Astronomy Research – Strategic Planning Vision 2015

Astronomy is entering an amazing era of giant new telescopes able to probe to the very limits of the visible universe, and huge national surveys to explore the entire sky, generating exabytes of data. UMass is poised with computing expertise to mine this data and a unique telescope to follow up on these surveys to make landmark discoveries for the next decade .

Astronomy at UMass is a small department, yet it has a very successful research program. Our faculty are highly successful in obtaining observing time with the major observatories on the ground and in space, and we have a highly-regarded theoretical astrophysics group, who carry out forefront research using high-performance computing (HPC). Our success has come from focusing on research on the origins and evolution of galaxies and of the universe. These themes combine our expertise in millimeter-wavelength astronomy, formerly with the Five College Radio Astronomy Observatory and now the Large Millimeter Telescope (LMT), our theoretical studies, and wide variety of observing programs using national and international facilities.

The decision to build the department around these themes was made in the 1990s as work on the LMT began, and it coincides well with some of the highest priorities identified by both NSF and NASA over the last decade. Our specialization in cosmic origins offers some excellent opportunities for the department in the future. We see both the LMT and HPC as essential links to that future. While federal funding for operating university-based telescopes has become extremely difficult to obtain, the LMT provides us with a unique resource for leveraging time at national and international observatories, which makes our faculty more competitive for other funding streams.

Furthermore, HPC is critical for analyzing and interpreting LMT data, carrying out theoretical simulations, and analyzing the major new astronomical data sets being created. UMass was a pioneer in creating and analyzing the all-sky 2MASS database, and one of the major national initiatives is to conduct a very deep all-sky survey (the Large Synoptic Suvey Telescope, or LSST) whose analysis and "data mining" will rely on specialized HPC techniques, some of which have been pioneered by UMass astronomers. Most of the HPC work in the department has relied on a local computing cluster; it could be carried out at the new green computing facility in Holyoke (MGHPCC), although moving away from a local facility does present challenges. Again, the kinds of HPC research our faculty will carry out should make us very competitive for grant funding.

Opportunities for individual investigator grants from NSF and NASA are shrinking as national projects take up a growing share of the total. We have remained competitive, but to remain so for future grants it is critical that we can demonstrate that we are well-supported by resources like the LMT and HPC. We see a potential to build closer links between our LMT and HPC efforts perhaps as a center for cosmic origins and data analysis. This might open up opportunities for funding through private foundations (such as Kavli or Simons).

Building for Success

We have an opportunity to move into the top tier of astronomy programs nationally. In our examination of other Astronomy Departments, both in our AQAD in 2011 and through our graduate program review in 2013, it is clear that our faculty size is small relative to other successful

programs, but we have remained competitive because of our strong observational and theoretical research programs. In addition to a larger faculty size, these other institutions, all public land-grant institutions, have substantial institutional commitments to a major telescope— the astronomer's research laboratory.

It is clear that a firm foundation for the LMT is crucial to maintaining a competitive program, and we need the university to take a very active role in helping to finalize the placeholder agreements under which the LMT is currently operating. Members of the department, the state and federal government, and UMass have worked very hard to raise about $50 million toward the building of this marvelous telescope, but for lack of operational funding we may have very little say over the future of the observatory. We recognize that building a broader collaboration is an important part of this plan, but this needs to be done wisely so that we are working cooperatively with our Mexican partners to have the best opportunity of securing external resources. Recent progress is promising, and the effort will need to be sustained.

Moving our existing computer cluster to join the MGHPCC has been investigated, but it is expensive, no support has been offered to facilitate such a move, and it is not clearly the right direction for HPC in astronomy. We have unique strengths in HPC such as data mining and sophisticated statistical analysis that fit well with the University's goals to be an investment of choice. While astronomical computing may seem far-removed from practical uses, in fact, the techniques astronomers use and develop are at the forefront of the field, and the techniques are broadly applicable. Graduates of our program have been sought out by Google, Amazon, and financial analysis companies, for example.

Identifying resources to take advantage of these opportunities is challenging. Over the coming decade, we can anticipate approximately 4 faculty retirements based on our demographics. These faculty are all very actively contributing to various aspects of our program, so it is not clear that we will make gains by replacement hires in other areas. We are understaffed, both in our office and in support of computing (as highlighted by our AQAD reviewers), and our general operating funds have never covered even our basic expenses such as phones, copying and office supplies. With an overall faculty size that is so small, we are already heavily tasked with teaching and mandatory service requirements. Therefore, any conversion of faculty lines to other purposes would increase the burden on our faculty, decreasing their research productivity. In the past our retiring faculty have often remained engaged in the department through teaching and research at a modest cost in space and salary, and we hope this will continue in the future. This might provide a means of spreading some of the load on the rest of our faculty, with some small budgetary gains.

We have added revenue in recent years through online teaching, which we have used to counterbalance a decline in grant support, primarily in maintaining support for our graduate students in years where grant support has been inadequate. Many faculty members have directed much of their RTF funding to graduate student support in an effort to maintain continuous support for our students as well. We may be able to expand our online offerings, but we suspect we have already saturated our local market of students (who are looking for an online option to complete their physical sciences general-education requirement), so we would have to move into a more general-interest market whose likelihood of enrolling is not at all clear to us.

We believe there may be some potential for offering a master's or certificate program that would be of interest for data mining or other computational skills. We are also aware of some students who have earned a bachelor's degree and are looking for an opportunity to improve their skills in order to go on to graduate school in astronomy (including some students from the Five Colleges). Both of these would require collaboration with other departments—Computer Science and Physics—and Astronomy's role and resulting revenue might be a relatively small fraction of the total. We are unsure of the size of the audience for these degrees, but it is something we will explore.

To remain attractive for future faculty and student candidates, we need to provide much better support for our basic computing and network infrastructure. This has been a continuing problem for the department over its 15 years, with commitments for support being unreliable at the College and Provost level. Access to basic computing and network resources has been subsidized by taxes on individual investigator grants, and with declines in grants, the situation has approached a crisis level. To make the situation even worse, Human Resources has refused to classify the job at a level of competence needed to hire a candidate with the necessary computing and networking skills. This affects our colleagues in Physics as well, as one of the critical core courses for both physics and astronomy students is currently subsidized by grant taxation. University efforts to raise the level of basic computing and network access are critical for making UMass an attractive destination.

Long-term Success

Beyond the LMT and HPC, there are other directions that we might grow in the future. In examining our peers and departments we aspire to compete with, we note several factors that would allow us to become competitive for other major research and grant opportunities.

One of the things we note is that all the most successful Astronomy Departments around the country have access to large optical telescopes. Often this is a small fraction of the total time available purchased on a very large instrument. Guaranteed access to one of these major telescopes is costly, but it is extremely attractive to faculty and students, and it provides greater competitiveness for grant applications. The LMT remains unique, and there are many large optical telescope projects, so there may be a possibility of "trading" some LMT time once it is fully functional and we have established a strong operating agreement with our partners. The combination of access to both would give UMass some remarkable opportunities for future research.

We also recognize that most other Astronomy Departments cover a broader range of research areas in astronomy. Given our department's size, we believe our current research focus has been the right choice over the last two decades, but there are other emerging areas of exciting research. One of these is Planetary and Exoplanetary Sciences, which we might carry out jointly with Geosciences. This is another of the major areas of future research identified by NSF and NASA, and funding opportunities are very strong. Our partner astronomy departments in the Five Colleges have some strength in these fields, and we might be able to build upon that, although building a sustainable group in this area at UMass would require major new investments.

Astronomy Strategic Planning 2015 – The Graduate Program

To examine our graduate program, we used information gathered by the university as well as more detailed information we have from our courses and interactions with our students. In addition, our Graduate Program Director created a Moodle site for our students to design their own survey, where they could both create and answer questions anonymously to help us get more insight into their own experiences. The survey contained 35 questions about the program. 90% of the students participated and provided thoughtful and often very detailed comments. All these sources have helped to inform this report.

Right-Sizing the Program

The single most important issue for our graduate program is the number of students we can support. History shows that we do a very good job of preparing our graduate students to be competitive for academic and research careers, but supporting all of our students is becoming challenging in the current funding climate. We are now admitting smaller classes than in the past, aiming for just 2 or 3 new students per year, and striving for a steady-state graduate student population of 14-16 students (down from our current population of 20).

There are many ramifications of admitting such a small class each year that drives us to reevaluate several aspects of our program. The challenges we face include:

1. Small number statistics make it very difficult to reliably achieve our targeted number of incoming students. An excessive number of acceptances over our expectations in one year may force us to admit no new students in the next year. This affects our teaching schedules and the availability of students at different stages for research projects.
2. Even with consistent admissions we may not be able to offer courses every year for such a small number of students. This would lead to our offering courses in an order that may not be optimal for learning.
3. If there is too small a pool of available students, when new grant funding is awarded, it is possible that none of them will be suitable or at the right stage to join the research project.
4. Small incoming classes could affect the camaraderie and morale of our students, perhaps leading to retention issues.

We have considered an alternative strategy of admitting students only in alternate years to alleviate some of these issues. This is an interesting idea, but the majority of faculty feel this approach would be a mistake. We would miss out on at least half of the strongest students who want to come to UMass for astronomy, and we would be digging down into weaker students to make a larger class every other year. We also think it would create a negative perception for applicants in years when we were accepting applications. This has been demonstrated by a drop in applications in previous years following years when we accepted few or no new students.

We are currently conducting meetings about how we might re-sequence or redesign the three graduate astronomy courses that we currently teach every year so that they were offered in alternate years. (We have also looked at whether it might be possible to combine some senior-level

topics courses with our graduate courses, but we do not believe this approach fits the needs of either our undergraduate or graduate students.)

Coursework and Training: Challenges and Opportunities

Advanced physics is extremely important for a good understanding of astrophysics. Unfortunately, even sub-disciplines in physics are broad and the approach taken in many graduate physics classes is not always very relevant for the kinds of research out students are likely to do. Because of this issue we reduced our physics requirements a decade ago by creating an astronomy course that covered the relevant physics. We now find that we need to take this step yet again but doing this would add to our graduate teaching load at a time when we are trying to reduce it.

We are now investigating how our teaching approach may change as a result of having smaller student-faculty ratios in order to dramatically better-serve our graduate students. One interesting idea is to offer a very intensive problem-solving course for our incoming students—perhaps taught by several different faculty - to introduce students to the kinds of problems investigated in different areas of astronomy. Such a focused nearly one-on-one course could help get our students started in their graduate studies and actually be a selling point for having a small incoming class. The pedagogical approach might also provide an opportunity to directly help our students improve their synthesis of coursework across topics.

Time to Degree

One of our concerns, also evident in the Graduate Program Review, is that the time to degree for our students is longer than we think is appropriate. We would like to see our students finish in 6 years, while the median time to degree (TTD) is currently closer to 7 years. It was interesting to see that our graduate students independently identified this as an issue, although they perceived it mostly as a problem with themselves as opposed to our program as a whole. An additional effect of a long TTD is that it increases the overall need for student support, limiting our incoming class.

We are currently examining whether we can speed up the process by having our students take more of their coursework earlier on, and by redesigning their research experience. Currently we require two research projects before we make a decision for admission to candidacy late in the third year. While this program design has many positive aspects, it tends to push off the start on a dissertation project longer than is consistent with finishing in a total of 6 years. This timing also creates situations in which a student *not* admitted to candidacy cannot apply to other programs for nearly a year. It also creates mid-semester funding complications when a student moves off of a grant-supported project and needs other support. We are now looking for approaches that might allow students to finish sooner and where we can make earlier decisions about their continuation in the program. This would be better both for the student and for incoming class size issues.

Most faculty and students believe that conducting two research projects prior to beginning dissertation work is a positive experience. However, relatively few of these projects reach completion in a published paper; and instead most of the students continue on with their second project as the start of their dissertation. Most students also do not start on their research project the first semester (as expected by our current curriculum), but instead focus on coursework. The

graduate students have indicated that it is therefore somewhat discouraging that this first semester is mostly devoted to advanced physics and computational techniques, instead of coursework more clearly linked to astronomy. We are examining a range of possibilities to address these issues.

Expanding the Graduate Program

While our primary focus has been on practical approaches to reducing the size of our graduate program to respond to declining federal funding, there are some possible alternatives that might allow our program to grow. Our graduate program offers excellent instruction and opportunities for research, and our graduates have good career potential if not necessarily in academics.

The most obvious way to take advantage of the strengths of our existing program would be to build stronger support for our students through additional assistantships. We recognize that the University budget is tight, but we note that when we examined seven peer institutions in our AQAD study (all public land-grant astronomy departments), all but one offered more TAs and fellowships to their students than we do. We believe our TA allotment has shrunk to the point where it is a limiting factor on the quality of our undergraduate course offerings. With additional TAs we could improve this and also increase our general-education offerings, so an increase in our TAs is a solid investment for UMass. Beyond the University we are also exploring the creation of an endowment of a graduate student fellowship by a private donor. We are adamant that finding sources of additional TA and/or fellowship support is very important for our program to thrive.

We have also explored what various master's degree programs in data analysis or astrophysics preparation might mean for our program. Besides offering new revenue possibilities, the additional students would help support us in offering our graduate courses more regularly. To make such programs viable it is important that they not require us to offer new courses, but there is room for some adaptation of our existing courses for a broader clientele. We note that graduate students outside of astronomy regularly take advantage of our graduate computational techniques course.

More speculatively, some faculty think that a terminal master's degree in Astronomy focused on our existing graduate curriculum might be of interest to some overseas students who have access to funding support (e.g. China). This support may not be at the level of paying the full tuition and fees of a professional master's degree student, but perhaps it would help the "balance sheet" of our graduate program if a suitable level of expenses could be negotiated. One further benefit of students in such a program is that we could identify the strongest and invite them to go on to a Ph.D.

Finally, graduate students and faculty have noted that we do not often present opportunities for our students to learn about or consider alternatives to a standard research career. Indeed, relatively few of our students go on in careers like our own. Unfortunately, there is also a perception among the students that attention to alternative careers may be perceived by some faculty as a lack of commitment to success. This problem of perception is being actively addressed by strong encouragement and participation by the faculty in programs designed to support alternative careers. We are now planning a regular annual seminar in the department where we bring in past students who have gone on to careers in finance, teaching and data-analytics, to help advise our current students in how to best prepare for careers outside of academia.