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Diversity and similarity of linear polarization among low-albedo NEAs: extremely high polarization of NEA 25330 (1999 KV4)

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Abstract. This study explores the diversity and similarity of linear polarization among low-albedo Near-Earth Asteroids (NEAs), focusing on the exceptionally high polarization of NEA 25330 (1999 KV4). Polarimetric observations are essential for understanding the physical properties of NEAs, providing insights into the nature of scattering particles and ambient physical processes that cannot be achieved using other observational methods.

Keywords: Polarimeters; polarimetric observations; asteroids: NEA 25330

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1 Introduction

Scattered radiation resulting from the interaction of unpolarized radiation with various media exhibits several properties, one of which is linear polarization. Consequently, polarimetric observations provide valuable insights into the nature of scattering particles and ambient physical processes that cannot be achieved using other observational methods.

There are several reasons for conducting polarimetric investigations of Near-Earth Objects (NEOs):

1. Obtaining the maximum phase dependence of polarization, including the polarization maximum.
2. Comparing polarization properties of comet-asteroid transition objects in the asteroid-comet continuum (ACC).
3. Identifying primitive asteroids with high volatile content that can form temporary atmospheres near the Sun.
4. Studying the physical properties of small, kilometer-sized bodies to compare surface properties of asteroids with different origins and regolith maturity.
5. Clarifying light scattering mechanisms by dust particles for various ACC objects.
6. Addressing the asteroid-comet hazard problem.

2 Observation results and analysis

Since 2019, polarization phase-angle data for 19 NEAs have been collected using the 2.6-meter telescope at the Crimean Astrophysical Observatory and the 2-meter telescope at Peak Terskol Observatory. Seventeen of these NEAs were observed for the first time, including medium-albedo S-type, high-albedo E-type (2010 XC15), and low-albedo asteroids. The polarization phase dependencies of these NEAs are illustrated in Fig.1, with a focus on low-albedo NEAs.

NEA 25330 (1999 KV4) showed a high polarization of 38.5% at a 75.7-degree phase angle. Its phase dependencies are similar to the NEAs 101955 (Bennu), 152679 (1998 KU2), and 162173 (Ryugu), allowing them to be grouped (see red curve 1 in Fig.1). Between phase angles of 30 to 50 degrees, NEA 25330's R-band polarization curve matches that of comet C/1995 O1 (Hale–Bopp) (Kiselev & Velichko 1997), though their wavelength dependencies differ.

Another group of dark asteroids with similar polarization phase dependencies (curve 3) includes 1580 (Betulia), 2100 (Ra-Shalom), and newly discovered 417264 and 37638. NEAs 159402 and 52768 (curve 4) likely resulted from the breakup of a parent body near the Sun (Kiselev et al. 2024; Emel'yanenko & Kartashova 2023).

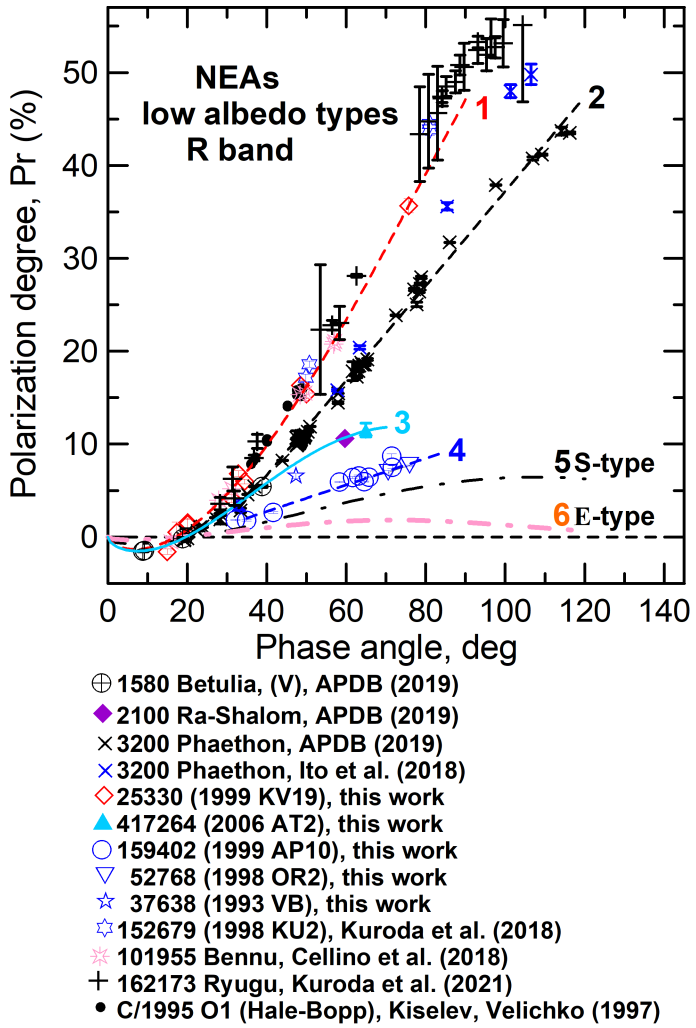

Fig. 1. Phase angle dependence of polarization (PDP) of NEAs observed with the 2.6-m telescope of the Crimean Astrophysical Observatory and the 2-m telescope of the Peak Terskol Observatory from 2019 to 2024. Data on previously observed NEAs are taken from APDB (Emel'yanenko & Kartashova (2023) and references therein). Curves 1–4 represent four groups of NEAs with differing characteristics (Kuroda et al. 2018; Cellino et al. 2018; Kuroda et al. 2021). For comparison, the average PDP of S-type NEAs (Curve 5) and PDP of E-type NEAs (Curve 6) are also shown.

Most NEA 3200 (Phaethon) data fall within the synthetic phase curve (2) margins (Lupishko 2019), but Ito et al. (2018) showed higher polarization, possibly due to Phaethon's activity. NEA 162173 (Ryugu) also shows high polarization at large phase angles, potentially indicating activity and a cometary origin with surface ice (Miura

et al. 2022). Large phase angles at small heliocentric distances can increase the photometric activity of NEAs, increasing the probability of detecting polarization changes.

3 Conclusions

New polarimetric observations of five low-albedo NEAs at large phase angles are presented, including the discovery of the asteroid 25330 (1999 KV4) with an extremely high degree of polarization. Currently, polarization data are available for only 11 NEAs. NEAs can be grouped into four clusters with close synthetic polarization curves. Additional observations are needed to study the diversity and similarity of polarization among low-albedo NEAs.

It can be assumed that the asteroid 25330 (1999 KV4), exhibiting a high degree of polarization, shows signs of sublimation activity.

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