

Diversity and inclusion in Australian astronomy

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Australian astronomy is undergoing a great change in culture, diversity and inclusion through major nationwide and university-scale initiatives. These initiatives include prestigious women-only faculty hires, broad diversity targets, concrete activities to overcome implicit bias, and innovative initiatives to change the academic culture and environment. Many of these activities were precipitated by the Pleiades Awards programme run by the Astronomical Society of Australia and by initiatives developed within the Australia-wide Centres of Excellence in astrophysics. I provide an overview of the nationwide programmes that are making an important impact on diversity, culture and climate, and describe the most promising and innovative initiatives in Australian universities and institutions. The striking changes seen in Australian astronomy can be triggered in other countries by similar awards programmes initiated by national astronomical societies or Academies of Science.

The Australian astronomical community has over 300 astronomers at PhD level or above, and over 200 PhD, Masters and Honours students across 14 universities and three organizations (CSIRO Astronomy and Space Science (CASS), the Australian SKA Office and the Murchison Widefield Array Organisation). This community hosts two Australian Research Council Centres of Excellence, each worth AU\$40 million: the All-Sky Astrophysics in 3 Dimensions (ASTRO 3D) and Gravitational Wave Discovery (OzGrav). These virtual centres each contain around 200 people within multiple universities and organizations in Australia, with about 10% members from international partners.

The 2016–2025 Australian Astronomy Decadal Plan showed that within Australian universities and organizations, the fraction of women astronomers in Australia was 33–37% at the PhD level between 2000 and 2013, but only 20% at the senior levels across the same timeframe. If women were retained in the field at the same rate as men, the fraction of women at senior levels in 2013 should have been at least 33%. The Astronomical Society of Australia (ASA) membership database from June 2018 lists 83 female members out of 302 (27%) PhD astronomers (fellows and full members, excluding international and retired members) and 83 female students out of 225 (37%) PhD, Masters and Honours students. The Decadal Plan recommended that institutions aim for at least 33% participation by women across all levels of employment by 2025, in alignment with the fraction of women in the PhD cohort. Longer-term (5-year) postdoctoral positions with part-time options, support to return to astronomy research after career breaks, and increases in the fraction of permanent positions relative to fixed-term contracts were proposed in the Decadal Plan to help to address the gender gap.

The Australian Higher Education Staff Database shows that the fraction of women decreases at the highest levels in universities across all of the natural and physical sciences in Australia and has remained this way for over a decade (Fig. 1). Widespread implicit bias in hiring¹, writing referee reports of papers², giving paper citations³, allocation of grants⁴ and (in astronomy) allocation of telescope time^{5,6} probably plays a major role in this imbalance by affecting recruitment rates and promotion rates and facilitating departures of women from the field. Research tracking the progress of PhD students in physics indicates that women leave the field more often than men owing to a lack of female role models who are seen to have a good balance between their family life and academic

career, a dislike of the culture or atmosphere, and doubts that they will attain a senior position⁷. To help to overcome these longstanding problems, many more women need to be supported, promoted and hired to senior levels in academia, implicit bias needs to be systematically addressed in all decision-making processes and the academic culture needs to be changed.

The Pleiades Awards

The Pleiades Awards were introduced by the Inclusion, Diversity and Equity (IDEA) Chapter of the ASA (formerly known as the Women in Astronomy Chapter) in 2014 to reward organizations that take multiple concrete actions to advance the careers of women, close the gender gap and improve the working environment for all astronomers. Based on the UK ATHENA Swan programme, the Pleiades committee awards bronze, silver or gold medals to organizations on the basis of a broad matrix of activities that promote awareness of implicit bias, encourage full participation of women at all levels and support work–life balance. To receive a bronze award, organizations are required, over a 2-year period, to examine their performance in achieving gender equity, establish a team of staff to identify, implement and monitor positive changes, demonstrate a commitment to implement a range of activities to improve gender equity, and measure the impact of these activities on gender equity and culture. Silver awards are given to institutions that have monitored their success for at least 2 years, demonstrate best practices in promoting gender equity, conduct an anonymous ‘climate survey’ with results presented to all staff and students, and show effective commitment from the head of the organization to achieve gender equity goals for the institution. Silver awardees are also required to identify further areas for improvement and propose new activities to address these areas. Gold awardees must satisfy the criteria of bronze and silver awardees over a 2- or 4-year period, address problem areas identified by their climate surveys, demonstrate widespread engagement and commitment within the organization, hold universal diversity training and show vocal promotion of diversity by senior managers. The IDEA chapter also holds annual Diversity in Astronomy workshops on topics such as women in STEM, indigenous culture and LGBTQIA+ Ally training.

Between 2014 and 2018, around 60 applications have been received for Pleiades Awards (Fig. 2). So far, 24 bronze awards, 11

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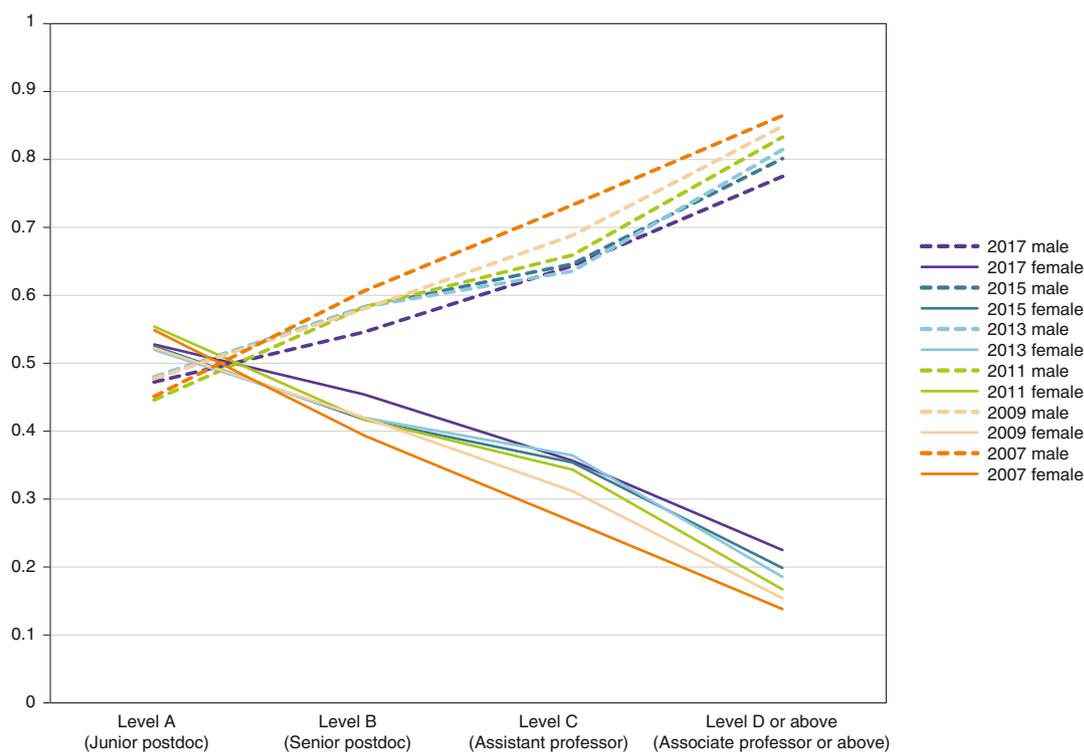


Fig. 1 | Gender fractions at university levels in science in Australia. The gender fractions encompass all full-time staff in the natural and physical sciences at all higher education institutions in Australia from level A to level E (associate to full professor), from 2007 to 2017.

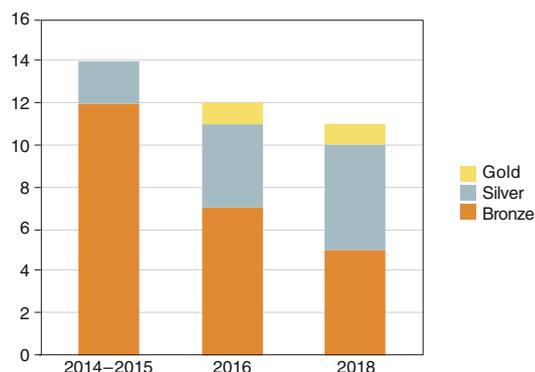


Fig. 2 | Pleiades Awards by year. The number of astronomy (or physics and astronomy) departments and organizations that have received bronze, silver or gold Pleiades Awards, from 2014 to 2018. The ASA accepted applications in both 2014 and 2015, and began accepting applications every second year from 2016.

silver and two gold awards have been issued, with 92% of applicants receiving a Pleiades Award between 2014 and 2018. Institutions can progress from bronze to silver or from silver to gold over a 2-year period, and institutions must reapply for the awards every 2 years if they wish to continue their Pleiades status. The broad uptake of Pleiades Awards is remarkable because institutions are not required to apply for the award and there is no financial incentive in receiving one; Pleiades Awards are given as a certificate and are listed on the IDEA website. The Pleiades Awards programme works through a combination of mentoring of organizations, buy-in from the major astronomical institutions, a broad sense of fairness (that is, that improving diversity is the right and fair thing to do) and

possibly a form of institutional peer pressure (“If those institutions are going for an award, we should too”). The ASA IDEA Chapter strategic priorities for 2019–2022 includes mentoring all Australian astronomy institutions to achieve at least bronze Pleiades status, and lobbying for Pleiades Awards to be used as a factor in deciding which organizations will host future Australia-wide astronomy meetings.

The programmes and initiatives developed at institutions to achieve Pleiades Awards are improving the gender balance and the climate and atmosphere for women and other minorities at every participating department and organization across Australia. These programmes and initiatives have produced flow-on effects across universities. Departments with Pleiades Awards were often first within their college or their university to form a diversity and equity committee and were usually the first to adopt a broad range of initiatives to support diversity and inclusion. For example, a year after the Macquarie Astronomy Research Centre received a bronze Pleiades Award, its Equity and Diversity Committee was expanded to include the entire Department of Physics and Astronomy, and all initiatives expanded to include the whole department. Similar flow-on effects have been seen at other universities, including the Australian National University (ANU). At the University of Sydney, astronomers within the School of Physics spearheaded their school diversity committee, benefiting areas outside astronomy. The former ARC Centre of Excellence in All-Sky Astrophysics (CAASTRO) initiated many policies including family-friendly Centre meeting hours, childcare at Centre-sponsored conferences, children allowed to be visible at workplaces, part-time options for all positions, and monitoring of gender balance within the Centre. These and other initiatives helped to produce a cultural change across the Centre and helped it to achieve a gold Pleiades Award. In 2017, CAASTRO produced a Gender Action Toolkit that other Centres of Excellence, both within and outside astronomy, are now using to drive change across their university nodes.

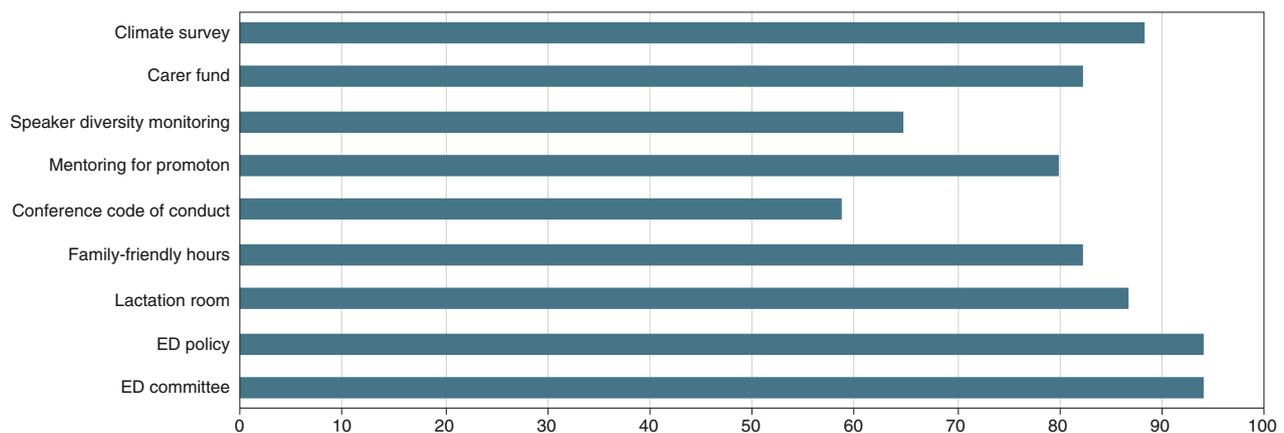


Fig. 3 | Percentage of Australian astronomer departments with diversity initiatives. The fraction of Australian astronomer departments and organizations that have (1) a regular climate/culture survey, (2) carer's funding for travel to external conferences, (3) monitoring of the gender balance of speakers for colloquia and seminars, (4) mentoring of women for promotion to senior levels, (5) a conference code of conduct, (6) family-friendly meeting hours for seminars, colloquia and staff meetings (10 a.m. to 2 p.m. or 9 a.m. to 3 p.m.), (7) a lactation room, (8) an equity and diversity (ED) policy, and (9) an ED committee. Institutions included in this survey are: ASTRO 3D, OzGrav, ANU, CASS, Curtin University, Macquarie University, Monash University, Swinburne University of Technology, University of Adelaide, University of Melbourne, University of New South Wales, University of Queensland, University of Southern Queensland, University of Sydney, University of Tasmania, University of Western Australia and Western Sydney University.

Diversity initiatives across Australia

To gauge how widespread the diversity and culture initiatives now are across Australian astronomy, I surveyed 17 institutions (14 universities, the OzGrav and ASTRO 3D Centres of Excellence, and CASS) based on the current institutional membership of Astronomy Australia Limited, Australia's peak body for facilitating access to astronomical research infrastructure. Within the universities, astronomers can be located in astronomy departments, physics and astronomy departments, or physics departments. These departments are referred to collectively as "astronomer departments". Astronomer departments contain astronomers but may also contain physicists, engineers, technical staff, professional staff and other scientists. The MWA organization and the Australian SKA Office were excluded from the survey to avoid duplication; MWA and SKA Office staff reside at Australian astronomer departments and are covered by the internal policies and initiatives of those departments. Responses were received from all 17 institutions, giving a completeness of 100% of Australian astronomy. A total of 14 out of 17 (82%) astronomer departments and organizations have applied for a Pleiades Award, and a further three institutions are preparing Pleiades applications for the next round. Twelve out of 17 (71%) institutions have received a Pleiades Award. Figure 3 shows the fraction of the 17 astronomer institutions that have adopted family-friendly initiatives and activities aimed at improving gender balance and diversity. Almost all (16 out of 17, 94%) astronomer departments or organizations have a diversity and inclusion committee, a diversity, equity and inclusion policy and a staff code of conduct. Some universities, such as the University of New South Wales, have hired dedicated equity, diversity and inclusion officers who operate at the Dean level, overseeing the individual equity and diversity committees in each department and enforcing the diversity goals of the university.

To improve the academic climate in departments, it is critical to identify issues and problem areas that might not be brought to the attention of the leadership of an organization. The majority (88%) of astronomer departments and organizations in Australia now run anonymous climate surveys either annually or every second year. These independently run surveys have proven highly effective in helping leadership to improve the climate in departments and organizations. For example, in response to the results of their 2018

culture survey, all ongoing staff in the Macquarie University physics and astronomy department attended 'Workplace Behaviour—Drawing the Line' workshops in 2019. These facilitated workshops examined the issues of unlawful and inappropriate behaviours, values of respect and teamwork, and how to draw the line between what is acceptable and unacceptable in various situations. To improve the climate outside departments, 59% of astronomer departments now have a departmental or college-wide conference code of conduct that specifies the conduct and behaviour expected of department members when they are at external conferences. The ASA recently updated its code of conduct (which has included expected conduct towards others and unacceptable behaviour at conferences for over a decade) to include specific actions in the case of breaches of the code. ASTRO 3D has a code of conduct for meetings, workshops and conferences, as well as a code of conduct that covers online behaviour within its workspace on the collaboration hub Slack. Together, these actions help to improve the working environment for everyone.

To support the need to balance work and families, 87% of Australian astronomer departments and organizations now offer a lactation room, and 82% have moved the timing of all seminars, colloquia and staff meetings to between 9 a.m. and 3 p.m., or 10 a.m. and 2 p.m., allowing working parents to attend these important events as well as drop off and pick their children up from school. Most (82%) astronomer departments and organizations now offer a carer travel programme whereby working parents of small children can apply for funding to allow children and carers to travel with the parent to conferences and on other work travel.

It is widely known that women are less likely to be nominated by others and are less likely to self-nominate for colloquia in science⁸. To provide more female role models and to avoid implicit bias in nominating speakers for colloquia, 65% of astronomy departments and organizations are monitoring the gender balance of colloquium and seminar speakers and are working to actively increase the fraction of women speakers to match the fraction of women in Australian astronomy. Monash University has found that Webinars provide a better gender balance than in-person talks for their particle physics talks, in part because travel funding is correlated with seniority at external departments. Women's participation and inclusion at Australian conferences are now also being monitored and, in some

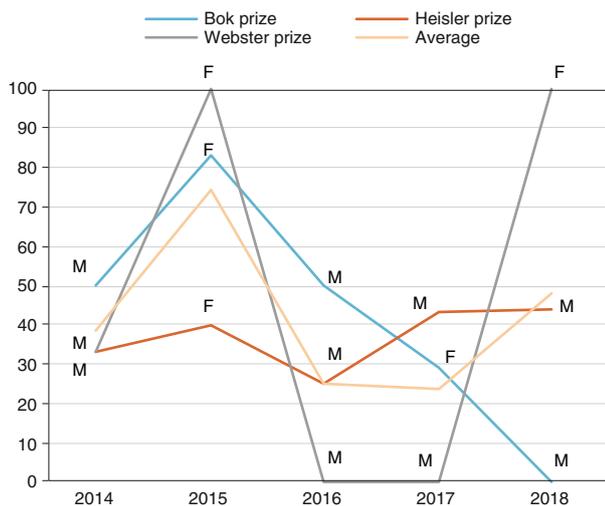


Fig. 4 | Percentage of female award and nominations for ASA awards. The percentage of male and female nominations for the ASA from 2014 to 2018 for the Bok prize (most outstanding Honours/Masters thesis), the Charlene Heisler prize (most outstanding PhD thesis) and the Louise Webster prize (outstanding early career research based on the impact of a single paper). The gender of the awardee in each year for each prize is shown.

cases, published. The gender demographics of delegates, presenters and awards at the 2018 Australian Space Research Conference were recently published with analysis showing that female representation at this conference has fallen between 2015 and 2018, except among Plenary speakers⁹. The ASTRO 3D Centre of Excellence has taken a proactive role in achieving gender balance at conferences. ASTRO 3D runs two national workshops and up to three international conferences per year, as well as sponsoring several external workshops and conferences. ASTRO 3D only funds conferences or workshops if the scientific organizing committee and speakers at all levels (review, invited, targeted and contributed) and participants are targeted to be 50% female.

Women receive awards at a rate that is lower (sometimes much lower) than the fraction of women in the field^{10,11}. It is difficult to estimate how much of this effect is due to a lack of nominations and how much to implicit bias in reference letters or committee deliberations, because the gender fraction of nominations is often not available to the public. To increase the number of female nominations for its prizes, the ASA has been publishing this information: the percentages of female nominations for ASA prizes from 2014 to 2018 are shown in Fig. 4, along with the gender of the person receiving the award. The average percentage of female nominations over 2014–2018 is 42% for the best Honours/Masters thesis (Bok prize), 37% for the best PhD thesis (Charlene Heisler prize) and 47% for the early career prize (Louise Webster prize), consistent with, or larger than, the fraction of female astronomers in the field at the age eligibility ranges (Honours, PhD, postdoc) of these awards. Female awardees over 2014–2018 average 40%, 20% and 40% for the Bok, Heisler and Webster prizes, respectively. Females are nominated and awarded the Bok and Webster prizes at a rate that is consistent with the fraction of females in the field, but females are receiving the Heisler prize at a rate that is lower than the fraction of female nominations and lower than the fraction of females in the field. Over the entire lifetime of the Charlene Heisler prize (2006–2018), only three out of 13 (23%) of the awardees were women. The ASA Council plans to address this imbalance in future years through a new merit-based system.

In Australian universities, females are less likely to be nominated or to self-nominate for promotion than males, causing them to

remain at lower university levels longer than males^{12,13}. This effect contributes to the gender gap seen at the higher levels in Australian universities (Fig. 1) and causes a salary gap because indexed salary rises are often based on a percentage of the current salary¹⁴. However, when women apply for promotion at Australian universities, they are commonly promoted with equal or greater success rates than men¹². To promote women's advancement to the senior levels, the majority (80%) of Australian astronomer institutions have recently introduced dedicated mentoring for women to support faster promotion of women to the senior levels.

Women are more likely to leave astronomy than men owing to the need to find a job for a spouse or partner in the same geographical area¹⁵. Over the past few years, some Australian universities have initiated dual-career hire programmes to help couples in academia to find positions at the same university. For example, the ANU has a dual-career hire programme that covers all fields at the university. This includes a central pool of funding that may be applied for which may cover a portion of the salary of the partner hire for 2 years. Shared funding arrangements are also possible. The central pool and shared funding provide incentive for the partner hire's department to fund the remainder of the partner salary, at least for 2 years. This programme and similar programmes across the country have allowed many couples, from postdocs to senior staff, to continue their careers in the same location.

Mitigating implicit bias in recruitment

It is now clear that previous hiring methods have not been effective in increasing the fraction of women at higher levels in universities, both within astronomy and across the sciences (Fig. 1). It is difficult to remove implicit bias at every decision-making stage, even on gender-balanced and trained recruitment committees, because on average, both males and females have an implicit bias towards male applications (see ref. 16 for a review). Modelling of the gender balance of organizations shows that even a 5% bias in decision-making in favour of men will cause the balance to change from 1:1 gender ratio at all levels to 25–30% women at the highest levels over a 10-year period^{16,17}, similar to that seen in science in Australia.

Meta-analysis of the effectiveness of diversity training programmes shows that single diversity training sessions provide useful information that is retained, but do not necessarily produce long-term change in behaviour¹⁸. Ongoing, consistent reminders about implicit bias are needed. Most astronomical departments and organizations in Australia require job selection committees to read information reminding the members about implicit bias before looking at applications or before interviews. The Macquarie University Physics and Astronomy department is trialling anonymized recruitment for postdoctoral positions up to the shortlisting phase. In this process, identifying information is completely removed from application materials for the creation of an initial ranking. Results from such trials will help to inform future recruitment processes.

Gender targets are one way to mitigate gender-based implicit bias. The OzGrav Centre of Excellence has a target of 50:50 gender balance for all new recruits by 2021. In OzGrav, gender balance is monitored amongst the selection panel members and applicants for positions, as well as on shortlists. The University of Sydney has adopted university-wide targets of 45% women at level D (associate professor) and 40% women at level E (full professor) by 2025, as well as at least 40% female appointments to continuing (permanent) academic positions. Human resources staff track departmental achievement towards these goals with reporting to diversity and equity committees and an annual report on gender statistics to the university executive. The University of Sydney School of Physics has exceeded these goals, with seven female appointments out of nine permanent positions over the past 3 years. The Swinburne Centre for Astrophysics and Supercomputing has a policy that hiring new staff should not decrease the fraction of female staff. However,

university-wide strategic appointments (including providing continuing positions to Australian Research Council Future Fellows) can work against such policies. To combat this issue, the Swinburne Centre for Astrophysics and Supercomputing is currently supporting only female external applicants for future fellowships.

The ASTRO 3D Centre of Excellence has an extremely ambitious target of 50:50 gender balance at all levels of the Centre by the end of 2021. Gender balance enables males and females to serve on committees, act as role models and take part in education/outreach programmes in equal numbers, providing equitable work balance for its members, as well as modelling the working environment that is needed to encourage equal numbers of girls and boys into STEM. ASTRO 3D has seen its gender balance rise from 30% to 38% women in its first 2 years and is currently on track to reach its 50:50 goal. This rise has not been through targeted hires, but through strong awareness of implicit bias and the need to achieve gender balance, diversity on hiring committees and shortlists, and open membership (astronomers and students working on science topics related to the Centre goals may apply to become members; a gender balance target encourages more females to become members or to apply for open advertised positions within the Centre). ASTRO 3D hiring committees and shortlists are required to be at least 50% female. The gender balance is tracked at all Centre university nodes, in all surveys/projects and at all levels in the Centre, with results presented annually to the Centre Executive Management Committee, the Advisory Board, the Centre Diversity, Equity and Inclusion Committee, and the Australian Research Council.

To improve the fraction of women at senior levels in astronomy, many astronomer departments in Australia are avoiding implicit bias in their committees by offering female-only continuing (tenured) positions. The Australian Commonwealth Equal Opportunity for Women in the Workplace Act 1999 states that all employers with 100 or more employees, and all higher education institutions, must implement an 'affirmative action programme' to promote equal opportunity for women. Individual states are bound by both this act and state-level Equal Opportunity acts. In several states, including Victoria, Western Australia and New South Wales, the Equal Opportunity acts specifically allow universities to advertise female-only positions to correct their historic gender gap. In some states, such as Tasmania, special governmental exemption is required to advertise female-only positions.

Female-only positions have been controversial in the past. One of the concerns often expressed is that the female hired may be labelled as a 'token' woman. Several Australian mathematics, physics and astronomy departments have shown that this concern is easily removed by making such positions highly prestigious and/or by making multiple offers simultaneously. Both of these mitigations encourage outstanding women in the field to apply for the positions, and these women might not have applied had it been an average open hire. This was the conclusion reached by the University of Melbourne Mathematics Department. To correct historical systematic hires of men, the Maths Department advertised two female-only positions. They received significantly more female applicants than they had received in a previous open position. When asked why they had not applied for previously advertised positions, the applicants said that by advertising for female faculty members, the University of Melbourne Maths Department had made it clear that it would be a female-friendly department, and they would like to work in such a department. The Maths Department received so many excellent applications that they made multiple offers. In a later, open position, they still received more applications from women than they had received in the past. The Maths Department has now almost doubled the number of women faculty from nine in 2014 to 17 by the end of 2018. This change has had two major effects: (1) the external perception of the department has changed

to a female-friendly department, and (2) the department has undergone an internal cultural change.

Astronomy departments across Australia are following the lead set by the University of Melbourne. As part of its negotiations with universities, ASTRO 3D secured several continuing positions at its node universities to help to provide career paths in Australia for its postdoctoral researchers. The University of Melbourne Physics and Astronomy Department and the University of Western Australia combined an ASTRO 3D 4-year fellowship with continuing (tenured) positions and created prestigious female-only fellowship+continuing positions. The University of Western Australia received so many outstanding applications that they made two offers, instead of one. The University of Melbourne Physics and Astronomy Department was keen to find the right fit for its small department, conducting two searches to fill this role. As part of long-term workforce planning, the Melbourne Physics and Astronomy Department has now instituted a policy that if future open searches lead to a male appointment, the following search will be female only. This policy allows the department to predict and control the minimal fraction of female staff on faculty into the future, retaining its female-friendly climate and mitigating implicit bias. The University of Sydney School of Physics has a similar policy.

The ANU Research School of Astronomy and Astrophysics has tried two approaches to removing implicit bias on hiring panels. One approach requires two positions to be advertised, of which at least one position will be offered to a woman. The selection panels create two shortlists, a male shortlist and a female shortlist, and select two candidates from each of these two shortlists. This method prevents gender-based implicit bias, although increasing the fraction of women with this approach is slower than through female-only hires. Recently, the Research School of Astronomy and Astrophysics and the Centre for Gravitational Waves at ANU advertised for a female astrophysicist working in gravitational wave research. Like the Universities of Melbourne and Western Australia, they received multiple outstanding applications and hired two females, rather than one. Similarly, the ANU maths department recently advertised a female-only position and received so many outstanding applications that they hired not one but three women. Other Australian departments, including the University of Adelaide Faculty of Engineering, Computing and Mathematical Sciences and the University of Melbourne Physics department, are now advertising female-only positions. All of these departments are significantly improving the gender balance in their department and bypassing the implicit bias that plagues open searches.

Bringing in female leaders on fixed-term or visiting fellowships is another way of increasing the fraction of women who can serve as role models in a department. Multiple role models enhance the sense among younger researchers that "if they can do that, so can I". The University of Sydney School of Physics recently offered a female-only Messel Fellowship. The International Centre for Radio Astronomy Research, which encompasses astronomers at both Curtin University and the University of Western Australia, has an annual Visiting Fellowship for senior women in astronomy to visit both Curtin and the University of Western Australia and provide mentoring opportunities for staff and students (particularly women), as well as to promote research and scientific interactions. In 2016, CASS began an engineering visitors' programme that has a focus on inviting and supporting female engineers. This is part of a broader CASS plan to create multiple pathways to recruit and maintain women engineers.

Mentoring students through their undergraduate and graduate careers is important for stemming the flow of women out of academia. The Monash University Women in Physics and Astronomy (WiPA) group provides regular informal morning tea and luncheons for female third-year, Honours, Masters and PhD students and staff. Attendees are encouraged to discuss matters of concern and seek

advice from any of the WiPA members about their career, work and study. In 2018, the group established a programme in which undergraduate female students are paired with a female PhD student or a postdoc for formal mentoring.

Some institutions in Australia are actively working to avoid contributing to stereotype threat, a situation that occurs when people are at risk for living up to a negative stereotype about their group, such as the false negative stereotype that girls are not good at mathematics or science. Both ASTRO 3D and OzGrav ensure that educational and outreach materials are gender-neutral, with imagery and videos reflecting a diverse and inclusive environment. Both males and females take part in education and outreach activities to provide a variety of role models. However, unless 50:50 gender balance is achieved, this requirement places additional workload on female staff members. To avoid overcommitting female staff members, the Murchison Widefield Array Organisation has a policy in which the speaker load is spread equitably amongst the staff, regardless of gender, with staff only asked to speak on topics that relate to their expertise.

Initiatives for broader diversity

Recently, most institutions in Australia have expanded their initiatives to include a broader range of diversity, rather than focusing solely on gender. Some universities have introduced indigenous astronomy into their education and outreach programmes. CSIRO have developed a Reconciliation Action Plan. This plan covers all of CSIRO (not limited to astronomy) and aims to improve awareness and understanding of Aboriginal and Torres Strait Islander people. The Macquarie University Physics and Astronomy department is working with Walanga Muru, the Macquarie Indigenous Centre, to incorporate Aboriginal astronomy into Astronomy Open Night events which are typically attended by about 2,000 members of the public. A similar programme is operated by the University of Western Sydney.

A 2019 [report](#) on the workplace for LGBTQIA+ physical scientists prepared by the UK Institute of Physics, Royal Astronomical Society and Royal Society of Chemistry concluded that nearly one-third of physical scientists from sexual and gender minorities in the United Kingdom have considered leaving their jobs because of their workplace climate, and that many have experienced or observed exclusionary behaviour in the workplace. In Australia, some universities, such as Curtin University, have converted single-occupancy (ambulant) toilets into unisex toilets. The Macquarie University Astronomy department has been proactive in the development of a campus-wide policy for creating gender-neutral toilets. Several institutions are running LGBTQIA+ events, such as morning teas or lunches, as well as providing LGBTQIA+ Ally training to their staff and students. Astronomers are active in the Australian QueersInScience organization. QueersInScience builds a supportive environment and cohort within universities for LGBTQIA+ researchers in STEM, support staff and students. In 2019, it ran the first Australian [LGBT STEM Day Symposium](#), which aimed to showcase and celebrate the achievements of internationally recognized Australian LGBTQIA+ researchers, provide role models for emerging professionals in STEM, and promote awareness and understanding of the issues faced by LGBTQIA+ people in science and ways to solve those issues. Held in Melbourne, and sponsored by several universities and science institutes, including the ASA, the Australian Academy of Science, CSIRO and ASTRO 3D, this event attracted over 200 attendees. The symposium was so successful that 98% of attendees stated that they would attend again, and 99% would promote the event to others. QueersInScience is now expanding to other universities across Australia.

People from ethnic and religious minorities experience racial prejudice and harassment in astronomy¹⁹. Research shows that encouraging people to express and share diverse cultural interests

in mainstream settings reduces prejudice against minority ethnic groups²⁰. The Curtin University astronomy diversity committee recently used their discretionary budget to fund a Cultural Intelligence workshop that covered how culture affects our workplace and society, identifying new ways to think about culture, and research-based solutions on how to bridge cultural gaps. The Curtin astronomy group also hosts an international/cultural lunch to celebrate the strong diversity within the department. The University of Sydney School of Physics has begun cultural morning teas, the most recent of which focused on Islam with a short talk by a Muslim staff member. The University of Melbourne Physics and Astronomy Department now has a dedicated prayer/meditation space that can be reserved by any staff or student member, and ASTRO 3D will provide a prayer/meditation space at its Annual Retreat for the first time in 2019. Curtin University has a convenience room which may be reserved for prayer, meditation, lactation or feeding/caring for infants.

Feeling empathy for others is one of the few proven ways to help people to modify their implicit biases^{21–24}. The University of Tasmania has engaged with the Hobart Human Library, which delivers diversity education workshops to schools and workplaces. The Human Library uses storytelling to challenge stereotypes and build empathy through personal stories about discrimination and bullying based on culture, religion, refugee background, gender, sexual orientation, physical or mental ability. Another proven method to help people overcome their implicit biases is through blurring inter-group boundaries²⁵. One way to do this is to help people get to know each other as whole people with lives, interests and activities outside the workplace. This method allows people to identify others with common interests across traditional in-group/out-group boundaries. The Australian Academy of Science developed a programme in 2016 called “Win of the Week” in which staff’s personal achievements and positive stories (both within and outside work) are collected and sent to the entire Academy Secretariat. Inspired by this programme, ASTRO 3D runs a “We Are People” section in their fortnightly newsletter, in which ASTRO 3D members describe their hobbies, sports, interests or recent travel. In addition to helping to reduce implicit bias, these activities model healthy work–life balance, which is critical for retaining women in the field⁷.

Along with building empathy, care for people’s health and the surrounding community is increasing. Several institutions and both Centres of Excellence are encouraging or requiring members to undertake mental health first-aid training to identify and effectively support colleagues, postdocs and students experiencing mental health problems. Some departments, including the ANU Research School of Astronomy and Astrophysics, have lunchtime yoga classes. ASTRO 3D will run its first Mindful Leadership course in early 2020, where mindfulness is taught as an aspect of effective leadership. CSIRO CASS has begun the process of being endorsed by the Community, Respect and Equality Agreement, which focuses on family violence and abuse in the town of Geraldton, one of the campuses at which CSIRO is based. CSIRO is also currently working on a domestic and family violence and abuse policy, and all equity contact officers and diversity committee members will be invited to be trained as first responders. These initiatives recognize that a healthy and supportive academic environment must include promoting the health and well-being of its members.

Conclusions and outlook

Australian astronomy has undergone a massive change in diversity and culture over the past few years. These changes have had positive flow-on effects into other departments and institutions. Areas for improvement in Australia include better representation of women awardees for science prizes, and in the mentoring and provision of role models for young women. Departments should require that the gender balance of speakers at least match the fraction of women

in Australian astronomy, as given in the Decadal Plan, and new programmes are needed to increase the fraction of female undergraduate and graduate students in astronomy programmes and in science in general. Cultural intelligence education would benefit more institutions in Australia, as well as programmes that promote acceptance of people from a broad range of religious backgrounds. All astronomer institutions should provide education on the issues faced by LGBTQIA+ members of the community, as well as further initiatives to build a welcoming culture for such members, such as support for QueersInScience programmes across Australia, encouraging and supporting applications from same-sex couples for dual-career hire funding and introducing non-gendered toilets at more astronomer departments and institutions. Departments should develop Reconciliation Action Plans or similar programmes to promote indigenous awareness and provide mentoring and pathways for indigenous students in STEM.

Astronomy is becoming more accessible to people with disabilities. Sonification software now allows blind and visually impaired astronomers to analyse astronomical data^{26,27}, and sophisticated voice recognition software enables astronomers who are unable to use keyboards to analyse data and write publications. Virtual access, recording and subtitling should be provided for conferences and workshops to promote the inclusion of people with disabilities, illness or other travel constraints. Universities also need to develop new methods to support the advancement of people with disabilities or major illness through the promotion process, which can be perceived as an insurmountable hurdle.

As the world prepares for the era of mega-telescopes, improving diversity in astronomy will be critical for maximizing new ideas and ensuring the future success of astronomy departments worldwide. The 2018 McKinsey *Delivering through Diversity* report showed a statistically significant correlation between greater levels of diversity in company leadership and likelihood of outperforming the relevant industry peer group on a key financial performance measure, profitability²⁸. It is reasonable to infer that greater diversity in astronomy organizations will also produce a greater likelihood of outperforming competition in astronomy key performance measures in discoveries and advances²⁸. The ASA Pleiades Awards programme is a proven model for improving diversity and culture across a country, without financial incentives. Astronomical societies in other countries could trigger similar nationwide change through the development of similar award programmes.

More broadly, Academies of Science in other countries could trigger change across science by introducing programmes similar to Athena SWAN. In late 2015, the Australian Academy of Science and the Australian Academy of Engineering and Technology jointly introduced the Science in Australia Gender Equity (SAGE) programme for universities, making Australia the first nation beyond the United Kingdom and Ireland to pilot the Athena SWAN programme. Forty institutions around Australia are currently engaged in the programme, in which they must apply for an Athena SWAN bronze institutional award over a 4-year period, demonstrating a solid foundation for eliminating gender bias and developing an inclusive culture that values all staff. So far, SAGE bronze awards have been given to 15 institutions, with a further cohort expected to complete their bronze accreditation at the end of 2019. If individual departments are required to systematically address low levels of diversity, SAGE and similar programmes in other countries are likely to produce broad changes across science over a relatively short timeframe of 4–8 years.

Data availability

Figure 1 was created with publicly available data from the Higher Education Staff Database: <https://www.education.gov.au/staff-data>. Figures 2 and 4 were created with publicly available data from the ASA: <http://asa.astronomy.org.au/awards.html> and <https://mailman.sydney.edu.au/pipermail/asa/Week-of-Mon-20190114/005234.html>. Information on diversity initiatives at astronomer departments and organizations in Australia (including Fig. 3) was provided solely for the purpose of this publication by the heads of department, directors and diversity committee chairs from the ARC ASTRO 3D and OzGrav, ANU, CASS, Curtin University, Macquarie University, Monash University, Swinburne University of Technology, University of Adelaide, University of Melbourne, University of New South Wales, University of Queensland, University of Southern Queensland, University of Sydney, University of Tasmania, University of Western Australia and Western Sydney University. The survey data and derived statistics can be provided by the author upon reasonable request, if agreement from the individual institution heads of department, directors and diversity chairs is obtained.

[sydney.edu.au/pipermail/asa/Week-of-Mon-20190114/005234.html](https://mailman.sydney.edu.au/pipermail/asa/Week-of-Mon-20190114/005234.html). Information on diversity initiatives at astronomer departments and organizations in Australia (including Fig. 3) was provided solely for the purpose of this publication by the heads of department, directors and diversity committee chairs from the ARC ASTRO 3D and OzGrav, ANU, CASS, Curtin University, Macquarie University, Monash University, Swinburne University of Technology, University of Adelaide, University of Melbourne, University of New South Wales, University of Queensland, University of Southern Queensland, University of Sydney, University of Tasmania, University of Western Australia and Western Sydney University. The survey data and derived statistics can be provided by the author upon reasonable request, if agreement from the individual institution heads of department, directors and diversity chairs is obtained.

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References

- Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J. & Handelsman, J. Science faculty's subtle gender biases favor male students. *Proc. Natl Acad. Sci. USA* **109**, 16474–16479 (2012).
- Helmer, M., Schottdorf, M., Neef, A. & Battaglia, A. Gender bias in scholarly peer review. *eLife* **6**, e21718 (2017).
- Caplar, N., Tacchella, S. & Birrer, S. Quantitative evaluation of gender bias in astronomical publications from citation counts. *Nat. Astron.* **1**, 0141 (2017).
- Viner, N., Powell, P. & Green, R. Institutionalized biases in the award of research grants: a preliminary analysis revisiting the principle of accumulative advantage. *Res. Policy* **33**, 443–454 (2004).
- Reid, N. I. Gender-correlated systematics in HST proposal selection. *Publ. Astron. Soc. Pacif.* **126**, 923–934 (2014).
- Patat, F. Gender systematics in telescope time allocation at ESO. *Messenger* **165**, 2–9 (2016).
- Whitelegg, E., Hodgson, B. K., Scanlon, E. & Donovan, C. Young women's perceptions and experiences of becoming a research physicist. *Proc. 12th Int. Conf. Women Engineers and Scientists* Paper no. 167 (Open Research Online, 2002).
- Nitrouera, C. L. et al. Gender disparities in colloquium speakers at top universities. *Proc. Natl Acad. Sci. USA* **115**, 104–108 (2018).
- Jones, E. G., Horner, J., Cairns, A. & Short, W. Gender balance and inclusion within the Australian space community: an overview of delegates at the 2018 Australian Space Research Conference. *Proc. 18th Australian Space Research Conf.* <https://arxiv.org/abs/1907.12358> (2019).
- Lunemann, P., Jensen, M. H. & Jauffred, L. Gender bias in Nobel prizes. *Palgrave Commun.* **5**, 46 (2019).
- Yifang, M., Oliveira, D. F. M., Woodruff, T. K. & Uzzi, B. Women who win prizes get less money and prestige. *Nature* **565**, 287–288 (2019).
- Winchester, H., Shard, L., Browning, L. & Chesterman, C. Academic women's promotions in Australian universities. *Empl. Relat.* **28**, 505–522 (2006).
- Winchester, H. & Browning, L. Gender equality in academia: a critical reflection. *J. High. Educ. Policy Manag.* **37**, 269–281 (2015).
- Challice, G., Compton, S., Phillips, B. & Vickers, N. 2018 Graduate Outcomes Survey—Longitudinal (GOS-L). <https://www.qilt.edu.au/about-this-site/graduate-employment> (2018).
- Ivie, R., White, S. & Chu, R. Y. Women's and men's career choices in astronomy and astrophysics. *Phys. Rev. Phys. Educ. Res.* **12**, 020109 (2016).
- Aloisi, A. & Reid, N. (Un)conscious bias in the astronomical profession: universal recommendations to improve fairness, inclusiveness, and representation. State of the Profession White Paper, Astro 2020 Decadal Survey (2019); <https://arxiv.org/pdf/1907.05261.pdf>
- Martell, R. F., Lane, D. M. & Emrich, C. Male–female differences: a computer simulation. *Am. Psychol.* **51**, 157–158 (1996).
- Bezrukova, K., Spell, C. S., Perry, J. L. & Jehn, K. A. A meta-analytical integration of over 40 years of research on diversity training evaluation. *Psychol. Bull.* **142**, 1227–1274 (2016).
- Clancy, K. B. H., Lee, K. M. N., Rodgers, E. M. & Richey, C. Double jeopardy in astronomy and planetary science: women of color face greater risks of gendered and racial harassment. *JGR Planets* **122**, 1610–1623 (2017).
- Brannon, T. N. & Walton, G. M. Enacting cultural interests: how intergroup contact reduces prejudice by sparking interest in an out-group's culture. *Psychol. Sci.* **10**, 1947–1957 (2013).
- Shih, M., Wang, E., Trahan Bucher, A. & Stotzer, R. Perspective taking: reducing prejudice towards general outgroups and specific individuals. *Group Process. Intergr. Relat.* **12**, 565–577 (2009).

22. Shih, M. J., Stotzer, R. & Gutiérrez, A. S. Perspective-taking and empathy: generalizing the reduction of group bias towards Asian Americans to general outgroups. *Asian Am. J. Psychol.* **4**, 79–83 (2013).
23. Mekawi, Y., Bresin, K. & Hunter, C. D. White fear, dehumanization, and low empathy: lethal combinations for shooting biases. *Cultur. Divers. Ethn. Minor. Psychol.* **22**, 322–332 (2016).
24. Teding van Berkhout, E. & Malouff, J. M. The efficacy of empathy training: a meta-analysis of randomized controlled trials. *J. Couns. Psychol.* **63**, 32–41 (2016).
25. Hall, N. R., Crisp, R. J. & Suen, M.-W. Reducing implicit prejudice by blurring intergroup boundaries. *Basic Appl. Soc. Psychol.* **31**, 244–254 (2009).
26. Candey, R. M. et al. xSonify: sonification software. Astrophysics Source Code Library Record ascl:1207.008 (2012).
27. Garcia, B., Diaz-Merced, W., Casado, J. & Cancio, A. Evolving from xSonify: a new digital platform for sonorization. *EPJ Web Conf.* **200**, 01013 (2019).
28. *Delivering Through Diversity* (McKinsey & Company, 2018); go.nature.com/32XV1VR

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Competing interests

The author declares no competing interests.

Additional information

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