

Optical Studies of GEO Debris with the 6.5-m Magellan Telescopes

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Large Telescope Studies of GEO Debris

- **Imaging:**
 - Does debris distribution continue to increase with fainter optical brightness?
 - In particular, what is distribution fainter than $R = 20$ (roughly 10 cm in diameter).
 - Goal: reach faintest limiting magnitude possible from the ground.
- **Spectroscopy:**
 - Compare observed spectra of GEO debris with laboratory measurements of actual spacecraft surfaces.
 - Due to possible debris tumbling at unknown rate and orientation, requires short exposure time.
- **Both require large telescope and excellent image quality.**



6.5-m Magellan Telescopes

Las Campanas Observatory, Chile

Baade – imaging & spectroscopy

Clay - spectroscopy



*Collaboration of Carnegie Institution, University of Arizona, Harvard University,
University of Michigan, and Massachusetts Institute of Technology.*

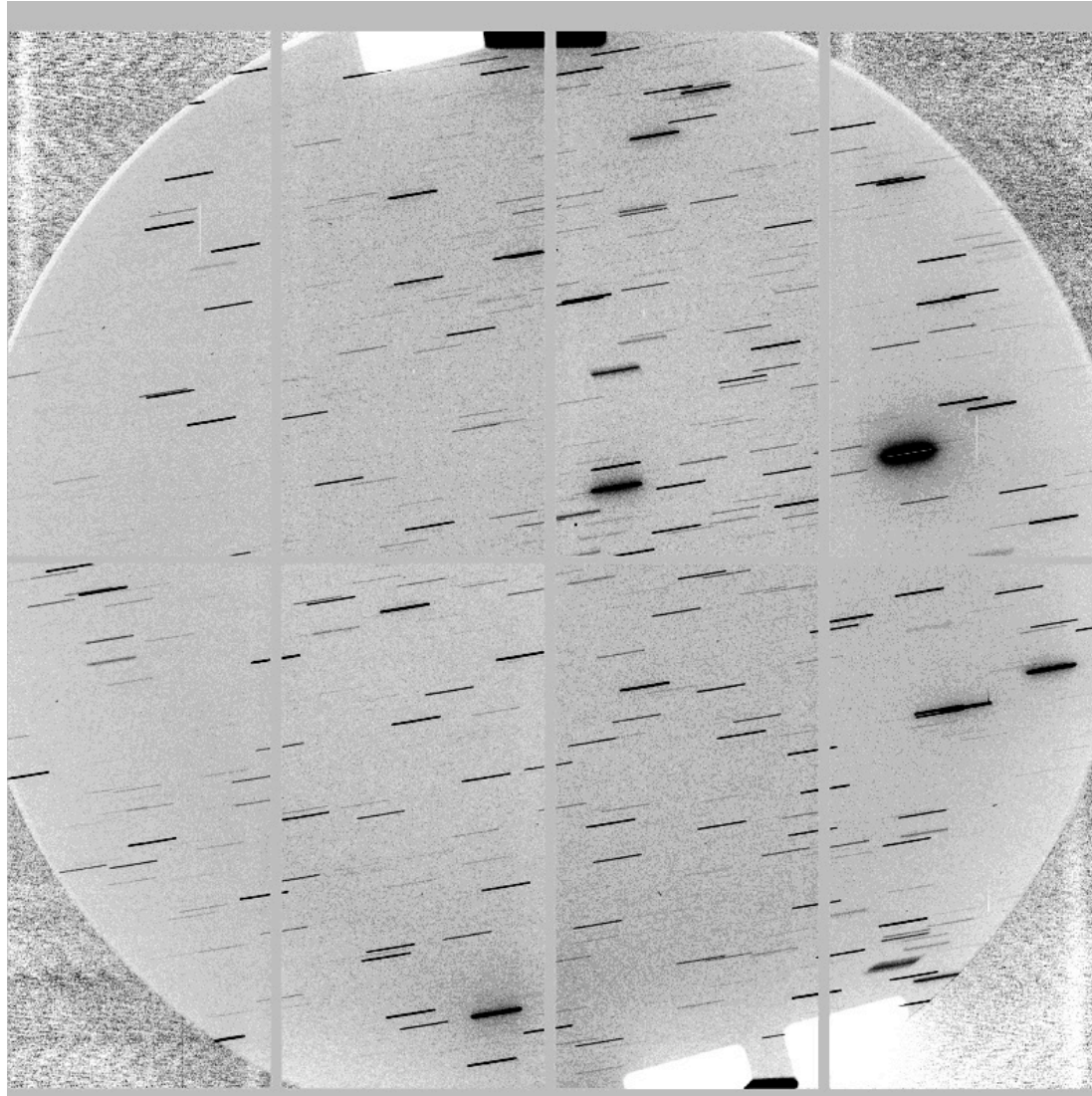


Instrument: IMACS f/2 camera

- **IMACS: Inamori-Magellan Areal Camera & Spectrograph**
- **IMACS f/2 camera used in imaging mode – 8 CCD mosaic**
 - 0.4 arc-second pixels in binned 2x2 mode – 4096x4096 pixels.
 - 30 arc-minute diameter field of view (FOV) – widest FOV on Magellan.
 - Sloan r' filter centered at 625 nm, FWHM = 150 nm.
 - 35 second cadence for 5 second exposures.
 - Detector saturates at $R=15$ for tracked 5-sec exposure.
- **Small field of view, but very deep probe. Limiting magnitude in 5 seconds measured to be fainter than $R= 21^{\text{st}}$ magnitude.**
- **Telescope can track at arbitrary non-sidereal rates (within limits!)**
- **Telescope and instrument best suited for specialized debris studies.**



Magellan imaging example: SSN 33513





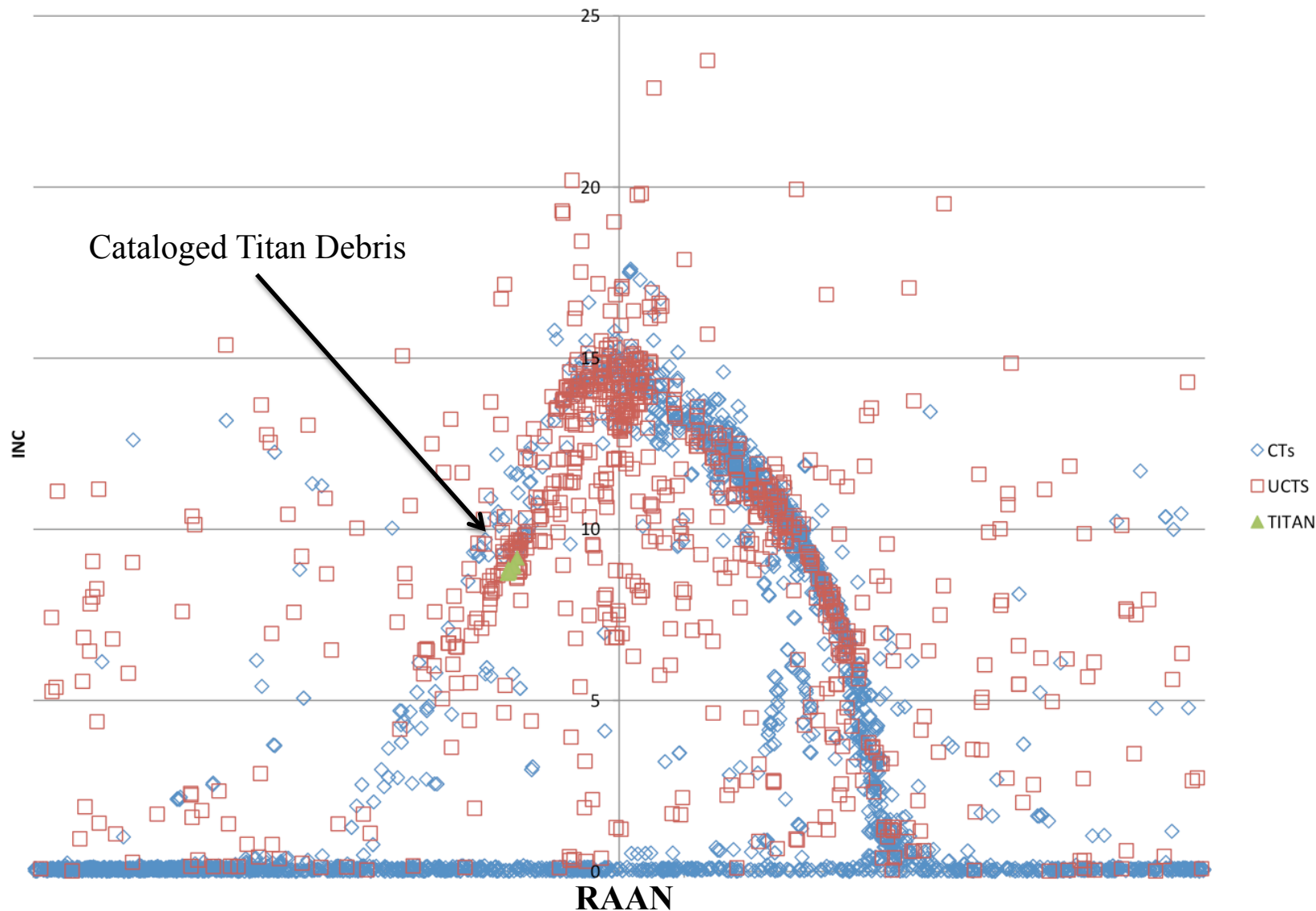
Magellan Target: Titan debris 1968-081

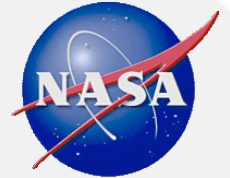
- **Fragmentation of Titan 3C Transtage at GEO – occurred 21 Feb 1992.**
 - *NASA History of On-Orbit Satellite Fragmentations (14th Edition, 2008)*
- **8 debris objects plus Titan 3C Transtage in catalog.**
- **All clustered in RAAN-INC space.**
- **Objective of this run – is there optically faint debris on circular orbits associated with this fragmentation?**
- **Observed two Titan debris fragments: 25001 and 33513.**
- **Observed ‘pseudo objects’ with same orbit as 25001 and 33513, but different mean anomalies – typical offset step 15 degrees.**
 - 30 x 5 second exposures while tracking at pseudo object rate.
 - 30 x 5 second exposures with telescope tracking off.



MODEST 2007-2009: RAAN vs Inclination

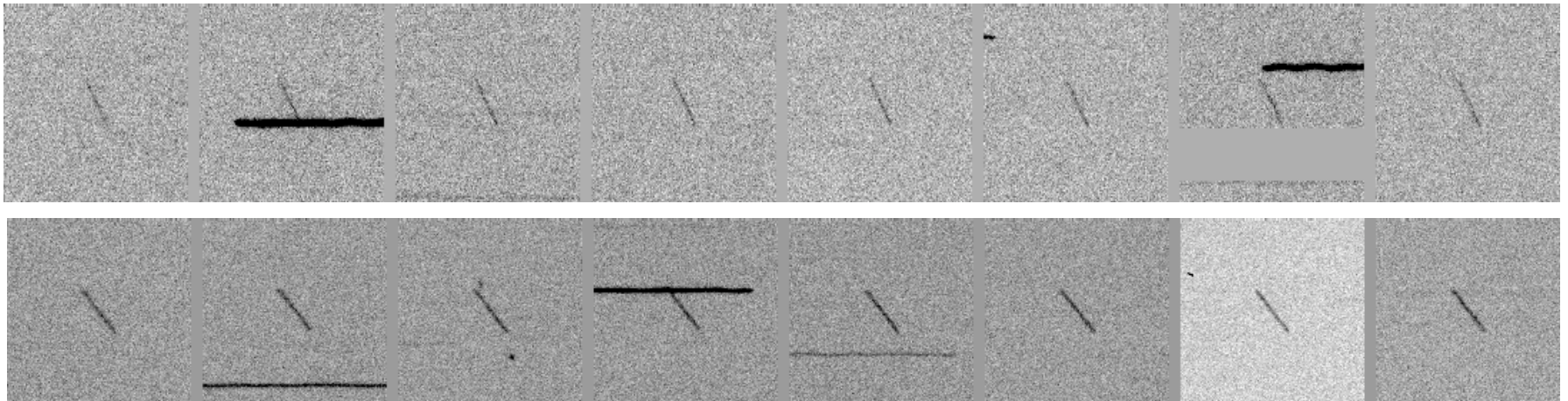
assuming circular orbits





Examples of Detections

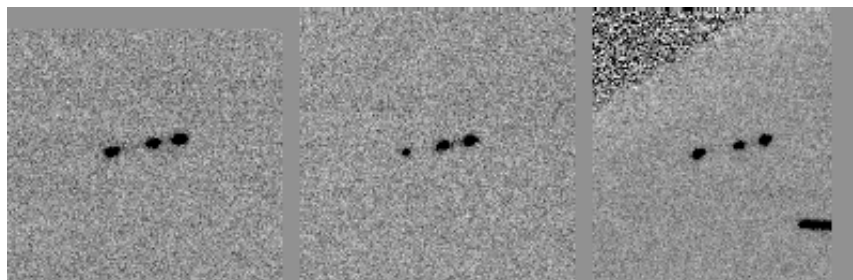
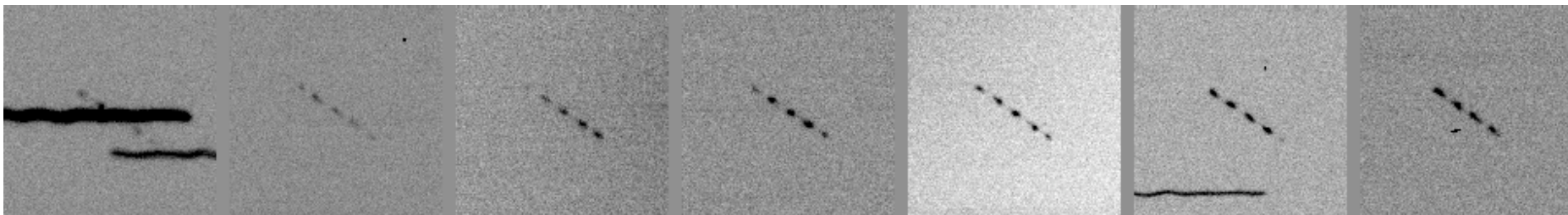
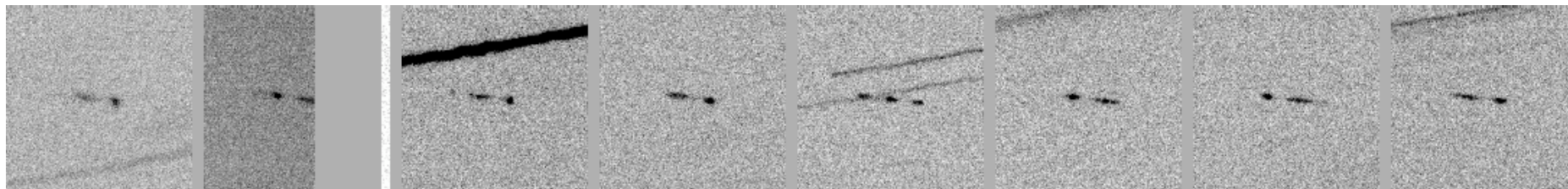
- **Postage stamp size 51.6x51.6 arc-seconds.**
- **5 second exposures.**
- **3 classifications:**
 - Streaks
 - Glints
 - Intermediate





Glints

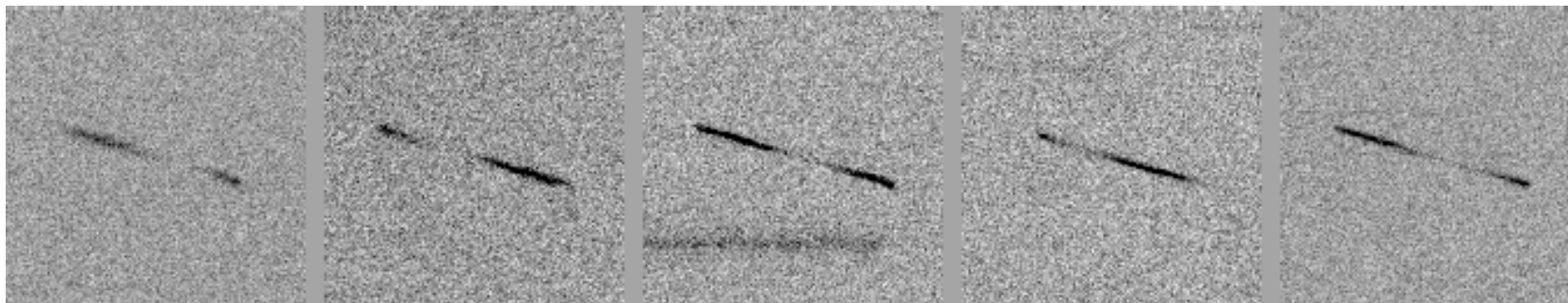
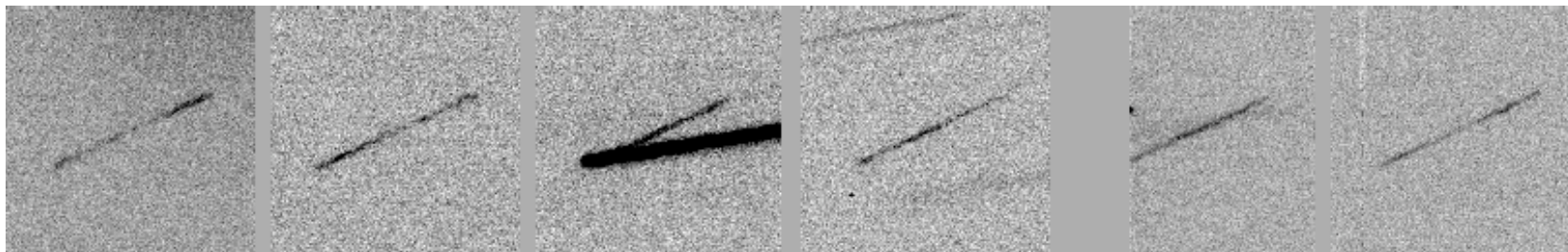
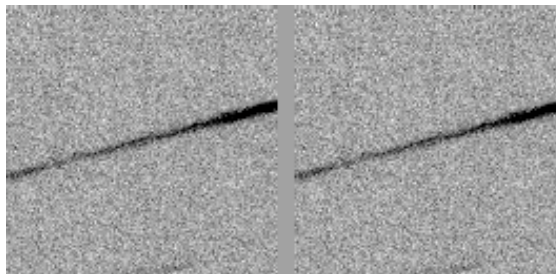
- **Glint brightness ranges from $R = 19.8$ to detection limit ($R > 21.0$).**

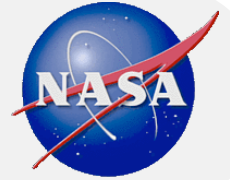




Intermediate Cases

- **Streak not uniform – slow tumblers?**





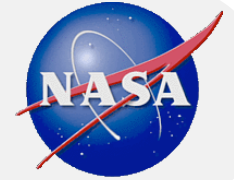
Preliminary Imaging Results

- **19 objects detected in 6 hours of observing with 0.5-deg diameter field (0.2 sq deg).**
- **Probably 12 have rates consistent with circular orbits at GEO.**
- **Detection rate for optically faint GEO objects: 10 per hour per sq/deg.**
- **Glints detected down to detection limit.**
- **All results based on small number statistics.**

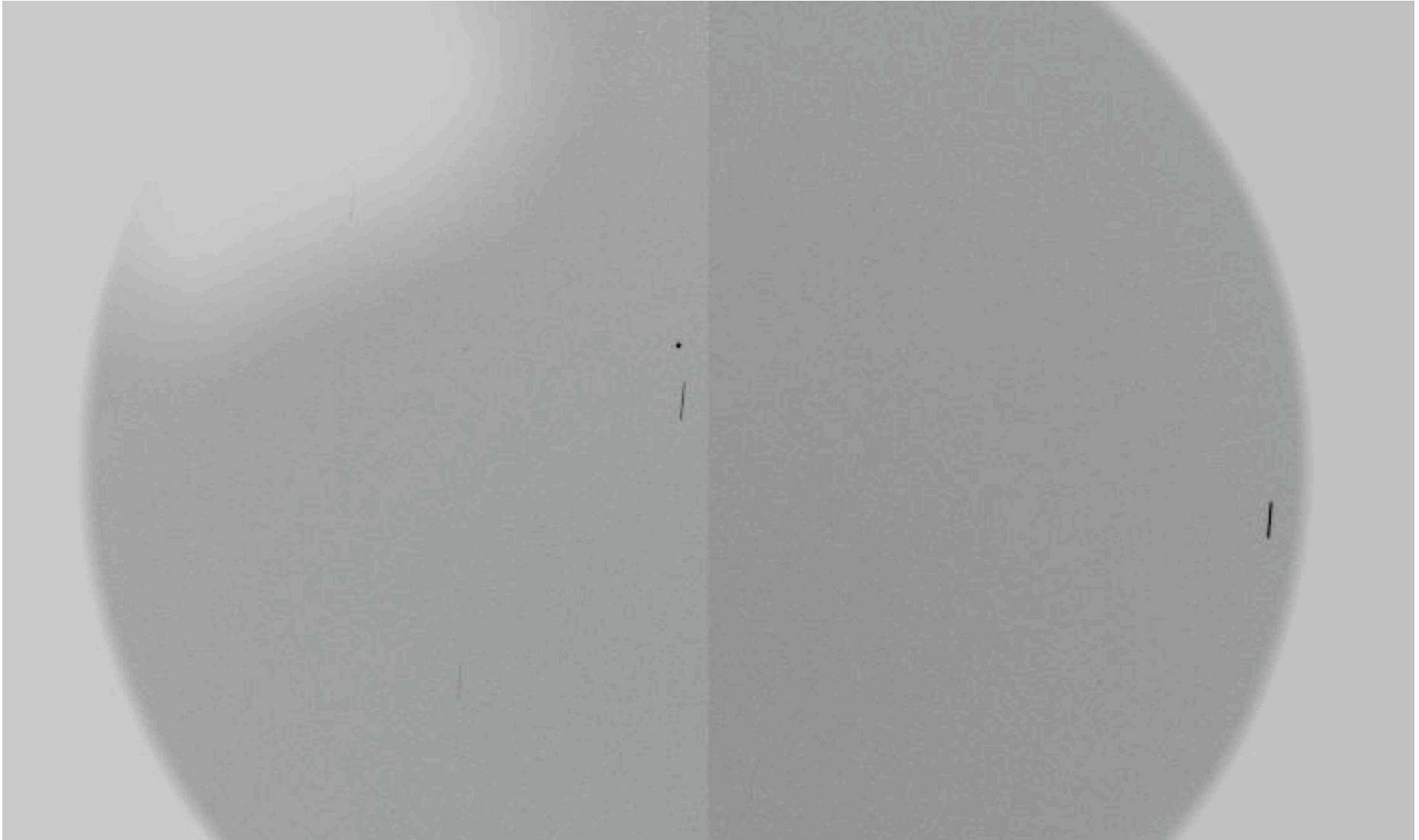


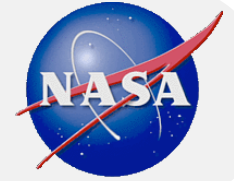
Spectroscopy

- **Goal – visible light (500 – 900 nm) spectroscopy of GEO debris for comparison with laboratory spectra of actual spacecraft materials.**
- **What are the possible surfaces seen at GEO?**
- **March 2012 – IMACS used in spectroscopic mode.**
 - 3 nights.
 - Acquire object in imaging mode, move in slit and grism for spectra.
 - Spectra acquired of 6 GEO debris pieces (1 high area to mass) and 3 IDCSP satellites.
 - Reductions in progress
- **May 2012 – LDSS3 imaging spectrograph on Clay.**
 - Two nights.
 - Spectra of 5 cataloged GEO debris pieces plus 1 IDCSP object.
 - Exposure time 30 seconds/spectra.

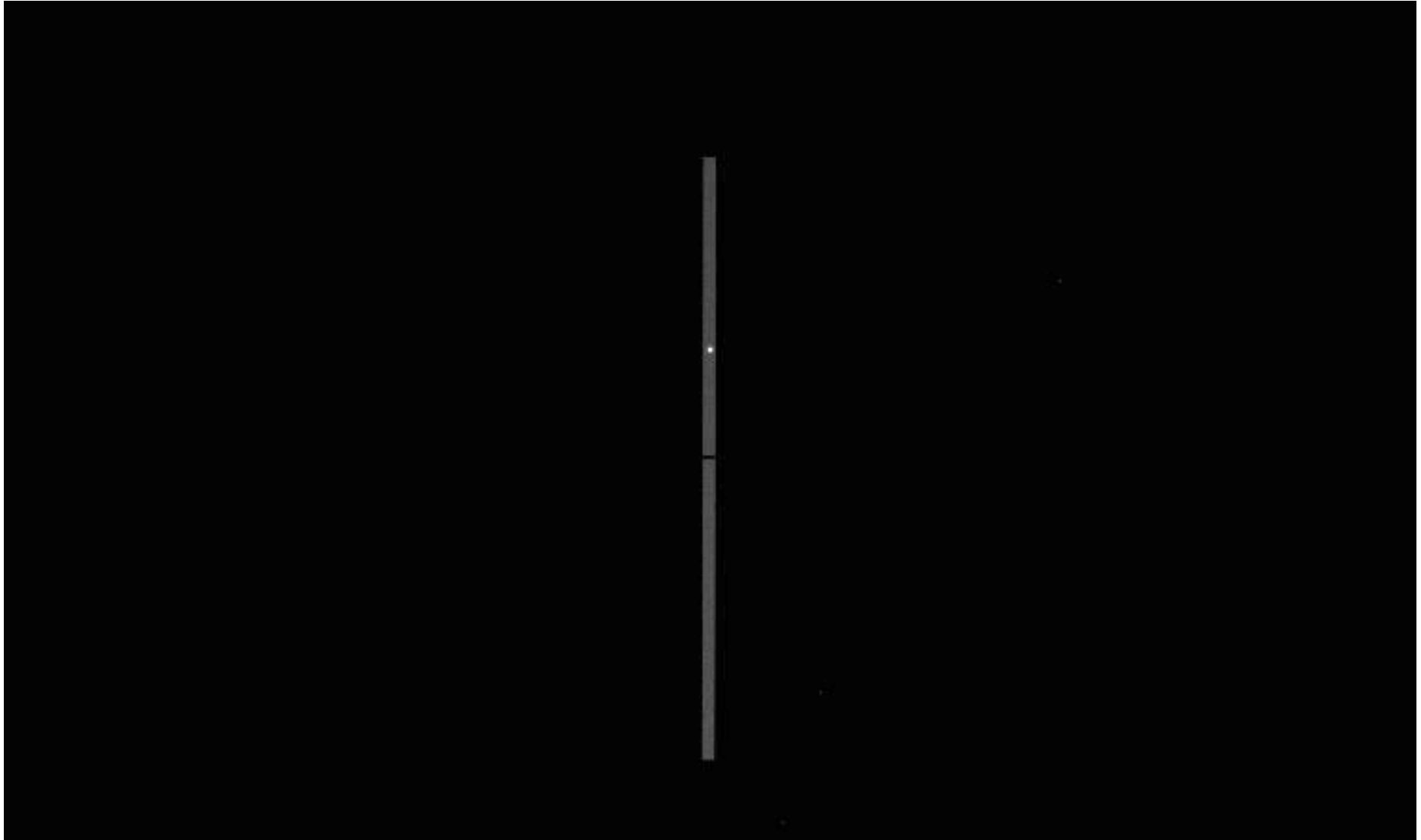


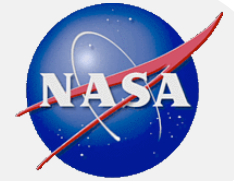
LDSS3 Acquisition Image – SSN25000



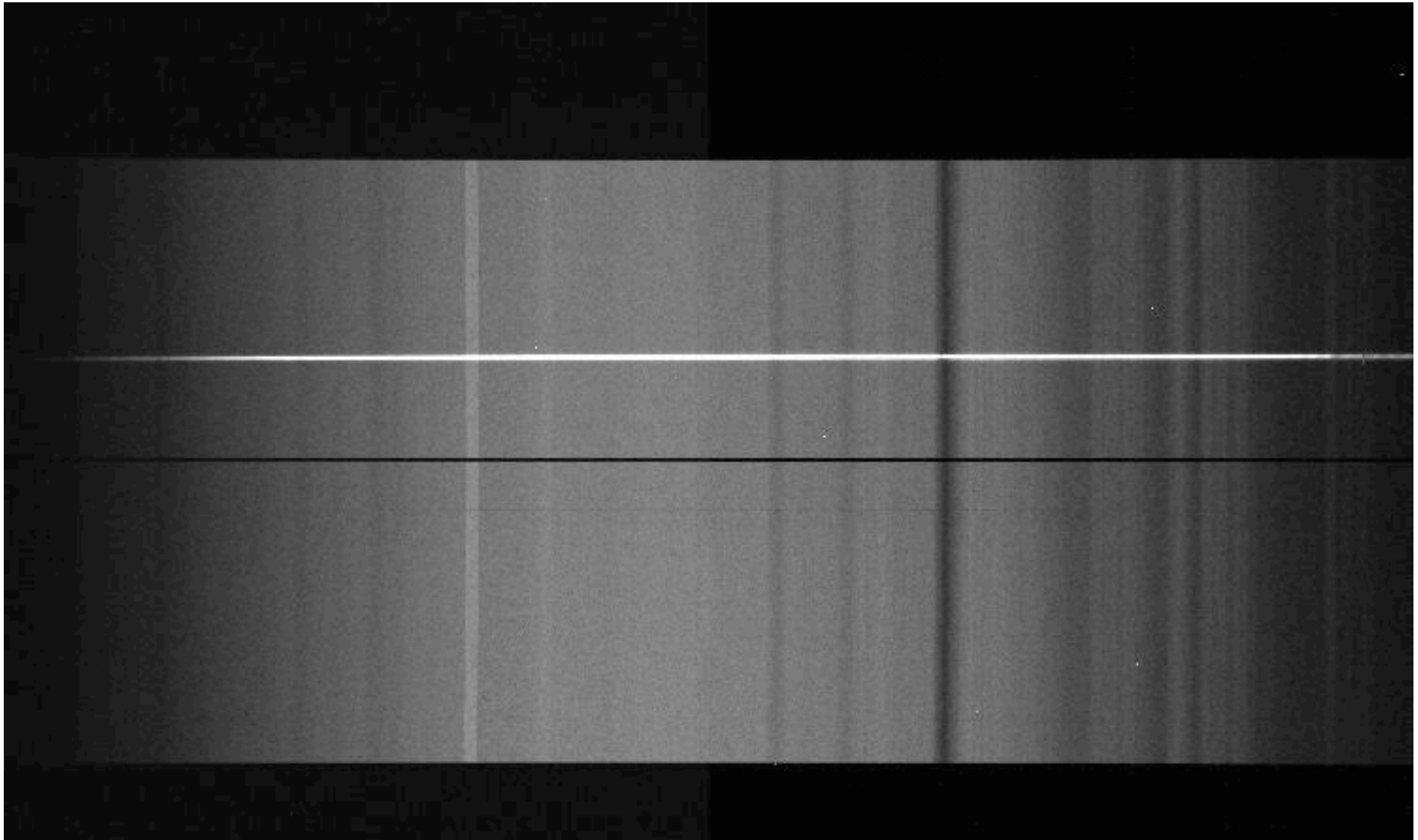


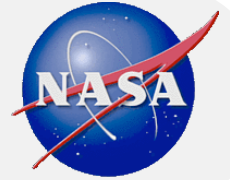
SSN25000 in 5.0 arc-second slit





SSN25000 Spectra – 30 seconds





Future Work

- **Improve blind tracking at non-sidereal rates.**
- **Minimize 6.5-m observing time to acquire and track object.**
- **Use MODEST (100 km to south) as acquisition scope to improve orbit prior to 6.5-m observations.**
- **Infrared observations (800nm to 2.5 microns) using Magellan IR spectrographs. Widest slit is 1 arc-second (a challenge!)**