Abstract IT-4a-1

OBSERVATIONS OF SCATTERED LIGHT FROM COMETARY DUST

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Observations of scattered light from cometary dust require accurate measurements and a high signal to noise ratio. In the first part of the talk ways to measure colour and polarization, and possible systematic errors in the measurements will be discussed. Then the observations available in the literature will be reviewed.

Observations of comet Hale-Bopp itself will be mentioned but no attempt of an exhaustive coverage will be made, as this is the matter of the contributed papers. The interpretation of the observations is yet dominated by question marks. Which dust properties mostly influence the observed colour and polarization? How can the colour gradient of polarization be explained? Can comets be classified according to their polarization behaviour?

Is there a correlation between the spatial dependence of colour and polarization and, if present, what does it tell us? Is there evidence for oriented particles from polarization measurements? Finally radar backscattering and forward scattering of stellar light by the cometary dust coma during stellar occultations will be briefly touched upon.

Abstract CT-4a-1

POLARIMETRY AND PHOTOMETRY OF COMET C/1995 O1 HALE-BOPP

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We present the results of polarimetric and photometric observations of giant bright comet Hale-Bopp (C/1995 O1) obtained at the 70-cm telescope of Kharkov University Observatory from June 18, 1996 to April 24, 1997. The phase angle of the comet was changing in the ranges 4.8-49.1°. The IHW and HB comet filters were used.

Photometry of comet showed that Hale-Bopp was one of the most dusty comets. The equivalent width W_{4845} describing gas-to-dust ratio changed in the ranges 120-60 Å. The colors UC-BC and BC-RC of dust were $\approx 2\%$ smaller and $\approx 13\%$ larger relative to the Sun, respectively.

The polarization of the comet Hale-Bopp at small phase angles 4.8-13.0 ° was in a good agreement with the data for the comet P/Halley at the same phase angles in spite of the fact that the heliocentric distances of comets differed nearly twice. However, at intermediate phase angles 34-49° the polarization of the comet Hale-Bopp was significantly larger than the polarization of dusty comets. It is the first real and very large diversity among the cometary continuum polarization. For the other comets the observed polarization differences were not too great and the variability of gas-to-dust ratios have played a large role. The deviation of the polarization plane from the perpendicular position to the scattering plane (about -6.5°) was observed for the different regions of coma from March 8 to April 1, 1997. It was accompanied by the small decreasing of polarization degree. We have systematicaly observed the high polarization degree of anti-sunward dust tail in comparison with the polarization of sunward shell side.

The polarization phase dependence of Hale-Bopp is discussed and compared with the synthetic polarization curve for dusty comets. Similarity of polarization at small phase angles and large polarization diversity of Hale-Bopp and other dusty comets at large phase angles is coincident with the change of jets radial structure in 1996 to the spiral-shaped arcs structure in 1997.

Abstract IT-4a-2

THERMAL EMISSION AND DUST PROPERTIES OF COMET HALE-BOPP

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The early detection and strong activity at large heliocentric distance, R, provided an unprecedented opportunity to observe Hale-Bopp in the thermal infrared over a wide range in solar heating. Even at R ¿ 4 AU, strong thermal continuum emission and a strong silicate feature indicated a large abundance of submicron sized silicate and absorbing grains. The temperature excess above that of a theoretical black body was the highest ever seen in a comet at R ¿ 1 AU. Photometry, imaging, and spectroscopy were carried out from the ground as well as with the Infrared Space Observatory. The 8-13 micron spectra revealed broad silicate emission, similar to that seen in P/Halley and several new and long period comets. Detailed spectral structure in the feature was consistent over time and with different instruments. Spectra at 16-40 microns taken with the ISO SWS displayed pronounced emission peaks due to crystalline olivine, consistent with the 11.25 micron peak. Imaging of the inner coma at sub-arcsec resolution revealed temporally variable structure similar to optical images. The observations will be summarized and the composition and size distribution of the grains will be discussed.

Abstract CT-4a-2

COMET HALE-BOPP IN THE THERMAL INFRARED - ISOPHOT OBSERVATIONS AND SIZE DISTRIBUTION MODELING

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The availability of the Infrared Space Observatory (ISO) is a unique possibility to study the thermal emission from cometary dust comae. After Comet C/1995 O1 (Hale-Bopp) was approved by ESA as an exceptional Target of Opportunity, photometric observations between 3-160μm were performed at four different heliocentric distances, 4.92, 4.85, 2.93 and 2.81AU. The first two observations in Spring 1996 revealed a dust temperature of 150K$\pm$10K. For the second set of observations in Autumn 1996, the dust temperature was 205K$\pm$15K. Extensive spectral modeling of the observations has been used to infer the dust composition and size distribution. Using astronomical silicate, amorphous carbon and water ice as the most likely constituents, twelve different grain size distributions were assummed. The properties of the grains were allowed to vary via the porosity of the material. The spring observations can be reproduced best by a mixture of silicate and carbon, and is dominated by large particles. The autumn observations consider a silicate-carbon coma to be the most likely but the grain size distributions indicate the dominance of small particles. A closer look at the properties of the grains itself reveals the silicate grains to be more solid while the carbon grains tend to be much more porous. 3-160μm photometry for C/1995 O1 (Hale-Bopp) will be obtained again on December, 25, 1997.

Abstract CT-4a-3

INITIAL RESULTS FROM A COMBINED GROUND AND SPACE BASED STUDY OF COMET HALE-BOPP

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In this work we report specifically on simultaneous multiwavelength observations of Comet Hale-Bopp obtained from ground based telescopes and from two spacecraft, the Infrared Space Observatory (ISO) and the Midcourse Space Experiment (MSX). On April 27-29 UT, 1996, we obtained 1 to 2.5 micron imaging in the J, H and Ks filters, using the 256x256 NICMOS camera at the University of Arizona 2.3 meter Bok telescope. On October 6-10 UT, 1996, we obtained 1-20 micron imaging and spectrophotometry using the BOLO and NSFCAM instruments at the NASA 3.0 meter Infrared Telescope Facility in Hawaii. On October 8-11 UT 1996, we obtained visible continuum imaging at the Lowell Observatory 1.1 meter Hall telescope, using a TI 800x800 CCD camera and narrowband filters at 4845 and 6840 angstroms. We are combining our ground based, ISO and MSX observations to constrain models of the composition and abundance of the coma dust particles.

Abstract CT-4a-4

FCRAO MILLIMETER CONTINUUM OBSERVATIONS OF COMET C/1995 O1

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In late Feb 1997, FCRAO expanded its intensive comet Hale-Bopp (C/1995 O1) spectral line mapping campaign with a program of millimeter wave bolometry observations of Hale-Bopp's dust coma. The observations were taken with the SuZIE multielement bolometer mounted on the FCRAO 14m radio telescope. This bolometer is capable of taking data simulta- neously at wavelengths of 1.1, 1.4, and 2.1mm.

Initial results from late February 1997 indicated that the equivalent blackbody cross section at 1.4mm was (6.1 +/- 0.2) x 10^4 km, implying a dust mass of M = 1.7 x $10^1$2 kg in the coma at the time of observa- tion, and a dust mass production rate dM/dt = 3.2 x 10^5 kg/s. For log[Q(OH)] = 30.35, this gives a dust/gas mass ratio of approximately 3.5. The slope of the continuum emission spectrum corresponds to an opacity index of beta = 1.36 +/- 0.30, intermediate between the values of beta for circumstellar dust disks and the ISM. Analysis of additional data from Feb 1997 support the previous, preliminary conclusions.

Abstract IT-4a-3

COMET HALE-BOPP, CIRCUMSTELLAR DUST, AND THE ISM

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The ISO-SWS spectrum of Comet Hale-Bopp is characterized by remarkable emission features of crystalline forsterite (Mg_2SiO_4). Crystalline silicate features are rare in the interstellar medium, but occur rather frequently in the circumstellar dust of young and evolved stars, as well as in solar-system dust. The similarity of the SWS spectrum of Comet Hale-Bopp with that of the disk surrounding the young main-sequence star HD 100546 is spectacular. An overview is given of the relevant ISO results on the dust spectra of molecular clouds, young stellar objects, and dusty main-sequence stars, and possible inferences for the early evolution of planetary systems and the Oort Cloud are discussed.

Abstract CT-4a-5

DISCOVERY OF MG-RICH PYROXENES IN COMET HALE-BOPP: PRISTINE RELIC ISM GRAINS REVEALED AT PERIHELION

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The NASA Ames HIFOGS spectrometer observed comet C/1995 O1 (Hale-Bopp) at epochs including 96Oct07-14UT (2.7 AU), 97Feb14-15UT (1.2 AU), 97Apr11UT (0.93 AU), and 97Jun22,25UT (1.7 AU). The 7.5-13.5 um spectrophotometry (R=360-180) of the silicate feature at the pre-perihelion distance of 2.7 AU is identical in shape to the ISO SWS spectra of comet Hale-Bopp (Crovosier et al. 1997); the strong 11.2 um peak in the structured silicate feature is identified as olivine. Upon close passage to the sun, the HIFOGS spectra at 1.2 AU and 0.93 AU reveals strong peaks at 9.3 um and 10.0 um, which are identified by comparison with IDPs (Sandford and Walker 1987) and laboratory minerals (Koike et al. 1993; Koike 1997) with pyroxenes. The 9.3 um and 10.0 um peaks in the post-perihelion spectra at 1.6 AU are weak and the silicate feature shape appears to be transitioning back to the pre-perihelion 2.7 AU silicate feature. The silicate feature post-perihelion reverts to its pre-perihelion shape so that there is no change in the dust chemistry by close passage to the sun. The appearance of the strong peaks attributed to pyroxenes only at small perihelion distances (less than about 1.4 AU) leads to the hypothesis that the pyroxenes are significantly cooler than the olivines, so that the pyroxenes are on the Wien side of the blackbody at $r > 1.4$ AU and on the Rayleigh-Jeans tail of the blackbody at $r < 1.4$ AU. Composite fits to the observed 10 μm silicate features using IDPs and laboratory minerals shows that a good emperical fit to the spectra is obtained when the pryoxenes are more than 10 times more abundant than, but 150 K cooler than, the olivines. The deduced perihelion temperature of the pyroxenes implies through preliminary Mie scattering computations (Mutschke et al. 1996) that the pyroxenes are Mg-rich, with $Mg_x\ Fe_{(1-x)}\ SiO_3$ and x=0.7-0.8. The large abundance of pyroxenes deduced from this analysis is in agreement with the flyby measurements of comet P/Halley (Schulze, Kissel, and Jessberger 1997). The presence of unprocessed mineral species suggests the

comet grains are pristine relic ISM grains that have not been significantly reprocessed in the early solar nebula.