women in Astronomy Chapter, 2014), also Athena SWAN influenced, is an astronomy-specific grassroots program that aims at establishing cultural change at a departmental, or school level. Here, proactive groups of volunteers seek to establish a departmental framework that is more inclusive of women’s needs. This process includes an acknowledgement of systemic bias within the scientific community, which is often explained to participants through the leaky pipeline metaphor, and discursive strategies to illustrate barriers and filters already established by pipeline research scholarship.

Presented as progressive policy, the voluntary SAGE and Pleiades certifications are highly desirable for competing institutions, which trade on their reputations for research funding and aim to attract exceptional staff and students. For those who work within the institution, participation in these schemes can potentially lead to better policy and work conditions. The issue, however, as a pipeline initiative, is that it only benefits those who have, or attain, long-term employment at institutions and has little value outside the career pipeline where many PhD graduates are located. Australian astronomy already has relatively high postgraduate numbers of women (37.3 percent in 2000-2004) for a physics-related field and this has not translated into a similar percentage of women working in astronomy post PhD (20.8 percent in 2014), let alone attain senior positions in the field (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 8). By focusing efforts on retaining women it ultimately restrains women by promoting the expectation that they will, or should, stay in the pipeline when most PhD graduates eventually transition into other fields. This way of thinking cuts off potential career resources and avenues that can be developed during postgraduate studies.

The pipeline has changed views of women’s education and work conditions. Though the pipeline metaphor is effective in encouraging students through a structured environment, the extension of its use into the workplace becomes problematic as it oversimplifies a linear pathway and diminishes women’s agency in decision-making and career choice. To account for agency, Hakim (2000) developed “preference theory” as a potential predictor of women’s work preferences and labour market patterns. She argues that “Individualisation frees people from the influence of social class, nation and family. Agency becomes more important than the social structure as a determinant of behaviour” (Hakim, 2006, p. 286). Much like the leaky pipeline’s elevation of structural barriers, Hakim’s theory focuses closely on agency and what could potentially happen when structural barriers are no longer the main issue. Neglecting the significance of structural barriers has prompted deep criticism of the theory by the sociological community (Crompton & Harris, 1998;
McRae, 2003; Crompton & Lyonette, 2005; Leahy & Doughney, 2006; Kan, 2007) Certainly, it seems Hakim’s theory is at best highly optimistic about the importance of agency and choice while the leaky pipeline simplifies women’s lives and underestimates the importance of agency in relation to employment. Both are important, but it is how women navigate structural barriers, create narratives, and exert agency in their lives and careers that are of interest in this thesis. By examining women’s standpoints, and how they experience complex decision-making factors outside the limitations of pipeline theory, this thesis better accounts for the complexity of women’s lives and how they perceive these decisions.

2.1.2 Building on to the Pipeline

The leaky pipeline is among many metaphors that attempt to account for women’s career movement. Husu (2001), however, warns that metaphors fall short in their inability to address “covert, informal and subtle cultural structures and processes that produce and reproduce inequalities” (p. 176). Easy to remember, metaphors and descriptors of women’s academic work environments have yielded ‘the chilly climate’, ‘the glass ceiling’ and other lesser known metaphors that Husu details as illustrative in that they compare women’s experiences to that of men within the workplace environment. This key issue, that metaphors are usually comparative and only describe inequality, is where women in science literature differs from other feminist considerations such as feminist standpoint theory (Harding, 2004) and situated knowledges (Haraway, 1988), which give preference to women’s experiences alone instead of in comparison to men.

At the risk of also using an ineffective metaphor, it is tempting to build new models that account for women’s career movement post-PhD on to the end of the leaky pipeline. This is quite literally building on flawed, or leaky if I may, foundations. Two of the more recent additions, that directly account for women in science are the “vanish box phenomena”¹ (Etzkowitz & Ranga, 2011) and “the roundabout” (Barthelemy, 2014) have both identified a major flaw; the linear accounting of women’s academic careers. Although still limited, these models do provide non-linear alternatives that better reflects careers outside the academy.

¹This title, though clever as it envisions the magician’s trick of the disappearing woman, is poorly chosen due to the gendered nature of traditional stage magic. Here, the tuxedo-clad male magician controls the trick as his conventionally attractive scantily clad female assistant seemingly follows instructions and poses seductively for the visible duration of the magic trick. While the non-linear concept is interesting, the visual nature of the metaphor is ironic and takes away from its potential use within women in STEM career programs.
In contrast to the leaky pipeline which presumes a largely static structure of science and technology and narrowly focuses attention on academia, the vanish box describes a dynamic social structure of science and technology, in which the ‘leaks’ or ‘drips’ are not necessarily a failure, but a re-direction of scientific potential and talent to other economic and socially valuable areas (Etzkowitz & Ranga, 2011, p. 142). That women’s potential is redirected and not necessarily a pipeline failure, is a concept that has influenced the development of this thesis and is present in other career pathway models. It is the application that differs, more specifically, its relation to the leaky pipeline, which is still present at a PhD level in both the vanish box and the career roundabout (Barthelemy, 2014).

The complicated four-stage process of the vanish box (Etzkowitz & Ranga, 2011) builds on the leaky pipeline as the first stage, with leaks as a catalyst for women to leave their academic fields. Secondly, it then invokes the Marxist (1867) concept of surplus workers who build a ‘reserve army’ that are ready to fill labour shortages. In this case, it refers to the surplus of highly educated women who are searching for non-academic employment. Thirdly, the vanish box considers structural, organisational and individual change, which marks the discrete creation of new industries and professions, that due to their newness and lack of prestige, offer more attractive working conditions for women. These conditions can be flexible work hours and interdisciplinary positions that are not yet subject to gender queuing theory so have little competition from men (Reskin & Roos, 1990). Finally, the metaphor sees women reappear in these newly created industries which, due to the relative newness of the industry, offer very little career growth or prestige for women employees.

Aside from being unwieldy and complex, Etzkowitz and Ranga’s (2011) vanish box indicates that women are willing to take lower paying and less prestigious positions in upcoming industries that are more women-friendly. Although the vanish box describes a value-free redistribution of labour, it also places a hierarchy on jobs that women choose which is defined by industry prestige in relation to masculine career ideologies. Here, the vanish box fails the same way as other metaphors; by comparing women’s and men’s career prestige (Husu, 2001). This metaphor, which has many moving parts combines several dynamic elements to account for women’s career movement as found in their longitudinal UK study. Though perhaps due to its niche market (academic women transitioning into new hybrid industries) and complexity, this metaphor is not popular. It does, however, illustrate that the redistribution of women’s labour market capital is reactionary and linked to multiple factors that work in a non-linear discrete fashion. This differs from my thesis, where discrete factors in finding employment are uncovered as women never ‘vanish’, and that women’s choices are not categorised by prestige, but other employment factors. Other work by this group on the innovation “triple helix” (Ranga & Etzkowitz, 2013) seeks to optimise the relationships between government, universities, and industry in relation to innovation in the creation of knowledge. In the context of their research collaboration’s
greater goals, women’s careers are only a small part of a larger function that extends beyond the scope of this study and into the nature of research, partnerships, and funding.

While the vanish box (Etzkowitz & Ranga, 2011) seeks to account for complex non-linear factors of women’s post-science careers, Barthelemy’s (2014) career ‘roundabout’ seeks to re-frame women’s career choices after completing a PhD. In this model, a roundabout, like the vanish box, is also attached to the end of the leaky pipeline. The conclusion of postgraduate study serves as a catalyst for women to disburse into different careers. Barthelemy (2014) suggests that:

> the career pathways of these women need to not only be seen as having a variety of options, but options of equal merit that take into consideration the desired lives and potential families these women want to build. (p. 98)

This approach to the re-distribution of women’s labour post-PhD challenges the expectation that women should want to stay in the pipeline post-degree to become an academic. Barthelemy’s concept was then furthered in a pilot study that attempted to project women’s career pathways post-astronomy PhD (Barthelemy, McCormick & Henderson, 2014). By positioning the roundabout at the end of the leaky pipeline, with the completion of the PhD as an endpoint, it avoids critical issues of the pipeline’s use in the labour market (Allen & Castleman, 2001) and attempts to move scholarship beyond the leaky pipeline (Bennett, 2011) to a more complex, nuanced, and non-linear understanding of career choice.

Building new metaphors on old does not, however, address the overall problem of agency within the pipeline. The roundabout model delays the conversation until a catalyst, or exit point, such as the completion of a PhD and in effect ignores tensions that arise during the PhD process, where career decisions are often actually made. New metaphors may potentially map career pathways and trends, but they do little to uncover decisions, actions, and barriers when transitioning from the PhD to non-academic careers. While illustrative and easy to understand, the use of metaphors as a primary influence on policy to account for women’s lives and decisions is inadequate. These approaches drive career expectations in a certain direction, which may or may not be desirable for the graduate/employee and sends conflicting messages regarding conformity and work. Here, although small changes are made to work conditions, women still must, to some degree, conform to the masculine norms of STEM fields in order to progress. This level of conformity can be at odds with other factors in their lives and devalues the decision-making processes of what are elite scientists.
In the next section, I will consider modern day astronomy workplaces and the complex factors that shape women’s involvement that are sometimes included in the leaky pipeline metaphor as examples of barriers and leakage points.

### 2.2 Modern Astronomy Workplaces

Present day astronomy is vastly different from the early years of Australian astronomy and technology has progressed rapidly to deliver large quantities of information. The astrographic plates have been superseded by digital images, painstaking hand calculations have been turned into computer coding scripts, and data modelling can now be conducted on both regular and supercomputers. Modern telescope facilities are larger and can gather more data for analysis than ever before. In Australia, the state-run observatories, which were essential for the Astrographic Catalogue, are now tourist attractions, historical museums, and archives.

While the technology and employment policies may have changed since the AC and days of Payne-Scott, there is now more lower level work that needs to be conducted cost efficiently. This labour, previously conducted by women astrophysicists, is now conducted by university postgraduate students who often join working teams of astronomers at a junior level over the course of their studies. Here, they conduct research assistant work in data reduction where they get a casual wage that supplements scholarships, publication credit for work done, and access to data and networks. This labour, undertaken as part of their PhD research or as a casual position seems ideal while they transform from a student into a researcher. This casualised model of research is not unique to astronomy and is part of a well-established system within the tertiary education sector. Doctoral students also conduct teaching as casual or sessional work in universities, which both employ them as academic staff yet divide them from the permanent workforce (Ryan, Burgess, Connell, & Groen, 2013; T. Brown, Goodman, & Yasukawa, 2010; Coates, H., Dobson, I. R., Goedegebure, L., & Meek, 2009). These precarious contracts, which often seem beneficial in the short-term actually mean that there is no need for institutions to create permanent jobs that could employ students post-graduation.

Women in STEM and greater academic literature universally acknowledge the importance of structural barriers that contribute to a lack of women in the field (Baker, 2012; Etzkowitz et al., 2000; Schiebinger, 1999). When combined with the gendered nature of workplaces (Acker, 1992, 1990, 2006, 2012), the gendered development, and use of technologies (Wajcman, 1991; Pettersson, 2011; Danielsson & Linder, 2009; Gonsalves et al., 2016), however, it is clear there is a more nuanced problem of not only numbers but also
how women interact with science and more masculine fields of work. These gendered barriers, which are organisational, disciplinary, and institutional, are not unique to astronomy, but similar for women across all fields and are thus heavily documented and researched (Koch, Muller, & Sieverding, 2008; Baker, 2009; Dever & Morrison, 2009; Vosko, MacDonald, & Campbell, 2009; Mervis, 2012; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Hutchison & Jenkins, 2013). Instead of a comprehensive review of these universal women and work barriers, I will focus on astronomy-specific issues with the caveat that most of these occur to various extents throughout all women’s high-level professional work, are not necessarily unique to astronomy, and have been recently identified in women in STEM, astronomy, and physics research.

2.2.1 Inequality Regimes and Gendered Workplaces

It has been clearly established that the sciences, particularly physics and mathematical disciplines, have a shortage of women. Harding’s (1991) strong objectivity and the over-adopted leaky pipeline both posit that the reason for women leaving, or not joining, these fields is the androcentric nature of the field, and the entrenchment of social and political inequalities within. Though feminist standpoint theory and STEM education offer broader perspectives of how women experience the workplace, organisational management theory offers targeted explanations of the mechanisms that influence women’s workplaces and entrench inequality. In this section, I will examine key elements of Acker’s work on inequality within the workplace. This work in the field of organisational management and feminist theory demonstrates that there is overlap between women in work and women in STEM scholarship that slightly shifts the focus from retentive and exploratory strategies to analytical perspectives that position women differently within the workplace.

The astronomy case study that is the core of this thesis is situated within a higher education and workplace context. Moreover, the case study identifies work opportunities and women’s transition into other fields of post-astronomy employment. Applying organisational management theory to doctoral experiences creates a focal shift from learning experiences to a work-oriented notion of acceptability and accountability within organisations. Here, the goalposts are different because workers, colleagues, and supervisors have a different power dynamic to students, academic supervisors, and their peers. In this context, levels of acceptable (and enforceable) behaviour, protocols and best practice vary considerably. This analytical strategy is influenced by Acker’s body of work on gendered organisations (1990, 2000, 2004, 2006, 2009, 2012).
Acker’s (2006) “inequality regimes” is a feminist organisational theory that seeks to explain layers of workplace inequality and asserts that it is difficult for organisations to overcome entrenched practices that perpetuate structural unfairness. Acker asserts that inequality can “be attributed to gender, race and class inequalities and although patterns differ in various organisations there are two characteristics that rarely vary: Class inequality, inflicted through gendered and racialised beliefs and practices” (p. 459). The link between gender, race and social class is also a fundamental pillar of intersectional feminism (Crenshaw, 1991), where complex, socially constructed categories accumulate to establish inequality. Acker maintains that to “consider only one of these factors oversimplifies and obscures interpenetrating realities” (p. 442). The recognition of the intersectionality of race, gender, and social class is what defines her theory and identifies why the issue of gender inequality is so difficult to address in the workplace. Acker observes that a single-pronged approach (for example, a race or gender initiative) is less effective in establishing workplace change than an intersectional approach. Although it may target an unequal group, a singularly focused initiative does not adequately address other intersectional elements, such as social class, which are intrinsically linked to both race and gender inequality.

To practically administer an intersectional program is difficult, however, and the established method is generally to address the largest element first then refine and expand. In the case of science, the focus has been on gender inequality. The ASA’s Women in Astronomy Chapter (WiA, 2015) adopted this strategy. Firstly, it implemented the Pleiades Awards as a gender-based initiative then, a year later, changed its name to the ASA Inclusion, Diversity and Equity Chapter (ASA IDEA, 2016) which identified additional intersectional categories such as race and LGBTI inclusive strategies for further initiatives.

Both Acker and Harding (1991) view industries, such as science and business, through “gendered substructures” (Acker, 2012) that produce barriers that enforce gender inequality. While Harding (1991) relates these substructures to the maintenance of structural and historical bias of science, Acker (2012) makes a further distinction between occupation (the official title) and jobs (the actual tasks performed) which is crucial in examining astronomy labour dynamics. These interactions can be further identified as institutional, or as direct controls that are obtrusive and include rules, punishments and rewards to alter workers’ behaviour. This type of control is entrenched in organisations and is presented as managerial rules and expectations. These rules are both explicit and implicit, and advantage the “ideal worker”, that is, an unencumbered worker that is a primary earner (Vosko, 2010) and disadvantage those who seek more flexible employment. Flexible workers who are usually women still tend to be the primary carers of family members and, as they often have competing priorities outside of work, are not considered ‘ideal’ workers. This distinction creates what is widely recognised as the ‘female ghetto’, where women are
trapped at lower levels with little prospect of promotion compared to their more ‘ideal’ colleagues (Schiebinger, 1999; Acker, 2000). Acker identifies indirect controls within the workplace such as technology monitoring, access, and selective recruitment. While many of these indirect controls are regulated by anti-discrimination policies, it is the complex mechanism of indirect control that further entrenches Acker’s (2006) inequality regimes as they are increasingly subtle and culturally situated.

Acker’s (2006) approach views race, gender, and social class as inextricably tied and examines programs from an organisational or institutional perspective above that of the individual. Although my case study does not include many intersectional factors such as race due to the relative homogeneity of Australian astronomy, it does include social class and mental health factors that affect both PhD studies and the workplace. This mixed analytical strategy provides a comprehensive and targeted analysis of PhD progression in a workplace context, which is how interviewees described their institutions during their studies. The classification of a PhD institution as a workplace separates this from other higher education literature which views interaction in the context of learning environments. Acker’s work provides a resource that feminist standpoint theory can utilise when ‘studying up’ to create a standpoint of women’s experiences.

2.2.2 Gendered Technology: Physics and Astronomy

As highlighted by the historical section of this review, one of the key gendering factors in astronomy has been the development and use of technology. Here, “male dominance in technology has in large part been secured by the active exclusion of women from areas of technological work” (Wajcman 1991, p. 35). This exclusion has divided observational astronomers (the men who used the telescopes), and the astrophysicists (women who did the calculations). Through recent developments of computer technology and automation, most observing is now conducted remotely and does not actually involve operating the telescope. This is a potential equaliser in the field of astronomy. Much as Harding (1991) observes the androcentric bias within science and Acker (2000) considers this same bias in organisational management, Wajcman (1991, 2004) engages with technologies, and in particular with the social biases that underlie its development and usage. Wajcman argues,

> technology is more than a set of physical objects or artefacts. It also fundamentally embodies a culture or set of social relations made up of certain sorts of knowledge, beliefs, desires and practices. (Wajcman, 1991, p. 149)

So, while the technological object itself may appear relatively neutral, the culture surrounding it is highly gendered. Much like the development of science, technology by
extension is overtly masculinised. The addition of gendered technologies to this study extends feminist standpoints (Harding, 1991) into a more nuanced disciplinary perspective of how technology influences field and career choice.

Wajcman (1991) observes that machines and technology are still considered to be masculine domains. Here this culture “transmits meanings and values that identify masculinity with machines and technological competence” (Wajcman, 1991, p. 151). Like the example of the women of the Astrographic Catalogue (Stevenson, 2016) and the ‘lady computers’ (Ensmenger, 2013), Wajcman’s work builds on Cockburn’s (1983) historical account of the printing press, and other parables of technological development and exclusion. Wajcman observes that “in our culture to be in command of the latest technology signifies being involved in directing the future so it is a highly valued and mythologized activity” (p. 144). Because of its ascribed value, the generation of computer technology has been dominated by “hegemonic masculinity” (Connell, 1987, pp. 186-186) which is described as “a social ascendancy achieved not by force but by the organisation of private life and cultural processes” (Wajcman, 1991, p. 143). This differs from “practical masculinities” (Wajcman, 1991, p. 143-144; Danielsson & Linder, 2009, p. 137) where men assert their dominance through mechanical competencies. The extension of technology into the elite physics/astronomy laboratory provides an overlap between industrial technology and computers, which are by extension ‘professional masculinities’ that centre around logic and technical expertise. It is this type of masculinity that is the dominant form in theoretical physics and astrophysics.

Though no studies in this field have specifically centred on astronomers and technology, other physics disciplines have been the subject of research. Pettersson’s (2011) study of masculinity and experimental plasma physics noted that practical masculinities disadvantage women in the lab because “a person with experience of building experimental devices and machines is defined as a highly valuable co-worker.” (p. 57). Danielsson (2012), who also studied laboratory physicists, which Urry (2011) asserts are more hierarchical than astronomers, observed that laboratory physics was less gendered than plasma physics, which uses bigger, heavier technologies. Women in experimental labs tended to undertake a large amount of gendered work such as note taking and were less active in experimentation. This disciplinary preference for ‘practical’ workers potentially holds the key to understanding women’s physics field choice. Here, the contrast between active (plasma/experimental) and passive (theoretical/astrophysics) areas of physics may partially explain the popularity of astronomy for women.

Current technology-centred physics literature focuses on gendered learning styles in educational postgraduate physics fields (Danielsson, 2012; Danielsson & Linder, 2009; Pettersson, 2011; Gonsalves Danielsson & Pettersson, 2016). By using Wacjman’s theory of
gendered technologies these studies have been able to identify that women do have different interaction with technologies than their male counterparts especially in more masculine areas of physics. Gonsalves, Danielsson, and Pettersson (2016) conclude that “many students and practitioners in physics operate largely within individualistic discourses that attribute success and academic achievement with individual skills and motivation” (p. 020120-13). These skills can be both intellectual and technical. Physicists do not necessarily view their behaviours as gendered as they are just ‘doing physics’, their field of study or work. In these studies, the construction of individual discourses, or narratives, contextualises how physicists interact with technology, each other, and their self-perceived position within the discipline. While their experiences are certainly gendered, this is an inherent and accepted part of the culture of the field that they choose.

While large complex machines are still highly masculinised, digital technologies, like those developed in the astronomical sciences, are not so easily divided between masculine and feminine. Wajcman (2010) explains that “gender relations can be thought of as materialised in technology, and masculinity and femininity in turn acquire their meaning and character through their enrolment and embeddedness in working machines” (p. 149). This importance and embeddedness differs between technical fields. In astronomy, for example, the development and use of technology is a by-product of researching astronomical phenomena and not, as in engineering, the product itself. The distinction is important on multiple levels. Firstly, it is facilitation technology and programming with a specific purpose that is not primarily developed for commercial application. Secondly, it solves a very distinct aspect of viewing/explaining/exploring theoretical concepts such as how the universe works, which constantly changes as understandings progress. And thirdly, as most astronomy uses computer coding, there is a large pool of shared data, computer code (for example, Github) and collaborative work on the technical aspects of programming. The ambition in astronomy is not to create the best computer code, but to discover a previously unseen element of the universe. This focus differs considerably from generating proprietary programs, processes, and knowledge. While the application of theory and gathering data is competitive and important, there is a clear distinction between analytical digital technologies and advanced mechanical technologies (telescopes, spectrographs etc).

Although it is still considered a mystery as to why more women choose astronomy over other areas of physics (Barthelemy et al., 2013), their choices can also perhaps be linked to technologies and their use. Like other areas of physics, astronomy is hierarchical and uses multiple advanced technologies that range from large, state-of-the-art equipment to simple personal computers. This connection is a potential avenue to help ascertain why women choose this field. Presently, women generally choose more theoretical fields such as astrophysics and radio astronomy and dedicate a higher proportion of their combined research effort to extragalactic astronomy (26 percent) than males (18 percent) (Australian
Extragalactic astronomy, that is the study of galaxies outside our own, is a largely theoretical field that utilises large telescopes, often operated remotely by computer, and a high-level of theory and coding. It also has the benefit of using pre-existing survey data, which can cut out the need for competitive telescope access thereby making it a more accessible area of study. Of course, there are some gendered hierarchies within this field that are primarily to do with networks and access to prestigious instruments, which currently lie outside the scope of this thesis. It is, however, important to note that the field of astronomical instrumentation is highly gendered as “males dedicate a higher proportion of their combined research effort to instrumentation (14 percent) than females (7 percent)” (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 27). This relationship between man and machine, or the elevation of practical masculinity, may account for the lack of women within instrumentation fields that are a hybrid of physics, astronomy, and engineering.

The combination of feminist standpoint theory (Harding, 1991), gendered workplaces (Acker, 2012) and gendered technologies (Wacjman, 1991) focus on multiple aspects of women’s experiences within the astronomical sciences. The complex relationship between institutions, technologies and the discipline itself interact to form a PhD educated scientist who will either try and stay in the field or branch out into different employment post-graduation. The addition of gendered technologies to complement other feminist theories allows for a more nuanced analysis of the highly technical area of astronomy and how women’s relation to technology shapes their profession post-degree.

2.3 Experiences of Women in Astronomy

Women’s experiences within astronomy vary dependant on factors such as field of study, institutional culture, and geographic location. In the previous sections, I have discussed a recent handful of scholarly studies that specifically sought to capture the experiences of working women astronomers and astronomy doctoral students. This includes studies on women in physics that inadvertently capture astronomers as part of the larger discipline. For the most part, information regarding women in astronomy comes from reporting data from professional associations such as the American Institute of Physics (AIP), The American Astronomical Society Committee for the Status of Women in Astronomy (AAS CWSA) and the International Astronomy Union (IAU). Most of this data is US-centric as they have more comprehensive reporting processes in place for the discipline. In Australia, reporting data comes from the Astronomical Society of Australia (ASA) and the
Australian Academy of Science (AAS).\textsuperscript{2} Though this reporting data provides quantitative information on the status of women and the gender imbalance within the field, I am going to concentrate on peer-reviewed literature, astronomer generated content such as media releases, social media movements, and policy. All of which have directly impacted on women’s experiences within the field of astronomy.

\subsection*{2.3.1 Discriminatory Practices}

Male advantage is a relatively acknowledged concept within the women in astronomy literature which focuses on structural barriers and discriminatory practices within the astronomy community. While there are larger case studies on the sciences (Etzkowitz et al., 2000) and detailed feminist accounts regarding the androcentric history and structure of science (Harding, 1991), astronomy-specific literature is essential in providing evidence, mostly to those who are in the dominant paradigm, that inequality and gendered barriers still exist in the field. In the case of scholarly literature, there is only a relatively small amount that directly focuses on astronomy. The major driving force of information for astronomers comes from professional associations as the American Astronomical Society’s Committee on the Status of Women (AAS) (American Astronomical Society, 2014), Women in Astronomy Blog (Patterson, Thomas, & Flewelling, 2018) and Astronomical Society of Australia Diversity in Astronomy Chapter (ASA IDEA) (Astronomical Society of Australia, 2018b). Their mandate, to improve conditions for women within the discipline, has been ongoing through virtual communities, annual meetings, and the provision of supporting literature and resources. It is not in the scope of this review to assess these resources, though it is important to note that this astronomer generated content is publicly available.

Perhaps the most public issue that has arisen during the course of this research is a number of high-profile international astronomers, namely Geoff Marcy and Christian Ott, who were found guilty of multiple sexual harassment allegations (Wilson, 2015; Urry, 2015; Witze, 2015, 2016). The public discussion of these high-profile cases has made the discipline of astronomy reflect on sexual harassment policy and has spread international awareness of these incidents. This new dynamic has been further encouraged by the \#metoo movement (Burke, 2018), which emerged during the writing of this thesis. This movement has demonstrated that sexual harassment is prevalent in all areas of employment.

\footnote{Astronomy is very well known for its over-use of acronyms, especially a high number of As. This means that America, Australia, and astronomy occur frequently. This generates a lack of clarity and the same acronyms for multiple places. A key example is the newly formed Australian Space Agency, which shares the same acronym as the Astronomical Society of Australia. Acronym confusion is all part of the daily experience of astronomers.}
and that no discipline, even elite sciences, should consider themselves immune. The rise of large digital communication platforms, such as Twitter, has further enabled women to have their voices heard and to publicly discuss incidents and institutional reactions. Presently it is unclear whether these public accounts of harassment will drive institutional and disciplinary change or whether, once the storm abates, it will continue to be, as Harding (1991) calls it, “science as usual” (p. 54).

While the Marcy and Ott cases were specific examples of sexual harassment in the United States, a relatively obscure research paper by Gaspani (2014) about the gendered organisation of Italian astronomy, illustrates a problematic snapshot of gender dynamics and the harassment of women. Gaspani explores the role that gender plays in the Italian astrophysical sector to examine women’s careers and contextualises their identity construction. By interviewing twenty men and twenty women astrophysicists, this representation of women in astronomy, as told to an Italian male, is alarming and overtly sexualised. In comparison to its British, American, and other European counterparts (Barthelemy, Grunert & Henderson, 2012; Barthelemy, McCormick & Henderson, 2014; McCormick, Barthelemy & Henderson, 2014; Fohlmeister & Helling, 2012; 2014, Murillo et al., 2012) the Italian study shows an overt gender bias embedded in a culture that values women for their physical appearance and roles as mothers and wives over their technical competence in the sciences. It was observed that while the undertaking of “scientific activity is a significant source of self-esteem” (p. 498), it is also considered counterproductive as “excessive involvement in science can often make women feel guilty” (p. 500). Gaspani asserts that this has led to an increased willingness by women to sacrifice their careers for a more socially acceptable family role. Due to the deidentification of data, it is unclear in this study whether these assertions were from male or female interviewees and which analytical standpoint the researcher took besides demonstrating the gendering of astronomy through experience. There was also a strong association between nepotism with women’s success and the assumption that they had used their sexuality to gain senior positions (p. 495). This contrasts with the idea of meritocracy within the sciences, which is what Castilla (2010) calls a paradox, when it is unquestioningly assumed that ‘the best man for the job’ is indeed ‘the best man for the job’. This is due to structural inequalities that elevate men’s achievements above those of women. In Italy, it seems that the best man for the job is still a man, unless it is a woman, then it is assumed that she most likely didn’t legitimately earn her place.

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3 At the time of writing, there were at least three ongoing Twitter conversations regarding specific examples of harassment within the discipline of astronomy and the lack of institutional support and progress. This is a possible avenue for future research.

4 Astrophysics is interchangeable with astronomy in this context.

5 Also known as Rossiter’s (1991) Matthew and Matilda effect.
Gaspani’s article is problematic and it is unclear to what extent the translation limits nuance, lexicon and grey areas of meaning (Eco, 1990). Gaspani does illustrate the organisational point that Acker (2012) makes, specifically that the field is still highly gendered. For a relatively international discipline where migration for work is common, competing workplace experiences, expectations, and culture between countries and institutions are brought into conflict with potentially damaging results.

In the United States, astronomy focused scholarly literature confirms that women in astronomy are still subject to workplace power differentials, which assert themselves with varying levels of visibility. McCormick, Barthelemy, and Henderson (2014) posit that as more overt aggression and gendered behaviour becomes less acceptable, and thus less common, women PhD students then experience discrimination in physics and astronomy departments through microaggressions. These microaggressions manifest in three main forms: microinsults (where unconscious bias drives inadvertent aggression), microassaults (where aggression is targeted), and microinvalidations (where women’s gendered experiences are dismissed as being imagined). These subtle power inequalities were also identified by Fohlmeister & Helling (2012; 2014), who focused on the ‘helpful’ and ‘hindering’ career experiences of female astronomers in Germany and the UK. Although not necessarily subject to the same aggressively gendered environment as Italian women (Gaspani, 2014), women in both studies were aware of gendered substructures that influenced their lives and careers. Acker (2012) describes these behavioural structures as indirect controls, where more obvious examples can be reduced by anti-discrimination policy. As such, more subtle and culturally situated forms of indirect control become harder to prove. To uncover these more subtle biases, feminist scholarship, especially standpoint theory (Harding, 2004), finds its current niche and highlights the complexity of women’s experiences. Barthelemy, McCormick, and Henderson further suggest that “those who report their experiences of microassaults were often ignored and left to survive for themselves” (p. 38). This issue of institutional support and validation will be taken up in Chapter Four where interview data from this study adds to the field.

Astronomer centred studies, which almost always take place in universities, illustrate that although women have made recognised contributions to the field, and have relatively high postgraduate numbers, the presence of sexual harassment cases indicates that the discipline does still have a ‘gender problem’. Fortunately, both female and male astronomers have participated in the discussion regarding harassment to send a message that overt harassment is not acceptable within the astronomy community. While workplace changes are progressing, however, there are more subtle cultural barriers to overcome for equality, especially in such an international discipline.
2.3.1.1 Networking

As evidenced by the importance of Twitter in the previous section, digital technologies show a great deal of potential in relation to facilitating astronomy networking. To continue working in the field, professional networks and collaborations are essential in obtaining a job. In a data science study, Murillo, Gu, Guillen, Holbrook, and Traweek (2012) use an interdisciplinary approach to trace astronomer movement and networks, which they refer to as “meshworks”. Computer science focused, the study uses “native astronomer language”, or astroinformatics, as a tool to communicate data findings and utilises Haraway’s (1988) concept of situated knowledges and the partial perspectives of knowledge generation. Using multiple sources such as publicly available CV data, Google Scholar publication data, and interviews, the study explores how data visualisation languages represent networking data. Also conducted in the US, initial results in astronomer movement and interaction are of interest and three main patterns start to emerge:

a) patterns in movement by individuals, showing clustering by gender, ethnicity, and nationality; b) patterns in mentorship practices across generational cohorts, showing clustering by gender and ethnicity; and c) patterns in co-authorship, showing that under-represented astronomers in large collaborations tend to be women and foreign-born astronomers (Murillo et al., 2012, p. 48)

These cluster patterns indicate that minorities tend to mentor and network with each other and that women and foreign-born astronomers are under-represented in large collaborations. The paper’s original intention was to assess whether an underrepresented group had tighter professional meshworks than European American men (p. 37) and though this paper shows initial patterns in understanding meshworks in relation to careers, its main recommendation was that more work was needed on career trajectories of underrepresented astronomers. This was a two-year pilot study which, from available data, does not appear to have been expanded upon. It does, however, link minority networks together in a tangible fashion. It also raises questions about; how minority sub-networks influence postgraduate student astronomy field choice and subsequent job prospects post-completion. These issues are explored in Chapters Four and Five of this thesis.

Astronomers’ choice of field relies on several factors that are primarily to do with opportunity and pre-existing post-graduate institutional networks. A variety of interlinked influential factors have been identified; including research funding availability, mentorship opportunities and personal encouragement (Barthelemy et al., 2013; McCormick et al., 2014; Gu, 2012). Regarding networking, mentor choice is critically important and allows access to networks through the “halo effect” (Cooper, 1981) where students gain status
from the reputation of their mentor/supervisor. This is most beneficial when the mentor is a senior astronomer who is connected to large networks that have status and funding. Etzkowitz, Kemelgor, Neuschatz, Uzzi, and Alonzo (1994) argue that to achieve a strong minority, or critical mass for change dynamics, numbers over 15 percent are enough (p. 51). This idea, which is a key concept for the leaky pipeline (Berryman, 1983) method of retaining women, assumes that critical mass will be enough to create change and influence other minorities to participate in the sciences. Etzkowitz et al (1994) cites sub-fields of science such as biology and chemistry as examples of this success arguing that “These fields tend to be ones that women select or are subtly or not so subtly directed into. In a snowball effect, as numbers increased, more women were attracted.” (p. 52). This, however, creates a paradox. Without changing the underlying structures of science, women become isolated and do not necessarily network with other women. This leaves them as individuals rather than a critical mass and therefore less able to affect change. Networking within the sciences is complex and there is currently a lack of knowledge about disciplines like astronomy, which have attained critical mass, and how these minorities bolster their networks beyond their immediate peer groups. As Murillo et al (2012) suggest, this is another potential avenue for further research.

2.4 Career Pathways Outside the Academy

The most problematic issue with studying PhD graduates who pursue non-academic careers is that they leave academia behind and focus on their new positions. This makes them difficult to find. Positioning their ‘loss’ from the PhD field as part of the leaky pipeline means that once potential participants have left academia they move forward in different professional circles. Czujko and Anderson (2015), as part of the PhD Plus 10 study conducted by the American Institute of Physics, located 503 physics PhD alumni ten to fifteen years after graduation in an attempt to account for long-term career movement (p. 7). While they were largely able to locate participants in the government and academic sectors, they observed that there were three primary reasons to account for a lack of data for physicists who worked in the US private sector; Firstly that it was difficult and expensive to locate people after they have been out of the university system for a decade, rather than students who were more available. Secondly, because PhD educated physicists mostly pursued a wide range of careers in industry, they were not necessarily affiliated with professional societies. Finally, that industry is more proprietary of employee data than universities and government research facilities, and that policies were in place to protect contact information (Czujko & Anderson, 2015, Appendix). Here, Czujko and Anderson highlight why there is very little research on non-academic career pathways of
scientists. During their PhD, scientists’ career interests diverge from the expected academic pipeline into other fields, yet PhD programs are slow to reflect this (Gibbs & Griffin, 2013; Fuhrmann, Halme, O’Sullivan, & Lindstaedt, 2011; Sauermann et al., 2012; Roach & Sauer, 2017). In addition, sociological studies in the area of physics establish that the attrition of women post PhD is well documented through professional association surveys by the American Institute of Physics and the National Research Council (U.S.) Committee for a Decadal Survey of Astronomy and Astrophysics (Ivie & Arnell, 2011; Ivie, 2014; Ivie & White, 2015; Ivie, White, & Chu, 2016). This data and follow up surveys are informative and follow an established pattern of monitoring career attrition and explaining why women choose to leave. Commonly identified factors for physicists changing fields are:

(i) completing a postdoc, (ii) time since degree, (iii) the imposter syndrome, (iv) mentoring and advising during graduate school, and (v) the two-body problem, which occurs when spouses or partners have difficulty finding jobs in the same geographic area. (Ivie et al., 2016, p. 020109-2)

This type of research still primarily focuses on why women leave rather than on where they go and how they get there. The career outcomes of graduates vary by geographic location and field of study and as shown earlier, in relation to gendered technologies, not all areas of physics attract and produce the same type of graduates. Ivie et al (2016) describes the problem that by studying attrition in relation to larger fields of science leaves “smaller fields such as physics and astronomy...buried among trends for larger fields that have much different economic prospects” (p. 020109-2). Astronomy as a discipline is varied and compared to optical physics, for example, there are very few astronomy research related or laboratory job prospects. Graduates must instead rely on the coding and interpersonal skills that they have learned during their doctorates for employment and how they transition is largely hidden.

Non-academic employment trends are not easily obtainable through reports and statistics collected by professional associations. In Australia, professional association data and reporting lists a significant number of graduate outcomes as “unknown” (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 10). Barthelemy, McCormick, and Henderson (2015), who work in the field of education, navigated the problem of finding ‘lost’ astronomers by interviewing current postgraduates about their projected career pathways. An approach that was like Fuhrmann et al. (2011) in the biological sciences. This study built on Barthelemy’s (2014) concept of a career pathway roundabout, which mapped potential pathways. While a methodologically convenient method of exploring career motivation and pathways, this type of research does not adequately reflect actual career pathways, transitional stages, and women’s experiences during the change
process. Investigating the pathways that have been taken, rather than predicted ones may, in fact, be a more valuable method to achieve the research goal; changing the status of non-academic pathways as an equally weighted career prospect.

2.4.1 Non-Academic Career Industry

Although locating non-academic career PhD graduates for university research can be problematic, there is an industry that caters for this transition. Here, opinion pieces and supportive articles attempt to fill an informational void. Both academic and non-academic contributors recognise that there is an imbalance between PhD graduate numbers and potential academic jobs available (Cyranoski, Gilbert, Ledford, Nayar, & Yahia, 2011; Gould, 2015; Field & Holmes, 2016; Editor Nature, 2017; Bodewits, Gramlich, & Giltner, 2018). This instructional genre consists of short, informative magazine articles that highlight transferable skills and tout the value of a PhD graduate to potential employers. Compiling a database of such articles, Pain (2016) recognises that changing careers is daunting and, as a correspondent for Science magazine, has archived articles dating back to 1998. This archive indicates that PhD graduates leaving their field of study for industry work has not been a recent phenomenon, yet universities have not updated their PhD programs. Instead, PhD candidates search out online resources such as The Thesis Whisperer (Mewburn, 2018) and The Professor is In (Kelsky, 2018) to fill the gap.

Transitioning from a PhD into a non-academic career is also the domain of career coaches, networking and job application services (Cracraft, 2018; Henkel, 2018; Kelsky, 2018; Polk, 2018). These commercial services, run by PhD graduates, provide insight and support for those who are preparing to make the transition into non-academic fields. Examples of two different approaches to commercial transition services and communities are PhDto-Life (Polk, 2018) and The Cheeky Scientist (Henkel, 2018). Polk, a humanities specialist, focuses her business on career coaching, transferable skills, constructive advice, and networking with a positive focus. In contrast, Henkel, a male scientist, focuses on networking, recruiters, PhDs being undervalued and has an almost apostatised view of academia that uses insecurity to recruit members. These contrasting approaches are both highly gendered and reflect the disciplinary biases from which the founders have originated. How these services perform and interact with each other and PhD students is outside the scope of this research. It is, however, important to note that networks like this may provide a valuable source of information for future researchers who seek to further legitimise non-academic career pathways and study transitions.
2.5 Knowledge Gaps

This chapter has considered some of the major factors affecting women’s experiences in astronomy and possible theoretical approaches that aid in this exploration. The majority of literature on women in astronomy, as demonstrated in the introductory chapter of this thesis, is historical and seeks to recognise previously excluded women’s contributions. This literature also demonstrates the progression of astronomy as a discipline from a Northern Field-centric, single object astronomy to the inclusion of the Southern Field and the industrialisation and computerisation of the discipline. In Australia, the damaging Public Service Act (1901) that excluded women after marriage, greatly impacted the number of senior women astronomers who have been able to obtain senior positions within the field and create substantive change.

Current Australian policy regarding women in science and subsequent gender equity programs focus on the outdated leaky pipeline approach to recruiting and retaining women to reach senior positions. While this approach was appropriate in the educational context for which it was created, thirty-five years later it has not made as much of an impact as expected. Still, the pipeline managed to bring together multiple disciplines to focus on one issue; the structural barriers that cause women to ‘leak’ from the pipeline. By tinkering with, and repairing, leaks and blockages in the pipeline, this model has resulted in marginal improvement and a greater understanding of a fundamentally flawed system. Unfortunately, it has not created the structural changes needed to substantially advance women’s participation in science. The ongoing problem with women’s numbers in science illustrates that the human capital approach of attracting and retaining more women is flawed, and more work needs to be undertaken to better understand other complex elements of the problem.

One of the key issues with the pipeline model is that it has been co-opted to explain women’s careers post-education, a function it was not designed for. The use of the leaky pipeline in career discussions, and other similarly styled metaphors (Husu, 2001) does not account for women’s agency and the complexity of their lives. In fact, dismissing women once they have ‘leaked’ is damaging as it implies that their career choices are not valued once the cross the leakage barrier. So far, little scholarly work has been done on non-linear career pathways, producing models such as the roundabout (Barthelemy, 2014) and the vanish box phenomena (Etzkowitz & Ranga, 2011), though these metaphors have essentially been added to the end of the already damaged and leaky pipeline which means that while these non-linear concepts are innovative, their foundations are still fundamentally flawed. To move forward in this field of study, the leaky pipeline metaphor should be
retired in a research context in favour of a more complex approach that accounts for increased intersectionality and the current labour market. This is something that cannot be adequately explained by a simple illustrative metaphor, though it is tempting to try.

Current research tends to capture women astronomers under the larger umbrella of women in physics. As demonstrated by this review, the development of astronomy, the use, and development of technology, and the culture that surrounds it is very different from other areas of physics (Pettersson, 2011; Danielsson & Linder, 2009; Gonsalves et al, 2016). Scholarly studies regarding the experiences of women specifically in the field of astronomy are limited and mostly in a higher education context (Barthelemy, Grunert & Henderson, 2013; Barthelemy, McCormick & Henderson, 2015). Though it is widely recognised that astronomy attracts significantly more women than other areas of physics it is still unclear as to why. Over the course of this review I have described several contributing factors; the historical precedent of women astrophysicists, the appeal of different sub-fields and their popularity by gender, astronomy networking, and also how astronomers interact with technology as a collaborative tool to gather knowledge rather than as the knowledge itself. These factors, as well as a women’s participation numbers over critical mass (Etzkowitz et al., 1994), may contribute to understanding why more women choose to participate in astronomy over other areas of physics, for example, plasma or experimental physics. While individual reasons for choosing physics may differ, there is scope for further research that takes these larger factors into account. These factors and create a comprehensive research position with the potential to answer why women chose astronomy over other fields of physics.

Perhaps the largest research gap, and the one that is addressed by this thesis, is that of non-academic research careers of PhD graduate women. So far, research has focused primarily on retaining women, yet more leave than are ultimately retained. This focus centred on the internal workings of the pipeline is exclusive, limiting, and does not adequately reflect the reality of women’s lives. While structural barriers do exist, the assertion of agency, how women navigate these barriers and ultimately make decisions requires comprehensive multi-disciplinary research that understands women in science, labour markets, and higher education in relation to post-PhD career choice. Currently, this knowledge gap is filled by opinion pieces, career blogs, private networks, and consultancy work. The move away from the academy into other more obscure fields has made it difficult for academics to locate research participants (Czujko & Anderson, 2015). By understanding career choices, transitional processes and outcomes outside the pipeline it is possible to better inform initiatives from within ‘the pipeline’ and better prepare graduates during their education.
Chapter 3

Constructing the Study: Methods and Data

This chapter outlines the methodological approaches that have informed this study and the methods of data collection, fieldwork, and additional analytical strategies used for data interpretation. This project is primarily a qualitative study that is supported by a quantitative database that provides background contextual data, which is used as a statistical tool to identify larger Australian post-PhD employment trends. It also assisted in the identification and recruitment of candidates for qualitative interviews. Though integral to the construction of this research, the database will only be used in a limited analytical capacity in Chapter Seven of this thesis. Other quantitative data that informs this research is public data from professional organisations and government reports from astronomy related bodies. By initially viewing the problem from a macro perspective, through public data and the constructed database, I gathered demographic information about Australian astronomy cohorts and astronomers who find work outside academic astronomy post PhD.

The main focus of the qualitative part of this research is in-depth interviews with a sample of PhD graduates who worked outside academic astronomy. These were supplemented with interviews with established astronomers, who hold prominent positions in the field, and current students, who were in the latter half of their PhD. These interviews explored interviewees’ narrative accounts of astronomy work culture, attitudes towards employment, and experiences post-PhD, with a focus on transitioning into new careers.
3.1 Positioning myself within the Australian astronomy community

I chose to conduct this research into the Australian astronomy community because of my previous work with key members of this community. Although I do not possess any scientific qualifications, I do have considerable experience working as an administrator in an astronomy research centre for approximately four years. During this time, I acquired beyond a lay person’s knowledge of astronomical research, the stratification of the astronomy community, the hierarchy and popularity of disciplines within the field, and the strategic decision making and programs that have been undertaken by institutions to address gender equity. This knowledge has enabled me to position myself more easily with interviewees and members of the astronomy community, has opened opportunities for collaboration, and provided an outlet for the discussion of research results.

The most significant benefit from working closely with astronomers for a number of years is that I possess a detailed knowledge of astronomy, its lexicon, conceptual understanding of astronomical phenomena, and related computer programs and techniques. This has provided a partial perspective (Haraway, 1988) where I can be considered both insider and outsider in the astronomy community (Mesman, 2007). The shared conceptual knowledge of astronomy and its sub-disciplines allowed me to approach interviewees and communicate using their scientific lexicon without needing to change their expression to accommodate me. Furthermore, the residual digital footprint from my previous work and connection to astronomers meant that potential interview candidates were able to vet me online and establish my legitimacy before replying to my interview requests. This connection has given me an advantage over a researcher who went in ‘cold’ without any pre-existing connections to the astronomy community.

Reflexively, I acknowledge that my experience within the Australian astronomical community gives me a specific situated knowledge (Haraway, 1988) of the field. It has also presented some ethical considerations in conducting this research. For example, I have insider knowledge about individuals and institutional practices that I have kept separate from this study. Because of this, I have developed strict protocols regarding the use of public data, and also interview data for my analysis. Here, I have considered Morse et al.’s (2002) concept of responsiveness, where the investigator is prepared to relinquish ideas that are not adequately supported by collected data (p. 17) which occurred after an applied thematic analysis (Guest, MacQueen, & Namey, 2012). I interpret this process as separating ideas regarding what I know about the community and letting the collected data guide analysis and ‘anecdotal data’. During the process of this research I have also
utilised Morse et al.’s (2002) five-point validation method “ensuring methodological co-
herence, sampling sufficiency, developing a dynamic relationship between sampling, data
collection and analysis, thinking theoretically, and theory development” (p. 18) to en-
sure that data is held to reliability and validity standards. In addition to this, I also
intentionally looked ‘outside’ astronomy, to post-astronomy careers, an area I had no prior
knowledge of, to ensure that my ‘insider’ knowledge of the astronomy community remained
separate as much as possible.

This reflexive and ethical approach extends from my previous experience as a teacher and
worker in the university and private sectors. Recently, the Australian Academy of Science
noted that “the loss of so many women scientists is a significant waste of expertise, talent
and investment, and this impacts our nations scientific performance and productivity”
(Australian Academy of Science, 2015). This research demonstrates that it is not only
the ‘loss’ of women scientists that contribute to a ‘waste of expertise’, but the systemic
failure to understand the distribution of post-PhD scientific labour and its connection to
industry.

3.2 Database of Post-PhD Exit Pathways

For this research I constructed a database that consisted of public alumni data manually
scraped from the alumni websites of the five largest astronomy cohorts from astronomy
centres/departments for a ten-year period, as identified in the Australian Academy of
Science’s National Committee for Astronomy (2015) Demographic Survey of Australian
Astronomy. This data was collected to analyse and interpret the career outcomes of
astronomy PhD candidates between 2005 and 2015. The database served a dual function in
this study; firstly, it partially answers the research question of where are women employed
outside academic astronomy? and secondly, it provided a database of potential interviewees
to inform key research questions such as: What do women gain from their non-academic
positions? How do their experiences with the PhD process influence their future career
pathways? What is the transition process? and How can we understand women’s career
pathways post PhD from an agentic perspective?

The data contained information on industries that employed post-PhD astronomers, gen-
der, and location. Due to its quantitative nature, this exit data was limited to answering
the questions: Where do alumni go after completing their PhD and what is their job title?
I refer to this again in Chapter Eight. While analysis of gender, industry, and position
title were conducted, how gendered these positions were, particularly in relation to jobs
and tasks performed (Acker, 2012; Wajcman & Martin, 2002) is unclear. The most critical
aspects of feminist research on women’s experiences: how and why women have chosen
specific career pathways were unattainable from this strategy given the number of alumni from Australian institutions in the 2005-2015 time period.

Analysis of my constructed alumni database shows that a disconnect between what universities are publishing/reporting as graduate outcomes, especially in relation to postdoctoral positions and the potential inflation of the number of alumni that stay ‘in’ astronomy. This is because the data groups precariously employed, short-term postdoctoral, or research assistant work in the same category as more extended, fully-funded postdoctoral positions. Although beyond the scope of this research, a possible solution to this ambiguity would be to revisit data sources and monitor postdoctoral movement at incremental periods.

3.2.1 Post-astronomy Career Data Collection

The discipline of astronomy in Australia is small in relation to the United States (US National Science Foundation, 2014b, 2014a; Australian Academy of Science, 2012; Australian Academy of Science’s National Committee for Astronomy, 2015). The advantage of this smaller size is that it is relatively simple to track post-astronomy alumni through these tighter social networks, rather than rely on larger, less personalised data sources. The Australian Academy of Science’s National Committee for Astronomy’s(2015) Demographic Survey of Australian Astronomy indicates that between 2010-2015 PhD educated astronomers were employed as follows: 59 percent in academic or research roles, 15 percent in industry positions (corporate and government), 2 percent teachers, and 24 percent unaccounted for (p. 11). Gender is omitted from this data, as are exact career pathways for PhD graduates. This means that 41 percent of Australian educated astronomy PhDs are not retained in astronomy field-specific research, and when further broken down; 17 percent are in identified non-academic careers, and 24 percent are unaccounted for. In a small community with strong networks, I consider this to be a large number of graduates that are ‘unknown’. Furthermore, as gender information was omitted from this data, it provides a limited overview of the demography of Australian astronomy and alumni.

In my previous employment, I was a contributor in Working Group 3.1 of the Demographic Survey of Astronomy, as part of the National Committee for Astronomys Australian Astronomy Decadal Plan 2016-2025 (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 4). This large-scale demographic survey of Australian astronomy institutions established a snapshot of Australian astronomy on a census date which could be used to aid in future disciplinary planning. The report showed that at census date there were 387 Full-Time Equivalent (FTE) employed astronomers (p. 4). In addition there were 266 were current PhD students, and 159 that had graduated in the last five years (p. 8).
Career outcomes for twenty-four percent of this 159 graduates were ‘unknown’ and also how many were women.

Participating institutions reported the following categories of post-degree employment data by type (academic, teaching, industry), area (astronomy, other science), and location (Australia, international) (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 11). This was only a small section of data provided for the survey. By providing institutional information for Working Group 3.1, I had prior experience in locating graduates who had left the field and later employed this method in constructing the alumni database. For the Decadal Plan, in addition to public website data, I employed the following methods; Google name and keyword searches, Facebook and LinkedIn searches, and National Aeronautics and Space Agency Astrophysics Data System (NASA ADS) publication searches. I also spoke to graduates, supervisors and asked social networks. Through these methods, I found that, although time-consuming, it was possible to locate a relatively high number of graduates who had left the field for this thesis. I applied a limited amount of these alumni finding methods from Decadal Plan reporting to construct a database of astronomers who had obtained non-astronomy positions, or \textit{post-astronomers}, that provided a quantitative overview of the field. Construction of my alumni database was limited to public searches, such as Google name and keyword searches, Facebook and LinkedIn searches, and National Aeronautics and Space Agency Astrophysics Data System (NASA ADS) publication searches to establish exit, or post-astronomy, career pathways.

Firstly, I narrowed down the search by institution and used information from Australian Academy of Science’s National Committee for Astronomy (2015, p.10) to choose the five astronomy institutions with the highest number of female PhD graduates which would provide the gender information that I needed for interviews and analysis. The universities chosen through this method were the largest astronomy departments in Australia and had a sizeable number of PhD graduates. Table 3.1 shows PhD graduate numbers for these institutions from Australian Academy of Science’s National Committee for Astronomy (2015, p. 10).

<table>
<thead>
<tr>
<th>Postgraduate Institution</th>
<th>Current Students</th>
<th>Graduates 2009-2013</th>
<th>Female Graduates 2009-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Sydney</td>
<td>38</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>Australian National University</td>
<td>33</td>
<td>26</td>
<td>9</td>
</tr>
<tr>
<td>Swinburne University of Technology</td>
<td>37</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>20</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Macquarie University</td>
<td>28</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

\textbf{Table 3.1:} Australian Institutions with the Highest Number of Women PhD Astronomy Graduates
From here, I projected that extending the period to a decade (2005-2015) would provide a larger sample size, especially in relation to women in post-astronomy carers. Czujko and Anderson (2015), in their longitudinal study on the career trajectories of physicists, noted that once a decade had passed for the alumni, it was much harder to locate candidates for surveys and/or get a response.

In early 2016, I scraped alumni data for the 2005-2015 decade from publicly available university astronomy websites to compile the alumni database. Information for the five universities was not complete as, due to the nature of university website administration, multiple years were missing. It did, however, provide enough information to observe employment trends (see Chapter Seven) and inform the next stage of the study. By filtering alumni lists and manually removing ineligible entries who had remained in the academy, I was left with 191 alumni to locate.

3.2.2 Locating Graduates Outside Astronomy

To locate graduates outside astronomy, I employed a similar method when compiling data for the Australian Academy of Science’s National Committee for Astronomy demographic survey (2015). From the alumni name list and with a combination of manual Google, NASA ADS, Academia, LinkedIn, Twitter, and Facebook searches I tracked the careers of the alumni by job title and company name. Of these, the first step was to try a Google name or LinkedIn search, which yielded the majority of results. From there, combinations of the other searches were used if needed to locate alumni. This process was dependant on career pathways or digital footprints. Searches were conducted systematically, and in one sitting per alumni name. Of the alumni names listed, I was unable to locate current employment information for only five percent of graduates. This five percent of astronomy graduates had left no easily detectable digital footprint after graduating. Reasons for this could be a change of name, workplace restrictions on digital footprints, common names that were too difficult to trace, not keeping a LinkedIn profile because of continuous employment, or disappearing from the digital world for personal reasons. For ethical reasons, I ensured that for this process, I only used publicly available data and did not approach any of the alumni, even those known personally to me. This unknown 5 percent was far smaller than officially reported data (Australian Academy of Science’s National Committee for Astronomy, 2015). The manual method of tracking graduate careers from only five universities was time-consuming, and while valuable in the context of this study, may not be feasible in an institutional environment unless constructing a database for long-term use. This may explain why there was such a high level of the ‘unknown’ category in the Australian Academy of Science’s National Committee for Astronomy decadal survey (2015).
Alumni data collected from institutions, was entered into an Excel database for filtering and comparison. The gender ratio of the alumni cohort was 62 percent male and 38 percent female which correlated with statistical data of students from the Australian Academy of Science’s National Committee for Astronomy decadal survey (2015) in the makeup of the Australian astronomy postgraduate student cohort. From there, I divided PhD exit pathways into three categories: Astronomy (postdoctoral positions, lectureships, and research work), Industry (jobs not in astronomy research), and Unknown (no data available).

The simplified Astronomy/Industry/Unknown exit data analysis was primarily to ascertain numbers and to filter by gender. An analysis of this data is available in Chapter Eight. This data presented the following information regarding PhD exit-pathways from five institutions. Table 3.2 shows exit career data from the constructed alumni database.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Astronomy %</th>
<th>Industry %</th>
<th>Unknown %</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>63%</td>
<td>32%</td>
<td>5%</td>
<td>73</td>
</tr>
<tr>
<td>Men</td>
<td>72%</td>
<td>23%</td>
<td>5%</td>
<td>118</td>
</tr>
<tr>
<td>Everyone</td>
<td>69%</td>
<td>26%</td>
<td>5%</td>
<td>191</td>
</tr>
</tbody>
</table>

From my previous knowledge of the astronomy community, and in particular how graduates are listed on departmental pages as postdoctoral researchers in the interim between graduation and a funded multi-year postdoctoral position, I suspected that the number of graduates listed as still working in astronomy was disproportionately high. With this method, there was no way of ascertaining if graduates had fully funded postdoctoral positions or were casual research assistants who were in transition. Institutions differ how they list graduates on their websites and, in some cases, bestow honorary affiliations to graduates to assist with publishing and prevent resume gaps. Without detailed staffing information, I was unable to validate the postdoctoral listings for PhD graduates and thus whether the percentage of graduates retained in astronomy was correct.

The percentage of those that fell into the ‘unknown’ category was statistically the same between men and women at 5 percent. I had anticipated there might be a difference as locating women alumni had proven to be more difficult than finding their male counterparts. This difference stems from long-established structural factors such as name change after marriage and full-time caring and parenting (Lerner, 1986). Full-time parenting produces no employment data, but in this research is considered to be work. When compiling the database, there were multiple instances where name changes and parenting occurred. These links were identified through public Facebook profiles for women alumni only and categorised as ‘industry’ because they exist outside academic astronomy research.
This alumni database, compiled from public information, although very limited in the data it could provide, indicated that there was a viable sample size of 73 women who had attained astronomy PhDs and were now working outside the field of academic research astronomy. This process enabled the identification of potential interview candidates for the next qualitative interview stage of this study.

3.3 Conducting Interviews with Astronomers and Post-astronomers

To address questions about why women choose careers outside academic astronomy, I decided to use qualitative interviews as the primary method of data collection for this thesis. Here, I conducted semi-structured qualitative interviews that were informed by patterns in the alumni database. This methodological approach was used to account for women’s experiences in and out of astronomy, examine variation in women’s lives, and provide a standpoint (Harding, 2004). Due to my previous employment in the astronomy research centre, I was fortunate to have many contacts within the Australian Astronomy community who were willing to advocate my study. These connections enabled me to recruit as many women as I did within a relatively short timeframe. The following section describes the recruitment and interview processes for the in-depth qualitative data that is the foundation of this research.

Interviews were undertaken between May and October of 2016 in various locations around Australia and via Skype depending on location and availability. Face-to-face interviews were conducted whenever possible at the time and place of the interviewees’ choice. I attended the 2016 Astronomical Society of Australia’s Annual Scientific Meeting in Sydney to meet with astronomers and conduct Sydney based interviewees. This meeting provided a fertile meeting ground for interview candidates sourced from all around Australia in a semi-professional environment.

3.3.1 Sampling and Recruitment Strategy

The sampling method that I chose for interviews is a targeted sampling strategy that used snowball or chain sampling (Patton, 1990) to identify three sampling groups; established astronomers (Group A), or astronomers who held senior positions in the Astronomical Society of Australia or at their host institutions, recent graduates (Group B), who completed an Australian astronomy PhD since 2011, and current students (Group C), who were at least one year in to their PhD and were starting to consider career options post-degree. The three-tiered approach was influenced by feminist standpoint theory (Harding 1991),
and situated knowledges (Haraway, 1998) where individuals view situations differently dependant on experience and status.

Interviewees in this study were all women. This aligns with the feminist standpoint theory underpinning of this work to elevate women’s standpoints without the requirement to compare experiences to that of men. This method avoids one of the problems that Husu (2001) identifies in relation to metaphor accounts of women in science in that “the focus has initially and still to a great extent been on women, or comparing women's performance, position or careers to men's.” (p.173). In this study, women’s experiences in the male dominated field of science (Harding, 1991) are already highly gendered and filtered through the comparative disciplinary lens.

As the main focus of this study is the recent graduate group, I conducted 22 interviews with recent Australian trained astronomy PhD graduates who worked outside academic research (Group B). Of these 22, two had chosen to leave during their PhD and had not completed. Their experiences, both during and after doctoral training, mirrored graduates who left post-completion of their degrees. For this reason, they were included within the graduate sample. The supplemental interview groups; established astronomers (Group A) and current PhD students (Group C) consisted of five interviews each which provide context to indicate the awareness of careers outside astronomy from within the astronomical community at junior and senior levels. I describe the recruitment of each of the three groups in the following sections.

3.3.1.1 Established Astronomers (Group A)

The established astronomer interview group, is classified as an “organisational elite” (Delaney, 2007) and consisted of five women who held senior positions within the astronomy community as academics and members of the Astronomical Society of Australia. Established astronomers were selected through my prior knowledge of them in the field as academics and supervisors, and also positions that they held within institutions and organisations. Though they held senior positions, not all established astronomers were previously known to me and I attempted to ensure that a range of institutions and positions were represented. Because of the introduction of the Pleiades’s Awards (Astronomy Australia Limited, 2014) and the SAGE Pilot (Australian Academy of Science, 2015), established astronomers were well-versed on gender equity initiatives and issues surrounding diversity within their field. Though experiences differed, their views on students and employment were largely in alignment.

Interviews with people in expert, or elite positions, provided personal and organisational insight into doctoral student experiences and subsequent career pathways. Interviews were
semi-structured and focused on policy, practice, and potential change more than details of the interviewee's personal experiences. While established astronomer interviews were supplemental, and the interviewees themselves were not the primary subject of study, the interview power dynamic posed some methodological issues that were not present in other more equal interviews.

Gaining access to elites can be a challenge for organising interviews, particularly the navigation of gatekeepers that restrict access, (Delaney, 2007; Thuesen, 2011; Mikecz, 2012). While this could have been problematic, I was fortunate to have some pre-existing connections and a research subject that interested them. As academics and organisational elites, interviewees were relatively easy to contact via email and, with a short synopsis of my project, agreed to be interviewed.

Interviews were primarily conducted in the interviewee's office, which created a host/visitor power dynamic in addition to the senior academic/student dynamic that was already present. Because of this power difference, I employed a dialogical interview approach (Kvale, 2006; Thuesen, 2011). Mikecz (2012) observes that location influences the interview process and that “[r]esponses obtained in an office can represent the official, public relation version” of answers (p. 212). Interviews were a mixture of personal and professional knowledge questions, and although at times interviewees gave the ‘public relations’ or as a spokesperson for the institution version of policy (Delaney, 2007; Mikecz, 2012), were receptive to detailed discussion about literature in the field. The interviews did, however, stray into research related topics in the semi-structured sections of the interview. This reflexive approach to interviewing is described in Thuesen’s (2011) phronesis view that good interviews “involv[e] deliberation, the management of emotions, and a strategy for context adaptation.” (p. 614) which is also cited by Mikecz (2012) as being “crucial for obtaining high-quality information” (p. 484).

Elite interviewees also provided contacts for snowball sampling (Patton, 1990) to locate current (C Group) and former (B Group) students who met the criteria for the study. This endorsement further legitimised my study and opened up networks to find interview candidates in the other groups.

3.3.1.2 Recent Graduates (Group B)

As mentioned, the database analysis showed that 73 women had completed a PhD and changed fields out of astronomy over the ten-year timeframe. For the interview part of this study, however, I set the timeframe to five-years. The reason for this was twofold; that women within this timeframe were more likely to remember their doctoral experience and transitional stages than those more established in their careers, and also that the closer
they were to their graduation date, the more accessible they were through astronomy networks.

While constructing the alumni database produced a list of potential interviewees, it was an unobtrusive data scrape of public information, as nobody, outside the university gatekeepers of this information, was approached. The prospect of finding, and speaking to 20 interview candidates was ambitious, especially since they were now removed from the astronomy community. Recent research by Barthelemy, McCormick & Henderson (2015a) indicated that women who leave might view themselves as an academic failure and be reluctant to talk. Because of these anticipated difficulties I used a number of recruitment methods that involved contacting every university astronomy department in Australia and not just the five universities that were used in the alumni database. This extension was done to engage post-astronomers who were from a combination of Group of Eight (Group of Eight, 2018), or elite universities, and smaller, modern universities where experiences differ. These differences will be explained in Chapter Five.

Initially, recruitment emails (Appendix B) were sent out to senior members of Australian astronomy departments requesting contact information and/or passing my request along for potential candidates fitting the recent graduate (Group B) parameters. Here, I received responses from all institutions contacted and the call for participants was widely circulated in the community by senior astronomy figures. This was an effective snowball sampling strategy, and I received names and contact details of eligible candidates, which then later gave me details of other potential candidates that were in their network.

Concurrently, I directly contacted eligible interview candidates from the 73 that were located while collating the alumni database and from other university websites. Here, of the 38 potential candidates that had completed their PhD within the last five years and worked in identified post-astronomy careers, 29 were approached. Approached interviewees were chosen because of communication accessibility and network connections. These candidates were sent a direct email (Appendix A) or a brief message via LinkedIn, Facebook, and via their employers requesting email addresses for official interview recruitment documentation to gauge their interest in participating. These messages were sent from my private accounts, gave a brief description of who I was, the project and my email address if they wanted further information. Approaching participants via LinkedIn and Facebook was only partially successful. The more successful route was via direct email contact. The email template with attachments did get filtered into spam folders multiple times and was discovered by the candidate after a follow-up email. Because of this, I implemented a three-strike contact policy, where after the initial email I would send two follow-ups, in case of the spam folder or forgetting, and then move to the next candidate. I reasoned
that if they were interested, three prompts would be enough to attract interest and if not, anything above three would be considered obtrusive.

In some cases, when snowball sampled, the name of the referee was also mentioned to establish legitimacy. I purposefully used my personal social media accounts due to my distinctive name and visible ties with members of the astronomy community. The goal of this communication was to obtain an address for official documentation to arrange an interview and not document social media interactions. If the primary recruitment method had been social media, then Palys and Atchison’s (2012) suggestion to set up a researcher profile and document interactions that way would have been more appropriate. As former postgraduate students, most were intrigued by the initial approach and responded with requests for further information.

Through publicly available information from university websites, I located 38 potential candidates, though contact details were not available for all of them. I approached 29 candidates and finished with 22 interviews. The recent graduate (Group B) sample consisted of 22 interviews of students who had obtained a PhD between 2011-2016 and had moved out of academic research. Two interviewees had started PhDs and had withdrawn from the programs without a PhD awarded. Of the 29 interview candidates approached 22 agreed to be interviewed, one declined an interview due to accepting a postdoc, and six did not respond at all.

Interviews for this group were conducted in a mixture of face-to-face interviews and on Skype for international and some interstate interviews. Skype participants were interviewed from home or a quiet room within their workplace. Face-to-face interviews were conducted in public spaces, private homes and in a meeting room at the Astronomical Society of Australia’s Annual Scientific Meeting in 2016 at the University of Sydney. Interviewees chose times and places that were both comfortable and convenient for them. This strategy was important as some were a little nervous at being interviewed and familiar surroundings allowed them to relax.

Interviews conducted for this group employed a similar dialogical approach (Thuesen, 2011) as the A Group established astronomer interviews. A key difference between the A group interviews, and B and C groups (which were approached the same way), is that B and C groups were interviewed about personal experience and not in a workplace context, where they hold a senior position. The interview dynamics for groups B and C could be considered as “studying sideways” (Plesner, 2011; Hannerz, 1998). Here,

Both the researcher and research participant bring interests to the table that both sides are familiar with, and although these interests may sometimes
conflict, the terms of the negotiation are not foreign to the participants, and their conditions are, in principle, equal. (Plesner, 2011, p. 471)

Here, the commonality between myself and the interviewees was twofold; that we both shared knowledge of astronomy and postgraduate education. This shared lexicon and cultural knowledge enabled discursive interviews. I was both an “insider” and an “outsider” dependant on interviewee experiences (Mesman, 2007) and as such, interviews were a negotiated space that varied between interviewees. Here, some interviewees felt more comfortable with standard interview techniques where I asked questions and led the interview while others preferred to cover research questions in a less formal conversational context. Interviewees were encouraged to ask me project and personal questions prior to the official start of the recorded interview. This was to establish rapport, legitimise my shared knowledge of astronomy, and clear up any concerns interviewees may have had about the purpose of this research.

Initially, interviewees were a little suspicious of my intentions and how they would be represented in this research. The most frequently asked question was “Why women astronomers?” but after explaining my background in astronomy research administration, education, and the gap in knowledge of where women go and the jobs they choose, they agreed to be interviewed. The request for interviews also came one year after the Geoff Marcy sexual harassment scandal (Urry, 2015; Wilson, 2015) that opened up a Pandora’s Box of harassment stories by women astronomers. Once interviewees realised that I was examining factors that shaped employment that were not necessarily related to sexual harassment and that data would be anonymous, their concerns were eased. My connection to the astronomy community, which is visible in my digital footprint, assisted in establishing rapport and knowledge of the field and its participants. This level of authenticity was beneficial in creating trust prior to interviews and during the informal conversation stage. The division between informal conversation and official interview protocol was initiated by the discussion of the Plain Language Statement (Appendix C).

Skype interviews, although technically face-to-face, were more challenging than in-person interviews as the rapport was more difficult to establish due to video time delays, and miscues in speech patterns and body language. One of the benefits of these interviews was the integration in the everyday lives of interviewees, who Skyped me from home, or a quiet place at work, and controlled the environment. Here, disruptions from partners, children, and pets, instead of derailing interviews, enriched them. These disruptions released tension and established a rapport that opened conversations into different areas of work/life priorities. A few times the Skype connection dropped out, which did derail the flow of the interviews, but as highly technical people who Skyped often, interviewees were not significantly affected by these glitches.
3.3.1.3 Current Doctoral Students (Group C)

The current doctoral student group was recruited to supplement the primary group, recent graduates (Group B). The five interviewees in this group were in the latter half of their PhD and approaching the postdoctoral/transitional period after submission. Recruited through snowball sampling (Patton, 1990), interviewees were either referred by established astronomers or had discovered that the study was being conducted and volunteered via email. Three of these interviewees approached me via email, and the other two were approached in the same way as the recent graduate group. After initial contact was established an official recruitment email was sent (Appendix A).

Interviews for this group were conducted in-person at times and places of their choosing, on or around their host university campus. The dynamics of these interviews differed from the previous groups because interviewees were current doctoral students, and were also interested in gaining different perspectives on post-astronomy careers, and viewed me as a conduit to that. Like the recent graduate group, I consider these interviews to be “studying sideways” (Plesner, 2011) as shared knowledge regarding postgraduate education and astronomy enabled discursive, style interview. The main difference with the current students group is that interviewees concentrated on their current experiences within astronomy and projected what they would like to do post-degree. They also used interviews as a tool to further analyse their career goals and gather information regarding possible career pathways.

3.3.2 Interview Guide and Time-frame

The interviews, all semi-structured, covered five core interview questions that differed between the three sample groups. The construction of interview questions were targeted for each interviewee group and took into consideration the position, experience and career stage of interviewees. Here, I took into account gender ratios and current gender equity initiatives in Australian astronomy (Astronomy Australia Limited, 2014; Australian Academy of Science, 2015), women’s experiences in American university astronomy programs (Barthelemy et al., 2013; Barthelemy, 2014; Barthelemy, Van Dusen, & Henderson, 2015; Barthelemy, McCormick, & Henderson, 2015a; McCormick et al., 2014), European women in physics studies that clearly differentiate between women’s experiences in specific fields of physics (Danielsson, 2012; Danielsson & Linder, 2009; Pettersson, 2011), and astronomer generated surveys and women’s anecdotal accounts of issues within the field (Astronomy Australia Limited, 2014; Fohlmeister & Helling, 2012, 2014) to target questions on gender and work related experience whether it was pre, during or post PhD.
studies. Interview questions were underpinned by feminist standpoint theory and a situated approach (Harding, 2004; Haraway, 1988) that was heavily influenced by Acker’s assertion of work inequality (Acker, 1990, 1992, 2000, 2004, 2006, 2009, 2012) and that science and technology has a highly gendered structure that favours men (Harding, 1986, 1991; Wajcman, 1991, 2004). Questions explored an agentic approach to career decision making while navigating structural barriers within the field and were positioned to empower and account for decision making processes rather than focus on barriers already identified within the established literature. While thematically broad with the focus on the exploration of careers and work, gender, opportunity, technical experience, PhD experiences, and barriers. Interviews focused on the overarching research question: Where do women astronomers go after completing their PhD and why do they make the choices that they do?

These core questions were used as an interview guide and were submitted to the interviewee via email prior to interview (Appendix B). This step was done for two reasons; to establish trust and research parameters and to allow interviewees to consider questions before the interview. As elite astronomers, all interviewees had experienced the scientific workplace, though they may not have had the opportunity to think critically about themselves and how it affected them and their decision making. Interviewees were only sent questions that related to their group. The interview guide for established astronomers (Group A) questions focused on institutional career initiatives and programs as well as the experiences of the interviewee and their peers. The recent graduate (Group B) focused on the personal experience of changing career pathways after PhD and the factors that influenced this during and post PhD. Current doctoral students (Group C) spoke about experiences during their PhD, future plans, and preparation concerning their PhDs and lives.

I conducted all 32 interviews which enabled me to refine interview questions and follow up on recurrent unanticipated themes within the semi-structured format. An example is the theme of why B Group interviewees chose to do an astronomy PhD in the first place, which was not an interview question but recurred in relation to the idea of a ‘PhD by default’ where they started their degree without much consideration of post-degree options. In addition to this, I was also able to segue children, partner, and pet disturbances, which were prevalent in the Skype interviews (on both sides), into discussions about lifestyle factors that influenced employment decision-making. While still work-related, the addition of personal data enriched interviews and linked the professional and personal lives of these women in an unanticipated way. Though only one question in the interview guide explicitly mentioned gender, interview questions regarding personal experiences were regarded within situated knowledges (Haraway, 1988) of the women interviewed.
Interviewees were all women who ranged from their mid-twenties to approaching retirement age (in Australia 65 years). There was a range of single, partnered and married women, some with and some without children. Employment types ranged from studentships and full-time parenting to part-time, full-time, contract, and permanent work. Of these interviewees, 28 were locally based, and four were international but had obtained their astronomy PhD from an Australian university within the designated five year time period. Interviewees held a mix of Australian and international citizenships, which did not appear to affect where they were located, though many Australians chose to stay in Australia and sought work accordingly.

Interviews were audio recorded, and notes were taken for main points and follow up questions. The guide was structured from Creswell’s (2009), suggested stages that included an icebreaker, structured and probe questions, a thank you, and the potential for a follow up if further clarification was needed.

Once recorded on audio devices, interviews were downloaded and transcribed verbatim. Files were then coded and deidentified. The anonymisation of data involved participant pseudonyms that corresponded with the first letter of their group allocation, for example, A Group is Amelia, B Group is Barbara, C Group Celeste and so on. This process both deidentified and organised groups for analysis. Names of people, places, institutions, fields of study were all filled with generic placeholders for example, [university] instead of the name of the institution. States and countries were also filled with generic markers so not to identify movement and finally, partners and spouses were generically referred to as partners so the marital status of participants remained ambiguous and was not easily identified. This anonymisation of data to protect interviewees came at the expense of being able to cross reference data from individual institutions, supervisors, and fields of study as there was some overlap due to snowball sampling strategies.

Two interviews suffered partial or full technical failure and were therefore not recorded. These interviews were reconstructed by extensive note-taking.

3.4 Analytical Strategies

This research utilises multiple analytical strategies to support both the structure and interpretation of data. The inclusion of thematic and narrative analysis (Riessman, 2005, 2008) provides a framework from which to construct standpoints (Harding, 2004) and temporally organises interviewee experience through their doctoral and transitional processes into post-astronomy careers.
3.4.1 Approaching the Data from a Feminist Orientation

This research is underpinned by a number of feminist theoretical approaches that inform my analysis of data. In addition to feminist standpoint theory (Harding, 2004) and situated knowledges (Haraway, 1988), which privilege the perspectives of women post-astronomers, I have included other analytical methods to further investigate women’s experiences with technology (Wajcman, 1991) and the enforcement of women’s inequality within gendered workplace structures (Acker, 2006, 2012). By positioning women in astronomy doctoral programs as workers, this strategy differs from current literature which considers women’s doctoral experiences within physics and astronomy in an educational context (Danielsson & Linder, 2009; Danielsson, 2012; Pettersson, 2011; Gonsalves et al., 2016; Barthelemy et al., 2013; Barthelemy, 2014; Barthelemy, McCormick, & Henderson, 2015b; McCormick et al., 2014). The view of doctoral students as workers places them outside leaky pipeline literature (Berryman, 1983), which was initially developed to encourage education pathways for minorities, and allows the complexity of women’s positions as early career researchers to be more fully recognised and include intersectional factors (Crenshaw, 1991) which influence complex decision making by women both in and outside the workplace. The re-positioning of PhD studies into the field of work separates educational leaky pipeline concepts such as ‘retention’ and ‘leakage’ to describe staying and leaving and prioritises agentic decision making when assessing and navigating gendered barriers and opportunities within the sciences.

This theoretical framework, particularly gendered analysis of women in work (Acker, 2006, 2012), the gendered environment in STEM fields (Etzkowitz et al., 2000; Harding, 1991) and criticisms of the leaky pipeline (Berryman, 1983; Allen & Castleman, 2001; Blickenstaff, 2006; Bennett, 2011) have influenced a “theoretical” thematic analysis (Braun & Clarke, 2006) of interview data where key themes were identified throughout the interview process and further investigated in relation to existing literature. In addition to the theoretical thematic analysis method of analysing data, I also focused on “collective narratives”, which Richardson (1990) describes as “[c]ollective stories which deviate from standard cultural plots [to] provide new narratives; hearing them legitimises a replotting of one’s own life.” (Richardson, 1990, p. 129). These collective narratives, though individualistic experiences all share a collective understanding of the field of astronomy, its stories, and historical significance. Here, there are certain narratives, for example, those presented by ‘women in STEM’ initiatives, that are repeated and shared by women in this field. I go further into this double-tailed analytical strategy below.

In addition to narratives as women scientists, who are the minority, the recent graduate interviewees provide new narratives of post-astronomy careers and transition. These perspectives are currently not adequately considered in women in STEM leaky pipeline
focused stories of retention and leakage. This approach, which is compatible with feminist standpoint theory (Harding, 2004) in that multiple perspectives are linked into a theoretically supported standpoint or story, enables women who are currently ‘lost’ due to leaving their field of study, to legitimise their collective narratives and re-frame their post-astronomy experiences from a ‘loss’ to a redistribution of expertise.

### 3.4.2 Thematic and Narrative Analysis

In this thesis I used a “theoretical” thematic analysis (Braun & Clarke, 2006), which took into account feminist theories of gendered structures within the workplace, particularly the division between “jobs” and “tasks” (Acker, 2012) which influenced the way that I approached current job descriptions of post-astronomers, their relation to gendered technologies (Wajcman, 1991), and how they are developed. In addition to Acker’s (2006) work on inequality regimes, which intrinsically links gender, race, and social class. I also used an intersectional (Crenshaw, 1991) approach to link other elements that, combined with gender, enforce women’s inequality in education and the workplace. These approaches, in conjunction with work on structural inequalities within the sciences (Harding, 1991; Etzkowitz et al., 2000), provided a comprehensive theoretical framework in which to develop thematic networks (Attride-Stirling, 2001) for detailed analysis.

In addition to these feminist analytical strategies, I utilised a narrative approach that is best described as a thematic narrative approach (Riessman, 2005, 2008). This approach includes a narrative structure throughout this thesis which is temporally organised into narrative themes, patterns, and chronology. Riessman (2005) describes the function of this is to “collect many stories and inductively create conceptual groupings from the data. A typology of narratives organised by theme as the typical representational strategy, with case studies or vignettes providing illustration” (Riessman, 2005, p. 2). In order to achieve this thematic typology, individual narratives were grouped and analysed in patterns with vignettes that emphasise certain elements.

By analysing narratives from a feminist standpoint perspective (Harding, 2004), I use what Gubrium and Holstein (1998) refer to as “‘analytic bracketing’ that allows focusing on one aspect of narrative practice by temporarily suspending analytic interest in the others.” (p. 165). In this case, the bracketing focuses on the ‘what’ is being said over the ‘why’ and ‘how’ used in other forms of narrative analysis. As semi-structured interviews, key questions were not arranged temporally, so narratives from interviewees were not constructed in a planned narrative format, but in response to follow up questions that followed individual accounts and experiences. Chase, defines personal narrative as,
a distinct form of communication: It is meaning making through the shaping of experience, in a way understanding one’s own or others’ actions; of organising events, objects, feelings or thoughts in relation to each other; of connecting and seeing the consequences of actions, events, feelings or thoughts over time (in the past, present and/or future). (Chase, 2018, p. 549)

These narratives were analysed both individually and in relation to each other. These connections where interviewees construct accounts of their past, present and future offer critical insight into the culture of astronomy. Here, interviewees construct narratives that are influenced by “institutional agendas, with preferred plot structures “points”, or morals.” (Gubrium & Holstein, 1998, p. 173). In this case, the expectation that astronomy PhD students desire to keep working within the field of astronomy and that post-astronomy careers are considered inferior and are attributed to a ‘fault’ or ‘failure’ is a large contributing factor to the way in which interviewees, recent graduates, in particular, constructed their stories.

The construction of “collective narratives” Richardson (1990), strengthens individual narratives into a standpoint (Harding, 2004) that reflects the experiences of women, and their account of leaving astronomy, which is against expectations and stigmatised within the field. It also conveys an implicit understanding by participants of acceptable career narratives and pathways. Interviewees who engaged in post-astronomy employment “accounted” for their decisions. Here, “[f]inding plausible causes and effects, goals and means, seems a tricky affair, especially in narratives dealing with allegedly negative courses of action...Accounts are born out of the distinctly human capacity to be blamed, charged, and held responsible.” (Järvinen, 2001, p. 267). The established approach that women in STEM fields should be retained, and that there is a degree of ‘fault’ (whether personal or institutional) in leaving meant that interviewees framed and accounted for their decisions in a way that both accounted to and subverted the established norms of the field. Järvinen (2001) asserts that,

Accounts involve not only a presentation of an action but also a presentation of the accounters self. When we justify and excuse our actions, we simultaneously try to recast ourselves as sensible and proper human beings. (pp. 267-268)

Because of the sensitivity of the subject matter, which is exploring women’s post-astronomy careers that are currently stigmatised within astronomy, I use an analytic bracketing approach (Gubrium & Holstein, 1998) that primarily focuses on the ‘what’ is being said over other areas of narrative analysis. This is because I did not want to overly focus on speech
patterns and how experiences were described, but rather what women experienced and to develop a standpoint (Harding, 2004).

The iterative grouping of narratives into temporally constructed and thematic typologies constructs a mechanism for understanding how women who undertake Australian PhDs in astronomy experience their doctoral experience and the complex factors that lead to their decision to pursue post astronomy careers. Richardson (1990) describes the importance of narrative in that,

> it makes individuals, cultures, societies and historical epochs comprehensible as wholes; it humanises time; and it allows us to contemplate the effects of our actions, and to alter the direction of our lives. (Richardson, 1990, p. 117)

By conveying the narratives of women in post-astronomy careers, not as ‘leaked’ from a metaphorical pipeline, but as “sensible and proper human beings” (Järvinen, 2001, pp. 267-268), who make informed decisions, this study demonstrates that the current methods of retaining and improving conditions for women in the pipeline are largely exclusive of women who do not conform to this expectation.

### 3.5 Limitations

Recruitment parameters were limited by gender, PhD completion date, and the award of an Australian astronomy or astrophysics PhD, or at least partial completion of the degree. Due to ethics concerns and to aid the anonymisation of data, I have purposefully excluded issues of sexuality, race, ethnicity, and nationality from analysis, and instead focus on women’s experiences in astronomy and beyond. In some cases, I have woven together multiple stories or given multiple examples rather than a singular exemplary example as suggested by Riessman (2008). As stated earlier in this section, I assured anonymity, and as the astronomy community is highly educated and connected, the risk of using large amounts of singular interviews increases the chance of identification. These restrictions have created a limitation in the data available for analysis and the format in which I can present it. I have purposefully traded depth of data for the safety of participants as it is highly likely that many members of the astronomy community, who have assisted me over the years, will read my work and check if there is anyone that they know. A more comprehensive, perhaps international study, could potentially include the missing data type. With a larger sample size, there would be less chance of participant identification.
3.6 Summary

This chapter detailed the data gathering and analytical strategies used to conduct this research. Here, I initially constructed a database from astronomy alumni public data to ascertain employment patterns of astronomers and whether it would be problematic finding an adequate number of interviewees for this study. I then outlined the methods for identifying, approaching and interviewing participants for this study which fell into three groups established astronomers (n=5), recent graduates (n=22), and current students (n=5).

Finally, I outlined the approaches used for analysis of interview data which includes a theoretical thematic analysis (Braun & Clarke, 2006), which takes into account overarching feminist theories discussed in the previous chapters of this thesis, namely feminist standpoint theory (Harding, 2004), gendered technologies (Wajcman, 1991) and gendered workplaces (Acker, 2006, 2012). These interact with other areas of women in STEM pipeline influenced research, that mainly focus on identifying leakage points and retaining women. An additional layer of thematic narrative analysis (Riessman, 2005, 2008), enabled a grouping of stories into typologies that enabled temporal storytelling and breaking down the patterns of the “collective narratives” (Richardson, 1990) of interviewees. This method, going across individual narratives to establish typologies allowed for a greater exploration of the relationship between motivation, doctoral experiences, and chosen post-astronomy career pathways of participants.
Chapter 4

PhD Experiences: In the ‘Pipeline’

This chapter explores the ‘golden three’ of university supervision, workplace culture, and access to networking that affects Australian doctoral students. These factors, as recounted by interviewees, provide insight into the nuanced workplace culture of astronomy, how it shapes the experiences of graduates within the field, and their career decisions post-astronomy. This chapter provides some overlap with the leaky pipeline understanding of postgraduate study, though, in this case, no single factor discussed in this chapter was the reason for women to leave the pipeline. As will be discussed later in this thesis, pipeline-related experiences combine with more complex motivational and intersectional factors that contribute to women deciding to leave astronomy for different careers.

For PhD candidates, their experiences seem to rely on a certain amount of luck with supervisory teams and university culture which can be a key influencer when deciding on future career pathways. In a survey of two Australian Group of Eight Universities, Harman (2002), observes that “While in principle a reasonably high proportion of PhD students see academic careers as attractive, many students have strongly negative views about academic work in Australian universities, especially with reduced government funding and increased academic staff work pressures” (p. 189). This means that once doctoral students become more familiar with the ‘business’ of university, they make decisions that are based on a multitude of factors beyond their direct supervisory and research project experiences. Some of these factors are the highly variable economic state of universities, strategic foci, workplace, and student cultures. Students, particularly women, are observant of these structural factors as they begin to envision a place for themselves in relation to the discipline.
4.1 PhD Supervision

Choosing a supervisory team is one of the most critical aspects of a PhD and one that is subject to, as a potentially stressful interpersonal relationship, a certain amount of serendipity. Students choose to enrol in PhD programs for a variety of reasons that are not necessarily related to wanting to become a research astronomer and, as such, make decisions that are influenced by a desire for continuity or change. Motivation narratives will be discussed in Chapter Five. For graduates, after deciding to continue into their doctorates, the choice of supervisor is linked to variables such as institution, project availability, and field of study.

Unlike students in other disciplines, who can often set their own research project and work as solo researchers, astronomy students generally join an established, funded project that already has some existing data and networks, and is in an active field. Due to the time, difficulty and expense of acquiring astronomical data it is desirable to be involved in a large scale collaboration or survey. In the relatively short term of the Australian doctoral program, supervisors ideally act not only in a supervisory capacity but as a conduit to more extensive networks and opportunities, what Murillo et al. (2012) referred to as ‘meshworks’. Taking these measures into account, senior supervisors are more objectively (due to metrics) valuable than others, but when other variables such as personality, experience, and workload are also considered it can be challenging to find an available supervisor that meets all the criteria.

Choices made early in the doctorate directly relate to formative experiences during candidature which in turn, positively or negatively influence career opportunities and choice post-PhD. In an all discipline survey of two Australian Group of Eight Universities, Harman (2002), describes the most commonly reported problem with supervision is supervisors being too busy and not dedicating enough time for students. After these, other identified issues are insufficient interpersonal skills, different views on the project, personality clashes, and a lack of supervisory interest. For a student that has been retained, they choose to follow opportunities presented by prospective supervisors, and for students attracted from other universities, while supervision is a consideration, it is part of the new overall experience.

This section investigates how interviewees in this study choose their doctoral supervisors and also how this choice impacted their studies and subsequent career options.
4.1.1 Supervisor Choice

Supervisor choice is an essential element of beginning a PhD, and interviewees used different strategies that both had positive and negative effects on their doctoral experiences. This element of the PhD is one of the main aspects of leaky pipeline scholarship, where women role models mentor and supervise graduate students. The importance of supervision and retention conforms to the academic norm, that when women leave the pipeline, there is a fault from which they leak. Yet, multiple interviews indicate this was not necessarily the case.

In this study, the way that interviewees joined doctoral programs meant that choosing an astronomy PhD supervisor was more about grasping a scholarship opportunity in a desired institution and research field than it was about a clear supervisory choice. Gender was also not an identifiable contributing factor for supervision, though interviewees expressed that it was beneficial to have a female role model and mentor when they did have a female supervisor. No matter how supervisors were chosen, factors in supervision affected how doctoral students were connected to the field, transitioned into researchers during their studies, and their initial engagement with the field.

Interviewees in this study were all familiar with the concepts of what makes good a supervision team, but attaining this goal proved to be difficult. Brigitte, who was retained at her undergraduate university, astutely describes the ‘golden three’ aspects of a good PhD experience and attributes successful, timely completion to good supervision:

\[ \text{In terms of going into it, you’ve got to have the key ingredients right. Like you’ve gotta get on with your supervisor, and you’ve got to have a decent uni that supports you, and you’ve got to have a project that you are really into. If one of those things is missing, more than likely, I think you will drop out. The people I have seen that have got through in decent time frames, have had the golden three...and the supervisor is just so important. (Brigitte, recent graduate)} \]

The ‘golden three’ is an ideal to strive for, and conducting due diligence and establishing whether there is professional and personal compatibility increases chances of good supervision (Miller, 2017a, 2017b; Fohlmeister & Helling, 2014). This advice assumes that students will have opportunities and the inclination to research their supervisor, which is already restricted by availability, funding, and field, prior to accepting a scholarship and enrolling. Interviewees indicated that when the research subject, postgraduate scholarship funding, and university choice are ideal, they were prepared to roll the dice on supervision and considered set supervisors as part of the doctoral package. For them, their supervisor’s
gender was not overly important, as they primarily chose subjects and institutions. So while ideally, Brigitte’s ‘golden three’ increases the likelihood of a smoother PhD experience, it does not necessarily indicate that it is a significant factor in retaining women in the pipeline though it appears to be a factor in leaving.

When given a choice, and given different motivations of undertaking doctoral studies, there was no major difference in the quality of relationships and PhD experiences between the interviewees who took the ‘package deal’ and those who chose carefully. Beverley, who retrained with the goal of being an astronomer, believes she chose her supervisor for the wrong reasons:

So being as I now know, not very good at self-reflection, I speed dated and talked to lots of people, but I got attracted to a project which is a very, very, hot field, very, very, sexy and the last person to work in my school in this was in [the most prestigious scientific journal] in their second year and I was dazzled by the prospect of fame rather than, is this a good person to work with or is this a project that I’m really interested in? (Beverley, recent graduate)

Beverley, who works professionally at a university in a postgraduate student-oriented area relates her PhD experience and naivete with self-deprecating humour. In her accounts, it is clear that while she is an expert on postgraduate studies now, she views her experience as a student through the lens of her current professional position and can clearly identify mistakes that she had made during her candidature. Beverley’s pitfall is easy to fall into, and with the rise and fall of different ‘hot’ astronomical fields, the temptation to choose supervisor for research prestige, and their halo effect (Cooper, 1981), is logical especially if the intention is to become a career academic.

Both Beverley and Brigitte left their doctoral studies and attributed this partly to their supervisory choice. In contrast to Beverley’s method of choosing a supervisor, Camille, a current student, chose the opposite approach. She understood what she wanted when choosing a supervisor and considered supervisory qualities over project potential.

I didn’t choose a PhD project so much as I chose the PhD supervisor. I went for someone that I really thought was in line with what I was looking for in a PhD. I wanted to learn and acquire new skills, and I wanted to do that at my own pace. I didn’t really go into it thinking that I wanted a career in astronomy necessarily. For example, some supervisors would be really good at pushing students to produce papers and things like that. That’s not...I’m not interested in that. I wanted someone who would really teach me how to navigate through problems. I had a class with a professor that I really liked and
met almost everybody at the [department]. I was really looking for a teacher, and this person just fit the bill. So I asked him if he had a project, he told me what he was working on, what his projects were and I signed up for one. It’s turned out to be really good. (Camille, current student)

Camille’s approach had unintentionally engaged her in a ‘hot topic’ and she managed to attain the ‘golden three’. Still, after much deliberation, Camille plans to move into a different field after graduation and her responses reflect this decision. This decision, she emphasises, is no reflection on her supervisor and during the interview, she expressed that she was concerned that her decision to leave might be interpreted as a failure to ‘stay’ that could reflect poorly on her supervisor.

Throughout interviews, I spoke to multiple women who, as the astronomy community is relatively small, had supervisors in common. Each had different relationships and perceptions of their supervisor. Like Camille, those with positive relationships emphasised that their career choices were through no fault of their supervisory team, but those with negative relationships did attribute to their supervisors as being partially accountable for their decision to leave. The implication that leaving was linked to a potential fault or short-falling (by the student or supervisor) implies that the decision to leave is a systemic flaw and not an agentic decision that has been made by the leaver that is not necessarily connected to their doctoral experiences. Although interviewees employed different strategies in choosing supervisors, it is the relationships that formed over the course of doctoral studies that enabled degree completion.

4.1.2 Navigation of Adversity

The transformative journey from student into a researcher is a difficult one from the perspectives of both doctoral students and their supervision team. There were no significant differences in the relationships between those who were retained by their undergraduate institution and the other types of PhD students, who carefully chose their supervisors or signed up for a project, in relation to supervisory satisfaction. The doctoral process is highly dynamic, and in Australia relatively short, which can present challenges for both students and supervisors.

Kiley (2009) considers the PhD in relation to “threshold” concepts where students attain developmental markers during the PhD process. “A threshold concept is one that, once grasped, leads to a qualitatively different view of the subject matter and/or learning experience and of oneself as a learner” (Kiley & Wisker, 2009, p. 432). The attainment of this involves navigating through the ‘liminal’ phase, or as interviewees described, ‘getting
stuck’ or the ‘PhD blues’. When students are stuck in this state for too long, they lose confidence and like Beverley and Brigitte, consider dropping out of the program. Beverley, who chose her supervisor because of a ‘hot field’, was not able to navigate this stage and describes how she chose to leave the PhD program.

I got to the two-year mark, which is the ‘PhD blues’ phase. I had a lot of data. I was getting interesting results, but I just couldn’t get myself to the stage where I was writing that paper. I was doing lots of procrastination. I was still working really long hours, but I was just reanalysing my data over and over again. I talked to my supervisors when I was realising my dissatisfaction. So, I was having conversations probably in the last three months [where] we talked about adjustments to my project. The more and more I thought about not doing it, the better I felt. I actually felt this huge sense of relief. (Beverley, recent graduate)

For Beverley, whose extended experience of being stuck in the “liminal stage” (Kiley, 2009) made her dissatisfied with the doctoral program and her progress within. She describes her supervisory team as inexperienced “I had supervisors who had recognised that I was struggling and I talked about this. They just didn’t have good strategies because they hadn’t completed students before.” Beverley was unable to break from her procrastination loop and decided that the better option for her would be to leave the program.

While Beverley was disillusioned with her studies and decided to leave, other students related positive contributions by supervisors who had ‘dragged them out of the fire’ and dissuaded them from leaving their doctoral studies. Celeste, a current student, who had originally wanted to be a researcher, encountered some, for a long time undiscovered, hardware issues with data that had derailed her research that made her consider quitting. In her case, however, her supervisor provided advice as to how to re-frame her research.

I was pretty much fed up and felt like quitting and even told my advisor I was going to quit, who then sat down and went with me went through the data, and said “You’ve got something here. We can work with this. Don’t give up.” That made me realise that I wasn’t going to give up on that. I was happy to finish the PhD. (Celeste, current student)

Though Celeste and Beverley’s supervisors had both suggested adjustments and re-framing data to aid completion, Celeste’s more positive relationship with her supervisor, meant she was able to evaluate her research critically and was more open to assistance in finding a solution so she could complete her doctorate. Here, Celeste was ‘fed up’ and frustrated
rather than ‘dissatisfied’ with the process, and had not given up on her goal of completion. She had also gone through the liminal stage of learning and referred to her supervisor as an ‘advisor’ to the project which indicated that she perhaps had more agency over her project than Beverley experienced.

Blair, another recent graduate, also reflected on how her supervisor worked with her to ‘save’ her thesis after a university policy changed regarding submission.

*I thought I wasn’t going to be able to submit. So we had this crazy period before Christmas before it was due, and my boss and I just went crazy, and when I realised that I just didn’t have enough, we had this wonderful period of maths, and we both didn’t sleep. It was wonderful.* (Blair, recent graduate)

Blair was another interviewee who stressed that her decision to exit astronomy post-PhD was personal and that it was no reflection on her supervisor. Her primary interest was mathematics, so the extended period of maths with her supervisor, or ‘boss’, was a unique experience. The long period of maths also indicated that their relationship was strong enough to work perhaps through the night to achieve their goal, which for Blair was one of the highlights of her PhD. As her degree was theoretical, this would have been unusual.  

While Blair and Celeste’s stories of supervisors that rescued their projects from the brink of disaster are unusual in this study (most reported less eventful PhDs), these examples illustrate the importance of clear communication and trust between supervisors and doctoral candidates. Though relationships varied considerably, most interviewees were generally positive about their PhD supervision yet still chose career pathways outside the field. This choice indicates that positive supervisory relationships, while integral to the PhD, do not necessarily aid in retaining graduates in the pipeline at a post-doctoral level. However, more negative supervisory relationships and experiences during the PhD tended to have more influence on non-academic career changes post-PhD.

### 4.2 Astronomy Workplace Culture and Gender

The literature on women in STEM documents areas of systemic bias as structural points to ‘fix’ within the pipeline. Areas such as minority networking advantage and exclusion (Murillo et al., 2012), meritocracy (Castilla, 2008; Castilla & Benard, 2010) and larger entrenched systemic biases that enforce male advantage (Harding, 1991; Etzkowitz et al., 2000) that have been examined in the literature review affect women within astronomy

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1For observational astronomy PhDs who visit telescopes, observing at night with a supervisor is relatively common and part of the doctoral process.
in much the same way as other STEM fields. However, there were incidents described by interviewees that changed their perception of astronomy and subsequently influenced their career change post PhD. These incidents included “science as usual” (Harding, 1991, p. 54) exclusionary behaviours that impacted networking and opportunity, in addition to serious experiences of sexual harassment. Although it is beyond the scope of this study to pursue this in great detail, these formative events, and their context within the Australian astronomical community’s practice and policy must be briefly scrutinised.

How doctoral students experience the transition from student into a researcher is largely dependant on the environment in which they are located. For example, each university is different as is the Australian Astronomical Observatory (which at the time of writing was a cohesive optical research group with access to Siding Spring’s Anglo-Australian Telescope) and the CSIRO (which specialises in radio astronomy and has access to the Parkes Radio Telescope and other affiliated radio telescopes).\textsuperscript{2}

In addition to universities and government facilities, PhD candidates also encounter astronomy culture in at the Australian Society for Astronomy’s Annual Scientific Meeting and the Harley Wood Winter School, both of which are hosted by universities throughout Australia. In recent years, the Inclusion, Diversity, and Equity in Astronomy chapter, formerly Women in Astronomy chapter, have held regular workshops. It is through these, and smaller affiliated programs that Australian astronomers become familiar with gender equity policy and practice. There are also opportunities to attend other conferences, observe at international telescope facilities, and as part of the prestigious discipline of physics (Harding, 1991), receive substantial funding for these opportunities. Astronomy doctoral host institutions vary in size, prestige, physical location, and facilities, and as such, interviewees have primarily experienced astronomy culture through this smaller lens, so to speak. Although experiences varied within these institutions, most interviewees reported awareness of a level of systemic bias within the field of research astronomy. Importantly, however, for interviewees, not all such bias was necessarily understood as being related to gendered experiences.

\subsection*{4.2.1 Sexual Harassment and the Desire to Leave Astronomy}

While the majority of interviewees experienced gender barriers that are well-documented by women in STEM literature, some had more negative experiences. These experiences went beyond the boundaries of ‘not right, but sadly normal’, where many gendered experiences sat with interviewees, onto the ‘completely wrong’ end of the behaviour continuum.\textsuperscript{2}

\footnote{Universities also have access to smaller telescopes at the Siding Springs complex and observational students spend nights observing the stars from these facilities to gain hands-on experience.}
Sexual harassment was a particular issue for Brigitte, who like Beverley, actively left before the completion of her doctoral studies.

Yes, it’s the reality. I think you are more likely to be sexually harassed than not in astronomy. I mean still most people are really cool, but there’s just a funny culture about it that is not explicitly addressed. (Brigitte, recent graduate)

Brigitte notes that while there is a conversation about harassment within the discipline now, it was largely ignored for a long time. Due to the nature of her research, Brigitte travelled to many isolated places as well as international conferences where she felt particularly vulnerable. Australian astronomers are subject to longer travel times, seasonal and time zone differences than their international counterparts. PhD students, due to budgetary requirements, often choose less efficient travel methods than their senior academic counterparts and, as such, are at a disadvantage. The “funny culture” Brigitte describes encompasses a hierarchy in which students fall at the bottom and, due to the international nature of the discipline, are expected to adapt to cultures at isolated telescopes without their supervisors being present. So, while there may be codes of conduct and codes of ethics within professional bodies (American Astronomical Society, 2017; Astronomical Society of Australia, 2018a), these are not internationally enforceable. As highlighted by Gaspani’s (2014) study account of sexual harassment in Italian astronomy, there is considerable variation in international views of gender and acceptable behaviour.

This feeling of safety, or lack thereof, inspired Brigitte to actively leave her doctorate and find work in a highly regulated section of the government. When she compares her experiences, she indicates relief, “It’s just that in terms of feeling safe at work, which was not the experience I had at astronomy conferences or remote observing sites...It’s not nice to talk about, but sexual harassment...but it’s the reality for a female student in astronomy.”

In keeping with ethics and interview guidelines, I did not press for details about Brigitte’s harassment experiences. She had given specific examples of negative behaviours, but due to the de-identification process, her stories were too specific for inclusion. They did, however, justify her prioritisation of workplace safety. Brittany’s interview further pinpoints the problem with a more common example.

I had some sort of weird experiences at different conferences where some of the professors would come up to me and just go...“Come on let’s just get out of here and go scuba diving”, and things like that. I’m just like what do you mean? I just found it really awful really and sort of undermining. I mean, hello just because you think I’m a female in my twenties, I’m going to be sort
of in awe of your professorship. I don’t want to go off and, you know, you really take me for an idiot. So, I really just found that that kind of mentality was more present than I would have liked it to be. No. I just wasn’t impressed with that at all. I just don’t want to have to try and progress in an archaically minded field. (Brittany, recent graduate)

Brittany instead chose to pursue a fast-paced and challenging career in finance. The key difference between Brigitte and Brittany’s views is perhaps due to age difference. Brittany, who was older, had a career prior to her doctoral studies, whereas Brigitte was retained from her undergraduate degree. Brittany’s account of fairly generic incidents is a way for her to express her displeasure at the hierarchy within astronomy, particularly at conferences. While these experiences were undermining, as they occurred at a conference, she was able to dismiss them more readily than Brigitte’s experiences that occurred inside her institution. By dismissing the behaviour as that of ‘dirty old men’, these incidents did not have a significant effect on Brittany’s self-confidence or PhD studies. It did, however, affect her career choice post PhD as she wanted a more flexible and modern field and felt that astronomy was ‘too archaically minded’, which was her way of saying ‘sexist’ and ‘inflexible’.

The issue of sexual harassment has been discussed more since 2015 when multiple senior astronomers were forced to resign after being found guilty of multiple sexual harassment allegations (Wilson, 2015; Witzte, 2015; Urry, 2015; Witzte, 2016). These incidents have led to a reflection on sexual harassment policy in American astronomy and has spread awareness through the international astronomy community. Incidents of sexual harassment in astronomy, also documented in Australia (M. Brown, 2016; Cohen, 2016), show that there is a need to investigate this serious problem further. It is alleged that perpetrators were well-known harassers who had been identified through informal “whisper networks” (M. Brown, 2016; Kirkpatrick, 2015). Brigitte identifies the role of a local whisper network,

We have all these things if new PhD students are going to a conference. Like, if you’re going to Sydney call this chick. She will come out for you any time of night even if you have been drinking afterwards; she’s got you. Also, advice to stay away from such and such, he’s not good news. (Brigitte, recent graduate)

Here, the purpose is to support more vulnerable members of the group, in this case, female astronomy students. Due to their nature, whisper networks are largely informal and hidden, so without word of mouth access, more isolated students are unable to obtain information about these groups rendering them less effective to the most vulnerable. The
whisper network described by Brigitte also focused on conferences, visiting academics, and observation, which is only a small part of doctoral candidature and incidents that occur at the student’s host institution and are subject to institutional policy and procedure.

Incidents of harassment and the subsequent conversations generated by them have led to the commission of surveys, reports and policy updates. Here, the Pleiades Awards (Astronomical Society of Australia Women in Astronomy Chapter, 2014), the SAGE Pilot (Australian Academy of Science, 2015) and the Human Rights Commission Report (Australian Human Rights Commission, 2017) have bought the conversation about sexual harassment, gender equity, and power dynamics into the forefront of astronomy and other STEM fields. In addition, the ASA Inclusion, Diversity and Equity in Astronomy (formerly Women in Astronomy) has published anti-harassment internet resources (Astronomical Society of Australia, 2018b) in order to provide access for isolated astronomers, or those without access to support networks. This transition from conversation, to policy and subsequent implementation in the workplace, is in its infancy and measuring the overall effectiveness in changing astronomy culture is a potential avenue for investigation in later research.

Current university gender equity and harassment policies focus on rectifying the long-term power imbalances within the system. However, much like the leaky pipeline approach to gender equity which focuses on removing structural barriers, these policies are primarily focused on the actions of university employees who exert power and have the ability to model good behaviours and the potential change the work environment. It is assumed that these cultural changes will trickle down and eventually influence student culture. Anti-harassment policies are primarily designed to stop senior men exerting their status and power over students and junior colleagues. Unfortunately, however, this is not the only form of harassment that interviewees had to contend with.

Beth experienced sexual harassment at work from another student. “This a is bit uncomfortable to mention it, also being hit on all the time is also not very nice. I spent about six months of not wanting to go to the office because one of my office mates was always trying to hit on me.” Beth dealt with this unwanted attention through avoidance of the situation thus missing out on important contact hours with the astronomy cohort at her university. “I was not very happy with how some people would speak to each other, and I don’t think I said anything because I was always kind of like “I can handle it. I can do it.”” Beth’s instinct to internalise the problem and ‘handle it’ stems from her acceptance of the masculine nature of sciences and academic culture where intellectual doggedness, independence, talent, and the ability to ‘tough it out’ are indicators of a successful scientist. For Beth, the issue was not necessarily the men in the field but also the women within the cohort.
I think it’s not even just men [that are the problem]. I think I’ve spoken to quite a few other women in astronomy have also rather negative experiences with other women who have been very discouraging, and it was one of those cases, I was very close to going to bring up a harassment complaint or something, but I also felt like it was also way over the top. (Beth, recent graduate)

This issue was raised briefly in other interviews and is not uncommon in male-dominated fields where women are competitive with not only men but other women. This can happen in the form of harassment, which is not necessarily sexual in nature but still highly gendered. Like Brigitte, Beth also moved out of astronomy into a clearly defined workplace with positive working conditions. Brigitte, Beth, and Brittany undertook their degrees at different universities, yet they all experienced forms of harassment that went beyond the boundaries of what is considered ‘the usual’ identified systemic bias within the field of science. They also felt that their institutions did not support them, or wouldn’t if they had made a complaint. In relation to sexual harassment, incidents that happen off the student’s host campus are covered by whisper networks and although difficult to prove, are subject to professional association standards. Beth found it more difficult to deal with harassment by a peer and the attitudes of women at her PhD institution as she felt that she would not be believed and needed to ‘tough it out’ herself. This highlights a major short-falling in the institutional handling of sexual harassment.

These perceptions are corroborated by an Australian Human Rights Commission Report (2017), where 51 percent of the 30,000 university students surveyed were sexually harassed over the course of 2016, with 26 percent occurring in a university setting (p. 3).

It is clear from the results of the survey that students face a range of barriers, both structural and attitudinal, to reporting or seeking support following sexual assault or sexual harassment. In addition, students who did report were often unsatisfied with the response of their university. (p. 4)

This indicates that the problem is system-wide and not just applicable to women in STEM fields. The report does not break down harassment by discipline, so it is unclear where astronomy fits within this survey. Only 6 percent (p. 4) of students believed that universities were doing enough concerning the prevention and reporting of sexual harassment and assault. While reports and data are a good measure of the general health of the university system, reflexive policy, and initiatives must be implemented to address the underlying structural problems within institutions.
4.2.2 Workplace Exclusion & Networks

Much of the inequality described by the interviewees is daily life for women in STEM fields (Harding, 1991; Etzkowitz et al., 2000) and many refrained from detailed answers for various reasons. Bobbie describes her reluctance to talk in much detail “I mean there’s some things I probably shouldn’t talk about because it’s a bit political and a bit personal, Certainly, there’s a lot of kind of boys club stuff that goes on and a lot of its inadvertent.” Bobbie’s view that much of the discrimination is ‘inadvertent’ rationalises the existence of commonplace subtle discrimination to cultural factors and the perceived ignorance of the ‘boy’s club’ as to the effect of their exclusionary behaviours. An off the cuff example Bobbie gave to support this was the continuation of scientific conversations across bathroom boundaries, where peers were discussing computer code and continued to discuss the problem in the bathroom, unintentionally excluding her from the professional conversation. This example stood out because of the inclusion of a literal barrier, the men’s bathroom, and the fact that the social exclusion was accidental and most likely not noticed by the men involved. Although a bathroom on this occasion, exclusion through social spaces, involvement on sport teams, or other divides such as cultural practices, affect networking and career advancement opportunities for minorities (Etzkowitz et al., 2000, p. 182).

The terminology of the ‘boy’s club’, ‘old man’s club’, ‘buddy system’, or various combinations thereof, were used by multiple interviewees when describing their experiences of exclusion and the informal support network between men in the field. Beth told of her experiences internationally

*I feel there is still a bit of a buddy system, and I was in the US for a while, and I felt like it was sort of an old man’s club in every meeting who would sit up the back and pass judgement on people. It’s really hard to get into that old man’s club, and it does exist, and even though they sometimes really say openly that they want to encourage more women to come, it still feels like it’s this old man buddy club a lot of the time.* (Beth, recent graduate)

This sentiment is expressed in much of the literature on women in academia and male advantage (Etzkowitz et al., 2000, p. 182; Howe-Walsh and Turnbull, 2016, p. 417) and one of the reasons that the academy is implementing diversity and equity programs. While these ‘old man’s clubs’ seem to want to encourage more women to join, they focus on stereotypical masculine traits in academia. Brigitte observes what she perceives to be a problem in the academy, “I think it’s wrong to ask people to be somebody other than themselves to succeed. Like if they are smart they should be able to succeed without having to, you know, bring out their balls.” This sentiment is reflected in the Baltimore
Charter, which states “Women should not have to be clones of male astronomers in order to participate in the mainstream of astronomical research” (Albert et al., 1993), and is one of the foci of making workplaces more female-friendly and breaking down barriers to networks. This is difficult as diverse sub-networks form outside of the ‘old boy’s club’ where minorities are drawn to each other (Murillo et al., 2012) thus strengthening their position yet in doing so, exclude themselves from the larger, more established networks.

Chloe felt let down by her supervisor for failing to open up networks in her field of study. Her supervisor was well connected to the ‘old boy’s network’ yet failed to introduce her making it awkward at conferences.

"I’m not very happy with my networking and I have to put the blame on my supervisor for that because he never actually introduced me to any of the people. I mean all the people that I’ve met was like I introduced myself. The only time when I actually met some people from that narrow field...it was last year at the [conference series]conference in [narrow field of astrophysics]. I was actually “introduce me to some people that I know all by name because I’ve read all the papers”. I don’t know many people. I don’t have a network, and I blame him for that." (Chloe, current student)

Consequently, Chloe feels that she is not well connected enough in the field to continue post PhD and at her institution, there are very few people who work in that field, which compounds this feeling of isolation. Chloe chose her supervisor, institution, and field of study carefully with the assumption that she would be included in an established network. Unlike Camille and others who stressed that their decision to leave was no ‘fault’ of their supervisor, Chloe directly addresses the perceived short-falling and assigns ‘blame’ to her supervisor for not introducing her to others in the field. It is unclear from Chloe’s interview whether this was because of her gender or other factors. She did, however, identify that the division of labour, especially in relation to conference organisation, was highly gendered which put her at a networking disadvantage during events.

The theme of exclusion continues for Bianca, who also completed her PhD without a professional network and made her own way post PhD.

"I think as far as I can tell the network for female astronomers is really bad. It’s a lot of that male colleagues will have close colleagues to work with all over the world, and they have lots of contacts and people that will help them get things. I know that I definitely do not have that and that is one thing that I’m trying to figure out if I can get...So, I would say a lack of a network would be one,
and the other is related to a lack of support from colleagues. (Bianca, recent graduate)

Bianca identifies a lack of support and the visible difference between male and female networks. Though she identified a women astronomer network, she had little way of accessing this due to her relative isolation and “lack of support from colleagues”. Bianca also identifies as an outsider due to her pathway into astronomy from a low socioeconomic background and although she does expect certain gendered behaviours and lack of support from male astronomers, whom she perceives as more advantaged with better networks, and feels more disappointed by the women in the field.

So there a very few female academics that I feel would support me in my career and some people are generically supportive, but some of the worst comments I’ve got from other people have been from other women astronomers. Such as “Why you even here? I didn’t think you were the kind of person who would be an astronomer.” The kind of stuff that you kind of expect from like stodgy old white men, I seem to find a lot more from middle-aged white women...It’s been a long, long time since a man has said anything to me that I would consider offensive. It’s not been very long since [a woman has said something], especially women who have more secure positions can be very unhelpful, not all of them, but more than I would have thought. So, it’s not a nice environment in that respect. (Bianca, recent graduate)

Bianca’s experience highlights the fact that the stratification of networks in astronomy occurs not just within gender, but across fields of study, institutional status and, to some extent, social class. Both Bianca and Beth experienced difficulties with women in the field, which possibly because less expected, were found more offensive than the expected stereotypical behaviour of men. Beth was close to filing a complaint, and Bianca withdrew from the unhelpful networks. This is perhaps one of the effects of the women in STEM and various women’s networks in astronomy, which as they are relatively well publicised on social media, are therefore thought to be inclusive and that there is some kind of ‘sisterhood’. In reality, like all other fields of science and academia, astronomy is stratified, vastly complex and the division between the ‘haves’ and ‘have-nots’ is divided not only by gender but by employment status. Here, gender equity initiatives such as the SAGE Pilot and Pleiades Awards focus on a pipeline approach of fixing working conditions for those already within the field. By focusing on women as a large relatively homogeneous group, these equity initiatives set up the expectation that women, as part of a network, will support each other. As Bianca and Beth found, this is not necessarily the case.
Although gendered issues of harassment and exclusion affected interviewees, these were in the identified realm of “science as usual” (Harding, 1991, p. 54) as covered by literature from professional bodies the their subsequent education programs and gender equity policies (Australian Academy of Science, 2015; Astronomical Society of Australia Women in Astronomy Chapter, 2014). It was the informal networking and interactions with women that had a greater impact on interviewees.

4.3 The Golden Three

This chapter considers a ‘golden three’ approach to undertaking an Australian doctoral program; supervision, workplace culture and access to networks. These elements are largely included in research, policy, and initiatives that are based upon the leaky pipeline model of retaining women. How women experience academic settings during their PhD may influence their decisions to change careers post PhD.

Although finding a compatible supervisory team is acknowledged as being an important and complex factor in PhD completion (Harman, 2002), how interviewees chose their supervisors did not make a significant impact in this study in relation to the decision to pursue post-astronomy careers. It did, however, make an impact towards completing their PhD, and students with stronger relationships with their supervisors were able to navigate adversity and complete their studies, whereas students with more tenuous relationships were more apt to leave prior to the completion of their doctorate. There was, however, a stipulation expressed by students who had positive relationships with their supervisors, that their decision to pursue post-astronomy careers was no reflection on their supervisor. In contrast to this, doctoral students who had poor relationships with supervisors attributed some of the ‘blame’ for their career change directly to their supervisors. This indicates that there is an underlying assumption by interviewees that their decision to pursue a post-astronomy careers implies a ‘fault’ in their supervisor and that changing careers is viewed negatively. This logic is dominant in leaky pipeline retentive strategies where faults are identified, leaks are plugged, and women continue down the same pathway.

Astronomy has many of the same cultural problems that are presented in male-dominated fields such as entrenched systemic bias and the foundation of meritocracy (Harding, 1991; Etzkowitz et al., 2000; Castilla, 2008; Castilla & Benard, 2010). While equity initiatives have made these issues more broadly recognised, an issue that has garnered attention has been that of sexual harassment by senior male astronomers (Wilson, 2015; Witze, 2015; Urry, 2015; Witze, 2016). Interviewees’ in this study also experienced degrees of sexual harassment, and for some, this influenced their decision to leave the field of astronomy as
they did not wish to progress in what Brittany termed “an archaically minded field.” Although not a central focus of this research, varying degrees of sexual harassment is present in the Australian astronomy community and is already identified by “whisper networks” (M. Brown, 2016; Kirkpatrick, 2015) which are accessible to women. Work in this area falls into one of the main focuses of Australian leaky pipeline focused literature, policy, and programs which have occurred since conducting interviews for this research (Astronomical Society of Australia Women in Astronomy Chapter, 2014; Australian Academy of Science, 2015; Australian Human Rights Commission, 2017; Astronomical Society of Australia, 2018a).

A more subtle bias, as identified by interviewees is the exclusion from ‘old boys’ networks which sets them at a disadvantage during and post-doctoral studies. These, as literature suggests can be subtle and firmly entrenched in the practices of institutions (Etzkowitz et al., 2000). Interviewees viewed these additional obstacles to completion and integration into the astronomy community. Moreover, they were, to a certain extent, accepted and expected as part of the process. What was more problematic, was that perhaps due to women in STEM initiatives, some interviewees mistakenly assumed that senior women in the field would be more supportive in their networking attempts. This created disappointment when women acted in a way that was perceived to mirror that of their senior male astronomy counterparts. By addressing women in STEM as a relatively homogeneous group, equity initiatives fail to adequately recognise intersectional and individual aspects that affect networking and inclusion and in some cases, create a misunderstanding regarding the ability and inclination of senior women astronomers to assist their junior counterparts.

This chapter demonstrates that there are still many barriers to overcome in Australian astronomy. Students who enrol in doctoral programs experience ‘the golden three’: supervision, workplace culture, and access to networks. These elements are guided by supervisory relationships that aid in integration into the astronomy community, provide access to networks, and help in navigating adversity. As such, the leaky pipeline view is an effective vehicle for improving university-based conditions during the PhD process, but as a vehicle for examining career pathways, it compounds the already existing implication of ‘fault’ or ‘leakage’ that is associated with the decision to change fields post-PhD.
Chapter 5

Entering Academia: Narratives and Motivation

This chapter focuses on the motivational narratives of interviewees as they recall their entry into the PhD program. Astronomy is a relatively well-funded discipline in Australian universities that draws from pools of domestic and international candidates to fill scholarships. Recruitment strategies differ depending on university prestige and the availability of viable candidates. Australian Universities compete with both international PhD programs and each other to recruit the most desirable PhD students. Before I begin the empirical analysis of interview data, I will briefly consider the structure of the Australian PhD, differentiating it from its North American counterpart, and consider the factors that affect the competitiveness of higher education astronomy in Australia. In addition, I will examine the educational filtering that effectively renders postgraduate astronomy a relatively homogeneous group, especially in relation to social class, where individuals from lower socioeconomic backgrounds are largely excluded prior to reaching postgraduate recruitment levels. These issues are illustrated by the narrative of one of the B group interviewees who overcame these obstacles to gain a doctorate.

The later analysis of interview data focuses on a thematic narrative analysis (Riessman, 2005) of how research participants talked about their entrance into PhD programs. Here, I have used an interactive, data-driven approach and developed a typology of PhD student motivational narratives when enrolling in the PhD program. These narratives types are: the accidental PhD narrative, usually a domestic student who is retained at university without much critical reflection on what they are doing; the adventure PhD narrative, a visitor to the world of astronomy who is undertaking postgraduate study out of personal interest and/or the desire to study in Australia; and the research career PhD narrative, the archetypal PhD student who wishes to become an academic. By going across individual
narratives to analyse the common patterns in terms of motivation, interviewees spoke of their entry into academia. It is clear from their accounts that very few interviewees commenced the PhD with the explicit goal of becoming an academic researcher. This shows that, although technically retained in the educational pipeline, interviewees already indicate a range of reasons, which for clarity I term motivations (Mills, 1940), for beginning their doctoral studies which would later affect post-PhD career outcomes.

5.1 Setting the Context: The Australian PhD

An Australian PhD, much like its British counterpart, takes 3-4 years and is based on an apprenticeship model that results in a thesis, or research by publication. This process involves a steep research learning curve with very little comparative coursework to form underlying theoretical knowledge. The Australian style differs considerably from the United States 5-7 year degree that contains two years of coursework then progresses to a research component that allows more time for publication, networking, presenting at conferences and achieving research metrics for academic career pathways. US doctoral candidates also undertake greater teaching loads, which gives them considerably more time during their degree to develop teaching pedagogy and practice, which are also vital skills for securing an academic research position (Etzkowitz et al., 2000). While both styles of degree offer advantages and disadvantages, this research concentrates on the Australian 3-4 year astronomy PhD program and women who have completed this qualification.

The Australian PhD, which can be completed directly after a Bachelor’s degree with honours, or a Master’s degree, is a relatively fast process that leaves little time for students to gain an in-depth theoretical understanding of subject matter, form a relationship with their supervisor/research teams, publish, and present their data. This means that Australian PhD students typically depend heavily on their supervisors for initial guidance with only undergraduate experience, vacation scholarships (usually undertaken as a paid research project during the summer months) or short conversations with them before application and commencement of the degree. As discussed in Chapter Four, supervisory relationships are one of the most critical aspects of the PhD, though are usually the element most left to chance. For students already at an institution who are retained, factors such as familiarity, field prestige and the observance of PhD students who are casual academics or tutors build an idea of what to expect during their doctoral studies. This, however, is only a partial view of the doctoral candidature at an Australian university.

By enrolling in a doctoral program, the student engages in two industries; research and research training (Australian Government Department of Education and Training, 2015,
Sections 4.1-4.2). Research training involves educational programs and institutional support that culminates in an advanced research degree for the student. The university receives money for this through course fees or government contributions. Research is the process of producing peer-reviewed research which is situated in a particular field, in this case, astronomy. Both of these industries encourage immersion in academic research culture, and the doctoral student becomes engaged in training that is preparation for conducting academic research and potentially joining the faculty (Austin, 2002). However, there is a misconception by doctoral students as to what being an academic is. Astrid, an established astronomer interviewee, observes that as a postgraduate student, it is difficult to attain the knowledge of what being an academic entails. She notes,

...that in some cases...that people [don’t] really know what they’re getting themselves in for. They’ve got this that one model academic who is amazing and has this great life and it’s not like that for all of us...So, if what they really enjoyed doing is the research, which of course would be what they’ve been trained to do, that’s not necessarily what the bulk of the job would be later on.

(Astrid, Senior Astronomer)

Astrid describes a partial perspective or filtered perception of academic roles. This understanding of academic positions is largely learned through student observation of academics undertaking roles as supervisors, mentors, and scholars. Sauermann et al. (2012) confirms “that the faculty research career is indeed by far the most often “strongly encouraged” career [during postgraduate studies]. A small number of students feel that certain other careers are explicitly discouraged, mostly teaching careers and careers in industry.”(p. 4). Although interviewees in this study did not speak of being actively discouraged, they experienced stigma (Goffman, 1963) regarding their decision to leave astronomy and consequently kept their decisions relatively private. This issue will be further discussed in Chapter Six. In an attempt to change this perspective paid industry placements have recently been introduced as part of science PhD programs (Swinburne University of Technology, 2018). This initiative is aimed at fostering closer connections to industry, providing work experience to doctoral students, and more importantly, illustrates that industry is not a poor or ‘second’ choice. As the program is in its early stages, there is currently no information regarding experiences and outcomes concerning student engagement, enrolment and exit employment.

5.1.1 Research and research training industries

In the previous section, I assert that Australia’s PhD students are caught between two industries: research and research training. For PhD Candidates, the main focus is on
experiences that facilitate their research. Prior to starting their PhD, students are already aware of university rankings (Hazelkorn, 2008) and factors that motivate them to join a PhD program. These motivational factors will be discussed later in this chapter.

The higher education, or research training, sector has its own separate discourse that is removed from what students, and potential students engage in. One of the key tensions within this sector is the concern about an over-supply of doctoral graduates, which, in turn, leads to the devaluation of PhD qualifications (Croucher, 2016; Editor Nature, 2011). Since the 1990s, postgraduate numbers have increased and there are now significantly more graduates produced than the academic labour market can employ (Cuthbert & Molla, 2015). This issue has been amplified by a neoliberal push within Australian universities and the mass casualisation of academic staff into precarious employment (T. Brown et al., 2010; Connell, 2013; Standing, 2011). Cuthbert and Molla (2015), describes an ‘employability crisis’ approach to PhD graduate training and implementation of a skill based PhD program to rectify this perceived deficiency. Here, they observe that “the quality of the actual research training graduates receive and the quality of the research they produce is glossed over with efficiency, relevance and employability serving as proxies for quality” (Cuthbert & Molla, 2015, p.49). The debate about efficiency, student numbers, employability outcomes, and PhD program relevance occurs largely in the background of the higher education industry and is largely visible when there are course changes. Interviewees in this study, aside from the established astronomer group, had very little understanding of, and exposure to this type of discourse. As such, it is outside the scope of this study to explore further. It is, however, an underlying tension within the Australian higher education and research training.

5.1.2 University Competition

Australian universities compete worldwide and domestically, and there is intense competition to attract the best candidates. To attract elite international astronomy students, many universities work with Australia’s main astronomy bodies, The Australian Astronomical Observatory (AAO) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and offer co-supervision with these institutions as well as financial incentives such as top-up scholarships, observing time, and travel funding. The competition between domestic universities to attract high-calibre international students is also high. Prestige ‘Sandstone’, or ‘Group of Eight’ universities (Group of Eight, 2018) an incorporated group of Australia’s oldest, most elite universities, brand themselves as Australia’s leading universities. The Group of Eight publicises their international ranking, and “All Go8 member Universities are ranked in the top 150 institutions worldwide in the Academic Ranking of World Universities from Shanghai Jiao Tong University (ARWU), the
Times Higher Education World Rankings (THES) and the QS World University Rankings (QS)" (Group of Eight, 2018). Combined with receiving 73 percent of Australian competitive grant funding and the fact that they award half of all doctorates produced in Australia (Group of Eight, 2018) means that Group of Eight universities are more likely to attract higher level postgraduate students than smaller, more modern, less-funded universities that rank lower on league tables (Hazelkorn, 2008).

Although no reflection on the quality of academic research conducted, this hierarchy within the Australian university system means that smaller institutions outside the Group of Eight have smaller domestic cohorts and attract fewer international students. This, in turn, makes it more challenging to fill scholarships with ‘top tier’ doctoral students, especially international ones, as they tend to be drawn to higher-ranking institutions, or those in attractive locations. In order to address this ‘prestige’ problem, smaller universities have re-branded themselves as ‘Modern Universities’ and compete with each other in the Fifty Under Fifty Rankings on the worldwide league tables. These smaller universities rely more on innovation and specialised programs to attract students and research funding to create a niche for themselves. The smaller cohorts, program innovation (Swinburne University of Technology, 2018) and targeted research of these young universities tend to attract students who pursue a PhD as an adventure or personal interest.

Worldwide league tables are likely to influence international students when choosing a university, especially if they are planning a career in astronomy. For domestic students, the hierarchy is already understood from their undergraduate choices, and there is limited mobility between institutions. PhD scholarship selection criteria differ between international and domestic students. International students are highly qualified, often with a US or European master’s degree, and have already produced a publication record that places them developmentally ahead of domestic students with honours degrees. Prior to 2017, international students were given less time to complete their doctoral studies than domestic students which meant that domestic students were able to ‘catch up’ over the more extended period. After the 2017 government funding changes, universities responded by tightening domestic student completion deadlines to the same level as international students (Australian Government Department of Education and Training, 2017).

5.1.3 Retaining Domestic Students

University competition to attract domestic students occurs differently from the international market. In astronomy, 71 percent of students who complete a Bachelor of Science honours degree continue to postgraduate study and 89 percent of these stay at the same
institution. Of those who change universities 7 percent move to another Australian university and only 4 percent move internationally (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 7). This small level of student mobility is predominantly due to university differences in specialisation between undergraduate and postgraduate level degrees. Not all universities offer astronomy at both undergraduate and postgraduate levels, and the 7 percent movement most likely reflects this. In addition to scholarship availability, prospective supervisors and available topics all influence the decision to change universities. The most common recruitment method for domestic students identified by participants in this study is retention from their undergraduate, honours or master’s degrees and involves a ‘tap on the shoulder’ from prospective supervisors.

Universities actively retain promising postgraduate students in a move that benefits their enrolment numbers, progresses research priorities, and benefits the student academically as they gain a higher qualification. Some strategies of retention are vacation scholarships (which are funded projects that run over a non-teaching university period), research assistant, and laboratory demonstrator work. These benefit domestic students by providing extra income, teaching, and research experience as well as publications that bolster their academic resume and open up pathways for further scholarships and study. They also have a secondary effect, that students tend to follow opportunities into doctoral studies without fully weighing implications.

This smooth retention occurs more often in well-funded areas of the university such as physics, as lesser-funded areas such as the Arts, generally do not have the resources to run full scholarships and bridging programs to financially link undergraduate studies with the PhD. When considering the effectiveness of these strategies, it is important to note that high performing students get these opportunities after an educational filtering process has already been enacted during undergraduate degrees where academic ability, background, and opportunity have already established who is likely to be most successful in the doctoral program.

5.1.4 Enforcing Inequality Through Educational Filters

Students from lower socioeconomic classes are often filtered at the PhD point, and it is the top performing students who have the opportunity to enter the program. In Australia, the government subsidises a limited amount of tertiary study per person, so pursuing higher education at a postgraduate level is not necessarily too disadvantageous, even when coming from a lower socioeconomic background. The availability of funding, as well as the mentorship students receive from working with researchers are reliable indicators that a
student will, if given the opportunity, most likely continue in astronomy at a postgraduate level (McCormick et al., 2014).

Efforts to retain women in STEM fields have worked on increasing women in academic staff positions by removing the barriers that limit women’s involvement in STEM fields. Still, as the tertiary sector looks to fix the leaky pipeline and improve conditions for women in education, it evident that ‘leakage’ is not the only barrier that influences the availability of qualified PhD students. Inequality regimes (Acker, 2006) apply not only to workplaces but at multiple levels of the education sector (Bathmaker, Ingram, & Waller, 2013; P. Brown, 2013; Polesel, Leahy, & Gillis, 2018). Here, a similar complex combination of factors such as race, gender and social class within tertiary education effectively filter out unsuitable candidates prior to the PhD program through metrics. During this meritocratic recruitment process, an unencumbered person who has accumulated the correct academic credentials and connections has an advantage over other students from lower socioeconomic or rural backgrounds who may effectively self-filter before graduate school. This process reduces the potential cohort to a relatively small and homogeneous pool of eligible students that can be recruited by the university. Filtering happens early from high school to undergraduate levels, meaning that eligible students are from a social class where they have an academic and financial background that enables them to attend university. McCormick et al.’s (2014) research into the undergraduate pathways of US women astronomy PhD candidates observed that social and financial resources gave participants “advantages that may not be available to others without similar access to such resources” (p. 333). Of the five interviewees in McCormick et al.’s pilot study, all but one did not consider finances to be a deciding factor in pursuing their postgraduate degree.

To extend the metaphor, these social and financial advantages are educational filters that effectively contribute to field homogeneity in relation to social class and by extension race and gender as described by Acker (2006). Upon fieldwork observations for this research at the Astronomical Society of Australia’s Annual Scientific Meeting, this was visually apparent as the group seemed to be largely homogeneous in terms of race and social class. In terms of cultural background, astronomy cohorts consist predominantly of individuals from Western countries in Europe, North America, and Australasia. So far, the working Australian astronomy community, as surveyed by nationality, found that 58 percent had Australian citizenship, 13 percent European, 9 percent North American, 8 percent UK, 6 percent Asia, 3 percent New Zealand and 3 percent South African and South American (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 23). This survey considers only nationality and not the racial and cultural background of astronomers and as such is only an indicator of the cultural makeup of the Australian astronomy cohort. It is also important to note that English language requirements for working in Australia may also play a part in shaping the workforce. Wakeling (2005), asserts that social class,
linguistic ability, and education are intrinsically linked, as language acts as a filter for postgraduate education opportunities. This is evident in astronomy, where English is the universal language, and those who have not attended an English speaking or bi-lingual university are effectively limited regarding Australian study opportunities and also in the job market post-degree.

While the discipline filters out specific individuals who are limited by opportunity, not necessarily merit, not all students are excluded by their backgrounds. To illustrate this, I will draw on a recent graduate as a case. Bianca is an exemplary case (Flyvbjerg, 2006), in that her narrative drew on overcoming a large number of intersectional barriers and filters to gain entrance into universities and the PhD program. Her story highlights many of the barriers that students without cultural and financial means face within the education system. For her, the attainment of a PhD, while challenging was not the most challenging part of her educational experience as she had already navigated a comprehensive range of barriers to enter graduate school.

During her interview, Bianca was asked a general question regarding obstacles that had impeded her studies and affected her career decisions. While many interviewees interpreted this to mean what happened during their PhD studies, Bianca did not differentiate between earlier and postgraduate experiences as they have all led to the one goal; becoming a PhD educated scientist. Bianca describes her early experiences:

So right off the bat, my first big career obstacle is that I was started out at seventeen very, very poor with no solid educational background because I had gone to a school that refused to allow me to access advanced algebra classes. So, I didn’t know multiplication...Pre-calculus, of course, was out of the question. I’d never even seen the upside-down triangle thing. No idea what about any of that stuff so I was really unprepared academically and I was really, really poor...it was that kind of place. It’s a kind of place that most people don’t make it out of. (Bianca, recent graduate)

For Bianca, who is from a low socioeconomic background, academic disadvantage was felt early and contributed to an adversarial relationship with educational institutions that she perceived as blocking her dream of becoming a scientist. However, Bianca managed to undertake alternative secondary education to receive her certificate and also managed to teach herself technical computer skills. She describes her early university work experience and strategic plan to ‘leave home’ and become a scientist:

So, I got a job through the [local] university with the foreign languages department and used that to teach myself computer skills and stuff like that. The
other thing that I had to get was work experience if I was going to go anywhere from there. It was also kind of a dead end system because they had some physics classes and math classes, but they didn’t really have much in the way of science or clear career path forward.

So the other thing that really would have stopped me was if I hadn’t been able to get out of [home state]. A friend of mine moved [interstate], and I did a bunch of research online and found out that they had a really good program. But yeah, so I was able to get [interstate] eventually by applying through a direct transfer program because I’d already been enrolled in a university.

So I applied to a bunch of different places. I applied to [prestigious universities] and all the stuff that you do because you hear about these things. I actually got into pretty much all of them. So, I got accepted into [very prestigious university], and I got accepted into a bunch of other ones but when I was looking at the actual programs the [chosen university] had lower tuition, and they allowed access to telescopes. (Bianca, recent graduate)

Bianca’s pathway into university is unusual for elite scientists. Her goals (to leave her home state and to become a scientist) may have been impossible for many in her socioeconomic situation. She attributes the completion of high school and subsequent acceptance to multiple universities as a combination of determination, hard-work, and luck. For her, the first insurmountable goal was to leave her hometown and engage in training to become a scientist. It was serendipity that a friend had also managed to attend an interstate university which opened up possibilities for Bianca to consider as well as peer support. While Bianca was accepted to prestigious universities she legitimates her choice of a less prestigious university, by focusing on factors other than reputation. For Bianca, lower tuition and access to university telescopes were significant factors that influenced her decision to attend a smaller, technical university. This pragmatic approach that considered degree value and technical opportunity over university prestige meant that Bianca chose an institution that aligned with her values. Her self-exclusion from more elite universities meant a loss of cultural prestige but also protected her from further financial burden. The next stage of Bianca’s story illustrates how even after leaving behind her hometown, structural inequalities become clear especially in relation to navigating institutional systems.

Bianca’s arrival at her interstate university coincided with the news of a major family health crisis that called her home immediately. This caused her to miss the first two months of classes. Unbeknownst to her, however, as she was attending to her family in another part of the country, the university transfer had been misaligned, and she was
placed in classes multiple years above her educational level. Bianca’s position as the first in family to attend university put her at a disadvantage as she was unfamiliar with university systems and culture (O’Shea, 2014). Here she was “not only disadvantaged by their parents’ lack of experience with, and information about, college, but also by other social and economic characteristics that constrain...educational opportunities” (Moschetti & Hudley, 2015, p. 247). Her reaction to this administrative error was not to ask for institutional support but to rely on herself. Moschetti and Hudley (2015) argue that first in family students from lower socioeconomic backgrounds “believe their own personal characteristics, rather than social capital, to be the best resources for their success” (p. 247). In other words, if they perceive administrative or support services as flawed, then they are more likely to rely on themselves instead of access university services that will help them accumulate the knowledge to navigate the systems. Bianca’s reaction to this setback is thus reflective of her socioeconomic background,

When I came back I was not only two months behind but I was in classes that were two years ahead of where I supposed to be, and I was well past the time where I could change or dis-enrol, so had the choice of to try to pass these classes or take a failing mark in everything and get a really low GPA and probably lose out. So, I just basically pulled apart every brain cell I had and destroyed my health to make it through those classes...and that would have been the other ‘you can fail here’ mark because I still don’t have any idea how I made it through that because I didn’t have the calculus and there was a couple of people who were...yeah, so it was like that would have ended it all right there, and I still hadn’t even left...[home country]. (Bianca, recent graduate)

Although Bianca had setbacks, due to her circumstances, she recognised this as a pivotal moment in her education where she would either ‘pass’ or ‘fail’ in her goal to become a scientist. While others may have weighed these challenges as too severe to overcome, Bianca, who was already used to struggle, sacrifice, and confrontation in her bid to become educated placed the onus on herself and made further sacrifices to her health. She didn’t want to ‘lose out’ and waste the many years she had already invested or go back to her hometown.

While Bianca’s early story is an exception in the level of social disadvantage experienced, multiple interviewees accessed alternative education systems to complete high school and the transition into university. Like Bianca, Beverley accessed an alternative high school certificate program, in Australia known as Technical and Further Education (TAFE), developed an interest in, and ultimately gained access to university level astronomy and the sciences.
While alternative education may provide the educational prerequisite knowledge for university entry, first in family, mature age entries, Indigenous, and other non-typical university students experience complex issues regarding identity, change and belonging (O’Shea, 2014). Bianca’s example illustrates the challenges faced by students from lower socioeconomic backgrounds who are the first in their family to attend university. Her method of dealing with adversity, her versus the problem, is not unusual for first in family students as they build social capital (Moschetti & Hudley, 2015) and as Acker (2006) asserts, gender, race and social class are intertwined elements that enforce inequality. Underlying complex issues effectively filter out postgraduate astronomy students prior to specialisation and in this sense, instead of implementing human capital approaches to retain women through gender diversity programs, universities are faced with more complex intersectional problems concerning student access and inter-university competition for government funding.

5.2 Narrative Accounts of Entering Doctoral Studies

In this section, I will investigate the motivations for undertaking doctoral studies in astronomy. This narrative approach (Riessman, 2005) examines how participants frame their entry into academia or the PhD program. As they reflect on their academic choices, interviewees seek to account for why they joined the program from the perspective of a recent graduate who has left the academy as well as a current student who is currently weighing up their career options.

Here, I will present three narratives of motivation evident in interviews with recent graduates (B Group) also supplemented by current students (C Group). These narratives can be roughly typified as accidental PhDs, adventure PhDs, and research career PhDs.

5.2.1 Accidental PhD Narratives: The PhD by Default

The idea of an accidental PhD, or as Bobbie called it ‘PhD by inertia’ seems largely limited to domestic students who are retained at the university where they obtained their previous degrees. Though it may seem absurd to ‘accidentally’ obtain a PhD, a pattern of ‘accidental’ decision making became clear in the analysis of interview data. As discussed earlier, universities are motivated to retain potential domestic candidates for PhDs and through research assistant work and vacation scholarships/internships, ensure that students need not have a break between degrees. Brigitte’s narrative outlines the active role her supervisor took in retaining her.
I went into maths and physics in the undergrad level because I didn’t know what to do and they were my good subjects. I just wanted to avoid a uni degree that had essay writing. I did that, and my undergrad was pretty decent. Then my supervisor approached me in third year and said “You should do honours with me. I’ve got a project for you” so I did that and after honours, I wasn’t ready to face the real world yet. So, I did well enough to get a PhD scholarship for three years, and I kept going with the same supervisor...Yeah, I sort of drifted into it more or less. (Brigitte, recent graduate)

Brigitte’s experience illustrates the accidental PhD narrative as it was repeated by a number of interviewees, who followed the ‘path of least resistance’ into a PhD qualification. Brigitte’s attraction to the PhD was a number of clearly identified factors; a chance to avoid ‘the real world’, to continue her honours work which she had already done well at and receive a guaranteed scholarship income for three years. Rather than seeking out the PhD qualification, Brigitte was attracted to continuity with an income to aid her studies. Brigitte’s educational choices were initially filtered by personal preference, an aversion to essay writing. After this, she describes her academic ability as ‘pretty decent’ and ‘good enough’ to progress further along to honours and into postgraduate education. The downplaying of abilities in a field that she was gifted in is typical in accidental PhD narratives. Instead, interviewees identified a mathematical or scientific aptitude and/or good work ethic as reasons why they did not overly struggle in undergraduate education. They then progressed by following opportunities available to them, as gifted or desirable students, to be recruited into postgraduate programs without significant effort on their part. Barbara also fell into a similar pattern once in the university pipeline.

I actually wanted to do medicine. I actually never had any interest in astronomy ever. I liked it as a sort of, you know, as a subject but it wasn’t something I was interested in pursuing. In high school, everyone said the way to get into medicine is you do double maths physics and chemistry because if you do that combination of subjects, you’ll get a really high score...I still wasn’t that committed to what I wanted to do so I just enrolled in a physics degree at the local university because it was something I could do while I was working part-time. During undergraduate, it turned out I liked maths and physics because I was OK at maths and physics, so I did alright. So I got to the end of it, and they were like “Hey, why don’t you do an honours degree? We will pay you a scholarship.” and I was like “Well, I’ve got no other plans. Why not?” (Barbara, recent graduate)

This pattern continued through to PhD level as Barbara reflects.
They’re “Why don’t you do a PhD? We will pay you to do it.” and so, well, you know, why not? And to be honest, I never put much thought into what the ultimate goal...not the ultimate goal but the ultimate endpoint of the career was going to be, and I was enjoying what I was doing, and it was easy in terms it was easy to get into for me. I know some people don’t find it easy to get into PhDs, but for me, it was essentially the course of least resistance through life. (Barbara, recent graduate)

Like Brigitte, Barbara downplayed her academic aptitude as ‘OK at maths and physics so, I did alright.’ As such, offers of scholarships and further study presented interesting opportunities and, like her previous education patterns, when senior figures suggested subjects and pathways and her response was ‘Well, I’ve got no other plans. Why not?’ Barbara’s description of her pathway as ‘easy’ indicates her university had a retention strategy in place where she was able to access opportunities such PhD funding and mentorship from senior academics as a ‘path of least resistance’ rather than an aspirational goal.

For others, such as Bianca who was subject to educational filtering because of her socio-economic background, every academic success was considered a major achievement as she was more likely to be filtered from the academic pipeline. From this perspective, gifted domestic students are relatively privileged in that they are well supported and encouraged to pursue further education with little hardship or change. This normalises their experience of privilege and may lead in turn the student to assume that careers post-PhD will follow the same pattern of ‘least resistance’.

Bobbie, one of the recent graduate interviewees terms this pattern a ‘PhD by inertia’ as she reflects on her ‘easy’ continuation from master’s degree into doctoral studies.

There was a certain amount of inertia involved in staying. It probably helps if I explained that my master’s was basically a feasibility study into what I ended up doing for my PhD and the result of my master’s was ‘yes, it is feasible’ so it was kind of a no-brainer to keep doing that. I think that it played a part in me staying. My supervisor asked me to stay on with her, and she asked me to keep working on that stuff, so that made it easy, right? I didn’t have to apply for anything; I just had to keep going... That said, I have talked to other people have said the same thing, that doing a PhD was less scary than just going out into the world. It took less effort doing than changing, than finding a job at that point. So, I think that it’s probably not that uncommon to go into a PhD through inertia. (Bobbie, recent graduate)
The ease in which Bobbie entered the PhD illustrates that her supervisor and institution were also very successful in retaining her into a doctorate. Like Brigitte and Barbara, Bobbie took advantage of the opportunity to continue familiar work with a known supervisor, avoid ‘the world’, and receive a scholarship income.

Bobbie, who viewed this a ‘PhD by inertia’ questions this type of recruitment and notes that from her observations, these students are more likely not to complete their doctoral degrees. She notes that before undertaking the PhD she spoke to a doctoral student who gave her the advice “If you even have the slightest doubt in your mind now, whether it’s what you want to do, for God’s sake don’t do it because you’re going to hate it so bad by the end. You have to love it to get through this.” Bobbie had enjoyed her previous master’s-level research and, like some of the others interviewed, did not quite understand what doing a PhD would mean both personally and professionally.

Blair, who after many false starts at university, had science suggested to her by her mother and also fell into astronomy, but not through active retention like Brigitte, Barbara, and Bobbie. She explains:

> I started off wanting to be an entomologist, so you know, studying bugs, and then I went into biology and really wanted to do animal behaviour, and then I found out you had to do a talk in third year and I went “Nup, I don’t want to do that”. [laughs] And so, I went into maths and had this tutor who and wants to come to [her current workplace] now and was like “I think you are good at maths. I think you would do well in astrophysics” (Blair, recent graduate)

Blair’s less conventional pathway into astronomy mirrors Barbara’s experience where study pathways were suggested to her based on aptitude and talent, not necessarily passion for the subject matter. Like Brigitte, whose pathway avoided essay writing, Blair’s avoidance of presentations also led her into mathematics and physics. Blair continues the theme of understating her abilities and describes others’ recognition ‘I think you are good at maths’ rather than identifying as being gifted in the subject. From these accounts, it is clear that Brigitte, Barbara, Bobbie and, Blair were all identified as displaying an aptitude for mathematics and physics which made them attractive candidates for retention by universities at higher postgraduate levels.

These findings contrast with research by McCormick et al. (2014), who found that women astronomy students used words like ‘love’ and ‘passion’ when describing their motivation to undertake astronomy. While the accidental PhD interviewees in this study were clearly good at astronomy, and to some degree liked it, they did not necessarily describe strong feelings for the discipline when reflecting on their initial recruitment into PhD programs.
It is possible that descriptions of recruitment processes have been adjusted to reflect interviewee’s post-astronomy career perspective. By accounting for their recruitment in such a way, interviewees’ reconstruct events to minimise their initial interest in the field. Here, participants frame their initial engagement in a way that shows them as retained by the pipeline, yet separate in that they never had the serious intention of becoming an astronomer post-degree. This ability to perceive the past in relation to present circumstances is a key element of contextualising narrative accounts.

Australian astronomy differs to American astronomy in that it is much smaller in scale. Currently, there are only 16 Australian universities that have postgraduate astronomy students (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 10). Due to scholarship stipends and domestic fee structures (where domestic students repay government subsidised tuition through future taxable income), an accidental PhD is possible without significant financial hardship. Unlike McCormick et al.’s (2014) graduate students who applied to up to eleven graduate schools and paid money for the applications, the accidental PhDs in this study were retained by their current university with no application fees or additional costs. Australian graduates do not need considerable financial resources to undertake a doctoral degree. They must, however, possess enough social and intellectual resources to navigate the university system and secure a scholarship. All interviewees in this study had been successful in attaining a scholarship and as such were given financial support that aided their retention.

My analysis of the accidental PhD narrative suggests that for some students engaging in doctoral studies is a way of postponing more active choices about career pathways. Australian domestic students who are actively retained by their undergraduate or master’s level university recount following opportunities into doctoral studies as a ‘path of least resistance’. As such, Bobbie, Barbara, Blair and Brigitte were all well into their doctoral degrees before deciding that a career in astronomy was not right for them. All had expressed doing one thing (a degree/PhD in astronomy) to avoid another (writing essays and going into the ‘world’), and an aptitude for maths and science as key incentives for entering doctoral programs. This motivation was not necessarily the ‘love’ or ‘passion’ described in McCormick et al.’s (2014) American study. Although this method of retaining talented women into Australian PhD programs is effective from a university point of view, it does raise questions regarding the leaky pipeline expectation of post-PhD academic careers. For example, how many doctoral students will follow the same patterns of least resistance post-PhD and leave astronomy? This is not a ‘leak’ but acting in their own interests and as such, the lack of information regarding post-astronomy PhDs is detrimental to this group in particular.
5.2.2 Adventure PhD Narratives: Just Visiting

Due to the relatively short nature of the Australian PhD program, Australia’s distance from the US and Europe, and its relatively generous scholarship stipends (at the time of writing around $26,000 per year), some interviewees described doing their PhD here as an adventure. Like the accidental PhDs, participants drawing on this narrative did not necessarily plan to have a career in astronomy in the long-term, but rather to concentrate on short-term goals and take the opportunity to live in a different part of the world and research an area of personal interest.

Bree, an international student, who after completing her undergraduate and master’s education in her home city sought independence and adventure in Australia.

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\text{I didn’t want to live with my parents anymore because it was in [home city]. So, I had to live with my parents for a long time while doing my degrees. I started looking one week after finishing my [master’s] degree and I checked online. Nobody actually suggested anything. I was only looking online, and I found out. “Oh look, there is the possibility of a PhD in Australia. It’s a place I want to go. Well, when is the deadline? Oh, it’s tomorrow. Well, I have to do it now then. If I don’t do it now, I’m not doing it anymore.” There was no other deeper reason. (Bree, recent graduate)}
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Bree describes the chance to move to Australia as an opportunity for adventure and to assert independence from her family. She describes a certain amount of luck in finding the PhD program online and her application as spontaneous, the day prior to the deadline. By her account, she was not initially invested in the outcome of the application and viewed it as a chance to visit ‘a place I want to go’. She describes ‘that there was no deeper reason’, though she had completed an undergraduate and master’s degrees in a related discipline that enabled entry into the PhD program. Bree had completed her master’s degree a week prior to applying and was in the initial stages of identifying further opportunities in study or work. Like others who drew on accidental PhDs narratives, Bree through her education background can be identified as having an aptitude for mathematics and physics, and as such saw a chance to pursue a higher degree in Australia. That it was PhD qualification made it more attractive, and perhaps an easier narrative to justify moving away from family and friends.

Betty, another international student’s narrative is a combination of accidental and adventure PhD types. Initially, as part of her education, she took an international traineeship in Australia as an adventure. During this time she decided to apply for the PhD program because she was already visiting her desired institution. This program gave her some
of the benefits of domestic students, such as access to lecturers and experience in both the field of study and also institutional culture. Like vacation scholarships, international traineeships are a way to screen potential PhD students and potentially retain them in postgraduate studies. This program is particularly important for universities without a physics undergraduate program from which to source potential candidates. For Betty, the pathway was relatively straightforward:

Well, I did the PhD pretty much straight after my studies. So I was still at uni. I was studying physics and I did a teaching degree as well, but I was still at uni doing that when I came to Australia for four months to do a traineeship and I really enjoyed that. I was already at (host university) with (current supervisor), and then while I was doing the traineeship, they had the rounds to apply for a PhD, and I was like “Oh yeah, I’m going to try. Why not? It’s fun.” So, yeah. But I just did a PhD in astronomy because I loved it. I always look up the stars, and I just did it because I enjoyed it. I knew it was going to take 3 or 4 years anyway so I didn’t really think what was going to happen afterwards. (Betty, recent graduate)

Her recollection of beginning the PhD program was a series of serendipitous events that began with a trip to Australia for an international traineeship. Here, as she was familiar with the institution and potential supervision team and, like accidental PhDs, she decided to apply. For Betty, the relatively short time frame of the Australian doctoral program was also a factor that enabled her to enter into the decision relatively lightly as three to four years of ‘fun’. The implication was that as a teacher, any additional qualifications would be, in her logic, beneficial for potential careers, so there was little to lose. Betty’s entrance into the PhD program may actually be termed ‘further adventure’, as she had already started the adventure during her previous studies and wished to extend it.

Both the length of the PhD program and the status of Australia as a relatively stable and safe country make this an attractive short-term prospect for postgraduate students. From this perspective, the act of pursuing a PhD is the facilitator of an intellectual or physical adventure. This is a crucial difference to accidental PhD narratives which rely on the continuity of experience and the postponement of choosing a career, rather than environmental and cultural change. As with its accidental PhD counterpart, there is little indication that adventure PhD students enter the program with the intention of becoming a research astronomer post-degree. There is a reasonable chance that, while some may wish to take postdoctoral positions, career decisions may follow the pattern of location and general interest rather than the strong desire to become a research astronomer.
5.2.3 Research Career PhD Narratives: A Stepping Stone Approach

Women in STEM programs that are influenced by the leaky pipeline literature, assume that the majority of people entering a PhD do so as a stepping stone to a further research career. While many students enrol in doctoral programs to fulfil a dream of becoming an astronomer, a significant number of candidates fall into accidental and Adventurous PhD narratives as I have illustrated above. In contrast, research career PhD narratives are goal oriented and reflect a conscious decision to become an astronomer post PhD. Here, the doctoral degree is viewed as a necessary stepping stone to achieve this goal. Bruna, who stayed at the same university for undergraduate and postgraduate degrees viewed becoming a researcher was the natural progression:

*I loved undergrad in terms of the general astronomy subjects. I absolutely loved them and found it so interesting but thought “OK, well, you know, I want to do research. That’s what you do. You do astronomy.”* (Bruna, recent graduate)

Here, Bruna ‘loved’ astronomy and wanted to pursue it as a professional researcher. For her, the connection between the PhD, doing research, and working as an astronomer was relatively linear and viewed as a package. She also assumed that astronomy was research and that attaining a PhD was the way to achieve the goal of working in the field professionally.

Somewhat in contrast, Bianca saw the PhD as a ‘black box’, or a passport to other places. Her career, as highlighted in the educational filters section, was one that was precisely planned for her to become a scientist. Because Bianca had two master’s degrees in different fields, she was more open to what type of astronomy-related career she may pursue. Her view was that,

*It was like you’ve got these skills and you can go to these other places. Now so it’s more of a black box because once you have your PhD, there are places you can go, but it’s much more flexible.* (Bianca, recent graduate)

Unlike Bruna, who viewed doctoral studies to research astronomer as a linear career progression, Bianca whose education had already taken many twists and turns, viewed the PhD as a passport to get her into other more flexible areas and didn’t necessarily set her sights on being a research astronomer. She also had a more technical background than Bruna that qualified her for a broader range of astronomy related careers, though researcher was still a strong contender.
Current students were in the later stages of their degree at the time of interviewing. Here, they viewed their initial reasons for beginning their degree as a major sustaining factor towards completing it, even though most were considering careers outside astronomy research. Like Bruna, it was this group who gave similar responses to McCormick et al.’s (2014) study that cited a ‘love’ or affinity for astronomy as a reason. Like Bianca’s long-term goals of pursuing science, Chloe cited a childhood interest in the field and saw herself as pursuing her dream of becoming a PhD qualified astronomer and ideally working in the field.

I always wanted to be an astronomer. I remember since I was a little girl, 9-10 years old. I was always fascinated by stars, wondering “What are those shiny objects in the sky?” And yes, since I was a little girl. It just fascinates me. The universe everything about it. (Chloe, current student)

Chloe’s relation of her long-term fascination with celestial objects and curiosity about the universe was a major contributor to pursuing her doctorate. During the latter stages of her doctoral studies and while considering other career pathways, she still focuses on her original intent; to know more about the universe and pursue the dream of becoming an astronomer, which will be fulfilled at the completion of her degree whether she works in the field or not.

Cassie also expressed a similar childhood interest in the field though, as an international student, she draws on both the research career and adventure PhD narratives.

I loved astronomy since I was a kid. It was really a passion of mine, and when I was growing up, I loved science fiction in books, science fiction and on TV. I really started to be interested in it and in high school where I learned about physics. Watching TV, I learned that astrophysics was actually a job. People were paid to do astronomy, and I found it amazing so I’m like “Yes, this is something that I think I might like to do”. I did my bachelor degree in physics with an option in astronomy. [While studying for her Master’s she visited Australia.] I loved it and I decided it would be a cool place to do a PhD. So I went back home finish my master’s degree, and came back for my PhD. (Cassie, current student)

Cassie’s interest began in physics and, due to television and popular culture, she discovered that astronomer was actually a job that she ‘might like to do’. Unlike Chloe who was fascinated by the stars, Cassie pursued a more technical approach that gathered initial information about working as an astronomer from popular culture. Though her main goal
was to be an astronomer, a secondary goal was to study in Australia, so Cassie was able to combine the two in the PhD program.

Chloe and Cassie’s connection to childhood interest illustrates why education programs and role models that enable women to envision themselves as scientists are so important. The recent Superstars of STEM program (Science and Technology Australia, 2018) aims to increase women’s media presence in STEM fields in the hope of inspiring more girls to provide role models and foster childhood interest in the sciences. Rectifying the absence of women role models is an integral part of leaky pipeline recruitment and retention (Blickenstaff, 2006). Chloe and Cassie’s narratives show them to be the archetypal PhD student who studies astronomy as part of a long burning passion for the subject area. However, both of them at the time of interviewing were looking into non-academic careers and were heavily favouring that option.

5.3 Education, Motivation, and Career Paths

In this chapter, I have contextualised and focused on the motivational narratives of interviewees as they recount their entrance into doctoral studies. Australian postgraduate education relies on retention and recruitment strategies for domestic and international students and, as such, interviewees drew on three narratives that led to their undertaking a PhD; the accidental PhD, the adventure PhD, and research career PhD.

At the point of entry into advanced postgraduate education, much of the diversity in the field has already been filtered out, and a relatively homogeneous cohort of students is left for recruitment. As illustrated by Bianca’s story, Acker’s (2006) inequality regimes focus on socioeconomic background that filters out less advantaged students rather than overt links to race and gender. This link, which decreases diversity in the field means that candidates are excluded prior to becoming eligible for postgraduate studies and are already removed from the potential talent pool for recruiting. In pipeline terminology, they have already ‘leaked’ at earlier stages of education.

In order to better understand motivations for beginning doctoral programs, I examined the three main recruitment narratives told by participants in this study. The accidental PhD narrative was related by domestic students who were retained by their undergraduate or master’s level institutions and identified entering the PhD as a ‘path of least resistance’. This pathway is a combination of familiarity, opportunity and a guaranteed three-year stipend to undertake doctoral research. While participants had an identified aptitude for mathematics and physics, they downplayed this and described themselves as taking the
‘easy’ route. This strategy successfully postponed any career decision making until post-degree. Accidental PhDs, while interested in the field of astronomy, did not necessarily describe the intention of having a career in astronomy after the conclusion of their studies.

The next identified narrative type, the adventure PhD, described a physical or intellectual adventure or change. In the interviews, this manifested by using education as a vehicle to travel to Australia and experience a different culture while pursuing an area of intellectual interest. This narrative could also encompass older students who do PhDs out of personal interest though none were identified in the context of this study. A key attraction for this type of narrative is that the Australian PhD program is relatively short, at only three to four years which makes it a better short-term investment than a longer US style five to seven-year program. At this point, students combine adventure, change, and the doctoral process as a package which also doesn’t necessarily involve a desire to become an astronomer post-PhD.

The last narrative, research career PhD, identified the doctoral program as a stepping stone into academic research. Although there was variation, these stories identified a strong affinity or ‘love’ of astronomy stemming from studies or childhood and a desire to become a research astronomer post-PhD. On the surface, this narrative fits best into the leaky pipeline ideology of retaining talented women who, at the beginning of their doctoral studies, have a definite interest in moving further along the academic research career route.

Although interviewees generally fell into three narrative categories when relating their reasons to begin a PhD, this did not necessarily correlate with careers post-graduation as some categories were more open to change than others. The next chapter explores interviewee accounts of perceived stigma concerning their decision to leave astronomy and how this shaped their approach transitioning into post-astronomy careers.
Chapter 6

Navigating Stigma and a Lack of Information about Leaving

This chapter investigates some of the unintended consequences of the leaky pipeline approach that emphasises the retention of women within STEM fields. By actively encouraging women to stay in academia, it raises the expectation that they should stay and work at attaining a more senior position when, in fact, it may not be the best outcome for them individually. Initiatives for women in STEM that focus on education surrounding the difficulties experienced by women and how to locate and navigate structural barriers. Though essential for improving conditions for those in the field, these programs sometimes have unintended effects. In addition, these leaky pipeline based initiatives work in conjunction with the implicit expectation that PhD students wish to become academics and, while there is much information on how to be retained in STEM fields, there is little information about leaving, or ‘leaking’. It is this informational void that contributes to the already difficult experience of leaving the academy post-PhD.

As an illustrative example of this, Beverley, who initially drew on a research career PhD narrative, left astronomy for a number of reasons. In addition to her extended experience in the liminal state of learning (Kiley, 2009), what she termed ‘PhD blues’, another contributing factor was her role on an organising committee for a gender equity event run by a professional association. This event, that was meant for the larger astronomy community, had an unintended effect on her. The event, which drew on leaky pipeline initiatives, discussed the barriers experienced by women in the academy and influenced Beverley’s decision to leave. She recounts,

*I was having conversations, and I was [becoming] aware of the unconscious bias. I was aware of programs for women re-entering for whatever reason you*
may take a break. So, this was something I was conscious of. I didn’t know if I was like anyone who was in astronomy except for the few occasional people. I might not be working as an astronomer in 10 years time given what I was seeing around me. Despite the conversations we were having, I wasn’t convinced that it would be good. (Beverley, recent graduate)

Through organising the conference and talking to people, Beverley discovered that she was at a structural disadvantage beyond what she had perceived when she entered the doctoral program. These conference programs typically discuss issues such as unconscious bias, the need for structures to enable women to re-enter workforce after a family break (and by default counter flexibility stigma), and the precariousness of the academic job market in a constructive way in order to educate, create awareness, and cultural change with the pipeline view to retention (American Physical Society Gender Equity, 2007; Astronomical Society of Australia Diversity in Astronomy Chapter, 2016). Rather than focusing Beverley on strategies to overcome these barriers, she added this knowledge to her current isolation from the astronomy community and liminal experiences in her candidature. In addition to this, the lone senior woman astronomer on staff left the university at approximately the same time. Beverley connected all of these factors, decided that she was not going to be an astronomer in the way that she had previously envisioned, and subsequently left the program. This discouraging effect experienced by students (and casual teaching staff) may be an unintended consequence of diversity programs that focus on retention and the removal of structural barriers for those who already have employment.

Bruna, who also discovered essential information about astronomy employment structures from a workshop had a similar experience;

I don’t know whether I was just incredibly naive and that, in combination just with the university I chose and the structure at that point, was what caused me to think [that astronomy was a stable career located at a single institution]. Then, to have that big surprise...I don’t know whether anybody else really thought the same thing. I think I was just too much in shock at the time and I just suck at socialising anyway. So, I wouldn’t have really talked to anybody from the other unis. (Bruna, recent graduate)

While Bruna’s conference was not centred on gender equity, but employment for early career astronomers, the effect was similar to Beverley in that they both experienced a certain degree of shock about the unexpected state of the discipline and questioned their fit. This experience caused Bruna to reevaluate her priorities regarding a research career before completing the PhD. It can be confronting the first time students discover that
the meritocratic ideal of science is flawed in reality (Castilla & Benard, 2010), and the system is set up to advantage some over others. While the effect of education programs is largely dependent on doctoral student personalities, both Beverley and Bruna illustrate that discovering additional barriers during their doctoral education may spark the ‘flight’ instinct rather than the ‘fight’ instinct as intended.

In addition to leaky pipeline influenced educational programs that aim to improve the experience of women in STEM fields, there is the implicit expectation that doctoral students wish to become academics. These programs reinforce the idea that a career in the academy is the best and most desirable option. Here, to continue to be successful, a woman must overcome the next level of barriers to pave the way for future women in the field. If they choose to leave the field, like Beverley, they feel a stigma associated with that.

6.1 Perceptions on Stigma and Leaving

Making the decision to leave astronomy, especially prior to thesis submission, can be a complicated process. For doctoral students who draw on an accidental PhD and research career PhD narratives going against the assumed cultural norm of becoming an academic presents challenges not only in their studies but in their relationships with supervisors and fellow doctoral students. For those who have come to astronomy from a previous career or those who draw on the adventure PhD narrative, the process is slightly less difficult as the motivation for entering academia was different in the first place. As demonstrated by Beverley and Bruna, there is a point during the doctoral process when students become aware of the difficulties in pursuing a career in academic research. Yet, as I will demonstrate in this section, there is a stigma that if someone decides to leave, that they are considered not good enough or are somehow ‘letting down the team’.

The presence of stigma in Australian astronomy, and more widely in academia, is related to social norms where it is expected that doctoral students will become academic researchers post-degree. This implicit expectation, as discussed in relation to leaky pipeline literature and the structure of Australian doctoral programs, is perpetuated by the academy. As such, students who view academic researchers (and their supervisors) as the industry ‘norm’ are uncertain how to proceed when they decide to leave the field. The decision to choose a path that differs from the norm delivers a conflict between what is conventionally accepted and what can be seen as a weakness, or failing, by leaving the system. While Goffman’s (1963) seminal work on ‘stigma’ and ‘spoiled identities’ focused on stigma related to social and physical difference, I use the concept to identify how interviewees construct narratives about how they should fit into the cultural norm of the academy and how they
perceive their decisions or ‘shortfallings’ in relation to this measure. Interviewees experienced a form of stigma (Goffman, 1963), where assumptions and expectations of what ought to be conflicted with individual realities. Here, though the descriptions of stigma differed slightly by participant, a key element was “not knowing what the others are really thinking about [them]” (Goffman, 1963, p. 14) and filling that void with a defence response. This perceived stigma that interviewees felt was projected on them by other astronomers and academics, shaped how viewed themselves and each other.

6.1.1 Established Astronomer Perspectives

When discussing the possibility that doctoral students felt ‘leaving stigma’, or that students felt like a failure if they left astronomy, the established astronomer group were relatively united in their responses about not judging students who decide to leave the field post-degree. Asha muses,

\[ I \text{ hate the idea of leaving because it's just what you do. Leaving your PhD because it ended. It's not like you're going to be a PhD student for the rest of your life. There’s some assumption that you’ve got a career path. (Asha, established astronomer)} \]

Asha, much like the five other members of the established astronomer group presented themselves with a flexible attitude towards post-PhD careers. Her view that the PhD is a program that lasts only for a number of years reflects her experience in doctoral supervision where there is a clear beginning and end to the process. This conflicts with the messages that doctoral students get regarding being ‘retained’ and the implicit expectation that academia is the preferred pathway for PhD graduates.

The established astronomers, all women, had experienced career interruptions and variations, so possibly had a more liberal view of what a career ‘should’ be post-PhD than other senior astronomers who followed more conventional pathways. They were also aware of my position as interviewer investigating non-academic careers which may have influenced their answers. During the interview, Asha liked Barthelemy’s (2014) idea of a post PhD roundabout where career pathways veer off in different equally weighted directions.\(^1\)

Amelia, also an established astronomer, viewed leaving as something that she had considered many times, and asks whether the perceived stigma around leaving is “kind of a shame/failure thing or whether it’s kind of just I’m done with that and moving on?”.

\(^1\)This was an example I presented at a workshop a couple of months prior to the interview. I have now established that adding structures to the end of the leaky pipeline is not an effective method to account for women in STEM fields.
She observes that perhaps the inability to talk about leaving is a compartmentalisation strategy or forward focus rather than coming from a place of failure or shame. This, in some ways, would account for the lack of contact by astronomers who had changed fields, but does not account for the process of leaving which can also be secretive. Amelia’s view contrasts with Abigail’s interview, who asserted that

*I would think there is little stigma, if not no stigma. I don’t think any of us use that as a criterion at all. It is an interesting question. Is the issue with the supervisor or the student? I don’t know the answer to that.* (Abigail, established astronomer)

Abigail, who holds a senior position at a university, approaches this from the perspective of the establishment in that she, and presumably her colleagues, don’t ‘use that as a criterion at all’, meaning that they don’t negatively judge students for leaving academia post-PhD. Although Abigail perceives that there is little stigma associated with leaving the field, she views it as an individual issue between student and supervisor rather than a universal problem for doctoral students within the sciences. Given the earlier mentioned tendency for this group to speak partly as experts and partly as ‘spokes-people’ it seems likely that the perspective emphasised by Abigail is the official version (Mikecz, 2012) rather than a more personal reflection on the area of stigma.

The lack of perceived stigma from the established astronomer group, and the assertion that they do not place value judgements on their students concerning career pathways, does not mean that their students do not experience what they perceive to be stigma coming from senior astronomers. This impression may perhaps be because of the nature of supervisory relationships with doctoral students, where students are reluctant to discuss aspects that are more sensitive such as stigma surrounding decision making.

### 6.1.2 Recent Graduate and Current Student Perspectives

In contrast to the established astronomers view of there not being a large amount of stigma associated with leaving, current students and recent graduate interview groups spoke openly about the stigma of leaving and the associated perception of failure. Bailey, a recent graduate, observes that “there is a bit of a stigma about leaving astronomy that is within the student culture. This needs to be overcome.” However, it is clear that this stigma operates because of the closed system in academic research, particularly in highly specialised non-industry partnered areas such as astronomy. Bianca, also a recent graduate, calls this a “weird layer of fiction covering what’s actually going on. There’s the fictional astronomy, which is this beautiful research ideal and its sort of blocking the reality
of what actually is going on. It’s not helpful.” Here, she refers to the shared identity of astronomers whom she perceives are embedded into the values of ‘astronomy’ as a pure research ideal, which is, in fact, different to the realities of disciplinary politics and the labour market, particularly the difficulties of employment and funding within such a small field. For a student working on funded astronomy research who is actively encouraged by their institution, supervisors, and peers to keep producing research, the decision to move out of academia to become one of the mysterious ‘them’ and not remain is akin to leaving a family of three plus years. This raises important questions from a student perspective; When do I tell my supervisors I want to leave and will they take it personally? Will my peers be supportive or view the decision as a reflection of poor academic ability? For interviewees, there were many reasons for deciding whether or not to tell supervisors and peers about their decision to leave astronomy.

Celeste, who decided to leave during her PhD, expected negative consequences and tells of a lack of support since deciding to leave the field.

*I have reflected a lot on that, I think. I was a bit hesitant when I first made the decision to leave because you don’t want to tell anyone because then you get the “[you] can’t hack it” crap but then also people stop supporting you. In some ways, I think that’s what kind of happened to me. I’ve had to plough through a whole PhD alone.* (Celeste, current student)

Celeste had encountered significant obstacles during her candidature and had hoped for some financial support in terms of work from her supervisor after her scholarship ran out, but found that this was not to be the case. Whether it was to do with her decision to leave astronomy or the extended length of her PhD, she still felt that the decision to leave was held against her and that resources were perhaps distributed to others that intended to stay.

### 6.1.3 The ‘Leaving’ Conversation

The majority of interviewees had discussed their decision to leave astronomy with their supervisors, though timing varied. For some, the conversation about where to apply for postdoctoral positions was a catalyst. Blair recalls her conversation with her supervisor;

*I my supervisor really wanted me to go on and at the time when you really should be preparing for that kind of thing he did kind of speak to me about it. He said “What do you want to do?” I said “I don’t really want to go overseas.” So, he’s like “OK, so you don’t want to go on.”* (Blair, recent graduate)
Blair’s account of the conversation with her supervisor illustrates one method that doctoral students use to indirectly tell their supervisors that they wish to leave the field; by not applying for postdoctoral positions. Her reluctance to go overseas and follow the international postdoctoral route, which is the established next career step as Australian astronomy is relatively small, was shorthand for her supervisor to establish that she would most likely be unable to continue in the field. Until this point, her supervisor had been in a position to support potential postdoctoral applications and her intention to leave subsequently moved her beyond his area of expertise. This type of indirect conversation about leaving astronomy also occurred between Blossom and her supervisor late in her candidature,

[about when the topic was bought up]...Not really during my PhD, it was really quite late, I think. It was really at the stage...Well, if you’re going to be a postdoc, I should really be talking and putting together postdoc proposals and job applications and that sort of stuff. Yeah, I think...I don’t remember any really detailed discussions. It was more I said I’m not going to and I can remember [supervisor’s name]. He suggested if I stay in [city] that the public service was something to look at if I wanted to. (Blossom, recent graduate)

By leaving these discussions to a later stage of candidature, both doctoral students and their supervisors use the process of attrition, where students do not apply for postdoctoral pathways, as a way of both concluding doctoral studies and leaving the field. From a student perspective, to delay a conversation about what they see as a stigmatised decision means that supervisors will have less time to withdraw support. In contrast, this approach also means that supervisors have less knowledge about potential career pathways and opportunities because they are not exposed to their student’s decision making processes. This may be one of the reasons that established astronomers are not aware of the stigma associated with leaving.

Camille, a current student, has been open with her supervisor regarding her intention to work in a post-astronomy field adds,

My supervisor that knows I kind of want to leave is very supportive, and he says “You do whatever you want” and “I can’t convince you otherwise.”, obviously. But I think he would have liked it if I stayed but he’s cool about it. (Camille, current student)

Camille relates how supportive her supervisor was even though he wanted her to stay in astronomy. By saying ‘do what you want, I can’t convince you otherwise’ her supervisor
shows what Camille perceives as acceptance of her decision. Camille, Blossom, and Blair’s supervisors all displayed a passive acceptance of their student’s intention to engage in different fields rather than be an active participant in encouraging this decision. In the power dynamic of student/supervisor relationships, supervisors are essential for student success, and the main indicator of progress, acceptance, and approval. The decision to tell their supervisor is more difficult for the student thus the gravitation of interviewees towards leaving the conversation to the end of their candidature. For the supervisor, however, a graduate student is only a small part of a larger workload, meaning that they are less invested than the student and their decisions. Here, like Celeste describes, there is a fear that the supervisor will no longer be as invested in the student and will withdraw resources.

6.1.4 Perceptions of Failure

Even though supervisors are reported to be understanding about their student’s decisions to leave astronomy, there is still a perceived underlying stigma that people who leave are inferior. Caroline, who spoke to her supervisor and received active support, remains cynical about how academics view people who choose ‘industry’.

“They’re all about industry partnerships...and they have to support that, and they know there’s not enough room for their students. They know that ultimately it comes down to what is just pragmatic. But at the end of the day there still is certainly this feeling that you and they’d hate to be saying this because they don’t want to be the people to say this, but you are failing the academic system if you step out into industry, even if industry suits you better because you’re not suited to academia. Academia is still higher than industry for them.

I talked to my supervisor she’s like “Yes. Yes. I agree. I don’t really think academia is really going to suit you. You’re definitely going to be more suited to industry.” It’s like she doesn’t mean to think this, and I’m sure she’s trying to not think or show it, but somewhere down there is that superiority of academia. I know it’s there with everybody and everybody knows it’s there. Talk to any student... There’s definitely hypocrisy. It’s just really underneath, so you do definitely feel like you’re failing. (Caroline, current student)

Although Caroline’s conversation with her supervisor was significantly more productive than conversations left to the last minute, there was an underlying assumption that academic jobs are superior and students are ‘failing’ the academic system, not the other way
around. This implication of supervisor or student fault is one of the main concerns that students have regarding their decision to leave. In this situation that Caroline describes there is a deeper underlying stigma within the astronomy community that goes beyond Abigail’s assertion that the negotiation of stigma is individualistic. That ‘everybody’, especially students, know about the ‘hypocrisy’ regarding industry as a viable and successful career option is telling about the culture within doctoral education. Caroline’s account highlights the tensions between the cultural norms of the academy and the construction of stigma (Goffman, 1963) that to some degrees protects those norms by creating a perceived animosity between choosing the academy or ‘industry’. Because the decision to leave is perceived as stigmatised and that in pursuing a post-astronomy career they will be viewed as a failure, supportive reactions from inside the academy are looked upon with scepticism.

Another interviewee, Belinda, who hires for a tech company, also discusses this bias that stretches through astronomy:

> If you tell it to people who are not close to you, I can see it in their minds that they are like “Oh, she’s probably not good enough to get a postdoc.” They can think whatever they want. I don’t care. I know there is a bias and that when I interview astronomy PhD people for a job, I am thinking to myself “Could you not get a postdoc?” So, I have the exact same bias. (Belinda, recent graduate)

Belinda reflects that she is part of the system that reproduces the biases she learned in astronomy of both judging and being judged for her decision to leave. Here, Belinda views leaving astronomy as a ‘fault’ or ‘failure’ under meritocratic principles rather than as a first choice career, even though she had made the decision to enter a post-astronomy career and has been highly successful. This example indicates that stigma is not only produced by those who are in the academy but continues to be reproduced by those who have left.

Bobbie, who embraced her decision to leave within the first year of her PhD and was very open about it, has a slightly different perspective:

> It’s not as bad as other fields, but there’s still there’s a perception in astrophysics that if you don’t stay you’ve failed and I think people need to get over that because it’s just not true. In fact, if anything I’m kind of proud of myself that I didn’t feel obliged to stay in the field. I thought about it for quite a while before I decided but I realise that it was just a simple as deciding what my priorities were. I feel like that is not really recognised in a lot of areas of astrophysics. I’m very fortunate that I had a supervisor who is much more progressive the most about this kind of thing. I know that there’s still some people where it would probably be a mistake for them to talk about this stuff
with a supervisor, but I had a very supportive supervisor. She was fantastic.
(Bobbie, recent graduate)

Bobbie’s approach to the identified stigma that ‘if you don’t stay you’ve failed’ was to
acknowledge it was there but dismiss it in relation to her decision and focus on the positives
of feeling like she was not ‘obliged’ to stay in the field. Here, in contrast to Caroline and
Belinda, Bobbie did not allow herself to be stigmatised and the support of her progressive
supervisor made this more comfortable. While Caroline viewed her supervisor’s acceptance
with scepticism, Bobbie’s perception was that her supervisor was genuinely supportive.
Another key difference in these perceptions of failure is the temporal element of storytelling.
Bobbie, who at the time of the interview was successful in her new career, whereas Caroline,
one of the current students, was still negotiating her doctoral studies and the uncertainty
of leaving while still immersed in institutional astronomy culture. This emphasises the
temporality of narratives: that we always tell our stories from the present and make sense
of the past in light of this.

For Beatrice, who left astronomy involuntarily due to administrative issues, her departure
from the field took place post-degree. Here, she identified feeling like a failure but for
different reasons to the other interviewees.

I wasn’t actually working in astronomy when I realised I had to leave. I chose to
leave astronomy. So, I didn’t really have to make the announcement to people,
and in a way, I felt like a failure in that...in a way, that I had this [postdoctoral]
job that I was so close to going to, and I didn’t know where I was. I didn’t
know what would be next, which is why I felt like a failure. (Beatrice, recent
graduate)

Her perceived failure was not that she was not good enough, it was that her planned
career pathway was replaced by uncertainty. Her situation differs from other interviewees
because she did not experience the stigma of intending to leave during her degree as she had
postdoctoral positions lined up. However, Beatrice who viewed academia as the number
one option felt loss and failure when it didn’t work out post-degree. Her shift from an
astronomy insider to an outsider took place after candidature yet she internalised what
she had learned during her candidature, that there is a sense of stigma that you are not
good enough if you leave the academy. Her anxiety was also heightened by the prospect
of moving to a post-astronomy career and starting again with very little information on
how to achieve this.


6.2 Uncertainty and a Lack of Information

In addition to descriptions by recent graduates and current students interviewed for this study regarding the stigma of failure that is embedded in academic astronomy culture and the decision to leave the field, interviewees also identified a lack of information in regard to post-astronomy careers. Bonnie observes,

*It’s weird because people know that the dropout rate is high, but they don’t really understand where the people go, and the difference between. I think there’s also a feeling like if that person didn’t make it in astronomy and so their second choice was this or something. [It’s not viewed] like these are the exciting opportunities that are available to you.* (Bonnie, recent graduate)

By creating a hierarchy and positioning astronomy as the first choice, Bonnie observes that ‘the drop out rate is high’ meaning that people leave for post-astronomy careers, not drop out of the PhD program. This view of post-astronomy careers as a ‘second choice’, the lack of understanding about where people go, and the difference between careers ultimately disadvantages those who, for various reasons, decide to pursue post-astronomy careers. The extent of this problem is also observed by Barbara,

*It is the old 10 percent that will make it, and they really want those opportunities, and they want to work for it...So I’m not necessarily saying it’s bad, but I’m saying it needs to have both sides. At the moment they’re only looking out for the 10 percent actually going to go through [into academia] and not actually looking out for the majority who won’t.* (Barbara, recent graduate)

Barbara’s observation that doctoral programs cater for the ‘old 10 percent’ who will ‘want those opportunities [in academia] and want to work for it’ hints at meritocracy (Castilla & Benard, 2010) as a factor for those who stay. Both Barbara and Bonnie, when talking about the high percentage of those who leave, still talk from the perspective of the dominant paradigm where staying is considered desirable and leaving is a ‘second choice’ or that students were not willing to ‘put in the work’ to stay. From their experience in post-astronomy positions, much like Belinda who reproduced leaving stigma in her new career, Bonnie and Barbara, when reflecting on PhD programs still speak from an astronomy insider perspective when considering the lack of knowledge and support for those who leave.

Bianca also reflects on the lack of transparency regarding post-astronomy careers and asserts that it should occur at an earlier level during doctoral candidature,
I think astronomy in general needs to be a lot better at explaining to students what the career paths are at an earlier level because a lot of the stuff you just won’t encounter until after your PhD. A lot of people who do encounter it. It’s sort of not a gentle run in. It’s sort of like you know, a train wreck rather than a tap on the shoulder. I mean there’s a lot of problems like the way that it’s [outside career options] presented in the academic community. Just the lack of transparent discussion and a lack of [visible] resources that are available.

(Bianca, recent graduate)

She pinpoints the problem with how non-academic careers are presented and illustrates a lack of information about outside options. Bianca, by criticising what is wrong articulates the need for a structured and resourced discussion of what is available. Her description of outside career transition as ‘like a train wreck’ rather than a ‘tap on the shoulder’ highlights the difference between the experiences of those who draw upon different motivation and retention narratives about finding work outside the field.

These accounts highlight a circular problem between the lack of information regarding post-astronomy careers and the generation of stigma associated with leaving academic research. Here, one contributes to the other, and the presentation of outside career options becomes problematic. Amelia, an established astronomer, notes the difficulty in discussing post-astronomy careers with students from the perspective of a tenured academic;

Me saying “go out into industry” is just disingenuous. It’s just everyone like me [in her earlier career] hearing an academic tell me that I can’t get a job in academia and me resenting it because they’ve got a tenured job so why can’t I have a tenured job? So, there’s no point in an academic saying that but you can say there are a myriad of options and here are some of the ways of finding out these options. (Amelia, established astronomer)

Here, Amelia highlights the tension between academic supervisors and their students regarding post-astronomy career pathway options. She notes the resentment that she felt at earlier stages of her career when presented with the same information to look outside astronomy and does not want to be ‘disingenuous’ by saying something that she disagreed with and ignored over the course of her career. This complex relationship between academics and doctoral students is perhaps one of the reasons why Caroline, a current student who spoke about stigma, was unable to accept that her supervisor who was supportive of her interest in non-academic career was being genuine.

This problem was partially overcome by the implementation of presentations from post-astronomers. Betty notes that her institution made an effort to engage students in post-astronomy career options.
We had meetings, and it was like directed lunch talks. It was quite often about what you could do if you leave astronomy. [For example,] go into a bank [or] we could go into insurance. Wherever stats are needed. (Betty, recent graduate)

When describing these directed presentations, Betty lists financial industry roles in banks, insurance, and statistics as main areas of potential employment. As a lunch meeting for their cohort, postgraduate students would be likely to attend whether receptive or not. Earlier in this chapter, Bonnie noted that one of the problems with the presentation of non-academic careers is the lack of excitement when compared to astronomy research or academic work. Betty’s brief account of these presentations within her interview gave the impression that while the program existed, she was not overly interested in the non-academic area of finance.

As identified by participants in this study, the lack of information regarding post-astronomy careers is problematic and cyclical. Firstly, there is a lack of information within the academy of potential career pathways to present to students engagingly and authentically. This lack of information leads to the impression that academic careers, where there is the most information available, are the superior option over post-astronomy careers. Secondly, this lack of information and established inherent superiority of the academy leads to a perceived stigma that leaving the field for a non-academic job constitutes failure and that post-astronomy careers are not exciting and a ‘second choice’. Lastly, this embedded stigma held by members of the academic cohort, in particular students, and makes it more challenging to engage them in discussions regarding non-academic career options as they are considered a ‘back up’ or secondary route.

### 6.3 The Cycle of Stigma

This chapter links some of the unintended consequences of education programs for women in STEM to leaving and the ‘leaving stigma’ identified by interviewees when they spoke about their experiences intending to transition out of astronomy. Although the established astronomers interviewed did not believe that there was much stigma associated with leaving astronomy post-PhD, interviewees from the recent graduate and current student groups spoke about the implicit expectation that astronomy research is the most desirable pathway post-PhD and that the pursuit of post-astronomy career pathways was considered an inferior option that was linked to personal or professional weakness. The lack of knowledge about post-astronomy career pathways combined with the stigma associated with leaving and ‘failing’ means that it is difficult to present engaging career information to doctoral cohorts.
One of the most challenging aspects of deciding to pursue a post-astronomy career is negotiating what interviewees identified as the underlying stigma of failure associated with leaving for a ‘secondary choice’ or not being good enough. This was described as ‘failing the academic system’, which trains doctoral students to become researchers. The feeling and subsequent stigma of failure is both internalised and externalised by students who reproduce this both during and after postgraduate studies. This issue was an underlying theme throughout interviews that affected all stages of PhD and transitional processes. An example of this was interviewees’ reluctance to tell peers and supervisors of their decision to leave for fear of withdrawal of resources or to be seen as a ‘failure’ by the astronomy community. Consequently, some doctoral students interviewed left the ‘leaving conversation’ until the last minute when it was time to apply for postdoctoral positions and used this process, and the lack of engagement with, as a natural attrition point.

Interviews with established astronomers indicated that within the higher levels of academic astronomy research there is very little reported stigma applied to students who leave the field post-degree to pursue other employment. Still, by considering the field as an established astronomer, or standpoint of an insider, senior figures within the field are perhaps are not able to adequately identify what is happening culturally at the lower levels in postgraduate spaces. For the established astronomer group the act of telling students to go into industry can be viewed as ‘disingenuous’ and even though they may be outwardly supportive, students such as Caroline, perceived them to be inauthentic and tended to believe the opposite of their advice.

Recent graduate and current students interviewed all articulated the expectation for them to stay in astronomy and a stigma associated with leaving. A number of factors generated this stigma; training specifically to become an academic researcher, by modelled behaviours of supervisors and mentors, and gender equity programs that seek to prepare women for the navigation of structural barriers to further succeed in the field. In addition, during the high-stress learning process of PhD studies, students compare themselves to others, suffer “impostor syndrome” (Clance & Imes, 1978), and become stuck in liminal stages of learning (Kiley, 2009; Kiley & Wisker, 2009) and uncertainty which makes a complex environment of both expectation and uncertainty. This, combined with gendered and other intersectional factors that enforce inequality make it challenging to engage doctoral students in conversations about post-academic careers, which in turn leads to a lack of information about transitioning to post-astronomy fields and adds to further anxiety about the unknown.

While the presence of ‘leaving’ and ‘failure’ stigma has been identified by interviewees as embedded in relation to astronomy doctoral studies it is a higher education issue and
beyond the scope of this thesis. It is, however, an important aspect of interviewee narratives as they relate their transition from astronomy into post-astronomy careers, which are seen traditionally as a ‘second choice’. The next chapter demonstrates three narrative typologies of leaving for a post-astronomy career and how the presence of the expectation to continue in astronomy and the stigma of leaving frames how interviewees recount their leaving narratives and strategies for transition.
Chapter 7

Leaving the Academy: Three Typologies

When considering interview data, an iterative approach uncovered three main stories described by women who left the field of astronomy, each attributed to a different degree of agency. These typologies, or stories of leaving, represent the decision-making practices of doctoral students as they experience varying degrees of difficulty and setback during their PhD. Here, I found it was not necessarily the setbacks that formed these stories but how the doctoral students reacted. It is important to note here that not all women who left the field of research astronomy experienced difficulties, some had the enviable position of having a relatively smooth and non-dramatic PhD. This section considers three narratives of how interviewees accounted for leaving research astronomy post-PhD.

The first narrative, which I will label the determined leavers, reflected interviewees, who during their PhD decided that they did not like academia and/or research and wished to obtain a non-academic position. Typically, they described experiencing an epiphany, that astronomy research was not what they wanted to do, and were active in seeking outside work before the completion or abandonment of their PhD. The reasons for this were mainly astronomy and PhD experience related.

The second, the flexible leavers, and the most common narrative are highly aware of their circumstances and subsequently, due to re-evaluation, decide that academic research does not suit their priorities. This group are more flexible in their decision-making and are affected by a complex cross-section of factors that include both their astronomy education experience and outside factors that have occurred in their lives. This group had the most substantial variance in reasons for leaving academic astronomy.
Lastly, *involuntary leavers* who drew on the career research PhDs motivation narrative, felt they were forced out of the discipline by circumstances that were beyond their control. Here, they described their decision as being taken away by factors in the PhD program, that made them less competitive for astronomy positions. As such, they decided that a more accessible route was to find a non-astronomy related career and redirected their expertise into other areas.

The primary difference between these leaving typologies is both agentic and temporal. As all interviewees excluding the A group, established astronomers, had or were considering leaving astronomy research, the question was not will they leave, but when do they decide? Here, the determined leaver group was faster coming to the decision which usually happened during the first third of to halfway through their PhD. The next group, flexible leavers, started to reevaluate and weigh employment decisions against other factors at the half-way point of their PhD, though continued to evaluate until towards the end of their doctoral programs.

Lastly, the involuntary leavers were the latest to decide to leave academic research, which occurred in the last six months or so of the program as they weighed employment options. As such, they tended to make a less planned transition compared to the other two leaving typologies who weighed options at an earlier stage of their doctoral studies. These typologies, which account for temporal and agentic factors, demonstrate that as interviewees progress through the PhD program they draw on different career narratives as they decide to attain post-astronomy employment.

### 7.1 Determined Leavers

The determined leaver narrative is the second most prominent with eight interviewees who made the decision during their PhD that academic research was not for them and wished to pursue non-academic employment. These interviewees drew on different motivational narratives going into their doctoral studies that were a combination of accidental and adventure PhD narratives, where they pursued study out of opportunity or personal interest, and were more flexible regarding doctoral expectations and potential careers. Their decision-making processes were directly related to an interest in astronomy without the apparent exertion of external factors, that affect both the involuntary and flexible leaver narratives.
7.1.1 Deciding to Leave

One of the characteristics of this narrative is the assertion of agency regarding leaving the field of astronomy occurred relatively early into their degree, from the six-month mark to just over the halfway mark. Belinda describes her formative moments,

Yep, I think halfway through my PhD I kind of knew I was done with astronomy and then you know, towards the end I was just chatting to people asking “What’s out there for useless astronomers like us in the real world?” Nobody wants you to be exploring stars in the real world so what can I do? I just realised that I was sitting in these meetings and people were all excited about the light curve of whatever, and I was just...I just realised that I didn’t care anymore and I wasn’t interested in that anymore. (Belinda, recent graduate)

Belinda realised that she no longer had the same enthusiasm for astronomy and physics as her colleagues. Once interest waned, she began to view the discipline of astronomy as superfluous in the ‘real world’. The division between ‘useless astronomers’ and the ‘real world’ was a core element in Belinda’s narrative, and by dismissing astronomy as impractical, she was able to re-position herself in relation to her future employment. Other interviewees, Blossom, Bobbie, and Brittany though, who did not describe experiencing the same level of disinterest, decided that ‘astronomy was not for them’. Brittany, though determined to leave had a backup plan; “I wasn’t really in love with astronomy. I decided I actually don’t know what I want to do so went for something completely different for two years, and if I miss it, I can go back.”. Instead of dismissing astronomy completely, she allowed herself the option to return. This approach was unusual for determined leaver narratives, where a lack of interest in the field framed decision-making.

Camille, who was doing her PhD when interviewed, planned to change fields and progress to a different industry. “I’ve always been interested in doing humanitarian work. I’ve been looking around, but I think that what you need to start doing that is experience in management, finance or something like that which is what they really need. That’s why I’m thinking about going into the finance sector as graduate and see where that takes me and ultimately working somewhere like the UN is what I want to be doing.” Camille describes a clear vision of where she wants to be, and while she is interested more in the ‘ingenuity of astronomy’ and will complete her degree, she understands that it is not her primary career ambition. Barbara, who also drew on the accidental PhD narrative, returned to her first career love, and after submitting her thesis on a Friday, started training for her new career on the Monday.
Unlike other determined leavers, Brigitte and Beverley, both left prior to completion of their PhD. Brigitte, who had many setbacks and experienced sexual harassment while studying became demotivated, decided to ‘cut her losses’ and leave. She notes that, “I had more than enough, easily enough for a master’s so I might as well write that up and make a dignifiedish exit.” Beverley, who left after being stuck in the ‘PhD blues’ for too long was affected by poor supervisory practices that further led to high levels of isolation and self-doubt during her doctoral studies.

So, they had some interesting approaches which didn’t really work for me, and I think it compounded my feeling of self-doubt and insecurity about my abilities. [When experiencing difficulties] They would say “If you don’t do this, we’re going to take your data away give it to someone else”, which is very heavy on the stick [as opposed to the carrot]. [There was not a discussion of] what’s actually the issue here? Or what kind of guidance or advice can we give you during the first stage of candidature? (Beverley, recent graduate)

Beverley had chosen her supervisor because of the ‘hot field’ and had the intention of becoming a career researcher. This intention did not last long. Her relationship with her supervisors, which from her account centred on negative reinforcement in order to bring out competitiveness, had a negative effect on her candidature. Like for many women documented in the leaky pipeline literature, this hostility contributed to her decision to leave, though it was not that simple. Like Brigitte, there were multiple reasons for Beverley to leave astronomy beyond negative experiences. Interviewees with this narrative were labelled determined leavers because they possessed the self-awareness to recognise that the situation was not right for them and exerted agency to find a better career fit.

7.1.2 Exit Strategies

After making the decision to leave astronomy those who drew on the determined leaver narrative related a variety of strategies for finding work. Some of these reported strategies overlap with the flexible leaver narrative, and as such, I will focus on experiences that are unique to determined leavers, Barbara, Bobbie, and Belinda.

Barbara, who originally drew on the accidental PhD narrative, decided that she was no longer interested in astronomy undertook a complex series of assessments to enter a different, very competitive training program. Unlike Celeste, who had supervisory resources withheld after her ‘leaving conversation’, Barbara took a different approach and accounts for her secretive decision making.
I didn’t tell my supervisor until after I’d been accepted. The reason for that was that if I didn’t get accepted there was still a chance that I might get a short postdoc in astronomy. I didn’t want to close off those options by saying that I wasn’t planning to have a career in it. Whether it would have closed off those options or not, I don’t know, but my suspicion is that it probably would have. If you said that you’re not really interested in it as a career, I don’t think people would make so much effort to organise a short-term contract while looking for postdocs overseas, for example. (Barbara, recent graduate)

Although she was determined to retrain in a different profession, Barbara viewed astronomy as the ‘secondary’ or back up plan in case she did not get immediately admitted to the next course and had to reapply the following year. Barbara’s secrecy was not due to leaving stigma, as such, but related to the preservation of resources from her supervisor. She indicated that only her partner knew about her decision to leave and that she managed to undertake multiple rounds of testing and assessment for the new course while completing her PhD thesis. As she saw potential opportunities in astronomy becoming more limited after her relatively smooth ride to a PhD, Barbara described an agentic decision to revisit a childhood field of interest. The level of secrecy displayed by Barbara is unusual, yet the motivation, to avoid being penalised for her decision to leave was a relatively common concern among all interviewees.

In contrast to Barbara’s individualistic, secretive approach to leaving, Bobbie, the most active of the determined leavers made the decision early in her PhD that she did not want to be an astronomer. Her narrative is an exemplar of networking. Bobbie describes her networking approach to finding a job,

I talked to people who I thought could provide me with contacts in areas I was interested in. Obviously, my supervisor was the first point of call there. I also talked to people from previous years of PhDs who had moved into other areas. I have a couple of friends at the [government scientific body] who did PhDs in other areas of physics, and they’ve been just wonderfully supportive. I also was lucky in that I had a family friend who has worked in the public service for a long time, and he was very helpful. (Bobbie, recent graduate)

Bobbie was fortunate to have initial contacts through her family and friends. Unlike Barbara, she told her supervisor early about her decision, and as she describes in the previous chapter, felt fortunate to have a progressive and supportive supervisor. Bobbie networked and told everyone that she met that she was looking for employment post-PhD but was unsure what. This approach led to situations where she made professional contacts.
I just started chatting to him and said “I’m actually looking for work at the moment and I don’t even know what in yet. But that’s what I’m doing with my life at the moment, networking and looking for work.” He told me not only that you could work at [large financial institution] and he offered me a job. He also put me in contact with other people who he knew, and that’s when I got the [other financial institution] job through a friend of his who is in a management position. So, the trick about networking is, I think, don’t stop at that first person. If they can’t help you say to them “I’m really interested, and it’s fine if you don’t have any funding to give me a postdoc at the moment but do you know anyone else who is [looking]?” I talked to people in [other scientific fields] and...I got interview offers for jobs in biosecurity risk analysis out of that. Never say no to connections. Whenever people say “I can hook you up with this person” then I say “Yeah, I’d love a meeting with them. Could you get me in contact?” (Bobbie, recent graduate)

Bobbie’s openness to ideas and enthusiasm led to five job offers before completing her PhD. Her networking strategy, to cast a wide net in regard to industry and work type meant that she moved from an accidental PhD narrative to actively take control and exert agency over her decision to leave the field. Bobbie related the job hunting process in terms of exploration rather than one of failure. It is this element that sets her apart from other interviewees. The main issue, after informational meetings with networking contacts, was the need to eventually decide on a route.

They would tell you these awesome problems...So, it’s not hard to get enthusiastic about that. By the end of a lot of these meetings, I was just sitting there being like “Oh, I do wish I hadn’t committed to something” but then you go to the next one, and you’d feel that way again because there’s so many cool problems out there.” (Bobbie, recent graduate)

Her openness to ideas and her inclination to become excited about solving problems made it difficult for her to stop this exploratory, or research process, of job hunting and settle on a career pathway. Bobbie is unusual in that she weighted completing her PhD and finding a post-astronomy job relatively evenly throughout her doctoral studies and applied the same level of intensity to both tasks throughout much of her PhD.

Belinda, who also reported deciding to leave the field halfway through her PhD, acted on this decision towards the end of her candidature. She described finding a job through private networks but was unsure of what she wanted to do. Here, she had made an agentic decision to leave but its execution came later. As an international student, Belinda
completed the final stages of her PhD in her home country where there are significantly more job options than in Australia. During a casual conversation at an affiliated university, who hosted her during the final stages of her PhD, she recalls the conversation that resulted in a job.

_I was in [university] at the time, and somebody said “Have you heard of data science?” and I was like “No” and I Googled it and thought ‘that looks cool. That looks like something I would enjoy.’ Then a couple of weeks later I heard that a friend of a friend had a start-up that was looking for a data scientist and I was like “OK, cool, let’s chat.”...I never really interviewed anywhere but that one start-up. So, I just kind of finished my PhD and a week later I started with them, and there we are. I’m still here._ (Belinda, recent graduate)

Belinda’s account of being at the right place at the right time indicates that even though she had decided to leave astronomy, she had delayed action until towards the end of her candidature. Like Bobbie’s approach, she found an area that she might enjoy and, due to connections did an interview, got the job, and still worked at the same company multiple years later. Belinda’s narrative of exiting is more typical of other interviewees than Bobbie’s networking or Barbara’s secret applications in that she represents herself identifying a pathway towards the end of her PhD rather than actively pursue it. It is her described agentic decision during her PhD that she was no longer interested in astronomy that places her narrative with the determined leavers.

Barbara, Bobbie, and Belinda’s stories all indicate different approaches to finding work post-astronomy. Drawing on the determined leaver narrative, they recognised their lack of interest in astronomy early, and by the time that they had completed their doctoral studies, had lined up post-astronomy careers.

### 7.2 Flexible Leavers

Flexible leaver narratives, which make up the majority of recent graduate interviewees are the most complex group. With regard to motivation typologies, flexible leavers draw on all motivational narratives; accidental, adventure, and career research PhDs. The flexible leaver narrative pattern is a hybrid of PhD related, external (or life-related), and highly gendered factors that shape future career pathways. The decision to leave academic astronomy takes these factors into account and primarily occurs in the latter half of the PhD when priorities regarding life and employment are assessed. While it could be argued that the decision to leave astronomy is largely outside the control of
many of the interviewees, it’s the critical evaluation of their limitations, and the perceived assertion of agency over their decisions that differentiates flexible leavers from other leaving narratives.

The situation of the flexible leaver narrative is also highly gendered, in that universal structural barriers are navigated during PhD studies. Gendered expectations are placed upon women as the carer, trailing spouse, and as such are the part of a heterosexual couple that is usually expected to compromise on their career. These factors, which hold back women’s careers have been established in the literature review in this thesis. Interviewees, who are the holders of scientific doctorates, account for their experiences through the partial perspectives (Haraway, 1988) of scientists, and as such, undertake what they perceive to be a ‘common sense’ approach to navigating various structural constraints presented to them, and do not necessarily associate them with gender, but just ‘living their lives’.

### 7.2.1 Assessment of Opportunity

For flexible leavers narratives, it is the combination of the precarious and competitive job market, and also the need to prioritise work over other areas of life, not necessarily directly family related, that influences the decision whether or not to leave astronomy. For Bonnie, staying in astronomy would mean sacrificing other elements of her life.

> I think you end up making a lot of sacrifices. I think particularly the idea that I would have to compete hard to get a postdoc, and if I was really lucky, I’d get a postdoc in Munich or Boston. That would go for two years and then and maybe go to San Francisco for two years if I was going to be doing that. I would be moving around at the time I wanted to be settling down and starting a family. If I was doing that, it would have to be for something that I was really passionate about. I really liked astronomy, and I really like my research, but I didn’t like it enough to be able to fight for it. I just knew it was going to be a fight. If it had of been easier to stay in astronomy, I definitely would have because it’s fun and it’s cool, but it’s a hard lifestyle at this point in your career. (Bonnie, recent graduate)

Bonnie reached this conclusion later in her doctoral studies, and it wasn’t necessarily that she wanted to leave astronomy, but she wanted to have a life that she enjoyed. Bonnie’s view encapsulates many who drew on the flexible leaver narrative, who would like to stay, but believe that the instability and competitiveness of academic research would adversely affect their lives. The perception that it is a ‘fight’ to obtain a temporary
position, especially after completing a PhD, shows that for early career researchers there is effectively no ‘end game’, or permanency any more. The best they see themselves aspiring to is multiple precarious positions. If they leave astronomy, then they have greater agency over where to live and, also if desired, when to start a family.

Bonnie, who is still well connected with peers from her cohort observes that:

> I can really see the difference when I talk to my friends who are still in astronomy and the ones who left in the way that they think about it. [For those] in astronomy it is still like “I’m just going to try and make it work for a little bit longer.” It’s not just the women but the men as well. Whereas the people who have left are just like, “You should have left ages ago.” (Bonnie, recent graduate)

Throughout interviews, there was no shortage of peer comparison stories where interviewees spoke of friends still struggling in astronomy and those who had left to pursue other areas of employment. In these stories, which are told by interviewees who have left the field, their astronomy peers pay the price for pursuing an academic research pathway. This price is usually the financial and personal impact of precarious international employment whereas the flexible leaver narrative represents a disciplinary compromise to achieve stability and receive other types of compensation.

### 7.2.2 Health Issues

While for flexible leaver narratives, an awareness of the difficulties in the postdoctoral job market is an influencing factor; many relate more personal reasons for leaving astronomy. Physical health issues are mostly well-understood within the workplace and are legislated accordingly, meaning that, while annoying and painful for the interviewee, they did not significantly influence whether or not they wished to leave astronomy. However, mental health issues made a significant impact on candidature and led to a re-organisation of priorities about family, stability, and support structures needed for a prosperous future.

Four interviewees who drew on the flexible leaver narrative undertook a significant reassessment of career pathways due to mental health issues. Blair relates what it was like suffering from a serious mental health issue during her studies.

> Well, I had my [mental health disorder] thing while I was doing my PhD. That was a great big setback and also the first two years of my PhD didn’t work out. So that’s what happens with a PhD. You start on an idea and then sometimes
it just doesn’t work out, and it didn’t. So we had to start again...I don't feel like I have been disadvantaged by these things. I feel like I have had a pretty normal PhD sort of timeline. You have setbacks. Things happen in your life.

(Blair, recent graduate)

Blair was fortunate that her mental health issue was not ongoing, and viewed it as a regular ‘PhD setback’. As a domestic student in the same city as her family, she had a stable support structure in place which she was not willing to give up to pursue postdoctoral programs outside her host city. This self-imposed limitation on career options has effectively cut her astronomy career short as she chose not to pursue a postdoctoral position. Through networks and good fortune, Blair fell into a teaching position at a college and was still planning her larger future when interviewed.

7.2.2.1 Mental Health Conditions

In addition to their own mental health, those who drew on the flexible leaver narratives also described their roles in caring for their partner’s mental health. Benita relates an eventful PhD experience during which she got married, moved countries, bought and renovated a house. Reflecting on her experience, Benita identified the largest influencing factor for future employment:

I bought and decorated a house, and that was the second most stressful thing I have ever done. I did that in my holidays, but that was quite stressful. [partner’s name] had severe depression for about 50 percent of the time and mild depression for the other 50 percent of the time. (Benita, recent graduate)

Being a primary part of the support network for her partner who suffered from depression, this severely impacted her studies. Fortunately, her supervisor was supportive, although far away in Australia, and she completed her doctorate. Benita’s husband, who is older than her and also has a more advanced career, is the primary wage earner in their family. Benita observes that her partner’s job will almost always have priority “He’s got a very good job. It’s hard to imagine me getting a better job that we would move for because I’m younger, I’ve had less career experience.” Because of this, and as they were both similarly trained in astronomy, Benita chose to shift her focus to a solid auxiliary backup career, as a contingency if her partner became worse. “Part of the reason I wanted to get a proper job like being a teacher is because if he wasn’t able to work, someone has got to have their feet firmly planted on the ground.” She also chose to teach in anticipation of eventually starting a family and its compatibility with family life, for example, school holidays and similar work hours to cut down on daycare costs. Benita chose science teaching for quite gendered
reasons: to be compatible with family life, as it is a traditionally female-friendly industry. This, however, is not the only reason, Benita enjoyed doing outreach and required a social career as ‘[she] was very lonely as a researcher [and she] looks forward to not being so lonely in a different sort of job.’. Benita observes that as a secondary school science teacher with an astronomy PhD she will be able to act as a role model and encourage young women to pursue scientific and technical computing careers.

While Benita’s decision to become a science teacher is highly gendered due to caring responsibilities and the move to the female-friendly area of teaching, she has assessed her decision for a ‘more social job’, exerted agency, and positioned herself as a positive role model for future women in science and technology.

Other stories of mental health came from current students who were in the process of planning their futures post-degree. Chloe, at the time of interviewing, also had a partner with a severe mental health condition was positioning herself to become the primary wage earner as a data scientist or in the financial sector. This choice, though she initially drew on a career research narrative, is purely economic to support her family. Cassie, who drew on the adventure PhD narrative who, in the isolation of her studies developed an anxiety disorder, is seeking out stable employment post-PhD and has excluded herself from the precarious postdoctoral cycle which requires frequent international movement for positions. Interviewee’s mental health may potentially be considered an additional intersectional element of their identity, especially if diagnosed with a long-term condition that impacts their lives. The role of carer and emotional support for a partner or family member with mental illness, however, would not strictly be part of intersectional identity. Though it is a barrier, and highly gendered, it is temporal and not a constant part of intersectional identity.

7.2.3 Flexible Career Factors

Although the previous two factors, assessment of opportunities and mental health, are relatively easily defined in flexible leaver narratives. The reality related by most interviewees was that their decision to leave astronomy, which occurred during the second half of their degree or even post-submission, was a combination of interlinked factors that included attachment to people, places and the need for certain economic conditions. These links can be seen in the forthcoming examples from the recent graduate group.
7.2.3.1 Negotiation with Partners

Blake, who drew on the adventure PhD narrative, came to Australia to study after a career in another scientific field. After her PhD, which was relatively smooth but not without its problems, it was time to decide on a viable career afterwards. Blake describes the difficulty of both her and her partner having PhDs in astronomy in different fields and the need for compromise.

Well, there’s obviously a two-body problem. [Partner’s name] only had started his postdoc here, so he wasn’t going to leave anytime soon. So if I had stayed in astronomy, I really wanted to go to Chile. As we had been in a long distance relationship beforehand, I was not really ready to go straight away again and this time all the way to Chile. I mean across the country, we could go there ... but across the globe. (Blake, recent graduate)

Her first compromise is typical of the “two-body problem” (Jorgenson, 2016), where two highly skilled partners find it difficult to get appropriate work in their fields at the same location. Blake and her partner, who had previously been in a long distance relationship, decided that they were not prepared to move more than across the country from each other. A key factor for this was that her partner had started his postdoctoral position recently and was not mobile at the time of interviewing.

Then in terms of astronomy, I love astronomy but to actually get a permanent position you have to do a few postdocs and maybe if you’re lucky you can get something somewhere. I moved from [European country] to [another European country] and then here, and I just don’t want to have to re-settle another three or four times. It’s not easy especially now I’m also getting to the age where I should have kids now and not ten years down the line. I guess the typical factors. (Blake, recent graduate)

Like many others who drew on the flexible leaver narrative, Blake still ‘loves’ astronomy but, as she had already moved countries multiple times was not attracted to the postdoctoral cycle of moving every few years. In addition to this, she begins to consider having children and the implications of having them sooner rather than later. These ‘typical factors’ are highly gendered, as women are generally expected to compromise their careers once they have children. These decisions become more difficult when both partners are trained astronomers. Blake talks about how decisions are reached by her and her partner:

I guess as I was saying, [partner’s name] and I, we started talking about if we are more interested in where we are going or what we doing. Because if we
interested in staying, or at least one of us staying, in astronomy then it really is like where we get a job. But if it’s really for us, more importantly, that we either stay in Australia or go to [her home country] or something and I think we can’t be picky with the job we just have to take what we get. (Blake, recent graduate)

This discussion of priorities, or if they were ‘more interested in where [they] were going or what [they] were doing’ is a largely typical conversation for women astronomers with high achieving partners where they weigh the importance of their jobs versus other aspects of their lives and decide on where they are willing to compromise. In Blake’s case, her partner was more advanced in his degree and landed a postdoctoral position first which she felt limited her mobility, even though her field of study was larger with more opportunities. This differs from Benita’s situation where her partner’s career was significantly advanced beyond hers.

While she enjoys her interdisciplinary support position at a university and works on interesting projects, like Bella who draws on the involuntary leaver narrative, Blake also feels a little nostalgic about leaving the field. “I think it’s always the lingering...I guess nostalgia or something. I did an astronomy PhD for a reason because I picked astronomy, right? So not working in astronomy, it’s always like, I mean it just feels like you’re lost somehow.” Blake’s complicated relationship with astronomy is one of the reasons that she is flexible about her employment, especially in regard to the future. Having a partner who is an astronomer is difficult as Blake is still linked to the field while doing post-astronomy work. Though the attachment to her partner was a major contributor to the decision to take her current job, after his postdoctoral position is complete, they will once more negotiate as to where they want to live and whose career to prioritise. In preparation for this, Blake, by taking a research adjacent position has kept her options relatively open. “So, in terms of the [current] job, I was thinking even if I want to get back into astronomy, it would teach me a lot more skills so I can go down the data science fellowship route within astronomy. So then I can go down the slightly different route that is maybe not 100 percent research focused.” Blake, while not currently in astronomy is positioning herself with the option to return to the field or further pursue the expanding related field of data science. By making herself more competitive, and as her partner is also an astronomer, this gives them more flexibility after he finishes his postdoctoral position.

Blake’s story, to a various extent, was echoed by Beth, who followed her partner to an international postdoctoral position and found local employment. Unlike Blake, Beth a recent graduate, who experienced sexual harassment and subsequently left astronomy, felt more comfortable with her decision to leave astronomy. At the time of interviewing Bo, also a recent graduate on contract employment was negotiating with her partner as to
what they would do when her contract ran out. Of the flexible leaver narratives, although many work outside astronomy, they did not explicitly decide that astronomy was not for them, instead they prioritised other aspects of their lives. As such, many interviewees expressed an interest in potentially moving back into astronomy if the ideal job appeared that fit into their lifestyle preferences.

The gendered dynamics of the “two-body problem” (Jorgenson, 2016) are too complex to fully address in this research, though interviewees did express difficulties in both partners finding suitable work in their field, especially in Australia where opportunities are so limited. Audrey, an established astronomer, describes a program at the Australian National University that assists in the problem of attracting academic families.

I think there is a proposal at ANU¹ that if they have if they want to appoint somebody, and he does have a partner that they then try and look around not just in that department but look around the whole University to see if there is a position and will help fund the salary. So, as a primary department, in astronomy, it would pay one and a half times the salary and the other department, who might be economics, engineering, medicine or whatever only have to pay half the salary. I think it’s for three to five years or something but enough time to make it attractive enough for the family to come. (Audrey, established astronomer)

Still, the assumption is that the primary employee will be the man. Through the SAGE Pilot Program (Australian Academy of Science, 2015), women-only jobs were being advertised at the time of writing this thesis. Still, it is more difficult to attract highly ranked women candidates with successful partners to move to, or stay in, an economically isolated place like Australia. While gender-specific posts and programs that support academic partners are commendable in attempting to address this gendered issue, the lack of permanent positions still remains, which is one of the key issues with finding a job in astronomy.

### 7.2.3.2 Individual Well-Being

Bruna’s also draws from the flexible leaver narrative, yet her experiences differ from Blake’s as decisions were not impacted by the two-body problem, as is typical in flexible leaver stories. Her initial motivation drew on the career research narrative but, due to the misrepresentation of what an astronomer actually was, quickly found that becoming a lecturer was an unrealistic goal. Though it may be arguable that Bruna has some aspects

¹Australian National University
of a determined leaver, it is the realisation that all her interests converged on a specific type of position toward the end of her doctoral studies, and her assertion of agency towards the end of her degree that led her into the field that she is currently involved in. This reflexive move focused on maintaining and building on what she had, more so than actively leaving astronomy research, separating her from the determined leaver narrative. Bruna’s decision was influenced by many interlinked factors.

One of Bruna’s primary influencing factors was an aversion to travel. Bruna describes her realisation that:

-I can’t just stay at one university and particularly not just one university in Australia. The odds of that happening is very very low. I don’t want to go abroad to work. I’m a homebody. At that point, the concept of even moving state was too much “Oh crap! What am I going to do?” and that was in my first year of my PhD. Just basically the PhD went [sound of something crashing with a downward hand gesture, much like a space shuttle] downhill from there on in. I was always like “This is not what I want to be doing.” I also found I kind of wasn’t a researcher. It really was not for me.

Fortunately towards the end, there was another student there who was working partially at [government institution name] education, and so he’s gone “Well, why don’t you come over here, and see what we do. You’ve done the planetarium. Come and see what we down here with the holiday programs.” He said “This is something you might like to do.” (Bruna, recent graduate)

Bruna’s interest in education developed during these holiday positions, and though she didn’t necessarily want to be a researcher, she still loved astronomy. Bruna’s network stemmed from her side interest in education and outreach, which she had developed during her doctoral studies, and it was the discussion of these interests, rather than purposeful networking that led her to her post-astronomy career. Upon learning of these holiday programs, she thought “This is cool. This is awesome. I could do this.” Her focus changed throughout her PhD and she further bolstered her outreach skills in preparation for a job search. Economic factors also influenced her desire to work in science education and outreach, as her PhD had run long and she was no longer receiving a scholarship. Aside from research assistant and tutorial work, at some institutions astronomy students also have the option to work in university outreach programs or are close to major outreach facilities that provide casual work.

-I got a casual job in science education, and unfortunately it was such a broad range of science, and I prefer my narrow field of astronomy, and I didn’t get
to do any astronomy there. But I really enjoyed it and enjoyed the vibe you get from doing these groups. Especially when everything goes perfectly, and I’m really connecting in with a group. I thought “OK. This is a kind of stuff I wanted to do.” I applied for a couple of full-time jobs with them but didn’t get them but received the internal job alert for the job down here in [city] for a maternity leave replacement. Being internal and I was a casual I could apply for it. I thought as astronomy it’s perfect space-related stuff. (Bruna, recent graduate)

Although some of her applications were unsuccessful, Bruna’s casual contract allowed her to access the internal recruitment process for a leave replacement position. Her attraction to the ‘vibe’ in outreach and the feeling ‘when everything goes perfectly’ was enough to convince her that moving to outreach education was the correct decision. Bruna’s temporary position was extended on a number of contracts, and she hoped to stay there for the next twenty or thirty years. Bruna, who through serendipity and the desire to stay close to her parents, during the course of her studies discovered a workplace with a good cultural fit and ultimately attained an astronomy-related position that was not academic research. Bruna notes that while a PhD is not technically required for the job, it was beneficial to have an astrophysicist on site.

I get people asking don’t you want to go back? Don’t you want to do some [research] stuff on the side? Don’t you want to work with astronomy? It’s like “No. I really don’t. I really, really, really don’t.” There wasn’t a huge amount I enjoyed about the [PhD] process, and PhDs are hard anyway, but for me, that was one of the most horrific things I’ve ever done, and I’m out. (Bruna, recent graduate)

Unlike Blake, Bruna had no nostalgic notions about astronomy research and described the PhD as ‘one of the most horrific things I’ve ever done’. This negative experience of the academy further reinforced her decision to remain out of astronomy research and concentrate on the element that she enjoys, science outreach. Bruna is fortunate that she discovered her ‘dream job’ soon after completing her doctorate. Throughout her studies, she discovered that she was incompatible with the lifestyle of an astronomy research academic and didn’t like research culture. While this realisation came early in her doctorate, no decision was made about future pathways, and she remained focused on astronomy-related activities rather than look outside for career opportunities. Also, due to some health issues that have not been disclosed in this story, Bruna felt that she was unable to travel internationally and needed stability such as family nearby and a stable workplace culture. Bruna encompasses the flexible leaver because instead of one singular epiphany,
like the determined leavers, it took the PhD process and a series of cumulative decisions for her to weigh-up strengths, weaknesses, and what kind of culture she wished to work in.

Both Blake and Bruna, typify elements described in the flexible leaver narrative, which involve a complex series of factors and decisions that lead to leaving astronomy research. With this narrative, individual circumstances vary in complexity. But what becomes clear is an attachment to people and places, and for many, a need for stability that astronomy research does not provide. There are also elements of compromise. Whether it is due to a singular, or multi-body problem, the decision to leave astronomy is highly personalised for those who draw on this narrative, as are methods of finding employment.

7.2.4 Exit Strategies

Interviewees who draw on flexible leaver narratives search for jobs slightly differently to their determined leaver counterparts. This is primarily because they seek employment at or towards the end of their doctoral studies and as such have had less time to develop strategies and form networks outside astronomy. Though there are many resources for job seekers that describe networking (Bolles, 2015; Evans, Lundsteen, & Vanderford, 2017; Levine, 2015) and paid memberships to networking societies available (Henkel, 2018), interviewees didn’t utilise any of these, preferring to apply for advertised positions rather than Bobbie’s approach of networking that opened up previously unconsidered pathways.

For most interviewees, a direct application was effective, as illustrated by Bruna and Blake, and jobs in the university and the government sectors are highly regulated which means that all significant positions must be advertised. This strategy compensates for the hidden job market of corporate industry, where networking more often leads to previously hidden positions (Bolles, 2015; Evans et al., 2017; Levine, 2015). Bruna, Brook, Bella, and Bo, all started their new careers on temporary contracts and were able to move within institutions and the government until they found a position that was the right fit, or had accumulated enough professional capital to progress to a higher position, often leading permanent employment.

Those who sought industry employment, like Brittany found work,

*Mainly just through websites say like ‘Financial Careers’. That kind of site has lots of jobs. You kind of get to know all of the big recruitment firms in finance when you start looking on the internet, so it’s just a case of meeting them to see what jobs are out there.* (Brittany, recent graduate)
Brittany, and other interviewees such as Beatrice, used employment websites to identify the larger employers in finance and then made connections within those companies through interviews. This structured approach to networking allowed interviewees to get a brief overview of the field and use the recruiter as an intermediary party to establish connections. By responding to an advertisement, rather than request an informal interview, flexible leavers had the opportunity to audit their skills in relation to employer need and ‘find out what’s out there’.

For Benita, the direct job application process in technology fields influenced her decision to retrain as a secondary school teacher. It wasn’t so much the work that made her question her fit but the make-up of the technological workplace.

*It was just so weird. I didn’t realise I was turning up in an all-male workplace.*

*I didn’t really want to work there. I was really put off by being the only person in a dress.* (Benita, Recent Graduate)

Benita, who initially looked for data science work, was surprised about the presence of all-male workplaces. While astronomy is still male-dominated, there is a significant female presence that is still not present in some technology companies. For her, that there were no women already employed was a red flag that she would have difficulties fitting in and that it may be a hostile culture for women. Benita, who was looking for a stable career in case her partner’s mental health further declined, decided that she was not a good fit for tech companies and decided that the more traditionally women-friendly job of teaching was a better match for her.

### 7.3 Involuntary Leavers

The third narrative, involuntary leavers, reflects more marginal experiences of being ‘forced’ out of astronomy. Key characteristics of these stories include the perceived lack of agency in relation to employment in astronomy post-degree. Unlike the determined and flexible leaver narratives, who weigh up factors that influence whether or not it is possible/preferable/viable to stay in astronomy, involuntary leavers are excluded from potential astronomy careers by academic and administrative factors directly related to their degrees. These conditions are typically not discovered by the doctoral student until late in candidature, and by the time the problems are identified, are too advanced to rectify. Though involuntary leaver narrative is a relatively rare occurrence in this study, it has had a long-lasting effect on interviewees.
Bella, who initially drew on a career research narrative, fits the model of having loved astronomy since she was a child and worked hard in her education to become a research astronomer. Though she recounted her supervisory relationships as largely positive, she received some core advice that changed the trajectory of her upcoming career.

*My immediate supervisory team panel had always advised me that getting publications wasn’t as essential as producing a good thesis when it came to life in academia. So, when I tried to identify opportunities for potential publication because there were null results, sometimes they stressed more on focus on producing a good thesis. When I got to this completion stage, I started hearing that I didn’t have [the needed] publications because I was so focused on producing the perfect thesis.* (Bella, recent graduate)

Bella’s project choice was problematic, in that it was not part of a large survey that had large scale publication potential. Hers was a smaller project that had more potential for risk, and in her case, produced null results, which are common in critical scientific research. Instead of focusing on publications which would have been difficult to achieve, her supervisors led her to believe that a good thesis would lead to future academic opportunities. A good thesis is important for an academic career, but now with fewer jobs and greater metrics required, a strong publication record is an important aspect of landing a postdoctoral position.

Bella, an international student, found that at the end of her PhD she was broke and the possibility of obtaining an Australian visa for being an academic, if she could get a position, was almost non-existent.

*Being more practical about my life and where I wanted to be, the practical side took over that dream side. The second thing that influenced me was that I was an international student and getting a visa to remain here if I were to go for an academic role, which was so niche, was going to be next to impossible.* (Bella, recent graduate)

Bella needed the job to stay and be close to her partner to provide enough time to gain a partner visa, which can be a lengthy process. That ‘her practical side took over from the dream side’ indicates that she had to choose between financial survival or to try to continue to pursue her astronomy dream, where she was already disadvantaged because of publication metrics and citizenship in addition to other gendered barriers. To do this, she closed off the astronomy route in order to survive.

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2 A null result is a result that does not support a hypothesis. It does not mean that there are zero results, but that the expected outcome is absent. These are valuable results but not as easily publishable as other result types.
I think I had about $500 in my bank account and at that stage, I was like, “I can’t survive even for another month. I need to find a job”. I applied for the first job that I thought I could do something with and got it. So, I fell into research management as opposed to actively seeking it out. (Bella, recent graduate)

She decided to stay near her host university and applied for a research management position, which she was successful in attaining. This, however, was not an easy decision and, as she drew on a career research PhD narrative, she had to give up her dream. Her decision to leave “cause[d] of a lot of grief when [she] had to give up astronomy. So, it was a very very difficult decision. In fact, the most difficult decision” she had ever made. Bella realised that although she had taken an administrative position at her doctoral university, she felt that by going off course she had closed off any astronomy options for the future. As she had initially drawn on a career research PhD narrative, the closure of academic pathways due to publication metrics, and additional financial difficulties took away her perceived choice as to whether she could continue in astronomy. It is the reactive response and perceived lack of agency that had a deep psychological impact on Bella and left her grieving for what might have been. Bella indicates that she now enjoys her job, and due to her transferable skills, has been promoted quickly. Still, at the time of interviewing Bella still felt a wistful nostalgia about leaving astronomy and did not want to dwell on it for too long.

Beatrice, who had a relatively successful PhD, reflects the involuntary leaver narrative due to administrative issues related to Australian PhDs and their incompatibility with international postdoctoral funding cycles. In Beatrice’s case, it was the lengthy and unpredictable process of thesis examination and administration issues that effectively cut her astronomy career short. Unlike Bella, who had been advised to concentrate on her thesis over publication, Beatrice was successful in attaining two postdoctoral positions in her very specialised field. As Beatrice describes,

The reason why I didn’t keep going with that [postdoctoral] offer was because my thesis took too long to accept. The reviewers took longer than planned so I’d already pushed back my start date to...I think it was something like the year before January or February and this is my when my thesis report was meant to be back in late November. So, I guess I assume with the funding situation that they have to hire within a certain year and because they weren’t able to do that. Note that they had already pushed back extended [the position for] me from something like July or August until February and they were just like, “Sorry, we can’t do it anymore.” So, I didn’t get that position. (Beatrice, recent graduate)
This delay compounded an experience from the previous year with another postdoctoral position that she could not accept due to administrative time lines. These delays effectively excluded Beatrice from relevant postdoctoral positions in her field. Upon completion of the thesis examination and subsequent administration, postdoctoral opportunities had dried up in that particular field, and the disappointment of losing these positions forced her to reassess her life.

*I didn’t get that position. After that, yes, I was a bit sad and I thought, “What am I going to do next?” Astronomy jobs take quite a long time to actually go for. I’ve already spent a lot of effort and time in trying to find a position in astronomy and that postdoc would have been amazing for me. It was 50% supporting a telescope that I definitely would have been wanting to use, and 50% my own research which meant finishing off my PhD projects and all the other things that I had started. It would have been amazing and then, the new country as well... (Beatrice, recent graduate)*

Though Beatrice described herself as ‘a bit sad’ that she was excluded from her planned postdoctoral positions, she did not describe the grief that Bella experienced. She did, however, clearly articulate areas of loss associated in being pulled from that ‘amazing’ postdoctoral position. As an Australian student, in a culture with specific lexical differences and a tendency for understatement, ‘a bit sad’ could mean any level of sadness or grief. The description of the lost job as ‘amazing’ and the clear identification of every element that she lost indicates that this was a significant event in her life. Waiting for examination results and being caught between two institutions essentially removed any level of agency Beatrice could assert concerning that job outcome and it was not her decision to be removed from the field. It is this perceived lack of agentic control that separates involuntary leaving stories from the other narrative typologies.

It is technically possible that both Bella and Beatrice might have continued towards astronomy postdoctoral positions had they worked hard, improved publication, and applied for more varied postdoctoral positions. From their perspectives, the obstacles presented were too large to navigate and effectively forced them out of the field. Their disappointment with the system, which stemmed from a lack of agency, combined with economic constraints meant that Bella and Beatrice both decided that they had lost their opportunity to continue in astronomy and adapted. Due to the late nature of their exclusion from astronomy, job hunting strategies were mainly ad hoc and are similar to that of the flexible leaver narrative.

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3The Australian PhD does not have a thesis defence. A thesis is sent to multiple examiners to mark. Depending on examiners availability, or if further examination is needed, this process can take many months. The longest time frame I have heard of is almost a year.
7.3.1 Exit Strategies

Both Beatrice and Bella, who draw on the involuntary leaver narrative, discovered late in their degree that they would not be able to competitively pursue academic astronomy positions. As such, their exit strategies were similar to those who drew on the flexible leaver narrative, where they pursued post-astronomy employment after the conclusion of their doctoral studies. Where Bella quickly attained a university administration job, Beatrice went through a lengthy process of investigating and pursuing different post-astronomy pathways. Beatrice, who had just accepted a finance job at the time of interviewing notes,

*The thing with job ads is that it’s a wish list of the ideal candidate. Even if you only have even if you only think you hit a few of the things, you should still try and apply for it. You should still talk to the person making the decision. To the recruiter, ask more about what does a company really want and what are they after? Yes, they might want someone who has experience in using these financial models but...they might just want someone who is able to show that they have learnt skills in the past.* (Beatrice, recent graduate)

Beatrice talks about a job application as a ‘wish list’ for the ideal candidate and she worked with recruiters to establish what companies were looking for and concluded that while specific skills may be required, an aptitude for learning is valuable. Beatrice, who draws on the involuntary leaver narrative, was caught by surprise at the end of her doctoral studies and decided that she needed a local job. Because of this, she had few networks to draw on outside the academy and found recruiters to be helpful in explaining the post-astronomy job market and to gain confidence.

7.4 Leaving the Field

Interviews in this study suggest that women tend to leave astronomy for many different reasons that can be divided into three main types of leaving narratives; determined leavers, flexible leavers, and involuntary leavers. Though individual reasons vary, these narratives, divided by temporal and perceived agentic factors, focus on both women in STEM pipeline related ‘leaks’, as well as other life events. The most notable aspect of this chapter is not necessarily reasons for leaving academic astronomy research, or ‘leaking’, but the assertion of agency when describing leaving typologies. Critically, agentic and temporal decision-making factors varied between narratives, yet how the majority of interviews described ‘leaving the field’ was remarkably similar. Interviewees described a range of individualistic factors that influenced their decision to leave astronomy. This decision involved assessing
their interest in astronomy against other intersectional factors such as location preference, income, mental health, family, and other priorities. These accounts of leaving demonstrate the complexity of women’s lives beyond that of the pipeline understanding.

For a woman to progress to a PhD level in a STEM field requires a certain degree of non-conformity regarding gendered expectations. This was perhaps one of the biggest drivers of the determined leaver narratives, who showed little interest in continuing in astronomy post-PhD. The determined leavers were the most advantaged when looking for external work because they had more time to network and sought employment earlier than the other two leaving narrative types. Of this group, Bobbie, the most active networker managed to amass a large network outside the field of astronomy. Her rejection of leaving stigma enabled her to actively seek out post-astronomy work. Other interviewees in this narrative type kept their decisions private and found work individually, and not through large-scale professional networks.

Though displaying agentic and temporal differences in their leaving narratives, the involuntary and flexible leavers employed similar strategies when seeking post-astronomy work. This is due to the decision to leave, reached at different times during (or in some cases after) their doctoral studies, being enacted post-submission of their thesis. At this point, an evaluative process of interests, skills, opportunity, and life priorities plays a vital role and is not ‘leaking’ but finding post-astronomy employment that best meets participant needs. Consequently, many interviewees in these groups found similar types of post-astronomy work.

This chapter illustrates that the decision to leave astronomy is complex and that women do not necessarily ‘leak’ from a pipeline but re-prioritise their needs. The motivation for this can be a lack of interest in staying in astronomy research, connection to people and places, and intersectional aspects such as mental health. These factors combined with labour market factors, such as a lack of stable employment, all contribute to women evaluating their lives and choosing employment that suits their needs. To attribute individual decisions of elite scientists, who are trained in gathering evidence and analysis, only to structural factors devalues their training and decision-making capabilities. In addition to this, it devalues one of the most critical aspects of this study; where women astronomers redirect their expertise and how they perceive their employment. It is this topic that will be addressed in the next section of this thesis that will further contextualise the experience of women and their views on employment post PhD.
Chapter 8

Accounts of Post-Astronomy Careers

This chapter investigates where graduates of Australian astronomy PhD programs find employment upon completion. As described in Chapter Three, in order to further situate the study and compare to data from the Australian Academy of Science’s National Committee for Astronomy (2015) demographic survey, I constructed a database of publicly available employment and alumni data from the five largest astronomy PhD cohorts to establish where graduates are employed. For a full account of gathering this data see Chapter Three Constructing the Study: Method and Data. This public alumni data collection worked twofold, as a contextual basis for this study, and to locate women graduates to potentially interview. From here I established more general employment patterns of astronomy graduates over the last decade.

The second section of this chapter analyses employment data from the B Group interviewees, or recent graduates, and focuses on what kind of post-astronomy careers they pursued, descriptions of their roles, and what they perceived as benefits of these positions. Although interviewees worked in a relatively broad range of positions, results indicate that they are performing job functions such as technical programming work, analysis, project management and outreach which are closely related to skills developed during their astronomy doctorates. This indicates that both technical and soft skills developed in the PhD program are instrumental in finding post-astronomy work.
8.1 Finding ‘Lost’ Astronomers

This section uses multiple data sources to explore where Australian astronomy graduates have been employed over the last decade. The data comes from two sources; The Australian Academy of Science’s National Committee for Astronomy (2015) demographic survey and my constructed database consisting of ten-years of public graduate data collated from the five largest universities identified in the Australian Academy of Science’s National Committee for Astronomy demographic survey which is one of the main sources of demographic data that informs Australian astronomy. Here, universities that had astronomy programs provided data about their astronomy cohort for the five years preceding the census date (in 2014).

During the decadal survey data collection, I was an institutional contact and responsible for data that included alumni information. A more detailed explanation of this process is included in Chapter Three. The collected institutional data was analysed by the report demographic team and simplified into three reported elements; type of employment, area of employment, and location. The report found that 59 percent of Australian PhD graduates over the period of 2010 - 2015 stayed in astronomy careers, with 15 percent in ‘industry’ positions, 2 percent were teachers, and the remaining 24 percent were unaccounted for (Australian Academy of Science’s National Committee for Astronomy, 2015, p. 11). The 59 percent who, at census date, stayed in astronomy included data from levels of employment.¹ This means that exact employment status information is unknowable from this particular data set. It does, however, confirm that a relatively high number of PhD graduate outcomes are unaccounted for.

This data identifies a large gap in employment outcome reporting for Australian PhD graduates within five years of completing their degree. Czujko and Anderson (2015), assert that it becomes more difficult to locate graduates the more time that passes since graduation. This can be attributed to new careers that distance graduates from their host institution and field of study. A decade after graduation, the institutional drift is almost complete and non-academic alumni are independent from their university networks and difficult to reach. The Australian Academy of Science’s National Committee for Astronomy (2015) decadal survey focused on the current and future state of astronomy, and as such, alumni data collection was not a major focus. This data, or lack thereof, did however, provide an incentive for me to discover where alumni were employed after graduating their PhD. To do this, I constructed my own limited database of alumni career exit data from the five largest astronomy cohorts in Australia.

¹This includes part-time, full-time, casual, contract, permanent, and honorary positions.
This database was compiled from publicly available data from the five Australian Universities with the largest PhD student cohorts as documented by the demographic survey (Australian Academy of Science’s National Committee for Astronomy, 2015). The process consisted of tracking 191 students who graduated between 2005 and 2016 from the following universities: The Australian National University, Swinburne University of Technology, The University of Sydney, The University of Melbourne, and Macquarie University. Here, I found only 5 percent of PhD graduates remained unaccounted for. Furthermore, 26 percent were employed out of astronomy, and 69 percent still worked in astronomy in some capacity. Like in the Australian Academy of Science’s National Committee for Astronomy (2015) demographic survey, information on employment status, as private data, was unavailable. Without this data, it is impossible to ascertain by this means the exact state of employment within astronomy or if the numbers are somehow inflated by zero-hour contracts, adjunct contracts or research associate status.

The construction of this alumni database indicates that, while it is possible to track a large number of alumni from public data sources, as numbers increase and there is more career movement it becomes more difficult to account for graduate employment outcomes. The alumni database indicated that after one postdoctoral astronomy job, the percentage of post-astronomy jobs increased from 26 percent to 32 percent. For more accurate information regarding career outcomes, a longitudinal study that is not retroactive may, in fact, be a more fitting approach. For this study, however, as an experiment in graduate tracking and locating potential interview candidates these results, while not optimal, are adequate.

8.1.1 What about Gender?

As established in the earlier section in by the alumni database, 32 percent of PhD graduates leave astronomy within ten years. This does not indicate whether women are more likely to ‘leak’ from the field than their male counterparts. As the aim of this research is not to establish a comparison between men and women who leave the field but to document the experiences of women, I will focus on women’s employment data and not a detailed comparison of gender and employment.

As described in Chapter Three, the results from the constructed alumni database indicates that a larger percentage of women leave astronomy post-PhD and go into ‘industry’ (32 percent). Here, ‘industry’ represents all types of employment outside academic research astronomy. The following table 8.1 is a duplicate of the table in Chapter Three and indicates the distribution of exit career pathways from five universities.
Table 8.1: Exit Careers Pathways of Alumni from Five Universities (duplicate)
Source: Own Database

<table>
<thead>
<tr>
<th>Gender</th>
<th>Astronomy</th>
<th>Industry</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>63%</td>
<td>32%</td>
<td>5%</td>
<td>73</td>
</tr>
<tr>
<td>Men</td>
<td>72%</td>
<td>23%</td>
<td>5%</td>
<td>118</td>
</tr>
<tr>
<td>Everyone</td>
<td>69%</td>
<td>26%</td>
<td>5%</td>
<td>191</td>
</tr>
</tbody>
</table>

In addition, there was no apparent gender difference in the number of graduates that were unaccounted for, or unknown as this was at 5 percent for both. The reduced level of ‘unknown’ results significantly improves on the 37 percent of unknown graduates listed in the demographic survey (Australian Academy of Science’s National Committee for Astronomy, 2015). It also indicates that there is a significant number of women alumni who left the discipline between 2005 - 2015.

When further refined, Table 8.2 indicates that the 32 percent of women employed in ‘industry’ (Table 8.1) can be traced to four types of employers; Corporate, Government, Universities (professional non-academic roles), and Other (e.g. parenting, medical roles, artists, and teachers).

Table 8.2: ‘Industry’: Where Women Work (further refinement of data from Table 8.1)
Source: Own Database

<table>
<thead>
<tr>
<th>‘Industry’: Where Women Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Women</td>
</tr>
</tbody>
</table>

The relatively even spread of employment categories in the ‘industry’ sector indicates that women in the database are drawn to a variety of post-astronomy positions and industries, without overly favouring one particular type. The data, as part of the alumni database, was constructed to account for overall trends in women’s employment and university exit data. It also enabled the locating of interviewees for stage two of this research, qualitative interviews.

8.1.2 Interviewee Career Pathways Outside Astronomy

The constructed alumni database indicated that women chose a variety of careers outside astronomy which was spread out between four main areas; Corporate, Government, Universities (professional roles), and ‘Other’. These are broad categories that cannot be adequately defined by a quantitative account of available public data. In addition to this broad data set, the recent graduate interviewee group provides more specific data, categorisation, and analysis of the larger trend as well as a detailed description of employment.
The following data is based on a qualitative sample with a small number of interviewees and is not generalisable. As such, recent graduate interviewees’ (n=22) employment fell into the following categories:

- **Corporate**: includes finance, data science, software, and other areas.
- **Government**: includes government scientific institutions such as the Bureau of Meteorology (BOM), Federal and State Government professional positions such as analysts, publicly funded museums and schools, and also the CSIRO when not related to astronomy research
- **Universities**: graduates employed in professional positions and non-astronomy or physics-related research.
- **Other**: employed by other industries such as medical-related professions, teaching, artists, and stay at home carers for children.

This further clarification of the previously vague category of ‘industry’ used in the demographic report (Australian Academy of Science’s National Committee for Astronomy, 2015) demonstrates the scope of employment within each category. The ‘Other’ category catches those who have less conventional employment, work in multiple areas, have easily identifiable jobs, or parental duties (which, as this is feminist research is considered full-time employment). As such, there is more variation to be found in this category.

Figure 8.1 (next page) indicates that recent graduate interviewees slightly favour government positions (n=7), closely followed by Corporate (n=6), and University employment (n=6).

The slight favouring of government positions can be better explained by Figure 8.2 (next page) which accounts for Area of Employment, or more accurately in what section of the institution recent graduates were employed. Here, education and research areas (n=6) provide the largest areas employment followed by technology (n=4).

The distribution between areas of employment in institutions establishes why the government is slightly favoured as an employer by recent graduate interviewees. The government sector in Australia is the largest employer for scientific research outside the university sector.\(^2\) Aside from scientific research, the government sector also funds major outreach and education programs at museums and educational facilities which employ people with

\(^2\)Many of the listed government positions are located within the CSIRO, Australian Astronomical Observatory, Australian Space Agency, Bureau of Meteorology, National Measurement Institute, Australian Nuclear Science and Technology Organisation, Australian Bureau of Statistics, Environmental Protection Agencies, and various other state and federal departments.
broad scientific backgrounds. These museum and education facilities are run at both State and Federal levels.

As indicated in Figure 8.2 Sub-Areas of Industry Employment, the two main areas of employment Research (n=6) and Education/Outreach (n=6), which in Australia most commonly occur in Government or University employment.

The third largest area of employment in Figure 8.2 is Technology (n=4). This category
relates to the testing and development of software and data technologies for government and business application. Fewer interviewees worked in Environment, Finance, and Other fields, but were relatively evenly distributed between the three.

When interviewee data on recent graduates was broken down further, the job function, which I define as what interviewees did every day, had a clear trend. Recent graduate interviewees were most commonly employed in an analytical capacity. Figure 8.3 Job Function of recent graduates indicates that while areas of employment had more variation, just under half of the interviewees were employed in analyst roles (n=9). While recent graduates may work in different industries favouring research and education, they may not necessarily be doing that type of work but serve a more analytical function. For example, only one interviewee worked as a researcher at a university, though six interviewees worked in the field of research.

For the purposes of Job Function (Table 8.3), Education (school teaching) and Outreach were separated due to levels of formal training. Though their function is similar, educating people in the sciences, the level of preparation and accountability separates how they conduct their work.

![Figure 8.3: Job Functions of Recent Graduates (n=22)](image)

The interviewee preference for analyst roles indicates that graduates utilise the most obvious transferable skill set of an astronomy PhD, data analysis. These positions also have a significantly higher pay scale to education and outreach fields, which may be another factor in their appeal.
These employment pathways patterns differ from that of Etzkowitz and Ranga’s (2011) vanish box phenomena, which posits that women are more likely gravitate towards interdisciplinary fledgling industries that have less status, such as technology transfer, that have more flexible work environments. This was not the case for most interviewees in this study who pursued analytical and technical roles within established parts of corporate industry and government. The more gendered areas of outreach, teaching and administration were also present in job outcomes. This indicates that recent graduate interviewees, upon leaving the discipline of astronomy, were generally attracted to areas where the work was close to their preferred skill set. The next section further considers career types and how interviewees describe their post-astronomy employment.

8.2 Post-Astronomy Career Types

This section further explores the type of work recent graduate interviewees chose to undertake post-PhD. As demonstrated in the previous section, quantitative methods were useful in breaking down general trends of recent graduate employment, though the exact nature of these roles is better explored through narratives of how interviewees describe their work. Here, from the position of current employment, recent graduates account for their work outside astronomy (Järvinen, 2001) and give brief job descriptions that help with the identification of work-type narratives. This answers one of the questions of this research; What kind of post-astronomy employment do PhD graduates engage in? Work narratives have been categorised as astronomy satellite careers, technical careers, and people oriented careers and will be explored in relation to job function.

8.2.1 Astronomy Satellite Careers

In the context of this study, the term satellite career refers to an astronomy-related job that is affiliated with the larger industry but is not academic astronomy research related. These satellite positions allow a ‘soft exit’ from academic research, while still contributing to the broader field of astronomy on a daily basis. Satellite positions are located in astronomy institutions, affiliates, or astronomy outreach environments such as museums and planetariums. For most interviewees, this re-positioning in relation to astronomy was described as positive. For Bianca, however, it was it was frustrating.

An astronomy satellite career typically draws upon astronomy-related skills and knowledge, which are not necessarily related to computer coding. Both Bo and Bruna work in outreach

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3In the context of this study a ‘soft exit’ is being employed in a field that is related to astronomy, or in a familiar environment such as at a university doing research or computer science.
positions, though Bo’s job is behind the scenes “Research/ing objects exhibition design and themes for 19th and 20th Century technology”, she still utilises astronomical knowledge every day. Bruna, who works both in front of and behind the scenes describes the type of work she does on a daily basis;

I present for school groups and other groups, such as Sudanese groups who visit, and talk to general public about space and space-related stuff, our missions, and what our complex does. I also handle bookings, booking everything, all the paperwork side, help run the Twitter feed, do a lot of reading trying keep up to date on everything. When I’ve got the time, answering general questions we’ve got coming through, help out with running events. If we have VIPs visiting on site, trying to think about how we can redesign things in the visitor’s centre. A reasonably broad range of stuff. (Bruna, recent graduate)

These positions both feature a ‘reasonably broad range of stuff’ and employ skills such as teaching, educational design, project and people management. This type of outreach satellite position is favoured by astronomers who enjoy outreach, and are some of the most popular jobs that astronomy graduates aspire to.

Bronwyn also has a diverse satellite career and works in administration for a large astronomy consortium. This administrative role requires her to “manage grants, reporting requirements and other things to do with the consortium” but like Bruna, and Bo’s position, her job varies,

It’s interesting in that it has a lot of different parts to it. As well as this, I’m working with the local communities, the local indigenous people and working with businesses. All that fun stuff. (Bronwyn, recent graduate)

Bronwyn’s ‘all that fun stuff’ and Bruna’s ‘reasonably broad range of stuff’ are the smaller tasks that are people and astronomy oriented. When discussing these satellite careers in interviews, Bronwyn, Bruna and Bo expressed enjoyment knowing that they are contributing to the ‘future’ of astronomy, whether it was educating the public or facilitating future research in a consortium. That they were still able to engage with astronomy on a daily basis was a major appeal of this type of position.

In contrast, Bianca, who also pursued a satellite position similar to Bronwyn’s describes her initial employment.

The actual job was a short-term contract to design build and launch a website for them. Also media outreach and increasing their profile in Australia.
Because I finished everything that they wanted to me to do, I branched out to include outreach. (Bianca, recent graduate)

Bianca, who took the job to stay connected to astronomy, was employed not for her astronomy expertise but her design experience from a prior career. After ‘finishing everything that they wanted [her] to do’ early she managed to integrate astronomy outreach into her position. While the others in this type of career reported the interaction with astronomy and astronomers as positive, Bianca’s experience was frustration in that the others were doing what she really wanted to do; astronomy research.

I really tried to get them involved in letting me do things that would have used my skills as an astronomer, but I was unable to convince my supervisor to expand my work in that direction. (Bianca, recent graduate)

Here, the division between professional and research staff was well-defined, and Bianca was unable to cross this threshold from inside a satellite position. This led to frustration. Her strategy of staying close to astronomy in order to facilitate a return to research or astronomy technical support was still in progress at the time of interviewing. However, it was clear that Bianca was not personally suited to that position as she considered it a ‘second choice’ and felt stigmatised being surrounded by research astronomers.

These accounts raise an important issue regarding interviewee experiences in satellite careers. When approached independently from astronomy research, they can be very rewarding, but used as a mechanism to return to academic research astronomy they can have negative effects. Here, the professional/academic divide is very difficult to navigate.

8.2.2 Technical Careers

The majority of recent graduate interviewees pursued some form of technical or analytical career. Usually, in a data science capacity, interviewees made a ‘hard exit’ which for the purposes of this research means that they left astronomy behind, compartmentalised, and engaged in different work. Interviewees who undertook this type of technical work were employed in three fields; commercial and product work, government data analysis work, and university/business hybrid work. These positions all fall under the relatively ambiguous term of ‘data science’ which is still considered a masculine field (Ensmenger, 2013).
8.2.2.1 Commercial and Product Oriented Work

Interviewees who took commercial work drew mainly on determined and flexible leaver narratives and obtained post-astronomy employment through networking and direct application to institutions. For the purposes of this research, I am separating commercial and government data work. This is due to the difference in work environments, focus, and data use. Commercial work, in the case of interviewees, describes jobs that develop primarily online products for companies. These jobs require strong analytical, programming, web development, and financial modelling skills.

An example of this type of job is Brittany’s employment in the financial sector. When asked to describe her work, she briefly described her function as ‘coding’ but went on to explain contextually what this meant.

*I code basically. The software that I work on is a multi-dimensional cube. It stores information for banks, for pension funds hedge funds excreta. They basically have a lot of data that they use to invest with and a product that kind of enables them to access those numbers and different calculations of the numbers for different aggregations of different factors. It’s quite high-speed, so I work on the code that underlies that. So, it’s kind of low-latency calculations, and it’s mainly just coding, you know.* (Brittany, recent graduate)

Though she’s ‘just coding’ Brittany contextualises the global applications and benefits of her job within the larger financial sector. Here, she is working on (what appears to be) risk assessing, analytical software that is considered integral to maintain financial stability for banks and pension funds that people rely upon. Brittany has combined her astronomy programming skills with prior knowledge of the financial sector and has engaged in a fast-paced, computer programming job. Belinda and Bailey who also ‘code’ in finance based data science give similar accounts of their roles.

Another commercial data scientist, Beth works as a project manager at a large, international technology company. She describes her job:

*On a day today day basis I work with the software development team, and we develop a lot of tools and internal software. [Company] is a [product] comparison website. So, we also work on some international topics for the [data] searches, like redirects and internationalisation topics.* (Beth, Recent Graduate)

Beth, while adept at coding holds a managerial position in her team. Like other post-astronomers, she clearly articulates her job purpose, to develop a product comparison site and links it to a larger global picture.
As well as doing a lot of the product content and prioritisation, I still also do a lot of testing of new software and explaining new software to the users which is also kind of fun for me because it’s really diverse. (Beth, recent graduate)

Beth combines transferable skills, such as explaining complex ideas and project management, with her technical skills of understanding computer programming as one of the more ‘fun’ aspects of her job. As the senior member of a small team, Beth still works in a male-dominated environment (though her team is more balanced than others in the company) she has a highly technical role and is actively involved in testing new software and explaining it to users. This managerial, technical, and specialist communication role is an example of some of the more diverse aspects of commercial, technical work.

Highly technical roles in computer science, while originally the area of women, are now in a highly masculinised field (Ensmenger, 2013). Contrary to the findings of Etzkowitz and Ranga (2011), women in this study did not move into lower status careers but transitioned into highly technical roles in data science. They also reported a high-level of engagement in masculine tasks (Acker, 2012) such as coding and computer analysis.

8.2.2.2 Data Analysis for the Public Sector

As demonstrated earlier in this chapter (Table 8.1), the government sector was the largest employer of interviewees, closely followed by universities. For many interviewees, attaining a position in the public sector outside astronomy allows a ‘hard exit’ from the field, yet allows graduates to maintain a steady and relatively familiar work environment. Complex data analysis, which astronomy PhD graduates are trained in, is a growing field and there is a strong cultural fit between astronomers and areas of government. In the government scientific sector, work is largely located at a federal level (CSIRO, Bureau of Meteorology and other scientific bodies). There is also an increasing need for data scientists in the State sector, though interviewees with government positions in this study were all employed at a Federal level.

Bobbie, who was offered five positions before graduating her PhD chose to work in the government sector for ‘sentimental reasons’ and took a lower paying position that she would have had in the commercial sector. Describing her data science job in an environmental related area, Bobbie defines it as,

software testing lead numerical modelling. When it was advertised, I was told that I would spend an awful lot of my time writing automated testing code to test the outputs of numerical models, to do unit testing on the numerical models.
It’s all part of this move towards probably best practice software engineering.
(Bobbie, recent graduate)

Her position description, however, was different to the actual job where she describes her job as “writing mountains and mountains and mountains and mountains of documentation. I have to say that writing up my thesis was good practice for that, I think.” Here, when she attempted to test numerical models, she identified an issue with documentation and development of computer programs and models. Bobbie, who was originally employed in a code testing role, convinced her employer that she needed to ‘future proof’ institutional research and code and subsequently found herself in a more investigative and documentary role. This documentary role, rather than more active coding and testing, though considered more gendered work, focuses on skills developed during the PhD such as accuracy and high-levels of documentation.

Brooke, who also works for the government in a different department focused on statistical analysis. Instead of background documentation work like Bobbie, Brooke describes how she works with,

all the agricultural statistics and a couple of smaller [areas]. One of the smaller ones is international trade…When you see in the newspaper that international students are worth X billion to the economy, that’s the number that came out of my computer. (Brooke, recent graduate)

For Brooke, statistical analysis was not overly challenging, but she gained job satisfaction from seeing her statistics used in a public forum. The relatively fast translation of data from Brooke’s computer into the public domain is one example of a main motivational factor identified by recent graduate interviewees’ across technical fields. Interviewees expressed the satisfaction of seeing their data/product used in a ‘real life’ context and were able to articulate what they were doing in relation to some form of public interest.

8.2.2.3 Data Analysis for Universities and Hybrid Sectors

In addition to corporate and government work, interviewees were employed as data scientists at universities. These positions offered a ‘soft exit’ from astronomy due to the familiar tertiary education environment and provided interviewees a chance to develop their data science skills. Interviewees in this field worked mostly on short-term contracts and were not as invested as others in the technical fields of employment.

Blake worked in a professional staff capacity at a university that was part of an interdisciplinary recruitment drive to make faculties more technologically competitive in developing
digital methods. Here, they employed ‘experts’ to assist academics with technical aspects of digital research. Blake describes her position:

> It’s like a virtual institute and we do computation in a broad way. This year they hired computational specialists to look after, maybe one for each of the faculties, and we are like an internal consultancy. They [academics] can come to us with requests like “I want to analyse this data. I don’t know how to go about it.” So, in a way we are kind of data scientists. You know what? Data scientist is just vague...I look after the humanities faculty and am usually trying to figure out how to get data from the internet [data scraping] or how to deal with different data structures and analyse data. (Blake, recent graduate)

Blake’s work as an ‘internal consultant’ to the humanities faculty places her in a complex position within the university system. As a data scientist and member of professional staff, she is a technical expert but, like those in satellite careers, she also works beside academic researchers without doing any research herself. Blake’s position was a short-term contract position, so while she found ‘trying to figure out how to get data from the internet’ and other problems interesting, she was not necessarily invested in the long-term. Bree, who also worked in a hybrid role between research and data science in a collaborative business-university context described her work:

> What I’m doing right now is really similar to what I was doing when I was doing my research, which is analysing data and trying to find patterns, solutions, statistical tools, and find a methodology to obtain results or to improve the efficiency of the businesses. (Bree, recent graduate)

Like Blake, Bree worked in an interdisciplinary university centre where she used her data science skills to work on a variety of research problems. This work, though problems differed, offered a relatively familiar work environment that supported university research. Although Blake and Bree reported finding their work interesting, they indicated that they were not particularly invested. Both also still considered rejoining astronomy if the ‘perfect’ position arose. Perhaps due to the close proximity of the academy, these technical positions were still viewed as temporary or ‘second choice’ by interviewees and they had still not decided on future career pathways.

### 8.2.3 People Oriented Careers

In addition to Bronwyn and Bruna who work in satellite careers, other graduates chose people oriented, or administrative careers that focus on soft, or transferable skills learned
during their doctoral studies. Of interviewee post-astronomy careers, it is this category that conforms most closely to gendered career pathways that are more often occupied by women (Etzkowitz & Ranga, 2011; Acker, 2012). Like government positions, university professional employment is advertised and guided by equal opportunity hiring policies and procedures that offer flexible work arrangements and other women-friendly employment factors.

Bella had sought an administrative position for economic reasons after finishing her PhD. Though she had little perceived agency in the decision to leave astronomy, Bella, who started administrative work on a series of contracts has been able to quickly rise to senior levels and undertake interesting and rewarding work. She describes the duties of her current position:

*I was [first] in the administrative paper side, but as I’ve climbed the food chain it’s more about staff management, ensuring operations run smoothly, and that relationships are maintained with various stakeholders. I am responsible for the day-to-day operations for the research activities for three schools in the college...I manage a small team of staff who work on everything from pre-award to post-award management of research grants, contracts milestones, essentially working with different areas of the university as well working with the philanthropic office, working with finance, human resources, and central research services.* (Bella, recent graduate)

She notes that she quickly progressed from the ‘administrative paper side’, or low-level positions, into managerial positions with a more diverse range of responsibilities. In her interview, Bella noted that her “practical side took over that dream side”, and as such she has focused on the practicalities of climbing the ‘food chain’ in her new position. She does, however, note that,

*I realised once I took up this position was that I’m actually quite curious by nature and I can be happy in other roles that I choose to invest my energy in. During my PhD I was just focused on one outcome and not even recognising the different possibilities around me. If given a choice, I would still always pick astronomy over everything else, but I do realise the stress that academics face, especially now dealing with academics on a day to day basis seeing what they have to go through* (Bella, recent graduate)

Because ‘[i]f given a choice [she] would still always pick astronomy over everything else’, Bella has ensured that she has not worked in or close to the astronomy department.
Her case is exceptional because as she drew on an involuntary leaver narrative, she was unable to continue into a postdoctoral position, yet she stayed at the same institution in a professional role. For Bella, this has been difficult as she is still torn between being very successful in her post-astronomy role and ‘giving up’ on astronomy research.

Beverley in contrast drew on the determined leaver narrative and made a ‘hard exit’ into university administration. Drawing on a difficult PhD experience, she has channelled her expertise into supporting graduate research at a different university.

I lead a small team. We are responsible for supporting staff in supporting graduate research at the university. The central graduate research administration is fully devolved, and faculties are responsible for administration and support of graduate research. Because you’ve got ten faculties, there’s more than two hundred departments with staff supporting academics, students and graduate research.

Our role is to provide a coordinated response to help support the faculties so that they can provide [a more specialised] experience to students. A lot of my role is communications based, so material that we have available online for graduate research. Students are able to understand where they can go and get support and what kind of help they can get during their candidature. (Beverley, recent graduate)

As a post-astronomer, Beverley is well situated to understand the needs of graduate students across the university. Her personal preferences bought her from more general university administrative roles into graduate research administration where she views her role as improving student experiences. Like Bella, she manages a small team and relies heavily on interpersonal skills and her organisational ability. Both Bella and Beverley work in specific areas of university administration that remove them from the astronomy department and any perceived stigma from astronomers associated with working as professional staff. They are also invested in their post-astronomy careers and are not looking to re-enter astronomy in the future. This contrasts with Bianca, who in a satellite career worked beside astronomers and tried to re-enter the field, Bree and Blake, who both did data science at a university were also considering re-entering astronomy.

8.3 Work Conditions and Benefits

When discussing their post-astronomy work, recent graduates identified a range of benefits in their current position. Some of these are tangible like permanent and long-term
contracts, pay conditions, leave conditions, and access to maternity leave. Details of these tangible or documented conditions are available from other sources (The Australian Government, 2018) and were not a priority in data gathered for this study. For example, Brittany who works in finance describes her employment package in the form of tangible benefits.

*There are the material ones, and then there are the kind of, I don’t know, other ones. Materially, I get private health care. I get 25 days annual holiday. I get to leave my job at five pm in the evening, and I don’t have to think about anything else. I don’t have to work on weekends. I don’t have to spend time away from my family on conferences or anything like that. What are the other perks with my job? I get a pension my employer contributes 5 percent of my salary into each month. I get dental care. I get paid maternity leave, like a really good sort of package for half a year to a year. I feel like I get respected and I kind of felt I didn’t really get that elsewhere.* (Brittany, recent graduate)

Though Brittany easily identifies the ‘material ones’, it is the ‘other ones’ that are currently undocumented in relation to post-astronomy careers. For Brittany, that her employers offer her ‘good’ money, stable work conditions, and benefits translates into feeling ‘respected’ in a way that she had not been before. It is the identification of intangible benefits, which are more subjective and closely related to PhD experiences, that I will explore in this section.

### 8.3.1 Different Ways of Working

Interviewees spoke about their current workplaces differently to how they spoke of their doctoral studies. The absence of an academic research environment, and the expectations that go with, that allowed recent graduates to consider their new post-astronomy workplaces from a different perspective. Here, the appeal of these positions was that the work turn-around was faster due to shorter projects, differences in workplace culture, team dynamics, and defined roles. Achievement was also measured differently and, while some found the adjustment easy, others who were used to the pace and structure of academic life found adaptation a little more difficult.

#### 8.3.1.1 Teamwork Structures

Interviewees often referred to their ‘teams’ when discussing their post-astronomy positions. These new workplace team structures differ considerably from experience in research teams. While maternity leave is legislated in Australia, some interviewees worked internationally and were subject to different workplace conditions. Internationally, the technology and finance industries offered the best-reported conditions for interviewees that included maternity leave.
during their doctorates. Beth, who worked as a project manager in software development, described a dynamic team structure and discussed the make-up of her workplace in detail.

*I don’t know if you know much about this Agile development Scrum system,5 but they’re really focused on small, dedicated teams so that they can cut down a lot of dependencies and stay focused. It’s a really different way to work compared to research.* (Beth, recent graduate)

As one of the original members of her diverse team, Beth has been able to train others and assert authority in a highly gendered field of work, software development. The dynamic work structure and rapid accomplishment of smaller tasks aids in team motivation. Beth then describes the scale of the company she works for and the more general culture.

*We all know what the other person is working on every day, and it really is sort of day-by-day updates on what everyone’s doing. I should maybe also mention that even though we’re eight members, there’s maybe ten other teams of that size as well that I’m also kind of connected to. There’s also a lot of exchange between teams. I really like the team size because it’s big enough to have different ideas from people and it’s not just sort of led by one person. It’s small enough that everyone knows what’s going on with everyone else.* (Beth, recent graduate)

Beth, as one of the more generalist members of her team, has knowledge of project management, testing, reporting, and computer coding which makes her a valuable asset. In addition, her workplace, a ‘progressive’ technology company, encourages team bonding and socialisation outside the office and funds social activities of the team’s choice.

*The company I work for is a little bit special...I mean it’s not that special in a lot of corporate companies for corporations. It’s where we have these organised team building things and team events where everyone is given a budget in the week and kind of do anything we want to improve our relationship. We go out and have fun and whatever. It sounds kind of silly, but it’s actually quite nice having these kind of organised events where everyone kind of relaxes a little bit and gets to know each other. I think it does help people work together.* (Beth, recent graduate)

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5Scrum is a computer based project management system for small teams that structures short periods of work called ‘sprints’ to achieve set tasks, followed by review and feedback. This process is repeated breaking down tasks into small achievable goals until project completion. It is widely used in computer science.
Beth views this collaborative, relatively equal, and dynamic work environment as being different from her oppressive PhD experience where she felt isolated due to sexual harassment. That she describes the team building aspect as ‘kind of silly but it’s actually quite nice’, indicates that this approach to team management suits her work style and that the structured team is important to her.

For many interviewees, after the relative solitude of writing a doctoral thesis, they actively seek out more social and dynamic workplaces. Betty, who works in data analysis also enjoys this style of work. She describes,

\[ I \text{ like the teamwork because in astronomy you have your team maybe four or five people work on the same thing as you, but I felt a lot more isolated because also in my group I was quite specialised compared to the other students. If I had a problem, I could be stuck on it for a week whereas now working for a company you can't afford to be stuck on a problem for a week. So you pretty much have to talk to somebody after two hours. That's really nice having people working on the same things, maybe a different project, but they all have the same problems. Here you can share the code. Where, in astronomy you always have to have your own code and nobody else would have a look at it. } \]

(Betty, recent graduate)

Though both Betty and Beth’s work are highly technical, they both enjoy extensive collaboration with their colleagues and find this, as well as the ‘fun’ of quick problem solving, to be essential for their well-being. These corporate management styles, designed to bond and motivate small teams, have been identified by interviewees as a key reason that they feel positive about their positions and move into post-astronomy careers.

Simple elements like socialisation, organised teamwork, and small tokens of appreciation are perceived to reflect good management and were one of the key differences that interviewees described when comparing their post-astronomy careers to their doctoral experience. This phenomenon was described more by interviewees who moved towards progressive technology workplaces over government and professional university positions that had more traditional work environments.

### 8.3.1.2 Diverse Social Interaction

Recent graduate interviewees in this chapter have identified teamwork as a major benefit in their post-astronomy positions. This social interaction, which occurs differently than in doctoral studies, is one of the perceived benefits of working outside academic research. Here, the diversity of social interaction was described by interviewees as ‘fascinating’, ‘interesting’, and one of the highlights of the job.
Bronwyn, in a satellite career, reflects on one of the main benefits of working in her broad administrative role.

I think sometimes I think that I’ve met a lot more people than I usually would. They expand your knowledge and horizons, and you see more of the real world. Well for me, I see more of the real world. Academics have more [restrictions]...maybe not [living in] a bubble, but it’s a different lifestyle. Take industry for example, so it’s kind of different having worked with industry people, I’ve learnt a lot, and I’ve made all of these connections that normally there’s no way I would have met these people for any other reason. That aspect is quite valuable, I think...It’s fascinating. (Bronwyn, recent graduate)

Bronwyn works for a large astronomy consortium and as such, acts as a conduit between different groups. She notes that academics, in the field of astronomy at least, have a more restrictive professional circle and less opportunity to meet different types of people in their everyday work. Bronwyn’s connection to, and the ability to learn from, different groups in the project was described as a highlight of moving into a post-astronomy career. This sentiment was echoed by Bella, who also in her administrative role enjoys engaging with different academic disciplines at the university.

The good thing about this role is that I get to meet so many interesting people, [see the] sort of research that they’re doing, and how it all links together. Because I’m not attached to one type of research, I can actually stand back and look at the broader connections. We’re moving into more of a research business development role at the university as a whole and so that will present us with opportunities to understand what researchers are doing, forge those connections, and bring about multidisciplinary projects that might be of more immediate benefit to society. So that’s very interesting...I would not like to go back to a role that’s very limited in my capacity to interact [with others]. (Bella, recent graduate)

Here, Bella’s interactive aspect differs from Bronwyn’s. Bronwyn works on a large-scale project and interacts with various interest groups such as indigenous communities, government bodies, and industry groups to negotiate the implementation of the project. Bella, in contrast, interacts with academics and other stakeholders to bring about multidisciplinary projects and collaboration that ‘will benefit society’. Now that these interviewees have interacted with a broad range of people, they are reluctant to go back to a singular discipline approach where there is less diversity of both stakeholders and ideas.
8.3.1.3 Academic Intensity in Workplace Culture

While Beth embraced the dynamic team and project management environment of her corporate job, Bobbie, who chose a government position, had trouble adjusting to the new, more relaxed pace of the government sector. At the time of interviewing, Bobbie had reflected on the problem and was working on ‘chilling out’, or dialling down the work intensity from her PhD experience. She describes that,

_I thought the [government institution employer] was like university. I thought it was like academia, but actually, it’s really different. The research department is kind of like academia but not. There’s less pressure to collaborate, and there’s less of a publish or die mentality. There’s a lot more job permanency. You’re measured less against your scientific output and more against the timeliness of your output, which is really interesting. So, there are some surprising differences._ (Bobbie, recent graduate)

Bobbie’s assumption that government work would be like academia led to a culture shock when her workload slowed down, and ‘timeliness’ became a measurable factor over output and collaboration. Through the observations of her coworkers, Bobbie has discovered that her work style is not considered sustainable in the government sector.

_Everyone in my group keeps telling me I work hard, and that I work harder than everyone in this group. People say I should work less and I think the PhD is responsible for that, for better or worse. It’s unusual, and it’s not a good thing. I’m trying to fight against it. I’m trying to break habits like those I had in my PhD._ (Bobbie, recent graduate)

Now that Bobbie is outside academia looking back, she recognises that the intensity is ‘unusual and it’s not a good thing. I’m trying to fight against it’. Bobbie’s situation highlights one of the issues that occur during the transition into post-astronomy careers; the continuation of the academic intensity of their PhD and risk of burn out. Here Bobbie’s perspective of the present re-frames past ‘intensity’, that was previously a desirable trait, into a flaw to be overcome. This issue also affected other interviewees, such as Bo, who had over scheduled both her work and personal life because she was unable to break the habit of academic intensity. In hindsight, Bobbie recognised during the interview that going directly from her PhD into a job without a break period was not ideal and, during the interview, assured me that she was planning a holiday.
8.4 The PhD in a Post-Astronomy Context

This section explores the connection between graduate and employer expectations of doctoral graduates, strategies used by recent graduates to bridge this gap, and the perceived value of a PhD in post-astronomy careers. Earlier in the chapter, recent graduates identified positives in working in post-astronomy careers that were intangible, or not directly linked to official employee benefits. The most valued aspect of these experiences, as described by interviewees, was different teamwork strategies, meeting a diverse range of people, and learning new information. As interviewees have shown, doctoral graduates can apply their transferable skills and intensity into other areas of employment and thrive. This process is not without its challenges, and one of the key problems is the lack of understanding of exactly what a PhD is, and how it relates to post-astronomy employment.

8.4.1 Expectations of Graduates and Employers

Recent graduate interviewees, while they did ultimately find post-astronomy employment, reported a disconnection between their PhD research and its potential application in other areas of employment which was due to misunderstandings between both graduates and potential employers. This issue links to the stigma of leaving, as discussed in Chapter Six. The described stigma cycle is partially due to the lack of knowledge of the academy about ‘industry’, or the outside world. Astrid, an established astronomer, observes this disconnection from the perspective of the academy,

*What I would really like to see is a much better understanding amongst our academics of the rest of the world. I mean the rest of the workforce, the non-academic work. For us and for academic staff to really understand that we aren’t just training ‘mini-mes’ but we’re training broader skill sets than that.*

(Astrid, established astronomer)

Here, Astrid identifies the issue of academics training ‘mini-mes’ or academic clones that are highly specialised in certain research areas. That academics are not aware of the ‘rest of the world’ is only part of the issue, the second part is that ‘the rest of the world’ does not understand the general value of a doctoral qualification in a potential employee.

Brooke who took multiple contracts in the government doing statistical analysis, notes that in her experience there is a lack of understanding of higher degrees and how graduates can contribute to the workforce. She notes,

*I think the ‘real-world’ people don’t see [a PhD] as real-world work, and it’s just having a qualification written down. It was quite demoralising that people*
didn’t appreciate or understand, I suppose, that PhDs aren’t undergrad arts degrees. A PhD is a job. To do it on time in astronomy is pretty full on, and I think people were surprised when I rocked up and I could do the [government] job, learn the context quickly, and had the data analysis skills. (Brooke, recent graduate)

Brook found it ‘demoralising’ that she had completed a ‘pretty full on’ PhD, and that employers had no frame of reference to compare an astronomy PhD to an undergraduate arts degree. Unlike Europe and the US, where there is a relatively high number of master’s degrees, postgraduate degrees are generally not given the same value by Australian employers. Her perception that people were ‘surprised when [she] rocked up and could do the job’ was a further indicator that her employer did not understand the level of training that she had undergone during her doctoral studies.

In confirmation of this, Beatrice spoke of the PhD stereotype, particularly in astronomy, of being a dysfunctional person who is good at one thing. During interviews, she got feedback that “technically you’re good, and you don’t portray the stereotype of not being able to communicate your information.” Until that moment, as someone with significant outreach experience, Beatrice had not realised how PhD holders were viewed in the financial sector. The idea that to be highly skilled in one area means that there is a deficiency in others is a damaging cultural stereotype that benefits neither employers or PhD graduates. Like the cycle of stigma described in Chapter Six, the cycle of disconnection between universities and industry or, ‘the rest of the world’, particularly concerning graduates, is a problem that is beyond the scope of this research and would benefit from further study.

8.4.1.1 Bridging the Gap

Once they identified the knowledge gap between their doctoral degrees and the industry perceptions thereof, recent graduate interviewees used a variety of strategies to bridge the skills, knowledge, and confidence gaps they felt they needed to obtain post-astronomy employment. Bailey, who worked at a large technology firm, felt that she needed some extra structured assistance during the transition process and accessed an internationally based bridging course where academics are trained for industry. As a graduate of this course, Bailey obtained a position in a large technology company that had a recruitment relationship with the course provider. This type of bridging course is available in the United States and the United Kingdom where candidates are given scholarships to attend and then recruited to corporations after graduation. The business model means that entry

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6In Bailey’s interview the recorder malfunctioned and data was reconstructed from notes.
is highly selective and course costs are absorbed by the employers of graduates. At the
time of writing, there was no equivalent available in Australia.

The more common route for astronomy graduates who wanted to learn new programs and
skills are Massive Open Online Courses (MOOCs) that are provided by private companies
such as Code Academy, or through platforms such as Coursera and EdX, which run short
self-paced courses with developed content from prestigious universities. In these courses,
there is a paid certificate option, but many courses are free. Belinda, who works as a data
scientist uses these courses as professional development.

So, for me, it’s watching Coursera and learning more techniques. I can read pa-
pers and learn about machine learning. Of course, you can do that in academia
but are limited to your niche, which is not super useful outside of academia.
So, I think I’ve just kind of learned many more skills that can help me in many
aspects of many other jobs if I wanted to move on. In astronomy you’re not
learning anything too applicable. (Belinda, recent graduate)

Belinda, in addition to highlighting further learning options, was positioning herself for
‘other jobs if [she] wanted to move on’. The appeal of leaving her ‘niche’ and exploring
other skills outside the academy was an important element for her. Beatrice, who moved
into finance, also used these courses to gain confidence in obtaining industry recognised
skills which she documented through the paid certificate option. The main advantage for
interviewees who had undertaken these courses was that they had additional certification
of their proficiency in highly technical computer programs and areas of management.
These specific short courses enable both graduates and employers to pinpoint areas of
commonality, for example, a proficiency in computer programs, to bridge the knowledge
gap of PhD related skills in the workplace.

8.5 Post-Astronomy Pathways

This chapter analyses the career pathways of women astronomy PhD graduates and an-
swers a fundamental question in this research; What do women astronomers do post-PhD?
Instead of being ‘leaked’ or ‘lost’, women’s post-astronomy career pathways are accounted
for.

In addition to data from the Australian Academy of Science’s National Committee for
Astronomy (2015) demographic survey, I constructed an alumni database of public infor-
mation and tracked career exit data for 191 astronomy PhDs. Here, through quantitative
statistical analysis, I found that 32 percent of women PhD astronomy graduates were employed in ‘industry’ roles. These industry positions were then broken down into smaller categories of corporate, government, university and ‘other’ to indicate further patterns of employment. Here, there was a slight favouring of the ‘university’ and ‘other’ categories. This database led me to find recent graduate participants for this study and indicated that it was possible to trace the careers of graduates through public data.

Of the twenty-two recent graduates interviewed in this study, I further broke down employment patterns to show that (n=9) or 41% (Figure 8.3) of recent graduate interviewees were employed in analyst positions in various industries. This indicates that astronomy PhD graduates are well suited to highly technical roles in data science. In addition to analytical positions, recent graduate interviewees were also well suited to outreach and education roles. The results of this relatively small sample of recent graduates (n=22), contradicts the idea that women are prepared to move into lower status employment after leaving science (Etzkowitz & Ranga, 2011) as interviewees moved into highly technical skilled positions.

I further broke down recent graduate employment data into more detailed descriptions of their post-astronomy career types. These were identified as astronomy satellite careers, technical careers, and people oriented careers. This mechanistic breakdown of careers into further sub-categories with short descriptors from interviewees serves to fill an information gap as to where post-astronomers are employed and what they do. Here, there was little connection between current employment, PhD motivation (Chapter Five) or leaving typologies (Chapter Seven). Recent graduates, however, did have two major strategies of exit, the ‘soft exit’ which I defined as remaining in a familiar field or environment (For example, a satellite career or university data science career) or a ‘hard exit’ which involved a separation from their identity as an astronomer to work in a different field. The success of these different approaches was highly individualistic and depended on the motivation for undertaking certain fields of employment.

In addition to employment pathways, this chapter identifies intangible benefits of employment, namely teamwork aspects and the diversity of social interaction in post-astronomy careers. Importantly, it demonstrates a cultural difference between doctoral intensity, as illustrated by Bobbie’s overwork, and the misunderstanding within ‘industry’ of what having a PhD actually means. Here, some employers are not able to differentiate between a bachelors graduate and a PhD degree, or impose cultural stereotypes on doctoral graduates such as they are ‘bad at communication’. This demonstrates an issue in both education, where the word ‘student’ implies doing coursework or a lack of expertise, and its translation into industry. The lack of professional recognition is a key problem with doctoral
graduates identifying and obtaining post-astronomy careers. By positioning doctoral students as ‘students’ and not employed as ‘postgraduate researchers’ gives the impression that they lack many of the transferable skills developed in postgraduate training. This makes the transition into industry more difficult than it would be if they had been framed as employees during their PhD.
Chapter 9

Conclusion: Brave New World

This thesis argues that the current way of understanding women in STEM careers fails to account for the complexity of women’s lives. Policies aimed at women in STEM and gender equity programs are often informed by the leaky pipeline approach, which aims to increase the number of women by preventing women-specific ‘leaks’ with the purpose of encouraging women to reach higher levels within their scientific field. The adoption of the leaky pipeline from an educational metaphor to a way of accounting for women’s careers is problematic for multiple reasons;

Firstly, it does not adequately correct a system that enforces the established androcentric bias that permeates STEM disciplines (Harding, 1991). Fixing leaks is an ad hoc approach that builds on the foundations of an already flawed structure, in this case, a metaphorical pipeline. For the last thirty-five years, this ‘repair’ approach, while improving conditions for women in the field, has not increased women’s participation to the levels desired.

Secondly, the assumption that women will by default choose to stay in the pipeline if given a chance. This assumes a level of conformity in women’s lives and careers. As demonstrated in the introductory and literature review chapters, that women astronomers were not necessarily conformist and, like Payne-Scott, have their own agendas. It is unreasonable to expect women who already do not conform to gender stereotypes as they enter STEM fields, to conform to the retentive agenda within the sciences if it is not perceived to be in their best interests.

This leads to the third problem, that the assumption of conformity minimises women’s agency in career decision making and assumes that they can be prevented from leaving the pipeline by improving work conditions and hiring practices within STEM fields. Making these fields more women-friendly by altering structural barriers is beneficial for both women
and the sciences, but the assumption that this is the default preferred pathway for women can be damaging and undermines women’s career decisions.

This, in turn, leads to the forth and most-significant problem with the leaky pipeline and all its career variants. By positioning it as being desirable for women to be retained and not ‘leaked’, ‘lost’ or ‘wasted’, it continues to frame staying in the academic field as the most desirable option and inadvertently stigmatises leaving. When combined with the implicit expectation that occurs in universities and beyond, that women who get a PhD in a field desire to work in that field, the notion of career decisions being discounted and related to ‘leakage’ is demoralising, undermines agentic decision-making processes, and limits women’s opportunity for future non-academic employment. By re-positioning non-academic, or post-astronomy, career pathways as a desirable and equally valid option and elevating agentic factors that surround how women navigate structural barriers, women may become more comfortable with their decisions and viewed as equally valued if they remain in astronomy or decide to pursue post-astronomy careers.

9.1 Research Framework

This interdisciplinary study draws from gender studies, labour market studies, sociology of higher education, and sociologically related fields to investigate the career choices of women who have graduated with astronomy doctoral degrees. The use of feminist standpoint theory (Harding, 2004), and situated knowledges (Haraway, 1988) underpins the epistemological approach of understanding how women navigate career barriers, make decisions, and transition from being a doctoral student into post-astronomy employment. This elevation of women’s standpoints allows women’s data to stand alone, and not engage in what Husu (2001) observes as a common problem, to compare women’s situations with men’s. This approach differs from the leaky pipeline (Berryman, 1983) view that is currently adopted by women in STEM initiatives (Australian Academy of Science, 2015) which aims to attract and retain women by removing structural barriers to make women competitive with men. While this approach is important, it is also subject to criticism that it does not adequately account for women’s agency (Allen & Castleman, 2001; Bennett, 2011; Blickenstaff, 2006; Husu, 2001).

Interviewee narratives of thirty-two women were then analysed through the lens of further feminist theories such as gendered workplaces (Acker, 2006, 2012) and also gendered technologies (Wajcman, 1991) to examine how women astronomers experience astronomy and post-astronomy fields. The main questions asked by this research are:
• How do the experiences of women during their astronomy PhD influence future career pathways outside academic research?

• Where are women employed outside academic astronomy? What do they gain from these positions?

• What does the transitional process look like and how does this correspond to university training?

• How can we understand women’s career pathways post-PhD from an agentic perspective?

Rather than concentrate on experiences related to the retention of women, this thesis focused on experiences that influenced career movement and how women navigated their transition out of the academic field. By focusing on narratives of recent graduates, supported by current student and established astronomer narratives, this thesis presents a multi-tiered perspective that connects women’s career choice with their experiences and prioritises agentic factors over the well-established structural ones.

In order to better understand how women viewed their experiences in transitioning from astronomy into post-astronomy careers, this research uses a number of analytical approaches. Firstly, a theoretical thematic analysis (Braun & Clarke, 2006) was employed which considered feminist theories of work and technology (Wajcman, 1991; Acker, 2006, 2012) and developed thematic networks (Attride-Stirling, 2001) for further exploration. A thematic narrative analysis (Riessman, 2005, 2008) was used to temporally organise and construct accounts (Järvinen, 2001) of interviewees’ experiences entering and leaving astronomy and pursuing post-astronomy employment. This approach resulted in motivation and leaving narrative typologies in addition to accounts of PhD experience, stigma, and new employment narratives that position women graduates as not ‘lost’ or ‘leaked’ but as redistributing their expertise into other equally valuable industries.

9.2 Research Findings

In addition to gathering career exit data of women astronomers and revealing post-astronomy career pathways, this research has a number of original findings that may help better understand how and why women choose various educational and career pathways. Though focused in astronomy, findings from this research are applicable to other STEM fields especially in relation to motivation and entry pathways, PhD experiences, and connection to post-PhD employment. This research goes some way into filling the gap by accounting for women’s career decisions within the sciences and provides a nuanced
narrative-based approach that may contextualise survey data regarding post-PhD career movement of graduates.

9.2.1 The influence of PhD experiences on career outcomes

This research indicates that although there is a distinct difference in motivation and leaving narratives for PhD graduates, positive or negative experiences during the PhD process did not necessarily correlate with the desire to stay in the field or leave for a post-astronomy position. The decision to pursue a post-astronomy position is an individual one where graduates weighed a complex range of factors and made the decision to stay or leave.

Recent North American studies have found that a number of interlinked factors such as research funding availability, mentorship opportunities and personal encouragement have influenced women to undertake PhDs in astronomy (Barthelemy et al., 2013; McCormick et al., 2014; Gu, 2012). During their time in graduate school women experience discrimination and microaggressions that make them feel unwelcome (Barthelemy, McCormick, & Henderson, 2015a). Similarly, European studies of women postgraduate physics students found that their learning experiences were highly gendered, especially in relation to technology and the masculine culture that dominates the field (Danielsson, 2012; Danielsson & Linder, 2009; Gonsalves et al., 2016; Pettersson, 2011). This study confirmed similar conditions within Australian astronomy, though not all interviewees perceived, or identified with, experiencing discriminatory behaviour. Here, the focus was primarily on factors that influenced career choices. It acknowledges that these well-documented gender issues within the culture of astronomy exist.

For a survey analysis of a large data set, the American Institute of Physics (AIP) Statistical Research Centre focused on similar structural barriers for women in astronomy through a quantitative lens. This data indicates that women still have unequal access to opportunity and resources (Ivie & White, 2015), are affected by impostor syndrome (Ivie & Arnell, 2011), and a longitudinal study that found that there were multiple steps that led to women leaving astronomy that were not necessarily directly related to gender (Ivie et al., 2016). Ivie et al. (2016), however, did find that indirect factors such as mentoring, impostor syndrome, poor advising and the two-body problem as key elements of women’s attrition in physics and astronomy. This paper recommended improving two elements; the two-body problem and advising relationships as areas of focus in order to retain more women in the field. This thesis differs fundamentally from the AIP’s retentive perspective as I have employed an agentic approach that considers women’s decision-making and post-astronomy careers have equal value to being retained in the academy.
By breaking the PhD process into three distinct stages; motivational typologies, PhD experience, and leaving typologies, this research distinctly separates elements into comparative categories that can individually model PhD graduate motivation, experiences, and career outcomes. This approach differs from current approaches to retention (Australian Academy of Science, 2015) and modelling of post-PhD career options which attach a range of pathways to the end of the leaky pipeline (Barthelemy, Van Dusen, & Henderson, 2015; Etzkowitz & Ranga, 2011). In this research, the decision-making process regarding post-astronomy career pathways begins at the start of PhD studies, which is the point where the educational metaphor of the leaky pipeline ends and ‘work’, in an apprenticeship model, begins.

9.2.1.1 Modelling Career Choices

When viewed as a whole, this research creates a way to understand how women enter, experience, and leave astronomy and documents the fields that they transition into post-PhD. Beginning with PhD motivational typologies; accidental PhD, adventure PhD and career research PhD, this thesis establishes that women join PhD programs for a variety of reasons and that they do not necessarily intend to become research astronomers after the completion of their doctoral studies. This provides a new perspective into leaky pipeline centred strategies for retaining promising students into postgraduate positions. This strategy while effective, particularly for those who drew on accidental PhD narratives, does not necessarily correlate with women deciding to stay in the field post-PhD. Here, PhD graduates who drew on the accidental PhD narrative were just as likely to choose another field post-PhD if the opportunity arose rather than an academic position. Their decision-making patterns, which involved following ‘the path of least resistance’ and following opportunities, continued unchanged post-PhD.

The next stage, during the PhD program, is covered in Chapter Four, provides a nuanced astronomy account of women’s experiences during their PhD and reflects critical factors that influenced either their progress or decision to leave. This area covers many of the elements produced by leaky pipeline literature (Etzkowitz et al., 2000; Schiebinger, 1999) and provides a contextual basis for the next assertion that women experience leaving stigma and ‘failure’ when they decide to transition out of astronomy. This issue will be discussed in finding 9.2.1.2.

Building on experiences that occur during PhD studies, recent graduate women draw on three types of leaving narrative; determined, flexible, and involuntary leavers. Leaving narrative typologies indicate that two main factors that influence leaving strategies; temporality (when women decide to leave) and agentic factors (why and how). These leaving
narratives do not necessarily correlate with motivation narratives for entering the PhD, and the adaption of these are highly individualistic. There is, however, the possibility to further examine motivation and leaving narrative typologies, and their connection to PhD experience. As all A and B group interviewees in this study either had or sought employment in post-astronomy careers, their navigation of these pathways indicated that, although women entered doctoral studies for a number of reasons, their approaches to leaving the academy were equally varied and far more complex than the leaky pipeline suggests.

Here, interviewees who drew on determined leaver narratives made an agentic decision to change fields relatively early in their doctoral studies. This narrative type tended to revolve around an epiphany that they were no longer interested in astronomy and felt determined to pursue other career options. The execution of these decisions ranged from leaving doctoral studies, actively pursuing post-astronomy employment, and locating work towards the end of their studies.

The next narrative type, the flexible leaver, is the most commonly reported in the study. Here, in the latter half of the PhD interviewees take into account complex intersectional factors and decide whether or not to pursue postdoctoral positions or post-astronomy employment. This assessment and reordering of priorities typically centres around the connection to people and places over the desire to remain in astronomy. Interviewees who drew on this narrative were flexible in finding work that fit their other priorities post-graduation.

The third narrative is least common, the involuntary leaver, which reflects the stories of interviewees who, because of PhD related factors beyond their control, discover at the end of the doctoral studies that they are not able to continue in the field. Here, the perceived lack of agency in their decision to leave astronomy had a negative impact on their self-esteem and influenced post-astronomy career decisions.

When motivation, doctoral experiences, leaving typologies, and exit data are combined, they serve as a functional map of women’s doctoral experiences and the varied routes into post-astronomy employment. This process highlights agentic factors and recognises the complexity of women’s lives as they navigate transitional barriers within the doctoral system and beyond. When this data is combined with findings in section 9.2.2.1, a fuller account of women’s post-astronomy careers comes to light. This research temporally arranges the stages of the doctoral processes and provides a conceptual map that is more complex than can be fitted into a neat metaphor. Although this study focused on women in astronomy, there is scope, once specific disciplinary cultures are identified, for modification to include all doctoral students and not necessarily only STEM areas. This way of
looking at employment decision-making processes during the PhD may enable institutions to destigmatise and better prepare students for post-academic careers.

9.2.1.2 Stigma of ‘Failure’ and ‘Leaving’ the Academy

One of the consequences of doctoral training, and also women in STEM initiatives, is that students get the message that academic positions are the most desirable career choice for graduates and that other ‘industry’ positions are inferior. This description of leaving stigma, or somehow ‘failing the academic system’ was present in recent graduate and current student narratives. The creation of this stigma was identified as twofold; firstly, that doctoral programs train individuals to become academics, and that to not continue in the academy implies that there is a ‘fault’ that is either at a personal or systemic level (or a leak in the pipeline). Secondly, the lack of information regarding post-astronomy careers, especially what they are and how to achieve them, leaves an informational void that creates anxiety about unknown career paths.

The identified leaving stigma meant that doctoral students were hesitant in telling supervisors and other members of their cohort about their decision to pursue post-astronomy employment. This hesitance was partially because they feared a withdrawal of resources as they thought supervisors might prioritise students who intended to pursue the established postdoctoral pathway into academic research. To avoid this, a preferred strategy of leaving was to avoid the ‘job’ conversation with their supervisor until the last minute and use the absence of applying for postdoctoral positions as an attrition point.

The problem of leaving stigma and it’s perpetuating cycle is identified in this thesis. Established astronomers who were interviewed in this study reported a difficulty from their academic perspective that telling students to ‘go into industry’ would be seen as ‘disingenuous’ as they had done the opposite and stayed in academia. Recent graduate and current students identified that the academic career pathway was so deeply ingrained as the established norm and that any information presented to the contrary during their candidature was approached with scepticism. In their post-astronomy careers, interviewees still felt the need to account (Järvinen, 2001) for their decisions even though they were successful in their new careers.

The perpetuating cycle of leaving stigma is present at multiple levels of higher education and also in women in STEM initiatives where the desired outcome is for women to stay in the field. By examining it from the perspective of doctoral students, it becomes clear that perceptions differ between academic and student levels and that a general lack of information combined with implicit expectation perpetuates this stigma cycle. It is beyond
the scope of this thesis to further examine these relationships though would make an interesting area for future higher education study.

9.2.2 Where do women go post-PhD?

This research employed a mixed method approach to explore where women found employment post-PhD. Firstly, a database of alumni was constructed using university public alumni data from the five largest astronomy cohorts identified in the Demographic Survey of Australian Astronomy (Australian Academy of Science’s National Committee for Astronomy, 2015). This data showed that of the 73 women who had graduated from an astronomy PhD in the five year period between 2010-2015, 32% had found jobs outside academic astronomy, though their exact job functions were unclear using this method. For a larger source of data outside Australia, The American Institute of Physics (AIP) Statistical Research Centre produces data from longitudinal surveys that charts career movement of astronomy graduates and astronomy faculty (Ivie, 2014; White, Ivie, Arnell, & Anderson, 2010). If future research were to be extended into North America, this AIP data would provide insights to inform early stages of the study.

In this study, this quantitative method did, however, provide a database from which to draw twenty-two participants for the next qualitative interview phase of the study. This interview stage provided a more nuanced understanding of where women graduates go, what they do, and how they got there. After interviews, I found that post-astronomers were relatively evenly divided between government, corporate, and university professional (non-academic) positions with a slight preference for government work. Post-astronomers predominantly worked in research, education/outreach, and technology related roles, which tied closely with their astronomy related skills. They were also more likely to choose positions in desirable geographic locations where they had connection to family and friends. Though the two-body problem (Jorgenson, 2016), or even a multiple body problem, was present for most interviewees, they had carefully weighed other factors such as interest, aptitude, health, and financial commitments before deciding to pursue a post-astronomy career. This decision-making was complex and individual.

9.2.2.1 Post-Astronomy Career Patterns

In order to better understand the career patterns of graduate astronomers, I employed a multi-method approach to gather and analyse career information. This study found that while recent graduate interviewees slightly favoured employment in government fields, corporate and university employment were a close second. This slight trend towards government work most likely reflects the Australian labour market where the majority
of astronomy or physics related jobs are located in government scientific bodies. Here, interviewees generally found jobs that aligned with priorities developed during their PhD. This included factors such as location, social support structures, and also preferences for education, technical or people management positions. Interviewees also favoured analytical positions that fit well with their skill set as data scientists and preferred roles that they perceived provided a societal benefit, such as financial modelling and product development.

This research divided post-astronomy career pathways into three main narratives; astronomy satellite careers, technical careers, and people oriented careers. Of these career types, satellite careers, which are defined as astronomy related careers such as outreach and working in an administrative capacity in an astronomy institution, were the most polarising where interviewees either expressed a deep satisfaction with their career choice or they were frustrated by the division of professional and research roles that they were unable to cross. These results indicate that while it may be appealing to remain in close proximity to astronomy, satisfaction with satellite positions was dependent on motivation.

While the majority of interviewees made a ‘hard exit’ from astronomy into their new careers, those who made a ‘soft exit’ into satellite careers or were employed in a data science capacity at a university, were more open to perhaps moving back into astronomy. This indicates that the close proximity to academic researchers may influence whether or not post-astronomers feel that their job is a ‘first’ or ‘second’ choice career, or still experience stigma related to their career choices. In contrast, post-astronomers who made a ‘hard exit’ and separated from astronomy and the academy framed their new careers as more rewarding.

This career pattern data differs from that described by the vanish box phenomena (Etzkowitz & Ranga, 2011), which found women tend to engage in employment in newer, less prestigious fields of work where there is more flexibility. In this study, interviewees sought out roles that fitted with their interest, skill set, and facilitated other priorities. This research also uncovers a different set of post-PhD pathways than identified in Barthelemy’s (2014) career roundabout and focuses not on astronomy related careers, but post-astronomy careers with corporate, government, university, and ‘other’ employers. As such, it extends the possibilities of women’s employment beyond currently identified pathways and the potential to improve career training in STEM post-graduate programs.

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1 A ‘hard exit’ is defined for the purposes of this thesis as a complete change and a ‘soft exit’ is a position related to their PhD field or environment.
9.2.3 Transitional Approaches

The transition from PhD student into post-astronomer was difficult for interviewees. Most identified a stigma associated with leaving (see section 9.2.1.2) the academy in addition to a lack of support from institutions in relation to the non-academic job market. While individually PhD graduates found their supervisors to be supportive of their decision to leave the academy, some felt that they were being judged for making an inferior career decision. The established astronomers interviewed were outwardly encouraging regarding different career outcomes for their graduates. They did, however, feel that they were better equipped to assist students who wanted to pursue academic careers and that discouraging an academic career trajectory would be seen as disingenuous. These senior figures had also succeeded in establishing an academic career in astronomy and indicated that they could not comfortably provide advice to the contrary.

As explored in Chapter Four, the Australian PhD model raises multiple issues in regard to student motivation, retention, and career outcomes. Firstly, Australia uses the three-year apprenticeship model where students engage in relatively unstructured learning and rely heavily on their supervisor for guidance and skill acquisition. During this time, academic career pathways are strongly encouraged (Sauermann et al., 2012) as these skills are essential to complete the PhD. Secondly, students, especially those who draw on the accidental PhD narrative, tend to stay at one institution with known supervision and networks to follow the ‘path of least resistance’. This puts them at a relative disadvantage when pursuing academic positions compared to their North American counterparts who undertake a longer PhD program, have more time to establish an academic track record, and spread their education over multiple institutions (Etzkowitz et al., 2000). It is implicitly expected that postdocs be geographically mobile and attend multiple institutions, which in some way will make up for a lack of experience. This is one of the key reasons that interviewees chose to leave the academy, so that they could remain at a specific location.

Chapter Seven found that of the determined, flexible, and involuntary leaving typologies, determined leavers were better equipped to find post-astronomy work as their job searches typically began as soon as they made the decision to leave the field post-PhD. This preparedness took the form of active networking and conceptual work to discover potential jobs and use their PhD time to develop non-academic skills. Those who drew on the flexible leaver narratives left their employment decision-making to the last minute and tended to follow opportunities rather than develop a plan earlier on. In this study, flexible leaver narratives were the most common accounts. Here, women spoke of an in-depth assessment of their work/life needs and finding employment to match. They also identified a lack of information regarding the next step in career development if they made the decision to leave the academy. This is a short-falling of women in STEM equity programs that
Some interviewees mentioned a tokenistic gesture by career programs at universities to educate PhD candidates about potential post-astronomy careers, mainly in data science and finance. Until the stigma surrounding ‘leaving’ the academy post-PhD is lifted, these programs will continue to have difficulty engaging PhD students if they are still implicitly regarded as undesirable pathways. One possibility to change this is to incorporate career training, both academic and non-academic, early in the PhD process with equal importance. Much like gender equity programs, career programs that are implemented early have the ability to destigmatise leaving decisions and remove the idea of ‘failure’. Starting the conversation early also facilitates one of the elements that the academic sciences is known for, networking. By creating a non-academic network, universities have the potential to broaden graduate career outcomes and engage with industry. This creation of graduate networks further aligns with university innovation and industry engagement strategies (Rampersad, 2015; Ranga & Etzkowitz, 2013).

9.2.3.1 Re-positioning the PhD into Work

This thesis demonstrates that the development of and transition into post-astronomy career pathways is more complicated than the leaky pipeline approach suggests and that the ‘pipeline’ metaphor is dated (Bennett, 2011). In order to achieve this, Chapter Four accounts for the recruitment and retention of students into Australian doctoral programs. As highlighted by Bianca’s example, there are more factors to educational inequality that can be addressed by gendered recruitment initiatives. As such, a relatively small number of women and other minority groups are eligible for doctoral studies as they are often filtered out of the field before the PhD entry point. It is preventing this filtering that was the original purpose of the leaky pipeline.

While the recruitment into doctoral studies was the goal of Berryman’s (1983) leaky pipeline, its extension into PhD studies and beyond into women’s STEM careers has changed the meaning of the metaphor. ‘The pipeline’ has now transformed from an educational concept of actively encouraging women to pursue scientific education by providing avenues for retention, into a way of accounting for the relatively low number of senior-level women working in STEM fields. As such, interviewees identified an expectation that women would continue within the pipeline post-PhD. This assumption is then combined with other implicit factors in the university environment to create pressure on women to ‘succeed’, or get an academic research job which is the most common measure of pipeline
success. When women choose a different pathway, they experience stigma (see section 9.2.1.2).

By reducing the achievement of elite women scientists who obtain a PhD to a stage in the pipeline view of employment undermines their ability to assert agency, adapt, and make their own decisions about preferred post-astronomy employment. Interviewees in this study mostly viewed the PhD as ‘a job’ as they were employed, or given a scholarship, to conduct research. As such, I have approached their experiences from a workplace context to legitimise this view further. This workplace approach better suits the Australian doctoral program which includes project work, managing data, time lines, strict benchmarks, and performance reviews. When viewed from this perspective, a doctoral student, like most of the workforce, is contracted to complete research and at the end of that research, they must seek further employment. This move away from the language of women ‘leaving’, ‘leaking’ and having ‘wasted potential’ provides an alternative framework from which to view the PhD process.

From a student perspective the distinction and re-positioning of the PhD as work is important for two reasons:

1) It offers more stringent protections for the worker under Australian workplace legislation rather than university policy. Interviewees who experienced harassment and poor occupational health and safety conditions as a student may me more fully protected under this classification. Position descriptions and work hours would also be regulated which could include teaching, currently casualised work, and wage conditions. This added stability and a set workload may allow the PhD candidate to better plan their lives and relieve some of the stress associated with conducting insecure sessional work concurrent with their doctoral research.

2) The classification as worker removes PhD candidates from the term ‘student’, which is perceived as undesirable for employers in regard to work experience. In Australia, employers have difficulty differentiating between Bachelor, Masters and PhD graduates (pp.170-171). This re-positioning removes the ambiguity between levels of expertise and experience.

The positioning of the PhD as work is not a new idea. In Denmark, for example, three-year funded PhD programs (PhD Fellowships) are covered by the same academic union agreement as other academic work classifications (Academic Positions, 2019; Dansk Magisterforening, 2019). The introduction of this and its application in Australia may be problematic in current funding conditions (Australian Government Department of Education and Training, 2015, 2017) and with the current casualisation of the Australian university workforce (Connell, 2013; Davies & Bansel, 2007; Ryan et al., 2013; Standing,
Still, in STEM, there is potential for university collaboration with industry. These partnerships may be an interim avenue to redefine PhD students into workers. By changing this classification universities have the opportunity to legitimise their PhD candidates as workers and strengthen ties to non-academic industry.

9.3 Limitations and Future Research Implications

This research used feminist standpoint theory to consider women’s standpoints and does not compare their experiences to that of men (Harding, 2004). The most notable limitation of this research is the exclusion of one element of Acker’s (2006) inequality regimes that bind together race, gender, and social class. Due to the demographic make up of the Australian astronomy community, and study sample size, I was unable to include race as a variable in this study due to the de-identification and anonymisation of data. As the Australian astronomy community is relatively small, the inclusion of race data posed too much of a risk for participant identification. In addition, the process of anonymising interviewees also meant that valuable data and identifiable narratives were excluded to ensure that interviewees would not be recognised by other members of the Australian astronomy community. These issues could be overcome if a similar study were to be conducted in a larger community with more member diversity, such as the United States or European astronomy communities.

Another limitation of this study is that single interviews were conducted with each participant. This was due to the time frame of the study, finding ‘lost’ recent graduate interviewees, and arranging face-to-face as well as Skype interviews. Another method for gathering more in-depth data may also be to conduct a longitudinal study beginning at PhD commencement with multiple interviews per participant, and the inclusion of group interviews or an online forum where women can compare experiences. This extended approach would enable further analysis of how narratives change over time.

As noted in Chapter Six, and the findings on Stigma (9.2.1.2), there is an opportunity for higher research education into the perpetuation of the leaving stigma cycle at universities. A more effective qualitative approach to this may be using a more traditional narrative approach (Riessman, 2005, 2008) to understand how women assess and talk about stigma associated with their decision to leave astronomy. This method may allow a more nuanced examination of the interactions that create the stigma cycle and their connection to student well-being.

Interviewees in this study experienced their doctoral candidature before the implementation of the SAGE Pilot (Australian Academy of Science, 2015) and the Pleiades Awards
These gender equity programs both generate a large amount of reporting data which may be useful in a qualitative or quantitative analysis capacity. Australian astronomy is unusual in that the same Athena SWAN (Equality Challenge Unit Athena Swan Charter, 2015) based initiatives have been implemented at the same time, one from the top-down, and one from the bottom-up. This double-tiered approach to gender equity initiatives creates an opportunity for further research on the effectiveness of either, or both, of these programs in changing the culture in astronomy institutions and whether it is, in fact, leading to increased engagement and retention of women in astronomy.

Findings of this thesis are focused on the Australian style astronomy PhD, which positions the doctoral candidate as an apprentice researcher with little coursework or mandatory teaching loads. Results, though focused on astronomy, are applicable to other male-dominated STEM fields where data science and analytic skills are developed. Here, women may make similar career decisions post-PhD and have similar accounts of this experience. This could be an area of further study. Certain results, such as the accidental PhD narrative, may not be compatible with North American style 5-7 year PhD programs or countries where cross-institutional movement is expected between degrees. As illustrated in the literature review, there is little work that has been done on motivational reasons for undertaking PhD programs and whether candidates actually aspire to become academic researchers. Engaging in a longitudinal study of astronomy PhD graduates of all genders, or perhaps a larger STEM-wide study, and examination of how the culture of graduate school effects motivational and leaving narratives may be an effective way to explore factors that influence career decisions post-degree.

9.4 Concluding Note

This thesis provides an understanding of women’s experiences as they transition from doctoral students in Australian astronomy programs into a variety of post-astronomy careers. By framing this transition as agentic, and not reactionary, I have used a feminist standpoint theory (Harding, 2004) approach to present a sophisticated account of women’s experiences in the PhD workplace and beyond. Instead of considering women’s careers from the leaky pipeline perspective, where expertise is ‘leaked’ or ‘lost’, I have re-contextualised women’s engagement with post-astronomy careers as a redistribution of labour that is influenced by the complex factors that shape women’s lives. In order to better understand the lives of women and the stigma that surrounds the decision to leave the field of astronomy, I have presented an alternative view and positioned post-astronomy careers as desirable alternatives to academic research.
Here, I have found that women astronomers are not ‘lost’ when they begin post-astronomy careers. They actively engage in a number of interesting and highly technical fields that utilise both technical and transferable skills developed in their doctoral programs. By temporally ordering accounts and forming narrative typologies to account for motivation, leaving, and charting where women are employed, this research sheds light on what has until now, been the mysterious process of what happens ‘post-PhD’. By shifting this hidden process into the open, this research has the potential to contribute to a better understanding of women’s careers, provide a framework for future research regarding women in STEM programs, and better prepare doctoral students for employment outside the academic norm. By examining the career pathways that have been travelled by recent graduate interviewees, I have demonstrated that for those who are or yet to become post-astronomers, it is indeed a brave new world.
Appendix A

Recruitment Emails

Dear xxxx,

I am writing to request an interview for my PhD project at the University of Melbourne on career pathways for women in Australian astronomy. I have received your name from XXXXXX and believe that you would be a good interview candidate for this research.

The research project has two key aims:

1. To conduct a study to identify post-PhD career pathways of women who have attained an astronomy PhD in Australia since 2010.

2. To examine the decision making factors and processes that influence career choices of women when/if they engage in alternative career pathways.

The primary aim of this research project is to locate and identify Australian university PhD educated women who have chosen work outside traditional areas of academia and research. This project’s goal is to uncover which decision making factors contribute to women’s employment pathways.

The target sample size for this study is 30 astronomy PhD educated professionals who work in, or have been educated in Australia. I am looking to interview participants at various stages from PhD student to senior positions, with the largest sample group being women who work outside astronomy.

I am looking to begin scheduling interviews as soon as possible. Interviews will take approximately 60 minutes at a time and location of convenience to the interviewee. Interview notes and recordings will be kept in password protected confidential files. Published findings that draw on interview material will be anonymised, with interviewees comments or excerpts referred to by a pseudonym.
I have attached here the plain language statement that provides further details on the project and interview process, as well as a sample list of interview questions. If you are aware of another potential interviewee, I would be grateful if you would forward this information through your personal and/or professional networks.

You are welcome to contact me to indicate their interest in participating, to ask any questions they may have, or to request additional information about me or the research project overall. My email is xxxxxxxx@xxxxxxx. My mobile is +61 xxxxxxxx.

Thanks in advance for your support of the research. Wishing you all the best in 2016.

Warm regards, Amanda
Appendix B

Sample interview guide for Astronomers:

**Group A: Established Astronomers**
- There is a current focus on the retention of women in science. How effective do you think astronomy is in retaining women within the discipline? Please give examples.
- What future do you envisage for recent PhD graduates? How do institutions prepare PhD students for the competitive job market?
- Which areas of industry are currently attracting PhD trained astronomers away from the traditional academic research areas? Why do you think this is so?
- How do you think career opportunities for female astronomers differ from their male counterparts?
- What are the pros and cons of research astronomy versus industry?

**Group B: Recent Graduates**
- What is your current job title? Please explain your role.
- How do you think your skills as an astronomer led you to your current position? What factors have influenced your chosen career pathway? Do you feel you were well prepared?
- Could you please describe the evolution of your career goals from PhD student until now? What about the future?
- How do you think career opportunities for female astronomers differ from their male counterparts [in relation to networks, mentorship, travel/publication/job opportunities]? Please describe your experiences and any career obstacles you have faced/overcome.
- What benefit do you get from your current position that a traditional career in astronomy was unable to provide?
Group C: PhD Students

• Why have you chosen to do a PhD in astronomy? Why here? (country/institution)
• What career plans do you have post-PhD? How open are you to working outside academic research astronomy? Which areas?
• How do you think career opportunities for female astronomers differ from their male counterparts [in relation to networks, mentorship, travel/publication/job opportunities]? Please describe your experiences and any obstacles you anticipate, have faced/overcome.
• How prepared do you feel that you will be able to gain employment post-PhD? Please describe any training/preparation provided by your institution or other training body
• What factors are most important to you when deciding on your future career?
Appendix C

Plain Language Statement

School Cultural Management
Department of Culture and Communications
Faculty of Arts

Project: Women in Contemporary Australian Astronomy: Where do they go? Where are they now?

Dr. Amanda Coles (Responsible Researcher)
Tel: +61 xxxxxxxxxx Email: xxxxxxxxxxxxx
Ms Amanda Manypeney (PhD student) Email: xxxxxxxxxxxxx

Introduction
You are invited to participate in the above project, which is being conducted by Amanda Coles (Supervisor) and Amanda Manypeney (PhD student) of the Department of Culture and Communication at The University of Melbourne. Your name and contact details have been selected as you have responded to recruitment initiatives/been identified by members of the astronomy community as possessing relevant experiences in relation to the development of astronomy/alternative career pathways.

Purpose of the research
The aim of this study is to investigate alternative career pathways of Australian University PhD educated women astronomers who work outside the academic research sector. This research has been approved by the Human Research Ethics Committee.

What will I be asked to do?
Should you agree to participate, you will be asked to contribute in the following way. Participants will be required to complete a face-to-face audio-recorded interview at a time and place of their convenience. It is possible that a brief, follow up interview will be conducted by phone or Skype to clarify any further questions.
How long is my participation expected to take?
We estimate that the time required for the interview is 60 minutes with a brief follow up interview if needed. The total time required of you would not exceed 90 minutes.

How will my confidentiality be protected?
We intend to protect your anonymity and the confidentiality of your responses to the fullest possible extent, subject to any legal requirements. Your name and contact details will be kept in a password-protected computer file, separate from any data that you supply. The data will be kept securely in the Department of Culture and Communication for five years from the date of publication, and may be destroyed after this time.

Do I have to take part?
Participation is completely voluntary. Should you wish to withdraw at any stage, or to withdraw any unprocessed data you have supplied, you are free to do so without prejudice.

What happens after the project is finished?
The results of this project will be presented in a PhD dissertation and related journal articles and presentations. These results will be available online in academic journals. It is possible that the results will be published and presented at academic conferences. Research material will de-identified and stored securely at the University of Melbourne and destroyed five years after publication of the thesis. If requested, copies of any reports or articles related to this study will be sent to you electronically.

Where can I get further information?
If you would like more information about the project, please contact the researchers; Dr Amanda Coles xxxxxxxxxx, or Amanda Manypeney xxxxxxxxxx.

What if I have any concerns about the project?
Should you have any concerns or complaints about the conduct of the project, please contact Ms Kate Murphy, Manager, Human Research Ethics - Office for Research Ethics and Integrity, the University of Melbourne VIC 3010. Tel: +61 3 xxxxxxxx or xxxxxxxx.

How do I agree to participate?
If you would like to participate in this project, please indicate that you have read and understood this information by completing the accompanying consent form and returning it in the envelope provided.
References


Astronomy Australia Limited. (2014). Information on career paths of Australian astronomy PhD graduates (Tech. Rep.).


Bennett, C. (2011). Beyond the Leaky Pipeline: Consolidating Understanding and Incorporating New Research About Women’s Science Careers in the UK. *Brussels
United States of America, 108(8), 3157–62. doi: 10.1073/pnas.1014871108


doi: 10.1038/528022a


McCormick, M., Barthelemy, R. S., & Henderson, C. (2014). Women’s Persistence into


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Author/s:
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Title:
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