CHEOPS ETC Tools

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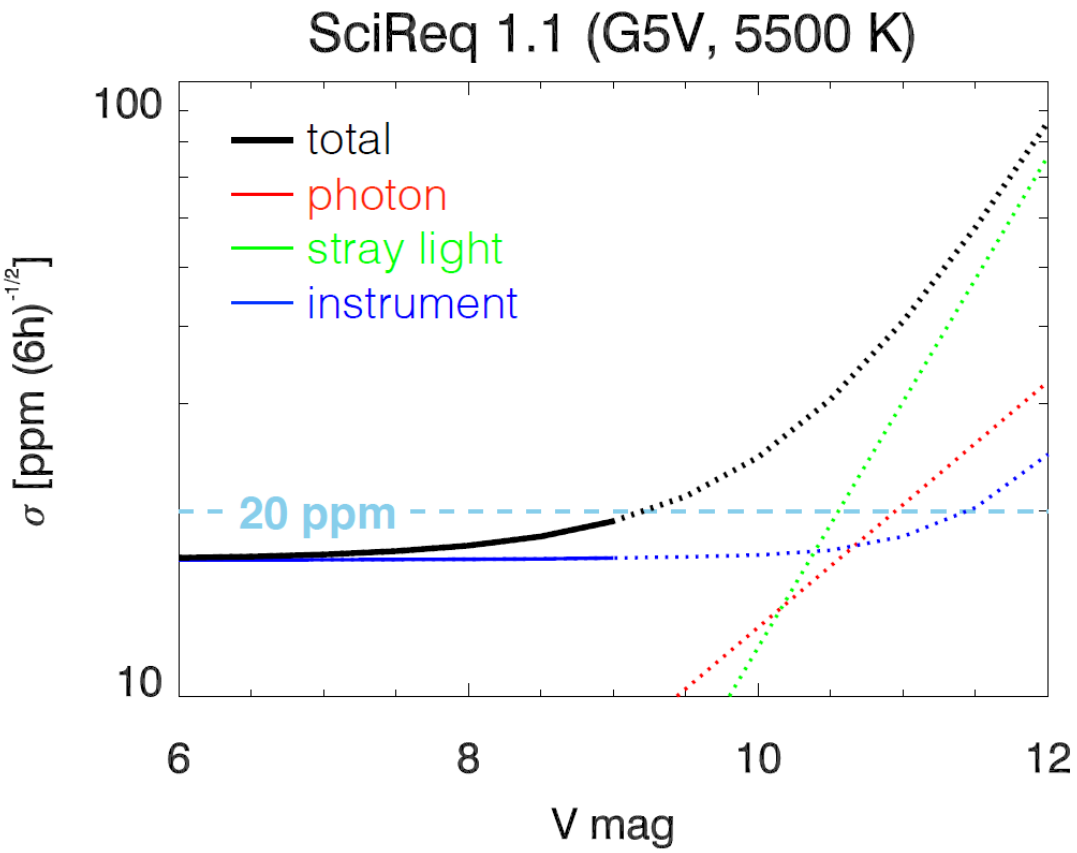
From idea to observation

CHEOPS photometric precision



What about *your* observations?

CHEOPS ETC tools

Exposure Time Calculator

What is the photometric precision reached by CHEOPS in a *given time interval?*

Useful for: a wide range of general science questions

Transit Signal to Noise Predictor

What is the Signal to Noise reached on the *detection of a transit* for a given planetary sysem?

Useful for: exoplaent transit detection and depth measurements

CHEOPS ETC tools

Exposure Time Calculator

Input:
- stellar magnitude
- stellar type
- duration of interest
- optional: coordinates (RA, DEC)

Output:
- photometric precision reached over the total specified time bin

Transit Signal to Noise Predictor

Input:
- stellar magnitude
- stellar type
- planetary radius
- planetary period
- transit impact parameter
- orbital eccentricity, argument of periastron
- optional: coordinates

Output:
- Signal to Noise of the transit detection

Noise Components

Backbone of the ETC tools is the CHEOPS Noise Budget
(see A. Fortier's talk)

White Noise:

Scales with sqrt(time)

- Photon noise
- Sky background
- Readout noise
- Analog chain (random component)
- Quantization
- Cosmic Rays

Red Noise:

Fixed amplitude

- Flat field + jitter
- Dark variability
- Analog electronics
- Timing
- Gain and quantum efficiency variability

Pink Noise:

Other behaviour

- Stellar granulation
- Straylight

Assumptions

General:

- Time of interest input by user
- Individual noise components are independent

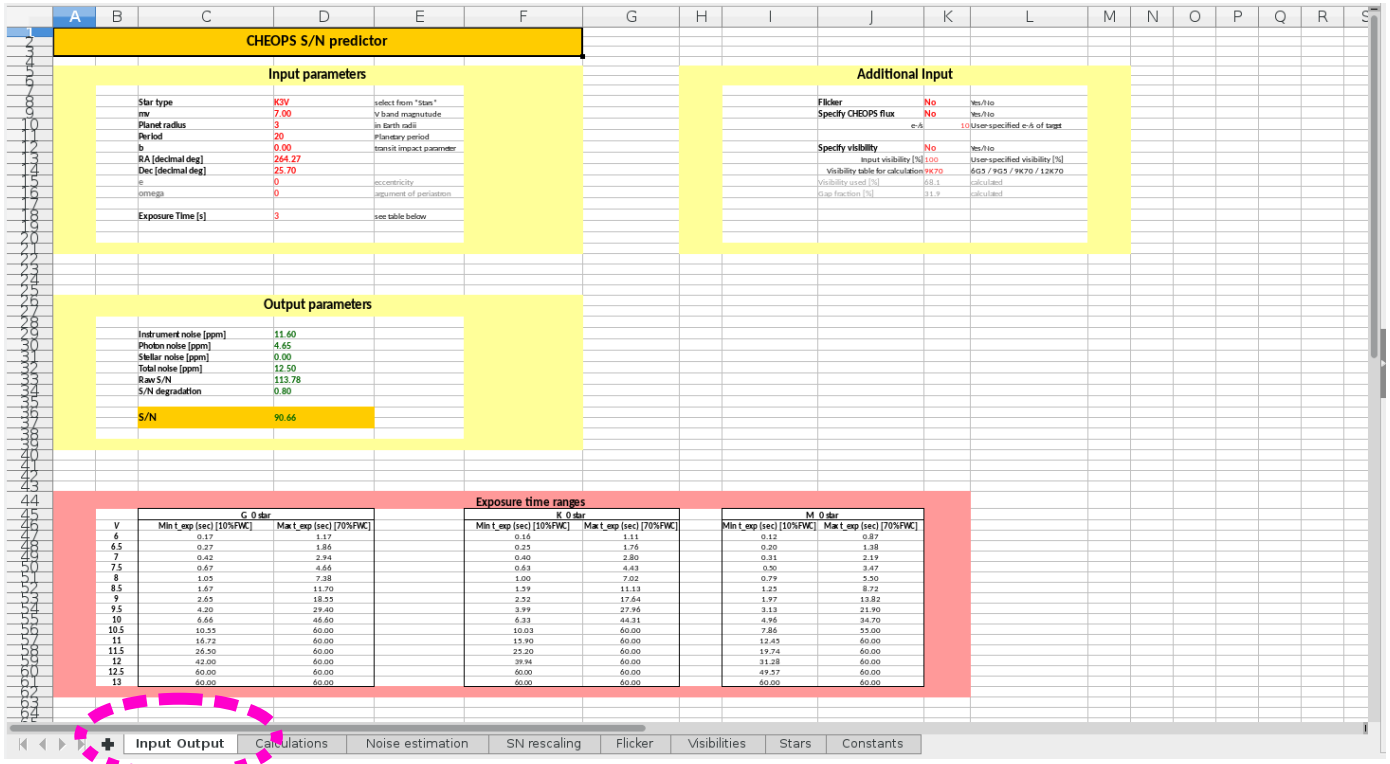
  → they add in quadrature

For Transit SNR predictor:

- Systematics well-characterized: they don't affect the in- and out-of-transit measurement individually
- Duration of out-of-transit observations = twice the duration of transit
- $M_P << M_S$

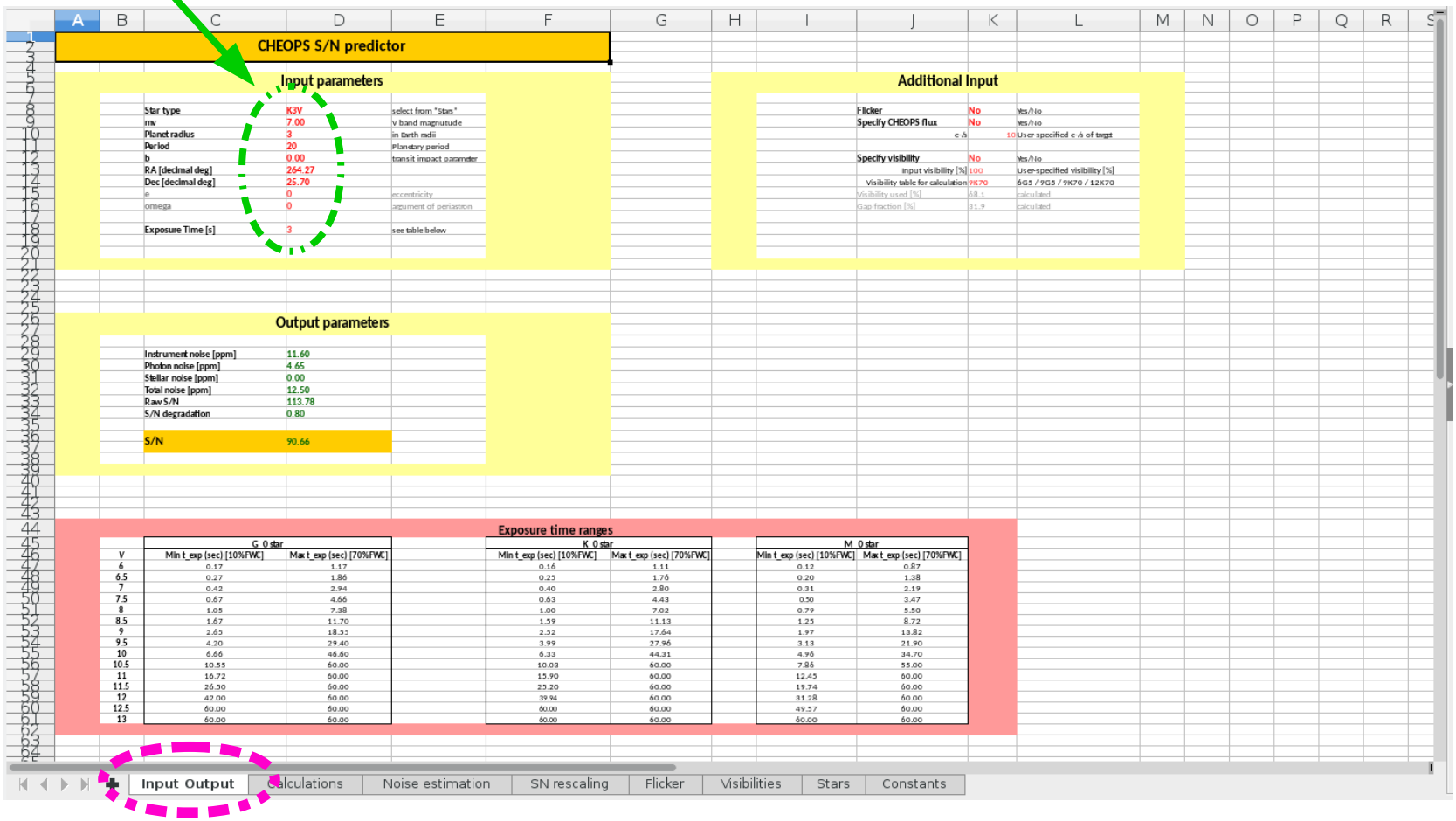
In a nutshell

- The ETC tools are spreadsheet based
- Input/Output on the top page
- Calculations carried out on the other pages



In a nutshell – Transit SNR predictor

Enter system parameters



CHEOPS S/N predictor

Input parameters

Star type	K3V	select from "Stars"
mv	7.00	V band magnitude
Planet radius	3	in Earth radii
Period	20	Planetary period
b	0.00	transit impact parameter
RA [decimal deg]	264.27	
Dec [decimal deg]	25.70	
e	0	eccentricity
omega	0	argument of periastron
Exposure Time [s]	3	see table below

Additional Input

Flicker	No	Yes/No
Specify CHEOPS flux	No	Yes/No
e-/s	10	User-specified e-/s of target
Specify visibility	No	Yes/No
Input visibility [%]	100	User-specified visibility [%]
Visibility table for calculation	9K70	6G5 / 9G5 / 9K70 / 12K70
Visibility used [%]	68.1	calculated
Gap fraction [%]	31.9	calculated

Output parameters

Instrument noise [ppm]	11.60
Photon noise [ppm]	4.65
Stellar noise [ppm]	0.00
Total noise [ppm]	12.50
Raw S/N	113.78
S/N degradation	0.80
S/N	90.66

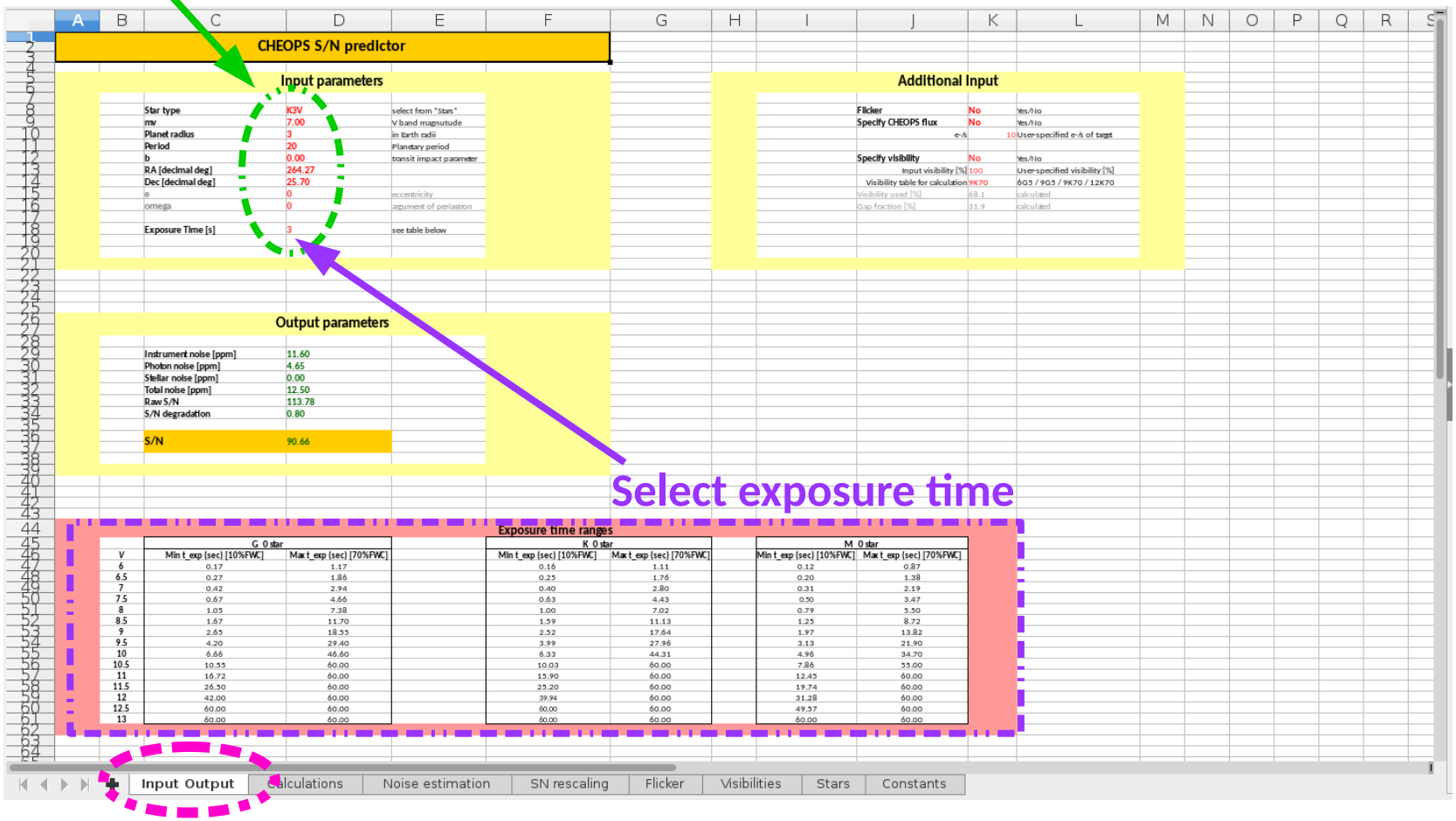
Exposure time ranges

V	G_0 star		K_0 star		M_0 star	
	Min t_exp (sec) [10%FWC]	Max t_exp (sec) [70%FWC]	Min t_exp (sec) [10%FWC]	Max t_exp (sec) [70%FWC]	Min t_exp (sec) [10%FWC]	Max t_exp (sec) [70%FWC]
6	0.17	1.17	0.16	1.11	0.12	0.87
6.5	0.27	1.86	0.25	1.76	0.20	1.38
7	0.42	2.94	0.40	2.80	0.31	2.19
7.5	0.67	4.66	0.63	4.43	0.50	3.47
8	1.05	7.38	1.00	7.02	0.79	5.50
8.5	1.67	11.70	1.59	11.13	1.25	8.72
9	2.65	18.55	2.52	17.64	1.97	13.82
9.5	4.20	29.40	3.99	27.96	3.13	21.90
10	6.66	46.60	6.33	44.31	4.96	34.70
10.5	10.55	60.00	10.03	60.00	7.86	55.00
11	16.72	60.00	15.90	60.00	12.45	60.00
11.5	26.50	60.00	25.20	60.00	19.74	60.00
12	42.00	60.00	39.94	60.00	31.28	60.00
12.5	60.00	60.00	60.00	60.00	49.57	60.00
13	60.00	60.00	60.00	60.00	60.00	60.00

Input Output | Calculations | Noise estimation | SN rescaling | Flicker | Visibilities | Stars | Constants

In a nutshell – Transit SNR predictor

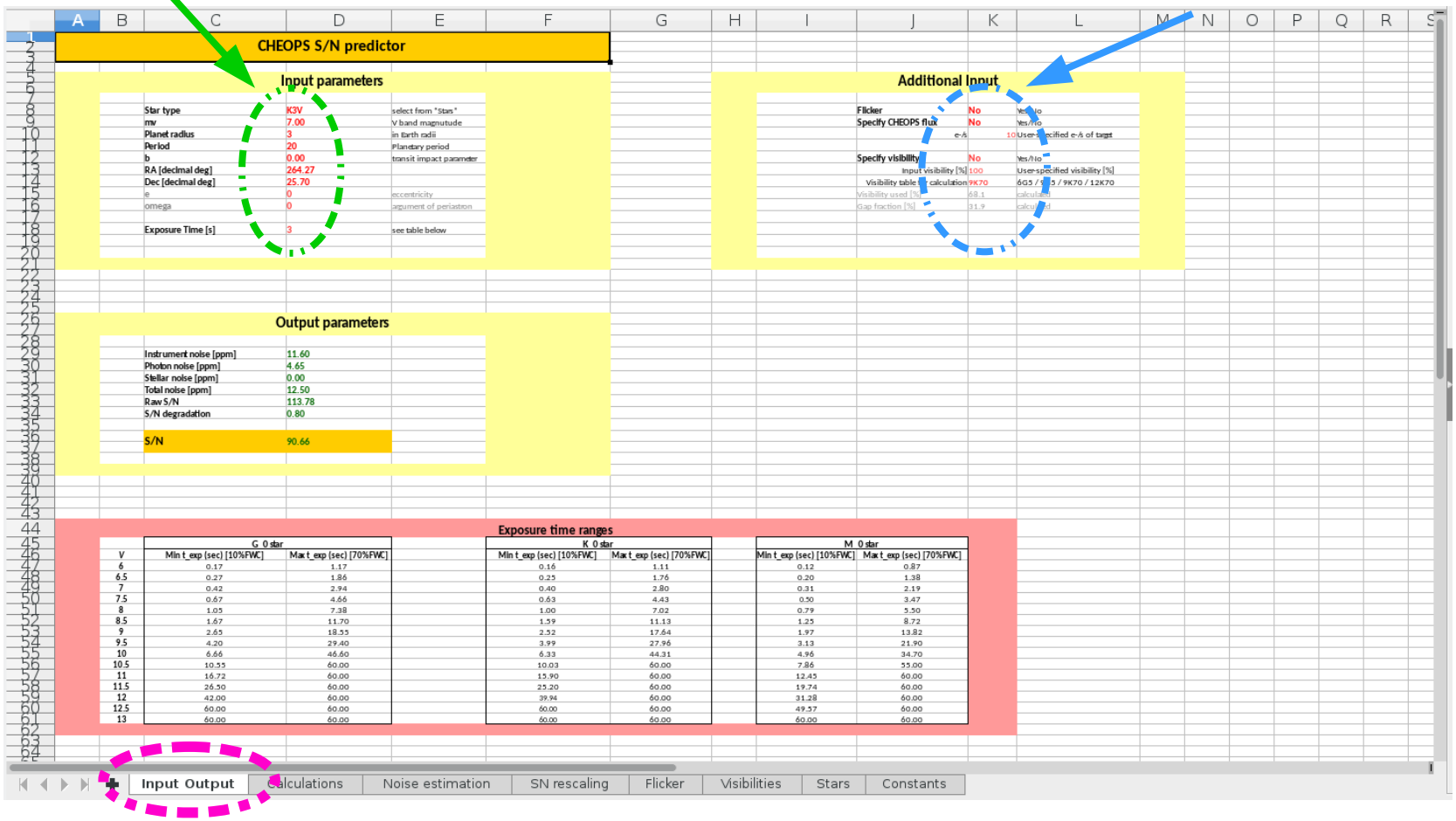
Enter system parameters



In a nutshell – Transit SNR predictor

Enter system parameters

Include flicker, specify visibility



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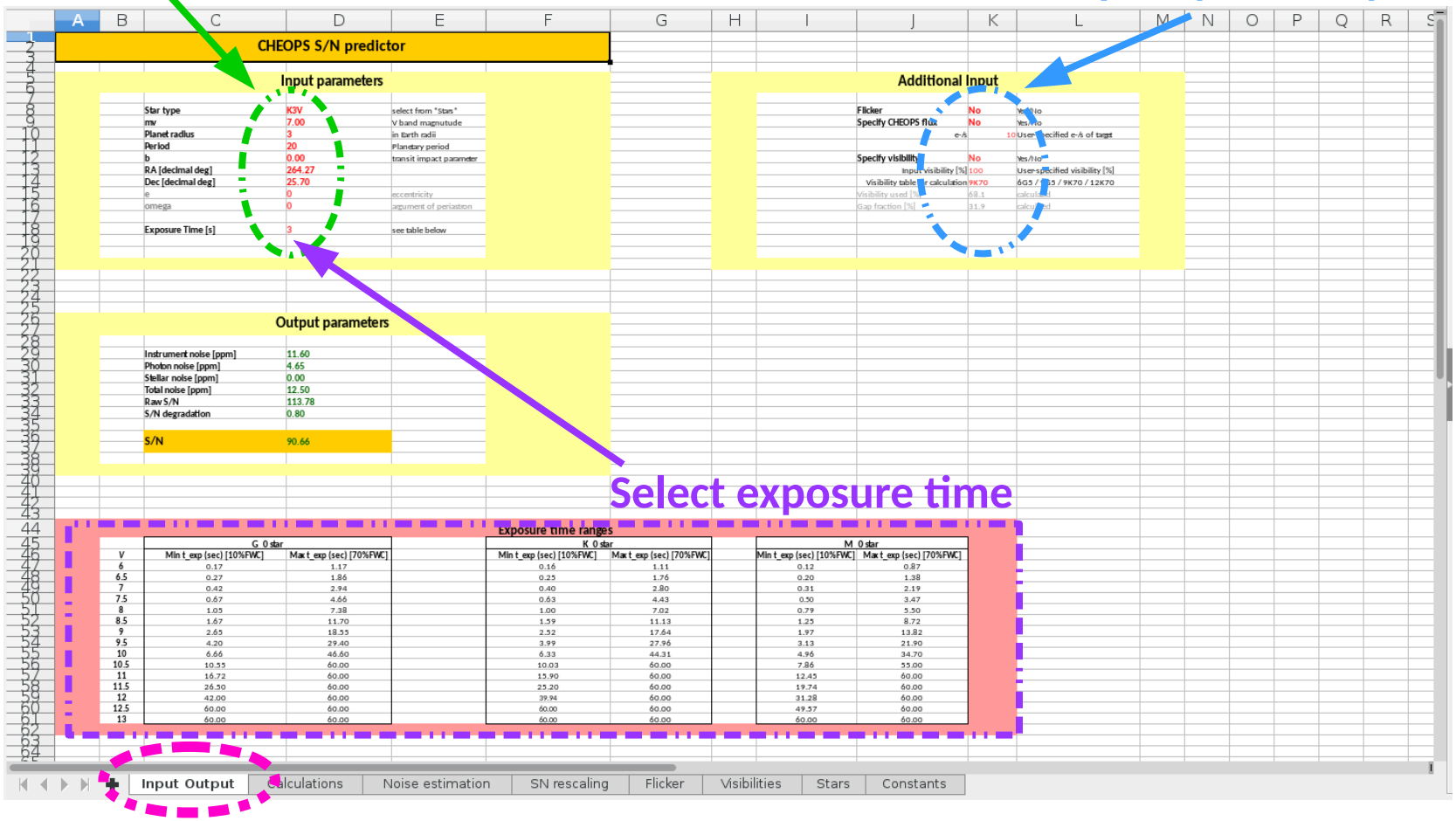
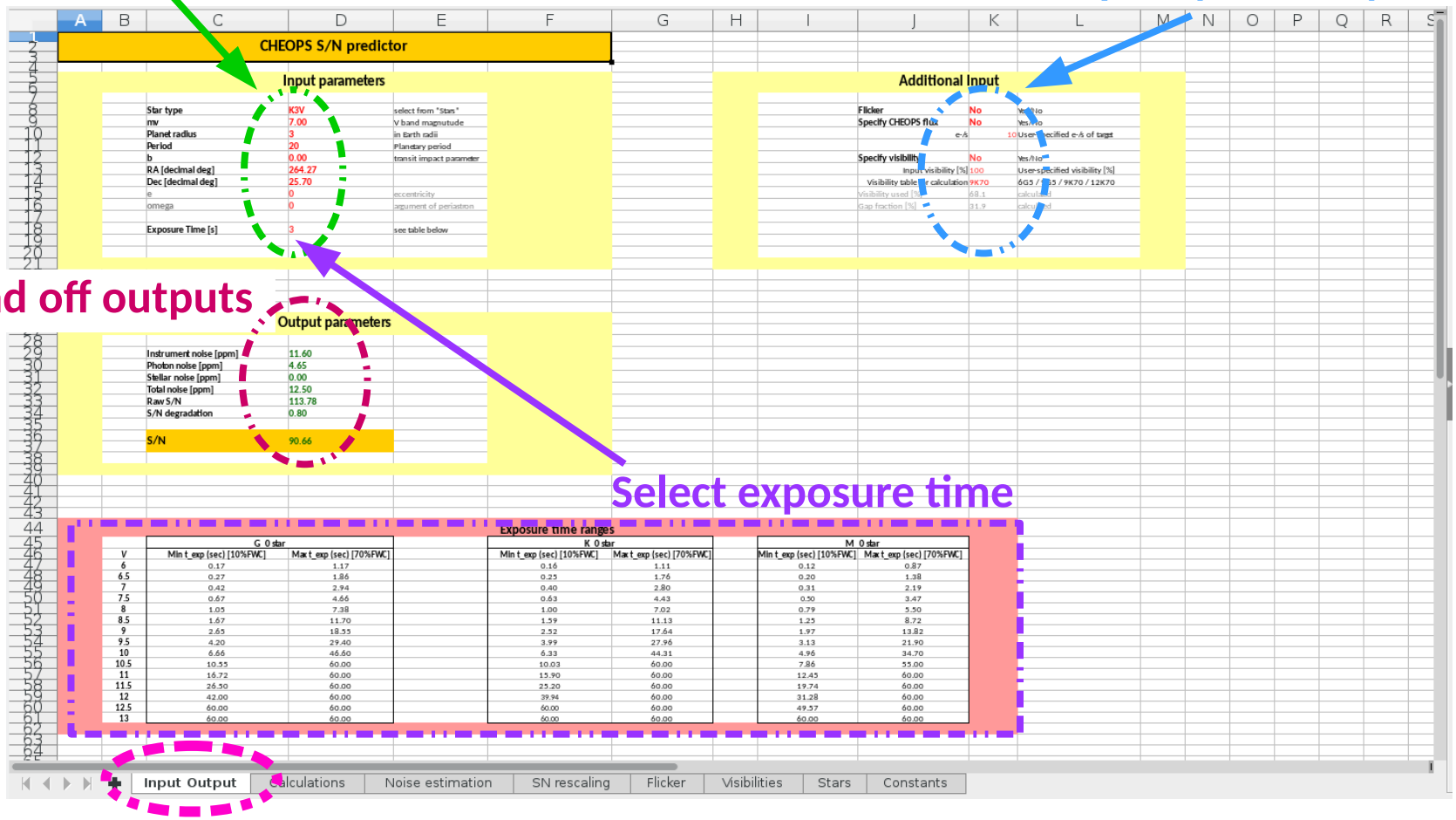


In a nutshell – Transit SNR predictor

Enter system parameters

Include flicker, specify visibility

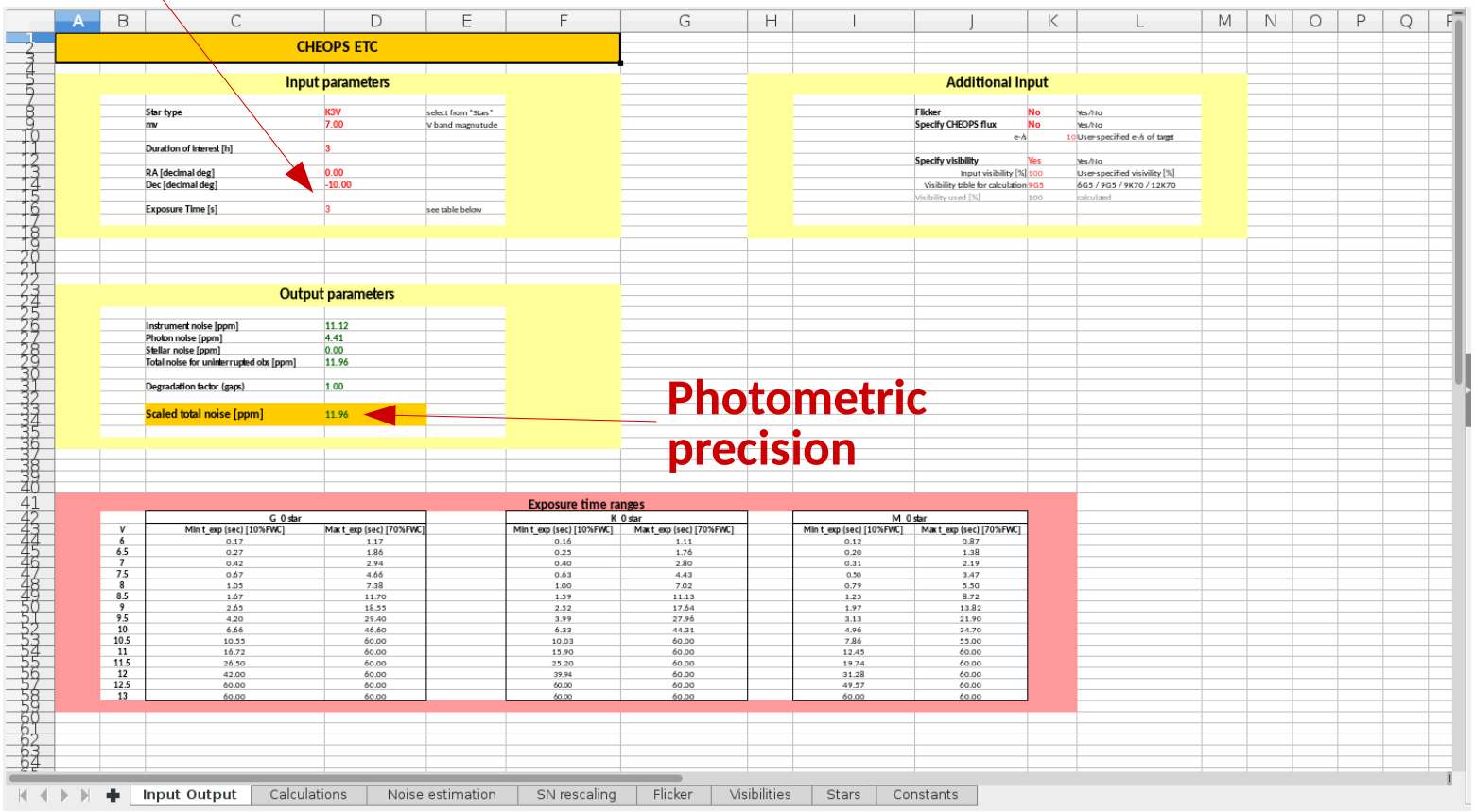


Read off outputs

Select exposure time

In a nutshell – ETC

Timescale



CHEOPS ETC

Input parameters

Star type	K3V	select from "Stars"
mv	7.00	V band magnutude
Duration of interest [h]	3	
RA [decimal deg]	0.00	
Dec [decimal deg]	-10.00	
Exposure Time [s]	3	see table below

Additional Input

Flicker	No	Yes/No
Specify CHEOPS flux	No	Yes/No
e-/s	10	User-specified e-/s of target
Specify visibility	Yes	Yes/No
Input visibility [%]	100	User-specified visivility [%]
Visibility table for calculation	9G5	6G5 / 9G5 / 9K70 / 12K70
Visibility used [%]	100	calculated

Output parameters

Instrument noise [ppm]	11.12
Photon noise [ppm]	4.41
Stellar noise [ppm]	0.00
Total noise for uninterrupted obs [ppm]	11.96
Degradation factor (gaps)	1.00
Scaled total noise [ppm]	11.96

Photometric precision

Exposure time ranges

V	G 0 star Min t_exp (sec) [10%FWC]	G 0 star Max t_exp (sec) [70%FWC]	K 0 star Min t_exp (sec) [10%FWC]	K 0 star Max t_exp (sec) [70%FWC]	M 0 star Min t_exp (sec) [10%FWC]	M 0 star Max t_exp (sec) [70%FWC]
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13	60.00	60.00	60.00	60.00	60.00	60.00

Input Output | Calculations | Noise estimation | SN rescaling | Flicker | Visibilities | Stars | Constants

Spreadsheet “Calculations”

Purpose:

- Calculates the planet and transit parameters: transit depth, duration (Transit SNR Predictor)
- Calculate the number of electrons registered per transit (or duration of interest)
- Summarizes noise components as on “Noise estimation” spreadsheet

Spreadsheet “Noise Estimation”

Purpose:

- Calculates the contribution of the individual noise componets on transit timescale (ETC: timescale of interest)
- For SNR predictor: also calculates the white noise contribution on the out-of-transit timescale
- Reproduces the amplitude of flicker as calculated from the “Flicker” spreadsheet
- Combines these noise factors to calculate:

  → ETC: the total noise on the timescale of interest

  → Transit SNR predictor: the total noise in and out-of transit and their combination

Spreadsheet “SNR rescaling”

Purpose:

- Takes into account the effect of light curve interruptions due to Earth occultations and SAA crossings
- ETC: precisions are scaled to the number of available data points
- Transit SNR predictor: we have studied the impact of light curve interruptions on the attained transit signal-to-noise ratio as

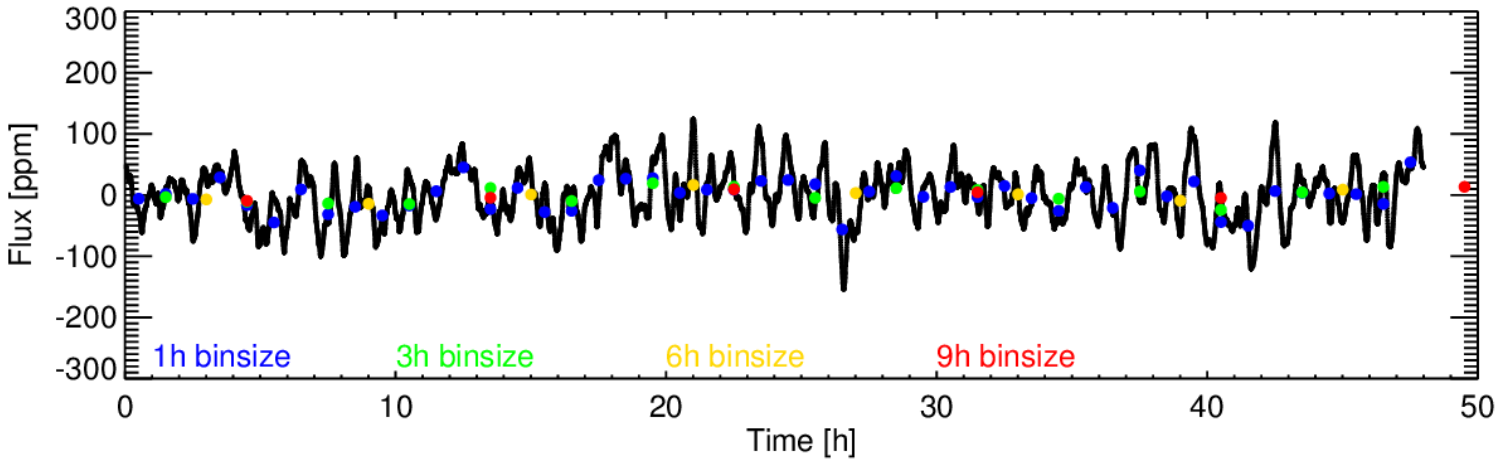
$$\frac{SN_{gap}}{SN_{nogap}} = 1 - 0.0064 * fgap\,,$$

This scaling factor is calculated here.

Spreadsheet “Flicker”

Purpose:

- Calculates the amplitude of “flicker” noise, i.e. noise introduced by stellar granulation on the in and out-of-transit timescales (ETC: timescale of interest)
- Details will be published in Lendl+ 2017c
- Based on the behaviour of simulated flicker light curves



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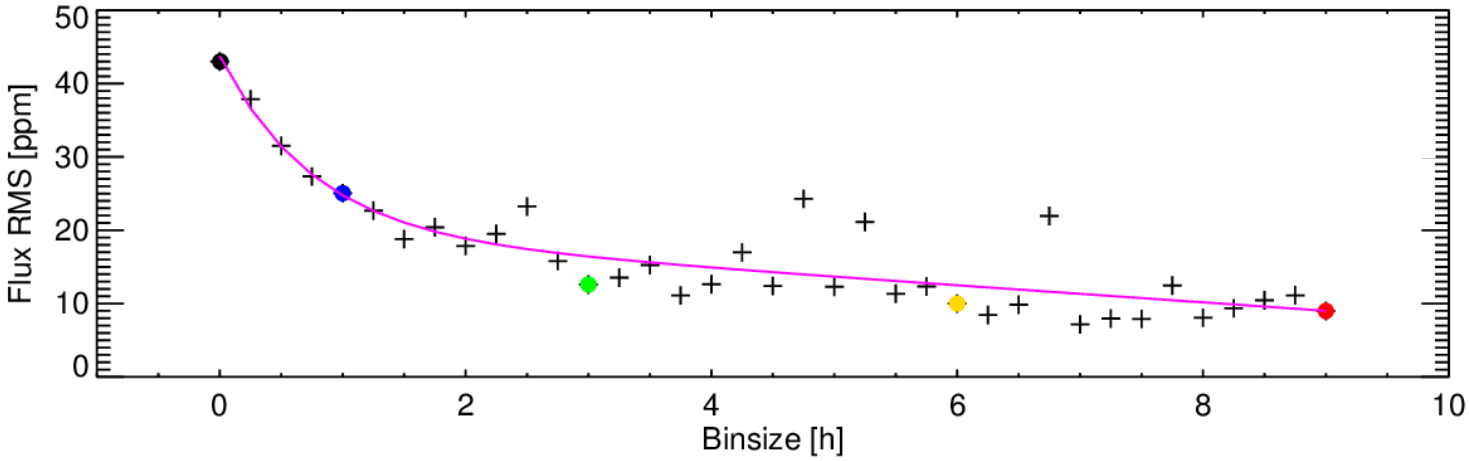
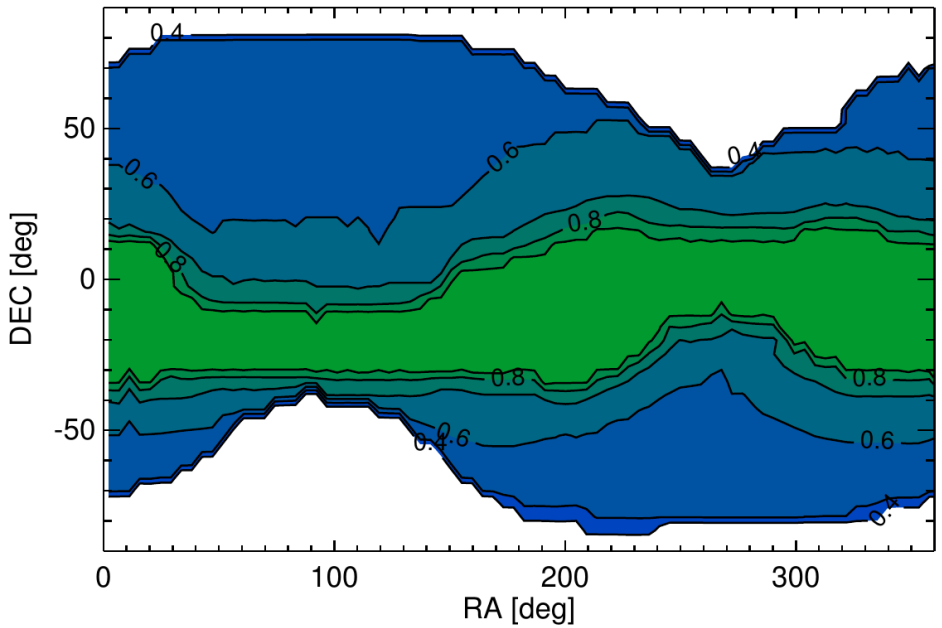


Spreadsheet “Visibilities”

Purpose:

- Estimates the fraction of the light curve free from interruption
- Based on a grid of tabulated values



Fraction of time spent on target during period of optimal target visibility

(calculated over 48h)

Spreadsheet “Stars”

Purpose:

- Estimates the number of electrons per second registered by CHEOPS
- Based on values calculated for V=8 stars, and scaled to the target magnitude

Spreadsheet “Constants”

Purpose:

- Physical constants used thoughout the document

CHEOPS ETC tools

Current version number is v1.4

Will remain frozen until guest obeservers call

Will be revised after in-orbit commissioning

Thank you, and see you at the hands-on session