

The impact constellations of low Earth orbiting satellites on Rubin Observatory

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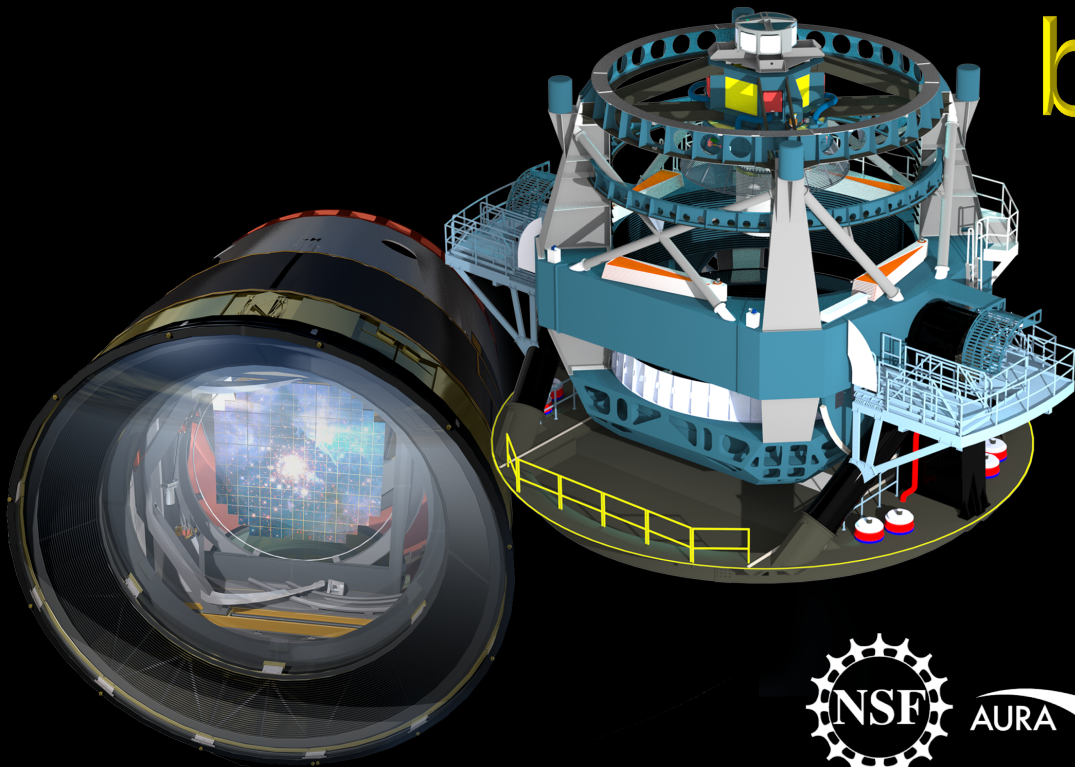


Astro2020 Satellite Constellations

April 27, 2020

Rubin Observatory

Most Impacted by satellites



AURA

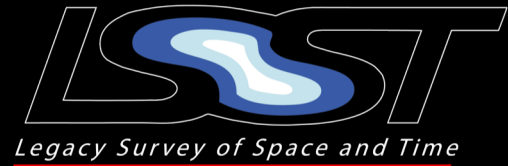
U.S. DEPARTMENT OF
ENERGY

SLAC

CHARLES AND LISA SIMONYI FUND
*** FOR ARTS AND SCIENCES ***

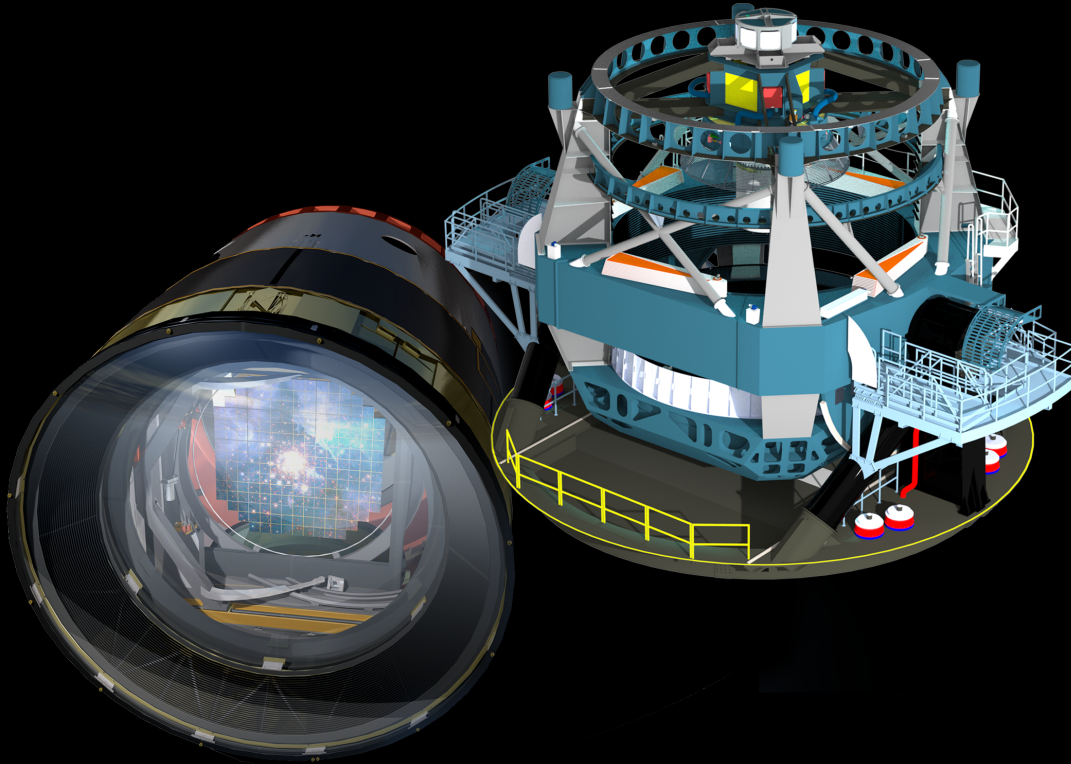
LSST
CORPORATION

Rubin Observatory



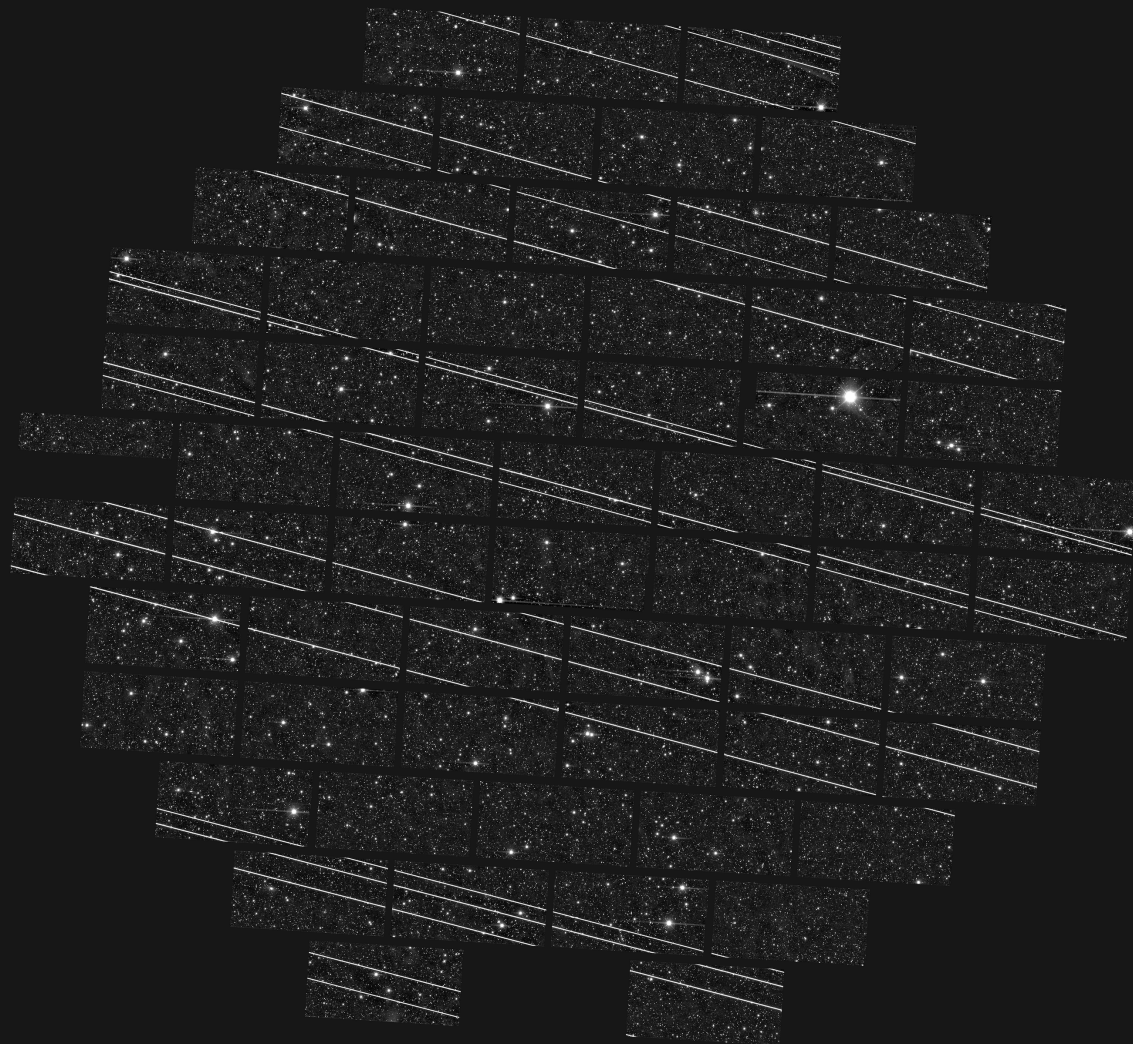
Rubin Observatory will execute the *Legacy Survey of Space and Time*, producing the deepest, widest, view of our dynamic Universe:

- 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



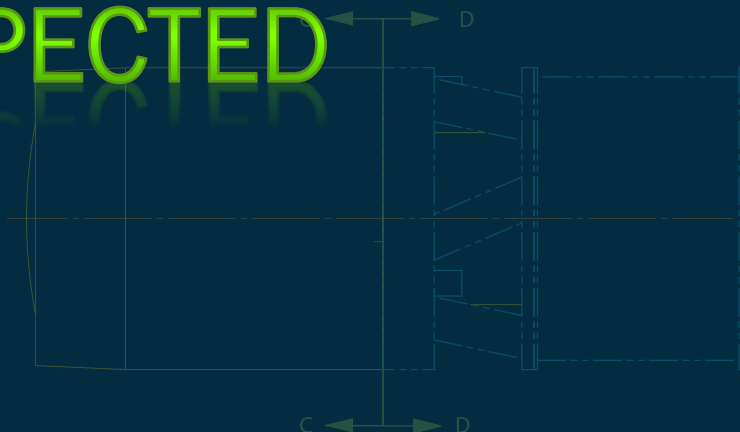


Alex Drlica-Wagner
CTIO, AURA

Automated discovery and data exploration



DISCOVERING
THE UNEXPECTED



The image contains two technical drawings. The one on the left shows a cross-section of a telescope structure with a central circular component and several smaller circles. The one on the right shows a side view of a telescope structure with a central vertical axis and several horizontal lines. Labels 'C' and 'D' are present near the bottom of the right drawing.



2018

A wide-angle photograph of the Rubin Observatory construction site on a mountain ridge at sunset. The sky transitions from a bright orange glow on the left to a deep blue on the right. In the center-left, a large, white, angular concrete structure is under construction, with a crane visible behind it. To the right, a completed observatory dome sits atop a rocky peak. The foreground shows a dirt road, several shipping containers, and a crane on the right side. The terrain is arid with sparse, dry vegetation.

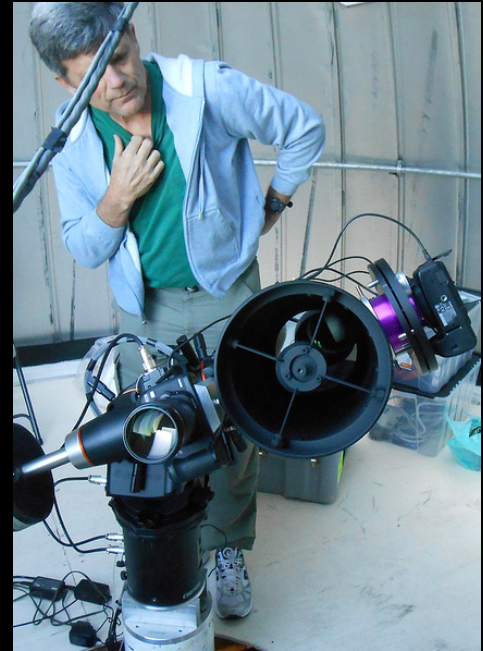
Rubin Observatory LSST survey 2022-2032

February 11, 2020

A wide-field astronomical photograph showing a dense field of stars. Two prominent, bright, diagonal streaks of light cross the upper half of the frame, representing Starlink satellites in motion. The background is a dark, star-filled sky.

Two Starlink satellites
in a 30 sec exposure

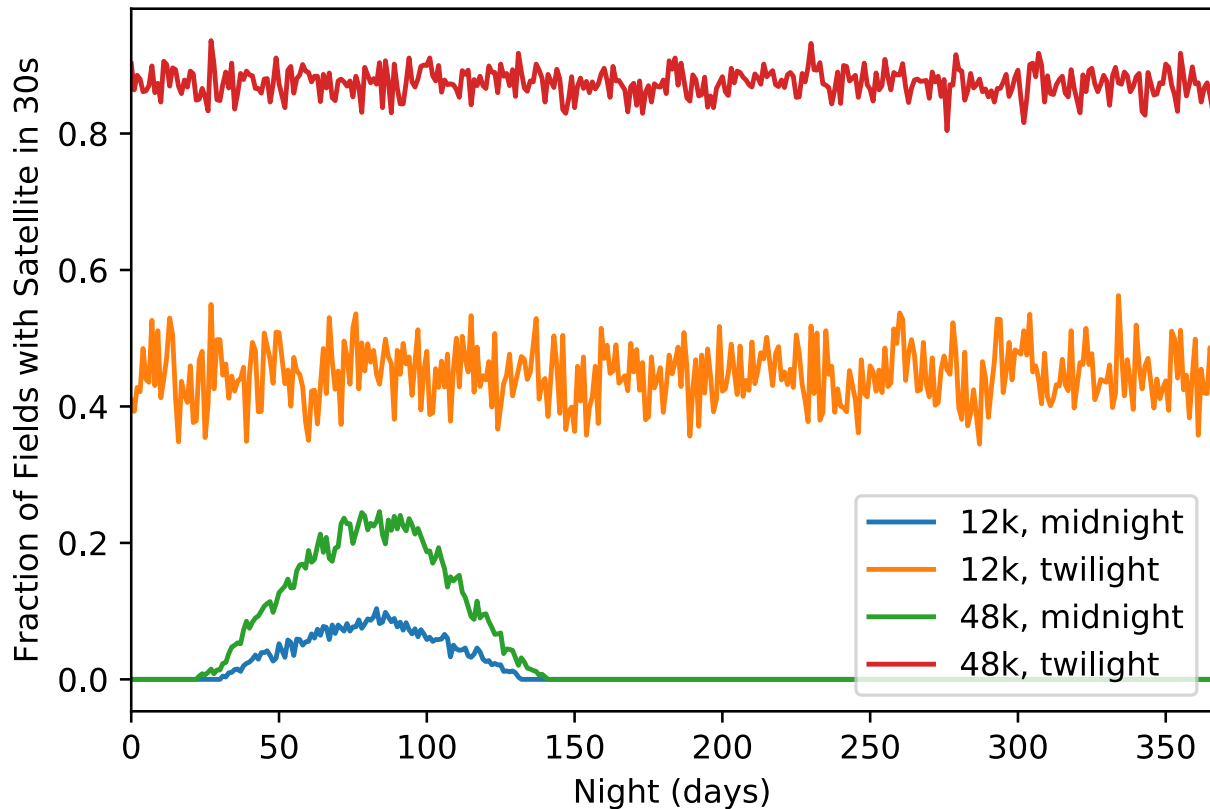
2019-08-27



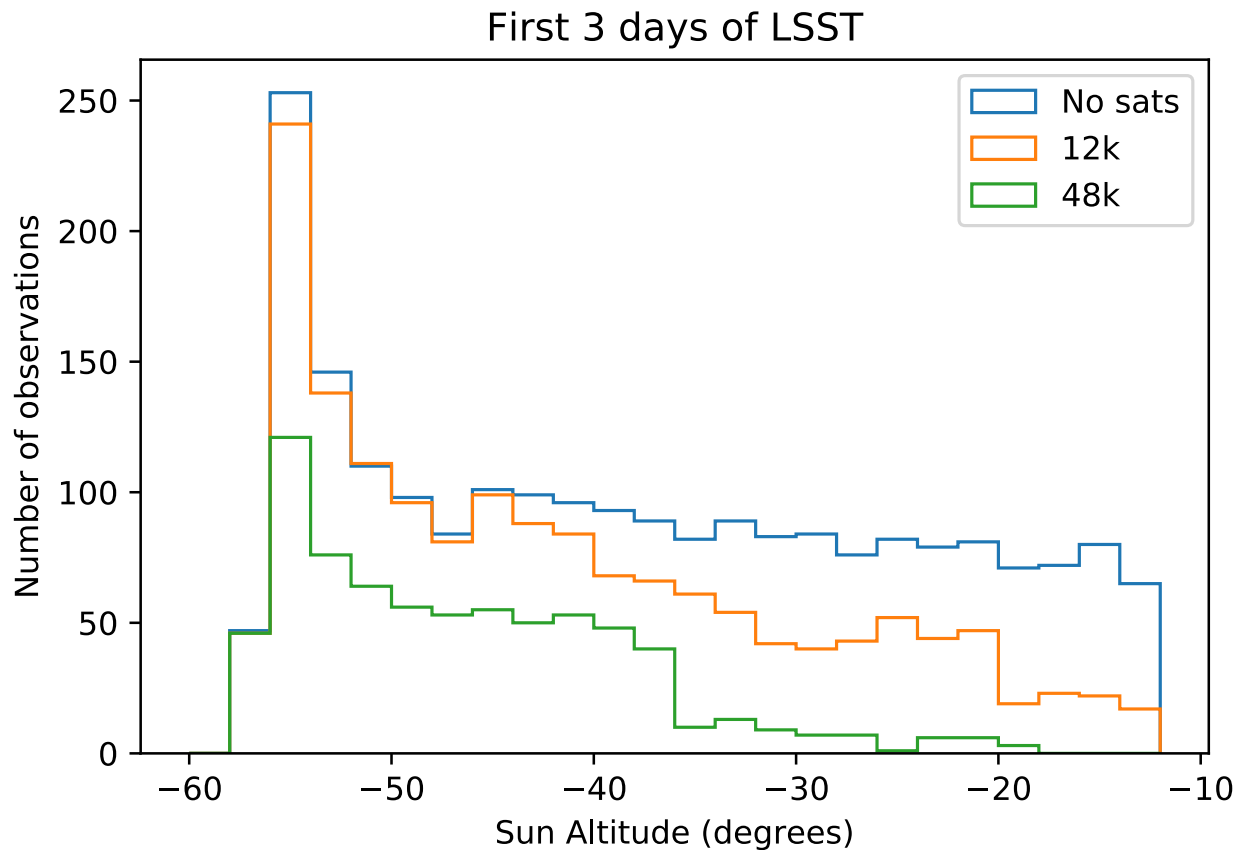
Very small
telescope with
wide field of view.

John Tonry
U Hawaii

12K, 48K LEO sats in normal LSST cadence

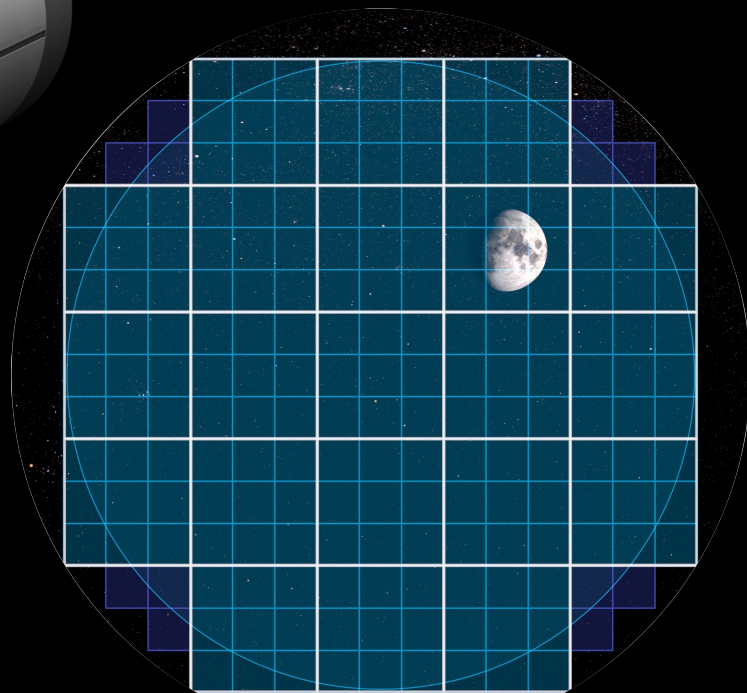
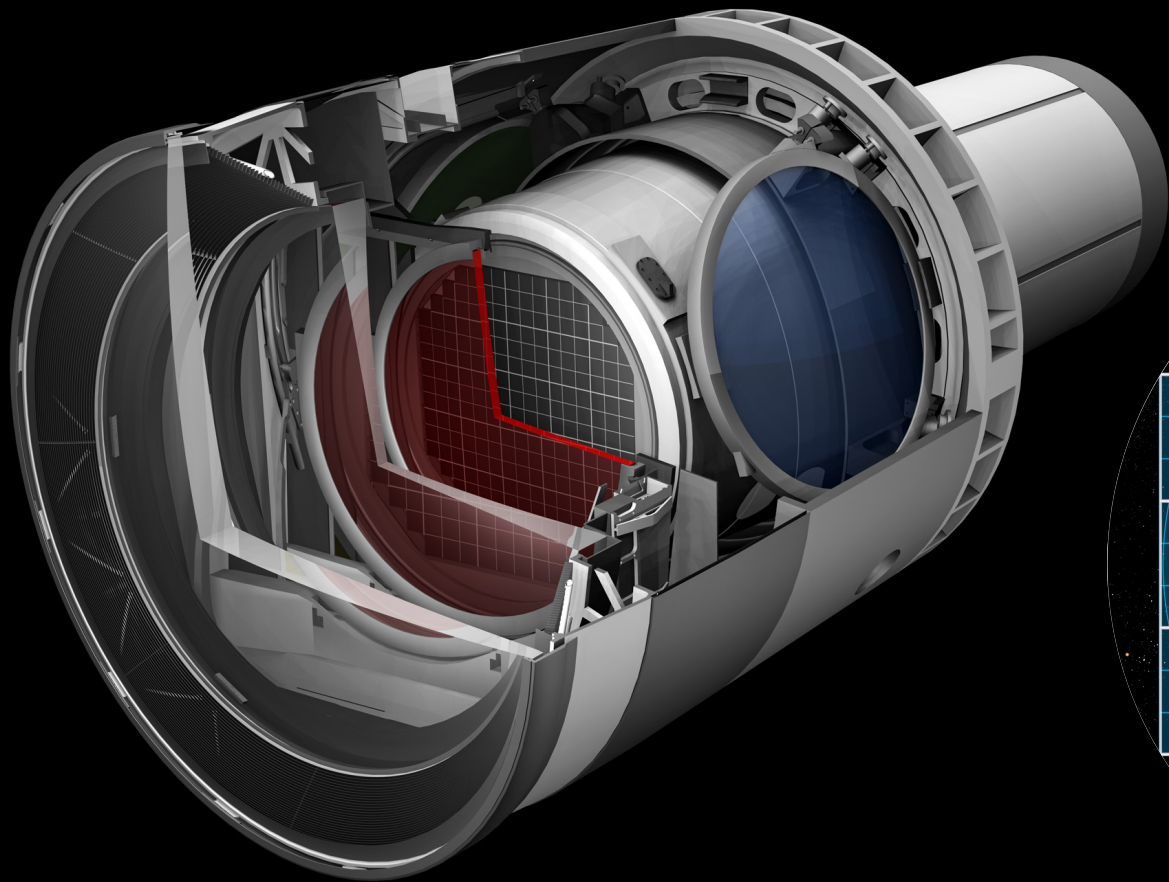


Dodging satellites: inefficient



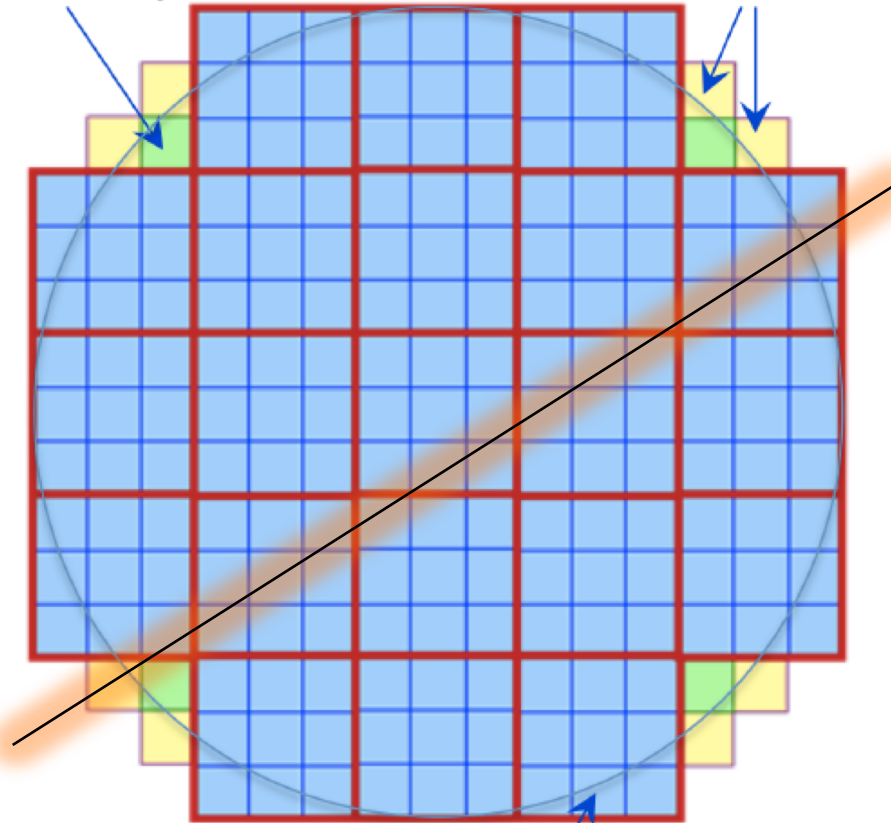
Rubin Observatory: a limiting case

- 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)**

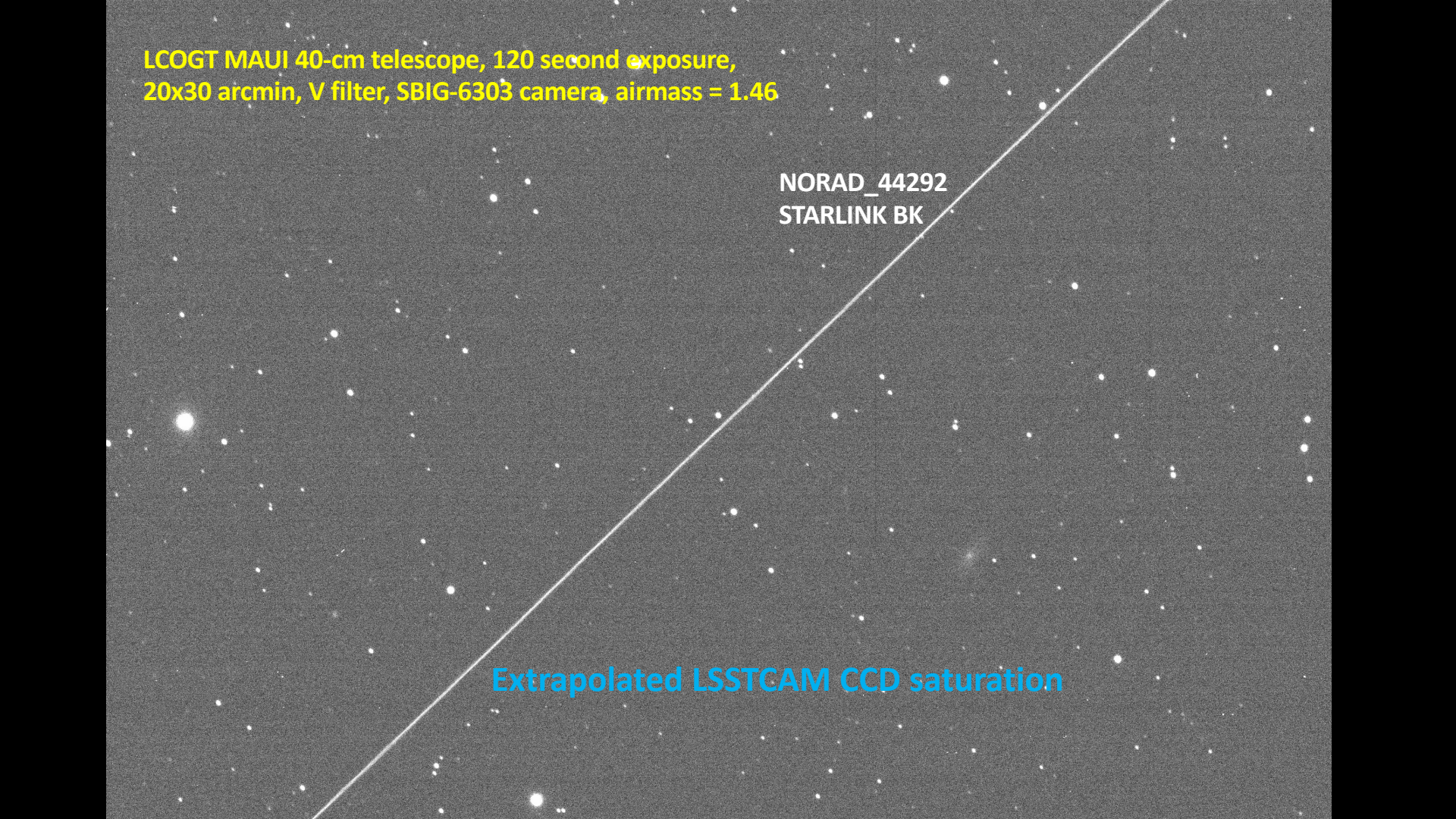


**3.5 degree field of view,
634mm diameter**

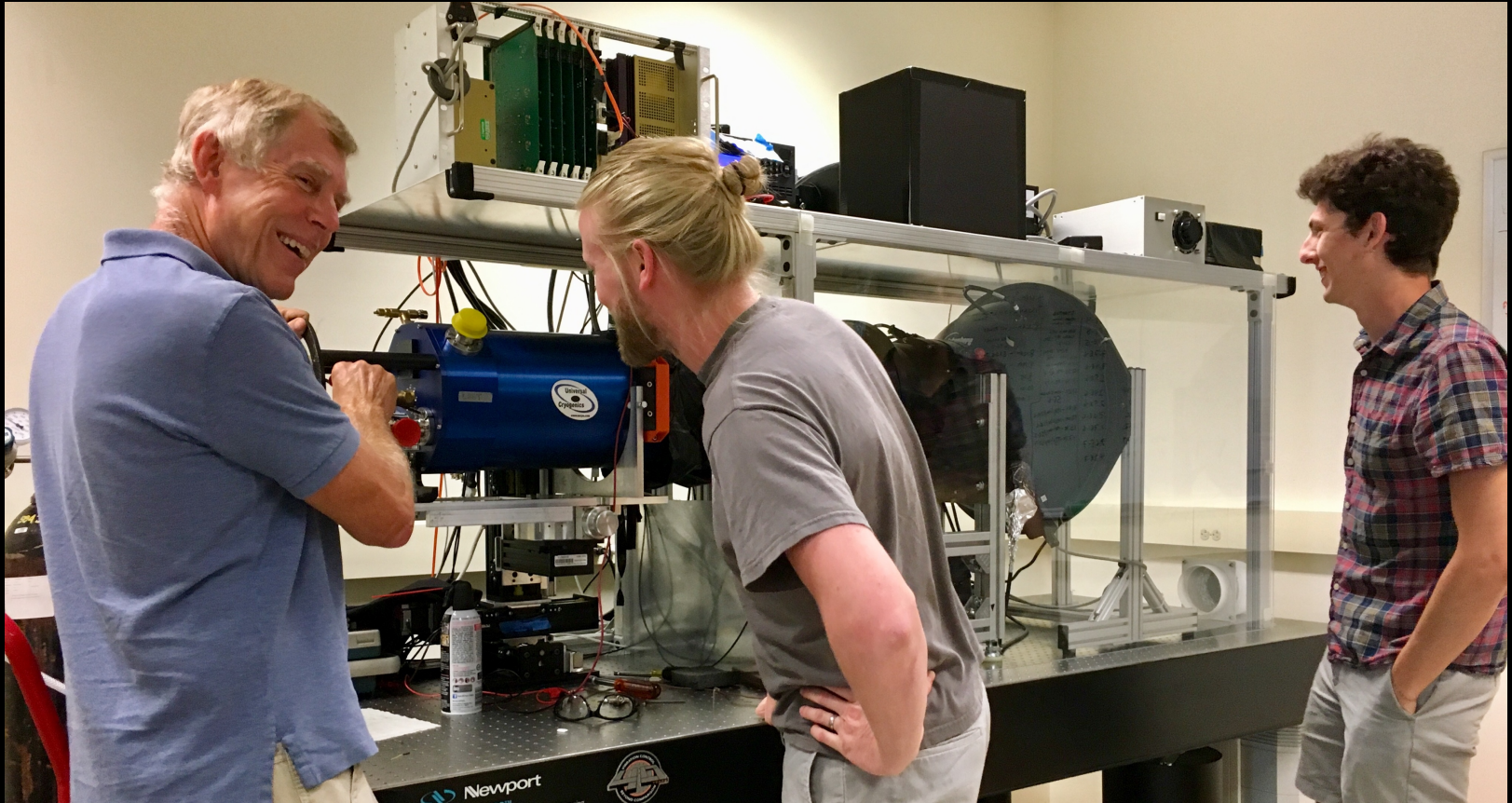
LCOGT MAUI 40-cm telescope, 120 second exposure,
20x30 arcmin, V filter, SBIG-6303 camera, airmass = 1.46

NORAD_44292
STARLINK BK

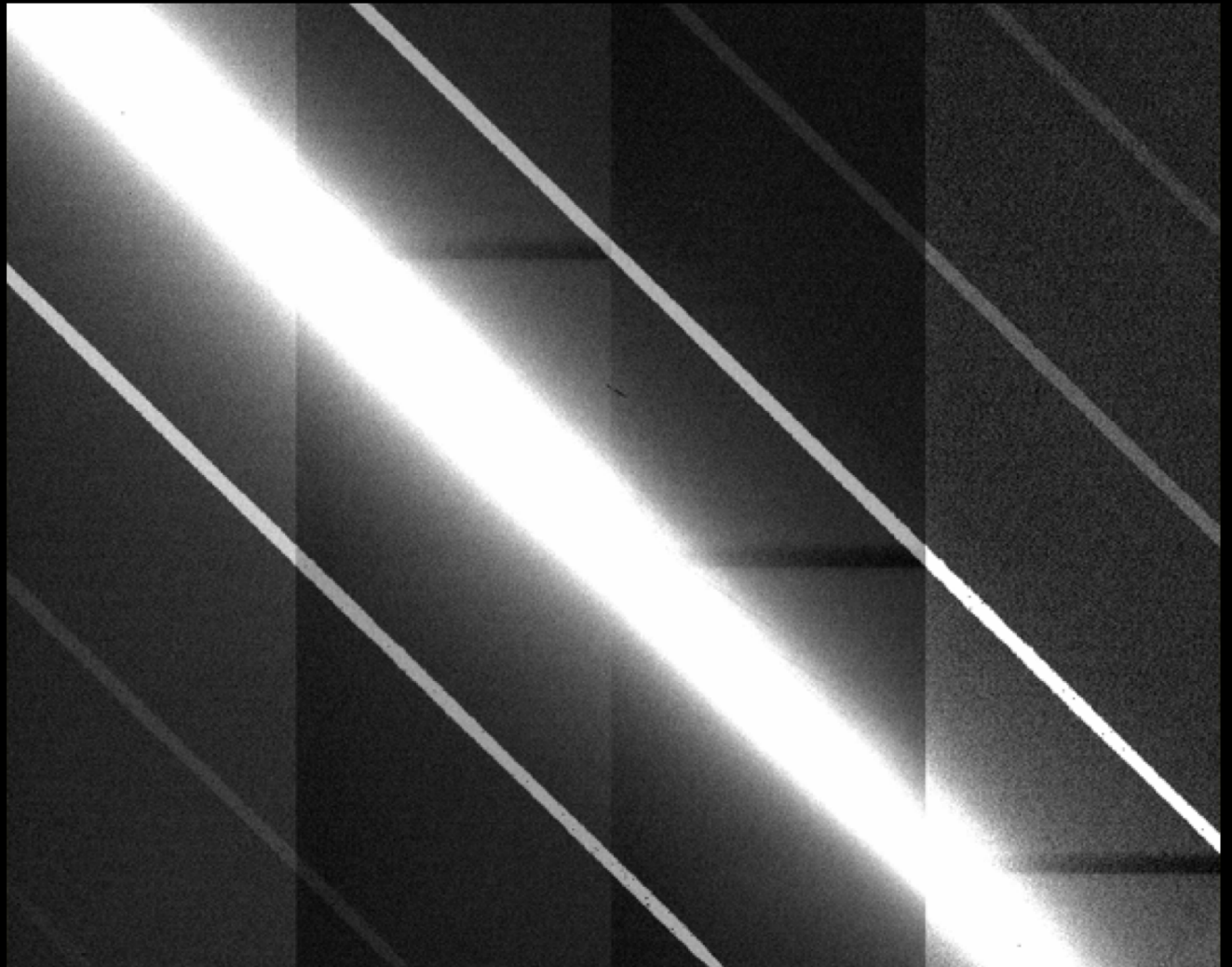
Extrapolated LSSTCAM CCD saturation



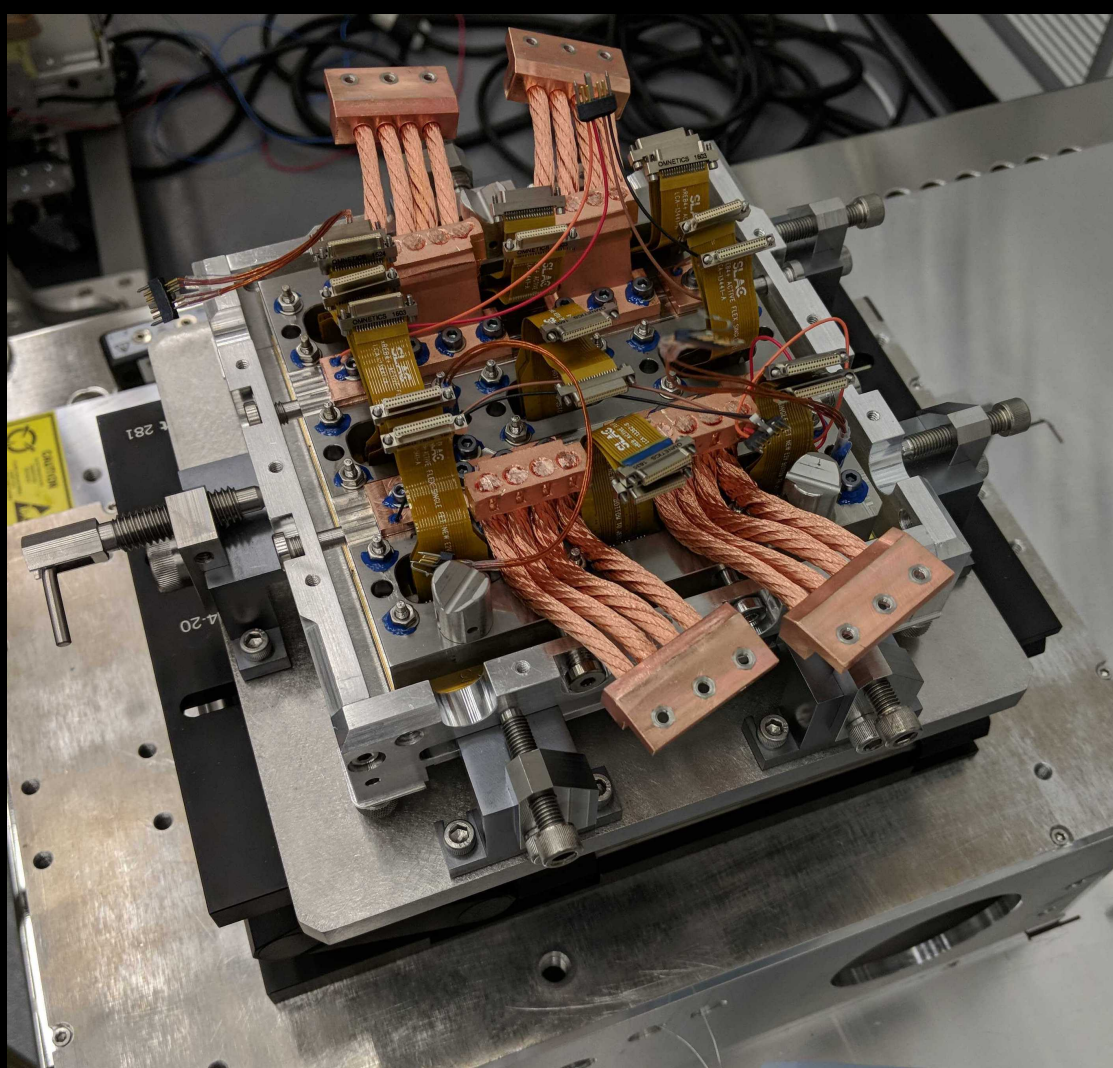
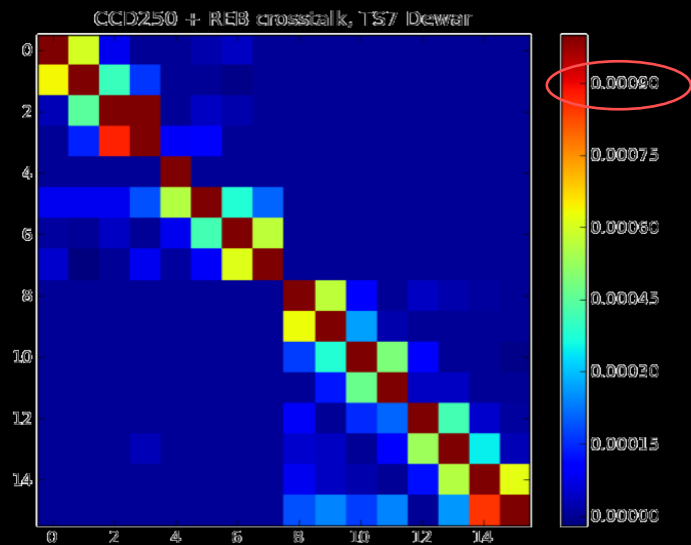
Test effect of Starlink trail on LSSTCAM CCD



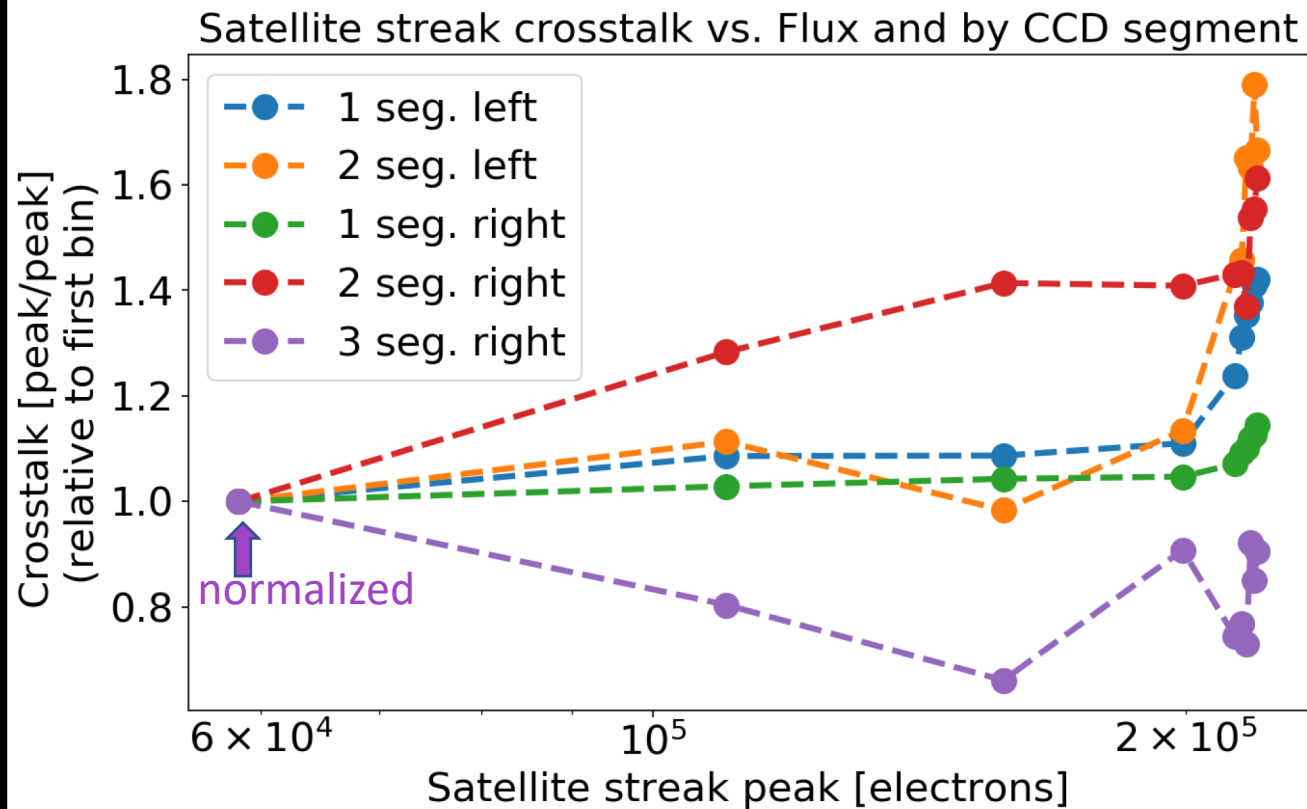
Satellite trail near
saturation in the
Rubin Observatory
camera induces
image artifacts



Crosstalk within one CCD



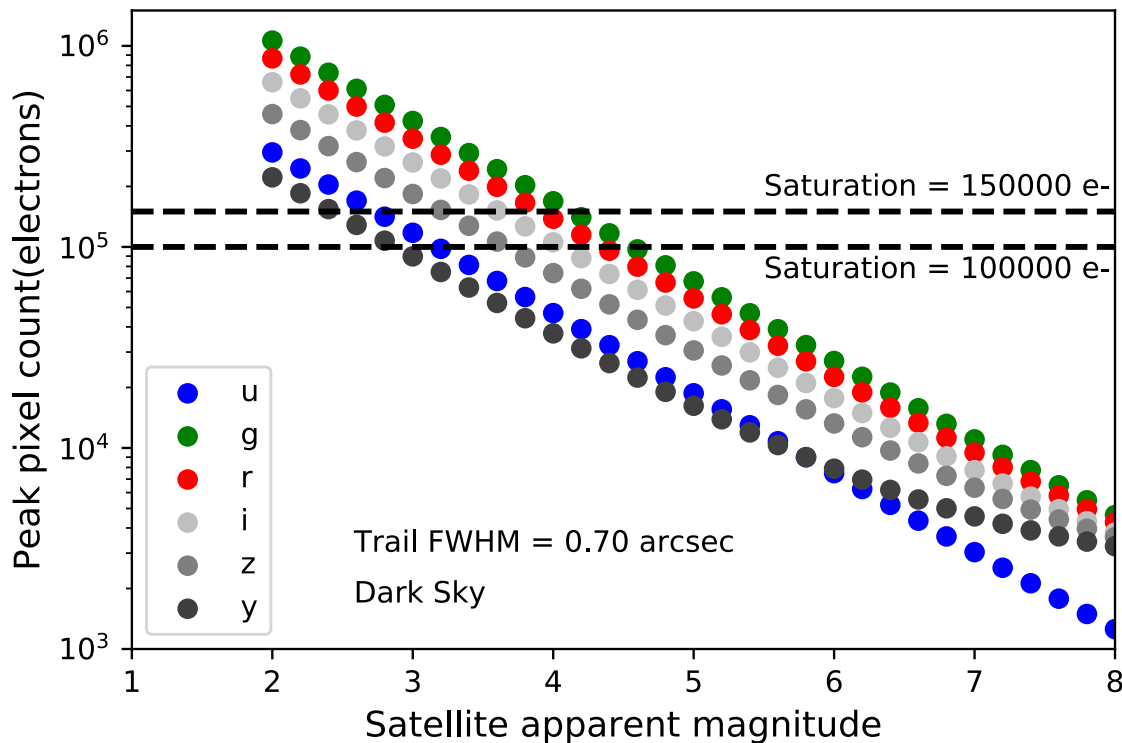
bright trail *nonlinear* crosstalk e2v CCD @ UCD



Response of LSST CCD vs LEO Sat brightness

550 km
altitude

Viewed at
zenith

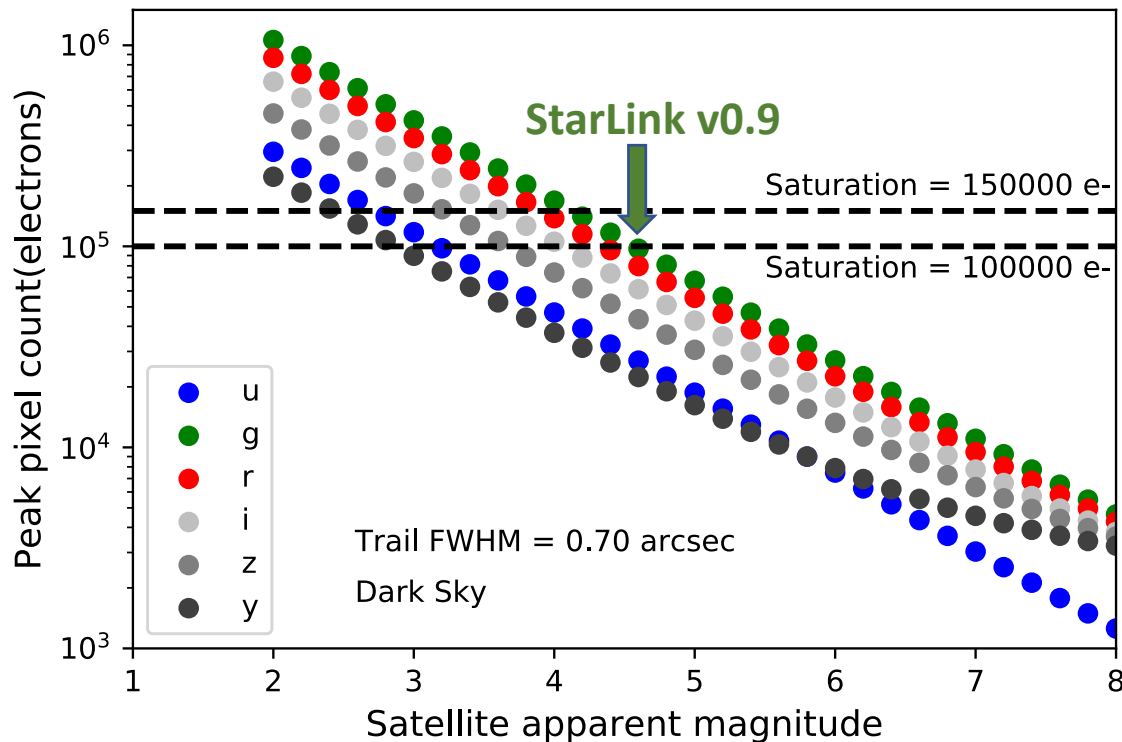


Bo Xin

Response of LSST CCD vs LEO Sat brightness

550 km
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Viewed at
zenith

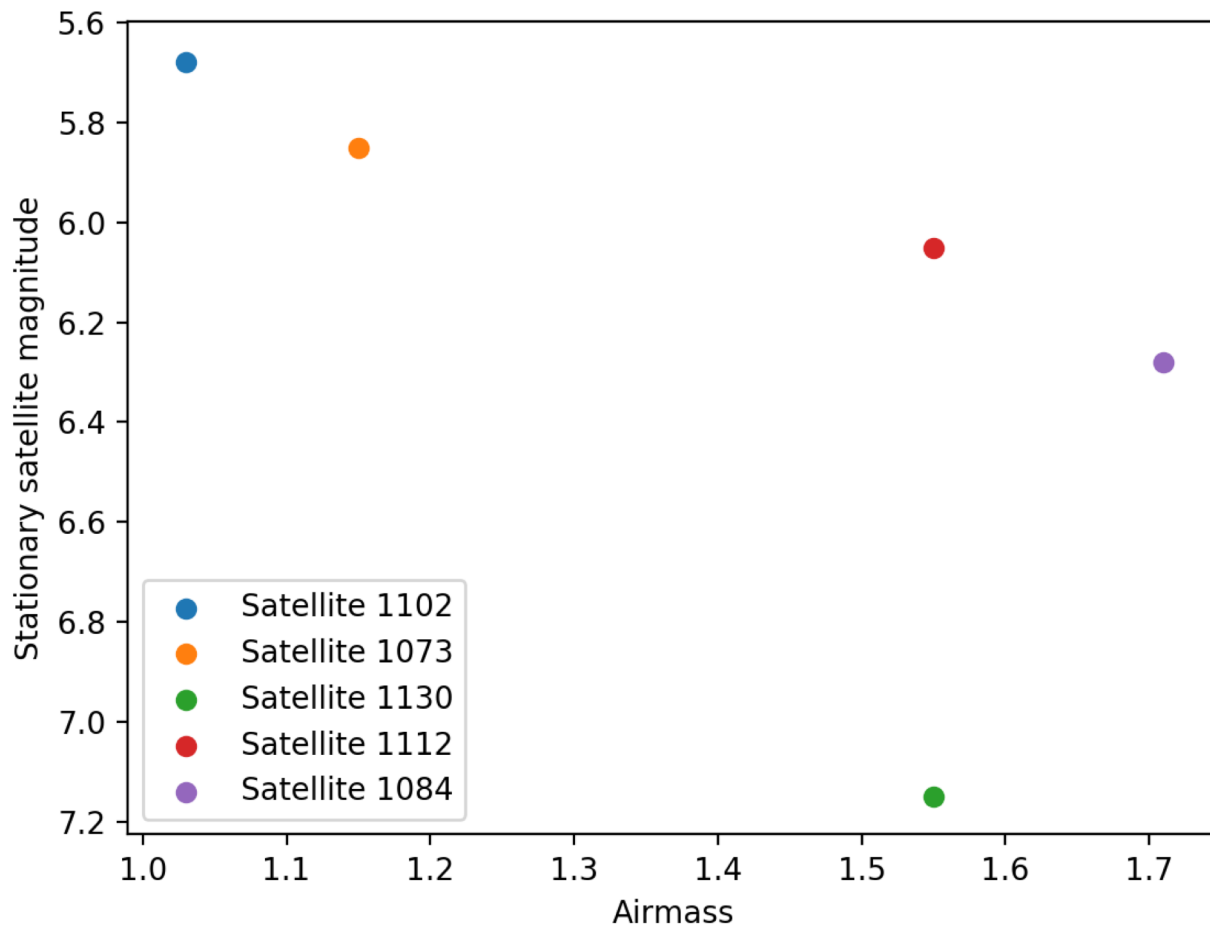


Bo Xin

Blanco imaging of recent Starlinks

Tim Abbott, CTIO

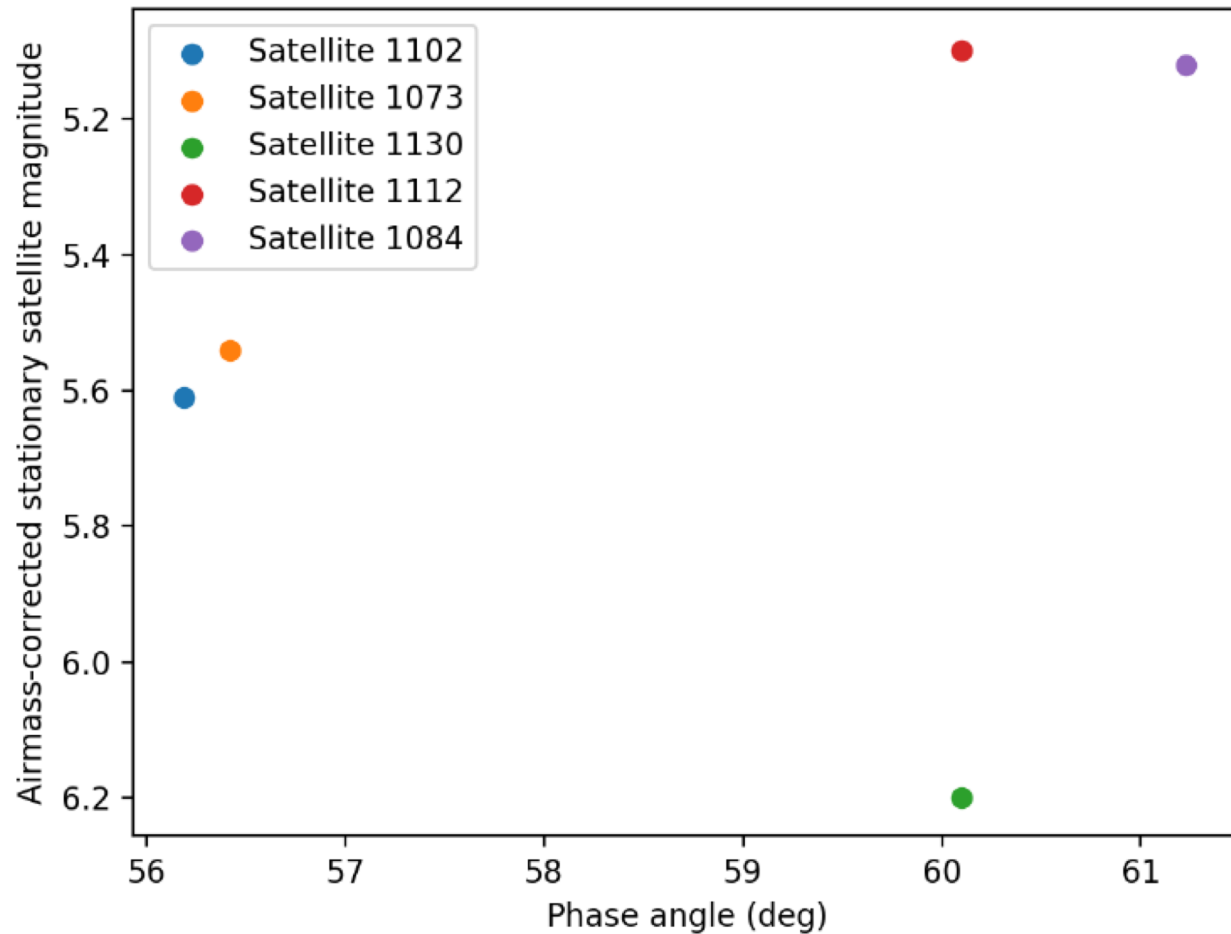
Meredith Rawls, UW



Blanco imaging of recent Starlinks

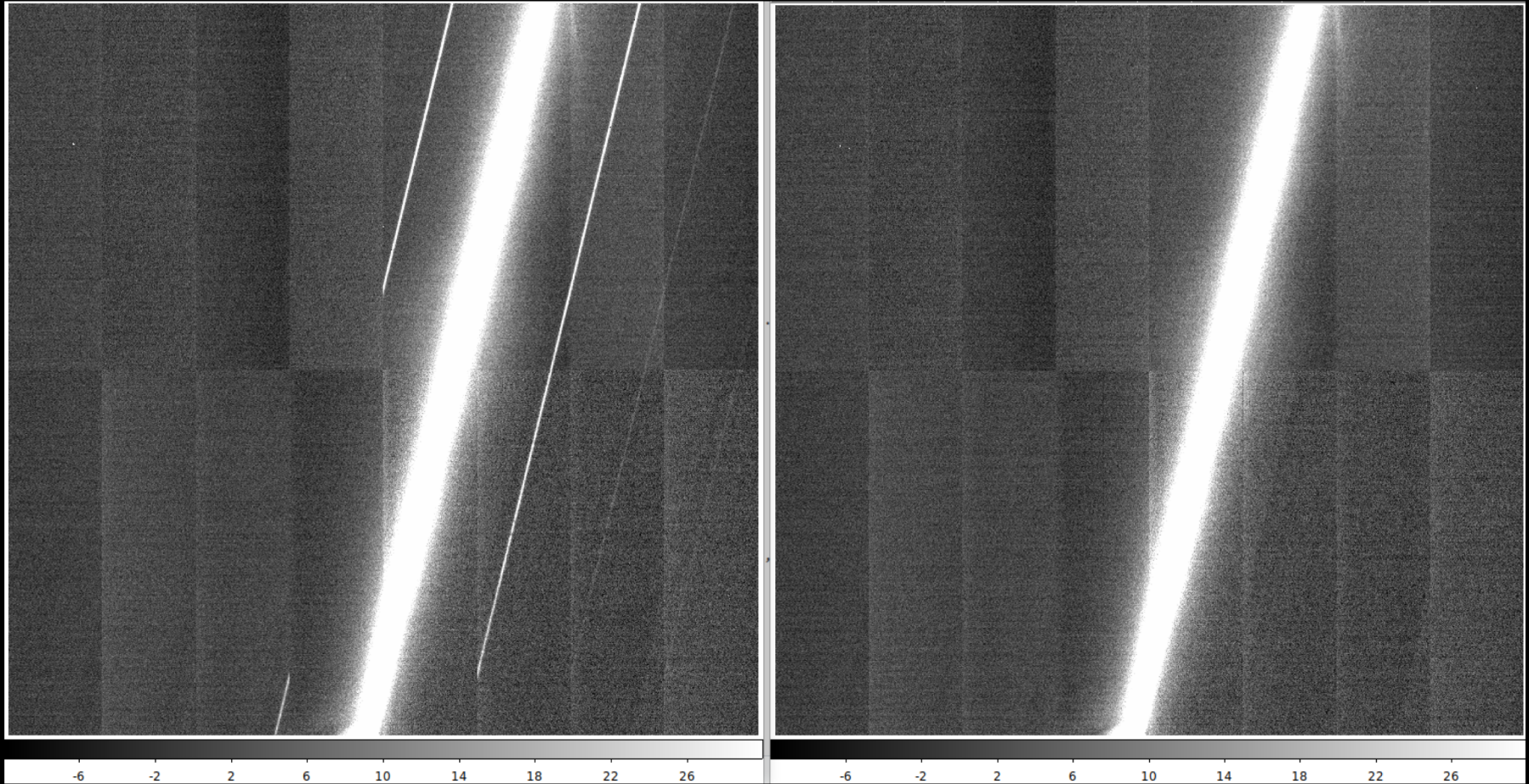
Tim Abbott, CTIO

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.