B. (APPENDIX) REPORT OF WORK DONE IN U.S.S.R. ON RADIO-ASTRONOMICAL STUDY OF MOON AND PLANETS

(prepared by V. V. Bazykin)

The radio-astronomical studies of the Moon and of the Solar System Planets were carried out at P. N. Lebedev Physical Institute, Academy of Sciences, U.S.S.R., Main Astronomical Observatory, Academy of Sciences, U.S.S.R., Institute of Terrestrial Magnetism, Ionosphere and Propagation of Radiowaves, Academy of Sciences, U.S.S.R., Institute of Applied Geophysics, Academy of Sciences, U.S.S.R., as well as at Gorky Radio Physics Research Institute, Ministry of Higher and Secondary Special Education, R.S.F.S.R.

1. *Study of Moon Radio-emission and Nature of its Surface*

From 1960 to 1963 Radio Physics Research Institute as well as Physical Institute, U.S.S.R., and Main Astronomical Observatory, Academy of Sciences, U.S.S.R., measured the Moon radio-emission in the millimeter, centimeter and decimeter frequency range. The analysis of the results gives the possibility to obtain new data on the physical nature of Moon surface layer.

A method of accurate measurement of radio emission by Moon and other sources (error within 1 to 2 per cent) has been worked out and successfully employed. The method is based on the comparison of the emission measured with the thermal radiation of an absolutely black disk of known angular dimensions (the 'artificial Moon' method, (**1**)). With the use of this method precision measurements of integrated radio emission by Moon were carried out on many wavelengths in the millimeter, centimeter and decimeter range (0·4, 1·62, 3·2, 10, 35, 36 and 50 cm) (**2, 3, 4, 5, 6**).

Besides, the Pamir alpine expedition at 3860 m, in addition to measurements on wavelength 0·4 cm has measured the radio-emission by the Moon on wavelengths 0·13 and 0.18 cm (**7, 8**). Together with the measurements made previously on wavelength 0·4 cm (**9**) and with those on wavelength 3·2 cm, which helped to discover the phase dependence (**10**), these new data were analyzed in a number of studies (**11, 12, 13, 14, 15**). As a result, the two-layer model of Moon surface was proved to be false and quasi-homogeneity of the surface layer represented by a hard foamy matter was established, first, to a depth of 1 m, and later, to a depth of 20 m. Among other values determined were the average spherical emissive capacity of Moon surface (0·96) and the average dielectric constant of Moon rock ($\epsilon = 1{\cdot}5$). The analysis of the precision data on the Moon effective temperature allows to determine the density of its rock ($\rho = 0{\cdot}5$ gr/cm^3) and the parameter $(k\rho c)^{-1/2} = 350 \pm 75$.

The theoretical study and the analysis of the precision measurements resulted in the conclusion, which looks very probable, that there exists a considerable thermal flux coming from the Moon interior (**16, 17**). The thermal flux density was found to be $1{\cdot}3 \times 10^{-6}$ cal/cm^2 sec, the specific thermal generation per gram of Moon matter $= 2.2 \times 10^{-7}$ cal/year which is five to six times higher than the specific thermal generation of chondrites and that of the Earth. New methods for direct measurements of the dielectric constant of the Moon rock were proposed (**18, 19**).

A series of measurements of brightness temperature distribution over the Moon disk were done with a 22-metre telescope on a number of wavelengths (0·8, 2, 3·2 cm). According to the measurements, 'radio images' of the Moon were constructed for the first time. The images show a systematic decrease of the brightness temperature on the limb and towards the poles, as well as a shift of maximum radio brightness area on the Moon disk. The analysis of the Moon 'radio images' allows to establish a law of the distribution of temperatures on Moon surface with the latitude ($\sqrt{\cos \psi}$), to determine independently the effective dielectric constant ($\epsilon = 1{\cdot}5$), and to derive the effective density of the material (near $\rho = 0{\cdot}5$). The analysis of the

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temperature phase dependence obtained supported the surface one-layer model theory (**20, 21, 22**). Detailed measurements of the brightness temperature distribution in the equatorial and the meridional areas made on wavelengths 0·8 cm and 0·4 cm (the latter in co-operation with Radio Physics Research Institute) revealed some difference in the radio emission intensity by the seas and the mainland areas of the Moon disk (**23, 24**).

Using the large Pulkovo radio telescope, one-dimension distribution of radio brightness over the Moon disk was obtained on 2·3 cm and an estimate made of the variable component amplitude in the disk centre ($\pm$ 13·5°K). On wavelengths 3·2 and 6·4 cm, linear polarization of Moon proper emission was detected and studied and data on the dielectric constant ($\epsilon = 1{\cdot}6 \pm 0{\cdot}1$) and on the nature of Moon surface emissivity (for the frequencies mentioned) obtained (emission cone $\pm$ 20°) (**25, 26, 27**).

2. *Study of Venus Radio-emission*

Venus emission was measured close to the time of its inferior conjunction in 1959 on wavelength 0·8 cm (**28**); in 1961, similar measurements were taken again in wavelengths 0·4, 0·8, 3·3 and 9·6 cm (**29, 30**). The temperature of the planet dark side averaged on the observed disk was found to be close to 400°K. It was shown for the first time that the Venus brightness temperature varies with the phase. The average temperature for the observation period near the dichotomia, measured on wavelength 3·3 cm, was equal to 542°K with a tendency to increase with the increase of the illuminated portion of the disk. On wavelength 9·6 cm the averaged brightness temperature for the observation period was close to 690°K. The difference in the temperature measured at millimeter wavelength and centimeter wavelength was explained by absorption of the surface radiation in the planet colder atmosphere. Some people believe that a Venus ionosphere accounts for the higher brightness temperature near 10 cm. The presence of the brightness temperature phase effect on wavelengths 0·4 cm and 0·8 cm is an evidence of the planet slow rotation and of the existence of mainland areas on its surface. Possible shifting of brightness temperature minimum after the inferior conjunction in the direction of the east elongations suggests a direct rotation (**31**).

The spectrum of Venus emission was measured in the centimeter range, close to the time of the inferior conjunction (**32**). Water content in the Venus atmosphere has been estimated (**33**) and the problem of its ionospheric model studied. The parameters of the ionospheric model that would fit the radioastronomical and radar data have also been determined and the possibility of detecting an emitting layer in the Venus low atmosphere demonstrated (**34**).

Venus observations between August and November 1962 on 3·02 cm with resolving power of about 1′ allow an estimate of the upper limit of the emission by the radiation zones (less than 6 per cent) and of the boundaries of the emission area ($< 1{\cdot}7\, R_♀$). The nature of the brightness distribution suggests some darkening at the disk edges on this wavelength. The absence of displacement of the radio emission center allows to determine the upper limit of the variable component of the Venus radio-temperature (less than 170°K).

On the basic of the study of recombination and ionization processes, similar to those observed in the Earth atmosphere, a model of the Venus ionosphere has been constructed (**35**) and the possibility of high electron concentrations in the Venus high atmosphere considered (**36**) since such concentrations are necessary to support the 'ionospheric' theory of its radio emission.

3. *Study of Jupiter Radio-emission*

From measurements of Jupiter radio-emission on 3·3 cm it was found that its average brightness temperature is about 193°K (**29**). The radio-emission of Jupiter on 8 mm (**31**) was detected for the first time.

Among other work performed were the calculations of the polarization, the intensity and the positional angle of the synchrotron emission in the dipole magnetic field (37). The Stokes parameters of synchrotron radio-emission in the dipolar magnetic field were calculated. It was shown that the intensity, the polarization degree and the position angle are functions of the energy spectrum index of the electrons and of their angular distribution. The problem of detecting the planetary radiation zones with the use of radio-astronomical methods was also considered.

4. *Radar Study of Planets*

The value of the Astronomical Unit determined during the radar experiment on Venus in 1961 has been confirmed by echoes on Mercury and some data on the surface reflexion coefficient of Mercury have been obtained (39).

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C. RADIO-EMISSION FROM THE GALAXY

(prepared by C. Westerhout)

Polarization

Undoubtedly the most outstanding development in the last three years is the discovery of the background emission and the Faraday rotation of the polarized component of the radiation from discrete sources. Measurements of the polarization of the galactic background emission were started in 1957 and seemed to be partially successful, but so uncertain that not much weight was attached to them. Since late 1960, 408 Mc/s measurements of the polarization provided full sky surveys down to about 0·5 °K in the linearly polarized components (**7, 46, 53**). Recently, the first series of observations at 610 Mc/s were obtained (**1a, 35**). The degree of polarization in most parts of the sky is a few per cent or less, whereas we expect 50% or more if the interstellar Faraday rotation is small and the magnetic fields are aligned. In one region of high polarization (up to 10%) there is some correlation with the polarization of starlight, the Faraday rotation seems to be rather small, and there are indications that the line of sight is at right angles to the direction of the magnetic field (**35**). It seems likely that the small degree of polarization is due to the fact that the galactic magnetic fields are rather tangled, particularly in the galactic halo. Higher resolving powers and observations at several different frequencies are planned in the near future. The linearly polarized component of the radiation from discrete sources, both galactic and extragalactic, suffers little Faraday rotation at high galactic latitudes, much at lower latitudes, indicating that the product of electron density and magnetic field strength NH increases towards the galactic plane, given the same path lengths (**1a**).

Unpolarized Continuum

One of the most important data needed for the interpretation of the galactic background emission is its spectrum. Accurate measurements of the absolute intensity up to 400 Mc/s have been made by the Cambridge group (**43, 47, 49**). At this frequency, where the background intensity goes down to 20°K or less, background radiation in sidelobes makes a determination of the zero level very difficult. We may hope that with great effort and specialized antennas, eventually the background intensity down to 21 cm might be determined; it is only a few degrees K at that wavelength. The spectral index between 38 and 400 Mc/s is in the neighbourhood of 0·5 or 0·6. At the low-frequency end, measurements of the background emission, averaged over a large part of the visible sky, were made with ground-based (**12, 21**) and rocket-borne receivers (Haddock), down to 1·25 Mc/s. They indicate that the spectral index decreases to zero at the lower frequencies and possibly becomes negative at the low-frequency end. It may be shown that at least part of this is due to absorption by the ionized interstellar medium.

Several high-resolution maps have been produced recently such as those at 19 Mc/s (beam-width 1·4 × 1·4 square degrees) (**26, 45**), at 38 Mc/s (1 × 1) (**23**), at 178 Mc/s (4·5 × 0·2) (**48**), at 408 Mc/s (0·8 × 0·8) (**28**), at 960 Mc/s (0·9 × 0·9) (**55, 56**), at 1400 Mc/s (0·9 × 0·9) (**31**) for the southern hemisphere, completing the earlier northern hemisphere map, and 2700 Mc/s (0·3 × 0·4) (**3**). The mapping with high resolution is now really underway, and many details become visible. The question of whether the spiral arms are really visible as

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