Department of Astronomy
2022 Self-Study

Natural Sciences Division

College of Arts and Sciences

University of Washington

Degrees Offered:

Doctor of Philosophy

Master of Science

Bachelor of Science

Department Chair: Thomas Quinn

Year of Last Review: 2010-2011

Date Submitted: August 29, 2022

Table of Contents

PART A: Background Information

Section I: Overview of Organization Mission & Structure

The Department of Astronomy in the College of Arts and Sciences (CAS) at the University of Washington (UW Astro) aims to carry out fundamental scientific studies of the contents, characteristics, and evolution of our Universe; to educate and train students in the principles and practice of Astronomy; and to share the natural wonders of the cosmos with the general public, both in Seattle and across the state of Washington. We employ a wide range of tools in our research work: telescopes (both ground- and space-based), data analysis and data mining, scientific instrument and survey development, numerical simulations, and theoretical studies. We prepare our students for careers in research, teaching and industry. We strive to broaden participation in Astronomy through education, research, and outreach, and to make it an inclusive, respectful, and welcoming field of study in which all department members are empowered to achieve their career goals.

The department has grown significantly in the last decade since our last review (see Appendix E), with success in both our teaching and research missions . We have seen a large increase in undergraduate credit hours, while student satisfaction has remained very high. We have turned into a research powerhouse thanks in part to our early investment in the Vera Rubin Observatory (formerly known as LSST) and founding of the Data intensive Research in Astrophysics and Cosmology (DiRAC). We continue to foster a thoughtful and welcoming department, with active participation by the undergraduates in research and outreach, a diverse graduate student body who spearhead creative research, outreach, and education projects, and a talented faculty who lead some of the largest research efforts in astronomy, having an impact at the national and international level, reflected in numerous grants and awards. We remain the largest partner in Apache Point Observatory which has continued to be upgraded with new instrumentation, and we are leaders in flagship interdisciplinary programs at the University of Washington, namely eScience and Astrobiology.

Degree offerings: UW Astro offers a Bachelor of Science for 120 undergraduate majors at a time (with ~40 graduates annually since 2018). Major admissions are capacity constrained as of 2019; transfer students are offered direct-to-major admission if they satisfy the major application requirements at the time they transfer to UW. Our honors program requires a significant investment of effort in original research (at least 6 credits of ASTR 499), supervised by Astronomy faculty, and a departmental GPA above 3.7. A listing of available tracks and courses is given in Appendix I.

The Astronomy department offers a Masters and Doctoral program for students accepted to our increasingly highly selective graduate program. On average, five students enroll in our Ph.D. program each year out of more than 350 applicants. The program emphasizes research, teaching, and outreach. En route to their Ph.D.s, students obtain a Masters in Astronomy (which is non-terminal) based on their coursework from the first two years. A listing of courses is given in Appendix I. Upon coursework completion, students take three oral exams and write a dissertation to graduate, described in more detail below.

In addition to the Astronomy Ph.D., we offer a dual-title Ph.D. in Astrobiology, a Graduate Certificate in Astrobiology, an Advanced Graduate Data Science Option, and a Graduate Data Science option. These are in conjunction with the UW Astrobiology Program and eScience Institute.

Degree growth: The University of Washington freshman class has grown substantially in the past several years, and these students have disproportionately indicated an interest in pursuing Natural Sciences majors. Since 2011, the number of UW Astro majors has more than doubled. Since 2018, Astronomy majors and degrees awarded have increased by approximately 80%, surpassing the rise in graduation rate of US Astronomy majors in a similar timeframe (~35% over 3 years). Every year, between 2 - 4 students switch from the Astronomy major, often in exchange for Earth and Space Sciences; sometimes for Math. Over 90% of students who declare an Astronomy major graduate with a BS in Astronomy (since 2010).

In addition to the growth in the number of majors, there has been significant growth in the number of credit hours offered per year. Thanks to the visibility and popularity of astronomy, both major and general education courses have grown 60-100% over the past decade. Appendix J (Figures 1-6) disaggregates this growth by general (non-major) and major courses, as well as research-based courses. Much of the non-major growth is driven by online courses, while upper-division growth has tracked with growth in the number of Astronomy majors.

The graduate program has quadrupled in the number of applicants over the last decade, but remained steady at 25-30 enrolled graduate students, due to limits based on available funding, space, and faculty to advise research.

Administration: The department enjoys a talented staff of six (see Appendix A), who provide academic and non-academic services. The department Administrator oversees the budget and staff. The Administrator and the Chair coordinate on budgetary and staffing strategy in weekly meetings. The Administrator, Chair, Associate Chairs, Human Resource Manager, Academic Counselor, Budget/Fiscal Analysis Lead and Fiscal Specialist/Payroll coordinator meet bi-weekly to communicate about current and upcoming administrative or advising issues. A Program Assistant and a couple of part-time student employees assist the staff in supporting department activities. For IT support, UW Astro shares a staff of four with Physics and the Institute for Nuclear Theory.

Currently, one Academic Counselor provides advising and student services for both Undergraduates and Graduate students. The Undergraduate Program Coordinator and Graduate Program Coordinator oversee and assist the Academic Counselor regarding their respective programs. One of the Teaching Professors assists the Academic Counselor for room and time scheduling.

Our undergraduates deserve a rich, personal experience engaged in learning and research. Given the significant recent growth in the number of astronomy majors in the last decade, as shown above, the staff academic counselor (Elisa Quintana) and undergraduate academic advisor (Prof. Werk) have been devoting significant hours in providing advising for pre-majors and majors in Astronomy. To meet our deeper goals of student engagement and apprenticeship, the department is now hiring a second advisor position from temporary funds, but will need to find a solution for the excess workload for these two critical department members.

Governance: UW Astro enjoys collegiality amongst its faculty, who meet every other week during the academic year to discuss academic issues, faculty hiring and department operations, with the Chair presiding. Three representatives from the Undergraduates, Graduate students and Postdocs attend the open portion of these meetings to communicate their constituents' concerns at the meeting, and to transmit the discussions at the meetings back to their respective groups. The Chair now meets every two weeks with an Executive committee of the two Associate Chairs and two other senior faculty members for guidance in setting the faculty meeting agenda and other strategic issues. Faculty committees carry out most of the business of the department. The Chair assigns membership in consultation with the Executive committee and the affected faculty. The Chair attends a monthly meeting of the Chairs of the Natural Sciences Division for information from the College and the University.

Budget & Resources

Appendix B shows the budget for the department over the last three completed biennia. The State Funding represents our permanent operating funds. The increase over the years reflects salary increases, while contracts and supplies have remained static. In fiscal year 2022 the department relied heavily on $133K in recapture funds (buyouts) from faculty on leave to support our teaching mission as well as $88K annually in Temporary Instructional Funds (TIF) monies. These funds cover the salaries of 2.0 FTE of Teaching Professors as well as 9-10 quarters of Teaching Assistants/Associates. Temporary College Funds include Start Up and Provost funding for faculty retention and research facilities. Our Grants and Contracts spending continues to be dominated by the Rubin/LSST construction grant, but we are seeing growth in other areas, including NASA and NSF awards. There are currently four graduate students in the department who are funded by department-administered research fellowships which are included in this category. Research Cost Recovery (RCR) funding, which returns a portion of grant overhead to the department, has seen strong biennium growth thanks to the growth in research funding, and while expenditures declined in the recent biennium, mostly due to COVID impacts, future projections for this funding source are of concern. The RCR funds 2.0 FTE of staff support for research and advising/administration. It also funds our colloquium program and acts as a backstop for GOF[1] budget overruns for expenses such as reader/graders and teaching assistants, as well as the Pre-MAP Program. Current reserves in the RCR are the outstanding balances for faculty startup/retention, including funding set aside for two new start-up packages in the coming year, as well as the potential for a retention offer should it arise. The RCR budget also covers the department's obligation for the ARC research facilities as outlined below. Self-sustaining budgets include lab fees, conferences, and extension programs. We expect to see a continued decline in these funds as we realign our current fee structure with actual expenses. The University

[1] General Operating Funds from the University of Washington.

recently changed the Summer Quarter to be a self-sustaining program with revenue returned to the department. We had a very successful first year of Summer Quarter revenue due to online course offerings during COVID. We expect to see an annual revenue of $40-$50K with the potential to grow this new line of funding. Gifts and Endowments has grown through the collaboration with the Heising-Simons Foundation and Schmidt Futures. Our overall endowments remain stable with spending accelerated due to the CAS new carry forward policies.

Funding for participation in the Astrophysical Research Consortium (ARC) stands at approximately $420K annually. Half of the funds for this expense come from the State and the Provost, with the College and Department sharing the remainder. The department will need to negotiate a new funding agreement with the Provost starting with the 2026 fiscal year (which begins July 1, 2025).

The department Chair and Administrator work together to monitor the budgets and ensure the best use of the funds. The Administrator has developed proformas for each budget with historical spending trends as well as 5-7 years of future projections.

UW Astro has a limited record of fundraising from external donors (save for DiRAC). Most annual giving comes from current and emeritus faculty, staff, and alumni ("Friends of Astronomy"). Outreach activities in which giving is encouraged include Planetarium Shows, TJO Telescope Outreach, and public lectures. Our newsletter is our primary tool for communicating with potential donors. Our chair and administrator meet monthly with the CAS Advancement team to identify potential donors and fundraising opportunities. We seek out opportunities for faculty to give talks for the general public and for audiences which include potential donors. The chair monitors new opportunities for funding from NSF and NASA, and broadcasts these to current faculty.

Academic Unit Diversity, Equity, and Inclusion

By some measures, UW Astronomy has one of the more diverse astronomy programs in the United States. Of eight full professors, three are women, which is nearly twice the national average for astronomy (19%). Of the 5 assistant professor tenure-line hires in the last decade, three are women (compared to 41% nationally). Additionally, we have led the way in adopting inclusive practices in graduate admissions, thereby diversifying our graduate student body. As a result, we have prioritized the support of underrepresented communities in our department. Nevertheless, we can also identify challenges. In particular, hirings at the postdoc and non-tenure faculty level have lagged in diversity. Of our tenure-line faculty, we have yet to hire a non-white or, e.g., non-binary faculty member. All of these shortcomings we plan to address in the future decade.

The department has an Equity committee, led by Prof. Sarah Tuttle, consisting of faculty and staff who are working to develop a charge. A staff subcommittee, including classified and prostaff, is led by Tyneshia Valdez. While graduate students have been invited to participate in the equity committee, none have yet chosen to take part.

The department's current diversity statements (Appendix D) mainly concern students and outreach activities. The department's diversity committee is working to shift the framing from diversity in outreach to equity and diversity amongst peer groups and in our academic community. Our goal is to link equity across all relevant structural work within the department, and involve all invested parties when particular activities come up. The diversity committee is currently working towards an updated diversity statement, which will then be circulated broadly for comment and update. The committee is also working on developing a formal code of conduct for on-campus and field work, as such documents can help to prevent conduct issues.

Our diversity and equity efforts within the department span a range of activities. At the undergraduate level, the Pre-Major in Astronomy Program (Pre-MAP) seeks to broaden participation in Astronomy by introducing first-quarter freshmen and community-college transfer students to astronomy research. The course partners with OMA&D to advertise, invite and enroll minoritized students in the program. The Pre-MAP course (ASTR 192) is designed to teach students research skills, introduce basic astronomy knowledge, build a cohort for support during the astro prerequisites, provide study skills, and partner them with graduate students, postdocs, and faculty on research projects. The program is entering its eighteenth year, and averages 10-15 students per cohort. Pre-MAP students also participate in cohort-building activities, such as a Spring field trip to a research site (save during a worldwide pandemic), and they are offered academic advising by a senior graduate student. Two advanced graduate students serve as the Instructor and Academic Advisor for the Pre-MAP program.

At the graduate level, during admissions, the department works with the Office of Graduate Student Equity & Excellence (GSEE; formerly GO-MAP) and the ARCS Foundation Seattle Chapter to pursue recruitment fellowships for prospective incoming graduate students from traditionally underrepresented minorities. These recruitment opportunities (including GSEE's Graduate Diversity Fellowships and Graduate Excellence Award and the ARCS Diversity Fellowship and Foundation Fellowshhip) have allowed the department to offer incoming fellowships to students from a broad range of backgrounds, including racial, sexual, gender, and religious minorities as well as first-generation students. These fellowships allow students from underrepresented groups to immediately engage in funded research pursuits upon arriving at the University of Washington, giving them valuable early experience that can often translate into future competitive research fellowships, grants, and other career opportunities.

In the last 3 years the Astronomy & Physics Ph.D. students have formed the Graduate Students of Color in Astronomy & Physics (GCAP) group, designed to be a space led by our students of color. While GCAP was initially designed to be relatively independent of the department, staff & faculty are working to transition some of the administrative burden of running the group to the department.

In our previous junior tenure-track hiring processes the department has followed college guidelines to reduce the amount of bias, and the last tenure-track faculty search resulted in the hiring of three female faculty members. In the most recent hire of a junior teaching faculty, the department used strategies to diversify the candidate pool (anonymized evaluations, advertising to minority serving organizations) and successfully hired an underrepresented minority candidate. This new hire has been connected with the Office of the Associate Vice Provost for Faculty Advancement for continued support. Diversity and inclusion in the hiring of research faculty has been challenging to implement. Because research faculty are not state-funded, these hires are usually closely tied to support from particular scientific projects and do not draw a wide pool of candidates, with less opportunity for diversity among applicants.

Section II: Teaching & Learning

The recent growth in the undergraduate program in Astronomy has put the department near the top of the nation in terms of both enrollment and degrees awarded. In the 2020 AIP survey (published in September, 2021) of 92 US institutions offering Astronomy degrees, the UW ranked **fifth in the nation** in the number of Bachelor's degrees awarded. Similarly, the number of junior and senior Astronomy majors place the department **fourth in the nation** in terms of size. The enrollment in our introductory courses that fulfill natural world requirements for non-science majors has also grown significantly; the department is **fourth in the nation** in introductory astronomy course enrollments. It is clear that any additional growth in our program would involve breaking new ground in the size of undergraduate Astronomy programs.

Student Learning Goals and Outcomes

Undergraduate Program: The undergraduate curriculum in Astronomy at UW is designed to optimize the preparation of astronomy majors for a variety of future endeavors, including graduate school, technical jobs (including laboratory, observatory and data science), and teaching. We additionally aim to create a supportive and collegial environment that is optimized for successful learning by students from all backgrounds, and which incorporates regular, detailed student assessment. The training for modern astronomy is data-intensive, and requires that students develop a diverse skillset that includes computer programming, analytical reasoning, and physical intuition.

Assessment: All astronomy majors are assessed in their upper division coursework through a combination of rigorous, quantitative problem sets, written and/or oral projects, midterm and final examinations. Check-ins are done with the advisors in quarterly all-major meetings, weekly “drop-in” hours, and students are additionally able to schedule 1:1 meetings with both the academic counselor and the faculty advisor as needed through an automated calendar scheduling system. By taking either ASTR 480 or conducting independent research through ASTR 499, students get a capstone experience in which they engage in project-based collaborative work focused on a current question in modern astrophysics.

We address student questions and concerns during group and individual meetings, and try to address all the issues they may be facing both inside and outside of the classroom (e.g. strategies for finding research advisors; REU applications). Our peer mentoring program for Astronomy majors includes assessment at the end of every quarter that allows students to discuss their experiences in peer mentoring and in the broader major and to offer suggestions for improving the student experience. Furthermore, the department has given long term support to sustaining Pre-MAP, which uses interviews with the cohort to evaluate and obtain feedback on the program.

In the Spring of 2022, we anonymously surveyed all of the undergraduate Astronomy majors using a template from a study published in *Teaching in Higher Education by Di Grandi et al.* Fifty students out of ~120 majors completed the (optional) survey. Undergraduate respondents unanimously indicated a high level of satisfaction with our program; this level of satisfaction did not vary with gender or race. 95 - 100% of Astronomy majors indicate that: that the department is a supportive community, that the professors care about student well-being, they feel supported by their advisors, and that they are proud to be an Astronomy major. Approximately 30% of our majors identify as being from a group underrepresented in the sciences.

Program improvements: About 50% of our recent BA graduates compete for data science positions in major tech companies and the finance industry, both in Seattle (e.g., Amazon) and nationally. Generally, our undergraduates report that their training in Python and data analysis are highly transferable, valuable skills. As a result, starting in 2015, we began redesigning our undergraduate curriculum to support data-science driven coursework. Toward this end, we developed a core that includes four courses that emphasize working in the UNIX and Python environments, with a focus on astronomical implementations: ASTR 300, 302 (Python for Astronomy I and II), 324 (Statistical Methods in Astronomy), and 480 (Intro to Astronomical Data Analysis). These courses take place in our department's computer lab, and require students to become proficient in programming with hands-on instruction. In partnership with eScience (a multi-departmental program at UW in which Astronomy plays an active role), undergraduates can take a number of statistics and computer science courses that will enhance their training in modern analysis methods. We are currently working on developing a formal, transcriptable "Data Science Option" for the Astronomy major (this option already exists for our graduate program). These efforts will require re-working the entire curriculum since our majors typically max-out on credits in Astronomy and Physics alone, and we will have to balance these new classes with the upper level Physics classes that are currently required.

In a 2018-2019 survey, undergraduate Astronomy majors indicated that they were having trouble connecting with their peers. The COVID-19 pandemic only exacerbated this feeling among students. In response, the undergraduate advisors (Werk, Quintana) developed a peer mentoring program in Astronomy, available to all Astronomy majors. The peer mentoring program empowers students to solve problems among themselves, and encourages cohort building. The regular, quarterly assessments have been overwhelmingly positive, with student feedback noting how valuable they find the opportunity for connecting with their peers.

Finally, the growth in our major has prompted two procedural changes to major admissions. In order to ensure declared astronomy majors continue to have access to required astronomy courses—and can graduate in a timely manner—the Department of Astronomy changed from a minimum requirements major to a capacity-constrained major in the Fall of 2019. Adding the capacity constraint to the major has allowed us to keep the number of students capped at a level where we can provide them with a quality education. This capacity is 120 students, and is approximately the current number of Astronomy majors. Admission to the major is based on a holistic review of the student's record and application as follows:

a. Academic performance. This aspect includes a review of overall GPA and content of all courses completed; frequency of incompletes or withdrawals and number of repeated courses; and an academic record that demonstrates interest in science, technology, engineering, and/or mathematics.

b. Personal Statement. This statement consists of a brief (500 – 1000 words) description of the student's interest and goals in the Astronomy major, and addresses strategies for success in the major. In exceptional cases with extenuating circumstances, a personal statement may also include a petition for a waiver of one of the stated minimum requirements (GPA in intro physics and math courses greater than 2.0).

We now allow students transferring to UW the opportunity to apply to the major directly during their UW application process, known as “direct-to-major” admissions for transfer students. As a result, transfer students who qualify can immediately enroll in the courses they will need to complete the major in a timely manner.

Graduate Program: The Ph.D. in Astronomy offers graduate courses to train in the theory, methods, and practice of astronomical research. There are a broad range of topics in the field of astronomy, from planets to stars to galaxies to the Universe as a whole, as well as numerous research methods - analytic and numerical computation, astronomical observation, data mining, scientific coding, statistical analysis, pipeline development, astrophysical simulation, visualization, instrumentation development, etc. A majority of Astronomy Ph.D. students have a long-term goal of carrying out research in Astronomy, which is why our Ph.D. program focuses strongly on academic research, and publishing papers, both of which are necessary in moving to the next step on the academic ladder, which is preponderantly a postdoctoral fellowship. Astronomers commonly work in multiple areas of astronomy throughout their careers, and can use a wide range of methods in their research. Thus, the goals of the coursework are to give students 1) an advanced understanding of the physical processes which occur in astronomical bodies; 2) a broad and deep knowledge of areas of astronomy in preparation for their dissertation work, for becoming astronomy educators, and for public outreach; 3) a familiarity with the mathematics, physics, programming, and technical skills (using telescopes, building instruments) required for carrying out astronomical research. At the completion of this coursework students should be able to understand research talks and literature within the field of astronomy; to embark on their Ph.D. dissertation research; and to be able to speak, converse, and teach about a wide range of topics within astronomy. Due to the growth in analysis of large datasets, we have recently introduced courses in data analysis, statistics, and machine learning, which have the added benefit of training students for jobs in data science (which is the stated career goal of ⅙ of respondents to a 2022 grad survey).

Assessment: Astronomy Ph.D. evaluation consists of course grades and three exams: Qual, General, and Final exams. The coursework includes academic grades - students who obtain passing grades in seven of eight required courses are eligible for a Masters degree (the interdisciplinary tracks - such as data science and astrobiology - have additional required courses which made schedules difficult with 12 required courses). Next, the research qualifying exam introduces Ph.D. students to astronomical research with an advisor during their first two years. The “Qual” exam includes a research paper and an oral presentation which is evaluated by the student’s mentoring committee and a faculty committee which oversees the Qual exam. After passing the Qual, students embark on preparing for their dissertation research, commonly with the same advisor. Once their dissertation plan is fleshed out, they take the oral General exam which evaluates their ability to synthesize the scientific literature on a topic related to their dissertation topic. After passing the General exam, the students are “All But Dissertation”, and once dissertation research is complete, they submit their dissertation for review, revision, and approval by their committee, followed by an oral exam.

Astronomy dissertations often include work that has been published as scientific papers during the course of their Ph.D., and thus the referee process provides an additional external means of evaluation of students' work. At the end of this process we expect students to be able to define and carry out original research projects in Astronomy and Astrophysics.

As our department has a small cohort of Ph.D. students (3-8 per academic year), student satisfaction is gauged informally. Each course has student evaluations. Students are given multiple channels of communication with faculty and staff. They are paired with a mentoring committee during their first 2-3 years consisting of several faculty with whom the students can interact with for professional development, and they are invited to voice concerns about their progress in the program with their committee. Students meet with the Graduate Program Advisor and Graduate Program Coordinator annually. The department has been financially supportive of GCAP (Graduates of Color in Astronomy and Physics); we have graduate student representation about a wide variety of issues, and concerns of underrepresented groups are often raised and considered carefully. We have a graduate student representative on faculty hiring committees, graduate student admission interviews and at every faculty meeting.

Program improvements: In the last decade we have made significant changes to the Ph.D. program based on feedback and input from our graduate students. 1) We reduced the number of required courses from 12 to 10 to be more in line with our peers, to allow more research early on, and to free up time for interdisciplinary courses, growing in popularity. 2) Based on students' desire for more support early on, we created the mentoring team program for each graduate student. This mentoring framework is unique among Astronomy graduate programs, which encourages interaction between students and faculty on their mentoring team, beyond their advisor/chair, and adds help for students if problems arise during their early Ph.D. 3) We changed the qualifying exam from a written one-day Qual based on broad astronomy knowledge to a research qualifying exam. Students had pointed out that they were already being tested in courses; that they preferred research to solving problem sets; that other programs dropped a written qual in exchange for a research-based exam; and that the exam provided more of a burden than a benefit. We carried out a survey of the graduate students in support of this self-study, and the results showed that students did not find the prior written Qual of long-term value (and added stress), while the new research Qual is viewed much more positively (with some exceptions).

General Education (Non-Majors) Program: A general survey of modern astronomy and cosmology has been a key fixture of liberal arts education since the very beginning of the academy, and our general education courses ASTR101 (Introduction to Astronomy) and ASTR150 (The Solar System) continue to play a key role in supporting UW's general education mission by providing Natural World (NW) and Quantitative and Statistical Reasoning (QSR) credit for over 2000 students per year. This number has increased significantly in the past decade due to the implementation of online versions of both courses. We also offer an honors version of our introductory astronomy course (ASTR102), and a version specifically targeted towards majors in other scientific disciplines (ASTR301) that support roughly 100 students per year.

In response to student demand we have added several new courses on the Moon (ASTR105), asteroid and comet impacts (ASTR216), and an introductory course on Astrobiology, ASTR115. The learning goals of these courses vary in their details, but all focus on developing the following: 1. literacy with key ideas and findings of modern astronomical research; 2. understanding of astronomy's historical and active role in diverse human cultures; and 3. familiarity with scientific and statistical methods. Student success is generally measured by examinations, lab activities, and both group and individual projects. Students are further surveyed using standard methods from the Office of Educational Assessment.

Instructional Effectiveness

Instructors work with the Office of Educational Assessment to carry out standard teaching evaluation surveys of each course. Faculty teaching is regularly reviewed by peers. Graduate teaching assistants are encouraged to enroll in ASTR 500, a course taught by a Teaching Professor on best-practices in teaching, and graduate students are encouraged to enroll in summer TA training through the Center for Teaching and Learning. Flipping the classroom, active learning, and peer teaching have each been employed at the undergraduate and graduate level courses in Astronomy to improve the learning experience of students.

Teaching and Mentoring Outside the Classroom

Undergraduate program: The practice of astronomy can be best taught in a hands-on manner, so about 50% of Astronomy majors (40 - 50 per year), carry out independent research at some point. Opportunities to engage in authentic research start first quarter freshman year with Pre-MAP (ASTR 192), continue with ASTR 400 in which faculty introduce majors to their research, and ASTR 499 in which students earn academic credit for research projects supervised by faculty and their research groups. Undergraduate Majors regularly present in the annual University of Washington Tri-Campus Mary Gates Research Symposium in May, in terms of both oral and poster presentations.

Undergraduates meet with their advisors 1:1 upon declaring the Astronomy major to develop a plan for their major coursework and research (if applicable), and every quarter thereafter in quarterly all-majors meetings, as well as schedulable 1:1 meetings as needed. Both advisors (Werk, Quintana) offer at least two hours of major “drop in” hours every week, via Zoom and in person. A common pitfall for undergraduate majors is the physics coursework required for the major. Astronomy advisors are in close contact throughout the academic year with the physics advisors and offer pre-approved course substitutions as needed. Students who are struggling are encouraged to meet regularly 1:1 with advisors and join a peer mentoring group. The advisors also run programs focused on mental well-being (through the “Be Real” UW program), and various workshops throughout the year focused on student needs (e.g. annual Fall essay-exchange workshop for faculty-student editing of graduate admissions essays).

Our Astronomy major, with its many upper-level and research-based courses, is designed in large part to prepare students for graduate study. Over the last five years, an average of 20 graduating Astronomy majors (nearly 50%) apply for admissions to graduate school in Astronomy, Astrophysics, or Physics Ph.D. programs. Of these students, approximately 10 - 12 will be accepted to increasingly competitive Ph.D. programs every year, and of the remaining 10, approximately 5 will remain in the Astronomy Department as post-baccs (serving as TAs for intro-level courses and research assistants) and apply again (of those 5, most – in some years, all of them – will eventually gain admission to a Ph.D. program after revising their application strategy and getting more research experience). The remaining ~five students who do not gain admission to Ph.D. programs in Astronomy/Astrophysics have considered a range of options, from Information Science Masters Programs, to teaching at the high-school level, to working at Seattle-based aerospace companies Boeing and/or SpaceX.

Regardless of which track Astronomy majors choose, the advisors are committed to supporting students in their goals throughout the major. Faculty advisor Jessica Werk meets 1:1 with most students planning to apply to graduate school, and runs an annual essay-workshop for these students to pair them with a faculty essay coach. Both advisors monitor the Career Center web page, and advertise relevant fairs and opportunities to students. Our email list is regularly used to advertise job and internship opportunities specifically for STEM students and Physics/Astronomy majors.

Graduate program: The primary function of the Astronomy Ph.D. is to involve and train graduate students in Astronomical research. Most Ph.D. students work closely with a faculty advisor to define their research projects and carry out their dissertation work. The faculty have sufficient grant funding to pay nearly all of the graduate students as RAs during their Ph.D. program, with the balance being funded by fellowships and/or TAs. As such, the graduate students are often involved in helping with fellowship and grant writing, which prepares them for being research PIs in future work.

The graduate program coordinator (Agol) and graduate student advisor (Quintana) meet with first and second year students annually to provide advice on coursework. A mentoring team of ~3 faculty meets with these students twice annually, and a graduate mentoring handbook describes this program, and other aspects of the Ph.D. Mentoring teams provide advice for the graduate students related to their coursework, research, financial support, and other topics related to individual development. Participation was thin during the pandemic; however, most of the students that did participate in the mentoring program found it very useful (2022 grad survey). After the Qual, the committee transitions to a dissertation committee.

Training in scientific communication is key. Towards this end, the journal club asks students to take turns presenting on research papers they have studied in detail. This prepares them for giving shorter talks, which are common at conferences, and also trains them in literature research. In 2018, Prof. Tuttle founded “Astrofest” in Autumn quarter which gives opportunities for graduate students to present their research to the department as a whole. We have also recently introduced a scientific writing course to help students overcome writer’s block; to introduce them to the style and content of scientific writing; and to help them with the mechanics of writing. Finally, the three oral exams accompany a written component; the final exam (dissertation defense) is expected to be similar to the level of a departmental seminar or colloquium, which are commonly part of academic job interviews. Evaluation and feedback from a faculty committee are provided for each of these exams.

Teaching is another prominent career goal of astronomy graduate students (academic jobs are a goal 50% of survey respondents). As such, the Astro Ph.D. requires students to serve as Teaching Assistants for at least three quarters during their Ph.D. This both serves for students to hone their knowledge of basic Astronomy, as well as to gain experience with teaching in a college setting. Pre-MAP is run and taught by graduate students who organize Pre-MAP cohort-building activities such as Planetarium or Observatory nights, and a Spring field trip. Finally, Astronomy Ph.D.s are encouraged to attend conferences, participate in collaborations (both national and international), and get involved in the American Astronomical Society, which are the primary ways in which professional networking is carried out in Astronomy.

Section III: Scholarly Impact

In this section we turn to the research efforts within UW Astro, and the impacts that past and current members have had on the field of Astronomy. Given the prominent role that education plays in our department, we begin with some of the successes of former and current UW Astro students, starting with our undergraduates.

Undergraduates: UW bestows the Husky 100 award each year on outstanding undergraduate students, who include UW Astro undergrads Lupita Tovar (‘17; now part of our Ph.D. program), Tyler Valentine (‘18), and Erik Solhag (‘22). UW Astro undergrads have won other awards, such as Lupita Tovar as NSF graduate fellow and Courtney Klein (‘18) as Dean’s Medal Finalist. Undergraduate Zakkir Rahman was featured in the College newsletter as the rare combination of an Astronomy and Dance major.

Numerous UW Astronomy undergraduates have gone on to become faculty elsewhere in the last decade, including Prof. Brant Robertson (‘01) at UC Santa Cruz, Prof. Dawn Erb (‘00) at University of Wisconsin-Milwaukee, Prof. Jeremiah Murphy (‘01) at Florida State University Tallahassee, Prof. James Davenport (‘07) at UW Astronomy, and Dr. Keaton Bell (‘10) starting at Queens College of CUNY.

Ph.D. Students: We are particularly proud of the successes of our former graduate students. Dr. Giada Arney (‘16, Astro/AB) was the recipient of the 2018 NASA Early Career Achievement Medal and the prestigious Presidential Early Career Award for Science and Engineering in 2019. Dr. Arney served as a Team Lead for the LUVOIR astrophysics flagship mission study, and is now a Deputy PI for the NASA DAVINCI mission to Venus. Prof. Aomawa Shields (‘14, Astro/AB) is the Clare Booth Luce Professor at UC-Irvine, and is an NSF CAREER Award recipient, a TED and Kavli Fellow, and is one of a growing number of female black faculty in Astronomy in the US. Prof. Sarah Loebman (‘13) is tenure-track faculty at UC Merced, Prof. Ferah Munshi (‘13) is tenure-track faculty at George Mason, Prof. Charlotte Christensen is tenured faculty at Grinnell and an NSF CAREER Award recipient, Prof. Nathan Kaib (‘10) is tenured faculty at U. Oklahoma and an NSF CAREER Award recipient, and Dr. Amy Kimball (‘10) is the Head of Operations for the NRAO VLA Sky Survey. Prof. Adam Kowalski (‘12) is faculty at the University of Colorado, Boulder and the National Solar Observatory. In 2022 Adam was awarded the early career Karen Harvey Prize by the Solar Physics Division of the AAS.

Two former Ph.D. students hold Canada Research Chairs, and are leads in the exciting new research field of Multi-Messenger Astrophysics: Prof. Daryl Haggard (‘10) is a professor at McGill, and Prof. John Ruan (‘17; also a former Dan David Prize Scholar) is a professor at Bishop’s. Prof. Haggard (‘10) was part of the team that discovered the first counterpart of a gravitational wave merger, which was the breakthrough of the year in Science Magazine in 2017, and Daryl was part of the Event Horizon Telescope team, winning the Breakthrough Prize in Physics in 2020 for the first image of a black hole in M87 (along with Jason Dexter, ‘11), and Sgr A* in 2022.

Recent Ph.D.s have been awarded prize postdocs: Kathryn Neugent (‘21), now a Hubble Fellow and CfA Fellow at Harvard; Trevor Dorn-Wallenstein (‘21), now a Carnegie Fellow; Margaret Lazzarini (‘21), now NSF Postdoctoral Fellow at Caltech; and Nicole Sanchez (‘22) who will be a joint NSF and Carnegie Postdoctoral Fellow.

Historically, UW Astro Ph.D. graduates have had an outsized impact on the field of Astronomy, as in the past decade. Prof. Robert Kennicut (‘78) led the 2020 Decadal Survey study of all US Astronomy & Astrophysics. Prof. Eric Wilcots (‘92) is now Dean of the College of Letters & Sciences at University of Wisconsin-Madison where he launched the Dean’s Initiative for Diversity, Equity and Inclusion and created the STEM Runway program in 2020. Dr. Dara Norman (‘01; now at NOIRLab) is leading efforts to diversify Astronomy with the AIP TEAM-Up Organization committee. Dr. Beth Willman (‘03) is now the Deputy Director of the National Optical-Infrared Astronomy Research Laboratory (NOIRLab) run by the National Science Foundation which operates the premier national facilities for Astronomy in the United States. Prof. Marcel Agüeros (‘06) founded the Pre-Major in Astronomy Program while at UW, and went on to found the Bridge to Ph.D. program in STEM at Columbia University, and was recently awarded a Fulbright for 2022-3. Our Ph.D. students have also had success beyond academia, such as Dr. Jake VanderPlas (‘12), now at Google Research, who is one of the leaders in the scientific Python community with a popular textbook the "Python Data Science Handbook", and the creation of numerous software packages that are widely used for time series analyses, visualization, and optimized numerical computations.

Postdocs & Research Scientists: UW Astronomy also employs and trains postdoctoral fellows and research scientists, who are a core participant and enabler of scientific research at the department. Over the past 5 years, the department has hosted an average of about 11 postdocs each year. Since the prior review in 2010, the department has hosted 5 NSF Fellows, 5 Hubble/Sagan Fellows, 8 DIRAC Fellows, and two B612 Asteroid Institute Fellows. Astronomy postdocs’ interests reflect the broad range of research interests, including astrobiology, Solar System, Exoplanets, time-domain astronomy, extragalactic astrophysics and cosmology, inference, and software systems. They collaborate in teams with faculty and colleagues throughout the department and the university. This diversity and interaction led to cross-cutting collaborations: a PNAS article on Hack Weeks, the introduction of X-ray astronomy techniques to asteroid light curve analyses, and the search for peculiar stars in 10^9+ Zwicky Transient Facility (ZTF) light-curves using cutting-edge big data analytics tools.

Since 2015, our postdocs have become heavily involved in the design and construction of large-scale scientific projects, especially the LSST (now Rubin Observatory). These positions combined work on Rubin analysis pipelines and preparatory science, with an opportunity to do cutting-edge science on precursor experiments (ZTF, for example). They are uniquely suited to (and provide a career path for) researchers with strong interest in astronomical software development, most of whom have moved on to research scientist positions either at UW or elsewhere.

Nearly all UW postdocs participate in student mentoring – both research and teaching. Teaching may encompass guest-lecturing a topic at a level of 1-2 lectures in a given class, or fully co-teaching with an official assignment as instructor. All of these provide valuable teaching experience, increasing their competitiveness for faculty position applications later on. Finally, some postdocs choose more interactive roles, such as teaching courses, running seminar series (such as the Astronomy lunch talks), serving as postdoc representatives, and public communication and outreach, such as Dr. Meredith Rawls' work mitigating the effect of satellite constellations on astronomy.

Many recent UW postdoctoral scholars have had career successes, including: Dr. Daniela Huppenkothen, who is now a tenure-track researcher and NWO WISE Fellow at the SRON Netherlands Institute for Space Research; Dr. Rebecca Phillipson, who was selected as one of the inaugural class of NSF MPS ASCEND prize postdoctoral fellows; Dr. Anson D'Aloisio received an assistant professorship at UC Riverside, recently receiving an NSF CAREER award; Dr. Gwendolyn Eadie is a professor at the University of Toronto; Dr. Siegfried Eggl a professor at the UIUC, and Dr. Stephen Portillo is a professor at Concordia University of Edmonton.

Faculty: UW Astronomy faculty have led a broad range of novel and exciting research projects and programs. UW Astronomy faculty have (co-)authored nearly 9000 papers, cited more than 380,000 times, with a cumulative h-index of 264 (NASA ADS 8/2/2022), and so the following examples only touch on the breadth and depth of work by UW Astro faculty and their research collaborations and teams.

Survey Science: Prof. Scott Anderson is the Program Head of the Black Hole Mapper in SDSS-V, (2017-present), and pioneered the study of rare "changing look quasars" (often from SDSS), which fluctuate dramatically on much more rapid timescales than expected. Prof. Zeljko Ivezić, as Director of the Rubin Observatory, leads the scientific design of Rubin Observatory and Legacy Survey of Space and Time. Prof. Mario Juric is the director of DiRAC (UW's Institute for Data-intensive Research in Astrophysics and Cosmology) and the PI of UW's contribution to Rubin Observatory. He led Rubin's Data Management subsystem through 2017, and now leads the Solar System pipelines/discovery team. Prof. Davenport is the Associate Director of DiRAC, leading research with TESS, Kepler and Gaia. Prof. Eric Bellm led a UW team that developed and operated a new alert distribution framework for ZTF, which will be used by Rubin. Prof. Andy Connolly has devoted his career at UW to Rubin, LSST, and survey science, founding DiRAC in 2016 with a gift from Charles and Lisa Simonyi to drive survey astronomy within the Department, and has expanded the eScience Institute with a Moore-Sloan award to apply his knowledge of data science to a broader set of problems beyond Astronomy. With Prof. Ivezić he released two editions of the textbook "Statistics, Data Mining, and Machine Learning in Astronomy" together with the astroML software package, which helped drive the adoption of machine learning in astronomy.

Stellar astronomy: Prof. Suzanne Hawley used NASA's Kepler spacecraft to make the novel finding that stellar flares *were not* temporally associated with the largest starspots. This implies that the flares originate in smaller spots spread over the surface. In 2020 Prof. Levesque led the publication of the first research to conclude that the Great Dimming of Betelgeuse (in 2019-2020, garnering international attention) was primarily caused by increased circumstellar dust. This result is now widely accepted as the conclusive explanation for this star's unprecedented dimming behavior. Prof. Paula Szkody showed how pulsating white dwarfs in dwarf nova systems change their asteroseismic modes following large accretion episodes during a dwarf nova outburst, bucking some theoretical predictions.

IGM/CGM: Prof. Matt McQuinn led a 2014 paper on studying foreground gas with Fast Radio Bursts, with three follow-up papers each with 200 citations, with one receiving the AAAS Cleveland prize for best paper in the journal Science in 2019. McQuinn also authored a 2016 *Annual Review of Astronomy and Astrophysics* article on the Intergalactic Medium. Prof. Jessica Werk co-authored the first *Annual Review of Astronomy and Astrophysics* article on the Circumgalactic Medium in 2017 (presently 470 citations), after having led or co-authored four of the top-ten most cited papers using the *Hubble Space Telescope's* Cosmic Origins Spectrograph to establish the circumgalactic medium as a major galaxian component - in terms of baryonic content and total spatial extent.

Exoplanets/Astrobiology: In the last decade Prof. Vikki Meadows' research group discovered significant non-biological mechanisms for the generation of the atmospheric oxygen biosignature, and described the importance of the exoplanet environment in assessing and interpreting potential signs of life on exoplanets. Prof. Meadows' Virtual Planetary Laboratory has influenced the planning and design of future NASA missions, as well as influencing the structure of NExSS, the successor to NASA's Astrobiology Institute. Prof. Meadows chaired a panel on the Astro 2020 Decadal Science Survey. Prof. Eric Agol led the discovery of the habitable-zone exoplanet, Kepler-62f, which at the time of its discovery was the most Earth-like to date. He was part of the team that found seven Earth-sized planets in TRAPPIST-1, which is the most highly cited paper in all of (exo-)planets since that year.

Galaxies: Prof. Quinn and N-body shop collaborators demonstrated that baryonic processes, in particular supernovae, can resolve a discrepancy between the observed and simulated dark matter profiles of low mass galaxies. Prof. Ben Williams discovered a global star formation episode in our neighboring galaxy M31 2-4 Gyr ago, possibly related to a merger event that has greatly influenced the evolution of M31 and its current morphology.

Press and Awards: UW Astro faculty research has been featured in numerous press releases and news stories, with some examples given in Appendix H. UW Astro Faculty have won an array of awards, distinctions, and recognitions from outside the department, including Fulbright, Sloan and Guggenheim Fellowships; further examples are given in Appendix H.

Distinguished Service: The Astronomy faculty have engaged in significant service roles in the past decade for the College of Arts and Sciences and the University. Prof. Hawley served as Divisional Dean of Natural Sciences from 2016-2020. Prof. Laws served as Chair of the Faculty Senate from 2020-2022. Prof. Connolly has served as Director of the interdisciplinary eScience program since 2020. Prof. Meadows has served as Director of the interdisciplinary Astrobiology program since 2011. Together with national service (Prof. Szkody served as the AAS President from 2020-2022) and outside research directorships (Prof. Dalcanton is presently Director of the CCA, Prof. Ivezic is presently director of Rubin Observatory - both of these faculty members are on leave), the senior faculty in the department are and have been heavily committed to service outside the Astronomy department. While this raises our profile within the university and the nation, it also means that the burden of carrying out department functions falls on a rather small number of faculty members, given the limited size of the faculty (only 14.5 FTE).

Trends and funding: In the last decade, several trends in astronomy have emerged which have influenced the research carried out by this department. Breakthroughs in the discovery and characterization of potentially-habitable exoplanets, the discovery of counterparts of fast radio bursts, advances in the characterization of the circumgalactic medium (see below), growth in time-domain and multi-messenger astronomy, growth in data mining/machine learning, the detection of gravitational waves and their counterparts, and the first images of black holes have all influenced (or been influenced by) faculty research in UW Astro. Funding in Astronomy has continued to become more competitive to obtain, with funding dollars remaining constant, eroded by inflation, with the number of astronomers competing for it growing. Given these trends, funding by private foundations has played a more influential role in funding for SDSS, ZTF, Rubin/LSST, DiRAC, and eScience.

Interdisciplinarity/external collaborations: UW Astronomy has pioneered numerous interdisciplinary and external collaboration efforts which have had wide-ranging impacts in the field of Astronomy: we discuss Astrobiology, Circumgalactic Medium, the Dark Universe, and Data Science in turn.

UW Astrobiology (UWAB) is one of the first Astrobiology programs in the world, founded in part by UW Astronomy. Since the 2010 UW Astro survey, UWAB leadership passed to Prof. Vikki Meadows, who introduced a multi-college dual-title Ph.D. in Astrobiology and hired Prof. Rory Barnes. Alumni of the astrobiology program have gone on to take leading roles in NASA with missions which involve the search for life, either in our Solar System or beyond. Astrobiology has boosted the visibility of our Astronomy program as a large fraction of our Ph.D. applicants wish to study extrasolar planets and/or astrobiology. Prof. Meadows also leads the Virtual Planetary Laboratory which comprises more than 75 researchers at 20 institutions, and involves a broad range of disciplines, from biology to atmospheric scientists, to tackle exo-biology questions which are beyond the capabilities of astronomers to solve on their own.

That the circumgalactic medium (CGM) is a dominant baryonic reservoir in galaxies is a major new astrophysical discovery in the last decade, *and* a science driver of the next flagship space telescope missions identified in the Astro 2020 Decadal Report. Four UW Astro faculty focus on this important driver of galaxy evolution - Profs. McQuinn, Quinn, Tuttle, and Werk - making it a leading department in CGM science among peer institutions. Since 2017, all four faculty, their students and postdocs, have been collaborating on science projects and co-advising students in this area of research with at least six joint publications in major peer-reviewed journals, and several additional forthcoming. The CGM group at UW has been developing plans, under the NASA APRA call, to build a far-ultraviolet narrow-band imager, called Maratus, to map the circumgalactic medium in OVI emission. Combining flight-proven hardware with recent technological improvements, the CGM group is tackling one of the most interesting questions bridging large scale structure and galaxy evolution in our current moment—"How does gas flow into and out of galaxies?" Answering this question is crucial for understanding the regulation of star formation, and the flow of matter, energy, and metals traveling between galaxies and the intergalactic medium. Maratus is a proof of principle instrument that will pave the way for large-scale mapping of the intergalactic medium and would further boost UW's leadership in CGM science.

The Dark Universe Science Center (DUSC) was created in 2014, with the goal of connecting the research efforts in cosmology and astroparticle physics in the Astronomy and Physics departments (which already share the same building). DUSC is the strongest current link between the two departments, with a weekly journal club, a seminar series that brings in a few speakers each quarter, and monthly social events. Its members aim to answer questions like what is the dark matter, the dark energy, and the initial conditions of the universe? DUSC has spurred collaborative efforts among the participating faculty, students and postdocs, and has strong links with the Institute for Nuclear theory that often brings in researchers on DUSC topics. Physics Prof. Morales and Astronomy Prof. McQuinn were the co-chairs of this effort until this past year, when new Physics faculty hire Prof. Marilena Loverde assumed these duties. The success of DUSC has helped to motivate hires in the Physics Department, with three recent DUSC hires. Its core group of primarily assistant and associate professors is positioning UW to be a leader in cosmology and astroparticle physics.

Data science is a rich source of interdisciplinarity and collaboration, done under the umbrella of the DiRAC Institute. DiRAC faculty lead UW's involvement in Rubin Observatory, as well as LINCC Frameworks – a new, multi-million dollar, 5-year, program supported by Schmidt Futures to develop science software for analyzing data from the Rubin in collaboration with the University of Arizona, Carnegie Mellon University, Northwestern University, and LSSTC. UW Astro Department members have collaborations with the eScience Institute, the Allen School of Computer Science and Engineering, the Department of Psychology, and Department of Earth and Space Sciences, on data and computationally-intensive research. Department members have collaborations with the eScience Institute and UW-IT on the development of software engineering, and data storage infrastructure for the University. Through the Rubin Observatory project, the DiRAC Institute has established collaborations with Princeton University, SLAC, NOIRLab, and the University of Illinois together with scientists from the LSST Science Collaborations (accounting for over 1000 researchers worldwide).

Promotion and Tenure policies: The success of our department in research is anchored by our junior faculty, who bring the energy, creativity, and enthusiasm needed for pushing the field in novel directions. Historically, the department has attempted to protect the research time of junior faculty by offering a lightened teaching load, including Junior Faculty Development quarter teaching relief, and by keeping their service roles on committees to a minimum. However, in recent years the department has found it more difficult to support tenure-line junior faculty due to the many outward-facing service roles that more senior faculty carry outside of the department, which limits their ability to serve in an inward-facing capacity and has limited their teaching due to buyouts, as well as a change in the university's accounting for teaching service which has led to a more demanding teaching load for all faculty, including junior faculty. With the recent leave of Prof. Dalcanton to lead the Center for Computational Astrophysics, and the promotion of Prof. Ivezić to Director of Rubin Observatory, this has further exacerbated this faculty shortage for the department, and a significant service burden has fallen on our more junior faculty. Mentoring of junior faculty has been rather informal, which has traditionally worked successfully given the small size of our department and the small number of junior faculty. However, the increased demands suggest that we may need to shore-up and/or formalize our mentoring policies to better support the success of our junior faculty and codify the expectations, milestones, etc., for promotion in a junior faculty handbook. The promotion and tenure guidelines for the department are given in Appendix F.

Section IV: Future Directions

A decade ago, we presented a vision in which flagship departmental programs such as Astrobiology, LSST/Rubin, and N-body Shop Simulations/Theory would lay the groundwork for fundamental discoveries about our universe. In the ensuing ten years, we built the Centers, platforms, and infrastructure to realize this vision and established the department as a leader in these fields, substantially contributing to some of the largest national and international astrophysical experiments. With JWST, Rubin, Roman, and more large observatories coming on line, as well as active planning for future NASA flagship missions underway, we have a once-in-a-generation opportunity to fully realize this investment. Building upon our well-established scientific strengths, the Astronomy department will continue to develop novel space-based and ground-based observational surveys and instruments that push the boundaries of our knowledge in exoplanetary, stellar, Galactic, extragalactic astronomy and cosmology; will construct and enhance cutting-edge computer simulations and develop new theories that explain and predict new astrophysical discoveries in all of these areas; and will continue to lead the field in training the next generation of astrobiologists and data scientists, whether or not they remain in the field of Astronomy.

In the next ten years, we hope to further diversify our department at all levels, as in diversity there is strength. Furthermore, we will strive to make minoritized members feel empowered to carry out their best work in a supportive and non-threatening environment. We have recently hired an assistant teaching professor, Dr. Sophia Cisneros, who will start in the Autumn as the first indigenous woman faculty member. We are approved for two new tenure-line hires for Autumn 2023, for which we are adopting equitable hiring practices, such as an initial anonymized application. Although these hires will help cover a current shortfall due to faculty on-leave/in-departure, we are expecting several retirements in the next decade which will require further tenure-line hiring to maintain our teaching, research, and advising capacity, and offer an opportunity for further diversifying our faculty. We would like to find ways to improve the graduate mentoring program, and the support of GCAP. We have attempted to broaden our pool of postdoc applicants by combining our calls into a single ad, with limited success due to the breadth of our research interests (Astrobiology to Cosmology), and so we would like to find ways to improve this.

Goals: The UW Astronomy faculty have three primary major investment goals for the next decade of their scientific endeavors at UW. First, all unanimously support a significant investment in a large aperture (10-m class) telescope not only to enable scientific discovery in all subfields, but also for recruitment of new faculty members, students, and postdocs. A large-aperture telescope is essential for studying, e.g., the properties of exoplanets and their atmospheres, the faintest components of galaxies, high-redshift probes of the intergalactic medium, and spectroscopic follow up of the faintest discoveries from Rubin/LSST. While current resources do not allow for a buy-in to an existing 10-m class telescope that would enable this observational science, the faculty have agreed that fundraising is a priority for this purpose. A way to offset the fees for buying into telescope time is to take a leading role in building a new instrument or a component of a new instrument, an avenue that would be open to us with an effort led by Professor Tuttle or future hires.

In parallel, we recognize a need to establish more sustainable, diversified, sources of funding for department initiatives. An example is a well-funded prize postdoc in UW Astronomy to make use of the novel space and ground-based surveys that will be well underway during the next decade. In order to realize the full scientific potential of our decades-long investment in the Rubin Observatory, and subsequently the Roman Space Telescope, we must also be able to fund our Centers and attract the top talent in the field to our program. We ultimately envision a deeply collaborative, active department at all levels engaged in ground-breaking scientific research, with access to the best possible resources.

Finally, as we realize the above goals we will again encounter the issue of space. While remote work during the pandemic has deferred the space crisis, the influx of new faculty starting larger groups than the faculty they're replacing, and the growth of projects around Rubin, is likely to reignite it within the next 2-3 years. The inability to offer positions due to space would quickly become a limiting factor in our ability to reap the rewards of long-term departmental investments. The solution is unlikely to be in converting common spaces into offices: this has already been done to a large extent, with a significant negative side-effect of reduced interaction between department members. Rather than relinquishing them, we see the need to add to and develop common spaces as a critical element to ensure short- and medium-term success. Overall, new space will be needed to sustain the level of research conducted.

Enabling High-Impact Science: These investments will sustain and grow UW Astronomy participation in key areas. 1). LUVOIR and HabEx: In the latest 2021 US Decadal Survey of Astronomy, the LUVOIR and HabEx telescope concepts were the two main flagship NASA missions called out for technology development and funding over the next decade, with the goal of detecting and characterizing Earth-like planets with direct imaging and further probing the evolution of our galaxy and universe. These mission concepts had been championed by UW Astronomers: Prof. Meadows' team developed the biosignatures concepts and mission design calculations; Prof. Agol developed the planet-finding and characterization ideas in the 2013 NASA 30-year Roadmap; Prof. Werk helped to define requirements for studying "cosmic ecosystems" as a way to understand our cosmic origins in the context of galaxy evolution; and Prof.

Dalcanton advocated for this mission in the 2015 AURA Report and Decadal Survey. UW faculty expect to continue to play a role in the development of LUVOIR/HabEx with investigations into exoplanets and galactic physics, further developing the science case for these missions. 2). Survey Science: Rubin Observatory builds on the legacy of many UW Astronomers who have developed and carried out survey science with the SDSS at APO, as well as successor surveys such as Pan-STARRS and ZTF. Prof. Ivezić is current Director of Rubin Observatory, the culmination of more than a decade of work on the telescope, and a career spent in survey Astronomy. UW Astronomy is a founding member of the project and was instrumental in prompting the 2005 donation by Simonyi and Gates of $30M for construction of the Rubin mirror. And DiRAC is a department Center for data-intensive research (also started by a gift from the Simonyi foundation) established to enable UW researchers utilize Rubin to its full potential. With first-light in 2023, and the start of Rubin's LSST survey in 2024, UW Astronomy is poised to lead the scientific studies with this groundbreaking dataset. 3). Astrobiology. The UW Astrobiology program is headquartered in UW Astronomy, led by Prof. Meadows, and UW Astronomy graduate students have infiltrated NASA to help in designing the next generation astronomy/astrobiology-related missions. UW Astrobiology will start to reap what it has sown with the successful launching and commissioning of JWST and with studies of planet systems such as TRAPPIST-1 has the potential to yield our first glimpse at the atmospheres of terrestrial planets beyond the Solar System, and perhaps lend clues to the presence of biospheres. 4). Computation. The N-body shop has led the way in the development of novel algorithms for high-resolution and large-scale simulation of galaxies and protoplanetary disks. UW Astronomers have developed novel machine-learning and data science algorithms, developed new ways of comparing observations with the simulations, and literally written the book on data science in Astronomy. With the advent of JWST and Rubin, the history of our universe is going to be rewritten, and simulations involving UW astronomers will play a crucial role in interpreting these discoveries.

PART B
UNIT-DEFINED QUESTIONS

1) What are our priorities for research and infrastructure investments, and how can we fund these goals (from private and/or government sources)?

As discussed in Section IV, we look forward to realizing the returns on a decade of investments in areas from astrobiology to survey astronomy. Besides continued support for people and initiatives, we urgently need to invest in a large-aperture telescope with coverage of the Southern hemisphere. Our Rubin involvement will lead to discoveries which require spectroscopic follow-up observations. As has been demonstrated with the pairing of photometric and spectroscopic facilities (e.g., the SDSS at APO or the Dark Energy Spectroscopic Instrument at CTIO), it is the combination of photometric imaging data together with followup spectroscopic observations that enables a detailed understanding of the physical processes that drive the evolution of the universe (whether searches for signatures consistent with life on exoplanets or measures of the expansion history of the universe). As we close out the last decade of new discoveries with HST/COS absorption-line spectroscopic studies of the CGM, we enter a new era in which detecting the CGM in emission is necessary to make progress. Only a large-aperture telescope with state-of-the-art IFU instrumentation (e.g. MUSE, KCWI) can enable the department to continue to lead in CGM science. And finally, to attract candidates with observational exoplanet expertise, who would further enhance the science of our Astrobiology program, the department will require access to a large-aperture telescope with high-resolution spectroscopic capability.

Realizing the scientific potential of Rubin is a primary objective for the department and will include spectroscopic classification of asteroids and interstellar objects, supernova classification, studies of the CGM, large-scale structure analyses (which also ties to work in DUSC), and real time followup of transient events (which is in turn tied to the department's leadership in real time processing of Rubin data for transient, variable, and moving sources). At the depth of even a single exposure from Rubin (r=24.7 magnitudes) current spectroscopic facilities on the APO 3.5.m would be capable of observing less than 5% of the sources on the sky (largely at low redshift). Access to larger aperture telescopes in the Southern hemisphere (i.e., 10-meter class telescopes) with multi-object and potentially wide field spectroscopic capabilities could increase this to over 50% and target the high-redshift universe. Part of this access could be achieved through the use of national facilities or in-kind access through the development of instrumentation; however, the oversubscription of national facilities will severely limit the time available to department members. In addition, UW Astronomy's access to the ARC 3.5m in the last decade was critical in attracting students, postdocs and faculty to our department, but at this moment in time, of the 18 US Astronomy departments that are ranked at or above the UW in the 2010 NRC R-Ranking, only the UW and one other institution (UMD) does not have, or plan to have, institutional access to a 6m or larger optical or sub-mm telescope, and 9 of those institutions are contributing to the building of 20m or 30m telescopes. For all of these reasons, developing a share in a 10-m telescope of at least 8-10 nights per year, and growing that share over the next decade would enable department researchers to have a comparable impact with Rubin data as was achieved with SDSS.

Access to state-of-the-art observational facilities necessary to maintain the department's leadership in astronomy and astrophysics and will require significant resources (e.g., buying-in to the facilities, providing operating expenses). Given current projections for funding from state and national resources, support from philanthropic individuals and foundations will be critical if the department is to achieve its 10-year goals and priorities – both large telescope buy-in and sustaining the research programs these can enable. The department's Centers and individual faculty have already had some success in obtaining funding from philanthropic sources, including the Moore and Sloan Foundations, the B612 Foundation, Heising-Simons Foundation, Schmidt Futures, and Charles and Lisa Simonyi foundation. These show that there is interest at the local and national level in supporting the research, students, and members of the department. However, to realize philanthropic investments at the scale necessary to acquire new observing facilities and sustain associated research programs and Centers, it will take a strategic approach to fundraising at a scale not achieved to date. This includes organization within the department, but also expanded University-level commitment and support at all levels (Advancement, Communications, etc.) for fundraising in Astronomy.

2) What are the goals of our graduate program, and what career paths should we be supporting?

Historically our graduate program has aimed to provide students with the skills needed to succeed in academia: experience in research, teaching, and scientific communication are emphasized strongly in our program. Lately, a growing fraction of our Ph.D. alumni have gone into data science jobs, either immediately or after a first postdoc. In recent years our program has added the goals of broadening participation in astronomy and supporting students in pursuing careers outside of academia. In response, during the last decade we have changed our program significantly (as detailed above). We have reduced the number of required courses from twelve to ten, but some faculty and students still feel that we may be overburdening students with coursework, which detracts from research and/or taking interdisciplinary courses. Are these changes working (Qual, mentoring team, narrowing Astro coursework, adding interdisciplinarity)?

In our spring faculty retreat, we identified issues related to communication between faculty and grad students, and amongst faculty. The issues primarily involve the requirements of the program and the processes and procedures for making progress, but also involves improving interactions between students and faculty, and amongst faculty, especially while emerging from the pandemic as student and faculty presence in the department has not yet recovered. How do we improve communication between faculty and graduate students? How do we better support our students, including students who may end up leaving academia, and minoritized students who may have significant barriers to contend with? In particular, we would like to find better ways to support GCAP, and students who are struggling in the program.

We also had some discussion about the right size of our Ph.D. program: some faculty feel it should expand, while some feel its current size should be maintained since the number of faculty available to advise Ph.D. students has stayed roughly the same. The number of applicants to our program has grown significantly, while each enrolled Ph.D. class has remained constant in size, averaging 5 students. TA positions are being filled with post-bacc students, some faculty have had difficulty in finding graduate students to fill RA positions, while others have had difficulty in finding support for students during a long Ph.D. (which in recent years has been exacerbated by the pandemic), and we have had a small number of students who have left the program (which can have a significant impact given the small number of students to start with). Should we modify or maintain the size of our program and/or make changes to our admissions process?

Another possibility we discussed would be to introduce a terminal Master's degree. It might address shortfalls in RAs and/or TAs, allow us to admit more students out of a significant number of highly-qualified applicants, give some students training who are unsure whether they would like to finish a Ph.D., help prepare students to enter a Ph.D. program elsewhere (or continue in our Ph.D.), and could provide them technical training for, say, a data science career outside of academia or a career in science communication and outreach. It might also provide a source of self-sustaining funding if we charged students tuition. However, there are some significant drawbacks we identified to instituting a terminal Master's degree. If students would pay for the program tuition themselves, is this ethical given the limited number of jobs in Astronomy and limited slots in Ph.D. programs? Most faculty are already at their limit in terms of advising student research, so it is not clear how an additional cohort of Master's degree students would find research advisors. There is also a mismatch with the other top Astronomy Ph.D. programs in the US which also offer a Ph.D. program without a terminal Master's, as we currently do. Would Master's graduates be required to retake courses elsewhere that they completed in our degree program? Finally, someone would need to take the lead in developing this program, the program would require additional staffing, and it is not clear what benefit such a program would offer the field of Astronomy in general, which is already bursting at the seams with qualified Ph.D. candidates.

3) What are the goals and what is the right size for our undergraduate program?

As more and more majors seek out research experiences within the department and require 1:1 support to navigate the major, the faculty are increasingly stretched thin to serve the students' needs. Our department's current capacity for undergraduate majors, 120, was not set thoughtfully through a rigorous assessment of student resources and faculty capacity. Instead, it was set in 2019 out of an immediate necessity to staunch the influx of new majors we were seeing, and primarily by the lack of available classroom space to accommodate our required upper-level coursework. As 40-50 students seek out meaningful research experiences every quarter, how can we accommodate their training? Are we able to instruct and guide our astronomy students under the current conditions and at the current major capacity? How can we fairly distribute the workload of advising undergraduates in research among faculty and research staff?

Every year, approximately 20-30 of our graduating students enter into the increasingly competitive graduate admissions landscape, spending thousands of dollars to apply to an average of 15 programs each, and exacerbating the growing problem of graduate admissions in Astronomy Ph.D. programs nationwide. Moreover, some faculty report having to write letters for ~15 undergraduates every year, each applying to 15 programs, each with their own letter submission site and deadline. Finally, many of these student applicants will never be admitted to a Ph.D. program in Astronomy and/or Astrophysics. Is it good for the general field of Astronomy to have grown such a large undergraduate population when tenure-track faculty lines and funding sources in Astronomy have remained roughly constant over the last decade?

At our recent faculty retreat, we discussed a number of possible solutions to the above issues which include the formal development of a data-science option and a "classic" (aka non-research-seeking, non-physics-focused) major track. At the time of admission to the major, the students would choose one of the three possible tracks: data-science, research, or classic. We would then set capacities within the major for each track, possibly reducing the burden of advising so many undergraduate research projects. However, completing research is not currently required for majors (it is required for the honors program, which only a handful of undergraduates complete each year), so it is not clear this would solve the research advising problem. Many students will likely continue to choose to pursue research and seek out help from the faculty undergrad advisor to find a research project that will prepare them for graduate study. Additionally, both the data science and "classic" track options would have to be decoupled from the physics major, which poses significant issues in terms of coordinating with other departments and dealing with a variety of pre-requisites and majors-only courses (e.g. Statistics, Computer Science, Earth and Space Sciences). Should we begin the work of developing these tracks/options? Is there another way to limit the number of undergraduates pursuing research without setting a GPA cutoff or having another "gatekeeping" process in place?

4) How can we manage and plan for possible growth in the number of people in the department and the availability of resources?

Over the decades our department has grown significantly in the complexity of our research, teaching and service missions along with a slight increase in personnel and a large increase in undergraduates. Interdisciplinary groups within the department such as Astrobiology, DUSC, and DiRAC have also grown. Participation in the construction of the Vera Rubin Observatory has increased our personnel count, and it is unlikely to decrease as our department will have a significant role in operations, not to mention the scientific return on our investment. Our undergraduate teaching has also grown, and our department also plays an outsized role in service for the University and the nation. The complexity of these missions is also increasing with increased proposal complexity, increased HR rules and our diversity of pedagogy.

This growth raises some specific needs. Space is always a consideration. While space is sufficient for our upcoming hires, if our new faculty are as productive in growing research groups as our current faculty, space could quickly be a limit. We have nearly filled our current floor in our building, so it is not obvious how to expand. For research projects, many larger departments have staff help for managing CVs, current and pending, and Collaborative and Other Affiliations information required for proposal submission, and to help with project reporting post award. Such help frees up faculty time to focus on the science of the proposal and the execution of the research. The increased size of our undergraduate program also impacts our staffing needs. Given limited resources, we need to strategically consider how to grow our staff support.

The growth in the department has implications for the overall management structure. With the appointment of the most recent chair, the department went from one to two associate chairs to help with administration, and instituted an executive committee to help with department strategy. While this was deemed necessary for management of the department, it puts an additional load on senior faculty who are already very active in research and in University and national service. Senior level (outside) service is frequently enabled by teaching buyouts. While fully funded and helpful to our research mission, if substitute adjunct/teaching faculty are not available the load on the remaining faculty can increase. Better anticipating buyouts, clear policies, and ensuring substitute availability may alleviate these issues. Also, our very active faculty necessitates a thoughtful succession plan to train people to move into administrative service as the currently most senior faculty move toward retirement.

More broadly, we need strategies to balance the core missions of research, teaching and service among the department members, so that all are appropriately engaged in these activities. Again, the strong leadership of our senior faculty in outward service puts a stress on this balance.

PART C: APPENDICES

Appendix A: Organizational Chart

FACULTY 2021 – 2022

Name	Rank	Appointment Type	Affiliations
Agol, Eric	Professor		Astrobiology, Physics
Anderson, Scott	Professor		
Barnes, Rory K.	Associate Professor		Astrobiology
Bellm, Eric C.	Research Assistant Professor		
Connolly, Andrew J.	Professor		Computer Science
Dalcanton, Julianne	Professor (on leave)		Physics
Davenport, James R.A.	Research Assistant Professor		
Fraser, Oliver J.	Assistant Teaching Professor		
Hawley, Suzanne	Professor		
Ivezić, Željko	Professor (on leave)		

Jurić, Mario	Associate Professor		
Kelly, Nicole M.	Lecturer Part-Time	Part-Time	
Laws, Christopher S.	Teaching Professor		
Levesque, Emily M.	Associate Professor		
McQuinn, Matthew J.	Associate Professor		Physics
Meadows, Victoria S.	Professor		Astrobiology
Quinn, Thomas R. (Chair)	Professor		Astrobiology, Physics
Sánchez-Gallego, José R.	Acting Assistant Professor		
Smith, Toby R.	Associate Teaching Professor		
Tuttle, Sarah E.	Assistant Professor		
Werk, Jessica K.	Associate Professor		
Williams, Benjamin F.	Research Associate Professor		

Emeritus Faculty 2021– 2022

Name	**Rank**
Balick, Bruce	Professor Emeritus
Brownlee, Donald	Professor Emeritus

Sullivan, Woodruff T.	Professor Emeritus
Szkody, Paula	Professor Emeritus
Larson, Ana	Lecturer Emeritus

Adjunct and Affiliate Faculty 2021 – 2022

Name	Rank	Appointment Type	Affiliations
Clark, Joanne	Affiliate Assoc Prof		
Morales, Miguel	Adjunct Professor		Physics, UW
Murphy, Thomas	Affiliate Asst Prof		
Tran, Kim-Vy	Affiliate Asst Prof		

Research Associates *(Postdocs)* 2021 – 2022

Name	Faculty Affiliation
Bell, Keaton	Bellm
Bernardinelli, Pedro Henrique	Jurić
Bostroem, Kyra Azalee	Jurić
Dorn-Wallenstein, Trevor Z	Levesque
Faerman, Yakov	McQuinn

Phillipson, Rebecca	Bellm
Rasmussen, Kaitlin	Meadows
Sedaghat Alvar, Nima	Bellm
Smercina, Adam	Quinn
Suberlak, Krzysztof L.	Connolly
Tchernyshyov, Kirill	Werk

Research Scientists 2021 – 2022

Name	Faculty Affiliation
Lincowski, Andrew Peter	Meadows
Phillips, Christopher A	Bellm
Davis, Christopher E	Meadows
Langford, Zach	Jurić, Agol
Mandeville, Travis Andrew	Tuttle
Findeisen, Krzysztof	Jurić
Greenstreet, Sarah	Jurić
Gupta, Pramod S	Meadows
Gupta, Pramod S	Anderson

Heinze, Aren N	Sullivan
Joswiak, David J	Brownlee
Kalmbach, John Bryce	Connolly
Rawls, Meredith	Jurić
Sayres, Conor	Tuttle
Yoachim, Peter	Jurić
Graham, Melissa	Jurić
Parejko, John K	Jurić
Slater, Colin T	Jurić
Sullivan, Ian	Jurić
Owen, Russell E	Jurić

Administrative Staff 2021 – 2022

Name	Title
Valdez, Tyneshia	Human Resources Manager
Ness, Jessica Crabb	Budget/Fiscal Analyst Lead

Detert, Ashley M	Fiscal Specialist 1 Payroll Coordinator
Quintana, Elisa	Academic Counselor - Senior
Young, Robert A.	Administrator
Gómez-Buckley, Adriana C	Program Assistant

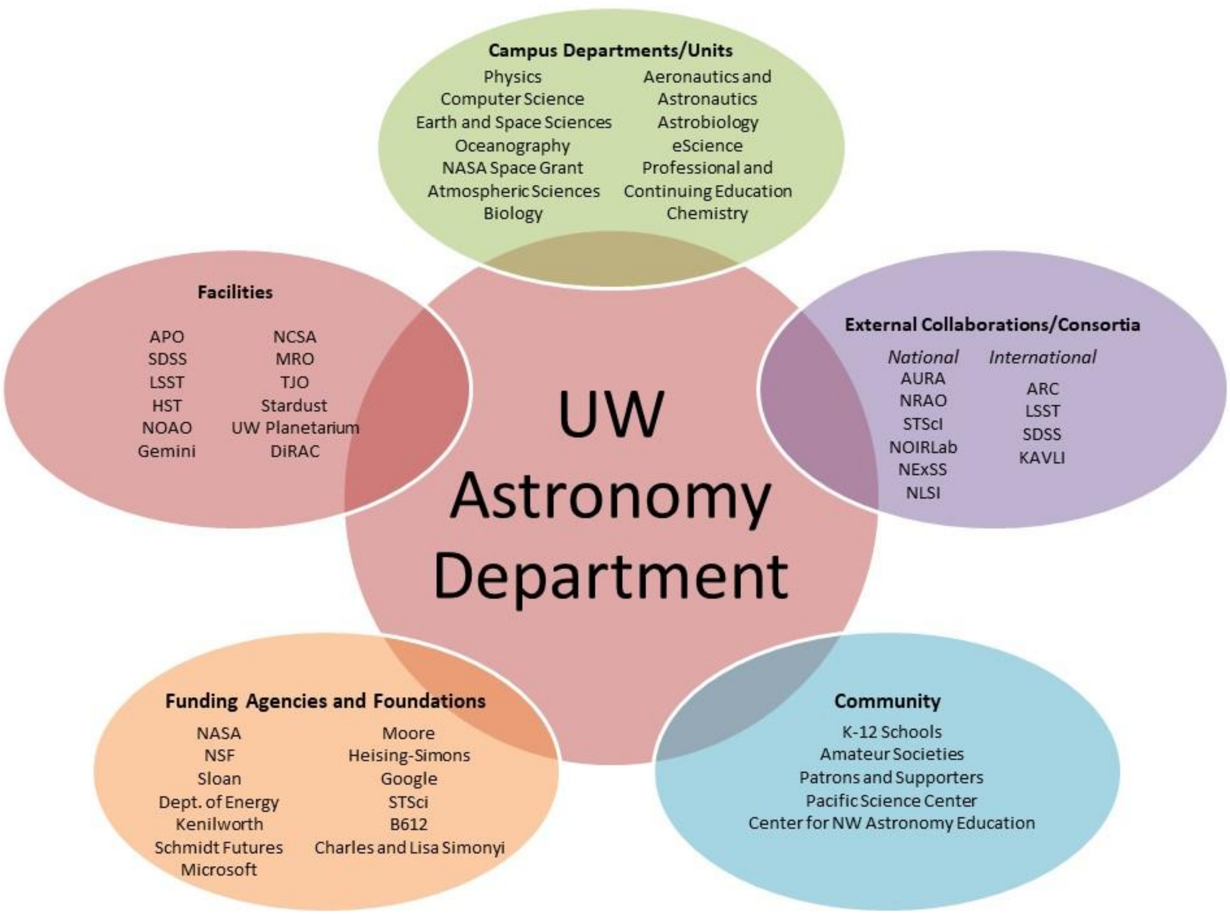
Astronomy Faculty Responsibilities 2021 – 2022

Responsibility	Faculty Assigned
3.5m Deputy Director	Williams
3.5m TAC	Williams, Hawley
ARC Board	Hawley
ARC Users Rep	Bellm
Associate Chairs	Agol, Werk
Associate Vice Provost for Data Science	Connolly
Astrobiology	Meadows
AURA Board Rep	Anderson
A-wing Telescopes	Fraser
Chair	Quinn
Computing Planning and Policy	Jurić
Development	Connolly
DEI Committee Chair	Tuttle
DiRAC Institute Director	Jurić

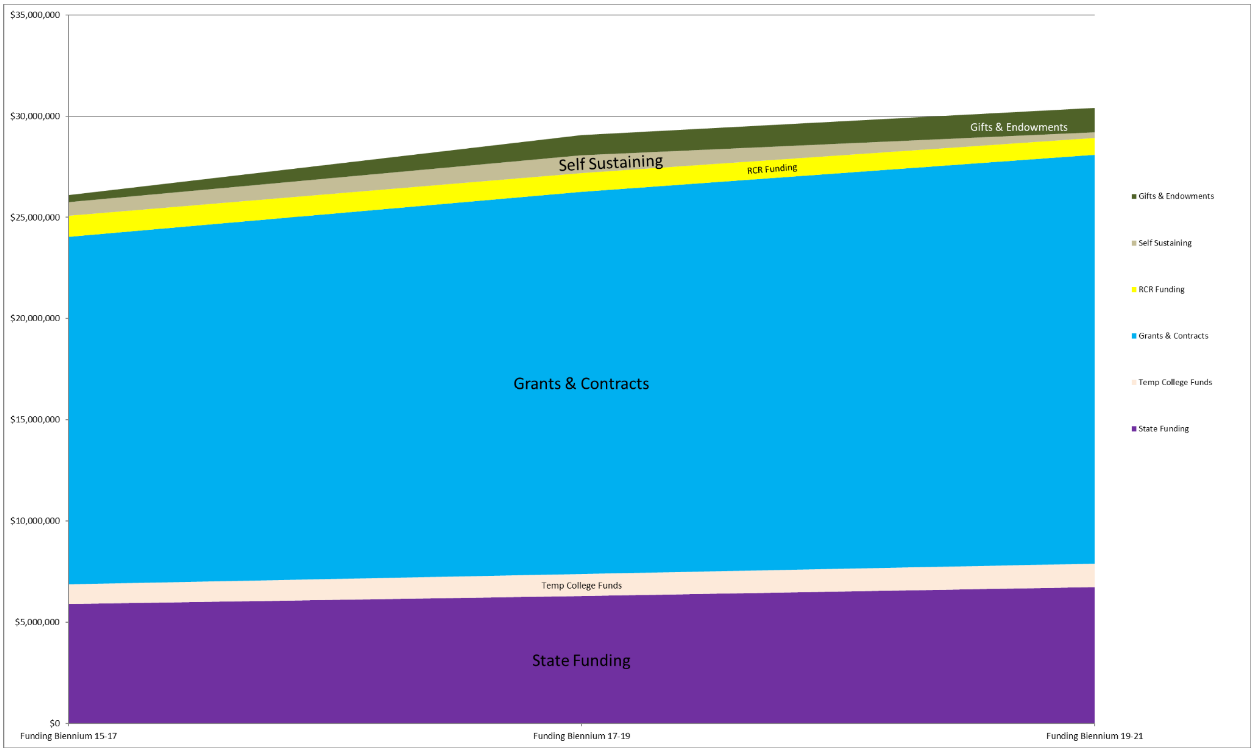
DiRAC Institute Associate Director	Davenport
eScience Institute Director	Connolly
Faculty Senate	Laws (Chair), Anderson
Graduate Admissions	Levesque
Graduate Advisor	Agol
Jacobsen Fund	Williams, Anderson
Lab Fee Allocation	Smith, Fraser
LSST Corporation Board	Hawley, Davenport
LSST Project Scientist	Ivezić
MRO Director	Fraser
Planetarium	Fraser, Connolly
Postdoc Committee	Juric, Bellm, Davenport
Pre-MAP	Agol
Qualifying Exam	McQuinn
SDSS-IV Advisory Council	Anderson
SDSS-IV CoCo	Anderson
TA Assignments	Agol

Telescope Engineering Group	Tuttle
TJO Director	Balick
Undergraduate Advisor	Werk

* Indicates Chair of committee



Appendix B: Budget Summary



	State Funding	Temporary College Funds	irants & Contract	RCR Funding	Self Sustaining	Gifts and Endowments	Total
Funding Biennium 15-17	$5,890,574	$982,460	$17,159,795	$1,055,782	$671,515	$340,014	**$26,100,140**
Funding Biennium 17-19	$6,290,858	$1,097,071	$18,874,334	$929,688	$875,723	$997,341	**$29,065,015**
Funding Biennium 19-21	$6,727,532	$1,161,626	$20,189,608	$844,512	$287,678	$1,184,835	**$30,395,791**
Total	**$18,908,964**	**$3,241,157**	**$56,223,738**	**$2,829,982**	**$1,834,917**	**$2,522,189**	**$85,560,947**

Appendix C: Information about Faculty

Faculty CV's are available here:
https://drive.google.com/drive/folders/194Uo-mGpoExknoZOaeRuqUjRXsk6xfuF?usp=sharing

Faculty 2021 – 2022

Name	Rank	Appointment Type	Affiliations
Agol, Eric	Professor		Astrobiology, Physics
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Hawley, Suzanne	Professor		
Ivezić, Željko	Professor		
Jurić, Mario	Associate Professor		
Kelly, Nicole M.	Lecturer Part-Time	Part-Time	
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Meadows, Victoria S.	Professor		Astrobiology
Quinn, Thomas R. (Chair)	Professor		Astrobiology, Physics
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Smith, Toby R.	Associate Teaching Professor		
Tuttle, Sarah E.	Assistant Professor		
Werk, Jessica K.	Associate Professor		

Williams, Benjamin F.	Research Associate Professor

Appendix D: Diversity Plan

UW Astronomy Diversity statement.

Appendix E: Response to Previous (2010-11) Report

The main recommendations from the 2010-11 review are given below in bold, followed by discussion of current status:

***Undergraduate major*: focus on coordination with physics, preparation for physics GRE, and preparing students for graduate school.**

Much has changed in the past decade, particularly with the large growth in the major, including many students who have no intention of going to graduate school and are using astronomy as a way to gain experience with data science for a career in industry. Also the physics GRE is no longer required for admission to most astronomy programs, including ours. The undergraduate major is currently in the midst of significant updating and is an important subject for the current review (see Section II and unit defined question 3).

Graduate program: TA training

We successfully implemented a TA training program during the first few years after the 2010-11 review. Recently, the significant change in the graduate curriculum including much more focus on early research experience has resulted in fewer of our students being TAs, and less focus on TA training which still remains an issue.

Diversity and outreach: secure funding for Pre-MAP

We have tried very hard to do this, but still basically use our RCR funds to cover the costs of Pre-MAP.

Advancement: establish funding priorities to participate in capital campaign

An initial push (led by Connolly) resulted in the formation of DiRAC, as a major success in advancement. Several smaller donor programs aimed at graduate students were funded by emeritus faculty members (Balick, Wallerstein, Lutz, Hodge)

Research: focus on key areas addressable by LSST and proposed CCO; identify theoretical astrophysics focus and coordinate with physics; establish leadership role in ARC/future of APO.

The previous (2010-11) review proposed the formation of a Center for Computational Origins (CCO). A successful fundraising effort led to the formation of an institute, renamed the DiRAC Institute (Data intensive Research in Astrophysics and Cosmology), which was facilitated by a large gift from Charles and Lisa Simonyi. It takes advantage of the significant survey science investment over the past two decades at UW (particularly in SDSS and LSST). We also leveraged funds from the Washington Research Foundation and the Department and College to buy into ZTF as a precursor survey to LSST. Significant College resources were allocated to providing space for DiRAC and expanding the department footprint to encompass almost all of the 3rd floor of PAB.

Theoretical astrophysics – the decision to focus on cosmology and the ISM led to two hires in CGM (McQuinn, Werk); McQuinn has developed strong ties to physics.

ARC/APO - There was significant involvement in SDSS-IV and V projects at APO, continued leadership of 3.5m (Hawley was director 2010-2016, followed by Williams as deputy director 2017-present), and a new hire (2016) Tuttle leading instrumentation efforts for both SDSS and 3.5m.

Faculty: faculty hiring plan for next decade, build core of 15 regular faculty, plan for research faculty, mentor mid-career faculty to prepare for leadership succession

Faculty hiring was very successful: 4 TT faculty hired (McQuinn, Levesque, Werk, Tuttle) to replace 4 retirements; 1.5 additional TT faculty positions were added through the UW data science initiative (Juric, 1.0) and the astrobiology program (Barnes, 0.5). Core faculty FTEs are now at 14.5. We also hired several research faculty (Williams, Barnes - 0.5, Bellm, Davenport, Sanchez-Gallego). Mid-career faculty member Dalcanton became Chair in 2016; mid-career faculty member Agol and recently promoted (to Assoc Prof) faculty member Werk are presently Associate chairs.

Additional Appendices

Appendix F: Promotion and Tenure Guidelines

In June, 2020 the department, in consultation with the College of Arts and Sciences adopted the following Promotion and Tenure Guidelines for Astronomy. These guidelines were approved by the CAS College Council in November, 2020.

For most promotion cases in tenure-track and research faculty appointments, the Department of Astronomy’s criteria for promotion are aligned with those outlined by the College of Arts & Science’s “Promotion Considerations.”

There are, however, a number of considerations that are applicable to certain subfields of Astronomy, but that are not fully captured by the College's guidelines. The most relevant to Astronomy are promotion cases of faculty whose scholarly activities are primarily focused on developing new scientific infrastructure, which can include both instrumentation and software. Both are essential for enabling subsequent scientific discovery, as well as being areas of scholarly activity on their own. Faculty members who are engaged in leadership roles in major instrumentation and software efforts are performing important, field-specific intellectual work that typically involves multi-year investments. While the multi-year, intensive nature of this work often suppresses the traditional journal publication by these projects' leaders, that same work can have a significant "multiplier" effect for creating new knowledge by the subsequent users of these important tools.

Substantial work in instrumentation or software infrastructure that is "science enabling" should therefore be considered a significant part of the scholarly record, with work that demonstrates notable creativity, innovation, quality, and/or likely scientific impact being of particular merit. It should also be considered that faculty who have taken on leadership roles in these areas will often have done so at the expense of other, more traditional forms of scholarly output.

Appendix G: Artifacts Associated with Student Outcomes

Profile of Undergraduate Alumnus and Current UW Astronomy Graduate Student Lupita Tovar: https://www.youtube.com/watch?v=_RNYStAev4M

Student-Directed Video Describing the Student Club "League of Astronomers": https://www.youtube.com/watch?v=3zok_5O0f1c

Mercedes Thompson's poster, Adriana Gómez-Buckley's poster, and Luke Serber's poster.

Appendix H: UW Astronomy Faculty in the News and Awards

Here are several examples of UW Faculty in the news in the last few years:

Prof. Levesque teaches one of The Great Courses.

Prof. Eric Bellm discovered a new example of a rare type of neutron star binary:

Prof. Mario Juric and Ph.D. candidate Joachim Moeyens track down killer asteroids (New York Times).

Prof. Eric Agol characterized temperate terrestrial TRAPPIST-1 exoplanets.

Prof. Sarah Tuttle advocated for renaming JWST.

Profs. Levesque, Tuttle & Werk were featured in a Scientific American article on the impact of women with Astronomy.

And here is a (non-exhaustive) list of awards to UW Astro faculty. Profs. Werk, Levesque and McQuinn were awarded Sloan Fellowships. Profs. Meadows and Brownlee were inducted into the Washington State Academy of Sciences. Profs. Agol, Dalcanton, Connolly and Werk have been awarded NSF CAREER awards. Profs. Werk and Levesque were made RCSA Cottrell Scholars, Prof. Bellm an RCSA Scialog Fellow. Profs. Agol and Levesque were awarded Guggenheim Fellowships, Prof. McQuinn a John Bahcall Fellowship, and Prof. Levesque a Fulbright Fellowship. Prof. Meadows was awarded the SETI Frank Drake Award. American Astronomical Society awards were bestowed on multiple UW Astro Faculty: Prof. Levesque - Newton Lacy & Annie Jump Cannon; Prof. Dalcanton - Beatrice Tinsley; and Profs. Bruce Balick, Suzanne Hawley, George Wallerstein, Zeljko Ivezić, Woody Sullivan, and Vikki Meadows - AAS Fellows. Prof. Balick is an AAAS Fellow.

Prof. Ivezić joined the Croatian Academy of Arts and Science and has been awarded a Fulbright for 2022-3. Prof. Connolly was bestowed the William P. and Ruth Gerberding University Professor in 2020. Prof. Connolly was made a Clare Hall Life Fellow at the University of Cambridge in 2014, and received substantial funding from Charles and Lisa Simonyi and Schmidt Futures to establish software engineering programs for science at UW. Prof. Woody Sullivan earned the 2012 Leroy Doggett Prize from the AAS Historical Astronomy Division. Finally, Thomson Reuters' 2015 list of "The World's Most Influential Scientific Minds" recognized Profs. Anderson, Ivezić, and Quinn.

Appendix I: Tracks and Courses offered

Undergraduate: Over 90% of our Astronomy majors double-major in Physics, as physics courses comprise more than half of required credits. UW Astro offers 4 main tracks: Astronomy Core, Astronomy + Comprehensive Physics Track, Astronomy + Applied Physics Track, and Astronomy + Data Science Track. Each track requires at least 27 credits in the Astronomy core courses: ASTR 300 (required), and at least 3 of 321, 322, 323, and 324 (12 credits), plus 15 credits from 302, 421, 423, 425, 427, 480, 481, 482, 497, 499 with at least 3 in 480 or 499.

Graduate: The Ph.D. curriculum includes eight required courses, seven of which are drawn from the core: ASTR 507 (Thermodynamics & Stat. Mech), ASTR 519 (Radiative Processes), ASTR 531 (Stellar Interiors), ASTR 511 (Galactic/Extragalactic stellar systems), ASTR 541 (Interstellar Medium), ASTR 558 (Exoplanets), ASTR 513 (Cosmology), and ASTR 581 (Observing), while the additional course can be drawn from electives such as ASTR 508 (Magnetohydrodynamics), ASTR 561 (High Energy Astrophysics), ASTR 598 (Introduction to Astrostatistics and Data Intensive Astronomy), and other offerings. In addition students enroll in colloquium (ASTR 575), journal club (ASTR 576), and research credits (ASTR 600/800).

Appendix J: Credit hour growth

Credit hour growth: Since 2010, UW Astro has steadily increased the total number of student credit hours owing mostly to the expansion of our online introductory course offerings for non-majors. The three bar charts below (Figs. 1-3) track credit hours per year since 2010, divided into online-only courses and in-person courses. Figs. 1 and 2 show our flagship courses, and Fig. 3 show the remainder of our non-major courses. While in-person credit hours have remained largely flat (declining in the last few years of COVID-19 restrictions), our online enrollment in non-major courses has increased substantially. Our flagship non-majors courses are ASTR 101 and 150 (each 5 credit hours), which are both offered in-person and online, peaking at about 2500 students total during the 2021-22 academic year.

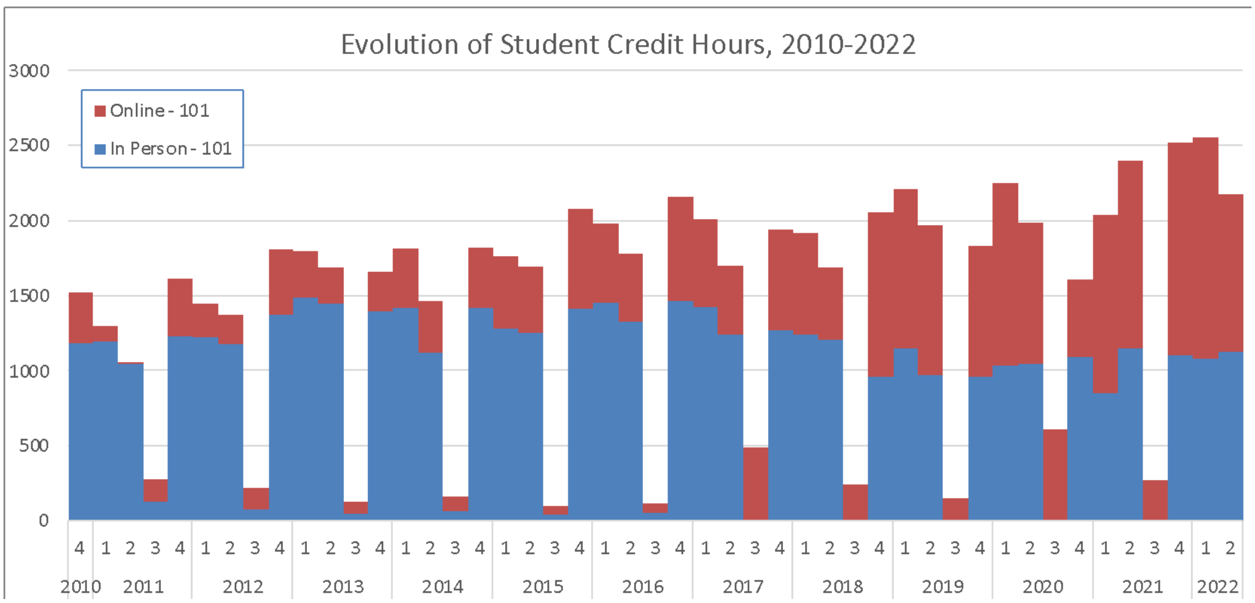


Fig. 1: ASTR 101 (Intro to Astronomy) online/in-person credit hours vs. academic quarter.

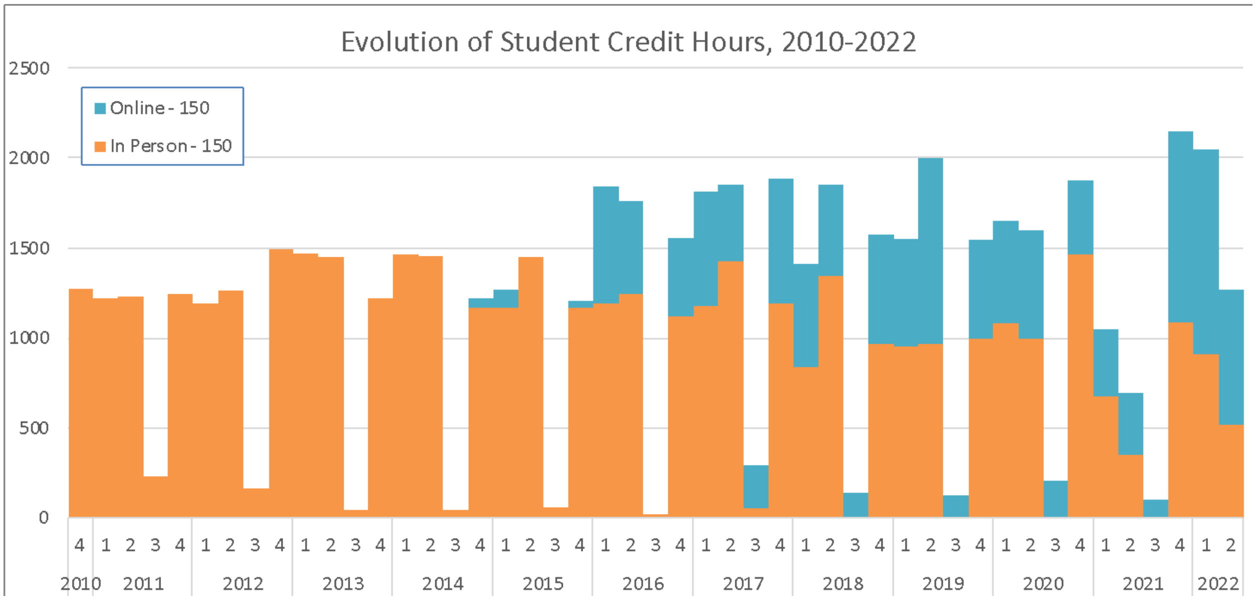


Fig. 2: ASTR 150 (The Planets) online/in-person credit hours vs. academic quarter.

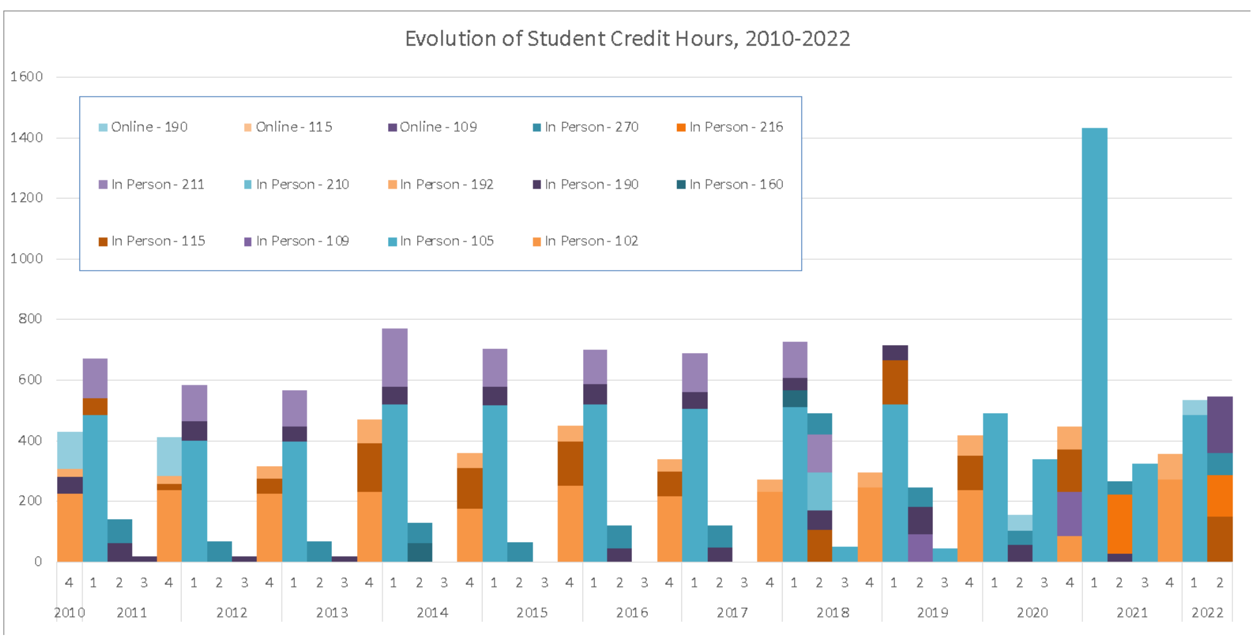


Fig. 3: ASTR 102, 105, 115, 109, 160, 190, 192, 210, 211, 216, 270 in-person/online vs. quarter.

In the charts below (Figs. 4-5), we explore trends in student credit hours of upper division Astronomy majors. The substantial growth in Astronomy majors since 2010 is reflected in the student credit hours in 300 and 400-level courses in these two figures. In 2017, we added a data-science astronomy course for astronomy majors, ASTR 324, which is colored orange in Fig. 4. ASTR 480, which is a project-intensive observational astronomy course, is responsible for much of the growth in 400-level astronomy student credit hours.

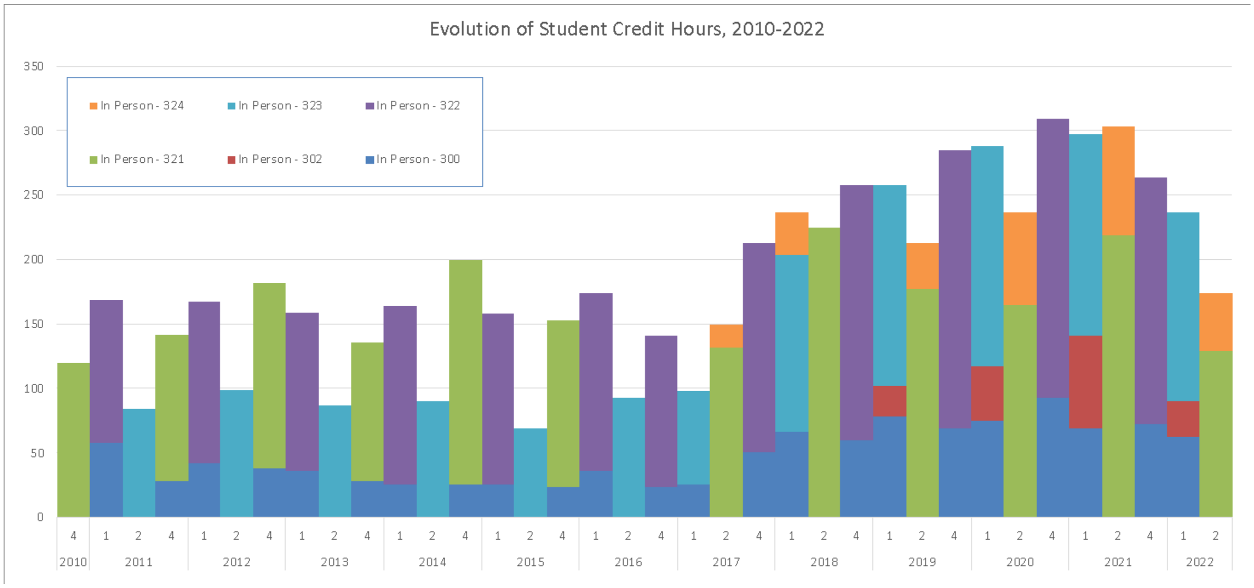


Fig. 4: 300-level Astronomy course credit hours vs. academic quarter.

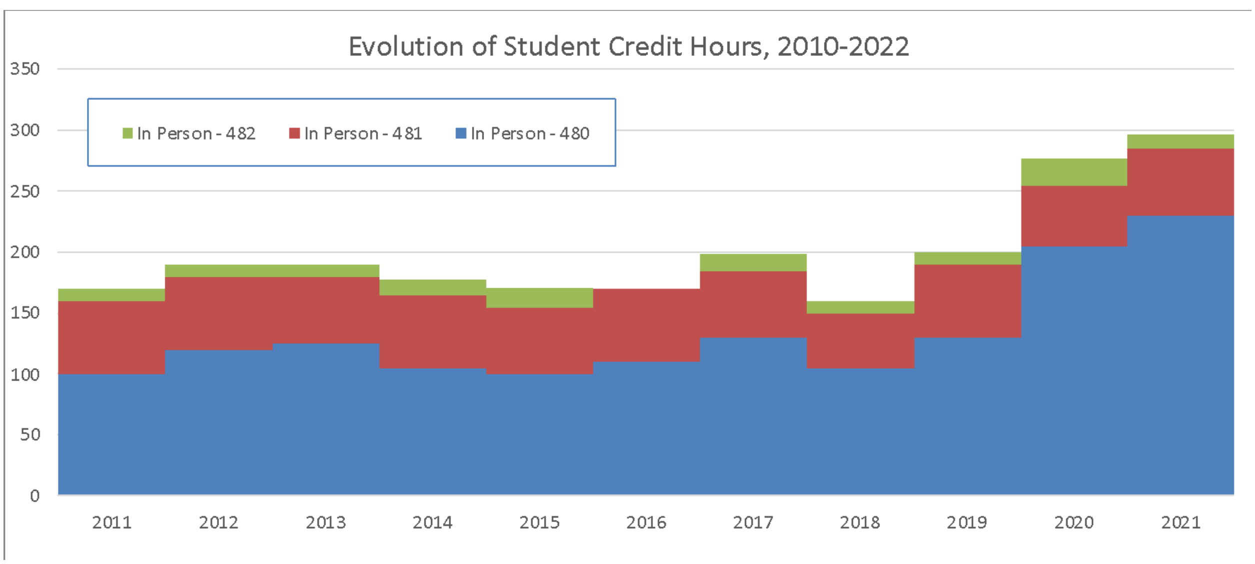


Fig. 5: ASTR 480, 481, 482 (observations/data analysis/writing) credit hours vs. year.

Our ability to train students in critical research skills depends upon students having an opportunity to interact directly with a research-active professor. More than half of our undergraduate majors pursue independent research under ASTR 499, which features one-on-one research mentorship. The growth in the Astronomy major has also meant a doubling in this plus 400-level courses. We are now offering twice as many student credit hours in independent research as we were in 2010, despite having a roughly constant number of faculty to advise those students. In the last ten years, the number of students per academic year that have received credit for ASTR 499 or 498 has grown from an average of 20 students in 2012-14 to 40 students on average in 2020-2022.

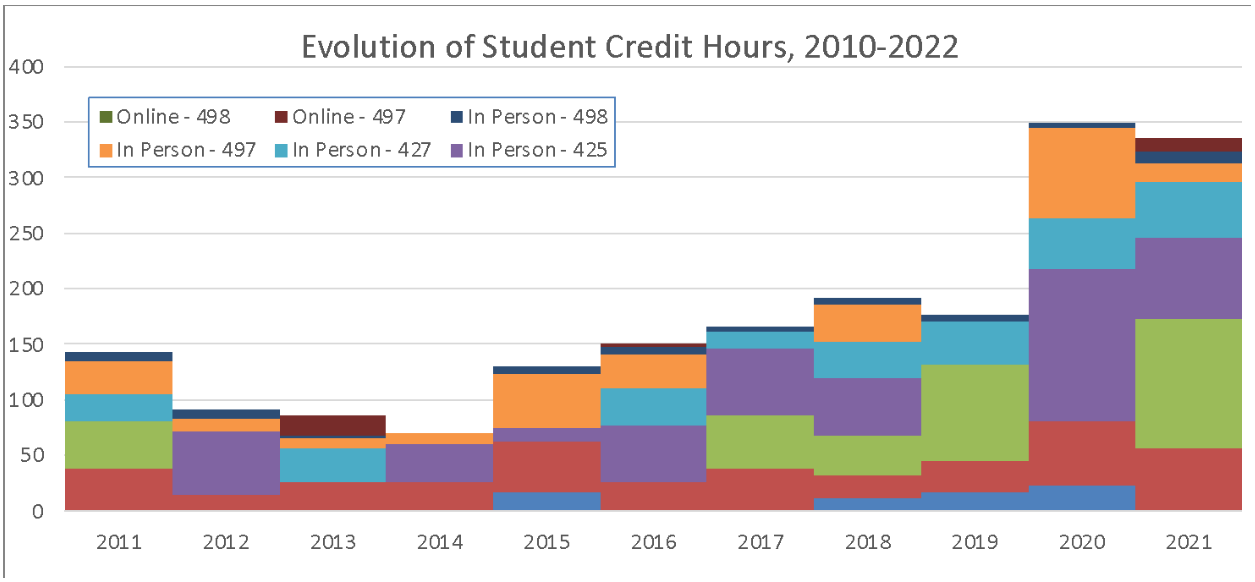


Fig. 6: 400-level Astronomy courses vs. academic year.

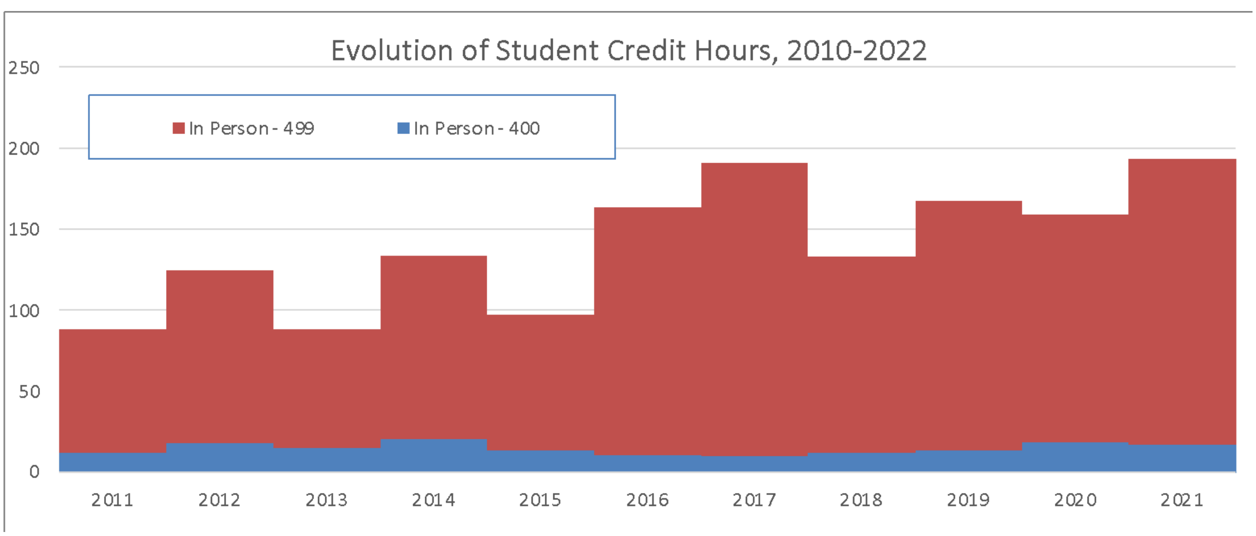


Fig. 7: ASTR 400 (intro to astro. Research) & ASTR 499 (research credits) vs. academic yr.

Appendix K: Responses to Review Committee Questions

Question:

[Was there] any demographic breakdown of the (small) number of people who left the Astro major compared to the overall Astro major program?

Response:
Since Sept. 2016, four people have applied to leave the Astronomy major. Demographic information was not officially collected on these four people, although students were consulted 1-1 by the undergraduate advisors. The primary reason for dropping the major was the inability to complete all of the astronomy course requirements in addition to other majors' coursework - two of those students were also completing majors in Mathematics; one student switched to the ESS major; and another student elected to pursue only the Physics degree.

Question:
Data Collection and Evaluation
I believe that collecting and analyzing demographic data wherever research, education, or training is conducted is required to provide a comprehensive demographic picture of the Department. To achieve the stated vision of a fully diverse and inclusive Department (maybe expanded survey of disabilities among members), a robust mechanism is required to (i) collect data, (ii) report those data for transparency and accountability, and (iii) use the data to compare outcomes to the desired state and adjust as needed. Without data, it is not possible to fully assess the health of the Department or whether desired outcomes are achieved.

I have a few requests regarding demographic data concerning

• Please provide the undergraduate students demographic landscape (gender, race, ethnicity). Provide demographic data for students applying and those admitted to the major. Is there a loss of potential talent as, e.g., students from underrepresented groups who are interested in physical sciences are less likely to be admitted to the major based on the outcomes of the holistic review? Provide demographic data for undergraduate students applying to and those accepted to graduate programs.

Response:

The following data[1] were collected from the University of Washington “BI Portal”.
The below table shows trends in female/male (the category is labeled as “sex”) of undergraduate majors during fall quarters over the past 10 years. The BI portal does not track non-binary genders, although we know from informal surveys of the majors that between 5-10% of our majors identify as non-cis-gender.

	Female		Male	
Academic Year	Percent of Students	Students	Percent of Students	Students
13-14	36.1%	22	63.9%	39
14-15	28.6%	12	71.4%	30
15-16	37.3%	19	62.7%	32
16-17	40.3%	27	59.7%	40
17-18	36.7%	22	63.3%	38
18-19	34.1%	28	65.9%	54
19-20	38.5%	45	61.5%	72
20-21	35.3%	30	64.7%	55
21-22	38.2%	29	61.8%	47

The following table shows trends in race/ethnicity of undergraduate majors during fall quarters over the past 10 years.

	American Indian or Alaska Native	Asian	Hispanic or Latino	White	Two or More Races	International (Nonresident Alien)	Not Indicated
Academic Year	Students	Students	Students	Students	Students	Students	Students
13-14		5	7	44	1	2	2

[1] In the Fall of 2021 (and beyond) approximately 40 new students were admitted to the major in October, which is not reflected in the University-wide systems until the start of Winter quarter, and which is why the sum of the astronomy majors in 21-22 is only 76. This is the result of the new capacity-constrained major and new application process (with deadlines in Fall and Spring).

14-15		3	5	32		1	1
15-16		4	5	37	3	2	
16-17		6	9	42	5	5	
17-18		4	7	42	2	3	2
18-19		9	8	52	5	8	
19-20		13	6	70	12	16	
20-21		10	6	49	9	11	
21-22	1	11	9	36	10	8	1

With respect to major admissions, we have so far been able to admit all students who meet the minimum requirements while operating just at full capacity. As we explain in the self-study document, this is somewhat by design. Thus, we have not had to turn students away after the holistic review. Moreover, there have been a couple cases in which students have not met the minimum requirements (e.g. < 2.0 in PHYS 121, 122, 123 or MATH 124, 125, 126) - in those cases, we work closely with the student to complete these requirements and retake classes, often at Seattle Central Community College (SCC) which offers course equivalencies for all of the 12X series in Math and Physics. The two students we asked to apply again under these circumstances completed a course or two at SCC and reapplied to Astronomy. They were then admitted to the Astronomy major in a subsequent quarter. We do our best to accommodate all students. (And in the meantime they are given course “add codes” when needed to jumpstart their upper-level astronomy coursework).

We have not been gathering and tracking student demographic data as a department. With new academic counseling staff, we will aim to do this moving forward.

Question:

• Please provide the graduate students demographic landscape (gender, race, ethnicity). Provide demographic data for students applying to and those admitted to the graduate program.

Response:

Sex trends[2] for graduate student enrollment over the past 10 years:

	Female		Male	
Academic Year	Percent of Students	Students	Percent of Students	Students
13-14	46.9%	15	53.1%	17
14-15	51.6%	16	48.4%	15
15-16	51.5%	17	48.5%	16
16-17	39.3%	11	60.7%	17
17-18	46.4%	13	53.6%	15
18-19	40.6%	13	59.4%	19
19-20	38.2%	13	61.8%	21
20-21	45.5%	15	54.5%	18
21-22	43.3%	13	56.7%	17

Race/ethnicity trends for graduate student enrollment over the past 10 years:

	Asian	Black or African American	Hispanic or Latino	White	Two or More Races	International (Nonresident Alien)	Not Indicated
Academic Year	Students	Students	Students	Students	Students	Students	Students
13-14	2	2	1	22	1	3	1
14-15	3	1	1	22	1	3	
15-16	2	1	1	25	1	3	
16-17	1		2	21	1	3	
17-18	1	1	3	19	1	3	
18-19	2	2	5	19		3	1

[2] Again, the BI portal does not track any genders other than M/F, but several of our graduate students identify as non-binary.

19-20	3	2	7	18	3	1
20-21	3	2	6	19	2	1
21-22	3	2	7	13	4	1

Graduate admissions selectivity and yield by sex:

		13-14	14-15	15 - 16	16-17	17-18	18-19	19-20	20-21	21-22	Avg.
Female	Application Selectivity	8%	11%	12%	9%	8%	6%	6%	8%	6%	8%
	Application Yield	67%	33%	29%	33%	38%	50%	29%	9%	40%	36%
Male	Application Selectivity	9%	7%	10%	6%	3%	4%	2%	4%	4%	5%
	Application Yield	43%	33%	40%	30%	20%	67%	25%	13%	22%	33%
Grand Total	Application Selectivity	8%	9%	11%	8%	5%	5%	4%	6%	5%	7%
	Application Yield	55%	33%	34%	32%	29%	58%	27%	11%	31%	34%

Graduate admissions selectivity and yield by race/ethnicity:

		2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	Avg
African American	Application Selectivity	0%	0%	33%	20%	33%	20%	0%	17%	14%	15%
	Application Yield			0%	0%	50%	100%		0%	0%	25%
American	Application	0%			0%		0%	0%		0%	0%

Indian	Selectivity										
	Application Yield										
Asian American	Application Selectivity	13%	0%	0%	40%	0%	8%	11%	5%	4%	9%
	Application Yield	100%			0%		50%	50%	50%	0%	42%
Caucasian	Application Selectivity	10%	12%	12%	5%	3%	5%	2%	4%	4%	6%
	Application Yield	38%	33%	42%	50%	25%	56%	0%	14%	38%	33%
Hispanic	Application Selectivity	0%	0%	29%	13%	14%	6%	17%	7%	7%	10%
	Application Yield			50%	50%	25%	100%	50%	0%	33%	44%
Two or More Races	Application Selectivity	0%	0%	17%	10%	0%	0%	0%	11%	6%	5%
	Application Yield			0%	0%				0%	0%	0%
Unknown	Application Selectivity	0%	0%		0%	0%	13%	17%	0%	14%	5%
	Application Yield						100%	0%		0%	33%
International	Application Selectivity	5%	0%	3%	4%	4%	3%	2%	6%	6%	4%
	Application Yield	100%		0%	50%	33%	0%	0%	0%	50%	29%
Grand Total	Application Selectivity	4%	2%	16%	11%	8%	7%	6%	7%	7%	7%

Application Yield	79 %	33%	18%	25%	33%	68%	20%	11%	17%	31%

(N.B., the "Grand Totals" change according to the breakdown; the total selectivity and yield for last year with no breakdowns is 5% and 32%, respectively.)

Question:
• Please provide the demographic landscape of postdoctoral fellows (gender, race, ethnicity).

Response:
We are not aware of the data the University has collected on postdoctoral fellows. It is likely that such data is collected, since it is collected for faculty; however, the department does not have access to this information. The department has not independently collected this information.

Question:
Is there a widespread adoption of research-based instructional strategies and inclusive pedagogy in first-year physics courses?
The first-year course in physics is among the most influential in a student's chances to continue not just astronomy, but in all STEM fields. These courses have drop-fail-withdrawal (DFW) rates of 30 percent or more in the country. Women, minoritized, and underprepared students' DFW rates are double that of white male students in the country. Can you provide the demographic landscape of students and their corresponding DFW rates? Physics Education Research demonstrates that specific instructional practices consistently achieve better student outcomes and retention than traditional lectures. Collectively known as "interactive engagement," this includes student-centered instruction and discovery-based learning practices such as peer instruction. Because physics courses are the gateway to astronomy degrees, I would like to know the current degree of implementation of inclusive pedagogy in both Physics and Astronomy education at UW.

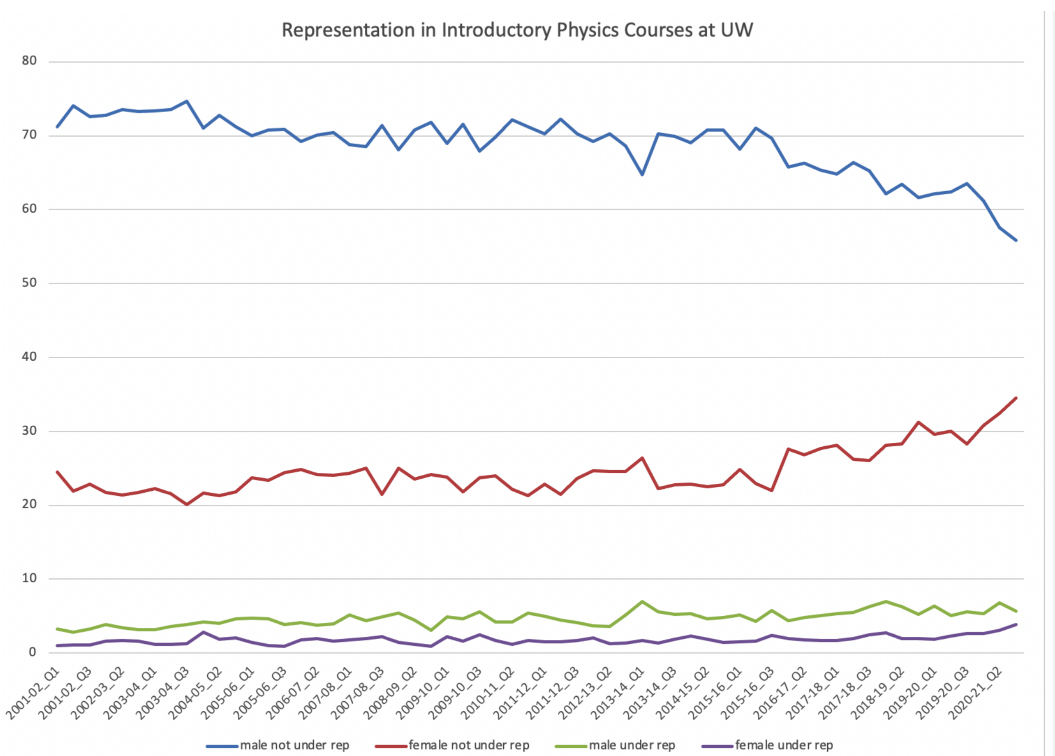
Response:

In order to answer this question, we spoke with Professor Kazumi Tolich, an Associate Teaching Professor in the Physics Department. For the introductory physics course series, PHYS 121, 122, and 123, all of the instructors are required to give students in-class quizzes. Some instructors do *Think-Pair-Share* with random calling. Additionally, these courses are accompanied by mandatory tutorial sections (QZ section in time schedule), that are 50 minutes per week where all students work in groups to solve conceptual problems on worksheets that are developed by the University of

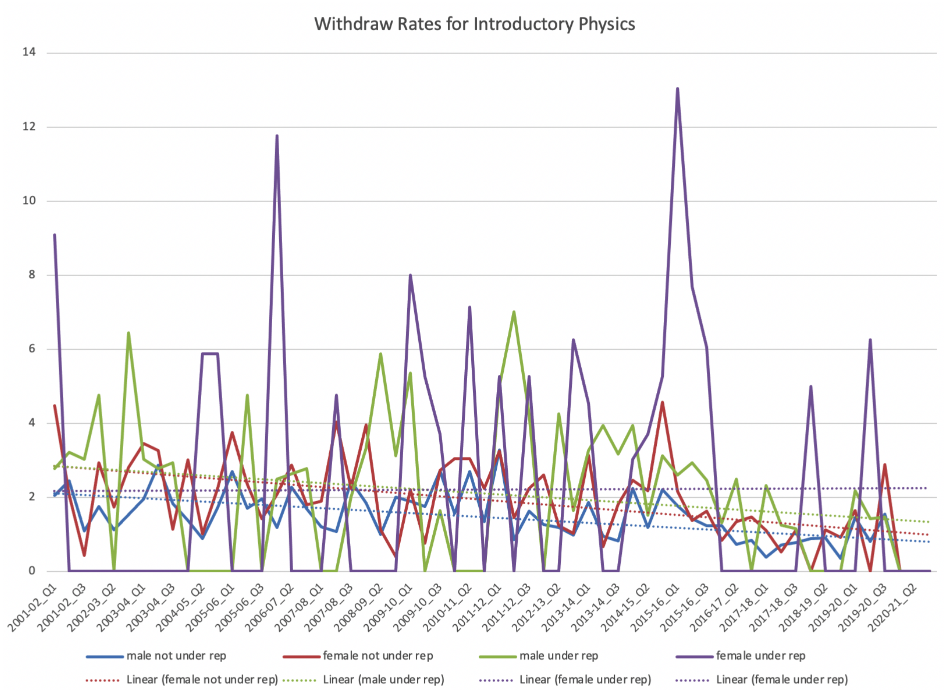
Washington Physics Education Group. All required physics labs (1 hours 50 minutes per week) are student-centered. Students are guided, but design their own experiments that excite them.

Below we include three charts provided by Professor Tolich that show student demographics and DFW rates for the introductory physics courses.

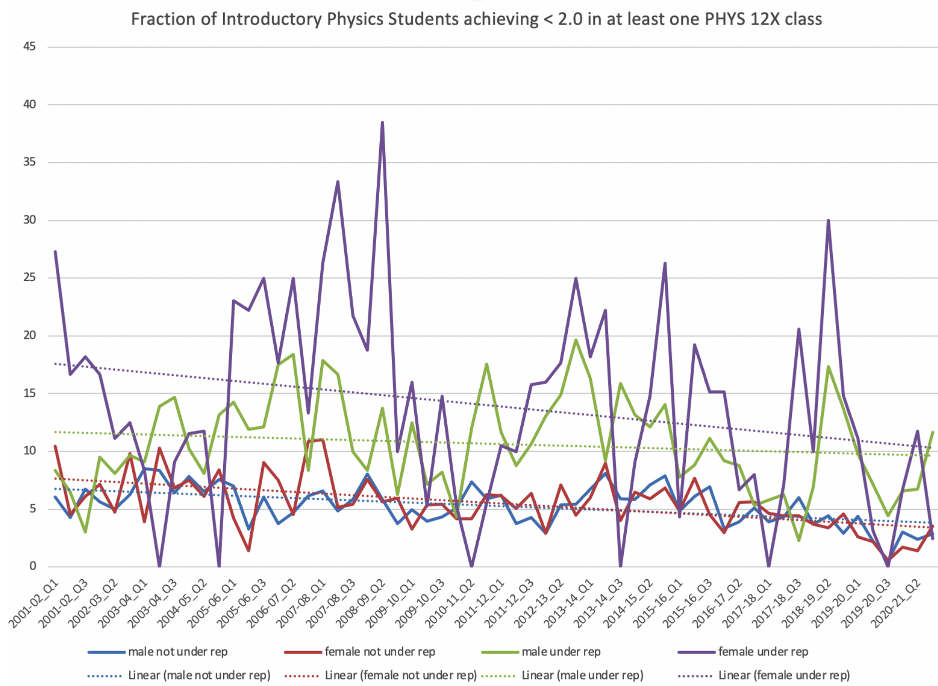
In the first chart, the representation of four different student groups in the introductory physics courses is given by percentage from the 2001-2002 academic year through the 2020-2021 academic year. Starting in 2015-2016 until 2020-2021, there is a small, but significant rise in the percentage of women from non-underrepresented groups (e.g. white women; red line) from 22% to 35%, and a corresponding drop in the percentage of men from non-underrepresented groups (e.g. white men; blue line) from 70% to 56% in the total student body taking the Physics 12X introductory course series (Between 1500 - 2000 total students over this time period). The fraction of both men and women from underrepresented groups (non-white men at 5 - 6%, green line, and non-white women at 2-4%, purple line) has stayed relatively flat over this same period at < 10% of the student body.



The next chart shows the course withdrawal rates as a percentage of students for the introductory physics series by student sub-group. Within the standard deviation, there is not a significant difference in the withdrawal rates of different groups, however, we do note some significant spikes in withdrawal rates for under-represented women in 2006-2007 and 2014 - 2016 that exceed 10% for this population of physics students. In these years, the total fraction of underrepresented women enrolled in the Physics 12X series was between 1-2%. With approximately 1500-2000 students total in these classes over this time period, that means we are dealing with 3-4 women students from underrepresented groups dropping the intro physics classes in these “spike” years seen in the purple curve.



Finally, the last chart shows the student outcomes in the introductory physics courses by student sub-group, specifically the fraction of students who obtained a 2.0 or less (which is the qualifying minimum to declare both a Physics and Astronomy major). These fractions are somewhat higher (approximately double) for both male and females from groups underrepresented in Physics, but show a small (and statistically insignificant given the huge standard deviation) decrease over the time period shown.



Question:

Support for effective mentorship practices

Are there any avenues in which the Department motivates and supports individual faculty to create healthy workplaces by demonstrating knowledge of evidence-based mentoring practices as well as resources for mentees as well as reporting and assessment of mentoring built into faculty assessment and training?

Response:

There are University resources for training faculty in mentorship, including the Advance Center for Institutional Change (focussed on mentoring tenure-track women faculty in STEM, https://advance.washington.edu/), and the Center for Teaching and Learning (https://teaching.washington.edu/). There are no formal incentives for taking these trainings.

In October 2018, the Astronomy department, along with the Physics and Biology departments, co-sponsored a critical mentoring training workshop, led by educator and author Dr. Torie Weiston-Serdan. We encouraged faculty, students, and postdocs to attend from all departments. In this workshop, faculty were introduced to the concept of critical mentoring, and guided in the best practices for mentoring students from underrepresented groups. The department hopes to sponsor events like these in the future, but funding is limited to bring in outside experts (in this case, the College of Arts and Sciences was able to cover 75% of the cost of bringing Dr. Weiston-Serdan to campus through a Diversity and Inclusion Seed Grant Co-PI'd by Astronomy professors Sarah Tuttle and Jessica Werk; the rest was pooled from department funds and Professor Jessica Werk's startup funds).

In the Fall of 2019, the Astronomy department began implementing a graduate student mentoring program. The rationale was to provide graduate students with a flexible but robust network of mentors and to establish regular structured mutual communication between mentors and students where goals and concerns can be clearly articulated. The construction of this program was led by Prof. Dalcanton, the previous chair. Best practices from other institutions (UC Berkeley) and other UW departments (Neuroscience) were consulted in creating IDPs and worksheets to structure the mentoring meetings. No formal assessments have yet been done; suggestions for frameworks to perform such assessments are welcome.

Question:
How is service and teaching in the Department distributed among faculty members?
When STEM organizations have become more diverse, it has been through the disproportionate labor of scientists who represent the communities that STEM fields seek to better serve. Individuals with historically underrepresented identities spend a significant amount of time on this "invisible" work, with consequences to their research productivity. How does the Department utilize the powerful levers at their disposal (teaching releases, service assignments, promotion) to recognize the existing, but currently invisible, labor of individuals within the organization? Does the Department have a workload service policy in which each service assignment is reviewed? How does the Department assess equity in service and teaching assignments?

Response:

Recognition of teaching and service:
Faculty self report teaching and service activities in their annual activity reports. These reports are used for merit evaluation, which influences the allocation of salary increases. Evaluation is separately carried out for research, scientific leadership, teaching, student mentoring, department service, and public engagement, equity and access. The final level of merit is determined by considering the results of a 3 year average of each of these categories. Teaching and service are also evaluated in the promotion process for tenure-track faculty. Large service responsibilities, i.e. the Graduate Program Coordinator and the Undergraduate Program Coordinator are given partial summer salary support funded by the department. The College of Arts and Sciences also awards junior faculty one quarter of ``faculty development'' in which they are relieved of instructional responsibilities, to be taken before awarding of tenure.

Workload service policy:
While not a written policy, the department generally expects an increase in service responsibilities as faculty grow in seniority. However, see Part B, question 4 for discussion of the significant number of senior faculty who recently/currently have large service roles outside the department, and the resulting effect of increased service responsibilities for all of the remaining faculty in the department (junior and senior).

Assessment:
The annual activity reports provide a tool for assessing equity in service and teaching assignments. This has only been done informally as part of merit evaluation.