OTHER PRESENTATIONS: AN OVERVIEW

This section overviews the papers which were presented at the oral and poster sessions but are not published individually in these Proceedings. The papers can be topically grouped in five blocks and they will be reviewed within these blocks, as follows: 1. Comets and Asteroids: Observations and Models; 2. Accretion and Formation Processes; 3. Dust Particles and Fluxes; 4. Near-Earth Asteroids: Observations and Dynamics; 5. Comet P/Shoemaker-Levy 9 and Related Phenomena. Abstracts of most of these papers were published in the IAU GA Abstract Book, Kyoto, August 17–30, 1997, pp. 24–31.

1. Comets and Asteroids: Observations and Models

P.R. Weissman and H.F. Levison discussed the origin and evolution of the unusual object 1996 PW which was discovered on August 9, 1996 by an automated search camera operating from Mt. Haleakala Observatory in Hawaii. Although asteroidal in appearance, it was soon determined that the object is in a near-parabolic orbit similar to that of a long-period comet. Speculation was focussed on whether the object is a dormant or extinct cometary nucleus, or an asteroid, and whether it is evolving into or out of the planetary system. The authors examined possible hypotheses and found that 1996 PW has most likely been a resident of the Oort cloud, probably ejected there early in the Solar System's history. However, they found it equally likely that 1996 PW is an extinct comet or an asteroid. Their calculations suggested that at least 1% of the population of the Oort cloud consists of asteroids from inside the orbit of Jupiter. Integration of the current orbit of 1996 PW forwards and backwards in time showed that it is likely to be ejected from the planetary system in ~200 returns, with a median lifetime of 7×10^5 years.

J.A. Fernández presented the results of a work, made in collaboration with G. Tancredi, J. Licandro and H. Rickman, on the population and size distribution of comets in the terrestrial planets zone. This study was aimed first of all to update the data set of absolute nuclear magnitudes of Jupiter family (JF) comets (periods $P < 20$ yrs). The results of recent CCD photometry of inactive or low-active comets have been compared with older photographic data, mainly taken by Elizabeth Roemer, in order to build a large data base of reasonably homogeneous quality. Constraints may then be placed on the nuclear sizes and fractions of active area by combining data on near-perihelion gas production rates with nuclear magnitudes, usually taken near-aphelion. These data may be used to study the size distribution and the distribution over perihelion distances (q) of the JF. Questions of special interest are if there exists a minimum size of an active JF comet and what fraction of such comets end up as extinct, asteroidal objects. It was shown that a large scatter exists in the absolute nuclear magnitudes of most JF comets and that those measured at the most remote locations are not always the faintest ones. Plausible reasons are both near-aphelion activity producing coma-contaminated magnitudes and, in some cases, errors of the coma subtraction in active comets near their perihelia. By means of a simple analytic model it was demonstrated that for heliocentric distances $r \lesssim 1.5$ AU the total magnitudes may be more than 5^m brighter than those of the bare nucleus for km-sized, not extremely inactive nuclei. Examples were given of how combined data on H_2O fluxes and nuclear magnitudes can place meaningful constraints on the nuclear radius (R_N), the active fraction and the visual albedo and also assess the reliability of the nuclear magnitudes in question. All the observed JF comets were shown to have $H_N < 19.5$ despite the recent discoveries of a large and ever-increasing number of much fainter near-Earth asteroids. It was thus concluded that comets with $R_N \lesssim 0.5$ km may not survive long enough to reach old dynamical states. Evidence was finally presented for a rapid growth of the JF comet population with increasing q. This was focussed around two points: *(a)* comets are on the average brighter for larger q (absolute total as well as nuclear magnitudes); *(b)* the discovery rate as a function of time shows a steep increase for $q \gtrsim 1.5$ AU.

The problem of early recovery of distant comets was discussed in a paper by O.R. Hainaut and

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K.J. Meech. As it is well known, observation of comets prior to the onset of the cometary activity gives direct measurements of some important physical parameters of the nuclei (size, rotation, shape). Moreover, the heliocentric distance, r, at which that onset takes place can directly be interpreted in terms of the physical nature of the volatile ice composing the nucleus. The authors have embarked upon a program to recover comets at large distances from the Sun. For this purpose, a very large CCD mosaic was built at the Institute for Astronomy ($8k^2$ pixels), providing a large enough field of view to encompass the uncertainty on the comet position. If the mosaic is installed on the UH 2.2m and CFHT 3.6m telescopes at Mauna Kea, it would enable to reach the required faint magnitudes ($R \sim 24 - 26$). Software has been developed to automatically search these huge images for moving objects. The observing methods and instrument, the search techniques and algorithms, and the first results of this program were presented.

Distant comet observations were also addressed by K.J. Meech and O.R. Hainaut. The authors reported on their long-term faint (to mag ≈ 30) distant comet observation program and the latest observations in this program, including recent data from Keck and HST. The goal was to obtain a uniform set of CCD images of short- and long-period comets as a function of heliocentric distance, r, comparison of activity levels and thus to get information about primordial and evolutionary differences between comets with different dynamical histories. Analysis of the extensive database of observations (≈ 50 comets over a range of r from 1 to ≈ 30 AU, on over 200 nights) showed a clear difference in activity level: Comets which have spent little time in the inner Solar System turned out intrinsically brighter than short-period comets, exhibiting dust comae and activity to large r where H_2O-ice sublimation is not possible. A comparison of these observations with laboratory experiments available on the condensation of low temperature ices, and new models of the solar nebula showed that the observations, lab experiments and theory could start to form a consistent picture of the early Solar System.

An application of a version of the method of apparent motion parameters, developed by Kiselev and Bykov at Pulkovo Observatory, to the analysis of CCD-observations of asteroids with the Spacewatch Telescope, was discussed by O.P. Bykov and P.P. Komarov. This method uses the basic Laplacian idea of preliminary orbit determination from positional observations. Its utilization showed that the method is best applied for near circular orbits within the range of $e < 0.2$, while elliptical or circular motion can be distinguished provided the angular acceleration of the body is available from CCD-observations. The authors suggested the use of this approach for calculations of circular orbits by observers, and to use the results for more detailed statistical investigations of the Main Belt Asteroid population. They also estimated that for the Kuiper Belt asteroids with small eccentricities the orbital parameters determined could remain valid within half a year after the last observation.

G. Tancredi, J.A. Fernández, J. Licandro and H. Rickman made an attempt to systematize the observational data on cometary activity. They compiled a new catalog of nuclear magnitudes to study physical properties of comets of the JF. As a source for the catalog they have used Kamél's (1991) compilation of data from many different sources, adding more recent data taken from the IAU Circulars, MPCs, ICQs and from their own observations. Among the few systematic observers of cometary nuclear magnitudes E. Roemer's long-term program (60's – 70's) is outstanding, having provided nuclear magnitudes for a large sample of JF comets from photographic plates. During the last decade the data set of nuclear magnitudes has been greatly enlarged and improved by using CCD detectors attached to medium- and large-size telescopes, and most of the recently published measurements of nuclear magnitudes came from J. Scotti who used a CCD camera attached to the Spacewatch Telescope. There is a tendency of the measured nuclear magnitudes to be fainter as JF comets are observed with CCD detectors. However, a few JF comets observed very far from the Sun (4–7 AU) showed brighter nuclear magnitudes than when they were observed closer in.

The coming of such an extraordinary comet as C/1995 O1 Hale-Bopp brought a very good opportunity of testing and improving cometary models. Indeed, due to the quantity of observations with which model output can be compared, the new data can be used to test the ability to do predictions and the dependency on initial parameters of the models. The results of one such model dealing with the problem of nucleus thermal evolution were discussed by M.T. Capria, A. Coradini and M.C. De Sanctis. In particular, it was attempted to reproduce phenomena such as the strong emission of CO and dust at large distance from the Sun.

In the paper presented by K. Muinonen and J.S.V. Lagerros the model of inversion of statistical shapes of small Solar System bodies was discussed. It has been hypothesized that the irregular shapes of such bodies can be modeled by using lognormal statistics (Gaussian random sphere). The Gaussian sphere is fully described by the mean radius and the covariance function of the logarithmic radius. The actual shape is thus fully described by the covariance function. Inverse methods were devised for deriving the covariance function from sample three-dimensional shapes. The inverse problem is challenging since the geometric centers (e.g., centers of mass for homogeneous bodies) do not necessarily coincide with the origins of generation. The amplitude-phase relationship was studied with the help of sample asteroid shapes generated by using the statistical parameters presently derived.

2. Accretion and Formation Processes

K. Yoshinaga, E. Kokubo and J. Makino dealt with the modeling of the long-term evolution of protoplanets. They admitted that although recent theoretical studies and N-body simulations of the system of planetesimals have shown that the planetesimals can grow to protoplanets of mass $\sim 1/10$ of the Earth-type planets in 10^6 years, the evolution of protoplanets after their formation is still largely unknown. Simulations of the evolution of protoplanets have been difficult because the timescale is very long ($\sim 10^7$ years) and the number of protoplanets is large (≥ 100). The authors reported the results of direct N-body simulation using a newly developed algorithm based on a time-symmetric integrator which can handle close encounters efficiently by means of individual timesteps. This approach allowed to achieve high accuracy for rather long timestep.

Knowledge on the evolution of molecular abundances in protoplanetary disks is indispensable for understanding the formation processes of comets and icy satellites from their molecular composition. The problem of evolution of molecular abundances in protoplanetary disks around young stars, in which planetary systems would be formed, was discussed in the paper by Y. Aikawa, T. Umebayashi, T. Nakano, and S.M. Miyama. It was assumed that in disk regions with surface density less than 10^2 g cm^{-2}, cosmic rays are barely attenuated even in the midplane of the disk and produce chemically active ions such as He^+ and H_3^+. Through reactions with these ions CO and N_2 are finally transformed into CO_2, NH_3, and HCN. According to the model, in the regions where the temperature is low enough for these products to freeze onto grain surfaces, large fractions of carbon and nitrogen are locked up in the ice mantles and is depleted from the gas phase on a time scale of several million years, whereas oxidized (CO_2) ice and reduced (NH_3 and hydrocarbon) ice coexist naturally in the disks. It was also shown that the molecular abundances both in the gas phase and in ice mantles varies with the distance from the central star.

A study of the depletion of the Hecuba gap in the asteroidal belt was presented by S. Ferraz-Mello, T.A. Michtchenko, D. Nesvorný, F. Roig, and A. Simula. Although gravitation alone was enough to form the gaps in the asteroid distribution at resonances, the Hecuba gap is the most difficult to explain. Indeed, simulations showed that some asteroids may remain in the resonant region for up to 1 billion years notwithstanding global stochasticity, and several well-known asteroids lie in the region. Some are just passing through but a few may remain there for the next billion years. The authors have investigated this problem using numerical integrations, Lyapunov exponent analysis, symplectic mappings and frequency map, taking as a framework for comparison the Hilda group remaining in the 3/2 resonance. The contrasting existence of a gap in one case and a group in the other was explained on the basis of different rates of chaotic transport. It was found that even in the most stable region of the Hecuba gap, diffusion is almost 2 orders of magnitude faster than in the region which accommodates the Hildas. The 5/2 near commensurability of Jupiter and Saturn was determinant in accelerating the diffusion rate in the Hecuba gap. Besides, if Jupiter and Saturn were secularly approaching the 5/2 resonance, the period of the great 5/2 inequality may have matched the asteroids' libration period, making the size of the stable regions still smaller and leading to an almost complete depletion of the gap. For instance, current stable asteroids would be late captures, when the Themis family formed 1 Gyr ago.

3. Dust Particles and Fluxes

K. Scherer and I. Mann investigated the influence of the interstellar medium on the dynamics of the dust particles in the outer heliosphere where the neutral gas density becomes larger than the solar wind density. Thus the drag force induced by the impact of the neutral gas on the dust particles

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is stronger than the electromagnetic or plasma Poynting-Robertson effect. It was also taken into account that, because of the axial symmetry of the inflowing neutrals, the induced drag force is asymmetric with respect to the orbital velocity. The first results of a study involving these effects were presented.

Beside the electromagnetic Poynting-Robertson effect, zodical dust particle motions are substantially influenced by plasma Poynting-Robertson drag forces induced by the solar wind passing over the dust particles. The dynamics of such particles in the region near the sonic surface of the solar wind was studied in a paper by M. Banaszkiewicz, H.J. Fahr, I. Mann, and K. Scherer. Calculations showed that the associated plasma drag coefficient strongly depends on whether or not the solar wind plasma is supersonic. Since this coefficient increases significantly with decreasing solar wind sonic Mach number, the study was focused on zodiacal dust dynamics in the region close to the sonic surface of the solar wind where the change from low to high Mach number flows occurs - most likely in the region near the ecliptic rather than at higher latitudes. On the basis of a parametrized 3-dimensional solar wind outflow model the zodical dust dynamics for particles was evaluated at different inclinations to demonstrate inclination-dependent radial migration periods. In the subsonic solar wind region it was taken into account that the plasma drag force has components normal to the orbital plane of the particles connected with the solar wind ion temperature anisotropies and inducing inclination drifts of the dust particles. Based on the results of calculations the authors concluded that observational studies of the zodiacal dust cloud close to the corona provide a diagnostic of the solar wind in its acceleration region.

A.V. Krivov and M. Banaszkiewicz investigated the sources of dust in the outer Saturnian system and delivery of dust material to Titan. They suggested neighboring Hyperion to act as the most effective dust supplier for Titan. Hypervelocity impacts of dust particles coming from the outermost moon Phoebe and bombardment by IDPs could produce impact ejecta from Hyperion's surface, an appreciable share of which would escape into planetocentric orbits initially close to that of Hyperion. The authors further assumed that, though such particles would initially be locked in a strong 4:3 mean motion resonance with Titan (so that encounters with this satellite would be prohibited) the solar radiation pressure and especially the plasma drag force would destroy the resonant locking. Once the resonance is broken, the orbits become unstable and experience multiple close approaches to Titan. Using numerical integrations, a statistical study of the grain trajectories was performed to find out the eventual fate of the debris and to construct a spatial distribution of dust in the Hyperion–Titan system. It turned out that most of the grains larger than $\sim 5\mu$m finally collide with Titan, whereas smaller particles either escape to interplanetary space or hit Saturn. A steady-state dust cloud in the Hyperion–Titan system is tilted off the equatorial plane of Saturn and has a structure that depends on the particle radii. Estimates of the dust influx to Titan showed that the upper limit of the income rate of the Hyperion particles may considerably exceed the direct influx of IDPs. Thus the influx of icy (H_2O) particles from Hyperion was suggested as a possible explanation of the observed abundance of CO_2 molecules in Titan's atmosphere.

New radiant areas of the Perseid meteor shower were studied by T. Yoshida, S. Suzuki, K. Suzuki, and T. Akebo. More than 100 Perseid meteors were recorded by using TV techniques at four stations on August 11/12 and 12/13, 1993. The lenses of MINOLTA f=135mm F2 (at two sites), CANNON f=85mm F1.2, and NIKON f=85mm F1.4 were used. A PC with a frame memory board was utilized in order to sample the video with a spatial resolution of 512×512 pixels and with 8 bit tone levels (i.e., 256 gray levels). The positional traceability was within $\pm$ 1 pixel at worst. Orbits of meteors were determined with an accuracy within 60″ with respect to the reference stars. The results for new radiant areas of the Perseid shower observed in 1993 were summarized.

In the paper presented by K. Scherer, J.D. Anderson, J.L. Lau, D.C. Rosenbaum, and V.L. Teplitz the results of observation of meteoroids during the passage of Pioneer 10 through the Kuiper Belt (between 35 AU and 65 AU) were analysed based on discontinuities in the Doppler signal that were recorded. These jumps in the signal correspond to velocity changes of the spacecraft caused by impacts of Kuiper Belt meteoroids. The mass and size of four impacts were analyzed. It was found that the spatial distribution of the meteoroids seems to be located in discrete regions around mean motion resonances. The authors discussed the implications of the results for the Egdeworth–Kuiper Belt and planetary evolution.

4. Near Earth Asteroids: Observations and Dynamics

In his overview of asteroid dynamics A. Morbidelli first addressed several analytical and numerical studies of the last years (e.g., Farinella et al., 1994) which pointed out that the ν_6 secular resonance and the main mean motion resonances with Jupiter (3/1, 4/1, 5/2, 7/3) are very efficient in pumping the eccentricity of resonant asteroids up to Earth crossing – often Sun grazing – values. Gladman et al. (1997) have recently integrated numerically the evolution of a few thousand particles initially placed into such resonances and determined that their median lifetime is ~ 2 Myr. It was shown that only particles which, under the effect of encounters with the terrestrial planets, happen to decrease their semimajor axis below 2 AU may live significantly longer (few times 10^7 years). The population of the known Near Earth Asteroids (NEAs), which is strongly biased towards objects on such long living orbits, has a halflife ~ 10 Myr. Despite such short timescales, the population of NEAs up to ~ 1 km in size should be in a sort of steady state, since ~ 400 1-km asteroids should be injected per Myr into the ν_6 or 3/1 resonances (Menichella et al., 1996). On top of such a steady state the history of the Solar System should have been characterized by sporadic episodes of NEA overproduction associated to the major family-creating break up. According to Zappalà et al. (1997), some known families should have injected into resonance several 10^4 1-km asteroids, thus increasing temporarily the number of NEAs as well as the number of collisions with the Earth. However such "asteroid showers" should have lasted only ~ 10 Myr, the rapid dynamical decay reducing the NEA population back to the steady state number on this timescale. Concerning multi kilometer NEAs, conversely, the injection rate into the main resonances seems to be too low to explain the existence of a few such bodies in the currently observed population. It may be conjectured that the origin of such asteroids is related to the existence of some slow channel, which may take asteroids out of the belt on timescales of $10^8 - 10^9$ yrs. Unfortunately, our knowledge of the dynamics of the asteroid belt over such long timescales is far from being exhaustive. Just a few results are beginning to form a very complicated puzzle. Milani and Farinella (1995) showed that asteroids close to the 5/2 resonance borders can be captured into resonance after several 10^7 yrs of slow chaotic diffusion, and the same seems to be true also for the 3/1 and ν_6 resonance up to a $\sim 10^8$ yrs timescale (Morbidelli and Gladman, 1997). Levison et al. (1997) have shown that the Trojan asteroids are not stable over the age of the Solar System, but some of them are presently leaking out of the 1/1 resonance, presumably encountering Jupiter in the close future. It is possible that the same is true for the asteroid belt, which could undergo a sort of "dynamical evaporation", thus supplying new – possibly large – objects to the NEA population. The existence of the Kirkwood gap associated with the 2/1 resonance can be fully understood only taking into account slow chaotic diffusion acting on $\sim 10^9$ yrs (Nesvorný and Ferraz-Mello, 1997; Morbidelli, 1996). This shows the importance of studying the dynamics over a timescale comparable to the age of the Solar System in order to understand the present structure of the asteroid belt and of the NEA population.

From the modeling of migration of small bodies from the Kuiper Belt it was revealed that under the gravitational influence of planets some bodies from the transneptunian region can reach the orbit of the Earth in several tens of million years. This problem was addressed in the paper of S.I. Ipatov. He found that the time interval during which the perihelion distance decreases from 10 to 1 AU can be less than 0.5 Myr. The limits of variations in orbital elements even for non-resonant Kuiper-belt objects highly depend on the initial orbital orientations of their orbits. Therefore, small variations in orbital elements due to collisions and mutual gravitational influence of the Kuiper Belt objects can cause large variations in orbits under the gravitational influence of the giant planets. Estimates of the mutual gravitational influence of the transneptunian objects show that variations of semimajor axes for some of them could exceed 1 AU during the age of the Solar System. The average intrinsic collision probability was obtained as about 10^{-21} km^{-2}yr^{-1} for $a = 40$ AU.

An intriguing problem of the possible influence of non-gravitational forces in decoupling cometary orbits from Jupiter was addressed by D. Asher. He emphasised that, although the orbits of most JF comets either overlap or at least closely approach the orbit of Jupiter, comets do exist within, and clearly decoupled from, the Jovian orbit. This generally permits a greatly increased dynamical timescale in the inner Solar System. The most notable example is 2P/Encke. As the non-gravitational force may not act in a consistent direction for long times, the question arises as to whether random small changes in orbital elements (particularly the semi-major axis) induced non-gravitationally can eventually produce the large orbital element changes necessary to decouple orbits from Jupiter. Numerical integration was used to quantify the likelihood of decoupled orbits resulting from Jupiter approaching orbits (and the timescale of this process), as a function of the size of small orbital element changes applied.

Near Earth Objects (NEOs) have different collision probabilities to the Earth depending on their sizes; to escape global or continental scale catastrophe, the activity should be at first targeted to detection of all NEOs. S. Isobe on behalf of the Japan NEO Team discussed a strategy to detect the NEOs using ground-based or lunar-based facilities. It was emphasised that all NEOs with diameters larger than 1 km can be detected during their passages through the asteroid belt by ground-based telescopes which are and will be in operation. All NEOs with diameters between 100 m and 1 km can be detected by space-borne or lunar-based telescopes, but it takes over 50 years after completion of these telescopes. Although the collision probability of a NEO with a diameter of 100 m with the Earth is once every several thousand years, its collision may occur within 50 years, during which it must be attempted to detect all these NEOs. In this regard the Team's close approach estimation of NEOs was referred to, which argues that 40% of NEOs approach the Earth from an area within 30° from the Sun. This means that collision will occur without any warning time. Therefore, space-borne or lunar-based continuous observations in the area are needed. In Japan, there is a discussion to build a lunar station in which the NEO detection telescope(s) are also considered. A strategy of the detection to minimize the possibility of being hit by a NEO was introduced and discussed.

The program of NEO observation in Beijing Astronomical Observatory was discussed by J. Zhu, R. Liu, J. Chen, X. Zhou, Z. Zheng, R. Chen, L. Deng, H. Yan, Z. Jiang, and Y. Li. This BAO Schmidt CCD Asteroid Program (SCAP) began in May 1995, and until Jan. 1997 over 1,000 asteroids were discovered. The SCAP recently found minor planet 1997 BR, an Apollo-type Earth crossing asteroid, whose orbit has an intersection with Earth's orbit within 0.0005 AU. It was reported that SCAP is going to pay more attention to NEO observations in 1997, and its relatively large CCD field of view ($58' \times 58'$) at the 60/90cm f/3.0 Schmidt telescope is suitable for follow-up observations to recover some lost NEOs.

5. Comet P/Shoemaker-Levy 9 and Related Phenomena

A.S. Hojaev, V.N. Dudinov, A.P. Zheleznyak, V.V. Shevchenko, and S.I. Ivanov presented the results of complex observations of the comet SL9 impact on Jupiter at High Altitude Maydanak Observatory, Uzbekistan. Multicolor photographic, polarimetric and speckle imaging observations of the Jovian clouds were carried out using the 1.5m reflector AZT-22 and the 1.0m Zeiss reflector to study the aftermaths of the cometary fragment impacts. Both integral and individual spectral band observations were performed, using the combination of ray and polarization filters. More than 150 high resolution photographic images and about 70 speckle series with more than 10 000 images of Jupiter were obtained with the 1.5m telescope. From the observations with the 1.0m telescope the parameters of a flash event above the limb produced by the S-impact fireball were estimated. The polarization map of Jupiter shows a North-South asymmetry and differences in the polarization indices for the impact sites. Analysis of halo dynamics and morphology of the dark spots formed by the impacts was performed, and their mean velocities were derived. Zonal wind velocities resulting in halo deformation during 10–12 rotational periods were determined to be $30 - 35$ m/s for jovicentric latitudes 42–44 deg. A phenomenological model for the impact events was proposed.

H. Hasegawa, S. Takeuchi, A. Mori, N. Yamamoto, and J. Watanabe analysed time variations of aerosols in the Jovian stratosphere produced by the SL9 impacts with the planet. The aerosol layer was observed as bright clouds in near-infrared methane absorption bands between 2.0 and 2.4 μm. Observations were made in May 1995 and July 1996 with near-infrared camera and spectrometer OASIS at the Okayama Astrophysical Observatory. A radiative transfer model was developed to reproduce the observed spectral features. The model includes multiple scattering by the stratospheric particles and tropospheric ammonia cloud layer, and molecular absorptions by hydrogen and methane. It allowed to determine the vertical distribution and optical thickness of the layer and its time variation, including the column density and aerosol distribution two years after the impact. The column density of the layer decreased by one order of magnitude between 1995 and

1996.

In the paper by D.C. Boice and J. Benkhoff the near-nucleus environment of the icy conglomerate fragments of comet SL9 was discussed. This environment was characterized during the two-year period between breakup and impact with Jupiter using a dusty coma model that included gas release from three separate sources (surface, subsurface, and distributed dust). It was assumed that the breakup exposed fresh surface layers undepleted in volatile ices, such as, H_2O, CO, CO_2, CH_3OH, and the time-dependent gas release from porous layers as they become progressively depleted in volatiles was investigated. The entrainment of dust by the calculated CO gas release was found to be consistent with observations of dust comae and tails of the fragments, such as, 1) the continuous release of dust into the coma prior to impact, 2) large grain sizes ranging from 10 to 500 μm in the dust comae, 3) estimates of the total dust release rates leading to dust-to-gas mass fractions on the order of two or less when compared with model CO release rates, and 4) upper limits imposed by observations of CO, OH and CO^+ column densities. The results of several comet simulations were presented to compare and contrast the effects of model parameters with observations.

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