The PLATO Science Performance

(PLAnetary Transits and Oscillation of stars)

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The PLATO Mission

- **Prime mission goals**:
  - detect and characterize a large number of extrasolar transiting planets including **Earth-sized planets up to the habitable zone of solar-like stars**
  - investigate seismic activity in stars, enabling the precise characterisation of the planet host star, including its **age**

- **Payload design drivers:**
  - **Planet detection**

    → large number of target stars
  - **Planet and star characterization**

    → bright target stars → wide field-of-view

Image credit: OHB

→ **multi-camera approach:**
  – 24 normal cameras (photometry)
  – 2 fast cameras (fine-guidance, photometry (red and blue))

Payload design drivers

plato

planet detection
(up to HZ solar-like stars)

80 ppm 1h — (planet yield)

long baseline (>2yr)

600s sampling

25s sampling

telemetry and data processing requirements

stellar characterization
(up to 10% age for Sun-like star)

noise requirements
in the Fourier domain

requirements on the
residuals of systematic noise

pointing
requirements

34 ppm in 1h
(3% Rp; 10% age)

random noise requirements

planet characterization
(down to 3% uncertainty in radius
for Earth-Sun analogs)

50 ppm in 1h
(5% Rp; 20% age)

V<11
(radial velocity)

P1 sample requirements

FOV requirements

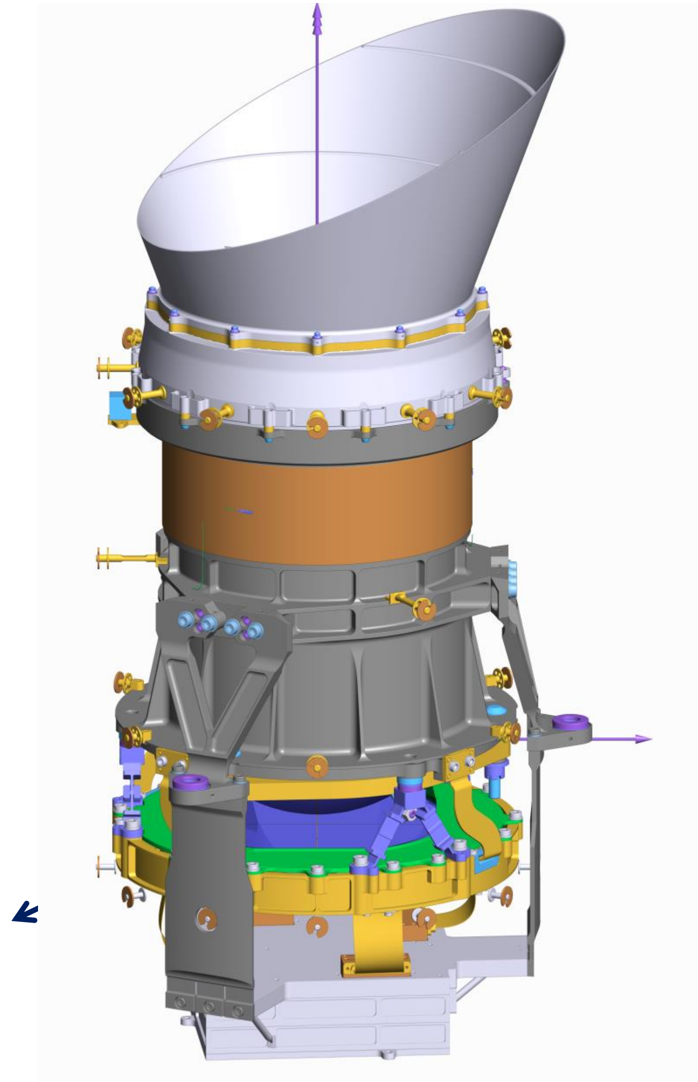
PLATO payload

24 Normal cameras:

- 12cm aperture telescopes
- range: ~8 (4) ≤ m_V ≤ 11 (13)
- FOV payload ~49°x 49°
- Each camera has 4 x CCD,
  each 4510×4510px
- Pixels size: 18 µm square
- read-out cadence: 25 sec
- operate in “white light”
  (500 – 1050 nm)

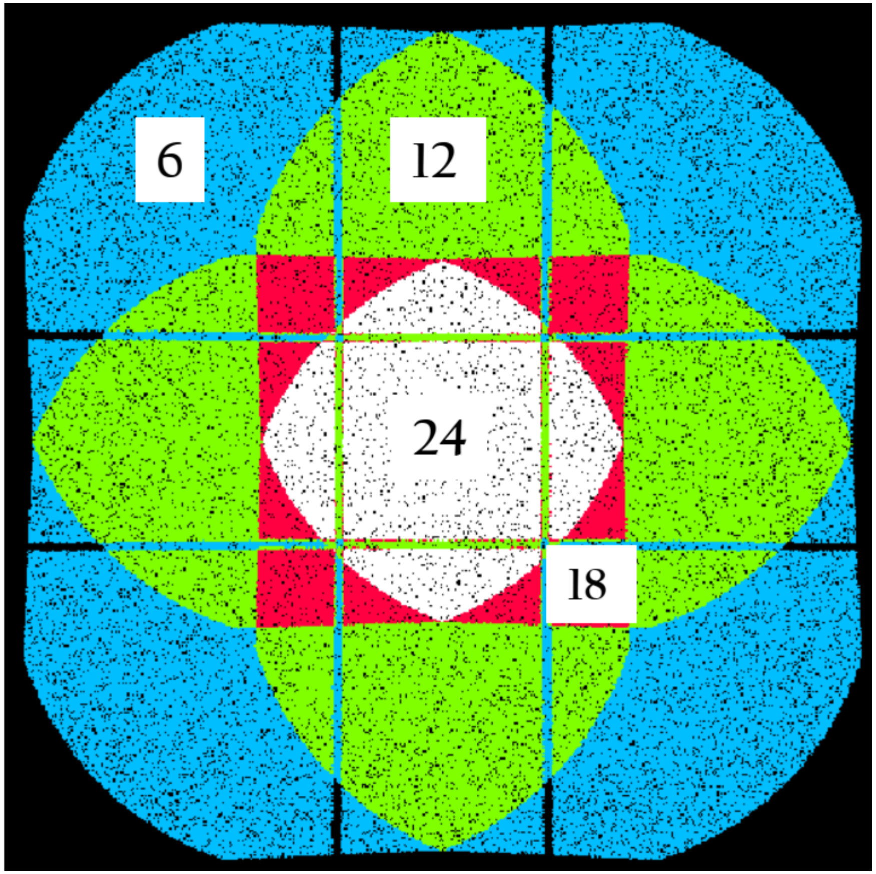
2 Fast cameras:

- read-out cadence: 2.5 sec
- one „red“ & one „blue“ camera



few words on performance

The instrument field of view is **2 200 square degrees** (vs 105 deg^2 Kepler)



It is spread over: ~2 billion pixels (2 000 Mpx vs 98 Mpx for Kepler)
~6 600 cm^2 of sensitive area (2x Gaia)

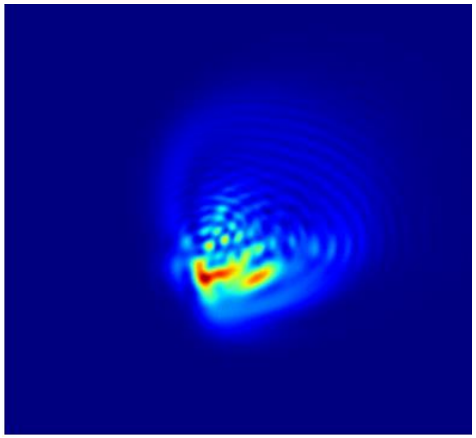
credit of slide: M. Pertenais, Performance Team

design

	N-cams/tel	equivalent diameter (m)	FOV (degrees^2)
CoRoT	1	0.27	4 (Exo channel) [~20 pointings]
Kepler	1	0.95	105 [1 long pointing] [~18 pointings as K2]
TESS	4	0.10	600/camera (3200/instrument) [full-sky survey]
PLATO	24	0.59	1100/camera (2124/instrument) [up to 50% of sky]

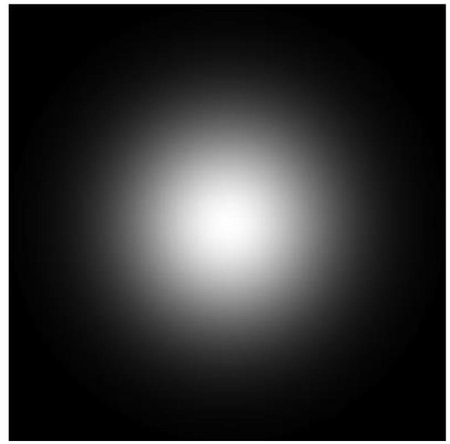
PSF

TOU PSF



+

detector PSF



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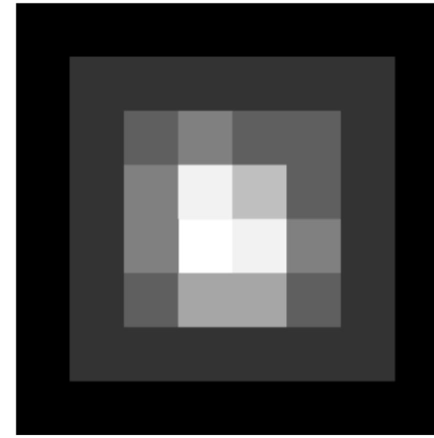
system PSF



Includes:
- TOU PSF
- Manufacturing errors
- Integration tolerances
- Depth of focus

Includes:
- Charge diffusion
- Brighter Fatter Effect
- Charge Transfer Efficiency
- ...

System PSF is additionally a function of stellar magnitude, stellar spectrum, position on the field of view, camera, temperature...

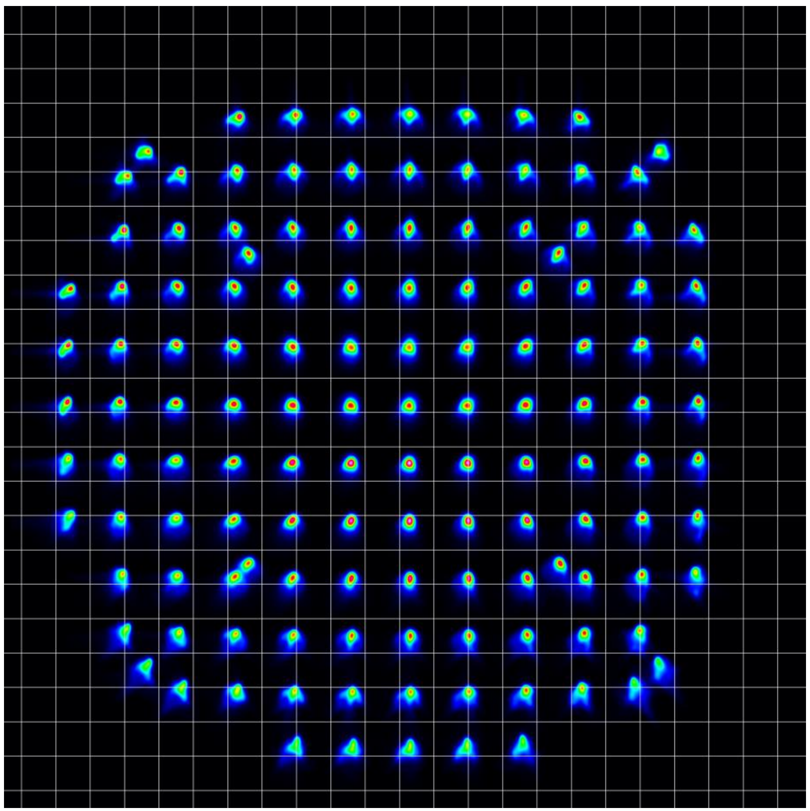
credit of slide: M. Pertenais, TOU Team, Performance Team

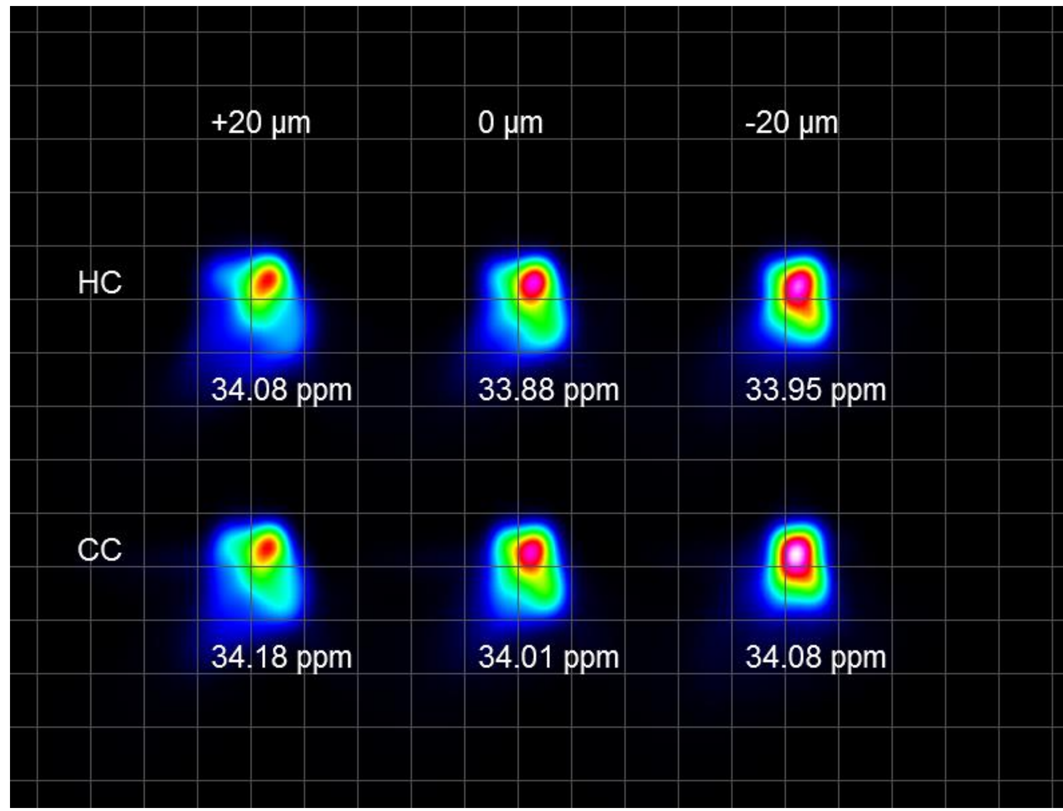
PSF

PSF shall have about 90% of the enclosed energy in 2x2 pixels.

PSF shape depends strongly on the position on the field of view (left) and focus (right).

The compromise is set such as the photometric requirements (in terms of noise budget) are achieved all along the field of view.

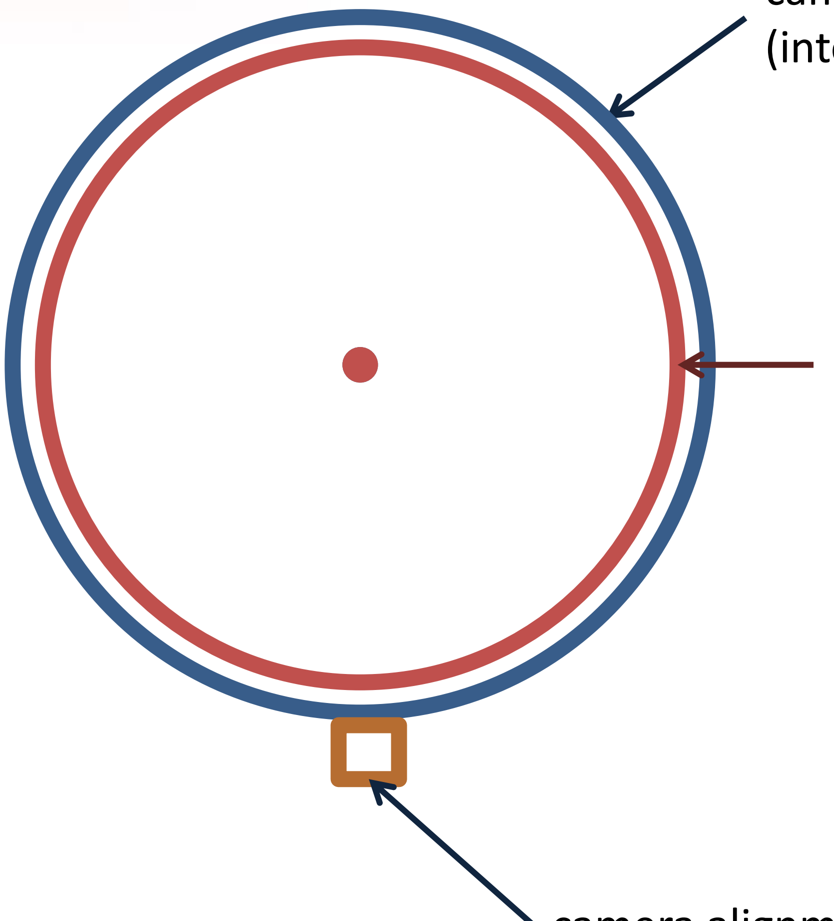




credit of slide: C. Paproth, Performance Team

pointing requirements

perfect alignment



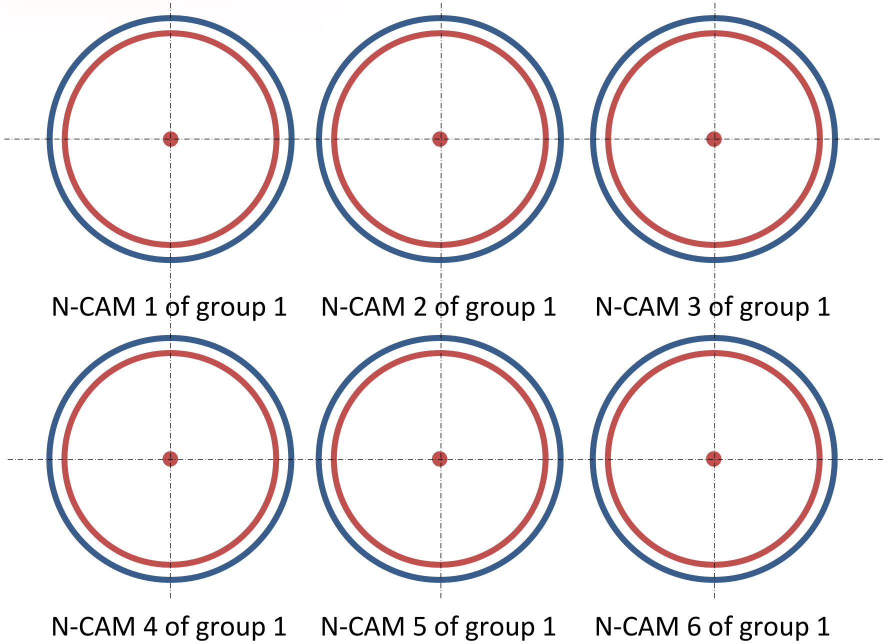
camera mechanical reference frame
(interface to spacecraft)

camera boresight reference frame
(optical axis/line-of-sight)

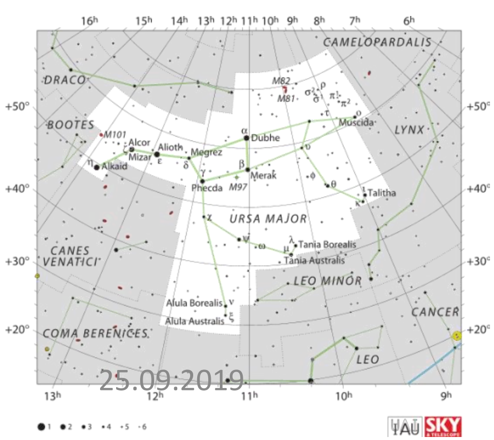
camera alignment reference frame

pointing requirements

perfect alignment



field of view on sky

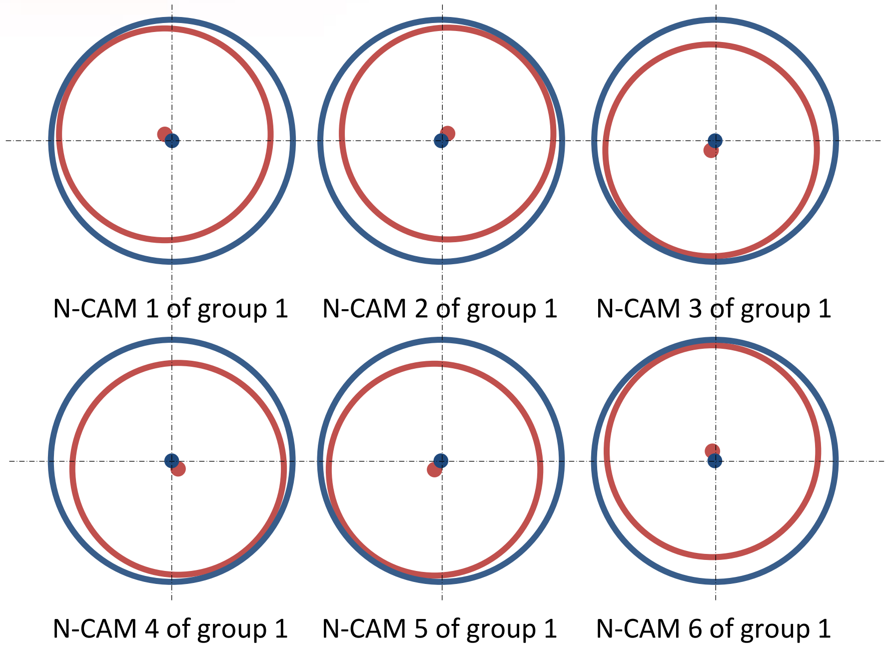


note: the actual field of view size of the PLATO instrument is comparable to Ursa Major

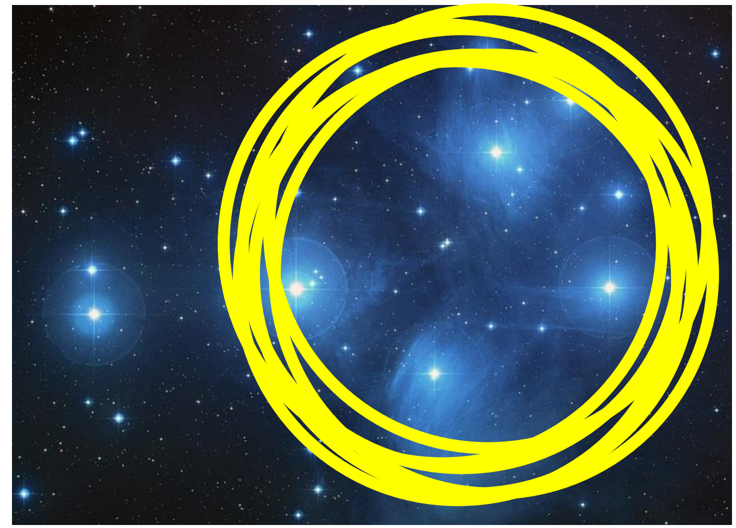
The Fine Guidance System (FGS) pointing performance is comparable to the size of a 2€ coin in Roma as seen from Padova.

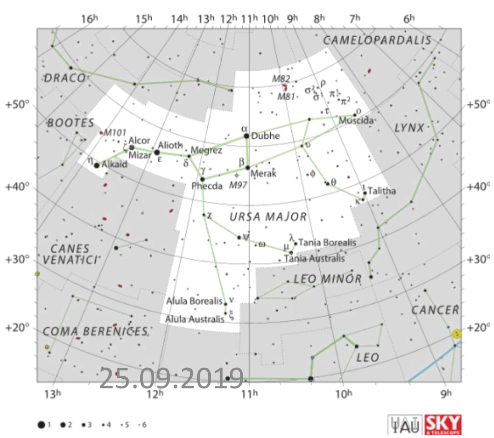
pointing requirements

camera mounting interfaces co-aligned



field of view on sky





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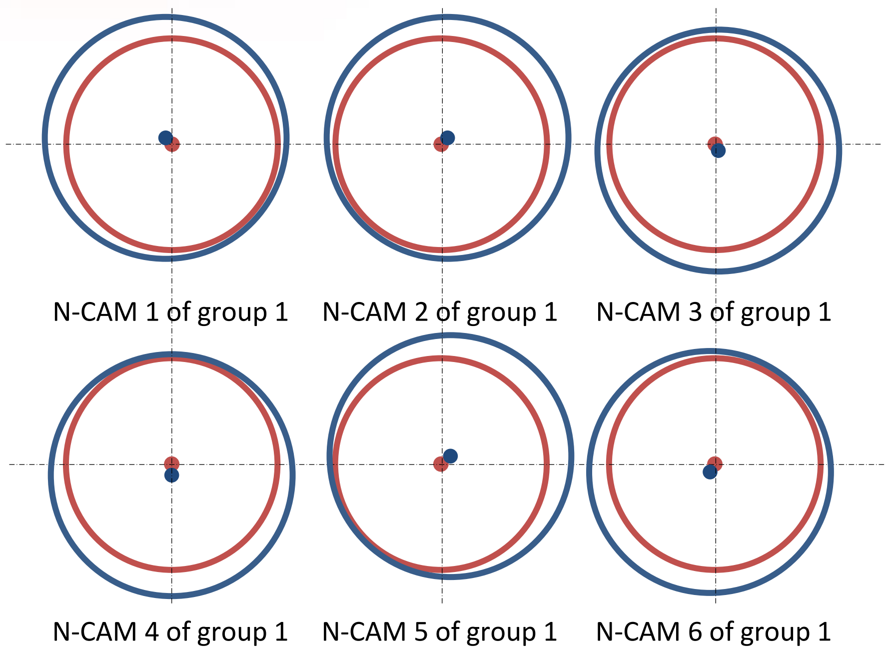
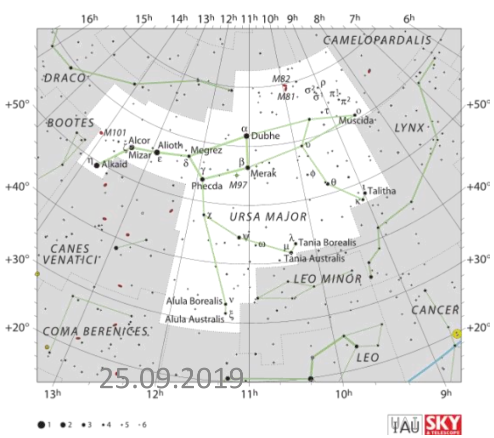
pointing requirements

camera boresight reference frames co-aligned



field of view on sky



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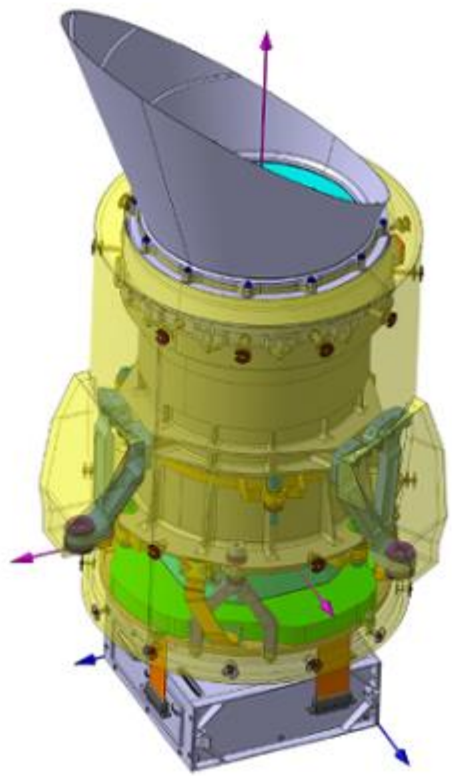
Instrument performance

- Motivation
  - NSR is PLATO's key performance parameter
  - NSR estimation is needed for
    - requirement definition and justification (PURD, TRD, URD, …)
    - Sensitivity analysis
    - Optimization, mitigation and trade-off analysis
    - Input and cross validation to other simulation tools, e.g. PLATOSim
    - Input for data processing chains
- How?
  - Physical models
  - Spatially distributed maps
- Thank you to: Alan, Bart, Carsten, Dave, Demetrio, Denis, Gisbert, Jason, Joris, Juan, Jürgen, Martin, Mattheo, Matthias, Peter, Reza, Stefanie 1, Stefanie 2, Steve, Thibaut, Tomasz, Valerio, Valery, Yves … the entire team

credit of slide: A. Börner, Performance Team

Performance impactors



Jitter

Aberration

Stray light

Vignetting

Radiation

Polarization

Temperature

Transmissivity

Contamination

Distortion

Thermo-elastic distortions

Point spread function

Gain stability

Quantum efficiency

Analogue-digital conversion

Charge transfer efficiency

Offset stability

Photo-resonse non-uniformity

Bias voltage stability

Dark signal

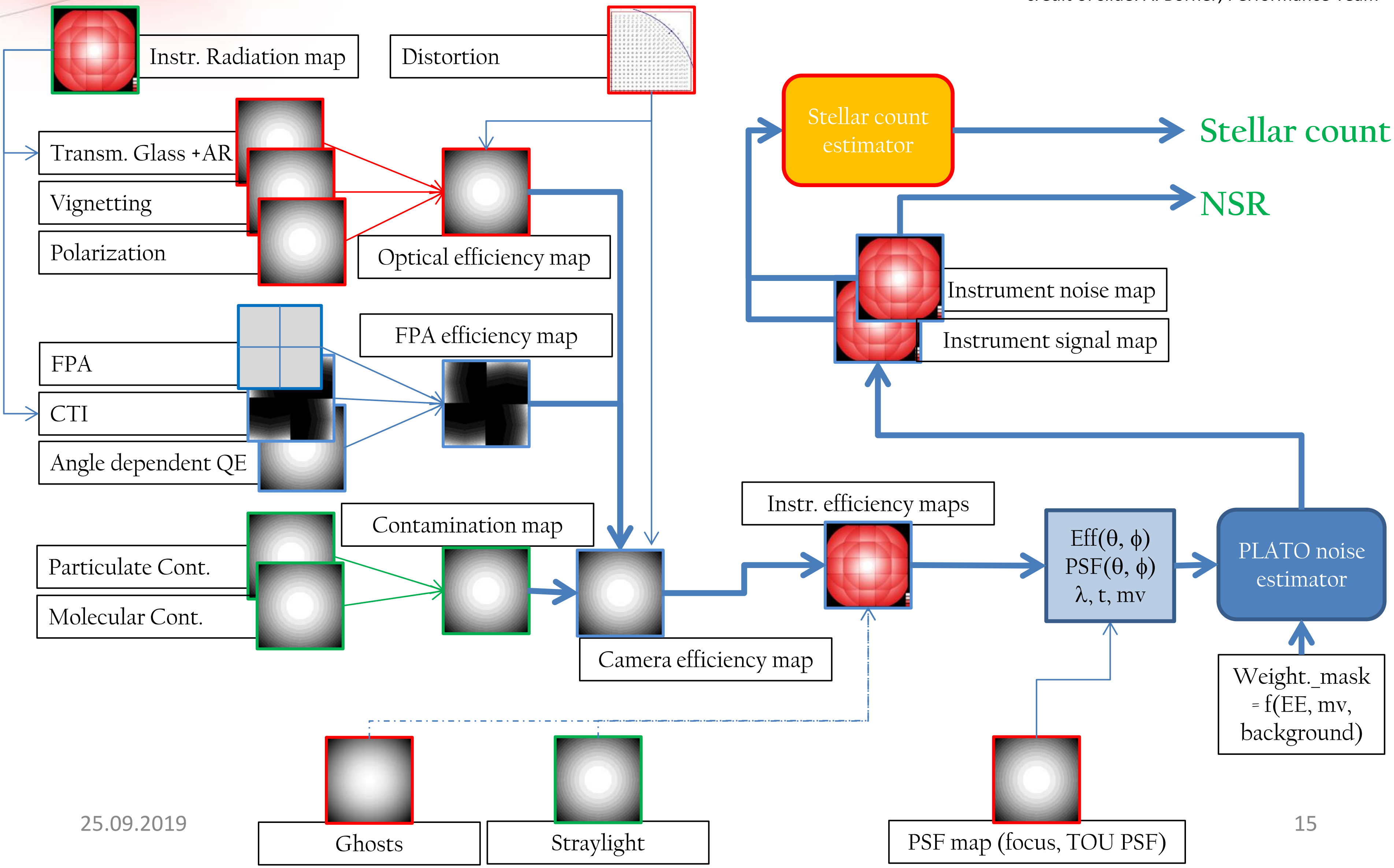
Masking

Read-out noise

credit of slide: A. Börner, Performance Team

Spatially resolved maps

credit of slide: A. Börner, Performance Team



PLATO Performance Team contribution to the PIC

Each star in the **PIC** is characterized by its **coordinates**, **proper motion**, **brightness** (in different magnitudes), **radius**, **mass**, and **temperature**, etc.

For each star in the **PIC**, the **Performance Team** used the spatially resolved maps to assign to each star a **noise budget**, including **random** noise sources (photon noise, readout noise...) and residuals from **systematics** (jitter, PSF breathing...).

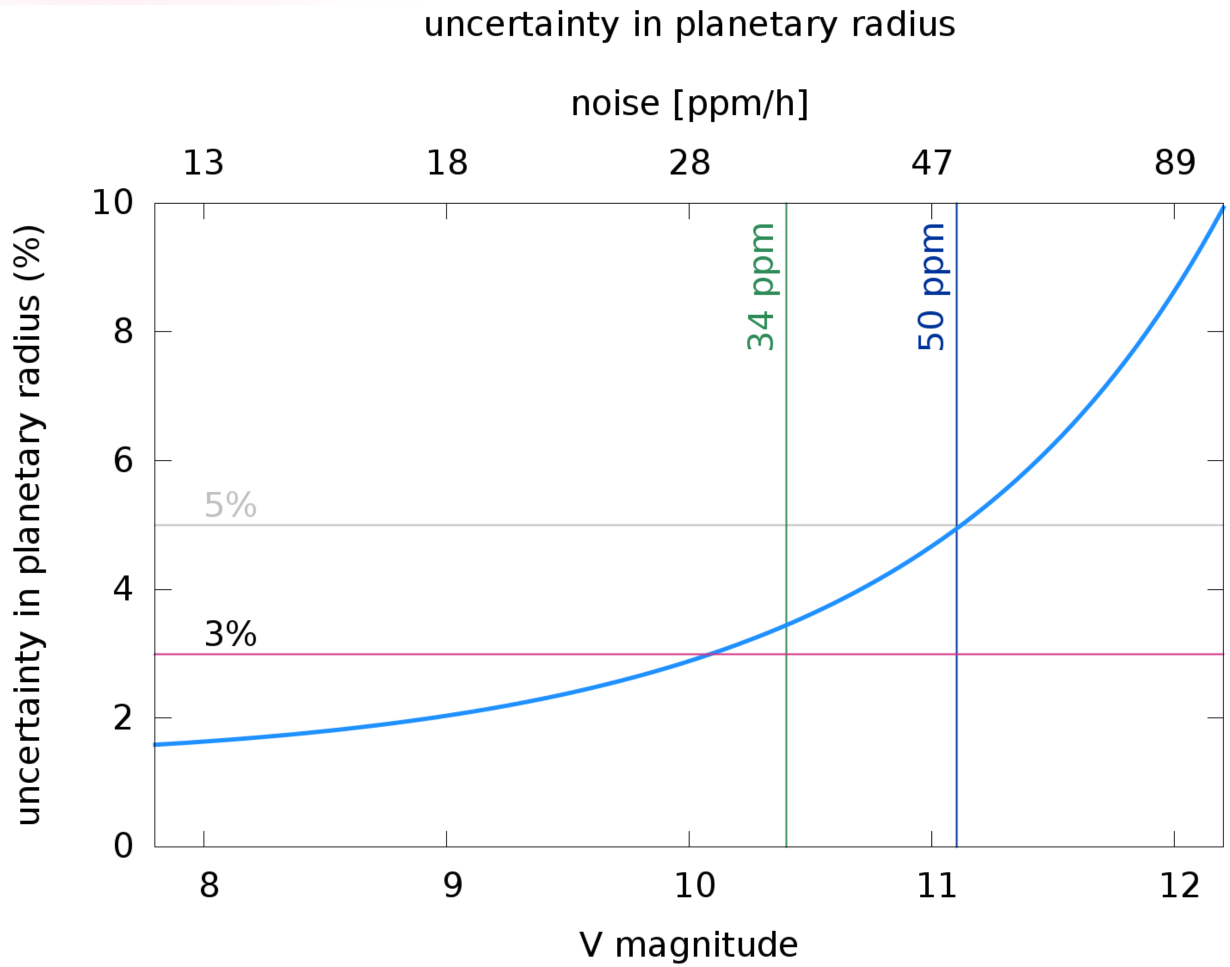
This information can be used:

- To estimate the expected **uncertainty in the planetary radius** for a transiting planet (with a given size and orbital period) around a given star (see next slide).
- To estimate the expected **uncertainty in the stellar parameters** obtained with asteroseismology.
- Etc.

Additionally, the work by the **Performance Team** is used to develop and validate light curve **simulators** (see next slides) with representative properties of the payload.

Please, remember so far we are <u>working on paper</u>, using worst case analysis. The knowledge of the real performance of the instrument will start in phase C, when we test real hardware.

Planetary radius precision



The current instrument design is compatible with the performance requirements for characterization of small planets

→ 3% planet radius precision for stars <10.3 mag (Earth around Sun case)

→ 5% radius precision for stars <11 mag

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PLATO Performance

There will be a paper (hopefully submitted 2019) providing a complete description of the model used for estimating the PLATO performance.

The performance benchmark will be the NSR in 1h reached for a given star in a given position of the field of view. The model used is the one used for justification of performance (requirements) and trade-off designs.

Additionally, you can use:

- **PLATOSim**: an end-to-end simulator at pixel level
  `http://ivs-kuleuven.github.io/PlatoSim3/`
  Marcos-Arenal et al. (2014) A&A, 566, A92.

- **PLATO Solar-like Light-curve Simulator** (PSLS): light curve simulator with realistic prescription of PLATO noise budget
  `http://psls.lesia.obspm.fr`
  Samadi et al. (2019) A&A, 624, A117.