Dean's Committee on Opportunities for Particle Theory at U.C. Davis

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1. Particle theory in an era of discovery

Particle collider experiments at the Fermilab Tevatron, and at the CERN Large Hadron Collider, are poised to explore the TeV energy regime for the first time, extending the energy frontier by an order of magnitude during the present decade. From these experiments we expect to discover and study the Higgs boson, a manifestation of the mysterious Higgs field assumed to pervade the universe, giving mass to most of the elementary particles.

Concurrently, an explosion of rapid progress and creative activity within particle theory is producing fundamental new insights about string theory, supersymmetry, gravity, gauge forces, and the physics of extra spatial dimensions. The possibilities for new physics at the TeV energy scale now appear far richer and more challenging than was suspected even as recently as 5 years ago.

String theory offers the promise of a unified description of all of the fundamental forces and matter. Enormous progress has been made in the development of string theory by employing mathematical consistency alone. String theory's message is that unification with gravity entails two new features for fundamental physics: supersymmetry and extra dimensions of space. Neither has been observed in the laboratory so far, but by a thorough exploration of the TeV energy scale we expect to find direct or indirect evidence testing both of these radical ideas.

Already recent experimental surprises pose new challenges to our understanding of fundamental theory. The discovery that the universe is filled with dark energy, for example, implies that we have somehow missed fundamental aspects of physics even at macroscopic distances and low energy scales. Another surprise was the discovery that neutrinos have tiny masses. This experimental fact is interpreted by theorists as meaning that neutrinos are directly probing either a new "superheavy" energy scale or new hidden dimensions of space.

The last period of comparable experimental and theoretical ferment occurred in the early 1970's, swiftly culminating in the development of the Standard Model of particle physics. Since this era the particle physics community has become much larger and more specialized. Particle experimenters push the cutting edge of detector technologies and grid computing, while string theorists push back the frontiers of mathematics. Creative approaches are needed to speed up and strengthen information exchange between frontiers of theory and experiment, at a time when the pace of new developments is accelerating on both fronts.

2. An opportunity in particle theory

Traditionally major universities have developed particle physics groups almost entirely according to three categories: particle experiment, phenomenological theory, and string theory. This leaves untouched the two areas that have already become among the most exciting and promising in all of physics. The first of these is the overlap between astrophysics and particle physics, as represented by the rapid advances and prospects for cosmology, experimental particle astrophysics, and particle astronomy. This opportunity is already being exploited by the U.C. Davis Cosmology Initiative.

The second opportunity is the challenging interface between advances in fundamental theory and discoveries in particle experiments. This is the interface where new ideas about large extra dimensions, warped extra dimensions, or "noncommutative" spacetime are shaped into models that can be tested in experiments. This is the interface where collider discoveries of superpartner particles will be understood in the much broader framework of dark matter, cosmic inflation, baryogenesis, and grand unification. As noted above, recent experimental data is already posing difficult challenges for fundamental theory, and we expect this trend to accelerate over the current decade. We have also seen recent examples where radical new ideas have been brought from the abstract level to concrete experimental tests with remarkable swiftness.

This interface currently accounts for a large and growing portion of the most exciting work in particle physics. The most successful recent example is the explosion of interest in the physics implications of extra dimensions of space. According to the SLAC SPIRES database, four of the top ten most-cited particle physics papers in the year 2000 (the most recent year listed) were papers on extra dimensions. The other six top-cited papers concerned string theory (4) or experimental data (2). This area has also captured the imagination of the media and the public. Prominent stories on new ideas for extra dimensions have appeared in the *New York Times* (several instances), *Nature*, *Science*, the *Economist*, the *Wall Street Journal*, the *London Times*, the *Los Angeles Times*, the *Boston Globe*, the *Chicago Tribune*, *U.S. News*, *Time*, *Wired*, as well as NPR and BBC radio.

Research on ideas related to supersymmetry has also been flourishing. As pointed out in a recent article in the *New York Times*, the discovery of supersymmetry may well tell us the identity of dark matter, and will be a giant step towards probing the inner workings of string theory. Exciting new ideas are being pursued at the challenging interface between formal supersymmetry as extracted from string theory and the possible patterns of spontaneously broken supersymmetry that we hope to see in experiments.

Traditional university groups are not optimized to be productive at this interface. Because of the difficulty of establishing and maintaining a string theory group of high quality and critical mass, many top universities have had to sacrifice their strength in other areas of particle theory. Conversely, universities that have concentrated on strong data-driven groups in particle theory find that they are missing out on the excitement and impact of research driven by radical new ideas. Discoveries of either supersymmetry or extra dimensions in the coming decade will define our view of the universe for this century. Institutions which have played a visible role in these discoveries will reap huge recognition.

3. An opportunity for U.C. Davis

U.C. Davis is in an excellent position to build a nontraditional "new ideas" particle theory group optimized to exploit this exciting interface between fundamental theory and experimental discovery. This group would have a strong overlap with the Davis cosmology initiative, and both groups would benefit enormously from cross-fertilization of ideas. Davis already has a strong presence in both the CDF experiment at Fermilab, and the CMS experiment at CERN. This gives Davis particle theorists better access to signals of new physics, and a better understanding of how to confront new ideas with data.

Jack Gunion can provide the ideal anchor for the more phenomenological end of this new group. Universally recognized as a top world leader in the area of applying new ideas to experiment, Gunion would be a dynamic force within the group, and his stellar reputation will help attract the best of new faculty, postdocs, and students. The presence of Steve Carlip will help to define the other end of the bridge, with his active research program on quantum gravity with connections to string theory.

Provided that it is implemented this year, an initiative in this area would be perfectly timed. Theorists who have gained fame for creating and developing new ideas like extra dimensions have only been in the "faculty shuffle" the past two years; many potential targets of opportunity remain. Furthermore, a large cohort of brilliant and accomplished postdocs working in this interface area is just matriculating into the junior faculty market. In the longer term, the experimental programs at the Tevatron and LHC, the B-factories, a probable Linear Collider, next generation neutrino experiments, as well as a flood of new data in cosmology and astrophysics, guarantees that this will be a vital and exciting area for twenty years to come. But to be in place and ready for discoveries from the Tevatron, the new Davis group needs to grow now.

4. An initiative for U.C. Davis

To create a strong "new ideas" group in particle theory, a minimum of three new faculty hires will be required. It is critical that these positions be committed up front, so that the initiative has credibility for faculty recruits. If the initiative proceeds successfully, there should be flexibility to add a fourth new hire.

One or two of these new faculty should have a strong background in string theory, able to keep up with latest developments at the level of both concepts and formal tools. Since we are not creating a traditional string theory group, we are looking for a person who is specifically attracted by the challenge of finding observational signals of string theory ideas. While a minority, first-rate candidates fitting this description do exist at both junior and senior levels.

One or two of these new faculty should have a strong research record in the application of new ideas from fundamental theory to concrete model building, and to integrating new concepts into more robust testable frameworks.

The ideal candidates will be attracted by the prospect of forming/joining a group devoted to new ideas, and by the overlap with the existing groups in cosmology and in particle experiment. Many first-rate people in this area are potentially available at both junior and senior levels.

The hiring strategy should be flexible, and it is important to begin recruitment efforts immediately. To achieve maximum impact, it would be optimal to make a senior appointment first. This could be pursued as a senior search in the first year, using the promise of two junior positions as a powerful recruiting incentive. Alternatively one could have an open search the first year, with the goal of making paired senior/junior appointments. It will not be easy to attract a senior person of high quality and the appropriate profile; in addition to an attractive salary and start-up package, it may be necessary to secure additional resources for visitors, workshops, and staff. This might entail the creation of a Particle Theory Institute in some form or another.

If aggressive senior recruitments do not seem to be working out after the first year, an attractive backup strategy is to make simultaneous multiple junior offers. This requires identifying at least two first-rate junior candidates who have sufficient overlap that they will be attracted by the prospect of working with each other. Multiple offers are a very concrete outward sign that a department is serious about building a group.

5. What other universities are doing

Most major universities are too restricted by their commitments to traditional string theory groups or phenomenology groups to contemplate any expansion in the crucial interface area. However a few have very recently made clear moves in this direction. Harvard has hired Lisa Randall and (it appears) Nima Arkani-Hamed, two of the inventors of the new field of extra dimensions. Yale has this year made three simultaneous offers (one senior, two junior) to theorists who match the profiles outlined above. The University of Washington, which already had a strong particle theory group in model building and phenomenology, has just hired Matt Strassler and Andreas Karch, two junior theorists with backgrounds in applications of string theory.

6. Connection to other initiatives and activity at Davis

New faculty, postdocs and students attached to the particle theory intitiative will be strongly attracted by the opportunity to interact with the Davis cosmology group. Thus it will be important to facilitate these interactions, through joint seminars, workshops, visitor overlaps, and proximity of offices. The greater the integration and overlap of the activities of these groups, the more each group will be strengthened. This consideration may weigh against the idea of any formalized Particle Theory Institute, although as mentioned above institute-like resources may be required to make a suitable senior hire.

Overlap with the Davis groups in particle experiment will also be important. These can best be encouraged through joint planning of workshops related to current or imminent experimental discoveries.

String theory has a natural overlap with Mathematics. Once a string theory presence is in place and the full particle theory initiative has matured, an attractive future direction would be to pursue joint appointments with the Math department. This could allow the recruitment of mathematically oriented string theorists, giving more depth to the formal side of a strong particle theory group.

Particle theory has a number of interesting connections to advanced computing. While it is difficult to predict *ab initio* specific overlaps, there is certainly a potential synergy between the particle theory initiative and the new Davis Center for Computational Science and Engineering.

The new Davis particle theory group will have strong overlaps with groups at other Bay Area universities and labs. Starting from a position of strength, it should be easier for the Davis group to foster closer ties with its neighbors, especially LBL/Berkeley. Joint workshops, sharing of visitors, and mini-sabbaticals could all be pursued.