Physics Update

Argon plasma generates coherent extreme UV light. In high-order harmonic generation (HHG), the electric field of a very intense laser pulse interacts nonlinearly with a gas to produce coherent emission at high harmonics of the laser frequency while ionizing the atoms. There is a cutoff energy above which HHG cannot produce emission. That cutoff has only been reached for neutral atoms, mainly because of laser defocusing effects as the gas ionizes. A group of physicists in Colorado has now overcome that limitation by putting the gas—in this case argon—into a hollow glass fiber. When an intense 1.55-eV (800-nm) laser pulse was fired into the fiber, the gas was ionized but the waveguide geometry counteracted defocusing. This method allowed the scientists to observe significant harmonic emission—up to an energy of 250 eV (5 nm)—resulting from further ionization of the argon ions. In contrast, neutral argon can generate harmonics only up to 100–150 eV. In general, HHG is useful for both ultrafast spectroscopy of materials and high-resolution imaging, including of biological and surface samples. The researchers say that coherent emission up to 1 keV will soon be seen in helium or neon ions, extending HHG to higher photon energies than previously possible. (E. A. Gibson et al., *Phys. Rev. Lett.* **92**, 033001, 2004.) —PFS

Caged hydrogen. When simple gases meet water at ambient conditions, little happens. But at high pressure and low temperature, hydrogen-bond networks within water can build polyhedron cages around guest molecules like methane, nitrogen, or argon to form hydrogen clathrates. Wendy Mao (University of Chicago) and her father Ho-kwang Mao (Carnegie Institution of Washington) have developed a way to store large concentrations of hydrogen within such clathrate cages. Using a diamond anvil cell, they compressed hydrogen gas and water to 250 MPa and noticed the mixture nucleate at about 250 K to form $H_2(H_2O)_2$, a clathrate cage with enclosed hydrogen gas clusters. Provided that it's stored at temperatures below about 140 K, the compound remains stable even when the pressure drops to ambient levels. At warmer temperatures, the clathrate decomposes to release its stored gas. The density of hydrogen stored within the hydrate is 50 g/L, significantly close to that of pure liquid hydrogen, about 70 g/L. The Maos argue that the search for other novel clathrates could lead to an optimized hydrogen-storage compound. Meanwhile, their study is helping researchers understand a very different puzzle: how icy planets managed to incorporate large quantities of hydrogen during their evolution. (W. L. Mao, H.-k. Mao, *Proc. Natl. Acad. Sci. USA* **101**, 708, 2004.) —RMW

Large, mature galaxies formed surprisingly early. You'd expect that a census of the farthest galaxies that formed earliest in the universe's history would feature numerous small, hot, young, blue galaxies, perhaps smashing into and coalescing with each other. But the new Gemini Deep Deep Survey (GDDS) shows something very different. The GDDS explored the so-called Redshift Desert, the poorly patrolled region of cosmic history roughly 3–6 billion years after the Big Bang. Galaxies there are redshifted into a spectral region that corresponds to a natural, obscuring glow in Earth's nighttime atmosphere. Astronomers used a sophisticated technique at the 8-m Gemini North telescope in Hawaii to reveal the feeble spectra of more than 300 galaxies. Survey team member Roberto Abraham (University of Toronto) now speaks of a "Redshift Dessert" with plenty of massive old galaxies where you'd expect few. He and his colleagues reported the results at the January meeting of the American Astronomical Society in Atlanta, Georgia. They found that, in a 4-billion-year-old universe, elliptical galaxies up to 3 billion years old already existed. Furthermore, the galaxies in the survey have many heavy atoms that need to be cooked up in repeated cycles of star birth and supernovae. Abraham says that all of their observations should make theorists sweat. (R. G. Abraham et al., *Astron. J.*, in press; S. Savaglio et al., *Astrophys. J.*, in press.) —PFS

The anomalous magnetic moment of the muon has now been measured to an exquisite precision of 0.5 ppm by the Muon ($g - 2$) Collaboration at Brookhaven National Laboratory. The group's recent paper culminates a 20-year effort led by Lee Roberts (Boston University) and the late Vernon Hughes (Yale University), who died last year (see PHYSICS TODAY, February 2004, page 77). The muon's magnetic moment is thought to be a particularly good place to look for indications of new physics beyond the standard model of particle theory. The Dirac equation yields a value of precisely 2 for g, the muon's gyromagnetic ratio. Standard-model corrections, calculated to eight significant figures, add a predicted anomalous moment of a few parts per thousand to the Dirac g. Hughes and coworkers searched for a tiny departure from the predicted $g - 2$ by measuring the very small difference between the muon's cyclotron and precessional frequencies in the group's muon storage ring. At this point, the measured $g - 2$ differs from the standard-model calculation by a tantalizing but inconclusive 2.7 standard deviations. In coming months, new empirical inputs from electron–positron collider data are expected to sharpen the standard-model prediction, and the Muon ($g - 2$) Collaboration is looking for funding to continue its experiment. (G. W. Bennett et al., http://arXiv.org/abs/hep-ex/0401008.) —BMS