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# DOPPLER VELOCITIES IN THE ION TAIL OF COMET LEVY 1990c

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**Abstract**

We have obtained time alternating sequences of column density maps and Doppler velocity fields in the plasma tail of comet Levy 1990c. We describe the observing technique and data analysis and present first results.

## OBSERVATIONS

The study of mass balance in cometary plasma tails requires the knowledge of column densities and velocities of the ions. From August 17 to 25, 1990, at the Observatory Hoher List comet Levy 1990c was observed to obtain these quantities and their temporal variation. On August 24 the geocentric distance was 0.43 AU and the heliocentric distance 1.41 AU. The phase angle was 20.3°. At the 1m-reflector our focal reducer/CCD system was used with its short focus camera. This gives a scale of 3 arcsec per pixel (corresponding to 938 km at the comet) and a field of about 20 arcmin diameter which in the corners is already limited by the hole in the main mirror of the telescope. The camera was rotated to put the antisolar direction along the long side of the chip to provide optimum coverage of the plasma tail. Our interference filter for $H_2O^+$ of 3 nm FWHM has its peak transmission at 620 nm. Following a suggestion of Scherb et al. (1990) it was decided to observe the short wave side of the

Table 1: Lines contributing to the interferogram

| $H_2O^+$ | Intensity | Int.×T(λ) | Order | $CO^+$ | Intensity | Order |
|---|---|---|---|---|---|---|
| 6135.54 Å | 2.3 | 0.01 | 2951.49 | 6194.28Å | 2 | 2923.50 |
| →6158.64 Å | 16.0 | 10.30 | 2940.42 | | | |
| 6158.86 Å | 10.7 | 6.89 | 2940.32 | 6189.71Å | 6 | 2925.66 |
| 6166.92 Å | 1.0 | 0.56 | 2936.47 | | | |
| 6166.96 Å | 0.8 | 0.45 | 2936.45 | | | |
| 6187.86 Å | 2.3 | 0.19 | 2926.54 | | | |
| 6198.75 Å | 26.0 | 0.18 | 2921.40 | | | |
| 6140.53 Å | 3.0 | 0.10 | 2949.09 | 6190.62Å | 5 | 2925.23 |
| →6146.80 Å | 16.0 | 3.41 | 2946.09 | 6192.80Å | 3 | 2924.20 |
| 6186.59 Å | 3.0 | 0.37 | 2927.14 | | | |
| 6134.76 Å | 3.0 | 0.02 | 2951.87 | →6189.27Å | 8 | 2925.87 |
| 6140.92 Å | 2.0 | 0.07 | 2948.91 | 6189.47Å | 7 | 2925.78 |
| 6147.38 Å | 8.0 | 1.98 | 2945.81 | 6191.59Å | 4 | 2924.77 |

0–8–0 band of $H_2O^+$. Therefore the filter was tilted by 11.25°. To minimize changes of the filter transmission along the plasma tail the axis of tilt was aligned with the long side of the CCD. Standard stars were observed for absolute calibration. In this way it was possible to obtain column density distributions of $H_2O^+$. To derive Doppler velocities we used a Fabry-Perot etalon with a fixed air gap of 0.90545 mm which was put into the parallel beam of the focal reducer. Interferograms were taken alternating with filter images. The etalon has a free spectral range of 2.1 Å and a finesse exceeding 20, which in the present setup was, however, reduced because of the undersampling caused by the combination of the short focus lens and the CCD. The tilted filter used for the images also was employed for the interferograms. Each night one image of the cometary continuum was recorded through a filter of 3 nm FWHM centered at 642 nm. Before and after each interferogram fringes of one rubidium and two neon lines at 6159.63 Å and at 6143.062 and 6163.593 Å were recorded via a diffusing screen placed at the Cassegrain focus. The exposure time was 15 min for the filter image and 30 min for the interferogram. One full cycle consisting of one image and one interferogram including instrument changes and calibrations took about 90 min. Interferograms were obtained on Aug 16, 17, 21/22, 23/24 and 24/25. In the last two nights three full cycles and one additional image were taken.

## DATA REDUCTION

In addition to the usual steps of CCD data reduction from each plasma image and interferogram the dust image of the same night was subtracted to remove the continuum contribution in the plasma frames. A slight $C_2$ coma (0–2 head of the Swan band) remains in the plasma images. The tail ion lines contributing to the fringes are listed in Table 1. For $H_2O^+$ intensity estimates are taken from Wehinger et al (1974) and are given also with the prefilter transmission taken into account (third column). For the lines of the 0–3 band of $CO^+$ the line strengths were assumed to decrease with distance from the (red degraded) band head as no better information is available. As can be seen from the fractional Fabry-Perot order the lines form three groups of which the strongest lines are marked with an arrow. The

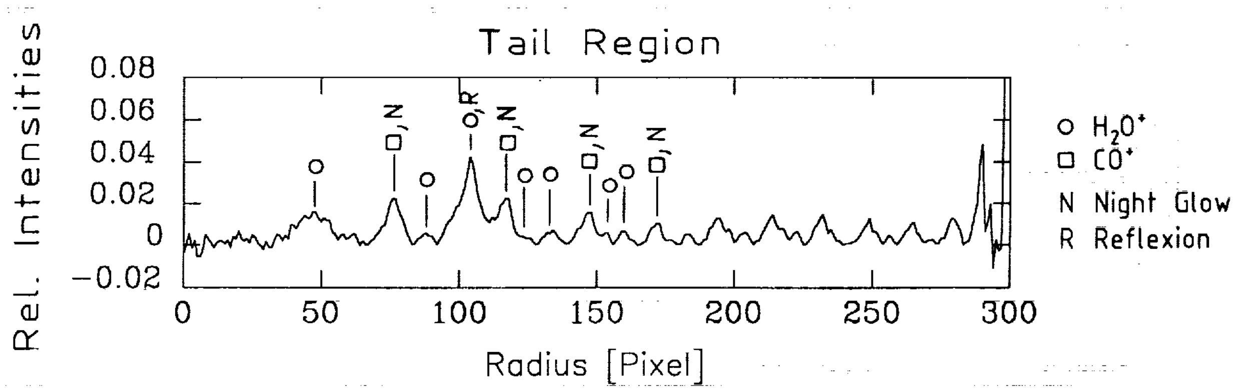


Fig. 1: Trace through interferogram from Aug 23/24 along the far tail.

third peak is caused by $CO^+$. An auroral oxygen line at 6155.98 Å (the observations were conducted during solar maximum at a geographic latitude of 53°) forms airglow fringes which partially blend the ion lines. Figure 1 gives a trace through the interference fringes along the tail as they were obtained in the night Aug 23/24. The width of the unblended $H_2O^+$ lines is about 0.5 Å. Figure 2 presents an example of $H_2O^+$ column density contours with

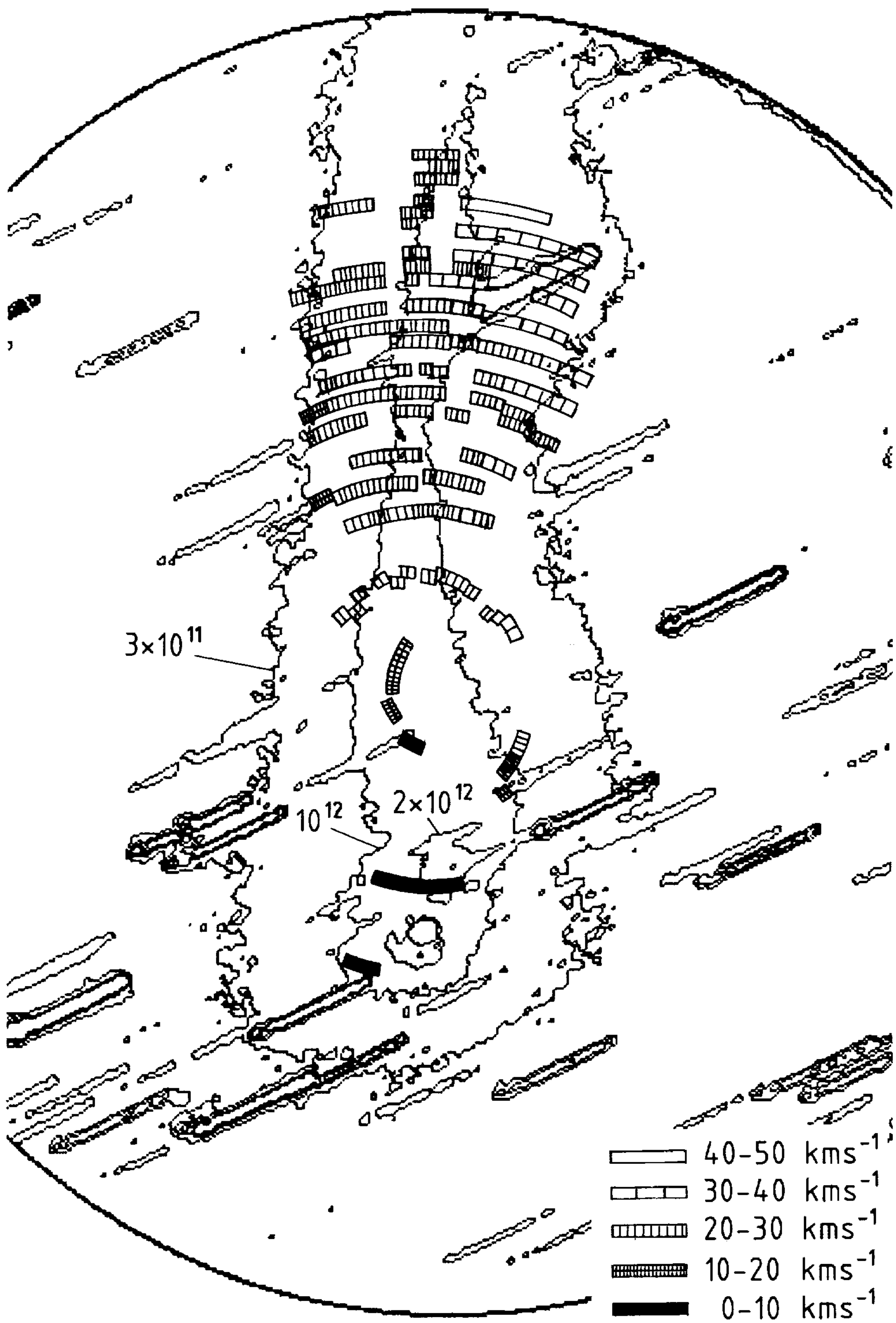


Fig. 2: Column density contours ($cm^{-2}$) of a plasma tail image obtained on Aug 23/24. Superimposed are the velocities along the tail derived from an interferogram.

superimposed velocities, derived from the Doppler shift under the assumption that the velocity vector is along the line of sight.

## RESULTS AND DISCUSSION

For the first time we are able to present a field of Doppler velocity and $H_2O^+$ column density measurements, taken nearly simultaneously. In Figure 2 one notices the acceleration of the plasma along the tail axis. At the same time, velocities are higher at the right side of the tail. At present it cannot be completely ruled out that the higher velocities at the right side may be caused by an instrumental effect induced by the tilted prefilter but we think that the effect is real and that the flow along a small streamer extending to the right side of the main tail is higher than in the bent main tail. In some of the interferograms velocities could be measured at the solar side of the comet. They increase toward the sun as expected.

The velocity measurements have been interpolated to produce a velocity field everywhere along the tail. Using the column density data and assuming that the flow vectors are parallel to the tail axis we have calculated the appearance of the tail for the next image. The result generally agrees in topology with the observed image. This indicates that the observed motions are indeed material motions and no waves. Most deviations can be explained by motions not parallel to the antisolar direction.

A line width of about 0.5 Å = 24 km $s^{-1}$ has been found. As compared to our line profiles the ones published by Scherb et al. (1990), which have a better signal to noise ratio, are wider and slightly asymmetric. This may be caused by the fact that the Fabry-Perot photometer of Scherb et al. has a large aperture of about $10^5$ km and is more sensitive than our setup. Therefore they record more of the higher velocities which occur at the sides of the tail. On Aug 17 no measurable line profiles appear in our interferogram indicating a high velocity dispersion. At that time our images show a narrow jet emanating from the nucleus.

From our measurements we derive a mean $H_2O^+$ production rate of $1.5 \times 10^{27}$ particles $s^{-1}$. On Aug 26 the water production rate, determined from OH observations (Feldmann et al. 1990) was $3 \times 10^{29}$ $s^{-1}$. From the rate coefficients of $H_2O$ destruction 2.8 % of the water, i.e. $8.4 \times 10^{27}$ should get ionized to $H_2O^+$. Our measurements give only 18 % of this value indicating loss by "invisible" $H_2O^+$ below the threshold of our measurements streaming with rather high speed.

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