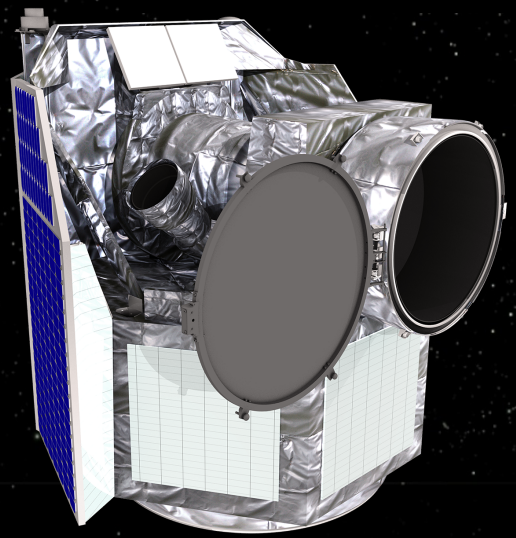
CHEOPS

esa



CHEOPS:

Characterising ExOPlanet Satellite

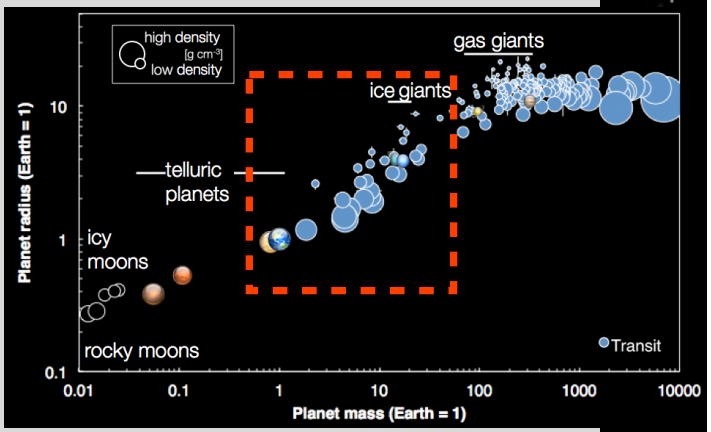
Melvyn Davies + Ignasi Ribas

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

What is CHEOPS?

- Mission dedicated to the search for exoplanet transits of local, bright stars already known to host exoplanets:

- Detection and first-step characterisation of transiting exoplanets smaller than Saturn (P<50 days) through high-precision, wideband transit photometry



- Follow-up, pointed observations of individual stars:
  - Know <u>where</u> and <u>when</u> to point → efficient way to measure shallow transits

- Bright host stars (V<12) → detailed knowledge of star, also accurate mass measurements (RV)

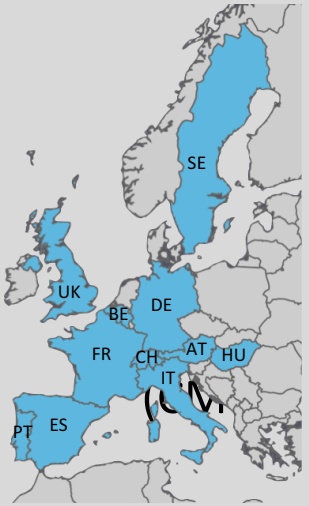
- Accurate measure of mass + radius → robust estimates of bulk density → …

CHEOPS science objectives

- Measurement of bulk density in a large sample of Super-Earths and Neptunes
  - Insight into physics and formation of planets
  - Identification of planets with atmospheres→ critical core mass, atmospheric loss
  - Constraints on planet migration
- Identification of golden targets
  - Thin atmospheres → 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
- Boundary conditions:
  - High technology readiness levels for platform and payload
  - Total cost ESA: ≤50M€ (2012 econ.cond), ≤150 M€ (ESA + MS)
  - Development time no more than 3.5 – 4 years
- Implemented in partnership with Switzerland, with a consortium (CMC) comprising 10 other ESA member states - PI Willy Benz (CH)



- Division of responsibilities very different from other, larger ESA science missions:
  - ESA: Mission architect, spacecraft (ADS), launcher (shared), LEOPS, IOC
  - CMC: Science Team+chair, CHEOPS payload, Mission and Science Operations Centres, science performance monitoring&evaluation
- Selected December 2012, adopted Feb 2014, launch-ready end of 2018

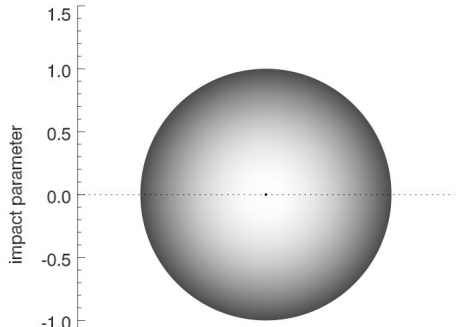
→ Test case for the S-class concept ←

Top level science requirements

- Photometric precision → high-precision light curves → accurate radii.
- Sky coverage→ accessibility of targets, repeated observations.
- Temporal resolution and uncertainty → sampling ingress/egress + measurements of Transit Time Variation .
- Mission lifetime of 3.5 years (goal 5 years).

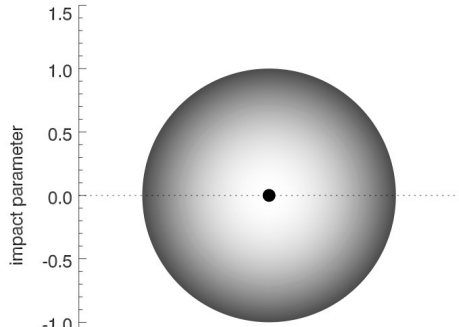
Detailed description at:
https://www.cosmos.esa.int/web/cheops/science-requirements

Requirements on photometric performance



Bulk density to 30%

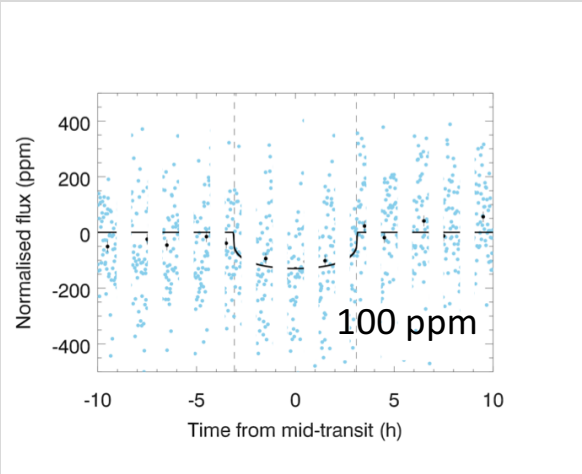
- $S/N_{transit}$ = 5
- transit depth to 20%
- radius to 10%



Best possible parameters

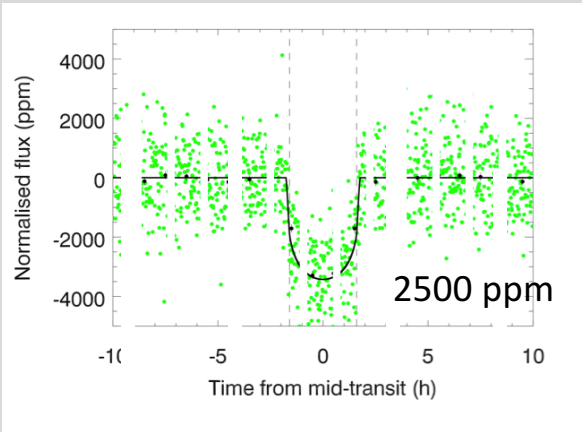
- $S/N_{transit}$ > 30
- transit depth to <5%
- radius precision limited by R★

Detection of Super-Earths transiting bright stars (6≤V≤9)



20ppm in 6 hrs for G5V star (T_{eff}=5500K) V=9
(tolerating interruptions due to SAA or earth occultations up to 50% of orbit)

Characterisation of Neptune transit light curves (9≤V≤12)

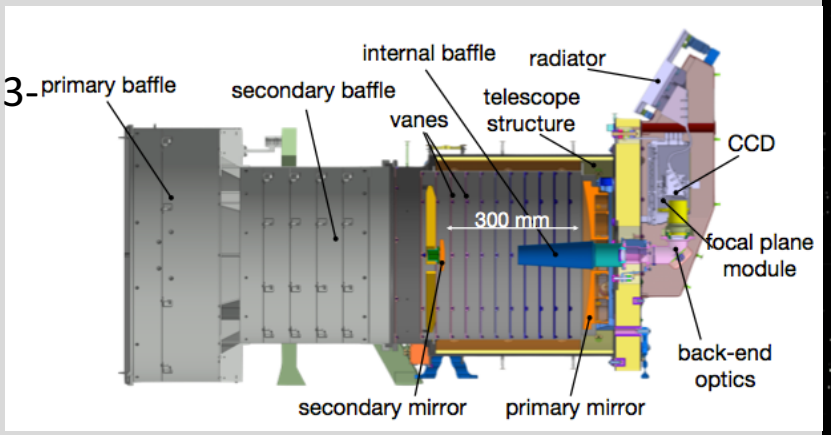


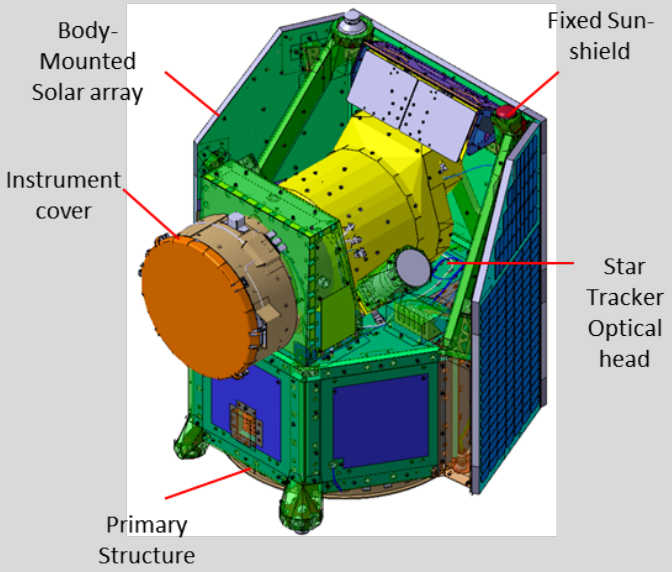
85ppm in 3 hrs for K-type stars with V≤12
(tolerating up to 20% interruptions)

CHEOPS in a nutshell: payload and platform

Payload:

- Single-band ultra high-precision photometer (0.33-1.1um).
- Single CCD, 1k x 1k pixels (+ frame store), 13 um pitch (~1"/pix):
  - Operating temp -40 deg C, stablised to 10 mK.
- Compact Ritchey-Chrétien telescope, effective Ødia.=300 mm:
  - Entrance baffle provides high stray-light rejection.
- Defocussed PSF to reduce impact of spacecraft jitter.
- 60 kg / 60 W / 1Gbit downlink budget per day.



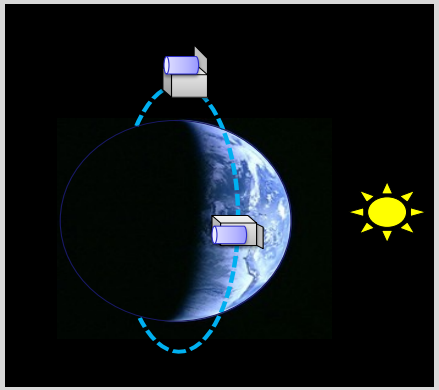


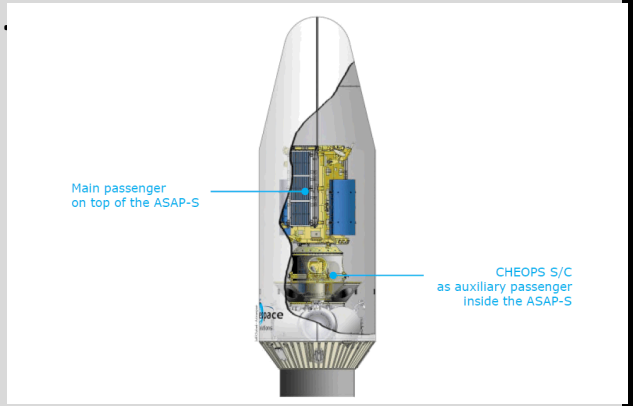
Platform:

- ~1.6 (h) x 1.5 x 1.5 m, ~ 280 kg.
- Pointing accuracy < 4 arcsec (rms), payload in the loop to centroid, roll around Line of Sight.

CHEOPS in a nutshell: launch, orbit and operations

- Shared launch:
  - Co-passenger on-board Soyuz, launching from Kourou.
  - Launch-ready end 2018.
- Low-earth orbit:
  - Sun-synchronous, dawn-dusk, local time of ascending Node (LTAN) 6AM, 700 km altitude.
- Mission Operations (Centre MOC):
  - Developed by GMV; operated by INTA from Torréjon.
    - Ground stations at Villa Franca and Torréjon.
- Science Operations (Centre SOC):
  - Developed by team led by UGE, including CH, FR, IT, PT, SE, UK; SOC run from Geneva Observatory.

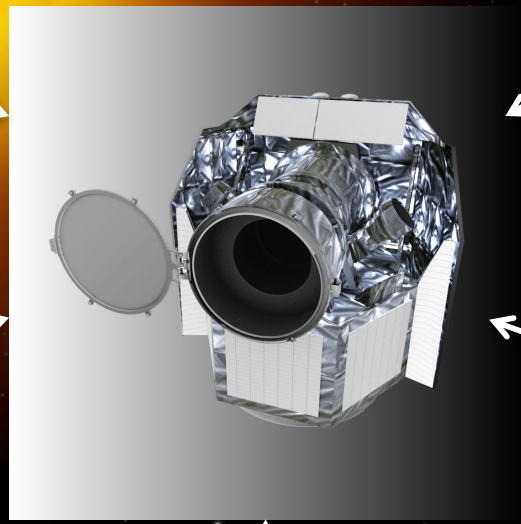




CHEOPS Targets

Ground-based transit surveys
eg. NGTS

TESS



Ground-based RV surveys
Eg. HARPS, HARPS-N, HIRES, SOPHIE
(on-going) ESPRESSO *(2017)*

Kepler/K2 survey

Open-time proposals (20%)

Adapted from CHEOPS Consortium slide

3.5 yrs baseline (5 yrs goal)

Observing with CHEOPS - I

80% : 20% split between CHEOPS Science Team (Guaranteed Time Observing, GTO) and Guest Observers' (GO) Programme.

- GTO under the responsibility of the CHEOPS Science Team.
- Follow-up mission → collection of different themes..
  - Transit configuration in known planetary systems discovered by other techniques
  - Improve determination of mass-radius relationship for low-mass planets
  - Detect new planets around stars known to host planetary systems
  - Pot-pourri
- Definition of GTO target list on-going
  - Frozen 6 months before launch → Reserved Target List → can be queried.
  - Updated throughout mission.

Observing with CHEOPS - II

- ESA manages the GO programme:
  - Annual Announcements of Opportunity, first call 6 months before launch, foreseen Summer 2018
  - Time allocated competitively by ESA-appointed TAC
  - Up to 25% of GO time available as Director's Discretionary Time (DDT) to enable quick turn-around on new targets between calls.
  - Targets on Reserved Target List blocked unless proposed science case is substantially different from GTO.

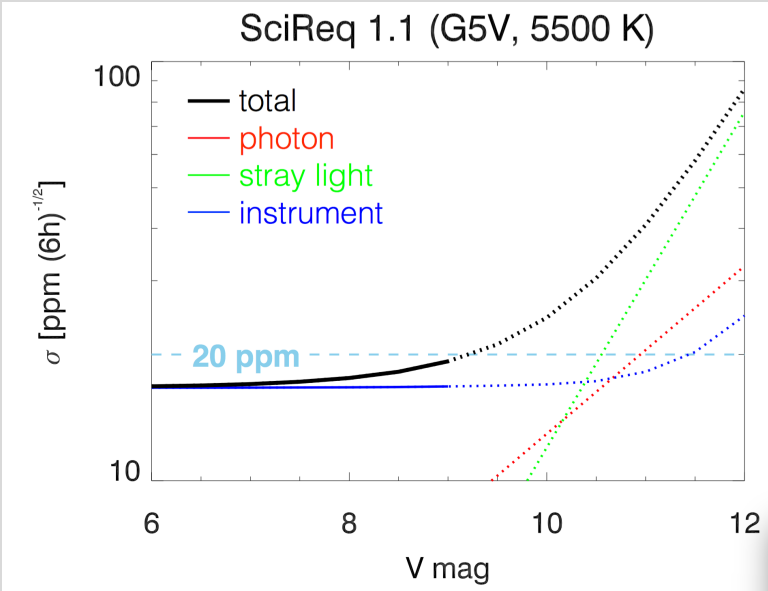
- Proprietary time on a target-by-target basis: 1 yr after last observation (1.5 yrs after first) → same for GTO and GO observations, up to that of GTO/GO for DDT.

- All data reduced by common Data Reduction pipeline at SOC
  - End product fully-calibrated light curve.
  - All data products, inc. raw and calibration/reference data available through CHEOPS archive, subject to proprietary status.

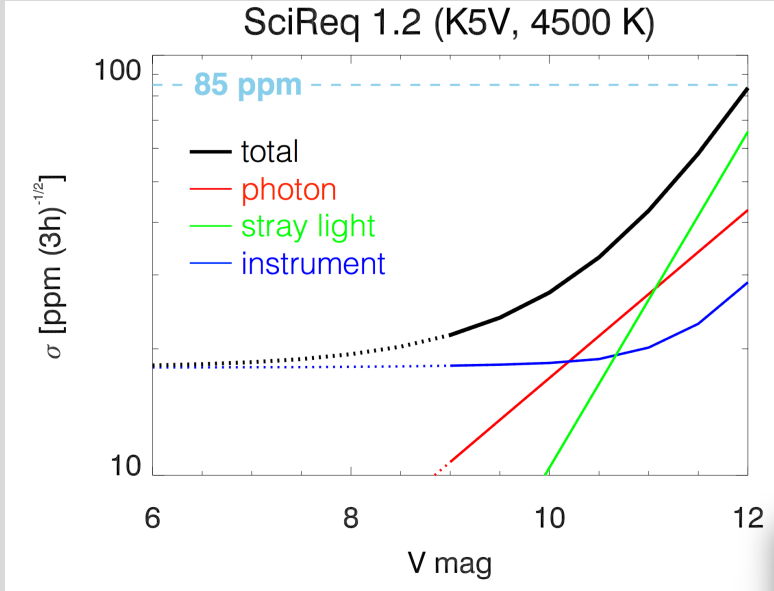
Presentations from CHEOPS Open Time Workshop held on 26/27th June 2017 available at the ESA website: https://www.cosmos.esa.int/web/cheops-guest-observers-programme/open-time-workshop-2017

CHEOPS Performances: photometric precision

Transit of an Earth-size planet with P=50 d



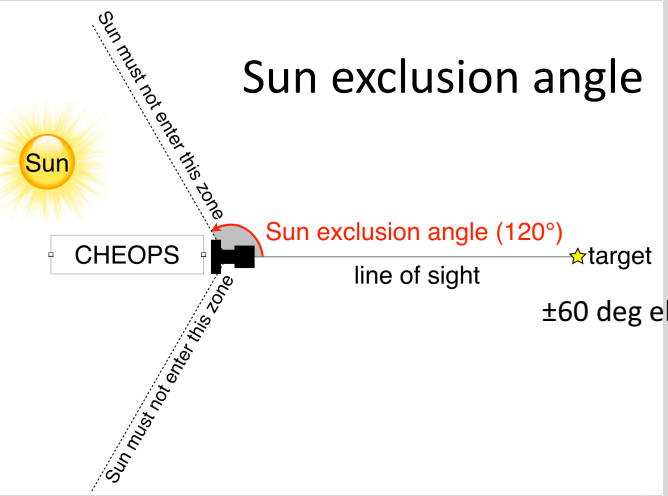
Transit of a Neptune-size planet with P=13 d

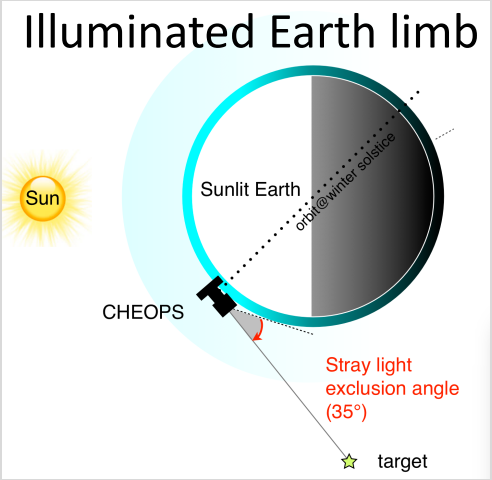


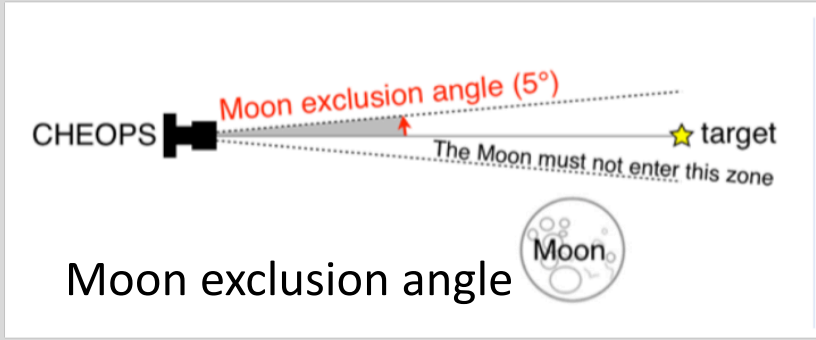
Performance maintained over 48 hrs

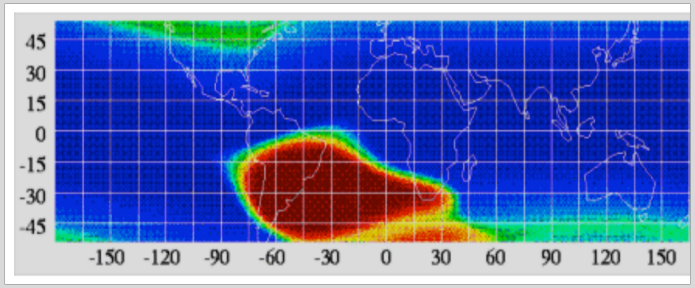
CHEOPS Instrument Performance v1.0 - CHEOPS Mission Consortium

CHEOPS Performances: pointing constraints



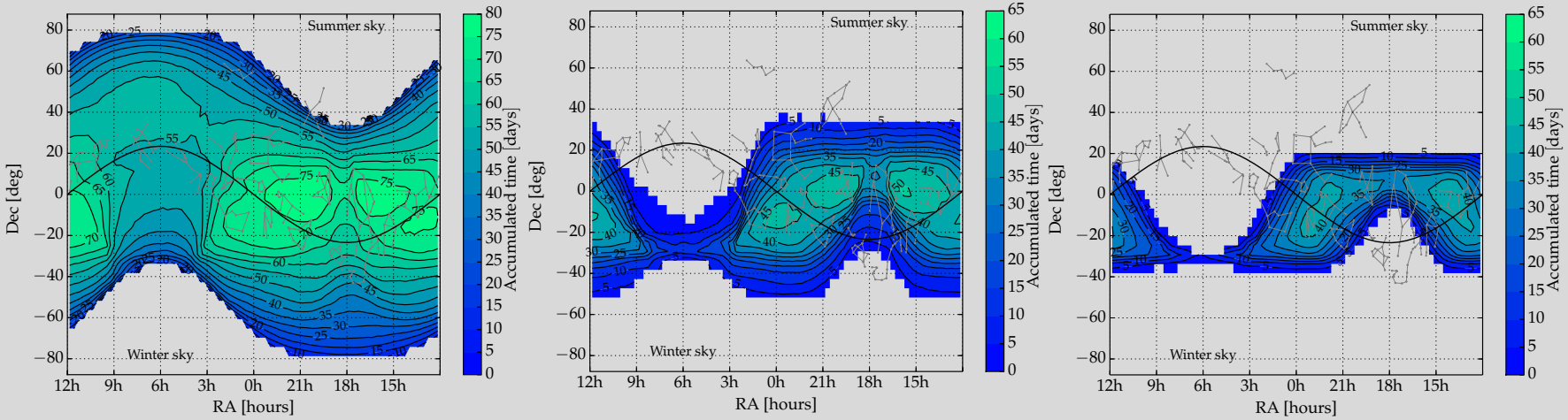






South Atlantic Anomaly (SAA)

CHEOPS Performances: sky coverage



No: days/yr for which one can observe with ≤50%/30%/20% interruptions/orbit, straylight threshold 5ppm for a G5V/m_v=9 star (6hrs) (equiv 70 ppm for K5V/m_v=12 star (3hrs))

- Detecting Super Earth transits: >50% of sky, ≤50% interruptions, 50 days/yr
- Characterising Neptune light curves: ~25% of sky (2/3rd in south), ≤20% interruptions, 13 days/yr

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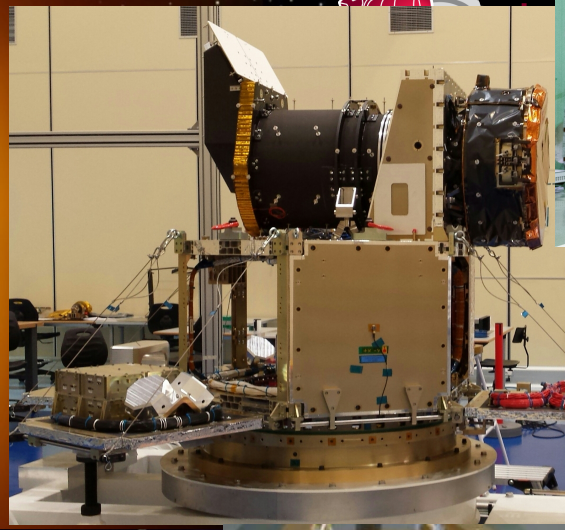
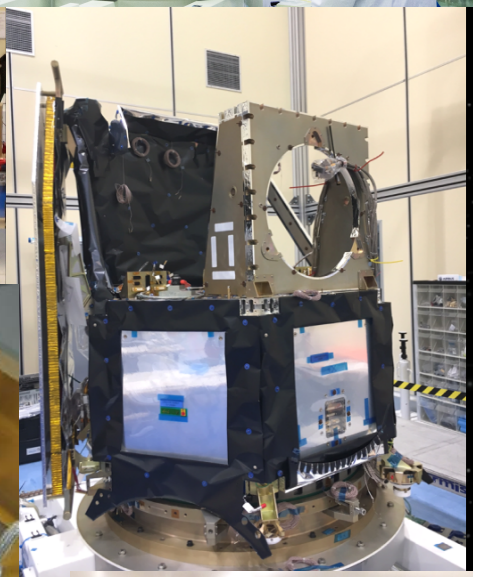
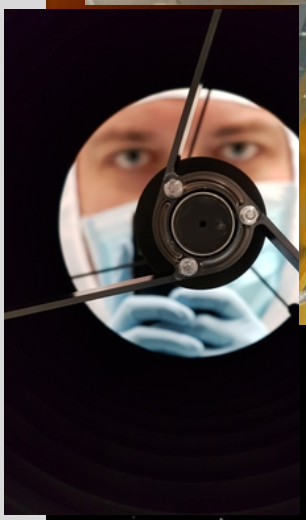
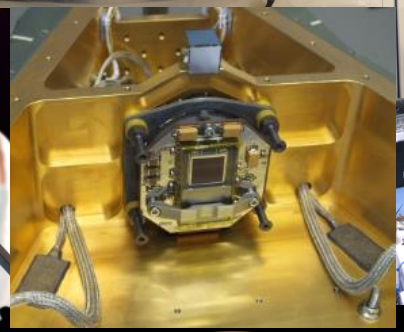
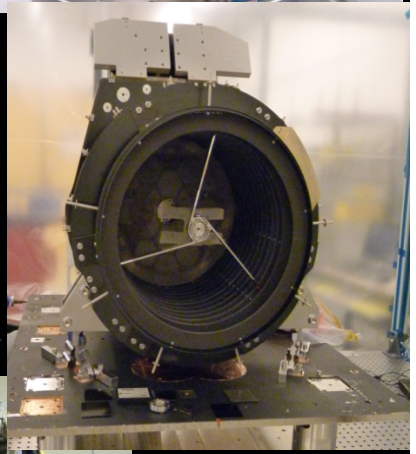
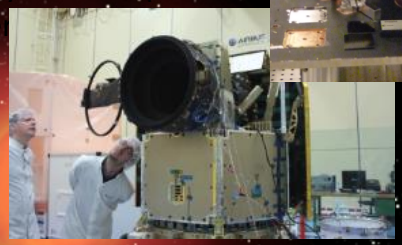
CHEOPS status

- Assembly of Instrument Flight Model complete
- Calibration campaign to start in January 2018
- Instrument integration into platform in Spring 2018
- Satellite environmental testing to follow
- Launch ready end 2018







Thank you for your attention

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Back up

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CHEOPS Guest Observers' Programme

- See poster "Observing with CHEOPS" for details

- Community Workshop providing an overview of CHEOPS capabilities and the CHEOPS Open Time Opportunity/Guest Observers' Programme was held in July 2017

  - Presentations available at: https://www.cosmos.esa.int/web/cheops-guest-observers-programme/open-time-workshop-2017

- First Call for Proposals/Announcement of Opportunity foreseen in Summer 2018

- Subscribe to the CHEOPS Guest Observers' mailing list to receive updates on the Guest Observers Programme and Mission status

  - Details on how to subscribe will be available shortly at: https://www.cosmos.esa.int/web/cheops-guest-observers-programme/

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