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

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INTRODUCTION

The ground-based research activity in the planetary field has increased very rapidly since the Prague meeting in 1967. The space probes into the atmosphere of Venus and the flybys of Mars have not only added directly to our knowledge of these planets but have stimulated further research.

Because of this rapid growth and the large expense which would be required to publish detailed descriptions of the very numerous research projects carried on in the last three years, this report will differ in important respects from the previous ones. Drs Levin, Pettengill, and McElroy have provided summaries of progress made in three important fields of planetary science, and Levin has also kindly contributed a summary of planetary research carried on in the U.S.S.R. since the Prague meeting. On behalf of its members, the President of Commission 16 gratefully acknowledges each of these important contributions.

The summaries will be followed by a résumé of current (unpublished) research being carried on elsewhere. Future projects will also occasionally be mentioned. The material presented here is that which has been sent to the President in response to requests contained in newsletters which have been sent at more or less regular intervals to all members of Commission 16.

In accordance with the new policy of the IAU Executive Committee, the number of detailed references given in commission reports must be drastically reduced. Bibliographies are now published in English, German, and Russian, and many are now more nearly up-to-date than any which could be given here. Table I lists a number of recent symposia, conferences, and meetings, and indicates where the papers presented at these gatherings have been or will be published.

An effort has been made to see to it that available reports and bibliographies were distributed to all members of Commission 16. The following reports or bibliographies have already (December 1969) been distributed:

Bibliography of Lunar and Planetary Research Supplement for 1966 and 1967 – Office of Aerospace Research, Air Force Cambridge Research Laboratories, L. G. Hanscom Field, Bedford, Mass., U.S.A. The volume for 1968 is in press and the bibliography for the first quarter of 1969 has appeared in the July, 1969 issue of *Icarus*. In the future, these are scheduled to appear quarterly.

Planetary Astronomy (*An Appraisal of Ground-Based Astronomy*) and *Planetary Exploration* 1968–1975 – two publications of the National Academy of Sciences, Washington, D.C.

Summaries of Science for the year 1964–1965 (Itogi Nauki) – Institute of Scientific and Technical Information, Moscow, U.S.S.R. The next summary is to appear in 1970.

INTERNAL CONSTITUTION OF PLANETS

(by B. J. Levin)

To obtain some insight into the internal constitution and composition of planets one must know the equations of state (pressure-density relations) for materials of which planets are composed, and one must study by numerical calculations the radial distributions of density. Only the conclusion that Jupiter and Saturn contain much hydrogen can be reached without detailed calculations

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Table 1. Symposia and Conferences Since Prague IAU Meeting

Subject	Date Place	Sponsor(s)	Publication
Physics of Moon and Planets	October 1968 Kiev	Astron. Council U.S.S.R.	Publishing House „Nauka", Moscow, 1970–71
Jupiter and the Outer Planets	December 1968 Dallas, Texas	Section D, AAS; AGU and GSA	*Icarus*, May 1969, See also *Science*, **162**, 588, (1968)
Working Group VII	May 1969 Prague	COSPAR	COSPAR
Planetary Atmospheres and Surfaces	August 1969 Woods Hole, Mass., U.S.A.	IAU, URSI	*Radio Science* February 1970
Arizona Conferences on Planetary Atmospheres	February 1967 Tucson, Ariz.	KPNO	Gordon & Breach, Publishers, 1968
	March 1968 Tucson, Ariz.	KPNO	*Journal of the Atmospheric Sciences*, July 1968
	May 1969 Tucson, Ariz.	KPNO	*Journal of the Atmospheric Sciences*, September 1969
Planetary Atmospheres	October 1969 Marfa, Texas	*IAU Symposium*, no. 40, McDonald Obs.	D. Reidel Publishing Co., Dordrecht, The Netherlands. Summer of 1970

(De Marcus, 1967). Unfortunately, the equations of state are poorly known and the improvement of planetary models strongly depends on the improvement of these equations.

Terrestrial planets

Pressure-density relations necessary to calculate models of the terrestrial planets can be obtained either by using the Earth as a prototype, or from experimental data. In the latter case one can use, for mantles, data on compressibility of olivine and its high-pressure modifications (spinel and post-spinel) or of principal oxides (SiO_2, MgO, Al_2O_3, CaO), assuming the additivity of partial molar volumes.

Differences in equations of state, naturally, lead to somewhat varying models. But the main controversy is about the nature of cores of the Earth and Venus: whether or not they contain metallized silicates. The problem is very difficult indeed. Experimental shock-compressions of rock-samples failed to effect their transition into metallic phase at pressures up to 5 million atmospheres. Therefore, many astronomers and geophysicists regard the metallized-silicate core hypothesis as disproved. Moreover, there is no doubt that Mercury contains about 60% metallic iron or nickel-iron (this seems to be the only possibility to account for its high density) and this proves that planets *can* contain much metal.

Although the iron core hypothesis, modified to suggest that the core is composed of an iron-nickel-silicon alloy, is able to explain the present-day mechanical structure of the Earth and Venus, there are unsurmounted and perhaps even unsurmountable difficulties connected with the *formation* of the iron core. Why did much iron remain in metallic form in the zone of accretion of the Earth, although the temperature dropped much lower than in the zone of Mercury? How did the interiors of the Earth and Venus become molten to permit iron to sink into the core? How do these planets get rid of heat liberated by segregation of iron into a core? As long as these questions remain unanswered, it is legitimate to regard the iron core hypothesis as unproven and continue to analyze the hypothesis of metallized silicates.

As Mars has only a small iron core compared to the Earth and Venus, if iron cores are accepted for the Earth and Venus, one can say that the content of metallic iron decreases with the heliocentric distance of the planet (Reynolds and Summers, 1969). This statement neglects the facts that the relative mass of the Earth's core is larger than that of Venus and that the absence of an iron core in the Moon requires a special explanation.

On the other hand, if one is to accept that the outer core of the Earth is composed of metallized silicates, while the inner one is of iron, and that the core of Venus has a similar constitution, then differences in composition of Venus, Earth, Moon and Mars are rather small – approximately within the limits of variants of composition for different types of chondritic meteorites (Levin, in *Interiors and Surfaces of Planets* (ed. A. Dollfus) Academic Press, 1970).

Calculations of the thermal histories of terrestrial planets are being done now for rather complicated models which take into account the gradual character of the melting of rocks, the dependence of heat conductivity on temperature and pressure, the redistribution of heat sources after partial melting of planetary interiors, etc. (Majeva, 1966, 1969; Fricker and Reynolds, 1968; Lee, 1968). Unfortunately, the variations of melting temperatures with pressure are only approximately known.

Calculations for Mercury show that it was never molten and therefore is probably core-less. At the present time its interior must be slowly cooling. If the core of Venus is composed of an iron-rich alloy, the release of gravitational energy during its segregation would lead to a molten state of the mantle and core of Venus. (The same would hold true for the Earth and this would be contradictory to seismic evidence for the solid state of the mantle.) Probably this cannot be reconciled with the locked-in rotation of Venus which requires some three-axiality of its figure. But calculations for a model with a metallized core indicate that all or nearly all mantle must be solid.

Thermal histories of Venus and the Earth, and probably also of Mars, critically depend on the possibility of stationary convection in their interiors. Mathematical theories of thermal and non-thermal convection were developed for highly idealized planetary models (Ashworth, 1968, 1969; Danes, 1969). But their applications to real planets are scarcely possible. (The same is true for the study of thermoelastic deformation of planetary globes by Kopal, 1968.) For example, although the thermal gradient, at least in some layers, is superadiabatic, and thus appropriate for thermal convection, the latter is scarcely possible because it requires a homogeneity of material, while in real semimolten interiors chemical and gravitational differentiation must block thermal convection.

Giant planets

The modern approach to the study of Jupiter and Saturn begins with the work by DeMarcus (1958) who analyzed cold ($T = 0$ K) models of these planets and checked the density distributions using values of multipole moments J_2 and J_4 derived from observations. Peebles (1964) took the temperature into account and obtained more precise values for H and He content. Hubbard (1968, 1969) improved the estimates of temperature, especially in a core of metallized hydrogen, and showed that the observed energy emission from Jupiter can derive from the thermal energy of an interior heated up to 10000–15000 K. For both planets – Jupiter and Saturn – Hubbard calculated chemically homogeneous convective models, but noted the possibility that they have small dense cores.

On the other hand, Smoluchovski (1967) proposed a qualitative model for Jupiter in which he takes into account a low solubility of He in metallized hydrogen at $P \lesssim 10^7$ bars. His model contains a He core surrounded by a "mantle" of metallized hydrogen which contains in its lower part some dissolved He. He assumes a slow motion outwards of the boundary between molecular and metallized hydrogen which, (a) shifts He admixed with molecular hydrogen towards the surface, and (b) produces a slow contraction of the planet. The shift of the boundary at the rate of 0·1 cm/y is sufficient to explain the observed heat flow from Jupiter.

Further studies of the internal constitution of Jupiter and Saturn must include a qualitative check of Smoluchovski's ideas, a check of the role of nonvolatile elements and compounds, and calculations of the thermal history of Jupiter, including the heating during accretion. Such heating would be the cause of a high energy emission in the past which would explain the stony composition of Io and Europa.

New models of Uranus and Neptune calculated by Ramsey (1967) differ only slightly from that by Reynolds and Summers (1965). (Ramsey includes metallic ammonium, NH_4 instead of NH_3, and includes Ne not with H and He but with CH_4, NH_4 and H_2O, and neglects the compressibility of the heavy component which forms a core in some models.) For Neptune the observed value of J_2 was used to select better models.

The new value of Neptune's diameter determined from photoelectric observations of the occultation of a star on April 7, 1968, will remove a peculiar large difference in the hydrogen content of Uranus and Neptune.

The result obtained by Kieffer (1967) is important for planetary cosmogony: calculating mass-radius relations for planetary bodies of different compositions, he showed that Jupiter can be composed of solar material, while Saturn is slightly enriched in less volatile elements.

An important step forward was taken recently in the classical field of the study of figures of rotating planets (in hydrostatic equilibrium). The Darwin-De Sitter theory has taken into account the second order terms. Zharkov and Trubizin (*Dokl. Acad. Nauk S.S.S.R.*, **186**, 791, 1969; *Astr. Zu.*, N6, 1969) developed a theory including the third-order terms, thus allowing the use of the multipole moment J_6 (besides J_2 and J_4). To begin with, the new formulae can be applied to studying the figure and internal structure of Jupiter.

Magnetic fields

Among the terrestrial group, the Earth seems to be the only planet possessing a substantial magnetic field (Mercury's field remains unknown). Combined analysis of measurements carried out by Venera 4 and Mariner V permitted substantial lowering of the upper limit for the magnetic field of Venus: it is at least 10000–15000 times weaker than that of the Earth (Dolginov, Eroshenko and Davis, 1969). The absence of the magnetic field on Venus is probably due to too slow a rotation of the planet. The Martian period of rotation is similar to that of the Earth and it must have a liquid iron core. However, to produce a magnetic field there must be systematic motions in the core, most probably thermal convection. The latter is impossible in the Martian core because of a low proportion of radioactive elements with metallic iron.

Radio-observations of Jupiter reveal that it possesses an intense magnetic field and strong magnetosphere. Variations of the plane of polarization observed at decimeter wavelengths, which are due to the tilt of the magnetic axis 10° from the rotation axis, have a period of $9^h55^m29\overset{s}{.}37$ which coincides with the period of bursts observed at decameter wavelengths. This period may be the most fundamental for Jupiter, because it probably reflects the rotation of the interior. Decametric radiation from Jupiter is influenced by the position of Io and Europa in their orbits, possibly through some unexplained interaction with the Jovian magnetosphere.

The most important problems for further study are the origin of the Jovian magnetic field, which is tied to the dynamics of the interior and its nonuniform rotation (Runcorn, 1964; Hide, 1967), and the nature of the radiation bursts and their influence on the atmosphere.

PLANETARY SURFACES

(by G. H. Pettengill)

Significant measurements of the surface properties of the terrestrial planets have been made over the past 3 years using radar techniques at frequencies between 430 and 7840 MHz, radiometric techniques at radio and infrared wavelengths, and optical telescopic observations. The results obtained using the first two of these three techniques have been well summarized in the joint IAU-URSI Symposium on Planetary Atmospheres and Surfaces, held at Woods Hole, Massachusetts in August, 1969 (Proceedings published in February, 1970, issue of *Radio Science*).

Mercury

The rotation of Mercury has been confirmed at a rate precisely 1·5 times faster than the average

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orbital revolution, using both radar and optical observations. The repercussions of this higher-order synchronism (as compared with the one-to-one synchronism between rotation and revolution assumed in earlier years) have received considerable attention, both from the point of view of possible modes of evolution and from a consideration of the likely effects on the distribution of subsurface temperatures. The latter have been observed radiometrically by several groups and have been found to display a marginally significant double maximum along the equator, as expected from the new value of rotation which forces the planet to expose the same two antipodal regions of the surface alternately to the sun at perihelion.

Observations of the surface characteristics of Mercury are not yet available in sufficient quantity or quality to permit firm deductions concerning its nature. Existing radar and radiometric observations, however, suggest a surface whose composition, density and roughness are not far different from the corresponding values for the Moon. Both radar and optical observations find evidence for separated surface areas with differing scattering characteristics. The relative difficulty of observing this planet, however, as compared to the other terrestrial planets, has held back good mapping of these areas.

Venus

This planet received intensive study during the interval surrounding the inferior conjunctions of 1967 and 1969. Radar observations at a variety of wavelengths yielded good agreement on rotation (retrograde sidereal period of $243{\cdot}0 \pm 0{\cdot}1$ d, with a pole approximately normal to the orbit) and the positions of half a dozen anomalously scattering surface features. Optical observations in the near ultraviolet found relatively longlived cloud formations that appear to circle the planet in a retrograde sense with a period of about 4 d.

Several relatively small regions with heights of 1·5 to 2 km above the average surrounding surface have been localized on Venus using radar techniques. The general impression, however, is of a surface (in the equatorial belt, at least) devoid of large-scale topographic relief. Some evidence exists for a slight (1·5 km) displacement between the center of mass and the center of shape.

It appears as though the surface dielectric constant as determined from interferometric observation of the emission polarization at radio wavelengths can now be reconciled with the corresponding value as determined from the radar reflectivity at normal incidence, when depolarization associated with the substantial absorption in the atmosphere of Venus is properly accommodated. The best current value for the dielectric constant of the radio surface is 4·8, which is significantly higher than for the Moon and Mercury (2·7), or Mars (3·5). A variety of radiometric evidence now favors a near-constant equatorial surface temperature of about 700 K.

Mars

The increasingly favorable oppositions of Mars in 1967 and 1969 have stimulated a considerable observing effort. Direct radar observations have disclosed substantial large-scale topographic relief in the northern tropics of about 12 km peak-to-valley vertical extent, when averaged over lateral distances of several hundred kilometers. No significant correlation between optical surface markings and this relief was noted, although fair correlation does appear to exist between the locations of regions exhibiting high radar reflectivity and low visual albedo. To the radar, Mars appears to have far more gentle slopes in its average small-scale surface structure than either Venus or the Moon, despite its significant large-scale topographic variations.

The successful photographs resulting from the Mariner space-probe missions in 1969 should make it possible to compare directly the small-scale structure of selected regions of the Martian surface with various areas of the Moon.

Icarus

Considerable radar and optical observing effort was expended on studying the minor planet Icarus during its close approach to earth in June of 1968. Several radar and a large number of optical observations were successful, yielding a rotational period for the asteroid of 2^h16^m, a radius lying between 0·5 and 1 km and an unexceptional surface reflectivity. The absolute optical magnitude was about 17. From the small amount of rotational modulation, a highly spherical shape was inferred.

RESEARCH IN PLANETARY ATMOSPHERES 1967–1970

(by M. B. McElroy)

Scope of this Review

This paper is intended to be a brief résumé of current research on planetary atmospheres. Work reported in the period 1967–1970 is emphasized. The preceding three years were reviewed by T. Owen in the report of Commission 16 to the Thirteenth General Assembly of the International Astronomical Union. He included a detailed bibliography which is not repeated or updated here. I would like to draw particular attention to the annual Arizona conferences (see Table I) on planetary atmospheres which were sponsored by the Kitt Peak National Observatory and offered a forum for review of research in planetary atmospheres. They were well attended by scientists both from the United States and from the international community.

The first conference, in February 1967, was devoted to the atmospheres of Mars and Venus and included a detailed review of the Mariner IV results. The proceedings give a good historical account of uncertainties in our understanding of Venus at that time. These uncertainties prevailed until the highly successful Mariner V and Venera 4 flights. The second Arizona conference was devoted specifically to Venus and the papers presented then reflected the great advances in the intervening year. The third Arizona conference was directed at the major planets and it was clear that our level of understanding of physical processes even for Jupiter is rudimentary, comparable to our understanding of Venus prior to the 1967 space observations.

The most recent broadly based conference was held at Marfa, Texas on October 1969 under the auspices of Commission 16. This conference included discussions of the recent Soviet Venus experiments (Veneras 5 and 6) and U.S. Mariner experiments (Mariners 6 and 7).

Our summary of present knowledge is ordered on a planet by planet basis, beginning with Mercury.

Mercury

Considerable effort was devoted to a spectroscopic search for an atmosphere on Mercury stimulated by the tentative identification of CO_2 by V. I. Moroz. This observation was not confirmed and present work establishes an upper limit of 0·58 m atm on the abundance of CO_2 in the Mercury atmosphere. Based on polarization studies, A. Dollfus concluded that Mercury had an observable atmosphere and estimated a surface pressure $p_s \sim 1$ mb. His conclusions are disputed, however, by B. T. O'Leary and D. G. Rea.

Venus

The important developments here are directly related to the Venera probes and to the Mariner 5 flyby. The Soviet measurements were made in atmospheric layers about 36–38 km thick and covered a pressure range from 0·5 to 27 bar and a temperature range from about 300 K to 600 K. The observed temperature gradient is close to the adiabatic limit and extrapolation of measurements gives surface pressure and temperature values of 140 bar and 800 K with Venera 5 data, 60 bar and 670 K with Venera 6 data. The difference between these results is attributed to a discrepancy in altitude measurements presumably related to malfunctions in the on-board radar altimeters. All three Veneras were crushed by pressure before reaching the planetary surface. Composition measurements indicated that CO_2 is the major constituent (93–97%) whereas N_2 and noble gases account for less than 5% of the atmospheric density. An upper limit of 0·4% was placed on the O_2

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mixing ratio and the water vapor content was measured to be 4–11 mg per liter at a pressure level of 0·6 bar. Water vapor was not saturated at this level.

Venera 4 and Mariner 5 also detected a hydrogen corona around Venus and interpretations of these data involve a number of interesting though still speculative hypotheses. Mariner 5 revealed the presence of two components to the observed $L\alpha$ emission. Their scale heights differ by an approximate factor of 2 and published theoretical models associate the less extensive component with either H_2 or D. In either case the implications are far reaching. The H_2 theory suggests unexpectedly large abundances for this gas in the lower atmosphere. The D theory, in its simplest form, requires an enhancement in the D/H ratio for Venus as compared with Earth.

Mariner 5 detected ionospheres on both day and night sides of Venus. The dayside measurements revealed a sharp cut-off in the ionization above about 500 km (termed the anemopause on the hypothesis that it is associated with a solar wind interaction). The physics of this cut-off are not yet understood although detailed models have been constructed for the ionization observed at lower altitudes. A number of ionospheric theories conclude that atomic oxygen is a minor constituent in the upper atmosphere, and several invoke the presence of He concentrations in the Venus atmosphere larger by several orders of magnitude than values observed for the Earth's atmosphere.

The composition of the Venus clouds remains uncertain although recent studies by G. P. Kuiper and co-workers represent considerable progress. They find that the albedo of Venus is closely reproduced by laboratory reflection from a fine partially hydrated $FeCl_2$ powder. However, the implications of this hypothesis with regard to physical and chemical processes in the atmosphere have not yet been subjected to detailed examination. A problem exists as to the correct abundance of H_2O. Kuiper estimates a mixing ratio of 10^{-6} from studies in the spectral region near 2μ. Observations at 8189 Å have been interpreted in terms of somewhat larger H_2O mixing ratios ($\sim 10^{-4}$), in better agreement with the Venera results. The discrepancy may be due in part to complications introduced by effects of radiative transfer which must be included in any completely consistent model of line formation. It is possible also that the strength of the H_2O absorption line is indeed variable. More work is required to clarify these problems and this research is directly relevant to the question of Venus cloud composition.

Mars

The only gases spectroscopically detected in the atmosphere of Mars are CO_2, H_2O and CO. The CO_2 abundance is 78 ± 11 m atm and the spectroscopically determined surface pressure is in the range 5·7–10 mb. Water vapor is variable but definitely established by the Texas observations (R. Schorn, paper presented at the Marfa meeting). Its average concentration is about 30μ and typically more H_2O is observed in the northern than in the southern hemisphere. There is no obvious seasonal effect although there appears to be more water in the midday atmosphere than in either morning or evening atmospheres. The CO concentration is about 5·6 cm atm which corresponds to a mixing ratio of approximately 10^{-3}. Important upper limits of 20 cm atm and 2×10^{-4} cm atm have been placed on the concentrations of O_2 and O_3. The latter result (unpublished) was derived by L. Wallace from analysis of data obtained from the Orbiting Astronomical Observatory.

The ultraviolet experiment on Mariners 6 and 7 failed to observe emissions associated with N_2 in the upper Martian atmosphere. This result should place an important upper limit on the N_2 concentration. Present preliminary analyses suggest an upper limit for the N_2 to CO_2 mixing ratio of about 5×10^{-2}. Emissions associated with H, O, CO and CO_2^+ were observed and the experiment establishes that Mars has a detectable H corona, a surprisingly small concentration of O in its upper atmosphere and an ionosphere composed mainly of CO_2^+.

M. Belton, D. Hunten and R. Wells recently reported a study of Martian topography which deserves special note. They observed the CO_2 band at $1{\cdot}05\mu$ using a three-channel multislit spectrophotometer with high spatial resolution on the planet. The observed strength of absorptions gives a quantitative estimate of elevation differences. They concluded that Syrtis Major was very high but found little correlation generally between elevation and albedo. Elevated areas were observed both in desert and dark regions. In several cases, dark areas were associated with relatively steep slopes. The spectroscopic survey is in good agreement with the radar maps derived earlier. The technique shows great promise as a new tool for exploration of the Martian surface.*

Jupiter

The only gases spectroscopically identified in Jupiter's atmosphere are H_2, CH_4, and NH_3. As for Venus, interpretation of absorption lines in terms of abundances is complicated due to the probable importance of radiative transfer in the line formation process. Errors are minimized to some extent if results are quoted in terms of mixing ratios.

The best estimate of the H_2 abundance is derived from observations of the quadrupole lines and with reflecting layer theory these observations give an abundance of 68 km atm above a cloud deck whose effective temperature is about 150 K. The mixing ratio of CH_4 to H_2 is about 5×10^{-4} and the distribution of NH_3 above the visible clouds is apparently determined by the saturation vapor pressure relation. The abundance of He remains unknown although spectroscopic studies suggest that the mixing ratio He to H_2 should not exceed 0·5. From studies of thermochemical equilibrium, J. Lewis concluded that apart from H_2, He, CH_4 and NH_3, the most abundant gases in the visible layers of Jupiter's atmosphere should be H_2O and H_2S. Their mixing ratios were estimated to be of order 10^{-12}. By way of comparison the current spectroscopic limits for mixing ratios of these gases are $7{\cdot}5 \times 10^{-7}$ and 4×10^{-6} respectively.

Accurate values for geometrical albedo as a function of wavelength are most important for many planetary studies and important data in the visual and near infrared spectral regions have been reported by W. M. Irvine and associates for Venus, Mars, Jupiter and Saturn. Recent rocket and satellite observations have yielded good data in the ultraviolet for Venus, Mars and Jupiter. The UV Venus and Jupiter observations confirm the importance of scattering for these planets and demonstrate the necessity of including radiation transfer effects in the interpretation of absorption lines.

Spectra of Jupiter in the far infrared have offered an important tool for the study of that planet's atmosphere above the visible clouds. They suggest the possibility of a thermal inversion at a temperature level of about 130 K. A similar result is indicated by recent data in the radio region near 1·25 cm. The existence of important internal energy sources for both Jupiter and Saturn has been demonstrated by F. Low and associates.

Saturn

Only H_2 and CH_4 have been established as component gases in Saturn's atmosphere. A recent study by Kuiper and associates has identified solid H_2O in the infrared reflection spectrum of the rings. As yet NH_3 has not been observed as an atmospheric gas.

Uranus

A recent analysis of the H_2 quadrupole lines indicates that the strength of these absorption lines may be consistent with an optically semi-infinite H_2 atmosphere, i.e. the lines are as strong as they can be and penetration of visible and near infrared radiation is limited by Rayleigh scattering. The only gas observed other than H_2 is CH_4 and there have been no recent revisions of its abundance ($\sim 3{\cdot}5$ km atm). The brightness temperature at 20μ is 53 K, and does not require the postulate of an internal energy source.

Neptune

The most important developments here are directly related to the occultation of the star

* See below the report of the current work on this problem being carried on at the McDonald Observatory.

BD − 17°4388 which occurred April 7, 1968. Observations of this event yielded a new radius for the planet of approximately 25000 km and suggested that the temperature in the highest atmospheric layers may be somewhat higher than values expected on the basis of model studies.

SHORT REPORT ON THE STUDIES OF PHYSICS OF PLANETS AND SATELLITES IN THE USSR IN 1967–1969

(by B. J. Levin)

As mentioned in the previous summary, Venera 4 revealed the existence of a hydrogen corona around Venus. The first signs of it were observed at the distance of 25000 km from the centre of the planet, while at 10000 km a hydrogen density of ~100 atoms per cm³ was measured (the Venera 4 data gave $n_H = 600/R/R_♀$ cm^{-3}). The measurements gave for the density of atomic oxygen at 300–350 km above the night side of Venus the upper limit $n_0 < 2 \times 10^3 cm^{-3}$.

From the absorption of $L\alpha$-radiation the CO_2 density at the height of about 100 km was estimated to be $n_{CO_2} \approx 3 \cdot 10^{11}$ cm^{-3}.

No radiation belts were observed.

Peculiar refraction in the atmosphere of Venus was studied by M. M. Skotnikov.

A model of the atmosphere of Venus based on data obtained by radioastronomy, radar, and Venera 4 was compiled by A. D. Kuzmin and Yu. N. Vetukhnovskaya. (Paper presented at COSPAR Meeting, Prague, 1969.)

Photometric studies of Venus by O. M. Starodubzeva (Kharkov Obs.) confirmed the existence of the quasispecular reflection effect discovered by N. P. Barabashov.

Photometric studies of Mars were continued by N. P. Barabashov and his colleagues in Kharkov and by I. K. Koval′ and his colleagues in Kiev. According to I. K. Koval′ the wavelength-dependence of contrast between the continents and maria on Mars speaks in favour of an elevation of the continents. For normal transparency the optical depth of the atmosphere over maria is 2½ times larger than over continents.

According to the suggestion by M. S. Bobrov, the first six frames taken by Mariner IV represent photographs of the cloud layer, not of the surface of Mars.

V. I. Moroz in 1967 observed Venus, Mars and Jupiter in IR (8–14μ) and found brightness temperatures: for Venus (the centre of the disk) 223^{+12}_{-3} K; for Mars (subsolar point) 263^{+13}_{-5} K; for Jupiter 107^{+5}_{-10} K. In 1969 he made spectral observations of these planets in the 1–2μ region. Some observations were done with high angular resolution (up to 1″) – with resolution 200 Å. Other observations of the whole disk were made with spectral resolution: 8 Å for Jupiter, 5 Å for Mars, 2 Å for Venus. The NH_3 band $\lambda 1{\cdot}53$ on Jupiter is more intense in a latitude near 50° than on the equator, probably because of lesser height of the cloud layer. Preliminary analysis indicates that on Mars the CO_2 bands are more intense in dark areas than in the bright ones. On Venus, near inferior conjunction, the intensity of these bands is reduced but, even so, near the horns, they are definitely more intense than on the intensity equator.

From spectroscopic observations in the red region, V. G. Teifel′ and his colleagues (Alma-Ata) confirmed that on Jupiter and Saturn the cloud layer has no definite boundary and that the visible surface is indicated by a layer of haze with a low density of aerosols ($\sigma_a \sim 10^{-7}$ cm^{-3}). From observations of the CH_4 band at $\lambda 6800$, the rotational temperature in the atmosphere of Uranus is found to be about 60–68 K at the level where the effective pressure is $2{\cdot}5 \leqslant P_e \leqslant 5$ atm. About 2000 polarimetric measurements of separate details of the surface of Jupiter and Saturn were carried out at the Abastumani Observatory (V. P. Djapiashvily *et al.*).

V. G. Teifel′ published a monograph, *The Atmosphere of the Planet Jupiter*, (in Russian) (Publ. House "Nauka", Moscow, 1969) in which he reviews the composition of the Jovian atmosphere, its constitution and thermal properties, optical properties, clouds, and atmospheric circulation.

M. S. Bobrov, from the analysis of worldwide observations of Saturn's rings done in 1966, concluded that their thickness is about 3 or 4 km. His monograph, *The Rings of Saturn* (in Russian) is to be published in 1970 by the Publishing House "Nauka" (Moscow).

Calculations of the internal constitution of Mercury made by S. V. Kozlovskaja indicate that it must contain about 60% of metallic nickel-iron. With such a composition the planet was never molten and therefore, probably, has no iron core (S. V. Majeva). For Venus, various models containing both metallized silicates and iron alloy are compatible with the available data (S. V. Kozlovskaja). Metallized silicates had to appear, not at the end of the accumulation phase of Venus, but much later when the heating up of its interior had decreased the critical pressure for phase transition. S. V. Majeva calculated the thermal history of Venus for two models: with the iron core and with a core of metallized silicates. In the first model the melting of the mantle is much more pronounced due to the release of gravitational energy during the segregation of iron into the core.

The connection between planetary cosmogeny and the problem of the origin of meteorites was discussed by B. J. Levin. He concluded that new data speak in favour of the common origin of the Sun and protoplanetary cloud, of the type suggested by F. Hoyle or E. Schatzman, but not of the type suggested by A. G. W. Cameron.

V. S. Safronov published a monograph, *Evolution of the Pre-Planetary Cloud and the Formation of the Earth and Planets* (in Russian) (Publ. House "Nauka", Moscow, 1969) in which he summarizes and develops further his studies on this problem.

CURRENT UNPUBLISHED RESEARCH

Venus

H. Camichel states that he is continuing his observations of Venus. Recent data confirmed the reality of a displacement of the visible surface at a velocity of approximately one rotation in four days in the retrograde direction. This does not contradict a value for the rotation of the surface in 243 d, if one finds a way to explain the persistence of motion of such great velocity in the high atmosphere with respect to a surface which almost does not turn.

C. H. Mayer reports that studies are being made at the U.S. Naval Research Laboratory of the brightness temperature of Venus over the phase cycle at 2·7 cm wavelength. These observations are being made to determine the difference in temperature between the sunlit and dark hemispheres and specifically to check the phase measurements of several years ago at a nearby wavelength. The new observations do not show a significant dependence of Venus' brightness temperature at this wavelength with the phase of solar illumination. This result is not in agreement with our previous observations at 3·15 cm wavelength and those of Drake at 10 cm which indicated a lower brightness temperature just after inferior conjunction than near quadrature. It is, however, in agreement with more recent measurements by others which have suggested little variation with time or phase. The reason for the discrepancy is not clear. The new measurements are made with a more sensitive radiometer, but the sensitivity for the 1961 measurements was adequate for the signals observed between inferior conjunction and quadrature where the measurements were made. One would prefer to speculate that both observations are real and perhaps there was a change in Venus, but as yet one has no basis for such speculation.

Spectroscopic programs at the McDonald Observatory have failed to reveal water vapor over the last two years. Apparent CO_2 variations are being studied as a function of position on the disk and phase of the planet with respect to the sun (Gray, Young, Schorn, Barker).

Laboratory studies at the University of Massachusetts of the infrared reflectivity for frosts and powders of a variety of minerals which have been suggested as possible Venus cloud constituents have been carried out by Plummer and Carson (1970*b*). The marked influence of particle sizes on spectral reflectivity has been shown, and it has been demonstrated that most of the compounds which have recently been suggested as possible cloud constituents have unacceptable spectra when compared with Venus. Of the compounds studied, only small ice particles provide a good match to the Venus data.

Mars

H. Camichel mentions the continuation of his observations of the planets, particularly Mars and Venus. He is presently calculating the positions of spots on Mars which will provide the final values for their coordinates for the oppositions from 1956 to 1969.

Harlan J. Smith reports that intensive planetary studies have been made at the McDonald Observatory with the 82-inch Struve reflector and also with the new 107-inch telescope and its large coudé spectrograph equipment. The principal observations have been of Mars in the 0·8–0·9 μ H_2O bands and the various CO_2 bands in the 0·7 to 1·2μ region. Water vapor has been found to be present on Mars especially in the hemisphere of the evaporating polar cap, with amounts ranging up to 40μ of precipitable water vapor, but declining at times to immeasurably low values, below 10μ. A systematic program of study of the water vapor by location on the planet throughout a full Martian year is in progress (Schorn, Little, Owen, Barker). The CO_2 programs have given improved data for the weak short-wavelength CO_2 bands (Gray, Owen), show clear correlation with radar determinations of relative elevation over different portions of the Martian disk (Barker, Woszczyk), and have given the first indications of varying total amount of CO_2 (and therefore that the atmospheric pressure on Mars may be a function of the Martian season) (Barker).

Further observations are in progress to determine the H_2O and CO_2 variations throughout a complete Martian year (Barker).

With a spectrum scanner on the 36-inch reflector, the reflectivity curve of Mars from 0·3 to 1·2μ has been determined (Tull).

G. de Vaucouleurs, in conjunction with J. Bergstrahl and C. Michelis, is about to publish a paper entitled "Martian Transits 1877–1969", which contains the reduction and analysis of aerographic longitudes derived from transits of surface markings at the central meridian of Mars (750 transit observations of 142 stations by 19 observers at 21 oppositions from 1877 to 1969).

He also states that final reports on the Mars Map Project 1958–1969 and on "Observations of Mars in 1969" are in preparation.

G. de Mottoni reports that the following work is in press: *Cartographie de la Planète Mars sur Documentation Photographique Internationale à Partir de 1907* – Memoire III Oppositions de 1954 à 1958 – Memoire IV: Oppositions de 1960 à 1967:

E. H. Collinson, Director of the Mars Section of the British Astronomical Association, reports the reappearance of the dark shading in the Aethiopis region, reported early in the apparition by de Vaucouleurs, has been observed and sketched; in addition to this, changes have been observed in the region of Lunae Palus. Lunae Palus was unusually large and dark, as was Nilokeras. A broad dark shading was observed proceeding from Lunae Palus to Aurorae Sinus and another shading proceeding from Lunae Palus towards Ceranius which are not recorded on the IAU Map. A darkening of the region between Niliacus Lacus and Margaritifer Sinus was also observed. The Thoth-Nepenthes was faint. Numerous intensity observations of the dark areas were made by J. H. Botham at Johannesburg and by Baron R. de Terwangne at Antwerp.

The motions of well-defined transient bright spots (often assumed to be clouds) on Mars have been investigated by W. A. Baum and L. J. Martin at the Planetary Research Center of the Lowell Observatory. A search of several thousand plates in the Lowell Observatory collection yielded 28 groups of plates on which the positions of bright spots could be followed on a nearly daily basis. These groups of plates were from fifteen different oppositions of Mars, starting from 1907 and ending with 1958. All but two of these spanned four nights or more, and the maximum interval covered was thirty nights. Clouds near the limb were ignored.

The 28 groups of plates yielded 95 cloud histories. More than half appeared to be relatively stationary. Others showed definite motion well in excess of observational error but sometimes followed paths that partly doubled back upon themselves. The mean velocity for non-stationary clouds was found to be 5·6 km per hour, and the most commonly occurring direction of motion was eastward, particularly at high latitudes. The range of velocities found by this mapping procedure is nearly an order of magnitude smaller than values that have been estimated earlier by others from visual observations. These earlier observations are evidently in error, unless there exist clouds at high elevation, visible only on the limb, that can move much faster than those that were mapped from this photographic survey. More clouds were found in the northern hemisphere than in the southern, and there seemed to be avoidance of the relatively darker areas of the Martian surface. Certain regions seem to be more favored than others. A few recurrences at identical positions suggest the existence of related topographic features.

Their study is being continued with the use of films obtained during the Planetary Patrol mentioned elsewhere in this report.

The seasonal behavior of the boundaries of the Martian polar caps has been investigated in detail by G. E. Fischbacher, L. J. Martin, and W. A. Baum at the Planetary Research Center of the Lowell Observatory. Measurements of the cap boundaries in aerographic coordinates were made on more than 3000 yellow and red photographs covering 60 y of observation from 1905 through 1965.

The receding phase of each cap was found to follow a well-defined curve that repeated itself very closely from one Martian year to another; the mean deviations of measurements from various plates were only about 1°, and the variation from one Martian year to another was of similar magnitude.

Laboratory investigations at the University of Massachusetts have shown that the reflectivity of carbon suboxide (C_3O_2) agrees extremely well with the reflectivity of Mars over the range from 0·3 to 1·2 μ (Plummer and Carson (1970*a*)).

Jupiter

C. H. Mayer reports that the Naval Research Laboratory has made fairly frequent observations of Jupiter at 1·6 and 2·7 cm wavelengths, partly to see whether its emission varies with time as has been suggested in the past. They have seen no evidence for variations over the past two or three years.

At the McDonald Observatory spectroscopic studies are concentrating on H_2 and on the behavior of the 1·1 μ methane bands as a function of position on the disk (Owen, Bergstralh).

W. E. Fox, Director of the Jupiter Section of the British Astronomical Association, states that the apparition of 1968–1969 was well observed and that during this period the Red Spot became exceedingly prominent, mainly due to the fading of a section of the south temperate belt and also of the south equatorial belt.

Saturn

P. Guérin reports his discovery of the fourth ring and a new dark division in the system of Saturn's rings. This discovery has been made by photography with the Pic du Midi reflector, with a focal length of 60 m and an exposure of one second only, using a 35-mm commercial Tri-X film.

This fourth ring, which he calls "Ring D", is weaker than Ring C. It is separated from the latter by a dark division, similar to Cassini's division, and it extends almost as far as the globe itself. Its light decreases as it approaches the globe. It is equal at the border of the ring to 1/18 of the maximum brightness of Ring B in the neighborhood of Cassini's division.

All the negatives show this structure, and the composite images show them even better. The resolution obtained was about 0·25 arc second.

Recent polarimetric measurements made in the ultraviolet by J. S. Hall and L. A. Riley confirm the suspicion, mentioned at the third Arizona Conference, that the anomalous polarization found in the east-west direction was spurious. The new data indicate radial polarization in the ultraviolet for the disk of Saturn.

Uranus and Neptune

C. H. Mayer reports radio observations of Uranus and Neptune at two wavelengths, 1·6 cm and 2·7 cm. These observations made with Jupiter and Mars as controls (along with radio sources) confirm the high brightness temperatures, near 200 K in this region of the spectrum, and along with published observations at other wavelengths suggest the possibility of a peak in the apparent temperature spectrum.

MISCELLANEOUS RECENT DEVELOPMENTS

Professor L. M. Barreto reports that micrometric measurements are being made of Venus, Jupiter and Saturn at the National Observatory of Brazil. Migon and Barreto are measuring the phase variation of Venus to study the difference (O–C) for the dichotomy. Measurements of Jupiter's belts for latitude determination are being made by Migon, Nogueira and Barreto. Further micrometric measurements of the belts and ring system of Saturn are being performed by Migon and Nogueira. The results are expected to be published in 1970.

At the McDonald Observatory, high resolution planetary photography is occasionally attempted (Marin) and also high-spatial-resolution spectral scanning is being carried on (Trafton). Furthermore, measurements of planetary and lunar fluxes at 1 mm are being initiated (Ulrich).

A design for an electronic system for stabilizing planetary images at the focus of a telescope (image tranquilizer) was described by Baum of Lowell Observatory at the IAU General Assembly in Prague. Preliminary tests of this system, as modified by Thomas Pettauer, indicate that it holds the centroid of a planetary image nearly stationary against atmospheric displacements ("seeing") with a frequency response up to about 200 cycles per second.

G. de Vaucouleurs reports an article now in press entitled, Photometrie des Surfaces Planetaires, in *Interiors and Surfaces of the Planets* (Ed. A. Dollfus, Academic Press, 1970).

S. Runcorn states that studies are being made at the University of Newcastle-upon-Tyne regarding the origin of magnetic fields of planets and on the topic of convection in the "solid" mantles of the Moon and planets. In general, the dynamo theory of the geomagnetic field enables one to understand the absence of magnetic fields in Mars and the Moon, which have no cores or very small ones, and the presence of a field, discovered by radio emissions, on Jupiter. The case of Venus is being studied.

Basic research on theoretical problems of radiative transfer in planetary atmospheres is being undertaken at the University of Massachusetts by W. M. Irvine, D. J. van Blerkom, and A. Uesugi (on leave from the Institute of Astrophysics, Kyoto). Irvine also reports that data from his multicolor photoelectric photometry of the brighter planets, which have been published, have more recently been analyzed to provide accurate phase curves and albedos. The observations of Mars, Jupiter, and Saturn are still being studied in order to separate the average behavior with phase angle from fluctuations due to rotational effects, the rings of Saturn, and meteorological conditions (Hopkins and Irvine; Irvine, Higdon, and Ehrlich: *IAU Symposium*, no. 40).

Results of research at the University of Massachusetts which are now in press are:

Plummer, W. T. 1970, Venus Clouds: Infrared Reflectivity of Several Suggested Materials, submitted to *J. Geophys. Res.*

Plummer, W. T., Carson, R. K. 1970*a*, Mars: The Red Surface, *Science*.

Plummer, W. T., Carson, R. K. 1970*b*, Venus Clouds: Test for Carbon Suboxide, *Astrophys. J.*

Uesugi, A., Irvine, W. M. 1969, Computation of Synthetic Spectra for a Semi-Infinite Atmosphere, *J. Atmosph. Sci.*

Uesugi, A., Irvine, W. M. 1970, Multiple Scattering in a Plane Parallel Atmosphere. I: Successive Scattering in a Semi-Infinite Medium, *Astrophys. J.*

PLANETARY DATA CENTERS

At the Berkeley meeting of the IAU in 1961, a resolution was proposed by Commission 16 to facilitate international collaboration on planetary studies by the eventual establishment of two data centers, one in the U.S. and one in Europe. Following the adoption of this resolution by the Executive Committee, the IAU centers were subsequently established at Meudon and at the Lowell Observatory in Flagstaff.

With NASA support, a suitable building for carrying out the functions of collecting, classifying, reproducing and studying planetary photographs was completed at Flagstaff in 1965.

Photographs provided by European observatories have almost all been reproduced at Meudon as positive "composites" resulting from the superimposition of several images on one photograph. Copies of 1183 such composites have been made and sent to the Data Center at Lowell.

Similarly, copies of 11214 photographs and composites obtained at the American observatories of Lowell, Lick, Yerkes, McDonald, and Mt. Wilson have been reproduced at Lowell and sent to the Meudon Center. A total of 627 of these are Lowell positive composites.

The process of classifying, copying, and exchanging (between the two centers) photographs obtained prior to 1968 can now be considered almost complete.

Many copies of photographs were supplied to users for illustrating books, periodicals, reports and for making educational films. Computer-printed catalogues of the collection have been sent from the Lowell Center to users who have requested them.

Both collections are accessible to all qualified scientists having a research program. The reproductions and positive composites are presented in a form easily accessible and reproducible. The original negatives are filed separately.

Meudon

Certain programs, such as cartography of the planet Mars since 1907, the study of the movements of ultraviolet clouds on Venus, and the atmospheric activity in the bands of Jupiter, have been the object of prolonged studies of photographs covering a number of years. Other short-term programs have been executed, such as on rotation, coordinates, and cartography of the planet Mercury, the movement of yellow clouds in the atmosphere of Mars, and the study of the rings of Saturn. Much of this material has already been published. Still further studies have been conducted by other visiting scientists who have utilized temporarily the facilities of the Meudon Center for special programs.

The scientific direction of the Center at Meudon was undertaken by J. H. Focas. After his regrettable death on the 3rd of January, 1969, he was replaced by Messrs Ch. Boyer and T. Weimer. In June, 1969, the Center was transferred to a new location in the Laboratoire "Physique de Systeme Solaire" at Meudon, where it has been reorganized.

Flagstaff

Studies of cloud motions on Mars and the Martian polar caps described above have been carried out by the staff of the Planetary Research Center. In addition to these, the plate and film collection at the Center has provided observational data for investigations being carried out by a number of other people. This has included four separate Martian cartography projects, two studies of secular changes in Martian surface markings, three projects concerning Martian clouds and polar caps, the compilation of data for ground-based support for the Mariner 1969 mission, and two investigations of Jovian belts. Photographs from the collection have also been used to supplement independent photoelectric data.

The total number of planetary film copies (not including duplicates) produced at, and contributed to, the Flagstaff Center by other NASA-supported observatories is presently as follows:

New Mexico State University composites – 1663
Table Mountain Observatory composites, – 282
and other sets – 481

The Planetary Center at Flagstaff has developed three major pieces of equipment which have already improved, or will soon improve, the effectiveness of this facility.

One of these is a projection image reader which has been extensively used to measure the positions of Martian features. It is briefly mentioned in *IAU Trans.*, **XIII B**, p. 96) and in *Sky Telescope* (**35**, 7, 1968). A second instrument of this kind will be available in early 1970. The second instrumental development is a modular planetary time-sequence camera which has already been extensively used in connection with the Planetary Patrol and is described below. The third piece of equipment, described in another section of this report, is an image tranquilizer.

The scientific staff of the Center in Flagstaff includes W. A. Baum (director), P. B. Boyce, R. L.

Millis, and occasional temporary appointees. Patrol observations and film editing are carried out by a group under the supervision of L. J. Martin. The staff of the photographic laboratory is supervised by S. E. Jones.

INTERNATIONAL PLANETARY PATROL PROGRAM

The Planetary Patrol is a worldwide cooperative program of six observatories, coordinated by the Planetary Research Center at the Lowell Observatory and supported by NASA Headquarters, for the ground-based photographic surveillance of the planets. This Patrol provides more observations with less interruption than ever before available. It will therefore help greatly in pursuing some of the current studies of Mars and Jupiter described elsewhere in this report, and it thus constitutes a valuable body of scientific data in its own right. The Patrol is under the direction of W. A. Baum, assisted by R. L. Millis and S. E. Jones.

At present, the Planetary Patrol network includes the Mauna Kea Observatory of the University of Hawaii, the Mount Stromlo Observatory in eastern Australia, the Republic Observatory in South Africa, the Cerro Tololo Inter-American Observatory in northern Chile, the Magdalena Peak Station of New Mexico State University, and the Lowell Observatory at Flagstaff. Equipment is now being prepared for adding the Kavalur Station of the Kodaikanal Observatory in India, and it is possible that further additions may follow.

All of the telescopes of the network have been optically equipped to produce identical image scales with diffraction-limited resolution. The planet cameras are also identical. They are of modular construction and include provision for focusing, guiding, color-filter selection, and sensitometric calibration. Exposures are made with 35-mm film transports controlled by solid-state electronic timing units with which each sequence of exposures is programmed in advance. The date, time, place, and color are automatically recorded on the edge of every film frame. At some stations the telescopes have been equipped with new ULE-quartz Cassegrain mirrors to produce the desired image scale directly (4·5 arc-seconds per millimeter), while at other stations the camera is preceded by a Barlow lens module to accomplish the same thing.

The present planning period of the Patrol spans five years, from 1969 through 1973. It includes three apparitions of Mars and five of Jupiter, which are the two primary targets. There will also be an ultraviolet campaign on Venus in the middle of 1970. Every patrol station photographs each accessible planet hourly on a pre-calculated schedule with fourteen-frame sequences in each of three colors. Observing logs are airmailed weekly to the Planetary Research Center at Lowell Observatory. Rolls of film are also airmailed there regularly for calibrating and processing under controlled conditions. After a number of steps related to inspecting, editing, copying, cutting into strips, mounting, labeling, and cataloguing, the final product for each color and each observing hour is a strip of film mounted in a fourteen-hole aperture card that is relatively easy to handle for image projection, measurement, microphotometry, and filing.

Except for relatively recent years, a large percentage of the available planet photographs obtained at various observatories in the past eighty years are now housed (at least in copy form) in Flagstaff. It is interesting to note that in 1969 alone, the Planetary Patrol has already nearly doubled the Planetary Center collection.

COMMITTEE 16C

Committee 16C was created at the Berkeley meeting to secure and to study continuous records of the evolution and of rapid changes in atmospheric and surface features of planets. In order to do this, the committee promoted and coordinated observations between stations at several longitudes. It was also given the task of encouraging the formation of data centers and the collection of planetary photographs.

The committee, headed by the late Focas, organized a number of valuable international campaigns. The most successful of these was concerned with the photographic studies of Venus clouds in the ultraviolet and of the rings of Saturn at the moment of the passage of the earth through their plane in 1966.

Because of the development and growth of the data centers and the undertaking by Lowell Observatory of the NASA International Planetary Patrol program, it appears that the principal aims of the committee have already been achieved. Consultation which the President of Commission 16 has had with the heads of the two data centers and with Dollfus has indicated that one or both of these centers can now best organize special international planetary programs.

J. S. HALL
President of the Commission