u^b SPACE RESEARCH & PLANETARY SCIENCES
UNIVERSITY OF BERN

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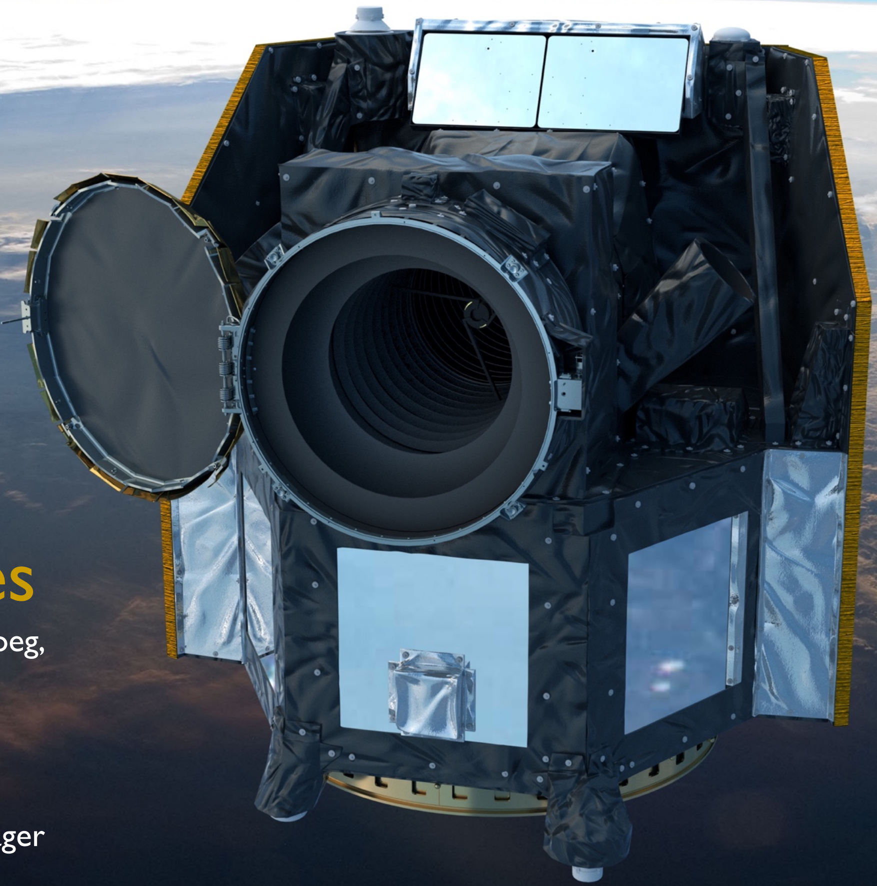
CHEOPS
CHARACTERISING EXOPLANET SATELLITE



CHEOPS Key Performance Figures

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On behalf of the CHEOPS mission consortium

CHEOPS Key Performances

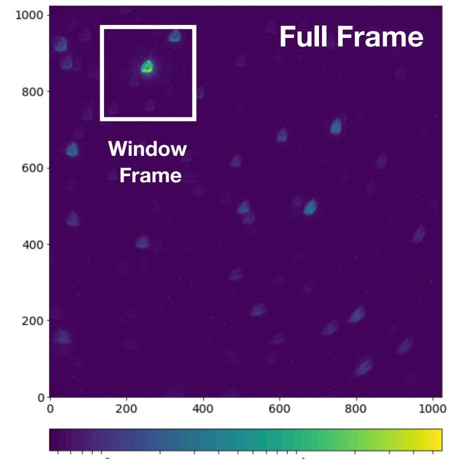
- The following slides provide a summary of key performances that have been determined during In-orbit commissioning. These include:
    - Photometric stability of a G~9 and G~12 star
    - Kelt-11b reference transit
    - Shape and extent of the Point Spread Function (PSF)
    - Guidance for assessing faint magnitude limits

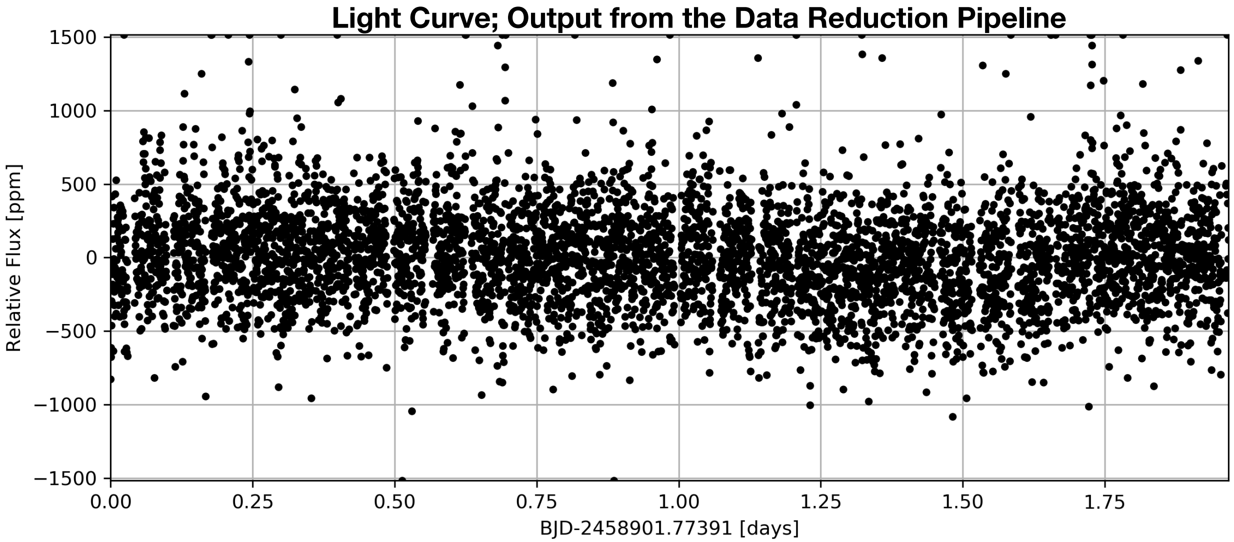
Data from the three reference observations referred to above, together with an observation of Pollux (CHEOPS-ultrabright), are available in the CHEOPS mission archive (https://cheops-archive.astro.unige.ch/archive_browser/). All have been processed with version cn02-20200619T125718 of the data reduction pipeline

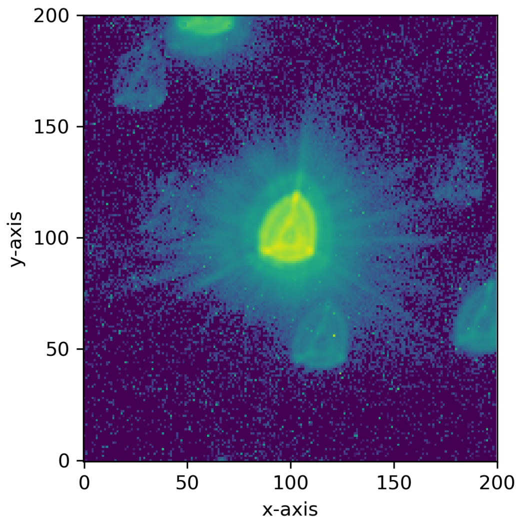
- Details provided in these slides supersede the equivalent performances given in the CHEOPS Observers Manual issued at the time of AO-1 (March 2019)
    - An additional plot illustrating the expected noise as a function of target magnitude is included here - this complement the sensitivity plots given in the CHEOPS Observers Manual. The user is referred to other documentation to instructions on how to calculate the integration times required to achieve specific sensitivities for different stellar spectral types.
- The CHEOPS spectral response/passband is very similar to that of GAIA. With this in mind, we are now using G magnitudes instead of V magnitudes for all target-specific information. The difference between V and G is negligible for earlier spectral types/hotter stars, becoming more significant for later, cooler stars and is around 1.1 for M3V, T_{eff}=3410 K

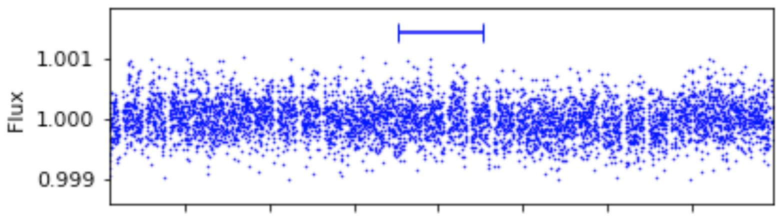
CHEOPS Photometric Performance (I)

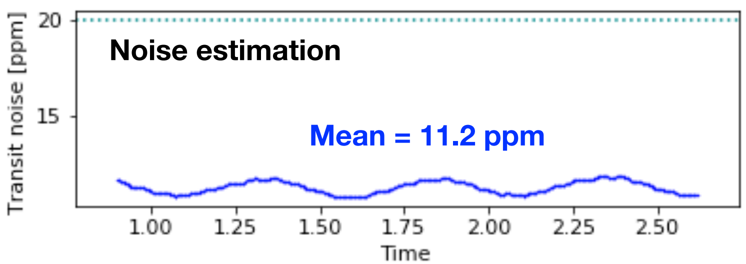
- Target: HD 88111; data set: PR300005_TG000101
- G_{mag} = 8.97 (V_{mag} = 9.18)
- T_{eff} = 5330 K (Gaia gives a radius of 0.9 R☉ for this star)
- Exposure time: 30 s (no stacking)
- Total integration time: 47 hours
- Aperture photometry using a circular aperture of 30 px in radius
- Data analysis using pycheops tool (https://github.com/pmaxted/pycheops)
- Photometric precision achieved in 6 hours (mean value): 11.2 ppm



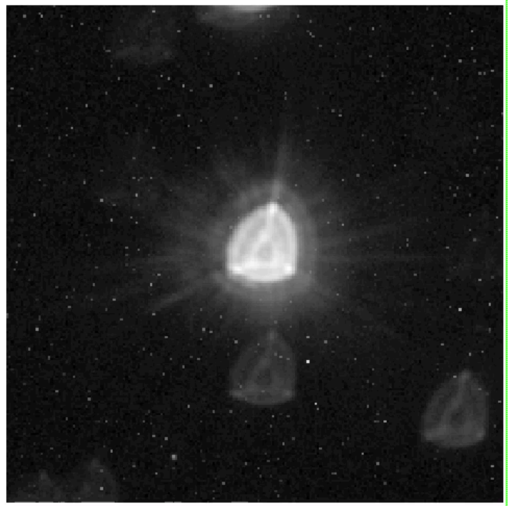








Noise metric: minimum transit depth that can be detected with S/N ratio of 1.
This is similar to the Kepler pipeline definition of CDPP*.
Computed using pycheops using the scaled error method, which is considered to be appropriate here as the scale factor is close to 1. When using the minimum error noise method, the precision achieved is 15.5 ppm in 6 hrs

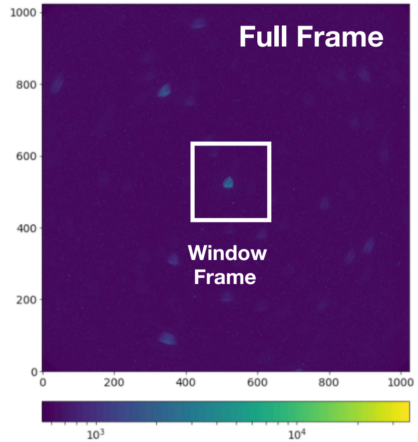


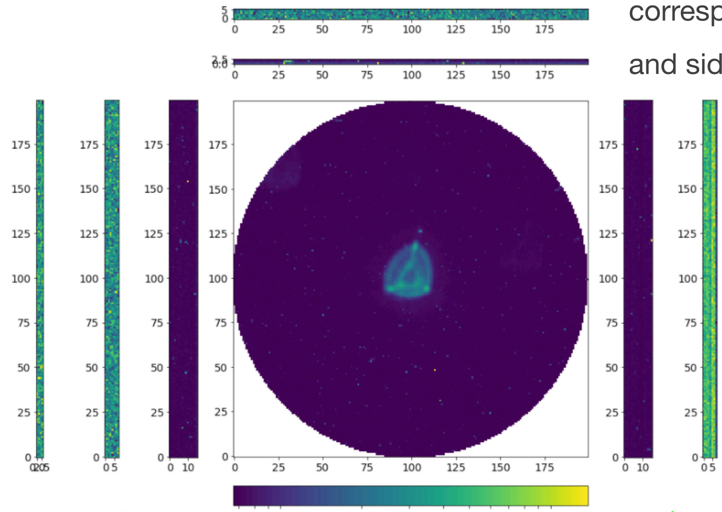
PR300005_TG000101.mov

Movie of one CHEOPS orbit (~ 100 minutes): Sequence of images showing the rotation of the field, cosmic rays hitting the detector and interruptions due to Earth occultations.

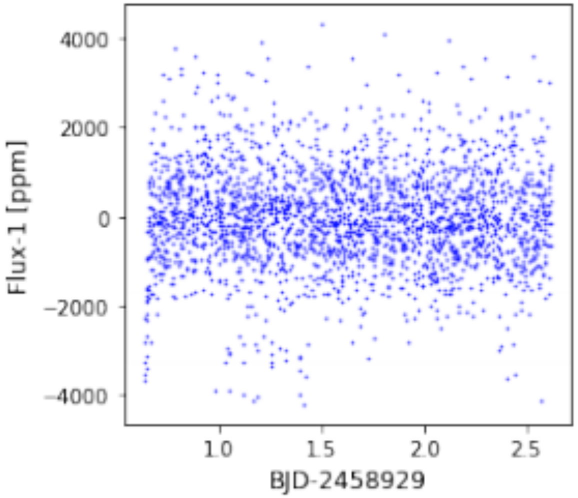
CHEOPS Photometric Performance (II)

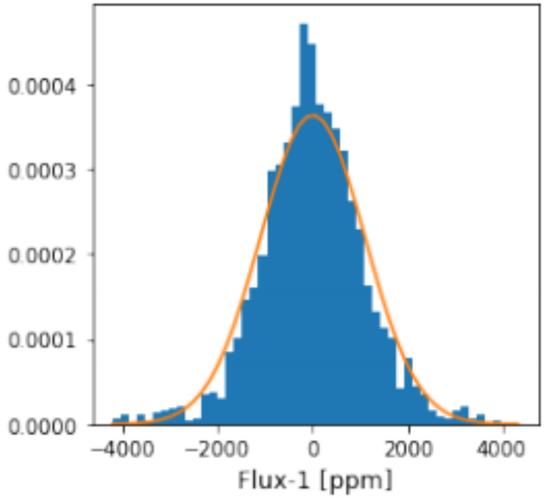
- Target: TYC 5502-1037-1; data set: PR300005_TG000501
- G_{mag} = 11.98 (V_{mag} = 11.92)
- T_{eff} = 4750 K (Gaia gives a radius of 0.7 R⊙ for this star)
- Exposure time: 60 s (no stacking)
- Total integration time: 47 hours
- Aperture photometry using a circular aperture of 25 px in radius
- Data analysis using pycheops tool (https://github.com/pmaxted/pycheops)
- Photometric precision achieved in 3 hours (mean value): 75 ppm

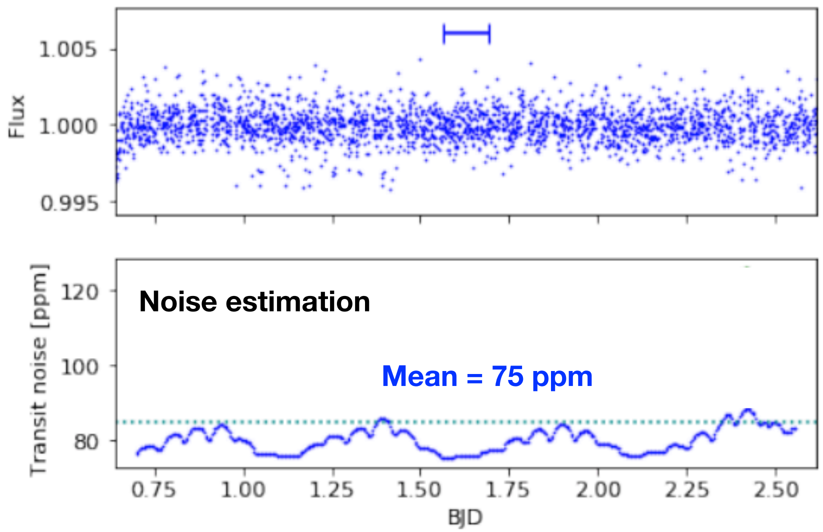




Circular window (default) and the corresponding top and side margins.







Noise metric: minimum transit depth that can be detected with S/N ratio of 1. This is similar to the Kepler pipeline definition of CDPP*. Computed using pycheops using the scaled error method, which is considered to be appropriate here as the scale factor is close to 1.

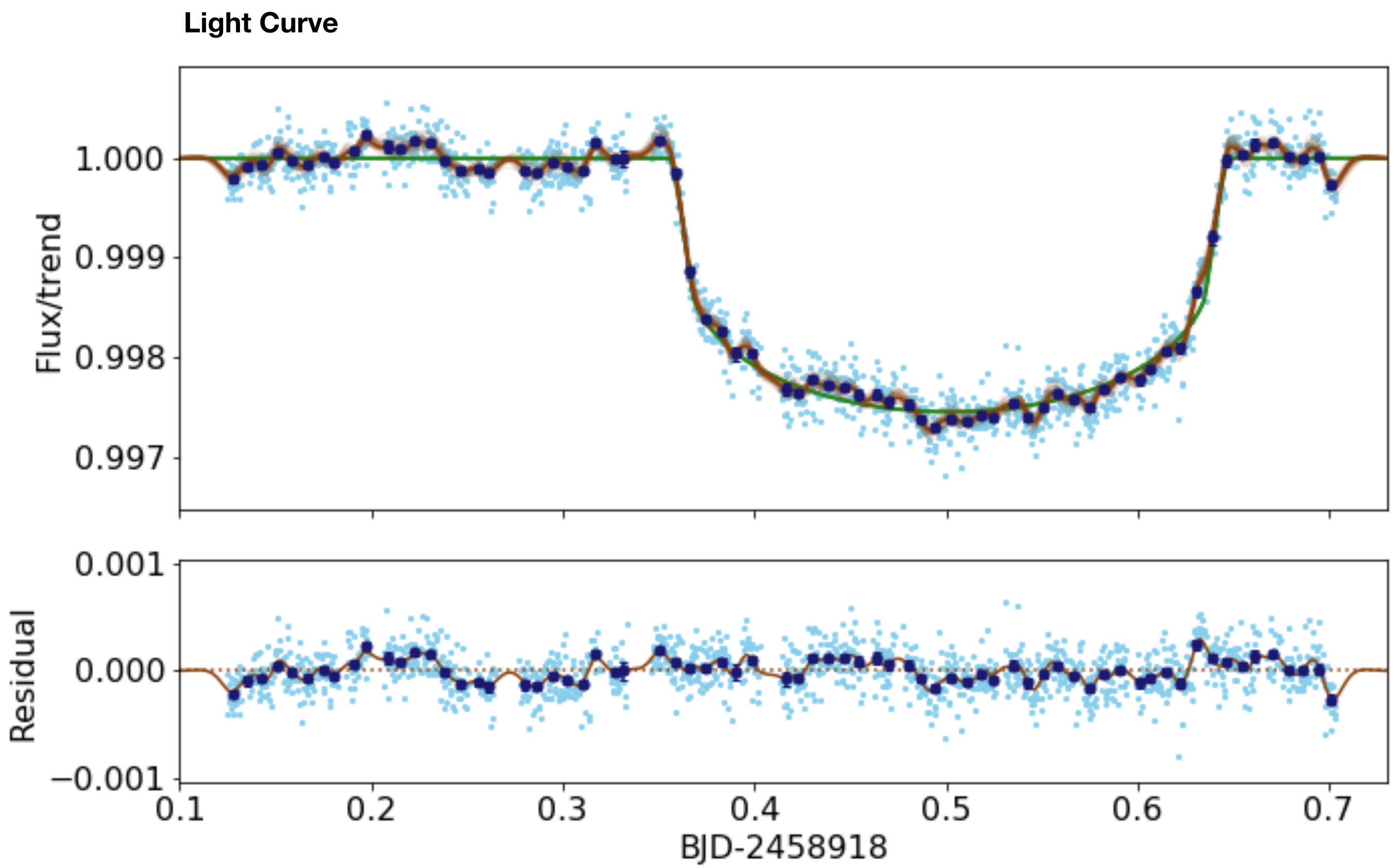
PR300005_TG000501.mov

Movie of one CHEOPS orbit (~ 100 minutes): Sequence of images showing the rotation of the field, cosmic rays hitting the detector and interruptions due to Earth occultations.

CHEOPS Photometric Performance (III)

Transit of Kelt-11b

- Target: Kelt-11; data set: PR300024_TG000101
- G_{mag} = 7.83 (V_{mag} =8.04)
- T_{eff} = 5370 K (Stellar radius 2.807 R☉)
- Exposure time: 15 s (stacking of 2 images)
- Total integration time: 14 hours
- Aperture photometry using a circular aperture of 29 px in radius
- Photometric precision achieved in 6 hours (mean value): 12 ppm



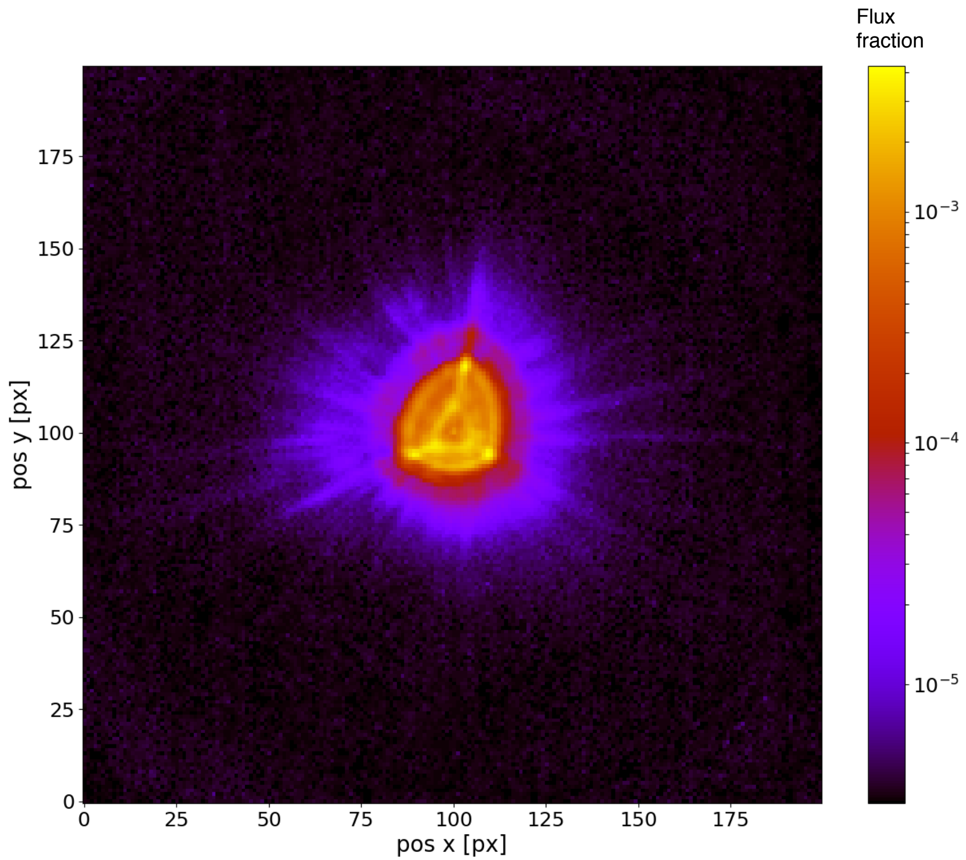
Observed light curve of KELT-11 and model fit from pycheops.

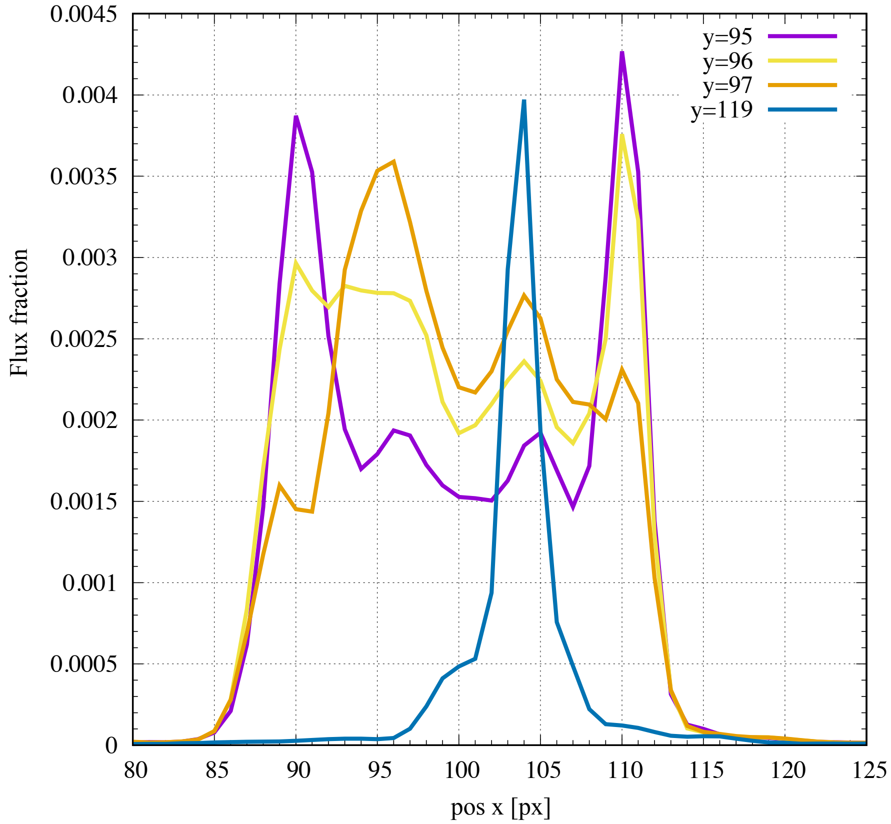
The measured fluxes (light blue points) are also shown binned in time (dark blue points). The transit model (green line, barely visible) is
shown in the upper panel together with the several realisations of our complete model including stellar noise
sampled from the posterior probability distribution.

The lower panel shows residuals from the transit model plus instrumental effects (blue points) together with the best-fit stellar noise model (brown line).

The radius obtained for Kelt-11b is 1.295 ± 0.025 R_{Jup}. This value is consistent with the one in Pepper et al. (2017) but with an error bar 5 times smaller.

PSF



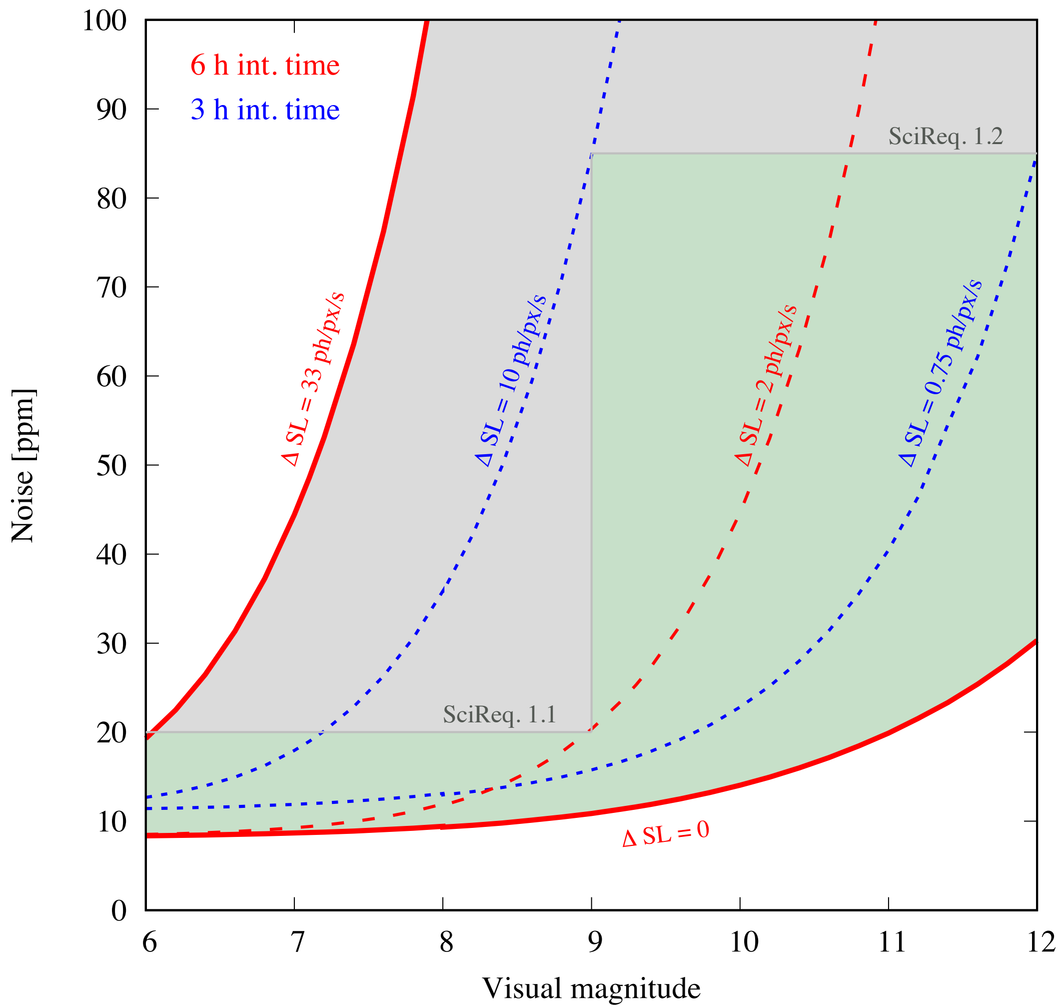


CHEOPS has a de-focused PSF where 90% of the total energy is inside a radius of ~16.5 pixels. In this figure the PSF flux distribution in white light is shown as measured during the in-orbit commissioning at the centre of the CCD.

PSF cuts along the y axis. The profiles contain the highest peaks of the PSF.

The PSF shape changes slightly with position on the CCD. For more details please refer to the PSF reference file:
CH_TU2020-01-29T00-00-00_REF_APP_WhiteCCDLocationPSF_V0101
which can be retrieved from the CHEOPS mission archive or from:
ftp://obsftp.unige.ch/pub/cheops/test_data/REF/WhitePSF/CH_TU2020-01-29T00-00-00_REF_APP_WhiteCCDLocationPSF_V0101.fits

Expected noise



Photometric noise as a function of the stellar magnitude based on the pre-launch assessment of the CHEOPS noise budget, based on a combination of simulated and measured (in the on-ground calibration campaign) inputs for individual noise contributors. The solid red curve labeled "ΔSL = 0" (no stray light contamination) represents the noise floor of CHEOPS (calculated for an M0 star). The solid red curve labeled "ΔS L = 33 ph/px/s" shows the noise behaviour when the stray light contamination dominates the total noise for all magnitudes.The green region defines the conditions that satisfy the science performance requirements.

Faint magnitude limit

- CHEOPS was designed to observe stars in the magnitude range G = 6-12

- Active tracking (Payload in the Loop) will be off for stars fainter than G ~11. This, together with the excellent absolute pointing of CHEOPS, means that neither pointing and target acquisition limit the magnitude of the target that can be observed.

- The main limitations to observing faint stars are stray light & zodiacal light together with the dark current (DC) in “bad” pixels caused by radiation damage.

- Potential CHEOPS users should carefully assess their sensitivity requirements for targets outside the design magnitude range (G > 12), taking the following into account:

  - the highest peak of the PSF is equal to the mean value of the DC of hot pixels (~12e-/s) for a G2V/solar-like star of G ~14.5

  - the mean value of a pixel in the PSF is equal to the 99%tile of hot pixels (~6 e-/s) for a G2V/solar-like star of G~13.8

  - the mean value of a pixel in the PSF is equal to the average zodiacal light (~2.5 e-/s) for a G2V/solar-like star of G ~14.8