COMMISSION 15: PHYSICAL STUDY OF COMETS, MINOR PLANETS AND METEORITES
(L'ETUDE PHYSIQUE DES COMETS, DES PETITES PLANETES ET DES METEORITES)

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I. Introduction

The illness which prevented Dr. N. Richter from presiding over Commission 15 sessions in Montreal proved fatal on November 26, 1980.

Books published since 1978 dealing with the subject matter of Commission 15 are: (1) Comets and The Origin of Life, ed. C. Ponnomperuma, 1981, D. Reidel Pub. Co., Dordrecht, Holland (designated C. P. Colloq. in Report); (2) Comets, ed. L. Wilkening, Univ. Arizona Press, 1982 (designated Comets, 1982 in Report) contains invited reviews of Tucson, IAU Colloquium No 61, "Comets" Gases, Ices, Grains, Plasma". Contributed papers will appear in a volume of Icarus. Papers dealing with cometary and asteroidal orbits appear in IAU Symp. 81, 1979 and with cometary grains and meteorites in IAU Symp. 90, 1981. Proceedings of Workshops are: (1) "Experimental Approaches to Comets", ed. J. Oro, 1978, Lunar and Planetary Institute, Pub. 361; (2) "Modern Observational Techniques for Comets", eds. J. Brandt et al., 1981, JPL Pub. 81-68, NASA.

Publications of meetings dealing with cometary missions include: (1) Report of the Comet Science Working Group, NASA Tech. Mem. 80543, 1979; (2) Cometary Missions, ed. Axofrd et al., 1979, Veroff Remeis-Sternwarte Bamberg-Ast. Inst. Univ. Erlangen-Nurnberg, 12, Nr. 132; (3) Several ESA publicatons on the Giotto mission to Comet Halley: SP-153, 1979 Comet Halley Micrometeoroid Hazard Workshop, ed. N. Longdon; SP-155, 1981, Comet Halley Probe-Plasma Environment, ed. N. Longdon; SP-169, 1981, Scientific and Experimental Aspects of Giotto Mission. Two publications deal with observations of Comet Halley 1986: The International Halley Watch (1980, NASA TM 82181) and The Comet Halley Handbook (Yeomans, 1981, Jet Propulsion Lab.-NASA).

The publication of the book Asteroids, ed. T. Gehrels, 1979, Univ. Arizona Press, contains several important review articles on asteroids and meteorites and constitutes a milestone of progress in our understanding of the relationship between meteorites and asteroids. Three issues of "Meteoritika" (MET. 37-39) were published containing more than 60 papers. Descriptions of many new meteorites as well as a variety of other information were published in the quarterly "Meteoritics". A volume of collected papers by Academician V. G. Fesenkov, Meteorites and Meteoritic Matter (1978), was published. Results of the chemical analyses of over 100 meteorites and their chemical classifications were published by D'yakonova, Kharitonova and Yavnel' as a book, Chemical Composition of Meteorites. A book, Meteorites -- Fragments of Asteroids, was published by Simonenko (1979). Yavnel' (MET. 38) published a review on the studies of meteoritic matter in the USSR for 1948-1977. Two important review papers on carbonaceous chondrites appeared: refractory inclusions in Allende by Grossman (1980, Ann. Rev. Earth Planet. Sci.) and carbonaceous chondrite matrix and their aqueous processing by McSween (1979, Rev. Geophys. and Space Phys.). Major review articles were also published on isotopes: Nd isotopes (O'Nions et al., 1979 Ann. Rev. Earth Planet. Sci.)

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and general isotopic problems (Lee, 1979, Revs. Geophys. Space Phys. 17, 1981; Podosek, 1978, Ann. Rev. A & A, 16, 293).

II. Comets

STRUCTURE, ROTATION AND ORIGIN OF COMETARY NUCLEI - F. L. Whipple

The first radar dection of a cometary nucleus is that of P/Encke by P. g. Kamound et al. (1982, Comets), with the great Arecibo dish. On the basis of certain assumptions they obtain a radius of 1.3 ± 0.2 km.

Evidence for spottedness or heterogeneous surfaces on comets, reported in 1979, is strikingly confirmed for P/Swift-Tuttle by Z. Sekanina (Astron. J., *in press 1981) who specifically locates several small active areas on the* nucleus. Observed narrow jets define these areas and also a rotation period of 66.5 hours. The active areas, 1% of the total surface, persist for short intervals up to 2 months and indicate that the outgassing process is much more complex than sublimation of simple stable ices.

A summary of spin-period calculations for the nuclei of 47 comets has been presented by F. L. Whipple (1982, "Comets"). He used the not-too-well tested halo method and finds a median period of 15.0 hr. The spin period increases with absolute brightness for the comets but appears not to correlate with other parameters. Comets appear statistically to be spinning much slower than the small asteroids, particularly the Apollos and Amors, adding a weak argument against the suggestion that the old comets may turn into apparent asteroids. Other evidence on this subject is summarized by Whipple (1981, C.P. Colloq., 1). C. Froeschle and H. Rickman (1980, A&A, 82, 183), from Monte Carlo orbital calculations, conclude that $\leq$1% of the Amor Asteroids may be derived from dead comets.

By U. V. spectroscopy of three comets P. D. Feldman (1981, C.P. Colloq, 31) finds no compositional evidence of stratification or aging. On the other hand, blanketing of the icy surfaces on cometary nuclei by meteoroidal debris is strongly suggested by the light curve and polar motion of P/Encke as studied by Whipple and Sekanina (Astron. J. 84, 1894, 1979). M. F. O'Hearn, E. Dwek and A. T. Tokunaga (1982, Comets), from infrared photometry of four comets at relatively large solar distances find no evidence of grains or surfaces covered with H_2O, CO_2, CH_4 or NH_3 ices. Processes of large dust migration on rapidly rotating nuclei are discussed by H. L. F. Houpis and D. A. Mendis (Ap. J. in press, 1981. See also Mendis and G. D. Brin, The Moon and Planets, 17, 359, 1978 and Ap. J. 229, 402, 1979).

SPLITTING OF COMETS - Z. Sekanina

On the basis of his model of split comets, Sekanina (Icarus 38, 300) formulates a test of splitting and finds that most observations of nucleus multiplicity refer to phenomena other than physical breakup. Among genuinely split comets, minor fragments subjected to differential nongravitational decelerations of more than 10^{-3} the solar attraction are probably the most numerous. The updated sample of split comets is no longer dominated by the 'new' comets. Breakups of at least two split comets are known to have been accompanied by bursts of dust and/or brightness flare-ups (also Sekanina & Farrell, 1978, AJ 83, 1675). Wallis (1980, MNRAS 190, 467) suggests that the observed separation velocities of fragments could result from pressure forces from evaporating ices. Sekanina (1979, IAU Symp. 81, p. 311) calculates the gravitational interaction between fragments upon splitting in the absence of a differential nongravitational force and finds quasi-stable periodic orbits are possible in certain cases. He also notices that there are physical similarities between suddenly dissipating comets and short-lived fragments of the split comets (1980, BAAS 12, 511). Weissman (1980, A&A 85, 191) considers splitting to be the most important process of physical loss of comets. Delsemme (1979, IAU Symp. 81, p. 265) suggests that fragments that had broken off from 'new' comets and later returned to the sun with a near-zero energy change are responsible for the secondary peak in his bimodal distribution of absolute magnitudes of the comets with 'original' semimajor axes in excess of 10^4 AU. Recent progress in the understanding of split comets is reviewed by Sekanina (1982, "Comets"). He concludes that the relatively high differential nongravitational accelerations and large erratic brightness variations of the nuclei of the split comets are consistent with a model of oblate, rrapidly precessing objects with dimenions in the subkilometer-size range. Short-lived companions of old and short-period comets could pancake-shaped fragments of a thick insulating dust crust with a thin layer of ice adhering to their base. Comet Bradfield 1980t was reported to suggest briefly a multiple structure of its central part (IAUC 3569), but the suspected secondary condensations were not confirmed.

ORBITAL DYNAMICS AND EVOLUTION INCLUDING OORT CLOUD - E. Everhart

A comprehensive review of the orbital dynamics of comets and minor planets is by L. Kresak (1980, Moon and Planets, 22, 83). He discusses stable orbits, such as those of main-belt asteroids, of Trojans, and of planetary satellites and compares these with unstable orbits, which include those of all comets, of Apollo objects, of special objects such as 914 Hidalgo and 2060 Chiron. He shows that stable orbits lie in one region on an orbital energy vs eccentricity plot, unstable orbits in another. This plot enables him to identify which "asteroids" are in all probability extinct comets. There is a discussion of the boundary line between stable and unstable orbits. Where there are non-gravitational effects of mass loss it is sometimes possible for an object to cross this boundary.

Chiron's exceptional orbit, whose perihelion is beyond Saturn's distance was studied by H. Scholl (1979, Icarus 40, 345). By means of extensive numerical integrations he showed that Chiron's orbit is unstable, agreeing with earlier work by Oikawa and Everhart (1979, Astron. J. 84, 134) that Chiron may eventually appear (many tens of thousands of years from now) in an orbit like those of the short-lived comets.

A quite surprising new result is by A. Carusi and G. B. Valsechhi (1981, A&A, 94, 226) who find that short-period comets are very often temporaily captured by Jupiter for a few revolutions around that planet. Such temporary capture events by Jupiter and Saturn were known, but no one had realized how common they are. In fact, they show that seven known periodic comets have been captured by Jupiter within the past 50 years. Indeed four comets, P/Kowal, P/Gehrels 3, P/Oterma, and P/Shajn-Schaldach, spent a total of 18 years as temporary satellites of Jupiter during the years 1930-1975. It is significant that the orbits of many newly-discovered short-period comets, when extrapolated backwards, come from the region of Jupiter. This work suggests that many of these had been temporary satellites of Jupiter.

Dynamics of comets preserved in the Oort Cloud have been investigated by Weissman (1979, IAU Symp. 81, p. 277); Monte Carlo simulation and cometary loss and deterioration were included. Effects of stellar perturbations were examined by Weissman (1980, Nature, 288, 242). Planetary and stellar perturbations also using Monte Carlo calculations were considered by Fernandez (1980, Icarus 42, 406; A&A 96, 26). Weissman (1982, "Comets") reviewed the present status of the Oort Cloud. Fernandez (1980, MNRAS 192, 481) proposed a comet Belt beyond Neptune to complement the Oort cloud source.

OPTICAL SPECTROSCOPY & SPECTROPHOTOMETRY - M. F. A'Hearn

Lists of line identifications were provided by Mo and Fan (1980, Chin. Astr. 4, 45) for Comet Arend-Roland 1957 III and by Cosmovici and Ortolani (1980 A&Ap. 88, L16) who included identification of lines from the elusive C_2 Phillips bands in Comet Bradfield 1979X.

Sivaraman et al. (1979 MNRAS 189, 897) and A'Hearn et al. (1980 AJ 85, 74) presented conflicting spectrophotometry for Comet West 1976 VI. Sivaraman et al. found substantial reddening of the continuum which varied systematically with phase angle while A'Hearn et al. found only slight reddening and also included an analysis of the NH_2 bands to provide the first abundance estimates. Danks and Dennefeld (1981 AJ 86, 314) obtained near IR spectra of Comet Bradfield 1979X in which they tentatively identified the C_2 Phillips bands and in which they obtained the first intensity measurements of the $\Delta v=0$ sequence of red CN system, which they analyzed to deduce a vibrational transition probability for CN. Barker (1981, unpublished) has obtained a complete spectrum of Comet Bradfield 1979X extending from the $\Delta v=0$ sequence of violet CN to the 0-0 band of red CN for which he obtained the first intensity measurements. Spinrad et al. (1981 Icarus in press) have obtained spectrophotometry of the nculear region of many comets and have reported large variations in the strength of OI relative to that of CN. Grudzinska (1979 Stud Soc Sci Torun 6, #2, 63) has presented older spectrophotometry on several comets. Abundances of ten metals in comet Keya-Seki, 1965 VIII were obtained by Arpigny (1979, 22nd Liege Astrophysics Conference, 189). Abundance of ten metals in comet Ikeya-Seki, 1965 VIII were obtained by Arpigny (1979, 22nd Liege Astrophysics Conference, 189).

CO^+ has been studied widely. Cochran et al. (1980 AJ 85, 474) first reported its existence in P/Schwassman-Wachmann 1 during an outburst and it was subsequently discovered by Larsosn (1980 ApJ 238, L47) during the quiescent phase of this comet.

Theoretical fluorescence calculations were carried out for several species. Krishna-Swamy and O'Dell (1980 ApJ 231, 624; 1981 ApJ in press) have calculated for C_2 the expected ratios of Swan bands to Phillips bands and of Swan bands to Mulliken bands as a funciton of the transition moment for the intercombination transition. These results were used by A'Hearn & Feldman (1980 ApJ 242, L187) to derive that transition moment. Krishna-Swamy (1981 A&A 97, 110) has also calculated the relative bands strengths for CN, CN^+, and CS. Schleicher and A'Hearn (1980 BAAS 12, 462; ApJ in press) have calculated absolute line and band intensities for OH including the Swings effect and demonstrated large intensity variations in the bands.

ULTRAVIOLET SPECTROSCOPY, PRODUCTION RATES AND COMA MODELS - M. Festou

During the last few years, most cometary observations have become quantitative. Systematic type studies have been conducted, wider spectral ranges were covered and, the activity of comets was monitored over a very large interval of heliocentric distances. Thus, correlative studies have produced numerous new results.

Extensive abundance correlations among comets (A'Hearn and Millis, 1980, Astron. J., 85, 1528; Feldman et al., 1980, Nature, 286, 132; Weaver et al., 1981, Icarus, in press) show a great composition homogeneity from comet to comet. While visible spectra are very similar, besides the value of the dust/gas emissions ratio, UV spectra reveal the presence of variable amounts of carbon or carbon bearing molecules (Smith and Stecher, 1980, Ap. J., 242, 402; numerous papers written from IUE observations). Smith and Stecher (1980) have identified S and CS emissions and suspected the presence of the C_2 Mulliken bands in the comet West spectrum. Those three identifications were confirmed by Jackson et al. (1978, A&A 73, L7) and A'Hearn and Feldman (1980, Ap. J. Lett., 242, L187).

The UV spectra have revealed some of the production mechanisms: the 1931 Å carbon line results very likely from the electron recombination of CO^+ (Feldman, 1978, A&A 70, 547) and the 2972 Å oxygen line essentially comes from the photodissociation of water (Feldman et al., 1980; Festou and Feldman, 1981, A&A, in press). Donn and Cody (1978, Icarus, 34, 436) have suggested that newly created CN radicals might be detected by an abnormal population of high quantum number rotational lines of the CN (0 – 0) band at 3883 Å. According to Festou (1981, A&A 96, 52), 2 to 3% of the OH radicals are created in the $^2\Sigma^+$ state and have a spatial repartition similar to the H_2O density distribution. Simultaneously, O(^{1}D) and O(^{1}S) atoms liberated and produced the green and red forbidden oxygen lines. O(^{1}D) atoms are not produced by electron impact (Ashihara, 1978, Icarus, 35, 369).

The emission spectrum of comet West was investigated over a very large range of heliocentric distances (Kumar et al., 1978, Ap. J., 232, 616; A'Hearn et al., 1978, Astron. J., 85, 74). The comparison between spectra of "new" and "periodic/old" comets showed that those latter had a much higher production of gas than their low brightnesses would have suggested (A'Hearn et al., 1979, Astron. J., 84, 570; Weaver et al., 1981). Comets were found to be very active at large heliocentric distances: a weak ion tail was observed in comet West at 6 AU from the sun (Degewij, 1980, Astron. J., 85, 1403) and comet Bowell (1980b) showed signs of activity at 7.17 AU (Cochran A. and McCall, 1981, PASP, 92, 854). The effects on comet gases of solar ultraviolet flux variations has been investigated by Oppenheimer and Downey (1980, Ap. J., 241, L123). Short time variations have been found in the gaseous emissions of comet West (Keller and Meier, 1979, A&A 81, 210) and comet Koutoutek (Tarashchuk and Terez, 1980, Solar Syst. Res., 12, 131).

Mendis and Brin (1978, The Moon and the Planets, 17, 77 and 359) have investigated the variation of monochromatic brightnesses with the heliocentric distance. Festou (1981, A&A 95, 69 and 96, 52) has reviewed the density models of neutral molecules in cometary comas and he has proposed a new model taking into account the vectorial combination of the velocity vectors of parent and daughter molecules. He has applied his model to the OH radical and found a value of the lifetime of this radical in close agreement with theoretical calcualtions by Jackson (1980, Icarus 41, 147). This model has been generalized to double dissociation products and tested with HI Lyman-alpha measurements made with the Copernicus satellite: the variation of the HI-1216 Å linewidth with the distance to the nucleus is compatible with the assumptions that water and OH are the main parents of the observed H atoms (Festou et al., 1979, Ap. J., 232, 318). Combi and Delsemme (1980, Ap. J., 237, 633) have developed a model similar to Festou's model but easier to use. However, it is limited to single dissociation products and to monokinetic ejection velocity distributions.

RADIO AND RADAR OBSERVATIONS OF COMETS – E. Gerard

The passive continuum emission at cm wavelength is reviewed by Gibson and Hobbs (1981, Ap. J. 248, 863): there is no confirmation of the 20-40 mJy signals detected once in Kohoutek (1973 XII) and West (1976 VI).

The spectral line studies are thoroughly analysed by Snyder (1982, Icarus). OH observations at λ 18 cm have continued to be very successful with Meier (1978 XXI), Bradfield (1979 X), Meier (1980 q), Bradfield (1980 t) and Encke (1980) (Despois et al, 1981, A&A, 99, 320; Bockelee-Morvan et al, 1981, Icarus, in press; Giguere et al. A. J. 85, 1276). The OH velocity field was directly measured for the first time, the OH parent production rate correlates well with the visual brightness of the coma as well as with the C_2 and CN production rates found from optical spectra over a large range of values.

All radio observations of molecules other than OH have failed so far and do not confirm previous detections, in particular H_2O (Crovisier et al., 1981, A&A, 97, 195; Hollis et al., 1981, Ap. J. 244, 357) in C/Meier (1978 XXI) and Bradfield (1979 X), HCN (Ekelund et al., 1981, Icarus, in press; Snyder et al., 1981, in preparation) in the same comets and unidentified transitions U8.18883, U86.2471, U89.0105 in Bradfield (1979 X) (Hollis et al., ibid; Ekelund et al., ibid).

From the statistical study of C_2, CN, C_3 in 14 comets (A'Hearn and Millis, 1980, A. U. 85, 1528) and OH in 10 comets (Bockelee-Morvan et al., ibid) a quantitative estimate of molecular production rates is possible: clearly past radio searches of molecules other than OH lacked sensitivity as the average column density seldom exceeds a few 10^{12} mol. cm^{-2}. Furthermore the excitation is such that some transitions are not favorable for detection (e.g., the λ 1.35 cm line of H_2O and the $\nu_8 = 1$, λ 2.71 mm lines of CH_3CN).

COMA CHEMISTRY - W. F. Huebner

Extensive chemical modeling of comet comae has been caried out by Giguere and Huebner (1978, Ap. J. 223, 638); Huebner and Giguere (1980, Ap. J. 238, 753) and Mitchell, Prasad and Huntress (1981, Ap. J. 244, 1087). In the first two of these papers, chemical equilibrium or near equilibrium was assumed for the composition of the nucleus appropriate to conditions of the comet formation in the region of the giant planets. Outstream velocity of the coma gas was constant in the first paper, supersonic in the second paper in which it also was shown that photodissociative ionization is an important mechanism for ionization in the inner coma, particularly CO^+ production. CN was produced in marginal agreement with observation at 1 AU, but C_2 and C_3 were underproduced. The ratio of CO^+ to H_2O^+ was never significantly above one. Data from comet Kohoutek indicates it should be about 30. Similar results were reported in the third paper, where the outstream velocity was again assumed to be constant. However, in this paper an "interstellar" composition of the nucleus was also tested. It produced CN, C_2, CH, and NH_2 in agreement and C_3 in marginal agreement with observations. Only a few per cent of CN-, C_2-, and C_3- bearing "interstellar" molecules need be in the composition of the nucleus. It was also found that the initial composition should not contain more than a few per cent of NH_3. Calculations by Biermann, Giguere, and Huebner (unpublished, but see review by Huebner (1981, C. P. Colloq) confirm these results and show that they also give agreement with observations at heliocentric distances from 0.5 to $\sim$3 AU. But the ratio of CO^+ to H_2O^+ was still not significantly above one. Oppenheimer and Downey (1980, Ap. J. 241, L123) have discussed the effect of solar UV variations on the chemistry of the coma gas. Yamamoto (1981,, Moon Planets 24, 175) modeled the chemistry of an H_2O comet. Huntress, McEwan, Karpas, and Anicich (1980, Ap. J. Suppl. 44, 481) published major ion-molecule reactions occurring in the coma; Jackson (1980, Icarus 41, 147) calculated the lifetime of OH in solar UV and Huebner and Carpenter (1979, Los Alamos Scientific Laboratory report LA-8085-MS) computed solar photo rate coefficients for cometary ions.

DUST COMA AND TAIL - Z. Sekanina

The physical properties of cometary dust are discussed from the optical (visual and infrared) standpoint by Hanner (IAU Symp. 90, p. 223), from the dynamical standpoint by Sekanina (ibid, p. 237). Both authors emphasize the likelihood of at least two distinct populations of particles (dielectric and absorbing) in comets; cf. also Saito et al. (13th Lunar Planet. Symp. Tokyo, p. 175) and Isobe (ibid. p. 183). Silicate models are employed by Krishna Swamy & Donn (AJ 84, 692) for 1973 XII and by Krishna Swamy (Ap. Space Sci. 57, 491) for 1965 VIII. Hellmich (A&A 93, 341), Hellmich & Keller (IAU Symp. 90, p. 255), and Keller (ESA SP-153, p. 57) conclude that moderate amounts of dust in the coma noticeably enhance the incident solar flux on the nucleus but the numerical results are questioned by von Roos (JPL Publ. 81-80). Narrow-band photometry is used by A'Hearn et al. (AJ 84, 570) to estimate the color of the dust grains in four comets, by Newburn et al. (AJ 86, 469) to infer the possible existence of an icy halo in P/Ashbrook-Jackson, and by Newburn & Johnson (Icarus 35, 360) to set an upper limit on the dust production rate in P/Encke consistent with the photographic results on the comet's antitail (Sekanina & Schuster A&A 68, 429). A'Hearn et al. (Ap. J. 248, L147) fail to detect icy particles in four comets by JHK photometry, but Hanner (Icarus, in press) concludes that the relevant bands of H_2O might be too shallow to detect.

Considerable attention has been paid to Comet West 1976 VI, especially its striated tail. Koutchmy & Lamy (Nature 273, 522), Koutchmy et al. (A&A 72, 45), and Lamy & Koutchmy (A&A 72, 50) propose that the striae resulted from the solar-wind and magnetic-field interactions with charged dust particles. Sekanina & Farrell (BAAS 11, 455; IAU Symp. 90, 267; AJ 85, 1538) use solar attraction and solar radiation pressure to fit the motions of 16 striae applying a method based on Sekanina's concept of particle fragmentation. A virtually identical scenario has been suggested by Akabane (13th Lunar Planet. Symp., Tokyo, p. 166). Hill & Mendis (Ap. J 242, 395) offer electrostatic breakup as an alternative fragmentation mechanism to rotational bursting at large distances from the nucleus. Sekanina & Farrell (AJ 83, 1675) find evidence for discrete bursts of dust and particle evaporation. A'Hearn & Cowan (Moon Planets 23, 41) interpret photometric data on the comet in terms of CO_2 dominated nucleus with a halo of icy grains of H_2O or clathrate hydrate. Bappu et al. (MNRAS 192, 641) find the comet's continuous spectrum redder than the sun, the excess increasing with distance from the nucleus. Feldman (IAU Symp. 90, p. 263) derives the albedo of dust in the coma at 2700Å to be about 0.3 its visual albedo.

A number of papers deal with the dust component of P/Halley (Sekanina, Newburn, and Hughes in ESA SP-153, pp. 25, 35, 51; Fechtig, ESA SP-169, p. 47; Newburn, Reinhard, Hellmich, Keller, Divine, Sekanina, and Schwehm in ESA SP-174, in press). Another comet of great interest for dust studies is Bowell 1980b. Observational evidence (cf. A'Hearn et al., Ap. J. 1981 248, L147; Cochran & McCall, PASP 1981, 92, 854; Spinrad, Comet News Serv. ## 80-3, 80-2; Veeder & Hanner, Icarus, in press) has led Sekanina (AJ, in press) to suggest that the comet has been dormant since long ago. Hanner et al. (BAAS 13, 705) detect the comet's thermal emission at 20 μm but not at 10 μm at 4.3 AU from the sun, consistent with a particle temperature not exceeding the BB temperature, and calculate a geometric particle albedo of only 6%. Searches for ice-particle signatures are reported by Campins et al. (ibid., p. 705) and by Jewitt et al. (ibid., p. 706).

Some other subjects addressed are the cometary particle-size distribution function (Sekanina, IAU Symp. 90, p. 251; Reinhard, ESA SP-153, p. 7; Hanner, ESA SP-174, in press); particle albedo, phase function, and production rate (Ney, 1982 "Comets"); JHK photometry and the 4.8 m/3.5 m flux ratio (Campins

& Hanner, ibid); dusty gas dynamics (Wallis, ibid.); and spectral reflectance variations (Barker et al., BAAS 13, 706).

PLASMA TAILS AND SOLAR-WIND INTERACTION - Malcolm B. Niedner and J. Brandt

General review articles with a broad observational and theoretical viewpoint were: (Brandt and Mendis, 1979, in "Solar system Plasma Physics", eds. Kennel, Lanzerotti and Parker, Norther Holland Pub., p. 253; and Ip et al., 1982 "Comets"); more specialized reviews were by (Brandt, 1982 "Comets"); tail observations (Ershkovich, 1980; Sp. Sci. Rev. 25, 3); Kelvin-Helmholtz instability: (Mendis, 1981; C. P. Colloq.) structure of cometary ionospheres; and Russell, Luhmann and Elphic (1982, "Comets") analogies between comets and Venus solar-wind interactions.

A. Observations

Profiles of a CO^+ band in Comet West (1976 VI) were analyzed by Combi and Delsemme (1980, Ap. J. 238, 381) to infer the existence of the contact surface, and its behavior. The latter was found to agree with an MHD model in which photoionization is the principal source of CO^+. This work represents the only claimed detections of the contact surface in comets.

Miller (1979, Icarus, 34, 443) analyzed and classified photographs of Tago-Sato-Kosaka (1969 IV) spanning a nearly 3-week interval. Of particular interest was a disconnected tail when the comet was near -60 heliographic latitude. Niedner and Brandt (1979; Ap. J. 234, 723; 1980, Icarus, 42, 257) continued their work on disconnection events (DEs) and concluded sector boundary traversals are preferred over high-speed stream encounters. A catalog of 72 DEs occurring in 29 comets during 1892-1976 was published by Niedner (1981; Ap. J. Suppl. 46, 141).

Jockers (1979, Atlas of the Tail of Comet Kohoutek, 1973 XII, Max Planck Institut fur Aeronomie) collected wide-field photographs of comet Kohoutek, 1973 XII to assemble a reasonably complete history of the plasma tail of the comet for 1974 January 9-25.

Brandt et al. (1980, Ap. J. Lett. 241, L51) examined possible solar-wind causes of a rapid turning of the plasma-tail axis of comet Bradfield 1979l. Ip (1980, Ap. J. 238, 388) offered a new interpretation of the 1974 January 19-21 plasma tail disconnection in comet Kohoutek in which a high-speed stream essentially blew the tail away. This work conflicts, however, with the statistical evidence presented by Niedner and Brandt (1979; Ap. J. 234, 723) that DEs are more closely correlated with sector boundary traversals than with stream encounters.

B. Theory

The strength of the plasma tail magnetic field is still controversial. Ershkovich (1979, Planet. Sp. Sci. 27, 1239; Moon and Planets, 21, 193) argued that field strengths are barely enhanced over local interplanetary values, i.e., $B \leq 10\gamma$. In contrast, Mendis and Morrison (MNRAS 186, 727) and Mendis (1979, Moon and Planets, 21, 197) defended the concept that the observed folding rate of ion rays into the tail necessarily imply tail fields 100 . Pioneer/Venus spacecraft measurements of the Venusian magnetotail have provided indirect evidence for Ershkovich's values: the Venusian tail field strengths are typically 10-20 (Russell, Luhmann, and Elphic 1982 "Comets") compared to typical interplanetary values at 0.7 AU. The estimate B 10 at 1 AU has been supported by numerical calculations by Fedder, Brecht, and Lyon (1981, EOS Trans. AGU 62, 367) and by Schmidt and Wegmann (1982 "Comets").

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Ershkovich (1981, MMRAS, in press) attributes the tail ray folding phenomenon to ExB drifting of cometary plasma. Ip (1980, A&A 81, 260) examined the accelerations likely to result in the tail due to the JxB curvature force. Perez-de-Tejada et al. (1980, Astrophys. Sp. Sci. 68, 233) modeled the viscous interaction of the solar wind with the cometary ionosphere near the terminator and suggested that the turning of tail rays might result from the transverse forces predicted by their theory to inject plasma into the wake region.

Three important investigations on the structure of the cometary ionosphere were published by Houpis and Mendis (1980, Ap. J. 239, 1107; 243, 1088; 1981, Ap. J. in press). The first study examined ion flow profiles interior to the tangential discontinuity separating pure cometary and mixed cometary/solar-wind plasmas. In the second paper, the nuclear distance of the standoff point for an H_2O dominated comet was found to be critically dependent on various parametric ratios. The third paper dealt with a CO or CO_2 dominated atmosphere. The results may explain the observed plasma activity in some comets at > 5 AU. Ip (1980, A&A 92, 95) analyzed the modification of the outer ion coma due to the inward-streaming solar wind for different size comets at various heliocentric distances.

Ip (1979, Planet. Sp. Sci. 27, 121) proposed that, even in the limit of tail magnetic fields < 10 γ, the substorm discharge mechanism of Ip and Mendis is capable of producing ionizing currents in the head region. Niedner (1980, Ap. J. 241, 820) found that flares in bright comets with plasma tails tend to occur at the times of tail disconnection events. Reconnection in cometary ionospheres at sector boundary crossings was studied by Niedner et al. (1981, Ap. J. 245, 1159). Mendis et al. (1981, Ap. J. in press) examined the bombardment of the nucleus by the solar wind at large heliocentric distances. In their model, the charging of the nucleus can create electric fields capable of causing a large-scale dust blow-off. This may be relevant to flare-ups of comet P/Schwassman-Wachman I.

c. Laboratory and Computer Simulation Studies

Laboratory simulations of the comet/solar-wind interaction have been carried out by Podgorny and his collaborators (1980, Moon and Planets, 23, 323) using a wax sphere of 2.5 cm radius to stimulate a comet and the hydrogen plasma flow produced by a coaxial electrodynamic accelerator for the solar-wind.

Schmidt and Wegman (1982, "Comets") and Fedder, Brecht and Lyon (1981, EOS, Trans. AGU, 62, 367) have used MHD computer codes to stimulate the 3-dimensional flow and magnetic field profiles in bright comets.

COMETARY HALLEY MISSIONS - J. Rahe, H. Fechtig

Several missions to intercept Comet Halley are now in preparation. ESA will fly a mission to Halley's comet, called "Giotto". The spacecraft's design is based on existing Geos spacecraft. It will be launched in July 1985 and fly by the comet in March 1986, about a month after the comet's perihelion passage (February 9, 1986). The encounter duration during which measurements can be performed, lasts four hours. The payload consists of a nucleus imaging camera, an optical probe for coma gas and dust, neutral and ion mass-spectrometer, dust impact detector and mass-spectrometer, electron/ion analyzer, energetic particle detector and magnetometer. The Japanese Institute of Space and Astronautical Science in Tokyo is planning its first interplanetary probe named "Planet-A", to intercept Comet Halley March 8 at 10 km. It will take

Lyman-alpha images of the comet and measure the solar wind plasma near the comet. Soviet spacecrafts will carry Venus entry probes to the planet's vicinity, and as a result of a Venus swing-by will be inserted into a trajectory to Halley's comet. They will encounter the comet March 8 and 15. Experiments consist of two imaging cameras, a three channel spectrometer for UV, visible and IR, three middle IR radiometers, dust detectors similar to the Giotto experiment, an ion analyzer, plasma wave analyzer, and energy spectrum detector and two magnetometers.

COMETARY RESEARCH IN THE USSR - B. Donn

Because of a delay in receiving the Soviet contribution this section was prepared by B. Donn using Astronomy and Astrophysics Abstracts designation. These compendia provides a comprehensive summary of Soviet publications "Problems of Cosmic Physics" in Russian, contains many papers on comets, minor planets and meteorites.

Several studies of orbital statistics were carried out by A. S. Demenko (28.102.013), orbits of cometary families; P. T. Veleshchuk (28.102.048), A. S. Guliev (28.102.049; 25.102.034), V. P. Tomanov (28.102.053), V. V. Radzievsky (27.102.034), Y. N. Ivashchenko et al. (27.102.053). Dynamical studies of orbits were published by V. P. Tomanov (27.102.032). V. V. Radzievsky (28.102.051), E. N. Kramer et al. (28.102.053), non-gravitational effects on P/Brorsen-Metcalf by T. A. Vinogradova and V. A. Shor (27.103.201), evolution of orbit of P/Chernykh by E. I. Kazimirchek-Polanskaya and N. S. Chernykh (27.103.221). Planetary capture by Jupiter was analyzed by Tomanov (28.102.010) and Kazimirchek-Polanskaya (25.102.008) and for Neptune (25.102.009).

Disintegration of comets was considered by D. A. Andrienka et al. (28.102.012) and O. V. Dobrovolsky (26.102.052). Flares and outbursts were studied by Andrienko and colleagures (28.102.011, 020, 044, 045, 050; 27.102.051, 055). The relation between outbursts and interplanetary magnetic fields was treated by V. A. Golubev (26.102.063). S. K. Vseksvyatsky considered effects of solar plasmoids (26.102.065). V. V. Konopleva and L. M. Shul'man (27.102.046, 049) discussed radii. Composition was considered by Shul'man (26.102.005) and E. J. Kajmakov and I. N. Matveev (26.102.053). Shul'man also treated nuclear structure (26.102.060). Metal atoms in comet heads were discussed by S. Ibadov (28.102.014). Dobrovolsky also re-examined Kreutz's family (26.102.050). Vseksvyatsky examined some current problems (26.102.064) and N.. A. Belyaev treated the rediscovery of lost comets (25.102.003).

LABORATORY RESEARCH - B. Donn

Spectroscopic results appear in the Commission 14 Report, attention is called to the comprehensive review by Huber and Herzberg (1979 "Constants of Diatomic Molecules"). Reaction rates for ion-molecule reactions are reviewed by Huntress et al (1980, Ap. J. Suppl. 44, 481). Laboratory photochemistry is discussed by Jackson (1981, Modern Observational Techniques for Comets). Papers on reaction rates, photochemistry and spectroscopy will be found in journals of physical chemistry, chemical physics and spectroscopy. Ultra-violet irradiation of ice mixtures is underway in Greenbergs group at Leiden University (Hagen et al, 1979, Astrophysics and Space Science 65, 215; Greenberg 1982, "Comets") at NASA/Goddard Space Flight Center 1 MV proton irradiation of cometary type ice mixtures continues (Donn, 1981, C. P. Colloq; M. H. Moore, 1981, Ph.D. Thesis, U. Maryland Astron. Prog.).

III. Meteorites

L. L. Wilkening, B. Yu Levin and A. A. Yavnel

The numbers of new meteorites recovered by Japanese and American teams in Antarctica continued to climb dramatically. In contrast to the 5-10 meteorites recovered annually from the rest of the earth, the collection rates in Antarctica are 300-3000 samples/year. Two other sources of meteoritic material are also becoming important namely, dust-size particles collected in the stratosphere and meteorite ablation spherules recovered from deep sea sediments.

Ordinary chondrites became increasingly popular subjects for study. Chondrules (Lux et al. 1981, Geochim. Cosmochim Acta (GCA) 45, 675; Kimur and Yagi, 1979, Allen et al., 1980, Geochim. Cosmochim. Acta (GCA) 44, 1161; Evensen et al., Earth Planet. Sci. Lett. (EPSL), 1979, 42, 222; also Proc. Lunar Planet. Sci. conf. 10) matrix (Huss et al. 1981, GCA, 45, 31) and metal phases, Affiatalab and Wasson, GCA, 1980, 44, 431; Woolum et al., LPSC, 9) were all targets of studies which show unequilibrated ordinary chondrites exhibit a range of textures and compositions consistent with their being primitive material. Scott and Rajan studied the petrography and composition of xenoliths in ordinary chondrites (GCA 1981, 45, 53). Chemistry of the L-group chondrites showed existence of possible subgroups (Neal et al. GCA 1981, 45, 891). Distribution of U and Pu in St. Severin was described by Jones and Burnett (1979, GCA 43, 1895). Elemental fractionation among ordinary chondrites was the topic of papers in LPSC 10. Ar-40/Ar-39 dating of shocked chondrites was the subject of papers by Bogard and Hirsch (GCA 1980, 44, 1667) and Turner et al. (LPSC 1978, 9, 978). Chen and Wasserburg measured uranium isotopes in 9 chondrites and found no evidence of excess U-235 reported by others (Geophys. Res. Lett. (GRL) 1980, 7, 275).

Origin and evolution of enstatite chondrites were the subjects of several papers (e.g., Biswas et al. GCA 1980, 44, 2097; Larimer and Bartholomay, GCA 1979, 43, 1455; Minster et al., EPSL 1980, 44, 420; Herndon and Rudee EPSL 1978, 41, 101).

Carbonaceous chondrites, CM type, have been subject of a number of studies which show them to be less primitive than previously believed (Bunch and Chang, GCA 1980, 44, 1543; Bunch et al. and McSween, GCA 1979, 43, 1727, 1761; Kerridge and Bunch, 1979, Asteroids). Studies of CM matrices with transmission electron microscopy were made by Barber, GCA 1981, 45, 945). Their chemical composition was studied by McKee and Moore, LPSC 1979, 10, 921. Malysheva et al. (LPSC 10, 977) studied by means of Mossbauer spectroscopy the kinetics of thermal metamorphism of carbonaceous chondrites under different redox conditions. Rare gases in carbonaceous chondrites continue to be the subject of controvery. A series of papers on this topic by Anders, Lewis, Frick and others can be found in the Proceedings of the 9th, 10th, 11th Lunar & Planet. Sci. conf. Shukolykov (Geokhimiya (GEOKH), 1980) proposed a model of primordial Xe in carbonaceous chondrites composed of a mixture of three components. Levskij (MET. 37; 38) found that atomic and isotopic ratios of primordial gases in carbonaceous chondrites were established before the capture of gases by meteoritic matter and that in the Saatov chondrite the planetary rare gasses (Ar) are concentrated in the light fraction enriched in plagioclase. Zaikowski and Schaeffer (EPSL 1980, 45, 141) showed that the solubility of rare gases in clay minerals was insufficient to account for rare gases in carbonaceous chondrites.

Descriptions and analyses of refractory, CA1-rich materials in CM and CV material also occupied the attention of many resarchers. Some of these papers

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can be found in LPSC 9-11, also EPSL (e.g., Macdougall, 42).

A number of advances were made in studies of irons, stony-irons and achondrites. Kracher et al. (GCA 1980 44, 773) published a refinement of classification of iron meteorites. Yavnel' (MET 39) from the analysis of distributon of Co and P between kamacite and taenite showed that equilibation of these two phases occurred in the temperature interval 500-400° C. Khodakovskij and Petayev (GEOKH, 1981) established differences in the formation conditions of nitrides in meteorites from a thermodynamic analysis of mineral equilibrium. Kaiser et al. (GRL 7) found isotopically anomalous silver in the Santa Clara and Pinon meteorites, due either to in-situ decay of extinct Pd-107 or cosmic ray spallation. Petrology of igneous clasts in mesosiderites and howardites was described by Mittlefehldt et al. (GCA 1979, 43, 673). Hewins studied the composition of metal in basaltic achondrites (GCA 1979, 43, 1663; also LPSC 9. 10. 11). A discordant set of ages of shergottites as measured by Bogard et al. (1979, GCA 43, 1047) and Nyquist et al. (1979, GCA 43, 1057). Petrology of shergottites was also studied by Stolper and McSween (GCA 1979 43, 589) and McSween et al. (EPSL 1980 45, 275).

Composition and structure of separate minerals from meteorites were studied by Kolomenskij et al. (MET 37; Mineralogichesky (MIN) 33, Larvukhina and Korotkova (Lunar Planet. Sci. Abs. (LPS), XII), Ivanov and Yudin (MET 37), Pokrovskij et al. (MET., 37), Semenenko et al. (MET., 38; 39), Yasinskaya and Semenenko (MIN., 33). Some new minerals in silicate inclusions in the iron meteorite Elga were studied by Osadskij et al. (LPSC, 12, 793). Composition, mineralogy and structure were studied for about ten stones and irons (Barsukova and others, MET., 37, 38, 39). Kuzminskij (Bull. Astron. Inst. Czech. (BAC), 31, 58) published the results of chemical and mineralogical study of the iron meteorite Morasko (Poland). Skripnik and Kirova (MET., 39, 38) determined petrological types for 94 chondrites from the collection of the USSR Academy of Sciences. Yavnel' (MET., 37; 39) published a critical analysis of modern meteorite classifications. Chemical criteria for classifications of chonrites and achondrites were supplmented and made more precise.

From the study of meteorite radioactivity Luvrukhina and Ustinova (MET., 14; LPSC, 9) found the existence of gradients of galactic cosmic rays. A disturbance in the mechanism of solar modulation of galactic cosmic rays' intensity about 2-6.10^6 years was found. It was shown that the intensity of nonmodulated galactic cosmic rays was constant during the last 6.10^6 years. Lavrukhina and others studied cosmogenic isotropes and tracks in several meteorites and determined their pre-atmospheric sizes (MET., 14, MET., 38). Korotkova et al. (LPSC, 1979 10, 907; MET., 14) showed the presence of two groups of tracks in the olivine from the Allende meteorite -- those from cosmic rays of low energy formed during a pre-accretional irradiation and from spallation fragments. Perelygin and Kasshkarova (MET., 38) from the analysis of tracks and thermoluminescence of several palalasites found that these meteorites were heated up to 80-200 C for a long time. Nishizumi et al. (EPSL 1981, 52, 31) published data for cosmic ray produced Cl and Mn in Antarctic meteorites.

VUV reflection spectra of L, LL, E and sosme achondrites were reported by Wagner et al., in LPSC 1981, 11, 775.

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IV. Minor Planets

Clark R. Chapman

Introduction

In the early 1970's, serious study of the physical properties of asteroids accelerated rapidly, spurred by the 1971 I.A.U. Colloquium in Tucson. The early and mid-70's was a period of intensive data collection plus preliminary interpretations and synthesis. At that time, these topics were incorporated into the responsibilities of Commission 15. The past three years have yielded a comprehensive synthesis of the voluminous data that has been consolidated within the TRIAD databank (TRIAD = Tucson Revised Index of Asteroid Data). A second Tucson asteroid meeting, held in March 1979, gave diverse researchers from around the world the chance to compare notes and hypotheses. It resulted in the publication of a new, definitive book, Asteroids (T. Gehrels, Ed., University Arizona Press, 1979). Tabulated in appendices of that book are the complete contents of TRIAD, as of mid-1979. The current version of TRIAD may be acquired in machine-readable form from B. Zellner of the University of Arizona.

Since the 1979 conference, there have been further advances in asteroid research. The first phase of an entirely new 8-color photometry program has been completed. Several other kinds of observations, notably lightcurve work, have made further strides. Some ideas that were once ridiculed are gaining a measure of acceptance (e.g., possible asteroidal satellites).

In the last few years, there has been increasing awareness throughout many scientific and engineering disciplines that asteroids have had an important effect on our planet in epochs past and may serve important utilitarian purposes in the not-too-distant future. The Alvarez et al. hypothesis (Science 208, 1095-1108, 1980) that an asteriod or comet impact was responsible for many of the species extinctions at the end of the Cretaceous, 65 million years ago, is gaining widespread experimental support and is helping to spur recognition of asteroid impact as a significant force in our own planet's geological and biological history. The proceedings of an October 1981 conference on the topic (Snowbird, Utah) are in press (see Kerr, Science 2 14, 896-898, 1981).

The hypothesis that asteroids are chiefly like meteorites in composition is continuing to gain observational support. This raises the possibility that asteroids, including Earth-approaching objects yet to be discovered, may have potentially valuable quantities of rare siderophile metals and other materials of potential use in space operations. For this reason, asteroid mining is a key linch-pin in the plans and proposals of space activists and futurists.

The developing scientific interest in asteroids and comets as remnant planetesimals from primordial epochs, combined with increasing popular interest, has led to further considereation of spacecraft missions to asteriods in several countries. (1980, "Strategy for the Exploration of Primitive Solar-System Bodies -- Asteroids, Comets, and Meteorites, 1980-1990, Am. Nat. Acad. Sci.) develops the exploration goals for asteroids, and several NASA-advisory groups have studied potential asteroid missions. The French space agency has also fostered a mission concept, Asterex, for the European Space Agency (Brahic et al., 1979, Icarus 40, 423). There is also some interest in missions to some Earth-approaching bodies.

Ground-based observing programs will remain the basis for asteroid research for some time, however, during the past three years several observing

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techniques have been newly applied to asteroids, with important results, including radar and speckle interferometry studies of main-belt asteroids. The latter technique seems to reveal asteroid satellites in several instances. After decades of ineffectual attempts to measure asteroid dimensions by stellar occulation, the last few years have seen an unprecedented number of successful observing campaigns. Another observing program that was progressing slowly during its early years but has proven very important recently is the Palomar Schmidt camera photographic search for Earth-approaching asteriods. A new project, designed to greatly increase the discovery rate, is under development: the spacewatch camera. It is a large asteroid telescope to be built on Kitt Peak which will employ a CCD-based, automatic scanning system to detect rapidly moving asteroids. Some IUE satellite data on asteroids have been published (cf. Butterworth et al., Nature 287, 701-703, 1980), and plans are moving ahead to analyze asteroid data expected to be obtained by the IRAS satellite (see "Proceedings" of Asilomar Conference, April 1980, in press).

In most cases, the cited papers merely exemplify the kind of papers that have been published. While asteroids dynamics are not the responsibility of Commission 15, dynamical processes are inseparable from our topic, particularly in connection with collisional evolution and the origin of asteroids. Therefore, a very abbreviated discussion of some of the more relevant dynamical papers appears toward the end.

Size, Albedos, Shapes, Masses, Configurations

The largest asteroids produce measurable perturbations of the orbits of a few other bodies permitting masses to be measured. Schubart & Matson (Asteroids, 84-97) summarize the latest measurements of Ceres, Pallas, and Vesta, yielding densities of about 2 1/2 g cm^{-3} for the first two and 3 1/2 for Vesta. All asteroids together total about 3 X 10^{24} g. Diameters for over 200 asteroids determined by radiometry are tabulated in TRIAD by Morrison and are discussed by Morrison and Lebofsky (Asteroids, 184-205). Brown et al. (BAAS 13, 716-717, 1981) have recently recalibrated the scale, reducing diameters by about 5%, well within the previously reported systematic uncertainties. Lebofsky, Lebofsky & Rieke (AJ 84, 885, 1979) have studied small, Earth-approaching asteroids using the radiometric technique; they believe the radiometric model applicable to large asteroids may not be appropriate for many of the smaller asteroids, probably because the latter lack significant surficial regoliths. A detailed radiometric study of Eros was made by Lebofsky and Rieke (Icarus 40, 297, 1979). The potential asteroid-mission-target 1943 Anteros has been studied by Veeder et al. (Icarus 46, 281, 1981). Since the tabulation of TRIAD, many additional radiometric observations have been made by Gradie, Tedesco & their collaborators, especially of family members and other belt asteroids. They report that small Nysa family members are very dark, contrary to expectation.

Attempts to test and calibrate the radiometric scale by direct measurement techniques have finally proven successful. Measurements for Pallas during the stellar occulation of 29 May 1978, yielding a mean diameter of 538 + 12 km (Wasserman et al., AJ 84, 259, 1979). Subsequent successful observations of occultations by 18 Melpomene, 3 Juno (Reitsema et al., AJ 86, 121, 1981; Millis et al., AJ 86, 306, 1981), and other asteroids are summarized by Millis and Elliot (Asteroids, 98-118) and by Maley (JRAS Can 74, 327, 1980). General stellar occulation studies are reviewed by Elliot (Ann Rev AA 17, 445, 1979). Although much less precise, diameter measurements compatible with the radiometric scale have also been obtained by speckly interferometry (Worden, Asteroids, 119; Worden & Stein, AJ 84, 140, 1979).

A surprising outgrowth of the occultation observations has been the recognition that some asteroids may be double or have one or more smaller satellites (sometimes confusingly termed "minor satellites"). Reliable confirmation of such a satellite has been difficult to achieve. Possible examples are discussed by Van Flandern, Tedesco, & Binzel, Asteriods, 443. An August 1981 occultation may have provided the first photoelectric confirmation of an asteroidal satellite (of Melpomene), but the data are not completely reduced at this writing. The Occultation Newsletter provides continuing reports on this phase of asteroid research.

Numerous unconfirmed visual reports of secondary occultations led Binzel and Van Flandern (Science 203, 903, 1979) to assert that retinues of minor satellites were the rule rather than the exception. Most experts are skeptical of this conclusion, but there is growing support for the view that some asteroids have companions. Speckle interferometry of both Pallas and Victoria suggest the presence of satellites (Hege et al., BAAS 12, 662, 1980); new work by Bowell et al. (BAAS 13, 719, 1981) is not inconsistent with the same conclusion. A possible photographic detection of a satellite for 9 Metis is reported by Wang et al. (Icarus 46, 285, 1981). Furthermore, some asteroid lightcurves resemble those of eclipsing binary stars (Tedesco, Science 203, 905, 1979).

Lightcurve studies have led to tentative conclusions regarding other unusual shapes and configurations for some asteroids. Hartmann and Cruskshank (Science 207, 976, 1980) have suggested a peanut-shaped model for the large Trojan asteroid 624 Hektor. Weidenschilling (Icarus 44, 807, 1980) suggests instead an equilibrium contact-binary model, and Poutanen et al. (BAAS 13, 725, 1981) a biaxial model. Peculiar shapes of several asteriods, especially some rapidly rotating ones, are discussed also by Zappala (Moon Planets 23, 345, 1980) and Tholen (S & T 60, 203, 1980). Statistics concerning asteroid shapes are reviewed by Burns and Tedesco (Asteroids, 494) and Bowell and Lumme (Asteroids, 132).

Lightcurves and Spins

Extensive observing programs in Europe, California, and elsewhere have led to a remarkable increase in the number of asteroids for which information is available about rotation. While most asteroids rotate in about a third of a day, a few rotate as rapidly as every two or three hours, and a few hardly spin at all, with periods of many days. There have been several recent attempts to study the statistics of spins (Burns & Tedesco, Asteroids, 494; Harris & Burns, Icarus 40 115, 1979; Tedesco & Zappala, Icarus 43 33, 1980; Dermott & Murray, Nature, in press 1981). The following trends are apparently real, although not obvious, in the data: Asteroids larger than about 200 km are comparatively fast rotators. The very samllest asteroids are often fast rotators. At any specific diameter, main-belt, non-family asterorids of the C-type rotate somewhat slower than S-type, which in turn rotate slower than non-(C,S,) types (see below for discussion of taxonomic types). M-types are often very rapid rotators. Members of major Hirayama families may rotate somewhat faster than average.

Papers reporting high-quality lightcurves for one or a few asteroids are exemplified by the following: Dunlap and Taylor, AJ 84 269, 1979 (reports a 74h rotation period for 887 Alinda); Scaltriti, Zappala & Schober, Icarus 37 133, 1979 (several more long-period asteroids); Zappala, van houten-Groeneveld & Van Houten, A&A Suppl Ser 35, 213, 1979 (rapid spins for asteroids 349 and 354); Debehogne & Zappala, A&A Suppl Ser 40 257, 1980 (rapid spin for 45 Eugenia); Schober et al., A&A 91 1, 1980 (lightcurves for large asteroids 31 and 65); Tedesco and Sather, AJ 86 1153, 1981 (lightcurves for 29 Amphitrite with up to 5 maxima); and Lagerkvist and Rickman, Moon Planets 24 437, 1981 (very rapid spin for 201 Penelope and M-Types). Largerkvist (Acta Astron 28 617, 1978) has summarized photographic lightcurve data for over 100 asteroids based on the program at Uppsala. harris and Young (1980 Icarus 43 20; 1981, BAAS, 13, 744) summarize photoelectric data for many asteroids; they forsake high precision photometry and high time resolution in order to determine periods for the largest possible number of asteroids.

Lightcurves also provide information on asteroid shapes and configurations and on spin axis orientations (cf. Taylor, Asteroids, 480. A new observing program has been started by Davis et al. (BAAS 13, 725, 1981), directed specifically toward large, rapidly-spinning bodies that may have equilibrium figures; it may yield improved knowledge of axis orientations. Research on lightcurves is treated regularly in the Minor Planet Bulletin of the Association of Lunar and Planetary Observers.

Photometry, Polarimetry, Radar: Surface Properties

Radar observations of four Earth-approaching asteroids were summarized by Pettengill and Jurgens (Asteroids, 206). Ceres and Vesta were the first main-belt asteroids to be detected by radar (Ostro et al., Icarus 40 355, 1979; Ostro et al., Icarus 43 169, 1980). More recently, Ostro, et al. (BAAS 13 716, 1981) reported radar detections of several more main-belt asteroids, including 16 Psyche. It has the highest radar reflectivity found yet for an asteroid, which suggests that it contains much metal although probably not a pure-metal composition. Asteroids generally exhibit rather low radar reflectivities as well as large-scale roughness consistent with the presence of regoliths and irregular surfaces and shapes. Passive radio observations of several large asteroids (Dickel, Asteroids, 212) are also consistent with regoliths, as are infrared radiometric data.

Optical photometry is sensitive to surface texture and properties in the uppermost millimeter of an asteroid's surface. All asteroids, big and small, exhibit photometric functions and polarization properties consistent with the presence of considerable surficial dust. Polarization measured as a function of phase angle is sensitive to albedo and grain opacities; recent work is reviewed by Dollfus and Zellner (Asteroids, 170); also Dollfus, Mandeville & Duseauz, Icarus 37 124, 1979, who discuss polarization of M-types and LeBertre & Zellner, Icarus 43, 172, 1980), who treat Vesta.

Optical phase curves have been discussed by Bowell and Lumme (Asteroids, 132; also two manuscripts in press) who have developed a new scattering model. They show that albedos can be derived from such data. Lupishko et al. (Pis'ma Ast Zh 6, 184, 1980) discuss the opposition effect observed for 16 Psyche and implications for its possible metal-rich composition.

Polarimetric data have demonstrated the most asteroids are exceptionally uniform in albedo. Except for Vesta (cf. Blanco & Catalano, Icarus 40 359, 1979) and a few other rather large asteroids, most asteroids also display uniform colors as they rotate (Degewij, Tedesco & Zellner, Icarus 40 364, 1979; (see also Bowell and Lumme, Asteroids, 132). The uniformity may reflect underlying compositional homogeniety or may reflect global blanketing by ejecta from comparatively recent, individual, large craters. The minor variations that do exist have been studied by Gaffey (BAAS 13, 711, 1981).

Colorimetry, Taxonomy, and Bias-Corrected Distributions

A major problem that has been addressed over the past 8 years is asteroid "taxonomy" (the classification of representative samples of asteroids, primarily by spectra and albedo properties) and studies of the distributions and correlations of the taxonomic types with other pysical parameters, including orbital elements. The taxonomic types used in the TRIAD file were defined by Bowell et al. (Icarus 35, 313, 1978). Zellner (Asteroids, 783) has performed the bias-corrections and puublished the definitive analyses of the distributions of those types. Briefly, the C-types are very dark and have neutral colors; S-types are reddish (often with absorption bands) and have moderate albedos; M-types are slightly reddened and have low to moderate albedos; E-types are neutral in color but highly reflective; R-types are very red and reflective, often with deep absorption bands; and U-types refers to all other asteroids that can't be classified C, S, M, E, or R. (Note an error in Zellner's Table II: the lower limit for the BEND parameter for M should be 0.06, not 0.0).

Zellner reports that size-distributions, analyzed separately for the different types and different zones of the asteroid belt separated by major Kirkwood gaps, vary substantially with type and solar distance and generally are not linear in log-log plots. Since publication of the Asteroids book, a major new 8-color observing program has been performed by Zellner, Tdesco & Tholen (Zellner et al., BAAS 13, 171, 1981; Tedesco et al., BAAS 13, 712, 1981). Supplementary radiometry by those observers and Gradie has greatly extended the taxonomic data base. A preliminary taxonomic classification and bias-correction has been performed by Gradie and Tedesco (Science, submitted 1981; also see Tedesco & Gradie, BAAS 13, 718, 1981). Two new types have been defined: a very low-albedo, very reddish type (D-type, called RD by Degewij & van Houten (Asteroids, 417), and a very low-albedo, slightly reddish type (P-type).

Gradie & Tedesco document a remarkable progression in asteroid types from inside the main belt to the vicinity of Jupiter. There are " rings", of typical width (1/3)a (where a is the semi-major axis of the middle of the zone), dominated by a particular type. There is a progression from types E and R inside 2.2 AU, to S in the inner half of the main belt, to M in the middle of the belt, to C in the outer half of the belt, to P beyond the 2:1 Jupiter commennsurability (chiefly Hildas), to D which dominates among the Trojans. There are hints that the zone boundaries may correlate with major Jupiter commensurabilities. Zellner, Gradie & Tedesco have been tempted to ascribe the ordered progression of types away from the sun to a tableau of solar nebular condensates. But processes that could implant asteroids (from the inner solar system, for example) into the asteroid belt (cf. Wasson & Wetherill, Asteroids, 926) are controlled by resonances. In either case there is strong presumptive evidence that the variation in asteroid composition (as reflected by the types) with distance from the sun reflects a primordial feature of the population and is not due to currently operating processes.

The above distribution studies have genenrally omitted the large Hirayama families on the supposition that they are fragments of a large disrupted asteroid. Analysis of the type distributions among family members (Gradie, Chapman & Williams, Asteroids, 359) sheds light on the nature of the precursor bodies. In general, the large families have fairly homogeneous compositions, but a large fraction of the less-populated families defined by Williams (Asteroids, 1040) are of heterogeneous composition. The family members cannot readily be "put back together again" in a way that makes geochemical sense. A recent surprising result that has emerged from the 8-color program and associated radiometry is that the small neutral-to slightly-bluish-colored members of the Nysa family are not E types (as is neutral-colored Nysa itself) but are very dark.

Spectrophotometry, Compositions, Relations to Meteorites

Visible and near-IR spectrophotometry, generally in 24 filters, has been published for 277 asteroids By Chapman & Gaffey (Asteroids, 655). Unlike the 8-color data, these spectra have sufficient spectral resolution (except for noisy spectra) to permit serious interpretation in terms of mineralogy. McFadden (BAAS 13, 718, 1981) has measured spectra of some small Earth-approachers. Potentially diagnostic absorptions exist for several important minerals in the near-UV and near-IR. More features exist in the region beyond 1.1μm out to 4μm where thermal radiation begins to mask reflection features. In particular there are features due to OH and organics near 3μm. However, due to detector insensitivity, less than 20 of the brighter asteroids have been measured (generally 0.9 to 2.5μm) by wedge-filter and interferometric techniques (reviewed by Larson & Veeder, Asteroids 724; also Feierberg et al., Geochim Cosmochim Acta 44 513, 1980; Gaffey & McCord, Asteroids, 688; Feierberg, Larson & Chapman, Ap. J. in press 1981). Many asteroids have been studied by JHK photometry (Larson & Veeder, Asteroids, 724) and by filter and CVF photometry near 3μm (Lebofsky, AJ 85 573, 1980; Cruikshank & Howell, BAAS 13 717, 1981). Detailed filter and interferometric studies have been made of the 3μm regions of Cere's spectrum (Lebofsky et al., BAAS 13, 718, 1981 and longer manuscript submitted).

Interpretations of spectral reflectance data in terms of mineralogy continue to suggest a relatinship to common meteorite types in the case of most main-belt taxonomic types, although absolutely firm identifications are usually not possible. Gaffey & McCord (Asteroids, 688 interpret C-type spectra in terms of carbonaceous chondrite-like assemblages, but important differences exist in some cases. Ceres and some other C-types show a prominent 3μm water absorption due to hydrated silicates (just as in CM-types carbonaceous chondrites), and possibly even frost in the case of Ceres, (see Lebofsky refs. in above paragraph). Feirgerg et al. (Ap. J. in press 1981) find that most S-types are consistent with ordinary chondritic assemblages. They rule out stony-iron compositions, like those represented by stony-iron meteorites, among the larger, well-observed S-types, but cannot rule out collisionally jumbled differentiated compositions in many cases. Gaffey (BAAS 13, 717, 1981), However, believes that IR pyroxene band positions rule out ordinary chondritic compositions for several S-types. There has been agreement on the basaltic composition of Vesta's surface but disagreement concerning a diagnostic composition for 349 Dembowska (Champman, Asteroids, 25; Feierberg et al., Geochimica loc cit; Gaffey & McCord, Asteroids, 688. Outer-belt and Jupiter-region types (D and P) apparently are not represented among meteorites, but Gradie & Veverka (Nature 283 840, 1980) suggest kerogen-like organics.

Collisional Evolution of Asteroids

It is clear that the dominant process affecting the physical properties of asteroids during most of solar system history has been their collisional evolution and processes of regolith formation. Although collisional evolution has been a subject of theoretical conjecture of three decades, the last few years have broght the topic to a new level of sophistication. Major new evidence from laboratory experiments in cratering and catastrophic fragmentation (e.g. Fujiwara, Icarus 41 356, 1980) and from meteoritics (e.g. Bogard Asteroids 558; Wood Asteroids 849 have been combined with new observational data on families, rotations, and asterodial satellites to yield a consistent -- though unproved -- model of asteroidal evolution.

Major collisions among asteroids result in catastrophic fragmentation and, if fragements exceed escape velocity, disruption. Especially for larger target asteroids, fragments may reaccumulate thus "jumbling" them and forming "megaregoliths". Davis et al. (Asteroids 528) characterize fragmentation/-disruption/reaccumulation scenarios and calculate the evolution of asteroidal size distributions.

A typical body larger than 30 km diameter survives disruption for about the age of the solar system but is likely to have been jumbled one or more times. Petrological studies of meteorites support the inferred re-accumulation processes (Rubin, Taylor, Scott and Keil, abstract for Nov. 1981 Houston workshop on Comparisons Between Lunar Breccias and Soils and Their Meteoritic Analogs). Collisional disruption presumably forms Hirayama families cf. Kozai, (Ann. Tokyo Astron. Obs. II 17 194, 1979).

Collisions also probably determine asteroid spins, although there is hope that some subset of asteroids may largely retain primordial spins that could shed light on formative processes. Theoretical studies of the evolution of asterodial spins are summarized by Davis et al (Asteroids, 528; see also Ip, Icarus 40, 418, 1979; Harris, Icarus 40, 145, 1979). Recently there has been appreciation of the role of off-center collisions and asymmetric ejecta escape (Burns and Dobrovolskis, BAAS 13, 719, 1981); these considerations may explain the observed tendency for smaller asteroids to spin slower than large ones, contrary to earlier expectations.

Collisional spin-up especially of larger asteroids, combined with the megaregolith/re-accumulation models of Davis et al., may yield quasi-equilibrium shapes and explain why few asteroids spin faster than 4 hours (Weidenshilling, Icarus 46, 124, 1981; Farinella et al., Icarus 46, 114, 1981). Weidenschilling and his colleagues show the bulk densities may be inferred for asteroids if they are, in fact, equilibrium figures. When additional angular momentum is delivered by collisions beyond the limits of stable single-body Jacoby ellipsoid figures, splitting into binaries may result. Chapman, et al. (BAAS 12, 662, 1980)suggest that a few percent of asteroids may evolve into binary configurations through collisional evolution.

Several researchers have studied processes of cratering and regolith formation of asteroids (Housen et al., Icarus 39, 317, 1979; Cintala, head, & Veverka, Proc. 9th Lun. Planet.·Sci. Conf. 3803, 1981; and Langevin, thesis, Univ. de Paris-Sud, 1978, and several later abstracts by Langevin and colleagues in Lun. Planet. Sci. Conferences). The topic is reviewed by Housen et al. (Asteroids 601) and updated by Housen (thesis, Univ. Ariz., 1981). Moderate to large asteroids generate up to 2 kilometers of surficial regolith prior to any catastrophic fragmentation events that may jumble moderate-sized asteroids. Asteroids smaller than 10 km diameter are expected to have negligible regoliths. The predicted characteristics of asterodial regoliths (more blanketing, less reworking, shorter exposure to solar wind, less agglutinate formation, coarser texture) are all qualitatively consistent with observed differences between lunar and meteoritic breccias although quantitative comparisons are not yet final.

Earth-approaching Asteroids, Derivation of meteorites, Relationships with Comets

The Palomar planet-crossing survey has been described by Helin and Shoemaker (Icarus 40, 321, 1979) and by Shoemaker et al. (Asteroids 253). Down to about 1 km diameter, it is expected that there are $\sim$100 Atens ($a < 1$ AU), 700 ± 300 Apollos, 1000-2000 Amors, 10000 ± 5000 Mars-crossers, and about 5000 Mars-grazers. As new discoveries are made each year by Helin and colleagues, these estimates are improved. Shoemaker finds these estimates to be consistent with the terrestrial and lunar cratering record, although he

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believes live comets may be significant additonal component to the cratering flux.

Wetherill (Icarus 37 96, 1979; also Sci. Am. 240 (3) 38, 1979) has discussed the Apollo/Amor population and concludes that a supply rate of 15 objects per million years (larger than 1 km diameter) is necessary to maintain a steady-state. The dynamical interrelations between comets and asteroids is discussed by Kresak (Asteroids 289; also Moon Planets 22, 83, 1980). Chapman & Greenberg (abstract 12th Lun. Planet. Sci. Conf.; also submitted to Nature 1981) have considered the collisional and cratering processes that might liberate meteorites from main-belt asteroids and deliver them to Earth-crossing orbits by dynamical mechanisms reviewed by Wasson & Wetherill (Asteroids 926). They believe that the principal traits of the terrestrial sample of meteorites can be understood by relying prrimarily on cratering impacts on large asteroids to supply most meteorites. An alternate view (Wetherill loc cit) is that many meteorites are pieces of small Apollos.

Chapman & Greenberg also treat the geophysical evolution of asteroids as meteorite parent bodies. They believe that just a few percent of the asteroids melted, presumably by one or more of the processes reviewed by Sonett & Reynolds (Asteroids 822). Subsequent regolith formation provided sufficient insulation to explain measured metallic meteorite cooling rates as occurring in bodies three times smaller than previously calculated (see also Wood, Asteroids 849). Metal-rich meteorites are derived from asteroids only 10 to 40 km in diameter that are the cores of the smaller differentiated bodies, which have been stripped of their mantles by catastrophic fragmentation and disruption. An alternate view of iron meteorites being derived from incompletely differentiated or second-stage parent bodies is discussed by Scott (Asteroids 892). Gaffey & Lazarewicz (submitted to Icarus 1980) have also studied the thermal evolution of asteroids, and have considered, in particular, zonal metamorphism and resulting mineralogical compositions. Relationships between asteroids and meteorites are reviewed by Wilkening (Asteroids 61-74).

Origin and Dynamical Evolution of Asteroids

There is wide agreement that the asteroids represent the remains of material that failed to accrete into a full-size planet in the asteroidal zone, probably due to indirect effects of Jupiter. (The alternate view of van Flandern, Icarus 36 51, 1978, taht asteroids and comets are remnants of a former planet has received little support). The early history of the asteroids is still not understood, of course, but there has been some convergence in thinking during the last several years. Papers by Davis et al., Chapman, Safronov, and Cameron in Asteroids all rely on the gravitational perturbations by large planet-sized bodies temporarily crossing the asteroid zone in elliptical orbits to explain the enhancement of eccentricities and incliniations of asteroids that presumably contributed to the failure of asteroids to accrete (collisions tend to result in discruption at 5 km sec).

Presumably a swarm of projectiles accompanying the largest Jupiter-scattered body could have depleted the asteroids by high-velocity collisional destruction (Safronov loc cit.). The importance of self-collisions in removing mass from the asteroid zone is not clear, depending on the original size distribution. If it was very steep (such as derived by planetesimal modelling of Greenberg et al., Icarus 35, 1978) then much mass could have been lost. Few asteroids approaching the size of Ceres would have been disrupted (Davis et al. loc cit.).

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Commensurabilities and resonances, due chiefly to Jupiter, have also been invoked to explain how asteroid velocities were pumped up (Torbett & Smolouchowski, Icarus 44, 722, 1980; BAAS 13, 719, 1981; Ward, submitted to Icarus 1981). The idea is that Jupiter resonances swept through the asteroidal zone during the period of solar system formation. The existing Kirkwood gaps reflect the effects of the resonances on the now-stable system (Greenberg & Scholl, Asteroids 310; Zhuravlev, Astron. Ah. 57, 1056, 1980). More problematical is the manner in which the regions between the Cybele group and the Trojans have been cleared; the truncation of the asteroid belt has been studied by Franklin et al. (Icarus 42 271, 1980).

V. *Interrelations Between Comets, Minor Planets, and Meteorites*

G. W. Wetherill

Almost all comets newly arriving from the Oort cloud are ejected from the solar system by planetary perturbations after only a few perihelion passages (Weissman Comets 1982). Either this same ultimate fate or physical disintegraton befalls the small fraction of the new comets captured into short period orbits. In contrast almost all minor planets are in orbits that are strictly confined to the asteroid belt. Therefore, except for possible mixing under the changing physical conditions that existed during the earliest history of the solar system (1979, Pollack et al. Icarus 37, 587; 1979, Wasson and Wetherill, 1979 Asteroids, 926), for the most part, from both the dynamical and compositional points of view, comets and asteroids constitute two distinct populations. However, the few possible exceptions to this rule, the planet-crossing asteroids (particularly the Apollo-Amor objects) should not be thought of as minor curiosities, inasmuch as they are prime candidates for meteorite sources and terrestrial planet crater-forming projectiles.

The question of whether some small fraction of the periodic comets evolve into devolatilized Apollo-Amor objects is discussed by Kresak (1979, Asteroids, 289); Degewij and Tedesco (1982, Comets); and Froeschle and Rickman (1980, A&A 82, 183). From the dynamic evidence, it appears likely that some significant fraction of the Apollo-Amor objects are extinct cometary cores; possible "dormancy" of comets is also supported by evidence for inactive regions of Swift-Tuttle (1981, Sekanina, Astron. J.) by observations of Comet Bowell 1980b (1981, Sekanina, Astron. J.), and by the recent derivation of the Geminid stream from an object in an Apollo-like orbit. Spectrophotometric data, on the other hand, indicate no obvious differences between Apollo-Amor and main belt asteroids (1981, McFadden, BAAS). At least superficial similarities are found between distant asteroids and cometary reflectance spectra (1981, Tholen et al. BAAS) but uncertainty regarding whether or not the bare comet nucleus is actually being observed obscures the interpretation of this important result. The alternative of deriving Apollo-Amors from the main belt is described by Simonenko (1978, Meteorites - Fragments of Asteroids', Nauka Moscow) and Wetherill and Williams (1979, Origin and Distribution of the Elements, L. Ahrens, ed. p. 19, Pergamon Oxford). New calculations of the positions of the secular resonance surfaces, of great importance for the dynamical evolution of asteroidal fragments, are given by Williams and Faulkner (1981, Icarus).

Cosmic ray exposure age distribution (1981, Crabb and Schultz, Geochim. Cosmochim. Acta) preclude obtaining any significant fraction of the meteorites directly from active comets; if there are cometary meteorites in our collections they are from extinct comets, probably Apollo-Amors of asteroidal appearance. Some evidence doess exist, however, for large meteors in cometary orbits with physical characteristics that may permit survival during passage through the earth's atmosphere (Wetherill and ReVelle, 1982 "Comets"). Some weaker carbonaceous meteorites (CI and CM) may be cometary objects of this kind. Data supporting an asteroidal origin for these meteorites has also been presented (Kerridge and Bunch, 1979, Asteroids, 743).

Evidence is accumulating for an asteroidal origin of most meteorites, even though important dynamical problems remain unsolved (Wasson and Wetherill, 1979, Asteroids, 926) and identification of particular meteorite types with specific spectrophotometric classes of asteroids remains uncertain (Chapman, 1979, Asteroids, 25).

An asteroidal origin for the differentiated meteorites (achondrites, stony-irons, and irons) is rarely questioned. A strong case for derivation of a major fraction of the basaltic meteorites, the eucrites, from 4 Vesta is provided by combination of spectrophotometric data (Feierberg and Drake, 1980, Science 209, 805) and petrological arguments (Drake, 1979, Asteroids, 765). Hostetler and Drake (1978, Geochim. et Cosmochim. Acta 42, 517) propose that an Apollo-size (1 km) fragment of Vesta was deflected by successive collisions and gravitational perturbations into an unstable orbit, thereby overcoming dynamical problems associated with the fact that Vesta is not close to a secular resonance or commensurability resonance. Derivation of all asteroidal meteorites from such a hierarchy of intermediate size bodies is very likely (Turner, 1979, 10th Lunar and Planetary Science Conf. 1917); Wetherill, 1980, Meteoritics 15, 386). However, it is not clear why material from Vesta should compete effectively with similar material from more conveniently situated asteroids from which much higher Earth-crossing yields shuold be expected. Discussions of other possible asteroidal sources of differentiated meteorites have been presented: S-asteroids (Wetherill and Williams, loc. cit. 1979), 346 Dembowska (Feierberg et al., 1979 Geochim. Cosmochim. Acta 44, 513), and inconsipicuous asteroidal cores as mesosiderite sources (Chapman and Greenberg, 1981, Lunar Science XII 129).

The principal evidence for an asteroidal origin of the most abundant class of meteorites, the ordinary chondrites, comes from chemical and petrographic investigations of these meteorites themselves, particularly the gas-rich brecciated chondrites. Theoretical modeling of asteroidal surface evolution provides at least semi-quantitative support for associating these breccias with plausible asteroidal regoliths (Housen et al., 1979, Icarus 39, 317; Langevin and Maurette, 1981 Lunar Sci. XII, 602) as argued on the basis of solar and galactic particle bombardment phenomena by Anders, 1978 (NASA Conf. Publ. 2053, 57). In contrast, Goswami and Lal (1979, Icarus, 40, 510) and Heymann (1978, Meteoritics 13, 291) interpret similar data as indicating alternative origins for carbonaceous meteorite regoliths. An asteroidal origin of ordinary chondrites is also suggested by additional Ar- Ar evidence for relatively recent regolith formation (1980, Keil et al. Earth and Planetary Sci. Lett. 51, 235). If an asteroidal origin of chondrites is assumed, meteorite and fireball orbital evidence supports sources at least fairly deep in the asteroid belt, acceleration being achieved by interaction of commensurability and secular resonance (Simonenko loc. cit. 1979, Levin, Zemlya Vselennaya no. 6, p. 5-9, 1980, Wetherill Meteoritics 16, 1981). Problems of identifying a sufficient number of ordinary chondrite sources spectrophotometrically still exist, but one interpretation of new IR data supports identification of the abundant S-asteroids with ordinary chondrites (Feierberg et al., 1980, BAAS 12, 664).

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President of the Commission.