16. PHYSICAL STUDY OF PLANETS AND SATELLITES
(ÉTUDE PHYSIQUE DE PLANÈTES ET SATELLITES)

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1. INTRODUCTION

Physical studies of the planets and satellites have been extremely productive over the past three years with much new information resulting from space missions, ground-based techniques and analyses. In keeping with the form of previous reports and further efforts to reduce the IAU publication burden, this report will not attempt to review in detail the large body of significant research accomplished over the period, or to provide a comprehensive bibliography. Brief summaries of recent research have been prepared for the report by Dr M. J. S. Belton, Dr. D. D. Morrison, Dr A. T. Young, and Dr V. G. Teifel. Their summaries are followed by short notes on the IAU Planetary Data and Research Centers. Individual references have been kept to a minimum, and where possible are given by the *Astronomy and Astrophysics Abstracts* number in parentheses.

2. TERRESTRIAL PLANET RESEARCH

(A. T. Young)

A. *General Comments*

Several reviews have appeared since the last report. Papers on Mariner 10 results on Mercury have appeared in *Science* for 12 July 1974 and in *J. Geophys. Res.* for 10 June 1975, and will appear in *Icarus* for July 1976. Venus was comprehensively covered in a conference held at Goddard Institute for Space Studies in October 1974; the formal papers were published in the June 1975 *J. Atmospheric Sci.*, and a transcript of the meeting is also available (NASA SP-382). The principal Mariner 9 results on Mars appear in the July 10, 1973 *J. Geophys. Res.* (78, No. 20) and in Vol. 22 of *Icarus*. Finally, *IAU Symp.* 65 (12.012.007) and a Symposium in Russian on the physics of the Moon and planets (09.012.024) cover the whole planetary system.

B. *Mercury*

The major new information on Mercury comes from Mariner 10. In agreement with ground-based data, the surface was found to be similar to that of the Moon with low thermal conductivity shown by infrared measurements and dominant impact features with evidence for volcanism and early differentiation. The major differences (a lack of long crater-ray systems and the presence of long scarps) are attributed to Mercury's higher surface gravity and to a greater internal tectonic activity; both are consequences of Mercury's greater mass. An intrinsic Earth-like magnetic field was discovered approximately aligned with the rotation axis and with a surface strength about one percent of that of the Earth providing evidence for an internal dynamo and an iron core. The atmosphere was found to have a surface pressure less than 2×10^{-9} mbar; helium is an important constituent. An accurate mass for Mercury will come

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from its repeated encounters with Mariner 10. Some surface features have been detected by radar (11.092.011), which should eventually fill in the details in the hemisphere unobservable from Mariner 10.

C. *Venus*

Major progress has been made in understanding the clouds of Venus. The accurate determination of their refractive index by J. E. Hansen and his co-workers, and the accurate ground-based measurements of the low atmospheric humidity by the Lunar and Planetary Laboratory and the McDonald Observatory groups, have allowed the cloud material to be identified by G. T. Sill and L. G. Young independently as a strong sulfuric acid solution. The concentration is about 80 ± 5% by weight at the visible cloud tops. This composition explains the detailed infrared spectrum of Venus, including the 11.2 μ band, as well as the existence of clouds at temperatures above 400 K as measured by Venera 8 (10.093.023). The ease of photochemical production of sulfuric acid is discussed by R. G. Prinn (10.093.020) and the detailed properties of the clouds are given by A. T. Young (09.093.017).

Their yellow color remains to be explained. Recent proposals include bromine (G. T. Sill), nitric acid (M. Shimizu), and elemental sulfur (B. Hapke). Whatever the short-wavelength absorber, it must be in the same region, about 50 mbar, as the visible cloud tops. The much higher haze seen at the limb in Mariner 10 pictures, which is responsible for twilight phenomena such as the extension of the cusps, is probably a thin upward extension of the main cloud; the aerosol has about half the scale height of the gas (A. A. Lacis; R. E. Samuelson *et al.*) in this region. The detailed properties of the clouds at large optical depths cannot be uniquely determined from Venera-8 data because there are no data for a critical region near the cloud top (11.093.031). The 'inverse phase effect' seen in the spectroscopic data is now explained by the backscattering lobe of the aerosol phase function (09.093.009; 10.093.016) instead of by a layered structure.

The apparent motions of the ultraviolet cloud features have been extensively studied from the ground, and are shown in finer detail by Mariner-10 pictures. Features as large as several hundred kilometers change greatly in a few hours. The apparent motions accelerate from about 80 m s^{-1} in the morning to about 120 m s^{-1} in the afternoon (10.093.009), a result confirmed by the high-resolution Doppler shifts measured by W. A. Traub and N. P. Carleton. A four-day atmospheric rotation is supported by Venera wind data. There may also be a four-day periodicity in CO_2 absorption (11.093.008), although E. S. Barker finds longer periods, and not all the spectroscopic data are consistent with atmospheric rotation. There is still no satisfactory dynamical explanation of 100 m s^{-1} winds on Venus; the several proposals are reviewed by C. B. Leovy (11.093.040).

The ultraviolet markings, and the Doppler and spectroscopic data, all show large long-term variations. Over 200 water-vapor measurements by E. S. Barker and about 40 CO_2 spectra by L. G. Young and co-workers show no simple relations among CO_2 absorption, water-vapor abundance, CO_2 rotational temperature, and UV features. The CO_2 abundance varies mainly with time, but the temperature and water abundance vary mainly over the disk. An average cloudtop temperature map has been extracted from existing thermal-IR data by Ingersoll and Orton (11.093.009).

The earlier problems with radio and radar models of the atmosphere have been reduced by an upward revision of the brightness temperatures at longer wavelengths (10.093.008). Both the radio and the Venera data agree with an atmosphere that is adiabatic near the surface. This is due to the high infrared opacity of the lower atmosphere, and the fact that about one per cent of the sunlight reaches the surface, as shown by the later Venera data; convection is required to remove the energy absorbed by the ground.

The light reaching the surface is comparable to that on a dark cloudy day on Earth, and was sufficient for Veneras 9 and 10 to photograph the surface clearly. The pictures show large flat rocks that must account for the planet's radar scattering characteristics. The radar maps of the surface are now quite detailed (11.093.018; 12.093.019) and show large impact craters as well as other features. The Venera measurements of surface composition show that Venus is an evolved and differentiated planet, like Earth in this respect. However, the low atmospheric water abundance (below 0.2 % at all levels, according to the radio and radar data) remains a puzzle.

D. *Mars*

The detailed Mariner-9 photographs of the surface have shifted the study of Mars away from astronomy and toward geology and geophysics. The main results were given in the last report, but the details were not published until 1973. Some Mars-2 and -3 results (09.097.099) and Mars-5 data (12.097.067 ff.) have also appeared in print.

Perhaps the most perplexing discovery of Mariner 9 was that of braided stream channels. Despite some skepticism, the present consensus is that these probably were made by running water. As the present Martian surface pressure is near the triple point of water, several people have suggested that Mars had a much higher atmospheric pressure at a time recent enough to prevent these features from being appreciably overlain by impact craters – say, a few times 10^8 yr ago. But if Mars had an Earth-like atmosphere for long, the older impact craters would have been eroded away. Various schemes have been proposed for providing a dense atmosphere temporarily (10.097.055; 12.097.017,.018). The question of climatic change on Mars is generally linked to climatic change, especially ice ages, on Earth, and the same mechanisms (solar variability, orbital and inclination variations, volcanic activity, etc.) have been invoked. A runaway greenhouse resembling that proposed for Venus might rapidly shift CO_2 stored in the polar caps into the atmosphere if the solar heating were moderately increased. But there is a question whether the amount of CO_2 in the caps is large or small compared to that in the present atmosphere. As the Mariner data provide no reliable estimates of the thickness or bulk composition of the 'permanent' caps, these ideas remain rather speculative.

The great dust storm of 1971 was well observed by spacecraft and ground-based observers, and has stimulated a large amount of theoretical work as well. Ground-based observations (12.097.054) show that the storms begin in a localized area in which the dust settles out at night and rises again, over a larger area, each day. Eventually a widespread and long-lasting cloud is produced. Many mechanisms have been suggested and several reviews of the problem have been published (e.g., 10.097.045; 10.097,121; 12.097.001; and 12.097.077). Attention has also shifted from problems of the general circulation to local meteorology, such as the slope winds (10.097.106) that may be responsible for sweeping light-colored dust from the classical dark areas such as Syrtis Major.

The amount of dust involved in the storms is small. The average suspended particle size is a few microns, and total optical depths seem to be on the order of 5 to 10. Thus the layer of dust deposited by the storm should have an average thickness of a few tens of microns. This thin coating is easily removed in local areas of high wind, such as the wakes of crater walls and other topographic features.

As for the dust itself, the infrared spectra indicate silicates containing water of hydration, similar to terrestrial clay minerals (09.097.040,.041; 11.097.050). Hydrated iron oxides, long thought to be major ingredients, are probably only minor contaminants.

The role of water on Mars is becoming recognised as a large one. Not only is it involved with surface features (channels and perhaps permafrost slumping) and composition (water of hydration), but it may be the major component of the 'permanent' pole caps. In the atmosphere, it appears both in white clouds and as a catalyst in the recombination of $CO + O_2$ separated by photolysis, and it suppresses ozone as well (12.097.051). There is also the problem of returning the water frozen out in the polar cold traps to lower latitudes, since the average relative humidity on Mars is comparable to that on Earth. Glaciation, the melting of permafrost, and liquid water in the soil – perhaps as a saturated salt solution – have been proposed.

Because of the low surface pressure, the photochemistry in the Martian atmosphere extends down to (and probably includes) the surface of the planet. At higher levels, the ionosphere might be expected to resemble that of Venus, but there are significant differences (11.097.056).

A number of photometric studies have been published, many of them based on groundbased data. OAO ultraviolet spectrophotometry is reported by Caldwell (09.097.043). D. T. Thomp-

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son has analysed 'blue clearings' and finds contrast reversals and changes that are due to activity in the bright areas. Unfortunately the Mariner television data have not provided reliable photometry, but some Mars-2 and -3 photometry and a review of *UBV* data have been published (12.012.007).

3. OUTER PLANET RESEARCH

(M. J. S. Belton)

A. *General Comments*

A number of colloquia and workshop proceedings have been published during the report period which contain major reviews and groups of specialized research papers on topics in Outer Planet Research. These include *Exploration of the Solar System* (Ed. by A. Woszczyk, *IAU Symp.* **65**, Toruń, Poland, 1973), *Physics of the Moon and Planets* (ed. by D. Ya. Martynov and V. A. Bronshtehn, International Symposium in Kiev, 1968), *Atmospheres of Earth and the Planets* (ed. by B. M. McCormac, Proceedings of Summer Advanced Study Institute, Liège, Belgium, 1974), *The Atmosphere of Uranus* (ed. D. M. Hunten, Proceedings of Workshop at Ames Research Center, 1974). In addition several special issues of journals have appeared with groups of research papers concerned with outer planet topics. These include *Phys. Earth Planet. Sci.* **6**, 1, 1972 (Lunar Science Institute Conference on High Pressure Physics and Planetary Interiors, Houston), *Planetary Space Sci.* **21**, 1465, 1973 (Planetary Atomospheres Advanced Study Institute, Istanbul), *Icarus* **24**, 277, 1975 (a group of papers concerned with Uranus), *J. Geophys. Res.* **79**, 3487, 1974 and *Science* **183**, 4122, 1974 (Papers on the Pioneer 10 Jupiter Flyby), *Science* **188**, 445, 1975 (Pioneer 11 Jupiter Flyby). The following books have also been published or are in press: An English translation of *Physical Characteristics of the Giant Planets* by V. G. Teifel (NASA TT F717, 1972), *Physics of the Solar System* (ed. by S. I. Rasool, NASA SP-300, 1972) and *Jupiter* (ed. by T. Gehrels).

B. *Jupiter: Atmospheric Structure, Chemistry and Dynamics*

F. W. Taylor has examined the possibilities for remote IR temperature sounding on Jupiter. Similar studies have been done by G. Ohring and by T. Encrenaz and D. Gautier. The latter found that it should be possible to infer the thermal profile and [H/He] ratio from absolute measurements of the spectra between 18 and 50 μ.

G. S. Orton has inverted infrared brightness temperatures obtained with Pioneer 10 to yield a vertical temperature structure. There is a stratospheric inversion which reaches 133–143 K near the 0.03 bar level. The molar fraction of H_2 that is most consistent with Pioneer-10 data is 0.88. J. S. Hogan, R. D. Cess, T. Encrenaz and D. Gautier find that a [H_2/He] ratio of 5 implied by the Pioneer-10 IR results. L. Wallace, M. Prather and M. J. S. Belton have computed theoretical temperature profiles which include stratospheric heating due to CH_4. The models are in excellent agreement with the revised Pioneer-10 radio occultation data.

Pioneers 10 and 11 produced three useful independent soundings of the neutral atmosphere. A temperature minimum of $\sim$ 110 K exists at the 100 mbar level. The derived profiles are consistent with the results derived from inversion of the thermal spectrum and theoretical calculations. Early published reductions of the spacecraft data which showed very high temperatures at the 1 atmosphere level were shown to be spurious by A. J. Kliore and P. M. Woiceshyn who have reanalyzed the data to include the effects of planetary oblateness on the ray path through the atmosphere. The importance of the latter effect was first recognized by W. B. Hubbard, D. M. Hunten and V. Eshleman.

The occultation of β Scorpii by Jupiter on 1971, May 13, was widely observed and recent detailed studies of the resulting light curves by W. B. Hubbard and associates, J. Veverka and associates, L. Vapillon and associates, and L. Wallace have shown that great care must be exercised in the inversion of the data to an atmospheric temperature profile and that much of the apparent detail may have little obvious physical significance. The high Jovian stratosphere is clearly at an elevated temperature.

The light curves showed strong intensity spikes which were measured with high time resolution in three colors by J. L. Elliot, L. H. Wasserman, J. Veverka, C. Sagan and W. Liller. Time delays between the spikes yield a value for the helium fraction in the atmosphere at ~0.16 by number.

Also J. Lecacheux, M. Coombes, L. Vapillon used precise timing of the occultation to derive an equatorial radius of 71 802 ± 55 km referenced to the occulting level.

A comparison of stratospheric temperatures measured during emersion and immersion yielded an estimate of nighttime cooling. L. H. Wasserman has utilized such an estimate to show that the $[CH_4/H_2]$ mixing ratio cannot be significantly greater than the other quoted value of 7×10^{-4}.

Observations of the eclipses of Galilean satellites have been used to vertically probe the transmission of the atmosphere by M. J. Price, J. S. Hull, P. B. Boyce and R. Albrecht but it was not found possible to arrive at a unique model to describe the observations. Further detailed observations of satellite eclipses have been made by R. W. Shorthill, T. F. Greene and D. W. Smith who find strong indications of aerosols present in the lower stratosphere.

The probable chemical nature and location of Jovian cloud has been studied by S. J. Weider-schilling and J. S. Lewis. H_2O, aqueous NH_3 and NH_4SH cloud are all possible. C. Sagan and G. Mullen have also discussed the possible presence of H_2O clouds. A preliminary discussion of NH_3-H_2O cloud droplet formation has been reported by D. Stauffer and C. S. Kiang from the standpoint of the theory of homogeneous nucleation theory.

G. E. Hunt and J. T. Bergstralh have observed extreme variability in the observed strength of hydrogen absorption lines presumably in response to rapid changes in the structure of the visible clouds.

V. G. Teifel has interpreted the variable 5-μ brightness-temperatures as the result of changes in transparency of the upper cloud layer from place to place. Detailed 5-μ maps of the planet have been published by C. Keay and associates and by J. Westphal.

A large number of new molecules have been detected in the atmosphere, primarily as a result of the application of Fourier transform spectrometers. Traces of CO were detected near 5 μ by R. Beer with a mixing ratio of $\sim 10^{-9}$. H. P. Larson, U. Fink and R. Treffers have announced the possible detection of GeH_4 and HCN, also in the 5-μ window. The probable presence of Germanium in the atmosphere was predicted earlier by R. J. Corice, Jr., and K. Fox. Larson, Fink, Treffers and T. N. Gautier III have also announced the detection of H_2O near 5 μ. They estimate a mixing ratio of $\sim 10^{-6}$ and an excitation temperature in excess of 300°K. Deuterat-ed methane, CH_3D, was also discovered in report period by R. Beer, C. B. Former, R. H. Norton, J. V. Martonchik and T. G. Barnes. The isotopic form $^{13}CH_4$ has also been tentatively identified by K. Fox, T. Owen, A. W. Mantz and K. N. Rao near 1.1 μ. They find an isotopic abundance ratio $[^{12}C/^{13}C]$ of 1100. HD was detected at 7467 Å by J. T. Trauger, F. L. Roesler, N. P. Carleton and W. A. Traub. The [D/H] ratio implied by the observation was estimated at 2.1×10^{-5}. C_2H_2 and C_2H_6 have been identified by S. Ridgway and confirmed by M. Combes and associates.

T. Encrenaz has completed a theoretical study which makes predictions on the structure of the 6–14 μ spectrum including H_2, CH_4 and H_2. Band models for the ν_4 CH_4 complex have been investigated by F. W. Taylor. The [D/H] ratio in the atmosphere implied by the observa-tions of CH_3D has been discussed by H. Reeves and Y. Bottinga and by R. Beer and F. W. Taylor. The latter authors stress the sensitivity of the determination on the degree of deuterium fractionation in the atmosphere. They provide a detailed analysis of the physical mechanisms that may be involved in fractionation.

Observations of the ν_2 NH_3 band between 8–13 μ have been discussed by several authors. Data has been reported by D. K. Aitken, B. Jones, S. Ridgway and also by D. M. Rank, C. H. Townes and their associates. The NH_3 is seen in absorption and the spectrum is in reasonable agreement with model predictions providing NH_3 is effectively absent above the tropopause. T. Encrenaz, T. Owen and J. H. Woodman report an improved abundance for NH_3 (13 ± 3 m atm) from observations of the band at 6450 Å. J. T. Bergstralh studied the $3\nu_3$ CH_4 band at 1.1 μ and has analysed several distinct models of line formation.

F. C. Gillett and J. A. Westphal have reported limb brightening of the planet in the 7.9 μ CH_4

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band. This observation is consistent with stellar and radio occultation results which indicate the presence of a substantial inversion in the stratosphere.

Evidence for the presence of rotation Raman scattering has been found by H. Fast, R. Poeckert and J. R. Auman by applying correlation techniques to the near UV spectrum.

The helium abundance problem was reviewed by D. M. Hunten and G. Münch who conclude that $[He/H_2] = 0.11$ is the most reliable value available.

G. E. Hunt and J. S. Margolis have made detailed calculations on the influence of collisional narrowing on the interpretation of the H_2 quadrupole lines formed in vertically inhomogeneous atmosphere and conclude that the mixing ratio of CH_4 to H_2 is not substantially different from the generally accepted value of 7×10^{-4} when the effect is included.

Airplane observations of the spectrum between 16 and 40 μ clearly show the structure of the pure rotational pressure-induced lines of H_2. This observation has been reported and analyzed by J. R. Houck, J. Pollack and associates. A broad, unexpected feature was also found in the spectrum at 23 μ. This is at present unexplained although K. Fox has ruled out many possibilities, including pressure-induced dipole transitions involving $H_2 + CH_4$ and $H_2 + HD$. C. deBergh, J. Lecacheux, M. Combes and J. P. Malliard report observations of the (2–0) pressure-induced H_2 band and estimate an effective abundance of 34 ± 16 km atm.

Observational work on motions in the Jovian atmosphere include the suggestion by R. G. Taylor that relative motions of photographic features visible in different colors may be due to vertical sheer. C. J. Banos, D. G. Dialetis, and C. E. Allissandrakis have obtained new photometric results on the red spot and E. J. Reese has given extended accounts of its photographic behavior. L. Krinsky and Z. Pokorny have documented an apparent relationship between the atmospheric rotation period and the 11-year solar cycle and J. L. Inge has published short term rotation profiles on the planet from planetary patrol plates taken between 1970–72. P. H. Stone has proposed that the observed difference between system II and III rotation rates is simply a reflection of a difference between phase speeds and true speeds. Estimated phase speeds for Rossby waves in Jovian conditions agree with this hypothesis.

A theoretical investigation of differential rotation is reported by V. P. Starr who has also looked into a dynamical model which ascribes the Jovian dark spots to the visible manifestation of planetary scale, vertical, convective systems. A model which views the alternation of zones and belts as a result of deep convective elements ordered by the rapid planetary rotation has also been outlined by F. H. Busse. In a different approach P. J. Gierasch suggests that the belt and zone structures are due to secondary circulations driven by radiative instability induced in the upper cloud layers by the solar insolation and radiation to space. The equatorial jet has also been the subject of a number of studies: T. Maxworthy proposes that planetary scale stratospheric waves are the source of the momentum. G. P. Williams and J. B. Robinson have looked into effects of large scale convective instability on the circulation pattern. New calculations on the radiative equilibrium state in the Jovian troposphere, which include the effects of NH_3 opacity, have been made by L. Trafton and P. H. Stone. The results are important for assessing the importance of radiative drives to the large scale atmospheric circulation.

T. Maxworthy and L. G. Redekopp have proposed that the great red and other spots are the manifestation of long lived solitary waves. The theory predicts an interaction between overtaking spots that is similar to what is observed. The origin of the red spot was also discussed by G. P. Kuiper.

In other work R. E. Newall and C. Boyer have made a search for seasonal changes in the Jovian atmosphere.

Space does not permit further detailed summary of all activities concerning Jupiter. There are some 40 papers on photometric studies, 20 on interior structure, 26 on radio observations and their interpretation, and about 30 on the Jovian magnetosphere. For most of the important results concerning the magnetosphere the reader is directed to the references concerning Pioneer 10 and 11 given under General Comments.

C. *Saturn*

L. W. Brown has detected non-thermal radio emission from the planet at 1 MHz providing the first direct evidence of magnetospheric activity. The properties of model magnetospheres have been discussed by F. L. Scarf. New observations at 69.7 and 21.4 cm have been reported by J. J. Condon, M. J. Yerbury, and D. L. Jauncey and used to set lower limits on the NH_3 mixing ratio. A. D. Kuzmin and his associates have also discussed the subcloud abundance of NH_3. Measurements at 2.07 and 3.56 cm (B. L. Gary), 21.4 cm (F. Briggs; G. L. Berge and D. O. Muhleman) and 49.5 and 94.3 cm (Yerbury, Condon and Jauncey) have also been reported. T. R. McDonough and N. M. Brice predict that H atoms escaping from the atmosphere of Titan may have established a toroidal ring with density between 1 and 10^3 H atoms cm^{-3} around Saturn. Such molecules are not able to escape the much larger gravitational field of the planet.

E. J. Reese gives the results of an extended photographic study of Saturn in which the latitudes of ten belts are mapped out. A very long lived spot had an average rotation period of $10^h36^m27^s.9$. O. T. Bukaenko and C. S. Galkin have found substantial fluctuations in the measured polarization of the disc at UV wavelengths. Anomalous behavior of the polarization vector is found in equatorial regions. In the infrared F. C. Gillett and G. S. Orton have made center to limb scans at 11.7 μ that show limb brightening and an unexpected enhancement near the south pole.

T. Encrenaz, M. Combes, Y. Zean, L. Vapillon and J. Berezne report the detection of C_2H_4, C_2H_6 and CH_3D in the planets atmosphere. A. Tokunga, R. F. Knacke and T. Owen have independently found C_2H_6. Several lines of the $3\nu_3$ band of $^{13}CH_4$ have been identified in spectra by M. Combes, C. deBergh and J. Lecacheux. They estimate a $^{12}CH_4/^{13}CH_4$ ratio of ~60. The $3\nu_3$ band of CH_4 has been the subject of a number of careful studies. The French group of C. deBergh and associates find an abundance for CH_4 of 42 m atm and an excitation temperature of 134 K. Similar studies by L. Trafton and by J. T. Bergstralh give varying results for the effective abundance but similar results on the temperature. Trafton and W. Macy Jr. have applied a homogeneous scattering model for line formation to their observations of this band and find a distinctly worse fit than is the case for a simple reflecting layer model and conclude that scattering plays only a minor role.

G. Ohring has performed an inversion of 7–14 μ brightness temperatures in order to deduce the vertical temperature profile in the atmosphere. A strong stratospheric inversion to a temperature of 134 K is indicated. The location of cloud layers has been investigated by V. G. Teifel and G. A. Kharitonova. They find clouds to exist at much higher altitudes in the equatorial zone on the basis of an analysis of a combination of photometric and spectroscopic measurements. New models of the interior structure have been presented by V. N. Zharkov, A. B. Makalkin and V. P. Trubitsyn and by M. Podolak and A. G. W. Cameron. The latter authors stress the role of the primitive condensation sequence in determining the chemical nature of the outer planets.

D. *Uranus*

New radiometric measurements include broad band albedos between 2000 and 4300 Å by B. D. Savage and J. J. Caldwell, narrow band albedos between 0.3 and 1.1 μ by W. Wamsteker, brightness temperatures at 24 μ by D. Morrison and D. P. Cruikshank and at 10.6, 12.6, 22.5 and 33.5 μ by G. H. Rieke and F. J. Low. New results at radio wavelength have been reported at 21 cm by F. H. Briggs and at 3.56 cm and 2.07 cm by B. L. Gary. L. D. Kavanagh, Jr. has computed the synchotron emission to be expected from pausable magnetospheric models for the planet. G. Siscoe has also given an extensive treatment of the properties of possible Uranian magnetospheres in which the peculiar rotational geometry of the planet is emphasized. S. K. Atreya and T. M. Donahue have constructed a photochemical equilibrium model for the planets ionosphere.

M. J. S. Belton, L. Wallace and M. J. Price have detected the Raman effect in the Uranus spectrum near 4000 Å. Stokes shifts corresponding to both the S(0) and S(1) rotational transitions in H_2 are present. The H_2 quadrupole lines have been the object of several studies. New results on lines in the (3–0) band are reported by B. L. Luz and for lines in the (4–0) band by M. Price, L. Trafton and by T. Owen, T. Encrenaz and their associates. The large

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column amounts of hydrogen and extreme mean scattering free paths deduced from earlier measurements and an excitation temperature near 100 K has been confirmed. A. McKellar has pointed out the importance of including pressure shifts in addition to collisional narrowing in the interpretation of the equivalent widths of these transitions. The pressure induced spectra of H_2 has also been investigated. Belton and H. Spinrad have presented new observations of the spectrum of each of the outer planets in the vicinity of the (3–0) S(0) pressure induced transition. Their analysis shows that a small amount of aerosol is present in the planets atmosphere. Spectral features near 6420 Å that had previously been associated with the (4–0) pressure-induced band of H_2 were shown to be due to some absorber other than H_2. Owen, Lutz, C. C. Porco and J. H. Woodman find these features to be due to CH_4 transitions. R. E. Danielson has proposed that pressure-induced simultaneous transitions in $H_2 + CH_4$ may be responsible for many features in the visible spectrum but there has been no confirmation of this. Lutz and Owen found no feature near the position of the (4–0) P(1) line of HD and have placed an upper limit on [D/H] at 4×10^{-4}. Discrete methane absorption near 6800 Å tentatively identified as R branch transition in the $5\nu_3$ band have been analyzed by Belton and S. H. Hayes and by J. T. Bergstralh with similar results. The $[CH_4/H_2]$ mixing ratio is model dependent: For simple reflecting layer model the value is 3 to 10 times the value expected for a solar composition while for a deep scattering model the same ratio is some three times less. CH_4 bands near 5000 Å imply much larger mixing ratios according to Owen and R. D. Cess. The excitation temperature of the $5\nu_3$ band is roughly 100 K, almost twice the value estimated previously from low resolution spectra and the effective pressure is ~2–3 atm. Belton and Hayes infer the presence in the atmosphere of large amounts of another gas in addition to H_2 from this latter result. Detailed models of the vertical structure of the atmosphere have been presented by L. Wallace which indicate the possibility of a strong thermal inversion of at least 140 K at a pressure of ~ 3 dyne cm^{-2} in the planets stratosphere. The result shows a strong dependence on the degree of saturation of CH_4 near the tropospause. In connection with the proposed Mariner Jupiter/Uranus mission important discussions of the interior structure (W. B. Hubbard), cosmogony (A. G. W. Cameron) and atmospheric dynamics (P. H. Stone) have been published.

E. *Neptune*

B. D. Savage and J. J. Caldwell report broad band albedos between 2000–4300 Å measured from OAO-2. The albedos may imply the presence of absorbing constituents in the upper atmosphere. W. Wamsteker has measured the wavelength dependence of the geometric albedo of the planet in many narrow bands from 0.3 to 1.1 μ. He finds the apparent abundance of CH_4 to be less than that present on Uranus. J. F. Appleby has also reported new photometric measurements in the visual. In the thermal-infrared D. Morrison and D. P. Cruikshank have measured the brightness temperature at 24 μ. Neptune appears to be significantly brighter than Uranus, a result confirmed by G. H. Rieke and F. J. Low. The latter authors also give new measurements of the brightness temperature at 34 and 22.5 μ. The wavelength dependence of the brightness temperature is not compatible with existing models. R. E. Murphy and L. M. Trafton interpreted the 24-μ brightness temperature to imply a major internal heat source in the planet, a conclusion considered premature by Rieke and Low. Trafton suggests that internal heating may be caused through tidal action by Triton. The occultation of BD–17°4388 by Neptune has received much attention with reanalysis of existing data by J. Veverka, L. Wasserman and their associates and by L. Wallace. Emphasis was placed on the information content of occultation curves particularly in the presence of what appear to large amplitude intensity spikes. The results indicate a strong thermal inversion is present in the planets stratosphere. Trafton reports the detection of two lines of the (4–0) band quadrupole transitions in H_2. The lines are effectively identical in strength to the same lines in Uranus. L. E. Rose has computed a new value for the mass of the planet from early measurements of Nereid by Van Biesbroeck. S. K. Atreya and T. M. Donahue have constructed a detailed ionospheric model for the planet based on photochemical equilibrium.

F. *Pluto*

J. S. Neff, W. A. Lane and J. D. Fix have resolved the ambiguity in the rotation period and have confirmed the 6.39-day period found previously by Hardie. Fix and L. A. Andersson have obtained photometric light curves which indicate that the planet has a large obliquity. Polarimetric results have also been reported by L. A. Kelsey and Fix which seem to indicate a negative branch to the phase dependence. M. H. Hart discussed the nature of possible atmosphere on the planet while Fix has considered the range of likely models appropriate to the interior structure.

4. SATELLITE RESEARCH

(D. D. Morrison)

During the report covered here, physical studies of the satellites have developed into an important area of planetary research. Two major review papers appeared in *Space Science Reviews* in 1973 and 1974: 'A Survey of the Outer Planets, Jupiter, Saturn, Uranus, Neptune, Pluto, and Their Satellites,' by R. L. Newburn, Jr., and S. Gulkis (09.091.005); and 'Physical Properties of the Natural Satellites' by D. Morrison and D. P. Cruikshank (11.091.004). In 1974 two workshop proceedings appeared as NASA Special Publications Nos. 340 and 343: *The Atmosphere of Titan* (ed. by D. M. Hunten); and *The Rings of Saturn* (ed. by F. D. Palluconi and G. H. Pettengill). In August 1974, *IAU Colloq.* **29**, 'Planetary Satellites,' was held at Ithaca, New York, and the proceedings of that conference (ed. by J. A. Burns), are to be published in 1976 by the University of Arizona Press. This book includes a bibliography of approximately a thousand titles. Contributed papers from the Colloquium were published in *Icarus* **24**, No. 4, and **25**, No. 3. Finally, the Galilean satellites, particularly Io, were discussed in *IAU Colloq.* **30**, 'Jupiter,' and the invited papers from that meeting (ed. by T. Gehrels), will be published by University of Arizona Press in 1976. In recognition of the growth of this area, in 1974 separate satellite listings were instituted in *Astronomy and Astrophysics Abstracts.*

Studies of individual satellites and their relationships to the rest of the solar system have profited greatly during this report period by increasingly sophisticated models for the chemical and physical evolution of the solar nebula discussed by J. S. Lewis, A. G. W. Cameron, L. Grossmann, J. B. Pollack, E. Anders, P. Goldreich, and their colleagues. However, these results will not be further discussed in this satellite report.

A. *Phobos and Deimos*

The two small satellites of Mars have been observed polarimetrically and photometrically by D. Pascu and B. Zellner. In addition a major increase in our knowledge has resulted from analysis of high-resolution Mariner-9 images by J. B. Pollack and others (08.97.087; 10.097.028). Both are irregular bodies with low albedo ($P_V = 0.06$) and fragmented, dusty surfaces. Their radii (in km) are: Phobos, $14 \times 11 \times 10$; Deimos, $8 \times 6 \times 6$. The surfaces are saturated with craters, and the regolith is estimated to be of the order of 100 m thick. The Mariner-9 instruments were also used by M. Noland and others for photometry at large phase angles and by I. Gatley and others for eclipse radiometry. T. C. Duxbury and J. Veverka and colleagues have discussed mapping of these satellites and published a complete Mariner-9 Atlas (12.097.202). A comprehensive review by Pollack is in press in *Planetary Satellites.*

B. *Io*

Studies of Io, its extended atmosphere, and its interactions with Jupiter, have constituted some of the most exciting developments of 1972–75, and at this writing it is possible to give little more than a progress report.

Multicolor photoelectric photometry by R. L. Millis and D. T. Thompson, by D. Morrison

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and others, and by C. Blanco and S. Catalano, have resulted in much improved determinations of the dependence of brightness and color on solar and orbital phase. Each of these observers has also reported an unexplained apparent secular brightening of this satellite, particularly well documented for 1972–74. Infrared photometry by F. C. Gillett and others, T. D. Lee, O. L. Hansen, and Morrison and others have demonstrated the remarkable extension of the high visible albedo out to wavelengths beyond 3 μm. High-resolution spectra by U. Fink and others show little spectral structure in the 1- to 3-μm region. Attempts by a number of photometric observers to confirm the elusive post-eclipse brightening of Io have resulted in both positive and negative reports, and the question of the reality of this phenomenon remains unresolved.

Infrared measurements by D. Morrison, D. P. Cruikshank, and O. L. Hansen of the temperature response of the surface to changing insolation during an eclipse indicate an insulating surface with a lunar-type thermal conductivity.

The occultation of β Sco C by Io in 1971 resulted in a precise diameter determination (3640 km) as well as setting upper limits on an atmosphere. The mass was established by J. D. Anderson and others from Pioneer-10 measurements (8.91×10^{25} g) and leads to a density of 3.52 ± 0.10, similar to that of the Moon. The inferred composition, based on chemical models by J. S. Lewis, A. G. W. Cameron, and others is primarily silicate, with a low fraction of volatiles.

Direct evidence of an atmosphere was first obtained in 1973 by R. A. Brown (11.099.222), who discovered the D lines of sodium to be in emission, and since that time many observers have contributed to the study of this atmosphere. L. Trafton and colleagues (11.099.218) demonstrated that the emission came not from Io itself but from a cloud tens of thousands of kilometers in extent. J. Bergstralh and others demonstrated from the dependence of line strength on Sun-satellite velocity that the main emission mechanism was resonance scattering of sunlight. In 1973 a second component of the extended atmosphere – hydrogen – was discovered by D. L. Judge and R. W. Carlson (11.099.021) with the Pioneer-10 ultraviolet photometer. Trafton discovered potassium emission in 1975. A substantial source for these materials is required on or near Io in order to maintain the observed clouds. The most plausible source for Na and possibly also K is sputtering at the surface of Io by Jovian magnetospheric protons, as first suggested by D. L. Matson, T. V. Johnson, and F. P. Fanale (12.099.206), but details including the possible contribution of other effects are unclear. The surface of Io, with its high visible and infrared albedo, its absence of infrared spectral features, and its apparent ability to provide a source of sodium is unique in the solar system. The most plausible suggestion for the surface, by Fanale and others (12.099.247), is sodium- and sulfur-rich evaporite deposits resulting from extensive former hydrothermal outgassing of the interior.

The Pioneer-10 radio occultation experiment (11.099.205) demonstrated the existence of a substantial day-side ionosphere. This ionosphere apparently provides sufficient electrical conductivity to explain the modulation by Io of the Jovian decametric emission, as postulated in 1969 by Goldreich and Lynden-Bell. Direct sweeping of Jovian charged particles, as well as local acceleration mechanisms and suggestions of an Io-Jupiter flux tube, were also obtained by Pioneers 10 and 11.

Reviews dealing primarily with Io by R. A. Brown and Y. L. Yung and by R. W. Carlson will be published in the book *Jupiter.*

C. *Other Satellites of Jupiter*

Among many physical studies of the Galilean satellites, the most important new results deal primarily with surface and bulk composition. In 1972 C. B. Pilcher, S. T. Ridgway and T. B. McCord (08.099.081), and U. Fink, N. H. Dekkers and H. P. Larson (09.099.017), used high-resolution spectroscopy in the 1- to 3-μm region to establish the presence of water frost on Europa and Ganymede and to set upper limits on its presence on Callisto, and additional measurements of the distribution of ice were made in 1975 by Pilcher and colleagues. Europa is probably primarily ice-covered, Ganymede consists in roughly equal parts of water and an unidentified silicate, and Callisto's surface is primarily silicate. Infrared eclipse radiometry of Ganymede and Callisto by D. Morrison, D. P. Cruikshank, and O. L. Hansen suggests two-layer models for thermophysical properties. Visible photometry and polarimetry (D. Morrison, R. L. Millis, B. Zellner, A. Dollfus, and their collaborators) indicate the Galilean satellites have porous, fragmented surfaces. The photometric and polarimetric differences between the two faces of Callisto are particularly striking.

The diameter of Ganymede (5270 km) and a suggestion of a possible atmosphere resulted from a 1972 stellar occultation (R. W. Carlson and others). An improved photometric diameter of 3050 km for Europa has been derived by F. A. Franklin, K. Aksnes, and others working with extensive photometry of occultations of this satellite by Io in 1973. These results together with precise new masses for all the Galilean satellites obtained by J. D. Anderson and colleagues from Pioneer 10 give reliable densities and clearly divide these satellites into two groups by bulk composition. Europa and Io are primarily silicate, with lunar densities, while Ganymede and Callisto have densities between 1.6 and 2.1 and must be primarily water. J. B. Pollack and R. T. Reynolds (11.099.212) suggested heating from the proto-Jupiter as the source of the division. J. S. Lewis proposed that the interiors of Ganymede and Callisto are primarily liquid water, and more detailed models have been computed by G. Consolmagno. Reviews by Cameron and Pollack and by Lewis and Consolmagno will be published in *Jupiter.*

New techniques being applied to the Galilean satellites include detections of Ganymede and Callisto by both radar and microwave radio and imaging of Ganymede with a resolution of about 200 km obtained by Pioneer 10.

A new satellite – J13 (Leda) – was discovered by C. Kowal at Hale Observatories. In the thermal infrared, G. Rieke has detected Amalthea (J5), and D. P. Cruikshank has detected Himalia (J6) and Elara (J7), leading to first estimates of their diameters and showing that all three satellites are of low albedo. New photometry and polarimetry have been reported on Himalia and Elara by L. Andersson and B. Zellner.

A comprehensive review of the Jovian satellites by D. Morrison and J. A. Burns will appear in *Jupiter.* Reference is also made to reviews of polarimetry and photometry by J. Veverka, of spectrophotometry by T. V. Johnson and C. B. Pilcher, and of radiometry by Morrison, all to appear in *Planetary Satellites.*

D. *Titan*

At the time the previous IAU Report was written, broad-band infrared brightness temperatures of Titan were being interpreted in terms of a high surface temperature, presumably produced by a methane-hydrogen greenhouse effect. In 1973, however, R. E. Danielson and J. J. Caldwell (10.100.025) suggested an alternative explanation of the infrared data, postulating a large atmospheric inversion generated by solar radiation absorbed in a high-altitude layer of photochemical smog. Spectroscopy in the 8- to 14-μm band with a resolving power of 50 obtained by F. C. Gillett and colleagues (10.100.005 and *Astrophys. J.* 1976) appears to confirm this explanation. Emission bands of methane and ethane are prominent, and features due to acetylene, ethylene, and mono-deuterated methane are probably also present. The temperature in the inversion region is about 160 K.

At longer infrared wavelengths new photometric data have been contributed by F. J. Low, G. H. Rieke, R. R. Joyce, R. F. Knacke, and their colleagues. The brightness temperatures from 18 to 34 μm are consistent with, but do not demand, a low surface temperature; there is no clear indication of pressure-induced features due to hydrogen. F. H. Briggs (11.100.207) obtained a brightness temperature at 8085 MHz, where atmospheric opacity should be negligible, of 100 ± 30 K, apparently permitting greenhouse elevations of surface temperature by ~50 K, but ruling out the more massive greenhouse effects postulated previously by J. B. Pollack and C. Sagan.

Continuing spectroscopic studies by L. Trafton and G. Münch confirm the amounts of methane reported earlier but do not resolve the question of the reality of the detection of hydrogen. Trafton also finds additional, unexplained features in the photoelectric infrared, and E. S. Barker and Trafton have studied the ultraviolet spectrum. J. Veverka and B. Zellner have each published polarimetric data indicating the presence of optically thick clouds. The bulk composition, surface pressure, and stability of the atmosphere are still in question. Particularly if hydrogen is a major component, escape is a problem, discussed particularly by D. M. Hunten (10.100.027), and in any case a major source of gas at the satellite seems required. T. R. McDonough and N. M. Brice have discussed the hydrogen torus filling the orbit of Titan that would be expected if large quantities are escaping from Titan.

M. Noland and colleagues demonstrated the independence of brightness of Titan on orbital position and measured the phase effect at six wavelenghts. L. Andersson, G. W. Lockwood, and other observers have found a remarkable and unexplained secular increase in brightness between 1971 and 1975 amounting to about 0.06 mag. in *V*.

Taking advantage of a lunar occultation of the Saturn system in 1974, J. Elliot and colleagues obtained a photometric diameter for Titan of 5800 km and demonstrated the presence of limb darkening. This large radius leads to a bulk density of only about 2 g cm^{-2}, suggesting a composition rich in water, methane, and ammonia. Much of the interior may be liquid water, and a liquid methane surface is a possibility.

Major review articles on Titan have been written by D. M. Hunten (11.100.209 and in *Planetary Satellites*) and by J. Caldwell (in *Planetary Satellites*). A bibliography complete through 1973 can be found in *The Atmosphere of Titan* (NASA SP-340).

E. *Rings of Saturn*

Studies of the rings have greatly accelerated during the past two or three years. Particularly important have been the addition of infrared, radio, and radar observations to the classical visual and photometric techniques. The existence of these new data, together with planning for investigation of the Saturn system late in this decade by the NASA Pioneer-11 and Mariner-11 and -12 spacecraft, is stimulating new thinking on the nature of this unique solar-system phenomenon.

Studies previous to this report period dealing with the dimensions and brightness of the rings were reviewed by M. S. Bobrov (04.100.017) and by A. F. Cook, F. A. Franklin, and F. D. Palluconi (09.100.008). Since then, additional photometry has been presented by W. M. Irvine and A. P. Lane, by M. J. Price, by N. A. Kozyrev, and by S. Koutchmy, and additional extensive unpublished work is underway at Hawaii, New Mexico, and Hale Observatories using photographic, photoelectric, and vidicon techniques. K. A. Hameen-Anttila, W. M. Irvine, Y. Kawata, M. J. Price, and others have modeled the optical properties. Polarization measurements have been made by A. Dollfus, by J. C. Kemp and R. E. Murphy, and by J. S. Hall and L. A. Riley. Several recent analyses agree that the normal optical thickness of ring *B* is between 0.8 and 1.2, with that of ring *A* about half as great. The opposition effect is large at all observed wavelengths, but substantial wavelength dependence in the magnitude of this effect is present, suggesting that the photometric properties of the rings are due to a combination of surface and ensemble effects. Improved infrared spectra confirm the identification in 1970 of water frost as the major surface constituent. M. S. Bobrov and B. A. Smith and colleagues have discussed the limited data existing on an outer (*E*) ring.

The temperature of the rings has been measured at infrared wavelengths by R. E. Murphy and by D. Morrison, who find a *B*-ring brightness temperature at maximum tilt of 90–95 K. A large temperature variation with tilt is indicated but is poorly documented at small tilt angles. Observations of a post-eclipse cooling by Morrison have been interpreted by H. H. Aumann and H. H. Kieffer in terms of particle size and thermal properties. Interferometric radio measurements of the rings at wavelengths from 8 mm to 21 cm have been made by F. H. Briggs, by G. L. Berge and D. O. Muhleman, by J. N. Cuzzi, and by others. Except perhaps at the shortest wavelengths, the rings have brightness temperatures less than 15 K, and in some cases they can be shown by their blockage of planetary radiation to be opaque as well as cold.

Of great excitement for students of the rings has been their detection by X- and S-band radar by R. M. Goldstein and G. A. Morris (10.100.014 and *Icarus*, 1976) at JPL. At both wavelengths, the reflectivity of the rings is remarkably high. This result together with the infrared and radio data has led to a re-evaluation of models for particle size and chemical composition by Goldstein, G. H. Pettengill, J. B. Pollack, and their colleagues. Most promising seem to be the models by Pollack *et al.* (10.100.015) that involve multiple scattering at microwave frequencies among water-ice particles a few centimeters in diameter. At the time of this writing, the wealth of new data has not been assimulated fully, and in some cases the observations appear to overconfine current theoretical models. A detailed review of the rings has been written by J. B. Pollack (*Space Sci. Rev.*, 1975, in press).

F. *Other Outer Planet Satellites*

New photometry of Enceladus, Tethys, Dione, and Rhea has been published by M. Noland and others, and by O. G. Franz and R. L. Millis. All are brighter on their leading sides and show modest phase coefficients. D. Morrison published 20-μm radiometry of Dione and Rhea and discussed their albedos and densities. The diameters of Dione and Rhea were found from lunar occultation photometry by J. Elliot and others, and new infrared (1- to 3-μm) photometry has been obtained by T. V. Johnson, D. Morrison, and their collaborators. All these satellites probably have high albedo ($p_V \sim 0.6$), low density ($\rho < 2$), and water ice on their surfaces.

Iapetus has been the subject of a number of studies. Improved photometry by R. L. Millis, by M. Noland and colleagues, and by F. A. Franklin and A. F. Cook demonstrate a large difference in phase coefficients between the hemispheres and show that the trailing/leading albedo ratio is 5:1. The occultation diameter of 1600 km obtained by Elliot *et al.* leads to a trailing side albedo of 0.5, in reasonable agreement with polarization data by B. Zellner and the radiometric value by D. Morrison and colleagues. Morrison *et al.* also measured a 20-μm rotational light curve, from which they estimate the trailing-side phase integral. Photometry in the 1- to 3-μm region by D. Morrison and others suggests a bright-side composition similar to that of the inner satellites.

Limited photometry of Hyperion and Phoebe has been published by F. A. Franklin and A. F. Cook, and by L. Andersson. A new and fainter estimate of the magnitude for Mimas has been obtained by O. G. Franz and by S. Koutchmy and P. Lamy, and L. Andersson has measured Titania and Oberon photoelectrically. T. V. Johnson and colleagues have measured colors of several satellites of Uranus, and R. Greenberg has investigated their masses. In general, however, little work has yet been done on the faint satellites of Saturn, Uranus, and Neptune.

5. BRIEF REPORT ON THE PLANETARY RESEARCH IN U.S.S.R. IN 1972–1975

(V. G. Teifel)

A. *Mercury*

From the observations of Mercury's transit on the Solar disk in 1970 Kiladze (Abastumani) estimated a horizontal refraction in Mercury's atmosphere about 0.″4–0.″8.

B. *Venus*

The measurements from Venera 8 have confirmed a presence of the adiabatic temperature profile on the day side of Venus in the entire region of the atmosphere below 55 km. The surface temperature and pressure are $T = 743 \pm 8$ K and $p = 93 \pm 1.5$ atm. The data about the horizontal wind altitudinal profile (an increasing of the wind velocity from 0 near surface to about 100 m s^{-1} at altitudes 50–60 km) may be considered as support for the suggestion on the common circulation system on Venus and the 4-days period of circulation. Marov, Feigelson *et al.* analysed a measured vertical profile of the Venus atmosphere illumination below 50 km and have calculated a model of optical properties of the Venusian atmosphere. A midday surface illumination was estimated about $(3–4)10^3$ lx. The cloud layer as obtained lies between 35 and 60 km.

From the consideration of radar observations Kuzmin and his colleagues (Lebedev Phys.Inst.) have estimated a relative abundance of the water vapor about 0.001 ± 0.001 and a dielectric conductivity of the surface matter about 3.6 ± 1.0.

Kuzmin and Marov published a monograph *Physics of the Planet Venus* ('Nauka', Moscow, 1974).

C. *Mars*

From the analysis of Mars 2–7 data Moroz and his colleagues in the Institute of Space Researches and Sternberg Astron. Inst. have obtained the following results. There were detected in the martian atmosphere about 25% of the noble gases (probably argon) and the presence of the ozone layer. The significant changes of H_2O abundance (from 10 to 100 μm of the precipitable water) were discovered. A thermospheric temperature (about 300 K) was first estimated from the width of Ly-α line. Some estimates were made for the dust storm clouds height (about 10 km), its optical thickness (~1–2 at λ 1.4 μm and ~2–3 at λ 0.7 μm) and for the dust particles sizes (~1–2 μm). The temperature of the Mars surface was obtained from IR-measurements and it was about 160 to 290 K in the different regions of the planet. The altitude profiles from the CO_2 absorption measurements shows the height differences to 10 km; the dark areas are more elevated in general.

The mean density of the martian ground is about 1.2 g cm^{-3} and rather more (1.4 g cm^{-3}) at a depth about 30–50 cm. Dielectric conductivity of the martian surface layer is about 3.1±0.3 according to Kuzmin *et al.*

Some optical parameters of the aerosole component of the martian atmosphere and surface were estimated by Morozhenko (Kiev) from the ground-based polarimetric observations. During the dust storms a mean radius of the dust particles was about 8 μm or more instead of 0.05 μm as observed for clear atmosphere. The TV-observations of Mars in Crimean Astrophys. Observ. were performed regularly by Prokofieva, Abramenko *et al.*

Golitzin *et al.* (Inst. Atmosph. Phys.) studied theoretically the martian dust storms dynamics taking into account the interaction between the wind, dust, surface and radiation as an effect producing the dust raising and the storm growth. Leikin and Zabalueva (Astron. Council Acad. Sci. U.S.S.R.) published also some suggestions on the evolution of the wind regime and the dust storms on Mars.

D. *Jupiter*

From the polarimetric observations Morozhenko, Yanovitskij *et al.* derived a mean radius of the cloud particles about 0.19 μm with dispersion $\sigma^2 = 0.30$ and a refractory coefficient of particles about 1.36 ± 0.01. The abundance of methane for the case of the reflecting layer model was obtained about 74 m-atm. Teifel (Alma-Ata) has estimated an abundance of CH_4 on the mean free path in the scattering cloud layer about 10–20 m-amagat from the analysis of CH_4 5430,6190,7250 Å and 1.1 μm absorption bands. Kuzmin *et al.* derived a relative abundance of NH_3 for undercloud atmosphere about 1.4×10^{-4} from the radio-astronomical data. Sorokina (Alma-Ata) has studied the atmospheric activity of Jupiter using the photometrical measurements during 1962–1970. Teifel has estimated from the spectral measurements the asymmetry parameter of the cloud phase scattering function $g \simeq 0.5–0.7$ and a hydrogen abundance over the cloud layer about 10–12 km atm. Bolkvadze and Djapiashvily in Abastumani made the polarimetric maps of Jupiter's disk for six phase angles. Interpretation of the photometric and spectral data on Jupiter was made also by Loskutov and Anikonov in Leningrad. Taranova (Moscow) analysed the data of the β_1 Sco occultation by Jupiter. The study of molecular absorption bands in the Jovian spectrum is continued by Ibragimof and his colleagues at Shemakha Astrophysical Observatory.

E. *Saturn*

The morphology of the molecular absorption distribution on Saturn's disk was studied in details by Kharitonova and Teifel (Alma-Ata). A minimal absorption is observed on the equatorial belt independently of the equator inclination to the direction of solar radiation input. The maximum of absorption is referred to temperate latitudes of Saturn but the intensity of the absorption bands is decreased toward the poles of the planet. As derived from the UV and absorption bands observations a cloud layer in the equatorial belt is about 10–12 km higher of the clouds on temperate latitudes. The relative abundance of ammonia below the clouds is about $(3-5) \times 10^{-5}$ as obtained by Kuzmin *et al.* from radio-astronomical data. A mean radius of the cloud particles estimated by Morozhenko and Yanovitskij from polarimetry is about 1 μm. The photometric properties of Saturn are in agreement with the phase function calculated for these particle sizes.

Bobrov (Astron. Council Acad. Sci. U.S.S.R.) continued his analysis of the photometric observations of Saturn's rings and has estimated an optical thickness of the outer *E*-ring ($< 5 \times 10^{-5}$).

F. *Theoretical Works*

Jarkov, Trubitzin and Makalkin (Schmidt Inst. Phys. Earth) continued a theoretical study of the internal structure of major planets. Golitzin published a monograph *An Introduction to the Planetary Atmospheres Dynamics* (Hydrometeorol. Publish. House, Leningrad, 1973) developing a similarity theory and using it to consider the dynamical processes in the Earth and planetary atmospheres. Sobolev published a monograph *The Light Scattering in Planetary Atmospheres* ('Nauka', Moscow, 1972) translated with additions by Pergamon Press in 1973. The theory of light scattering and radiative transfer in planetary atmospheres was developed also in the works of Yanovitskij, Dlugatch, Kolesov. Levin, Safronov *et al.* published some new papers on planetary cosmogony, thermal history of Earth, planets and cosmochemistry. Levin concluded that the protoplanetary cloud had a primary radius about 200–300 AU and its mass was about 2–3 solar mass.

6. IAU PLANETARY RESEARCH CENTER AT THE LOWELL OBSERVATORY

(W. A. Baum)

The Center is both an institution for planetary research and a library for planetary photographs gathered from worldwide sources. The photographic collection now includes about 128 000 different plates and films spanning 80 years of telescopic observation. About 101 000 of these have been produced since 1969 under the International Planetary Patrol Program, with the participation of observatories at Mauna Kea, Mount Stromlo, Perth, Kodaikanal, Johannesburg, Cerro Tololo, New Mexico, and Lowell (where the program has been managed). Associated facilities include a machine-searchable catalogue, an image digitizer/computer system, a microdensitometer, and projection image readers. The collection and facilities are available to qualified guest investigators.

The resident research staff of the Center includes W. A. Baum (director), R. L. Millis (astronomer), E. L. G. Bowell (astronomer), L. H. Wasserman (post-doctoral fellow), L. J. Martin, C. F. Capen, D. T. Thompson, H. M. Ferguson, and L. A. Riley. Important functions are performed by H. S. Horstman, S. E. Jones, J. H. Chastain, and H. W. Culp, supported by assistants. Other Lowell staff, as well as various guest investigators, have collaborated in Center projects.

In addition to the systematic analysis of photographic images, the research program of the Center includes photoelectric, spectrophotometric, and polarimetric observations at various telescopes. Recent and current research includes Martian dust storms, polar hoods, short-term contrast fluctuations, seasonal albedo changes, cartography, and albedo-topography relationships; the Jovian cloud flow pattern, the dependence of differential flow on color, and the distribution of polarization; variations in Venus polarization; *UBV* photometry of Galilean satellites, mutual eclipse and occultation light-curves of Galilean satellites, improved photometry of Saturn satellites, and electronographic imaging of Uranus and Neptune satellites; *UBV* photometry of asteroids, polarimetry of asteroids, and a detailed analysis of Eros; observations bearing on the constancy of Solar System dimensions over cosmic time; and participation in the Viking Mars 1975 mission. The support of NASA Headquarters is gratefully acknowledged.

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7. IAU PLANETARY PHOTOGRAPH CENTER (IAUPPC) PERIOD 1973, 1974, 1975

(A. Dollfus and R. Servajean)

The IAU Planetary Photograph Center (IAUPPC) is open to all qualified scientists wishing to conduct an appropriate research program on Solar System bodies which is based upon imaging, photographic documents or their direct analysis.

The IAUPPC was established at Meudon Observatory (France) in 1961 on the recommendation of IAU and was operated since this date for the scientific exploitation of the ground-based telescopic results.

In 1973, IAUPPC reorganized itself to make available in Europe, together with equipments and facilities for analysis, not only the telescopic planetary images, but also the large collections of imaging data returned by the recent space missions to Mercury, Venus, Mars and Jupiter. In addition, the field of the Center was extended to cover the imaging documents concerning the Moon (cf. report to Commission 17, same volume).

The enlarged IAUPPC is now hosted in a new building erected for the purpose in 1970 at Meudon Observatory (13 offices). This building provides data storage facilities for the IAU plate collections, safe for the original negatives, instrumentation for analysis, lodging and working facilities for visitors.

After the death of J. H. Focas, in January 1969, Ch. Boyer was appointed new curator of IAUPPC; then, in 1974, R. Servajean.

Between 1973 and 1975, in addition to the activities for responding to the general information needs, 26 scientists from eight different countries visited the Center for asking documents or information. Among their publications, we record 17 papers which are specifically using documents from the IAUPPC collections (two on Mercury, seven on Venus, six on Mars, two on the galilean satellites of Jupiter, and one on Saturn). Several of these works could not have been feasible at all without the availability of the IAUPPC facility. The authors are French, English, Italian, Finnish, Japanese. Several of them have their visits to the IAUPPC at Meudon helped by IAU support.

C. H. MAYER
President of the Commission