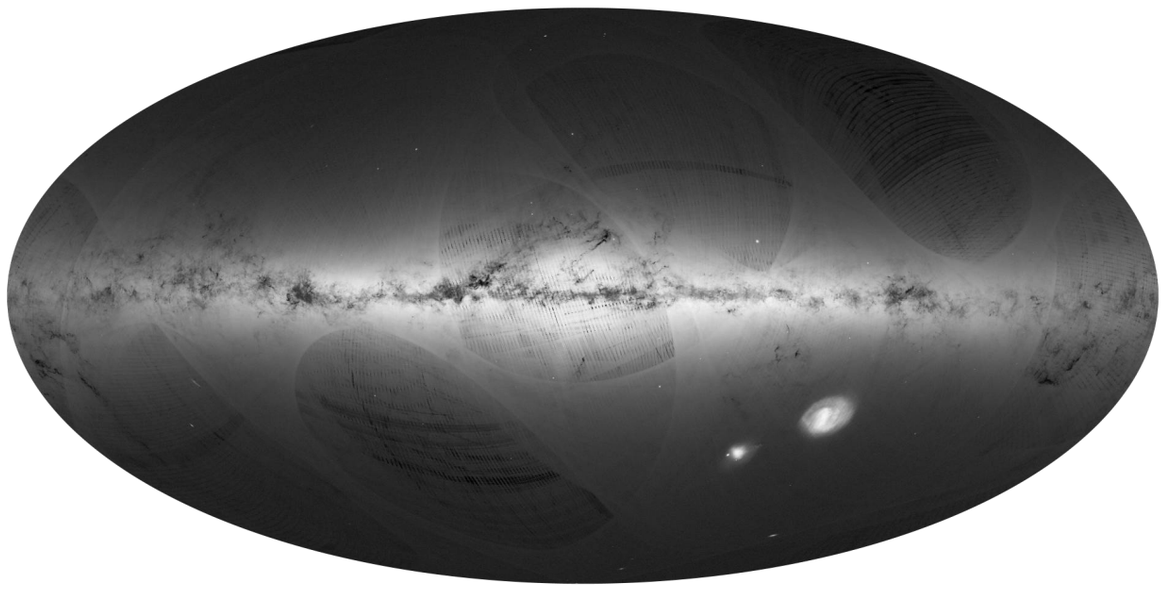
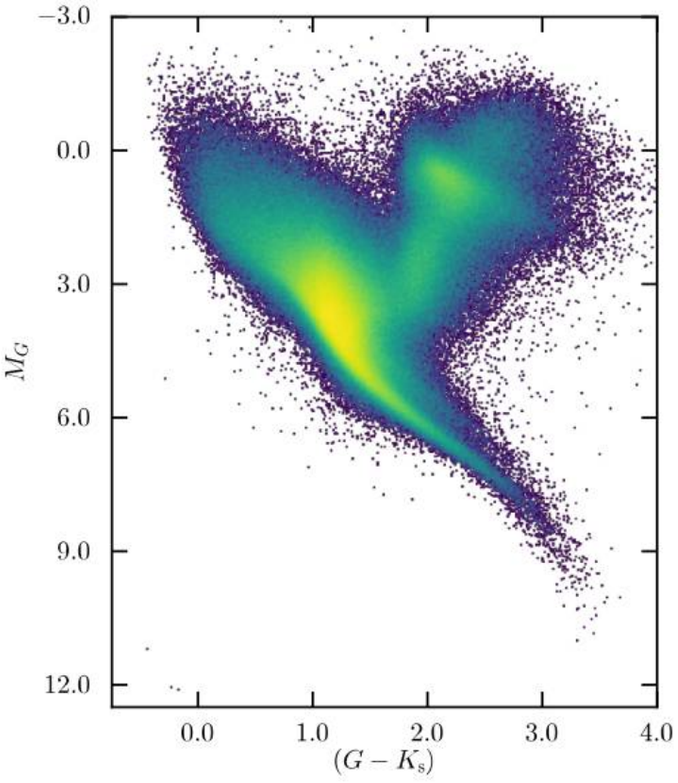
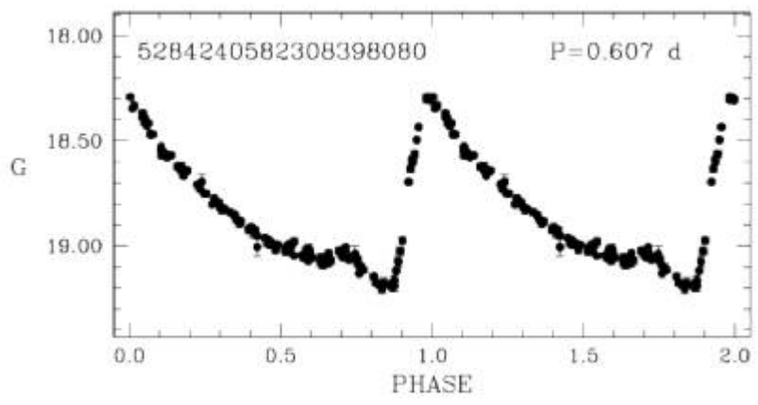
Gaia DR1

Carine Babusiaux

l'Observatoire de Paris – GEPI



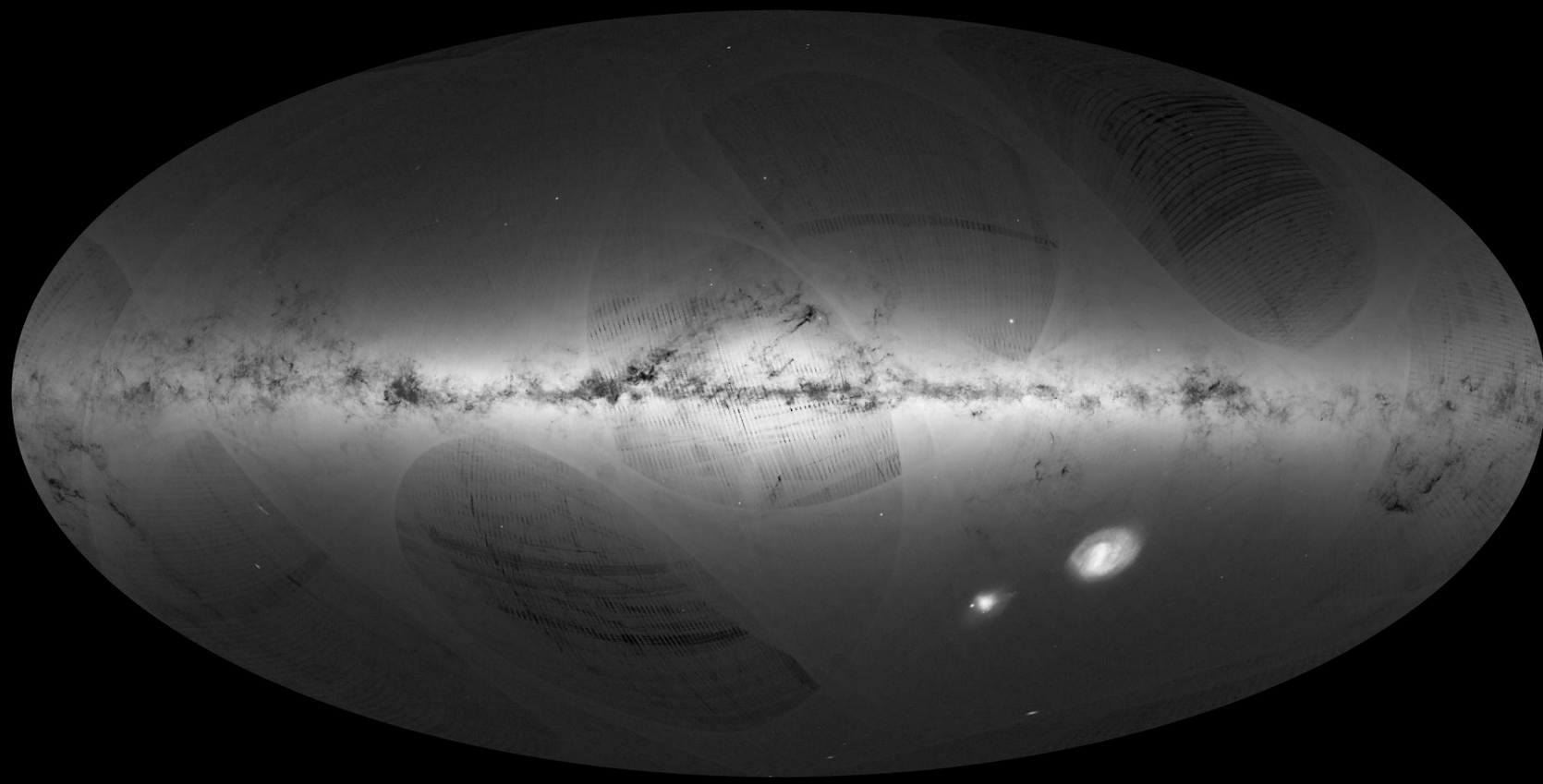




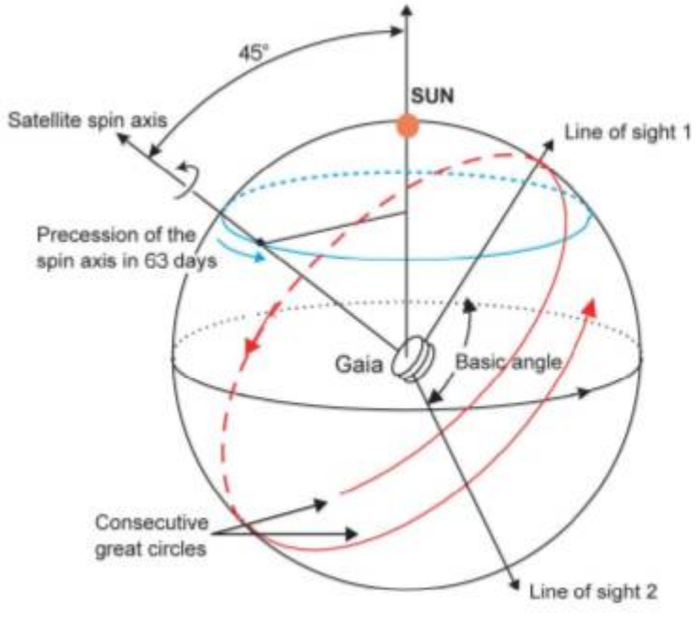
10 Oct 2016

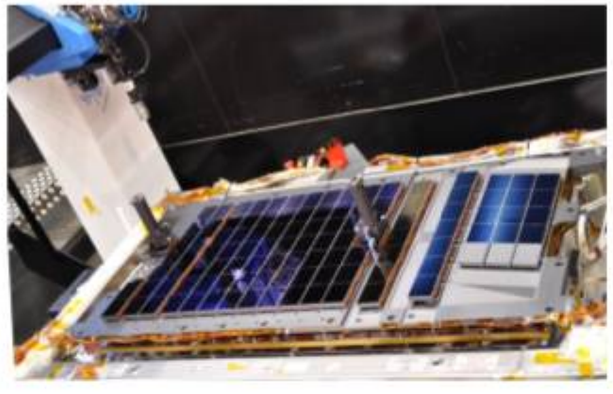
A first data release

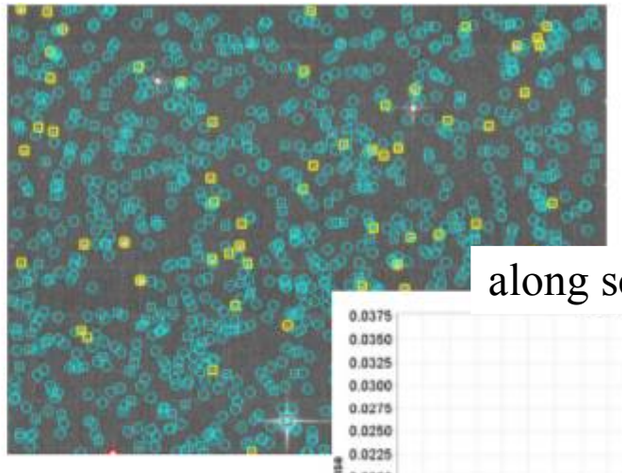
- Gaia mission overview
- Gaia DR1 content
- Validations and limitations



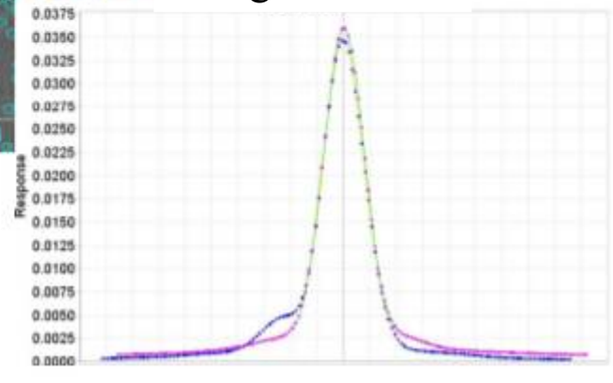
Gaia instruments and measurements

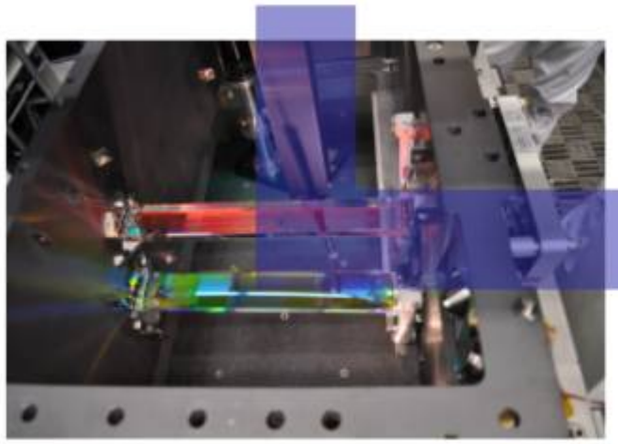




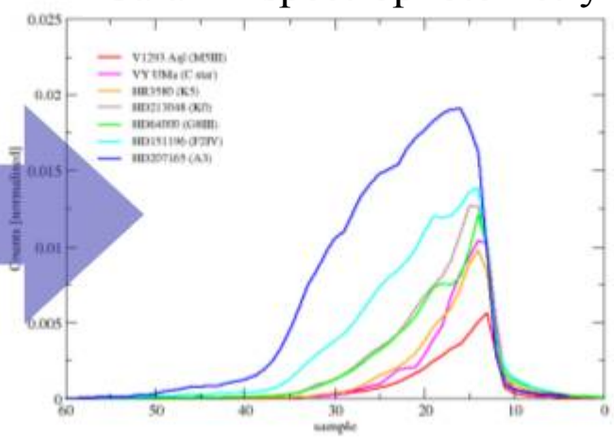


along scan LSF

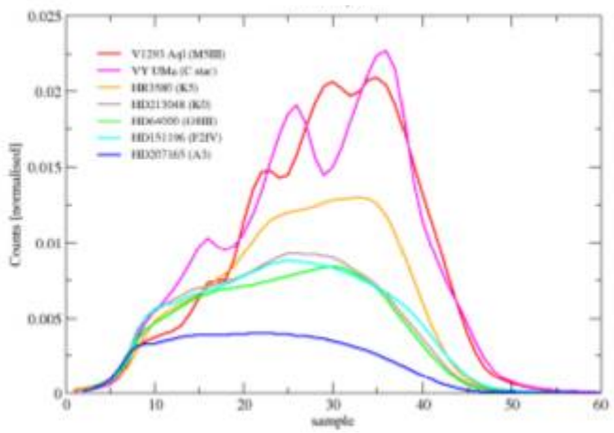


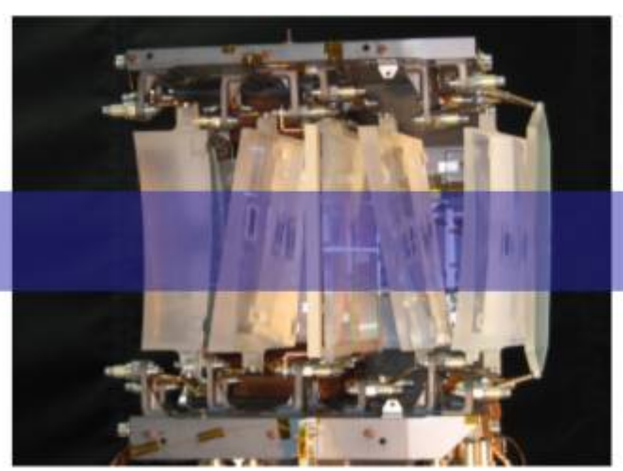


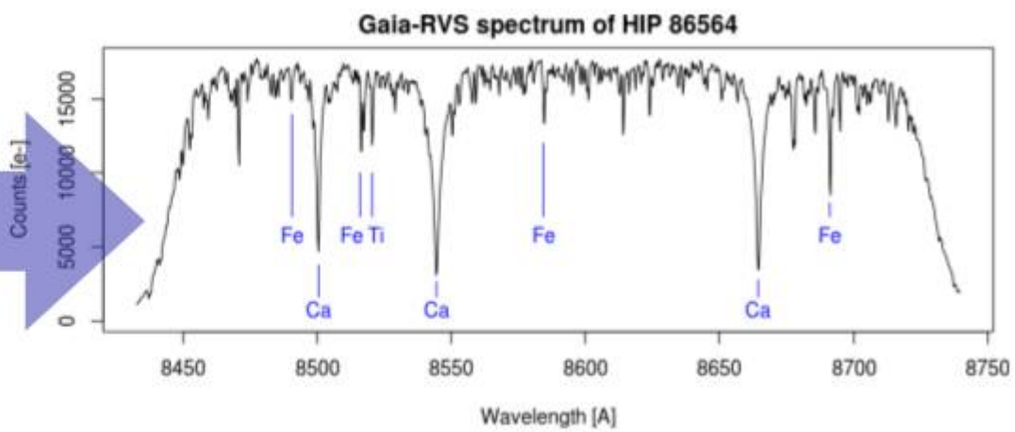
Gaia BP spectrophotometry



Gaia RP spectrophotometry



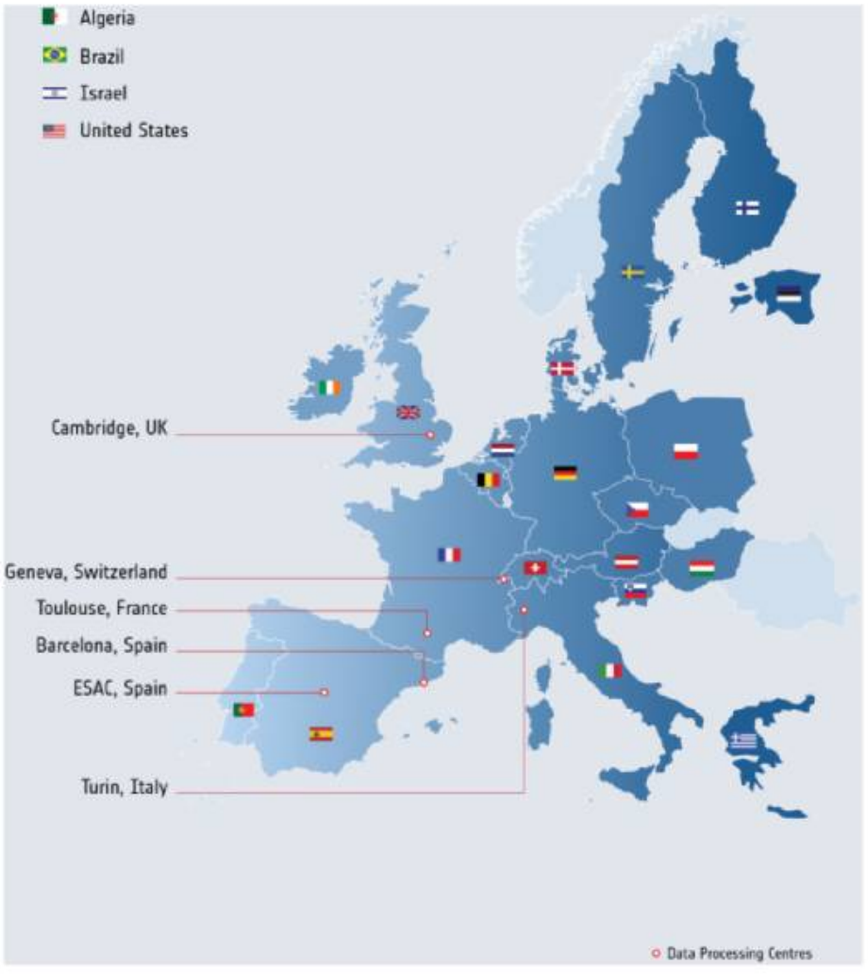


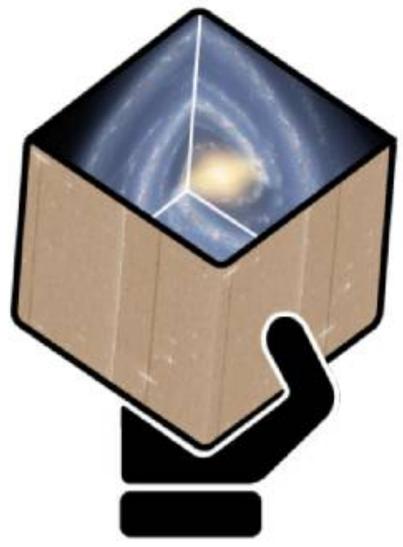


Figures:
ESA/Gaia/DPAC/Airbus DS

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





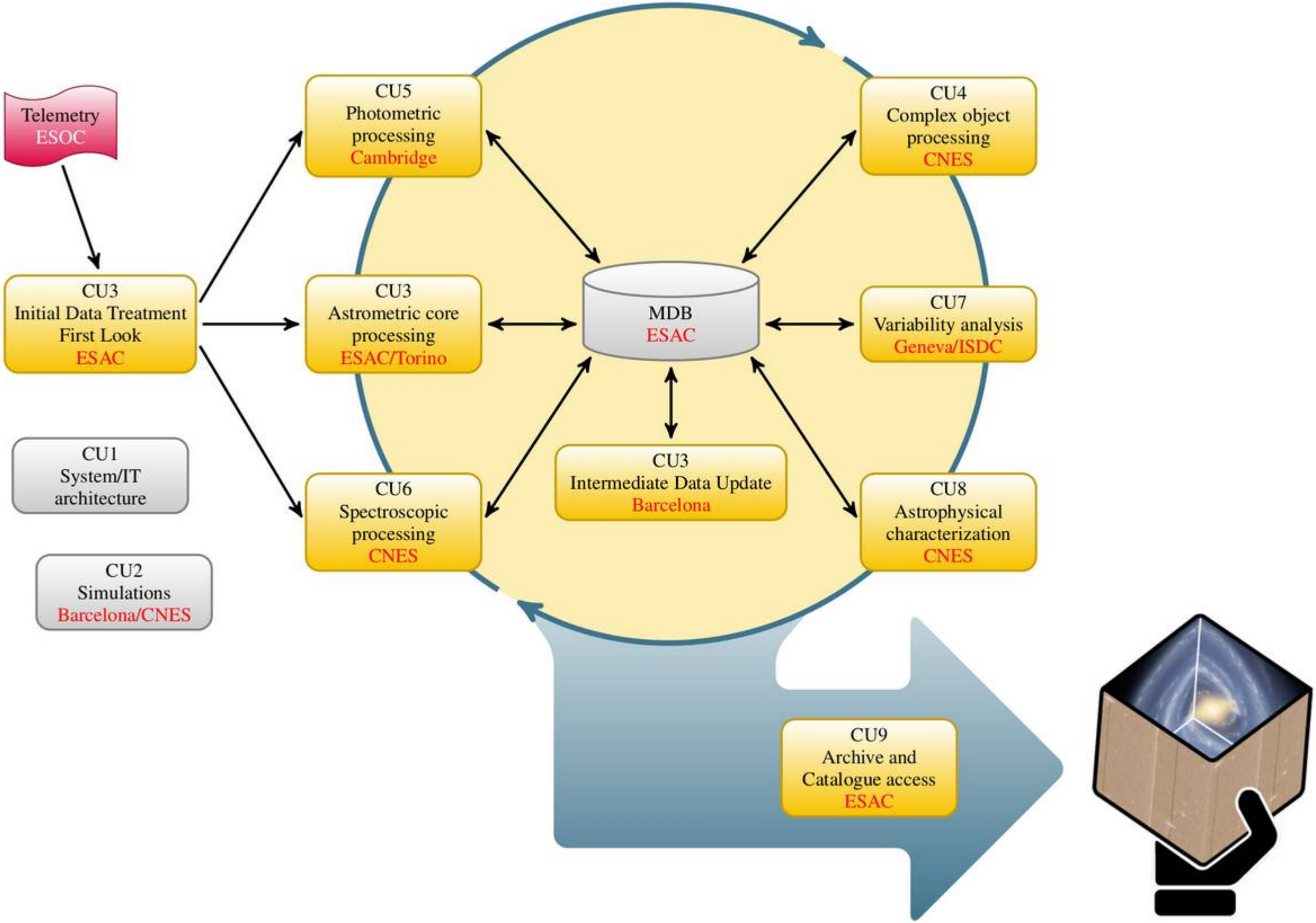
gaia

0 1 0 0 0 0 0 0 1 1 0 0 1 0 0 1 1 0 0 1 1 0 1 1 0 0 1 0 1 0

Gaia DPAC Data Processing & Analysis Consortium

α δ B $\mu_{\alpha*}$ μ_δ G ...

Gaia data processing



The Gaia schedule

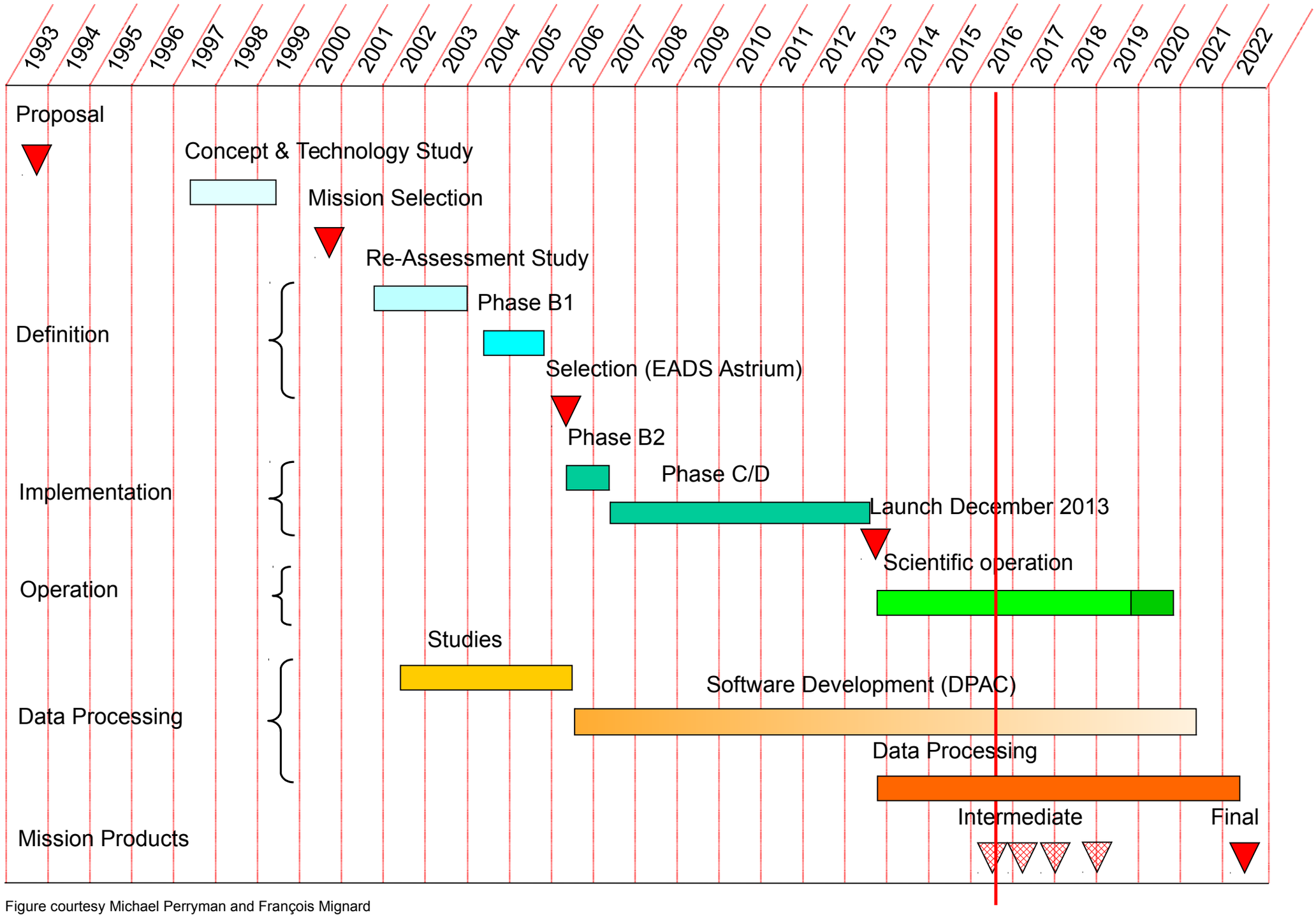
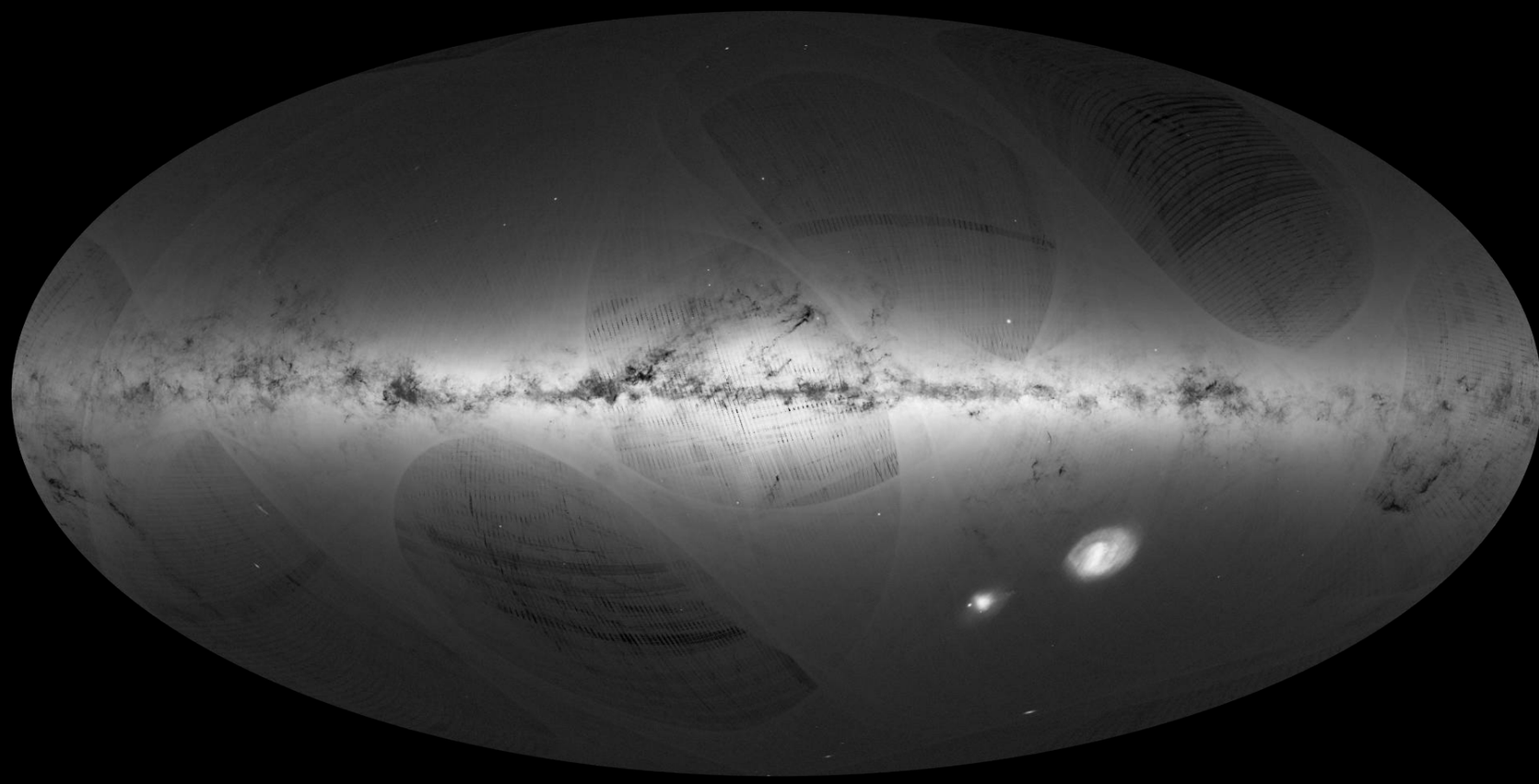


Figure courtesy Michael Perryman and François Mignard

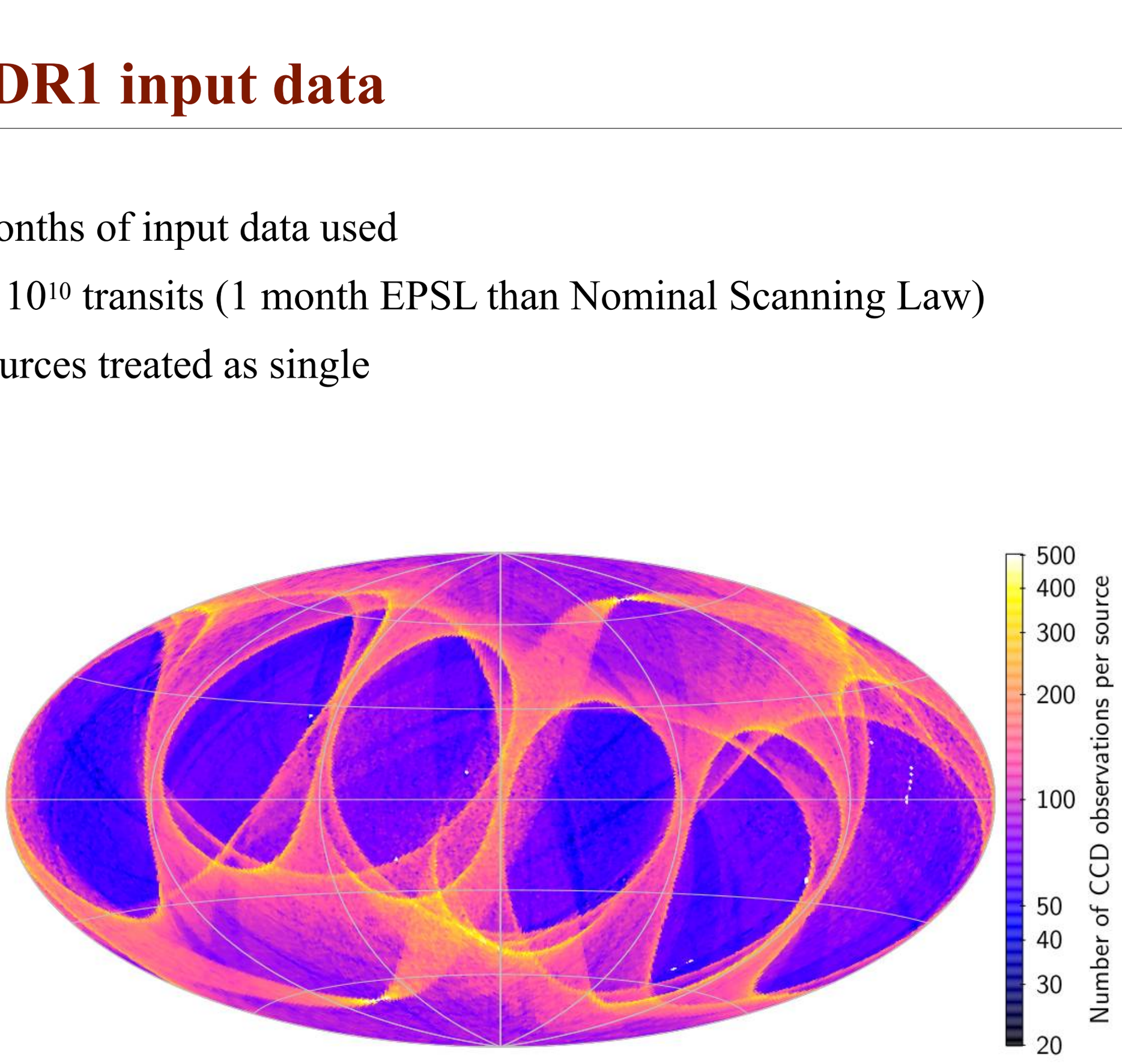
A first data release

- Gaia mission overview
- Gaia DR1 content
  - astrometry
  - photometry
- Validations and limitations



Gaia DR1 input data

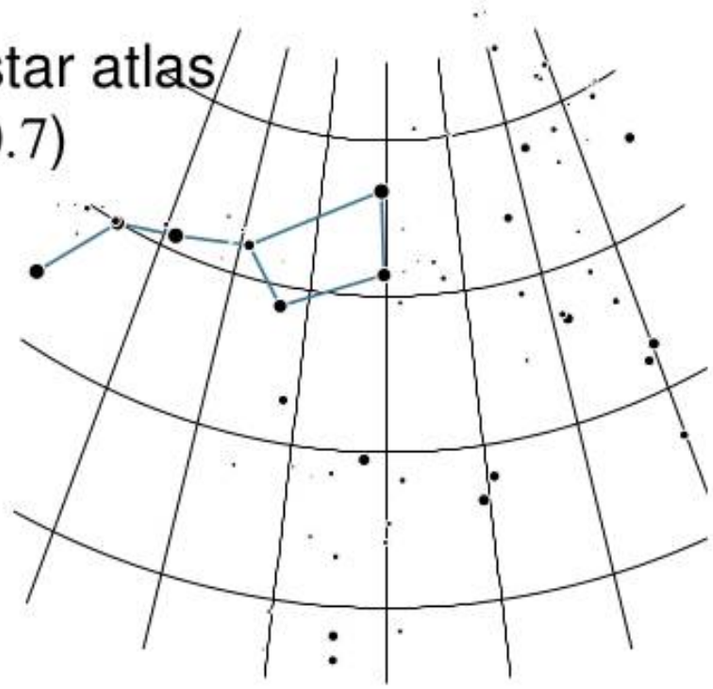
- 14 months of input data used
- ~ 2.3 10^{10} transits (1 month EPSL than Nominal Scanning Law)
- all sources treated as single

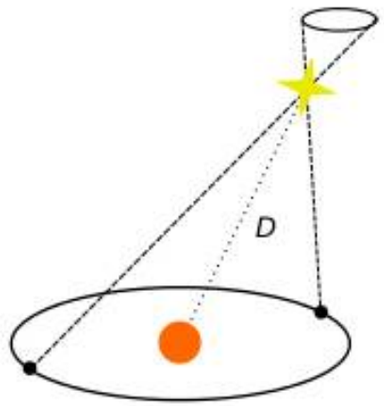


DPAC/CU3/Lindegren et al., 2016, A&A

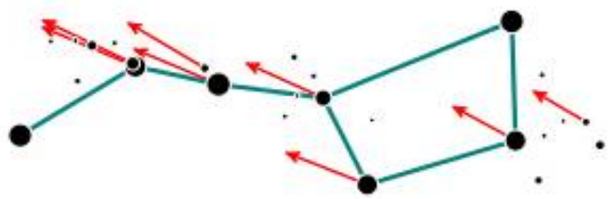
What's in the Gaia DR1 delivery

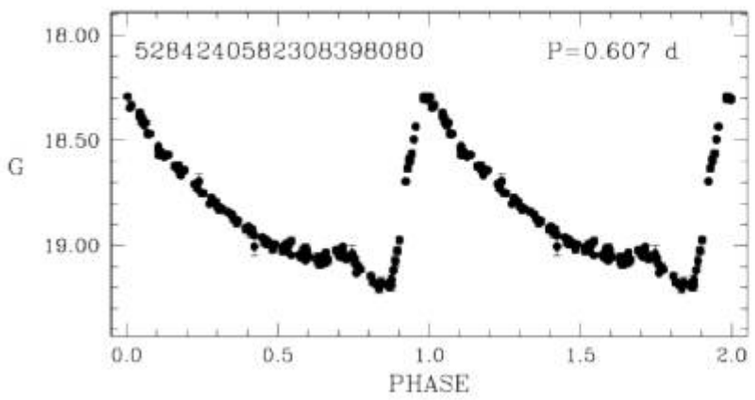
Billion star atlas
($G \lesssim 20.7$)





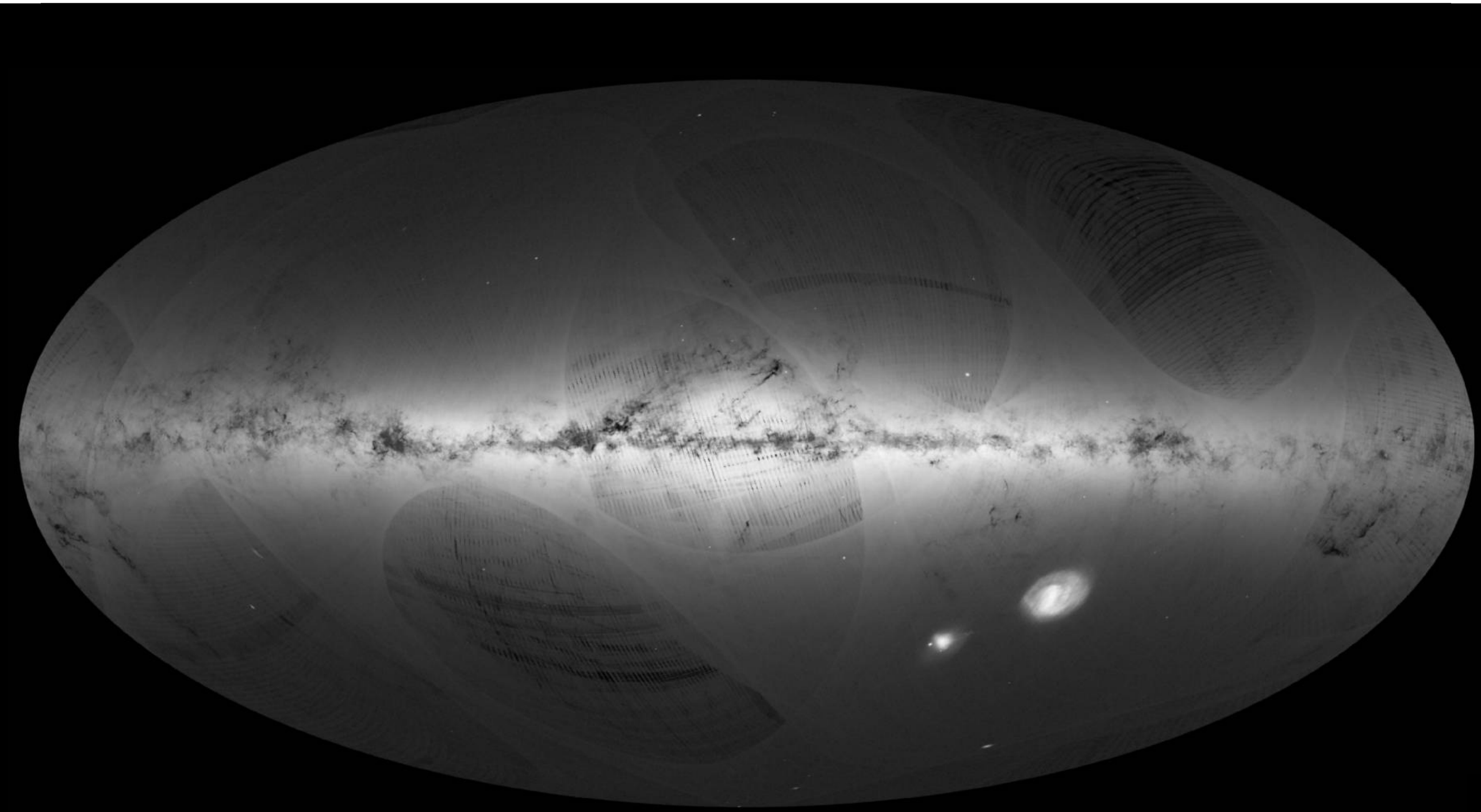
Tycho-Gaia
Astrometric Solution
($\sim$ 2 million, $G \lesssim 12$)





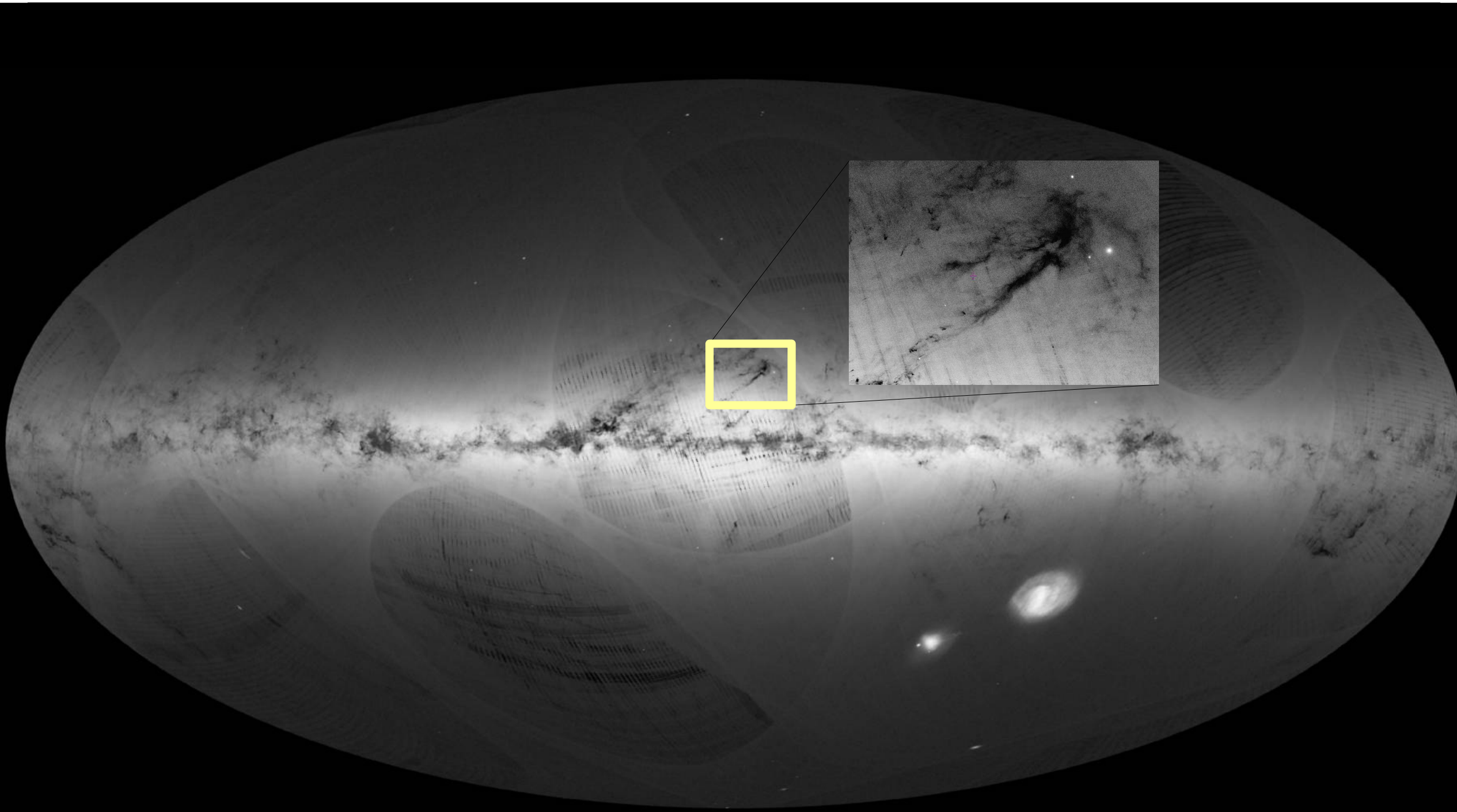
Variable stars near
south ecliptic pole
($\sim$ 600 Cepheids,
$\sim$ 2600 RR Lyrae)

Gaia DR1 skymap



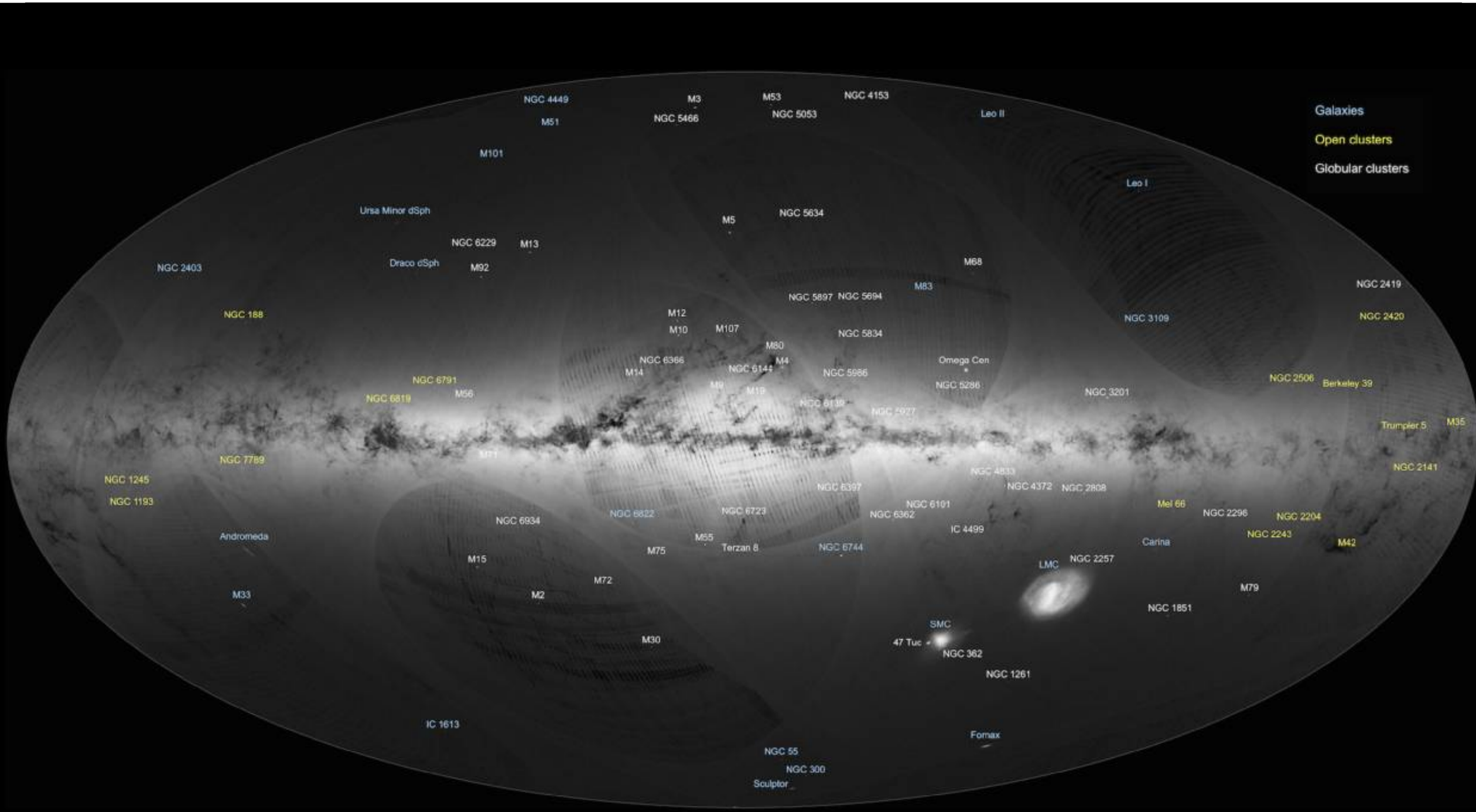
ESA/Gaia/DPAC/André Moitinho & Márcia Barros (CENTRA - University of Lisbon)

Gaia DR1 skymap



ESA/Gaia/DPAC/André Moitinho & Márcia Barros (CENTRA - University of Lisbon)

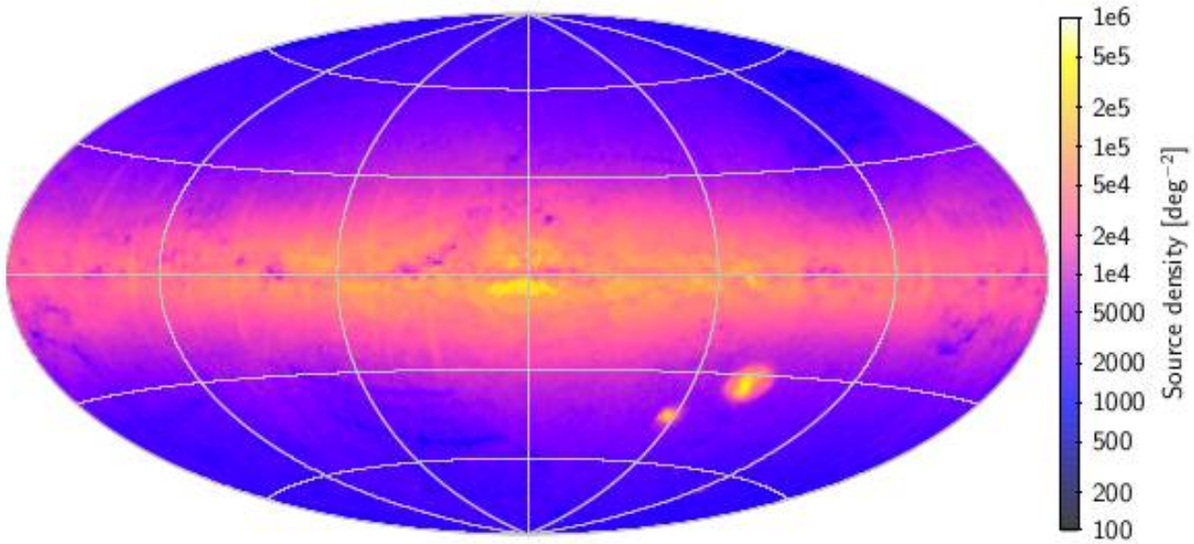
Gaia DR1 skymap



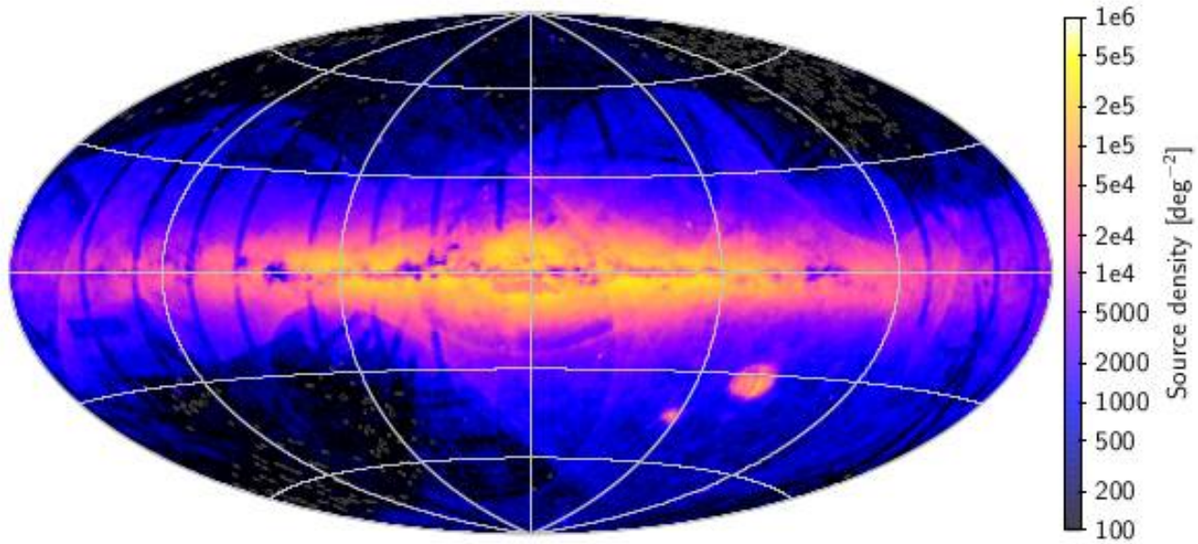
ESA/Gaia/DPAC/André Moitinho & Márcia Barros (CENTRA - University of Lisbon) Annotations: Francois Mignard (OCA Nice)

Gaia DR1 astrometry

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

TGAS

Tycho-Gaia Astrometric Solution (Michalik et al., 2015, A&A)

- Use Hipparcos or Tycho-2 position as prior to disentangle parallax and proper motion
  - 2 million stars in common with these catalogues
- 5-parameter astrometry from $\sim$ 1 year of Gaia data
- *No Hipparcos parallaxes used*

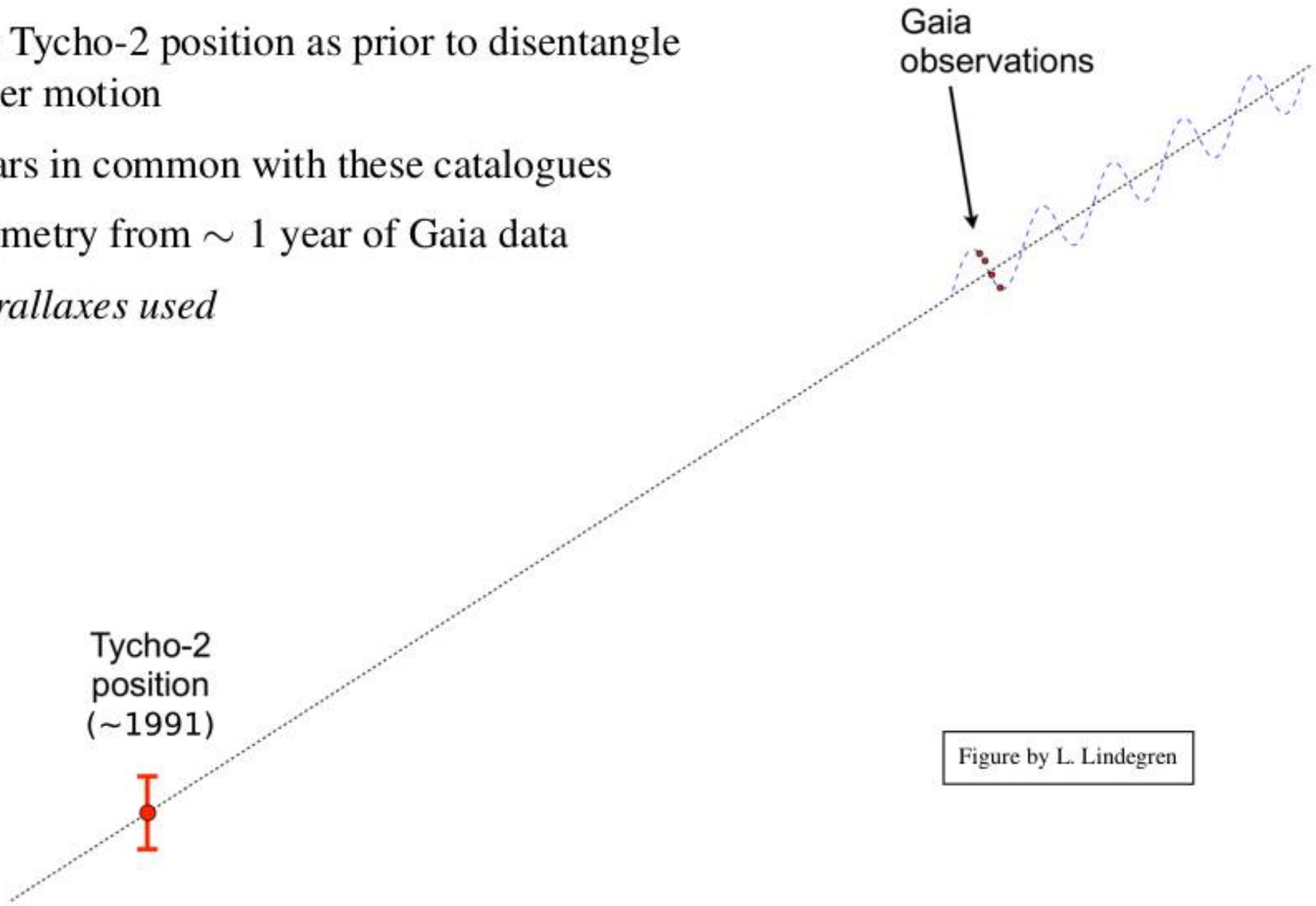
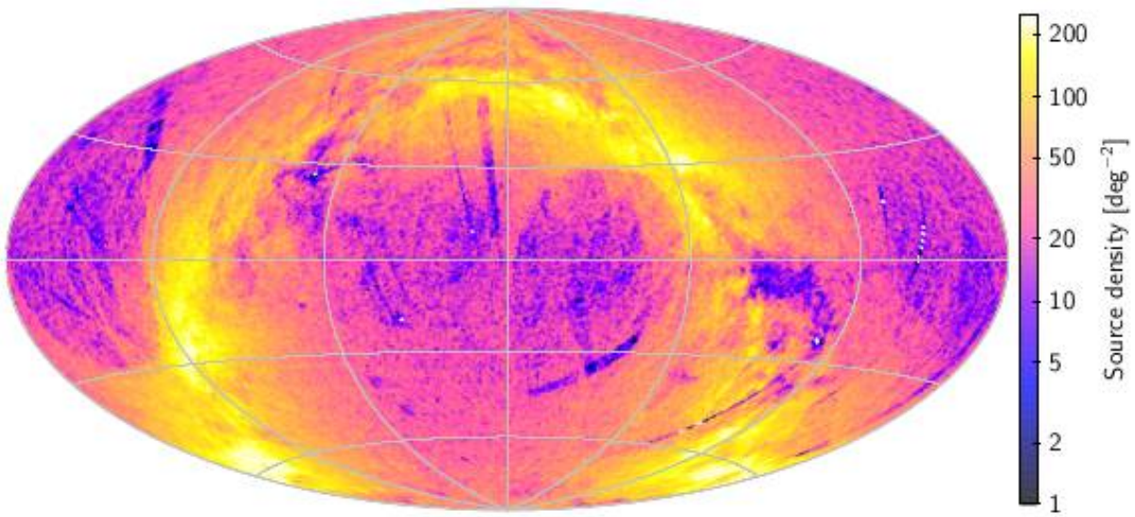


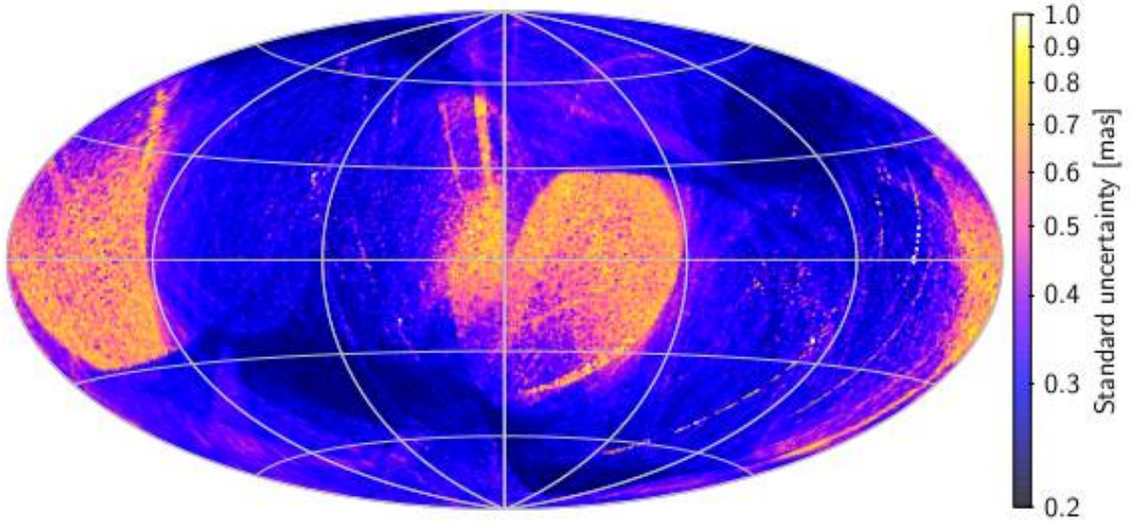
Figure by L. Lindegren

TGAS

TGAS source density



TGAS median parallax uncertainty

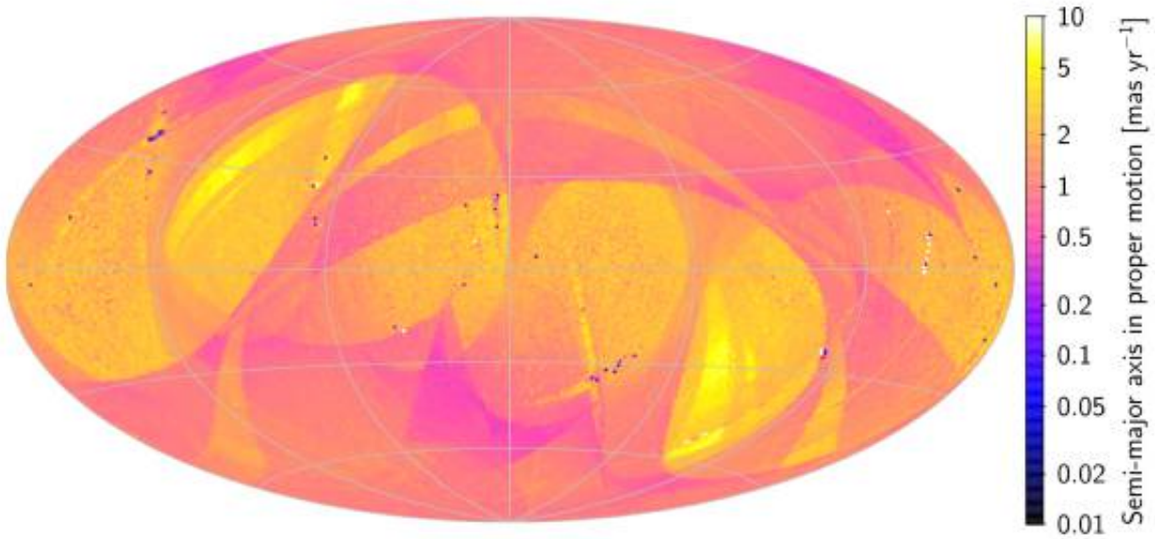


DPAC/CU3/Lindegren et al., 2016, A&A

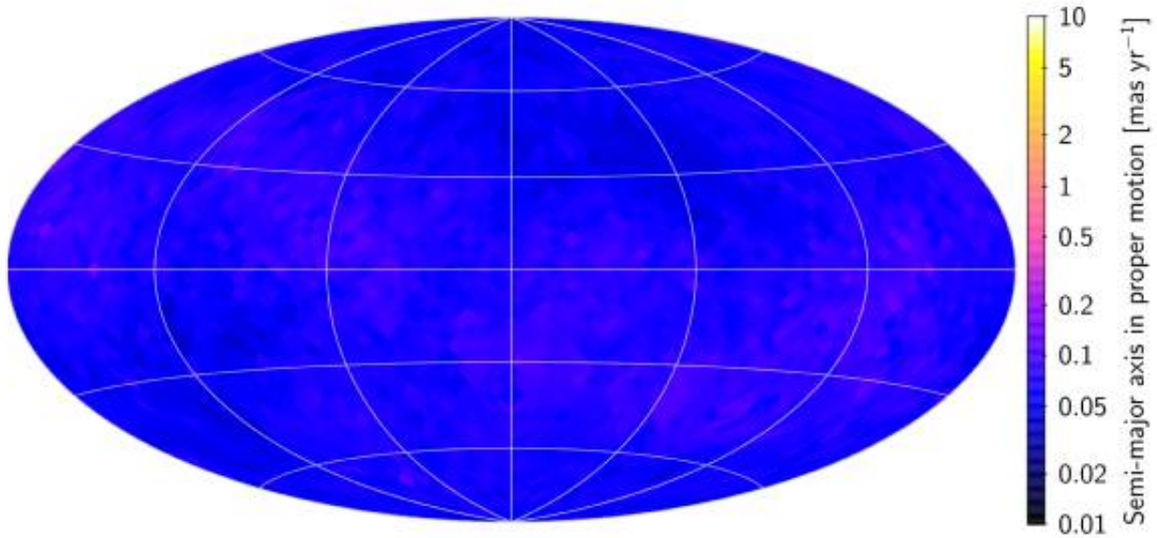
- Parallaxes and proper motions for $\sim$ 2 million sources to $G \sim 11.5$ (TGAS)
- Realistic errors derived from Gaia-Hipparcos comparison
- Median position uncertainty $\sim$ 0.3 mas
- Median parallax uncertainty $\sim$ 0.3 mas; global zeropoint below $\pm$0.1 mas; systematics at 0.3 mas level

TGAS

TGAS median proper motion uncertainty



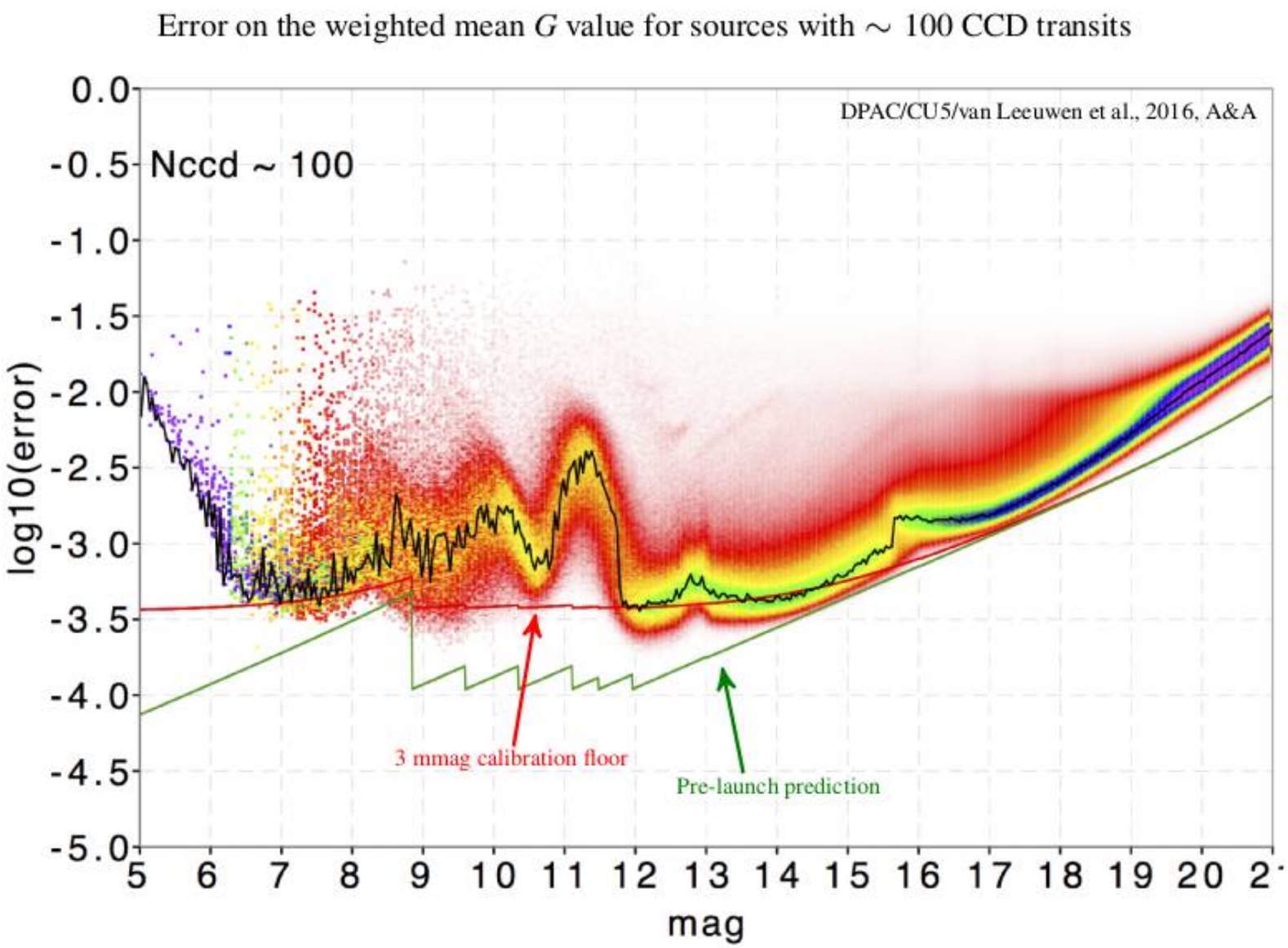
Hipparcos subset



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

- Median TGAS proper motion uncertainty ~ 1.3 mas yr^{-1} (semi-major axis error ellipse)
  - Hipparcos subset: ~ 0.07 mas yr^{-1}

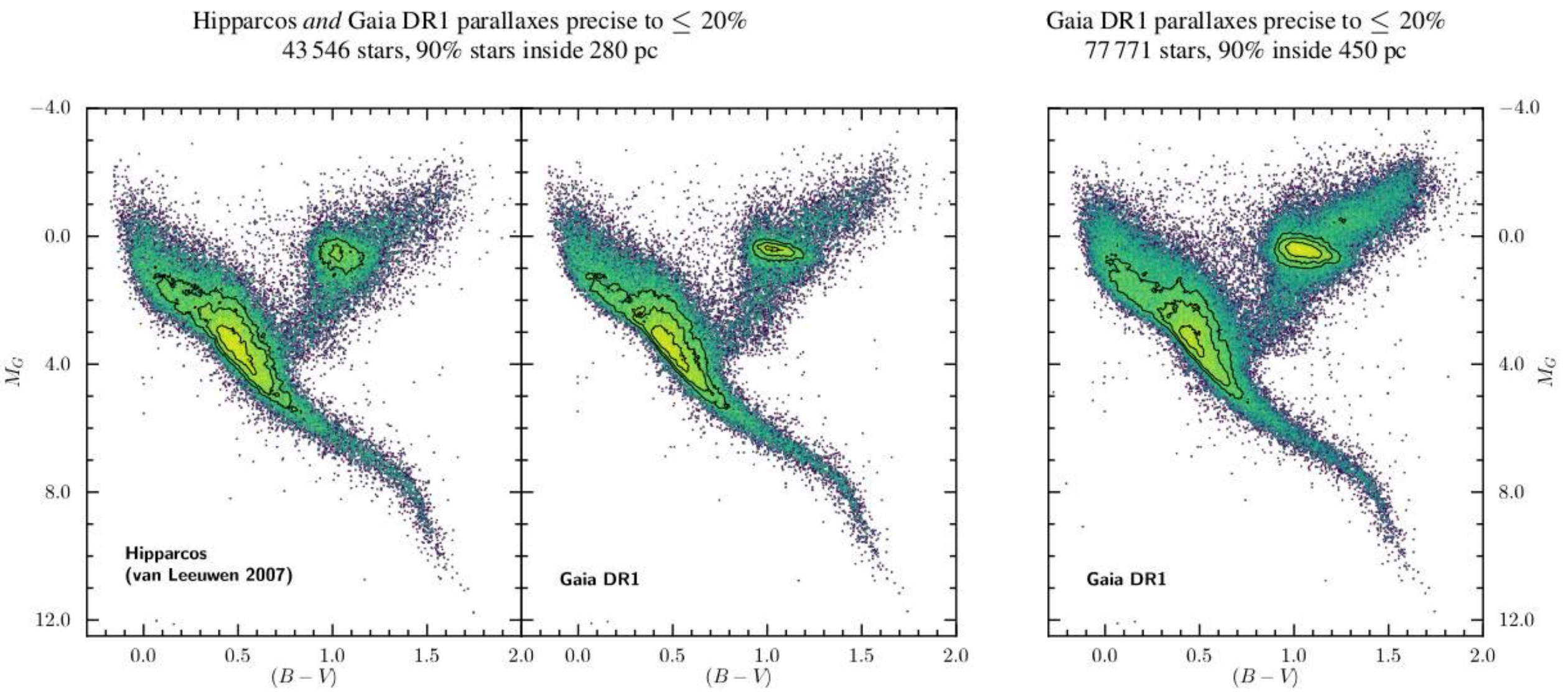
Gaia DR1 Photometry



- Mean *G*-band fluxes and errors for all Gaia DR1 sources
  - *G* magnitudes in VEGAMAG, zeropoints for AB
  - No pass-band calibrations, transformations to other systems to be provided

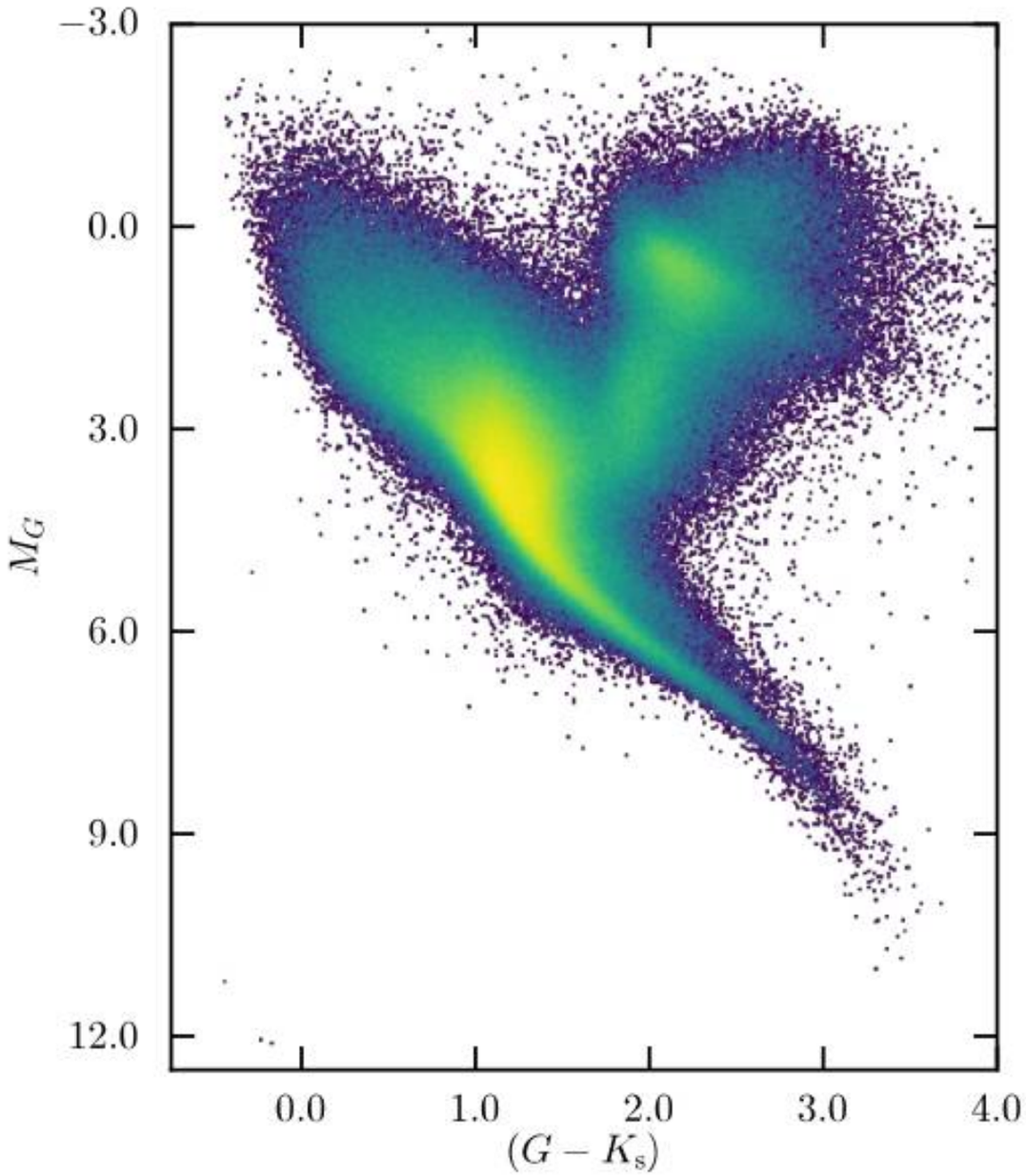
- CCD-transit *G*-band calibration systematics at the ~ 3 mmag level
- Bright end features related to on-board instrument configuration changes
  - will be calibrated out in future releases

TGAS HR diagram of the Hipparcos stars



Gaia Collaboration, Brown et al. 2016, A&A

TGAS full HR diagram

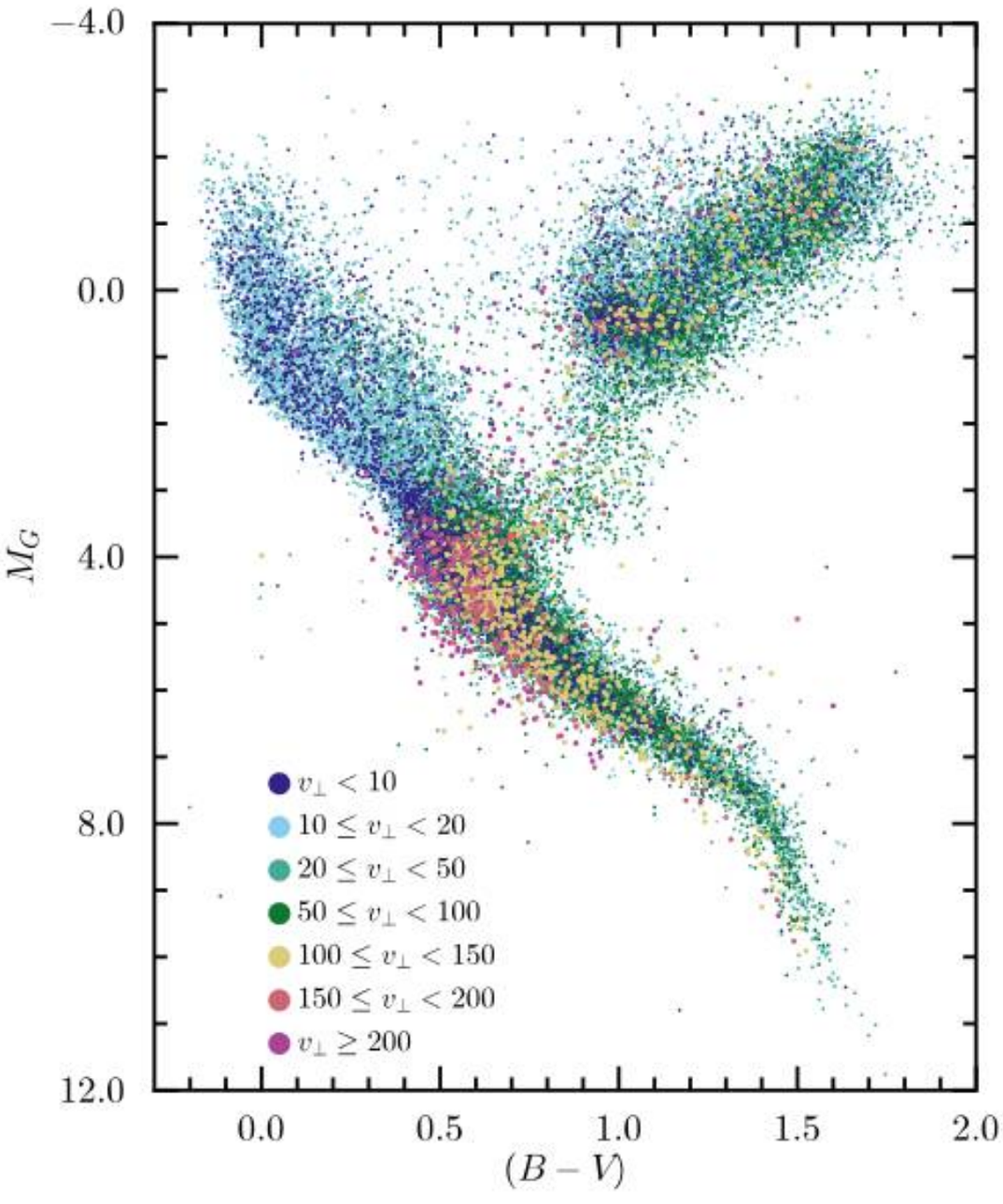


Full Gaia DR1 data set

- 1 million stars with parallaxes precise to $\leq 20\%$
- 90% inside 590 pc
- Future
  - $\sim$ 10 million parallaxes precise to 1%
  - $\sim$ 150 million precise to 10%
  - $\sim$ 280 million precise to 20%

Gaia Collaboration, 2016, A&A

HR diagram & tangential velocity

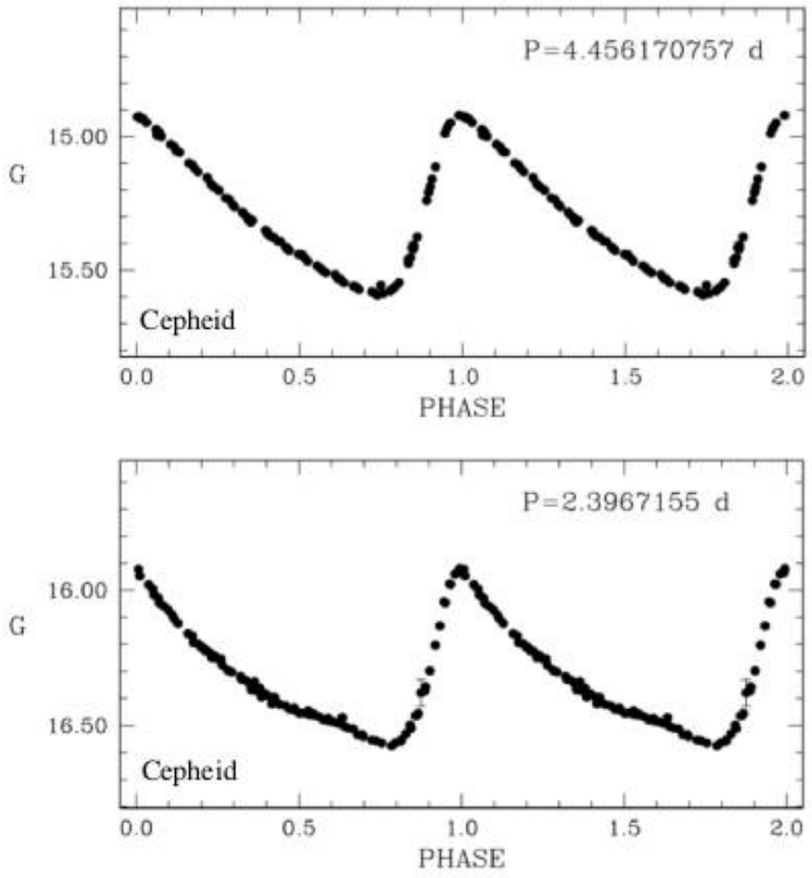


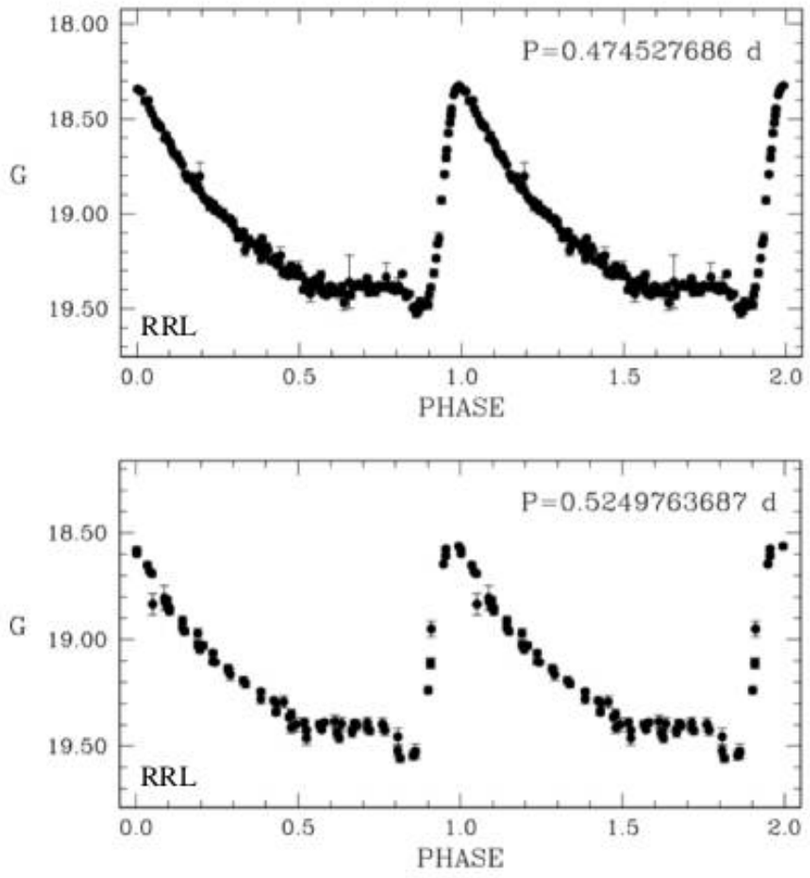
HR diagram colour coded by tangential velocity

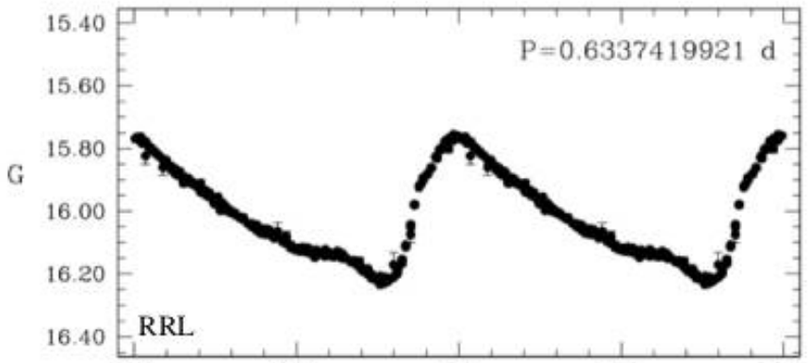
- 41 136 stars with $(B-V)$ photometry selected according to: $G \leq 7.5$ or $\mu \geq 200$ mas yr^{-1} or $\varpi \geq 10$ mas
- 90% inside 360 pc

Gaia Collaboration, 2016, A&A

Gaia DR1 Variable Stars





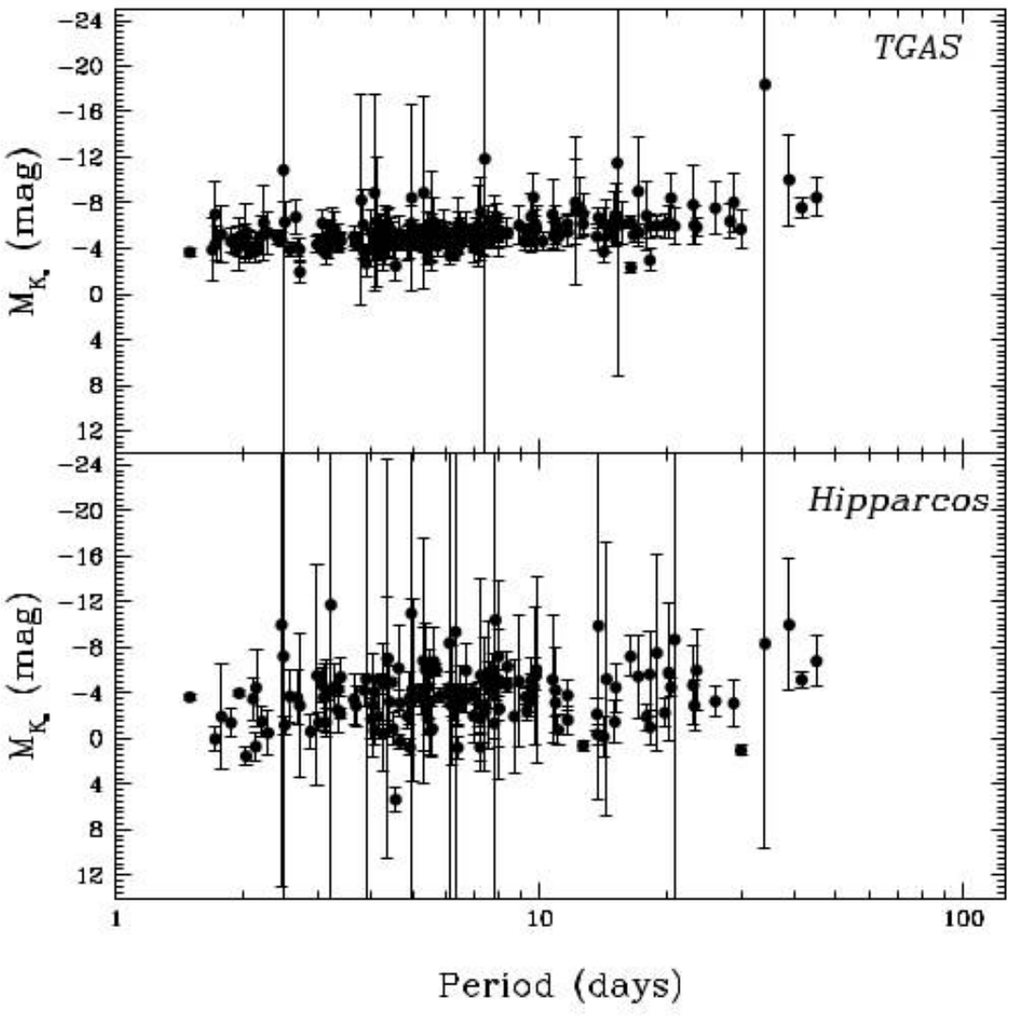


- *G*-band light curves for variables near South Ecliptic Pole
  - 599 Cepheids (43 newly discovered)
  - 2595 RR Lyrae (343 newly discovered)
- Classification information
- Statistical information on time series

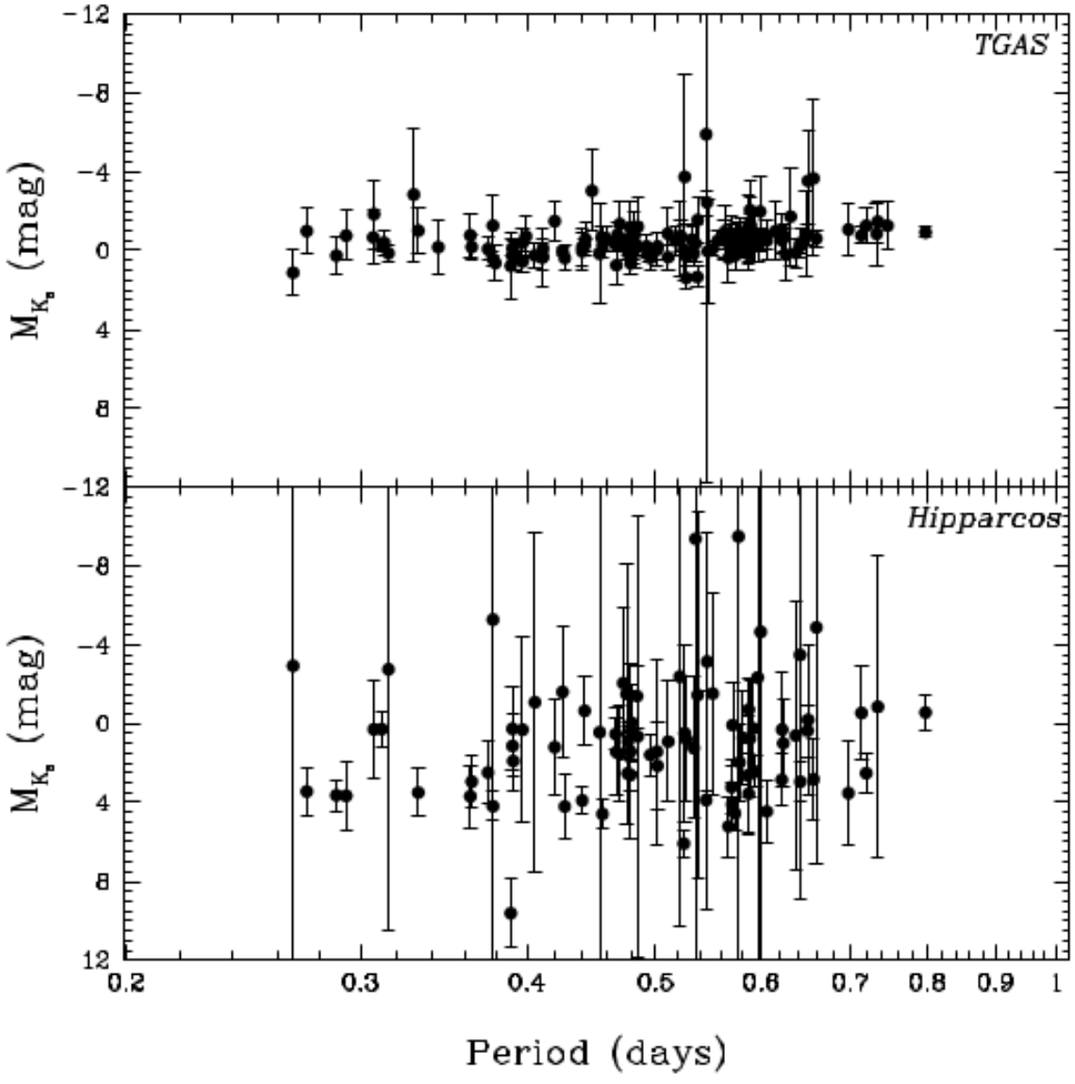
DPAC/CU7/Clementini et al., 2016, A&A

Gaia DR1 Variable stars

Classical Cepheids



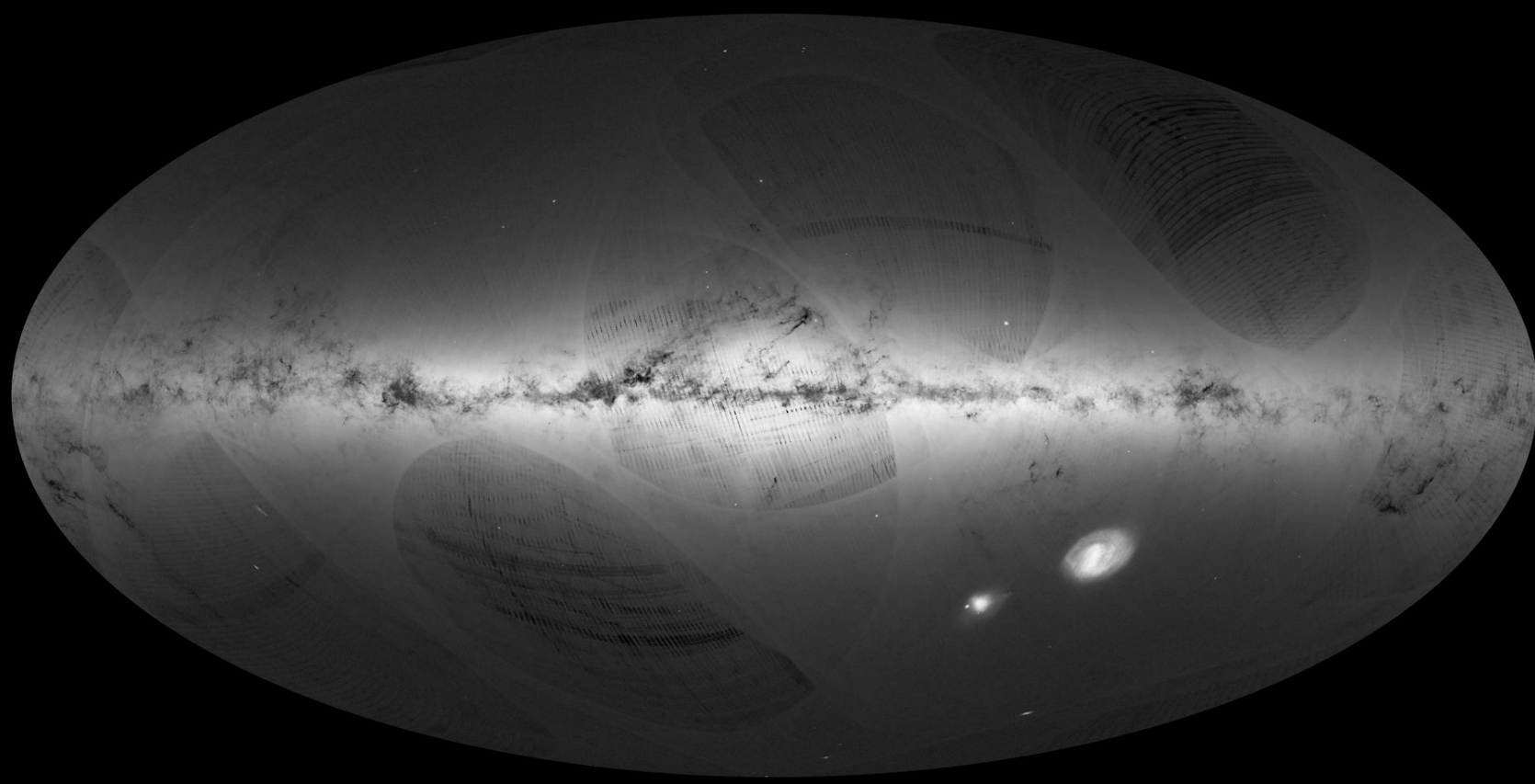
RR Lyrae



Gaia Collaboration, Clementini et al. 2016, A&A (in prep)

A first data release

- Gaia mission overview
- Gaia DR1 content
- Validations and limitations
  - Completeness
  - Astrometry
  - Photometry



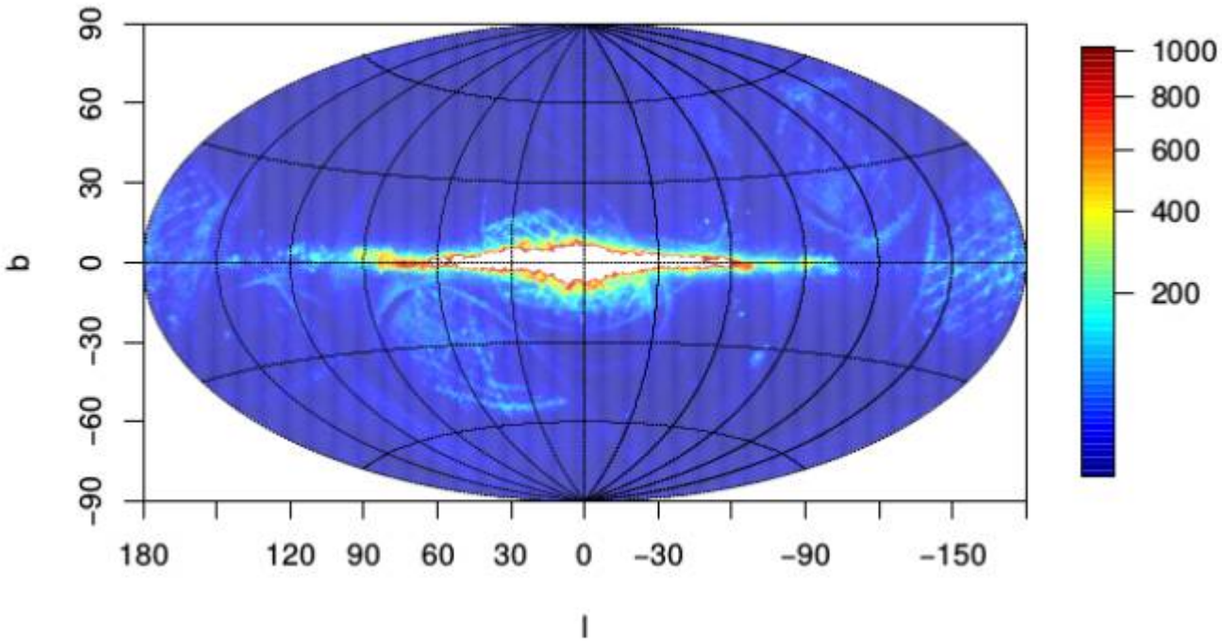
Compromise needed for an early first data release

- Short observing period (14 months)
  → Bright stars position prior (Hipparcos/Tycho)
- Calibration models not completed
  → Bright stars affected
- Attitude and other un-modeled effects (basic angle)
  → Systematics
- Sub-optimal cross-match
- All sources treated as single stars

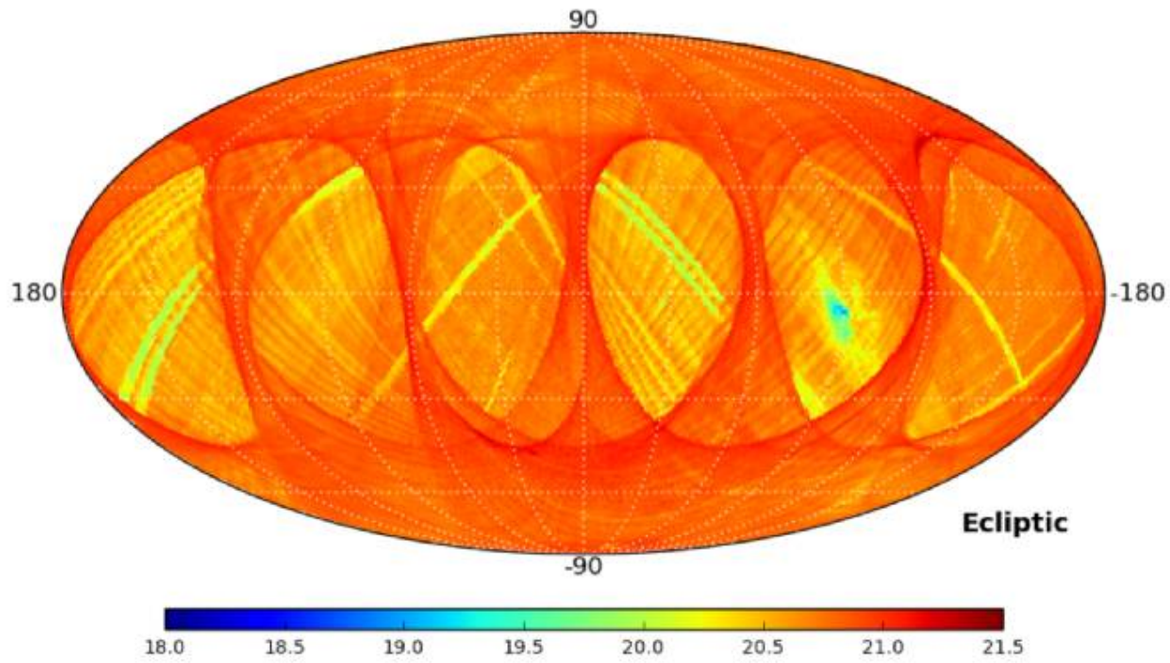
DR1 incompleteness

- Scanning law inhomogeneities

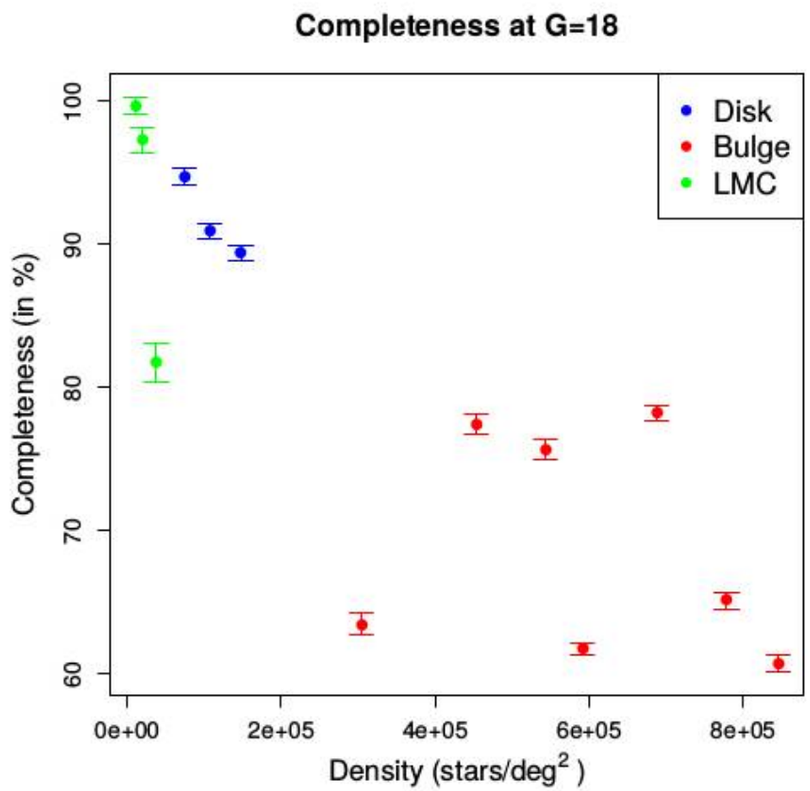
2MASS sources not found in DR1



99% percentile of the G mag distribution

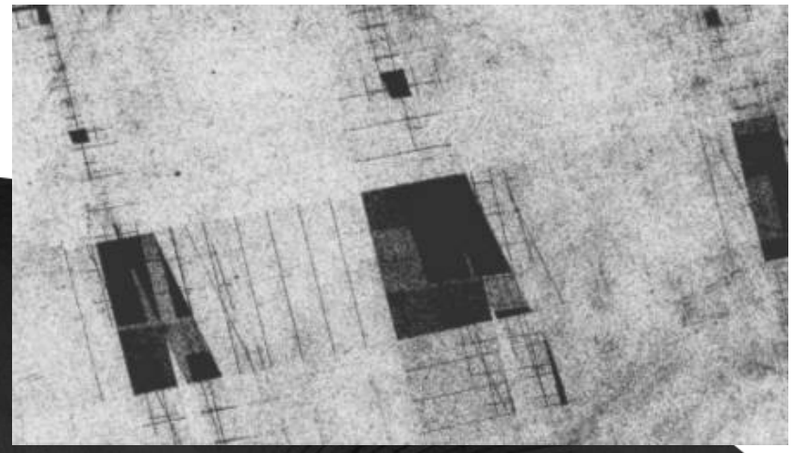


- Worst incompleteness in dense regions



Incompleteness : holes

- Scanning law + selection of sources with > 5 observations



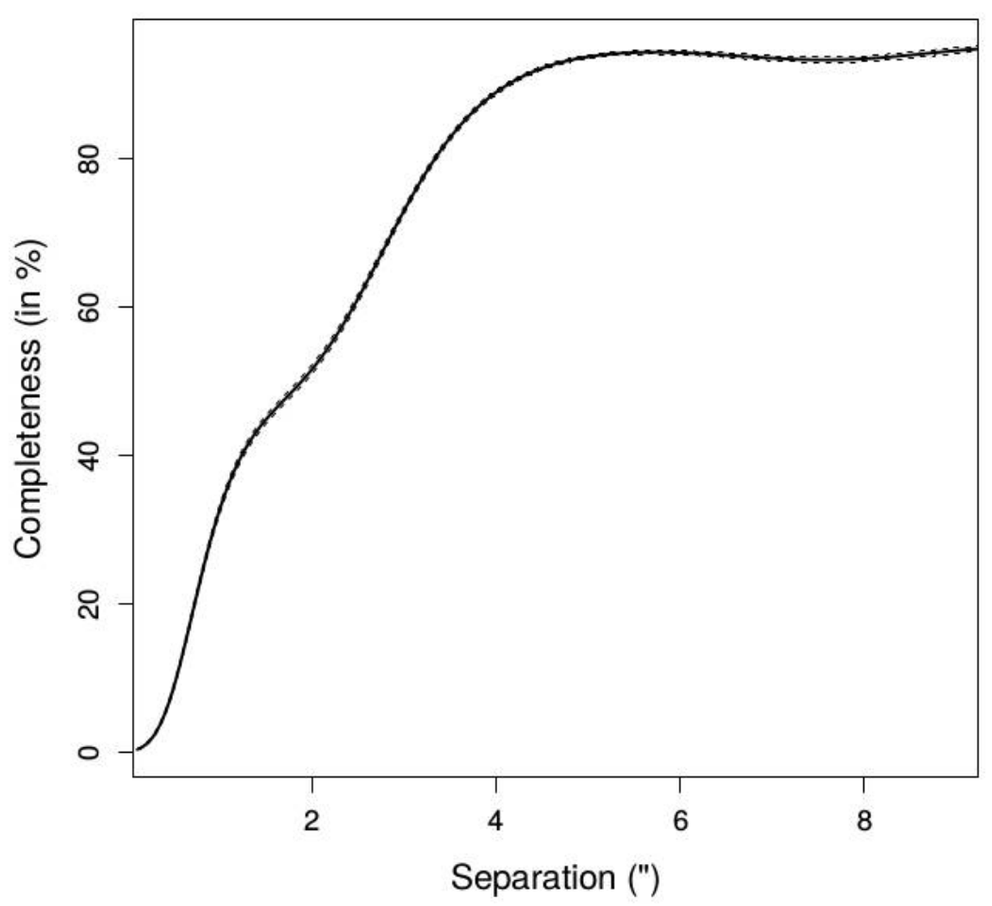
- On-board resources limited on-board for dense regions

Incompleteness: angular resolution

- On-board resolution as expected

- In DR1 low separation incompleteness

WDS double stars completeness vs separation

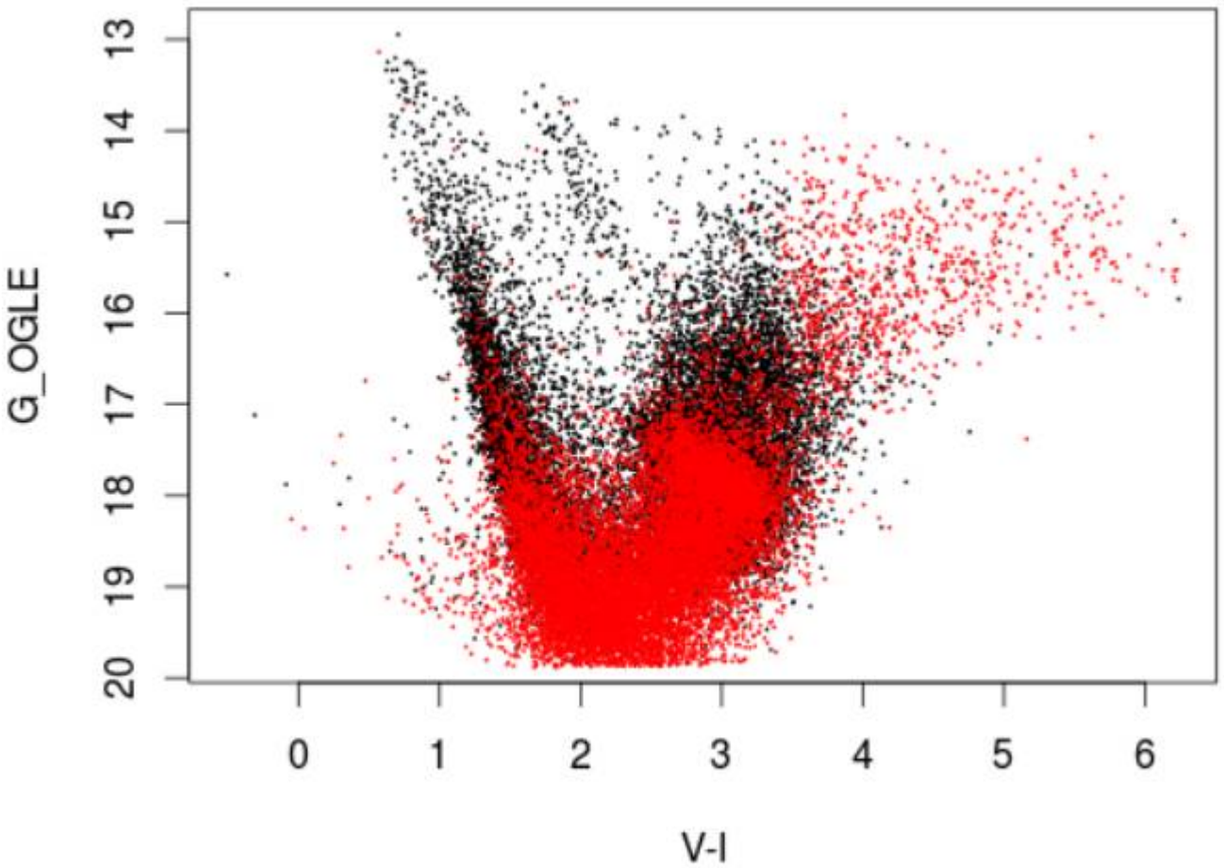


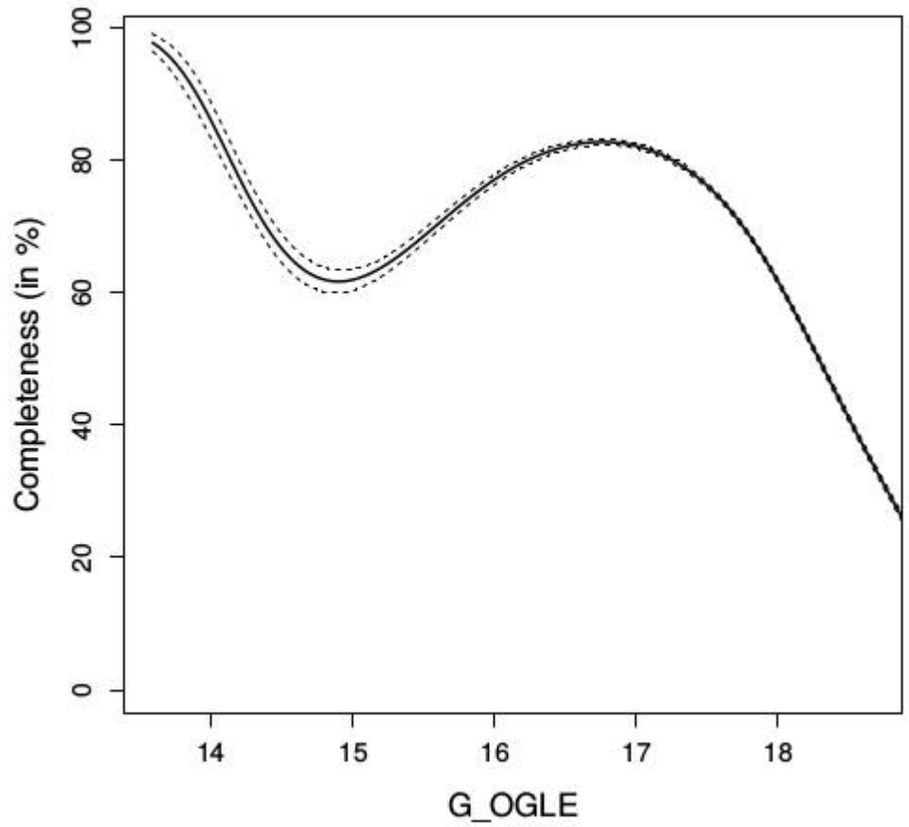
Incompleteness : colour effect

- Very blue and very red stars missing

OGLE bulge field

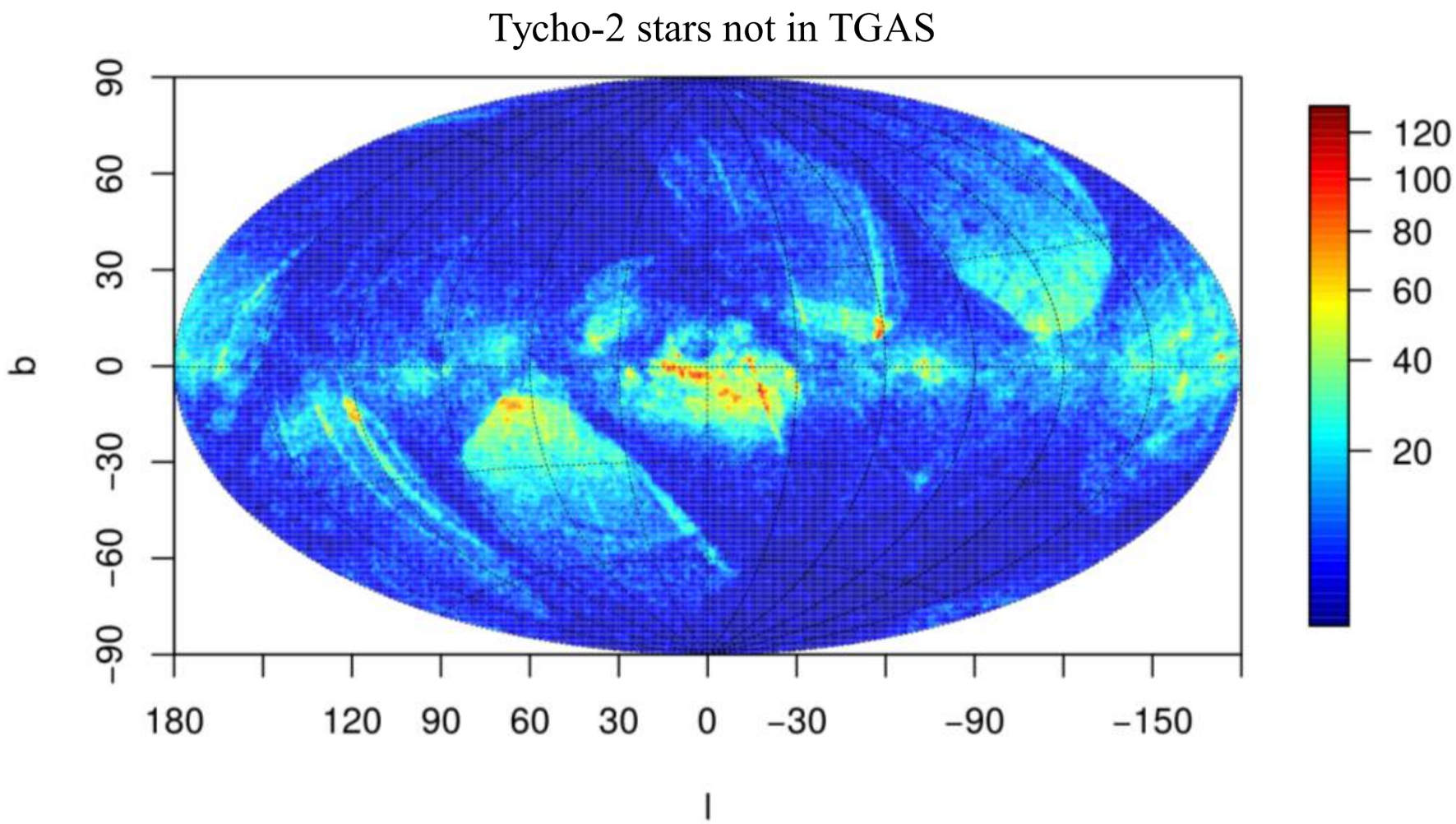
- not found in DR1





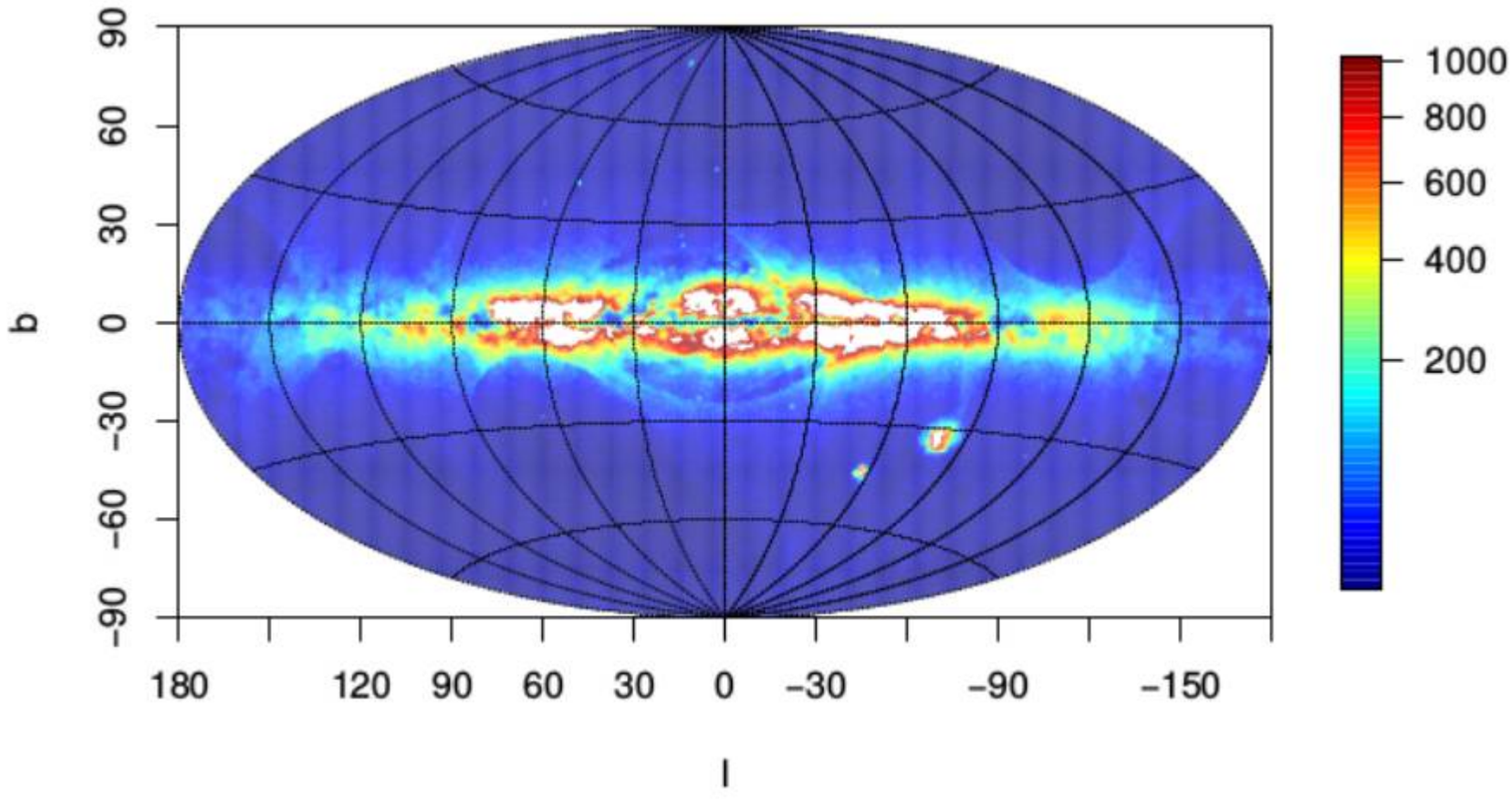
TGAS incompleteness

- Many bright stars missing
- High proper motion stars missing
- Cross-match issues



Duplicated sources remain

Multiple matches with 2MASS

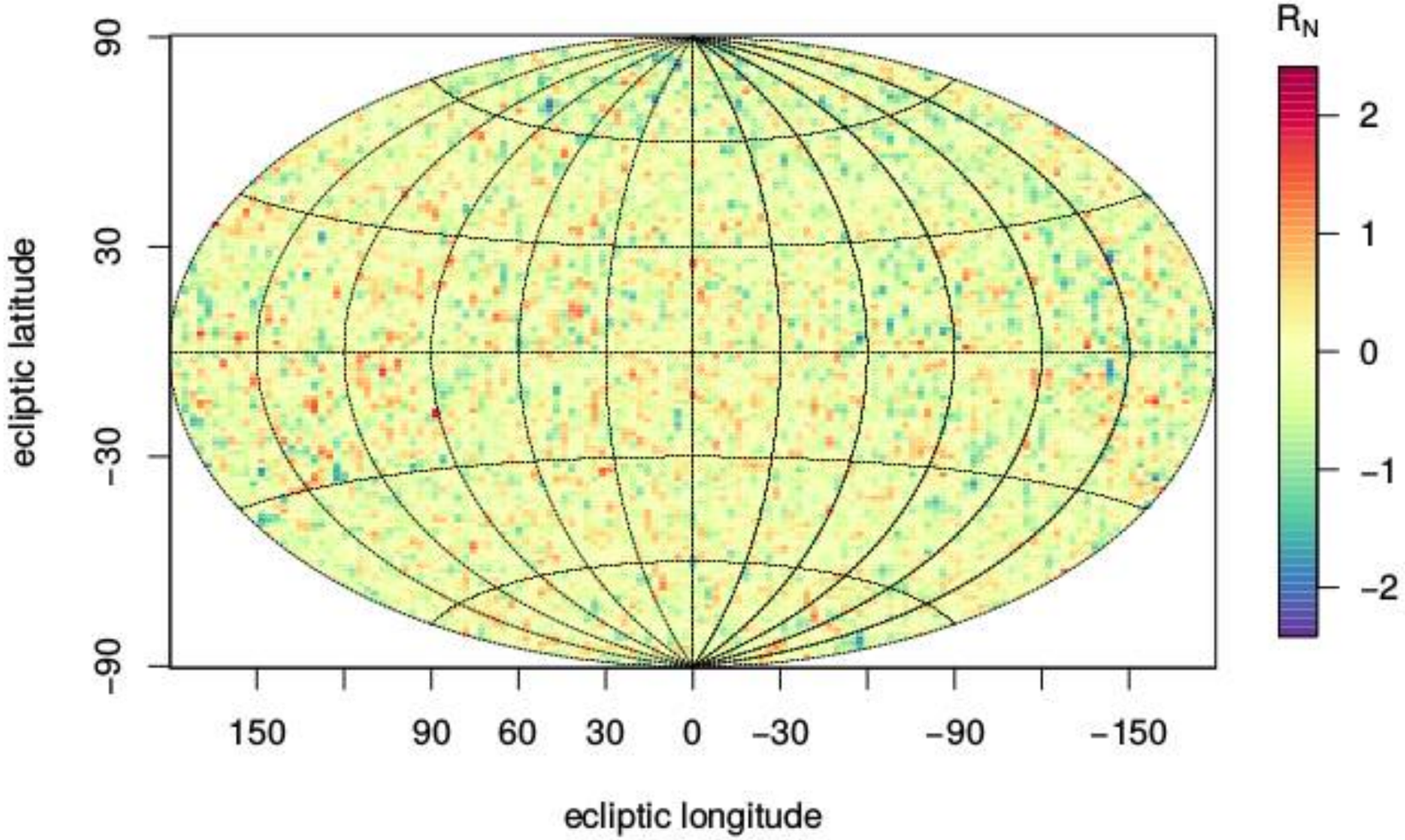


TGAS Parallaxes

Parallaxe zero point and uncertainties versus external catalogues

Catalogue	Outliers	ϖ difference	ϖ extra dispersion
Hipparcos	0.09%	-0.094 ± 0.004	0.58 ± 0.005
VLBI	0 / 9	0.083 ± 0.12	-
HST	2 / 19	-0.11 ± 0.19	0.6 ± 0.2
RECONS	0 / 13	-1.04 ± 0.58	-0.9 ± 0.5
VLBI & HST & RECONS	2 / 41	-0.08 ± 0.12	0.42 ± 0.13
Cepheids	0 / 207	-0.014 ± 0.014	-0.18 ± 0.01
RRLyrae	0 / 130	-0.07 ± 0.02	-0.16 ± 0.02
Cepheids & RRLyrae	0 / 337	-0.034 ± 0.012	-0.17 ± 0.01
RAVE	47 / 5144	0.07 ± 0.005	-0.06 ± 0.02
APOGEE	0 / 2505	-0.06 ± 0.006	-0.12 ± 0.01
LAMOST	6 / 317	-0.01 ± 0.02	-0.17 ± 0.02
PASTEL	1 / 218	0.05 ± 0.02	0.1 ± 0.05
APOKASC	0 / 969	-0.07 ± 0.009	-0.15 ± 0.01
LMC	2 / 142	0.11 ± 0.02	-0.14 ± 0.03
SMC	0 / 58	-0.12 ± 0.05	-0.09 ± 0.09
ICRF2 QSO auxiliary solution	1 / 2060	-0.046 ± 0.01	-0.17 ± 0.01

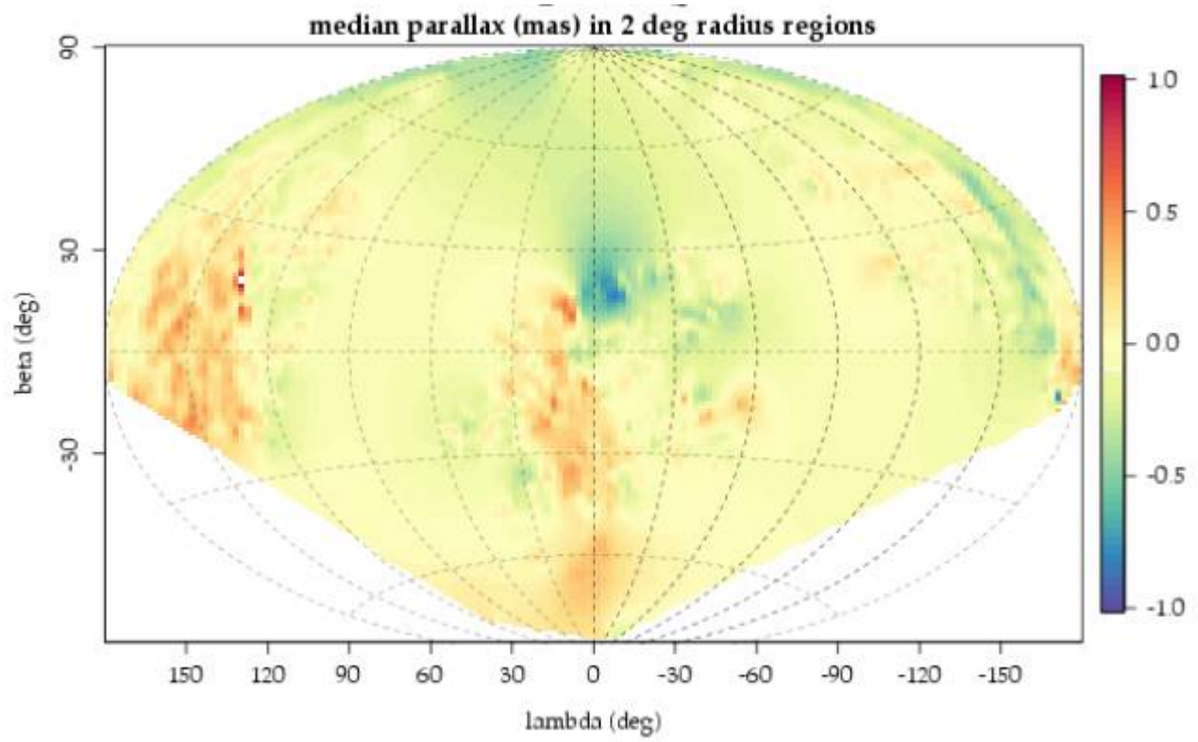
TGAS parallaxes versus Hipparcos



TGAS Parallaxes

QSO auxiliary (5-parameter) solution:

- 10% of the sky with $|\varpi|>0.3$
- Mediane: 0.04 mas

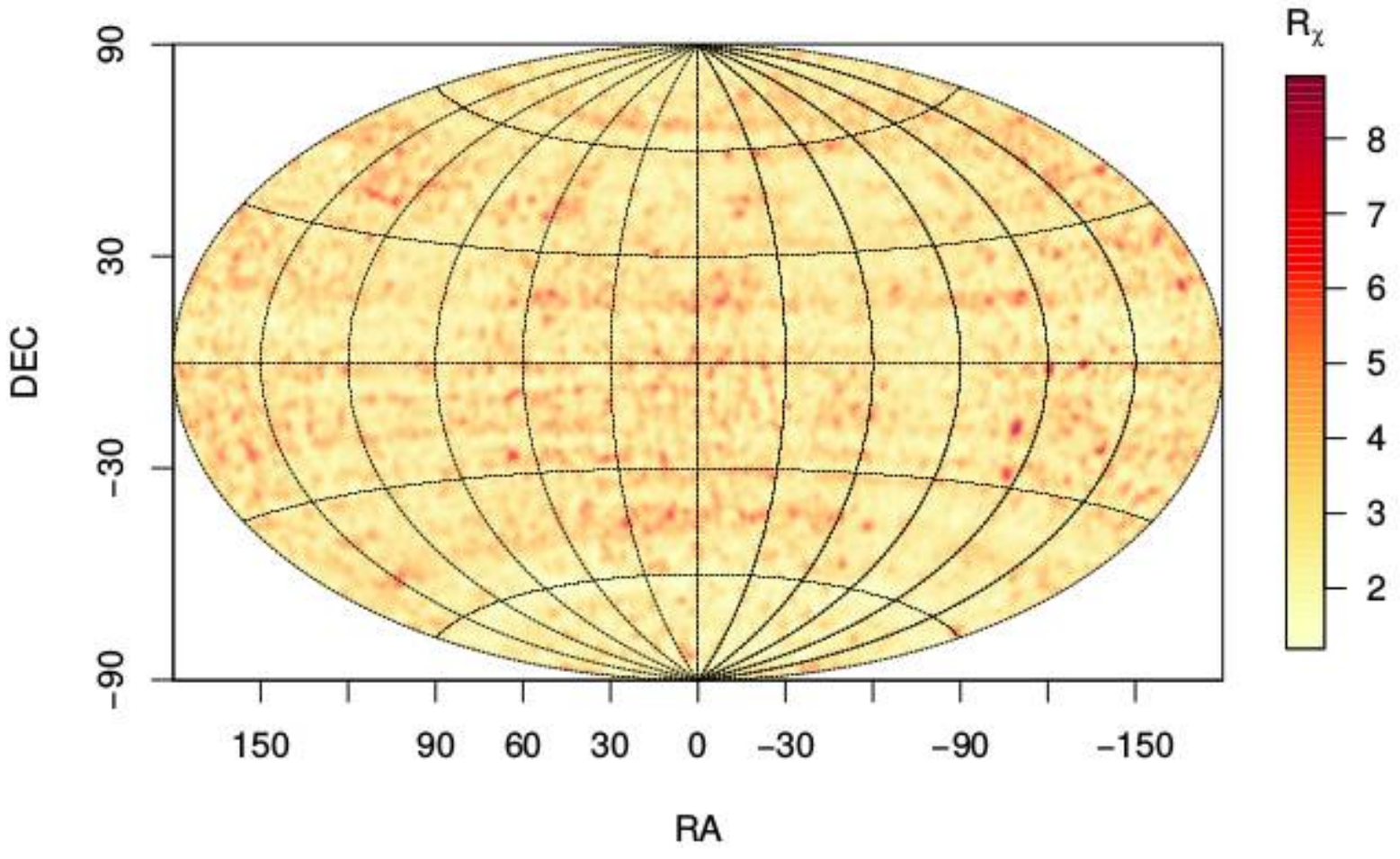


→ local systematics at the same level as the uncertainties :

→ no √N improvement (e.g. clusters...)

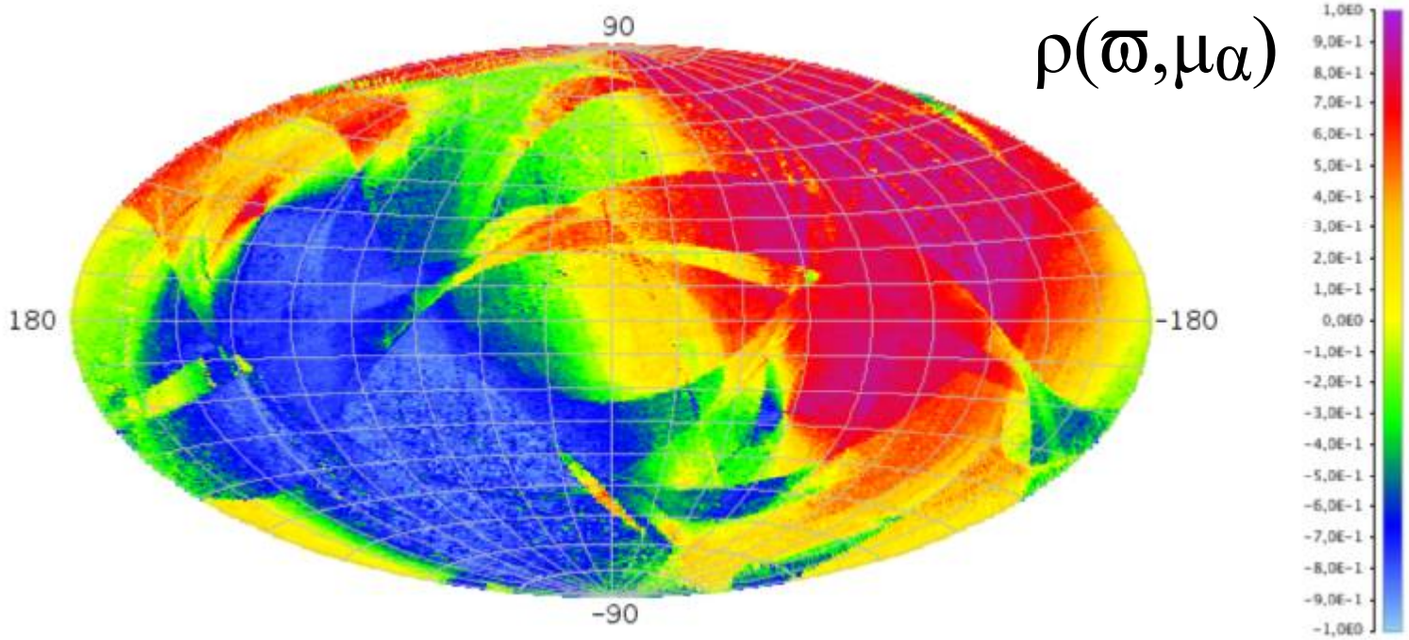
→ $\varpi = x \pm \sigma$ (rand.) **$\pm$ 0.3 (syst.)** mas

TGAS proper motions versus Tycho-2

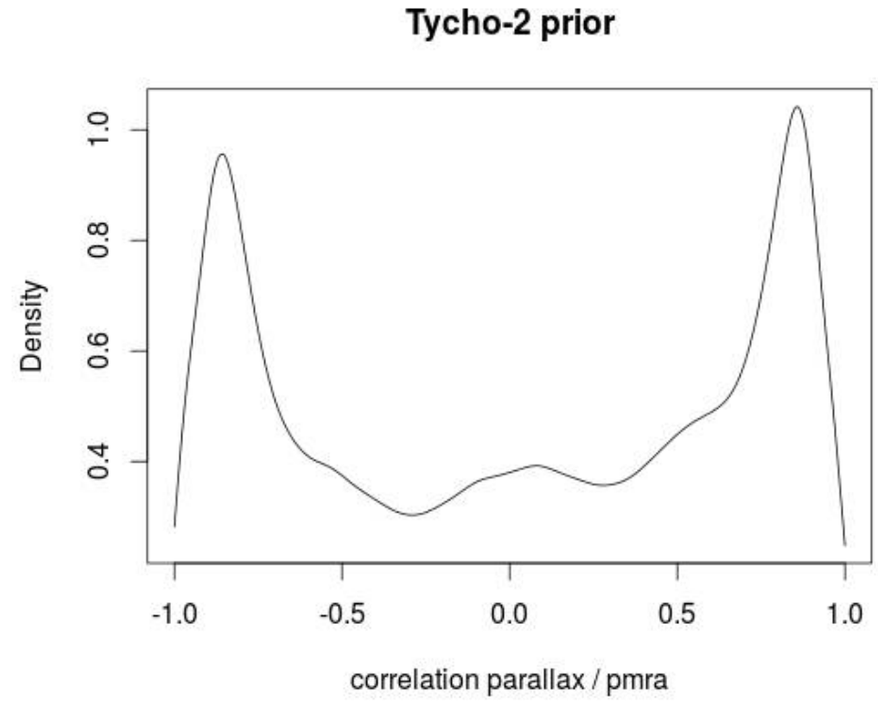


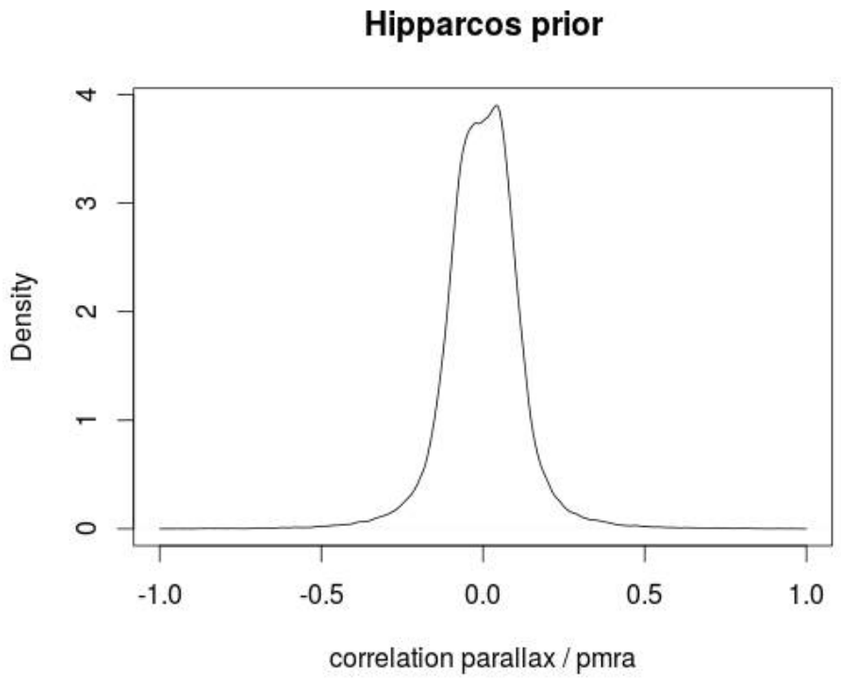
TGAS correlations

Significant correlations between astrometric parameters, need to be taken into account



$\rho(\varpi,\mu_\alpha)$

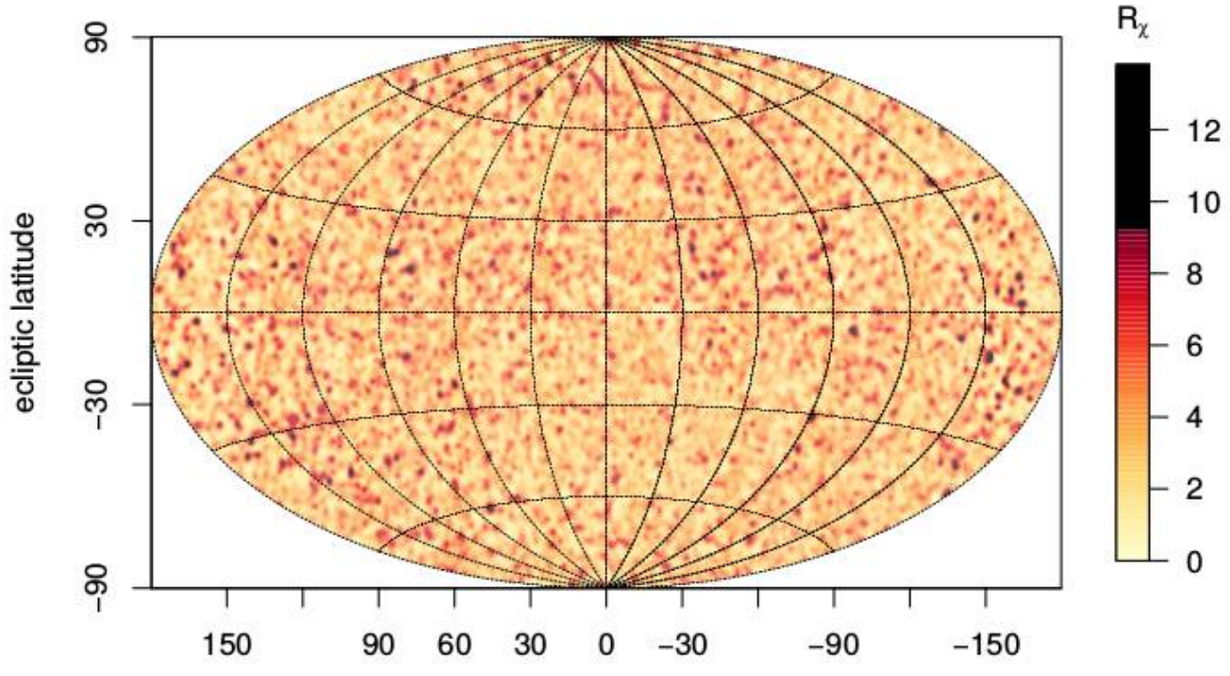


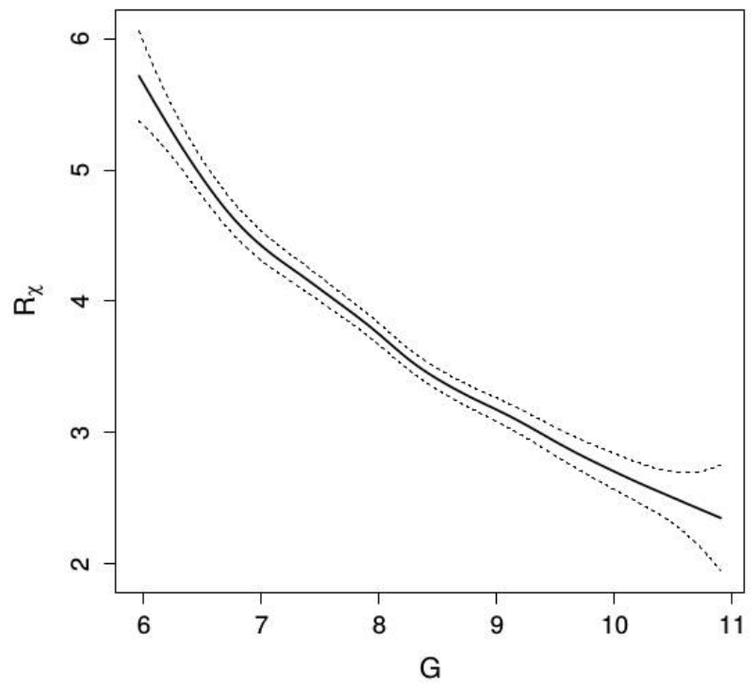


DR1 correlations

- Extra correlations may be missing (attitude/calibration issues)

- Chi2 test shows increase of the global residuals with magnitude in the comparison with Hipparcos proper motions and QSOs positions (not seen in the individual parameters residuals)





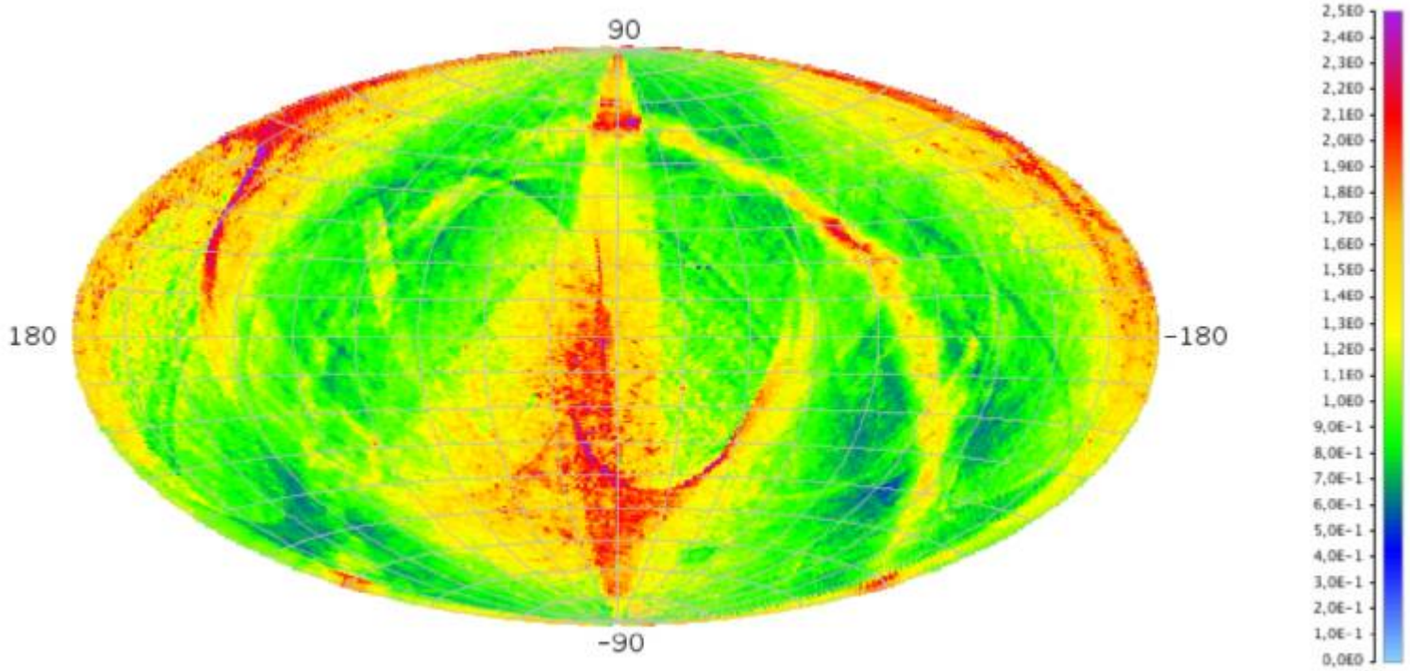
How to detect problematic stars ?

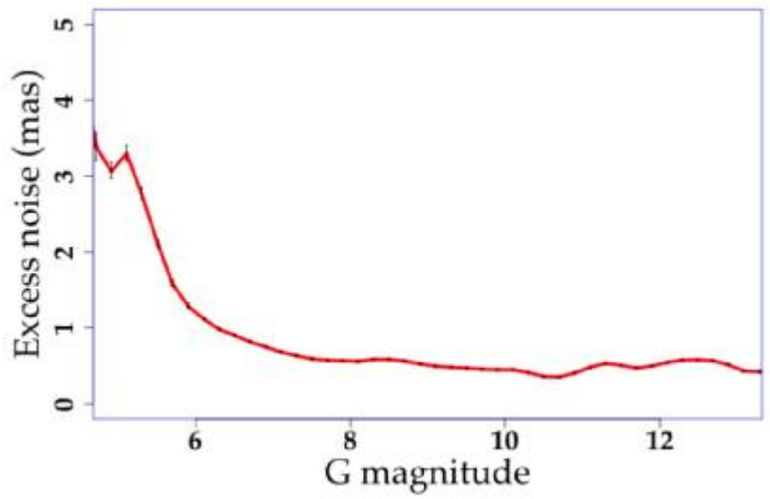
- Binaires
- Visual pairs
- Calibration issues (PSF fit, attitude...)

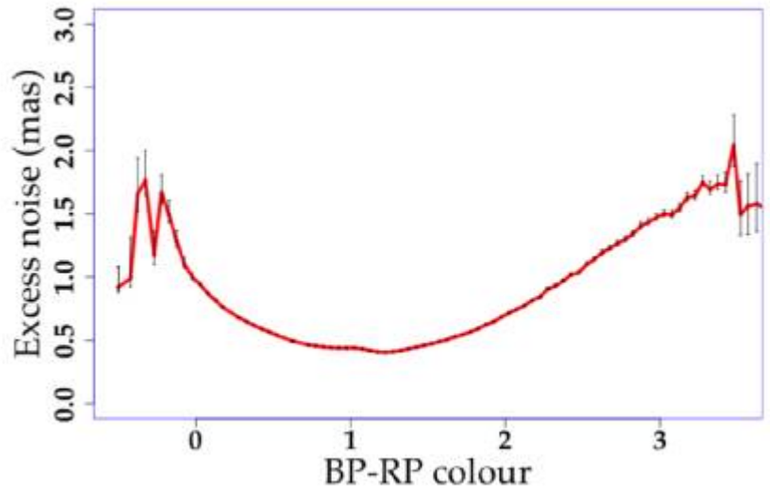
  → excess noise

  → correlations, scanStrenght, nbobs...

Excess noise

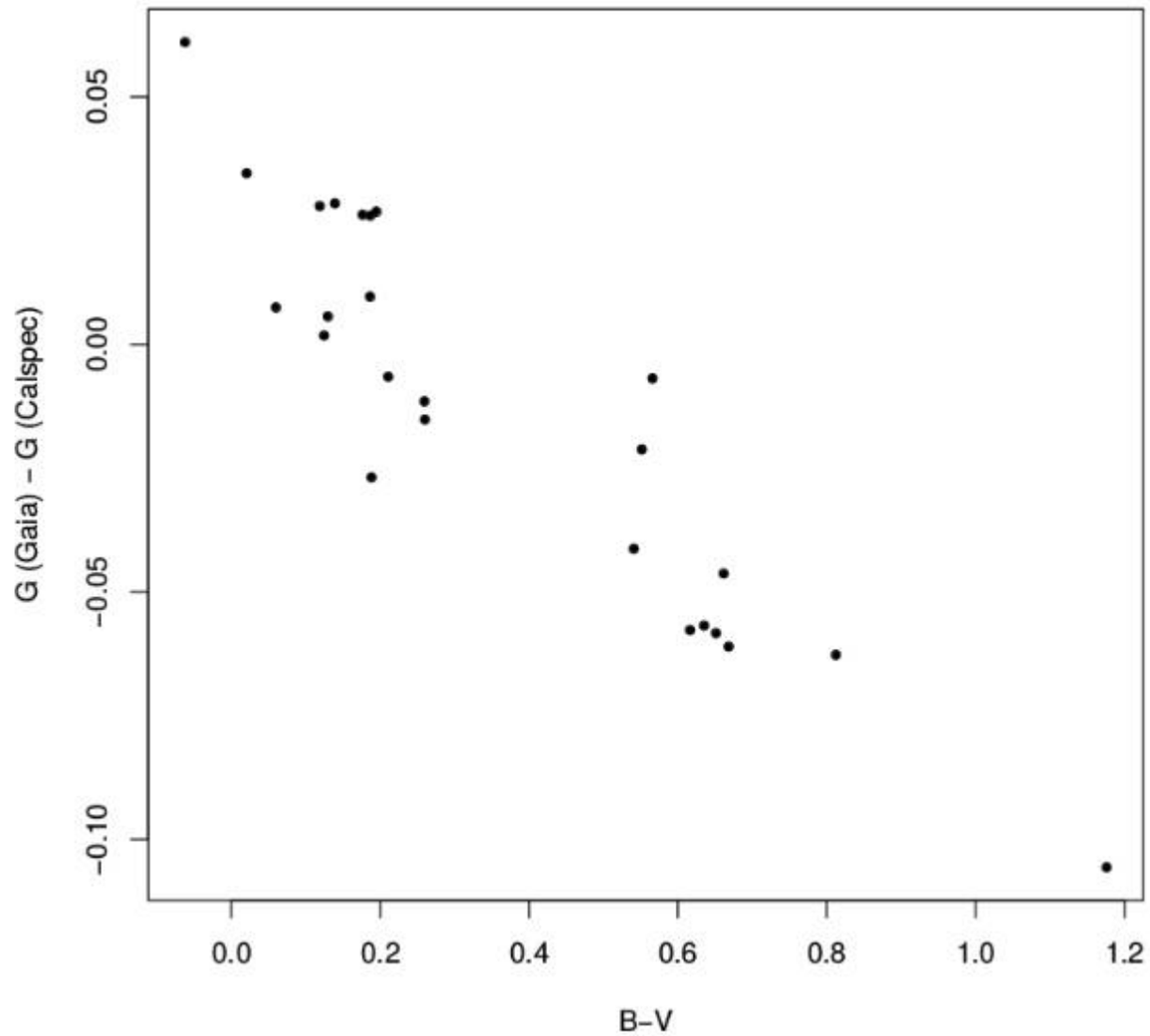






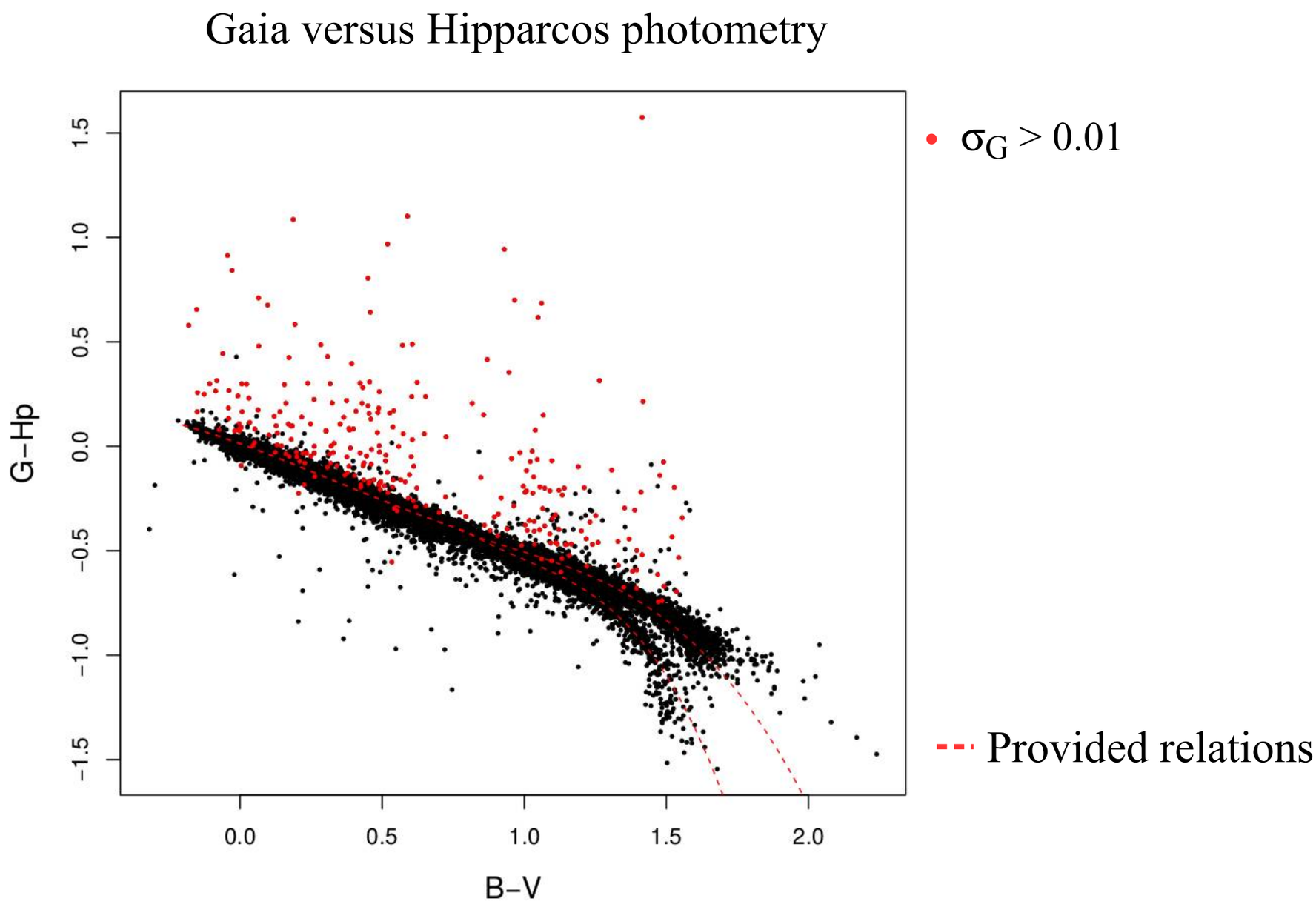
DR1 photometry

- No filter model available for DR1



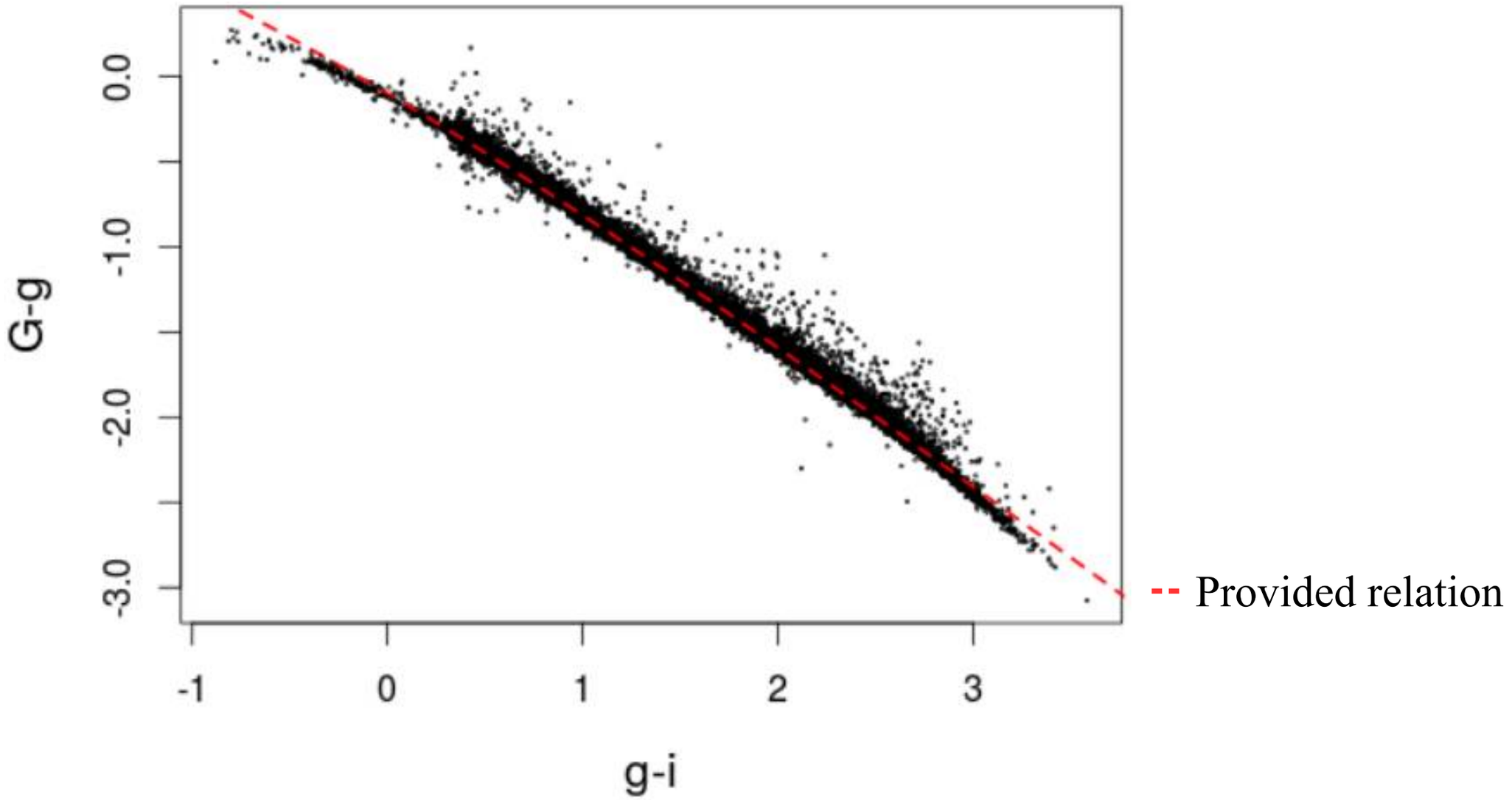
→ photometric transformations provided in the release documentation

DR1 photometric outliers

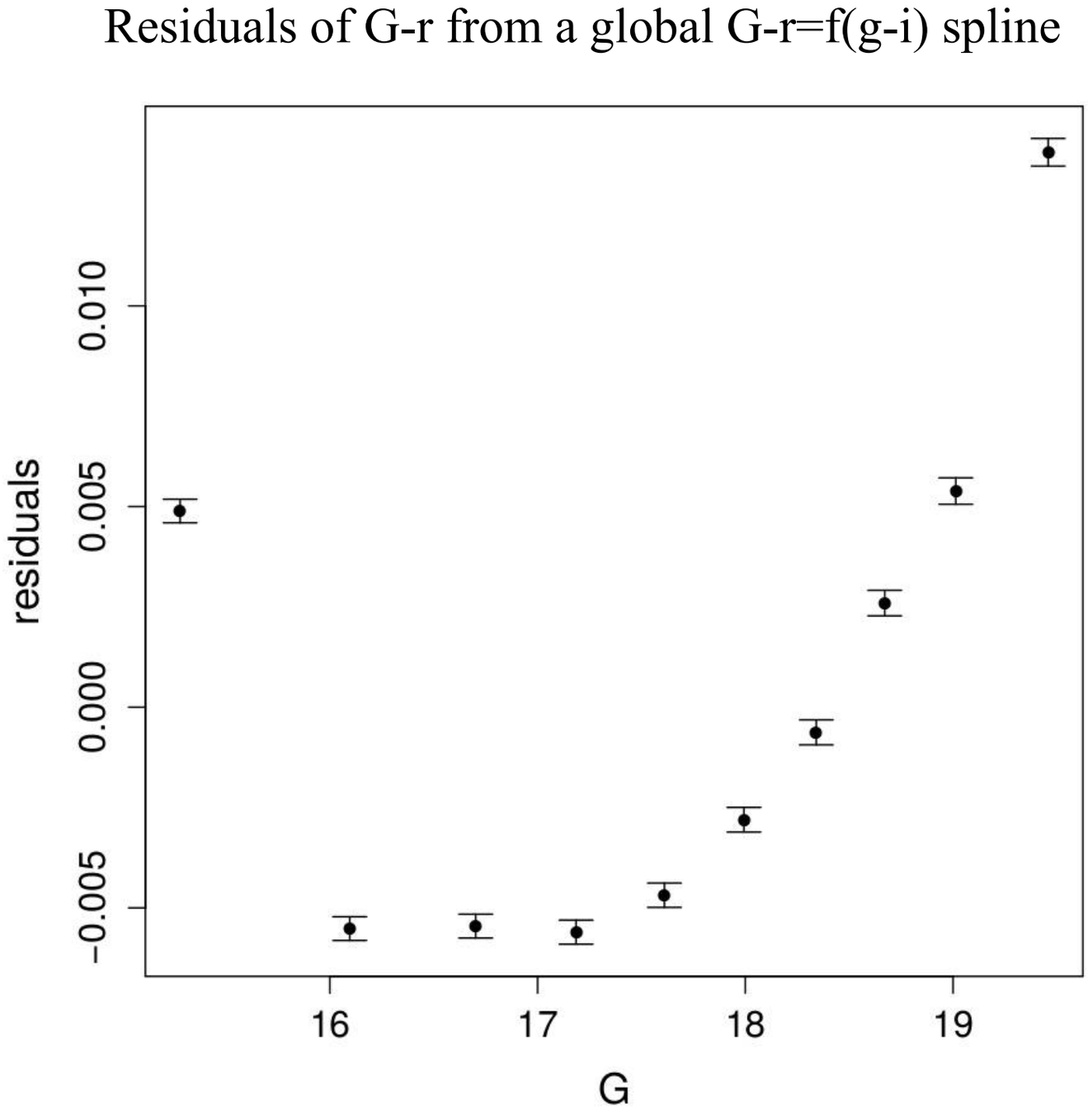


DR1 photometry

Comparison with SDSS tertiary standards of Betoule et al. 2013

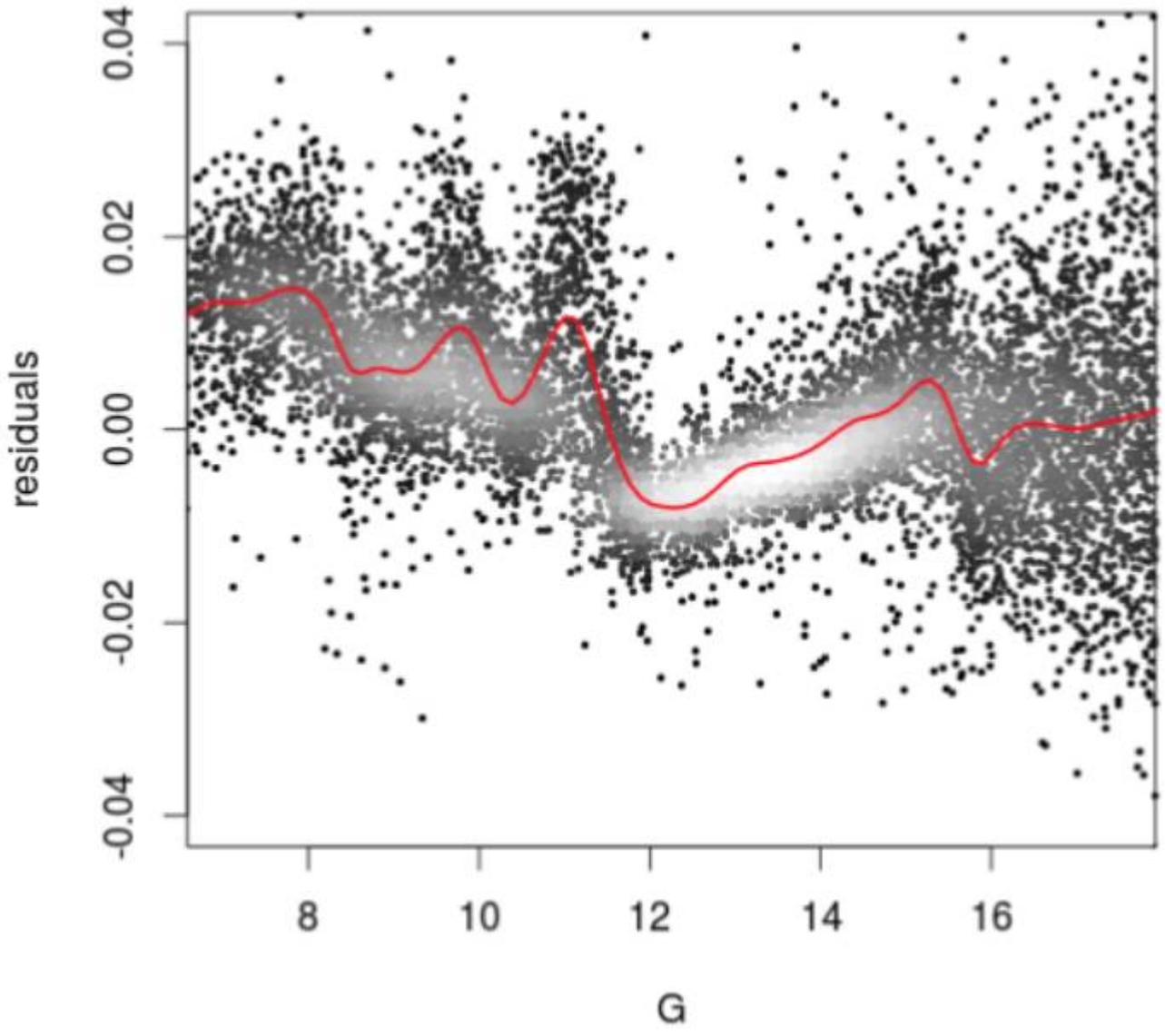


DR1 photometric systematics



DR1 photometric systematics

Residuals of $G-G_{RP}$ from a global $G-G_{RP}=f(G_{BP}-G_{RP})$ spline



Data access

Main portal: `http://archives.esac.esa.int/gaia`

- Online documentation, VO compatible, TAP interface, visualization apps
- Pre-computed cross-match to large catalogues: UCAC4, 2MASS, SDSS, GSC2, WISE, PPMXL, URAT1

  +

- Fast visualization and analysis entire DR1: `http://vaex.astro.rug.nl`
- Command line access: `https://pypi.python.org/pypi/pygacs`

Partner data centres

- CDS: `http://cds.unistra.fr/gaia`
- ASDC: `http://gaiaportal.asdc.asi.it`
- ARI: `http://gaia.ari.uni-heidelberg.de`
- AIP: `http://gaia.aip.de`

Gaia DR1 - conclusion

- Significant increase in the amount and precision of astrometry and photometry

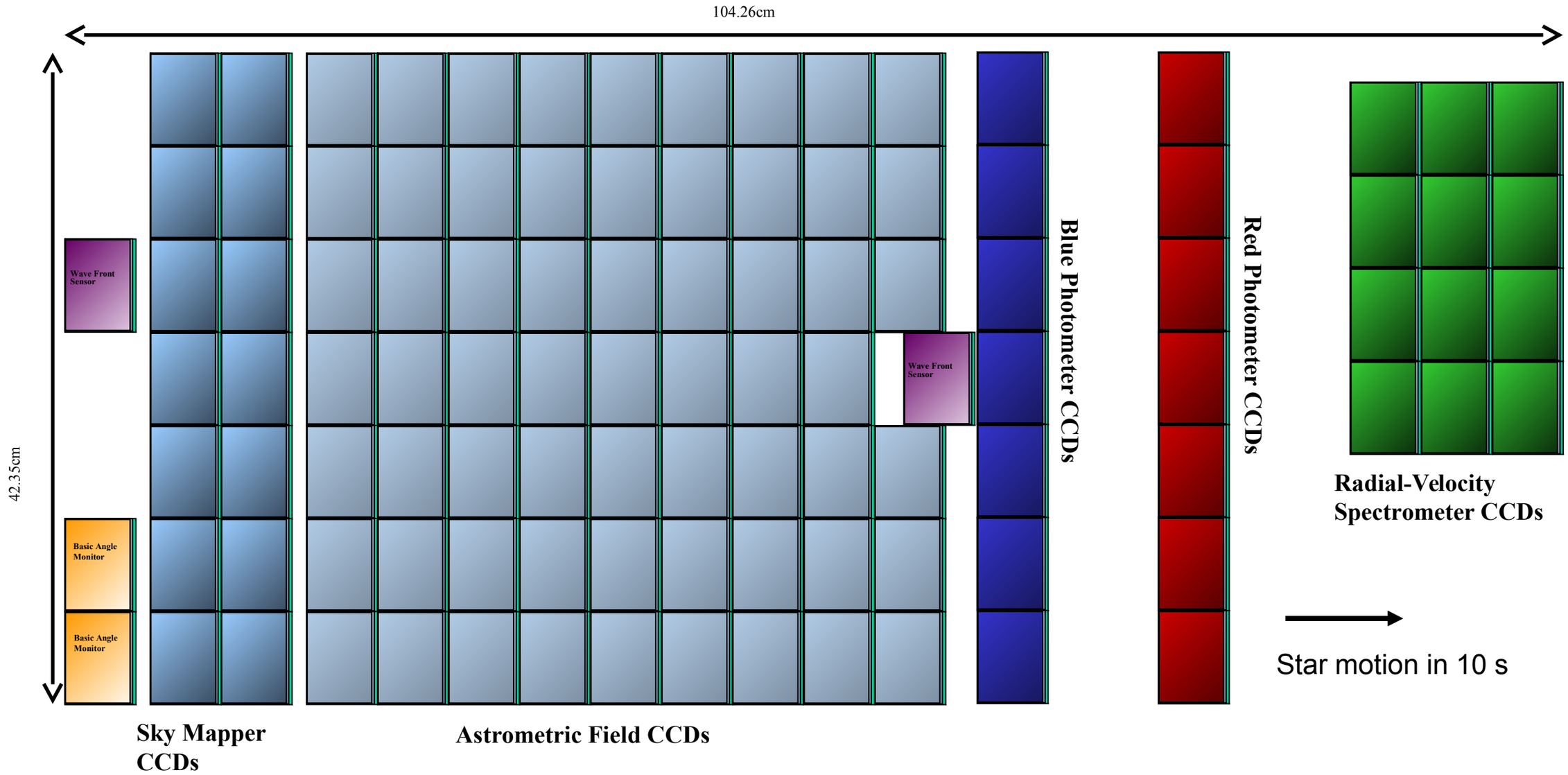
- Preliminary data with issues to take into account in the exploitation

- Major improvements already planned for DR2 in ~ 1 year:
  - 1 billion parallaxes
  - Photometry $G/G_{BP}/G_{RP}$
  - Radial velocity for the brightest stars
  - …

Gaia: complete, faint, accurate

	Hipparcos	Gaia
Magnitude limit	12 mag	20.7 mag
Completeness	7.3 – 9.0 mag	20 mag
Bright limit	0 mag	3 mag (assessment for brighter stars ongoing)
Number of objects	120,000	47 million to G = 15 mag
		360 million to G = 18 mag
		1192 million to G = 20 mag
Effective distance limit	1 kpc	50 kpc
Quasars	1 (3C 273)	500,000
Galaxies	None	1,000,000
Accuracy	1 milliarcsec	7 μarcsec at G = 10 mag
		26 μarcsec at G = 15 mag
		600 μarcsec at G = 20 mag
Photometry	2-colour (B and V)	Low-res. spectra to G = 20 mag
Radial velocity	None	15 km s^{-1} to G_{RVS} = 16 mag
Observing	Pre-selected	Complete and unbiased

The Gaia Focal Plane



Total field:
- active area: 0.75 deg^2
- CCDs: 14 + 62 + 14 + 12 (+ 4)
- 4500 x 1966 pixels (TDI)
- pixel size = 10 μm x 30 μm
  = 59 mas x 177 mas

Sky mapper:
- detects all objects to G=20 mag
- rejects cosmic-ray events
- field-of-view discrimination

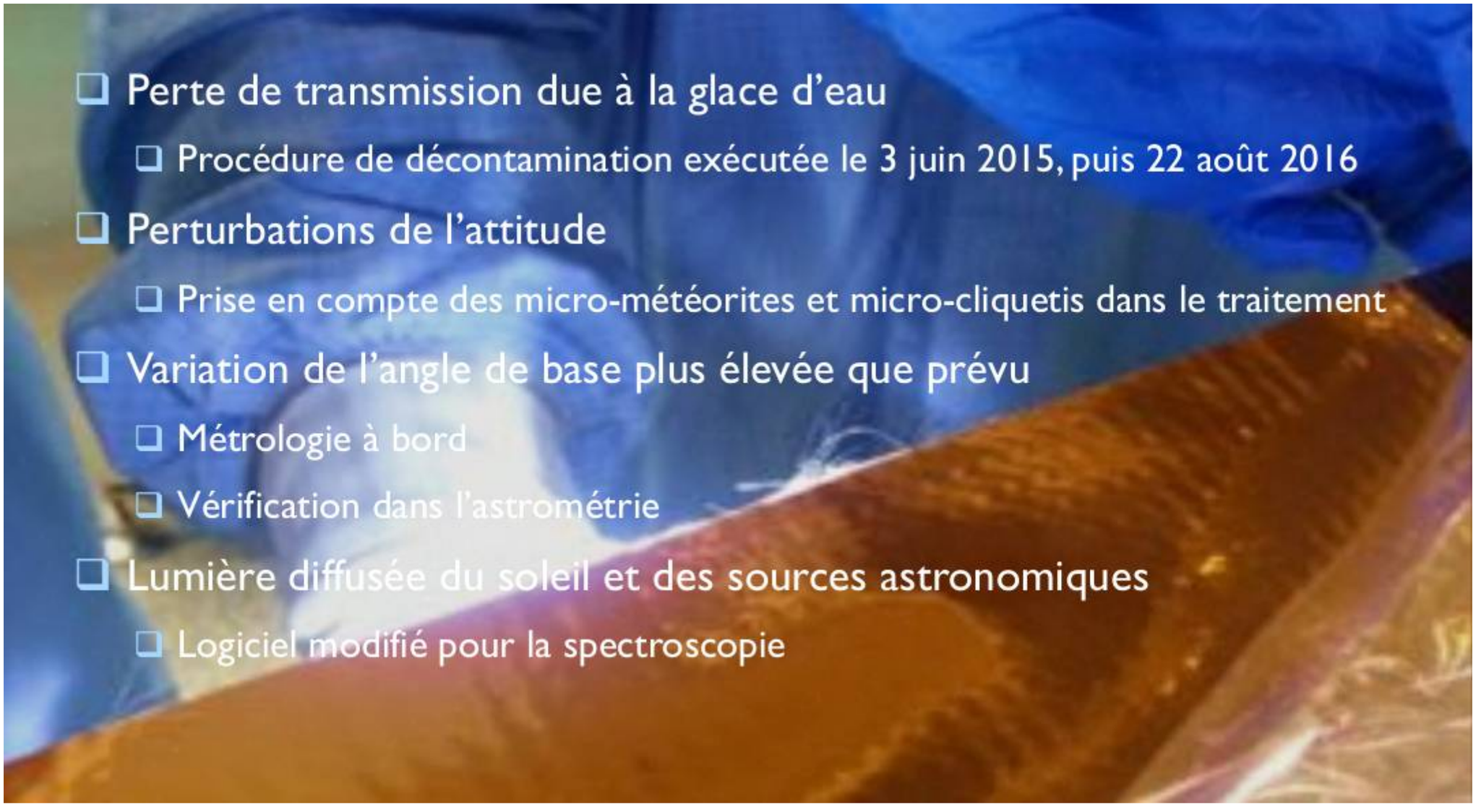
Astrometry:
- total detection noise ~ 4 e$^-$

Photometry:
- spectro-photometer
- blue and red CCDs

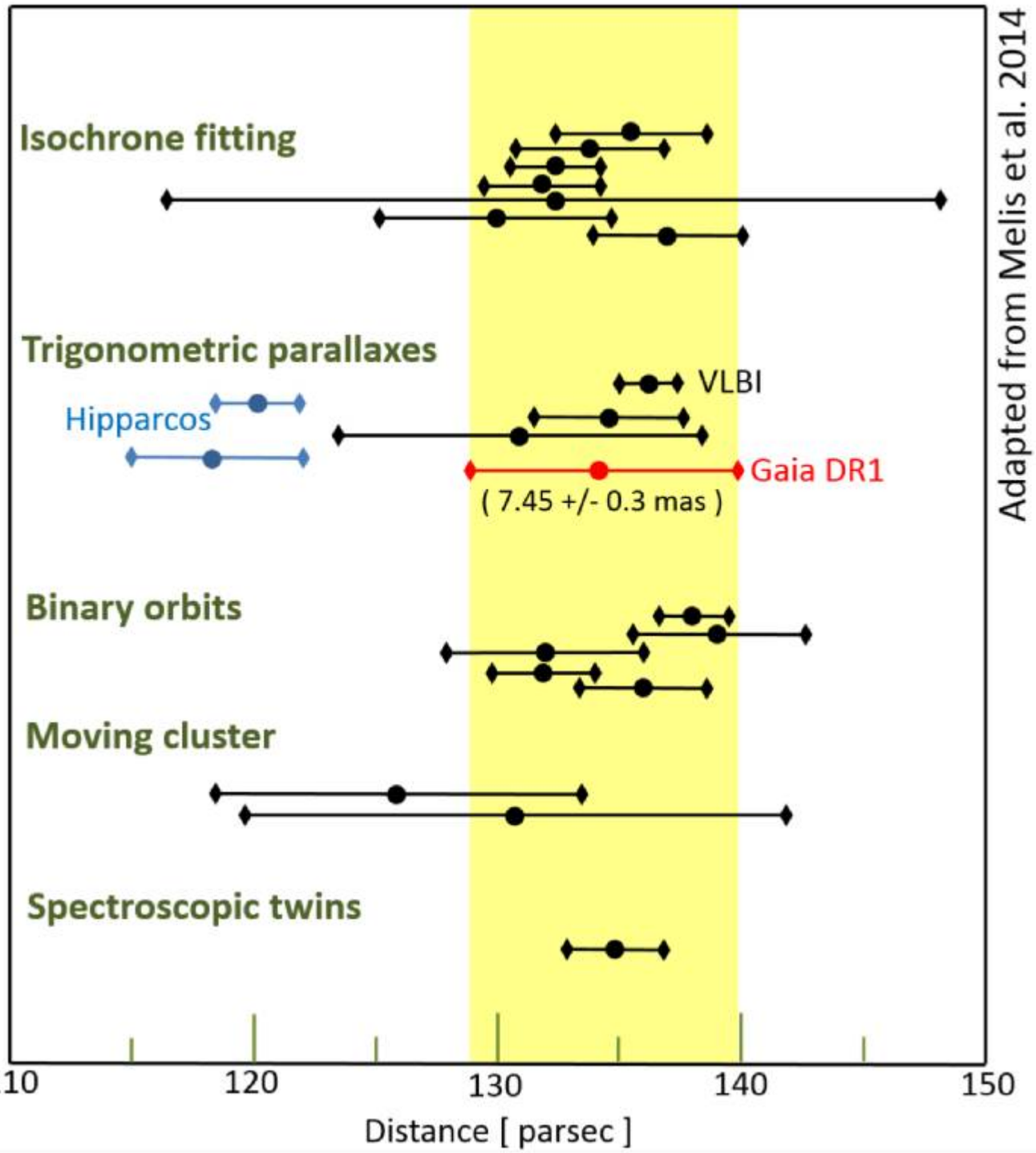
Spectroscopy:
- high-resolution spectra
- red CCDs

Figure courtesy Alex Short

The bad surprises



Pleiades



- Pleiades distances not (yet?) incompatible with Hipparcos
- Other clusters in common with Hipparcos give coherent results

Gaia Collaboration, Brown et al. 2016, A&A