longitudes for Saturn and recommends that a Working Group be established to undertake a study of this matter with a view to proposing a definitive system for adoption as soon as practicable.

JOINT MEETING OF COMMISSIONS 16, 17 AND 40 ON 'RADIO AND RADAR STUDIES OF THE MOON AND PLANETS'

First Morning Session

J. E. B. Ponsonby: 'Moon Mapping by CW Radar at 162 MHz'.

The mapping of the Moon has been carried out at Jodrell Bank using a CW-radar technique similar to aperture synthesis. By observing the echoes in the same sense of circular polarization as the transmitted waveform, sensitivity only to diffuse scattering by small-scale surface roughness is assured. It is possible that a significant fraction of the energy is reflected from a depth of some 20 m. Observations were reported for several days in early 1970, when the lunar-terrestrial geometric configuration was favorable for the application of this technique. Angular resolution as viewed from earth was about 2′ arc, with the crater Tycho forming a particularly prominent scattering feature.

I. I. Shapiro, M. E. Ash, R. P. Ingalls, G. H. Pettengill, A. E. E. Rogers, M. Slade, W. B. Smith, and S. H. Zisk: 'Topography of the Moon, Mercury and Venus'.

Four radar methods of gaining topographic information on the surfaces of the Moon and planets were discussed. The first method depends on the accumulation of measurements of the radar time-of-flight to the sub-earth point. As the target rotates these may be used to explore the topography along the sub-earth track. Resolution is determined by the pulse-width used. The second method uses both delay and Doppler resolution to derive a profile along the equator of apparent rotation which may be compared with that expected from a spherical target. The third method involves stereoscopic comparison of delay-Doppler maps taken at different rotations. While applicable to large areas of the target, this method does not possess high accuracy. The fourth, and most sophisticated, method uses interferometry to fill in the coordinate otherwise missing in delay-Doppler mapping.

The second and fourth methods have been applied at M.I.T. to derive contours of the lunar surface good to an absolute accuracy of better than 500 m, while the first two methods have been applied to Venus and Mercury. The preliminary lunar results so far obtained show good agreement with optically-derived lunar maps over short distances, but seem to indicate 'drifts' in the absolute control of the optical method over longer distances. Very little topographic variation, at least at the resolution so far available, has been found on Venus in the equatorial belt, with only one region of about 2 km height in evidence. No departure from sphericity can yet be reliably reported for Mercury.

C. C. Counselman, M. E. Ash, G. H. Pettengill, A. E. E. Rogers, I. I. Shapiro and W. B. Smith: 'Radar Map of Martian Topography'.

Observations of Mars with the Haystack Radar ($\lambda = 3.8$ cm) during the oppositions of 1967 and 1969 have been combined to map variations of surface elevation, reflectivity, and roughness for nearly all longitudes and for latitudes from 2° to 22° North. Variations in height of approximately 15 km have been found. The radar maps show that the locations of dark visible markings are not systematically high or low, but certain prominent dark features occur on slopes. The dark visible features Syrtis Major, Trivium Charontis, and Cerberus are relatively smooth and have high radar reflectivity.

Following this paper, *R. A. Wells* presented his interpretation of Martian topography based on optical maps and an assumed internal structure.

G. C. Pimentel called attention to topographic results for Mars obtained from spectrographic observation of CO_2 pressures during the Mariner 6 and 7 flyby's. These consisted of a number of spot measurements between 0° and 40°S.

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G. H. Pettengill, D. B. Campbell, R. B. Dyce, R. P. Ingalls, R. F. Jurgens, and A. E. E. Rogers: 'Venus Radar Maps at 3.8 and 70 cm'.

During a four-week period surrounding inferior conjunction in April 1969, Venus was mapped using radars at a wavelength of 3.8 cm (M.I.T. Haystack Observatory) and 70 cm (Cornell University, Arecibo Observatory). The technique used was delay-Doppler mapping augmented with sufficient interferometry to remove the hemispheric ambiguity. The linear surface resolution was about 300 km in both maps, with coverage confined to a region between $+40°$ and $-50°$ in latitude and extending over about 80° (3.8 cm) and 120° (70 cm) in longitude. Only the sense of received polarization corresponding to quasi-specular scattering was analyzed. The maps agreed in respect to the location of most outstanding anomalously scattering features, including several dark, crater-like ring structures. The relative intensities differed between the maps, however, suggesting variability in the small-scale roughness from feature to feature.

D. O. Muhleman and G. L. Berge, 'Interferometric Observations of Venus and Mercury'.

Venus has been observed interferometrically at the Calif. Inst. of Technology's Owens Valley Observatory using baselines up to 1 km at wavelengths of 6 and 21 cm. Contrary to expectation a uniform disk brightness was found, both along the equator and towards the poles. The polarizations of the emission were in good agreement with those computed from a model assuming a surface dielectric constant of 4.8 and CO_2 atmosphere. A value of 6063.1 ± 3.7 km for the apparent radius of Venus was calculated from the zeroes of the 6-cm visiblity function. This may be compared with a value of approximately 6050 km for the surface radius as determined by radar. The 6-cm brightness temperature was found to be 660 ± 33 K.

For Mercury, a mean brightness temperature of 365 ± 15 K was observed at 3.1 cm. An observation at 6 cm near a 'hot equatorial pole' yielded a brightness temperature of 417 ± 43 K.

Second Morning Session

J. R. Dickel: 'The Microwave Spectrum of Venus'.

Observations of Venus at a number of microwave frequencies show that the brightness temperature of the planet increases markedly toward longer wavelengths as the emission arises from deeper within the atmosphere. Although calibration is difficult because there are no good 'absolute' standard sources for comparison, differential observations with respect to the single source Hydra A (assumed to have a straight spectrum) have given a good indication of the shape of the spectrum. The maximum brightness temperature of about 700 K occurs at a wavelength of about 6 cm where the surface is presumably reached but the evidence suggests that the temperature then decreases again toward still longer wavelengths. This apparent decrease has not been accounted for by any present models of the lower atmosphere and surface of Venus.

C. H. Mayer and T. P. McCullough: 'New Observations of Venus, Mars, Jupiter, Uranus and Neptune'.

Observations of Venus at 2.7 cm wavelength over a complete cycle of phase have yielded a brightness temperature of 614 ± 9 K (rms), independent of phase.

Observations of Mars and Jupiter at 1.65 and 2.7 cm are consistent with most other recent measurements. Observations of Uranus and Neptune at 1.65, 2.7 and 6 cm yielded brightness temperatures near 200 K for both planets at all three wavelengths.

E. E. Epstein: 'Microwave Spectrum of Mars and 3-mm Data on Mars, Jupiter, Saturn and Uranus'.

The microwave and millimeter-wave, illuminated-hemisphere brightness temperature of Mars appears to show no significant change with wavelength or phase. At 3 mm no secular variation in the brightness temperature of Jupiter and Saturn was observed between April, 1966 and November, 1969. The brightness temperature of Uranus at 3 mm was measured to be 105 ± 13 K.

A. G. Kislyakov, V. A. Efranov, I. G. Moiseev and A. I. Nauprov: 'Observations of Mars at 2.3 and 8 mm'.

The brightness temperature of Mars has been measured at 2.3-mm and 8-mm wavelengths as 240 ± 30 K and 210 ± 30 K, respectively. From the observed increase at short wavelengths, and using Troitsky's lunar radiation theory, we find for Mars:

$$\tan \delta/\rho = 0.015 \,^{+0.01}_{-0.008} \text{ and } m = \delta/\lambda = 1.2 \,^{+0.6}_{-0.4}.$$

These are approximately the same values as observed for the Moon.

A. D. Kuzmin, B. Losovsky and Yu. Vetukhnovskaya: 'Radiometric Observations of Mars at 8.22 mm'.

The radio emission of Mars at 8.22 mm wavelength has been measured using the 22-m Lebedev Radio Telescope and a maser receiver. The ratio of the Mars-to-Jupiter brightness temperatures was found to be 1.22 ± 0.04, which corresponds to $T = 176 \pm 5$ K for Mars. The best fit of these data to theory yields a ratio for loss tangent-to-density of: $\tan\delta/\rho = 5 \times 10^{-3}$. Thus the Martian surface material is a good dielectric.

A. D. Kuzmin and B. Losovsky: 'Radiometric Observations of Uranus at 8.22 mm'.

The radio emission of Uranus at 8.22 mm wavelength has been measured using the 22-m Lebedev Radio Telescope. The ratio of the Uranus-to-Jupiter brightness temperatures was 0.91 ± 0.01, corresponding to $T = 131 \pm 15$ K for Uranus. This value agrees well with a model for the atmosphere of that planet which requires saturated ammonia.

T. D. Carr: 'Jupiter's Magnetospheric Rotation Period'.

Five independent decametric determinations of the mean value of Jupiter's rotation period averaged over approximately one orbital period yield a value of $09^h55^m29^s.76 \pm 0.04$ sec. An analysis of all the available decametric data meeting certain criteria confirms the existence of a cyclic effect due to the variation in the Jovicentric declination of the Earth. The most probable value of the Jovian magnetospheric rotation period, based on both decametric and decimetric observations, is 09 hr 55 min 29.75 ± 0.04 sec.

S. Gulkis and B. Gary: 'Circular-Polarization and Total-Flux Measurements of Jupiter at 13.1 cm.'

Circular-polarization and total-flux measurements of Jupiter at a wavelength of 13.1 cm were made during April and May, 1969, with the 210-foot JPL radio telescope at Goldstone, California. An upper limit of 1 percent to the degree of circular polarization can be placed over the longitude range, 10°–100° and 160°–250° System III (1957.0). This contrasts with an earlier determination deduced from interferometric fringe data which suggested the presence of 2 percent circular polarization at this wavelength and within the same longitude coverage. Total flux data have been used to derive a magnetosphere rotation period of $09^h55^m29^s.72 \pm 0.11$. This period is longer than the standard IAU System III (1957.0) by $0^s.35$.

R. G. Conway: 'Polarization of Jupiter's Decimetric Emission'.

Observations made at 49 cm using Jodrell Bank radio telescopes have deduced a rotational period for Jupiter in close agreement with the values given in the preceding two papers. The degree of circular polarization noted is consistent with a magnetic field of a few tenths of a gauss at a distance of 3 Jupiter radii.

G. L. Berge: 'The Position of Jupiter's Radio Emission Centroid at 21 cm'.

The interferometer at the Owens Valley Radio Observatory has been used to determine the position of Jupiter's 21-cm emission centroid in a rotating coordinate system fixed to the planet. There appears to be a small displacement between the emission centroid and the planet's center amounting to 0.13 ± 0.06 polar semidiameters. The difficulties associated with measuring the position of the source to an accuracy of 2 or 3% of its size were overcome by the excellent phase stability of the instrument which allowed high angular accuracy despite the use of baselines short enough to avoid resolution of the source.

Summaries of contributed papers to IAU Commission 16

G. de Vaucouleurs: 'Areographic Coordinates and New Maps of Mars.'

A twelve-year Mars map project, now 90 % complete, has as its principal objectives the derivation in a uniform coordinate system of the areographic positions of several hundred individual markings on Mars from all available groundbased observations (since 1877); and the production of albedo maps from this coordinate net. The principal results include a new value of the rotation period [$P_t = 24^h 37^m 22^s.665 \pm 0.003$ (m.e.)]; a new estimate of the phase effect in longitudes, improved areographic longitudes, areographic coordinate maps of Mars and the development of planning charts for the Mariner Mars 1971 mission.

T. Gehrels: 'Recent Polarimetric Observations of Planets.'

Gehrels reported on the polarimetric work of himself and his collaborators. The wavelength dependence of polarization between 0.3 and 1.0 μ is flatter for Mercury than for the moon and may indicate an appreciable difference in surface composition between the two bodies. The integrated disc of Venus was observed at 97.9° phase angle with the Polariscope balloon system; at 2150 Å the polarization was 23%. Groundbased scans of Venus show that the cloud pattern contrast in the ultraviolet has a rather sudden onset near 4000 Å attaining a constant value over the range of 3600–3100 Å. Ultraviolet polarization scans appear to correlate inversely with the intensity scans. Coffeens's computations of single Mie scattering and multiple Rayleigh scattering give the following conclusions: the atmospheric pressure at the cloud tops is less than 50 mb; the bulk of the highest cloud particles (responsible for single scattering) have diameters of about 2.5 μ; and a real part of the refractive index between 1.43 and 1.55 with some uncertainty should the particles be non-spherical. The opposition effect is found to be the same for the asteroids (20) Massalia, (4) Vesta, and (110) Lydia. The opposition effect appears connected with surface texture only and not with composition.

Neil B. Hopkins, William M. Irvine, and Adair P. Lane: 'Monochromatic Albedos for Saturn.'

Multicolor photoelectric photometry at wavelengths $0.315 \leqslant \lambda \leqslant 1.06\ \mu$ for Saturn during 1963–65 has provided albedos for the disk of Saturn. The disk spectrum appears generally similar to that of Jupiter, but Saturn has a steeper slope for $\lambda \leqslant 6250$ Å and so appears redder. A marked opposition effect, apparently due to the rings, is noted.

Brian O'Leary: 'The Halo Effect of Venus and the Opposition Effect of Mars.'

Photometric observations of Venus near the 1969 inferior conjunction indicate an anomalous brightening of about 0.07 magnitude at 158° phase angle. The width of the brightness maximum is about 3° and its peak is between 1.1 and 4.4 standard deviations, depending on color, from the expected background phase curve. This is precisely the behavior expected if the Venus cloud tops were to contain at least a few percent of hexagonal water-ice crystals, producing a halo effect analogous to the common terrestrial 22° halo phenomenon. The results may be considered provocative but not unambiguous.

Photometry of the full disk of Mars near opposition 1969 confirms the existence of a moderate opposition effect, i.e. a non-linear surge in brightness toward zero phase. Observations of small areas on the disk suggest a very strong opposition effect for Syrtis Major; the extent is somewhat similar to the lunar case. We also confirm a 13% absorption feature near 1.0 μ in the ratio spectrum Syrtis Major/Arabia. Contrary to earlier analyses, the color of Syrtis Major/Arabia appears to have changed from previous observations such that the brightness contrast is greater in the red and near-infrared than at shorter wavelengths.

Peter B. Boyce: 'Specific Martian Studies.'

Direct photoelectric area scans and photometric analysis of the Lowell planetary patrol films have yielded the following results: (1) Contrast in the red, 6200 Å is a linear function of contrast in the blue, 4340 Å; red contrast is high at times of blue clearing. (2) For Syrtis Major the contrast in all spectral regions shows a definite dependence upon phase angle, being highest at small phase angles and decreasing symmetrically with increasing phase angle. (3) For Syrtis Major the contrast in red, green, and blue light shows a diurnal variation. Maximum contrast apparently occurs at the angle of specular reflection. (4) In red light Syrtis Major shows no significant limb darkening out to viewing angles of 45° from the center of the disk. These conclusions have been shown to be unaffected by seeing variations in the Earth's atmosphere. These data were obtained for the noted features at the 1969 opposition and, in view of the variability of the Martian features, extrapolation to other features and times is probably not valid.

J. Rösch, H. Camichel, F. Chauveau, M. Hugon, and G. Ratier: 'An Upper Limit to the Diameter of Mercury.'

During the 7 November 1960 transit of Mercury across the Sun, we previously obtained by the Hertzsprung photoelectric method a value for the diameter of Mercury at unit distance of 6.84 arc sec. An attempt to confirm these results by the transit of 9 May 1970 was thwarted by cloudy skies both at Pic du Midi and at Athens. Nevertheless, despite the dispersion in the data points, significant results seem to have been obtained with the 40 cm Doridis refractor, giving a value consistent with our earlier results (corresponding to a diameter of 4920 km) and implying an upper limit to the density of the planet at 5.10 gm cm^{-3}.

T. Encrenaz, D. Gautier, L. Vapillon, and J. P. Verdet: 'Far Infrared Spectrum of Jupiter.'

The far infrared spectrum of Jupiter, between 20 and 250 cm^{-1}, is computed with high resolution from three atmospheric models. The results of the spectroscopic analysis of H_2 and NH_3 are used for the radiative transfer calculations. The detailed study of the derived spectra shows how the H_2/He ratio and the thermal Jovian structure can be deduced for far infrared measurements of the Jovian flux. In particular, such measurements provide an obvious test of the existence of an inversion in the Jovian temperature profile; the experimental accuracy needed for this information is shown to be obtained with the existing equipment.

G. E. Thomas: 'Results of the Mariner Mars 1969 Ultraviolet Spectrometer Experiment.'

The results for the atmospheric composition of Mars are summarized. The dominant constituent is carbon dioxide with less than 5% nitrogen by volume. Laboratory experiments on pure CO_2 have now simulated every emission feature observed on the bright atmospheric limb. Carbon monoxide, atomic hydrogen, carbon and oxygen are minor constituents. Three topics which were discussed in some detail are: (1) the observed reflected spectrum in terms of atmospheric scattering, ground reflection, aerosols, and large dust particles; (2) the use of the spectrometer as a means of determining local relief, 'UV cartography'; and the data which show that the Hellas region is a very extensive low region on Mars; and (3) the discovery of a strong absorption feature at 2500 Å over the polar cap. Various explanations are put forward to account for the presence of ozone on the polar caps, but not over the land areas. Either adsorbed ozone in the solid CO_2 itself could account for the observations or ozone distributed uniformly over the planet, but in a thin boundary layer near the surface.

Harlan J. Smith: 'Seasonal Changes in Atmospheric Water Vapor on Mars.'

McDonald Observatory coudé spectra and analysis, primarily by E. Barker, R. Tull, and S. Little of the University of Texas, A. Woszczyk of Torun University, and R. Schorn of the Jet Propulsion

Laboratory, establish that water vapor appears at detectable levels (about 10 μ) in the Martian atmosphere during the late spring of each successive hemisphere. By midsummer it has risen to about 40 μ of precipitable H_2O in a vertical column. The water vapor then falls below detectable levels over the entire planet, effectively disappearing for the several months of early autumn, before reappearing with the new late spring season of the opposite hemisphere. The data suggest that the appearance may be delayed a few weeks in the southern hemisphere spring, but that the amount of water may be slightly greater during the southern hemisphere summer.

F. Link: 'On the Optical Radius of Venus.'

The aim of this paper is to connect the provisional Venus atmospheric model of Marov, based on Venera data, with observed optical phenomena. Horizontal refraction is calculated and compared with the refraction curve deduced from the Regulus occultation. A positive correction of about 0.5 in logarithms is required to the model at 6165 km. The aureole (the refracted image of the Sun produced by the atmosphere of Venus) observed during the past 4 transits indicates a refraction of about 1 minute, but at an indefinite altitude. The refraction curve gives the transit level at between 6128 and 6132 km. This should be the level of horizontal transparency. For a pure atmosphere the extinction is too small. Another source of extinction may be indicated in the Venera 5 and 6 results which indicate a layer of high water content whose upper limit is just at the transit transparency level. The upper water level in the Venera results should therefore be considered as the cloud level of the Venus atmosphere. These results provide an indirect confirmation of Marov's model in this region.

Stephen E. Dwornik: 'Mariner Venus-Mercury 1973 Mission.'

The National Aeronautics and Space Administration will conduct a mission to the planets Venus and Mercury in the fall of 1973. The spacecraft will be a Mariner Class spacecraft and will weigh about 455 kg. The launch period will be 12 October to 20 November 1973, with Venus encounter between 19 March and 3 April 1974. The primary mission objective is to conduct exploratory investigations of the planet Mercury's environment, atmosphere, surface and body characteristics and to obtain environmental and atmospheric data from Venus. Secondary objectives include interplanetary experiments. The following is the science payload, with principal investigator and his organization: Imaging – B. Murray, California Institute of Technology; Radio Science – H. T. Howard, Stanford University; Plasma Science – H. Bridge, Massachusetts Institute of Technology; Magnetometer – N. Ness, Goddard Space Flight Center; Ultraviolet Spectrometer – A. L. Broadfoot, Kitt Peak National Observatory; Infrared Radiometer – S. Chase, Santa Barbara Research Center, and Energetic Particles – J. Simpson, University of Chicago.

In discussion A. D. Kuzmin stressed the utility of passive microwave observations from Venus flybys or orbiters.

William E. Brunk: 'Mariner '71, Viking '75 and Pioneer F and G Missions.'

Brief summaries of three future planetary missions planned by the National Aeronautics and Space Administration were presented. In 1971 two Mariner spacecraft will be placed into highly eccentric orbits about Mars with nominal 90-day lifetimes. One space vehicle is intended for mapping a large fraction of the planet at 1 km resolution; the other for looking for time-variable features. Experiments include two television cameras, an ultraviolet spectrometer, infrared interferometric spectrometer, two infrared radiometers, an S-band occultation experiment and a celestial mechanics experiment. A wide range of information on the atmosphere, surface and interior of Mars are anticipated. It is planned to follow up with the Viking 1975 mission, currently envisioned as involving two orbiters and two soft landers, each to be ejected from its own orbiter. Rendezvous with Mars occurs in 1976. Among a variety of Lander experiments now planned are some intended to search for life. The nominal life time of the landers and orbiters is 90 days. The Jupiter 1972–73 mission involves two space vehicles which fly by Jupiter and perform a detailed investigation of its particle and field environment as well as single line imagery and photopolarimetry of the surface, and examination of Jupiter in the vicinity of the 584 Å line of helium. In addition there are experiments devoted to the passage through the asteroid belt which precedes the Jupiter rendezvous. Emphasis was placed on the anticipated contributions of these three programs to our understanding of the solar system.

In discussion Carl Sagan stressed that mission B of the Mariner Mars 1971 program is designed to have an orbital period four-thirds the Martian rotational period so that every four days the spacecraft observes the same area under the same lighting conditions. In this way intrinsic Martian albedo changes can be distinguished from effects due to the scattering phase function of surface material. He also mentioned the possibility that photographic mapping of Phobos and Deimos by the Mariner Mars 1971 mission would provide cartography of these moons superior to the best groundbased cartography of Mars.

PLANETARY PATROL – AN INTERNATIONAL EFFORT

W. A. Baum

Lowell Observatory

Abstract. An international photographic planetary patrol network, consisting of the Mauna Kea Observatory in Hawaii, the Mount Stromlo Observatory in eastern Australia, the Republic Observatory in South Africa, the Cerro Tololo Inter-American Observatory in northern Chile, and the Lowell Observatory, has been in operation since April 1969. The Magdalena Peak Station of the Mexico State University also participated temporarily. New stations are now being added at the Perth Observatory in western Australia and at the Kavalur Station of the Kodaikanal Observatory in southern India. During 1969 Mars and Jupiter were photographed through blue, green, and red filters; and the network produced more than 11000 fourteen-exposure filmstrips with images of a quality suitable for analysis. Observations of Jupiter and Venus in 1970 are expected to add another 15000.

All telescopes of the network have apertures in the 60-to-70 centimeter range, have been designed or modified to produce identical image scales, and are equipped with identical planet cameras that provide for the automatic recording of basic data associated with each exposure. All of the patrol observations are being calibrated, processed, edited, copied, and catalogued by the staff of the Planetary Research Center at the Lowell Observatory. The support of NASA Headquarters is gratefully acknowledged.

ACTIVITIES OF THE PLANETARY RESEARCH CENTER OF THE LOWELL OBSERVATORY

W. A. Baum

Lowell Observatory

Abstract. The research program of the Planetary Research Center at Lowell Observatory, established through the IAU, includes photoelectric measurements at the telescopes, the development of new instruments for planet observation, and the analysis of photographic images. In addition, the Center is managing the International Planetary Patrol Program (described separately).

Photoelectric observations have particularly utilized pulse counting and multichannel storage in the scanning of planetary spectra, planetary brightness profiles, planetary polarization distribution, and satellite brightness changes. The spectrum scanning and area scanning methods have been applied by Boyce to Mars and Jupiter. Hall and Riley have made photoelectric scans of Mars, Jupiter, and Saturn. Millis and Franz have used area scanning to show that the Jovian satellite Io does not brighten anomalously on its emergence from eclipse.

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