Gaia:Review, Status & News

José Hernández

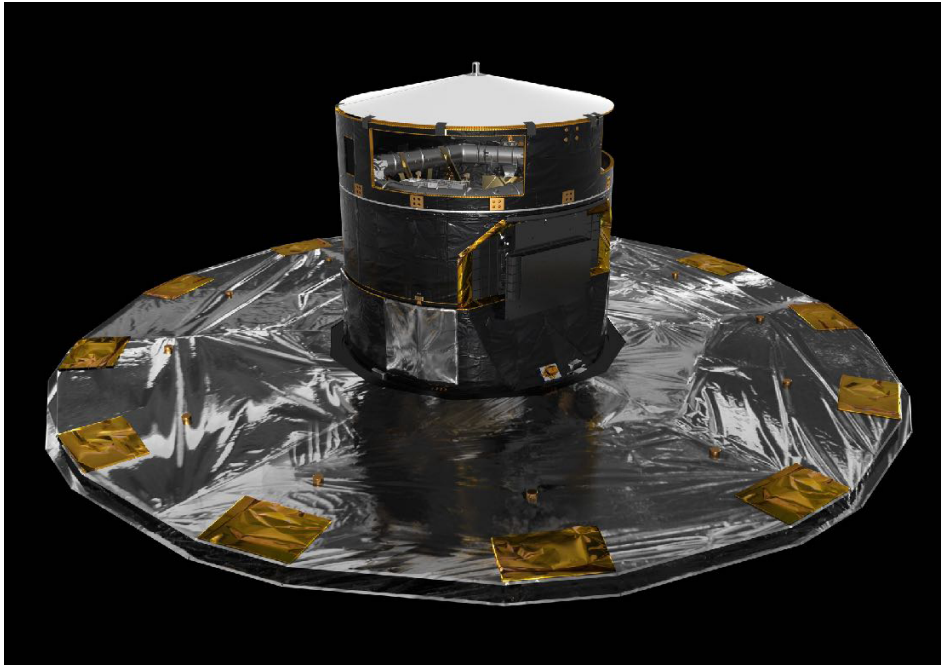
SFM, El Escorial, June 16, 2017

Outline

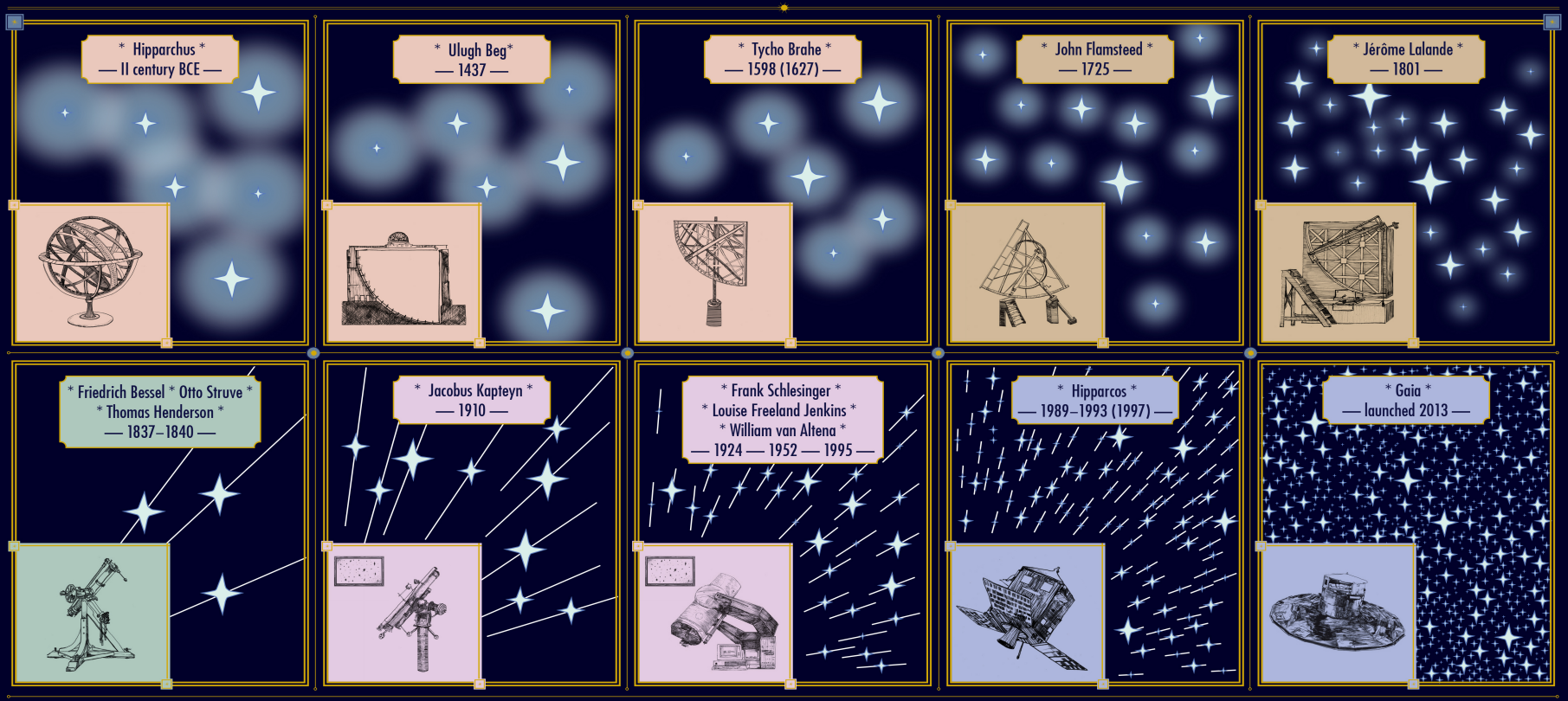
- Gaia, mission concept, operations, status
- Gaia DR1
- Plans for Gaia DR2
- Questions and Answers
- Thanks to Anthony Brown, Timo Prusti & Lennart Lindegren
- IAUS 330: Astrometry and Astrophysics in the Gaia Sky

Gaia Summary

- ESA cornerstone mission building on the Hipparcos heritage
- Astrometry, Photometry and Spectroscopy
- Satellite, including the payload, by industry (Airbus DS), management and operations by ESA and data processing by scientists (DPAC)
- Launch 19 December 2013 with Soyuz from Kourou
- 5 years of operations in L2
- Gaia DR1 14 September 2016
- Science Alerts started 2014
- Gaia DR2 April-2018



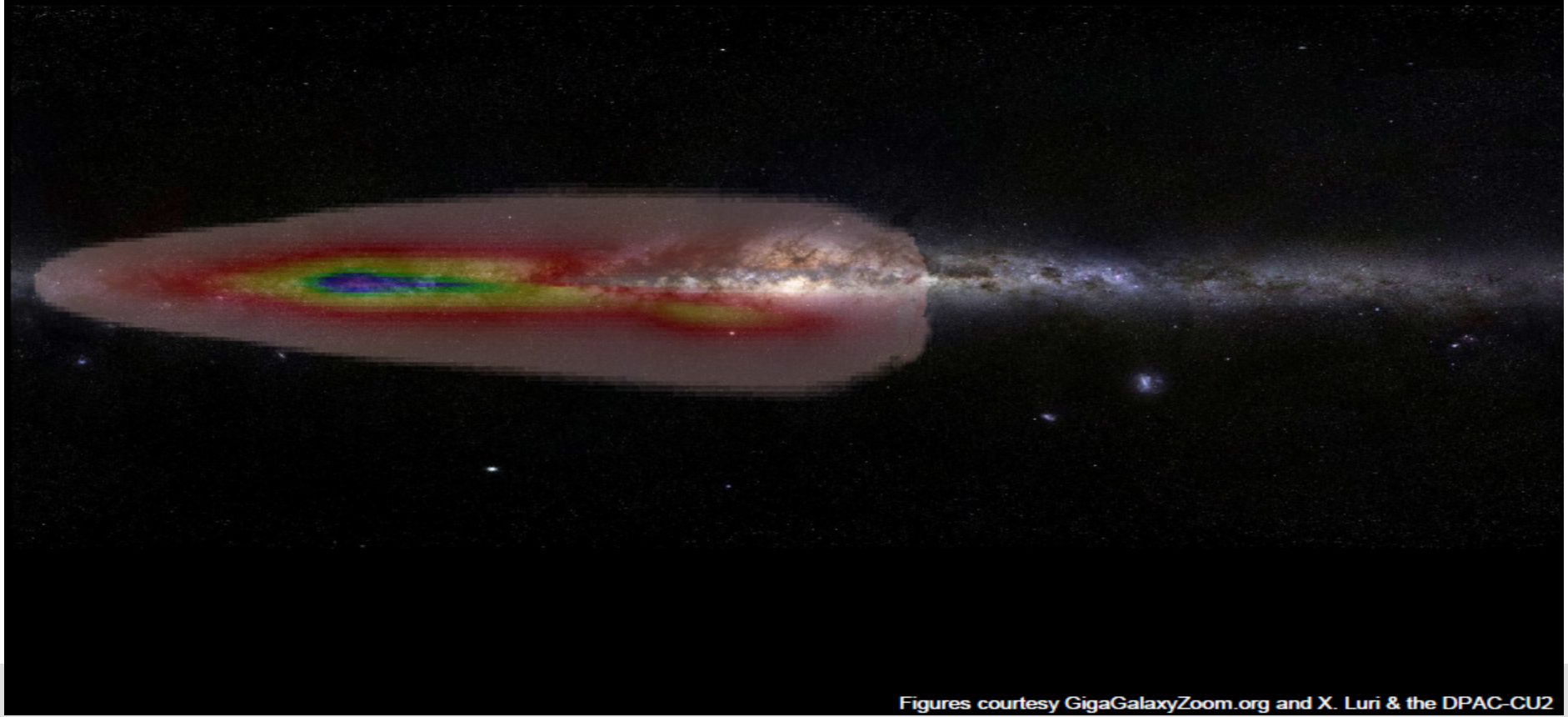
→ ASTROMETRY THROUGH THE AGES



The required reach of Gaia

Figures courtesy GigaGalaxyZoom.org and X. Luri & the DPAC-CU2

The required reach of Gaia



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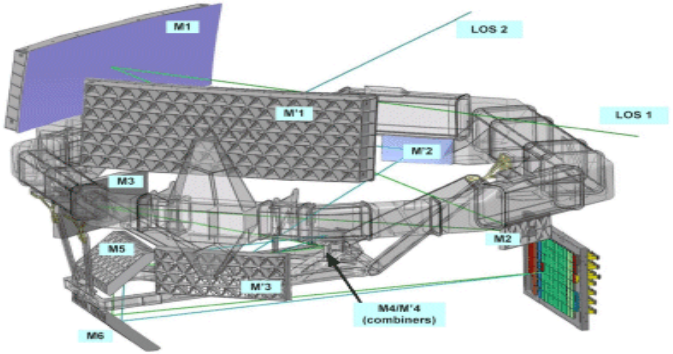
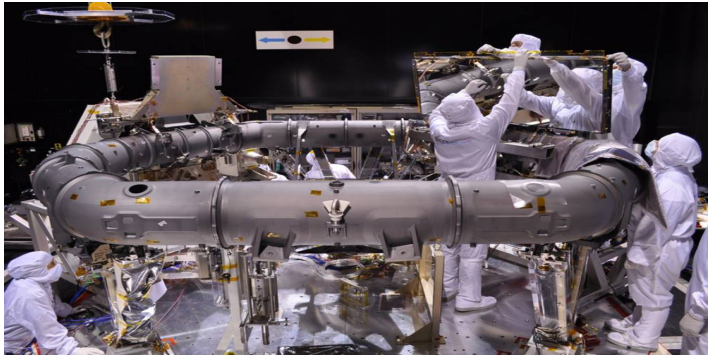
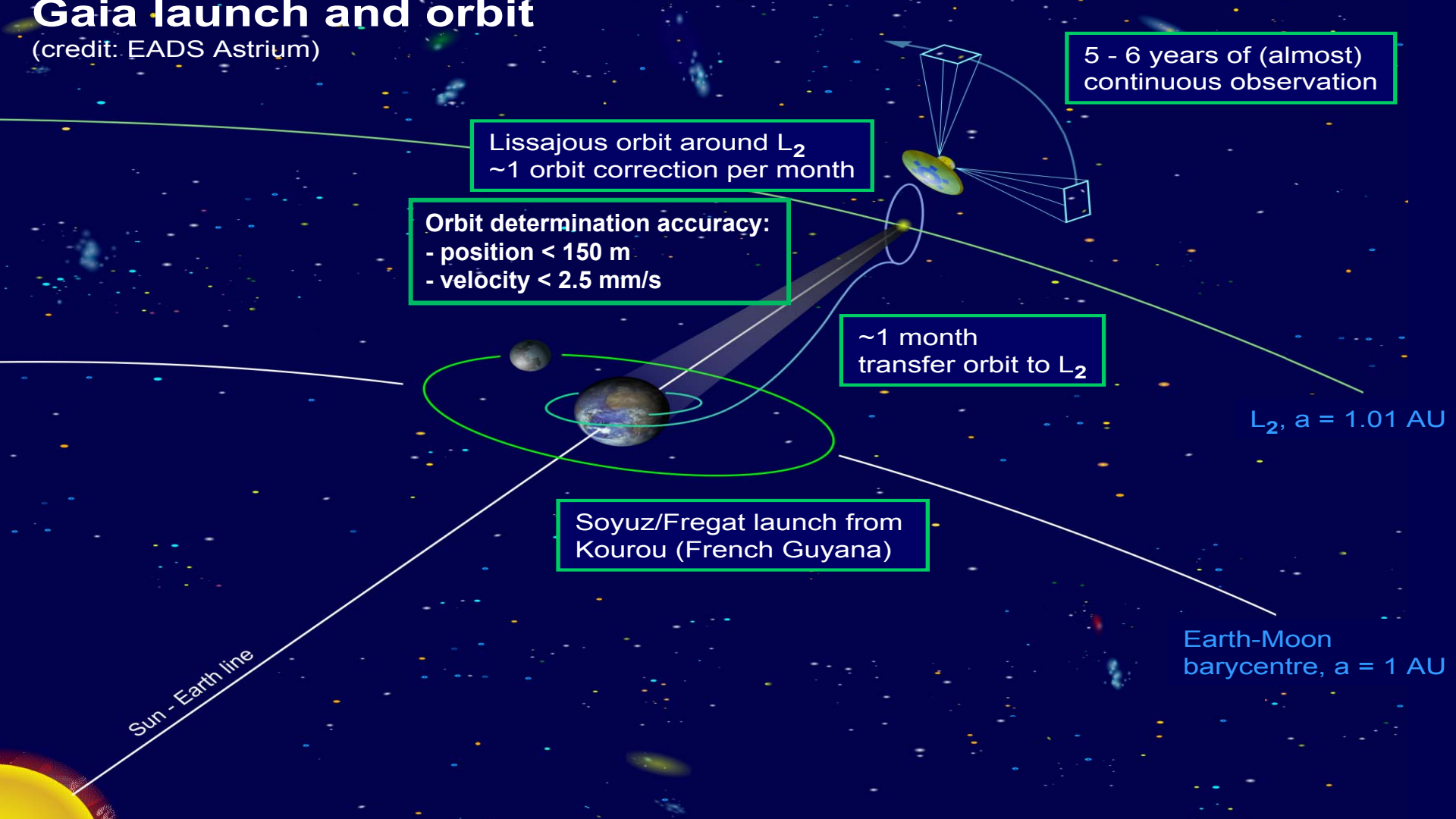




- How you can measure micro-arcsec:
  - Very stable thermal environment
  - New materials
  - Very Large Focal plane
  - Ultra-precise atomic clock
  - 80 observations of every source during 5 years
  - Very complex Data Processing, self calibration

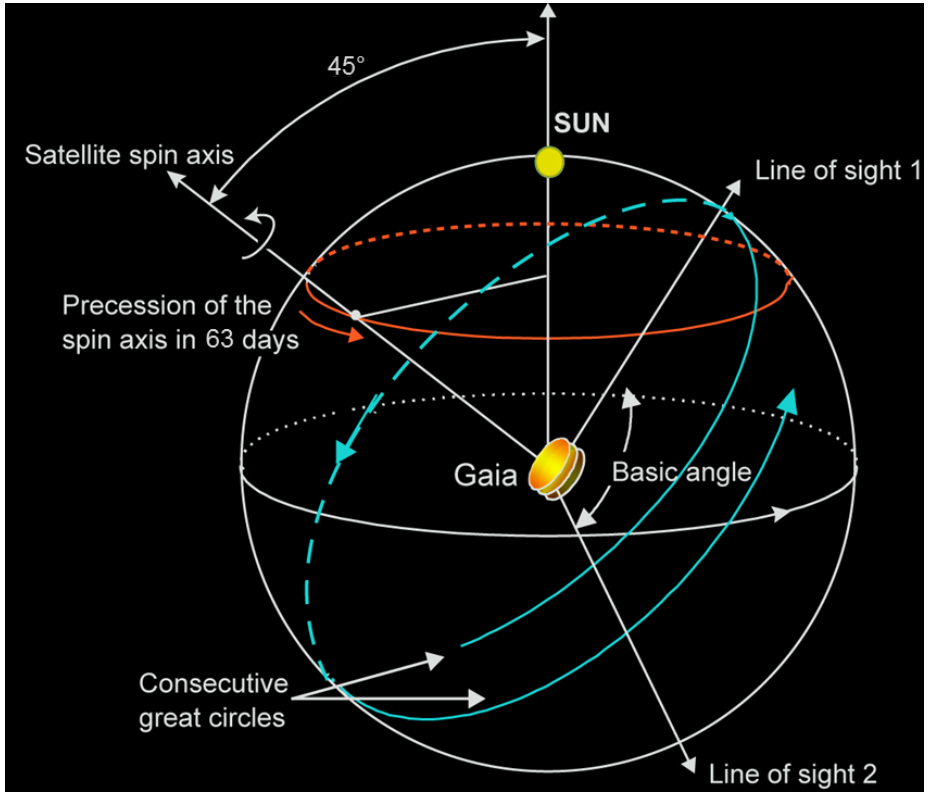
Gaia launch and orbit

(credit: EADS Astrium)



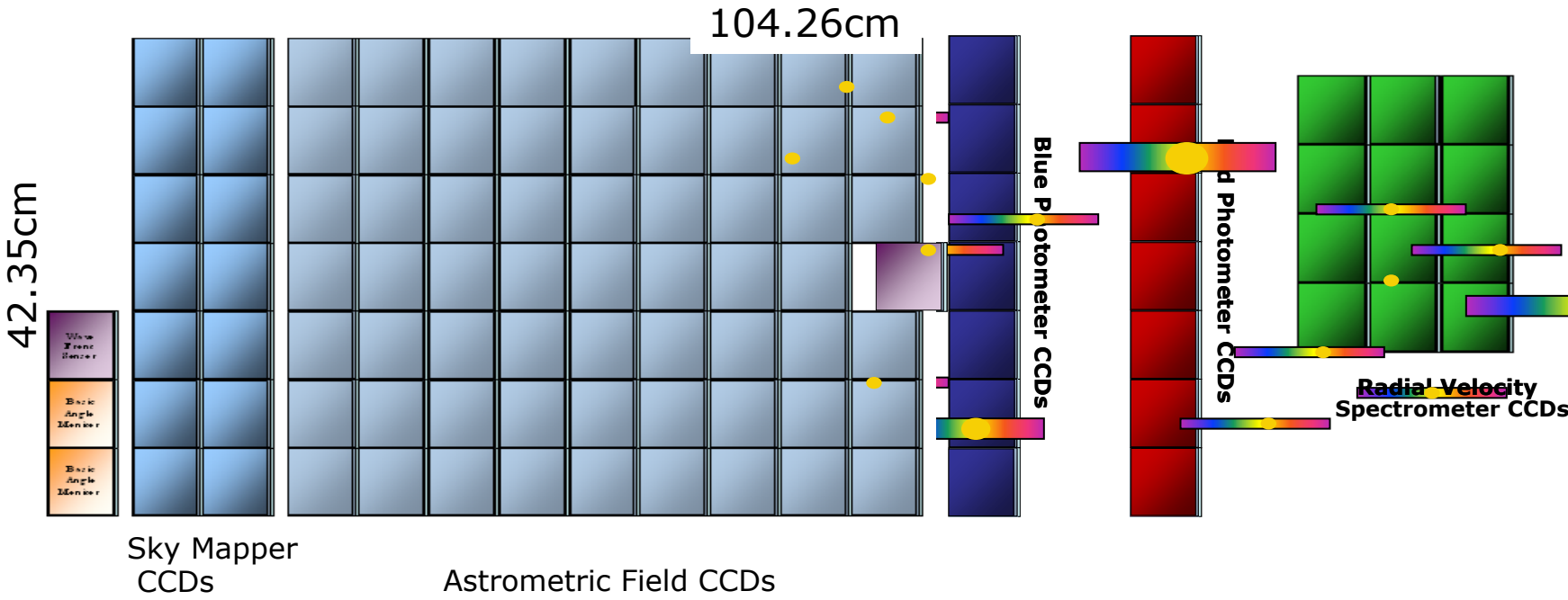
Gaia Operations

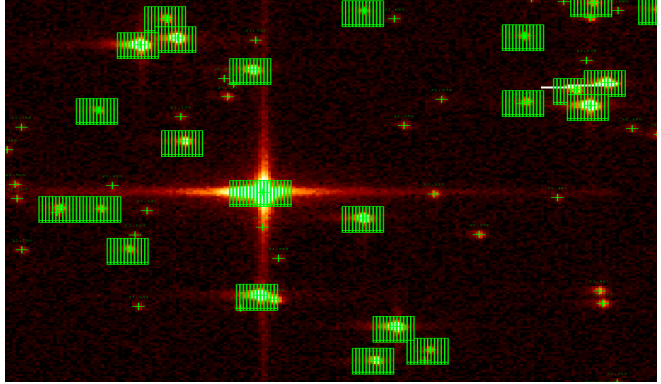
- Gaia in routine operations since July 2014
- 1,000 days routine phase reached 20 April
- Operations: nominal
- 76 billion transits observed
- Nominal 5-year mission ends mid-2019
- Estimated end of mission due to cold gas exhaustion end-2023 (±1year)
- Mission extension process started

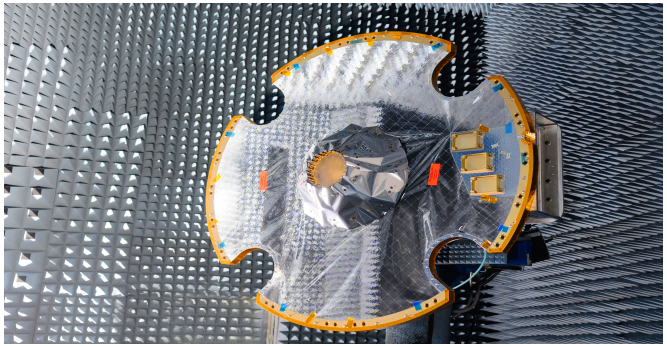


One GigaPixel Focal Plane

106 CCDs , 938 million pixels, 2800 cm²



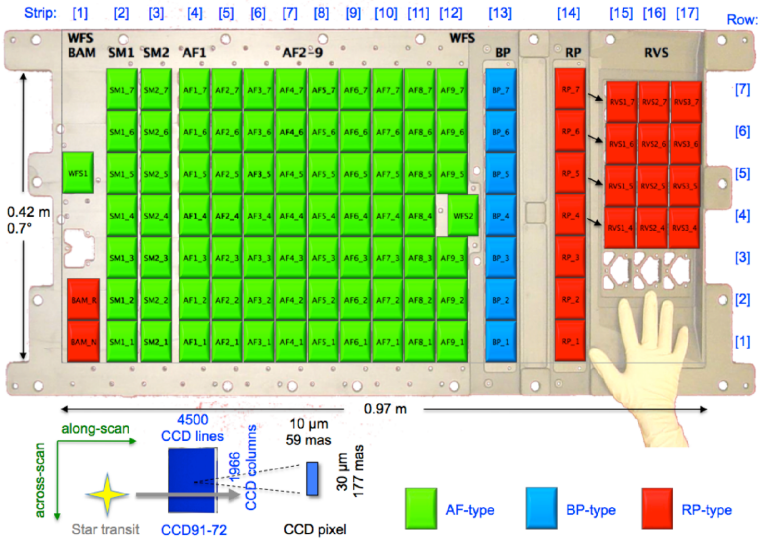




- Not all the CCD data gets read and sent to Earth
- On board Video Processing Units read the windows around the detected stars
- Data is binned and stored compressed on board
- Data sent to Earth during the night (~50 Gb/day, 100Tb in 5 years)
- Three ESA DSN antenas used:
  - New Norcia
  - Cebreros
  - Malargüe
- Time shared with other missions

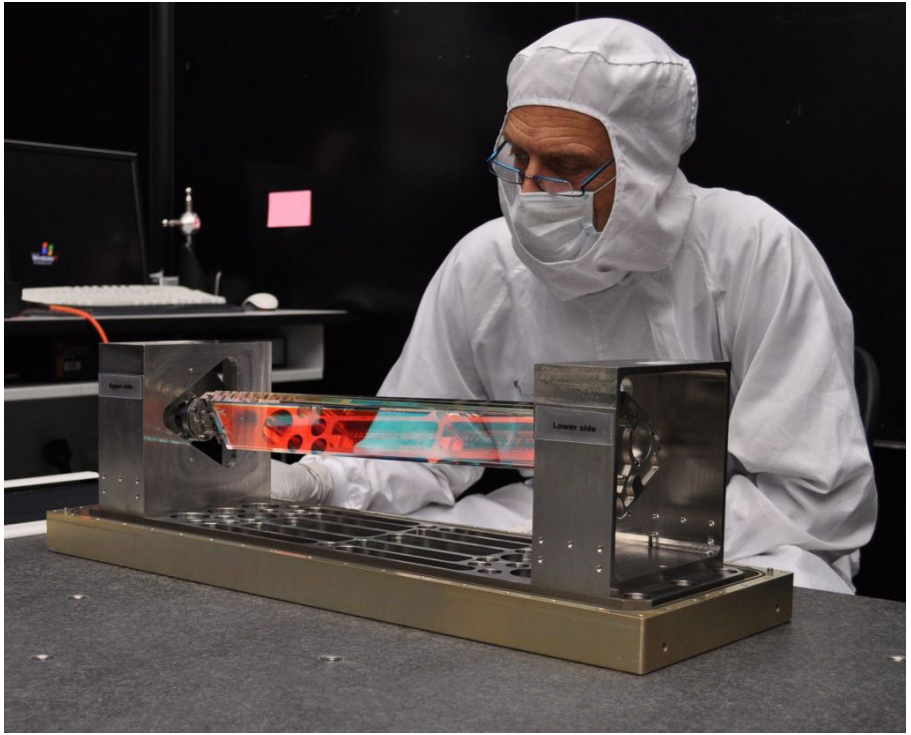
Astrometric Measurements

- Astrometric measurements: 761billion G<20.7 mag
- Bright limit around G=2-3 mag
- All bright stars covered with special measurements
- Selected crowded regions imaged with Gaia Sky Mapper



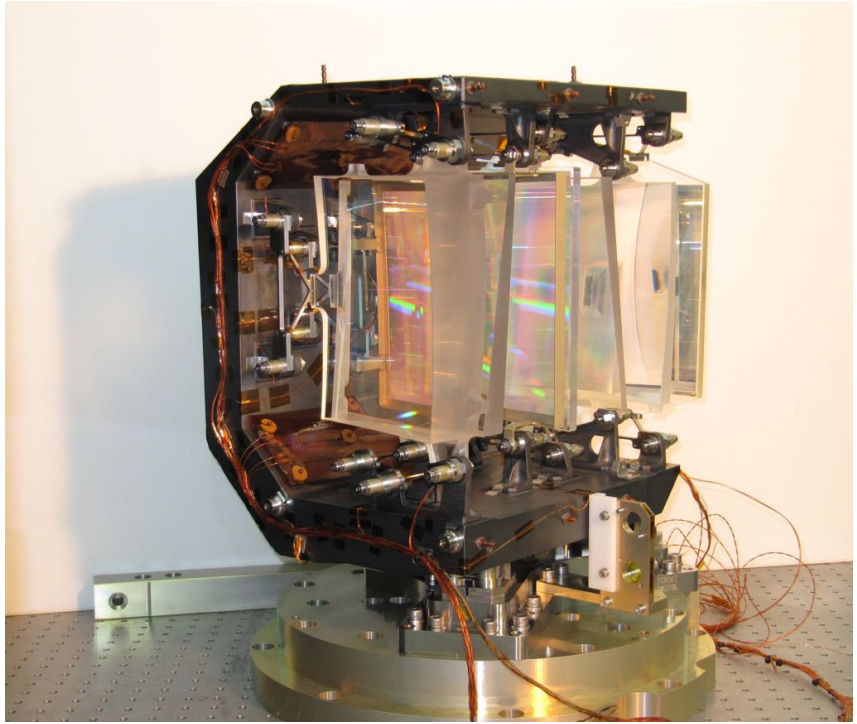
Gaia Photometry

- Photometric measurements: 156 billion G<20.7 mag
  - Spectrophotometry
    - 330-680 nm BP
    - 640-1050 nm RP
  - Can also integrate BP and RP to get high precision measurements and a colour
- Astrometric measurements also photometric in G-band



Gaia Spectroscopy

- Spectroscopic measurements: 13.7 billion
- GRVS<16.2 mag
- 845-872 nm with R about 10,800
- Radial Velocity Spectrometer for >100 million radial velocities
- Spectroscopy till about GRVS=11-14 mag

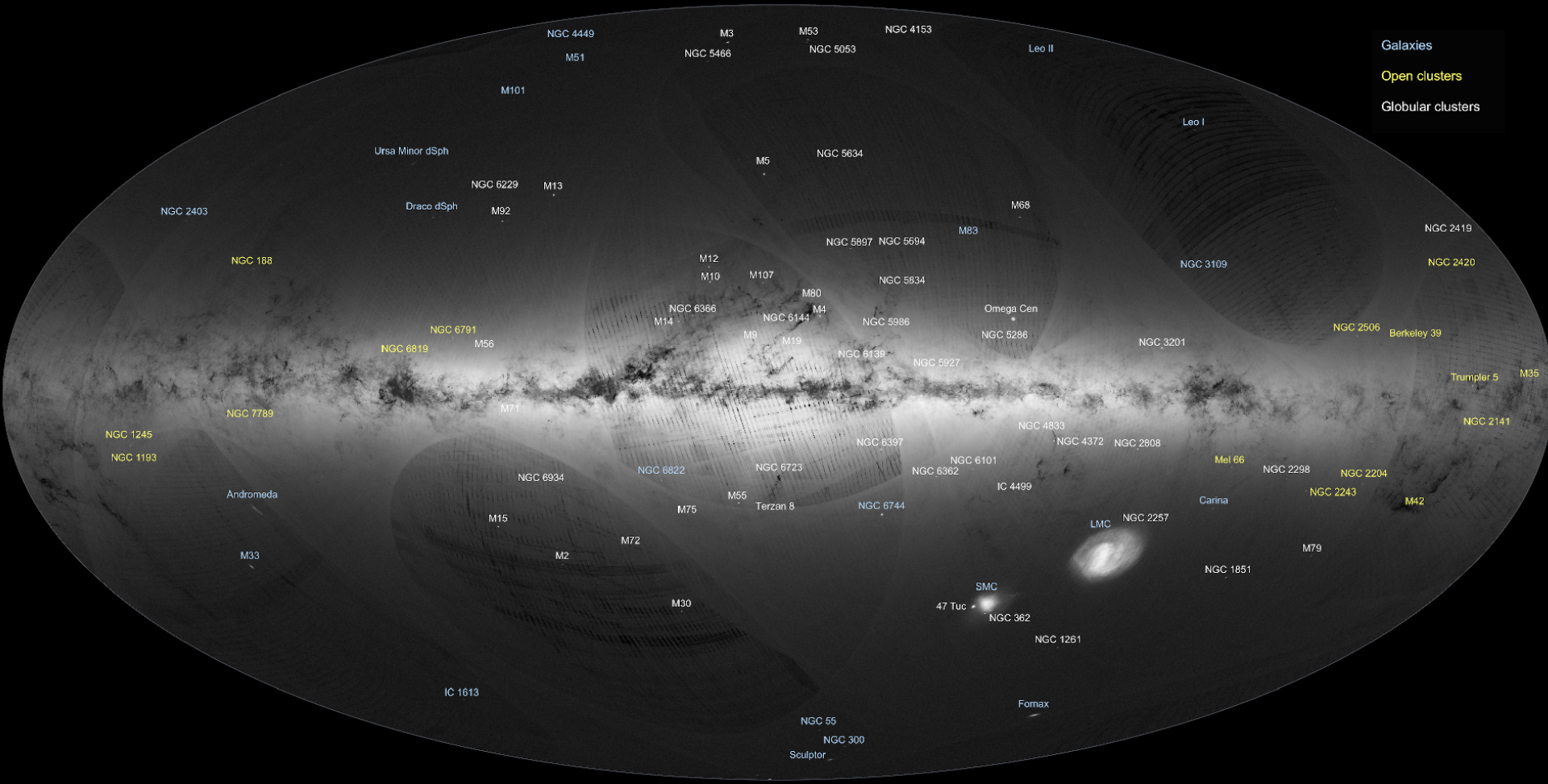


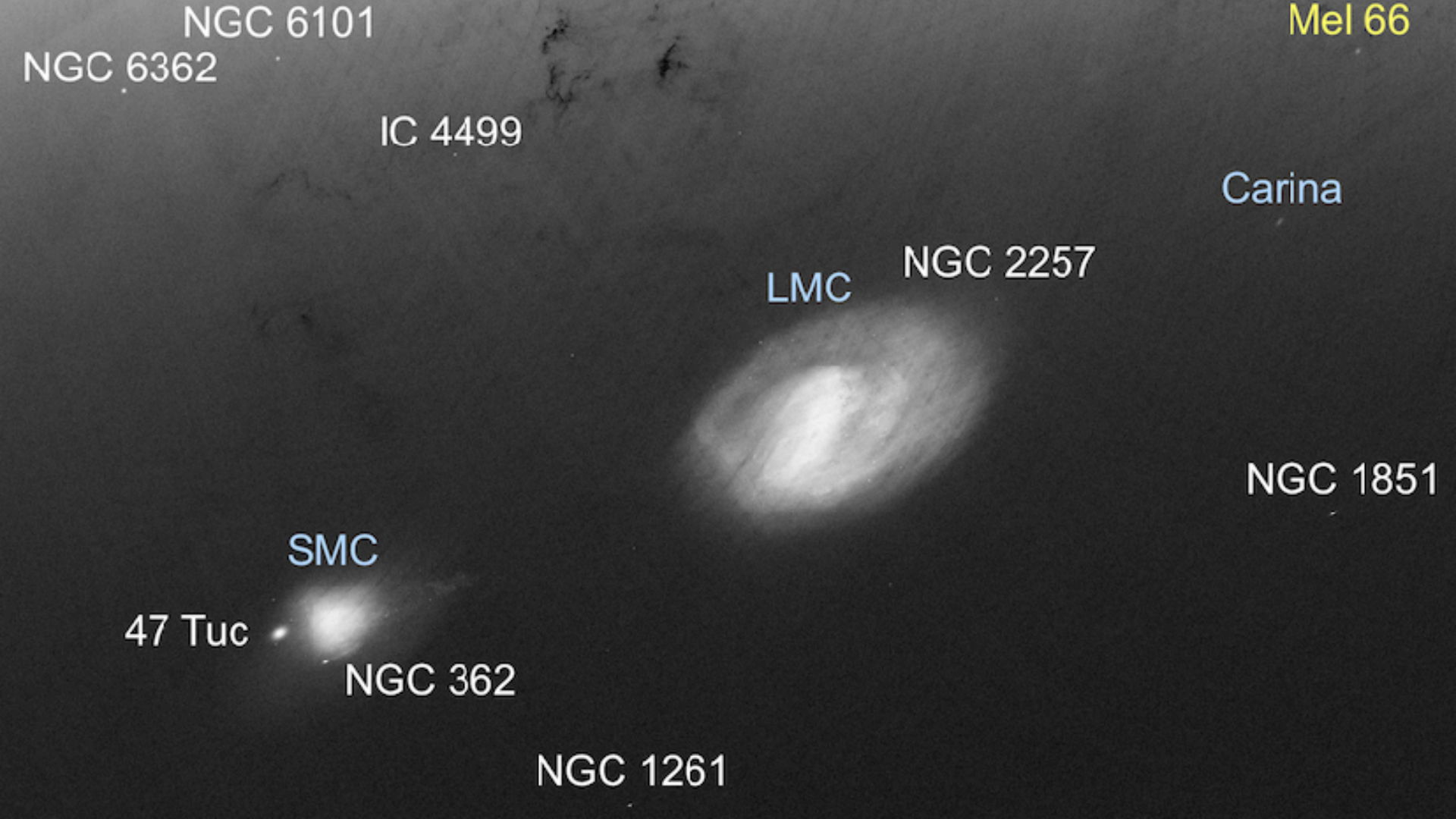
Unwanted features

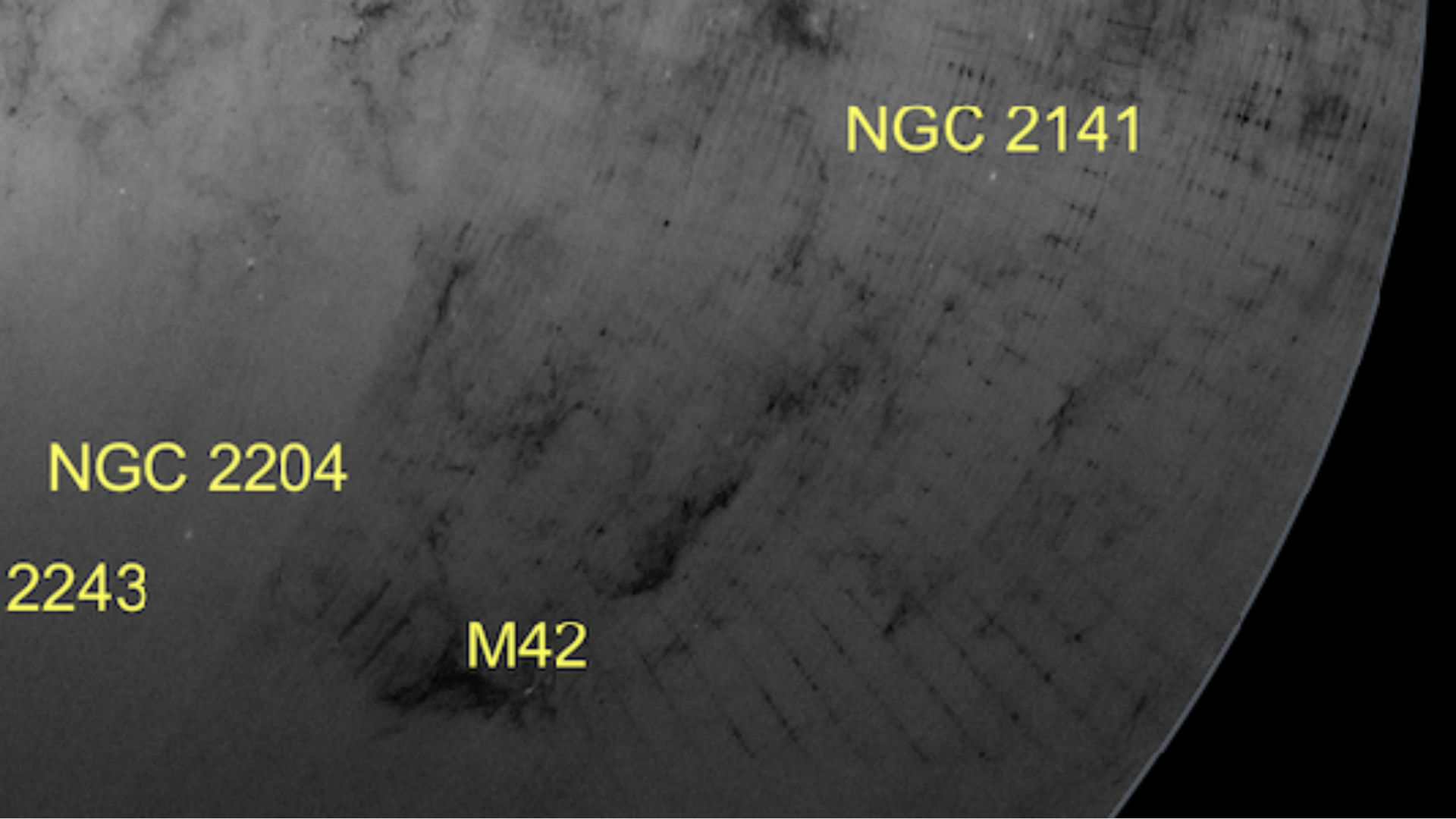
- Contamination
  - Last decontamination in August 2016; no sign of transmission loss yet
- Micro-clanks and micrometeoroids
  - Taken into account in data processing for Gaia DR2
- Basic Angle Variation
  - Corrected with Basic Angle Monitor data for Gaia DR1 and DR2; more sophisticated analysis planned for the future
- Stray light
  - Impact on faint sources; on-board software modified from read-out dominated to background dominated case for faint objects
- Radiation damage
  - First signs visible, but less than anticipated before launch; pre-launch calibration work will become relevant in the future

Gaia DR1

Credits: ESA/Gaia/DPAC
Image acknowledgement: Moitinho & Barros
Video acknowledgement: de Bruijne

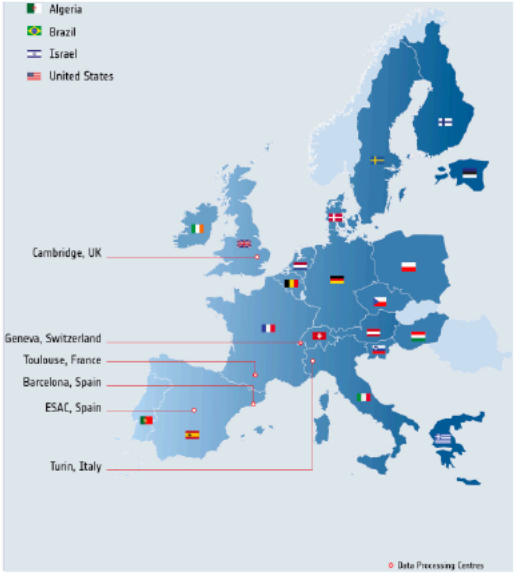

Galaxies
Open clusters
Globular clusters
NGC 4449
M3
M53
NGC 4153
M51
NGC 5466
NGC 5053
Leo II
M101
Leo I
Ursa Minor dSph
M5
NGC 5634
NGC 6229
M13
NGC 2403
Draco dSph
M92
M68
M83
NGC 2419
NGC 5897
NGC 5694
NGC 188
M12
NGC 3109
NGC 2420
M10
M107
NGC 5834
M80
NGC 6366
M4
Omega Cen
M14
NGC 6144
NGC 5986
NGC 6791
M9
NGC 5286
NGC 2506
Berkeley 39
NGC 6819
M56
M19
NGC 3201
NGC 6139
NGC 5927
Trumpler 5
M35
NGC 7789
M71
NGC 2141
NGC 1245
NGC 4833
NGC 1193
NGC 6397
NGC 4372
NGC 2808
NGC 6101
Mel 66
NGC 6934
NGC 6822
NGC 6723
NGC 6362
NGC 2298
NGC 2204
Andromeda
IC 4499
NGC 2243
M55
Carina
M42
M75
Terzan 8
NGC 6744
M15
LMC
NGC 2257
M72
M79
M33
M2
NGC 1851
SMC
M30
47 Tuc
NGC 362
NGC 1261
IC 1613
Fornax
NGC 55
NGC 300
Sculptor


NGC 6101
Mel 66
NGC 6362
IC 4499
Carina
NGC 2257
LMC
NGC 1851
SMC
47 Tuc
NGC 362
NGC 1261


NGC 2141
NGC 2204
2243
M42

Teamwork to deliver the promise of Gaia

- 10+ years of effort
- 450 scientists and engineers
- 160 institutes
- 24 countries and ESA
- Six data processing centres



gaia

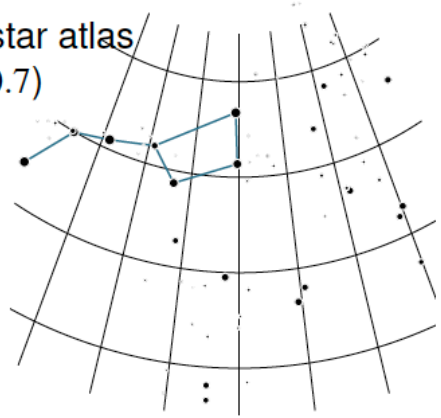
Gaia DPAC
Data Processing & Analysis Consortium

$\alpha \; \delta \; \varpi \; \mu_{\alpha*} \; \mu_\delta \; G \; \ldots$

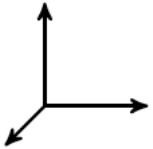
IAUS330 - 2017.04.24 - 2/22

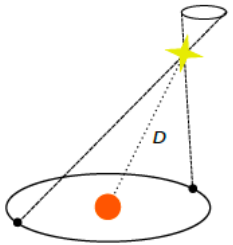
What's in the Gaia DR1 delivery

Billion star atlas
($G \lesssim 20.7$)

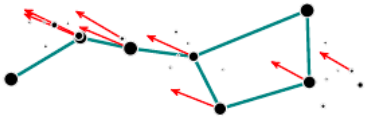


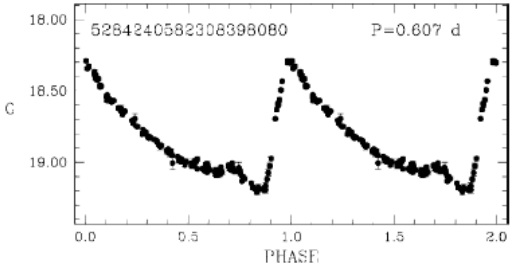
Positions and magnitudes
for ~ 2000 ICRF quasars





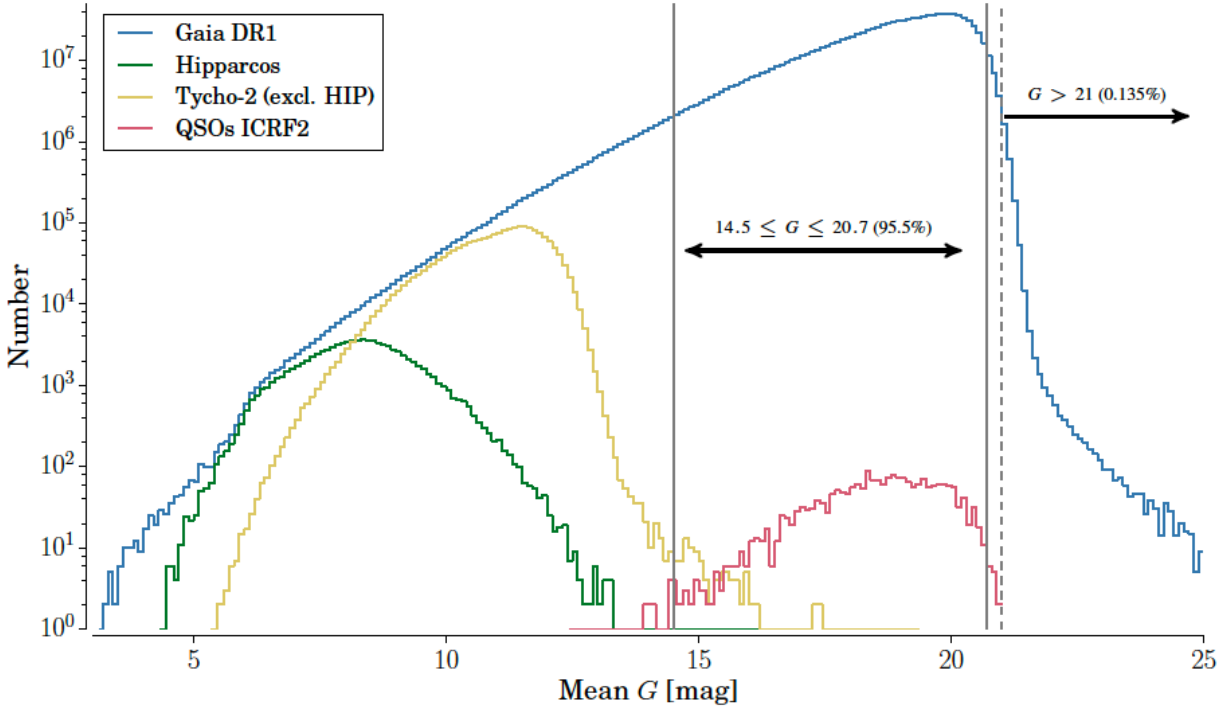
Tycho-Gaia
Astrometric Solution
(~ 2 million, $G \lesssim 12$)





Variable stars near
south ecliptic pole
(~ 600 Cepheids,
~ 2600 RR Lyrae)

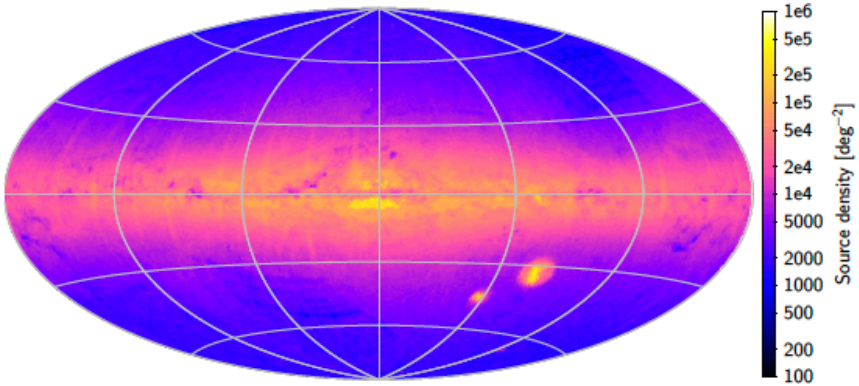
Gaia DR1 magnitude distribution



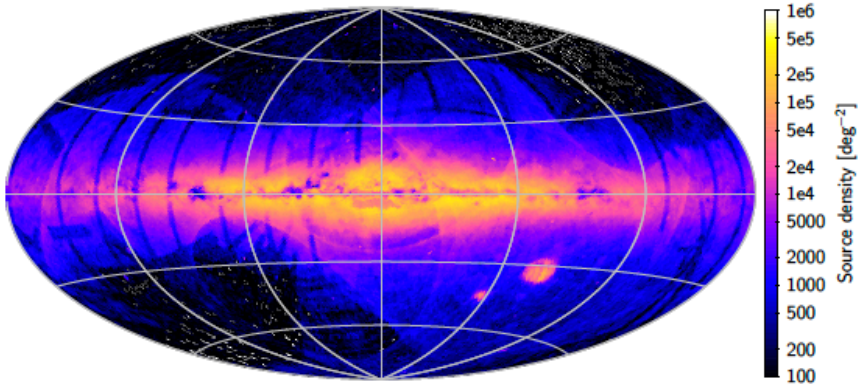
Gaia Collaboration, 2016, A&A

Highly precise positions, new sources

685 million sources matched to IGSL



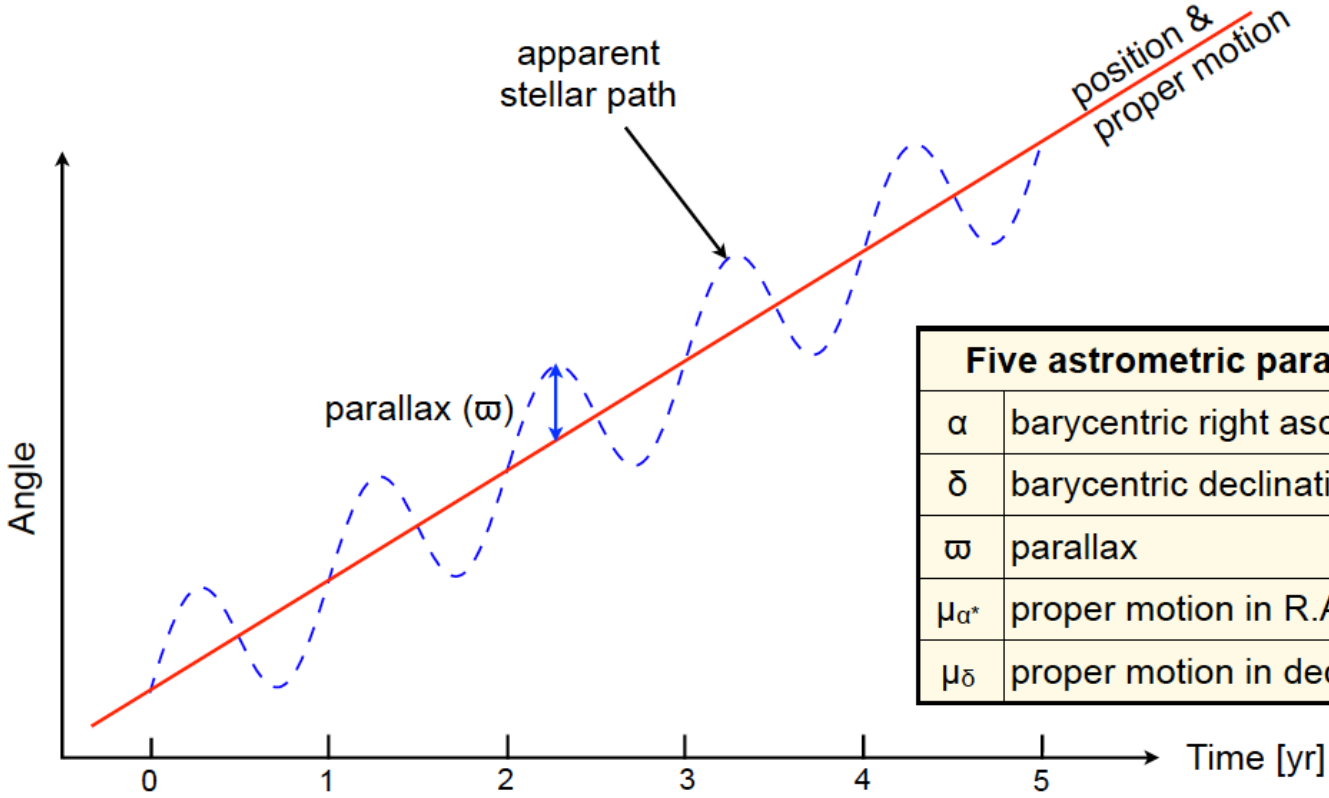
456 million new sources in Gaia DR1



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

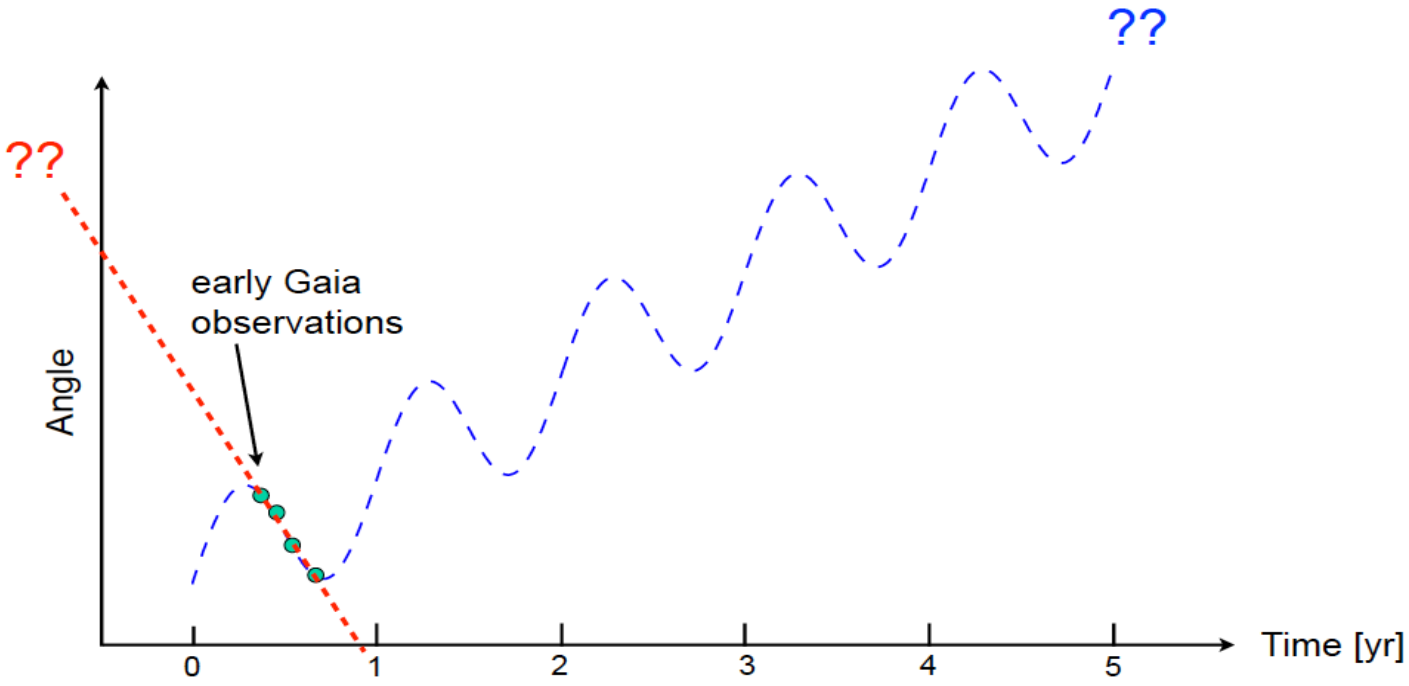
- (α, δ) for ~ 1.1 billion sources to $G = 20.7$
- Epoch J2015.0, alignment to ICRF < 0.1 mas, rotation < 0.03 mas yr^{-1}
- Typical position uncertainty ~ 10 mas
- Positions of 2191 ICRF sources from special astrometric solution (Mignard et al., 2016, A&A)
  - 90% with $\sigma_{\rm pos} < 3.35$ mas
  - no systematic differences with radio positions of more than few tenths of mas

Astrometric model for a single star



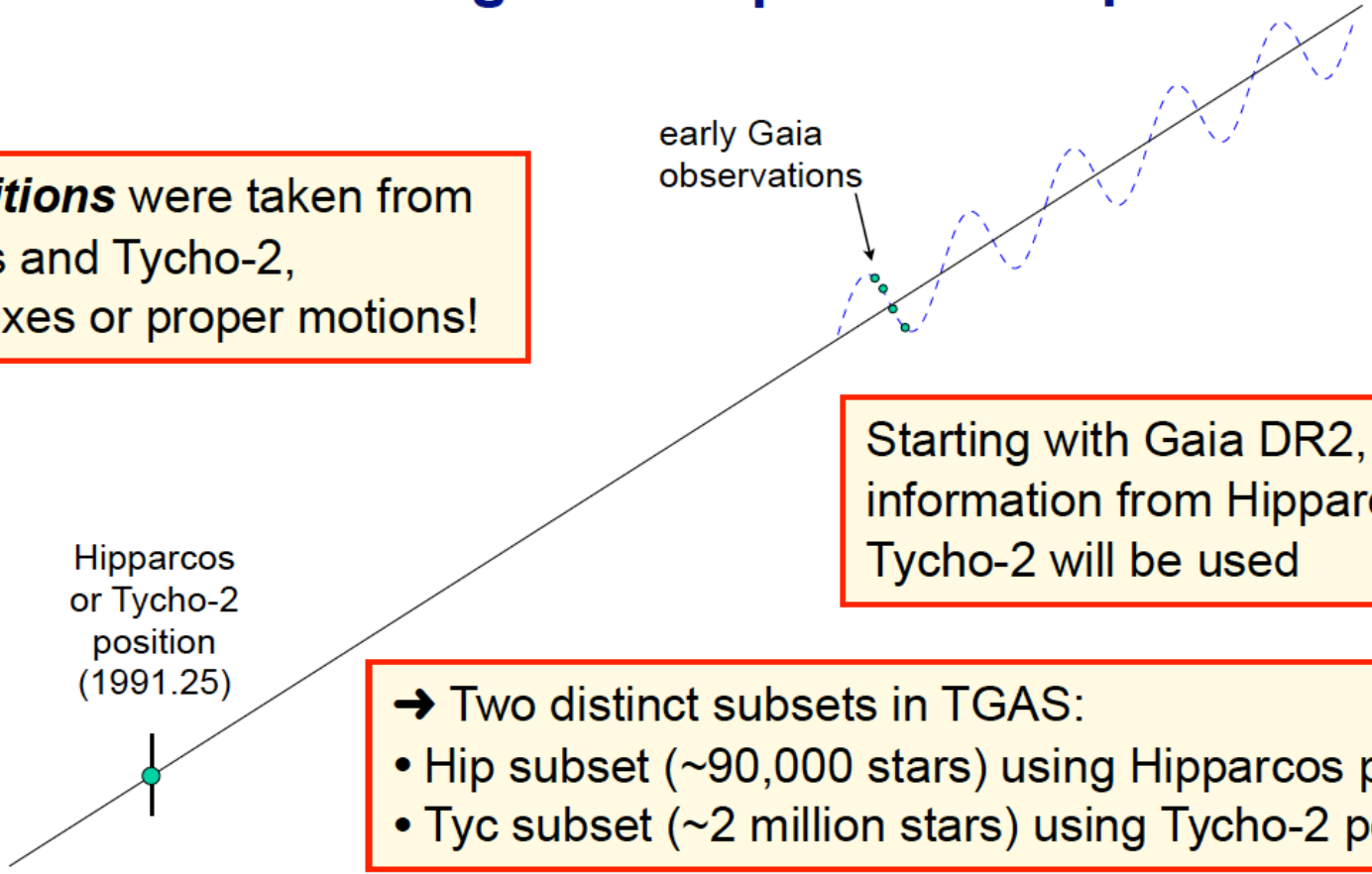
Five astrometric parameters per star	
α	barycentric right ascension at 2015.0
δ	barycentric declination at 2015.0
ϖ	parallax
μ_{α^*}	proper motion in R.A. (× cos δ)
μ_δ	proper motion in declination

Degeneracy for <1 yr of observations



TGAS: Using the old position as prior

Only ***positions*** were taken from Hipparcos and Tycho-2, no parallaxes or proper motions!



Starting with Gaia DR2, no prior information from Hipparcos and Tycho-2 will be used

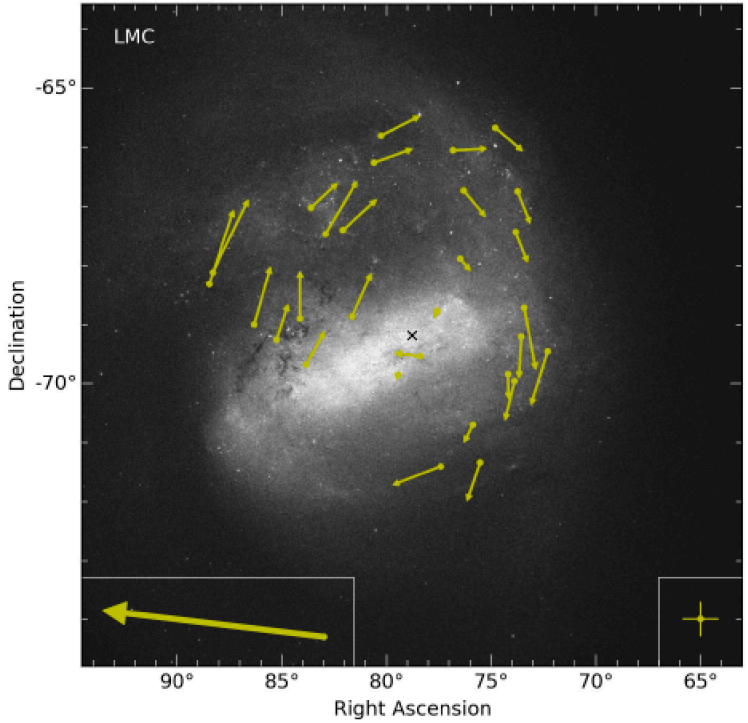
➜ Two distinct subsets in TGAS:

- Hip subset (~90,000 stars) using Hipparcos positions
- Tyc subset (~2 million stars) using Tycho-2 positions

About 100 papers using Gaia DR1 since 2016-09-14

- Parallax validation
  - No global offsets from Cepheids and RR Lyrae (PL relations)
  - Offsets claimed in samples of eclipsing binaries and in comparison to asteroseismic distances (Methodology? Assumptions about the stellar types involved?)
- Verification of quoted TGAS errors
  - Various indications of 10–20% overestimate of the errors: depends on sample of stars used
- Gaia DR1 positions and photometry already a reference for other surveys
  - new proper motion catalogues

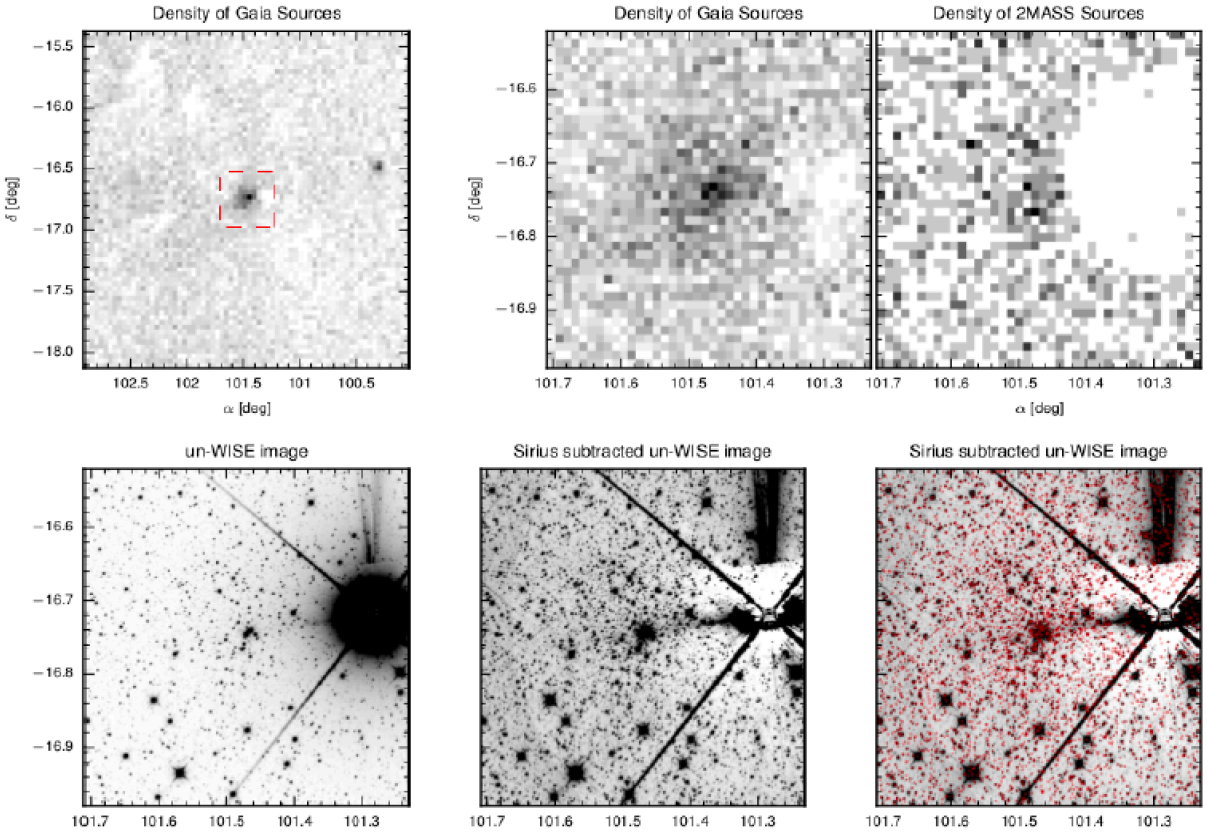
Magellanic cloud kinematics



van der Marel & Sahlmann, arXiv:1609.04395

- Measured proper motions of LMC and SMC consistent with HST result
- Residual kinematics in LMC show clear rotation pattern
  - also seen in HST studies
  - rotation curve from proper motions consistent with result from line-of-sight motions
  - Kinematic distance modulus of 18.54 ± 0.39

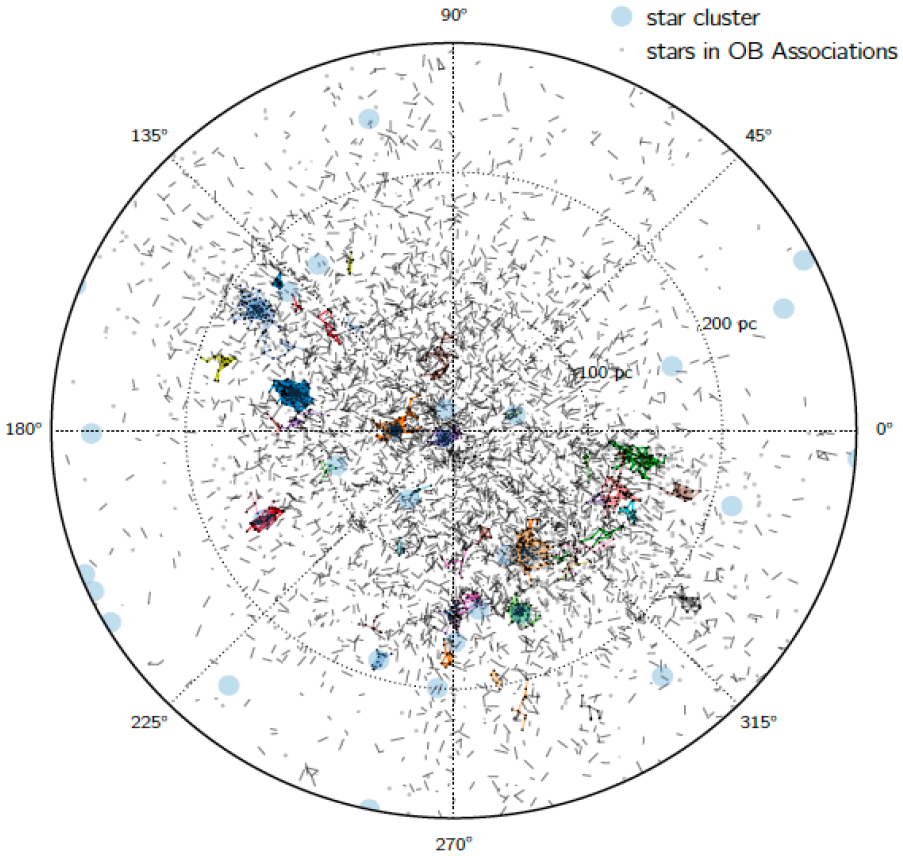
Gaia 1



- Cluster hiding behind Sirius
- Power of all-sky, deep, high resolution, star-map

Koposov et al., 2017, arXiv:1702.01122

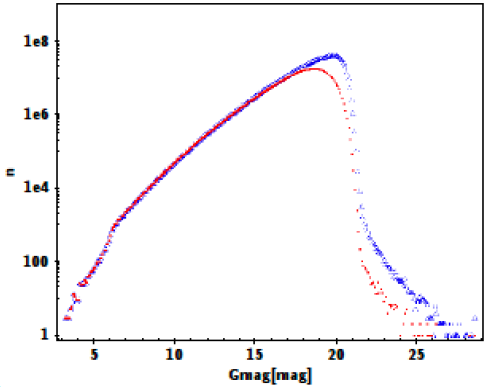
Co-moving pairs

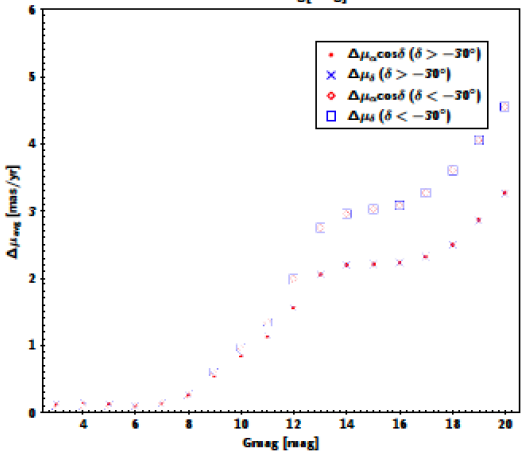


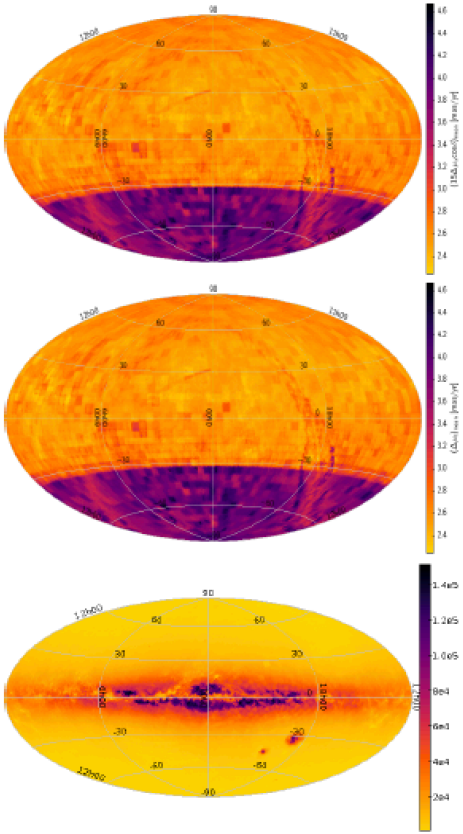
- 13 085 co-moving pairs identified in TGAS
  - based on proper motions, parallaxes, and marginalized model for 3D velocities
- Find pairs as well as networks of co-moving stars (clusters, associations, moving groups)
- Excess of pairs with > 1 pc separation, wide binaries drifting apart?

Oh et al., arXiv:1612.02440

Hot Stuff for One Year







- 583 million proper motions
- Gaia DR1 – PPMXL combination
- Altmann et al., 2017, A&A 600, L4 (arXiv:1701.02629)

Gaia DR2: April 2018

- Five-parameter astrometric solutions for all sources with acceptable formal standard errors ($> 10^9$ anticipated), and positions (α, δ) for sources for which parallaxes and proper motions cannot be derived
- G and integrated G_{BP} and G_{RP} photometric fluxes and magnitudes for all sources
- Median radial velocities for sources brighter than $G_{\mathrm{RVS}} = 12$
- For stars brighter than $G = 17$, estimates of T_{eff} and, where possible, A_V, based on integrated photometry
- Photometric data for a sample of variable stars
- Epoch astrometry for a pre-selected list of $> 10\,000$ asteroids