UNIVERSITY OF WASHINGTON

Astronomy

College of Arts and Sciences

Department Chair: Professor Suzanne Hawley

Degrees Offered:
Doctor of Philosophy
Master of Science
Bachelor of Science

Year of Last Review: *1999 - 2000*
Date Submitted: *November 1, 2010*

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EXECUTIVE SUMMARY

The Astronomy Department at the University of Washington is a national leader in both research scholarship and teaching. Our mission is to learn and teach about the Universe, fostering a broad perspective of its nature, constituents, and evolution--from planetary systems like our own in which life on Earth emerged, to the most distant galaxies and quasars that may reveal fundamental aspects of physical cosmology. Our approach to promoting understanding and education in astronomy has been multifold. This ten year review document summarizes our progress in the past decade and describes a strategic plan for the next decade that will capitalize on our previous investments.

On the educational side, over the past 45 years, we have developed a mature and highly ranked graduate program that prepares our students for successful long-term career contributions in astronomy and other STEM fields. In the last two decades our undergraduate major in astronomy has grown to become one the largest in the nation, with a strong emphasis on research. Our innovative undergraduate general science courses and dedicated public outreach programs in astronomy bring science into the lives of thousands of students and other Washington residents every year. The Department has provided leadership in improving access to astronomy education for under-represented groups, achieving near-parity in gender among recent student cohorts, and a flagship program (Pre-MAP) to engage diverse undergraduates in research starting in their freshman year.

Our previous ten-year review document (1999- 2000) provided a guiding roadmap that transported us to our current excellent position in research, including especially the strategic foundation to build our expertise in survey science through investment in faculty and facilities. Our research success may be gauged in part by our strong associated faculty publication profile, and the marked expansion in external grant support in the past decade. The writing of the current ten-year department review came amidst an unusually exciting time for astronomers, with the recent release of the astronomy community's decadal survey, Astro2010. This provided an opportunity to consider the Department's goals in the broader context of the future of the astronomical community as a whole. In particular, the Large Synoptic Survey Telescope (LSST) was enthusiastically endorsed this past August in the Astro2010 recommendations as the highest priority ground-based astronomy project for the upcoming decade.

Our key initiatives in this review include the formation of a new Center for Computational Origins, and our continued participation in the Large Synoptic Survey Telescope; the Astrophysical Research Consortium which operates the 3.5m Telescope and the Sloan Digital Sky Survey at Apache Point Observatory; and the interdisciplinary Astrobiology Program. In the past decade, we have managed and sustained growth in many aspects of our program, much of which was facilitated by a significant increase in research grant funding. However, a major concern for the next decade is the aging demographic of our faculty, with multiple retirements likely, and no current state-funded faculty at the assistant professor level. Renewal of the faculty will be essential for our continued growth and success.

PART A: BACKGROUND INFORMATION

SECTION I. OVERVIEW OF ORGANIZATION

I.1 MISSION AND ORGANIZATIONAL STRUCTURE

I. 1. 1 MISSION

Our mission is to learn and teach about the Universe. As a major astronomy department at a large state research university, we are committed to the conduct of outstanding forefront astronomical research, while providing leadership in the field of Astronomy at the national and international level. We promote graduate student scholarship while preparing our students for both research and teaching careers. We also teach astronomy to a broad range of undergraduates, including one of the largest programs for astronomy majors in the nation, an extensive range of non-major general science courses that satisfy College distribution requirements and a flagship freshman diversity initiative. Finally, we embrace the opportunity to provide outreach to the general public and to bring science into the daily lives of Washington state residents.

I. 1. 2 STAFFING AND GOVERNANCE

The Astronomy organizational structure is typical of an academic department, with faculty (state-funded, research, emeritus, adjunct, affiliate), lecturers, and postdocs on the academic side, and research scientists (associated with faculty research groups, or supporting our telescope operations) and administrative employees on the staff side. Appendix A (A1-A6) shows the names and titles of people in each of these categories for the 2009-2010 academic year. Of note is the large number of postdocs (17 in 2009 – 2010), which has more than doubled in the past two years. Also of note is the very small size of the administrative staff. Even so, two of the four staff members are partially supported through grants and other temporary funding. The computing staff is not shown, but is shared with Physics through the PACS (Physics and Astronomy Computing Support) group and amounts to about 1 FTE per year spread over several people, paid for primarily from grant funds.

Appendix A (A7) also shows the breakdown of faculty responsibilities for the 2009-2010 academic year. As a relatively small department, with only 12 state-funded faculty, and a few research faculty and lecturers, each person shoulders a significant burden of service to the department. Fortunately the department is amicable, faculty meetings are restricted to approximately once a month, and governance is typically by consensus after reasonable discussion. Most of the duties involving budgets, reviews, oversight, documentation, promotion and tenure, searches and various other communication with the College are handled by the Chair and Associate Chair, who consult the faculty and constitute ad hoc committees as needed.

The inter-relationship chart in Appendix A (A8) illustrates the relationships of the Astronomy Department with other parts of the UW and local community as well as with outside agencies, facilities and collaborators.

A foundation of our department is our current and future telescope facilities which play the same role as laboratories or research facilities in other science departments. We are a founding member of the Astrophysical Research Consortium (ARC) which was formed in 1984 and now operates several telescopes at Apache Point Observatory (APO) in New Mexico, including the ARC 3.5m Telescope and the Sloan Foundation 2.5m Telescope. We have the largest (25%) share in ARC; our partners include Princeton, U. Chicago, Johns Hopkins, U. Colorado, U. Virginia, and NMSU. UW Professor Suzanne Hawley serves as Director of the ARC 3.5m Telescope. We are also a founding member of the Large Synoptic Survey Telescope (LSST) project which is preparing to build an 8m telescope in Chile. LSST membership now comprises more than thirty scientific institutions including Stanford, NOAO and U. Arizona. UW Professor Zeljko Ivezic serves as Project Scientist for LSST.

I. 1.3 DEGREE PROGRAMS

Astronomy offers an undergraduate Bachelor of Science degree, which is nearly always obtained as a double major with Physics, since the physics classes required for the Astronomy degree also fulfill the Physics major requirement. In the 2009-2010 academic year we had an average of 77 undergraduate students enrolled as declared majors in Astronomy, and during the past decade an average of 15 students graduated per year. Appendix E describes the requirements for the undergraduate Astronomy B. Sc. Degree (E1), and illustrates the sample 4 year curriculum (E2) leading to the double major in Astronomy and Physics. There is no Astronomy minor program and we do not currently have any fee-based programs.

A centerpiece of the department is our graduate program leading to a PhD in Astronomy. In the 2009-2010 academic year we had 31 graduate students enrolled in the PhD program, and during the past decade an average of 4 students graduated per year. A Master's degree may be obtained by students in the PhD program but is not required. Astronomy graduate students may also apply to be accepted into the Astrobiology certificate program. Appendix E (E4) shows the Astronomy graduate course plan and core curriculum requirements for the PhD. First and second year graduate students take a comprehensive PhD qualifying exam given after spring quarter each year. They are expected to pass at the end of the second year of study, after they have completed all of their course work. After passing the qualifying exam, they enter into full time research with a faculty advisor, and take a general exam during their third or fourth year indicating preparation for the PhD. Following the general exam, they spend an additional two or three years working on their dissertation research, culminating in a PhD defense and submission of their dissertation, usually during the sixth year of graduate study. The average time to degree is 6 years. Appendix E (E5) lists the 39 Astronomy graduate students who received their PhDs during the 2000-2010 decade, and indicates their current employment status. Also included in Appendix E (E6) is the Graduate School statistical summary. We are extremely proud of our four-decade record of educating excellent graduate students, nearly all of whom are still active in astronomical research and teaching.

In addition to our degree programs, we teach a large number of students in the general science curriculum through our flagship ASTR 101 (Introduction to Astronomy) and ASTR 150 (The Planets) courses and through several smaller special topics courses of widespread interest (for example on Astrobiology, Extrasolar Planets, Black Holes, and the Apollo space program). Appendix E (E7) lists all of the Astronomy courses that have been taught in the past decade, together with the student credit hours (E8) taught in each segment of the program. ASTR 101 and 150 are separately reported, with other 100-200 level (non-major, general science) 300-400 level (majors) and 500 level (graduate) courses aggregated. The 499, 600 and 800 level courses are research for undergraduates, beginning graduate students, and PhD candidates, respectively. The large enrollments in ASTR 101 and 150 in the early years of the decade were enabled by our ability at that time to teach night sections. The University made night courses part of the self-supporting extension program and this affected our enrollment beginning in the middle part of the decade. We have made up for part of this loss in the general science program by adding additional 100-200 level, smaller courses which have been very popular. The graduate and undergraduate majors courses have been growing fairly steadily as our enrollment has been increasing over the decade. In summary, we have been teaching about 10,000 student credit hours (SCH) per academic year with only small fluctuations for the past 10 years.

I. 2 Budget and Resources

I.2.1 Budget Outline and Evaluation

Academic departments at the University of Washington are funded on a biennium basis. Appendix B (B1) shows the budget breakdown for the Astronomy department for the four most recent biennia, including the one in progress (2009-2011). The funding lines are reported in terms of the expenditures in each line, because those are tracked explicitly by date. In contrast, grants are often awarded for a three or five year period, making it difficult to track them across more than one biennium if it is reported only at the time of the award.

The state funding line is primarily faculty and administrative staff salaries, with some smaller permanent and temporary funding for telescope operations at Apache Point Observatory (APO) and Manastash Ridge Observatory (MRO). Nearly all instructional costs are borne by this budget line. Two new faculty members were hired in 2007, which increased the state funding line for the more recent biennia. There is essentially no discretionary money in this line, with all funds being proscribed for specific purposes.

The federal grant funding has shown an overall increase from $3.7M in 2003-2005 to nearly $5.6M projected for the present biennium (2009 – 2011). This increase is due in large part to the successful grants of our recent faculty hires. Federal grants are obtained primarily through proposals to NSF and NASA.

The non-federal grant funding has also shown an increase, from $1.4M in 2003-2005 to a projected $2.3M this biennium. The sources of non-federal funding are from our telescope consortia (LSST, ARC), the Kenilworth fund, and internal UW competitions.

At a much lower level, the department receives funds from Gifts and Endowments, temporary money for faculty start-up and retention (primarily from the College and Provost's office), and Recovered Cost Return (RCR) funds which are returned from the University overhead (indirect charges) on grants. The RCR funds are directly linked to the previous year's grant expenditures, and are rising with the grant funding. Note that the Gifts and RCR lines are the only ones which provide discretionary funds that may be used for department initiatives such as buying computer equipment and funding the colloquium series.

The total department budget rose from about $7.4M in 2003-2005 to $12.2M in 2009-2011, with more than half of the increase coming from new federal grants.

I. 2.2 Fund Raising

Appendix B (B2) provides a breakdown of gifts and endowment revenue for the past several years. With the exception of a one-time gift of $300K that was paid out between 2001 – 2006, the endowment and gift income for the department has amounted to ~$40 - $50K per year, equivalent to a ~$1M endowment for the department (assuming a return of 4%). Although there is a strong interest in Astronomy from the local community (as evidenced by the popularity of public events), the donor base for the department remains small with about 80 individuals contributing regularly each year (typically in amounts less than $250). The largest gifts are consistently from current and former faculty and alumni.

In the last two years, coinciding with the International Year of Astronomy (IYA) in 2009, we have started the work to increase the overall pool of donors with a long-term goal of generating resources to support future initiatives such as buying additional telescope time, funding a new center, and establishing stable support for students and faculty. Our efforts include popular astronomy talks (including Danz Lecturer Dava Sobel, an IYA 2009 series, an Astrobiology lecture series and an ongoing program by graduate students on a range of current astronomical topics), planetarium shows, Theodore Jacobsen Observatory (TJO) talks and observing opportunities, outreach events in and outside of Washington State, and a biannual astronomy newsletter. In the past year, 2000 people attended the planetarium and 1200 people participated in TJO telescope outreach programs. In the current year the planetarium, in collaboration with Microsoft, will be upgraded to a fully digital dome. Based on these initiatives we have compiled a list of 500 people, designated as Friends of Astronomy, who regularly receive announcements of events and information about the department.

SECTION II. TEACHING AND LEARNING

Astronomy education in the Department involves several components. Although these are intertwined, for simplicity we discuss them separately: section II.1 describes our highly ranked graduate PhD program; section II.2 describes our large undergraduate major program; and section II.3 discusses our service courses for non-majors, as well as public outreach which engages thousands of people in the local community each year.

II.1 GRADUATE PHD PROGRAM IN ASTRONOMY

II. 1.1 GRADUATE PROGRAM STUDENT LEARNING GOALS AND OUTCOMES

The goal of the graduate program in astronomy is education and mentoring of our students toward their long-term careers in research and teaching in astronomy or related STEM fields. Although most students obtain a master's degree along the way, our program emphasizes the doctoral degree. The core curriculum during each quarter of the first two years includes: two main graduate courses in astronomy, which form a sequenced set, as shown in Appendix E (E4); a third formal course in a related field (e.g., physics, astrobiology, statistics, etc.) or faculty supervised research (ASTR 600); and weekly participation in colloquium and journal club. The core courses provide the academic foundation for the students' future careers, while ASTR 600 and seminars engage the students in exploring research.

Prior to advancement to candidacy, each student must pass two significant exams that allow for broader assessments outside the classroom. The "Qualifying Exam" is a 6 hour written exam, offered annually, and is usually passed in the 2nd year; a range of questions are contributed by departmental faculty to assess breadth and depth of the students' academic preparation in astronomy. In the 3rd or 4th year, the student then takes the oral "General Examination", which includes a written research proposal, and an open colloquium level talk (on a topic complementary to the dissertation), followed by a closed session of further questions from the PhD supervisory committee (of 4-5 faculty).

In their 3rd-6th years (median time to PhD is 6 years), graduate students emphasize their dissertation research. Most advanced students are research assistants, and actively publish, write proposals, and present scientific talks (including at biannual meetings of the American Astronomical Society, which every 4 years is conveniently held in Seattle). Graduate student research (e.g. travel funding) is often supported by the department's Jacobsen Fund endowment, and the UW graduate school. Graduate student research culminates in the PhD dissertation and final defense. The final exam is an open colloquium level talk on the dissertation, followed by a closed session with the candidate and faculty supervisory committee. Dissertation topics span the range of student and faculty interest, and utilize the full suite of departmental and national research facilities including: the ARC 3.5m telescope; the large survey databases of SDSS (and in the future LSST); the computational facilities of the "N-body shop"; the interdisciplinary Astrobiology program; strong interaction with the Physics department; and broad departmental success in securing access to national facilities such as HST, Chandra, Spitzer, etc.

The graduate program excels in student satisfaction. In the 2001 National Association of Graduate and Professional Student survey, our astronomy program was ranked number 1 in "recommended practices" and number 2 in "satisfaction." In 2008, our program was presented a Gold Star Award from the UW Graduate and Professional Student Senate; this award recognizes UW programs that have "exhibited outstanding achievement in faculty-student relations, professional development and training, and the funding and support of students and their research."

Another independent and positive assessment of our graduate program is provided by the recent NRC ranking of doctoral programs http://www.nap.edu/rdp. According to the overall S- or Survey-ranking, we are between 4th and 11th by the NRC's very broad 5-95 percentile measure. We similarly appear to rank high in multiple other measures from the NRC: between 4th and 13th (5-95 percentile) in Research Activity, between 1st and 14th (5-95 percentile) in Student Support and Outcomes, 8th in placing students into academic positions, 3rd in graduate completion ratio within 6 years, and 4th in both publications per faculty member and citations per publication. By a variety of measures emphasizing quality in the NRC survey, we appear to be within the top ten US astronomy graduate programs. Additional discussion is provided in Appendix E (E9).

We are also a key participant in the interdisciplinary Astrobiology Program. Graduate students in this program work for a Certificate via courses, workshops, seminars, and an interdisciplinary research rotation, in addition to the requirements of their home department. In Astronomy, 5 faculty are active, 5 students have completed the Certificate, and 5 more are currently in the Program. The Astrobiology Program underwent its own external review in 2006 and was judged the best in the world for its graduate training in this emerging field.

II. 1.2 Graduate Program Instructional Effectiveness

Instructional effectiveness of graduate courses is monitored via standardized UW student teaching evaluations and collegial evaluations, providing continuing fresh feedback to our faculty involved in teaching. Student evaluations are reviewed by the teaching faculty member, and by the Chair on a quarterly basis and in annual faculty merit reviews. In addition, at the graduate level many measures of instructional effectiveness are not based on formal courses, but rather on the effectiveness of preparing students for careers in astronomy; such aspects are detailed in section II.1.3.

Although the emphasis of our PhD program is on research, preparation for teaching is an additional key component for our students. In their entering Fall quarter, most graduate students complete a skills-based course (ASTR 500) on teaching introductory astronomy, including planetarium training. Each student is also required to complete 3 quarters as a teaching assistant (TA) usually in the ASTR 101 and 150 courses. Graduate students also have the opportunity to serve as TAs for our upper division hands-on research courses including helping to supervise undergraduate research, or to serve as the lead course instructor in our summer offerings of ASTR 101.

II. 1. 3 Graduate program teaching and mentoring outside the classroom

Mentoring outside the classroom is a fundamental aspect of our PhD program, starting at the recruitment stage. Our graduate program historically has enrolled about 25 students per year; but in recent years, growth in external grant support, major new initiatives, and vigorous recruiting boosted our 2009-10 enrollment to 31 PhD students. Our recruitment approaches include both in-person contact and web-based information for prospective applicants. Each prospective offered admission is contacted directly by our astronomy graduate students, postdocs, and faculty (matched in interest or peer/cohort). Initial contact is by phone, with in-person contact during prospective student visits, thanks to Graduate School travel recruitment funds. Recent revisions to the web pages include both a broad overview and also detailed discussions of Departmental research and teaching activities, application procedures, and graduate student life. To highlight our interest in attracting underrepresented graduate students, we include upfront information about our diversity efforts via 'Diversity' links from our main Departmental and graduate program pages http://www.astro.washington.edu, and http://www.astro.washington.edu/grad/index.html.; we also recruit students at the National Society of Black and Hispanic Physicist meetings.

Leadership in developing our Departmental diversity plan came from our former graduate students M. Agüeros (2006), K. Covey (2006), and A. West (2005). They have completed their PhDs, moving on to postdocs or faculty positions, and in 2008 were honored by the National Society of Black Physicists for their diversity efforts. We are pleased that these student-led efforts continue. With only 4-5 students entering our PhD program each year, statistics on minorities are sparse, but have remained level at about 9-18% over the past several decades. A more robust gauge of our success in attracting underrepresented students is the growth among women in our program: 6% in 1970-79, 17% in 1980-89, 18% in 1990-99, and 45% in 2000-2009. The latter is well above the national average as reported by the American Institute of Physics (http://www.aip.org/statistics/trends/highlite/edastro/figure4a.htm). Our marked growth seems plausibly coupled to the relatively high fraction (about 1/3) of women mentors among our tenured faculty. We are actively working to expand our success in recruiting and retaining underrepresented groups in astronomy.

Following recruitment, entering graduate students are introduced each September to our primary program elements via a week-long departmental orientation. This extended orientation was a direct response to suggestions from previous graduate students. Each incoming student is also paired with an interim faculty mentor, who provides guidance to the student and serves as an informed resource for our annual assessment of student progress and satisfaction during their initial years. By selective practices in admissions and attention to mentoring, our attrition rate is quite low, averaging 8% since the PhD program started in 1965. Feedback from graduate students is accomplished through informal discussions and formally from an appointed graduate student representative. The graduate student representative meets regularly with the Chair and attends faculty meetings.

Along with the student satisfaction and the NRC measures discussed in section II.1.1, another measure of the success of mentoring in our program is the employment paths of our graduates after receiving their PhDs. Among the 39 PhDs in the past decade, all secured employment in a STEM related field immediately upon completion of the PhD (e.g., Appendix E5); and 12 of our past-decade PhDs were/are recipients of prestigious prize postdoctoral fellowships (e.g., Hubble, Spitzer, NSF, CfA, NASA, NAI, McDonald, CITA, CIERA). The longer-term trajectories of our past graduate students are also an indicator of success in which we take considerable pride: among the 82 past PhD recipients from our department who are at least 10-years beyond their PhDs, 84% are still employed in STEM fields, with the vast majority involved in astronomy research or teaching.

II.1.4 Graduate program: further considerations

Our graduate program is highly successful, and significant expansion of the graduate program is feasible, from the perspective of the number of qualified applicants, adequacy of external grant support, our high ranking in independent assessments, and involvement in current/future major programs or facilities for astronomy, such as the ARC 3.5m, SDSS-3, the N-body shop, LSST, and the interdisciplinary Astrobiology and e-Science programs. We are limited in marked expansion of the graduate program by several factors, including: office space (critically short now), and the essential need to hire junior faculty to assure continuing graduate student mentoring.

II.2 Undergraduate Major in Astronomy

II. 2. 1 Learning Goals and outcomes for majors

In the last decade, our undergraduate major in astronomy has emerged as one of the largest in the nation. The major's growth is partly due to our active involvement of undergraduates in research. Research experiences range from our Pre-Major in Astronomy Program (Pre-MAP, see section II.2.3) early engagement of underrepresented freshman and sophomores (often leading to a subsequent decision to major in astronomy or other STEM field), to a senior year capstone sequence of research related courses for all majors.

The learning goals for the major are to enable our students to:

(1) Understand the principal findings, common application and current problems within astronomy as a scientific discipline.

(2) Be versed in the computational methods and software resources utilized by professional astronomers.

(3) Have experience operating modern astronomical instrumentation and analyzing a range of experimental data.

(4) Be able to assess, communicate and reflect an understanding of astronomy and the results of astrophysical experiments in both oral and written formats.

(5) Learn in a diverse environment with a variety of individuals, thoughts and ideas.

(For easy student access, these goals are posted at http://www.astro.washington.edu/undergrad/undergrad.html).

The Astronomy major emphasizes a basic foundation in physical and mathematical sciences, with most of our students obtaining a double major in astronomy and physics. The major requirements described in Appendix E (E1) have evolved since the last review to better fulfill our goals. For example, we have added a capstone sequence of 3 senior level courses in which students learn how to use astronomical imagers and software via our rooftop telescopes (ASTR 480), use this knowledge in a research project (ASTR 481, 499 or an REU project), and write up the results (ASTR 482). To assist students in becoming computer-savvy, we have added a course on Introduction to Programming for Astronomical Applications (ASTR 300), which ensures all students have the skills they need to be successful in our senior level classes. This combination of textbook and practical learning provides excellent preparation for graduate school and industry jobs.

Research training for our undergraduates relies on several facilities. Students have privileged access to Manastash Ridge Observatory (MRO), an 0.8m telescope facility located in the remote, dark foothills of Mt. Rainier in central Washington. Built in 1972, MRO was a site of extensive faculty and graduate student research for its first three decades, but since 2004 has functioned mainly as a professional grade training facility for our undergraduate majors. MRO provides a unique level of hands-on field experience in advanced astronomical observation methods, and is one of the central pieces in the senior capstone sequence, through the summer ASTR 481 course. In addition, multiple Student Tech Fee grants led by our undergraduates have been awarded in the last decade, allowing upgrades of the undergraduate computer lab to keep our student computing resources modern and powerful. Grants have also funded an undergraduate-run radio telescope, and a 16-inch research and instruction telescope both located on rooftops of buildings on the UW campus. The continued involvement by our students in the improvement of our department helps us to provide them with an outstanding education experience.

In 2008, we initiated exit surveys for our majors that include measures of student satisfaction, such as departmental quality ratings. The following percentages (2008-09 averages) of responding seniors ranked the department as “excellent” in the 4 survey quality categories: overall content--73%, instruction--64%, faculty expertise--100%; interest in undergraduate education--88%. All respondents in both years ranked the department as either "good" or "excellent" in all 4 categories.

II. 2. 2 Instructional effectiveness in the undergraduate major

Undergraduate major courses are evaluated via standardized UW student teaching evaluations forms; these are reviewed by both the instructor of the course, and by the Chair on a quarterly basis and in annual faculty merit evaluations. In addition, with funding from the University Learning Initiative and assistance from the UW Office of Educational Assessment, in 2008 the department developed the aforementioned online senior exit survey. This survey also covers such topics as time to degree, delays in degree plan, courses, post-graduation plans, departmental quality (see preceding paragraph) and success in meeting learning goals. Among 5 surveyed categories, the following percentages of exiting seniors rated the department as meeting its learning goals fairly or very well (2008, 2009 averages): written communication--80%; oral communication--74%; instrumentation and analysis--73%; computational methods--97%; content, findings, problems--97%.

Other measures of the success of our undergraduate program are its large size, and the future directions of our graduating seniors. With 77 declared undergraduate majors in Spring of 2010, our program is one of the largest in the country. Nearly half these students are from groups traditionally under-represented in astronomy: 35% are women and 13% self-identify as a member of an ethnic minority group. On average, the department graduates 15 students per academic year, with median time to graduate of 5 years; in 2009-2010, we had one of our largest classes ever with 27 graduating and anticipate a similar size this next year. Respondents to the 2008 and 2009 senior exit surveys discussed above indicate that about 45% plan to go on to graduate school in astronomy, 26% to graduate school in another field, 26% will be entering full-time employment, and 3% are undecided.

II. 2. 3 Teaching and Mentoring of Majors Outside the Classroom

Over the past 10 years, astronomy undergraduate research has seen a significant increase as shown in Appendix E (E5). In 2001-2002 an average of 8 undergraduates per quarter were involved in research, while in 2008-2009 this number doubled to 16 students. Participation in the UW Undergraduate Research Symposium (UWURS), held each spring, has dramatically expanded: in 2001, five astronomy students presented their research at UWURS, but by 2009 this number had increased five-fold to 25 undergraduates. Contributing substantially to these increases are Pre-MAP participants (discussed below).

Communication with our undergraduates is key to maintaining an open and friendly atmosphere. Quarterly meetings are held with the Departmental advisers to review courses, discuss program changes, and receive feedback from students on classes, research and professional development. We also have recently appointed undergraduate representatives to participate in faculty meetings and to improve communication between the Chair and the undergraduate population.

The Department offers a variety of professional development opportunities to undergraduates. Typically four undergraduates per year are hired to work with SDSS equipment, including manufacturing spectroscopic plates. Every year our students take a field trip to either Boeing (Renton, WA) or the Very Long Baseline Array (Brewster, WA). Undergraduates also have the opportunity for teaching preparation through ASTR 500, as well as through grader positions in our introductory courses. In spring 2008, a workshop on Careers in Astronomy was held for undergraduates. This workshop, coordinated by Prof. Emeritus Julie Lutz, invited speakers from local community colleges, high school science departments and our own graduate students to talk with undergraduates about the wide range of opportunities available to them – including various teaching and science outreach jobs, as well as various pathways to graduate school.

Pre-MAP (Pre-Major in Astronomy Program) is a substantive new endeavor in our department for involving undergraduates in research and mentoring starting in their first quarter at UW. Pre-MAP was developed by our graduate students (see Section II.1.3), and is supervised by faculty lead Associate Professor Agol. The primary goal of Pre-MAP is to increase retention of students traditionally underrepresented in STEM fields. Students enroll in the Pre-MAP seminar during Autumn quarter to learn astronomical techniques that they apply to small-group research projects. The seminar meets three hours a week and offers instruction in basic computing skills, data manipulation, science writing, and statistical analysis, for up to 15 participants. Students choose from research projects conceived by astronomy faculty, postdocs, and graduate students, and are encouraged to continue their research during winter and spring quarters for academic credit. The seminar leader meets with students individually and mentors them formally during fall quarter. Students also receive one-on-one mentoring, as well as peer support and cohort building (e.g., field trips, study sessions and outreach events) for the duration of the academic year and beyond. Successful Pre-MAP students have subsequently become astronomy and physics majors, expanded their research projects, presented posters at the UWURS, and received research fellowships and summer internships. We hope that, with adequate funding, Pre-MAP will endure as a long-term, legacy program, promoting diversity in STEM fields and become a model for undergraduate research in other departments and at other institutions.

II.3 Astronomy undergraduate service courses, and public outreach

II.3.1 Student learning goals and outcomes in service courses

Each year we introduce basic concepts in astronomy to approximately 1600 UW undergraduates; these are non-majors, and indeed most are not science majors. Our two principal courses are ASTR 101 (a general introduction to astronomy) and ASTR 150 (emphasizing the solar system), both taught every quarter, with enrollments of 250 students each. For many undergraduates, these courses comprise their principal exposure at UW to the physical sciences, satisfying both the Natural World and Quantitative and Symbolic Reasoning distribution requirements. Several new service courses (now taught annually) were developed recently, including ASTR 105 (Exploring the Moon) and ASTR 270 (Public Outreach in Astronomy). Appendix E (E7) lists all the course options. ASTR 101 is also now routinely available as an on-line course (http://www.pce.uw.edu/online.aspx?id=4243).

The large service courses are often taught by our three outstanding lecturers, and involve notable innovations. For example: Senior Lecturer Dr. Toby Smith has developed an extensive set of web-based exercises for his ASTR 150 course; Senior Lecturer Dr. Ana Larson is now including a research-based component in her ASTR 101 class (an intriguing experiment in a class of 250); and Lecturer Dr. Christopher Laws leads an ASTR 101 section that is paired with an English 199 writing course (as far as we are aware, this is the only such case at UW among the physical sciences).

Our broad learning goals for these courses are to guide students to a cosmic perspective of the nature of the universe in its scale, constituents, and evolution, as well as a closer-to-home understanding of the solar system in which the Earth and life emerged. Instructors also provide the students with a specific set of learning goals custom tailored to each individual course. The topics in these classes provide an accessible and exciting introduction to the role of comparison of theory and observations in science, hypothesis testing, and basic physics. We aim these courses to inspire the students about astronomy, and more generally about science and technology in modern society.

In the service classes, our assessments of student learning take a variety of forms, including essay writing, in-class polling (cards or clickers) to gauge learning success in real time and web exercises, along with standard exams and term papers. A key aspect of evaluating student learning on a more personal basis is provided by weekly lab/discussion/quiz sections, overseen by graduate student TAs, as a supplement to the large lectures led by instructors and faculty.

Assessing student satisfaction is accomplished via a mid-quarter evaluation administered by the UW Center for Instructional Development in many courses, informal feedback in discussion sections, and formal end-of-the quarter student evaluations in each course and discussion section. Of particular note is that our instructors for 101 and 150 are often very highly ranked in their evaluations; they have received multiple UW Distinguished Teaching Award nominations, including Dr. Laws' Honorable Mention in 2009 – 2010. Also in 2009-10, Dr. Smith was honored by the student Panhellenic Association and Intrafraternity Council as a UW "Faculty Member of the Year."

II.3.2 Instructional effectiveness in service courses

Instructional effectiveness is monitored in our service classes through standardized teaching evaluation forms, collegial teaching evaluations (instructors are evaluated in the classroom by other faculty every 1-3 years), and instructor evaluations of the TAs. These evaluations are reviewed by the instructors, and by the Chair quarterly and annually in merit considerations.

Some of the recent classroom innovations described have already improved the effectiveness in student learning. For example, students in Dr. Laws' interdisciplinary writing link program of ASTR 101 with ENGL 199 received significantly higher grades in their Astronomy course compared to students who took ASTR 101 only. Based on the limited data available for Dr. Larson's 2009 research-based offering of ASTR 101, more than two-thirds of the students ranked the effectiveness of her new approach in helping them learn at a value of 4 or 5, on a 5-point scale.

A number of additional improvements in the service courses have been made by the instructors in response to student feedback or assessments. For example, the majority of the courses have moved away from an all-lecture format to a combination of lecture, peer-learning, and hands-on (e.g., computer, individual talks) projects. In the main service courses, instructors have initiated on-line tutorials and quizzes with exact deadlines to encourage students to come to class better prepared.

II.3.3 Teaching and mentoring outside the classroom: service courses

Members of the department are also engaged in other areas of UW education outside the traditional classroom. For example, Professor Balick has led several Exploration Seminars for undergraduates abroad, exploring the history and development of cosmology (and its interaction with religion) in Italy and Vatican City. Over the past decade, Senior Lecturer Larson has led Robinson Center for Gifted Youth Summer classes on topics such as "The Physics of Roller Coasters" and "The Physics of Sports". Dr. Larson additionally teaches a Discovery Seminar for entering freshmen that provides an introduction to observational astronomy using hands-on experience with the Department's 16" telescope. Senior Lecturer Smith and Professor Emeritus Lutz often contribute to The Osher Lifelong Learning Institute at UW, a continuing education program for adults over 50.

II.3.4 Some specific areas of future consideration for service courses

Despite the overall success of our undergraduate service course offerings, there are some items of concern related to future teaching effectiveness, with budgetary concerns underpinning several of these. Space in the Astronomy Department is extremely tight, and it is crucial for us to retain our very limited classrooms (e.g., two classrooms on the second floor of the Physics/Astronomy Auditorium building) for their current function in order to conduct effective discussion sections for ASTR 101 and 150. Further, we have inadequate audio-visual media in our teaching classrooms for optimal projection of color and high contrast astronomical images.

Budgetary considerations have recently forced us to experiment with elimination of one TA position in each of the large introductory courses (ASTR 101, 150) each quarter, reducing the TA-led discussion sections to just once a week compared with our previous practice of twice per week. TAs and instructors have both expressed concern that this has markedly curtailed individual contact with undergraduates in service courses, reducing teaching effectiveness; TAs now report insufficient time to review lecture material in their sections, with time enough barely to complete lab exercises. Finally, most of our large courses are already over-subscribed, with limited options on campus to consider larger lectures due to lack of room availability, so expansion in the number of students we might teach in service courses will be difficult. An option we would like to pursue is to reintroduce an evening section of ASTR 101, if the tuition were commensurate with the day-time courses. We are also considering online courses, see Part B.2.2.

II.3.5 Community outreach and additional educational activities

The department is highly active in extending astronomy education to the broader community. Our outreach programs include annual open houses, departmental involvement in high school and middle-school astronomy programs, and strongly reinvigorated (often over-subscribed) use of the on-campus Theodor Jacobsen Observatory, and the department planetarium. The 2009 International Year of Astronomy activities marked a banner-year for our departmental outreach efforts: we estimate that the combination of our astronomy outreach efforts engaged over 3200 members of the general public. Further details on our outreach efforts are provided in Appendix H.

SECTION III. SCHOLARLY IMPACT

In the following section, we discuss the major science themes and research groups in the department. More details, including individual faculty and postdoc CVs can be found at the website: http://www.astro.washington.edu/10year.html. Faculty research descriptions are also provided in Appendix C.

In our self study of ten years ago, we outlined a strategy to concentrate our research effort in a few key areas, taking advantage of new opportunites that we identified in survey science, computational astrophysics, space-based research, and astrobiology. By focusing our resources in these areas, the department has made a significant impact in astronomy. A quantitative measure of this impact is that in the past decade, through mid-2010, the faculty in the department have authored 2219 papers with 54725 citations and an h-index of 113.

III.1 RESEARCH

The major science themes of the department are shown in the table below. Each faculty member participates in at least one, and typically several, of these areas. This overlap promotes significant collaborative effort among the faculty, as well as interdisciplinary effort within the University (see table) and with many other institutions, both national and international.

Survey Science	Astrobiology and Exoplanets	Computational Astrophysics	Space-based Science
Agol	Agol	Agol	Agol
Anderson	Brownlee	Connolly	Anderson
Balick	Hawley	Dalcanton	Balick
Becker	Meadows	Governato	Brownlee
Connolly	Quinn	Ivezic	Dalcanton
Dalcanton	Sullivan	Meadows	Hawley
Hawley		Quinn	King
Ivezic			Meadows
Quinn			Szkody
Szkody			
Collaborative Units within UW			
Computer Science	Aeronautics and Astronautics	Applied Math	Aeronautics and Astronautics
e-Science	Earth and Space Sciences	Computer Science	Earth and Space Sciences
Physics	Microbiology	e-Science	Physics
Statistics	Oceanography		

Survey science was the most prominent area that we identified for investment in the past decade. The Department pursued this area with new faculty hires, infrastructure investment, investment of faculty time and numerous research proposals. This strategy paid off with significant returns in impact across a large number of research areas. The exemplar is the Sloan Digital Sky Survey (SDSS), the technical description of which is the most highly cited paper produced by members of the department. While the primary SDSS science goal was cosmology and extragalactic astronomy (the second most highly cited paper by members of the department presents the large scale structure results of the SDSS), the department has used SDSS data to produce a number of high impact publications across many areas of astronomy. Here we give a few of the highlights. Professor Ivezic developed a technique to map out the 6 dimensional distribution of stars in the Milky Way and thereby create new insights into Milky Way structure. Professor Hawley led an effort to characterize the low mass stars found by SDSS to understand their magnetic activity and mass functions. Former graduate student Willman under the supervision of Professor Dalcanton discovered the first of a class of faint satellite galaxies. Professor Anderson combined SDSS data with spectra taken on other telescopes to investigate faint quasars. Professor Szkody has discovered many new cataclysmic variables, which provide constraints on binary evolution theories. Professors Ivezic and Quinn used the large number of asteroids detected by the SDSS to determine their mass function and potential impact threat. Research Assistant Professor Becker used the SDSS-II Supernova survey to further characterize the nature of the accelerating universe and dark energy. Associate Professor Connolly was integral to the development of Google Sky, which was accessed by over 4 million people in the first three days of operation, demonstrating the distribution enhancement possibilities with a simple, intuitive interface to large datasets.

Building on the legacy of survey science we became a founding member of the Large Synoptic Survey Telescope in 2003. The Department has taken on a leadership role in the development of the LSST, leading up to its ranking as the number one priority for ground-based facilities in the Astro 2010 decadal review. With the hires of Professors Connolly, Ivezic and Becker the department is generating high-fidelity simulations for the LSST, developing the analysis pipelines to detect transients sources from the 30TB per night LSST data stream, and is prominent in the science collaborations and the LSST science council (notably with Professor Ivezic serving as the project scientist).

Computational astrophysics is another area in which the department invested over the past decade. Professor Quinn took over the leadership of the "N-body" group, continuing the cosmology and planet formation research being examined with large parallel computation. This group has been very productive with Professor Quinn contributing to understanding the distribution of dark matter in galactic halos, and Research Associate Professor Governato leading an effort that was the first to demonstrate that the standard cold dark matter stucture formation scenario can successfully produce spiral galaxies similar to those observed. The group has also made contributions to the theoretical understanding of both terrestrial and giant planet formation. This theoretical effort is highly complementary to the survey work described above, and has produced numerous collaborative papers between observers and theorists on the faculty.

The department has also invested in the significant research opportunity provided by space-based research, running the gamut from solar system objects to high redshift quasars. Professor Brownlee is the PI of the Stardust comet sample return mission which is providing results that challenge current theories of planet formation. Associate Professor Agol has developed techniques to use the Hubble Space Telescope (HST) and the Kepler mission to discover planets as small as the Earth, and has also used the Spitzer Space Telescope to create the first map of a planet orbiting another star. Professor Balick is a member of the science team for the recently installed Wide Field Camera 3 on HST, which he is using to study planetary nebulae and supernova remnants. Professor Dalcanton is leading an HST Treasury project to understand the structure and star formation history of nearby galaxies, and was recently awarded nearly 1000 orbits through the Multi-Cycle HST program to carry out the most extensive survey yet conceived of the Andromeda Galaxy. Professor Anderson has been using data from the Chandra X-ray and Spitzer IR observatories to study distant quasars and GALEX and HST to study the intervening IGM. Professor Szkody obtained UV data from GALEX, FUSE and HST and X-ray data from XMM and Chandra to determine the temperatures, X-ray emission, and the location of the instability strip for accreting white dwarfs in close binaries. Professor Hawley is using HST, Chandra, GALEX, and Kepler to study flares on low mass stars. Associate Professor Meadows used observations of the Earth from the NASA EPOXI spacecraft to develop predictive modeling tools for the remotely observed Earth, to support the design of future terrestrial exoplanet characterization missions. Resesarch Professor Ivan King uses HST to study the structure and content of star clusters.

The final key research opportunity that the department has invested in is the interdisciplinary and growing field of Astrobiology. Professor Sullivan was instrumental in obtaining two competitive NSF IGERT grants to fund graduate student research for the entire decade. Astronomy plays a leading role in the multi-departmental Astrobiology program which includes research done under the Astrobiology PhD Certificate Program. With the hire of Associate Professor Meadows, the department now hosts the NASA Astrobiology Institute "Virtual Planetary Laboratory" (VPL). VPL is a group of researchers focusing on understanding exoplanet environments and observational characteristics (annual report: http://astrobiology.nasa.gov/nai/library-of-resources/annual-reports/2009/vpl-uw/). The Astrobiology Program is discussed further in Section III.3.2 on virtual institutes and Section III.4 on interdisciplinarity, and is undergoing its own 10 year review this year.

An essential aspect of our involvement in both survey and space-based science is the ability to obtain complementary observations at the ARC 3.5m telescope. The UW has a 25% share of this facility, located together with the Sloan Foundation 2.5m telescope at Apache Point Observatory (APO). The flexible scheduling and remote observing capabilites of the 3.5m make it perfect for ground-based observing in support of space missions and for rapid, detailed followup of interesting targets identified in surveys. In additon, graduate students obtain essential training in observational techniques and take advantage of sizable time allocations to carry out surveys that would be impossible at national facilities.

A distinguishing feature of the department's research is the integration among the various research groups. This is most obviously demonstrated by the results in a multitude of areas produced by the survey science efforts, but there are other examples. The models produced by the N-body shop are used by the stellar populations group. The low mass stars group and the N-body shop are working with the VPL group to explore the effects on planetary habitability of both stellar activity and the gravitational interaction between star and planet. The significant overlap of faculty between the four science themes shown in the table has served us very well in promoting outstanding, collaborative research. By following through on our strategic decisions of 10 years ago, the department has attained a high scientific impact at relatively low cost. Much of this impact was enabled by being on the leading edge of innovations, including remote observing, surveys and interdisciplinary science.

III.2 STUDENT AWARDS

III.2.1 GRADUATE STUDENTS

Our graduate students have made a number of major contributions to Astronomy research. Space permits highlighting only a sample here. Yoachim estabilished the existence of thick disks in galaxies other than our own. Willman was the first to detect ultrafaint dwarf galaxies in the SDSS. Cowan founded the field of "Exo-cartography" by creating the first longitudinal maps of exoplanets. Roskar changed the way we think about galactic stellar populations by demonstrating that even stars on circular orbits can migrate large distances. Kaib identified a new dynamical pathway for long period comets to enter the inner Solar System. Using SDSS, Plotkin obtained the largest extant samples of BL Lacs, extremely rare active galaxies viewed along their highly relativistic jets. Bochanski produced a definitive low-mass stellar mass function using observations of more than 30 million stars from SDSS.

Department graduate students have won a number of national competitions for support for their research while at the UW. In the past decade, these include 5 NSF Graduate Research Fellowships, 3 NASA Graduate Student Research Program Fellowships, 3 NASA Space Grant Fellowships, a National Virtual Observatory Research Initiative Award, an Astronaut Scholarship Foundation Scholarship, and a National Sciences and Engineering Research Council of Canada Scholarship. Recently, one of our students received the UW Outstanding Dissertation Award for the Physical Sciences.

Over the past 10 years, our graduate students have been extremely involved in programs to enhance education and outreach. To reward their efforts, they have won 2 NSF Graduate Teaching Fellowships, and 3 McNair graduate adviser awards. They have also been awarded fellowships supporting underrepresented students including 2 NASA Harriett G. Jenkins Predoctoral Fellowships and a Dorothy Danforth-Compton Minority Graduate Fellowship.

Following their Ph. D. work, our students have gone on to numerous prize postdoctoral fellowships including those from the NASA Postdoctoral Program, the NSF Astronomy and Astrophysics Program, the Hubble and Spitzer Space Telescopes, the Magellan Observatory, the MacDonald Observatory, the Smithsonian Astrophysical Observatory (Clay) CITA and CIERA.

III.2.2 Undergraduate Students

The department has a strong commitment to involving undergraduates in research. This is a key feature of our Pre-MAP program for incoming freshmen, and therefore research opportunities are available to undergraduates at all levels. The research component attracts very strong students, including a recent College of Arts and Sciences Dean's Medalist, Ben Cowin (2009). The Astronomy department regularly ranks among the top departments at the University in participation in the annual Undergraduate Research Symposium. Undergraduates have also been successful at competing for University funds to support their research and attendance at scientific meetings.

We have also focused on involving undergraduates in publishable research. Again the results are too numerous to list here in their entirety, but we describe a small sample. Professor Emeritus Lutz led a group of Pre-MAP students in publishing a catalog of planetary nebula and symbiotic stars from the MACHO survey. Pre-MAP student and Astronomy undergraduate Pope participated in the publication of theoretical models of galaxy formation by the N-body shop. Undergraduate Silvia took the lead in modeling an eclipsing binary T Tauri star and producing evidence for large dust grains in the circumbinary ring. Pre-MAP student and Astronomy undergraduate Arraki contributed to the discovery of solar system bodies from the ESSENCE Supernova Survey. Undergraduate Robertson used rotation curves of low surface brightness galaxies to constrain the distribution of dark matter. The total publications involving department undergraduates in the past decade number 50, including 9 as first author. These are listed in Appendix G.

III.3 Paradigm Shifts

Several changes in the way Astronomy research is carried out have occurred over the past decade, and the Astronomy department has evolved along with these paradigm shifts. In fact, the department has been at the leading edge as Survey Science, Virtual Institutes and large research groups have begun to dominate Astronomy research.

III.3.1 Survey Science

By focusing our efforts on the SDSS, the SDSS follow-up surveys [the Baryon Oscillation Spectroscopic Survey (BOSS), the Sloan Extension for Galactic Understanding and Exploration (SEGUE), the APO Galactic Evolution Experiment (APOGEE), and the Multi-object APO Radial Velocity Exoplanet Large-area Survey (MARVELS)] and more recently on the Large Synoptic Survey Telescope (LSST), the department has led the field in creating an emphasis on science performed with large data sets rather than individual observations carried out by a single researcher. The availability of previously obtained data in archives such as MAST (the HST archive), and the attempt to federate all astronomical data via Virtual Observatories will make this mode of conducting astronomy research even more prevalent. As well as the obvious ability to answer questions requiring data on large (statistically significant) numbers of objects, this paradigm allows the deeper understanding of individual objects via studies that span multiple wavelengths and/or need rapid followup. In support of this mode, a well-instrumented 3.5 meter telescope will continue to be a valuable complementary facility that will enhance the department's participation in surveys.

We have made substantial investment in developing the tools that will be required to process and analyzed the massive data streams that will come from these new surveys. Through support from grants from the NSF, DOE and NASA we have developed tools that improve the speed and ease of access, and also enable new science discoveries (e.g. the algorithms that enabled the detection of asteroids within the SDSS).

III.3.2 Virtual Institutes

The Virtual Institute (VI) concept encompasses the use of electronic tools to enable research and scientific communication among geographically dispersed teams of collaborating scientists. The department's Virtual Planetary Lab (VPL) research team and Astrobiology program rely heavily on VI technology and concepts. Among the VPL's widely geographically dispersed team typical scientific interactions via e-mail and telecon are augmented with regular use of desktop interaction and sharing software, and high-definition videoconferencing for team meetings, seminars and workshops. As a virtual institute, the VPL team can comprise the very best researchers at any institution, and provides student researchers with regular, substantive interactions with off-campus mentors and a broader community. The VPL team was recently recognized in a NASA magazine as a showcase for virtual research. The astrobiology graduate students embraced VI technology to organize an innovative conference at the UW, with streamed lectures and an interactive poster session available for remote participants via the 3-D virtual world Second Life. The UW Astrobiology Seminar Series, organized out of the astronomy department, was the first non-NASA originated virtual seminar series in astrobiology, and remains one of the few available.

III.3.3 Evolution to larger groups

Our participation in surveys and virtual institutes has led to faculty becoming part of large research groups. The stereotype of the lone astronomer working in isolation has become dated, and the faculty have distinguished themselves as leaders of large multi-institutional projects. Even our youngest faculty are already established leaders, with Professor Ivezic's appointment as Project Scientist for LSST, Associate Professor Meadow's leadership of the Virtual Planetary Laboratory, Associate Professor Connolly's role as head of the UW Data Group for LSST, and Associate Professor Agol leading the theoretical support for the MARVELS project.

III.3.4 Funding Patterns

As described in the budgetary material in Section I.2 of this document, the department has been very successful at increasing the amount of grant funding this decade from both federal and non-federal sources. The RCR (indirect cost return) from these grants has been increasing in the past several years, which has enabled us to support new inititatives, including SDSS-III and LSST, and to continue to provide essential department services in the face of declining state budgets. We have been fortunate to have the support of the College and University in maintaining our access to both the 2.5m and 3.5m telescopes at Apache Point Observatory. As LSST assumes a major role in the department's future efforts, we anticipate both new funding opportunities and additional challenges to balance our portfolio of facilities in order to meet the needs of the various research groups in the department.

III.3.5 Postdocs

The paradigm shifts described above have all contributed to another major shift in the department, with an increase from 7 postdocs to 17 postdocs in the past two years. Several of these postdocs are part of the growing LSST survey science group; others have joined the interdisciplinary Astrobiology program or have been hired into other large groups such as Dalcanton's HST treasury program. We have also attracted several prize postdocs in the past two years, including three NSF fellows (Murphy, Wisniewski, Hicks) a Hubble fellow (Gilbert) and a Sagan fellow (Dobbs-Dixon). Postdoc research has increased commensurately. Some highlights are work by Graciela Matrajt on comet samples from the Stardust mission; John Wisniewski's work on the Subaru SEEDS project to spatially resolve protoplanetary/debris disks; Ben Williams efforts on large X-ray surveys including the XMM-Newton Legacy Survey of M33 and the Chandra X-ray Survey of the Local Volume; and Erin Hicks' measurements of black hole masses in active galaxies. These projects illustrate the breadth of science being carried out in the department independent of the major research groups. Many of the postdocs are staying past the six year postdoc limit at the UW by taking advantage of the research scientist option (see Appendix F).

III.4 Interdisciplinarity

Collaboration with external organizations is a prominent feature of the research performed in the department. Several of the department's larger group research efforts, such as survey science and astrobiology, are also strongly interdisciplinary. Interdisciplinarity is a powerful way to address significant scientific questions that cannot be answered using expertise from a single discipline. This new mode of research has attracted very high-quality students, postdocs, and younger faculty to the department, has driven collaboration both within and beyond the department, and opened up significant new funding opportunities.

III.4.1 LSST

The UW is a founding member of the LSST project, which is now a collaboration of more than 30 research institutions, including Stanford, Princeton, University of Arizona, Caltech, NOAO, UC-Davis and Carnegie-Mellon. In addition to observational astronomers, the collaboration draws on the expertise of statisticians, high-energy physicists, instrumentalists, theoretical astronomers and super-computing experts. Specific LSST driven collaborations with the UW Oceanography and Computer Science departments, Google and IBM have focused on developing techniques to analyze large datasets. This opportunity has also allowed cross-training of computer science and astronomy graduate students.

III.4.2 Astrobiology/VPL

The UW's Astrobiology Graduate Program, in which the Astronomy department is a key player, promotes and funds interdisciplinary research among graduate students in seven participating departments at the UW, including Earth and Space Sciences, Atmospheric Sciences, Oceanography and Microbiology. This program supports joint advising and mentoring of students, and has produced key interdisciplinary publications between students and faculty in these different departments. Many of these papers showcase research in the broad and challenging areas of the astronomical search for life, and the nature and maintenance of planetary habitability, where significant progress can only be made via collaborations between astronomy researchers and those in the other participating departments.

The VPL project is an interdisciplinary collaboration based in the Astronomy department and encompassing 18 different institutions nationwide including Caltech, NASA's Jet Propulsion Lab and Ames Research Center, Penn State University, Stanford, Yale and UC-Berkeley, and internationally with Universidad de Autonoma de Mexico, the University of New South Wales, Australia and L'Observatoire de Bordeaux, France. As research done by the VPL focuses on simulating extrasolar planet environments, the team expertise spans a wide range of disciplines including molecular evolutionary biology, planetary biogeochemistry, atmospheric climate and photochemical modeling, Earth remote-sensing, radiative transfer, planetary orbital dynamics and stellar astrophysics. The team typically publishes 70-90 research and conference publications per year in the interdisciplinary field of astrobiology, including several publications that include co-authors from 2-6 distinct scientific disciplines. Astronomy graduate and undergraduate student research is increasingly being supported by this project.

III.4.3 e-Science/Computational Science

Both the computational astrophysics and survey efforts have led to interdisciplinary collaborations with computational and computer science disciplines. The N-body shop has consulted with colleagues in the applied math department, and has a long collaboration with a Computer Science Parallel Program Laboratory at the University of Illinois at Urbana-Champaign (UIUC) in order to scale calculations to the most powerful computers available. The large datasets generated by the surveys have led to collaborations with database experts in Computer Science and with faculty in Statistics. The Survey Science Group has established collaborations with Computer Science (at the University of Washington and Carnegie Mellon) and Statistics (at Carnegie Mellon) that address the interface between astrophysics and computational statistics. Support from NSF, NASA and DOE enables the development of data mining and machine learning for astrophysics.

The large datasets produced by both astrophysical simulations and large surveys have made Astronomy one of the featured disciplines in the UW e-Science Institute, recently formed to address the technical skills and resources needed to handle such datasets. The Institute includes Astronomy-trained staff, and Astronomy faculty have collaborated on proposals at the University, State and Federal level to investigate data-intensive science.

III.5 Junior Faculty

Junior faculty are a precious asset in the department, as we have had only three state-funded hires at the Assistant Professor level (Dalcanton, Ivezic, Agol) since 1998. (Meadows was granted tenure immediately after completion of a probationary year of teaching and Connolly was hired with tenure.) Mentoring proceeds primarily through discussions with the Chair. Principal topics are teaching, grant-writing, mentoring of students and postdocs, obtaining national recognition through research and service, and preparation for the tenure process. Other members of the faculty also make themselves available for informal discussion of these and other topics, as we are a small, collegial unit and consider the success of our junior members to be instrumental to our success as a department. We give one quarter of teaching relief each year for Assistant Professors. We also encourage participation in the UW Center for Instructional Development and Research (CIDR) which provides access to effective training and teaching tools. Both of our traditional Assistant Professors (Dalcanton, Agol) received NSF CAREER awards in the past decade, while the third (Ivezic) who was hired at a more advanced stage, was awarded early tenure after becoming Project Scientist for the LSST. Associate Professor Connolly also received an NSF CAREER award while at the University of Pittsburgh before joining the UW Astronomy Department.

We have had several Research Assistant Professors pass through the department, and anticipate that we may do additional hiring in the near future. The Research Assistant Professor track is discussed in more detail in Part B.3, where we describe how the mentoring process often starts at the postdoc level.

III.6 Diversity

Faculty diversity is an important goal at the University of Washington, and the Astronomy department has been a leader in promoting diversity in its faculty and student body. We have among the highest ratio of women faculty (presently 4 of 12, 33%) in any of the Natural Science departments, and are even much farther ahead when considering only Math and Physical Science departments which are traditionally male-dominated. Our women faculty are not at the junior level; indeed, we now have three full professors and one associate professor, indicating that this commitment to diversity is not new, but has been in place for decades. A primary reason for our success in attracting and retaining excellent female faculty is the gender equity throughout the department, with nearly half of our undergraduates, graduate students, and postdocs being women. Several visitors have commented that visiting Astronomy at the UW feels like "real life" in contrast to many other departments across the country. A significant sign of this acceptance of women was apparent two years ago, when five members of the academic ranks were all pregnant at the same time. What better sign that we are a family friendly department! The ADVANCE program that the UW participated in for many years was also an important resource for many of our faculty, and the "Mentoring for Leadership" lunches have been well-attended.

Our next goal is to increase diversity among under-represented populations. Hiring diverse faculty is hampered by the competition among astronomy departments to hire the few ethnic minority candidates that apply. Consequently, we have been working towards alleviating this problem by nurturing diversity in the pipeline of astronomers at the undergraduate and graduate levels to eventually affect diversity at the faculty level.

SECTION IV. FUTURE DIRECTIONS

Here we present a strategic plan that describes the strengths and aspirations of the department, identifies the relevant external opportunities likely to materialize in the next decade, and details the resources needed, and the impact of the proposed investments on the vitality of the department and the quality of its scholarship.

IV.1 DEPARTMENT STRENGTHS

Our assessment of our strengths includes:

(1) We are a first-class department with an outstanding international reputation and well-performing research and teaching facilities including APO, SDSS and MRO;

(2) We have significant depth in survey science, as evidenced by many highly cited papers based on SDSS data and our early and very active engagement in LSST;

(3) We have strong and growing activity in computational astrophysics with applications from the formation of planets to the origin of structure in the Universe;

(4) We have a decade-long record of capitalizing on interdisciplinary research opportunities, starting with our faculty's founding of one of the first Astrobiology programs in the nation, continuing with our excellent relations with our colleagues in the Physics Department, and most recently with our expanding ties with Computer Science, Statistics, and Applied Math, as a means to utilize the scientific exploitation of large complex data sets;

(5) We excel at a large array of research in programs ranging from planetary and stellar astrophysics to the structure of the Milky Way, and the origins and early evolution of galaxies and the Universe, often taking advantage of data from the federally funded Great Observatories (including the Hubble Space Telescope) and the US national observatories;

(6) We have superlative, gender-balanced, undergraduate and graduate programs designed to build rewarding careers, not just to issue degrees. We involve our undergrads in research from their first quarter at UW. Our graduate students usually pursue academic careers in astronomy (with a high level of success) but we are also fully supportive of those who choose instead to gain the expertise needed to succeed in the local workforce, or in alternate career paths; these students are making important contributions to education and research throughout the Seattle area.

IV.2 DEPARTMENT ASPIRATIONS

Over the coming decade, we intend to capitalize on our success by increasing our research impact, improving our graduate training, and expanding our undergraduate offerings. Our overall strategy is as follows:

(1) To evolve the faculty to maximize future opportunities in state-of-the-art astrophysical research, preferably in a way that complements and/or solidifies our existing strengths;

(2) To carry out a measured program of capital investment to increase our research impact and productivity, allowing us to attract and retain faculty and students alike, while enabling substantial new grant activity;

(3) To be vigilant and continuously update our courses and teaching mission to respond to the need to provide high-quality undergraduate science coursework to greater numbers of students, and to provide graduate training that reflects the current research landscape and employment opportunities;

(4) To play an essential role in meeting university objectives that emerge from high-level community planning (e.g. "2Y2D"). We intend to remain a star in the UW STEM constellation;

(5) To extend our ongoing efforts to welcome under-represented students in our undergraduate and graduate programs, and to enhance our considerable public outreach programs;

(6) To manage the growth in both personnel and funding with required infrastructure investment in space and administrative staffing.

IV.3 Key Opportunities in the Coming Decade

We have identified two key areas for focused effort and strategic investment in the 2011-2020 decade:

- A Center for Computational Origins (CCO), to build on our department's strength in tackling deep astrophysical problems of high complexity.

- LSST, anticipated to see first light in the latter half of the decade.

These two major projects (described in more detail below) form the framework for us to capitalize on a number of upcoming opportunities in both funding and facilities. Notably, the Astro2010 Decadal Survey process recently ranked the LSST project as the first priority for ground-based projects in the next decade. Their assessment of science priorities includes both planetary and cosmological origins. Our proposed growth areas are therefore well aligned with national goals and funding opportunities. On the federal front, the major opportunities available in the next decade will be the James Webb Space Telescope (JWST) and the Atacama Large Millimeter Array (ALMA). We also need to position ourselves to take advantage of upcoming opportunities including Extremely Large Telescopes (ELTs), the European Space Agency's GAIA mission and the development of extrasolar planet characterization and detection missions. These many projects will all either produce large data volumes, or address issues that require extensive computation to allow theoretical interpretation, and thus should have synergy with the CCO.

In the following sections, we describe in more detail the two proposed areas for growth and investment, together with our assessment of anticipated activity in our current research facilities and infrastructure, education and faculty hiring. We realize that we are operating in a climate of severe fiscal constraints. Hence we plan to utilize faculty retirements, exploit federal and shared facilities on and off campus, pursue collaborations with faculty in many other UW departments and colleges, harness recovered cost return (RCR) funds, and repurpose our limited space to every possible extent. However, the realization of our goals will likely also require strategic investments at critical junctures from College and University sources, and from private foundations and donors.

IV.3.1 Center for Computational Origins (CCO)

Over the last decade, the department has taken on a number of leadership roles in astrophysics: astrobiology though the Virtual Planetary Laboratory, high-resolution simulations of the formation of galaxies from the N-body Shop, space-based observations of local galaxies by the ANGST team and survey-based astronomy through our work on the SDSS and the LSST. These distinct areas of astrophysics share a common theme: the advancement of science through the analysis and interpretation of massive and/or complex data streams.

Today we face the challenge of how to undertake science in an era of Petabytes of data and Petaflops of computing. How do we extract meaning from data sets with 10^{10} sources each with thousands of measurements? How do we relate observations to simulations to understand the physical processes that drive the formation and evolution of the universe? This is not just a question of the size of the data (collecting and aggregating Petabyte data sets scales well with projected technology developments). It is a fundamental question of how we discover, represent, visualize and interact with the knowledge that these data contain.

To address these fundamental questions we propose to create a Center for Computational Origins (CCO). This Center will serve as a focal point for our research efforts; we envision that it would support workshops on scientific and computational challenges, develop courses that address science in the era of massive datasets, fund graduate student fellowships and prize postdoctoral fellowships in the area of computational astronomy and provide support for faculty. Appendix I contains the current draft of a white paper that describes our vision for CCO in more detail, written in preparation for an upcoming visit from the Kavli Foundation in early 2011.

CCO is well-positioned relative to other initiatives in the University and in our region. The development of an e-Science center by the University is fostering connections between data intensive fields; the start of the NSF Ocean Observatories Initiative (with a large component at the University of Washington) has many parallels with the LSST and shares many of the computational challenges; the Pacific Northwest National Laboratory is creating the DIRAC program which will sponsor research in data intensive science in collaboration with the University of Washington; and the local area has many large technology companies, with whom we are already collaborating, including Microsoft, Google, Yahoo, and the Institute for Systems Biology.

The CCO will situate the department to exploit the resources we have invested heavily in over the last decade, train our students to succeed in data intensive fields, increase our visibility in the astronomical community, and attract new faculty and students. Initial funding of the program, including staff, fellowships and faculty support is expected to cost ~$0.5-1 million per year. Growth and eventually maintenance of the program would come through new grant support enabled by the Center.

To initiate such a program will require support from the University including space to house the CCO, bridge funding for support staff while it grows, and development efforts to highlight the Center for donors and foundations in current and future campaigns.

IV.3.2 Large Synoptic Survey Telescope

A significant activity of the department is preparatory work for the LSST project, which presently funds about $700K of research per year. This is projected to grow to $1.5-2 million per year when construction funding starts in 2014. The department now has responsibility for three primary components: Professor Zeljko Ivezic is the LSST project scientist, the Survey Science Group is developing the transient analysis pipeline (i.e. the real-time reduction of LSST data to search for transient and moving sources), and the Simulation Group is leading the generation of high-fidelity simulated images and source catalogs. In the next few years, leading up to the start of construction in 2014, we propose to establish an LSST Data Group of approximately 10 – 15 scientists and software engineers, funded by the LSST project, with oversight of all aspects of the LSST nightly pipelines.

With the positive review from the Astro 2010 decadal committee, we expect first light about five years after the start of construction. As such, the LSST will be a priority for the department well into the next decade. Preparing our students to work with LSST data, ensuring that the department is visible in the resulting science, and attracting high quality students and postdoctoral fellows is of primary importance. This will require a number of changes in the way we teach astrophysics so that we can integrate LSST data and analysis into the graduate curriculum (as described below). The Center for Computational Origins will be central to this effort, as will establishing collaborations with the Computer Science and Statistics departments, the UW e-Science Center, and other data intensive groups. Much of this work is already underway but it will require sustained effort and support over the years prior to first light to ensure that these collaborations endure.

Beyond collaborative work, early science discoveries with the LSST require that we establish an infrastructure within the department for working with LSST data. Current computer resources, such as the Athena cluster, will be decommissioned or outmoded by the start of the LSST. LSST will provide two data centers for general access to the data but, if we expect to be competitive, we will need significant new storage and computer resources (either as local clusters or provisioned on the cloud), as well as network bandwidth within the department.

IV.4 Research facilities

The facilities at Apache Point Observatory, including the ARC 3.5m telescope used by individual investigators, and the Sloan Foundation 2.5m telescope used for the Sloan Digital Sky Survey (now in its 10th year of operation, as SDSS-III) have been the cornerstone of the ground-based observational research in the department in the past decade, and have been highly productive in terms of papers and citations. A particularly important use of the 3.5m has been follow-up of sources found in the SDSS surveys. Another major use is to enable graduate student training and research, which accounts for approximately 50% of the UW observing time. APO is presently soliciting pre-proposals for post-2014 (when SDSS-III ends) use of the 2.5m and 3.5m telescopes. Several faculty are actively involved in one or more of the pre-proposals, which will frame the consortium-wide discussion of the evolution of APO. Our expectation is that new instrumentation and observing modes will be enabled on the 3.5m, and that some new combination of surveys will be carried out on the 2.5m telescope; we also expect that the UW will continue to play a leading role in these developments as we have in the past twenty years. The ongoing operations fees for these telescopes (presently about $400K/year for the 3.5m and about $70K/year for SDSS) are cheap by any measure, and the scientific productivity has been outstanding. In addition, through the efforts of Professor Hawley, who serves as 3.5m Director, we have been able to exert direct control over the 3.5m budget, which has been flat or even decreased for the past three years. We therefore anticipate that a continuation of funding for APO in the next decade, through a combination of University (Provost), College and Department sources as is currently in place, will be essential for our research and teaching mission.

Although LSST will be located in the Southern hemisphere, we will be able to use the APO 3.5m for follow-up of brighter LSST sources in the equatorial region. However, fainter and southern sources will be out of our reach. Also, we realize that we are at a disadvantage in recruiting faculty and graduate students due to our lack of privileged access to "large glass". Nearly all of the top public university astronomy departments in the US have privileged access to 8-10 meter telescopes (along with all the major private institutions, of course). Typically such access is bought using large private donations or through instrumentation contributions. As we no longer have an active instrumentation group, the donor route is likely our only option. Consequently, we propose to make purchase of a share of a large telescope a priority for development efforts, and request College and University assistance in advertising this as another opportunity (along with CCO and LSST) to donors, especially in the upcoming capital campaign. We think that the synergy between LSST, CCO and a share of a large telescope should be easy to frame in a way that is attractive to a variety of donors.

IV.5 Education

We have been extremely successful in training graduate students who have gone on to rewarding careers in Astronomy, with nearly all of our former PhD students presently employed in a STEM field. In response to the paradigm shift in astronomical research taking place as survey science, massive datasets, and large-scale numerical simulations become the norm, we plan to expand the graduate curriculum by instituting a modern computational astronomy course. This course will be complementary to our existing course in observational techniques, and will focus on advanced numerical and statistical methods, data mining techniques, and such practical aspects as correct syntax and documentation for code that will be made publicly available. Several of our current faculty are eager to develop and perhaps co-teach such a course. It may also be feasible to teach the class as a summer school offering made available to students outside the UW, within the proposed CCO framework. Finally, we are considering the evolution of the existing Graduate Certificate in Astrobiology into a dual-title degree program in the home department discipline (e.g. Astronomy) and Astrobiology, with an even greater emphasis on training and experience in interdisciplinary research.

At the undergraduate level, we plan to build on our flourishing programs for both majors and non-majors with two initiatives. First, we will design and implement a new introductory course for non-majors on astronomical origins, drawing on other disciplines as they tie in to the astronomical context. This course will rely on the expertise and cross-campus connections residing in the Astrobiology program, and will fit well with the mission of the CCO. This will increase our presence in 100-level course offerings and we are willing to go even further in this area if faculty size and TA support are commensurate with our efforts.

Second, we plan to institutionalize the Pre-Major in Astronomy Program (Pre-MAP, see Sec II.2.3, website at http://www.astro.washington.edu/users/premap/). This program is designed to involve freshmen in research during their first quarter at the UW, and has been extremely successful in attracting a diverse range of students to Astronomy and other STEM disciplines. It serves as a teaching and mentoring opportunity for graduate students and postdocs, and allows faculty to introduce undergraduates to their research programs at an early stage. Pre-MAP has also had the synergistic benefit of improving the education and public outreach (broader impact) section of our grant proposals, which may in part contribute to our recent high success rate in obtaining external funding. To date, Pre-MAP has been supported by temporary funds, initially by a UW President's Diversity Initiative grant, and recently through an NSF CAREER award (to Associate Professor Agol) and a Kenilworth Foundation grant. The cost is relatively low, ~$20-30K/year for TA support and cohort-building activities such as field trips to nearby observatories. We welcome the opportunity to engage the College and University in discussion about how to promote and maintain Pre-MAP, including the possibility of replicating it in other departments to increase the impact on increasing diversity in STEM fields. One avenue that we are pursuing is to leverage our participation in the Northwest Louis Stokes Alliance for Minority Participation (LSAMP) to further disseminate the program across campus.

IV.6 Faculty hiring

The state-funded faculty currently numbers 12 people filling 11.5 FTE positions. Three of the 12 will reach 70 years of age by 2014, with a fourth reaching that age in 2018. We thus expect at least four retirements in the next decade. In addition, there is a very real possibility of attrition through mid-career faculty being hired at other prestigious institutions. We lost four faculty in the past decade to this route, and several of our current faculty have already been targeted for recruitment.

To offset retirements and attrition, we therefore expect that we will need to hire a new faculty member every 1-2 years in the coming decade. Keeping the faculty at the current size (i.e. replacing all retirements and unsuccessful retentions) will be essential for us to maintain our present successful teaching and research missions. If our aspirations for growth in the areas of the CCO and the LSST Data Group are realized, we will likely need to add faculty to keep pace with those efforts. In addition, as discussed further in Part B.3 below, hiring new assistant professors is becoming increasingly urgent as the faculty is now entirely tenured, consisting of 9 full professors and 3 associate professors (one of whom is up for promotion to full professor this year).

We had very good success in pursuing the faculty hiring plan described in our previous (2000) 10-year review, with two hires in survey astronomy (Ivezic, Connolly), one hire in theory (Agol) and one hire in astrobiology (Meadows). We will consider hiring any world-class astronomer to maintain our breadth, but we are not afraid of specialization if we find an extremely talented candidate in a current area of strength. We are confident that any hires we make will be broadly interested in the CCO and/or LSST focus areas, but particular subareas we have identified are:

Cosmology and/or star formation theory. With the loss of Craig Hogan, we simply maintained our theory level, and Agol and Ivezic have shifted their interests to observational pursuits, whilst our goal was to grow our theory group. Top ranked astronomy programs typically have ~30% theorists among their faculty, while we presently have less than 20%, which is particularly burdensome for teaching theoretical graduate courses. We thus need ~2 hires in theory. Ideally these would focus on theoretical cosmology and star formation (either local, or high redshift), although we would consider other areas as well.

Interstellar medium or star formation. One of the strengths of our department is our breadth, especially important for graduate education. We lack a strong observational presence in interstellar medium or star formation; hiring in these areas would take advantage of JWST and ALMA.

Astrobiology/exoplanets. One of the fastest growing fields of astronomy is the study of extrasolar worlds. We have already built a strong group in this area, but to attract the growing number of excellent graduate student applicants with such interests, we need to build a group competitive in size with other large programs across the US and the world.

In conjunction with faculty hiring, we wish to pursue donor funding for endowed professorships in Astronomy so that we can attract top talent to the department. The CCO will be an excellent vehicle for promoting this discussion with donors, and could possibly support part of new faculty lines.

PART B: UNIT-DEFINED QUESTIONS

B.1 HOW LARGE DO WE WANT TO GROW AS A DEPARTMENT, AND WHAT SHOULD LIMIT OUR GROWTH?

The fundamental limitation on the growth of the department is the size of the faculty. Time commitments on the faculty for teaching, research, mentoring and administration all limit the size to which any group or research area within the department can grow.

At the time of the last 10-year review the department comprised 11 faculty, 7 postdoctoral fellows, 25 graduate students, 60 undergraduate majors and 2.5 administrative staff. In the intervening decade the student body grew by about 25%, the number of postdoctoral fellows expanded to nearly 20 and number of faculty increased to 12. In the same period the administrative staff increased by 1.5 FTE (partially funded by research grants). This growth placed substantial stress on space and administrative support within the department. Postdocs, who were two per office at the start of the decade, are now often three per office and, in some offices (i.e. "the bullpen"), has been as high as six. Space for postdoc offices came at the expense of meeting and study areas for the undergraduate students.

Considering the initiatives outlined in the Futures Section (Part A, Section IV), we estimate that, over the next decade, the graduate program will continue to grow (by about five positions), the size and diversity of the undergraduate student body will increase, and postdocs and research scientists will soon exceed thirty in number (from growth in the Astrobiology and LSST programs, and in the development of the Center for Computational Origins). Without further faculty hires, i.e. not just replacing retiring/leaving faculty, it is difficult to see how we can continue to successfully support and mentor such a large group of students and postdoctoral fellows. To maintain the current, already stretched, faculty-to-student/postdoc ratios, the projected growth in the department would require at least two new faculty hires in this decade in addition to replacements.

Managing this growth will also require a balance between enabling programs to develop and thrive organically, providing sufficient resources to support those programs, and preserving the open culture that exists within the department. We need to maintain an environment with few barriers between students and faculty, and where there is regular and open discussion between all members of the department. Thus, we do not promote unlimited growth, but instead envision a department of ~15 faculty, 35 graduate students, 25 postdocs and research scientists, close to 100 undergraduates and ~ 6 staff (this does not include the separately funded LSST Data Group). This expansion will require an increase of 6 – 8 offices, replacement of the undergraduate common areas, and the development of new meeting and common spaces at the graduate level.

B.2 Should we consider developing on-line and/or self-sustaining programs?

B.2.1 Self-Sustaining Programs

Our department consistently receives applications from students drawn to our strong record of teaching and outreach. While these students are excellent fits to our department culture, they typically do not have academic records quite as strong as the students we admit into our PhD program. However, they are sufficiently prepared that they would benefit from our graduate curriculum, and would eventually embark on outreach and teaching careers with significant societal benefit. This consistent pool of applicants indicates that there is unmet demand for training that UW Astronomy can offer. For example, we could consider offering a dedicated masters program that focuses on training for a career in outreach and teaching, rather than astronomical research.

Many departments on campus offer paid degree programs that provide advanced training outside the standard Bachelor of Science or Ph.D. programs. These programs are typically administered through Educational Outreach, the continuing education branch of UW. A list of such graduate degree programs can be found at http://www.pce.uw.edu/progtype.aspx?aoi=162. In general, they are oriented towards professional development, and lead to advanced employment opportunities. Other departments often find that the students in the professional degree programs have higher ability levels than the students in their state-funded graduate degree programs, due in large part to several years of experience in the work force. The students in the paid degree programs also expect a high level of service.

For our department in particular, a paid degree program in astronomy outreach might offer several benefits. These include an opportunity to serve more students, while supporting additional personnel in the department. The program could allow us to institutionalize our outreach efforts, which are currently done on an ad hoc volunteer basis. There is also a possibility that the program could yield a net cash flow to the department.

However, we find that there are additional concerns that likely outweigh these benefits. First, the program would set up a "two-tier" status for students, with the additional risk of diluting graduate coursework by our state-funded PhD program by enrolling weaker students (in contrast to the professional degree programs). Second, there is little justification that we would be fulfilling a need of surrounding industries. Having students go into debt to receive accreditation in a field with poor job prospects is of questionable morality. Third, there are many logistical concerns, including program staffing. It is not clear that there are currently any faculty committed enough to the success of this idea to devote the needed time to develop curriculum and administer the program. Our superb team of lecturers would be a natural alternative, but then graduate training would be carried out by people who are not considered part of the Graduate School.

In summary, while the idea of developing a paid degree program has some merit, we find that the obstacles to its success are too many for it to be considered a realistic option at this time.

B.2.2 Online Programs

Many of the instructors for the introductory astronomy classes have recently implemented online components, mostly using the Catalyst Web Tools system. The initial motivation for this was the reduction in teaching assistant support due to budget constraints. However, from this apparent negative motivation, the introduction of online components has had some unseen positive aspects. Important background material and assignments that would previously use valuable class time have been moved online. Since the Catalyst system allows instructors to set class-wide due dates, we can be assured that the students have seen the material by the appropriate time. The most positive result of this move to online work is that now the instructor has direct feedback of the progress of the students, rather than learning about their progress second-hand through the filter of the teaching assistants.

Since 2005, we have offered Astronomy 101 in an online-only form (ASTR 101DL) through University of Washington Educational Outreach (UWEO), at equal credit and with material fully equivalent to our "traditional" ASTR 101. Registration for the course is "open", allowing students maximal flexibility to begin their 3-month session at any time. Students are provided with online lectures and multimedia presentations to augment their textbook readings, and assessment of their learning is conducted through weekly online quizzes, a series of interactive exploratory lab exercises, and two exams proctored by the UWEO staff or its proxies. While this general format has been in place since 2005, the course's curriculum has undergone several revisions since its inception to increase student engagement, and to keep up with astronomical developments and changes in online teaching technology. Along with all other UWEO classes, ASTR 101DL is currently in the process of being ported to the Moodle curriculum design and presentation environment, which will allow instructors even greater flexibility to alter the course content as needed.

ASTR 101DL has been a success by many standards – course evaluation figures closely match those of our ASTR 101 classes, and we have been able to serve a broader audience than is possible on the UW campus alone. However, on average we have only about 5 students enrolled at any given time, and over the past five years the course has served an average of only 25 students per year (less than 3% of those served in our other ASTR 101 offerings). While students who pass the course give A101DL high marks, the dropout/failure rate has hovered near 30% since 2005 – a figure much higher than the ~4% seen in our "brick-and-mortar" offering. Also, we have yet to see any of our highly successful A101DL students pursue further astronomy studies in the way that routinely occurs in our ASTR 101 courses.

In seeking to address these issues and expand the reach and impact of our online course offerings, we have recently begun discussion with UWEO and the College of Arts and Sciences about participating in a pilot project to develop "group-start" classes. These courses are designed for matriculated students, run in step with the standard UW quarter system, and are available through the normal course registration process. We are in the process of preparing a proposal to UWEO for online, group-start versions of our primary service courses, ASTR101 and ASTR150, which we anticipate making available possibly within the next academic year (2011 – 2012).

B.3 With a limited number of anticipated tenure-track hires in the next decade, how will we counteract the aging of the faculty? Are research faculty a viable alternative?

The state-funded tenure-track faculty presently consists of nine full professors and three associate professors, with two of the three associate professors anticipated to become full professors by academic year 2012-2013. Thus, within the first three years of this decade, the faculty will likely be composed almost entirely of full professors. The age profile is also an issue, with more than half of the faculty already over the age of 50. We are therefore concerned with how to bring younger faculty, at the assistant professor level, into the department during a time when hiring is expected to be very limited. While we have argued vigorously in other parts of this document for maintaining or even increasing this size of the state-funded faculty, the University budget situation suggests that this may be difficult to attain. We may face a situation where most of the faculty will be nearing or over the age of 60 by 2020. We need to decide on a cogent plan of action now so that we can proceed on a conscious path to address this issue. Hiring research assistant professors, which does not require state funding, is one possible option.

At present, we have a ready pool of possible research assistant professors already working in the department. Our postdoc population has been growing rapidly in the past few years, and once postdocs are here, they often want to stay. At the UW, postdoc positions are limited to six years (three years if the PhD was also obtained at UW). Postdocs at the UW are not allowed to be Principal Investigators and thus it is difficult for them to demonstrate that they can obtain their own grant funding. To provide a path forward, in 2008 we implemented a "postdoc paths" policy (see Appendix F) that allows for a transition from a postdoc (academic) position to a research scientist (professional staff) position. Research scientists can be granted PI status by the Dean, and this allows them to write grants and support themselves. Several postdocs have made or are in the process of making this move to a research scientist position. It is clear that some of these postdocs/research scientists would be eager and willing to fill research faculty positions, were we to decide to offer them. Whether we would be best served by hiring from within is another question, and the social/morale implications of hiring outside applicants rather than local people who will certainly apply is another issue we would need to be prepared to face.

The question of whether to expand the research faculty has other implications. Research faculty at the UW have full voting rights in their department. Since we have only 12 regular faculty, increasing the number of research faculty significantly would create a situation where departmental votes could be strongly influenced by faculty who are not vested in the teaching mission. Also, because many of the faculty have large grants enabling them to buy out of their teaching, we also have a need for additional teaching support in the department. Since research professors are not required to teach (though they may if they wish to), we may need to hire lecturers in addition to, or instead of, research professors.

The faculty has not reached a consensus on this issue as yet, but the renewal of the faculty in the next decade is a subject that needs ongoing discussion and the development of a coherent, well-informed plan.

B.4 What role does a dedicated library in our building play in our future?

The Department has shared a Physics/Astronomy Library (PAL) with the Physics Department for at least 40 years. This Library, which now occupies a beautiful space on the sixth floor of the Tower portion of our Building, used to be a regular branch of the UW Libraries system. Since July 2009, it has been demoted to a "Reading Room", with significantly less staffing provided by the UW Libraries system, shorter hours, transfer of computer support to the Physics/Astronomy Computing Staff (PACS), and transfer of any future maintenance to the Departments (such as replacing chairs, etc.). For 2009-2011 the Physics and Astronomy Departments have an MOU with the UW Libraries whereby we contribute the operating expenses, ~$21K/yr, (of which Astronomy is about one-fourth) to keep PAL open. The reason for the drastic change in 2009 was, of course, large budget cuts to the UW Libraries, resulting in the elimination of several branch libraries and many reductions in overall services. In fact, only huge protests from Physics and Astronomy led to the avoidance of a complete closure of PAL at that time.

The larger question is this: during the second decade of the 21st century, is there a need for an Astronomy Department to have a dedicated Library space with shelves of books and journals, tables and chairs for reading and studying, and computers for access to online catalogs and databases? As journals (including from the distant past), databases, and to some extent books have all gone online, does anybody need a physical Library? The current number of visits to the sixth floor by faculty and graduate students is relatively low with the main usage being to access textbooks and conference proceedings, and to take advantage of the quiet scholarly environment of the reading area. Undergraduates do use the space frequently as a quiet place for study. Class materials for upper-level and graduate courses are also available in PAL.

Although it is painful for those of us from previous generations to admit, the space occupied by the PAL could possibly be put to better use by our Departments. This assumes that the vital services of the UW Libraries system, such as online subscriptions, maintenance of databases, delivery of books and journals from stacks and storage, etc. would continue even without a physical PAL. It also assumes that, should the PAL close down, the College would transfer control of the space from the UW Libraries to the Physics and Astronomy Departments.

The Astronomy Department has not yet reached a decision about what to do beyond 2011. Discussions are ongoing with the Physics Department and the College.

PART C: APPENDICES

Appendix A :DEPARTMENT ORGANIZATION

A1. FACULTY 2009 – 2010

Name	Rank	Appointment Type	Affiliations
Agol, Eric	Associate Professor		Astrobiology, Physics
Anderson, Scott (Assoc. Chair)	Professor		
Balick, Bruce	Professor		
Becker, Andrew	Research Assistant Professor		
Brownlee, Donald	Professor	Part-time	Astrobiology, Earth and Space Sciences
Connolly, Andrew	Associate Prof		
Dalcanton, Julianne	Professor		Physics
Governato, Fabio	Research Associate Professor		
Hawley, Suzanne (Chair)	Professor		Physics
Ivezic, Zeljko	Associate Professor		University of Zagreb
King, Ivan	Research Professor	Part-time	
Meadows, Victoria	Associate Professor		Astrobiology
Quinn, Thomas	Professor		Astrobiology, Physics
Sullivan, Woodruff	Professor		Astrobiology, History
Szkody, Paula	Professor		
	Lecturers		
Larson, Ana	Senior Lecturer	Part-time	
Laws, Chris	Lecturer		
Smith, Toby	Senior Lecturer	Part-time	

A2. EMERITUS FACULTY 2009 – 2010

Name	Rank
Bohm, Karl-Heinz	Emeritus Professor
Bohm-Vitense, Erika	Emeritus Professor
Hodge, Paul	Emeritus Professor
Lutz, Julie	Emeritus Research Professor
Wallerstein, George	Emeritus Professor

A3. ADJUNCT AND AFFILIATE FACULTY 2009 – 2010

Name	Rank	Affiliations
Debattista, Victor	Affiliate Associate Professor	University of Central Lancashire
Gardner, Jeffrey	Affiliate Assistant Professor	Physics, UW
Hogan, Craig	Affiliate Professor	Fermi Lab
Hughes Clark, Joanne	Affiliate Professor	Seattle University
Linnell, Albert	Affiliate Professor	Michigan State University – Retired
Morales, Miguel	Adjunct Assistant Professor	Physics, UW
Murphy, Thomas	Affiliate Assistant Professor	University of California, San Diego
Rosenberg, Leslie	Adjunct Professor	Physics, UW
Ward, Peter	Adjunct Professor	Biology, ESS

A4. RESEARCH ASSOCIATES 2009 – 2010

(Postdocs)

Name	Faculty Affiliation
Barnes, Rory	Meadows
Claire, Mark	Meadows
Cowan, Nicolas	Agol
Dobbs-Dixon, Ian	Agol
Domagal-Goldman, Shawn	Meadows
Gibson, Robert	Connolly
Gilbert, Karoline	Dalcanton
Hicks, Erin	Quinn
Huang, Wenjin	Wallerstein
Krughoff, Simon	Connolly
Mukadam, Anjum	Szkody
Murphy, Jeremiah	Agol
Pizagno, James	Connolly
Radburn-Smith, David	Dalcanton
Silvestri, Nicole	Connolly
Williams, Ben	Dalcanton
Wisniewski, John	Agol

A5. Research Scientists 2009 – 2010

Name	Faculty Affiliation
Jones, Lynne	Ivezic
Joswiak, David	Brownlee
Matrajt, Graciela	Brownlee
Wiley, Keith	Connolly
Telescope Engineering Group	
Carrey, Larry	APO, Engineer
Evans, Michael	APO, Business Manager
Kohlenberg, Erin	APO, Project Specialist
Leger, Roger	APO, Engineer
MacDonald, Nick	APO, Engineer
Owen, Russell	APO/LSST, Engineer

A6. Administrative Staff 2009 – 2010

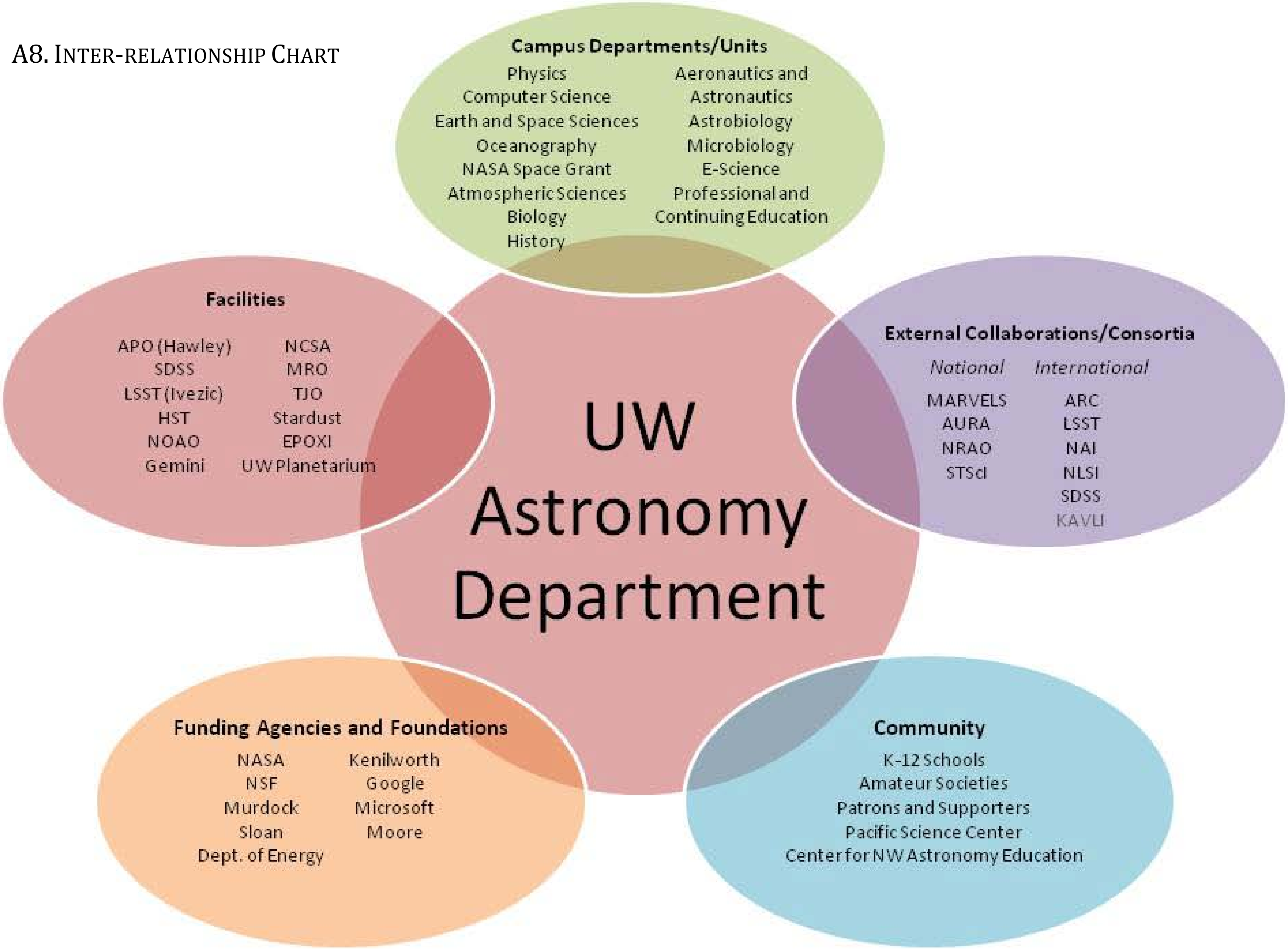
Name	Title
Garner, Sarah	Program Coordinator
Kim, Young	Fiscal Specialist I
Taylor, Pat	Fiscal Specialist II
Vlcek, Stan	Administrator

A7. Astronomy Faculty Responsibilities 2009 – 2010

Responsibility	Faculty Assigned
ARC 3.5m Director	Hawley
ARC 3.5m TAC	Hawley*, Becker, Wisniewski
ARC Board	Anderson
ARC Users Rep	Anderson
Associate Chair	Anderson
Astrobiology	Meadows, Sullivan
AURA Board Rep	Szkody
A-wing Telescopes	Larson
Chair	Hawley
College Council	Anderson
Computing Planning and Policy	Quinn
Development	Connolly*, Dalcanton, Balick
e-Science	Quinn
Faculty Senate	Becker
Graduate Admissions	Dalcanton*, Agol, Connolly
Graduate Advisor	Anderson
Jacobsen Fund	Wallerstein, Anderson
Lab Fee Allocation	Larson, Smith
Library	Sullivan
LSST Board	Lee Huntsman
LSST Data Management, Simulations	Connolly
LSST Project Scientist	Ivezic
MRO Assoc Director	Laws
MRO Director	Lutz
Planetarium	Brownlee, Smith
Pre-MAP	Agol
Qualifying Exam	Brownlee*, Meadows, Sullivan
SDSS-III Advisory Council	Hawley
SDSS-III CoCo	Agol
TA Assignments	Anderson
Telescope Engineering Group	Hawley
TJO Director	Larson
Undergraduate Advisor	Szkody
Web pages	Governato

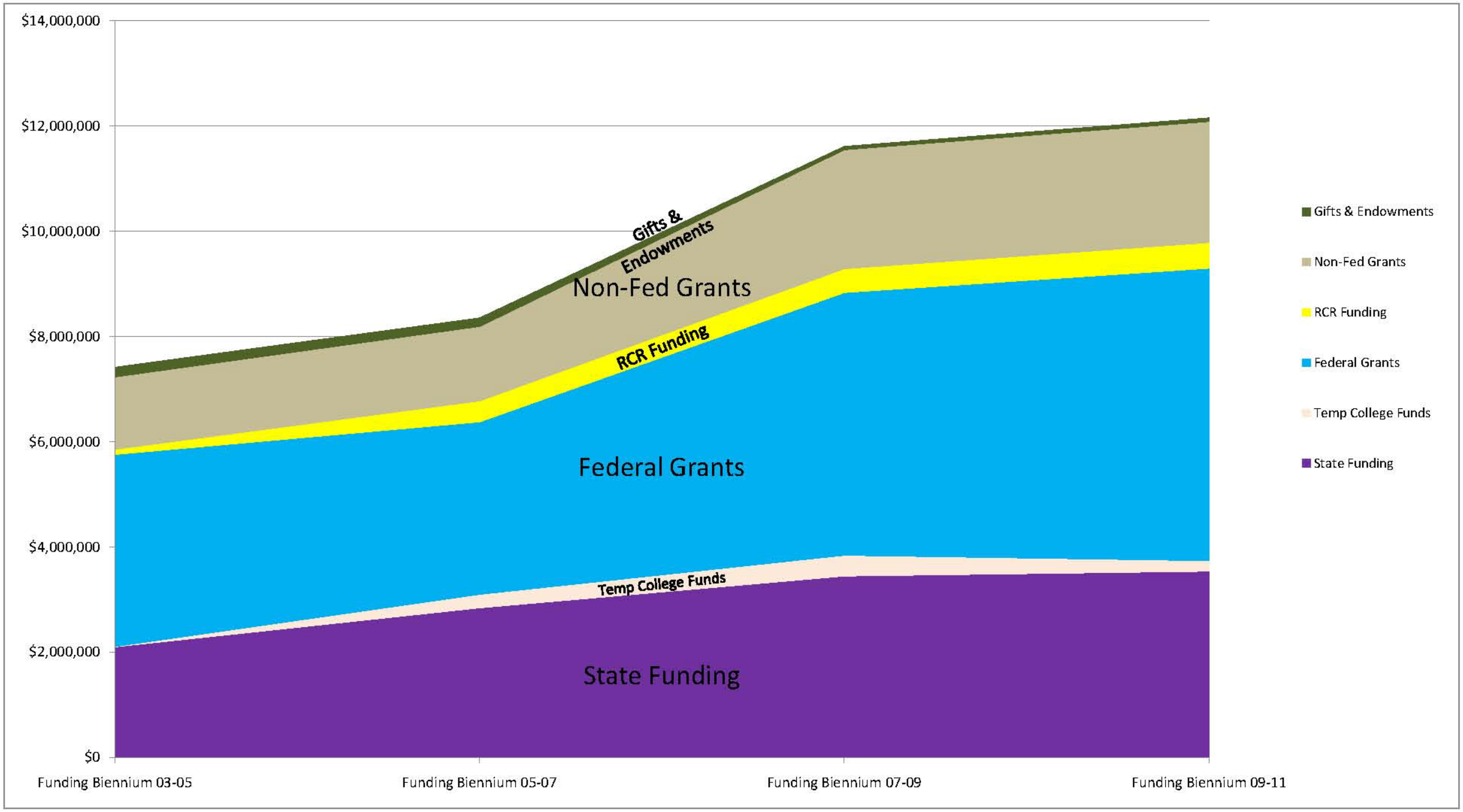
* Indicates Chair of committee

A8. INTER-RELATIONSHIP CHART



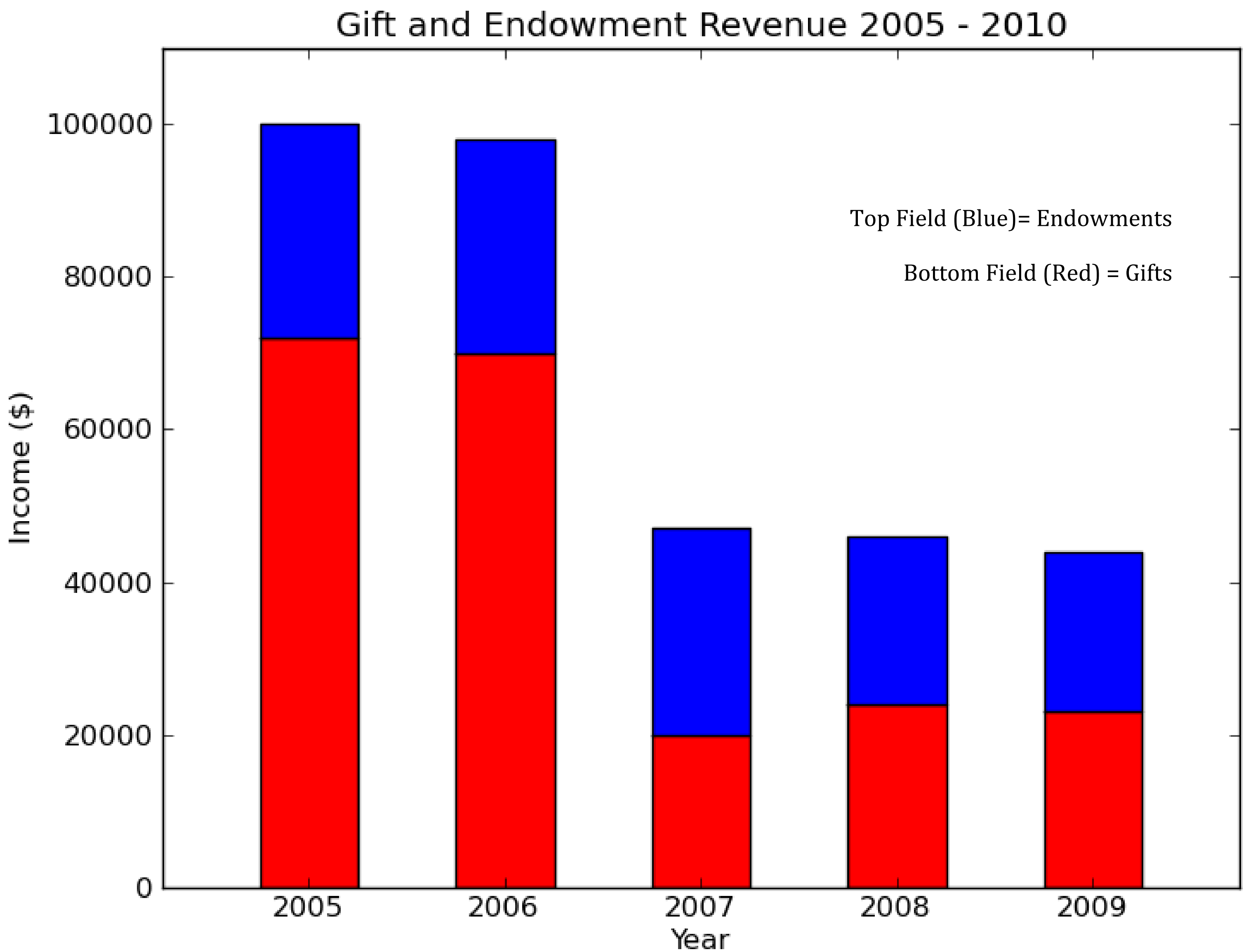
Appendix B : Budget Summary

B1. 2003 – 2011 Department Budget



	State Funding	Temporary College Funds	Federal Grant	RCR Funding	Non-Fed Grants	Gifts and Endowments	Total
Funding Biennium 03-05	$2,102,796	$8,145	$3,647,498	$98,438	$1,374,866	$184,547	**$7,416,290**
Funding Biennium 05-07	$2,844,368	$256,750	$3,276,397	$398,786	$1,414,736	$162,686	**$8,353,723**
Funding Biennium 07-09	$3,448,544	$394,745	$4,990,802	$452,969	$2,260,183	$64,920	**$11,612,163**
Funding Biennium 09-11	$3,540,250	$200,000	$5,556,845	$487,790	$2,300,000	$69,750	**$12,154,635**
Total	**$11,935,958**	**$859,640**	**$17,471,542**	**$1,437,983**	**$7,349,785**	**$481,903**	**$39,536,811**

B2. FUNDRAISING



Appendix C : Faculty

Information about Faculty

Faculty CVs are available online at http://www.astro.washington.edu/10year.html.

Faculty Research Descriptions

Eric Agol

Eric Agol studies extrasolar planets, black holes, and gravitational lenses. He uses analytic computations, numerical simulations, and observations to discover and characterize these objects. With collaborators, he was the first to propose that radio observations could be used to image the shadow of the event horizon of a black hole; he was the first to create an infrared longitudinal map of an extrasolar planet; he has written computer code used to characterize over 50 transiting extrasolar planets; and he has proposed a novel technique for finding planets as small in mass as the Earth, and used it to demonstrate that Earth-mass planets could be detected in resonance with transiting planets, were they present.

Scott Anderson

Anderson's current research interests focus on multiwave length observational studies of high energy phenomena, including quasars and accreting binary systems. Along with affiliated students and postdocs, Anderson makes use of data from a variety of ground- (e.g., 3.5m) and space-based instruments (e.g., Hubble Space Telescope and the Chandra X-ray Observatory). He is also actively involved in the Sloan Digital Sky Survey including recent studies of rare accretion-driven objects, such as weak-lined quasars and ultracompact binaries.

Bruce Balick

Balick's interests range from how planetary nebulae eject their envelopes to the rate at which they inject helium, carbon, and nitrogen into the ancient ISM in the halos of M31 and the Milky Way. Balick and his collaborators focus on the nebular hydrodynamics and the construction of numerical models in which detailed physical processes are included. Balick is an active user of large optical telescopes such a s Gemini and the Hubble Space Telescope. He serves on the design team for the next generation camera, WFC3, that was installed in HST in 2009. He is a member of the Astronomy and Astrophysics Advisory Committee which monitors the progress and funding of interagency projects and advises Congress annually. Balick is the chair of the Faculty Senate at UW for 2009-10.

Andrew Becker

My research interests in the past have focused on detecting and following-up unusual microlensing events in real-time (with MACHO, GMAN, and MPS). However, my pursuits have since broadened to the generalized problem of detecting and classifying astronomical variability regardless of type (with DLS, SDSS, and LSST). In particular, if one wants to recognize rare classes of transient events, the background of more prosaic astronomical variability must first be recognized and removed. Modern surveys that simultaneously survey faint, fast, and wide are now at a threshold where we expect these new sorts of discoveries. Accomplishing this will require advances in the integration of computing and information management necessary to extract and model astronomical variability information in real-time. Recent science pursuits include: mining survey data for distant Trans-Neptunian Objects, phasing large time-series of 2MASS data for periodic variability, pursuing a novel method to estimate Supernova Type Ia distances and constrain cosmology, undertaking a Principal Component Analysis of M-dwarf spectra, and writing reams of software for the Large Synoptic Survey Telescope.

Don Brownlee

Don's primary research interests focus on the origin and evolution of planetary materials, planets and planetary systems. He is extensively involved with the laboratory study of primitive materials from asteroids and comets and he is PI of the NASA's Stardust comet sample return mission. He is also a member of the UW Astrobiology program and he has recently co-authored two books with UW paleontologist Peter Ward on the Earth's evolution to become a habitat for advanced life and the remarkable aspects of the processes involved as viewed from the perspectives of space and time.

Andrew Connolly

My work focuses on using large surveys to study cosmology and the evolution of galaxies. This ranges from studying the clustering of galaxies and their evolution with redshift, weak gravitational lensing of galaxies, and estimating the properties of galaxies based on their colors (aka photometric redshifts). The common theme to this work is addressing the need for massive data sets and how to work with them. One area that interests me a lot at the moment is the Large Synoptic Survey Telescope (LSST) where I lead the development of simulations of what LSST might observe. Beyond cosmology, I am also interested in how to make the technologies that companies use to search the internet useful in research and education. As part of this, a couple of years ago I was on sabbatical at Google where I created "Google Sky"; an extension to Google Earth that streams many Terabytes of astronomical images and provides an easy way to zoom and pan throughout the universe.

Julianne Dalcanton

Julianne Dalcanton works on galaxy formation and evolution, focusing primarily on what can be learned in the nearby universe. Her group is currently working on several large projects studying the resolved stellar populations of nearby galaxies using HST, their neutral gas distribution with the VLA, and their stellar mass, dust, and star formation properties with Spitzer. She also works closely with the N-body shop on the interface between observation and numerical theory.

Fabio Governato

Fabio works on cosmic structure formation using N-Body simulations as his primary tool. His current interests focus on understanding how galaxies formed and evolved and on how to compare observations from HST and the other Great Observatories with theoretical predictions based on the "Cold Dark Matter" model. He gets his best ideas while eating vegan donuts.

Suzanne Hawley

Suzanne Hawley works in stellar astrophysics, particularly in the areas of magnetic activity, low mass stars, brown dwarfs and variable stars. In addition, she studies star clusters, the stellar content of dwarf galaxies, and galactic structure. She is co-author of a graduate textbook with Neill Reid entitled "New Light on Dark Stars" (Springer-Praxis 2 edition, 2005). Suzanne also serves as the Director of the ARC 3.5-m telescope at Apache Point Observatory.

Zejko Ivezic

Zeljko Ivezic (pronounced something like Gelco Evazich) is interested in detection, analysis and interpretation of electromagnetic radiation from astronomical sources. He has spent the last six years working (and having lots of fun) on the Sloan Digital Sky Survey, and is currently using SDSS (and other) data to study asteroids, Milky Way structure, and multi-wavelength properties of stars, galaxies and quasars. He is also interested in radiative transfer and is engaged in studies of dusty environments around young and old stars, and active galactic nuclei. These days, most of Zeljko's time is spent on his duties as the System Scientist for the Large Synoptic Survey Telescope

Ivan King

Ivan King works on the structure and population content of star clusters, mainly with images taken by the Hubble Space Telescope. His research combines high-precision measurements of the positions and brightnesses of stars in globular clusters, in order to separate the member stars of a cluster from the superposed field stars, to delineate the stellar populations that make up each cluster, and to use the individual stellar motions to understand the dynamics of the clusters. His present interests concentrate particularly on clusters that have a mixture of stellar populations, in an effort to understand their possible origin and development.

Victoria Meadows

Victoria Meadows is an astrobiologist and planetary astronomer whose research interests focus on acquisition and analysis of remote-sensing observations of planetary atmospheres and surfaces. In addition to studying planets within our own Solar System, she is interested in exoplanets, planetary habitability and biosignatures. Since 2000, she has been the Principal Investigator for the Virtual Planetary Laboratory Lead Team of the NASA Astrobiology Institute. Her NAI team uses models of planets, including planet-star interactions, to generate plausible planetary environments and spectra for extrasolar terrestrial planets and the early Earth. This research is being used to help define signs of habitability and life for future extrasolar terrestrial planet detection and characterization missions.

Thomas Quinn

Tom leads the N-body shop, where he works on running and analyzing N-body simulations of structure formation in the Universe. His other research interests include Galactic and Solar System dynamics, and planet formation. He is a member of the UW Astrobiology program. He is also involved in developing scientific software for the Sloan Digital Sky Survey and chairs the SDSS Solar System working group.

Woodruff Sullivan

Sullivan's interests are in astrobiology, in particular the search for extraterrestrial intelligence (SETI), as well as the history of astronomy. Recent SETI activity has included a collaboration with the Serendip group, using the Arecibo 1000-foot dish for an all-sky search for a wide variety of signal modulation at 21 cm (seti@home project). History of astronomy research has been on the twentieth century, in particular the development of early radio astronomy (Cosmic Noise: A History of Early Radio Astronomy,2009) and ideas about extraterrestrial life, as well as a long-term project designed to produce a biography of William Herschel. Together with John Baross (Biological Oceanography) he has produced the graduate textbook Planets and Life: The Emerging Science of Astrobiology (2007).

Paula Szkody

Szkody uses a multiwavelength approach to study close binary stars with active mass transfer (Cataclysmic Variables). Her current research involves ultraviolet observations with the Hubble Space Telescope and the GALEX and FUSE satellites, X-ray observations with Chandra and XMM, infrared observations with Spitzer as well as APO and ground-based optical facilities around the world. With colleagues participating in the Sloan Digital Sky Survey, she is currently finding the faintest, lowest mass transfer CVs. These observations have led to insights into the nature of mass transfer and accretion onto magnetic and non-magnetic white dwarfs, the structure of accretion onto magnetic and non-magnetic white dwarfs, the structure of accretion disks and their X-ray-emitting boundary layers, stellar coronae, and the effects of irradiation on the upper atmospheres of late-type secondary stars. The results are elucidating the long-term evolution leading to the formation of these ultrashort period binaries. Szkody has served as the Editor of the Publications of the Astronomical Society of the Pacific since 2005.

LECTURERS

Ana Larson

Teaching interests: My interests lie in teaching introductory astronomy courses incorporating active student participation in lectures, labs, and on-line exercises, and curriculum development for these courses, including an on-line text book and exercises. I am also involved in the outreach program here, primarily with the old campus observatory and with teaching summer camps with young scholars.

Chris Laws

My primary interest is working with students - both in and out of the Astronomy major - to get all they can from their time here at the University. I dedicate most of my working hours to developing the courses I teach, and to mentoring those students who wish to extend the reach of their education beyond the classroom. I also directly investigate ways of improving the experiences of undergraduates in Astronomy, and have led the development in recent years of University-sponsored Learning Goals for our undergraduates, along with metrics to assess the department's performance in helping students to meet those goals. Finally, I'm an adjunct member of a number of active observational research programs, focused primarily (but not exclusively!) on studies of extrasolar planetary systems. These include the MARVELS planet-search survey, the APOSTLE transit monitoring program, and a host of other projects I'm associated with in my role as Associate Director of MRO.

Toby Smith

My primary research and teaching interests are focused on the processes that shape the surfaces of the worlds of our solar system. In particular, my research has focused on investigating and sampling terrestrial meteorite craters to study the physical process that create and distribute meteoritic material around them. My primary teaching interests are the geological processes and history of the solar system and the history of the Apollo Lunar missions.

Appendix D : HEC Board Summary

EXISTING PROGRAM REVIEW: HEC BOARD SUMMARY
Name of unit: Astronomy
Name of school/college: Arts and Sciences
Degree title(s): Doctorate of Philosophy, Masters of Science, Bachelor of Science
Year of last review 2000
Current date 2010

A. Documentation of continuing need, including reference to the statewide and regional needs assessment (you may cut and paste from Part A, Section IV, above).

The HECB statewide and regional assessment report indicates a strong need to increase the number of science and technology degrees. The Astronomy Department is directly addressing this need in particular with the Pre-Major in Astronomy Program (Pre-MAP), and the increasing number of undergraduate and graduate degrees we are awarding.

B. Assessment information related to expected student learning outcomes and the achievement of the program's objectives (you may cut and paste from Part A, Section II, above).

The learning goals for the Astronomy major are to enable our students to:

(1) Understand the principal findings, common application and current problems within astronomy as a scientific discipline.

(2) Be versed in the computational methods and software resources utilized by professional astronomers.

(3) Have experience operating modern astronomical instrumentation and analyzing a range of experimental data.

(4) Be able to assess, communicate and reflect an understanding of astronomy and the results of astrophysical experiments in both oral and written formats.

(5) Learn in a diverse environment with a variety of individuals, thoughts and ideas.

The goals of the graduate program in astronomy are education and mentoring of our students toward their long-term careers in research and teaching in astronomy or related STEM fields. The graduate program has recently been assessed by the NRC, receiving an overall S-ranking between 4^{th} and 11^{th} among all U.S. astronomy programs studied.

These goals are assessed through student evaluation of courses, classroom assessment, a capstone sequence, independent research, exit surveys, and student leadership roles in department governance.

C. Plans to improve the quality and productivity of the program (you may cut and paste from Part A, Section IV, above).

The Department of Astronomy is committed to exceptional education and outstanding research. To accomplish this, the Department aims:

(1) To evolve the faculty to capitalize on future opportunities in state-of-the-art astrophysical research, preferably in a way that compliments and/or solidifies our existing strengths;

(2) To carry out a measured program of capital investment to increase our research impact and productivity, allowing us to attract and retain faculty and students alike, while enabling substantial new grant activity;

(3) To be vigilant and continuously update our courses and teaching mission to respond to the need to provide high-quality undergraduate science coursework to greater numbers of students, and to provide graduate training that reflects the current research landscape and employment opportunities;

(4) To play an essential role in meeting university objectives that emerge from high-level community planning;

(5) To extend our ongoing efforts to assimilate under-represented students in our undergraduate and graduate programs, and to enhance our considerable public outreach programs.

(6) To manage the growth in both personnel and funding with required infrastructure investment in space and administrative staffing;

Number of instructional faculty, students enrolled, and degrees granted over last three years (Autumn-Summer)

	2007-2008	**2008-2009**	**2009-2010**	**TOTAL**
FTE* instructional faculty	11.67	11	12.67	35.34
FTE* graduate teaching assistants	12	12	10	34
Degree Program	*PhD*	*PhD*	*PhD*	*PhD*
Headcount of enrolled students	27	26	31	84
Number of degrees granted	5	2	7	14
Degree Program	*Bachelors*	*Bachelors*	*Bachelors*	*Bachelors*
Headcount of enrolled students	52	56	71	179
Number of degrees granted	10	14	26	50
TOTAL				

* 1 FTE = 3 Quarters

Appendix E : DEGREE INFORMATION

E1. UNDERGRADUATE MAJOR REQUIREMENTS

Mathematics

124	Calculus w/ Analytic Geometry I	5
125	Calculus w/ Analytic Geometry II	5
126	Calculus w/ Analytic Geometry III	5
308	Matrix Algebra with Applications	3
324	Advanced Multivariable Calculus	3
TOTAL MATH*		21

* Add'l math courses are highly recommended in preparation for graduate study.

Physics Credits

121	Mechanics	5
122	Electromagnetism and Oscillatory Motion	5
123	Waves	5
224	Thermal Physics	3
225	Modern Physics	3
227	Elem. Mathematical Physics	4
228	Elem. Mathematical Physics	4
321	Electromagnetism	4
322	Electromagnetism	4
334	Electric Circuits Laboratory	3

Plus 12 credits chosen from†:

226	Special Relativity	3
311	Relativity and Gravitation	3
323	Electromagnetism	4
324	Quantum Mechanics	4
325	Quantum Mechanics	4
328	Statistical Physics	3
331	*Optics Laboratory*	*3*
335	*Electric Circuits Laboratory*	*3*
421	Atomic & Molecular Physics	3
422	Nuclear & Elem. Particle Physics	3
423	Solid State Physics	3
424	Mathematical Physics	3
431	*Modern Physics Lab*	*3*
432	*Modern Physics Lab*	*3*
433	*Modern Physics Lab*	*3*
434	Application of Computers to Physical Measurement	3
TOTAL PHYSICS		52

Astronomy

321	The Solar System	3
322	The Contents of Our Galaxy	3
323	Extragalactic Astronomy & Cosmology	3

Plus 9 credits chosen from (with at least 3 in 480 or 499):

421	Stellar Observations & Theory	3
423	High Energy Astrophysics	3
425	Cosmology	3
480	Intro to Astronomical Data Analysis**	5
481	Intro to Astronomical Observation	5
482	Scientific Writing	2
497	Topics in Current Astronomy (max 9)	1-3
499	Undergraduate Research or 500-level Astronomy courses (with permission) max.	1-15
500	Astronomy Instruction	1-3
TOTAL ASTRONOMY		18

** ASTR 300 is a prerequisite for ASTR 480.

As a capstone sequence of hands-on research and dissemination of results, the following is highly recommended: ASTR480, followed by either ASTR481 or ASTR499 or an REU project, and ending with ASTR482.

Departmental Honors Requirement: cumulative 3.7 GPA in astronomy courses and 6 credits of ASTR 499 undergraduate research.

†Students double majoring with Physics should refer to the Physics degree requirement s in order to select courses that count towards both programs. Courses in bold are required for Physics; choose from two of the courses *italicized*. Note the Physics major requires only 10 credits from this category while Astronomy requires 12 credits.

E2. Undergraduate Sample 4-Year Curriculum

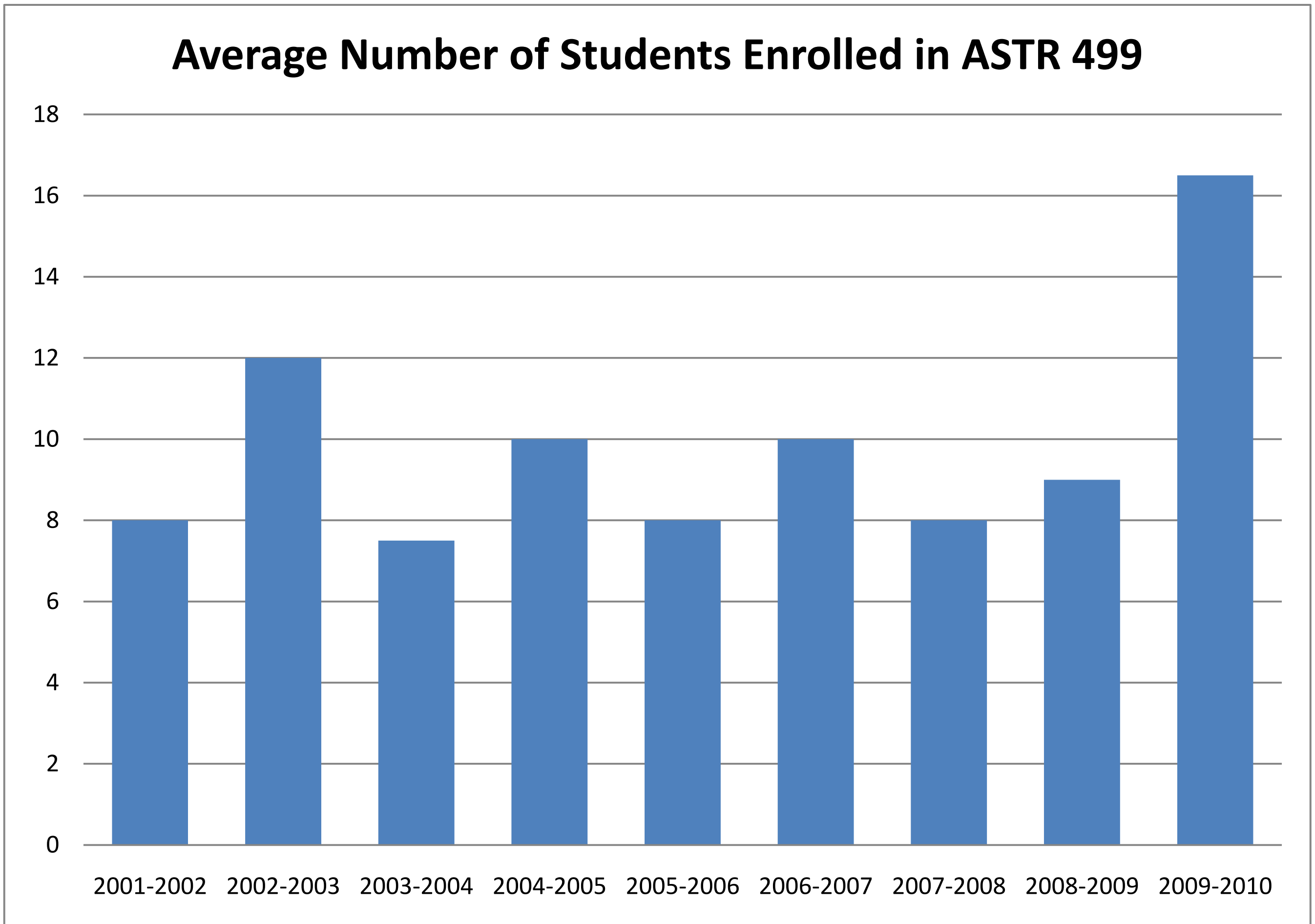
	Autumn		**Winter**		**Spring**		**Summer**		Total
	Course	*Credit*	*Course*	*Credit*	*Course*	*Credit*	*Course*	*Credit*	
Year 1	**Phys 121** **Math 124**	5 5	**Phys 122** **Math 125**	5 5	**Phys 123** **Math 126**	5 5			
Total credits									
Year 2	**Astr 321** **Phys 224** **Phys 227** **Math 324** Astr 400	3 3 4 3 1	**Astr 322** **Astr 300** **Phys 225** **Phys 228** **Math 308**	3 2 3 4 3	**Astr 323**	3			
Total credits									
Year 3	**Phys 321** **Phys 324**	4 4	**Phys 322** **Phys 334**	4 3	*Phys 335* **Astr 480**	*3* 5	Astr 481	5	
Total credits									
Year 4	Astr 482 *Phys 331* *Phys 433*	 3 3	 *Phys 431*	 3	 *Phys 432*	 3			
Total credits									
								TOTAL	**180**

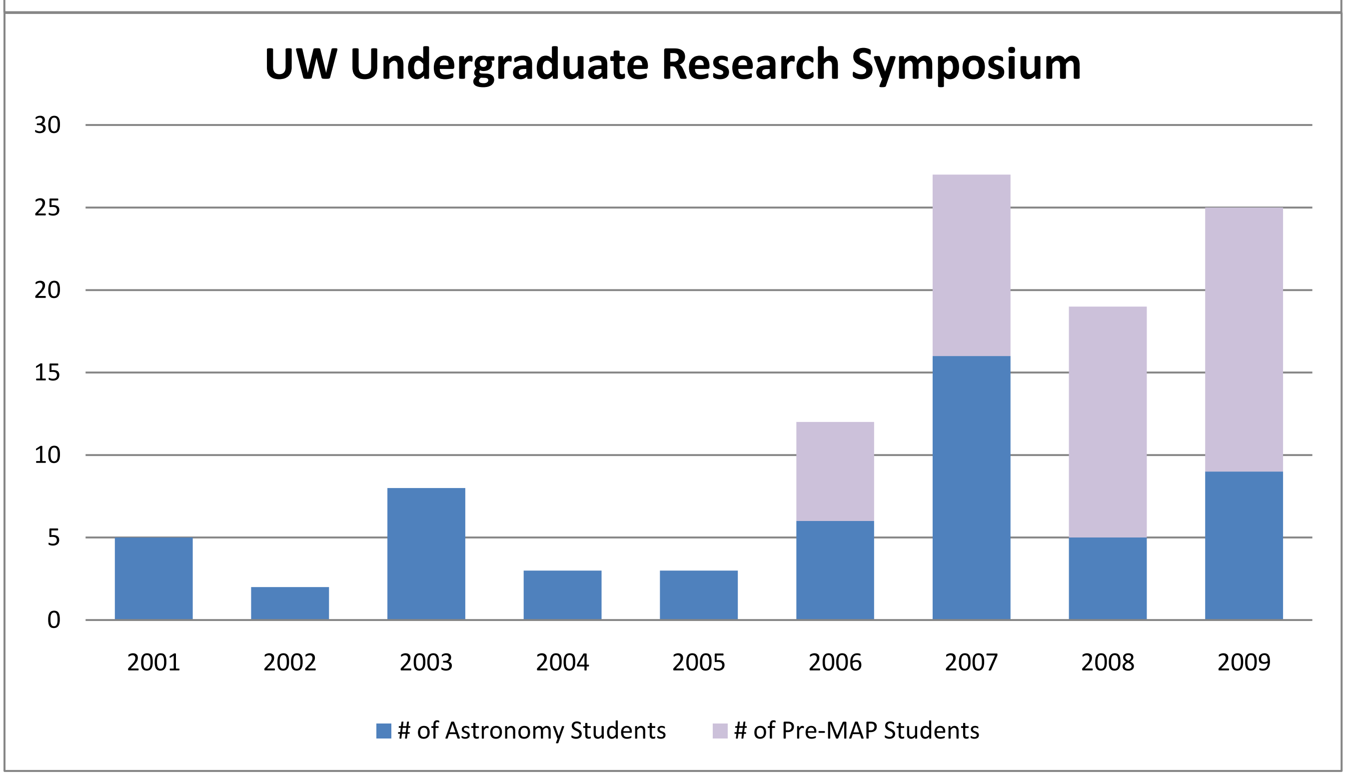
Courses in **Bold** are required.
Courses *italicized* are Physics lab courses (students must select two).

Courses underlined are suggested courses for Astronomy majors as part of our capstone sequence (ASTR 480, 481, 482) and for learning about research opportunities in the Department (ASTR 400).

This sample contains the core program requirements for a student to complete a double major in Astronomy and Physics. Students need to complete additional College of Arts and Sciences requirements to graduate.

E3. Undergraduate Research Participation





E4. Graduate Course Plan

	Autumn	Winter	Spring	Summer
Year A	ASTR 507 ASTR 519	ASTR 521 ASTR 557	ASTR 531 ASTR 561	ASTR 581
Year B	ASTR 508 ASTR 541	ASTR 509 ASTR 511	ASTR 512 ASTR 513	

Core Graduate Curriculum

ASTR 507 Physical Foundations of Astrophysics I: Thermodynamics from an astronomer's point of view: black body radiation, basic radiative transfer, equation of state, degenerate gases, crystallization at high density.

ASTR 508 Physical Foundations of Astrophysics II: Introduction to astronomical hydrodynamics and magnetohydrodynamics, basic theorems and application to stellar and interstellar magnetic fields. Introduction to plasma physics and waves in a plasma.

ASTR 509 Physical Foundations of Astrophysics III: Potential theory as applied to astrophysical systems. Orbits. Integrals of motion. Equilibrium and stability of stellar systems. Encounters of stellar systems. Kinetic theory of collisional systems. Applications of stellar dynamics to star clusters, galaxies, and large-scale structure.

ASTR 511 Galactic Structure: Kinematics, dynamics, and contents of the galaxy. Spiral structure. Structure and evolution of galaxies.

ASTR 512 Extragalactic Astronomy: Types of galaxies. Integrated properties, content, and dynamics. Extragalactic distance scale, groups and clusters. Radio sources. Observational cosmology.

ASTR 513 Cosmology and Particle Astrophysics: Big bang cosmology; relativistic world models and classical tests; background radiation; cosmological implications of nucleosynthesis; baryogenesis; inflation; galaxy and large-scale structure formation; quasars; intergalactic medium; dark matter.

ASTR 519 Radiative Processes in Astrophysics: Theory and applications of astrophysical radiation processes: transfer theory; thermal radiation; theory of radiation fields and radiation from moving charges; bremsstrahlung; synchrotron; Compton scattering; plasma effects.

ASTR 521 Stellar Atmospheres: Theory of continuous radiation and spectral line formation. Applications to the sun and stars.

ASTR 531 Stellar Interiors: Physical laws governing the temperature, pressure, and mass distribution in stars. Equation of state, opacity, nuclear energy generation, computational methods. Models of main sequence stars and star formation.

ASTR 541 Interstellar Matter: Physical conditions and motions of neutral and ionized gas in interstellar space. Interstellar dust, magnetic fields, formation of grains, clouds, and stars.

ASTR 557 Origin of the Solar System: Nebular and nonnebular theories of the solar system origin; collapse from the interstellar medium, grain growth in the solar nebula, formation of planetesimals and planets, early evolution of the planets and other possible planetary systems; physical and chemical evidence upon which the ideas concerning the origin of the solar system are based.

ASTR 561 High Energy Astrophysics: Observed properties of supernovae, x-ray stars, radio sources, quasars. Theories explaining such objects. Origin of cosmic rays.

ASTR 581 Techniques in Optical Astronomy: Theory and practice of obtaining optical data. Astronomical photoelectric photometers, spectrographs, interferometers, CCDs, and infrared equipment. Data-reduction techniques with emphasis on statistical analysis using digital computers. Observations with MRO thirty-inch telescope and ARC 3.5m telescope.

E5. List of Ph.D.s Granted 2000 – 2010

Name	Qtr	Year	Advisor	Current Employment	Position
Gardner, Jeffrey	S	2000	Quinn	University of Washington	Deputy Director, e-Science
Becker, Andrew	A	2000	Stubbs	University of Washington	Research Asst. Prof.
Krisciunas, Kevin	A	2000	Stubbs	Texas A&M University	Lecturer
Wyder, Ted	A	2000	Hodge	CalTech	Staff Scientist
Rodgers, Bernadette	Sp	2001	Balick	Gemini Observatory	Gemini South Head of Science Operations
Stadel, Joachim	Sp	2001	Quinn	University of Zurich	Research Scientist
Zucker, Daniel	A	2001	Hodge	Macquarie University/Anglo-Australian Observatory	Asst. Prof.
Williams, Benjamin	Sp	2002	Hodge	University of Washington	Research Assoc.
Matt, Sean	S	2002	Winglee	NASA Ames	Prize Senior Fellow
Rest, Armin	A	2002	Stubbs	Harvard	Research Assoc.
Buchman, Luisa	A	2003	Bardeen	CalTech	Visitor
Armstrong, John	Sp	2003	Quinn	Weber State University	Asst. Prof.
Reed, Darren	A	2003	Quinn	Los Alamos National Lab	Research Assoc.
Willman, Beth	A	2003	Dalcanton	Haverford College	Asst. Prof.
Desai, Vandana	S	2004	Dalcanton	CalTech	Research Scientist
Barnes, Rory	A	2004	Quinn	University of Washington	Research Assoc.
Laws, Christopher	A	2004	Hawley	University of Washington	Lecturer
Raymond, Sean	Sp	2005	Quinn	Laboratoire d'Astrophysique de Bordeaux	Research Scientist
West, Andrew	S	2005	Dalcanton	Boston University	Asst. Prof.
Seth, Anil	Sp	2006	Hodge	Harvard	Research Assoc.
Agueros, Marcel	S	2006	Anderson	Columbia	Asst. Prof.
Covey, Kevin	S	2006	Hawley	Cornell	Hubble Fellow
Covarrubias, Ricardo	S	2007	Dalcanton	Gemini Observatory	Magellan Fellow
Stinson, Gregory	S	2007	Quinn	University of Central Lancashire	Jeremiah Horrocks Research Fellow
Yoachim, Peter	S	2007	Dalcanton	University of Texas	Harlan J. Smith Fellow
Bochanski, John	S	2008	Hawley	MIT	Research Assoc.
Brooks, Alyson	S	2008	Governato	CalTech	Sherman Fairchild Prize Fellow
Claire, Mark	S	2008	Sullivan/Catling	University of Washington	NASA/NAI Fellow
Fraser, Oliver	S	2008	Hawley	Waldorf School	Teaching Faculty

Walkowicz, Lucianne	S	2008	Hawley	University of California, Berkeley	Research Assoc.
Gogarten, Stephanie	S	2009	Dalcanton	University of Washington (Biostatistics)	Research Scientist
Plotkin, Richard	S	2009	Anderson	Astronomical Institute Amsterdam	Research Assoc.
Cowan, Nicholas	A	2009	Agol	Northwestern University	CIERA Fellow
Kaib, Nathan	W	2010	Quinn	Queen's University	CITA Fellow
Haggard, Daryl	S	2010	Anderson	Northwestern University	CIERA Fellow
Kimball, Amy	S	2010	Ivezic	National Radio Astronomy Observatory	Research Assoc.
Roskar, Rok	S	2010	Quinn	University of Zurich	Research Assoc.
Sesar, Branimir	S	2010	Ivezic	CalTech	Research Assoc.
Solontoi, Michael	S	2010	Ivezic	Adler Planetarium	Research Assoc.

E6. Graduate Student Statistical Summary

Astronomy

C	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Autumn Quarter Enrollment										
Enrollment History										
Total	25	23	23	26	26	25	29	27	26	31
Full-Time	22	22	23	25	26	24	29	26	26	29
Part-Time	3	1	0	1	0	1	0	1	0	2
Male	19	18	17	17	19	17	18	16	14	14
Female	6	5	6	9	7	8	11	11	12	17
Ethnic Minority	3	4	3	3	2	3	1	0	2	4
International	2	1	1	1	4	4	5	4	4	4
Wash. Resident	14	16	16	16	15	15	11	11	7	7
Non-Resident	11	7	7	10	11	10	18	16	19	24
New Student Enrollment	6	4	5	5	4	3	8	2	5	8
Continuing	19	19	18	21	22	22	21	25	21	23
Annual Application (Sum-Spr qtrs)	64	68	79	107	90	86	89	107	110	
Autumn Quarter Application	64	68	79	107	90	86	89	107	110	90
Autumn Quarter Denials	40	49	53	84	77	77	72	88	83	69
Autumn Quarter Offers	22	19	26	21	13	9	17	18	26	21
Autumn Quarter Percentages										
% Denied (of Applications)	62.5%	72.1%	67.1%	78.5%	85.6%	89.5%	80.9%	82.2%	75.5%	76.7%
% Offers (of Applications)	34.4%	27.9%	32.9%	19.6%	14.4%	10.5%	19.1%	16.8%	23.6%	23.3%
% New Enrollees (of Apps)	9.4%	5.9%	6.3%	4.7%	4.4%	3.5%	9.0%	1.9%	4.5%	8.9%
% New Enrollees (of Offers)	27.3%	21.1%	19.2%	23.8%	30.8%	33.3%	47.1%	11.1%	19.2%	38.1%
Autumn Minority Admissions										
Applications	8	4	9	8	6	12	13	13	13	12
Denials	3	3	7	8	5	11	12	9	9	9
Offers	5	1	2	0	1	1	1	4	4	3
Autumn International Admissions										
Applications	14	15	12	19	11	12	13	6	22	11
Denials	11	14	11	17	7	12	11	6	18	7
Offers	1	1	1	1	4	0	2	0	4	4
Applicant Average GPA										
Denied	3.46	3.42	3.47	3.45	3.55	3.48	3.46	3.46	3.53	3.50
Accepted But Not Enrolled	3.73	3.41	3.75	3.72	3.75	3.83	3.66	3.84	3.69	3.78
Accepted and Enrolled	3.68	3.41	3.65	3.80	3.59	3.71	3.71	3.76	3.51	3.79
Applicant Average GRE Scores										
Denied										
Verbal Score	568	583	552	563	581	562	558	543	544	560
Quantitative Score	730	730	723	741	738	740	732	725	747	733
Analytical Score	678	688	670	652	651	700	599		650	
Accepted But Not Enrolled										
Verbal Score	632	604	640	641	597	644	613	639	595	590
Quantitative Score	764	772	773	770	762	754	769	762	755	772
Analytical Scor	713	738	761	755	800	520				
Accepted and Enrolled										
Verbal Score	582	575	624	586	573	637	599	565	578	551
Quantitative Score	760	758	744	756	743	773	759	760	724	759
Analytical Score	665	645	756	774	800	520				
Annual Degrees Awarded (Sum-Spr qtrs)										
Masters:	3	4	5		5	6	6	3	5	
Doctoral:	6	2	3	3	4	2	2	3	6	
Ph.D. Candidates:	5	3	3	4	4	3	4	8	2	
Autumn Quarter Financial Support										
Teaching Assistants	10	10	8	13	12	7	15	13	8	8
Research Assistant	15	11	15	11	13	13	15	14	18	23
Fellowships	0	4	8	5	5	5	1	6	3	5
Traineeships	0	0	0	0	1	1	0	0	0	1

E7. Astronomy Courses Offered 2000 – 2010

Course	Number of sections taught
101: Introduction to Astronomy[1]	78
102: Introduction to Astronomy (calculus)	8
115: Introduction to Astrobiology	7
150: The Planets[1]	53
190: Modern Topics in Astronomy for Non-Science Majors[2]	20
192: Pre-MAP seminar	5
211: The Universe and Change	9
270: Public Outreach in Astronomy	5
300: Intro to Astronomical Computing	5
301: Astronomy for Scientists and Engineers	15
313: Science in Civilization – Physics and Astrophysics since 1850	8
321: The Solar System	11
322: The Contents of Our Galaxy	11
323: Extragalactic Astronomy and Cosmology	11
400: Undergraduate Research Seminar	7
421: Stellar Observations and Theory	9
422: Interstellar Material[3]	1
423: High-Energy Astrophysics	10
425: Cosmology	5
427: Numerical Methods in Astrophysics	2
480: Introduction to Astronomical Data Analysis	11
481: Introduction to Astronomical Observation	9
482: Writing Scientific Papers	6
497: Topics in Current Astronomy[4]	16
500: Practical Methods for Teaching Astronomy	11
507: Physical Foundations of Astrophysics I	5
508: Physical Foundations of Astrophysics II	5
509: Physical Foundations of Astrophysics III	4
510: Nuclear Astrophyiscs	3
511: Galactic Structure	3
512: Extragalactic Astronomy	5
513: Cosmology and Particle Astrophysics	5
519: Radiative Processes in Astrophysics	3
521: Stellar Atmopsheres	6
531: Stellar Interiors	5
541: Interstellar Matter	6
555: Planetary Atmospheres	1
557: Origin of the Solar System	7
561: High Energy Astrophysics	5
575: Journal Club Seminar	30
576: Astronomy Colloquium	30
581: Techniques in Optical Astronomy	6
597: Topics in Observational Astrophysics[5]	11
598: Topics in Theoretical Astrophysics[6]	1
599: Advanced Astronomy Seminar[7]	23

[1] Includes evening sections.

[2] Topics include: Extrasolar Planets, Cosmology, Introduction to Observational Astronomy, Our Place in the Cosmos and Lunar/Martian Exploration

[3] Course has been offered in past 10 years but is no longer part of the curriculum.

[4] Topics include: Extrasolar Planets, IDL Programming and Radio Astronomy

[5] Topics include: Case Studies in the History of Astrobiology, Order of Magnitude Seminar and Statistical Methods in Astrophysics.

[6] Topic: Astronomy in SDSS

[7] Course is most often taught as the Astrobiology Seminar

E8. Student Credit Hours

	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
ASTR 101	5755	4535	6200	4355	4405	4050	3432	4200	3865	3905	4100
150	4060	3455	5230	4355	3785	3580	3725	3685	3885	3860	3975
100-200	114	160	66	0	300	393	385	495	750	1065	1011
300-400	478	522	876	656	814	561	557	625	683	817	764
499	109	88	93	91	69	91	112	105	142	102	123
500	289	283	270	341	331	268	368	412	370	347	467
600	229	227	149	171	164	271	242	372	247	220	144
800	283	217	192	211	271	299	326	238	327	358	423
Total	**11317**	**9487**	**13076**	**10160**	**10139**	**9513**	**9147**	**10132**	**10269**	**10674**	**11007**

Years are from Autumn – Summer quarter

E9. NRC Review of the Astronomy Graduate Programs

In late September of 2010, the NRC rankings of doctorate programs were released http://www.nap.edu/rdp, and the following is a preliminary summary of our understanding of these for the UW Astronomy Department. By the overall S=Survey ranking we are likely within the top ten US astronomy programs. According to the NRC's broad 5-95 percentile range we are S-ranked between 4th and 11th among 33 programs studied; five astronomy programs score higher on the S-ranking than UW (and it is the same 5 programs in both the 5th and 95th percentile ratings for the S-rankings): Princeton, Caltech, Penn State, UC Berkeley, and University of Chicago. Under the overall R-rankings (which we understand may tend to favor larger programs), the NRC's ranking for UW astronomy is between 8th-24th for the 5th to 95th percentile range; the broad range encompassed for the R-ranking appears to provide less useful direct information on our program.

Two other main summary measures of quality (which we understand are also S-based), however, again seem to confirm our ranking within the top ten: In Research Activity, Student Support and Outcomes, our program ranks between 4th and 13th, and 1st to 14th, respectively by the NRC's preferred 5-95 percentile range. In fact, the only S-based summary measure where we rank in the mid-range (NRC quoted range of 13th to 26th) is on Diversity of Environment, at the time of the survey. Initially, we were surprised by this, as our past-year percentages of women (underrepresented in astronomy) among graduate students and faculty were at near-record highs of 52% and 33%, respectively. It is the case that our percentages were lower at the time of the NRC survey, then at 32% female graduate students and 20% female faculty; nonetheless, the latter already ranked us 6th in female faculty percentage among astronomy programs in 2006, according to the NRC. We speculate then that our modest ranking on Diversity may plausibly reflect a strong weighting of the NRC Diversity measure toward minority populations. In the particular year of the NRC survey, we had no minority faculty, and only ~5% minority graduate students (unusually low, versus our more typical 9-18%). Our current program includes 1 minority adjunct professor and 1 minority affiliate professor, and 10% minority graduate students; along with our expanding percentages of women faculty and students, we thus infer we might rank higher on the NRC's Diversity measure now.

A few specific other highlights of our strengths that appear to have contributed to our overall high ranking under most of the S-measures include at least the following: On the NRC measure of average graduate student completion ratio in 6 years or less, we scored at 3rd highest (70%) among all astronomy programs. We tied for 8th in the percent placement of students into academic positions. Reflecting the high quality of research in our program, we ranked 4th in both publications per allocated faculty member, and average number of citations per publication. Thus, by multiple numeric and most S-based summary measures emphasizing quality in the NRC survey, we thus generally appear to be within the top ten astronomy departments nationwide.

Appendix F : Post-doc to Research Faculty Policy

Post-doc to Research Faculty Policy
Department of Astronomy

Spring 2008

Committee:
Tom Quinn (chair)
Scott Anderson
Woody Sullivan

Purpose:

Research Faculty are substantial contributors to the scientific and educational missions of the Astronomy department. Furthermore, they do so while receiving very little direct funding from the University. We wish to promote the welfare of these individuals and continue the productivity of our department in research, education, and service to which they contribute. To this end, we wish to insure that those promoted to Research Faculty positions are likely to be successful on such a career path and, given the status of Research Faculty as full voting members (University Handbook Section 21-32), have a vision compatible with the long term goals of the department. Furthermore, we wish to establish expectations for those seeking to move into such a position.

Policies for appointment to Research Assistant Professor:

Qualifications for Research Assistant Professor include actual and potential scientific leadership. This is demonstrated by highly cited publications, mentoring of more junior scientists, and other leadership roles in the scientific community. Note that these qualifications are similar (with the exception of an instructional component) to those of state-funded tenure-track faculty. Of particular importance to the research position is the ability to secure resources for performing science. It is expected that a person qualified for the Research Assistant Professor would compete favorably in a national search.

Therefore, if a person currently appointed as a Research Associate wishes to be considered for promotion to Research Assistant Professor, the faculty must be given notice at least one year before their termination date to evaluate their record with regards to the above.

If the candidate clearly meets and exceeds the qualifications above, then following a national search as per University regulations a promotion to Research Assistant Professor may be recommended to the Dean.

If the candidate shows great potential, but has not had the opportunity to fully demonstrate their qualifications then the faculty shall recommend that they be appointed to the position of Research

Scientist for a period of three years contingent on funding and satisfactory performance according their supervisor. The faculty shall annually petition the Dean to give the candidate Principal Investigator status. After a period of less than two years, the faculty shall again review the candidate's qualifications, and make a final decision as to making a Research Faculty position available. Following a successful National search following University regulations, a recommendation for appointment to Research Faculty may be made to the Dean.

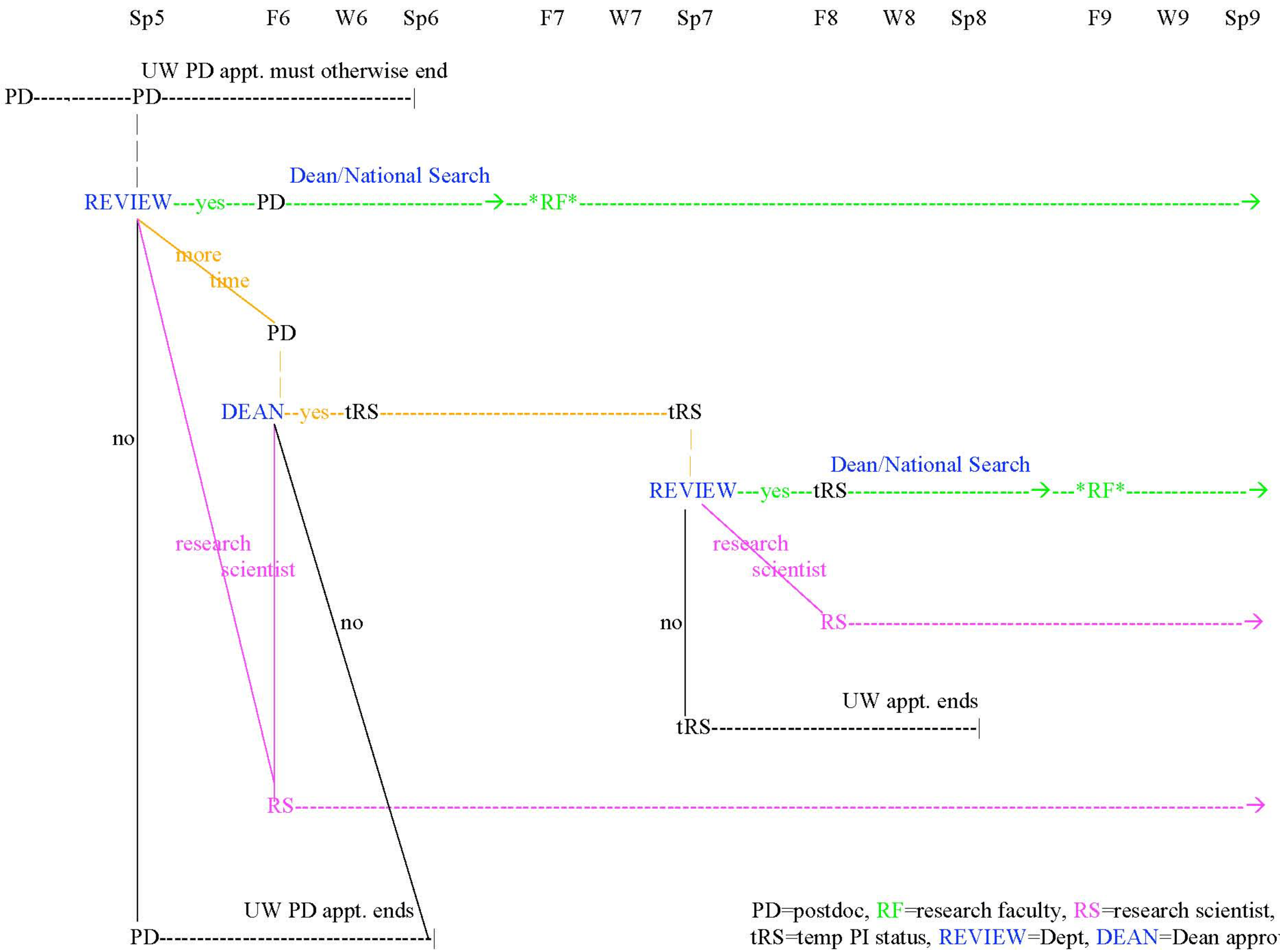
The possible paths for a postdoc wishing to continue as Research Faculty are summarized in the attached chart.

The following statement shall be distributed to postdocs (Research Associates):

The Research associate position is a junior academic rank which has a maximum term of three years, and can be renewed for a maximum of six years (Faculty Code Section 24-34.B.4). Most Research associates will likely move on to positions at other institutions no later than the end of that 6th year. Any further employment in an academic position at the University of Washington requires being promoted to the rank of Research Assistant Professor. Qualifications for Research Assistant Professor include actual and potential scientific leadership. This is demonstrated by highly cited publications, mentoring of more junior scientists, securing of resources (e.g. external funding, research grants) to perform your science, and other leadership roles in the scientific community. Continuation as a Research Assistant Professor also depends on continued funding at least at 50% as specified in Faculty Code Section 24-41.J. Research faculty are expected to participate in the scientific direction of the Astronomy Department. Promotion to the rank of Research Assistant Professor is decided upon by the Astronomy Faculty as a whole. A person desirous of this promotion should make their intent known to their supervisor at least one year before their termination date to give the Faculty and the Dean time to consider their case.

Continued employment beyond six years at the University of Washington in a research position is also possible as a Research Scientist. This is a non-academic appointment; therefore, mentoring and participation in faculty meetings is not expected, and Principle Investigator status on grants is not permitted without special dispensation.

It is recognized that Research Associates who have the potential for scientific leadership may not have an opportunity to express their leadership abilities in their current position. A particular issue is that Research Associates do not have Principle Investigator status, so the opportunity to secure resources is limited. If a Research Associate desires consideration for promotion to Research Assistant Professor, and the faculty deems that although they have potential for excelling as a Research Faculty, they have not had the opportunity to demonstrate their abilities, the faculty may appoint them as a Research Scientist for three years, and request the college that they have Principle Investigator status. The faculty will then evaluate their performance after two years with respect to their qualifications for a Research Faculty position.



PD=postdoc, RF=research faculty, RS=research scientist,
tRS=temp PI status, REVIEW=Dept, DEAN=Dean approve tRS

Appendix G : UNDERGRADUATE BIBLIOGRAPHY

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Appendix H : Community Outreach and Additional Education Activities

As outlined in section II.3.5, our department is very active in extending astronomy education to the broader community. Our outreach programs include annual open houses, departmental involvement in high school astronomy programs as well as programs for sight-impaired middle-school students, and high demand (often over-subscribed) public access to both the on-campus Theodor Jacobsen Observatory, and the astronomy department's planetarium. In addition, faculty and graduate students frequently give public talks at venues such as the Pacific Science Center, Museum of Flight, and local amateur astronomy groups.

Departmental involvement with students in middle- and high-schools includes two noteworthy programs. The UW in the High School (UWHS) program offers qualified Washington teachers the opportunity to teach the UW ASTR 101 course in their high schools for UW credits. With initial training and guidance from Professor Emeritus Lutz, over the past five years, the UWHS Astronomy 101 course has thus far been offered by 5 high school teachers serving a total of about 250 students. Approximately 30% of the high school students who take the course later matriculate at the UW. Both the numbers of high schools offering the program and the numbers of students enrolling are expected to grow over the next 10 years as the popularity of offering college courses for credit in a high school setting increases. In another program, Dr. Larson and collaborators are engaged in the development of a formal astronomy curriculum for blind and sight-impaired middle-school students; this is in its final stages as they work with the DO-IT center on campus for student testing and evaluation of the content. When published, the curriculum will be available nationwide.

Public outreach in astronomy is flourishing in the department. In March of 2001, the Jacobsen Observatory (which had been closed to the public for some time) reopened with a repaired and refurbished telescope, thanks to volunteer effort by a member of the Seattle Astronomical Society. A group of undergraduate astronomy students, overseen by Dr. Larson, took charge of the observatory, opening it for public open houses every first and third Wednesday. This outreach program has grown significantly--so much so that now we have more than 20 undergraduate (and often some middle- and high-school) volunteers during most quarters and consistently exceed 100 visitors each month. For the close approach of Mars a few years ago, we estimate that about 900 visitors came on a single night. Groups we serve include Scout troops, home-schoolers, local student astronomy clubs, community college classes, campus freshman interest groups, and families.

Our planetarium has similarly seen striking expansion in its educational outreach programs in recent years. Whereas a decade ago, it was used primarily for the introductory service courses (ASTR 101, 150) for about 4-5 days each quarter, the planetarium now opens its doors every Friday to local K-12 school groups. Organized and run by graduate students, this program has become enormously popular with the public; for example, almost two dozen school groups attended presentations during Spring Quarter, 2010 alone. Topics cover the full range of astronomical concepts and research, and presentations can be tailored to teacher requests, with pre- and post-exercises and activities available to teachers on-line. Thanks to support from Microsoft, the Dean's office, Professor Connolly, and graduate student Philip Rosenfield, the planetarium is being upgraded to become fully digital – one of only a handful of planetaria in the nation (e.g., along with Adler and Hayden) equipped with the sophisticated Microsoft WorldWide Telescope software.

Finally, we note that each Spring, a substantial fraction of the department participates in our public open house. Organized by graduate students, these open houses include talks, demonstrations, planetarium shows, tours, activities for a range of ages, and small telescope demonstrations by the Seattle Astronomical Society. During 2009, the International Year of Astronomy (IYA), the department further hosted a series of visits and talks by renowned astronomers and astrobiologists, and held extra open houses and star parties. The IYA celebrations marked a banner-year for our recent departmental efforts: we estimate that the combination of our coordinated astronomy outreach programs engaged nearly 4,000 members of the general public.

Appendix I : Center for Computational Origins

Over the next ten years, astrophysicists will build new telescopes and conduct new experiments that could lead to discoveries of Earth-like planets, an understanding of the nature of dark energy, and many other breakthroughs in our understanding of the universe. Previous breakthroughs in science and technology have enabled the collection of vast amounts of data about the universe. Curiously, this boon to science poses a major obstacle to future achievement in astrophysics: analyzing such large amounts of data can take years, and we are not keeping up with the new data produced every day by telescope surveys. The Center for Computational Origins at the University of Washington (UW) brings together researchers from multiple disciplines to devise solutions for better interacting with data, thereby providing other researchers throughout the world the resources to move from research question to answer in a much shorter time than has been previously possible.

A New Era of Discovery: Challenges and Opportunities

Within the next decade astrophysicists expect to discover Earth-like planets around nearby stars, characterize the nature of the dark energy that drives our accelerating universe, identify the most energetic events within the universe, and detect the dark-matter particles that make up over 75 percent of the matter within the universe. To accomplish these fundamental objectives astrophysicists are designing and building new telescopes that will map the sky and new experiments that will measure the composition of the universe. These surveys will detect billions of stars and galaxies reaching back to a few million years after the Big Bang, collect hundreds of petabytes of images (exceeding all of the written information collected throughout the history of mankind), and map the universe at over 30 different wavelengths.

This new generation of astrophysical experiments presents great opportunities as well as fundamental challenges for astronomy in the 21st century. Telescopes generate an enormous amount of data because the signatures we need to extract are extremely small. Scientists can easily collect and process the data because experiments are designed to process and store data at the rate at which they are generated. The real difficulty arises when scientists try to analyze the collected data as a whole. Extracting complex signatures that describe the nature of dark energy or the detection of a planet orbiting a nearby star, requires advanced analysis techniques that often scale with the square or cube of the number of data points. Due to the richness of the scientific data (with data sets of billions of sources) provided by telescope surveys, the amount of time it takes between developing a question and discovering an answer can take years. Our analyses need to be thousands of times faster than current approaches if we hope to keep up with the data. In an era of precision astrophysics, our inability to interact with these massive data sets will be the ultimate bottleneck in advancing our research.

Research questions are broad and complex, needing a detailed understanding of the underlying physical properties of the data as well as their statistical and systematic uncertainties. When analysis times are reduced to hours or days as opposed to weeks or years we do not just increase efficiency, we create opportunities for new questions to be asked. For example, UW student Jake Vanderplas developed a new way to estimate the three-dimensional distribution of dark matter in the universe that is two orders of magnitude faster than previous approaches. This means that we can use data from the Large Synoptic Survey Telescope to study the evolution of mass within the universe in detail because it takes only tens of hours rather than years to process the data.

The Center for Computational Origins: Making Data Usable

The challenge of managing and interacting with data faces many fields and companies. The Large Synoptic Survey Telescope will produce about 30 terabytes of data each night. Compare this to Facebook, which uses more than 1 petabyte of storage space to manage users' photos, and to Google, which processes more than 20 petabytes of data a day. The success of Google, Facebook, Microsoft, Yahoo, and other companies depends on an ability to manipulate massive amounts of data in many different ways. These companies develop systems that enable their researchers to try out new ideas without needing to know all of the details about how the data are stored or how the computing resources are distributed. In addition to techniques for quick access to large data, companies such as Google produce new ways of usefully combining large datasets. To facilitate the scientific breakthroughs of the 21st century, we need to develop new ways of thinking about data. The Center for Computational Origins will focus on the challenge of working with large data sets. It will create an environment where scientists from varied disciplines can combine their expertise and creativity to inspire new ways to analyze mountains of data and develop algorithms that will enable the astrophysics and cosmology community to undertake the science to understand how the universe formed. The Center will be like Google, Microsoft, and Yahoo in that it will enable scientists to study the universe without having to address the engineering of how to work with massive data sets.

Why the University of Washington?

The UW is a unique place for this research to occur because our researchers work at the interface of massive data with cutting-edge science. At the UW there is expertise across a broad range of areas including large survey datasets, computational astrophysics, particle phenomenology, and experimental astrophysics. Also, there is a strong history of innovative cross-disciplinary research ranging from the Astrobiology program to collaborations with Computer Science in scalable algorithms, and a history of partnering with technology companies, such as Google and Microsoft, to tackle data challenges.

The UW is one of four founding institutions for the Large Synoptic Survey Telescope (LSST), which has recently been endorsed by the National Research Council. LSST will be built in northern Chile and will photograph the visible Southern Hemisphere sky every three nights. University of Washington scientists have also played key roles in the Sloan Digital Sky Survey, which has generated 1.3 million astronomical images. The UW has also won grants from the National Science Foundation to use cloud computing to examine and interact with large astronomical data sets.

Affiliated Faculty

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