Abstract P-2-1

OBSERVATIONS OF THE COMET HALE-BOPP WITH NEGATIVE FILMS IN CHINA

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During the brightest period of the Comet Hale-Bopp from March to April of 1997, it is possible to get high quality pictures with a small telescope, even with a popular camera. In China, thousands of astronomers and amateurs got a lot of pictures with negative films. Especially, with a 35 cm telescope (field of view is about half degrees), a 22 cm telescope (field of view is about 8 degrees) and a Canon camera (field of view can be 7-60 degrees), we got hundreds of pictures at a high mountain station (the elevation is 3200 meters) in south-west of China. Those pictures show that the comet had a fan structure of a fountain region, its appearance looks like the "comma" structure found by HST earlier. This fountain region seemingly rotated "clockwise" on the images. Near the nucleus of this comet, a "shell" structure were often seen in clear night-sky. But in large field pictures, the ratio of the length of the plasma tail to the dust tail was rather big in February than in April. Also, the variations of plasma tail were most plentiful. From the near-nucleus part, sometimes, the tail might have two or three main strong streamers, but sometimes the tail was divided into over ten streamers. This variation could happen in two or three days. In the middle part of the plasma tail, turbulent whirlpools, disconnect event could be seen sometimes. We also attempt to do some interpretation for all of those phenomena in this paper.

Abstract P-2-2

THE GLOBULAR EJECTIONS OF COMET HALE-BOPP

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An outburst of Comet Hale-Bopp(C/1995O1) was observed in September 1996 with 1.56m telescope and a cooled CCD camera(1024 x 1024pixel) in Shanghai Observatory. Two ejections were found near the nuclear of the Comet on Sept. 10 and 11, 1996, and grew into two big jets several days later. The projected velocity of ejections is about 100m/s.

Because of the outburst, light curves of Comet Hale-Bopp show that the nuclear magnitude of the Comet on Sept. 10,1996 is about two magnitudes brighter than other days.

Abstract P-2-3

OBSERVATIONS OF COMET HALE-BOPP'S JETS AND SHELLS

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In this paper, we have succeeded in image processing of the near-nuclear region of Comet Hale-Bopp, jets and shells being clearly separated from the coma background by means of the wavelet analysis approach. Based on the morphological information, we made a preliminary estimation of expanding speed of shells. We also found the relative position of jets varied slightly from Aug. to Dec. 1996.

Abstract P-2-4

COMET HALE-BOPP: EVOLUTION OF JETS AND SHELLS IN THE PERIOD AUGUST 1996 - MAY 1997

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Hundreds of high quality CCD images obtained by the GAT group with the 33.5 cm reflector of the Sozzago Astronomical Observatory (SAS) provide a detailed insight into the temporal evolution of comet Hale-Bopp. The images cover the time period from May 1996 until May 1997.

These images allowed us to analyze a number of numerical parameters such as brightness evolution of the comet, radial profiles, short term and long term variations as well as detailed near nucleus phenomena.

Jet structures could be analyzed from August 1996 till May 1997, whereas shell structures could be resolved in the period from February 1997 to May 1997. For a number of features numerical fits could be obtained.

Basic image processing tools described in [1,2,3] were supplemented by more recent animation tools providing visual confirmation of dynamical effects.

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Abstract P-2-5

ANALYSIS AND STUDY OF THE VISUAL PHOTOMETRIC EVOLUTION, GAS GENERATION AND MORPHOLOGY OF THE INNER COMA OF COMET HALE-BOPP C/1995 O1

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Spain

This study pretend in first place carry out a complete analysis of the Hale-Bopp light curve, that is to say, calculate the photometric parameters pre-perihelium, during the perihelium, and post-perihelium, calculating their absolute magnitude and the comet increment of shine by means of lineal regression. We have also studied the effect of the lunar light on the observations of the different parts of the comet, like the tale, the coma and the nucleus, establishing some patrons of measuring in order to could quantify the effect on the comets in general and provisionally. We have also been studied in order to could establish a conclusion, the methods of Bobrovnikoff and Sigdgwick, comparing them both and establishing a result on both.

By means of the photometric method of Newburn has been calculated the evolution of gases production in the comet, basing us in the atmosphere of powder and gas that exist in a comet, and model the apparent shine of the coma in function of the rate of production of hydrogen.

And we lastly have studied by means of CCD, as well as with photography and drawning the several structures that the comet presented along their orbit, carrying out calculations about the speed of expansion of the waves, the period of rotation, etc... that they were gone presenting along their aproach to the Sun, establishing a hypothesis on the helical structures that they came off of the nucleus of the comet.

They settle down a series of conclusions on the comet and new hypothesis, for futures comets that one could present for the coming years, as well as new methods of work on these bodies.

Abstract P-2-6

CCD IMAGING OF COMET HALE-BOPP AT 4.1 AU AND AT PERIHELION

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We obtained CCD images of Comet Hale-Bopp on June 15 and 16, 1996 when the comet was at 4.08 AU from the Sun, inbound, and on April 7, 1997, six days after perihelion when the comet was at 0.92 AU, outbound. The 1996 observations were made with the 200" Hale telescope and the COSMIC CCD camera on Mt. Palomar, and the 1997 observations were made on the McDonald Observatory 82" telescope with the White Guider camera. The images of the comet reveal multiple jet structures near the nucleus on all dates. The images and an analysis of the jet structures will be presented. This work was supported by the NASA Planetary Astronomy Program.

Abstract P-2-7

DUST MORPHOLOGY OF INNER COMA OF HALE-BOPP

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Dust continuum imaging of comet C/1995 O1 (Hale-Bopp) was carried out with the 50 cm Swedish Vacuum Solar Telescope (SVST) on La Palma, Canary Islands, during the period April 21-25, 1997 within the framework of the European Hale-Bopp Team. Observing time was restricted to about one hour per night around 21 UT, at an altitude of 20 to 7 degrees.

Observations were performed with an uncooled 10-bit KAF-400 CCD chip and Ealing 550 nm and 830 nm filters, with bandpasses excluding major cometary emissions. The pixel scale was 0.26 arc seconds and exposures times $1000 - 15000$ ms. Images were reduced according to standard procedure, aligned, averaged, navigated and enhanced with azimuthal renormalization, rotational and temporal derivative and unsharp masking techniques.

The rotational period of the nucleus was determined to 11.3 h and the mean dust outflow velocity to $v_r = 3D0.42$ kms^{-1} at radii $r = 3D5000 - 4500 = 0$ km.

No difference in dust morphology between the filter wavelengths was seen. Up to five shell envelopes were visible in the sunward side of the coma up to $r = 3D80000$ km, separated by $\sim 15000 - 20000$ km on the sky plane and spiralling inwards towards smaller radii in the direction of local evenin= g.

Outer boundaries of shells were more sharply defined than inner, with she ll intensity maxima at $\sim 40°$ past the sun-comet line in the direc= tion of rotation. Small scale inhomogeneities of the order of 2000 km, plausibly correlated with variations in dust emission activity, were seen at radii ≤ 20000 km. Two overlapping shell systems with a relative lag angle of $\sim 45°$ were evident at the time. This is interpreted a s a result of emission from two major areas of nucleus jet activity on the observable hemisphere. Outflow activity from ≥ 3 jets can be observed= emanating from illuminated longitudes.

Abstract P-2-8

SIZE AND PHYSICAL PROPERTIES OF THE COMET HALE-BOPP (C/1995 O1) NUCLEUS

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One of the reasons of anomalous brightness of comet Hale-Bopp (C/1995 O1) is the considerable diameter of its icy nucleus. To estimate the real size of the nucleus is also possible from equation of energy balance, using some parameters which were obtained through space experiment tied with exploration of comet Halley. We have also taken the albedo value 4% (for that part of the nucleus surface which is covered with mineral crust and does not sublimate). Representing the nucleus of comet Halley as threeaxial ellipsoid $a \times b \times c = 15 \times 8 \times 7.5 km$ we can calculate the parameter of its form by Opik (1958) $B = RS/V = 3.20$, where $R = (a \times b \times c)^{1/3}$, S - the total surface of the ellipsoid, V - its volume. The heat conductivity coefficient of the mineral crust for comet Halley's nucleus was obtained equal to $\lambda = 2 \times 10^{-3}\ erg \times cm^{-1} \times c^{-1} \times grad^{-1}$, that exceeds by one order the value which is used for porous meteoroids, so called "dustball" (Opik, 1958). This result from our point of view is important for investigation of such meteoroids. Parameters B and l were also used for comet Hale-Bopp's nucleus. Equation of the energy balance for comet Hale-Bopp's nucleus is analyzed for the moment when the comet passed perihelion and the sublimation rate (for water) was $9 \times 10^7\ g \times s^{-1}$. The energy balance equation contains the following component: energy coming from the Sun and absorbed by the comet nucleus; sublimation energy; energy of heat radiation of that part $(1 - \kappa)$ of the nucleus surface which does not sublimate and is covered with mineral crust; and energy spent on heating of the mineral crust. The mean temperature of the nucleus surface (of the mineral crust) in perihelion according to our calculations is 310 K. As a result dependence of value R from κ , part of the nucleus surface which is a source of sublimation was obtained. The minimal value of the nucleus radius R (for $\kappa = 1.0$, i.e the total surface sublimates) equals 7.1 km. For $\kappa = 0.5$ the value R = 9.8 km, for $\kappa = 0.1 - 0.05$ (approximately comet Halley nucleus had this value of κ) R = 18.5 - 22.3 km. This value coincides with one obtained by Weaver et al. (1996, 1997).

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Abstract P-2-9

RECURSIVE JET ACTIVITY OF COMET 1995 O1 (HALE-BOPP) DURING 1995: EVIDENCE FOR A COMPLEX ROTATION

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Three spiral jet events were observed in Comet Hale-Bopp, by means of broad-band CCD imaging whith the 82cm. IAC-80 telescope at Teide Observatory (Instituto de Astrofísica de Canarias) from Aug. 14 to Oct. 31, 1995. Five large photometric outbursts of the near nucleus region were also detected during the same period. Three of the outbursts are strongly correlated with the jet events, and the smallest one is correlated with a small jet also detected in our images. A periodicity of $\sim$ 20 days in the apparition of the jets is determined from both morphological and photometric observations. We suggest that this period is related to the precession of the nucleus.

AbstractP-2-10

DETERMINATION OF ROTATIONAL PARAMETERS FROM THE INVERSION OF DUST JET POSITIONS

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An inversion technique for the determination of rotational parameters of cometary nuclei is presented. It is based on the iterative minimization of a merit function which is the sum of squared differences between observed and computed positions of dust jets. The inversion code implements the Marquardt algorithm and the so-called response functions, i.e., the derivatives of the merit function with respect to the free parameters of the model. In order to ensure self-consistency, the whole set of parameters considered relevant for the problem are retrieved simultaneously. This makes it possible, for instance, to handle more than one jet at a time, which results in better determined solutions. We discuss the geometric model adopted to reproduce the observables and present the corresponding response functions. The various modules of the inversion code are also briefly described.

Abstract P-2-11

THE ROTATION PERIOD OF COMET HALE-BOPP FROM OBSERVATIONS OF THE DUST JETS AT PIC DU MIDI OBSERVATORY

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The dust jets of comet Hale-Bopp (C/1995 O1) have been monitored in the visible range from Pic du Midi Observatory at the 1-meter telescope during 82 nights from February 1 to May 10, 1997 with broad-band and IHW narrow-band filters. In addition, observations during day-time have been performed at several occasions in order to follow the jets during a full rotation, and accurately retrieve the rotation period of the nucleus.

The analysis of the images allows us to identify at least two dust jets, whose curvature, brightness and position change with time. We have measured the temporal variation of their position angle, and compared it to a simple geometrical model, assuming that the nucleus is in a pure spin rotational state. This, together with the change of curvature observed in early March, allowed us to derive a rotation period of $11.35 \pm 0.03°$ and an equatorial longitude and latitude of the North pole of 280° and −48°. The corresponding obliquity of the equator to the orbital plane is 85°, implying strong seasonal effects. According to this model, the South pole was in view from the Earth during 1995 and 1996.

Abstract P-2-12

A DETERMINATION OF THE NUCLEAR SIZE OF COMET HALE-BOPP (C/1995 O1)

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A deconvolution technique, described in Sekanina (1995), has been applied to six images of the near-nucleus region of this comet, obtained with the Hubble Space Telescope's (HST) WFPC-2 in the PC mode (0.0455 arcsec per pixel) between 23 October 1995 and 17 October 1996. From five images in the period of October 1995–September 1996, the R_{Cousins} nuclear magnitudes, reduced to opposition and to 1 AU from Earth and the Sun using a phase coefficient of 0.035 mag/deg and an inverse square distance law, are found to average 9.46 ± 0.09. This result becomes 9.50 ± 0.08, if the nucleus signal on the October 1995 image consisted of combined contributions from two unresolved nuclear components (cf. Sekanina 1998). In either scenario, no systematic variations are apparent in the nuclear brightness with time, which suggests the absence of any significant contamination by the ambient coma. From the October 1996 image, the R_{Cousins} nuclear magnitude is derived to be 10.13. Assuming a geometric albedo of 0.04, the corresponding effective diameter is 72 ± 3 km (formal error) from the October 1995–September 1996 images and 53 km from the October 1996 image. These numbers substantially exceed the size estimates published by Weaver et al. (1997), which are based on only the October 1995 observation and a different reduction method. The runs in which a power law for the extended source was assumed to be valid down to a small fraction of a pixel from the peak brightness yielded distinctly inferior solutions.

Abstract P-2-13

MONTE-CARLO SIMULATION OF THE DIURNAL EVOLUTION OF A DUST JET IN COMET HALE-BOPP (C/1995 O1)

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A Monte Carlo computer code for simulating dust features in comets is applied to comet Hale-Bopp to model the diurnal evolution of a bright jet observed on 28 February 1997 to point in the southwesterly direction from the nucleus. The jet's morphology is closely matched by a model, which is based on the assumption that the ejecta were released nearly continuously from an isolated source on the nucleus surface. The fitted characteristics include the initial direction of the ejecta's motion, the feature's overall dimensions and shape, and its temporal variations during the rotation cycle. In particular, it is found that the relatively faint appendage some 10 to 15 arcsec to the south from the nucleus can be identified with the residual ejecta from the previous rotation cycle. No attempt has been made to fit the observed brightness changes, which apparently are affected by variable seeing, especially in daylight. It is also shown that if the system of concentric halos, which has extensively been observed to expand to the south from the nucleus, consists of two independent branches, its southwesterly branch can be identified with the same ejecta that made up the jet a few rotations earlier. Modelling of a diurnal evolution of jet and other dust features presents a powerful tool in our quest for understanding the problem of dust emission from discrete active regions on cometary nuclei.

Abstract P-2-14

MODELLING OF THE RECURRENT DUST COMA STRUCTURE OF COMET HALE-BOPP

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The results of CCD photometry of the dust coma of Comet Hale-Bopp will be presented. The observations were carried out with 0.6 meter reflector of the Mt. Suhora Observatory during five nights of March and April 1997 using R and I filters. A number of recurrent arc structures was visible in each obtained frame. These structures were interpreted as the result of repeated irradiation of active region on the surface of a rotating nucleus. A simple Monte Carlo model of the dust coma was developed taking this scenario into account. The inversion method called "time-directional deconvolution" was used for retrieving of the time sequence of the directional distributions of dust emission. This sequence covering one rotation period and obtained from a number of recurrent structures is valid under the assumption that the rotation status does not change from one revolution to another. The series of maps of the directional distribution of dust emission will be presented. The results of attempts of revealing of the rotation parameters as well as the dust ejection velocity and the dust size distribution will be reported. A number of values of the total dust production obtained based on our standarized frames will be also given.

Abstract P-2-15

IS P/HALE-BOPP A 'JUVENILE' COMET? — STUDY OF THE ENERGY BALANCE TO EXPLAIN THE VAPOR FLUX OF VOLATILES FROM THE SURFACE

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Sublimation of minor gases from ices inside of a porous comet nucleus strongly depends on the effective energy input. Our new model to describe the gas flux inside the porous nucleus more accurately has been used to study the influence of physical and structual parameters on the energy input. We solve a set of conservation equations for up to nine different volatiles (H_2O and up to eight minor components of higher volatility (CO, CH_4, CO_2, CH_3OH, HCN, NH_3, H_2S, C_2H_2)) under appropriate boundary conditions. As a result, one gets the gas flux from volatile, icy components inside the porous nucleus, temperature profiles and changes in relative chemical abundances, porosity and pore size distribution as a function of depth. In addition, we obtain the gas flux into the interior and into the atmosphere for each of the volatiles at various positions of the comet in its orbit. We will show that for a comet like P/Hale-Bopp with a rotation period of about 12 hours a fast rotator approximation underestimates the effective energy input. This yields to lower gas fluxes from the surface. Depending on the structure of the surface the energy input varies also by orders of magnitude. We will relate measurements of molecule fluxes to available energies and try to yield hints about the evolution status.

Abstract P-2-16

THERMAL MODEL OF H_2O-ACTIVITY OF COMET HALE-BOPP

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A thermal model has been applied to calculate the H_2O-activity of comet Hale-Bopp. The strong obliquity of the spin axis causes pronounced seasonal effects and, therefore, production rates that are asymmetric with respect to perihelion. The influence of the heat conduction of the cometary matter and of shape effects is discussed. The results are compared with the measured activity.

Abstract P-2-17

THE TEMPERATURE OF FORMATION OF COMETS HALLEY, HYAKUTAKE AND HALE-BOPP

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Water vapor, when deposited as ice on a cold surface, in the presence of gases such as CO, can trap considerable amounts of the gas, as a function of the gas properties and temperature of deposition. The amount of trapped gas depends exponentially on the temperature. Based on these experimentally found parameters, we established that comets Halley and Hyakutake were formed at 48 and 65K, respectively (Bar-Nun and Kleinfeld 1989, Notesco et al. 1997). The $\sim 20\%$ CO abundance in comet Hale-Bopp (Biver et al. 1997) suggests a formation temperature of ~ 45K. It is not clear whether the ice particles, which agglomerated into these three comets, were formed from the vapor phase in the outskirts of the solar nebula, or settled intact from the relatively warm outer shell of the collapsing interstellar cloud. The ratios of the noble gases Ar, Kr and Xe and their isotopic ratios, when trapped in water ice, were measured experimentally. Comparison of these ratios with those on Earth suggest a cometary (~ 50K) contribution to its atmosphere.

Abstract P-2-18

PHYSICAL CHEMISTRY OF A HETEROGENEOUS MEDIUM: TRANSPORT PROCESSES IN COMET NUCLEI

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We present a time dependent transport model of a binary gas mixture through a porous comet nucleus.

We critically discuss the modeling of this process in previous cometary models.

We give the relationship between the time required to reach steady state, t_c, and the permeability of the porous nucleus. It is shown that t_c is very short ($\sim$ a few seconds to a very few hours) compared to the rotation time ($t_R \sim$ a few hours to a day).

We show qualitatively what could be the effect of the structure of the nucleus on the H_2O/CO ratio, for a comet approaching the Sun. We find that $H_2O/CO = f(P)$, (P, the total pressure), passes through a maximum.

We use this to propose an indirect method to study the internal physical heterogeneity of comet nuclei by using α.

It is shown that our approach considerably improves the modeling of mass transport in porous comet nuclei.