Gaia: Mission status and performances

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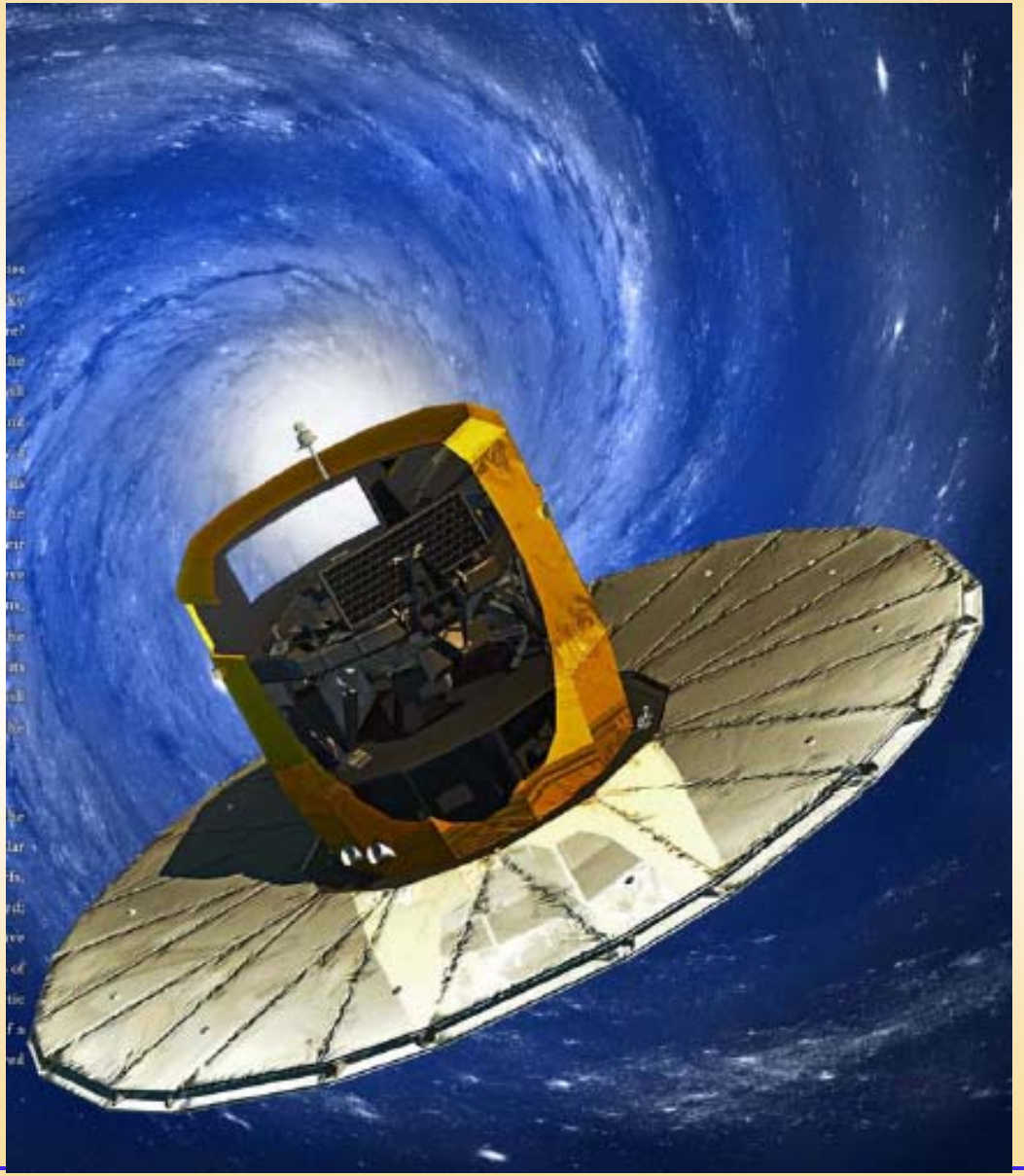
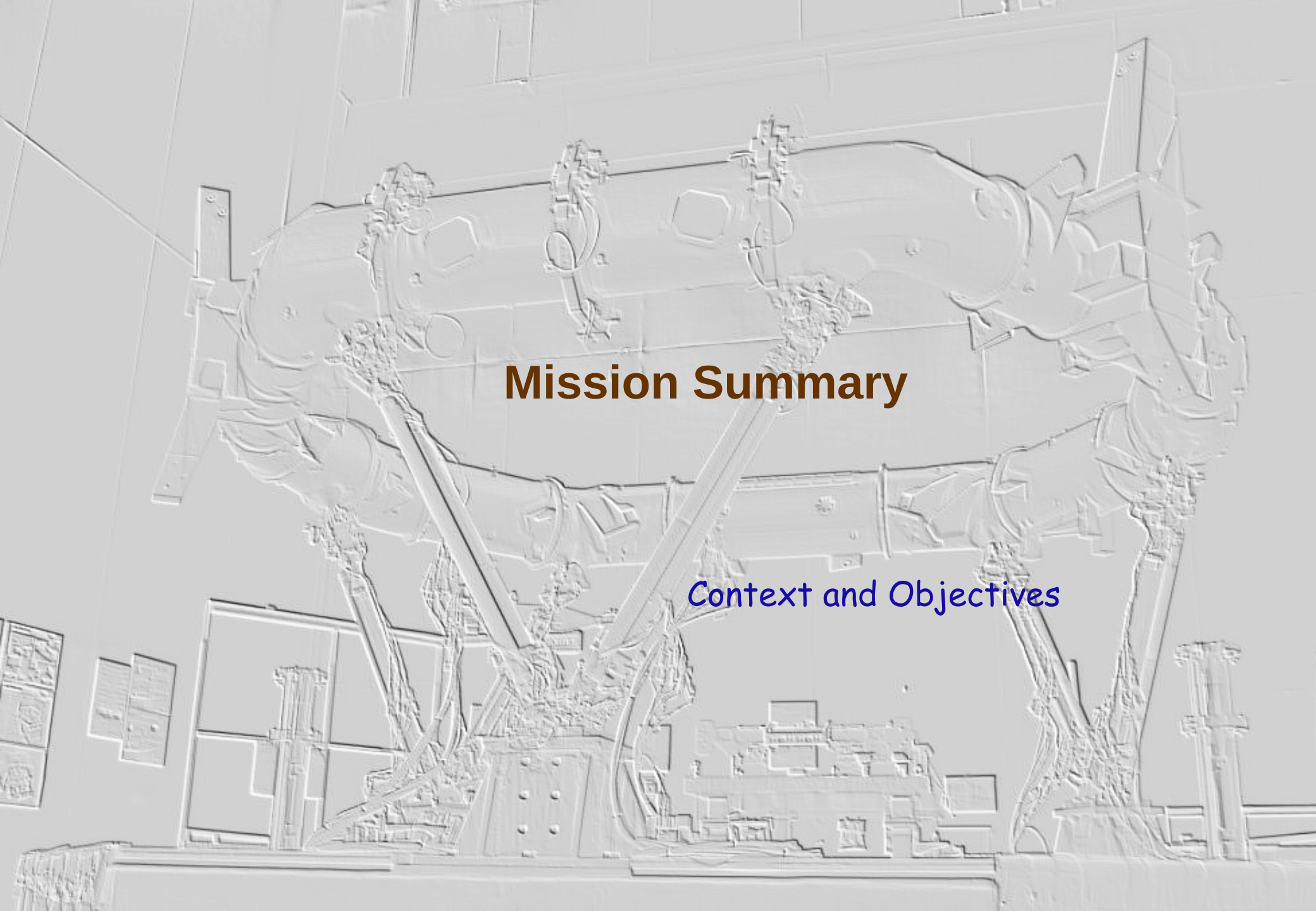
Outline

- Mission context
- Principles
- Gaia Performances
- Data releases





Mission Summary

Context and Objectives

GAIA

- 10^9 stars
- 25 μas @ V = 15 mag

ESA mission
Launch: 2013
Mission : 5 yrs

- Photometry (~ 25 bands)
- Radial velocity
- Low resolution spectroscopy

Goals of Space Astrometry

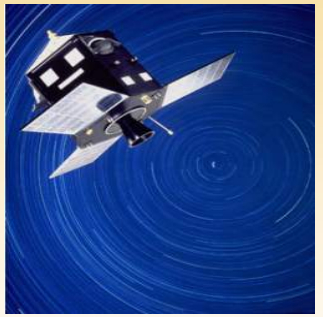
- Primary Objectives not achievable from Earth
  - Ascertain the distances of the stars
    - **absolute** stellar parallaxes for astronomers
  - Define and materialise the inertial frame
    - now based on extragalactic sources

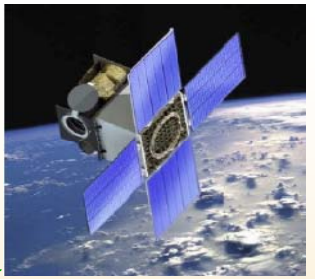
- Secondary objectives
  - Astrophysics with astrometry, photometry, spectroscopy
    - stellar and galactic physics
    - detection of extrasolar planets
    - solar system dynamics
  - Tests of fundamental physics in space
    - based on light path geometry

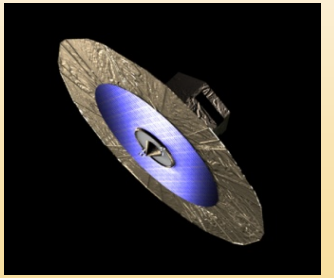
Space Astrometry: Past & Present

- A successful forerunner: HIPPARCOS (ESA)
  - accuracy of 1 mas ~ a coin @ 1000 km
- The unfortunate followers
  - accuracy of 0.1 mas ~ a nail @ 1000 km
  - Roemer, FAME-1, FAME-2, DIVA, Lomonossov, AMEX

    ESA US US DE RU US
- Study phase
  - JASMINE (Japan) in the IR
- Cancelled (Dec 2010)
  - SIM (US) with 1 μas accuracy
- Funded – launch 2011 - 2014
  - NanoJasmine [4 mas], J-MAPS (US) [1mas]
  - Gaia (ESA) : 25 μas (a hairwidth @ 1000 km)

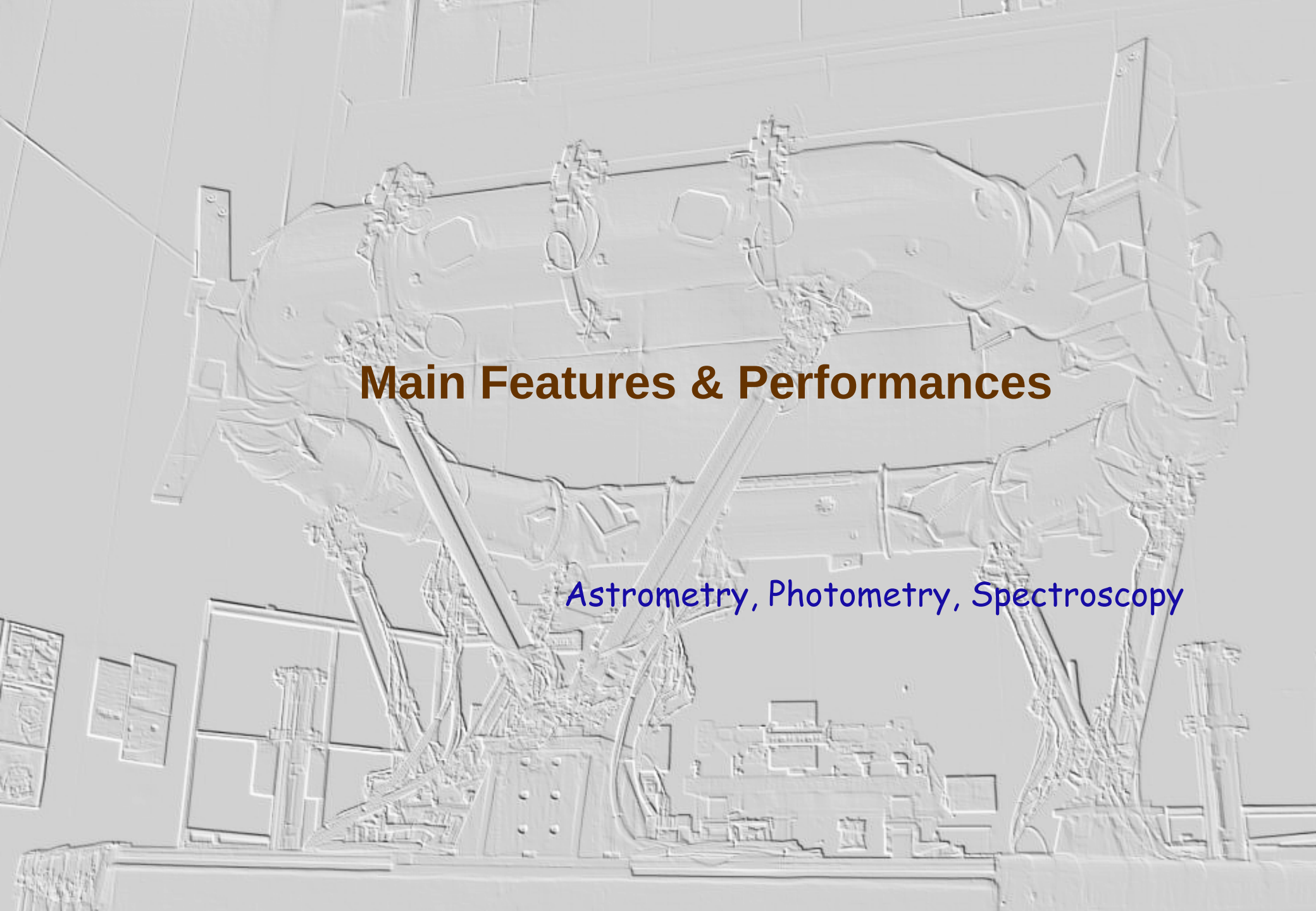






Mission requirements summary

- A Stereoscopic Census of Our Galaxy
- Astrometry (V < 20):
  - completeness to 20 mag (on-board detection) 10^9 stars
  - parallax accuracy: 7 μas at <10 mag; 12–25 μas at 15 mag 100–300 μas at 20 mag
- Photometry (V < 20):
  - astrophysical diagnostics (low-dispersion photometry) + chromaticity
  - 8–20 mmag at 15 mag: Teff ~ 200 K, log g, [Fe/H] to 0.2 dex, extinction
- Radial velocity (V < 16.5–17):
  - Third component of space motion, perspective acceleration
  - <1 km/s at 13-13.5 mag and <15 km/s at 16.5-17 mag



Main Features & Performances

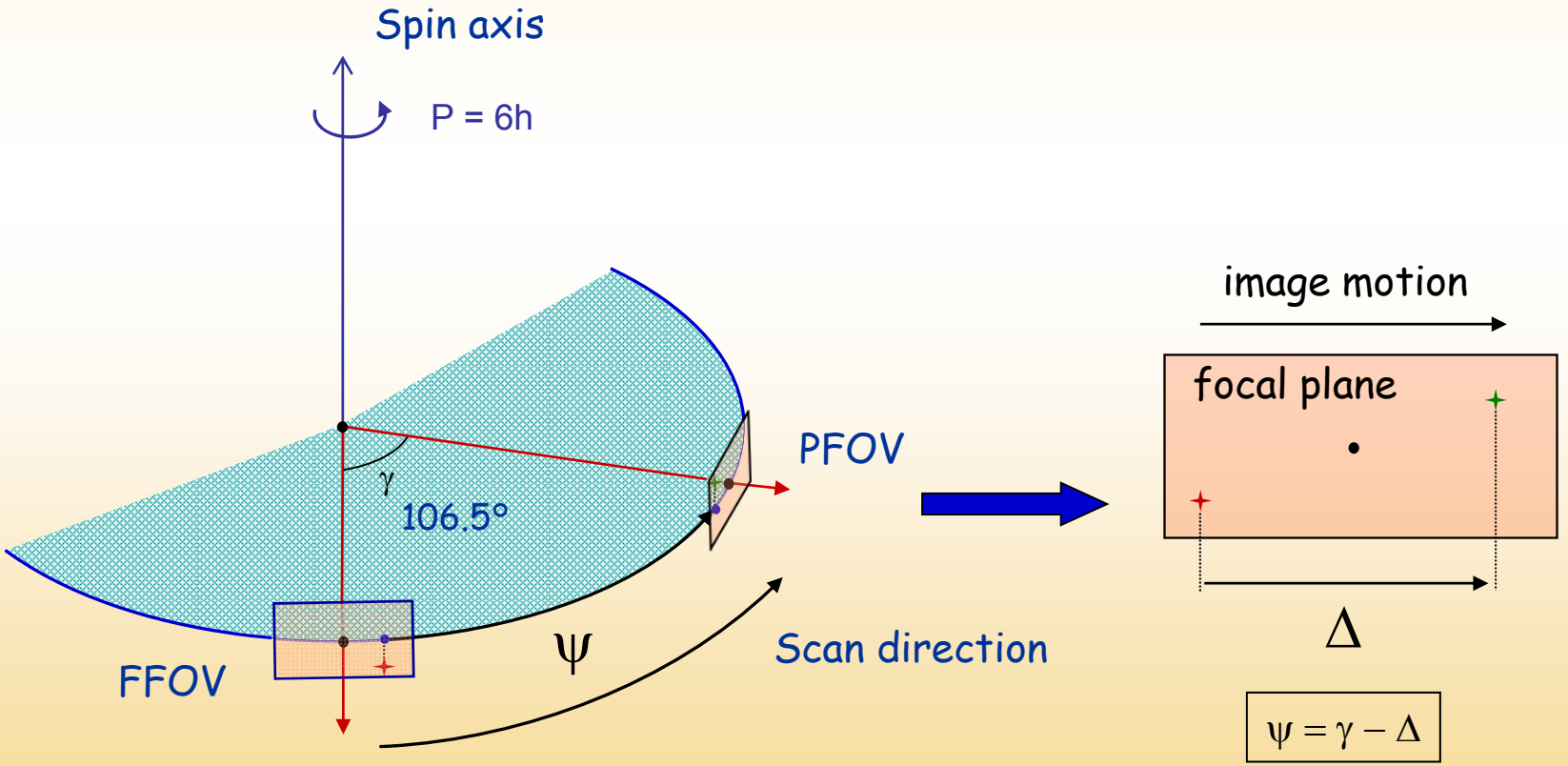
Astrometry, Photometry, Spectroscopy

Assets of Gaia

- A single mission with three nearly synchronous data taking
  - Astrometric, photometric and spectroscopic data
- GAIA is a scanning mission
  - no pointing, no change in the schedule Uniform coverage of the sky
- Quasi regular time sampling over 5 years
  - ~ 80 observations ➔ photometry, orbits of binaries, asteroids
- Survey mission sensitivity limited
- Internal and autonomous detection system to G = 20
- Global astrometry of staggering precision
  - Internal metrology, thermal and mechanical stability
- Experienced and motivated community in Europe after Hipparcos
  - scientific and in industry

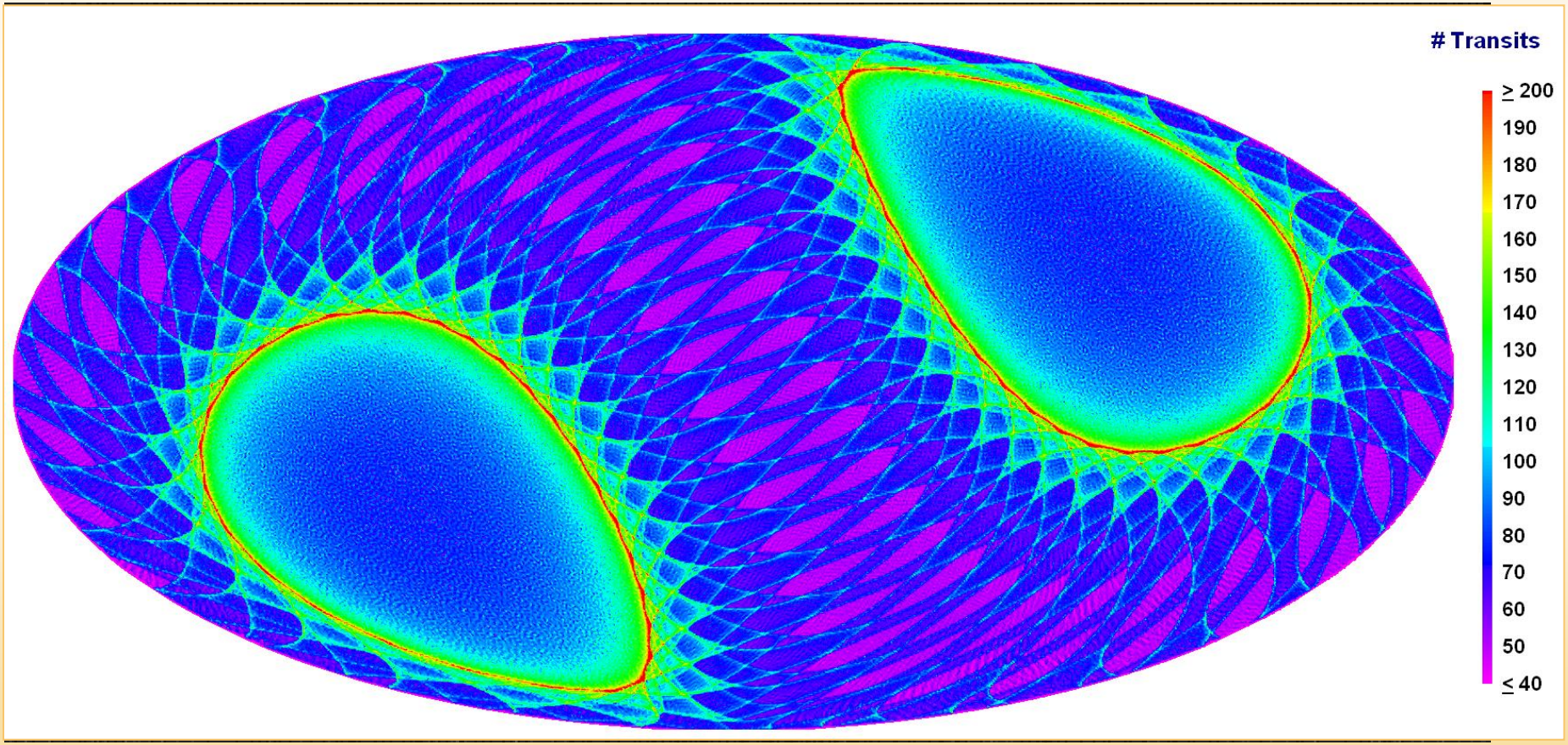
Global astrometry in space

- Wide angle measurements
- Two fields of view
- One common focal plane



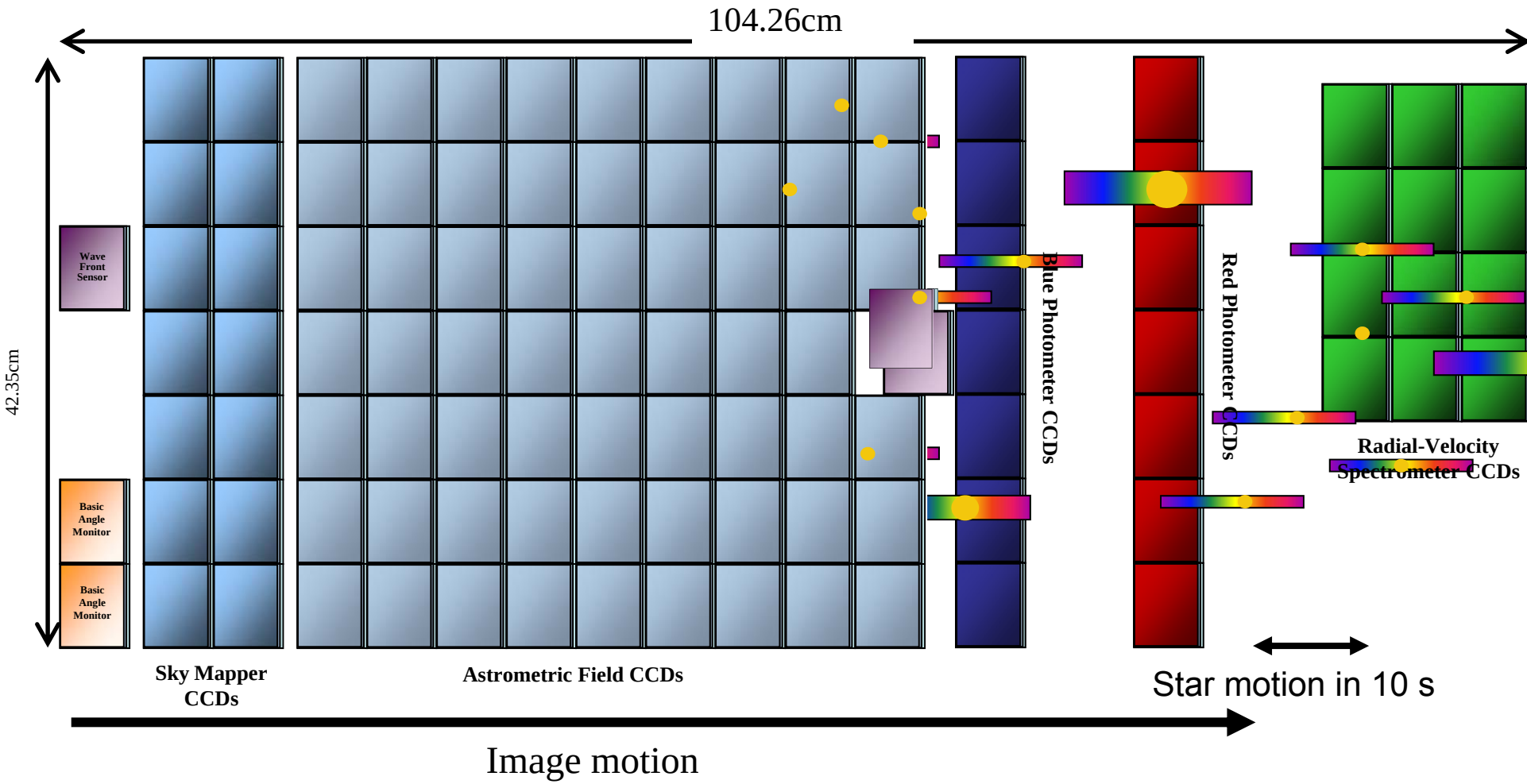
Scanning & Sky coverage

- Time average is a combination of the sky distribution and the scanning law
  - two different symmetries: galactic plane and eclitpic plane



Multiplexing observations

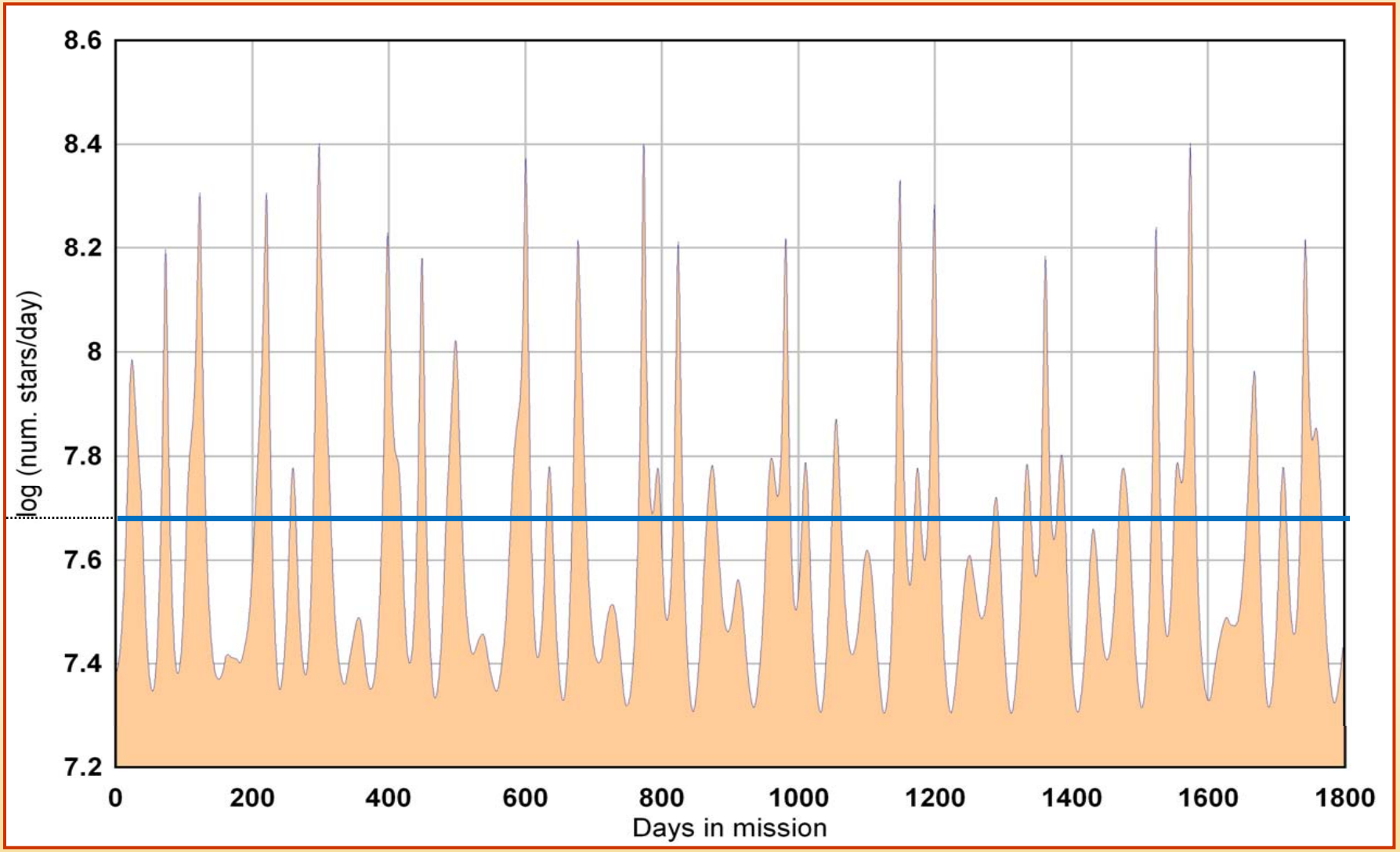
106 CCDs , 938 million pixels, 2800 cm^2



Credit: A. Short, W. O'Mullane

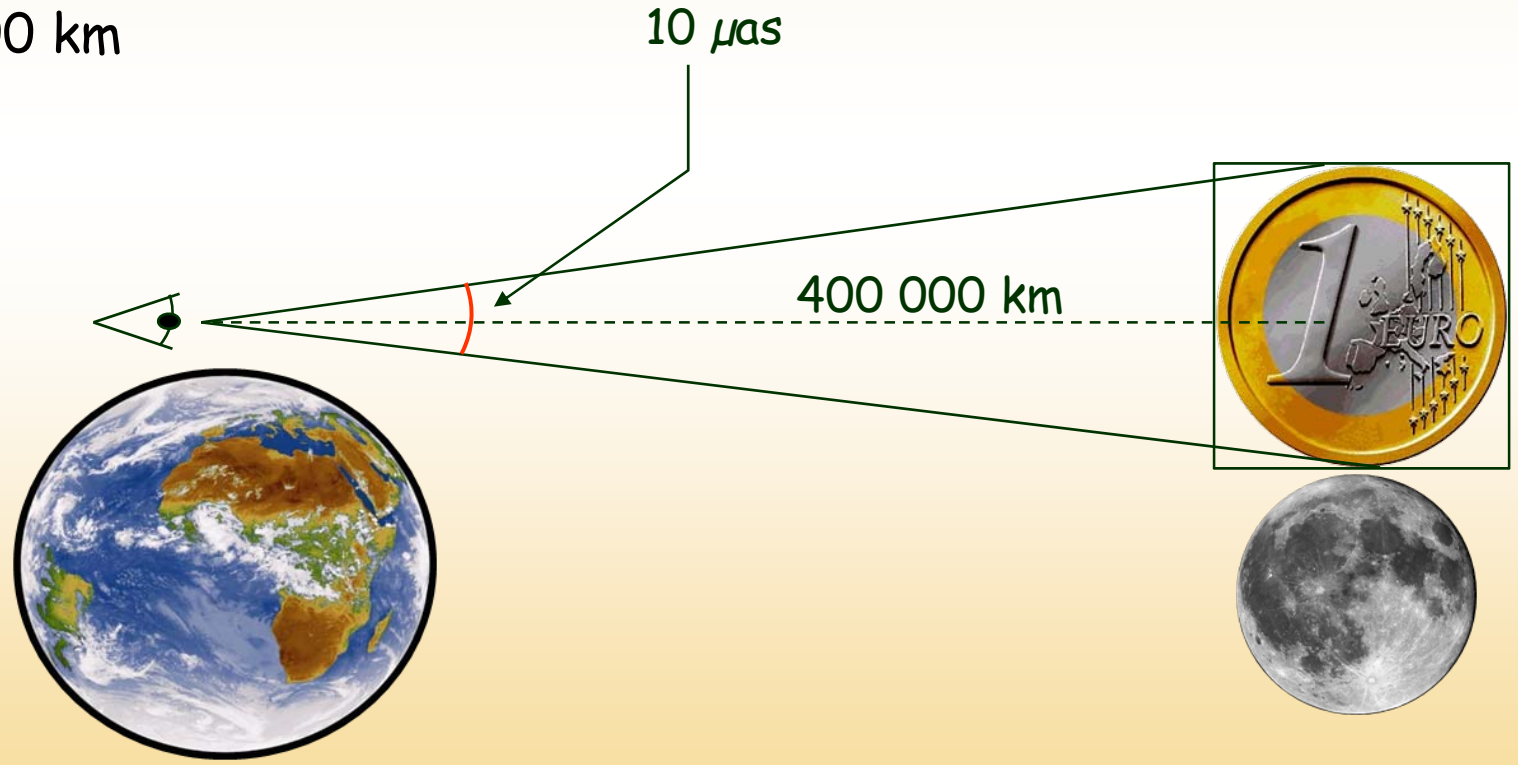
Number of sources per day

- Number of sources detected per day (log scale) during the mission



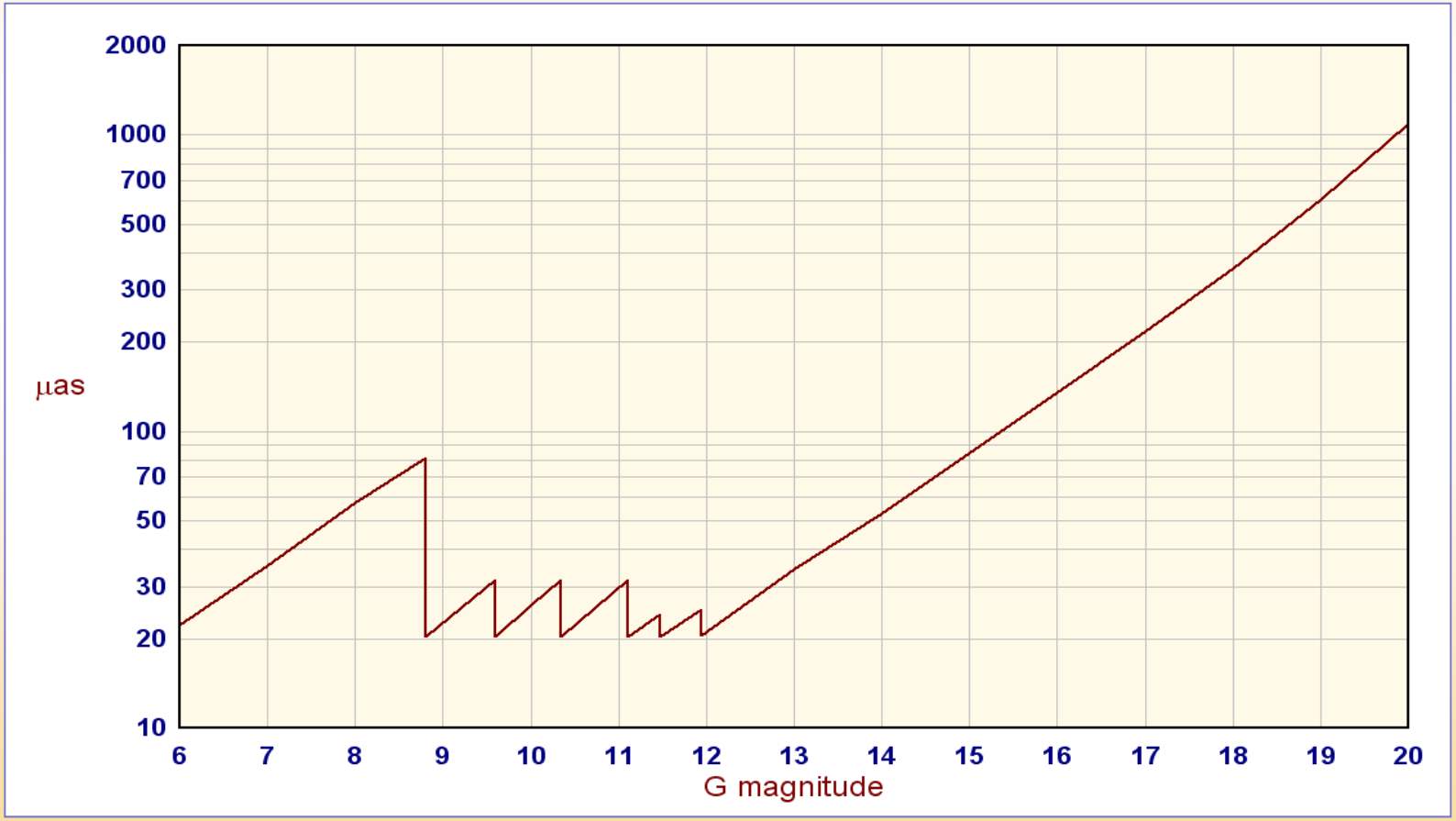
Performances 10 µas ➔ Incredibly small !

- 0.3 mm displacement on the Earth
- Displacement of a 100 mas/yr star in one hour
- Motion of a fast moving minor planet in 100 *µs*
- edge-on sheet of paper @ 2000 km
- 1 hair @ 1000 km

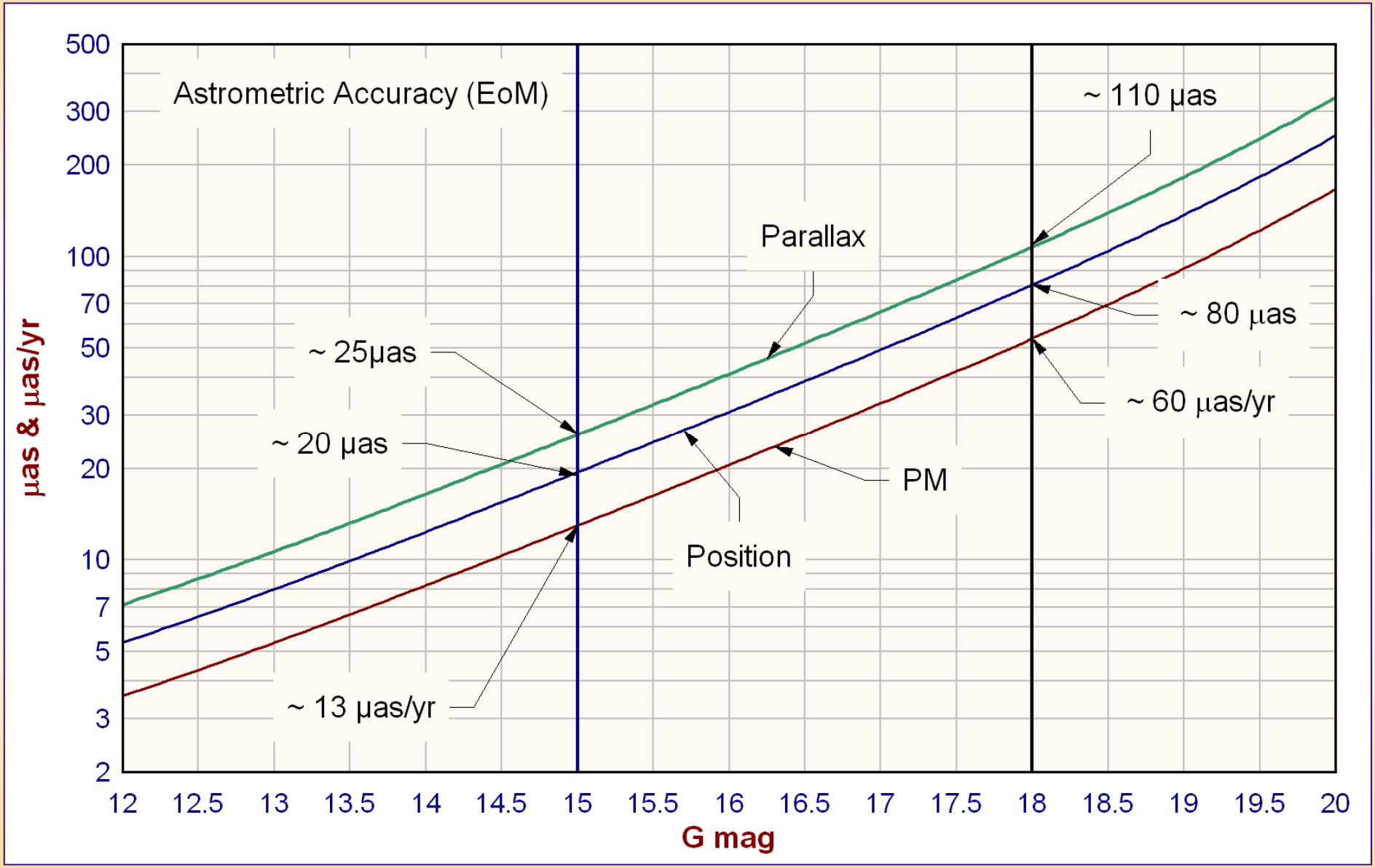


Astrometric accuracy: single transit

- Single observation accuracy ➔ orbit, solar system
  - one field transit: integration over 9 AF CCDs
  - point source, 1D astrometry

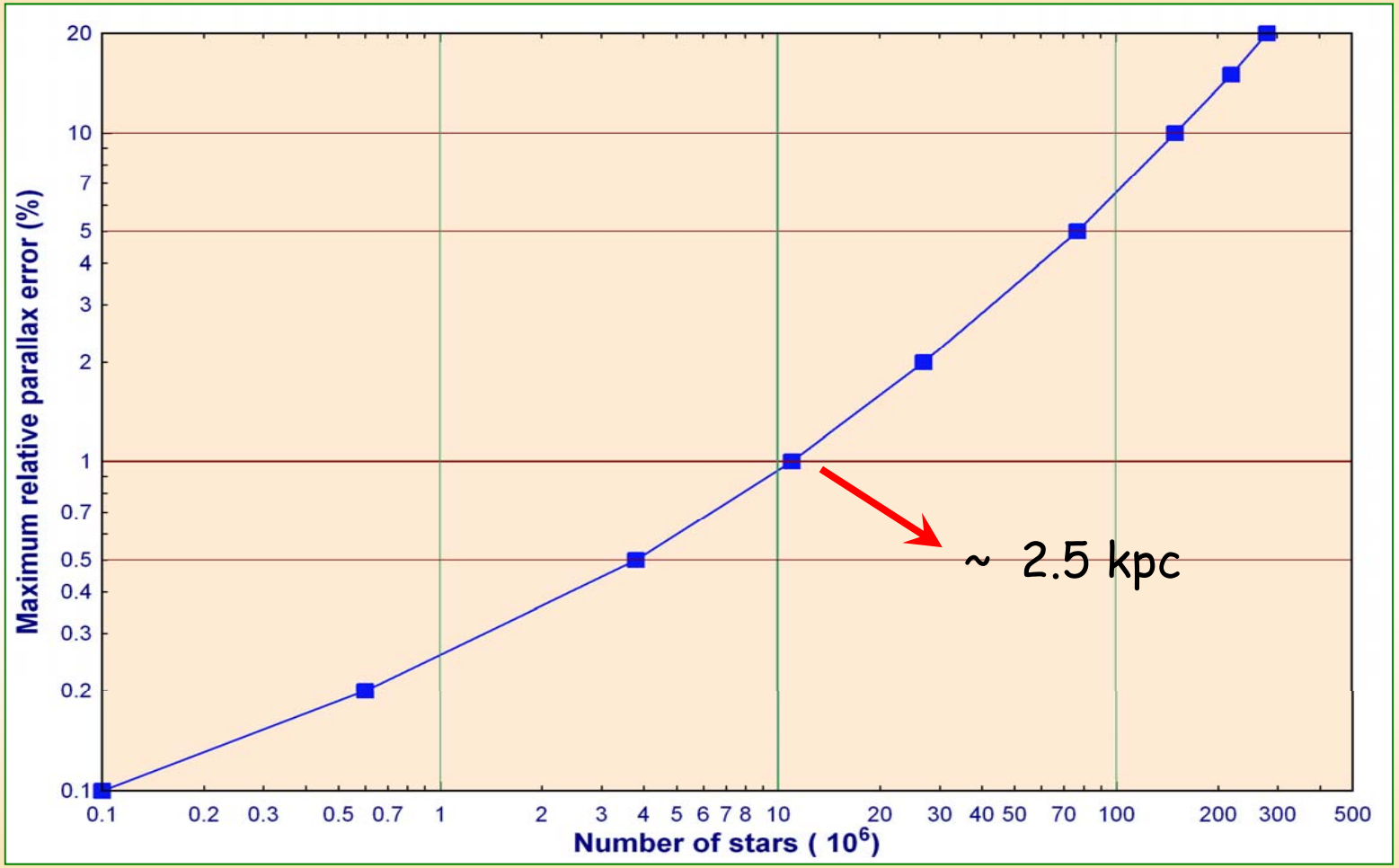


Astrometric Accuracy : EOM



Distances for stellar physics

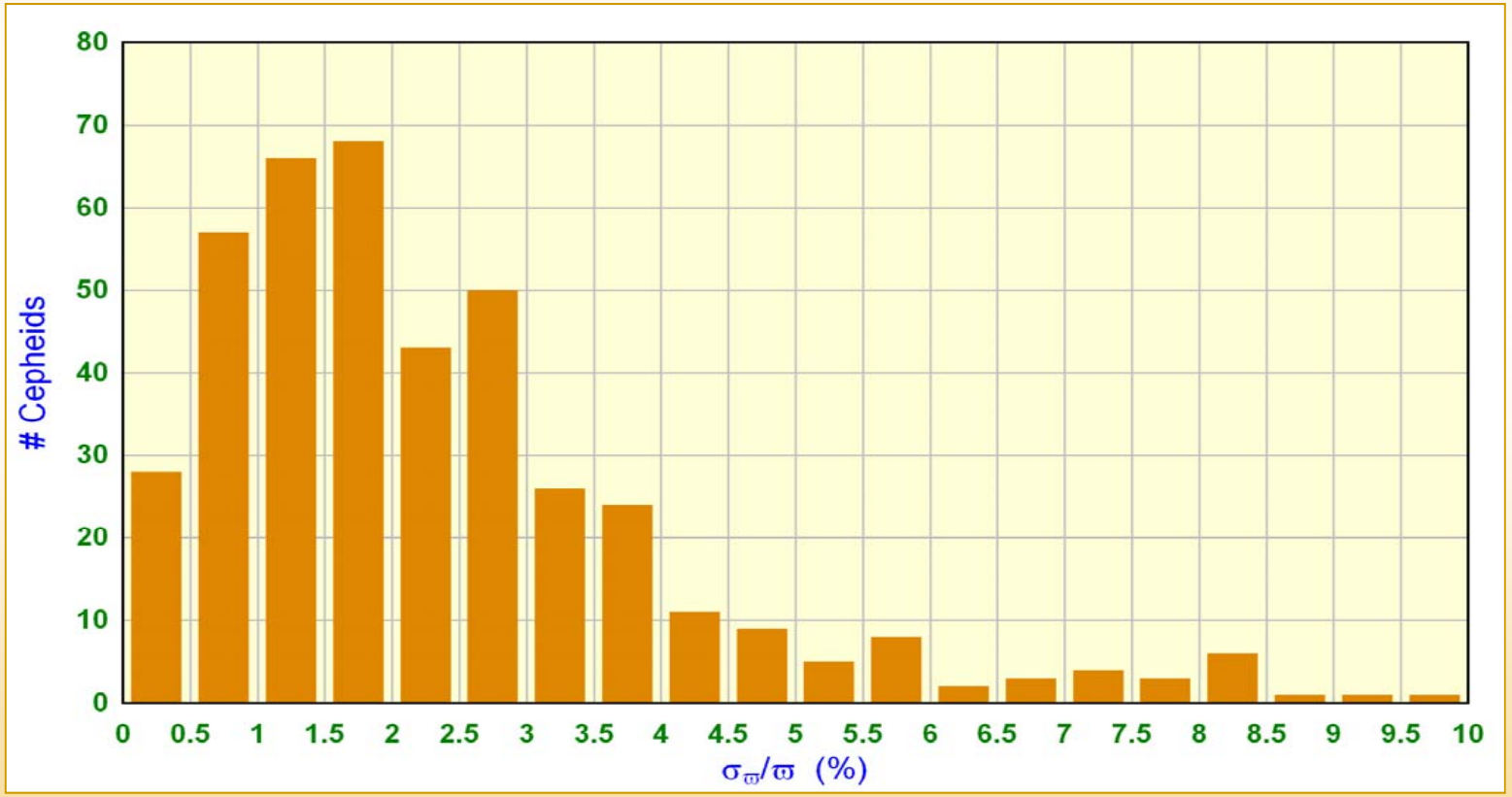
- Accurate distances through the Galaxy



Recall: Hipparcos : 20,000 stars with $\sigma_\pi/\pi < 10\%$

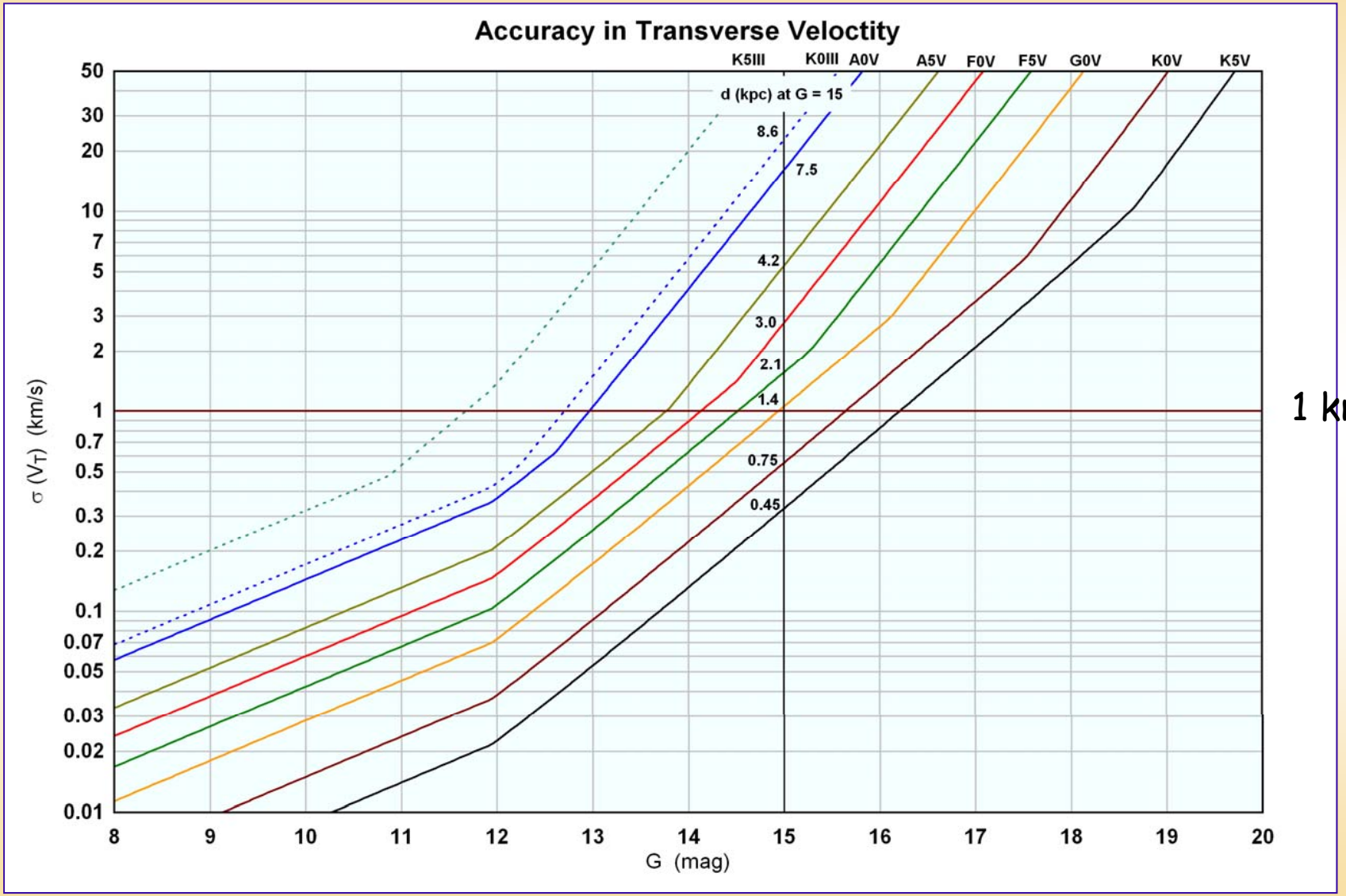
Cepheids with Gaia

- 15 d < 0.5 kpc, 65 d< 1 kpc, 165 d < 2 kpc
  - bright enough (V < 14)
- In the plot : 400 galactic cepheids from David Dunlap DB
  - distance and magnitude ➔ Gaia predicted accuracy for parallax



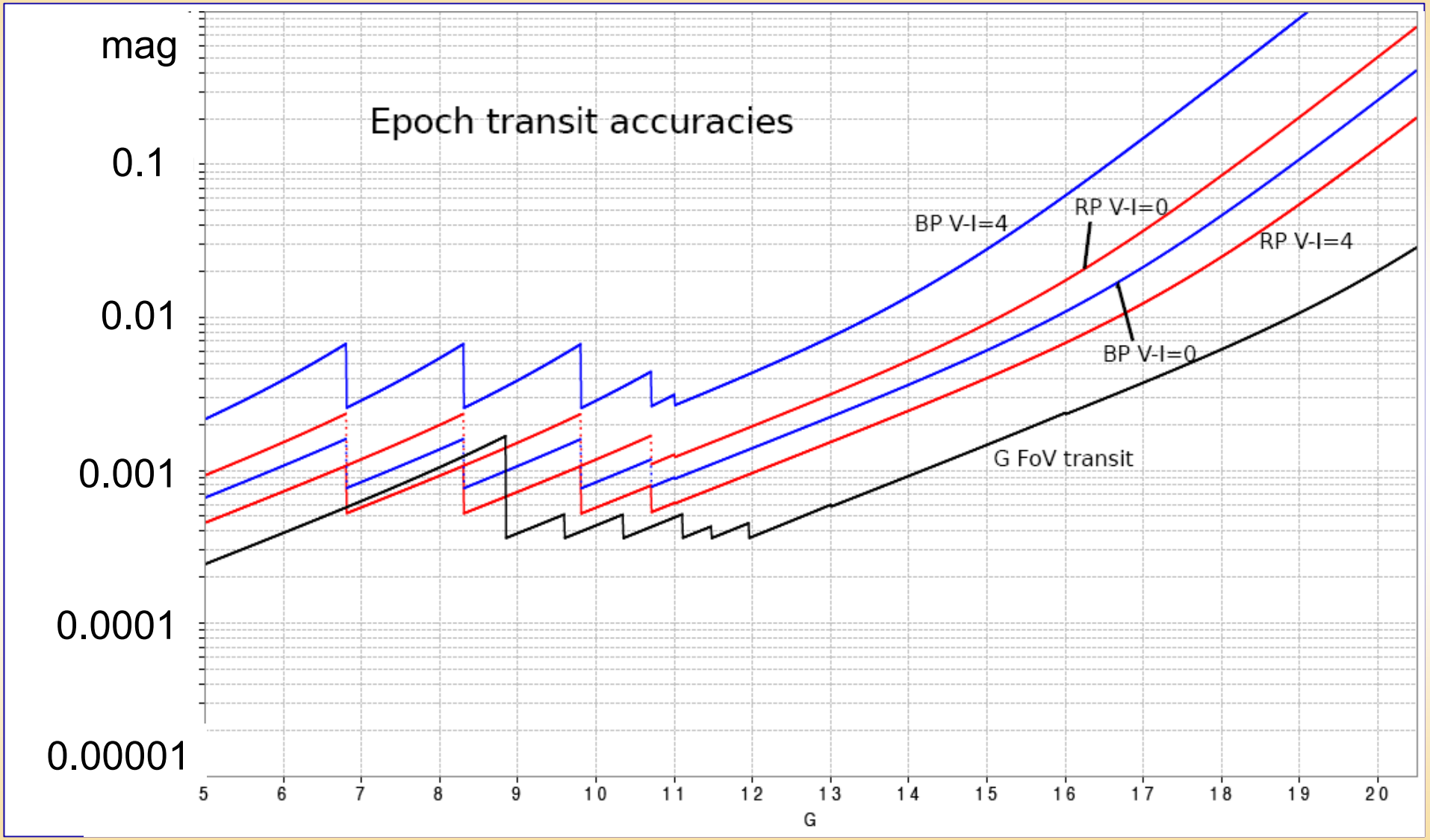
F. Mignard 2002, 2009

Transverse velocity estimate with Gaia



1 km/s

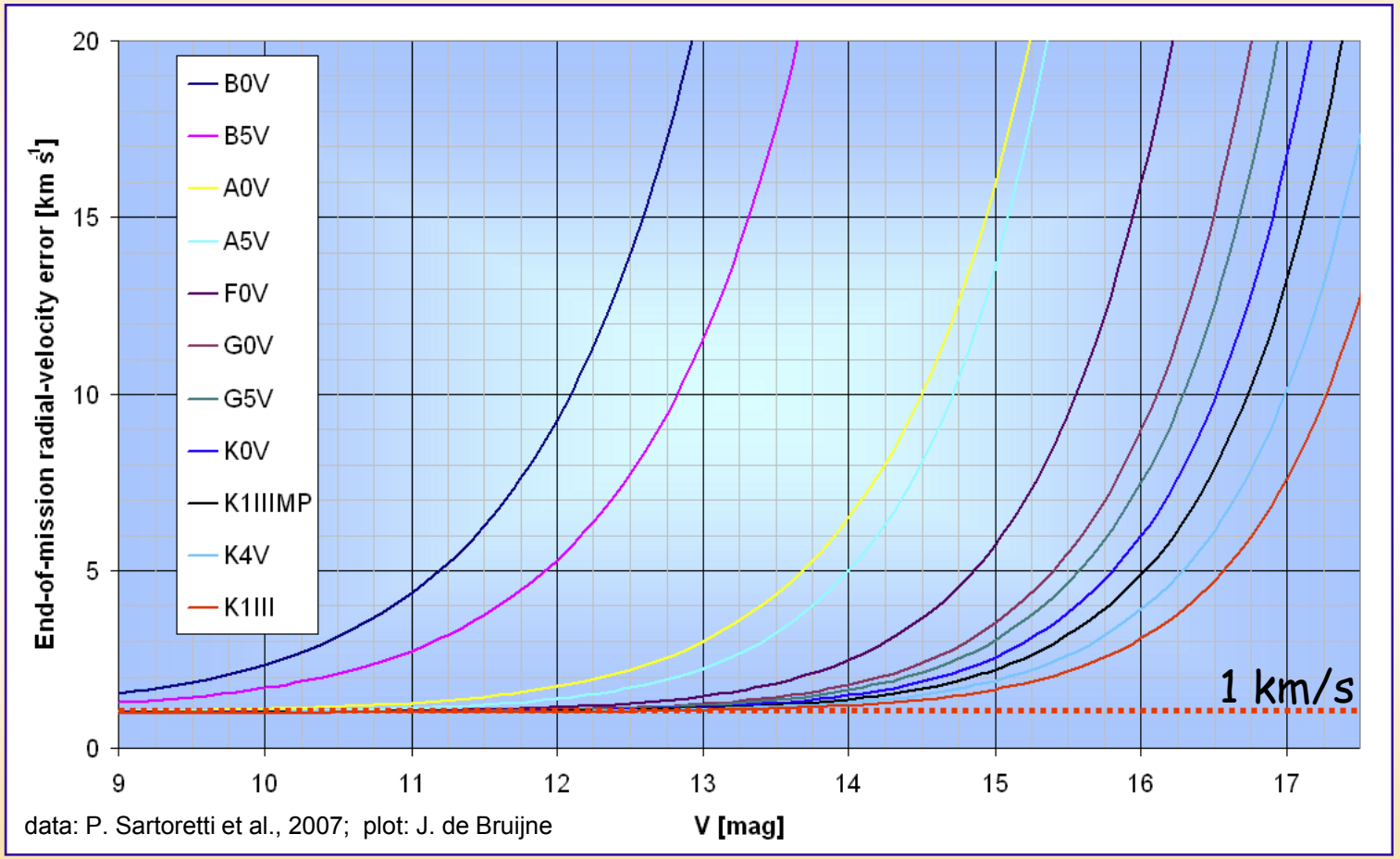
Photometric Performance over a transit



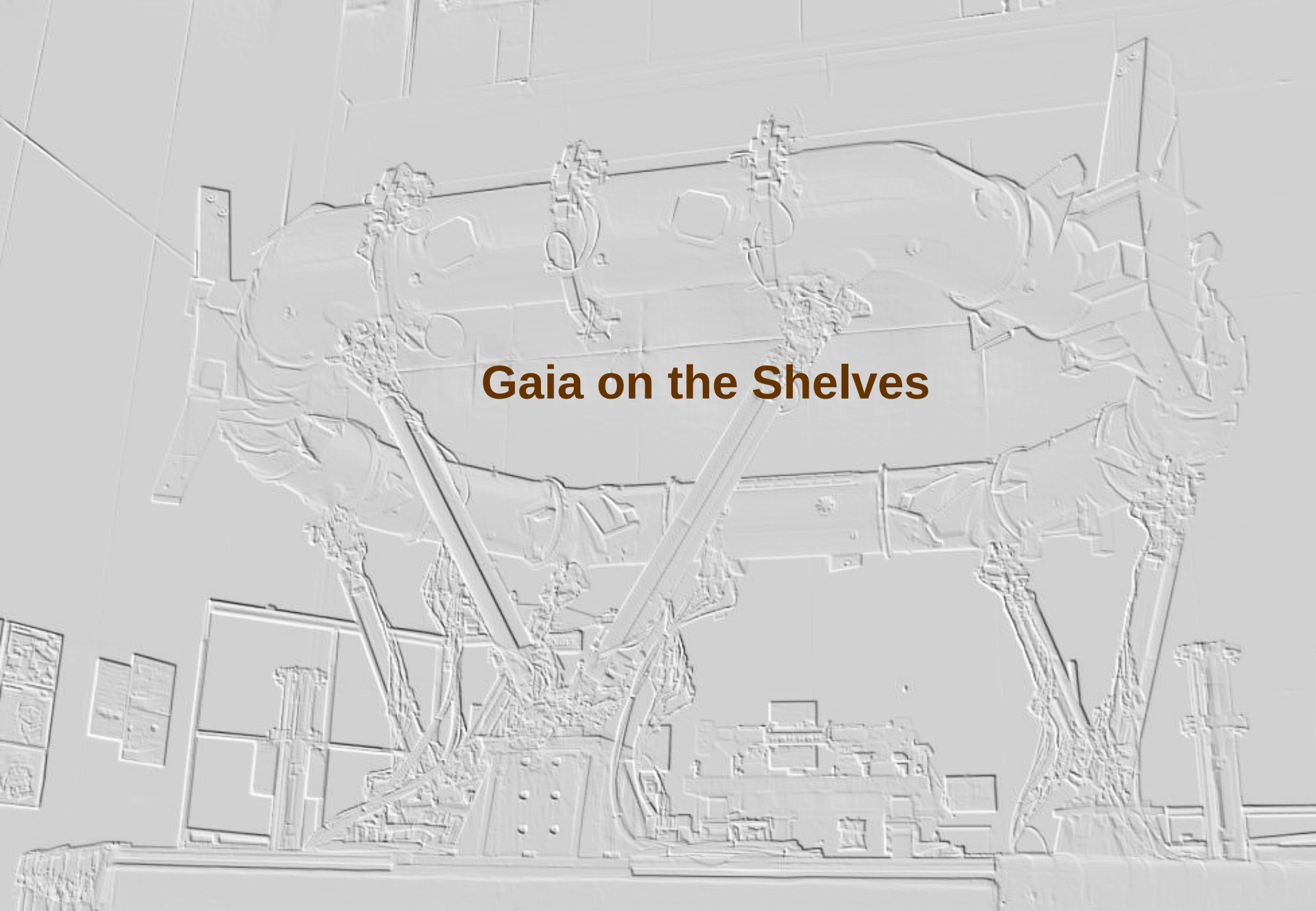
Credit: D. Evans

Radial velocity accuracy (EOM, km/s)

- Performances strongly dependent on stellar type
- Average of 40 transits (*i.e* 120 CCD crossings)

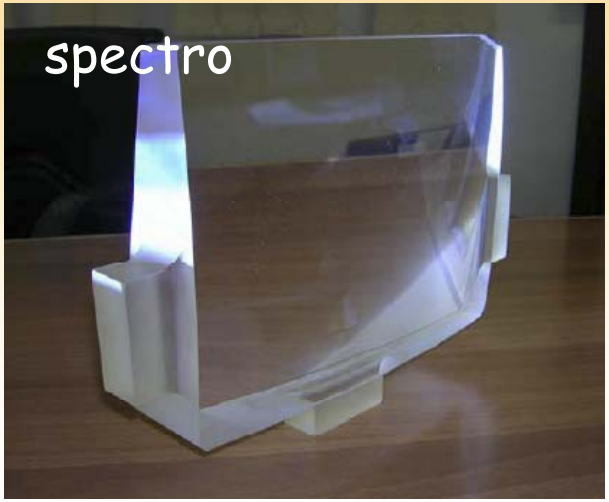


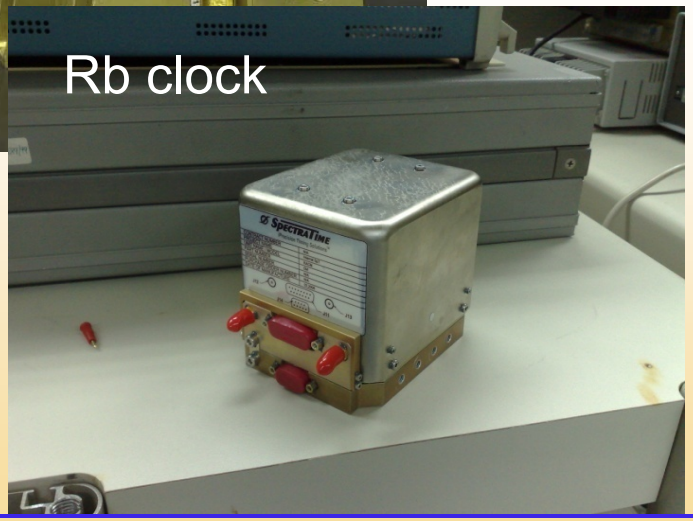
RAVE : $\langle V_r \rangle \sim 2$ km/s, $9<I<12$

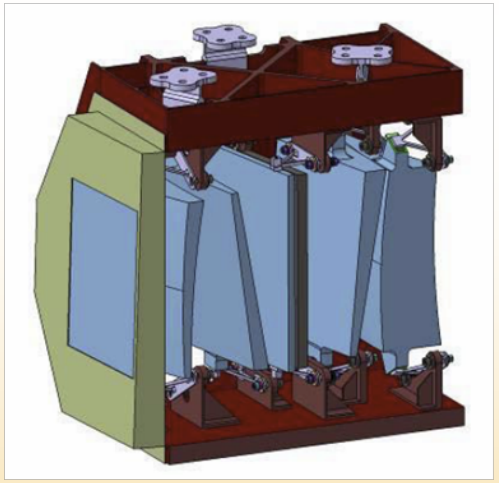


Gaia on the Shelves

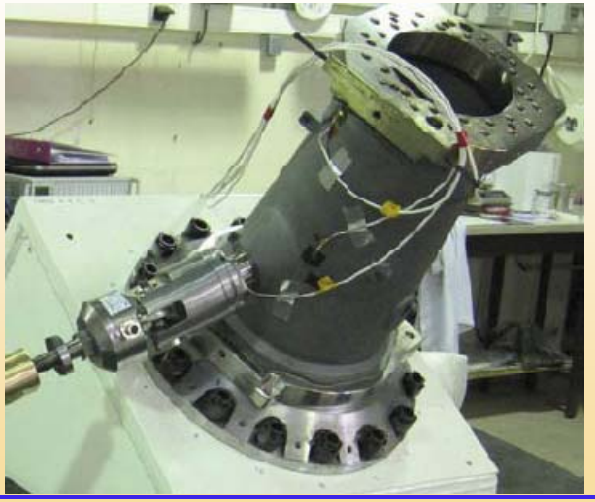
‘Hardware ' already manufactured







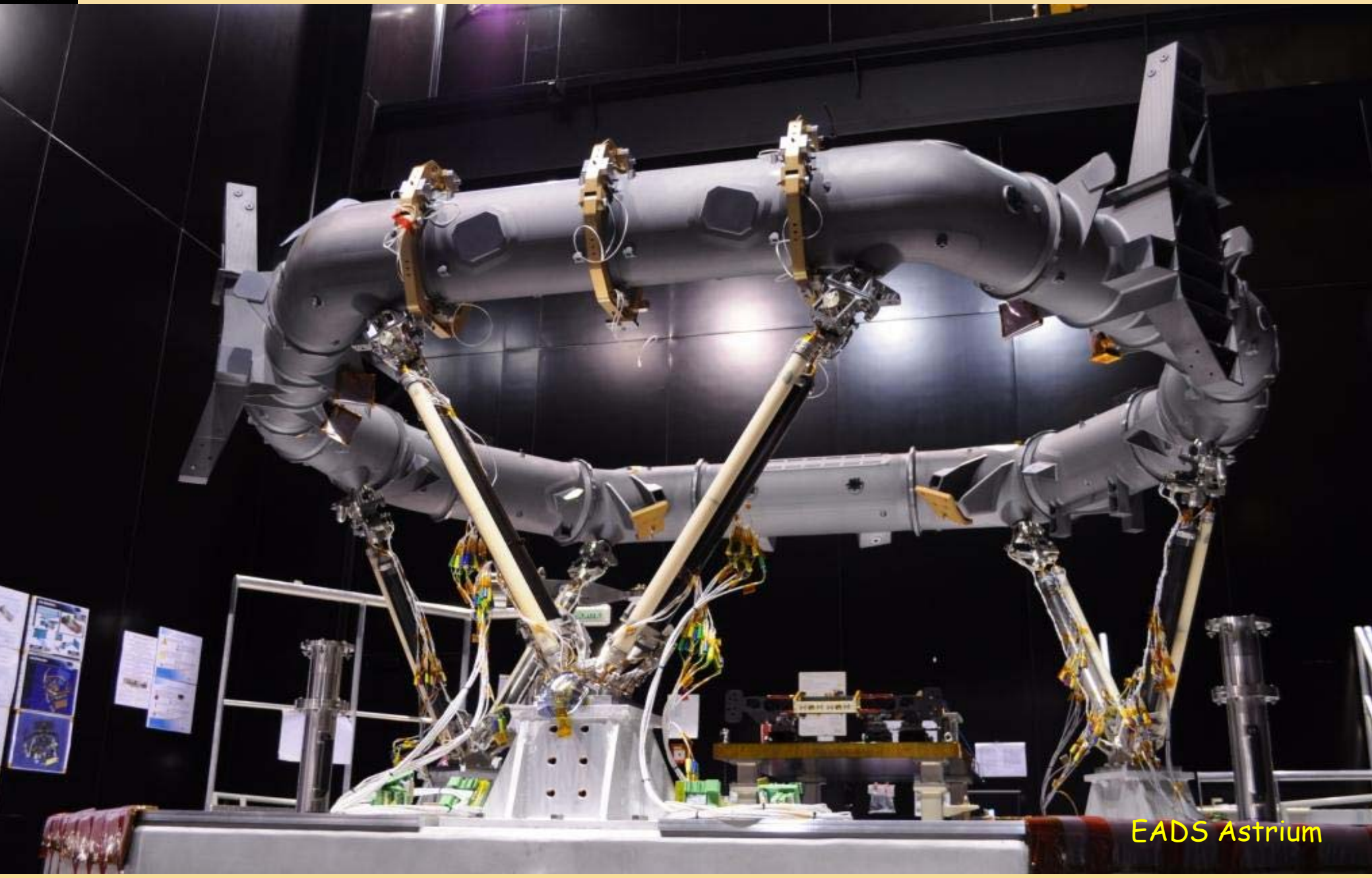
Credit : EADS Astrium



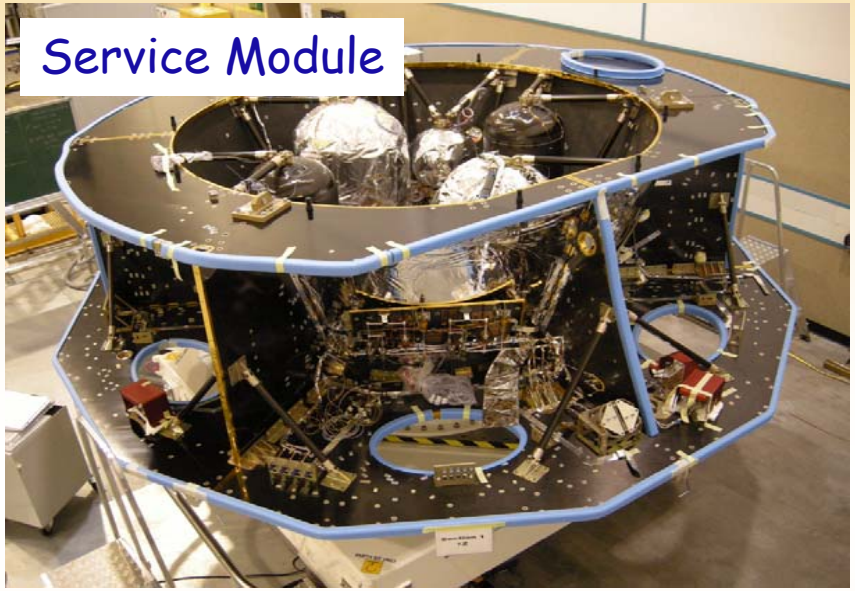
Gaia: Brased torus in place December 2009

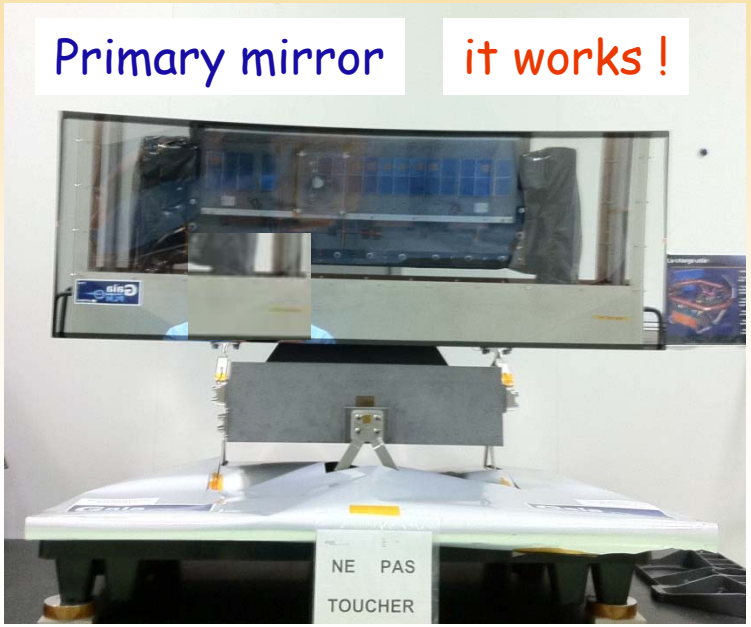
EADS Astrium

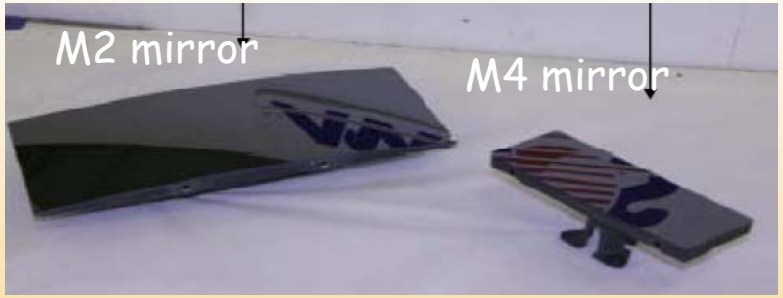
Torus with supporting bipods (July 2010)



Gaia in construction early 2011







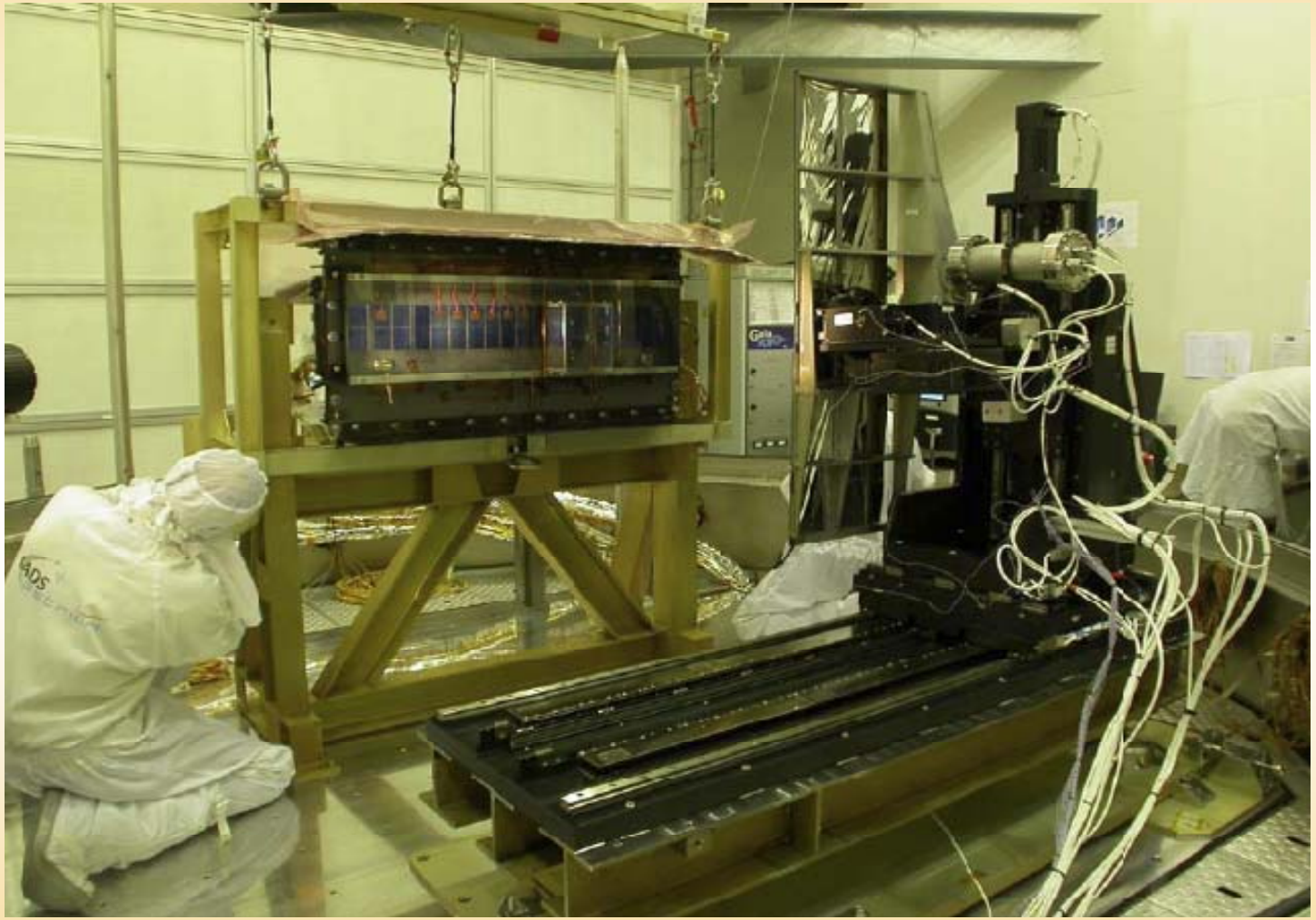
Credit: EADS Astrium

- Nine out of the ten mirrors have been delivered

Credit: EADS Astrium, Boostec

- Rehearsal of the M1 mounting (March 2011)

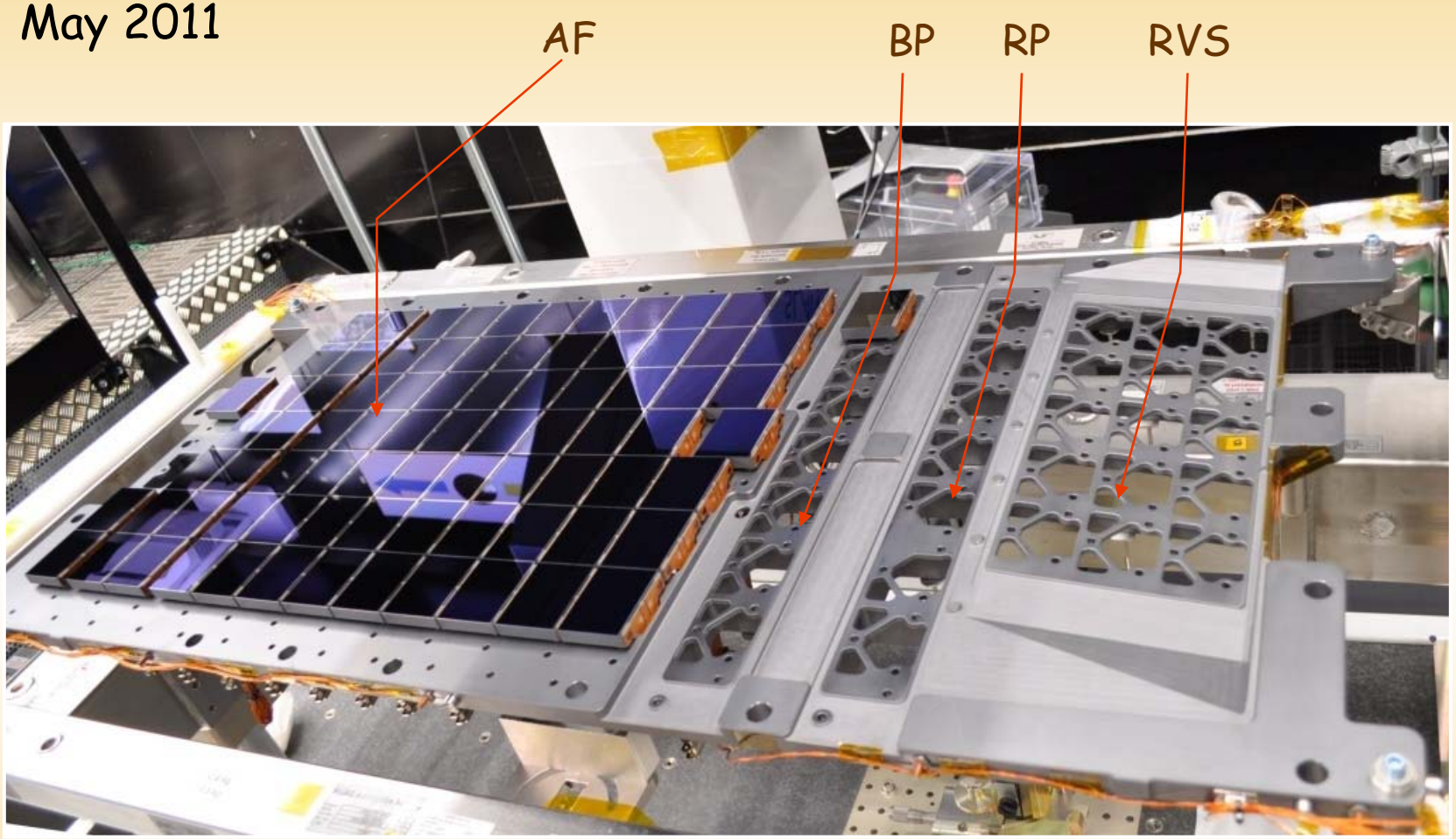
Testing CCD acquisition mode



EADS Astrium

CCD integration

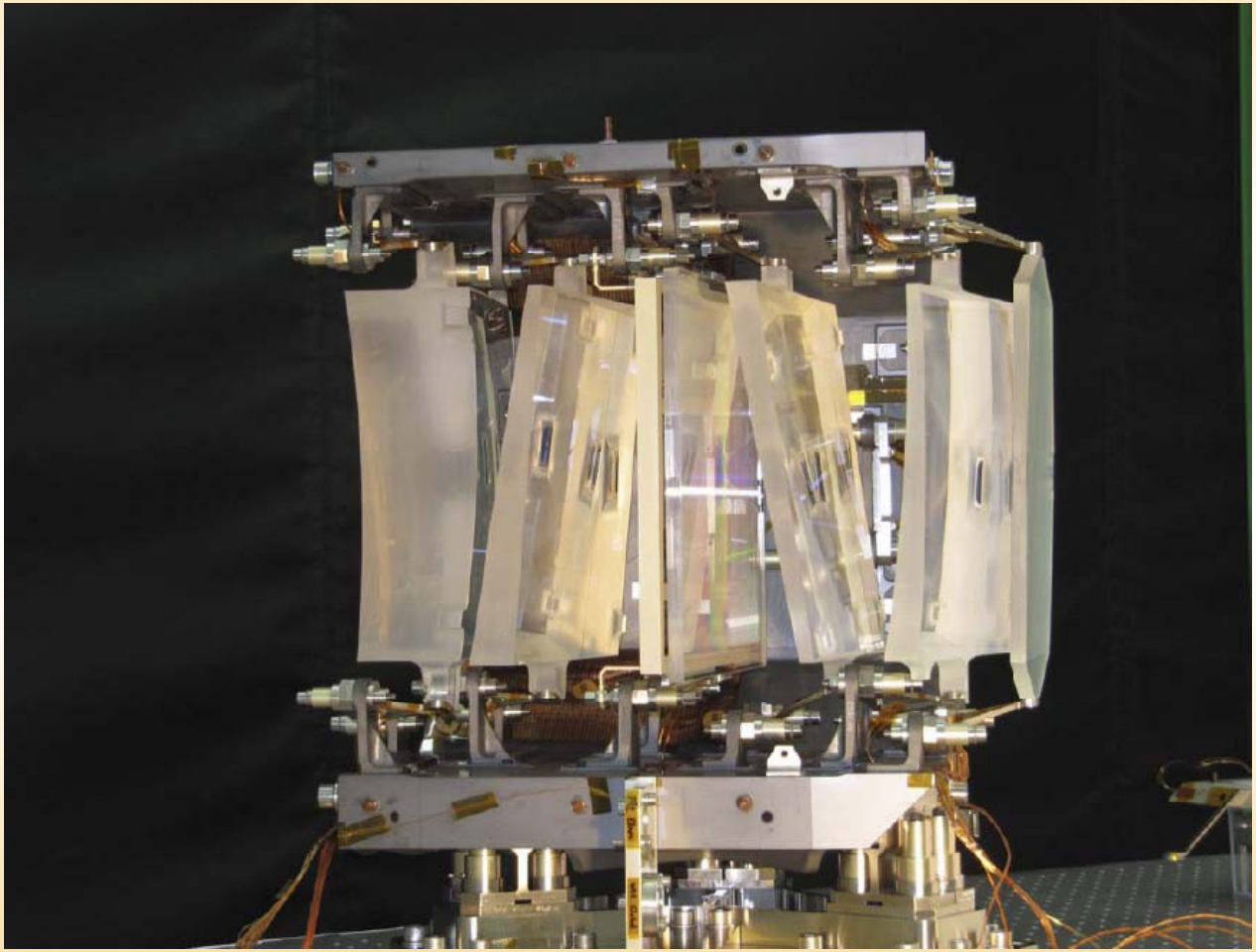
- May 2011



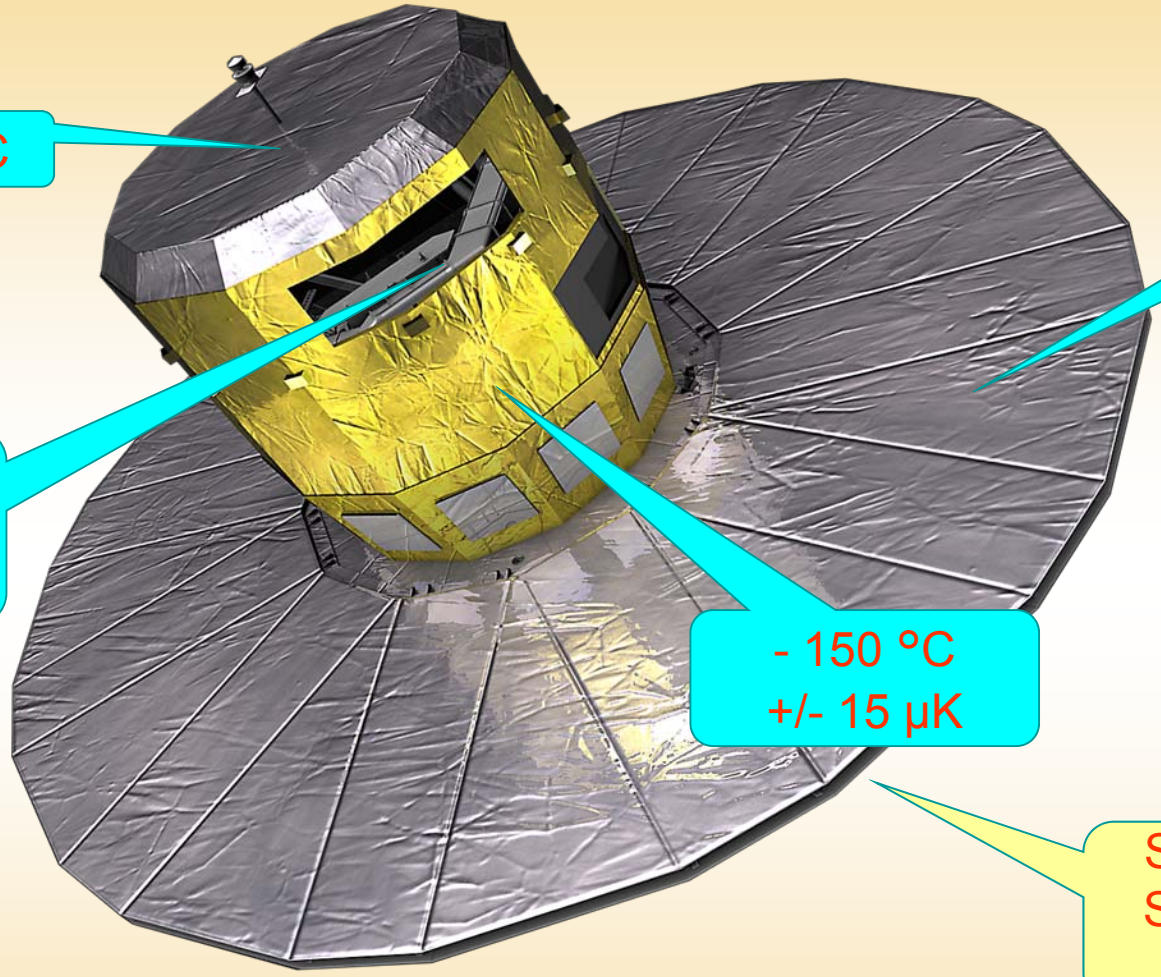
June: CCD integration completed !

RVS Integrated

- May – June 2011

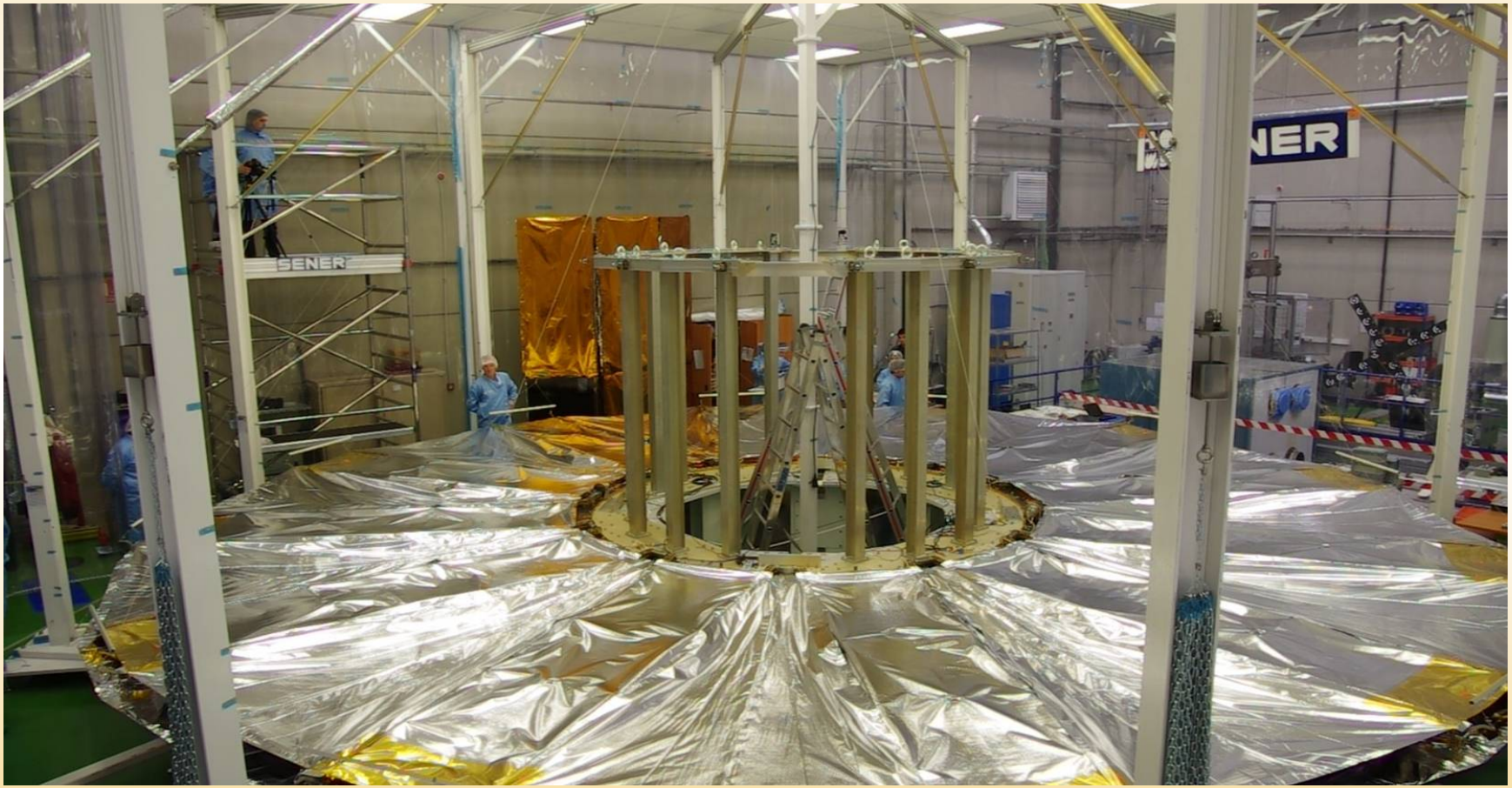


Thermal Insulation

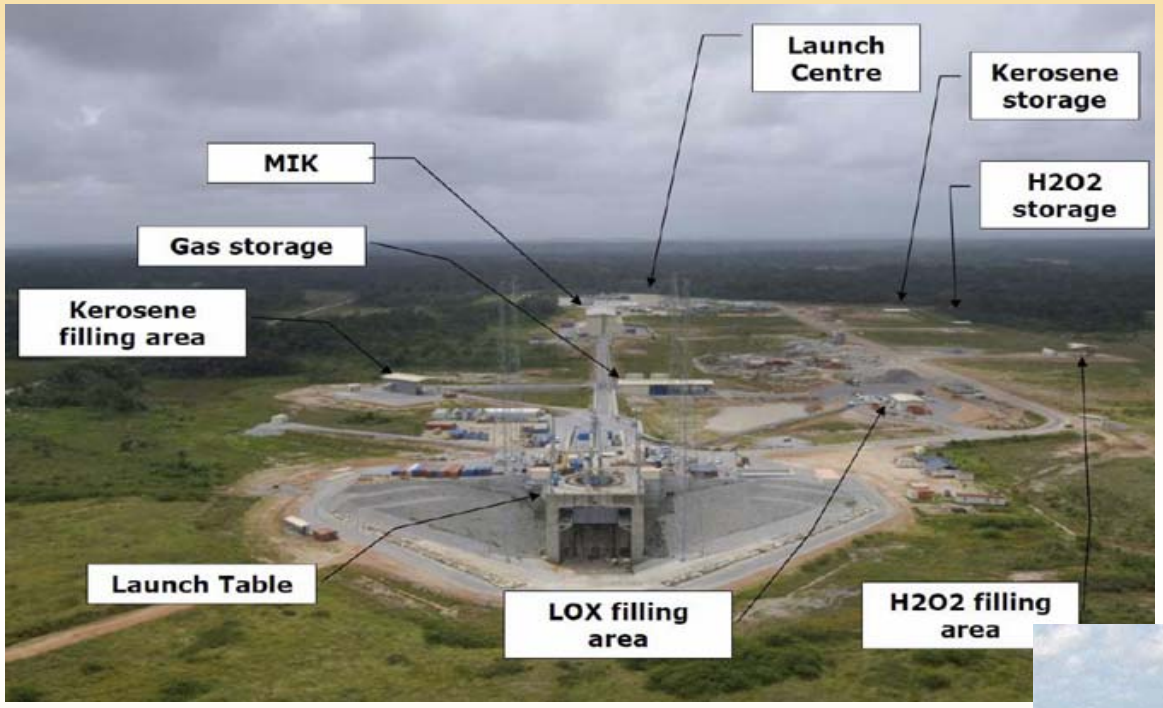


Credit: F. Chassat, Astrium

First full deployement test with new motor

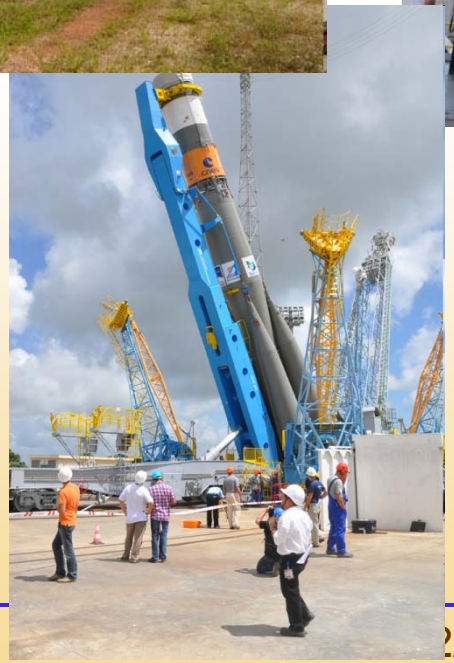


Soyuz Launchpad near Kouru

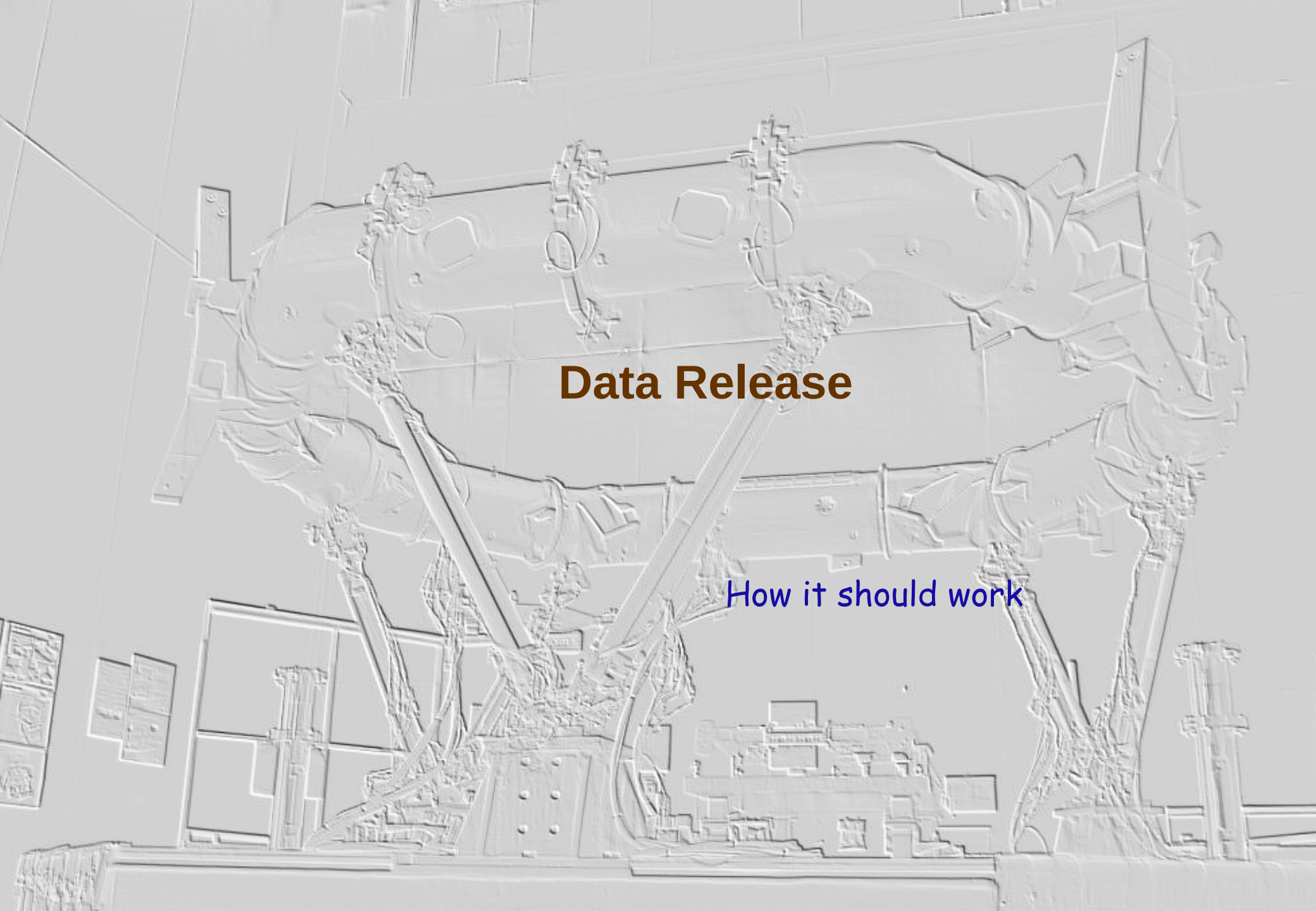


Preparations for the simulated first Soyuz flight

- Pictures taken on the 29/04 and 02/05
- First dry "lift-off" successful



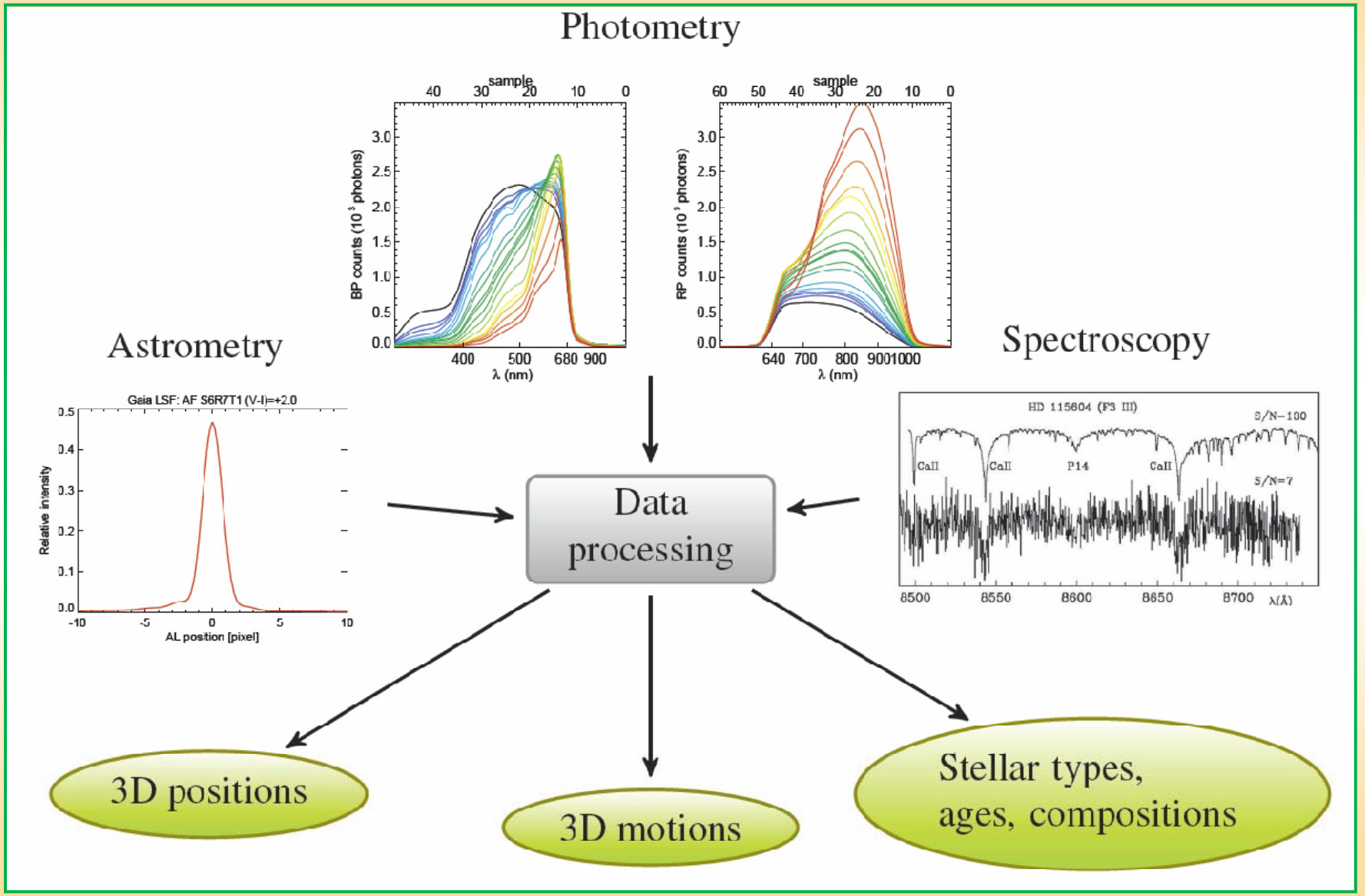
Credit: Arianespace



Data Release

How it should work

What Gaia will deliver: wide variety



cartoon: A. Brown

Data Release

- Overall principles defined in the SMP (Science Management Plan)
  - Top level document ESA/SPC covering scientific aspects of the mission
- Intermediate results should be communicated to the Community
  - calibration will be still in imperfect state
  - feedback is expected to improve the final catalogue
- Intermediate catalogues should not delay the final catalogue
- There will be at least several intermediate coordinated release
  - this will include a first astrometric catalogue and integrated photometry
  - global accuracy will be already remarkable
    - but non statistical errors may lie everywhere
    - generic error (eg: $\sigma(G, \alpha, \delta)$) may replace source level error

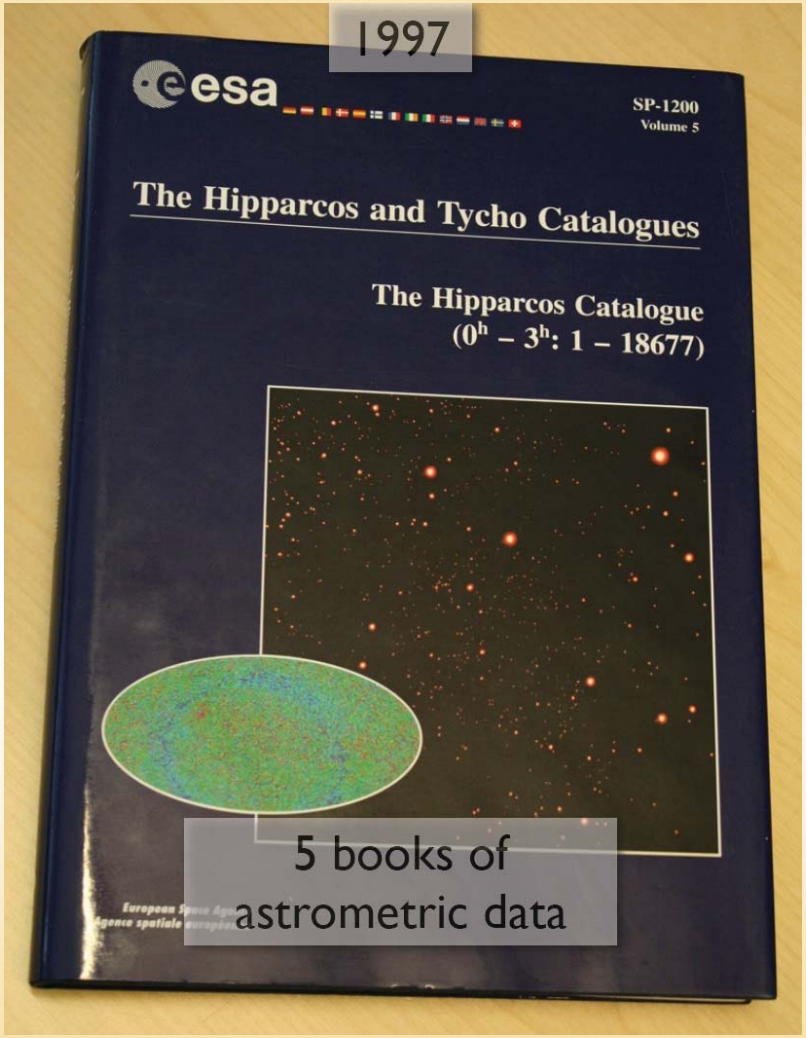
Possible content of the early releases

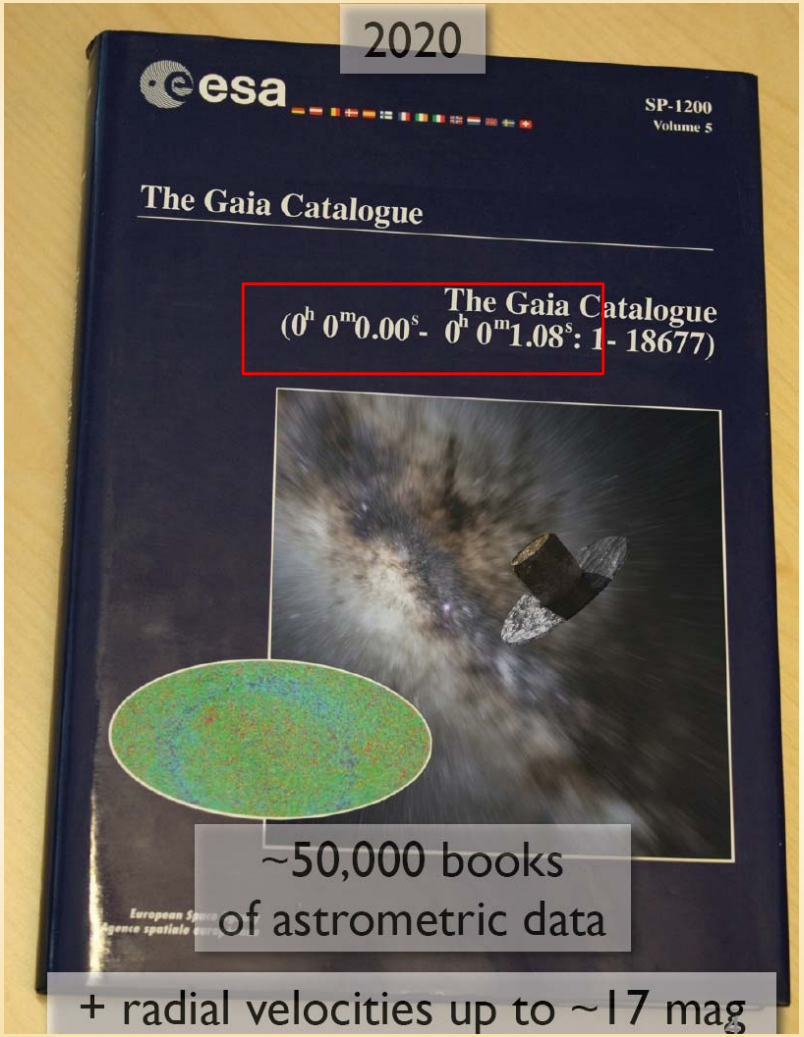
- A position catalogue (mas precision) and G mag, when 90% of the sky is covered
  - 6-8 month of data
- The Hundred Thousand Proper Motion catalogue based on Hipparcos and Gaia positions (~ 6-8 month of data)
- Special release for the ecliptic pole region observed in the Ecliptic Pole Scanning Law
- A 5-parameter astrometric solution of astrometrically well behaved stars when it can be done for at least 90% of the sky
  - possible early results for fundamental physics parameters
- BP/RP spectrophotometric data when 5% calibration accuracy has been reached
- Mean radial velocities for stars bright enough for single epoch Rv determination with sufficient epochs and 90% of the sky
- High resolution mean spectra for mag <10 and S/N at least 50 when 90% of the sky covered
- CU defined releases like Solar System astrometry, non single stars, Epoch variability data

Science Alert Mode & Release

- Gaia has a built-in science alert mode:
  - Science data that would have little or no value without quick ground-based follow up
- Astrometry, Photometry and Spectroscopy could be the source of a Gaia Alert
  - a transient photometric/spectro event evidenced in the Gaia data,
  - or a fast-moving solar system object without known orbit.
    - but without possible monitoring by the Spacecraft
- Gaia releases the alert to the science community
- Immediate follow-up needs the participation of the community

Gaia Catalogue:





Catalogue Access

- Intermediate and final release will be accessed on-line
- A dedicated CU (Coordination Unit) will be set up soon
  - it will be formed sometime in 2012
  - a dedicated AO will be released by ESA
  - An embryonic version is in place with the GAP group in the DPAC
    - GAP: Gaia Archive Preparation
  - It will develop all the necessary data mining tools to handle requests
- The actual tasks are in the process of early definition
  - requirements and specification document drafted
- Funding (not included in the current DPAC) being discussed with the national agencies
- large Expressions of Interest received from groups or countries


Thanks for your attention
esa