THE GAS PRODUCTION RATE OF COMET BENNETT
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Comet Bennett (1970 II) was observed with the ultraviolet photometers on OAO-2 from April 13.39 to May 13.88, 1970, while its heliocentric distance increased from $R = 0.77$ to 1.26 a.u. An analysis of the photometer data for the emission features of OH $\lambda$3090 and H $\lambda$1216 indicates the production rates of OH and H were $2.0 \times 10^{29}$ molecule sec$^{-1}$ and $5.4 \times 10^{29}$ atom sec$^{-1}$, respectively, at $R = 1$ a.u. During this period the production rates of H and OH varied as $R^{-2.3}$. This is consistent with the assumption that water vaporization controls the production rate of gas in comets at small heliocentric distances.

The OAO spacecraft was stabilized in three-axes and pointed to the nucleus of the comet with a nominal accuracy of $+1'$. The comet was observed during the 10 minute period between comet-rise and sun-rise, as seen from the spacecraft. The OAO-2 photometers consisted of an off-axis parabolic mirror, aperture, fabry lens*, and photomultiplier tube. The aperture provided a 10 arc min diameter field-of-view. Each filter isolated an $\sim$300 A bandpass in the 1050 - 4600 A region. Figures 1 and 2 show the measurements.

*no Fabry lens was used in the Lyman-alpha photometer.
Figure 1 The OH $\lambda 3090$ photometer observations of comet Bennett from April 13 to May 13, 1970. The lower curve shows the logarithm of the observed brightness (right ordinate) from two different photometers, ST 1 F4 ($\triangle$) and ST 2 F4 ($\bullet$), versus the logarithm of the heliocentric distance, R. The upper curve ($\square$) shows the observations, corrected for field-of-view effects, in terms of the production rate of OH (left ordinate) versus log R.
Figure 2  The hydrogen La photometer observations of comet Bennett from April 13 to May 13, 1970. The logarithm of the brightness observed with ST 4 F4 in relative units is shown versus the logarithm of the heliocentric distance, R, by filled circles (●). The production rate of hydrogen derived from the observations, corrected for field-of-view effects, versus log R is shown by open squares (○).
obtained with the bandpasses centered on 2980 A and 1260 A, respectively. The lower curve shows the logarithm of the observed brightness plotted versus the logarithm of heliocentric distance. An examination of the spectrometer data for Comet Bennett (Lillie, 1975) indicates that 85% of the signal in the long wavelength bandpass is due to emission from the (0-0) band of OH \((A^2\Sigma^+ - X^2\Pi_1)\), and \approx 95% of the signal in the short wavelength bandpass is due to the Lyman-alpha line of atomic hydrogen.

Our observational material only provides the mean column densities of OH and H in a 10' field-of-view centered on the nucleus of the comet. In order to convert these observed intensities of H and OH into production rates, we adopted Haser's (1957) parent-daughter model for the radial distribution of atoms and molecules in the head of a comet.

If we assume the coma is optically thin, its average brightness in a field-of-view of radius \(s\) will be:

\[
B(s) = \frac{gQ_p t_d}{\pi s^2} f
\]

where \(g\) is the photo-excitation factor in photon molecule\(^{-1}\) sec\(^{-1}\), \(Q_p\) is the production rate of parent molecules in molecule sec\(^{-1}\), \(t_d\) is the lifetime of the daughter molecules and \(f\) is a function which corrects for the limited field-of-view of the instrument. This correction depends on the scalelength of parent and daughter molecules.
We can understand the data qualitatively if we assume the parent molecule production rate, \( Q_p \), is proportional to \( R^{-2} \). The excitation rate, \( g \), is proportional to the incident solar flux which goes as \( R^{-2} \); the lifetime of a molecule, \( t \), is inversely proportional to the solar wind and solar radiation flux and goes as \( R^2 \); the size of the field-of-view, \( s \), is proportional to geocentric distance, \( A \), which in this case increases monotonically with \( R \), and, therefore, the field-of-view factor \( f = 0 \) as \( A \to \infty \). Detailed calculations for the field-of-view factor (Keller and Lillie, 1974) show that \( f \) was roughly proportional to \( R^{-1} \) during the period of observations. Thus, we may write

\[
B(s) \propto \frac{R^{-2} \times R^{-2} \times R^2 \times R^{-1}}{R^2} \propto R^{-5}
\]

An examination of Figures 1 and 2 shows the observed brightness goes as \( R^{-5.1} \), and \( R^{-5.4} \) for \( \text{OH} \) and \( \text{H} \), respectively.

The upper curves in Figures 1 and 2 show the production rates of \( \text{OH} \) and \( \text{H} \) derived from the observations after a rigorous correction for field-of-view effects. In the log \( Q_{\text{OH}} \) versus log \( R \) diagram the points lie close to a straight line with a slope of \(-2.3 \pm 0.2\), while the slope of the \( Q_{\text{H}} \) variation was \(-2.2 \pm 0.35\) from April 13 to 25, 1970.

Using the OAO calibration data and assuming \( g_{\text{OH}} = 1.2 \times 10^{-3} \) photon sec\(^{-1}\) and \( g_{\text{H}} = 2.5 \times 10^{-3} \) photon sec\(^{-1}\)
for the mean solar flux, we find $Q_{\text{OH}} = (2.0 \pm 0.8) \times 10^{29}$ molecules sec$^{-1}$ and $Q_{\text{H}} = (5.4 \pm 2.7) \times 10^{29}$ atoms sec$^{-1}$ at 1 a.u. The production rates for OH and H run parallel, suggesting a mutual formation process and a mutual parent molecule, presumably water. This conclusion is supported by the ratio of the production rates $Q_{\text{H}} / Q_{\text{OH}} = 2.7$, close to the expected ratio of 2. The hydrogen production rates are in excellent agreement with the French OGO-5 observations of Comet Bennett (Bertaux et al., 1973; Keller, 1973). The production rates of H and OH can be combined to find the production rate of water

$$Q_{\text{H}_2\text{O}} = (2.2 \pm 0.9) \times 10^{29} \text{ molecule sec}^{-1}$$

at $R = 1$ a.u.

We may use these results to compute the mass loss by Comet Bennett during perihelion passage. Assuming the exponent for the production rate of water, $E_{\text{H}_2\text{O}} = 2.3$, was constant for $R < 2.5$ a.u., the loss of water was $\sim 2 \times 10^{14}$ g, neglecting the water molecules (<10%) which were ionized before they could be dissociated. If we take a radius of 3.8 km for the comet (Delsemme and Rud, 1973) and a density of 1, the total mass of water ice was $\sim 2.4 \times 10^{17}$ g. Consequently, Comet Bennett lost about 0.1% of its total mass and its radius decreased by $\sim 1$ meter during perihelion passage. The presence of an appreciable amount of dust does
not change these figures significantly. From their dust
tail model for Comet Bennett, Sekanina and Miller (1973)
estimated the maximum dust production at perihelion was \( \sim 0.5 \) of the gas production by mass.

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REFERENCES


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