End-to-end simulations as an indispentable tool for PLATO's core and complimentary science program

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PLATO Stellar Science

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Overview

1) Performance 2) Core sciences 3) Complimentary sciences

PlatoSim

End-to-End PLATO Simulator

KU LEUVEN

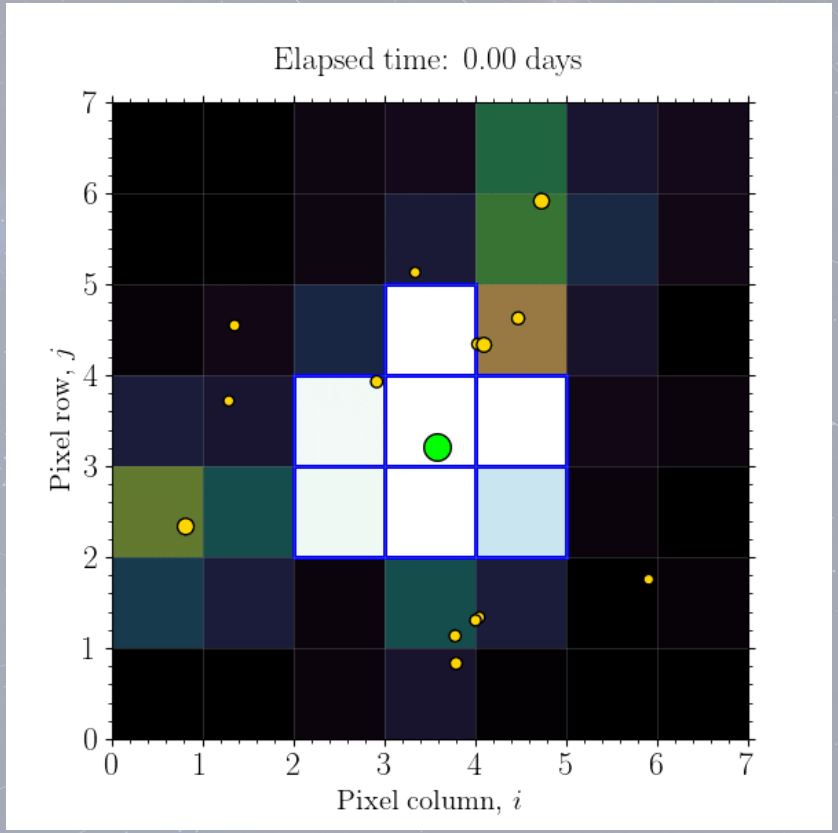
The need for simulations

Future challenges:

- Low pixel-sampling of PSF
- Stability of the spacecraft pointing
- Stellar contamination
- Etc.

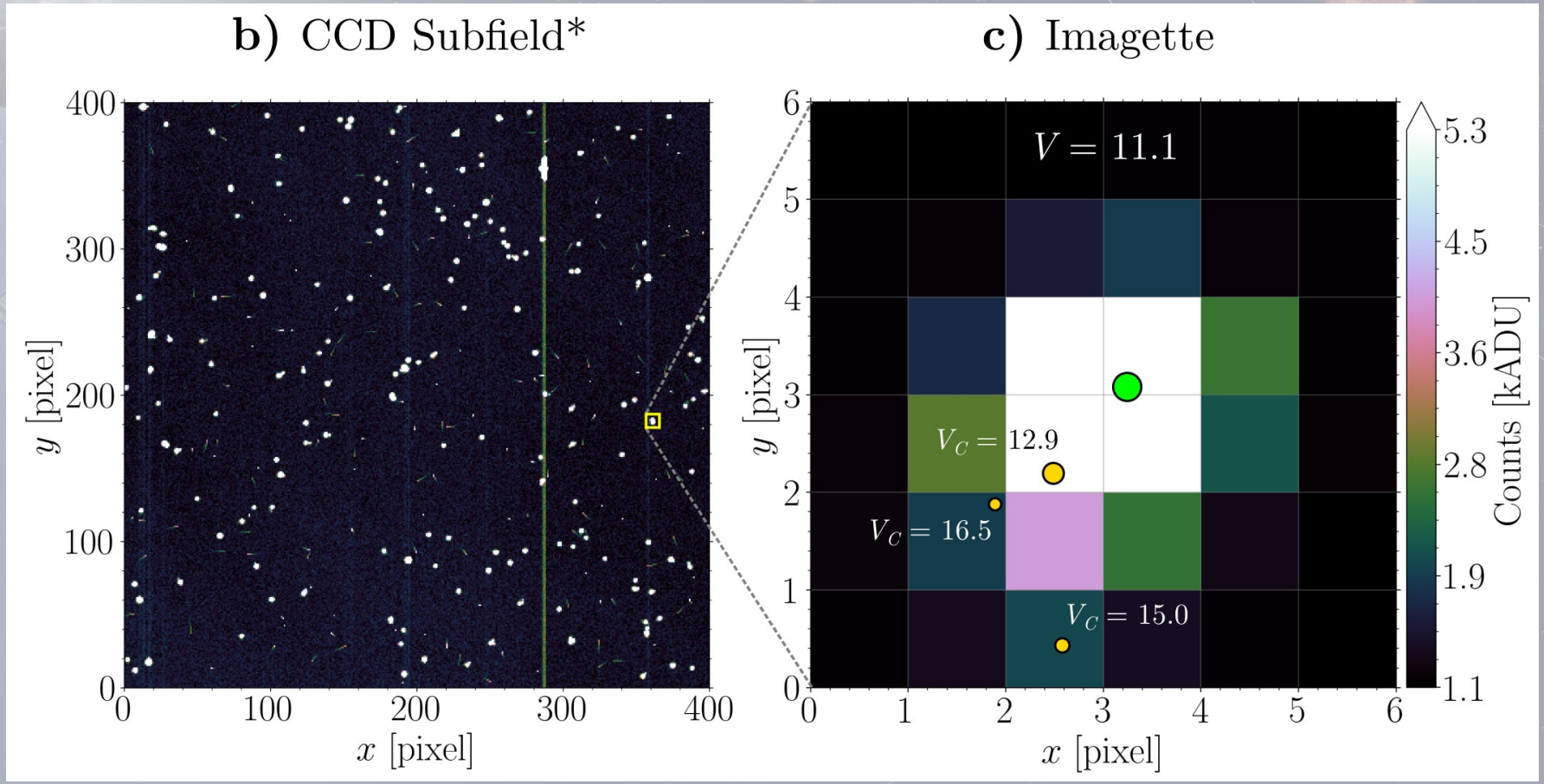
What is the dominating spacecraft systematic(s) for PLATO?

12.5 mag, 1 quarter, **with** *drift*

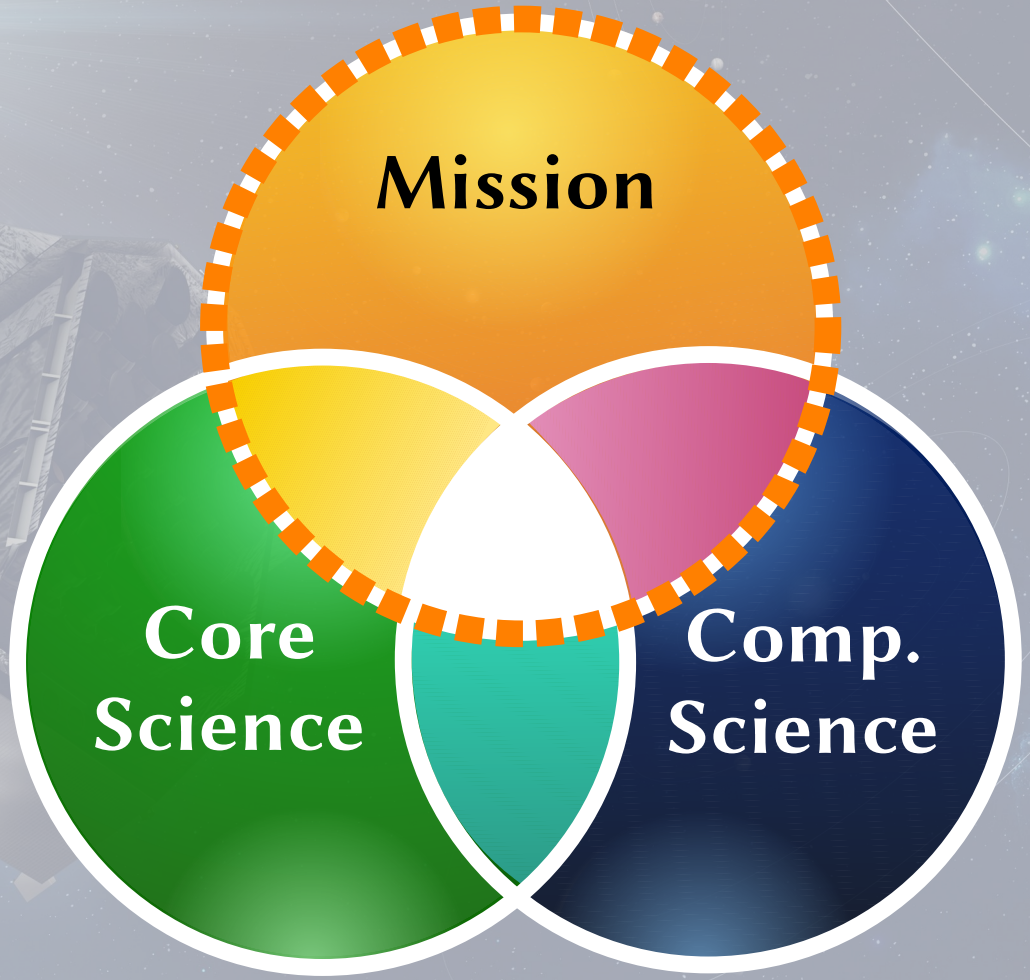


PlatoSim in a nutshell

Goal: realistic modeling of the CCD subfield for *all* PLATO cameras



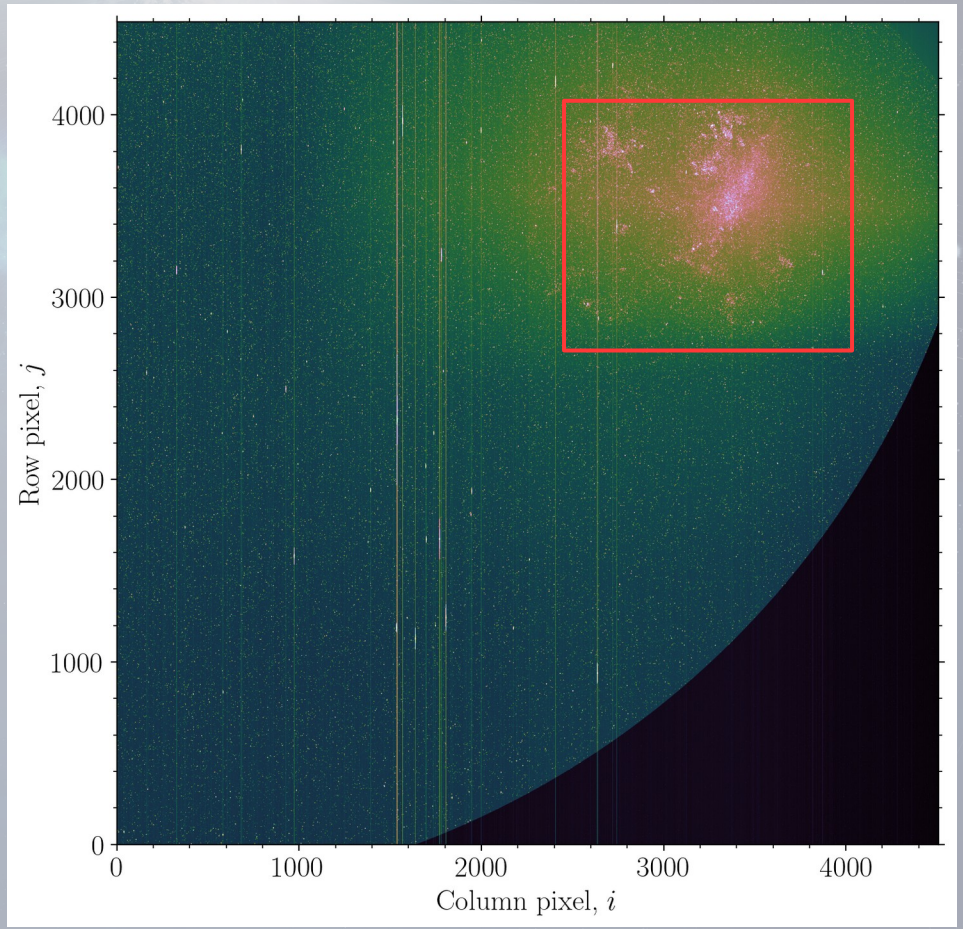
Simulations: Mission preparation



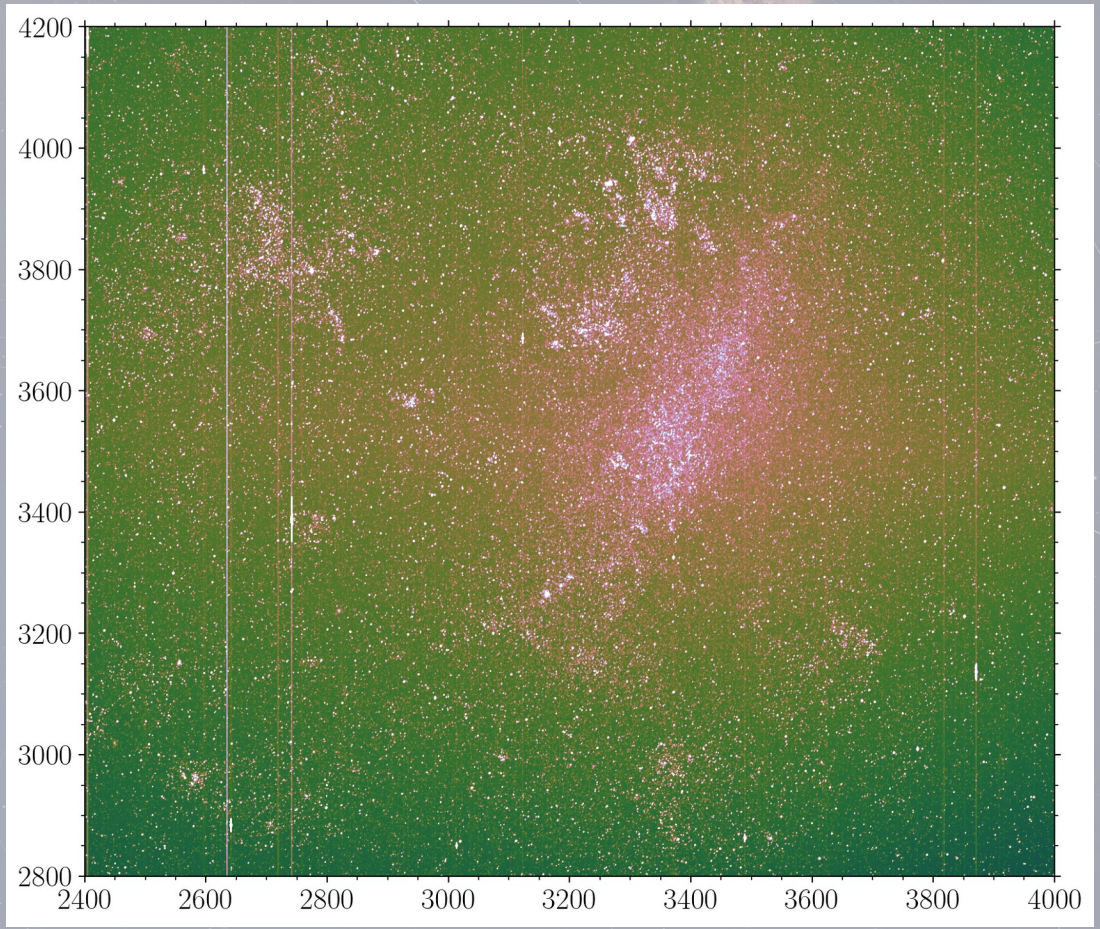
- Performance studies of the payload
- Development of the reduction pipelines
- Mechanical integration and alignment

Mission preparation

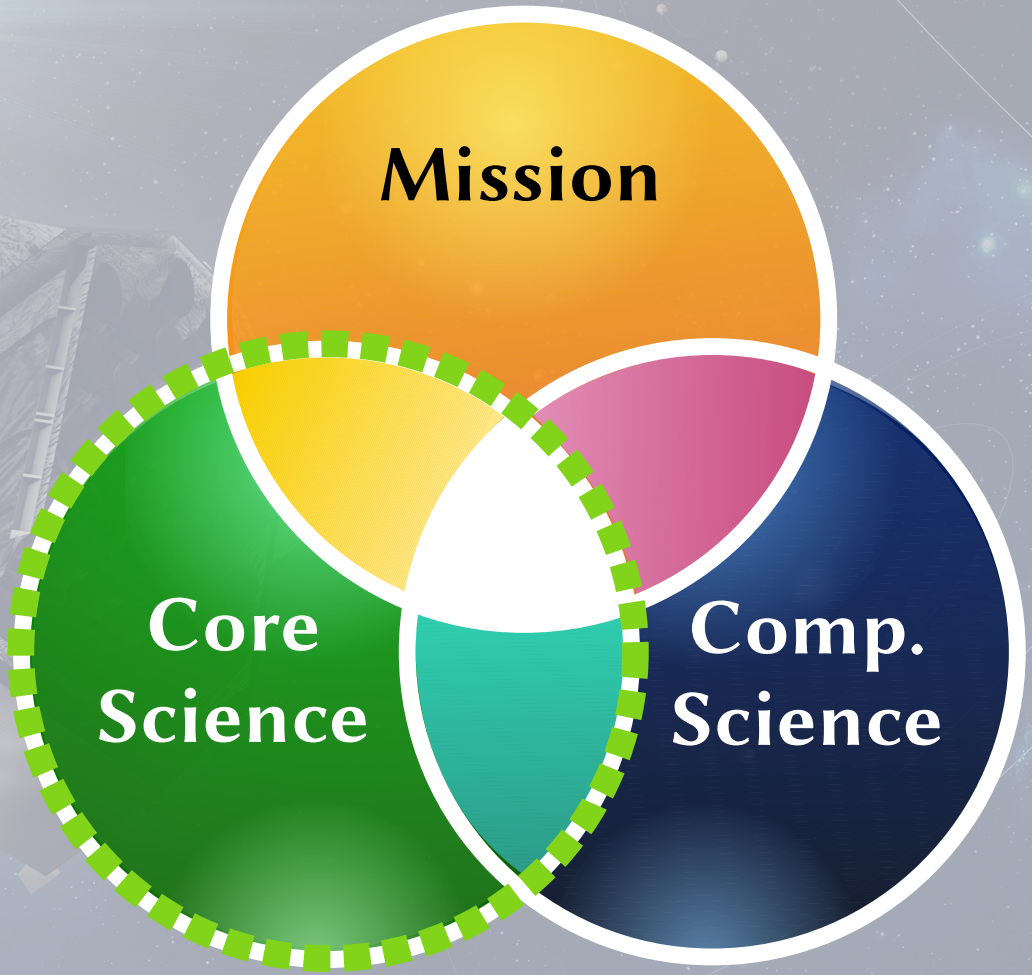
Full-frame CCD image



Zoom-in on LMC (red box)

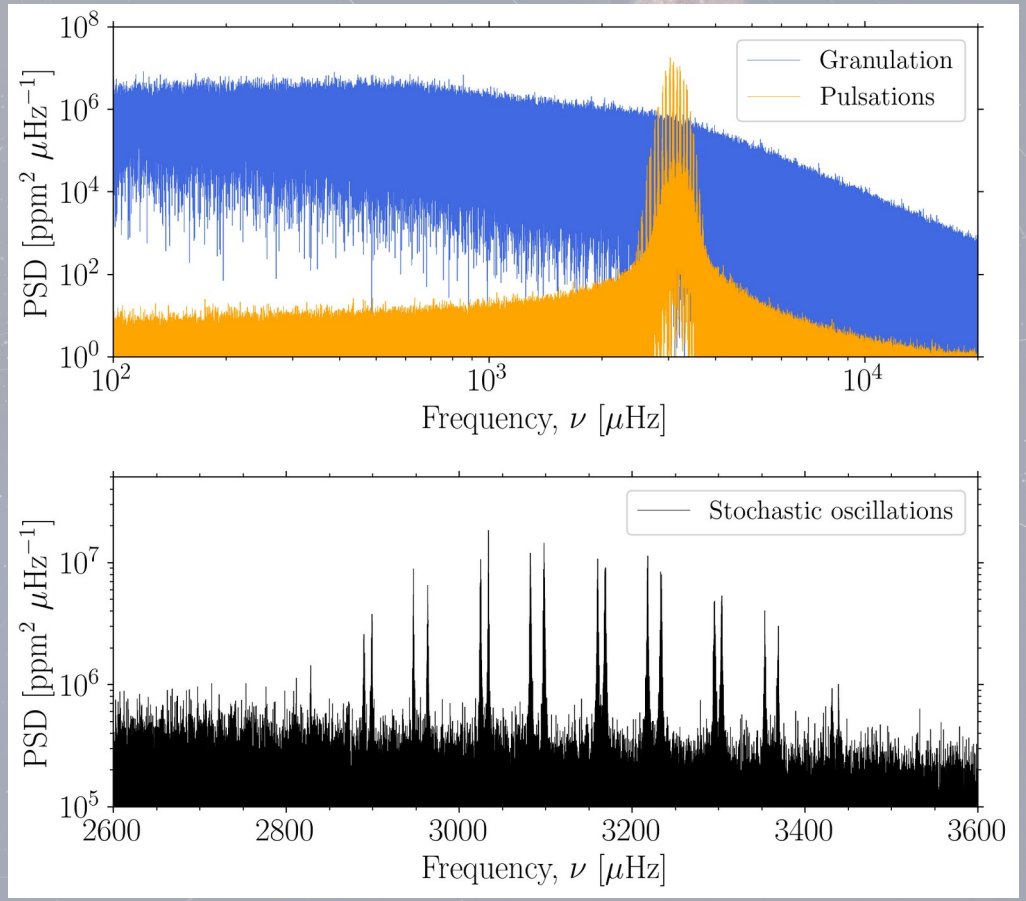


Simulations: Core Science

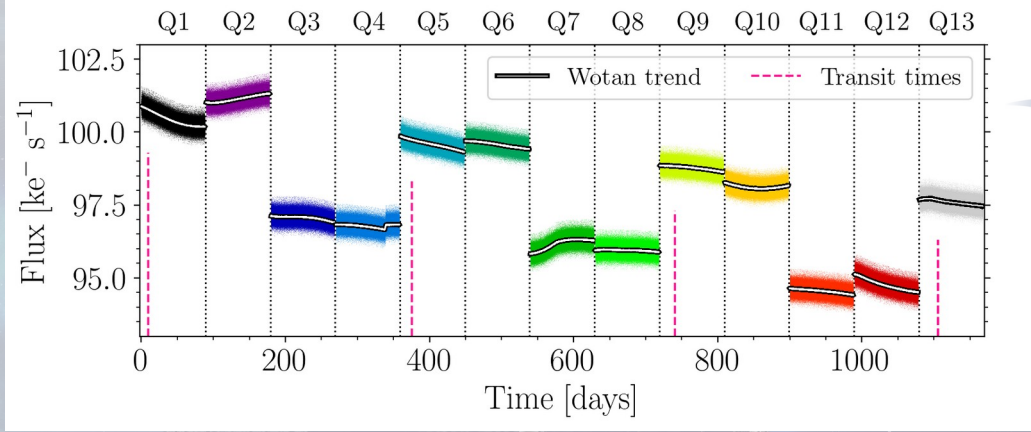


Core science validation: Setup

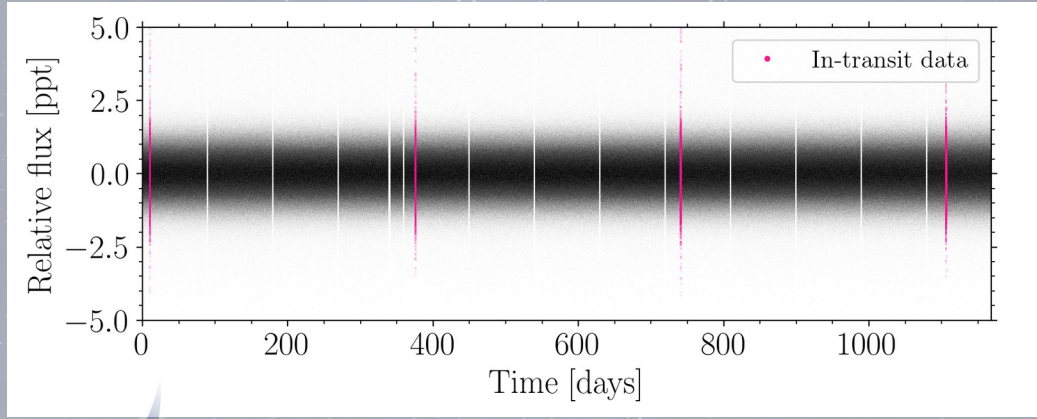
- **Hare and Hound exercise for a Earth-Sun analogue** (Jannsen+2023, subm.)
- Showcase with a G2V host star of $V = 10$ ($P = 10.4$) mag
- No third bodies and with: $e = 0$, $i = 90^{o}$, $\delta = 103$ ppm
- Including granulation noise and stochastic oscillations (cf. De Ridder+2006)

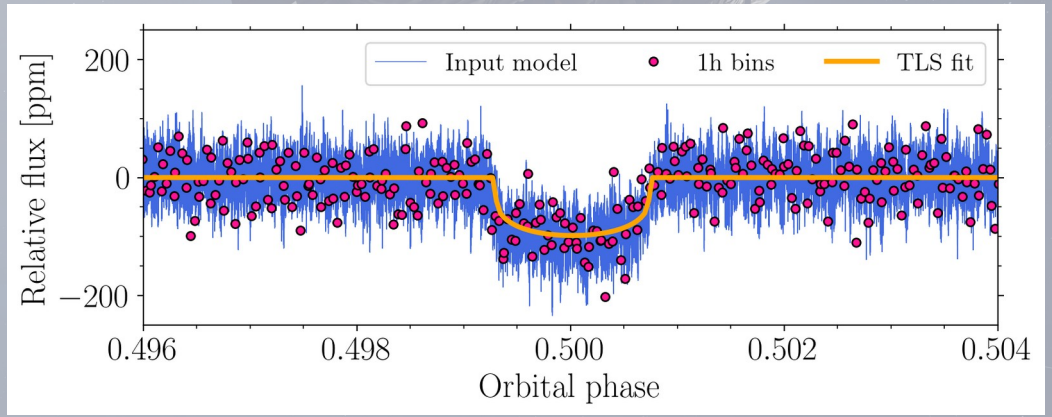


Core science validation: Results



Wõtan : Hippke & Heller 2019a
TLS : Hippke & Heller 2019b



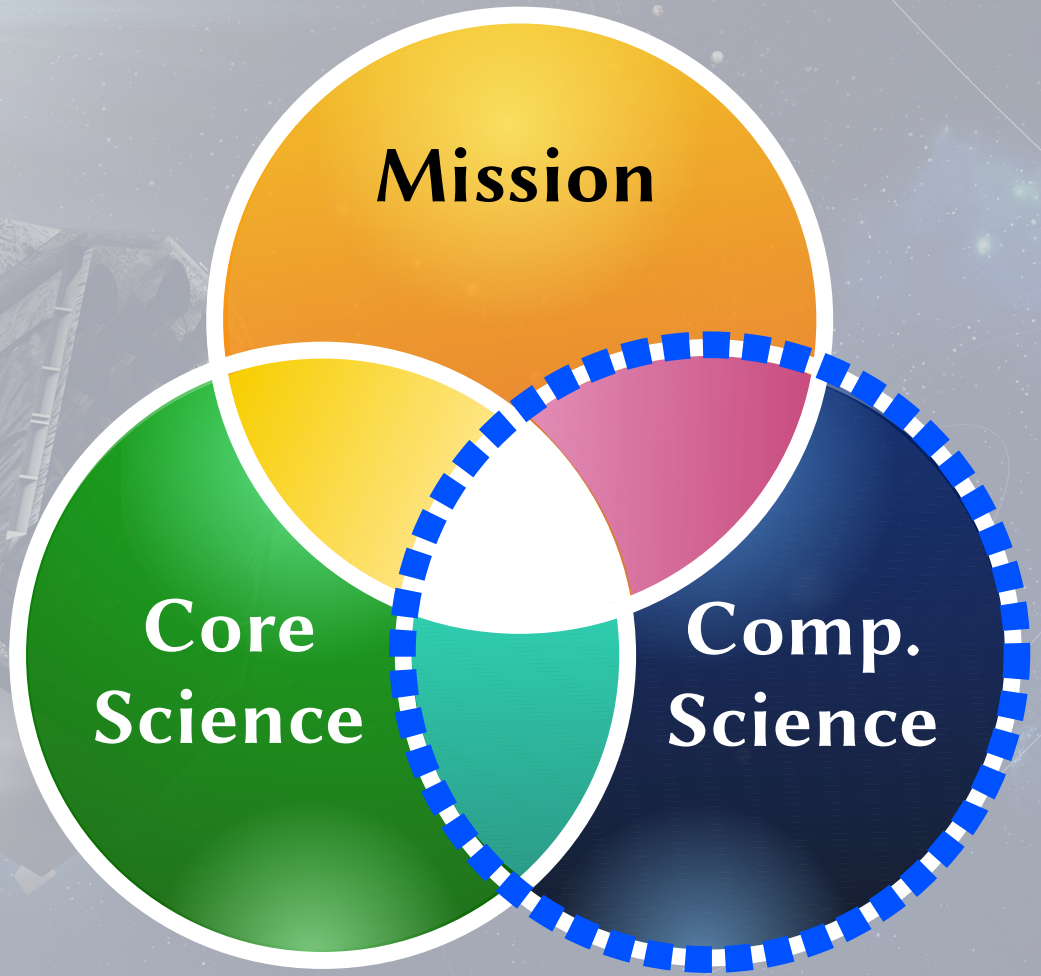


Results of TLS vetting:

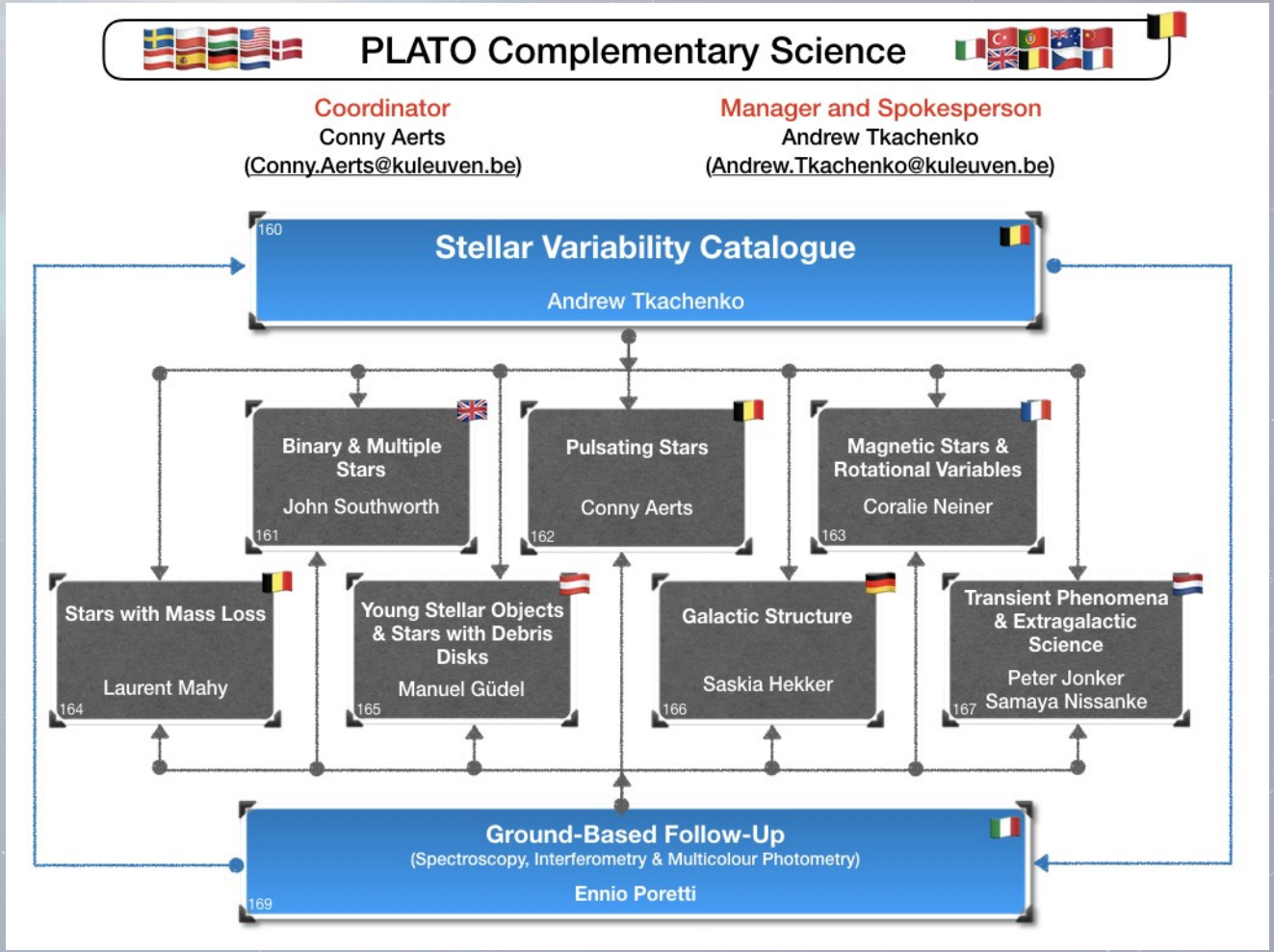
→ SDE ≥ 9 and SNR > 7

→ Earth-Sun analogue is detectable!

Simulations: Complimentary Science



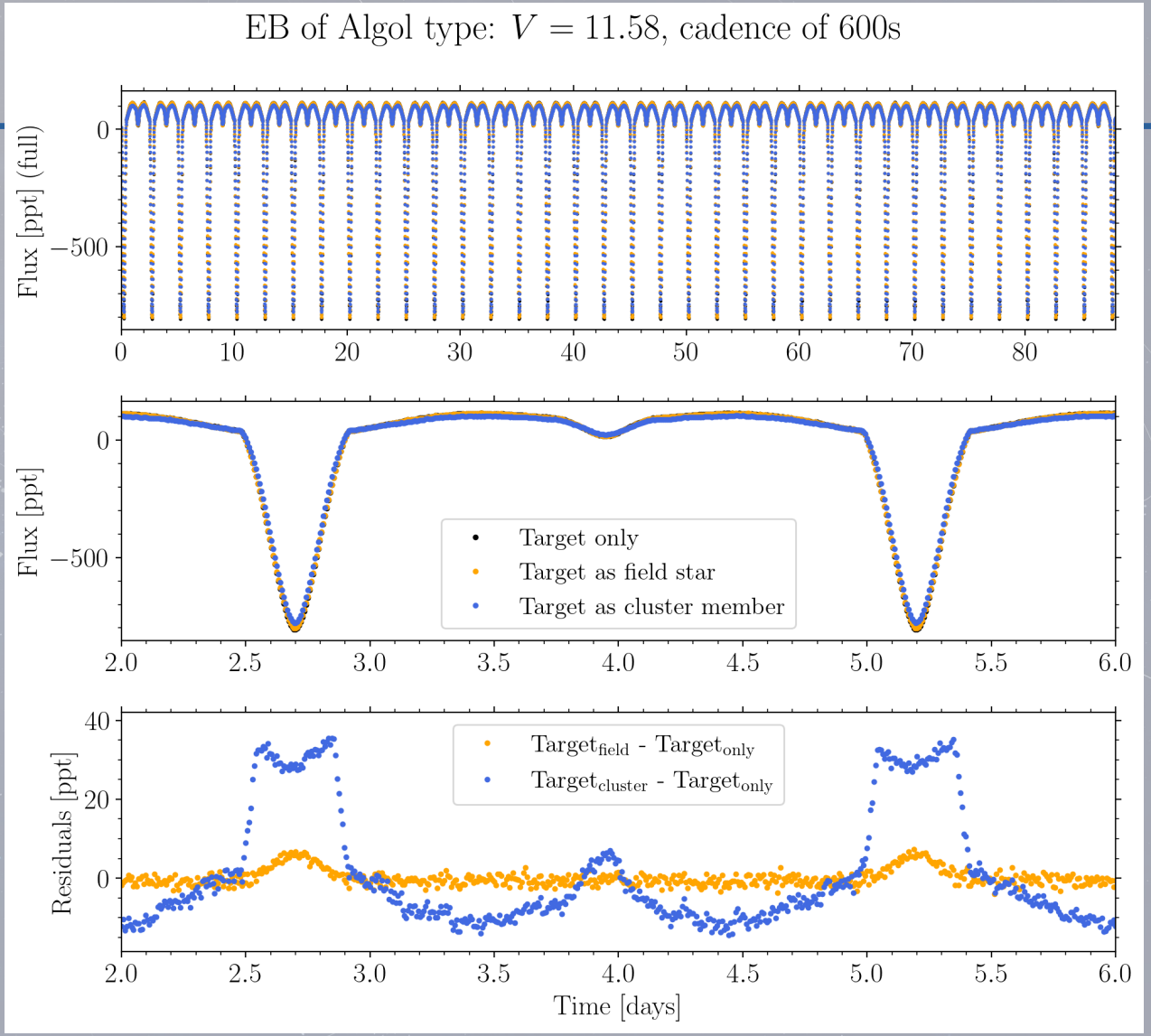
Complimentary science program



- Cf. Thursday's talk by Konstanze Zwintz
- New set of simulations for each Work Package

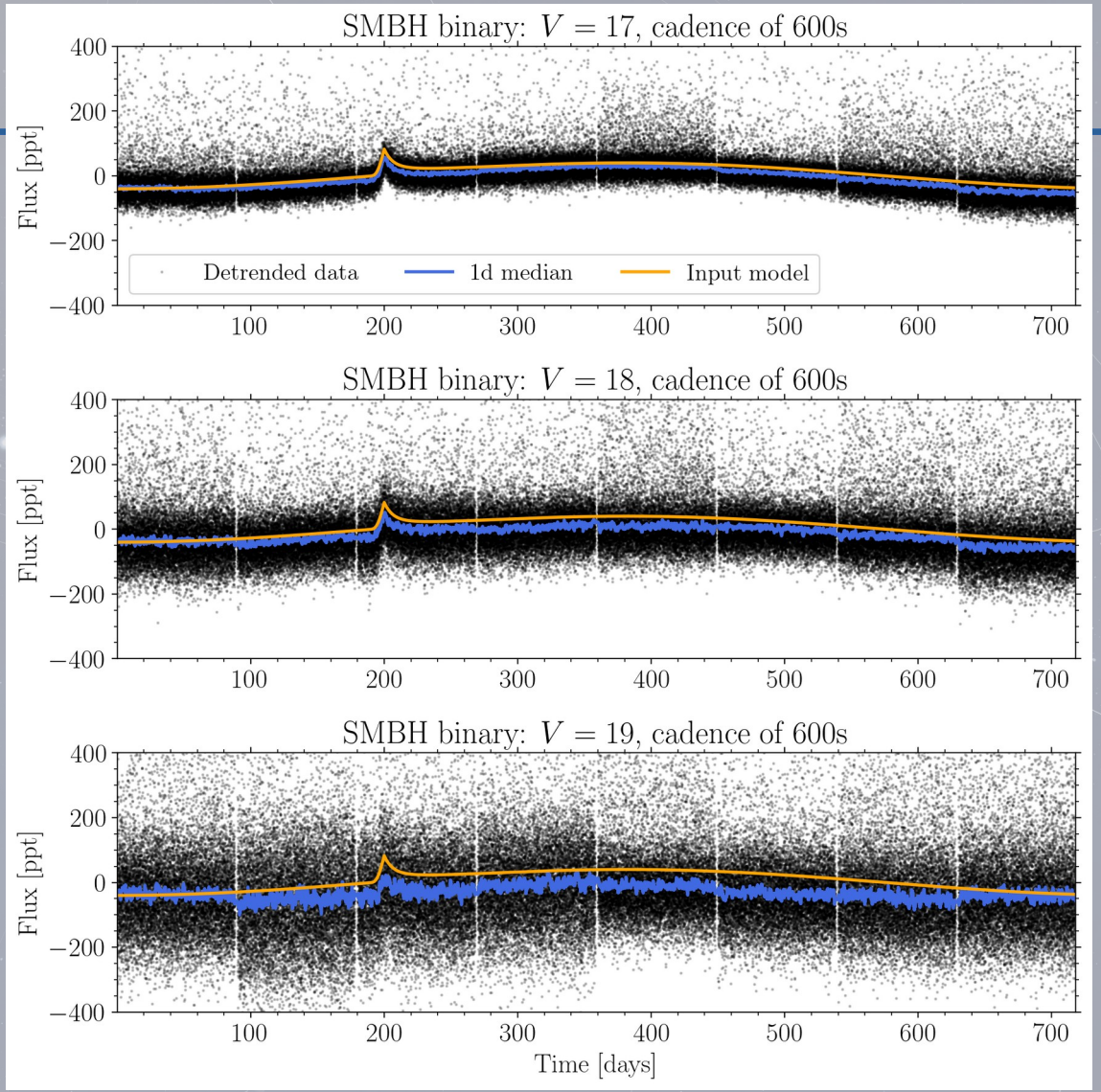
Example: EB

- **Eclipsing binary (EB)**
- **Orbital period:** 2.5 days
- **1Q** simulation of 600s cadence
- **Contamination cases:**
  → Field star (orange)
  → Cluster member (blue)
- **Special attention to stellar contamination in order to model EBs with PLATO!**



Example: Transients

- Super Massive Black Hole (SMBH) binary
- Showcase of “Spikey” observed by Kepler (Hu+2020)
- Feasible with PLATO?



Summery

- PlatoSim takes us from the raw pixel data to the final light curves we can analyse!
- Look out for:

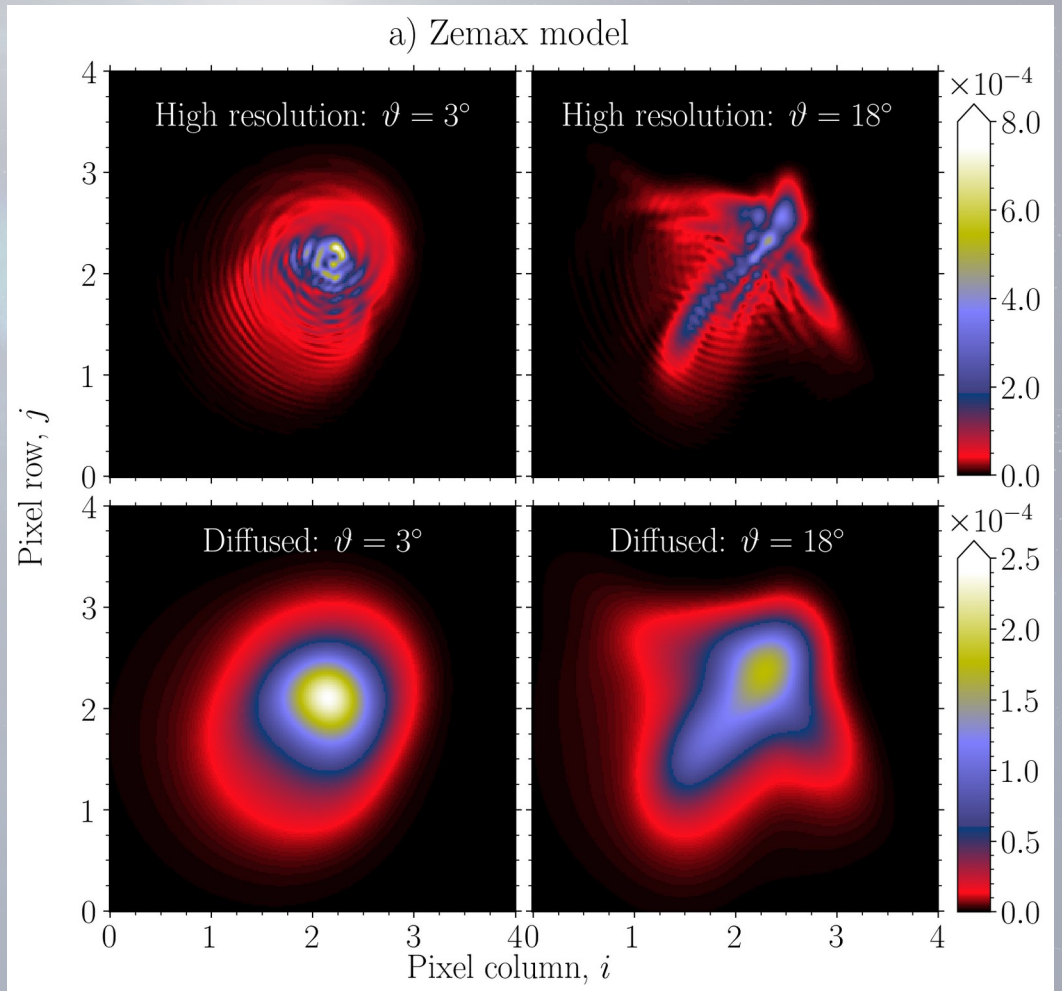
New suite of simulations for the Complimentary Science program

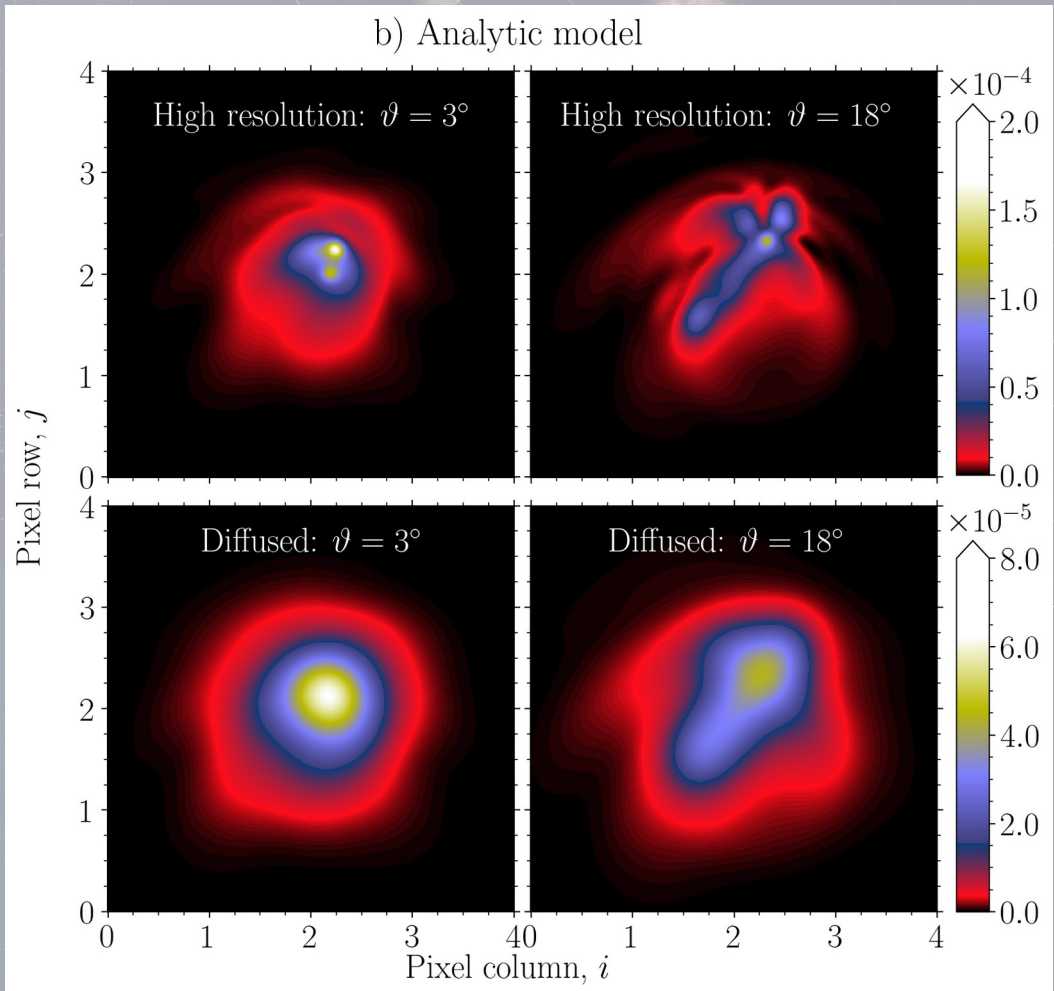
PlatoSim: An end-to-end PLATO camera simulator for modelling high-precision space-based photometry

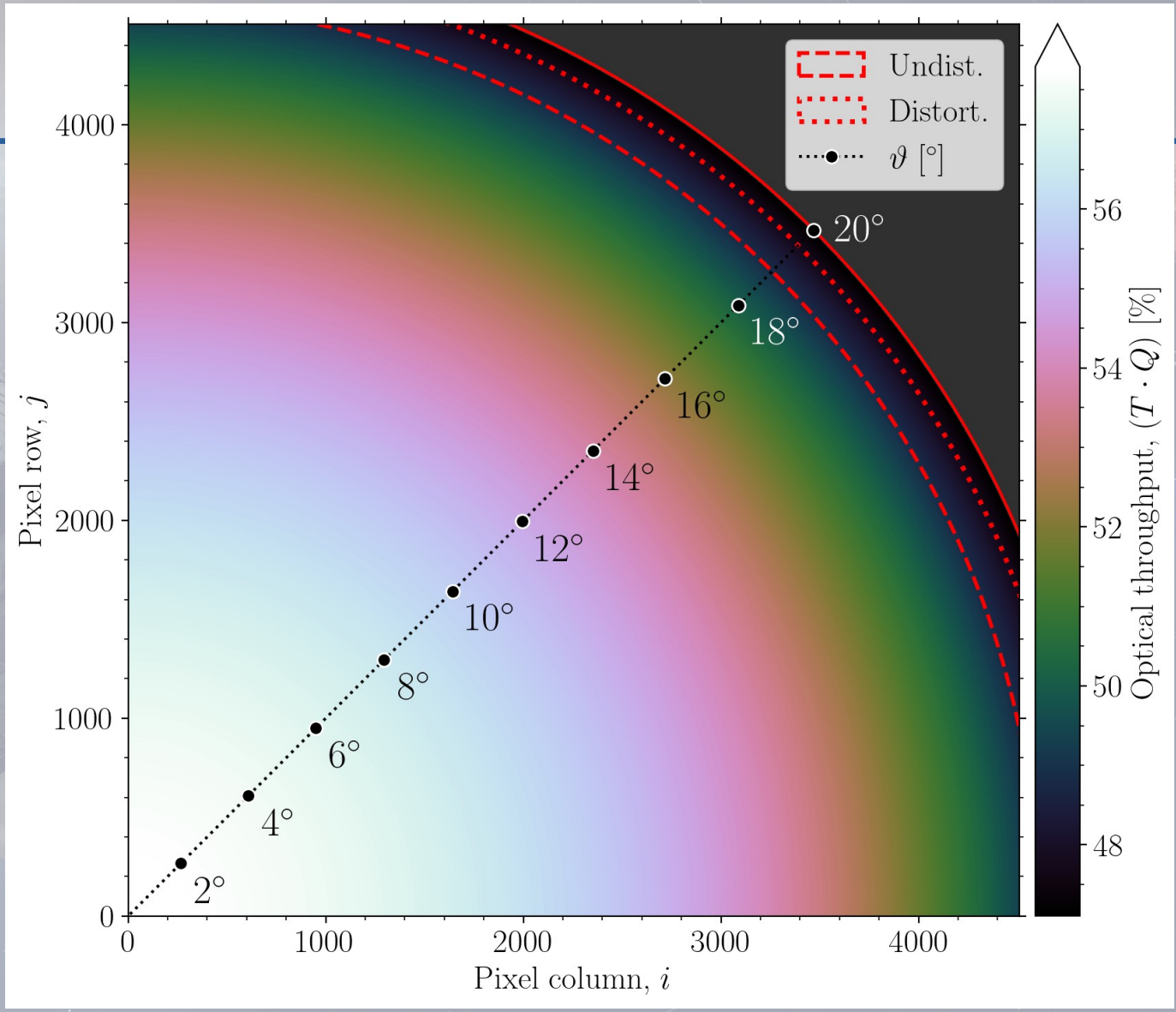
N. Jannsen[1], J. De Ridder[1], D. Seynaeve[1], S. Regibo[1], R. Huygen[1], P. Royer[1], C. Paproth[2], D. Grießbach[2], R. Samadi[3], D. R. Reese[3], M. Pertenais[2], E. Grolleau[3], R. Heller[4], S. M. Niemi[5], J. Cabrera[6], A. Börner[2], S. Aigrain[7], J. McCormac[8], P. Verhoeve[5], P. Astier[3], N. Kutrowski[9], B. Vandenbussche[1], A. Tkachenko[1], and C. Aerts[1, 10, 11]

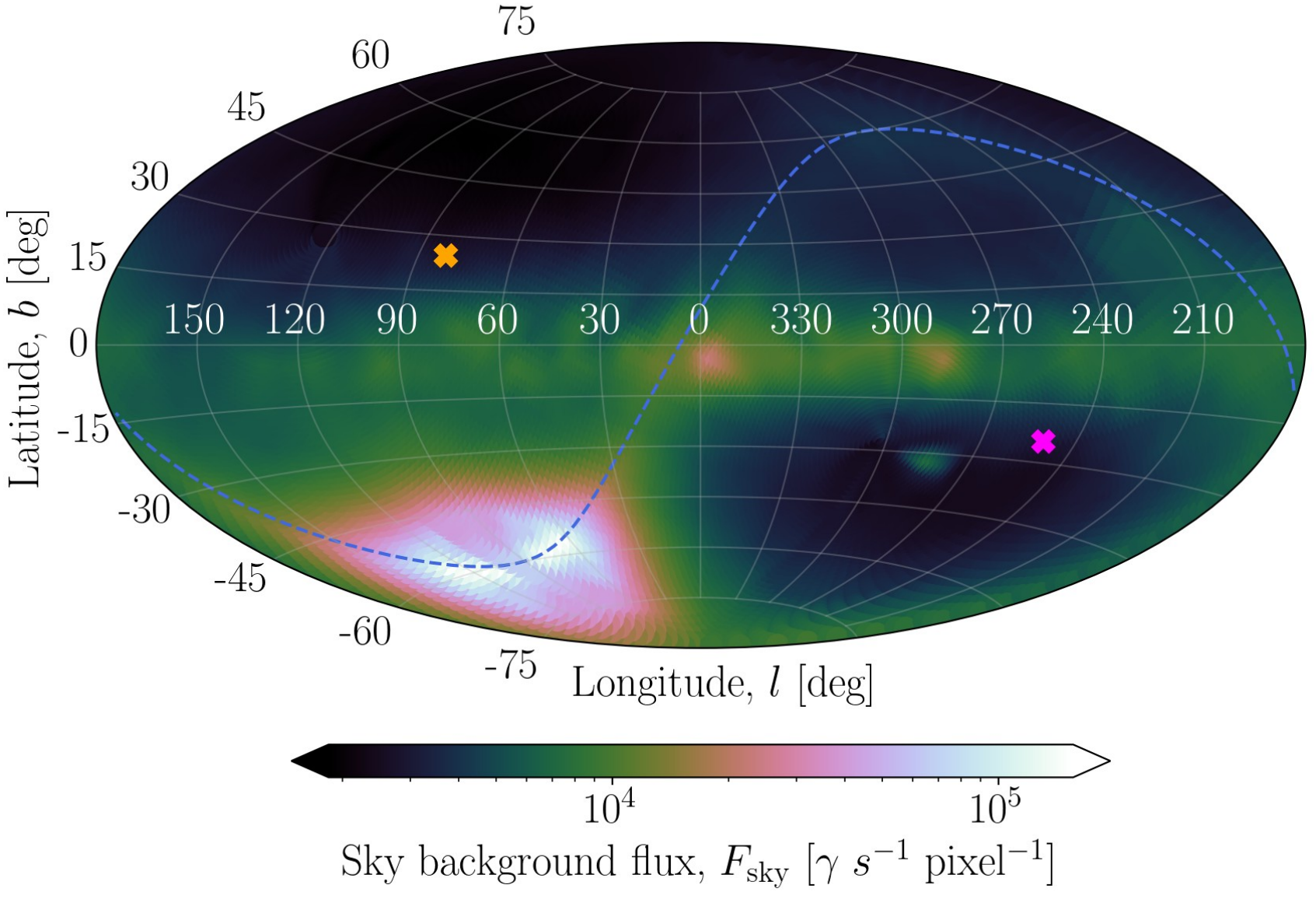
PLATO PSFs

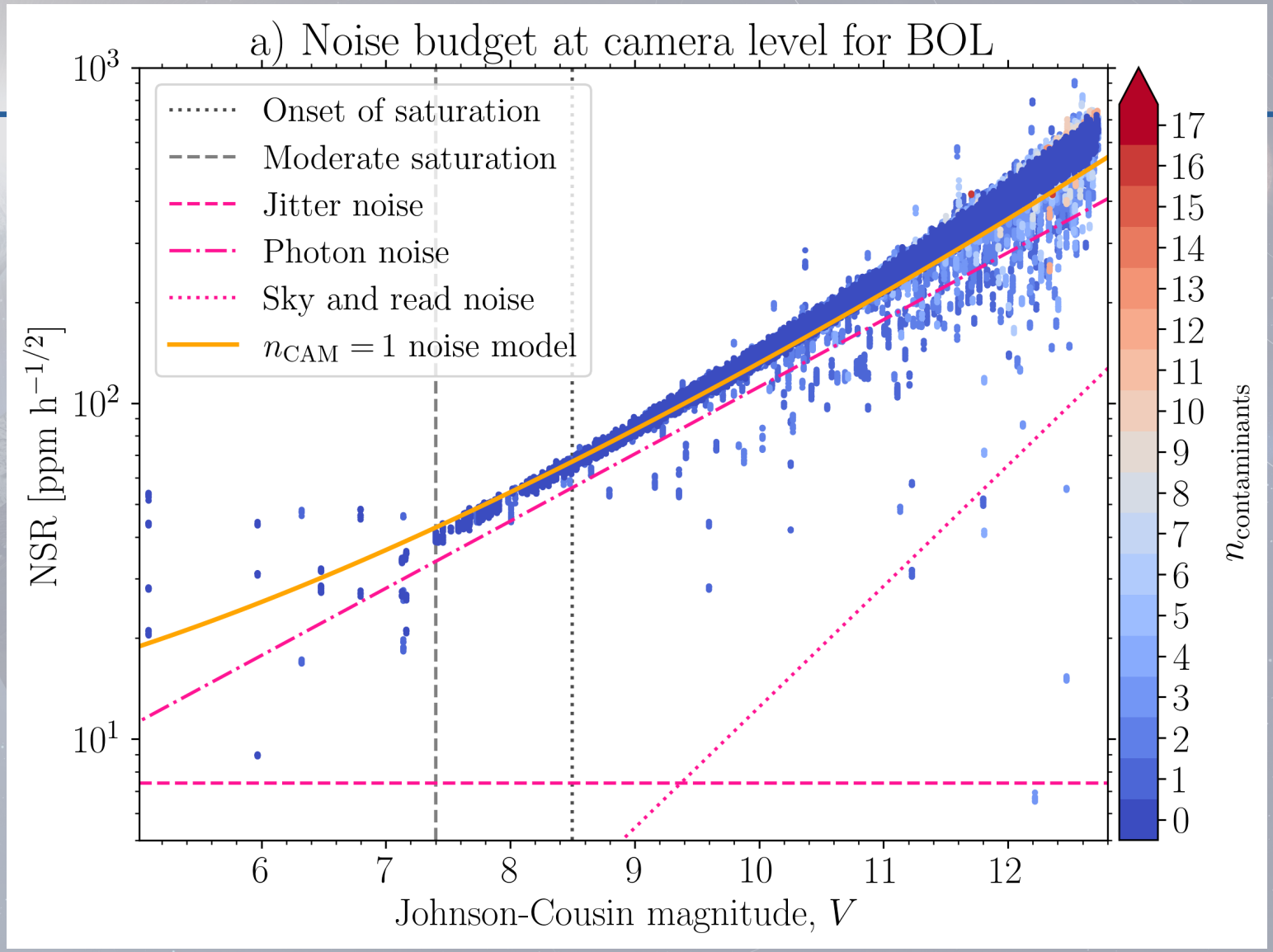
Model by Carsten Paproth

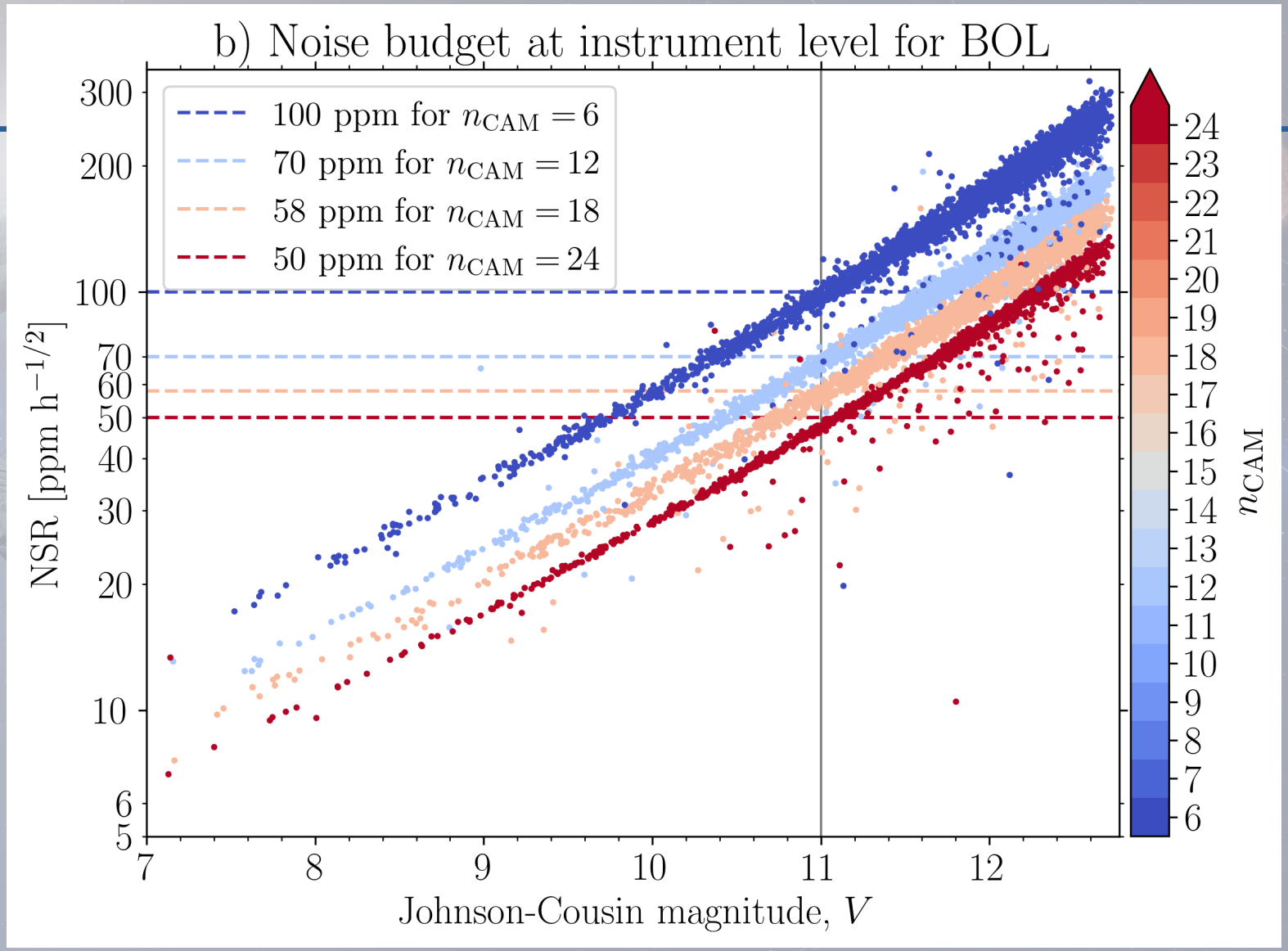





Undist.
Distort.
ϑ [°]
2°
4°
6°
8°
10°
12°
14°
16°
18°
20°
Pixel row, j
Pixel column, i
Optical throughput, $(T \cdot Q)$ [%]
0
1000
2000
3000
4000
48
50
52
54
56


75
60
45
30
15
0
-15
-30
-45
-60
-75
Latitude, b [deg]
150
120
90
60
30
0
330
300
270
240
210
Longitude, l [deg]
10^4
10^5
Sky background flux, $F_{\rm sky}$ [γ s^{-1} pixel^{-1}]


a) Noise budget at camera level for BOL
Onset of saturation
Moderate saturation
Jitter noise
Photon noise
Sky and read noise
$n_{\mathrm{CAM}} = 1$ noise model
NSR [ppm h$^{-1/2}$]
10^3
10^2
10^1
6
7
8
9
10
11
12
Johnson-Cousin magnitude, V
$n_{\mathrm{contaminants}}$
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0


b) Noise budget at instrument level for BOL
100 ppm for $n_{\mathrm{CAM}} = 6$
70 ppm for $n_{\mathrm{CAM}} = 12$
58 ppm for $n_{\mathrm{CAM}} = 18$
50 ppm for $n_{\mathrm{CAM}} = 24$
NSR [ppm h$^{-1/2}$]
300
200
100
70
60
50
40
30
20
10
6
5
7
8
9
10
11
12
Johnson-Cousin magnitude, V
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
n_{CAM}