SPECTROPHOTOMETRY OF COMET BRADFIELD (1980t) DURING POST-PERIHELION PERIOD

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Abstract. Spectrum scans of the head of Comet Bradfield (1980t) covering the wavelength range λλ365–640 nm were made on two nights when the heliocentric distance of the comet varied from 0.55 to 0.58 AU. The emission features of the CN band at λ388 nm and Swan band sequence of C_2 at λ474 nm, λ516 nm, and λ563 nm are identified and absolute fluxes in these bands as well as in the continuum are derived. The continuum energy distribution curves of the comet have been compared with those of the Sun and the star β Crv (G5 III). An estimate of the number of C_2 and CN molecules in the head of the comet has been made through the measured intensities of their respective bands lying in this region.

1. Introduction

Spectrophotometry of cometary heads still constitutes one of the most important source of information about the physical processes taking place in the cometary atmospheres. Most of the present estimates of molecular lifetimes are based on the observed distribution of molecules in the cometary head and the assumption of a particular kinematical behaviour of the matter in the cometary atmospheres. It is, however, essential that the observations should refer as far as possible, to the radiation emitted or reflected by different kinds of particles (dust, C_2, C_3, CN, CO^+, etc.). It is, therefore, evident that the interpretation of the structure of comets requires monochromatic observations.

When near perihelion, Comet Bradfield (1980t) showed the enhanced visual brightness (Ney, 1981) due to forward scattering, previously seen in the case of Comet 1976 VI. Observations on January 1, 2, and 3 indicate that Comet Bradfield (1980t) is very similar to Comet 1973 XII at the same heliocentric and geocentric distances (Ney, 1981), except that Comet 1973 XII (post-perihelion) was about one magnitude brighter. Predicted maximum brightness ($V = 2.5$) of Comet Bradfield (1980t) was on December 31, 1980. Its orbital elements have been given by Marsden (1981). We report here the results of a study based on spectrophotometry of Comet Bradfield (1980t).

2. Observations

Comet Bradfield was observed on the nights of January 14 and 15, 1981 in its post-perihelion period. The observations were obtained with the spectrum scanner, mounted at the Nasmyth focus ($f/13$) of the 56-cm reflector. The image scale in the Nasmyth focal plane is 29 arc sec mm^{-1}. A circular diaphragm of 3 mm diam., which corresponds to

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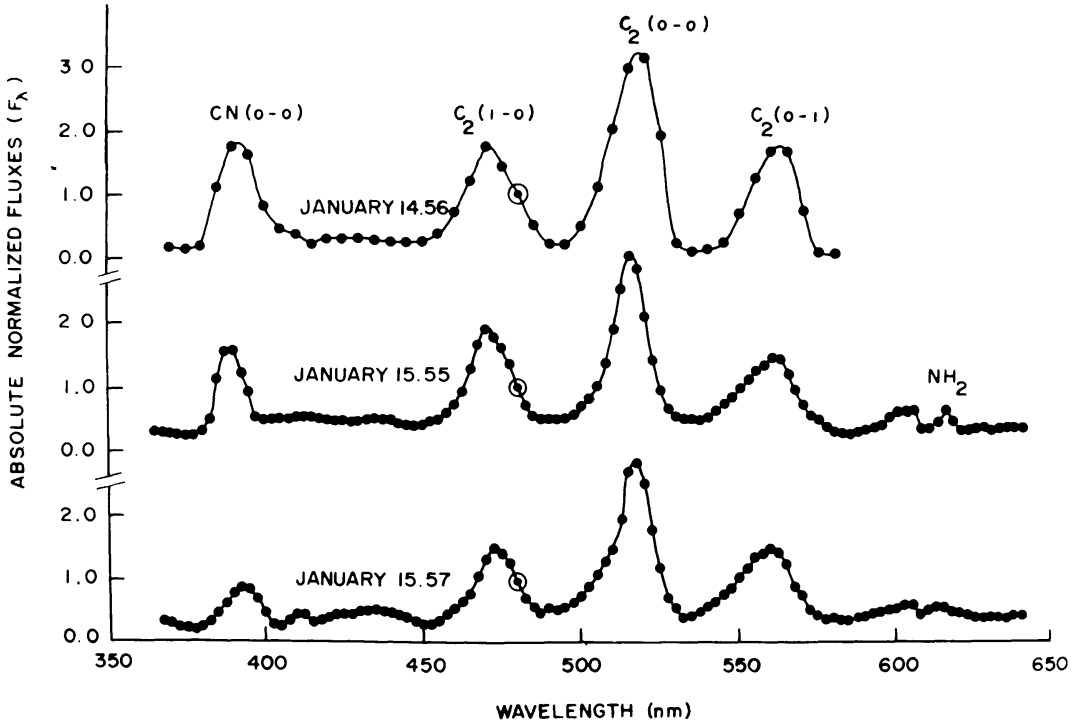

Fig. 1. Absolute flux distributions of the head of Comet Bradfield (1980t) on various dates normalized to λ479 nm. The normalization point is shown as a circle with a dot.

TABLE I

Basic data of Comet Bradfield (1980t)

Date January, 1981 (U.T.)	Geocentric distance Δ (AU)	Heliocentric distance r (AU)	m_V (predicted)	m_V (observed by us)	Area of the sky at distance Δ admitted through diaphragm (km²) × 10^8
14.56	1.14	0.55	+ $6^m.7$	+ $6^m.20 \pm 0.05$	39.37
15.57	1.18	0.58	+ 7.0	+ 6.25 ± 0.05	42.08

87 arc sec as projected on the sky, was used on both the nights. The exit slot was kept at 50 Å in the first order. The instrument and the observational procedures were the same as described earlier (Babu and Saxena, 1972; Babu, 1974).

In addition, α Leo and γ Gem were observed on each night as the standard stars. On 1981 January 14, the comet was observed at discrete wavelengths (step size of 5 nm), while on 1981 January 15, two continuous scans of the comet were taken. For the last two scans, the difference between two data points being 2.5 nm. The observations of the comet after being corrected for atmospheric extinction were reduced to absolute fluxes (F_ν). The fluxes were normalized to wavelength λ479 nm. The resulting flux distribution is shown in Figure 1.

TABLE II

Absolute fluxes of emission bands and continuum in the head of Comet Bradfield (1980t)

Date January, 1981 (U.T.)	$F(C_2, \Delta V = 0)$; 516 nm (erg cm^{-2} s^{-1}) × 10^{-9}	$F/F(C_2, \Delta V = 0)$					
		CN $\Delta V = 0$ (388 nm)	C_2			NH_2 (610 nm)	Continuum (479 nm)
			$\Delta V = -1$ (474 nm)	$\Delta V = 0$ (516 nm)	$\Delta V = +1$ (563 nm)		
14.56	21.5	0.763	0.623	1.000	0.386	–	0.319
15.57	10.0	0.517	0.632	1.000	0.542	0.094	0.345

TABLE III

Adopted absolute monochromatic magnitudes of Comet Bradfield (1980t), β Crv, Sun and solar light scattered according to λ^2 law normalized to λ479 nm.

Date January, 1981 (U.T.)	Wavelength (nm)						Name of the object
	370	447	479	535	580	615	
14.56	$+ 0^m.642 \pm 0.15$	$- 0^m.011 \pm 0.10$	$0^m.000$	$+ 0^m.040 \pm 0.05$	$+ 0^m.121 \pm 0.05$	–	Comet Bradfield (1980t)
15.57	$+ 0.840 \pm 0.15$	$+ 0.011 \pm 0.10$	0.000	$+ 0.080 \pm 0.05$	$+ 0.194 \pm 0.05$	$+ 0.280 \pm 0.05$	
	$+ 1.044 \pm 0.08$	$+ 0.025 \pm 0.05$	0.000	$- 0.211 \pm 0.01$	$+ 0.340 \pm 0.01$	$- 0.446 \pm 0.01$	β Crv
	+ 0.51	− 0.05	0.000	+ 0.15	+ 0.30	+ 0.43	Sun
	+ 1.11	+ 0.12	0.000	− 0.14	+ 0.24	− 0.33	Solar light scattered according to λ^2 law.

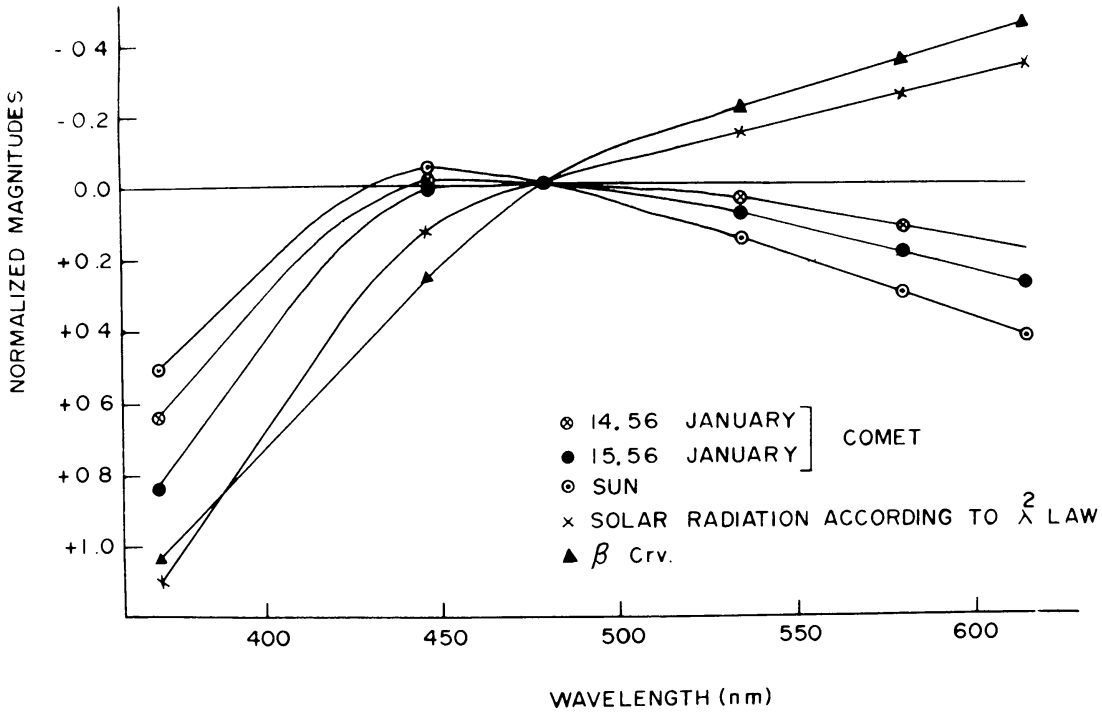

Fig. 2. Continuum energy distribution curves of the head of Comet Bradfield (1980t), compared with those of β Crv, Sun and solar light scattered according to λ^2 law. All curves are normalized to λ479 nm and the Balmer discontinuity is smoothed out.

3. Emission Band Sequence Flux Ratios

Figure 1 shows the absolute normalized flux distribution of the head of the comet. The emission features of CN and principal Swan band sequences of C_2 have readily been identified. In Figure 1 one can also see an emission doublet in the wavelength region λ610 nm. This emission may be due to NH_2. No trace of sodium emission is found in the comet during our observational period when the mean heliocentric distance of the comet was 0.56 AU (Table I). The absence of sodium emission at a distance of 0.56 AU during a solar maximum period is rather unusual for the comet. Although in Comet Ikeya-Seki 1965 VIII Bappu and Sivaraman (1969) also found that the sodium emission from that comet ceases at $r = 0.595$ AU. In order to measure the fluxes in the emission bands the continuum in the spectrum was located by selecting wavelength regions free of emission lines, based on Table III of the *Atlas of Representative Cometary Spectra* (Swings and Haser, 1956). The areas of the emission bands were planimetered to obtain the band fluxes, which are given in Table II, relative to the $C_2(\Delta V = 0)$ band sequence. It appears from Table II that the $C_2(\Delta V = 0)$ band was the strongest. The continuum flux at λ479 nm is also given relative to the $C_2(\Delta V = 0)$ flux at λ516 nm.

It is clear from Figure 1 that the fluxes of the CN (0–0) band and the principal Swan band sequence of C_2 decreased with increasing r during our observations.

Dobrovolskii (1961) has pointed out that the emissions due to C_2 are less dependent on r when $r < 1.5$ AU. Since our observations are obtained when r was 0.56 AU, the

fluxes due to this molecule are expected to be nearly constant as r increases. But in the present case, the absolute fluxes of C_2 emissions show a decrease with even a slight increase in r. This decrease in fluxes can be explained only in terms of decrease in the abundance of C_2 in the head of the comet due to some processes which depend on r.

4. Continuum Energy Distribution

The continuum energy distribution in the head of Comet Bradfield (1980t) on both the dates have been obtained independently by taking the line-free regions and using α Leo and γ Gem as the standard stars. The adopted monochromatic absolute magnitudes normalized to wavelength λ479 nm are given in Table III and are plotted in Figure 2. The absolute magnitudes correspond to Hayes and Latham (1975) calibration of α Lyrae. The energy distribution of the Sun (G2 V), the solar light scattered according to the λ^2 law (Mie scattering), given by Arpigny (1965) and the late type star β Crv (G5 III) (Babu, 1974), are plotted in the same figure for comparison.

Figure 2 shows that the observed energy distribution curves of the comet are found to fall between those of β Crv and the Sun. The comet seems to have reflection continuum spectra close to the Sun.

In the previous studies, however, some comets are known to have a pure reflection continuum, meaning thereby that the continuum spectra were unreddened with respect to that of the Sun (Arpigny, 1965; Gebel, 1970), whereas some others were found to produce reddened scattered continuum spectra matching to those of late type stars around G8 (Bappu and Sinvhal, 1960; Kharitonov and Rebristyi, 1974; Liller, 1960; Vanýsek, 1960 and Walker, 1958).

Arpigny (1965) has pointed out that the dust grains on comets possibly have a certain range of sizes. The sizes predominant in a particular comet may account for the reddened or unreddened scattered continuum observed in that comet.

5. Number of CN and C_2 Molecules

To calculate the number of molecules in the head of comet, we used the formulation (cf. O'Dell and Osterbrock, 1962): namely,

$$N = \frac{Lm_e}{\pi e^2 f p \rho(\nu, r)},$$

where

L = the luminosity of respective band;
m_e = the mass of an electron;
e = the 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 IV

Number of CN and C_2 molecules over a column of 40.72×10^8 km^2

Band	f	p	$\rho(v, r)$ (ergs cm^{-3})	log N
CN (0–0) 388 nm	0.0342	0.9200	$4.214 \times 10^{-20} r^{-2}$	31.080
C_2 (1–0) 474 nm	0.0089	0.2409	$7.140 \times 10^{-20} r^{-2}$	31.981
C_2 (0–0) 516 nm	0.0243	0.7335	$6.445 \times 10^{-20} r^{-2}$	31.316
C_2 (0–1) 563 nm	0.0071	0.2142	$8.390 \times 10^{-20} r^{-2}$	31.903

The number of CN and C_2 molecules in an 40.72×10^8 km^2 area of the comet head estimated by us at the mean distance $r = 0.56$ AU are listed in Table IV along with the used molecular constants.

In Table IV, the f values of C_2 have been calculated by using the recent values of electronic transition moments of C_2 Swan bands given by Cooper and Nicholls (1975). The f value of CN has been taken from Lambert (1978). The p value for CN has been taken from Kohoutek (1974). The p values for C_2 Swan bands are taken from Spindler (1965) and $\rho(v, r)$ is estimated from absolute central intensity listed by Vernazza *et al.* (1976).

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