



**DARK  
& QUIET  
SKIES**

# Dark and Quiet Skies for Science and Society II

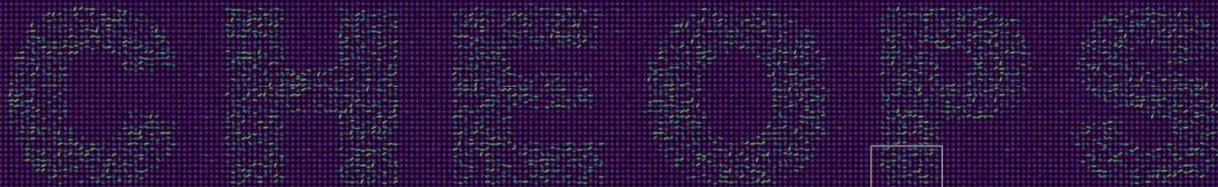
Implementing the recommendations

La Palma, Canary Islands, Spain

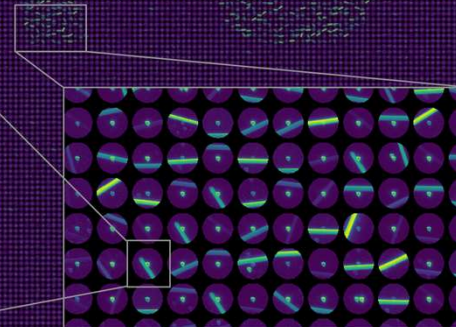
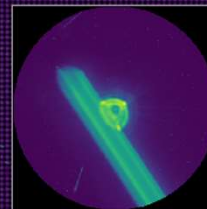
3 - 7, October, 2021

## Intruding trails in space-based astronomical observations: The CHEOPS case study

Nicolas Billot - University of Geneva<sup>+</sup>  
On behalf of the CHEOPS Consortium



Dark and Quiet Skies for Science and Society II  
La Palma, Canary Islands, 5<sup>th</sup> October 2021



5 October 2021



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# Dark and Quiet Skies for Science and Society II

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## CHEOPS: CHAracterising ExOPlanet Satellite

 Switzerland



 Austria

 Belgium

 France

 Germany

 Hungary

 Italy

 Portugal

 Spain

 Sweden

 UK



**First S-class mission in ESA's science programme**

**Partnership between ESA and Switzerland**

Consortium of 11 European countries led by the University of Bern  
CHEOPS was built within schedule and within budget!

**High-precision photometry: ~50 parts per million!**

Launched in December 2019  
=> 1.5 years of routine operations



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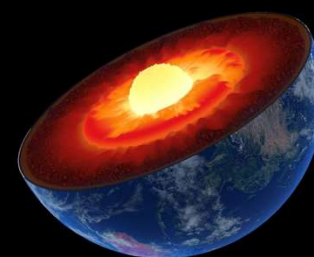
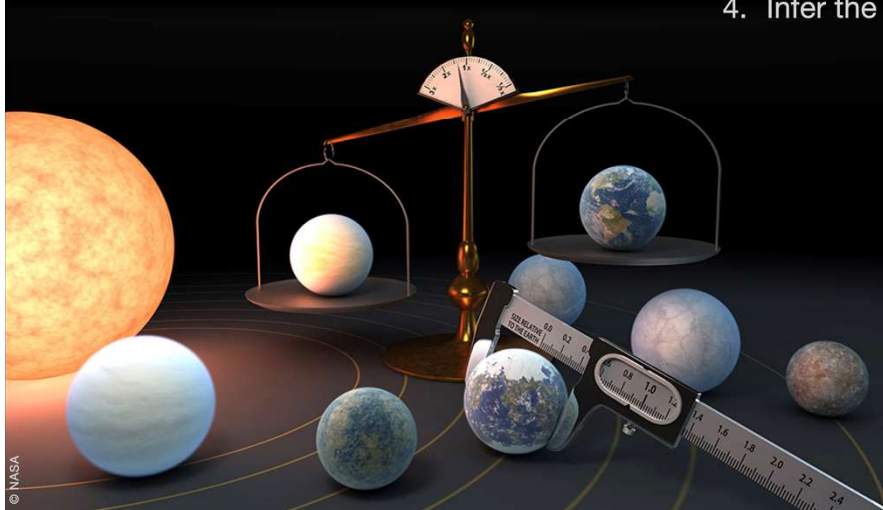
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**CHEOPS**  
CHARACTERISING EXOPLANET SATELLITE

## CHEOPS: Prime science goal

What are exoplanets made of ?

- 1. Measure the **mass** via the radial velocity method
2. Measure the **radius** via the transit method
3. Deduce the bulk **density**
4. Infer the internal **structure**



© NASA

3

© Argonne National Labs

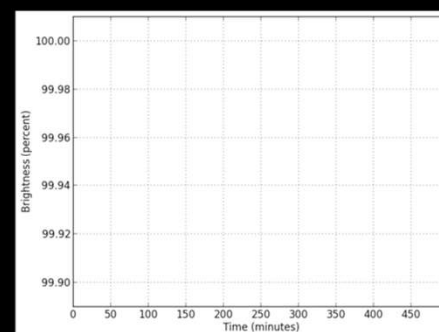
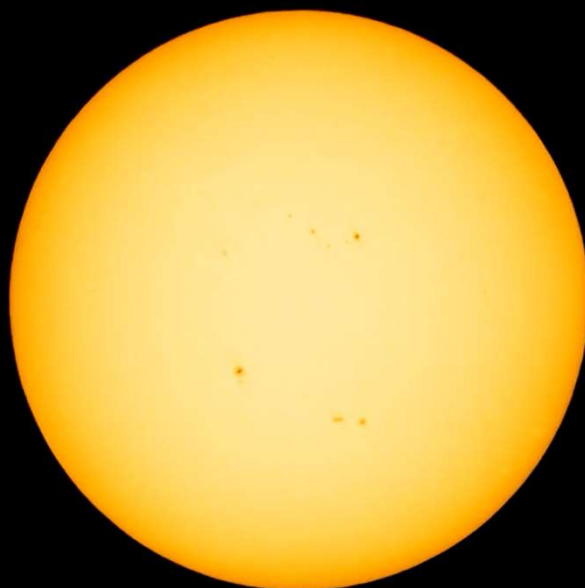
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## CHEOPS: Transit method to measure radii



Transit of Venus in 2012

Credit: Jamie Gilbert

4





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### CHEOPS: Orbital parameters



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

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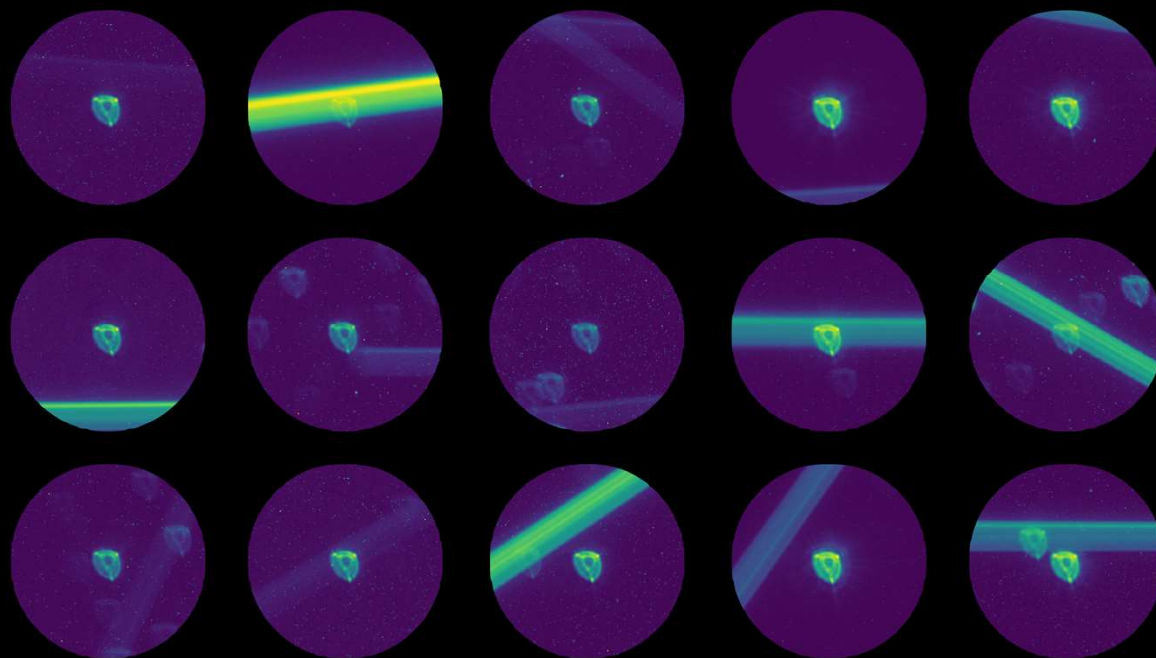
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## CHEOPS: Gallery of intruding trails



6

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### Trail occurrence: complete census

- Over **600 000 images** have been searched for linear features
- Pattern recognition algorithm based on the Hough transform

**=> 1000+ trails** identified in science data over the past 1.5 years

About 0.2% of 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)
- ✦ Faint or partial trails are well detected

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

Look for trends in images metadata/properties

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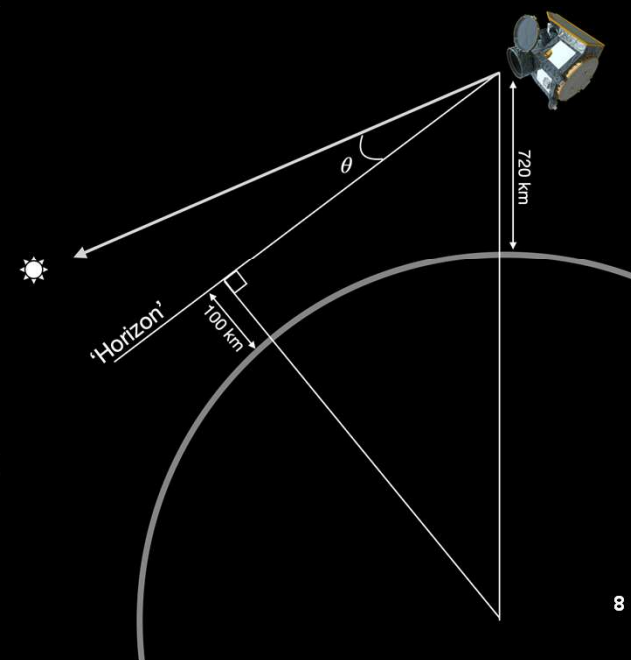
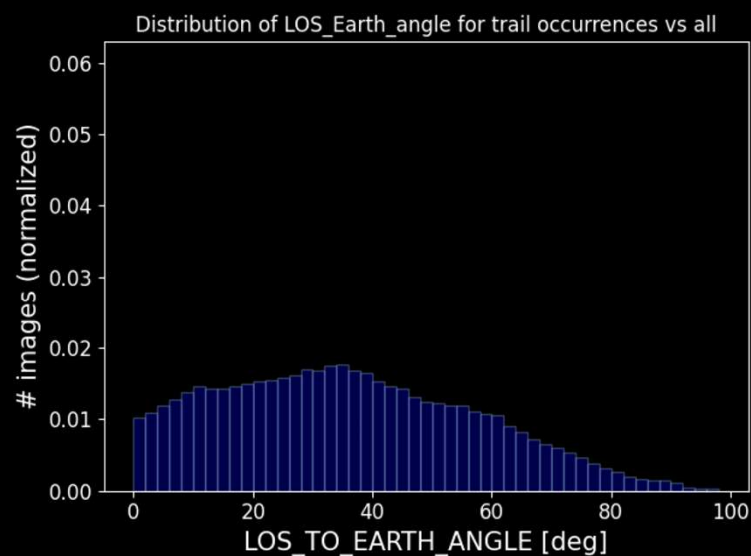
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## Trail occurrence: LOS to Earth angle



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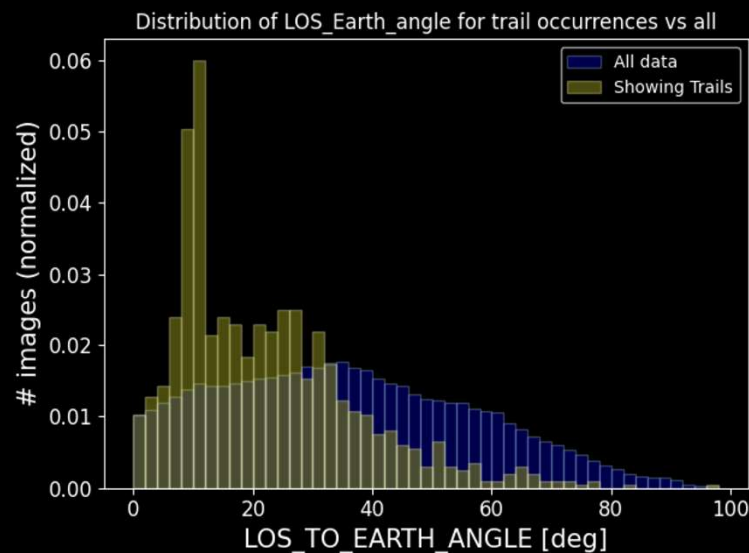


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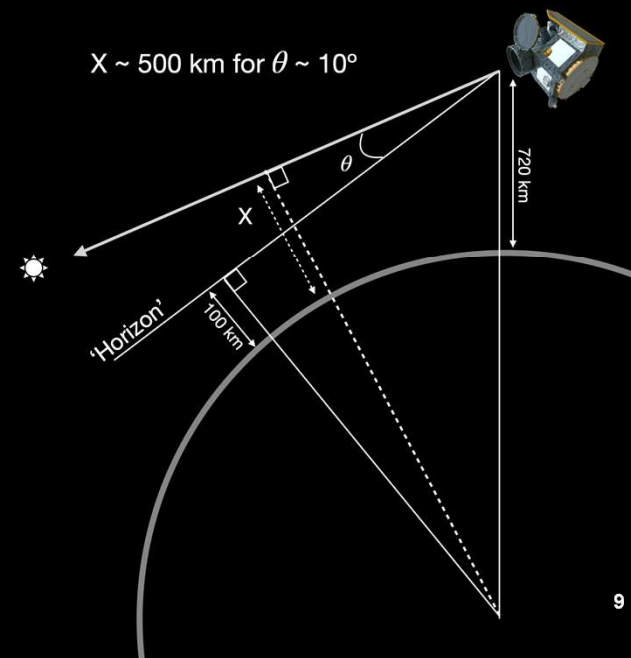




## Trail occurrence: LOS to Earth angle



Shell of satellites/debris at ~500+ km altitude





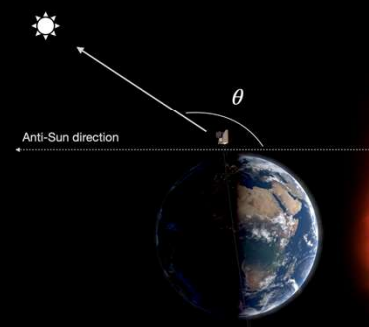
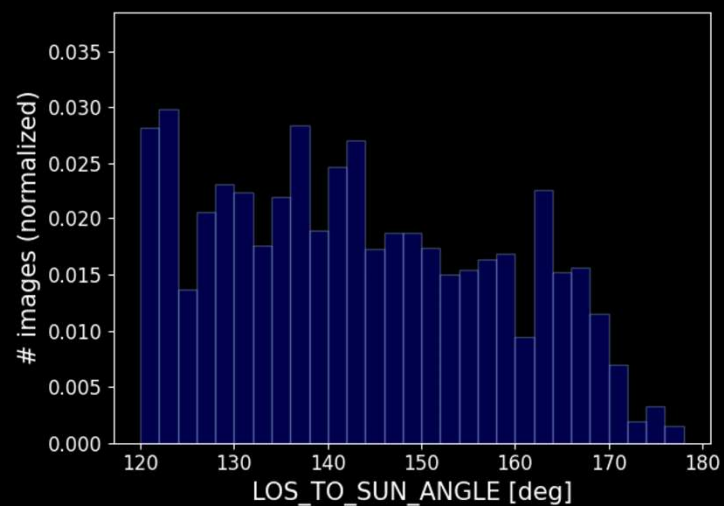
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## Trail occurrence: LOS to Sun angle



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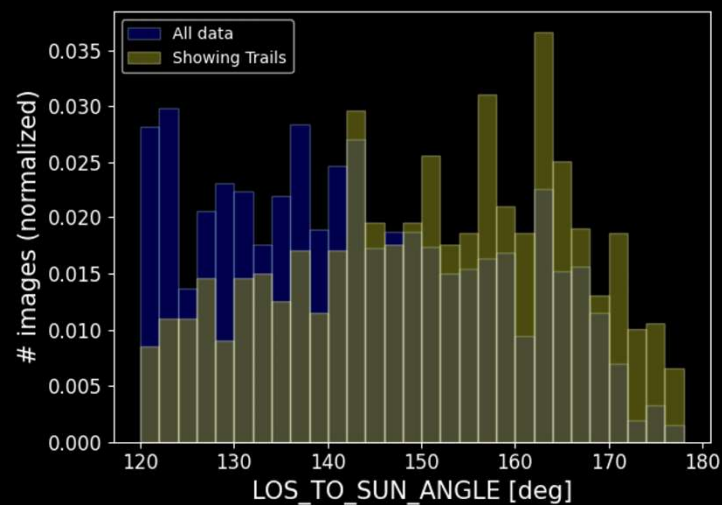


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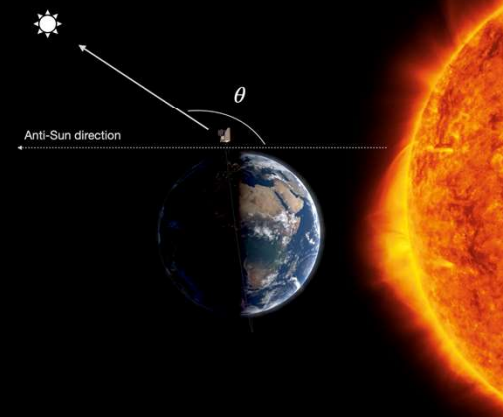
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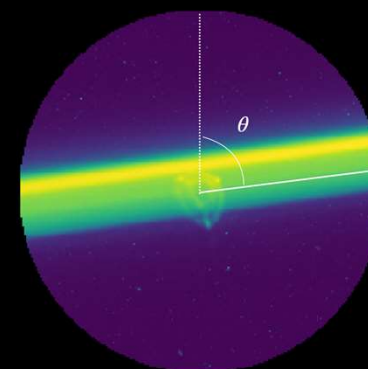
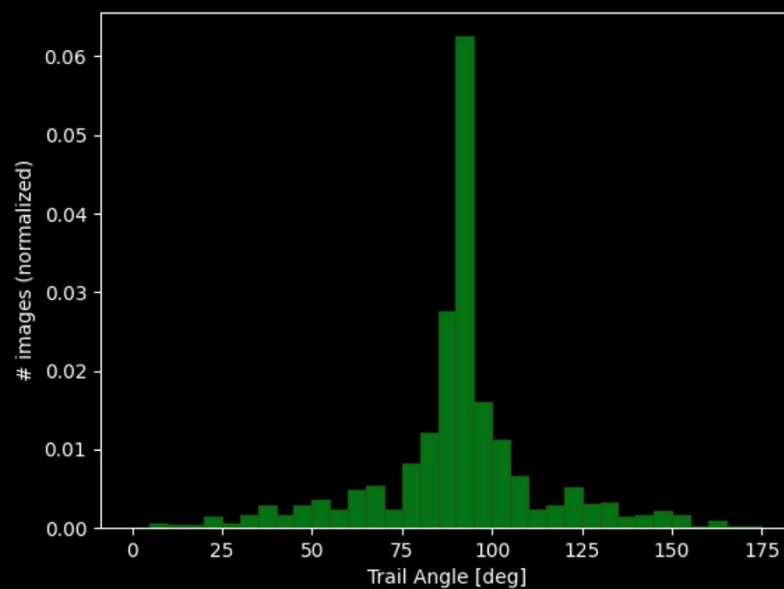
## Trail occurrence: LOS to Sun angle



**More detections at low phase angles**  
**Brighter appearance due to sunlight reflections?**



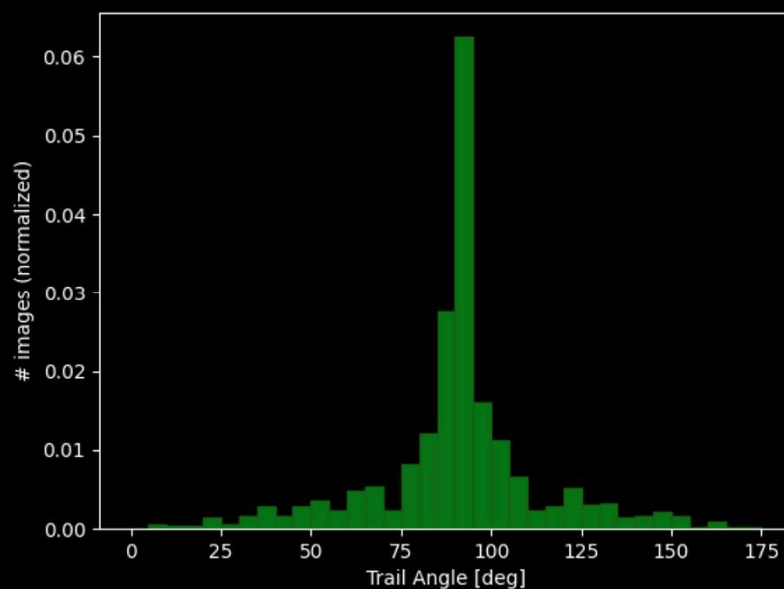
## Trail occurrence: orientation



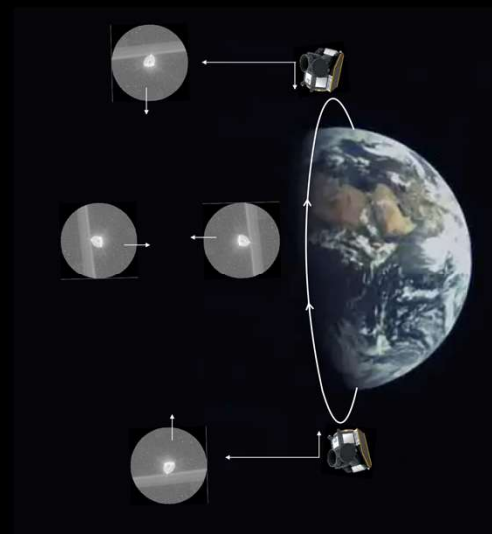
12



## Trail occurrence: orientation



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



CHEOPS is nadir-locked

13



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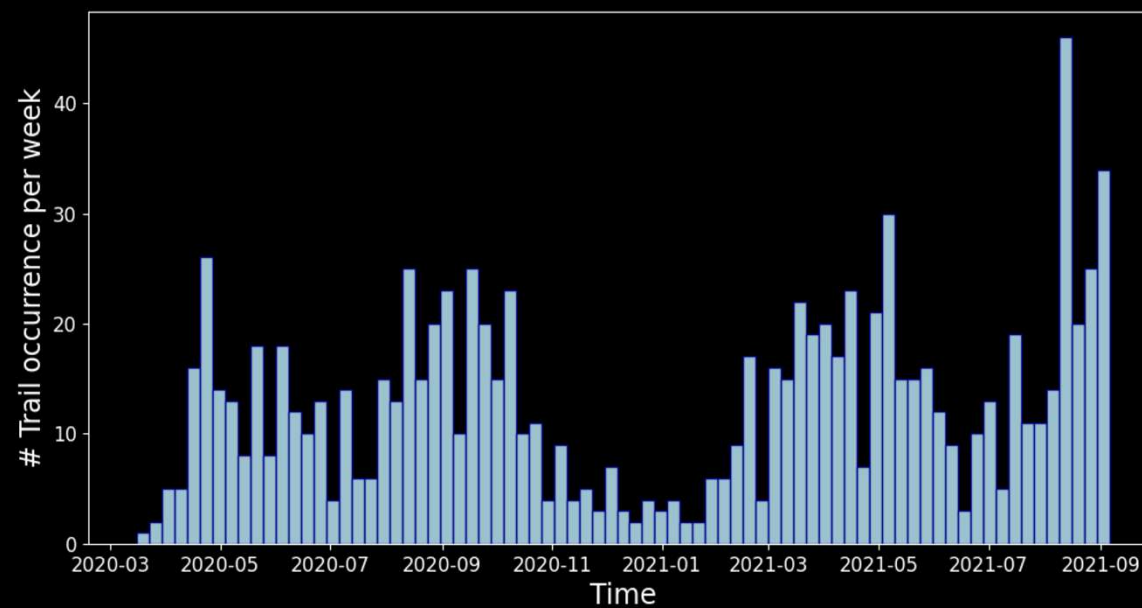
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### Trail occurrence: Weekly counts



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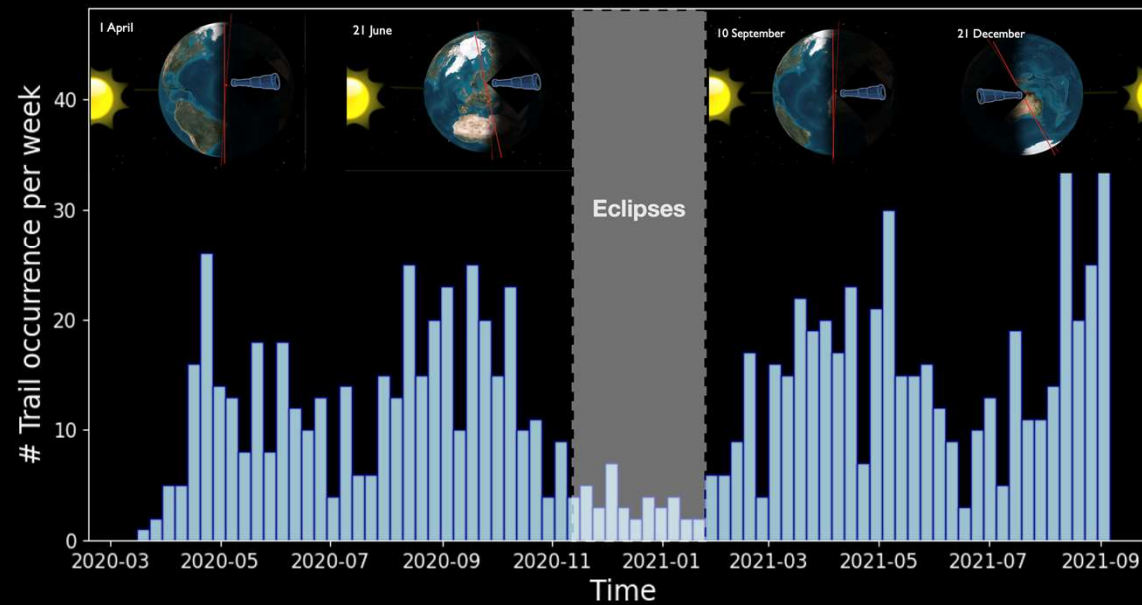
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## Trail occurrence: Weekly counts



Seasonal effects

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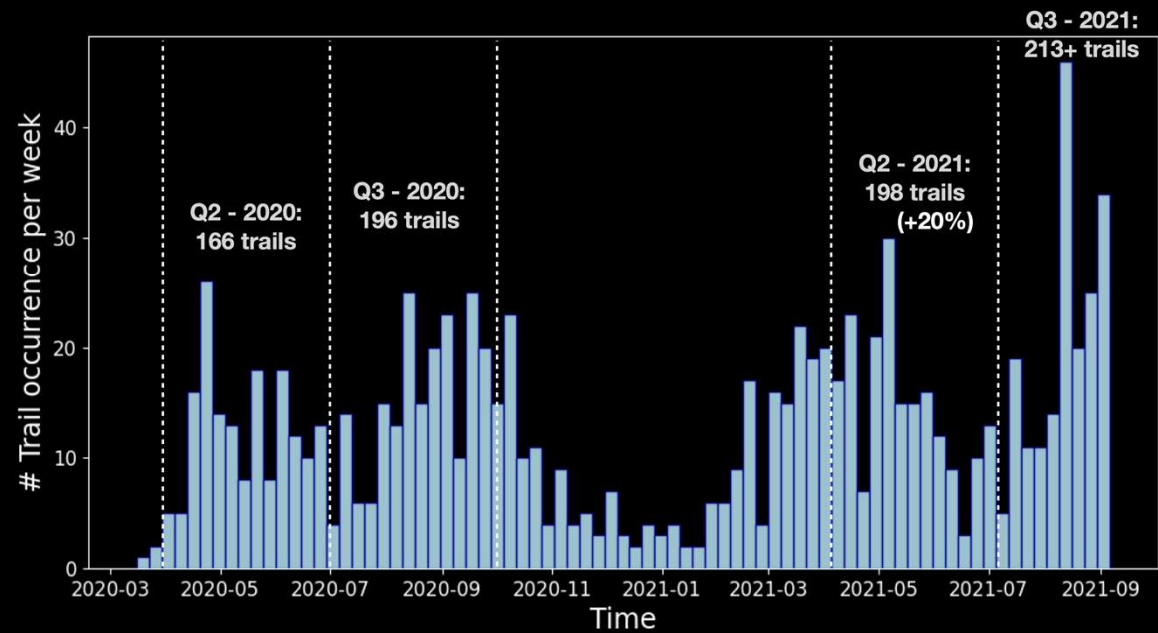
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## Trail occurrence: Weekly counts



Increased number of trails overall

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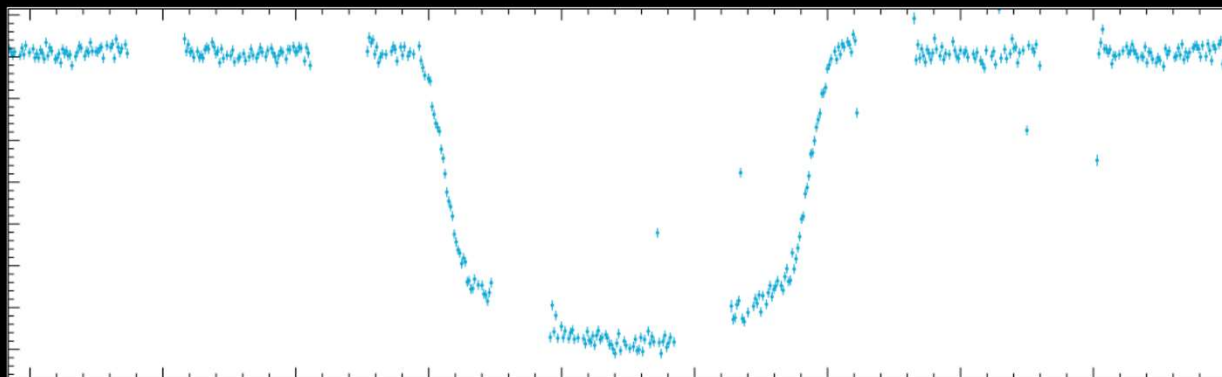
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### Impact on Science

CHEOPS light curve: end product for scientists



17

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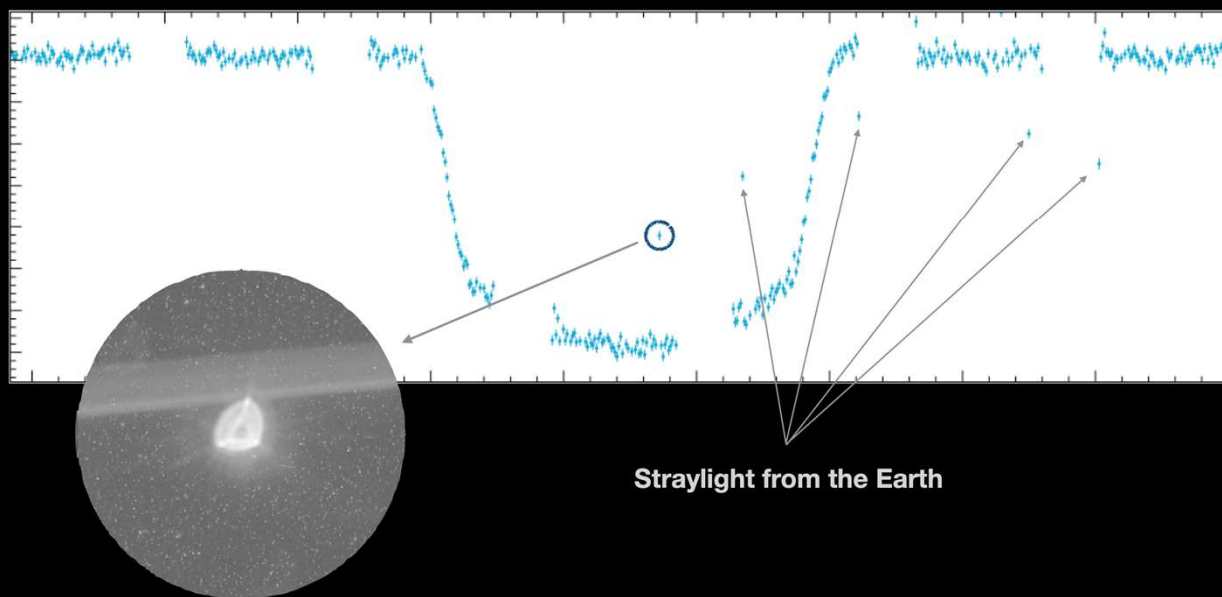
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## Impact on Science

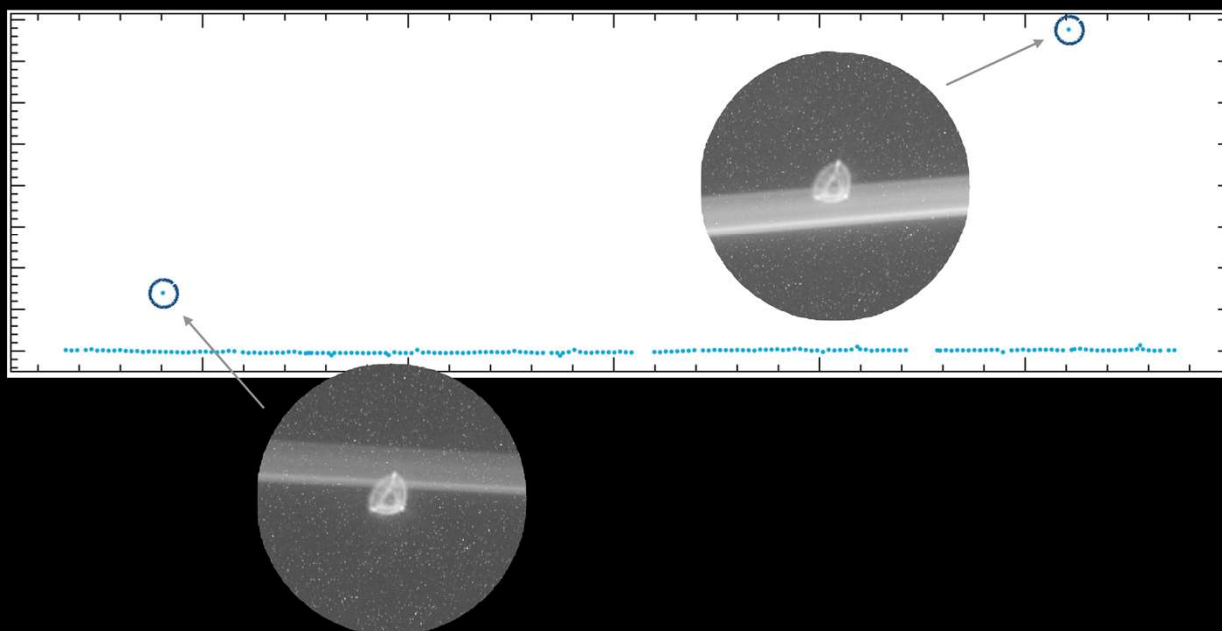
CHEOPS light curve: end product for scientists



18

## Impact on Science

CHEOPS light curve: end product for scientists



19

## 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 1.5 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. Hubble Space Telescope get 2-8% images affected (Kruk et al., in prep.)

20





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Show Menu

Last Tracked

- Tracked in the last day
- Tracked in the last week
- Untracked in the last week

Thank you for  
your  
attention!

21

LEO LABS  
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2019-10-14 08:23 UTC  
1349 objects displayed  
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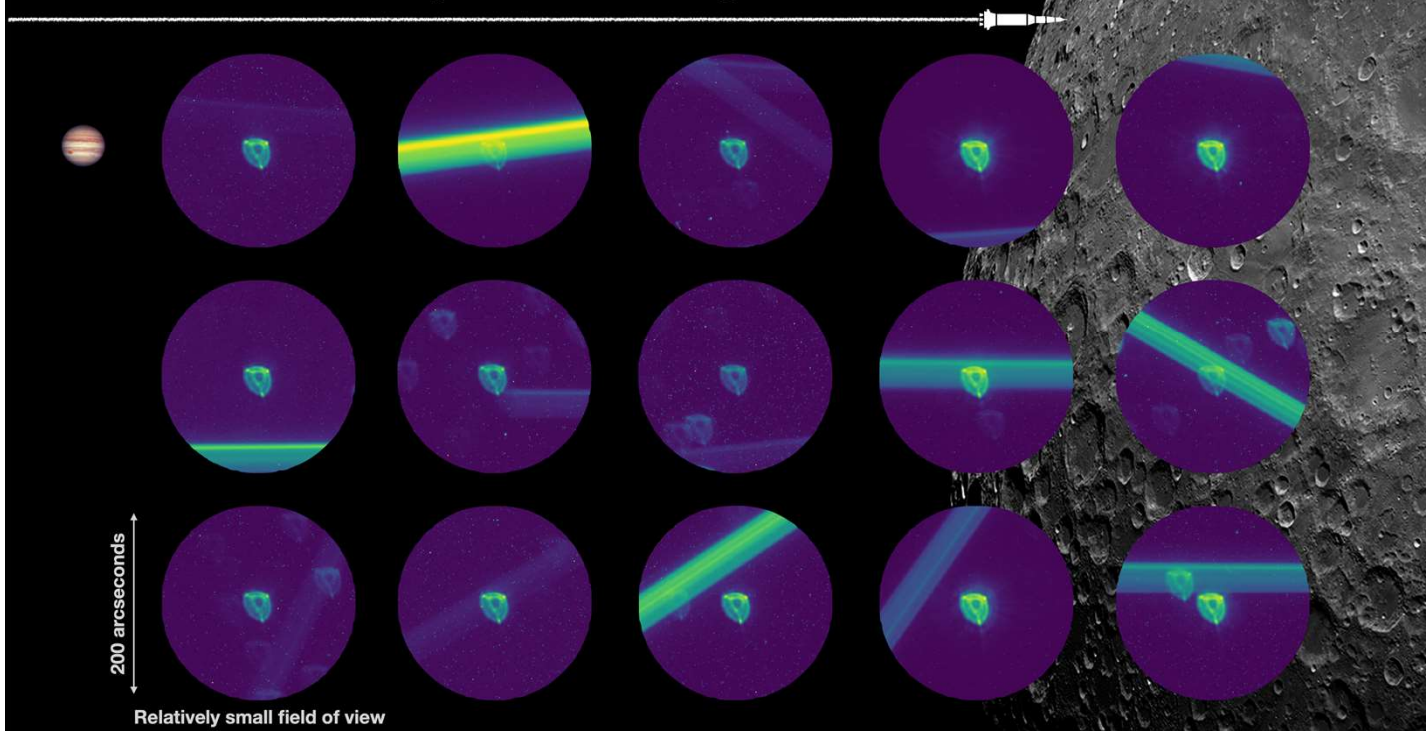
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## CHEOPS: Gallery of intruding trails



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