Bull. Astr. Soc. India (1989) **17**, 107–113

Narrow band photometry of comet Halley in the emission bands and the continuum

G. S. D. Babu, J. S. Nathan, R. Rajamohan and K. R. Sivaraman

Indian Institute of Astrophysics, Bangalore 560 034

Received 1989 April 24; accepted 1989 May 30

Abstract. IHW filter photometry of comet Halley was carried out on seven nights during pre-perihelion period and on six nights during post-perihelion period using the 40 cm telescope at the Vainu Bappu Observatory, Kavalur as a part of the Indian Halley Observation Program. The pre-perihelion observations show large amplitude fluctuations in the emission fluxes, superimposed on the general trend of their slow increase with the decreasing R_h. The respective abundances of the CN, C_3, CO^+, C_2 and H_2O^+ molecules contained in a cylinder of diameter 86 arcsec in the line of sight through the comet have also been estimated. Their individual emission strengths are very low due perhaps to the comet's several approaches to the sun.

Key words : filter photometry—comet Halley

1. Introduction

Narrow band photoelectric observations of comet Halley were carried out as part of the Indian Halley Observation Program (IHOP) within the International Halley Watch (IHW) photometry and polarimetry net. The observations were done on three different occasions, between 1985 December 26 and 1986 April 16, covering seven nights during the pre-perihelion and six nights during the post-perihelion periods of the comet. We report here the results of the photometric observations viz., the fluxes in the emission bands as well as in the continuum, and the corresponding molecular abundances.

2. The observations

All the observations were made using the 40 cm reflector at the Vainu Bappu Observatory, Kavalur. A conventional single channel photometer consisting of a refrigerated EMI 9658B tube was mounted at the Cassegrain focus (f/12) of the telescope, and the recording was done with the standard pulse counting system. An entrance diaphragm of 2mm diameter equivalent to a projected sky area of

86 arcsec was used all through the observations. The comet was observed on seven nights during the pre-perihelion, from 1985 December 26 to 1986 January 1 and on six nights during post-prehelion period between 1986 March 5 and April 16. In addition, observations were made on several other nights which, however, had to be rejected because of a variety of reasons. The dates of the useful observations and the associated details are given in table 1.

Table 1. Ephemeris of comet Halley (Yeomans 1981)

Date 1985–86 UT	Δ in a.u.	r in a.u.	Phase angle (β)	Magnitude (m_1)
Dec 26.59	1.05	1.10	54.6	5.6
27.59	1.07	1.09	54.5	5.6
28.61	1.09	1.07	54.4	5.6
29.59	1.11	1.06	54.2	5.5
30.58	1.13	1.04	54.0	5.5
31.58	1.15	1.03	53.7	5.4
Jan 01.58	1.17	1.01	53.4	5.4
Mar 05.99	1.16	0.79	57.6	5.0
06.99	1.14	0.80	58.7	5.0
07.99	1.11	0.81	59.7	5.0
12.98	0.99	0.88	63.8	4.9
Apr 14.82	0.44	1.39	23.1	4.3
15.80	0.45	1.41	21.9	4.4

We used the interference filters, supplied by the IHW photometry net, to isolate the emission bands of CN (3871), C_3(4060), CO^+(4260), C_2(5140), H_2O^+(7000), as well as the continuum regions at 3650, 4845 and 6840Å. Each observation through a given filter typically consisted of several integrations at the rate of 1s duration on the comet followed by similar sky measurements. The mean of these integrations was adopted as a single observation at the corresponding mean epoch after deducting the respective sky values. One sequence of such single observations through all the above mentioned filters constituted one set of observations. At least three such sets were obtained on every possible night by placing the brightest region (approximately the centre of the coma) at the centre of the entrance diaphragm. Further, a minimum of two standard stars were observed in the same manner at different zenith distances, which provided the coefficients of the atmospheric extinction. After correcting for these extinction effects, each observation of the comet was transformed to the IHW magnitude, with the help of the instrumental constants obtained from the observations of several IHW standard stars. Then, the mean of these standard magnitudes of the comet corresponding to a given filter was adopted as the value for that night for that filter band. The errors in these magnitudes, which are expected to be primarily due to the photometric uncertainties, are found to be in the range of 0.05 mag to 0.15 mag, with very few of the values reaching upto 0.20 mag. Hidden in this estimated error are the intrinsic short time variations in the monochromatic brightness of the cometary coma, although such variations would possibly be averaged out in the large entrance aperture used by us.

The observations through all the filters were obtained during the post-perihelion period, while only those through the filters of CN(3871), C_2(5140) and of the continua at 3650 and 4845Å could give useful data during the pre-perihelion period. The standardized magnitudes of the comet were then transformed to the absolute flux values using the flux transformation equations of A'Hearn (1986). These values which are good to about 5% are presented in table 2.

Table 2. Observed fluxes in comet Halley

Date 1985–86 UT	Log $F_{Cont(3650)}$	Log $F_{CN(3871)}$	Log $F_{C_3(4060)}$	Log $F_{CO^+(4260)}$	Log $F_{Cont(4845)}$	Log $F_{C_2(5140)}$	Log $F_{Cont(6840)}$	Log $F_{H_2O^+(7000)}$
Dec 26.59	—10.93	—8.84	—	—	—11.43	—8.54	—	—
27.59	—10.98	—8.67	—	—	—11.42	—8.45	—	—
28.61	—10.93	—8.56	—	—	—11.37	—8.33	—	—
29.59	—10.94	—8.63	—	—	—11.34	—8.39	—	—
30.58	—10.95	—8.78	—	—	—11.44	—8.40	—	—
31.58	—11.20	—8.91	—	—	—11.55	—8.60	—	—
Jan 01.58	—11.15	—8.57	—	—	—11.25	—8.29	—	—
Mar 05.99	—10.93	—7.77	—8.34	— 9.01	—10.45	—7.80	—10.53	—9.09
06.99	—10.81	—7.78	—8.64	— 9.34	—10.36	—7.72	—10 43	—
07.99	—11.06	—7.66	—8 27	— 9.36	—10.45	—7.73	—10.47	—9.85
12.98	—11.06	—7.97	—8.72	—10.38	—10.69	—7.95	—10.79	—
Apr 14.82	—11.29	—8.88	—9.29	—	—11.11	—8.67	—11.18	—10.28
15.80	—11.36	—8.60	—8.71	— 10.49	—10.99	—8.46	—11.11	—

Log F_λ = log of total flux in ergs cm^{-2} s^{-1} in the emission band at λ and ergs cm^{-2} s^{-1} $Å^{-1}$ in the continuum band at λ.

3. Results

Flux variations

The fluxes corresponding to the various emission and continuum locations (at $\Delta =$ 1.0 AU) are plotted in figures 1 and 2 against the dates of observation as well as the respective heliocentric distances R_h. The pre-perihelion observations (figure 1) show a large amplitude fluctuation superimposed on a general trend of the slow increase in the brightness with decreasing R_h. Unfortunately our data are insufficient to determine any periodicity of these fluctuations.

During the post-perihelion period (figure 2), fluxes are higher during 1986 March than those in April showing a general decrease with increasing R_h. However, the fluxes of CN and C_2 on 1986 April 15.8, are higher than those measured on the previous night, thus showing an increasing trend in a shorter time scale. A similar upward trend is also seen in the observations of Millis & Schleicher (1986, their figure 1) during the same period. We do not attempt to compare our measurements of the absolute fluxes with theirs, but would be satisfied with emphasizing the similarity in the trend. An identical trend can be noticed in our flux measures

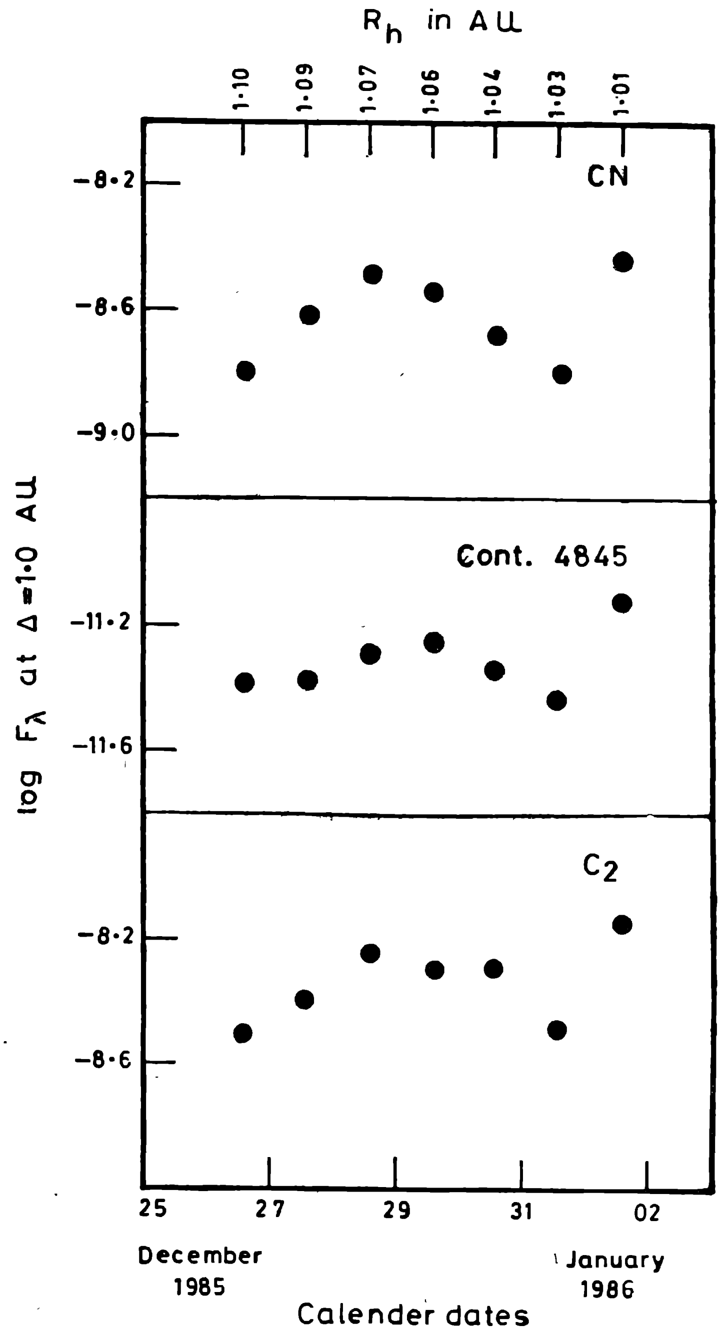

Figure 1. The fluxes (at $\Delta = 1.0$ AU) corresponding to the emission features of CN and C_2 as well as the continuum at 4845Å of comet Halley are shown against the dates of observation and the respective heliocentric distances R_h of the comet during its pre-perihelion period.

of C_3 and also the continuum at 4845Å, giving a clear indication of the sporadic increase in the total output (gas and dust) by the comet. The demonstration of the existence of the large amplitude flare-like sporadic variations in the output of the comet over a long base-line of time by Sterken *et al.* (1987) prevents us from fitting a linear relationship between our 1986 March and April observaions in the traditional way.

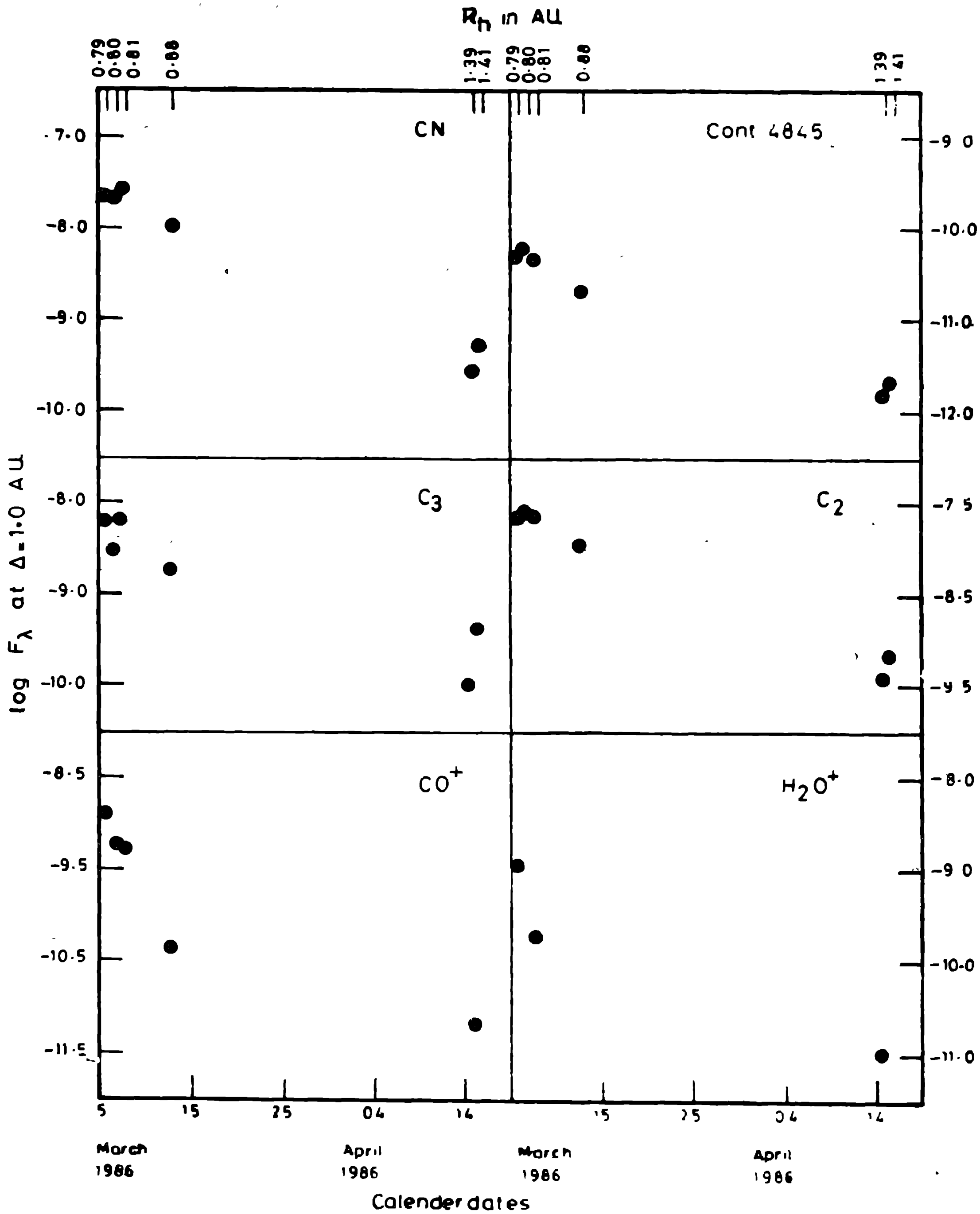

Figure 2. The fluxes (at Δ = 1.0 AU) corresponding to the emission features of CN, C_3, CO^+, C_2 and H_2O^+ as well as the continuum at 4845Å of comet Halley are shown against the dates of observation and the respective heliocentric distances R_h of the comet during its post-perihelion period.

Molecular abundances

We have estimated the total number of molecules (M) of each of the species i.e., CN, C_3, CO^+, C_2 and H_2O^+ contained in a cylinder of diameter 86 arcsec in the line of sight and extending through the comet, using the relation for the resonance flourescence mechanism, given in Sivaraman *et al.* (1987).

The following formulae were used for estimating the total number of molecules.

$$\log M_{CN} = \log F_{CN} + 2 \log r\Delta + 39.938 \text{ (at } \dot{R}_h = -26 \text{ km s}^{-1})$$
$$+ 39.923 \text{ (at } \dot{R}_h = +23 \text{ km s}^{-1})$$
$$\log M_{C_3} = \log F_{C_3} + 2 \log r\Delta + 39.262$$
$$\log M_{CO^+} = \log F_{CO^+} + 2 \log r\Delta + 40.890$$
$$\log M_{C_2} = \log F_{C_2} + 2 \log r\Delta + 39.800$$
$$\log M_{H_2O^+} = \log F_{H_2O^+} + 2 \log r\Delta + 38.972.$$

The results are presented in table 3.

Table 3. Total number of molecules in the observed column of comet Halley

Date 1985–86 UT	R in 10^4 km	Log M				
		CN (3871)	C_3(4060)	CO^+ (4260)	C_2(5140)	H_2O^+(7000)
Dec 26.59	6.54	31.22	—	—	31.38	—
27.59	6.67	31.40	—	—	31.48	—
28.61	6.79	31.51	—	—	31.60	—
29.59	6.92	31.45	—	—	31.55	—
30.58	7.04	31.29	—	—	31.54	—
31.58	7.17	31.17	—	—	31.34	—
Jan 01 58	7.29	31.50	—	—	31.65	—
Mar 05.99	7.23	32.08	30.85	31.80	31.92	29.81
06.99	7.11	32.07	30.54	31.47	32.00	—
07.99	6.92	32.18	30.90	31.44	31.98	29.03
12.98	6.17	31.85	30.42	30.39	31.73	—
Apr 14.82	2.74	30.64	29.55	—	30.70	28.27
15.80	2.80	30.95	30.16	30.01	30.95	—

R is the projected diameter of the 86 arcsec diaphragm on the comet at the geocentric distance of observation.

We are tempted to make a comparison of the total number of molecules obtained by us for comet Halley with those of comet West observed through a much smaller diaphragm of 25.9 arcsec (Sivaraman *et al.* 1979), at similar heliocentric distances. A similarity can be noticed in the respective magnitudes of the two comets. That is, in order to have similar strengths of the emission features as that of comet West, a much larger area had to be covered in the coma of comet Halley. This indicates that the density of the constituents in the coma of comet Halley is much less than that in comet West which can perhaps be related to several apparitions of comet Halley as against the possible first appearance of comet West.

Acknowledgements

We are grateful to Prof. J. C. Bhattacharyya, Director, Indian Institute of Astrophysics, for making the 40 cm telescope exclusively available for the comet Halley program. We thank the Indian Space Research Organisation, Bangalore, for providing partial financial support for this program. Most of the observations were taken with the help of Messers K. Jayakumar, M. Appakutty, M.J. Rozario and V. Moorthy. Their invaluable cooperation and sincere efforts at the telescope are gratefully acknowledged. We thank Mr P. Santhanam who helped us with the setting up of the pulse counting unit.

References

A'Hearn, M. F. (1986) in *IHW communication for the photometry and polarimetry net members*, 26 Jan.

Millis, R. L. & Schleicher, D. G. (1986) *Nature* **324**, 646.

Sivaraman, K. R., Babu, G. S. D., Bappu, M. K. V. & Parthasarathy, M. (1979) *M.N.R.A.S.* **189**, 897.

Sivaraman, K. R., Babu, G. S. D., Shylaja, B. S. & Rajamohan, R. (1987) *Astr. Ap.* **187**, 543.

Sterken, C., Manfroid, J. & Arpigny, C. (1987) *Astr. Ap.* **187**, 523.

Yeomans, D. K. (1981) in *Comet Halley handbook : An observer's guide* (IHW), NASA, p. 29.