P02

木曽超広視野高速 CMOS カメラ Tomo-e Gozen の開発 --- 広視野動画観測によるスペースデブリの観測的研究への貢献

Development of the Kiso Extremely Wide-Field CMOS Camera: Tomo-e Gozen --- Investigation of Space Debris with Wide-Field Movie Observations

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Tomo-e Gozen は東京大学木曽観測所が開発中の次世代超広視野 CMOS カメラである. Tomo-e Gozen は 84 枚の CMOS センサを用いておよそ 20 平方度の領域を 2 Hz でモニタリング可能な動画観測カメラである. 達成される限界等級はおよそ 18 等 (2 Hz) であり, スペースデブリを含む地球近傍を高速で運動する物体の観測に極めて有効である. 我々は 2015 年 12 月に 8 枚の CMOS センサからなる試験機を完成させ, これまで 3 回の試験観測を実施した. 本発表では試験観測の結果と Tomo-e Gozen によるスペースデブリ観測への貢献可能性について議論する.

The Tomo-e Gozen is a next-generation extremely wide-field CMOS camera being developed by Kiso Observatory of the University of Tokyo. The Tomo-e Gozen, equipped with 84 CMOCS sensors, continuously capture a sky as large as about 20-square-degree at 2 Hz. It will become the first astronomical movie camera for science. The limiting magnitude of the movie data at 2 Hz is estimated to be 18 magnitude in the V-band. The Tomo-e Gozen will provide unique opportunities to observe fast-moving objects, including space debris. A prototype of the Tomo-e Gozen with 8 CMOS sensors was developed in December 2015. Three experimental observational runs have been completed. In the presentation, the results of the experimental observations are shown and possible contributions to observations of space debris are discussed.

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木曽超広視野高速CMOSカメラ Tomo-e Gozen の開発 —広視野動画観測によるスペースデブリの観測的研究への貢献

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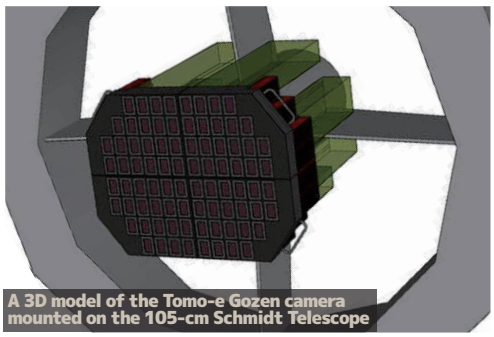
the Tomo-e Gozen camera

The Tomo-e Gozen is the first astronomical CMOS camera, which will be mounted on the 105-cm Schmidt Telescope in Kiso Observatory of the University of Tokyo. The Tomo-e Gozen can monitor a sky of about 20 sq-degree at 2 Hz, providing a great oppotunity to detect small and fast-moving objects. We present an overview of the Tomo-e Gozen project and describe the performance of the Tomo-e Gozen camera in the context of observing space debris, along with the observations with a prototype of the Tomo-e Gozen camera developed in 2015.

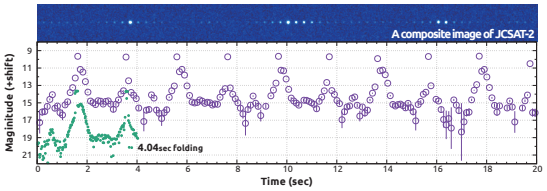
Telescope	Kiso 105cm Schmidt
Effective FOV	20deg^2 in Φ9deg circle
Detectors†	2160×1200 CMOS sensor
# of Detectors	84 chips
Pixel Scale	1.2 arcsec/pix
Data Size	380 MB/exposure
Frame Rate	2 Hz (max) Higher time resolution available by reducing the size of the field of view
Data Rate	27 TB/night (max)

†Operated at a room temperature and under a normal pressure



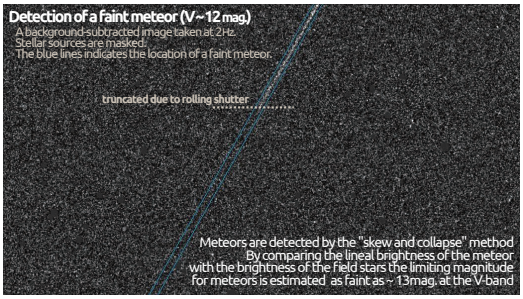
Video Photometry of Satellites (JCSAT-2)

The Tomo-e Gozen will provide a suitable data for photometry with a high time-resolution. JCSAT-2, a non-operating Japanese satellite, was observed with the prototype of the Tomo-e Gozen. The 10 Hz movie data provided a precise measurement of its rotational period and the existence of flashes.

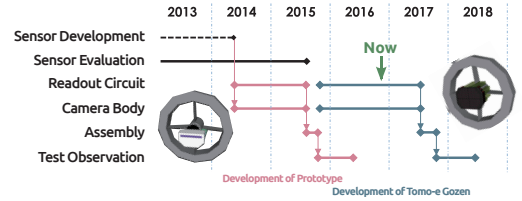


Detection of Faint Meteors

We have developed an algorithm to efficiently detect faint meteors (Ohsawa +, Proc. SPIE, 2016). Results of the test observations suggest that the Tomo-e Gozen can detect meteorsas faint as or fainter than V ~ 13mag.



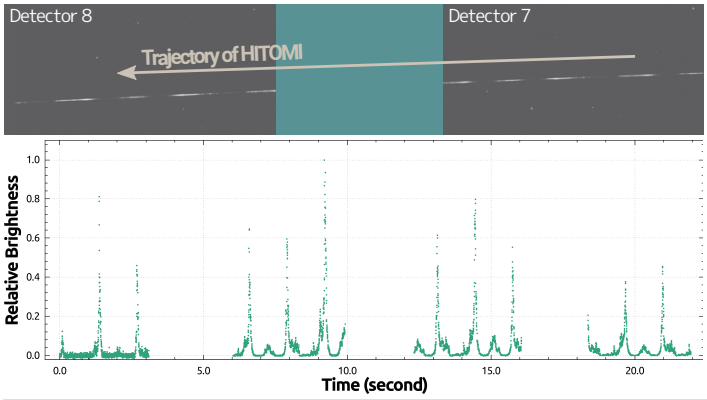
Schedule of the Tomo-e Gozen Project



Commissioning of Tomo-e Gozen is scheduled in 2017. We have developed a prototype of Tomo-e Gozen (Tomo-e PM, Sako+, Proc. SPIE, 2016). Development of Tomo-e PM is successfully completed in 2015.

Follow-up observation of HITOMI (astro-H)

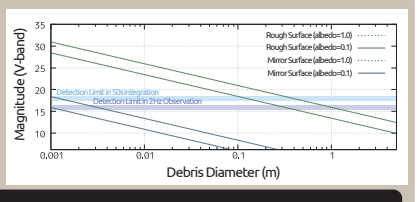
Kiso Observatory made observations of the X-ray Astronomy satellite "Hitomi" (astro-H) with the prototype of the Tomo-e Gozen in a cooperation with JAXA. The folowing pictures ware created from a 2 Hz movie obtianed on 2016-03-31. The upper panel shows the trajectory of "Hitomi". "Hitomi" moved with rapidly changing its brightness. The bottom panel shows the light curve of "Hitomi", indicating that the brightness of "Hitomi" was periodically changing with the period of about 5.2s.

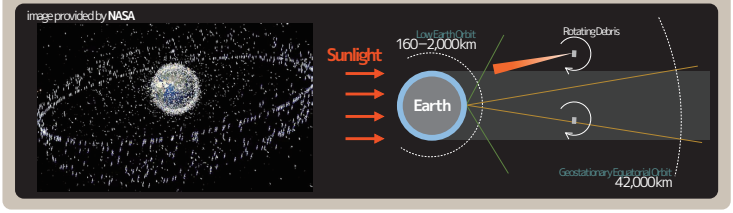


Observations of Debris with the Tomo-e Gozen

The Tomo-e Gozen will provide a great oppotunity to detect small debris around the Earth. The wide field-of-view of the Tomo-e Gozen will be beneficial in observations of debris in the low earth orbit. The sub-second time resolution is important to investigate the rotation of debris.

The figure below shows a rough estimate of the limiting magnitude of debris in the geostationary equatiorial orbit (GEO). It indicates that **the Tomo-e Gozen can detect 1m-size debris in the GEO** if a debris has a rough surface. If a debris has a mirror surface, **the Tomo-e Gozen can detect the debris which is smaller than 10mm as a flash-like object**. In the experimental observations with the prototype of the Tomo-e Gozen, several flash-like objects were detected. Large fraction of them are assumed to be small rotating debris in the GEO. The size distribution of the debris in the GEO can be revealed by observations with the Tomo-e Gozen.





This research is supported in part by JSPS Grants-in-Aid for Scientific Research (KAKENHI) Grant Number **JP25103502**, **JP26247074**, **24103001**, and **JP16H02158**. This research is also supported in part by **PRESTO**, Japan Science and Technology Agency (JST). This work was achieved using the grant of Joint Development Research by the Research Coordination Committee, National Astronomical Observatory of Japan (NAOJ). The fabrication of Tomo-e PM was conducted in collaboration with the Advanced Technology Center of NAOJ. This research was conducted using the **full-HD CMOS sensors** developed in collaboration with **Canon**.

the 7th Space Debris Workshop at JAXA, 2016.10.18–2016.10.20