# THE GAS PRODUCTION RATE OF COMET BENNETT

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Comet Bennett (1970 II) was observed with the ultra-violet 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 $\pm$1'.  The comet was observed during the 10 minute period between comet-rise and sun-rise, as seen from the space-craft.  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

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*no Fabry lens was used in the Lyman-alpha photometer.
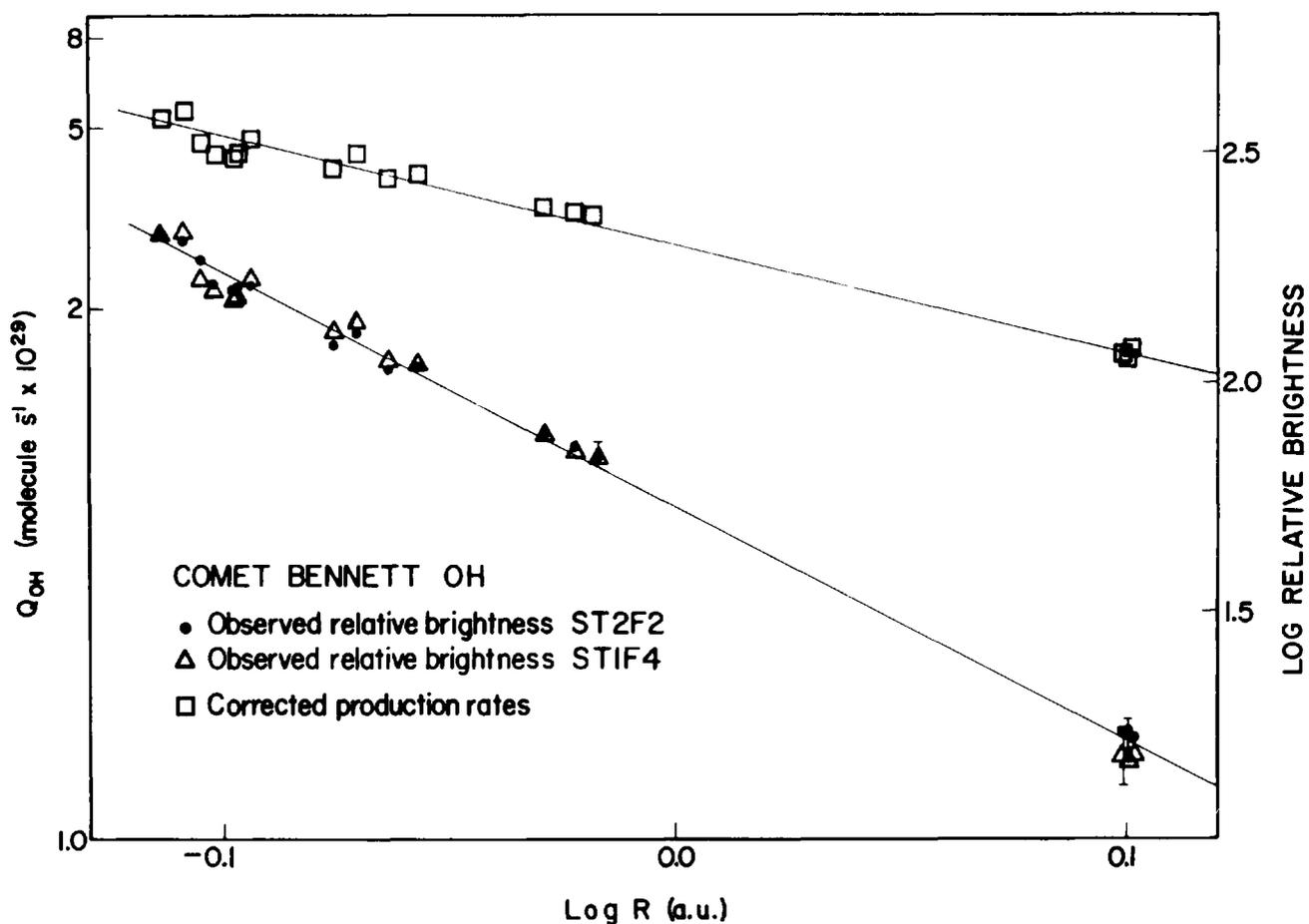
Figure 1   The OH λ3090 photometer observations of comet
           Bennett from April 13 to May 13, 1970.   The lower
           curve shows the logarithm of the observed bright-
           ness (right ordinate) from two different photom-
           eters, ST 1 F4 (Δ) and ST 2 F4 (●), versus the
           logarithm of the heliocentric distance, R.   The
           upper curve (□) shows the observations, corrected
           for field-of-view effects, in terms of the pro-
           duction rate of OH (left ordinate) versus log R.

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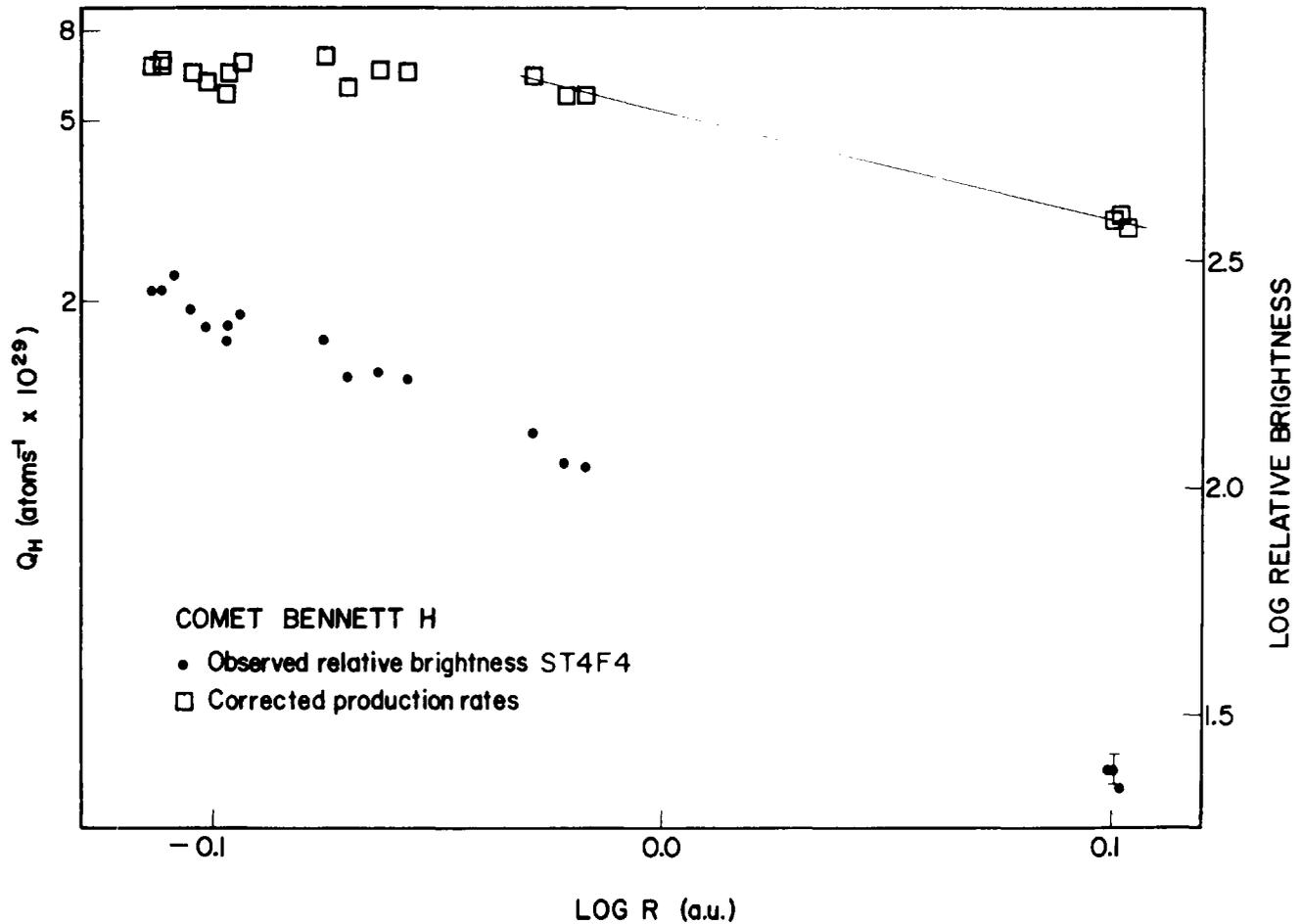
Figure 2    The hydrogen Lα photometer observations of comet
            Bennett from April 13 to May 13, 1970.  The logarithm
            of the brightness observed with ST 4 F4 in relative
            units is shown versus the logarithm of the helio-
            centric distance, R, by filled circles (●).  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 helio-centric 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 $(A^2\Sigma^+ - X^2\Pi_i)$, and $\sim$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 mole-cule$^{-1}$ 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

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We can understand the data qualtitatively 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, $\Delta$, which in this case increases monotonically with R, and, therefore, the field-of-view factor $f \rightarrow 0$ as $\Delta \rightarrow \infty$. 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 OH and H, respectively.

The upper curves in Figures 1 and 2 show the production rates of OH and H derived from the observations after a rigorous correction for field-of-view effects. In the log $Q_{OH}$ 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 $Q_H$ variation was $-2.2 \pm 0.35$ from April 13 to 25, 1970.

Using the OAO calibration data and assuming $g_{OH} = 1.2 \times 10^{-3}$ photon $sec^{-1}$ and $g_H = 2.5 \times 10^{-3}$ photon $sec^{-1}$

for the mean solar flux, we find $Q_{OH}$ = (2.0 $\pm$ 0.8) x $10^{29}$
molecules $sec^{-1}$ and $Q_H$ = (5.4 $\pm$ 2.7) x $10^{29}$ 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 $Q_H/Q_{OH}$ = 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

$$Q_{H_2O} = (2.2 \pm 0 9) \times 10^{29} \text{ molecule sec}^{-1}$$

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, $E_{H_2O}$ = 2.3, was
constant for R < 2.5 a.u., the loss of water was $\sim$2 x $10^{14}$ 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 x $10^{17}$ g.  Con-
sequently, 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

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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 $\sim0\,5$ of the gas production by mass.

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