THE PLANETARY SCIENCE WORKFORCE: WHO IS MISSING? J. A. Rathbun[1], S. Diniega[2], L. C. Quick[3], D. H. Grinspoon[1], S. M. Hörst[4], E. S. Lakdawalla[5], K. E. Mandt[6], M. Milazzo[7], J. Piatek[8], L. M. Prockter[9], E. G. Rivera-Valentin[9,10], A. S. Rivkin[6], C. Thomas[1], M. S. Tiscareno[11,] E. P. Turtle[6], J. A. Vertesi[12], N. Zellner[13], [1]Planetary Science Institute (rathbun@psi.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, [3]Center for Earth and Planetary Studies, Smithsonian Institution, [4]Johns Hopkins University, [5]The Planetary Society, [6]Johns Hopkins Applied Physics Lab, [7]USGS, [8]Central Connecticut State University, [9]Lunar and Planetary Institute, [10]Arecibo Obsevatory, [11]SETI Institute, [12]Princeton Universiy, [13]Albion College.

Introduction: The planetary science workforce is not nearly as diverse as the society from which its membership is drawn and from which the majority of our funding comes. The most recent survey (2011) of the planetary science workforce [1], showed that only 25% of responding planetary scientists were women; while by ethnicity 87% were white, 7% were Asian, and 1% each were Black or Latinx. The US population in 2010 was 51% women and 64% white, 13% Black, 16% Latinx, and 5% Asian [2]. Hence the current planetary science workforce has an overrepresentation of men relative to the general population, particularly white and Asian men.

Who is in the field? Rathbun et al. [3] looked at the net planetary science pipeline. By assuming that the demographics of the group entering the pipeline matches the 2010 US census distribution, they normalized the number of people entering the pipeline by assuming that the number of white men entering is equal to the number of white men planetary scientists. Based on this assumed success rate of 100% for white men, they found that the success rate for white women is 32%, Asian men is 92%, Asian women is 30%, Black men is 5%, Black women is 1.5%, Latino men is 5%, and Latino women is 1.5%. The representation of other racial identities, such as Native American, were so low that they were not included in the Planetary Workforce Survey or this analysis, a testament to gross underrepresentation in the pipeline. This calculation demonstrated that women of color (not including Asian women) are the most underrepresented group in science. Furthermore, white women are closer in representation to white men than to women of color: For every 3 white men that make it though the pipeline, there is 1 white woman. But, for every 20 white women, there are only 1-2 women of color.

Prior studies [4] demonstrate differential status effects for different minority groups in STEM fields, as well as different effects based on immigration status. Stereotypes of "model minority" cultures are frequently to blame in producing these disparities [5-6]. Calculations based on Rathbun et al.'s [3] study suggest that similar effects are likely at play in the planetary science community, for instance with an overrepresentation of Asian minority participants vis a vis African American or American Indian members.

Who succeeds in planetary science? Considering involvement in a spacecraft mission as one possible measure of success as a planetary scientist, Rathbun et al. [4, 7-10] determined the percentage of women participating in the original science teams of 26 NASA robotic missions over a 41-year period. They found that since 2001 the average rate of participation of women has remained constant at about 15%, substantially less than the overall percentage of women planetary scientists, dramatically different from the US population, and more likely to trigger poor outcomes.

Although Rathbun et al. [4, 7-10] studied the participation of women on US planetary spacecraft science teams, they did not determine membership of other underrepresented groups, such as race. Personal experience on spacecraft science teams, and the earlier data on the dearth of scientists of color (excluding Asian scientists) in planetary science (see previous section), strongly suggests that there are very few scientists of color on spacecraft science teams. Hence, these earlier studies almost exclusively consider the experiences of white (and, possibly, Asian) women. Clancy et al.'s [11] study of astronomers demonstrates the value in considering the additional factors that affect the participation of women of color.

Why is diversity important? Rathbun et al. [10] discussed how diversity and inclusiveness along gender, ethnicity, ability, sexual orientation, generational, and other axes is a business as well as a social imperative. They demonstrated that innovation and funding are two important reasons for increasing diversity in planetary science. Furthermore, the ability of planetary scientists to continue scientific advances relies upon mentoring and educational relationships. Recruitment of diverse students and effective mentoring of these students is aided by having diversity within the mentor-population (i.e., the professional scientists) [12]. Additionally, a lack of diversity within the mentor-population can enhance the emotional and "service" labor requested from those present. As this labor is unevenly requested (and generally less valued) [13], this creates further unfair barriers for scientific contribution by both students and professionals within underrepresented populations.

Barriers to entry: In industries that pride themselves on meritocratic advancement, one might suggest

that the best junior participants will rise like cream to the top. Related, there can be a notion that well-qualified minorities fail to make it in science because they are not good candidates. Both of these beliefs have been disproved by a barrage of sociological studies of the sciences and technical domains. For example, studies have shown that beliefs in "innate talent," meritocracy, and gender- or colorblind approaches can yield more unequal access and participation [e.g., 12, 14-16].

Rathbun et al. [10] discussed the role of culture as a barrier to underrepresented groups, where masculine work cultures can create self-fulfilling prophecies, where the right person for the technical or scientific job can only be white and male.

The role of demographics: In addition to cultural barriers, studies of organizations demonstrate that environments with fewer than 30% minorities are subject to devastating interpersonal dynamics that punish those same minority individuals for their participation. 15% or fewer minorities invokes a tokenist environment, where individuals are negatively impacted by their heightened visibility [17].

Suggestions for equity: The above data suggest that there are individual- and system-level barriers in place prior to and within planetary science which prevent equal participation from certain groups. Furthermore the participation of scientists from underrepresented ethnic groups (male or female) lags far behind the participation of white (and, possibly, Asian) women in planetary science. Addressing these issues and increasing inclusivity for all will take a multi-pronged approach, including different approaches for getting people into the field and then getting people to have equal access to success. These approaches need to take into account discrimination against multiple axes, inclosing both gender and race. Here, we focus on:

Recruitment of scientists of color: More recruitment and retention efforts are needed to focus on the groups that are the most underrepresented groups in planetary science: racial groups other than white and Asian. While the current efforts in recruiting women should continue, more efforts need to be focused on scientists of color, particularly Black, Native American, and Latinx groups, in order to bring about true equity and diversity in STEM.

We suggest focused recruitment from minority serving institutions, such as Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), and tribal colleges, and developing mentorship networks such as those that support women in STEM. Further, deploying targeted internships, scholarships, graduate and postgraduate fellowships will enable these students to apply their strong knowledge from areas such as physics, math, and engineering, to planetary science. As with the recruitment and retention of promising female scientists, the planetary science community would be well served by gathering data about our community's racial demographics and evaluating race-focused programs for their effectiveness in bringing and welcoming more diverse voices into the field.

Changes within planetary science: Earlier work included suggestions for systemic changes within planetary science that could increase diversity and equity [7-10]. Here, we focus on suggestions for individuals within planetary science and how they can assist with increasing diversity and equity within our field.

What can you do? At an individual level, we encourage increased and open learning about current issues that affect members of our community, and increased attention towards which we regularly interact with (and who we don't). Discussions and education should result in re-evaluation of assumptions, biases, and how we do things. For example, Bystander Intervention Training [18] can help one practice options for gentle correction against inadvertent, but still impactful, transgressions. We also suggest that planetary scientists actively seek out collaborations with professors from minority serving institutions on NASA-funded research projects/proposals. Having **professors** and other mentors working in planetary science ensures that students see people in underrepresented groups that they can relate to working in these career-fields, which can help the recruitment problem.

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