Astronomy-driven Careers in the 2020's

An Astro2020 Decadal Survey *State of the Profession Consideration* White Paper

Respectfully submitted by the members of the
American Astronomical Society's Committee on Employment (AAS CoE)
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Overview: The structure of U.S. graduate education has a natural tendency to produce more astronomy and astrophysics PhDs than available academic positions. In the past decade, this ratio has tipped further out of balance. As a result of this imbalance, combined with a wide range of additional factors that enter into career decisions, more astronomers are moving out of "traditional" academic and/or research career paths than in the previous decade. We address the specifics and implications of this trend as we consider the employment prospects of those with advanced degrees in astronomy and astrophysics, both within and outside academia, over the coming decade. We conclude with recommendations for commitments of resources by the U.S. astronomical community aimed at ensuring there continues to exist a robust, diverse set of career options for those with graduate training in astronomy and astrophysics in the 2020s.

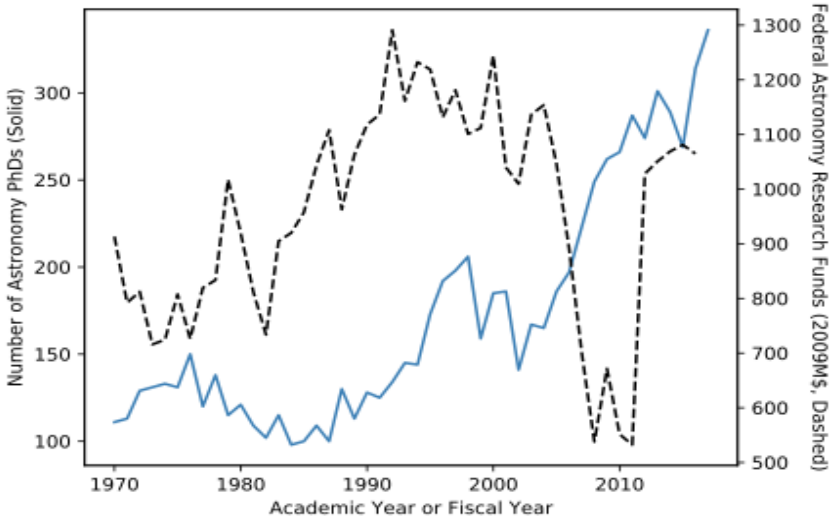

Figure 1: Number of PhDs awarded in Astronomy and Astrophysics according to the National Center for Science and Engineering Statistics (blue line), and total federal spending on astronomy research (of which ~ 75% is via NASA), adjusted for inflation to real 2009 dollars (dashed black line).

Degrees Awarded: The past few years have seen a notable jump in the number of PhDs awarded in astronomy and astrophysics, rising from about ~ 220 doctorates per year in the mid-to-late 2000s to a record-breaking 336 in 2017 (Figure 1).[1] Of those 336, 91 (27%) were temporary visa holders.[2] Unlike the similar rise seen in the 1990's, this rise has not been accompanied by a commensurate increase in federal astronomy

[1] National Center for Science and Engineering Statistics (NCSES), https://ncses.nsf.gov/pubs/nsf19301/data (Table 13). AIP statistics are lower because NCSES numbers include astronomy PhDs from physics departments.
[2] NCSES, https://ncses.nsf.gov/pubs/nsf19301/data (Table 22).

research funding; instead, federal spending in real dollars has been slightly decreasing since the 1990's, with a recent recovery from a significant dip during the 2008 financial crisis and subsequent years.[3]

Bachelors degrees in astronomy have also risen sharply in the past decade, from about 330 in the mid-2000s to an also-record-breaking ~ 530 in 2017.[4] For the classes of 2010-2012, about half went on to graduate studies (23% to astronomy/astrophysics, 16% to physics, and 12% to other fields).[5] Of course, graduate astronomy programs also recruit students from bachelor's degrees in physics and other fields.

Availability of Positions: To collect data concerning the availability of positions in astronomy, we examined job postings on the AAS Job Register from 2003-2019 (thereby building on the study by Metcalfe 2008[6]). For jobs posted from June 2016 - May 2019, we also collected the country location of each job posting, as the "Foreign" category is not used consistently among job posters; for earlier years, we estimated the number of foreign postings based entirely on those employers who self-designated as such. This is an underestimate of foreign postings for year 2015 and earlier.

Use of AAS Job Register data to assess the number of job postings involves some caveats. These data can overestimate the number of positions available in various ways: some searches are failed or postponed, and some represent a shuffling of senior faculty between institutions. On the other hand, some job postings included multiple openings (e.g. fellowships) in one advertisement, which would increase the total number available. Job postings also do not necessarily include long-term soft-money employment and provide an incomplete listing of foreign positions.

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[3] NCSES, Survey of Federal Funds for Research and Development, https://nsf.gov/statistics/srvyfedfunds/#, tables titled "Federal obligations for research, by detailed field of science and engineering." Adjusted for inflation using Office of Management and Budget Fiscal Year 2017 Historical Tables, https://www.govinfo.gov/content/pkg/BUDGET-2017-TAB/pdf/BUDGET-2017-TAB.pdf.
[4] American Institute of Physics (AIP) Statistical Research Center (SRC), https://www.aip.org/statistics/reports/women-physics-and-astronomy-2019 (Figure 7)
[5] AIP Statistical Research Center, Astronomy Degree Recipients Initial Employment (April 2015), https://www.aip.org/sites/default/files/statistics/employment/initialempbsmsphd-a-12.pdf (Figure 1)
[6] Metcalfe, T.S. The Production Rate and Employment of Ph.D. Astronomers, *Publ. Astron. Soc. Pacific*. **120**, 229-234 (2008).

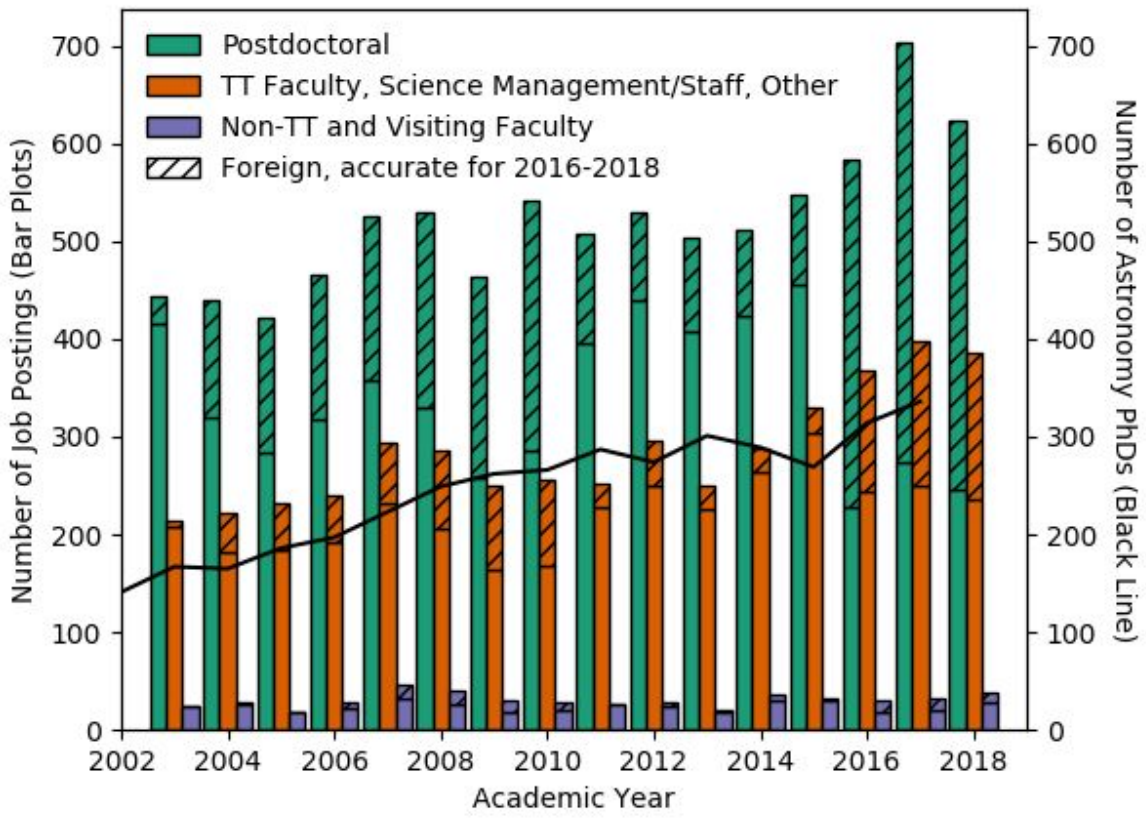

Figure 2: Number of postings in the AAS Job Register by academic year (June - May). For each year, the postdoctoral category is shown first in green, followed by a combination of potentially permanent positions that include tenure and tenure-track faculty positions, science management, science engineering, scientific/technical staff, and other (all in orange). The final (purple) bars represent visiting and non-tenure faculty positions, which are a mix of temporary and potentially permanent. Hatched regions represent foreign job ads, which are *only* accurately represented for the 2016-2018 academic years. Other years rely on the institute classification "Foreign," which is generally *not* utilized for foreign jobs. The number of astronomy PhDs granted according to the NCSES is also shown as a black solid line (same numerical scale).

In Fig. 2 we display the available Job Register data for 2003-2019, broken down by type and location of position (U.S. vs. foreign). In the three academic years spanning job postings from June 2016 through May 2019, there were an average of ~ 640 postdoctoral positions and fellowships advertised; this is a slight rise from the previous decade of about 500 from the comparable period in 2006-2009. This rise is not comparable to the rise in new PhDs; the ratio of postdoctoral positions to new PhDs has

dropped from ~ 2.3 to 2.0. Moreover, about 60% of the postdoctoral positions advertised on the AAS Job Register over the past 3 years are in foreign locations; in the 2017 academic year there were only 274 postdoctoral job advertisements in the United States, which could only possibly accommodate 80% of the PhD graduates that year (but far fewer in practice, since many astronomers are also applying for a second or third postdoc in any given year). Thus the postdoctoral job market within the US alone is not able to sustain the current number of US PhD graduates. We warn against a reliance on the availability of international positions as it further increases the complexity of the postdoctoral lifestyle. The impact of such residency decisions during the junior career stage likely disproportionately affects women and minorities, for whom leaving the country is less likely to be a viable option due to financial or family commitments (spouse, children, parents).

The overall number of potentially permanent positions advertised on the Job Register (which include tenure-track faculty, science management, science engineering, scientific/technical staff, and other) has slightly increased in the past decade, to ~ 380 per year in the past three years compared to ~ 270 ten years earlier, roughly keeping pace with the increase of new PhDs. About 37% of current job ads in these categories are foreign. About 30-40% of the jobs in these categories are tenure-track faculty jobs, the traditional permanent job for the academic astronomer. Though these faculty members can be partially funded by federal grants, to some extent the continued existence of these jobs depends on state funding, private funding, and tuition revenue. The decline in the US birth rate beginning in 2008 will begin to affect university enrollment in the mid-2020s, and will likely affect elite research schools the least[7].

Trends in Employment Outside of Astronomy: The 2010 Decadal Survey stated that "Although training in astronomy for astronomers is valuable, in practice at least 20 percent of astronomers leave the profession for other careers following the Ph.D., the postdoctoral, and even the faculty/research position level." The available data suggest that this number has been much higher than 20% in the past decade and will continue to rise, given current trends, though it is difficult to determine to any degree of precision how many astronomers currently leave the field. Post-graduation commitments for recent astronomy doctoral graduates are not disaggregated from the much larger physics community for the NCSES Survey of Earned Doctorates. However, in the past decade, the NSF-funded Longitudinal Study of Astronomy Graduate Students (LSAGS[8]) followed all US astronomy graduate students in 2006-2007 with three surveys, conducted in 2007-08, 2012-13, and 2015. The most recent data indicate that the

[7] https://people.carleton.edu/~ngrawe/HEDI.htm See Figures 4.3 and 6.3-6.5.
[8] https://www.aip.org/statistics/lsags

postdoctoral acceptance rate for new astronomy PhDs for the classes of 2014-2016 is ~55%, down from a high of just over 80% a decade earlier, implying that nearly half of new PhDs did not go on to a postdoc position during this period. Of new PhDs that were in a potentially permanent position one year after degree, 32% were in physics or astronomy, and 68% were in another field (computer software/data science, engineering, business/finance, education, other). Given that almost half of newly minted PhDs are not moving on to postdocs, this suggests that a large fraction (perhaps ~30%) of PhD astronomers have already left the field immediately after graduation. The total who then leave after one or two postdoctoral positions is therefore even higher, and will continue to rise so long as the job market remains saturated with PhD graduates. Furthermore, a postdoc position may not be the best choice for newly minted PhDs who have their eyes on non-academic careers[9].

Recommendations for Commitments of Resources

- At present, overproduction of PhDs relative to the number of permanent positions in the academy is essentially built into the system of graduate training. Assuming this basic structure persists, then graduate students should be actively supported in investigating and preparing for alternative careers after earning an astronomy PhD. This support should include recognition -- and rejection -- of the longstanding stigma associated with leaving academia. In fact, the increasingly tight astronomy job market is already forcing a shift in how non-traditional career paths for astronomers are viewed by the community. Professional societies such as the AAS are already leading the way in changing the tenor of the conversation around non-traditional career paths, and are providing much-needed resources to the astronomy community. These career guidance tools and resources should be further developed and broadly disseminated via entities that include the newly initiated AAS “Beyond Astronomy Academe” Task Force and the AAS Committee on Employment as well as via workshops, panels, and other open forums at AAS meetings. In this way, faculty at graduate-degree granting institutions can become (or remain) apprised of the availability of both academic and non-academic career options for their students.
- While support from individual faculty is important, it is not sufficient to prepare graduate students en masse for non-academic career paths, as most university faculty have neither the connections nor requisite experience outside of academia. Graduate programs and departments themselves must adapt to prepare students for a changing job market. The form of this adaptation should

[9] https://www.nature.com/articles/d41586-018-07652-y

be considered thoughtfully but may include changes to graduate curricula, increasing access to career resources, and fostering relationships between academia and the industrial and commercial job sectors. Departments and individual faculty should also maintain their own networks of alumni who have left academia, so as to take full advantage of the potential for career “peer mentoring” represented by these graduates.

- The community should consider whether the PhD need represent the ultimate goal of graduate study in astronomy. Cross-disciplinary masters-level programs (in combination with, e.g., engineering, computer science, management, and/or education) could harness student interest in astronomy while providing MS students with employable skills in astronomy-related fields. In order to conserve resources and time, astronomy/astrophysics departments should be encouraged to reach out to departments at their institutions with an interest in similar skills training or events which explore careers outside of academia. Successes and failures in this endeavor should be shared across the community. Building broader professional development into astronomy graduate programs will enable the astronomy community to better weather changes in federal funding and the job market in the long-term.
- Studies on career outcomes and post-graduate commitments, such as the NSF Survey of Earned Doctorates or successors to LSAGS, should disaggregate post-graduation commitment by detailed field, if they are not already astronomy-focused. Post-graduation commitments outside of the academe should include information about the specific types of industry/private sector employment, so that graduate programs and professional societies can best tailor their training to the types of non-academic jobs that astronomers actually pursue. For example, anecdotally, it is clear that many job seekers with graduate-level training in astronomy are encouraged to pursue (and are pursuing) data science careers, but we presently lack the data necessary to understand the extent to which astronomers switch into this and other careers. Moreover, we lack data to help anticipate and recognize the next major field(s) that may be attractive and well-suited to those with formal astronomy training.
- Post-graduate-school career direction studies should also consider astronomy training in its full global context and gather data on, for example, the rates of new astronomy PhDs granted outside the US, the number of available foreign astronomy positions (both temporary and long-term), and the retention of US-trained graduates within the US. A complete picture of the state of astronomy employment requires this bigger picture given the high rates of international mobility in the field; i.e., a significant percentage of graduate students and postdocs trained in the US relocate elsewhere, and vice versa. Indeed, given the

high percentage of foreign jobs advertised on the AAS Job Register, it is possible that a significant portion of federal funds spent on graduate training do not result in graduates who are able to secure employment in astronomy in the US.

- Finally, we emphasize that real long-term improvement in the "traditional" (academic/research) astronomy job market will require stronger commitments for astronomy and astrophysics research and education funding from federal and state funding agencies and philanthropic organizations. We echo the call of the "Employment and Funding in Astronomy" white paper from the previous decadal survey, which noted that the over-investment in early career temporary jobs at the expense of longer-term positions has created an employment path that reduces the diversity of the field and fails to attract and retain the best astronomers.[10]

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[10] https://sites.nationalacademies.org/BPA/BPA_049492