F1

TDI モードを応用したデブリの短周期ライトカーブ観測

Short-period light-curve observations of space debris using TDI technique

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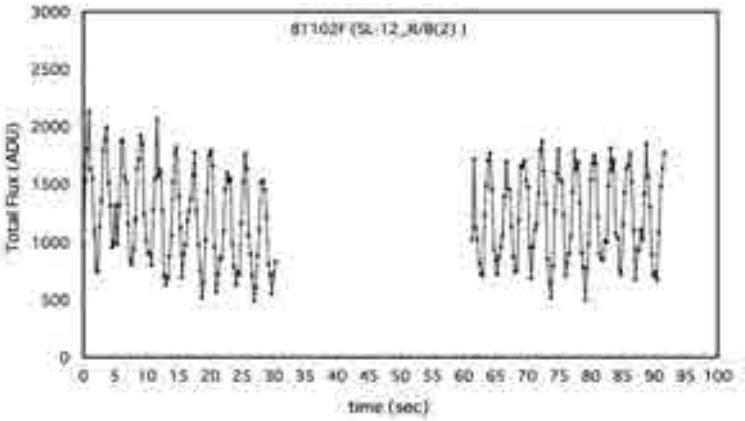
TDI(Time Delay Integration)モードを応用した、スペースデブリの短周期ライトカーブ観測の例を紹介する。TDI モードとはシャッターを開けた状態で電荷転送をするような CCD の読み出し手法であり、通常は視野の中で移動する物体を点状に撮像するために利用される。ここでは発想を転換し、スペースデブリの動きに合わせて望遠鏡を駆動させ、視野の中で止まった状態にして TDI で読み出すことにより電荷転送方向にのびた星像を人工的に作りだし、そのプロファイルから短時間における光度変化をとらえることを試みた。81102F(ロケットボディ SL-12)の短時間ライトカーブ(図)など、デブリや運用中の衛星のライトカーブ観測結果について他の撮影手法と比較しながら紹介する。

I present the method and the examples of light-curve observations of space debris, using TDI (Time Delay Integration) technique. TDI mode is a readout technique of shifting the charge on the CCD while the shutter is open. It is usually applied to the moving objects with the expected motion, so that they appear as point sources. I tried to apply the TDI method to non-moving objects to derive their short-period light-curves. The advantage of the method and the result of the test observations will be presented here.



5th space debris workshop

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(Japan Spaceguard Association)

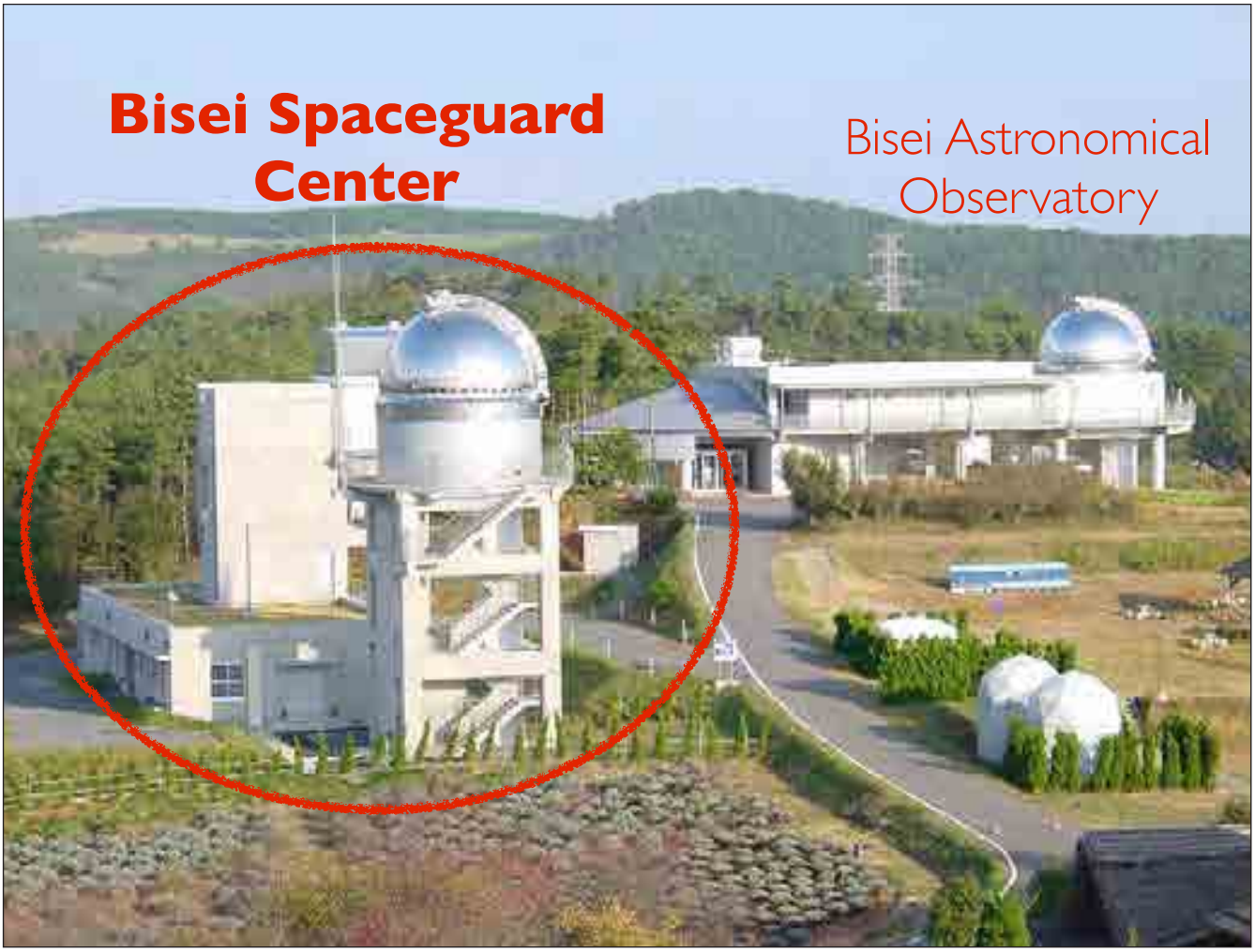
CONTENTS

- Introduction about Bisei Spaceguard Center and our Instruments
- about TDI mode
- Light-curve Observations using TDI mode and its advantages
- Examples of our observations

Okayama prefecture

Bisei Spaceguard Center

Bisei Astronomical Observatory



1m-telescope

- Equatorial fork mount
- Classical Cassegrain, focal length=3000mm (F/3), with five correcting lenses
- Field of view: 1.2°×2.3°

INSTRUMENT
(MOSAIC CCD CAMERA "VOLANTE")

- Detector： Hamamatsu 2k×4k back-illuminated, fully depleted CCD ×4
- Control： Mfront2 (front end), MESSIA-V (back end)
  (developed by National Astronomical Observatory of Japan)

we can customize its clock pattern
the camera is widely applicable
(usages such as TDI mode, etc., „„)

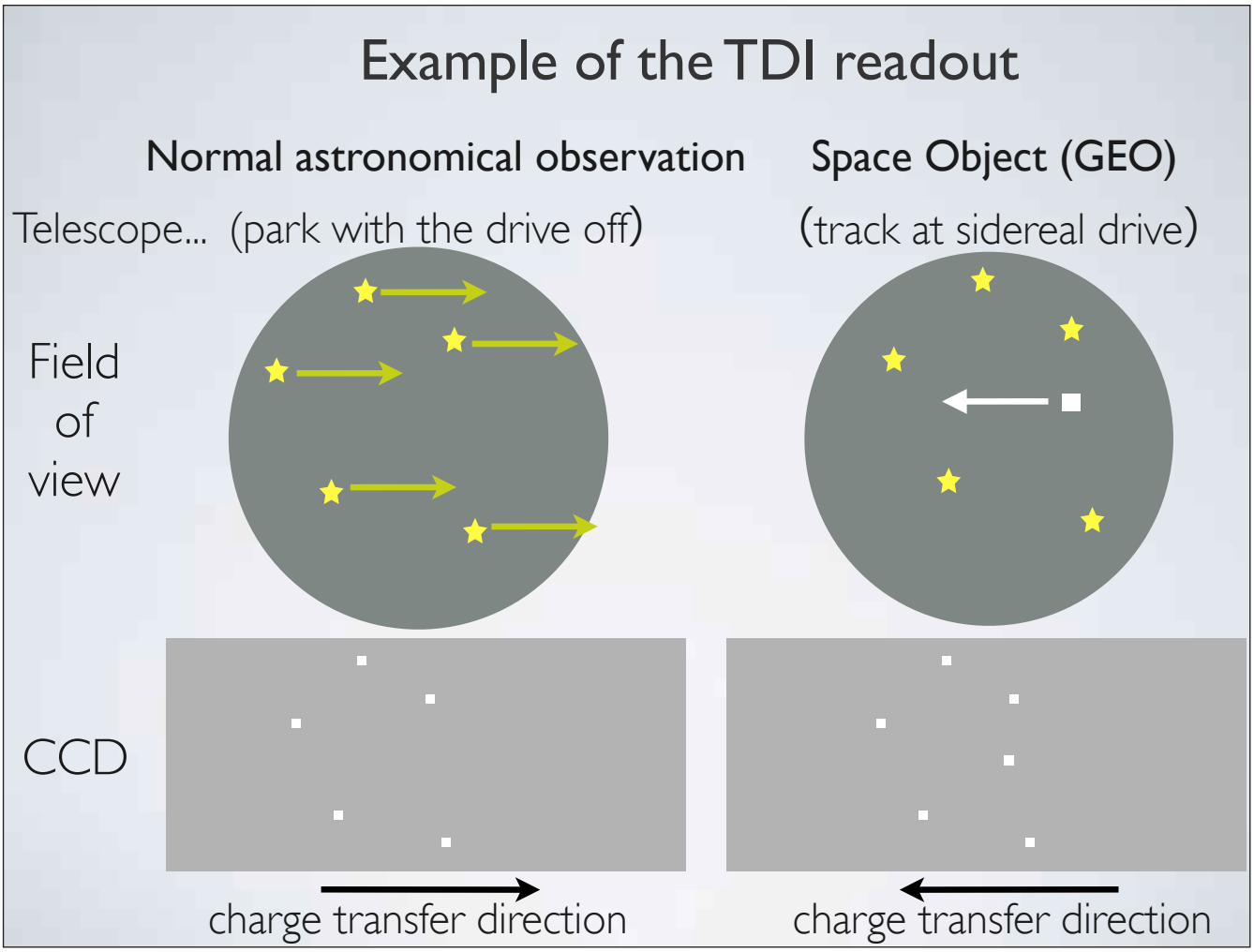
MAIN OBJECTS

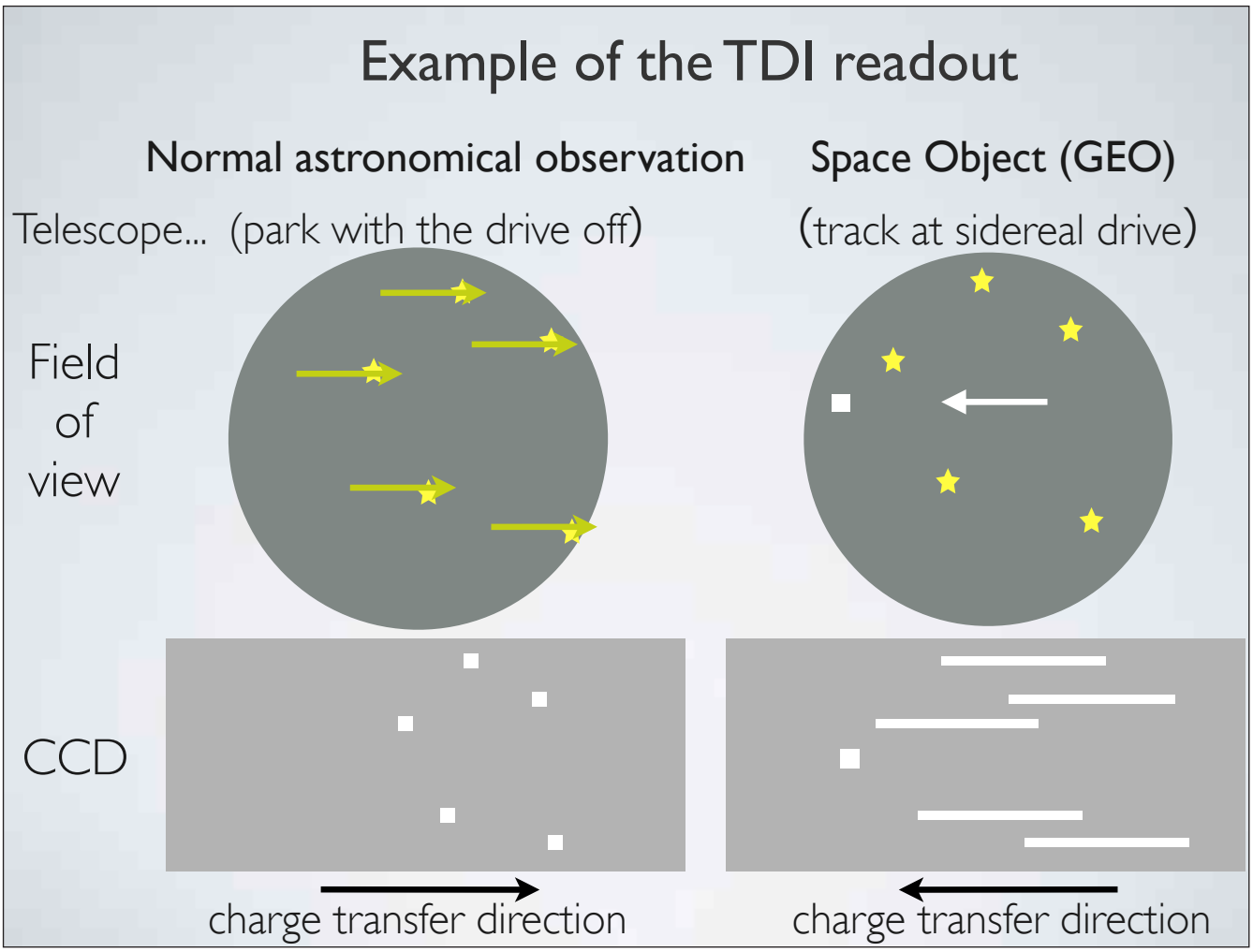
- Astrometry for space objects and space debris
- Discovery and confirmatory follow-up observations of Near Earth Objects
- Research observations of asteroids and space objects

TDI MODE

- Normal exposure on CCD
  …readout (charge transfer) after exposure (after shutter closing)
- TDI
  …shifting the charge on the CCD while the shutter is open

  It is usually applied to the moving objects with the expected motion, so that they appear as point sources on the readout image



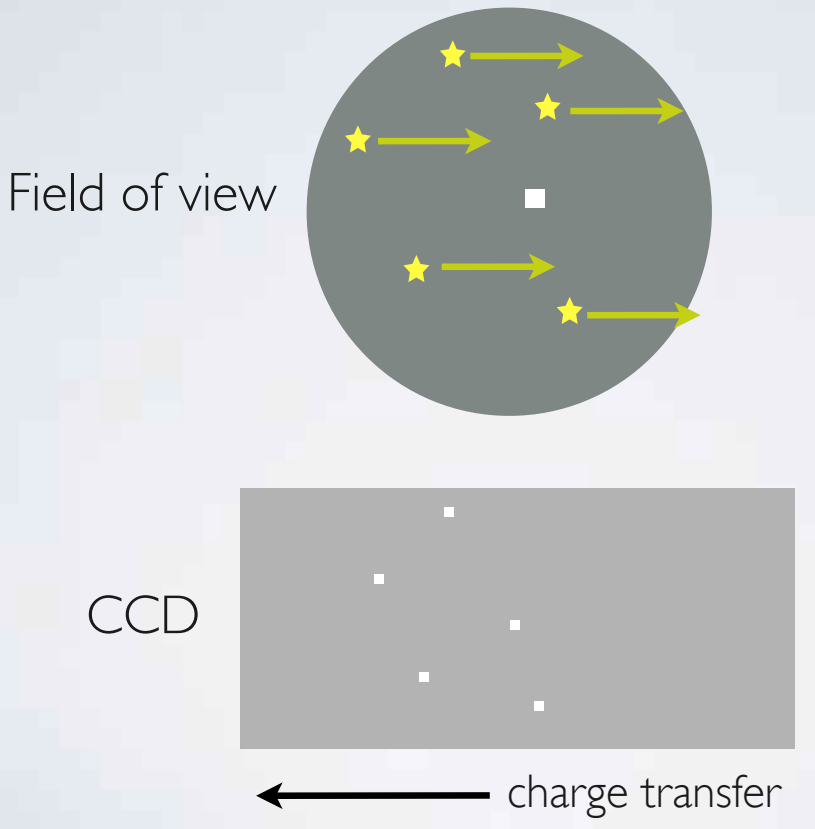


• TDI・・・a technique to image moving objects

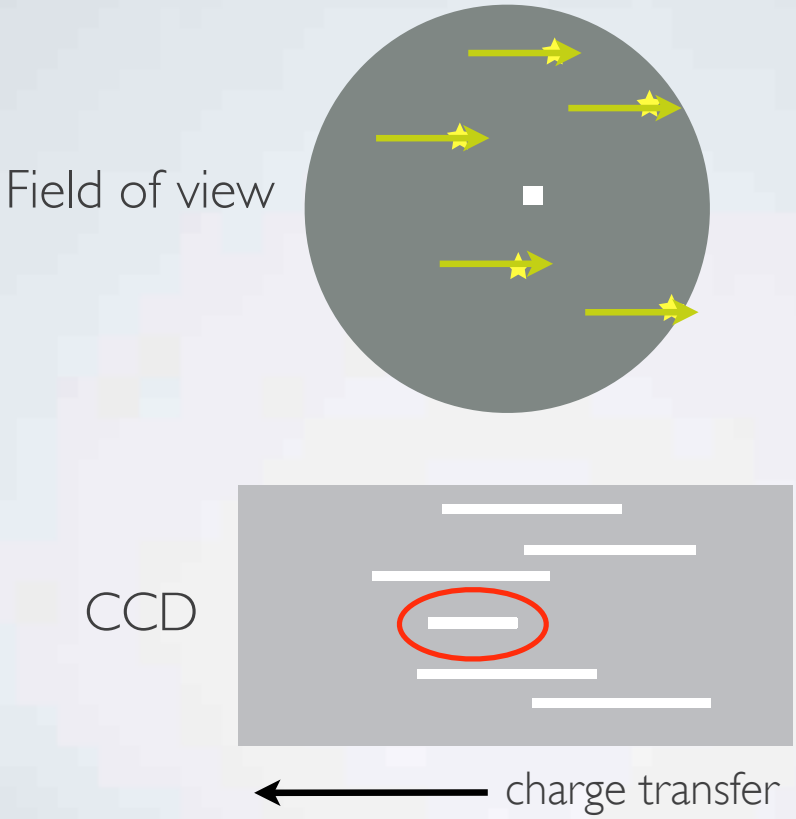
↓

Are there any advantages
in applying the technique for the objects which
stands still at a point in a field of view ??

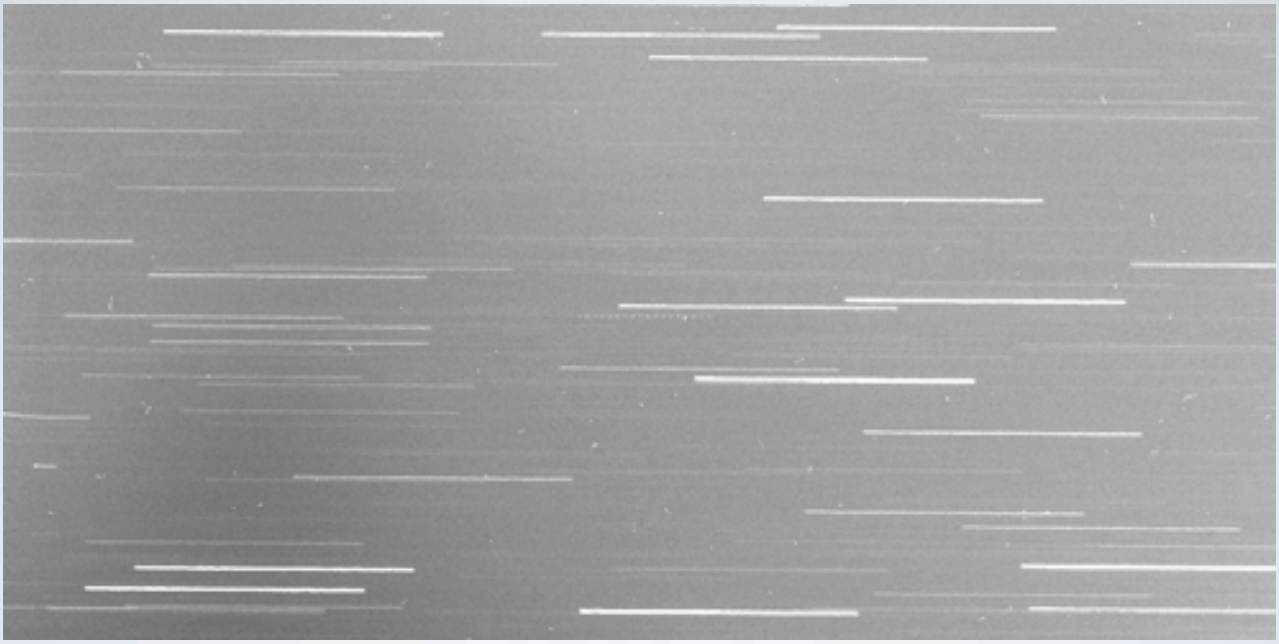
(telescope is tracking for a space object)



(telescope is tracking for a space object)

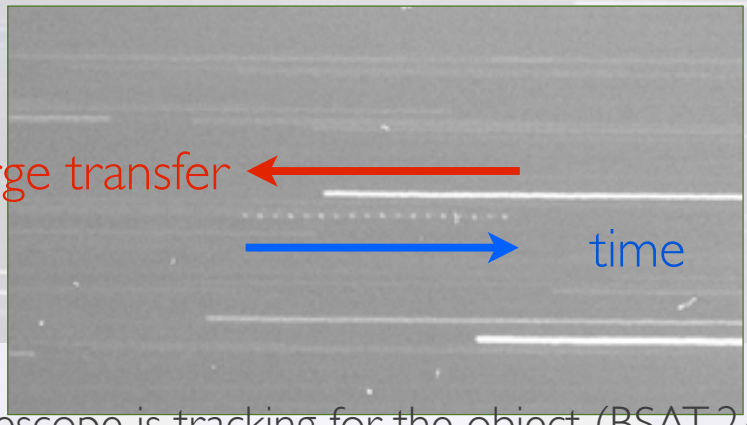


BSAT-2A



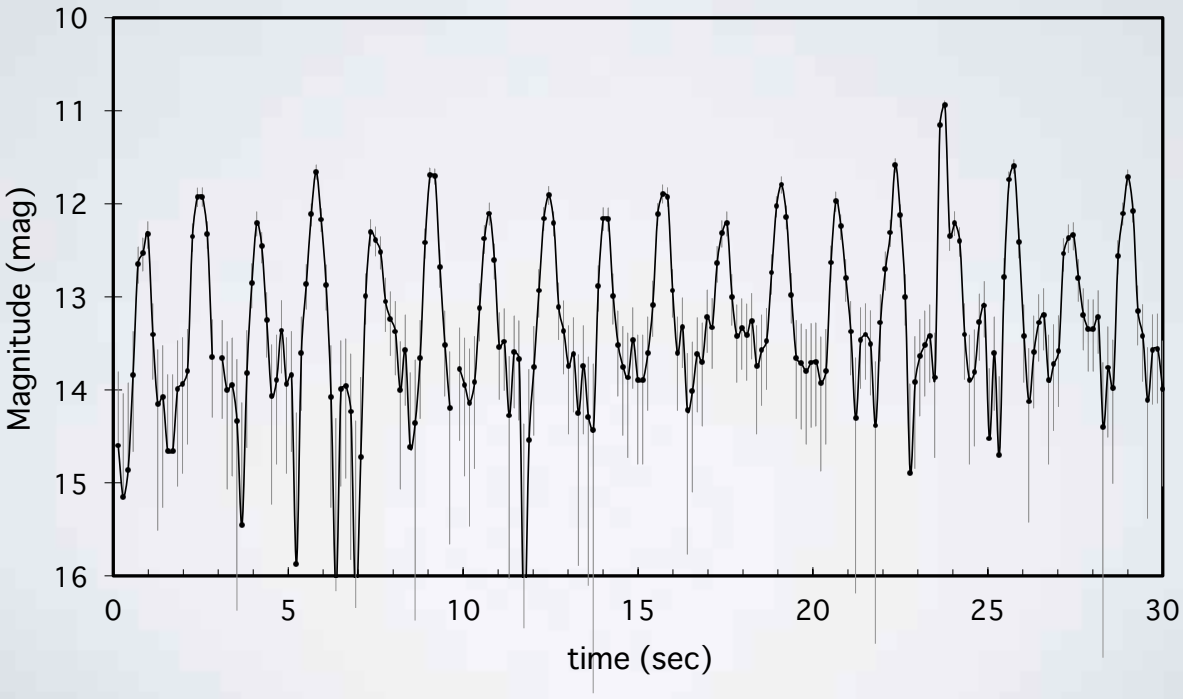
telescope is tracking for the object (BSAT-2A),
and 30-seconds exposure for TDI mode

BSAT-2A

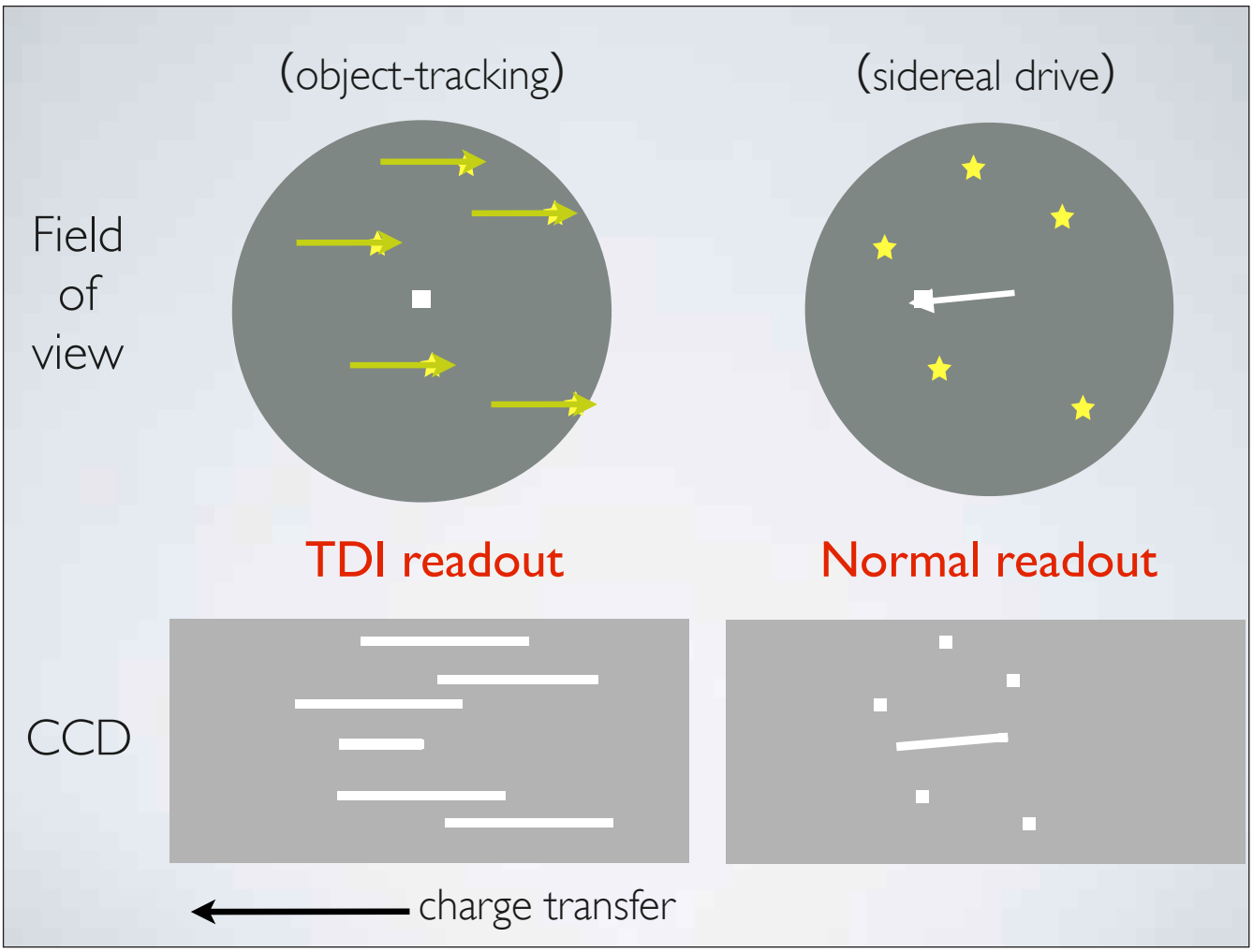


telescope is tracking for the object (BSAT-2A),
and 30-seconds exposure for TDI mode

BSAT-2A



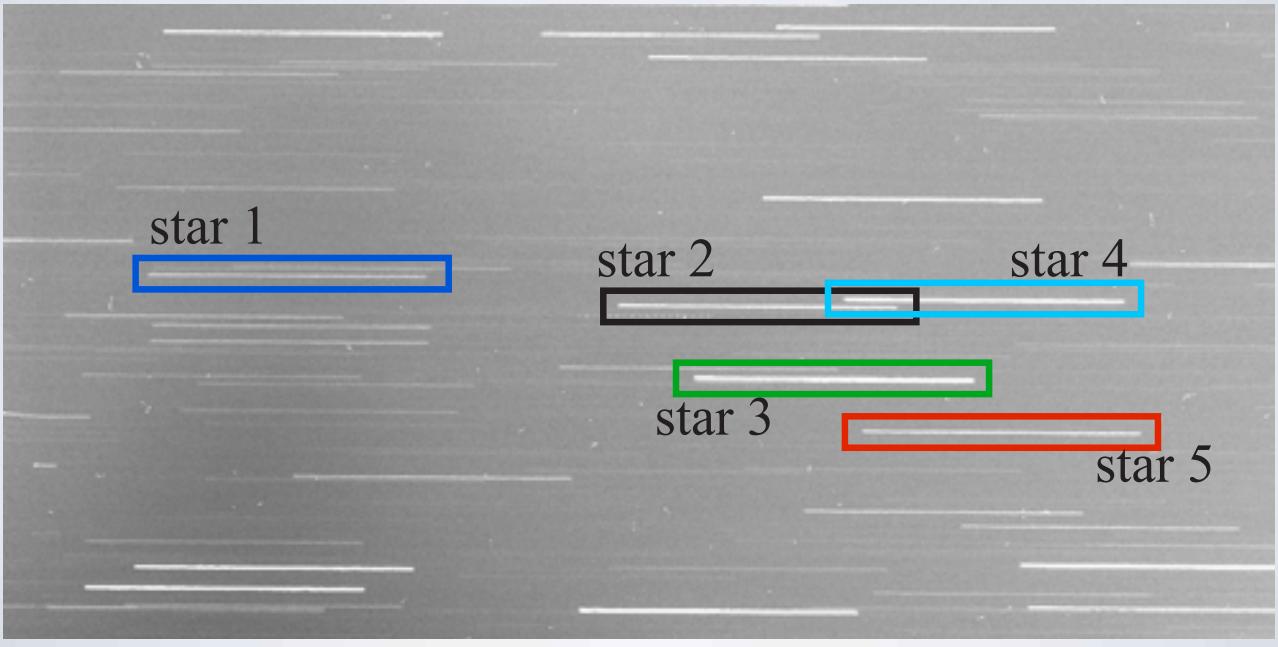
Comparison with other methods



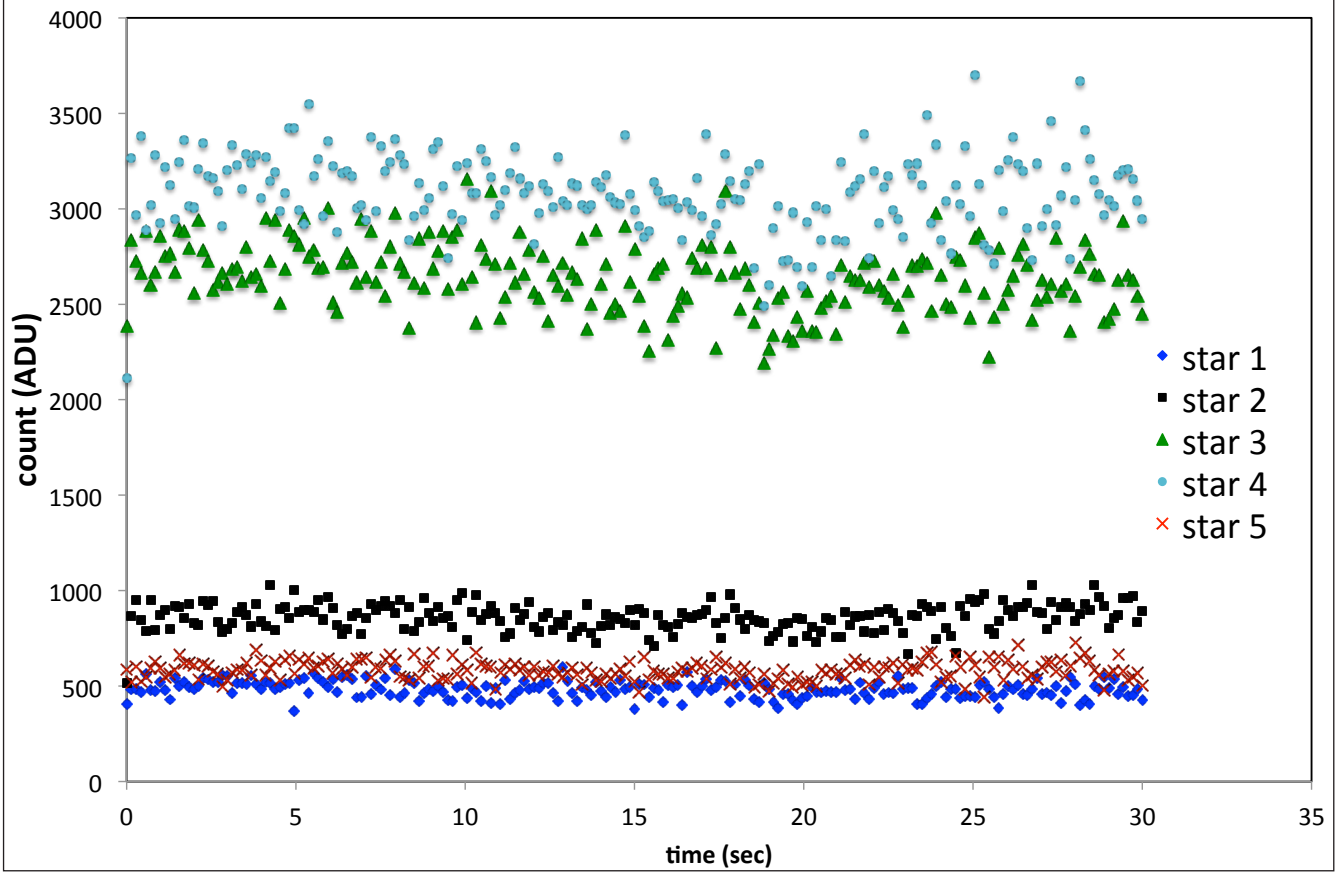
Advantages in using TDI mode
(compared with the sidereal-drive mode)

- variable sampling interval is available by the adjustment of charge transfer timing
- variability of atmospheric transmittance and photometric error can be estimated with referring the trailed image of background stars
- object is continuously in one field of view
- trailed image of the object always horizontally stretched on the CCD
- It can be applied to the observations of not only GEO objects, but Low Earth Orbit Objects, in case that the telescope can track the objects

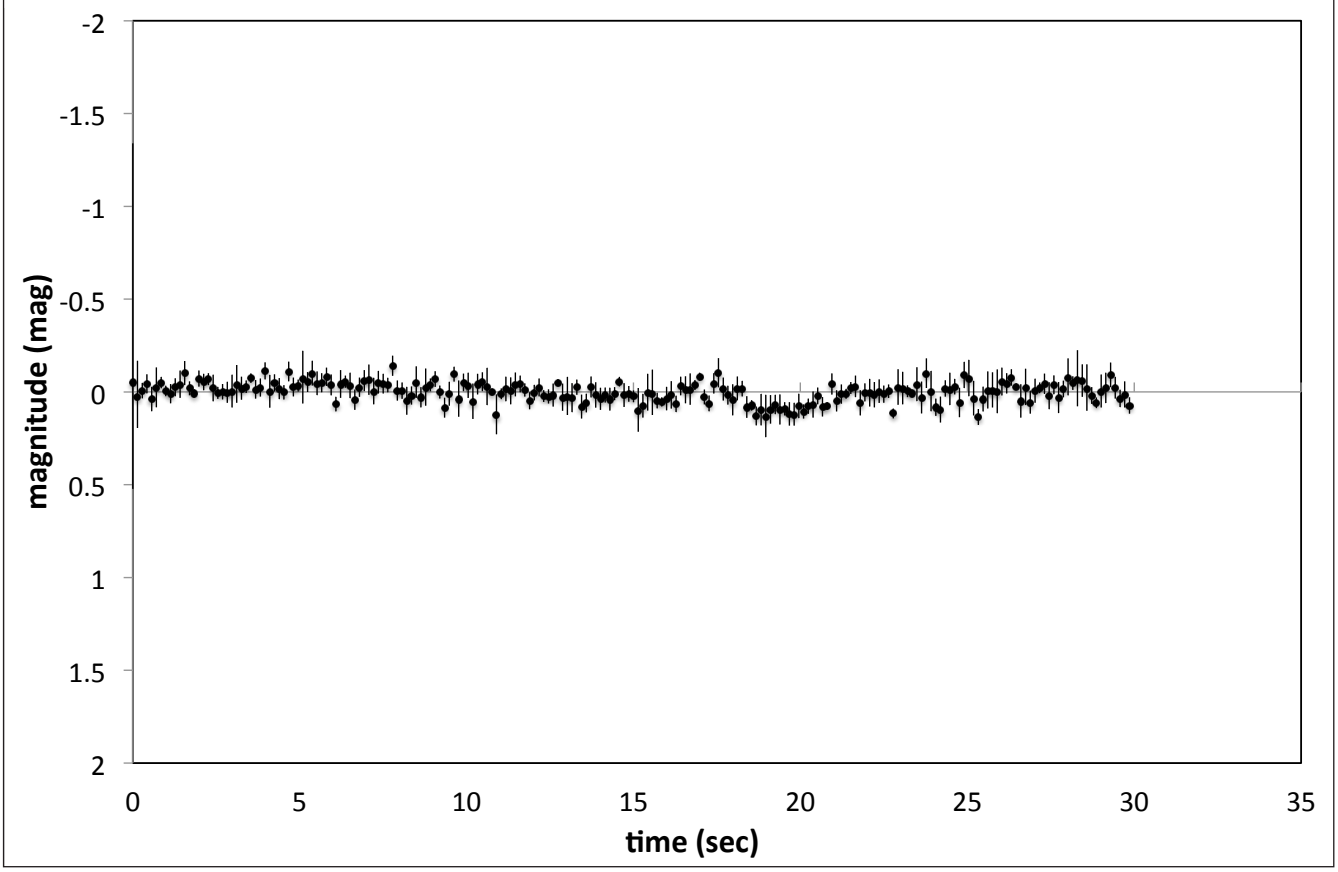
Estimation of the variability of atmospheric transmittance and photometric error



Flux variability of the reference stars



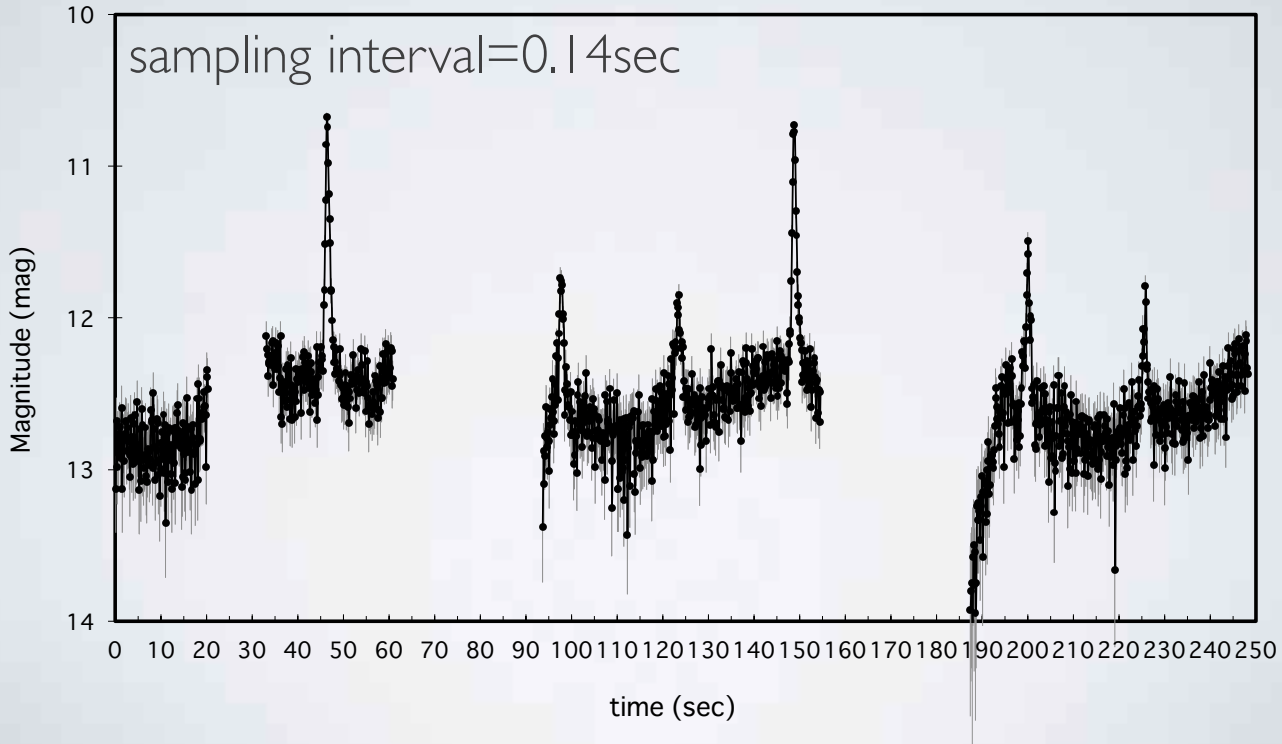
Flux variability and photometric error



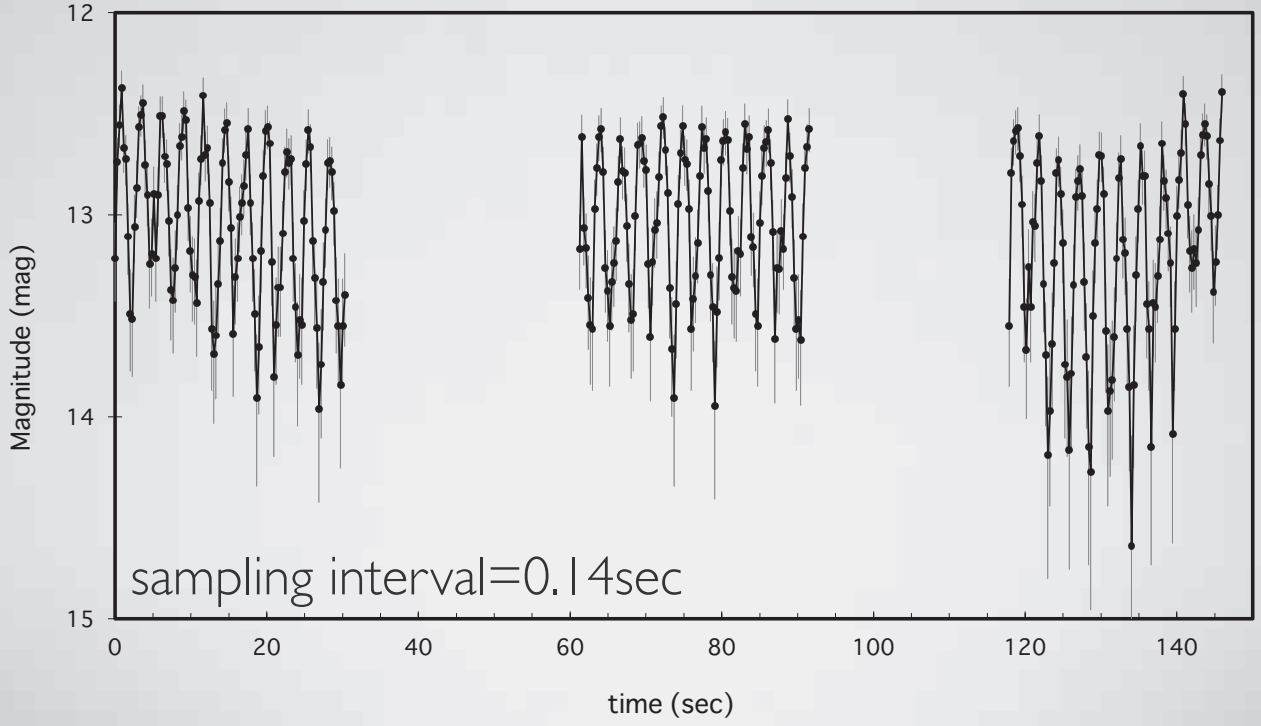
Limiting Magnitude
(BSGC 1m telescope, S/N=10)

exposure	sampling interval (charge-transfer timing)		
	1 sec	0.1415 sec	0.028 sec
30 sec	14.9 mag	12.8 mag	11.0 mag
5 sec	15.9 mag	13.8 mag	12.0 mag
1 sec	16.7 mag	14.6 mag	12.8 mag

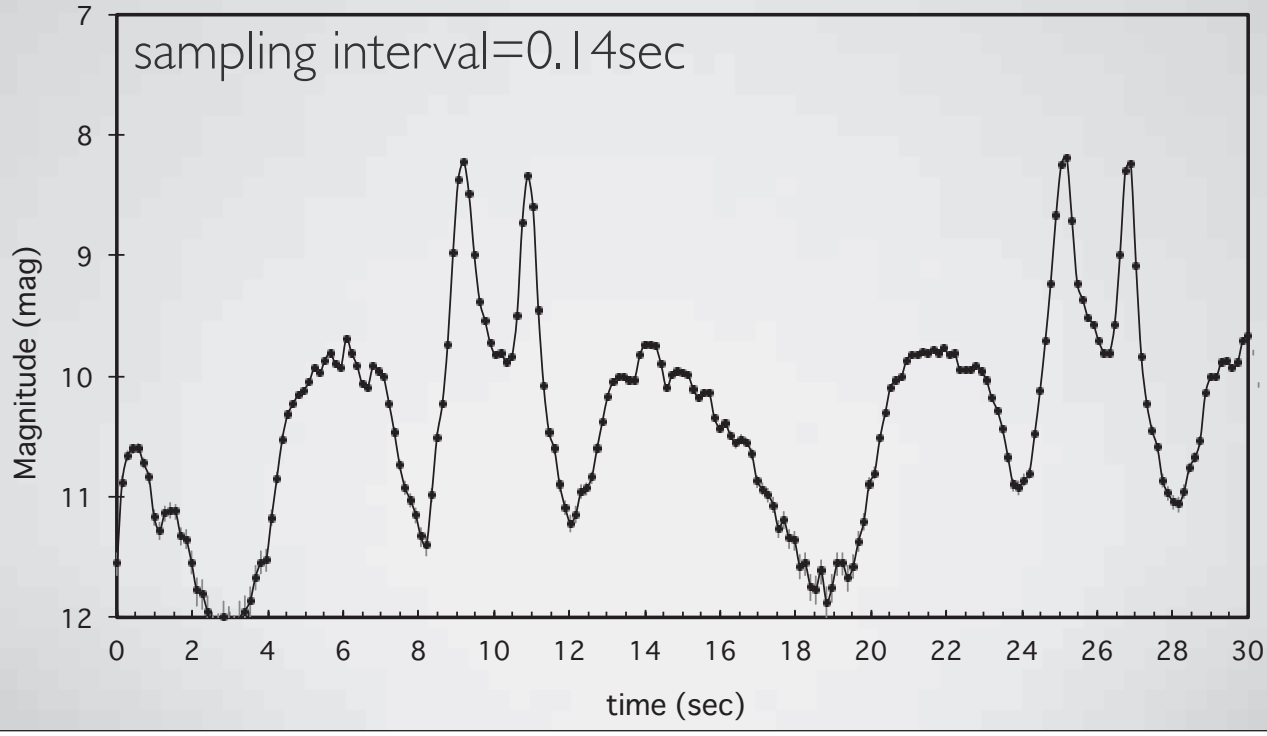
EXAMPLE：GORIZONT 33



EXAMPLE：
ROCKET BODY（SL-12_R/B(2)）



EXAMPLE:
H-2A R/B (WINDS/KIZUNA)



SUMMARY

★Details of the TDI-mode readout
and its applications to the observation of space objects,
especially short-period light curve observations

★Advantages of the TDI mode
in short-period light curve observations

- variable timing sampling rate
- flux variability (atmospheric transmission) and photometric error can be corrected
- object is continuously in one field of view
- "trailed image" of the object always horizontally stretched
- applicable to the observations of not only GEO objects, but Low Earth Orbit objects