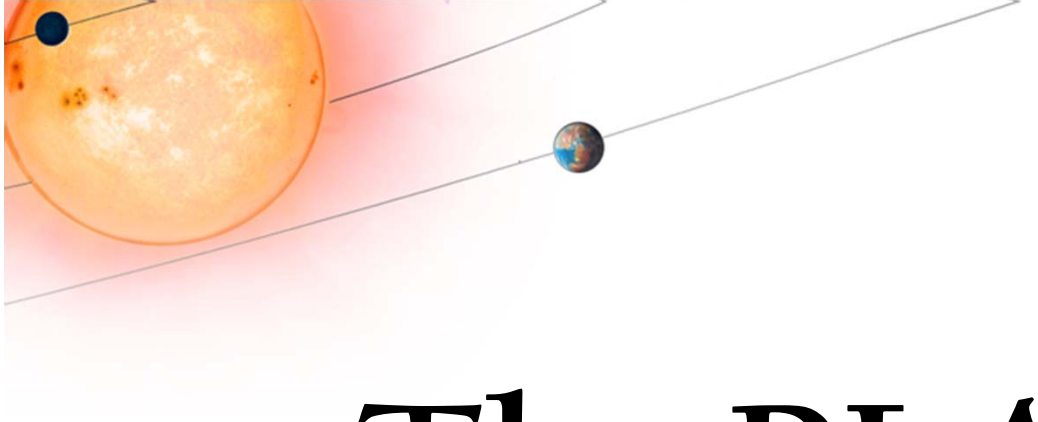


The PLATO Fine Guidance System

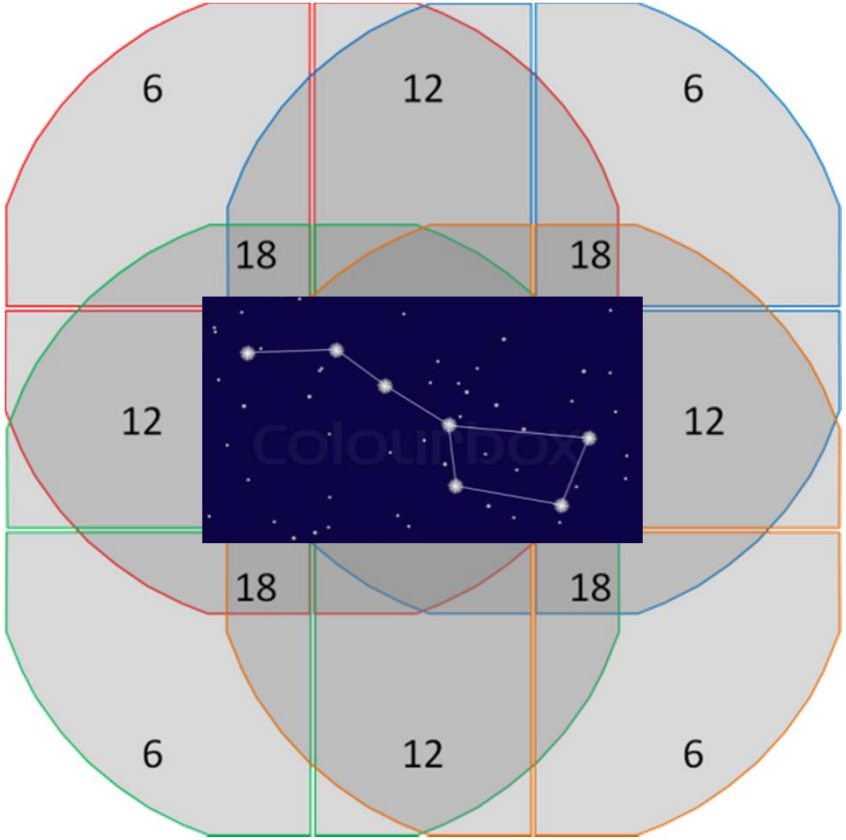
Denis Grießbach

German Aerospace Center

- Institute of Optical Sensor Systems/ Space Instruments
- Actual contributions for space missions: MERTIS, InSight, CHEOPS, PLATO, SOFIA/GREAT, GRACE follow-on, FireBIRD: TET & BIROS, DESIS, EnMAP, KompSat

PLATO

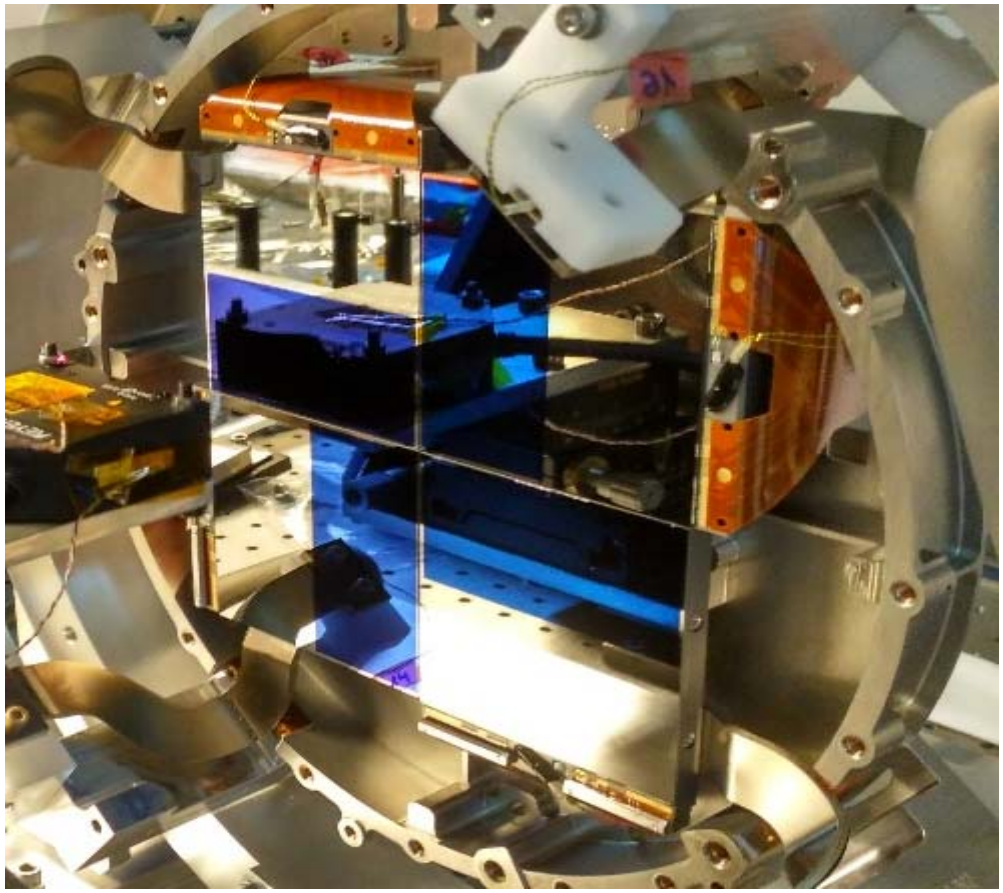
- Detection and Characterization of potentially habitable planets down to Earth-size



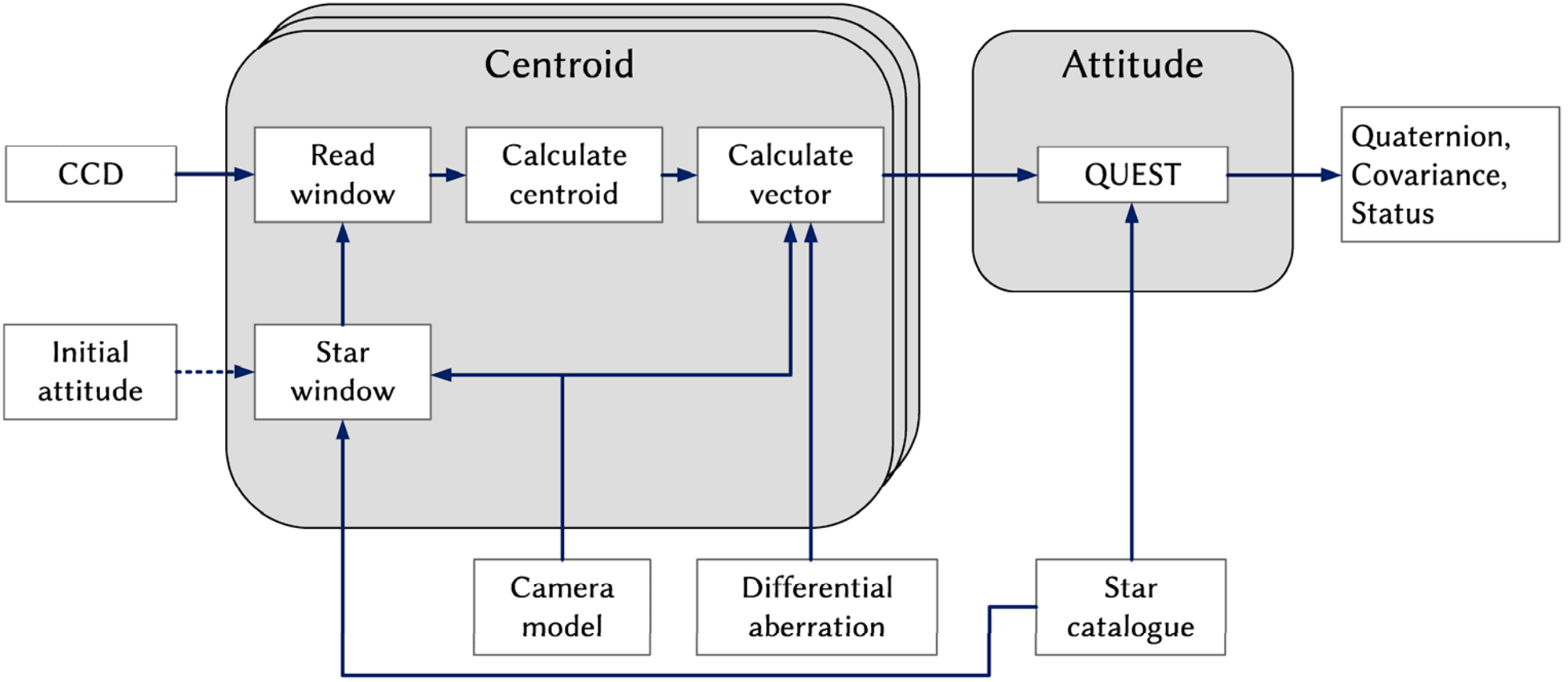
PLATO - CCDs

- N-Cams
  - 4×4510×4510 pixel²
  - Pixel: 18 µm ≡ 15 arcsec
  - FPA: 163×163 mm²
- F-Cams
  - 4×4510×2255 pixel²
  - Frame transfer
  - Used as Fine Guidance System (FGS)

FPA-Prototype



FGS Overview



FGS Comparison

- Exoplanet missions using the instrument to improve pointing performance (non-exhaustive list)

	COROT - 2006	KEPLER - 2009	TESS – 2018	PLATO - 2026
FGS [arcsec], 2σ	xy: 0.1/ z: 0.45	≈ xy: 0.03/ z: 0.1	< xy: 0.3/ z: 1.3	xy: 0.025/ z: 0.1
FoV [deg], 1 cam	2.7×3.05	4 ×±0.27	24×24	±18.8
iFoV [arcsec]	2.32	1.92	21	15
Pixel size [µm]	13.5	13	15	18
PSF size [pixel]	7×7	6.4×6.4	4×4	2×2
Cadence [Hz]	1.0	9.6	2.0	0.4
# stars	2	40	200	30

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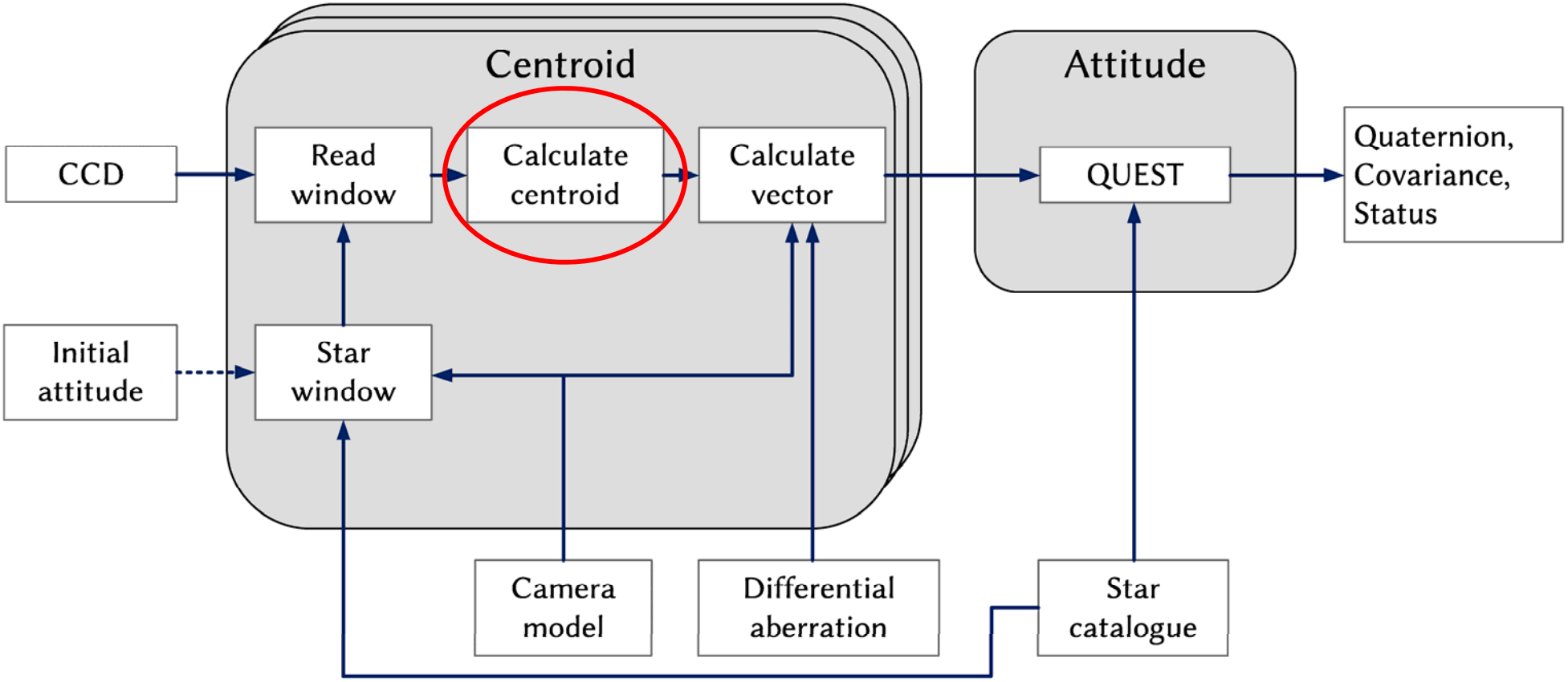
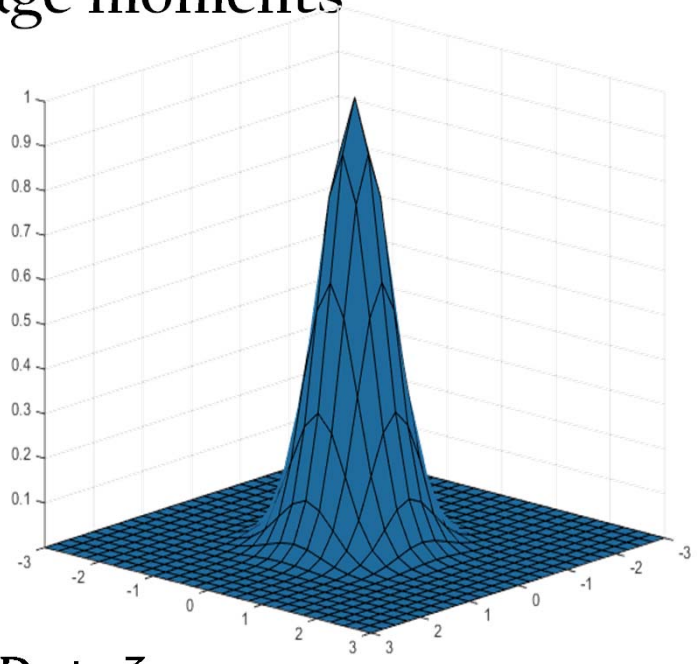


Centroid Algorithm

- State of the art: CoM based on first order image moments

$$x_0, y_0 = \frac{M_{10}}{M_{00}}, \frac{M_{01}}{M_{00}} \quad \text{with } M_{pq} = \sum_i \sum_j i^p j^q y(i,j)$$

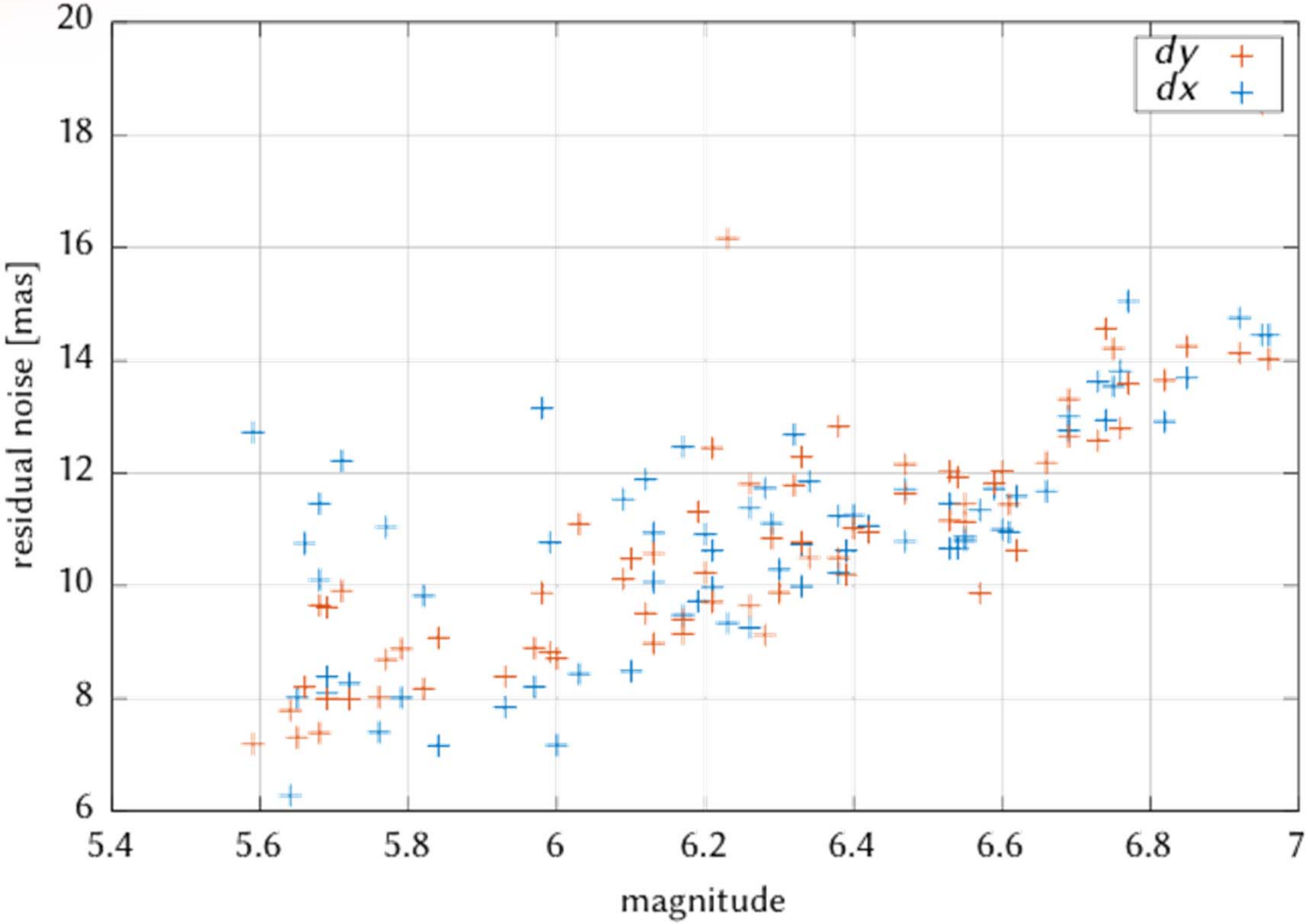


- Better: Gaussian PSF model with intensity I_0, centroid x_0, y_0, PSF-width σ, background D, and noise ζ

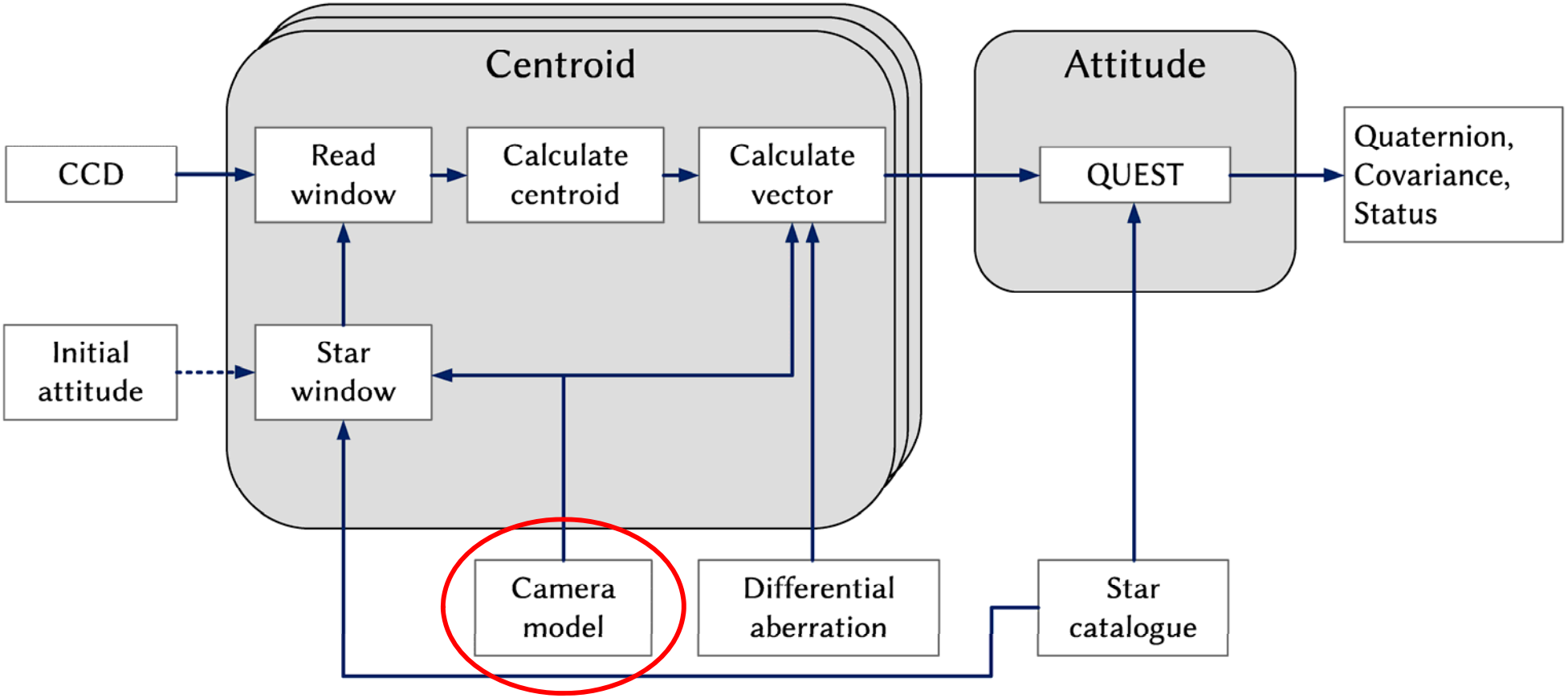
$$y(i,j) = I_0 \int_i^{i+1} e^{-\frac{(x-x_0)^2}{2\sigma^2}} dx \int_j^{j+1} e^{-\frac{(y-y_0)^2}{2\sigma^2}} dy + D + \zeta$$

- Non-linear optimization problem: $\min_{x_0, y_0, \boldsymbol{\sigma}, \boldsymbol{D}, \boldsymbol{I_0}} \|\hat{\boldsymbol{y}} - \boldsymbol{y}\|^2$

Centroid Noise

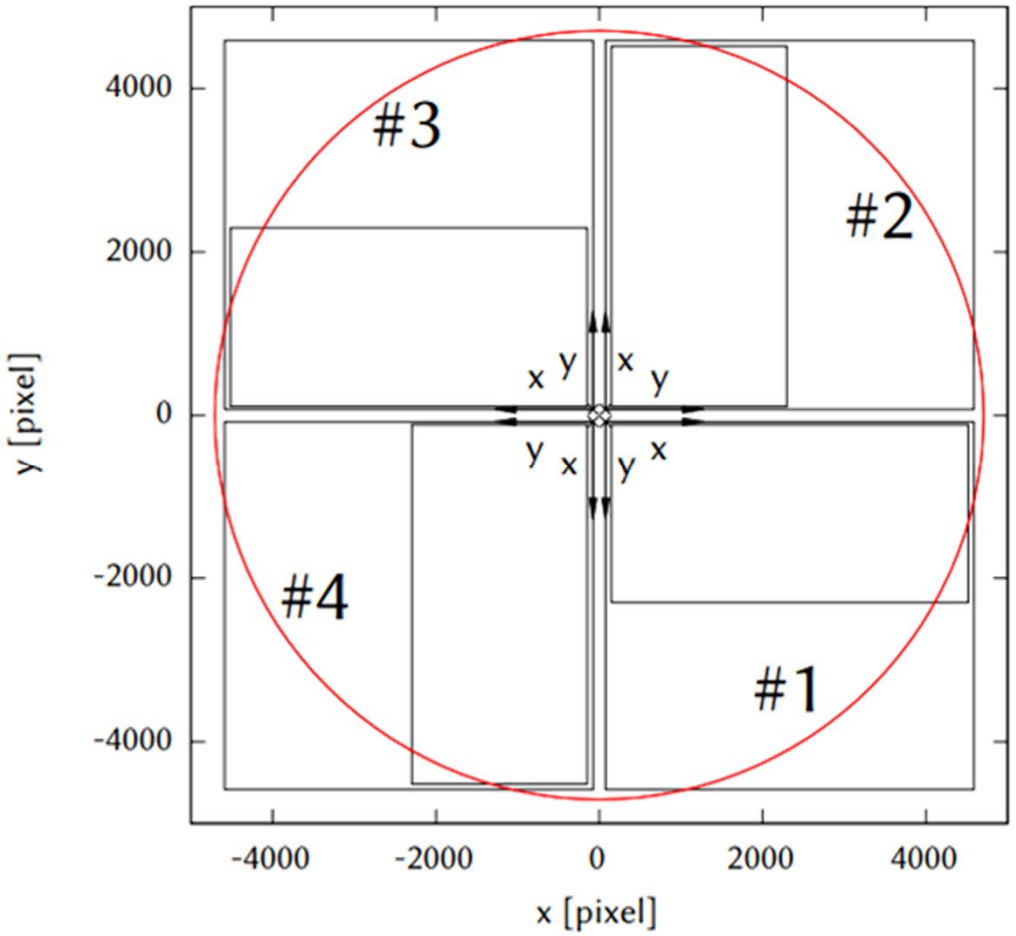


FGS Overview



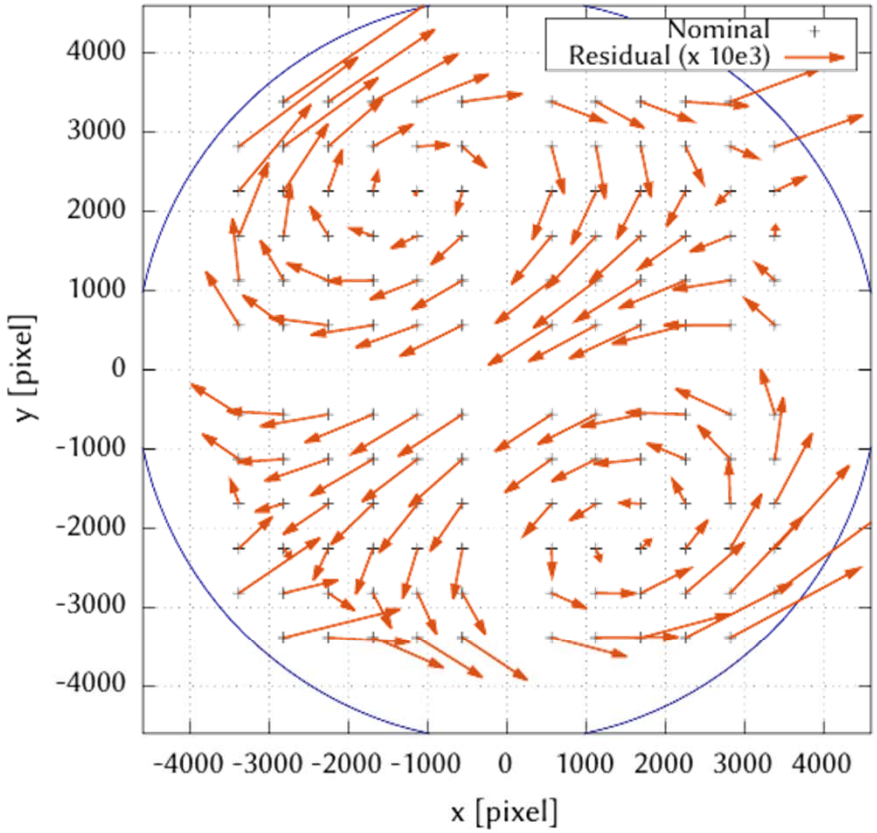
Camera Model

- Models the direction represented by each pixel
  - Focal length
  - Geometric distortion
    - radial-symmetric
    - tangential
  - Individual CCD position & rotation

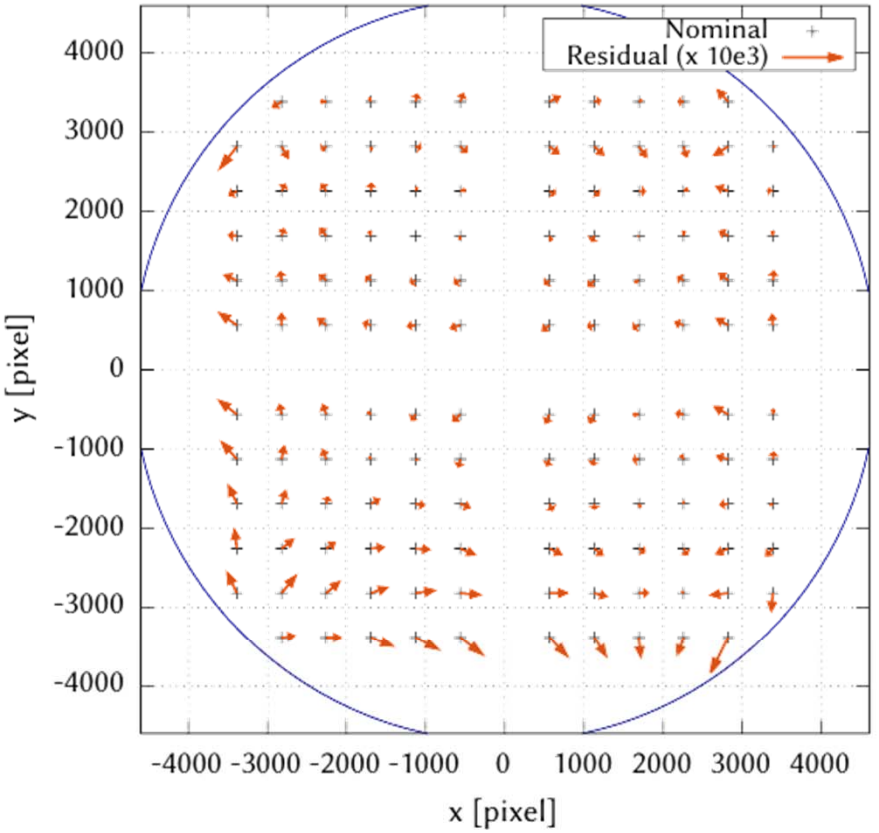


Geometric Calibration

- Residual accuracy: ‹0.03 pixel @95% confidence

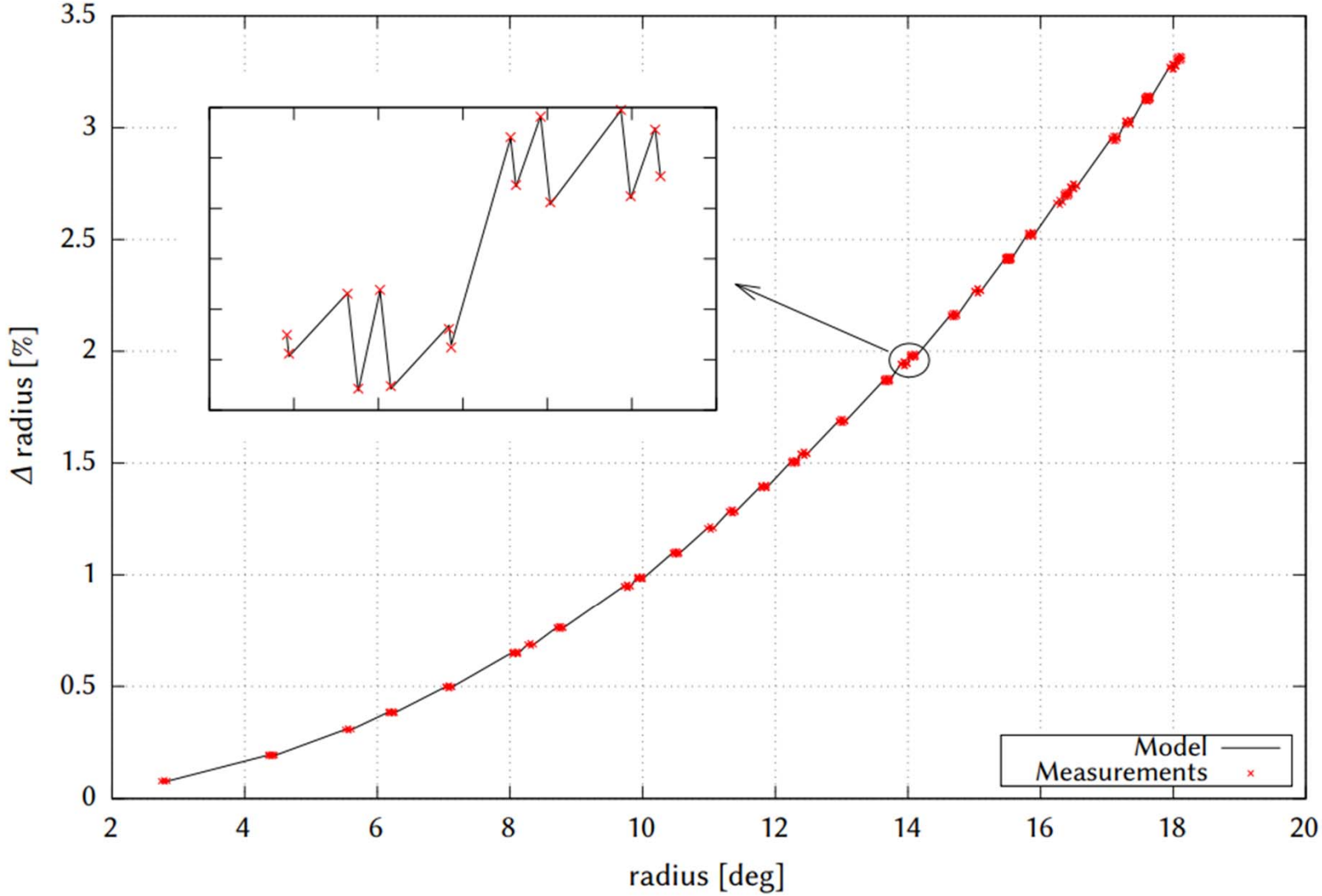


(a) Radial-symmetric model

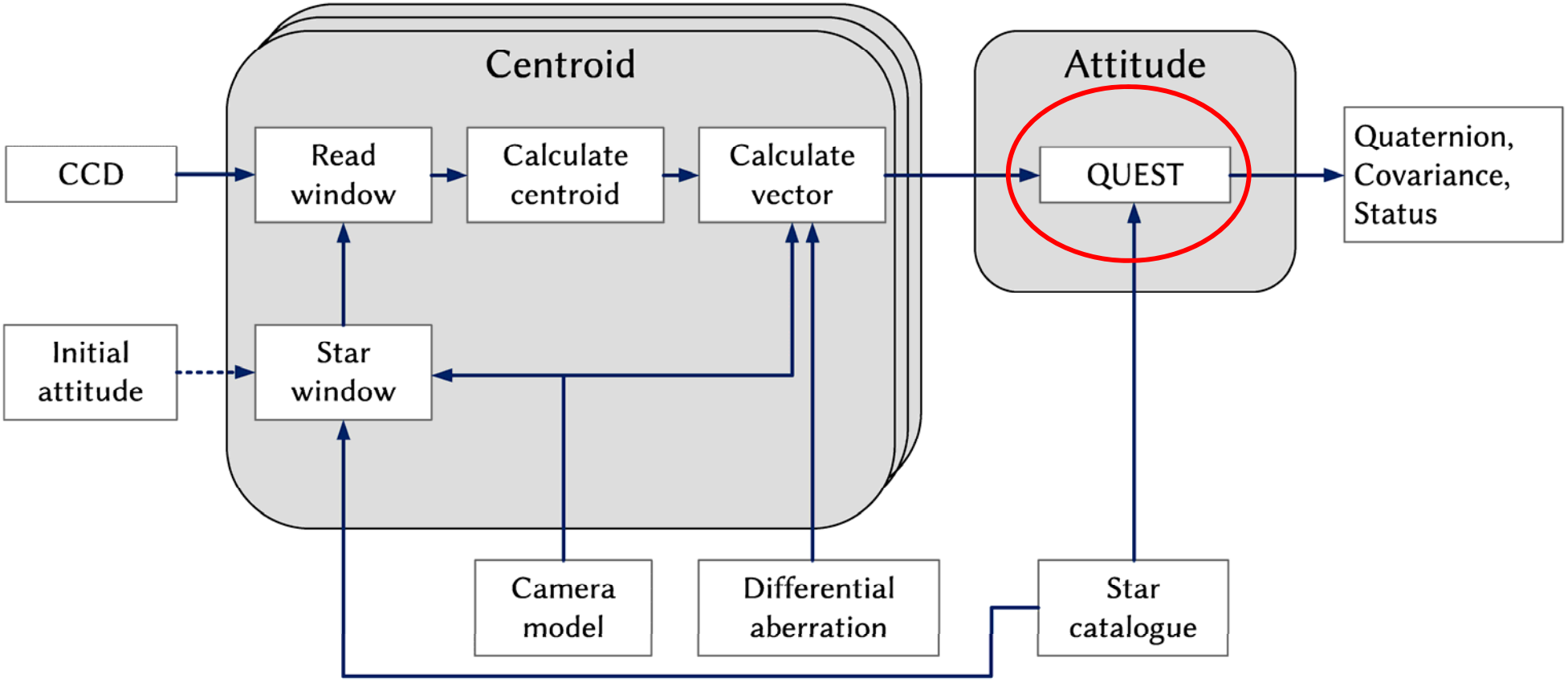


(b) Radial-symmetric and tangential model

Lens Distortion



FGS Overview

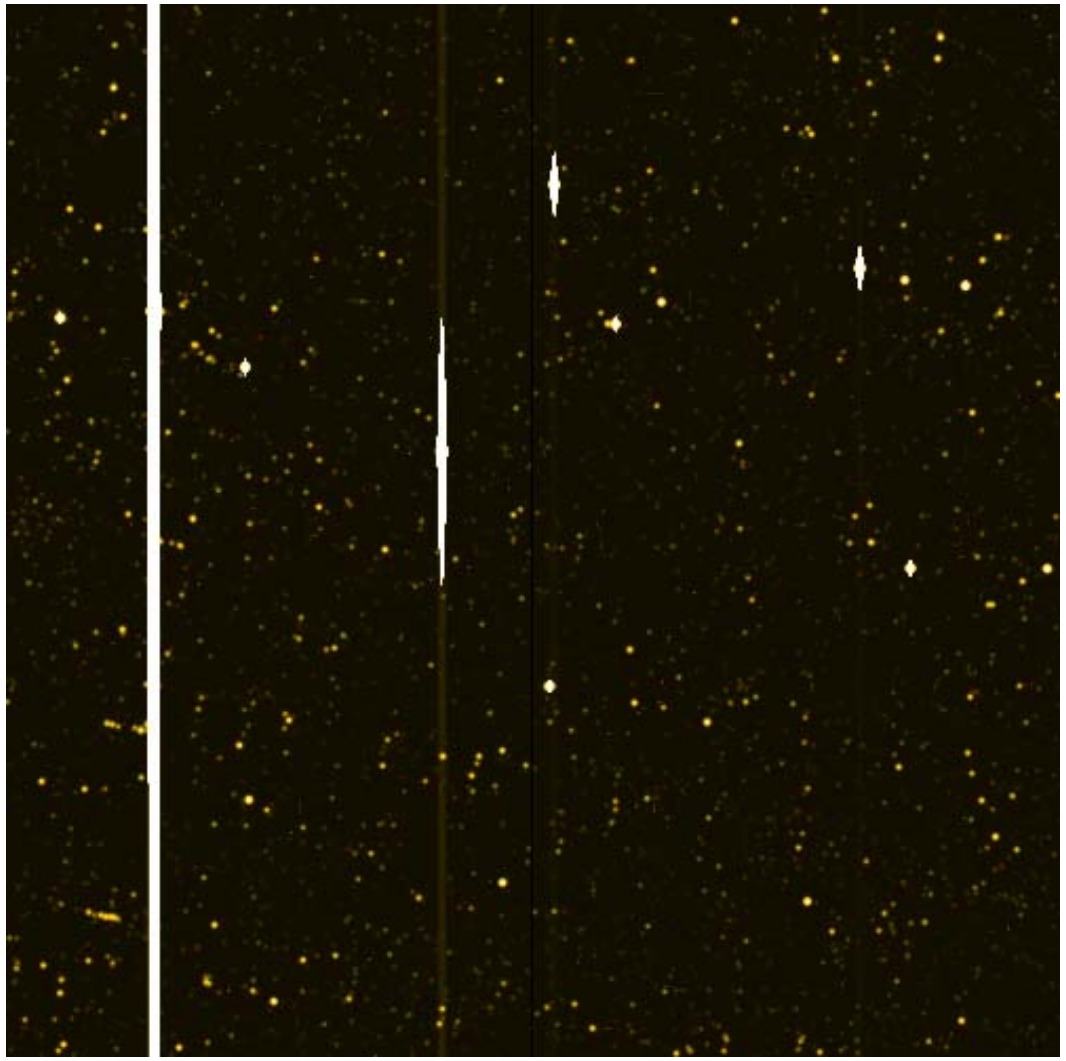


FGS Performance

- 30 guide stars used for attitude estimation
- Noise Equivalent Angle (NEA)
  - xy: ‹10 mas, z: ‹40 mas
- Bias instability (14h)
  - xy: ‹5 mas, z: ‹10 mas

- Leon2-FT processor @80 MHz
- ‹ 300 ms
  - Faster calculation = increased AOCS performance
  - Algorithm could be parallelized

Questions/Remarks



2x2 degree image simulation (PlatoSim)