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COLOR GRADIENTS IN THE COMA OF P/HALLEY

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Some important information relevant to the understanding of the gas/dust dynamics near the surface of a comet nucleus concerns knowledge of the grain composition and scattering properties as well as the particle size distribution of dust in the coma. Ground-based measurements of light scattered from the dust comae can provide some information about the physical grain properties, in particular about the mean optically dominant grain size (Jewitt and Meech, 1986, hereafter JM86). Optical spectra of continua of nine comets presented in the paper show that all of the scattered light is reddened with respect to the Sun.

There is, in addition, significant scatter in the amount of reddening seen for different comets. In the near-IR regions, the reddening decreases until near 2-3μm where the reflectivity is nearly neutral. Beyond 2-3μm the scattered radiation is somewhat blue with respect to the sunlight. Figure 1 (Fig. 4 from JM86) illustrates the change in reflectivity (expressed as percent per 10^3Å) as a function of wavelength. The trend is consistent with: (1) scattering from $\approx$ micron-sized and larger slightly absorbing spheres, (2) scattering from power law grain-size distributions where the mean grain size is a $\geq 1\mu$m, or (3) scattering from the surfaces of macroscopic grains (which cannot be treated by Mie theory). Therefore, the slope of the continuum reflectivity may be used as a diagnostic of the mean optical sizes of grains in the comae of comets.

It is of particular interest to see if there are any observable changes in the grain-size distribution during outbursts. Time series spectrophotometric observations were made of P/Halley during 15-22 November 1985 using the McGraw-Hill 1.3m telescope at Kitt Peak (Meech and Jewitt, 1987). The effective spectrograph resolution was $\approx$ 15 Å in the wavelength range $3700 \leq \lambda$ (Å) ≤ 6900. Two outbursts of about 0.6 mag and 0.4 mag occurred near 15 November 1985 at $\sim$ 10 UT, and 21 November 1985 at 4:30 UT, respectively. Although the dust continuum level increased by nearly a factor of two during the outbursts, the continuum color, measured as a reflectivity gradient, remained essentially constant during the entire eight-day observation interval. The reflectivity gradient found for P/Halley was S' = (9±2)% per 10^3 Å in the wavelength interval $4390 \leq \lambda$ (Å) ≤ 6820. This is consistent with the optical reflectivity gradients found for other comets (see Fig. 1).

Although no coma color changes were observed during the November 1985 outbursts, a color gradient within the coma has been observed in P/Halley. Observations were obtained by D. Jewitt with the IIDS spectrograph using the Kitt Peak 2m telescope on 2 May 1986. Spectra were obtained at 12 different positions in the coma along the projected sun-comet line. The continuum reflectivity gradients computed from the spectra as a function of distance from the nucleus are shown in Figure 2. It is clear from the figure that the dust is all reddened with respect to the sunlight (neutral scattering has S'=0). However, the grain color becomes systematically bluer in the anti-solar direction (negative displacement from the nucleus) as compared to the solar direction. The color gradient indicates a change in the mean optically dominant grain size in the coma. A plausible explanation is that grains with a large radiation pressure factor, β, ejected in the sunward direction are decelerated and turned around by solar radiation pressure much sooner than are the grains with small β. Since β is a function of particle size, the radiation pressure introduces a grain-size sorting in the coma.

Radial color gradients in J, H, and K images of P/Halley such as reported by Campins

(1987) have not been observed by us. We have found no difference between the optical V and R profiles in a sample of ten comets observed with high-precision CCDs (Jewitt and Meech, 1987). However, we have found that focus differences between filters can cause apparent color gradients on scales a few times the seeing disk, qualitatively similar to the gradients reported by Campins.

REFERENCES

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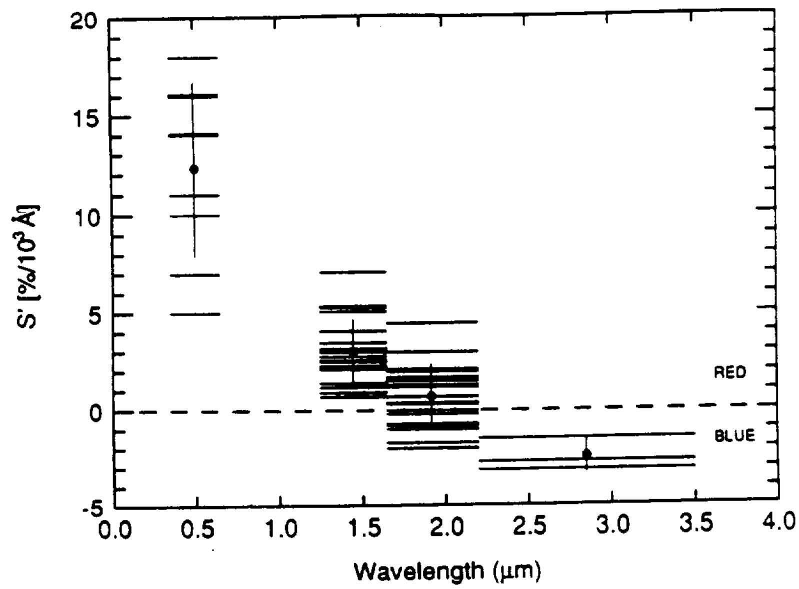

***Figure* 1.** The normalized reflectivity gradient, $S'(\lambda_1,\lambda_2)$, measured in %/10^3 Å, is shown as a function of the wavelength of observation λ (in μm). Each comet is represented by a horizontal bar connecting the end point wavelengths λ_1 and λ_2. Neutral scattering is indicated by the dashed horizontal line at $S'(\lambda_1,\lambda_2) = 0$. Reddening of the scattered radiation is indicated by $S' > 0$ while enhanced blue scattering is indicated by $S' < 0$. The mean S' within each measured wavelength interval is plotted with a black dot and the 1 σ standard deviation on the mean is shown with a vertical line. The figure shows that the color of the scattered radiation varies systematically with the wavelength of observation.

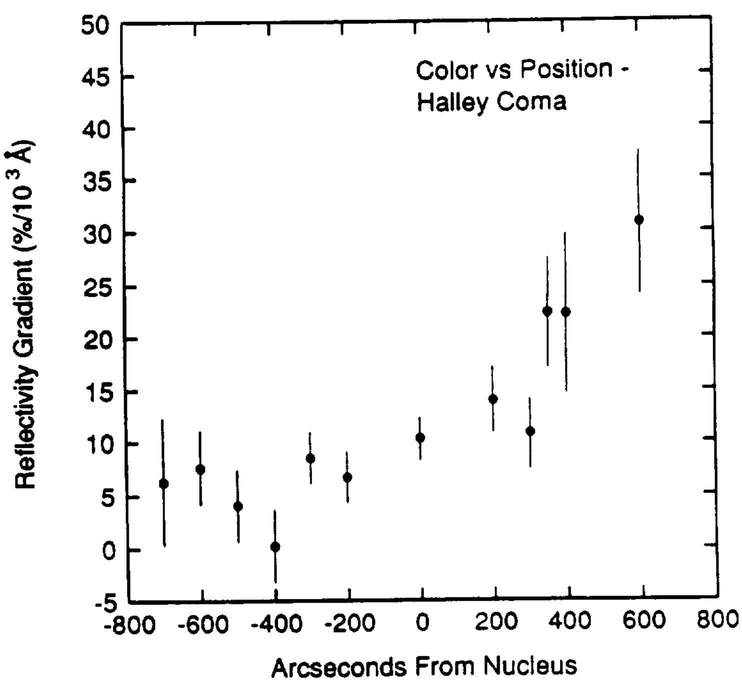

***Figure* 2.** The reflectivity gradient in the grain coma of comet P/Halley versus distance along the projected sun-comet line, measured in arcseconds from the nucleus. Positive units on the x-axis indicate displacement towards the sun. The graph shows that the reflectivity gradient is a weak function of position on the coma. The approximate gradient is $dS'/dx = 0.01\%$ per 10^3 Å per linear arcsecond. The observations were obtained on UT 1986 May 3, when the comet was at $R = 1.6$ AU, $\Delta = 0.7$ AU.