

quark bound to an ordinary antiquark (charmed meson) or to two ordinary quarks (charmed baryon).

Meanwhile, two experimental observations suggested the existence of a fifth and sixth quark. At SLAC Martin Perl and his collaborators found evidence for a heavy lepton, the tau, with a mass of about 2 GeV. Subsequent experiments at DESY in Hamburg, by the Pluto and DASP groups, have tended to confirm the indications of a heavy lepton. The tau would presumably have a neutrino associated with it, making six leptons. By symmetry arguments, a fifth and sixth quark would be in order.

The second observation was of the so-called "high- $\gamma$  anomaly," found in neutrino scattering by a Harvard-Penn-Wisconsin-Fermilab group and a Caltech-Fermilab group. To explain the anomalous energy distribution, in 1974 Michael Barnett (SLAC) suggested the existence of new right-handed quarks, to be contrasted with the left-handed quarks (up, down, strange and charmed). But recent experiments at CERN by an Aachen-Bonn-CERN-London-Oxford-Saclay group and by a CERN-Dortmund-Heidelberg-Saclay group and at Fermilab by a Caltech-Fermilab group have reported seeing no rapid energy variation of the cross section. So perhaps one no longer needs additional right-handed quarks to explain a high- $\gamma$  anomaly. The absence of a high- $\gamma$  anomaly does not rule out new left-handed quarks.

Nevertheless, several groups of theorists have talked about adding pairs of quarks to the standard model. Feza Gursey (Yale University), Pierre Sikivie (University of Maryland) and Pierre Ramond (Caltech) and Barnett proposed a total of six quarks, the new ones both having charge  $-\frac{1}{3}$ . Groups from places such as Harvard, Princeton, University of Hawaii and Caltech have suggested adding to the standard model pairs of quarks, one with charge  $+\frac{2}{3}$ , and one with charge  $-\frac{1}{3}$ . More than one pair is also a possibility. The new quarks have been called top (charge  $+\frac{2}{3}$ , like the up and charmed quark) and bottom (charge  $-\frac{1}{3}$ , like the down and strange quark) or truth and beauty. In January Estia Eichten (now at Harvard) and Kurt Gottfried (Cornell) predicted that for a quark of mass greater than 4 GeV, three bound states (analogous to  $J/\psi$  and  $\psi'$ ) should be seen in electron-positron collisions. In a fixed-target experiment this would be seen as very narrow peaks in a  $\mu^+\mu^-$  spectrum.

Lederman notes that the consensus of theoretical argument he has received is that the upson is a bound state of a bottom quark and its antiquark but says that "confirmation of this hypothesis will depend on a clearer delineation of the mass distribution. This is in progress at Fermilab. Conclusive proof will require the observation of 'naked bottom,' that is, particles containing only one bottom

quark." However, he notes that other interpretations are tenable.

Another possibility would be a bound state of a top quark and its antiquark. However, some very recent theoretical work suggests that the production estimates fit a bottom quark better.

Some theorists have calculated (on the basis of Zweig's rule) that the upson should have an extremely narrow width, just as the  $J/\psi$  does.

Still other explanations of the upson are possible, of course. For example the  $T'$  could be a bound state of yet another quark. It will be interesting to watch the results coming from other lepton-production experiments now under way at Fermilab (four of them), CERN (six of them), and Serpukhov and an electron-positron annihilation experiment at DESY. And the new electron-positron storage rings at Cornell, SLAC and DESY should probably see a spectrum of excited states much richer than charmonium. —GBL

### Hawaiian observatory starts lunar ranging

The Lunar Ranging Observatory of the University of Hawaii recently began ranging measurements from its site atop the mountain of Haleakala on the island of Maui. The data will support the existing program at McDonald Observatory at the University of Texas and will be useful for a wide variety of geophysical observations.

The neodymium-YAG laser produces infrared pulses that are frequency doubled before transmission; the pulse length is about 0.2 nanosec. The beam is aimed at the Moon by a movable mirror placed in front of a fixed telescope with a 16-inch aperture. This system enlarges the laser beam and collimates it to provide a divergence of about 2 arcseconds under optimum conditions (about 2 miles on the Moon). The beam is reflected from the Moon by five arrays of retroreflecting prisms placed there by the Apollo astronauts and by the unmanned Soviet landers. Each array has many high-quality prisms slightly deformed from a perfect corner cube to compensate for the small movement of the Earth that occurs while the pulse makes its round-trip.

The returning light pulse is received with a telescope consisting of 80 small refracting telescopes whose lenses are mounted in a single faceplate; the whole assembly is set on an altitude-azimuth mount. Timing is done to about 200 picosec, corresponding to a range uncertainty of 2-3 inches in the raw data. By measuring the distance several hundred times in quick succession, the Earth-Moon distance can be determined with even greater accuracy.

A program is underway to determine if the Observatory is really fixed on the surface of the Earth, or if it is moving up,

down, or sideways, and by how much. Several tide gauges are to measure differential changes in sea level; tiltmeters will measure changes in the direction of gravity; strain meters are to detect uplift or subsidence; geodetic surveys will establish the amount and direction of shifts relative to the rest of the island. From the aforementioned measurements, the observers hope to learn more about the motions of the Moon about the Earth, the Earth's rotation, the wobble in this rotation, and, in conjunction with the McDonald Observatory, the displacement of the Hawaiian Islands relative to the continental United States due to continental drift. Eventually, the Observatory hopes that other ranging stations in Australia, Japan, France and Germany will be able to join the program.

### Out-of-ecliptic mission planned by US and Europe

NASA and the European Space Agency are planning a joint 1983 mission outside the plane that contains the Sun and planets. Although the out-of-the-ecliptic mission has not yet been approved by Congress, NASA and ESA are inviting scientists to propose experiments now.

Two unmanned spacecraft, one supplied by NASA and one by ESA, would be launched simultaneously on looping trajectories that would bring them out to 748 million km from the Sun. The spacecraft would pass over both of the Sun's poles during its five-year mission. Instruments aboard the two spacecraft would investigate, as a function of solar latitude, the properties of the solar corona, the solar wind, the structure of the Sun-wind interface, the solar magnetic field, solar and nonsolar cosmic rays, and the interstellar and interplanetary neutral gas and dust.

Interested US scientists should write to Adrienne F. Timothy, OOE Study Scientist, Code ST, NASA Headquarters, Washington, DC 20546. ESA will solicit European candidates separately; its member nations are Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. All others should write to the Office of International Affairs, NASA Headquarters.

### in brief

Princeton University has signed a five-year contract for about \$100 million with Ebasco Services, Inc to provide engineering, design and management for the Tokamak Fusion Test Reactor, now under construction at the Plasma Physics Laboratory. Ebasco's major subcontractor is the Grumman Aerospace Corp. □