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HELIOCENTRIC DISTANCE DEPENDENCIES OF THE C₂ LIFETIME AND C₂ PARENT PRODUCTION RATE IN COMET P/BRORSSEN-METCALF (1989o)

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1 Summary

Comet P/Brosen-Metcalf (1989o) has been extensively observed in the visible and in the ultraviolet during its latest apparition of summer 1989. In this paper we report a preliminary determination of the C₂ production rates and lifetimes and we compare those rates to the H₂O production rates obtained from UV data.

2 Observations.

Visible spectra of P/Brosen-Metcalf (1989o) were recorded from 26 July until 25 August 1989 while the heliocentric and the geocentric distances changed from 1.1 to 0.6 AU and 0.6 to 0.7 AU, respectively. This set of 14 spectrophotometric optical observations (7 of them analyzed; see table I) overlaps a set of 6 ultraviolet observations obtained with the International Ultraviolet Explorer (IUE) collected around 1 August 1989.

The long slit visible spectra were collected with the 1.5 m f/8 Cassegrain telescope of the Loiano Observatory (I) equipped with a Boller & Chivens spectrograph and a CCD as detector. As shown on table I, the spectra cover usually the range 4500-5800 Å or 4000-7000 Å, with an instrumental FWHM of 5 or 10 Å, depending on the diffraction grating used. The projected slit length was 4.8 arc min on the sky (\Rightarrow 120-150 10^3 km at the comet distance) with a pixel size of 1.6 arc sec (\Rightarrow 700-800 km). The effective spatial resolution was dominated by the seeing conditions and by the guiding errors of the telescope. In a typical night of observation two cometary spectra were recorded, with different slit position angles: one in the sun-comet direction and the other perpendicular to that line. Bias, flat field, calibration lamp, sky and standard star spectra were recorded each night in order to calibrate the cometary spectra. These data allow the study of the spatial profiles of the C₂, $\Delta\nu = +1, 0, -1$ Swan band emissions and the determination of C₂ production rates as a function of heliocentric distance.

Low resolution IUE spectra recorded between 27 July and 5 August 1989 are used to determine the water production rate.

Table I - Observing log of the analyzed visible spectra

Date	R_h AU	Δ AU	β deg.	Spectral Range (\AA)	Dispersion $\text{\AA}/\text{pixel}$
29 Jul.	1.09	0.67	65.2	3800-6800	5.9
31 Jul.	1.06	0.65	66.5	3800-6800	5.9
7 Aug.	0.94	0.62	77.9	3800-6800	5.9
10 Aug.	0.89	0.63	82.0	5800-7100	2.6
13 Aug.	0.84	0.64	85.6	4500-5800	2.6
18 Aug.	0.75	0.68	89.9	4500-5800	2.6
21 Aug.	0.70	0.71	91.1	4500-5800	2.6

3 Data reduction and analysis.

Since the comet and sky spectra were not recorded at the same time and in similar conditions, sky spectra were only used to determine the position of the strongest undesirable lines in the comet spectra. Those latter were used to perform the sky subtraction in the manner described by Festou et al. (1990), i. e. by using information contained near the edge of each frame, away from the emission lines of the comet.

The dust component in this comet was generally weak, so that no particular care was necessary to subtract it from the cometary spectra. When it was stronger, at the end of August, a synthetic dust spectrum has been created and subtracted.

The radial intensity profiles for each observed species were constructed using the largest possible bandpass. The actual extension of these profiles were almost the same, of the order of 10^5 km during the entire observing period, which allowed us to perform an investigation of the creation and destruction processes of the observed species.

After discarding the non photometric data (standard stars were observed before and after the comet observations), it was found that the absolute calibration errors were always below the $\pm 15\%$ level.

Absolute calibration, reduction procedure, seeing, tracking quality and S/N affect the relative uncertainty of the individual data points in a complex manner. The sky subtraction procedure can *a priori* introduce a significant systematic error: our technique, that use the comet frames themselves in regions where no comet lines are present, allows to reduce this source of uncertainty to a very low level. Far from the center of the coma, where the signal is weak, the scattering of the data points gives an idea of the internal consistency of the data. Near the center of the coma, where relative photometric inaccuracies are small, the shape of the profile is mostly determined by the tracking quality. The quality of this parameter can be determined by examining the shape of the continuum near the center of

the coma: in the worse case, the combined effects of tracking and seeing are equivalent to a drift of 5 arc seconds along the sun-comet line. That effect was taken into account in the data analysis by appropriately enlarging the simulated instrumental slit.

4 Interpretation.

The entire data set was interpreted with the vectorial model (Festou, 1981a,b). Parent molecule velocities were assumed to vary with the heliocentric distance according to the law $0.85R_h^{-0.5}$ km/s (Cochran and Barker, 1986). Water and OH lifetimes were computed for the solar flux conditions of mid 1989.

The water production rate has been computed from the mean intensity, averaged over the 10 by 20 arc sec IUE slit, of the OH(0-0) and OH(1-0) bands.

The nucleus activity was assumed to be steady, an assumption found *a posteriori* to be valid over periods of time of the order of one day. In our model-data fitting attempts, once the production channel for the coma species is selected (one or two photodissociation steps), only the parent lifetime, the daughter species velocity and lifetime are adjustable parameters. In what follows, we will restrict ourselves to the results concerning the C₂ radicals.

Guided by preceding analysis of similar nature, we first tested a single photodissociation as the production channel of the radicals. When the comet is far from the sun, only the parent lifetime significantly affects the computed profile and this parameter can be evaluated (the lifetime of the radicals is then taken as 10^5 s at 1 AU and the velocity is set to 1 km/s). A value close to $20 \cdot 10^3$ s was found using our complete set of profiles. This value is not compatible with the C₂ radicals being produced by the dissociation of C₂H₂ parents. When the comet is closer to the sun, since our profiles still extend out to about 10^5 km, the radical lifetime and velocity become measurable quantities. The two parameters have non independent values: as an example, if the C₂ velocities are assumed to be 1 and 1.4 km/s, C₂ lifetimes of 0.9 to $1.5 \cdot 10^5$ and 1.2 to $2 \cdot 10^5$ seconds are found, respectively.

It is important to note here that none of the inner coma theoretical profiles fits the observations: the observed profiles are too flat (see Fig.1), a strong indication that either the C₂ radicals are produced via a two step process or that two parents at least contributed to their production. An extended source of the nature of that found in comet P/Halley (1986 III) does not seem likely (or it would not contribute much) since the comet was not very dusty.

We evaluated the C₂ production rates assuming the canonical value of 1 km/s for the radial velocity (other parameters are thus derived quantities). Fig. 2 shows our results: i) short term variations of no more than 15-30% are possibly present (each point in this figure represents generally an average of about 6 individual measurements), ii) the long term variation of the water and the C₂ production rates vary according to $R_h^{-3.5 \pm 0.3}$ law, iii) the water to C₂ production rate ratio is of the order of 500, which indicates that comet

1989o was "normal", iv) the variation of the C_2 lifetime is compatible with a R_h^2 variation and photodissociation of parent molecules appears as the most likely production process.

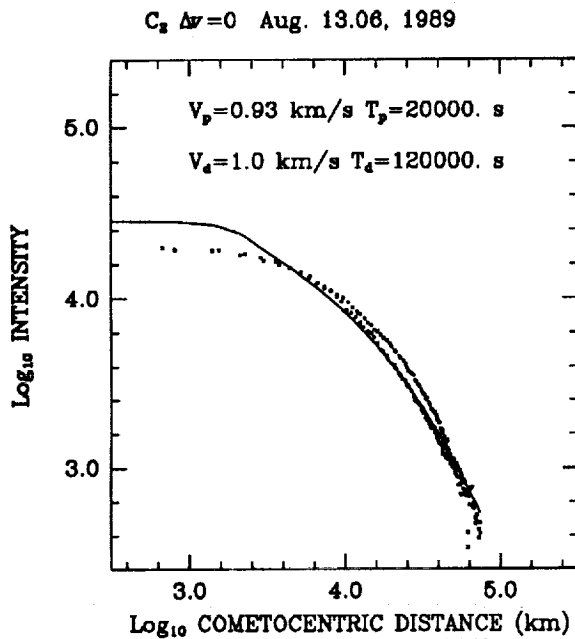


Fig. 1 - Intensity profile of C_2 $\Delta v=0$ band.

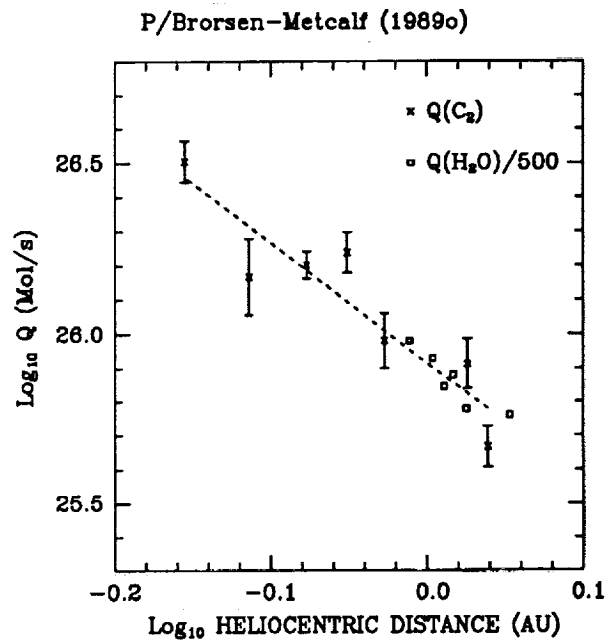


Fig. 2 - Gas production rate vs R_h

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