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H_2O^+ IONS IN THE PLASMA TAIL OF COMET IKEYA-ZHANG

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Abstract. We present observations of Comet Ikeya-Zhang, obtained on May 4, 2002 with the Focal Reducer Rozhen (FoReRo), attached to the 2-m telescope of the National Astronomical Observatory, Rozhen, Bulgaria. A narrow-band interference filter was used to isolate the emission line of H_2O^+ at 6158.86 Å. Several structures have been identified in the plasma tail of this comet. The gradual tailward displacement of these structures has been used to determine the velocity of the ions in the plasma tail of comet Ikeya-Zhang. The derived velocity has been used to estimate the water production rate of comet Ikeya-Zhang by using the similarity laws of magnetohydrodynamics.

1. INTRODUCTION

The most abundant molecule in comets is water. When a comet approaches the Sun the frozen water ice sublimates and the neutral gas molecules flow radially outward with a thermal speed of about 1 km s^{-1}. Different neutral coma gases have different lifetimes in the radiation field of the Sun. Typical photoionization rates are 10^{-6} s^{-1}. The photoionization rate is inversely proportional to the lifetime of the neutrals, i.e. the neutral coma extends to about 10^6 km. But photoionization is not the only mechanism which destroys the neutral gases. Water has a photodissociation rate greater than 10^{-5} s^{-1}, and therefore the neutral water coma extends to distances less than 10^5 km. Thus, the water ions are born closer to the nucleus in comparison to the most of the other ions in a cometary plasma tail. Because H_2O is faster destroyed by photodissociation a relatively small amount of the neutral water is converted into H_2O^+.

In order to obtain this amount from observations we have to derive the ion flux into the tail and to compare it with measurements of the water production rate acquired at the same time. To calculate the flux of ions we need a sequence of well calibrated images and the tailward velocity of the ions. The ion velocities can be measured by two methods. First, by the Doppler shift, measured in a spectrum of the comet, and second, by tracing stable structures in the plasma tail.

In this paper we present observations of water ions in the plasma tail of comet Ikeya-Zhang. We have found several structures in the tail of this comet and traced one of them to determine the plasma velocity. We first describe the image processing applied to the data for enhancement of the observed structures. Then we measure the locations of these structures in our sequence of images. Finally, we derive the velocity and use it to estimate the water production rate of comet Ikeya-Zhang by applying the similarity laws of magnetohydrodynamics.

2. THE OBSERVATIONS AND THEIR REDUCTION

The images analyzed in this paper are presented in Fig. 1. Here they are shown after bias subtraction, flat-fielding, and conversion to one-second-exposures. The numbers above the images are the Start-times of the exposures (UT). The plasma tail consists of several streamers, well distinguished at greater cometocentric distances. Close to the nucleus the plasma structures are hidden in the strong continuum contribution coming from solar radiation scattered by the cometary dust particles, and from the denser cloud of ions at smaller cometocentric distances. We applied several image

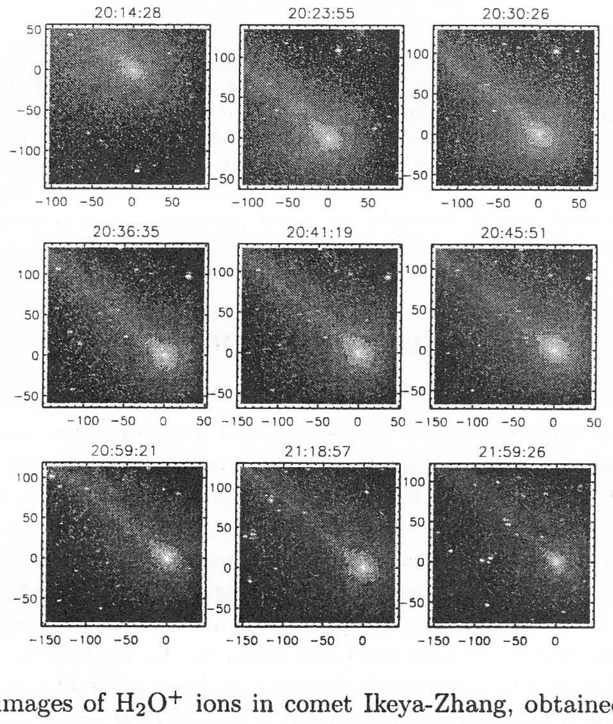

Fig. 1: The images of H_2O^+ ions in comet Ikeya-Zhang, obtained on May 4, 2002. The UT-start times of the exposures are given on top of each particular image. The spatial scale is in 10^3 km.

processing steps in order to reveal the plasma structures close to the nucleus. The most important of these steps are described below:

2. 1. TRANSFORMATION TO POLAR COORDINATES

We have measured the extent of the plasma tail in azimuthal direction and have transformed to polar coordinates only that sector of the image which contains the tail. The result of this procedure is shown in Fig. 2.

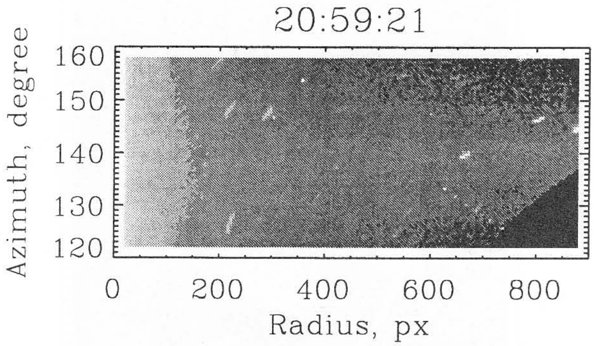

Fig. 2: Example of an image transformed to polar coordinates.

2. 2. ENHANCING THE STRUCTURES

In this subsection we show the result of a procedure which was conceived to enhance the structures in a cometary tail. The structures should extend predominantly in radial direction.

The described procedure is similar to the rotational shift-differencing method used by Larson and Sekanina (1984), and later by Hoban et al. (1989). The difference consists in the usage of an image which is averaged in azimuthal direction instead of taking simply an image rotated by a given angle. The azimuthal averaging has been done by taking a mean vector of the image in polar coordinates along the second dimension, and by expanding this mean vector back to a 2-dimensional array with the dimensions of the original image in polar coordinates. In the next step the difference between the original and the averaged image is calculated. As the plasma structures are extended in radial direction, this step enhances their contrast.

2. 3. BACK TO CARTESIAN COORDINATES

Here, the result of the previous subsection is transformed back to Cartesian coordinates. One example of an image from our sequence after this step is shown in Fig. 3. It is well seen that the bright smooth contribution close to the nucleus has disappeared and only the discrete structures have remained.

2. 4. TRACING OF THE STRUCTURES

The images have been rotated at the position angle of the extended radius- vector. The aim of this transformation is to bring the Sun-Comet radius-vector in direction of the positive X-axis. We have extracted only that portion from the rotated image which contains the tail. The result is shown in Figs. 4, 5, and 6.

The axes are transformed to the projected linear scale calculated at the comet's geocentric distance. Several structures in the plasma tail can be distinguished but only one is particularly stable. It can be identified in all 9 images and its tail-ward motion can be traced. We have marked this structure with an arrow.

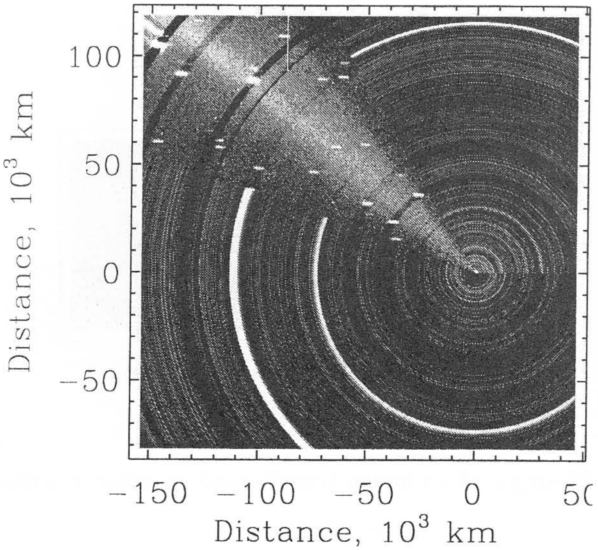

Fig. 3: This image is transformed back to Cartesian coordinates after the image processing described in the previous sections

3. DISCUSSION

In Fig. 7 the cometocentric distance of the marked structure is plotted against the time elapsed from UT 0.0 on May 4, 2002. The full line represents a linear fit to the data. The slope of the fitted line gives a mean velocity of the ions in the plasma tail of comet Ikeya-Zhang of 17.6 km s^{-1}. During the observations the phase angle was 64°. After correcting with this angle for the aspect of the observations we obtain a velocity of 19.4 km s^{-1}. for the tailward plasma flow. Wegmann et al. (1987) modeled the plasma tail of comet Halley for the time of the Giotto encounter. According to their model comet Halley should have a velocity of 20 km s^{-1} at a distance of about 5 10^4 km tailward of the nucleus. A comparison between our measured velocity and the models by Wegmann et al. (1987) can be used to estimate the water production rate of comet Ikeya-Zhang. This comparison can be made by utilizing the similarity law of the magnetohydrodynamic description of the solar wind – comet interaction (Wegmann (1995), Jockers et al., (1999)). If all other conditions have been equal, the water production rate of comet Ikeya-Zhang during our observations has been about 2 times smaller in comparison to comet Halley during the Giotto encounter.

4. CONCLUSION

We have presented narrow-band images of H_2O^+ ions in the plasma tail of comet Ikeya-Zhang The images reveal structures in the tail and close to the nucleus. We have enhanced the structures by subtracting an azimuthal average from the original image. By tracing one of these structures we derived a mean velocity of 17.6 km s^{-1} at a cometocentric distance 10^5 km in tailward direction. The derived velocity of the plasma structures suggests that at the time of our observations the H_2O production

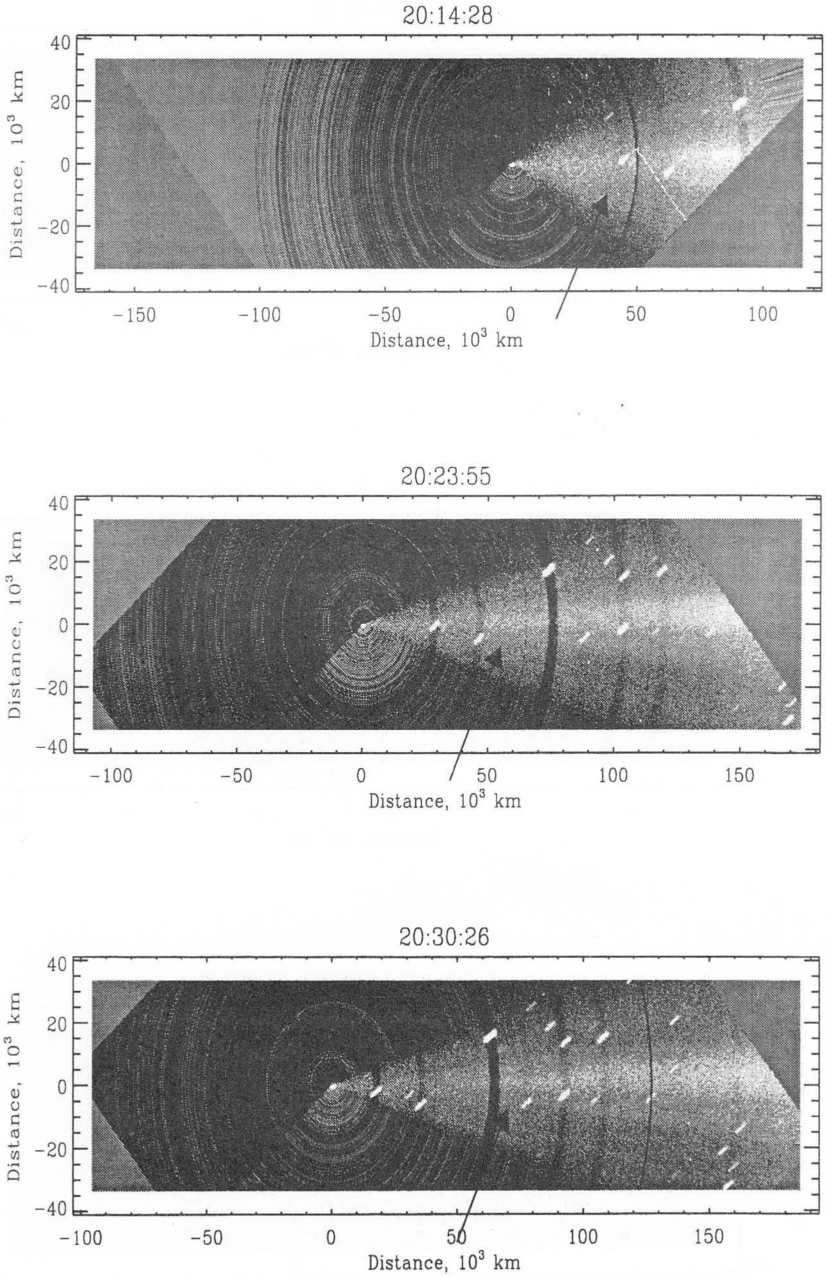

Fig. 4:

rate of comet Ikeya-Zhang has been about 2 times lower in comparison to that of comet Halley during the Giotto encounter.

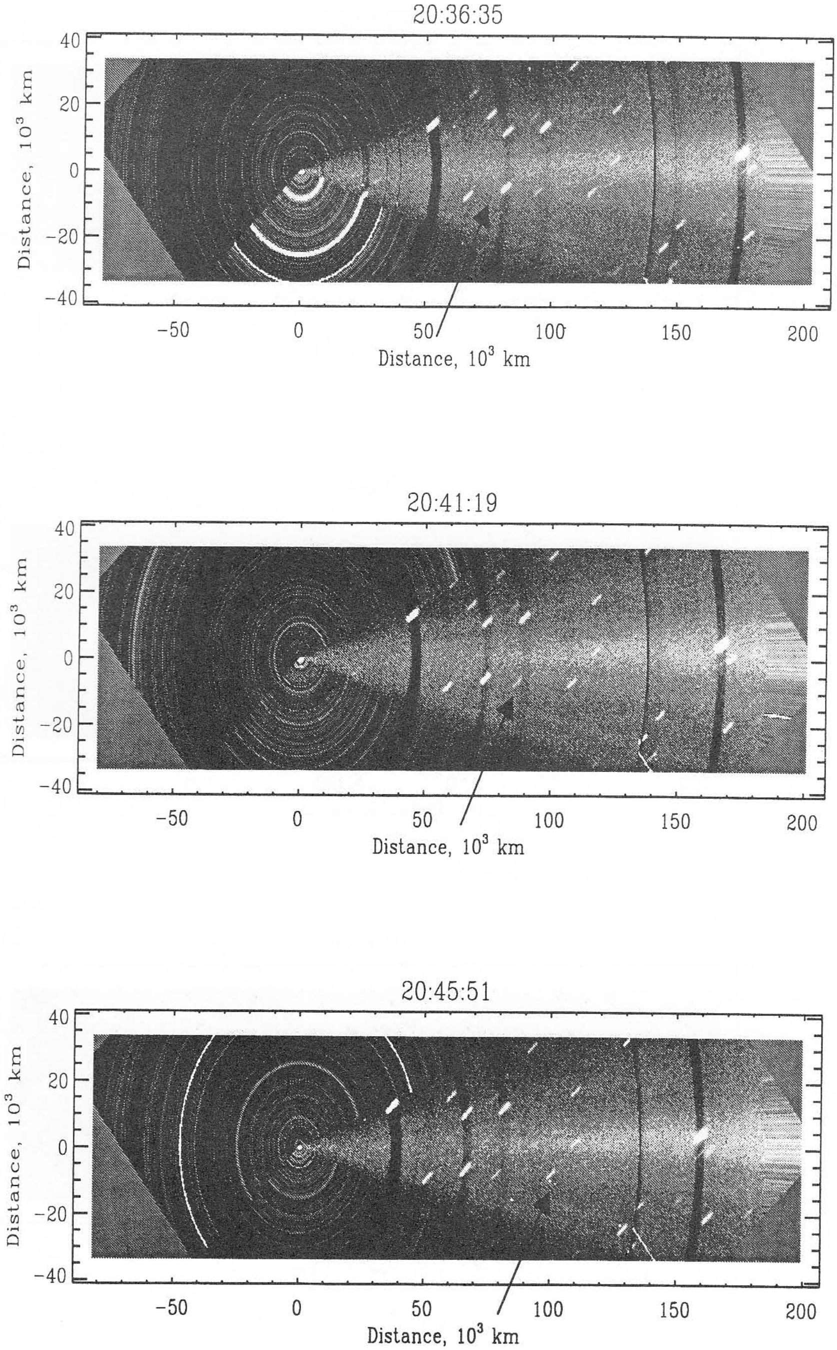
20:36:35
20:41:19
20:45:51
Distance, 10³ km
Distance, 10³ km
40
20
0
-20
-40
-50
0
50
100
150
200

Fig. 5:

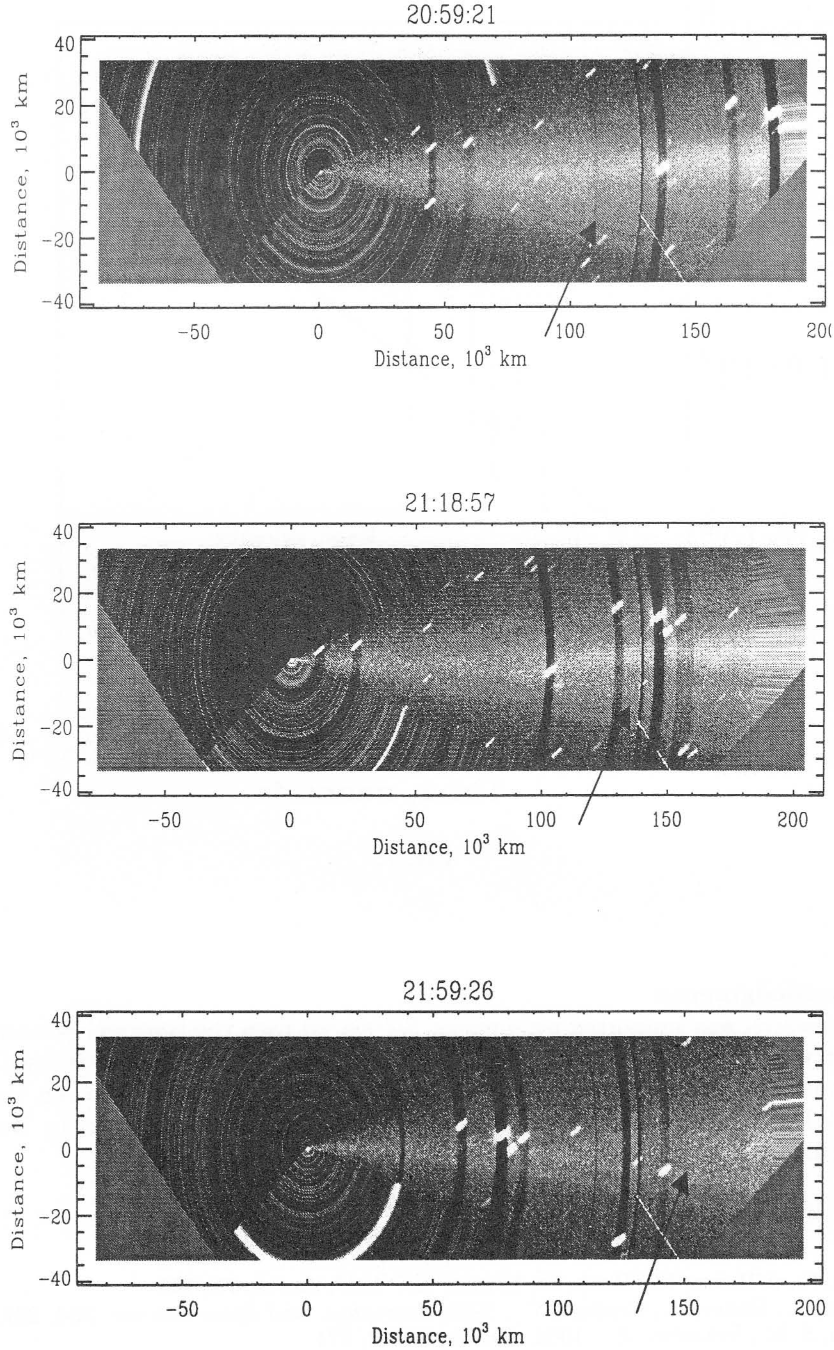
20:59:21
Distance, 10^3 km
Distance, 10^3 km
21:18:57
Distance, 10^3 km
Distance, 10^3 km
21:59:26
Distance, 10^3 km
Distance, 10^3 km

Fig. 6:

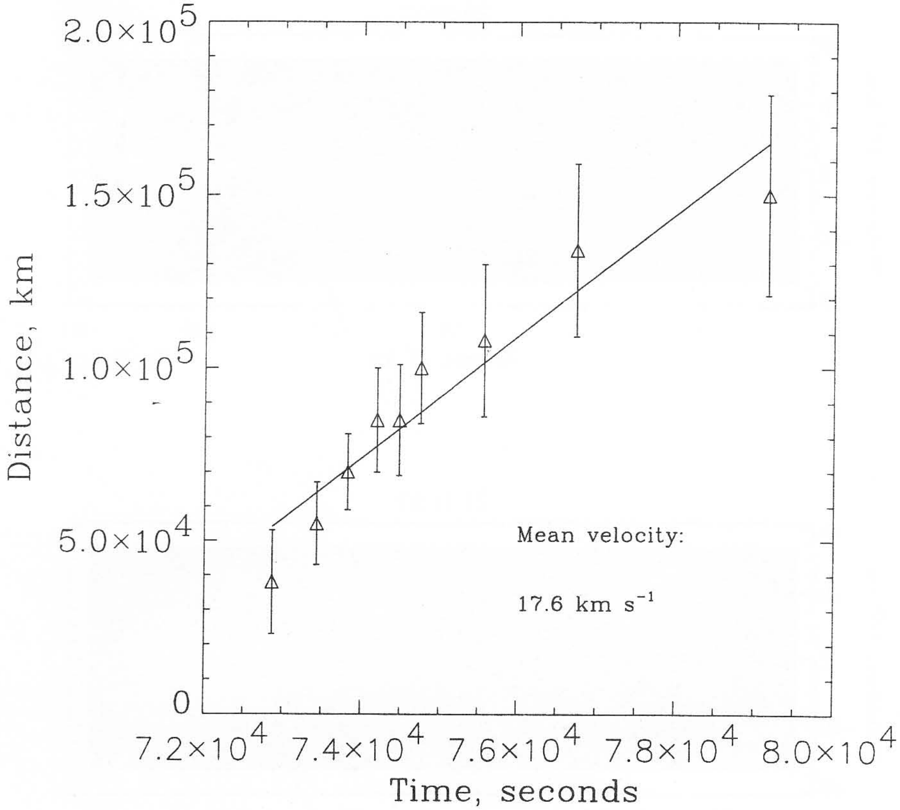

Fig. 7:

Acknowledgments:

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