Rubin's LSST as a large-scale time-domain photometric survey

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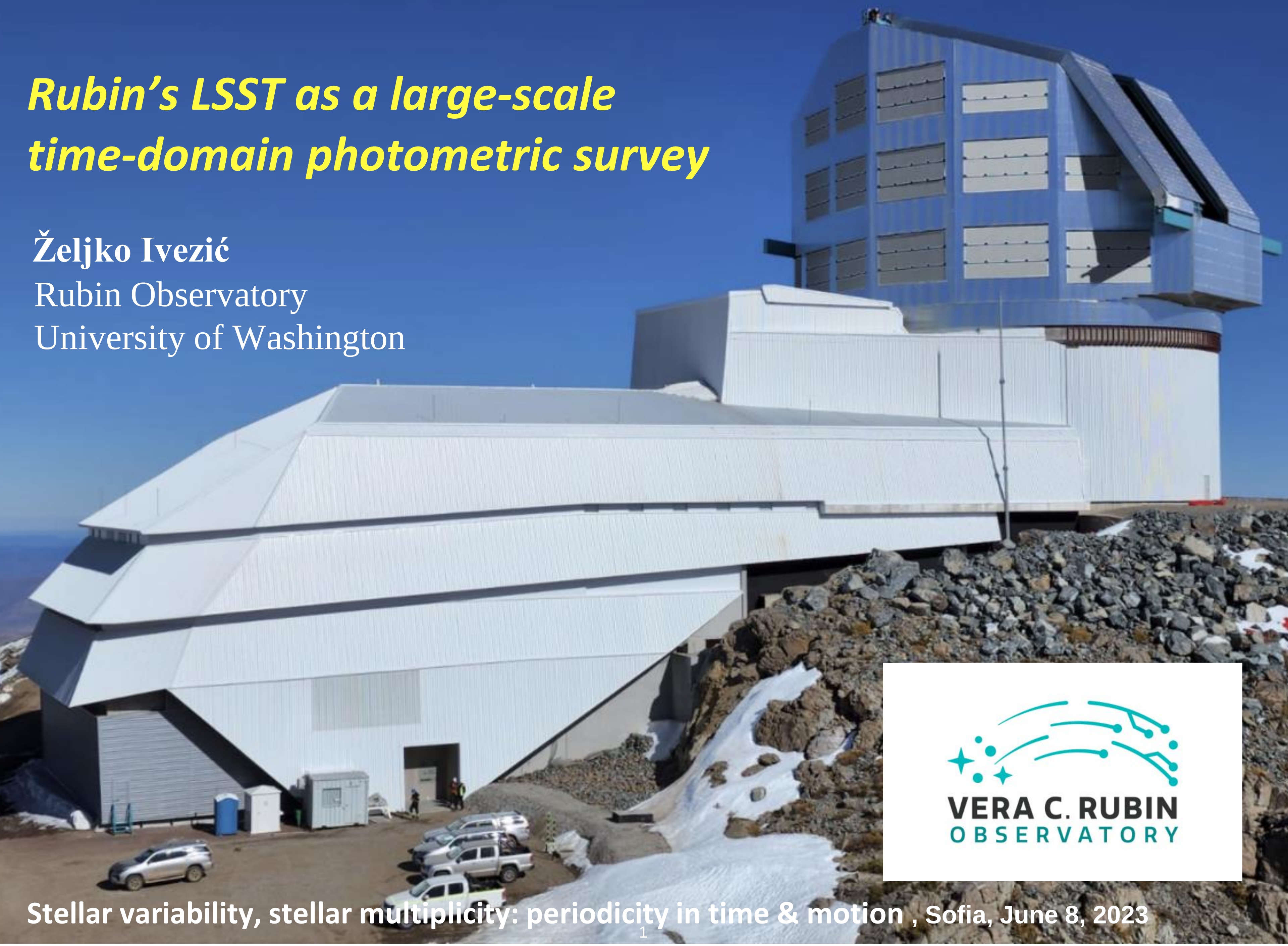


Stellar variability, stellar multiplicity: periodicity in time & motion , Sofia, June 8, 2023

Science motivation for undertaking the Legacy Survey of Space and Time

More details about science drivers and system design: Ivezic et al. (2019): ls.st/lop

Expansion and history of the Universe and the growth of structure
(dark matter, dark energy, cosmology, spatial distribution of galaxies, gravitational lensing, supernovae): "Was Einstein right?"

Time domain: what changes on the sky?
(cosmic explosions, variable stars, unknown unknowns)

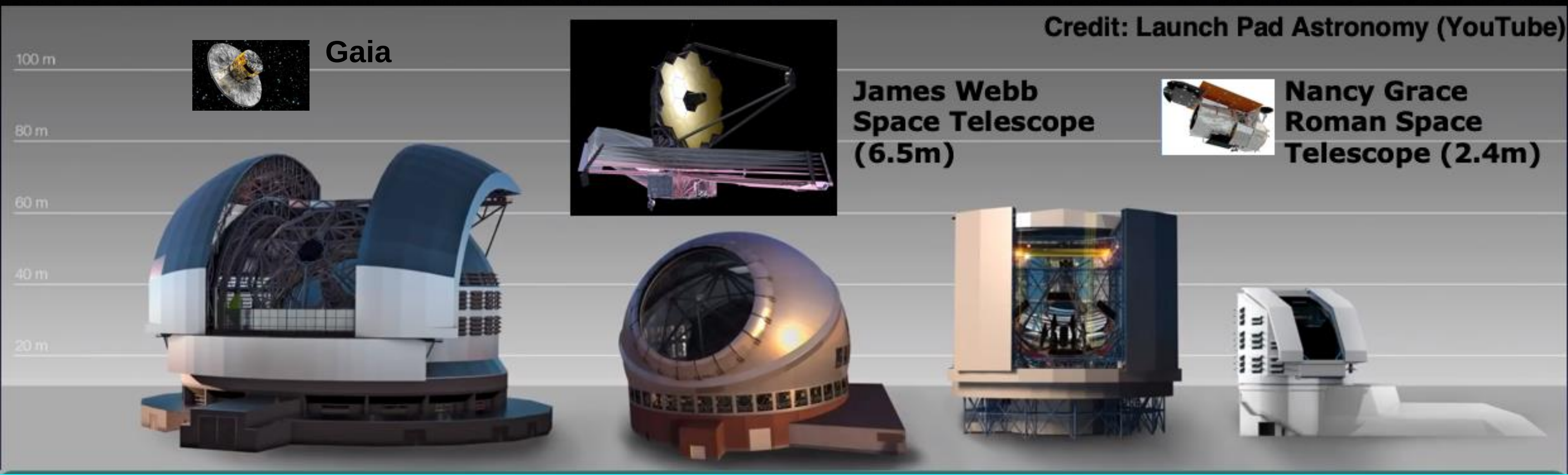
The Solar System structure
(near-Earth hazardous asteroids, main-belt asteroids, trans-Neptunian objects, comets)

1

The Milky Way structure
(stars as tracers of the structure and evolution of our Galaxy, interstellar matter, the physics of stars)

3

A key point: most of science programs will utilize the same dataset.



ELT: ~40m TMT: ~30m GMT: ~25m

Rubin: 8.4m

Rubin Obs. will not have the largest mirror but will have by far the largest product of the mirror area and the field-of-view size (etendue or throughput)

Vera C. Rubin (1928-2016)

Basic idea behind LSST: **a uniform sky survey**

- 90% of time will be spent on a uniform survey:
  every 3-4 nights, the whole observable sky will be scanned twice per night (ugrizy bands, 0.3-1.1 micron)
- in 10 years, half of the sky will be imaged about 1000 times:
  a digital color movie of the sky, 5-sigma r mag ~ 24
- ~100 petabytes, or 100,000 terabytes, of data:
  about a billion 16 megapixel images, enabling measurements for 40 billion objects, **coadded map depth 5-sigma r mag ~ 27**

SDSS
gri
3.5’x3.5’
r~22.5

3 arcmin is 1/10 of the full Moon’s diameter

LSST’s field of view is 3000 times larger

HSC
gri
3.5’x3.5’
r~27

3 arcmin is 1/10 of the full Moon’s diameter

like LSST depth (but tiny area)

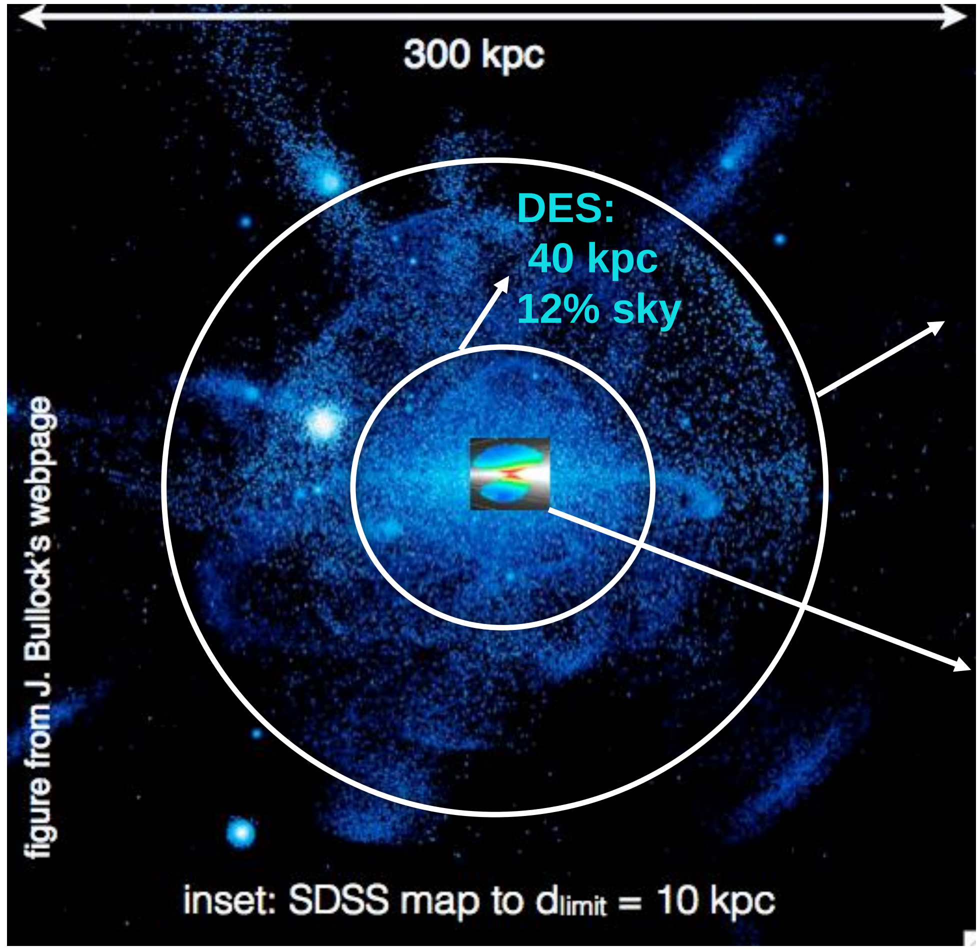
LSST will deliver 5 million such images

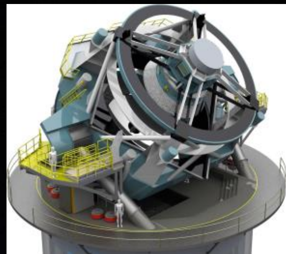
Milky Way science with upcoming coadded LSST data

Distance limits for (very numerous!) **turn-off stars:**

A few hundred million turn-off stars (with [Fe/H]!) out to ~100 kpc.

We will go beyond the limit of 100 kpc for main sequence stars with luminous variable stars RR Lyrae!





Transients with LSST

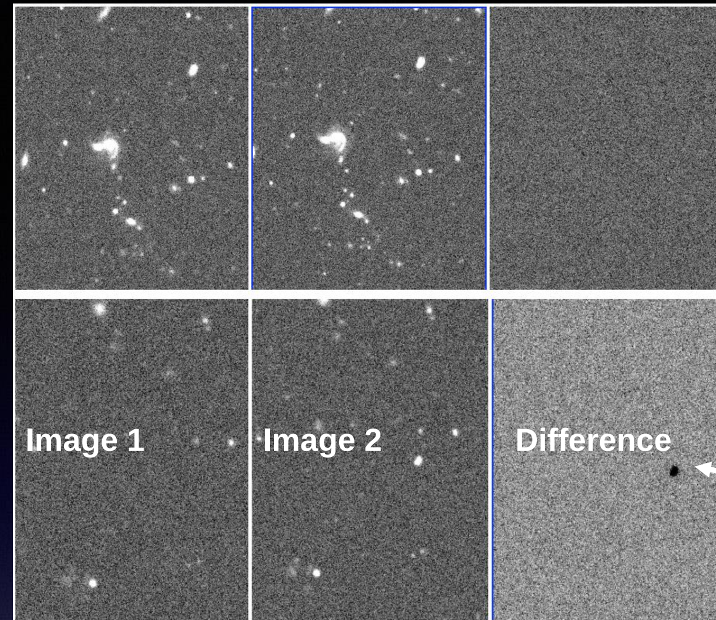


Image 1 Image 2 Difference

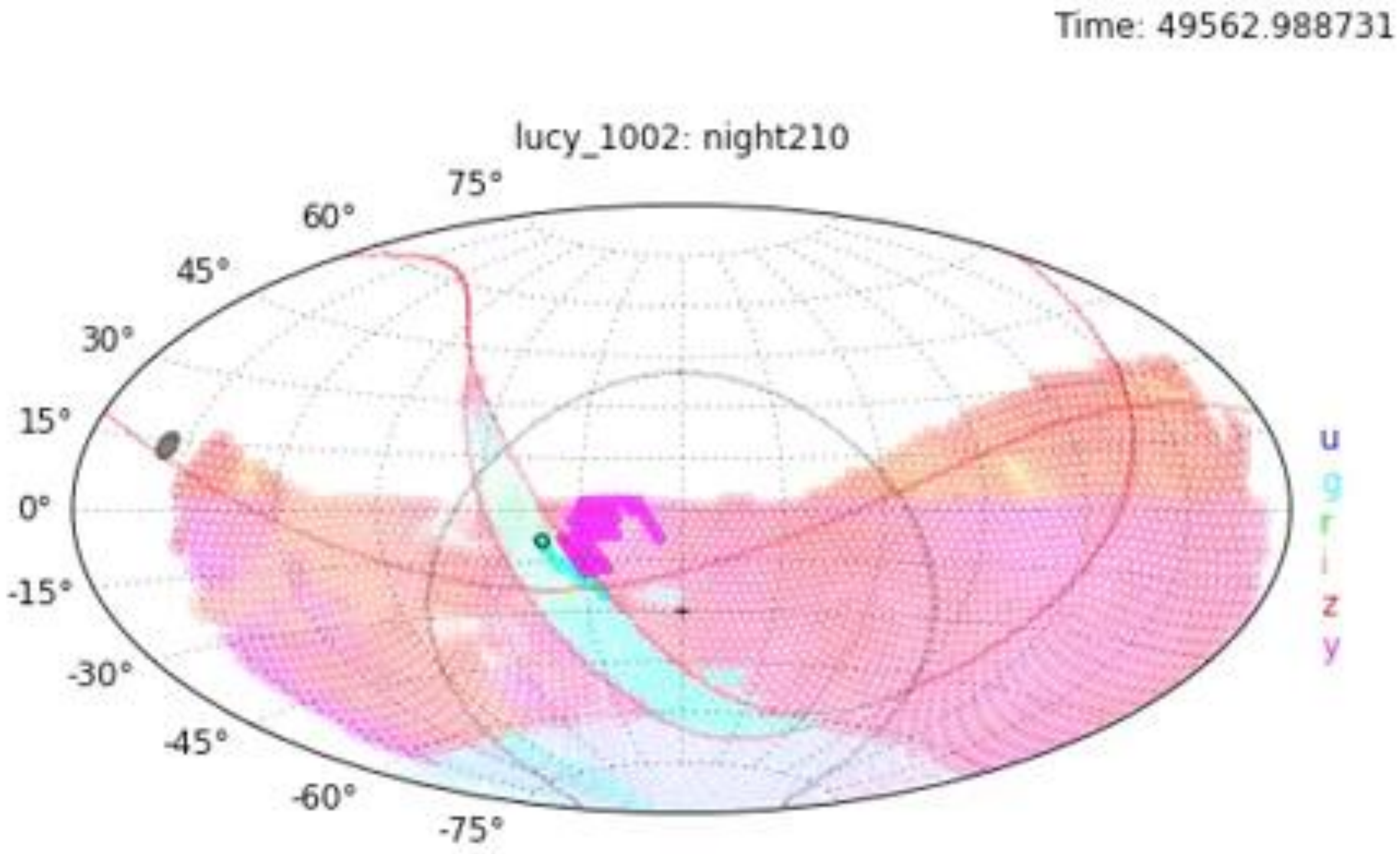
Alert!

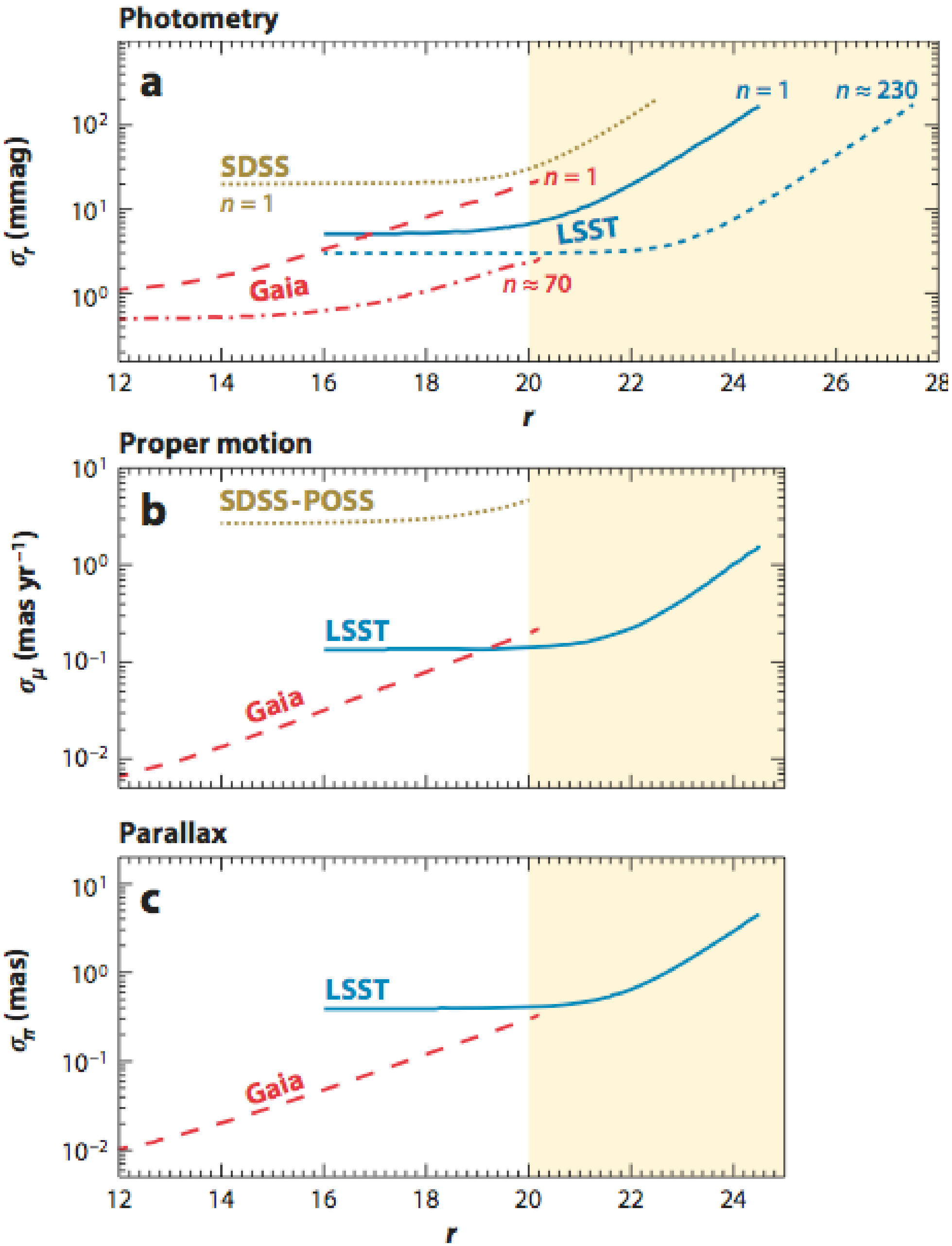
Additional "followup" data obtained to:
- confirmation and classification
- provide better temporal resolution
- use different filters/wavelengths
- obtain spectra (distance!)
- other measurements (e.g. polarimetry)

LSST Science Requirements Document (ls.st/srd):

Report alerts within 60 sec after closing the shutter.

Automated scheduling of LSST observations (speed 1000x)





Ivezić, Beers, Jurić 2012, ARA&A, 50, 251

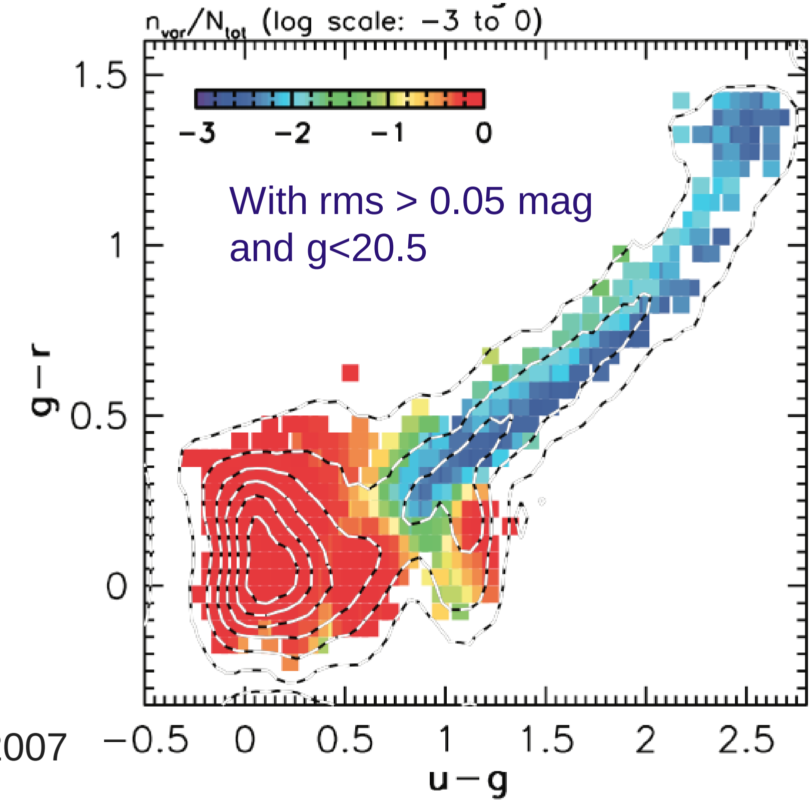
Astrometric and photometric performance comparison for Gaia and LSST

Photometric accuracy: random errors 0.005 mag, calibration to 0.01 mag; for light curves, LSST “takes over from Gaia” around r ~ 17

Time-resolved measurements: photometric variability, and parallax and proper motions from astrometric measurements

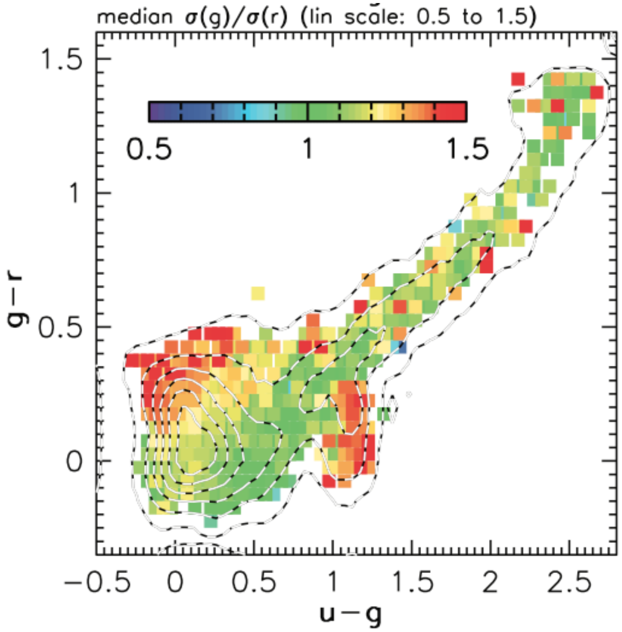
Gaia vs. LSST: complementarity of the two surveys: photometric, proper motion and trigonometric parallax errors are similar around r=20

The fraction of variable point sources in SDSS



Sesar+2007

The sample is dominated by quasars and variable stars called RR Lyrae.

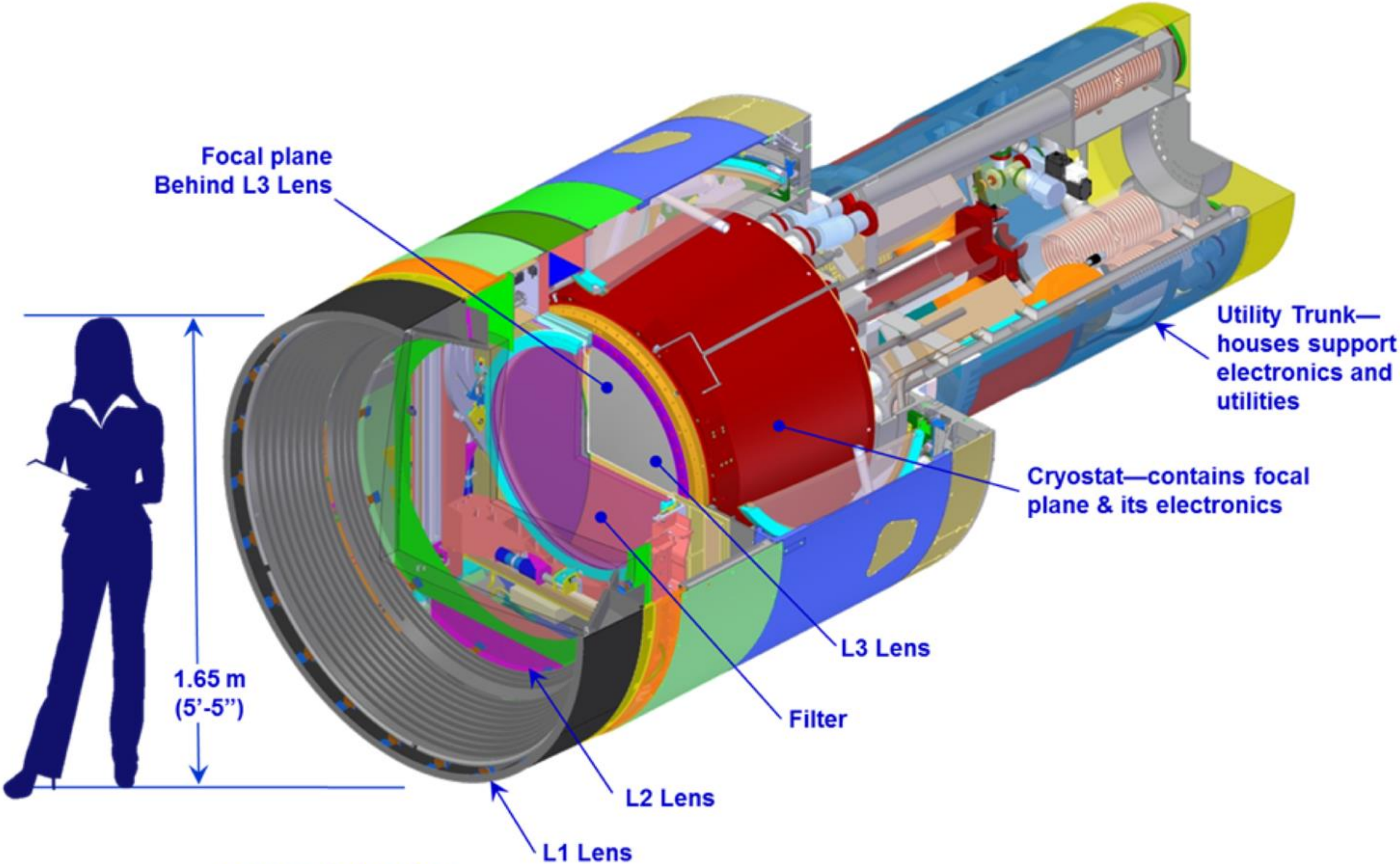


Rubin Observatory Construction Status

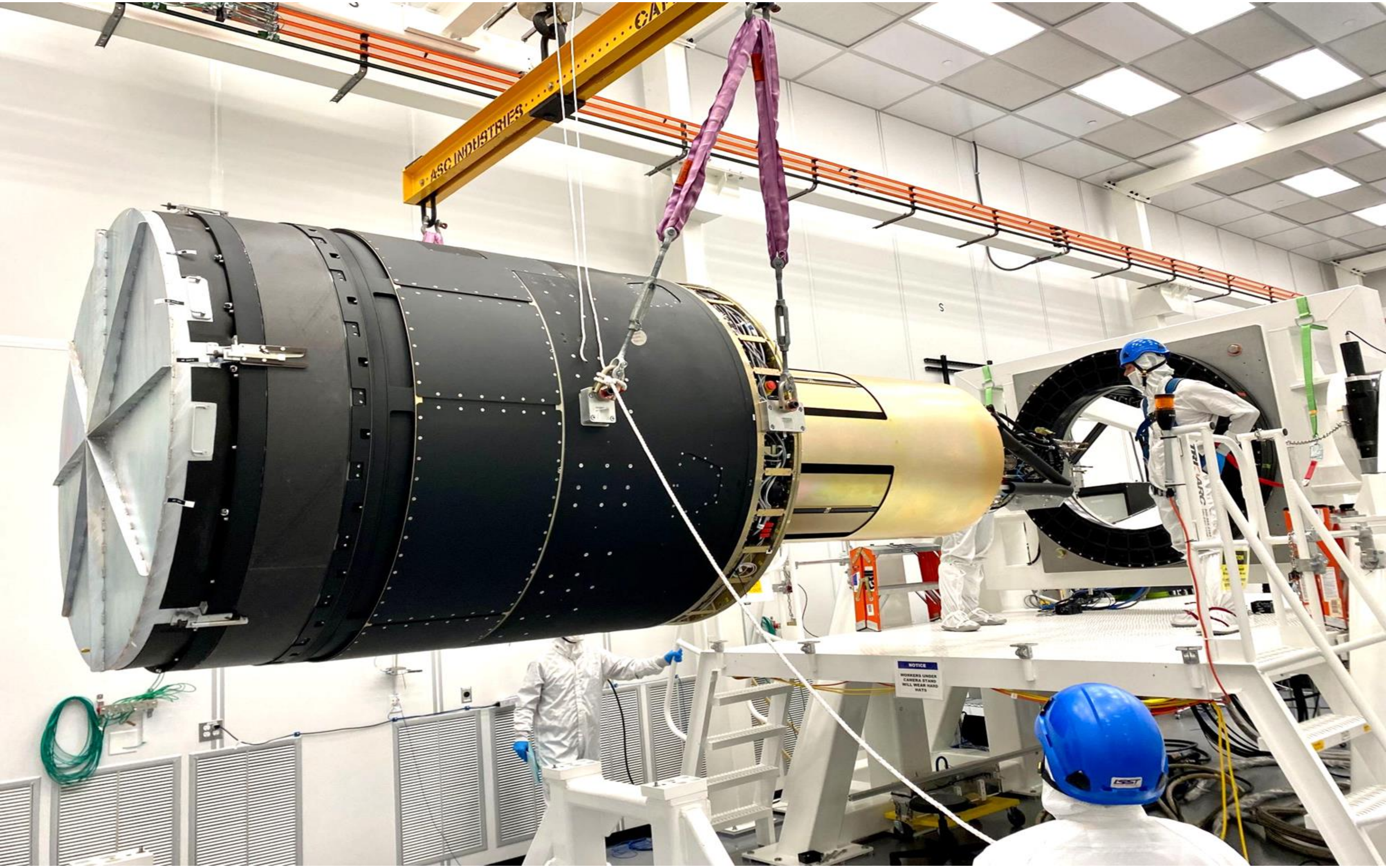
Rubin Observatory Team, August 2022, Tucson, AZ and a British site, too!

TMA Moves

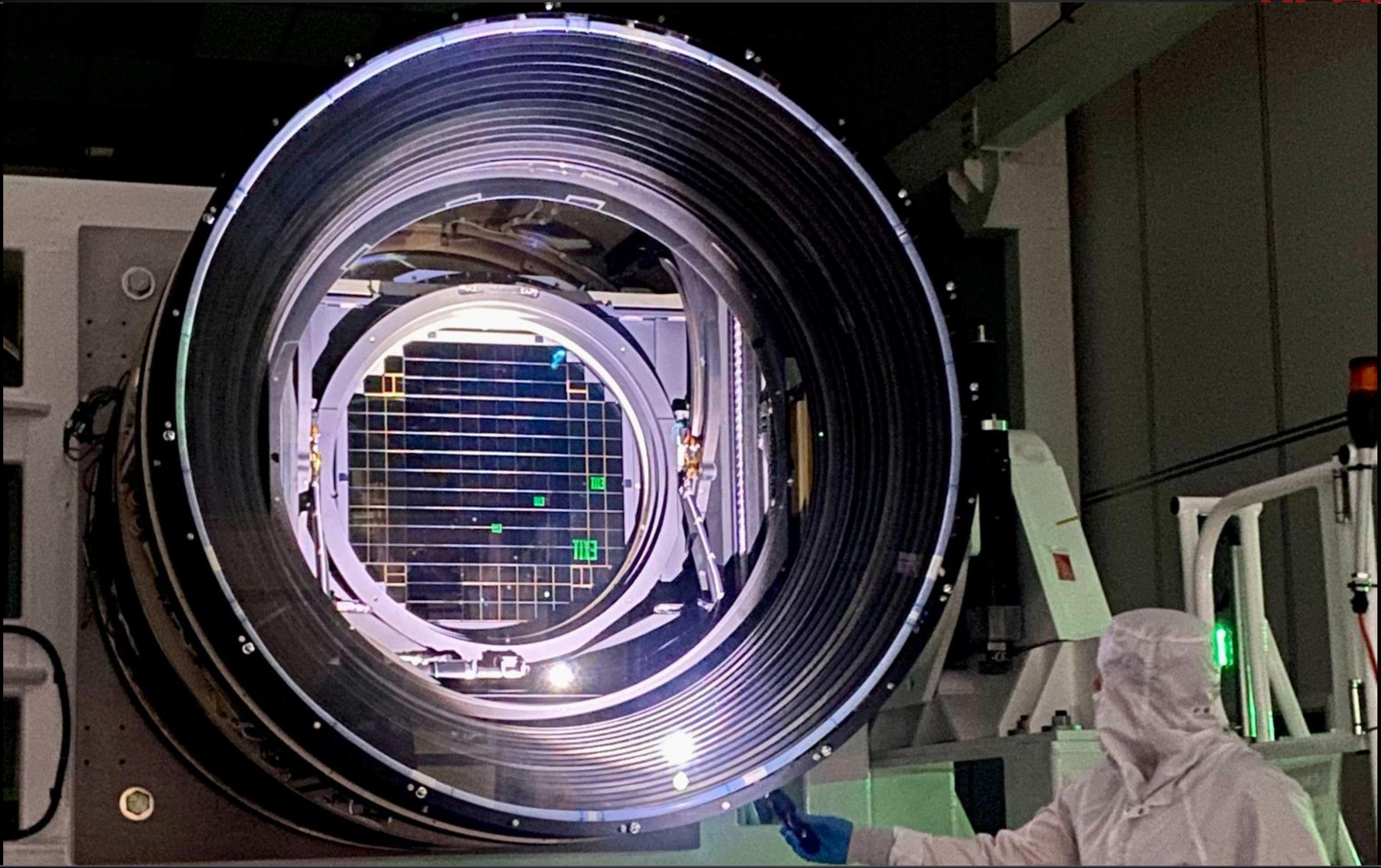
December 2022

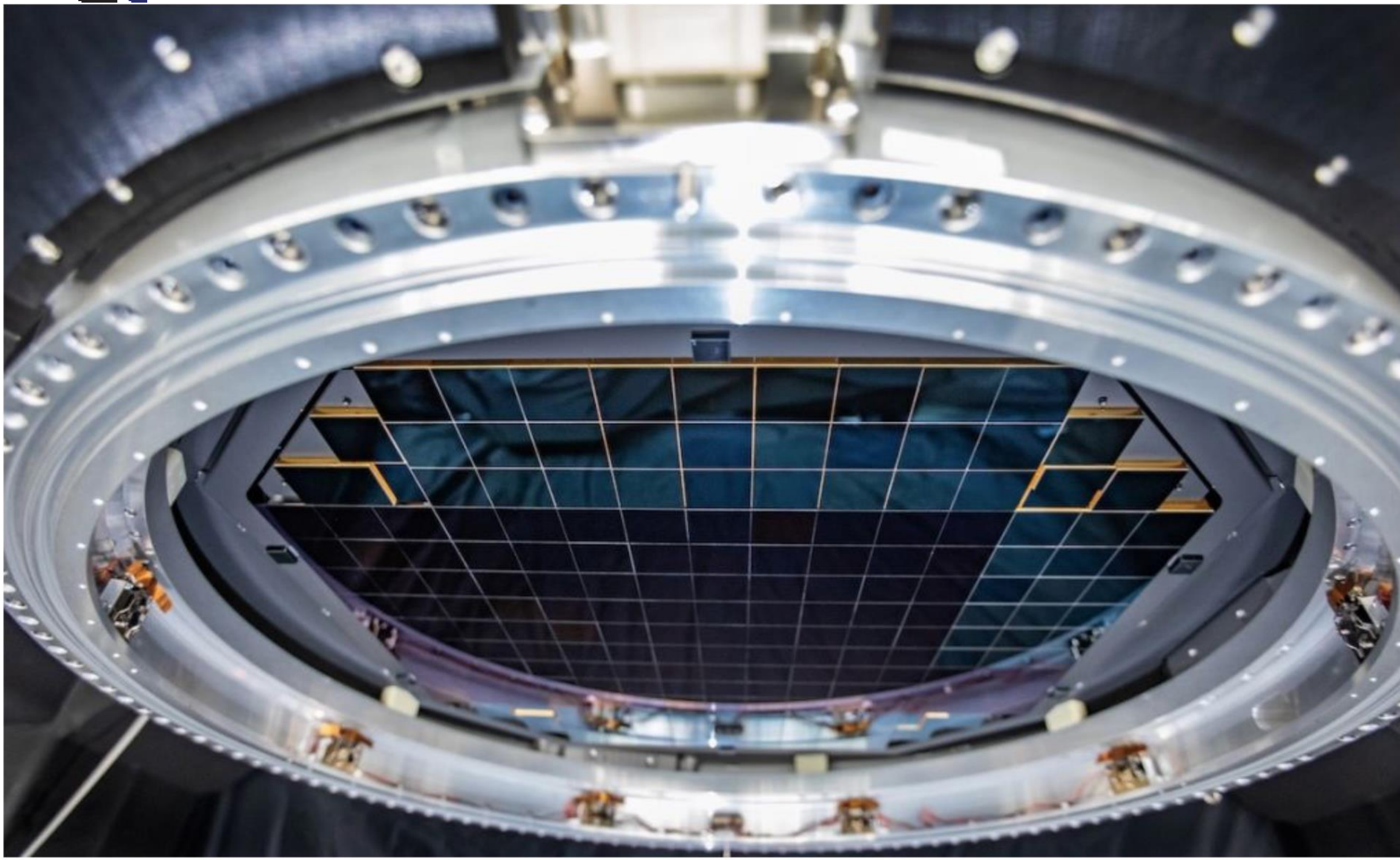


Camera ¾ Section

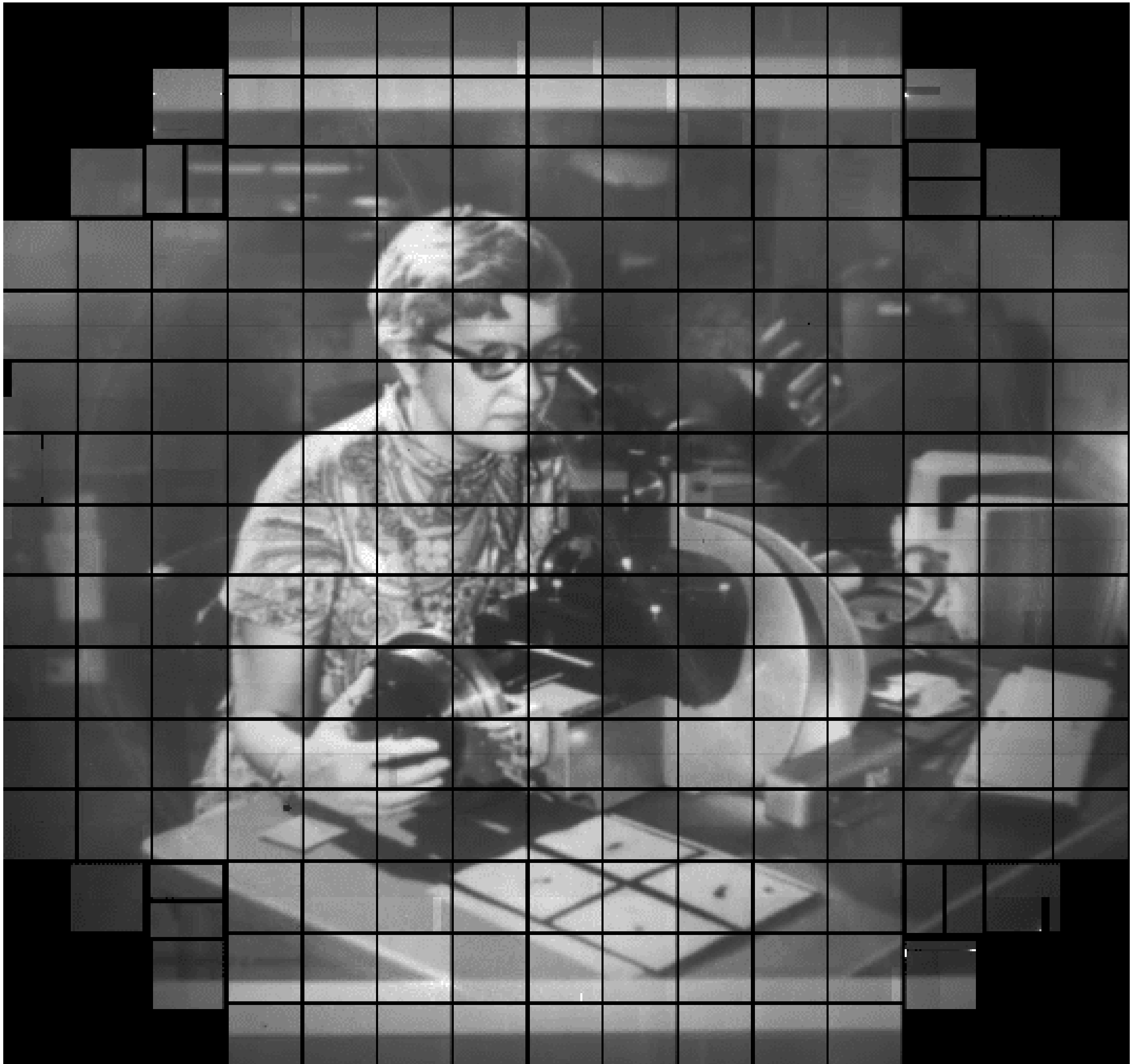

ASC INDUSTRIES
NOTICE
WORKERS UNDER CAMERA STAND WILL WEAR HARD HATS

SLAC





The complete focal plane of the future LSST Camera is more than 2 feet wide and contains 189 individual sensors that will produce 3,200-megapixel images.



Rubin Construction Timeline

start of LSST: early '25

now

12 months for remaining system integration, including 3 months after first photon

4 months for system optimization

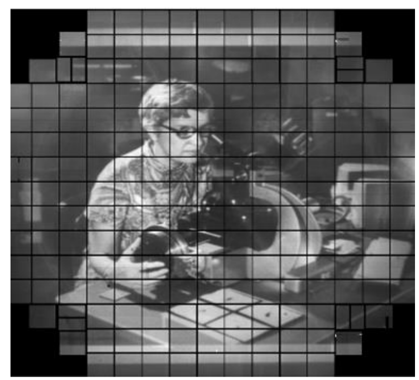
CY 2023 2024 2025

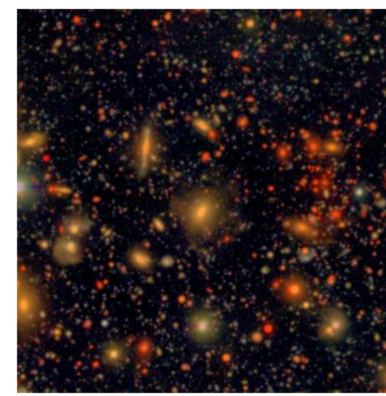
Oct 2023 : Arrival of LSSTCam on the summit

System First Light October 2024

Legacy Survey of Space and Time (LSST) starts early 2025

DP2





Significant reduction of schedule uncertainty with the arrival of LSST Camera to the Observatory site in Chile (October 2023).

Data Preview 2 (DP2):
2 months of commissioning survey data (Aug '25) via Rubin Science Platform

Legacy Survey of Space and Time: a 10-year survey starting in 2024

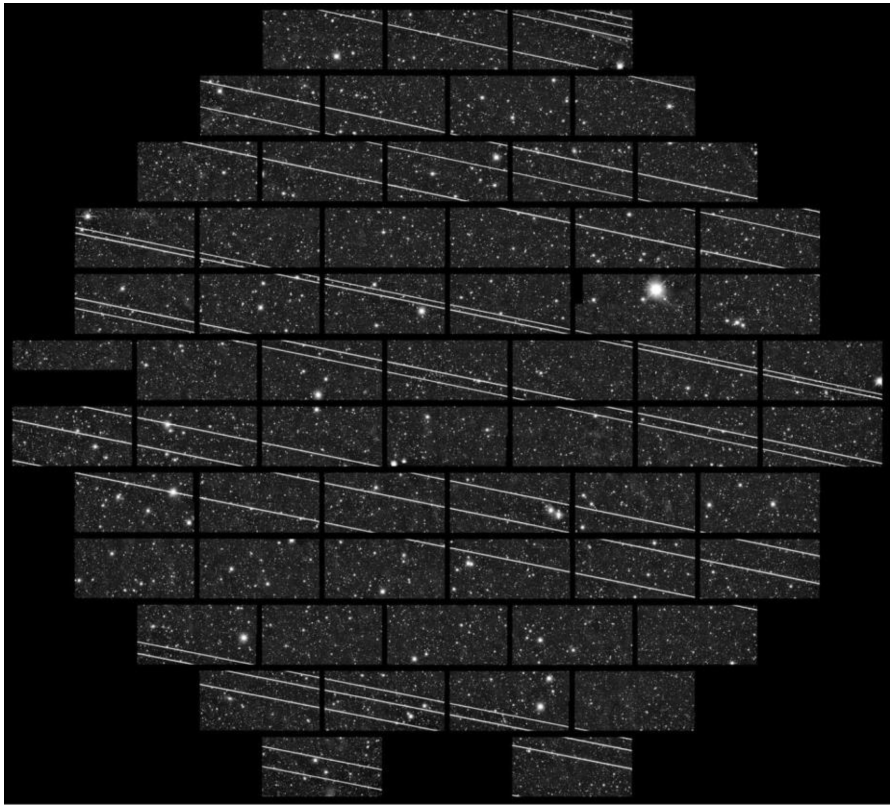
More details: ls.st/lop

multi-color time-resolved faint sky map

- 20 billion galaxies
- 20 billion stars
- 10 billion alerts
- "millions and millions" of SNe, quasars, asteroids…

VERA C. RUBIN OBSERVATORY

Low-Earth orbit satellite constellations



DECam image: 333 sec exposure, 19 Starlink streaks (Clara Martínez-Vázquez and Cliff Johnson)

How bad is that?

A few points to make:

- at that time, satellites were still much closer to the observer then when in their final orbits (the so-called “at station”)
- LSST visit is ~10 times shorter and the FOV is somewhat larger: ~2-3 streaks
- there are many other quantitative details that need to be taken into account...

So, really, **how bad are these satellite constellations for LSST?**

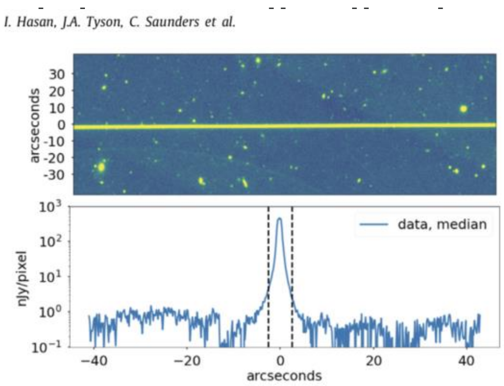
Impact of LEO Satellite Constellations on Rubin Observatory and LSST science

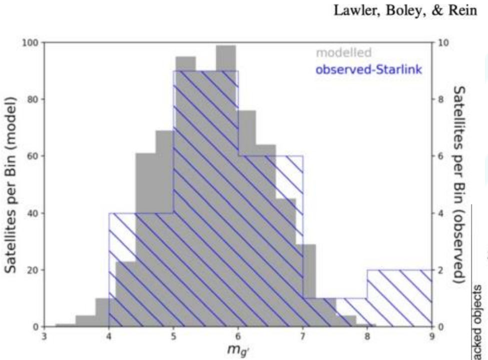
Quantitative assessment depends on several imperfectly known quantities:

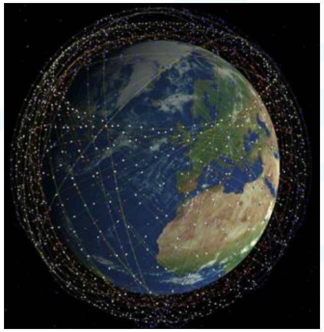
1) The number of satellites and their (

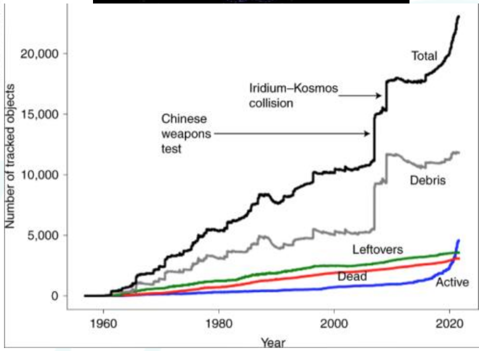
2) The satellite b

3) Impact on
LSST imag
and
mitigation

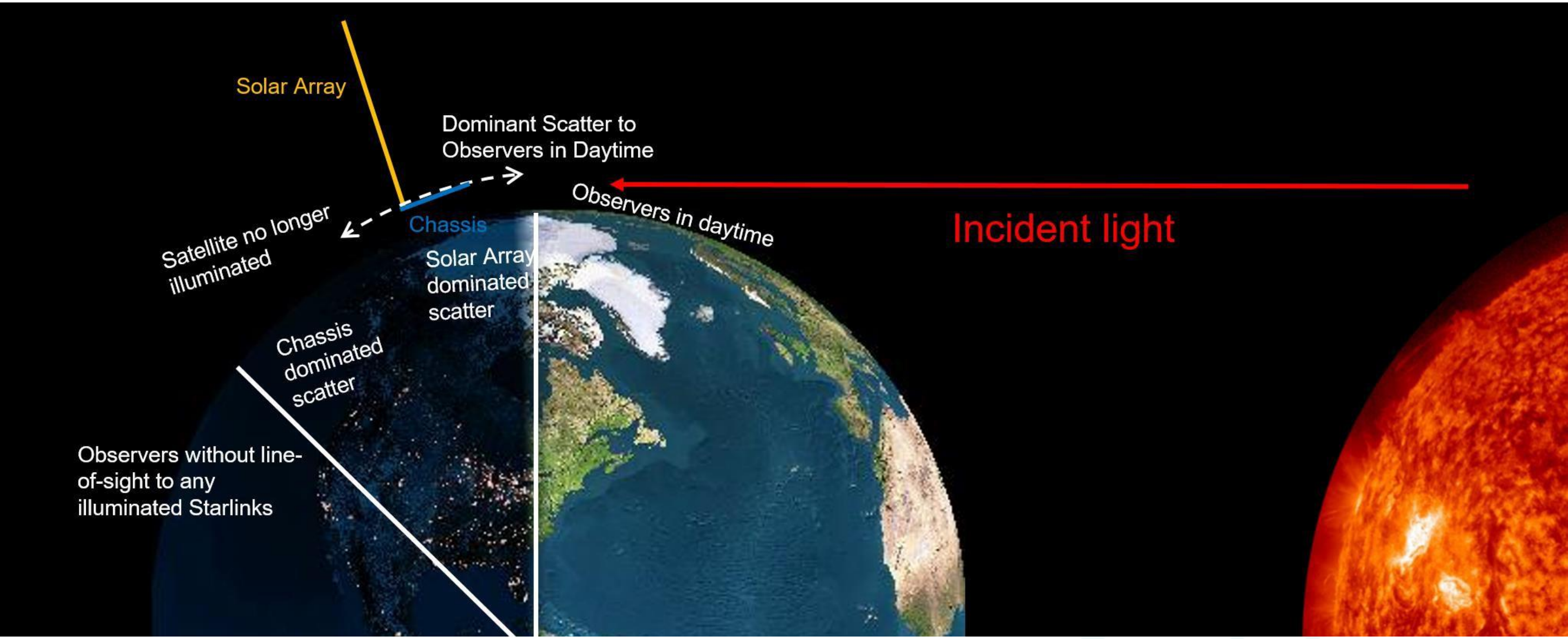








2) The satellite brightness distribution



Summary (from Rubin/LSST point of view)

With tens of thousands of LEOsats, generally
no combination of mitigations can completely
avoid the impacts of the satellite trails
on LSST science programs.

However, current predictions of the impact correspond to a **“nuisance”** that we have to plan for (~1% of pixels lost), rather than a ”catastrophic” impact (>10% of pixels lost).

We need to continue to **constructively** communicate with satellite providers.

A potentially **misleading** figure: most streaks are actually stars!