



Gaia explores the Milky Way

F. Mignard

Observatoire de la Côte d'Azur/Lagrange



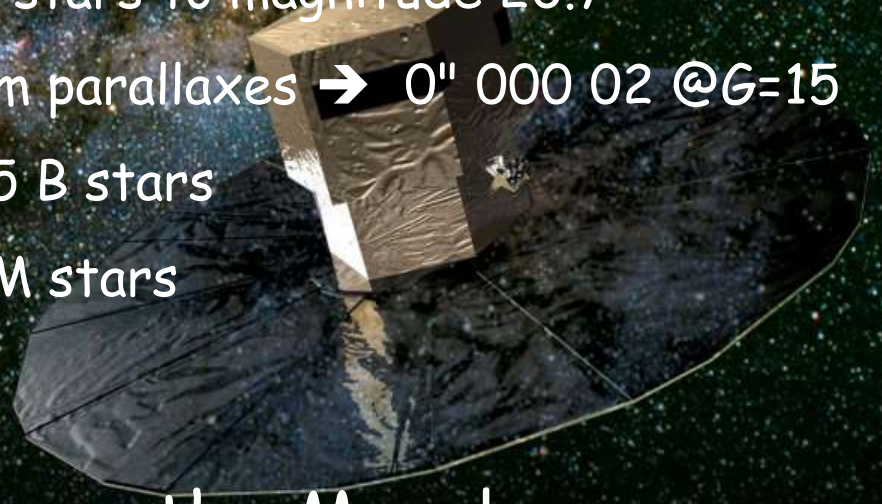




The Gaia Mission

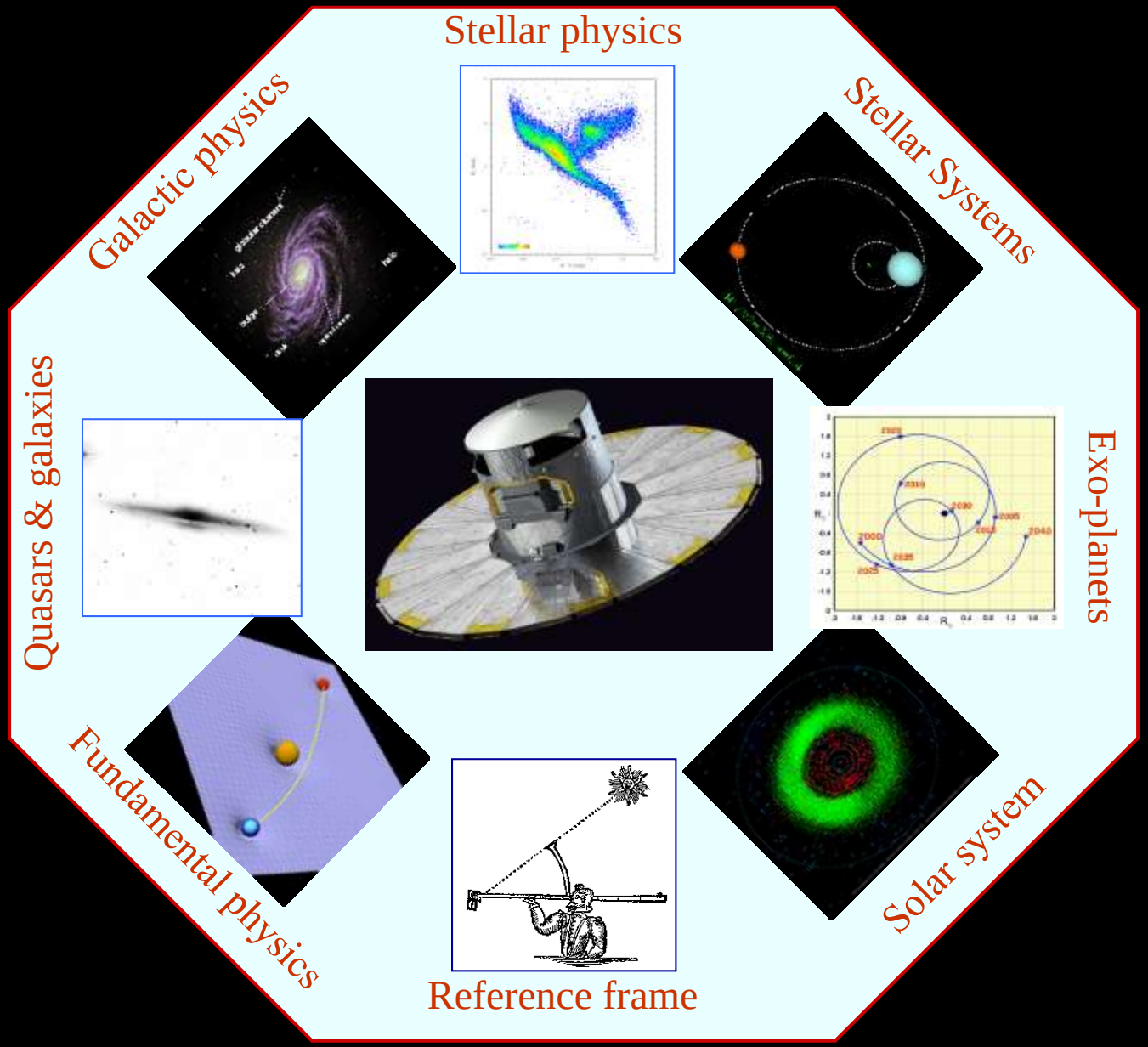
- Mission of ESA selected in 2000
- Launched on 19 December 2013
- Nominal operations to June 2019

- Goal : Study of the history, composition of the Milky Way
  - Observation of a 1.5 billion stars to magnitude 20.7
  - Distance measurement from parallaxes → 0" 000 02 @G=15
  - Spectrophotometry for 1.5 B stars
  - Radial velocities for > 100 M stars



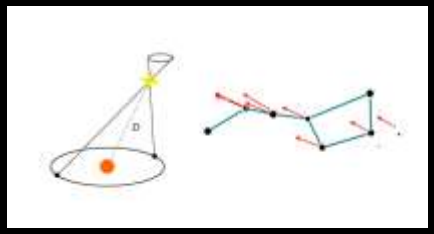
10 μas ~ 1 coin on the Moon!

Gaia : the Astrophysics Toolbox

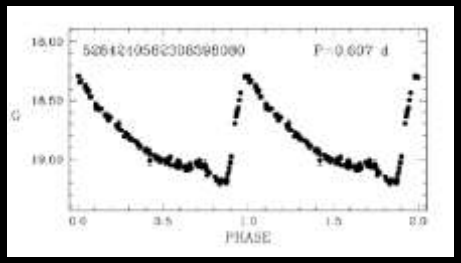


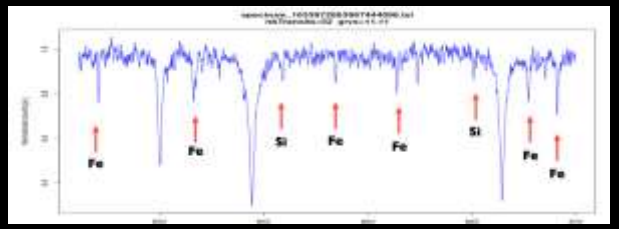
Strengths of Gaia

- A survey with a scanning mission
  - High yield and repeated visits to sources



- Three instruments working synchronously
  - Astrometry with 9 measurements per transits
  - Spectrophotometry from 0.4 to 1.1 mum
  - Spectroscopy (R ~13,000) in Ca-triplet

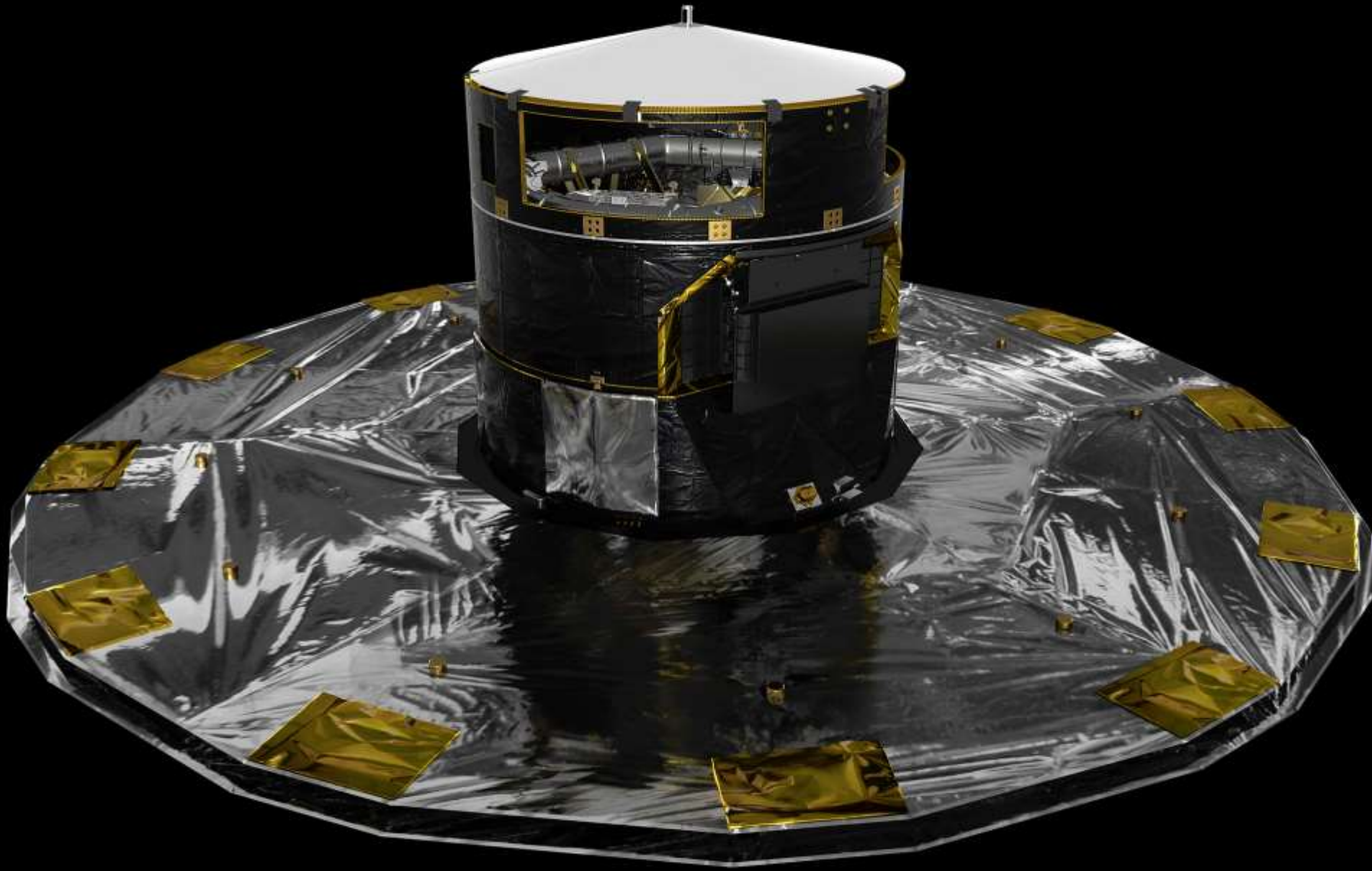




- A European highly experimented & dedicated community
  - DPAC (Data Processing Consort.) with 450 participants
  - 25 countries + ESA

Gaia DPAC

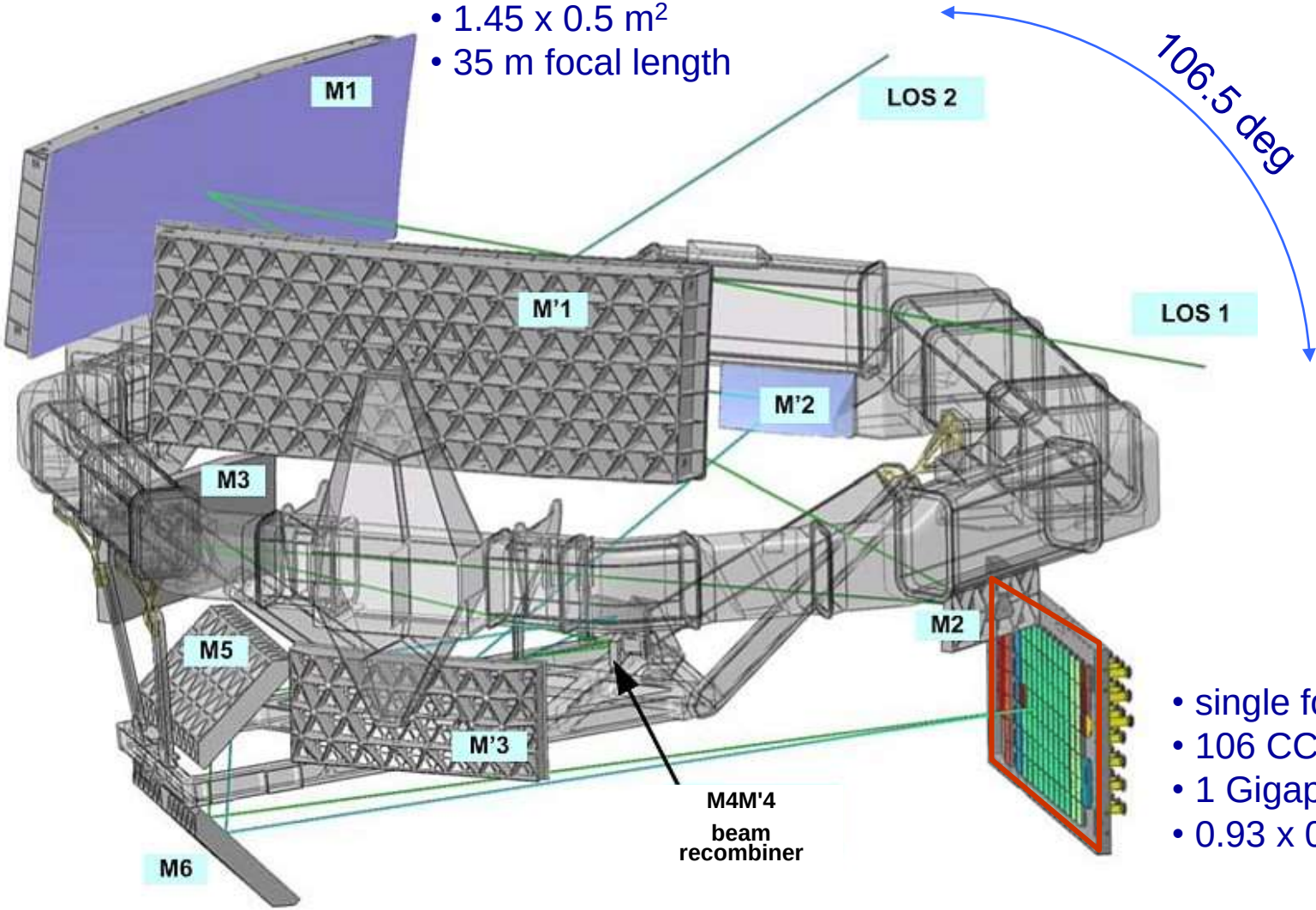
A realistic view



Credit : EADS/Astrium (Airbus Defense & Space)

Gaia : telescopes and detector

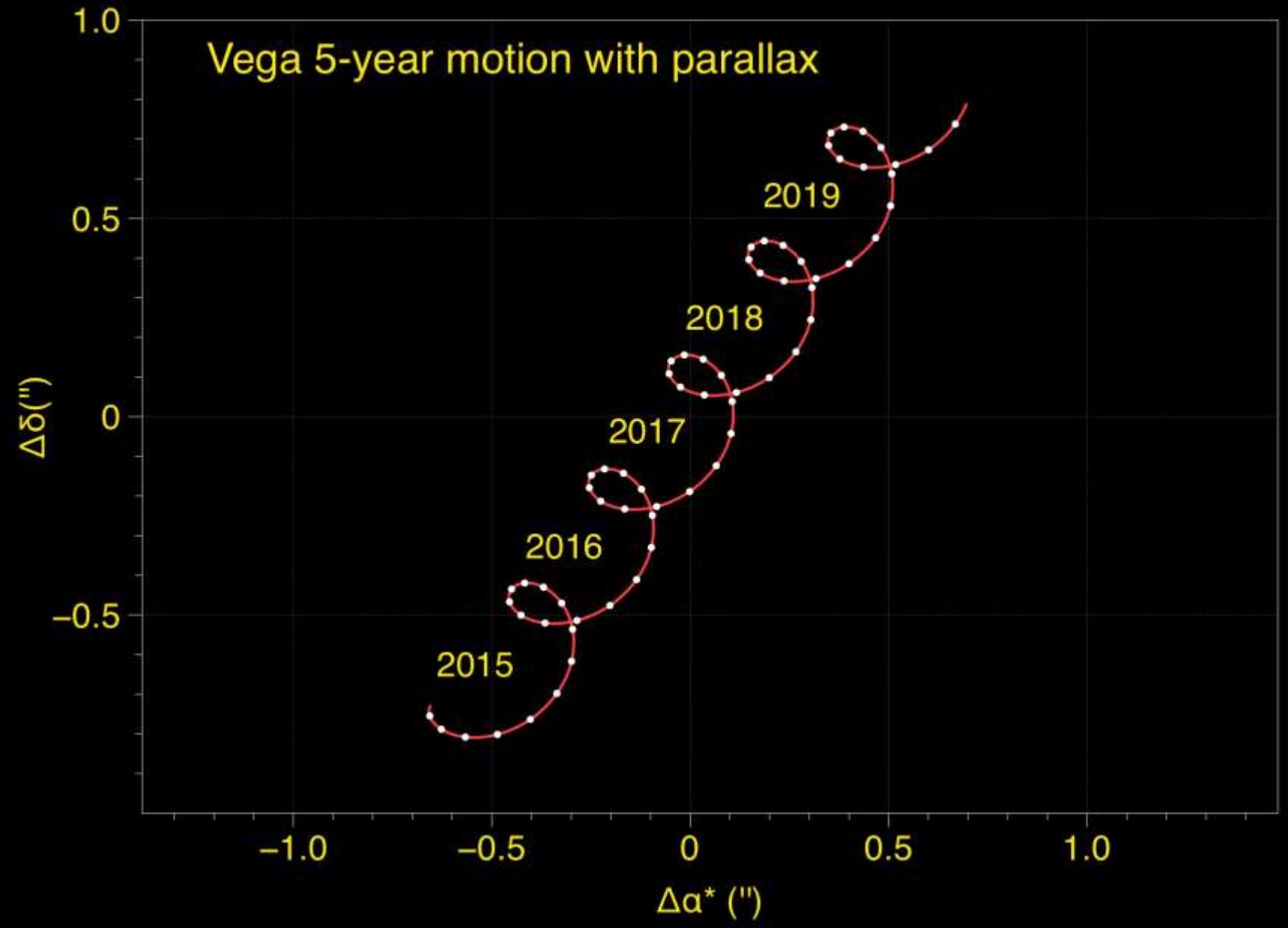
- 2 off-axis telescope
- 1.45 x 0.5 m^2
- 35 m focal length



- single focal plane
- 106 CCDs
- 1 Gigapixel
- 0.93 x 0.42 m^2

Credit : EADS/Astrium (Airbus Defense & Space)

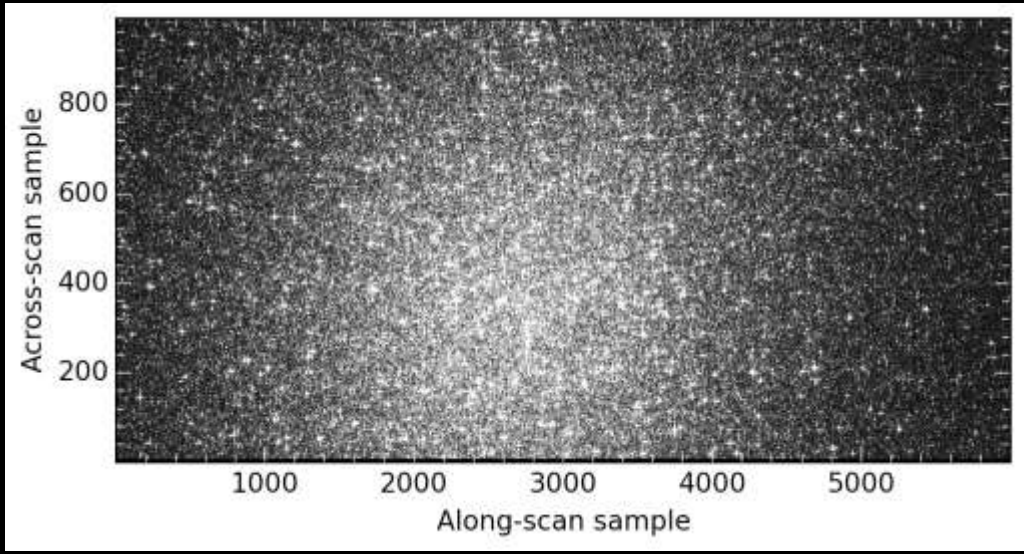
Basic stellar model



Credit : F. Mignard

A typical Gaia day

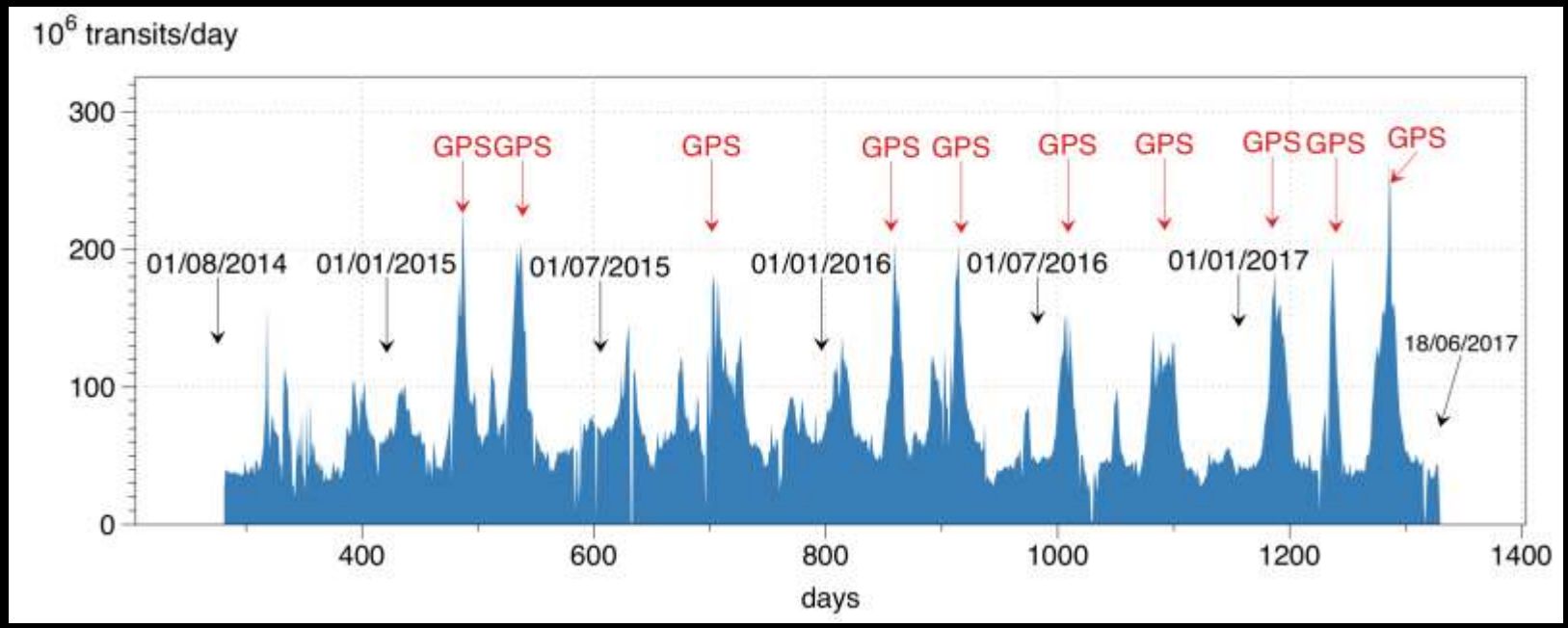
- 24h of continuous sky scanning
  - 70 million sources detected
  - 600 million astrometric measurements
  - 155 million photometric measurements
  - 13 million spectroscopic measurements
  - 40 GB of data on the ground



Credits: ESA/Gaia/DPAC/SOC calibration team

Data collected over 31 months

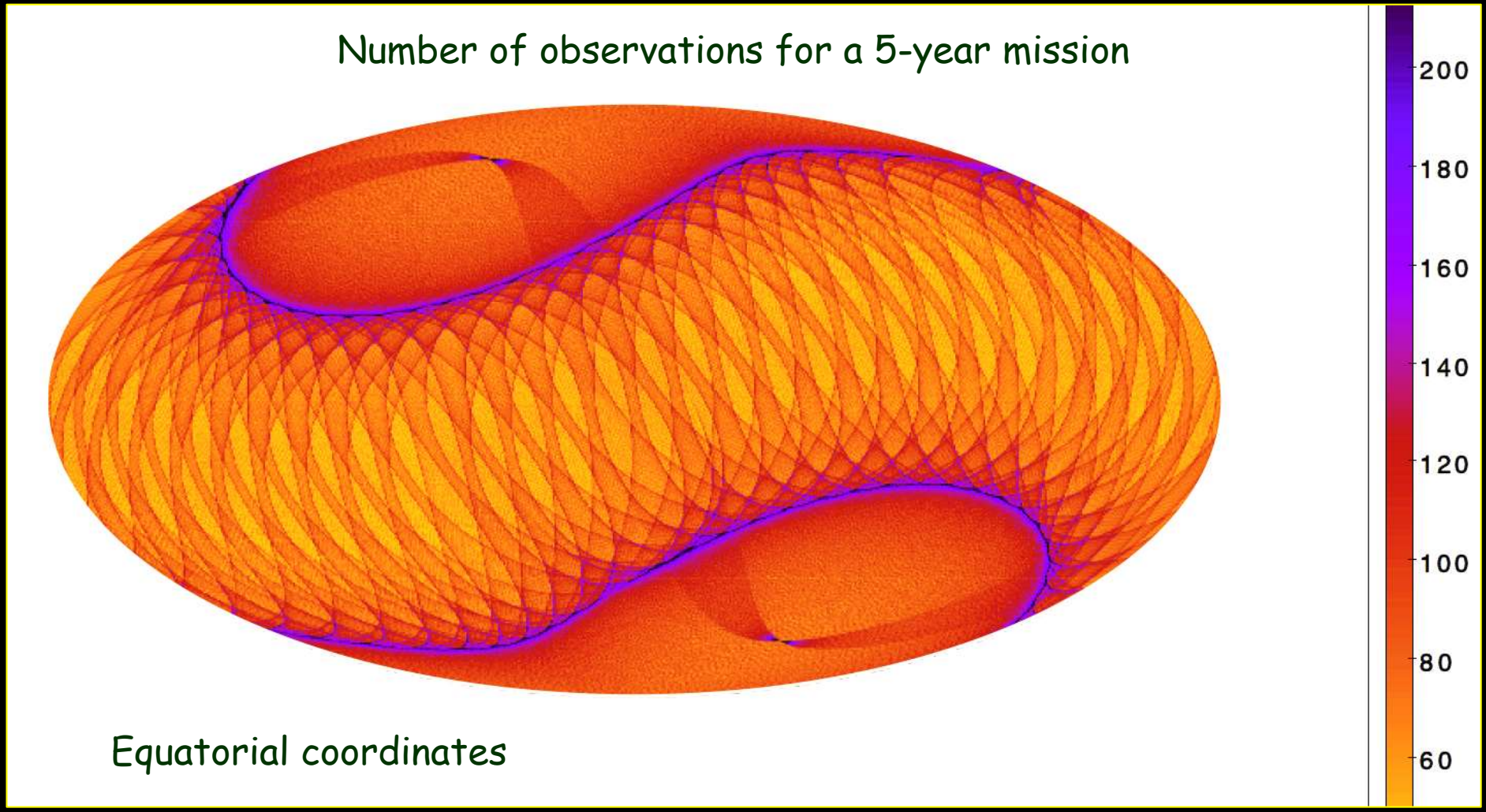
- From 25 July, 2014 to 04 September, 2017 (1137 days)
  - Science data volume : 44 GB
  - 85 x 10^9 observations (sources detected on-board ~ number of transits)
  - 835 x 10^9 astrometric measurements
  - 170 x 10^9 spectro-photometric spectra
  - 15 x 10^9 RVS spectra
  - 3 billion sources in the working catalogue



GPS : Galactic Plane Scan

binsize = 1 day - Unit : million transits

Gaia: Scanning the sky



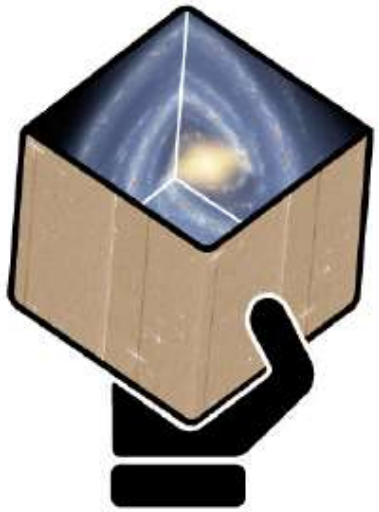
Credit : ESA/Gaia/DPAC – F. Mignard

Wednesday 14 September 2016

Gaia DR1





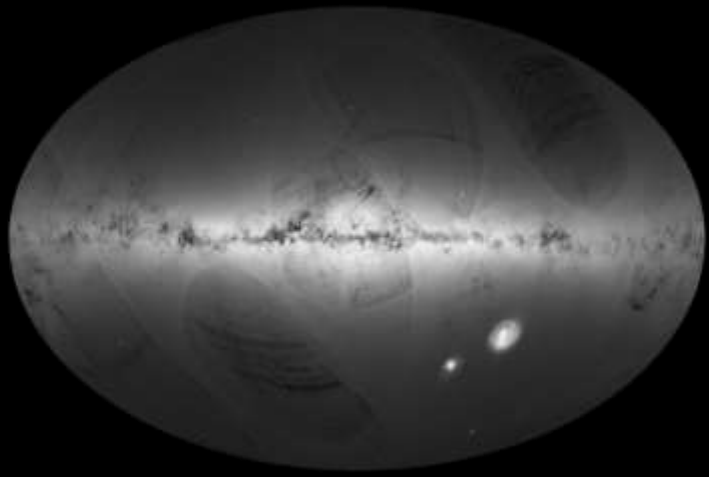


14 September 2016 : Gaia DR1

- First public data release
  - Exactly 1000 days after launch
  - Processing of data from July 2014 to Sept 2015
  - 30 billion transits exploited
    - 300 billion astro-elementaries
    - 3 billion sources identified (but not all real)

Gaia DR1

- Press conference on 14/09, international coverage
- Immediate access to the archive
  - >10.000 users within 24h
  - Over the first two weeks > 60 TB downloaded
  - 1st science publication came 9h later
- Most accessed ESA site
- Went smoothly at ESAC and CDS



- Several WS dedicated to the DR1
- Data release policy positively received

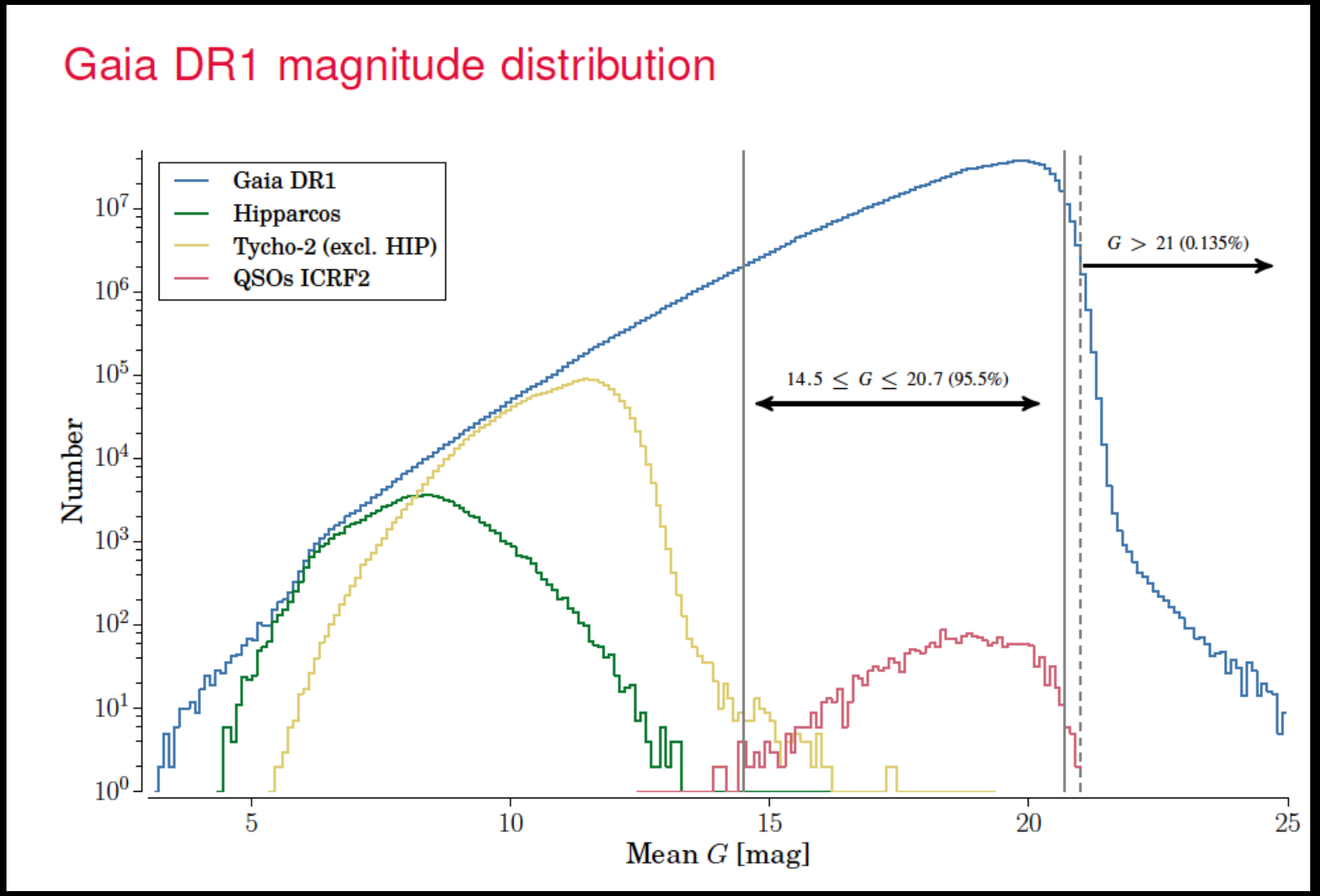


Gaia DR1 content

- A billion star position catalogue
- A full astrometric solution for 2 M stars
- A sub-mas reference system with QSOs
- A set of 3500 light-curves with Cepheids

The Sky Survey

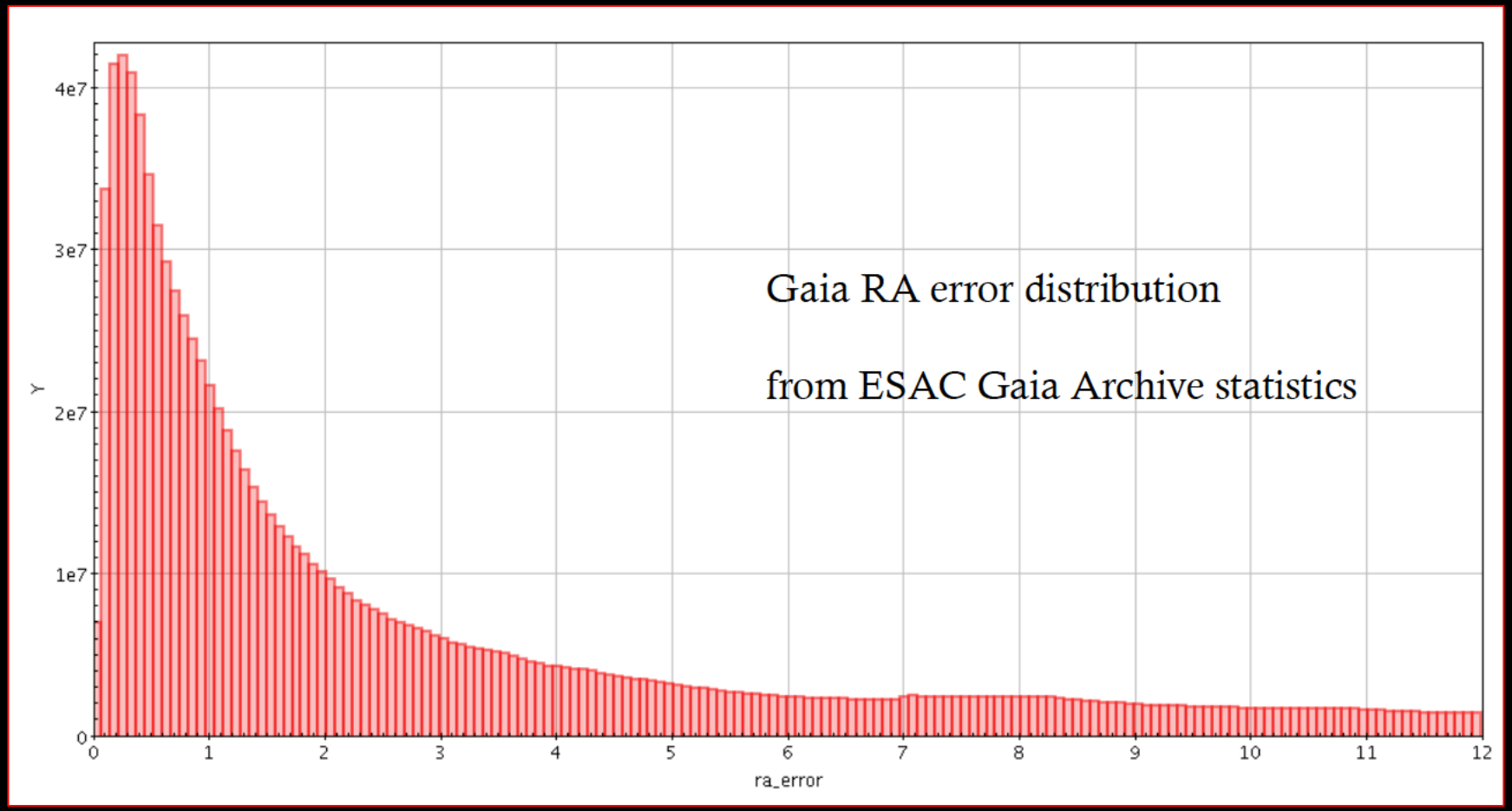
- Completeness level



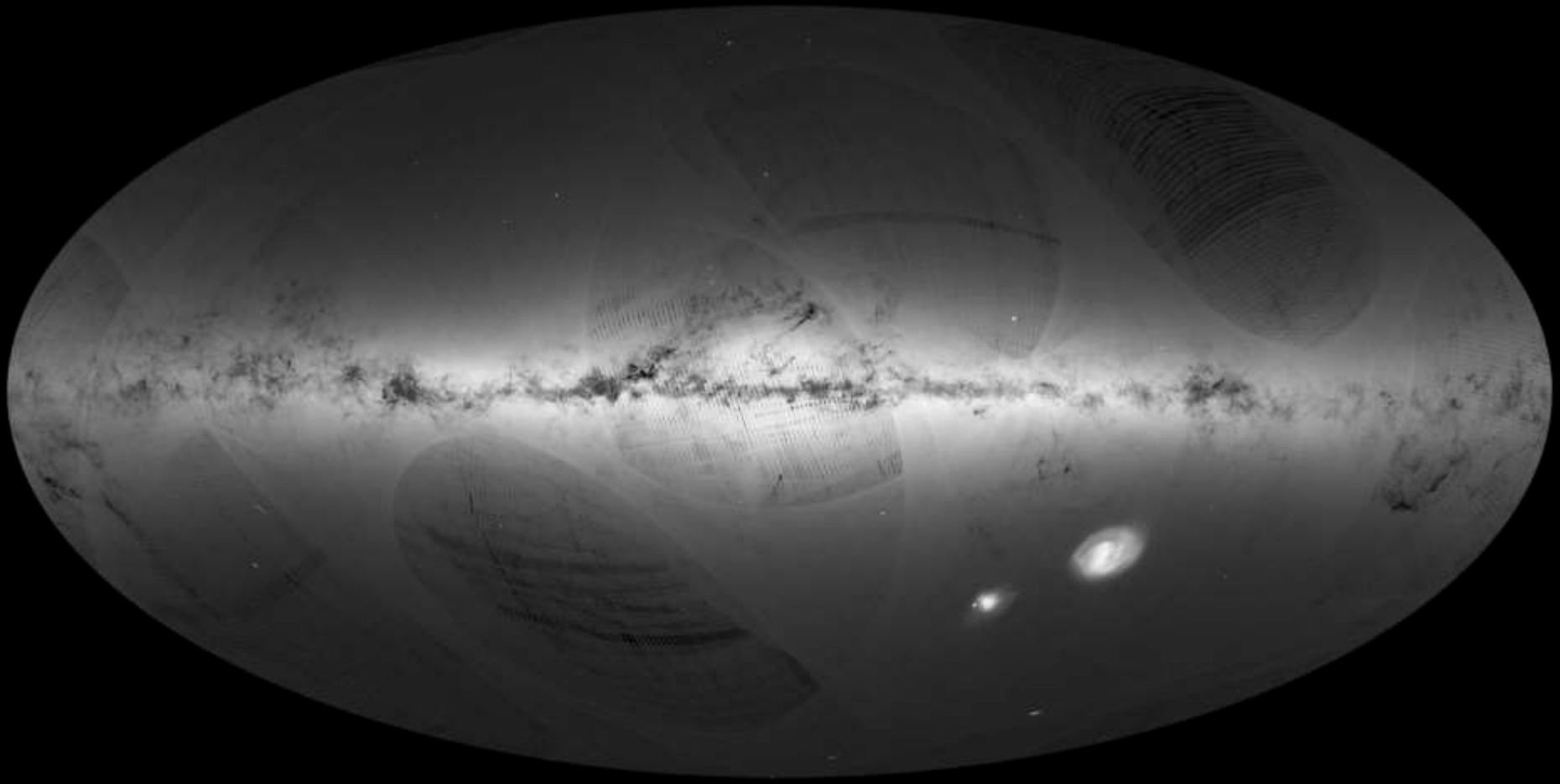
credit : ESA/Gaia/DPAC

The Sky Survey

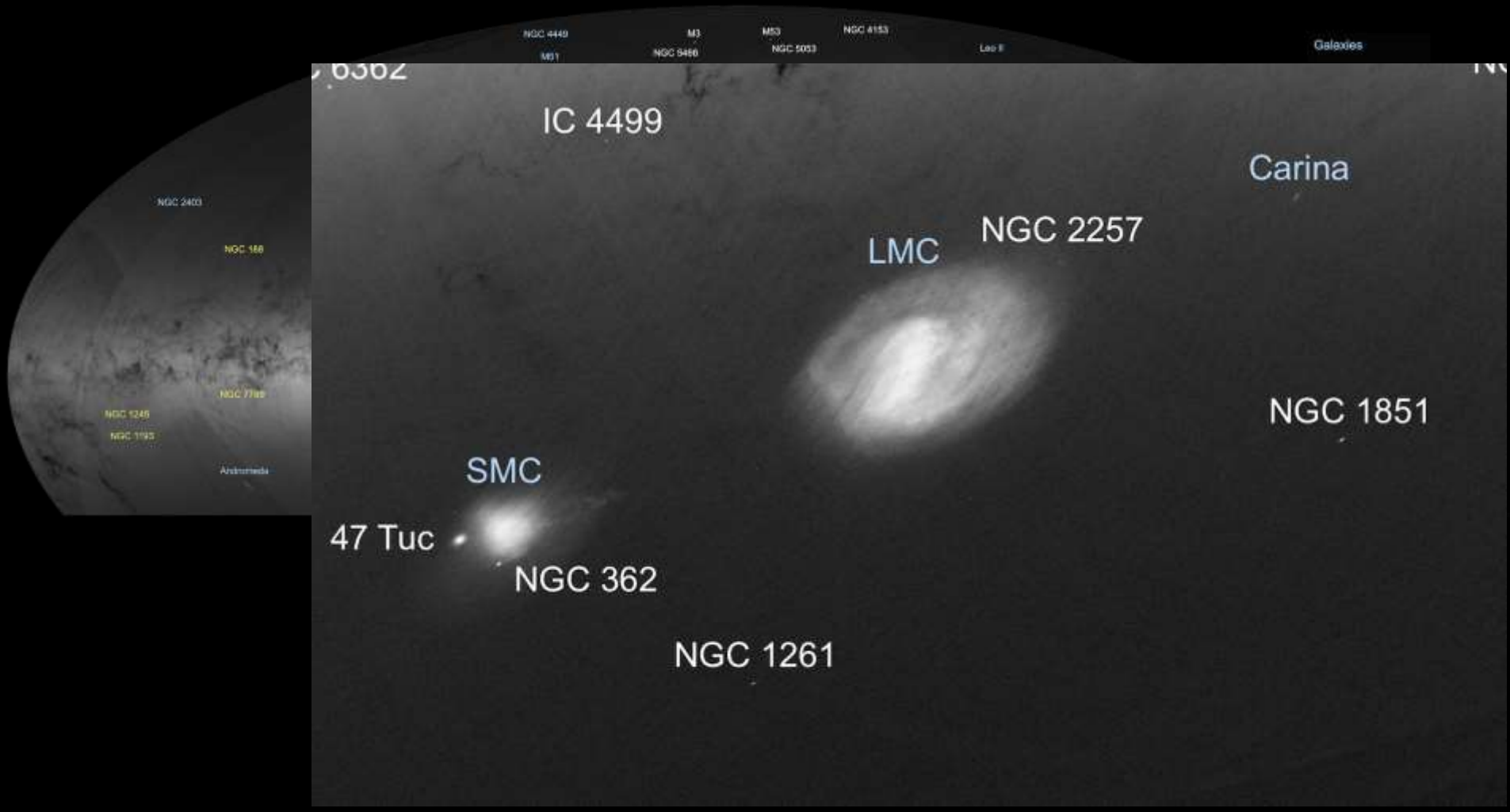
- Estimated accuracy in right ascension
  - Median = 2.3 mas (et ~ 1 mas @ $G < 18$)
  - Best ground-based survey at same mag ~ 200 mas



credit : ESA/Gaia/DPAC



Credit: ESA/Gaia/DPAC
Image generated by: André Moitinho & Márcia Barros (CENTRA - University of Lisbon) on behalf of DPAC



Credit: ESA/Gaia/DPAC
Image generated by: André Moitinho & Márcia Barros (CENTRA - University of Lisbon) on behalf of DPAC

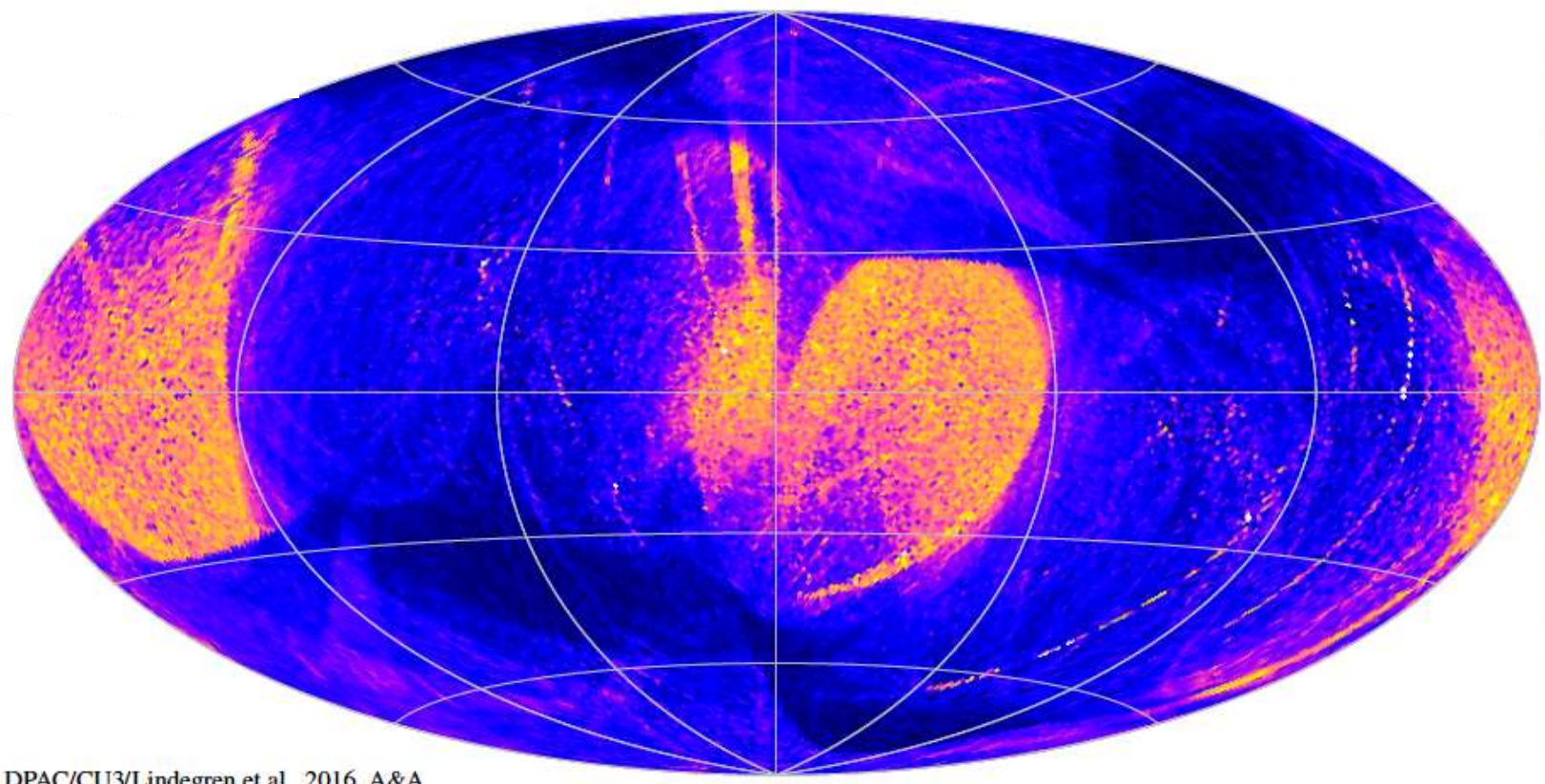
TGAS : Property of the solution

- Combined solution Hipparcos/Tycho(TGAS)
  - 2.06 million sources, $G < 11.5$
  - positions, parallaxes, proper motions
  - no very bright stars($G < 6$), and $\mu < 3.5$ "/yr
- Median uncertainty in position: 0.23 mas (in 2015.0)
- Uncertainty of parallaxes ~ 0.3 – 0.6 mas - median = 0.32 mas
- Uncertainty in proper motions➔ Hipparcos ~ 0.07 mas/yr

  Tycho ~ 1.2 mas/yr

Parallaxes of TGAS

- Accuracy of the parallaxess
  - 2 to 3 times better than Hipparcos
  - 20 times more stars



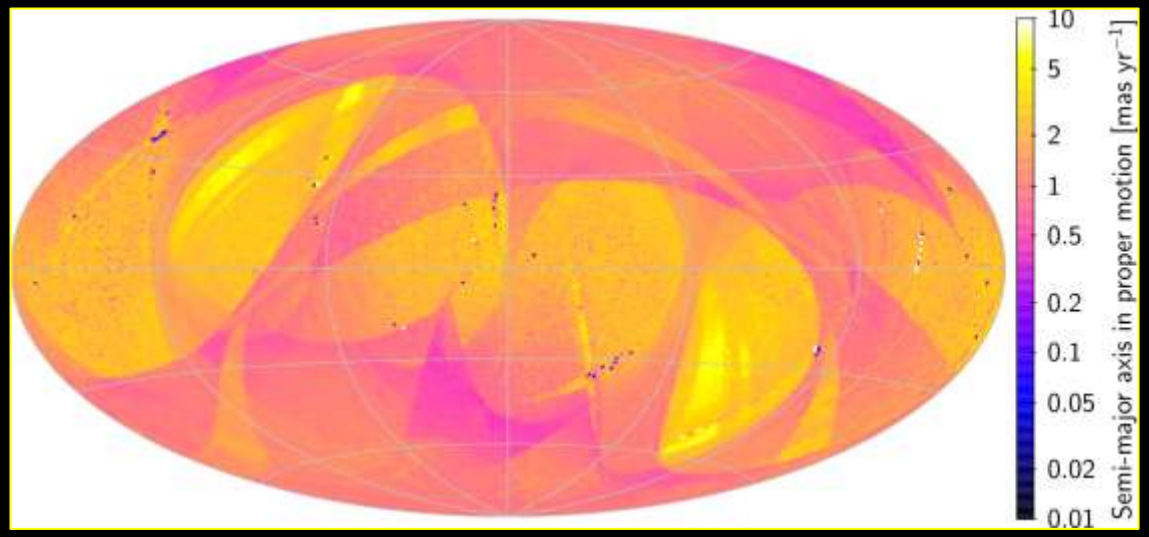
DPAC/CU3/Lindegren et al., 2016, A&A

credit : ESA/Gaia/DPAC

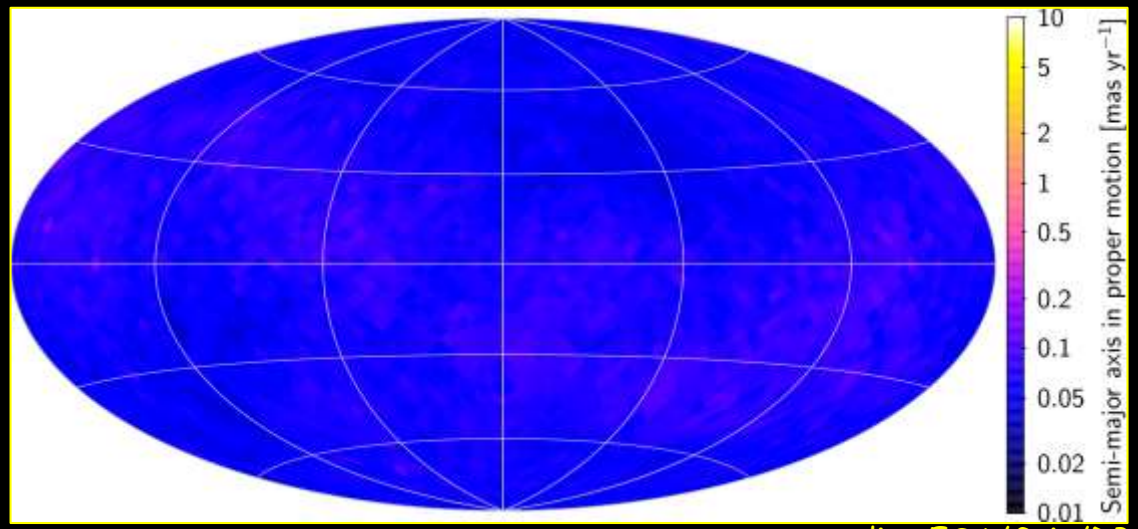
Proper motions in TGAS

- Separate population Hipparcos and Tycho

Tycho ~ 1 mas/yr
2 million stars



Hipparcos ~ 0.05 mas/yr
100,000 stars

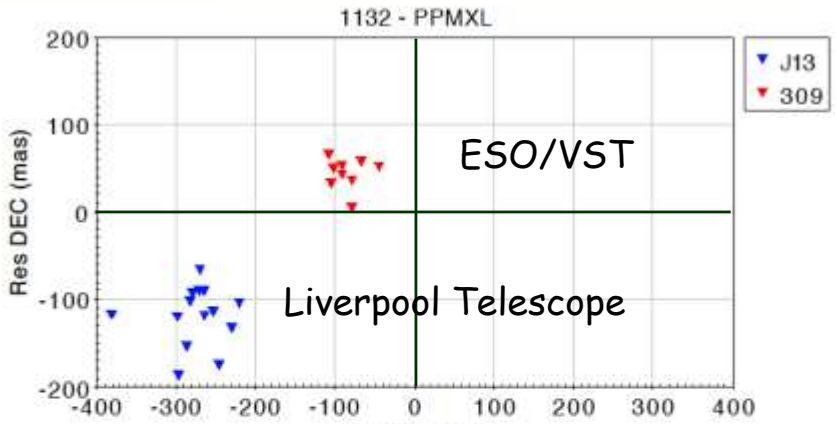


credit : ESA/Gaia/DPAC

Astrometric use of the Gaia DR1

- Residual of ground-based observations on asteroid (GBOT)
  - Planet (1132) Hollandia
  - Reduction with PPMXL and then Gaia/DR1

Reduction with PPMXL

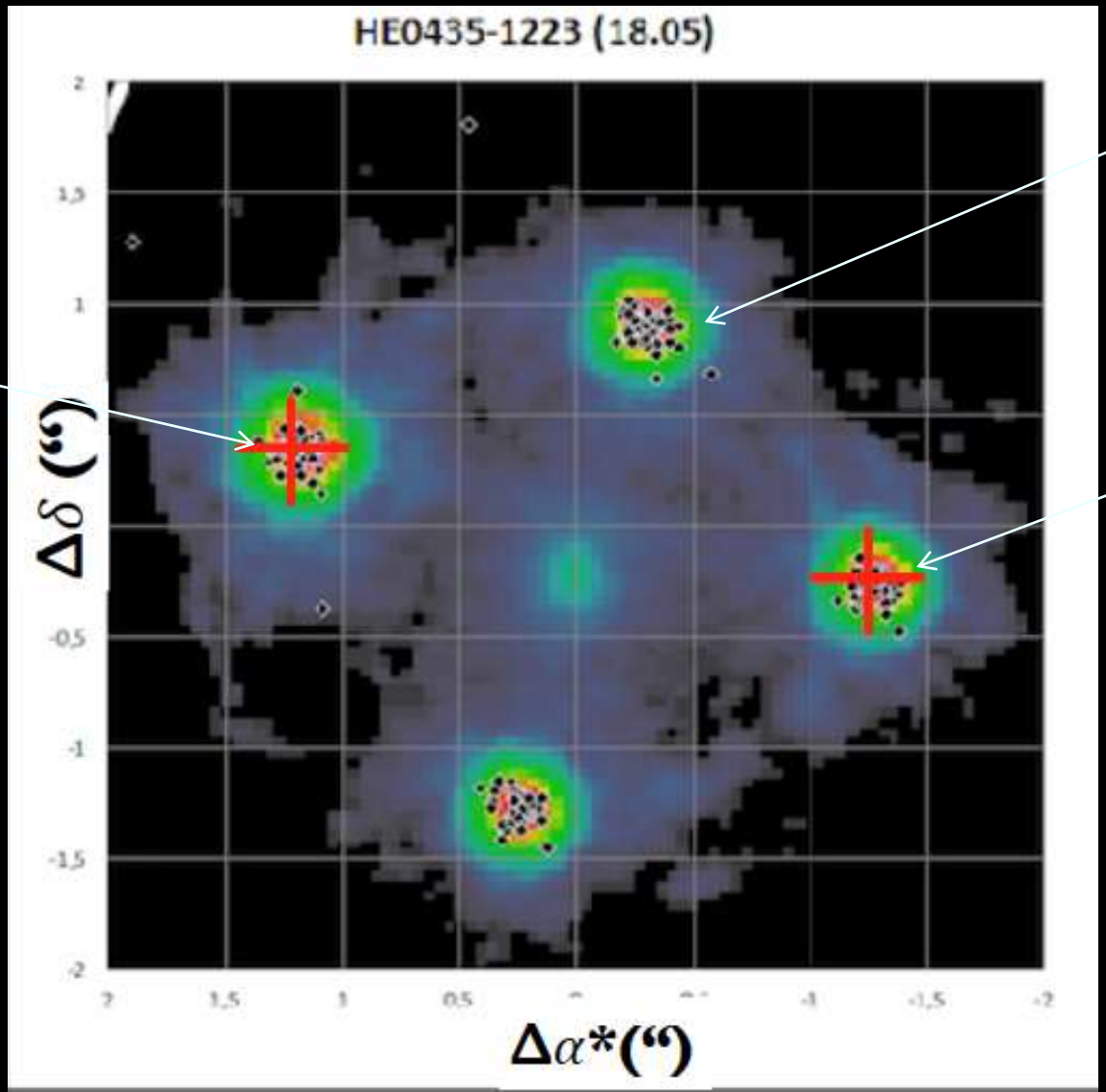


Reduction with Gaia-DR1

F. Spoto et al., 2017

Lensing in DR1 solution

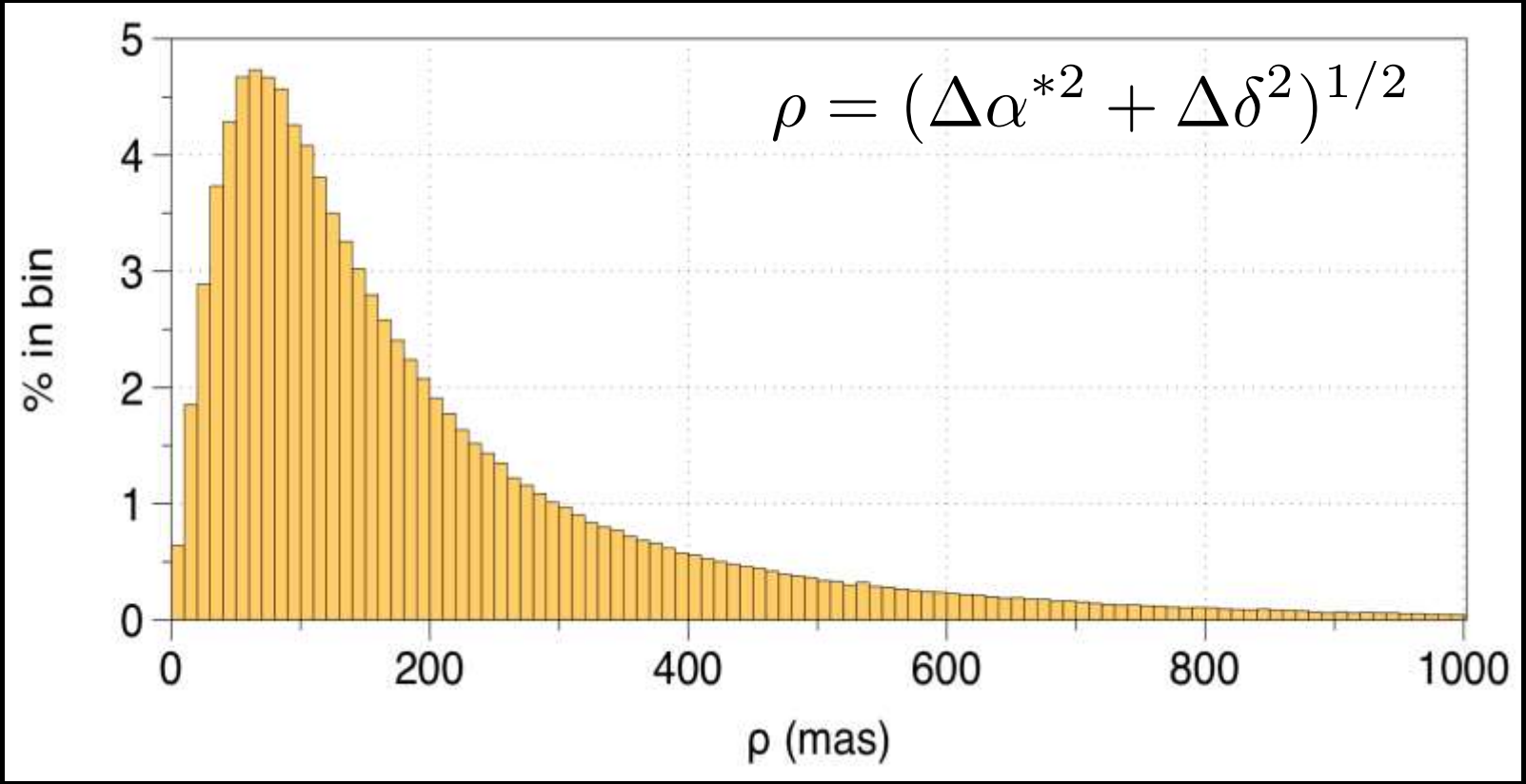
- A known lens with DR1 positions of components
  - superimposed to a HST image



Ducourant et al., 2017

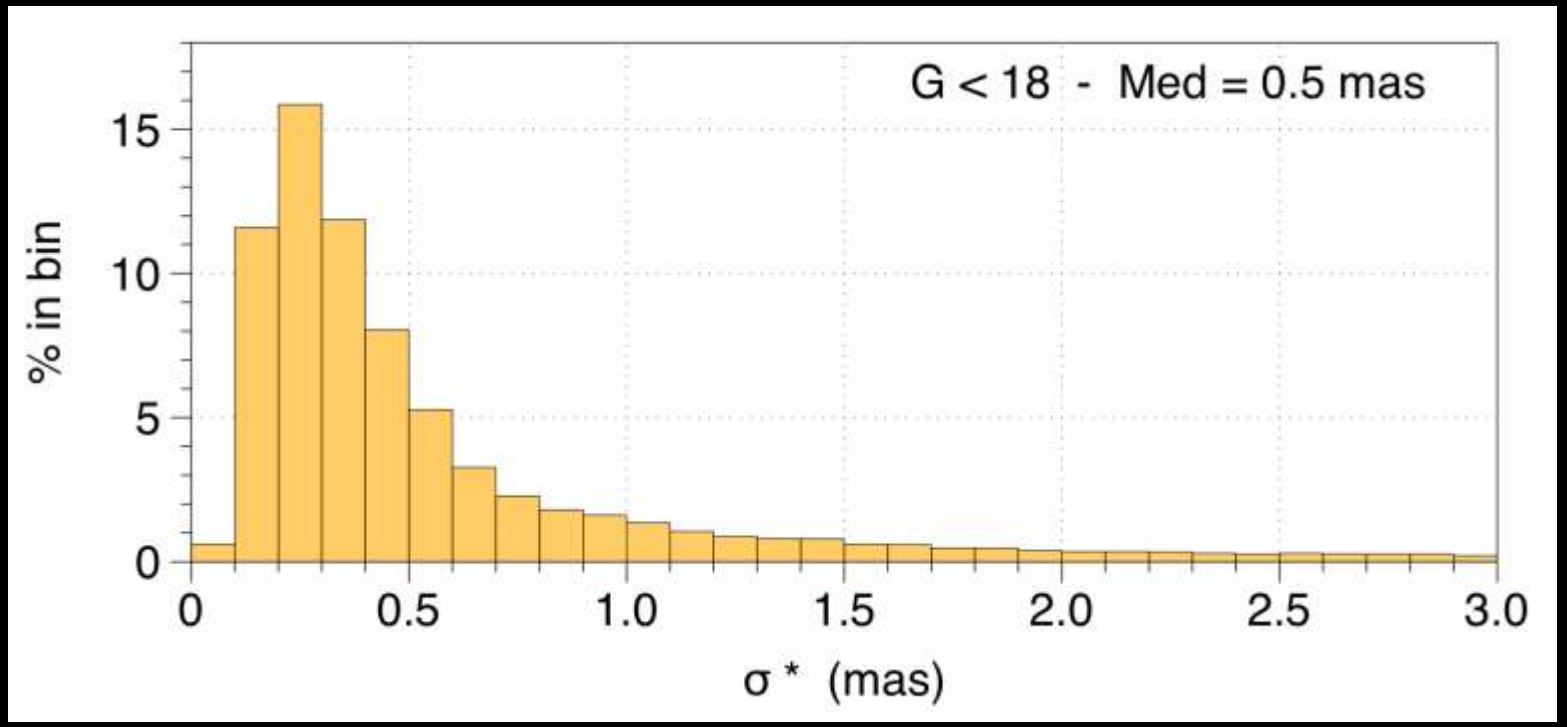
The Gaia sky achievement

- DR1 solution for AllWISE AGNs
  - 570,000 AGNS,
  - Pre- Gaia deep sky to ~150 mas



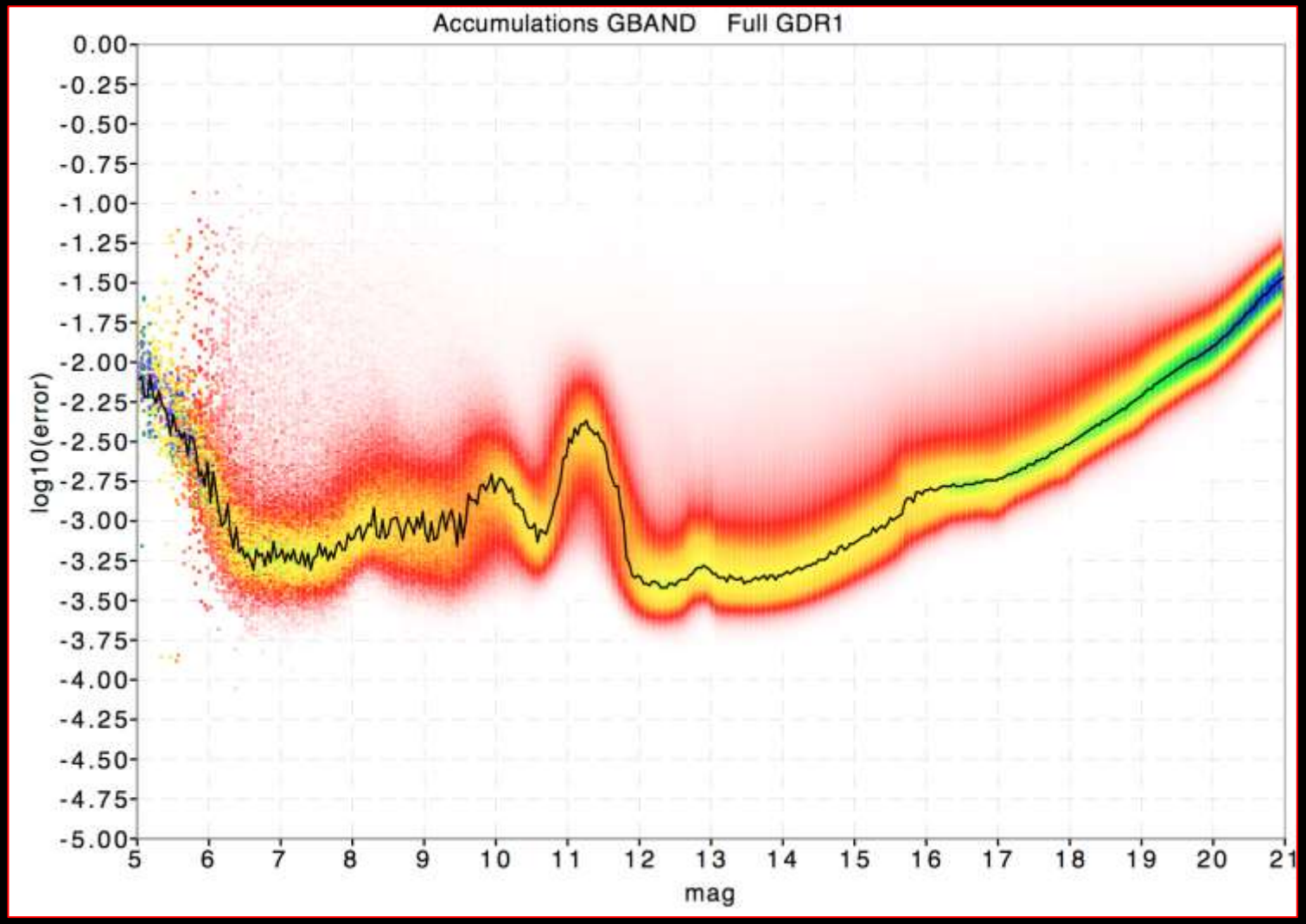
The Gaia sky achievement

- DR1 solution for AllWise AGNs
  - $G < 20$ & $G < 18$
  - Gaia formal uncertainty
  - access to the optical frame with > 1 source/deg^2 at sub-mas level axis of error ellipse)



Photometric accuracy

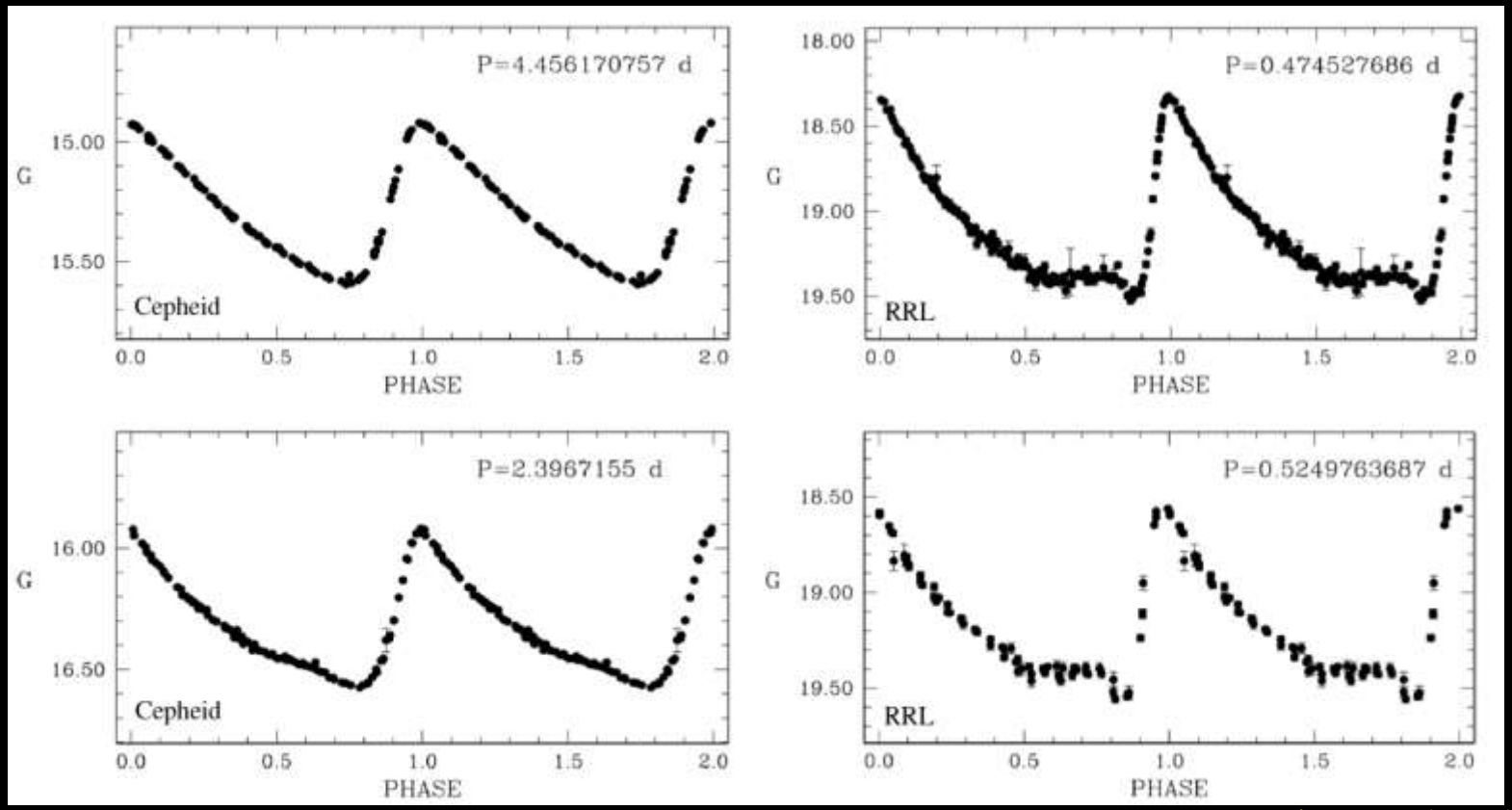
- Accuracy based on 14 months of data in G - σ_G ~ 0.003 mag



Credit : F. van Leeuwen et al., 2016

DR1 Content in variable stars

- Light curves for ~ 3200 étoiles
  - 2600 RR Lyr (343 new) , 600 Cepheids (43 new)
  - Most are found in the LMC (during the EPSL)
  - Accuracy of individual measurement ~ 0.003 -0.01 mag



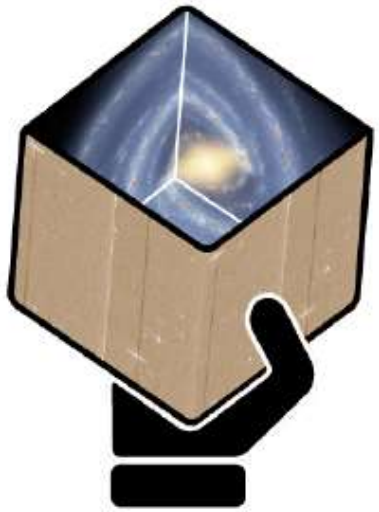
credit : ESA/Gaia/DPAC

April 2018

Gaia DR2





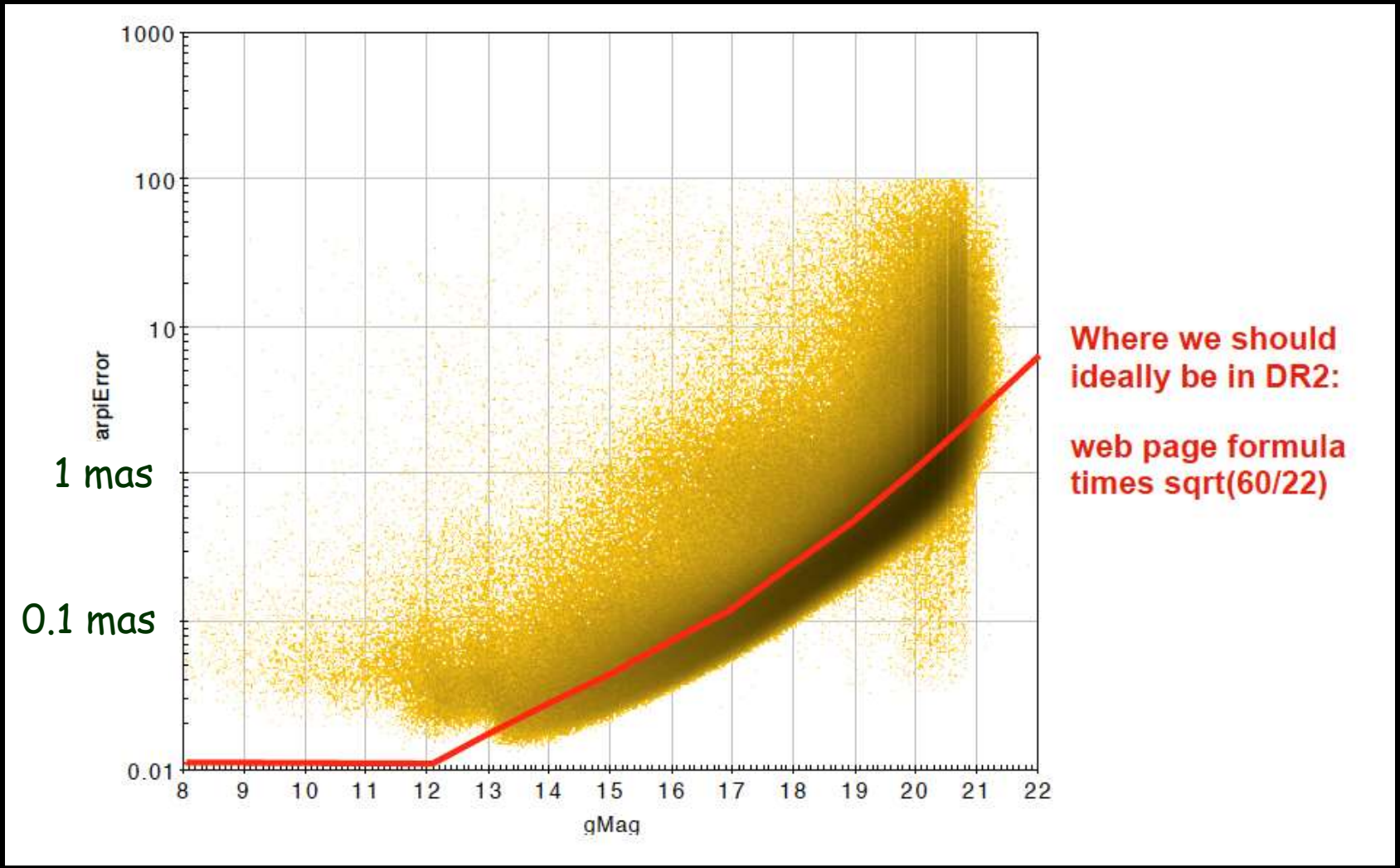


DR2 Schedule and Content

- DR2 scheduled in April 2018
  - 22 months of data – (July 14 to May 16)
- Content
  - Astrometry with parallaxes & PM for > 1 B sources
  - Position catalogue for 500 M more
  - Reference frame with 500,000 QSOs with sub-mas accuracy
  - Broad band photometry G, G_{BP}, G_{RP} externally calibrated
  - Radial Velocity for $G < 12$ for stable sources ~ 3M sources
  - Stellar variability with light-curves for > 10^5 sources
  - Solar system astrometry at the mas level for ~ 12,000 objects
  - Early stellar Atmospheric Parameters (T_{eff}, A_V for $G < 17$)

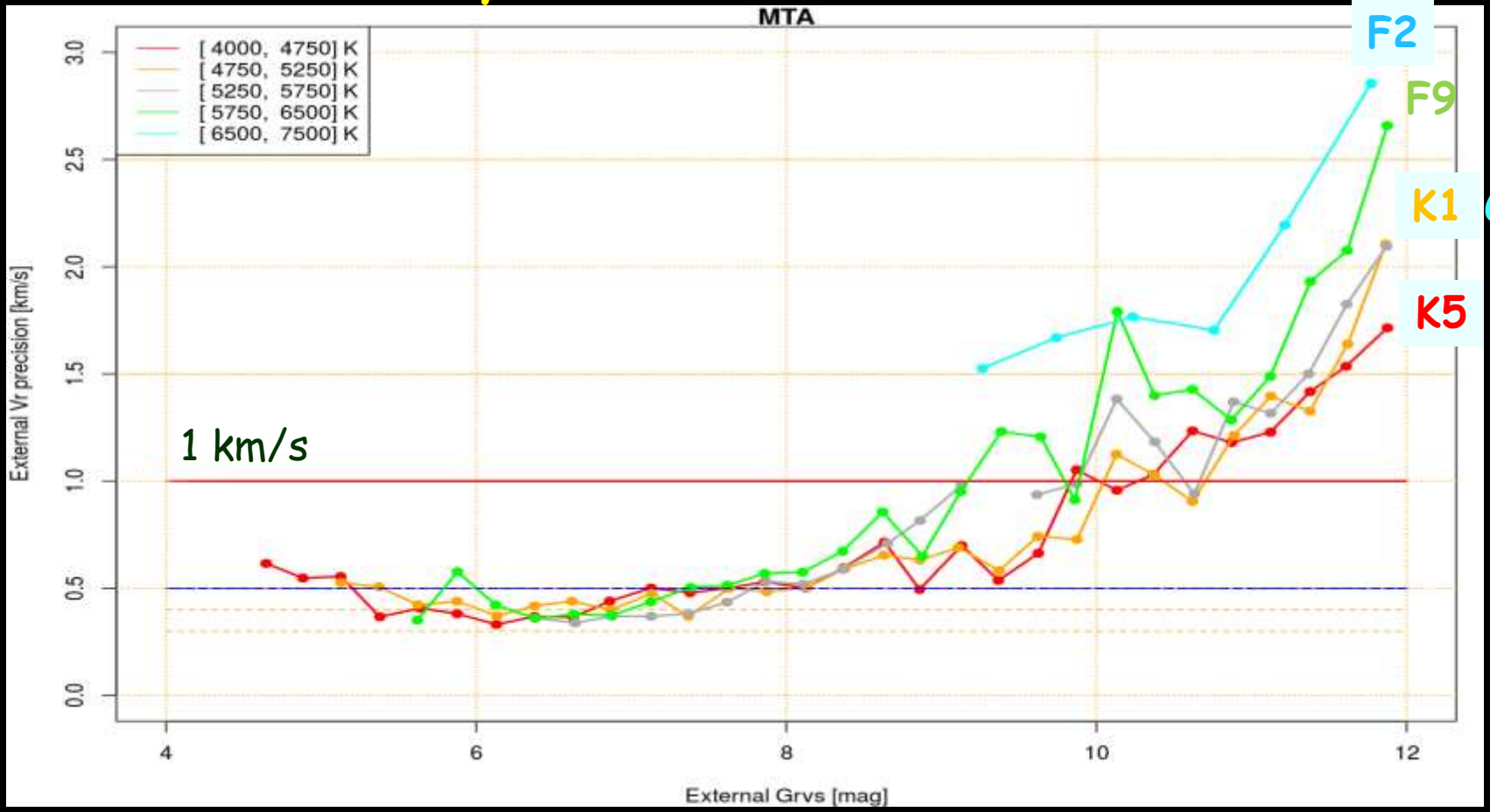
AGIS-02

- First indication of quality : Formal error in parallax
  - systematics below 0.1 mas



Credit: AGIS team

Accuracy of the radial velocities



Bright *G-K* stars:

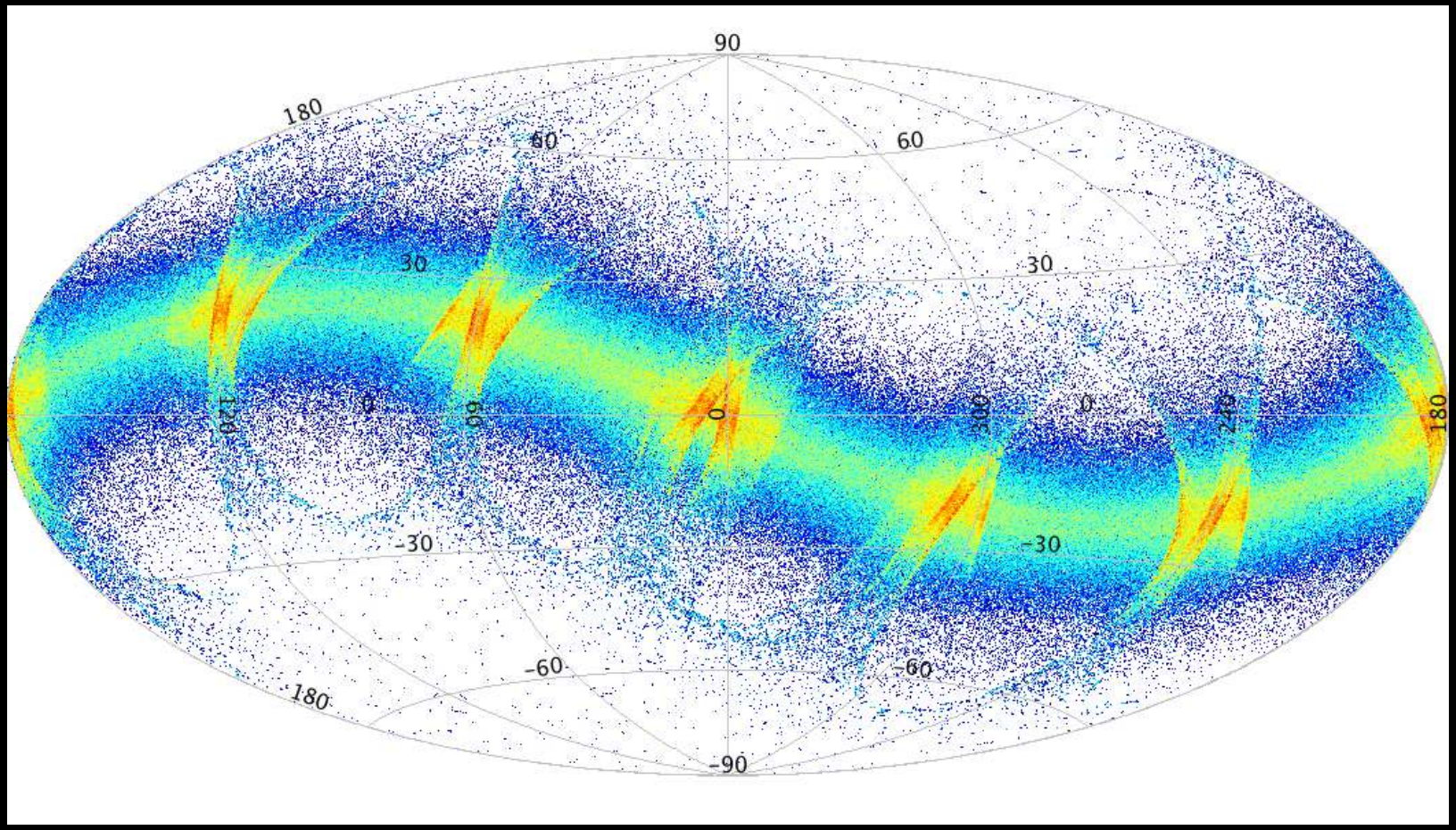
- **σVr ~ 400 m/s**
- Pre-launch specification was 1 km/s
- Close to current calibration floor

Faint end:

- K5 : σVr ~ **1.7** km/s
- *G5* : σVr ~ **2.1** km/s
- F9 : σVr ~ **2.7** km/s
- Will improve with number of transits

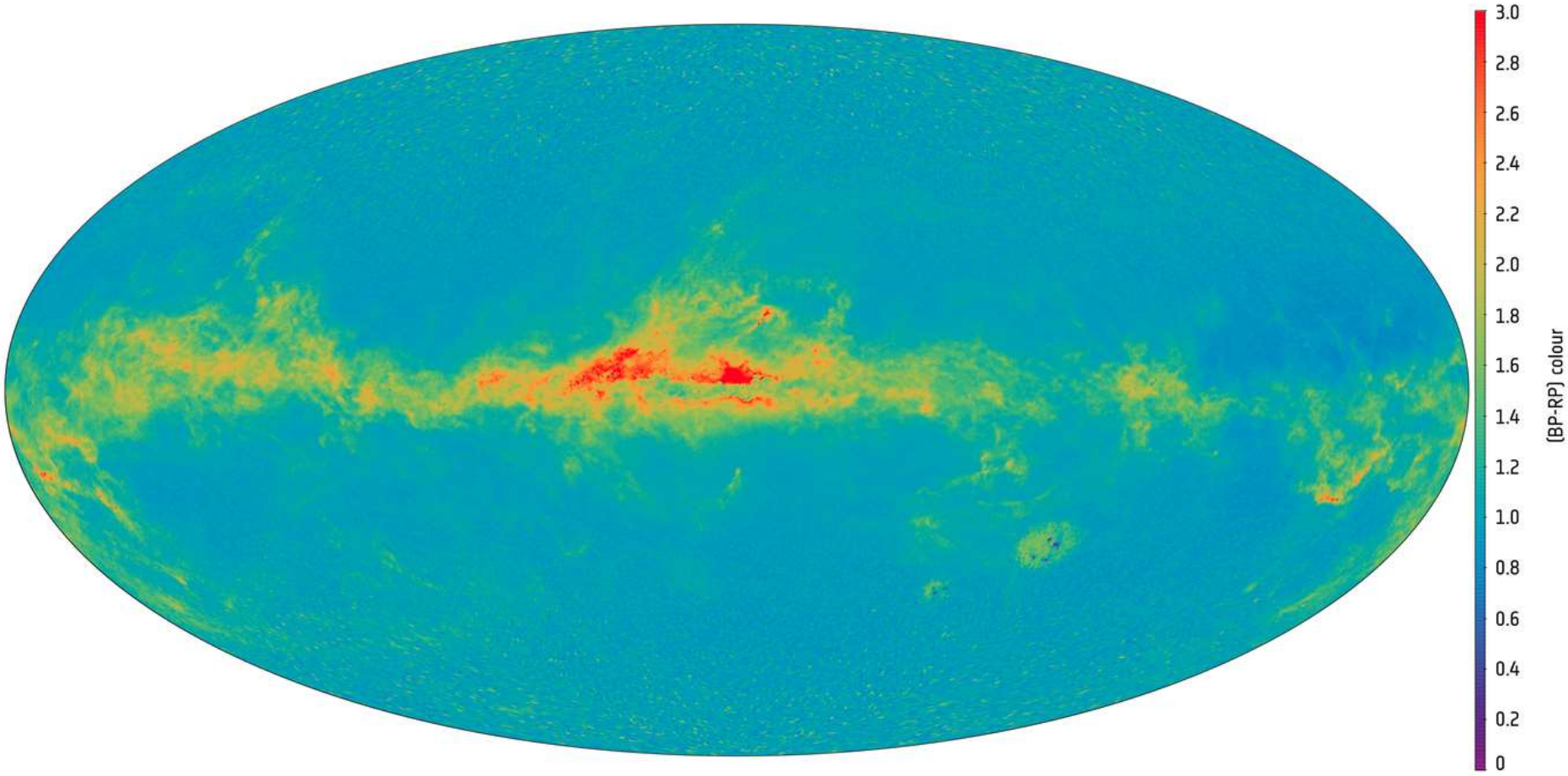
Where are the asteroids seen with Gaia ?

- ~ 13,000 planets will be in the DR2
- 300,000 passages over 22 months



The whole sky 'in color'

Each pixel coloured with the mean colour of the stars



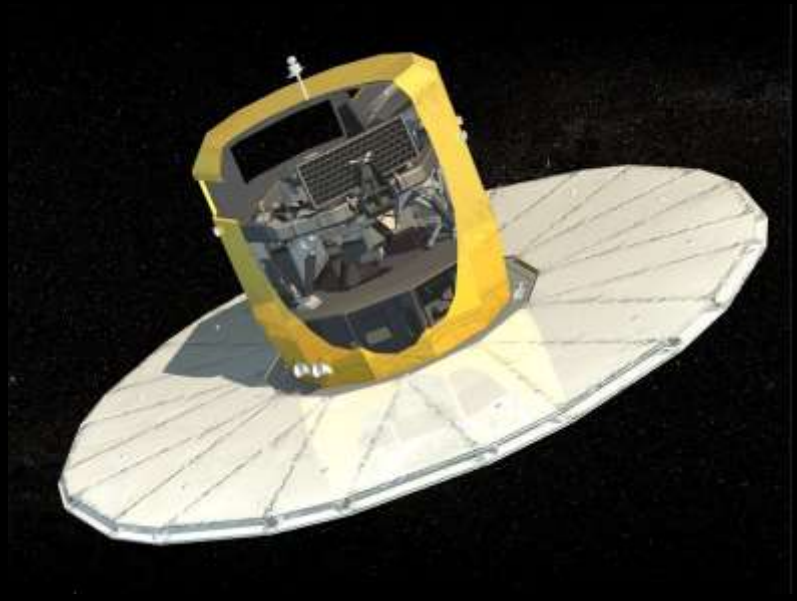
crédit : Gaia/ESA/DPAC

How the mission continues

- DR3 in mid 2020 – DR4 late 2022
- Nominal observation mission to June 2019
  - 5 years of continuous measurements (180 B detections)
  - 2 to 3 more years of processing
- But Gaia could work few more years
  - until 2023-24 in principle
  - an extended mission is under study
  - will be decided by ESA next year



Thanks for your attention



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gaia