Lunar laser-ranging reflector package. This device, shown at Fra Mauro landing site, was installed by Apollo-14 astronauts. It contains 100 solid fused-silica corner reflectors mounted in a 46-cm square aluminum panel. Each reflector is 3.8 cm in diameter.

theories of gravity. Among his conclusions was that any violation of the equivalence principle should be detectable in the Earth–Moon–Sun system. More specifically, there should be a variation δr in the Earth–Moon distance, with a synodic period of 29.53 days, such that

$$\delta r = C_0 \cdot \eta \cos D$$

Here C_0 is a constant equal to about ten meters, and D is the difference in the mean longitudes of the Moon and the Sun. The so-called "Nordtvedt parameter" η, which is zero for general relativity, was evaluated for those metric theories with energy–momentum conservation and spatial isotropy as

$$\eta = 4\beta - \gamma - 3$$

Here β and γ are two of the PPN (Parametrized Post Newtonian) parameters often used to distinguish among the various metric theories of gravity. For general relativity, γ is one; for Brans–Dicke–Jordan theory, which adds a scalar field with coupling constant ω to Einstein's tensor theory, γ is $(1 + \omega)/(2 + \omega)$.

The LURE group and the Massachusetts group both estimated η by analyzing the roundtrip travel times of 3-nanosec duration ruby-laser pulses from the McDonald Observatory towards one or another retroreflector package on the Moon and back again. Both groups used a lunar librational model developed by members of the LURE group. The analyses were in all other ways believed to be independent, with the Massachusetts group being the first one to obtain reliable results, according to both teams.

The LURE group found $C_0 \cdot \eta$ to be 0 ± 30 cm. This uncertainty, roughly eight times the statistical error, is estimated from possible systematic errors and limitations in the model. Taking C_0 as 9.26 meters, they find η to be 0.00 ± 0.03, equivalent to a ratio of $1 \pm 1.5 \times 10^{-11}$ for gravitational to inertial mass. They note that this is consistent with Brans–Dicke–Jordan theory only for $\omega > 29$, whereas Dicke's most recent prediction is 7.5. They expect that improvement in the distance measurement and in data analysis will lead to an order-of-magnitude improvement in the estimation of η within the next few years. Shapiro, Counselman and King find that η is -0.001 ± 0.015, with the uncertainty roughly four times the statistical error. The Mars–Sun–Jupiter system, they point out, is a promising independent one for verifying the equivalence principle for massive bodies, with the larger magnitude of the effects roughly cancelling the larger uncertainty in the measurement of interplanetary distances by radar. —MSR

References

1. J. G. Williams, R. H. Dicke, P. L. Bender, C. O. Alley, W. E. Carter, D. G. Currie, D. H. Eckhardt, J. E. Faller, W. M. Kaula, J. D. Mulholland, H. H. Plotkin, S. K. Poultney, J. P. Shelus, E. C. Silverberg, W. S. Sinclair, M. A. Slade, D. T. Wilkinson, Phys. Rev. Lett. **36**, 551 (1976).
2. I. I. Shapiro, C. C. Counselman, R. W. King, Phys. Rev. Lett. **36**, 555 (1976).

Searches for intelligence beyond Earth continue

The first timid searches for life in space began in 1959 with Project Ozma. Since then quite a number of groups have expanded the search for extraterrestrial intelligence, although the amount of effort is still small in comparison to the difficulty of the problem. At the February meeting of the American Association for the Advancement of Science in Boston, several groups discussed their pioneering attemps, which, as the reader may suppose, have so far proved unsuccessful.

There are still no definitely known planets outside our solar system, according to George Gatewood, who described the observing program at Allegheny Observatory of the University of Pittsburgh, in which 33 stars (within 15 light years of Earth) are being studied; all could have planetary-like systems around them. The most likely candidate to have a genuine planet is Barnard's star, which is being vigorously observed. Gatewood feels nothing definitive will be known for 5–10 years. Other suspected planetary systems include Epsilon Eridani and BD+43°4305. Gatewood noted that a space-borne telescope would revolutionize astrometry, making measurements two orders of magnitude more precise.

L. Frank Baum's Ozma was a land very exotic and very far away. Frank Drake's Ozma, initiated in 1959, was a search for exotic lands in two stars, studied for several hundred hours, at a frequency of 1420 MHz, the 21-cm line of hydrogen. It employed an 85-foot dish, a one-channel filter system and a receiver at 350 K.

Ozma II, a search conducted from November 1972 to August 1975 by Patrick Palmer (University of Chicago) and Ben Zuckerman (University of Maryland), used the 300-foot dish and the 140-foot dish at Green Bank, West Virginia, at a frequency of 1420 MHz. They had a receiving system equivalent to 384 channels, and the receiver operated at 50 K.

Palmer and Zuckerman observed 659 stars all told, tracking each source for four minutes at a time. In no sense did they monitor one star continuously. Typically each star was observed six or seven times. The stars studied were 6–76 light years away and similar to our Sun. They searched for a narrow signal with time variability. After scanning 90% of the data (without automation), no convincing evidence of extraterrestrial intelligence was found. Palmer feels that improvements in sensitivity are not the most important factor. Instead, he feels we must develop techniques that will analyze all radio frequencies simultaneously.

N. S. Kardashev of the Institute for Cosmic Research in Moscow was on the program but did not appear. In his place Carl Sagan (Cornell University) mentioned that the Moscow institute and one at Gorky University are each operating a network to search for extraterrestrial intelligence. To Sagan's knowledge, the Soviet observers have no convincing positive results.

Arecibo. Frank Drake, who is director of the National Astronomy and Ionosphere Observatory in Arecibo, Puerto Rico, discussed work done by him and Sagan at Arecibo, which has a 1000-foot-diameter dish with a total collecting area of 20 acres. In connection with the resurfacing of the dish, the transmitter, which operates at 2380 MHz, was used to send a 3-minute message to outer space, in the direction of the globular cluster Messier 13. When the beam was focused, it had an effective isotropic radiative power of 1.5×10^{13} watts. In tests preparatory to sending the message to Messier 13, the message was transmitted with the radio beam sweeping the sky, due to the Earth's rotation. Thus many stars received 12-second pieces of the message—not enough time to interpret it. Drake remarked that if an intelligent being picked up the signal, he would start watching our position in the sky for more messages, but none would be forthcoming. Thus the greatest discovery of the century would only result in another scientist managing to lose his job.

Most of the Arecibo effort on extraterrestrial intelligence has been devoted to looking for signals rather than sending them. Drake and Sagan are looking at four frequencies: 1420 MHz (21-cm line of hydrogen), 1667 MHz (spectral line of the OH radical), 1652 MHz (where no observations have yet been made; the frequency is associated with the center of gravity of the H_2O molecule and is in the middle of the so-called "waterhole"), and 2380 MHz (which happens to be one of the antenna's radar frequencies). At all but the last frequency, the system noise is 100 K; at 2380 MHz, it is 42 K. A 1008-channel receiver was used. All frequencies have a bandwidth of 1 kHz—much less than that used in other searches, but still too wide, Drake believes. They observed with a 32-second integration time, making two independent samples and inspected the results immediately on an oscilloscope. If something looks interesting, the observers can look again promptly.

The observers looked for signals from nearby stars, such as Barnard's star, which they would have been able to detect with an effective isotropic radiative power greater than 10^{10} watts (10^{-3} Arecibos).

They also searched in four nearby galaxies, testing 10^{12} stars. These were Messier 33, Messier 49, Leo I and Leo II; the nearest is 1.5 million light years away. They are able to detect a power equivalent to 200 million Arecibos—something far beyond our technology. In the course of their observations, Drake and Sagan saw what appeared to be an intelligent signal coming from six different directions in Leo I. To their dismay, the signal turned out to be a terrestrial source intercepted by the sidelobes of the antenna.

The final speaker was Philip Morrison (MIT), who is chairman of a NASA advisory committee that is examining observational strategies. He noted that we should not be looking for a signal, but a high gradient in the signal. Morrison feels that we are still in the pioneering stage of the search. The second stage requires dedicated instruments: he would like to see a small, dedicated enterprise built now. —GBL

Group meets in USSR on Very Big Accelerator

This month, beginning on 17 May, an international study group will meet in Serpukhov in the Soviet Union, to discuss the prospects and possibilities of constructing a "Very Big Accelerator" by a world collaboration among many different countries. It would be a machine with much higher energy than any accelerator being planned by an individual nation.

In March 1975 a meeting was held in New Orleans, attended by about 25 high-energy physicists from the US, Western Europe, the Soviet Union and Japan to discuss various forms of international collaboration. The future development of high-energy physics was discussed, and many participants emphasized the desirability of extending the energy frontier beyond the limits presently available or recently proposed. any Many fundamental problems seem to require this extension for their solution, such as the question of the existence of a quantum of the weak interaction, the relation between the weak and electromagnetic interaction, and problems related to the quark hypothesis.

Many believe that national and regional authorities may no longer be willing to support projects that are considerably larger than those presently in existence or in the planning stage. Thus the Very Big Accelerator is being discussed.

At the meeting this month in Serpukhov, the American participants are expected to be J. D. Bjorken (SLAC), Robert E. Diebold (Argonne National Laboratory), Leon Lederman (Columbia University), Wolfgang K. H. Panofsky (SLAC), Victor Weisskopf (MIT) and Robert R. Wilson (Fermi National Accelerator Laboratory).

The international group will consider the possibility of building a proton accelerator of the order of 10 TeV (10^{13} eV) or an electron–positron colliding-beam device with each beam of about 100 GeV. Weisskopf emphasized to us that much of the discussion will probably focus on the best choice for an instrument and an energy range. To that end, the group is expected to consider the physics problems requiring higher energy and the numerous technical problems of achieving it.

"A world collaboration on the Very Big Accelerator," Weisskopf said, "would have important significance besides the mere scientific advantages, as a symbol of common human values beyond competition and strife, and as an example of intensive international collaboration across ideological frontiers." The former director of CERN said that the history of that laboratory has shown that high-energy physics is very conducive to such efforts because of its distance from commercial and military applications. There are many obvious political and social difficulties and problems in the way of such a project, Weisskopf notes, with little hope for an early realization. But, he feels, it is advisable to begin with this international study group.

Weisskopf urges that the vision of the Very Big Accelerator should not interfere in any way with further development of national or regional high-energy facilities. "Indeed," he says, "any international effort can be successful only if it is based upon well-developed national and regional research activities."

ERDA and the National Science Foundation are sponsoring the American participation. —GBL

Solar oscillations

continued from page 17

see at what frequencies there is significant power. Hill says that the Fourier transform is unaffected by the smearing effect of the terrestrial atmosphere.

The group, which consists of Hill, Robin Stebbins (National Center for Atmospheric Research) and Timothy Brown (High Altitude Observatory, NCAR), work at the Santa Catalina Laboratory for Experimental Relativity by Astrometry in Tucson. They made their initial announcement last June at the Fifth International Conference on Atomic Masses and Fundamental Constants, held in Paris. By now the group believes they have seen 20 modes in the 6–70-minute range. There is a broad peak at a period of 68.3 minutes, which the group feels may contain the fundamental acoustic mode. The longest period, Stebbins told us, that looks like it is clearly there is 109 minutes.

Hill says that the amplitudes of each period are all of the order of 5–10 arcmillisec out of a total solar diameter of 2000 arcsec. A naive interpretation of these results would mean that the sun was changing in size by 4–8 km during an oscillation. The Birmingham results for comparable oscillations imply size changes of the order of 0.4 km, Hill said; he explains the discrepancy by saying that the SCLERA group, unlike the Crimean and Birmingham observers, is not only seeing a deformation of the Sun itself, but also a change in the light-distribution curve. The whole sun is oscillating, he goes on, with waves reflecting in and out of the core. All one can see, however, is the outer 0.1%, and this outside portion acts like the end of a whip, moving with larger (but still relatively small) amplitude. Hill and his collaborators claim that the large amplitudes they see are primarily from brightness fluctuations caused by temperature variations. A small fraction of the amplitude, however, may be caused by an actual physical displacement, Stebbins says.

Most of the data were collected last October and November, when a typical run lasted 6–8 hours. The length of the data set determines the feasibility of observing longer periods. However, the SCLERA workers hope that they can string data sets from one day to the next by matching phases. If so, resolution of the period will be vastly improved. For example, the 68-minute period, which has an 8-minute uncertainty would, by linking three days, be defined to 0.75 minutes.

Stebbins outlined the group's arguments for believing that the pulsations observed are normal modes of the sun. He points out that other observers over the last 15 years have seen solar oscillations with periods of about five minutes, but Stebbins says that they were localized and lasted only a few cycles. More recently Franz-Ludwig Deubner (Fraun-