16. COMMISSION POUR L'ETUDE PHYSIQUE DES PLANETES ET DES SATELLITES

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MEMBRES: Ashbrook, Barabashov, Barreto, Bobrov, Bullen, Camichel, Chamberlain, Collinson, DeMarcus, De Mottoni, de Vaucouleurs, Drake, Focas, Fox, Gehrels, Giclas, Gold, Guérin, Günther, Hall (J. S.), Hunten, Ingrao, Jeffreys, Jelley, Kaplan (L), Kellog, Kiess, Kopal, Koval, Levin, Link, Lipsky, Luplau-Janssen, Martynov, Menzel, Middlehurst, Miyamoto, Murray, O'Keefe, Öpik, Peek†, Pettengill, Rösch, Safronov, Shoemaker, Sinton, Smith (B. A.), Smith (Harlan J.), Spinrad, Strong, Tombaugh, Urey, Whitaker, Wilson (A. G.).

INTRODUCTION

Owing to the formation of Commission 17, which has, since 1964, cognizance of all lunar studies, this report deals only with research on other satellites and the planets published during the period from 1964 until 1966. Unforeseen circumstances have forced the President of Commission 16 to distribute the work of compiling this report among several members, to whom he is greatly obliged for assuming this responsibility. Their respective contributions are:

- Photometry, Polarimetry of the Planets and Observations of Planetary Surfaces, by J. H. Focas.
- Spectroscopic Studies of the Planets, by T. Owen.
- Radio Studies of the Planets, by C. H. Mayer and M. Spangler.
- Internal Constitution of the Planets, by W. C. DeMarcus.
- Exobiology, by C. Sagan.

An appendix has been added, prepared by D. Ja. Martynov, on the Physics of the Planets in the U.S.S.R. (1963–66), although some of the above sections take Soviet publications into full account.

AD HOC COMMITTEE ON MARTIAN NOMENCLATURE

Professor Robert B. Leighton of the California Institute of Technology, who is the principal investigator of the TV experiment conducted during the Mariner IV flight, has sought the advice of Commission 16 in regard to the problem of devising a nomenclature suitable for the Martian surface features discovered on the prints developed from the Mariner IV data.

Accordingly, the President of Commission 16 appointed an Ad Hoc Committee to advise Professor Leighton, consisting of the following members of Commission 16: G. P. Kuiper (chairman), A. Dollfus, J. S. Hall. This committee met in Pasadena in September 1965 and thereafter continued deliberations by correspondence. It is hoped that report can be submitted to Commission 16 at the next General Assembly.

PHOTOMETRY, POLARIMETRY OF THE PLANETS AND OBSERVATIONS OF PLANETARY SURFACES

(prepared by J. H. Focas)

A. Planetary Data Centers and International Cooperation for the Observation of the Planets

An extensive work was developed by the two Data Centers established at the Lowell and the Meudon Observatories since 1961 by the IAU. Dr J. H. Focas is in charge of the Meudon Planetary Data Center, and Dr. W. A. Baum in charge of the Lowell Observatory Planetary Data Center. For the time being, a total of more than 15 000 documents are available at the Lowell Center and approximately 10 000 documents at the Meudon Center. Such documents are listed and filed according to the geometrical data of the individual planets. They are consultable under the form of original negatives, or counter-copies of original negatives, original composite images, negatives of the composite images or reproductions on paper or/and films.

The observatories which have contributed by exchanging documents with the Centers and/or performing observations, in the line of the International Cooperation for the observation of the planets, are the following:

Africa:	Brazzaville, Johannesburg.
Asia:	Kwassan, Tokyo (Japan).
Europe:	Athens (Greece); Genova, Rome (Italy); Juvisy, Meudon, Nice, Pic-du-Midi (France).
U.S.A.:	Harvard (Mass.); Lick, Mt Wilson, Table Mountain (Calif.); Lowell, Tucson (Arizona); MacDonald (Texas); New-Mexico (New-Mexico).
U.R.S.S.:	Kiev, Volgograd, Alma-Ata.

'The Brighter Planets' published in 1964 by the Lowell Observatory is the last work of the late Dr E. C. Slipher. It contains a great number of photographs of Venus, Mars, Jupiter and Saturn taken by him in the last 60 years. Such photographs are among the best ever taken and are accompanied by an extensive explanatory text reflecting the most salient characters of the planetary phenomena.

This Commission, through Committee 16*c* 'International Cooperation for the Observation of the Planets' has organized the following observational campaigns:

Venus: Photography in short wavelengths for studying evident periodicities of atmospheric phenomena.

Mars: Apparition 1964–65. Photography and polarization in different wavelengths for studying the nature of the soil, clouds and their motion; high resolution mapping; coordinated ground based observations with the flight of Mariner IV to Mars.

Jupiter: Photographic patrol of the planet at one minute intervals for many hours per night, for the revision of the rotation period as a function of the zenographical latitude, study of proper motions of atmospheric formations as well as the short or long term atmospheric activity of the planet.

Saturn: Photographic, visual and photometric observations during the transits of the Sun and the Earth from the plane of the Rings in 1966–67. Professor Bobrov and Dr P. Muller mostly contributed to the preparation of the program of this international campaign.

B. Specific Results Concerning Individual Planets

The results obtained during the period 1964–66 for each one of the planets, including those obtained by the International Cooperation for the Observation of the Planets and research carried out by the two Planetary Data Centers are summarized in the following.

The Planet Mercury

Observations: G. P. Kuiper and T. Gehrels using a 154 cm reflector at *F*/13 are performing a program of photometric and polarimetric measurements on the planet with seven filters between 0·3 and 1·0 microns and with experiments at shorter and longer wavelengths.

A. Hämeen-Anttila using photographs of the planet taken at Pic-du-Midi Observatory in 1942–44 by B. Lyot and H. Camichel, carried out at the Meudon Observatory a photographic study on the purpose to compare the contexture of the soil of Mercury to that of the Moon.

B. Smith and cooperators have been successful in photographing the planet in red light (77 plates) at the New-Mexico Observatory. Surface markings which may be seen on many of the plates, are being studied as a possible source for an optically derived rotation period. To-date, no conclusive results have been obtained.

Dr Menzel and W. M. Irvine report that multicolor photoelectric photometry of the planet was made by the Harvard College Observatory at the Stations of Boyden (South-Africa) and the Houga (Southern France), using ten narrow band filters between 0·315 and 1·06μ plus *UBV* on the purpose to obtain monochromatic phase curves and albedos.

A. Dollfus carried out in 1966 systematic visual observations at the Pic-du-Midi Observatory for the study of the rotation period of the planet.

Theoretical investigations: C. Sagan studying the photometric properties of Mercury, suggests a common cause for the similarities of the surfaces of this planet and the Moon. The solar proton wind cannot penetrate the atmosphere of Mercury implied by spectrometric and polarimetric observations, and contemporary solar cosmic ray protons have sufficient intensity to account for the observed properties with the age of the solar system. A conceivable alternative source of proton irradiated powders is accretion of interplanetary dust slowly falling through the thin Mercurian atmosphere (**1**).

The Planet Venus

Observations: Ch. Boyer, H. Camichel and P. Guérin carried out at the Pic-du-Midi Observatory (106 cm reflector) an extensive photographic patrol of the planet in violet and ultra-violet light during the evening elongation in 1965 and the morning elongation in 1966. High quality series of photographs taken uninterruptedly during one or two, up to seven hours, allowed stereo-photogrammetric measurements, tracing of isophote maps and composite images of the planet, for the study of the motion of bright or dusky areas through the disk. The motion of such atmospheric formations is in general retrograde; the recurrence of a Y-shaped formation normal to the line joining the cusps follows a cycle of approximately four days. Some connection seems to exist between the position of the sub-solar point on the disk and the aperture of the Y-shaped formation, which is variable (**2, 3**).

G. P. Kuiper and T. Gehrels using a 154 cm reflector at *F*/13, are performing a photo-polarimetric program on the planet with seven filters between 0·3 and 1·0 micron and with experiments at shorter and longer wavelengths.

R. Younkin has conducted spectrophotometric measurements on the planet at JPL from 0·32 to 1·1μ.

B. Smith and cooperators at the New Mexico Observatory photographed the planet (1081 plates) in ultra-violet, blue and red light during the last three years. Measures of the height of the scattering layer in the atmosphere and studies of motions of atmospheric clouds have been continued (**4**).

D. Menzel and W. M. Irvine report that multicolor photoelectric photometry of the planet was made by the Harvard College Observatory at the Stations of Boyden (South Africa) and the Houga (Southern France) using ten narrow band filters between 0·315 and 1·06μ plus *UBV* on the purpose to obtain monochromatic phase curves and albedos.

A. Dollfus and E. Maurice carried out a photometric study of photographs of Venus taken by him in 1964 at the Pic-du-Midi Observatory during the inferior conjunction of the planet. The photometry of the aureola lengthening the horns shows that the Venusian atmosphere overlying the clouds layer is charged with particles of approximately $1{\cdot}5\mu$ diameter, the number of which decreases by a factor 2 over 2·8 km approximately; their diffusion factor per cubic centimeter opposite to the Sun amounts to $3{\cdot}10^{-8}$ stilb/phot at the level of the clouds layer (**5**).

A. Dollfus and collaborators carried out during the period 1964–66 systematic polarimetric observations of the planet in the spectral ranges $\lambda = 0{\cdot}47, 0{\cdot}55, 0{\cdot}65, 0{\cdot}84, 0{\cdot}95, 1{\cdot}05\mu$ at the Pic-du-Midi and the Meudon Observatories for the study of the variation of the polarization with the wavelength. This variation is connected with the size of the particles diffusing the light in the atmosphere of the planet. The non-uniform distribution of the polarization over the disk was studied; the deviation of the direction of the polarization at the limb can be explained by multiple scattering in the atmosphere overlying the clouds layer.

C. Capen at the Table Mountain Observatory carried out systematic photographic observations of the planet during the last four years.

H. Prinz and H. Obendorfer carried out respectively photographic (*UV*) and visual observations of the planet, at the Volkssternwarte in Munich in 1964.

I. L. Thomsen at the Carter Observatory, Wellington, New Zealand, conducted visual observations of the bright cusp-caps and terminator peculiarities of the planet.

Theoretical investigations: According to J. B. Pollack and Carl Sagan, an intercomparison of passive microwave observations at a variety of phase angles and frequencies, coupled with the radar reflectivities, can potentially provide information on the chemistry and structure of the Cytherean surface material. A variety of silicates, carbonates and oxides and one variety of organic molecule-polycyclic aromatic hydrocarbons—can be postulated as primary constituents of the Cytherean surface. The thermal, magnetic and electrical properties of these materials have been analyzed as a function of frequency, temperature, porosity, granularity and impurity content. The comparison of Venus and laboratory data shows that fused quartz and a wide range of powdered oxides, carbonates and silicate may, to within observational uncertainty be primary Cytherean surface materials. Magnetic materials, granite and the hydrocarbons are excluded. The surface is likely to be a desert. The low radar reflectivity at 3·6 cm cannot be due to a general 3·6 cm absorption by the atmosphere and clouds. The result can be attributed to a localized high absorption above a surface cold spot in the first radar Fresnel zone, or to variation of porosity of surface material and therefore of the dielectric constant with depth (**6**).

C. Sagan and J. Pollack established surface temperature distributions on Venus needed to match the microwave phase and polarization observations which are consistent with observations made by Mariner II (**7, 8**).

According to C. Sagan and J. Pollack, balloon observations of near infrared reflectivity of the clouds of Venus and ground based infrared spectrometric observations show the presence of condensed water in the clouds and water in the atmosphere above the clouds. The amount of water vapor in the underlying atmosphere of Venus required to maintain the clouds is of the order of 10 g cm^{-2}. The opacity of this amount of water vapor, combined with that of carbon dioxide and of the clouds themselves, provides an efficient greenhouse effect, quantitatively capable of maintaining surface temperatures ~ 700° Kelvin (**9**).

E. R. Lipincott, R. Eck, M. O. Dayhoff and C. Sagan, by studies of the thermodynamic equilibrium chemistry of the planet, indicated the absence of significant quantities of organic materials, particularly polycyclic aromatic hydrocarbons on the surface of Venus (**10**).

N. P. Barabashov (Kharkov Astron. Observatory), performed a theoretical analysis of data on brightness distribution across the disk of Venus which made it possible to estimate the value of the optical thickness of the layer situated above the cloud cover, $\tau \leqslant 0{\cdot}07$ (**11**).

The Planet Mars

Martian cartography: Continuing the program of Martian cartography established by the Meudon Planetary Data Center, G. de Mottoni prepared, on the basis of photographic documents taken at the Lowell Observatory, three photographic maps of Mars covering the apparitions of 1907, 1909 and 1911. This work is being published by the Milan Observatory in cooperation with the Meudon Planetary Data Center. The photographic maps of Mars prepared till now by G. de Mottoni from documents existing at the Meudon Planetary Data Center cover the apparitions of 1907, 1909, 1911, 1941, 1943, 1946, 1948, 1950, 1952, 1954, 1956 (two), 1958. The details contained in these maps are of the order of $< 0{\cdot}5$ second of arc. They show the evolution of the seasonal phenomena of the dark areas of the planet and accidental variations of the surface.

The maps covering the apparitions of 1914, 1916 and 1918 are in preparation.

A high resolution (up to 0·25 second of arc) photovisual map of Mars was established at the Meudon Planetary Data Center on the basis of photographic documents and visual observations taken by H. Camichel, A. Dollfus and J. H. Focas, at the Pic-du-Midi Observatory (107 cm reflector) and Meudon Observatory (83 cm refractor) during the 1964–65 apparition of the planet. This map, as well as ground based polarimetric observations, taken by A. Dollfus and J. H. Focas at the Meudon Observatory, were designed to help in the interpretation of the photographs taken by the spacecraft Mariner IV.

An Atlas containing rectified photographs of Mars taken by Mariner IV was prepared by G. de Mottoni; the same studied the altitude of a cloud appearing on Mariner's IV photographs at the Amazonis region.

During the 1964–65 opposition, Ch. Capen *et al.*, at the Table Mountain Observatory carried out a systematic photographic and visual patrol of the planet and especially of the Amazonis desert – Trivium Charontis – Elysium Regions and related atmospheric phenomena. A photovisual map of Mars of the Mariner IV scan longitudes has been prepared by the same as well as a pictorial map of Mars Atlas 1964–65 (358 photographs). The former established also the regression curve of the north polar cap (**12, 13**).

Observations: R. G. Tull through spectral scan of Mars made at the 82-inch (208 cm) telescope in the range of $0{\cdot}5$ to $1{\cdot}2\mu$ obtained a spectral reflectivity curve of this planet extrapolated with the aid of published data to $1{\cdot}52\mu$. He finds the Russell-Bond albedo rising to a maximum of 39% at $0{\cdot}84\mu$. A shallow minimum occurs near 1μ followed by a rise to 49% at $1{\cdot}52\mu$. The radiometric albedo is found to be 0·287. Earlier conclusions that the surface layer of Mars consists largely of limonite are consistent with these observations (**14**).

G. P. Kuiper and T. Gehrels using a 154 cm reflector at $F/13$, are performing a photopolarimetric program with seven filters between 0·3 and 1·0 micron and with experiments at shorter and longer wavelengths.

R. Younkin has conducted at the JPL spectrophotometric measurements of the planet from $0{\cdot}32$ to $1{\cdot}1\mu$. The monochromatic reflectance of Mars has been measured as a function of phase angle and the specific intensity of the maria compared to the continents.

H. Camichel, A. Dollfus and J. H. Focas carried out systematic photographic observations of the planet during the apparition of 1964–65 at the Pic-du-Midi Observatory through the 106 cm reflector in the spectral ranges $0{\cdot}32$ to $0{\cdot}85\mu$. High resolution visual observations of the planet were made through the 106 cm reflector of the Pic-du-Midi Observatory and the 83 cm refractor of the Meudon Observatory to complement the photographic observations.

A. Dollfus and J. H. Focas conducted systematic polarimetric observations of the planet during the 1964–65 apparition of the planet in the spectral ranges 0·47 to 1·05μ at the Pic-du-Midi and the Meudon Observatories.

A. Dollfus and E. Bowell carried out laboratory work by studying simultaneously the polarimetric and photometric properties of samples for the purpose of matching them with analogous properties of the soil of Mars. They conclude that the surface of the soil of the ochre colored desertic bright areas of Mars is similar to a mixture of fine grains of any size, wrapping each other and forming a sufficiently areated deposit of a low roughness. The grains consist of limonite, or a pulverized absorbent and opaque material with the surface of the grains coated by a deposit of hydrated iron oxide of the limonite type.

As regards the dark areas, new polarimetric data confirm previous results as per which the seasonal darkening of these areas is associated with the change of their microscopic contexture.

A. Dollfus studied the scattering coefficient of the atmosphere of Mars in 0·61μ. He infers the depth for the Martian atmosphere, under normal conditions to be $7 \cdot 10^4$ cm and an atmospheric pressure on the ground of approximately 30 millibars (**15**).

A. Dollfus and J. H. Focas studied the transparency of the Martian atmosphere in the blue and concluded that the luminance of the atmosphere amounts, for the phase angle zero, to 0·07 times the luminance of the soil (**16**), proving a fairly good agreement with the Rayleigh scattering law λ^{-4} for the atmosphere of Mars.

J. H. Focas studied the visibility of the surface markings of Mars in blue and ultra-violet light, on photographs taken mainly at the Lowell Observatory during the last 40 years. He concludes that: semi-tone markings show an increasing intensity in the short wavelengths and provoke deformation of the usual aspect of the planet; the surface of the planet remains for the most part of the time visible irrespectively of the wavelength; there are tenuous veils of variable opacity seen in short wavelengths which seem to follow a seasonal cycle (**17**).

J. H. Focas using a polarizing micro-photometer at the Meudon Observatory measured the contrast between bright and dark areas of Mars on photographs taken at Pic-du-Midi Observatory in the spectral area 0·32 to 1·08μ during the apparition of the planet in 1963. This contrast decreases with decreasing wavelength, a limb darkening is evident in the absence of bright areas at the limb.

C. Banos using a microdensitometer at the Meudon Observatory obtained tracings from photographs of the planet taken at the Pic-du-Midi Observatory in 1963 and 1965, confirming the existence of limb darkening as above.

B. Smith and cooperators at the New Mexico Observatory took photographs of the planet (946 plates) in UV, blue, green, red and infrared light. Studies of photographs have included measures of the aerographic coordinates of features recorded during the 1965 apparition and a more general investigation relating to the morphology of the Martian surface. A correlation between reported radar reflectivity and optical features has been found. Comparison between the dark areas recorded in red light and the so-called 'atmospheric' features recorded in blue light are being thoroughly investigated. Photoelectric-photometric observations made during 1965 apparition tend to support the opinion of J. C. Robinson and B. A. Smith that many, perhaps most, phenomena observed in blue and ultraviolet light are related to the Martian surface and not to its atmosphere (**18, 19**)..

Photoelectric observations of the planet were taken at the New Mexico Observatory (145 *UBV* sets).

At the Main Astronomical Observatory of the Ukrainian Academy of Sciences, U.R.S.S., I. K. Koval and A. V. Morozhenko obtained during the period 1963–65 series of polarimetric observations of the planet in eight spectral intervals (355–600 mμ) through an automatic photoelectric polarimeter attached to the 28-inch (71 cm) reflector.

It has been found from the phase curves of polarization that the angle of inversion shifts from 27° ($\lambda = 600\,\mathrm{m}\mu$) to 15° ($\lambda = 355\,\mathrm{m}\mu$). Analogous laboratory investigations on 16 terrestrial samples having the same photometric properties as Mars show that the angle of inversion is independent from wavelength. They explained the displacement of the angle of inversion as due to the Martian atmosphere and determined the atmospheric pressure at the surface (19 ± 8 mb). The comparison of the polarization properties of Mars and terrestrial samples shows the best resemblance of Fe_2O_3, $2H_2O$ to the Martian surface (**20, 21, 22**).

Mrs L. A. Bugaenko, O. I. Bugaenko, I. K. Koval, A. V. Morozhenko, during the period 1964–65 carried out photoelectric scans of the planet. These observations were paralleled by scanning turbulent disks of stars at approximately the same zenith distances. A conclusion is that photometric investigations of planets (contrasts, limb darkening) have to be accompanied by scanning stars as their image profiles undergo essential time-variations due to variations in the state of the Earth's atmosphere. Preliminary calculations show that the results based on photometric measurements of contrast and limb-darkening are to be revised critically for the planets of small angular size (Mars for example). A mathematical method has been developed taking into account the distorting effect of the Earth's atmosphere in the photometric observations of Mars.

E. G. Yanovitsky reports that 'the problem of diffuse reflection and transmission of light in planetary atmospheres for an arbitrary but not very elongated indicatrix is solved approximately.' Calculations indicate that the discrepancy between the pressure of the Martian atmosphere obtained by photometric and spectroscopic methods may be explained as due to a great amount of aerosol particles with radii $r \leqslant 10^{-6}$ cm in the Martian atmosphere. The full amount of aerosol particles of radius 10^{-6} cm in the column of the atmosphere is estimated as $10^{15}\,\mathrm{cm}^{-2}$ (**23**).

D. Menzel and W. M. Irvine report that multicolor photoelectric photometry of the planet was made by the Harvard College Observatory at the Stations of Boyden (South Africa) and the Houga (Southern France) using ten narrow band filters between 0·315 and 1·06μ plus *UBV* for the purpose of obtaining monochromatic phase curves and albedos.

F. A. Gifford Jr. suggests that the Martian canals are chains of desert sand dunes. The necessary physical conditions for dune formation probably exist on Mars. Sand driving winds are a factor of seven higher and so Martian dune chains should be longer than on the Earth (**24**).

Tombaugh, Reese and Robinson (New Mexico State University Observatory) carried out systematic visual observations of the planet along with photographic ones. Temporary observations were noted in the Trivium Charontis area and whitishness over certain desert areas diminishing around Martian noon and reformed in later afternoon. At the time Mariner IV was sweeping over Mars, a good appraisal of Martian atmospheric conditions and surface details was possible owing to superb seeing. Tombaugh was able to identify on Mariner's pictures features recorded telescopically.

G. de Mottoni carried out at the Collurania-Teramo Observatory, Italy visual observations and color estimates of Mars, during the 1965 apparition (**25**).

R. Prinz and M. Oberndorfer carried out, respectively, photographic and visual observations of the planet during the 1964–65 apparition at the Volkessternwarte of Munich.

Theoretical investigations: Accurate aerographic coordinates of several hundred stations in the revised physical ephemeris system were determined by G. de Vaucouleurs and his collaborators at the University of Texas (**26, 27, 28**).

The geometric and photographic parameters of the terrestrial planets were discussed by G. de Vaucouleurs and best values derived, including the radiometric albedo of Mars $A = 0{\cdot}29$ (**29**).

C. Sagan, J. P. Phaneuf and M. Ihnat compared ultra-violet, visible and near infrared spectra of the Martian bright areas with the corresponding laboratory reflectivities of a variety of minerals containing ferric oxides and silicates, as solids and in pulverized form. The results obtained show that pulverized limonite, a ferric oxide polyhydrate, matches the shape and amplitude of the Martian Russell-Band albedo (30). The large amounts of limonite suggested by photometric polarimetric and spectrometric observations of Mars are not inconsistent with geophysical expectation. Iron can be considered as a principal constituent of the Martian surface (31).

A comprehensive theoretical analysis of the photometry and polarimetry of the Martian surface was made by J. Pollack and C. Sagan according to which: the material of the surface of the bright areas of Mars is a powder rather than porous rock; the spectra of the bright and dark areas are controlled by the Fe_2O_3 moiety in the wavelength region between 3000 and 11 000 Å, as is indicated by the low, nearly constant reflectivity between 3000 and 4500 Å and the good fit to the laboratory spectral data between 4500 Å and 11 000 Å; a large drop in the reflectivity between 2·4 and 3·1 microns in both the dark and the bright areas indicates the presence of sizeable hydration in both regions. Neither Martian ice clouds nor carbonates are capable of accounting for this reflectivity decline; comparison of theoretical spectra between 3·0 and 3·8 microns that allow for thermal emission with observed spectra and the index of refraction implied by the polarization phase angle curve, for the bright and dark areas show that there is one water of hydration molecule attached to Fe_2O_3 although others may be present, attached to other mineral; the maximum in the Martian reflectivity near 1·4 microns also implies the presence of water of hydration; goethite is a principal component of the bright and dark areas, their absolute reflectivities giving a first approximation of the actual particle sizes; the bright areas are characterized by particle sizes of about 50 microns, while the dark areas have an average particle diameter of 200 microns outside the seasonal wave of darkening and about 400 microns during the darkening (32).

C. Sagan, J. Pollack and R. Goldstein studied elevation differences between bright and dark areas for the opposition of 1963 and 1965; there is a strong correlation between high reflectivity at radar frequencies and dark areas at optical frequencies; there are occasional displacements between the reflectivity maximum and the centers of dark areas which can be understood in terms of a systematic elevation difference between bright and dark areas; some regions undergoing marked secular changes have very shallow slopes 1 to 2 degrees and elevations of the order of 6 km; canals have steeper slopes larger than 4° and elevations of the same order while large dark areas such as Syrtis M and Moeris Lacus have elevations between 10 and 20 km (33). They attribute the discrepancy between the dynamical and optical oblateness of Mars to the concentration of dark highlands near the Martian equator; the results may also bear on the discrepancy between ground based infrared spectrometric and polarimetric values, on the one hand, and Mariner IV occultation values on the other hand, of Martian surface préssures. The infrared pressures ~ 12 mb refer to an average of the bright and dark areas. The occultation pressures ~ 6 mb are necessary biased towards elevations; both ingress and egress occurred in or very near dark areas (34–38).

According to C. Sagan and J. Pollack, secular changes observed near dark areas characterized by shallow slopes are due to the drifting wind-blown dust alternatively covering and uncovering dark areas at slightly higher altitudes (35).

The progressive springtime darkening of the dark areas of Mars was discussed by J. Pollack, E. Greenberg and C. Sagan in terms of two models, one in which the darkening is due to biological activity in response to the increased temperature and humidity, the other in which fine dust is wind-blown off dark Martian highlands in spring. The observational data of Focas on darkening waves of Mars were subjected to a statistical significance analysis which shows very significant correlation between latitude and time of maximum darkening. On the other hand, correlations were found on the dust model. The obtained data do not permit a choice between the biological and the wind-blown dust models (**36**). The particle size modulation required in the dark areas to explain the seasonal photometric and polarimetric changes can be accounted for by Martian winds; according to the same model, the intrinsic contrast between bright and dark areas becomes very small at 4500 Å; the blue haze is not an atmospheric phenomenon but an intrinsic loss of surface contrast (**37**).

Using the photographic, polarimetric and visual observations of the planet collected in ten observatories throughout the world in the scheme of the International Cooperation of IAU, during the apparitions of 1954, 1956 and 1958, A. Dollfus prepared a synthesis giving the following results: diameters of the planet $d_e = 6790$ km; $d_p = 6710$ km; volume: $1620 \cdot 10^{26}$ cm^3 ± 1%; mean density: 4·09; ellipticity of the globe: 0·0117. The distribution in altitude of the opaque yellow veils can not be proportional to the atmospheric pressure; such particles should remain in the lower atmosphere layers. The 'blue' clouds are in general very tenuous. A light and transparent haze persists in the polar areas by the end of the Martian spring, discernible only polarimetrically. The yellow clouds appeared in 1956, as in the past, above some privileged bright temperate areas: they were, at start associated with white ice crystal clouds, the size of the constituing particles ranging up to 10 or 15 microns; their reflecting power, when in suspension in the atmosphere is approximately the same as that of the bright areas of the soil. The atmospheric circulation during the Martian spring and summer is of the laminar type, due to the topography of the planet and not to turbulence (**48**).

A wide program of investigation of the Martian photographs taken in short wavelengths by E. C. Slipher at the Lowell Observatory during the last 40 years is in progress at that observatory.

A. Palm and B. Basu investigated the extent of blue clearings as a function of the number of the meteor showers intersecting Mars' orbit at 10° intervals of heliometric longitude. A rank correlation method has been employed. The analysis indicates a small but statistically significant negative correlation between the extent of blue clearing and meteor shower activity. This result, combined with the optical properties of the Martian atmosphere and the close resemblance between the characteristics of the blue haze and those of the terrestrial noctilucent clouds suggests that variable amounts of interplanetary dust are suspended in the Martian atmosphere and that the occasional clearings of the blue haze are caused by a diminishing influx of these dust particles (**39**).

B. T. O'Leary and D. G. Rea computing the radiation balance on Mars and the observed duration of the Mountains of Michell suggest that they are CO_2 condensations in depressions with depths of $\sim$ 6–9 km. The appearance of bright spots on Hellas and other areas in the southern hemisphere can also be explained by depressions where the minimum night time temperature is low enough for CO_2 to condense. The possibility of H_2O condensation in depressions is also discussed. Such results support the hypothesis that the Martian deserts are lower than their surroundings (**40**).

D. G. Rea presents evidence from polarization and brightness measurements to improve the model which requires transport of dust on and off certain areas to explain the seasonal darkening of Mars. He suggests that variations in brightness for all times and areas may be due not to variations in chemical properties but to variations in particle size. He discusses the consequences of the possibility of the Martian surface being composed of finely divided goethite or limonite (**41**).

J. A. Roth describes a method of making colored globes of Mars from drawings, photographs and observations (**42**).

R. A. Wells discussed observations of Martian cloud occurrences during the past century; yellow clouds show a maximum occurrence several weeks after perihelion and constant occurrence for the remainder of the orbit: white clouds show two groups of maximum occurrence;

insolation occurrency at perihelion produces the strongest winds and yellow clouds; a cyclic relationship appears between white clouds frequency and waxing and waning of polar caps; aerographic positions of clouds reveal interesting topographic implications; yellow clouds show definite relations to the dark maria. Select occurrences of white clouds may reveal the possible presence of volcanoes and mountain ranges. The 'W' shaped clouds in Tharsis may be explained by the presence of mountain ridges. An examination of certain white clouds implies that at least some of the dark maria are elevations (**43, 44**).

R. A. Wells suggests white clouds formations to be physical evidence of the presence of mountain ranges of Mars (**45**). Re-evaluating Wright's plates for the 1924 and 1926 oppositions of Mars, he derives a diameter of the planet of 6682 km (**46**).

The Planet Jupiter

Observations: G. P. Kuiper and T. Gehrels using a 154 cm reflector at *F*/13 are performing a polarimetric and photometric program with seven filters between 0·3 and 1·0 micron and with experiments at shorter and longer wavelengths, covering the poles of the planet.

R. Younkin has conducted at the JPL spectrophotometric measurements of the planet from 0·32 to 1·1 μ.

D. Menzel and W. M. Irvine report that multicolor photoelectric photometry of the planet was made by the Harvard College Observatory at the Stations of Boyden (South Africa) and the Houga (Southern France) using ten narrow band filters between 0·315 and 1·06 μ plus *UBV* for the purpose of obtaining monochromatic phase curves and albedos.

At the Lowell Observatory, S. Jones and colleagues carried out systematic photographic work of the planet in the course of the International Cooperation. High quality photographs, and a cinematographic film showing 1/4 of rotation of the planet, were taken.

C. Banos (Athens) working on photographs taken at the Athens Observatory in 1964–66 through the 25-inch (63 cm) refractor obtained variations of the coefficient of short term atmospheric activity of the order of three months.

J. B. Orr (New Zealand) followed the phenomena connected with regression of veils covering the equatorial area of the planet since 1960.

R. A. McIntosh (New Zealand) analyzed his own observations of the peculiar disturbance phenomena occurred in the southern hemisphere of Jupiter in 1962 (**49**).

P. Guérin obtained in November 1963 at the Pic-du-Midi Observatory high resolution photographs of the planet and the Galilean satellites. Such photographs show the fine structure of filamentary strips, the Red Spot, etc. (**50**).

A. Dollfus, J. H. Focas and M. Marin obtained, at the Pic-du-Midi Observatory, photographs of the planet in different spectral areas during the apparitions of the planet of 1964–65 and 1965–66.

A. Dollfus and J. H. Focas using the 83-cm refractor of the Meudon Observatory took series of photographs of the planet during the 1965–66 observational campaign prepared by the IAU.

J. H. Focas using the 16-inch (38 cm) refractor of the Nice Observatory developed a program of photographic observations of the planet during the 1965–66 observational campaign.

S. Ferraz-Mello and P. Sudbury started at the Pic-du-Midi Observatory a program of photographic observations of Jupiter and its satellites for the determination of the positions of the Galilean satellites and particularly the Vth.

T. Coupinot working at the Pic-du-Midi Observatory developed a general method of photometric scanning of the planet.

Photoelectric observations of the planet were taken at the New Mexico Observatory (177 *UBVO* sets.)

B. Smith and cooperators at the New Mexico Observatory photographed the planet (3409 plates) in *UV*, blue, green, red and infrared light. Patrol photographs have been measured to obtain zenographic coordinates and corresponding proper motions of the Red Spot, the three bright oval spots in the South Temperate Zone and other features of special interest. Special photographic observations followed a rapidly moving current perhaps analogous to the 'Jet Stream' moving along the South edge of the South component of the North Temperate Belt. A spectral photographic program also documented the interaction between a small spot in the 'circulation current' of the South Tropical Zone and the Red Spot. The photographs show conclusively that there exists a counter-clockwise vortical motion of the Red Spot (**51, 52, 53**).

At the Astrophysical Institute of the Academy of Sciences of Kazakstan (U.R.S.S.): V. G. Teifel studied the photometric and spectral properties of the Red Spot for different distances to the disk's limb. He concludes that the Red Spot is a gaso-aerosol formation which, optically, resembles the surrounding clouds (**54, 55**). V. G. Teifel, A. N. Aksenov, Z. N. Grigor'eva, and Z. G. Romanenko carried out a photographic-photometric work on the short-term atmospheric activity of the planet. They conclude for the period 1965–66 a periodic variation of the coefficient of activity of the order of three months. Such periodicity was found in the green, orange and red. This is not the case for the blue and the violet (**56, 57**).

A. Binder and D. P. Cruikshank report: Photometric observations of eclipse reappearances of Jupiter I and II were made in 1962–64 to search for a possible anomalous brightening of the satellite after eclipse. A brightening, if present, would suggest a frost or snow deposit or a haze layer caused by a surface temperature drop during eclipse. In each of four cases of J I eclipse reappearances, a brightness anomaly was indeed observed, having an average value of 0·09 stellar magnitudes. The anomaly decayed in about 15 minutes. A single observation of J II showed no anomaly (**58**).

A. B. Binder and D. P. Cruikshank, report: An observation of an eclipse reappearance of J II with the Kitt-Peak 36 inch (91 cm) telescope showed a brightness anomaly of 0·03 ± 0·01 stellar magnitudes. The anomaly decayed in 10 minutes. Two high quality observations of J III showed no brightness anomaly greater than 0·01 stellar magnitudes (**59**).

S. K. Vsekhsviatsky (Kiev State University) noted an unusual activity of Jupiter in 1962–65 and explained it as a display of volcanic activities (**60, 61, 62, 63**).

O. R. Bolkvadze at the Abastumani Astrophysical Observatory carried out electro-polarimetric investigations of the planet in the focus of the 40 cm refractor which showed: 0·1% to 0·5% of polarization for the planet's integral light with no dependance on the phase angle. Polarization in the central and polar regions is comparatively high depending on the phase angle; a stronger polarization (9·4%) was recorded at the southern region of the planet (**64**).

Tombaugh and Reese (New Mexico State University Observatory) carried out systematic visual observations of the planet. Reese made approximately 5000 central meridian transits of Jovian markings. Evolution of colors of Jovian markings was particularly studied as well as the structure of the belts. Two dark spots have been observed whirling around the Red Spot counter-clockwise. The Red Spot faded markedly in 1966 and its North perimeter became deformed.

A. P. Lehnan (B.A.A.) studied the rotation period and location of the Red Spot and concludes that there is a periodicity in the rotation period and a relationship between the variation in rotation periods and latitude fluctuations (**65**).

R. Prinz and H. Obendorfer at the Volkssternwarte Münich carried out, respectively, photographic and visual observations of the planet in the 1964–66 period.

E. H. Collinson, W. E. Fox, A. W. Heath, N. V. Jones, J. B. Murray, members of the B.A.A. carried out systematic visual observations of the planet in 1964–66.

C. Capen at the Table Mountain Observatory, conducted systematic multicolor photographic observations of the planet in 1964–66.

T. Akabane at Kwasan Observatory (Japan) using the 24-inch (61 cm) reflector, carried out systematic multicolor photography of the planet in 1966.

Theoretical investigations: M. Combes using the Lallemand electronic camera mounted on the 40-inch reflector at the Pic-du-Midi Observatory obtained high quality photographs of Jupiter allowing an accurate photometry for establishing the center-limb darkening curve. He obtained the following values of the center-limb darkening coefficient: $q\ (U) = 0{\cdot}65 \pm 0{\cdot}05$; $q\ (B) = 0{\cdot}75 \pm 0{\cdot}10$; $q\ (V) = 1{\cdot}10 \pm 0{\cdot}07$. He concludes: that the optical depth in the *UV* is comprised between 0·50 and 0·80; that the value of the abundance of molecular hydrogen ranges between 75 and 150 km atm **(66).**

The Planet Saturn

Observations: G. P. Kuiper and T. Gehrels using a 154 cm reflector at $F/13$, are performing a photoelectric program with seven filters between 0·3 and 1 micron and with experiments at shorter and longer wavelengths, covering the poles of the planet.

R. Younkin has conducted spectrophotometric measurements of the planet at the JPL from 0·32 to 1·1μ.

G. Wlérick and cooperators, obtained in December 1965 at the Pic-du-Midi Observatory through the electronic camera series of photographs of the planet in different spectral regions (Vapillon, **67**).

B. A. Smith and cooperators photographed the planet at the New Mexico Observatory in blue, green, red and UV light (225 plates). Successful photographic observations were made of the rings of Saturn during the Earth's passage through the ring plane on 29 October 1966. A continuous sequence beginning several days before 29 October and lasting more than a week afterwards, will permit a determination of the exact time of passage through the plane and a lower limit for the thickness of the rings. Photoelectric observations of the planet, made during the latter part of 1966 (16 sets *WUBVRI*) will establish the phase coefficient for the globe of Saturn in six colors, without interference from the rings.

D. Menzel and W. M. Irvine report that multicolor photometry of the planet was made by the Harvard College Observatory at the stations of Boyden (South Africa) and the Houga (Southern France) using ten narrow band filters between 0·315 and 1·06μ plus *UBV* on the purpose to obtain monochromatic phase curves and albedos.

O. R. Bolkvadze at the Abastumani Astrophysical Observatory carried out electro-polarimetric investigations of the planet in the focus of the 40 cm refractor which showed 0·1% to 0·5% of polarization for the planet's integral light with no dependence on the phase angle; polarization in the central and polar regions is comparatively high depending on the phase angle; a stronger polarization (11·7%) was recorded at the southern region of the planet. Especially high polarization (up to 14–15%) is displayed by the east and west sides of the outer ring of the planet, and in this respect the west side always dominates over the east side (**68**).

Transit of the Earth and Sun through the plane of the Rings in 1966. The Sun crossed the plane of the Rings on 15 June and the Earth on 29 October and 17 December. According to information received till now (December 1966) by the Committee of Commission 16 'International Cooperation for the Observation of the Planets', the following observers collected observations of the above said phenomena:

C. Banos (Athens, Greece)	63 cm refr.	Photographic Yellow	Tricolor
C. Capen (Table Mountain, U.S.A.)	40 cm refr.	Photog. and Vis.	Multicolor
A. Dollfus (Pic-du-Midi	106 cm refl.	Photog. and Vis.	Yellow blue
and Meudon, France;	60 cm refl.	Photog. and Vis.	Yellow blue
U.R.S.S.)	70 cm refl.	Photog. and Vis.	Yellow blue
J. Focas (Meudon, France)	60 cm refl.	Photog. and Vis.	Vis.

D. Read (New Zealand)	20 cm refr.	Visual	Yellow
McIntosh (New Zealand)	30 cm refr.	Visual	Yellow
I. Thomson (New Zealand)	20 cm refr.	Visual	Yellow
I. Kiladze (Abastumani, U.R.S.S.)	70 cm refl.	Photographic	Yellow
M. Martin (Pic-du-Midi, France)	106 cm refl.	Photographic	Yellow
R. Prinz (Munich, W. Germany)	30 cm refl.	Photographic	Yellow blue
H.W. Oberndorfer (Munich, W. Ger.)	20 cm refl.	Visual	Yellow
J. Texereau (McDonald, U.S.A.)	200 cm refl.	Photographic	Yellow
C. Tombaugh (New Mexico, U.S.A.)	40 cm refl.	Visual	Yellow
E. Reese (New Mexico, U.S.A.)	40 cm refl.	Visual	Yellow

Theoretical investigations: M. S. Bobrov, analyzing photometric data, showed that Saturn's rings are a system of a certain thickness, composed of many particles. Taking into account on the inter-darkening theory the dispersion of particle sizes, he obtains a good agreement between theory and observation (**69, 70**).

F. A. Franklin and A. F. Cook using photometric data of the Rings A and B of Saturn taken through the 60-inch (152 cm) reflector of the Boyden Observatory (S. Africa) studied the optical thickness of five representative portions of the ring and the phase variation and albedo of the ring particles. The non-linear and color-dependent phase curves of the ring near opposition allow two possible interpretations. The more likely model gives the fraction of the ring volume occupied by particles (Ring A $= 1{\cdot}0 \times 1{\cdot}0^{-3}$, Ring B $= 1{\cdot}3 \times 10^{-3}$) and a characteristic size of 7μ. The other model gives values of the former quantity (Ring A $= 6 \times 10^{-3}$, Ring B $= 4 \times 10^{-3}$), and in addition particle radii of about 300μ and a ring thickness of about 10 cm.

I. N. Minin presented an approximate method of solving the problem of polarized light dispersion in the planet's atmosphere taking into account aerosol component and light reflection from the surface (**71**).

The Planet Uranus

Observations: R. Younkin has conducted at the JPL spectrophotometric measurements of the planets from $0{\cdot}32$ to $1{\cdot}1\,\mu$.

G. Coupinot obtained at the Pic-du-Midi Observatory through rapid photoelectric scanning records allowing the determination of the diameter and the limb darkening of the planet (**72**).

B. Smith and cooperators obtained at the New Mexico Observatory photographs (19 plates) of the planet in blue light.

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A REVIEW OF SPECTROSCOPIC STUDIES OF THE PLANETS, 1964–67

(prepared by T. Owen, IIT Research Institute)

Explanatory Remarks

This review covers the period from 1 January 1964 to 1 December 1966, with the exception of those papers (published in early 1964) already reviewed in the previous Commission 16 report. The review is based on a survey of current periodicals supplemented by communications with astronomers working in this area. Where preprints were available, papers accepted for publication have been included in order to extend the currency of the review. The dedicated assistance of Mr Ron Wojcik in carrying out the overwhelming majority of the survey work is gratefully acknowledged.

The review is organized to follow the usual plan of considering each planet in turn, proceeding outward from the Sun. Each section is independent, having its own page numbers and list of references. In several cases, papers have been published which discuss observations of more than one planet. In such instances some redundancy has been permitted in order that each topic may be complete. Because of the relative scarceness of published material, however, the major planets have been considered in two groups: Jupiter-Saturn and Uranus-Neptune.

A. Mercury

Several attempts were made to determine whether or not Mercury possesses an atmosphere and, if so, what its composition might be. N. A. Kozyrev (**1**) presented spectra of Mercury indicating emission components in the cores of Fraunhofer hydrogen lines. He concluded that this was evidence for an accreted hydrogen atmosphere. H. Spinrad and P. W. Hodge (**2**) showed that this effect could be produced by the superposition of the spectrum of the twilight sky on the Mercury spectrum, when the latter exhibits a pronounced Doppler displacement. Under these conditions, each absorption line appears as an unresolved doublet, while the small space between the cores of each pair of lines imitates an emission line. Kozyrev (**3**) has rejected this interpretation since he states that he monitored the twilight spectrum very carefully and rejected those plates on which the contribution from twilight was appreciable.

V. I. Moroz (**4**) observed the spectrum of Mercury from 1·0 to 3·9μ. His most significant finding was an apparent enhancement of the telluric CO_2 bands near 1·6μ which he has interpreted as evidence for the presence of a CO_2 atmosphere about Mercury. The amount of CO_2 remains uncertain because the strength of these bands makes their intensity pressure-dependent. Moroz estimates 0·3–7 g cm^{-2}. H. Spinrad, G. B. Field, and P. W. Hodge (**5**) have looked for the weak CO_2 band at 8689 Å that would give the abundance directly, but found no trace, setting an upper limit of 57 m-atm (11·2 g cm^{-2}), consistent with Moroz' observations. Reviewing available evidence, Spinrad *et al.* concluded that Mercury probably does have a tenuous atmosphere, although its mass remains uncertain.

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B. Venus

The ultraviolet spectrum of Venus below 3000 Å was observed for the first time by D. Evans (**1**). He found a broad absorption-like feature extending from 3300 Å to the short-wave limit of his observation (2300 Å) with a maximum at 2500 Å. Evans points out that this feature can be interpreted as either the result of true absorption by ozone (1/3 to 1/10 the amount present in the Earth's atmosphere) or as the combined effect of a Rayleigh scattering atmossphere above a cloud layer having a reflectivity which decreases toward shorter wavelengths. It is not yet possible to determine which is the correct interpretation. I. N. Glushneva (**2**) reported observations indicating that the albedo of Venus diminishes slightly with decreasing wavelength in the region 4500–3200 Å.

H. Spinrad and E. H. Richardson (**3**) determined an upper limit of 57 cm-atm of O_2 in the atmosphere of Venus using high resolution spectra in the region of the A band (7600 Å). This result is in disagreement with the tentative identification of oxygen previously reported by Prokofiev and Petrova (**4**) and suggests a relative abundance of $< 8 \times 10^{-5}$ for O_2 in the planet's atmosphere. H. Spinrad (**5**) reported the discovery of a new hot band of CO_2 in the region near 8750 Å from which he deduced a rotational temperature of $\sim 400°$K.

M. Bottema, W. Plummer, and J. Strong (**6, 7, 8**) used a balloon-borne telescope to obtain spectra of Venus in the region in the strong water vapor band near $1{\cdot}13\mu$. They detected water vapor in excess of the residual amount present above the balloon in the Earth's atmosphere and concluded that the atmosphere of Venus above the clouds contains between $5{\cdot}2 \times 10^{-3}$ and $22{\cdot}2 \times 10^{-3}$ g cm^{-2}, depending on the pressure at the cloud tops. A. Dollfus (**9**) observed the spectrum of Venus in the region of the $1{\cdot}4\mu$ water vapor band, using interference filters to compare the intensity in this region with the neighboring continuum. He found evidence for absorption due to water vapor in the atmosphere of Venus and derived an abundance of 7×10^{-3} g cm^{-2}. M. Bottema, W. Plummer, J. Strong, and R. Zander (**10**) obtained a low resolution spectrum of Venus in the $1{\cdot}7$–$3{\cdot}4\mu$ region which they have shown to be closely matched by the laboratory spectrum of an ice cloud. They conclude that the Venus clouds consist of ice crystals.

M. J. S. Belton and D. M. Hunten (**11**) announced the discovery of Doppler shifted components in the wings of telluric water vapor lines near 8200 Å. They attributed these components to absorption by water vapor in the atmosphere of Venus. This result was confirmed by H. Spinrad and S. J. Shawl (**12**) and appears to lend strong support to the identifications at longer wavelengths.

J. A. Westphal, R. L. Wildey, and B. C. Murray (**13**) were able to produce detailed maps of isotherms on the planet's disk by means of observations in the 8–14μ region. From an examination of these maps, the authors found that rather large, complex variations occur in the atmosphere of Venus at the levels producing the 8–14μ emission. J. A. Westphal (**14**) presented reduced data from diametric scans of Venus carried out with 8-14μ radiation. These data indicate an unexpected brightening near the planet's limb, suggesting a more complex atmospheric structure than that postulated by previous models.

V. I. Moroz (**15**) reobserved the $1{\cdot}2$–$3{\cdot}8\mu$ spectral region with improved resolution and presented a table of wavelengths and equivalent widths of the planetary CO_2 absorption bands. He deduced an abundance of 25 g cm^{-2} for the CO_2 above the cloud layer and a total pressure at the cloud tops of 0·3 atm. An earlier tentative identification of CO absorption at $2{\cdot}35\mu$ was confirmed; the derived abundance was 1·5 cm-atm. Strong absorption for $\lambda > 3\mu$ was observed leading to an albedo at $3{\cdot}3\mu$ of $\sim 1\%$. The identity of the absorber remains unknown but Moroz suggests that it may contribute to a strong greenhouse effect in the planet's atmosphere.

B. Guinot (**16**) used a specially designed spectrograph employing a Fabry-Pérot etalon to examine different parts of the disk of Venus in the 5500-5700 Å region. He found evidence for an equatorial velocity of 110 ± 8 m s^{-1} corresponding to a period of retrograde rotation of 4·1 ± 0·7 days.

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C. Mars

The ultraviolet spectrum of Mars was observed by D. Evans (**1**) by means of a rocket-borne spectrograph. The region covered was 2400 to 3500 Å with a resolution of about 50 Å. The ultraviolet reflectivity derived from the observations was interpreted in terms of a Rayleigh scattering atmosphere composed of some mixture of N_2, CO_2, and Ar, with a surface pressure in the range of 5–20 mb (a value of 10 mb was favored). No evidence of absorption was detected; Evans concluded that solar UV radiation in the 2000–3000 Å region will reach the planet's surface.

B. T. O'Leary (**2**) reinterpreted Martian spectra (obtained by Kiess, Karrer, and Kiess) with the help of laboratory spectra of NO_2 and derived an upper limit of 0·1 mm-atm for the abundance of NO_2 in the Martian atmosphere. J. V. Marshall (**3**), using spectra of Mars obtained at the Mt Wilson Observatory and his own laboratory spectra, set an upper limit of 0·008 mm-atm on the NO_2 abundance. T. Owen (**4**) obtained a new Martian spectrum showing no trace of the NO_2 absorption feature studied by O'Leary and Marshall in the laboratory, thereby confirming their conclusions that detectable concentrations of the gas are not present in the Martian atmosphere.

The determination of the composition and surface pressure of the Martian atmosphere by means of curve-of-growth studies of the CO_2 absorptions has continued. T. Owen (**4**) obtained new observations of the 8689 and 10 486 Å bands of CO_2 from which he derived a CO_2 abundance of 65 ± 20 m-atm. Using this value of the abundance and a curve-of-growth determined in the laboratory to interpret observations of the 1·6μ CO_2 band obtained by Kuiper, Owen derived an atmospheric surface pressure of 9^{+11}_{-4} mb. Belton and Hunten (**5**) observed the 10 486 Å band in detail and fitted a synthetic spectrum to the observations. In this way they derived a CO_2 abundance of 68 ± 26 m-atm and a rotational temperature of 194°K. Relying on an analysis of the strong 2·0μ CO_2 bands in the Martian spectrum carried out by L. D. Gray (**6**), Belton and Hunten derived a surface pressure in the range of 5–13 mb, with 6 mb as a preferred value. H. Spinrad, R. A. Schorn, R. Moore, L. P. Giver and H. J. Smith (**7**) carried out an extensive series of observations of the 8689 Å band. They determined a CO_2 abundance of 90 ± 27 m-atm which they used in conjunction with previous analyses of the 2·0μ and 1·6μ bands to deduce a surface pressure of 10^{+10}_{-5} mb. Comparing their work with the results obtained from the Mariner IV occultation (5 or 6 mb), the authors concluded that Mars must have an almost pure CO_2 atmosphere. L. D. Gray (**6**) has used a random Elsässer band model for the interpretation of the $2{\cdot}0\mu$ bands. She was able to derive an expression for the absorption in terms of the product of the amount of gas (m) and the pressure (p), viz. $mp = 500 \pm 100$ m-atm mb. For m in the range of 60 to 85 m-atm, Gray derived a surface pressure of $7{\cdot}1 \pm 2{\cdot}2$ mb.

R. A. Schorn, H. Spinrad, R. Moore, H. J. Smith, and L. P. Giver (**8**) reported new observations confirming the presence of water vapor in the Martian atmosphere. They were able to detect Doppler-shifted Martian components in the water vapor band at 8200 Å and derived an abundance of 10 to 20μ precipitable water. The concentration of water vapor appears to vary with time and location on the planet, and to depend on the size of the Martian polar caps. F. J. Heyden, C. C. Kiess, and W. R. Willauer (**9**) have cautioned that care must be taken in interpreting planetary vapour absorptions near 8200 Å because of the presence of many faint telluric features in this region. A. Dollfus (**10, 11**), using the same technique employed in studying Venus, deduced an amount of 45μ precipitable water in the Martian atmosphere from observations of the $1{\cdot}4\mu$ absorption band.

R. L. Younkin (**12**) made spectrophotometric measurements of Mars from $0{\cdot}5$ to $1{\cdot}1\mu$ in a search for reflectance features typical of limonite as observed in the laboratory. He found no evidence of such features in the Martian spectrum, placing an upper limit of 2% on their intensity. R. G. Tull (**13**) also observed this region of the spectrum and used published data to extend the observed spectrum to $1{\cdot}52\mu$. His results essentially confirm Younkin's work but add a distinct minimum at 1μ. Tull concludes that his observations are not inconsistent with the presence of limonite on the Martian surface. A. B. Binder and D. P. Cruikshank (**14, 15**) compared the spectrum of Mars in the $0{\cdot}8$ to $2{\cdot}4\mu$ region with naturally occurring limonite found on desert rocks. They found that the limonite provided a good match for the Martian bright areas, and that basalts and basaltic volcanic ash did not have a reflection spectrum comparable with that of the Martian dark areas. These results are consistent with the findings of A. L. Draper, J. A. Adamcik and E. K. Gibson (**16**) who used 1 to 2μ reflection spectra of mixtures of goethite and hematite as comparisons for the Martian spectrum.

V. I. Moroz (**17**) reported an extensive series of observations of the Martian spectrum in the $1{\cdot}1$ to $4{\cdot}1\mu$ region. From his own measures of the $1{\cdot}6\mu$ and $2{\cdot}0\mu$ CO_2 bands and the CO_2 abundance determined by Kaplan, Münch, and Spinrad, Moroz derived a surface pressure of 15^{+10}_{-5} mb. The relative concentration of CO_2 was found to be given by $\alpha = 40/p^2$, such that a pure CO_2 atmosphere would exert a pressure of $6{\cdot}3$ mb. Moroz confirmed Kuiper's discovery of ice absorption bands in spectra of the Martian polar caps. He also found evidence of the bands near $3{\cdot}5\mu$ originally discovered by Sinton. Moroz considered his determinations of the planet's infrared reflectivity to be in satisfactory agreement with the spectrum of limonite.

J. S. Shirk, W. A. Haseltine, and G. C. Pimentel (**18**) suggested that the bands observed by Sinton near $3{\cdot}5\mu$ in the Martian spectrum might be due to deuterated water vapor in the Martian atmosphere. D. G. Rea, B. T. O'Leary, and W. M. Sinton (**19**) re-examined the observational evidence and found a correlation between the intensities of the $3{\cdot}5\mu$ bands and the amount of telluric water vapor in the optical path. They concluded that these features were probably due to telluric water vapor and should not be attributed to the Martian atmosphere or surface.

L. P. Giver (**20**) pointed out the need for additional observations of the CO_2 hot band at $10{\cdot}4\mu$ in the spectrum of Mars, since presently available results do not appear to be consistent with the latest values for the surface pressure and CO_2 abundance.

J. Connes, P. Connes, and L. D. Kaplan (**21**) announced the discovery of new absorption bands in the near infrared spectrum of Mars which they tentatively attributed to reduced gases in the Martian atmosphere.

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D. Jupiter and Saturn

The ultraviolet spectrum of Jupiter was recorded by T. Stecher (**1, 2**) from 2100 to 3000 Å, and verified by D. Evans (**3**) to 2300 Å. Stecher found that the continuum observed in this region could be explained by a Rayleigh scattering atmosphere consisting of 10 km atm of H_2. However, the constituents responsible for an absorption feature at 2600 Å and a sharp drop in intensity below 2100 Å remain to be identified. I. N. Glushneva (**4**) reported measurements of the albedo of Jupiter from 3200 to 4500 Å. The albedo falls off sharply at 4100 Å reaching a minimum at 3500 Å with a recovery toward shorter wavelengths.

D. J. Taylor (**5**) determined a bolometric Bond albedo of 0·45 for Jupiter from a series of spectrophotometric measurements in the 3400 to 10 000 Å region. Using this albedo, Taylor derived an equilibrium temperature of 105°K, considerably lower than measured infrared temperatures.

D. Clarke and J. F. Grainger (**6**) observed the profile of Hβ in the spectrum of Jupiter and found no differences between solar and Jovian profiles to within 1%. This negative result is in agreement with a search for aurorae carried out by G. A. Dulk and J. A. Eddy (**7**) who looked for evidence of emission components in the profile of Hα.

V. G. Teifel' (**8**) studied the behavior of several methane absorption bands in the 0·7 to 1·0μ region of the spectrum of Jupiter. Teifel' found that the absorption declines slightly toward the planet's limb, increases slightly at intermediate latitudes and declines toward the poles. A two layer model was suggested as necessary to account for the absorption pattern. T. Owen, E. H. Richardson, and H. Spinrad (**9**) found a new ammonia band in the spectrum of Jupiter near 7600 Å.

T. Owen (**10, 11**) compared laboratory absorption spectra of several gases with the spectrum of Jupiter in the regions 9700 to 11 200 Å, and 7750 to 8800 Å. All non-solar absorptions were identified as due to NH_3 or CH_4 and upper limits were set on the abundances of the other gases studied as well as on the value of D/H in the Jovian atmosphere. The $3\nu_3$ band of CH_4

at 1·1μ was analyzed to obtain a rotational temperature of 200 ± 25°K. A methane band which overlaps the 7900 Å ammonia band was considered to be responsible for the misidentification of ammonia in the spectrum of Saturn. L. P. Giver (**12**) announced marginal detection of ammonia in the spectrum of Saturn at 6470 Å.

L. P. Giver (**12**) reported no anomalous inclination of ammonia or methane lines in spectra of Jupiter and Saturn obtained in 1964–65. H. Spinrad and L. P. Giver (**13**) confirmed this result in a later report.

R. E. Danielson (**14**) reported observations of Jupiter's spectrum from 0·8 to 3·1μ obtained from a balloon at an altitude of 84 000 feet (26 km). Broad absorption features observed at 0·85, 0·99, 1·15, 1·37, and 1·7μ were attributed to CH_4, while NH_3 was considered to be responsible for an absorption at 3μ. A feature observed at 2·25μ was ascribed to the (1–0) band of 40 km-atm of H_2.

B. C. Murray, R. L. Wildey, and J. A. Westphal (**15**) mapped the 8 to 14μ brightness temperature distribution across the disk of Jupiter. They found no latitudinal variation of brightness temperature greater than 1°K nor variations greater than 0·5°K across the band structure although an enhancement of as much as a factor 30 was found associated with the position on the disk of a satellite shadow. Subsequent studies of satellite shadows by Wildey (**16, 17**) failed to show the enhancement originally discovered. On the other hand, improved resolution permitted Wildey, Murray and Westphal (**18**) to detect variations in brightness temperature across the disk of Jupiter. The light bands were found to be about 0·5° cooler than the dark bands and the Red Spot appeared to be 1·5 to 2·0° cooler than the surrounding disk.

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E. The Galilean Satellites of Jupiter

A. B. Binder and D. P. Cruikshank (**1**) observed an anomalous brightening of Io (in the UV) after it emerged from Jupiter's shadow. They interpreted this result as possible evidence for the presence of a tenuous atmosphere. B. C. Murray, R. L. Wildey, and J. A. Westphal (**2**) found that the observed integral brightness temperatures of Ganymede and Callisto exceeded the values expected from simple equilibrium with solar radiation. T. Owen (**3**) found no evidence of the strong 8873 Å absorption of methane in spectra of Io, Ganymede, and Callisto indicating an upper limit of 100 cm atm for the abundance of methane in possible satellite atmospheres.

V. I. Moroz (**4**) examined the spectrum of all four Galilean satellites in the region 0·8 to 2·5μ. He found no evidence of atmospheric absorptions but pointed out that the reflection spectra of Io and Callisto resembled that of Mars, while the spectra of Europa and Ganymede were similar to spectra of Saturn's ring and the Martian polar caps, i.e., indicative of snow or ice covering.

A. A. Kalinyak (**5**) presented observations of Io, Europa, and Ganymede in the region 5800–6600 Å in which he found several new lines in addition to the solar Fraunhofer lines. However, A. B. Binder and D. P. Cruikshank (**6**), obtained spectra having superior resolution which did not show the lines in question.

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F. Uranus and Neptune

F. Low (**1**) measured the brightness temperature of Uranus at 20μ and found a value of 55 ± 3°K. T. Owen (**2**) derived a temperature of 60 ± 15°K from an analysis of the fine structure of a methane band at 6800 Å. T. Owen (**3**) has identified the bands discovered by Kuiper near 7500 Å in spectra of Uranus and Neptune; they are due to methane in the atmospheres of these planets.

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RADIO STUDIES OF THE PLANETS

(prepared by C. H. Mayer and M. Spangler)

Radio studies of the planets in the past three years have been particularly fruitful, with such outstanding developments as the discovery from radar observations that the rotation period of Mercury is 59 days rather than the long accepted value of 88 days (**1**); the observational identification of the 10 cm radio emission of Venus with the solid surface (**2**); the very successful demonstration of a new method of radio investigation of planets by the observation of the occultation of the radio signals from the Mariner IV spacecraft by Mars (**3**); the discovery that the occurrence of the decameter bursts from Jupiter is dependent on the orbital position of the satellite Io (**4**); and the observation for the first time of radio emission of the planets Uranus (**5, 19**) and Neptune (**6**).

The papers (or summaries) presented at the Symposium on Planetary Atmospheres and Surfaces, Dorado, Puerto Rico, 24 to 27 May 1965, sponsored by the International Scientific Radio Union and the International Astronomical Union were published in a special issue of Radio Science (*NBS Journal of Research*, Section D), and references to those papers not concerned exclusively with the Moon are listed together (**7–38**) in the bibliography.

A number of reviews of planetary investigations by their radio emission and radar reflection properties have been published in the report period (**7, 11, 17, 27, 29, 207, 208, 39–49**).

Mercury

Radar observations at JPL in 1963 at 12·5 cm wavelength indicated a radar cross-section for Mercury of 5%, a surface rougher than that of Venus or Mars, and spectra consistent with an 88-day rotation period (**50, 35**). Radar observations at MIT at 23 cm wavelength in 1964 indicated a radar cross-section of 10% and a surface roughness greater than that of Venus (**51**).

In 1965, Pettengill and Dyce made radar observations at 430 MHz at Arecibo (**1, 32**) which showed that the rotation period of Mercury was not synchronous as had long been believed, but instead was 59 days direct. The shorter than synchronous rotation period for Mercury was shown to be a likely consequence of solar tidal friction with an expected range of period between 56 and 88 days (**52, 53**). It was demonstrated that the new radar rotation period could be reconciled with the reported visual observations (**54**), and further theoretical investigation indicated a stable, locked-in rotation at 2/3 the orbital period of Mercury, 58·65 days, very close to the radar period, as the most likely rotation period (**55, 56, 57, 58, 59**).

The discovery that the rotation of Mercury is not synchronous and that all parts of the planet receive direct solar radiation at some time provides an explanation for the lack of sizeable phase effect in the radio emission observed at 11 cm wavelength (**60, 19, 5**) whereas a larger phase effect is indicated by observations at 8 mm wavelength (**20, 61**). Reported observations at 3·4 mm wavelength appear to be at variance as they suggest a smaller phase effect at this wavelength (**62, 63**).

The implications of the non-synchronous rotation of Mercury with regard to the characteristics of the atmosphere are considered by Rasool *et al.* (**64**).

A test of general relativity by the effect of solar gravity on the delay times for radar echoes from the planets Mercury and Venus has been proposed (**65, 66**).

Venus

A large number of observations have again been made of the radio emission of the dark side of Venus confirming the general features of the spectrum including the small decrease of brightness temperature at wavelengths longer than 21 cm (**5, 18, 19, 67–82**). The region of the spectrum in the vicinity of the 1·35-cm water vapor resonance was examined in detail, but the results were conflicting and no definite evidence for the line was found (**17, 21, 22, 23, 83**). A number of studies were made to investigate absorption in the Venus atmosphere and clouds as the explanation of the decrease in brightness temperature at short centimeter and millimeter wavelengths and the greenhouse effect (**25, 26, 39, 84–94**).

Measurements of the brightness temperature of the illuminated hemisphere of Venus confirm an appreciable phase effect at short wavelength, but indicate a very small amplitude of phase dependence at 10 cm and 20 cm (**5, 71, 75, 95, 96, 97**). A theoretical derivation of the microwave phase effect has been made to relate the observations to planetary characteristics (**98**), and the analytical treatment of the lunar phase effect has been applied to Venus (**99**).

The polarization of the thermal radiation from a solid planetary surface has been analyzed theoretically (**100, 101, 28, 102**), and observations of the integrated radiation over the disk of Venus show a very small polarization (**2, 103, 104**).

A crucial experiment was performed by Clark and Kuz'min (**2**) at the 1964 inferior conjunction using the high-resolution of the Cal Tech interferometer at 10 cm wavelength to measure the distribution of polarization over Venus. They observed differential polarization over Venus as predicted for thermal radiation from a solid surface with a dielectric constant of 2·5, providing the first direct observational link between the radio emission of Venus and the solid surface. They also found a slightly higher brightness temperature at the limb than at the center of the un-illuminated disk, a lower brightness temperature at the pole, and a diameter for the radio disk slightly smaller than the diameter of the visible disk.

The 1·9 cm radiometer carried by the Mariner-2 spacecraft to the vicinity of Venus provided three scans across Venus with a resolution of 1/6 the diameter of the disk which indicated limb darkening (**105**).

Several attempts to reconcile the ionospheric hypothesis for the origin of the radio emission of Venus with the experimental observations have been published (**106, 107, 108, 109**). Walker and Sagan (**110**) conclude that the difficulties of explaining the required ionization are too great and that the ionosphere of Venus cannot have an important effect on the microwave spectrum.

Two investigators have reported possible correlations of the radio emission of Venus with solar activity (**69, 111**).

Alternative radiation sources to supplement the thermal radiation of the surface and atmosphere of Venus have been investigated by Vakhnin and Lebedinskiy (**112**) who speculate that a general planetary glow discharge in the atmosphere of Venus may generate radio waves, and by Plummer and Strong (**113**) who speculate that electrical discharge radiation may be observable at radio wavelengths in the atmospheres of both Venus and the Earth.

A very small radar cross-section of 1% is measured for Venus at 3·6 cm wavelength (**114**) which is only 1/10 that measured at 12·5 cm wavelength indicating the possibility of some absorption in the atnosphere of Venus. The surface of Venus appears uniformly rough at 3·6 cm, like the surface of the Moon at optical wavelength.

Radar observations of Venus at 12·5 cm wavelength made in 1962 gave a rotation period of 230 days retrograde from the day to day motion of a feature across the spectrum and 266 days retrograde from the bandwidth of the spectrum, a radar cross-section of 10% and a surface dielectric constant of 3·75, and scattering characteristics of a surface smoother than the Moon (**115, 116, 117, 118**). The Faraday rotation of the Venus echo was measured and found consistent with rotation in the terrestrial ionosphere with no evidence for extraterrestrial rotation (**119**).

Radar observations of Venus at 12·5 cm in 1964 gave a rotation period of 250 days retrograde from spectral width of the echoes (**30, 120**), but a rotation period from comparison of surface features which appeared on the spectra in both 1962 and 1964 of 244 days retrograde (**120**). The reflectivity was measured as 0·114 corresponding to a surface dielectric constant of 3·75 (**120**), and scattering theory applied to the echo spectrum shows that Venus deviates only slightly from isotropic scattering (**35**).

Radar observations in 1964 at 23 cm wavelength (**51**) gave distance measurements accurate to 1·5 km, a radar cross-section of 15% and scattering properties indicating a surface smoother than the Moon with mean slope of 8°.

Radar observations at 700 MHz in 1962 (**121**) and 1964 (**37, 122**) found a value for the astronomical unit of 149 598 000 ± 400 km, a radar cross-section of 19%, and a rotation period from the spectral width of 230 ± 25 days.

Radar measurements of Venus at 410·25 MHz in 1962 (**123**) and 1964 (**124**) gave a value of the astronomical unit of 149 596 600 ± 900 km and showed that the rotation period is between 100 and 300 days.

Radar observations at 70 cm wavelength gave a rotation period for Venus of 247 ± 5 days and indicate surface slopes about one-half the average inclination of the Moon (**29**).

A variable radar cross-section was measured at 50 MHz (**125**) with an average value of 20%, and at 38 MHz (**126**) where the average value was about 15%.

It has been suggested that the rotation period of Venus is locked at 243·61 days retrograde so that the same face of Venus is presented to Earth at successive inferior conjunctions (**127**).

The analysis of radar observations to obtain surface roughness (**128, 38**) and rotation information (**36**) has been discussed.

Mars

In 1963, radar observations at 700 MHz in Russia (**129, 205**) showed narrow band echoes suggesting smooth reflecting areas, and different radar reflectivity at different Martian longitudes with the average 7%.

Arecibo radar observations in 1965 at 430 MHz (**33**) provided measures of the radar reflectivity as a function of Martian longitude with values which varied between 3% and 13%, a tendency for the strongest echoes when dark regions of Mars were near the sub-radar point, and an especially strong reflection at Martian longitude 200 degrees.

Radar observations at JPL at 12·5 cm wavelength (**31, 130**) showed a strong narrow band echo from Martian longitude 200–210°, and a somewhat wider band echo from the region 240–250°. Analysis of these observations (**131**) indicates that the correlation of high reflectivity near dark regions may correspond to the dark regions being elevated areas like continental blocks and the bright areas being lower elevations similar by analogy to dry ocean basins.

The radio emission of Mars was observed over the wavelength range from 3·2 mm to 21·3 cm and unsuccessful measurement attempts made to 154 cm, with the following observed disk brightness temperature or upper limits of intensity: 3·2 mm, 240°K (**132**); 3·4 mm, 190°K (**63**); 8 mm, 225°K (**20, 133**); 8·6 mm, 230°K (**132**); 3·75 cm, 190°K (**134**); 6 cm, 190°K (**75**); 6 cm, 192°K–11 cm, 162°K–21·3 cm, 190°K (**5, 19, 135**); 12·5 cm, 225°K (**24**); 21·2 cm, 271°K (**71**); 70 cm, $S < 0{\cdot}024 \times 10^{-26}$ w m^{-2} Hz^{-1}–154 cm, $S < 0{\cdot}05 \times 10^{-26}$ w m^{-2} Hz^{-1} (**18, 74**). These observations describe a spectrum consistent with thermal radiation from the surface of Mars with no evidence for non-thermal radiation or for ionospheric or atmospheric effects.

The atmosphere and ionosphere of Mars have been investigated (**3**) using a new technique of observing the occultation of the radio signals of a spacecraft by a planet (**136, 137**), and a number of interpretations of the results have been presented (**138–142**). A recent analysis indicates a tenuous atmosphere with a surface molecular number density only 0·8% that of the Earth, carbon dioxide at the principal atmospheric constituent with principally atomic oxygen above 90 km, the principal ion in the main daytime ionosphere is O$^+$, the temperature is low about 180°K near the surface and about 80°K at ionospheric heights, and the atmosphere is confined near the planet (**143**).

Jupiter

Radar contact with Jupiter in 1963 was reported by the Russian group (**144**) at 700 MHz who found a radar reflectivity of 10%, and by JPL (**145**) who found an echo from a zone centered on Jovian longitude 32° corresponding to a reflectivity of 60%, but no echo from other longitude zones. However, JPL did not find any echoes from Jupiter in 1964 using the same apparatus (**146**), and no echoes were observed at 430 MHz in 1964 using the Arecibo radar (**33**).

It was discovered by Bigg (**4**) using the observations of the High Altitude Observatory (**147, 148**) that the probability of occurrence of the decameter radiation depends on the position of the satellite Io in its orbit. This correlation has been confirmed by other observations (**8, 149–153**), and it has been pointed out (**150, 151**) that the decameter activity of Jupiter is most likely when the longitude of the central meridian in System III is either 110° or 250°, and at the same time Io is opposite longitude 200° on Jupiter which is in the plane of the magnetic axis. An investigation of the radiation from Jupiter at 3·75 cm shows no dependence on Io (**154**). One study (**153**) suggests weaker effects on the decameter radiation by positions of the satellites Europa and Ganymede, but another (**152**) shows no dependence. Evidence is presented that the decameter emission may depend on the relative positions of the Sun, the Earth, and Jupiter, and may be related to a magnetospheric tail (**155**). No pronounced correlation with solar activity was found (**156, 157**).

Catalogs have been published of the observations of Jupiter with the swept-frequency interferometer at the High Altitude Observatory for 1960–63 (**147**), and 1964–65 (**148**). Results of the high resolution spectral observations of the decameter radiation made at the University of Helsinki including the effects of Io are available in (**158–161**). Observations of the decameter radiation at six frequencies at the University of Tasmania are presented and analyzed (**162**), and the recent decameter observations of the University of Florida are given in (**8, 163, 164**). The polarization of the decameter radiation has been investigated (**165–168**). The very short time and narrow band decameter bursts from Jupiter have been the subject of a number of investigations (**10, 169, 170**). The apparent sizes of the decameter sources on Jupiter have been measured (**9, 171**), and effects of the Earth's ionosphere in producing scintillations (**172**) and Faraday rotation (**173**) have been studied. Observations of weak decameter radiation from Jupiter (**174, 175**) suggest that there may be a steady low-level component.

A study of the variable period of rotation found from the decameter sources (**176**) indicates that the apparent rotation period varies cyclically about a constant mean value in 11·9 years, Jupiter's orbital period, and the variation may be associated with beaming of the radiation.

Mechanisms of origin of the decameter radiation are discussed in (**7, 177, 178**), and the propagation of the radiation in the source is considered in (**179**).

Observations at shorter wavelengths have given the intensity of radiation from Jupiter (or disk brightness temperature) at 3·2 mm, 4·3 mm, and 8·6 mm (**132**); 8·35 mm (**180**); 2·07 cm (**67**); 3·02 cm (**181**); 6 cm (**75**); 6·5 cm (**182**); 13 and 21 cm (**68**); 43 cm (**183, 206**); 70 cm (**184**); and 70·16 cm (**185, 186**). The spectrum between 49 and 170 cm is discussed in (**16, 187**). Anomolously intense radiation at 8·6 mm was reported (**14**).

The intensity and polarization of the radiation has been measured at 21·2 cm (**188**), and at 70 and 155 cm (**15**). The intensity, polarization and beaming has been measured at 21·5 cm (**189**). Observations of the intensity, polarization, beaming, and rotation period have been made at 10 cm (**190**) and 21·2 cm (**71**). These parameters and in addition the angular diameter of the radio source have been determined at 49 cm (**191**), and a comprehensive study of the above parameters has been made at wavelengths of 6, 10, 11, 21, 74, and 100 cm and the characteristics of the radiation belts derived (**192**).

Further information about Jupiter's radiation belts is given by the measurements of the brightness distribution of the decimeter radiation (**12**), and other observations (**193–196**). The theory of synchrotron radiation in a dipolar field has been developed (**13, 197**).

Related theoretical work is available on the thermal emission of Jupiter (**198**), the atmosphere of Jupiter (**199**), and the magnetic field (**200**).

Saturn

Measurements of the brightness temperature of Saturn confirm the upward trend with increasing wavelength: 3·2 mm, 97°K–4·3 mm, 103°K – 8·6 mm, 116°K (**132**); 8 mm, 132°K (**20, 201**); 6 cm, 190°K (**75**); 11·3 cm, 182°K (**202**); 6 cm, 179°K–11·3 cm, 196°K–21·3 cm, 303°K (**5, 19**); and 21·2 cm, 286°K (**71**).

Attempts to measure linear polarization of the radiation at 11·3 cm (**5, 19, 202**) gave negative results with an upper limit of about 6%.

Uranus and Neptune

Uranus and Neptune have been added to the list of planets studied by their radio emission. An attempt to detect Uranus at 11·3 cm (**203**) gave an upper limit to the disk brightness temperature of 320°K. Later observations provided measurements of the disk temperature of 130°K at 11·3 cm (**5, 19**), 159°K at 3·75 cm (**204**), and 220°K at 1·9 cm (**6**). Observations of Neptune at 1·9 cm gave a disk brightness temperature of 180°K.

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PLANETARY INTERIORS

(prepared by W. C. DeMarcus)

A set of new models for Jupiter and Saturn has been published by P. J. E. Peebles (**1**). In his work the effects of temperature were included in more detail than earlier works. The hydrogen abundances derived by Peebles for these two planets are in very good agreement with previous models published by Ramsey (**2**), Fessenkov and Massevitch (**3**), DeMarcus (**4**) and Öpik (**5**). However the thermal effects, although significant only in the outermost layers, do alleviate a discrepancy in the ratio of the two accepted non-spherical terms in the external potential of Saturn. R. T. Reynolds and A. L. Summers (**6**) have published a set of models for Uranus and Neptune. In agreement with previous work, (**7, 8**) they find that hydrogen atoms (in whatever chemical form) are present only to the extent of 1/5 and 1/6 the mass of the total planet.

For the terrestrial planets, new models of the Earth have been calculated by F. Birch (**9**), R. G. McQueen, J. N. Fritz and S. P. Marsh (**10**) and S. P. Clark and A. E. Ringwood (**11**). In general these models incorporate new data from high pressure experiments and use the much more precise value of the coefficient of the second zonal harmonic derived from artificial satellite observations. Although the change in this coefficient is only about 1/3%, the density of the Earth's core is increased by roughly 5% which is in the direction and almost of the required amount to allow the assumption that the core is 'pure iron'. Detailed models of the other terrestrial planets have been published by S. Plagemann (**12**) (Mercury), D. L. Lamar (**13**) (Mars), R. A. Lyttleton (**14**) (Mars) and K. E. Bullen (**15**) discussed the interior of Mars.

Review articles on the Interiors of the Terrestrial Planets have been published by G. J. F. MacDonald (**16**) and R. L. Kovach and D. L. Anderson (**17**).

Some mention of recent observational results, presumably significant for the theory of planetary interiors in ways as yet not completely understood, may be made. Of necessity such citations can only be made in a fragmentary way. B. C. Murray and R. L. Wildey (**18**) measured the 8–14μ flux from Jupiter at the bottom of the Earth's atmosphere and reported that a 128°K black body at Jupiter's position would give the same results. F. E. Low (**19**) reported a set of monochromatic fluxes in the same region and deduced that a 132°K black-body would produce the same total 8–14μ flux but found the monochromatic fluxes gave a decidedly non-black spectral distribution. Low also measured the 8–14μ flux of Saturn and found it to agree with that of a 103°K black-body. W. J. Welch and D. D. Thornton (**20**) found an 'equivalent disk temperature' of 144°K ± 23°K at 8·35 mm wavelength. D. J. Taylor (**21**) studied the bolometric geometric albedo of Jupiter using data of essentially constant epoch. The time homogeneity of such data is rendered important by Harris (**22**) substantiation of

W. Becker's conclusion that the opposition visual magnitude of Jupiter varies with an amplitude of perhaps 0·5 magnitude. He found $p_B = 0{\cdot}28$ (± 10%). Assuming a conventional phase function this would imply an equilibrium temperature for Jupiter, if there were no internal heat sources, of 150°K. Spectroscopic estimates of 'temperatures' are summarized and discussed by T. Owen (**23**), T. Owen and T. E. Walsh (**24**) and more recently by R. E. Danielson (**25**) who reported some new measurements at the same time. In general the spectroscopic 'temperatures' are much larger than the bolometric ones. T. E. Stecher (**26**) utilized rocket measurements of Jupiter's reflectivity in the ultraviolet and found that they could be interpreted as implying about 11 km atm of H_2 above Jupiter's Cloud Layer. By way of contrast Rank, Fink and Wiggins (**27**), by other methods, estimate 270 km atm of H_2 above Jupiter's cloud level.

The physics of planetary interiors relies heavily on the physics of phase equilibria, (e.g. fusion, polymorphism, etc.). It would be impossible to incorporate a bibliography for these fields in a report of this size. Consequently a very few works are reported either because their results were surprising or because they may serve as key references for entry to more extensive bibliographical information.

K. F. Sterrett, W. Klement and G. C. Kennedy (**28**) redetermined the melting curve of iron and warned of the risks involved in extra-polation to pressures in the few megabar range. Also E. A. Kraut and G. C. Kennedy (**29**) have formulated a new empirical fusion law which, if extrapolated, implies a finite fusion temperature at infinite pressure. This result contrasts markedly with the Simon empirical fusion curve in current use which extrapolates to infinite melting temperature at infinite pressure. As 'key' references to a vast array of other physico-chemical work one can list two papers by A. E. Ringwood (**30, 31**).

The known existence of equatorial currents on Jupiter and Saturn pose vexing problems in fluid dynamics indeed. A paper by G. Carrier (**32**) indicates some of the perhaps surprising phenomena which occur in rotating fluids with density stratification and geometrical constraints. The possibility of even more complex hydrodynamic behavior for multi-component compressed gases is mentioned by W. C. DeMarcus and R. Wildt (**33**) in the last paragraph of a speculation on the nature of Jupiter's Red Spot.

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EXOBIOLOGY

(prepared by C. Sagan)

Four recent books provide general discussions of many aspects of exobiology. A lively symposium on prebiological organic chemistry and the origin of life, with attention to areas of common interest with astronomy is *The Origins of Prebiological Systems*, edited by S. W. Fox (Academic Press, 1965). A comprehensive discussion of exobiology in general, and the possibility of life on Mars in particular, written by 66 scientists of various disciplines over two years, is *Biology and the Exploration of Mars*, edited by C. S. Pittendrigh, W. Vishniac and J. P. T. Pearman (U.S. National Academy of Sciences, Washington, D.C., 1966). A companion volume containing a selection of representative papers, including a discussion of the Mariner IV results, and an extensive bibliography is *Extraterrestrial Life: An Anthology and Bibliography*, compiled by E. A. Shneour and E. A. Ottesen (U.S. National Academy of Sciences, Washington, D.C., 1966). See also *Intelligent Life in the Universe* by I. S. Shklovskii and C. Sagan (Holden-Day, 1966).

The prevailing belief—by no means rigorously proved—is that wherever we have a non-diffuse atmosphere of approximately cosmic composition at moderate temperatures and supplied with energy sources, organic molecules are produced in such profusion that self-replicating molecular systems capable of evolution by natural selection invariably arise (see for example, Pittendrigh *et al.*, 1966). Since the primitive atmospheres of planets in the solar system are, in many theories of origin, thought to contain reduced gases, and to have moderate temperature regions and energy sources at some atmospheric level, it is possible that the origin of life and life-related organic molecules is a pervasive accompaniment to the early evolution of planetary atmospheres. To determine whether the contemporary planets support indigenous life, three general procedures can be used:

(1) Determine the physical characteristics of the planetary environment. Some conditions, for example, very high temperatures, will be so severe as to exclude the possibility of life.

(2) Simulate the environment and test the capabilities of terrestrial microorganisms to survive there. A positive result will indicate that there are no insuperable physical or chemical constraints on indigenous life, but will certainly not prove the presence of indigenous life. It will, however, underscore the need for sterilization of space vehicles intended for such planets.

(3) Search for direct evidence for indigenous extraterrestrial life.

Progress in these three topics since 1963 are treated below:

(1) *Planetary Environments*

(*a*) *Mercury*

Studies of the disk-integrated microwave emission at wavelengths less than 2 cm indicate brightness temperatures varying with phase between 210° and 360°K (Kellermann, 1967, Epstein, 1967). These results combined with the radar reflectivities and the solution of the one-dimensional equation of heat conduction, indicate that some decimeters below the surface of Mercury on both the bright and dark sides biologically moderate temperatures prevail.

(*b*) *Venus*

Identification of water vapour above the clouds of Venus has been accomplished (Bottema, Plummer and Strong, 1964; Dollfus, 1963; Belton and Hunten, 1966; Spinrad and Shawl, 1966). The upper levels of the clouds have been shown to consist of ice (Bottema, Plummer, Strong and Zander, 1965; Sagan and Pollack, 1967*a*). Temperatures at greater depths in the clouds appear to be high enough to permit the formation of supercooled water droplets (Pollack and Sagan, 1965*a*; Sagan and Pollack, 1967*a*), which in turn seem capable of explaining the microwave spectrum (Basharinov and Kutuza, 1965). This combination of water, moderate temperatures and the known carbon dioxide content makes the clouds a possible biological habitat, since the major requirements for photosynthesis are provided, the principal uncertainty is the amount of inorganic minerals supplied by convection from the surface (see Sagan, 1961). Thermodynamic equilibrium studies have suggested that no substantial quality of hydrocarbons or other organic materials are present either in the clouds or on the surface (Mueller, 1964; Lippincott *et al.*, 1967). This result is consistent with an analysis of radar and passive microwave observations (Pollack and Sagan, 1965*b*).

The possible biological interest in the surface of Venus depends on the origin of the centimeter and decimeter microwave emission. The principal alternatives to a hot surface are the ionospheric model (Jones, 1961); the glow discharge model (Vakhnin and Lebedinsky, 1966) and the cloud electrical discharge model (Tolbert and Straiton, 1962; Plummer and Strong, 1966). The ionospheric model is inconsistent with the 19 mm limb darkening found by Mariner II (Barath *et al.*, 1964); in addition it encounters very serious difficulties because of the high ionospheric electron densities required (Walker and Sagan, 1966). The glow discharge conjecture assumes charge separation between the bright and dark sides of the planet, implying a maximum in the brightness temperature at dichotomy for the disk-integrated phase observations, and at the terminator for observations which resolve the disk. These predictions are inconsistent with the observations (Pollack and Sagan, 1965*c*; Clark and Kuz'min, 1965; Pollack and Sagan, 1965*b*). The electrical discharge model in all reasonable variants predicts limb brightening at 19 mm (Pollack and Sagan, 1967*a*); this is inconsistent with the Mariner II microwave observations. Hot surface models are in agreement with these various observables. If the microwave emission does arise from the surface of Venus, then there appears to be little likelihood of indigenous life on the planet, except for a bare possibility at high elevations in the polar region.

(*c*) *Mars*

The presence of water vapor in the Martian atmosphere has been confirmed spectroscopically, and has been shown to increase in the vicinity of the vaporizing polar cap in the Martian spring. (Schorn *et al.*, 1967). Here again, water, CO_2, and light are present, as well as a range of minerals at the surface and suspended in the atmosphere. Lower pressures than had previously been estimated have been found on Mars by ground-based spectroscopy and by the Mariner IV occultation experiment (see, for example, H. Brown, *et al.*, editors, 1965). Computer studies of insolation, heat conduction and carbon dioxide phase changes on Mars suggest that the polar cap is composed largely of condensed carbon dioxide (Leighton and Murray, 1966; Leovy, 1966). Both of these studies have no direct bearing on the possibility of life. The triple point pressure of water is just under 6 mb; therefore, where the total atmospheric pressure is 6 mb or less, liquid water at any temperature is forbidden. Variations of atmospheric pressure with topography (Sagan and Pollack, 1966) and with season (Leighton and Murray, 1966) have been suggested. The lower pressures imply that solar and galactic cosmic rays arrive at the Martian surface with relatively undiminished intensity (O'Gallagher and Simpson, 1965). However, the resulting increase in mutation rate is not significant compared to the spontaneous rate in terrestrial organisms (Horowitz, 1966). The Mariner IV results seem to have established a substantial topographical heterogeneity of the Martian surface. Therefore, it can be argued that even if the average conditions are inclement for indigenous biology, there may exist microenvironments (Lederberg and Sagan, 1962) which are more favorable.

The initial results of the Mariner IV photographic mission were converted into cratering statistics and compared with similar statistics for the Moon; it was concluded that the mean age of the fraction of the Martian surface viewed was comparable to the age of the planet (Leighton, Murray, Sharp, Allen and Sloan, 1965). Since no striking examples of water erosion features were found in these photographs, it was concluded that no liquid water had been present during the history of the planet. Since liquid water would seem an essential prerequisite for the origin of life on Mars, these results seemed to imply that life never arose on Mars. However, re-evaluations of the cratering statistics (Anders and Arnold, 1965; Baldwin, 1965; Witting, Narin and Stone, 1965) have reduced the age to several hundred million years, thus permitting several billions of years for extensive liquid water on early Mars (see also Hartmann, 1966). The radar implication that the Martian bright areas are lowlands analogous to terrestrial ocean basins (Sagan, Pollack and Goldstein, 1967) does not necessarily imply the existence of early oceans on Mars. If the Martian bright areas are composed—as the photometric and polarimetric data suggest—of limonite or goethite—hydrated ferric oxides—there is a very significant amount of water weakly chemically bound to the Martian surface; it is not out of the question that this source of water could be tapped by Martian organisms. This and related exercises in hypothetical Martian biochemical ecology are treated by Vishniac *et al.* (1966). The Martian exospheric temperature implied by the Mariner IV occultation experiment (Kliore, Cain, Levy, Eshleman, Fjeldbo and Drake, 1965) seems too low to permit the escape of any significant quantities of atomic oxygen during the age of the planet. The origin of limonite or goethite seems to imply the presence of substantial amounts of liquid water on primitive Mars (Sagan, 1966), now bound to the crust. Rocket observations (Evans, 1965) have indicated that solar ultraviolet light in the 2000–3000 Å region is falling unimpeded on the Martian surface. While the solar flux at this wavelength is lethal to many varieties of terrestrial microorganisms, possible protection mechanisms—some of them involving limonite or goethite—exist, and this observation cannot be considered to exclude life on Mars (see, for example, Vishniac *et al.*, 1966).

(*d*) *The Jovian Planets*

Computer exercises on quenched thermodynamic equilibrium (Lippincott *et al.*, 1967) as well as some laboratory experiments (Ponnamperuma, 1967) indicate that high temperatures, electric discharges or ultraviolet light applied to the presumed constituents of the atmospheres of the Jovian planets produce substituted benzenes and substituted polycyclic aromatic hydrocarbons in significant yield. Some of these compounds are brightly colored, and may contribute to the observed variable coloration of the clouds of the Jovian planets. Despite the low temperatures recorded in the infrared, the 2 cm brightness temperatures of the Jovian planets appear approximately constant from Jupiter to Neptune (Kellermann and Pauliny-Toth, 1966); a circumstance explicable in terms of the microwave absorption properties and the vapor pressure curve of ammonia. These and related observations seem to imply that long wavelength thermal emission is arising from deeper and warmer layers in the atmospheres of the Jovian planets, and that biologically more clement conditions exist deep in the atmospheres of these planets, as had been envisioned some years earlier (Sagan, 1964).

(2) *Simulation Experiments*

The wide range of habitats populated by terrestrial organisms – especially microorganisms – implies that very severe conditions are required to exclude the possibility of life. In experiments simulating Martian pressures, atmospheric composition, moisture content, diurnal temperature variation and ultraviolet irradiation, every sample of terrestrial soil tested contained some varieties of microorganisms capable of surviving the simulated Martian conditions indefinitely (Packer, Scher and Sagan, 1963). When the available amount of water is increased, growth and replication of microorganisms take place (Young *et al.*, 1964). However, at pressures below 6 mb, growth of terrestrial microorganisms does not take place, as anticipated (Hawrylewicz, 1967). There seems little doubt that at least in favored microenvironments, where the water content is higher than the Martian average, terrestrial microorganisms introduced to Mars may replicate. Planet-wide dissemination of contaminants by winds in a period of the order of a few years seems possible. To avoid interference with subsequent life detection experiments, and for other reasons, sterilization of Mars-bound spacecraft is mandatory (see Chapters 25–29 in Pittendrigh *et al.*, 1966). Growth of bacteria and fungi in ammonia-methane and ammonia-hydrogen atmospheres have been demonstrated by Siegel and Giumarro (1965). These conditions are not dissimilar from conditions expected in the Jovian atmosphere below the clouds. It seems likely that terrestrial microorganisms can grow in the warmer lower regions of the atmospheres of all the Jovian planets.

(3) *Direct Evidence*

The only samples of extraterrestrial materials currently accessible for laboratory investigation for organic matter and indigenous life are the meteorites. In the carbonaceous chondrites there is unambiguous indigenous organic matter of high molecular weight. While some mass spectrometric and other similarities have been reported with biogenic organic matter, the bulk of recent evidence suggests that these molecules can be produced at thermodynamic equilibria at temperatures of a few hundred degrees C in the solar nebula. Highly structured, so-called organized elements have been found embedded in the carbonaceous chondrites. Some of these have later proved to be terrestrial contaminants; others remain of unknown origin. There are no reliable cases of growth of viable organisms which are indigenous to the carbonaceous chondrites. For a discussion of these topics, see Anders and Fitch (1962); Fitch and Anders (1963); Urey and Arnold (1966); Staplin (1965); Studier, Hyatsu and Anders (1965).

A variety of previously supposed lines of evidence for life on Mars have now been shown to have alternative explanations. The Sinton bands at 3·45, 3·58 and 3·69μ attributed by Sinton (1957, 1959) and Colthup (1961) to methyl, methylene and aldehyde groups in the Martian dark areas now appear to have other explanations. The two longer wavelength features match the spectrum of HDO (Shirk, Haseltine and Pimentel, 1965) and similar features are found in spectra of the Sun taken through the Earth's atmosphere (Rea, O'Leary and Sinton, 1965). The 3·45μ features, if real, can be explained in terms of inorganic carbonates (Rea, Belsky and Calvin, 1963). The Martian seasonal changes previously attributed to biological activity appear to be quantitatively explicable in terms of windblown dust and elevation differences on Mars (Sagan and Pollack, 1966*b*, 1966*c*) following earlier suggestions of Sharanov (1957) and Rea (1964). Alternative a biological models of the seasonal changes include frost heaving of microhills (Otterman and Bronner, 1966) and presumably reversible ultraviolet interaction with crystals in the Martian surface (Smoluchowsky, 1965). Martian secular changes can also be understood in terms of drifting and windblown dust on regions of low slope (Pollack and Sagan, 1967*b*).

An inability to detect Martian life unambiguously over interplanetary distances does not of course exclude life on Mars. Studies of the Earth by meteorological satellites have shown it is extremely difficult to detect life on our planet even with resolution substantially better than the best ground-based or space-borne photography of Mars (Kilston, Drummond and Sagan, 1966). Substantial improvements in resolution are necessary for the remote photographic detection of life on Earth (Sagan *et al.*, 1966).

Despite a fair amount of speculation, a very small amount of actual observational work has been performed in attempts to detect intelligible radio transmission from planets of other stars. Despite an occasional provocative result — such as the apparent sinusoidal variation of the emission of radio source CTA 102 at 32·5 cm, but at no other wavelengths—nothing remotely approaching an unambiguous detection of intelligible radio signals has been performed. These questions are further discussed in Cameron (1963) and by Shklovskii and Sagan (1966).

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APPENDIX. STUDIES ON THE PHYSICS OF PLANETS IN U.S.S.R.

(prepared by D. Ya. Martynov)

This is a brief summary of the most important works published in U.S.S.R. within the period of 1963–66.

Mercury

V. I. Moroz investigated Mercury's spectrum between 1 and 13μ. It was found that CO_2 bands at 1·6μ are somewhat stronger than telluric bands. Possible contents of CO_2 are within limits from 0·3 up to 7 g cm^{-2}. Mercury's spectra were obtained close to perihelion, when its temperature was highest. Already in the 2–2·5μ region thermal radiation is more intense than reflected radiation. Brightness temperature near the 2·2μ region is 650° ± 20°K (reduced to the sub-solar point), colour temperature in the interval of 2·2–3·4μ is 670°K. Integral albedo makes up about 0·15 (**1, 2, 3**).

Brightness temperature of 530 ± 130°K on 8-mm wave, averaged over Mercury's disk and reduced to the standard distance, was obtained with the 22 meter radio-telescope RT-22 at the P. N. Lebedev Physical Institute in 1964–65.

The corresponding temperature of the sub-solar point of the planet turned out to be $T_0 = 660 + 120$°K, the temperature lapse to the terminator following the law $T = T_0 \cos^{1/4} \varphi$. On uniformly brightly illuminated part of the disk T equals 540 ± 85°K. The received data are in agreement with the measurements in the infra-red range and shows the possibility of interpreting the millimetre radiation as caused by heating only at the expense of solar radiation (**4**).

Venus

T. A. Polojentseva (Pulkovo) on the basis of photographic spectrophotometry confirmed the absorption of violet terminal of solar spectrum by Venus and drew attention to the variability of this absorption (**5**). N. P. Barabashov, I. L. Belkina came to the same results (**8, 9**).

N. A. Kozyrev (Pulkovo) received spectra of night sky of Venus.

Luminescence of atmosphere low layers was preliminarily identified with formadehyde luminescence. On 28 May 1964 he fixed a bright flash on the night part of Venus. It had a continuous spectrum which corresponded to much lower temperature than spectral energy distribution in the crescent of Venus. There are also emission lines and bands, especially in the region Hp. The full flash energy was estimated to be equal to 10^{22} erg (**6**).

N. P. Barabashov (Kharkov Astronomical Observatory) performed a theoretical analysis of data on brightness distribution across the disk of Venus which made it possible to estimate the value of the optical thickness of the layer situated above the cloud cover, $\tau < 0{\cdot}07$ (**7**).

V. I. Jezersky and V. N. Jevsjukov (Kharkov Astronomical Observatory) considered the problem of interpreting Regulus brightness attenuation curve for the polytropic model of upper atmosphere during an occulation by Venus (**10**).

In 1963–66 V. I. Moroz obtained and processed a large number of records of infra-red spectra of Venus. In the region of 3–4μ albedo of the planet does not exceed a few per cent. Probably in this interval a strong real absorption takes place which remains present also in the longer wavelength region. It is doubtful whether the cloud layer is composed of ice particles because ice bands are not found at 1·5 and 2μ region and they are clearly noticed in the terrestrial cirrus spectrum (**11, 12, 13, 14, 15**). Intensity of CO_2 bands in the region of 1–2·5μ is considerably reduced near the lower conjunction. Changes in the bands with phase make us inevitably to reject the 'simple reflection' model in which the cloud layer is considered to be a sharp optically equivalent to the solid surface above which an absorption layer CO_2 is situated. Observations are well presented by the model supposing that CO_2 absorption bands are formed inside the cloud layer possessing the properties of homogeneous dispersing medium. Optical thickness of the atmosphere of Venus in the visible and neighbouring infra-red spectral region (up to 2μ) makes up apparently 10–30, parameter $\frac{2\pi_2}{\lambda} \approx 20$, dispersion factor is about 10^{-5} cm^{-1}, relative concentration of CO_2 is about 2% (**17**).

Radio-emission spectrum of Venus in the wavelength range from 4 mm to 10 cm was measured with radio-telescope RT-22 of the Physical Institute. It was proved for the first time that brightness temperature of Venus is considerably lower in the millimetre range than in the centimetre one.

To explain the received spectrum, models of Venus are worked out in FIAN and NIRFI

(**18, 19, 20, 21, 22**). They include the model with 'cold' atmosphere, according to which high-temperature radiation of the centimetre region is emitted from the planet's hot surface, but the lowering of the brightness temperature in the millimetre region, is caused by absorption and re-radiation by the planet's colder atmosphere.

Joint Soviet-American measurements made by the Physical Institute of the Academy of Sciences and the California Technological Institute discovered differencial polarization and thus proved that radio-emission from Venus in 10 cm wavelength region is really caused by the hot surface of the planet; temperature of the equatorial part at Venus' midnight accounts for 650 ± 70°K (**23**). The day-time temperature on the surface of Venus slightly differs from the night temperature. Near the planet's poles there were discovered some regions, the temperature of which is approximately by 150°K lower than the temperature of the disk's equatorial part.

It was determined that dielectric constant of the planet's surface is $\epsilon = 2\cdot5$ and the planet's surface radius is 6060 ± 60 km.

In the Institute of Radio-Engineering and Electronics radio-emission and absorption in water cloud formations and in rain-drops were investigated, which made it possible to determine their electric parameters (**25, 26**). These investigations gave ground for making a conclusion on the origin of the cloud layer of Venus as consisting of overcooled water drops (**27**).

In the period of 11–30 June 1964 in the Soviet Union radar observations of Venus on frequency of about 700 MHz were continued.

Distance measurement accuracy as compared with 1962 was increased by eight times and as to speed – by two times, they made up accordingly 2 km and $2\cdot5$ cm s^{-1}.

Comparison of the results of different years showed that Venus was reflecting as more smooth sphere in the observation period in 1964 than in 1962.

Reflection factor of the surface of Venus determined by full energy of the received signal averages 19%.

Measurements on determining the rotation period of Venus carried out in 1964, confirm the conclusion on reverse rotation, and the value of this period, as follows from the results of 1962 and 1964, is equal to 230 days ± 25 days (**28**).

Judged by pictures of Venus in the region 7000 Å obtained in 1964 in the Crimean Astrophysical Observatory, the presence of oxygen in the atmosphere of Venus (upper-cloud layer) was confirmed; equivalent width of the most intensive lines of the band amounts to 5 mÅ. Oxygen content is estimated as not more than 150 cm-atm (**29**).

Mars

Polarimetric observation series of Mars were obtained at the time of oppositions in 1963 and 1965 (Kiev, Golosejevo). The series were received on the 28-inch (71 cm) reflector with the help of an automatic electric polarimeter in eight regions of spectrum which are cut out by light filters in spectrum interval of 355–600 mμ. Phase polarization curves were formed, they showed clearly the decrease of polarization inversion angle from 27° (λ = 600 mμ) up to 15° (λ_{eff} = 355 mμ). Analogous laboratory measurements of 16 samples of ground bed-rocks, which are close to the Martian ones by their photometric properties, showed that the inversion angle value for them does not depend on wavelength. Explaining the change of the inversion angle by the influence of the Martian atmosphere, an attempt was made to determine the optical parameters of the Martian atmosphere. The atmospheric pressure near the surface of Mars proved to be 19 ± 8 mb. Xantoderith-material of $Fe_2O_3 \cdot 2H_2O$ compound – comes closer of all to the Martian surface by its polarization properties (J. K. Koval, A. V. Morejenko) (**30, 31, 32, 33**).

Calculations were made which showed that the difference between total atmosphere pressure on Mars obtained from photographic investigations, on the one hand, and from spectroscopic ones, on the other hand, could be explained by the presence in the Martian atmosphere of a large quantity of aerosol particles with radius $r \leqslant 10^{-6}$ cm. The total quantity of aerosol particles with radius of 10^{-6} cm in the atmosphere column of 10^{15} cm^{-2} was estimated by E. G. Janovitskij (**34**).

In 1963 and 1965, V. I. Moroz measured the equivalent width of CO_2 bands in the interval of 1·1–2·5μ (**11, 35, 36, 37, 38**). Equivalent width of CO_2 bands near 1·6μ were used to estimate total pressure near the Martian surface. If we assume that the content of CO_2 in the Martian atmosphere is equal to 60 m-atm, then full pressure will be $p \approx 20 \pm 10$ mb (**37, 38**). Contents ratio O^{18} : O^{16} in the Martian atmosphere in the limits of error does not differ from that of the Earth. Dependence of the Martian albedo on the wavelength is close to limonite reflecting power (albedo). Spectrum of polar capes contains details resembling snow reflecting spectrum (**37**).

Photographic comparison of spectra made at Pulkovo made it possible to establish dependence of the reflecting power of the Martian atmosphere on the wavelength with maximum at $\lambda = 5200$ Å. Comparison of snow and ice parameters with the results of laboratory researches made it possible to conclude that particles which disperse light in the Martian atmosphere are snow (**39**).

In the FIAN of the Academy of Sciences of the U.S.S.R. brightness temperature of the illuminated part of Mars was determined. The temperature turned out to be 225°K ± 10°K, which shows that the temperature of the layer responsible for millimeter emission is superior to planet's average temperature (**40**).

In the Institute of Radio-Engineering and Electronics, in February 1963 radio-location of the planet Mars was carried out on the frequency of 700 MHz. Average reflection factor of Mars' surface is 7% (**41**).

Jupiter and Saturn

At the Astrophysical Institute of the Kaz. SSR Academy of Sciences (Alma-Ata) researches were carried out concerning latitudinal distribution of methane absorption across Jupiter's and Saturn's disk. The absence of an increase in absorption towards the edges of Jupiter's disk was again confirmed and, contrary to Hess' data, a decrease in absorption towards Saturn's poles is found similar to Jupiter.

Theoretical calculations on absorption distribution were carried out with allowance for the change of absorption facts with regard to depth in the Jupiter's cloud layer. It was found that the Jovian outer atmosphere should be by approximately four times more rarefied than it is usually assumed, hence pressure on the cloud layer surface amounts to about 0·5 atm (**42, 43, 44, 45, 46**).

Photometric and spectrum properties of the Red Spot, changes in contrast with the Spot approaching the edge of the disk were studied in different wavelengths. The Red Spot by its optical properties is similar to the surrounding cloud layer and is apparently of gas-aerosol formation (**47, 48**).

On the basis of radiometric observation data on Jupiter, obtained by Murray, Wildey and others, V. G. Tejfel made an attempt to determine the value of adiabatic temperature gradient in the Jovian atmosphere. The deduced value $4{\cdot}3 \times 10^{-5}$ degree/cm is in good agreement with theoretically calculated values (**49**).

N. P. Pribojeva measured intensity distribution in spectra of three Galilean satellites of Jupiter. Colour-indices were calculated (**50**).

According to data, obtained by V. I. Moroz, strong absorption bands of Jupiter's spectrum situated in the region of 1–2·5μ are identifiable with NH_4 and CH_4, but at 2μ and 1·23μ contribution of induced H_2 absorption is possible. Analysis of intensities conducted in the framework of the model of simple reflection gives total pressure near the upper limit of the cloud layer $P = 2$ atm, the amount of $CH_4 \approx 75$ m-atm, $H_2 \leqslant 50$ km-atm (**11, 3, 51**).

Spectra of Jupiter's satellites II and III possess peculiarities which can be explained by the presence of ice or snow on their surfaces (decrease of albedo in the region of $1 > 1{\cdot}4\mu$). In the spectra of satellites I and IV these peculiarities are absent (**3, 52, 53**).

U. V. Alexandrov (Kharkov Astronomical Observatory) analysed theoretically data received by the Kharkov Astronomical Observatory in 1933–58 concerning brightness distribution across the Jovian disk for one-layer and two-layer models of atmosphere and determined the values of the optic parameters (**54**).

At the Main Astronomical Observatory (Pulkovo), inner radiation belts of Jupiter were discovered (**55**) by goniometrical observations on the wavelength 6·4 cm. It was shown that the presence of gyrotropic atmosphere or phase temperature effect leads to some polarization of the planet's integral radio-emission (**56**).

A. A. Kaliniak discovered indications of non-stable atmosphere around three Galilean satellites of Jupiter (**57**).

S. K. Vsekhsviatskij (Kiev State University) noticed an unusual activity of Jupiter in 1962–65 and explained it as a display of volcanic activities (**58, 59, 60, 61**).

At the Crimean Astrophysical Observatory considerable intensity fluctuations of the ultraviolet spectral region for equatorial and polar sections of the Jovian disk connected with periods of greater activity in its atmosphere were discovered (**62**).

At the Abastumani Astrophysical Observatory electropolarimetric investigations of the surfaces of Jupiter and Saturn were carried out in the focus of the 40 cm refractor.

Polarization of the planet's integral light is low (from 0·1% to 0·5%) and does not show any evident dependence on the phase angle. Polarization in the central and polar regions is comparatively high and it depends on the phase angle. For all this, for both planets, the southern regions show greater polarization than the northern ones (maximum degree of polarization of the southern region of Jupiter is equal to 9·4%, and of Saturn 11·7%).

Especially high polarization (up to 14–15%) is displayed by the east and west sides of the outer ring of Saturn, and in this respect the west side always dominates over the east side (**63**).

At the Gorky Scientific Research Institute (NIRFI) brightness temperatures of Jupiter and Saturn near 1·25 cm region (ammonia resonance) were estimated. The difference between the brightness temperature and the infra-red temperature of the cloud layer for Jupiter and Saturn makes up 50°K (**64**).

Plasma frequency concerning the origin of decametrical radio-emission of Jupiter, with allowance to the planet's magnetic field, was discussed. The presence of characteristics of decametric emission may be explained if the magnetic field in the planet ionosphere amount to some oersteds and the electron concentration is $3 \cdot 10^5$ electrons cm^{-3}. In particular, this value of concentration is enough to explain direction of emission owing to gyroresonance absorption (**65, 67, 68**).

The movement of ionized gas in Saturn's exosphere under the influence of a force due to its rings, which is perpendicular to the magnetic field, was considered. The character of plasma drain due to the rings, and the magnetic field distortion in case of fully or slightly ionized gas was investigated in detail. The received criteria of considerable distortion of force lines allow (when there are experimental data of orientation of the polarization plane of radio-emission of Saturn) to judge over physical conditions in the planet's exosphere as well as over possibilities of existence of Saturn's radiation belts (**66**).

In September and October 1963 in the U.S.S.R., Jupiter's radio-location on the frequency 700 MHz was carried out. Average reflection factor of Jupiter is equal to 10% (**69**).

On the basis of photometric data analysis M. S. Bobrov (Astronomical Council of the U.S.S.R. Academy of Sciences) showed that Saturn's rings present a system with thickness of many particles. Divergences in observing the phase curve and the theory of 'inter-darkening' are explained by the fact that in the inter-darkening theory dispersion of particle sizes was not taken into account; and taking this fact into account leads to a good agreement between theory and observations. It was shown that neither diffraction of separate particles nor the opposition effect of Hapke and Gerels can explain the observing factors. Problems of ring dynamics were considered (**70**).

M. S. Bobrov gave an account of a number of rare phenomena in the Saturnian system, which will take place in 1966 and worked out a programme for their world-wide patrol observations (**71**).

According to his proposal, IAU Commission 16 circulated proposals dealing with observations of Saturn at the time of the Earth's and Sun's passage across their plane and with observing the non-illuminated side of the rings.

V. I. Moroz identified with CH_4 the strong absorption bands in Saturn's spectrum in the region of 1–2·5μ. In spectra of rings obtained with the 2·6 m reflector at a highly satisfactory signal to noise ratio details typical to reflection from icy particles are very distinctly seen (**3, 51, 72**).

Saturn's brightness temperature measured at FIAN of the U.S.S.R. averaged only over its disk, equals 132 ± 9°K, what is very close to the value received by the measurements in the infra-red region. Allowance for the radio-emission of the ring allows, according to M. S. Bobrov, to adjust the received value with the latest data of measurement in the region of 8–14μ (**73**).

Laboratory and Theoretical Research. Cosmogonical Problems

In the astrophysical laboratory of Pulkovo Observatory a 97 metre tube has been installed and tested; its purpose is investigation of molecular spectra of gas absorption. Changes in equivalent width of oxygen absorption lines (Band A) were studied depending on pressure change in the range from 0·1 to 1 atm for single and triple of passage light through the tube. (Mitrofanova, L. A., Jukova, L. N., Derviz, T. E.) (**74**).

U. V. Alexandrov and V. I. Garaja (Kharkov Astronomical Observatory) made a calculation of polydispersive indicatrices of light dispersion on particles, electrical properties of which differ slightly from the properties of surrounding medium (**75**).

E. G. Janovitskij (Kiev, Golosejevo) received approximate solution of a problem on diffuse reflection and light transmission through planets' atmospheres when dispersion indicatrix is arbitrary (but not very much oblate) (**76**).

V. V. Sobolev (Astronomical Observatory of the Leningrad State University) obtained average optical characteristics of the atmosphere of Venus (dispersion indicatrix, albedo of single dispersion). Meanwhile a modern theory of light dispersion and new observations data about changes in the stellar magnitude of Venus with phase were employed (**77**).

Some works by V. V. Sobolev and I. N. Minin (**78–81**) are devoted to theoretical investigation of light dispersion in the planet's atmosphere with regard to atmosphere layers' curvature. In the paper (**78**) integral and in (**79**) approximate differential equations of the problem are considered. These equations are solved approximately by the method of averaging by angles for homogeneous (**80**) and inhomogeneous (**81**) atmospheres. The obtained results can be applied to problems connected with studying twilight phenomena and planets' luminescence near terminator.

I. N. Minin offered an approximate method of solving the problem of polarized light dispersion in planet's atmosphere taking into account aerosol component and light reflexion from the surface (**82**).

B. Ju. Levin (Institute of Physics of the Earth) made a review of works dealing with the study of the formation process of planets. He also treated the problem of changing the content of metallic iron of primary and secondary origin in planets depending on the distance towards the Sun (**84**).

V. S. Safronov (Institute of Physics of the Earth) made a critical review of modern hypotheses on the origin of the protoplanetary cloud (**85**). The problem of the origin of asteroids and dispersion of their speeds was studied (**86**) as well as the origin of thermal inhomogeneities in the primary Earth connected with the dropping of large bodies into it during its formation (**87**). From the inclinations of the planets' rotation axes it was discovered that the masses of the largest bodies fallen on planets were of the order of a thousandth of their mass (**88**).

E. L. Ruskol (Institute of Physics of the Earth) considered the problem of dissipation of a considerable part of lunar tidal energy in the layer of reduced viscosity in the depth of 100–300 km (**89**).

S. V. Kozlovskaja (Institute of Physics of the Earth) tabulated the most probable mass values and radii of planets and satellites (**90**). From the comparative analysis of the inner structure of the planets' of the terrestrial group, it was found out that the substance of Mars and Venus on the whole is slightly denser than the substance of the Earth (**91**).

S. V. Majeva (Institute of Physics of the Earth) investigated the possibility of heating-up bodies of asteroid sizes by long-lived radioactive elements (**92**). She constructed curves of temperature distribution by depth for equal time moments for Mars and the Moon (**93**).

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