frontiers | Frontiers in Astronomy and Space Sciences

TYPE Mini Review
PUBLISHED 09 August 2024
DOI 10.3389/fspas.2024.1425500

OPEN ACCESS

EDITED BY
Joseph E. Borovsky,
Space Science Institute (SSI), United States

REVIEWED BY
Olga V. Khabarova,
Tel Aviv University, Israel
Fran Bagenal,
University of Colorado Boulder, United States
Larry Lyons,
University of California, Los Angeles, United States
Michelle Thomsen,
Planetary Science Institute, United States

*CORRESPONDENCE
Michael W. Liemohn,
liemohn@umich.edu

RECEIVED 29 April 2024
ACCEPTED 24 July 2024
PUBLISHED 09 August 2024

CITATION
Liemohn MW (2024) Practical actions towards equity in space physics.
Front. Astron. Space Sci. 11:1425500.
doi: 10.3389/fspas.2024.1425500

Practical actions towards equity in space physics

Michael W. Liemohn*

Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI, United States

To mitigate the issues of inequity, exclusion, and a lack of diversity in the solar and space physics research community, a Research Topic collection gathered articles of how scientists in this discipline are taking strides to make this community more welcoming. This review summarizes the key advice from those articles and offers practical actions for both immediate and long-term implementation. There are six major topical categories into which the collection's article can be grouped: early-year improvements (pre-college and undergraduate); inclusive project teams; diversity in awards; equity in hiring and promotion; leadership development; and the workplace environment. The scope of suggestions ranges from the very localized, such as the language choices we make in everyday conversations, to the institutional, such as the establishment of codes of conduct with a definition and enforcement of consequences for inappropriate behavior regarding inclusion and equity issues. It is hoped that the recommendations are applicable not only to the space physics community but also to others.

KEYWORDS

space physics, diversity, equity, inclusion, demographics, recommendations

1 Introduction

There are compelling reasons to support diversity, equity, inclusion, accessibility, and justice (DEIAJ) action. The first and foremost is that it is considerate, polite, and thoughtful workplace behavior and policy. In addition, it is worthwhile to combat the long-lasting and still-prevalent systemic biases of centuries of marginalization and disadvantage for certain identities (e.g., Elphick and Fredrickson, 1983; Haacker et al., 2022). There is also the well-established case that diverse teams lead to better outcomes. Specifically in scientific collaboration, the review by Nielsen et al. (2018) documents that gender diversity leads to better science, and AlShebli et al. (2018) detail how ethnic diversity yields better scientific results.

Whenever a demographics survey of solar and space physics is conducted, however, it has consistently found that the field is dominated by white men (e.g., Jones and Maute, 2022; Liemohn et al., 2023a; Bagenal, 2023; Yalim et al., 2023). As stated by Liemohn et al. (2023a), the Space Physics and Aeronomy section of the American Geophysical Union (AGU) has a student population with twice as many men as women (and gets worse with seniority), and the percentage of Latine and Black people within the American Astronomical Society is four to six times lower than the US population (see their Tables 1, 2). The student gender gap of space physics is similar to other areas of science, technology, engineering, and mathematics (STEM), as exemplified by the 2-to-1 men-women ratio found among STEM students at a multi-campus university in Mexico (Ortiz-Martínez et al., 2023).

While this indicates a "pipeline" issue in the education years, there is also an issue in the STEM workplace. Marin-Spiotta et al. (2020) note that a hostile work environment contributes to a lack of diversity in the geosciences. Ford et al. (2018), Ford et al. (2019) conducted an analysis of presentations at the annual meetings of AGU, finding large disparities in both gender and race among those invited and those given the prized oral session slots. In a large survey of Earth and space scientists, Popp et al. (2019) found that women face twice as much negative gender bias acts as their male colleagues (e.g., in the style of supervision, promotion and pay, support of mentors, selection for presentations, and awards). An analysis of acceptance rates in Earth and space science journals (Lerback et al., 2020) discovered that racially diverse coauthor teams have a lower overall acceptance rate. An assessment of scientist participation in competed space missions (Centrella et al., 2019) found that the teams are far less diverse than the research community. Studies have routinely shown that white, able-bodied, heterosexual men have intersectional privilege in STEM (e.g., Cech, 2022). In short, systemic biases against nondominant cultural groups–women; black, indigenous, and people of color (BIPOC); and lesbian, gay, bisexual, transgender, and queer (LGBTQ+), to name a few–exist in our community. The field of solar and space physics is not diverse and there are large structural issues that lead to slow progress on this issue. The net result is that two people with the same scholarly record might have gotten there through very different lived experiences.

To raise awareness of DEIAJ action in the space science research community, a special collection in Frontiers in Astronomy and Space Sciences was organized (Liemohn et al., 2023b). These articles were by space scientists writing about their DEIAJ work. This review summarizes a few key findings from the collection, focusing on the practical actions that individuals can take to make the research community and work environment more diverse, equitable, inclusive, accessible, and just. These recommendations are hopefully applicable not only to the space physics research community but also to many other scientific disciplines.

2 Practical actions for equity

The six major categories into which the collection's articles are grouped below cover the Research Topic collection but additional content has been added throughout this discussion for supplementary context.

2.1 Early-year improvements

Gallagher Dunn et al. (2023) addresses the issue of maintaining interest in STEM across a diverse student body within the pre-college years. One key point they make is to drop the strict disciplinarian mindset because a positive teacher-student relationship serves the students better (e.g., Rivas-Drake et al., 2014). This is evidenced by the concept of stereotype threat (Steele, 1997; Lewis et al., 2016), in which the judgment of other people negatively influences the performance of those in marginalized groups. Another conclusion to highlight from this article is the need for long-term mentorship, which has significant positive impacts (e.g., Hund et al., 2018). Scientists should serve as role models for the next-generation of scholars.

Because the STEM workplace is not fully inclusive of women (e.g., Settles and O'Connor, 2014), Lin et al. (2023) founded a program for undergraduate and graduate students focusing on marginalized genders in STEM fields, the HUG Initiative–Historically marginalized and Underrepresented Genders. The HUG initiative instituted a three-pronged approach to inclusion (e.g., Grogan, 2019): building the career skillset; building community and networks; and building awareness of policy issues. They created an impressive action list of sponsored workshops, seminars by alumni, fellowship activities, and a campus peer mentoring program.

Following the advice of Lopatto (2007) that undergraduate research experiences support science career decisions, Yalim et al. (2023) describe their summer programs in plasma physics and technology. About 50 undergraduate students, mostly from marginalized demographic groups, get to work on a science or engineering project and gain valuable life skills. This takes a concerted effort; it is a continual process to get buy-in from departmental colleagues to participate in these programs.

Bagenal (2023) synthesized several national reports on pre-college and undergraduate engagement in STEM. Higher education should be accessible for everyone (McNutt, 2022), and there are specific actions that can be taken to make this a reality. One finding is a pinch point of participation in the early college years. The recommendations to alleviate this are to improve teaching in those first-year courses, especially getting rid of the "weed-out" mentality. This is the mindset in which instructors intentionally make it difficult to get a high grade in these courses, advantaging those with prior knowledge of the subject. It is a practice that disproportionately discourages students from underrepresented groups from continuing in STEM (e.g., Bradforth et al., 2015). Also, undergrad research experiences are powerful motivators towards STEM disciplines (e.g., Russell et al., 2007).

2.2 Actions for inclusive project teams

In 2020, NASA's Heliophysics Division created a new research and analysis program: the DRIVE (Diversity, Realize, Integrate, Venture, Educate) Science Centers. One of the projects is SHIELD (Solar wind with Hydrogen Ion charge Exchange and Large-Scale Dynamics), focusing on the edge of the solar system where the charged gases from the Sun interact with the local interstellar medium. As described by Buxner et al. (2023), the team embraces the cross-disciplinary nature of their work. Knowing that scientists from historically excluded groups face hostile environments (e.g., Berhe et al., 2022), the SHIELD project created a seminar series on DEIAJ topics, covering mental health awareness, outreach activities, and LGBTQ+ issues. The SHIELD project is also collecting individual testimonials; inspiring personal interviews allowing everyone–from a very broad range of backgrounds–to see themselves within the research community.

Another group fostering an inclusive atmosphere is the mission team for MAVEN (Mars Atmospheric and Volatile EvolutioN), as detailed by Curry (2023). When she became leader of this

mission to Mars, she undertook DEIAJ as a priority, amplifying existing actions and instituting new ones. Adopting the findings of Fernando et al. (2022), they have included early career researchers in leadership positions. Following Davies et al. (2021), they work to change the discriminatory reward system in STEM fields (e.g., gender and racial bias in citation metrics (Nielsen and Andersen, 2021), course evaluations (Madera et al., 2019), and letters of recommendation (El-Alayli et al., 2018)). Another key practice is the rules of the road document for team meetings, which sets the tone for group cultural expectations. As Cortina and Areguin (2021) discuss, Codes of Conduct should go well beyond overt harassment (e.g., assault or coercion) and also address microaggressions (like insults and rudeness). The MAVEN team does many small actions, accumulating to substantial change.

2.3 Improving diversity in awards

Within the annual AGU Fellows process, the Space Physics and Aeronomy (SPA) section usually gets 15–20 nominations. In 2017, no women were nominated for Fellow in the SPA section. Seeing this problem, Dr. Liz MacDonald formed the Nomination Task Force (NTF) to proactively submit nominations of senior women colleagues (Keesee et al., 2022). Part of the success of the NTF is to get the nominations fully drafted a month early, and then review each other's packages. This pre-submission review better highlights the strength of each nomination.

Soon after the NTF formed, a similar group in the UK followed (Walach et al., 2022). One big recommendation for the community is that awards are highly competitive; even a strong candidate needs a strong nomination to be selected. Another suggestion is for transparency in the selection criteria and process. Another proposition: take the risk of nominating your peers.

On the concern from Walach et al. (2022) of wanting more transparency in the selection process, Halford et al. (2022) detail the actions of the SPA Fellows selection committee for the year they served. They note that there are multiple paths to selection for this honor, and the community should take advantage of these options. A decision they made was to deemphasize metrics and instead focus on the nominee's story of significance. This is because there is a first-author gender gap in the geosciences (Pico et al., 2020), and use of the h-index without context and adjustment leads to a negative impact on diversity (Chapman et al., 2019).

2.4 Fostering equity in hiring and promotion

A large part of the hiring and promotion process is the letter of recommendation. Studies have shown, though, that academics are biased. Earth and space scientists are biased in how letters of recommendation are written, with stronger letters for white men on average (Dutt et al., 2016). There is help out there, though, as described by Burrell et al. (2023). This article details best practices for how to write a strong letter. In addition, the group provides a service, reading draft letters and offering suggestions to remove bias and better highlight aspects of the person's record that best addresses the specific evaluation criteria.

DEIAJ best practices in hiring and promotion is the primary focus of Liemohn et al. (2023a). It has been demonstrated that workshops to equip faculty to conduct an equitable search are quite effective at achieving this objective (Sekaquaptewa et al., 2019). One key piece of advice is, early in the hiring process, to develop a holistic set of job-relevant criteria that expands the definition of excellence beyond the standard metrics (c.f., Stewart et al., 2016). Then, during the process, recenter these holistic criteria. Standard metrics are often biased towards white men, like citations in high impact journals (Chatterjee and Werner, 2021). Another significant recommendation is the use of equity checkpoints (O'Meara, 2021). These are intentional pauses in the search and applicant evaluation process to specifically refocus DEIAJ and consider if any adjustments to the workflow are needed to ensure equity.

2.5 Equipping ourselves for leadership

Leading a spaceflight mission proposal is an enormous task, posing a major learning curve for those unfamiliar with the process. Seeing that this disadvantages newcomers, the NASA PI Launchpad Workshop was created (Hamden et al., 2022). This event equips scientists with the skills and contacts to get through that barrier to being a principal investigator of a spaceflight mission. One of the significant tasks is to learn the mission-proposal-specific method of writing the science story, which is quite different from a standard research and analysis proposal (Wessen et al., 2022).

Another path to leadership is serving as an editor of a peer-reviewed journal. Liemohn (2022) documents the DEIAJ lessons learned over 6 years as Editor in Chief of the Journal of Geophysical Research Space Physics. A strong suggestion is to stop assuming that anonymous reviewers of manuscripts are men. This assumption is offensively sexist (e.g., Atherton et al., 2016). Instead, use "they" when gender is unknown. Also, do a thorough literature review instead of only including those papers from your close-friend group; expansive searches lead to a more diverse reference list. Finally, the prevalence of colorblindness, particularly in men, means that certain color maps cause confusion (Moreland, 2016). In particular, avoid the rainbow scale; there are much better ones that support accessibility and readability.

Research community leadership also includes conference organization. Jones and Maute (2022) are part of the steering committee for an annual upper atmospheric physics conference and, after a demographics survey quantified the prevalence of white men, the organizing committee created a DEI Task Force. Their recommendations build on the inclusive meetings guidelines of Pendergrass et al. (2019) and an updated version of this guide is now available (Jack-Scott et al., 2023). This research community now has events during the workshop week as well as monthly virtual events. They also offer childcare grants to make attendance more accessible for scientists who are also parents. A key point they make is that this work takes time and that it is beneficial to develop systems and norms to reward those that conduct DEIAJ work. This reward system should acknowledge not only the visible DEIAJ work of leaders and committees but also the invisible service workload (Daniels, 1987) in supporting underrepresented students, a task that systematically burdens those from marginalized

groups, especially BIPOC scientists (e.g., Jimenez et al., 2019; Gewin, 2020).

Similarly, Smith-Keiling and Keiling (2023) note that conferences often have a less-than-positive climate for women [e.g., overt sexist attitudes, as well as condescending remarks, flirtatiousness, or exclusion from discussions, (Biggs et al., 2018)]. They focus on the value of building a diverse organizing team and emphasize the importance of personal interactions at creating a positive culture for inclusion of all, not only at the conference but also in the planning meetings. That is, listening fosters cultural wellness, so the organizing committee should go beyond introductions and the members should get to know each other more deeply (Smith-Keiling et al., 2020).

2.6 Research workplace recommendations

While it is true that the lack of diversity in the field is a "pipeline" issue because women and BIPOC leave STEM during their schooling, another major reason for a lack of diversity is that they leave due to toxic and hostile work environments [e.g., words or behavior than denigrate an individual based on their sex (Cortina et al., 2022)]. One example is described by Settles et al. (2018), who found that faculty of color experience both invisibility (with respect to leadership and recognition) and hypervisibility (with respect to interpersonal interactions and evaluations). Unfortunately, a racial bias against BIPOC faculty still persists in the academic workplace, and this was amplified by the antiscience rhetoric that arose during the Trump presidency and the extraordinary burdens of the pandemic (McGee et al., 2021). The situation is worse for those with multiple marginalized identities because intersectionality compounds the inequalities (e.g., Clancy et al., 2017; Kozlowski et al., 2022). Following the ten simple rules towards healthier research labs of Maestre (2019), Halford et al. (2023) give many ways in which space scientists can improve the workplace. This includes thinking beyond our normal close-knit colleagues when forming a new team. It also means designing the workplace for universal accessibility, including access to affordable childcare, a family task that still disproportionately burdens women. When running hybrid meetings, establish norms that foster connection between the local and remote participants. Finally, it is recommended to develop policies with consequences for inappropriate behavior.

Turner and Smith (2023) address the topic of neurodiversity in space physics. One significant point made by Turner and Smith (2023) is that word choice matters. Table 1 offers a quick guide to neurodiversity-affirming language and some key phrases to avoid. When pathologizing language is noted, politely take correction and learn to use more inclusive words. Taboas et al. (2022) found that autistic adults prefer to be called autistic rather than "having autism." This is akin to being left handed, for which we would never refer to someone as "having lefthandedness." Furthermore, avoid moralizing about neurodivergent behavior; people work differently and we should accept these styles rather than conform to past standards. Finally, we should move past compliance and towards supportive caring and universal accessibility.

Nikoukar et al. (2023) raise awareness of mental health issues in the space physics community. The pandemic was a stressor (Gewin, 2021), but not the only one (Evans et al., 2018; Wong et al., 2019). STEM scientists experience isolation, burnout, poor-work-life balance, endure a toxic research culture, and suffer the negative consequences of our hierarchical institutional structures (e.g., Hall, 2023). Furthermore, there is a stigma against openly talking about this topic. Nikoukar et al. (2023) recommend the development of programs that foster good stress management to build resilience to stressors. Also, mental health should be included in surveys to better understand the scope.

TABLE 1 A brief language guide for more inclusive conversations with and about neurodiverse colleagues and students (from Turner and Smith, 2023).

Use this (neurodiversity-affirming language)	Avoid this (pathologizing language)
Autistic person	"Person with autism"
Autism	Autism spectrum disorder (ASD)
Traits	Symptoms
Identification	Diagnosis
Neurotype	Disorder
Co-occurring	Comorbid
Passions or interests	"Restricted interests"
Typical	Normal
Naming specific supports or accommodations	Functioning levels (e.g., high-functioning or low-functioning)

Burt et al. (2022) detail findings from surveys conducted of alumni of the Advanced Studies Program (ASP) at this institution. There are two main motivations as to why people become engaged in DEIAJ work. One is the business case: many studies show that diverse teams lead to more creativity and productivity. Another is the moral case: historical marginalization has been going on for centuries, and there is an ethical and social responsibility to take part in dismantling those policies and practices. Burt et al. (2022) found that these ASP alumni resonate more with the moral case than with the business case. Also, as shown in Figure 1, young researchers are stepping up and getting engaged, with 87% of ASP alumni doing some form of DEIAJ work–many of them engaging in multiple forms–at their new institutions.

3 Conclusion

Below are a dozen recommendations to implement across the solar and space physics research community. While these recommendations are distilled from actions within this particular scientific community, they are hopefully applicable across all STEM research fields.

First, immediate actions to create a more inclusive culture:

- Make kinder and more respectful language choices
- Speak up and intervene when you see or hear racism, sexism, prejudice, and harassment

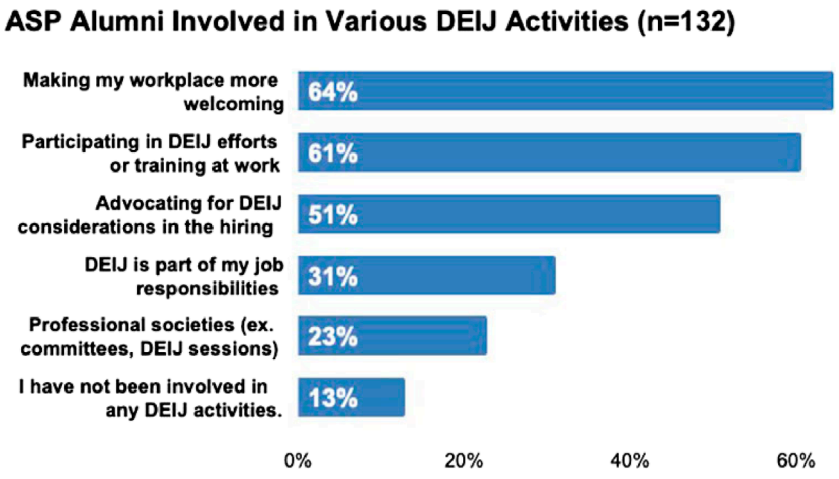

FIGURE 1
Involvement of ASP alumni in DEIAJ activities at their new institutions. From Burt et al., 2022.

- Make space for the voices of those from marginalized identities
- Take correction from others with humility rather than getting defensive

Second, additional actions towards equity as the situation arises:

- Adopt positive teacher-student interactions, especially in introductory STEM courses
- Mentor pre-college and undergraduate researchers
- Take the risk to nominate your peers for awards and proactively strengthen the nomination
- Expand your definition of excellence when evaluating other scientists for hiring, promotion, and awards

Third, some policy changes to enact to make the workplace better for all:

- Proactively plan for universal accessibility
- Develop codes of conduct and safety protocols for the lab, group meetings, and field work
- Establish processes to acknowledge DEIAJ work, especially the invisible service of helping students and colleagues through difficult situations
- Introduce and enforce appropriate consequences for the full range of workplace inclusivity offenses

DEIAJ action is about treating others with decency and respect. Systemic racism, sexism, and inequality still exist in our workplace culture and these reinforce individual biases and stereotypes. We should work to break this cycle, so that, some day, equity and equality might mean the same thing.

This work is for all of us to do. Inequity and exclusion negatively influence everyone, in particular those from marginalized groups, and those in the current dominant cultural group in solar and space physics–white men–should use their privilege to address it. Whichever of the various motivations for engaging in DEIAJ work best appeals to you, you are strongly urged to get involved.

Author contributions

ML: Conceptualization, Funding acquisition, Resources, Writing–original draft, Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. The author would like to thank the University of Michigan for its financial support, as well as the US government, in particular research grants from NASA (80NSSC23M0040, 80NSSC19K0077, 80NSSC21K1127, and 80NSSC21K1405) and NSF (AGS-1414517).

Acknowledgments

Soon after Dr. Joe Borovsky became the Topical Chief Editor for Space Physics for Frontiers in Astronomy and Space Sciences, he asked me to lead a special collection on diversity issues in the field. Thank you, Joe, for spotlighting this matter. I also thank him for the invitation to give a plenary session presentation at the celebratory conference, "A decade of discovery and advancement–10th anniversary conference of Frontiers in Astronomy and Space Sciences," and thank all of those at "Frontiers In" that made that conference possible. This review is based on that presentation. I would especially like to thank my co-editors on this Research Topic–Drs. Xochitl Blanco-Cano, Chigomezyo Ngwira, John Coxon, Alexa Halford, and McArthur Jones Jr.–without whom this collection would not have happened. I am very grateful to all–editors, reviewers, authors, and staff–who invested time and effort on that Research Topic. I am also grateful for my opportunities to be involved in DEIAJ work at the University of Michigan, including my role as an Associate Director of the U-M ADVANCE Program. Finally, I would also like to state that the University of Michigan is located on land obtained from indigenous peoples through unjust treaties. While I cannot change the past, I can work

towards a more equitable and sustainable future. Please support indigenous nation sovereignty.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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