

COMMENTARY

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Key Points:

- Women of color in this sample of astronomers and planetary scientists experience greater gender and racial harassment than any other group
- Women of color in this sample report feeling unsafe in their workplace due to gender (40%) and race (28%)
- Women of color and white women in this sample skip professional events due to feeling unsafe, leading to a loss of career opportunities

Supporting Information:

- Supporting Information S1
- Data Set S1

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Double jeopardy in astronomy and planetary science: Women of color face greater risks of gendered and racial harassment

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Abstract Women generally, and women of color specifically, have reported hostile workplace experiences in astronomy and related fields for some time. However, little is known of the extent to which individuals in these disciplines experience inappropriate remarks, harassment, and assault. We hypothesized that the multiple marginality of women of color would mean that they would experience a higher frequency of inappropriate remarks, harassment, and assault in the astronomical and planetary science workplace. We conducted an internet-based survey of the workplace experiences of 474 astronomers and planetary scientists between 2011 and 2015 and found support for this hypothesis. In this sample, in nearly every significant finding, women of color experienced the highest rates of negative workplace experiences, including harassment and assault. Further, 40% of women of color reported feeling unsafe in the workplace as a result of their gender or sex, and 28% of women of color reported feeling unsafe as a result of their race. Finally, 18% of women of color, and 12% of white women, skipped professional events because they did not feel safe attending, identifying a significant loss of career opportunities due to a hostile climate. Our results suggest that the astronomy and planetary science community needs to address the experiences of women of color and white women as they move forward in their efforts to create an inclusive workplace for all scientists.

Plain Language Summary Women generally, and women of color specifically, have reported hostile workplace experiences in astronomy and related fields for some time. However, little is known of the extent to which individuals in these disciplines experience inappropriate remarks, harassment, and assault. We conducted an internet-based survey of the workplace experiences of 474 astronomers and planetary scientists between 2011 and 2015. In this sample, in nearly every significant finding, women of color experienced the highest rates of negative workplace experiences, including harassment and assault. Further, women of color reported feeling unsafe in the workplace as a result of their gender or sex 40% of the time, and as a result of their race 28% of the time. Finally, 18% of women of color, and 12% of white women, skipped professional events because they did not feel safe attending, identifying a significant loss of career opportunities due to a hostile climate. Our results suggest that certain community members may be at additional risk of hostile workplace experiences due to their gender, race, or both.

1. Introduction

Astronomy and planetary science, as the fields concerned with celestial objects and processes, help shift human attention outward. Gazing at the stars is an accessible introduction to science, one that gets many young children dreaming of being an astronaut, astronomer, or planetary scientist one day. Recent discoveries within these fields have been groundbreaking, from the Laser Interferometer Gravitational-Wave Observatory team's detection of the first gravitational wave [Abbott *et al.*, 2016] to recent discoveries about Pluto [Stern *et al.*, 2015] learned from the New Horizons spacecraft. These important discoveries excite the public and lead to engagement through citizen science projects. For example, amateur astronomers participate in astronomical and planetary science discoveries by mapping the surfaces of the Moon and other planetary bodies [Lehan *et al.*, 2011–2015] observing meteor showers and identifying extrasolar planets and observing variable stars.

At the same time, the accessibility and inclusive atmosphere within science, including astronomy and planetary science, has been called into question. Science syllabi use gendered language that not only can show women as incompetent but also normalizes masculine behaviors, belief systems, and priorities [Bejerano and Bartosh, 2015]. Several studies of Science, Technology, Engineering, and Mathematics (STEM) fields

have found implicit bias, or the bias in judgment resulting from implicit attitudes that operates below cognitive awareness, related to both gender and race limits opportunities in mentorship [Milkman *et al.*, 2015], hiring [Moss-Racusin *et al.*, 2012], and opportunities in the classroom [Eddy *et al.*, 2014, 2015; Grunspan *et al.*, 2016], as well as workplace conflict [Williams *et al.*, 2016] and experiences that map onto stereotypes of scientists' racial-ethnic identification [Williams *et al.*, 2014, 2016]. Women of color faculty in STEM are also more likely to experience the dominant culture of their disciplines as outsiders, with their views validated less than the dominant group [Rios and Stewart, 2015]. Further, the number of women of color science faculty has recently decreased, even while the number of white women science faculty has increased [Armstrong and Jovanovic, 2015]. These marginalities are further compounded by power differentials, as women of color are more likely to be junior in rank compared to those with majority identities [National Science Foundation (NSF), 2015].

Within physics and astronomy, the literature suggests that women generally, and women of color specifically, are isolated and experience microaggressions—subtle, indirect, or unintentional acts of discrimination—in the workplace [Barthelemy *et al.*, 2015a, 2015b]. Women of color must employ multiple navigation strategies in order to persist in physics and astronomy, using time and energy that could have increased work productivity [Ko *et al.*, 2014]. Women of color and white women are also underrepresented in the physical sciences to a far greater degree than the social or biological sciences [NSF, 2015]. Small numbers may make it seem as though the total proportion of negative experiences are not high, from the view of the majority in the astronomical community. However, within each group of women of color or women generally who have been sampled thus far, a troubling picture has emerged of low support, isolation, stereotype threat (feeling at risk of conforming to stereotypes), and the need to develop strategies and expend significant mental resources to stay in their respective fields. What is more, women and people of color generally, as well as women of color specifically, have been found to experience more workplace incivilities, even when those incivilities are general rather than gender or race based [Cortina *et al.*, 2013; Kabat-Farr and Cortina, 2012].

The important work cited above lays the groundwork for a study of the factors that influence the workplace in the astronomical community and how scientists' experiences of this workplace may differ based on their gender, race, and rank. Recent work has highlighted the extent to which sexual harassment and assault, and their negative career consequences, are found in the field sciences [Clancy *et al.*, 2014]. Here we expand upon the notion that harassment and assault persist across many science disciplines with an intersectional approach that looks at the targeting that can occur among those with multiple marginality, particularly the "double jeopardy" frequently described for women of color [Berdahl and Moore, 2006; Buchanan and Fitzgerald, 2008; Carter, 1988; Kabat-Farr and Cortina, 2012; Williams *et al.*, 2014], as well as those marginal due to their rank in a culture that can be very hierarchical [Bargh *et al.*, 1995; Clancy *et al.*, 2014; Popovich and Warren, 2010]. To this end, we test four hypotheses in a national survey of over 400 astronomers and planetary scientists.

1. Hypothesis 1. Female respondents will report more verbal and physical harassment than men.
2. Hypothesis 2. Respondents of color will report more verbal and physical harassment than white respondents.
3. Hypothesis 3. Trainees will report more verbal and physical harassment than those scientists of a higher rank.
4. Hypothesis 4. Women of color experience double jeopardy where they are especially at risk for verbal and physical harassment compared to white women or men of color.

2. Methods

2.1. Ethics Statement

We obtained human subjects approval from the University of Illinois Institutional Review Board (#15354). Informed consent was obtained from all respondents. As the research measure was an online survey, the front page text informed potential respondents about the study and that continuing on to the survey signified consent to participate.

2.2. Study Construction

The questions in this survey are based on a 2011 survey conducted by the American Physical Society's Forum of Graduate Student Affairs regarding the workplace climate in physics [Long, 2012]. Permission was granted

by the survey administrator, the LGBT + Physicists group, to adapt the survey questions to reflect concerns of the astronomical and planetary science community. Thus, while the survey was not validated per se, it contained questions already developed for a similar population in a style common across many studies of workplace climate.

The survey consisted of 39 questions and was administered electronically via the Survey Monkey website from 5 January to 15 March 2015. Individual participants were asked their current career position (undergraduate, graduate student, postdoc, staff scientist/research scientist/nontenured professor/equivalent, senior staff scientist/senior research scientist/tenured professor/equivalent, and others) and to respond to questions regarding personal experiences in that position. If the participant had changed their career position in the previous 5 years, then they were asked to provide answers to the same personal experience questions regarding their prior position. At the end of the survey respondents were also asked to provide demographic information, including gender, gender identity, race and ethnicity, and ability-status. Please see the supporting information for a complete list of the survey questions.

The personal experience questions were categorized into three sections: (1) negative language, (2) safety, and (3) responses to harassment. Respondents were asked to identify how often they hear negative language from their peers, supervisors, or others (not necessarily targeting themselves), regarding sexual orientation, race, sex, gender, femininity/masculinity, physical or mental ability, or religion. Concerning safety, respondents were asked to identify if they feel unsafe because of personal characteristics related to these same factors. Subsequently, respondents were asked if they skipped any type of activity (school or work related) because of feeling unsafe. The safety section concludes by asking respondents if they encountered verbal or physical harassment because of their personal characteristics, and if so, they were asked to identify if the harasser(s) was a peer, supervisor, or another member of their school or work community. Lastly, respondents were asked to identify if they reported a personal harassment experience. Respondents were asked to provide information regarding the resulting actions that followed their report or to provide information on why they did not report the incident.

2.3. Study Recruitment

Recruitment of the study respondents was done through multiple outlets within the planetary science and astronomical sciences community. Recruitment procedures were intended to oversample women given their small numbers in astronomy and planetary sciences. The announcement of the survey was done through the Women in Astronomy Blog [Richey, 2015b] on 5 January 2015 and was also featured at the 225th American Astronomical Society (AAS) Meeting [Richey et al., 2015]. On the same week, the announcement of the survey was released to several society and community news outlets within planetary science and the astronomical sciences, including (but not limited to) the AAS Division for Planetary Sciences [Membership Announcement, 2015], The Planetary Exploration Newsletter [Benecchi, 2015], and The AAS Women Newsletter [Haggard et al., 2015]. The announcement on the Women in Astronomy Blog site was additionally shared on social media, including to multiple Facebook groups attached to the communities, LinkedIn groups affiliated with the communities, and Twitter. Several departments within the field communicated to their entire staff and students the information via email. On 2 March 2015, a final reminder to participate was posted on the Women in Astronomy Blog [Richey, 2015a] and the survey was closed on 15 March 2015. Respondents to the survey were not compensated for participation.

2.4. Statistical Analysis

Individuals from all U.S. Census Bureau races were represented. However, in order to produce a high enough sample size to be able to compare the experiences of scientists of color and white scientists, as well as women scientists of color and white women scientists, we grouped all individuals who selected at least one racial category other than White or European American were grouped into the “person of color” category. Similarly, though genderqueer and transgender identities are represented in this sample, in order to conduct quantitative, comparative analyses with a great enough sample size we limited gender comparisons to those who identified as cismale or cisfemale. We grouped undergraduates, graduate students, and postdocs as “trainees” to compare trainee experiences to the scientist and senior scientist categories. Seven individuals who reported administrative career positions were removed only from the career position analysis because they did not fit within the career categories of trainee, scientist, and senior scientist which characterized

Table 1. All Racial, Gender, Gender Identity, and Rank Categories Represented in the Sample^a

	Total	Percentage
<i>Self-Identified Racial Categories (n = 421)</i>		
White or European American	355	84.32%
Native American, American Indian, or Alaska Native	1	0.24%
Middle Eastern or Arab American	3	0.71%
Black or African American	3	0.71%
Asian or Pacific Islander	17	4.04%
Hispanic, Latino, or Latina	16	3.80%
Multiracial	26	6.18%
<i>Self-Identified Gender Categories (n = 429)</i>		
Female	287	66.90%
Male	137	31.93%
Nonbinary	5	1.17%
<i>Self-Identified Gender Identity Categories (n = 423)</i>		
Cisgender	414	97.87%
Transgender	9	2.13%
<i>Self-Identified Career Rank Categories (n = 464)</i>		
Undergraduate student	14	3.02%
Graduate student	110	23.71%
Postdoc	104	22.41%
Staff scientist/research scientist/nontenured professor/or equivalent	109	23.49%
Sr. staff scientist/Sr. research scientist/tenured professor/or equivalent	120	25.86%
Administrative/managerial role	7	1.51%

^aRespondents who selected more than one racial category were assigned the multiracial category.

the majority of our sample. Not all participants answered every question, which is why the total number of participants answering questions about race, gender, and rank are not the same. Follow-up, qualitative analyses will draw from the respondents whose experiences may be less visible by these statistical comparisons. The demographics of the sample regarding race, gender, gender identity, and rank categories can be found in Table 1, and Table 2 shows the race, gender, and rank categories used in our analyses.

Calculations for differences in career position and frequency of negative remarks heard at current position for male/female and white/respondents of color comparisons were performed using Fisher's exact test, as were calculations for feeling unsafe at current position (male/female and white/respondents of color). Difference in career position by intersection race/gender group (for the frequency of negative comments heard at current positions, as well as for the feeling unsafe at current position), were calculated using log-likelihood ratio (goodness-of-fit) test with Williams' correction for small values. Calculations of differences in experiencing verbal and physical harassment (male/female and white/respondents of color) were performed using Fisher's exact test. To determine if there was a relationship between any kind of negative comments in current career position, any type of verbal harassment, or any type of physical harassment and the likelihood of skipping events, these events were converted to a binary never/occurred condition. Then unpaired Wilcoxon rank-sum tests were used to test if the number of events skipped was associated with the presence or absence of negative comments, verbal harassment, or physical harassment across any identity axis. All statistical analysis was performed using RStudio with R versions 3.2.2 and 3.3.1 (packages used include reshape2, plyr, and DescTools).

In order to address the extent to which respondents experience a hostile environment in the astronomical community, and the extent to which these experiences are due to race, gender, or related to hierarchy, we

Table 2. Grouped Demographic Categories

	Women of Color		White Women		White Men		Men of Color	
	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage
Trainees	32	8%	110	28%	43	11%	7	2%
Scientist	8	2%	57	15%	22	6%	5	1%
Senior scientist	5	1%	57	15%	39	10%	4	1%
Total	45	11%	224	58%	104	27%	16	4%

performed four types of comparative analysis. We compared all women to all men; all people of color to all white people; women of color, white women, men of color, and white men to each other; and we compared across the trainee, scientist, and senior scientist ranks. Cell underpopulation did not permit intersectional analyses by rank so we were unable to run rank-gender or rank-race analyses.

2.5. Study Limitations

The nonrandom nature of this study's survey recruitment methodology means that these data cannot provide a direct assessment of prevalence of any of the experiences noted here, and prevalence studies are exceedingly uncommon in research of this nature. However, a nonrandom sample can indicate that these experiences are present in the population. It is also possible that the extent to which negative workplace experiences happen in the astronomical community is underreported in this sample, since there is a general bias in the literature of lower response rates to surveys on these topics [Greco *et al.*, 2015]. Further, because our survey instrument used the terms "verbal harassment" and "physical harassment," it meant that participants had to implicitly name their experience as harassment to select any option other than "no." This raises the bar for participants selecting in the affirmative for these questions and leads us to believe our numbers in this sample are especially conservative.

We attempted to use analysis of variance (ANOVA) methods to examine interaction effects of race and gender; however, ANOVA proved inappropriate for this data. When treating the ordinal Likert-score variables as interval variables, assumptions are violated for linear regression (homogeneity of variance and normal distribution of residuals) and logistic regression with Poisson distribution (mean equal to variance). A zero-inflated Poisson model fitted with binary independent variables was considered, but interpreting this more complex model does not add meaningful interpretation to our results and is potentially biased due to the low response rates of women of color and men of color and the low incidences of negative experiences and harassment by white men in our sample. By using statistical methods which are intended for count data, such as chi-square, Fisher's exact, and log-likelihood ratios, we are testing the hypothesis that the proportion of people who experience negative working conditions or harassment differ between groups more than expected by random chance.

Eighty-four percent of the study sample identified as White or European American, which appears to be consistent with national data on astronomy and planetary sciences [Norman *et al.*, 2013]. However, nearly 67% of respondents identified as female, which is much higher than national samples [NSF, 2015], consistent with our goal to oversample women. The sample appears in particular to overrepresent white women, which is likely related to survey recruitment occurring first among the Committee on the Status of Women in Astronomy where there is high white female involvement. The fact that we were unsuccessful at recruiting a greater number of people of color in the sample weakens our ability to speak to the experiences of those people of color historically underrepresented in astronomy and planetary science. Finally, in order to avoid further categorizing respondents into increasingly smaller categories, we did not analyze additional differences by sexuality, neurodiversity, or physical alter-abilities. Future research will address these additionally underrepresented groups.

3. Results

In our sample, 88% of respondents reported hearing negative language from peers at their current career position, 51.9% reported hearing negative language from supervisors, and 88% reported hearing negative language from others. Thirty-nine percent of respondents report experiencing verbal harassment at their current position, and 9% report experiencing physical harassment. Twenty-seven percent of respondents report that they have felt unsafe at their current position, and 11% report that at their current position they have skipped attending at least one professional event such as a class, meeting, conference, or fieldwork opportunity because they felt unsafe attending.

Skipping school or work events due to feeling unsafe was associated with hearing negative comments from peers ($p = 0.006$) and negative comments from supervisors ($p < 0.001$), experiencing verbal harassment ($p < 0.001$) and physical harassment ($p < 0.001$), and feeling unsafe at current school or career position ($p < 0.001$). Hearing negative comments from others was not associated with skipping school or work ($p = 0.08$).

Table 3. Comparison of Remarks Observed by Women and Men

Category	Group	Never	Rarely	Sometimes	Often	<i>p</i> Value
<i>Remarks From Peers</i>						
Sexist remarks	Women (<i>n</i> = 285)	21% (60)	39% (111)	33% (95)	7% (19)	<0.001*
	Men (<i>n</i> = 137)	37% (51)	40% (55)	22% (30)	1% (1)	
Comments not masculine/feminine enough	Women (<i>n</i> = 282)	50% (140)	29% (83)	17% (49)	4% (10)	<0.001*
	Men (<i>n</i> = 137)	72% (98)	25% (34)	4% (5)	0% (0)	
Remarks about physical ability/disability	Women (<i>n</i> = 284)	45% (127)	33% (94)	19% (53)	4% (10)	0.023*
	Men (<i>n</i> = 137)	58% (79)	31% (42)	11% (15)	1% (1)	
<i>Remarks From Supervisors</i>						
Sexist remarks	Women (<i>n</i> = 284)	56% (159)	23% (65)	16% (46)	5% (14)	< 0.001*
	Men (<i>n</i> = 135)	75% (101)	20% (27)	5% (7)	0% (0)	
Comments not masculine/feminine enough	Women (<i>n</i> = 283)	77% (218)	13% (38)	7% (19)	3% (8)	< 0.001*
	Men (<i>n</i> = 135)	93% (125)	6% (8)	2% (2)	0% (0)	
<i>Remarks From Others</i>						
Sexist remarks	Women (<i>n</i> = 281)	15% (43)	31% (87)	42% (118)	12% (33)	< 0.001*
	Men (<i>n</i> = 136)	27% (37)	46% (63)	24% (33)	2% (3)	
Comments not masculine/feminine enough	Women (<i>n</i> = 281)	40% (113)	36% (101)	19% (53)	5% (14)	< 0.001*
	Men (<i>n</i> = 135)	67% (91)	26% (35)	6% (8)	1% (1)	
Remarks about physical ability/disability	Women (<i>n</i> = 281)	40% (112)	36% (101)	22% (61)	3% (7)	0.018*
	Men (<i>n</i> = 137)	50% (69)	38% (52)	11% (15)	1% (1)	
Remarks about mental ability/disability	Women (<i>n</i> = 281)	35% (97)	41% (115)	22% (61)	3% (8)	0.003*
	Men (<i>n</i> = 136)	52% (71)	35% (47)	12% (16)	2% (2)	

*Significance set at 0.025 for two-tailed analyses.

3.1. Hypothesis 1: Female Respondents Will Report More Harassment and Assault Than Men

Women were more likely than men to observe remarks that they interpreted as racist, sexist, that one was not feminine or masculine enough, or disparaging someone’s physical abilities or mental abilities (Table 3, see supporting information Table S1 for all analyses). Women were also significantly more likely than men to report that they experienced both verbal and physical harassment because of their gender. When asked if they had ever felt physically unsafe in their current position, more women than men reported that they felt unsafe as a result of their gender (30% versus 2%, *p* < 0.001). Finally, women were also more likely than men to report skipping at least one class, meeting, fieldwork, or other professional event per month because they felt unsafe (13% versus 3%, *p* = 0.01).

3.2. Hypothesis 2. Respondents of Color Will Report More Harassment and Assault Than White Respondents

Respondents of color were significantly more likely than white respondents to observe remarks that were racist (from peers and others, *p* = 0.0001 and 0.023) or homophobic (from supervisors, *p* < 0.0001, Table 4, see supporting information Table S2 for all analyses). Respondents of color were also significantly more likely than white respondents to report that they experienced both verbal and physical harassment because of their race. When asked if they had ever felt physically unsafe in their current position, more respondents of

Table 4. Comparison of Remarks Observed by Participants of Color and White Participants

Category		Never	Rarely	Sometimes	Often	<i>p</i>
<i>Remarks From Peers</i>						
Racist remarks	People of color (<i>n</i> = 66)	42% (28)	30% (20)	26% (17)	2% (1)	0.001*
	White or European American (<i>n</i> = 354)	57% (202)	34% (119)	8% (29)	1% (4)	
<i>Remarks From Supervisors</i>						
Homophobic remarks	People of color (<i>n</i> = 64)	91% (58)	2% (1)	6% (4)	2% (1)	<0.001*
	White or European American (<i>n</i> = 352)	91% (321)	8% (29)	0% (1)	0% (1)	
<i>Remarks From Others</i>						
Racist remarks	People of color (<i>n</i> = 66)	32% (21)	38% (25)	27% (18)	3% (2)	0.023*
	White or European American (<i>n</i> = 350)	46% (162)	38% (132)	15% (52)	1% (4)	

*Significance set at 0.025 for two-tailed analyses.

Table 5. Frequency of Hearing Negative Comments Related to Religion or Lack Thereof From Peers

	Never	Rarely	Sometimes	Often	<i>p</i> Value
Trainee (<i>n</i> = 226)	30% (68)	32% (72)	30% (66)	9% (20)	<0.0001*
Staff (<i>n</i> = 109)	47% (51)	24% (26)	22% (24)	7% (8)	
Senior staff (<i>n</i> = 118)	53% (63)	31% (37)	12% (14)	3% (4)	

*Significance set at 0.025 for two-tailed analyses.

color reported they felt unsafe as a result of their race (24% versus 1%, $p < 0.001$). Respondents of color and white respondents reported similar frequencies of skipped classes, meetings, fieldwork, or other professional events per month because they felt unsafe (15% versus 9%, $p = 0.08$).

3.3. Hypothesis 3. Trainees Will Report More Harassment and Assault Than Those Scientists of a Higher Rank

Trainees were significantly more likely than staff or senior staff scientists to observe remarks from peers disparaging religion or a lack thereof ($p < 0.001$; Table 5, see supporting information Table S3 for all analyses); no other forms of remarks were differently observed by rank. Trainees were significantly more likely than staff or senior staff scientists to report that they experienced verbal harassment because of their gender ($p = 0.025$); no differences by rank were found for other forms of verbal harassment, and none were found for any form of physical harassment. Trainees (7%) were more likely than staff (2%) or senior staff scientists (3%) to report that they felt unsafe in their current position because of their race, but this finding was not statistically significant ($p = 0.066$). Respondents across ranks reported similar frequencies of skipping a class, meeting, fieldwork, or other professional event because they felt unsafe.

3.4. Hypothesis 4. Women of Color Experience Double Jeopardy Where They Are Especially at Risk for Harassment and Assault Compared to White Women or Men of Color

When we broke down the sample of respondents by both gender and race, additional trends emerged. Across most statistically significant analyses, women of color observed the highest frequencies of problematic remarks (Table 6, see supporting information Table S4 for all analyses).

Women of color were the most likely to experience verbal harassment related to their race (35%, $p < 0.001$), and women of color and white women experienced verbal harassment related to gender equally (44% and 43%, respectively, $p < 0.001$). Among the four categories, women of color and white women were also the most likely to experience physical harassment related to gender, though this comparison was not quite significant (16% and 11%, respectively, $p = 0.027$).

Women of color were the most likely to feel unsafe in their place of work due to their race (28%, $p < 0.001$), gender (40%, $p < 0.0001$), and religion, though this last comparison was not significant (13%, $p = 0.069$, Figure 1). Finally, women of color and white women both report significantly higher frequencies of skipping a class, meeting, fieldwork, or other professional event because they felt unsafe. (18% and 12%, respectively, $p = 0.024$, Table 7).

4. Discussion

4.1. Workplace Experiences Vary With Gender, Race, and Rank: Hypotheses 1–3

We assessed the extent to which survey respondents in the astronomical community experience a hostile workplace environment and tested four hypotheses on the ways in which these experiences are related to gender, race, and career rank. Our results suggest that there is not only a hostile climate in the astronomical community but that the community is experienced differently depending on one's gender and race.

We hypothesized that women and trainees would both be at particular risk of harassment and assault (Hypotheses 1 and 3). Both were at least partially supported. Women were more likely than men to observe negative remarks across several categories, and trainees were more likely than scientists or senior scientists to observe negative remarks on religion or a lack thereof. Women and trainees were both significantly more likely to report experiencing verbal harassment. Women, but not trainees, reported higher rates of physical harassment. The ways in which women and trainees do report observing more negative remarks and

Table 6. Comparison of Remarks Observed by Women of Color, White Women, White Men, and Men of Color

Category		Never	Rarely	Sometimes	Often	p
<i>Remarks From Peers</i>						
Racist remarks	WW (n = 237)	52% (124)	38% (90)	8% (19)	2% (4)	0.0001*
	WOC (n = 47)	34% (16)	34% (16)	30% (14)	2% (1)	
	WM (n = 114)	68% (77)	25% (28)	8% (9)	0% (0)	
	MOC (n = 17)	71% (12)	18% (3)	12% (2)	0% (0)	
Sexist remarks	WW (n = 236)	22% (52)	37% (87)	35% (83)	6% (14)	<0.001*
	WOC (n = 47)	17% (8)	47% (22)	26% (12)	11% (5)	
	WM (n = 114)	37% (42)	43% (49)	19% (22)	1% (1)	
	MOC (n = 17)	53% (9)	24% (4)	24% (4)	0% (0)	
Comments not masculine/feminine enough	WW (n = 234)	51% (120)	28% (65)	18% (42)	3% (7)	<0.001*
	WOC (n = 46)	41% (19)	37% (17)	15% (7)	7% (3)	
	WM (n = 114)	72% (82)	25% (28)	4% (4)	0% (0)	
	MOC (n = 17)	71% (12)	24% (4)	6% (1)	0% (0)	
<i>Remarks From Supervisors</i>						
Sexist remarks	WW (n = 235)	56% (131)	23% (55)	16% (37)	5% (12)	0.0001*
	WOC (n = 47)	55% (26)	21% (10)	19% (9)	4% (2)	
	WM (n = 114)	76% (87)	19% (22)	4% (5)	0% (0)	
	MOC (n = 15)	67% (10)	27% (4)	7% (1)	0% (0)	
Comments not masculine/feminine enough	WW (n = 235)	79% (185)	12% (29)	7% (16)	2% (5)	0.01*
	WOC (n = 46)	67% (31)	20% (9)	7% (3)	7% (3)	
	WM (n = 114)	92% (105)	6% (7)	2% (2)	0% (0)	
	MOC (n = 15)	100% (15)	0% (0)	0% (0)	0% (0)	
<i>Remarks From Others</i>						
Sexist remarks	WW (n = 232)	13% (30)	31% (71)	45% (104)	12% (27)	<0.001*
	WOC (n = 47)	28% (13)	30% (14)	30% (14)	13% (6)	
	WM (n = 114)	30% (34)	46% (53)	22% (25)	2% (2)	
	MOC (n = 16)	19% (3)	44% (7)	31% (5)	6% (1)	
Comments not masculine/feminine enough	WW (n = 233)	40% (93)	36% (84)	19% (45)	5% (11)	<0.001*
	WOC (n = 46)	43% (20)	33% (15)	17% (8)	7% (3)	
	WM (n = 112)	71% (79)	23% (26)	5% (6)	1% (1)	
	MOC (n = 17)	59% (10)	35% (6)	6% (1)	0% (0)	

*Significance set at 0.025 for two-tailed analyses.

experiencing more harassment match other recent studies of academic science [Clancy *et al.*, 2014]. Our work also aligns with the increasingly overwhelming evidence from workplace climate literature that women and people who are more junior in the hierarchy are at greater risk for incivility, discrimination, and harassment [Chan *et al.*, 2008; Hershcovis and Barling, 2010]. However, our results on the particular impact climate, verbal harassment, and physical harassment play on the trainee role was weaker than what has been found in other work, and in general, the supervisor role was not as responsible for making negative remarks or perpetuating harassment and assault. We consider two possibilities for this difference. First, we attribute the lower reports of supervisor abuse in part to the fact that hostility from peers is a cultural norm within astronomy and planetary science. We found that the overall proportion of negative comments witnessed was incredibly high, with remarks coming from peers observed by 96% of women of color, 91% of white women, 88% of men of color, and 75% of white men, contrasted with slightly lower findings of remarks coming from supervisors: they were reported by 62% of women of color, 55% of white women, 47% of men of color, and 35% of white men. Similar findings occurred when combining all categories of verbal and physical harassment. Second, we also consider the possibility that the sampling method of reaching out through professional societies might have led to undersampling of trainees, particularly trainees that may feel withdrawn or disengaged from the discipline due to negative experiences. It is important to note that while rank effects were not as strong as expected in this sample, there may still be ways in which power differentials contribute to the ways in which individuals experience incivility and harassment in their workplace [Ashburn-Nardo *et al.*, 2014; Cleveland and Kerst, 1993; Popovich and Warren, 2010].

Hypothesis 2, that respondents of color would be more likely to report harassment and assault than white respondents, was also supported. Respondents of color were more likely than white respondents to observe remarks on racism and homophobia. People of color were also significantly more likely to report physical

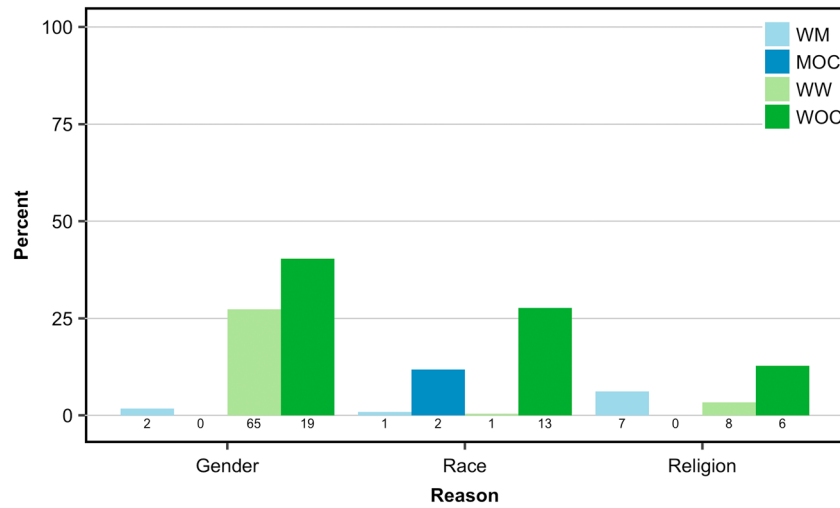


Figure 1. A significant difference exists in the percent of individuals in each category who have felt unsafe at their current position due to gender ($p < 0.001$) and race ($p < 0.001$), and there is a trend toward differential experiences with feeling unsafe due to religion or lack thereof ($p = 0.069$). Light blue is white men (WM), dark blue is men of color (MOC), light green is white women (WW), and dark green is women of color (WOC). Numbers at the bottom are the raw count for each category.

harassment related to their race. Again, these data are in accordance with the broader literature that suggests a more hostile climate in academia and the workplace for people of color [Berdahl and Moore, 2006; Raver and Nishii, 2010; Sue, 2010; Sue et al., 2007a, 2007b; Williams et al., 2016]. As far as we know, while other studies referenced throughout this paper have focused on racial discrimination, this is the first report of its kind to specifically address racial physical harassment in academic science. Because the number of people of color in astronomy and planetary science is so small, reports of such abuses may be infrequent, leading to the idea that it is a rare occurrence in this discipline. However, the evidence from this sample suggests that it is occurring in a significant proportion of astronomers of color (24%), meaning that it can have a profound effect on those smaller numbers.

4.2. Double Jeopardy for Women of Color: Hypothesis 4

Comparing women of color, white women, white men, and men of color revealed an even starker picture in support of Hypothesis 4. Across nearly every comparison, women of color experienced the most hostile environment, from the negative remarks observed to their direct experiences of verbal and physical harassment. These findings are consistent with workplace literature that places women of color in double jeopardy, as they occupy a space of being at greater risk of both gendered and racialized harassment [Berdahl and Moore, 2006; Carter, 1988; Cortina et al., 2013]. Women of color have been pointing out the effects of oppression of intersecting gender and race identities for decades [e.g., Carter, 1988; Gutiérrez y Muhs et al., 2012; Hull et al., 1982; Moraga and Anzaldúa, 1981; Prescod-Weinstein, 2014, 2015; Turner, 2002]. Women of color in academia report being “defined out” based on their identities rather than being “defined in” [Turner, 2002]. Their work has pushed scholarly awareness of the physical, mental, personal, and career tolls that the double jeopardy of being a woman of color takes. At the same time, it is important to point out that rather than simply viewing the effects of double jeopardy as additive, it may be more useful to understand the ways in which those with multiple subordinate-group identities might also experience different kinds of

Table 7. Number of Events at Current Position Skipped Due To Feeling Unsafe

	0	1–2	2–3	4–5	6 or More
WW ($n = 230$)	88% (202)	9% (21)	2% (4)	0% (1)	1% (2)
WOC ($n = 44$)	82% (36)	9% (4)	2% (1)	0% (0)	7% (3)
WM ($n = 112$)	98% (110)	1% (1)	1% (1)	0% (0)	0% (0)
MOC ($n = 17$)	94% (16)	6% (1)	0% (0)	0% (0)	0% (0)

oppressions to those with a single subordinate-group identity [Buchanan et al., 2009; Purdie-Vaughns and Eibach, 2008]. To this end, one limitation of our data collection was our inability to oversample women of color and thus be able to compare the varying experiences they may have had based on different racial-ethnic identities; this is a fairly robust finding across other, similar studies [Hurtado and Figueroa, 2013; Ko et al., 2013, 2014; Norman et al., 2013; Rios and Stewart, 2015; Towns, 2010; Williams et al., 2016].

Women of color in this sample observed higher rates of not only negative gender and race remarks but also negative remarks that one is not masculine or feminine enough, or about physical ability. Women of color observed the highest frequencies of most of the other types of negative remarks, though not all of these differences were statistically significant. That is, either majority group individuals feel more comfortable sharing inappropriate or oppressive opinions in the presence of women of color, or women of color, as those who occupy a double subordinate-group identity, are more attuned to problematic remarks even when those remarks are not targeted at their own identity groups.

Women of color also tend to be the direct targets of gender and racial discrimination [Buchanan et al., 2008, 2009; Higginbotham and Weber, 1999; Jean and Feagin, 1998]. In the astronomical community, women of color are present in very small numbers—for instance, the most recent National Science Foundation report shows that only 6.5% of physical science bachelor's degrees are obtained by minority women [NSF, 2015]. This leads to two major problems with community perceptions of racial abuse. First, it may be less apparent to the broader community the toll this high proportion of targeting takes on women of color [e.g., Buchanan and Fitzgerald, 2008; Sojo et al., 2016]. Second, social support, one of the best protections against the toll discrimination and harassment takes [Hunter and Lewis, 2010; Mossakowski, 2003; Prelow et al., 2006], is less possible when you are the only, or one of a few, woman of color in your department or program. The smaller numbers of women of color in astronomy and planetary science gives them substantially less power than those with majority group identities, which is another element that may contribute to their greater rates of harassment [Ashburn-Nardo et al., 2014; Cleveland and Kerst, 1993; Popovich and Warren, 2010].

4.3. Career Consequences to Hostile Climate, Harassment, and Abuse

A related finding to that of the incidence of negative remarks, harassment, and assault was the extent to which respondents felt unsafe at their jobs, or had even avoided professional opportunities as a result of feeling unsafe. Those who skipped school or work events due to feeling unsafe were more likely to have witnessed negative remarks from supervisors or peers, experienced verbal harassment, experienced physical harassment, or felt unsafe at work. A full 40% of women of color in our sample, and 27% of white women, reported that they had felt unsafe in their current career position due to gender; further, 28% of women of color reported feeling unsafe in their current position due to race. Significant proportions of women compared to men, as well as men and women of color compared to white men and white women, reported that they had ever skipped a class, meeting, fieldwork, or other professional event because they did not feel safe. This represents a significant failure in the astronomical community to create safe working conditions for all scientists. What is more, these data suggest that this failure has led to the loss of professional opportunities for women generally and men and women of color.

The differences in remarks observed, harassment and assault experienced, and workplace safety by certain constituents of this sample of the astronomical community are consistent with the barriers already identified by astronomers of color. Norman et al. identified the following nine barriers for women of color in astronomy and astrophysics: (1) difficulty building networks/collaborations, (2) difficulty achieving insider status, (3) lack of effective mentoring, (4) unfavorable department climate and lack of support, (5) cultural alienation, (6) hostility, (7) accumulation of disadvantage and underestimation of performance, (8) solo status/lack of critical mass in job searches, and (9) stereotype threat [Norman et al., 2013, pp. 160–161]

In particular, women of color respondents' reports of negative remarks, verbal harassment, physical harassment, and feeling unsafe in their workplace can directly affect their ability to build networks, achieve insider status/increase their power, and receive mentoring. A hostile climate keeps numbers low for women and people of color generally, and women of color especially, which increases the risk of stereotype threat [Steele, 1997; Steele and Aronson, 1998], underestimation of performance [Keller and Dauheimer, 2003; Nielsen, 2015; Shapiro and Williams, 2012], and a lack of critical mass in job searches [Valian, 1998]. Thus, should the astronomical community feel both a scholarly and ethical commitment to improving inclusion

and equity measures in their disciplines, they need to directly address the lived experiences of those individuals with subordinate group status.

The accumulation of even minor distresses across the work day can, over time, have profound physical and mental consequences [Loi *et al.*, 2015]. Discrimination and harassment have been found across several other studies to increase inflammation, waist circumferences, psychosocial distress, and physical pain [Barling *et al.*, 1996; Beatty Moody *et al.*, 2014; Flores *et al.*, 2008; Lewis *et al.*, 2011, 2010; Mays *et al.*, 2007; McClure *et al.*, 2010; Stock and Tissot, 2012]. Several recent meta-analyses of counterproductive work behaviors demonstrate a relationship between harassment and negative health and work outcomes [Chan *et al.*, 2008; Hershcovis and Barling, 2010]. In particular, studies of workplace behaviors have shown that those receiving negative feedback in line with negative stereotypes display more disengagement [Major *et al.*, 1998], and those targeted for harassment express greater job turnover intentions [Cortina *et al.*, 2013]. This is especially true among women of color, the most targeted group. Thus, the disproportionate gender- and race-based harassment experienced by women of color in astronomy and planetary science represents a clear condition under which women of color are less likely to have social support, less likely to feel engaged in the workplace, and less likely to wish to stay. Rather than seeing the dearth of women of color in the astronomical community as a passive circumstance, these data indicate that their numbers are at least in part a result of being pushed out by hostile workplace experiences.

4.4. Seeking Solutions

Norman *et al.* [2013], Cortina *et al.* [2013], and Clancy *et al.* [2014] suggest solutions to the hostile workplace climate faced by women of color, men of color, and white women. These solutions are multilevel, and no one solution alone will sufficiently improve the hostile workplace climate. First, a code of conduct or other education on appropriate work behavior should be required of all trainees and employees at all levels [Clancy *et al.*, 2014; Cortina *et al.*, 2013]. Second, diversity and cultural awareness training is necessary to raise awareness and understanding of the problems faced by women of color and other underrepresented groups [Norman *et al.*, 2013]. This training should include interpersonal skills training in order to help scientists understand expectations of appropriate behavior toward others [Cortina *et al.*, 2013]. Third, leaders in the discipline and in individual programs need to model appropriate behavior and define an inclusive, equitable culture for their workplaces, disciplines, and professional societies [Clancy *et al.*, 2014; Cortina *et al.*, 2013; Settles *et al.*, 2006]. Finally, when abuses are reported, “instigators should be swiftly, justly, and consistently sanctioned” [Cortina *et al.*, 2013, p. 1600] as this is the only way to signal consequences to the target and the broader community. Norman *et al.* also point out several important initiatives to increase numbers for women of color, which should also help lessen the hostile workplace climate: build cohorts of women of color graduate students to enable the creation of peer networks; encourage fair hiring practices to minimize implicit bias; and, incentivize departments and individuals who support women of color [Norman *et al.*, 2013].

At this time, we want to remind the reader that the findings of this study cannot be attributed to events from long ago: respondents were asked to only report experiences they had had in their current career position over the last 5 years. The events and experiences reported in this survey happened between 2011 and 2015. Further, a recent meta-analysis of 343 studies demonstrated a significant response bias such that people are far less likely to agree to participate in counterproductive workplace behavior research, which tends to lead to the underreporting of negative experiences [Greco *et al.*, 2015]. Therefore, it is imperative that readers from the astronomical community recognize that this is a current problem, with ongoing effects for those witnessing and targeted by hostile workplace behaviors, and that these problems may be arising in their programs and workplaces whether or not they are personally aware of them.

In that spirit, we conclude with the following recognition: never has awareness of hostile workplace behaviors in the sciences been so strong, and the possibility for change so great. We are living in a time when advances in the culture of science could match the advances in science and technology. This should lead to an increase in the diversity of questions we ask, hypotheses we test, in the way we interpret our data, and the priorities we make in our disciplines. These data point to a problem, but they also point to a solution. More than ever before, we have the opportunity to create conditions for the best possible science to happen.

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Erratum

In the previously published version of this paper, a sentence in Section 3.4 was incorrectly typeset as: "Finally, men of color and women of color both report significantly higher frequencies of skipped classes, meetings, fieldwork, or other professional events per month because they felt unsafe (21% and 18%, respectively, $p = 0.023$, Table 7)." However, the text should read, "Finally, women of color and white women" and the values should be "(18% and 12%, respectively, $p = 0.024$, Table 7)." This error has since been corrected and this may now be considered the authoritative version of record.