The spectrum of periodic comet Encke

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Periodic comet Encke (P/Encke) was observed spectrophotometrically during its apparition in 1984 March, before perihelion. We observed emission features due to CN and C_2 molecules, but sodium emission was absent from the nucleus of the comet at $r = 0.38$ AU. Spinrad[1] has also found that sodium emission was not present in 1980 November. The lack of sodium emission is probably due to a different composition for this comet and to its old age.

Introduction

To understand the nuclear structure and chemical composition of comets properly, we must observe them in the visible region, where comets radiate most of their energy in the form of emission lines from various molecules. Identification of the emission features from different radicals can help us to identify the chemical composition of comets. Study of a comet's spectrum also gives information on the evaporation processes that result in the production of radicals, on the abundances of molecules and on their production rates, and this knowledge helps us understand the nature of the nucleus.

Ideally, the abundance and production rate of a given type of molecule can be estimated from monochromatic observations of the comet; that is, observations, in the light of an emission band caused by a particular molecule. It is very important, in particular, to detect the beginning and end of the emission from sodium, in terms of distance from the Sun, because the measurements can be used to infer some characteristics of the solar wind, as has been pointed out by Bappu and Sivaraman[2].

The periodic comet Encke has been studied during some 52 apparitions. Its orbit is well known and has been determined by Marsden[3]. This comet has a period of 3.3 years, which is the shortest of any comet known. P/Encke is one of the best known of the comets that have spectra showing only an extremely weak continuum. This shows that dust is practically absent from the comet, and makes a negligible contribution to the light curve, as shown by Delsemme[4]. Some of the comet's physical parameters, such as size, rotation rate, pole position, and so on, have been estimated by Whipple and Sekanina[5].

After comet P/Crommelin, comet P/Encke was the second interesting object to be subject to close scrutiny prior to the current apparition of comet Halley. Comet P/Encke was brighter than P/Crommelin. We observed comet P/Encke spectrophotometrically in the visible region, to identify emission features caused by different molecules. The aim of the observations was to look for any changes in the comet's chemical composition when compared to observations of its past apparitions. The observations also form a practical exercise as part of the International Halley Watch (IHW) prior to the observations of comet Halley.

During this apparition, comet P/Encke was at perihelion on 1984 March 27. It was then at its maximum brightness ($m_1 = 6^m.6$); its heliocentric distance (r) was 0.350 AU and its geocentric distance (Δ) 0.785 AU.

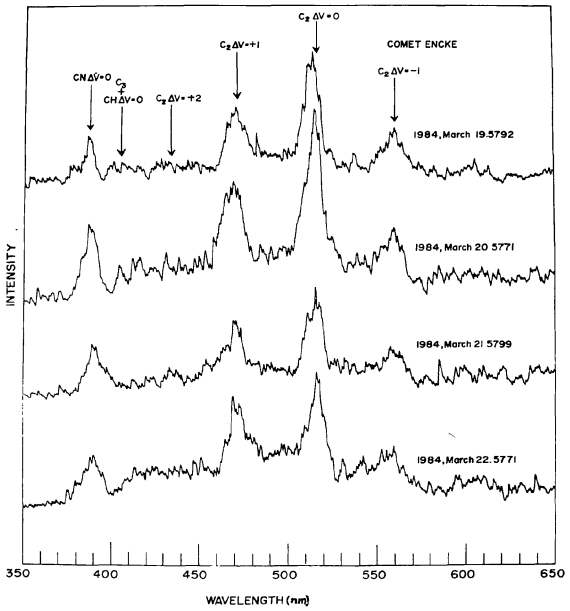

Figure 1. Spectrophotometric tracings of comet P/Encke showing different emission features. The mean positions of the wavelength of emission bands are indicated by the arrows.

Observations

Comet P/Encke was observed on four nights (1984 March 19, 20, 21 and 22) when it was near perihelion. A Hilger and Watts monochromator, giving a dispersion of 7 nm/mm and resolution 0.3 nm in the first order, was used at the Cassegrain focus (f/13) of the Observatory's 104 cm reflector to obtain scans of the comet's spectrum. An exit slit allowed 5 nm of the spectrum to pass on to a photomultiplier, and scans were obtained in the wavelength range 350-650 nm.

The standard star Gamma Geminorum was also observed, to check the wavelength calibration of the scanner, and to standardise the observations of the comet at a wavelength of 550 nm. We used these results

to estimate the visual monochromatic magnitude (m_{550}) of the comet, converting the observations at this wavelength (after correction for atmospheric extinction) into standard magnitudes. The values thus obtained correspond to the absolute calibration of Vega (Alpha Lyrae) as given by Tug, White and Lockwood[6]. The values m_{550} for P/Encke on the four nights of observation are listed in table 1 along with other basic parameters, including the coordinates of the comet as measured by us. During this return, other estimates of the comet's visual magnitude have been made in 1984 January, February and March, by Bortle and Morris[7]; Morris, Keen and Green[8]; Green, Bortle and Morris[9]; and Bortle, Keen, Morris and Machholz.[10]

Table 1
Data on comet P/Encke during nights of observations

Date 1984 March (UT)	*RA* (1984)	*Dec* (1984)	Δ (*AU*)	*r* (*AU*)	*Mag.* m_1	*Mag.* m_{550}
19.5792	$01^h 19^m.58 \pm 0^m.03$	+12° 9′.6 ± 0′.1	0.910	0.403	6.85	8.92
20.5771	01 20 .47 ± 0 .03	+11 52 .6 ± 0 .1	0.885	0.390	6.75	8.51
21.5799	01 21 .17 ± 0 .03	+11 31 .1 ± 0 .1	0.860	0.375	6.65	8.20
22.5771	01 21 .10 ± 0 .03	+11 04 .3 ± 0 .1	0.840	0.370	6.60	8.07

The positions and values of m_{550} are from our observations. The geocentric distance (Δ), the heliocentric distance (*r*) and the total visual magnitude (m_1) are values interpolated from the ephemeris given in the *International Astronomical Union Circular* No. 3915 (1984).

Discussion

During the previous return of comet P/Encke in 1980, Spinrad obtained spectra of the nucleus region with an image dissector scanner. Newburn and Spinrad[11] obtained column densities for CN, C_3, CH, C_2 and OI; new Haser parent scale lengths for CN, C_2 and C_3; and data on the composition of the coma as a function of heliocentric distance. It is desirable to observe this comet on every return, so that changes in its behaviour can be investigated. With this aim in mind we looked for these spectral features during the comet's next apparition, in 1984. In figure 1, we have displayed the tracings of original spectral scans of comet P/Encke as obtained on the four nights listed in table 1.

The prominent emission features in figure 1 are: the CN (ΔV=0) emission at 388.3 nm, and C_2 (ΔV=+1, 0, -1) emissions at 469.5 nm, 516.5 nm and 553.8 nm respectively. The weak emission feature of C_3 merged with CH (Δ=0) at 405.0 nm and C_2 (ΔV=+2) at 435.8 nm are also seen in the scan. The C_2 (ΔV=0) emission is the strongest feature in the whole spectrum, followed by the C_2 (ΔV=+1), CN (ΔV=0) and C_2 (ΔV=-1) emissions repsectively. It is clear from figure 1 that no trace of the sodium D-line (589 nm) is seen in the spectrum of comet Encke. Spinrad identified many emission features in the comet's spectrum during its apparition in 1980; but he also found that sodium D-line emission was absent.

Bappu and Sivaraman[2] have shown that a comet generally displays sodium D-line emission when its heliocentric distance is less than 0.8 AU. Hence it is surprising to find that sodium D-line emission is absent from the spectrum of P/Encke at a heliocentric distance as small as 0.38 AU. Previous studies have shown that comet Beljawsky[12] 1911IV and comet Borrelly[13] 1890I also have this type of peculiarity: in comet Beljawsky 1911IV, sodium was found to be absent at *r*=0.32 AU; and in comet Borrelly 1890I, no trace of sodium was detected at *r*=0.35 AU. Hence there may be a few comets that have a common characteristic of lacking sodium emission at small heliocentric distances.

A study by Donn[14] shows that although there is a wide range in the gas/dust ratio of comets, there is probably no systematic difference in this ratio between old and new comets. This idea was also supported by A'Hearn *et al.*[15] We would counter this argument by suggesting that the exceptional spectrum of P/Encke indicates a large variation in the chemical composition of comets. Another possibility is that comet P/Encke could be very free of dust, and that the gas/dust ratio changes from comet to comet and with age. The dust concentration in the vicinity of comet P/Encke has always been regarded as low[15], although Sekanina and Schuster[16] have recognised the emission of submillimetre- to centimetre-sized dust particles from the comet. It is often said that short-period comets have a much higher gas/dust ratio than comets which on dynamical grounds (very long period or parabolic orbit) are considered to be new.

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