Polarimetry of comets

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Linear polarimetry is a powerful diagnostic tool that can provide information that may not be available from total intensity alone. While total-intensity imaging in two band-passes yields a color and places some constraints on the gross dust properties in a comet, there remain significant difficulties in interpreting such color information, and especially determining the detailed structure, composition, shape/size, or orientation of the dust particles. By adding polarimetry observations (even in a single band-pass) these properties can be highly constrained, improving significantly the characterization of cometary dust particles (e.g., [1,2]).

The polarization of light scattered by cometary dust depends on the angle through which the light is scattered, often parameterized using the Sun-Target-Observer (STO) angle, or phase angle α, which is related to the physical scattering angle via $\alpha = 180$ - scattering angle. Maximum polarization occurs at $\alpha \sim 90$–100 degrees with the plane of the scattered-light dominant electric vector (plane of polarization) perpendicular to the STO scattering plane. However, for $\alpha \lesssim 20$ degrees, the plane of polarization often can be in the STO plane, a phenomenon referred to as "negative polarization".

While aperture polarimetry can yield the globally averaged properties of dust particles, imaging polarimetry provides even more diagnostic power by enabling different populations of particles, in structures such as jets, to be identified and characterized. Ground-based imaging polarimetry of comets obtained at various phase angles usually show different polarization levels throughout the coma, indicating an inhomogeneous distribution of dust particles [3–6]. While much of the coma is often positively (or slightly negatively) polarized, the innermost region, called the circum-nucleus halo, can have a large negative polarization (~ -6 percent) at small phase angles ($\alpha \sim 10$–15 degrees). This implies that particles in the circum-nucleus halo must have composition, shape/size, or orientation different from other particles in the coma.

The spatial resolutions achieved with typical ground-based imaging polarimetry can still be problematic, because polarimetric features can become beam-diluted and washed-out and, as with aperture polarimetry, the net measured polarization may not represent the polarization of a given feature correctly. While ground-based systems are beginning to achieve spatial resolutions at near-infrared wavelengths approaching those available from, e.g., the Hubble Space Telescope (HST), none has such resolution at visual wavelengths. Therefore, detailed imaging polarimetry of structures on comets at visual wavelengths has typically been confined to objects fairly close to the Earth, and rarely more distant than the water-ice sublimation distance from the Sun.

In this talk, I will briefly review the general state of imaging polarimetry observations of comets, and discuss a few problems that can confound interpretation of measured polarizations. I also will present state-of-the-art imaging polarimetry of Comet ISON (C/2012 S1) taken at two epochs with HST ([7]: 1) when the comet was at 3.81 au from the Sun and thus beyond the water-ice sublimation distance; 2) when the comet was at 1.12 au about a month before perihelion.

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