



Satellite Constellations and Rubin Observatory: Overview

Meredith Rawls | Rubin PCW | August 10, 2023

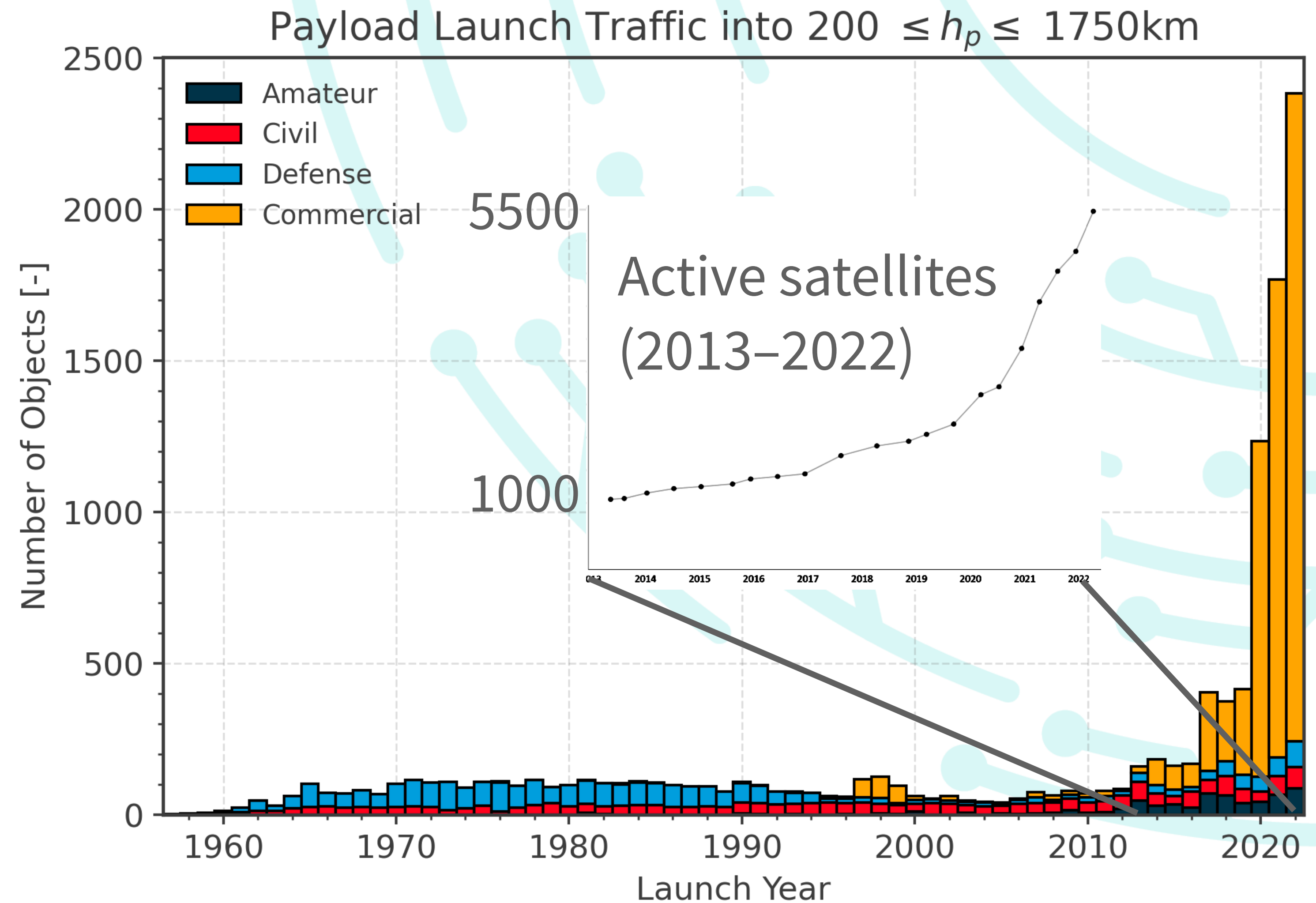


U.S. DEPARTMENT OF
ENERGY



A new source of globally visible light pollution

- Over 4400 SpaceX Starlink satellites launched since 2019
- Over 50% of all active satellites
- Provisional permission from FCC to launch and operate 42,000
- Many other companies want in
- We are rapidly heading toward **tens to hundreds of thousands** of low-Earth orbit satellites

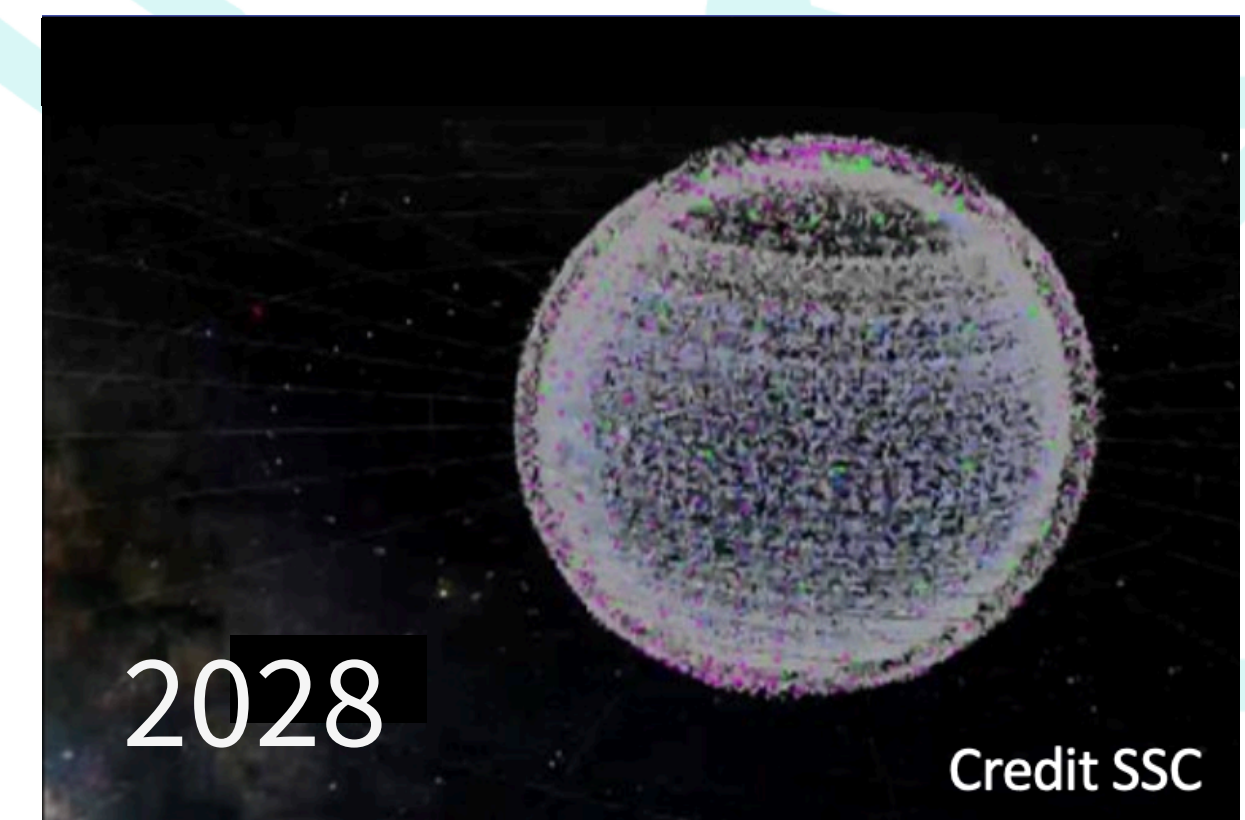
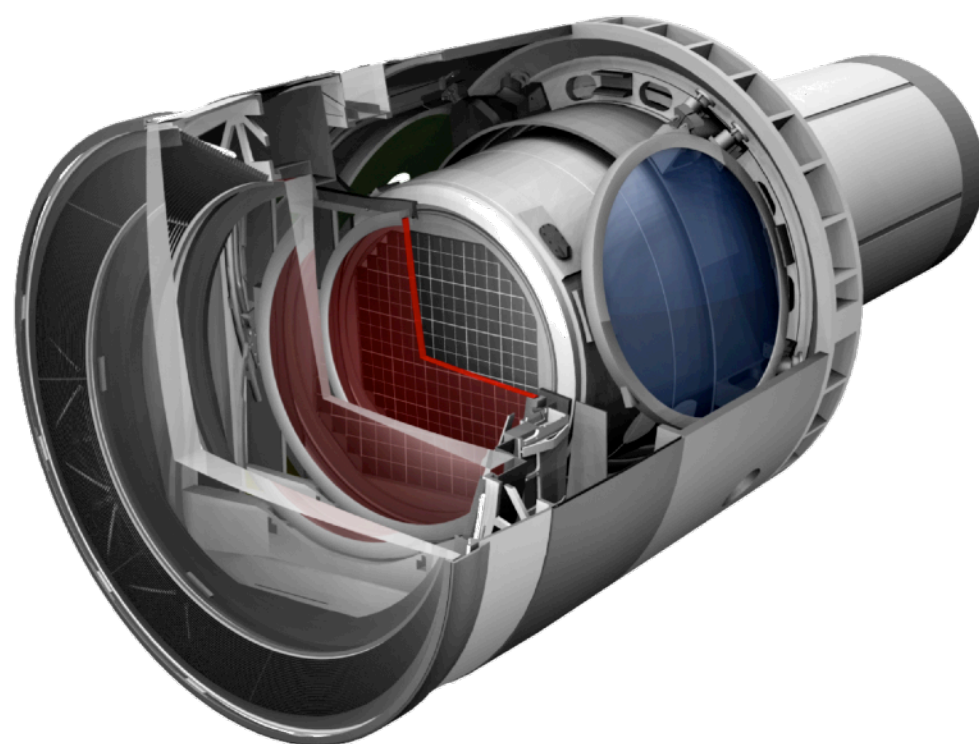


Quantifying the impact on Rubin science

Depends on several imperfectly known quantities!



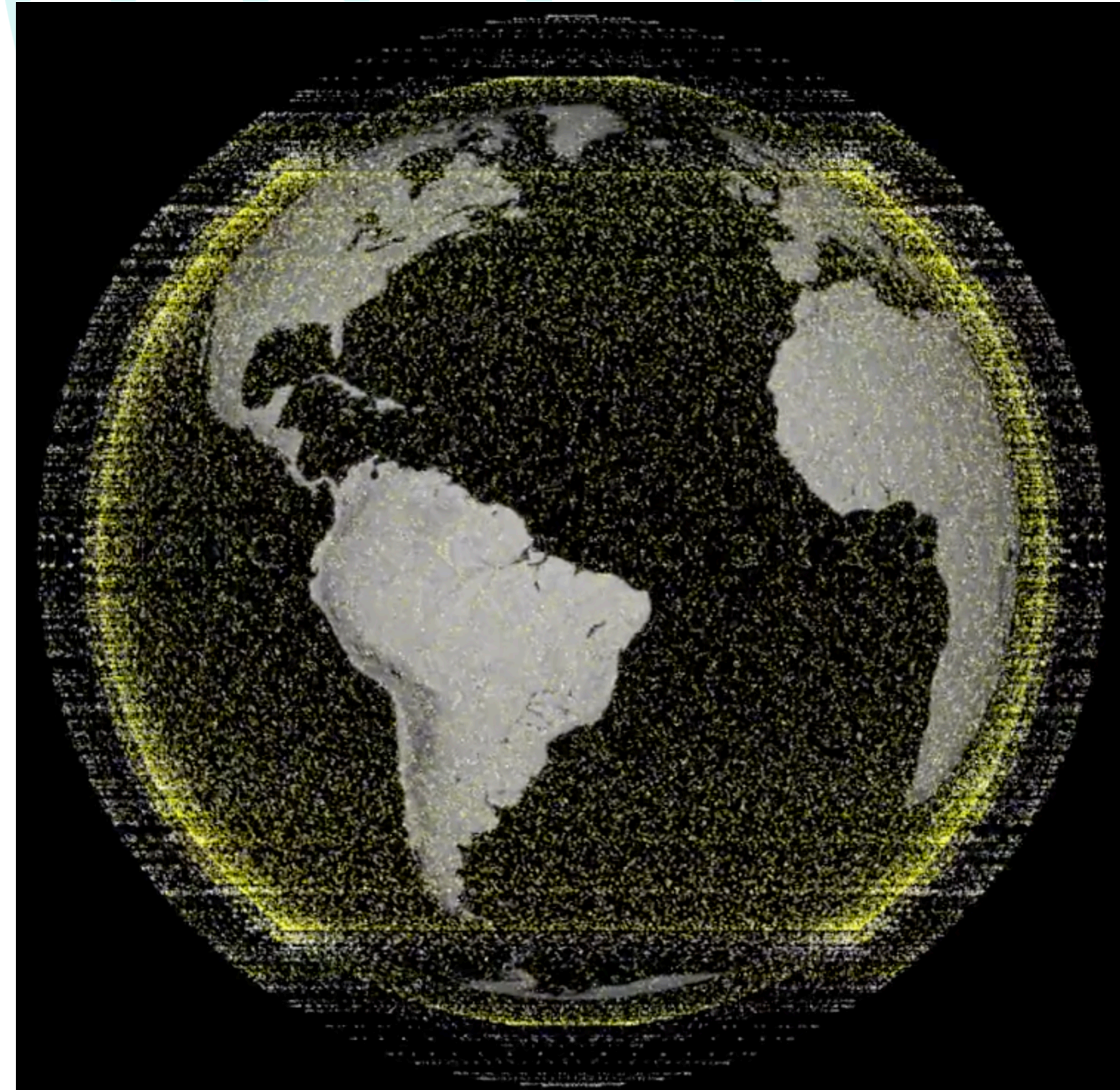
1. Number of satellites and their orbits
2. The satellite brightness distribution
3. How the LSST Camera responds
4. Image processing pipelines



Number of satellites and their orbits

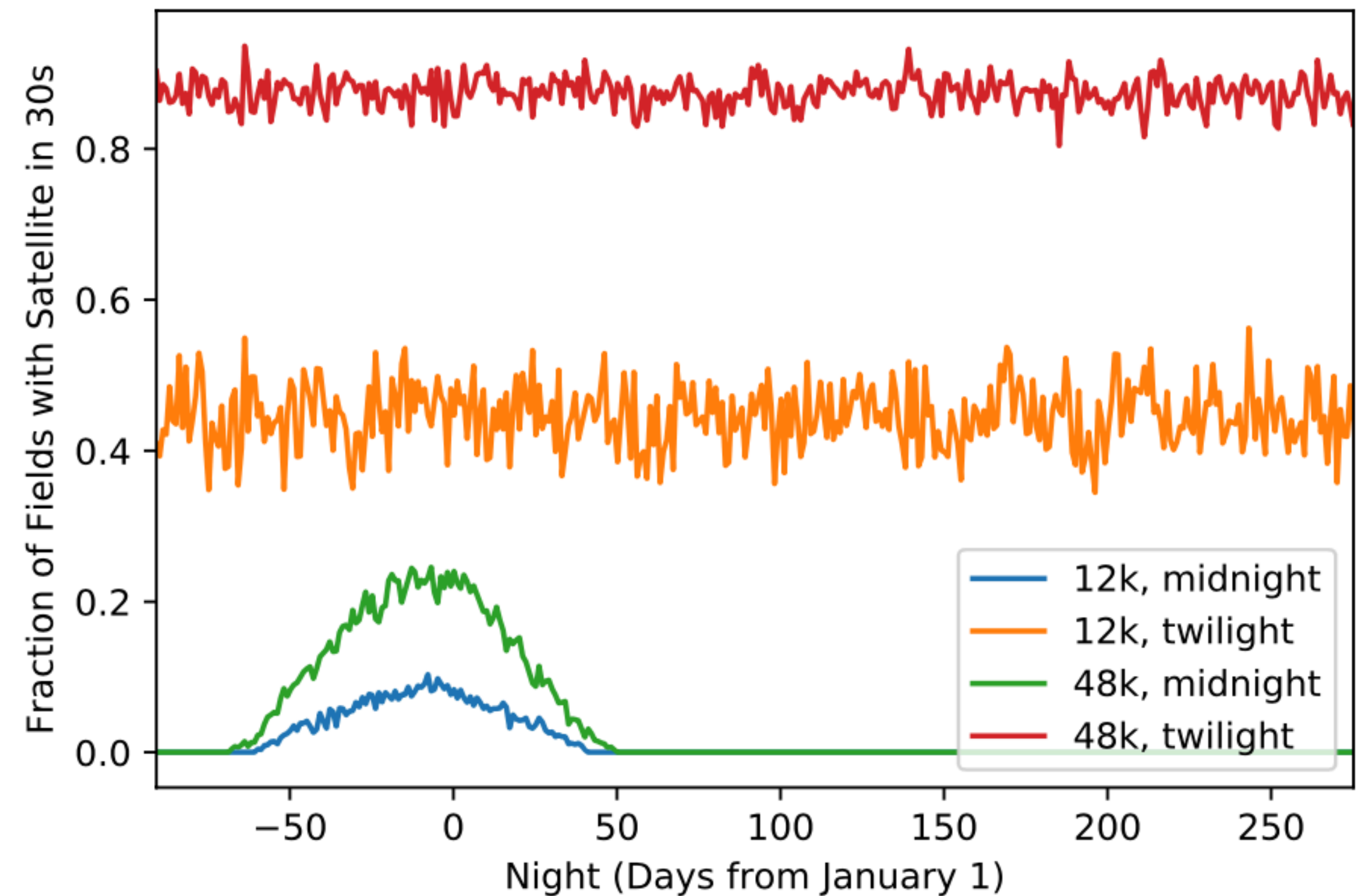
- Low-Earth orbit period ~90 minutes
- At any time, ~4% of LEO sats above the horizon
- At any time, ~0.6% of LEO sats above 30 deg
- Total in next decade likely 50,000 – 500,000
- Depends on economics, regulations, etc.
- Physical carrying capacity is not well known
- Do you feel lucky?

René Schulze via NYTimes, based on filings from Starlink, OneWeb, Kuiper, Telesat, Guowang, Astra, and Globalstar



Number of satellites and their orbits

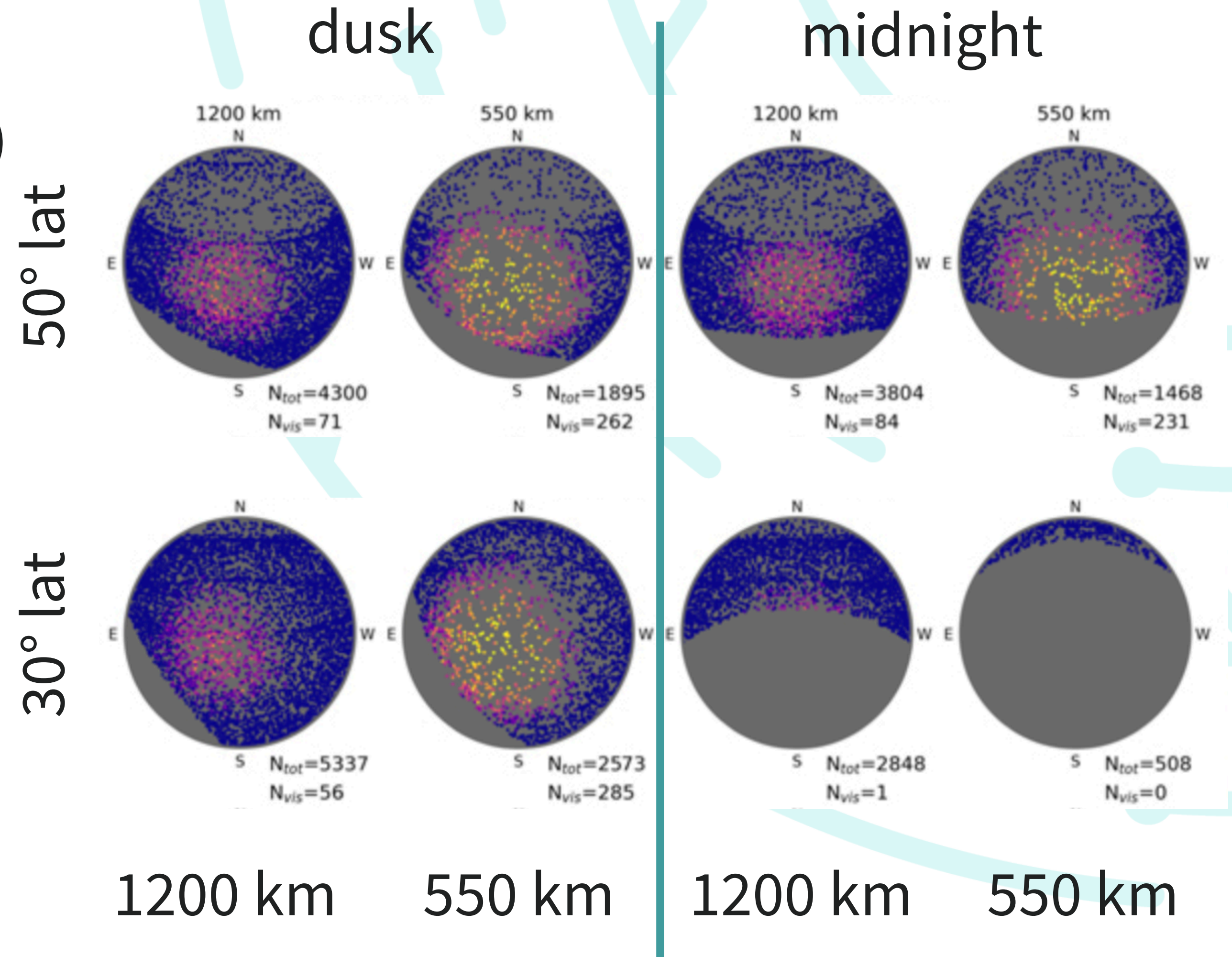
- Lower altitude orbits are better because...
 - Out of focus streaks (lower peak brightness)
 - Satellite moves out of the way faster
 - Fewer illuminated satellites in the middle of the night during summer
- HOWEVER —
 - Lower orbits require more satellites for a company to achieve global coverage
 - Higher latitudes are more impacted



Tyson et al. 2020

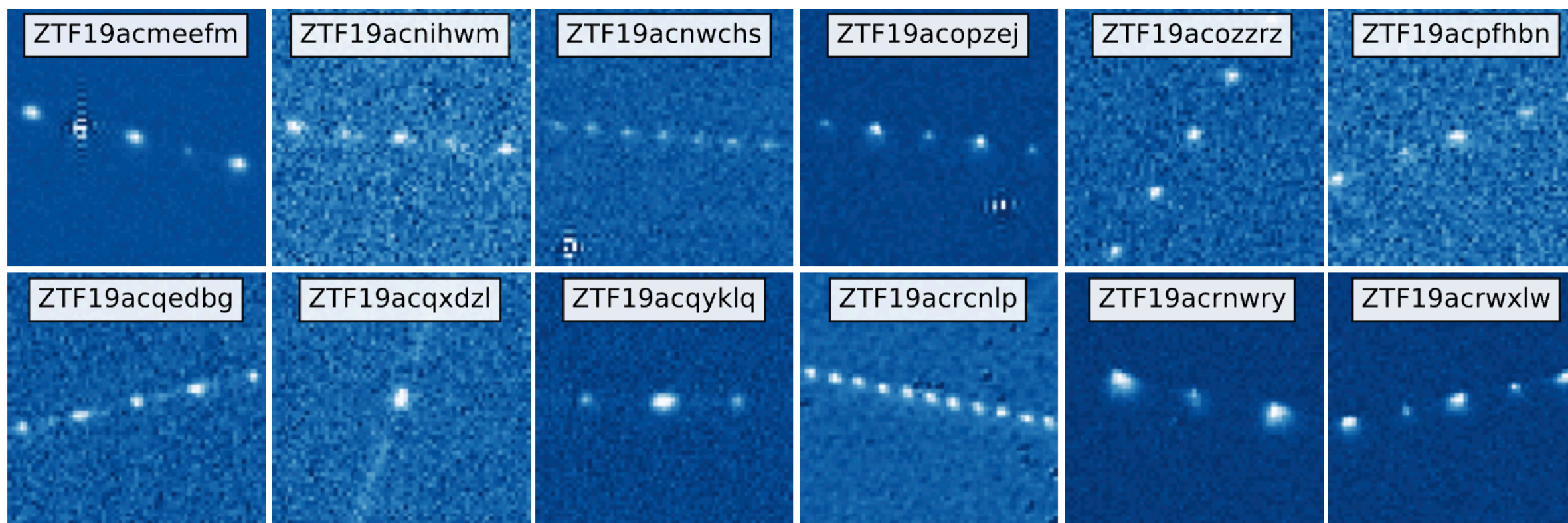
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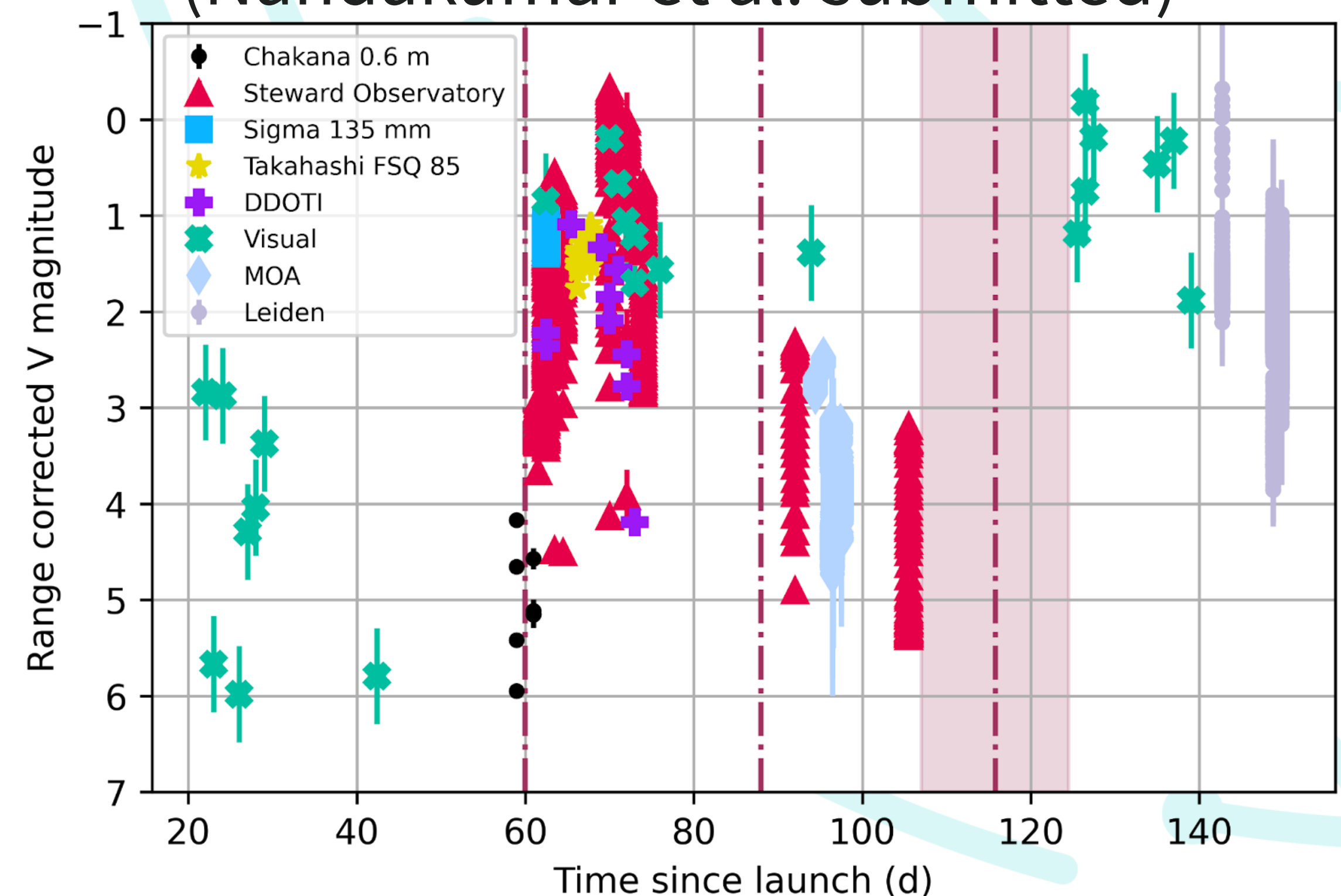


The satellite brightness distribution

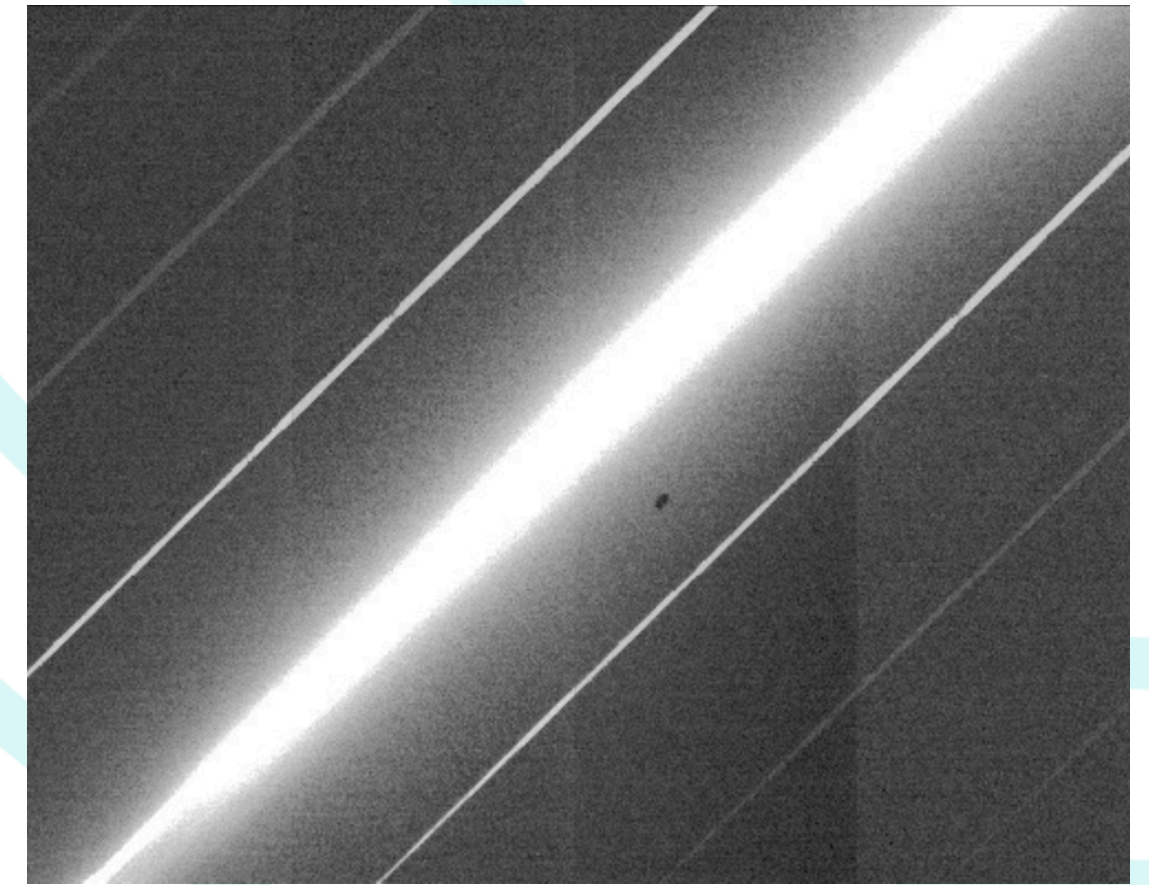
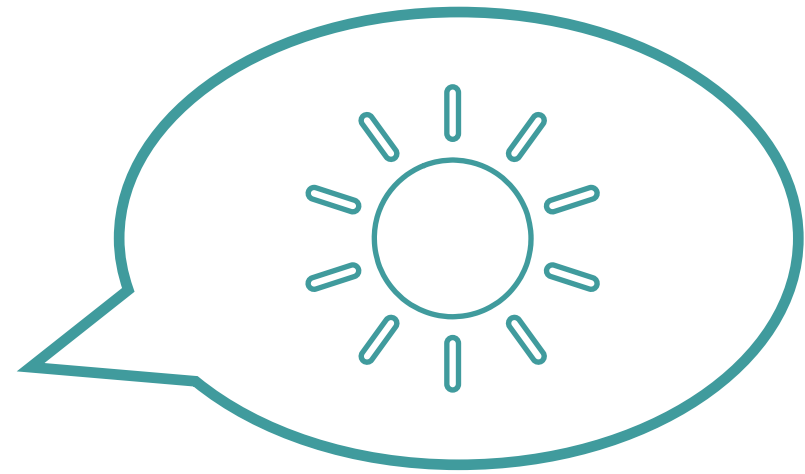
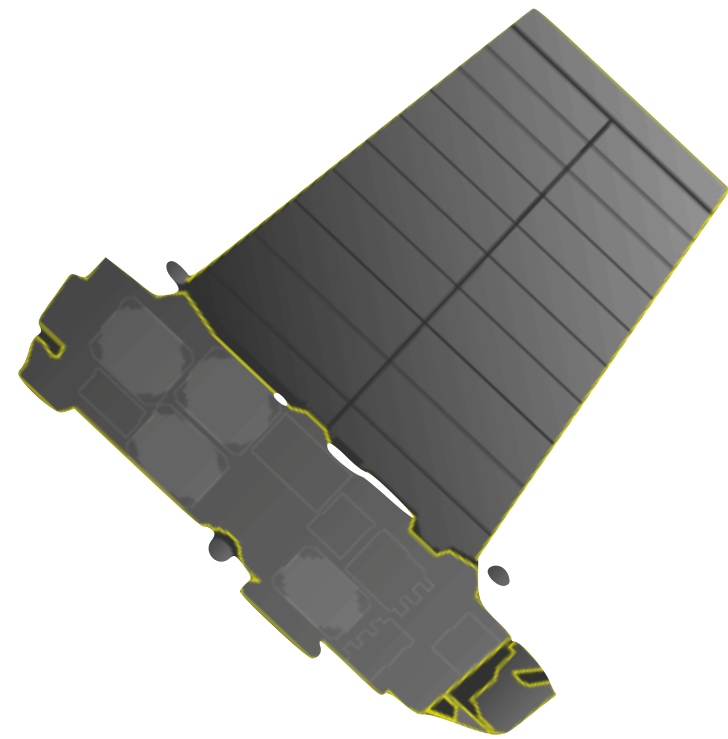
- There are no rules limiting satellite brightness
- Stationary g-band magnitude ~ 7 would be invisible by eye and mitigate some bad effects
- Various darkening mitigations are underway, but this target has not been achieved yet
- Launches, deorbits, maneuvers, can be brighter than idealized “on-station” magnitude



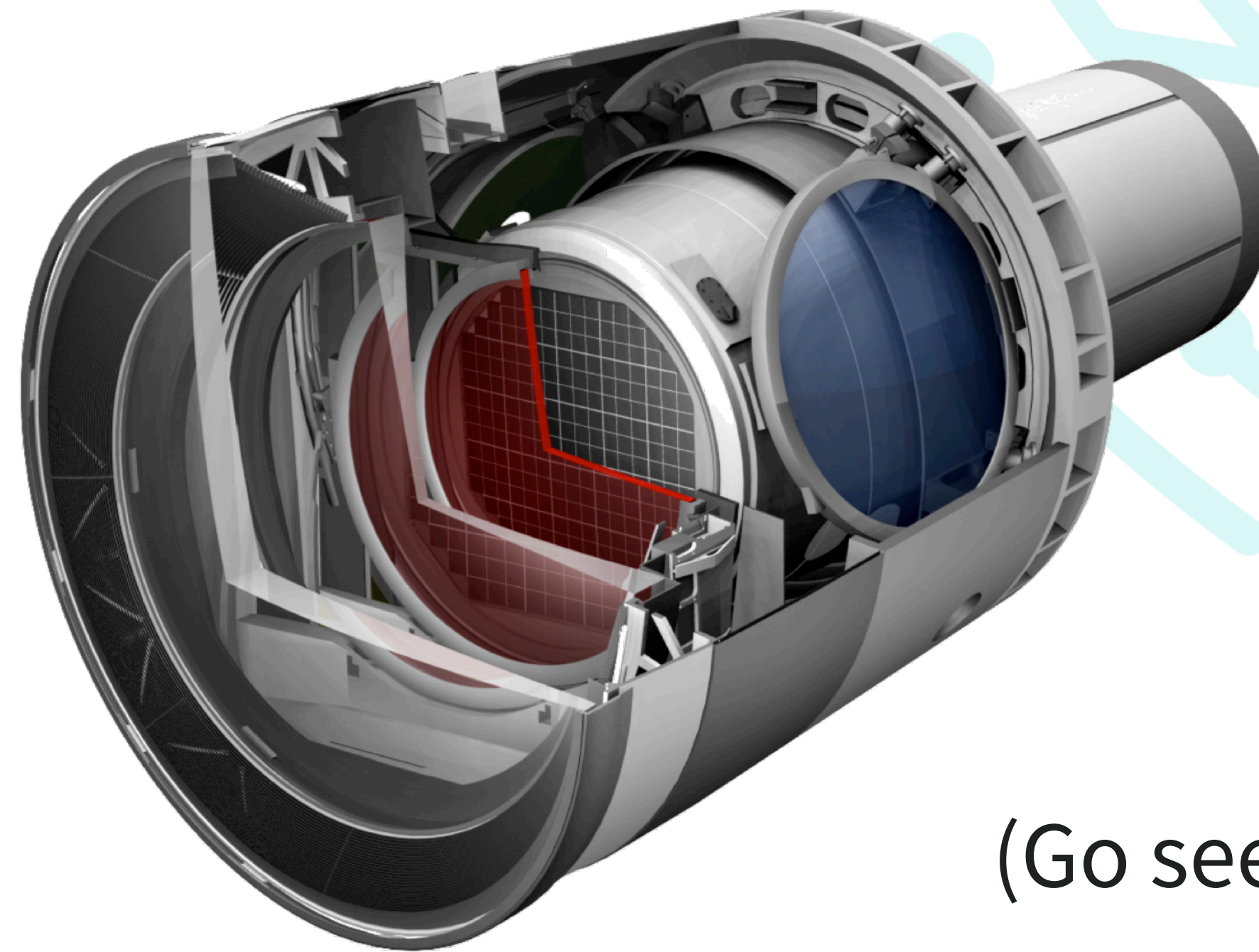
AST SpaceMobile's BlueWalker 3 (Nandakumar et al. submitted)



How the LSST Camera responds



I'm very sensitive

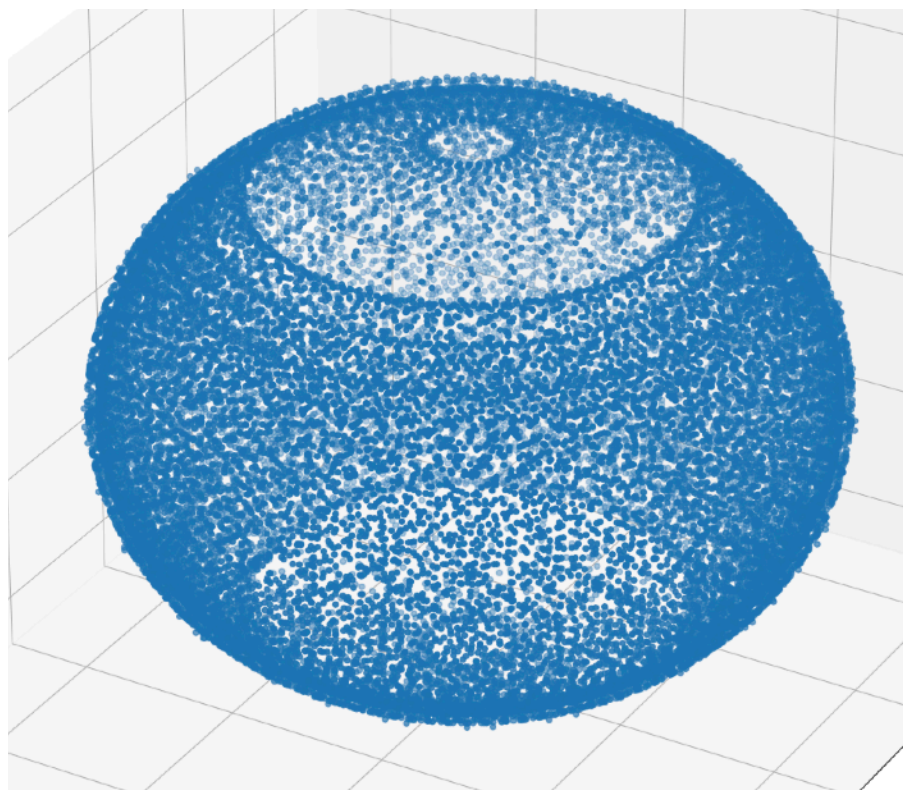


(Go see Daniel Polin's poster!)

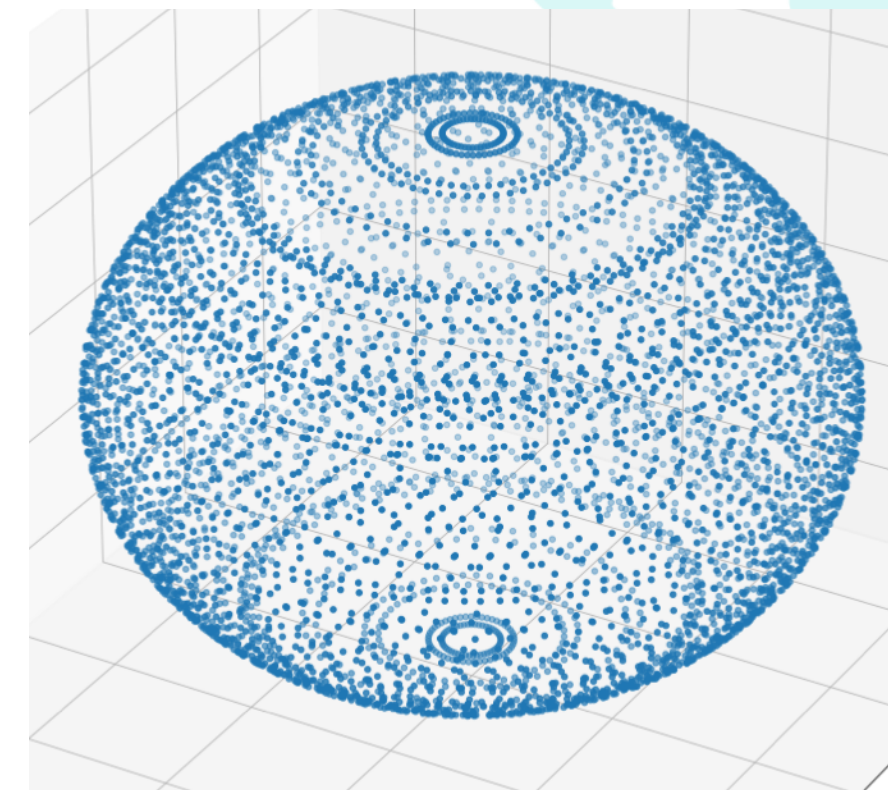
How the LSST Camera responds

... and where we point it!

- Technically feasible for LSST to dodge regions with highest satellite density
- BUT satellite position forecasting accuracy and precision may limit efficacy
- Reducing trails by a factor of 2 would require a 10% loss in total observing time



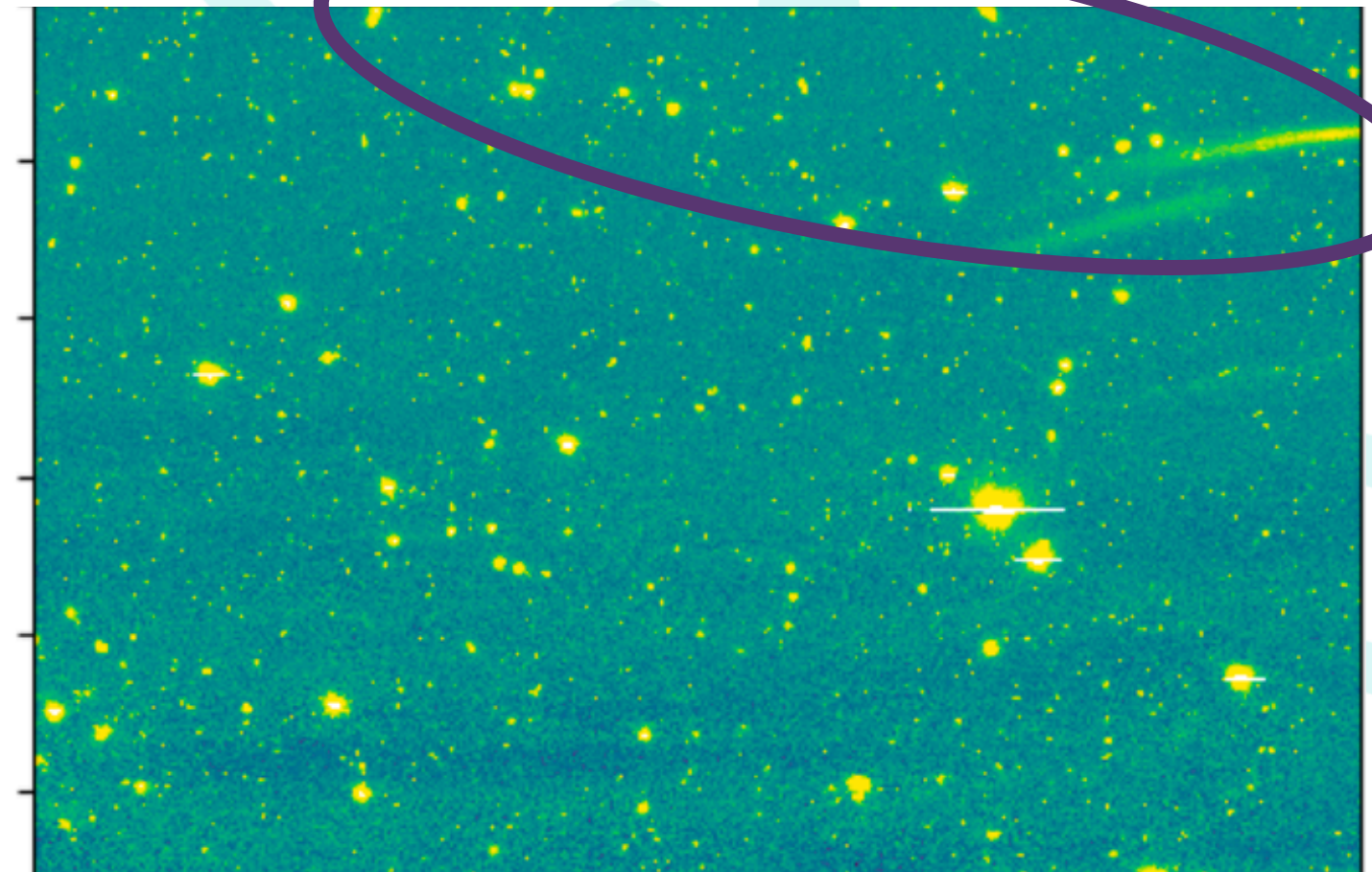
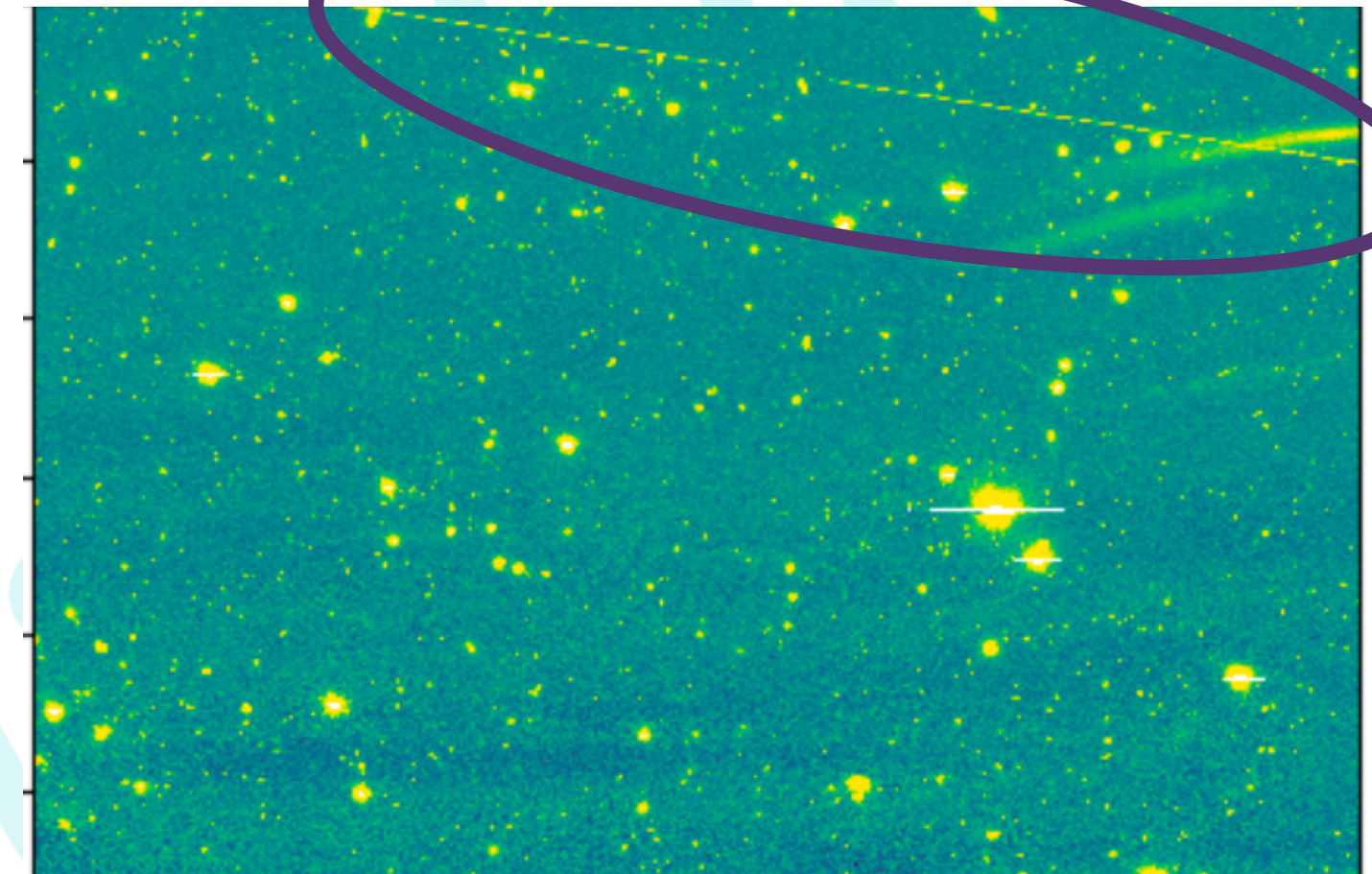
Avoiding Starlink Gen2



Avoiding OneWeb

Image processing pipelines

- You will find some streaks/glints in Rubin data products despite our best efforts
- Science Pipelines uses the Kernel-Based Hough Transform to mask streaks in coadds ([DMTN-197](#))
- UC Davis team uses a similar technique to find streaks in lab-simulated streak images
- **Soon:** streak detection in single-frame processing
- **Remaining challenge:** glints as false alerts
- **Future:** use real satellite streaks in Rubin data to measure impacts of optical satellite interference on science and make decisions about dodging etc.



Clare Saunders

This is a problem, I want to help?!?!!!

International Astronomical Union Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference



cps.iau.org

Led by NOIRLab (USA, optical/IR) and SKAO (UK, radio) with Contributing Members and Affiliated Members

- **SatHub**, co-led by Meredith Rawls, Mike Peel, and Siegfried Eggl, for collection and analysis of satellite observations, software tools, training and outreach
- **Policy Hub**
- **Community Engagement Hub**
- **Industry and Technology Hub**

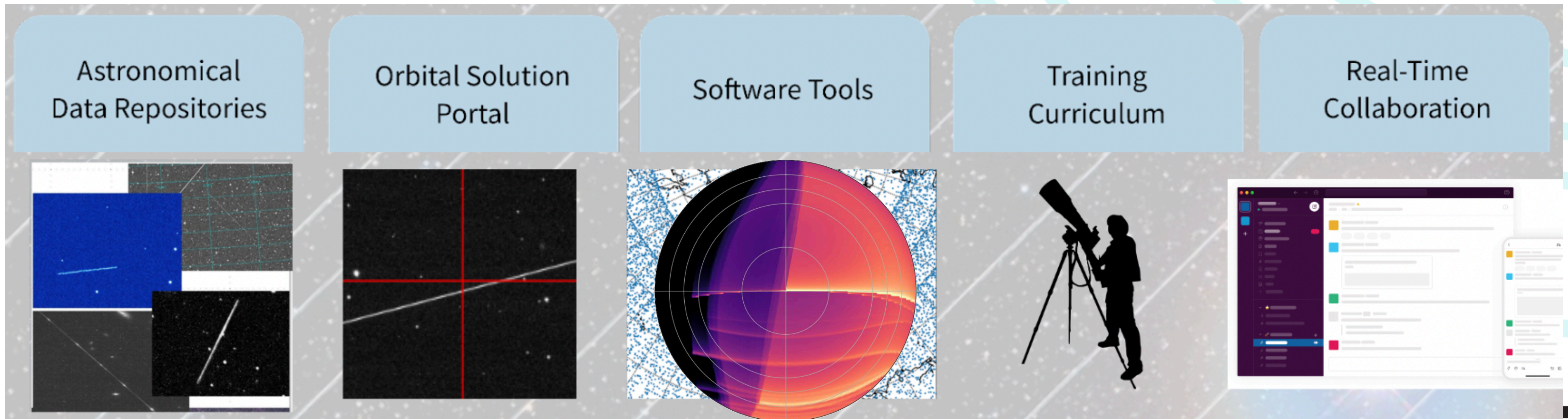


Join me at SatHub to help!

- Aims to be a **one-stop shop** for training, outreach, and collection & analysis of satellite observations
- **IAUS385 Symposium on Astronomy and Satellite Constellations**, 2–6 October 2023, La Palma, Canary Islands, register by 15 August <https://research.iac.es/congreso/iaus385>

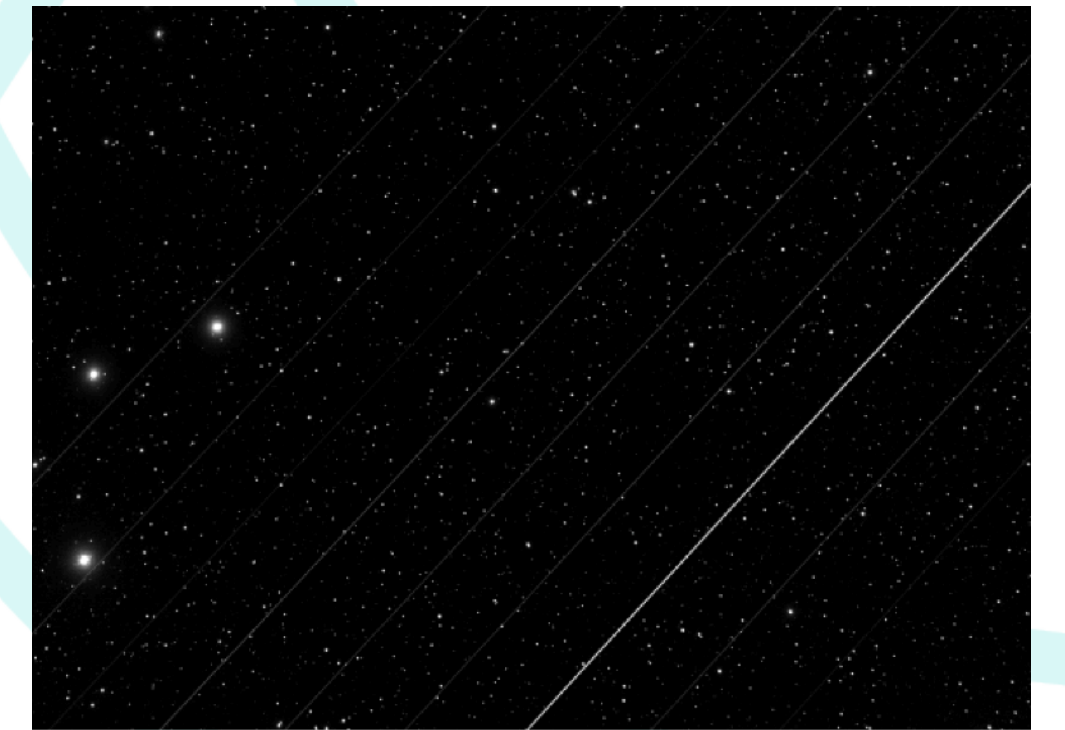


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Overview of Rubin and satellite constellations

- **Impacts depend on:** number and orbit, brightness, camera response (+ where we look), and software
- All mitigations are largely voluntary
- Identifying and masking trails is only a band-aid for some science
- Coordination with operators is a good precedent, but does not scale well
- Rubin may have to dodge some satellites, adding a year to operations and halving our losses
- Expect ancillary effects as we embark on this rapidly evolving night sky experiment



If 100,000 low-Earth orbit satellites are deployed,

“...no combination of mitigations can fully avoid the impacts of the satellite trails on the science programs of current and planned [...] astronomy facilities.” —SATCON1 Report, 2020