Cometary gas relations 1P/Halley

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Abstract. Photographic and photoelectric observations of comet 1P/Halley's ionised gas coma from CO^+ at 4,250 Å and neutral gas coma from CN at 3,880 Å were part of the Bochum Halley Monitoring Program, conducted at the European Southern Observatory, La Silla, Chile, from February 17 to April 17, 1986.

In this spectral range it is possible to see the continuum formation, motion and expansion of plasma and neutral gas structures. To observe the morphology of these structures, 32 CO^+ photos (glass plates) from comet 1P/Halley obtained by means of an interference filter have been analysed. They have a field of view of 28.6×28.6 degrees and were obtained from March 29 to April 17, 1986 with exposure times between 20 and 120 minutes.

All photos were digitised with a PDS 2020 GM microdensitometer. After digitisation, the data were reduced to relative intensities, and those with proper calibrations were also converted to absolute intensities, expressed in terms of column densities. The CO^+ absolute intensity values still contain the continuum intensity. To calculate the CO^+ column density it is necessary to subtract this continuum intensity.

The relations between CO^+ and CN in average column density values ($\overline{N_{CO^+}/N_{CN}}$) are 11.6 for a circular diaphragm with average diameter ($\overline{\Phi}$) of 6.1 arcminutes which corresponds to a distance from the nucleus (ρ) equal to 6.3×10^4 km; 20.0 for $\overline{\Phi} = 7.1$ arcminutes and $\rho = 7.3 \times 10^4$ km; 8.1 for $\overline{\Phi} = 8.5$ arcminutes and $\rho = 8.7 \times 10^4$ km; 35.6 for $\overline{\Phi} = 11.9$ arcminutes and $\rho = 1.2 \times 10^5$ km; and 31.3 for $\overline{\Phi} = 16.7$ arcminutes and $\rho = 1.7 \times 10^5$ km. These values are in perfect agreement with the data for short distances (ρ from 3.9×10^3 to 1.2×10^4 km) and small slit diameters ($\overline{\Phi}$ from 0.4 to 1.2 arcminutes).

With the use of diaphragms with large diameters it is possible to get some information about the outer coma of the comet (in this paper, from 60,000 until 170,000 km away from the nucleus). At these distances, the CO^+ column density changes only due to the geometrical dilution, because the CO^+ parent molecules are already photoionised or photodissociated.

Keywords. comets: 1P/Halley - comets: general

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1. Introduction

Comet 1P/Halley (1P/1982 U1) was observed photographically at the European Southern Observatory (ESO), La Silla, from February 17 to April 17, 1986 by a group of the *Astronomisches Institut der Ruhr-Universität Bochum*. Altogether 1,216 images were taken in 57 of consecutive 60 nights with exposure times between one second and 170 minutes. Photoelectric photometry of the cometary coma was obtained from February 24 to April 17, 1986 using the 61 cm-Bochum telescope. The observations aimed the study of structure, dynamics, and physical properties of the coma, dust and plasma tail in full spatial extent, and looked for correlations in different parts of the comet with the solar wind. The reader should refer to Celnik *et al.* (1988) for a complete list of all obtained cometary images and associated technical data.

Table 1. CO^+ Plasma images absolute intensities

Date	Image	Decimal Day in April 1986	Absolute Intensity in 10^{-9} erg s^{-1} cm^{-2}
01.04.1986	5530	1.340	1.405
02.04.1986	5546	2.252	1.269
02.04.1986	5556	2.304	1.108
04.04.1986	5602	4.239	0.868
04.04.1986	5619	4.335	0.672
06.04.1986	5675	6.243	1.473
06.04.1986	5685	6.339	1.316
07.04.1986	5693	7.090	1.103
07.04.1986	5716	7.255	1.158
08.04.1986	5732	8.094	0.691
08.04.1986	5751	8.248	1.233
13.04.1986	5881	13.234	2.229
14.04.1986	5913	14.057	0.606
14.04.1986	5949	14.223	0.621

2. Data Reductions

Thirty two CO^+-filter Wide-Field-Camera cometary images and their spot calibrations were digitised with a PDS 2020 GM microdensitometer at the *Astronomisches Institut der Westfälischen Wilhelms-Universität* in Münster. The step of the scan was $\Delta x = \Delta y = 25\ \mu$m so that one pixel is $25 \times 25\ \mu$m and corresponds approximately to 46.9×46.9 arcseconds.

These 32 cometary images from March 29 to April 17, 1986 are the best series of images available because at this time the comet 1P/Halley was nearest to Earth. So 1P/Halley's coma is shown in maximal resolution (approximately 30.0 arcseconds, about 10,210 km at a distance from 0.52 AU (Celnik & Schmidt-Kaler, 1987) and the comet was visible all night at this time, thus two long plasma images could be taken per night ($t \geqslant 20$ minutes).

Just twenty of 32 relative calibrated pictures could theoretically be calibrated absolutely since photometric measurements were not available in all the nights. In fact, only fourteen of these twenty pictures could be calibrated absolutely because their duration of exposure was that long that in six cases the nucleus region of the comet was wider than the largest diaphragm. These fourteen remaining plasma-images were analysed, i.e., they were effectively absolutely calibrated (Voelzke, 1996; Voelzke *et al.*, 1997) making use of MIDAS image processing system. The images and their absolute intensities are listed in Table 1.

3. Results of the absolute calibration of the plasma images

The values of the absolute intensities were calculated by subtracting the values obtained with the largest diaphragm from those values obtained with the second largest, i.e., the difference between the measured values of diaphragms 25 and 26 was determined.

The values of the entire brightness and the continuum background in the CO^+ emission filter were converted into relative units of intensity I'(CO^+). For the evaluation of the CO^+ radiation flow, A'Hearn & Vanysek (1986) equation was used. The thusly calculated CO^+ radiation flow has the dimension [erg s^{-1} cm^{-2}]. After the relative calibration of all the images, the background of the image was subtracted, then the cometocentrical coordinates were included.

These calculated absolute intensity values still contain the continuum intensity. To obtain a column density of CO^+, the intensity of the continuum must be subtracted, i.e., the values for continuum background in the CO^+ emission filter must be subtracted

Table 2. CO^+ radiation flow, CO^+ column density and proportion between CO^+ and CN column density for the diaphragms 25 and 26

Date	Picture	$F(CO^+)$ $(10^{-9}$ erg s^{-1} cm^{-2})	$N(CO^+)$ $(10^{13}$ molecules cm^{-2})	N_{CO+}/N_{CN}
01.04.1986	5530	0.643	1.288	8.53
02.04.1986	5546	0.507	1.040	7.88
02.04.1986	5556	0.346	0.710	5.38
04.04.1986	5602	0.106	0.229	5.45
04.04.1986	5619	−0.09	—	—
06.04.1986	5675	0.711	1.612	15.35
06.04.1986	5685	0.554	1.259	11.99
07.04.1986	5693	0.341	0.789	17.15
07.04.1986	5716	0.396	0.920	20.00
08.04.1986	5732	−0.071	—	—
08.04.1986	5751	0.471	1.121	12.88
13.04.1986	5881	1.467	3.918	—
14.04.1986	5913	−0.156	—	—
14.04.1986	5949	−0.141	—	—

from the values of the total brightness (see Table 1). For this, first the CO^+ radiation flow equation of A'Hearn & Vanysek (1986) was used. Following to this equation, the estimated continuum in the CO^+ filter is partly stronger than the total flux observed in the filter because the emission band is weak compared to the continuum background. Consequently, different negative values for the flow of the band are obtained. This effect can also be observed at other comets (Wolf & Vanysek, 1987).

Table 2 shows the CO^+ radiation flow and column density as well as the proportion between the CO^+ and the CN column density.

4. Conclusions

(*a*) Regarding Figs. 1 and 2 it becomes clear that the results calculated for the large diaphragms apply well to the data determined for the smaller diaphragms. This suggests that the utilised method to avoid negative values for the CO^+ radiation flow provides correct results.
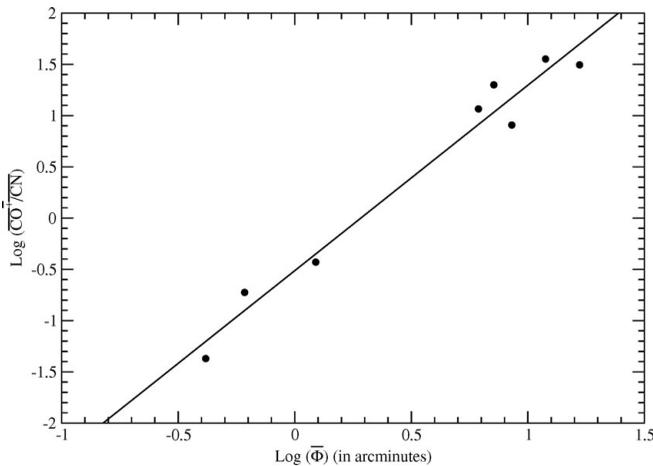
Figure 1. $\overline{N_{CO+}/N_{CN}}$ as function of $\overline{\Phi}$
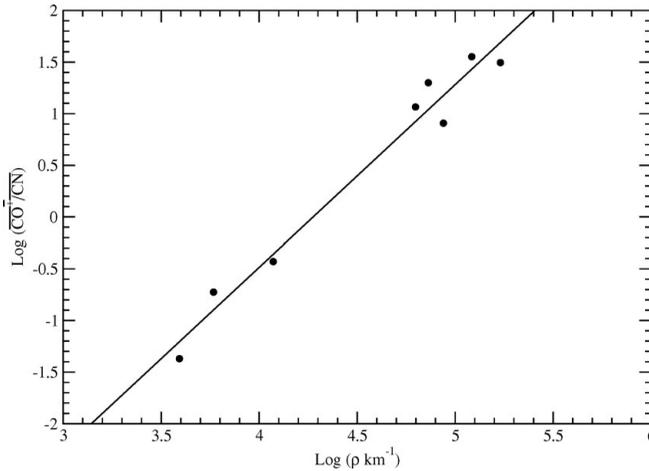
Figure 2. $\overline{N_{CO^+}/N_{CN}}$ as function of the distance ρ

(b) A possible explication for the increase of the curve in Fig. 2 is that the CN column density decreases the bigger the distance is, i.e., the lifetime of CN is shorter than the one of CO$^+$ (Schlosser *et al.*, 1992). The CN molecule photodissociates in C and N with a rate of 3.2×10^{-6} s^{-1} with a minimal sun activity (Huebner *et al.*, 1992). On the other hand, the lifetime of the CO$^+$ ion increases along with a larger distance to the comet since the electronical recombination and also the reaction with neutral water is reduced (Häberli *et al.*, 1995).

(c) The data of 1P/Halley comet make certainly a contribution to the question of resemblances and diversities of comets (for ex. Hyakutake (C/1996 B2) and Hale-Bopp (C/1995 O1)), which is of a basic interest. The optical data also help to make a connection betweeen data measured *in situ* (observations of spacecrafts) and earthbound data. The data of this work give a spacious resolution (column density as function of the cometary distance) which can be compared to data of the Giotto spacecraft measured *in situ*, or to results of comet missions - as for example Rosetta.

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