

Figure 2 | Percentage of women in planetary science as a function of time from several different workforce surveys. The dashed line shows a linear fit to the survey data. DPS survey data taken from refs 8,9; CSWA data excludes students and is taken from ref. 10; workforce survey data taken from ref. 11.

and complexity — from small Discovery and New Frontiers teams, to Flagship missions that may employ hundreds of scientists — team size is an important factor in determining proportionality, but missions with small team sizes and higher proportions of women may still represent a small number of women in key roles.

Figure 1 shows our primary results. The pre-2000 average is 5.7% women on spacecraft teams. Since 2000, the percentage of women has remained flat at 15.8%. When we fit a line to our data over that time period, we get a very small negative slope. Due to the scatter in the data, we do not believe this linear fit to be significant, only illustrative that there has been no growth in the percentage of women on spacecraft science teams in the past ~16 years. Groups with 15% participation of a minority population result in tokenist dynamics, which set in motion “self-perpetuating cycles that reinforce the low numbers”⁷.

To determine whether these numbers and proportions represent changes in the composition of the field, Fig. 2 shows the percentage of women in planetary science overall. There is no single measurement for this number so we used the 2011 planetary workforce survey (red triangle), the American Astronomical Society’s Division of Planetary Science (DPS) surveys (blue squares; although not all planetary scientists are members of DPS), and the most detailed survey of women in astronomy by the Committee on the Status of Women in Astronomy (CSWA). The green diamonds show the percentage of women non-students in the CSWA survey. According to these surveys, the percentage of women in the field reached ~15% in the late 1990s and has increased since then to more than 25% in 2013. The

line shows a linear fit to the data and predicts that the field will reach parity in 2049. If the trend continues, the percentage of women in 2017 should be just under 30%. Only four of the 26 (15%) missions shown in Fig. 1 are above the line on Fig. 2, demonstrating that professional women in the field are still proportionally under-represented on mission teams

PIs typically form spacecraft or instrument teams at or before a mission’s inception, but in the 2000s NASA created participating scientist (PS) and guest investigator (GI) programs to provide an influx of fresh personnel onto a mission’s science team. These programs are solicited through the annual NASA Research Opportunities in Earth and Space Science (ROSES) call and the resulting selections are available on the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). While PS and GI programs select people through a proposal and review process using a panel of peer scientists, the original teams are, in most cases, selected by a single principal scientist. Figure 3 shows how these programs affect the make-up of spacecraft science teams. We examined the names of the selected scientists and determined their gender in the same way as for the original teams. Figure 3 shows results for several missions, with a green bar indicating the number of women in the selection and the purple bar the number of men.

The average percentage of women selected in PS and GI programs is

substantially higher than the originally selected teams (24.2%), which roughly corresponds to the percentage of women in the field circa 2008 (Fig. 2). By comparing the percentages of women on the original team (leftmost bars) and composite team (rightmost bars), we find that, of the teams shown, only the Mars Curiosity mission substantially increased its percentage of women participation (from 13.5% to 25%). This is because the two PS calls for this team resulted in substantial additions to the team. However, in most cases, even with the additional members selected through PS and GI programs, the resulting percentage of women on missions remained well below that in the field.

While the percentage of women in planetary science appears to be increasing, their representation on spacecraft science teams has not been commensurate, demonstrating that the planetary science community is not benefiting from the expertise of many qualified women scientists. So, how do we increase their participation? A clue may lie in the fact that PS and GI programs are doing a demonstrably better job at selecting women than the original science teams.

NASA has recently begun collecting demographic information through its grant application portal, NSPIRES. It will be informative to compare the percentage of women applying for NASA programs to the percentage selected. Furthermore, the latest announcement of opportunity

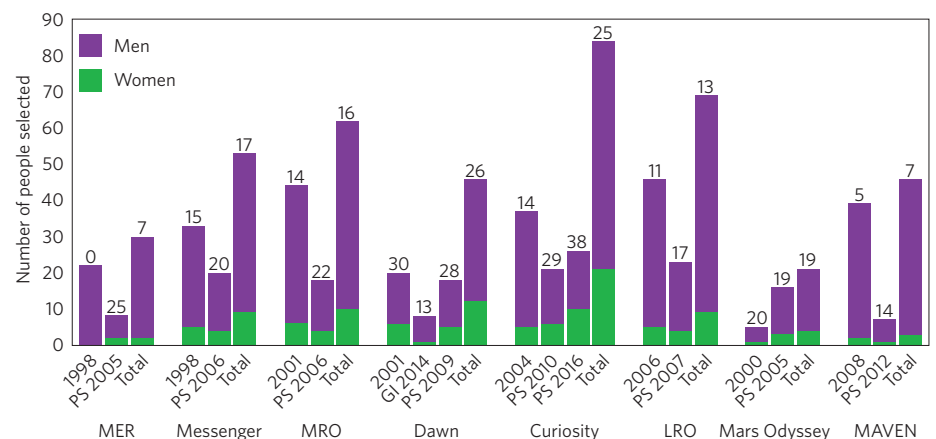


Figure 3 | Effect of participating scientist (PS) and guest investigator (GI) programs on the participation of women in spacecraft teams. For each team, the leftmost bar indicates the numbers of men (purple) and women (green) on the originally selected team on the year the team was selected. Subsequent bars show additions to the teams through PS or GI programs. The rightmost bar for each mission indicates the total science team by adding all selections, although the same individual may be counted more than once if there are multiple PS selections. The number above each bar indicates the percentage of women selected at that time, and the number above the rightmost bar indicates the percentage of women on the final team. MER, Mars Exploration Rovers; MRO, Mars Reconnaissance Orbiter; LRO, Lunar Reconnaissance Orbiter; MAVEN, Mars Atmosphere and Volatile Evolution mission.

for a robotic spacecraft science team in the New Frontiers program and the 2017 NASA ROSES call for proposals, adds this sentence: “NASA recognizes and supports the benefits of having diverse and inclusive scientific, engineering, and technology communities and fully expects that such values will be reflected in the composition of all proposal teams as well as peer review panels (science, engineering, and technology), science definition teams, and mission and instrument teams.” Assuming this directive is actively pursued in the selection/award process, it will hopefully result in an increase in the participation of women on the proposal teams.

While our study concentrated on gender, future studies should also consider race and membership in other under-represented groups. The planetary

science workforce survey¹¹ found that 87% of planetary scientists identified as white, substantially above the percentage of the US population (64% in 2010). Anecdotal data suggest that white scientists are similarly over-represented on spacecraft mission science teams and that white women are over-represented compared to women of colour. The planetary science community and robotic spacecraft mission teams have a long way to go to become a diverse and inclusive community, but new data collection and policies are a small positive step in the right direction.

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References

1. Shen, H. *Nature* **495**, 22–24 (2013).
2. Dutt, K., Pfaff, D. L., Bernstein, A. F., Dillard, J. S. & Block, C. J. *Nat. Geosci.* **9**, 805–808 (2016).
3. Merton, R. K. *Science* **159**, 56–63 (1968).
4. Caplar, N., Tacchella, S. & Birrer, S. *Nat. Astron.* **1**, 0141 (2017).
5. Rathbun, J. A. *et al.* In *47th Meeting of the Division for Planetary Science* 312.01 (AAS, 2015).
6. Rathbun, J. A. *et al.* In *48th Meeting of the Division for Planetary Science* 332.01 (AAS, 2016).
7. Kanter, R. *Men and Women of the Corporation* (Basic Books, 1977).
8. *DPS Employment Survey Results* (AAS, 1989); <http://go.nature.com/2p8NYFX>
9. *DPS Survey Results* (AAS, 2010); <http://go.nature.com/2pFnXiE>
10. Hughes, A. M. *Portrait of a Generation of Women in Astronomy* (CSWA, 2013); <http://go.nature.com/2p8MqvN>
11. White, S., Chu, R. Y. & Ivie, R. *2011 Survey of the Planetary Science Workforce* (LASP, 2011); <http://go.nature.com/2p8Gr9X>

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