Survey Observations of Geosynchronous Orbit Objects and Short-Term Variability Observations Using the Time-Delay Integration Method

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The "Time-Delay Integration (TDI)" method is an electronic scan technique which captures the image of a moving object across the field of view. In this case an exposure is made by shifting electrical charge while a mechanical shutter is open. To make the electronic scan, the CCD parallel registers (the CCD columns) are precisely oriented in the direction of the moving object and the clocking rate of parallel charge transfer must be synchronized to the motion of the object. In its simplest use in astronomy, the parallel transfer rate is tuned to sidereal rate, so that the charge is moving across the CCD at the same rate as the sky moving across the field of view, when the telescope tracking is turned off. This technique was used to perform the Sloan Digital Sky Survey [1] and many other digital sky surveys.

In contrast to this method, the TDI technique can be applied backwards in case of detecting geosynchronous Earth orbit objects [2,3]. In this manner, the CCD chip is aligned such that its parallel registers are oriented in the East-West direction but turned 180°. The telescope tracks at sidereal rate and the charge on the CCD is shifted in reverse, also at the sidereal rate. The two sidereal rates cancelled each other and the effect of Earth rotation is removed.

To synchronize the parallel charge transfer rate to the motion of the object, charge transfer timing can be set by editing a clock pattern description file. For an object drifting northward or southward, its drift motion can be canceled by adjusting the mount position angle of the CCD, e.g., by using the mechanical Cassegrain instrument rotator [3].

We also propose a new application method of getting short-term light curves with TDI mode. When the stationary object is observed in TDI mode, it is imaged as a streak. The light curve is easy to extract from the streak, because the streak is sure to be horizontal. We applied this technique to observe short-term light curves of space debris, with the telescope drive at the "track rate" (object-tracking) mode [3].

Figure 1 shows an example of the extraction of the light curve of a geosynchronous object. Light curves of the reference stars can also be extracted from the image and used to correct the short-term variation in atmospheric conditions. The time resolution can be adjusted suitably according to the brightness and the variable period of the object. This method of detecting a short-term variability can be applied for a variety of objects such as stars, solar system bodies, geosynchronous orbit objects, and low Earth orbit objects. It can also be used for the light-curve observations of transient objects which might show short-term variability and of which the precise time information is needed.

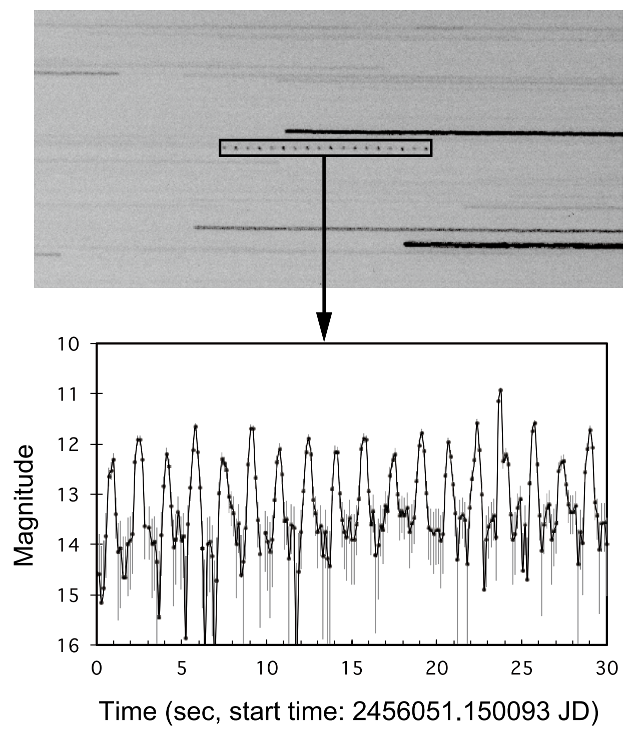

Figure 1: Example of the extraction of the light curve of a geosynchronous object. Upper: close-up of a TDI image obtained with a 30-s exposure, lower: light curve of the object, extracted from the upper image. Sampling interval is 0.14 sec.

References

[1] Gunn, J. E., et al.: 1998, *AJ*, **116**, 3040.
[2] Gehrels, T.: 1991, *Space Sci. Rev.*, **58**, 347.
[3] Okumura, S., et al.: 2014, *PASJ*, **66**, 115.