Bull. Astr. Soc. India (1998) **26**, 439-443

CN and C_2 in Hyakutake (C/1996 B2)

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Abstract. CN (Δv=0) and C_2 (Δv = + 1,0, -1) emission fluxes at 388.3, 469.5, 516.5 and 553.8 nm respectively and continuum flux at 484.0 nm have been analysed to get the production rates of molecular species CN and C_2 and dust in the coma of the comet Hyakutake (C/1996 B2). Using water vaporization theory the size of the nucleus has also been estimated.

Key words: comet-molecular emission-production rates-mass loading function-radius

1. Introduction

The comet Hyakutake (C/1996 B2) was discovered in early 1996. Schleicher (IAU cir.6311) gave the production rates based on narrow band photometry of CN, C_2 and OH. We observed the comet spectrophotometrically and identified the molecular emission features due to CN and C_2. Using Haser model we have analysed CN and C_2 emission features. We have determined dust mass production rates following Newburn and Spinard (1985) using continuum flux at 484.0 nm. We have also estimated nuclear radius using water vaporization theory (Delsemme 1982).

2. Observations

The comet was observed on 3 nights 26 March, 2 and 3 April 1996 in the wavelength region 360.0-610.0 nm, using spectrophotometer having the reticon array detector, mounted at the Cassegrain focus (f/13) of Uttar Pradesh State Observatory, Naini Tal. The spectral dispersion of the spectrograph attached with the detector is 100 A/mm. The reticon array consists of 1024 elements of size 2 mm × 25 microns. A circular diaphragm of 3 mm corresponding to 45 arc sec as projected on the head of the comet was adopted for obtaining the spectral scans.

Alongwith the comet the standard star α Leo was observed to check the wavelength calibration of the scanner and to standardize the observations of the comet. The absolute values of magnitudes thus obtained correspond to calibration of standard stars given by Taylor (1984). The standard deviation of an individual measurement does not exceed $0^m.02$. The area of emission bands were measured and converted into total flux. Basic data of the comet is given in Table 1 whereas the production rates and other related results are tabulated in Table 2.

Table 1. Observational data of the comet Hyakutake (C/1996 B2).

date	r_h (AU)	r_d (AU)	s (meter)	flux at 484.0 nm (erg/sec/cm^2/Hz)	phase angle(θ) (Degree)	scattering function $\phi(\theta)$
26/3	1.028	0.104	1.69(6)	5.63(–23)	68	0.40
02/4	0.876	0.273	4.44(6)	4.80(–23)	109	0.68
03/4	0.854	0.303	4.95(6)	5.18(–23)	110	0.68

Table 2. Production rates in the coma of the comet Hyakutake (C/1996 B2).

	log prod. rate					
date	CN	C_2	gas (gm/sec)	dust (gm/sec)	dust loading function	radius (km.)
26/3	27.02	26.71	7.39	7.29	0.80	1.8
02/4	27.15	26.84	7.52	7.16	0.44	1.8
03/4	27.06	27.04	7.43	7.18	0.56	1.5

3. Column densities and production rates of CN and C_2

The number of molecules of CN and C_2 contained in a cylinder of radius defined by the diaphragm and extending through the head of the comet was evaluated using the standard formula by Millis et al. (1982):

$$\log M(\rho) = \log F(\rho) + 27.449 + 2\log(r_h r_d) - \log g$$

where F is the observed flux in cgs units, $r_h$and r_d are the heliocentric and geocentric distances of the comet respectively in AU, and g is the fluorescence efficiency (in cgs units) per molecule at 1 AU. Fluorescence efficiency for C_2 molecules were adopted form Sivaraman et al. (1987). Because of the Swings effect, g(CN) varies significantly with the comets heliocentric radial velocity. To calculate radial velocity the orbital elements of the comet were taken from the BAA cir. 753 and value of g was then obtained from the figure of Tatum and Gillespie (1979). The column densities thus obtained were converted into production rates (Q), assuming a Haser model through the relation given by A'Hearn and Cowan (1975). Following Delsemme (1982) we assumed $v = 0.58/\sqrt{r_h}$. The parent and daughter molecule scale lengths were taken from Cochran (1985). Bessel functions were calculated from the table of Abramowicz and Stegun (1964) and the extrapolation formula therein. The resulting production rates are listed in Table 2.

4. Gas production rate and size of the nucleus

Taking Q(CN) / Q (H_2O) = 1.6 x 10^{-3} and considering the cometary gas as a mixture of H_2O and 10 percent other gases, the gas mass production rate is given as (Newburn and Spinard, 1985):

$$Q(g) = 2.33 \times 10^{-20} Q(CN) \quad (g/s)$$

The production rate ratio of CN to H_2O assumed by us is a value found in several other comets.

Once we know the gas production rate, we then follow Landaberry et al (1991) to get the size of the nucleus. We found the radius of the nucleus around 1.8 km.

5. Dust production rate

Following Newburn and Spinrad (1985), the dust mass production rate is given by :

$$M_d = \int_{a_o}^{am} (4\pi / 3)\, a^3 \rho(a)\, n(a)\, da \quad (g/s)$$

where a is the radius of the grain which lies between a_o = minimum radius of grain and a_m = maximum radius of the grain, ρ(a) is the grain density and n(a) is the particle distribution function.

The grain size distribution function is given as

$$n(a) = K (1 - a_o / a)^M (a_o/a)^N \ cm^{-1} s^{-1}$$

The parameters M and N locate the maximum in the distribution function at large particle size. Since we do not have observations of dust coma in IR, therefore, for N we have taken a value of 4.2. This value of N is in agreement with other cometary dust data reduction. For M we have taken a value of 15. The sensitivity of dust mass production rate to the value of M is quite small, amounting to only 20 percent in mass for a change in M from 18 to 10 (Newburn and Spinard, 1985). K is given by:

$$K = (2A_p(\lambda)/(\pi^2 p_g(\lambda)s)) \left[\int_{a_o}^{am} (a^2 / V(a))(1-a_o / a)^M (a_o/a)^N da\right]^{-1} \ cm^{-1} s^{-1}$$

where

pg (λ) = geometric albedo of grains.

s = comets as viewed through 3 mm diaphragm at telescope focus.

V(a) = grains velocity.

Ap (λ) is given as

$$Ap(\lambda) = r_h \pi r_d f_{cont.} (4840) / (\phi(\theta) f_{\odot} (4840)) \text{ cm}^2$$

Here,

r_h and r_d are the heliocentric and geocentric distances of the comet,

$\phi(\theta)$ is the scattering function at phase angle θ (Divine, 1981) and

f_{cont} (4840) and $f_{\odot}$ (4840) are the cometary and solar fluxes respectively at 4840 A.

For V (a) we have utilized the formulation and approximation as considered by Newburn and Spinard (1985).

The resulting dust production rates are tabulated in Table 2.

6. Discussions

The production rates of molecular species have been tabulated in Table 2. We note that because of the short coverage of the heliocentric distance no systematic variation in production rates of molecular species, dust and gas are noticeable. It is also obvious that no large outburst occurred during this short period. Unlike most of other comets, comet Hyakutake (C/1996 B2) gives a higher value of CN production rates as compared to C_2, indicating that CN is over abundant. A'Hearn et al. (1979) found a similar over abundance of CN in case of comet P/Grigg-Skjellerups. We have assumed that 20 percent of the total nuclear surface area (R = 1.8 km) of the comet was active during the period of observations. In such a model where there is an uncertainty of about a factor of 2 to 3 in the dust production model (Newburn and Spinard 1985) the dust mass varies around 1.5 x 10^7 g/s.The dust production rate is considerably high as compared with other comets. However the dust loading function is in agreement with the corresponding range (0.833 to 0.1) found in several other comets (Ney 1982) showing that the comet behaved like a normal one in dust loading function. A value of 1.8 km. as the radius of the nucleus of the comet is consistent with other nuclear radius estimates (Landaberry et al. 1991). However, since CN is over abundant, the estimated value of radius may be higher.

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