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SPATIAL AND TEMPORAL VARIATIONS IN THE COLUMN DENSITY DISTRIBUTION OF COMET HALLEY'S CN COMA

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ABSTRACT

Mean radial column density profiles of comet P/Halley's CN coma were derived by combining photographic and photoelectric observations. The shape of the profiles as well as their temporal variations were analysed in detail and compared with the results of other CN observations of the comet.

INTRODUCTION

Several surprising characteristics were discovered in the CN coma of comet P/Halley during its apparition in 1986. Firstly, the structural analysis of CN photographs and CCD images led to the detection of shells (Schlosser et al., 1986) and jets (A'Hearn et al., 1986) in the CN coma and secondly, short term variabilities in the photometric lightcurve of comet Halley were also found by photoelectric measurements of the CN emission (Millis and Schleicher, 1986). To clarify, whether there is a connection between the variations in the CN production rate and the occurence of structures in the CN coma, it is necessary to analyse the temporal variations of the CN distribution in the whole coma in detail. For this purpose a series of CN column density profiles covering several consecutive days was determined by combining photographic and photelectric observations. Here, a sequence of mean radial column density profiles derived from April 1 to April 10, 1986 is presented.

OBSERVATIONS AND DATA REDUCTION

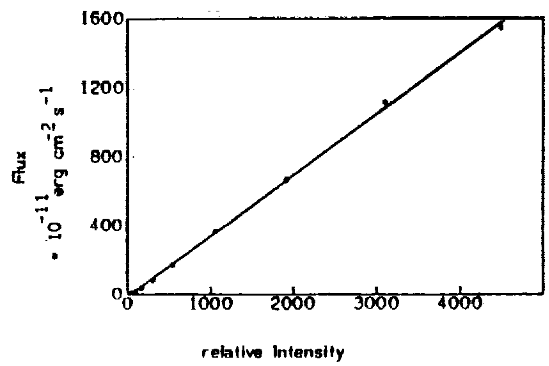
The CN observations were carried out as a part of the Bochum Halley Monitoring Program at ESO/La Silla from February 17 to April 17, 1986. The observation techniques were photographic as well as photoelectric photometry. A synopsis of the whole observation program is given by Celnik et al. (1988). The photographic CN observations are described in detail by Schulz and Schlosser (1989). The presented column density profiles were derived from CN photographs taken with a Lichtenknecker Flat-Field-Camera (focal length 760 mm, field of view $1^{\circ}\!.8 \times 2^{\circ}\!.7$) between 1 April and 10 April, 1986, respectively. The photographs were digitized and relative intensity calibrated with the use of sensitometric spots. Simultaneously to the photographic observations photoelectric measurements of the comet were obtained in nine different diaphraghm sizes at the Bochum 61 cm Cassegrain telescope at La Silla with the standard IHW filter set. The photoelectric measurements were standard star calibrated and then converted into absolute CN fluxes using the calibration procedure described by A'Hearn and Vanysek (1986, 1989). With these data the relative intensities of the corresponding images were transformed into absolute fluxes. Figure 1 shows a typical calibration curve for the transformation of the relative intensities of the images into absolute CN fluxes. The integrated flux F in each aperture evaluated from the photoelectric measurements is plotted against the corresponding background corrected integrated intensity I_{rel} of each image. The slope m of the resulting straight line gives the calibration factor and the CN fluxes can then be converted into column densities by using the following equation:

$$N = 4\pi\,\Delta^2 \cdot \frac{r^2}{g}\,\frac{F(CN)}{A} = 4\pi\,\Delta^2 \cdot \frac{\Delta t}{E_{O2}}\,\frac{F(CN)}{A}$$

with Δ : geocentric distance r : heliocentric distance / AU
E_{O2}: excitation energy g : g - factor (normalized to 1 AU)
A : comet area corresponding to area of one pixel
Δt : time difference between two excitations

The time difference between two excitations was set to Δt = 18 s as derived from the accelerated movement of the CN shells in tail direction (Schulz and Schlosser, 1989). The resulting images represent two-dimensional column density profiles of the CN coma.

Fig. 1 Calibration curve for the transformation of the relative intensities in the CN images into absolute fluxes
Photograph of April 8th, 1986, 7.35 - 8.25 UT



COLUMN DENSITY PROFILES

For the analysis of the column density distribution of the CN radical as a function of the nucleus distance, a one-dimensional mean radial column density profile was constructed from each image by azimuthal averaging around the nucleus. This presumes the column density distribution to be circular symmetric around the nucleus in first approximation, which means that the elliptical distortions caused by solar radiation pressure must be neglectable. To prove whether this is the case, one-dimensional cuttings through the coma were prepared and compared to the mean radial profile. This is demonstrated in Fig. 2.

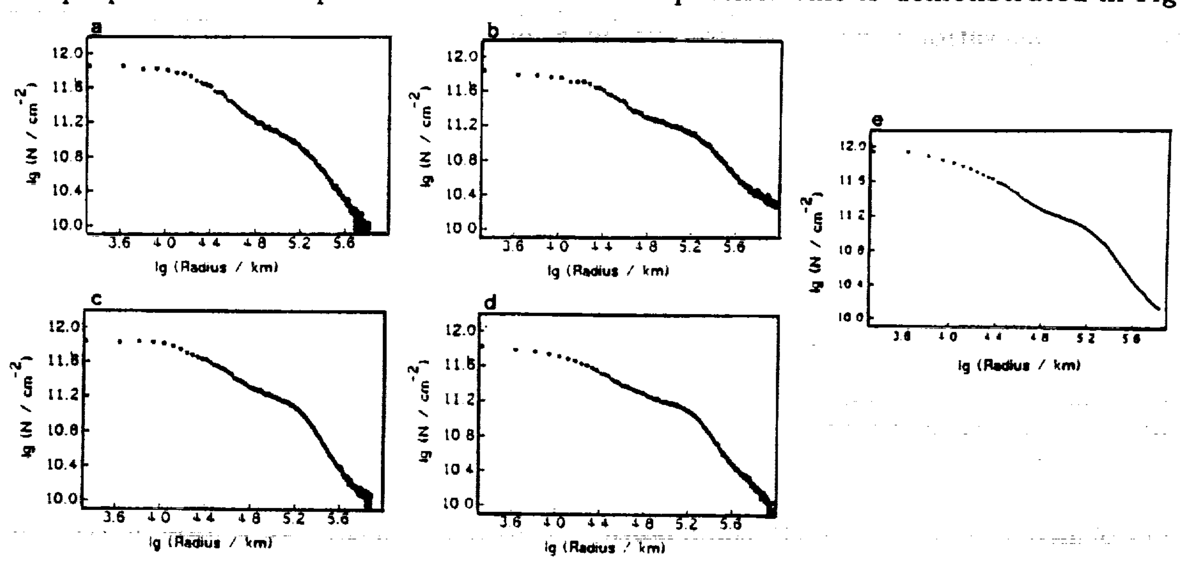


Fig. 2 One dimensional column density profiles of the CN coma in projected sun direction (a), projected tail direction (b) and the perpendicular profiles (c: upper part, d: lower part of the coma) compared to the mean radial column density profile (e). Photograph of April 8, 1986, 2.16 - 3.36 UT

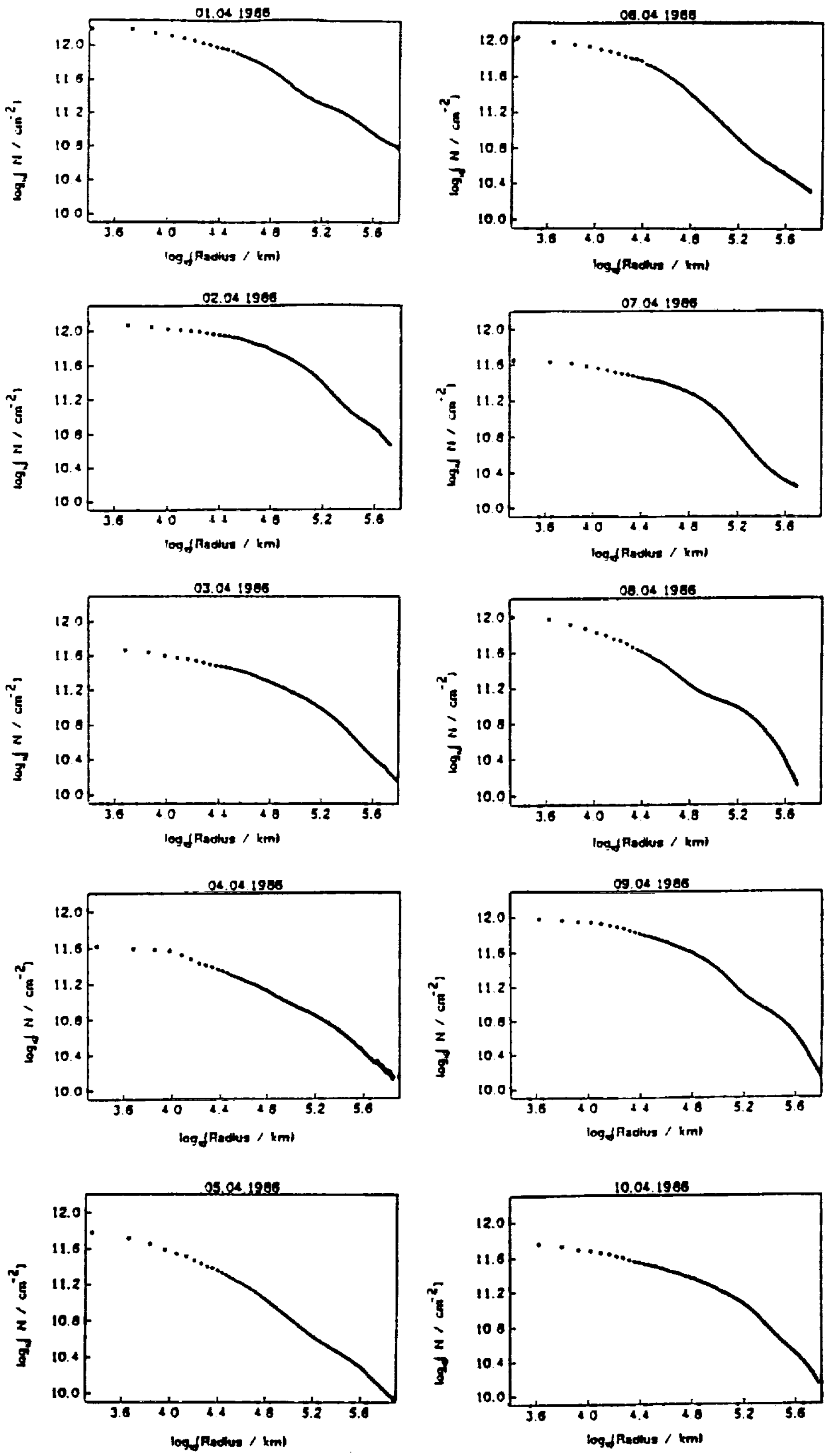


Fig. 3 The mean radial column density profiles of the CN coma between April 1st and April 10th, 1986

The column density profiles of one image of April 8, 1986 in sunward (2a) and tail direction (2b) and the perpendicular profiles (2c: upper part, 2d: lower part of the coma) are compared with the mean radial column density profile (2e). The profiles parallel to the sun-comet line (2a, 2b) clearly show the effects of solar radiation pressure on the coma geometry. There is more material in tail direction (2b) in the outer coma reagions than in sun direction (2a) or perpendicular to the tail (2c, 2d). However, the comparison of the four one-dimensional cuttings through the coma (2a - d) with the mean radial profile (2e) shows that this mean profile is an appropriate approximation for the general shape of the column density profile on April 8, 1986. Therefore, all forthcoming profiles will be shown in this representation.

Fig. 3 shows the mean column density profiles of the CN coma obtained between April 1 and April 10, 1986. The shapes of the profiles show continuously new formed 'bumps', which are shifted to outer coma regions as a function of time. The column density inside these bumps is up to 15% higher than the column density expected for a smooth course of the curve. There expansion velocity is about 1 km/s. To be visible in the mean radial profiles the bumps must correspond to two-dimensional structures, which are almost circular symmetric around the nucleus. All this indicates, that these bumps correspond to the CN shells found in the coma of comet Halley and in fact this can be proved by comparing the bumps and their kinematic behaviour with the two-dimensional CN shells. For April 1 to April 10, 1986 these shells can be inspected in a paper by Schulz (1991).

The absolute values of the column density in the near-nucleus region show temporal variations corresponding to those found by Millis and Schleicher (1986) and reflect the variations of the CN production rate. If the movement of the bumps in the profiles is extrapolated backwards to the nucleus, their expected formation times coincide with maxima in the CN production rate. This confirmes the results of Festou et al. (1990), who suggested an outburst to explain the bump in the column density profiles of December 4, 1985. All this indicates that a raise in the production rate finally results in expanding shell structures in the coma. Further detailed studies of the two-dimensional structures (jets and shells) in the CN coma, however, led to strong evidence for a connection between both structures and a complex formation mechanim for the shells from jets (Schulz and Schlosser, 1990). Nevertheless, it can be concluded that, whatever the formation mechanism of CN shells is like, it is in any case correlated to the activity of the nucleus.

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