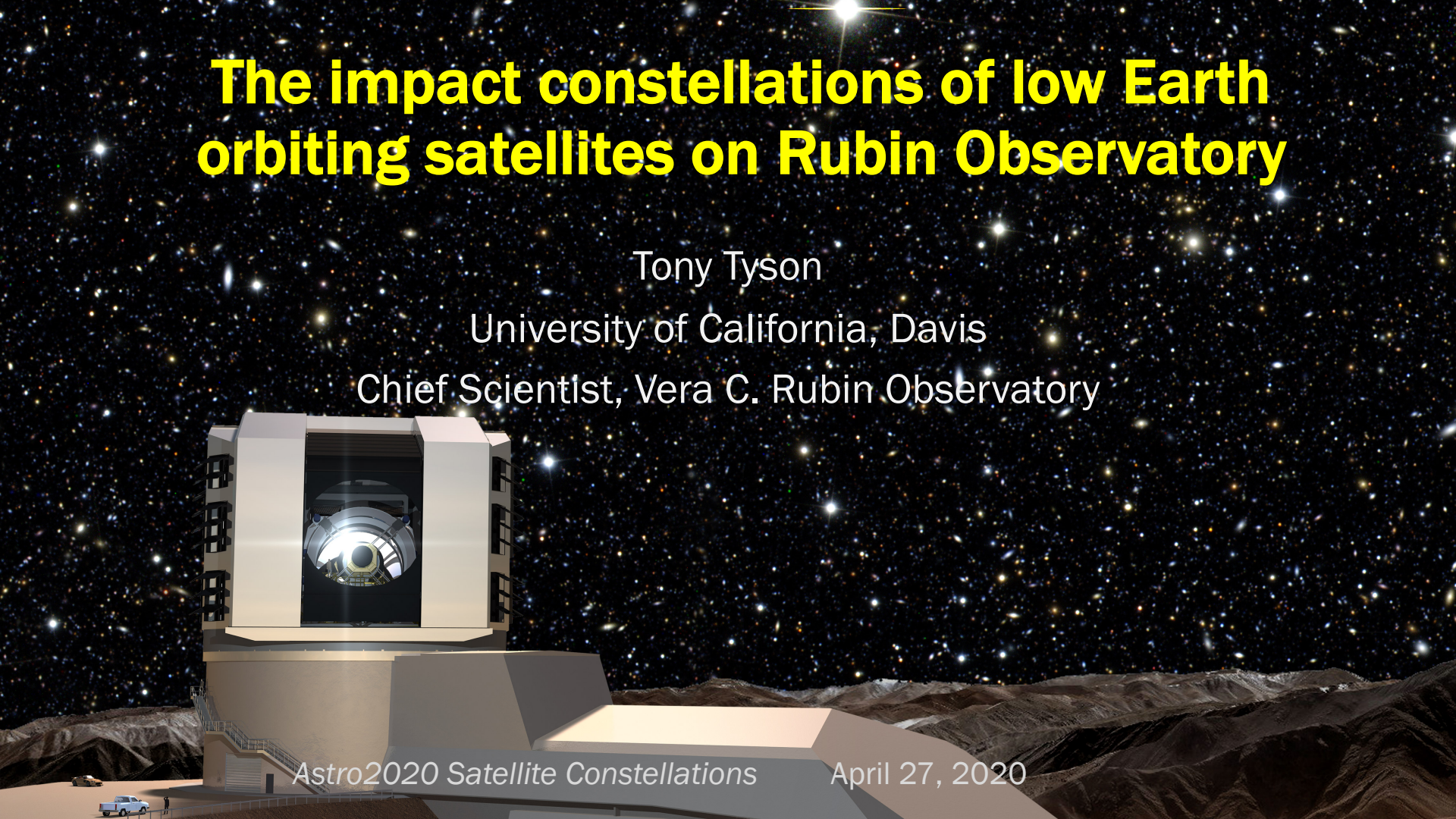
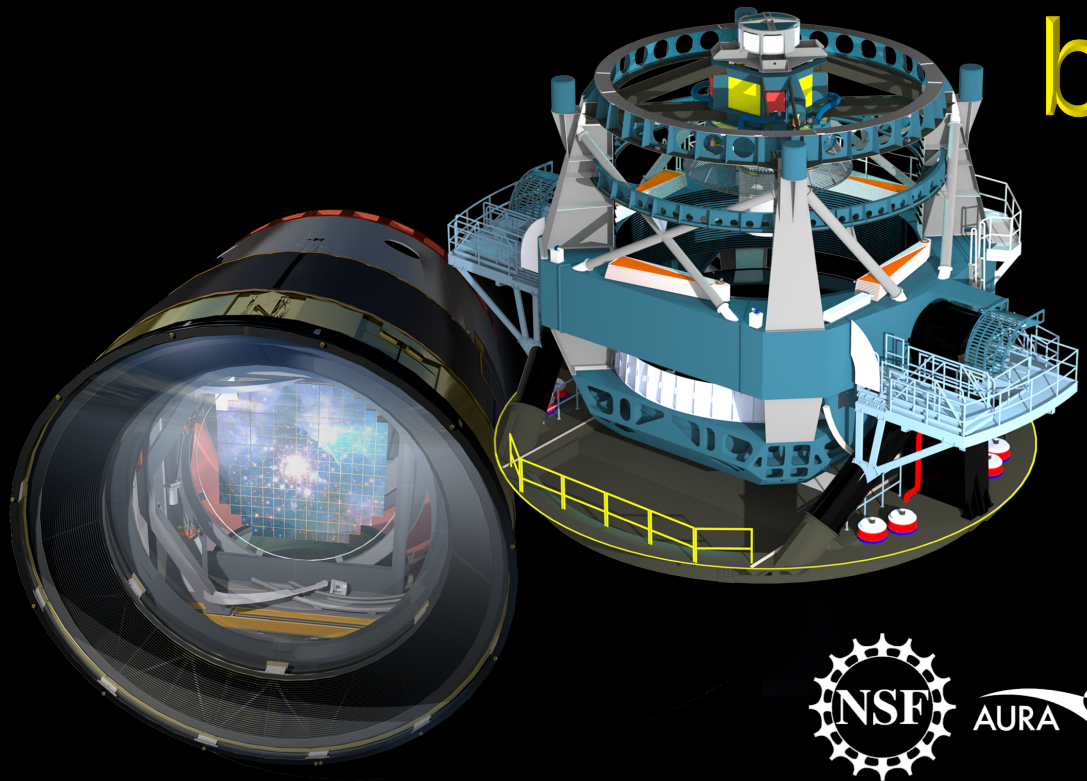
The impact constellations of low Earth orbiting satellites on Rubin Observatory

Tony Tyson
University of California, Davis
Chief Scientist, Vera C. Rubin Observatory



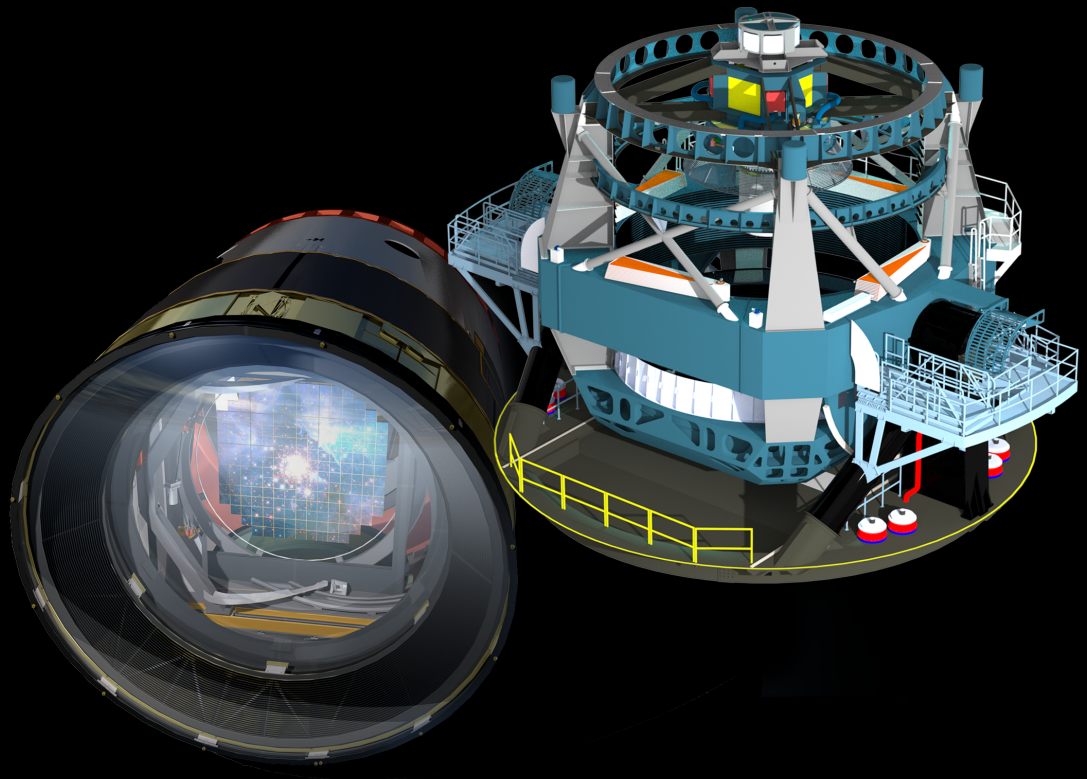
Rubin Observatory

Most Impacted by satellites



NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

Rubin Observatory

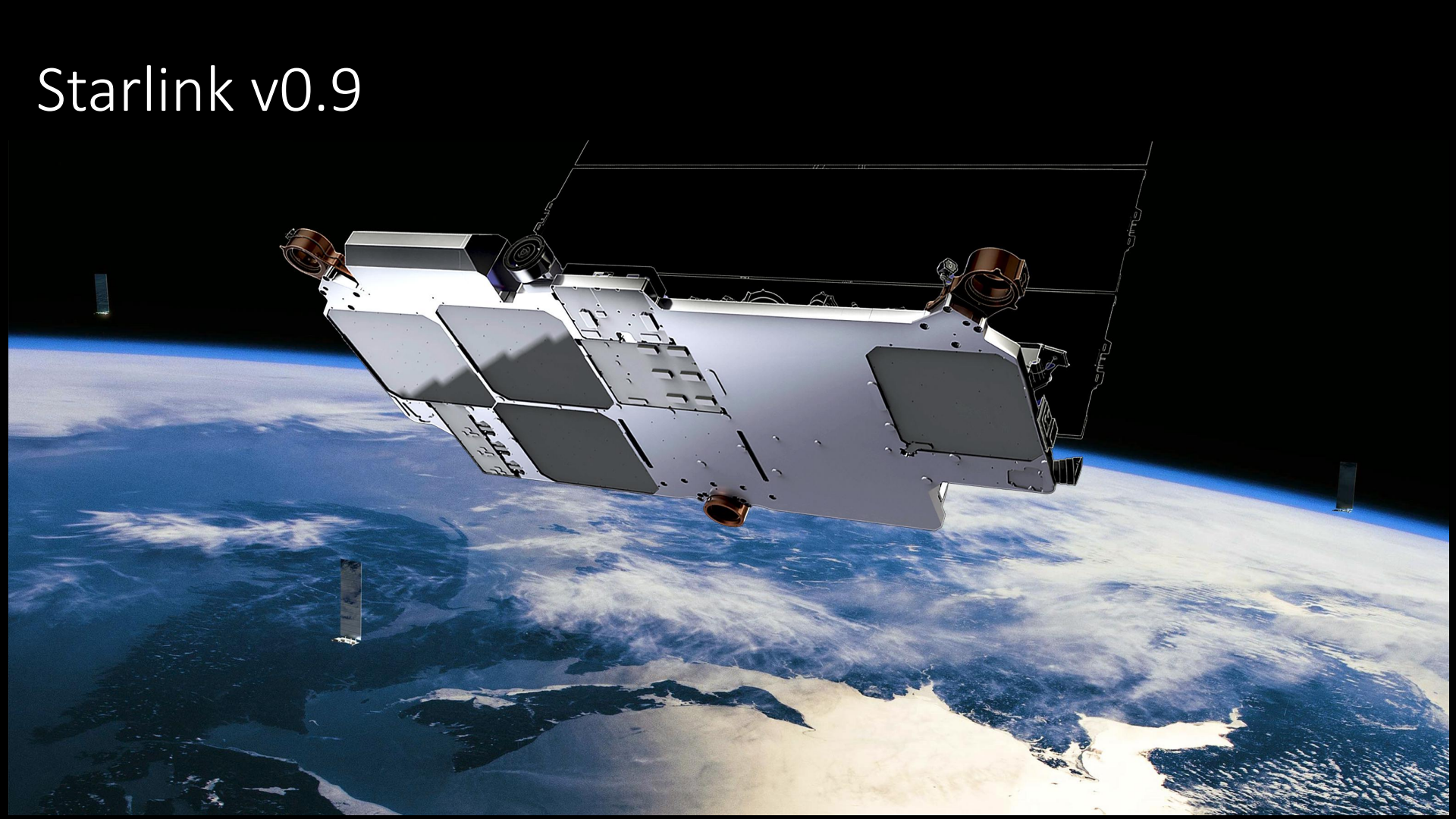


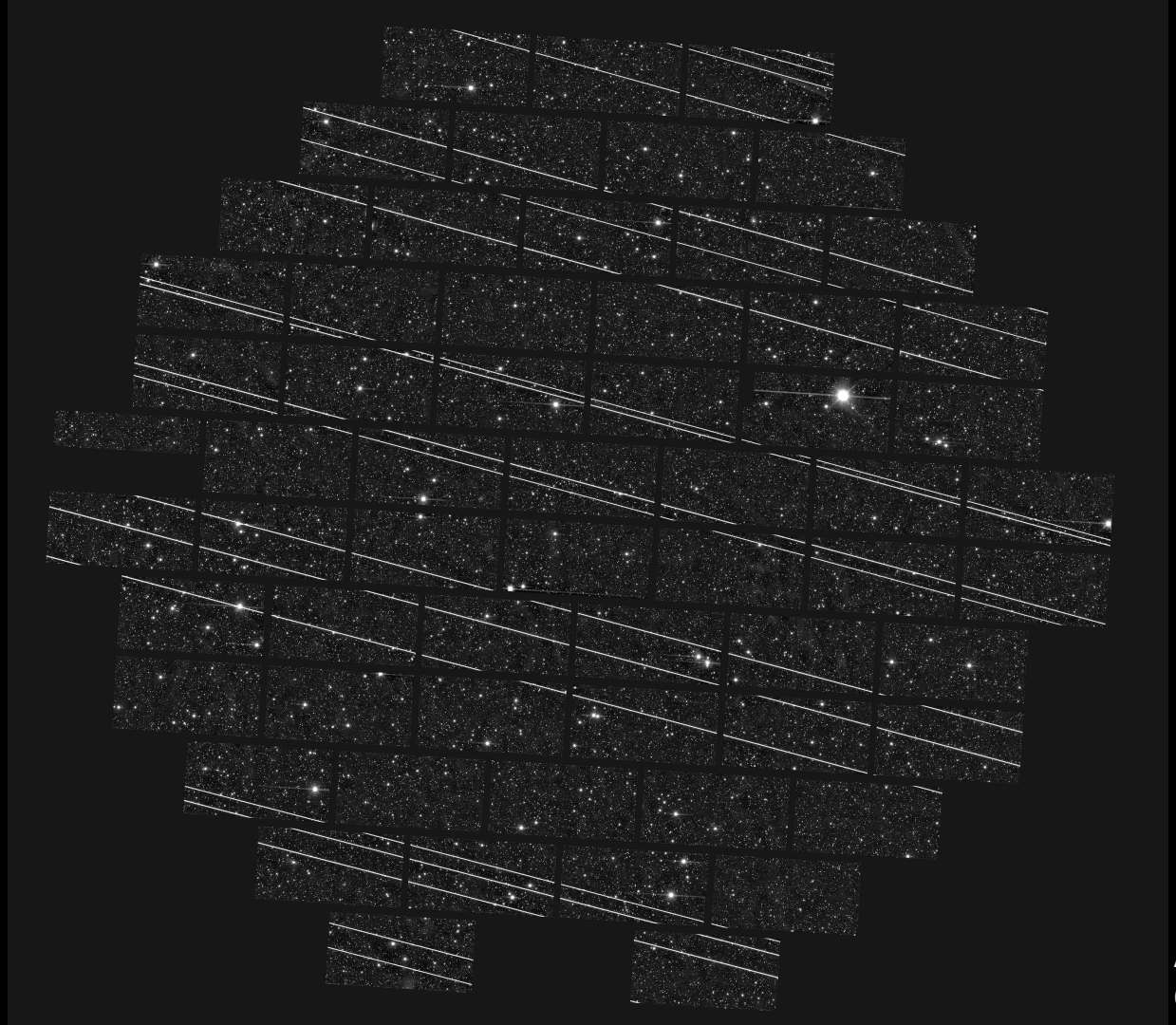
Legacy Survey of Space and Time

Rubin Observatory will execute the *Legacy Survey of Space and Time*, producing the deepest, widest, view of our dynamic Universe:

- 8.4-m mirror
- 3200 megapixel camera
- Each image the size of 40 full moons
- Scans the sky with 2000 images per night
- 10 year survey of the sky 2022-2032
- 37 billion stars and galaxies
- 10 million alerts, 20 Terabytes of data .. every night!
- **Significantly impacted by bright satellite trails**

Starlink v0.9

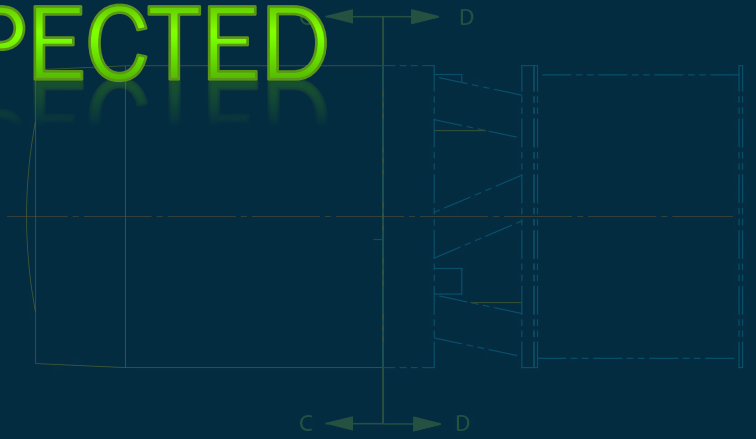




Alex Drlica-Wagner
CTIO, AURA

Automated discovery and data exploration

DISCOVERING
THE UNEXPECTED




2018


Rubin Observatory LSST survey 2022-2032
February 11, 2020

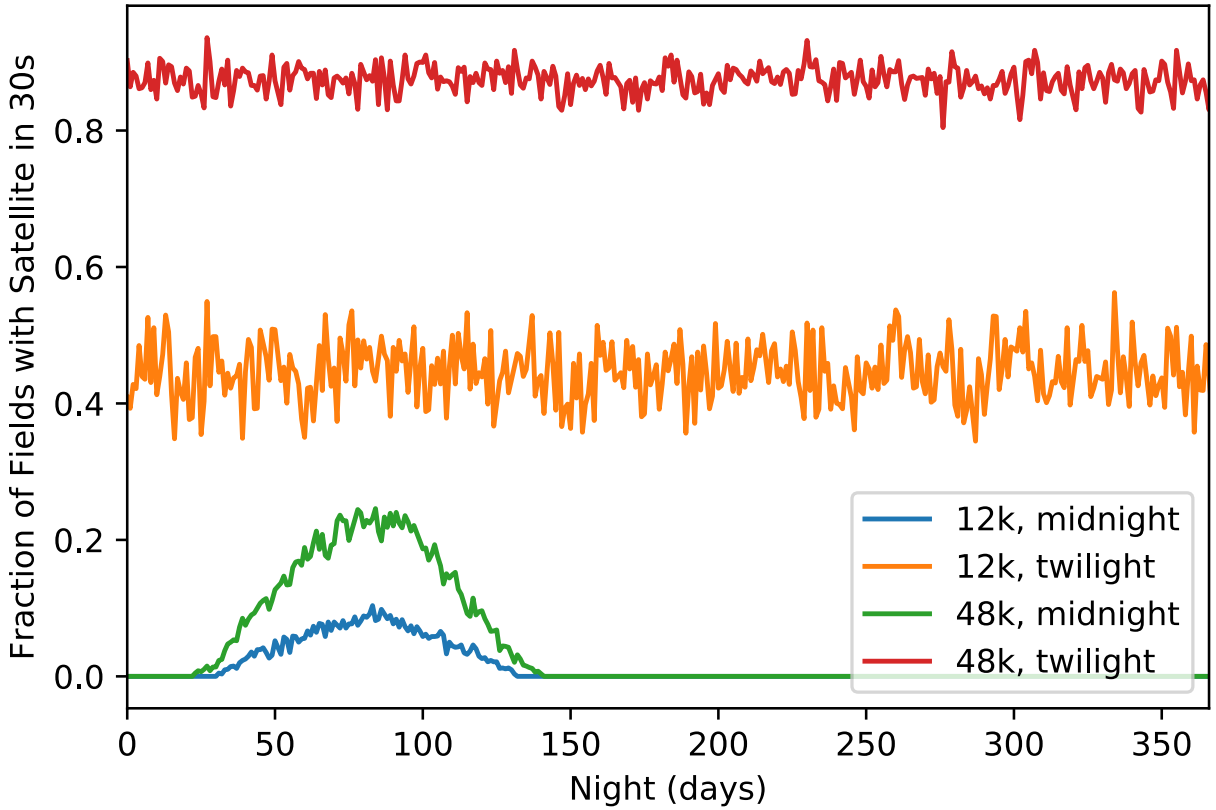
Two Starlink satellites
in a 30 sec exposure

2019-08-27

Very small
telescope with
wide field of view.

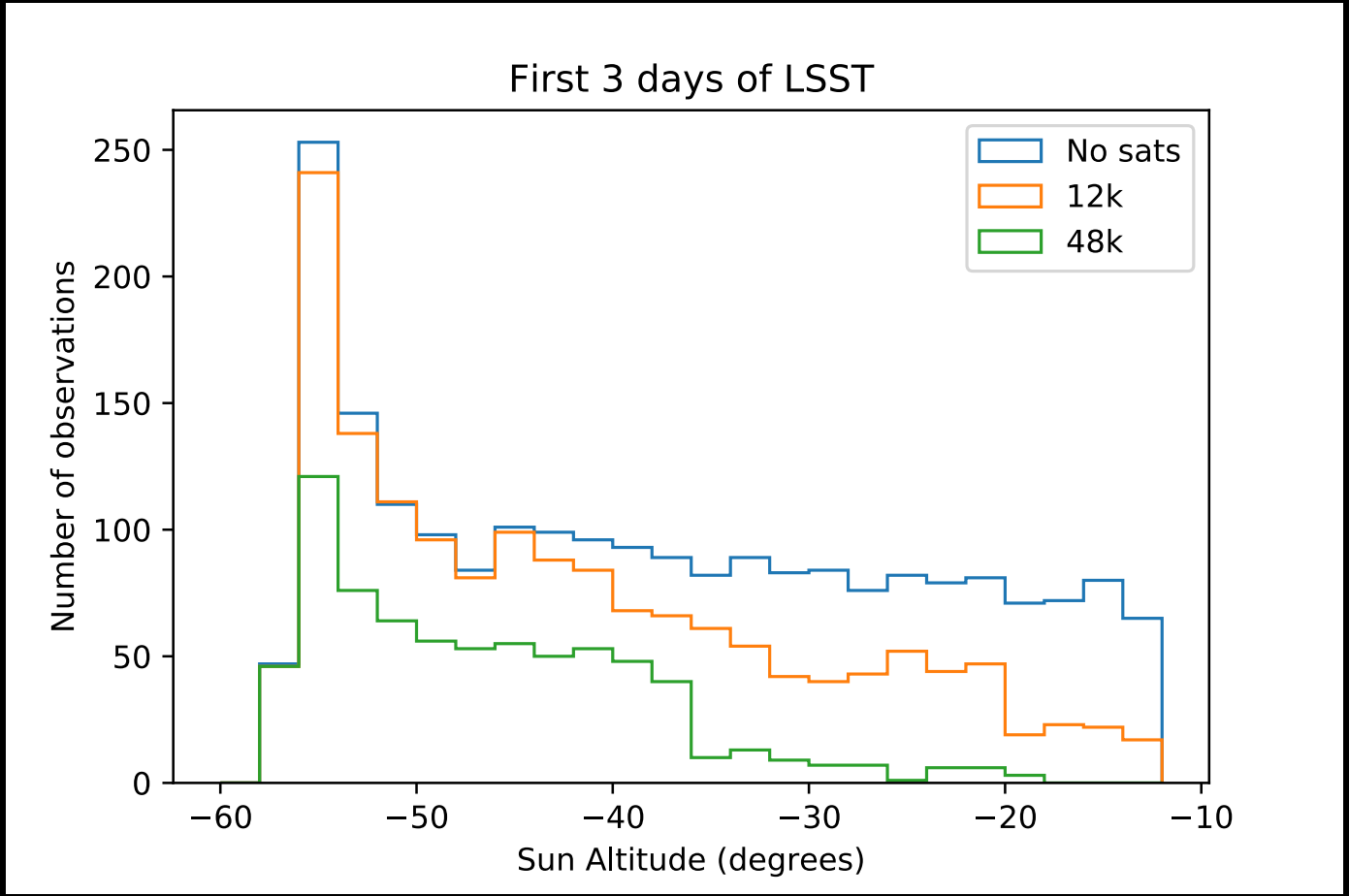
John Tonry
U Hawaii

12K, 48K LEO sats in normal LSST cadence



Peter Yoachim

Dodging satellites: inefficient

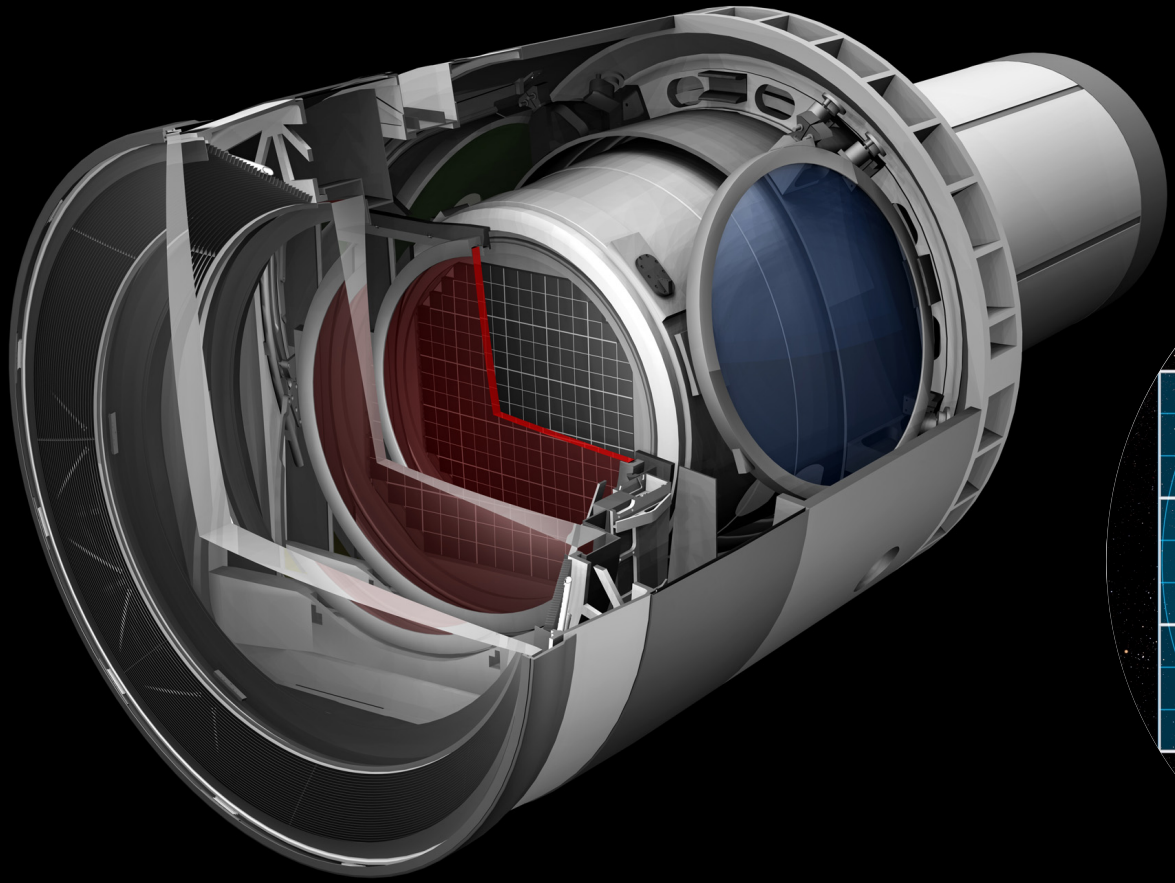


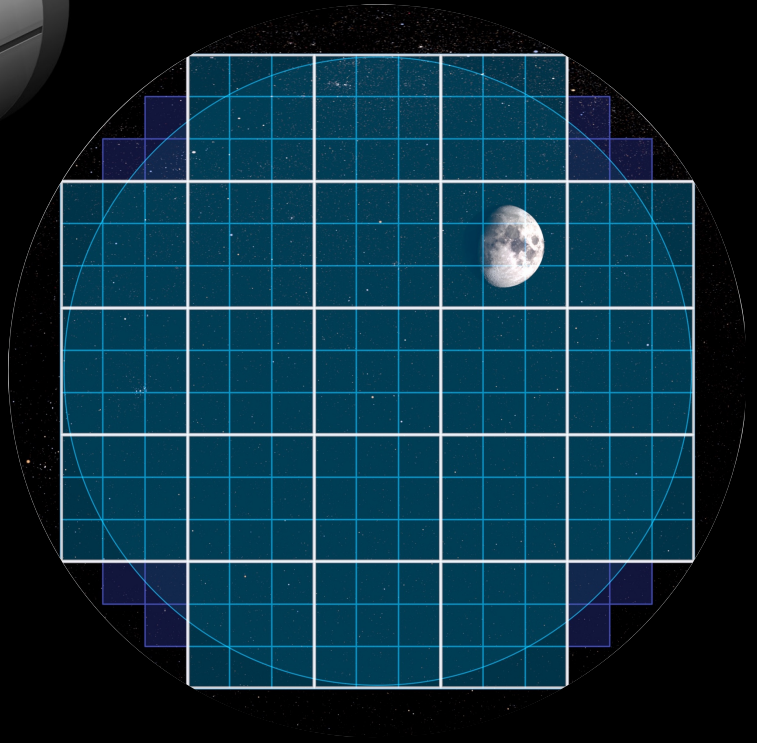
Peter Yoachim

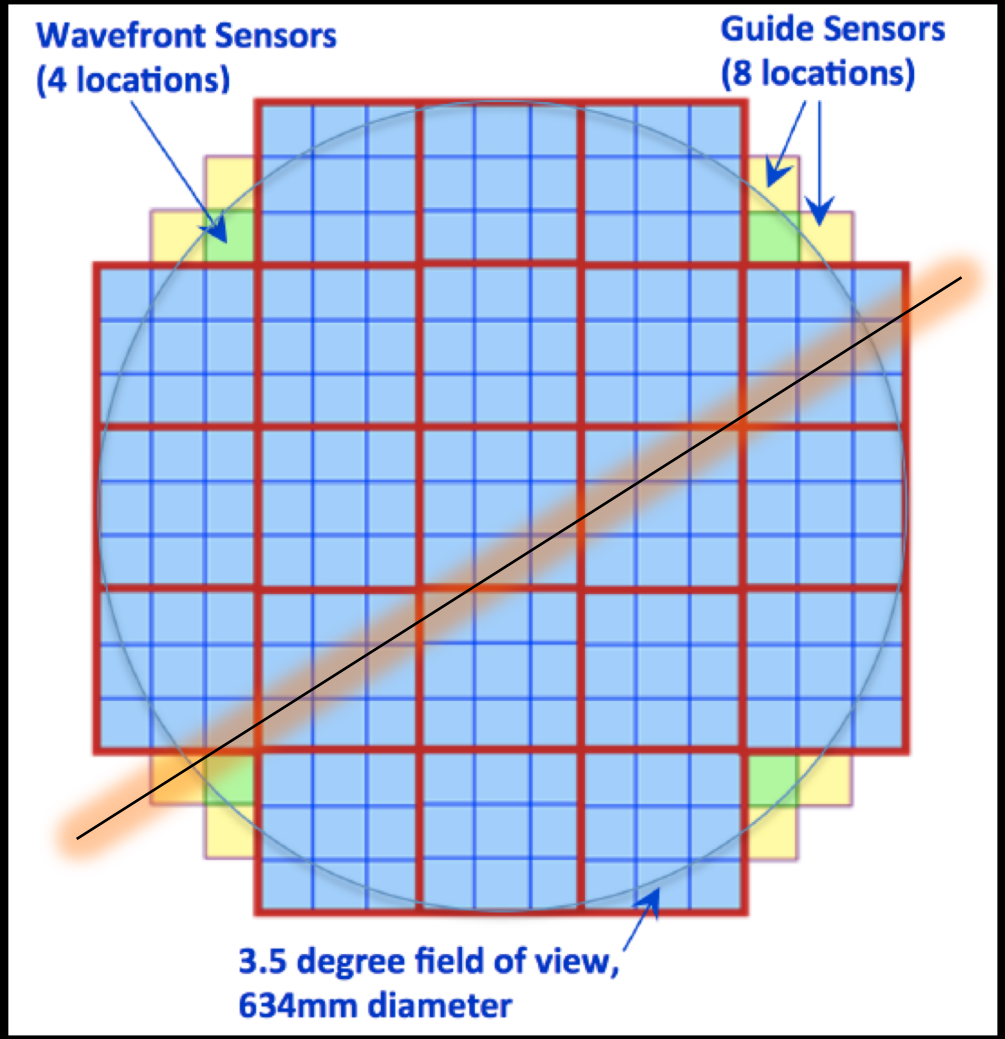
Rubin Observatory: a limiting case

- All optical astronomy observatories will be affected to some degree by the light pollution generated by LEO Sats. The issue is frequency of LEOsat trails in their data and their brightness.

- Rubin Observatory is the limiting case because of its unprecedented etendue: the product of its light collection and the wide field of view per exposure.

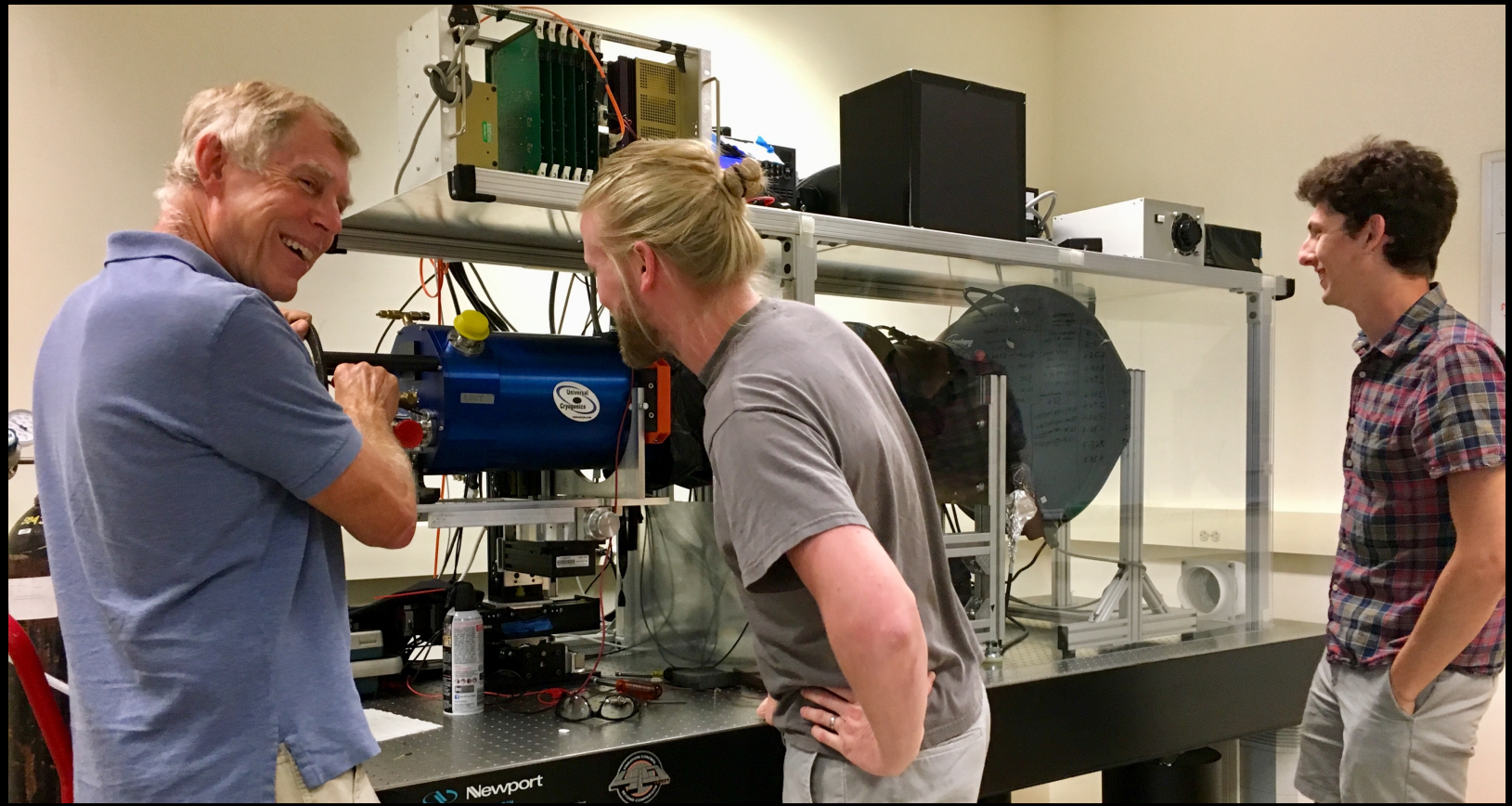




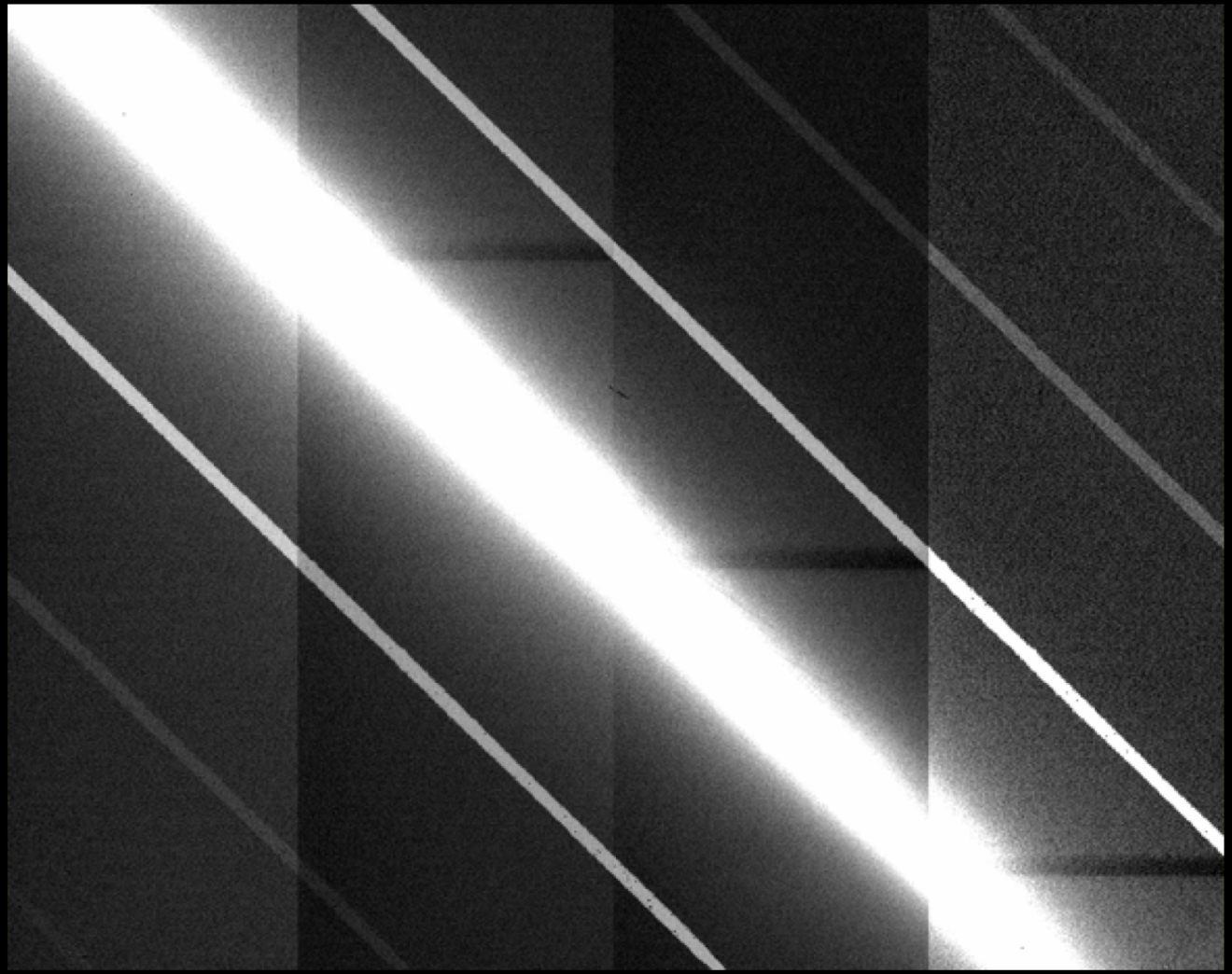

Wavefront Sensors
(4 locations)
Guide Sensors
(8 locations)
3.5 degree field of view,
634mm diameter


LCOGT MAUI 40-cm telescope, 120 second exposure,
20x30 arcmin, V filter, SBIG-6303 camera, airmass = 1.46
NORAD_44292
STARLINK BK
Extrapolated LSSTCAM CCD saturation

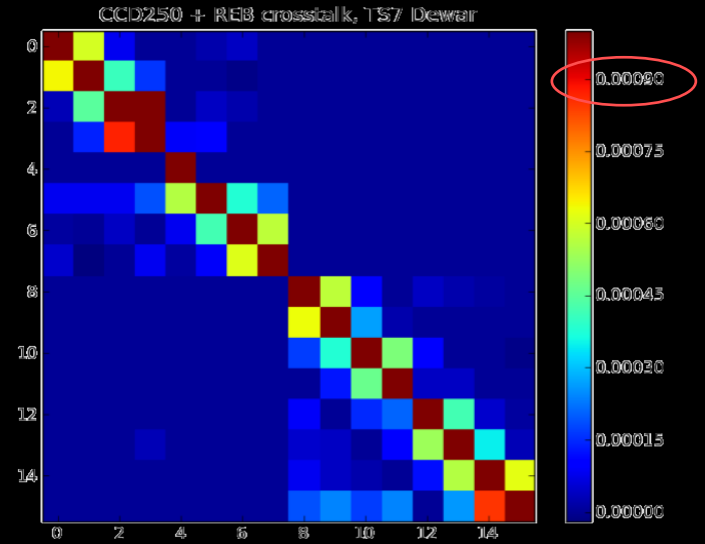
Test effect of Starlink trail on LSSTCAM CCD

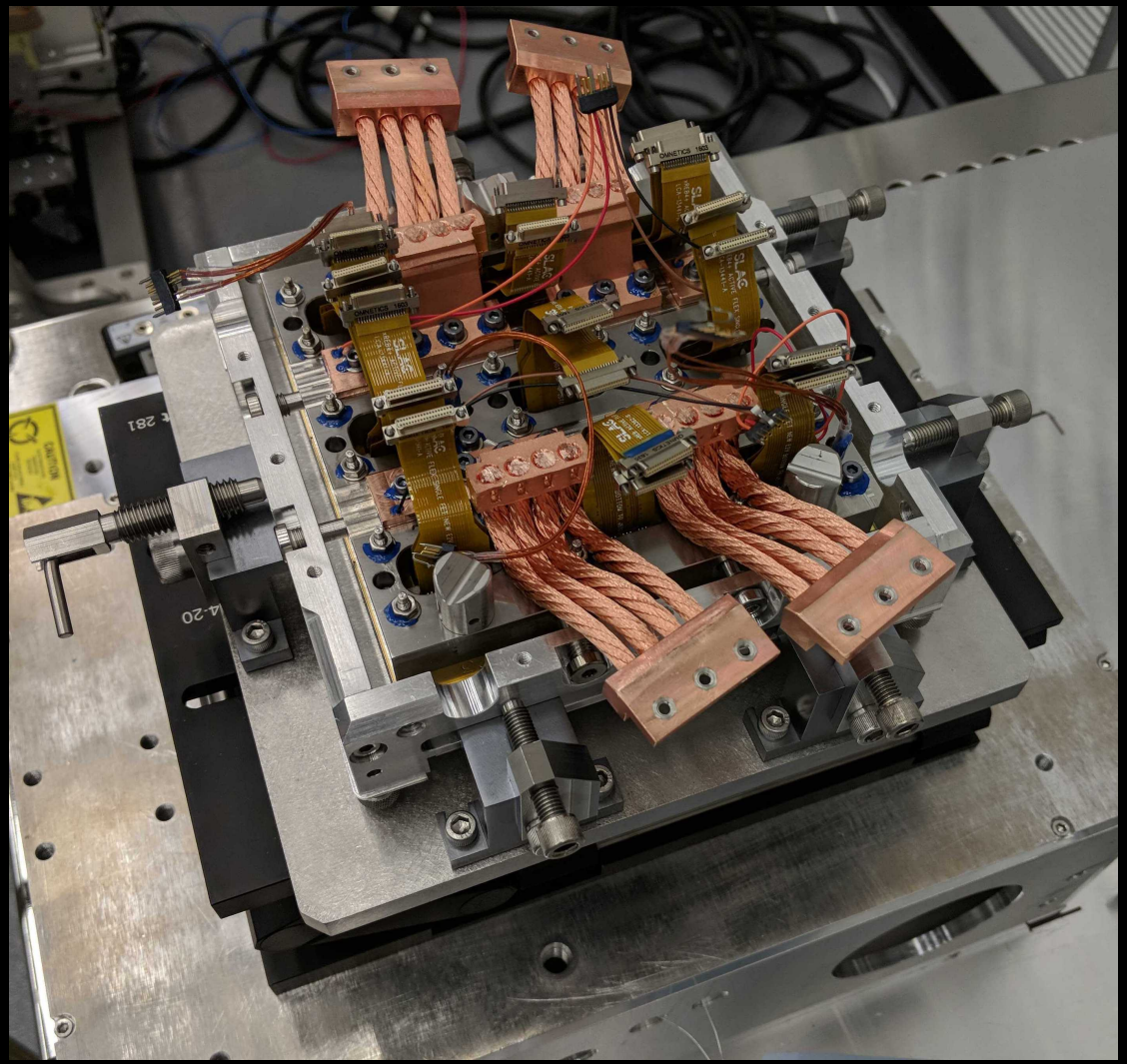


Satellite trail near saturation in the Rubin Observatory camera induces image artifacts

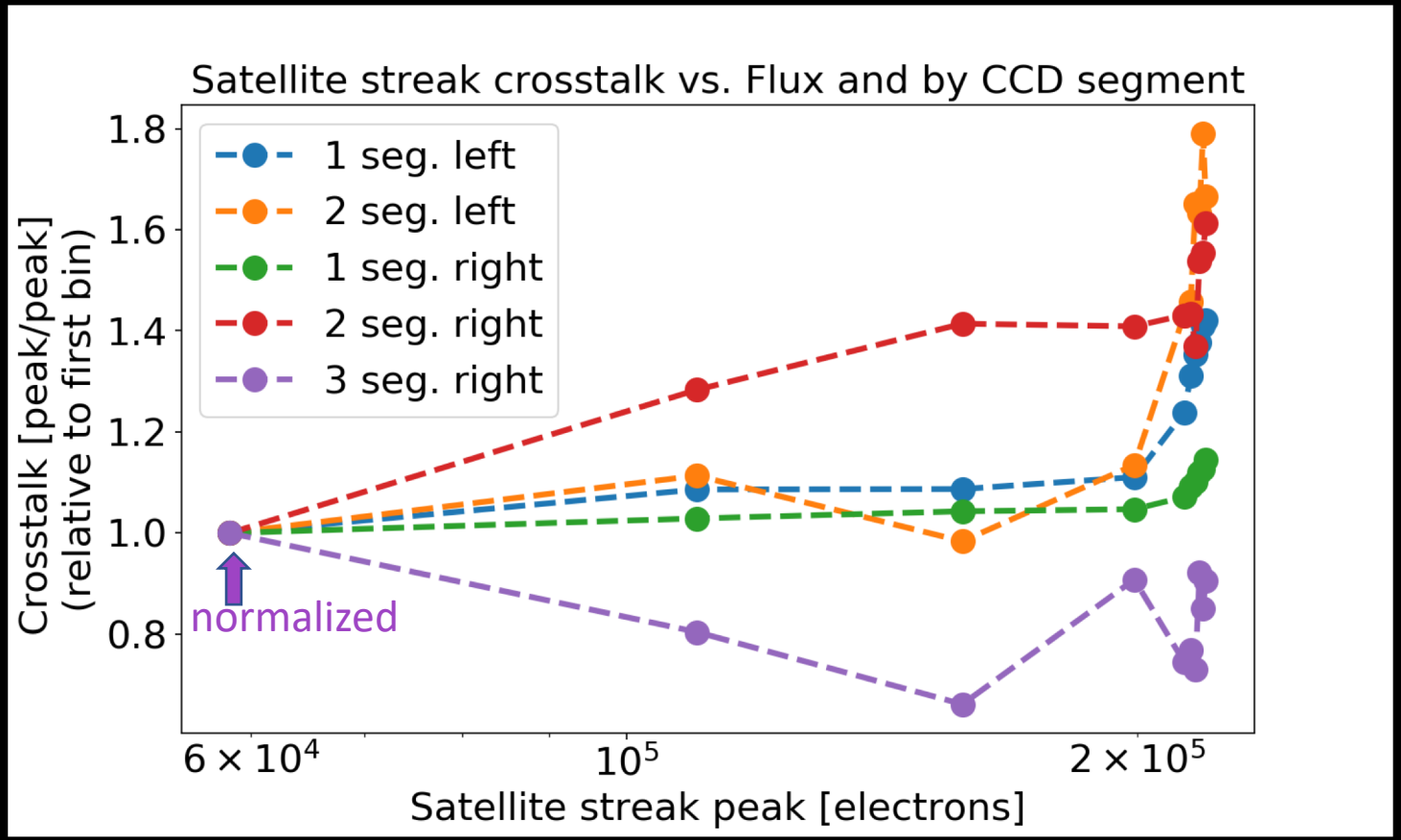


Crosstalk within one CCD





bright trail *nonlinear* crosstalk e2v CCD @ UCD

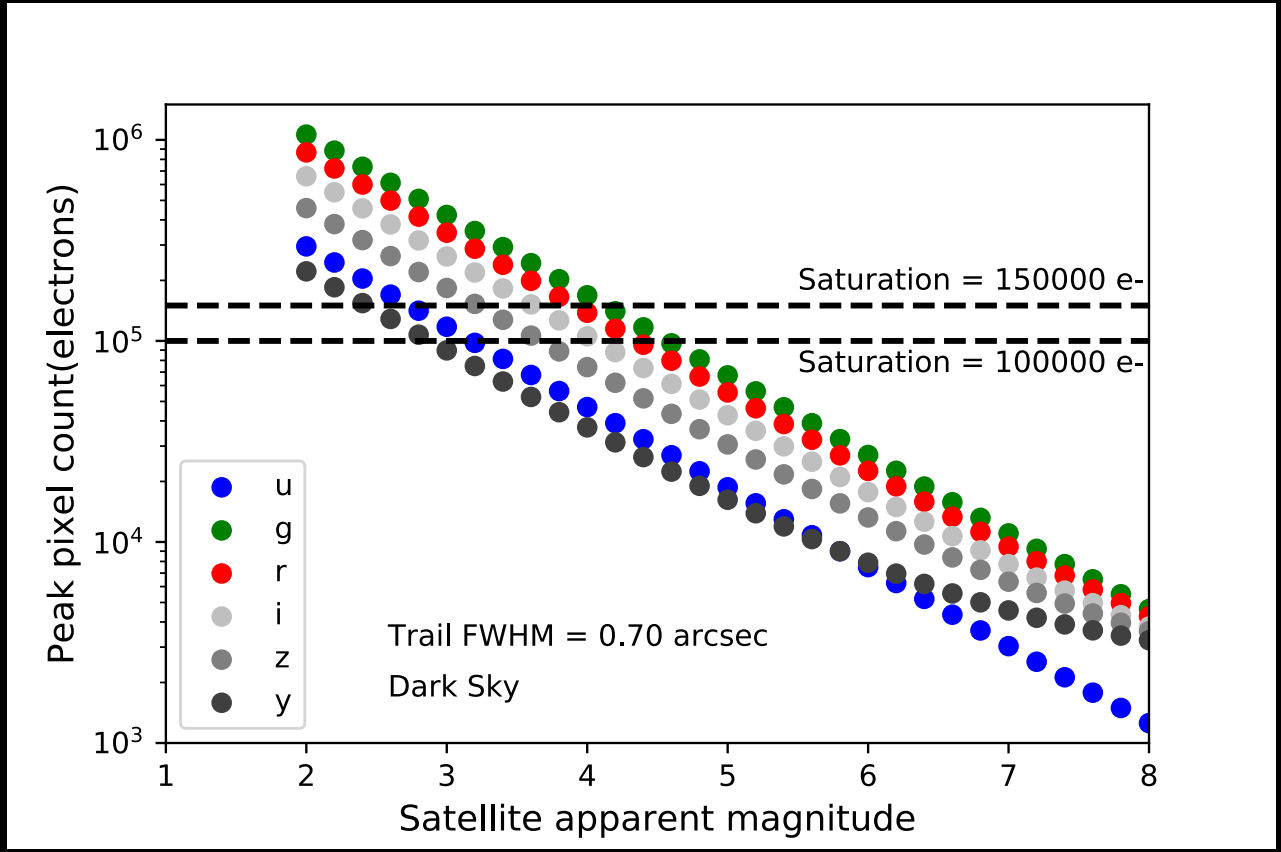


Andrew Bradshaw

Response of LSST CCD vs LEO Sat brightness

550 km altitude

Viewed at zenith

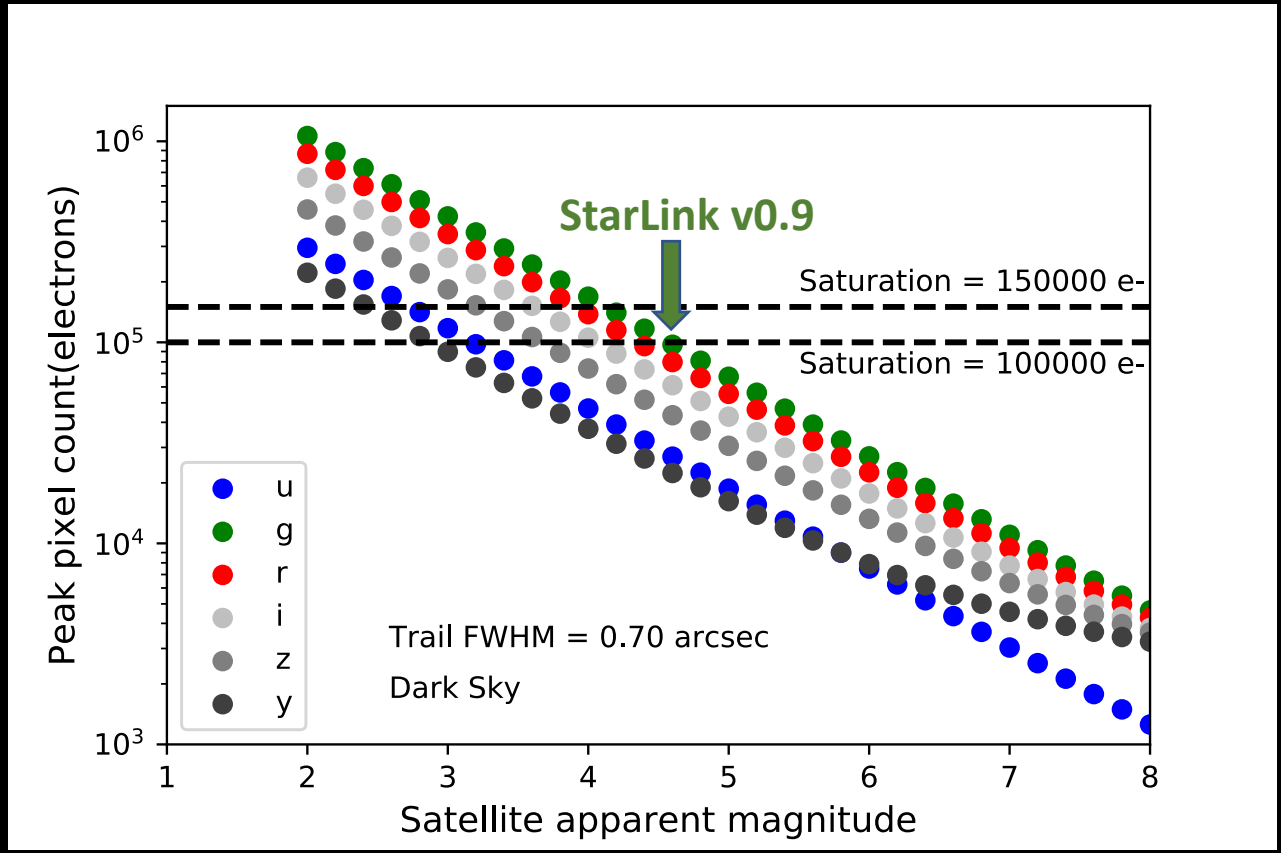


Bo Xin

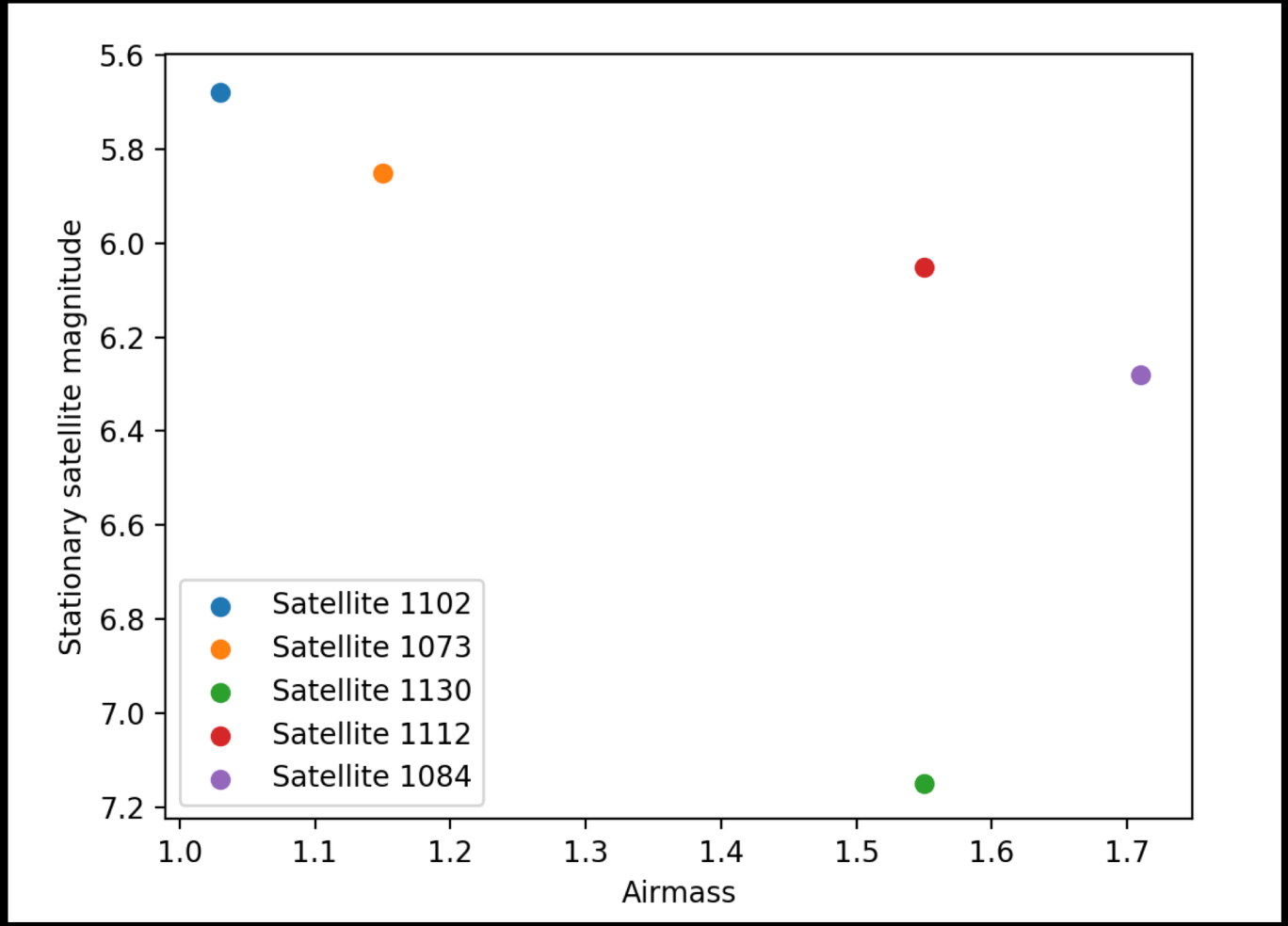
Response of LSST CCD vs LEO Sat brightness

550 km altitude

Viewed at zenith



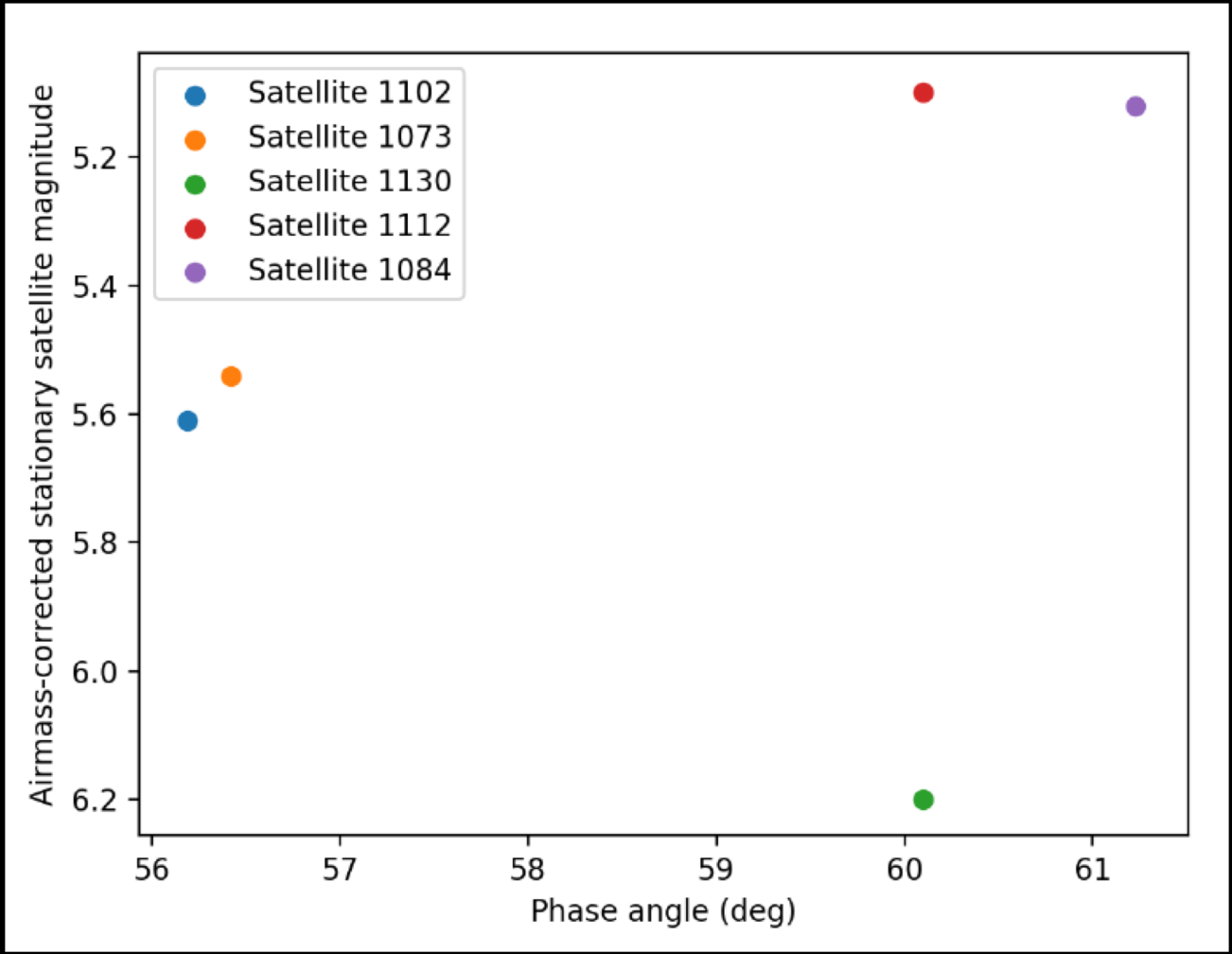
Bo Xin



Blanco imaging of recent Starlinks

Tim Abbott, CTIO

Meredith Rawls, UW



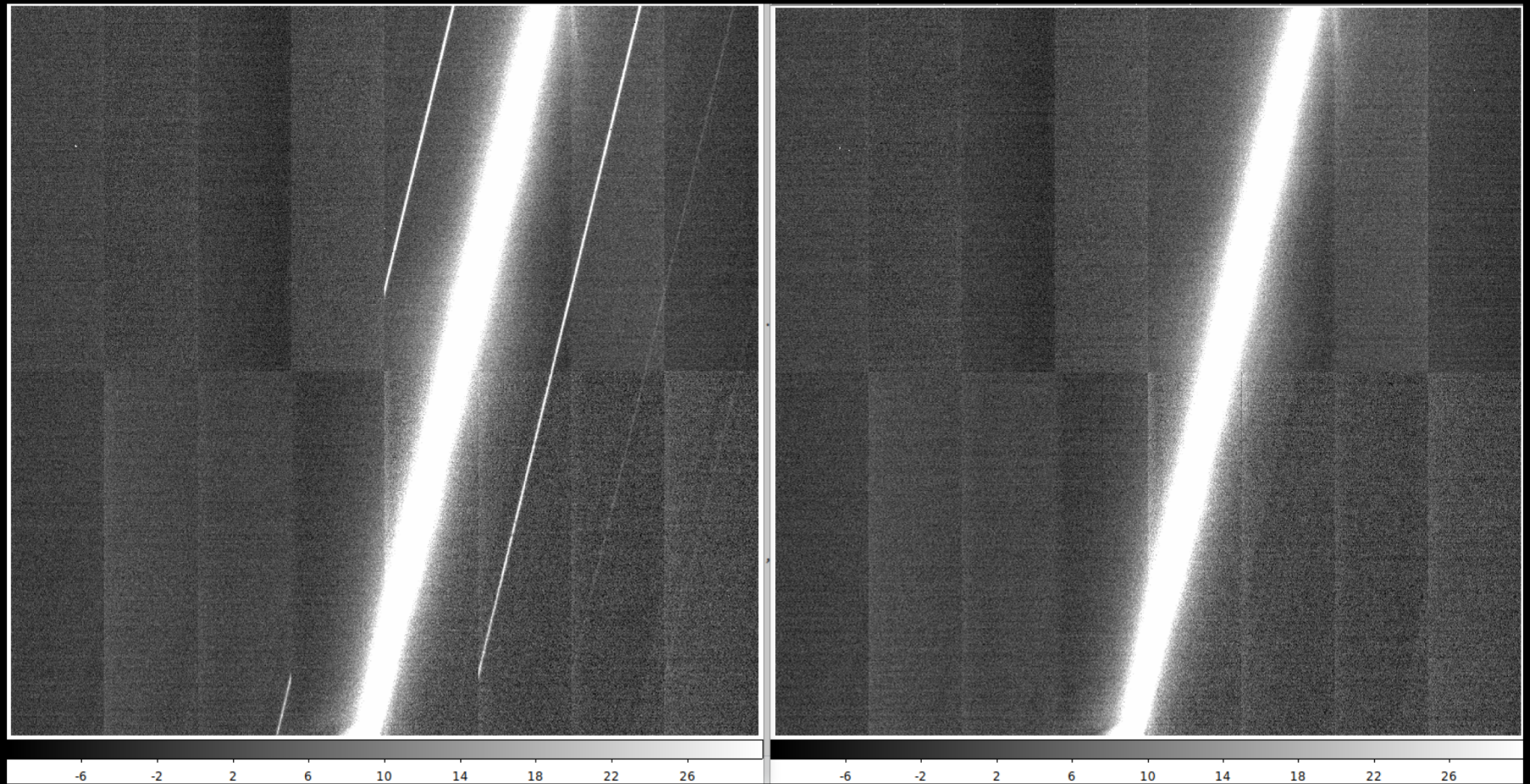
Blanco imaging of recent Starlinks

Tim Abbott, CTIO

Meredith Rawls, UW

Crosstalk corrected with non-linear matrix

No visible residuals from 10x fainter trail down to noise level. More work needed..



- SpaceX is working with the astronomy community to reduce the light pollution effects on optical astronomy

- Making the spacecraft 10 times darker may remove some satellite trail artifacts in the Rubin Observatory camera

- We are working with SpaceX to measure the effect of darkening test satellites in future launches

- However, *even if that works*, evidence of satellite trails will clearly be in the data – complicating data analysis and limiting discoveries

Analysis of Blanco telescope imaging of 5 recent Starlinks demonstrates progress to darkening goal

- *Darksat* ~6 *g* mag extrapolated to zenith
- *Visorsat* may reach the goal of 7.5 *g* mag

Looking to the next decade, the astronomy community must address these issues directly

- Work with industry to develop joint operations solutions to minimize science impact. Tools for efficient scheduling.

- Develop observing strategies and new data analysis methods to correct for statistical and systematic effects caused by satellite trails.

- Operate surveys longer if needed to compensate. But science opportunity cost.