Report of the External Visiting Committee for the Tufts University Physics and Astronomy Department

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Prof. Pulak Dutta, Northwestern University
Prof. Alan Guth, M.I.T.,
Prof. Edward Kearns, Boston University (chair)
Prof. Rosemary Wyse, Johns Hopkins University

Executive Summary

The Tufts Department of Physics and Astronomy is small but with selected strengths that serve as a nucleus for building a department that can be among the very best for its size.

The aging demography and historically low size puts the department at risk for collapsing to a state unsuitable for the standard of undergraduate education that Tufts is offering.

The hiring program proposed by the department is basically sound. The department should grow to a size of at least 19-20. The theme should be building around strengths in cosmology, creating a small core of astronomy/astrophysics faculty, preferably with bridges to cosmology, maintaining particle physics, and rebuilding a contemporary effort in condensed matter physics.

Hiring should continue with no delay for upcoming retirements in the department. The department may temporarily grow larger than the target size of 19-20. A multi-year hiring plan should be made, particularly for the concerted multi-hire effort to establish a strong effort in soft condensed matter physics. The administration should clearly communicate its priorities to the department to facilitate this planning.

Several aspects of undergraduate education are below the standard for a top-rank physics and astronomy program. These include: lack of a ‘majors’ introductory physics sequence for the most well-prepared freshmen. Advanced undergraduate courses should be taught in a consistent sequence every year rather than based on alternating years.

The graduate program size should be tailored to match the proposed growth and rejuvenation of faculty. The standard should be teaching support for the first two years with research support for subsequent years, with the exception of teaching support for theoretical students one semester out of every two or three.

Introduction

The external review committee was charged by Tufts administration to assess the strengths and weaknesses of the Tufts University Physics and Astronomy Department. This was the second in a new series of departmental reviews at Tufts (following one in Anthropology). This review process is consistent with new administrative attitudes at Tufts, particularly the continuing theme of moving Tufts from being a small teaching-oriented college to becoming a premier research university. The committee received various written materials. The committee relied heavily on a departmental self-study, in particular a long-range planning document originally drafted in 2005, updated in January 2007. On April 3-4 the committee had several meetings with students, faculty, and deans, as well as tours of the Science and Technology Center where experimental facilities are located. The committee was received very graciously by all involved and warmly thanked, and we would like to reciprocate with our appreciation of the effort and hospitality that made the visit enjoyable and productive.

Administration and faculty alike identified the overwhelming issue facing the department: the age distribution of current faculty. Whereas two junior faculty have been hired within the last two years, the previous hire was several years before that and was a mid-career transfer. The faculty rolls are dominated by tenured full professors, many nearing retirement. This demographic, coupled with the small number of the physics & astronomy faculty, leaves the future prospects of the department in peril. Therefore, a great deal of committee discussion was spent on this issue. Indeed, the committee wondered: “how did this situation get so far along that it is nearly in an emergency state”? The answer seems to lie in the historical relationship between the department and earlier University administrations, with the conclusion being that the current administration was acting quite differently and was much more supportively than previous ones. This conclusion is supported by the two hires made in the past two years, as well as by statements by the Deans and Provost. The challenge is to now make the best decisions given the current situation, and the committee spent little time dwelling on past practices.

The second important consideration for this review is the small size of this department. The Tufts Physics and Astronomy department is currently 17 faculty, down from a historical level of 19. The department proposes to restore the number of full-time faculty to that number. There are other physics or physics & astronomy departments in the country at that size, but all of the widely recognized top-rank schools are larger[1]. Barring a drastic reconsideration, the future of the Tufts physics & astronomy department must take into account that it will be a small program, and the comments in this report will take this into account. We recommend emphasis on existing core strengths.

Another important consideration is the relationship of the department to the rest of the University. Tufts is a first-rate university for undergraduate education, with a few top

[1] According to the 1995 NRC Physics Department ranking, the 42 universities in the top quartile had an average of 49 faculty per physics department, with only two special cases under 30. The second quartile averaged 32, and the third quartile, where Tufts was ranked near the top, averaged 22.

ranked and highly competitive programs such as International Relations. However, the physical sciences are not at the forefront of the identifying characteristics of the university. The August 2005 Strategic Plan “Tradition and Innovation” offers essentially no encouragement to the physics department. The committee found that the current administration somewhat distances itself from the precise statements of this report, but also must conclude that the priorities of the university are reflected at some level by the emphasis found within the report. Of greatest relevance is whether the proposed growth of 60 additional positions over the next decade will translate into growth of the physics and astronomy department. The committee hopes that all involved realize that a strong School of Arts and Sciences is essential to the goal of a high-quality liberal arts education, and that a strong physics and astronomy department plays an essential role, not just for majors but in exposing the broader student body to the scientific method and problem solving skills.

Undergraduate Education

The Tufts Physics & Astronomy Department plays four essential roles related to the objectives of undergraduate education at Tufts University. First, physics is an essential requirement for a number of majors, particularly engineering and premedical. Second, some Tufts undergraduates seek connections to physics/astrophysics research, even if they are not interested in majoring in physics. Third, a certain number of Tufts undergraduates will elect to major in physics, often with the intent of later pursuing graduate study. Fourth, electives in astronomy are offered and show large enrollments; however other physics electives that could broaden the liberal arts education are only rarely offered, due to the small size of the department.

The committee met with several undergraduate physics majors for lunch. They were bright and enthusiastic. They uniformly commented on the high quality of instruction and good faculty contact as highlights of their experience. The fact that faculty teach discussion sections played a major role in their opinion. Several students were applied physics or engineering physics majors, and others were pure physics or astrophysics majors. One senior was grad school bound with several offers to the best schools in the country. When asked “how did you find your way to majoring in physics at Tufts”, all but one answered that they came to Tufts undecided or expecting to do something else, but later found their way into physics, attracted by the rigor and interest of their introductory courses as well as opportunities for research. Two things are clear: first, this speaks well of the undergraduate program run by the physics & astronomy department, and second, this is not surprising considering the demographic of college students Tufts seeks to attract. Tufts requires strong standardized test scores and high school records for the entering class, but is not positioned to attract the best students who seek to do science. However, good students often find their way into science, and the department should nurture this model. It is unlikely that Tufts will be able to attract the best prospective physics and astronomy majors directly from high school, although there can be some exceptions such as one student we met who was attracted to Tufts thanks to the well-known strength in cosmology.

The committee found one outstanding deficiency, the lack of a separate freshman physics sequence for prospective physics/astrophysics majors. The standard for a top-rank physics department is to offer two semesters of freshman-level calculus-based physics with extra mathematical rigor. This course would emphasize the critical thinking and skills expected of physics/astrophysics majors, as well as expose students to current research that is of interest to young scientists but is less appealing to premeds or engineers who are merely satisfying requirements. This sort of course may increase the number of physics majors although that is not the particular goal of this recommendation. This course would not be required of physics majors, to facilitate late transfers into the major, nor would only physics/astrophysics majors populate it. Advising would direct the very best and most well prepared students from all science, math, and engineering to such a course. A target class size would be 25 or so, small enough that no further division of lab or discussion sections is needed. All of the students in the class, but especially clearly identified physics and astronomy majors, would benefit from learning in an environment with the most highly qualified and motivated cadre. Students we talked to did identify the lack of such courses as a shortcoming and remarked on the discouraging atmosphere in the large prerequisite-oriented introductory courses.

Upper level instruction suffers from the small size of the department. Advanced courses in quantum mechanics, electromagnetism, classical mechanics and statistical physics are offered on a rotating basis. This is atypical of top-rank departments, where a fixed sequence is offered every year although this is correlated with the fact that such departments are consistently much larger. This upper level instructional sequence may be a necessary evil for a department with 5 or so physics and astronomy majors per year. If the faculty grows as outlined in the departmental report and endorsed in this external report, it may be possible to eventually address this and arrive at a fixed sequence. This will result in smaller class sizes, as juniors and seniors no longer merge to form larger enrollments per class.

The department is essentially unable to offer creative elective courses in physics. A few interesting courses such as Nuclear Age, Physics for Humanists, and Music and Color are listed but seem to be offered infrequently. A growth in the department should allow such electives to be offered, at least one every year on a rotating basis, and this would serve the liberal education goals of the university. Offering elective courses will also address the impression that the department does not reach out to the broader Tufts community. In fact, physics is positioned to offer courses related to energy or biomechanics that fit in with university themes such as Civic Engagement and the Life Sciences. The committee feels that a larger department will relieve the pressure on offering the required minimum of instruction and allow faculty, especially new hires, to develop such courses.

The introductory astronomy courses are a notable exception: they are a popular elective with enrollments in the hundreds. At present, the large part of the astronomy course instruction – both elective and for majors – is taught by non-regular faculty; the committee identified this as a significant shortcoming, sub-standard for a top-rank research institution. For the majors, it limits their ability to see astronomy/astrophysics as a real option and for the non-majors it prevents the department from being seen as committed to the broad undergraduate experience. The large enrollment of the elective astronomy courses clearly means that the student body appreciates learning about astronomy, and regular faculty should be hired to support this demand. The astrophysics majors also need more courses, and more faculty would enable this. Finally, more faculty in astronomy will provide more undergraduate research opportunities. At present the students most commonly find mentors at Harvard CfA.

Graduate Program

The graduate program in physics and astronomy at Tufts is small, is focused on a few areas, and is moderately successful. The self-study reported 12 Ph.D. recipients spanning 3 years from 2003 to 2006, a rate of 4 per year. The standardized tests scores of the matriculating students were suitably high. The mean entering class size was not provided, but based on the graduate program size of 30, it is apparent that there is some small but acceptable attrition. Further study by the department to track the history of the matriculating graduate students may prove helpful for future planning. Of those who did graduate, the thesis topics listed were of high quality. The 12 Ph.D. students were advised by 7 faculty, with 7 theoretical topics, and with only one topic in experimental condensed matter physics and the majority in astrophysics/cosmology. On the face of it, it is not obvious how this demographic reflects the activity in the department, but it seems somewhat imbalanced. However, with such small statistics it is impractical to draw a conclusion.

The department proposes to increase the graduate student class size from 30 to 40 in parallel with the proposed expansion and rejuvenation of the department. The committee finds this proposal basically sound, provided there is careful tracking of faculty additions and their research grant success, as stated in the long-range planning document. Besides enhancing the research component of the graduate program, a growth in teaching positions will have a positive effect on undergraduate instruction, particularly the number of laboratory sections.

The committee met with numerous current graduate students and found a lively and happy bunch. The graduate stipend is competitive with Boston area schools. The committee did not see graduate student offices, but the communal desktop computing pointed out was substandard and due for an upgrade. There was concern for the issue of health insurance and student health services; this should be reviewed by the department in consultation with university-wide policies for all of the graduate programs. The committee learned that several of the students were teaching fellows despite being well advanced in their research careers. This indicates a possible mismatch between the number of students and the research grant funding. The department does have access to the Burlingame Graduate Fellowship, secured by Prof. Schnepps 27 years ago, and uses it to good effect to augment graduate support.

The committee feels that the standard for a top-rank research oriented physics department is that experimental graduate students be supported entirely on research funds after they have completed their coursework and advanced to candidacy (occasional exceptions may occur). Theoretical students would be supported by research funds for 1 of every 2 or 3 semesters. The department should make it a goal to reach this level of support, and tailor their admissions program to match.

As with the program of undergraduate instruction, the graduate course schedule is carefully constructed around the inevitable small class sizes. The historical record shows that the requisite core courses are regularly offered and the base of instruction is on par with top-rank graduate programs. However, the graduate program suffers from a dearth of advanced courses, a problem that strikes larger programs as well, although it seems more acute based on recent offerings at Tufts.

It was noted that the presence of other schools in the Boston area provides an opportunity for extending the educational opportunities for graduate students. Tufts University has a formal cross registration program with Boston University, Boston College and others, but it seems to be very rarely taken advantage of. Unfortunately, Tufts does not have a simple commute to Boston University; the most accessible school is Harvard, and although many students collaborate with researchers at the Harvard Smithsonian Center for Astrophysics, it seems there is no formal opportunity for coursework for credit. Because travel is difficult and hard to coordinate with other classes, such opportunities are likely to be sporadic. However, the opportunities are there: last semester a course in LHC physics was taught at Boston University for 3 hours once per week in the evening and was attended by students from MIT and Harvard; whether Tufts students were made aware of this opportunity is unknown, as well as whether B.U. did not pull strongly enough, or whether Tufts advisors did not advocate. The committee has no obvious solution other than urging Tufts faculty to generally strengthen their integration into the Boston area community.

Research

The greatest strength in the department is the well-regarded Tufts Institute of Cosmology. Prof. Vilenkin is a recognized leader in the field. The field of cosmology is currently of great intellectual merit, as this historically theoretical field is benefiting from a wealth of brand new experimental and observational data that are driving exciting advances. The committee endorses the departmental strategy of hires with ties to the Institute of Cosmology.

Despite being named a Department of Physics *and Astronomy*, the quantity and impact of astronomical research is limited. The committee did not meet Prof. Lang, the sole full-time faculty astronomer, who has made very visible contributions in speaking and textbook publication but is not currently as active in research. The committee learned that the visiting and research faculty are in a state of flux and contributing sporadically to the research mission. Overall, the astronomy/astrophysics arm of the department is weak, which represents a missed opportunity when connections to the strong cosmology effort could be built upon. It is clear that the first step is to succeed in the current search for an observational astronomer. Beyond that, the committee recommends that the department incorporate strategic hires in astronomy/astrophysics as part of the theme of building around strengths, where in this case the strength is the related field of cosmology.

The department has a long history of Department of Energy funded research in elementary particle physics. The 2006 funding was $945K including base grants plus supplements plus subcontracts. The group focuses in two areas: neutrino physics and hadron collider physics. These are optimum choices for specialization in experimental particle physics.

The Tufts neutrino group has a distinguished record, having been leaders in the Soudan 2, DONUT, and MINOS experiments. They are now well integrated into the upcoming MINERvA and NOvA experiments. They have recently hired an outstanding assistant professor, Hugh Gallagher. This group is securely established for the moment, but replacements for Schnepps and eventually Mann should be integrated into the rejuvenation plan. Neutrino physics is a strong area of current interest, as identified by the APS Multi-Divisional Study of the Physics of Neutrinos and the National Academies oEPP2010 report. The role of the neutrino in astrophysics has some synergy with the effort in cosmology. Maintaining strength in this area is sensible objective for the department.

The hadron collider group is smaller, consisting of Sliwa and Napier, with some detector R&D by Oliver. Sliwa has played an identifiable role in physics analysis at CDF. The group is now turning to the Atlas experiment at the LHC, one of the great scientific opportunities of the 21st century. A group this small runs the risk of being marginalized and will simply have to rely on concerted effort to have an impact. However, it is likely that the scientific productivity of this effort will be high and provide very good research opportunities for the graduate program.

Theoretical particle physics research at Tufts, offered by a single faculty member (Goldstein), does not sufficiently match or complement the experimental effort. Since experimental particle physics has been identified as a strength of the department, and one that should be maintained, it is logical to also augment the theoretical particle physics effort. This is correlated with the proposed expansion and strengthening of cosmology. It would be advisable to hire a theoretical particle physicist, preferably one who would profit from the excitement expected with LHC operation. Although a steady state of 1-2 particle theorists may seem to be too small, there are several factors that suggest that it could succeed. First, the strong group in cosmology will provide natural colleagues; second, the local activity in particle experiment will be synergistic. If successful, the new faculty member will have interesting and important roles in graduate instruction, thesis readership and so on. Finally, the Boston area has a thriving theoretical community that would provide a natural outlet for the sorts of interactions out of which theoretical ideas emerge. The faculty member would have ready access to the Joint Theory seminar series that rotates between B.U., Harvard, and M.I.T. each Wednesday. Therefore, Tufts has a chance of attracting and keeping a high quality person without facing difficult critical mass issues in starting up. The committee endorses the proposal to include a particle theorist in the growth and rejuvenation plan.

Tufts is not particularly well known in the area of Condensed Matter. In fact, however, it has had a distinguished although small group of people in this area. Unfortunately, it is now an aging group; their last hires were made some years ago and at a senior level. We were impressed with the quality of the experimental facilities and with the level of interaction with other departments. One faculty member from Electrical Engineering has an adjunct appointment in Physics and appears to be an enthusiastic addition to the group. This ameliorates but does not eliminate the prospect of dwindling Condensed Matter activity in this department. Condensed Matter is one of the core areas of Physics and should not be allowed to become sub-critical at Tufts. It is the area of Physics that is best positioned for interdisciplinary and interdepartmental research, and there is very significant potential (not currently well-realized) for strong gains in federal research funding. The department correctly recognizes that the future of Condensed matter lies not in traditional areas (such as electronic transport) but in soft matter, biological physics, etc. Not only the experimental tools developed by physicists, but also the ways physicists approach and solve problems, have the potential to make a huge difference in these interdisciplinary areas.

Facilities

The external review documents drew attention to inadequacies of Robinson Hall. The committee was not given a sufficient tour to remark on this. Although not modern, the building seemed well kept, with video projectors in many classrooms, and the common area in which the committee met with students was sizeable and seemed well used. Robinson Hall is well situated on the campus, close to the central quadrangle. The other main physics building, the Science and Technology Center is distant and seemed isolated from campus foot traffic. This separation also contributes to intellectual separation of the department, isolating some students and faculty from others and inhibiting activities such as seminar attendance. The committee agrees that uniting the department in a single building or at least bringing the experimental labs, theorist offices, central departmental office, and instructional space closer together would have a positive impact on the department. However, the committee also realizes that campus space on Tufts is a difficult issue that can only be addressed by a more specialized planning effort.

The Science and Technology Center has a well-equipped machine shop that seems to have a steady stream of work, particularly for particle experiment. It has contributed to the construction of several neutrino detectors as well as detectors for the LHC. The department and university are to be commended for maintaining this facility with a generous and appropriate subsidy. Such facilities at other universities, even top-rank ones, have fallen by the wayside. This facility is a distinguishing point for the physics department and especially helps Tufts particle physicist make important contributions to experiments and helps attract funding. It also provides a focal point for on-campus research activities that engage students, including non-physics majors.

Faculty Rejuvenation

The most important issue facing the Tufts Physics and Astronomy department is the age profile of the department, with many faculty nearing retirement age. This is coupled with recent shrinkage to a size of 16, a number that stresses the teaching mission. The senior faculty are in many cases active in research, however that is no substitute for the vitality expected with a healthy number of junior faculty. Ideally, the department and university would have made several junior hires over the preceding decade and maintained the historical department size of 19.

In the departmental Long Range Planning document, the first key point was to restore the faculty size to 19. The committee discussed department size at length, and although we arrived at no precise number, 19 or 20 was generally taken to be the minimum healthy size. Therefore, the committee strongly endorses the department's request to hire to a size of at least 19 full-time research-active faculty positions. This will still be a comparatively small physics department among research universities, and is unlikely to dramatically alter subjective rankings. However, the Tufts Physics and Astronomy Department and administration should work together with the goal of making the department the best of its size and being recognized as such. This is consistent with many of the mission statements outlined in the 2005 Tradition and Innovation plan including the university-wide increase in faculty number.

To accomplish the rejuvenation, the committee considered several of the questions asked by the Deans, either of the department or of the committee. "Are there crucial areas not covered or inadequately covered? Are there areas of particular strength? Are there areas in which the department needs to hire in order to keep pace with changing fields? Are there areas of decreasing relevance? Are there emerging subfields that the Department should consider building?" The committee concluded that the rejuvenation plan should be based on replenishing and building around current strengths in cosmology and particle physics, including astrophysics, and further establishing the solid effort in condensed matter physics. Within the broad fields of condensed matter physics, the department has rightly proposed to seek researchers in soft matter and biological physics with an eye towards strengthening ties to medicine and engineering. In fact, these are already areas in which many other departments are expanding, particularly astrophysics and biological physics.

Because of the emergency state of the department, the committee recommends to the administration that further hiring be implemented immediately. The stated policy is that retirements become open positions within the School of Arts and Sciences. There was some sense that senior faculty were delaying retirement due to fear that the department would wither should they not be replaced. If Tufts is to seriously address the state of the Physics and Astronomy Department, we expect that hires will now take on relatively high priority from this pool. The committee believes the priority should be clearly communicated from administration to department to facilitate retirement planning[2]. Furthermore, to establish a large number of new hires, it is anticipated that the department may temporarily grow larger than the final target of 19-20. This will help to establish new curricula with course sequences and advanced offerings as outlined above.

The department broadly outlined a sequence of hires. The plan stems from the recent hires of Gallagher and Blanco-Pillado, which kept the situation from reaching a disastrous condition. Currently, the department is searching for an observational astronomer, an important hire to help fill instructional demand. The committee recognizes the importance of this hire and recommends that it be completed. Next, the department proposes to hire in the area of experimental condensed matter physics, as a first step for their proposed expansion in that area. The committee found general agreement among faculty from all specializations that this was the appropriate next hire. However, to accomplish the objective of a new center of excellence, the current model of one hire at-a-time, rotating between fields, with uncertain administration approval each year, will be insufficient.

The committee recommends that a more detailed plan for CME hiring be established, with a target of at least three new hires over the next three years. The committee endorses the department's proposal that at least one condensed matter theorist be included in this plan. For this plan to be successful, a champion of the hiring plan should be identified. Within the current faculty, Prof. Cebe is a logical and qualified candidate. The committee expressed some concern that organizing this hiring effort might distract from Prof. Cebe's active research program. Alternatively, if a carefully selected senior hire is made, then further hires might be tied to their offer and they would lead the selection. There are numerous serviceable scenarios and the committee leaves it to the department and administration to arrive at one together. However any scenario should be based on multi-year planning.

In parallel with this effort, selected hires can be made to build around the synergistic activities in astrophysics, cosmology, and particle physics. Since there have been two recent hires in this broadly defined area, the next hire can be deferred a year or at most two. The most logical specific choice would be to hire a particle theorist whose research overlaps with the interface between cosmology and particle physics, and/or someone who would exploit the expected windfall from the LHC experiments. After that, the proposal to add a second observational astronomer or astrophysicist[3], particularly with interests in aspects of observational cosmology, is sound.

The two paragraphs above outline at least four new hires in four years, which would bring the faculty to a size of 21 if there are no retirements in that time. However, we expect that there will be retirements and the department and university can reevaluate the

[2] At other institutions, phased retirements with financial incentives have been popular, but that would require linking retirements to assurances of hires within physics and astronomy. We would not endorse links to hires within specific specializations, given the stated Tufts policy.
[3] The committee sees no need for the administration to buy time on existing telescopes or to invest in new facilities for the proposed astronomy/astrophysics hires.

situation as it progresses. The theme should be building around strengths in cosmology, maintaining particle physics, rebuilding a contemporary effort in condensed matter physics, and creating a small core of astronomy/astrophysics faculty, preferably with bridges to cosmology. This is a great opportunity to construct a Physics and Astronomy Department that suits the new research-oriented Tufts. Happily, the existing strengths of the department are present to build around, which brings this opportunity well within reach.