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Rotating-drift-scan observations of the fast-moving near-Earth asteroid 2021 CA_6

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Abstract. The Rotating-drift-scan (RDS) charge-coupled device (CCD) technique is a promising approach to observing fast-moving NEAs during their close approaches to the Earth. Follow-up observations of a newly discovered NEA 2021 CA_6 were carried out with a 0.5 m telescope utilizing the RDS technique. Astrometric positions have been obtained with a competitive precision of about $0''.3$. With the RDS technique, the network of small-aperture telescopes would substantially benefit our global NEAs monitoring system to ensure Earth's safety from any asteroid impacts.

Keywords. CCD observation, Near-Earth objects, Astronomical techniques

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1. Introduction

Near-Earth Asteroids (NEAs) often have high apparent velocities when they are close to Earth. Long-exposure observations can cause streaked images and reduce the precision of astronomical measurements. This poses challenges for determining their positions. The Rotating-Drift-Scan (RDS) Charge-Coupled Device (CCD) technique offers a solution for high-precise positional measurements of fast-moving NEAs during their close approaches to Earth (Tang et al., 2014). By mounting the camera on a rotation platform, adjusting the CCD charge transfer direction and velocity, point-like images can be obtained in the time delay integration (TDI) mode. Previous studies (Maigurova et al., 2018; Pomazan et al., 2021, 2022) have successfully applied RDS technique to observe hundreds of NEAs. Statistical analysis of RDS observations confirms the technique's effectiveness in observing fast-moving NEAs and newly discovered NEAs with inaccurate ephemerides (Tang et al., 2024).

In this article, we utilize the RDS technique in observing a newly discovered NEA 2021 CA_6 to present this observational technique in detail.

2. Follow-up observations

Follow-up observations are crucial for refining NEAs' orbit, enabling reliable future predictions. The RDS technique allows small-aperture telescopes to observe NEAs during their close approach to Earth. One such newly discovered NEA, designated 2021 CA_6, caught our attention as it was to pass by the Earth on 2021 February 13, with a Minimum Orbit Intersection Distance (MOID) of 0.0011 au and a maximum apparent velocity of $8''.4\,\mathrm{s}^{-1}$.

The NEA 2021 CA_6 was discovered at Pan-STARRS 1, Haleakala on 2021 February

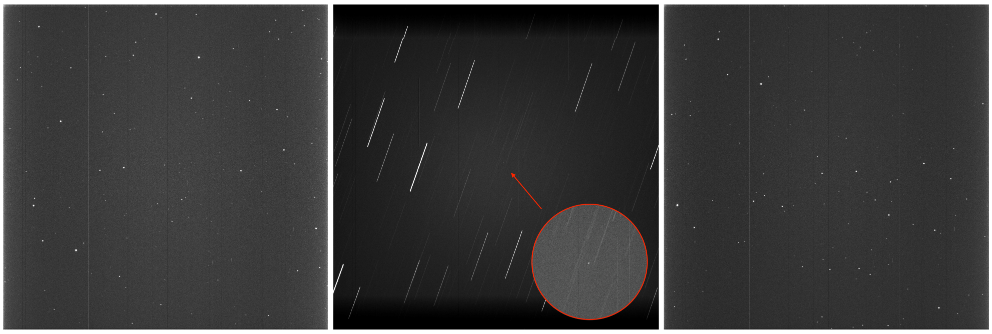
(a) field stars (b) 2021 CA_6 (c) field stars

Figure 1. CCD frames of field stars and 2021 CA_6 obtained with the RDS technique through the 0.5 m Cassegrain telescope at the LiShan Observatory on 2021 February 13.

10. Its follow-up observations reported here were taken with a 0.5 m Cassegrain telescope at the LiShan Observatory, in China (Minor Planet Center, MPC code: O85). The focal length is 3445 mm. We used an Alta U9000 CCD detector without a filter. This CCD supports the TDI scanning mode and has 3056×3056 pixels of size 12 μm. The field of view (FOV) is $36'\!.7\times36'\!.7$ with a pixel scale of $0''\!.72$. The full width at half-maximum (FWHM) is $2''\!.3$. The orbital elements of 2021 CA_6 provided by the MPC's database were used to generate its ephemeris for coordinating follow-up observations. Two parameters were notably calculated for subsequent RDS observations: drift-scanning speed and camera rotation angle.

Follow-up observations and data reduction of 2021 CA_6 were carried out as described in Pomazan et al., 2021, 2022. An example of one observation round is shown in Figure 2, including two CCD frames of field stars with a 2 s exposure, and one CCD frame of 2021 CA_6 (apparent magnitude: 17.2) whose exposure time is 60 s. A point-like image of 2021 CA_6 appears in the central panel of Figure 2, where all field stars trail owing to the long exposure. Another two auxiliary frames in the right and left panel of Figure 2 provided the information of field stars for the RDS astrometric reduction.

Up to now, 66 total positions of 2021 CA_6 exist in the MPC database†, among which 22 were obtained at the LiShan Observatory on 2021 February 13. For convenience, all observed data were split into three data sets according to the observing period and observatory: DS1. observations before 2021 February 13.1 (UTC) when the apparent velocity of the NEA is smaller than $2''\!.0\,\mathrm{s}^{-1}$; DS2. observations from the ATLAS-MLO, Haleakala and Mauna Loa (MPC code: T05 and T08) after 2021 February 13.1 (UTC); DS3. observations from the LiShan observatory. In Figure 3, all astrometric data are distributed along the line of velocity-distance relation. As this asteroid was close to the Earth, its apparent velocity became very high. This moment was recorded by the 0.5 m telescopes at the ATLAS-MLO, Hawaii and ours.

The orbit of 2021 CA_6 was determined based on all Earth-based optical observations. The residuals between the observed and calculated (O-C) values in right ascension and declination are present in Figure 4. For the observations acquired at the LiShan Observatory, mean values of the (O-C) differences with their standard deviations in right ascension and declination are $0''\!.00\pm0.27$ and $0''\!.08\pm0.19$ respectively. As is apparent in Figure 4, these RDS observations are of high precision, unaffected by the influence of high apparent velocity.

† `https://minorplanetcenter.net/tmp/2021_CA6.txt`

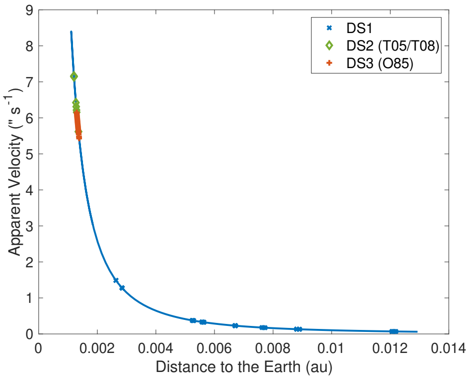

Figure 3. Distribution of the 2021 CA_6 observations which follow the line of velocity-distance relation. DS1, DS2, DS3 are presented in blue x-marks, green diamonds, and red crosses separately.

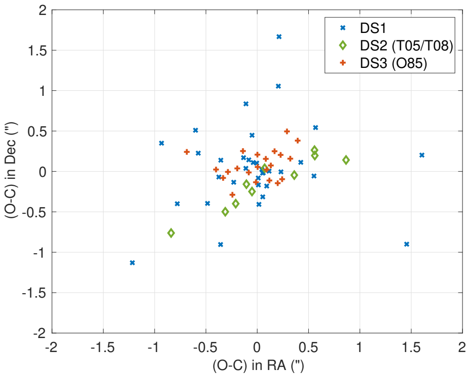

Figure 4. Distribution of the (O-C) residuals in right ascension and declination for the 2021 CA_6 observations. DS1, DS2, DS3 are presented in blue x-marks, green diamonds, and red crosses respectively.

3. Conclusion

The goal of current research is to obtain precise astrometric positions of NEAs during their close approaches to the Earth. The RDS technique was introduced to conduct precise positional measurements of fast-moving NEAs, involving the equipment upgrade, observation procedure, and data reduction. A camera is mounted on the rotation platform which is fixed on a telescope and NEAs are observed in the TDI mode. The following astrometric reduction of the RDS data relies on three CCD frames —— two frames of field stars sandwich a frame of the target object.

A newly discovered NEA 2021 CA_6 was observed at the LiShan observatory employing the RDS technique. We fit its integrated orbits to all observations including these RDS data. The mean values and standard deviations of the residuals for the RDS observations in right ascension and declination are $0''.00\pm0.27$ and $0''.08\pm0.19$ respectively. Competitive precision results can be achieved with the RDS technique.

The RDS technique is a promising approach to the problem of observing fast-moving NEAs with long exposure times. With this technique, more follow-up observations of NEAs could be performed to acquire precise astrometric positions and assist the orbit refinement. The network of small-aperture telescopes equipped with cameras supporting the TDI mode would substantially benefit the global NEAs monitoring system.

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