Summary of Research Presentations at the CAMOS Meeting in October 2010

Precision Measurements and Tests of Fundamental Laws

The Committee on Atomic, Molecular, and Optical Sciences (CAMOS) is continuing to monitor progress in atomic, molecular and optical (AMO) physics since the National Research Council's (NRC's) publication in 2007 of its report Controlling the Quantum World: The Science of Atoms, Molecules and Photons, known in the AMO field as the 2010 AMO Decadal Survey. Precision measurements and tests of fundamental laws were the focus of one of the six chapters in this report. At the fall 2010 CAMOS meeting, a focus session featured a series of talks on the overlap of AMO physics and high energy physics. Two experimentalists spoke, Jerry Gabrielse (Harvard) and Norval Fortson (University of Washington), as did two theorists, Jonathan Sapirstein (Notre Dame) and Peter Graham (Stanford).

These talks gave many examples of AMO-based experiments and AMO theory that support physics goals generally considered to be in the domain of high-energy physics. Most of the experiments are in the form of precise tests of the Standard Model of physics, which has been a running story in atomic physics since the first g-2 and Lamb-shift measurements—that is, since before there even was a Standard Model. The speakers noted that the particle physics community is generally dissatisfied with many aspects of the Standard Model even though it has been surprisingly successful in its description of aspects of particle physics. There is thus intense interest in Beyond-the-Standard-Model physics or, simply, New Physics. The speakers made strong arguments that AMO physics will play an important role in finding New Physics, a role that is large compared to the relatively modest cost of the AMO physics experiments.

Ongoing experiments along these lines were described in the talks:

- Atomic parity nonconservation, which gives information that is complementary to high-energy scattering experiments;
- Electron g-2 tests, which along with cutting-edge atomic theory and atomic photon recoil measurements provide the most precise tests of quantum electrodynamics;
- Atomic clocks that test for possible time variation of the fine structure constant, the electron-proton mass ratio, and other fundamental constants;
- Searches for charge-parity-time violation with and without particle-antiparticle comparison, which might explain the universe's baryon asymmetry;
- Lorentz invariance and general relativistic tests;
- Searches for electric dipole moments (EDMs) of fundamental particles, which are not zero in the Standard Model but which are predicted to have much higher,

measurable values in many extensions to the Standard Model, including supersymmetry; and

- Atomic measurements of nuclear properties, like anapole and magnetic octupole moments, that can test quantum chromodynamics.

Further experiments along these lines are being considered and developed, including the use of atomic interferometers to detect gravitational waves and axion dark matter and to test general relativity.

Most of these precision measurement experiments are enterprises with only a single or a few principal investigators. They are usually performed in university-like labs, although some are performed at user facilities or in larger collaborations. In any case, they present a challenge for common funding models. Like most experiments, they need sustained funding, but unlike other AMO experiments, there is often a long time between results in precision measurement experiments, especially the spectacular results that are the ultimate experimental goals. These experiments are therefore hard to undertake with only conventional AMO funding. Although there is fairly deep intellectual support for this kind of work within the AMO community, it takes an uncommon leap of faith to start a project likely to take more than 6 years on a 3-year funding cycle.

Two speakers pointed out that a natural way to rectify this situation and to enable atomic physicists to pursue their best ideas in this area would be to obtain support from the high-energy physics community. Another speaker made the provoking observation that some collider physicists believe experiments without colliders cannot be important or interesting. The result is that even when the physics goals are the same, support from high-energy physics sources is rare. This incongruity is perhaps most stark in EDM searches, where there is a consensus among high-energy theorists that while EDMs are an important piece of the Beyond-the-Standard Model puzzle, the tabletop AMO experimental methods common to these searches are unfamiliar to the high-energy physics community, and there is no mechanism for AMO scientists to pursue funding from the high-energy physics programs.

A special funding issue that was mentioned was the difficulty in finding support for an AMO experiment at a user facility. Here, even when the methods are closer to those of high-energy experiments, support is typically found only from AMO funding sources, where there is budgetary mismatch between the costs of the proposed experiments and other experiments to be funded from the same programs. A number of speakers acknowledged that AMO program managers are not able to direct a large fraction of their budgets to proposed projects with unusually large budgets, and thus closer coordination with the managers of high-energy programs would seem desirable given a shared interest in the underlying physics.