Astro2020 APC White Paper:
Training the Next Generation of OIR Instrumentalists

Thematic Area:
State of the Profession Considerations

Corresponding Author:
Jessica R. Lu (UC Berkeley; jlu.astro@berkeley.edu)

Co-authors:
Michael Fitzgerald (UCLA),
Richard Dekany (Caltech),
Shelley Wright (UC San Diego),
Sarah Tuttle (University of Washington),
Marshall Perrin (STScI),
Cynthia Froning (UT Austin),
Jennifer Lotz (Gemini Observatory),
Lisa Hunter (UC Santa Cruz),
Laird Close (University of Arizona),
Katie Morzinski (University of Arizona),
Nicholas McConnell (UC Santa Cruz),
Claire Max (UC Santa Cruz),
Quinn Konopacky (UC San Diego),
Vanessa Bailey (JPL/Caltech),
Erika Hamden (University of Arizona),
Renate Kupke (UC Santa Cruz),
Christoph Baranec (University of Hawaii),
Phil Hinz (UCSC),
Mark Chun (University of Hawaii),
Jared Males (University of Arizona),
Michael Bottom (University of Hawaii)

We present a white paper submission on the state of professional development and education in adaptive optics and, more broadly, optical and infrared instrumentation in the US. Specifically, we address two factors that negatively affect the astronomical instrumentation workforce in the US: (1) a shortage of adaptive optics (AO) scientists and instrumentalists and (2) a lack of diversity in optical/infrared (OIR) instrumentation overall.

Key Issue and Overview of Impact on the Field

US Leadership in Adaptive Optics Begins with Training

Astronomy and astrophysics is very much a technology-driven field; each time a new telescope or instrument is built, unanticipated discoveries emerge. Adaptive optics (AO) has been one of these transformational technologies as it has enabled ground-based telescopes to realize their full potential and image at their diffraction-limit. AO development has led to the discovery of the supermassive black hole at the Galactic Center, the first images and spectra of extrasolar planets, and direct evidence for the existence of dark subhalos as predicted by cold dark matter models. AO is increasing in importance thanks to (1) new flavors of AO that will deliver spatial-resolution improvements over larger fields of view and over a broader range of optical and infrared wavelengths, (2) the use of wave-front sensing and active optics in future large space telescopes (JWST, WFIRST, LUVOIR, HabEx), and (3) the advent of larger (20-40 m) ground-based telescopes that are being built with AO at first light.

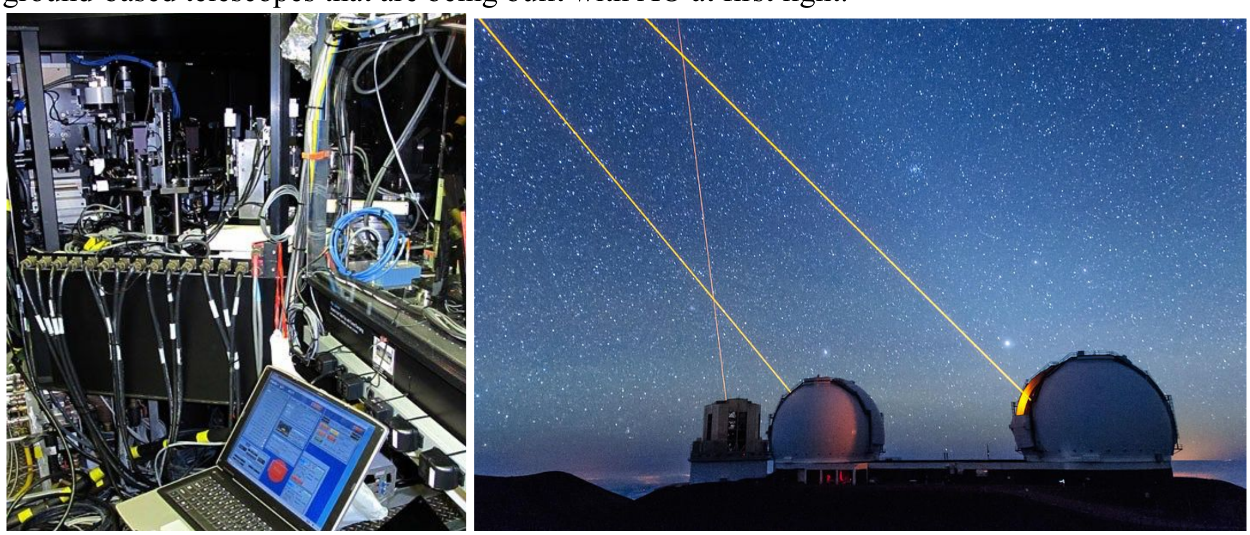

Figure: Adaptive Optics systems are complex to design, build, and operate as shown on the *left* for the Keck laser-guide star AO system. Yet they are essential to maximize the science impact of large ground-based OIR telescopes as shown on the *right* where all of the large 8-10 m class telescopes on Maunakea routinely utilize LGS AO. The field of AO instrumentation has enormous room to innovate as our current AO systems are still not fully optimized nor have many theoretical AO concepts been verified experimentally. Image credits: Andrew Cooper (left), Jason Chu (right).

Despite the importance of AO instrumentation and technology development to US astronomy, the US does not train a sufficient number of AO scientists to fulfill the AO needs of US telescopes now and into the future. In large part, this is due to limited funding for AO, and also

AO systems being designed and built at the telescopes themselves (e.g. Keck AO, Gemini MCAO, TMT AO, GMT AO). Note that most of these AO systems were designed and constructed primarily by permanent engineers and staff and possibly a few postdocs. Relatively few undergraduate or graduate students were involved.

Only a few AO systems have been built in whole or in part at US university labs where students have extensive opportunities to participate (e.g. Gemini Planet Imager, Robo-AO at Caltech and UH, Magellan AO and LBTI AO at U of Arizona, Lick AO at UCSC). This stands in contrast to other countries where nearly all AO projects are being developed with the active participation of students and postdocs even in large-scale projects (e.g. TMT AO at NRC in Canada, VLT and E-ELT AO at universities across France and Italy, Gemini MOAO at Dunlap Institute/U Toronto in Canada, GeMS MCAO and some Keck AO at ANU in Australia, GRAVITY AO at MPE in Germany). As a result, it is difficult to hire AO scientists at US universities and telescopes and frequently we must hire from Europe or Canada instead. In the longer term, this also puts the US at a competitive disadvantage as much of the AO technology innovation is still performed abroad in labs affiliated with universities where access to students and postdocs allows for easier exploration of new ideas.

Innovative Instrumentation is Enhanced by a Diverse Workforce

More broadly, the field of astronomical instrumentation sits at the intersection of science, technology, and engineering and benefits from cross-disciplinary and diverse ideas. Unfortunately, those who work in this field are not as diverse.

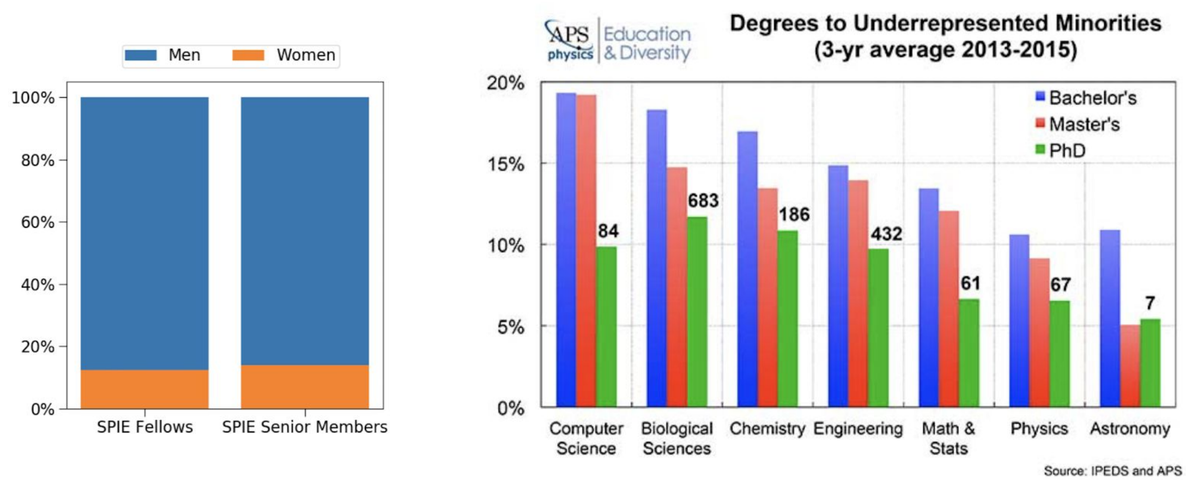

Figure 1: *(Left):* We have compiled the fraction of women elected as SPIE Fellows (all career levels) and SPIE Senior Members in 2017-2018 is <20%, which is well below the level of women in astronomy as a whole (34%, [1]) and in the US population (50%). *(Right):* The fraction of underrepresented minorities in instrumentation can be estimated as the average over physics, engineering, and astronomy, which is <10% and well below the 32% of URMs in the US [2].

While rigorous statistical studies of gender and race/ethnicity do not exist for this sub-field of astronomy, there are several useful proxies we can examine (Tuttle 2018, d'Orgeville et al. 2014, Women in Astronomy 2008). For instance, we calculated that the fraction of women elected to be Fellows and Senior Members of the SPIE (the professional society that encompasses astronomical instrumentation, optics, and photonics) is ~15% (Figure 1), less than half the fraction in astronomy as a whole. Similar data doesn't exist for race/ethnicity in SPIE membership; however, the number of URMs employed by the Association of Universities for Research in Astronomy (the parent organization for the Gemini Observatory, National Optical Astronomy Organization, National Solar Observatory, the Large Synoptic Survey Telescope, and the Space Telescope Science Institute) in science, engineering, and technical positions is only 9% (Figure 2) compared with 32% of the URMs in the U.S. population (NSF NCSES Study 2018). The fraction of women employed by AURA in science, engineering, and technical positions is 26%.

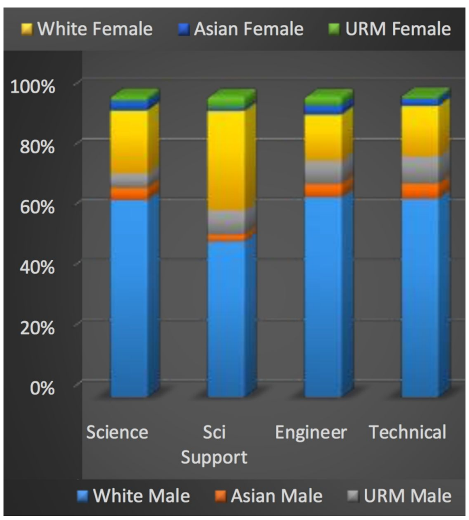

Figure 2: Representation of women and URMs at AURA, which is the parent organization for many astronomical observatories, including Gemini, NOAO, NSO, LSST, and STScI. Within the science, engineering, and technical fields, ~9% of AURA employees are from URM groups and 26% are women. Plot modified from the 2016 AURA Diversity Study [7].

Broadening participation in astronomical instrumentation (and all STEM fields) is a challenging problem that needs more than just attracting underrepresented groups into the field (Mercury Newsletter 1992, Dahlroos 2016. Research-informed strategies that support retention and advancement in the field are also needed (Ivie et al. 2016). Increasingly, studies are pointing to the importance of changing how the STEM community teaches and mentors, as well as how they interact in the workplace, in order to make STEM more diverse and inclusive (NRC Report 2013). Research indicates that there are many ways that teaching can be more inclusive (Tanner 2013), including thorough support of the affective aspects of learning and participating in STEM (e.g., self-efficacy, belongingness, identity; (Trujillo & Tanner 2014). Similarly, there is a growing body of evidence that training is needed for educators and professionals to be more inclusive in teamwork and collaboration. For example, gender studies have documented that women experience reattribution of their ideas much more often than men: i.e., an idea suggested by a woman is overlooked, but the idea is then taken up when repeated by a man (Williams et al. 2014). In summary, research in the social sciences can inform how we teach, train, and mentor today's students. In training the next generation of instrumentalists, we should use strategies emerging from this research to create an inclusive and equitable training program focusing on undergraduates and early graduate students to increase participation of women and other underrepresented groups in astronomical instrumentation.

Strategic Plan

In order to address the US shortage of AO scientists as well as underrepresentation of women and minorities in the broader OIR instrumentation field, we advocate for increased support for training and mentoring the next generation of adaptive optics and OIR instrumentalists. Such support could come in the form of

(1) internship and visiting scholars programs at labs and observatories,

(2) student training supplements in NSF and NASA funding of large instrumentation projects,

(3) travel awards for Jr. scientists to attend SPIE or other instrumentation-focused conferences,

(4) summer schools aimed at undergraduate and graduate students,

(5) use of inclusive and equitable training methods in instrumentation courses,

(6) retention and advancement of women and underrepresented minorities in the field with instrumentation-inclusive grad and postdoc fellowships, and

(7) training programs for instrumentalists that establish inclusive professional practices.

Many of the above recommended programs already exist; but are inadequately funded. For instance, Keck has a visiting scholar program; but it is supported with a minimal travel budget and no salary/stipend. Research advisors may be hesitant to have students work on observatory instrumentation projects unrelated to the primary funding. Furthermore, many of the visiting scholar programs are too short to make significant contributions to an instrumentation project.

A few instrumentation summer schools exist in the US (the Center for Adaptive Optics summer school); however they tend to target graduate students and postdocs and are very expensive for attendees outside of the local institutions (i.e. University of California for the CfAO summer school). We advocate for summer schools to establish explicit equity and inclusion objectives in addition to their instrumentation content goals. Establishing more inclusive professional practices within instrumentation will require working with researchers specifically specializing in diversity and inclusion. This includes using validated, tested methods to increase access and provide support to underrepresented populations.

Transitioning students from summer schools to instrumentation-focused research requires projects with funding that can support student. While NSF and NASA instrumentation grants allow student support, it is not explicitly required and the financial pressures are such that more efficient, senior labor is often preferred. We recommend that NSF and NASA instrumentation calls for proposals identify student training in instrumentation as a review criteria for all projects, large and small.

Overall, we believe the recommendations above are essential for building a larger pool of excellent and diverse adaptive optics and OIR instrumentationalists in the US and fostering the next-generation of innovative astronomical instrumentation over the long-term.