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CONCLUDING LECTURE by

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The preceding papers have demonstrated the remarkable development of the radio-astronomical investigations of the solar system during the last few years. The subject of meteors has been intentionally excluded, since this is now far too extensive to be included in a symposium of this kind. The radio echo, or radar, techniques have now been extended to reach the moon, and a further extension to the nearer planets can be anticipated soon. In the meantime, the study of the thermal and nonthermal radio emissions from the planets is developing rapidly, and important new results have been presented here. It will be convenient first of all to consider the implications of the new work on the radio echo investigations of the moon.

1. RADAR INVESTIGATIONS OF THE MOON

Fading.—A prominent characteristic of the echoes from the moon is the variation in amplitude of the received echo. It is now agreed that the fading is of two quite distinct types:

(*a*) A slow variation in the mean amplitude of the received echoes with periods of many minutes, which is caused by the rotation of the plane of polarization in the ionosphere (Faraday effect). This work has not been described here but it has become an important tool for ionospheric investigations, since by measuring the amount of rotation it is possible to derive the total number of electrons in a column of unit cross section along the line of sight from the earth to the moon. So far the information obtained has related mainly to the distribution in depth of the electron concentration in the earth's ionosphere, but in the future, when these measurements are combined with earth-satellite investigations, a new technique should become available for measuring the electron density in interplanetary space.

(*b*) A short-period fading, which manifests itself as a variation in amplitude of successive echoes. The early suggestion that this is a direct result of the libration of the moon has now received adequate confirmation. For example, Evans has shown that the diurnal effect in this short-period fading is exactly what can be expected from the libration hypothesis, since the principal component is due to the observer's motion. Reference will be made below to the significance of the autocorrelation function of this fading in the scattering theories.

Range.—The measurements of the earth-moon distance using high-power apparatus on 10-cm wavelength, with pulses of only a few microseconds' duration, have yielded interesting results. Yaplee has claimed that his measurements at NRL are accurate to 0.2 miles, but when the actual radar-range measurements are compared with the calculated ranges there are residuals up to 6 miles. Although not explicitly stated in Hughes' contribution, it seems that the measurements at RRE in Great Britain show similar discrepancies. These departures are as yet unexplained. At present it would seem that the discrepancy must be taken up either in the scattering theory or by a change of geophysical parameters.

Scattering theory.—There appears to be complete agreement that the scattering of radio waves in the 10-cm to 3-m wavelength range so far investigated takes place from the hemispherical cap of the moon to a depth of about 50 miles only. The supporting evidence is considerable: principally, that if short pulses are transmitted they are lengthened to about only 100 microseconds by the scattering; and that the autocorrelation function of the fading due to libration is consistent with the scattering from a small hemisphere. Even so, as was evident from Siegel's paper, there is some dispute about the scattering theory. The main differences of view rest on the argument that the scattering is either from a very small number of centers—say half-a-dozen or less—or from a larger number—say greater than ten. Both Yaplee and Hughes have presented evidence that the correlation between successive pulses decreases away from the front edge of the reflected pulse, but this might be expected with either theory. A decision between the rival views must await a detailed study of the variation of the autocorrelation function with the increasing depth from the front of the reflecting cap.

2. THE FUTURE OF RADAR INVESTIGATIONS OF THE SOLAR SYSTEM

In the short period during which the moon has been studied by the radar technique an unexpectedly wide field has been opened. Two major items require more study in the immediate future; namely, the final clarification of the scattering process, and the final clarification of the range discrepancies. Future investigations can then be expected to give interesting information about the detailed topography of the lunar surface and its electrical characteristics. It seems likely, also, that the measurement of the Faraday rotation in the ionosphere using the moon as the reflecting target, will become an important feature of ionospheric investigations. Finally, this lunar-echo work has revealed the possibility of using the moon as a scattering surface in transatlantic communication, thereby adding another important chapter to the practical applications of radio astronomy.

Later we can look forward to another field of activity in the study of Venus and Mars by the radio-echo technique. Important tasks that come to mind immediately are the investigation of the rotation period of Venus, the study of the Venusian surface and ionosphere, and the measurement of the electron density in interstellar space.

3. THE LUNAR ATMOSPHERE

Elsmore has reported a positive effect in his studies of the lunar occultation of the radio source associated with the Crab nebula, which is attributed to refraction by the ionized lunar atmosphere. The information about the density of the lunar atmosphere would appear to be about a thousand times better than the existing optical data. Further work on occultation may be expected to give more precise information, and the technique seems likely to become important in the study of the radio sources themselves.

4. COMETS

The close approach of Comet Arend-Roland in 1957 provided an excellent opportunity for radio-astronomical investigations. Elsmore has reported the Cambridge failure to detect any emission or refraction on meter wavelengths, thus adding to the number of failures reported at the 1957 URSI meeting. It now seems difficult to accept the positive results reported from Ohio on meter wavelengths and from Bonn and Belgium on 21 cm until further confirmation can be obtained from studies on future comets.

5. THERMAL RADIO EMISSION FROM THE PLANETS

During the Session significant additions have been reported to the studies of the thermal radio emission from the planets. In particular Yaplee has described the unique experiments at NRL, which would seem to represent the first radio astronomical measurements using a maser, on a 3.37-cm wavelength. The collected results show interesting and unexplained features in respect to both Venus and Jupiter. In the former case the black-body temperature on the dark side of the planet is about 550 °K in the range 3 to 10 cm but is only 250 to 570 °K on 8.6 mm. In the case of Jupiter the measurements on 10 cm give a black-body temperature averaging 580 °K but with a variation of from 395 to 860 °K during the course of a night. The maser measurement on 3.37 cm gives only 145 °K as the black-body temperature with a variation of less than 10 per cent dependent on the rotation of the planet. Gallet has suggested that the low value on 3.37 cm might be caused by an ammonium absorption band. It is evident that these topics need further study to relate the results to the optical measurements.

Apart from the reference to Gibson's work on 35 Gc/s by Smith (paper 1), no new results on the thermal emission from the moon have been reported. It is obvious though that further measurements of this type over a range of wavelengths will be needed to associate with the radio-echo results concerned with the characteristics of the lunar surface.

6. NON-THERMAL RADIO EMISSION FROM THE PLANETS

No new results have been reported from Ohio on the Venus emissions, whereas several other observers have now failed to obtain a positive effect. Harlan Smith has described his work on Saturn and this, too, requires a further series of experiments before the existence of nonthermal radiation can be certain. In the case of Jupiter, however, Gallet has described his important work on these phenomena. He concludes that the radiation comes from about 5 or 6 discrete sources on the planetary surface in the form of bursts in a narrow bandwidth of about 0.5 Mc/s. He explains the frequency spectrum observed on the earth and the decrease in activity during the last few years in terms of the Jovian ionosphere. The most remarkable feature of this phenomenon is the intense energy involved. Gallet has calculated that 10^{18} ergs are emitted in each burst, which probably needs a basic energy source of 10^{24} ergs. The only known terrestrial features capable of generating such great energies are the larger kinds of volcanic explosion. It would indeed be an impressive development if radio astronomy can give so much detail about the events on a planetary surface that is completely obscured from view.