CHEOPS

CHEOPS in a nutshell

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Representing the contributions of many: from ESA Project Team and the CHEOPS Mission Consortium

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Outline of presentation

1. An overview of the CHEOPS mission and its science

2. In detail: performances - what CHEOPS offers

3. In detail: CHEOPS observations and data products

4. In detail: applying for CHEOPS observing time

5. Conclusions

1. An overview of the CHEOPS mission and its science

CHEOPS

CHEOPS – mission history

First S (small) mission in ESA’s Cosmic Vision Programme

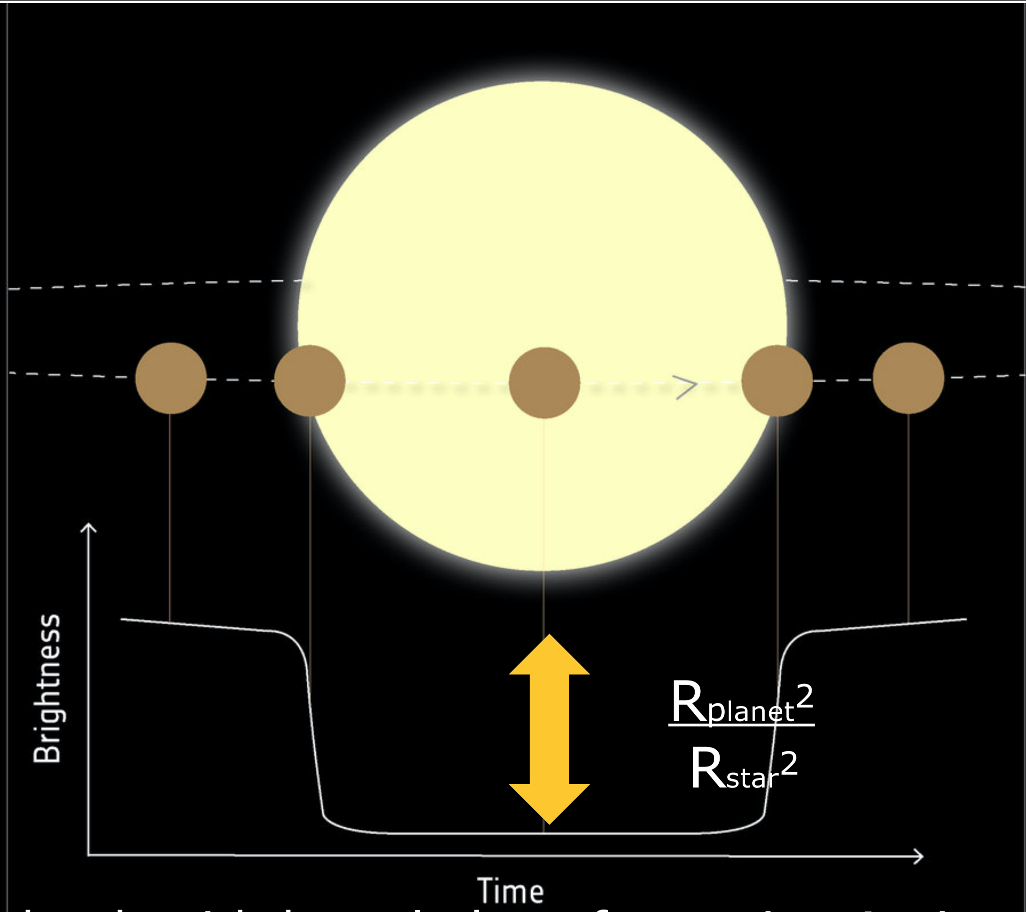
- Cooperation between ESA and the Swiss Space Office, with important contributions from 10 other ESA member states
- Consortium led by University of Bern, CH (PI: Willy Benz)
- ESA’s financial contribution capped at 50 M€uros:
    - Division of responsibilities very different from larger missions
    - Fast development schedule, relying on existing technology - selected end 2012, adopted 2014, launched end 2019 → FAST
    - Shared launch opportunity

→ All of the above drivers of the mission design ←

CHEOPS – mission characteristics I

- Mission dedicated to the follow-up of **bright stars** (V ≤ 12) already **known to host exoplanets**, using technique of high precision transit photometry:
    - **bright stars –** for which follow-up, including radial velocity (mass measurements) and detailed characterisation, with other facilities is possible
    - **known to host exoplanets –** efficient use can be made of observing time as one knows which targets to point to, and when, to catch exoplanet transits

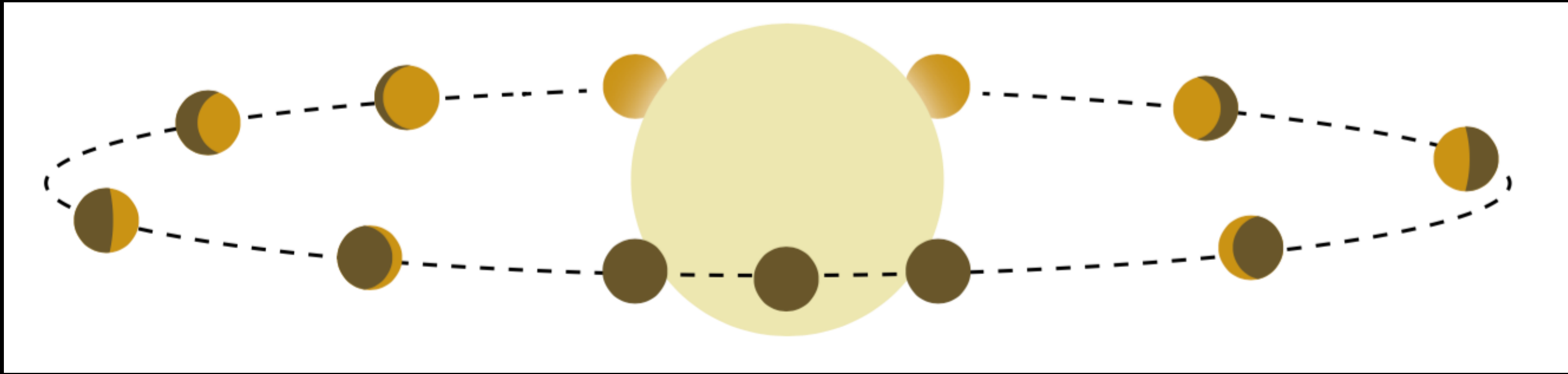
Transit photometry



Jupiter:Sun ~ 1%
Earth:Sun ~0.01%

Combining transit depth with knowledge of star size → size of the planet

Phase curves



Phase curves – monitor the star light over a full orbit of the planet

CHEOPS Science I

- First-step characterisation of super-Earths and mini Neptunes: using precision radii from CHEOPS and masses from other facilities) one can determine a planet’s bulk density:
  - Provides insight into physics and formation of these planets
  - Can be used to identify planets with atmospheres
  - Places constraints on planet migration
- Identification of golden targets for spectroscopic characterisation
- Probing the atmospheres of hot-Jupiters using phase curve measurements
  - Study of physical mechanisms and efficiency of energy transport

CHEOPS – mission characteristics II

- Follow-up character sets science requirements:
  - High photometric precision → driving requirement → accurate and precise sizes of planets:

→ 20 ppm in 6 hrs ($6 \le V \le 9$); 85 ppm in 3 hrs ($9 \le V \le 12$)

→ High photometric precision drives all aspects of the mission design

  - Targets all over the sky → access to large fraction of sky
  - High temporal cadence and precision (shape of egresses, transit timing variation)

CHEOPS – key requirements I

Photometric precision

SciReq 1.1 **Photometric precision for transit detection (L1)**
CHEOPS shall be able to detect Earth-size planets transiting G5 dwarf stars (stellar radius of 0.9 $R_\odot$) with *V*-band magnitudes in the range $6 \leq V \leq 9$ mag. Since the depth of such transits is 100 parts-per-million (ppm), this requires achieving a photometric precision of 20 ppm (goal: 10 ppm) in 6 hours of integration time. This time corresponds to the transit duration of a planet with a revolution period of 50 days.

SciReq 1.2 **Photometric precision for transit characterization (L1)**
CHEOPS shall be able to detect Neptune-size planets transiting K-type dwarf stars (stellar radius of 0.7 $R_\odot$) with *V*-band magnitudes as faint as V=12 mag (goal: V=13 mag) with a signal-to-noise ratio of 30. Such transits have depths of 2500 ppm and last for nearly 3 hours, for planets with a revolution period of 13 days. Hence, a photometric precision of 85 ppm is to be obtained in 3 hours of integration time. This time corresponds to the transit duration of a planet with a revolution period of 13 days.

SciReq 1.7 **Time scale for photometric performance (L1)**
CHEOPS shall maintain its photometric performances (SciReqs 1.1 and 1.2) during a visit (out of interruptions), with duration of up to 48 hours (including interruptions).

CHEOPS – key requirements II

Sky coverage

SciReq 2.1 **Stars with planets detected via Doppler velocimetry (L1)**
50% of the whole sky shall be accessible for 50 (goal:60) cumulative (goal: consecutive) days per year and per target with time spent on-target and integrating the target flux longer than 50% of the spacecraft orbit duration (e.g., >50 min for a 100-min spacecraft orbital period).

SciReq 2.2 **Stars with planets detected via ground-based transit surveys(L1)**
25% of the whole sky, with 2/3 in the southern hemisphere, shall be accessible for 13 days (cumulative; goal: 15 days) per year and per target, with time spent on-target and integrating the target flux longer than 80% of the spacecraft orbit duration (>80 min for 100-min spacecraft orbit).

CHEOPS – key requirements III

Cadence and timing precision

SciReq 5.1 **Temporal resolution of the measurements (L1)**

CHEOPS shall be able to provide one photometric measurement per minute (goal: one per 30 seconds) in order to characterise the transit light curves of Neptune-size planets (SciReq 1.2).

SciReq 5.2 **Time stamp uncertainty (L1)**

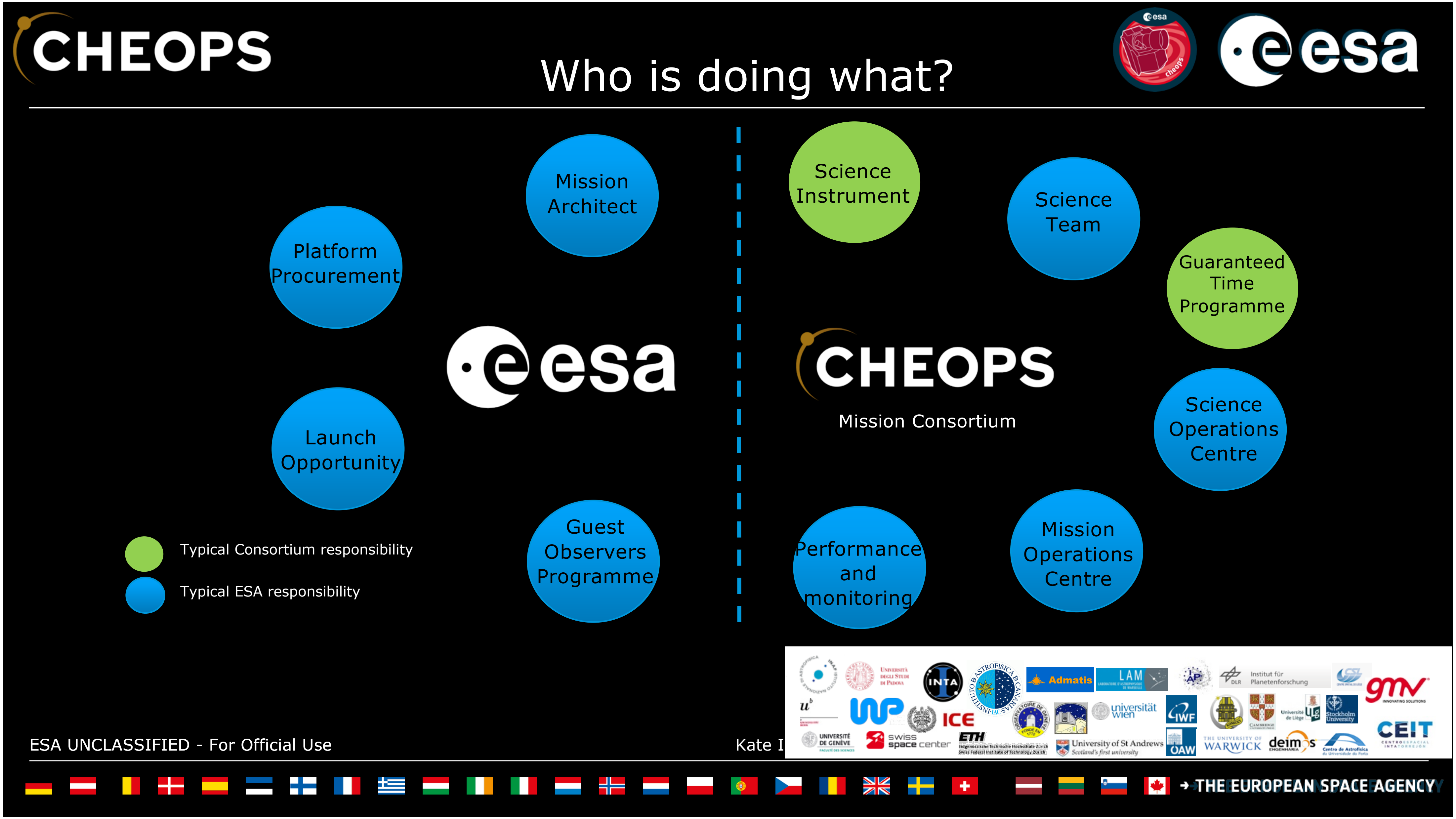
CHEOPS shall be able to provide photometric measurements with time stamp (UTC) uncertainties of 1 second (goal: < 0.01 second) for transit light curves. The goal value is set to provide a better time stamp precision for ancillary science.

See Science Requirements Document available at https://www.cosmos.esa.int/web/cheops/the-science-of-cheops for further details

CHEOPS

CHEOPS – the mission

- Launched 18 December 2019 from Kourou
- In-orbit commissioning January - mid March 2020
- Start of nominal operations/Year 1 – 25 March 2020
- 3.5 years science operations ending September 2023, mission extension to end 2026 and beyond under discussion


CHEOPS
Who is doing what?
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Mission Architect
Platform Procurement
Launch Opportunity
Guest Observers Programme
Science Instrument
Science Team
Guaranteed Time Programme
CHEOPS
Mission Consortium
Science Operations Centre
Performance and monitoring
Mission Operations Centre
Typical Consortium responsibility
Typical ESA responsibility
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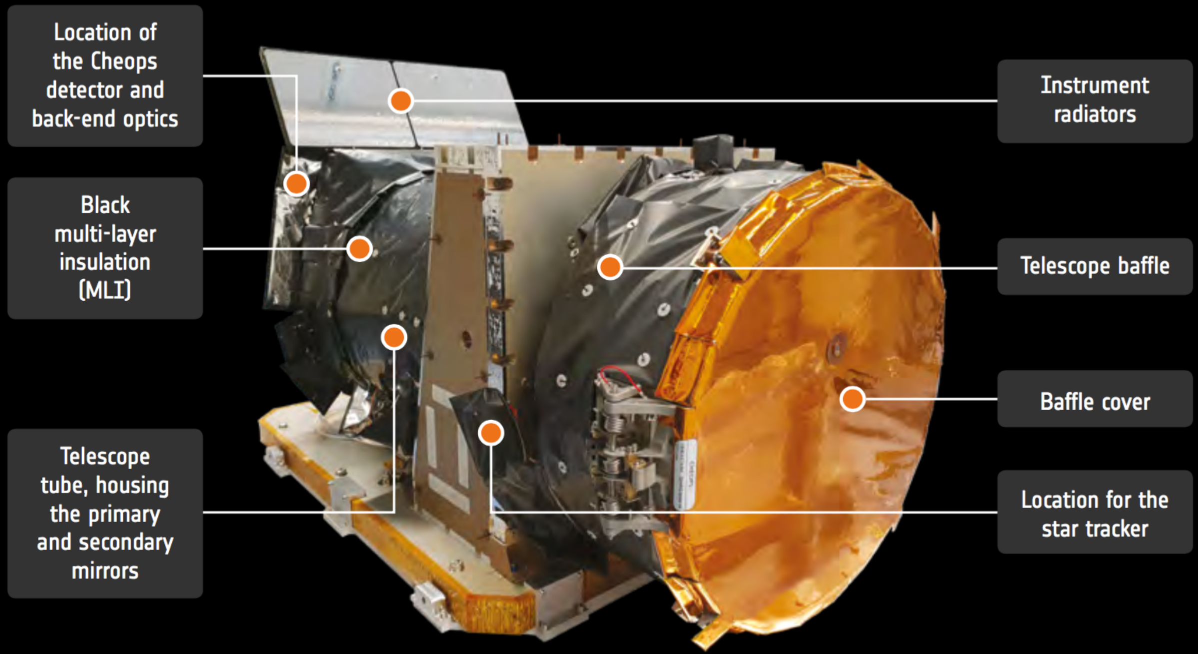
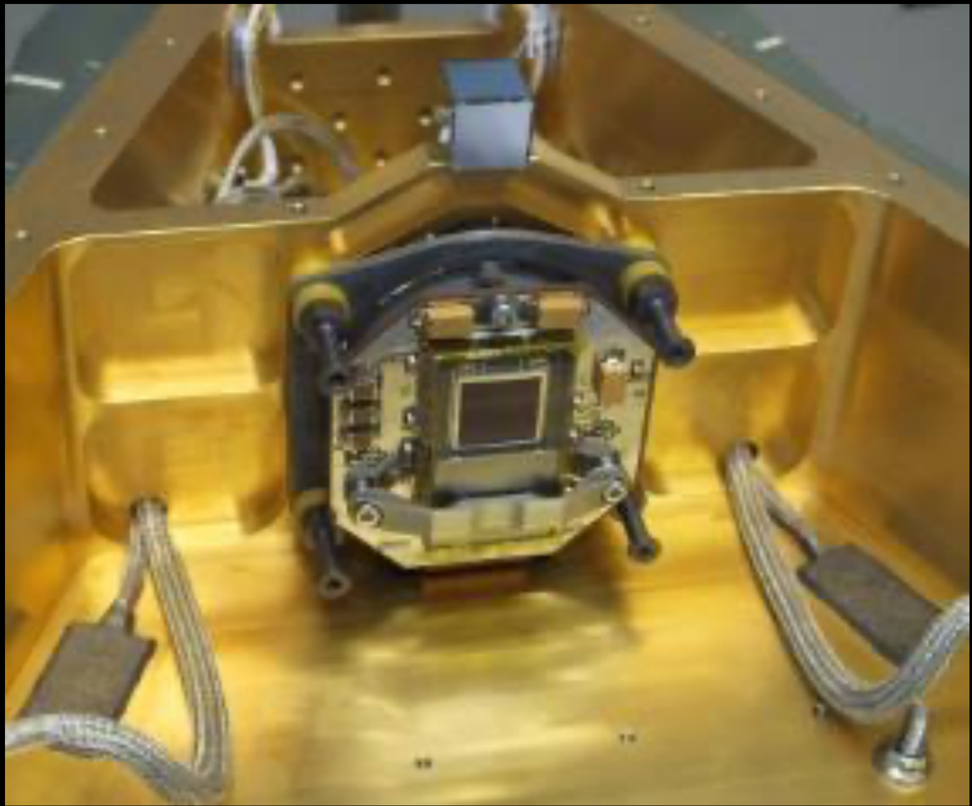
Single wideband ultrahigh precision photometer



- Compact Ritchey-Chrétien telescope, effective Ødiameter =300 mm
- Defocussed Point Spread Function
- Baffle to minimise straylight impinging on the detector

8Credit: ESA/CHEOPS Mission Consortium

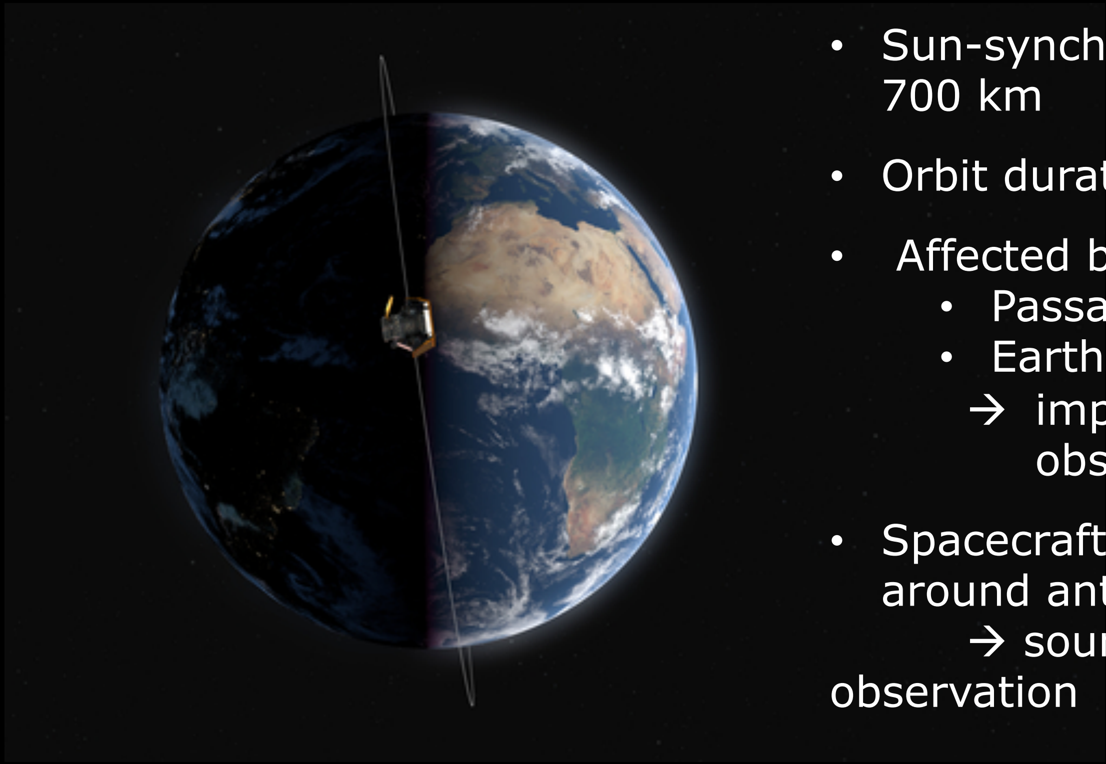
Single CCD



- Single E2V AIMO CCD47-20 CCD
  - Cooled to - 45º C to minimise dark current/noise
  - 1024 x 1024 pixels, frame-transfer, back-illuminated
  - 330 – 1100 nm bandpass (single band, no filter)
  - 13 micron pitch pixels (~1″/pixels)

Credit: CHEOPS Mission Consortium

CHEOPS orbit



- Sun-synchronous polar orbit/dawn-dusk – altitude of 700 km
- Orbit duration ~ 99 minutes
- Affected by:
  - Passage through the South Atlantic Anomaly
  - Earth occultations in northern winter

    → impacts observing efficiency/on-source observing time
- Spacecraft rolls around the pointing direction (cone around anti-sun direction)

  → sources in the field of view rotate during observation

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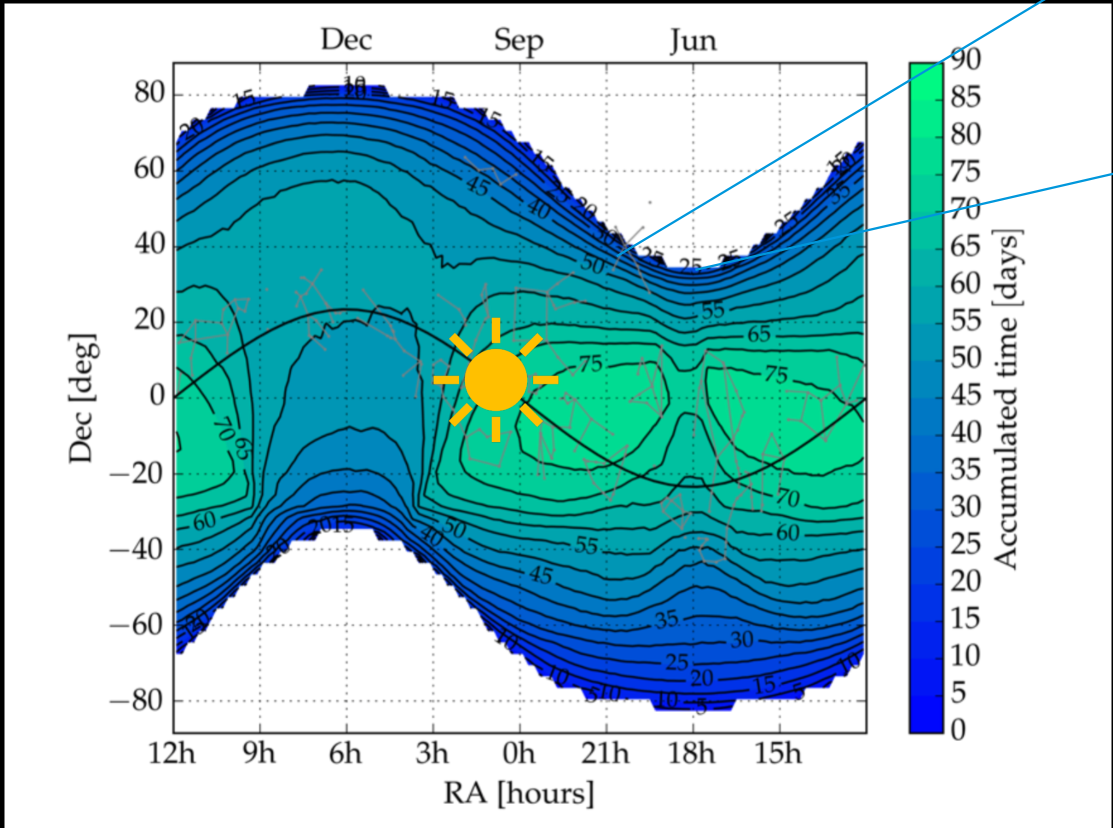
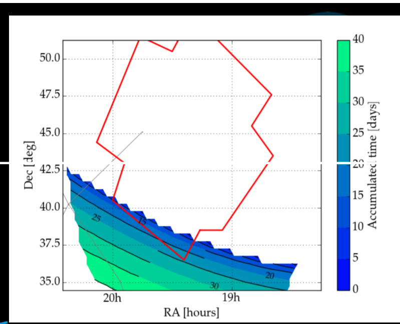
CHEOPS sky





Kepler field

- Annual sky visibility map – number of days a given position in the sky can be observed during a year, allowing for up to 50% orbital interruptions
- Interruptions due to Earth occultations and passage through the South Atlantic Anomaly
- White regions are excluded
- Black line - ecliptic plane

CHEOPS operations

Mission Operations Centre, Madrid (during testing)

Science Operations Centre, Geneva Observatory

- Ground stations in Spain, back-up in Kiruna, SE
- Mission Operations Centre near Madrid, ES
  - spacecraft and instrument monitoring and control
  - ground station operations
  - orbit/attitude determination and control
- Science Operations Centre in Geneva, CH
  - mission planning
  - data reduction pipeline
  - mission data archive

Credit: CHEOPS Mission Consortium

CHEOPS Science II - themes

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Planetary atmospheres through phase curves and secondary eclipses

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Searching for exo-moons, rings, planet distortion

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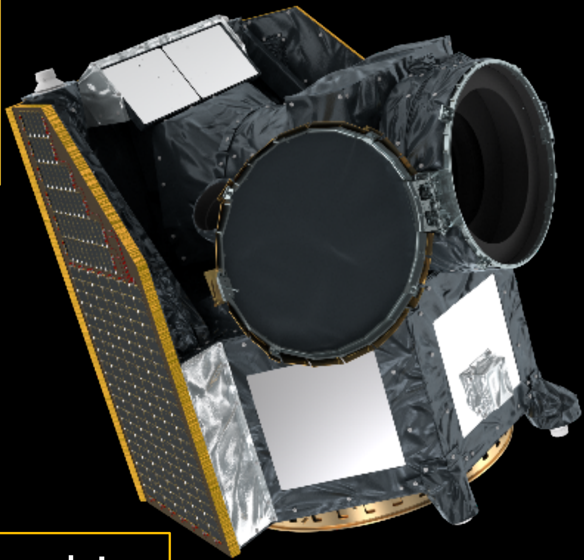
Improving M-radius relationship for sub-Saturn mass planets



Searching for new planets in existing systems

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Pot-pourri – stellar activity, trans-Neptunian objects

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Transits of planets found by other means

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ESA-run Guest Observers Programme (20%)

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CHEOPS Images

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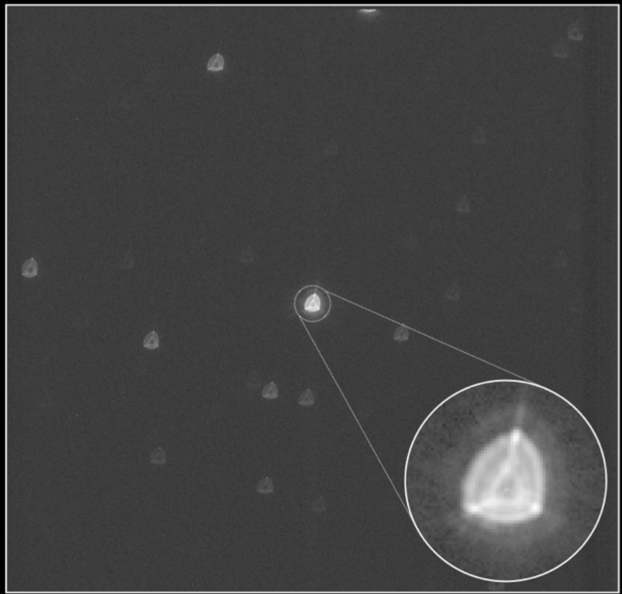
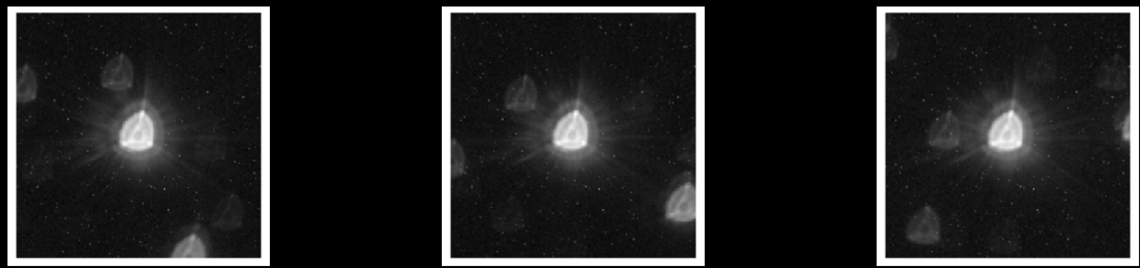


January 2020



Target remains at the centre of the image during orbit, field rotates

First images … perfectly blurred ….

Credit: ESA/Airbus/CHEOPS Mission Consortium

CHEOPS early papers

- Results of in-orbit commissioning presented in the CHEOPS mission paper: "The CHEOPS Mission", Benz et al. (2021), Exp Ast, 51, 109 (https://doi.org/10.1007/s10686-020-09679-4)

- First occultation measurements: "The hot dayside and asymmetric transit of WASP-189 b seen by CHEOPS", Lendl, M. et al. (2020) A&A, 643, 90 (https://doi.org/10.1051/0004-6361/202038677)

- Hunting planets: "Six transiting planets and a chain of Laplace resonances in TOI-178", Leleu, A. et al. (2021) A&A, 649, 26 (https://doi.org/10.1051/0004-6361/202039767)

- First phase curve: "CHEOPS precision phase curve of the Super-Earth 55 Cancri e ", Morris, B. et al. (2021) A&A, 653, A173 (https://doi.org/10.1051/0004-6361/202140892)

- Searching for transit timing variations: "Exploiting timing capabilities of the CHEOPS mission with warm-Jupiter planets", Borsato, L. et al (2021) MNRAS, 506, 1310 (https://doi.org/10.1093/mnras/stab1782)

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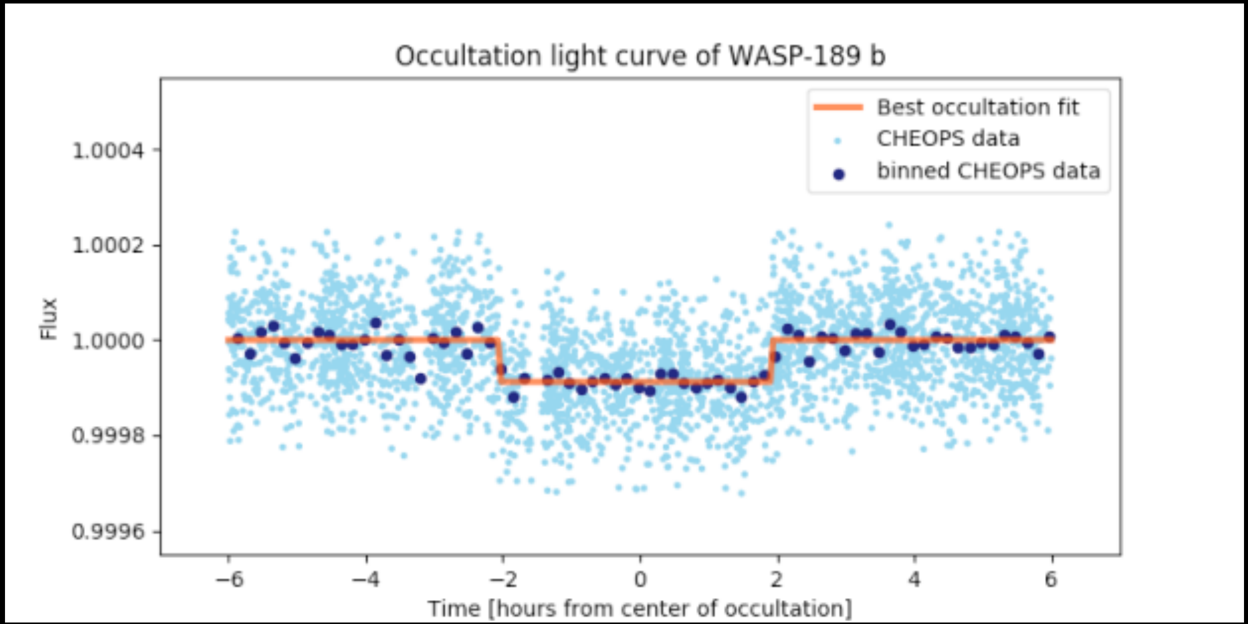

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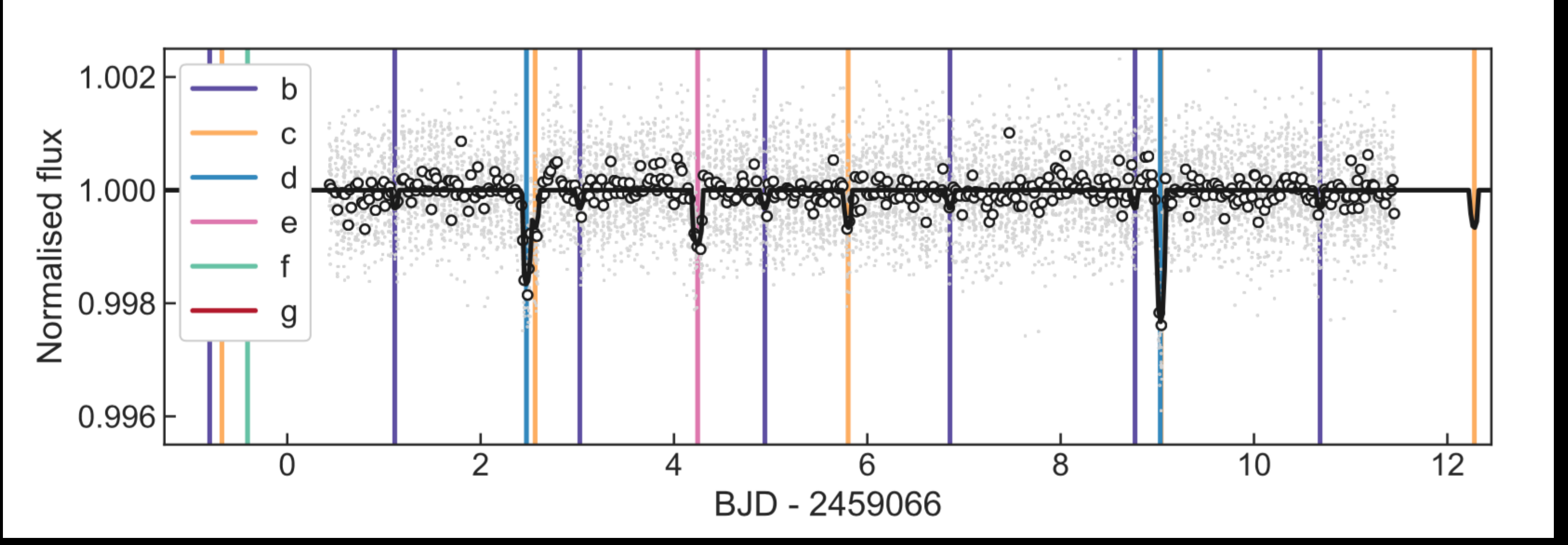
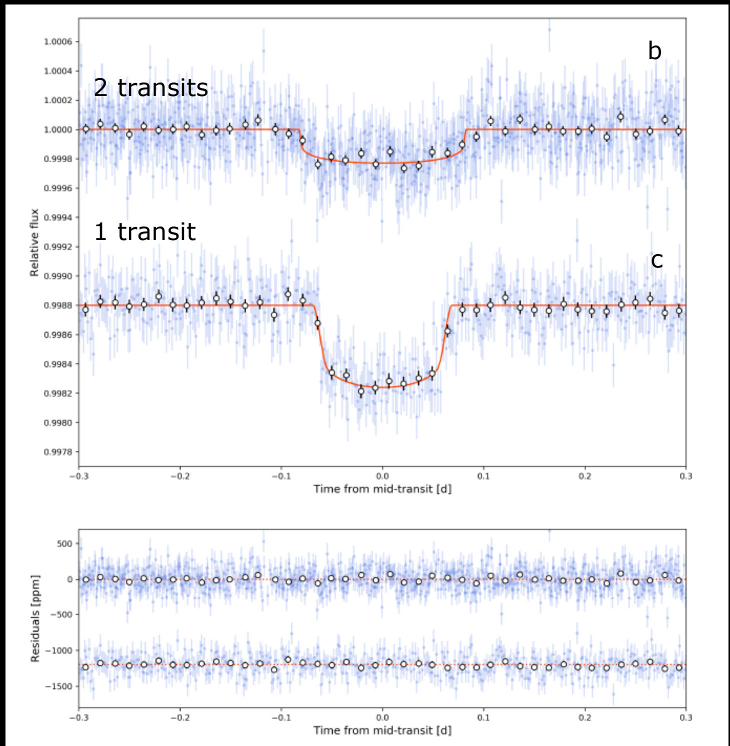
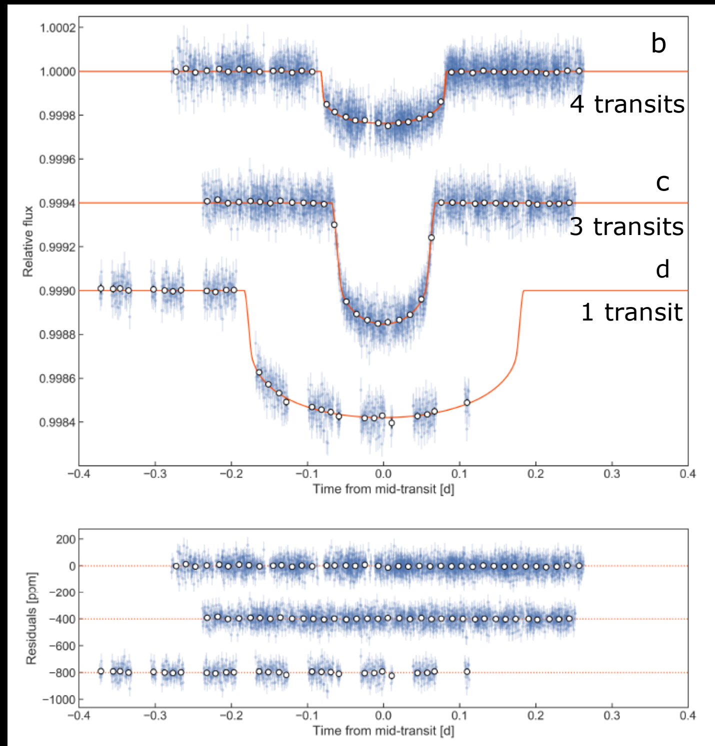


CHEOPS early papers

- "Transit detection of the long-period volatile-rich super-Earth ν² Lupi d with CHEOPS": Delrez, L. et al. (2021) Nat. Astron., 5, 775 https://doi.org/10.1038/s41550-021-01381-5

TESS





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RMS of the individual detrended light curves:

TESS: 80 ppm/10 min; 30 ppm/1 hr

CHEOPS: 15 ppm/10 min; ~6 ppm/1 hr

CHEOPS early papers

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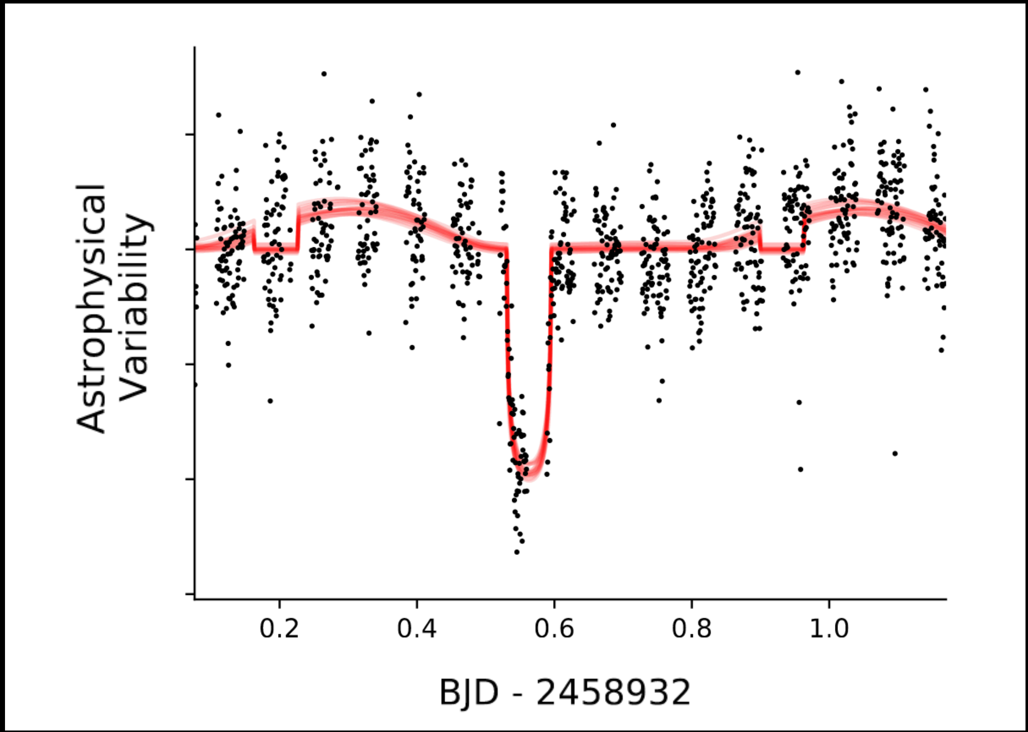

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2. In detail: CHEOPS performances – what CHEOPS offers

CHEOPS – performances

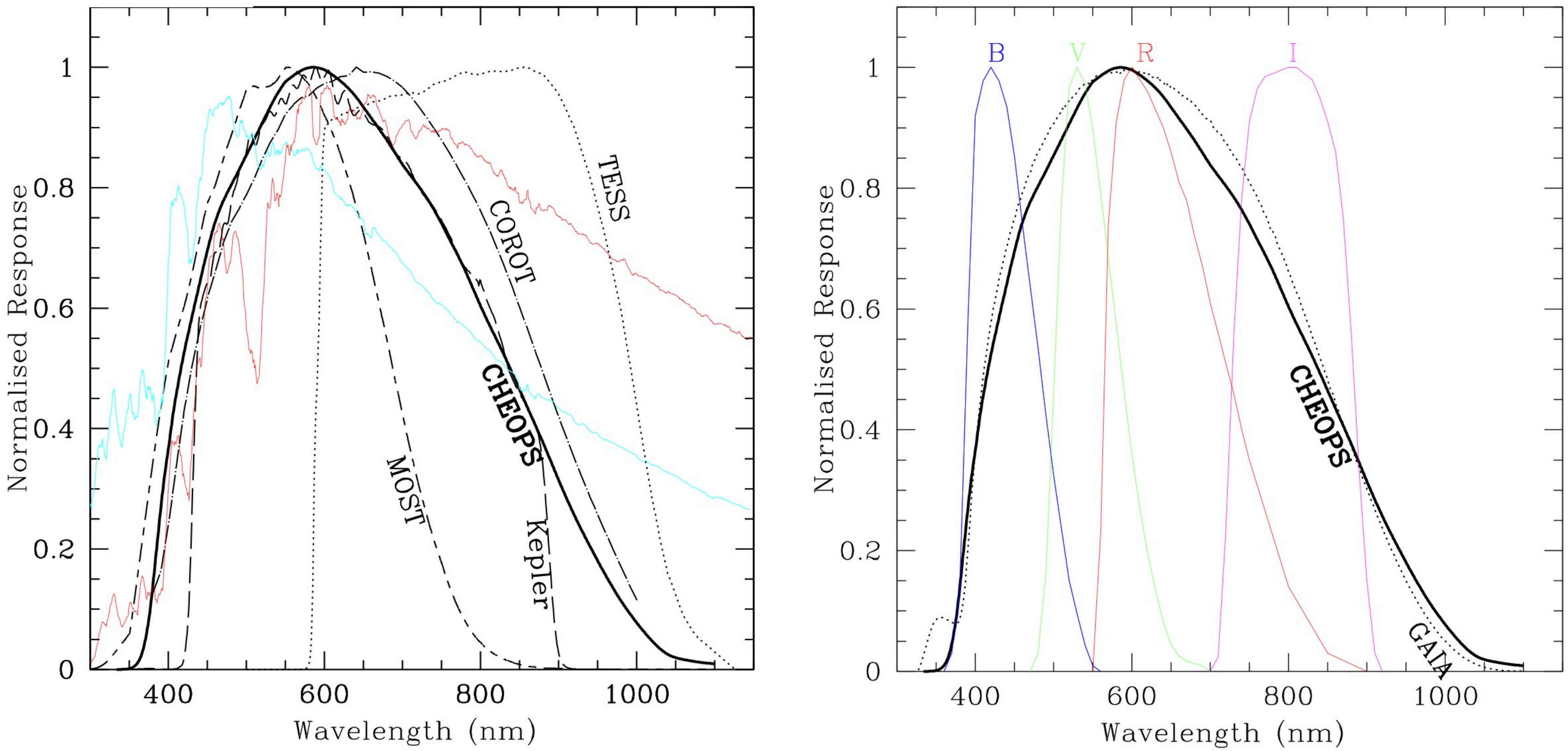
- Monitoring and characterisation programme
- Bandpass
- Point spread function (PSF)
- Photometric precision
- Timing precision

CHEOPS – monitoring & characterisation programme

- To characterise key aspects of CHEOPS performance and to monitor their evolution
- Led by the CHEOPS Instrument Scientist, with support from Science Team working group.
- Include:
    - Establishing and monitoring CHEOPS photometric precision
    - Establishing and monitoring the CHEOPS PSF
    - Establishing bright and faint target limits of CHEOPS
    - Monitoring radiation damage/ageing of the CHEOPS CCD, and effects
    - Optimising the choice of location of CHEOPS images on the CCD

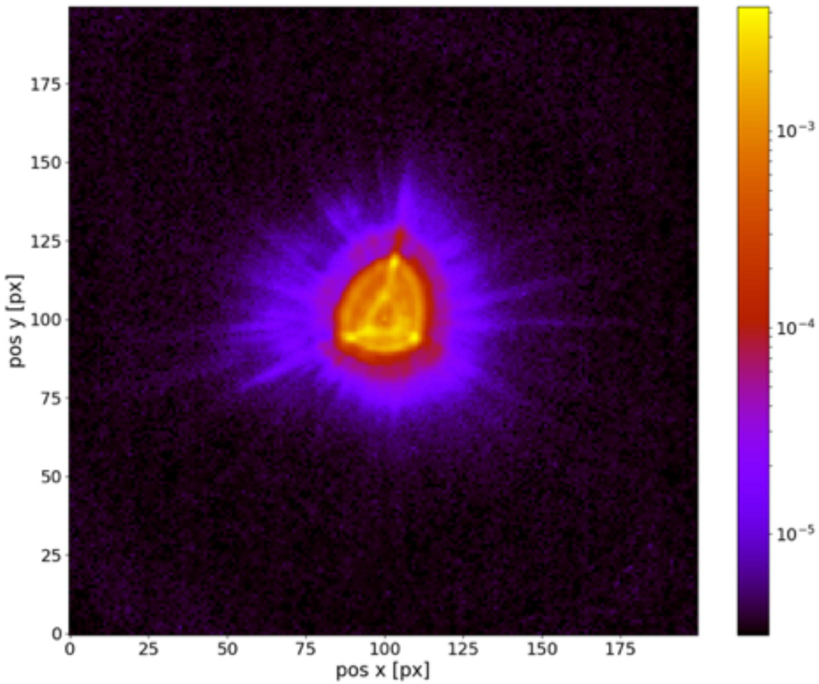
Paper covering first year of observations (including commissioning) foreseen to come out in coming months, with intermediate updates provided in the form of slides/presentations made available on the CHEOPS guest observers webpages

CHEOPS – bandpass



CHEOPS bandpass normalised to its peak value as a function of wavelength: overplotted are the equivalent curves for other exoplanet missions together with the spectral energy distributions (SED) of a T_{eff}~5500K (cyan) and T_{eff}~4500K (orange/brown) dwarf star (left panel), and bandpasses of the BVRI filter set together with GAIA (right panel). Note the similarity between the CHEOPS and GAIA bandpasses.

CHEOPS – PSF



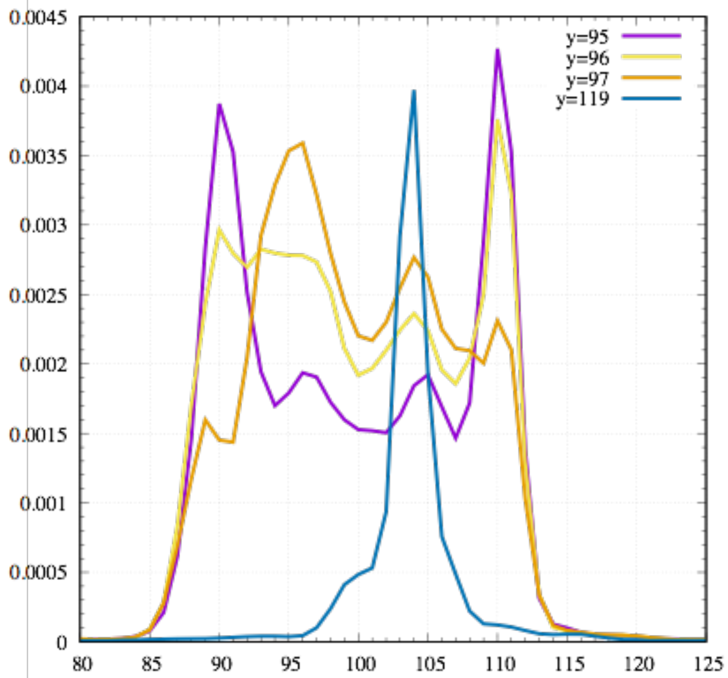
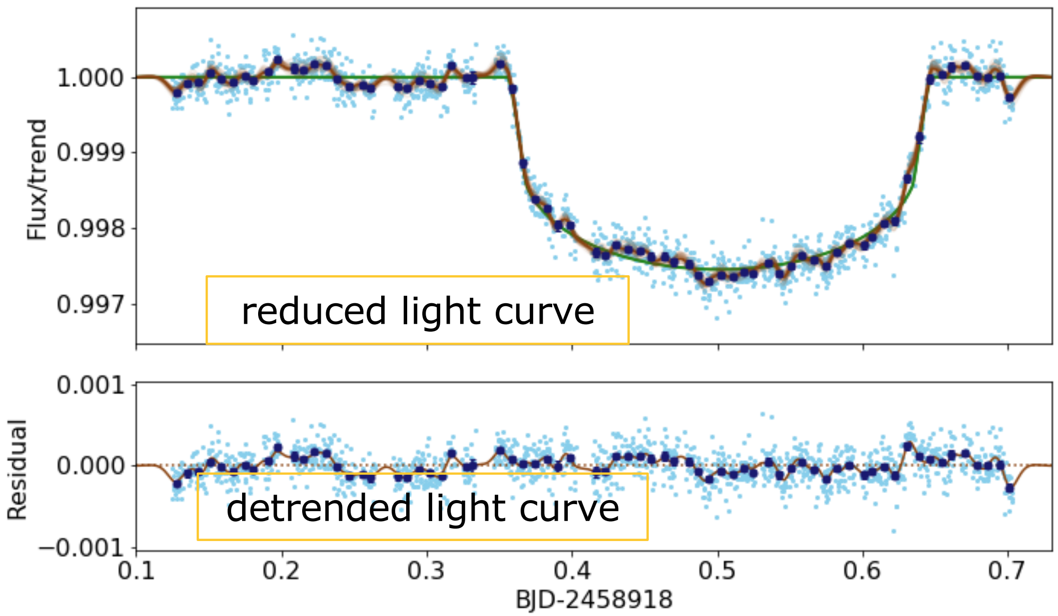


Image of the defocused point spread function (PSF) measured during in-orbit commissioning – 90% of the energy is within a radius of c. 16.5 pixels. Left: flux distribution, x and y axis in pixels. Right: PSF profiles along the y axis for different horizontal cuts. The y values chosen for the figure contain the pixels with the highest flux of the PSF.

Transit observations - KELT-11b

Target: Kelt-11; data set: PR300024_TG000101
Gmag = 7.83 (Vmag =8.04)
Teff = 5370 K (Stellar radius 2.807 R⊙)



- 14 hr observation, T_{exp} = 15 s
- Data processed at the Science Operations Centre using an automated pipeline (DRPv12), detrended with pycheops (v0.9.3)
- Upper panel: data (light blue points are individual exposures, dark blue points binned to 10 minutes) + the transit fit (green line) and best fit stellar model (brown line).
- Lower panel: residuals from the transit model fit, together with stellar model fit.
- Photometric precision of 12 ppm obtained in a 6 hr bin

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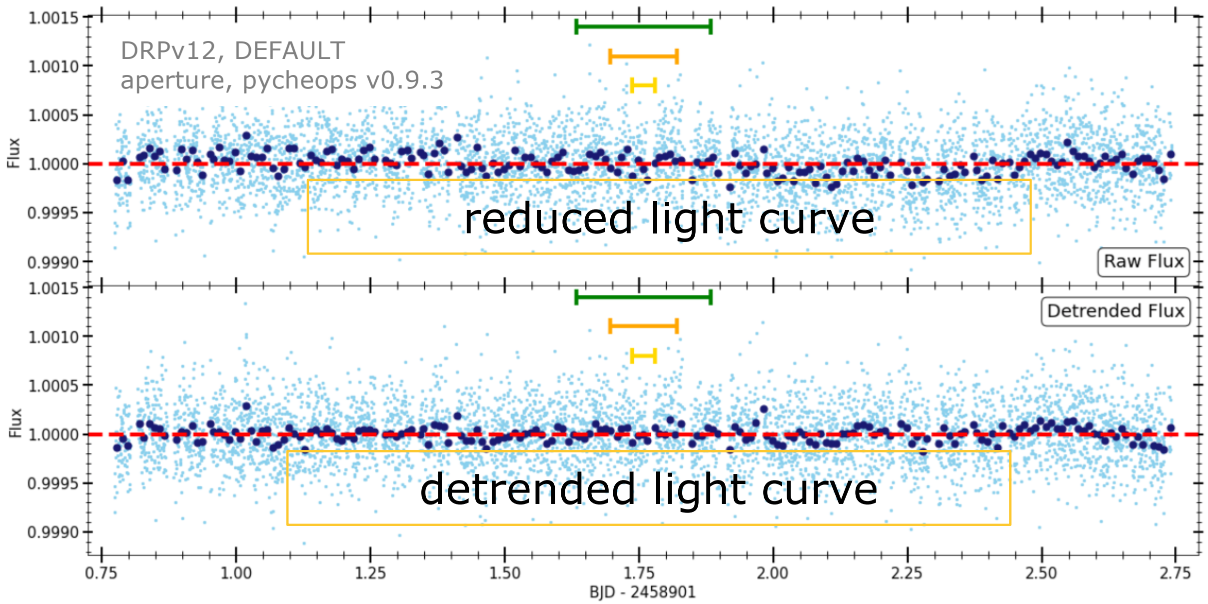
HD88111*

G_{mag} = 8.97, T_{eff} = 5330 K

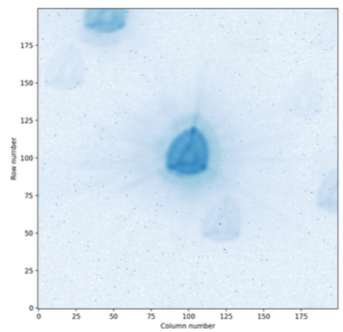
Target observed to verify Science Requirement 1.1

- Exposure time: 30 s
- Visit Duration: 47 h
- Observation Date: 22/02/2020

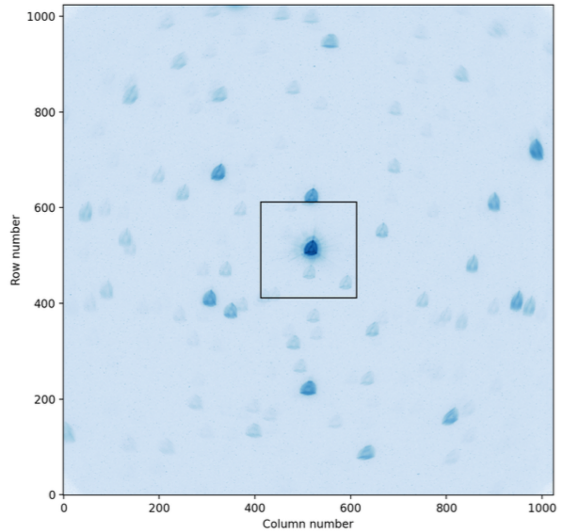


6 hours
3 hours
1 hour

Window Image



Full Field of View



[1]Noise calculated using the Scaled Error Method

Noise [ppm]	1 min	10 min	30 min	1 h	3 h	6 h
Raw LC[1]	202	75	45	31	18	12
Detrended LC[1]	193	62	36	27	15	11
ETC	235	84	49	32	20	15

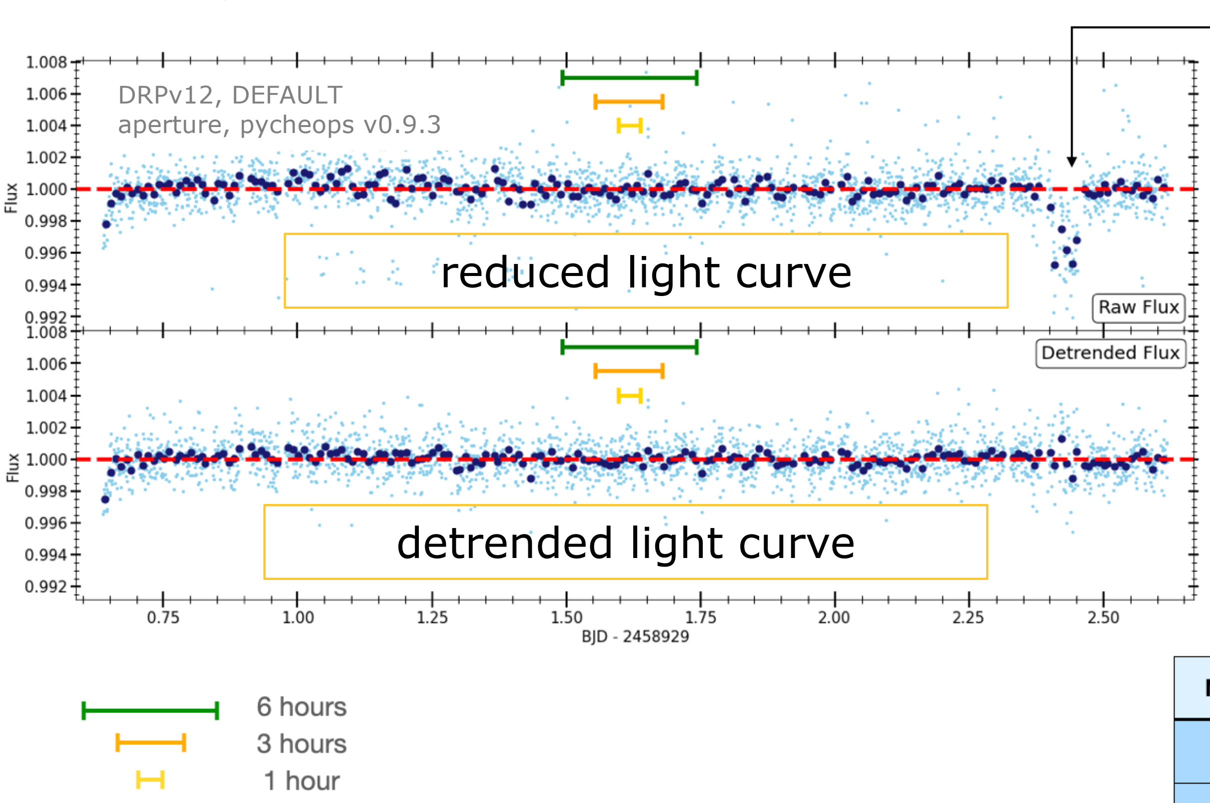
* See Benz et al. (2020) for more details. All data publicly available.

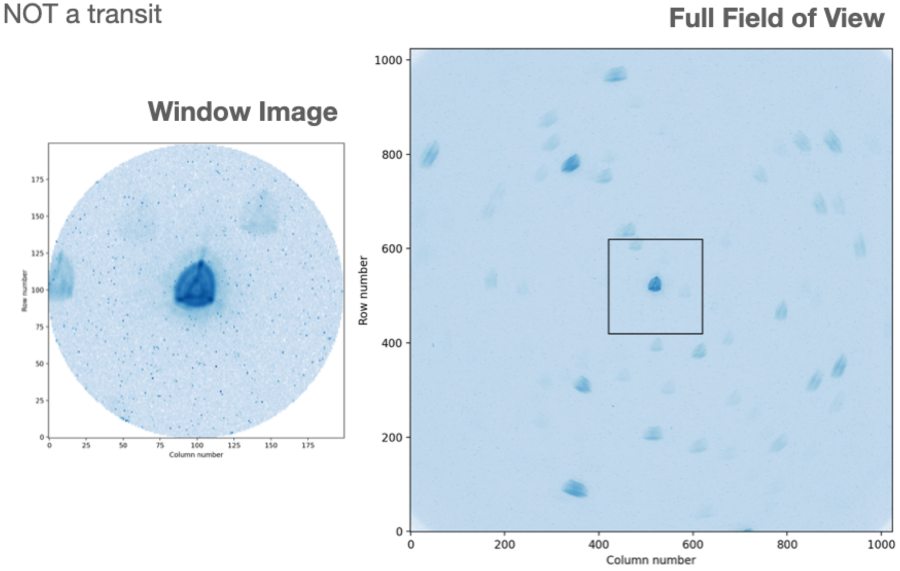
TYC5502-1037-1*

G_{mag} = 11.98, T_{eff} = 4750 K

Target observed to verify Science Requirement 1.2

- Exposure time: 60 s
- Visit Duration: 48 h
- Observation Date: 21/03/2020



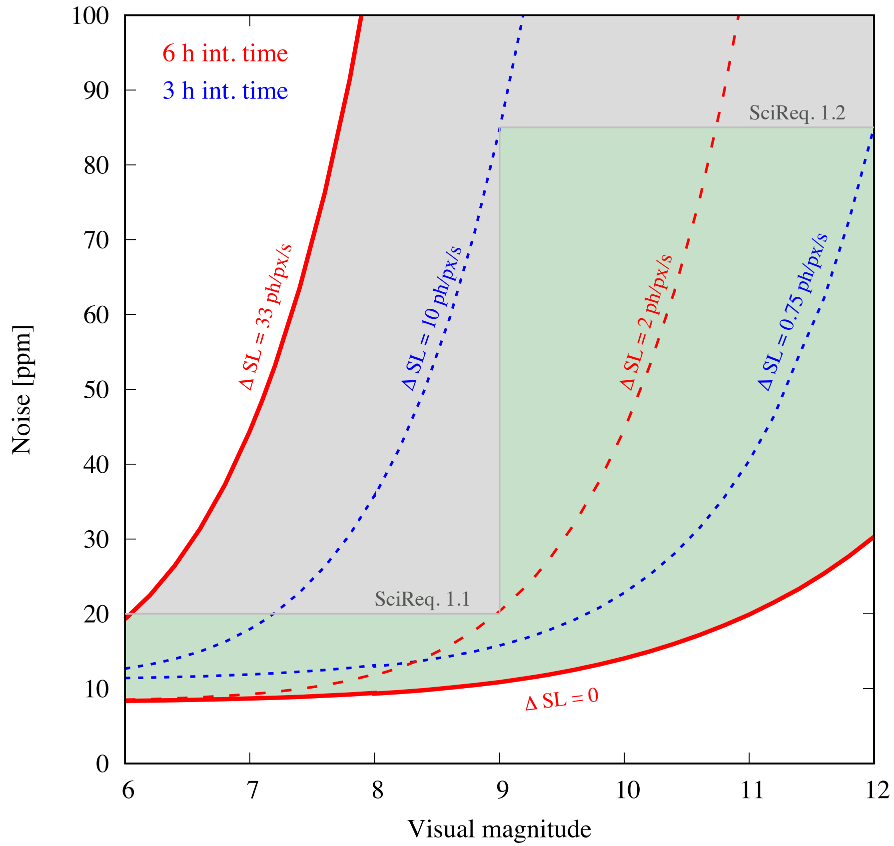


[2]Noise calculated using the Minimum Error Method

Noise [ppm]	1 min	10 min	30 min	1 h	3 h	6 h
Raw LC[2]	1100	440	269	188	108	76
Detrended LC[2]	953	434	264	184	105	74
ETC	799	265	164	126	94	84

* See Benz et al. (2020) for more details. All data publicly available.

CHEOPS – photometric performance I



See Benz et al (2021) Exp Ast for further details

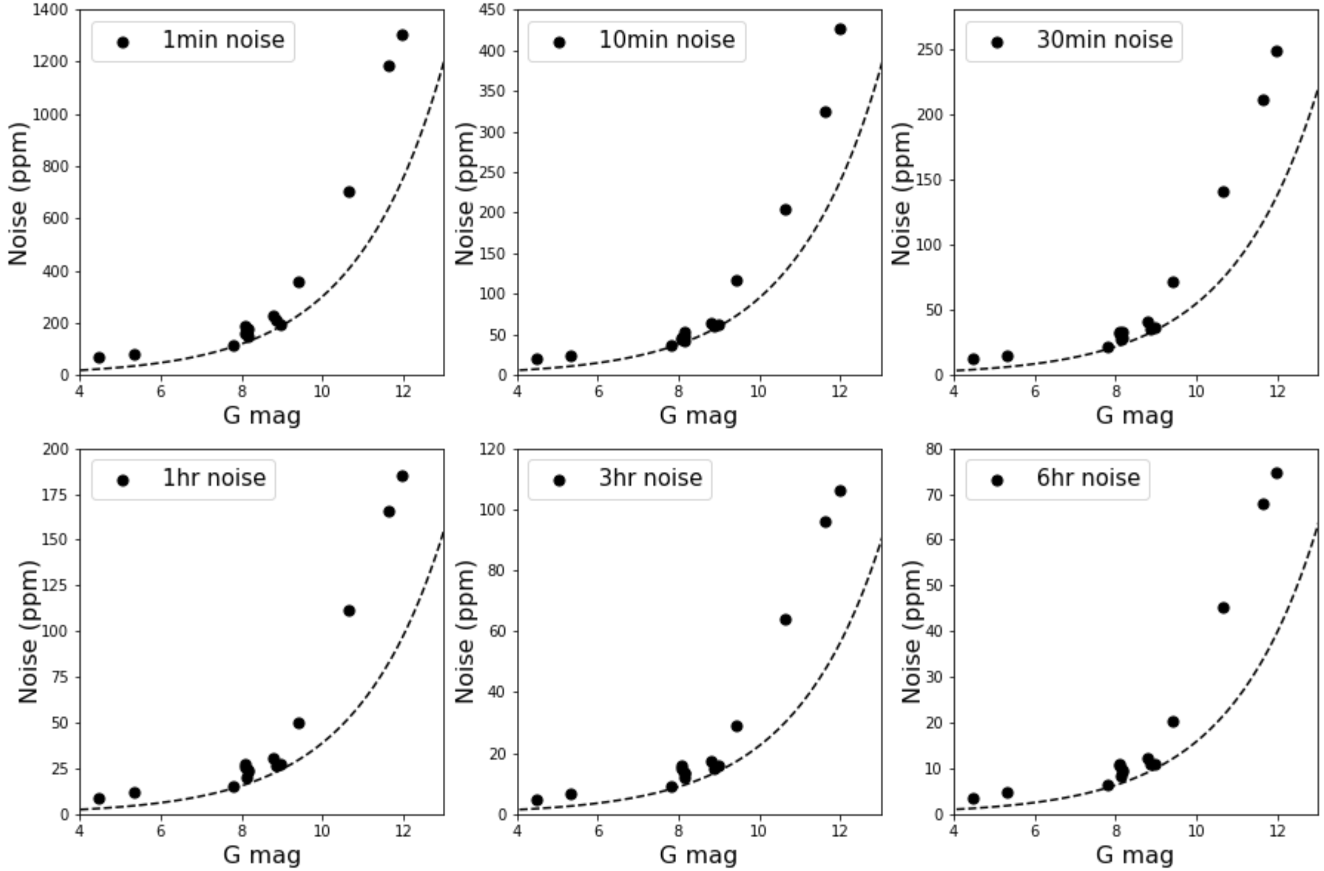
Photometric noise as a function of stellar magnitude (pre-launch assessment of the CHEOPS noise budget)

- solid red curve labeled “ΔSL = 0” (no stray light contamination): noise floor of CHEOPS in a 6-hour integration time (calculated for an M0 star → best case within science requirements)

- solid red curve labeled “ΔS L = 33 ph/px/s” : noise behaviour when stray light contamination dominates the total noise for all magnitudes (calculated for an G0 star → worst case within science requirements)

- The green region defines the conditions that satisfy the science performance requirements

CHEOPS – photometric performance II



- Measured photometric precision (noise) as a function of the G magnitude of a star for different integration times/timescales
- Results obtained with the PYCHEOPS package (v1.0.0) from light curves extracted using DRPv13 with a photometric aperture of r = 25 px
- The dashed curve represents the photon noise

CHEOPS – timing accuracy & precision

- Measured during in-orbit commissioning phase (Jan – March 2020) using the eclipsing binary HW Vir

- Comparing observations made with CHEOPS with those from ground-based telescopes

→ accuracy and precision of the CHEOPS time stamp are better than 1s and 0.3s respectively

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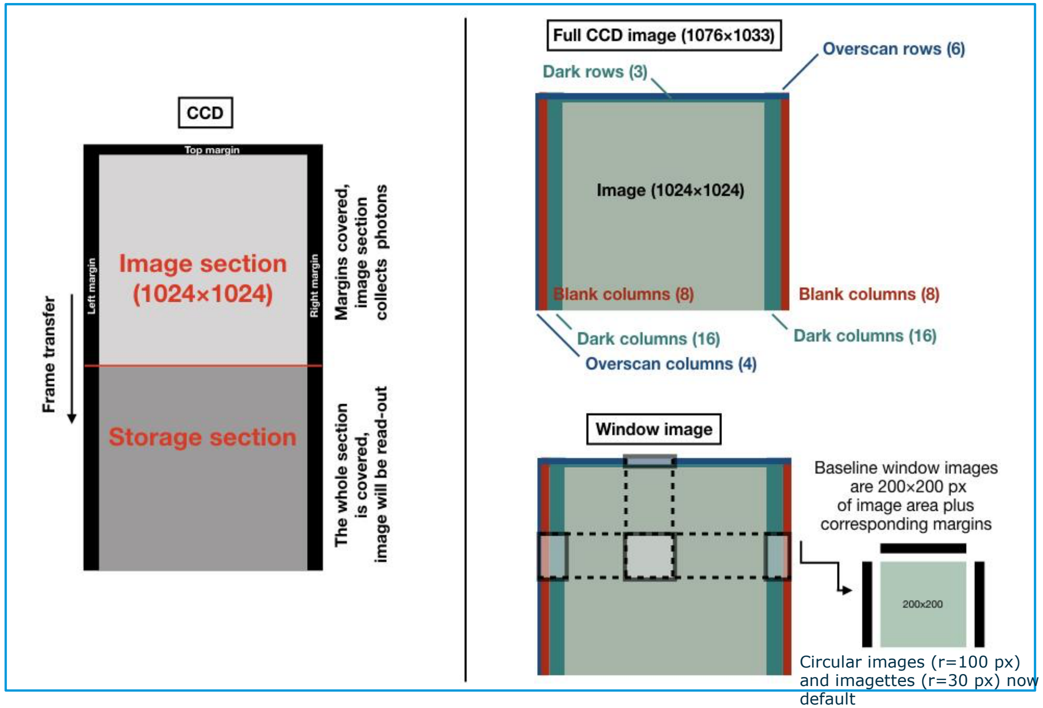
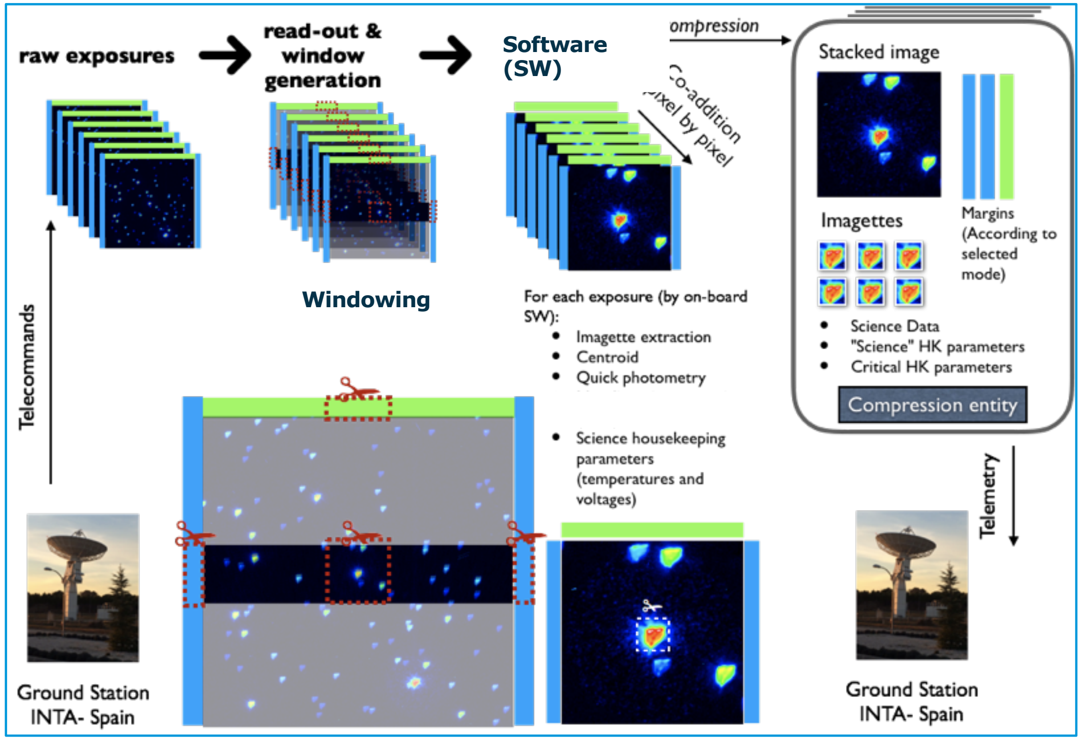
3. In detail: CHEOPS observations and data products

CHEOPS observations

- Individual CHEOPS observations are known as visits.
- Each visit starts with a Calframe – full-frame (single 1024 x 1024 pixel image), centred on the target. This is downlinked to ground.
- All subsequent exposures in a visit are window images - 200 pixel in diameter, centred on the target. Individual images may be stacked in case of short exposure times.
- Cadence of the stacked images is 1 minute or higher, depending on exposure time (1 ms - 60s, depending on target brightness).
- Imagettes of 60 pixels in diameter, also centred on the target, are downlinked to the ground unstacked.

Observing with CHEOPS





CHEOPS full-frame CCD images are typically "windowed" (circular) to reduce the data volume which is constrained by the satellite downlink budget . Window images are also stacked for exposures shorter than 23 s. Imagettes (circular) are not stacked thus the exposure cadence is maintained.

CHEOPS data products - I

- Once successfully processed by the automated pipeline at SOC, all data are ingested into the CHEOPS mission archive
- Science data products include:
    - Level 0: Telemetry packets as received from the Mission Operations Centre (science+ housekeeping)
    - Level 0.5: Unpacked data (FITS) sorted by visits. Time-tagged in UTC/MJD. Housekeeping data is in physical units
    - Level 1: Calibrated and corrected science images – full array as well as window images and imagettes. Time-tagged in UTC, MJD and BJD
    - Level 2: Light curves
- Proprietary period of 1 year after last visit, and no longer than 18 months after the first

CHEOPS data products - II

- All data – public and proprietary science data as well as calibration/reference files. Available from the CHEOPS Mission Archive:

  https://cheops.unige.ch/archive_browser/

- Calibration/reference data from the on-ground calibration campaign + in-orbit monitoring&calibration programme are also available from the archive

- Details of the data that is available to inform the CHEOPS User can be found on the CHEOPS data page:

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/cheops-data/

Full details of the content of the CHEOPS data products can be found in the CHEOPS Observers Manual and references therein

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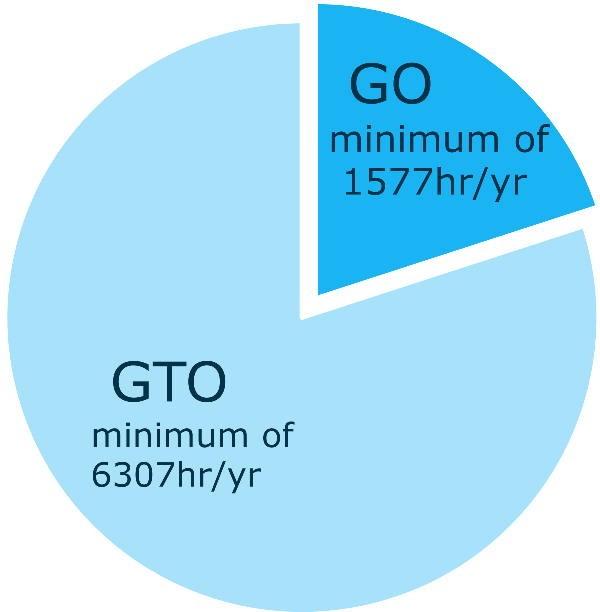
4. In detail: applying for CHEOPS observing time

Observing time on CHEOPS

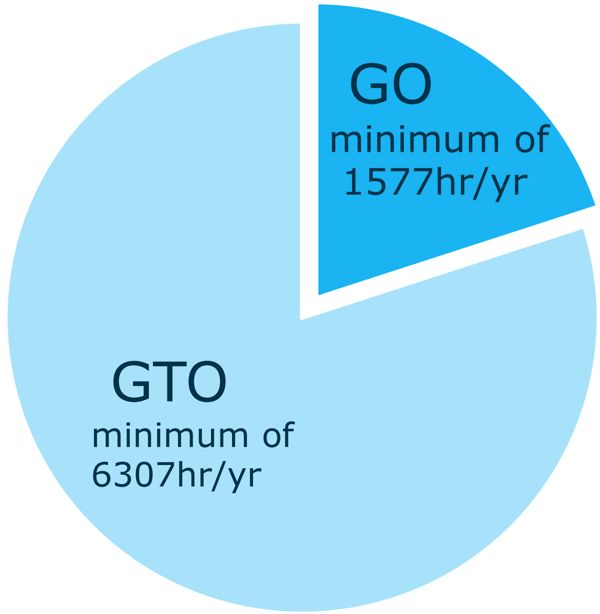
- Up to 10% of CHEOPS time top-sliced for:
  - space-craft/instrument-related activities
  - CHEOPS Monitoring and Characterisation programme, monitoring all aspects of CHEOPS instrument performance

- Remaining 90% - science time (min. 7884 hrs/yr)
  - Split 80:20 between the CHEOPS Guaranteed Time Observing (GTO) Programme and the ESA-run CHEOPS Guest Observers (GO) Programme



Guest Observers (GO) Programme

- ESA-run programme to enable Community access to CHEOPS
- 75%: 25% split of time between annual calls and the Discretionary Programme
- Open to the World-wide community, regardless of nationality
- Selection of proposals based on scientific merit and the applicability of CHEOPS to the proposed science.



Proposal and observing constraints

Parameter	Comments
Duration of a single observation (1 orbit ~ 99 minutes)	Min: 5 orbits to enable efficient detrending of lightcurves Max: 100 orbits/ ~1 week). Longer possible by concatenation
Total time requested in a single proposal	No limit on the maximum number of orbits that can be requested
Solar System objects	CHEOPS does not support nonsidereal tracking. It is possible to use static coordinates (RA, Dec), however observations become highly time-critical/very challenging to schedule
Simultaneous observations with other facilities	Challenging due to planning constraints, however can be considered in exceptional cases
Targets on the reserved target list	Currently may not be included in proposals.
Targets for which data exists in the mission archive	Contact cheops-support@cosmos.esa.int to request further information on what has been done

→ All constraints will be the Policies and Procedures document for the Call ←

Proposal preparation checklist - I

- Register as a Guest Observer (needed to submit proposal and access tools)

https://www.cosmos.esa.int/web/cheops-guest-observers-programme/register/

- Are my targets visible with CHEOPS?
  - Visibility maps and scheduling feasibility checker tool

- Are my targets already reserved/part of other programmes?
  - Check the Reserved Target List

Tool to check individual targets: https://cheops.unige.ch/pht2/search-reserved-targets/

Text file: available from Call webpage shortly before an AO opens

Proposal preparation checklist - II

- Have the targets I am interested in already been observed?
  - Check the CHEOPS Mission Archive
    https://cheops.unige.ch/archive_browser/
- How much time should I request/precision can I expect to achieve?
  - Exposure time calculator (ETC) + past observations
- CHEOPS overview – CHEOPS observers Manual

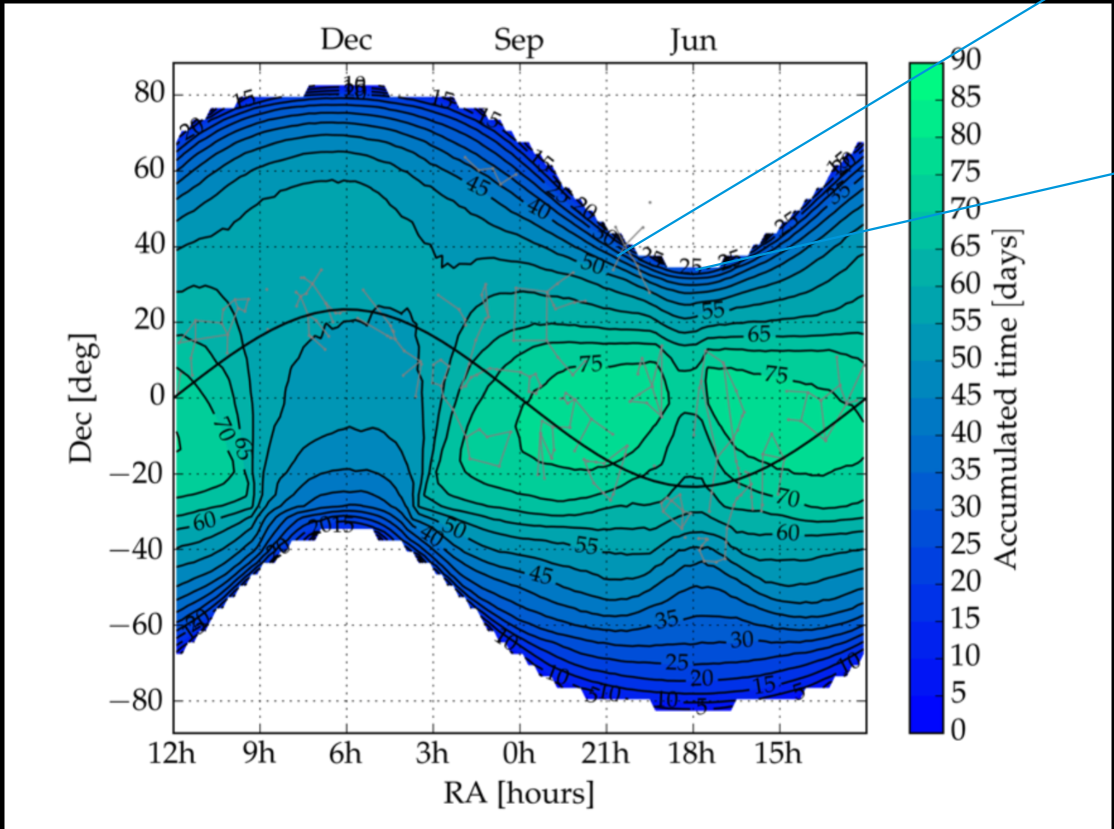
Target visibility

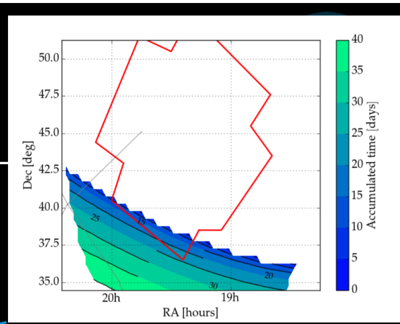
- First check maps of CHEOPS sky – annual + instantaneous
- Interruptions due to passage through the South Atlantic Anomaly (increased noise) and Earth Occultations (line-of-sight to target blocked)
- More detailed checks are then needed using the scheduling feasibility checker (stand-alone tool)

https://www.cosmos.esa.int/web/cheops-guest-observers-programme/scheduling-feasibility-checker/

Note: tools provide an estimate/guidance of visibility, but no guarantee

CHEOPS sky



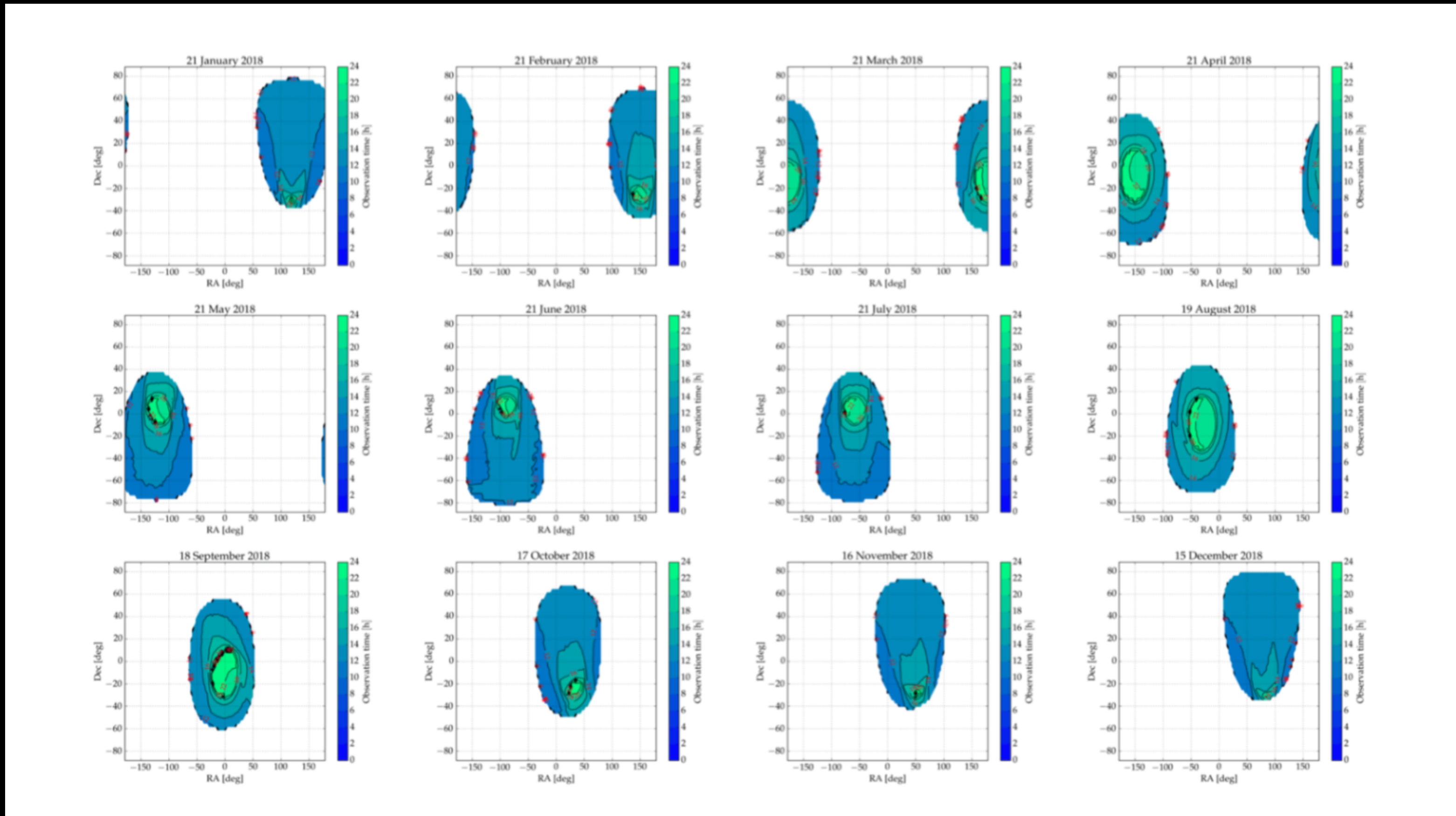


Kepler field

- Annual sky visibility map – no: days a given position in the sky can be observed during a year, allowing for up to 50% orbital interruptions
- Interruptions due to Earth occultations and passage through the South Atlantic Anomaly
- White regions are excluded
- Black line - ecliptic plane

CHEOPS

CHEOPS sky – instantaneous visibility maps



Number of hrs that a point in the sky can be observed with up to 50% interruptions on different days of the year

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Target availability

- The CHEOPS mission archive should be checked to see if a given target has already been observed:

  https://cheops.unige.ch/archive_browser/

  If it has, and the data is still proprietary, then contact cheops-support@cosmos.esa.int to request further details

- The list of reserved targets is available in machine-readable form at the time of opening of an AO
  - It can also be queried at any time from this webpage

    https://cheops.unige.ch/pht2/search-reserved-targets/

  This includes science targets that are part of both GTO and GO programmes

How much observing time to request?

- This will depend on your science objectives
- Photometric precision:
  - Integrating down – number of repeat visits

  → Use the Exposure Time Calculator /consider plots in section 3. of presentation and experiences of the CHEOPS Science Team (see Policies and Procedures document for the AO)

  - Detrending – duration of individual visits

  → Recommendation from the CHEOPS Science Team to include a minimum of 5 orbits out-of-transit (see Policies and Procedures document for the AO)

CHEOPS

Photometric precision

- The photometric precision that can be achieved with CHEOPS can be checked using the Exposure Time Calculator (ETC), developed by the Mission Consortium

https://cheops.unige.ch/pht2/exposure-time-calculator/

Exposure Time Calculator

Input Parameters

Target G Magnitude 0.0

Target Effective Temperature 0.0 **[K]**

Spectral type (stellar granulation) N/A

Defined time interval 0.0 **[h]**

Exposure Time 0.0 **[s]**

Right Ascension 0.0 **[hh:mm:ss / decimal deg]**

Declination 0.0 **[dd:mm:ss / decimal deg]**

Additional Parameters

- [ ] **Specify flux in CHEOPS passband**

Flux 0.0 **[e-/s]**

- [ ] **Specify visit/observation efficiency**

Efficiency 0.0 **[%]**

Calculate Clear

Exposure time guidelines

Minimum suggested exposure time: PSF peak at 10% of full well capacity

Maximum suggested exposure time: PSF peak at 85% of full well capacity, or the limit exposure time of 60s

Cheops ETC V 2.0.1

Copyright ©2018-2020 Space Research Institute, Austrian Academy of Sciences

Monika Lendl, Harald Ottacher

uses jsPDF

Copyright ©2010-2016 James Hall, https://github.com/MrRio/jsPDF

Exposure Time Calculator

Help ?

Input Parameters

Target G Magnitude	9.5	
Target Effective Temperature	5600	**[K]**
Spectral type (stellar granulation)	N/A	
Defined time interval	3.0	**[h]**
Exposure Time	60.0	**[s]**
Right Ascension	129.5	**[hh:mm:ss / decimal deg]**
Declination	37.2	**[dd:mm:ss / decimal deg]**

Additional Parameters

☐ **Specify flux in CHEOPS passband**

Flux	0.0	**[e-/s]**

☐ **Specify visit/observation efficiency**

Efficiency	0.0	**[%]**

Calculate Clear

Calculation Results

Computed or specified efficiency	56.9							[%]
Saturation level at PSF peak [% FWC]	73.1							[%]
ASSUMING 100% EFFICIENCY	**USER INPUT**	**1 MIN**	**10 MIN**	**30 MIN**	**1 H**	**3 H**	**6 H**	
Stellar granulation noise	0	0	0	0	0	0	0	[ppm]
Photon noise	17.79	238.74	75.5	43.59	30.82	17.79	12.58	[ppm]
Total noise including stellar granulation	51.61	282	106.72	72.29	59.15	51.61	49.53	[ppm]
Total noise without stellar granulation	51.61	282	106.72	72.29	59.15	51.61	49.53	[ppm]
ASSUMING COMPUTED OR SPECIFIED EFFICIENCY								
Stellar granulation noise	0	0	0	0	0	0	0	[ppm]
Photon noise	23.64	238.74	97.47	57.9	40.94	23.64	16.67	[ppm]
Total noise including stellar granulation	53.93	282.06	124.6	85.99	67.39	53.93	50.74	[ppm]
Total noise without stellar granulation	53.93	282.06	124.6	85.99	67.39	53.93	50.74	[ppm]

Comment on exported PDF

Export results

Measured vs. predicted photometric performance

- Overall, the ETC has proven to be a good predictor for the expected performance. However, the following trends have been seen:
  - For bright stars (G < 7), the ETC is usually slightly “pessimistic”. The origin of this discrepancy is under study, but it is likely that the noise allocated due to cosmic rays is overestimated for the bright stars.
  - For stars in the middle of the nominal magnitude range (G ~ 9), the ETC provides estimations very close to the measured values.
  - For fainter stars (G> 11) the ETC slightly underestimates the noise for short timescales (less than 3 hours). This is thought that contamination due to background stars (not included in the ETC) might be responsible for this.

Observing outside the nominal magnitude range

- CHEOPS has been designed to observe stars with $6 \leq G \leq 12$
- Main limitations for observing fainter stars:
  - background contamination (**straylight**, stars in the FoV)
  - bad pixels, esp. hot pixels
  - cosmic rays

Keep in mind that a 1-m ground-based telescope will perform photometrically better than CHEOPS for stars fainter than G ~ 13. Therefore, the reason to use CHEOPS in these cases should be well justified (e.g. long, uninterrupted observations needed).

- Main limitations for observing very bright stars:
  - should avoid saturation (i.e. very short exposure time)
  - strong self-smearing trails (manual reduction of images required)

Accessing CHEOPS data

- All CHEOPS data available through the CHEOPS mission archive:
  https://cheops.unige.ch/archive_browser/
- All CHEOPS science data subject to a proprietary period of 1 year after last visit, and no longer than 18 months after the first
- Applies to data taken in the Guaranteed Time Observing Programme AND the Guest Observers Programme

Applying for observing time - I

Two-step process:

- Phase I input via a dedicated proposal handling tool (PHT1). Includes:
  - Proposer information, abstract and target list
  - Science justification (pdf)
  - Technical justification (pdf)
  - Checks of reserved target list and archive (pdf)
  - ETC results (pdf)

coordinates of targets are used in observations - need to be checked very carefully

- Phase II input (PHT2) – detailed observing plan (observation requests)
  - Completed by Pis of successful proposals only

Applying for observing time - II

Two-step process:

- Phase I input via a dedicated proposal handling tool (PHT1).

https://www.cosmos.esa.int/web/cheops-guest-observers-programme/pht1-ao3

- Phase II input (PHT2) – detailed observing plan (observation requests)

https://cheops.unige.ch/pht2/your-profile/

Next Annual Announcement of Opportunity - AO-3

- AO-3, the final AO for the nominal mission, to come out on 15 February 2022, closes 15 March 2022 (midday, GMT)
- Covers the observing period between very end of June 2022 – end September 2023
- Webpage dedicated to the Call available at: https://www.cosmos.esa.int/web/cheops-guest-observers-programme/ao-3/
  - Pre-opening of the AO contains material/links to tools to aid in proposal preparation
  - Will include Policies and Procedures (guidelines + instructions for the Call) + links to tools, proposal handling tool and documentation

Timeline of AO-3

Date/duration of AO step	Comment
15 February 2022	AO-3 opens Webpage for the Call goes "live", including Policies and Procedures document Phase I Proposal Handling Tool can be used Reserved Target List is available
15 March 2022 (midday GMT)	AO-3 closes
Mid-May 2022	Time Allocation Committee meets List of proposals to be awarded time (priority 1/2/3) put forward to Director of Science
No later than 25 May 2022	Results of AO-3 are announced – PIs of all submitted programmes are informed of the status of their proposals
1 June 2022 (start)	Preparation of Phase II inputs. Steps include submission of observation requests (by 14 June), ESA/SOC review (by 21 June) and update (by 24 June)
Very end of June 2022	Start of observations from AO-3 programmes

All details of the Call will be available at:
https://www.cosmos.esa.int/web/cheops-guest-observers-programme/ao-3/

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Discretionary Programme

- Proposals can be submitted at any time
- Proposal components largely the same as for an AO, except:
    - Single target only, discovered or declared to be of high scientific interest since the time the most recent call closed

→ High interest target requirement waived for PhD student/early career researcher (up to 2 yrs since award of PhD)-led proposals

- Proposal evaluated by ESA project scientist + TAC chair
- Turnaround can be as short as few days
- Potential to be observed within 2-3 weeks of proposal being submitted

See https://www.cosmos.esa.int/web/cheops-guest-observers-programme/discretionary-programme for details

Annual Call vs. Discretionary Programme

Parameter	AOs	Discretionary Programme
% of annual GO time	minimum 75%	Up to 25%
When to submit	Once per year	All year round
What to submit	Full Proposal	Full Proposal
Max. # orbits	No maximum	Guideline
Target constraints	Not on reserved target list. Archive check also required	Not on reserved target list. Single target. Discovered/deemed to be of high scientific interest since last AO. Waiver on target type for PhD/early career researcher-led proposals
Eligibility	Open to all	Open to all

List of useful webpages

Webpages:

- CHEOPS for scientists – ESA website

  https://cosmos.esa.int/web/cheops/

- CHEOPS Mission Consortium website

  https://cheops.unibe.ch/

- CHEOPS mission archive

  https://cheops.unige.ch/archive_browser/

- CHEOPS in the Literature

  https://www.cosmos.esa.int/web/cheops/cheops-in-the-literature/

- CHEOPS data

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/cheops-data/

- CHEOPS Guest Observers Programme

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/

- CHEOPS AO-3

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/ao-3/

- CHEOPS Discretionary Programme

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/discretionary-programme/

- CHEOPS Guaranteed Time Programme

  https://www.cosmos.esa.int/web/cheops/the-cheops-guaranteed-time-observing-programme/

List of useful tools/manuals

Tools/manuals:

- CHEOPS Observers Manual

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/cheops-observers-manual/

- Reserved target list checker

  https://cheops.unige.ch/pht2/search-reserved-targets/

- Exposure Time Calculator (ETC)

  https://cheops.unige.ch/pht2/exposure-time-calculator/

- Scheduling Feasibility Checker

  https://www.cosmos.esa.int/web/cheops-guest-observers-programme/scheduling-feasibility-checker/

User-contributed tools/aids ("as-is"/no support):

- PYCHEOPS - python package for analysis of CHEOPS light curves

  https://pypi.org/project/pycheops/

- CHEOPSim (CHEOPS simulator)
  - Detailed in a paper by Futyan et al. https://doi.org/10.1051/0004-6361/201936616/
  - Source code, installation instructions and documentation: https://github.com/davefutyan/CHEOPSim/

- Linea – linear detrending package (python) for analysing CHEOPS observations

  https://linea.readthedocs.io/en/latest/

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5. Conclusions

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To summarise …

- CHEOPS is living up to its promise as an exoplanet follow-up mission
- First science results confirm the mission capabilities and scientific potential
- CHEOPS is available to the Scientific Community
- Next AO opens 15 February 2022, Discretionary Programme is open year round

Questions?

Feel free to send any questions that you have – big or small – to cheops-ps@cosmos.esa.int (ESA CHEOPS Project Scientist) and/or cheops-support@cosmos.esa.int (CHEOPS help-desk)

The CHEOPS Guest Observers Programme is run by a very small team. The response time to your questions may therefore be a little longer than for larger space missions/observatories