CHEOPS

cheops

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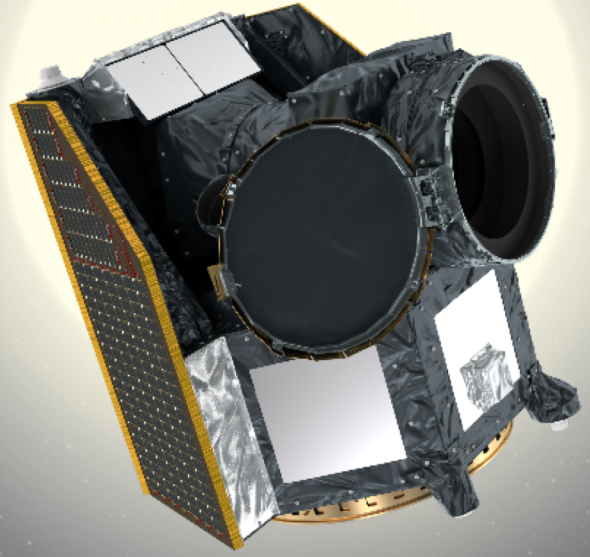


CHEOPS: first S-Class mission in ESA's Science Programme

Kate Isaak (ESA Project Scientist), ESTEC, The Netherlands

on behalf of the ESA CHEOPS Project Team and the CHEOPS Mission Consortium/ Science Team

What is CHEOPS?

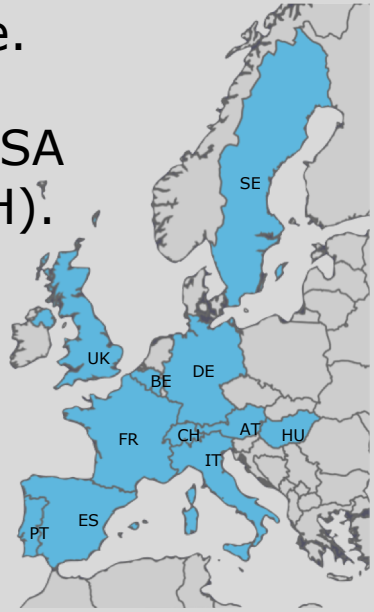
- CHEOPS – CHaracterising ExOPlanet Satellite
- First ESA mission dedicated to follow-up of bright stars known to host exoplanets.
- Observations of individual, bright stars known to host exoplanets
  - Know when and where to point → build up signal-to-noise.
  - Ideal for determining accurately and precisely shallow transits.
- Bright → planet masses using RV from ground possible → follow-up.
- Size + mass → determine mean densities → first-step characterisation.

CHEOPS science

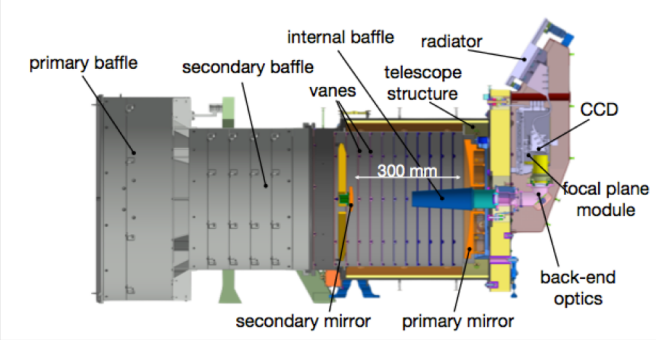
- Measurement of mean densities of large samples of small planets.
  - Insight into their formation and evolution.
  - Constraints on planet migration.
  - Identification of planets with atmospheres.
- Identification of “golden targets” for spectroscopic follow-up.
- Probing atmospheres of hot Jupiters using phase curve measurements.
  - Albedos and occurrence of clouds.
  - Study of physical mechanisms and efficiency of energy transport from day -> night side.

CHEOPS: an S-class mission

- First small (S)-class mission in the ESA Science Programme.
- Partnership with Switzerland - consortium comprising 11 ESA member states, led by PI Willy Benz, University of Bern (CH).
- Boundary conditions:
  - Mature technology;
  - Cost;
  - Development time.
- Opportunity for smaller ESA member states to lead a mission.
- Mission selection Nov 2012 → launch by end of this year.



CHEOPS science payload

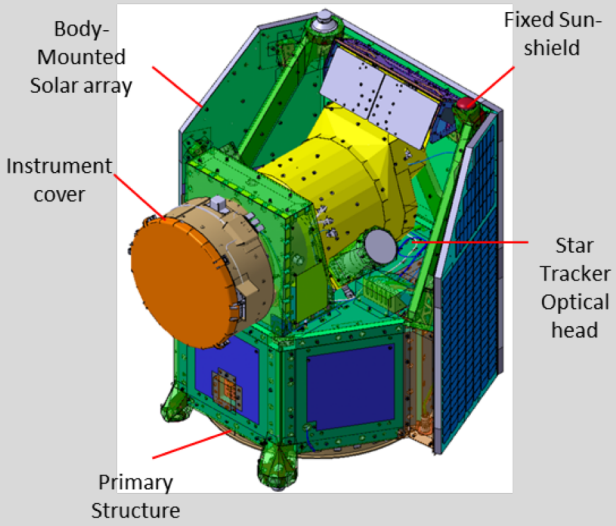


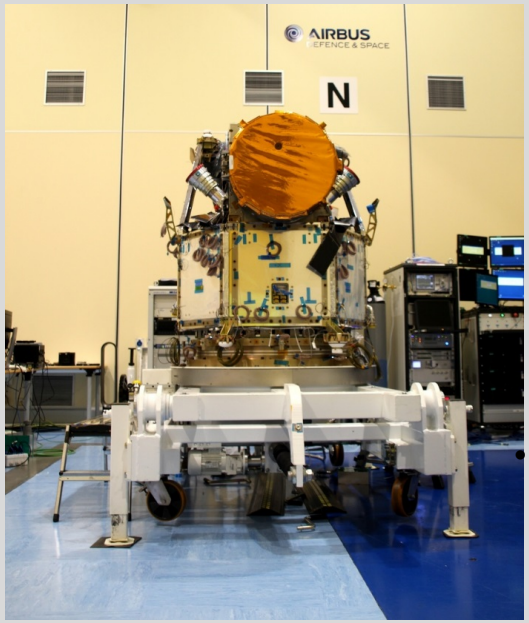
Credit: CHEOPS Mission Consortium

- Single-band ultra high-precision photometer (330 - 1100 nm).
- Single E2V AIMO CCD47-20 CCD: 1k x 1k pixels, frame-transfer, back-illuminated.
  - 13 um pitch (~1"/pix), 0.32 deg ^{2}
  - Cooled to -40 C.
- Compact Ritchey-Chrétien telescope, effective Ødia.=300 mm:
  - Defocussed beam→ radius ~12.4 pix (radius, 90% encircled energy).
- Baffle provides high level of stray-light rejection.
- 1 min cadence (stacked images); <u>unstacked</u> imagettes

→ Photometric stability requirement has driven design ←

CHEOPS platform





- Based on the AS-250 platform
  - ~ $(1.5\ m)^3$, ~ 290 kg, 200 Watts

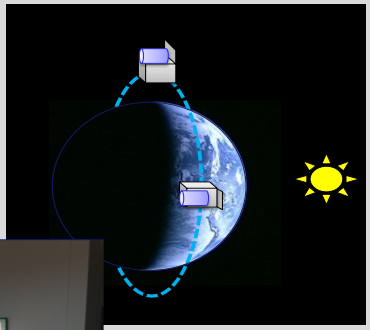
Payload-in-the-loop to further improve pointing stability

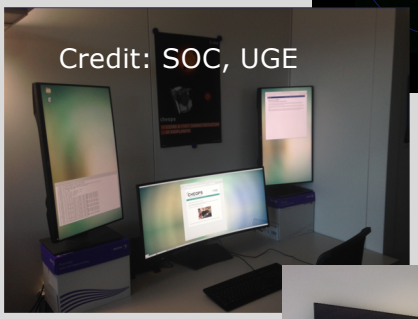
Credit: Airbus, Spain

CHEOPS launch, orbit and operations

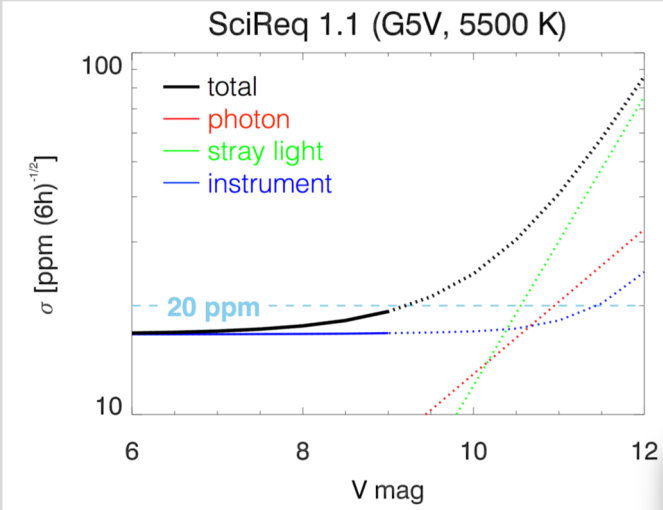
- Shared launch on-board Soyuz from Kourou.
- Sun-synchronous orbit: c. 100 mins, dawn-dusk, 700km altitude.
- 4-5 day LEOP; 2 months In-orbit Commissioning;
  3.5 yr nominal lifetime (5 year goal).
- Mission Operations Centre at INTA in Torréjon (ES).
- Ground stations at Villa Franca and Torréjon (ES).
- Science Operations Centre in Geneva (CH).

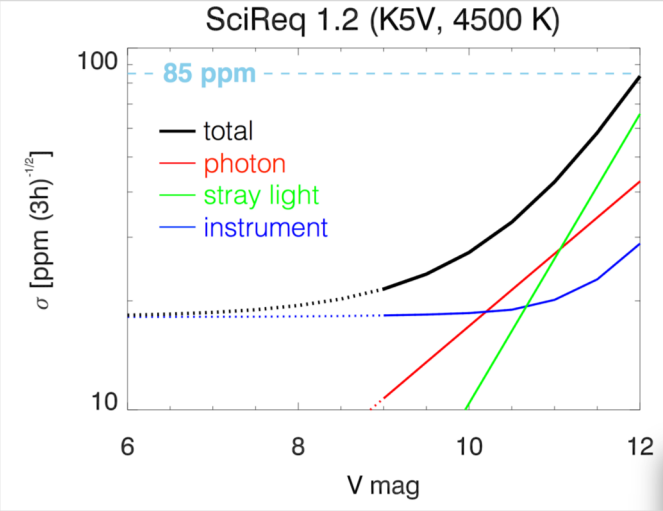
→ Launch planned before the end of this year ←





Expected photometric performance





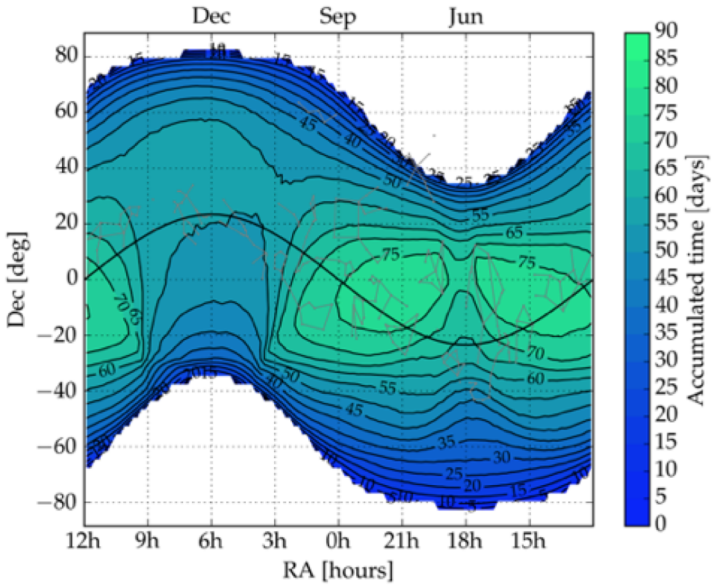
Requirements:

20 ppm 6hr 6≤V≤9

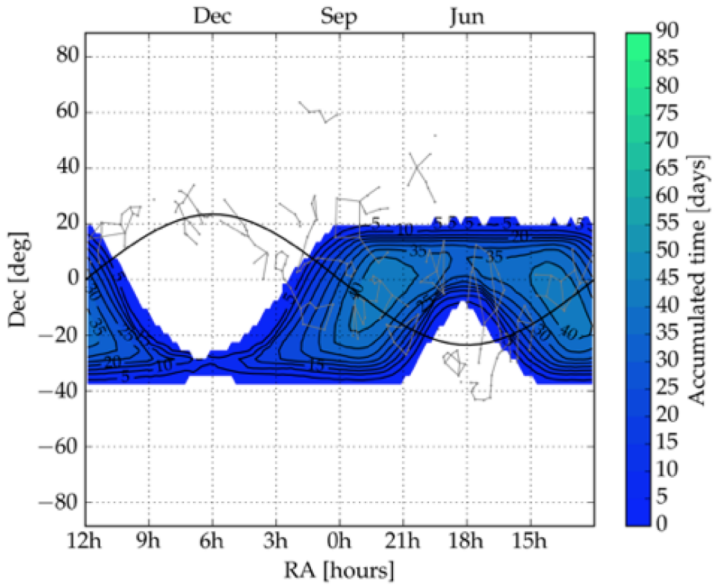
85 ppm 3hr 9≤V≤12

Estimated sensitivity that can be achieved based on allocations/on-ground measured instrument parameters can be made using the Exposure Time Calculator available on the CHEOPS AO-1 website

CHEOPS sky: annual visibility maps

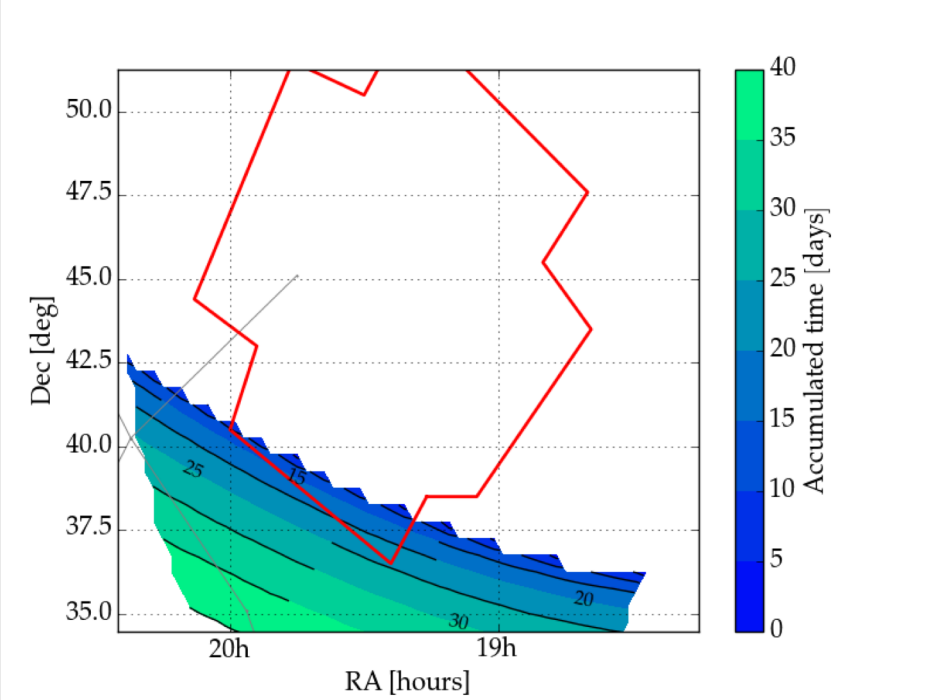


Min. 50% of orbit interruption-free

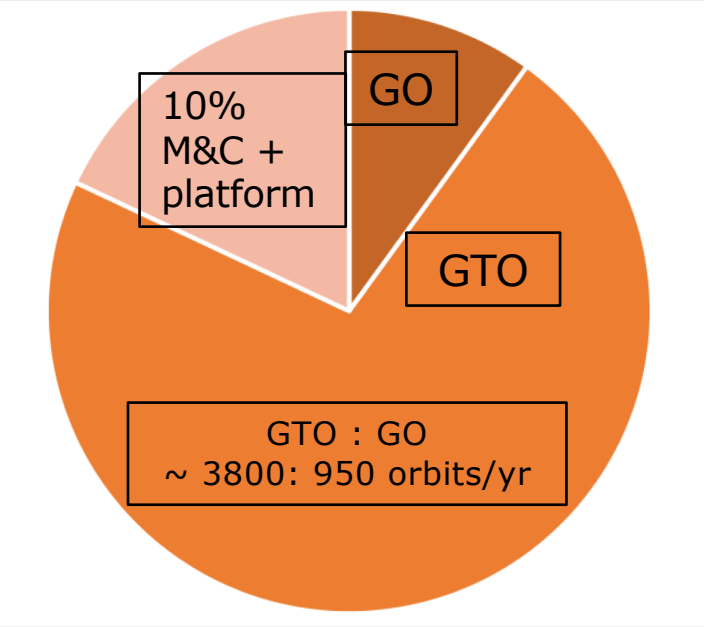


Min. 80% of orbit interruption-free

CHEOPS visibility of the Kepler Field



Observing with CHEOPS



- 3.5 year lifetime.
- ~5260 orbits (~ 100 mins) per year.
- 10% top-sliced for monitoring&calibration (M&C)/engineering.
- 80:20 split between Guaranteed Time Observing (Science Team) and ESA's Guest Observers Programme.
- 3790 orbits (GTO): 947 orbits (GO) per yr.
- Oversubscription to facilitate scheduling of the many time-critical observations.

Observing with CHEOPS

- Mission planning (inc. science planning) done at SOC.
- All data processed by the SOC using an automated pipeline.
- Data available through the archive at SOC.
  - Data products include: raw data, calibrated images, light curves, calibration files.
  - Data reduction report also provided.
- Proprietary period same for GTO and GO – 1 year after last visit of observation request, no longer than 1.5 yrs after first visit in an observation request.

Guaranteed Time Observing Programme

- Collection of themes:
  - Transit.find – Transits of known planets discovered by other techniques eg. RV.
  - MR.Improve -- Improve determination of mass-radius relationship for low-mass planets, relating this to planet formation and evolution models.
  - Atmo.Characterise – Study of atmospheres through phase curves and secondary eclipses.
  - Feature.Characterise – Study of detailed transit features eg. rings, exo-moons.
  - Explore – Detection/characterisation of new planetary systems, inc. TTVs.
  - Ancillary Science – planetary and stellar science.

Description from Science Team available at: https://www.cosmos.esa.int/web/cheops-guest-observers-programme/

ESA's Guest Observers Programme

See poster #112

- 20% of the science observing time available to the Community.
- Proposals solicited through annual announcements of opportunity (AOs).
- Open to all, selected on scientific merit by an ESA-appointed TAC.
- Proposals can be on any science topic that demonstrates good use of existing capabilities of CHEOPS:
  - Targets in GTO are blocked.
- First call (AO-1) closed 16 May 2019, results on AO webpages
- Date and timeline for AO-2 TBC; up to 25% of GO awarded through Discretionary Programme:
  - Will run all year, opening date around completion of commissioning.

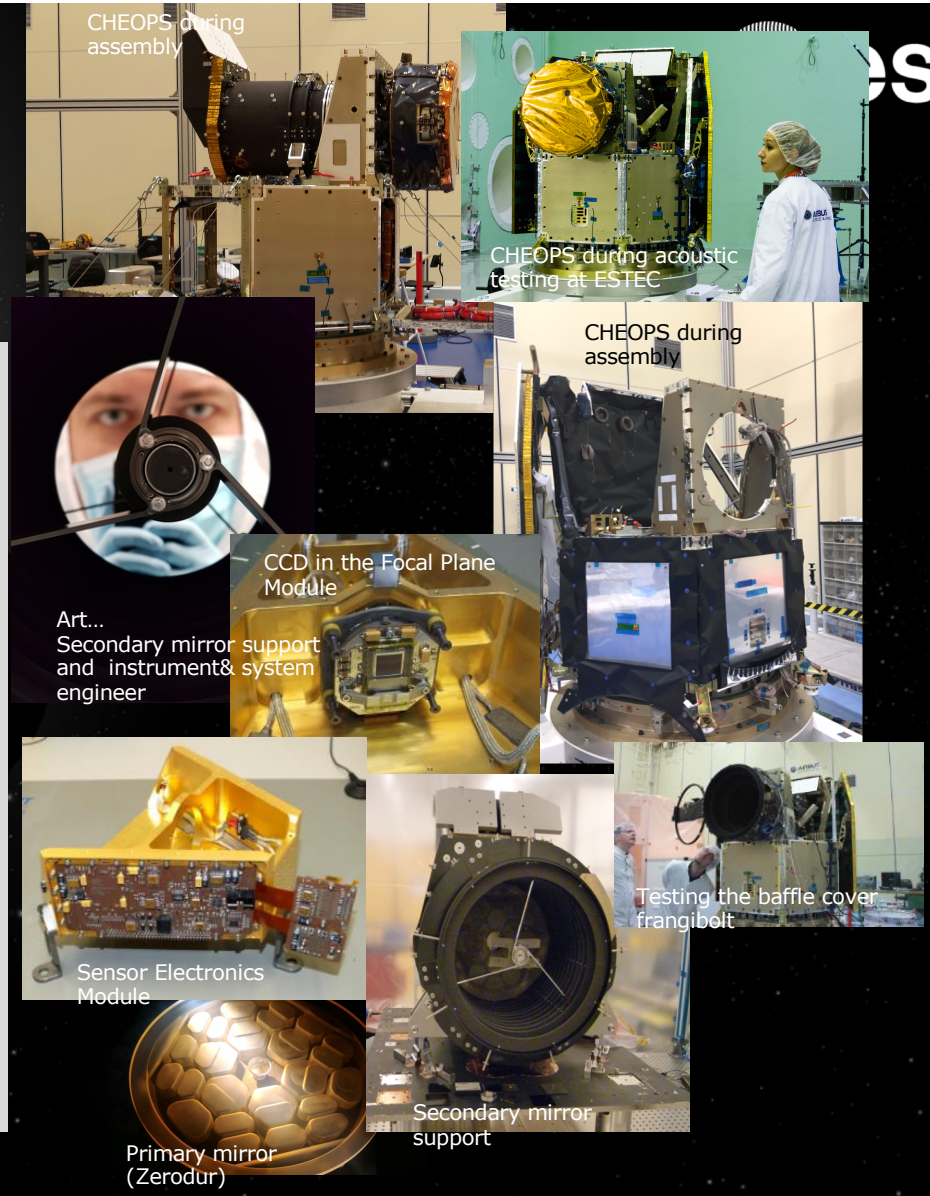
Small mission, small support team!

Prep. tools same as those used by Science Team

CHEOPS

CHEOPS status

- Satellite in storage, awaiting go-ahead to ship to Kourou.
- First AO (yr 1) complete, date of AO-2 TBC.
- Launch by the end of year, date expected in coming weeks.
- Baseline for start of nominal operations 1 Feb 2020.
- Discretionary Programme foreseen to open around time of completion of In-orbit Commissioning.



More Information on CHEOPS

- Website for CHEOPS Guest Observers Programme:
  - https://cosmos.esa.int/web/cheops-guest-observers-programme
  - Observers' manual, exposure time calculator, scheduling feasibility tool, details of AO-1
- CHEOPS fact sheet available from front desk/at poster (also on website).

Extra material

CHEOPS

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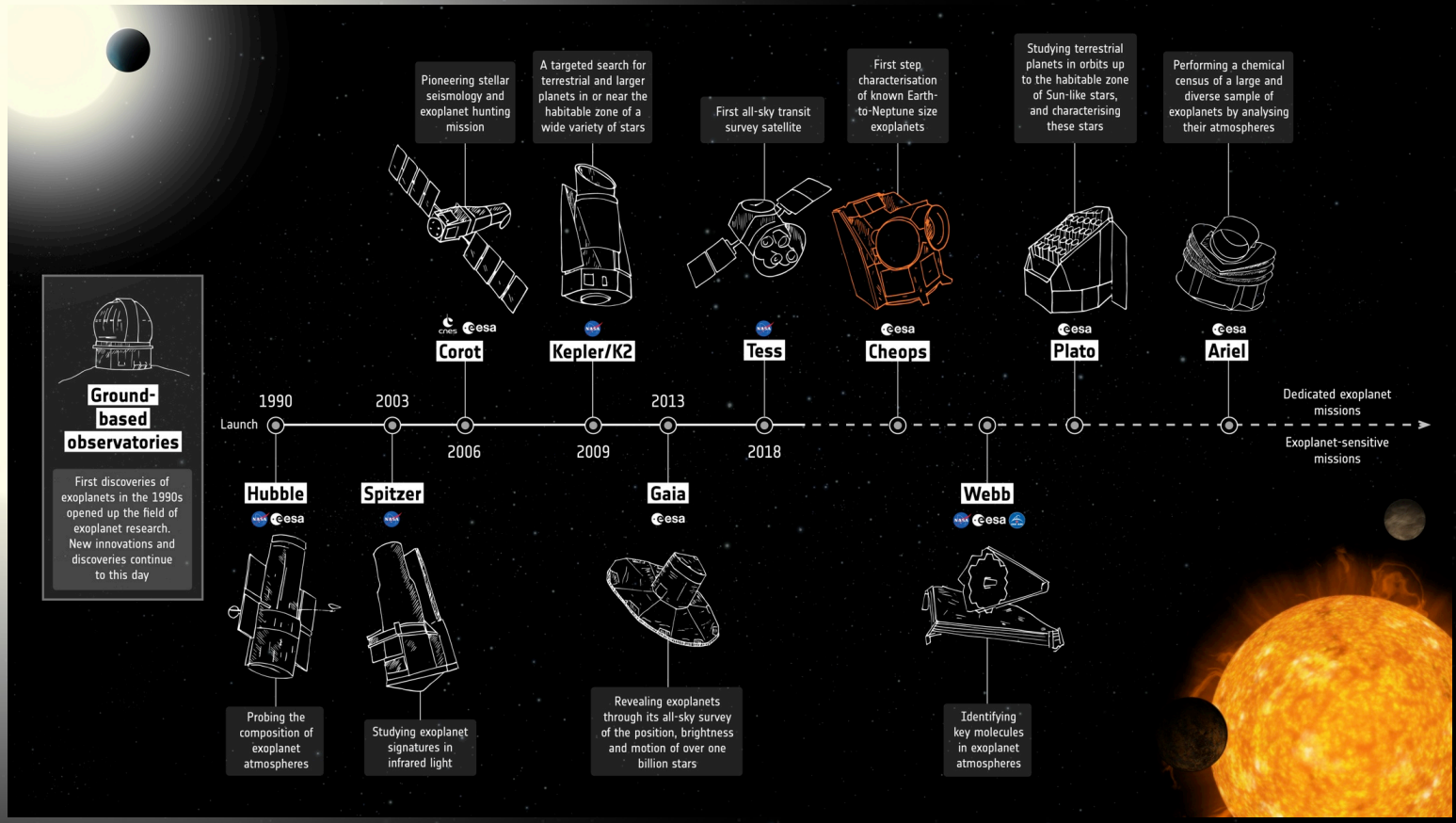
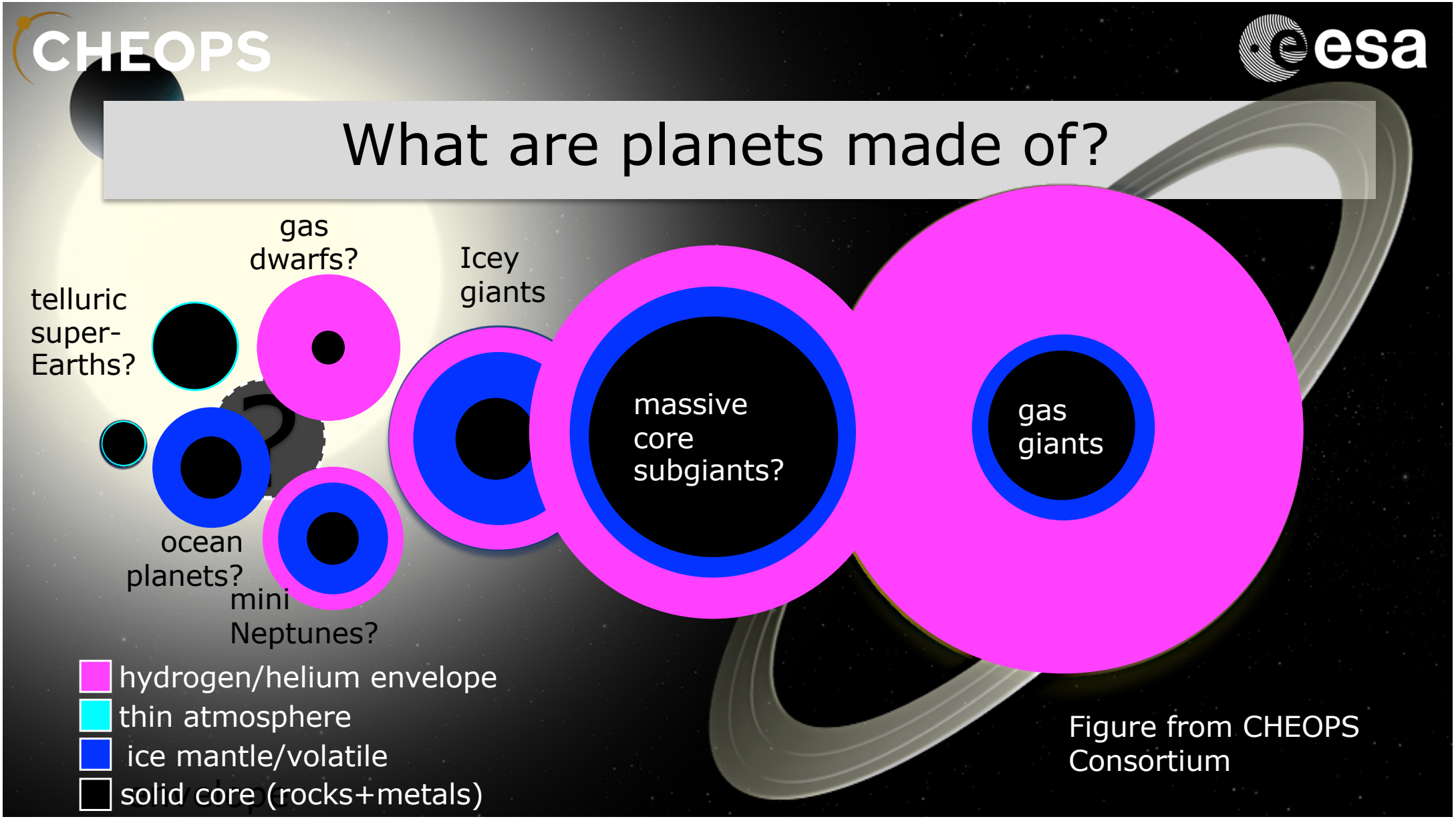
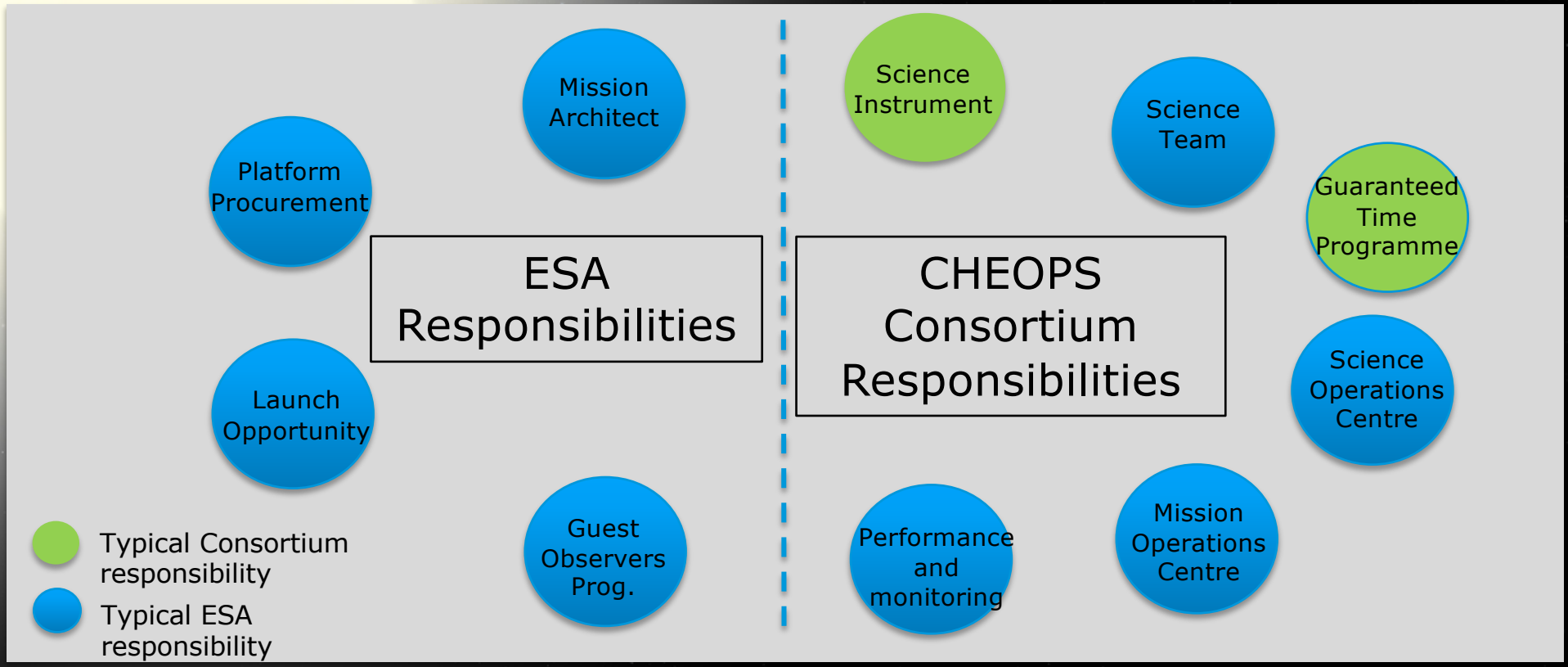

Ground-based observatories
First discoveries of exoplanets in the 1990s opened up the field of exoplanet research. New innovations and discoveries continue to this day
Launch
1990
2003
2006
2009
2013
2018
Dedicated exoplanet missions
Exoplanet-sensitive missions
Hubble
Probing the composition of exoplanet atmospheres
Spitzer
Studying exoplanet signatures in infrared light
Corot
Pioneering stellar seismology and exoplanet hunting mission
Kepler/K2
A targeted search for terrestrial and larger planets in or near the habitable zone of a wide variety of stars
Gaia
Revealing exoplanets through its all-sky survey of the position, brightness and motion of over one billion stars
Tess
First all-sky transit survey satellite
Cheops
First step characterisation of known Earth-to-Neptune size exoplanets
Webb
Identifying key molecules in exoplanet atmospheres
Plato
Studying terrestrial planets in orbits up to the habitable zone of Sun-like stars, and characterising these stars
Ariel
Performing a chemical census of a large and diverse sample of exoplanets by analysing their atmospheres

Key requirements

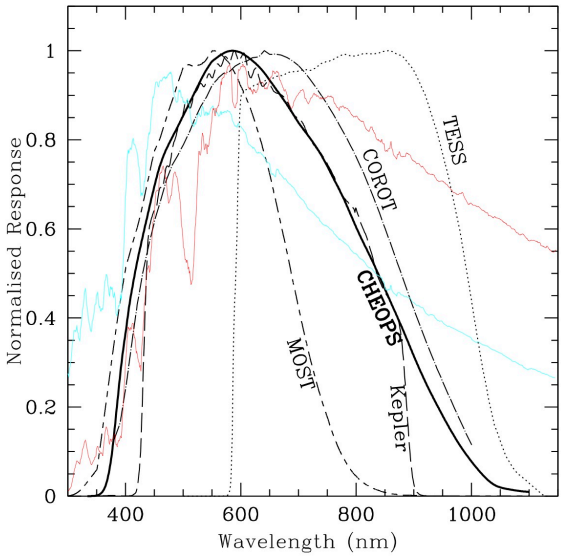
- Ultra-stable photometry:
  - High-precision light curves → accurate and precise planet sizes.
- Sky coverage:
  - Accessibility of targets → ability to observe multiple transits one year.
- Temporal resolution and high timing accuracy:
  - Sampling of transit ingress/egress.
  - Precision timing of transits → variation → planet masses/new planets.


CHEOPS
esa
What are planets made of?
gas
dwarfs?
Icey
giants
telluric
super-
Earths?
massive
core
subgiants?
gas
giants
ocean
planets?
mini
Neptunes?
hydrogen/helium envelope
thin atmosphere
ice mantle/volatile
solid core (rocks+metals)
Figure from CHEOPS
Consortium

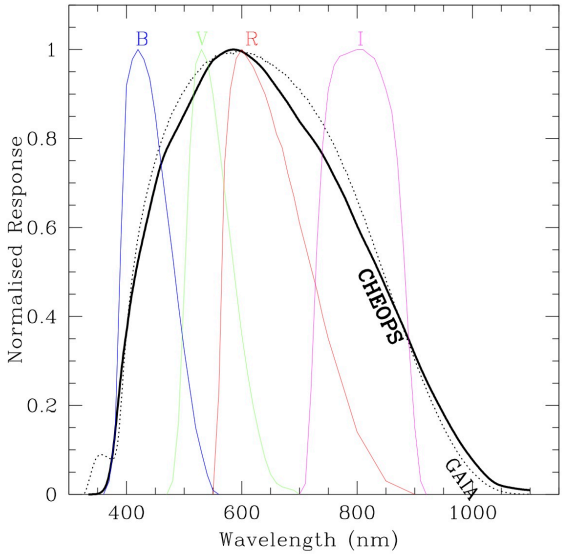
Division of responsibilities



CHEOPS passband



Stellar SEDS based on sizing cases for photometric requirements



CHEOPS point spread function

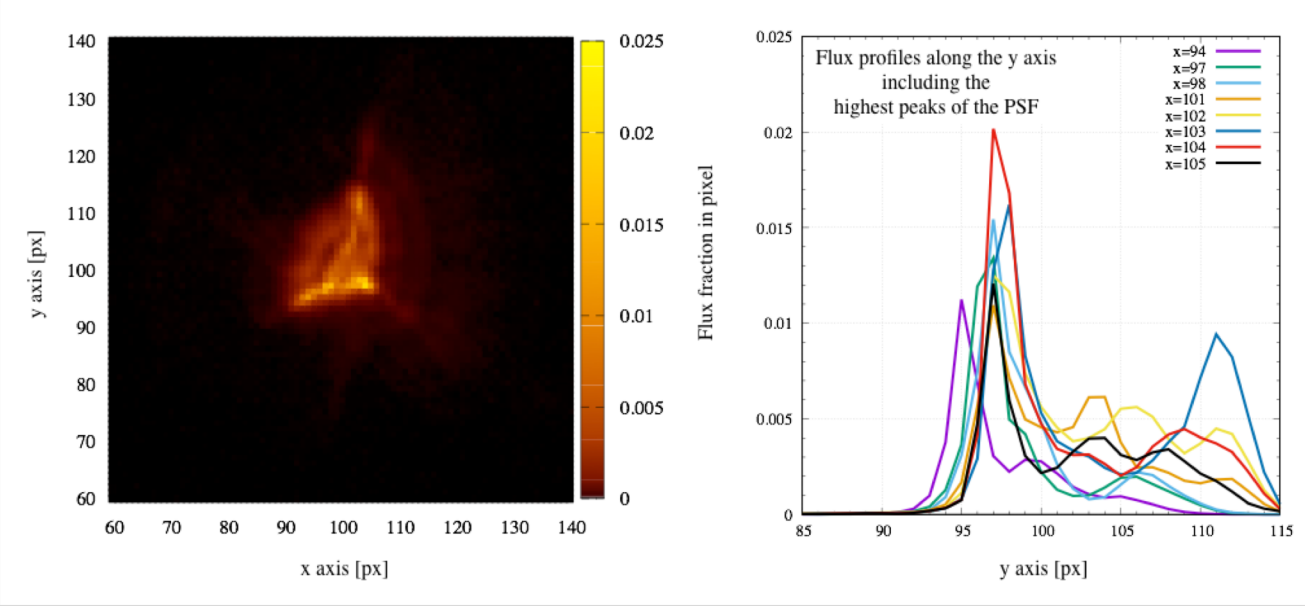
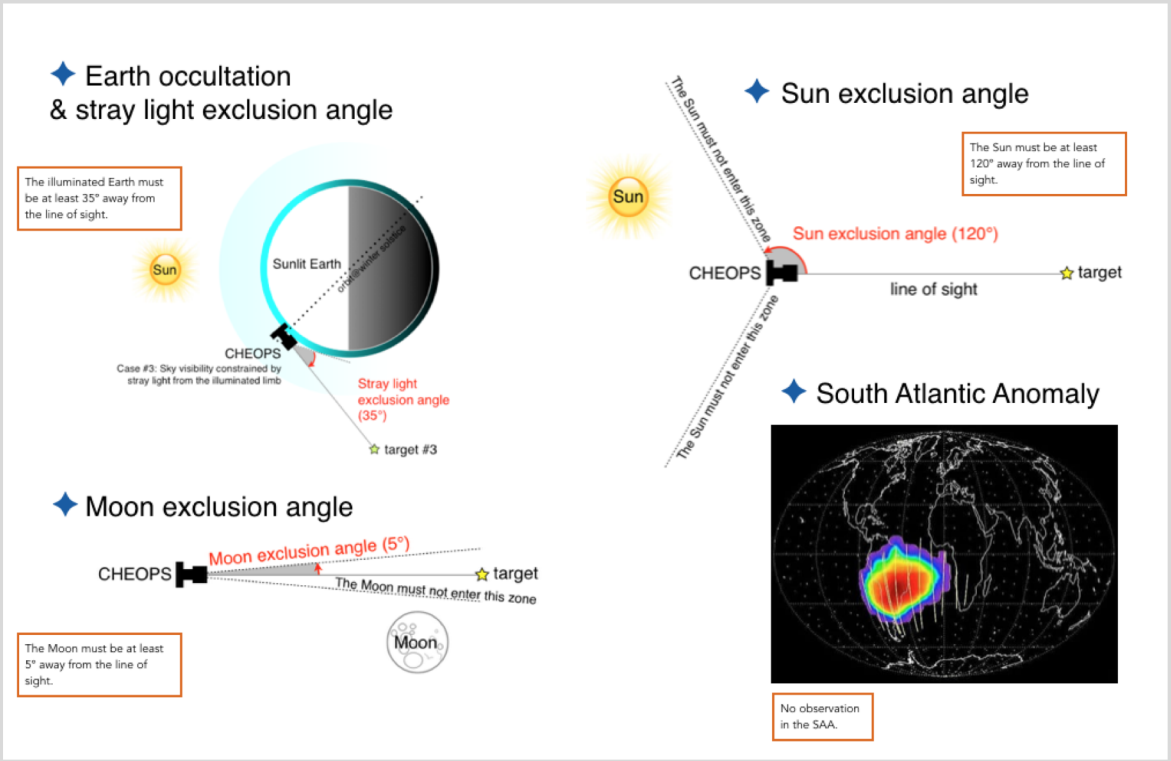
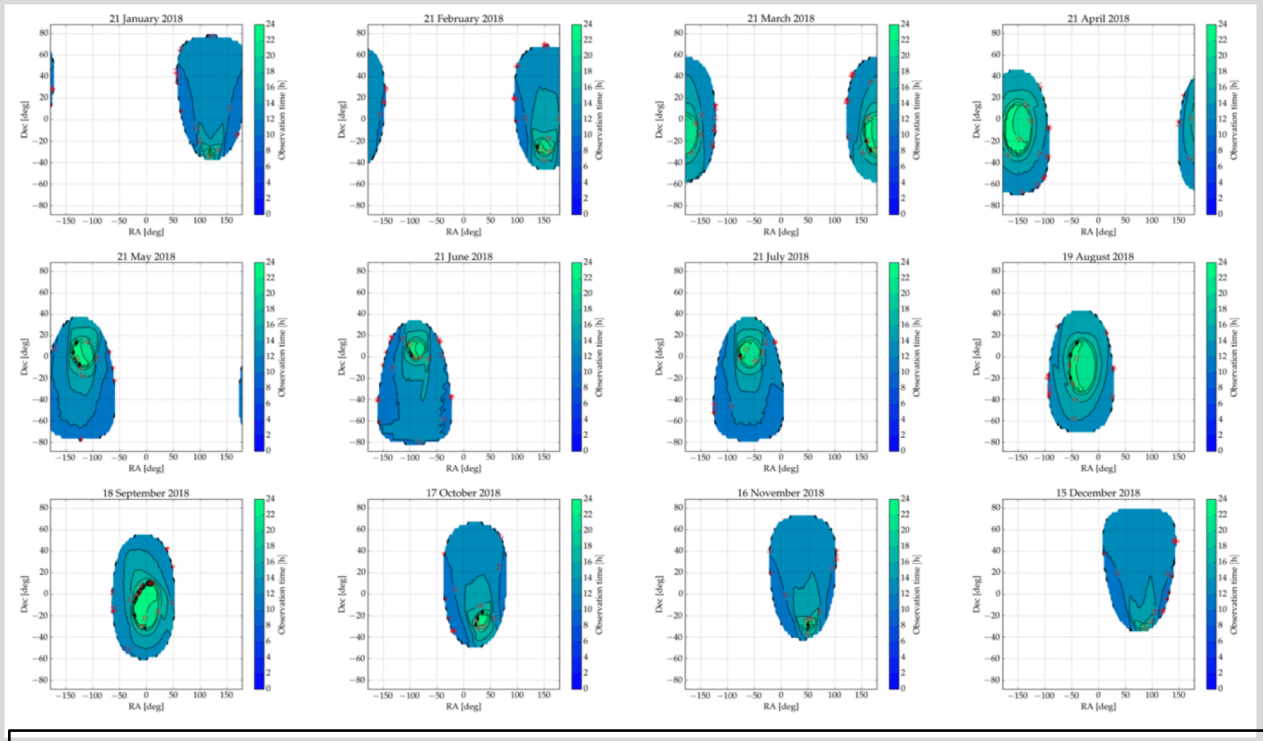


Image of the CHEOPS point spread function (PSF) measured during the on-ground calibration campaign in white light. Left: flux distribution, x and y axis in pixels. Right: PSF profiles along the y axis for different vertical cuts (colour curves). The x values chosen for the figure contain pixels with more than 1% of the total flux of the PSF.

CHEOPS pointing constraints

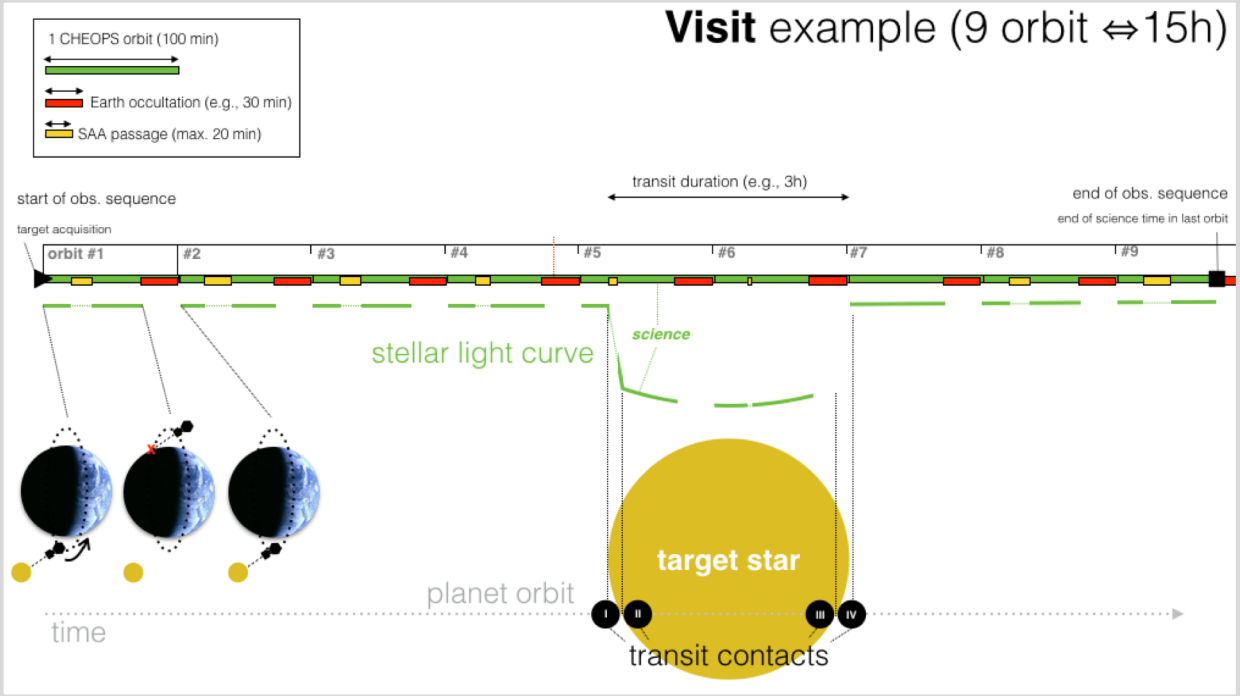


CHEOPS instantaneous monthly visibility maps



See CHEOPS Observers Manual on the GO webpages for more details

CHEOPS visit



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Additional views of the CHEOPS payload

Credit: CHEOPS Mission Consortium