POLARIMETRIC PROPERTIES OF HALLEY'S DUST

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Abstract: Comet P/Halley was observed polarimetrically for seven nights in IHW and other continuum filters, during the pre and post perihelion passages. The polarimetric observations have been combined with the observations taken by other investigators, to get a complete picture of phase angle and wavelength dependence of polarization of comet P/Halley. Assuming Mie type scattering by cometary grains, the observed polarization data were fitted for a set of complex refractive indices which are (1.387, .032), (1.375, .040) and (1.374, .052) at .365, .484 and .684µm respectively.

1 Introduction: Linear polarization measurements of comet P/Halley in the continuum were made by several investigators during it s recent apparition (Bastien et al., 1986; Brooke et al., 1987; Dollfus and Suchail, 1987; Kikuchi et al., 1987; Lamy et al., 1987; Le Borgne et al., 1987b; Sen et al., 1988 etc). Polarization occurring due to the molecular fluorescence emission also has been studied by some investigators (Le Borgne et al.,1987a; Sen et al., 1989). The observed value of continuum polarization is a function of (1)incident wavelength (2)phase angle (3)shape and size of the cometary dust particles and (4)the composition of dust particles in terms of complex refractive index (n,k). The cometary grains are irregularly shaped and since the scattering computations for irregularly shaped grains are rather complicated, we make the simple assumption that the cometary particles are spherical in shape and proceed in this paper to study the dust properties of comet P/Halley using Mie theory.

2 Observations: Observations were made with the 1 m telescope of the V. B. Observatory, Kavalur, India on Dec 9 and 10, 1985 and Mar 17, 18 and 19, 1986, with entrance aperture diameter of 60 and 24 respectively, through the IHW continuum filters (centered at .365, .484 and .684 µm). On Mar 14 and 15 observations were taken through several other non IHW continuum filters (centered at .342, .442, .526, .575 and .641 µm, FWHM .005µm), with aperture 15". A photopolarimeter (Deshpande et al., 1985) was used at the Cassegrain focus, for polarimetric measurements.

3 Results and Discussions: In figure 1 and 2 the polarization observed through non-IHW and IHW filters are plotted respectively. The observed features are:

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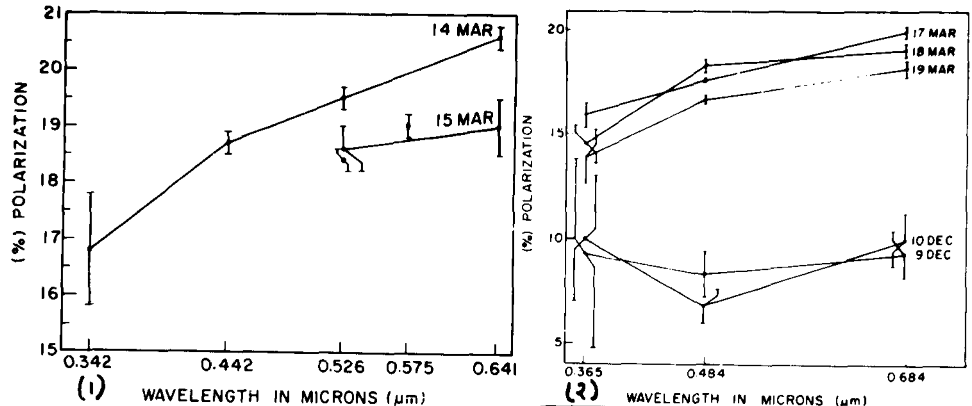

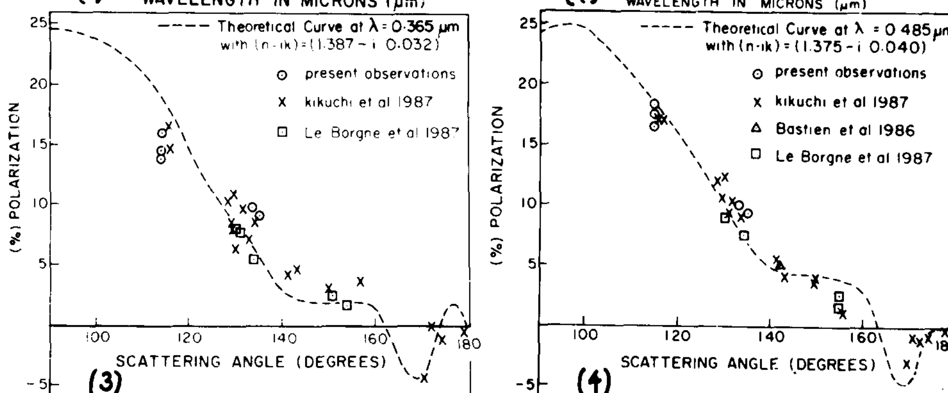

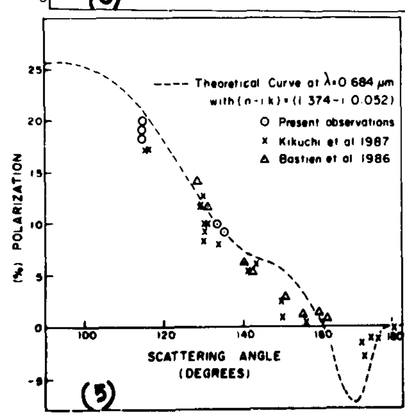

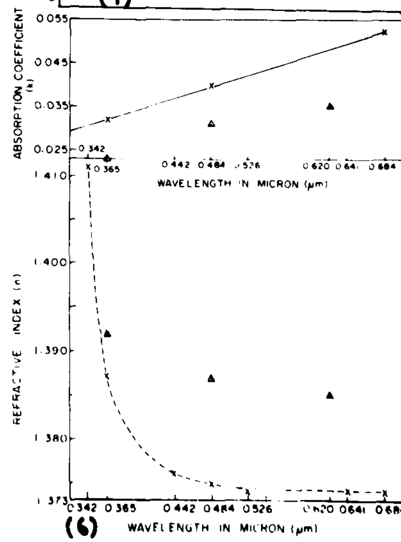

Fig 1-2 Polarization observed through non-IHW and IHW filters. Fig 3-5 Mie theory fit to the observed polarization data. Fig 6 (n,k) values at different wavelength. X present work ▲ Mukai et al (1987).

(1)At large phase angles polarization increases with wavelength, where at low phase angles no dependence is seen. As has been reported by other authors (Kikuchi et al., 1987; more general review by Dollfus et al., 1988) comet P/Halley's polarization showed a clear increase with the wavelength for higher phase angles, but no such dependence was seen for smaller phase angles. Brooke et al.(1987) confirmed this trend from their IR polarimetric observations also. (2)To see whether the polarization changes with the size of the entrance aperture, we have repeated the observation at .526μm with 24" on the night of Mar 15 (Pl. see fig 2). The polarization does not seem to change, within the errors, when we change the aperture from 15" to 24". Bastien et al.(1986) have found by changing the aperture from 4" to 18", a general trend for the polarization to decrease as the aperture increases (barring some exceptions). Kikuchi et al.(1987) changed the aperture from 13" to 33", and found no systematic dependence of polarization on aperture size.

4 Cometary grain properties: In order to study the cometary grain properties, we combined the polarization values reported by other authors, at wavelength .365, .484 and .684 μm and plotted them in figures 3,4, and 5 respectively. The dust mass detectors on board Vega and Giotto spacecraft, have found the dust mass distribution functions of comet P/Halley. Assuming that the grains are spherical in size (with density $\rho \sim 1$ gm/c.c) the following dust size distribution functions are those obtained by Mukai et al. (1987) from the in situ measurements (Mazets et al., 1987)

$$n(s) \sim s^{-\alpha} \quad \text{where } \alpha = 2, 2.75, \text{ and } 3.4 \qquad (1)$$

for $s < 0.62$; $0.62 < s < 6.2$; and $6.2 < s$ μm respectively, where s = radius of the grain in μm and n(s)= number of grains with radius s. From Krishna Swamy and Shah (1988) we adopt the upper and lower limit of particle size to be .001 and 20 μm, meaningful for optical polarimetric work. Having the grain size distribution fixed, we explored a wide range of (n,k) values to calculate the expected values of polarization using Mie theory, which will match with the observed values at different phase angles. For this we have employed the method of least square and minimized the sum of square of deviations between observed and expected polarization values. We introduce a quantity σ^2, equal to the above sum divided by the number of data points. Thus at σ_{min} we get the following best fit values of (n,k).

(n,k) is (1.387, .032) at .365 μm with σ = 2.9
(1.375, .040) at .484 μm with σ = 1.6
(1.374, .052) at .684 μm with σ = 2.4.

As can be seen from figure 6, the k values can be fitted into a straight line '$k = 0.062\,\lambda + 0.009$' by the method of least square. The dependence of 'n' on λ seems to be nonlinear and does come out clearly only from three data points. However, from the k-λ straight line, we interpolate the k values at the wavelengths .342, .442, .526 and .641μm and keeping these k values fixed, we find out the n values which can generate the polarization values as close as possible to the observed polarization values. As a result we get more data points along the n-λ curve (in figure 6), which now help us to see the n-λ dependence in more detail. For a comparison we have also plotted n and k values obtained by Mukai

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et al.(1987) in a similar work. There seems to a discrepancy between the two sets of (n,k) values. It is not clear whether Mukai et al.(1987) also followed the method of least square for the selection of (n,k) values, otherwise the discrepancy between the two sets of (n,k) values may be resulted. It should also be noted that Mukai et al. (1987) have fitted the theoretical polarization curve, on the polarization values which they have observed. But in the present case we have tried to include all the polarization values available in the literature till now. As a result with more number of data points, we expect to get more accurate values of (n,k) which can fit to the observed data.

Brooke et al. (1987) have found that a two-component grain model explains better their IR polarization data. By extrapolating the (n,k) values towards the IR wavelength side (using figure 6) we found that, in a single component grain model, it fails to explain the IR polarization. While doing these calculations one should keep in mind that the dust properties of comet may change with heliocentric distance and also they may be different for different parts of the comet (Sen et al.,1990). Further it is most probable that the grains have a density somewhat smaller than 1 gm/cc and assuming a smaller value say, ρ=.7 gm/cc, we find that the size limits .62 and 6.2 in relation (1) only change to .7 and 7. Such a change in grain size limits does not appreciably change the best fit values of (n,k). Also we know that the grains are far from being spherical, but at present any treatment on nonspherical grains is beyond the scope of this paper. Assuming that the nonspherical grains don't produce polarizations significantly different from that produced by the spherical ones, we conclude that, the dust distribution obtained by Mazets et al. (1987) explains the observed polarization of comet P/Halley for particular kind of grains discussed above.

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