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The importance of recruitment and retention in Heliophysics: it's not just a pipeline problem

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A major obstacle in cultivating a robust Heliophysics (and broader scientific) community is the lack of diversity throughout science, technology, engineering, and mathematics (STEM) fields. For many years, this has been understood as a "leaky pipeline" analogy, in which predominately minority students initially interested in STEM gradually fall (or are pushed) out of the field on their way to a scientific research position. However, this ignores critical structural and policy issues which drive even later career Ph.D.s out of a career in Heliophysics. We identify here several systemic problems that inhibit many from participating fully in the Heliophysics community, including soft money pressure, lack of accessibility and equity, power imbalances, lack of accountability, friction in collaboration, and difficulties in forming mentorship bonds. We present several recommendations to empower research-supporting organizations to help create a culture of inclusion, openness, and innovative science.

KEYWORDS

workforce, science policy, informal education, diversity, mentoring, evaluation and assessment frontiers

1 Introduction

The Heliophysics field faces significant challenges in maintaining a diverse and inclusive community (Clancy et al., 2017; American Geophysical Union, 2021; Batchelor et al., 2021). It is often referred to as the leaky pipeline phenomenon, whereby underrepresented and minority populations leave the field at higher rates. The leaky pipeline indicates that the current culture is not conducive to their growth and retention (American Geophysical Union, 2021). This paper follows the discussion initiated by Katherine Garcia-Sage and Alexa Halford during the Helio2050 workshop and the recent publication Halford et al. (2023), highlighting the importance of investing in Heliophysics's culture and community. By examining the need for inclusivity, addressing unconscious biases, and recognizing the impact of power imbalances and microaggressions, we aim to provide insights and recommendations to create a culture that fosters and supports the success of all individuals within the field (e.g., Blue et al., 2018). Through collective efforts, we can create a vibrant and diverse Heliophysics community that benefits from the inclusion of different perspectives and ensures that the field attracts and retains talented individuals from all backgrounds (e.g., Liemohn et al., 2023).

However, not everyone within the Heliophysics community is convinced that having a culture where all are respected, accepted, and welcomed will benefit science. Likewise, not everyone is yet convinced that these issues affect them, are something they should worry about, or are something that they have control over. Therefore, it is important to emphasize the following (e.g., Page, 2008; Medin et al., 2014; Gibbs et al., 2019):

- Equity and inclusion benefit everyone.
- Both intentional and unintentional actions by peers and organizations have a major impact.
- Everyone has unconscious biases. The key is understanding them and implementing a conscious ethic of identification/detection and mitigation.
- Antiracism is an important principle to understand. It focuses on what we are doing to address racism at all levels and encourages all to help eliminate individual and institutional racism.
- Power imbalances, particularly indirect power imbalances, do impact careers.
- People tend to interact socially (both at work and after work) with people they feel most comfortable with. This can result in exclusion from important connections, access to networking opportunities, and in severe cases, the social climate phenomenon of "invisibility."
- Microaggressions are commonplace, often unintentional, actions contributing to a climate of exclusion or hostility. Studies show that many identify microaggressions integrated over time as more harmful and damaging than explicit racism or sexism.

Parts of our culture and policies systematically push portions of our community out of Heliophysics. A clear example of how our culture can unfairly burden certain groups is by relying on metrics like the number of scientific publications as a basis for promotions and awards. However, women, non-binary, and people of color typically have disproportionate Diversity, Equity, Inclusion, Accessibility, Justice (DEIAJ), and other service responsibilities, pulling them away from their research and writing papers (e.g., Guarino and Borden, 2017; Jimenez et al., 2019; Gewin, 2020; Simien and Wallace, 2022). Acknowledging and appreciating the contributions of the subgroup responsible for growing, supporting, and maintaining an inclusive community is absolutely essential in a professional capacity. Neglecting to do so would not only undermine their efforts but also go against the core values of inclusivity and fairness. If a particular subgroup is experiencing a higher degree of implicit and explicit biases, then we will see a pattern where people from underrepresented and minority groups are leaving our field at a disproportionate rate. This is why it is crucial for our institutions to take measures to change our culture, policies, and spaces so that everyone is supported. Otherwise, our efforts to improve diversity and the overall health of our community will have the opposite effect, pushing these groups out of the field even more disproportionately.

For decades, a leaky pipeline analogy has been used when discussing diversity issues in science, technology, engineering, and mathematics (STEM) fields. However, this imagery is overly simplistic and does not capture critical issues contributing to people leaving the field. It puts distance between structural issues, our actions, and why people leave. A leaky pipeline is passive: it lets the water flow out. What we have within STEM and the Heliophysics community is something more active. Our systems and infrastructure, at times, actively push people out of our field. When we view our research structure as something more intentional, we can start taking ownership and frame more impactful solutions instead of misidentifying important issues and providing ineffective short-term solutions.

An inclusive workplace culture must be actively developed and continuously maintained. Many of the issues discussed in Halford et al. (2023) regarding inclusivity in the heliophysics community have counterparts within our policies and institutions. To fully address and mitigate the current problems within our field, we have identified a need to cultivate a positive, safe, inclusive, and effective environment. However, we need both cultural and programmatic changes. In this current paper, we have considered the obstacles that hinder complete participation and provided practical solutions. Furthermore, we have emphasized the industries and communities that have effectively employed optimal strategies to foster innovative environments.

2 The scientific process

Science occurs through collaborations, but we have not always acknowledged this (e.g., Nobel Prize Outreach, 2019). Discoveries require scientists to cooperate, evidenced by the increasing size of successful scientific collaborations (e.g., Cooke and Hilton, 2015; Stanchak, 2016; McGranaghan et al., 2020). How we do science and collaborate directly impacts the results we achieve. How we build collaborative teams, mission teams, proposal teams, and even the selection of conference coordinators, chairs, and speakers impacts who can participate in science. Perhaps even more importantly, this also determines who drives the conversation about how our science questions should evolve (Cooke and Hilton, 2015; Garcia-Sage et al., 2020).

2.1 Open science

Open Science has many schools of thought, but it is based on a few key ideas: open data, open code, and open access to reading journals, all of which help improve diversity and inclusion within our community (e.g., Max Planck Society, 2003; Bloomstone et al., 2022; Roscoe, 2022; Xenopoulos et al., 2022). All of these lower barriers to entry to science and help with the reproducibility of scientific results. Some groups within our field are already adopting these best practices, and groups like the United States of America's National Aeronautics and Space Administration (NASA) Transform to Open Science (TOPS) team are working to make the field more accessible through a focus on open science, open software, and open data (NASA, 2022; Gentemann et al., 2023). The Python development community within Heliophysics is one such community. Best practices identified for open code are referenced in Burrell et al. (2018).

2.2 Best practices in team formation—a move away from collaboration cliques

Science is a team endeavor. The formation of teams impacts who participates and how science is conducted. Science of Team Science is a field of research that looks at how scientists work best within teams and collaborative environments (e.g., Bang and Frith, 2017; Maestre, 2019). The National Academies has reviewed the Science of Team Science and best practices for different types of groups (geographically dispersed, culturally diverse, different types of leadership, etc.) (Cooke and Hilton, 2015). The field of Team Science will allow us to more easily link the sciences to other disciplines, such as industry or the humanities, which is vital to our goal of achieving a more diverse, inclusive, and safe research environment (e.g., Skorton and Bear, 2018; McGranaghan et al., 2020, and references therein).

For instance, it matters who is invited to a team's first few meetings. Inviting only those we think of first, typically those who look like us and have similar backgrounds to ourselves, when forming a collaboration or a proposal team is exclusionary. It limits knowledge transfer between groups and a team's ability to identify missing links and deficiencies. If diverse people are added later in the process, they may have missed the opportunity to become essential. Individuals added later must expend extra time and effort to catch up to the rest of the team. This may include learning the team's jargon, tools and codes, and the background of the work. This inhibits an individual's ability to be a fully functioning member, and some infer an inability of new team members to be constructive contributors. Thus, new members need support and resources to come up to speed and feel that they can be full members of the team. Subsequently, when minority and underrepresented groups within our community are continually added after initial meetings, they will continue to feel looked over, secondary, and not fully valued.

2.3 Interdisciplinary scientists and projects require a home

Interdisciplinary expertise is required to understand the interconnectedness of the heliosphere. Therefore, making it easy to participate in multidisciplinary work is necessary for Heliophysics to flourish beyond the advancements made in the past decades (Garcia-Sage et al., 2020). The high-level best practices in the Science of Team Science lead to effective teams, improved creativity, and innovative scientific results. Often, we see that individuals who do interdisciplinary work are not considered to belong to any sub-field and find themselves at times out of these close networks. Scholars in minoritized groups, such as women and people of color, are often more likely to work in subfields beyond the core of a discipline (Gonzales, 2018; Settles et al., 2021; Stevens et al., 2021).

Furthermore, journals focused on interdisciplinary science often are valued lower than the (traditional) disciplinary publication forums. Unless we want to lose multidisciplinary expertise from the field, we need to make sure that there are jobs for these individuals (e.g., Settles et al., 2021, and references therein). Thus, it is crucial to make decisions for hiring and committee appointments for relevant positions where interdisciplinary expertise is considered a strength.

Similarly, genuinely interdisciplinary projects often struggle to find a funding source, as funding agency divisions may not consider interdisciplinary proposals core to their objectives (Hoppe et al., 2019). Likewise, interdisciplinary science questions are often not seen as compelling by review panels, who are often looking at very focused science topics with clear outcomes. A possible way to mitigate this is to build funding sources and academic departments within the field, whose core objectives are to foster interdisciplinary projects. An example could be the formation of a trans- or interdisciplinary division within NASA and other funding bodies, recognizing the potential for scientific discoveries in our field in the vast unknowns between disciplines.

3 Soft money science

Most of us will be or have been on soft money for at least a portion of our career (DeJong et al., 2020, and references therein). The Heliophysics community often regards soft-money positions as temporary, being filled by graduate students or early career researchers. However, many members of the Heliophysics workforce are supported by soft money throughout their careers, and the success of groups building space experiments or comprehensive databases, models, or simulations often critically depends on the contributions of these researchers (e.g., Herschberg et al., 2018, and references therein). Soft money positions can have benefits, such as fewer or no teaching obligations and greater flexibility in work locations and hours, but there are also pitfalls (e.g., Barinaga, 2000; Kean, 2001; López et al., 2018). Some difficulties that soft-money employees encounter are directly related to HR and grant and contract policies of their employers and funding agencies. Heliophysics research can bring millions of dollars to universities and other institutions, but the departments and investigators who secured this funding often see little or no return on their overhead. For example, the facilities and administration (F&A) costs charged on grants and contracts that support soft-money employees go into the general fund accounts of these institutions. That is, the PI of the grant does not directly control them. This can make it difficult for individual PIs or their departments to provide adequate computing resources, laboratory access, office space, and furniture to soft money employees, as these "general-use" spaces and equipment often cannot be directly paid for by grants and contracts. A further example is that the department may deem that a software tool like MatLab is necessary and vote to spend those funds for MatLab licenses while one or more of the researchers who contribute to those funds do not use MatLab and instead need IDL.

Additionally, many institutions include a separate line item in grant/contract budgets for fringe benefits (e.g., healthcare, worker's compensation, tuition assistance, retirement benefits). When their institutions classify soft-money employees as full-time, regular employees, they often receive these benefits. However, soft-money employees classified as temporary or independent contractors may not have access to these benefits, providing little incentive for these individuals to continue working in Heliophysics. Policies that encourage hiring full-time employees over temporary workers would contribute to a more stable, experienced Heliophysics workforce while improving the productivity of the groups.

The issue of increasing term and soft money positions leading to toxic impacts within a research field is not new or limited to the Heliophysics field (Cardelli, 1994; Cameron, 2014; Bourne, 2018). The short time frames and budgets of grants and contracts drive the need for soft money researchers and employees working at full-cost accounting institutions to write new proposals constantly. Anxiety over job security can motivate researchers to leave academia and the field. For example, researchers supported through soft money are often regarded as less capable than those holding tenure-track faculty positions, even if their scientific contributions are of equal quality. Many soft-money researchers mentor students and post-docs, manage projects, and serve on service committees. In effect, soft-money researchers carry out many of the same duties as faculty (e.g., Haviland et al., 2017; Flaherty, 2018). Still, they are often ineligible for many opportunities that support professional development, mentoring, and large-scale or long-term projects (e.g., the United States of America's National Science Foundation [NSF] CAREER awards, Major Research Infrastructure). Including soft-money researchers in these policies and proposal calls would help ease the anxiety and improve the Heliophysics workforce morale. For example, the overhead allocation to support bridge funds could support all employees between grants for a month or two. Another idea would be to return a fixed portion of each grant's overhead (2%, 5%) directly to each researcher on the grant and pooled into discretionary 'rainy-day funds that do not expire. Every step to improve financial and funding security helps keep people in Heliophysics.

4 Accessibility and equity across different sections of our community

Many subfields and social communities within Heliophysics have different needs to participate fully in day-to-day science activities. For example, physics buildings at US research institutions are often old and "grandfathered" into not meeting Americans with Disabilities Act (ADA) requirements. Due to the lack of funding at many institutions, these challenges are not adequately addressed, and the burden falls on the disabled individual to navigate campus support. While renovating an entire building may be impossible under budget constraints, minor improvements, such as retrofitting automatic doors on restrooms or wheelchair lifts, are within possibilities and should be pursued more actively. Additionally, participating in conferences is physically demanding and presents restrictions to many. Catching a specific talk may require moving quickly from a poster hall to another room. Scientists with physical limitations may be forced to stay in one area and miss out on other opportunities. Individuals not able to stand for several hours in a poster session can request chairs, but this can also cause issues, as sitting in a chair makes it difficult to support a crowd of people visiting the poster. The standards for ADA accommodations at conferences need to change from special requests which burden the disabled individual to standards that present minimal barriers to networking.

There are many more elements than conferences and building layouts that can be adapted to make community members feel welcome. While we are not able to list them all in this paper, we have tried to highlight some key areas where more work is needed surrounding accessibility and equity across different sections of our community:

- Consideration of the needs of those with visible and invisible disabilities in the initial phases of policy making and planning.
- Accommodation for scientists with disabilities (e.g., teleworking, virtual conference participation, live captioning).
- Reasonable deadlines that fit into the months-long clearance processes that many within our community are tied to.
- Family care inclusivity and equity.
- Child/family care grants, including care at conferences and support at home;
- Ability to work half-time for extended periods;
- Continued support for family leave.
- Reduced costs of participation, e.g., cost of conferences, laptop computers, software, and publishing in and reading scientific journals.
- Hybrid or fully online options for conferences and workshops mitigates issues with travel. Many smaller workshops found that more people attended from a broader geographical representation of home institutions during the pandemic as the barrier of travel costs was removed.
- Encouraging open science practices such as using freely available coding languages (e.g., Python, Julia), publishing in open access journals (e.g., providing NASA/NSF funding for gold open access like other agencies do, such as National Environmental Research Council [NERC]), and making our research open will enable more people to participate as well as enhance the reproducibility of scientific results.

5 Promoting hybrid meetings

With the increasing pace of technology and online connections tools, we have greater flexibility than ever in how we collaborate. We are no longer limited to being in the same physical space for meaningful discussions. There are benefits and challenges unique to in-person or virtual collaboration (e.g., Sarabipour, 2020; Ostler et al., 2021; Tao et al., 2021; Ellis et al., 2022). Hybrid meetings allow for the best of both worlds: more accessible in-person discussions and networking for those who can come on-site and the ability to contribute viewpoints and scientific debate for those unable to travel. However, we must be careful that this physical separation between on-site and online colleagues does not also produce a "participatory" bias. Care must be taken in establishing the culture/norms of these hybrid meetings, ensuring online and in-person voices are equally heard. Some possible suggestions include:

- Having someone on-site with the specific responsibility for raising the voices of those not physically present (e.g., reading out questions, raising a hand on behalf of a virtual participant).

- Having laptops/phones/etc. Out for engaging with the remote team members via chat.
- Dual online/in-person poster sessions; webcams and screens for live chat with online participants.
- Asynchronous collaboration, including recorded talks, continuously available poster access, or question and answer in a message board format.

6 Common, collaborative, affordable tools

Science is a collaborative endeavor and is often best done when we collaborate across institutions. We have many different tools for virtual collaboration available to us. Today, we can communicate and collaborate via options as diverse as Email, Google Meet (Google, 2023 Accesssed: 2023-7-07), Stack Overflow (Stack Overflow, 2023 Accesssed: 2023-7-07), Overleaf (Overleaf, 2023, which was used in the collaboration of this project), Github (github, 2023), and Jupyter Notebook (Kluyver et al., 2016). However, many institutions, especially within the government and industry sectors, limit employees' access to collaborative tools. This impacts the ease and effectiveness of collaborations across institutions. Our collaboration tools and relationship with them can greatly impact how welcome we feel within the community, especially if we do not have access to them. However, this also means that there are a large number of spaces we have to monitor. Although internet-based collaboration tools may always be "on", we must develop a culture that does not necessarily expect us always to be on and interacting with those tools. A healthy balance between synchronous and asynchronous collaboration will maintain connection and productivity.

7 Need to address power imbalances

In the current academic infrastructure, there is inherent unbalanced power at all career levels. Whether it is a graduate student at the mercy of their Ph.D. advisor, a postdoc who is unsupported by their supervisor, or a senior scientist who experiences unhealthy dynamics with their mission PI, individuals deserve a structural system that allows them to report abuse and harassment safely (Turner, 2018; Gómez-González et al., 2022). Our current structure is insufficient, and we can work to build better support systems. For example, students and early career researchers often have only one mentor. By having two mentors or co-mentors/co-advisors, individuals may have an ally who can help before things escalate. Other solutions, such as the Faculty Allies at the University of Michigan, can also help (The Regents of the University of Michigan, 2023). Everyone deserves to exist in a safe environment to perform their research, see abusers held accountable, and help ensure our field is safe for those who come next. In short, they deserve a chance for justice (Milazzo et al., 2021). We must build institutional systems that check power imbalance. One example of such a process is the dual anonymous peer review, which has been demonstrated to increase the diversity of researchers who win proposal calls (Witze, 2019; Radebaugh et al., 2021).

8 Accountability for bad behavior

Accountability is a necessary but complex topic. We want to acknowledge that people can grow and change. However, we need precise mechanisms for reporting and accountability for bad actors and continual harassers. There is a quantifiable risk to the careers and the reputations of people who bring forward complaints (See "Picture a Scientist", the 2017 documentary (Witze, 2020) and Turner (2018)). This can include further implicit bias when the harasser or their supporters review papers and proposals. While the risk may never be zero, some mechanisms can help mitigate this risk and address other issues of bias. We need precise tools for reporting and accountability for bad actors and continual harassers.

Further, we know that harassment disproportionately impacts women of color. A recent study by Clancy et al. (2017) found that of astronomers, 40% of women of color felt unsafe due to their gender or sex and 28% due to their race. The authors also found that 18% of women of color and 12% of white women skipped professional events due to these concerns, leading to fewer opportunities for networking and furthering their careers.

The current institutional and agency mechanisms for accountability for unethical behavior, such as Title IX in the United States of America, are fundamentally flawed (Walters and McNeely, 2010; of Education, 2023; Civil Rights Division, 2023; Das, 2003; Hartman, 2020; Swan, 2020). As an example, Title IX forbids discrimination on the basis of sex in any US Federally-funded activity. However, it does not provide a national resource for addressing harassment (Walters and McNeely, 2010; Civil Rights Division, 2023; of Education, 2023). The handling of individual cases is left to the institutions themselves, and the effectiveness of their responses can vary. Additionally, non-retaliation policies only apply within an institution—but our careers require us to transcend communication across institutions and around the globe (Mattheis et al., 2022). There is currently no policy in place to prevent influential scientists from retaliating against their subordinates or victims. This retaliation can take the form of unfair reviews of their papers or proposals, negative references, and even depriving them of career advancement opportunities or awards (Wadman, 2017a; Wadman, 2017b; Witze, 2020; CULOTTA, 2018; Fortney and Morris, 2021; Liemohn, 2022). These actions are unethical and must be addressed. The Geoff Marcy case is just one example of how powerful scientists can maintain positions of power and continue to influence individual careers and the culture of a field (Ghorayshi, 2015). Additionally, imperfect implementation and enforcement require the person harmed to have significant resources, both financially as well as strong emotional and career support networks, thus putting the onus on the person harmed.

Consequently, individuals have an inherent career risk when reporting harassment and seeking justice for enduring harmful working conditions. This is unacceptable and must be addressed immediately. Therefore, we recommend that government institutions like the European Space Agency (ESA), NASA, and the NSF create trans-institutional Human Resource (HR) support for safe, anonymous reporting. As harassment can and does occur and impact individuals' careers at any stage, scientists from all career levels would benefit from such trans-institutional HR support.

ESA, NASA, and the NSF can help hold researchers accountable by creating an ombudsperson role for missions (which are virtual institutions within themselves) and non-mission-related projects (such as proposal calls) (McDonald et al., 2014). These ombudsperson roles could start as extensions of a Project Scientist role on a mission or equivalent point of contact on proposal calls and eventually be integrated into a newly created position to ensure maximum accountability for unethical behavior in all forms.

Scientific societies can also help play a role here. Societies often cross not just institutional boundaries in a single country but across the globe. They also often are associated with the primary journals of a field which can then more easily survey a much broader community (Ford et al., 2018; Langenberg, 2018; Hanson et al., 2020; American Geophysical Union, 2021; Roscoe, 2022). Having societies and journals help with cross-institutional enforcement would help protect those harmed within their specific research community. The American Geophysical Union (AGU) has rewritten its ethics code to define discrimination, harassment, and bullying as forms of scientific misconduct (Science suffers from harassment, 2018), and other professional organizations should follow this lead.

9 Mentorship

Mentoring can be incredibly valuable in supporting the careers of individuals (Bernstein et al., 2010; Mullen and Klimaitis, 2021). Many of us who have succeeded have benefited from supportive mentoring (e.g., Fuselier, 2022; Smith, 2022; Liemohn et al., 2023). This mentoring may have been informal or formal. For example, it may have been a principal investigator (PI) or Co-I engaging us in the development of a science traceability matrix, or it may have come in weekly coffees to discuss career goals and how to navigate through the community. Formal and informal mentoring is incredibly invaluable and a key component of retention and future success.

Mentoring can take many forms. It may be informal (e.g., Mummery et al., 2021, and references therein), it can be peer-to-peer (of Colorado, 2023), or it can be structured either through group mentoring (Whitebeck, 2001; Daniell, 2006) or one-on-one mentoring within organizations, (Hund et al., 2018; Stelter et al., 2020; Ålund et al., 2020). There is a strong need to convey the importance of mentor networks within our community (Adams et al., 2016; Womack et al., 2020). Researchers need counsel on science, emotional support, next career steps, leadership, resilience, work-life balance, and more (Fuselier, 2022; Smith, 2022; Liemohn et al., 2023). One's advisor/supervisor cannot be all these things simultaneously. Thus we support the idea that people should have multiple mentors.

For example, the Significant Opportunities in Atmospheric Research and Science Program (the SOARS®) has used a multiple mentorship model with much success (Windham et al., 2004). SOARS is a multi-year undergraduate-to-graduate bridge program focusing on increasing the diversity of the atmospheric and related sciences and career pathways. Specifically, an excerpt from Haacker (2015) describes that mentoring the whole student is extremely important: "Beyond just a research experience, the (SOARS) program provides a multi-pronged approach to supporting students in their summer research and throughout their higher education and entry into the workforce. Students are paired with a research advisor and mentors covering other aspects of being a scientist, including writing, public speaking, and programming. Perhaps most importantly, each student works with a formal peer mentor and a life coach to handle stress and help with life choices. This gives the student a broad sense of support and multiple opportunities to make a meaningful personal connection. The formalized mentoring relationships are focused on the summer internship part of the program. At the same time, a strong peer cohort and support from staff run year-round and, to a lesser degree, over many years. The personalized, caring, and consistent support is one of the key elements of the program's success; since its inception 20 + years ago, 90% of SOARS participants have entered graduate school or STEM (science, technology, engineering, and mathematics) careers after graduation."

Concerning formal mentoring, some institutions have developed and used documented mentoring plans between early-career scientists and their mentors or supervisors (OConnell, 2015). When used properly, mentoring plans ensure both the mentor and mentee get the best out of the relationship and have clear communication and expectations (Klinge, 2015). But, more often than should be the case, these documents are not taken seriously (Eby et al., 2000; Murray, 2001, Murray, 2002).

Additionally, the power imbalance between mentor and mentee can have significant consequences. For example, a mentor who implicitly or explicitly acts in ways that harm a mentee's career, including sexual harassment, will often face minimal or no consequences (e.g., John et al., 2016; Johnson et al., 2018; Deloitte Access Economics, 2019; Ro, 2021; Marin-Spiotta et al., 2022). Establishing clear expectations with accountability should be the norm. This mentorship agreement could hold more weight if monitored by the institutions or agencies running the mentoring program and if mentees know and feel safe to report incidences to the relevant institution. Just as with other unethical behavior, the institutions should hold mentors and mentees found acting unethically, bullying, or harassing accountable.

Formal mentor-mentee roles and responsibilities must be communicated and agreed upon, informed by community norms across institutions, and use transparent mechanisms for accountability (Treasure et al., 2022). One commonly used tool for this is the Individual Development Plan (Brown University, 2022; Fuhrmann et al., 2023). Other mechanisms include mentoring agreements (Together Software, 2022). In all cases, oversight is needed to ensure mentors and mentees do not treat these accountability methods as a box-ticking exercise. It is important that we normalize and make transparent the using of mentorship agreements that have accountability for all involved.

Mentoring is a skill that is not taught in a standard STEM Ph.D. curriculum. However, it is a skill that can be learned (e.g., OConnell, 2015). Agencies can help play a role in teaching new skills, such as mentoring. The NSF requires graduate students who receive funding to take a science ethics class. However, all scientists would benefit from this type of knowledge and benefit from continued study of ethical practices. It is important that we support regular training on topics such as mentoring and ethics for all researchers funded by NSF, NASA, and other agencies and institutions.

Mentorship is not only crucial for students who are new to the field but also for researchers at all career levels (Daniell, 2006; Lozier and Clem, 2015; Morris, 2017; Curran et al., 2019). These mentors can include peer mentors, mentors ahead of them in the career stage, and mentors more recent to the field. Researchers need a web of mentors to reach out to at different times. Peer mentors can be within the same area and location, but there is also a need for peer mentors at various institutions and even different sub-fields to get a breadth of perspectives (OConnell, 2015; Casad et al., 2021). Mentors ahead of the mentee in their career stage are beneficial for "next steps" since they recently went through those transition stages and have the most relevant experience. Mentors even further along in their careers are excellent for networking, contacts, science, leadership, etc. Mentors who are more recent to the field than the mentee bring new ideas, techniques, and enthusiasm. Many of these conversations and mentoring webs are forming on platforms - such as Slack (Slack, 2023) and Discord spaces (Discord, 2023)—but need more motivation and encouragement (if not formality) from institutions and professional societies. More platforms that all people can easily access should also be provided for these mentoring discussions.

It is clear that there is a need within the Heliophysics community for multi-generational and multiple formal and informal mentoring types. Additionally, there is a need for more communication about where to find such activities and groups or how to form new groups [e.g., as described in the book "Every Other Thursday" (Daniell, 2006)]. Thus we see a need for the following:

- Mentor/supervisor training - Most scientists have not been trained to be mentors or supervisors. This skill set can be learned and should be continually cultivated. Mentoring and supervising is also an opportunity to learn and grow the mentor/supervisor's network, mentorship training (Lee et al., 2007; Fleming et al., 2013; University of Wisconsin Institute for Clinical and Transactional Research, 2022).
- Peer mentoring groups - Peer mentoring groups are a fantastic way to provide mentoring and build a network. It has been shown that pairing similar demographics helps with career success, such as women in STEM (Dennehy and Dasgupta, 2017) and lesbians (Gedro, 2006). Some groups adjacent to Heliophysics have peer mentoring groups [e.g., the Earth Science Women's Network (ESWN, 2022)].
- Many mentoring opportunities are available but are often difficult to find. There is a need to advertise these opportunities better and where to find them.

For all community members, especially new members and early career researchers, broad and equitable support systems are fundamental to ensure a safe and accessible work environment, professional growth, and career success. Each individual's needs vary, so support systems must be varied and applied equitably to different cases. The role of mentors and mentoring is a crucial pillar of these support systems.

Examples of the support that needs to be provided by mentoring include Inclusive Mentoring from the Sheridan Center (Brown University, 2022) as well as:

- Emotional and personal support and advice.
- Guidance with the science process (e.g., research project development, paper writing)
- Guidance through bureaucratic processes (e.g., proposals and grants, assessments)
- Sponsorship (e.g., Letters of recommendation, networking introductions, travel support)

Opportunities for mentor training and mentoring experience should be formally available and advertised, including inter-institution and inter-disciplinary opportunities. For example, AGU provides some programs to connect mentoring groups (American Geophysical Union, 2022). Peer-to-peer mentoring opportunities should also be available and encouraged in Heliophysics, with models to be learned from adjacent fields [e.g., ESWN—An international peer-mentoring network of women in the Earth Sciences (ESWN, 2022)].

Mentors should also have the support they need, especially those with underrepresented identities (Whitaker, 2017). Underrepresented mentors often do more of this type of service work without credit and to the detriment of their scientific output compared to those in the majority (e.g., Guarino and Borden, 2017; Jimenez et al., 2019; Gewin, 2020; Simien and Wallace, 2022). Mentorship should be evaluated, and good practices and outcomes in mentoring should be valued and rewarded, for example, in hiring or tenure decisions. This can be achieved by taking a holistic approach to the criteria applied for hiring or promotion, as discussed by Liemohn et al. (2023).

Critically, women, non-binary individuals, and people of color typically have disproportionate mentoring, outreach, and other DEIAJ responsibilities (Gedro, 2006; O'Meara et al., 2017a; O'Meara et al., 2017b). These activities are rarely valued in performance evaluations to the same degree as other job functions. If the burden of promoting a diverse, inclusive community falls disproportionately on a subgroup, it should be recognized and valued professionally. Otherwise, these actions aimed at improving DEIAJ have the opposite effect, disproportionately pushing members of under-represented groups out of the field.

10 Recommendations

Individuals need the support of organizations to help create a culture of inclusion, openness, and innovative science. Through building this culture of inclusion, openness, and innovation, we can improve retention and start building a more diverse community. The recommendations below help empower individuals and institutions to ensure our community is welcoming to all.

- Work more closely with experts in the Diversity, Equity, Inclusion, Accessibility, and Justice (DEIAJ) research community and adopt the best practices they have identified for creating a positive climate and culture for our field.
- Create a database of resources and models/frameworks for cultivating an open and inclusive climate.
- Create and maintain clear and easily accessible tools for reporting bad conduct and holding individuals and institutions accountable.
- Coordinate across agencies to bring awareness to reports of harassment. Create and maintain a list of convicted harassers shared within the field. This is one wayvadjust

to address the challenge of the disconnect between institutions/societies/organizations/funding agencies when reporting harassment.

- Create effective and thorough protection regarding retaliation for reporting cases of harassment, especially in imbalanced power dynamics (faculty vs. graduate student, civil servant vs. contractor, and so on).
- Enable access to bystander/allyship and other types of training to encourage fundamental change by enabling people to speak up and act when they see something.
- Codify codes of conduct for the field, e.g., mentoring relationships, workshops, or committees.
- Address wage gaps. While not discussed here, this is an important issue regarding why some people leave the field.
- Agencies and institutions (e.g., government research centers, community societies such as AGU, and universities) need to work more closely with groups and people in the DEIAJ research community and adopt the best practices they find for creating a positive climate, culture, and mentorship for our field.
- Embed metrics and incentives into hiring, proportion, awards, and funding structures that value mentorship and other service activities.
- As an example for external awards, within the SPA fellows nomination committee mentoring was included as part of the broader impact one has on the field (Halford et al., 2022)
- As an example for external proposals, service activities need to be prioritized as a larger impact need than just mentioned in the bio sketch.
- As an example of internal promotion, proposal success rates and papers published are often the primary, if not the only, metrics used to evaluate researchers up for a promotion. Including mentorship activities as an essential part of annual evaluations and promotion, reviews would better incentivize these activities.
- As an example of internal performance evaluation at universities, we suggest the weighting of research, teaching, service be re-examined and balanced to account for the importance of service roles.
- Succession planning at agencies like NOAA and NASA, as well as at university institutions through mentorship, ensures that knowledge is not lost as people leave the field and provides new and more leadership opportunities and training.
- Opportunities for cross-generational leadership within the field across all areas (e.g., AGU, Universities, NASA).
- The Space Physics and Aeronomy Section of AGU, in cooperation with government agencies, industry partners, research institutes, and academia, should regularly sponsor a collaborative Heliophysics research space at the Fall AGU Meeting similar to the AGU Sharing Science SciComm space. This space would be used for scheduled meet and greets for research collaborations and job recruiting, interdisciplinary networking sessions for researchers looking for collaborators on future proposals, and tutorials on using data sets, models, and tools.

11 Nomenclature

Nomenclature is important—and perhaps even more so when discussing cultural issues. We created a glossary within our poster, which we hope individuals will find helpful (Halford et al., 2021).

Author contributions

AH lead the conception of the effort and the writing. All coauthors assisted in editing and revising. MJ wrote the information on the SOARS Program. NT assisted in editing and including information on harassment in the sciences and relevant policies. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare 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

Author disclaimer

The positions, experiences, and viewpoints expressed in this work are those of the authors as scientists in the space research community and are not the official positions of their employing institutions. Additionally, this work is a portion of the work and efforts from many within the Heliophysics community and those that helped produce this and other posters/talks/sessions through 2050 Heliophysics efforts and others.

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