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The loss of negative polarization after depletion of sub-micron-sized particles in regolith simulant

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Abstract

In Escobar-Cerezo et al. (2018)[1], experimental measurements of the scattering matrix of the lunar regolith simulant JSC-1A were presented. In that work, the role of the fraction of smaller particles of the sample was studied as these particles were depleted by a collecting device. By comparing the measurements before and after this depletion, we discovered that the observed negative polarization branch in the original sample disappeared when the smaller particles were removed. This seems to show that the phenomenon that triggers the negative polarization branch is associated with structures smaller than the wavelength.

1. Introduction

The polarization of light can be fully described by the Stokes vector, which represent exactly the polarization state and intensity of a beam of light propagating in certain a direction. The scattering matrix **F** in Eq. (1) characterizes the polarimetric response of a particle or an ensemble of particles under incident electromagnetic radiation. This scattering matrix relates the Stokes vector of the incident light into the Stokes vector of the scattered light. The matrix **F** depends on the physical properties of the sample, such as size distribution, shape of the particles, and their refractive indices.

$$\mathbf{F} = \begin{pmatrix} F_{11} & F_{12} & F_{13} & F_{14} \\ F_{21} & F_{22} & F_{23} & F_{24} \\ F_{31} & F_{32} & F_{33} & F_{34} \\ F_{41} & F_{42} & F_{43} & F_{44} \end{pmatrix} \quad (1)$$

The IAA-CODULAB apparatus (Muñoz et al. 2010 [2]) is devoted to perform laboratory measurements of the scattering matrices of irregular particles and offer these results to the scientific community through the Amsterdam-Granada light scattering database (http://www.iaa.es/scattering). The device illuminates the sample with an Ar-Kr laser. Thanks to several optical elements that may be arranged in different configurations, the scattering elements of Eq. (1) can be measured. As the sample is under single scattering conditions with random particle orientation and equal amounts of particles and their mirror images, only six of these elements are independent.

2. Degree of linear polarization

The degree of linear polarization under unpolarized incident light equals the ratio $-F_{12}/F_{11}$ where F_{11} as a function of the scattering angle is known as the phase function. In Fig. 1 we show the degree of linear polarization measured for the lunar regolith simulant JSC-1A at three different wavelengths. This plot presents the typical bell shape for irregular randomly oriented particles, with a maximum of polarization near 90° and a small negative branch at backscattering (∼-2 %) (Muñoz et al. 2012 [3]).

In Fig.2, we show the degree of linear polarization of the pristine sample and the sample once have been recovered from the collecting device. During this recovery process, the smaller particles cannot be recovered from the collecting unit as they cling to the walls through electrostatic force or remain stuck in the filters. The effective radius of the size distribution then increases and its scattering response changes. As can be seen, the negative polarization branch disappears, and the maximum of the function increases and moves towards smaller scattering angles.

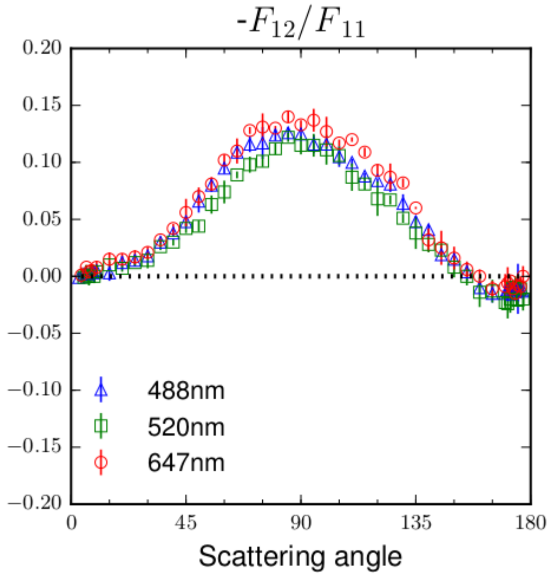

Figure 1: Degree of linear polarization for unpolarized incident light of the lunar regolith simulant JSC-1A at three different wavelengths.

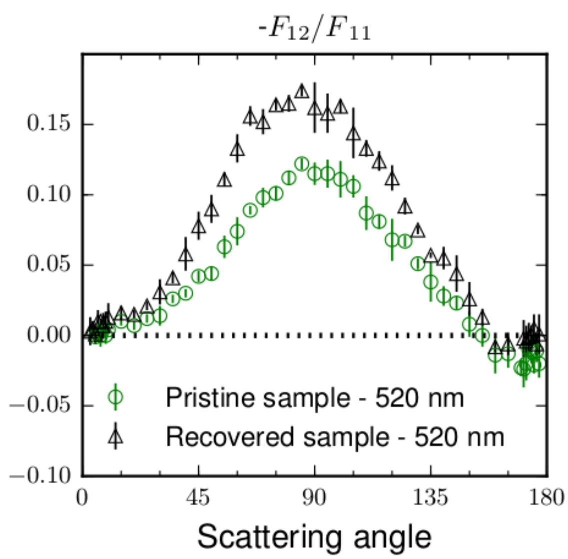

Figure 2: Comparison of degree of linear polarization at 520 nm between the pristine sample and the sample recovered from the collecting device.

3. Summary and Conclusions

This is a very interesting result, as the negative branch has been observed consistently in both comets and asteroids (e.g. Zubko (2012)[4]), and until now there was no proof of the mechanism determining this polarization feature. However, it is still soon to consider this as an answer to this question. Further measurements are planned to test this hypothesis, along with computational simulations to give the theoretical background necessary.

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