The PLATO Science Performance
(PLAnetary Transits and Oscillation of stars)

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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

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

- **planet detection** (up to HZ solar-like stars)
  - 80 ppm 1h (planet yield)
  - long baseline (>2yr)
  - 600s sampling
  - 25s sampling

- **stellar characterization** (up to 10% age for Sun-like star)
  - noise requirements in the Fourier domain
  - requirements on the residuals of systematic noise
  - 34 ppm in 1h (3% Rp; 10% age)
  - 50 ppm in 1h (5% Rp; 20% age)

- **planet characterization** (down to 3% uncertainty in radius for Earth-Sun analogs)
  - V<11 (radial velocity)
  - P1 sample requirements
  - FOV requirements
24 Normal cameras:
- 12cm aperture telescopes
- range: $\sim 8 \ (4) \leq m_V \leq 11 \ (13)$
- FOV payload $\sim 49^\circ \times 49^\circ$
- Each camera has 4 x CCD, each $4510 \times 4510$px
- Pixels size: 18 $\mu$m square
- read-out cadence: 25 sec
- operate in “white light”
  $(500 – 1050 \text{ nm})$

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 deg² Kepler)

It is spread over:  
- ~2 billion pixels (2 000 Mpx vs 98 Mpx for Kepler)
- ~6 600 cm² of sensitive area (2x Gaia)
<table>
<thead>
<tr>
<th>N-cams/tel</th>
<th>equivalent diameter (m)</th>
<th>FOV (degrees²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoRoT</td>
<td>1</td>
<td>0.27</td>
</tr>
<tr>
<td>Kepler</td>
<td>1</td>
<td>0.95</td>
</tr>
<tr>
<td>TESS</td>
<td>4</td>
<td>0.10</td>
</tr>
<tr>
<td>PLATO</td>
<td>24</td>
<td>0.59</td>
</tr>
</tbody>
</table>
System PSF is additionally a function of stellar magnitude, stellar spectrum, position on the field of view, camera, temperature...

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

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

credit of slide: M. Pertenais, TOU Team, Performance Team
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.
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The actual field of view size of the PLATO instrument is comparable to Ursa Major.
pointing requirements

camera boresight reference frames co-aligned

N-CAM 1 of group 1  N-CAM 2 of group 1  N-CAM 3 of group 1

N-CAM 4 of group 1  N-CAM 5 of group 1  N-CAM 6 of group 1

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.
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

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Performance impactors

- Aberration
- Vignetting
- Polarization
- Transmissivity
- Distortion
- Point spread function
- Quantum efficiency
- Charge transfer efficiency
- Photo-resonse non-uniformity
- Dark signal
- Jitter
- Stray light
- Radiation
- Temperature
- Contamination
- Thermo-elastic distortions
- Gain stability
- Analogue-digital conversion
- Offset stability
- Bias voltage stability
- Masking
- Read-out noise
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 working on paper, using worst case analysis. The knowledge of the real performance of the instrument will start in phase C, when we test real hardware.
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
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/


- **PLATO Solar-like Light-curve Simulator** (PSLS): light curve simulator with realistic prescription of PLATO noise budget
  
  http://psls.lesia.obspm.fr