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High Frame Rate, Simultaneous Multi-Point Observations Using the OSCOM System

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Abstract

The Optical tracking and Spectral characterization of CubeSats for Operational Missions (OSCOM) system is designed to enable high frame rate observations of satellites to produced time resolved photometry by utilizing low cost, high throughput optics and CMOS machine vision cameras. The resulting light curves can be used to determine if a satellite is operating nominally, whether it is spin stabilized, 3 axis stabilized or tumbling. Knowing the satellite shape a priori can allow for its attitude to be determined based off its light curve. The portability of the OSCOM system allows for deployment in areas such as the College of Arts and Sciences building at Embry-Riddle Aeronautical University's Daytona Beach campus or in the field. In this poster, we will present OSCOM's high frame rate and simultaneous multi-point observational capabilities and provide photometric results which demonstrate these abilities.

High Frame Rate and Multi-point Photometry

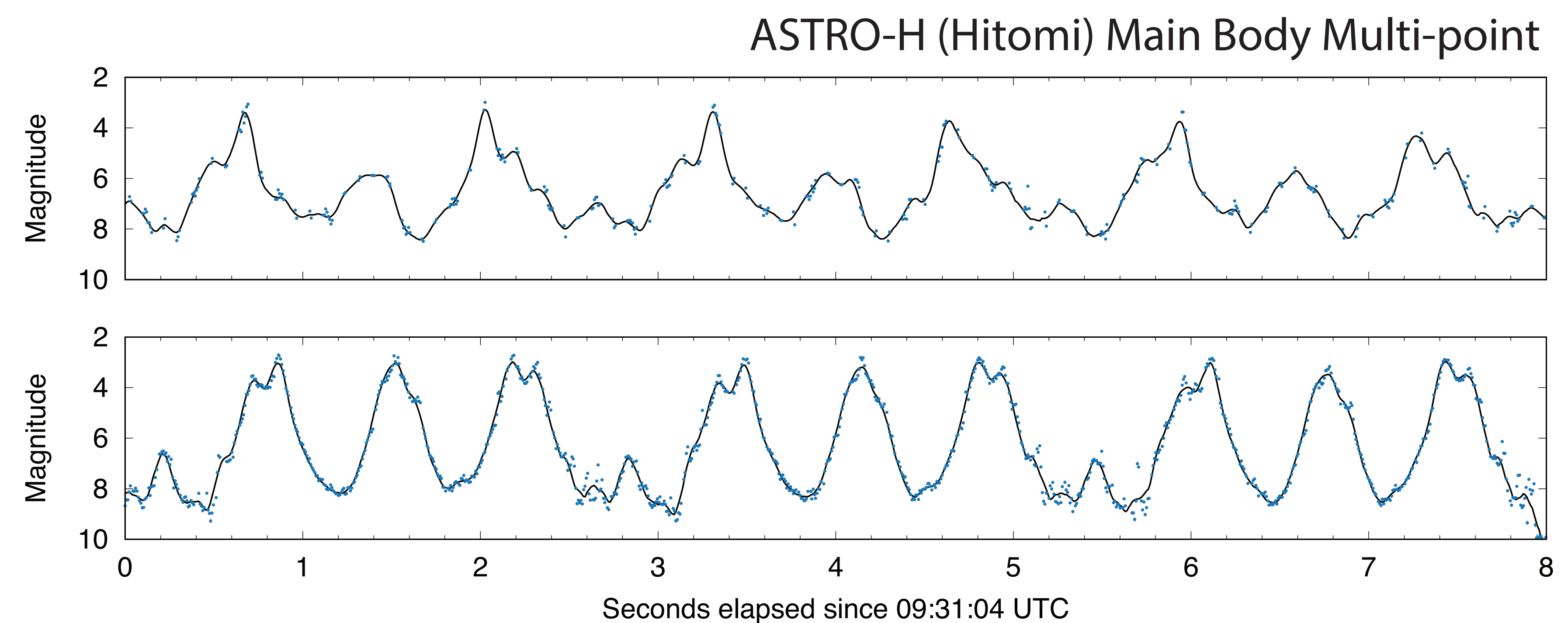
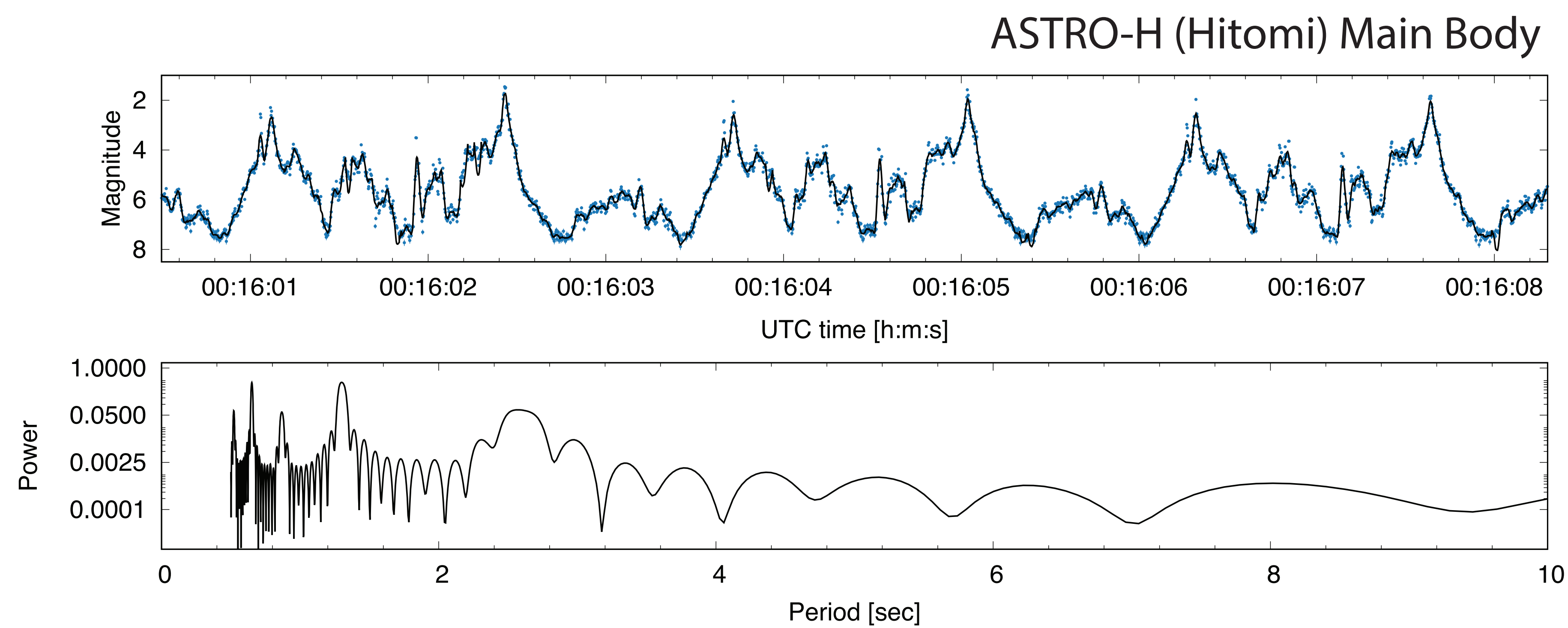
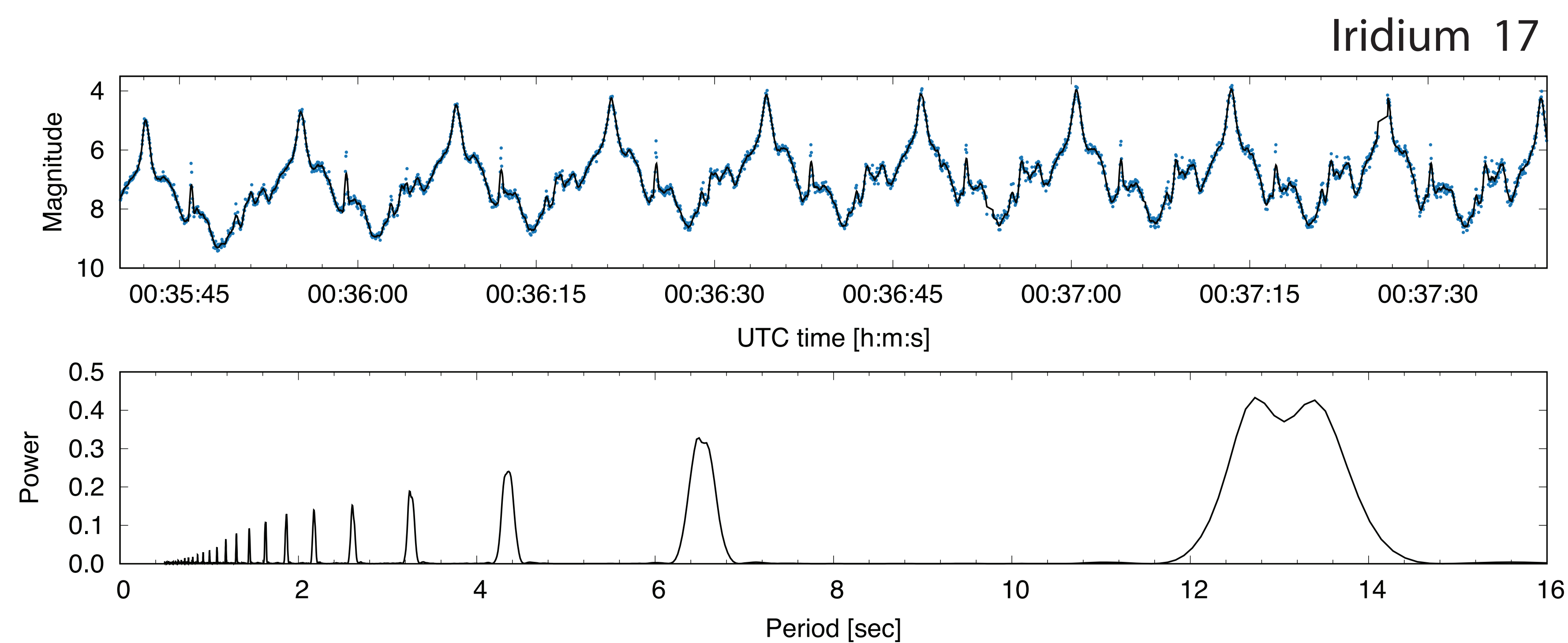
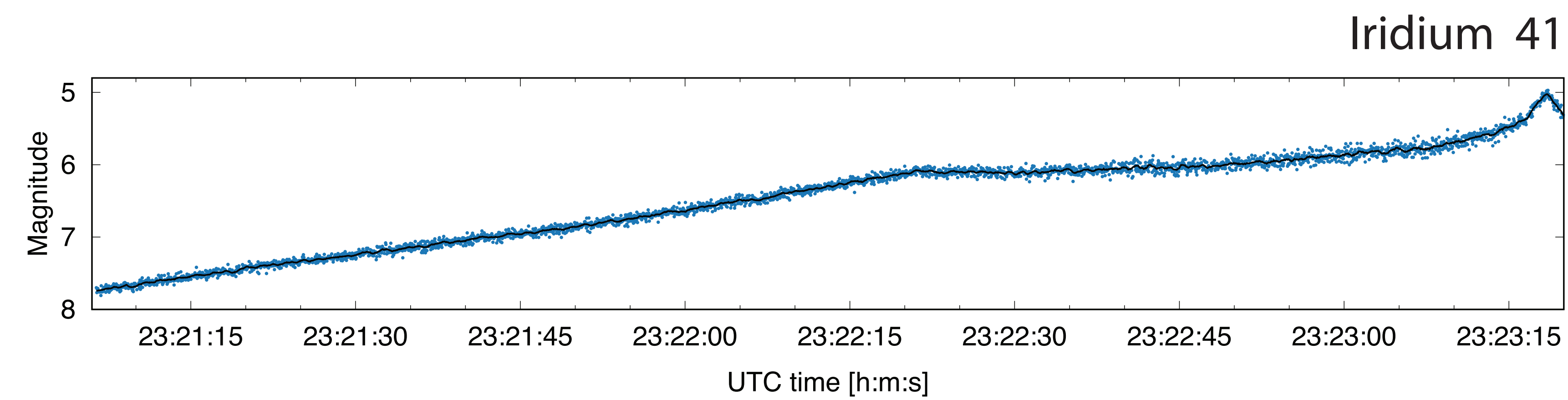
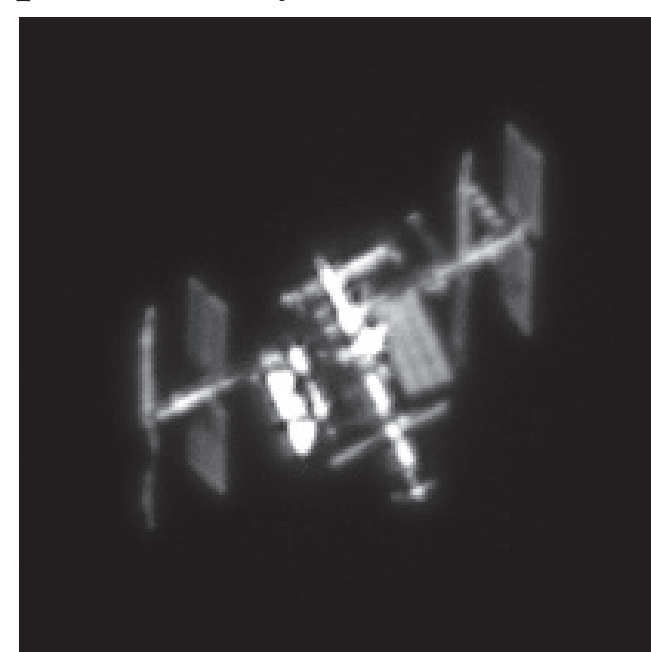
The OSCOM system offers portable, inexpensive, commercial-off-the-shelf hardware to provided time resolved photometry of satellites of various sizes. OSCOM utilizes a Manta G-235 CMOS machine vision camera made by Allied Vision to acquire data at relatively high frame rates compared to CCD cameras. Frame rates of 25 fps can be achieved while imaging with the full sensor. However, sub-frames can be selected and used instead to yield higher frame rates of up to 350 fps. This data rate has been achieved for large satellites, such as communication and observational satellites. OSCOM uses an Celestron 11"/f/2.2 Rowe-Ackermann Schmidt Astrograph (RSA). The advantage of this optical system is a wide field of view, $1^\circ \times 0.7^\circ$, for easier acquisition of satellites and portable design. The portability of this system enables it to be deployed into locations such as the veranda of the College of Arts and Sciences building at Embry-Riddle Aeronautical University's Daytona Beach campus or in the field. Using multiple systems allows for simultaneous observations of satellites. By utilizing the portability of the OSCOM system, identical systems can be deployed to provide photometry of satellites from different observing angles.

Description of Observed Satellites

To the right is data which demonstrates the OSCOM system's high frame rate and simultaneous multi-point observational capabilities. Iridium 41 and 17 are part of the Iridium low earth orbit (LEO) satellite constellation. The constellation consists of 66 communication satellites, spread out between 6 polar orbits to provide full coverage of the Earth. Iridium 41 is still operational and is 3 axis stabilized, while Iridium 17 is uncontrolled and is tumbling, as shown by its light curve. ASTRO-H, also known as Hitomi, is an x-ray satellite that was launched by the Japan Aerospace Exploration Agency (JAXA) in February, 2016. After nearly a month in orbit, the attitude control system encountered an anomaly which caused the spacecraft to enter an uncontrollable spin. As result, the extendable optical bench (EOB) and solar panels are believed to have been separated from the main body. The Joint Space Operations Center (JSpOC) reported 10 debris pieces associated with the main body. The light curves to the right are the results from observations of the main body. The first demonstrates high frame rate photometry at 350 fps. This data was taken on April 8, 2016. Nearly one month later, a simultaneous multi-point observation was conducted. Identical systems were placed at Embry-Riddle's Daytona Beach campus and in West Palm Beach, FL. ASTRO-H's flash period, 2.6 seconds, changed negligibly between the time these data sets were acquired.

Future Work

OSCOM has been able to acquire high frame photometry of various large satellites. Future plans include increasing the number of multi-point observations of satellites to provide time resolved photometry from different locations and viewing angles and improving the quality of photometry results. OSCOM will be acquiring a new 14" telescope which will provide dual functionality as a wide field, higher throughput telescope and as a longer focal length telescope, which can be used for resolved imaging of large satellites such as the International Space Station (ISS), shown in the image to the right, which was taken using Embry-Riddle's larger CDK 20" telescope.



Iridium Communication Satellites

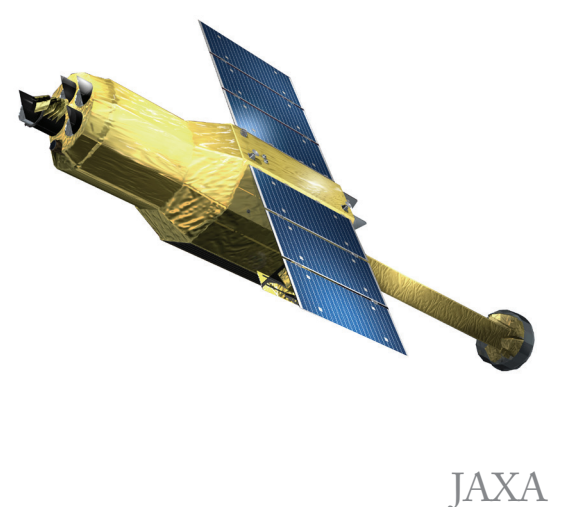
Iridium 41
NORAD ID: 25040
Mission: Communications
Orbit: 776 x 779 km, 86.4° inclination
Dimensions: 14 ft long
Status: Operational
Attitude control: 3-axis stabilized
Camera gain: 2.0 e-/ADU
Exposure time: 15 ms
Frame rate: 25 fps
Observation sites: Daytona Beach, FL
Observation date: 2016-10-23



Iridium 17
NORAD ID: 24870
Mission: Communications
Orbit: 771 x 774 km, 86.4° inclination
Dimensions: 14 ft long
Status: Uncontrolled
Attitude control: Tumbling
Camera gain: 2.0 e-/ADU
Exposure time: 20 ms
Frame rate: 25 fps
Observation sites: Daytona Beach, FL
Observation date: 2016-10-23

New Exploration X-Ray Telescope

NORAD ID: 41337
Mission: X-ray astronomy
Orbit: 564 x 581 km, 31.0° inclination
Dimensions: Unknown, previously 46 ft long
Status: Spun apart in March, 2016
Attitude control: Tumbling



High Frame Rate Photometry

Camera gain: 2.0 e-/ADU
Exposure time: 1 ms
Frame rate: 350 fps
Observation sites: Daytona Beach, FL
Observation date: 2016-04-08

Multi-point Photometry

Camera gain: 2.0 e-/ADU
Exposure time: 5 ms
Frame rate: 135 fps
Observation sites: Daytona Beach, FL (top figure),
West Palm Beach, FL (bottom figure)
Observation date: 2016-05-07

