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# Precise astrometry of Near-Earth-Object with Rotating-Drift-Scan CCD

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**Abstract.** The principle of a new technology called rotating-drift-scan CCD is presented. Observational results of Near-Earth-Objects with this technology are given.

**Key words.** Instrumentation: detectors – Minor planets, asteroids: general

## 1. Introduction

Near-Earth objects (NEOs) are Solar System objects whose orbits bring them into proximity with the Earth. All NEOs have a closest approach to the Sun (perihelion) of less than 1.3 au (Morbidelli et al. 2002). It is now widely accepted that collisions in the past have had a significant role in shaping the geological and biological history of our planet. NEOs have become of increased interest since the 1980s because of increased awareness of the potential danger some of the asteroids or comets pose to Earth, and active mitigations are being researched.

Since the motion speed of NEOs are quite different from that of stars (few tens of arcseconds per minute), especially when they are close to the Earth, it is impossible to track both NEOs and the field stars together in the same CCD frame.

For a normal CCD on an optical telescope, after the exposure is finished and the shutter closed, charges of all pixels are read out pixel by pixel with the help of a continuously changing of voltage of each pixel to transfer charges from one pixel to the next pixel, and then stored in memory of computer. Drift-scan CCD, also called 'time delay integration (TDI)' CCD (Gehrels et al. 1990), is an imaging technique which accumulates charges of one object during the exposure time with the speed of charge-transferring equal to the speed of the images of the object on the CCD, i.e. charge-tracking. Usually the telescope does not track the object when the CCD works on drift-scan mode. Drift-scan CCDs have been widely used on meridian circle telescopes for sky surveys and searching for asteroids.

## 2. Basic idea of rotating drift-scan CCDs

Normal drift-scan observing is often used to survey the sky to get images of stars in the drift-scan mode at the apparent sidereal rate. Considering the fast motion speed of NEOs, simple drift-scan CCD can not be used to observe such objects directly. The initial idea

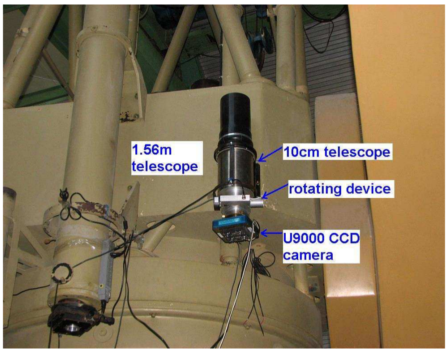


**Fig. 1.** The RDS-CCD prototype system mounted at SHAO.

of a new technology, called Rotating-Drift-Scan CCD (RDS-CCD) was presented in 2006 (Tang et al. 2006). After installing a drift-scan CCD camera on a rotating device to make the direction of pixel line parallel to the motion direction of the object, the CCD then works with drift-scan mode. Considering the directions of the motion of NEOs are usually close to those of the stars, drift-scan mode can be used to observe stars too, but with apparent sideral speed. Then circular images of stars will be obtained when the exposures are relative short (<10s).

The basic procedure of using RDS-CCD to observe NEOs is:

(I) Point telescope to the object and rotate CCD camera to make its charge transfer line parallel to the predicted direction of the object's motion, then stop motors of the telescope.
(II) Make shorter exposures under drift-scan mode with apparent sideral speed to image the stars.
(III) Expose CCD in drift-scan mode at the speed of the target untill the stars disappeared from the CCD fields.
(IV) Make shorter exposures under drift-scan mode with apparent sideral speed to image the stars again.
(V) Point the telescope to the another direction of the object and rotate CCD camera, repeating steps (I) (IV) again till the object can not be observed.

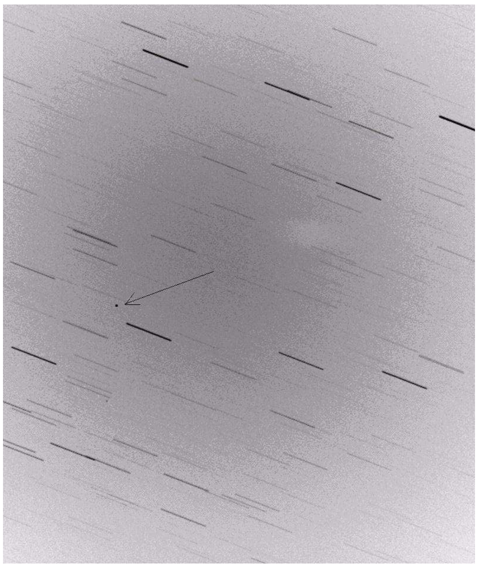

**Fig. 2.** Sample image of one GPS satellite got from RDS-CCD prototype system in Shanghai.

Since the telescope keeps stable from step (I) to step (IV), during one round of observation, the plate model parameters remain unchanged during this time interval, i.e. each pixel of CCD points to the same direction in the sky.

The steps for data reduction of rotating-drift-scan CCDs are:

(A) Using reference catalogue and Earth Orientation Parameters to calculate azimuth and elevation of stars and their ideal coordinates on CCDs, measured coordinates of stars in the CCD frames obtained in step (II) and (IV).
(B) Calculate the plate model parameters.
(C) Input measured coordinates of the object to the plate model to calculate the coordinates of the object and then get its azimuth and elevation.

The advantages of RDS-CCD are:

(1) Precise astrometry and photometry of targets can be obtained, since images of both objects and reference stars are circular.

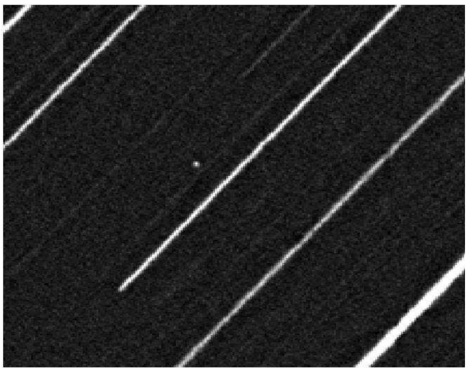

**Fig. 3.** Image of NEO 2012LJ from RDS-CCD on NAO telescope. The distance is 0.005au, speed is 306”/min, exposure is 120s.

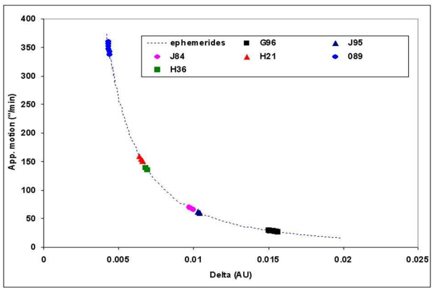


**Fig. 4.** Observational information of NEO 2012LJ got from RDS-CCDs of NAO telescopes and other authors. G96: Mt. Lemmon Survey. J95: Great Shefford. J84: South Observatory, Clanfield. H36: Sandlot Observatory, Scranton. H21: Astronomical Research Observatory, Westfield. O89: NAO

While with normal CCD readout, when the telescope tracks the object with different speed of reference stars, the accuracy of centers of stars will be 3-5 times worse than those got from RDS CCD.

(2) No need of a precise orbit prediction. Since the motors of the telescope were stopped, and drift-scan mode was continuously carried out, when the object will appear in CCD is not important, which means the position prediction can be less precise.

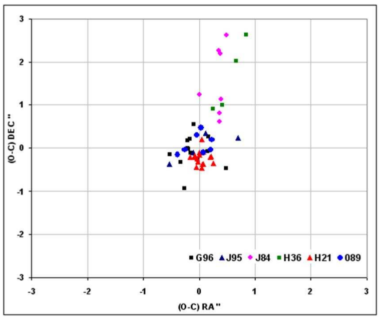


**Fig. 5.** Positional error of NEO 2012LJ got from RDS-CCDs of NAO (circular spots) telescopes and other authors.

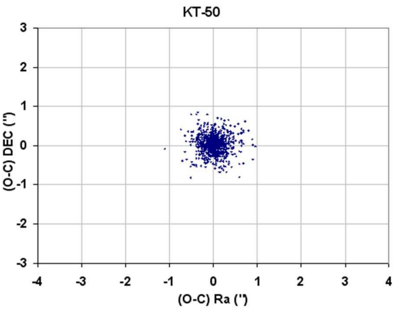


**Fig. 6.** Positional error of 1139 observations of 70 NEOs got from RDS-CCDs of NAO telescope.

(3) Long exposure time can be realized with a bigger field of view when observing faint objects. Since time of drift-scan can be prolonged when the field of view is larger.

### 2.1. Observational results of NEOs with RDS-CCDs

During 2007-2008, the prototype RDS-CCD system in Figure 1 was developed in collaboration between the Shanghai Astronomical Observatory (SHAO) and the Research Institute Nikolaev Astronomical Observatory (NAO). It has been used to observe some middle and low orbit satellites of the Earth.

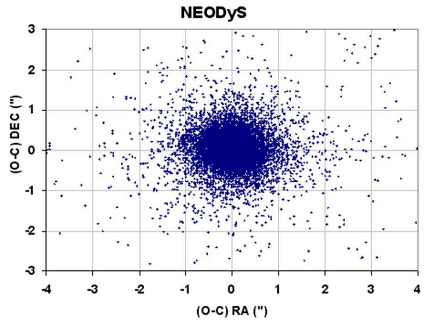


**Fig. 7.** Positional error of 20571 observations of 70 NEOs got from NEODyS website.

The basic parameters of the prototype system are:

Telescope: D=10cm, F=50cm, Mount: 1.56m telescope of Sheshan station of SHAO.
CCD: Apogee U9000, pixel number: 3K*3K, pixel size: 12um*12um.
FOV: 4 deg * 4 deg.

In Figure 2 we show the observation of a GPS satellite, indicated by the arrow, using the SHAO RDS-CCD prototype system. The telescope is fixed and the moving object is kept fixed by charge tracking while the stars show the difference between the siderial motion and the drift scanning.

Figure 3 shows one image of the asteroid NEO 2012LJ using a RDS-CCD mounted on a 50cm telescope at NAO. NEO 2012LJ was observed at various distances from the earth using RDS-DDCs at different telescopes as shown in the caption of Figure 4. The moton slows with distance from the Earth as expected and we estimated a trajectory over the whole campaign. In figure 5 we plot the residuals at the different campaigns using the same smybols as figure 4.

Finally in Figure 6 we plot the positional errors for 1139 observations of 70 NEOs from RDS-CCD of NAO and in Figure 7 for 20571 observations of 70 NEOs from the NEODyS website. The sigmas of the two distributions are 0".2 and 0".4 respectively.

## 3. Conclusions

Preliminary results show that RDS-CCD works well on precise astrometry and photometry of fast moving NEOs objects on Earth orbits. Such technology can also be used to observe the Gaia satellite to get better positions and velocities of Gaia, which are important to calculate the orbit of the satellite and directly impact the determination of the abberation and the parallaxes of solar system asteriods.

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## References

Gehrels, T., et al. 1990, ASPC, 8, 51

Morbidelli, A., et al. 2002, in Asteroids III, eds. W. F. J. Bottke, A. Cellino, P. Paolicchi, & R. P. Binzel (Univ. of Arizona Press, Tucson), 409

Tang Z. H., Pinigin G., Shulga A. 2006, Proceedings of the international scientific conference "Enlargement of Collaboration in Ground-Based Astronomical Research in SEE Countries. Studies of the Near-Earth and Small Bodies of the Solar System". Nikolaev, September 25-28, 2006, p. 184-191