STUDY OF PERIODIC COMET ENCKE DURING ITS APPARITION IN 1984

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Abstract. Scanner observations of the coma of periodic comet Encke (P/Encke) are presented for four nights in March 1984 during its post-perihelion period. The strong emission features of CN and C_2 molecules have been identified and the abundances of CN and C_2 are estimated. The production rates of these molecules have also been derived from their band luminosities. No trace of sodium emission has been found in this comet.

1. Introduction

Comet P/Encke is an interesting comet having the shortest period of any known comet, 3.3 years. It has been studied during about 52 apparitions. Comet P/Encke is also one of the best-known comets whose spectra show an extremely weak continuum. Because of the exceptional behaviour of this comet it is desirable to observe it during its every return so that the changes in its behaviour can be investigated. From this point of view we observed P/Encke during its recent apparition in 1984.

2. Observations

The comet was observed on four consecutive nights during March 1984, with the spectrum scanner at the Cassegrain focus ($f/13$) of the 104 cm reflector of the Observatory. The basic data are given in Table I. The telescope has a plate scale of 15 arcsec mm^{-1} at the Cassegrain focus. The scanner consists of a Hilger and Watts monochromator giving a dispersion of 70 Å mm^{-1} in the first order. A cooled (−20°C) EMI 9658B photomultiplier and standard d.c. techniques were employed for recording the signal. A circular diaphragm of 3 mm aperture corresponding to 45 arcsec as projected on the sky was used to admit the coma of the comet into the scanner. An exit slit of 50 Å band pass, in the first order, was opened for obtaining spectral scans. Scans of the neighbouring sky taken before and after each scan of the comet enabled us to eliminate the contribution of the background sky. During every night three scans of the comet were obtained and the mean of them was taken.

Along with the comet the standard star γ Gem was observed for calibration purposes. The observations were corrected for atmospheric extinction and were converted to absolute fluxes through the recent calibration by Taylor (1984). The data points were measured every 25 Å of the entire spectrum. The absolute flux

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TABLE I

Basic data of comet P/Encke

Date (UT) March, 1984	Δ (AU)	r (AU)	Mag m_1	Radius of the circular region in sky at distance Δ (km) $\times 10^4$	Area of the sky at distance Δ admitted through diaphragm (km^2) $\times 10^8$
19.5729	0.910	0.403	6.85	0.655	5.391
20.5771	0.885	0.390	6.75	0.634	5.051
21.5799	0.860	0.375	6.65	0.609	4.661
22.5771	0.840	0.370	6.60	0.601	4.539

distribution of the comet on the four nights is displayed in Figure 1. Since the observations were made near the horizon the error due to atmospheric extinction may be of the order of ± 0.20 magnitude.

3. Strength of Emission Bands

The prominent emission features which are clearly seen from the spectrum scans (λλ3500~6500 Å) shown in Figure 1 are: The CN($\Delta V = 0$) emission at λ3883 Å and C_2($\Delta V = +1, 0, -1$) emissions at λ4695 Å, λ5165 Å, and λ5538 Å, respectively. The weak emission feature of C_3 merged with CH($\Delta V = 0$) at λ4050 Å and the C_2($\Delta V = +2$) emission at λ4358 Å are also seen in the scans. The C_2($\Delta V = 0$) emission is the strongest feature in the whole spectrum followed by C_2($\Delta V = +1$). CN($\Delta V = 0$) and C_2($\Delta V = -1$) emissions, respectively. It is clear from Figure 1 that no trace of sodium D-line emission is seen in the spectrum of comet P/Encke. All the emission features are indicated by vertical arrows. In order to measure fluxes in the emission bands, the continuum in the spectrum was located by selecting wavelength regions free of emission lines. The area of the strong emission bands was planimetered and was converted into fluxes. The fluxes of the emission bands relative to C_2($\Delta V = 0$) are listed in Table II. The observed flux of the C_2($\Delta V = 0$) band is

TABLE II

Observed fluxes of emission bands relative to C_2($\Delta V = 0$)

Date (UT) March, 1984	Apparent flux F (C_2, $\Delta V = 0$) (ergs cm^{-2} s^{-1}) $\times 10^{-10}$	F/F (C_2, $\Delta V = 0$)				
		CN ($\Delta V = 0$)	C_2 ($\Delta V = +1$)	C_2 ($\Delta V = 0$)	C_2 ($\Delta V = -1$)	Luminosity (L) of C_2($\Delta V = 0$) (ergs s^{-1}) $\times 10^{17}$
19.5792	2.78	2.144	0.727	1.000	0.396	6.423
20.5771	4.42	1.548	0.805	1.000	0.281	9.658
21.5799	2.84	3.014	1.232	1.000	0.521	5.860
22.5771	2.49	3.133	0.980	1.000	0.494	4.902

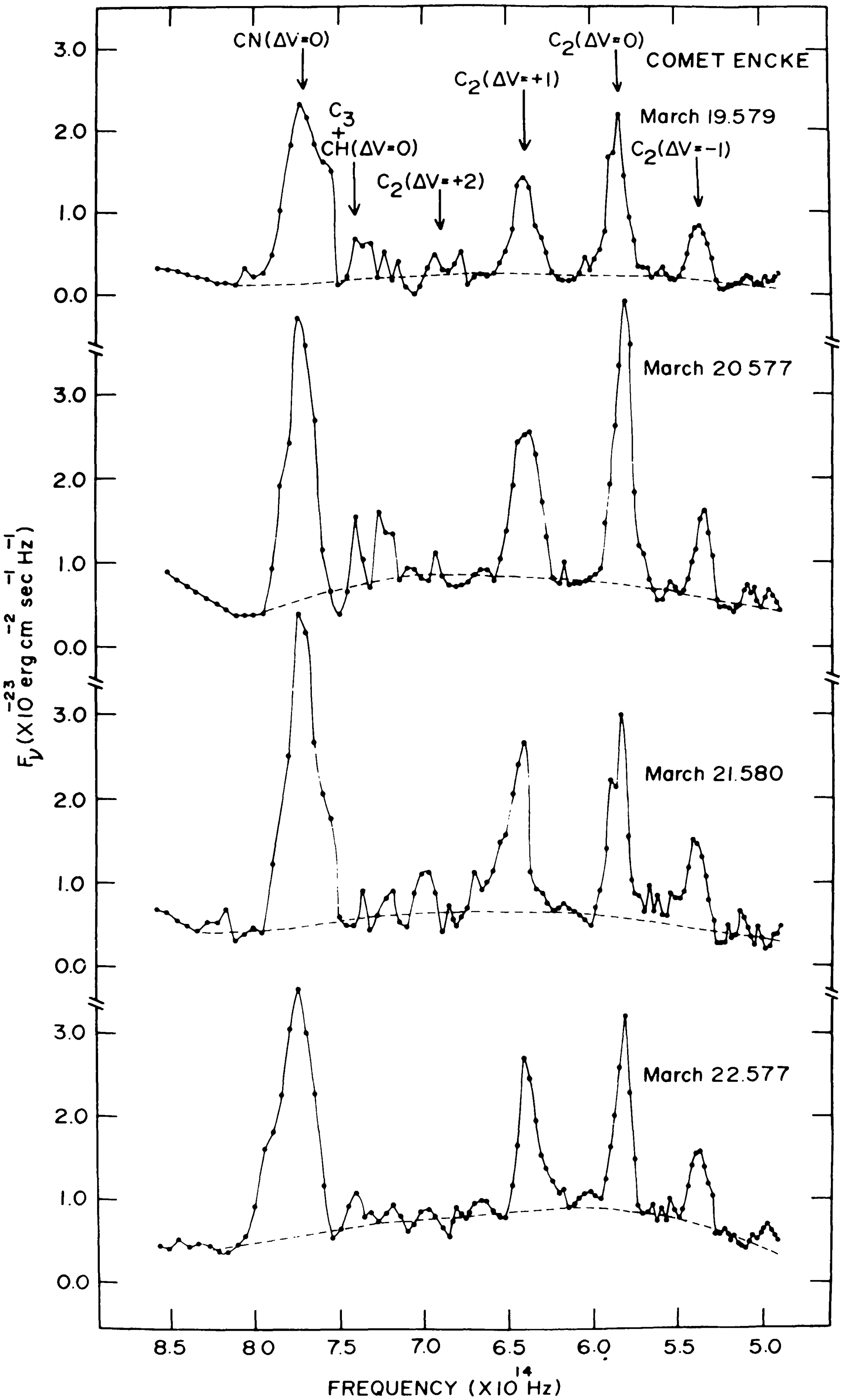

Fig. 1. Flux distribution of comet P/Encke. The dashed lines represent the continuum level.

TABLE III

Number of CN and C_2 molecules

Band	f	p	$\varrho(\nu, r)$ (erg cm^{-3})	log N
CN($\Delta V = 0$)	0.0342[a]	0.9200[b]	$4.214 \times 10^{-20}\, r^{-2}$ [b]	30.30
C_2($\Delta V = +1$)	0.0089[b]	0.2409[b]	$7.140 \times 10^{-20}\, r^{-2}$ [b]	29.37
C_2($\Delta V = 0$)	0.0239[a]	0.7335[b]	$6.445 \times 10^{-20}\, r^{-2}$ [b]	29.71
C_2($\Delta V = -1$)	0.0071[b]	0.2142[b]	$8.390 \times 10^{-20}\, r^{-2}$ [b]	29.27

References:
[a] Lambert (1978);
[b] Goraya *et al.* (1982).

given in the second column. The total luminosity of the C_2($\Delta V = 0$) band is given in the last column of Table II.

4. Abundances of CN and C_2 Molecules

The total number of molecules of CN and C_2 contained in a cylinder of diameter 45 arcsec in the line of sight and extending through the head of the comet can be computed from the monochromatic fluxes. The total number of molecules contributing to the emission band have been computed from the well-known relation (cf. O'Dell and Osterbrock, 1962) used in our earlier paper (Goraya *et al.*, 1984). The values of f, p, and $\varrho(\nu, r)$ used in our calculations are given in Table III along with their sources. The total number of molecules estimated by us are also listed in the same table.

5. Production Rates of CN and C_2 Molecules

Molecular production rates can be derived from the total luminosity of the respective band. For deriving the production rates we assume that the excitation processes responsible in the coma are those induced by solar radiation. Collisions within the

TABLE IV

Lifetimes and emission rate factors of CN and C_2 species

Species	Emission rate factor (g)[a] (photon s^{-1} mol^{-1})	Lifetime[b] τ (s)
CN	7.42×10^{-2}	14.8×10^4
C_2	4.38×10^{-2}	6.6×10^4

References:
[a] Newburn and Johnson (1978).
[b] A'Hearn and Cowan (1975).

TABLE V

Production rates of CN and C_2 molecules

Date (UT) March, 1984	log Q(CN, $\Delta V=0$)	log Q(C_2, $\Delta V=+1$)	log Q(C_2, $\Delta V=0$)	log Q(C_2, $\Delta V=-1$)
19.5792	25.40	25.51	25.65	25.25
20.5771	25.44	25.73	25.83	25.28
21.5799	25.51	25.70	25.61	25.33
22.5771	25.45	25.52	25.53	25.23

coma and excitation by solar wind particles are neglected. The production rates are derived through the relation used by us earlier (Goraya *et al.*, 1986). The values of g and τ used in our calculation are given in Table IV along with their sources. The production rates of CN and C_2 molecules are tabulated in Table V. The g and τ values may be uncertain by as much as $\pm$ 50% producing the same order of uncertainty in production rates.

6. Discussion

During the previous return of comet P/Encke in 1980, Spinrad (1982) obtained the image dissector scanner spectrum of the nuclear region. He identified many emission features but sodium emission was found to be absent. Our observations of this comet during its recent return in 1984 also show no trace of sodium emission at the mean heliocentric of 0.385 AU.

Bappu and Sivaraman (1969) have shown that, in general, comets display sodium D-line emission when their heliocentric distance is less than $\sim$ 0.8 AU. But the absence of sodium emission in comet P/Encke at a short heliocentric distance ($r = 0.385$ AU) is astonishing. In previous studies the Comet Beljawsky 1911IV (Konkoly, 1911) and Comet Borrelly 1890I (Backhouse, 1890) were also found to have this type of peculiarity. The absence of sodium at such a short distance shows that a few comets are peculiar in behaviour. This type of exceptional behaviour may be because of a large variation in the chemical composition in some comets. Another possibility is that comet P/Encke could be dust free. The gas/dust ratio changes from comet to comet.

A'Hearn *et al.* (1979) have pointed out that the dust concentration in comet P/Encke has always been regarded as low. Comet P/Encke is an old comet and shows an extremely weak continuum which also indicates the absence of dust concentration. It is often said that short-period comets have a much higher gas/dust ratio than long-period comets.

During its previous apparition in 1980, Newburn and Spinrad (1983) obtained column densities for CN, C_3, CH, C_2, and O I. They have also derived the production rates of different species over a wide range of heliocentric distance (1.89–0.78 AU).

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