BIBLIOGRAPHY

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1. Motion of the Moon and Dynamics of the Earth–Moon System: Shape and Gravity Field of the Moon

Bruno, A. O. (Inst. of Applied Mathematics, Moscow, 125047, U.S.S.R.): 'On Periodic Flybys of the Moon', *Celest. Mech.* **24**, 255–268. (1981)

This paper considers the plane circular restricted three-body problem for small μ. Symmetric periodic solutions of the second species (passing near the body of mass μ) and their distance from the center of the body of mass μ are studied by constructing perturbations of arc-solutions (solutions with consecutive collisions) existing for $\mu = 0$. Orbits which also pass near the body of mass $1\text{-}\mu$ are studied in detail. The results are applied to finding periodic orbits in the Earth–Moon system and in the Sun–Jupiter system.

Cappallo, R. J., Counselman, C. C. III, King, R. W. and Shapiro, I. I. (Dept. of Earth and Planetary Sciences, MIT, Cambridge, MA 02139): 'Tidal Dissipation in the Moon', *J. Geophys. Res.* **86**, 7180–7184. (1981)

Euler's equations of motion, modified to include elasticity and solid friction, were used to study the rotation of the Moon. Two heuristic models for the anelasticity were considered: Q independent of frequency and Q inversely proportional to the frequency of the strain oscillation. Parameters in each model were estimated by weighted least squares from 9 yr of lunar laser range observations. The root mean square of the postfit range residuals was 19 cm in each case. For a strain period of 1 month, the estimates of Q obtained with the two models were similar and surprisingly low: 23 ± 6. The range of uncertainty, ± 6, represents our estimate of the true standard deviation of the estimate of Q, as affected by systematic errors; it is 3 times larger than the formal, statistical, standard error.

Eckhardt, D. H. (Air Force Geophysics Lab., Hanscom Air Force Base, MA 01730): 'Theory of The Libration of the Moon', *The Moon and the Planets* **25**, 3–49. (1981).

In 1693, Jean Dominique Cassini disclosed his finding that the rotational motion of the Moon could be neatly described by the superposition of two uniform motions, a prograde rotation of the Moon about its polar axis and a retrograde precession of the Moon's equator along the ecliptic. The description of these motions is now called Cassini's laws. The theoretical explanation of Cassini's laws shows that physical librations with amplitudes less than $0''.5$, as seen from the Earth, must also exist. Until 1970, the physical librations were just marginally discernible, and the dynamical theory was developed to a level far superior to the quality of the observations.

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In 1970 the resolution of libration observations jumped by a factor of 10^4 over earlier techniques, and existing theories became inadequate for analyzing the observations. This paper presents a new semianalytic libration theory that is of use for analyzing observations. In this development the Moon is assumed to be either rigid, elastic or anelastic, and its gravity potential is represented through its fourth-degree harmonics. The Moon is considered to be moving about the Earth in an orbit that is perturbed by the Sun (the ALE of Deprit, Henrard and Rom), and by the planets and the figures of the Earth and Moon (from the ILE, principally derived by Brown). The direct effects of the rotation of the plane of the ecliptic and the figure of the Earth are also considered. Tables for physical libration variables are tabulated which are truncated at 0."010.

Janle, P. (Institut für Geophysik der Universität, D-2300 Kiel, F.R.G.): Investigations of local Bouguer Gravity Anomalies of the Apennines and Taurus Mountains of the Moon', *Phys. Earth Planet. Interiors* **27**, 47–59. (1981)

Local line-of-sight (LOS) Bouguer gravity anomalies of the Apennines and Taurus Mountains of the Moon have been calculated from low-altitude LOS free-air Doppler gravity profiles. The topography of the mountain areas is reflected by free-air gravity highs indicating no complete isostatic compensation. The resultant Bouguer gravity shows no anomalies for the Apennines, indicating lack of isostatic compensation. For the older Taurus Mountains significant local Bouguer minima of about −15 mgal indicate at least partial compensation.

If a viscoelastic compensation mechanism (bending of a viscoelastic plate overlying a fluid half-space) is assumed, models for the crustal viscosity as a function of time give limits of the range of possible models from 10^{24} to 5×10^{25} P at 4.4×10^9 y BP, 10^{26}–10^{27} P at 3.0×10^9 y, and 5×10^{26}–10^{28} P at 3.0×10^9 y. For earlier times only a lower bound of 10^{27} P can be given.

Two profiles of the Taurus area have been invistigated; they show no significant Bouguer anomalies across the mare basalt patches of Lacus Bonitatis and Sinus Amoris and thus can be used to estimate an upper limit for the basalt thicknesses. For Lacus Bonitatis this limit is 1.3 km; the limit is reached for Sinus Amoris at an average thickness of 0.3 km, with 1.5 km in the centre. Earlier results from DeHon and Waskom are consistent with the gravity data.

Meeus, J. (Vereniging voor Sterrenkunde, Belgium): 'Extreme Perigees and Apogees of the Moon', *Sky Telesc.* **62**, 110–111. (1981)

The perigee and apogee Earth–Moon distances have been computed for the period of 365 yr (1750 through 2125), and extreme cases are presented.

Rubin, A. E. (Dept. of Geology, Univ. of New Mexico, Albuquerque, NM 37131): 'The Origin of the Moon', *Griffith Observer* **45**(10) 2–10 (1981)

The Moon is an old and familiar friend, and it has been circling the Earth for a lot longer than we've been around. Despite our intimate knowledge of the Moon's motion and appearance and our visits to its surface, we are still puzzled about the Moon's origin. Was it formed along with the Earth, or did the Earth capture it during some primordial close encounter? Or is there some other explanation for the Moon's being here. Alan Edward Rubin provides us with possible answers but still leaves us guessing.

Stumpff, P. (Max-Planck-Institut für Radioastronomie, auf dem Hügel 69, D-5300 Bonn 1, F.R.G.): 'The Motion of the Earth–Moon System between 1700 and 2100 in Newcomb's Theory and in JPL-Ephemerides', *Astron. Astrophys.* **101**, 52–71. (1981)

The motion of the Earth–Moon barycenter in Newcomb's (1898) theory is compared with the JPL ephemerides DE102 (relativistic) and DE28 (newtonian) within the 400-yr interval 1700–2100. In the analysis, both the conventional and the new (IAU, 1976) precession theories are applied. Newcomb's periodic perturbations are corrected by least-square methods, and additional periodic terms are obtained by harmonic analysis. With Newcomb's theory modified in this manner, corrections to all orbital elements are determined, including secular terms in T and T^2. The final residuals are ≤ 0."05 within the entire 400-yr interval.

It is shown that the instantaneous mean orbital plane of the DE102 deviates from the IAU 1976 ecliptic by a small amount which is nearly constant during the 400 yr; it corresponds to a change in obliquity of $\sim 0''.04$ and to an equinox correction of $\sim 0''.12$.

For the newtonian, inertial portion of Newcomb's perihelion motion, the same correction ($+ 1''.11$ per century) is obtained from both ephemerides if one takes into account the different masses in the ephemerides, and employs the theoretical relativity effect ($+ 3''.84$ per century) and Bretagnon's value ($+ 6''.56$ per century) for the secular lunar perturbation (instead of Newcomb's value $+ 7''.68$).

The DE102 in connection with the IAU 1976 precession requires the correction $\Delta L = -0''.235 + 1''.081T + 0''.039T^2$ to Newcomb's expression for the mean longitude.

Vondrák, J.: 'On the influence of the secular change in the eccentricity of the Earth's Orbit on the Motion of the Moon', *Bull. Astron. Inst. Czechoslovakia* **32**, 315–317. (1981)

The influence of the quadratic term in the eccentricity of Earth's orbit round the Sun on the motion of the Moon is derived. It is shown that this effect, especially in the case of the Moon's longitude, cannot be neglected.

2. Physical Structure of the Moon; Thermal and Stress History of the Moon

Fomenko, A. T. (Moscow State Univ., Moscow, U.S.S.R.): 'The Jump of the Second Derivative of the Moon's Elongation', *Celest. Mech.* **29**, 33–40. (1981)

We present some results of new calculations of $D''(t)$ – the second derivative of the Moon's elongation as a function of time. The paper contains an explanation of the well-known R. Newton's effect – the rapid decline in $D''(t)$ from about 700 yr to about 1300 yr. The new graph of D'' is based on the revised dates of the ancient eclipses and has a qualitatively different character; in particular, the decline in $D''(t)$ vanishes completely and $D''(t)$ oscillates at a roughly constant value, which coincides with the modern one. This fact acrees with the independent chronological results in the author's earlier work.

Gangi, A. F. (Dept. of Geophysics, Texas A & M Univ., College Station, TX 77843): 'Pressure Dependence of the Velocity of Lunar Soil: The Velocity/Depth Variation in the Shallow Lunar Crust', *J. Geophys. Res.* **86**, 9562–9566. (1981)

Some recent measurements (Johnson *et al.*, 1981) of the velocity variation with pressure (up to 2.0 bars) for lunar soil are compared with results from the Hertzian-contact theory. Contrary to the original contention of Johnson *et al.* (1981), the data are shown to be consistent with the results of the Hertz theory when the effects of nonrecoverable compaction are taken into consideration. A simple analysis is given which shows that the velocity of loosely packed soil (which has only a fraction, f, of the grain contacts of a well packed soil) will be smaller than that of the well packed soil by the factor $f^{1/3}$ $(0 < f < 1)$. A reanalysis of some earlier experimental data by Talwani *et al.* (1973) for the velocity variation with pressure (up to 2.5 kbar) of a volcanic ash also shows that the modified Hertzian-contact theory can be used to fit those data. It is found that the velocity function $v(P) = 2.94P^{0.232}$ gives a better fit (rms error: $\pm$ 65 m s^{-1}) to the experimental data than a best fit equation of the form proposed by Talwani *et al.* (1973): $v(P) = 1.147(1 + (P/0.711))^{1/2} - (P/2.45)$ which has an rms error of $\pm$ 84 m s^{-1} for the same data. The curves fitted to the data of Johnson *et al.* (1981) would give a velocity variation for the shallow lunar crust equal to $v(z) = 225\ (\pm 25)z^{1/6}$ m s^{-1} for z in meters (down to 64 m depth). This compares quite well with the velocity rariation for the first 10 m of the Moon as interpreted by Gangi and Yen (1979), $v(z) = 220z^{1/6}$, using the data from the Apollo 14 and Appollo 16 Active Seismic Experiments (up to 32 m separation) on the Moon (Kovach *et al.*, 1971, 1972). The results reinforce the proposal by Gold and Soter (1970) and Gangi (1971, 1972) that the velocity variation in the very shallow lunar crust (the top 10 to 20 m) is due to self compaction of the lunar soil.

Haggerty, S. E. (Dept. of Geology, Univ. of Massachusetts, Amherst, MA 01103): 'Pyroclastics Yield Clues to Interior', *Geotimes* **26**(6) 29–30. (1981)

Some recent measurements (Johnson *et al.*, 1981) of the velocity variation with pressure (up to 2.0 bars) for lunar soil are compared with results from the Hertzian-contact theory. Contrary to the original contention of Johnson *et al.* (1981), the data are shown to be consistent with the results of the Hertz theory when the effects of nonrecoverable compaction are taken into consideration. A simple analysis is given which shows that the velocity of loosely packed soil (which has only a fraction, f, of the grain contacts of a well packed soil) will be smaller than that of the well packed soil by the factor $f^{1/3}$ $(0 < f < 1)$. A reanalysis of some earlier experimental data by Talwani *et al.* (1973) for the velocity variation with pressure (up to 2.5 kbar) of a volcanic ash also shows that the modified Hertzian-contact theory can be used to fit those data. It is found that the velocity function $v(P) = 2.94P^{0.232}$ gives a better fit (rms error: $\pm$ 65 m s^{-1}) to the experimental data than a best fit equation of the form proposed by Talwani *et al.* (1973): $v(P) = 1.147(1 + (P/0.711)^{1/2} - (P/2.45)$ which has an rms error of $\pm$ 84 m s^{-1} for the same data. The curves fitted to the data of Johnson *et al.* (1981) would give a velocity variation for the shallow lunar crust equal to $v(z) = 225$ ($\pm$ 25)$z^{1/6}$ m s^{-1} for z in meters (down to 64 m depth). This compares quite well with the velocity variation for the first 10 m of the Moon as interpreted by Gangi and Yen (1979), $v(z) = 220z^{1/6}$, using the data from the Apollo 14 and Appollo 16 Active Seismic Experiments (up to 32 m separation) on the Moon (Kovach *et al.*, 1971, 1972). The results reinforce the proposal by Gold and Soter (1970) and Gangi (1971, 1972) that the velocity variation in the very shallow lunar crust (the top 10 to 20 m) is due to self compaction of the lunar soil.

Song, G.-X.: 'On the Relation between the Internal Structure of the Moon and the Moonquakes', (in Chinese), *Acta Astrophys. Sinica* **1**, 197–202. (1981)

This paper deals witth the relation between the internal structure of the Moon and the radial distribution of the focuses of moonquakes. It has been shown from lunar probes that most of the focuses of Moon quakes located at the Moon mantle near the possible liquid core of the Moon.

3. Morphology of the Lunar Surface: Origin and Stratigraphy of Lunar Formations: Mapping of the Moon

Hall, J. L., Solomon, S. C., and Head, J. W. (Dept. of Earth and Planetary Physics, MIT, Cambridge, MA 02139): 'Lunar Floor-Fractured Craters: Evidence for Viscous Relaxation of Crater Topography', *J. Geophys. Res.* **86**, 9537–9552. (1981).

In this paper we evaluate quantitatively the hypothesis that topographic modification of floor-fractured craters on the Moon was accomplished predominantly by viscous relations. Adopting the simple assumption that the Moom may be modeled as having a uniform Newtonian viscosity, we compare the observed topographic profiles for a number of floor-fractured craters with the profiles predicted from the viscous relaxation of topography of fresh craters of similar diameter. Despite the simplicity of the rheological model, the comparison is quite good. The floor uplift, the rim subsidence, and the apparent subsidence outside the rim for the several floor-fractured craters considered are well matched by the viscous relaxation hypothesis. Floor fractures, while indicating that a purely viscous model is not strictly valid, can be explained by the effects of isostatic adjustment on a thin brittle lithosphere. The association of many floor-fractured craters with impact basins and with the time of mare volcanism can be understood in terms of a pronounced acceleration of crater relaxation in local regions of anomalously high near-surface temperatures and therefore of low effective viscosity and thin lithosphere. The quantitative extent of relaxation of floor-fractured craters can be interpreted in terms of a limited time interval of substantial relaxation for each crater. That time interval ended for each crater after local cooling had been sufficient for the viscosity to rise, for the lithosphere to thicken, and for the present topographic relief to be 'frozen in'. Thus viscous relaxation is a viable hypothesis to explain the topographic profiles of a number of lunar floor-fractured craters, and the extent of viscous relaxation of crater topography may serve as a toll to map lateral and temporal variations in the shallow thermal structure of the Moon and of other planets and satellites.

Mouginis-Mark, P. J. (Dept. of Geological Sciences, Brown Univ., Providence, RI 02912): 'Remote Sensing on the Moon Craters, Basins', *Geotimes* **26**(6) 26–27. (1981)

Moutsoulas, M. and Preka, P. (Univ. of Athens, Greece): 'Morphological Characteristics of Lunar Craters with Moderate Depth/Diameter Ratio. I ($0.08 < d/D < 0.12$)', *The Moon and the Planets* **25**, 51–66. (1981)

The morphological characteristics of craters, the depth/diam. ratio of which is between 0.08 and 0.12, are discussed. It is observed that craters having that moderate d/D ratio are, mainly, either small, presenting signs of degradation, or large young craters.

Psarev, V. A. (Astronomical Observatory, Kharkov State Univ., U.S.S.R.): 'Review of the Results of Photometric Investigations of the Reverse Side of the Moon', *Solar System Res.* **15**, 1–7. (1981)

We review the photometric investigations of the reverse side of the Moon, and we analyze the results briefly. We point out that spacecraft should be used in the near future to carry out a global photographic survey of the Moon in several spectral regions, and over a broad range of phase angles, allowing for the special requirements of photographic photometry.

Raitala, J. (Dept. of Astronomy, Univ. of Oulu, Finland): 'Lunar "En Echelon within en Echelon" Structures', *The Moon and the Planets* **25**, 105–112. (1981)

Some en echelon structures, tension gashes and compressional ridges may form similar patters. The N-S compression activates diagonal conjugate zones of weakness with tension gashes in the vicinity of the compressional direction. In the case of E-W compression similar arrangements of en echelon compression ridges are generated.

The global N-S compression existing at the time of fracturing of the lava-flooded Oceanus Procellarum basin is arguable. It is possible to interpret some different scale mare ridge arrangements as 'en echelon within en echelon' structures. Major ridge ranges evidently have Riedel and opposite Riedel orientations and they consist of minor en echelon structures which may in places be intruded tension gashes but are evidently mostly sheared and compressed Riedel fractures.

The 'en echelon within en echelon' structures of mare ridges manifest the significance of different scale strike-slip movements along the lithosphere zones of weakness indicated by present mare ridge zones. The orientation of these Riedel-fracture-like en echelon structures also points to the existence of an areal compression during shearings along the zones of weakness. The Oceanus Procellarum basin sinking caused by lava loadings and lunar internal cooling led to the lithosphere shortening and the compressional circumstances. The angle between proposed Riedel structures and the mare ridge zones varies within this area, possibly indicating differences in compression and shearing in distinct parts of the shortened basin lithosphere.

Savill, M. and McKay, R. (Selwyn College, Cambridge, CB3 9DQ, UK): 'The Lunar Crater Birt' *J. Brit. Astron. Assoc.* **91**, 463–472. (1981)

This paper has two aims. Firstly, to show that even in an age of sophisticated professional lunar studies, the amateur observer of the Moon can still make a useful contribution by undertaking investigations of the type described in this report. Secondly, resulting from one such investigation of the crater Birt, the report attempts to describe the appearance, morphology and mode of formation of a lunar feature of great interest.

Shevchenko, M. Yu.: 'A Modification of a Selenographic Reference Method for Lunar Images Obtained from Outer Space, by Use of the Earth' Cosmic Research Vol. **19**, 209–213. (1981)

A selenographic reference method is given for lunar images obtained from outer space, by use of the Earth, and which is based only on the information which is contained in the picture itself, without drawing on trajectory data and reference points on the lunar surface. The selenographic coordinates of 18 points have been determined from two pictures obtained by the Zond 8 automatic interplanetary station; and estimate of the accuracy of the coordinates has been carried out on the basis of a comparison with existing catalogs.

Thompson, T. W., Zisk, S. H., Shorthill, R. W., Schultz, P. H., and Cutts, J. A. (Planetary Science Inst., Science Applications Inc., Pasadena, CA 91101): 'Lunar Craters with Radar Bright Ejecta', *Icarus* **46**, 201–225. (1981)

A small fraction of the lunar impact craters with diameters of 1 km and greater have extensive enhanced 3.8 cm radar echoes associated with their ejecta deposits. The physical properties of these ejecta deposits and the ages of the central craters have been characterized via various infrared, radar, and optical signatures. Most of these ejecta deposits are radar bright at the 3.8 cm wavelength but are not radar bright at the 70 cm wavelength. Some ejecta have large infrared signatures, others do not. Although most of these ejecta have bright albedos in full-moon photographs, a significant fraction of the bright albedo markings do not extend beyond the crater. This mix of remote-sensing signatures indicates that craters with 3.8 cm radar bright halos are young and have ejecta deposits containing an excess of surface or near-surface rocks relative to the surrounding terrain. Abundant centimeter-sized rocks are inferred from the high 3.8 cm radar and infrared signatures. The low 70 cm radar signatures indicate that larger blocks are much less numerous. The population of craters with 3.8 cm radar bright craters on the Moon is much smaller than the population of craters in a similar size range on a young mare (Oceanus Procellarum) and has a different slope. This population is interpreted as a steady-state population reflecting a balance between the production of fresh craters and the destruction of the high infrared and radar signatures by small-scale cratering. The slope of difference between visual and radar craters is attributed to more rapid destruction of the radar signatures in smaller craters.

Relative densities of 3.8 cm radar bright craters and mare craters are estimated to be $0.4^{+0.016}_{-0.012}$ at a 4 km diam. and $0.100^{+0.07}_{-0.04}$ at a 32 km diam. Assigning ages on the basis of these relative densities raises the question of whether the 4 to 32 km diam. visual crater population is truly representative of a 3.3-by age. If it is, and if crater rates between 3.3 by and the present have been uniform, then the 3.8 cm radar crater lifetimes are estimated to be $0.13^{+0.05}_{-0.04}$ by and $0.03^{+0.23}_{-0.13}$ by at diameters of 4 and 32 km, respectively. Similarly, lifetimes of the infrared signatures of 4 km diam. craters may be as short as 10^7 yr. However, some data suggest that these estimates may be in error by a factor of 5 too small. Comminution of blocky ejecta material and the smoothing of slopes by lunar surface processes could account for the elimination of radar signatures on these time scales and the development of a steady-state crater population. An alternative interpretation, which we do not favor, is that the 3.8 cm radar bright crater population is formed by a subpopulation or primary bodies or by secondar cratering.

4. Chemical Composition of the Moon: Lunar Petrology, Mineralogy, and Crystallography

Horai, K. -I. (Lamont-Doherty Geological Observatory of Columbia Univ., Palisades, NY 10964): 'The Effect of Interstitial Gaseous Pressure on the Thermal Conductivity of a Simulated Appollo 12 Lunar Soil Sample', *Phys. Earth Planet. Interiors* **26**, 60–71. (1981)

The thermal conductivity of a simulated Apollo 12 lunar soil sample was measured with a needle probe under vacuum. The result showed that the sample, with bulk densities of 1.70–1.85 g cm^{-3} held in a vertical cylinder (2.54 cm in diameter and 6.99 cm long) has a thermal conductivity ranging from 8.8 to 10.9 mW m^{-1} K^{-1}. This is comparable to the lunar regolith's thermal conductivity as determined in situ. Besides the dense packing of the soil particles, an enhanced intergranular thermal contact, due to the self-compression of the sample, is necessary to raise the sample's thermal conductivity from the level of loose soil (< 5 mW m^{-1} K^{-1}) to that of the lunar regolith deeper than 35 cm (~ 10 mW m^{-1} K^{-1}). A model of the lunar regolith, a thin layer of loose soil resting on a compacted self-compressed substratum, is consistent with the lunar regolith's surface structure as deduced from an observation of the lunar surface's brightness temperature. Martian regolith surface structure is similar, except that its surface layer may be missing in places beacuse of aeolian activity. Measurements of thermal conductivity under simulated Martian surface conditions showed that the thermal properties of loose and compacted soils agreed with the two peak values of the Martian surface's thermal inertia as observed from 'Viking' orbiters, suggesting that drifted loose soil and exposed compacted soil are responsible for the bimodal distribution of the Marrian surface's thermal inertia near zero elevation. For compacted soil exposed to the Martian surface to have the same thermal conductivity as that buried under the surface layer, a cohesion of the soil particles must be assumed.

Yaniv, A. and Marti, K. (Chemistry Dept., Univ. of California at Sand Diego, La Jolla, CA 92093): 'Detection of Stopped Solar Flare Helium in Lunar Rock 68815', *Astrophys.* **247**, L143–L146. (1981)

We detected steep increases in the concentration profiles of ^{3}He and possibly of ^{21}Ne in the near-surface layers of lunar rock 68815, which was exposed on the lunary surface for 2 Myr. The concentration profile of ^{3}He is inconsistent with either spallation or solar wind components, but it agrees with expected ranges of stopped solar flare particles. Although the ^{3}He retention in this rock is determined to be very low (~ 3% at the surface), we can estimate a long-term average solar flare ratio $^{4}He/^{3}He$ of 12 to within a factor of about 3. This ratio is two orders of magnitude smaller than the same ratio observed in the solar wind, but it is consistent with solar flare data from recent satellite observations.

Aaniv, A., Rao, M. N., and Venkatesen, T. R. (Dept. of Physics and Astronomy, Tel Aviv Univ., Ramat Aviv, Israel): 'Solar-Flare Produced 3He in Lunar Samples; and Reply', *Nature* **292**, 866. (1981)

6. Radiation of the Moon; Optical and Thermal Properties of the Lunar Surface

Shkuratov, Yu. G. (Astronomical Observatory of the A. N. Gorki State Univ., Kharkov, U.S.S.R.): 'The Color of Regions on the Moon', *Solar Systems Res.* **15**(2) 51–59. (1981)

We present photographs of certain portions of the lunar surface in different colors. The spectral range is 0.43–0.62 μm. We also present a fragment of a digital photographic colorimetric map of the Moon in the spectral region from 0.48 to 0.69 μm. We undertake a comparative analysis of the digital map and a color map with the results of discrete spectrophotometry. On the basis of the results which we obtain, we consider ways in which the results of global colorimetry might possibly be utilized in lunar geology.

Shkuratov, Yu. G.: 'The Relationship between the Albedo and the Polarization Properties of the Moon. Fresnel Component of Reflected Light' (in Russian), *Astron. Zh.* **59**, 862–868, (1981). English translation in *Soviet Astron.* **25**, No. 4.

The possibility of mapping the new lunar optical parameters is confirmed. This parameter describes the regional distribution of deviations from the well-known correlation between the albedo and the maximum polarization coefficient. A two-component model of light reflection is used for establishing the relationship of the new parameter with the refractive index and with the structure characteristics of the lunar soil.

8. Exploration and Utilization of the Moon

Roedder, E. (U.S. Geological Survey, National Center, Stop 959, Reston, VA 22092): 'Use of Lunar Materials in Space Construction', *Space Solar Power Review* **2**, 249–258. (1981)

Large construction projects in Earth–Moon space, such as solar power satellites (SPS), will certainly be undertaken in the future; the only question is when? Such projects will consists of hundreds of thousands of tons of a variety of materials. What meterials will be needed, where will we get them, and how and where will they be processed into the desired form? At a workshop on Glass and Ceramic Industries in Space held at NASA-Houston in April 1979, people from a very wide range of disciplines and interest were brought together to explore some of the many options and constraints. Of the three possible sources for such materials, Earth, Moon, and Earth-orbit-crossing asteroids, only the first two are of immediate concern, although the last may eventually become the optimum source. The choice between a source on Earth and one on the Moon, for a material available from both, is easy. Several studies have proven that for two reasons, the Moon presents a tremendous physical and hence financial advantage over the Earth as a source for materials available from both. The 'gravity well' we live in on Earth requires a huge expenditure of energy to overcome. Although the Moon's gravity is one-sixth that of the Earth, the energy needed for a given mass to escape from the Moon is only ~ 5% of that needed for it to escape from the Earth; the resistance of the Earth's atmosphere increases this difference. This lunar advantage is multiplied, however, by still another major factor. To take a payload off the Earth by currently available technology (e.g., chemical rocket) requires a vehicle whose payload normally consists of ~ 1.5% of the original lift-off mass. On the Moon, however, as a result of the lack of an atmosphere, essentially pure payloads, without a vehicle, could be accelerated to escape velocity on the surface, by using solar-derived electrical energy in a linear electric motor or 'mass driver'.

Thus, the energy requirements alone make it obvious that for any given space application, lunar materials should be used if at all possible. Certainly not all materials needed for space construction can be obtained most economically from the Moon, and much additional research and development is needed to optimize the system. The possible ramifications of such a new and developing technology are so numerous that input from individuals having widely differing experiences and backgrounds might well be useful.

PLANETS

Arkhangel'skij, V. A., Kerzhanovich, V. V., and Trusov, B. P.: 'Radiotechnical Methods for Investigation of the Circulation of the Atmospheres of Planets', (in Russian), *Kosm. Issled.* **19**, 574–590. (1981)

Ballani, L.: 'Schwerefelder von Planeten und Mond – Zur Entwicklung des modernen Kenntnisstandes. III', *Sterne* **57**, 172–181. (1981)

Ballani, L.: 'Schwerefelder von Planeten und Mond – Zur Entwicklung des modernen Kenntnisstandes. IV', *Sterne* **75**, 301–311. (1981)

Ballani, L.: 'Schwerefelder von Planeten und Mond – Zur Entwicklung des modernen Kenntnisstandes. V', *Sterne* **57**, 342–346. (1981)

Barsukov, V. L. and Florenskii, C. P. (V. I. Vernadsky Inst. of Geochemistry and Analytical Chemistry, Academy of Sciences of the U.S.S.R, V-334 Moscow, U.S.S.R.): 'Study of the Moon and Comparative Planetology: Problems and Perspectives', *Advances in Space Research* **1**, 41–47. (1981)

On the basis of the comparative planetologic study of the Moon and terrestrial planets two fundamental features of their history and structure have been established.

Firstly, shell-like structure of the terrestrial planets could be understood only in the terms of the heterogeneous accretion theory. At the final stages of major terrestrial planet formation the leading role belonged to the planetosimals of carbonaceous chondritic composition. Secondly, there are two types of the crust on the planetary surface. Their formation are considered to be independent and differing in the geological time. The primary planetary crust of predominantly feldspathic composition is considered to form during the pregeologic period at the final stage of planetary formation due to the impact-explosive processes. The hydrosphere and atmosphere is thought to appear contemporaneously. The basaltic planetary crust is forming later due to the radioactive decay and superimposed on the primary feldspathic crust.

Beneš, K.: 'About the Terrestrial Planets', (in Czech), *Vesmír* **60**, 197–199. (1981)

Bogolyubov, G. M.: 'On the Vertical Statistical Structure of Planetary Atmospheres', (in Russian), *Vest. LGU,* **4**, 46–52. (1981)

Bretagnon, P. (Service de Mécanique Céleste du Bureau des Longitudes, Equipe de Recherche Associée au CNRS, 77 Avenue Denfert-Rochereau, F-75014 Paris, France); 'Construction of a Theory of the Outer Planets Through an Iterative Method', (in French), *Astron. Astrophys.* **101**, 342–349. (1981)

Together with a solution working order after order with respect to the masses, we have undertaken, at the Bureau des Longitudes, the construction of a theory for the outer planets Jupiter, Saturn, Uranus, and Neptune through an iterative method.

This method makes it possible to reach a high order with repsect to the masses, particularly for Jupiter and Saturn (6th order), which is necessary, as shown in Figures 1 and 2. The variables we use are a, λ, k, h, q, p. The solutions are analytical functions of the mean longitudes of the eight planets and are numerical with respect to other integration constants.

We develop the formulae we need and illustrate the difficulties of convergence appearing in the iterations for the variables a and λ of Uranus and Neptune. For the other variables of Uranus and Neptune and for the 6 variables of Jupiter and Saturn, the convergence works at the precision of 0″.001 for the short period arguments (about some 10 yr) and around 0″ or 0″.1 for the long period arguments (1000 yr and over).

The precision as a whole for the solutions is shown (Figures 3–6) by comparisons to numerical integrations over 1000 yr. Except for very long period terms in the longitudes of Uranus and Neptune, the residuals are about 0″.3 in the mean longitudes and 0″.1 in the other variables.

Cole, G. H. A.: 'Aspects of the Physics of Planetary Interiors', *Contemp. Phys.* **22**, 397–442. (1981)

Galkin, N. I., Nikolaev, A. V., Rozhdestvenskij, M. K., Serbin, V. I., Khavroshkin, O. B., and Tsyplakov, V. V.: 'On the Specific Character of Seismic Investigations of the Terrestrial Planets', (in Russian), *Issled. Zemli Nevzryvn. Sejsmich. Istochnikami. Moskva*, 64–75. (1981)

Gajkovich, K. P. and Naumov, A. P.: 'On the Interpretation of Radio Emission of Giant Planets', (in Russian), *13-ya Vses. Konf. Po Radioastron. Issled. Soln. Sistemy, Kiev* **73**. (1981)

Golitsyn, G. S. (Inst of Atmospheric Physics of Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.): 'Comparative Atmospheric Dynamics for Terrestrial Planets', *Advances in Space Res.* **1**, 141–149. (1981)

A review is presented of theoretical ideas on the general circulations in the atmospheres of Earth, Mars, and Venus and also of results of their theoretical modelling. The role of various factors is discussed in the formation of the circulations. These results are compared with observational data obtained by different means. Data of direct local measurements of meteorological parameters in the atmospheres of Venus and Mars are discussed including those obtained at their surfaces.

Head, J. W. and Solomon, S. C. (Dept. of Geological Sciences, Brown Univ., Providence, RI 02912): 'Tectonic Evolution of the Terrestrial Planets', *Science* **213**, 26–76. (1981)

The style and evolution of tectonics on the terrestrial planets differ substantially. The style is related to the thickness of the lithosphere and to whether the lithosphere is divided into distinct, mobile plates that can be recycled into the mantle, as on Earth, or is a single spherical shell, as on the Moon, Mars and Mercury. The evolution of a planetary lithosphere and the development of plate tectonics appear to be influenced by several factors, including planetary size, chemistry, and external and internal heat sources. Vertical tectonic movement due to lithospheric loading or uplift is similar on all of the terrestrial planets and is controlled by the local thickness and rheology of the lithosphere. The surface of Venus, although known only at low resolution, displays features both similar to those on Earth (mountain belts, high plateaus) and similar to those on the smaller planets (possible impact basins). Improved understanding of the tectonic evolution of Venus will permit an evaluation of the relative roles of planetary size and chemistry in determining evolutionary style.

Henbest, N.: 'The Birth of the Planets', *New Scientist* **92**, 173–176. (1981)

An account of our present understanding of the creation of the solar system is presented.

Hood, L. L. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'A Comparison of Characteristic Times for Satellite Absorption of Energetic Protons Trapped in the Jovian and Saturnian Magnetic Fields', *Geophys. Res. Lett.* 8, 976–979. (1981)

The relative symmetry of the Saturnian magnetic field with respect to the rotational equatorial plane results in characteristic times for satellite absorption of trapped energetic protons that are typically one to three orders of magnitude smaller than the corresponding Jovian satellite absorption times. The maximum difference occurs for nearly equatorially mirroring particles. Assuming that the rates of radial diffusion are comparable within the two magnetospheres, the inner Saturnian satellites are more efficient absorbers of inwardly diffusing ions than their Jovian counterparts. Thus, via the mechanism of satellite absorption, the rotational symmetry of the planetary magnetic field may play an important indirect role in determining gross properties of the radiation environment at Saturn.

Hubbard, W. B. (Dept. of Planetary Sciences, Univ. of Arizona, Tucson, AZ 85721): 'Interiors of the Giant Planets', *Science* **214**, 145–149. (1981)

Unlike the terrestrial planets, the giant planets – Jupiter, Saturn, Uranus, and Neptune – have retained large amounts of the carbon, nitrogen, and oxygen compounds that were present in their zone of formation. A smaller fraction of the available hydrogen and helium was retained. The distribution and relative amounts of these components in the interiors of the Jovian planets can be inferred from theoretical and experimental data on equations of state and from the planets' hydrostatic equilibrium response to rotation.

Klemola, A. R. (Lick Observatory, Board of Studies in Astronomy and Astrophysics, Univ. of California at Santa Cruz, Santa Cruz, CA 95064): 'Astrometric Observations of Planets, Minor Planets, and Satellites: 1976–1980; *Astron. J.* **86**, 1108–1109. (1981)

Equatorial coordinates for Uranus, Neptune, selected minor planets, and the Jovian satellites have been measured on direct photographs taken with the 0.51 m Carnegie double astrograph of the Lick Observatory during the period 1976–1980.

Kolosnitsyn, N. I. and Osipova, A. V.: 'The Equivalence Principle and Anomal Motions of Bodies in the Solar System', (in Russian), *Astron. Zh.* 58, 888–897 (1981). English Translation in *Soviet Astron.* **25**, No. 4.

Anomal secular and periodic motions of the solar system's planets and of the Moon which are caused by a violation of the equivalence principle for massive bodies are calculated. The greatest effects arise from Jupiter and from the neighbouring planets.

Kondrat'ev, K. Ya. and Moskalenko, N. I. (Main Geophysical Observatory, Leningrad, U.S.S.R.): 'Comparative Analysis of Chemical Composition and Optical Properties of Gaseous and Disperse Phases of the Earth-Group Planetary Atmospheres', *Advances in Space Research* 1, 53–58, (1981)

The models of chemical composition and structure of the Earth-type planetary atmospheres are offered. The optical properties of gaseous and disperse phases of the atmospheres are investigated.

Kondrat'ev, K. Ya. and Moskalenko, N. I. (Main Geophysical Observatory, Leningrad, U.S.S.R.): 'The Correlation of the Planetary Atmosphere Structural Characteristics with Their Optical Properties and Radiative Heat Exchange Peculiarities', *Advances in Space Research* 1, 59–64. (1981)

The structure characteristics of the Earth-type planetary atmospheres are calculated solving the radiative heat exchange problem. Their correlations with the surface reflection characteristics and optical properties of their atmospheres are considered.

Kozlov, Yu. P.: 'Interrelation between the Value of Gravitational Acceleration on Planets, the Distance of Planets from the Sun, and the Size of Planets', (in Russian), *Kazan. Khim. Technol. Inst. Kazan.* (1981)

Lebofsky, L. A., Rieke, F. H., and Lebofsky, M. J. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Infrared Reflectance Spectra of Hyperion, Titania, and Triton', *Icarus* **46**, 169–174. (1981)

Medium-resolution infrared (1–2.5 μm; $\Delta\lambda/\lambda \sim 0.05$) photometry of Triton, Titania, and Hyperion and medium-resolution (1.5–2.4 μm; $\Delta\lambda/\lambda \lesssim 0.01$) spectroscopy of Triton are presented. Hyperion and Titania have spectra roughly similar to the laboratory spectrum of water frost, while the spectrum of Triton is inconsistent with the spectra of frosts likely to be major surface constituents.

Lutz, B. L., De Bergh, C. Maillard, J. -P., Owen, T. and Barult, J. (Lowell Observatory, Box 1269, Flagstaff, AZ 86002): 'On the Possible Detection of CH_3D on Titan and Uranus', *Astrophys. J.* **248**, L141-145. (1981)

Based on the analysis of a new band of CH_3D near 6425 cm^{-1}, possible identification of it in Fink and Larson's (1979) spectra of Titan and Uranus is proposed.

McCord, T. B.: 'Developments in the Use of Spectral Signature for Mapping the Surface of Solar System Objects Other Than the Earth', Sessions on Remore sensing 1980. Proceedings of the Topical Meeting of the COSPAR Interdisciplinary Scientific Commision A (Sessions A1 and A2) of the COSPAR Twenty-Third Plenary Meeting Held in Budapest, Hungary, 12-14 June, 1980, A. B. Kahle, G. Weil, and W. D. Carter (editors). *Adv. Space Res.* **1**, No. 10, 3–17. (1981)

Reflection spectroscopy and multispectral mapping. Especially when used in conjunction with other remote sensing data, have proved to be very important tools for studying the structure and composition of surface units of solar system objects. Several example applications are discussed to illustrate both the methods and the rewards.

McElroy, M. B. and Prather, M. J. (Center for Earth and Planetary Physics, Harvard Univ., Cambridge, MA 02138): 'Noble Gases in the Terrestrial Planets', *Nature* 293, 535–539. (1981)

Abundance of primordial noble gases are lower for Mars than for Earth, but are higher for Venus. The data for Venus attributed to implantation of solar wind in small preplanetary particles. Results for Mars are explained by escape of gas from planetesimals with radius between 5 and 100 km which form within the first 10^7yr of the Solar System. Volatile losses associated with melting caused by short-lived radioisotopes such as ^{26}Al.

Moore, P. (Farthings, 39 West Street, Selsey, Chichester, West Sussex): 'Some Thoughts on Planet "X"', *J. Brit. Astron. Assoc.* **91**, 483–487. (1981)

The discovery of Pluto is discussed and the difficulties mentioned of supposing it to be the disturbing force acting on Neptune. The suggestion that there is a large unknown planet still to be detected is examined and an estimated position is given.

Ness, N. F. (NASA-Goddard, Space Flight Center, Greenbelt, MD 20771): 'The Magnetic Fields of Jupiter and Saturn', *Advances in Space Res.* **1**, 171–176. (1981)

Jupiter and Saturn are two of the more 'exotic' planets in our solar system. It is the purpose of this talk to summarize what is presently known about the magnetic fields of these planets and the characteristics of their magnetospheres, which are formed by interaction with the solar wind.

Pavlov, A. K.: 'The Influence of External Sources and Dissipative Processes on the Abundance of Rare Gases in the Atmospheres of Terrestrial Planets', (in Russian), *Izv. AN SSSR. Ser. Fiz.* **45**, 621–625. (1981)

Pavlov, A. V.: 'Variation of the Coefficients of Velocities of Photoionization of the Neutral Components of the Planetary Upper Atmospheres with Solar Activity", (in Russian), *Kosm. Issled.* **19**, 907–912. (1981)

Pollack, J. B. and Cuzzi, J. N.: 'Rings in the Solar System', *Scientific American* **245**(5), 104–129. (1981)

Three of the giant planets are now known to have them, and the rings around Saturn are now known to consist of myriad ringlets. The form of the rings is maintained by a complex interplay of sculpturing forces.

Ross, M. (Univ. of California, Lawrence Livermore National Lab. Livermore, CA 94550): 'The Ice Layer in Uranus and Neptune – Diamonds in the Sky?', *Nature* **292**, 435–436. (1981)

Many of the current models of Uranus and Neptune postulate a three-layer structure, consisting of an inner rocky core, a middle 'ice' layer of fluid, H_2O, CH_4, NH_3 and an outer hydrogen–helium layer of solar composition. The estimated pressures and temperatures of the ice layer ranges from about 6 Mbar and 7000 K at the inner core-ice boundary, to ~0.2 Mbar and 2200 K at the outer ice/hydrogen–helium boundary. I point out here that shockwave experiments on these liquids, as well as theoretical studies, imply that the H_2O and NH_3 in the ice layer are almost totally ionized and the CH_4 has been pyrolysed to carbon, possibly in the metallic or diamond form.

Russell, C. T. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'The Magnetic Fields of Mercury, Venus, and Mars', *Advances in Space Res.* **1**, 3–20. (1981)

Just as clearly as Mariner 10 established that Mercury has an intrinsic magnetic field, the Pioneer Venus orbiter has established that Venus has no significant intrinsic field. This is perhaps the opposite of what might be expected. Mercury, a small planet might be expected to cool rapidly and its internal dynamo to cease, while Venus, which is almost as large as the Earth, should not have lost much heat. On the contrary the source of energy of the Mercury dynamo appears to be extant whereas that of Venus appears to be extinct.

The existence of a Martian magnetic field is controversial. No unambiguous signature of a Martian magnetic field has been reported. If the field on the nightside of Mars is of planetary rather than solar origin the Russian Mars spacecraft observations indicate the Martian dipole lies near the planetary equator rather than its pole.

Scarf, F. L., Gurnett, D. A., and Kurth, W. S. (Space Science Dept., TRW Defense and Space Systems Group, Redondo Beach, CA 90278): 'Plasma Wave Turbulence at Planetary Bow Shocks', *Nature* **292**, 747–750. (1981)

Voyager 1 observations of plasma wave turbulence at Saturn's bow shock are discussed and compared with corresponding data from Jupiter, Earth, and Venus. The results suggest that the plasma instabilities that develop at the lower Mach number bow shocks of the terrestrial planets differ from those found at the high Mach number bow shocks of the outer planets.

Sinnott, R. W.: 'Fear no Syzygy', *Sky Telesc.* **62**, 221. (1981)

Exaggerations and erroneous conclusions in the book of J. R. Gribbin and S. H. Plagemann 'The Jupiter Effect' are pointed out.

Surkov, Y. A. (Vernadsky Inst. of Geochemistry and Analytical Chemistry, Academy of Science of the U.S.S.R., V-334, Moscow, U.S.S.R.): 'Radioactivity of the Moon and Planets', *Advances in Space Res.* **1**, 21–38. (1981)

In this report the main results of the study of radioactivity of the solar system bodies are considered. The radioactivity of the Moon and planets was measured by means of vehicles in situ. The radioactivity of the lunar samples, brought to the Earth was studied with laboratory equipment.

Thompson, L. G. (U.S. Military Academy, West Point, NY 10996): 'On the Trail of the "Jupiter Effect"', *Sky Telesc.* **62**, 220. (1981)

The tidal forces exerted on the Earth by the Sun, the Moon and the planets are computed in order to demonstrate that the fears expressed in connection with the 'alignment' of planets on March 10, 1982, is baseless.

Vityazev, A. V. and Pechernikova, G. V.: 'Solution of the Problem of Rotation of Planets in the Statistical Theory of Accumulation", (in Russian), *Astron. Zh.* 58, 869–878 (1981). English translation in *Soviet Astron.* **25**, No. 4.

An analytical theory is derived for the rate of rotation acquired by a planet as it grows. The values of regular and random components of angular momentum are determined by a time-dependent mass and velocity distribution function of the bodies. It is shown that large obliquities of planets and retrograde rotation of some of them are due to the large random component of angular momentum. For planets which were not slowed down by tidal friction the theoretical dependence of the specific angular momentum on the mass of the planet is in agreement with the observed one.

Volland, H.: 'Magnetfelder im Sonnensystem. Teil 1', *Sterne Weltraum* **20**, 209–414. (1981).

Volland, H.: 'Magnetfelder im Sonnensystem. Teil 2', *Sterne Weltraum* **20**, 446–451. (1981)

Vorontsov, S. V. and Zharkov, V. N.: 'Free Oscillations of Giant Planets. Influence of Rotation and Ellipticity', (in Russian), *Astron. Zh.* **58**, 1101–1114 (1981). English translation in *Soviet Astron.* **25**, No. 5.

A second-order perturbation theory is developed for the calculation of the influence of all effects of rotation-Coriolis forces, centrifugal forces and ellipticity on the free oscillations of a gaseous-liquid planet or a star. The perturbation theory is constructed taking into account the coupling between different modes of oscillations caused by rotation. Theoretical spectra of the free oscillations of Jupiter and Saturn are computed.

Vorontsov, S. V.: 'Free Oscillations of Giant Planets. Influence of Differential Rotation', (in Russian), *Astron. Zh.* 58, 1275–1285, (1981). English translation in *Soviet Astron.* **25**, No. 6.

A perturbation theory is developed for the calculation of the influence of differential rotation on the free oscillations of a gaseous-liquid planet or a star. Effects of Coriolis forces, centrifugal forces and ellipticity are investigated simultaneously using a second-order perturbation theory. Theoretical spectra of free oscillations of Jupiter and Saturn are computed for simple models of differential rotation distributions.

Wilson, L. and Head, J. W. (Lunar and Planetary Unit, Dept. of Environmental Sciences, Univ. of Lancaster, LA1 4YQ, UK): 'Ascent and Eruption of Basaltic Magma on the Earth and Moon', *J. Geophys. Res.* **86**, 2971–3001. (1981)

Geological and physical observations and constraints are applied to the development of a model of the ascent and emplacement of basaltic magma on the Earth and Moon. Mathematical models of the nature and motion of gas/liquid mixtures are developed and show that gas exsolution from terrestrial and lunar magmas commonly only occurs at shallow depths (less than 2 km); thus the ascent of bubble-free magma at depth can be treated separately from the complex motions caused by gas exsolution near the surface. Magma ascent is related to dike or conduit width; a lower limit to width is determined by the presence of a finite magma yield strength or by excessive magma cooling effects related to magma viscosity. For terrestrial basalts with negligible yield strengths and viscosities greater than 10^2 Pa s, widths in the range 0.2–0.6 m are needed to allow eruptions from between depths of 0.5–20 km. Fissure widths of about 4 m would be needed to account for the output rates estimated for the Columbia River flood basalt eruptions. As the magma nears the surface, bubble coalescence will tend to occur, leading to intermittent explosive strombolian-style activity. For commonly occurring lunar and terrestrial basalts the magma rise speed must be greater than 0.5–1 m s^{-1} if strombolian activity is to be avoided and relatively steady fire fountaining is to take place. Terrestrial fire fountain heights are dictated by the vertical velocity of the magma/gas dispersion emerging through the vent, increasing with increasing magme gas content and mass eruption rate, and decreasing with increasing magma viscosity. Terrestrial fire fountain heights up to 500 m imply the release of up to 0.4 wt% water from the magma, corresponding to initial water contents up to 0.6 wt%. The presence of extremely long lava flows and sinuous rilles on the Moon has often been cited as evidence for very high extrusion rates and thus a basic difference between terrestrial and lunar magmas and crustal environments. However, the differences between terrestrial and lunar magma rheologies and crustal environments do not lead to gross differences between the effusion rates expected on the two planetary bodies, for similar-sized conduits or fissures. Thus the presence of these features implies only that tectonic and other forces associated with the onset of some lunar eruptions were such as to allow wide fissures or conduits to form. The surface widths of elongate fissure vents need to be no wider than 10 m to allow mass eruption rates up to 10 times larger than those proposed for terrestrial flood basalt eruptions; 25 m widths would allow rates 100 times larger. It therefore appears unlikely that source vents on the Moon with widths greater than a few tens of meters represent the true size of the unmodified vent. The main volatile released from lunar magmas was probably carbon monoxide, released in amounts proportionally less than terrestrial magmas by more than an order of magnitude. However, decompression to the near-zero ambient lunar atmospheric pressure causes much greater energy release per unit mass and this, coupled with vertical and horizontal expansion of the gas, suggests a much more efficient use of the available gas on the Moon than on the Earth. Some amount of magma disruption must always have taken place in lunar eruptions unless the gas content was truly zero or the magma possessed an appreciable yield strength. Pyroclastic deposits, such as the extensive lunar dark mantling material, could be produced from a single source vent and extend to diameters of up to 200 km. Such deposits could result either from steady eruptions at high effusion rates (with less than 1% of the magma disrupted into sub-millimeter droplets) or low effusion rate eruptions in which strombolian activity occurred. The wide dispersal of pyroclastic debris is a result of small particles being locked into the expanding gas cloud. Finally, we consider the details of basaltic eruption processes on the Moon and predict the nature and geometry of several types of volcanic landforms (flows, pyroclastic blankets and conse, cinder and spatter ridges, etc.) that should result from specific eruption conditions.

1. Jupiter

Acuna, M. H., Neubauer, F. M., and Ness, N. F. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Standing Alfvén Wave Current System at Io: Voyager 1 Observations', *J. Geophys. Res.* **86**, 8513–8521. (1981)

The enigmatic control of the occurrence frequency of Jupiter's decametric emissions by the satellite Io has been explained theoretically on the basis of its strong electrodynamic interaction with the corotating Jovian magnetosphere leading to field-aligned currents connecting Io with the Jovian ionosphere. Direct measurements of the perturbation magnetic fields due to this current system were obtained by the Goddard Space Flight Center magnetic field experiment on Voyager 1 on March 5, 1979, when it passed within 20 500 km south of Io. An interpretation in the framework of Alfvén waves radiated by Io leads to current estimates of 2.8×10^6 A. A mass density of 7400–13 600 proton mass uniter per cm^3 is derived, which compares very favorably with independent observations of the torus composition characterized by 7–9 proton mass units per electron for a local electron density of 1050–1500 cm^{-3}. The power dissipated in the current system may be important for heating the Io heavy ion turus, inner magnetosphere, Jovian ionosphere, and possibly the ionosphere or even the interior of Io.

Alexander, J. K., Carr, T. D., Thieman, J. R., Schauble, J. J., and Riddle, A. C. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Synoptic Observations of Jupiter's Radio Emissions: Average Statistical Properties observed by Voyager', *J. Geophys. Res.* **86**, 8529–8545. (1981)

Observations of Jupiter's low-frequency radio emissions collected over one-month intervals before and after each Voyager encounter have been analyzed to provide a synoptic view of the average statistical properties of the emissions. Compilations of occurrence probability, average power flux density, and average sense of circular polarization are presented as a function of central meridian longitude, phase of Io, and frequency. The results are compared with ground-based observations. The necessary geometrical conditions and preferred polarization sense for Io-related decametric emission observed by Voyager from above both the dayside and nightside hemispheres are found to be essentially the same as those observed in earth-based studies. On the other hand, there is a clear local time dependence in the Io-independent decametric emission. The emission is prevalent at longitudes $> 200°$ when observed from over the dayside hemisphere but is dominant at longitudes $< 200°$ when observed from over the postmidnight sector. Decametric emission, which comprises the dynamic spectral lesser arcs near 10 MHz, displays a distinct, bimodal polarization pattern that is predominantly in the left-hand sense at longitudes below 150° and in the right-hand sense at longitudes above 150°. The central meridian longitude distributions of occurrence porbability and average flux density at hectometric wavelengths appear to depend significantly on both the observer's latitude and local time. Io appears to have an influence on average flux density of the emission down to below 2 MHz. The average power flux density spectrum of Jupiter's emission has a broad peak near 9 MHz. integration of the average spctrum over all frequencies and all longitudes gives a total radiated power for an equivalent isotropic source of 4×10^{11} W.

Armstrong, T. P., Paonessa, N. T., Brandon, S. T., Krimigis, S. M. and Lanzerotti, L. J. (Dept. of Physics and Astronomy, Univ. of Kansas, Lawrence, KS 66045): 'Low-Energy Charged Particle Observations in the 5–20 R_J Region of the Jovian Magnetosphere', *J. Geophys. Res.* **86**, 8343–8355. (1981)

Ion (> 0.5 MeV) and electron (> 30 keV) measurements made by the low-energy charged particle instrument during the Voyager 1 and 2 traversals of the 5–20 R_J region of the Jovian magnetosphere are presented. The spatial morphology of particle intensities, energy spectra, and composition is emphasized. Diffusive radial transport is also discussed. The Jovian magnetosphere seemed to be much more disturbed during the Voyager 2 passage than during that of Voyager 1. Significant inbound–outbound asymmetries of the radial profiles of intensities are observed; an appropriate magnetic field model to provide closure has not been found. Low-energy electrons are not enhanced or depleted in the Io torus region except at the inner edge, about 2.5 R_J, where they sharply decrease. This may be due to enhanced electron loss associated with a region of increased plasma density.

Atreya, S. K., Donahue, T. M. and Festou, M. (Dept. of Atmospheric and Oceanic Science, Space Physics Research Lab., Univ. of Michigan, Ann Arbor, MI 48109): 'Jupiter: Structure and Composition of the Upper Atmosphere', *Astrophys. J.* **247**, L43–L47. (1981)

The Voyager ultraviolet stellar occultation data yield a temperature of 200 ± 50 K at about 400 km, and the solar occultation data give 1100 ± 200 K at 1450 km above the ammonia cloud tops. The temperature gradient between 400 and 1450 km is approximately 1 k km^{-1}. The mesospheric temperature structure gives no strong indication of an Earth-like mesopause. The heating of the upper atmosphere appears to result from a combination of magnetospheric charged particle precipitation, ion drag, inertia gravity waves, and solar EUV. The volume mixing ratios of CH_4 and C_2H_6 at 325 km are measured to be $2.5\,(+3, -2) \times 10^{-5}$ and $2.5\,(+2.0, -1.5) \times 10^{-6}$, respectively, which are lower than in the stratosphere. The C_2H_2 volume mixing ratio is $\leqslant 5 \times 10^{-6}$ at 300 km. The homopause value of the equatorial eddy diffusion coefficient is found to be $1\text{–}2 \times 10^6$ cm^2 s^{-1}.

Bagenal, F. and Sullivan, J. J. (Center for Space Research, MIT, Cambridge, MA 02139): 'Direct Plasma Measurements in the Io Torus and Inner Magnetosphere of Jupiter', *J. Geophys. Res.* **86**, 8447–8466. (1981)

A model of the Io plasma torus has been constructed using the in situ plasma measurements of Voyager 1. A sharp gradient in plasma temperature of $\sim 7 \times 10^5$ K R_J^{-1} at 5.7 R_J divides the torus into two parts, a cold inner region, where the ions are closely confined to the centrifugal equator, and a warm outer region, which includes the orbit of Io and has a thickness scale height of 1 R_J. The outer edge of the warm torus is defined by a drop in plasma density near 7.5 R_J. The bulk motion of the plasma, i.e., the average velocity vector, is within 1% of the value expected on the basis of strict corotation in the inner part of the torus but probably deviates by 5 to 10% from corotation outside the torus. This breakdown from corotation may occur at the outer boundary of the warm torus. The energy per charge spectra show well-resolved peaks in the inner part of the torus but strongly overlapping peaks in the outer part. In the inner torus there is a significant variation in the abundances of different ionic species over spatial scales $< 10^4$ km. However, in the plasma sheet of the middle magnetosphere the ionic composition appears to be uniform from 12 to $42 R_J$ and is strongly dominated by ions with a ratio of atomic mass to charge of 16. These ions are most probably some combination of O^+ and S^{2+} ions. One consequence of the observations is that the Alfven speed is uniformly low in the outer part of the torus, with values less than 250 km s^{-1}.

Barbosa, D. D. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Dissipation and Turbulent Heating of Plasma in Jupiter's Magnetosphere', *Geophys. Res. Lett.* 8, 1111–1114. (1981)

Voyager 1 observations of plasma waves in the dayside Jovian magnetosphere which show a correlation with measurements of localized concentrations of cool thermal plasma are presented. This moderately intense broadband electrostatic noise is shown to be of sufficient intensity to accelerate superthermal ions to energies ~ 1 keV and higher. This process can account for the extensive heating of plasma in the magnetosphere and can energize a fraction of heavy ions to injection threshold for a high-energy second stage acceleration mechanism. A brief discussion of the relation of this noise to Jovian magnetospheric dynamics is included.

Barbosa, D. D. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'On the Injection and Scattering of Protons in Jupiter's Magnetosphere', *J. Geophys. Res.* **86**, 8981–8990. (1981)

We investigate a model by which 10 keV protons accelerated on Jovian auroral field lines are scattered and localized to the magnetic equator. The criterion that the beam density be sufficiently large to generate magnetosonic waves leads to the evaluation of proton beam fluxes consistent with recent Voyager observations of a hot high β plasma sheet in the magnetosphere. A model of the Alfvén speed in the plasma sheet for both inbound and outbound legs of the Voyager 1 encounter is presented. This model confirms Piddington's limit of departure from rigid corotation beyond the point where the rigid body corotation speed euqls the Alfvén speed. Finally, we explore the possibility of nonadiabatic scattering of super-Alfvénic ions by magnetohydrodynamic waves throughout the plasma sheet as a basis for high-energy tail formation of ambient particle distributions.

Barbosa, D. D., Scarf, F. L., Kurth, W. S., and Gurnett, D. A. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Broadband Electrostatic Noise and Field-Aligned Currents in Jupiter's Middle Magnetosphere', *J. Geophys. Res.* **86**, 8357–8369. (1981)

Voyager 1 plasma wave observations have revealed the presence of an impulsive electrostatic emission localized to the Jovian middle magnetosphere $10 < R < 30 R_J$ that appears on the edges of the plasma sheet. This plasma mode has the same spectral and morphological characteristics of an emission that has been extensively studied in the earth's magnetosphere and has been associated with the presence of field-aligned currents. We present the results of a detailed study of the properties of this Jovian emission by using comparisons with terrestrial observations as a basis for mode identification. The occurrence regions of the waves are compared with the measured magnetic field configuration to establish a correspondence with the plasma sheet. We then argue for a quasi-permanent global system of field-aligned currents linking the ionosphere of Jupiter to the middle magnetosphere, which powers energetic plasma heating processes occurring there. On the basis of knowledge of the consequences of field-aligned currents in the terrestrial magnetosphere, we suggest a scenario for acceleration/precipitation of inverted V electrons concomitant aurorae, and energetic (~ 10 keV) proton deposition into the middle magnetosphere resulting from field-aligned potential drops associated with this current system.

Barrow, C. H. (Dasop, Observatore de Meudon, F-92190 Meudon, France): 'Latitudinal Beaming and Local Time Effects in the Decametre-Wave Radiation from Jupiter Observed at the Earth and from Voyager', *Astron. Astrophys.* **101**, 142–149. (1981)

Occurrence probabilities and frequency characteristics of the decametre-wave Jovian sources have been computed from over 20 yr of Earth-based observations. These have been used as a guide for comparing short periods of simultaneous Earth-based observations with the decametric observations made by the Planetary Radio Astronomy experiment on board Voyager-1 during the 30-d periods immediately before and after encounter. The results have been assessed with respect to possible Jovian local time effects and latitudinal beaming. The effects of terrestrial ionospheric absorption have been considered in relation to characteristic decametric source intensities and frequency ranges. It is found that long-term ground-based observations, made from opposite sides of the Earth's orbit, indicate a small but significant reduction in Non-Io A occurrence probability with a constant or slightly increasing Non-Io B occurrence probability corresponding to a change in Jovian local time of about one hour. The effect is enhanced somewhat for years during which the Jovigraphic latitude D_E was positive. Shorter periods of Earth-based observations, adjacent to or overlapping the Voyager-1 encounter, show changes in occurrence probabilites some of which are difficult to reconcile with the Voyager results but cannot be unambiguously regarded as local time effects. Distributions of the frequency extent of the DAM events show that the Non-Io A emission exhibits essentially the same frequency characteristics seen from either Voyager or from the ground. Non-Io B emission, however, shows an intensity effect consistent with the different sensitivities of the receiving systems used on Voyager and on the Earth. Both Voyager and ground-based observations confirm that a linear relation exists between the position, in central meridian longitude (1965.0), of the centre of the Non-Io A source and D_E.

Behannon, K. W., Burlaga, L. F., and Ness, N. F. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'The Jovian Magnetotail and Its Current Sheet', *J. Geophys. Res.* **86**, 8385–8401. (1981)

Analyses of Voyager magnetic field measurements have extended our understanding of the structural and temporal characteristics of Jupiter's magnetic tail. The magnitude of the magnetic field in the lobes of the tail is found to decrease with Jovicentric distance approximately as $r^{-1.4}$, compared with the power law exponent of -1.7 found for the rate of decrease along the Pioneer 10 outbound trajectory. Voyager observations of magnetic field component variations with distance from the magnetic dipole axis are consistent with the variations expected from the geometry of a magnetotail field and hence do not unambiguously support the uniform radial plasma outflow model derived from Pioneer 10 data. Voyager 2 has shown that the azimuthal current sheet which surrounds Jupiter in the inner and middle magnetosphere extends 'tailward' (in the antisun direction) to a distance of at least $100 R_J$. IN the tail this current sheet consists of a plasma sheet and embedded 'neutral' sheet. In the region of the tail where the sheet is observed, the variation of the magnetic field as a result of the sheet structure and its 10 hr periodic motion is the dominant variation seen. Studies of both the large-scale configuration of the current sheet viewed as a surface and of the internal structure of the sheet and its orientation indicate that (1) at distances $\gtrsim 30 R_J$ in the tail the sheet is oriented within $\pm 10°$ of the Jovian equatorial plane, most likely as a result of the solar wind interaction with the Jovian magnetosphere, (2) the surface moves north and south with an amplitude of several R_J with respect to that plane, and (3) at large distances this motion is primarily due to a rocking of the current sheet about the Jupiter-sun line. A mathematical model that takes the tail geometry into account provides a simpler description of sheet motion in the deep tail than do models based on axial symmetry. The plasma sheet in the tail is estimated to have an average thickness of $\leqslant 5 R_J$.

Belcher, J. W., Goertz, C. K., Sullivan, J. D. and Acuna, M. H. (Dept. of Physics and Center for Space Research, MIT, Cambridge, MA 02139): 'Plasma Observations of the Alfvén Wave generated by Io', *J. Geophys. Res.* **86**, 8508–8512. (1981)

The interaction of Io with the magnetosphere of Jupiter has been, and continues to be, a subject of intense interest in space plasma physics. In most description of the Io interaction, the motion of Io through the corotating magnetosphere results in the generation of an Alfvén wave propagating away from Io into the magnetospheric plasma. Voyager 1 measurements of the magnetic field perturbation near the Io flux tube have been interpreted as being due to the presence of a large-amplitude Alfvén wave propagating wouthward along the magnetic field lines from Io. The velocity perturbation δV

associated with this Alfvén wave is related to the field perturbation $\delta\mathbf{B}$ by the usual Alfvénic relation, that is

$$\delta\mathbf{V}/V_A = -\delta\mathbf{B}/B \quad (1)$$

where V_A is the Alfvén velocity, B the magnetic field magnitude, and the minus sign is appropriate for propagation in the direction **B**. We describe below the positive ion measurements obtained near Io by the plasma instrument on board Voyager 1. These measurements are consistent with the flow field predicted by (1) and lend further support to the Alfvén wave interpretation of the Io-associated perturbations.

Birmingham, T. J., Alexander, J. K., Desch, M. D., Hubbard, R. F., and Pedersen, B. M. (Lab. For Extraterrestrial Physics, Goddard Space Flight Center, Greenbelt, MD 20771): 'Observations of Electron Gyroharmonic Waves and the Structure of the Io Torus', *J. Geophys. Res.* **86**, 8497–8507. (1981)

Narrow-banded emissions were observed by the planetary radio astronomy experiment on the Voyager 1 spacecraft as it traversed the Io plasma torus. These waves occur between harmonics of the electron gyrofrequency and are the Jovian analogue of electrostatic emissions observed and theoretically studied for the terrestrial magnetosphere. The observed frequencies always include the component near f_{uhr}, the upper hybrid resonant frequency, but the distribution of the other observed emissions varies in a systematic way with position in the torus. A detailed discussion of the observations is presented. A refined model of the electron density variation, based on identification of the f_{uhr} line, is also included. Spectra of the observed waves are analyzed in terms of the linear instability of an electron distribution function consisting of isotropic cold electrons and hot loss cone electrons. The positioning of the observed auxiliary harmonics with respect to f_{uhr} is shown to be an indicator of the cold to hot temperature ratio T_C/T_H. It is concluded that this ratio increases systematically by an overall factor of perhaps 4 or 5 between the inner ($L \sim 5R_j$) and outer ($L \sim 9R_J$) portions of the torus. Other relevant plasma and spectroscopic data are discussed.

Boischot, A. and Aubier, M.G. (Observatoire de Meudon, 92190 Meudon, France): 'The Jovian Decametric Arcs as an Interference Pattern', *J. Geophys. Res.* **86**, 8561–8563. (1981)

It is proposed that the nested arc structures, observed in the decametric Jovian radio emission by the planetary radio astronomy experiment, are due to the interference of two rays from a single source at each frequency, the relative phase changing with rotation of the planet. This idea can explain at the same time the shape of the arcs and their repetitivity. But the nature of the two interfering rays is not understood yet.

Boischot, A., Lecacheux, A., Kaiser, M. L., Desch, M. D., Alexander, J. K. and Warwick, J. W. (Observatoire de Paris, Meudon, France): 'Radio Jupiter after Voyager: An Overview of the Planetary Radio Astronomy Observations', *J. Geophys. Res.* **86**, 8213–8226. (1981)

We present an overview of Jupiter's low-frequency radio emission morphology as observed by the planetary radio astronomy (PRA) instrument onboard the Voyager spacecraft. The PRA measurement capabilities and limitations are summarized following over two years of experience with the instrument. As a direct consequence of the PRA spacecraft observations, unprecedented in terms of their sensitivity and frequency coverage, at least three previously-unrecognized emission components have been discovered: broadband and narrow-band kilometric emission and the lesser-arc decametric emission. Their properties are reviewed here. In addition, the fundamental structure of the decameter wavelength and hectometer wavelength emission, which is now believed to be almost exclusively in the form of complex but repeating arc structures in the frequency time domain, is described here for the first time. Dramatic changes in the emission morpholog y of some components as a function of the sun-Jupiter-spacecraft angle (local time) are described. Finally, the PRA in situ measurements of the Io plasma torus hot-to-cold electron density and temperature ratios are summarized.

Broadfoot, A. L., Sandel, B. R., Shemansky, D. E., McConnell, J. C., Smith, G. R., Holberg, J. B., Atreya, S. K., Donahue, T. M., Strobel, D. F., and Bertaux, J. L. (Earth and Space Sciences Inst., Univ. of Southern California, Tucson, AZ 85713): 'Overview of the Voyager Ultraviolet Spectrometry Results Through Jupiter Encounter', *J. Geophys. Res.* **86**, 8259–8284. (1981)

The Voyager ultravoilet spectrometers (UVS) have been making almost continuous observations, in the 500 to 1700 Å wavelength range, of sources in the solar system and galaxy since launch in 1977. Due to their sensitivity, stability, and dynamic range, the spectrometers have made a remarkable number of discoveries pertaining to the Jupiter system, the interstellar medium, astronomical, and astrophysical sources. The most surprising general aspect of these results has been the wide variety of emission processes and species which have been observed. On Jupiter's disc, the emissions detected to date are H Lyα, H Lyβ, He (584 Å), and the H_2 Lyman and Werner bands. The atomic emissions are excited by resonance scattering of sunlight, while the H_2 bands appear to be excited by particle precipitation. On the nightside disc, only H Lyα is present. Jupiter's auroral region is clearly delineated by intense emissions of H and H_2 bands on both dayside and nightside of the planet. Emission from He is also present in the auroral regions. At Jupiter, the atmosphere was also probed by means of solar and stellar ocultation experiments. The solar occultation has revealed the distribution of H_2 and H in the upper atmosphere, while the stellar occultation has probed the structure of the upper mesosphere and lower thermosphere. Current analysis indicates an eddy diffusion coefficient $\sim 10^6\,cm^2\,s^{-1}$ with a mesospheric temperature ~ 200 K. The solar occultation analysis suggests an exospheric temperature of 1450 ± 300 K. The thermospheric lapse rate appears to be $\sim 1\,K\,km^{-1}$. The Lyα observations of the disc have revealed a longitudinal asymmetry in H which may reflect longitudinal asymmetries in Jupiter's magnetosphere. Strong EUV emission from a plasma torus at the orbit of Io has been observed in transitions of sulfur and oxygen ions with a possible small contribution from potassium. The effective electron temperature of the dense regions of the plasma is estimated to be 8×10^4 K. No localized EUV emission has been detected from Io, limiting mass loading at Io to $\sim 10^{27}$ ions s^{-1}. The partitioning of ion sub-species shows deviation from pure collisional equilibrium, but preliminary analysis indicates a low diffusive loss rate. The radiative cooling rate of the torus is $\sim 3 \times 10^{12}$ W. The appearance of the entire sky in the outer solar system has been mapped in the emission lines of He (584 Å) and H Lyα (1216 Å) arising from resonant scattering of the solar lines by neutral interstellar hydrogen and helium entering the solar system. Diffuse galactic EUV emission has been measured in a number of selected directions. Stellar photospheric emissions shortward of the Lyman limit of atomic hydrogen at 912 Å have been measured. Finally, spectral images, in several emission lines, have been obtained of the Cygnus Loop supernova remnant. Sections of this article review the progress in the study of these subjects and the relationships of the EUV results to the other Voyager experiments. We include a discussion of the characteristics of the instrument and the methods of spectral analysis to verify the integrity of the reported results.

Brown, R. A. and Ip, W.-H. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Atomic Clouds as Distributed Sources for the Io Plasma Torus', *Science* **213**, 1493–1495. (1981)

Several recent developments have implications for the neutral particle environment of Jupiter. Very hot sulfur ions have been detected in the Io torus with gyrospeeds comparable to the corotation speed, a phenomenon that would result from a neutral sulfur cloud. Current evidence supports the hypothesis that extensive neutral clouds of oxygen and sulfur exist in the Jupiter magnetosphere and that they are important sources of ions and energy for the Io torus.

Carbary, J. F., Krimigis, S. M., Keath, E. P., Gloeckler, G., Axford, W. I., and Armstrong, T. P. (Applied Physics Lab., Johns Hopkins Univ., Laurel, MD 20810): 'Ion Anisotropies in the Outer Jovian Magnetosphere', *J. Geophys. Res.* **86**, 8285–8299. (1981)

We present results from the Voyager 1 and 2 low-energy charged particle measurements of ion anisotropies in the outer Jovian magnetosphere ($R \gtrsim 20\,R_J$). These anisotropies represent the first observed from an instrument rotating in the spin plane of Jupiter. For the several ion species investigaed the first-order anisotropies are all strongly in the corotational sense throughout most of the Jovian magnetosphere and out to the magnetopause on the dayside. There is some evidence for a small component of outward flow in the corotating region. Beyond ~ 130–150 R_J along the Voyager outbound trajectories the anisotropies indicate a magnetospheric wind flowing outward from Jupiter. The change from corotational to tailward flow on the nightside occurs well inside the magnetopause. The anisotropy amplitudes increase linearly with radial distance and, in the disc regions, decrease with distance from the magnetodisc mid-plane. In one case examined in detail using separately identified H, He, and O/S ions the convection speed at 58 R_J is found to agree with the cororotation speed (ΩR) to within ~ 3%. A linear Compton-Getting analysis reveals that the convective speeds in the dayside magnetosphere are in agreement with rigid corotation whenever the plasma flow direction is approximately in the corotation sense, while at other times the convection speeds are substantially less than corotation.

Cess, R. D., Carlson, B. E., Caldwell, J., Nolt, I. G., Gillett, F. C., and Tokunaga, A. T. (Lab. for Planetary Atmospheres Research, State Univ. of New York, Stony Brook NY 11794): 'Latitudinal Variations in Jovian Stratospheric Temperature', *Icarus* **46**, 249–255. (1981)

Ground-based observations of Jupiter show that the planet's stratospheric and tropospheric thermal emission are anticorrelated. The observations can possibly be explained by latitudinal variations in cloud altitude. These variations cause differential stratospheric heating by sunlight which is reflected off the clouds and then absorbed within the stratosphere by visible and near-infrared bands of methane.

Chen, R. H. (Center for Radar Astronomy, Stanford Univ., Stanford, CA 94305): 'Studies of Jupiter's Lower Ionospheric Layers', *J. Geophys. Res.* **86**, 7792–7794. (1981)

Theoretical calculations are made of the fluxes of heavy ions necessary to form the layers of enhanced ionization observed in the lower ionosphere of Jupiter. The results show that if the layers are formed from sodium or sulfur ions of Galilean satellite origin injected into the Jovian atmosphere then, in order to match the Pioneer 10 observations of the L_6 layer, the Na^+ flux must be about 3×10^4 cm^2 s^{-1} and the S^+ flux must be about 4×10^3 cm^{-2} s^{-1}. From the shape of the ionization layers estimates of ion drift velocities and neutral wind speeds may be made. The vertical ion drift velocities range from a few centimeters per second to meters per second while the zonal wind shear ranges from 50 m s^{-1} westward to 200 m s^{-1} eastward over a 70 km altitude range and small (centimeters per second) meridional winds are sufficient to form the layers.

Clancy, R. T. and Danielson, G. E. (California Ints. of Tech., Div. of Geophysical and Planetary Sciences, Pasadena, CA 91125): 'High Resolution Albedo Measurements on Io from Voyager 1', *J. Geophys. Res.* **86**, 8627–8634. (1981)

The photometric properties of the surface of Io were investigated at high spatial resolution by a choice of 220 sample regions from the four-color, 8 km/line pair resolution photomosaic of Io taken by Voyager 1. The mosaic longitudinal coverage extends from ~ 200 to 350°W (phase angle ~ 10.5°). The regions were categorized on the basis of their visual color in the color print. Categories include: white, yellow, orange, red, brown (polar), and black regions. The photometrically corrected data were plotted as a function of intensity versus photometric angles for each of the color regions in all four filters (orange, blue, violet, UV) using a Minnaert function. The plots of these color regions show large scatter about the least squares fitted lines. The large scatter, particularly for the darker regions, indicates a continuous distribution of albedos on Io and gives evidence of compositional mixing. In all cases, limb-darkening coefficients with useful error bounds (e.g., error < 0.2) are found only for the white ($k = 0.6 \pm 0.1$) and brown ($k = 0.8 \pm 01.$) regions. The larger coefficient found for the brown regions is biased upward due to polar darkening. Computed values of the limb darkening do not change significantly among filters. Color ratio plots of the reflectances for each of the regions were constructed (UV/blue and violet/blue versus orange/blue). The distributions of ratios of the various color regions are compared to laboratory measurements of solid SO_2 (Nash *et al.*, 1988) and various allotropes of sulfur (from J. Veverka and J. Gradie, unpublished data, 1979). These comparisons indicate that SO_2 is the major component (photometrically) of the 'white' regions. Red and white sulfur are seen as variable components of these regions. Color ratios of 'brown' regions suggest a mixture of white and red sulfur. A significant portion of the 'brown' regions have color ratios near those of pure white sulfur. A component of SO_2 is found for all 'brown' regions and appears to be latitude dependent. Red regions appear well described by a mixture of red and orange sulfur.

Clarke, J. T., Moos, H. W., and Feldman, P. D. (Dept. of Physics, Johns Hopkins Univ., Baltimore, MD 21218): 'IUE Monitoring of the Spatial Distribution of the Lyman-Alpha Emission from Jupiter', *Astrophys. J.* **245**,L127–L129. (1981)

North-south spatial maps of the Jovian H Lyα emission observed with the *IUE* satellite support the identification of a marked longitudinal asymmetry in the equatorial brightness, with the peak around $\lambda_{III}(1965) = 50$–$100°$ longitude, and show a weaker planet-wide equatorial brightening above the level predicted by a plane-parallel layer model. IUE observations made 18 months after the initial discovery of the localized emission bulge establish that it is fixed with respect to Jupiter's magnetic longitude (λ_{III} system) and not with respect to atmospheric longitude (λ_{II} system). In addition, a decrease in brightness of $\sim 20\%$ in the region of the emission bulge has been observed over a 1 yr interval, while the rest of the planet remained roughly constant in brightness. This decrease is more than would be expected as a result of changes in the incident solar Lyα flux, indicating a real decrease in reflectivity in this region of Jupiter's upper atmosphere.

Cochran, A. L., Trafton, L., Cochran, W. D., and Barker, E. S. (McDonald Observatory and Astronomy Dept., Univ. of Texas at Austin, Austin, TX 78712): 'Spectrometry of Jupiter at Selected Locations on the Disk During the 1979 Apparition', *Astron. J.* **86**, 1101–1107. (1981)

We measured Jupiter's reflectivity as a function of wavelength between 3000 and 10 500 Å on 26 February and 1 March, 1979 in order to permit a calibration of the Voyager images and to establish differences from previous apparitions. The observations were tkaen in the prominent belts and zones and both polar caps along the central meridian using a slit of dimensions 2.33×2.5 arc sec^2. We measured the equivalent widths of the 6190- and 7270 Å CH_4 bands and found significantly less CH_4 absorption in the north tropical zone than occurred during the 1976 apparition.

Cochran, W. D., Trafton, L., Macy, W. Jr., and Woodman, J. H. (McDonald Observatory, Univ. of Texas at Austin, Austin, TX 78712): 'Raman Scattering in the Jovian atmosphere', *Astrophys. J.* **247**, 734–740. (1981)

Raman scattering by H_2 in the atmosphere of Jupiter is detected by a correlation technique using high-resolution spectra of Jupiter with high signal-to-noise ratio in the 3800–5000 Å region. The pure rotational H_2 $S(0)$ and $S(1)$ lines are detected. The ratio of the relative number of Raman scattered photons in the $S(0)$ and $S(1)$ features indicate that the H_2 in the Jovian atmosphere is in the equilibrium; rather than the normal state. Therefore some sort of nonradiative process is responsible for transitions between the ortho and para states of H_2.

Collins, S. A. (Jet Propulsion Lab., California Inst. of Tech., Passadena, CA 91103): 'Spatial Color Variations in the Volcanic Plume at Loki, on Io', *J. Geophys. Res.* **86**, 8621–8626. (1981)

Multicolor Voyager 1 photographs of the Loki volcanic plume, on Io, have been analyzed to determine the nature and quantity fo the scattering material within the plume. This work indicates that there are two particle populations. The first population consists of particles with radius of 0.001–0.01 μm, while the second population, which is concentrated near the source, comprises particles with radius greater than 1 μm. The population of smaller particles includes most of the particulate mass in the plume. This work increases the previously estimated particulate mass (Johnson *et al.*, 1979) and suggests that the SO_2 gas spectroscopically identified by Pearl *et al.* (1979) may represent transient flow from the volcano instead of an atmosphere in stable equilibrium with the local surface.

Connerney, J. E. P., Acuna, M. H., and Ness, N. F. (Lab. for Extraterrestrial Physics, NASA-Goddard Space FLight Center, Greenbelt, MD 20771): 'Modeling the Jovian Current Sheet and Inner Magnetosphere', *J. Geophys. Res.* **86**, 8370–8384. (1981)

Voyager 1 and 2 magnetic field observations confirm and extend the earlier Pioneer 10 detection of the Jovian magnetodisc, a region of enhanced charged particles and plasma and reduced magnetic field intensity located near the magnetic equatorial plane. Modeling of the azimuthal current sheet by a finite thickness annulus of inner radius $5R_J$, $5\text{-}R_J$ thickness, and extending to $\sim 50R_J$ provides detailed fits of the vector magnetic field perturbations observed in relation to the planetary field for distances less than $30R_J$. Field line geometry is also investigated, and better insight into the phenomena of charged particle absorption by the Galilean satellites is obtained which provides improved explanations of observed effects due to Ganymede.

Connerney, J. E. P. (Planetary Magnetospheres Branch, Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'The Magnetic Field of Jupiter: A Generalized Inverse Approach', *J. Geophys. Res.* **86**, 7679–7693. (1981)

The estimation of planetary magnetic fields from observations of the magnetic field gathered along a spacecraft flyby trajectory is examined with the aid of generalized inverse techniques, with application to the internal magnetic field of Jupiter. Model non-uniqueness resulting from the limited spatial extent of the observations and noise on the data is explored and quantitative estimates of the model parameter resolution are found. The presence of a substantial magnetic field of external origin due to the currents flowing in the Jovian magnetodisc is found to be an important source of error in estimates of the internal Jovian field, and new models explicitly incorporating these currents are proposed. New internal field models are derived using the vector helium magnetometer observations and the high field fluxgate observations of Pioneer 11, and knowledge of the external current system gained from the Pioneer 10 and Voyagers 1 and 2 encounters.

Connerney, J. E. P. (Lab. for Extraterrestrial Physics, Planetary Magnetospheres Branch, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Comment on "Azimuthal Magnetic Field at Jupiter"; and Reply by M. F. Thomsen and C. K. Goertz., *J. Geophys. Res.* **86**, 7796–7797. (1981)

Conrath, B. J., Flasar, F. M., Pirraglia, J., Gierasch, P. J., and Hunt, G. E. (Goddard Space Flight Center, Greenbelt, MD 20771): 'Thermal Structure and Dynamics of the Jovian Atmosphere 2. Visible Cloud Features', *J. Geophys. Res.* **86**, 8769–8775. (1981)

Investigation of the thermal structure above selected cloud features in the Jovian atmosphere, making use of Voyager IRIS data, reveals strong similarities among a broad range of features which differ considerably in visual appearance. The atmosphere above anticyclonic features, including the major white ovals, the Great Red Spot, and a zone, are cold relative to the immediate surroundings in the upper troposphere and tropopause region. These results are consistent with upwelling and divergence in this part of the atmosphere. In contrast, a 'hot spot' and a 'barge', which are localized cyclonic features, are found to be warm relative to their surrounding, implying subsidence with accompanying convergence. In all cases, the thermal wind shear associated with the features indicates a decay of the vorticity with height in the upper troposphere and lower stratosphere. Vertical velocities inferred from the observed temperature perturbations imply an upper limit of vertical mixing times near the tropopause of ~ 20 yr. Temperatures in the upper stratosphere above the anticyclonic features show considerable variation, but in most cases are found to be relatively warm. At the present time, no satisfactory explanation for this behaviour appears to exist.

Consolmagno, G. J. (Dept. of Earth and Planetary Sciences, MIT, Cambridge, MA 01239): 'Io: Thermal Models and Chemical Evolution', *Icarus* **47**, 36–45. (1981)

A combined thermal and chemical evolution model of Io is presented, outlining limits on the possible starting materials, heating history, chemical history, and present state of Io. Our best scenario starts with Io being accreted from material in a proto-Jovian nebula which condensed between 400–600 K. Radionuclides and tidal heating would lead to large-scale convection within Io and chemical reactions leading to the outgassing of water and methane. Reactions between Fe^0–FeS and water, at least near the surface, go to completion, resulting in all Fe being oxidized with elemental sulfur producing a low-conductivity crust. In the deep interior, these reactions may not completely exhaust Fe metal, and an FeS-rich core may be formed.

Cook, A. F., Danielson, G. E., Jewitt, D. C., and Owen, T. (Herzberg Inst. of Astrophysics, National Research Council, Ottawa, Canada, K1A OR6): 'Dust Observations in the Jovian System', *Advances in Space Res.* **1**, 99–101. (1981)

Two observations of dust in the Jovian system have been made from the two Voyager spacecraft. Jewitt and Danielson report observations of dust enveloping the newly discovered Ring of Jupiter. This dust manifests itself in three ways.

Firstly, a halo is seen above and below the Ring and also extending a short distance outside the ansae. Isophotes of the halo are much less flattened than those of the Ring itself.

Secondly, the far arm of the narrow bright ring within the Ring is always brighter than the near arm at any given phase angle. Jewitt and Danielson interpret this observation as being caused by scattered light from the dust distributed above and below the plane of the Ring. This effect is due to the greater optical thickness of the halo encountered on the far side.

Thirdly, the shadow of the planet appears as a brightness discontinuity intersecting the narrow bright ring parallel to the limb and approximately normal to the plane of the Ring. We interpret this as probably due to a concentration of dust outside the discontinuity. We shall return to this matter below.

The other observation is of the UV halo about Plume 2 on Io also called Loki by the Working Group for Planetary System Nomenclature. This halo extends to great height fading out gently against the background and exhibits Rayleigh scattering from particles. Johnson *et al.* have proposed that these particles and others like them are charged to about -10 volts by the Jovian plasma and then swept off by the Lorentz force associated with the relative motion of Io in the Jovian magnetosphere. They propose that this dust interacts with the Jovian Ring to produce the cloud of dust enveloping the Ring.

In this discussion we do not regard the particles in the plane of Jupiter's Ring as dust although their characteristic radius is only 5 μm. The dust particles discussed here are approximately an order of magnitude smaller.

Cook, A. F. and Duxbury, T. C. (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138): 'A Fireball in Jupiter's Atmosphere', *J. Geophys. Res.* **86**, 8815–8817. (1981)

One fireball was photographed during two encounters with Jupiter. Its total luminosity was 1.2×10^5 0 mag s (at standard range 100 km). If we employ the luminous efficiency proposed by Cook *et al.* (1981) for slip flow of a meteroid in its own vapors we obtain an estimated mass of 11 kg. A rough absolute magnitude is -12.5. If we note that we searched for a total of 223 s during two exposures, we estimate a number density near Jupiter of 7×10^{-28} cm^{-3} for masses of meterioids of 3 kg and greater. This value is about a factor of 6 smaller than a rough upper limit reached from an extrapolation from terrestrial observations of meteors and comets.

Cook, A. K., Jones, A. V., and Shemansky, D. E. (Herzburg Inst. of Astrophysics, National Research Council of Canada, Ottawa, Ontario, Canada K1A OR6): 'Visible Aurora in Jupiter's Atmosphere?', *J. Geophys. Res.* **86**, 8793–8796. (1981)

The darkside limb pictures obtained by the imaging experiment on Voyager 1 have been reexamined. It is concluded that the observed luminosity is very likely due at least in part to Io torus aurora. If the effective wavelength of the emission lies in the 4000 to 500 Å region, the slant intensity is estimated to be about 20 kR. The observed double structure may be due to a number of cuases such as horizontal structure in auroral emission, aurora plus twilight or photochemical airglow plus aurora.

Danielson, G. E., Kupferman, P. N., Johnson, T. V., and Soderblom, L. A. (Div. of Geological and Planetary Sciences, California Inst. of Tech., Pasadena, CA 91125): 'Radiometric Performance of the Voyager Cameras', *J. Geophys. Res.* **86**, 8638–8689. (1981)

The Voyager Imaging Experiment provided high-quality data of Jupiter and the Galilean satellites with the two flyby tradjectories in March and July of 1979. Moderately accurate radio-metric measurements have been made using these data. This paper evaluates the radiometric results and describes the inflight and ground geometric and radiometric correction factors. The radiometric quantities of intensity I and geometric albedo I/F are derived, and scaling factors for each of the filters are tabulated for correcting the 'calibrated' data from the Image Processing Laboratory at JPL. In addition, the key characteristics of both Voyager 1 and Voyager 2 cameras are tabulated.

Davies, J. K.: 'A Brief History of the Voyager Project – Part 4', *Spaceflight* **23**, 208–211. (1981)

After launch on 31 August, 1977 Voyager 1 flew through the Jovian system in March 1979. During the encounter over 15 000 photographs and a wealth of other scientific results were returned to the scientists on Earth. Voyager 2, launched earlier, but flying a slower trajectory, was due to arrive at the planet on 9 July, 1979 some four months behind its twin.

Davies, M. E. and Katayama, F. Y. (The Rand Corp., Santa Monica, CA 90406): 'Coordinates of Features on the Galilean Satellites', *J. Geophys. Res.* **86**, 8635–8657. (1981)

Control nets of the four Galilean satellites have been established photogrammetrically from pictures taken by the two Voyager spacecraft during their flybys of Jupiter in 1979. Coordinates of 504 points on Io, 112 points on Europa, 1547 points on Ganymede, and 439 points on Callisto are listed. Selected points are identified on U.S. Geological Survey maps of the satellites. Measurements of these points were made on 234 pictures of Io, 115 pictures of Eurpoa, 282 pictures of Ganymede, and 200 pictures of Callisto. The systems of longitude were defined by craters on Europa, Ganymede, and Callisto. Preliminary solutions have been found for the directions of the axes of rotation of the Galilean satellites. New mean radii have been determined as 1815 ± 5 km for Io, 1569 ± 10 km for Eurpoa, 2631 ± 10 km for Ganymede, and 2400 ± 10 km for Callisto.

Debehogne, H. and MacHadd, L. E. (Observatoire Royal de Belgique, Avenue Circulaire 3, B 1180 Bruxelles, Belgium): 'Jupiter and Galilean Satellites' positions Obtained in December 1978 at Uccle with the Double Astrograph of 40 cm ($f = 2$ m)', *Astron. Astrophys. Suppl.* **45**, 183–185. (1981)

In December 1978, we observed Jupiter and the Galilean Satellites at the Double Astrograph ($f = 2$m, $D = 40$ cm) of Uccle.

Measures and reductions were performed at the Royal Observatory of Belgium with the Ascorecord measuring machine ($0.1\,\mu$) and by means of five reference stars on the computer Burrough at the Universidade Federal do Rio de Janeiro. The SAO Catalogue, the Least Squares and Dependences Methods were used.

Decker, R. B., Pesses, M. E., and Krimigis, S. M. (Applied Physics Lab., Johns Hopkins Univ., Laurel, MD 20810): 'Shock-Associated Low-Energy Ion Enhancements Observed by Voyagers 1 and 2', *J. Geophys. Res.* **86**, 8819–8831. (1981)

Observations of shock-associated $\geqslant 30$ keV ion enhancements are presented using data from the Low Energy Charged Particle (LECP) experiments on Voyagers 1 and 2, launched on days 248 and 232, 1977, respectively. The observations include examples of energetic storm particle (ESP) events associated with flare-produced shocks and examples of corotating particle events (CPE) associated with forward and reverse shocks that bound corotating interaction regions in the outer heliosphere. The first well-defined CPE are not seen at Voyagers 1 and 2 until late in 1978 when each spacecraft was at a heliocentric radial distance of ~4 AU. Thus far, seven CPE have been identified in the Voyager 1 LECP data from launch through day 170, 1979. Most of these CPE show features similar to many of those observed at Pioneers 10 and 11, e.g., they have recurrent double-peaked intensity enhancements showing little or no velocity dispersion at peak intensities, time durations of several days, soft ($\gamma \gtrsim 4$ for protons ~1 MeV) energy spectra extending up to ~5 MeV/nucleon and p/α ratios that are lowest at the reverse peaks. The new LECP measurements also show for the first time that the CPE ion spectra extend, with no sign of a low-energy turnover, to energies as low as 30 keV/ion. If the CPE are produced by shock acceleration of an ambient particle source, the fact that the observed CPE exhibit well-formed high intensity peaks at 30 keV/ion means that the pre-acceleration energy of the source particles was < 30 keV/ion. In several of the shock events, the lowest energy ion enhancements are confined mainly downstream of the CIR shocks, with the magnitude and duration of the upstream enhancements increasing with increasing ion energy. The similarities in the low energy ion morphologies observed near the shock during an ESP event and a CPE suggest that the same shock acceleration mechanism and propagation processes were operative in each case. These observations are consistent with the dynamical and kinematical effects expected when low energy ions are accelerated at quasi-perpendicular shocks.

Eviator, A., Siscoe, G. L., Johnson, T. T. and Matson, D. L. (Dept. of Atmospheric Sciences, Univ. of California, Los Angeles, CA 90024): 'Effects of Io Ejecta on Europa', *Icarus* **47**, 75–83. (1981)

We examine the effects of Io ejecta on the surface and environment of Europa. We find that the observed sulfur on the trailing side of Europa, when interpreted as a deposit in equilibrium between implantation of, and sputtering by, corotating Io ejecta, implies a slow loss of material from Europa by sputtering. From this we infer that the spectrum of particles sputtered from water ice is soft. The quantity of observed sulfur and its confinement to the trailing hemisphere appear to exclude significant implantation and sputtering by energetic heavy ions. We also conclude that the contribution from Europa to the magnetospheric plasma (even at Europa itself) is negligible compared to the matter ejected from Io.

Ferrini, F., Milani, A., and Nobili, A. M. (Istituto di Fisica, Universita di Pisa, Pisa, Italy): 'On the shape of Amalthea', *Advances in Space Res.* **1**, 191–197. (1981)

Voyager's photographs show a highly prolated and asymmetrical Amalthea. We tried to fit these data into the equations for an approximately equipotential surface and conclude that its density must be 1.8 g cm^{-3} if it is formed on a synchronous orbit around Jupiter.

Festou, M. C., Atreya, S. K., Donahue, T. M., Sandel, B. R., Shemansky, D. E., and Broadfoot, A. L., (Space Physics Research Lab., Dept. of Atmospheric and Oceanic Science, Univ. of Michigan, Ann Arbor, MI 48109): 'Composition and Thermal Profiles of the Jovian Upper Atmposhere Determined by the Voyager Ultraviolet Stellar Occultation Experiment', *J. Geophys. Res.* **86**, 5715–5725. (1981)

Occultation of the star Regulus–α Leo–by the Jovian atmosphere was monitored by the Voyager 2 spacecraft on July 9, 1979. The absorption recorded in the 910–1200 Å range was caused primarily by the H_2-Lyman and Werner bands. These data provide the first complete measurements of atmospheric density and temperature profiles between 330 and 830 km above the ammonia cloud tops. The molecular hydrogen density at 380 km is found to be $3^{+4}_{-1} \times 10^{13}$ cm^{-3}, where the atmospheric temperature is 200 ± 50 K. The thermal gradient above 830 km altitude is found to be approximately 1 K km^{-1} to reconcile the stellar occultation data with the Voyager 1 solar occultation data for the exosphere. Both experiments were performed in the equatorial region. The observed temperature gradient in the upper atmosphere rules out inertia gravity wave propagation as the primary heating mechanism; the heating must be caused by one or many of a host of other potential sources such as magnetospheric electrons (soft or hard), Joule heating and even solar extreme ultraviolet radiation. The data do not prsent a strong argument in favor of an earthlike mesopause on Jupiter. The absorption in the 1250–1600 Å range yields volume mixing ratios of methane and ethane of $2.5^{+3}_{-2} \times 10^{-5}$ and $2.5^{+2.0}_{-1.5} \times 10^{-6}$, respectively, at a height of 325 km above the ammonia cloud tops. An upper limit of 2.5×10^{-6} for the mixing ratios of acetylene has been found at the altitude of 300 km. The Voyager infrared data yield mixing ratios of these hydrocarbons deeper in the stratosphere. A study of the density profiles of the hydrocarbons deduced from the stellar occultation data yields a value of the eddy diffusion coefficient at the homopause to be $1.4^{+0.8}_{-0.7} \times 10^6$ $cm^2\,s^{-1}$ in the equatorial region which is consistent with the value deduced from the hydrogen Lyman alpha and helium 584 Å emission data.

Flasar, F. M., Conrath, B. J., Pirraglia, J., Clark, P. C., French, R. G., and Gierasch, P. J., (NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Thermal Structure and Dynamics of the Jovian Atmsophere 1. The Great Red Spot', *J. Geophys. Res.* **86**, 8759–8767. (1981)

Temperatures and thermal winds over the Great Red Spot (GRS) and its environs are derived from Voyager infrared spectroscopy (IRIS) data. The atmosphere over the GRS is characterized by a tropopause which is cold relative to its environment and an upper stratosphere which is relatively warm. The cold tropopause implies a decrease in anticyclonic vorticity with height above 500 mbar through the lower stratosphere. IRIS observations at 5 μm indicate little emission from the GRS itself, but enhanced emission in a ring about it, in agreement with recent ground-based results. The behavior of the tropopause and 5 μm temperatures can be consistently interpreted as resulting from a circulation which rises within the GRS and subsides in the area around it. The explanation of the upper stratospheric temperatures is not so straightforward. A previous suggestion that they may be a manifestation of the linear vertical propagation of Rossby waves appears inconsistent with the gross east-west symmetry in the stratospheric temperatures over the GRS. The implications of the present results for various theoretical modesl of the GRS are examined, and the possibility that latent heat release drives the GRS is discussed. Dynamical scalings based on an axisymmetric, frictionally controlled vortex suggest that, aside from the nonlinearities inherent in the parameterization of small-scale moist convection, the large-scale dynamics of the GRS are linear, as distinct from those of a tropical cyclone, which are markedly nonlinear.

Gautier, D., Conrath, B., Flasar, M., Hanel, R., Kunde, V., Chedin, A., and Scott, N. (Observatoire de Paris, 92190 Meudon, France): 'The Helium Abundance of Jupiter from Voyager', *J. Geophys. Res.* **86**, 8713–8720. (1981)

The helium abundance in the Jovian atmosphere is derived from Voyager 1 data by two methods. The first method uses only infrared spectra from selected locations on the planet while the second method uses a thermal profile independently derived from radio occultation measurements and infrared spectra recorded near the occultation point. A hydrogen mole fraction of 0.897 ± 0.030 is obtained from the first method, while the second method gives 0.880 ± 0.036, corresponding to helium mass fractions of 0.19 ± 0.05 and 0.21 ± 0.06, respectively. The estimated errors for the first method are primarily due to systematic uncertainties in the H_2 and He absorption coefficients, while those for the second method result mainly from errors in the radio occultation profile and are less well known. Random errors in the measured infrared spectra are found to be negligible in both cases. The results are consistent with a uniform mix of hydrogen and helium within Jupiter's interior, but a modest amount of helium depletion ($\Delta Y \leqslant 0.05$) cannot be excluded.

Gehrels, N., Stone, E. C., and Trainor, J. H. (California Inst. of Tech., Pasadena, CA 91125): 'Energetic Oxygen and Sulfur in the Jovian Magnetosphere', *J. Geophys. Res.* **86**, 9906–8919. (1981)

This paper reports measurements made by the cosmic ray subsystem onboard Voyager 1 and 2 in the Jovian magnetosphere. Energy spectra of oxygen ions in the energy range 1–20 MeV/nuc between 5 and $20 R_J$ are presented and used to calculate phase space densities. There is a steep positive radial gradient in the phase space density of the energetic oxygen ions in this region, indicating an inward diffusive flow. Solutions of the diffusion equation assuming a diffusion coefficient D and loss lifetime τ of the forms $D = D_0 L^n$ and $\tau = \tau_0 L^m$, where D_0, τ_0, n, and m are constants, and L is the McIlwain parameter, are fit to the radial phase space density profiel of oxygen ions with magnetic moments of 680 MeV/nug-G. The best fits are found to have $n + m \approx 6$ and $3 < n < 6$. on the basis of the diffusion coefficient upper limit obtained from these fits, the upper limit on the rate at which oxygen ions with >400 MeV/nuc-G diffuse inward across $10 R_J$ is $5 \times 10^{21 \pm 1}$ ions s^{-1}. The observations suggest that oxygen and sulfur ions in the Io plasma torus diffuse radially outward, are nonadiabatically accelerated in some region outside $17 R_J$ and then diffuse inward and outward from the acceleration region.

Genova, F. and Boischot, A. (Dasop, Observatoire de Meudon, 92190 Meudon, France): 'Structure of the Source of Jovian Decametric Emission and Interplanetary Scintillation', *Nature* **293**, 382–383. (1981)

Since its discovery in 1955, Jupiter decametric emission has been extensively studied with ground-based instruments, and more recently by planetary radiostronomy experiment on board the Voyager spacecraft. However, we are still far from understanding the origin of the emission, mainly because we have no direct information about the position and structure of the source, due to the low spatial resolution of instruments at those wavelengths. Previous theories have assumed that the source emission takes place along magnetic field lines, close to the local gyrofrequency. We propose here a method to test this hypothesis by studying interplanetary scintillations which modulate the emission when received on Earth, and quantify the predicted effects. Preliminary results indicate that the emission is probably spatially distributed and could occur along field lines, and that Io controlled A and B sources are on opposite sides of Jupiter.

Genova, F. and Leblanc, Y. (Observatoire de Paris, Section D'Astrophysique de Meudon, F-92190 Meudon, France): 'Interplanetary Scintillation and Jovian Dam Emission', *Astron. Astrophys.* **98**, 133–139. (1981)

The influence of interplanetary scintillations (IPS) on Jovian decametric (DAM) emission (10–40 MHz) is studied on broad-band dynamic spectra, for the whole range of solar elongations. We confirm that L-bursts are the result of IPS, and moreover, we show that they are broad-band bursts. This implies that IPS are correlated on our whole frequency range of observation. It is concluded from observations at conjunction that the intrinsic time scale of Jovian emission is either some milliseconds (S-bursts) or some minutes (arcs). On the other hand, when the elongation is about 130° – East, a clear decrease in scintillation appears, which has already been observed by Erskine. We show that this is a permanent feature of IPS. It could interpreted as an effect of the interplanetary magnetic field on IPS.

Goertz, C. K. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'THe Orientation and motion of the Predawn Current Sheet and Jupiter's Magnetotail', *J. Geophys. Res.* **96**, 8429–8434. (1981)

From the observed times when Pioneer 10 and Voyager 1 observe particle flux maxima and minima and when the magnetic field strength is a minimum we derive a geometric description of the current sheet in Juipter's magnetosphere. It laggs the planetary rotation by an angle δ which varies as a function of radial distance as $\delta = 22^\circ + 0.80\ (r - 16.3)$. The maximum latitude of the current sheet is roughly 10° inside of $60R_J$ and decreases beyond. Thus there is a hinge point near $60R_J$. The position of the hinge point moves in response to the external solar wind pressure variation. We discuss the variation of $\delta\,(r)$ theoretically and show how it is related to the magnetic field topology and plasma flow. We conclude that the distant field lines do not corotate with Jupiter and that the Alfven speed at $50R_J$ is of the order of $1500\,\mathrm{km\,m^{-1}}$. The topology of the current sheet is affected by centrifugal forces, outward mass transport and solar wind–magnetosphere interaction. We show how these effects can be related to different current systems.

Goldstein, M. L. and Thieman, J. R. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'The Formation of Arcs in the Dynamic Spectra of Jovian Decameter Bursts', *J. Geophys. Res.* **86**, 8569–8578. (1981)

A model is presented that can account for several features of the dynamic spectral arcs observed at decameter wavelengths by the planetary radio astronomy experiment on Voyagers 1 and 2. We first show that refraction of an extraordinary mode wave inditially exctied nearly orthogonal to the local magnetic field is significantly influenced by the local plasma density, being greater the higher the density. We assume that the source of the decameter radiation lies along the $L = 6$ flux tube and that the highest frequencies are produced at the lowest altitudes, where both the plasma density and magnetic field gradients are largest. We further assume that the decameter radiation is emitted into a thin conical sheet, consistent with both observation and theory. In the model the emission cone angle of the sheet is chosen to vary with frequency so that it is relatively small at both high and low frequencies, but approximately 80° at intermediate frequencies. The resulting emission pattern as seen by a distant observer is shwon to resemble the observed arc pattern. The model is compared and contrasted with examples of Voyager radio data.

Gurnett, D. A., Maggs, J. E., Gallagher, D. L., Kurth, W. S., and Scarf, F. L. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Parametric Interaction and Spatial Collapse of Beam-Driven Langmuir Waves in the Solar Wind', *J. Geophys. Res.* **86**, 8833–8841. (1981)

This paper presents observations of the parametric decay and spatial collapse of Langmuir waves driven by an electron beam streaming into the solar wind from the Jovian bow shock. High-resolution frequency-time spectrograms from Voyager 1 and 2 show that long wavelength Langmuir waves upstream of the bow shock are very effectively converted into short wavelength Langmuir waves which are no longer in resonance with the beam. This conversion is shown to be the result of a nonlinear interaction involving the beam-driven pump, a sideband emission and a low level of ion-acoustic turbulence which always appears to be present in the solar wind. The onset of the interaction occurs at about the time that the amplitude of the pump wave saturates, which indicates that parametric processes are probably playing an important role in stabilizing the electron beam. Detailed examination of the electric field waveforms shows that the beam-driven Langmuir wave emission breaks up into a very complex sideband structure with both positive and negative Doppler shifts. Positive frequency shifts correspond to waves propagating away fron the sun and negative frequency shifts correspond to waves propagating towards the sun. In some cases the sideband emissions consist of isolated wave packets with very short durations, sometimes lasting only a few msec. These short duration bursts, which are usually very intense, are thought to consist of envelope solitons which have collapsed down to spatial scales of only a few Debye lengths.

Gurnett, D. A., Scarf, F. L., Kurth, W. S., Shaw, R. R., and Poynter, R. L. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Determination of Jupiter's Electron Density Profile from Plasma Wave Observations', *J. Geophys. Res.* **86**, 8199–8212. (1981)

This paper summarizes the electron density measurements obtained in the Jovian magnetosphere from the plasma wave instruments on the Voyager 1 and 2 spacecraft. Three basic techniques are discussed for determining the electron density: (1) local measurements from the low-frequency cutoff of continuum radiation, (2) local measurements from the frequency of upper hybrid resonance emissions, and (3) integral measurements from the dispersion of whistlers. The limitations and advantages of each technique are critically reviewed. In all cases the electron densities are unaffected by spacecraft charging or sheath effects, which makes these measurements of particular importance for verifying in situ plasma and low-energy charged particle measurements. In the outer regions of the dayside magnetosphere, beyond about $40R_J$, the electron densities range from about 3×10^{-3} to $3 \times 10^{-2}\,cm^{-3}$. On Voyager 2, several brief excursions apparently occurred into the low-density region north of the plasma sheet with densities less than $10^{-3}\,cm^{-3}$. Approaching the planet the electron density gradually increases, with the plasma frequency extending above the frequency range of the plasma wave instrument (56 kHz, or about 38 electrons cm^{-3}) inside of about $8R_J$. Within the high-density region of the Io plasma torus, whistlers provide measurements of the north-south scale height of the plasma torus, with scale heights ranging from about 0.0 to $2.5R_J$.

Hamilton, D. C., Gloeckler, G., Krimigis, S. M., and Lanzerotti, L. J. (Dept. of Physics and Astronomy, Univ. of Maryland, College Park, MD 20742): 'Composition of Nonthermal Ions in the Jovian Magnetosphere', *J. Geophys. Res.* **86**, 8301–8318. (1981)

We present observations from Voyager 1 and 2 of nonthermal ions from H through Fe in the Jovian magnetosphere using the low-energy particle telescope (LEPT), one of the two sensors of the low-energy charged particle (LECP) experiment. At ~1 MeV/nucleon the major constituents of the ion population were H, He, C, O, Na, S, and the hydrogen molecules H_2 and H_3. Relative to He, the abundance of H and H_3 at equal energy/nucleon was highest in the outer magnetosphere, the abundance of O, Na, and S was highest in the inner magnetosphere, and the abundance of C was constant throughout the magnetosphere. He and C may be of largely solar origin, while H_2, H_3, O, Na, and S are largely of local origin. The variations in abundance ratios were accompanied by a general hardening of the energetic particle spectra near 1 MeV/nucleon with decreasing radial distance. We are able to find a parameter η, assumed to be a species-dependent constant times energy/nucleon, in terms of which the flux ratios among most species do not change with radial distance. These 'invariant' ratios indicate that there are approximately equal numbers of nonthermal O, S, and He ions, with the abundance of H ions being a factor of ~ 15 higher. The large ratio changes at equal energy/nucleon can then be ascribed to the changing spectral slopes. The parameter η may be reasonably identified with energy/charge, in which ase we are able to deduce relative charge to mass ratios for H, He, C, O, and S. If He is doubly ionized, we find that the nonthermal carbon has an approximate charge state of +6, typical of solar wind particles, while oxygen and sulfur have low charge states (+2 to +4), typical of local plasma sources. Spectral changes over the range of ~ 30 to ~ $16R_J$, in this interpretation, are consistent with particle energization by inward radial diffusion conserving the first adiabatic invariant. In the Jovian magnetotail, at the time of the Voyager 2 outbound pass, the energetic particle population was a combination of Jovian particles with soft spectra and interplanetary particles (probably of solar flare origin) with much harder spectra. Above ~ 1 MeV/nucleon the interplanetary particles were dominant. Beyond ~ $160R_J$, in the 'magnetospheric wind' region, the nonthermal ion intensity increased and reflected an oxygen- and sulfur-rich composition typical of the middle magnetosphere. Two short-lived intensity increases were observed at ~ $290R_J$ which had heavy ion abundance ratios and spectra similar to those found in the inner magnetosphere. The release of these particles was apparently associated with the arrival at Jupiter of a fast solar wind stream.

Hanel, R., Conrath, B., Herath, L., Kunde, V., and Pirraglia, J. (Lab. for Extraterrestrial Physics, Goddard Space Flight Center, Greenbelt, MD 20771): 'Albedo, Internal heat, and Energy Balance of Jupiter; Preliminary Results of the Voyager Infrared Investigation', *J. Geophys. Res.* **86**, 8705–8712. (1981)

Full disk measurements recorded 31 days before the Voyager 1 encounter with Jupiter by the radiometer (0.4–1.7 μm) of the infrared instrument Iris indicate a geometric albedo of 0.274 ± 0.013. The given error is an estimate of systematic effects and therefore quite uncertain; the random error in the radiometer measurement is negligible. Combining this measurement with the Pioneer-derived phase integral of 1.25 of Tomasko *et al.* (1978) and our error estimate of 0.1 yields a Jovian Bond albedo of 0.343 ± 0.032. Infrared spectra recorded at the same time by the Michelson interferometer (4–55 μm), along with a model extrapolation to low wave numbers not covered by the instrument, yield a thermal emission of $1.359 \pm 0.014 \times 10^{-3}$ W cm^{-2}. This corresponds to an equivalent blackbody temperature of 124.4 ± 0.3 K, in agreement with results of Ingersoll *et al.* (1975) and Erickson *et al.* (1978) but lower than all other previous estimates. As in the case of the albedo measurement the quoted errors in the emission measurement reflect estimates of systematic effects and are uncertain, while the random component is negligible. From these measurements the internal heat flux of Jupiter is estimated to be $5.444 \pm 0.425 \times 10^{-4}$ W cm^{-2}, and the energy balance defined as the ratio of emitted thermal to absorbed solar energy is 1.668 ± 0.085.

Hatzes, A., Wenkert, D. D., Ingersoll, A. P., and Danielson, G. E. (California Inst. of Tech., Div. of Geological and Planetary Sciences, Pasadena, CA 91125): 'Oscillations and Velocity Structure of a Long-Lived Cyclonic Spot', *J. Geophys. Res.* **86**, 8745–8749. (1981)

Dark brown cyclonic spots ('barges') at 14° N were studied by using Voyager 1 and 2 images of Jupiter. Movie sequences were made to study the spots' behavior over intervals of 50 days and longer. These movies revealed that the length and width vary by ± 9% with a period of about 15 days, while the area remains approximately constant. The horizonatal velocity field was investigated for an interval of about 1 day. FLow around the largest barge (feature 6) occurs as a ring current. The vorticity inferred is about 2½ times that of the ambient cyclonic zonal circulation, and about one-half the value of the local planetary vorticity. Length and width variations appear to be associated with a nonzero horizontal divergence field. If the osciallations are a natural mode of the system, the 15-day period will provide an important datum for testing models of stable closed vortices.

Hunt, G. E., Conrath, B. J., and Pirraglia, J. (Lab. for Planetary Atmospheres, Dept. of Physics and Astronomy, University College London, London WC1E 6BT, England): 'Visible and Infrared Observations of Jovian Plumes During the Voyager Encounter', *J. Geophys. Res.* **86**, 8777–8781. (1981)

Observations by the Voyager imaging instrument has shown an organized train of features moving in a westerly current at 9° N with a zonal speed of 100–120 m s^{-1}. The measurement reports show that the number of plumes varied between 13 at the time of the Voyager 1 encounter, and 11 at the time of the second spacecraft passage. The infrared interferometer spectromer (Iris) measurements suggest that the effect of these plume features propagates throughout the Jovian troposphere. A mechanism is suggested for the origin of the plumes in terms of wave interactions with the Jovian flow.

Ingersoll, A. P., Beebe, R. F., Mitchell, J. L., Garneau, G. W., Yagi, G. M., and Muller, J. -P. (Div. of Geological and Planetary Sciences, California Inst. of Tech., Pasadena, CA 91125): 'Interaction of Eddies and Mean Zonal Flow on Jupiter as Inferred from Voyager 1 and 2 Images', *J. Geophys. Res.* **86**, 8733–8743. (1981)

Voyager 1 and 2 narrow-angle frames were used to obtain displacements of features at resolutions of 130 km over time intervals of 1 Jovian rotation. The zonal velocity $\bar{u}$ was constant to 1.5% during the 4 months between the Voyager 1 and 2 encounters. The latitudes of the zonal jet maxima (extrema of $\bar{u}$) are the same as inferred from earth-based observations extending over the past 80 years. The curvature of the velocity profile $d^2\bar{u}/dy^2$ varies with latitudinal coordinate y in the range from -3β to $+2\beta$, where β is the planetary vorticity gradient. The barotropic stability criterion is violated at about 10 latitudes between ± 60°. The eddy momentum flux variation with latitude $\overline{u'v'}$ is positively correlated with $d\bar{u}/dy$ for both Voyager 1 and 2 data. The rate of conversion $\{K'\bar{K}\}$ of eddy kinetic energy into zonal mean kinetic energy is in the range 1.5–3.0 Wm^{-2}, for a layer 2.5 bar deep. The time constant for resupply of zonal mean kinetic energy by eddies is in the range 2–4 months, less than the interval between Voyager encounters. The rate of energy conversion is more than 10% of the total infrared heat flux for Jupiter, in contrast with earth were it is only 0.1% of the infrared heat flux. This hundred-fold difference suggests that the thermomechanical energy cycles are very different on the two planets.

Jewitt, D. C. and Danielson, G. E. (Div. of Geological and Planetary Sciences, California Inst. of Tech., Pasadena, CA 91125): 'The Jovian Ring', *J. Geophys. Res.* **86**, 8691–8697. (1981)

The results of further measurements of the Jovian ring system are presented. The system has three major components: the bright ring, the faint sheet, and the out-of-plane halo. The bright ring has an outer radius of $1.81 \pm 0.01 R_J$, an inner radius $1.72 \pm 0.01 R_J$, an eccentricity not greater than 0.003 and a normal optical depth 3×10^{-5}. The faint sheet extends from the inner edge of the bright ring to the surface of Jupiter. Its optical depth is approximately 7×10^{-6}. Three arguments are presented to show that a halo of material envelops the above two rings and extends 10^4 km above the ring plane. A simple model is invoked to account for the halo by means of interactions between the Jovian magnetic field and charged ring particles less than 0.5 μm in diameter. The source of small particles is probably within the bright ring itself and may be due to micrometeorite impact into larger ring bodies. Small particles evolve in towards Jupiter under Poynting Robertson and other drag forces. The outer edge of the ring system is defined by the satellite 1979J1.

Johnson, R. E., Lanzerotti, L. J., Brown, W. L., and Armstrong, T. P. (Dept. of Nuclear Engineering and Engineering Physics, Univ. of Virginia, Charlottesville, VA 22901): 'Erosion of Galilean Satellite Surfaces by Jovian Magnetosphere Particles', *Science* **212**, 1027–1030. (1981)

The Galilean satellites of Jupiter – Io (J1), Europa (J2), Ganymede (J3), and Callisto (J4) – are embedded in the intense ion and electron fluxes of the Jovian magnetosphere. The effect of these particles on the icy surfaces of the outer three satellites depends on the fluxes and the efficiency of the sputtering of water ice by such particles. Recent laboratory measurements provided data on the erosion of water ice by energetic particles and showed that it occurs much faster than would be expected from normal sputtering theory. The Voyager spacecraft encounters with Jupiter provided the first measurements of ion fluxes (energies $\gtrsim$ 30 keV) in the vicinity of the Galilean satellites. Using the laboratory sputtering data together with particle measurements from the Voyager 1 low-energy charged particle experiment, the effects of erosion on the surfaces of J2 to J4 are estimated. It is shown that the surface of Europa could be eroded by as much as 100 meters over an eon (10^9 yr).

Column densities of water vapor that could be produced around the three satellites from particle bombardment of their surfaces are also calculated, and the sources and losses of oxygen in the gravitationally bound gas produced by sputtering or sublimation are estimated.

Komesaroff, M. M. and McCulloch, P. M. (Div. of Radiophysics, CSIRO, P.O. Box 76, Epping, NSW 2121, Australia): 'The Position Angle of Jupiter's Linearly Polarized Synchrotron Emission and the Jovian Magnetic Field Configuration', *Monthly Notices Roy. Astron. Soc.* **195**, 775–785. (1981)

Plotted as a function of Jovian central meridian longitude, the position angle of Jupiter's linearly polarized microwave emission describes a curve which has been substantially invariant over a period of 16 yr. This curve can be represented with considerable accuracy as a two-term Fourier series. The amplitude of the fundamental is between 9° and 10° and of the second harmonic between 1°.0 and 1°.5.

Using a simplified model of Jupiter's inner magnetosphere, we show that the measured amplitudes and phases of these two terms are in good agreement with values deduced from the dipole and quadrupole components of Jupiter's magnetic field as measured from *Pioneer 11*.

Krimigis, S. M., Carbary, J. F., Keath, E. P., Bostrom, C. D., Axford, W. I., Gloeckler, G., Lanzerotti, L. J., and Armstrong, T. P. (Applied Physics Lab., Johns Hopkins Univ., Laurel, MD 20810): 'Characteristics of Hot Plasma in the Jovian Magnetosphere: Results from the Voyager Spacecraft', *J. Geophys. Res.* **86**, 8227–8257. (1981)

The low-energy charged particle (LECP) experiment on the Voyager 1 and 2 spacecraft made measurements of the intensity, energy spectra, angular distributions, and composition of ions (30 keV $\lesssim E \lesssim$ 150 MeV) and electrons (14 keV $\lesssim E \lesssim$ 10 MeV) during encounters with the Jovian magnetosphere in 1979. Detailed analysis of the multicomponent (H, He, O, S) low-energy (~ 30 keV to ~ 4 MeV) ion population reveals the Jovian environment to be dominated by magnetospheric ions to distances $\gtrsim 200R_J$ upstream and $\gtrsim 350R_J$ downstream from the planet. Inside the magnetosphere, ions move generally in the sense of corotation to the dayside magnetopause, and on the nightside to distances of ~ 130–150R_J, beyond this distance, but inside the magnetopause, ion flow abruptly changes to an antisunward, anti-Jupiter direction and continues to large ($> 350R_J$) radial distances outside the magnetosphere. The ion particle spectrum is characterized by a nonthermal power law ($E^{-\gamma}$) component for $E \gtrsim 200$ keV, and a convected Maxwellian for $E \gtrsim 200$ with characteristic temperatures (kT) of ~ 20–45 keV. Temperature maxima generally coincide with crossings of the Jovian plasma sheet, while at higher energies spectra become softer at the equator. The ion spectra and composition are affected strongly by convective flows in all parts of the magnetosphere. By using the observed spectra and angular distributions, density and pressure profiles are produced for ions measured above the lowest LECP detector threshold ($E \gtrsim 30$ keV) and are compared with reported ambient total electron densities and magnetic field pressures. The particle pressures are found to be comparable to magnetic field pressures to at least ~ $10R_J$, i.e., Jovian magnetosphere dynamics are determined by pressure variations in a high β plasma. Energetic ion densities are found to be comparable with the total electron densities in the outer ($\gtrsim 40R_J$) dayside magnetosphere but are generally lower at smaller radial distances and exhibit substantial variability. We interpret the hot plasma outflow on the nightside of Jupiter as a 'magnetospheric wind' and estimate the mass and energy loss through this region at $\sim 2 \times 10^{27}$ ions s^{-1} and $\sim 2 \times 10^{20}$ ergs s^{-1}, respectively. We find the plasma source from the active volcanoes on Io to be adequate for supplying the mass outflow; only the rotational kinetic energy of Jupiter is sufficient to provide the energy in the flow, although energy from the solar wind interaction can perhaps contribute a significant fraction. A phenomenological model of Jupiter's magnetosphere is presented which accounts for the observations.

Kurth, W. S., Gurnett, D. A., Scarf, F. L., Poynter, R. L., and Sullivan, J. D. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Voyager Observations of Jupiter's Distant Magnetotail', *J. Geophys. Res.* **86**, 8402–8412. (1981)

Observations of nonthermal continuum radiation by Voyager 1 and 2 at large distances from Jupiter have led to the identification of brief encounters eith the Jovian magnetosphere at distances greater then $700R_J$ and in directions substantially far from the Jupiter-sun line. In addition, a number of examples of continuum radiation apparently trapped in local density depressions in the solar wind are observed. Simultaneous measurements by the Voyager plasma instrument have verified the distant magnetotail crossings and are used to correlate the occurrence of trapped continuum radiation events within solar wind density rarefactions. The Voyager observations of the distant Jovian magnetotail are compared with observations in the distant terrestrial magnetosphere and also with observations of the plasma tails of comets. Viable explanations of the observations are that the Jovian tail consists of filamentary structures, some of which extend to large distances in the predawn direction, or that the Jovian tail may be offset in the dawn direction by a combination of corotation angular momentum and forces associated with high-speed streams in the solar wind. The observations of continuum radiation trapped in low-density regions of the solar wind suggest that Voyager may at times be connected to the distant tail by a low-density trough which acts as a wave guide and allows radiation from the tail to reach the spacecraft. This may provide an indirect method of detecting the tail extending more than 2 AU downstream from Jupiter.

Lanzerotti, L. J., Maclennan, C. G., Armstrong, T. P., Krimigis, S. M., Lepping, R. P., and Ness, N. F. (Bell Labs., Murray Hill, NJ 07974): 'Ion and Electron Angular Distributions in the Io Torus Region of the Jovian Magnetosphere', *J. Geophys. Res.* **86**, 8491–8496. (1981)

Angular distributions are presented of ion (~ 0.5–2 MeV) and electron (> 10 MeV) fluxes measured during the Voyager 1 spacecraft passage through the inner regions of the Jovian magnetosphere (radial distances from the planet $\lesssim 10R_J$). In the regions of peak flux intensities, just outside the orbit of Io, the ion angular distributions are most sharply peaked at 90° local pitch angle, a configuration consistent with diffusion of the particles inward from larger radial distances. Inside the orbit of Io the lower-energy ions exhibit angular distributions depleted at 90° local pitch angles, suggesting the possibility of charge-exchange scattering loss of these particles. In the vicinity of the Io flux tube, no significant effect is observed in the flux or pitch angle distributions of the ions. The relativistic electrons are depleted in the flux tube region and exhibit an asymmetrical pitch angle distribution, with more electrons appearing to arrive from the equatorial region (the direction of Io) than from the low-altitude mirror point.

Leblanc, Y. (Observatoire de Paris, Section d'Astrophysique de Meudon, 92190 Meudon, France): 'On the Art Structure of the Dam Jupiter Emission', *J. Geophys. Res.* **86**, 8546–8560. (1981)

An analysis of the dynamic spectra of the Jovian DAM emission (1.3–40 MHz) has been made from Voyager data; it appears that the different Jovian sources can be defined by spectral characteristics, rather than by occurrence probability. The non-Jo emission consists of two families: vertex early arcs (VEA) and vertex late arcs (VLA). These two families are superimposed at all longitudes, but one is always more intense than the other. The characteristics of the two families are specified; in particular, it is shown that the VEA family is more stable in time than the VLA family. The Io-controlled emission consists of the four sources already known from the ground-based observations in addition to a new source. (Io-A')sp, identified by its dynamic spectrum alone. All of the sources are partially superimposed on non-Io emission. The (Io-B)sp and (Io-A')sp sources are made up of low-curvature arcs having low-frequency limits above 5 MHz. The high-frequency limit of the (Io-B)sp source is strongly modulated by Io-phase. The (Io-A)sp source has a spectrum similar to the non-Io VLA emission. The other two sources, (Io-C)sp and (Io-D)sp, are not structure into well-defined arcs. A comparison is made between the occurrence of these sources in the Io-CML plane with the sources defined from ground observations by probability of occurrence. Local time effects are observed only in the non-Io emission when compared before and after encounter. Before encounter, the VEA family is very weak and the VLA family very intense. After encounter, the opposite effect is observed. The Io-controlled sources are not affected by these local time effects.

Leblanc, Y. and Genova, F. (Observatoire de Paris, Section d'Astrophysique de Meudon, 92190 Meudon, France): 'The Jovian *S* Burst Sources', *J. Geophys. Res.* **86**, 8564–8568. (1981)

By using the high resolution observations of Nancay observatory, we have been able to identify the *S* burst emission on the planetary radio astronomy (PRA) records of Voyager. It is shown that the *S* bursts occur in two regions of the Φ_{IO}-CML plane (*S*-IoB and *S*-IoA'C regions). In these regions the *S* burst emission is arranged into a pattern of repetitive features, drifting negatively. These features could be incomplete vertex late arcs. We show that the *S* burst pattern is distinct from the pattern of the Io-controlled emission. These results are discussed in the frame of Goldstein and Thieman's arc model.

Lecacheux, A. (Observatoire de Meudon, 92190 Meudon, France): 'Ray Tracing in the Io Plasma Torus: Application to the Pra Observations During Voyager 1's Closest Approach', *J. Geophys. Res.* **86**, 8523–8528. (1981)

An attempt is made to simulate propagation of the low-frequency radio waves in the vicinity of the Io plasma torus near Jupiter. In absence of a definitive and detailed electron density model for this torus, a number of minimal hypotheses were used. Nevertheless, the anomalous radio dynamic spectrum observed during the day of Voyager 1's closest approach could agree with an emission source situated around the planet in the southern hemisphere and related to the local gyrofrequency.

The major conclusion is that the entire low frequency (up to a few megahertz) dynamic radio spectrum of Jupiter could be modified by refraction inside and around the Io torus. The magnitude of the effects depends on the location of the source and on the plasma parameters distribution inside the torus.

Lepping, R. P., Burlaga, L. F., Klein, L. W., Jessen, J. M., and Goodrich, C. C. (Lab. for Extraterrestrial Physics, Planetary Magnetospheres Branch, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Observations of the Magnetic Field and Plasma Flow in Jupiter's Magnetosheath', *J. Geophys. Res.* **86**, 8141–8155. (1981)

Large scale (many minutes to 10 hr) magnetic field structures consisting predominantly of nearly north-south field directions have been discovered in Jupiter's magnetosheath from the data of Voyagers 1 and 2 and Pioneer 10 during their outbound encounter trajectories. The Voyager 2 data, and those of Voyager 1 to a lesser extent, show evidence of a quasi-period of 10 hr (and occasionally 5 hr) for these structures. For all three spacecraft the changes in the field throughout these structures for many tens of hours are approximately restricted to a plane parallel to Jupiter's local magnetopause, according to a variance analysis of the field. Similar directional changes in the field occurred in the inbound magnetosheath for the Voyager spacecraft, but the occurrence was much less frequent, no quasiperiodicity was apparent, and the scale lengths were on average much shorter. The north-south components of the field and plasma velocity are strongly correlated in the outbound magnetosheath as observed by Voyagers 1 and 2, and the components orthogonal to the north-south direction show weak correlations. For both Voyager encounters the sense (positive or negative) of the north-south correlations has been directly related to the direction of the ecliptic plane component of the interplanetary magnetic field (IMF) using the field and plasma measurements of the non-encountering spacecraft. Some outbound magnetopause and bow shock crossings, on Voyager 2 especially, are phase locked in system III with some of the large scale magnetosheath field and plasma structures. These structures may be accounted for in terms of field line draping around the magnetopause of the convected IMF and solar wind, where the temporal properties are controlled by the motion and shape of a flattened magnetosphere which, in turn, depend on the rapid rotation of the current sheet within the magnetosphere.

Levy, G. S., Green, D. W., Royden, H. N., Wood, G. E., and Tyler, G. L. (Jet Propulsion Lab., Pasadena, CA 91103): 'Dispersive Doppler Measurement of the Electron Content of the Torus of Io', *J. Geophys. Res.* **86**, 8467–8470. (1981)

As Voyager 1 made its swing-by of Io, it passed through and behind the satellite's plasma torus. The phase paths of the coherent 13 cm and 3.6 cm wavelength signals transmitted from the spacecraft were

shortened differentially by the plasma, resulting in the observation of a dispersive Doppler signature in the signals received at the NASA/Jet Propulsion Laboratory (JPL) deep space network (DSN) stations. Ray path integration through threee different models of the electron distribution of the torus of Io have been performed. The results of the integrations are compared with the dispersive Doppler data.

Lindal, G. F., Wood, G. E., Levy, G. S., Anderson, J. D., Sweetnam, D. N., Hotz, H. B., Buckles, B. J., Holmes, D. P., Doms, P. E., Eshleman, V. R., Tyler, G. L., and Croft, T. A. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91103): 'The Atmosphere of Jupiter: An Analysis of the Voyager Radio Occultation Measurements', *J. Geophys. Res.* **86**, 8721–8727. (1981)

Coherently related S (2.3 GHz) and X band (8.4 GHz) signals transmitted from Voyager 1 and 2 have been used to probe the Jovian atmosphere during occultations of the spacecraft by Jupiter. The observations have yielded profiles in height of the gas refractivity, molecular number density, pressure, temperature, and microwave absorption in the troposphere and stratosphere of Jupiter at latitudes ranging from 0° to about 70° S. The data cover a pressure range from 1000 to 1 mbar over a height interval of 160 km. At the 1000 mbar level, the temperatures was 165 ± 5 K, and the lapse rate was equal to the adiabatic value of 2.1 K km^{-1}, within the resolution of the measurements. The ammonia abundance in this region of the atmosphere was about 0.022 ± 0.008%, in approximate agreement with the value derived from cosmic abundance considerations. The tropopause, which was detected near the 140 mbar level, had a temperature of 110 K. Above the tropopause, the temperature increased with increasing altitude, reaching 160 ± 20 K in the 10 to 1 mbar region of the stratosphere. Significant horizontal density variations were detected in the stratosphere. This may imply a nonuniform temperature and aerosol distribution across the Jovian disk or high- and low-pressure regions due to local atmospheric dynamics. The zenoid or gravity equipotential surface which best fits the 100 mbar isobaric surface has an equatorial radius of 71 541 ± 4 km and a polar radius of 66 896 ± 4 km.

Luchkov, B. I.: 'On the Origin of the Great Red Spot of Jupiter', (in Russian), *Pis'ma Astron. Zh.* 7, 566–569. (1981). English translation in *Soviet Astron. Lett.* 7.

The origin of the Great Red Spot (GRS) is connected with the structure of the magnetic field and the radiation belt of Jupiter. A comparison of the GRS with the earth field negative anomaly (Brasil anomaly) is given. It is qualitatively shown that the GRS arrived in the region of a Jovian magnetic field anomaly and is constantly supplied by high energy particle precipitation from the radiation belt.

Marten, A., Rouan, D., Baluteau, J. P., Gautier, D., Conrath, B. J., Hanel, R. A., Kunde, V., Samuelson, R., Chedin, A., and Scott, N. (Observatoire de Meudon, 92190 Meudon, France): 'Study of the Ammonia Ice Cloud Layer in the Equatorial Region of Jupiter from the Infrared Interferometric Experiment on Voyager', *Icarus* **46**, 233–248. (1981)

Spectra from the Voyager 1 infrared interferometer spectrometer (IRIS) obtained near the time of closest approach to Jupiter were analyzed for the purpose of inferring ammonia cloud properties associated with the Equatorial Region. Comparisons of observed spectra with synthetic spectra computed from a radiative transfer formulation, that includes multiple scattering, yielded the following conclusions: (1) very few NH_3 ice particles with radii less than 3 μm contribute to the cloud opacity; (2) the major source of cloud opacity arises from particles with radii in excess of 30 μm; (3) column particle densities are between 1 and 2 orders of magnitude smaller than those derived from thermochemical considerations alone, implying the presence of important atmospheric motion; and (4) another cloud system is confirmed to exist deeper in the Jovian troposphere.

Martin, J. M., Tyler, G. L., Eshleman, V. R., Wood, G. E., and Lindal, G. F. (Stanford Univ., Stanford, CA 94305): 'A Search for the Radio Occultation Flash at Jupiter', *J. Geophys. Res.* **86**, 8729–8732. (1981)

The 'evolute flash', a focusing effect caused by the cu·vature of a planet's limb, was sought in the radio data taken during the occultation of Voyager 1 by Jupiter, using a modified matched-filter technique. The expected frequency structure of the flash signal is double branched, while the intensity

structure is highly localized in time. The search for the signal was carried out over a 6.4 s period. The signal parameters were varied to span the uncertainties introduced by imperfect knowledge of the orbit of the spacecraft and the shape of Jupiter. Several peaks at the 8 standard deviation level were present in the filter output. However, these peaks were separated in time by up to 3.3 s, and none could be identified as the flash. From this negative result a lower bound on the absorption along a ray with periapsis near the 4 bar level at Jupiter's atmosphere can be established at 25 dB. Employing the new Voyager results on the structure of the atmosphere of Jupiter and the mixing ratio of the absorbent ammonia as well as the improved knowledge of flash characteristics resulting from this study, we estimate that the flash would have been detected if the distance behind the planet where the spacecraft trajectory crossed the evolute were at least 20 Jupiter radii, as compared with a value near 7 in the experiment. For focusing at this greater distance, the atmospheric pressure at the ray periapsis would be between 1.5 and 2 bar.

McNutt, R. L. Jr., Belcher, J. W., and Bridge, H. S. (Dept. of Physics and Center for Space Research, MIT, Cambridge, MA 02139): 'Positive Ion Observations in the Middle Magnetosphere of Jupiter', *J. Geophys. Res.* **86**, 8319–8342. (1981)

We consider the positive ion data gathered by the Voyager Plasma Science experiment in the middle magnetosphere of Jupiter. The experiment measures positive ions with energies per charge between 10 and 5950 V. The observations are analyzed to obtain the mass and charge densities, velocity components, and temperatures of the low-energy plasma population. The reduced data set is discussed in the context of the outstanding questions concerning this plasma population and its dynamics. We find that on the dayside, there exists a transonic to highly supersonic positive ion population which tends to move azimuthally but does not rigidly corotate with the planet. These ions provide the inertia of the magnetospheric plasma inside of $\sim 40 R_J$. The mass density is everywhere dominated by heavy ions, and the mass density gradient is consistent with outward diffusion from the Io plasma torus via flux tube interchange. The ions tend to be concentrated in a plasma sheet which is associated with the current sheet inferred from the magnetic field observations. The plasma in the sheet is relatively cool (~ 20 eV) in comparison with plasma at higher magnetic latitudes ($\gtrsim 100$ eV). In addition to the azimuthal flow pattern, we find a local time asymmetry in the data which we interpret as flow away from the current sheet on the dayside and toward the current sheet on the nightside. This dynamic expansion and contraction of the plasma sheet is presumably driven by the asymmetry in the magnetosphere due to the solar wind interaction.

Meyer-Vernet, N., Daigne, G., and Lecacheux, A. Observatoire de Paris-Meudon, F-92190 Meudon, France): 'Dynamic Spectra of Some Terrestrial Ionospheric Effects at Decametric Wavelengths – Applications in Other Astrophysical Contexts', *Astron. Astrophys.* **96**, 296–301. (1981)

Ionospheric perturbations in the dynamic spectra of solar and Jovian radio emission in the decametric range are presented. A theoretical interpretation is given in terms of focusing and diffraction by large scale ionospheric inhomogeneities, namely quasi-periodic travelling disturbances producing large phase changes.

The interpretation does not involve ad-hoc parameters; it takes into account the source size and gives the effects on the visibility function.

Other astrophysical situations where such an approach would be useful are shortly discussed: similar effects could account for some broad-band interplanetary scintillations observed recently; in addition, it is suggested that propagation effects through the Jovian plasma torus could serve to interpret unexplained features of the Jupiter radio emission.

Mitchell, J. L., Beebe, R. F., Ingersoll, A. P., and Garneau, G. W. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Flow Fields Within Jupiter's Great Red Spot and White Oval BC', *J. Geophys. Res.* **86**, 8751–8757. (1981)

Using sequences of Voyager 1 high-resolution images of Jupiter's Great Red Spot (GRS) and White Oval BC we map the flow fields within the GRS and Oval BC. We compute relative vorticity within these features as a function of semi-major axis length and position angle in a corrdinate system consisting of concentric ellipse of equal eccentricity. Both the velocity and the relative vorticity profiles are nearly identical for Oval BC and the outer portion of the GRS. Wind speeds of 110–120 m s^{-1} are observed near the outer edges of both features. Along their minor axes relative vorticity profiles reach a maximum of $\sim 6 \times 10^{-5} s^{-1}$. This is several times greater than the ambient $1.5 \times 10^{-5} s^{-1}$ meridional shear of zonal winds at the latitudes of the GRS and Oval BC. Maximum Rossby numbers of 0.36 are computed for flows within both the GRS and the Oval BC. Generally, the Rossby numbers within these features are much lower, indicating strongly geostrophic constraints on the flow. The difference in streamline curvature within the GRS and the Oval BC is found to compensate for the difference in planetary vorticity at the respective latitudes of the features. Motions within the central region of the GRS are much slower and more random than around the spot's outer portion.

Owen, T. and Terrile, R. J. (Earth and Space Sciences, State Univ. of New York, Stony Brook, NY 11794): 'Colors on Jupiter', *J. Geophys. Res.* **86**, 8797–8814. (1981)

The colors present in the clouds of Jupiter at the time of the Voyager encounters are described as they appeared in high resolution images. Although many different tints are present in these pictures, some cloud units can be characterized by very discrete colors. We can show that latitude, altitude, and dwell-time are all critical factors in determining which colors appear where, but the identities of the responsible chromophores remain unestablished. Simultaneous ground-based 5 μm observations permit the determination of the relative altitudes of these cloud systems. In descending order we have the white clouds (presumably ammonia cirrus), the light brown or tawny clouds (ammonium hydrosulfide and/or monosulfide(?)), a dark brown cloud belt present only at some latitudes, and the blue-gray 'hot spots' of the equatorial region. The top of the Great Red Spot may exceed the altitude of the white clouds on occasion. Despite the turbulence of the Jovian atmosphere, correlations between cloud color and certain latitudes have been maintained for decades, suggesting the importance of the internal energy source and the deep circulation in generating some of the observed chromophores.

Parmentier, E. M. and Head, J. W. (Dept. of Geological Sciences, Brown Univ., Providence, RI 02912): 'Viscous Relaxation of Impact Craters on Icy Planetary Surfaces: Determination of Viscosity Variation with Depth', *Icarus* 47, 100–111. (1981)

Spacecraft images show that the icy Galilean satellites have surfaces with very low topographic relief. Impact craters on Ganymede and Callisto are anomalously shallow and are characterized by sharp well-defined rims and domed floors. These morphological characteristics can be explained by viscous relaxation of topography on an icy crust in which the viscosity is uniform or decreases with depth. Under these conditions, large craters relax more rapidly than small craters, therefore explaining a possible underabundance of large craters. Viscous relaxation on an icy crust that is thin compared to the crater diameter or on a thick icy crust in which viscosity increases with depth could not produce this crater morphology and would result in the more rapid relaxation of small craters rather than large craters. The results of this study suggest that more detailed analysis of relaxing impact crater morphology may resolve the rate of viscosity decrease with depth and so provide evidence on the interior thermal evolution of icy planetary bodies.

Pearce, J. B. (Radiophysics, Inc., Boulder, CO 80301): 'A Heuristic Model for Jovian Decametric Arcs', *J. Geophys. Res.* **86**, 8579–8580. (1981)

A field line emission cone model is proposed that fits the frequency-time profiles of decametric arcs emitted by the Jupiter system. Four parameters (latitude of the observer, longitude of the excited flux tube, emission cone angle, and field line L shell value) can be varied to fit most of the observed radiation.

Prinn, R. G. and Olaguer, E. P. (Dept. of Meteorology and Physical Oceanography, MIT, Cambridge, MA 02139): 'Nitrogen on Jupiter: A Deep Atmospheric Source', *J. Geophys. Res.* **86**, 9895–9899. (1981)

A study of irreversible reactions involving molecular nitrogen on Jupiter indicates that vertical motions are sufficiently rapid in the deep atmosphere to transport large amounts of N_2 from the 900–1700 K levels where it is stable up to the cold visible regions. Both homogeneous gas-phase and heterogeneous iron-catalyzed reactions between N_2 and H_2 were considered. We predict N_2 mixing ratios of 0.6–3 ppmv if catalysis is effective and up to 10 ppmv if it is not. Thus N_2 may be the most abundant non-equilibrium species in Jupiter's troposphere and potentially detectable by the neutral mass spectrometer which will be on board the 1986 Galileo Entry Probe.

Richardson, J. D. and Siscoe, G. L. (Dept. of Atmospheric Sciences, Univ. of California at Los Angeles, CA 90024): 'Factors Governing the Ratio of Inward to Outward Diffusing Flux of Satellite Ions', *J. Geophys. Res.* **86**, 8485–8490. (1981)

The primary loss process for the ionized component of satellite debris in Jupiter's magnetosphere appears to be radial transport, which carries the satellite-derived ions away from the source satellite. Cross L (interchange) diffusion is a likely candidate for the radial transport mechanism. Many consequences are predicted to result from satellite ions that reach regions close to and remote from Jupiter. The ratio of the inward to outward flux of diffusing ions from a given satellite is therefore important as an input to the estimates of the magnitudes of expected consequences. In the formal analysis of cross L diffusion, the flux ratio depends on poorly known boundary conditions and on a poorly determined diffusion coefficient. We present here an analysis of the sensitivity of the flux ratio to the uncertainties in the mentioned parameters. The main result is that if the diffusion is driven externally, for example by winds in Jupiter's ionosphere, the inward flux exceeds or is of the same order of magnitude as the outward flux. On the other hand, if the diffusion is driven locally by the centrifugal interchange instability, as one interpretation of Voyager plasma data suggests, the outward flux can be one or two orders of magnitude greater than the inward flux. Fits to the Voyager in situ plasma torus data obtained from solutions to the transport equations appropriate to wind driven and centrifugally driven diffusion are compared. In both cases, good fits are obtained. Both require a substantial discontinuity in the diffusion coefficient at Io's orbit, and both require an onset of ion injection a finite time prior to Voyager encounter. The values of the source strength, the duration of injection, and the percentage of inward flux transport, determined thereby differ by a factor of four or less between the two types of diffusion.

Sagdeev, R. Z., Shapiro, V. D. and Shevchenko, V. I.: 'The Great Red Spot as Synoptic Vortex in the Jovian Atmosphere', (in Russian), *Ris'ma Astron. Zh.* **7**, 505–509 (1981). English translation in *Soviet Astron. Lett.* **7**.

A solution of hydrodynamic equations for an ideal incompressible fluid is obtained in the form of a Rossby solitary wave developing in a zonal plane flow with shear of velocity. A qualitative agreement between the obtained solution and characteristics of the Great Red Spot on Jupiter is shown.

Scarf, F. L., Gurnett, D. A., Kurth, W. S., Anderson, R. R., and Shaw, R. R. (Space Sciences Dept., TRW Defense and Space Systems Group, Redondo Beach, CA 90278): 'An Upper Bound to the Lightning Flash Rate in Jupiter's Atmosphere', *Science* **213**, 683–685. (1981)

Scarf, F. L., Gurnett, D. A., and Kurth, W. S. (Space Sciences Dept., TRW Defense and Space Systems Group, Redondo Beach, CA 90278): 'Measurements of Plasma Wave Spectra in Jupiter's Magnetosphere', *J. Geophys. Res.* **86**, 8181–8198. (1981)

The Voyager 1 and 2 plasma wave instruments had to be designed without direct knowledge of the intensities or spectral characteristics of waves in Jupiter's magnetosphere, the possible environmental problems at Juipiter, or the possible in-flight interference effects from Voyager subsystems. The wave instruments operated continuously during the 1979 Voyager encounters, and now we can assess in detail the performance of the receiver/spacecraft system within the magnetosphere of Jupiter. We present compressed plots of E field averages for all of the 16-channel spectrum analyzer data from the Voyager 1 and 2 magnetosphere traversals to provide an overall framework fro the discussion. We illustrate the importance of considering peaks as well as averages by using 16-channel measurements from

the first inbound and last outbound bow shock for Voyager 2. We also present selected wideband measurements from the waveform receivers to demonstrate how many important wave bursts are variable in times less than or comparable to the 4 s scan period of the 16-channel analyzer. These signal characteristics could not be determined by using the 16-channel analyzer data alone. in addition, we show how the continuous frequency coverage of the waveform data link provides extremely valuable information on the complex spectra of Jovian plasma waves. These wideband frames also lead to the identification of significant variable interference effects assocated with the changing interaction between spacecraft subsystems and the Jupiter plasma environment.

Schardt, A. W., McDonald, F. B., and Trainor, J. H. (Lab. for High Energy Astrophysics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Energetic Particles in the Predawn Magnetotail of Jupiter', *J. Geophys. Res.* **86**, 8413–8428. (1981)

A detailed account is given of the energetic electron and proton populations as observed with Voyager 1 and 2 during their passes through the dawn magnetotail of Jupiter. In general, the results of the Pioneer 10 pass at 90° to the Jupiter-sun line have been confirmed and extended. The region between 20 and $150 R_J$ is dominated by a thin plasma sheet, and open field lines were observed at $42 R_J$ at a magnetic latitude of only 15°. Trapped energetic electron and proton fluxes reach their maximum in the plasma sheet and decrease rapidly even a few degrees away from it. The spectra of trapped protons can be represented by an exponential in rigidity and have a characteristic energy of ~ 50 keV. Proton anisotropies in the plasma sheet were consistent with corotation even at $100 R_J$, but the preliminary analysis is not yet conclusive. A major proton acceleration event and several cases of field-aligned proton streaming were observed. Comparable proton fluxes were observed in the plasma sheet by Voyager 1 and 2. The flux of > 0.4 MeV protons decreases by 3 orders of magnitude between 20 and $90 R_J$ and then remains relatively constant from there to the boundary layer near the magnetopouse. Between 20 and $30 R_J$ in the antisolar direction, the trapping region has a latitudinal extent which is comparable to that observed during the inbound pass at −30° solar aspect. The plasma sheet positions in the magnetotail can be represented by a distorted disk which rotates about the Jovian spin axis. Fine structure in the data indicates longitudinal asymmetries with respect to the dipole orientation. Electron spectra in the outer magnetosphere, the magnetosheath, and interplanetary space are modulated by the Jovian longitude relative to the subsolar point; this confirms the Pioneer 10 and 11 results.

Schubert, G., Stevenson, D. J., and Ellsworth, K. (Dept. of Earth and Space Sciences, Univ. of California, Los Angeles, CA 90024): 'Internal Structures of the Galilean Satellites', *Icarus* **47**, 46–59. (1981)

New models for the interiors of Io, Ganymede, and Callisto are proposed. The model of Io consists of a thin, high-rigidity outer layer separated from a solid interior by a thin, molten or partially molten shell. The modulus of rigidity of the outer layer must be at least 100 times larger than that of the underlying partially molten shell. These layers have thicknesses of order 100 km or less. The near-surface partially molten layer was most likely produced early in Io's history as a consequence of accretional heating; enhanced tidal heating in the outer rigid layer has kept the underlying region partially molten to the present day. The model of Ganymede consists of an ice outer layer, a shell of undifferentiated, primordial ice–silicate mixture, and a rock core. Accretional heating is responsible for melting the ice in the outer layers of Ganymede's initially homogeneous ice–silicate interior. Most of the rock in this outer lyaer accumulate in a shell on top of Ganymede's early cold and rigid central region; the water in the outer layer quickly refreezes. Heating fo the undifferentiated region by the decay of radioactive elements in the silicate fraction would gradually warm it and reduce its viscosity. The rock layer would become gravitationally unstable and sink through the undifferentiated meterail to form a rock core. Callisto's heavily cratered surface strongly suggests that relatively little, if any, ice–rock differentiation has occurred in its interior.

Scudder, J. D., Sittler, E. C. Jr., and Bridge, H. S. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'A Survey of the Plasma Electron Environment of Jupiter: A View from Voyager', *J. Geophys. Res.* **86**, 8157–8179. (1981)

A survey of the plasma environment within Jupiter's bow shock is presented in terms of the in situ, calibrated electron plasma measurements made between 10 eV and 5.94 keV by the Voyager Plasma Science Experiment (PLS). These measurements have been analyzed and corrected for spacecraft potential variations; the data have been reduced to nearly model independent macroscopic parameters of the local electron density and temperature. The electron parameters are derived without reference to or internal calibration from the positive ion measurements made by the PLS experiment. Extensive statistical and direct comparisons with other determinations of the local plasma charge density clearly indicate that the analysis procedures used have successfully and routinely discriminated between spacecraft sheath and ambient plasmas. These statistical cross correlations have been performed over the density range of 10^{-3} to $2 \times 10^{2}/cm^{3}$. These data clearly define the bow shock, the magnetosheath (30–50 eV) the magnetosphere ($10^{-2}/cm^{3}$, 2–3 keV) as well as the periodic appearances of the plasma sheet which are illustrated to be routinely cooler than the surroundings. The proximity of the plasma sheet defines a regime in the magnetosphere where very cold electron plasma (as low as 50 eV) at $40R_J$ can be seen in unexpected density enhancements. These plasma 'spikes' in the density can often represent an order of magnitude enhancement above the ambient density and are correlated with diamagnetic depressions. These features have been seen at nearly all magnetic latitudes within the plasma sheet. The temperature within these spikes is lowered by similar factors indicating that the principal density enhancements are of cold plasma. The plasma sheet when traversed in the outer magnetosphere has a similar density and temperature morphology as that seen in these 'spikes'. In all cases the plasma sheet crossing lasts for intervals commensurate with that defined by the diamagnetic depression in the simultaneously measured and displayed magnetic field. The electron temperatures in the plasma sheet in the outer and middle magnetosphere appear to have a positive radial gradient with jovicentric distance. The electron temperature is observed to be lower on the centrifugal side of the minimum magnetic field strength seen in each sheet, while the suprathermal electron density is enhanced symmetrically about the locally indicated magnetic equator. The electron distribution functions within the plasma sheet are markedly non-Maxwellian; during the density enhancement of the plasma sheet the thermal sub-population is generally enhanced more than the suprathermal population. The suprathermal fraction of the electron density within the plasma sheet is an increasing function of jovicentric distance. Direct, in situ sampling of the electron plasma environment of Io's torus clearly illustrates that the system is demonstrably removed from local thermodynamic equilibrium; these measurements illustrate that between 5.5 and $8.9R_J$ there are sizeable systematic variations of the macroscopic and microscopic parameters; there are at least three electron thermal regimes within the torus. These three regimes have mean electron energies in the outer, temperate, and inner torus of the order of 100, 10–40, and less than 5 eV, respectively. The distribution functions in these regimes are always non-Maxwellian with the suprathermal population an increasing fraction of the density and partial pressure with increasing distance from Jupiter. The common non-Maxwellian character of the electron torus plasma unequivocally implies that the electrons and ions cannot locally have the same temperature if binary Coulomb collisions are the only scattering present in the plasma torus. The direct in situ torus electron spectra are shown to be compatible with a number of indirect assessments of the electron state in the torus including observations of plasma hiss, whistler Landau damping, gyro-harmonic emissions, possible asymmetric sink for collisional ionization of sodium, and capacity to ionize sulfur whose presence is implied by the optical and EUV measurements. It is also suggested that the Io plasma torus is the limiting form of the plasma sheet, possibly being its complete direct source, since a progression in the fractional number in the cold, or thermal number density is clear: this fraction is 0.999 in the inner torus, but only 0.5 in the plasma sheet by $40R_J$. We have tentatively concluded that the radial temperature profile within the plasma sheet is caused by the intermixing of two different electron populations that probably have different themporal histories and spatial paths to their local observation. The cool plasma source of the plasma sheet and spikes is probably the Io plasma torus and arrives in the plasma sheet as a result of flux tube interchange motions or other generalized transport which can be accomplished without diverting the plasma from the centrifugal equator. The hot suprathermal populations in the plasma sheet have most recently come from the sparse, hot mid-latitude 'bath' of electrons which are directly observed juxtaposed to the plasma sheet. As the cool plasma is diluted by filling an increasing volume as it undergoes radial expansion, the outer hot bath of electrons can increasingly dominate until at sufficient radial distance the sheet per se does not exist anymore.

Shemansky, D. E. and Smith, G. R. (Space Science Inst., Univ. of Southern California, Tucson Labs., Tucson, AZ 85713): 'The Voyager 1 EUV Spectrum of the Io Plasma Torus', *J. Geophys. Res.* **86**, 9179–9192. (1981)

The Voyager 1 EUV spectrum of the hot Io plasma torus has been analyzed by using a collisional model. The estimated effective electron temperature of the central dense region of the plasma is 8×10^4 K. The torus halfwidth number densities (cm^{-3}) obtained from the model calculation are O II (50), O III (340), O IV (< 17), S II (44 ± 20), S III (160), S IV (220), S V (≤ 11), and K III (≤ 80). The relative oxygen/sulfur number densities are $\Sigma On/\Sigma Sn \simeq 0.9$. Comparison of the model calculations with other spectroscopic observations that can be clearly identified as originating in the hot plasma torus shows satisfactory agreement. However, the EUV observations show strong morphological differences with recent ground-based observations of S II emission, raising questions concerning excitation mechanisms and radial dependence of the observed characteristics. The ion densities indicated by the EUV data analysis show distinct differences with the in situ Voyager 1 plasma science estimates.

Sinton, W. M. (Inst for Astronomy, Univ. of Hawaii, Honolulu, HI 96822): 'The Thermal Emission Spectrum of Io and a Determination of the Heat Flux from its Hot Spots', *J. Geophys. Res.* **86**, 3122–3128. (1981)

Observations of thermal emission from Io in the near infrared made during an eclipse were combined with unpublished 8 to 13 μm intermediate band photometry and a 16 to 22 μm spectrum to specify Io's emission spectrum from 2.2 to 22 μm. Models were calculated having 'hot spots' at several different temperatures superposed on a surface, the major part of which is assumed to be at the solar equilibrium temperature. It was possible to fit the entire composite spectrum with this mdoel. It is argued that the total emission from the hot spots can be equated to the nonsolar energy input into Io. The disk-averaged heat radiated by the hot spots is found to be $180 \pm 60\,\mu W\,cm^{-2} = 14\,\mu cal\,cm^{-2}\,s^{-1}$. A possible bimodal temperature distribution of the hot spots is discussed.

Siscoe, G. L., Eviator, A., Thorne, R. M., Richardson, J. D., Bagenal, F., and Sullivan, J. D. (Dept. of Atmospheric Sciences, UCLA, Los Angeles, CA 90024): 'Ring Current Impoundment of the Io Plasma Torus', *J. Geophys. Res.* **86**, 8480–8484. (1981)

A newly discovered feature in the Io plasma formation that may be described as a ramp separating a high-density plasma ledge on its Jupiterward side from the lower-density radially distended Io plasma disc on its anti-Jupiterward side is observed to coincide with a marked inward decrease in the ring current population. The spatial congruencey of the counter-directed maximal gradients in both plasma bodies reveals a profound coupling between them. The existence of the ramp requires a local order-of-magnitude reduction in the diffusion coefficient that governs radial mass transport. We demonstrate that the diminished diffusive efficiency there is caused by strong pressure gradient inhibition of the interchange instability that underlies mass transport. The Io plasma torus, which is defined as the region of strong ultraviolet emissions, is identified as the plasma ledge. The plasma density in the ledge is high and, incidentally therefore, able to emit strongly because it is impounded against rapid, centrifugal expulsion by the inwardly directed pressure of the ring current at its inner edge.

Siscoe, G. L. and Summers, D. (Dept. of Atmospheric Sciences, Univ. of California, Los Angeles, CA 90024): 'Centrifugally Driven Diffusion of Iogenic Plasma', *J. Geophys. Res.* **86**, 8471–8479. (1981)

The plasma distribution around Io as measured by Voyager 1 displays an asymmetric discontinuity at Io's orbit that has been suggested to be the signature of centrifugally driven interchange diffusion fed by plasma derived from Io. We explore this hypothesis here further and find it to be valid. The particular form for the diffusion coefficient appropriate to centrifugally driven turbulence is derived. The nonlinear character of this kind of diffusion is thereby made explicit. Solutions to the nonlinear, time-independent and linearized, time-dependent diffusion equations are given. These display a markedly conservative behavior. The nonlinear, steady state solutions are identical in form to the solutions of the previously studied equation of linear, atmospherically driven diffusion. The linearized, time-dependent solutions exhibit a negative feed-back quality that buffers the response of the density to changes in the source strength. Estimates of the source strength, the diffisuion coefficient, and the signal propagation speed are also given.

Squyres, S. W. (Lab. for Planetary Studies, Cornell Univ., Ithaca, NY 14853): 'The Topography of Ganymede's Grooved Terrain', *Icarus* **46**, 156–168. (1981)

Using the technique of photoclinometry, topographic profiles acorss areas of grooved terrain and several other features on Ganymede have been constructed. The grooved terrain examined consists of subparallel grooves spaced 3–10 km apart. Topographic amplitudes are typically 300–400 m, with a maximum of about 700 m. Slopes are very gentle and tend to be primarily concave upward. Very few major positive relief features exist on Ganymede. The most important of these is a broad, gently sloping dome-shaped feature 260 km in diameter and over 2 km high.

Squyres, S. W. and Veverka, J. (Lab. for Planetary Studies, Cornell Univ., Ithaca, NY 14853): 'Voyager Photometry of Surface Features on Ganymede and Callisto', *Icarus* **46**, 137–155. (1981)

The photometric properties of selected surface features on Ganymede and Callisto have been studied using Voyager images over phase angles from 10 to 124° taken with the clear filter (effective wavelength ~ 0.5 μm). Normal reflectances on Ganymede average 0.35 for the cratered terrain and 0.44 for the grooved terrain. The value for the ubiquitous cratered terrain on Callisto is 0.18. The photometric properties of these regions are described closely by a simple scattering function of the form $I = Af(\alpha)\mu_0/(\mu + \mu_0)$, where A is a constant, μ is the cosine of the emission angle, μ_0 is the cosine of the incident angle, and $f(\alpha)$ is a function of the phase angle, α, only. For these terrains the shape of $f(\alpha)$ is qualitatively similar to that for the Moon – generally concave upward. By contrast, bright craters on both satellites have $f(\alpha)$'s which are concave downward. The scattering properties of these bright features are definitely not Lambertian, but are described approximately by the scattering law given above. The brightest craters on Callisto have reflectances which are only 10% lower than the brightest craters on Ganymede; both have closely similar scattering laws. We estimate that the brightest craters on Ganymede may reach normal reflectances of 0.7. Our phase functions yield phase integrals of $q = 0.8$ and 0.6 for Ganymede and Callisto, respectively.

Staelin, D. H. (Research Lab. of Electronics, MIT, Cambridge, MA 02139): 'Character of the Jovian Decametric Arcs', *J. Geophys. Res.* **86**, 8581–8584. (1981)

The planetary radio astronomy (PRA) experiment on the Voyager 1 and Voyager 2 spacecraft reveals strong radiation in the form of arcs when the data are displayed in time-frequency coordinates. The vertex frequencies of these arcs, i.e., the central frequencies at which the arcs are first or last observed, are correlated with the magnetic field strength at the foot of the $L = 6$ shell magnetic flux tubes that emitted the arcs, provided that the emission is conical with a cone angle that varies slightly in a prescribed way. This interpretation further supports the association of the left circularly polarized arcs with the southern hemisphere, where the relation between vertex frequency and magnetic field strength is preserved. One way to produce a frequency dependent cone angle is described; it is relevant to processes where the cyclotron emission originates directly from streaming electrons with apparent cyclotron frequencies that are both relativistically depressed and Doppler shifted. This process is qualitatively consistent with the cone angles inferred from the PRA data.

Stone, E. C. (California Inst. of Tech., Pasadena, CA 91125): 'The Voyager Mission Through the Jupiter Encounters', *J. Geophys. Res.* **86**, 8123–8124. (1981)

Strickland, R. N. and Burke, J. J. (Univ. of Arizona, Optical Sciences Center, Tucson, AZ 95721): 'Rectification and Enhancement of Three Severely Distorted Images of Jupiter's North Polar Region', *Applied Optics* **20**, 3612–3618. (1981)

A number of high-resolution images of Jupiter's northern hemisphere were received from the imaging photo-polarimeter (IPP) aboard Pioneer 11 in 1974. Erratic scanning of the IPP caused severe distortions in three scientifically important images, which until now have never been satisfactorily restored. We report new rectification and enhancement techniques, implemented on up-to-data image processing hardware, yielding images of sufficient quality to enable full scientific exploitation of the photometric data.

Strom, R. G., Schneider, N. M., Terrile, R. J., Cook, A. F., and Hansen, C. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Volcanic Eruptions on Io', *J. Geophys. Res.* **86**, 8593–8620. (1981)

Nine erruption plumes were observed over a period of 6½ days during the Voyager 1 encounter with Io. During the Voyager 2 encounter, 4 months later, eight of these eruptions were still active. The largest plume viewed by Voyager 1 became inactive sometime between the two encounters. However, a major eruption occurred at Surt sometime between the two encounters and deposited an ejecta blanket comparable in size to those associated with the largest plumes. The plumes range in height from about 60 to over 300 km with corresponding ejection velocities of about 0.5 to 1.0 km s^{-1}. Where topographic information exists (plumes 1 and 8), the plume source is located on level plains rather than topographic highs and consists of either fissures of calderas. With the exception of plume 1 (Pele), the brightness distribution monotonically decreases from the core to the top of the plume. The shape and brightness distribution together with the pattern of the surface deposit of at least plume 3 (prometheus) can be simulated by a ballistic model in which the ejection velocity is constant (0.5 km s^{-1}) and ejection angles vary from vertical (0°) to 55°. The brightness distribution of plume 1 is probably better explained by a shock front near the top of the plume. Numerous surface deposits similar to those associated with active plumes probably mark the sites of recent eruptions. The distribution of active and recent eruptions appears to be concentrated int he equatorial regions and indicates the volcanic activity is more frequent and intense in the equatorial regions than the polar regions. This suggests that the depositional rate is greater and the surface age younger in the equatorial regions, which may account for the darker polar regions. The geologic setting of certain plume sources and the very large reservoirs of volatiles required for the active eruptions suggests that sulphur volcanism rather than silicate volcanism is the most likely driving mechanism for the eruption plumes.

Strom, R. G., Woronow, A., and Gurnis, M. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 95721): 'Crater Populations on Ganymede and Callisto', *J. Geophys. Res.* **86**, 8659–8674. (1981)

The discovery of heavily cratered surfaces on Ganymede and Callisto by Voyager 1 shows that like the inner Solar System, a period of heavy bombardment also occurred in the outer Solar System. Comparisons among the crater size/density curves of Ganymede, Callisto and the terrestrial planets show several striking features. The overall crater density of the most heavily cratered terrain on Ganymede is down by a factor of about 3 compared to Callisto, and when allowance is made for the difference in crater production rate due to the influence of Jupiter's gravity field it is down by a factor of nearly 6. This indicates that the oldest regions of Ganymede began recording the observed crater population at a later time than Callisto, and therefore Ganymede either experienced a large-scale (perhaps global) diameter-independent resurfacing event or simply developed a rigid crust capable of retaining craters later than Callisto. In either case, this process took place during the period of late heavy bombardment. Based on earlier studies of the terrestrial-planets' cratering record, neither Ganymede nor Callisto is saturated with craters. Compared to Callisto, a diameter-dependent loss of craters in the size range 10–40 km occurs on the grooved terrain of Ganymede and probably results from obliteration of small craters due to the formation of new ice. A similar but less severe loss also occurs on Ganymede's heavily cratered terrain and may be due to an earlier period of ice formation and/or the formation of arcuate troughs in this terrain. Seven different crater curves, in the diameter range of about 40–130 km, representing vastly different crater densities, different surface ages, different terrain types, and even different satellites all possess nearly the same distribution function. This together with other observational evidence strongly suggests that at least in this diameter range the curve basically represents its production function which is completely different from that on the terrestrial planets. This indicates that the population of bodies responsible for the period of late heavy bombardment in the inner Solar System was very different from that responsible for the late heavy bombardment in the outer Solar System. We can only speculate at this early stage that Ganymede and Callisto may principally record a population of bodies that never penetrated the inner Solar System in numbers great enough to leave a recognizable signature.

Synnott, S. P. (Jet Propulsion Lab., Pasadena, CA 91103): '1979J3: Discovery of a Previously unknown Satellite of Jupiter', *Science* **212**, 1392. (1981)

During a detailed search of Voyager 1 frames for additional observations of the satellite 1979J1, two small dark spots were observed in transit in several consecutive wide-angle frames of the Jovian atmosphere. The size, spacing, and motion of these pairs of dark spots indicated that they were the images of 1979J1 and its shadow. Subsequent analysis of images spanning 6 days, however, proved that the satellite observed in these Voyager 1 frames would have been occulted by Jupiter at the times of the Voyager 2 images of 1979J1 and was, therefore, a new satellite. It was subsequently found in transit on Voyager 2 images within 13° of the Voyager 1 prediction. Its period is 7 hr 4 min 30 sec ± 3 sec, and its mean distance is 1.793 Jupiter radii (Jupiter radius = 71 400 km). The observable profile appears to be roughly circular with a diameter of 40 km, and the albedo is ~ 0.05, similar to Amalthea's.

Teifel, V. G., Kharitonova, G. A., and Khudyaeva, G. I. (Astrophysical Inst. Academy of Sciences of the Kazakh SSR, U.S.S.R.): 'Zonal Spectrophotometric Properties of the Jovian Cloud Cover', *Solar System Research* **15**(2) 71–78. (1981)

Latitude and longitude variations in the color properties of cloud formations on Jupiter have been studied using spectrograms of the central meridian of Jupiter obtained in 1979. A characteristic of these properties is the relative spectrophotometric gradient (G) determined in the region λ0.40–0.68 μm. During the period of observations the north tropic zone was bluest ($G = 0.03$); the southern dark equatorial belt ($G = + 0.46$) was reddest. Differences have been noted in the color of the northern and southern polar regions on Jupiter. There is a clear correlation between the color and relative albedo for cloud features, but it is not the same for different belts on the planet, and is not explained by a simple variation in the relative concentration of neutrally scattering particles of solid NH_3 and a mixture of colored material. As in various years, limb darkening in the polar regions is almost independent of wavelength, which may be explained only by the presence of aerosol in the upper atmosphere at high altitudes over the polar regions. An aerosol haze or an aerosol layer restricted in terms of altitude should have significant intrinsic absorption which is enhanced toward the short-wavelength region of the spectrum.

Tejfel', V. G., Kharitonova, G. A. and Khudyaeva, G. I.: 'Zonal Spectrophotometric Characteristics of Jupiter's Cloud Cover', (in Russian), *Astron. Vestn.* **15**, 95–104. (1981)

The latitudinal and longitudinal colour effects variations of Jupiter's cloud complexes were studied using central meridian spectrograms of Jupiter made in 1979.

Thomsen, M. F. and Goertz, C. K. (Max-Planck-Institut für Aeronomie, 3411 Katlenburg-Lindau 3, F.R.G.): 'Further Observational Support for the Limited-Latitude Magnetodisc Model of the Outer Jovian Magnetosphere', *J. Geophys. Res.* **86**, 7519–7526. (1981)

The distinction between the magnetic anomaly model of the outer Jovian magnetosphere and the magnetodisc model is reviewed, and a further observational comparison of the two models is pointed out. The comparison involves the latitudinal variation of the intensity of energetic charged particles confined near the magnetic equatorial plane. Because of this confinement, there should be a direct relationship between the maximum latitude excursion (relative to the magnetic equatorial plane) made by a spacecraft during one 10 hr planetary rotation period and the ratio of the maximum intensity observed in the magnetic equatorial plane to the minimum intensity observed off the equator. Thus if the maximum latitude excursion is large, the minimum between two maxima should be quite deep. If the maximum latitude excursion is known, a scale height for the energetic particle confinement can be

estimated from observed maximum-to-minimum ratios. The two magnetospheric models (magnetic anomaly and magnetodisc) in general predict different maximum latitude excursions. For the outbound passes of Voyagers 1 and 2, these predictions are combined with observations of energetic particle intensities to calculate the confinement scale heights for the energetic particles. For the magnetodisc model, the scale height is generally less than $2R_J$ and is a weakly decreasing function of r, in excellent quantitative agreement with the scale height derived from a combination of simple MHD theory and a magnetic field model based on Pioneer 10 outbound magnetic field measurements. The magnetic anomaly model, on the other hand, yields a scale height which apparently increases to large values at large radial distances. Furthermore, when the calculation is reversed for the magnetodisc model, so that the observed max/min ratio is combined with the theoretically predicted scale height to yield a maximum latitude excursion for each of the current sheet encounters, it is found that the resultant current sheet latitude agrees very well with the current sheet latitude estimated on other grounds, namely, the timing of the intensity maxima. Moreover, as shown by Goertz (1981), excursions of this current sheet latitude away from the nominal value of 9.6° are reasonably well associated with periods of enhanced solar wind dynamic pressure.

Tyler, G. L., Marouf, E. A. and Wood, G. E. (Stanford Univ., Stanford, CA 94305): 'Radio Occulatation of Jupiter's Ring: Bounds on Optical Depth and Particle Size and a Comparison with Infrared and Optical Results', *J. Geophys. Res.* **86**, 8699–8703. (1981)

The Jovian ring is not detectable in Voyager 1 radio occultation data, setting the bounds on its optical thickness of 2×10^{-4} and 5×10^{-4} at 13 and 3.6 cm wavelengths, respectively. Comparison of results at radio, infrared, and optical wavelengths suggests a population density that either falls more rapidly than the inverse square of the linear size or is sharply bounded in maximum particle size. A fragmentation power law, $\sim a^p$ for $a_{min} < a < a_{max}$, where a is the particle radius, and power index p between -3 and -4 leads to a minimum size estimate $a_{min} \simeq 1$–$2\ \mu$m. A specific model which is consistent with all observations consists of a power law distribution of lossless or very slightly absorbent Mie scatterers with refractive index near 1.62, power law index p approximately -3.5, and a minimum particle size or about 1.5 μm. In this model the upper size limit a_{max} is not critical, provided that it is greater than about 4 μm.

Vasyliunas, V. M. and Dessler, A. J. (Max-Planck-Insitut für Aeronomie, D-3411 Katlenburg-Lindau 3, F.R.G.): 'The Magnetic-Anomaly Model of the Jovian Magnetosphere: A Post-Voyager Assessment', *J. Geophys. Res.* **86**, 3435–8446. (1981)

We reexamine the three predictions that we previously put forth as tests for the magnetic-anomaly model (in which the anomalously weak magnetic field region in the northern hemisphere of Jupiter influences the outer Jovian magnetosphere by one or more plasma interaction processes), taking into account the Voyager and other recent observations. Concerning the prediction of a restricted longitude range of enhanced interaction between Io and Jupiter's ionosphere, the longitudinal asymmetries seen in groundbased observations of sulfur emissions from the Io torus as well as in Voyager observations of Jovian auroral emissions agree with the predicted asymmetries. The lowered estimates of the Alfvén speed in the Io torus as a result of Voyager composition determinations modify many earlier ideas on the magnetosphere/Io interaction, but the conclusion remains that longitudinal asymmetries with a 360° period can be plausibly explained only by reference to magnetic-anomaly effects. Concerning the predictions of plasma, energetic particle, and magnetic field periodicities in the outer magnetosphere being related to either a current sheet or a magnetic-anomaly effect, we conclude that the hitherto common interpretation of Voyager observations in terms of a current sheet with no logitudinal asymmetries is seriously deficient because a bending of the current sheet from 40 to $60R_J$ outward is required whereas the Pioneer 10 observations demand that there be no such bending; attempts to reconcile Voyager and Pioneer by invoking time variations or solar wind effects are inconsistent with the observed constancy of propagation speeds for configurational changes and with the observed ratio of magnetic pressur to solar wind pressure. We construct a simple quantitative model with a sinusoidal longitudinal variation of inverse speed and show that the inclusion of such a variation of propagation speed (as implied by the magnetic-anomaly model) into the description of the current

sheet removes these inconsistencies and allows a unified interpretation of both Voyager and Pioneer observations. Concerning the prediction of a longitudinally restricted distribution of magnetopoause crossings, the evidence for a clustering of magnetopoause crossings near the active sector remains suggestive but statistically inconclusive. These results, combined with a number of other observed phenomena that cannot be accounted for by a pure magnetodisc model with no longitudinal asymmetries, provide eivdence that magnetic-anomaly effects play a significant role in determining the behavior of the Jovian magnetosphere.

Ververka, J., Thomas, P., Davies, M. E., and Morrison, D. (Lab. for Planetary Studies, Cornell Univ., Ithaca, NY 14853): 'Amalthea: Voyager Imaging Results', *J. Geophys. Res.* **86**, 8675–8692. (1981)

Voyager images of Amalthea reveal a very irregular satellite with dimensions of some 270 × 165 × 150 km, in synchronous rotation relative to Jupiter. Amalthea is nearly as elongated and as large as the Trojan asteroid Hektor. Its surface is scarred by large craters, sharp ridges, and other prominent topography suggestive of a long history of cosmic battering. The largest crater on the satellite, Pan, is about 90 km across. The normal reflectance of the surface is very low (5–6%); the color is very red. We find that Amalthea's mean opposition magnitude is $V = +14$ and that the magnitude difference between eastern and western elongation does not exceed + 0.1. The phase coefficient between phase angles of 0.8° and 42° of 0.042 ± 0.004 mag/deg indicates that the phase integral does not exceed 0.3 and that the Bond Albedo is less than 0.02. Amalthea is redder than typical Trojan asteroids, but not quite as red as parts of Io. Laboratory simulations show that the combination of low albedo and red color probably requires contamination of the surface by sulfur, the most likely source of which is Io. A noteworthy mystery concerning Amalthea is the composition of the material in several prominent bright spots. These isolated spots (typically 10–50 km across) occur preferentially on local slopes and ridges, have albedos several times higher than the background, and have a greenish color (the spectrum bends down beyond 0.56 μm).

Veverka, J., Simonelli, D., Thomas, P., Morrison, D., and Johnson, T. V. (Lab. for Planetary Studies, Cornell Univ., Ithaca, NY 14853): 'Voyager Search for Posteclipse Brightening on Io', *Icarus* **47**, 60–74. (1981)

Observations of three eclipse reappearances of Io were made during the two Voyager encounters. No posteclipse brightening of the type reported by some Earth-based observers – a brightening by some 10% just after eclipse which gradually disappears on a time scale of 10 to 15 min – was detected. Our negative result has a number of implications. First, it suggests that large areas of the surface of Io might not consist predominantly of yellow elemental sulfur (S_8), because the reflectance of this material changes measurably over the temperature range experienced by the surface of Io following an eclipse. Other allotropes or sulfur compounds are probably responsible for the yellow color of some areas of Io. Second, at most locations the amount of SO_2 vapor above the surface at local noon must be considerably less than the 0.2 cm atm measured by IRIS near the erupting volcano Loki, on March 5, 1979. We note that our data suggest a slight posteclipse brightening of the south polar region of Io, but with an amplitude (~3%) and a time scale (about 3 min) quite distinct from those reported for the classical whole-disk phenomenon. This small possible effect needs to be confirmed by detailed picture differencing, but if real, it appears to involve both the brightening and darkening of small localized areas.

Warwick, J. W. (Radiphysics, Inc., Boulder, CO 80301): 'Models for Jupiter's Decametric Arcs', *J. Geophys. Res.* **86**, 8585–8592. (1981)

Several papers of the present issue attempt to explain the remarkable arc-shaped structures that dominate Jupiter's decametric emissions as recorded by Voyagers 1 and 2. Since these papers approach this subject from very different points of view, the introduction is designed to place these perspectives in context. The present paper understands these arcs in terms of a magnetic fine structure undetected by Pioneer 11 on account of its rather large closest approach distance (50 or 60 times the smallest scales in the structures involved). The nested sequences of arcs manifest the occurrence of widespread fine structures, similar in size and shape to the white ovals so ubiquitous over Jupiter's visible surface. An arc concave toward increasing time (vertex early) occurs at the east limb passage of such a structure, and the arc convex (vertex late) occurs at the west limb passage. This is consistent with the early source producing vertex early arcs and the late (and main) source producing vertex late arcs. Since arcs seem naturally to classify themselves into two large families – greater arcs (reaching frequencies ⩾ 20 MHz) and lesser arcs (below 20 MHz) – polarized invariably right hand, or right hand or left hand symmetrically in longitude, respectively, we identify the righ-hand greater arcs with north polar cap cources, the lesser right-hand (left hand) arcs with north (south) temperate sources, and call for the absence of fine magnetic structure in Jupiter's southern polar cap.

West, R. A., Hord, C. W., Simmons, K. E., Coffeen, D. L, Sato, M., and Lane, A. L. (Lab. for Atmospheric and Space Physics, Univ. of Colorado, Boulder, CO 80309): 'Near-Ultraviolet Scattering Properties of Jupiter', *J. Geophys. Res.* **86**, 8783–8792. (1981)

The Voyager 2 photopolarimeter experiment obtained photometric observations of Jupiter at four phase angles between 20° and 80° and at various illumination angles from limb to terminator. These data were analyzed to determine the altitude distribution and scattering properties of the material responsible for Jupiter's low geometric albedo at 2400 Å. In polar regions the absorber must be higher than 40 mbar. In mid-latitudes, center-to-limb measurements indicate that most of the absorbing material lies deeper than 100 mbar. Absolute reflectivity requires a considerable amount above 400 mbar. The maximum amount of solar UV flux below 2550 Å available for heating the stratosphere at 20° latitude is only 10^{-4} of the solar constant at Jupiter. The latitudinal distribution of stratospheric absorbers suggests that energy deposition from the magnetosphere is important in their formation. We examine the scattering properties of model atmospheres containing three distinct aerosol size distributions. Rayleigh's phase function fits our data at several phase angles better than any particle phase function. We derive an upper limit to the column abundance of particles larger than 0.05 μm radius in the north tropical zone and north equatorial belt. These regions contain less than one extinction optical depth at 2400 Å of such particles above the 100 mbar altitude. Rayleigh scattering from the top 100 mbar obscures effects due to scattering from the deeper absorbing particles over our range of phase angles. We are unable to determine whether the absorbers are particulate or molecular.

Woronow, A. and Strom, R. G. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Limits on Large-Crater Production and Obliteration on Callisto', *Geophys. Res. Lett.* 8, 891–894. (1981)

By comparing results of Monte Carlo simulations of the crater population on Callisto with the observed surface, we demonstrate that the relative dearth of large craters on Ganymede and Callisto, compared with the terrestrial planets, can not be totally ascribed either to craters relaxing or to craters piercing a thin icy crust. Consequently, the population of objects responsible for the heavy bombardment of the Jovian system differed markedly from that responsible for the late heavy bombardment of the terrestrial planets.

Yoder, C. F. and Peale, S. J. (Jet Propulsion Lab., Pasadena, CA 91109): 'The Tides of Io', *Icarus* **47**, 1–35. (1981)

The Galilean satellites Io, Europa, and Ganymede interact through several stable orbital resonances where $\lambda_1 - 2\lambda_2 + \tilde{\omega}_1 = 0$, $\lambda_1 - 2\lambda_2 + \tilde{\omega}_2 = 180°$, $\lambda_2 - 2\lambda_3 + \tilde{\omega}_2 = 0$ and $\lambda_1 - 3\lambda_2 + 2\lambda_3 = 180°$, with λ_i being the mean longitude of the ith satellite and $\tilde{\omega}_i$ the longitude of the pericenter. The last relation involving all three bodies is known as the Laplace relation. A theory of origin and subsequent evolution of these resonances outlined earlier (C. F. Yoder, 1979b, *Nature* **279**, 747–770) is described in detail. From an initially quasi-random distribution of the orbits the resonances are assembled through differential tidal expansion of the orbits. Io is driven out most rapidly and the first two resonance variables above are captured into libration about 0 and 180° respectively with unit probability. The orbits of Io and Europa expand together maintaining the 2:1 orbital commensurability and Europa's mean angular velocity approaches a value which is twice that of Ganymede. The third resonance variable and simultaneously the Laplace angle are captured into libration with probability ~ 0.9. The tidal dissipation in Io is vital for the rapid damping of the libration amplitudes and for the establishment of a quasi-stationary orbital configuration. Here the eccentricity of Io's orbit is determined by a balance between the effects of tidal dissipation in Io and that in Jupiter, and its measured value leads to the relation $k_1 f_1/Q_1 \approx 900 k_J/Q_J$ with the k's being Love numbers, the Q's dissiptation factors, and f a factor to account for a molten core in Io. This relation and an upper bound on Q_1 deduced from Io's observed thermal activity establishes the bounds $6 \times 10^4 < Q_J < 2 \times 10^6$, where the lower bound follows from the limited expansion of the satellite orbits. The damping time for the Laplace libration and therefore a minimum lifetime of the resonance is $1600 Q_J$ years. Passage of the system through nearby three-body resonances excites free eccentricities. The remnant free eccentricity of Europa leads to the relation $Q_2/f_2 \gtrsim 2 \times 10^{-4}\, Q_J$ for rigidity $\mu_2 = 5 \times 10^{11}$ dynes/cm^2. Probably capture into any of several stable 3:1 two-body resonances implies that the ratio of the orbital mean motions of any adjacent pair of satellites was never this large.

A generalized Hamiltonian theory of the resonances in which third-order terms in eccentricity are retained is developed to evaluate the hypothesis that the resonances were of primordial origin. The Laplace relation is unstable for values of Io's eccentricity $e_1 > 0.012$ showing that the theory which retains only the linear terms in e_1 is not valid for values of e_1 larger than about twice the current value. Processes by which the resonances can be established at the time of satellite formation are undefined, but even if primordial formation is conjectured, the bounds established above for Q_J cannot be relaxed. Electromagnetic torques on Io are also not sufficient to relax the bounds on Q_J. Some ideas on processes for the dissipation of tidal energy in Jupiter yield values of Q_J within the dynamical bounds, but no theory has produced a Q_J small enough to be compatible with the measurements of heat flow from Io given the above relation between Q_1 and Q_J. Tentative observational bounds on the secular acceleration of Io's mean motion are also shown not to be consistent with such low values of Q_J. Io's heat flow may therefore be episodic. Q_J may actually be determined from improved analysis of 300 years of eclipse data.

Zwickl, R. D., Krimigis, S. M., Carbary, J. F., Keath, E. P., Armstrong, T. P., Hamilton, D. C., and Gloeckler, G. (Univ. of California, Los Alamos Scientific Lab., Los Alamos, NM 87545): 'Energetic Particle Events (≥ 30 keV) of Jovian Origin Observed by Voyager 1 and 2 in Interplanetary Space', *J. Geophys. Res.* **86**, 8125–8140. (1981)

Short-lived and long-lived ion flux increases ($E \geqslant 30$ keV) of Jovian origin have been observed by the low energy charged particle (LECP) instrument on the Voyager 1 and 2 spacecraft. The short-lived events are observed more than $860 R_J$ upstream and more than $1500 R_J$ downstream of Jupiter. Observations of long-lived events appear to be confined to $\lesssim 200 R_J$ upstream of Jupiter. The short-lived events last from a few minutes to a couple of hours, while the long-lived events last from 8 to 21 hr. Both types of events have sharp onsets and decays, are usually confined to energies below 1 MeV total energy, and show a large general enrichment of $Z \geqslant 6$ particles relative to proton and helium particles when compared with energetic particle events of solar or interplanetary origin. Many of the events have a noticeable peak in the energy spectrum above 100 keV after the main portion of the event. In addition, the short-lived events (upstream and downstream) are (1) extremely anisotropic with a flow direction consistent with flow away from Jupiter, (2) display no noticeable velocity dispersion, and (3) display initially steep energy spectra that flatten with time. The peak flux level at the lowest energies in the magnetosheath is similar to that observed during long-lived events. We conclude that a significant fraction of the particles observed during Jovian ion events originate from within the magnetosphere of Jupiter and simply leak out into the magnetosheath. If the interplanetary magnetic field favorably connects to the bow shock, particles can leak out into the interplanetary medium. Together with the necessary leakage model, the observations presented here cannot rule out the existence of a wave particle acceleration region located immediately upstream of the bow shock.

2. Mars

Débarbat, S. and Sanchez, M. (Observatoire de Paris, 61 Avenue de l'Observatoire, F-75014 Paris, France): 'Mars Around 1975 and 1978 Oppositions' (in French), *Astron. Astrophys.* **96**, 193–197. (1981)

After the 1975–1976 campaign of the planet Mars, a new set of observations has been obtained at the San Fernando and Paris astrolabes, during the winter 1977–1978.

The observations are analysed, in a first step, in the same way as it has been made previously. Figure 1 and Table 1 show the results for differences 'Astrolabe–American Ephemeris', both for right ascension and declination (with, in Table 1, results of the 1975–1976 campaign). Figure 2, to be compared to Figure 1 of Débarbat *et al.* (1979a), shows results obtained for two kinds of ephemerides (American Ephemeris and the ones provided by P. K. Seidelmann).

In a second step, a possible phase effect, mentioned by various authors, is studied. First: the classical phase corrections are studied; mean square errors and accuracy of the smoothing curves are given in Table 2. Second: comparison of results for the 1975–1976 campaign is made with other instruments (Fig. 3). Third: the two campaigns and the two ephemerides are taken into account for the astrolabe observations (Figures 4 and 5); the results with the revised ephemerides (Figure 6) are to be compared with those from Standish *et al.* (1976, Figure 5c).

Despite the very small number of data, conclusions are the following: the 1977–1978 campaign confirms the results of the previous one (Débarbat *et al.*, 1979a) regarding the explanation given by Duncombe, Kubo and Seidelmann, concerning the error in the inclination of the Mars orbit; the possible phase effect is found in the astrolabe observations but some discrepancies remain to be explained. New observations, with various techniques and instruments, are needed.

Eberhart, J.: 'Return to Mars – Economy Class', *Science News* **120**, 42–44. (1981)

Five years after the first successful Mars landing, planners of follow-up missions are thinking small.

Gogoshev, M. M. and Komitov, B. P. (Central Lab. for Space Research, Astronomical Observatory, 6000 Stara Zagora, Bulgaria): 'Spectra of Fresh Photoelectrons in the Martian Atmosphere', *Advances in Space Research* **1**, 155–160. (1981)

In this paper the latest neutral and ionospheric models of the upper Martian atmosphere, created on the Viking data are used. For the calculations of the photoelectron spectra the Hinteregger's measurements fo the solar flux together with the theoretical photoelectron distribution are also used.

Guinness, E. A. (Dept. of Earth and Planetary Sciences, Washington Univ., St. Louis, MO 63130): 'Spectral Properties (0.40 to 0.75 Microns) of Soils Exposed at the Viking 1 Landing Site' *J. Geophys. Res.* **86**, 7983–7992. (1981)

The bidirectional reflectance and photometric function (Hapke, 1981) was determined for seven patches of soil located near the Viking Lander 1 spacecraft. The soil photometric function is strongly backscattering and has a prominent opposition effect such at the ratio of reflectances at 1° and 10° phase angles averages 1.25, 1.24 and 1.19 in blue, green, and red wavelengths, respectively. The reflectance of the soil also exhibits a wavelength dependence as a function of phase angle. For instance, red/blue ratios can vary by up to 33% as the phase angle increases from 10° to 75°. Estimates of soil reflectance at a 5° phase angle averaged over the blue and green passbands of the Viking Lander cameras are 0.11 and 0.17, respectively, while estimates of soil reflectance averaged over the red channel range from 0.30 to 0.39. There is little need to call upon mineralogical variations to explain the subtle color variations exposed at the landing sites. Rather, brightness and color variations within the soil can be correlated with particle size, with finer-grained soil being brighter and redder than coarser-grained soil. When compared to earth-based reflectance data, the soil at the Viking 1 site is most like Martian bright areas. Such a result is consistent with the Lander soil being part of a globally homogenized soil unit.

Hoffert, M. I., Callegari, A. J., Hsieh, T., and Ziegler, W. (Dept. of Applied Science, New York Univ., New York, NY 10003): 'Liquid Water On Mars: An Energy Balance Climate Model for CO_2/H_2O Atmospheres', *Icarus* **47**, 112–129. (1981)

Geologic evidence of the prior existence of liquid water on Mars suggests surface temperatures T_s were once considerably warmer than at present; and that such a condition may have arisen from a larger

atmospheric greenhouse. Here we develop a simple climate model for a CO_2/H_2O Mars atmopshere including water vapor–longwave opacity feedback in the atmosphere and temperature–albedo feedback at surface icecaps, under the assumption that once the Martian surface pressure was $p_s \geqslant 1$ atm CO_2. Longwave flux to space is computed as a function of T_S and p_S using band-absorption models for the effect of the 15 μm fundamental, and the 10 and 15 μm hot bands, of the CO_2 molecule; as well as the pure rotation bands and *e* continuum of H_2O. The derived global radiative balance predicts a global mean surface temperature of 283 K at 1 atm CO_2. When the emission model is coupled to a latitudinally resolved energy balance climate model, including the effect of poleward heat transfer by atmospheric baroclinic eddies, the solutions vary, depending on p_S. We considered two cases: (1) the present Mars ($p_s \simeq 0.007$ atm) with pressure-buffering by solid CO_2 icecaps, and limited poleward heat flux by the atmosphere; and (2) a hypothetical 'hot Mars' ($p_S \simeq 1.0$ atm), whose much higher CO_2 amount augmented by H_2O evaporative feedback yields a theoretical T_S distribution with latitude admitting liquid water over 95% of the surface, water icecaps at the poles, and a diminished equator-to-pole temperature gradient relative to the present.

Hunt, G. E., Pickersgill, A. O., James, P. B., and Evans, N. (Lab. for Planetary Atmospheres, Dept. of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK): 'Daily and Seasonal Viking Observations of Martian Bore Wave Systems', *Nature* **293**, 630–633. (1981)

A Martian atmospheric phenomenon called a 'bore wave' has been observed by the Viking imaging system during late spring and early summer of two Martian years, in the Tharsis Ridge region of the planet. Here we present the observational data and offer a tentative explanation for the occurrence of this feature, formed by airflow and which behaves like a thermally induced diurnal katabatic breeze.

Illes, E. and Horvath, A. (Konkoly Observatory, 1525 Budapest, Box 67, Hungary): 'On the Origin of the Grooves on Phobos', *Advances in Space Res.* **1**, 49–52. (1981)

L-grooves are the consequence of layered structure of Phobos, which are made up of parallel layers of different composition or hardness.

Imshenetsky, A. A., Murzakov, B. G., Evdokimova, M. D., and Dorofeyeva, I. K. (Inst. of Microbiology, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.): 'Biological Studies of Martian Soil Analogues', *Advances in Space Res.* **1**(14), 21–26. (1981)

Results of the study of the influence of Martial soil analogues, both as described by American scientists and as prepared by us, and of hydrogen peroxide on the viability of microorganisms are presented. The experiments were carried out using mixtures of soil analogues with desert soil and black earth (chernozem) samples, and pure cultures of microorganism. Microorganisms capable of withstanding a concentration of hydrogen peroxide in the medium as high as 1.5–2.0% were isolated. None of the 40 strains of microorganisms studied, all belonging to different systematic and physiological groups, exhibited growth inhibition on solid media in the presence of Martian soil analogues. In view of the fact that Martian soil cannot contain microorganisms in great quantities, we suggest using electroadsorption for their concentration, to make detection reliable. A device was designed for this purpose, using the principle of electroadsorption on a polarisable carrier (sterile cotton wool or cheesecloth). The concentrated suspension of microorganisms thus obtained was then characterized by various physicochemical methods.

James, P. B. and Evans, N. (Dept. of Physics, Univ. of Missouri at St. Louis, St. Louis, MO 73121): 'A Local Dust Storm in the Chryse Region of Mars: Viking Orbiter Observations', *Geophys. Res. Lett.* 8, 903–906. (1981)

A local dust storm was observed near the Viking Lander 1 site by Viking orbiter 1 in September, 1977, when the aerocentric longitude of the Sun, L_s, was 340° (shortly before vernal equinox). This orbiter observations, which consisted of a time sequence of picutres, show that the storm moved at about 50 m sec^{-1} to the ENE from the Lunae-Planum region into the Chryse basin. Both baroclinic waves and topography may have been associated with the generation of the storm.

Kahn, R., Goody, R., and Pollack, J. B. (Center for Earth and Planetary Physics, Harvard Univ., Cambridge, MA 02138): 'The Martian Twilight', *J. Geophys. Res.* **86**, 5833–5838. (1981)

The changing sky brightness during the Martian twilight as measured by the Viking lander cameras is shown to be consistent with data obtained from sky brightness measurements. An exponential distribution of dust with a scale height of 10 km, equal to the atmospheric scale height, it consistent with the shape of the light curve. Multiple scattering resulting from the forward scattering peak of large particles makes a major contribution to the intensity of the twilight. The spectral distribution of light in the twilight sky may require slightly different optical properties for the scattering particles at high levels from those of the aerosol at lower levels.

Lambeck, K. and Christensen, E. J. (Research School of Earth Sciences, Australian National Univ., Canberra 2600, Australia): 'Comment on "Development and Analysis of a Twelfth Degree and Order Gravity Model for Mars"; and Reply', *J. Geophys. Res.* **86**, 6382–6383. (1981)

Neukum, G. and Hiller, (Institut für allgemeine und angewandte Geologie, Ludwig-Maximilians-Universität München, 8000 München 2, F.R.G.): 'Martian Ages', *J. Geophys. Res.* **86**, 3097–3121. (1981)

The subjects of this paper are a discussion of the methodology of relative age determination by impact crater statistics, a comparison of currently proposed Martian impact chronologies for the determination of absolute ages from crater frequencies, a report on our work of dating Martian volcanoes and erosional features by impact crater statistics, and an attempt to understand the main features of Martian history through a synthesis of our crater frequency data and those published by other authors. Two cratering chronology models are presented and used for inference of absolute ages from crater frequency data: model I, with nearly equal Martian and lunar cratering rates around (ca.) 4 to 10 km crater sizes, and model II, equivalent to model I for ages $> 3.5 \times 10^9$ yr but with a factor of 2 higher Martian cratering rate at ages $< 3 \times 10^9$ yr. Those model cratering chronologies are applied to the data. The interpretation of all crater frequency data available and tractable by our methodology leads to a global Martian geological history that is characterized essentially by two epochs of activity. The division between the two epochs is measured at a cumulative crater frequency value for 1 km craters (crater retention age) of $N(1) = 8 \times 10^4 (\text{km}^{-2})$ corresponding to an absolute age of ca. 3×10^9 yr (applying model I cratering chronology) and of ca. 1.5×10^9 yr (applying model II cratering chronology). In the ancient epoch all major events like emplacement of the plains lavas, the piling up of most volcanic constructs, and large-scale erosion of channels and mensae (highland/northern lowland boundary) have taken place. During the younger epoch, only the big Tharsis shield volcanoes were active, and some minor erosion took place. This means that Mars is not a youthful planet but an ancient one with respect to most of its surface features.

No Author Cited: 'Mars 5 Years After', *Astronomy* 9(7) 6–17. (1981)

The impact of the Viking data on Martian science is emphasized.

Peebles, C.: 'The Martian Rovers', *Spaceflight* **23**, 202–204. (1981)

In the early hours of 20 July, 1976, mankind received its first photos from the surface of Mars. In the months and years that followed, more images would come from the cold lonely Martian plains. Yet for all the accomplishments of the two Viking landers, they had shown us only a small area of Mars. Dividing the red dustry surface and the orange sky was the distant unknown horizon, always beckoning onward. And for all the stationary landers could tell us just beyond that horizon awaited the fabled, jewelled towers of some long dead Martian civilization.

Ryan, J. A., Sharman, R. D. and Lucich, R. D. (Dept. of Earth Science, California State Univ., Fullerton, Fullerton, CA 92634): 'Local Mars Dust Storm Generation Mechanism', *Geophys. Res. Lett.* **8**, 899–901. (1981)

On $L_s = 340°$, first Mars year of Viking on the surface, a local dust storm was observed at the Viking Lander #1 site by Viking Orbiter A. The storm lasted less than one Martian day (sol) with the dust raised affecting the site for about three sols. It is concluded that this storm was caused by baroclinic waves and that the threshold wind speed for saltation was 25–30 m s^{-1}.

3. Mercury

Cordell, B. M. and Ronca, L. B. (Dept. of Physics, Central Connecticut State College, New Britain, CT 06050): 'Early Fluctuations in the Radius of Mercury', *Modern Geology* 7, 209–216. (1981)

Observations of the surface of Mercury reveal many dozens of fault escarpments that record an episode of global contraction early in the planet's history. There is no evidence for global expansion. Homogeneous accretion models for Mercury involving heating and fore formation predict significant global expansions shortly after planet origin. Where are the resultant rifts? A statistical argument shows that cratering is inadequate to destroy all hypothetical rifts. A simple analytical model of magma ocean convection indicates that planetary lithospheres become elastic in times short compared to the interval between planet origin and core formation (i.e. expansion), so surface fractures could have occurred. Comparative planetology and stratigraphic relations argue that volcanism should have not obscured all rifts. Therefore, an early global expansion may not have occurred and alternate models for the early evolution of Mercury may have to be explored.

Goldstein, B. E., Suess, S. T., and Walker, R. J. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Mercury: Magnetospheric Processes and the Atmospheric Supply and Loss Rates', *J. Geophys. Res.* **86**, 5485–5499. (1981)

Magnetospheric processes at Mercury are investigated to determine how they affect the source and loss rates of the neutral He and H atmosphere. The atmospheric source rate caused by direct impact of the solar wind on the planetary surface is estimated by using a model that included the effect of the large planetary core upon the compressibility of the magnetosphere. As the nonconducting planetary surface could inhibit Birkeland currents that cause erosion of the dayside magnetosphere, the impact of the solar wind on the surface is modeled with and without the effects of erosion. The solar wind impacts the surface, at most, only about 6% of the time, and the resulting atmospheric supply rate is negligible. The flux on closed dayside field lines is estimated to be roughly comparable to the flux to the surface along open dayside field lines in the polar cap region. The flux to the surface from the plasma sheet is estimated as being about three times either of these sources, provided that all sunward convected particles in the tail precipitate to the surface. A comparison of the flux available form convection with the flux that would precipitate to the 'auroral zones' under the assumption of strong pitch angle scattering shows that the strong pitch angle scattering assumption may be invalid at Mercury, owing to the large size of the loss cone. Observations of a correlation between the lunar atmosphere He content and *Kp*, and consideration of surface processes, suggest that a significant fraction of the He striking the surface eventually enters the atmosphere. Loss mechanisms are also investigated. The extent to which magnetospheric convection recycles photoions (created at both high and low latitudes) back to the planetary surface, and to a lesser extent the uncertainty in the number of atoms exposed to sunlight, leads to considerable uncertainty in atmospheric loss estimates. An examination of atmospheric losses caused by electron impact ionization in the 'auroral zone' indicates that this mechanism does not compete with photoionization. The estimated solar wind supply of He to the surface is in the range 3.9×10^{22}–2.3×10^{23} s^{-1}, the estimated radiogenic supply is between 6.9×10^{21} and 4.6×10^{22} s^{-1}, and the loss rate is estimated as between 1.2×10^{22} and 1.1×10^{23} s^{-1}.

Jeffreys, H. (160 Huntingdon Road, Cambridge, UK): 'The Mass of Mercury', *Quart. J. Roy. Astron. Soc.* **22**, 320–321. (1981)

Lyttleton, R. A. (Inst. of Astronomy, Madingley Road, Cambridge, CB3 0HA, Cambridge, UK): 'More Thoughts About Mercury', *Quart. J. Roy. Astron. Soc.* **22**, 322–323. (1981)

4. Neptune

Belton, M. J. S., Wallace, L., and Howard, S. (Kitt Peak National Observatory, Tucson, AZ 87526): The Periods of Neptune: Evidence for Atmospheric Motions', *Icarus* **46**, 263–274. (1981)

An extended photometric time series in the J and K bands of Neptune has a complex appearance which appears to require the simultaneous presence of three periodicities plus related harmonics in the $(J-K)$ color. The most apparent of the fundamental periods is N1 = 17.73 hr. The two others are at N2 = 18.56 and N3 = 18.29 hr and may be the result of amplitude modulation of a previously reported period of 18.42 hr. We interpret the presence of multiple periodicity as indicating that distinct systems of zonal winds exist on the planet. We argue that these wind systems are probably confined to moderate or high latitudes on the basis of recent images of the planet taken in a spectral region of strong CH_4 absorption, and, by analogy to the zonal wind systems that exist in Jupiter's atmosphere, deduce a period of rotation for the body of the planet of 18.2 ± 0.4 hr. Zonal wind contrasts of up to 109 m s^{-1} are implied in the atmosphere of Neptune by these observations.

Combes, M., Encrenaz, T., Lecacheux, J., and Perrier, C. (Observatoire de Paris-Meudon, 92190 Meudon, France): 'Upper Limit of the Gaseous CH_4 abundance on Triton', *Icarus* **47**, 139–141. (1981)

A spectrum of Triton between 6000 and 9000 Å was recorded in June 1980 at the ESO 1.52 m telescope in La Silla. From these data, an upper limit of 3.5 m am is derived for the CH_4 gaseous abundance on Triton.

Johnson, J. R., Fink, U., Smith, B. A., and Reitsema, H. J. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 95721): 'Spectrophotometry and Upper Limit of Gaseous CH_4 for Triton', *Icarus* **46**, 288–291. (1981)

Spectra of Triton with a CCD spectrometer yielded a relative spectral reflectivity curve from 0.56 to 1.05 μm at a resolution of 25 Å. Using low-temperature band model parameters from Fink *et al.* (1980), an upper limit for the one-way path gaseous CH_4 abundance of 1 m am was derived.

Kerr, R. A.: 'Neptune's Rings Fading', *Science* **213**, 1240. (1981)

Rieke, G. H., Lebofsky, L. A., Lebofsky, M. J., and Montgomery, E. F.: 'Unidentified Features in the Spectrum of Triton', Prepr. Steward Obs., No. 333, 5 pp. (1981).

The infrared spectrum of Triton, the largest satellite of Neptune, has some resemblance to the spectrum of methane or methane frost, but this identification is not consistent with all available data. The authors have used the Multiple Mirror Telescope (MMT) to obtain an improved infrared spectrum of Triton. These observations show features that are not in detailed agreement with the identification of methane, although the general spectral behavior that led to this identification is confirmed. A satisfactory identification of the surface and/or atmospheric composition on Triton does not seem possible at present.

5. Pluto

Hege, E. K., Hubbard, E. N., Drummond, J. D., Strittmatter, P. A., Worden, S. P., and Lauer T.: 'Speckle Interferometric Observations of Pluto and Charon', Prep. Steward Obs., No. 355, 26 pp. (1981).

The authors report speckle interferometric observations of Pluto and its moon Charon obtained on 5 June, 1980 with a single 1.8 m mirror of the Multiple Mirror Telescope. The observations yield a separation of 0\".31 (± 0\".05) between Pluto and Charon at position angle 285° (± 7°) for JD 2444395.75. This result and other direct observations indicate an adjustment of 4.0 hr to the orbital epoch of Harrington and Christy (1981).

Mignard, F. (C.E.R.G.A., F-06130 Grasse, France): 'On a Possible Origin of Charon', *Astron. Astrophys.* **96**, L1–L2. (1981)

The newly discovered Pluto's satellite, Charon, shows very interesting features: first it is likely tidally locked; second we establish in this paper that the toal angular momentum of this system is very similar to the one required for a rotational break-up of an initial fluid planet. Moreover such an origin is greatly supported by the now known value of the mass-ratio M_P/M_C and by a subsequent tidal evolution to the synchronous state.

6. Saturn

Acuna, M. H., Connerney, J. E. P., and Ness, N. F. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Topology of Saturn's Main Magnetic Field', *Nature* **292**, 721–724. (1981)

The Voyager 1 magnetic field observations at Saturn confirm the principally dipolar topology of the planetary magnetic field and suggest the need for more general models which incorporate non-potential field sources external to the planet and within the planetary magnetosphere.

Alfvén, H. (Dept. of Plasma Physics, Royal Inst. of Tech., Sweden): 'The Voyager 1 Saturn Encounter and the Cosmogonic Shadow Effect', *Astrophys. Space Sci.* **79**, 491–505. (1981)

If an electrically conducting medium (e.g. a dusty plasma rotates around a gravitating central body, which possesses an axisymmetric dipole field, the medium is supported by two-thirds by the centrifugal force and to one-third by electromagnetic forces under the condition that the magnetic field is strong enough to control the motion. If the electromagnetic forces disappear – e.g. by a de-ionisation of the dusty plasma – the medium will fall down to two-thirds of its original central distance. The result of this process will be a 'cosmogonic shadow effect' which is described in some detail.

The Voyager 1/Saturn results demonstrate that the macro-structure of the Saturnian ring system can be explained as a result of this effect working at the formation of the system. The agreement between the theoretical results and the observations is better than a few percent.

A similar analysis of the asteroidal belt shows that its macro-structure can also be explained by the cosmogonic shadow effect. The agreement between theory and observations is perhaps even better than in the Saturnian ring system.

The observational results demonstrate that duringt heir formation both the Saturnian ring and the asteroidal belt passed a plasma state dominated by electromagnetic effects.

Atreya, S. K. and Waite, J. H. Jr. (Dept of Atmospheric and Oceanic Science, Space Physics Research Lab., Univ. of Michigan, Ann Arbor, MI 48109): 'Saturn Ionosphere: Theoretical Interpretation', *Nature* **292**, 682–683. (1981)

Voyager 1 high latitude and Pioneer 11 equatorial ionospheric structure indicate a solar EUV-controlled ionosphere with possible molecular ion in the topside. Vibrationally excited H_2 in the high latitudes may be an important loss mechanism. Dynamical effects are expected to be important for determining the peak density and its location.

Baum, W. A., Kreidl, T., Westphal, J. A., Danielson, G. E. Jr., Seidelmann, P. K., Pascu, D., and Currie, D. G. (Lowell Observatory, Post Office Box 1269, Flagstaff, AZ 86002): 'Saturn's E Ring', *Icarus* **47**, 84–96. (1981)

The tenuous E ring of Saturn is found to commence abruptly at 3 Saturn radii, to peak sharply in the vicinity of the orbit of the satellite Enceladus (about 4 radii), and spread out thinly to more than 8 radii. This distribution strongly suggests it to be associated with Enceladus and perhaps to be material ejected from Enceladus. The spread of E-ring material above and belwo the ring plane is greater in its tenuous outskirts than in its denser inner region, suggesting that the E ring may be at an early stage in its evolution. Thus far, our analysis reveals only a marginal variation of the ring with time or Enceladus azimuth. In this paper we describe the special instrumentation used for photometric observations of the E ring, and we present some of the data obtained in March 1980. In Paper II we shall derive the three-dimensional distribution of material in the E ring and discuss its cosmogonic implications.

Beatty, J. K.: 'Saturn: "An Even Better Look"', *Sky Telesc.* **62**, 329–332. (1981)

Preliminary results of the Voyager-2 mission to Saturn are presented.

Beatty, J. K.: 'Voyager at Saturn, ACT II', *Sky Telesc.* **62**, 430–444. (1981)

A comprehensive report of the Voyager-2 mission is given.

Behannon, K. W., Connerney, J. E. P., and Ness, N. F. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, MD 20771): 'Saturn's Magnetic Tail: Structure and Dynamics', *Nature* **292**, 753–755. (1981)

Voyager 1 magnetic field observations have provided evidence of a saturnian magnetic tail. Tail current system distributions are inferred through comparison of the observations with a realistic magnetotail current system model. Tmeporal variations observed in the tail were probably produced by solar wind variations.

Berry, R.: 'The Voyager Casebook', *Astronomy* **9**(10) 18–22. (1981)

Berry, R. and Burnham, R.: 'Voyager 2 at Saturn' *Astronomy* **9**(11) 6–30. (1981)

Bjoraker, G. L., Larson, H. P., and Fink, U. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'A Study of Ethane on Saturn in the 3 Micron Region', *Astrophys. J.* **248**, 856–862. (1981)

We have detected C_2H_6 in absorption in high altitude spectroscopic observations of Saturn in the 3 μm region. Based upon comparisons with laboratory spectra of C_2H_6, our abundance estimate is $\eta a = 7.5 \pm 3.5$ cm amagat, equivalent to a column abundance of 3.0 ± 1.4 cm amagat. This value agrees well with predictions of models of CH_4 photolysis in the stratospheres of the outer planets. Compared to previous observational studies of gaseous hydrocarbons at thermal infrared wavelengths ($\lambda \sim 10\,\mu$m), out abondance is very much less dependent upon modeling the detailed atmospheric temperature profile and the vertical distribution of C_2H_6 in Saturn's atmosphere. Our observed column abundance is used as a constraint in the Strobel and the Yung and Strobel photochemical models to determine the vertical distribution of ethane on Saturn for two profiles of the eddy diffusion coefficient $K(z)$. In our analysis, we find the vertical distribution of C_2H_6 between the stratospheric production region and the reflecting layer boundary at the cloud top is consistent with a mixing ratio profile $f(z) = 2.3 \times 10^{-7} \exp(z/90\,\text{km})$. The corresponding profile of the eddy diffusion coefficient in Saturn's stratosphere is given by $K(z) = 500 \exp(z/90\,\text{km})\,\text{cm}^2\,\text{s}^{-1}$.

Boischot, A., Leblanc, Y., Lecacheux, A., Pedersen, B. M., and Kaiser, M. L. (Observatoire de Paris, F-92190 Meudon, France): 'Arc Structure in Saturn's Radio Dynamic Spectra', *Nature* **292**, 727–728. (1981)

The dynamic spectra of Saturn's kilometric radiation show arc structures whose main characteristics are described and compared with those observed in the decametre emission of Jupiter. The origin of the arcs is probably similar for the two planets.

Bugaenko, O. I. and Morozhenko, A. V. (Main Astronomical Observatory of the Ukrainian Academy of Sciences, Kiev, U.S.S.R.): 'Physical Characteristics of the Upper Layers of Saturn's Atmosphere', *Advances in Space Res.* **1**, 183–186. (1981)

Analysis of polarimetric observations of Saturn was carried out. In the long wavelength spectral range ($\lambda > 0.5\,\mu$m) polarimetric observations do not contradict the model of spherical or irregular randomly oriented particles. In the short wavelength spectral interval ($\lambda < 0.5\ \mu m$) it is necessary to take into account the scattering by oriented particles.

Capone, L. A., Prasad, S. S., Huntress, W. T., Whitten, R. C., Dubach, J., and Santhanam, K. (Dept. of Meteorology, San Jose State Univ., Sand Jose, CA 95192): 'Formation of Organic Molecules on Titan', *Nature* **293**, 45–46. (1981)

The unique atmospheric environment on Titan has stimulated great interest in its organic chemistry. Recently we proposed that simple organic-nitrogen compounds such as HCN could be efficiently formed by cosmic ray bombardment of a nitrogen-containing atmosphere on Titan. Voyager 1 has now verified that molecular nitrogen is indeed the major constituent on Titan and that HCN is also present. Based on these new data, we now propose that even morec omplex organic-nitrogen molecules such as ethyl cyanide (CH_3CH_2CN), vinyl cyanide (CH_2CHCN), and cyanoacetylene (HCCCN) may be formed efficiently in the lower atmosphere of Titan, where lower temperatures and higher densities will ensure the efficicy of three-body ion–molecule association reactions. Interestingly, these compounds have been found in several dark interstellar clouds, thus the chemistry suggested here is analogous to that proposed as an explanation of interstellar cyanopolyynes. The only difference is the role played by three-body association reactions in the dense lower atmosphere of Titan. The mechanism proposed here rests upon a firmer experimental foundation than the analogous radiative association reactions in interstellar clouds.

Carr, T. D., Schauble, J. J., and Schauble, C. C. (Dept. of Astronomy, Univ. of Florida, Gainesville, FL 32611): 'Pre-Encounter Distributions of Saturn's Low Frequency Radio Emissions', *Nature* **292**, 745–747. (1981)

An analysis of Voyager 1 pre-encounter data is presented in which one-month averages of flux density from Saturn are determined as functions of both central meridian longitude and frequency. Comparisons of corresponding distributions for two one-month intervals seven months apart yield information on their stability, and a redetermination of the magnetospheric rotation period.

Chaikin, A. L.: 'Robots for the Longest Voyage', *Sky Telesc.* **62**, 328. (1981)

A brief description of the Voyager spacecraft is given.

Connerney, J. E. P., Acuna, M. H., and Ness, N. F. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Saturn's Ring Current and Inner Magnetosphere', *Nature* **292**, 724–726. (1981)

The Voyager 1 magnetic field observations at Saturn reveal an equatorial system of (eastward) azimuthal currents, very similar in certain respects to that responsible for the Jovian magnetodisk.

Cuzzi, J. N., Lissaer, J. J., and Shu, F. H. (Ames Research Center, NASA, Moffett Field, CA 94035): 'Density Waves in Saturn's Rings', *Nature* **292**, 703–707. (1981)

Certain radial brightness variations in the outer Cassini division of Saturn's rings may be spiral density waves driven by Saturn's large moon Iapetus, in which case a value of $\sim 16\ g\ cm^{-2}$ for the surface density is calculated in the region where the waves are seen. The kinematic viscosity in the same region is $\sim 170\ cm^2\ s^{-1}$ and the vertical scale height of the ring is estimated to be a maximum of ~ 40 m.

Desch, M. D. and Kaiser, M. L. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Planetary Magnetospheres Branch, Greenbelt, MD 20771): 'Saturn's Kilometric Radiation: Satellite Modulation', *Nature* **292**, 739–741. (1981)

There is an episodic 66-h modulation of the Saturn kilometric radiation which is both frequency and Dione-phase dependent. The behaviour is significantly different from the way in which Io modulates the Jovian emission.

Eberhart, J.: 'Voyager 2; All Eyes and Ears for Saturn', *Science News* **120**, 106–108. (1981)

Eberhart, J.: 'First-Look Maps of Saturn's Moons', *Science News* **119**, 100, 108–109. (1981)

Evans, D. R., Warwick, J. W., Pearce, J. B., Carr, T. D., and Schauble, J. J. (Radiophysics, Inc., 1885 33rd Street, Boulder, CO 80301): 'Impulsive Radio Discharges Near Saturn', *Nature* **292**, 716–718. (1981)

An unexpected type of emission was observed during the Voyager 1 Saturn encounter. This consisted of periodic episodes of many impulsive discharges throughout the frequency range (20.4 kHz to 40.2 MHz) of the planetary radio astronomy experiment.

Flasar, F. M., Samuelson, R. E., and Conrath, B. J. (Lab. for Extraterrestrial Physics, NASA-Goddard Space Flight Center, Greenbelt, MD 20771): 'Titan's Atmosphere: Temperature and Dynamics', *Nature* **292**, 693–698. (1981)

In the lower atmosphere of Titan IR brightness temperatures exhibit meridional contrast $\lesssim 3$ K. Seasonal variations are absent because of the large radiative time constant. In the upper stratosphere meridional contrasts are ~ 20 K, consistent with 100 m s^{-1} cyclostrophic zonal winds, and the radiative time constant is short, implying a large seasonal variation in the temperature and wind field. The absence of longitudinal thermal structure implies that zonally symmetric flows effect the meridional transport of heat. A simple model yields meridional velocities $\sim 0.04 \text{ cm s}^{-1}$ and vertical eddy viscosities $\sim 10^3 \text{ cm}^2 \text{ s}^{-1}$ in the lower troposphere, and meridional velocities $\sim 5 \text{ cm s}^{-1}$ in the upper stratosphere.

Franck, S. (Central Earth Physics Inst., Academy of Sciences of the GDR, Potsdam, GDR): 'On the Luminosity of Saturn', *The Moon and the Planets* **25**, 131–132. (1981)

The paper gives a new explanation of Saturn's large heat output.

Gehrels, T.: 'Saturn from the Pioneer Spacecraft', *Cosmic Research* **19**, 190–208. (1981)

The article reviews the results of investigations of Saturn's magnetosphere, atmosphere, and internal structure, of Saturn's rings and satellites, and of the atmosphere of Titan, based on data from the Pioneer spacecraft which flew close by Saturn on September 1, 1979. The atmosphere of Saturn shows itself as a deep hazy layer in which not very many details are seen, but in which is revealed some similarity to jet streams. The distribution of the particles of material in the A and B rings is apparently bimodal. The rings consist of lumps of impure snow about 6 cm in diameter, formed by the intial accretion, whereas smaller lumps fill the Cassini division and the C ring. The F ring probably consists mainly of small satellites; this is apparently true also for the G ring, discovered by Van Allen and located immediately outside the F ring at a distance of about $2.52 R_S$ ($1 R_S = 60\,000$ km) from the center of Saturn. The E ring, discovered by Feibelman, is visible even from the earth. It is situated at a distance of between 4 and $6 R_S$, i.e., approximately in the same zone where there is strong absorption of trapped radiation and there is plasma: in the so-called slotted zone of the magnetosphere.

Gehrels, T. and Esposito, L. W. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 95721): 'Pioneer Fly-by of Saturn and Its Rings', *Advances in Space Res.* **1**, 67–71. (1981)

We report results from analysis of data from Pioneer Saturn's Imaging Photopolarimeter. These include the discovery of a new ring and satellite, the structure of the atmosphere of Saturn and Titan, the inhomogeneous nature of Saturn's rings, and a model for the ring's formation and bimodal particle size distribution.

Georgiev, K. G. and Papkov, O. V.: 'Analysis of Several Schemes of Flight to Saturn', *Cosmic Research* **19**, 148–152. (1981)

Trajectories of flight to Saturn are studied using a perturbational maneuver with fly-by of Earth or Mars. The characteristics of optimal trajectories are cited. The scheme of flight to Saturn with a fly-by of Earth is examined in detail, and analysis of the trajectory is presented subject to temporal characteristics. A calendar of trajectories to Saturn with full flight duration of 6 and 7 years in the interval 1985–2000 is also presented. A comparison of these schemes is given on the basis of their fundamental characteristics, and their effectiveness is shown.

Goertz, C. K., Thomsen, M. F., and Ip, W. -H. (Max-Planck-Institut für Aeronomie, 3411 Katlenburg-Lindau 3, F.R.G.): 'Saturn's Radio Emissions: Rotational Modulation', *Nature* **292**, 737–739. (1981)

The unexpected rotational modulation of the Saturn kilometric radiation and Saturn electrostatic discharges, as revealed by Voyager 1 observations, are discussed in terms of a ring-current system and the geometry of the dipole field.

Grzedzielski, S., Macek, W., and Oberc, P. (Space Research Centre, Polish Academy of Sciences, Ordona 21, PL-01 237 Warsaw, Poland): 'Expected Immersion of Saturn's Magnetosphere in the Jovian Magnetic Tail', *Nature* **292**, 615–616. (1981)

Voyager 2 approaches Saturn (♄) this month, August 1981, after the possible encounter of the planet with the tail or wake of Jupiter (♃). With the magnetic flux in the tail of $\phi \cong 2 \times 10^{12}$ Wb (refs 4, 5) a simple model suggests that the tail is very long (7–15 AU) and wide enough ($\sim$0.6 AU) to engulf Saturn. This could result in a sudden drop (by a factor of $\sim$40) of the ram pressure on the magnetosphere of Saturn. The ensuing inflation of the magnetosphere may cause effects observable from Voyager 2 and/or Earth-orbiting satellites, including a flare-up of kilometric radiation and enhancement of the Lyα limb brightening. Such events, if observed, could shed light on the magnetic and plasma nature of the Jovian tail and on the electrodynamics of the saturnian magnetosphere.

Gupta, S. K., Uchiai, E., and Ponnamperuma, C. (Dept. of Chemistry, Univ. of Maryland, College Park, MD 20742): 'Organic Synthesis in the Atmosphere of Titan', *Nature* **293**, 725–727. (1981)

Titan, the largest satellite of Saturn, is one of the smallest known bodies with an atmosphere. Since the detection of an atmosphere on Titan by Kuiper, various models have been proposed for the structure of the atmosphere. These models were based on information from ground-based observations which, although advanced, failed to yield a sufficiently accurate and quantitative picture of the atmosphere. The IR, UV and radio science investigations on Voyager 1 have now provided much needed information on the composition, structure and dynamics of the atmosphere of Titan. The IR and radio science data indicated a mean molecular weight of 28 for the atmsophere of Titan and it was thus concluded that the atmosphere concists predominantly of N_2. The minor components of the atmosphere as identified by the spectra from the IR Radiometer and Interferometer. Spectrometer (IRIS) spectra include methane, acetylene, hydrogen cyanide, ethane, ethylene and possibly propane and methylacetylene. The other IR bands observed in the spectra have not been firmly identified, although several other hydrocarbons and nitrogen-containing compounds are suspected. The minimum atmospheric temperature of $\sim$70 K was deduced to prevail near the 200 mbar level, which can acts as a cold trap for methane and thus regulate and maintain a constant abundance of stratospheric CH_4 which has been estimated to be about 1% of N_2. The IRIS data also indicate that the stratospheric temperature near 1 mbar level is about 20 K colder in the north than at the equatorial and south latitudes but that it shows practically no diurnal and longitudinal thermal variation.

Gurnett, D. A., Kurth, W. S., and Scarf, F. L. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Narrowband Electromagnetic Emissions from Saturn's Magnetosphere', *Nature* **292**, 733–737. (1981)

A series of narrowband electromagnetic emissions were detected by the plasma wave instrument on board Voyager 1 coming from the inner region of Saturn's magnetosphere in the frequency range 3–30 kHz. These emissions have many similarities to continuum radiation detected in the Earth's

magnetosphere and narrowband kilometric radiation in the Jovian magnetosphere. The observed frequency spacing suggests that the emissions are being generated near Tethys, Dione and Rhea, probably in regions of large plasma density gradients associated with boundaries of the plasma sheet.

Harrington, R. S. and Seidelmann, P. K. (U.S. Naval Observatory, Washington, DC 20390): 'The Dynamics of the Saturnian Satellites 1980S1 and 1980S3', *Icarus* **47**, 97–99. (1981)

The orbits of the Saturnian satellites 1980S1 and 1980S3 have approximately the same semimajor axes, but the difference in longitude librates between values of approximately $+6°$ and $-6°$ in 3000 days. Thus the satellites never approach extreme proximity and the orbits appear to be stable for extended periods of time.

Henon, M. (CNRS, Observatoire de Nice, F-06007 Nice Cedex, France): 'A Simple Model of Saturn's Rings', *Nature* **293**, 33–35. (1981)

The distribution of particle sizes in Saturn's rings is probably continuous over amny orders of magnitude; there is no 'typical particle size'. A model based on this view accounts for a number of observed properties of the rings: apparent thickness, radar and radio observations, number and size distribution of the gaps discovered by Voyager 1, and optical thickness.

Kaiser, M. L., Desch, M. D., and Lecacheux, A. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Saturnian Kilometric Radiation: Statistical Properties and Beam Geometry', *Nature* **292**, 731–733. (1981)

Analysis of the average properties of Saturn's kilometre wavelength radio emission suggests that the source region is near noon meridian in the northern auroral zone and/or the polar cusp.

Kirsch, E., Krimigis, S. M., Ip, W. -H., and Gloeckler, G. (Max-Planck Institute für Aeronomy, D-3411 Katlenburg-Lindau 3, F.R.G.): 'X-ray and Energetic Neutral Particle Emission from Saturn's Magnetosphere', *Nature* **292**, 718–721. (1981)

Although Voyager 1 was not equipped for the detection of X-rays and neutral particles, its low energy charged particle detector records suggest a significant flux of these radiations. X-rays could be due to substantial precipitating electron fluxes in the auroral region or the rings whereas energetic neturals could be due to charge-exchange between trapped ions and Saturn's neutral hydrogen disk.

Kunde, V. G., Aikin, A. C., Hanel, R. A., Jennings, D. E., Maguire, W. C. and Samuelson, R. E. (Goddard Space Flight Center, Code 693.2, Greenbelt, MD 20771): C_4H_2, HC_3N and C_2N_2 in Titan's Atmosphere', *Nature* **292**, 686–688. (1981)

The compounds C_4H_2, HC_3N, and C_2N_2 have been detected in trace amounts in the stratosphere of Titan. The identification of two compounds containing nitrogen, in addition to HCN, provides further evidence for the abundance of free N_2 on Titan.

Kurth, W. S., Gurnett, D. A., and Scarf, F. L. (Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242): 'Control of Saturn's Kilometric Radiation by Dione', *Nature* **292**, 742–745. (1981)

Voyager 1 observations of Saturn's kilometric radio emissions reveal a strong but apparently transitory control by the orbital phase angle of Dione. This may be a geometrical effect and a time-variable plasma torus associated with Dione could explain most of the observed details of the Dione modulation by creating a shadow zone near the equatorial plane.

Kyrala, A. (Physics Dept., Arizona State Univ., Tempe, AZ 85287): 'On a Magnetic Anomaly Origin for the Braids of Saturn's F-Ring', *The Moon and the Planets* **25**, 129–130. (1981)

From the numerator of the expression for the torsion of a space curve a necessary and sufficient condition for the existence of aplanarity in a closed periodic orbit is derived. It is shown that *only the* *component of force orthogonal to the velocity can contribute to aplanarity*. The aplanarity is thus associated with a force which does no work and this suggests a magnetic force anomaly as the cause of the braid configurations of the F-Ring. Following this suggestion one finds that such a magnetic field cannot be oriented parallel or orthogonal to the velocity.

Laberis, B.: "'Voyager 2' to Skirt Planet Saturn Tomorrow", *Computerworld* **15**(43) 4. (1981)

Lamy, P. L. and Mauron, N. (Laboratoire d'Astronomie Spatiale, Les Trois Lucs, 13012 Marseille, France): 'Observations of Saturn's Outer Ring and New Satellites During the 1980 Edge-on Presentation', *Icarus* **46**, 181–186. (1981)

Observations of Saturn's satellites and external rings during the 1980 edge-on presentation were obtained with a focal coronograph. A faint satellite traveling in the orbit of Dione and leading it by 72° has been detected, together with the two inner satellites already suspected (cf. J. W. Fountain and S. M. Larson, 1978, *Icarus* **36**, 92–106). The external ring has been observed on both east and west sides; it may extend up to $\simeq 8.3$ Saturn radii, and appears structured.

Larson, S. M., Smith, B. A., Fountain, J. W., and Reitsema, H. J. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'The 1966 Observations of the Coorbiting Satellites of Saturn, S10 and S11', *Icarus* **46**, 175–180. (1981)

Most of the positions of faint satellite images obtained during the 1966 Saturn ring plane crossing fit the period of the coorbital satellites 1980S1 and 1980S3. In 1966 the satellites were separated by 137° in orbital longitude. Until the mutual interaction of the satellites is understood and applied to derive the precise orbital motion, the 1966 and 1980 observations cannot be linked.

Lepping, R. P., Burlaga, L. F., and Klein, L. W. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Surface Waves on Saturn's Magnetopause', *Nature* **292**, 750–753. (1981)

Voyager 1 magnetometer data have shown that small-amplitude surface waves occurred on Saturn's dayside magnetopause, causing multiple inbound crossings of this boundary. These waves were travelling approximately parallel to Saturn's equatorial plane along the magnetopause ('tailward'), suggesting that they were drive by the rotation of Saturn's magnetosphere. hydromagnetic waves (possibly slow mode) were observed in the adjacent magnetosheath.

Lin, D. N. C. and Bodenheimer, P. (Lick Observatory, Board of Studies in Astronomy and Astrophysics, Univ. of California, Santa Cruz, CA 95064): 'On the Stability of Saturn's Rings', *Astrophys. J.* **248**, L83–L86. (1981)

We show that collision-dominated particle disks around planets may be unstable against a 'pinch' instability induced by the nature of viscous diffusion. We propose that the existence of ringlets around Saturn is a manifestation of this instability.

Lissauer, J. J., Shu, F. H., and Cuzzi, J. N. (Univ. of California, Berkeley, CA 94720): 'Moonlets in Saturn's Rings?', *Nature* **292**, 707–711. (1981)

The brightness structure within Cassini's division in Saturn's rings is explained in terms of perturbations produced by moonlets embedded within an optically thin disk of smaller ring particles. The moonlets exert gravitational torques on neighbouring ring particles and create gaps; diffusion acts to fill the gaps. A new explanation is offered for the inner edge of the Cassini division being located at the 2:1 resonance with Mimas.

Lukkari, J. (Dept. of Astronomy, Univ. of Oulu, Finland): 'Collisional Amplification of Density Fluctuations in Saturn's Rings', *Nature* **292**, 433–435. (1981)

The encounter of Voyager 1 with Saturn in November 1980 revealed the ringlet structure of its rings. As the theoretical examination of the collisional evolution of Keplerian systems had predicted such a structure in dense matter as a consequence of amplified fluctuations in density, some new computer simulations have now been carried out to check this effect. These simulations have now been carried out to check this effect. These simulations actually led to a strong, irreversible growth in the density maximum.

Lukkari, J. and Piironen, J. O. (Dept. of Astronomy, Univ. of Oulo, Oulo, Finland): 'The East-West Asymmetry of Saturn's Rings: New Measurements', *The Moon and the Planets* **25**, 133–136. (1981)

Measurements made during 1976–1979 at the Aarne Karjalainen Observatory show slight east-west asymmetry of Saturn's ring B.

Maguire, W. C., Hanel, R. A., Jennings, D. E., Kunde, V. G., and Samuelson, R. E. (Goddard Space Flight Center, Greenbelt, MD 20771): 'C_3H_8 and C_3H_4 in Titan's Atmosphere', *Nature* **292**, 683–686. (1981)

Four bands of propane C_3H_8 and two of methyl acetylene C_3H_4 have been identified in the Voyager IR spectrum of Titan. Stratospheric abundances of 2×10^{-5} for C_3H_8 and 3×10^{-8} for C_3H_4 have been determined for the mid-latitude region. A feature at 1154 cm^{-1}, previously assigned solely to CH_3D, is now identified at least in part due to C_3H_8.

No Author Cited: 'Saturnalia', *New Scientist* **92**, 178–179. (1981)

A feast of images from the latest spacecraft to fly by the 'ringed' planet.

No Author Cited: 'One Last Run for the Rings', *Science 81* **2**(9) 40–43, (1981)

Voyager 2 photographs of Saturn's rings and satellites are presented.

No Author Cited: 'Voyager 2's Saturn: Still Surprising', *Science News* **120**, 132–133. (1981)

No Author Cited: 'Secrets of Saturn: Anything but Elementary', *Science News* **120**, 148–149, 157-158. (1981)

No Author Cited: 'Saturn: Scanning the Unseen Scene', *Science News* **120**, 182. (1981)

Orton, G. S., Ingersoll, A. P., Froidevaux, L., Neugebauer, G., Munch, G., and Chase, S. C. Jr. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Scientific Results from the Pioneer Saturn Infrared Radiometer', *Advances in Space Res.* **1**, 179–182. (1981)

The Pioneer 11 Infrared Radiometer instrument made observations of Saturn and its rings in broad-band channels centered at 20 and 45 μm and obtained whole-disk information on Titan. A planetary average effective temperature of 96.5 ± 2.5 K implies a total emission 2.8 times the absorbed sunlight. Correlation with radio science results implies that the molar fraction of H_2 is 90 ± 3% (assuming the rest is He). Temperatures at the 1 bar level are 137 to 140 K; regions appearing cooler may be overlain by a cloud acting as a 124 K blackbody surface. A minimum temperature averaging 87 K is reached near 0.06 bars. Ring boundaries and optical depths are consistent with those at optical wavelengths. Ring temperatures are 64–86 K on the south (illuminated) side, ~ 54 K on the north (unilluminated) side, and at least 67 K in Saturn's shadow. There is evidence for a south to north drop in ring temperatures. Titan's 45 μm brightness temperature is 75 ± 5 K.

Pedersen, B. M., Aubier, M. G., and Alexander, J. K. (Observatoire de Paris, Section d'Astrophysique de Meudon, 92190 Meudon, France): 'Low-Frequency Plasma Waves Near Saturn', *Nature* **292**, 714–716. (1981)

Voyager planetary radio astronomy observations of low frequency emissions detected around the time of closest appraoch to Saturn and near the outbound ring plane crossing are presented. Near the ring plane an electron density of between 5 and 20 electrons cm^{-3} at distances of ~ $6R_S$ is estimated.

Pirraglia, J. A., Conrath, B. J., Allison, M. D., and Gierasch, P. J. (NASA-Goddard Space Flight Center, Code 693.2, Greenbelt, MD 20771): 'Thermal Structure and Dynamics of Saturn and Jupiter', *Nature* **292**, 677–679. (1981)

High resolution Voyager IRIS measurements for Saturn and Jupiter are assembled in meridional cross-sections of the retrieved upper tropospheric temperatures. The calculated thermal wind shear in the upper troposphere is high correlated on both planets with the cloud top winds derived from the imaging data. In contrast, temperatures below ~ 300 mbar are not simply related to the zonal jet structure. The upper tropospheric temperatures seem to have been more consistently correlated with cloud top winds than with major albedo features at the time of the Voyager encounters.

Rossbacher, L. A.: 'Rings and Ice: Voyager 2 at Saturn', *Episodes* **1981**(3) 9–12. (1981)

The objectives of NASA's Voyager 2 mission were adapted to pursue the many startling findings of Voyager1's encounter with Saturn last November (see EPISODES 1980, No. 4, p. 9–11). The harvest of scientific data reaped from this latest voyage through the Satrunian system will challenge the understanding of planetary geologists and meterologists for years to come.

Samuelson, R. E., Hanel, R. A., Kunde, V. G., and Maguire, W. C. (Goddard Space Flight Center, Code 693.2, Greenbelt, MD 20771): 'Mean Molecular Weight and Hydrogen Abundance of Titan's Atmosphere', *Nature* **292**, 688–693. (1981)

The 200–600 cm^{-1} continuum opacity in the troposphere and lower stratosphere of Titan is inferred from thermal emission spectra from the Voyager 1 IR spectrometer (IRIS). The surface temperature and mean molecular weight are $94\ K < T_G < 97\ K$ and $28.3 < M < 29.2$ AMU, respectively. The mole fraction of molecular hydrogen is 0.002 ± 0.001, which is equivalent to an abundance of $\sim 0.2 \pm 0.1$ km amagat.

Sandel, B. R. and Broadfoot, A. L. (Earth and Space Sciences Inst., Univ. of Southern California, Tucson, AZ 85713): 'Morphology of Saturn's Aurora', *Nature* **292**, 679–682. (1981)

Aurorally-excited emissions of atomic and molecular hydrogen come from a narrow circumpolar band near 80° north and south altitude on Saturn. The aurorae, which lie near the edge of the polar cap region, are continuously excited in both the north and south. If the strong variations observed in the auroral intensity are temporal, rather than longitudinal, they may be related to the periodic structure in the Saturn kilometric radiation.

Scarf, F. L., Kurth, W. S., Gurnett, D. A., Bridge, H. S., and Sullivan, J. D. (Space Sciences Dept., TRW Defense and Space Systems Group, Redondo Beach, CA 90278): 'Jupiter Tail Phenomena Upstream from Saturn', *Nature* **292**, 585–586. (1981)

Voyager 2 plasma wave and plasma probe measurements from February 1981 suggest that phenomena associated with a well defined tail of Jupiter have been detected at a distance of about $6200 R_J$. This indicates that Saturn's magnetosphere will be affected by the Jovian tail and that by comparing Voyager 1 and 2 observations information on the physics of Saturn's magnetosphere can be obtained.

Sittler, E. G., Scudder, J. D., and Bridge, H. S. (NASA-Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Distribution of Neutral Gas and Dust near Saturn', *Nature* **292**, 711–714. (1981)

The distribution of neutral gas and dust within the magnetosphere of Saturn has been inferred from the electron velocity distribution functions measured by the Voyager 1 plasma science experiment. Substantial enhancements of neutral material near Titan and in the vicinity of Enceladus are found. The E ring is also shown to be larger than previously thought.

Smith, B. A.: 'Voyager 2 Imagery puzzles Scientists' *Aviation Week and Space Technology* **115**(10) 74–79. (1981)

Smith, W. H., McCord, T. B., and Macy, W. Jr. (McDonnell Center for Space Sciences, Washington Univ., St. Louis, MO 63130): 'High-Spectral-Resolution Imagery of Saturn', *Icarus* **46**, 256–262 (1981)

High-spectral-resolution images of Saturn over the wavelengths of the 6196.8 Å feature of CH_4 were obtained and used to extract line profiles for the observed feature over the disk of Saturn and to determine the spatial variation of the equivalent width at the time of the observations. The result of the observed feature over the disk of Saturn and to determine the spatial variation of the equivalent width at the time of the observations. The result of the observations is consistent only with a single class of models for the vertical structure of the atmosphere of Saturn, namely, the homogeneous scattering models. Reflecting-layer or two-layer models are at a striking variance with the observations. With these data, the requirements for new observations to determine the finer details of the vertical structure of Saturn's atmosphere can be specified.

Sromovsky, L. A., Suomi, V. E., Pollack, J. B., Krauss, R. J., Limaye, S. S., Owen, T., Revercomb, H. E., and Sagan, C. (Space Science and Engineering Center, Univ. of Wisconsin-Madison, Madison, WI 53706): 'Implications of Titan's North–South Brightness Asymmetry', *Nature* **292**, 698–702. (1981)

Voyager 1 images of Titan, when normalized to remove limb darkening, reveal an axially symmetric brightness pattern with significant north–south asymmetry. This interhemispheric contrast seems to be a response to seasonal solar heating variations resulting from Titan's inclined spin axis. The contrast significantly lags the solar forcing, indicating that its production involves the atmosphere well below the unit optical depth level. The contrast has a significant effect on Titan's disk-integrated brightness as seen from Earth, and probably accounts for most of the observed long term variation, with solar UV variations accounting for the remainder.

Stone, E. C. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'How Voyager 2 Has Been Reprogrammed') *Nature* **292**, 675–676. (1981)

Sutton, C. (Jet Propulsion Lab., Pasadena, CA 91109): 'Saturn Yields to Voyager's Brief Caress', *New Scientist* **91**, 507–510. (1981)

The first results from the Voyager 2 mission to Saturn are presented, with a summary of our present knowledge about the planet and its satellites.

Sutton, C. (Jet Propulsion Lab., Pasadena, CA 91109): 'Voyager Trips – But Still Does Its Job', *New Scientist* **91**, 580–582. (1981)

Thompson, W. T., Lumme, K., Irvine, W. M., Baum, W. A., and Esposito, L. W. (Dept. of Physics and Astronomy, Univ. of Massachusetts, Amherst, MA 01003): 'Saturn's Rings: Azimuthal Variations, Phase Curves, and Radial Profiles in Four Colors', *Icarus* **46**, 187–200. (1981)

Four-color photographic photometry of Saturn for the 1977–1979 apparitions has been analyzed to determine the dependence of ring brightness on wavelength, solar phase angle, ring particle orbital phase angle (azimuthal effect), declination of the Earth relative to the ring plane (tilt angle), and radial distance from Saturn. Azimuthal brightness variations up to ± 20% relative to the ansae are clearly apparent for the maximum of ring A, but are not detectable for ring B or the outer portion of ring A. The shape of the intensity (I) versus orbital phase angle (θ) curve varies with ring tilt (B) and probably with wavelength, and shows 180° symmetry. As characterized by its slope near the ansae, this curve suggests that the azimuthal effect increases as B decreases from 26 to ~ 11°. The phase curves $I(\alpha)$ for the ansae show very little dependence on ring tilt ($26^3 > B > 6°$), on wavelength, or on radial distance from Saturn; possibly the curves are somewhat steeper at the smallest tilt angles and for ring A relative to ring B. The radial profile of both rings becomes flatter with decreasing tilt angle and with decreasing wavelength. The latter effect is a natural result of the classical, many-particle-thick ring model.

Veillet, C. (Centre d'Etudes et de Recherches Geodynamiques et Astronomiques, Av. Copernic, F-06130 Grasse, France): 'Location of Faint Objects in the Orbits of Tethys and Dione', *Astron. Astrophys.* **102**, L5–L7. (1981)

An observing run on the Danish-ESO 1.5 m reflector (La Silla) provided in April 1981 a series of positions of three faint satellites of Saturn on the L_4 Lagrangain point of Saturn : Dione and the L_4 and L_5 points of Saturn : Thetys. This series permitted to determine an accurate position of the Thetys L_4 (1981S1) and L_5 (1981S2) objects, observed only sparsely and not exactly located in 1980, and to discover a periodic variation of the Dione L_4 object (1980S6, often called Dione *B*), which can be explained by an eccentricity 0.0115, a very high value with respect to that of Dione (0.0022). The facility in recording these objects (photographic plates at the Cassegrain focus of the instrument) suggests the examination of old plates taken in equivalent conditions in order to get other positions or to affirm they were not present at a given epoch. Thus would be clarified the study of the evolution of these objects.

Waldrop, M. M.: 'The Puzzle That is Saturn', *Science* **213**, 1347–1351. (1981)

Waldrop, M. M.: 'Saturn Redux: The Voyager 2 Mission', *Science* **213**, 1236–1237, 1240. (1981)

Despite a sticky camera platform, the encounter achieved most of its scientific goals; next stop, Uranus.

7. Uranus

Atai, A. A., Vdovichenko, V. D., Kuratov, K. S., and Teifel, V. G. (Astrophysical Inst., Academy of the Sciences of the Kazakh SSR, U.S.S.R.): 'Spectrum of Uranus at λλ 0.47–1.00 Microns: A Comparison with the Simplest Models of the Formation of the CH_4 Absorption Bands', *Solar System Res.* **15**, 13–18. (1981)

A comparison is made of the observed spectral geometrical albedo of Uranus with theoretical calculations for the three simplest models of the formation of absorption bands: simple reflection models, models with a homogeneous scattering semiinfinite aerosol layer, and models with a homogeneous semiinfinite Rayleigh atmosphere. The latter model assumes a dependence of the scattering coefficient on wavelength ($\sigma_R \sim \lambda^{-4}$). It shows the best agreement with the geometrical albedo of Uranus both at the centers of weak and medium CH_4 absorption bands and in the continuous spectrum between bands, where even relatively small CH_4 absorption is sufficient to decrease the reflectivity of the planet to the observed values.

Veillet, C. (Centre d'Etudes et de Recherches Geodynamiques et Astrophysiques, Av. Copernic, F-06130 Grasse, France): 'New Determination of the Orbit of Miranda', *Astron. Astrophys.* **98**, 218–222. (1981)

Regular observations of Uranus' satellite Miranda have been made to the Pic-du-Midi Observatory since 1977. They show an important discrepancy with the calculated positions derived from Whitaker and Greenberg's orbit, a deviation which has been predicted by Greenberg. Gathering all published positions of Miranda from her discovery, an orbit has been calculated including a gravitational effect of Ariel and Umbriel on Miranda. The new orbital elements confirm the irregularities (inclination and eccentricity) of the precendent orbit, in spite of some differences in the values found. The derived mass product of Ariel and Umbriel is $(1.10 \pm 0.25) \times 10^{-10}$. The value found of Miranda's apsidal precession rate ($22.58 \pm 0.37° \text{ yr}^{-1}$) and the last J_2 determinations from occultations by Uranus give for Titania's mass $(1.47 \pm 0.10) \times 10^{-4}$.

The program of Miranda's observations will be carried on over the next few years to improve the accuracy of the present results.

8. Venus

Beletskii, V. V., Levin, E. M., and Pogorelov, D. Yu. (m. V. Keldysh Inst. of Applied Mathematics, U.S.S.R. Academy of Sciences, U.S.S.R.): 'On the Problem of the Resonance Rotation of Venus. II', *Soviet Astron.* **25**, 110–115. (1981)

The influence of the tidal moment from the Sun on the resonance rotation of Venus is analyzed in the three-dimensional case. The gravitational moments from the Sun and from the Earth are taken into account. The action of the tidal moment causes the following evolution of the rotational motion of Venus near resonance: relatively rapid capture into the region of resonance motion occurs, accompanied by the slow 'overturning' of Venus from the cosmogonically original [N. N. Kozlov and T. M. Éneev, Preprint No. 134, Inst. Prikl. Mat. Akad. Nauk SSR (1977); N. N. Kozolv and T. M. Éneev, Preprint No. 135, Inst. Prikl. Mat. Akad. Nauk SSSR (1978); N. N. Kozlov and T. M. Éneev, Sov. Astron. Lett. **5**, 508 (1979)] retrograde rotation into direct rotation. The "overturning" process occurs so slowly that the inclination of the equator of Venus to the plane of its orbit is still small.

Cazenave, A. and Dominh, K. (Group de Recherches de Geodesie Spatiale, Toulouse, France): 'Elastic Thickness of the Venus Lithosphere Estimated from Topography and Gravity', *Geophys. Res. Lett.* 8, 1039–1042. (1981)

The very close correlation observed on Venus between topography and gravity on a regional scale is clearly related to the isostatic compensation of the topographic loads. Observed gravity anomalies over topographic features of moderate lateral extent, located in the equatorial region (0° to 40°N latitude and 10°W to 60°E longitude) are somewhat larger than those computed with a model of local isostatic compensation (of Airy type). They may rather be explained by a model of compensation including elastic forces within the lithosphere which contribute to support topographic loads through elastic stresses. We have applied the theory of lithospheric flexure: to explain in wavelength and in amplitude the observed gravity anomalies, a flexural rigidity of $\sim 4 \times 10^{28}$ dyne cm has been estimated for the Venus lithosphere in the rolling plains province. This value is very low compared to the oceanic terrestrial lithosphere (ranging from $\sim 10^{28}$ dyne cm near ridge crests to $\sim 2 \times 10^{31}$ dyne cm near subduction zones). The corresponding thickness of the elastic upper layer able to maintain elastic stresses for long time duration is $\sim$ 7.5 km. This value may not be representative of the entire Venus lithosphere.

Cloutier, P. A., Tascione, T. F., and Daniell, R. E. Jr. (Dept. of Space Physics and Astronomy, Rice Univ., Houston, TX 77001): 'An Electrodynamic Model of Electric Currents and Magnetic Fields in the Dayside Ionosphere of Venus', *Planet. Space Sci.* **29**, 635–652. (1981)

The electric current configuration induced in the ionosphere of Venus by the interaction of the solar wind has been calculated in previous papers (Cloutier and Daniell, *Planet. Space Sci.* **21**, 463, 1973; Daniell and Cloutier, *Planet. Space Sci.* **25**, 621, 1977; Cloutier and Daniell, *Planet. Space Sci.* **27**, 111, 1979) for average steady-state solar wind conditions and interplanetary magnetic field. This model is generalized to include the effects of (a) plasma depletion and magnetic field enhancement near the ionopause, (b) velocity-shear-induced MHD instabilities of the Kelvin–Helmholtz type within the ionosphere, and (c) variations in solar wind parameters and interplanetary magnetic field. It is that the magnetic field configuration resulting from the model varies in response to changes in solar wind and interplanetary field conditions, and that these variations produce magnetic field profiles in excellent agreement with those seen by the PIONEER-VENUS Orbiter. The formation of 'flux-ropes' by the Kelvin–Helmholtz instability is shown to be a natural consequence of the model, with the spatial distribution and size of the flux-ropes determined by the magnetic Reynolds number.

Covey, C. C. and Schubert, G. (Dept. of Earth and Space Sciences, Univ. of California, Los Angeles, CA 90024): '4-day Waves in the Venus Atmosphere', *Icarus* **47**, 130–138. (1981)

Ultraviolet albedo contrasts in the Venus atmosphere are probably large-scale atmospheric waves propagating slowly with respect to the rapid cloud-top zonal winds. Using a simple theoretical model and profiles of mean wind and thermal structure based on Pioneer Venus data, we find planetary-scale gravity waves with phase velocities matching the speeds of the uv markings. We propose an upward-propagating wave and waves trapped at cloud levels as candidates to explain the observed uv features.

Dlugach, Z. M. and Yanovitskij, E. G. (The Main Astronomical Observatory of the Ukrainian Academy of Sciences, Kiev, U.S.S.R.): 'The Optical Parameters of the Atmosphere of Venus', *Advances in Space Research* **1**, 167–170. (1981)

This work is devoted to the derivation of the optical properties of the Venus atmosphere from 'Venera-10' optical measurements. Within the framework of a two-layer model of Venus atmosphere it is found that in the spectral interval 0.52–0.85 μm the optical thickness of the upper cloud layer is ≈ 50 and the optical parameters of the lower layer are similar to the Rayleigh ones. Comparison is made between the measurements of radiation field within the atmosphere and the results of strict calcualtions. A preliminary conclusion is suggested that there are considerable numbers of aerosol particles with a radius $\lesssim 0.03$ μm in the lower layer. The altitude of the upper boundary of the cloud layer is estimated to be ≈ 70 km.

Esposito, L. W. (Lab. for Atmospheric and Space Physics, Univ. of Colorado, Boulder, CO 80309): 'Absorbers Seen near the Venus Cloud Tops from Pioneer Venus', *Advances in Space Res.* **1**, 163–166. (1981)

Spin–scan images from the Pioneer Venus Orbiter UV Spectrometer and the Cloud Photopolarimeter provide a set of planetary constrast measurements in the wavelength range 1990 to 3650 Å and phase angles form 33–130°. The planet is darkest at the point where the UVS line of sight penetrates perpendicular to the cloud tops: thus the absorbing material responsible must be deep in the atmosphere. Sulfur dioxide absorption can explain the amount of contrast seen between 200 and 3200 Å. At the longer wavelengths, the persistence of contrast requires another absorber which is deeper in the atmosphere and strongly associated with the location of the SO_2. Part of the observed contrast is due to the high-lying haze discovered from Pioneer Venus polarimetry. The correlation between planetary contrast and polarization does not support large scale clearing or major vertical motions of the cloud tops as the sole cause of the observed contrast. However, a scheme in which absorbers subject to photochemical destruction are mixed upward into the cloud top region provides a consistent explanation for the origin of these markings.

Hunten, D. M. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'The Upper Atmosphere of Venus: Implications for Aeronomy', *Advances in Space Res.* **1**, 139–140. (1981)

The detailed, in-situ measurements by the Pioneer–Venus Orbiter (PVO) have given a rare opportunity to test the predictive power of aeronomy. For many years the only data were the dayside electron-density profile and the Lyman-alpha distribution, both measured by Mariner 5, and a rew rocket spectra; Venera 4 had established CO_2 as the major gas. Almost coincident with the Mariner 10 encounter, Kumar and Hunten proposed an ionospheric model consistent with an exospheric temperature of 350 K, a value immediately verified through measurements of the 584 Å helium line. In essence, this calss of model was verified by PVO. However, plasma temperatures were found to be unexpectedly hgah; the shocked solar wind is a much stronger heat source than had been surmised.

The nonthermal corona of atomic hydrogen is still not fully explained, although the best candidate is the reaction of O^+ with H_2. The PVO data are consistent with this mechanism; in particular, H_2^+ is found in somewhat greater abundance than the mechanism predicts.

An influential line of research has been the work of Dickinson and Ridley on the thermospheric circulation. Assuming that vertical eddy mixing is weak, they found an intense day-to-night flow, with the return flow at lower altitudes. The flow was sufficient to carry atomic oxygen out of the thermosphere and maintian the rather low observed abundance. The observed Venus is tantalizingly similar, but vastly different in detail. Specifically, the nightside temperature, some 80° colder than the mesopause, is totally inconsistent with the model. There is no thermosphere on the night side; instead, it is a 'cryosphere'.

The only known mechanism that can remove heat against a temperature gradient is externally forced vertical mixing, or "eddy heat conduction". This is possible because the gradient of potential temperature is still downward. An eddy coefficient of order $2 \times 10^7 \, cm^2 \, s^{-1}$ would suffice, but this value does not allow for conduction of the heat deposited by dissipation of the eddies themselves. The relation between these two effects is still obscure; in principle they could cancel each other entirely, as seems to be true for Earth where both are usually omitted altogether. It can be speculated that the cooling effect dominates for Venus (and Mars), but no convincing reason has been put forth why this should be so. *A proper inclusion of these eddy effects (heating and conduction) is a major unsolved problem in aeronomy.* We cannot pretend that we understand the thermal balance of the Earth's thermosphere until it is solved.

Kasnopol'skii, V. A. and Parshev, V. A. (Space Research Inst., Academy of Sciences, 117810 Moscow, U.S.S.R.): 'Chemical Composition of the Atmosphere of Venus', *Nature* **292**, 610–613. (1981)

Measurements onboard the Venera 11, 12 and Pioneer Venus spacecrafts stimulated us to study the chemical composition of the subcloud atmosphere of Venus in terms of the thermochemical equilibrium calculations, comparison of typical mixing and chemical times and a rule of height-independent element mixing ratio in the absence of condensation. The photochemistry of the atmosphere down to 50 km was calculated using transport effects and number densities of CO_2, H_2O, HCl, SO_2 and CO at the lower boundary and rate coefficients of 102 reactions. These reactions include catalytical cycles of COCl and $COCl_2$ which accelerate O_2 destruction and CO_2 formation. Altitude profiles of 27 components agree well with those measured in the upper and middle atmosphere. H_2O and SO_2 mixing ratios are very similar and sharply decrease at 60 km due to SO_2 photolysis and sulphuric acid formatin. Calculations show that sulphuric acid and sulphates are the main components of the second and third modes of particle size distribution in the upper and middle cloud layers. The lower cloud layer may consist of $AlCl_3$ and $FeCl_3$.

Krasnopol'skii, V. A. and Parshev, V. A. 'Photochemistry of the Atmosphere of Venus at Altitudes Greater than 50 km II. Calculations', *Cosmic Res.* **19**, 179–189. (1981)

A model of the neutral composition of the atmosphere of Venus at altitudes of 50–200 km which determines the altitude variations of the concentrations of the photolysis produces of CO_2, H_2O, HCl, and SO_2, is constructed. A series of new components and processes that play an important role in the photochemistry of the atmosphere of Venus, which were not taken into account earlier, are examined; the inadequacy of earlier models is overcome (the artificial separation of sulfur and chlorine compounds). An analysis of the initial data, the methods of setting boundary conditions, and the method of solving the system of equations that describe the model is presented. The present models for the upper atmosphere agrees well with observational results. Approximate analytical expressions are derived for the concentrations of a few components, in addition to the values calculated on the basis of the system of equations which was obtained. It is shown that, for a given relative SO_2 concentration $f_{SO_2} = 1.3 \cdot 10^{-4}$ at 50 km (in accordance with the gas chromatography results from Venera 12 and Pioneer–Venus), the best agreement between the model and ground-based measurements of H_2O emission in the upper portion of the cloud layer is obtained for $f_{H_2O} = 1.9 \times 10^{-4}$ at 50 km, which was confirmed by water measurements on the Venera landers. Sulfuric acid and its products cannot be in the second mode ($r \approx 1 \, \mu m$) alone, but also in the third mode ($r \approx 4 \, \mu m$) of the aerosol particle-size distribution in the middle cloud layer. The amount of sulfur is an order of magnitude less than the amount of sulfuric acid; the relative concentration of H_2SO_4 in aqueous solution changes with altitude and is 80–87% at 55–70 km. O_2 forms a layer at 80–85 km with a total column density of $3.7 \times 10^{19} \, cm^{-2}$. The results of the model are not contradicted by the presence of O_2 in the cloud layer; however, it is difficult to explain its origin there, and this raises some doubts. An interpretation of observations of the O_2 1.27 μm band is carried out: in addition to the photolysis of ozone, the creation of $O_2 \, (^1\Delta_g)$ also occurs in the reactions of O_3 with Cl and O with ClO, because of which the sum of the propabilities of obtaining $O_2 \, (^1\Delta_g)$ in these two processes is close to unity. The collisional deexcitation constant for collisions of $O_2 \, (^1\Delta_g)$ with CO_2 is $5 \times 10^{-20} \, cm^3 \, s^{-1}$. The band is formed in a 7 km-thick layer with a maximum at 98 km. The emission line O (^1D–^3P) 6300 Å is also considered: its maximum is at 160 km, the thickness of the layer is 30 km, and the zenith intensity for $z_{\odot} = 60°$ is 700 rayleigh.

Limaye, S. S. and Suomi, V. E. (Inst. for Space Studies, Goddard Space Flight Center, NASA, New York, NY 10025): 'Cloud Motions on Venus: Global Structure and Organization', *J. of the Atmospheric Sci.* **38**, 1220–1235. (1981)

We present results on cloud motions on Venus obtained over a period of 3.5 days from Mariner 10 television images. The implied atmosphere flow is almost zonal everywhere on the visible disk, and is in the same retrograde sense as the solid planet. Objective analysis of motions suggests presence of jet cores ($-130\,\mathrm{m\,s^{-1}}$) and organized atmospheric waves. The longitudinal mean meridional profile of the zonal component of motion of the ultraviolet features shows presence of a midlatitude jet stream ($-110\,\mathrm{m\,s^{-1}}$). The mean zonal component is $-97\,\mathrm{m\,s^{-1}}$ at the equator. The mean meridional motion at most latitudes is directed toward the pole in either hemisphere and is at least an order of magnitude smaller so that the flow is nearly zonal. A tentative conclusion from the limited coverage available from Mariner 10 is that at the level of ultraviolet features mean meridional circulation is the dominant mode of poleward angular momentum transfer as opposed to the eddy circulation.

Moroz, V. I. (Space Research Inst., Academy of Sciences, Moscow, U.S.S.R.): 'The Atmosphere of Venus', *Space Sci. Rev.* **29**, 3–127. (1981)

The investigations of Venus take a special position in planetary researches. It was just the atmosphere of Venus where first measurements *in situ* were carried out by means of the equipment delivered by a space probe (Venera 4, 1967). Venus appeared to be the first neighbor planet whose surface had been seen by us in the direct nearness made possible by means of the phototelevision device (Venera 9 and Venera 10, 1975).

The reasons for the high interest in this planet are very simple. This planet is like the Earth by its mass, size and amount of energy obtained from the Sun and at the same time it differs sharply by the character of its atmosphere and climate.

We hope that the investigations of Venus will lead us to define more precisely the idea of complex physical and physical-chemical process which rule the evolution of planetary atmospheres. We hope to learn to forecast this evolution and maybe, in the far future, to control it.

The last expeditions to Venus carried out in 1978 – American (Pioneer-Venus) and Soviet (Venera 11 and 12) – brought much news and it is interesting to sum up the results just now. The contents of this review are:

1. The planet Venus – basic astronomical data.
2. Chemical composition.
3. Temperature, pressure, density (from 0 to 100 km).
4. Clouds.
5. Thermal regime and greenhous effect.
6. Dynamics.
7. Chemical processes.
8. Upper atmosphere.
9. Origin and evolution.
10. Problems for future studies.

Here we have attempted to review the data published up to 1979 and partly in 1980. The list of references is not exhaustive. Publications of special issues of magazines and collected articles concerning separate space expeditions became traditional last time. The results obtained on the Soviet space probes Venera 9, 10 (the first publications) are collected in the special issues of *Kosmicheskie issledovanija* (**14**, Nos. 5, 6, 1975), analogous material about Venera 11, 12 is given at *Pis'ma Astron. Zh.* (**5**, Nos. 1 and 5, in 1978), and in *Kosmicheskie issledovanija* (**16**, No. 5, 1979). The results of Pioneer-Cenus mission are represented in two Science issues (**203**, No. 4382; **205**, No. 4401) and special issue of *J. Geophys. Res.* (1980). We shall mention some articles to the same topic among previous surveys: (Moroz, 1971; Sagan, 1971; Marov, 1972; Hunten *et al.*, 1977; Hoffman *et al.*, 1977) and also the books by Kuzmin and Marov (1974) and Kondrat'ev (1977). Some useful information in the part of ground-based observations may be found in the older sources (for example, Sharonov, 1965; Moroz, 1967). For briefness we shall use as a rule the abbreviations of space missions names:

V4 instead of Venera 4, M10 instead of Mariner 10 and so on. The first artificial satellites of Venus in the world (orbiters Venera 9 and 10) we shall mark as V9-O, V10-O unlike the descent probes V9, V10. Fly-by modeuls of Venera 11 and Venera 12 we shall mark as V11-F and V12-F. Pioneers descent probes – Large (Sounder), Day, Night and North – will be marked as P-L, P-D, P-Ni, P-No, orbiter as P-O, and bus as P-B.

Phillips, R. J., Kaula, W. M., McGill, G. E., and Malin, M. C. (Lunar and Planetary Inst., 3303 NASA Road 1, Houston, TX 77058): 'Tectonics and Evolution of Venus', *Science* **212**, 879–887. (1981)

The global tectonics of Venus differs significantly from that of Earth, most markedly in that the surface is covered predominately by gently rolling terrain; there apparently are no features like ocean rises; the gravity is positively correlated with topography at all wavelengths; and the few highlands are estimated to be supported or compensated at a depth of approximately 100 km. The surface of Venus appears to be covered mainly by an ancient crust, the high surface temperature making subduction difficult. It seems likely that well over 1 billion years ago water was destabilized at the surface and, soon after, plate tectonics ceased. The highlands appear to be actively supported, presumably as manifestations of long-enduring hot spots.

Reasenberg, R. D., Goldberg, Z. M., MacNeil, P. E., and Shapiro, I. I. (Dept. of Earth and Planetary Sciences, MIT, Cambridge, MA 02139): 'Venus Gravity: A High-Resolution Map', (1981).

The Doppler data from the radio tracking of the Pioneer Venus Orbiter (PVO) have been used in a two-stage analysis to develop a high-resolution map of the gravitational potential of Venus, represented by a central mass and a surface mass density. The two-stage procedure invokes a Kalman filter-smoother to determine the orbit of the spacecraft, and a stabilized linear inverter to estimate the surface mass density. The resultant gravity map is highly correlated with the topographic map derived from the PVO radar altimeter data. However, the magnitudes of the gravity variations are smaller than would be expected if the topography were uncompensated, indicating that at least partial compensation has taken place.

Russell, C. T. and Neugebauer, M. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'On the Possibility of Detection of Ions from Venus at 1 AU', *J. Geophys. Res.* **86**, 5895–5997. (1981)

The possibility that singly ionized helium enhancements observed near 1 AU are due to ion pickup from Venus is examined and found to be implausible. It is still possible that Venus ions are present in the solar wind with sufficiently high fluxes to be detectable by earth-orbiting spacecraft near the time of inferior conjunction. Because of the inclination of Venus' orbit to the ecliptic, some inferior conjunctions are more favorable for such a searth than others. In particular, the inferior conjunctions on June 17, 1972, and June 15, 1980, are most favorable for detection.

Spenner, K., Knudsen, W. C., Whitten, R. C., Michelson, P. F., Miller, K. L., and Novak, V. (Fraunhofer-Institut für Physikalische Messtechnik D-7800 Freiburg, F.R.G.): 'On the Maintenance of the Venus Nightside Ionosphere: Electron Precipitation and Plasma Transport', *J. Geophys. Res.* **86**, 9170–9178. (1981)

Suprathermal integral electron spectra between 5 and 45 eV measured by the Pioneer Venus orbiter RPA are presented for the Venus nightside ionosphere. The observed integral electron flux is relatively constant with time and altitude. The simultaneously measured plasma density is much more variable and not correlated with the electron flux. For a typical electron spectrum the ionization rates and the ion density height profiles for O^+ and O_2^+ are calculated for 10 and 90° magnetic dip angle. The O^+ and O_2^+ ion density height profiles are also calculated for a downward flux of O^+ ions at 10, 30, and 90° magnetic dip angle. Comparison of the numerical modeling results with median profiles of O^+ and O_2^+ ions measured by the RPA reveals that a downward flux of O^+ ions of between 1 and 2×10^8 $cm^{-2}\,s^{-1}$ satisfactorily repreduces both the O^+ and O_2^+ measured median nightside density profiles. The typical suprathermal electron spectrum produces an O_2^+ density profile with peak density approximately

half that typically observed and produces an O^+ profile which is about an order of magnitude too small. From the evidence presented in this paper, from previous measurements of adequate O^+ transport across the Venus terminator, and from interpretation of ion thermal measurements, we conclude that transport of O^+ ions from the dayside ionosphere is responsible for most of the ionization rate required to maintain the nightside ionosphere. Variation in the O^+ transport mechanism is primarily responsible for the large variation of the nightside ionosphere density. Suprathermal electrons provide a relatively constant ionization rate which is of the order of one fourth that of O^+ transport and which contributes principally to the O_2^+ peak.

Taylor, F. W. (Dept. of Atmospheric Physics, Oxford Univ., UK): 'Equatorial Cloud Properties on Venus from Pioneer Orbiter Infrared Observations', *Advances in Space Res.* **1**, 151–154. (1981)

Infrared observations of Venus from the Pioneer Orbiter have been used to study the limb darkening properties of the cloud tops at wavelengths and spatial resolutions not previously attained. The preliminary results show evidence for an extensive haze feature over the equatorial morning terminator and for small amounts of a far-infrared absorber concentrated near local noon, also near the equator. The evidence for these features is reveiwed and their possible origins briefly disucssed.

White, B. R. (Dept. of Mechanical Engineering, Univ. of California, Davis, CA 95616): 'Venusian Saltation', *Icarus* **46**, 226–232. (1981)

Estimates of the trajectories of saltating particles on Venus show the level of saltation to be low when compared to either Earth or Mars. Particles in saltation on Venus obtain maximum heights of only 1 cm over a wide range in particle size and surface wind speed. Their path lengths are only a few centimeters at the wind speed of 1 and 2 m s^{-1}. The entire saltation process and particle trajectories are insensitive to changes in surface pressure over the range form 70 to 100 bars and to changes in surface temperature over the range from 600 to 900 K. Secondly, the net rate of surface material transport due to saltation on Venus is small when compared to Earth or Mars. This result is due to the dense Venusian atmosphere. It is estimated that approximately 10 times more surface material is transported by saltation on Earth than on Venus for dynamically similar conditions. And approximately 250 times more material is moved by the saltation process on Mars than on Venus, again for dynamically similar conditions. Both these estimates apply over a wide range of particle diameter, from 0.01 to 7 mm. Thirdly, the ripple wavelengths may be small, such that they may not be detected by the high-resolution radar images of the surface of Venus.

Zharkov, V. N. and Zasurskii, I. Ya. (Inst. of the Physics of the Earth, Academy of Sciences of the U.S.S.R., U.S.S.R.): 'Distribution of the Shearing Stresses in the Silicate Mantle of Venus', *Solar System Res.* **15**, 8–12. (1981)

The shearing stresses in the silicate mantle of Venus are calculated. The maximum shearing stresses, of ~ 13.6 bar, act in the equatorial plane at the liquid core boundary. These stresses rapidly diminish with distance from the mantle – core boundary, and in the upper mantle of the planet ($l < 750$ km, where l is depth) they are about 1–3 bar. Stresses in the planet's polar planes are approximately half of what they are in the equatorial plane. In view of the low level of stresses in the Venusian interior, the conclusion is drawn that the planet's interior deeper than its lithosphere ($l > 200$ km) is asiesmic. An estimate is made of Venus' rotation paleo-period $T_{J_2} \approx 16.9^{+0.3}_{-0.4}$ days, which shows that at some earlier time the planet rotated considerably faster. Also, shearing stresses in the silicate mantle of Mars are calculated. The maximum shearing stresses of ~ 94 bar act in the equatorial plane at the boundary with the liquid core. The distribution of shearing stresses in the silicate mantles of Mars and Mercury is given.

OTHER OBJECTS

1. Asteroids

Boninsegna, R.: L'observation des occultations d'étoiles par les petites Planètes', *Ciel Terre*, **97**, 297–302. (1981).

Occulations of stars by minor planets are new vistas open to amateur astronomers as well as to professional ones. Visual careful timings of these events lead to data of great value.

Carlsson, M. and Lagerkvist, C.-I. (Astronomiska Observatoriet, Box 515, S-751 20, Uppsala, Sweden): 'Physical Studies of Asteroids IV: Photoelectric Observations of the Asteroids 47, 95, 431', *Astron. Astrophys. Suppl.* **45**, 1–4. (1981)

Photoelectric lightcurves are presented. The synodic period of rotation of asteriod 95 was found to be $0\overset{d}{.}3620 \pm 0\overset{d}{.}0005$. The asteroids 47 and 431 showed no significant brightness variation throughout the observing runs of 8 hr.

Debehogne, H., De Freitas Mourao, R. R., Tavares, O. C., and Nunes, M. (Observatoire Royal de Belgique, Belgium): 'Minor Planets' Positions Obtained in May–June 1980 at the GPO Telescope of ESO La Silla – Two Discoveries', *Astron. Astrophys. Suppl.* **45**, 79–83. (1981)

In May and June 1980, we have observed Minor Planets at the ESO La Silla. The instrument GPO ($f = 4$ m, $D = 40$ cm) was used. By clear sky, magnitude 18 could be attained.

Measures and reductions were performed at the Observatorio do Valongo with the Ascorecord measuring machine (0.1 μ) and by means of five reference stars on the Burrough computer (UFRJ) and on the IBM 370 computer at the Rio Datacentro PUC (Pontificale Universadade Catolica), as well as a part on the UNIVAC at Uccle (SAO Catalogue, Least Squares and Dependences Methods). UFRJ is the Universidade Federal of Rio de Janeiro.

Djakov, B. B. and Reznikov, B. I. (Ioffe Physico-Technical Inst., U.S.S.R. Academy of Sciences, Leningrad, U.S.S.R.): 'Computer Simulation of the Formation of Asteroid Belt Structure', *The Moon and the Planets* **25**, 113–128. (1981)

The system of two gravitational centers with variable separation between components one of which (the primary) loses its mass onto another (the secondary) is investigated under condition of total mass and angular momentum conservation. When the primary/secondary mass ratio becomes about that of Jupiter/Sun the small bodies ejected with the gaseous matter through the inner Lagrange point from the Roche lobe of the primary form a ring similar to the asteroid belt of the solar system. The formation of ring structure is calculated by numerical integration of Newtonian equations of N-body problem in orbital plane of the gravitational centers. The results are compared with the planar subsystem of the asteroid belt. The presence of the main gaps in the distribution of their mean motions at 2/1, 3/2, 5/2 and some other commensurabilities with the primary mean motion is found. More fine details of the belt structure are obtained, e.g. the gap asymmetry and a qualitative agreement with the eccentricity distribution. Within the scope of the same model the external part of the ring is investigated all the pairwise interactions being included. The clustering of bodies near 3/2 commensurability isolated from the main belt by the wide gap centered at 5/3 commensurability is obtained. It is supposed that the ring structure and the interplanetary spacing law for the terrestrial planets are due to the same mechanism.

Farinella, P., Paolicchi, P., and Zappala, V. (Osservatorio Astronomico di Brera, Merate, Italy): 'On the Shape of Rapidly Rotating Asteroids', *Advances in Space Res.* **1**, 187–189. (1981)

By means of a statistical analysis of the rotational properties of asteroids, we define a class of large amplitude and short period objects. A possible interpretation of their collisional evolution and present physical status, in terms of ellipsoidal figures of equilibrium, is proposed.

Hughes, D. W. (Dept. of Physics, Univ. of Sheffield, Sheffield, UK): 'Minor Body Mass Determination', *Nature* **292**, 406. (1981)

Lagerkvist, C.-I. and Rickman, H. (Astronomiska Observatoriet, Box 515, S-751 20 Uppsala, Sweden): 'Physical Studies of Asteroids V: Photoelectric Observations of the Asteroids 70, 101, 369 and 432', *Astron. Astrophys. Suppl.* **45**, 177–179. (1981)

Observations of asteroids 70, 101, 369 and 432 are reported. Photoelectric lightcurves, rotation periods, maximum amplitudes, absolute magnitudes and *UBV* colours are presented. The following synodic periods of rotation and maximum amplitudes were derived: $0^{\mathrm{d}}.965$ and $0^{\mathrm{m}}.13$ for 101 Helena, and $0^{\mathrm{d}}.3453$ and $0^{\mathrm{m}}.15$ for 432 Pythia.

Lupishko, D. F., Tupieva, F. A., Velichko, F. P., Kiselev, N. N., and Chernova, G. P. (Astronomical Observatory, Kharkov State Univ., Inst. of Astrophysics, Academy of Sciences of the Tadzhik SSR, U.S.S.R.): 'UBV Photometry of the Asteroids 19 Fortuna and 29 Amphitrite', *Solar System Res.* **15**, 19–24. (1981)

The light curves, phase dependences, and values of the opposition effect for the asteroids Fortuna and Amphitrite were obtained from observations in August–November 1978, The values of the absolute stellar magnitude and colors are $V(1, 0) = 7^{\mathrm{m}}.14$, $B-V = 0^{\mathrm{m}}.71$, and $U-B = 0^{\mathrm{m}}.30$ for Fortuna and $V(1, 0) = 5^{\mathrm{m}}.83$, $B-V = 0^{\mathrm{m}}.82$, and $U-B = 0^{\mathrm{m}}.47$ for Amphitrite. The diameters were refined: 272 km for Fortuna and 240 km for Amphitrite. It is shown that, contrary to data available in the literature, the surface of Fortuna is photometrically uniform in color. A brightness increase of about $0^{\mathrm{m}}.08$ (secondary maximum) is recorded on the phase curve of Fortuna in the region of $\alpha = 6$–$8°$, which may be explained by the rainbow effect, i.e., by light scattering on large spherical particles having an index of refraction of 1.73. On the basis of their total cross section, the required number of such particles with an average radius of 50 μm corresponds to 0.01–0.05% of the surface area of the asteroid.

Scaltriti, F., Zappala, V., Schober, H. J., Hanslmeier, A., Sudy, A., Piironen, J., Blanco, C., and Catalano, S. (Osservatorio Astronomico di Torino, I-10025 Pino Torinese, Italy): '14 Irene: A Puzzling Asteroid', *Astron. Astrophys.* **100**, 326–329. (1981)

Observations in different oppositions are analyzed in order to deduce the rotational properties of the asteroid 14 Irene. The very small amplitude of the lightcurve prevented us obtaining an unambiguous result for the rotational period. Two hypotheses, equally well supported by several physical considerations, were made giving the following values for the synodic period: $P_1 = 9^{\mathrm{h}}.35$ and $P_2 = 18^{\mathrm{h}}.71$. In both cases the total amplitude should reach a maximum of 0.10 mag at 90° of aspect, while for smaller angles it becomes 0.03 mag only. The magnitude-phase relation was also obtained, and gave $\beta_V = (0.046 \pm 0.001)$ mag/degree and $V_0\,(1, 0, 90°) = (6.55 \pm 0.02)$ mag.

Scaltriti, F., Zappala, V., and Harris, A. W. (Osservatorio Astronomico di Torino, 10025 Pino Torinese, Turin, Italy): 'Photoelectric Lightcurves and Rotation Periods of the Asteroids 46 Hestia and 115 Thyra', *Icarus* **46**, 275–280. (1981)

Results of photoelectric observations of the asteroids 46 Hestia and 115 Thyra, performed in a co-operative program between the Torino and Table Mountain Observatories, are presented. The rotation periods and the maximum amplitudes are: $P_{\mathrm{syn}} = 21^{\mathrm{h}}.04 \pm 0^{\mathrm{h}}.01$, Amplitude = 0.12 mag and $P_{\mathrm{syn}} = 7^{\mathrm{h}}.241 \pm 0^{\mathrm{h}}0.01$, Amplitude = 0.20 mag, for Hestia and Thyra, respectively. The multiple-scattering factors, Q, inferred from the phase relation data are 0.054 ± 0.003 and 0.058 ± 0.002 for Hestia and Thyra, respectively. The low value obtained for Thyra disagrees with the mean one given by Bowell and Lumme (1979, in *Asteroids*, T. Gehrels, (ed.), pp. 132–169. University of Arizona Press, Tucson) for *S*-type asteroids.

Schober, H. J. (Institut für Astronomie, Universitätsplatz 5, A-8010 Graz, Austria): 'Rotation Period of 234 Barbara, A Further Slowly Spinning Asteroid)', *Astron. Astrophys.* **96**, 302–305. (1981)

The S-type asteroid 234 Barbara was observed photoelectrically for variations at CTIO, Chile during the opposition in September 1979. A rotation period of $P = 26^{\mathrm{h}}.5 \pm 0^{\mathrm{h}}.1$ ($\cong 1^{\mathrm{d}}.104 \pm 0^{\mathrm{d}}.004$) was derived, with a lightcurve amplitude of at least $\Delta m \geqq 0^{\mathrm{m}}.24$. The lightcurve seems to show double wave characteristic, though the primary maximum and one of the minima are not observed directly. Absolute magnitude is $\bar{V}(1, 0) = 9^{\mathrm{m}}.34$ with $B - V = +0^{\mathrm{m}}.92$ and $U - B = +0^{\mathrm{m}}.48$; a phase coefficient of $\beta = 0.035$ mag/deg was derived.

Schober, H. J. (Institut für Astronomie, Universitätsplatz 5, A-8010 Graz, Austria): 'Photoelectric Photometry of the Asteroids 404 Arsinoe and 628 Christine', *Astron. Astrophys.* **100**, 311–313. (1981)

The asteroids 404 Arsinoe and 628 Christine were observed during their opposition approaches in 1979, using the ESO-0.5 m telescope at the European Southern Observatory, Chile.

For 404 Arsinoe a period of rotation could be derived with $P = 8^{h}.93 \pm 0^{h}.02$ ($0^{d}.372 \pm 0^{d}.001$) which rules out the previous value $P = 6^{h}.0$? given by Tedesco (1979). The double wave lightcurve has a total amplitude of $\Delta m = 0.36$.

628 Christine was observed for more than seven hours, showing only one minimum. The period could be expected to be $14^{h} < P < 21^{h}$; the minimum amplitude of the lightcurve is $\Delta m \geqq 0.40$.

Absolute magnitudes were computed and *UBV* colors were measured frequently; colour indices did not show any variations during rotational phases, exceeding the scatter.

Schober, H. J. (Institut für Astronomie, Universitätsplatz 5, A-8010 Graz, Austria): 'Rotational Properties and Lightcurves of the Asteroids 679 Pax and 796 Sarita', *Astron. Astrophys.* **99**, 199–201. (1981)

The asteroids 679 Pax and 796 Sarita were observed photoelectrically during their opposition approach in 1978, using the ESO 0.5 m telescope at the European Southern Observatory (Chile). No detailed photoelectric observations with respect to lightcurves or rotation rates of either object had been previously reported.

For 796 Sarita a period of rotation $P = 7^{h}.75 \pm 0^{h}.05$ ($0^{d}.323 \pm 0^{d}.002$) with a double wave lightcurve and a total amplitude $\Delta m = 0.29$ could be derived. Absolute mean magnitude is $\bar{V}(1, o) = 9.38$ and $V_0(1, 0) = 9.26$ with $B - V = 0.70$ and $U - B = 0.27$, using a mean phase coefficient $\varphi = 0.039$ mag/deg.

For 679 Pax the rotation period is $P = 7^{h}.625 \pm 0^{h}.005$ ($0^{d}.3177 \pm 0^{d}.0002$), also with a double lightcurve characteristic and $\Delta m = 0.07$. Absolute magnitude is $\bar{V}(1, 0) = 9.18$ and $V_0(1, 0) = 9.15$, with $B - V = 0.86$ and $U - B = 0.45$.

For both asteroids frequent color measurements were made during all phases of the rotation but no variations exceeding the scatter of $B - V = 0.01$ and $U - B = 0.02$ could be detected.

Sichao, W., Yuezhen, W., Mengxian, B., Liwu, D., and Sufang, W. (Purple Mountain Observatory, Academia Sinica, Nanjing, China): 'A Possible Satellite of 9 Metis', *Icarus* **46**, 285–287. (1981)

We attempted by means of photographic observations to search for satellites of asteroids in 1979 and 1980. An elongation of the image of 9 Metis has been detected on plates taken during 6 nights. The data suggest that there is a possible satellite with an orbital period of approximately 4.61 days and a mean distance of approximately 1100 km. We tabulate orbital parameters as well as predicted and observed position angles. A comparison with the secondary occultation results taken on 11.35 December 1979 is discussed.

Tedesco, E. F. and Sather, R. E. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Minor Planets and Related Objects. XXIX. Asteroid 29 Amphitrite', *Astron. J.* **86**, 1553–1558. (1981)

UBV photometry and lightcurves of asteroid 29 Amphitrite from all observed apparitions (March 1956–May 1977) are combined to obtain a phase function having a linear phase coefficient of 0.030 ± 0.002 mag/deg and a mean absolute magnitude $\bar{V}(1, 0)$ of 6.19 ± 0.04. Amphitrite displays a reddening of its $B - V$ color index with increasing solar phase angle: 0.816 ± 0.004 at a phase angle of 2° and 0.848 ± 0.004 at 23°. Since Amphitrtie's orbital inclination is low (6°) and its light curve amplitudes range between 0.06 and 0.11 mag, and are well distributed in longitude, we conclude that the obliquity of its pole is significantly different from zero. During some apparitions Amphitrite's lightcurves display only one maximum and minimum per 5.3904 ± 0.0007 hr rotation period while in others as many as five of each are present. We interpret this to mean that Amphitrite has a quasi-spherical shape with a highly irregular and/or variegated surface.

Townsend, C. L. (3521 San Juan Avenua, Oxnard, CA 93033): 'The Return of a Celestial Maverick – The Minor Planet Ra-Shalom', *J. Brit. Astron. Assoc.* **91**, 488–490. (1981)

Brief details are given of Minor Planet 2100, Ra-Shalom, an unusual Apollo-type object. A predictive ephemeris is given for its 1981 August return to enable astrophotographers to obtain satisfactory pictures.

Van Houten-Groeneveld, I. (Leiden Observatory, Huygens Laboratorium, Wassenaarseweg 78, Leiden, Netherlands): 'Photoelectric Light Curve of Pallas', *Astron. Astrophys.* **98**, 203–204. (1981)

Pallas was observed photoelectrically in 1965. The light curve is given in the figure. The observations were used by Schroll *et al.* (1976) to determine a preliminary value of the pole of rotation ($\lambda_0 = 228°$, $\beta_0 = +43°$).

Veeder, G. J., Tedesco, E. F., Tholen, D. J., Tokunaga, A., Kowal, C. T., Matthews, K., Neugebauer, G., and Soifer, B. T. (Jet Propulsion Lab., California Inst. of Tech. Pasadena, CA 91109): 'The Diameter and Albedo of 1943 Anteros', *Icarus* **46**, 281–284. (1981)

We report the results of broadband visual and infrared photometry of the Apollo–Amor asteroid 1943 Anteros during its 1980 apparition. By means of a radiometric model, we calculate a diameter of 2.3 ± 0.2 km and a visual geometric albedo of 0.13 ± 0.03. The albedo and reflectance spectrum of Anteros imply that it is a type *S* asteroid. Thus, Anteros may have a silicate surface similar to other Apollo–Amor asteroids as well as some stony-iron meteorites.

Zagouras, C. G. and Moran, P. E. (Dept. of Mechanics, Univ. of Patras, Greece): 'Examples of Predominantly Two-Body Orbits in the Sun–Jupiter Asteroid System', *The Moon and the Planets* **25**, 67–94. (1981)

Accurate numerical continuation of families of plane symmetric direct periodic orbits around the large primary in the Sun-Jupiter case of the restricted problem of three bodies allows the determination of the 'vertical branching points' where families of three-dimensional symmetric periodic orbits bifurcate from the planar ones. Three families of plane periodic orbits, and the initial segments of ten bifurcating families of three-dimensional ones are determined. The stability of these families is examined and examples of their orbits are illustrated.

Zappala, V., De Sanctis, G., and Ferreri, W. (Astronomical Observatory of Torino, I-10025 Pino Torinese, Italy): 'Positions of Selected Minor Planets (1979–80)', *Astron. Astrophys. Suppl.* **45**, 93–96. (1981)

343 precise positions of 22 minor planets, observed during the period September 1979–July 1980 at the Observatory of Torino, are given.

2. Comets

A'Hearn, M. F., Dwek, E., and Tokunaga, A. T. (Astronomy Program, Univ. of Maryland, College Park, MD 20742): 'Where is the Ice in Comets?', *Astrophys. J.* **248**, L147–L151. (1981)

We present the results of narrowband filter photometry of Comet Bradfield 1979 X for postperihelion, heliocentric distances from 0.57 to 1.65 Au. The emission-to-continuum ratio was found to be larger than that for any other comet measured by us, including P/Encke, although much of the 'continuum' in both comets is probably due to weak emission features. A sharp change in this ratio observed at 0.85 Au is attributed to the sudden appearance of an emission feature in our continuum bandpass. For the first time, we present OH production rates obtained contemporaneously with the production rates of the species more usually observed from the ground. All molecular species show a very steep variation with heliocentric distance, averaging about $r_H^{-3.2}$. This appears inconsistent with simple models of vaporization equilibrium and suggest that other factors, such as an insulating mantle or chemical reactions in the coma, may be important in controlling the gas production of this comet. There appear to be changes in the relative production rates with heliocentric distance in the sense that the comet was very CN-rich for a short time at discovery (heliocentric distance 0.5 AU post-perihelion), then became 'normal' from 0.6 to 1.0 Au, and gradually became somewhat CN-rich at heliocentric distances beyond 1 AU.

A'Hearn, M. F., Millis, R. L., and Birch, P. V. (Astronomy Program, Univ. of Maryland, College Park, MD 20742): 'Comet Bradfield 1979 X: The Gassiest Comet?', *Astron. J.* **86**, 1559–1556. (1981)

JHKL photometry of comets P/Tuttle, Meier 1980q, P/Stephan-Oterma, and Bowell 1980b has yielded $J - H$ and $H - K$ colors, uncontaminated by thermal emission, which are nearly identical for all four comets. The colors are inconsistent with the reflection spectrum from a cloud of icy particles, if the particles are composed primarily of any of the ices (H_2O, CO_2, CH_4, or NH_3) commonly assumed to be present in the nuclei of comets. Circular variable filter spectra of comet Stephan-Oterma confirm the absence of any absorption features due to these ices. The reflection spectra of these comets appear most like those of C- and S-type asteroids and the ring of Jupiter. Mie calculations for core-mantle particles suggest that ices could be present as thin mantles on inherently reddish, refractory cores, such as magnetitie.

Carusi, A., Kresák, L., and Valsecchi, G. B. (I.A.S.-C.N.R., Rep. Planetologia, Viale Dell'Universita 11, I-00185 Roma, Italy): 'Perturbations by Jupiter of a Chain of Objects Moving in the Orbit of Comet Oterma', *Astron. Astrophys.* **99**, 262–269. (1981)

In a model computation, a chain of 80 objects placed along a 10° arc of the precapture orbit of comet P/Oterma is followed during and after a passage near Jupiter. In spite of the minimum separation of the two orbits before the interaction exceeding 0.6 Au, very close encounters take place on a long arc, producing a broad variety of jovicentric orbits. These include temporary satellite captures by Jupiter with persistence of over 100 years, as well as orbits of small aphelion distance (down to 4.5 AU) and moderate perihelion distance (down to 2.5 AU) in which the objects can remain locked for several centuries at least. With the assistance of nongravitational effects, the latter type of objects is a potential candidate for further evolution giving rise to orbits of Encke, Apollo or Amor type. The occurrence rate of these extreme cases is low, and most of the orbits would change rather erratically. No hyperbolic ejections are found on the time scale examined. Analogy is drawn to the deformation of a meteor stream encountered by Jupiter; the patterns shown in Figures 9 and 10 becomes still more complicated as time goes on, and any continuity is destroyed very soon. The appreciable probability of a strong perturbation (at least 2.6% per revolution for a temporary satellite capture) sets a very low limit on the persistence of orbits of this type, and on the lifetimes of any streams of interplanetary particles occupying them.

Crovisier, J., Despois, D., Gerard, E., Irvine, W. M., Kazes, I., Robinson, S. E., and Schloerb, F. P. (Dept. de Radioastronomie, Observatoire de Meudon, F-92190 Meudon, France): 'A Search for the λ 1.35 cm Line of H_2O in Comets Kohler (1977 XIV) and Meier (1978 XXI)', *Astron. Astrophys.* **97**, 195–198. (1981)

The λ 1.35 cm line of H_2O was searched for and not detected in comets Kohler (1977 XIV) and Meier (1978 XXI) with the Effelsberg and Haystack radio telescopes. The observed upper limits are consistent with the low signal expected for a thermal excitation of the water molecule if H_2O is the parent molecule of OH. The previous detection of H_2O in comet Bradfield (1974 III) by Jackson *et al.* (1976) is difficult to interpret even if non-thermal excitation prevailed in this comet.

Despois, D., Gerard, E., Crovisier, J., and Kazes, I. (Departement de Radioastronomie, Observatoire de Meudon, F-92190 Meudon, France): 'The OH Radical in Comets: Observation and Analysis of the Hyperfine Microwave Transitions at 1667 MHz and 1665 MHz', *Astron. Astrophys.* **99**, 320–340. (1981)

Observations: the main lines of OH at 1667 MHz and 1665 MHz were searched in five comets: Kobayashi-Berger-Milon (KBM) (1975, IX), West (1976, VI), Encke (1977, XI), Kohler (1977, XIV), and Bradfield (1978, VII). Both transitions were observed in C/West and Kohler; the 1667/1665 line ratio is compatible with the LTE value of 1.8. At a heliocentric distance (r_h) of 1 AU the 1667 MHz profiles have a line width (FWHP) of 3 km s^{-1}, probably decreasing with increasing r_h. The line profile is generally asymmetrical with respect to the nucleus radial velocity but there is no significant radiation beyond 2 km s^{-1}.

The OH cloud is extended: 1667 MHz emission (or absorption) is detectable at 3ʹ.5 from the nuclei of both comest and up to 7ʹ in C/Kohler where a strong East-West asymmetry was found.

C/KBM and Bradfield were also detected but the signal is an order of magnitude fainter than in C/West and Kohler. Periodic comet Encke was never detected despite lengthy integration times.

Fernandez, J. A. (Max-Planck-Institut für Aeronomie, D-3411 Katlenburg-Lindau 3, F.R.G.): 'New and Evolved Comets in the Solar System', *Astron. Astrophys.* **96**, 26–35. (1981)

Numerical computations are carried out for a large sample of hypothetical comets to analyze how planetary perturbations affect the orbital properties of incoming comets. The computed results are then compared with some properties derived from the observed comet sample. The frequency of apparitions of 'new' comets is estimated to be about 1 passage within the Earth's orbit each 3 yr. In addition, nearly 500 evolved long-period comets enter the planetary region within Neptune's orbit each year. A maximum number of incoming long-period comets is predicted for perihelion distances somewhat greater than the radius of Saturn's orbit. The fast increase in the number of observed long-period comets with perihelion distance is in better agreement with a model of the cometary nucleus in which water ice controls its rate of vaporization. The slower dynamical evolution of long-period comets with retrograde orbits prevents us to observe them in their final stage with short-period orbits, since before reaching such a stage they will most probably be destroyed by vaporization. The number of 'new' comets returning to the 'Oort regions' (i.e. the region where stellar perturbations are strong enough to modify appreciably their orbits), will be larger for greater inclinations of their orbital planes. Therefore, a surplus of comets with retrograde orbits in the Oort regions is predicted, as a result of the incorporation of comets that have already passed through the planetary region. This could explain the observed excess of long-period comets in retrograde orbits. It is noted that an interstellar comet origin would imply a strong concentration of evolved long-period comets towards small inclinations which is in contradiction with observations.

Festou, M. C. (Service d'Aeronomie du CNRS B.P. No. 3, F-91370 Verrieres le Buisson, France): 'The Density Distribution of Neutral Compounds in Cometary Atmospheres II. Production Rate and Lifetime of OH Radicals in Comet Kobayashi-Berger-Milon (1975 IX)', *Astron. Astrophys.* **96**, 52–57. (1981)

Monochromatic observations of comet Kobayashi-Berger-Milton (1975IX) at 3090 Å are presented. The use of the vectorial model enables us to derive the lifetime and the production rate of the OH radicals in that comet at 0.85 AU from the Sun.

Gibson, D. M. and Hobbs, R. W. (Dept. of Physics, New Mexico Inst. of Mining and Tech., Socoro, NM 87801): 'On the Microwave Emission from Comets', *Astrophys. J.* **248**, 863–866. (1981)

We have derived a formula which can be used to predict the microwave flux density from the icy grain halo of a new comet. This model can account for all of the radio continuum observations of comets made to date, provided the gas production rate, Z is allowed to vary about its nominally accepted mean value by about a factor of 5. An implied consequence of this model is that the thermal radio emissions arises from grains which are approximately a few cm in size, not ~ 1 mm as given in earlier models.

Houpis, H. L. F. and Mendis, D. A. (Univ. of California, San Diego, La Jolla, CA 92093): 'The Nature of the Solar Wind Interaction with CO_2/CO-Dominated Comets', *The Moon and the Planets* **25**, 95–104. (1981)

The varying overall nature of the solar wind interaction with the ionospheres of CO and CO_2-dominated comets is investigated and compared with previous results for H_2O-dominated comets. It is shown that as a comet approaches the sun, it may exhibit one or two types of ionospheric transitions. (In rare circumstances, the cometary ionosphere may display a third type of transition in addition to one of the first two.) For both transitions, the ionosphere turns from being hard (in other words, the ionosphere is not susceptible to compression under sudden solar wind pressure increases) to soft. However, for one type of transition, the bow shock changes from being weak ($M \approx 2$) to being strong ($M \approx 10$), whereas for the other type of transition, the bow shock remains weak. The heliocentric distance at which these transitions may occur is found to be a function of the cometary nuclear radius, the latent heat of sublimation of the surface voltatiles, the surface bolometric albedo and the following ionospheric properties; the optical depth, the average ionization time scale and the amount of heat addition. Two important consequences of the strong shocks are the large solar wind velocity modulation of the energization of electrons at the bow-shock and the relatively quick formation of cometary plasma tails.

These results are applied to the case of comet Humason (1962 VIII). It is shown that either a CO or CO_2 dominated surface can explain not only the strong coma and tail activity of this comet at large heliocentric distances, but it can also explain the irregular activity of this comet at such distances.

Kresák, L'.: 'The Lifetimes and Disappearance of Periodic Comets', *Bull. Astron. Inst. Czechoslovakia* **32**, 321–339. (1981)

Among the 117 short-period comets discovered so far, there are 30 objects which have not been observed at their last returns to the Sun. All of these cases are analyzed for possible reasons of the loss. Even without presuming a progressive decrease of their absolute brightness, it is found that most of these comets failed to be rediscovered simply because their geocentric configurations at the missed returns were much less favourable than at the observed perihelion passages. The only cases where the loss was almost definitely due to an ultimate extinction are P/Biela dn P/Brorsen. For two additional objects P/Westphal and P/Neujmin 2 a complete extinction appears probable, and for a few others possible. These results are used to estimate the mean active lifetimes of comets. For the comets of Jupiter's family these amount to 2500–3000 yr, or to 400 revolutions in a short-period. For the comets of Halley type the mean lifetime seems to be of the order of 200 revolutions, or 10 000–15 000 yr. The corresponding slow rate of aging is consistent with the requirements of the formation of meteor streams but inconsistent with a rapid secular brightness decrease of comets.

Krishna Swamy, K. S. (Dept. of Applied Mathematics and Astronomy, University College, P.O. Box 78, Cardiff CF1 1XL, UK): 'Intensities of Various Bands of the Molecules CN, CN+, and CS in Comets', *Astron. Astrophys.* **97**, 110–113. (1981)

The resonance fluorescence calculations have been carried out for the (A–X) and (B–X) bands of CN, (c–a) and (f–a) bands of CN^+ and (A–X) bands of CS. The expected intensities are compared with the available rocket observations.

Kronk, G.: 'Mr. Halley's Hairy Star', *Astronomy* 9(9) 17–22. (1981)

Comets are the fuzzy tramps of the solar system. In they sweep, past the outer planets, growing bright and glorious for a time in the warmth of the Sun, only to return once more to their cold dark home, a light-month or more from the solar hearth. Their shows are always unexpected; we enjoy them and save up stories of spectacular apparitions to tell to our grandchildren.

But earlier ages saw no delight at all in comets. Far from being pleasant spectacles, they were demons or evil omens, foretelling disaster and riot in veiled, oblique ways. When a comet appeared, everyone from the king to the serf conferred anxiously with astronomers and astrologers about what it portended and how best to guard against its ill effects.

Our name for them goes back to the Greek *kometes* meaning hairy star – a fine naked-eye description. But the ancients weren't sure what a comet was. Demokritos believed they occurred when two planets came too close together, and Aristotle thought they were phenomena given birth in the Earth's atmosphere. Later, in Roman times, Seneca noted that since comets weren't affect by wind or weather,

they could hardly be atmospheric. But the beliefs of Aristotle prevailed. It wasn't until 1577, when Tycho Brahe proved that the bright comet of that year lay far beyond the Moon, that the Aristotelian view begins to lose its hold. Even so, it took about a century of observations and heated debate before cometary astronomy really began.

Levasseur-Regourd, A. C., Schuerman, D. W., Zerull, R. H., and Giese, R. H. (Service d'Aeronomie du CNRS, BP. 3, 91370 Verrieres le Buisson, France): 'Cometary Dust Observations by Optical in-situ Methods', *Advances in Space Res.* **1**, 113–120. (1981)

Remote optical observations of comets provide information only along the whole line of sight and require some assumptions to be interpreted. Due to the advent of cometary space missions, a two-step strategy has been defined to derive without any assumption spatial distribution and physical properties of dust by in-situ optical observations. First, an *Optical Probe Experiment*, suitable for a fast fly-by, should provide passive in-situ measurements in the direction of the approaching (or receding) comet near encounter; by suitably differencing such observations, the brightness and polarization per *unit volume* can be recovered along the trajectory of the spacecraft. Secondly, a *Light Scattering Dust Analyzer*, suitable for a rendez-vous mission, should permit the determination of the scattering properties of *individual particles*. Both experiments also provide a connecting link between non-optical in-situ measurements (from mass spectrometers or impact detectors) and remote optical observations.

No Author Cited: 'Halley's Comet – Messenger from Space', *Spaceflight* **23**, 212–213. (1981)

No Author Cited: 'Looking for Halley's Comet', *Sky Telesc.* **61**, 500–501, (1981)

Radzievskii, V. V.: 'Probability of Discovery of Comets as a Criterion of Their Origin', (in Russian), *Astron. Zh.* 58, 1286–1290 (1981). English translation in *Soviet Astron.* **25**, No. 6.

On the basis of the observed distribution of parabolic comets with respect to the perihelion distance q and the well-known formula of the probability of the discovery of comets their true distribution is found. It is shown that this distribution is incompatible with the hypothesis of Oort of capture and eruption of the comets by giant planets.

Radzievskii, V. V. (Gorki Pedagogic Institute, Gorki, U.S.S.R.): 'A Qualititative Analysis of the Problem of Comet Migration', *Solar System Res.* **15**, 24–27. (1981)

An examination is carried out of individual consequences which result from the Tisserand criterion concerning the direction of comet migration. It is shown that migration from the field of almost-parabolic comets (H) into the family of elliptical comets (E) does not contradict the data of cometary statistics. It is determined that the statistical material is incompatible with the $E \rightarrow H$ direction of migration.

Shulman, L. M. (Main Astronomical Observatory of the Ukrainian Academy of Sciences, 252127 Kiev, U.S.S.R.): 'The Contemporary Model of Cometary Nucleus and the Prospects of Its Improvement by Space Research', *Advances in Space Res.* **1**, 91–98. (1981)

No cometary nucleus has ever been observed directely. A model is deduced from ground-based and space data on cometary atmospheres. The main features of the chemical composition of cometary nuclei and the estimation of their sizes are described. The treatment of the process of vaporization of dusty ice shows, contrary to widespread opinion, that the islands on the non-volatile porous mantle are formed, not in perihelion but at large heliocentric distances and on the coldest parts of a nucleus. It is shown that the mantle does not disappear when the comet approaches the Sun, as it is often supposed, but is fluidized. The proposed model can give a number of propertis of cometary nuclei but some of them can be established by direct space methods only. Such properties are the masses, the rotational velocities, the homogeneity of the dust-ice mixture, the internal structure, the power of the internal sources of energy.

Trogus, W., Ockert, R., and Auer, R. D. (Dornier System Gmbh, Postfach 1360, 7990 Friedrichshafen, F.R.G.): 'A European Probe to Comet Halley', *Advances in Space Res.* **1**, 131–136. (1981)

A European probe to comet Halley is proposed. The probe's model payload consists of 8 scientific instruments, viz. neutral, ion and dust impact mass spectrometers, magnetometer, medium energy ion and electron analyzer, camera, dust impact detectors and plasma wave experiment. Fly-by of the comet Halley nucleus will take place on November 28th, 1985, at about 500 km miss distance. The main spacecraft serves as relay link to transmit the observed data to Earth. As probe, a modified ISEE 2 design is proposed. Becuase of the cometary dust hazard expected in the coma a heavy dust shield (27 kg) is required, consisting of a thin front sheet and a 3 layer rear sheet. The probe is spin-stabilized (12 rpm), has no active attitude and orbit control capability and uses battery power only to provide about 1000 Wh for a measuring phase. A despun antenna transmits up to 20 kbit s^{-1}, in X-band. The total probe mass is estimated at 250 kg. The 3 model development programme should start in mid 1981 with Phase B.

Wallis, M. K. and MacPherson, A. K. (Dept. of Applied Mathematics and Astronomy, Univ. College, Cardiff CF1 1XL, Wales, Great Britain): 'On the Outgassing and Jet Thrust of Snowball Comets', *Astronomy Astrophys.* **98**, 45–49. (1981)

We discuss the characteristics of free molecular and fluid flows from a kilometric-sized snowball sublimating in the solar radiation. The net back-thrust is more than 50% lower than hypothesized by Whipple (1977) and reconcilable with derived non-gravitational forces only if mean comet densities are low (under 0.7 g/cm^3). The densities on the sunward face are high enough to ensure collisional subsonic flow, but the density and pressure on the shaded side for probably comet rotation rates are much lower. Models with approximately radial outgassing are invalid; instead we postulate pressure-driven flow to the shaded side, where condensation partially compensates for radiative heat losses. The reduced net jet–thrust from such sublimation-condensation flows implies still lower limits on comet masses and densities.

Wilkins, D. (Instituto di Astrofisica Spaziale, C.P. 67, I-00044 Frascati, Italy): 'Perturbation of Parabolic Comets by a Transient Solar Companion', *Astron. Astrophys.* **98**, 30–33. (1981)

Kirk (1978) argued that a companion star to the Sun, suggested by Harrison (1977), cannote be excluded by means of the data on nearly parabolic comets, provided its speed is large enough. An exact calculation confirms Kirk's result. The encounter does not affect the mean energy of the comets. But their spread of energies is increased. If the mass, speed and present distance of the companion are held fixed, the amount of broadening is the largest for those encounters in which the two stars have approached closest. The extra spread in energy falls belwo the observed value when the companion's mass is small, or its speed and present distance are large.

Discussion of the several approximations adopted shows that the results should be accurate at the 10% level under nominal values of the parameters.

Yabushita, S. and Hasegawa, I. (Dept. of Applied Mathematics and Physics, Kyoto Univ., Kyoto 606, Japan): 'On a Correlation between the Reciprocal of Cometary Semi-Major Axis and Absolute Brightness', *Monthly Notices Roy. Astron. Soc.* **195**, 361–370. (1981)

An investigation is made as to whether there exists a correlation between $1/a$ (a denotes the semi-major axis) and H_{10} (the absolute magnitude) of a comet. Adopting the original values of $1/a$ calculated by Marsden Sekanina & Everhart and the numerical values of H_{10} given by Vsekhsvyatskij and by Meisel & Morris, it is found that the increase in H_{10} from nearly parabolic orbits (D) to orbits of P (period) $\sim 10^2$ yr (B) is 1.6. On the other hand, the number of revolutions, N required for a comet to evolve from D to B orbits by planetary perturbations is calculated and it is found that $N \simeq 700$. On the icy nucleus model of comets, the original value of the nuclear radii can be estimated on the assumption that comets evolve from nearly parabolic to short periodic orbits. The radius so estimated is consistent with Roemer's and O'Dell's values for observed comets with nearly parabolic orbits. Thus, the process of dynamical diffusion is consistent with the observational results.

3. Meteorites

Axon, H. J. (Metallurgy Dept., Univ./Umist, Manchester M1 7HS, UK): 'Disruption of Meteoritic iron Parent Bodies', *Nature* **292**, 779. (1981)

The discovery by Clarke *et al.* of preterrestrial shock polymorphism (ϵ structure) and shock-induced diamond in Allan Hills A77283 has implications for the process by which the parent body of this meteroite disrupted.

The internal metallographic structures of meteoritic iron seem to require well insulated parent bodies of 10–100 km size, whereas iron meteorites typically fall to Earth as bodies of 10–100 cm with occasional crater-forming masses of perhaps up to 100 m size. However, of the 70 or so IA irons (exlcuding A77283) only 3 show sufficient signs of mechanical damage to produce the ϵ structure. Of these three Cañon Diablo is well known to contain diamond, but is a crater-forming mass and the indications are that this shock effects arose during Earth impact. Cranbourne and Magura are showers, not associated with known craters, and are badly corroded. Magura has been reported to contain diamond.

In the absence of ablative heat effects it is difficult to say whether the shock effects in Cranbourne and Magura are pre-terrestrial or not, but the Allan Hills A77283 observations now open up the possibility that they may be.

Thus, the disruption of the IAB parent body seems to have been effected with major damage (ϵ) to only two or three of the resulting fragments. By contrast, most of the 130 or so members of the IIIAB group show ϵ structures or shock heating effects.

It is therefore easy to accept a collison process for the disruption of the IIIAB parent body but the marked absence of shock polymorphism in the IAB irons is puzzling. One possibility is that the distribution of non-metal phases (silicates, sulphides) was different in the two parent bodies and allowed damage to be more concentrated in the non-metal portion of the IAB parent. The new eivdence on A77283 and the possible pre-terrestrial character of shock effects in Cranbourne and/or Magura now indicate that collision was involved in the disruption of the IAB parent body. The nature of the assumed non-metal portion of the IAB parent which bore the brunt of collision damage remains unresolved but the position of the shocked diamondiferous ureilites might be reconsidered in this context.

Bevan, A. W. R., Kinder, J., and Axon, H. J. (Dept. of Mineralogy, British Museum (Natural History), London, UK): 'Complex Shock-induced Fe–Ni–S–Cr–C Melts in the Haig (IIIA) Iron Meteorite', *Meteoritics* **16**, 216–267. (1981)

The Haig (IIIA) iron meteorite material (BM 1968,280) in the Collection of the British Museum (Natural History) displays pre-terrestrial shear deformation which transects a small troilite-daubréelite-cohenite nodule. Five globular areas (<1 mm) with dendritic structures indicating rapid solidification from melts occur within and around the larger part of the transected nodule. All shock deformation structures and shock-heating effects exhibited by Haig are of pre-terrestrial origin and at least four successive alterations to the original structure are evident.

Partial bulk analyses of the melt globules indicate complex mixtures of approximately 55 wt % troilite, 24 wt % metal, 14 wt % daubréelite and 7 wt % cohenite. It is suggested that a compressive environment maintained the melts as discrete pools of liquid.

The diameters of the globules (<0.5 mm) and spacing of the dendrite arms ($<1\ \mu$m) indicate solidification at $>10^6\ {}^\circ C\ s^{-1}$ which is the fastest cooling rate yet recorded in meteorites.

Bevan, A. W. R., Axon, H. J., Scott, E. R. E. R. D., and Rajan, R. S. (Dept. of Mineralogy, British Museum (Natural History), Cormwell Road, London, SW7 5BD, UK): 'Comments on "Metallic Minerals, Thermal Histories and Parent Bodies of Some Xenolithic, Ordinary Chondrite Meteorites"; and Reply', *Geochim. Cosmochim. Acta* **45**, 1957–1958. (1981)

Bevan and Axon (1980) proposed that polycrystalline γ (taenite) in the unequilibrated (H3) chondrite Tieschitz is a relic of rapid, non-equilibrium solidification of Fe–Ni–S melts during chondrule formation. Scott and Rajan (1980) dismissed our observations and conclusions. Here we defend and clarify our position. Grain boundaries as observed in polycrystalline γ (taenite) could not have been established either during sloz, sub-solidus cooling of homogeneous γ (taenite), or, in the absence of γ/γ grain-boundary α precipitates, by deformation and annealing (hot working).

Chou, C.-L., Sears, D. W., and Wasson, J. T. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Composition and Classification of Clasts in the St. Mesmin LL Chondrite Breccia', *Earth Planet. Sci. Lett.* **54**, 367–378. (1981)

Seven samples of the unique St. Mesmin meteorite have been analyzed by instrumental and radiochemical neutron activation analysis for Na, Ca, Sc, Cr, Mn, Fe, Co, Ni, Zn, Ga, Ge, Se, In, Sm, Yb, Ir and Au. St. Mesmin is unique in being the only ordinary chondrite known to contain an unmelted xenolith of another ordinary chondrite. Data for two host matrix samples and three light clasts are consistent with their classification as LL chondrite material. The composition of the large dark xenolith confirms earlier evidence that it is an H chondrite; volatile abundances are consistent with it being highly shocked, petrologic type-4 material. In an olivine microporphyry, siderophile abundances are mostly about 0.13 times LL abundances, an apparent indication of metal loss during the shock melting which produced the clast. As in other regolithic chondrites, the dark host has higher contents of highly volatile elements than do the light clasts. We suggest that this results from a combination of differences in intensity of preexisting metamorphism as well as a redistribution of volatiles during regolith gardening.

The H-group xenolith in St. Mesmin is a relatively recent addition to the parent body (<1.4 Ga ago), but it is argued that this does not require regolith activity at that time. Rather the view is supported that the regolith period occurred very early in the meterorite's history ($\gtrsim 4.0$ Ga ago) and may have been related to the growth of the parent body. The H-group fragment may be part of the projectile whose impact excavated the St. Mesmin meteroid from the LL parent body.

Durrani, S. A., Bull, R. K., and Green, P. F. (Dept. of Physics, Univ. of Birmingham, Birmingham B15 2TT, England): 'Some Parameters Involved in the Interpretation of Meteorite Ages: A Review of the Present Status', *Nuclear Tracks* **5**, 223–228. (1981)

In obtaining fission-track ages for meteorites, the effects of cosmic-ray primaries and induced fission must be taken into account. The presence of ^{244}Pu tracks allows the cooling rates of meteorite parent bdoies to be determined with good time-resolution.

Chondrites and IA irons cooled at rates of a few degrees K per Myr and probably originated in bodies of ~ 100 km in radius. The mesosiderites cooled rather more slowly.

No fission-track evidence for the existence of extinct superheavy elements in meteorites has yet been obtained.

Eberhardt, P., Jungck, M. H. A., Meier, F. O., and Niederer, F. R. (Physikalisches Institut, Univ. of Bern, Sidlerstr. 5, 3012 Bern, Switzerland): 'A Neon-E Rich Phase in orgueil: Results Obtained on Density Separates', *Geochim. Cosmochim. Acta* **45**, 1515–1528. (1981)

He, Ne and Ar were measured with the stepwise heating technique in 8 density separates from the Ne-E rich phase G4j of the carbonaceous chondrite Orgueil. The density separation technique was successful in further enriching the Ne-E carrier phases. Ne-E seems to be virtually pure ^{22}Ne with $(^{20}\mathrm{Ne}/^{22}\mathrm{Ne})_E \leqq 0.15$ and $(^{21}\mathrm{Ne}/^{22}\mathrm{Ne})_E \leqq 0.0022$. At least two separable carrier phases exist. The l-carrier phase releases its Ne-E at low temperatures ($\leqq 900\,^\circ$C) and is heavily enriched in the low density separate ($\leqq 2.3\,\mathrm{g\,cm^{-3}}$). h-carrier phase is very retentive (release temperatures $> 900\,^\circ$C) and is associated with higher density material (~ 3 to $3.5\,\mathrm{g\,cm^{-3}}$). The *l*-carrier phase could be a form of carbon. Our evidence does not support spinel as an *h*-carrier phase, as proposed by Alaerts *et al.* (1980). Ne-E and its carrier phases are most likely of presolar origin.

Fudali, R. F. (Dept of Mineal Sciences, Smithsonian Institution, Washington, DC 20560): 'The Major element Chemistry of Libyan Desert Glass and the Mineralogy of Its Precursor', *Meteoritics* **16**, 247–259. (1981)

Pieces of high-silica, natural glass (Libyan Desert Glass), found on the desert surface of western Egypt, have been treated as an enigma for 50 years although it is virtually certain they are similar to tektites in being impact-derived products. New major element analysis of four Libyan Desert Glass specimens agree extemely well with the only other recent analysis and demonstrate that the original bulk analyses reported by Spencer (1939) are in error. The five modern analyses define a very tight chemical range for SiO_2 (97.38–98.25 wt %), Al_2O_3 (1.16–2.26 wt %), total Fe (0.15–0.60 wt % as Fe_2O_3) and TiO_2 (0.13–0.19 wt %). Measurable MgO (0.04–0.20 wt %) was found in one specimen. No other elements are present in greater than trace amounts. Microprobe analyses show that Al, Fe and Ti are all positively correlated with one another and are almost ubiquitously distributed throughout the glass. They must also have been so distributed in the LDG precursor material as mechanical mixing and elemental diffusion in the short-lived melt were limited. In contrast, Mg is sharply restricted in occurrence and correlates only with Fe, strongly suggesting a precursor Mg-Fe oxide or silicate mineral present as rare, discrete grains. Aside from rare accessory minerals, the parent material was a sand or sandstone composed of quartz grains coated with a mixture of kaolinite, hematite and anatase. This conclusion is based solely on the elemental distribution in the glass but is buttressed by the occurrence of both sand and sandstone, in southwestern Egypt, with the requisite mineralogy. However, mineralogic identity need not, in general, translate to a chemical match and it is entirely possible that the specific sand or sandstone facies involved in the glass formation no longer exists after 28 million years. Consequently, it may well be that evidence other than chemical comparisons will be needed to identify the presently unknown parent crater.

Fredriksson, K., Miller, J., Nelen, J. and Darsa, S. (Dept. of Mineral Sciences, Smithsonian Institution, Washington, DC 20560): 'The Tambakwatu Chondrite', *Meteoritics* **16**, 77–81. (1981)

According to its petrography, uniform olivine, $Fa_{23.8}$, and pyroxene, $Fs_{20.4}$, total iron content of 22.9 wt % Fe, 16.4 wt % FeO and an FO/FeO + MgO ratio of 24.7 mol %, the Tambakwatu is a veined, intermediate hypersthene (Cia) or L6 chondrite.

Goswami, J. N. (Physical Research Lab., Ahmedabad 380009, India): 'Solar Flare Irradiation Records in Antarctic Meteorites', *Nature* **293**, 124–125. (1981)

Petrographical studies indicate that most meteorites collected from the Antarctic ice sheets are L and H chondrites of different metamorphic groups. Achondrites and iron meteorites constitute $< 5\%$ of the total collection of about 1600. Radionuclide, specifically ^{53}Mn, studies have suggested a multiple exposure history for some of the meteorites involving shielded exposure to cosmic rays either in large asteroidal-size parent bodies, from which the meteorites were ejected, or in relatively smaller-size objects that broke up in space in recent times. Relatively fewer Antarctic meteorites have been studied for their noble gas content and records of cosmic ray heavy nuclei tracks; here has been no evidence of solar flare tracks and solar wind noble gases in the analysed samples. I now report the first observation of solar flare heavy nuclei tracks in Antarctic meteorite samples. Two interior specimens of sample 77216, an L-3 chondrite, contain track-rich grains indicating their exposure to solar flare irradiation before compaction of this meteorite. Preliminary noble gas data also indicate the presence of solar-type gases. Results of nuclear track studies of other Antarctic meteorite samples are presented.

Grossman, L., Olsen, E., Davis, A. M., Tanaka, T., and MacPherson, G. J. (Dept. of the Geophysical Sciences and Enrico Fermi inst., Univ. of Chicago, Chicago, IL 60637): 'The Antarctic Achondrite Alha 76005: A Polymict Eucrite', *Geochim. Cosmochim. Acta* **45**, 1267–1279, (1981)

ALHA 76005 is a basaltic achondrite containing few, if any, orthopyroxenes. Its bulk major and trace element composition is like that of a non-cumulate eucrite, and unlike that of a howardite. It contains a variety of igneous clasts which differ in their textures, pyroxene/plagioclase ratios and pyroxene and plagioclase compositions. One clast, No. 4, was found to have the REE pattern of a cumulate eucrite and an oxygen isotopic composition of clast No. 4 suggest that it was derived from a source different from its host. These observations lead to the conclusion that ALHA 76005 is a polymict eucrite.

Hajduk, A. and Cevolani, G.: 'Simultaneous Radar Meteor Observations at Ondrejov and Budrio', *Bull. Astron. Inst. Czechoslovakia* **32**, 304–310. (1981)

Radar meteor observations carried out simultaneously by the Ondrejov (Czechoslovakia) and Budrio (Italy) radar equipment during the Orionid shower period in October 1978 were used to obtain the variation of shower activity. The resulting peak rate is placed at $\lambda_{\odot} = 208.1 \pm 0.3$. A rapid increase of meteor activity, exceeding the shower peak rate, was found at $\lambda_{\odot} = 214.6$ and is ascribed to a filament of the stream.

Heymann, D. and Dziczkaniec, M. (Dept. of Geology, Rice Univ., Houston, TX 77001): 'Tellurium: Should It Be Isotopically Anomalous in the Allende Meteorite?', *Geochim. Cosmochim. Acta* **45**, 1829–1834. (1981)

Isotopically anomalous Te is a by-product of the nuclear processes in zones of supernovae that have been proposed as sources for isotopically anomalous Xe. The calculated composition of the anomalous Te is roughly consistent with the disputed measurements made by Ballad *et al.* (1979) and Oliver *et al.* (1979) of samples of the Allende meteorite with the exception that the large ^{123}Te overabundance reported by Oliver *et al.* (1979) is not predicted by the theory.

Hohenberg, C. M., Hudson, B., Kennedy, B. M., and Podosek, F. A. (Dept. of Physics, Box 1105, Washington Univ., St. Louis, MO 63130): 'Xenon Spallation Systematics in Angra dos Reis', *Geochim. Cosmochim. Acta* **45**, 1909–1915. (1981)

We have resolved literature Xe data for the Angra dos Reis meteorite into constituent spallation, fission and trapped components. The spallation Xe compositions vary over a range wider than observed in any other samples, including lunar samples. These variations are due to the mixing of spallation Xe from Ba and rare earth element targets. It is possible to infer the Ba and rare earth spallation Xe compositions. Angra dos Reis spallation Xe compositions are systematically different from those observed in lunar samples, possibly because of differences in the irradiation conditions (geometry and shielding). Thus the Angra dos Reis data appear to be superior to lunar data for predicting spallation Xe compositions in *other meteorites*.

Hughes, D. W. (Dept. of Physics, the University, Sheffield, UK): 'Meteorite Falls and Finds: Some Statistics', *Meteoritics* **16**, 269–281. (1981)

The statistics of meteorite falls and finds are presented. Histograms give the distribution of falls as a function of year, month and time of day. The distributions of the retrieved masses of fallen and found meteorites are given, as is also their distribution over the Earth's surface. The data for this analysis have been taken from the British Museum's Catalogue of Meteorites (1966) and Appendix (1977).

Hutchinson, R. (British Museum (Natural History), London, UK): The Significance of Unique or Rare Meteorites', *Nature* **293**, 260. (1981)

Hutchinson, R. (British Museum (Natural History), London, UK): 'How "Unique" can Meteorites Be?', *Nature* **293**, 11. (1981)

King, E. A., Jarosewich, E., and Daugherty, F. W. (Dept of Geology, Univ. of Houston, Houston, TX 77004): 'Tierra Blanca: An Unusual Achondrite from west Texas', *Meteoritics* **16**, 229–237. (1981)

Tierra Blanca is an achondrite (*sensu stricto*) composed chiefly of orthophyroxene, olivine, plagioclase and clinopyroxene. The mineralogy, major element chemistry and texture are similar to Winona and also Mt. Morris, Acapulco and Antarctic meteorite ALHA 77081 to some degree. The designation of this group as 'Winonaites', as suggested by Prinz *et al.* (1980), seems justified and useful.

Knab, H. -J. (Max-Planck-Institut für Chemie (Otto-Hahn-Institut), Saarstr. 23, D-6500 Mainz, West Germany): 'The Distribution of Trace Elements in Carbonaceous Chondrites', *Geochim. Cosmochim. Acta* **45**, 1563–1572. (1981)

12 carbonaceous chondrites, amongst them representatives of nearly all known petrologic types were analyzed for twenty trace elements by spark source mass spectrography combined with the isotope dilution method. Data on different element groups (refractory, moderately volitile and volatile) show that the distribution of the trace elements in the carbonaceous chondrites, with the exception of Renazzo, can be well explained by Anders' two-component model. This is also valid for the highly metamorphised CV5 chondrite Karoonda.

Furthermore, it is observed that the Zr/Hf-ratios in the carbonaceous chondrites increase with increasing petrologic type which is interpreted as the result of mixing two components with different Zr/Hf-ratios.

Kracher, A. and Willis, J. (Inst of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Composition and Origin of the Unusual Oktibbeha County Iron Meterorite', *Meteoritics* **16**, 239–246. (1981)

We have analyzed Oktibbeha County, the most Ni-rich iron meteorite, for Ni, Co, Cu, Ga, Ge, As, Sb, Ir, and Au. Cu and Sb are higher than in any other iron, but other trace elements are within the ranges typically found in iron meteorites. Extrapolation of trace element trends in group IAB indicates that Oktibbeha County is a member of this group. This sheds light on the origin of groups IAB and IIICD, which are thought to be derived from impact melts on parent bodies of chondritic composition.

Lafayette (iron), another sample reported in the literature to have a similarly high Ni content, is probably a pseudometeorite.

Lambert, P., McHone, J. F. Jr., Dietz, R. S., Briedj, M., and Djender, M. (Center for Meteorite Studies, Arizona State Univ., Tempe, AZ 85287): 'Impact and Impact-Like Structures in Algeria. Part II. Multi-ringed Structures', *Meteoritics* **16**, 203–227. (1981)

While Part I was devoted to the study of bowl-shaped depressions in Algeria, the present article focuses on multi-ringed structures of possible impact origin on the Algerian Sahara platform. Four structures were selected from orbital aviation and geologic documents but only three were visited. TIN BIDER (27°36′N; 005°07′E) is a concentric multiple ring structure at least 6 km in diameter. Upper-Cretaceous sedimentary beds outside the structure dip inward a few degrees at the periphery and become extremely folded nearer the center, yet a general circular symmetry is always retained. A clearly exposed contact between upper deformed beds and underlying on-deformed beds is remarkably flat, dipping less than 10° inward. The upper beds display strong centrifugal folding. In the center of the structure Lower-Cretaceous sandstones about 0.5 km above their normal stratigraphic position are exposed. Although no shatter cones, intensive brecciation, or fracturing were observed, there is definite petrographic evidence of shock metamorphism (planar elements) in the quartz grains of the central sandstones. Tin Bider is a probable impact structure. It is the only astrobleme known with such prominent ductile deformations, a characteristic which may be due to the nature of the target materials. Detailed studies are now required to understand the mechanism of deformation of this multi-ringed structure. Its formation may be early Tertiary in age. FOUM TEGUENTOUR (26°14.5′N; 002°25′E) is an 8 km diameter bull's eye ring pattern. Although the high circularity and the morphology are consistent with an impact origin, the prominence of ductile deformation, the nature of the formations (clay-gypsum with sandstone intercalations), the type of folds, the relationships between the structure and a surrounding plateau, and the lack of any evidence of shock effects better support a diapiric origin. MAZOULA (28°24′N; 007°49′E) is an 800 m diameter multi-ring feature with a 300 m wide anticlinal dome which rises some 30–35 m above the surrounding horizontal strata. The dome is capped by a flat-lying massive carbonate layer dipping on the flanks in accordance to the surface topography.

Lebedinets, V. N. (Institute of Experimental Meteorology, State Committee on Hydrometeorology of the U.S.S.R., U.S.S.R.): 'Quasicontinuous Fragmentation of Meterorites', *Solar System Res.* **15**, 27–34. (1981)

Equations for calculating the luminous intensity curves and estimating the deceleration and other characteristics of meteors produced by meteorites experiencing quasicontinuous fragmentation are

derived. Comparison with observation data shows that all the basic observed characteristics of photographic meteors can be adequately explained within the framework of the model of quasi-continuous fragmentation of compact stone meteorites with an effective fragmentation energy of 1.6×10^{10} erg g^{-1} and a fragment mass of 10^{-5}–10^{-4} g.

MacDougall, J. D. (Scripps Institution of Ocenography, La jolla, CA 92093): 'Refractory Spherules in the Murchison Meteorite: Are They Chondrules?', *Geophys. Res. Lett.* **8**, 966–969. (1981)

Refractory spherules in the Murchison carbonaceous chondrite show a range of compositions similar to those of coexisting irregular inclusions. However, the shape and internal texture of the spherules are suggestive of formation from a liquid. The coexistence of these two types of refractory inclusions suggests that the spherules were formed by melting of previously condensed irregular inclusions. If so, they can be properly termed chondrules.

Marvin, U. B. (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA)2138): 'The Search for Antarctic Meteorites', *Sky Telesc.* **62**, 423–427. (1981)

Mold, P., Bull, R. K., and Durrani, S. A. (Dept. of Physics, Univ. of Birmingham, Birmingham B15 2TT, England): 'Constancy of 244PU Distribution in Chondritic Whitlockite', *Nuclear Tracks* **5**, 27–31. (1981)

The relationship between published Pu/U ratios in chondritic whitlokite and the presently measured uranium concentration has been examined. The correlation is found to be consistent with the assumption that the average plutonium content in the whitlockite crystals was approximately constant at a certain reference time, a conclusion supported by known plutonium contents of five chondrites. Fission-track ages of 4.31 Gyr have been obtained for the whitlockites of the LL5 chondrites, Olivenza and Alta'ameem, assuming a mean plutonium content of 20 ppb, 4.57 Gyr ago. In both these chondrites, track studies show that severe fractionation of plutonium relative to uranium has occurred between whitlockite and chlorapatite. The need for a more reliable reference element than uranium for indicating plutonium-244 concentrations is discussed, and samarium is suggested as a possibility.

No Author Cited: 'Mystery Meteorites May Come from Mars', *New Scientist* **91**, 219. (1981)

Olsen, E. J. (Field Museum of Natural History, Chicago, IL 60605): 'Estimates of Total Quantity of Meteorites in the East Antarctic Ice Cap', *Nature* **292**, 516–518. (1981)

Since 1969 ~ 5000 meteorite fragments have been recovered from two regions, the Yamato Mountains and Victorialand, on opposite sides of the East Antarctic ice cap. Based on a steady-state model for the ice cap, and current estimates of meteorite influx, a model is developed here which predicts that the steady-state number of meteorites being carried in and on the ice is at least 760 000. Most of these are being carried within the ice and are only exposed at peripheral regions by a combination of wind ablation and blockage of ice movement by protruding mountain barriers. The large steady-state population of meteorites does not require unusual conditions of influx. It is solely the cold, dry climate which preserves virtually all meteorites that fall except for the fragile, porous carbonaceous chondrites. The same model applied to the Greenland ice cap indicates a steady-state population of ~ 61 000 meteorites.

Ott, U., Mack, R., and Chang, S. (Dept. of Physics, Univ. of California, Berkeley, CA 94720): 'Noble-Gas-Rich Separates from the Allende Meteorite', *Geochim. Cosmochim. Acta* **45**, 1751–1788. (1981)

Predominantly carbonaceous, HF/HCl-resistant residues from the Allende meteorite were studies before and after applying physical and chemical separation methods. Samples were characterized by SEM/EDXA, X-ray diffraction, INAA, C (including isotopic composition), S, H, N and noble gas analyses. Isotopic data for carbon showed little variation ($\lesssim 5‰$); isotopic data for noble gases confirmed previously established systematics. In our samples, noble gas abundances correlated with those

of C and N but not with those of S and metal; concomitant partial loss of C and 'normal' trapped gas occurred during treatments with oxidizing acids; and total gas loss accompanied combustion of carbon. In addition, HF/HCl demineralization of bulk meteorite resulted in similar fractional losses of C and trapped noble gases. These results lead us to conclude that various macromolecular carbonaceous substances serve as

– the main host phase ('Q') for 'normal' trapped noble gases in acid-resistant residues from Allende,

– the main host phase for 'anomalous' gas in the acid-resistant residues, and

– the carrier of the major part of trapped noble gases lost during HF/HCl demineralization ('solubles').

At present little information exists concerning what fraction of the carbonaceous material in Allende consists of noble gas host phases; and the possibility is not yet ruled out that very minor amounts of dense non-carbonaceous minerals also could act as trapped gas carriers, especially if they were inseparable from the lighter carbonaceous matter by our methods. Limits on the possible abundances of dense mineralic host phases in the residues have been obtained, however; if Q were an Fe/Cr mineral or a sulfide, its abundance has to be more than an order of magnitude lower than inferred previously from etching experiments. By analogy with C1 and C2 meteorites, where carbonaceous phases play host to noble gases with anomalies of nucleogenetic origin, we also favor a nucleogenetic origin for CCF-XE. These considerations hold open the possibility that carbonaceous host phases and various forms of organic matter in carbonaceous meteorites may have had a presolar origin.

Rambaldi, E. R. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Relict Grains in Chondrules', *Nature* **293**, 558–561. (1981)

It is not widely recognized that a significant fraction of the chondrules from ordinary chondrites contain silicate grains that survived the chondrule formation process without melting. In the most typical case these grains consist of coarse olivine, rarely orthopyroxene, crystals located in the core of chondrules and displaying a zoning that is inconsistent with crystallization from a silicate melt. The surrounding groundmass contains abundant glass and fine grained euhedral olivines that appear to be of igneous origin. The relict grains still preserve the imprint of processes that occurred in the solar nebula and, in some cases, may include the isotopic record of interstellar gains. The original properties of these chondrules are best preserved in the most unequilibrated ordinary chondrites. I present here important information with regard to the chondrule precursor materials and the process of chondrule formation which was acquired by a compositional and textural study of three of the most unequilibrated type 3 ordinary chondrites.

Tsuchiyama, A., Nagahara, H., and Kushiro, I. (Geological Inst., Univ. of Tokyo, Hongo, Tokyo, 113, Japan): 'Volatilization of Sodium from Silicate Melt Spheres and Its Application to the Formation of Chondrules', *Geochim. Cosmochim. Acta* **45**, 1357–1367. (1981)

The rates of volatilization of Na from liquid spheres of chondrule compositions have been determined as functions of time, temperature, partial pressure of oxygen, and sizes of the spheres. The Na_2O content in the sphere is uniform in each run, but it decreases with time of the run, indicating that the rate of diffusion of Na in the liquid is greater than that of volatilization, and that the latter is the rate-controlling process. The rate of sodium volatilization becomes greater with increasing temperature and with decreasing P_{O_2} and size of the spheres. The relation of the Na_2O content in the liquid sphere with time and its size indicate that the amount of Na_2O volatilized from the liquid spheres within unit time is proportional to the surface area of the spheres and the concentration of Na_2O in the liquid. From these relations, the rate of volatilization of sodium can be obtained at constant temperature and p_{O_2}. The rate of volatilization of sodium satisfies the Arrhenius relation within the temperature range from about 1450–1600°C at $10^{-9.2}$ atm p_{O_2}; the activation energy for the sodium volatilization is approximately 100 kcal·mole^{-1}. The rate is also approximately proportional to $p_{O_2}^{-1/4}$ within the range of P_{O_2} from $10^{-10.2}$ to $10^{-5.0}$ atm at about 1500°C. Based on the present results and the Na_2O contents in chondrules, it is suggested that they experienced an instant heating with maximum temperature of 1400–2200°C followed by an immediate cooling.

Turco, R. P., Toon, O. B., Park, C., Whitten, R. C., Pollack, J. B., and Noerdlinger, P. (R and D Associates, Marina Del Rey, CA 90291): 'Tunguska Meteor Fall of 1908: Effects on Stratospheric Ozone', *Science* **214**, 19–23. (1981)

In 1908, when the giant Tunguska meteor disintegrated in the earth's atmosphere over Siberia, it may have generated as much as 30 million metric tons of nitric oxide (NO) in the stratosphere and mesosphere. The photochemical aftereffects of the event have been simulated using a comprehensive model of atmospheric trace composition. Calculations indicate that up to 45% of the ozone in the Northern Hemisphere may have been depleted by Tunguska's nitric oxide cloud early in 1909 and large ozone reductions may have persisted until 1912. Measurements of atmospheric transparency by the Smithsonian Astrophysical Observatory for the years 1909 to 1911 show evidence of a steady ozone recovery from unusually low levels in early 1909, implying a total ozone deficit of 30 ± 15%. The coincidence in time between the observed ozone recovery and the Tunguska meteor fall indicates that the event may provide a test of current ozone depletion theories.

Ustinova, G. K., Gorin, V. D., and Lavrukhina, A. K. (Inst. of Geochemistry and Analytic Chemistry, Academy of Sciences of the U.S.S.R., U.S.S.R.): 'Radiation History of the Dhajala Chondrite and the Heliolatitude variations of Galactic Cosmic Rays', *Solar System Res.* **15**, 43–49. (1981)

The radiocativity of the cosmogenic isotopes Sc^{46}, Mn^{54}, Na^{22}, Al^{26}, and Co^{60} in the recently fallen Dhajala chondrite has been measured by the low-background γ spectrometry method. Theoretical calculations of the depth distribution of these cosmogenic radiosotopes were also performed for chondrites of various sizes whith chemical composition and time of fall similar to those of the Dhajala chondrite. In view of the high inclination of the orbit of the Dhajala chondrite, the observed excess in the experimental values of the radioactivity of Mn^{54}, Na^{22}, and Al^{26} over those calculated permits concluding that significant transverse gradients of galactic cosmic rays existed in the solar system during the anomalous period of development of the solar cycle in 1972–1975. It is found that the average transverse gradient during this period at average heliocentric distances of 1.6–1.7 Au in the southern hemisphere as 3–5% per deg of heliolatitude with recession from the ecliptic by 0.3–0.4 AU, whereas the average transverse gradient over the past million years has been (0.4 + 1.4)% per deg of heliolatitude at these distances.

Voloshchuk, Yu. I., Kashcheev, B. L. and Tkachuk, A. A.: 'Velocities of Meteroids from Radar Observations. I. Velocity Distributions', (in Russian), *Astron. Vest.* **15**, 118–126. (1981)

The results of velocity measurements of individual meteors up to $+12^m$ from Kharkov observations carried out in 1973–1974 are analyzed with a computerized radar of high sensitivity. A new method for obtaining the true velocity distribution of meteoroids in the neighbourhood of the earth's orbit is proposed. The variation of the parameters of distribution of the meteoroids versus the velocity outside the earth's atmosphere and the heliocentric velocity for various sections of the celestial sphere are investigated by means of this method.

Willis, J. and Goldstein, J. I. (Dept. of Metallurgy and Materials Engineering, Lehigh Univ., Bethlehem, PA 18015): 'Solidification Zoning, and Metallographic Cooling Rates of Chondrites', *Nature* **293**, 126–127. (1981)

The cooling rates of meteorites provide important clues to the sizes of their bodies. The cooling rates of chondritic meteorites have been determined by measuring the concentration of nickel in the interiors of taenite grains of various sizes and by comparing these data with computer models for the Ni distribution as a function of cooling rate. It has been recently suggested that in some meteorites the measured Ni gradients in taenite are not entirely produced by solid-state diffusion but partly reflect Ni gradients produced during solidification coring. If this is correct, Wood's cooling rate method would be invalidated for these meteorites. We have investigated the effect of zoning produced during solidification on the formulation of the Wood model, and report here that solidification zoning is erased during kamacite growth and has no influence on the resultant taenite Ni gradients for all cases in which the cooling rate is sufficiently slow ($< 1000\ K\ Myr^{-1}$) to allow Ni to diffuse to the taenite grain centre.

Woolum, D. S. and Burnett, D. S. (Harvard-Smithsonian Centre for Astrophysics, Harvard Univ., Cambridge, MA 02138): 'Metal and Bi/Pb Microdistribution Studies of an L3 Chondrite' Their Implications for a Meteorite Parent Body', *Geochim. Cosmochim. Acta* **45**, 1619–1632. (1981)

We find strong localizations (relative to bulk) of Bi and to a lesser extent Pb, in some of the kamacite grains in Khohar. Other kamacite grains show no such enrichments. There are distinctive and correlated differences in the Ni contents of the two kamacite populations with the Bi/Pb-rich kamacite grains having consistently lower Ni levels (sometimes unusually low, ~2% Ni) than the Bi/Pb-poor kamacite, which typically have ~6–7% Ni. The Bi/Pb-rich kamacite grains are also distinguished on the basis of their etching behavior, exhibiting a highly reactive attack, which has not been observed previously and which we believe may be due to the fact that the Bi/Pb-rich kamacite is finely polycrystalline.

We conclude that the trace element microdistributions were not established in the nebula. Nor is it likely that the enrichments occurred with slow cooling in the presence of a vapor phase during the kamacite–taenite phase transition. Rather, the Bi/Pb-rich kamacite most likely reflect the occurrence of a brief reheating episode (or episodes), which may have been shock-induced and which was followed by rapid cooling. We find fine-grained metal-sulfide intergrowths which testify to such a reheating event, and one likely candidate for the site of this event is a hot ejecta blanket at the parent body surface. Iron oxides are found in our Khohar sections. We believe that they are not due to terrestrial alteration, that they are magnetite and that the magnetitie probably originated in the same dynamic event in which the Bi/Pb distributions were established. The present data do not allow us to confidently determine whether the even occurred prior to, during, or after the compaction of this meteorite, although the simplest interpretation of the data would indicate the first alternative. Bulk Bi data for Khohar has been used for inferring accretion temperatures and this now appears inappropriate.

4. Cosmic Dust, Other Particles, etc.

Alexander, W. M. and Corbin, J. D. (Dept. of Physics, Baylor Univ., Waco, TX 76706): 'Submicron Lunar Ejecta in the Magnetosphere Associated with Meteor Showers', *Advances in Space Res.* **1**, 107–110. (1981)

Recent studies of the lunar ejecta from lunar impacts of interplanetary dust particles indicate that during favorable lunar phases, over 80% of the submicron ejecta enters the Earth's magnetosphere. This "pulse" of lunar ejecta produced by the sporadic meteor background will follows the random variations of the sporadic flux. An additional enhancement of this flux can be related to major meteor showers. Since the annual periods of these showers occur during varying lunar phase angles, magnetosphere ejecta flux associated with major showers will vary depending on the coincidence of shower periods and favorable lunar phase angles. The results of an analysis of the 'pulse' of ejecta flux in the magnetosphere during the Quadrantids, Geminids, Leonids, and Perseids meteor showers are presented. These results are comapred to the satellite measurements of 1959 Eta and HEOS II.

Corbin, J. D. and Alexander, W. MM. (Dept. of Physics, Baylor Univ., Waco, TX 76706): 'Orbital Dynamics of Magnetospherically Trapped Lunar Ejecta', *Advances in Space Res.* **1**, 103–106. (1981)

In situ measurements by dust experiments on HEOS II showed significant enhancement of fluxes for submicron particles. Recent studies have shown that lunar ejecta in this size range can, in a highly simplified model, be trapped in the earth's magnetosphere. The present work is a more detailed study of the dynamics of lunar ejecta in the magnetosphere. The particle size ranges for which the guiding center approximation is valid, for which corotation is negligible, and for which electromagnetic forces dominate gravitational forces have been calculated. Temporal details of charge acquisition by ejecta in the plasmasphere are considered.

Daniels, P. A. and Hughes, D. W. (Dept. of Physics, The University, Sheffield S3 7RH, Sheffield, UK): 'The Accretion of Cosmic Dust – A Computer Simulation', *Monthly Notices R. Astron. Soc.* **195**, 1001–1009. (1981)

This paper presents the results of a three-dimensional computer simulation of the growth of cosmic dust aggregates. The sphericity and packing fraction of the resulting dust aggregates are quantified as a function of size. Similarities are noticed between the aggregates so produced and micrometeorites found in the decay products of cometary nuclei.

Using a mass distribution index of 1.73 for the accreting particles resulted in an aggregate with a mean volume packing fraction of about 0.25 ± 0.1. This predicts an ice to dust mass ratio in cometary nuclei of about 1, a value similar to observed ratios.

Hickey, L. J. (Div. of Paleobotany, Smithsonian Institution, Washington, DC 20560): 'Land Plant Evidence Compatible with Gradual, Not Catastrophic, Change at the End of the Cretaceous', *Nature* **292**, 529–531. (1981)

Field study of the fossil and sedimentary record across the Cretaceous–Tertiary (K–T) boundary in Wyoming and Montana has been combined here with a reassessment of the published record of terrestrial palynomorphs to test recent hypotheses that a universal biotic catastrophe caused by an asteroid, cometary impact or a supernova terminated the Cretaceous. Evidence from land plants is particularly critical because plants form the base of the terrestrial food chain. Thus, massive disruptions of the Earth's vegetation by the postulated effects of a cosmic disaster (blocking of solar radiation for several years by a dust cloud, severe atmospheric heating or ionizing radiation) would have an amplified effect on the land fauna. However, I report here that the geographically uneven and generally moderate levels of extinction and diversity change in the land flora, together with the non-synchroneity of plant and dinosaur extinctions, contradict hypotheses that a catastrophe caused terrestrial extinctions.

Kresák, L. (Astronomical Inst., Slovak Academy of Sciences, 89930 Bratislava, Czechoslovakia): 'The Flux of Earth-Crossing and Moon-Cratering Interplanetary Bodies', *Advances in Space Res.* **1**, 85–90. (1981)

Methods fo determining the present flux and total number of kilometer-sized Earth-crossing objects are disucssed, including (1) probability considerations based on the frequency of chance rediscoveries of the lost objects, (2) evaluation of large-scale photographic surveys for the detection of fast moving objects, and (3) evaluation of close encounters of interplanetary bodies with the Earth. The results are interfaced with the lunar and terrestrial cratering history. It is shown that the discrepancies between these two independent lines of evidence are still within the margin of uncertainty set by observational biases, cratering efficiencies, and surface reflectivities of the objects, in particular as regards extinct cometary nuclei. Impacts of active comets can only be held responsible for a very small fraction of the craters, and impacts of high-albedo Apollo asteroids are consistent with a steady state. There is no definite enhancement of the present-day flux as compared with the average level of cratering during the last 3 Gyr which would require significant variations in the stellar environment of the solar system, affecting the rate of delivery of new comets from the Oort cloud. There is also no evidence of a recent major collisional event in the asteroid belt. Deviations from an equilibrium between source and sink only become effective in the size range of meteor particles, where no long-term cratering record is available. They are apparently due to a very limited number of parent objects, and appear on a time scale which is very short compared with the age of the solar system.

Zacharov, I., Surkov, Yu. A., Rybakov, A. K., Vasyukova, Z. V., Vasil'ev, Yu. D., Apati, I., and Semirej, I,: 'Results of Investigating Meteoric Matter on the Intercosmos 14 Satellite', *Bull. Astron. Inst. Czechoslovakia* **32**, 239–242. (1981)

The results of recording micro-meteroic bodies on the interkosmos 14 satellite are studied. It is shown that flux density of particles with mass $m \geqslant 6 \times 10^{-14}$ in the neighbourhood of the Earth at an altitude of 1000 km is not more than 5 times higher than the density in interplanetary space. A correlation was observed between the fluxes of particles of the sporadic background and of the particles combined into groups. The results of the experiments are compared with the data of other investigators.