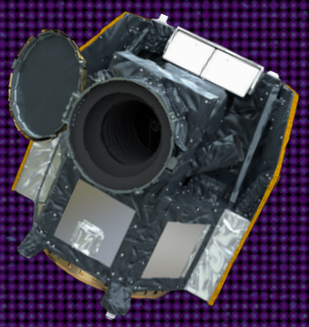
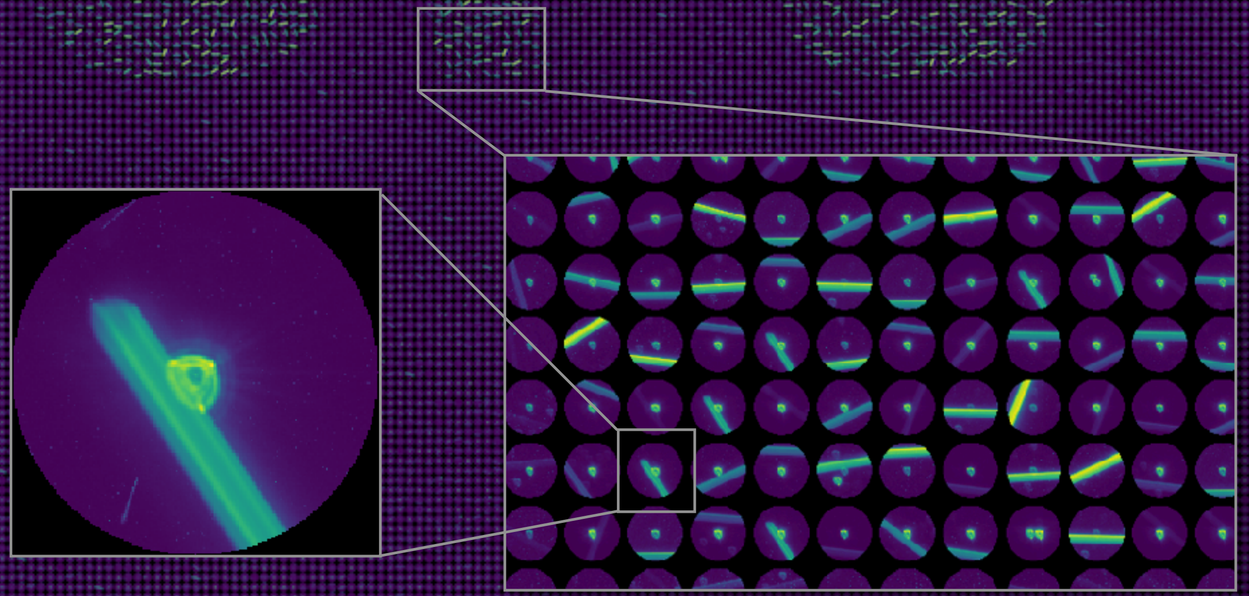
CHEOPS' view on orbital light pollution

Nicolas Billot - CHEOPS Operations Scientist - University of Geneva
On behalf of the CHEOPS Consortium

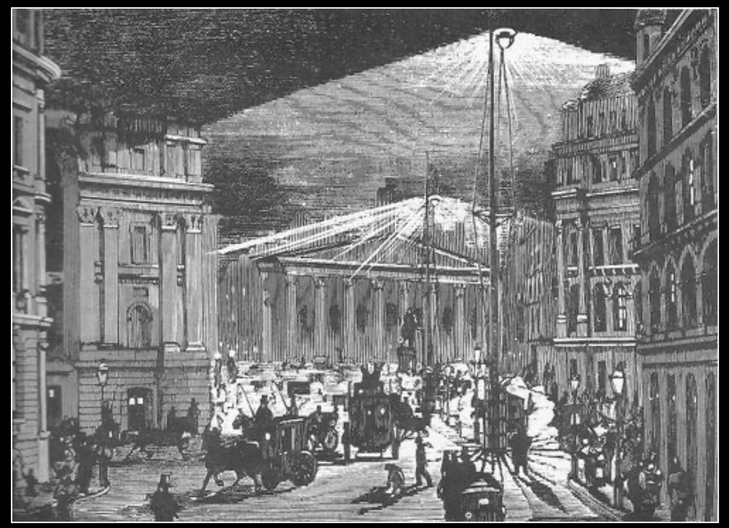


CHEOPS Science Workshop VI
“Bern”, SwitZoomland, 13th January 2022



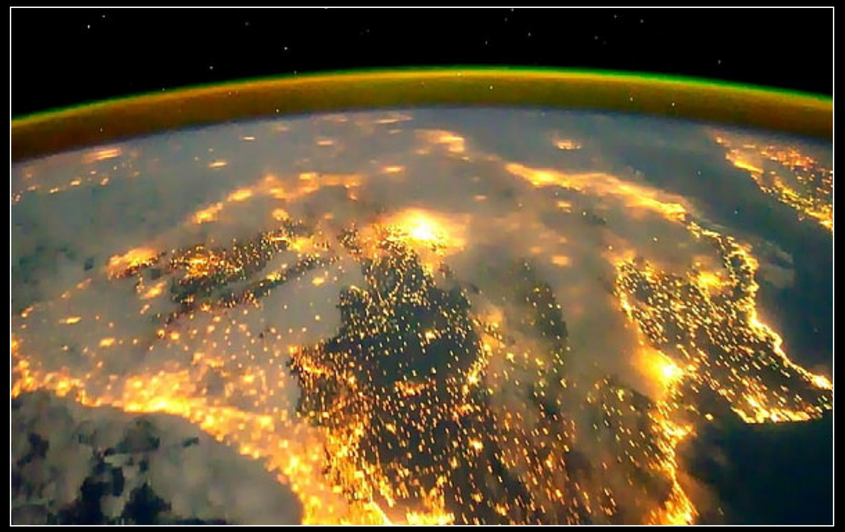
Light pollution originating from the ground

200 years



19th century

Today



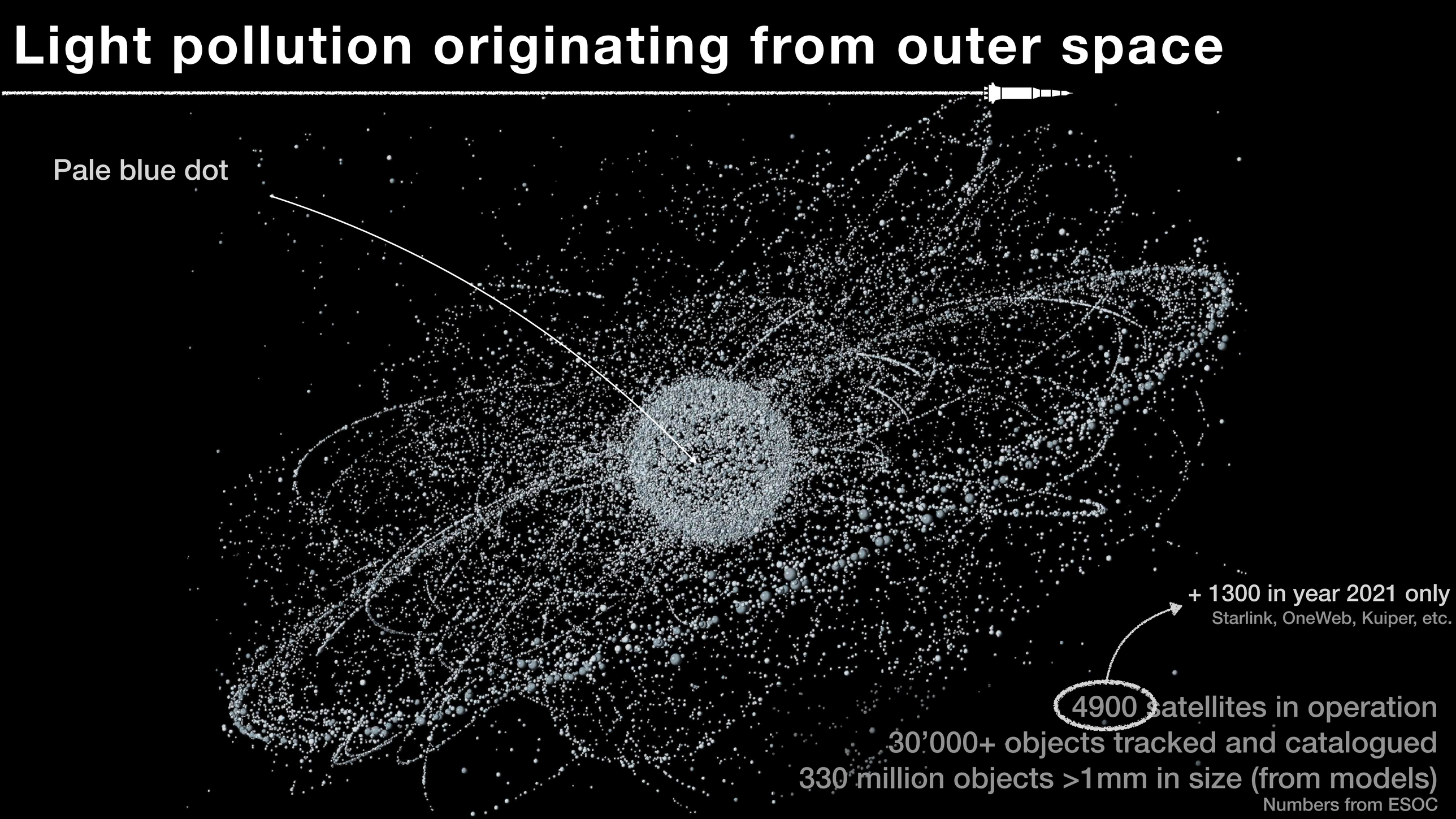
Global concern

International Astronomical Union

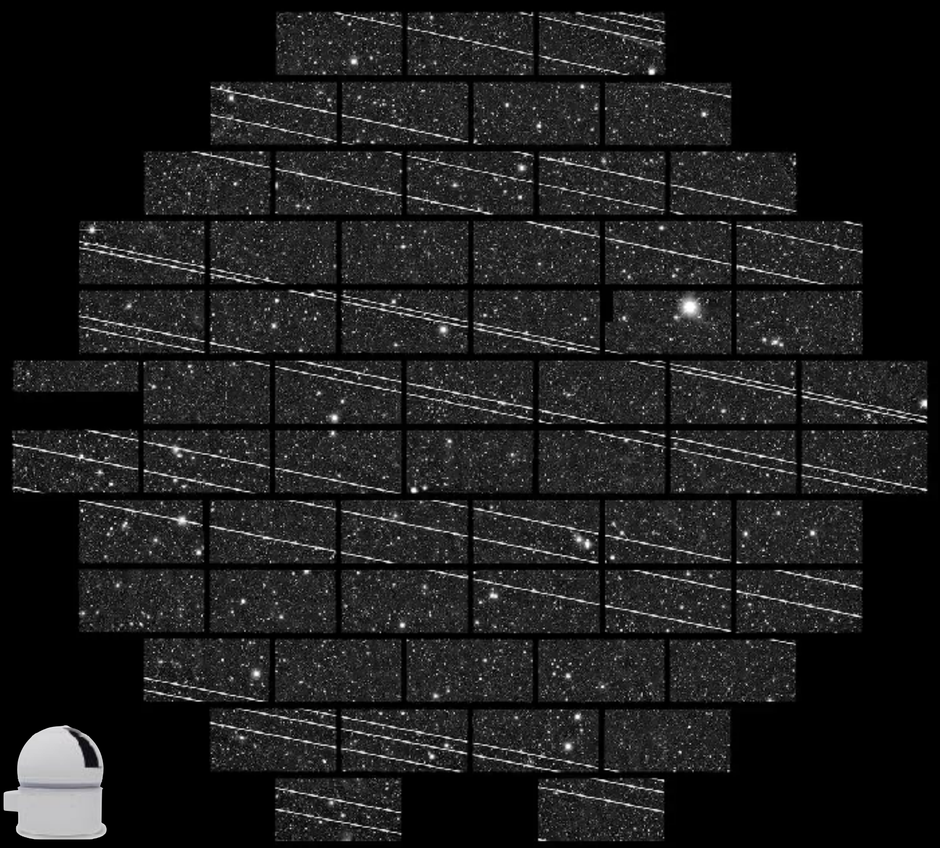
UNITED NATIONS
Office for Outer Space Affairs

Workshops on ***Dark and Quiet Skies for Science and Society***.
with comprehensive reports and constructive mitigation measures

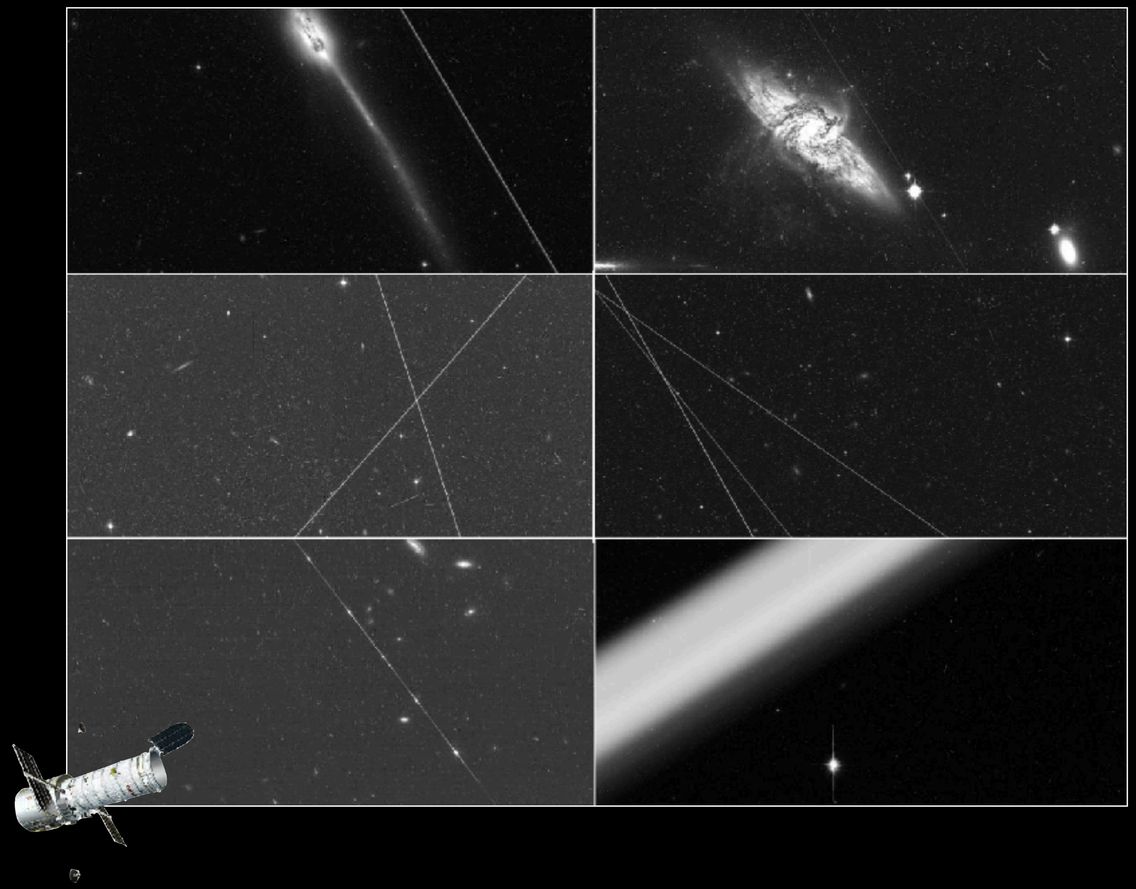
Light pollution originating from outer space



Light pollution originating from outer space

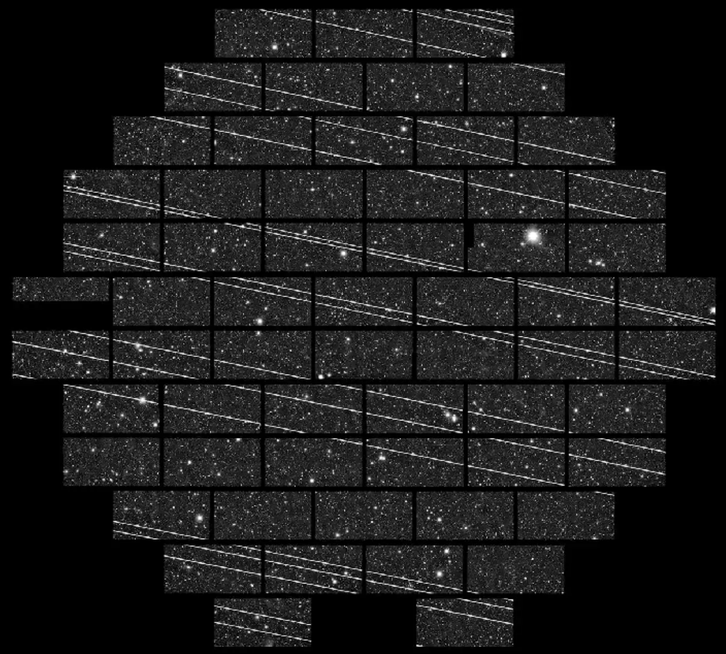


Starlink satellites from CTIO (Nov. 2019)
5-minute exposure, 2.2 degrees field of DECam



Satellite trails in raw HST ACS images
8% composite images affected in 35-minute exposures
(Kruk et al., in prep)

Light pollution originating from outer space



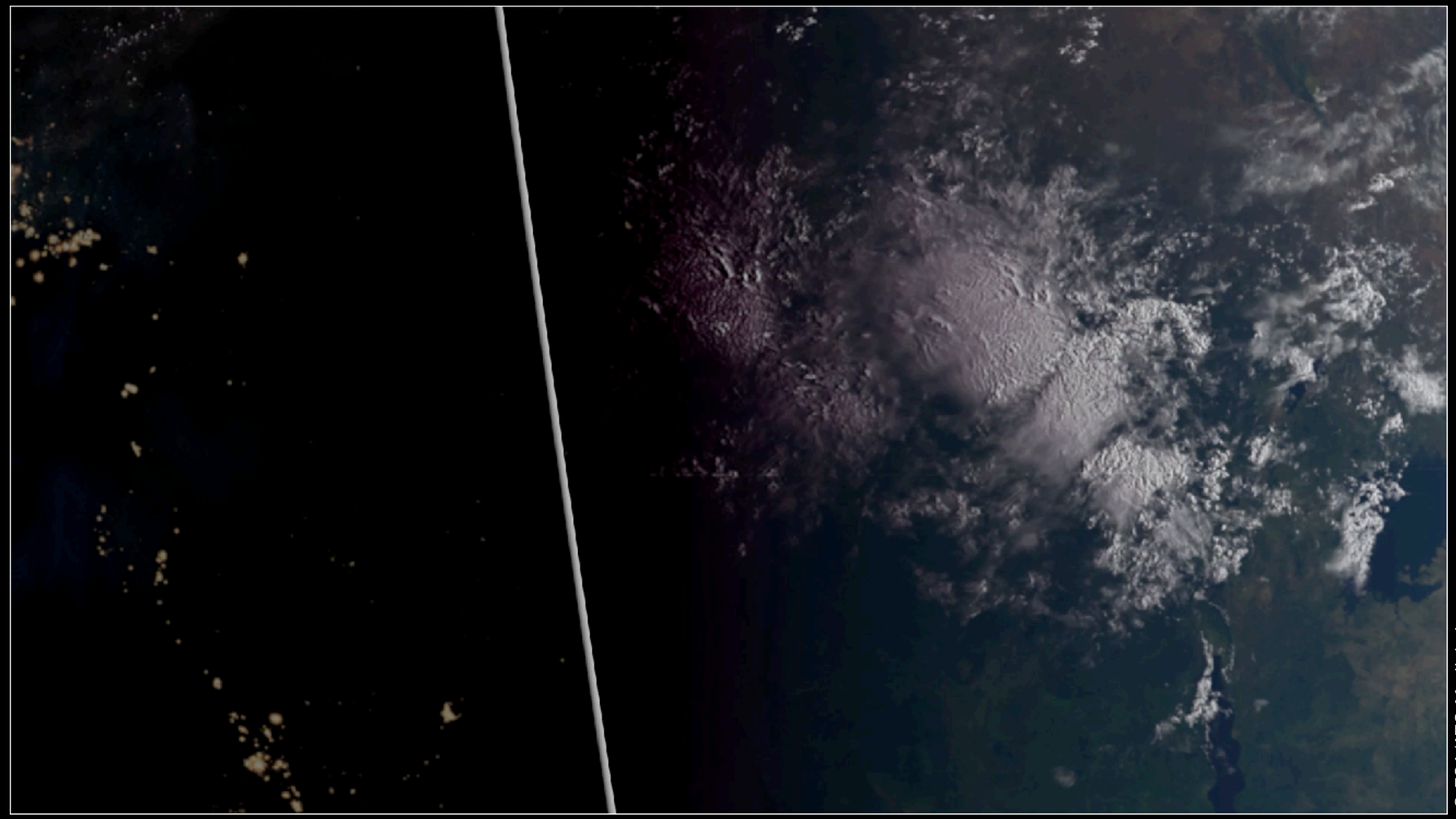
200 years **?**

Committee on the Peaceful Uses of Outer Space (COPUOS)

Forum for the development of Space Law Treaties and Principles

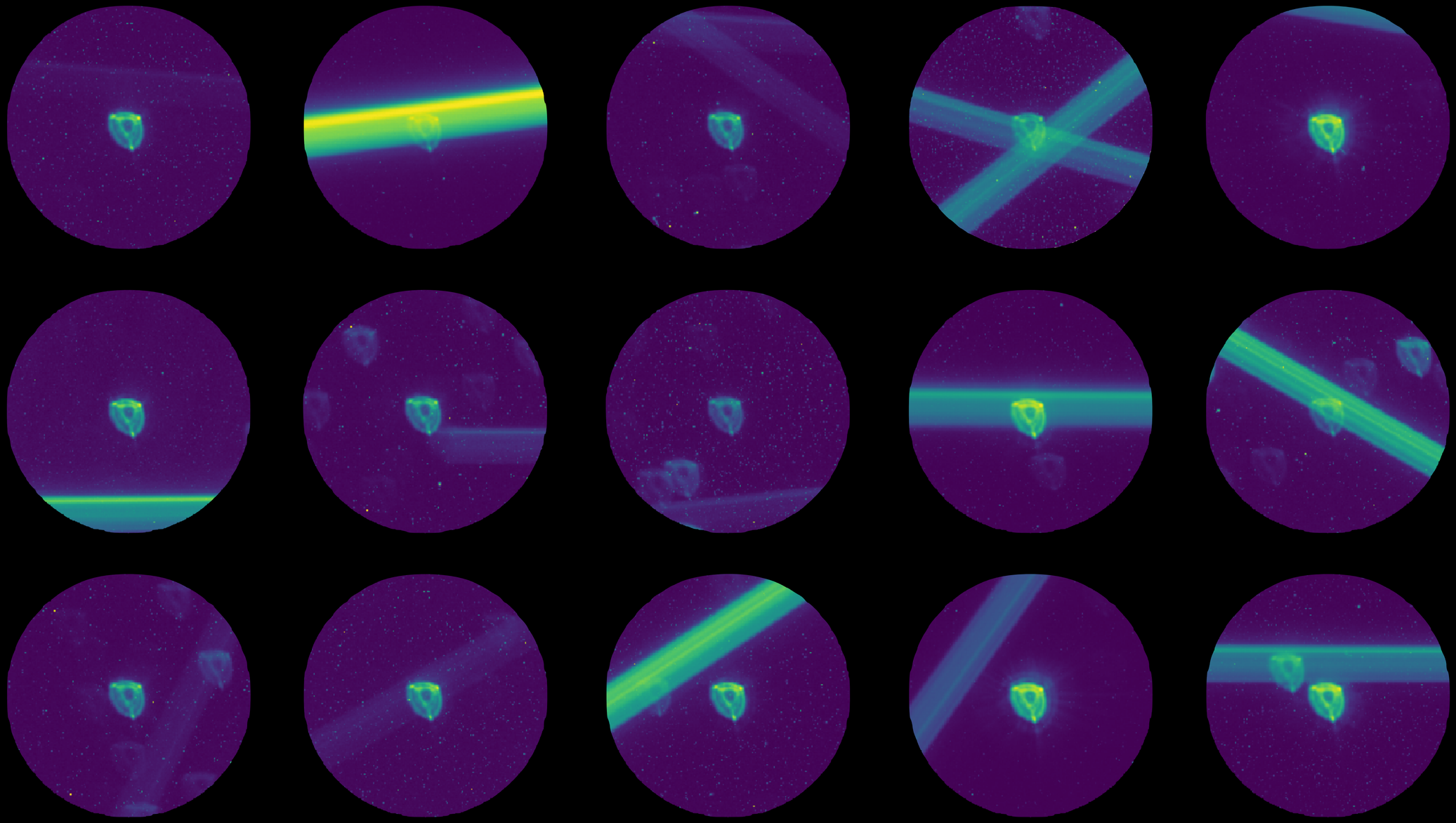
CHEOPS: Orbital parameters

Launched on
18 December 2019

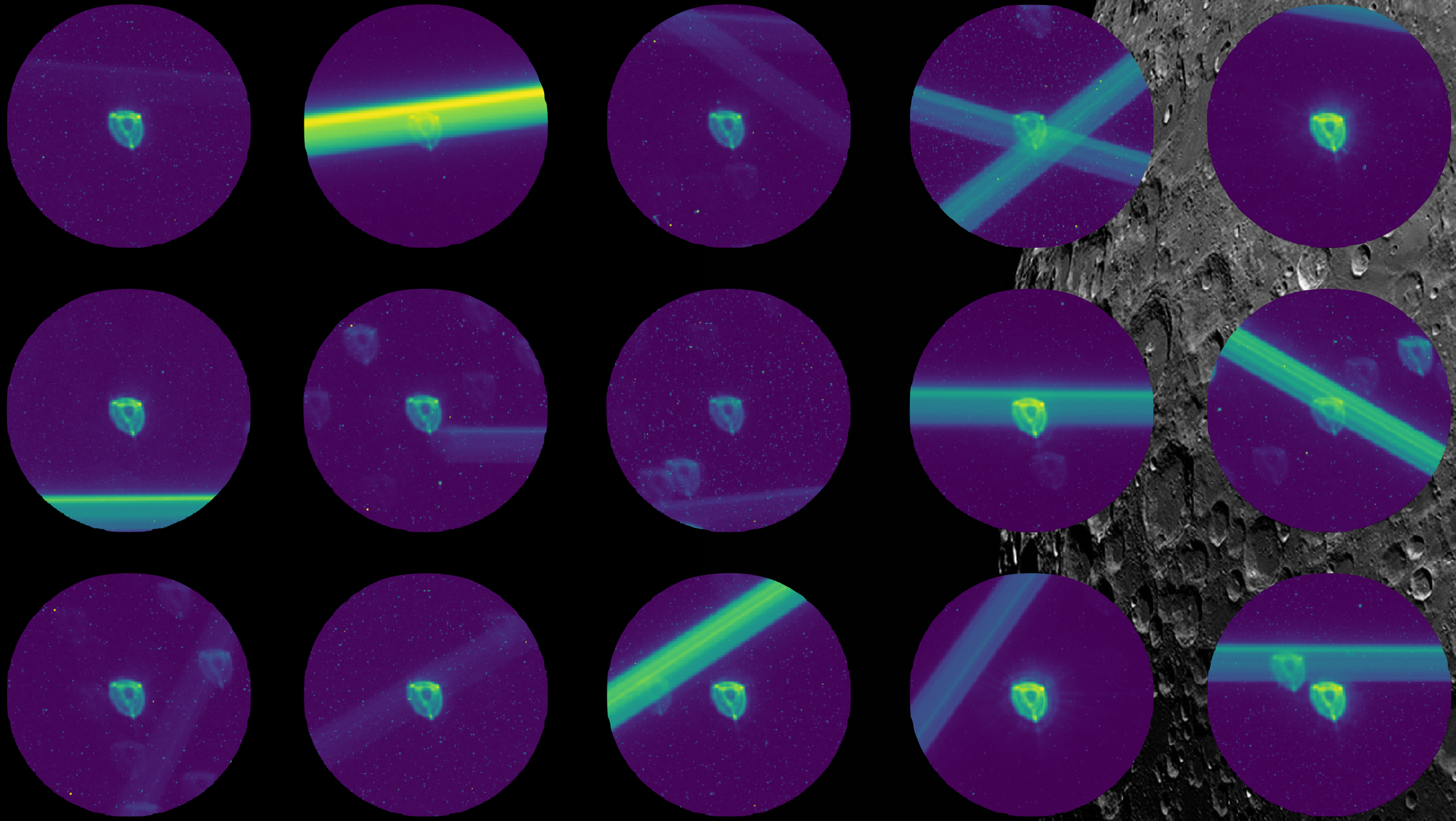


Sun-Synchronous polar orbit at ~700km altitude, nadir-locked

CHEOPS: Gallery of intruding trails



CHEOPS: Gallery of intruding trails



200 arcseconds

Relatively small field of view

Exposure time < 60s

Trail occurrence: complete census

- Over **735 000 images** have been searched for linear features
- Pattern recognition algorithm based on the Hough transform

==> **1200+ trails** identified in science data over the past 2 years

About 0.16% of science images collected so far

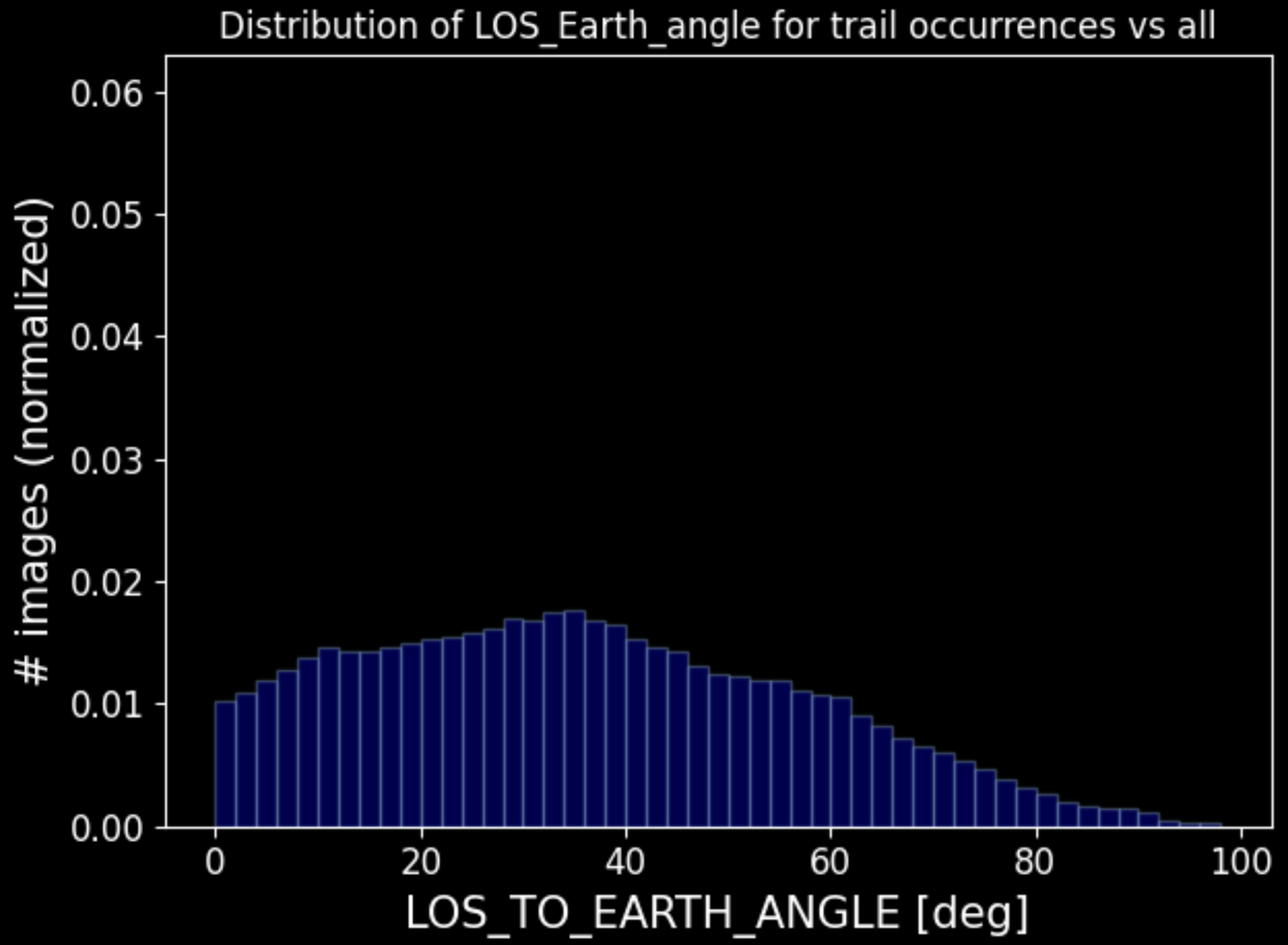
Census is relatively complete (estimate of 95+%)

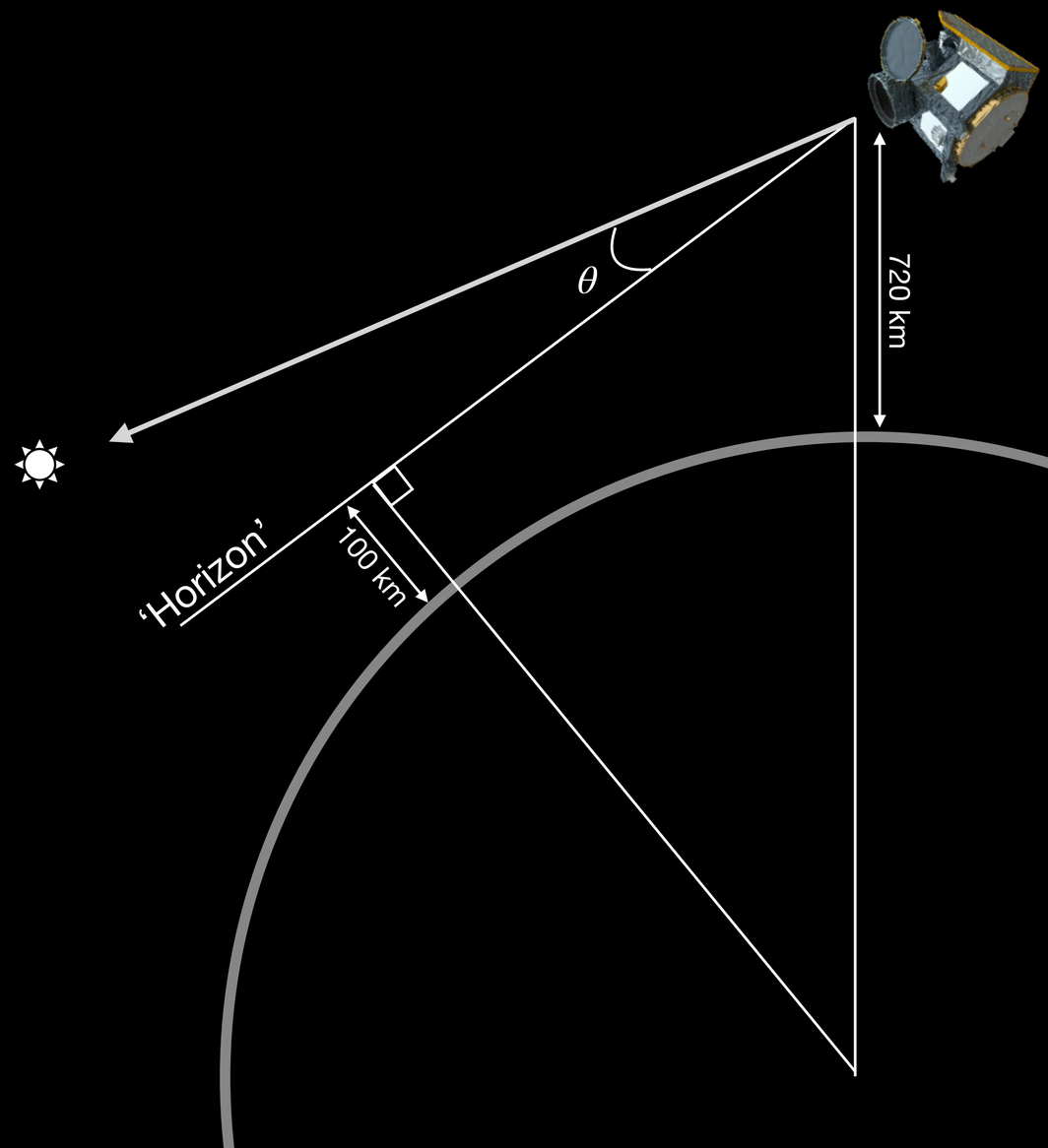
- Very few false positives (cosmic rays)
- Very few false negatives (misclassified as smearing trails)
- Multiple, faint and/or partial trails are well detected

Characterise population of objects crossing CHEOPS' field-of-view

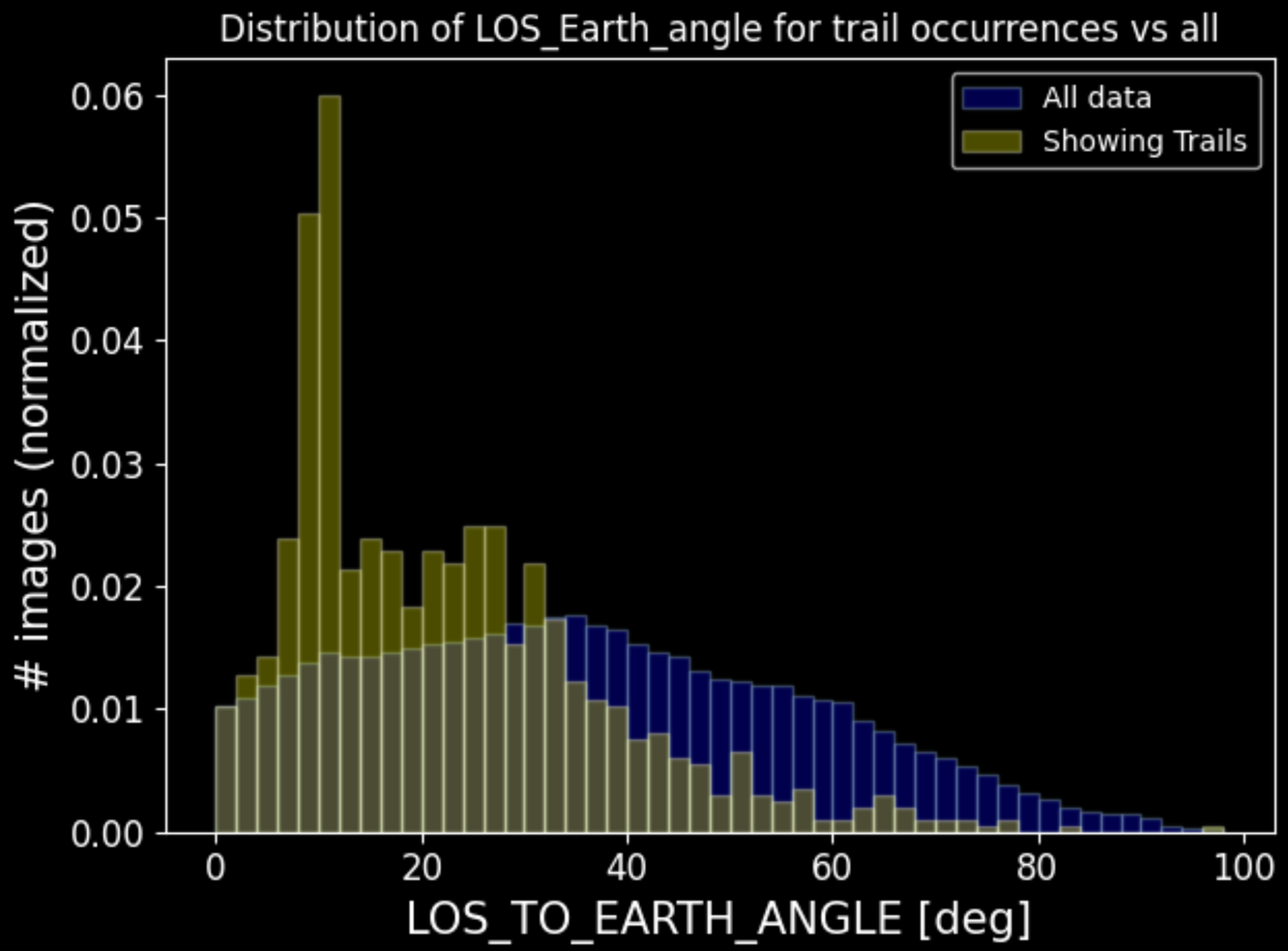
Look for trends in images metadata/properties

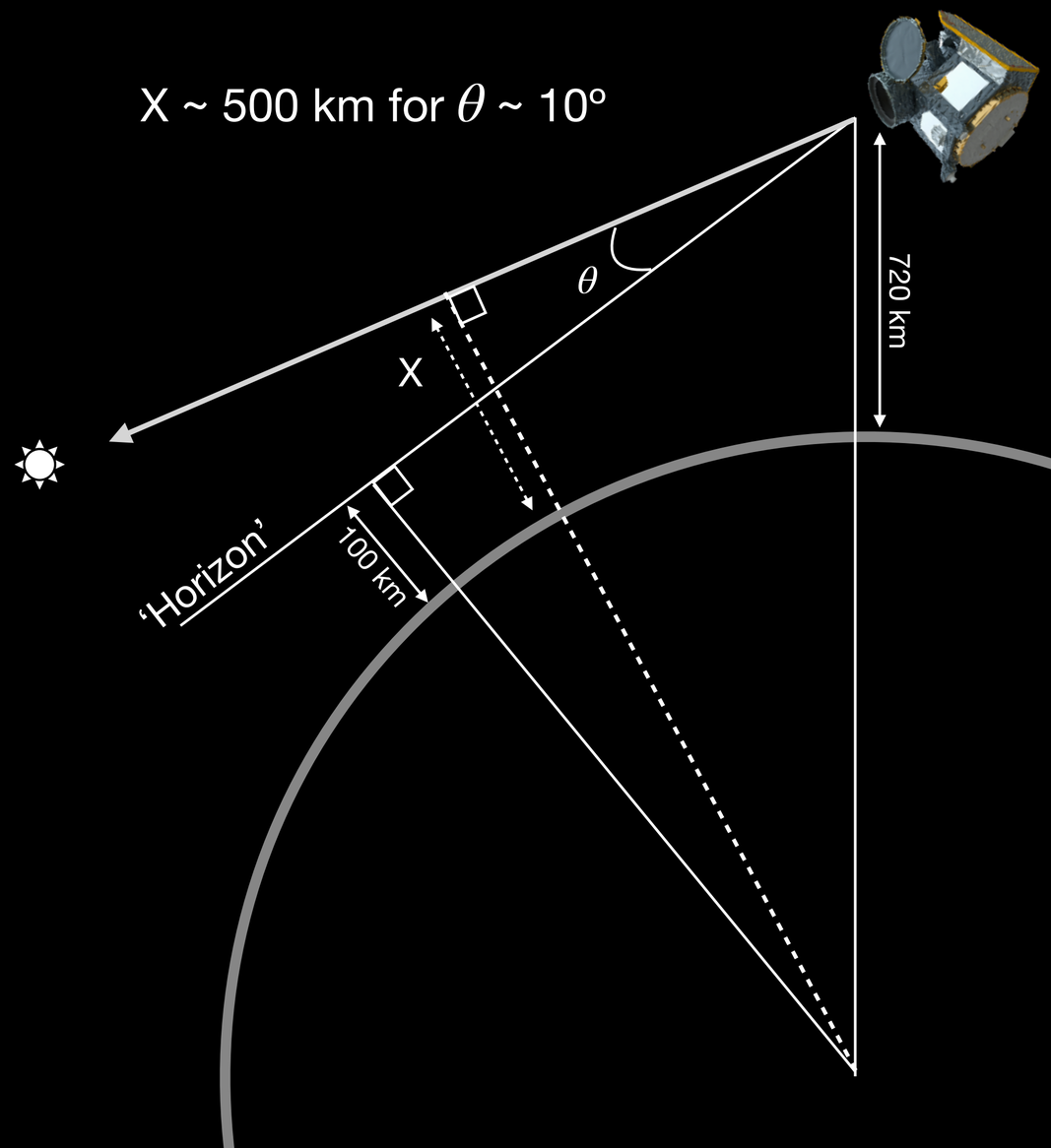
Trail occurrence: LOS to Earth angle





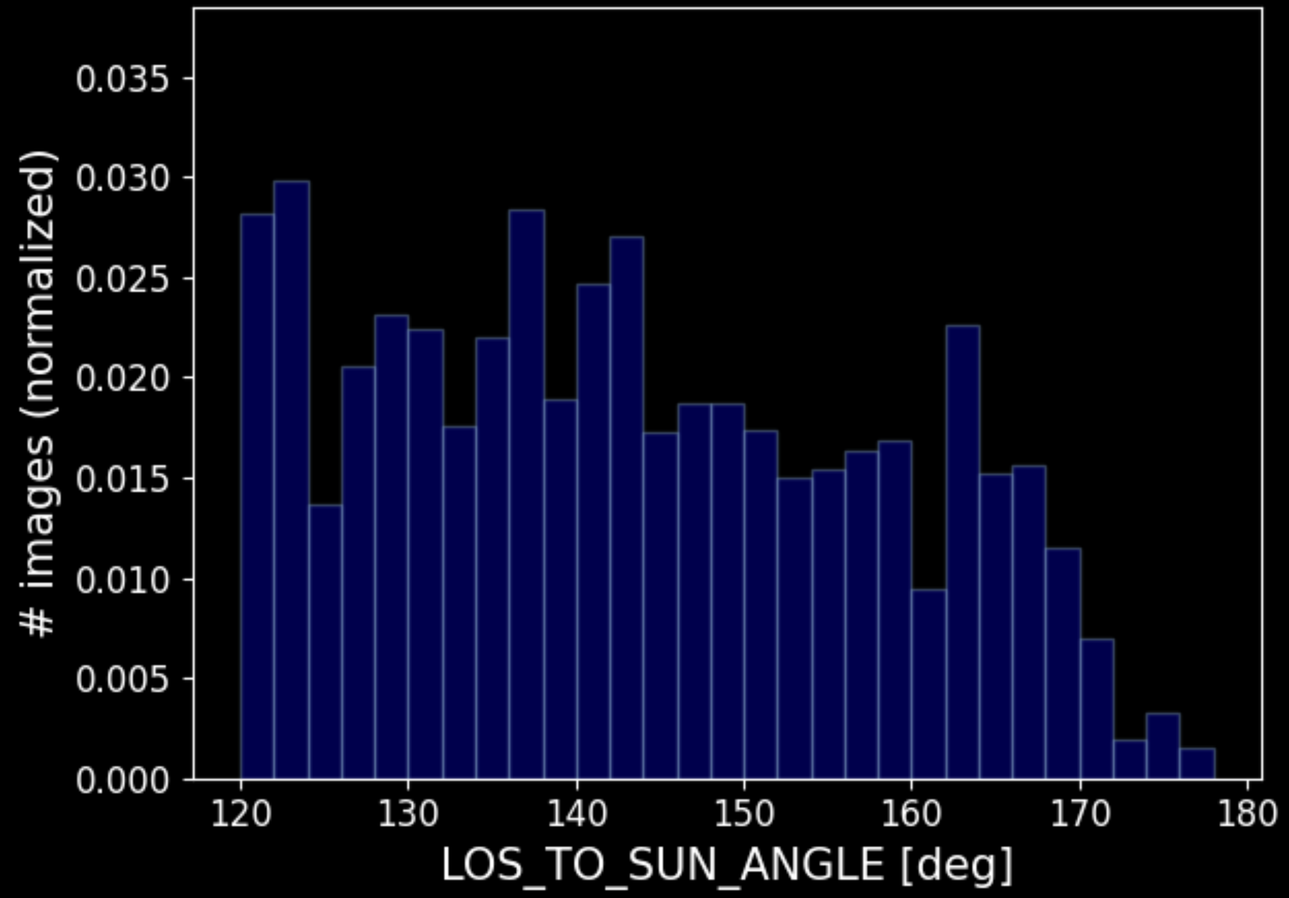
Trail occurrence: LOS to Earth angle

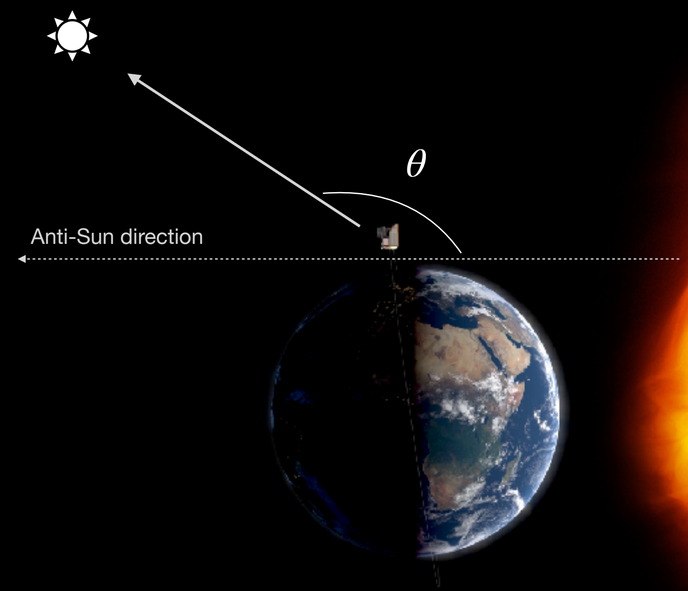




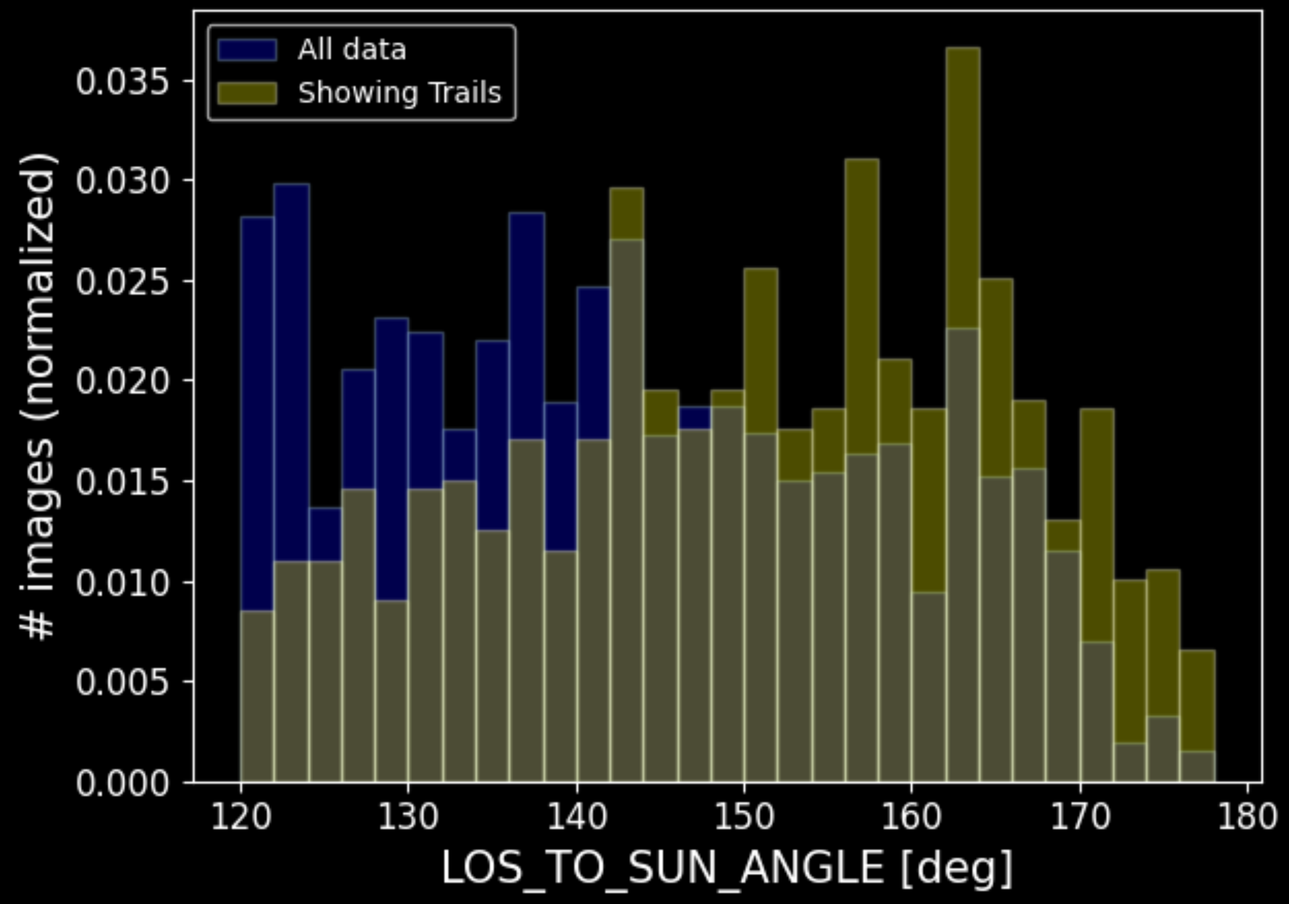
Shell of satellites/debris at ~500+ km altitude

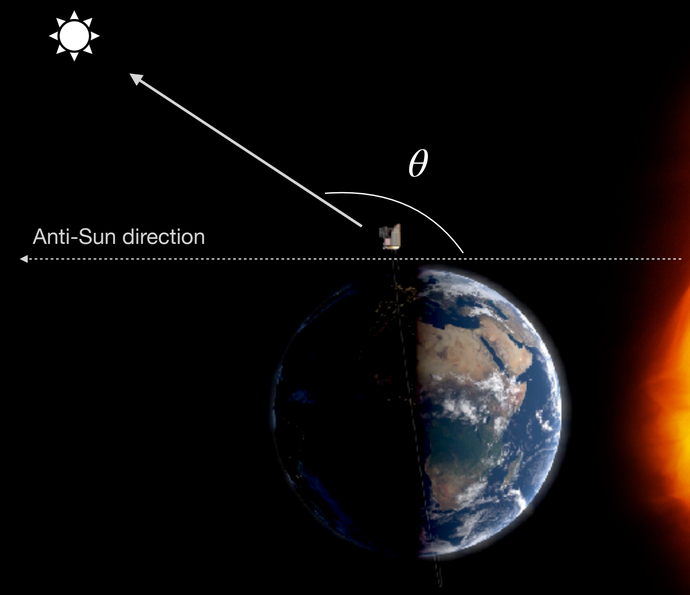
Trail occurrence: LOS to Sun angle





Trail occurrence: LOS to Sun angle

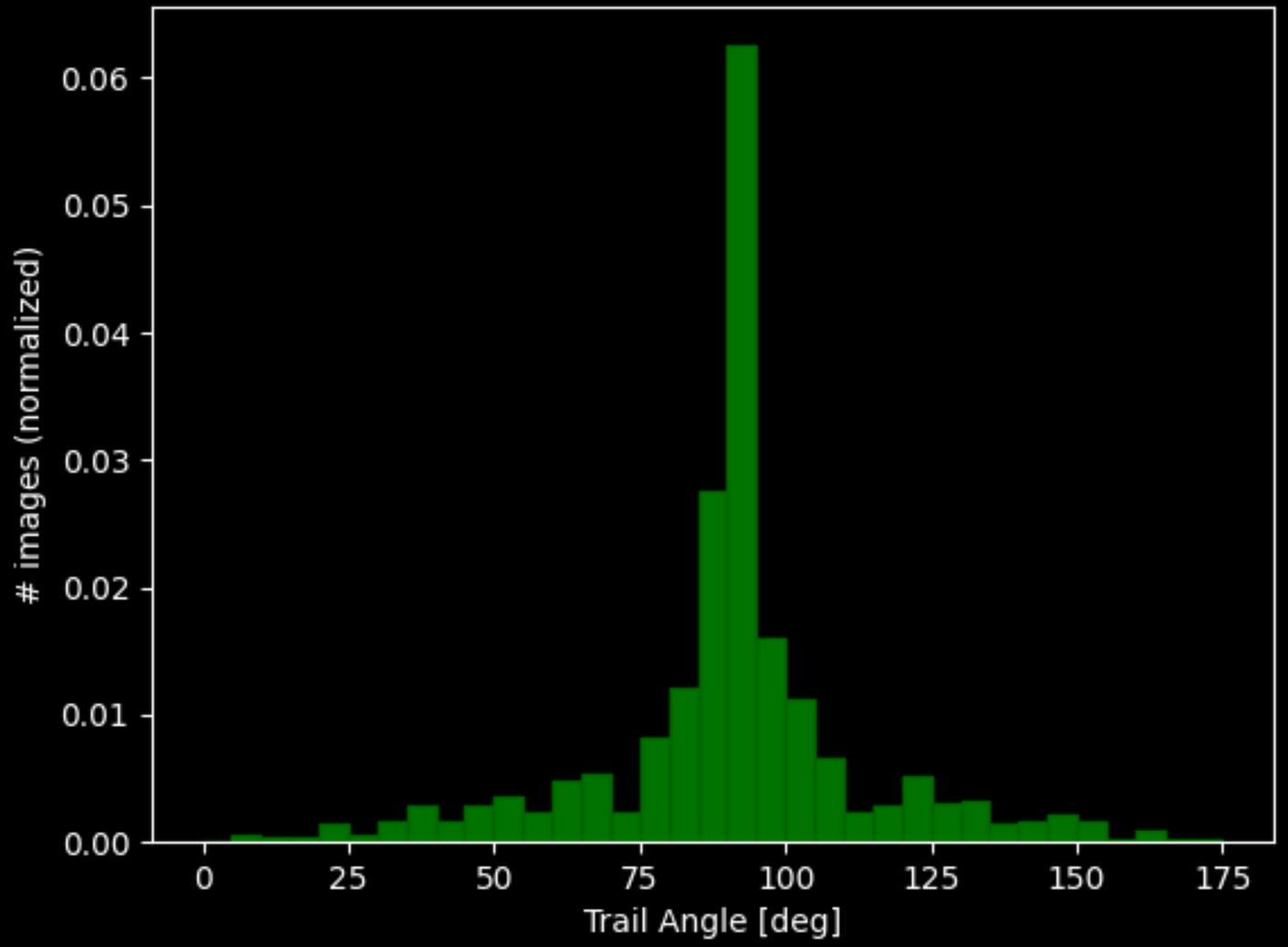


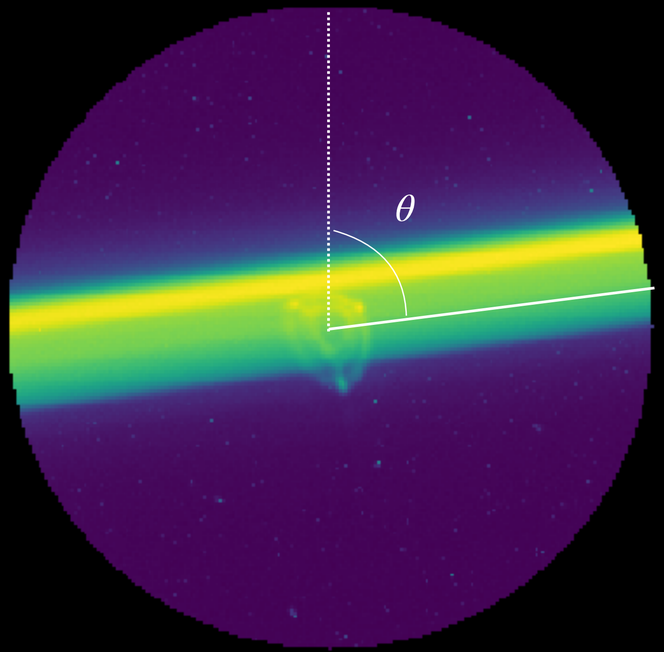


More detections at low phase angles

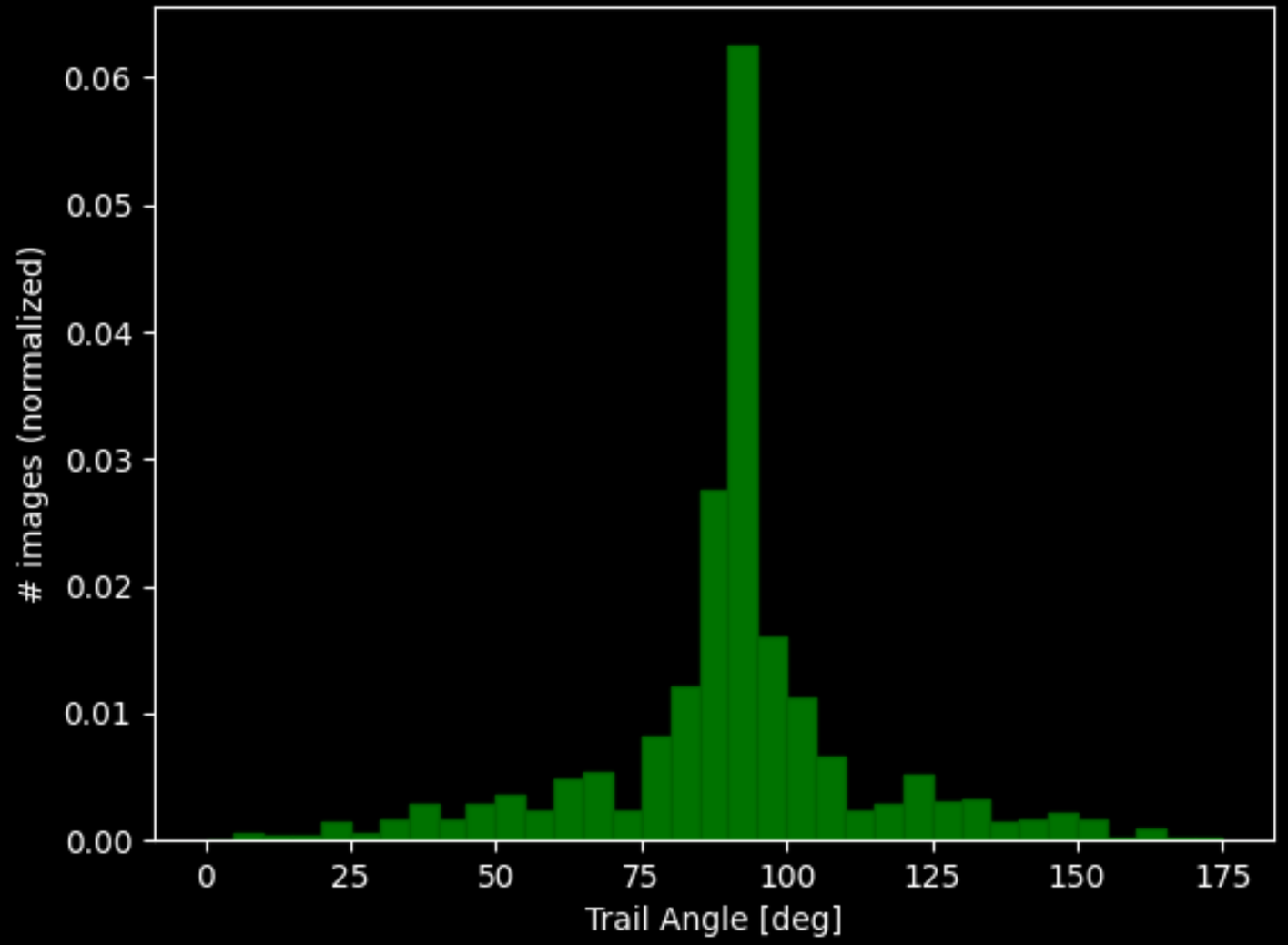
Brighter appearance due to sunlight reflections?

Trail occurrence: orientation

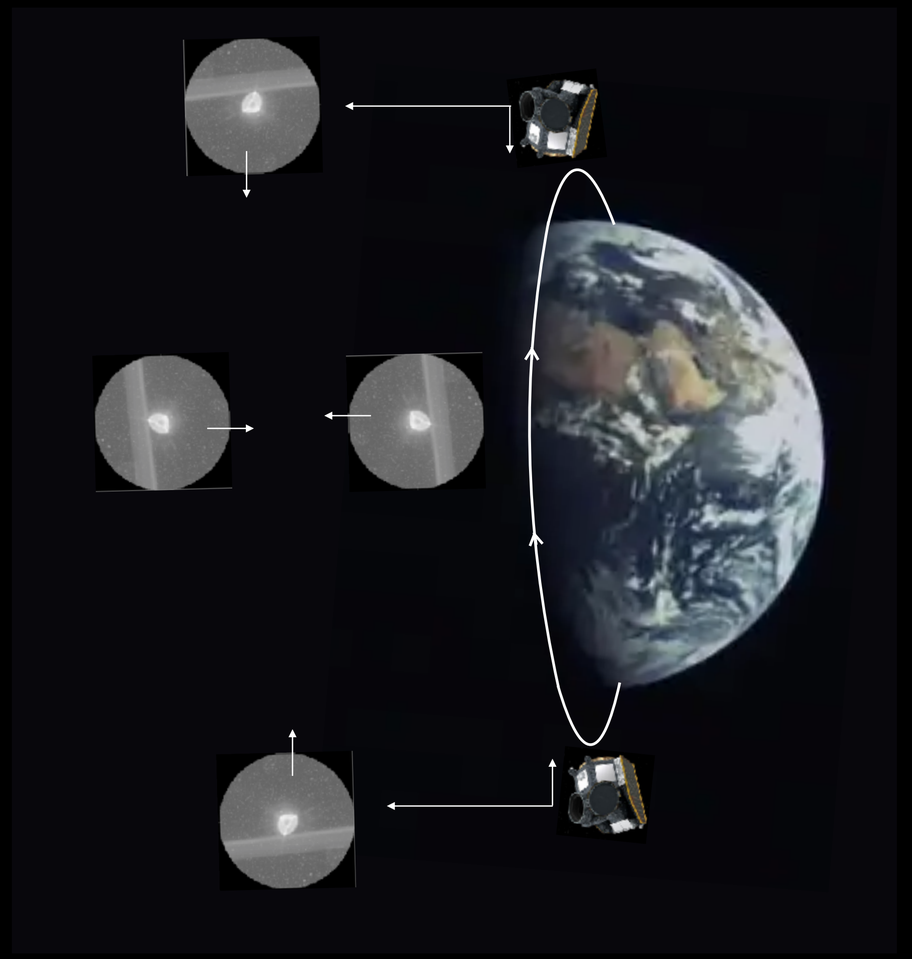




Trail occurrence: orientation

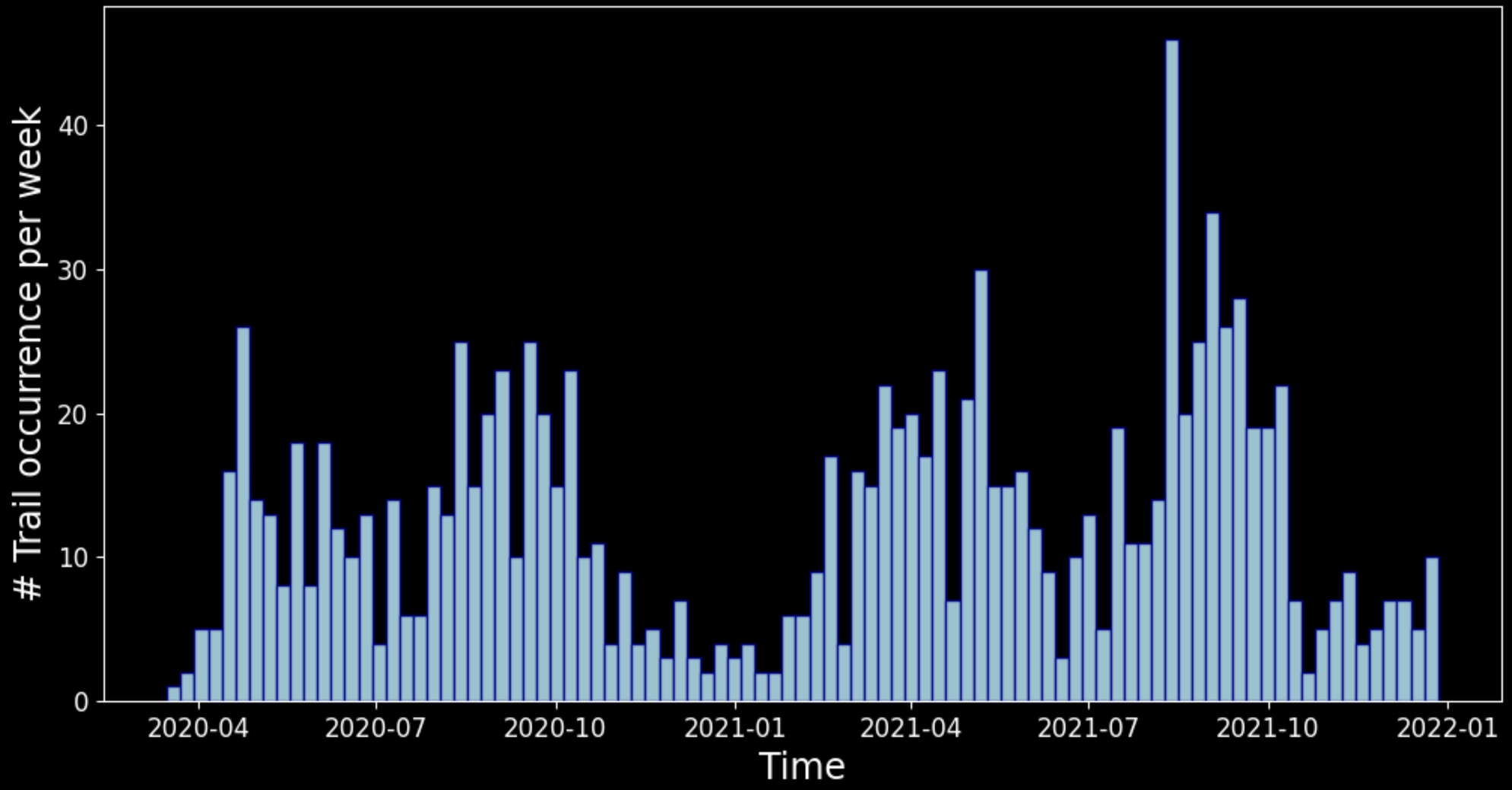


Trails mainly originate from orbits parallel to CHEOPS'
==> high number of Sun-Synchronous satellites-debris
or possible observational biais?

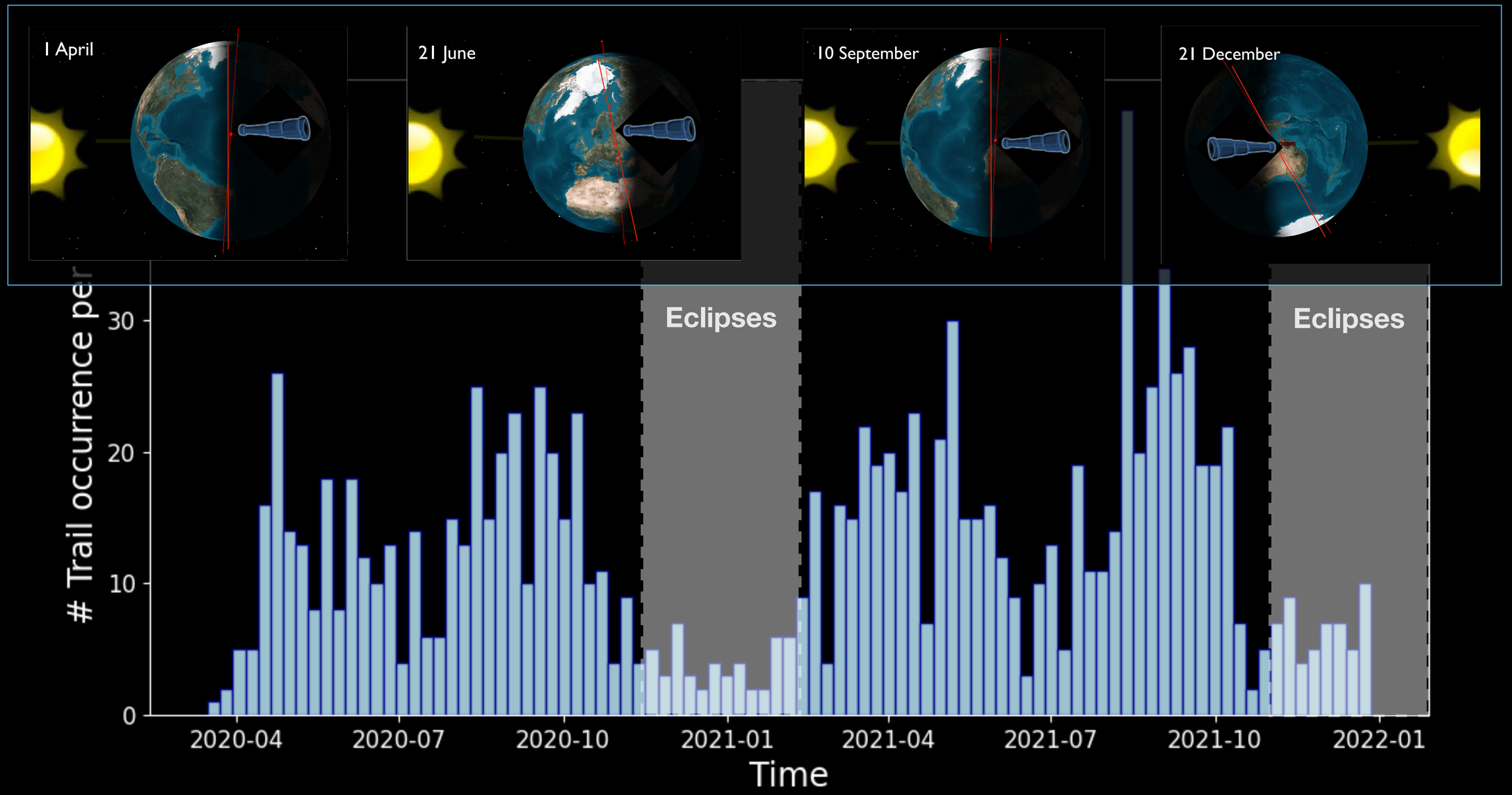


CHEOPS is nadir-locked

Trail occurrence: Weekly counts

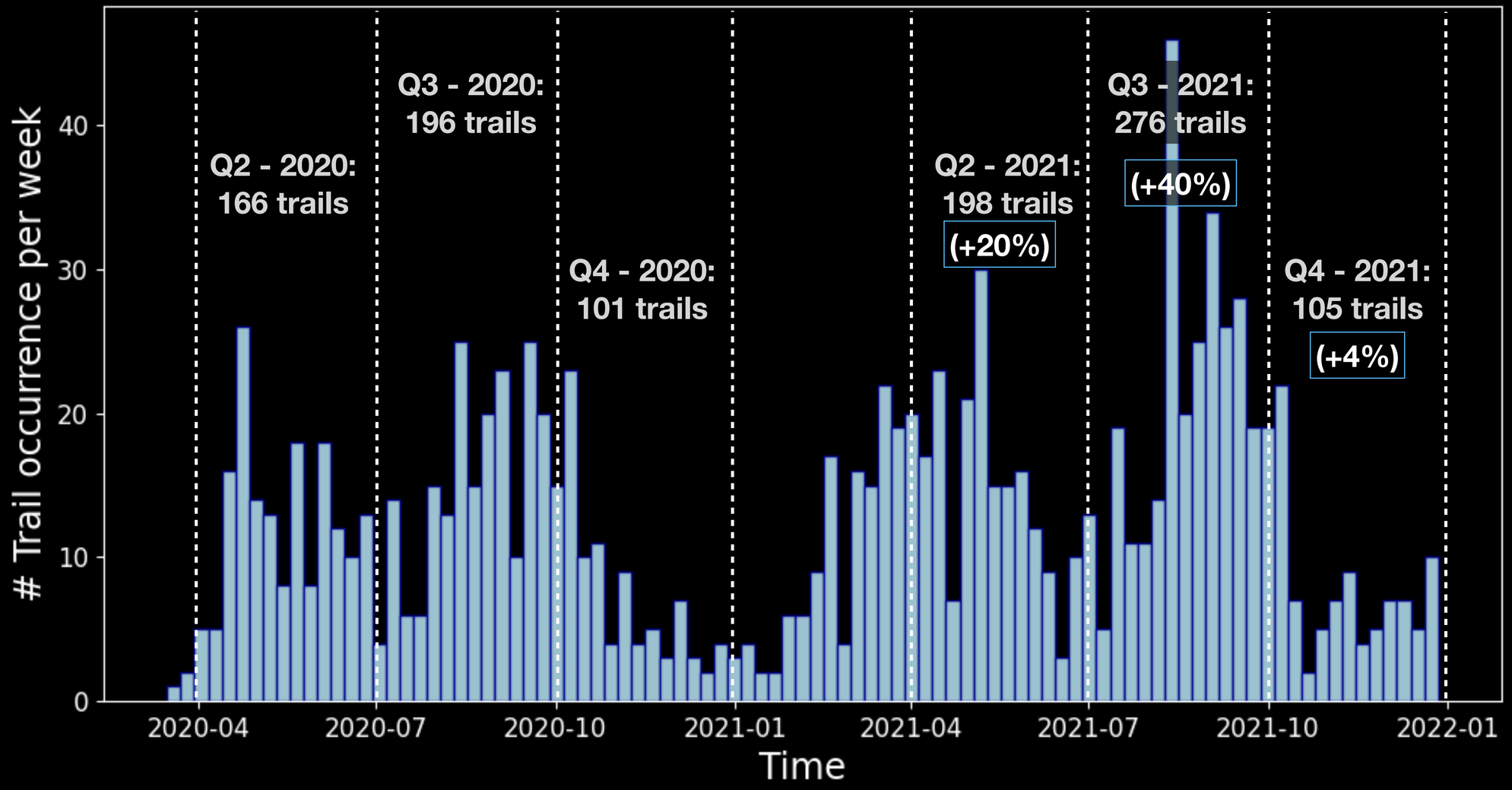


Trail occurrence: Weekly counts



Seasonal effects

Trail occurrence: Weekly counts



Increased number of trails overall

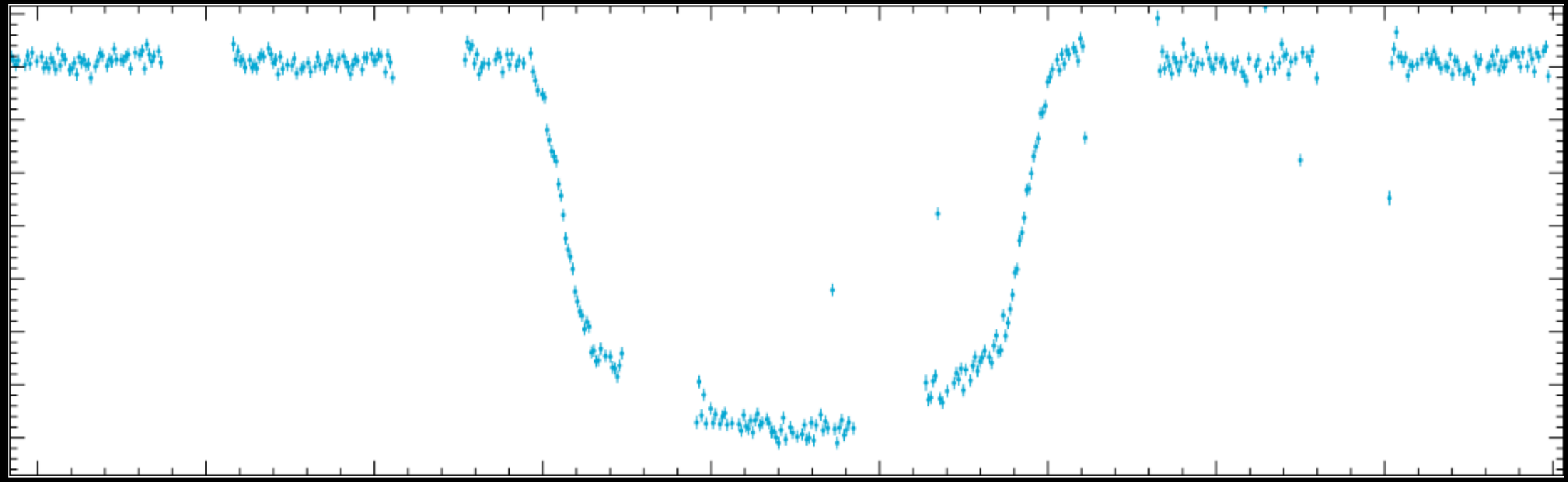
Identification of crossing objects

Initially led by **Mark McCaughrean** and his team of ESA summer interns

Using **Jonathan McDowell**’s software

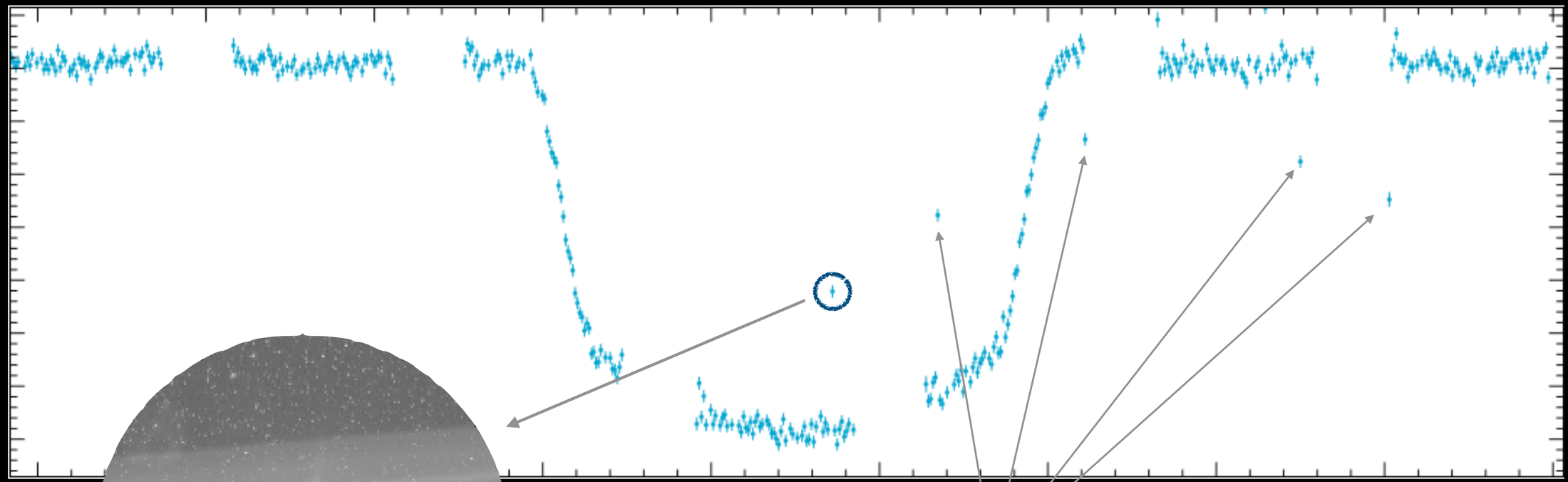
Impact on Science

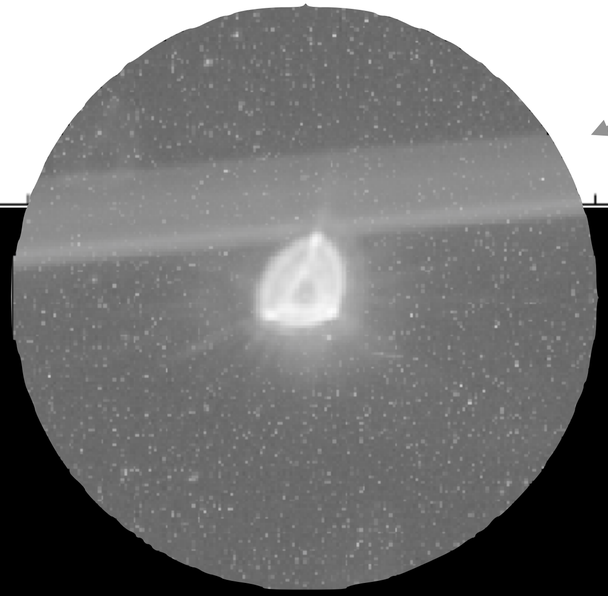
CHEOPS light curve: end product for scientists



Impact on Science

CHEOPS light curve: end product for scientists

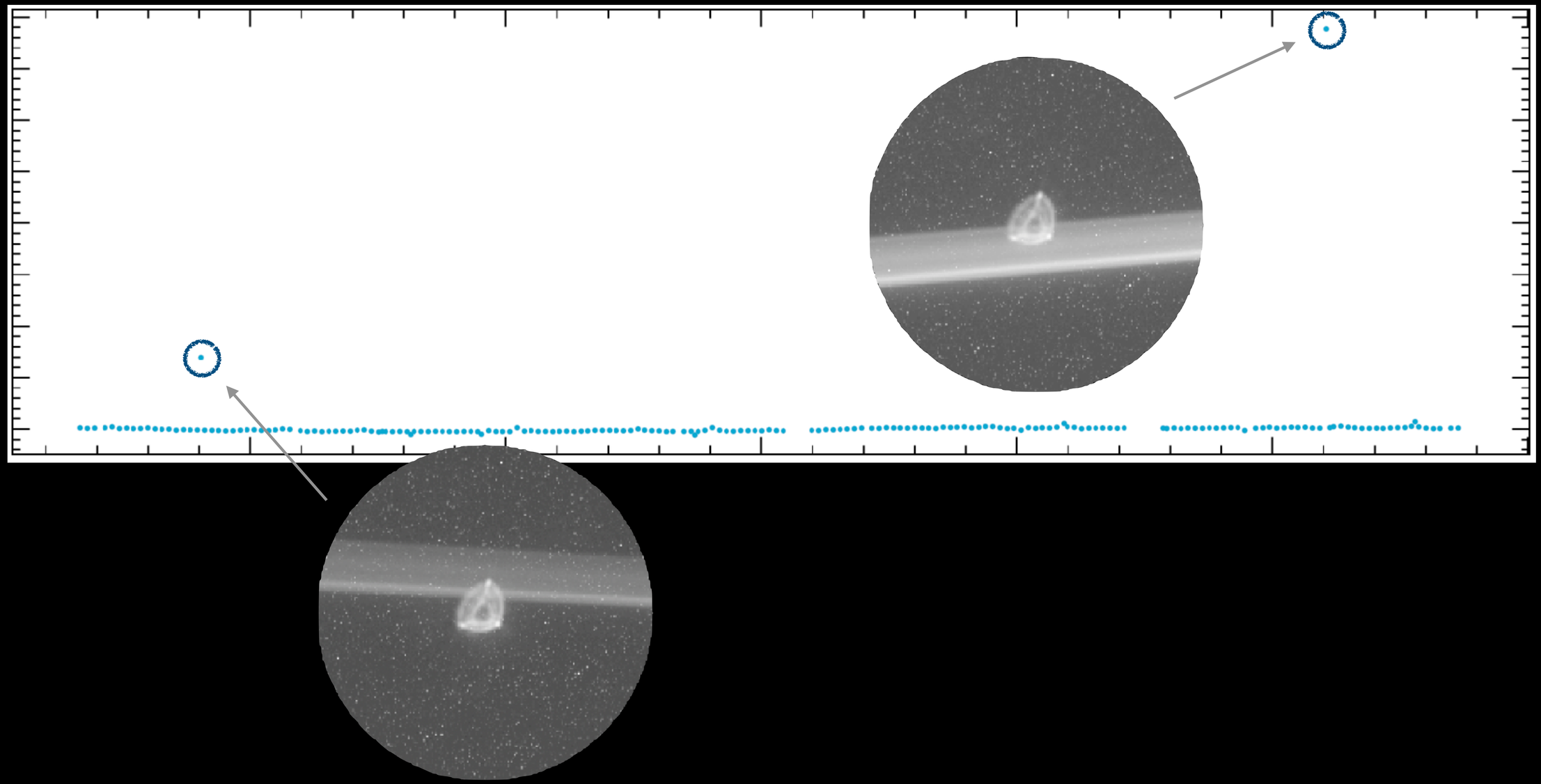




Straylight from the Earth

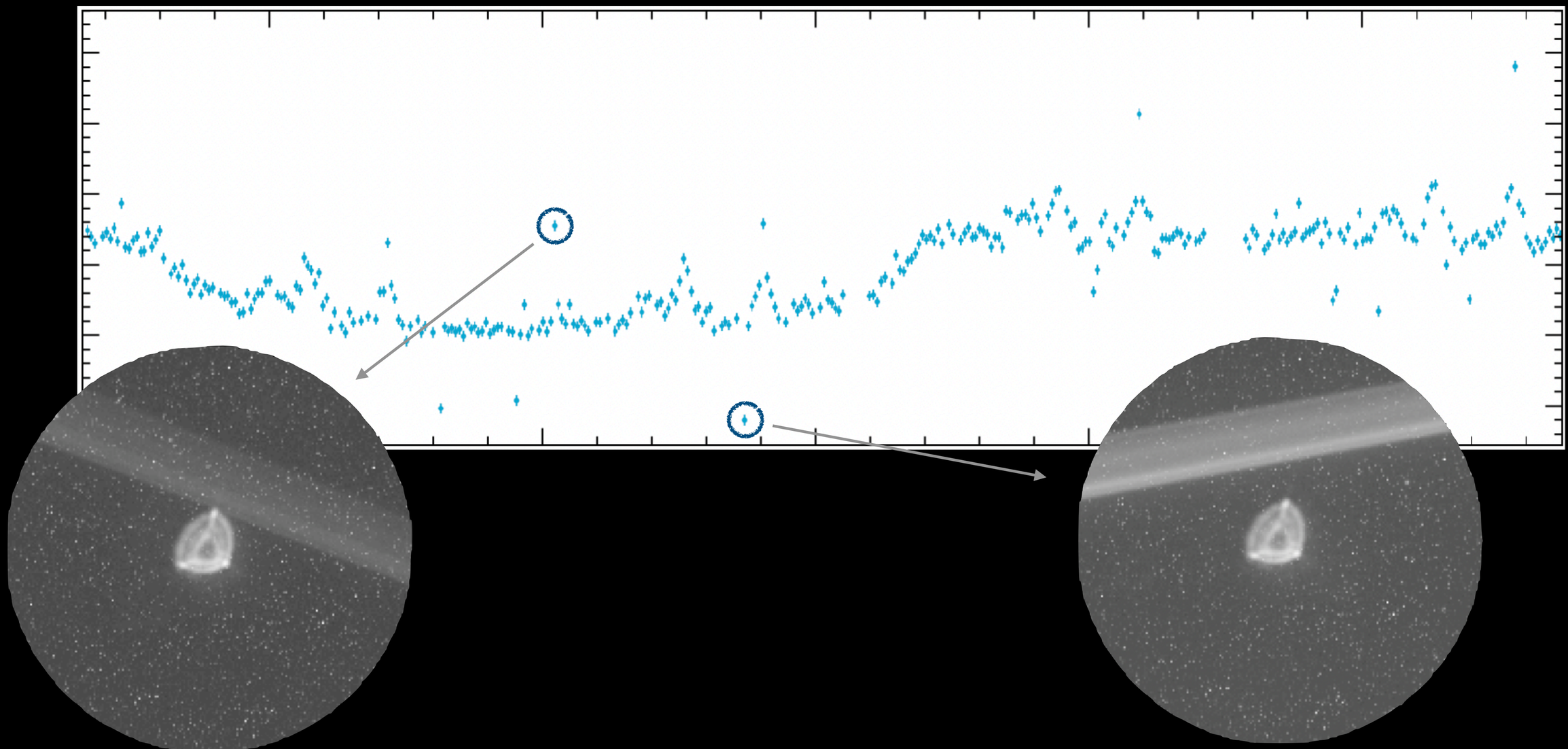
Impact on Science

CHEOPS light curve: end product for scientists



Impact on Science

CHEOPS light curve: end product for scientists



Conclusions

- **Space-based astronomical observations do get affected by other LEO satellites/debris**
- **Trails in CHEOPS' images show interesting trends:**
  - Shell of satellites/debris at 500+ km altitude
  - Reflections at low phase angles lead to higher detection rate
  - Seasonal effects (eclipses)
- **Meaningful increase in the number of trails seen in CHEOPS' images over the past 2 years**
- **Currently negligible impact on science programme (small field of view, short exposures)**
- **More LEO satellites also mean more space hazards and collision avoidance manoeuvres**

- **Extrapolation to other space observatories is complex/uncertain (different orbits)**
- **Large field of view and/or long exposures increase the chances of being affected**
  e.g. Vera C. Rubin Observatory: 30% of all images will contain at least 1 trail from Starlink satellites or Xuntian (CSST - Chinese Space Station Telecope) with wide field of view at 400 km altitude