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Polarimetric Measurements of Scattered Light by Dust Grains in Earth and Microgravity Conditions. Tentative Interpretation of the Dichotomy between Comets.

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Abstract: The evolution of the polarization of light scattered by dust particles (e.g. cometary dust) with the phase angle is an indicator of the physical properties of the particles. For grains large compared to the wavelength, the maximum value of polarization P_{max} increases with increasing size. A dichotomy is pointed out in the cometary polarimetric phase curves, showing two ranges of values for P_{max}. A comparison between laboratory measurements performed under Earth and microgravity conditions is presented. P_{max} and the corresponding α_{max} appear to be smaller in microgravity than for ground based measurements. The comparison between ground based, microgravity and cometary results is then tentatively discussed in term of physical properties of the grains.

1. Introduction

The solar light scattered by cometary dust is partially linearly polarized. Previous laboratory studies by ground based experiments (Dollfus et al., 1971; Giese et al., 1978) have suggested empirical relationships between polarimetric parameters (e.g. the maximum value of polarization degree P_{max} and the corresponding phase angle α_{max}) and microtexture, porosity, dominant size, or albedo of the dust. In the case of comets, empirical phase curves show a value of P_{max} between 10-30 % and the corresponding α_{max} value of the order of 90° (Levasseur-Regourd et al., 1995a). The properties of a loose interplanetary or cometary dust cloud can hardly be inferred from measurements on surfaces. The purpose of the microgravity measurements is to study the polarimetric response for grains in a bulk distribution. The first results obtained in microgravity allowing measurements on clouds of dust (Levasseur-Regourd et al., 1995b) can be compared to the ground based measurements.

2. Laboratory measurements

To provide measurements under microgravity conditions, an instrument called PROGRA^2 has been designed (Worms et al., 1995). The incident laser beam is randomly polarized and the light is guided by a multimodal optical fiber. To allow comparisons, the same instrument is used for ground based measurements. In that case, the sample of powder is horizontal and the beams rotate in a vertical plane.

The incident beam and the direction of observation are symetrical with respect to the normal to the sample. The measurements are made with ground and sieved irregular basaltic grains of different sizes in the 10-300 μm range. The adhering smaller particles are removed by washing the grains in alcohol and the size range is controlled with a microscope. In a first series of measurements, the powders are packed by compression with a glass plate. Figure 1a presents the variation of the polarization with the phase angle for different grain sizes. P_{max} increases with increasing grain size and α_{max} decreases. In a second series of measurements, the powders are sifted, thus producing irregular surfaces and a lower number density of the scatterers. The polarization and the value of α_{max} are found to be lower than in the previous case. Figure 1b shows a comparison between the two approaches. Similar results are obtained for boron carbide, silicium carbide and corundum.

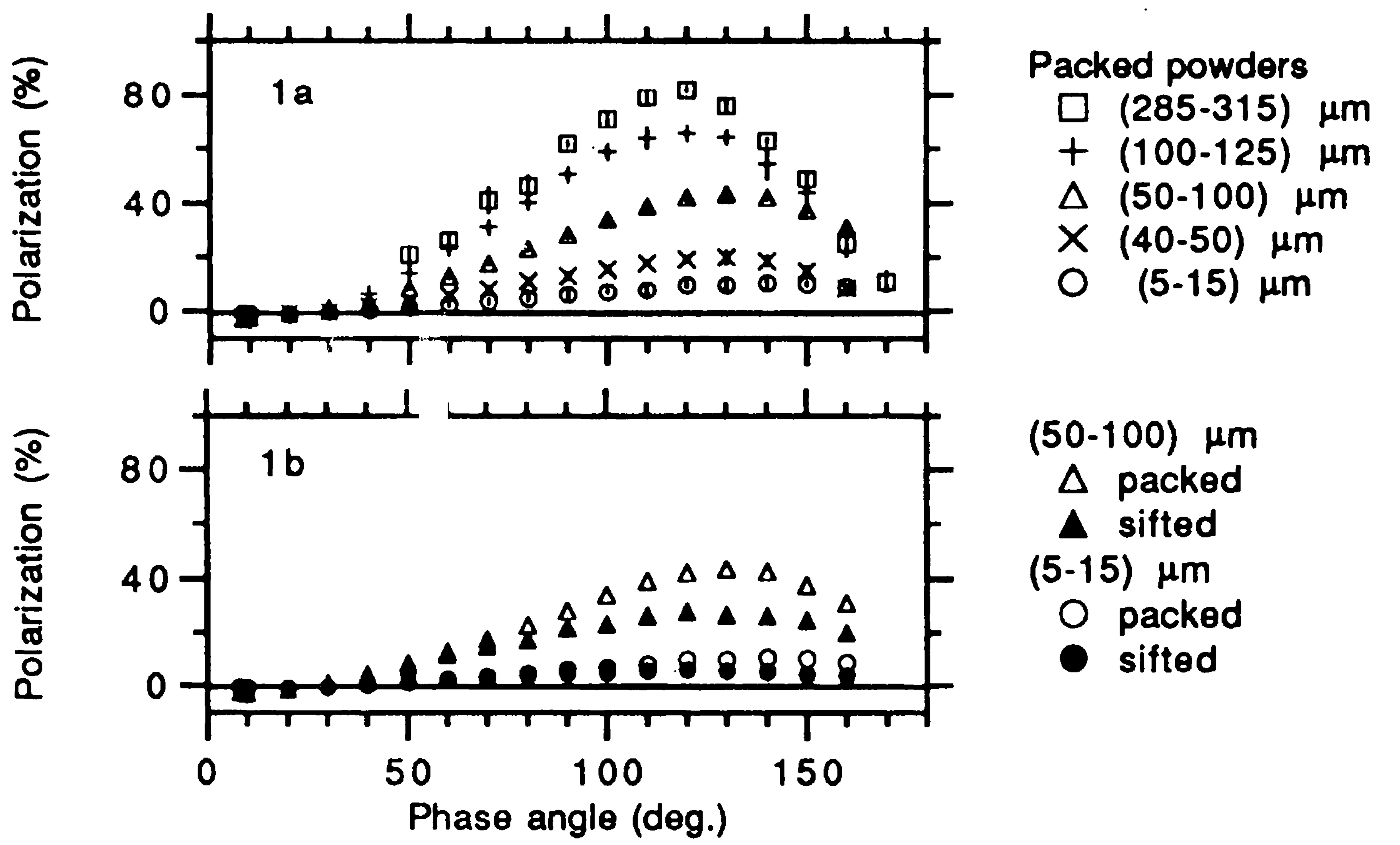

Figure 1 Variation of polarization with phase angle for powdered basalt: 1a-different sizes of grains; 1b-packed and sifted powders

Up to now our microgravity results have only been obtained for dense "clouds" of dust floating in loose and irregular agglomerates. A comparison between the phase curves obtained under microgravity and ground based conditions (Levasseur-Regourd et al., 1995b; Worms at al., 1995b) shows that P_{max} and α_{max} are lower under microgravity conditions (Figure 2). The spacing of the grains and the irregularity of the surfaces or, of the agglomerates, seem to strongly influence the values of P_{max} and of α_{max}, as depict the results obtained for samples of packed, sifted and floating dust.

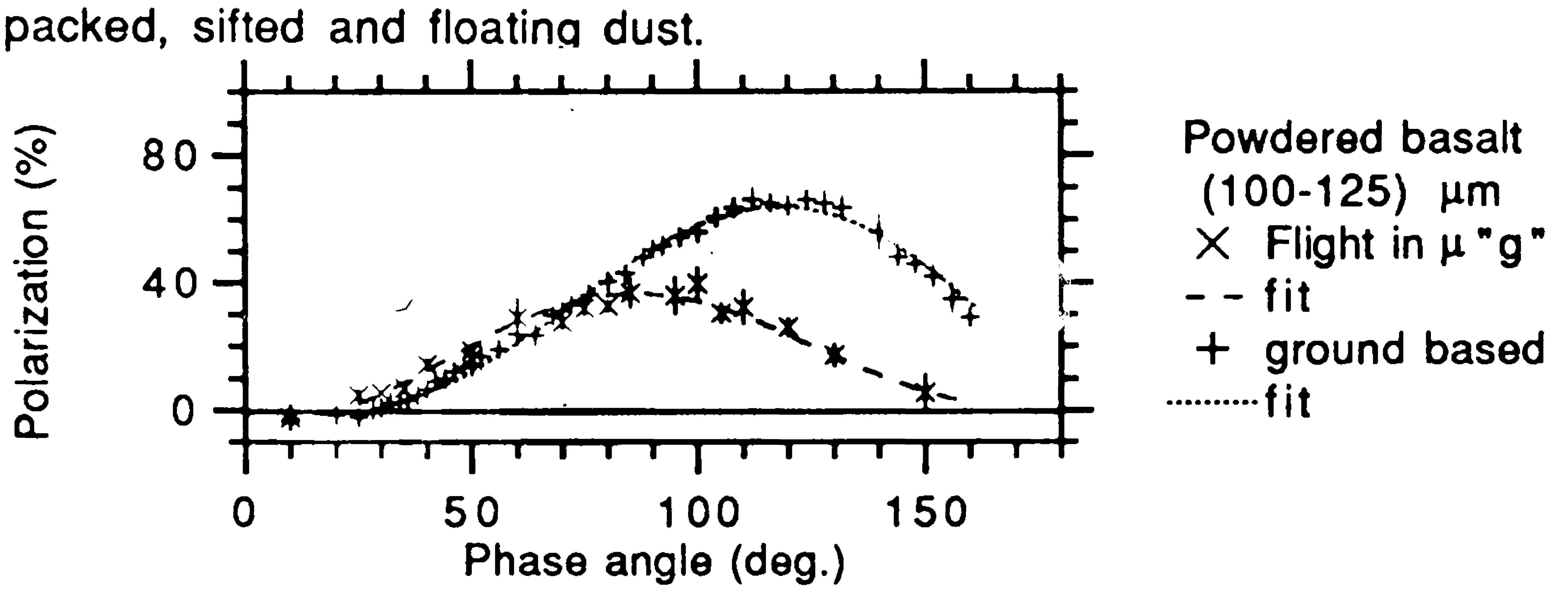

Figure 2: Comparison between data obtained in one "g" and microgravity conditions

3. Cometary observations

Differences in P_{max} are similarly observed in comets. A significant dispersion (Figure 3a) is noticed in the polarimetric properties of cometary dust (whole coma) at large phase angle (Hadamcik, 1994). This dispersion is considerably reduced by defining five spectral ranges, and in each one, by dividing the cometary data in two subsets.

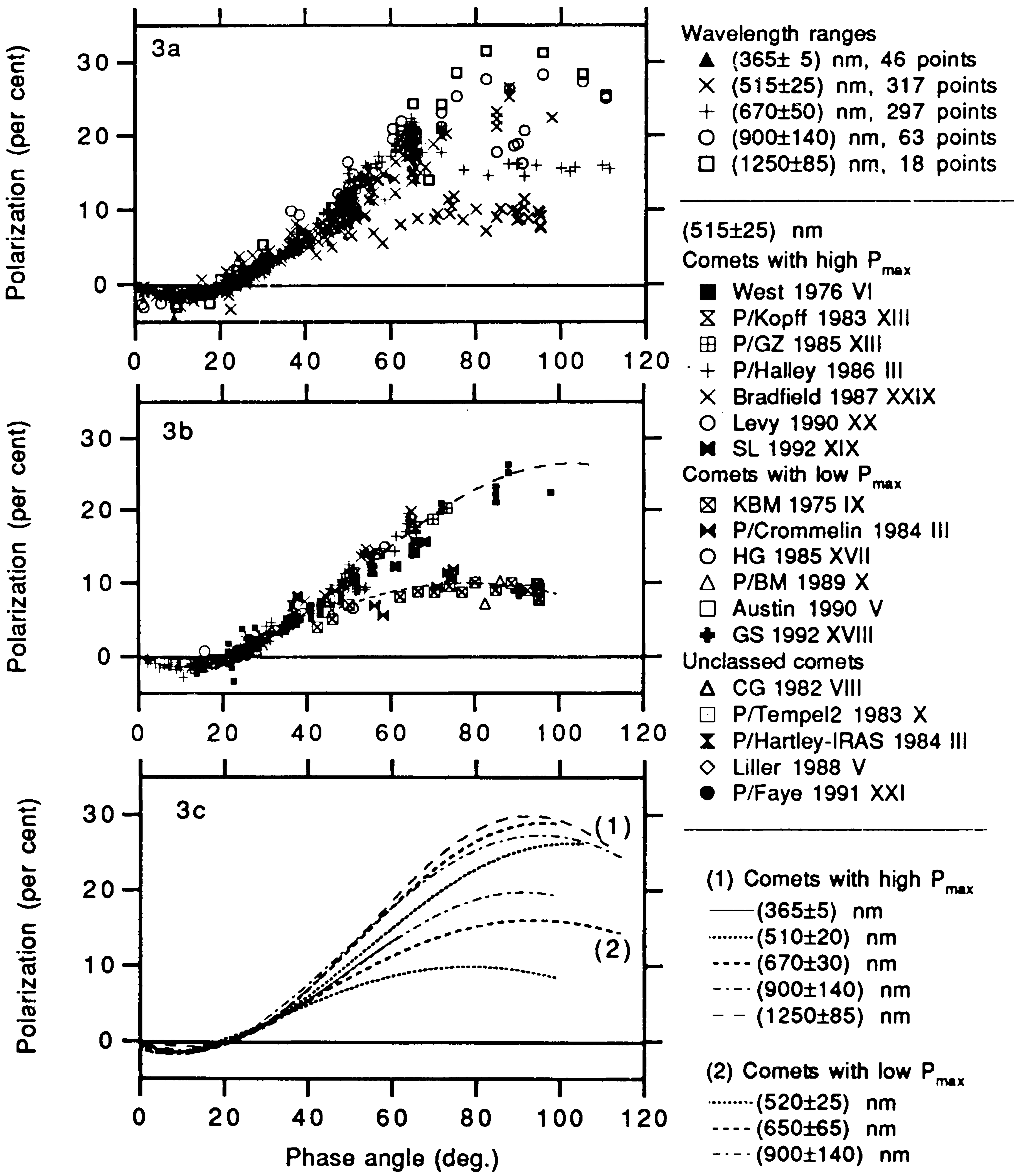

Figure 3: Phase angle dependance of cometary dust (whole coma) with polarization 3a-All data points (741) for five wavelengths ranges; 3b-Data points in the green domain; fits for the two classes, high Pmax, low Pmax; unclassed comets if no data above α > 50°; 3c-Fits for the five spectral domains and for the two classes of comets.

These subsets are defined by the polarization values at large phase angles (Levasseur-Regourd et al., 1995a): the first class has a P_{max} of about 30 per cent, while the second one has a P_{max} smaller than 20 per cent. "Synthetic" phase curves showing the average variation of polarization versus phase angle are derived, in a given wavelength range, for the two classes (Figure 3b). The same dichotomy is found for all spectral domains (Figure 3c). The degree of polarization seems to increase with increasing wavelength. It should be noticed that comets with large P_{max} such as comet P/Halley 1986 III, West 1976 VI and Levy 1990 XX are mostly "active", i.e. exhibit dust jets or sudden variations in brightness. Comets with lower P_{max} such as Austin 1990 V, Kobayashi-Berger-Milon 1975 XXIX and P/Grigg-Skjellerup 1992 XVIII seem to be "quieter". By a spectroscopic approach Hanner et al. (1994) have obtained a similar dichotomy and suggest that the "active" comets are rich in submicronic grains.

4. Discussion and conclusion

From the laboratory measurements, P_{max} is found to increase with increasing size of the grains, in agreement with Geake and Geake (1990) results for grains in the 0.05-40 μm range, which could be in favor of the presence of larger grains in comets with high P_{max}. This result seems in discordance with the suggestion that submicronic grains are responsable of the high P_{max} for active comets. However other parameters (e.g. number density of scatterers, albedo, shape of the grains) can affect the value of polarization. Indeed, the dust in cometary jets presents a higher polarization (Renard et al., 1992). Elongated submicronic grains could be oriented in the dust jets and then produce larger polarization values (Watanabe et al., 1992). Besides, assuming with Greenberg and Hage (1990) the existence of large fluffy aggregates, the high values obtained for P_{max} could be indicative of very low albedos and large aggregates build up of submicronic grains.

More laboratory (ground based and microgravity) polarimetric measurements for micronic and submicronic grains, more observations of comets at large phase angles and at different wavelengths, should allow to characterize the various populations that fill the two classes of cometary coma.

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