CCD polarimetry of distant comets with the 6-m telescope at SAO RAN

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Usually, polarimetric measurements are used to study the physical properties of comets approaching the Sun. Since the dust in distant comets differs from the dust in short-period comets, the study of polarization of the distant comets is very important for the investigation of their physical properties. However, little is known about the dust properties in the cometary coma as well as about the cometary nuclei at large heliocentric distances. So far, there are no comets studied with polarimetric techniques at heliocentric distances more than 4 au.

We have started a comprehensive program of polarimetric, photometric, and spectral investigations of active distant comets (or without noticeable activity) with the focal reducer SCORPIO attached in the prime focus of the 6-m telescope BTA (Special Astrophysical Observatory, Russia). We performed broad-band polarimetry and long-slit spectroscopy of comets C/2011 S1 (LINEAR) and C/2010 R1 (LINEAR) in the visible wavelength range. The data were obtained on November 12, 2012, at the phase angle of 10.4°, when the comet C/2011 S1 (LINEAR) was at the heliocentric distance of 6 au, and, on February 6, 2013, at the phase angle of 9.1°, when the comet C/2010 R1 (LINEAR) was at the heliocentric distance of 5.9 au, respectively. The data on the degree of linear polarization of the distant comets C/2011 S1 (LINEAR) and C/2010 R1 (LINEAR) are the first ever obtained at such large heliocentric distances.

We present the results and preliminary analysis of imaging polarimetric observations of comets C/2011 S1 (LINEAR) and C/2010 R1 (LINEAR). These comets show considerable levels of activity not only within the zone of water sublimation (up to 3 au), but also at heliocentric distances far exceeding this limit. Molecular emissions are not detected in the observed cometary spectra. The cometary comae display a degree of linear polarization of about -2% and -2.2%, respectively. This value is significantly higher, in absolute terms, than that ($\sim$ 1.5%) typical for comets close to the Sun. We have made an attempt to compare the obtained observational data with the results of numerical modeling performed for light scattering media composed of particles of different refractive index, shape, and size. Our computations have been performed by using the T-matrix and superposition T-matrix methods. Firstly, we have adopted the cometary particles in the form of densely packed aggregates composed of different numbers of submicron spherical monomers with refractive index $m = 1.65 + i0.05$. The morphology of the aggregates is described by a statistical scaling law. For a wavelength $\lambda = 0.55$ µm, we have obtained a negative branch of polarization in the range of phase angles $\alpha < 20°$, which is somewhat weaker than the observed one, but at $\lambda = 0.4$ µm the negative branch of polarization disappears. Also, we have assumed the cometary particles to have a chemical composition close to the water ice. The results of computations show that the model of optically thick layers composed of oblate spheroids with refractive index in the range 1.28–1.33, effective radius in the range 0.28–0.33 µm and aspect ratio in the range 1.2–1.6 permit to obtain a satisfactory agreement between the observed and computed values of the degree of linear polarization. But it should be emphasized that the small amount of observational data does not permit to make reliable conclusions about the physical properties of particles in the atmospheres of the investigated comets.