GROUND-BASED PHOTOMETRY OF COMETS IN THE SPECTRAL INTERVAL 3000 TO 3500Å

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INTRODUCTION

During the past four years we have conducted an extensive program of narrow-band photometry of comets in the spectral region between 3800 and 5300 Å (A'Hearn and Millis, 1980). In the course of this program we have determined abundances and production rates of CN, C_3, and C_2 for fifteen comets and have monitored the variation of these parameters with heliocentric distance for two comets. While these measurements have provided much new information about the similarities and differences among comets, we have really sampled only a small fraction of the total material in any of the comets observed.

There are a number of cometary emission bands, including those of the presumably most abundant species, which have not previously been measured quantitatively and reliably from the ground. Among these are the 0-0 band of OH at 3085 Å and the 0-0 band of NH at 3360 Å. The OH band is the strongest feature in cometary spectra and is of particular interest because OH is derived from water, which is believed to be the dominant constituent of cometary nuclei. Quantitative measurements of the NH band would also be very useful because the interpretation of observations of this diatomic radical in terms of a molecular abundance is relatively straightforward compared to that of NH_2, the only related species observed in comets.

A few measurements of the OH band have been made from high-flying aircraft (Blamont and Festou, 1974) and spacecraft (e.g., Feldman and Brune, 1976; Keller and Lillie, 1978; and Feldman et al., 1980). So far as we are aware, there have been no measurements of the NH band published.

Clearly it would be very desirable to measure these bands with ground-based telescopes. In that way observations could be extended to fainter comets and more complete temporal coverage could be achieved than is generally the case with presently available spacecraft. Such ground-based measurements have not been attempted or have not been successful in the past because of the large atmospheric extinction in the ultraviolet. This paper summarizes our efforts to measure the strength of the 0-0 band of OH in the spectrum of Comet Bradfield (1979l) using the 0.6-meter Planetary Patrol telescope at Mauna Kea Observatory.

OBSERVATIONS

At 3085 Å there are three significant contributors to atmospheric extinction: Rayleigh scattering by air molecules, aerosol scattering by particles, and molecular absorption by ozone. Most of the ozone resides between 10 and 35 km altitudes; therefore, except for small seasonal and latitudinal variation, its contribution to extinction is more or less the same for all observatories. Extinction due to both Rayleigh and aerosol scattering, on the other hand, varies with altitude (h) as $e^{h/c}$, where c is a constant (Hayes and Latham, 1975). High-altitude observatories for this reason do have an advantage when ultraviolet measurements are being attempted.

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TABLE I.

Extinction Coefficients – Mauna Kea Observatory

Filter	λ Angstrom	Δλ (FWHM)	1980 29 Jan	30 Jan	5 Feb	8 Feb	12 Feb	Average	Standard Deviation
1	3135	150	0.829	0.862	0.881	0.835	0.796	0.841	0.033
2	3300	50	0.580	0.580	0.600	--	--	0.587	0.012
3	3365	70	0.499	0.501	0.517	0.507	0.490	0.503	0.010
4	3675	60	0.338	0.338	0.358	0.338	0.336	0.342	0.009
5	3870	30	0.329	0.278	0.292	0.273	0.272	0.289	0.024
6	4045	20	0.229	0.234	0.244	0.231	0.227	0.233	0.007
7	4120	30	--	--	--	0.223	0.212	0.218	--
No. of Observations			5	4	4	3	6		
Range of Air Mass			2.2	1.6	1.8	1.5	3.2		

We obtained observations of Comet Bradfield (1979l) from Mauna Kea Observatory on seven nights in January and February of 1980 through a series of narrow-band filters between 3135 and 5240 Å. On five of these nights, extinction coefficients were carefully measured by repeated observation of a standard star as it rose or set. The resulting extinction coefficients are listed at the top of Table I. The extinction coefficients at the three shorter wavelengths (3135 Å, 3300 Å, and 3365 Å) were well determined and quite stable from night to night. They are comparable to values found for the U passband near sea level. The Mauna Kea extinction coefficients are compared in Figure 1 with those obtained using the same filters at Lowell Observatory, a site whose altitude is about half that of Mauna Kea. The advantage of the higher altitude site for photometry in the near ultraviolet is apparent, but the difference is not so great as to preclude accurate photometry in this spectral region from more typical mountain sites such as Flagstaff.

The steep increase in extinction by ozone across the passband of our OH filter causes its effective wavelength to be shifted from the central wavelength at 3135 Å to near 3165 Å. The OH bands, however, are centered at approximately 3085 Å. Consequently, the measured extinction coefficient for this filter, while appropriate for reduction of the standard star observations, is significantly smaller than the value to be applied to the comet observations. We have computed an extinction coefficient of 1.38 mag/air mass at 3085 Å for Mauna Kea using formulae given by Hayes and Latham (1975). The value for the total ozone at 20°N latitude in January was taken from Allen (1963) and the absorption coefficient for ozone from Toolin (1965). At this wavelength, extinction by aerosols is expected to be negligible compared to the contributions of ozone and Rayleigh scattering and has been ignored. Extinction coefficients computed in this way for longer wavelengths are shown as the solid curve in Figure 1. The agreement between the computed and observed extinction coefficients is excellent, giving confidence that the result for 3085 Å cannot be far off the mark. This assertion is supported by the fact that, on nights when several OH measurements of Comet Bradfield were made over a range of air masses, the r.m.s. scatter in the comet's brightness when reduced to the top of the atmosphere was less than 0.02 mag.

The OH production rates for Comet Bradfield derived from our Mauna Kea observations are compared in Figure 2 with the nearly contemporaneous results from I.U.E. (Weaver et al., 1980). Also plotted are the results from two nights' photometry at Lowell Observatory. While the production rates of OH from the Mauna Kea and Lowell Observatories agree reasonably well, they are about 45 percent larger than the I.U.E. results. The source of this discrepancy is not readily apparent nor is it clear which data set is to be preferred. The same lifetimes and scale lengths for OH were used in reducing the ground-based and spacecraft observations. However, the ground-based measurements were made through an aperture about 2 arcmin in diameter, while the I.U.E. observations were made with a small rectangular aperture about 10 x 15 arcsec on a side. The large difference in the fraction of the coma sampled may contribute to the difference in derived production rates, especially if the coma is not axially symmetric. The ground-based and I.U.E. observations were reduced relative to different standard stars. Errors in the absolute calibrations of these stars will be reflected in the derived OH production rates. Furthermore, uncertainties in the OH filter transmission curve due to variation with temperature or tilt would impact the production rates.

CONCLUSIONS

While the agreement between our results and those of I.U.E. is not as close as we would like, we are convinced that accurate photometry of the OH bands in the spectra of comets is possible from the ground. The extinction coefficients in the near ultraviolet both at Mauna Kea and at Flagstaff were found to be sufficiently small and stable as to present no serious obstacle to precise photometric measurement.

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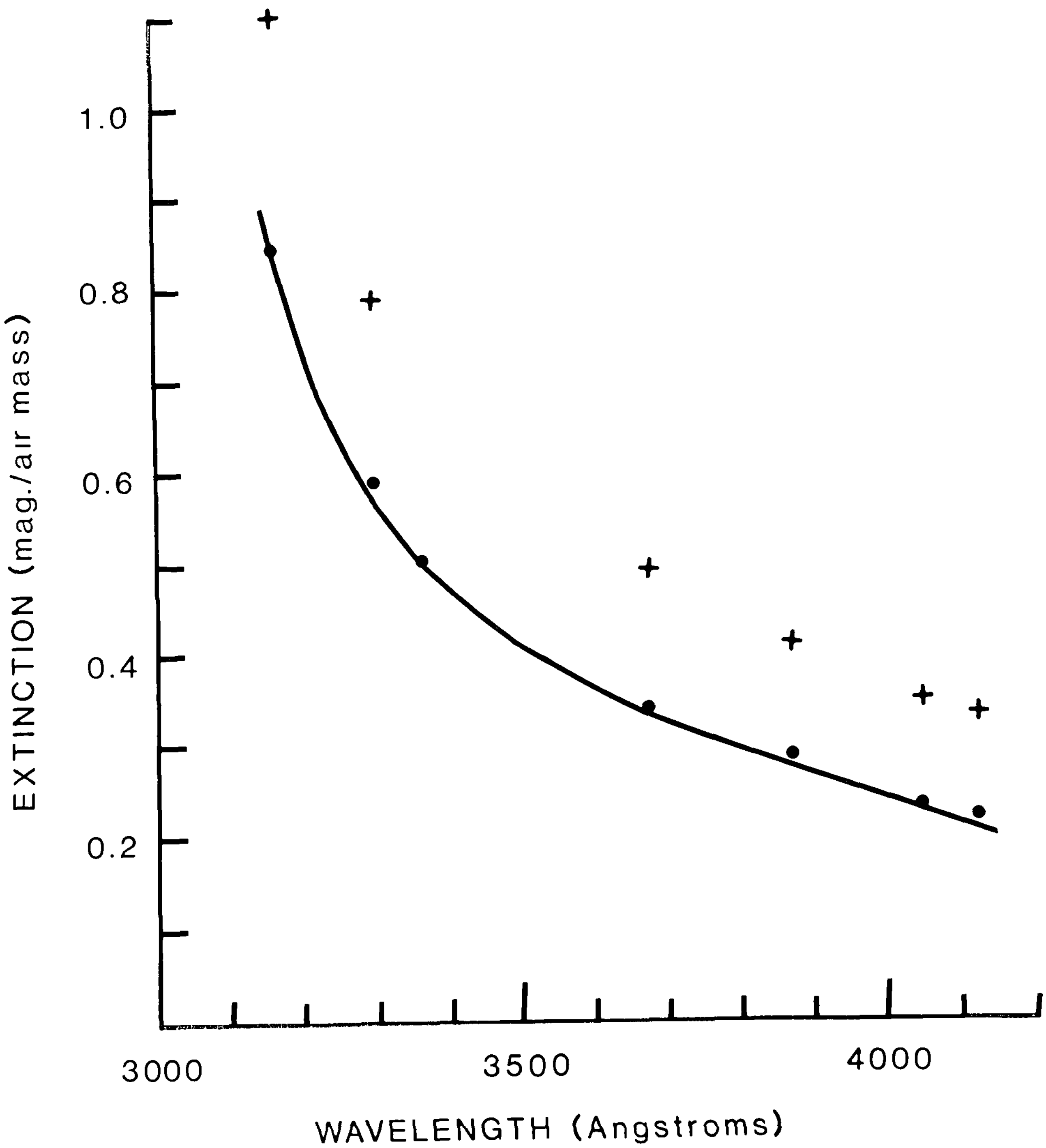

Figure 1. Extinction coefficients measured at Mauna Kea Observatory (filled circles) compared with those determined at Lowell Observatory (crosses). The solid curve represents calculated extinction at Mauna Kea due to ozone and Rayleigh scattering.

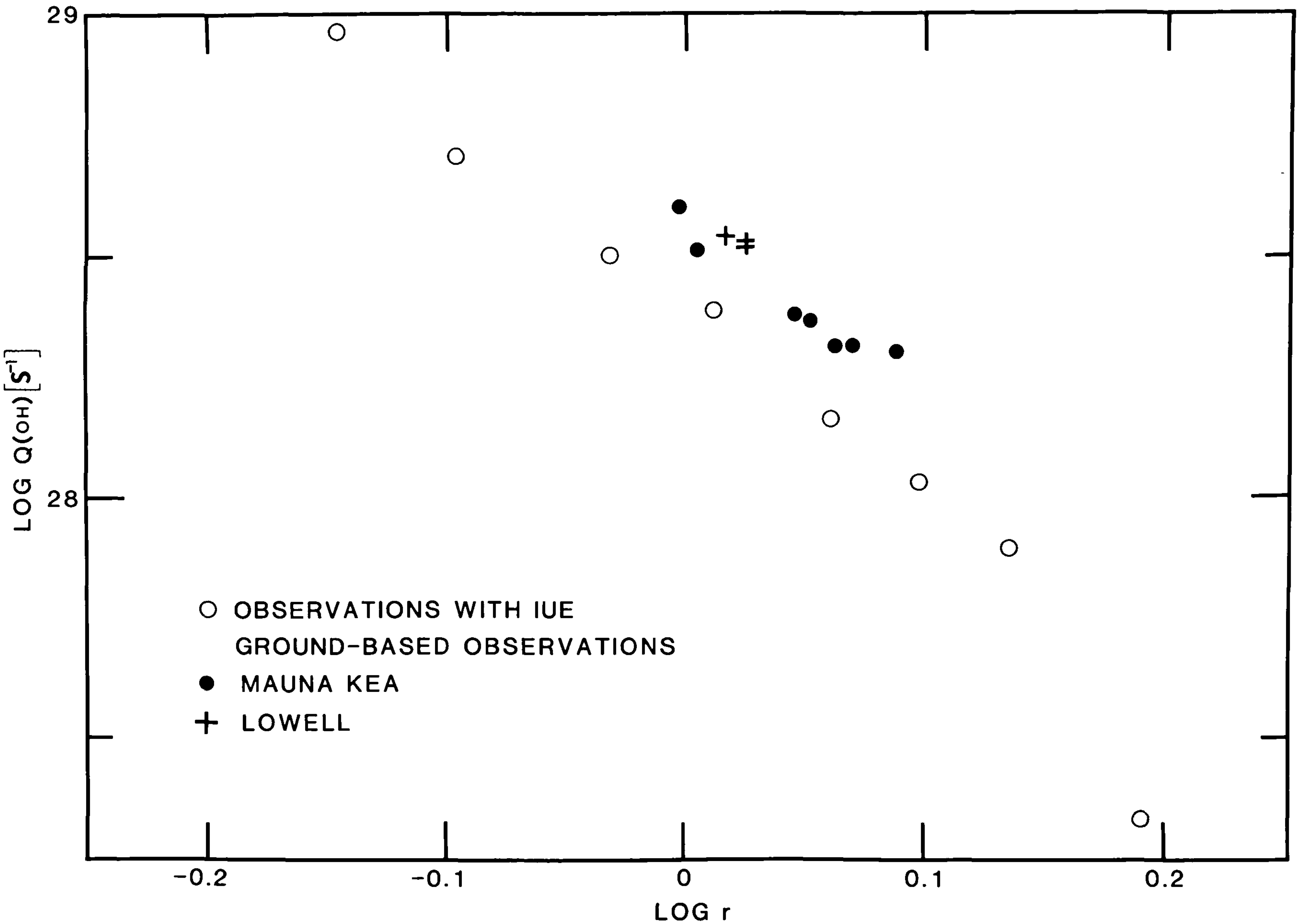

Figure 2. Production rates of OH for Comet Bradfield (1979l) plotted against heliocentric distances. Filled circles represent observations from Mauna Kea Observatory. Crosses represent observations from Lowell Observatory. The open circles are based on observations made with the International Ultraviolet Explorer.

NOTE ADDED IN PROOF

Further calculations of theoretical extinction coefficients show that the attenuation of the cometary OH band should be nearly linear with air mass. However, the attenuation of a flat continuum source such as an early-type star, is very non-linear with air mass due to the shifting of the effective wavelength by the atmosphere. Thus stellar extinction coefficients observed between zero and three air masses significantly underestimate the attenuation between zero and one air mass. Allowance for this effect eliminates a large part of the discrepancy in production rates of OH as determined from IUE and from the ground.

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