SPECTROPHOTOMETRIC OBSERVATIONS OF COMET HARTLEY-GOOD (1985l)

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Abstract. Spectrophotometric observations of Comet Hartley-Good (1985l) during five nights in 1985 are presented in the wavelength range λλ3200–7000 Å. The emission bands due to CN, CH, C_2, and C_3 molecules are observed. The abundances (*N*) and production rates (*Q*) of the molecules are derived.

1. Introduction

Comet Hartley-Good (1985l) was discovered on 11 September 1985 on the 1.2 m Schmidt telescope of U.K. At the time of discovery the total integrated magnitude (m_1) was ~12 and the comet had developed a tail (Hartley and Good, 1985).

Goraya and Rautela (1985) and Goraya *et al.* (1986b) were the first observers to report diffeent emission features observed by them in comet Hartley-Good. They observed the emissions due to CN, CH, C_2, and C_3 molecules in it. In the present investigation, we present spectrophotometric study of comet Hartley-Good.

2. Observations

The observations were made on five nights during November and December, 1985 when the comet was sufficiently bright for the limit of our instrument (cf., Table I). Observations were made with Hilger and Watts spectrum-scanner (Goraya *et al.*, 1982, 1984) at the Cassegrain focus (*f*/13) of the 104 cm reflector of the Naini Tal Observatory. The spectrum scanner gives a dispersion of 70 Å mm^{-1} in the first order. We used a circular diaphragm of 3 mm which corresponds to 45 arc sec as projected on the sky to allow the whole light from the head of the comet to enter the instrument. An exit slit of 0.7 mm allowing 50 Å of the spectrum to fall on the photomultiplier was used. The photomultiplier EMI 9658 B was cooled to −20 °C, and standard d.c. techniques for detecting and recording the signal were followed (Goraya *et al.*, 1982, 1984). At least three spectral scans of the comet were obtained every night and were reduced to instrumental magnitudes individually at a step of 25 Å. The means of the instrumental magnitudes were adopted. We also obtained scans of the neighbouring sky before and after each scan of the comet to eliminate the contribution of the background sky.

Along with comet Hartley-Good, the standard star ξ^2 Cet was observed many times during each night to evaluate atmospheric extinction and to convert mean

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instrumental magnitudes of the comet to standard magnitudes, which thus corresponds to the recent calibration of ξ^2 Cet given by Taylor (1984). Finally, the standard monochromatic magnitudes (m_λ) of the comet were converted to fluxes (F_ν) by using the relation

$$\log F_\nu = -19.447 - 0.4 m_\lambda . \quad (1)$$

3. The Strength of Emission Bands

The final spectra of comet Hartley-Good are displayed in Figure 1. The positions of different emission features are indicated by vertical arrows pointing downwards. There are no large gradual variations in the strength of emission bands. The continuum level has also not changed appreciably during the observing period. Figure 1 clearly shows the emission due to CN(1–0) λ3580 Å, CN(0–0) λ 3880 Å, CN(0–1) λ 4200 Å, CH(0–0) + C_3 λ 4050 Å, CH(0–0) + C_2 (2–0) λ 4350 Å, C_2(1–0) λ 4700 Å, C_2(0–0) λ 5160 Å, C_2(0–1) λ 5640 Å and C_2(0–2) λ 6190 Å molecules. To derive the emission strength of different species, we measured the total area under the mission bands relative to the continuum level. The continuum in the spectrum was drawn by selecting wavelength regions free of emission lines. The area of the emission bands was covnerted into flux. The total apparent fluxes in different emission bands relative to C_2(0–0) band flux are given in Table II. The total luminosity in the C_2(0–0) band is given in the last column of Table II.

4. The Number of CN and C_2 Molecules

The total number of molecules (N) of CN and C_2 contained in a cylinder of diameter 45 arc sec in the line of sight and extending through the head of the comet have been derived from the total energy emitted in the CN and C_2 emission bands. A gross estimate of the total number of molecules of different species is made by using the well

TABLE I
Basic data of Comet Hartley-Good

Date (UT) 1985	Geocentric[a] distance (Δ) (AU)	Heliocentric[a] distance (r) (AU)	Predicted[a] m_1
Nov. 28.55	1.02	0.73	6.11
29.54	1.03	0.73	6.10
30.55	1.04	0.72	6.10
Dec. 1.53	1.05	0.72	6.10
5.53	1.07	0.71	6.11

[a] Marsden (1985).

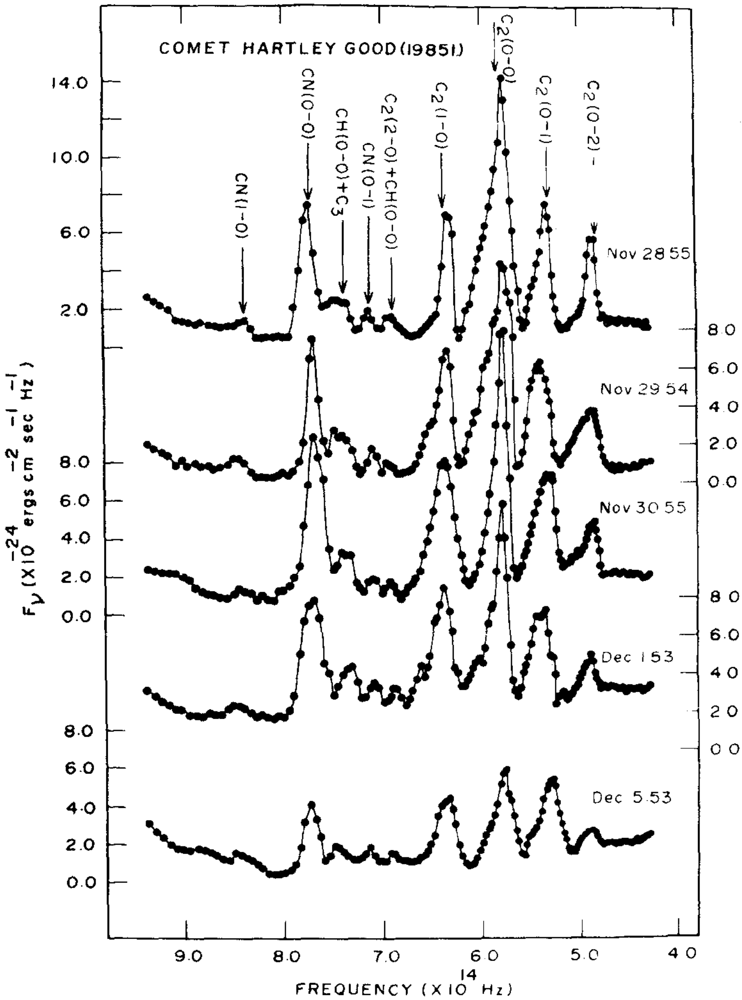

Fig. 1. Flux distribution of Comet Hartley-Good (1985l).

known relation (cf. O'Dell and Osterbrock, 1962) and recently adopted by many authors (Sivaraman *et al.*, 1979; Goraya *et al.*, 1982, 1984, 1986a): i.e.,

$$N = L\ [m_e/(\pi e^2 f p \rho(\nu, r))], \qquad (2)$$

where

L = luminosity of the respective band;
m_e = mass of an electron;
e = charge of an electron;
p = the vibrational transition probability;
f = the oscillator strength; and
$\rho(\nu, r)$ = the solar radiation density at frequency ν at a heliocentric distance r.

TABLE II

Observed fluxes of emission bands relative to $C_2(0-0)$

Date (UT) 1985	Apparent flux (F) in the C_2 (0–0) band (ergs cm^{-2} sec^{-1}) $\times 10^{-10}$	F/F [$C_2(0-0)$]									Luminosity (L) in the $C_2(0-0)$ band (ergs sec^{-1}) $\times 10^{17}$
		CN(1–0)	CN(0–0)	CH(0–0) + C_3	CN(0)–1)	$C_2(2-0)$ + CH(0–)	$C_2(1-0)$	$C_2(0-0)$	$C_2(0-1)$	$C_2(0-2)$	
Nov. 28.55	3.314	0.033	0.389	0.151	0.049	0.043	0.284	1.000	0.344	0.214	9.697
29.54	3.050	0.057	0.351	0.164	0.048	0.021	0.462	1.000	0.400	0.256	9.100
30.55	2.280	0.033	0.851	0.211	0.051	0.025	0.833	1.000	0.557	0.232	6.935
Dec. 1.53	2.190	0.041	0.721	0.228	0.091	0.053	0.726	1.000	0.530	0.174	6.790
5.53	1.130	0.124	0.558	0.195	0.069	0.034	0.743	1.000	0.885	0.354	3.638

TABLE III

Number of CN and C_2 Molecules

Band	f	p	$\rho(\nu, r)$ erg cm^{-3}	log N				
				Nov. 28.55	Nov. 29.54	Nov. 30.55	Dec. 1.53	Dec. 5.53
CN(0–0)	0.0342[a]	0.9200[b]	$4.214 \times 10^{-20} r^{-2}$ [b]	29.280	29.202	29.462	29.375	28.986
CN(0–1)	0.0024[a]	0.8108[b]	$6.910 \times 10^{-20} r^{-2}$ [b]	29.378	29.330	29.233	29.472	29.073
C_2(1–0)	0.0089[b]	0.2409[b]	$7.140 \times 10^{-20} r^{-2}$ [b]	30.080	30.259	30.391	30.316	30.049
C_2(0–0)	0.0239[a]	0.7335[b]	$6.445 \times 10^{-20} r^{-2}$ [b]	29.760	29.726	29.602	29.587	29.309
C_2(0–1)	0.0071[b]	0.2142[b]	$8.390 \times 10^{-20} r^{-2}$ [b]	30.243	30.275	30.295	30.258	30.204

[a] Lambert (1978).
[b] Goraya *et al.* (1986a).

The values of f, p and $\rho(\nu, r)$ used in our calculations are adopted from Lambert (1978) and Goraya *et al.* (1986a) and are listed in Table III along with the total number of molecules estimated by us.

5. The Production Rates of CN, C_3 and C_2 Molecules

Production rates have been derived from the total luminosity of the emission band. For making an estimate of the production rates of different molecules we assumed that the excitation processes responsible in the coma of the comet are induced by solar radiation. Collisions within the coma and excitation by solar wind particles are neglected. For resonance scattering and fluorescence, the luminosity L is related to the total number of atoms or molecules N and to the emission rate factor g by the relation (Barth, 1969)

$$L = gN. \tag{3}$$

In terms of life time, τ, we have

$$Q = (N/\tau) = (4\pi\,\Delta^2 F)/g\tau, \tag{4}$$

TABLE IV

Life times and emission rate factors of CN, C_2 and C_3 species

Species	Emission rate factor (g)[a]	Life time[b] (τ) sec	Product ($g\tau$)
CN	7.42×10^{-2}	14.8×10^4	1.098×10^4
C_2	4.38×10^{-2}	6.6×10^4	2.892×10^3
C_3	4.40×10^{-1}	4.0×10^4	1.760×10^4

[a] Newburn *et al.* (1978).
[b] A'Hearn and Cowan (1975).

TABLE V

Production rates of CN, C_3 and C_2 molecules

Date (UT) 1985	log r (AU)	log Q CN(1–0)	log Q CN(0–0)	log Q CN(0–1)	log Q C_3	log Q				
						C_2(2–0)	C_2(1–0)	C_2(0–0)	C_2(0–1)	C_2(0–2)
Nov. 28.55	– 0.137	23.770	24.839	23.944	24.223	23.467	24.281	24.829	24.365	24.160
29.54	– 0.140	23.978	24.767	23.902	24.231	23.123	24.466	24.801	24.403	24.209
30.55	– 0.143	23.627	25.033	23.810	24.222	23.089	24.604	24.683	24.429	24.050
Dec. 1.53	– 0.146	23.708	24.953	24.055	24.248	23.398	24.535	24.674	24.398	23.913
5.53	– 0.149	23.917	24.570	23.663	23.908	22.930	24.274	24.403	24.350	23.952

where

Δ = the comet-Earth distance;
F = the observed flux from the comet;
τ = the life-time of the scattering species, and
g = the probability that a solar photon will be resonantly scattered or produced by resonance fluorescence.

The value of g and τ used in our calculations are given in Table IV alongwith their sources. The production rates of CN, C_2 and C_3 molecules are listed in Table V. Actually, the lifetimes are never observed directly. They are derived by dividing the observed scale-length s by the assumed mean expansion velocity of the molecules. The life-time τ is principally determined by photodestruction process, the product $g\tau$ is independent of the heliocentric distance r (Feldman *et al.*, 1974) and can be conveniently evaluated at 1 AU. The g-factors and life-times may be uncertain by as much as $\pm$ 50%, producing the same order of uncertainty in the production rates.

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