Gaia status

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ESA/ESTEC

GREAT-ESF Brown Dwarf Workshop, 24–26 March 2014, Torino

Layout

1. Astrometry with Gaia, including performance predictions

2. Gaia status update

3. Brown dwarfs with Gaia

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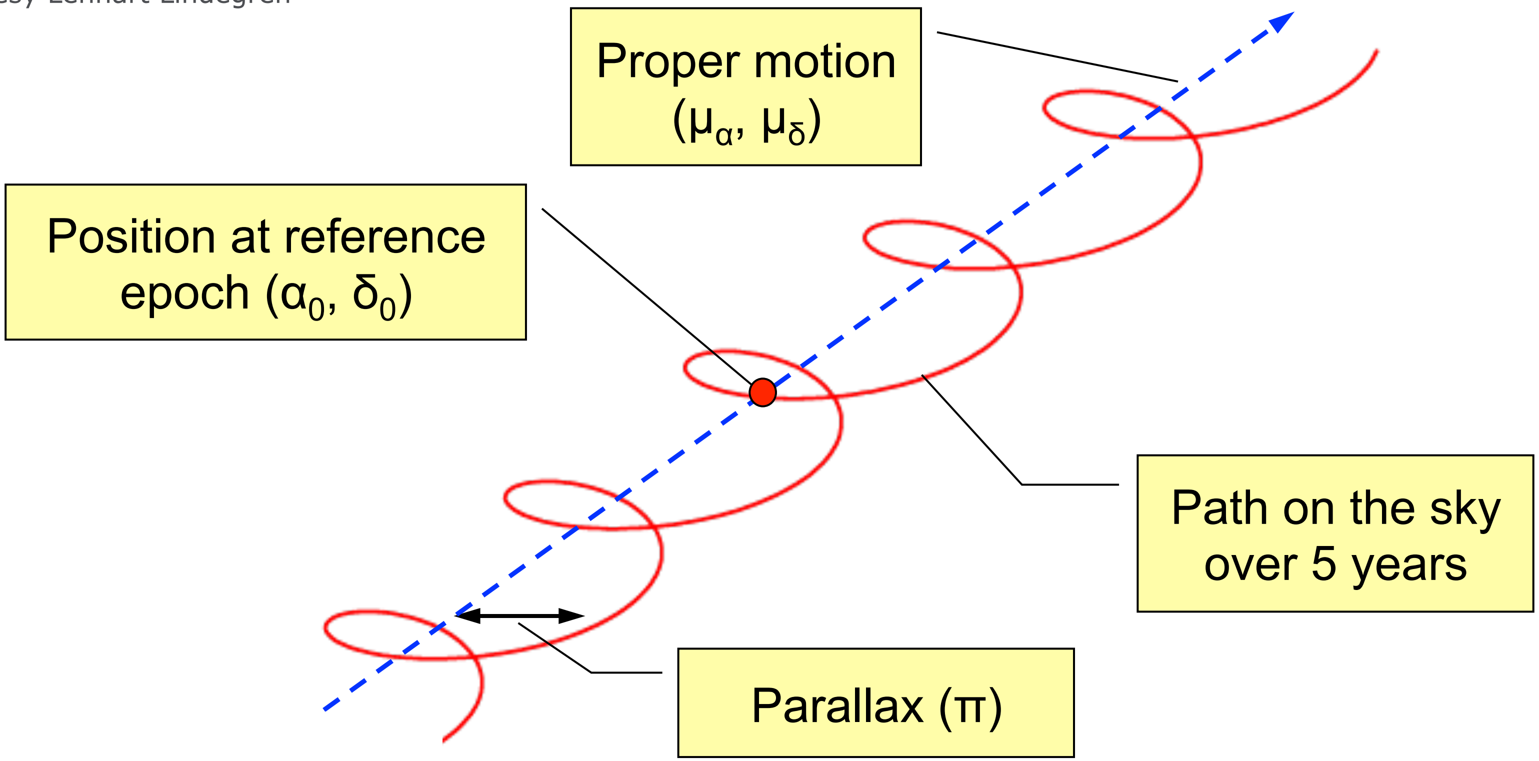
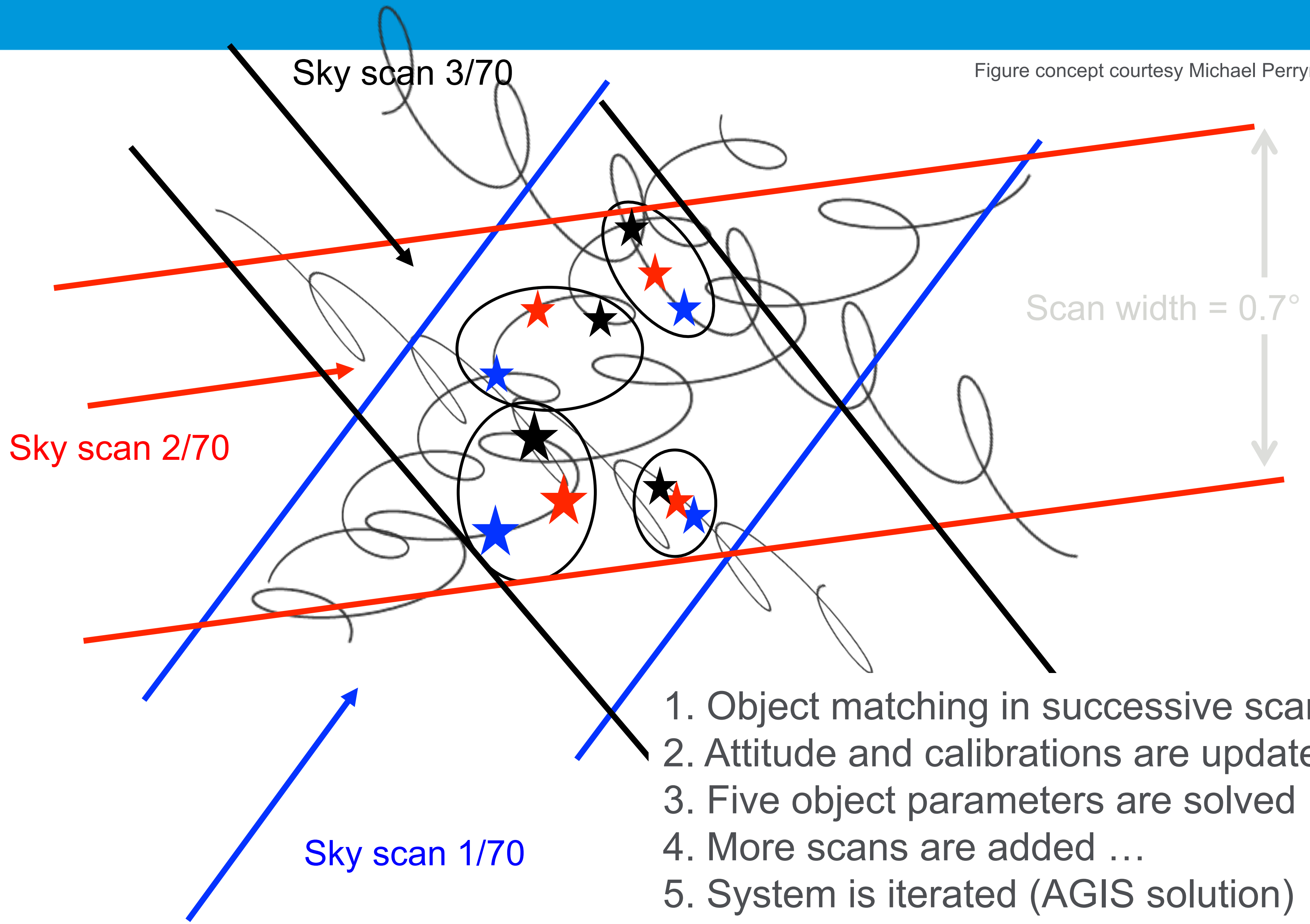
Gaia astrometry in one viewgraph

Figure courtesy Lennart Lindegren



Monitor this path for 10^9 stars during 5 years and fit, for each object, a 5-parameter model to retrieve reference position, proper motion, and parallax (for a "given" instrument calibration and attitude)

Well, actually two viewgraphs …



1. Object matching in successive scans
2. Attitude and calibrations are updated
3. Five object parameters are solved
4. More scans are added …
5. System is iterated (AGIS solution)

Astrometry in one equation

End-of-mission parallax standard error:

$$\sigma_\pi \ [\mu\mathrm{as}] = m \cdot g_\pi \cdot \sqrt{\frac{\sigma_\xi^2 + \sigma_{\mathrm{cal}}^2}{N_{\mathrm{eff}}}}$$

m	= scientific contingency factor (margin) = number
g_π	= geometrical parallax factor (CCD to end-of-mission) = number
σ_ξ	= single-CCD location-estimation (centroiding) error (μas) = function(G)
σ_{cal}	= residual calibration error (μas) = function(G)
N_{eff}	= end-of-mission number of detected CCD transits = sky map

Astrometry in one equation

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Single-CCD centroiding error σ_ξ

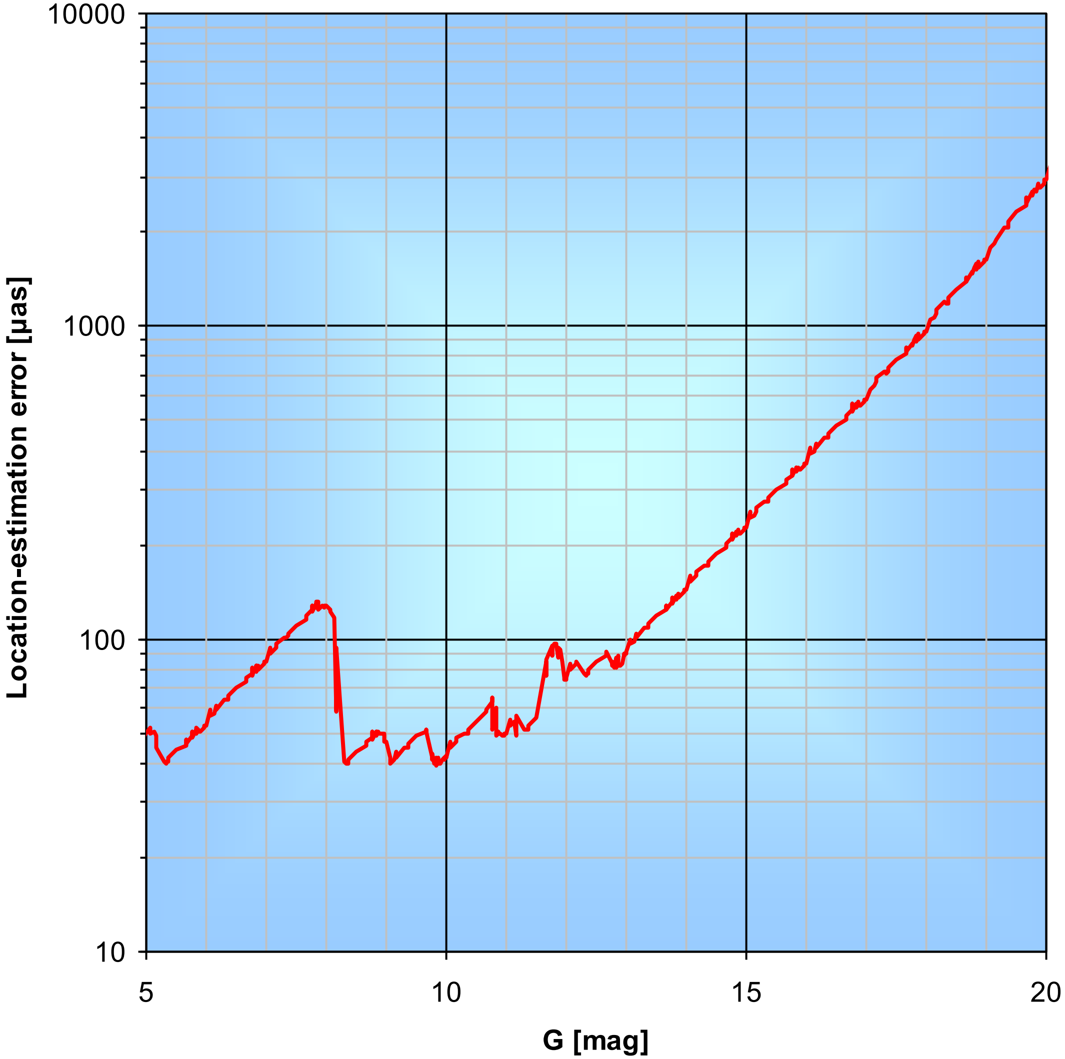

Figure from GAIA-CA-TN-ESA-JDB-053

Based on Monte Carlo simulations, including "everything", e.g., CCD QE + MTF, telescope wave-front errors + transmission + optical distortion, LSF smearing due to attitude jitters + TDI motion, CCD noise + offset non-uniformity, radiation-damage-induced charge loss + bias calibration, sky background, windowing / sampling, magnitude, extinction, spectral type, …

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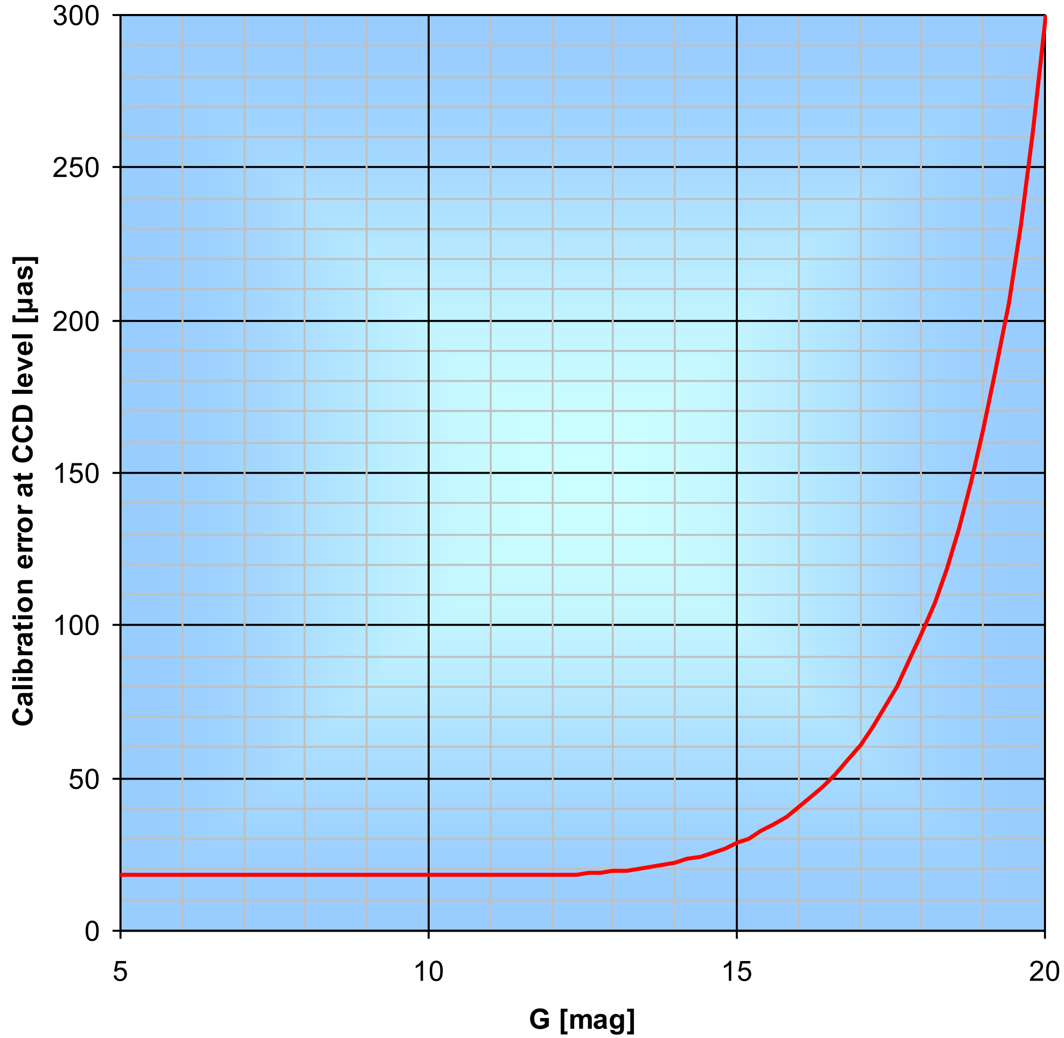
Residual calibration error σ_{cal}



Residual errors, including "everything", e.g., chromaticity calibration, geometrical transformation from focal plane to field coordinates, satellite attitude model, thermo-mechanical stability of telescope + focal plane, metrology errors associated with basic-angle monitoring, …

Small compared to random errors and relevant only for bright-star noise floor

Figure based on data from GAIA.ASF.RP.SAT.00005 (Science performance budget report)

Astrometry in one equation

End-of-mission parallax standard error:

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Number of field-of-view transits

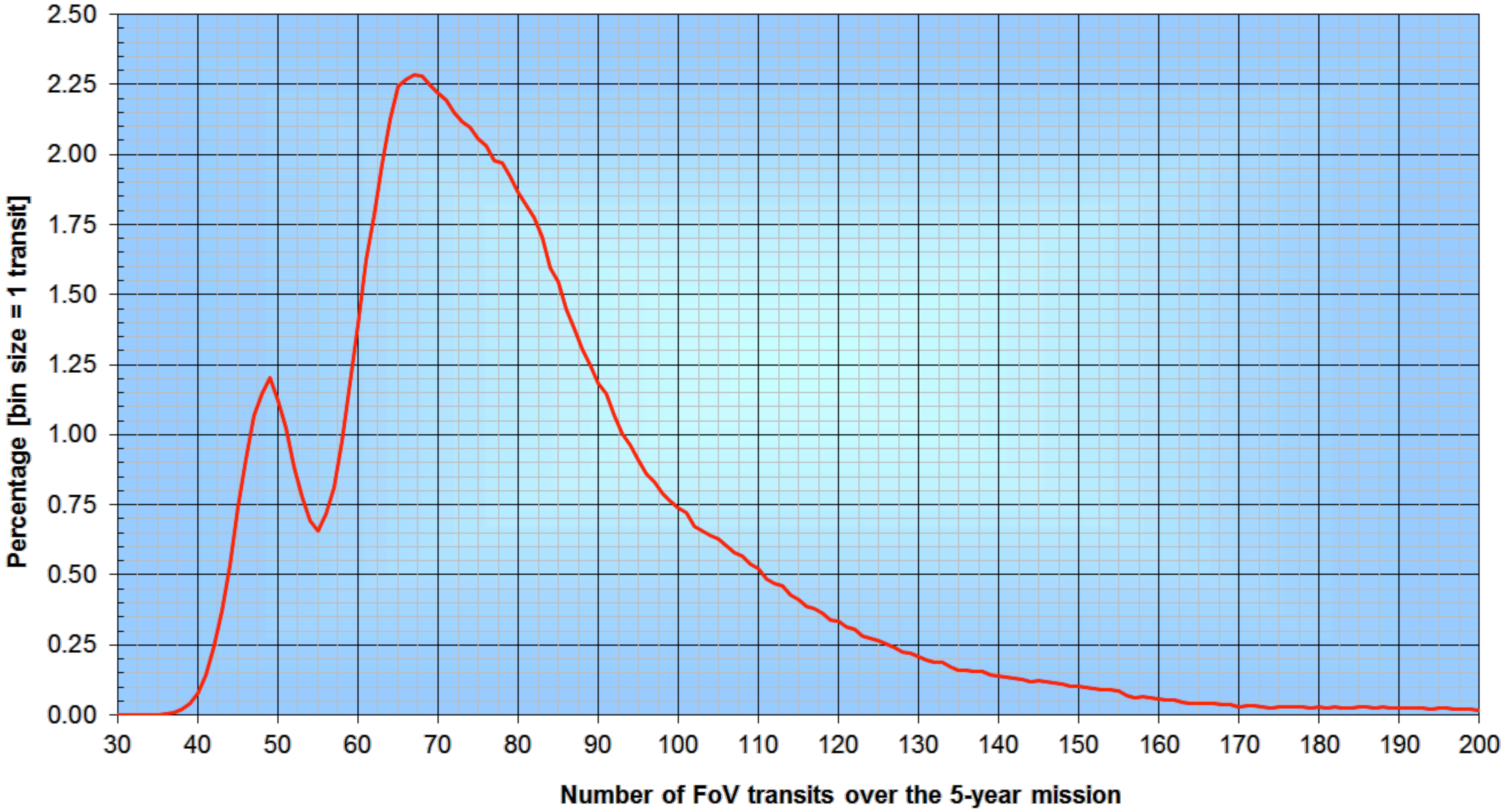

Figure courtesy Jos de Bruijne

Astrometry in one equation

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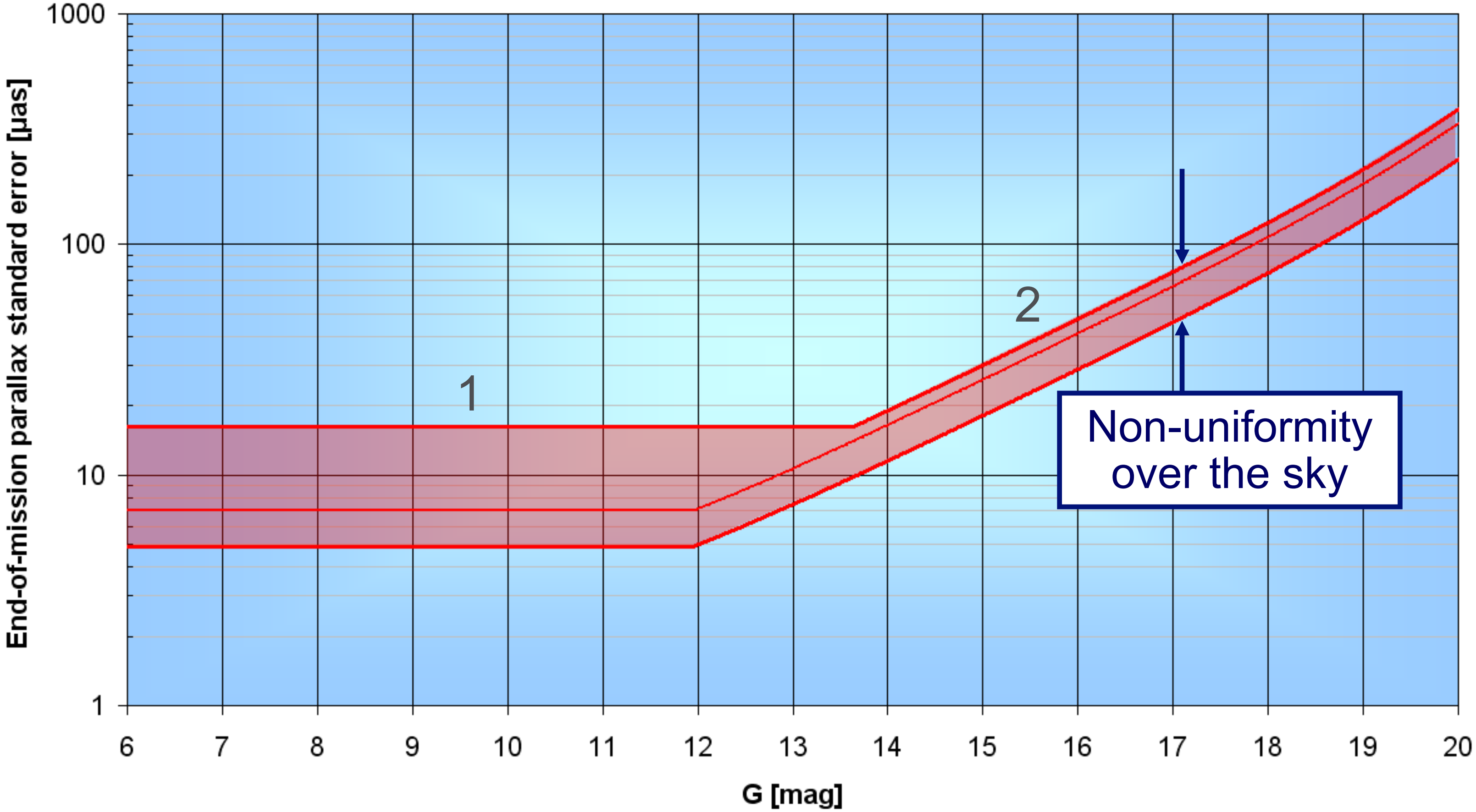
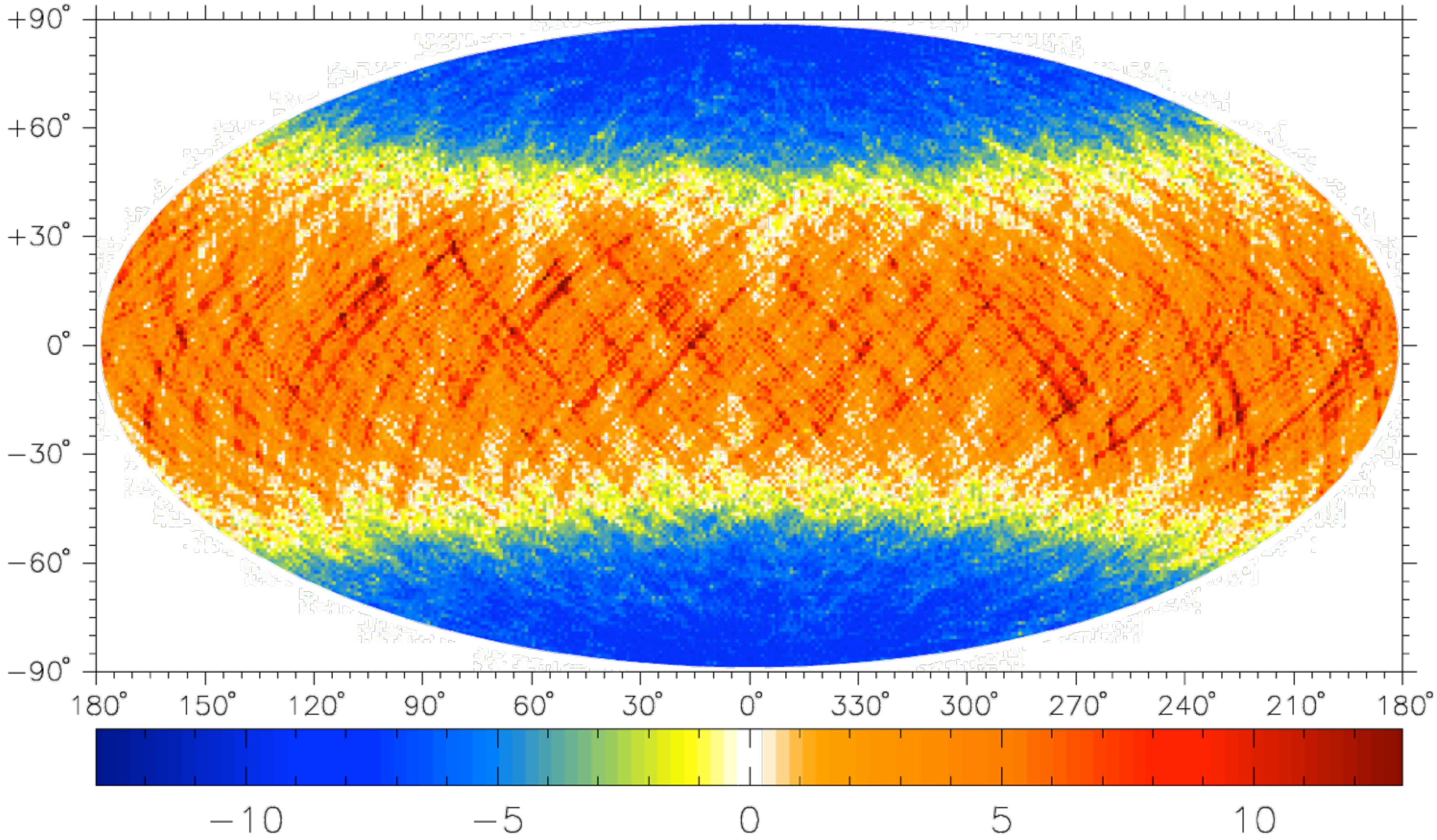
End-of-mission parallax standard errors



1. 6 < G < 12: bright-star regime (calibration errors + CCD saturation)
2. 12 < G < 20: photon-noise regime, with sky-background noise and electronic noise setting in around G ~ 20 mag

Figure from http://www.cosmos.esa.int/web/gaia/science-performance

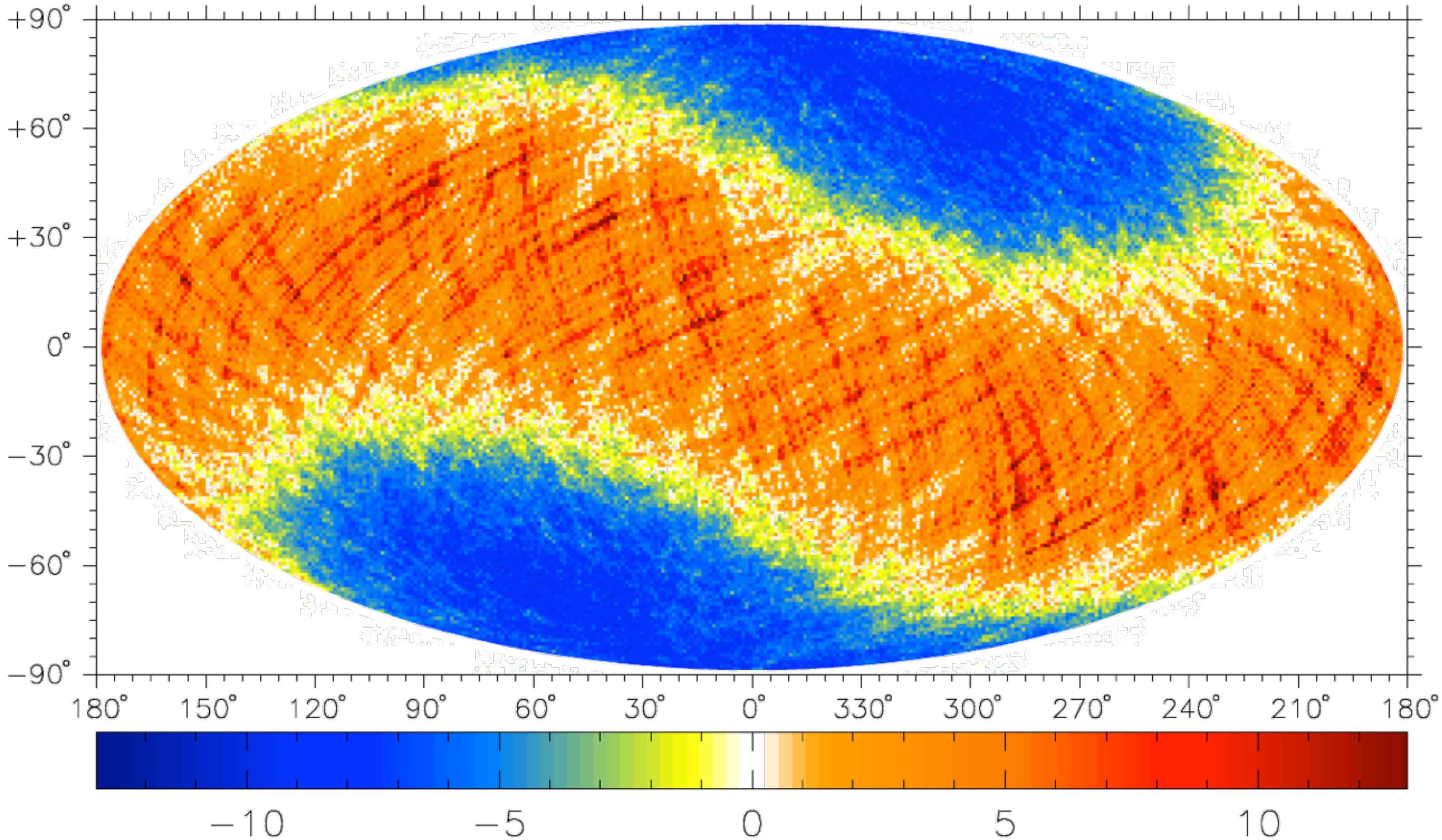
Parallax-error-variation map @ G=15 mag



Sky-average: σ_π = 25.8 µas

Figure from http://www.cosmos.esa.int/web/gaia/science-performance – ecliptic coordinates

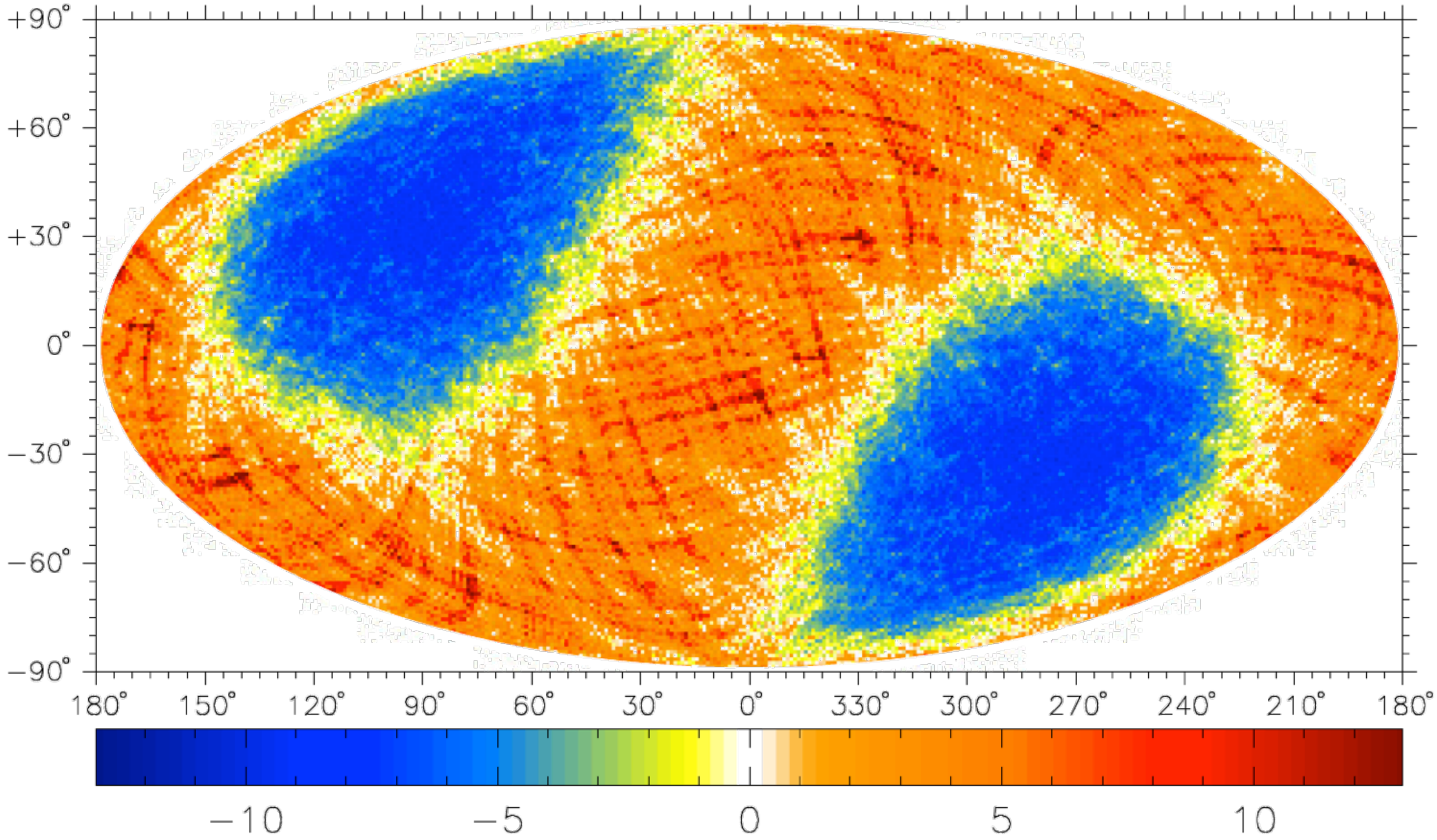
Parallax-error-variation map @ G=15 mag



Sky-average: σ_π = 25.8 µas

Figure from http://www.cosmos.esa.int/web/gaia/science-performance – equatorial coordinates

Parallax-error-variation map @ G=15 mag



Sky-average: σ_π = 25.8 μas

Figure from http://www.cosmos.esa.int/web/gaia/science-performance – galactic coordinates

End-of-mission astrometry

For a 5-year Gaia mission, sky-averaged position and proper-motion standard errors, σ_0 [µas] and σ_μ [µas yr^{-1}], are:

$$\sigma_0 = 0.743 \cdot \sigma_\pi$$

$$\sigma_\mu = 0.526 \cdot \sigma_\pi$$

For any given V magnitude and V-I colour index, the end-of-mission parallax standard error, σ_π [µas], averaged over the sky, is:

$$\sigma_\pi \text{ [µas]} = \sqrt{(9.3 + 658.1 \cdot z + 4.568 \cdot z^2)}\ [0.986 + (1 - 0.986)\ (V\text{-}I)]$$

$$z = \mathrm{MAX}[10^{0.4\,(12 - 15)}, 10^{0.4\,(G - 15)}]$$

$$G = V - 0.0107 - 0.0879 \cdot (V\text{-}I) - 0.1630 \cdot (V\text{-}I)^2 + 0.0086 \cdot (V\text{-}I)^3$$

Equations and variations over the sky available on http://www.cosmos.esa.int/web/gaia/science-performance

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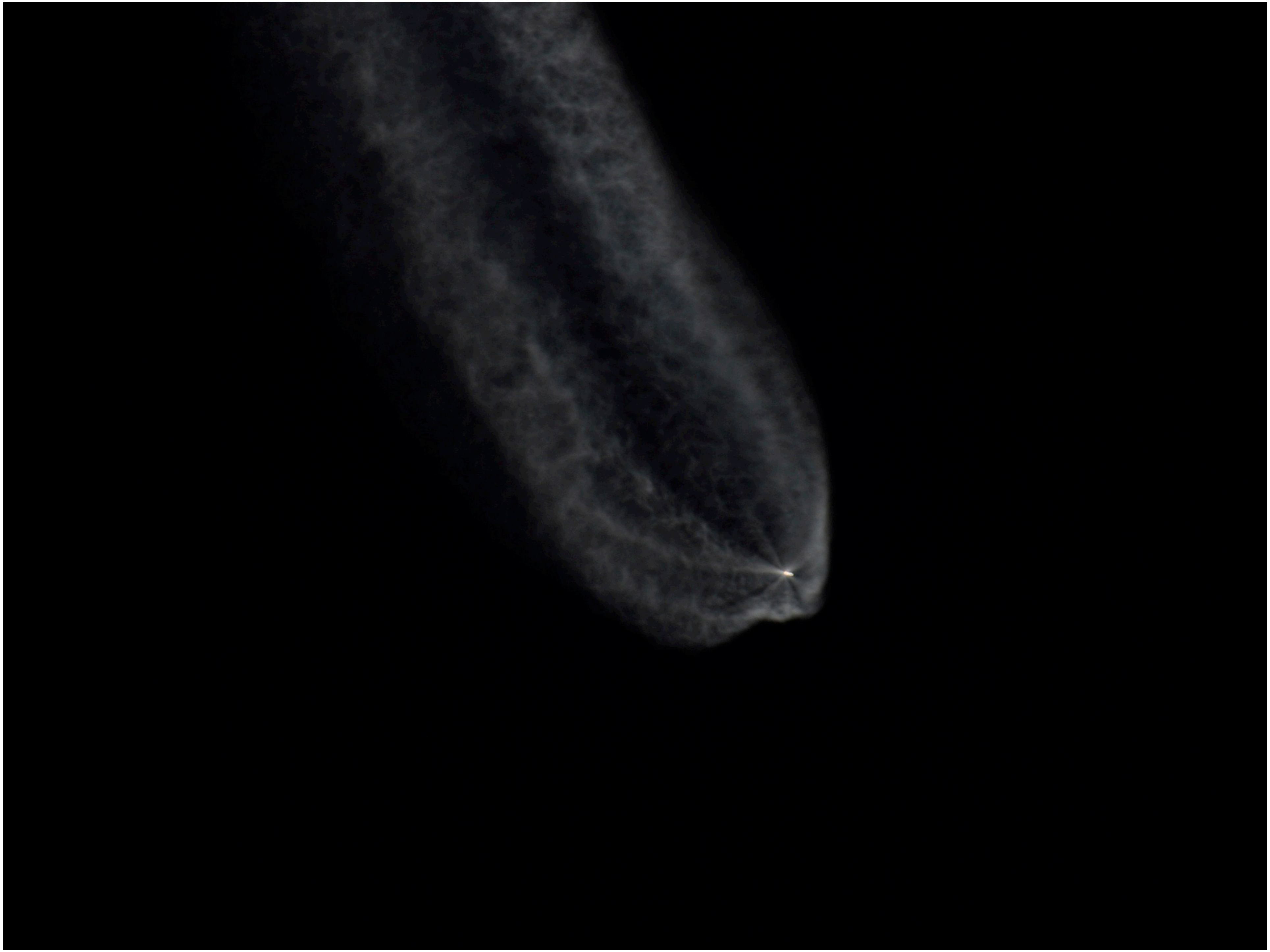
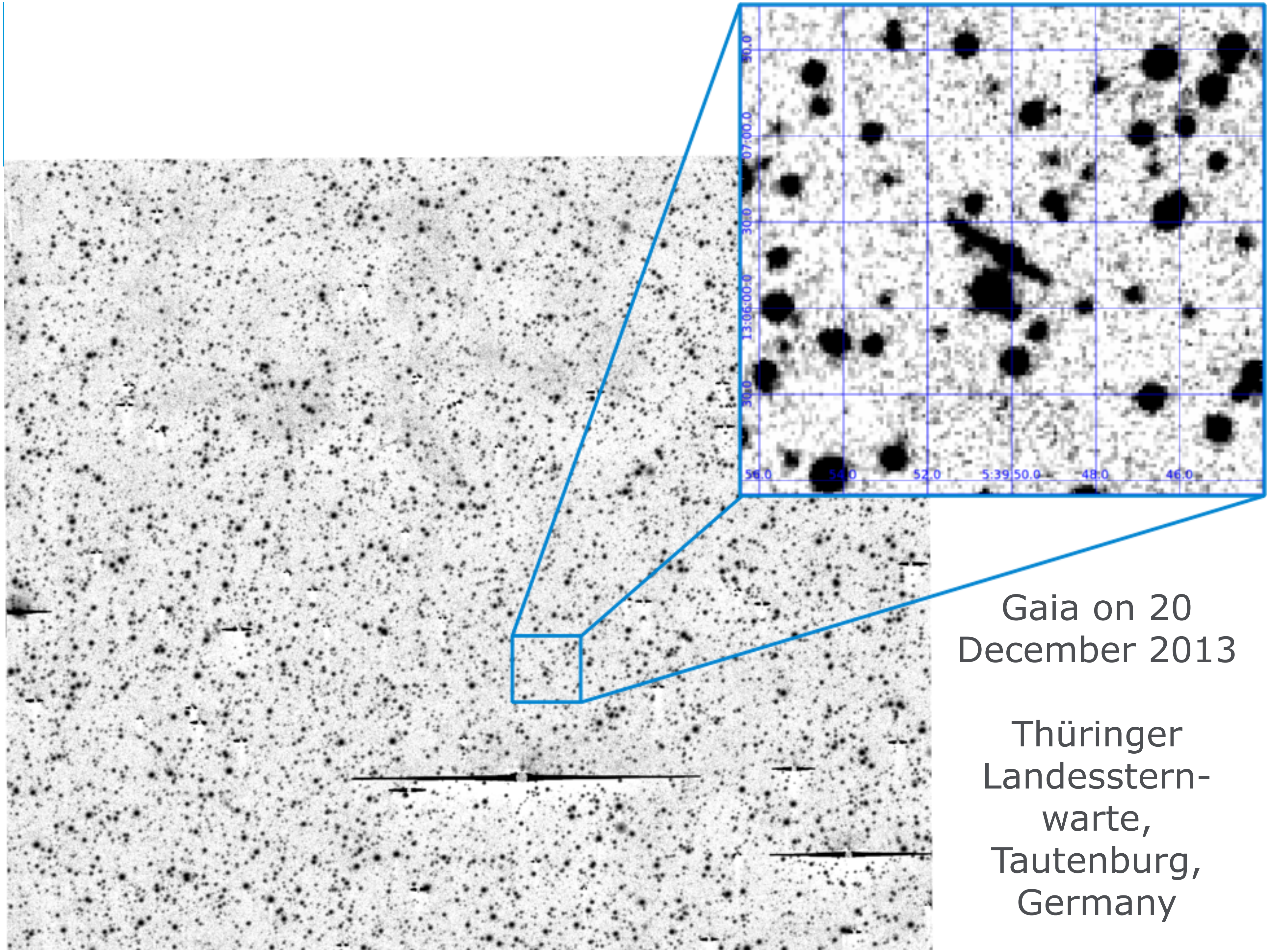




Gaia on 20 December 2013

Thüringer Landesstern-warte, Tautenburg, Germany

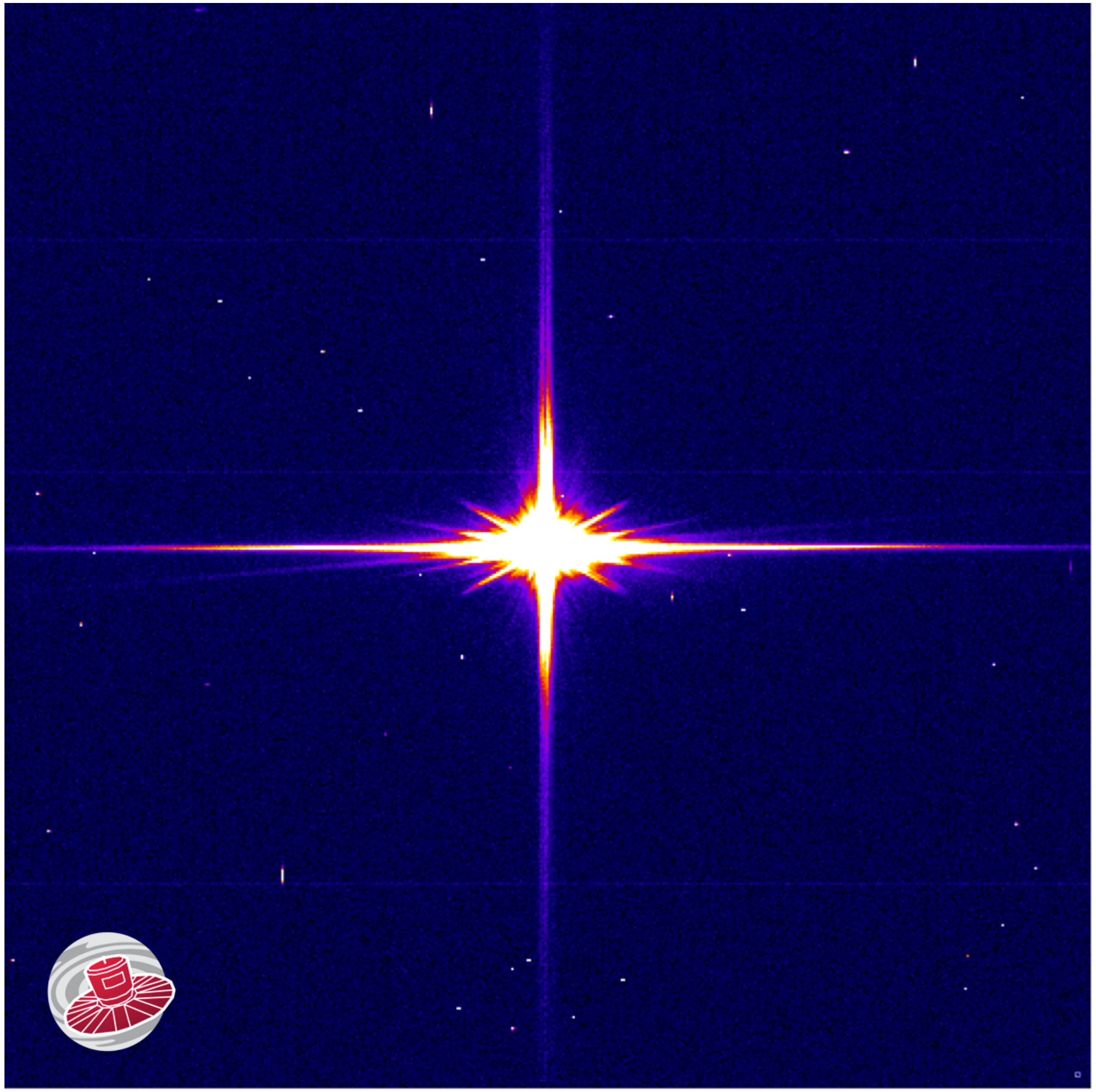
Gaia on 23 January 2014 as seen with ESO's VST

gaia European Space Agency

Overall status

- Launch on 19 December 2013
- L2-orbit-insertion burns on 7 + 14 January
- Ecliptic-pole scanning + 6-h spin started on 8 January
- Service-module commissioning completed (one micro thruster and one chemical thruster misbehave – all budgets OK+)
- Payload-module commissioning (convergence phase) ongoing
- Telescope alignment + best-focus search nearly completed
- Unexpected straylight from Sun and sky (Milky Way?) observed (median level = 7 e-/pixel/s in AF – cf. G = 20 ➔ 185 e-/s)
- Payload decontamination (water ice) currently ongoing to stop throughput degradation trend and remove / reduce straylight
- Periodic basic-angle variations are a factor 100 larger than expected (monitoring device seems to work fine): thermal coupling between service and payload modules?

“First light”



A random bright star, before focusing

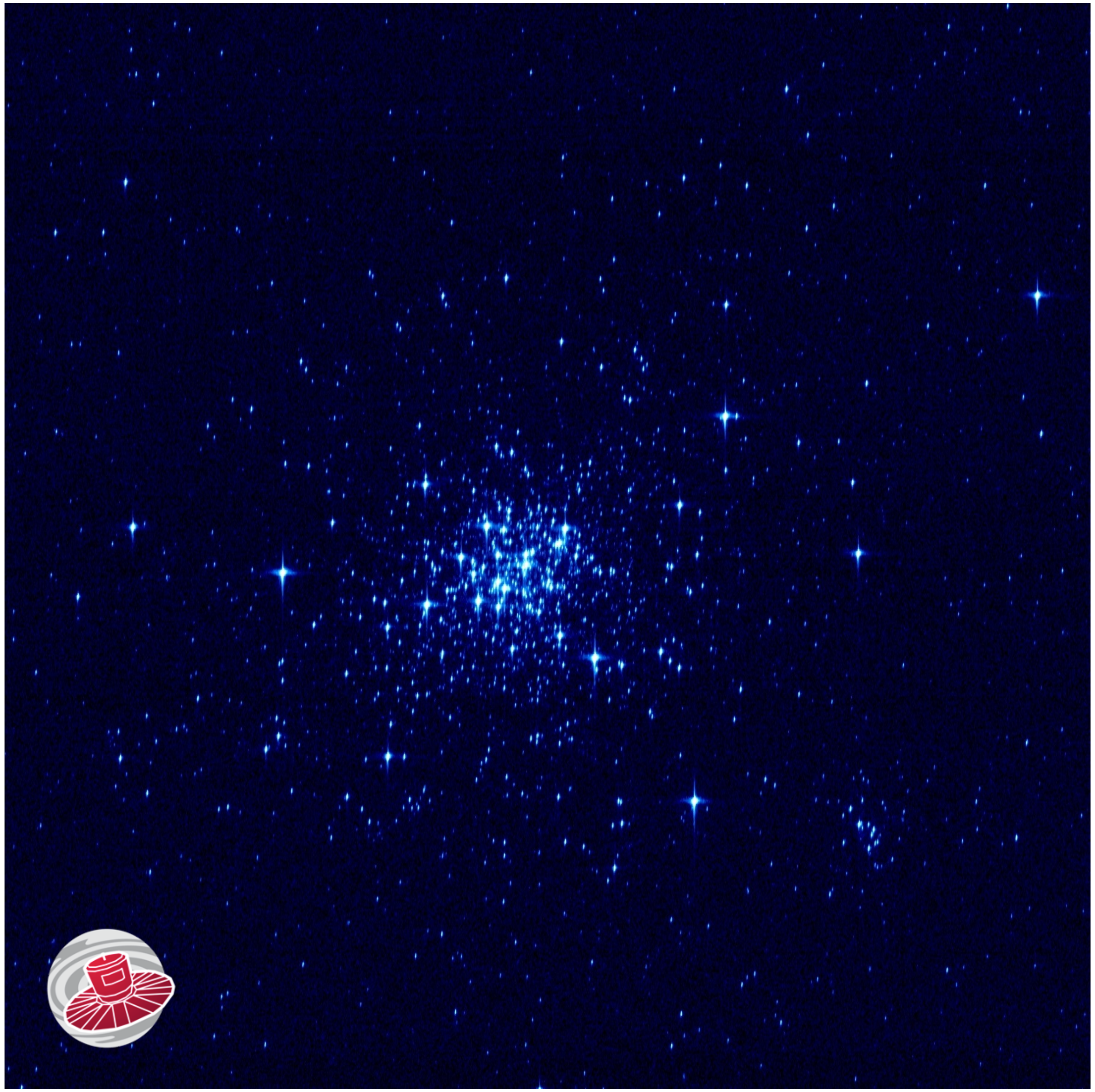
Sadalmelik ("Luck of the king”) = Alpha Aquarii

SpT = G2 Ib

V = 2.94 mag

2.85 s integration time

“First light”



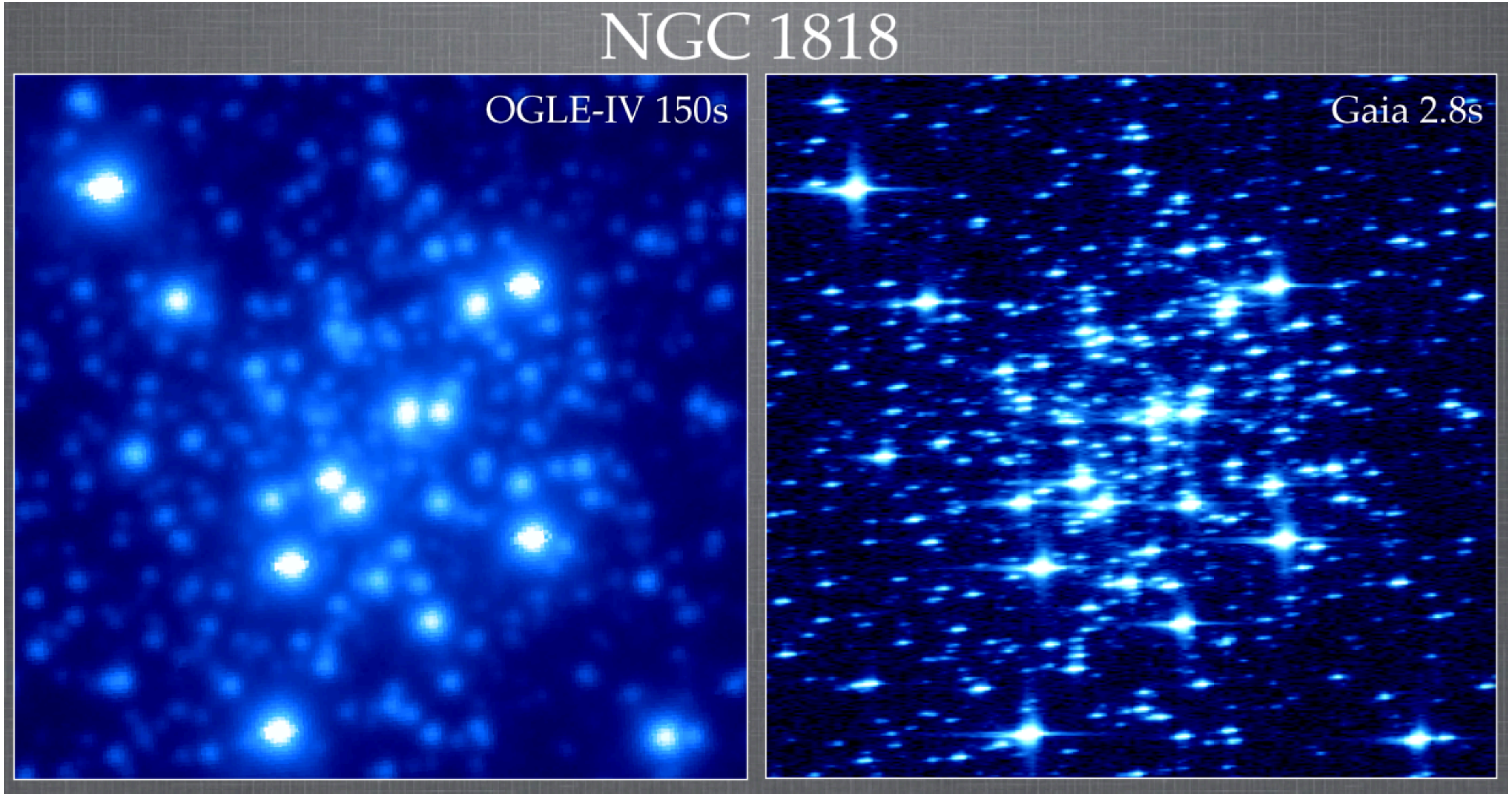
NGC1818 in the LMC,
after a bit more focusing

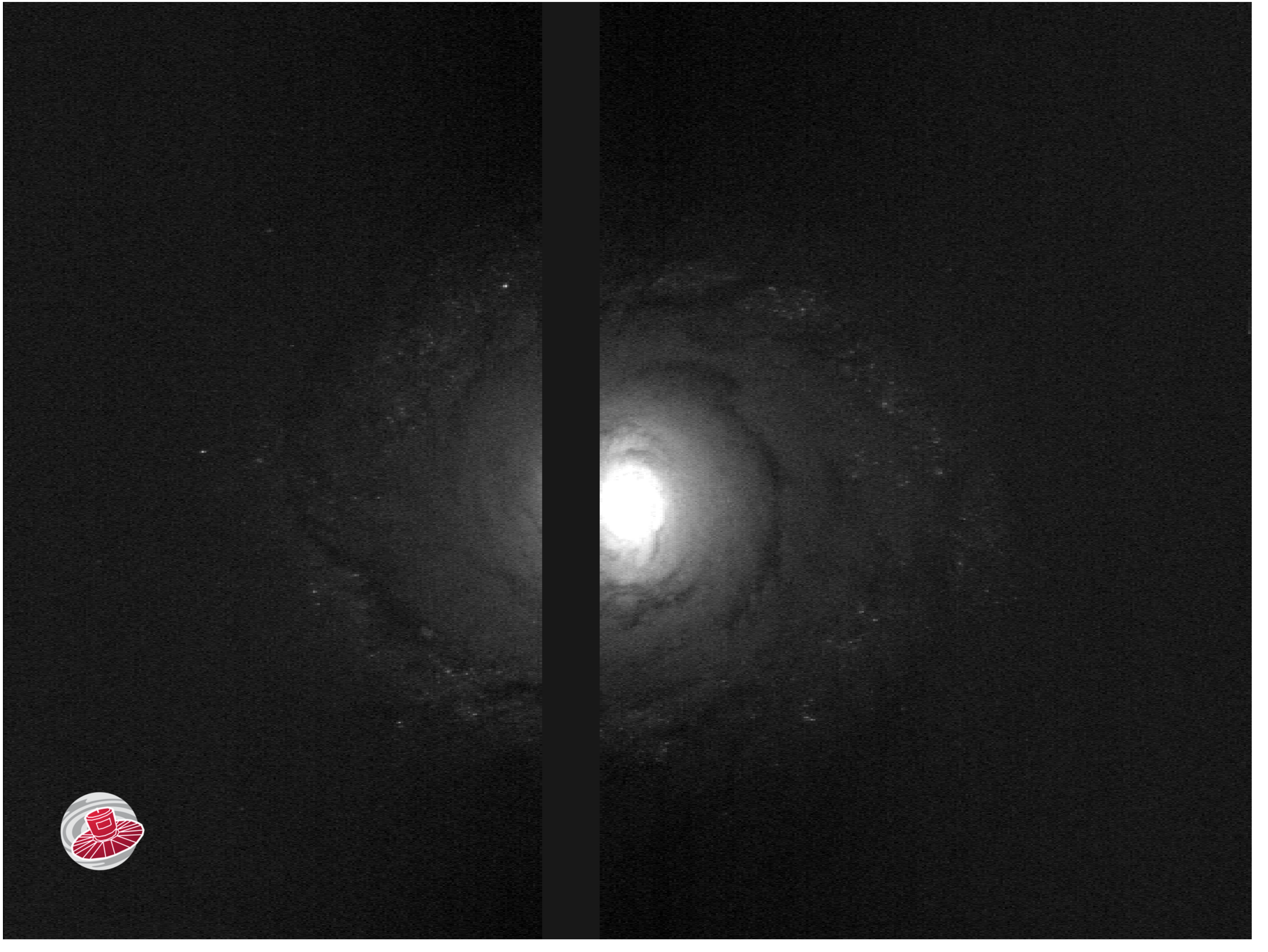
212 × 212 arcsec^2
(~1% of AF FoV)

2.85 s integration time

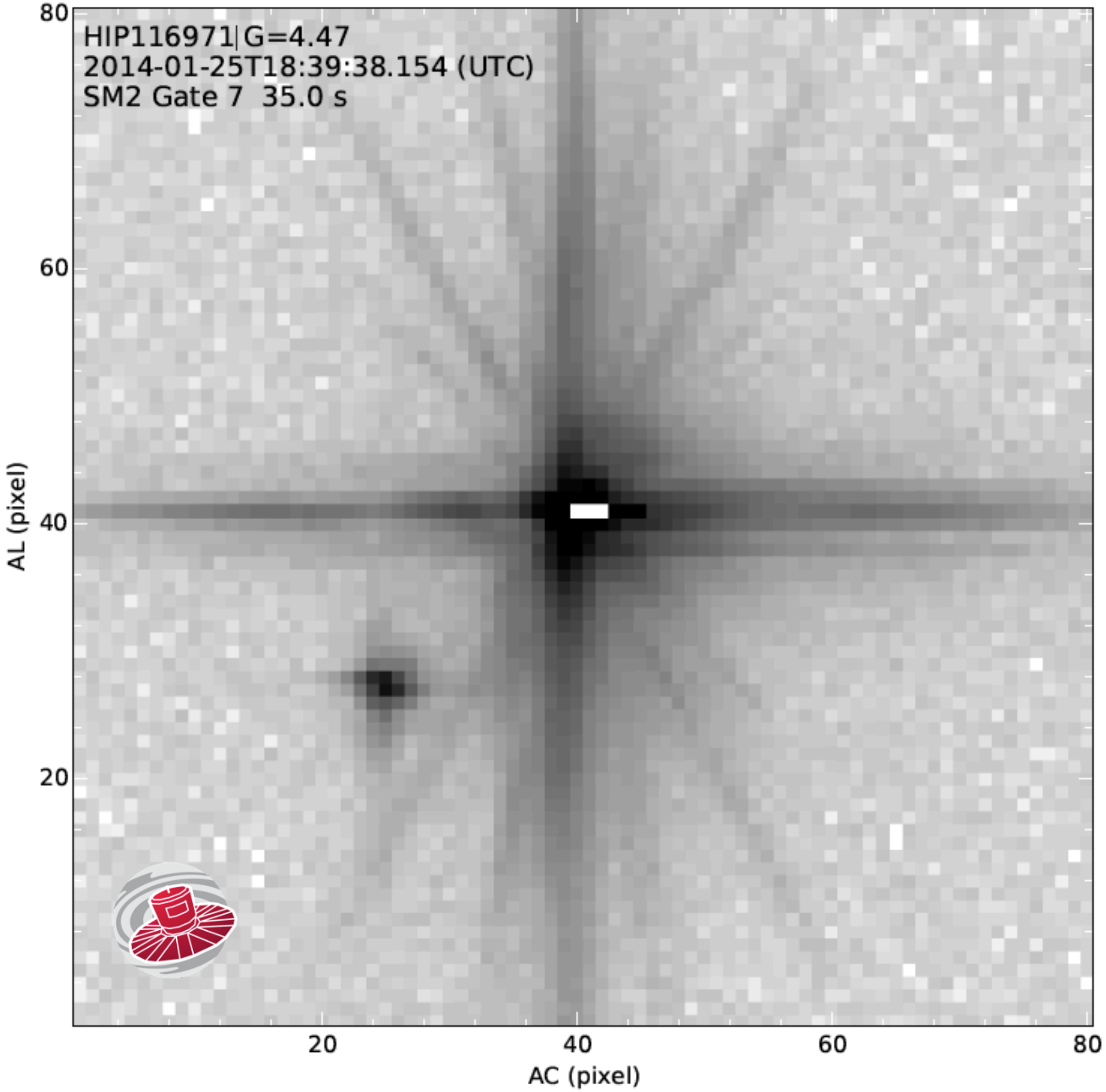
“First light”

Image courtesy Łukasz Wyrzykowski





More "first light"



HIP116971 (ω^2 Aquarii), before focusing

Binary with V = 4.5 and V = 10.6 mag @ 5.7 arcsec separation

0.13 s integration time

Figure from JSA-002

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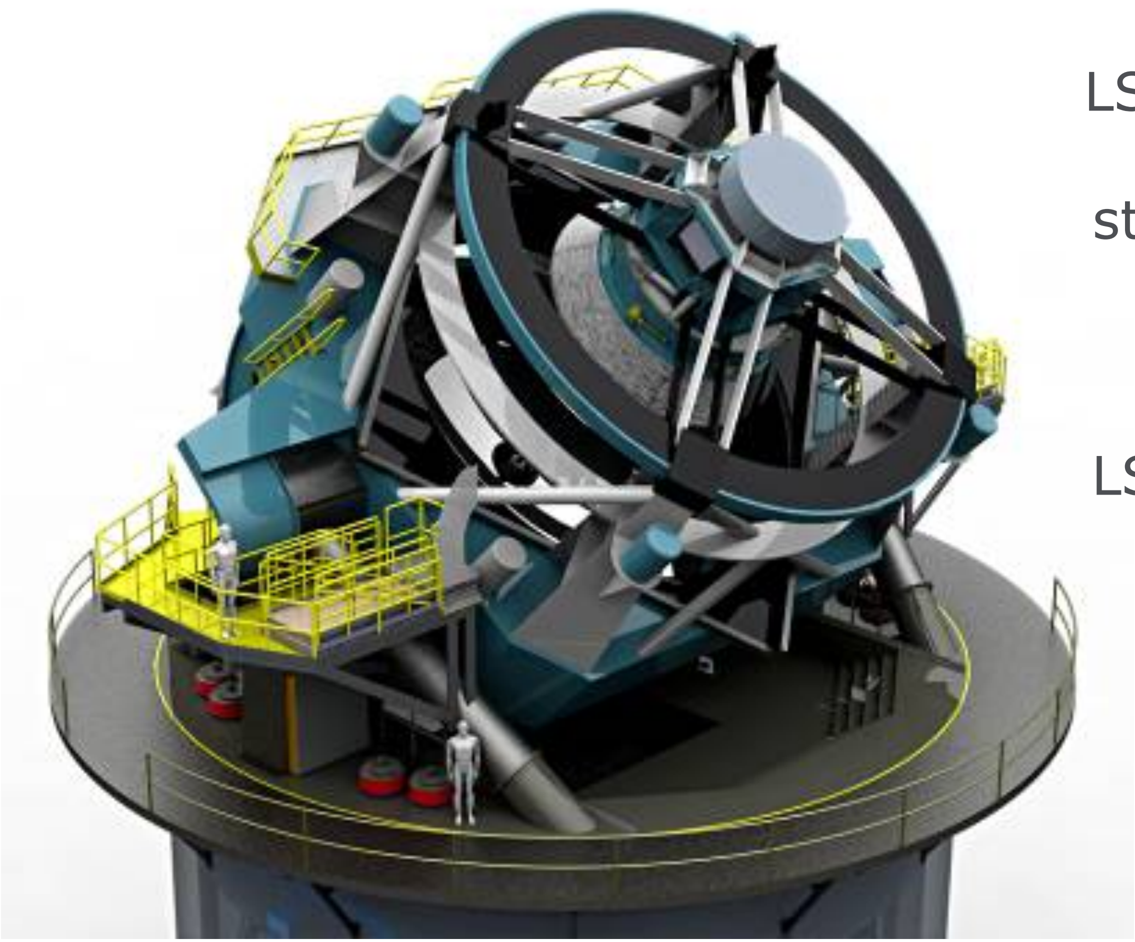
Brown dwarfs with Gaia

- Gaia's faint-star limit is G = 20 mag, yielding 50,000 BDs
- Should we push to G = 21 mag, to bridge the gap with LSST?



LSST = six-band photometry (u,g,r,i,z,y) for 10 billion stars to 24th mag in 20,000□ observed twice per week during 10 years

LSST will smoothly "extend" Gaia by 4 magnitudes

Brown dwarfs with Gaia

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- Should we push to G = 21 mag, to bridge the gap with LSST?

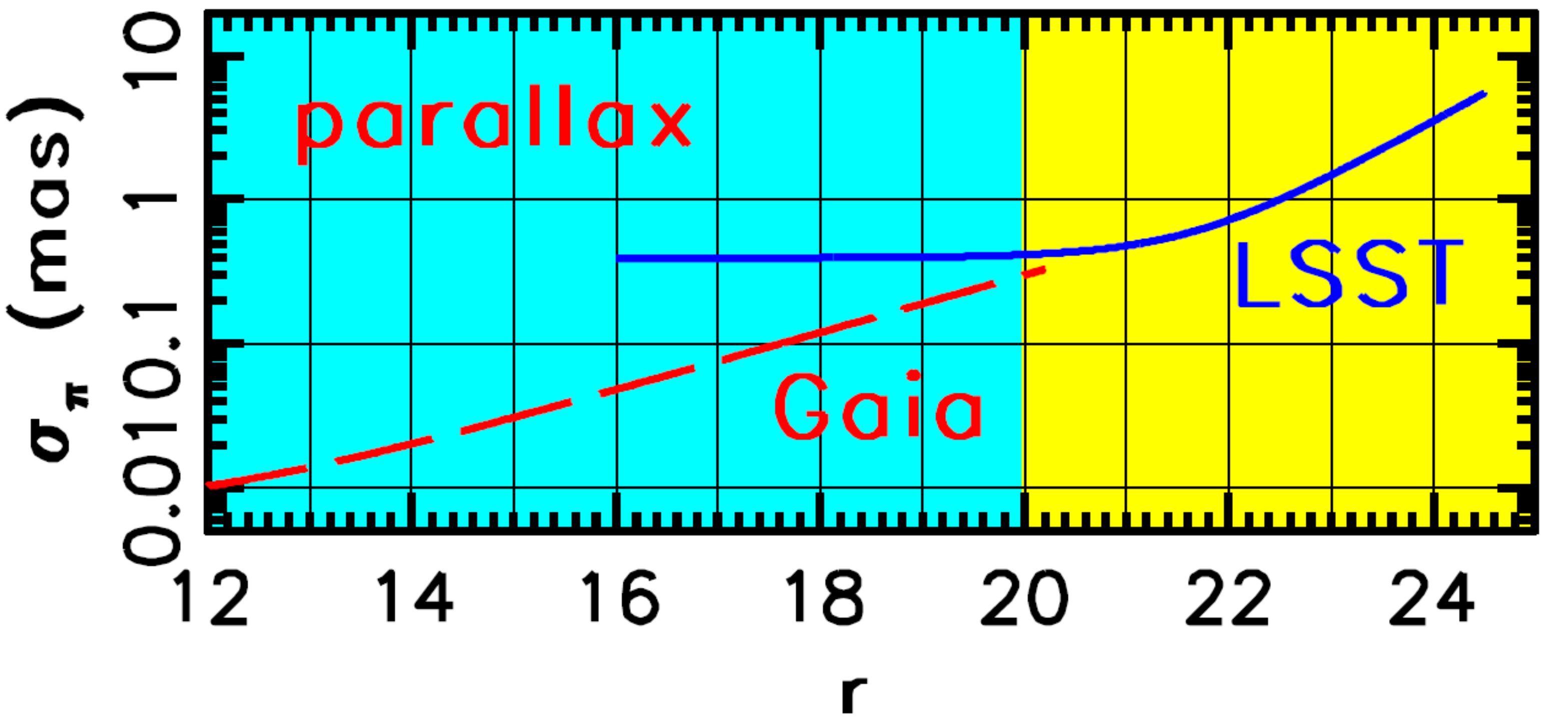


Figure courtesy Laurent Eyer and Željko Ivezić

Note: 0.5 mag deeper means a volume increase of a factor 2
1.0 mag deeper means a volume increase of a factor 4

Science between 20 and 21 mag

- Main science drivers to go deeper are:
  - Halo proper motions, from Gaia itself but also using Gaia–LSST baseline
  - Solar-neighbourhood brown-dwarf science (but see RLS-005)
  - Sub-mas solar-neighbourhood white-dwarf parallaxes
- Other science cases:
  - Ultra-faint dwarf galaxies
  - Asteroids
  - Global parameters for which quasars are used (reference-frame parameters, acceleration of the solar-system barycentre, energy flux of primordial gravity waves)
  - …

Astrometry between 20 and 21 mag

- Parallax/position/proper-motion standard error with p_{det} = 100%
  - G = 20.0: 332 [233 – 384] / 247 / 175 µas (yr^{-1})
  - G = 20.5: 466 [326 – 539] / 346 / 245 µas (yr^{-1})
  - G = 21.0: 670 [469 – 775] / 498 / 353 µas (yr^{-1})
- With p_{det} = 80%
  - G = 20.0: 372 [260 – 430] / 276 / 195 µas (yr^{-1})
  - G = 20.5: 521 [365 – 602] / 387 / 274 µas (yr^{-1})
  - G = 21.0: 749 [525 – 866] / 557 / 394 µas (yr^{-1})
- With p_{det} = 50%
  - G = 20.0: 470 [329 – 543] / 349 / 247 µas (yr^{-1})
  - G = 20.5: 659 [461 – 762] / 489 / 347 µas (yr^{-1})
  - G = 21.0: 948 [664 – 1096] / 704 / 499 µas (yr^{-1})

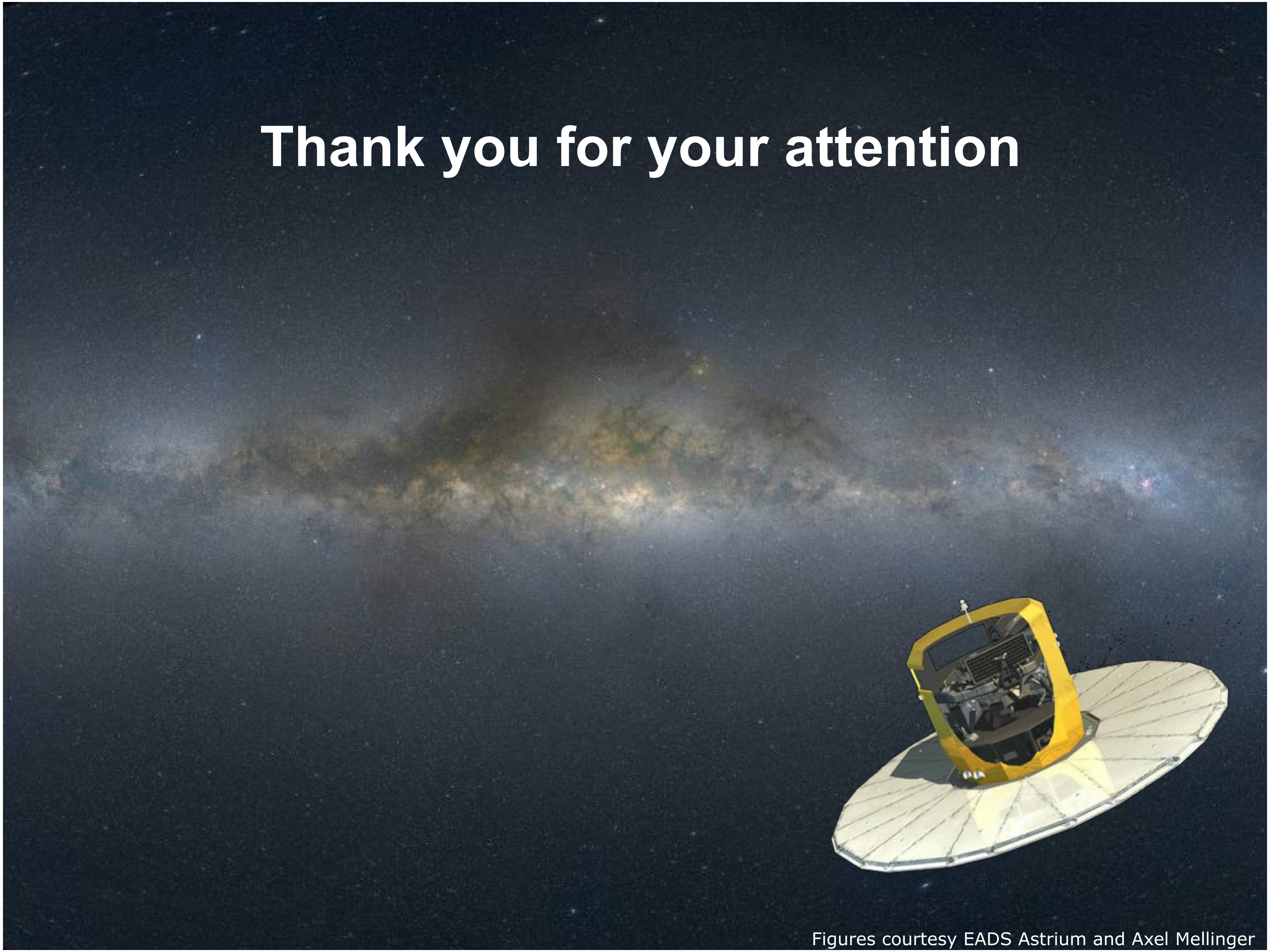
Brown dwarfs between 20 and 21 mag

- One magnitude deeper = two brown-dwarf sub-classes:
  - G = 20.0 mag: L4 @ 30 pc (M_V = 21.1 mag, V-I = 5.1 mag)
  - G = 20.5 mag: L5 @ 30 pc (M_V = 21.8 mag, V-I = 5.2 mag)
  - G = 21.0 mag: L6 @ 30 pc (M_V = 22.3 mag, V-I = 5.3 mag)
- One magnitude deeper = 60%/300% distance/volume increase:
  - G = 20.0 mag: L5 @ 24 pc (0.8% parallax with p_{det} = 100%)
  - G = 20.5 mag: L5 @ 30 pc (1.6% parallax with p_{det} = 80%)
  - G = 21.0 mag: L5 @ 38 pc (3.6% parallax with p_{det} = 50%)
- One percent parallax accuracy:
  - G = 20.0 mag: L4 @ 30 pc (p_{det} = 100%)
  - G = 20.5 mag: L7 @ 20 pc (p_{det} = 80%)
  - G = 21.0 mag: T1 @ 10 pc (p_{det} = 50%)

Conclusions

- Gaia's commissioning is ongoing
- The spacecraft is healthy but the science data contains some surprises among which throughput evolution, straylight, and periodic basic-angle variations
- These issues are currently being addressed
- Gaia's faint-end limit will be tested during commissioning and subsequently decided upon
- Even with a survey limit of 20 mag, Gaia will significantly contribute to brown-dwarf science (as you know ...)

- ESA websites (gaia.esa.int and cosmos.esa.int/gaia)
- Gaia-mission app from the University of Barcelona
- @ESAGaia and ESA Gaia Mission


Thank you for your attention
Figures courtesy EADS Astrium and Axel Mellinger

Data-release scenario (astrometry)

esa

First release: launch + 22 months

- Positions (mean epoch) for single stars with reasonable formal errors
- Ecliptic-pole-scanning-law (EPSL) commissioning data
- The Hundred-Thousand-Proper-Motion (HTPM) proper motions

Second release: launch + 28 months

- Positions and parallaxes (mean epoch, possibly truncated to 1 mas, possibly with generic error functions) for well-behaved stars with acceptable formal errors

Third release: launch + 40 months

- Five-parameter astrometric solution for bona-fide single stars, possibly truncated to 1 mas
- Orbital solutions for periods between 2 months and 75% of the observation duration

Fourth release: launch + 65 months

- Updates of astrometry, possibly truncated to 0.5 mas
- Orbital solutions for periods between 2 months and 75% of the observation duration
- Non-single star catalogue

Final release: end of mission + 3 years ~ launch + 100 months

- Everything