High Cadence Photometry of the Tumbling Hitomi X-ray Satellite

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Abstract

Hitomi was a Japanese X-ray astronomy satellite launched February 17, 2016. After only about a month in orbit, the satellite experienced an anomaly and broke up into several pieces. Shortly afterwards, the spacecraft body was optically tracked and observed from Daytona Beach, Florida using the OSCOM system, originally designed for observation of small satellites. The brightness of the main piece, peaking between magnitude 2 and 3 in the SDSS r' band, allowed photometric measurements to be made at over 100 Hz for several passes of the satellite over the span of a month. Additionally, Hitomi was observed simultaneously from two sites 180 miles apart to provide two different look angles at the tumbling satellite. The high cadence measurements show a consistent flash pattern with a primary period of about 2.6 seconds. A Lomb-Scargle periodogram analysis of the photometry did not measure a meaningful change in the tumble rate of Hitomi between the beginning of April and May.

Hitomi

Hitomi, also known as ASTRO-H, is an X-ray astronomy satellite, shown below, operated by the Japan Aerospace Exploration Agency (JAXA). Only a month in orbit after its launch in late February 2016, the spacecraft experienced an anomaly which caused it to enter an uncontrollable spin. Shortly after communications were lost, the Joint Space Operations Center (JSpOC) detected 10 debris pieces in the vicinity of the main body. Initially, it was believed that an explosion within the satellite caused the breakup, but further analysis by JAXA suggests a faulty inertial reference unit gave an incorrect reading that the satellite attitude control system attempted to correct. The satellite eventually entered a real spin and exceeded the structural design limits for the solar arrays and extensible optical bench (EOD), which are believed to have separated from the satellite body. JAXA announced in late April that efforts to restore the satellite were ceased.

OSCOM

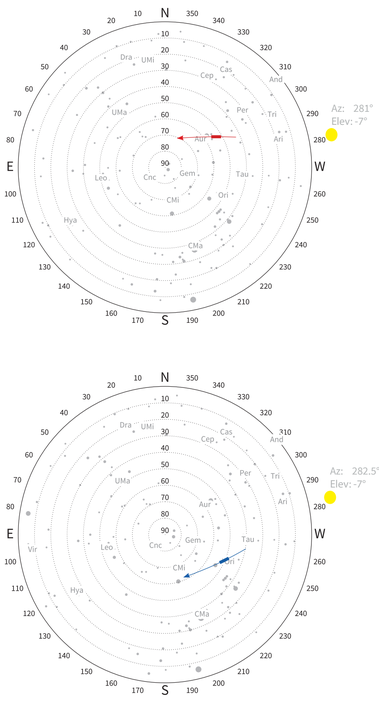
OSCOM is a system originally designed for observation of small satellites and space debris using commercial-off-the-shelf (COTS) hardware and custom analysis tools. To observe Hitomi, we used an 11 inch f/2.2 Rowe Ackermann Schmidt Astrograph (RASA) telescope made by Celestron and paired it with a CMOS machine vision camera made by Allied Vision (shown at right). All data presented here are in the SDSS r' filter. The telescope is mounted on a Paramount ME mount which tracks the satellite as it moves through the sky using custom control software. Aperture photometry is then performed on the resulting series of images. Although Hitomi and its debris did not fit into the category of small and dim space objects usually observed by OSCOM, its low magnitude meant it could be observed using short exposure times (~ 5 ms) and high cadence (~100 fps). These high frame rates allow OSCOM to resolve bright specular glints caused by sunlight reflecting off of different parts of the satellite as it rotates.

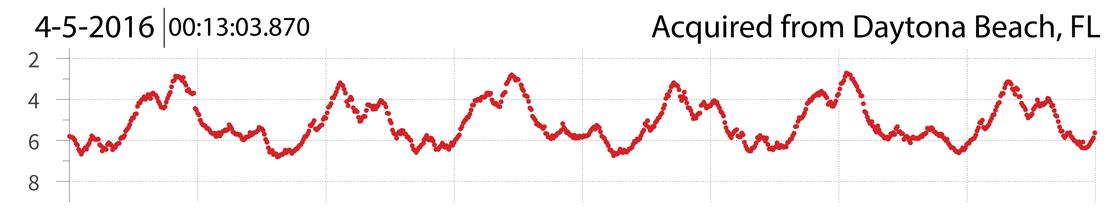
Lessons Learned & Future Work

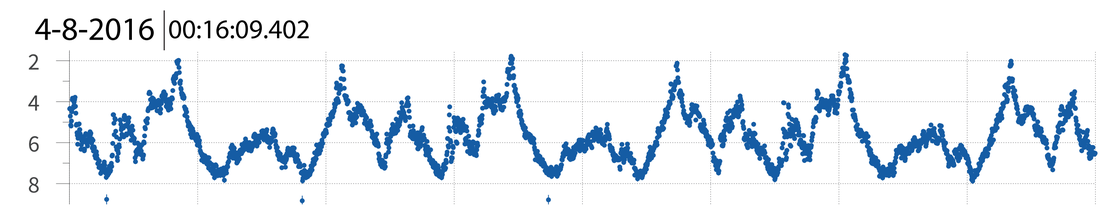
Light curves can be used to estimate satellite attitude if the shape of the satellite is known. Flat panels on a satellite, for example, will produce the brightest reflection when the surface normal is pointing halfway between the sun and observer. For complex or unknown shapes this problem is very difficult to solve. The attitude solution can be produced faster by observing the satellite from two different illumination geometries simultaneously. On May 7, we observed Hitomi using two identical OSCOM systems from 180 miles apart. The difference in the light curves are easily seen. Future work will focus on development of algorithms to estimate satellite attitude from multiple single-site or simultaneous multi-site observations of a known satellite.

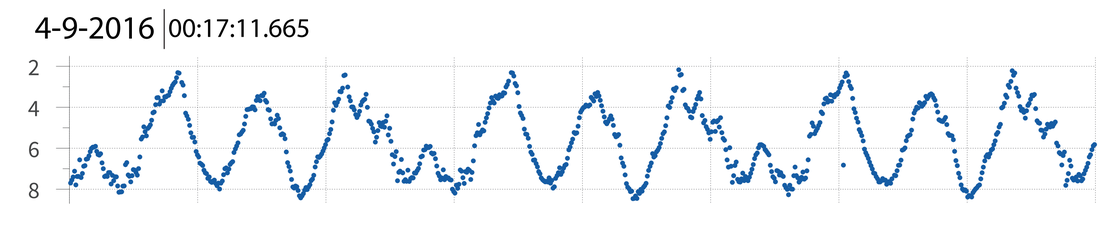
Acknowledgments

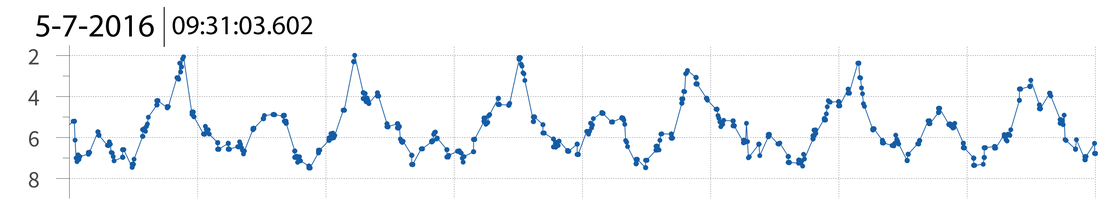
We thank Peter Erdman and Damon Burke for providing equipment for the observations and Jason Aufdenburg and the Physical Sciences Department for supporting the simultaneous observations and participation in this conference. Initial funding of OSCOM was provided by National Science Foundation grant AGS-1450999.



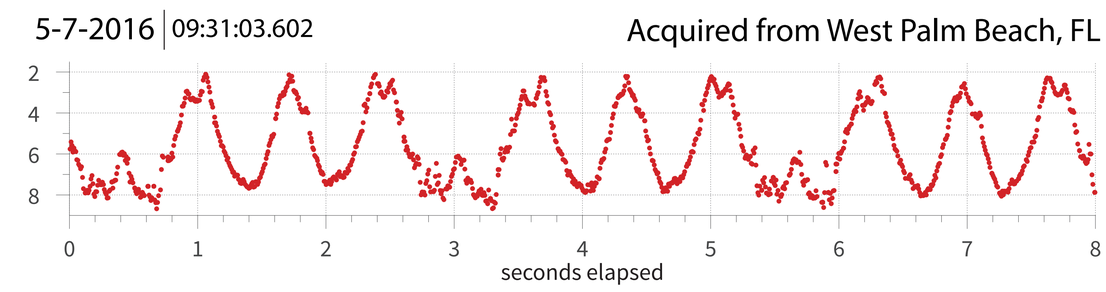


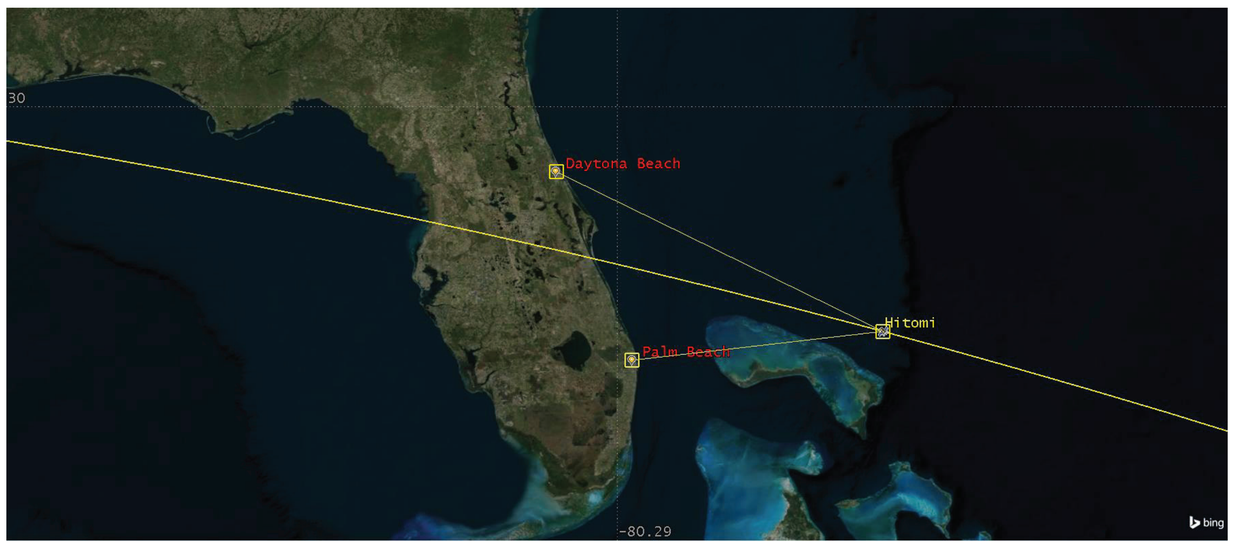






Simultaneous observations were conducted on May 7th, using duplicate equipment.





Shows the location of the observations conducted on May 7th along with the orbit path of Hitomi.