Characterizing ExOPlanet Satellite (CHEOPS)

CHEOPS-UBE-INST-TN-083

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Earth Stray Light time series for CHEOPSim

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List of documents

Applicable documents:	
AD01	**CHEOPS-EST-SCI-RS-001_I2.7 CHEOPS Science Requirements Document**
AD02	**CHEOPS-UBE-INST-RP-001_i3.3 Noise Budget**

Reference documents:	
RD01	**CHEOPS-UBE-MA-LI-005-i0.1_List of Abbreviations**
RD02	**Simulation of Stray Light Contamination on CHEOPS Detector (Master Thesis, Thibault Kuntzer)**
RD03	**CHEOPS-UBE-INST-TN-001 (Earth Stray Light Calculations)**
RD04	**CHEOPS-UBE-INST-TN-033_i1.1 (Sky Coverage: impact of the Earth Stray Light on the observable sky and implications for the PST)**
RD05	**CHEOPS-ESOC-TN-003 (CHEOPS Sky Coverage Analysis – Final)**
RD06	**CHEOPS-INAF-INST-RP-001-3.5-TEL-SL**
RD07	**CHEOPS-UBE-INST-TN-074 (Sky coverage analysis considering the CHEOPS instrument performance)**

1 Introduction

Science Requirements (SciReqs.) 3.1 to 3.5 (see AD01) impose constraints on the accessible sky of CHEOPS. The residual Earth Stray Light (eSL) is not negligible and compliance with the requirements has been extensively studied (RD02 through RD05). The aim of this work is to provide CHEOPSim the eSL photon flux. The eSL is constant across the detector plate, but varies as a function of the position in the orbit (the true anomaly), the orbit height, the date and the pointing direction. To avoid having to make assumptions on the date of observation and the position of the star in the plane of the sky, we provide four different eSL time series that use typical pointings taken at different seasons. Several orbits are computed and averaged to get a folded average flux for each pointing.

1.1 Scope of the document

This document summarizes the steps undertaken and the assumptions necessary to generate the times series of Earth Stray Light that impact the detector. The results presented in this document are based on the model described in RD02 through RD05 and uses the PST described in RD06.

1.2 Abbreviations and Acronyms

For general abbreviation, refer to CHEOPS' List of Abbreviations (RD01).

2 Simulations of the eSL photon fluxes

In this section, the pipeline for the generation of eSL is briefly described.

2.1 The observable regions in the sky

The authorised regions in the sky are computed for an orbit at 650 km with a RAAN of 6am with the following constraints:

Minimum Sun separation angle:	120°
Minimum Earth limb separation angle:	25°
Minimum Moon separation angle:	N/A (position of the Moon depends on date)
Minimum altitude of pointing above surface:	100 km
SAA model:	N/A

No SAA model was assumed in this work since the crossing times depend on the date and we aim at only computing the eSL signal here. The position of the Moon in the sky also depends on the date, thus it was not included in the computations. The time resolution of the observable regions in the sky is 60 seconds.

The lowest possible orbit was chosen to simulate the worst case scenario in terms of eSL contamination.

2.2 The eSL simulation

As previously done in RD07, we will use the code SALSA (RD02, RD03) to estimate the sky coverage for different orbits. In this work, however, we simulate only 10 orbits at three given dates. The eSL signal is fairly constant over 10 orbits (which spans ~16 hours at 650 km) which gives the possibility to fold the eSL from 10 to 1 orbit.

The Earth is simulated as a perfect sphere that reflects all the incoming sun-light (albedo = 1). In reality, the albedo of the Earth depends on the kind of surface and the weather. The mean albedo of the Earth is ~0.3-0.5, but in reality it can be far from the mean, being ~ 0.7 for the oceans and ~0.9 for pure ice. Clouds can have an albedo as high as 0.8. The most extreme pointing of CHEOPS place the line of sight directly over the poles of the Earth. Setting the albedo to 1 provides a worst case estimate of the Earth stray light values.

PST assumes:

- Particulate contamination: 300 ppm,
- Monochromatic light (wavelength= 400 nm, worst case scenario),
- M1 Microroughness: 10Å rms@400 nm,
- M2, M3 and BEO lenses Microroughness: 5Å rms@400 nm.

COATING Internal Baffle, Back End Optics & SPIDERS	**COATING External Secondary Baffle Primary**	**COATING External Primary Baffle**	**COATING M1 Border**	**Telescope Focal Diaphragm Diameter (mm)**	**BEO Internal Pupil Diaphragm Diameter (mm)**
Map	AEROGLAZE Z306+ACKTAR FRACTALBLACK	AEROGLAZE Z306	Black scattering (FB)	11	12

The PST used for the computations is

ANGLE PST[1]

1 Some values of this table are slightly different than those in table 6 of RD06. This is due to a small correction in the contribution of the spiders from the original table calculated in April 2015 (the one used in this document). This small difference does not affect the results.

25	7.434E-09
30	2.936E-09
35	1.797E-10
40	1.11E-10
45	6.75E-11
50	4.385E-11
55	2.588E-11
60	1.035E-11
65	2.143E-12
70	2.837E-13
75	2.256E-13

Values for angles larger than 75° are estimated by the value of the PST at 75°.

Note: the final PST will be available in a couple of months. Simulations will be updated accordingly when INAF delivers their final compuations.

2.3 Post-processing: generation of the time series

The output of SALSA is a file per minute with the eSL photon flux for each possible pointing. At the post-processing stage, we select pointings that can be continuously observed for 10 orbits. eSL fluxes for those pointings are then folded onto a single orbit and rebinned with a resolution of 100 eSL estimates per orbits (the time resolution is now 58.5 seconds). The time series is then interpolated[2] using a one-dimensional interpolating spline of degree 3 and finally rebinned such that the time resolution is 30 seconds.

3 The different time series

The four different cases are:

Name	Start date	# evaluated pointings	Notes
low	10.04.2018 10:00	3102	Median flux of all possible pointings
medium	04.02.2018 10:00	696	Median flux of all possible pointings
high	21.12.2018 10:00	423	Median flux of all possible pointings
Ultra high	21.12.2018 10:00	423	eSL flux peaks at 2 ph/sec/px

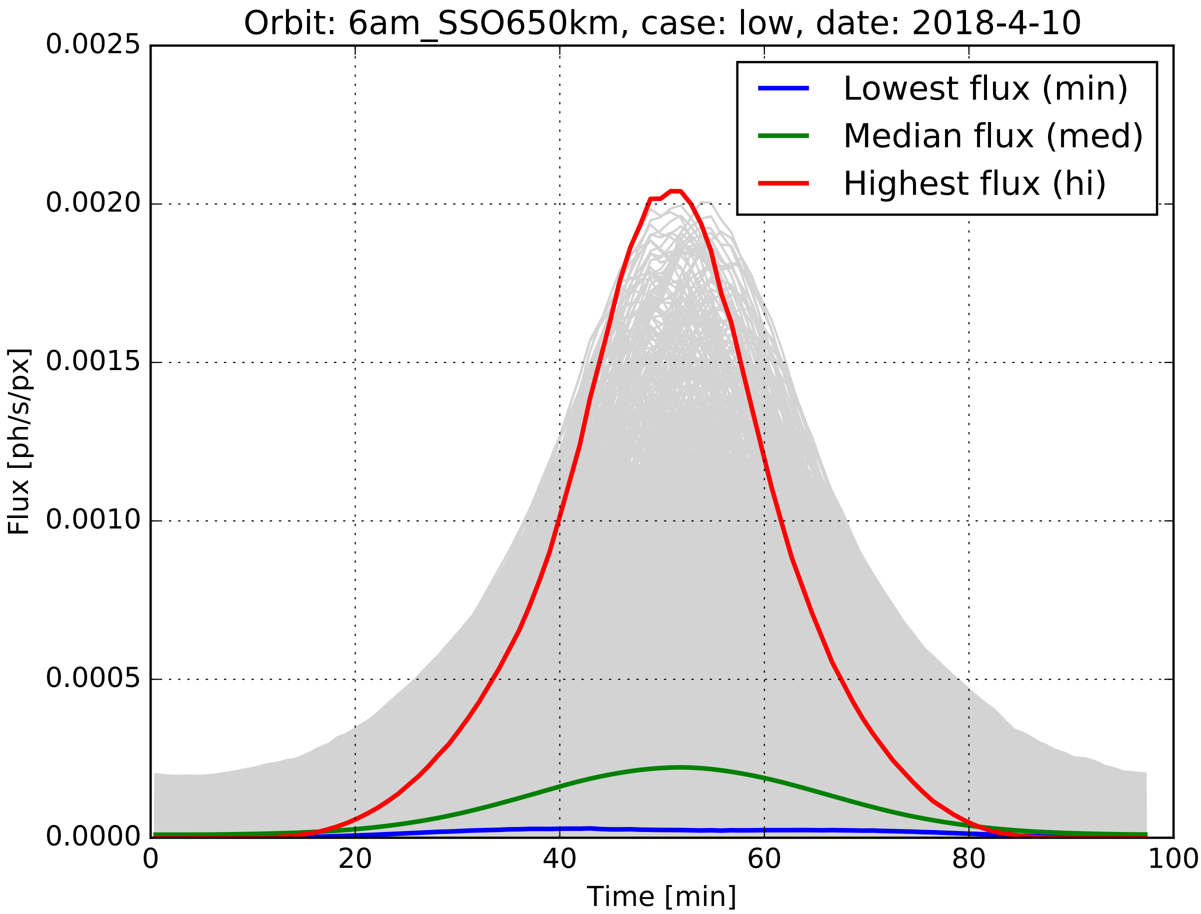
2 Using the Scipy function scipy.interpolate.InterpolatedUnivariateSpline.

catastrophic	21.12.2018 10:00	423	Highest integrated flux over simulation

3.1 Case “low”

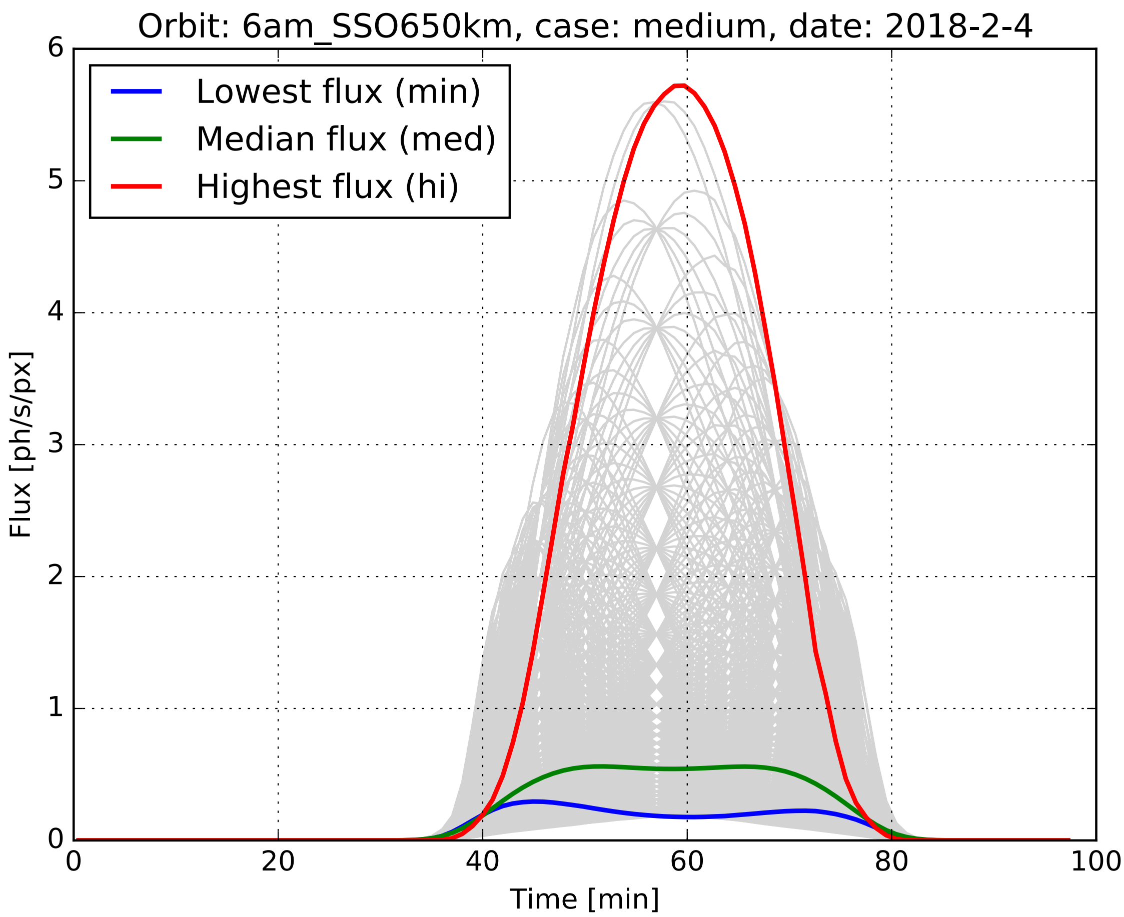
The selected time series is the median flux. The file name is:

sl_timeseries_6am_SSO650km_low.dat



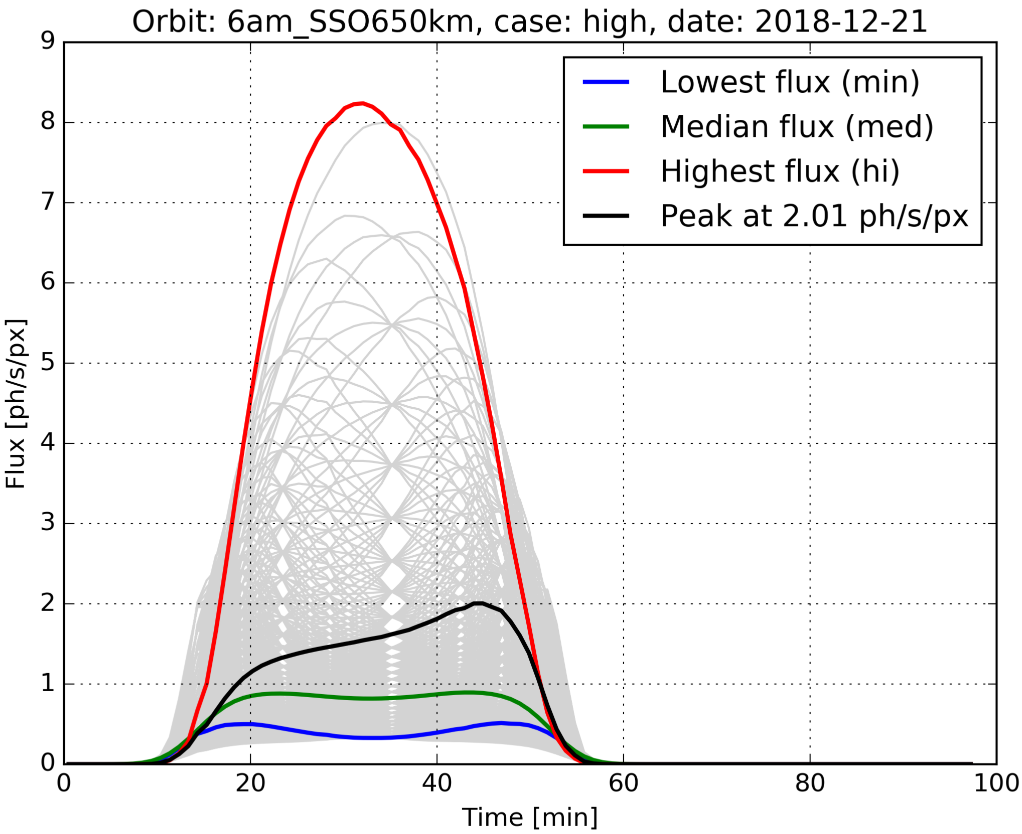
3.2 Case “medium”

The selected time series is the median flux. The file name is:
sl_timeseries_6am_SSO650km_medium.dat



3.3 Cases "high", "ultra high" and "catastrophic"

The "catastrophic" case is the red one, which was selected by considering its integrated flux over the orbit (i.e. the catastrophic case is the pointing that generates the most photons). The file is: sl_timeseries_6am_SSO650km_catastrophic.dat. The median flux is the green one, selected as the "high" case. The file is: sl_timeseries_6am_SSO650km_high.dat. The "ultra high" case corresponds to an orbit where the eSL flux peaks at 2 ph/sec/px. This case was selected because it resembles the values used in the Noise Budget for the SL noise. The file is: sl_timeseries_6am_SSO650km_high_select_2.01peak.dat.



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