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MODELING THE COMA OF 2060 CHIRON ; D.C. Boice[1], I. Konno[1], S. Alan Stern[1,2], and W.F. Huebner[1], [1]Southwest Research Institute, San Antonio, TX 78228, and [2]Visiting Scientist, SwRI

There has been much interest in 2060 Chiron since observations of comet-like activity and a resolved coma established that it is a comet. Determinations of its radius range from 65 to 200 km. This unusually large size for a comet suggests that the atmosphere of Chiron is intermediate to the tightly bound, thin atmospheres typical of planets and satellites and the greatly extended atmospheres in free expansion typical of cometary comae. Under certain conditions it may gravitationally bind an atmosphere that is thick compared to its size (depending on molecular weight, temperature, heliocentric distance, and the size and mass of Chiron) while a significant amount of gas escapes to an extensive exosphere. These attributes coupled with reports of sporadic outbursts at large heliocentric distances (> 12 AU) and the identification of CN in the coma make Chiron a challenging object to model. Simple models of gas production and the dusty coma have been recently presented by several investigators (see, e.g., 1-3) but a general concensus on many basic features has not emerged. We have begun development of a more complete coma model of Chiron (4). The objectives of this paper will be to report progress on this model and give preliminary results for understanding Chiron.

Throughout its orbit, Chiron remains too far from the Sun for direct sublimation of water to be important, but CO, N_2, and CH_4 ices exhibit activity during its complete orbit (1,4). CO_2 production "turns on" only about 10 years prior to perihelion. At perihelion, on the order of a Mg/s of CO can be released even if only a small amount (few %) of Chiron's surface is active. At these activity levels, the mean free path of a CO molecule at the surface is on the order of 100 m, much smaller than the flow scale length, so the sublimating gas is collisionally coupled and the fluid dynamic approach is required.

The sublimation of a volatile like CO leads to a gas temperature close to 30 K throughout Chiron's orbit (2), far below that of a blackbody. This results in a thermal velocity that is comparable to the escape velocity (4), given uncertainities in the size and mass of Chiron, and may lead to a bound atmosphere with extensive exosphere. Other processes can heat and cool the gas (4), including photo reactions (heating), radiative cooling, collisions with grains that are hotter than the gas (heating), sublimation from icy grains, and expansion cooling of the gas. In the case of photo destruction of CO, typical rates (5) at 10 AU yield a lifetime of 4.5 years, making this a minor source of energy and ions on smaller timescales. Charge exchange with the solar wind may be an important ion source at Chiron.

The sublimating gas entrains dust particles as it leaves the surface. The dust dynamics is also influenced by the gravity and rotation of Chiron within a sphere of influence, $R_{GS} \approx 1500 R_{Chiron}$ (4). The maximum particle size that can be lifted by gas drag has been estimated to be on the order of 100 μm with CO sublimation (2). In a typical comet, once lifted off the nucleus, these particles will escape. However, considering gas production from restricted active areas and the effects of gravity on the gas, the gas density will decrease more rapidly than R^{-2} and larger particles may decouple from the gas before escape, traveling in bound orbits that may eventually fall back to the surface. The extent of the gas–dust interaction region depends on particle size and density. Based on our preliminary model, we estimate the size of this region to be on the order of a few tens of Chiron radii for 1 to 10 μm particles.

In this preliminary model of Chiron, based on one-dimensional fluid dynamics with dust (6), CO was assumed to be the only volatile. Other model parameters were $r_{hel} = 10.5$ AU, $R_{Chiron} = 120$ km, $A = 0.03$, $\rho_{Chiron} = 1$. The dust-to-gas mass ratio was 1 and two sizes of dust ($a = 1, 10\mu$m) were considered. The inclusion of dust had two important effects on the gas flow. The first was an initial mass-loading of the gas, reducing the gas velocity to subsonic values close to the surface. The second effect was a strong coupling of the gas and dust temperatures near the nucleus. Upon release, the dust heats rapidly to its radiative equilibrium value of 85 K. Collisions of molecules with dust particles heat the gas (initially at 30 K) to 75 K within a Chiron radius. This results in a terminal gas velocity about 20% higher than that calculated from a pure gas model. Additional features of the dusty coma model (including a CO_2 coma) will be discussed.

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CHAOTIC BEHAVIOR OF COMET NUCLEI by Eric Bois, Pascal Gherti, and Claude Froeschle; Observatoire de la Cafe d' Azur, Dept. CERGA, Ave. Copernic, France

Abstract:

Numerical experiments of the rotational behaviour of comet nuclei have been performed, including the Sun and Jupiter's disturbing torques in the models. In stable position, the solar torque induces great librations on comet nuclei, and Jupiter's close approach leads to a limited change on the rotational motion compared to the orbital one. But, because of the motion sensitivity to initial conditions, the rotational features can be largely perturbed. Moreover, the comet rotational behaviour is suspected to be chaotic for particular initial conditions. This phenomenon may be important when studying non-gravitational effects. The unstable configuration is characterized by great librations of the nutation angle, and the existence of a possibly large chaotic zone in the phase space.

H_2O^+ STRUCTURES IN THE INNER PLASMA TAIL OF COMET AUSTIN

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To study the spatial distribution and temporal behaviour of water ions in the inner coma, comet Austin 1989c$_1$ was observed with a focal reducer and tunable Fabry-Perot interferometer (FPI) at the 1m Cassagrain telescope of the Hoher List Observatory in the period Apr 30 - May 7 1990. The piezoelectrically controlled FPI has a spectral resolution of 3.7Å. Images were taken at wavelengths of 6203 and at 6199Å to register continuum and the line doublet at 6198.747 and 6200.030 Å of the 0-8-0 transition of the $\tilde{A}^2A_1 - \tilde{X}^2B_1$ electronic system of H_2O^+. At the 1m telescope the angular size of one image element is 1.6 arcsec which corresponds to approximately 600 km at the comet. The exposure time was 20 min and the time difference between individual images was 22 - 23 min.

A special formalism was applied to correct the spatial modulation of the monochromatic signal introduced by the FPI and to completely remove the continuum. The doublet structure of the emission was explicitly taken into account. The images were absolutely calibrated and converted to column densities. After the full processing cycle a portion of approximately 2×10^5 km of the cometary images remains usable. These images will be presented and discussed.

The column densities in the inner parts of these images are varying from 1×10^{11} cm^{-2} to 3×10^{11} cm^{-2} without significant correlation to the changing heliocentric distance. Sometimes the maximum of the H_2O^+ column density is offset tailwards from the optical center of the continuum emission by as much as 5000 km. Associated with the column density variations are morphological changes in the plasma distribution near the nucleus. The development of tail rays can be observed starting at a distance of 5000 km from the nucleus. By integrating the column densities across the tail at 5×10^4 km tailwards, we obtained for the number of ions per unit tail length a mean value of 3×10^{20} cm^{-1}. With an assumed outflow velocity of 35 km s^{-1} this yields a water ion production rate of 1×10^{27} s^{-1}. The mean value of the total ion content up to 5×10^5 km into the tail is 3.5×10^{30} ions. It varies from night to night, again without any significant correlation to the heliocentric distance.

A (semi-)analytical method was developed for calculating number densities from the observed column densities under assumption of axial symmetry with respect to an arbitrary axis in the image plane. During the observations the comet-Sun line was very close to the image plane, so it was possible with this method to derive densities under the assumption of axial symmetry with respect to the comet-Sun axis. This assumption is clearly not correct at the tail side of the nucleus. Model calculations found in the literature indicate, however, that it may be valid sunward of the nucleus. Using this method, we obtain on May 3 an H_2O^+ density of 200 ions cm^{-3} at a distance of 2000 km from the nucleus in the direction perpendicular to the comet-Sun line.

Probable causes for the temporal variation of the column densities and their possible relation to the observed morphological changes will be discussed.

Initial Overview of Disconnection Events in Halley's Comet 1986

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The most spectacular of all plasma tail phenomena is the disconnection event or DE, in which the plasma tail is severed from the cometary head. Several individual DEs have been analyzed in comet Halley in order to understand the physical mechanisms involved. The number of analyzed DEs is sufficient to begin considering them in groups.

As a test of the front-side magnetic reconnection mechanism (Niedner and Brandt 1978), we can consider a specific area of the calculated heliospheric current sheet, which is projected into interplanetary space from potential models giving the magnetic field at approximately 2 $R_{\odot}$. The projected positions of the heliospheric current sheet can be checked against the direct measurements from spacecraft such as IMP-8, ICE, and PVO. We find that while the heliospheric current sheet for January through April 1986 had a complex shape which changed with the solar rotation, the gross, qualitative features remained relatively constant during this period.

Thus, we calculate that the same area of the heliospheric current sheet or sector boundary encountered comet Halley on 9 January, ~ 21 February, 15 March, and 10 April. On all four of these crossings, we find the corresponding DEs. At the times of these DEs, the solar-wind speeds were average to somewhat elevated, and the solar-wind densities were normal with the possible exception of the 10 April DE. Therefore, we conclude that the occurrence of DEs caused by front-side magnetic reconnection is a general phenomenon in cometary plasma tail dynamics.

Reference

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ASTEROID CLASSIFICATION WITH FIVE ECAS COLORS. D.T. Britt and L.A. Lebofsky. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Observations of asteroids have progressed so that many of the larger/brighter asteroids in the main belt have at least some spectral data available. These data have lead to the spectral classification of a large number of asteroids in several classification systems [1,2,3]. But a major limitation on spectral observation is the brightness of the target asteroid. Observations in the near-infrared and the blue/ultraviolet wavelengths often require long integration times because of either low solar flux or strong atmospheric attenuation. In the case of the ECAS filters the integration time required for the ultraviolet u-filter can be many times longer than the visible wavelength v-filter. This has tended to limit spectral observations to those objects that are brighter, or larger, or both. However, some major questions in asteroidal science concern compositional relationships between small and large asteroids, and between the typically small planet-crossing asteroids and main belt asteroids [4,5]. One way to address these questions is to extend the asteroid spectral classification system to smaller and/or darker (ie lower magnitude) objects such as planet-crossing asteroids. But the difficulties of observing these low magnitude objects often result in limited spectral coverage. In the case of a number of planet-crossing asteroids spectral data is only available in five colors [6]. A primary question to address is can asteroids with only five color spectral data be classified in the Tholen (1984) classification system which is based on eight color data?

The Tholen (1984) asteroid classification system used principal components analysis to quantify the spectral similarities and differences in the ECAS data set [7] and defined a system of 14 single-letter spectral classes. Shown in **Figure 1** are the first two principal components of the 8-color spectral data from 412 single letter class asteroids. The domains in statistical space occupied by each asteroid class are outlined. Most asteroid classes can be defined in terms of occupying a unique zone in statistical space. The exceptions are the E, M, and P classes which are very spectrally similar so occupy the same statistical zone, but can be recognized by strong differences in albedo. Shown in **Figure 2** are the results of the same principal components analysis using only five of the eight ECAS colors. The filters on the wavelength extremes of the ECAS system, the ultraviolet s and u-filters and the IR z-filter, have been dropped. The result of the reduced spectral information is to shift the domains of the asteroid classes and blur the distinctions between some of the classes. The A, D, Q, R, S, T, and V-classes are still well-defined by occupying unique areas in statistical space. The low-albedo B, C, G, and G-classes were close to each other in the 8-color statistics and the reduced filter set moves these classes into overlaping zones in statistical space. The E, M, and P-classes also overlap the domain the the C-class. Another limitation of this reduced spectral data set would be increased difficulties in determining the olivine/pryoxene ratio in S-type asteroids. The five-color asteroid spectral data can be used to uniquely classify objects into seven of the fourteen asteroid spectral classes. For the other classes this limited spectral data can be used to narrow the possible classifications and identify interesting objects for more intensive observations.

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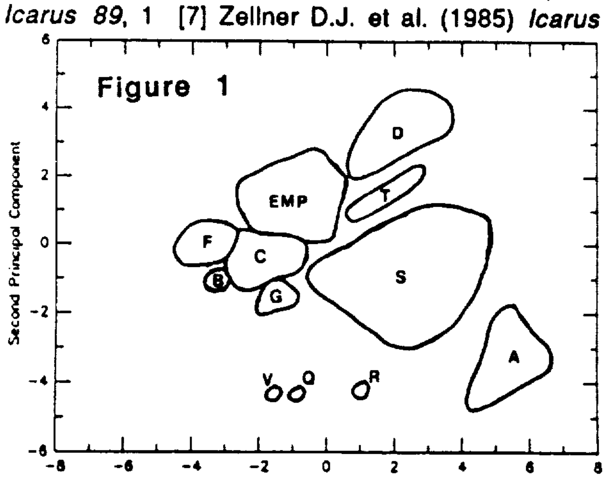

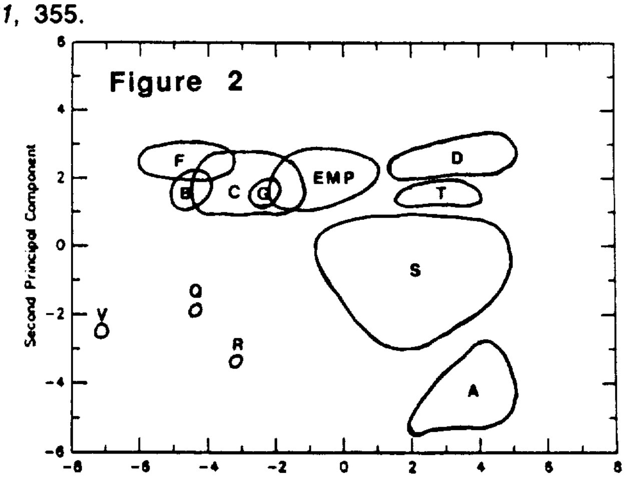

OBSERVATIONS OF THE VELOCITY AND SPATIAL DISTRIBUTIONS OF HYDROGEN IN COMETS AUSTIN AND LEVY

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We have obtained high resolution ($\sim$ 0.05Å) long-slit spectra of Hα 6562Å emission in comets Austin and Levy. Hα is excited by solar Lyβ emission and provides direct information about the spatial and velocity distribution of hydrogen, a probable daughter and grand-daughter product of H_2O. We model the hydrogen velocity distribution assuming simple radial outflow with velocity contributions from 20 km/sec (product of $H_2O + \gamma \rightarrow H + OH$ reaction), 8 km/sec (from $OH + \gamma \rightarrow H + O$), and 4 km/sec (from collisional thermalization in the dense nuclear region) components. Previous observations of cometary Hα have not had sufficient spectral resolution to disentangle the different velocity components of the hydrogen (Magee-Sauer, Ph.D. thesis, 1988). Our observations are of sufficient quality to show that all three velocity components are important: The velocity profile from our Austin spectrum of 14 May 1990 (UT) contains a narrow core that cannot be fit without some contribution from a slow thermal component. In addition, the profile has distinct high velocity wings that require a substantial fraction of gas to be at a minimum of 20 km/sec. The Levy velocity profile, observed on 12 September 1990 (UT), shows a similar distribution in the central 200 km, but on the sunward side, from about 200 km to 2500 km, the emission is dominated by even faster hydrogen with a velocity of approximately 35 km/sec. Possible causes for this unusual and unexpected fast component will be discussed. Comets Austin and Levy also differed in their spatial distribution of hydrogen. Austin showed an unusual distribution: the gas emission was confined to a spatial region that was even narrower than the region of dust emission. The peak of hydrogen emission was also observed to be shifted 150 km to the tail side of the peak of dust emission. Levy showed a different distribution: the hydrogen was more widely distributed than the dust, consistent with the large-scale distributions observed in Lyα images of previous comets.

Implementation of Moving-Target Programs

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NO ABSTRACT AVAILABLE