ULTRAVIOLET ALBEDO OF COMET WEST (1976 VI)

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ABSTRACT

The ultraviolet spectrum of Comet West (1976 VI) in the range 1200-3200 Å was recorded by rocket-borne instruments on March 5.5, 1976. At the time of launch, r = 0.385, Δ = 0.84 and the phase angle was 78°. Longward of 2100 Å the continuum of solar radiation scattered by cometary dust is detected and is found to closely follow the solar spectrum. Since the dust coma is completely included in the spectrometer slit, the ultraviolet albedo can be determined relative to the visible and this ratio is found to be ≈0.3 at 2700 Å. There is evidence for a further decrease in albedo near 2200 Å. Using a visible albedo of 0.2 gives a value of 0.06 for the cometary albedo at 2700 Å, a value similar to that found for the moon and lunar dust in this spectral region.

Comet West (1976 VI) was the first comet to be extensively studied spectroscopically in the ultraviolet below 3000 Å. Of particular interest are the results concerning the emission lines of cometary species produced by resonant scattering or fluorescence of sunlight (Feldman and Brune 1976) and their implications for the chemistry of the neutral and ionized gas coma (Feldman 1978). Comet West was also a very dusty comet and showed a marked increase in brightness due to fragmentation of the nucleus shortly after perihelion passage. The ultraviolet spectra show reflected solar continuum to wavelengths as short as 2100 Å and it is the nature of this dust scattered radiation that is discussed below.

The rocket experiment has been described by Feldman and Brune (1976). Comet West was observed on March 5.5, 1976 with r = 0.385, Δ = 0.84 and the phase angle was 78°. The long wavelength spectrometer had a projected area on the sky of 5' x 35'. Observations were made with two different geometries: In the first the coma was nearly centered in the slit with the tail parallel to the long dimension of the slit. The entire dust coma and the tail out to ~ 6 x 10^5 km were included in the slit. In the second geometry, the slit was displaced

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~ 2.5 x 10^5 km and rotated ~130° from the sun-comet axis. The neutral gas emission features, particularly the very strong OH emission at 3090 Å are sharply reduced in this case and the spectrum is more characteristic of the dust and ion tails.

Spectra obtained at 22 Å resolution in these two geometries are shown in Figs. 1 and 2, respectively. The neutral features are due to

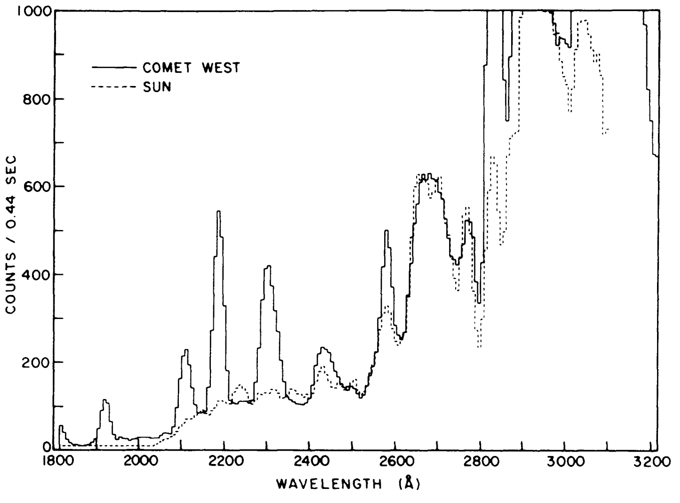

Fig. 1. Ultraviolet spectrum of comet West with the dust coma completely included in the spectrometer slit.

OH (2820, 3090 and 3142 Å), CS(2580 Å), CI(1931 Å) and SI(1813 Å), while the ion emission is from CO^+ (first negative system, 2100-2500 Å) and CO_2^+ (2890 Å). Notice the greatly reduced OH emission and the absence of the other neutral features in Fig. 2. The remainder of the spectrum, in both cases is attributed to scattering of sunlight by cometary dust. To demonstrate this, the figures also show the solar spectrum in this wavelength range (Broadfoot 1972) folded through the instrument response function and normalized to the data near 2700 Å. The solar spectrum is found to give an excellent fit to both sets of data in the wavelength range of 2500-3000 Å. Below 2500 Å, the continuum appears to lie below the solar predicted level, indicating a decrease of albedo at shorter wavelengths. However, the data are not completely conclusive because of the presence of numerous CO^+ first negative bands in this spectral region. A synthetic spectrum analysis of this system indicates that near 2230 Å and 2380 Å there is no CO^+ emission so that the observed signal is all continuum. The variation in albedo, about 30%, is greater than the *relative* uncertainty in the instrument calibration and the reddening in the ultraviolet is probably

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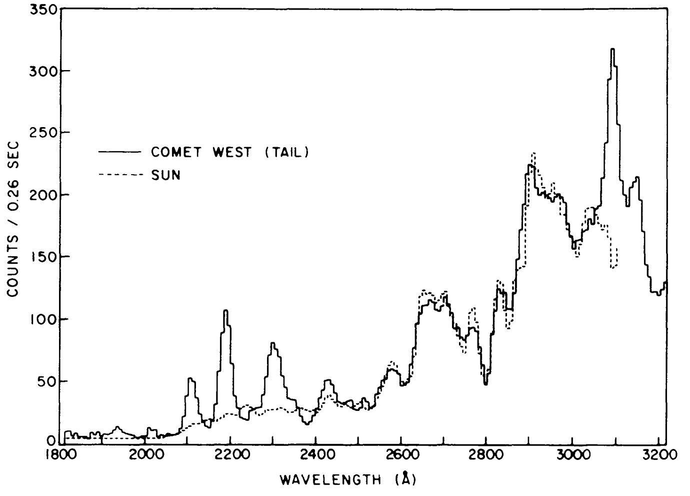

Fig. 2. Same as Fig. 1 but with the spectrometer slit displaced from the optical center of the comet.

real. The same effect, which most likely results from the variation of refractive index of the grains with wavelength, was also observed in the spectrum of the zodiacal light made two years earlier with the same payload (Feldman 1977). Below 2100 Å the solar output decreases very rapidly and there is no hint of any scattered sunlight which might indicate the presence of a large quantity of sub-micron dust particles.

Since the data of Fig. 1 include the flux from the entire visible coma, a comparison with the total visual magnitude of the comet can provide a determination of the dust albedo in the ultraviolet, although with some uncertainty. The contribution of the dust tail to the observed counting rate is probably of the order of 20-30%, based on a comparison of Figs. 1 and 2. There are two sources of the total visual magnitude: the rocket star-tracker, which is blue sensitive, gave a value of $+0^{m}.5$ and since there was very little ion emission in the blue at the time of the launch (Koutchmy *et al*. 1979) this can be used to obtain the continuum magnitude in the visible. The other source of magnitudes is the collection of visual observations compiled by Bortle and Morris and given by A'Hearn *et al*. (1977). Using their light curve gives $m_v = +0.4$ but individual data points for the launch date appear to fall $\sim 0^{m}.4$ below the light curve. Similar values have also been tabulated by Sekanina and Farrell (1978). We adopt the value of 0.4 for the total visual magnitude with the caveat that the comet brightness at 5500 Å may be 40% too high. Note that the uncertainties in both the ultraviolet and visible fluxes are in the same direction. A comparison with the solar flux directly gives the ratio of the albedo

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at 2700 Å to that at 5500 Å, $A_{2700}/A_{5500} = 0.3$. Even with all of the uncertainties included (the absolute calibration uncertainty is ±15%), the evidence for strong reddening between the visible and ultraviolet is clear. This behavior is qualitatively similar to that derived theoretically for interplanetary dust by Röser and Staude (1978). The absolute albedo can now be obtained by using the data of Ney and Merrill (1976) for the same day (and hence same scattering angle) to derive a value of $A_{5500} \approx 0.2$ which gives $A_{2700} \approx 0.06$. Thus, in terms of both absolute albedo and reddening, the cometary dust has the same behavior in the ultraviolet as does moon dust (and the moon itself) (Lucke *et al.* 1976).

It remains to consider the effect of the dust coma on the neutral and ion chemistry of the species vaporized from the icy nucleus of the comet insofar as the dust will prevent the solar extreme ultraviolet radiation responsible for ionization and dissociation of the parent molecules from reaching the inner coma where gas densities are highest. To find the radial distance at which the dust becomes optically thick to ultraviolet radiation, we calculate the radius of the equivalent disk of the same albedo to be $\rho \approx 1000$ km. Thus, in the simple application of the Haser equation to derive the density of H_2O and its daughter OH it should be assumed that no photo-dissociation occurs within 1000 km of the comet's center rather than the value of 1-10 km, the nuclear radius, often adopted in such calculations. The effects of the dust on coma chemistry can be even more complex, as dust grains may serve as additional sources of gas molecules or provide suitable surfaces for molecular or atomic recombination.

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