Abstract IT-3b-1

ION COMPOSITION AND SOLAR WIND INTERACTION

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Cometary parent molecules dissociate and ionize quickly by photo- and collisional processes. In addition to observations of the parents and their neutral daughter molecules, ions offer the opportunity to complete our knowledge on the coma composition and the chemical processes present in the inner coma. However, the comet-solar wind interaction complicates the distribution and kinematics of cometary ions. On a large scale the interaction with the solar wind leads to the numerous structures seen in cometary plasma tails.

Ions in comet Hale-Bopp (C/1995 O1) have been investigated with imaging filters, high-resolution spectroscopy and observations at radio frequencies, resulting in new insights in the composition and dynamics of cometary ions. An overview of ion observations in comet Hale-Bopp will be given and discussed.

Abstract IT-3b-2

MODELING THE SOLAR WIND - COMET INTERACTION

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Our 3D MAUS-MHD model is used to investigate the interaction of an expanding cometary atmosphere with the solar wind. The effects of mass loading, recombination and ion–neutral friction are taken into account by the governing equations, which are solved using a MUSCL-type numerical technique. This method is applied on an adaptively refined unstructured grid. The combination of the adaptive refinement with the MUSCL-scheme allows the entire cometary atmosphere to be modeled, while still resolving both the shock and the near nucleus region of the comet.

Using our fully three–dimensional MHD model of cometary plasma environments we have also computed the intensity and spatial distribution of x–rays emitted from the coma caused by the charge exchange of heavy solar wind ions, as first proposed by *Cravens* [1997]. When approching the comet, the heavy, high charge state solar wind ions will undergo charge exchange with cometary atoms/molecules of the form $O^{8+} + H \rightarrow O^{7+*} + H^+$. Since the process is exothermic, the resulting O^{7+} will be in an excited state, most likely in the $(5g)$ state. This state will subsequently decay into the ionic ground state by emiting radiation in the UV and X–ray range.

Using the three–dimensional flow of the solar wind in the coma as computed by our MHD model we have integrated the continuity equations for the most abundant heavy ions in the solar wind (O, C). We consider charge exchange of these ions with the cometary neutral gas (H_2O, OH, CO, O, H) and have computed the resulting volume emission rates of the most intense EUV and x–ray lines. By integrating the volume emission rates over line–of–sight we have computed the spatial distribution of emitted x–rays.

Abstract CT-3b-1

A COMPARATIVE STUDY OF DIFFERENT IONS IN COMET HALE-BOPP

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Narrowband images of comet Hale-Bopp obtained from August 1996 to April 1997 are presented. They were taken with the two-channel focal reducer of the Max-Planck-Institut für Aeronomie, attached to the 2m-telescope of Pik Terskol Observatory, Northern Caucasus.

This system allows simultaneous imaging at two different wavelengths, and therefore excludes effects caused by temporal changes in the comet.

The field of view is 8' x 8', equivalent to about 400.000^2 km^2 (March 97). Partly a tunable Fabry-Perot was used in order to suppress the unwanted and in the case of Hale-Bopp very strong continuum emission.

The main goal is to derive the spatial distribution of the ions OH^+, H_2O^+ and CO^+ and the corresponding ion production rates. Of particular interest is the relation between the OH^+ and H_2O^+ distributions because both ions are daughter products of the water molecule. OH^+ images, taken at a wavelength of 359 nm, are presented for the first time and show a wealth of interesting spatial structures.

Maps of the dust color will also be shown. They are needed for an accurate subtraction of the dust continuum from the ion images. In addition they could offer information about the cometary dust properties.

Abstract CT-3b-2

MOLECULAR LINE IMAGING OF HCO^+ IN COMET C/1995 O1

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We present a comprehensive set of images of comet C/1995 O1 Hale-Bopp in millimeter-wave emission of the ion HCO^+. The maps were assembled over the time period from 10 March to 23 June, 1997, using the QUARRY 15-element focal plane array receiver on the Five-College Radio Astronomy Observatory (FCRAO) 14-m antenna. Maps made throughout the apparition show significant time variability in the structure of the HCO^+ coma, with common dominant features. The HCO^+ emission is detectable over an extended region corresponding to 300,000 km at the comet. The strongest HCO^+ features are not typically located at the nucleus position: a peak in the emission generally occurs 50,000 – 100,000 km anti-sunward from the nucleus. Individual spectra within the maps display broad ($\approx$ 4 km/s) lines, redshifted by 1–2 km/s or more from the nominal nuclear velocity. The observed features of the HCO^+ emission require not only that ions accelerate away from the sun, but that their formation is inhibited in a critical region surrounding the nucleus. HCO^+ formation is presumably inhibited by the high abundance of H_2O, which destroys HCO^+ and collisionally cools hot photo-electrons, keeping electron temperatures low and the HCO^+ recombination rate high. At larger distances from the nucleus, diffusion and photodestruction lower the water abundance producing a transition region towards higher electron temperature (with lower recombination rates) thereby producing favorable conditions for the formation of molecular ions such as HCO^+. To set constraints on the formation of HCO^+ in the coma, as well as the location and proportions of this transition region, the data are compared with the results of ion-molecule chemistry models.

Abstract CT-3b-3

COMET HALE-BOPP: VELOCITY FIELD OF IONS FROM FABRY-PEROT IMAGING

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Fabry-Perot interferograms of comet Hale-Bopp were obtained on several nights in March and April 1997. For this purpose we utilized the Max-Planck-Institute for Aeronomy 2-channel focal reducer on the 2-m telescope at the Pik Terskol Observatory.

Solid Fabry-Perot etalons of resolving power 30000 were used in both channels of the focal reducer.

The main aim of this study is to measure the velocities and abundances of OH^+ and H_2O^+, both ions closely related to the same parent molecule, H_2O.

In the blue channel interferograms we identified several individual OH^+ rotational lines of the $A^3\Pi_i - X^3\Sigma^-$ (0–0) transition and measured their Doppler shifts. The target emissions in the red channel were the H_2O^+ lines of the $\tilde{\mathrm{A}}^2\mathrm{A}_1 - \tilde{\mathrm{X}}^2\mathrm{B}_1$ (8–0) band. We found that the line of sight velocities, obtained from the Doppler shifted wavelenghts, do not exceed 10 km s^{-1} in the usable field of view ($<$ 6 arcmin). The corresponding value, deprojected in antisolar direction, is less than 15 km s^{-1}, which fairly agrees with predictions by magnetohydrodynamical models of the solar-wind-comet interaction when one accounts for the extremely high gas production rate of comet Hale-Bopp. The fringes were also photometrically calibrated and converted to column densities. The column density data when combined with the velocity measurements will yield the fluxes of the observed ions. We will present a comparative analysis of the data for both ions and discuss our results in the light of contemporary knowledge on chemical and physical processes in the near-nucleus region of comets.

Abstract CT-3b-4

SUB-MM MAPS OF HCO^+ EMISSION AND MOLECULAR ION MORPHOLOGIES IN C/1995 O1 (HALE-BOPP

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On-the-Fly maps were obtained of the HCO^+ J=3-2 at 267.6 GHz emission in C/1995 O1 (Hale-Bopp) on 1997 Mar 15.6 UT using the NRAO 12-m telescope with high spectral resolution. The HCO^+ emission exhibits two components: 1) a bright region with peak emission occuring $\sim$ 130,000 km anti-sunward from the nucleus, and 2) a weaker cloud of emission $\sim$ 25,000 km wide and centered $\sim$ 7,000 km anti-sunward from the nucleus. The bulk HCO^+ emission also appears to be rotated slightly from the sun-comet direction. The HCO^+ linewidths are measured to be broad (FWHM $\sim$ 5 km/s) and red-shifted from the nuclear velocity by 1 – 2 km/s; however, significant variations are observed for the linewidths and lineshifts in the coma. The HCO^+ 3-2 mapping data are compared the spectra of the HCO^+ 1-0 and CO^+ N=2-1 transitions as well as optical images of CO^+ to study the morphology and behavior of molecular ions.

Abstract CT-3b-5

DYNAMICS OF STRUCTURES IN THE PLASMA TAIL OF COMET HALE-BOPP

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Comet Hale-Bopp was observed on April 6, 7, 10 and May 4, 5 1997 from Skinakas/Crete to study the dynamical evolution of structures in the plasma tail. To suppress light scattered by the dust particles a filter with a central wavelength of 4273Å (CO^+) and a width of 76Å was used. The high resolution CCD images deliver a picture of very fine structuring in the plasma tail.

The intensities have been calibrated with standard star images that were taken during the same nights. Assuming a simple model for molecular fluorescence in the cometary tail (A'Hearn [1990]), the CO^+ column densities of tail ray structures can be calculated. The results are values of about $5 \cdot 10^{10}$ molecules per cm^2 at a distance of $10 \cdot 10^6$ km from the nucleus and tail ray radius of about 10^5 km. Assuming cylindrical symmetry of the flux tubes the mean density of the stuctures can be determined. This is done for several suitable structures. The calculated densities are in the range of 2 to 0.2 molecules (CO^+) per cm^3 for distances from the nucleus from $5 \cdot 10^6$ to $10 \cdot 10^6$ km.

Series of several images of the comet are taken and the evolution of some prominent features is traced. In all cases only insignificant dynamical evolution not suitable for further analysis can be detected on the timescale (≈ 2 hours) of the observation. On the other hand a comparison of two images taken in two consecutive nights reveals an evolution rate which is so high that it is not possible to uniquely identify the same structures on both images.

To study the general aspects of the dynamical evolution we also use data from comet Austin observed from Skinakas in May 1990. Several plasma structures are traced and their mass, velocity and acceleration are determined. Analysis of the data shows that the acceleration rates of these density enhancements do not fit our theoretically derived values.

To describe the dynamics of structures in the cometary plasma tail a bi-ion fluid MHD model (see Sauer et. al. [1994]) is used. A 3D-code has been developed. Preliminary

simulation results for cometary plasma environments indicate that this approach can be used to reproduce dynamic phenomena observed in the cometary tail such as tail rays, knots, oscillatory sructures and perhaps disconnection events.

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Abstract CT-3b-6

A RELATION OF OPTICAL AND X-RAY EMISSIONS IN HALE-BOPP

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We report on the first evidence for a relation between the intensities of emissions observable in the optical and in X-rays which was found from contemporary observations of Hale-Bopp in both spectral ranges. The comet was observed with the 2.2-m Telescope at ESO, La Silla, Chile around 3.1 AU preperihelion for 8 consecutive days from September 10 to 17, 1996. Narrow band images reflecting emissions of C_2, CN and continuum were obtained together with long-slit spectrophotometric observations. The observations show that an outburst has occured approximately one day before our first observation which has produced a dust cloud expanding through the coma. This dust cloud is not related to the multiple jets continually present during August and September 1996. The comparison of the intensities of soft X-ray emission observed with the *Beppo*SAX satellite on Sept. 10-11, 1996, and EUVE on Sept. 14-19, 1996, indicate that the outburst might be directly related to the strength of the X-rays detected in Hale-Bopp during this time period. The intensity of the outburst as observed in different components of the coma, its impact on the gas-to-dust ratio, and its morphological evolution will be presented. The results of the optical observations will also be discussed in view to the still open question how cometary X-rays are produced.

Abstract CT-3b-7

X-RAYS FROM COMET HALE-BOPP

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X-ray observations of comet C/1995 O1 (Hale-Bopp) were obtained using the ROSAT and ASCA spacecraft in Autumn 1996, by XTE in March 1997, and again by ASCA in Autumn 1997, when the comet was in the 75 to 105 degrees elongation viewing window of the satellites. In this talk, we present results from our x-ray imaging, photometry, and spectroscopy measurements.

The lack of detection of the comet by ASCA at 0.6 to 2 keV in Sept 1996 and by XTE from 2 to 10 keV in March 1997, along with detection of emission by ROSAT, EUVE, and BeppoSAX in Sept 1996 at 0.1 to 2 keV, would seem to confirm the extreme softness of the x-ray emission.

Localization of the x-ray emission between the comet's nucleus and the Sun, as best seen in the EUVE maps of Krasnopolsky and Mumma (1997) (and to a lesser extent in our ROSAT images of Sep 1996), is consistent with a production mechanism that is based on a solar-wind/solar magnetic field - comet interaction. The reason for the large offset from the Sun-comet line is unknown, but may be due to projection effects.

We now have observed x-ray emission from over 10 comets, suggesting that x-rays are a ubiquitous cometary phenomenon. The x-ray luminosity of Hale-Bopp as measured by ROSAT was much lower than expected from assumming the relation $L_x \sim L_{optical}$. Since Hale-Bopp was anomolous in its high rate of dust production, this result would seem to support the finding of Dennerl et al. (1997) of an inverse correlation between cometary dust production and x-ray luminosity.