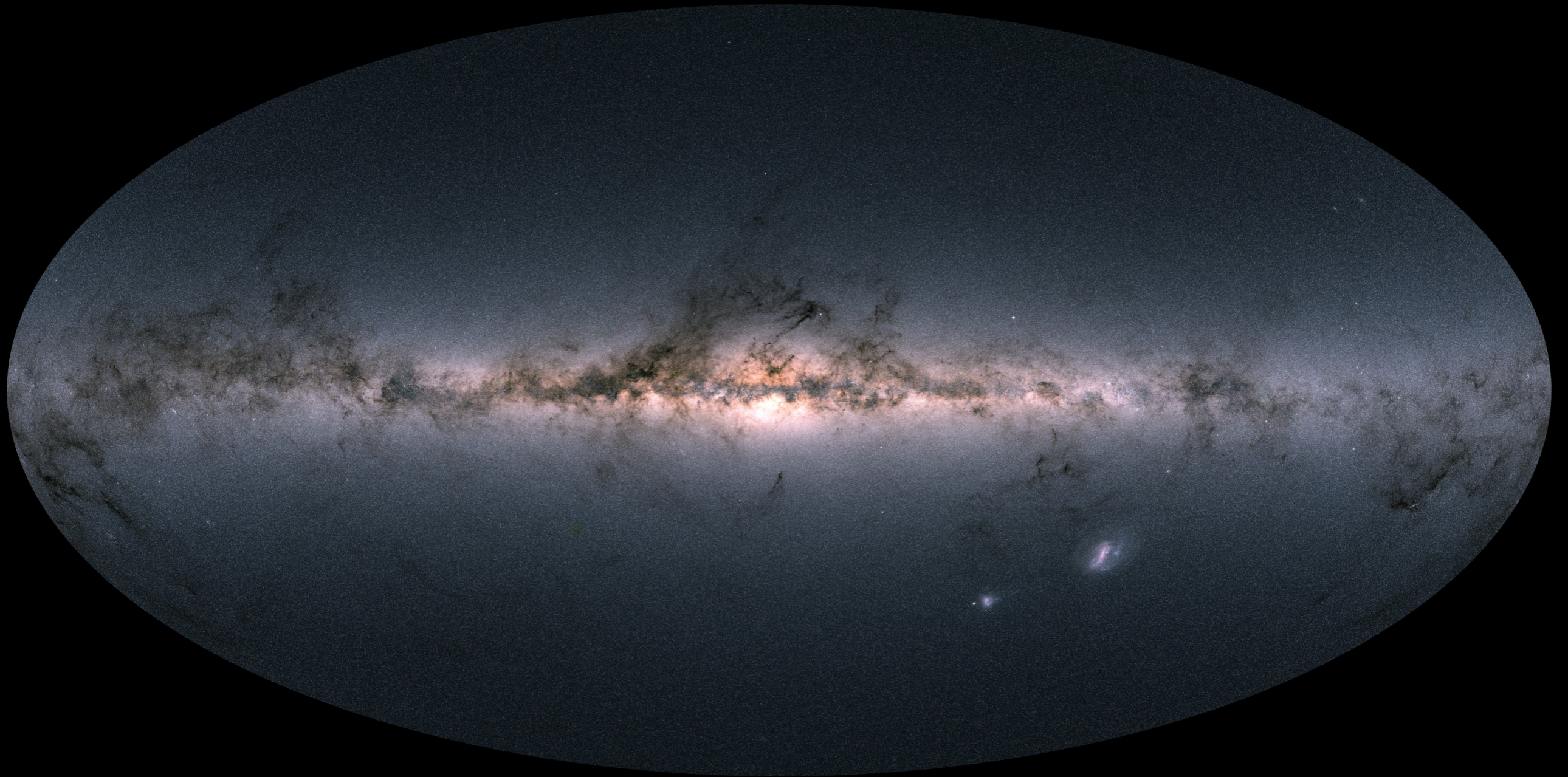




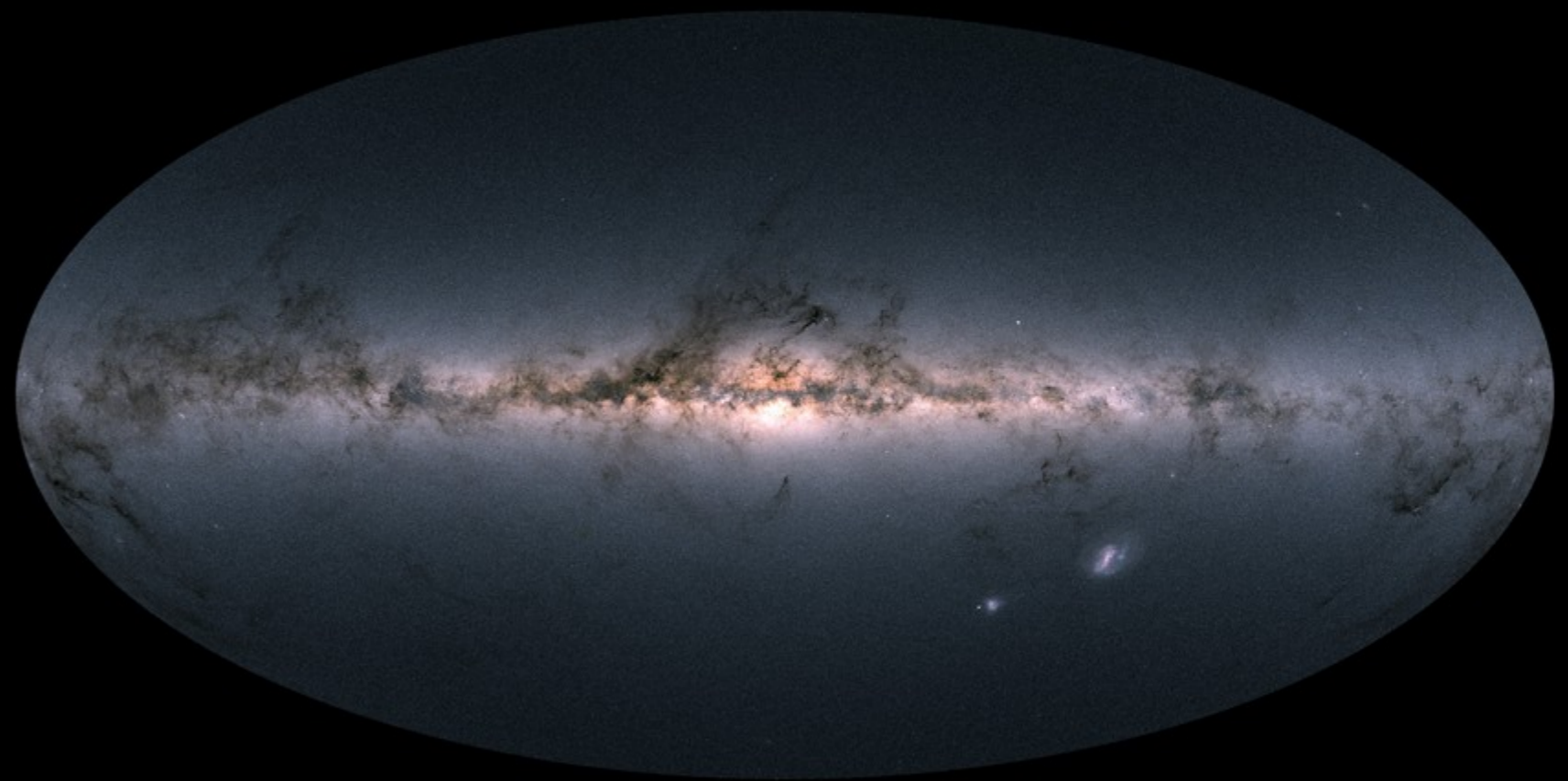
Gaia DR2



Carine Babusiaux
IPAG / OBSPM

The second Gaia data release

- Gaia mission overview
- Gaia DR2 content and limitations
- A few (biased!) applications



The Gaia mission

ESA cornerstone mission

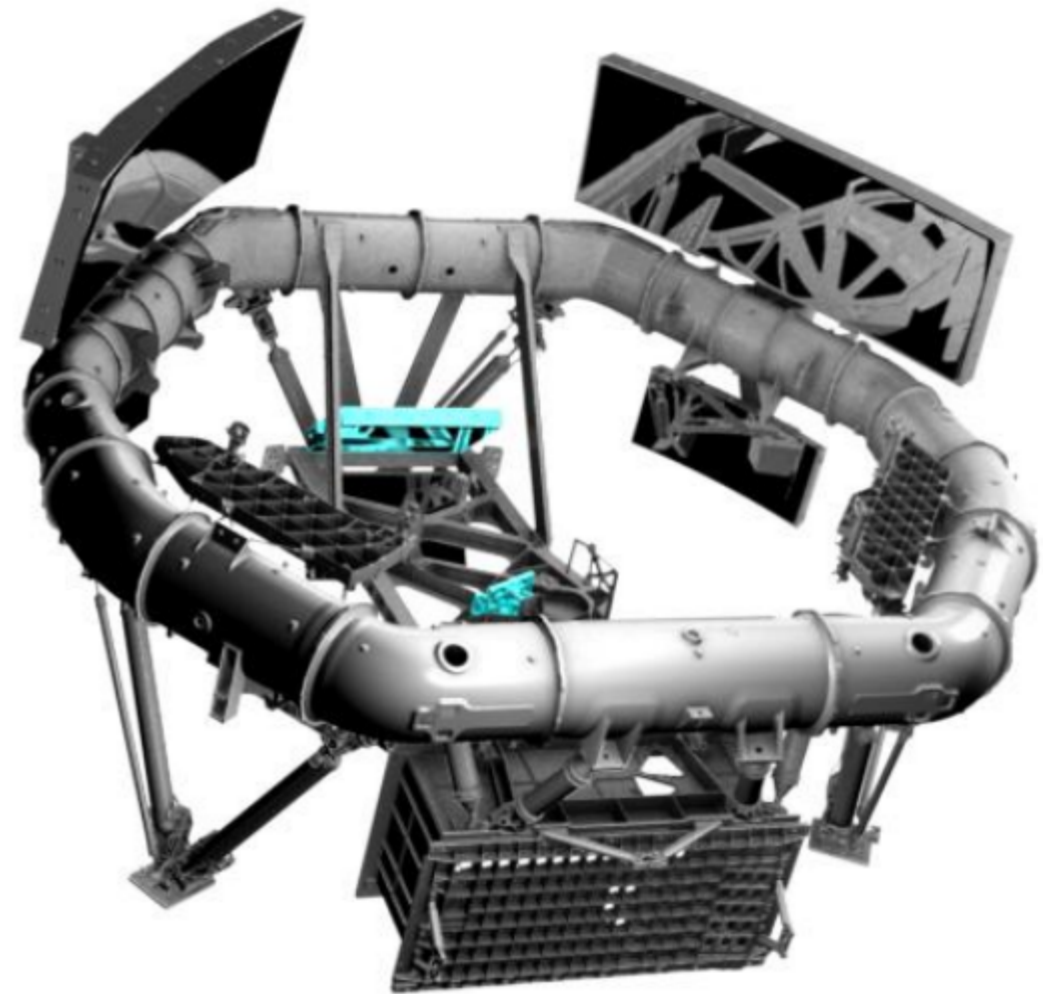
5 years (+) of mission

3 instruments

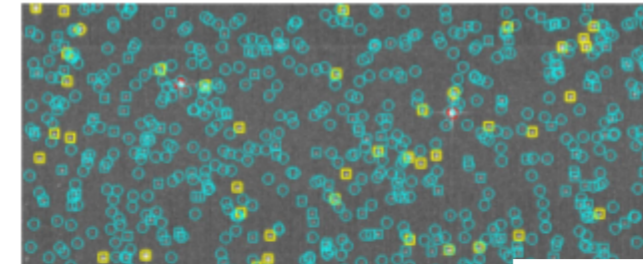
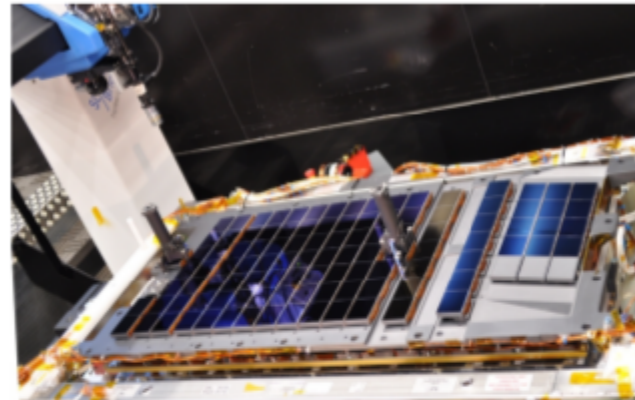
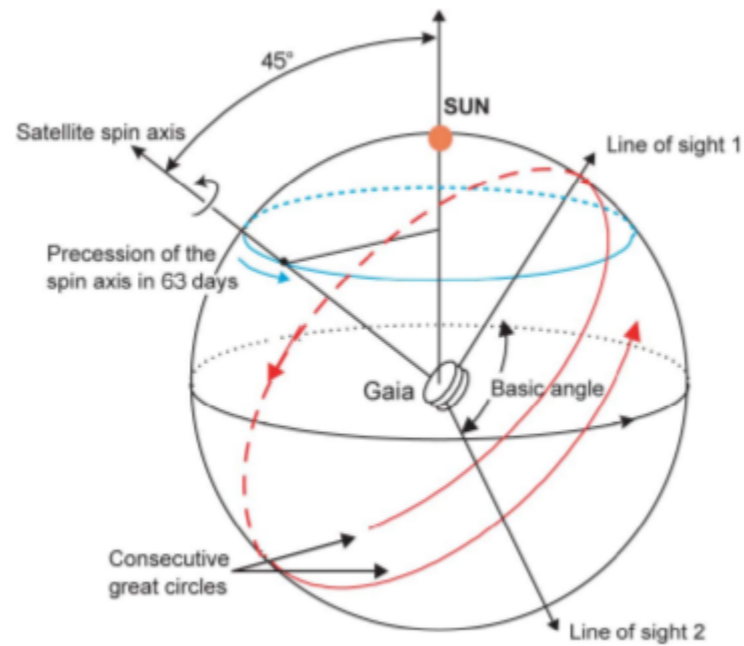
- Astrometry
- Spectrophotometry
- Spectroscopy (RVS)

> 1 billion stars $3 < G < 20.7$

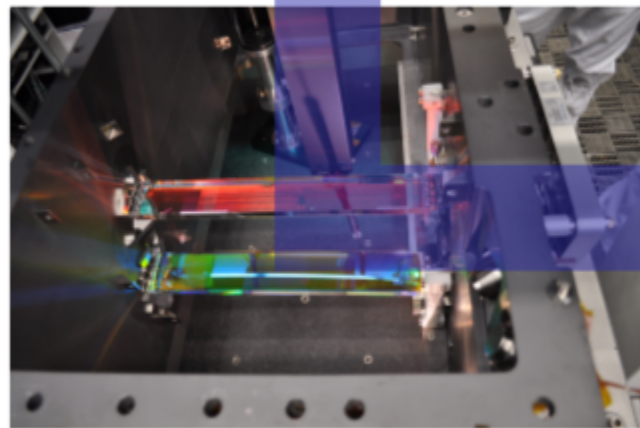
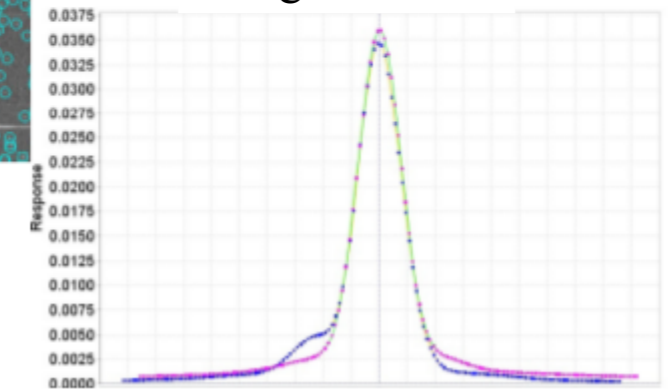
~ 70 observations per source



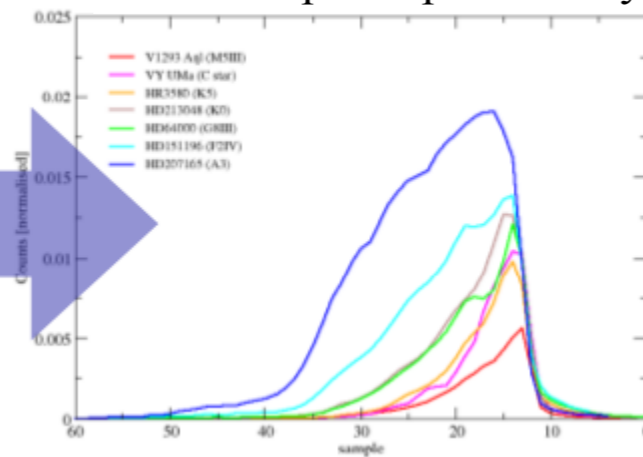
Gaia instruments and measurements



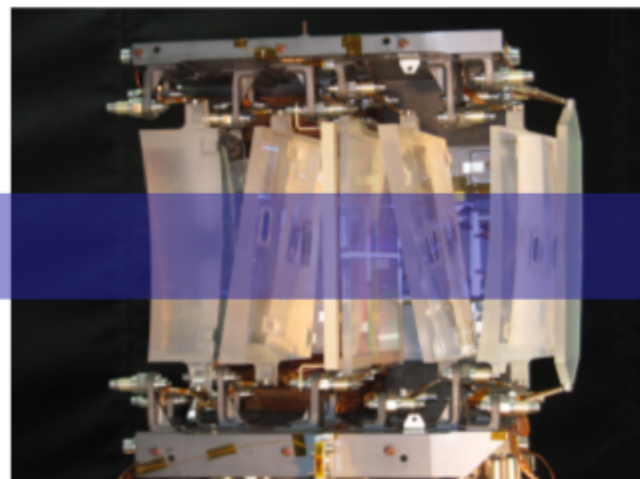
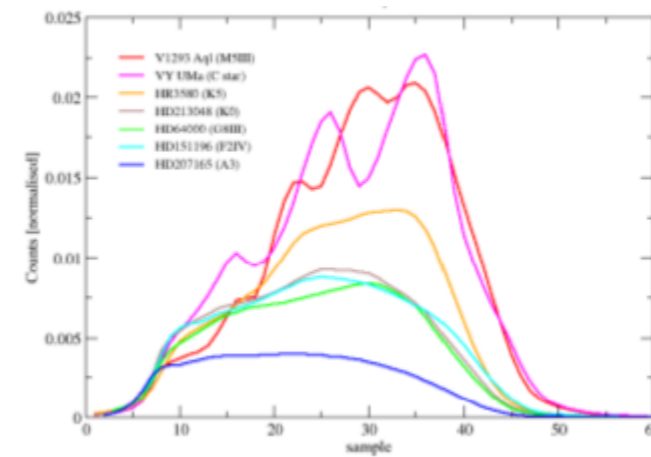
along scan LSF



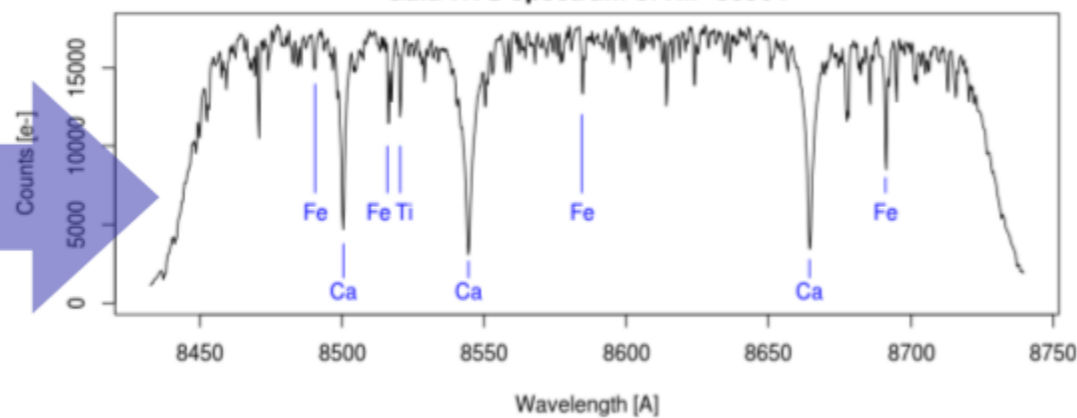
Gaia BP spectrophotometry



Gaia RP spectrophotometry



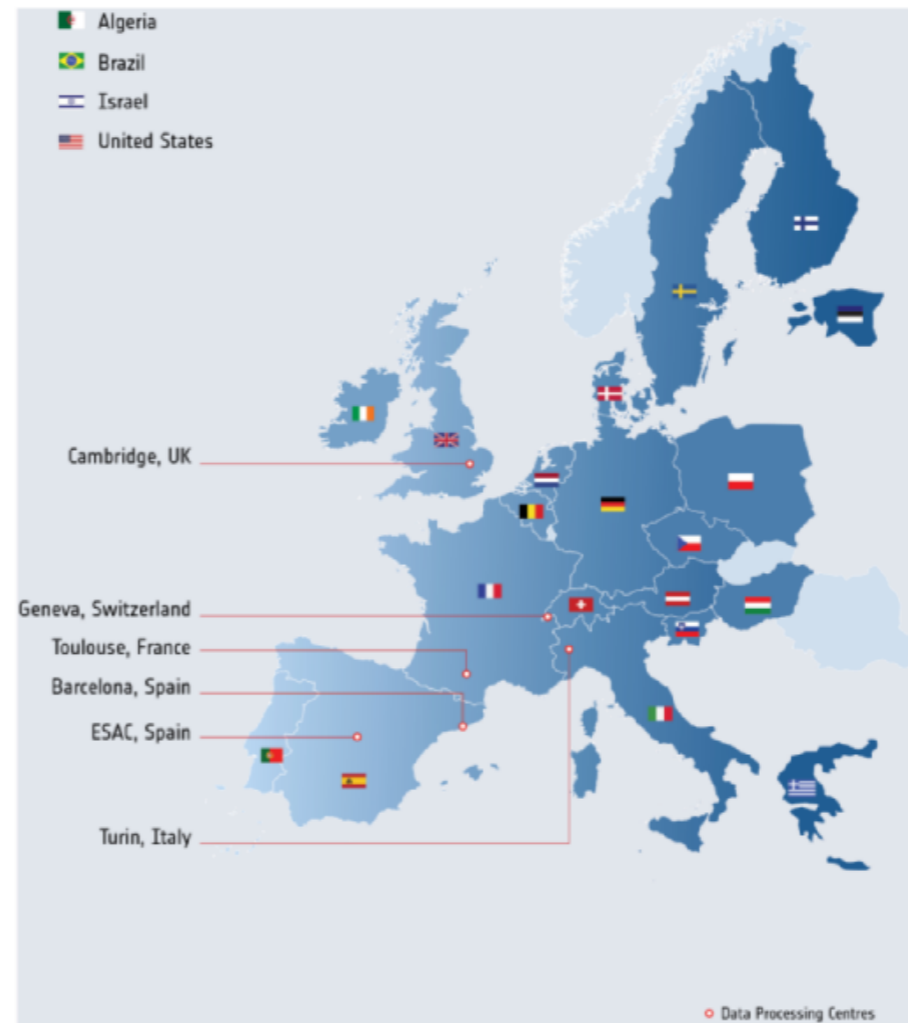
Gaia-RVS spectrum of HIP 86564



Figures:
ESA/Gaia/DPAC/Airbus DS

Teamwork to deliver the promise of Gaia

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

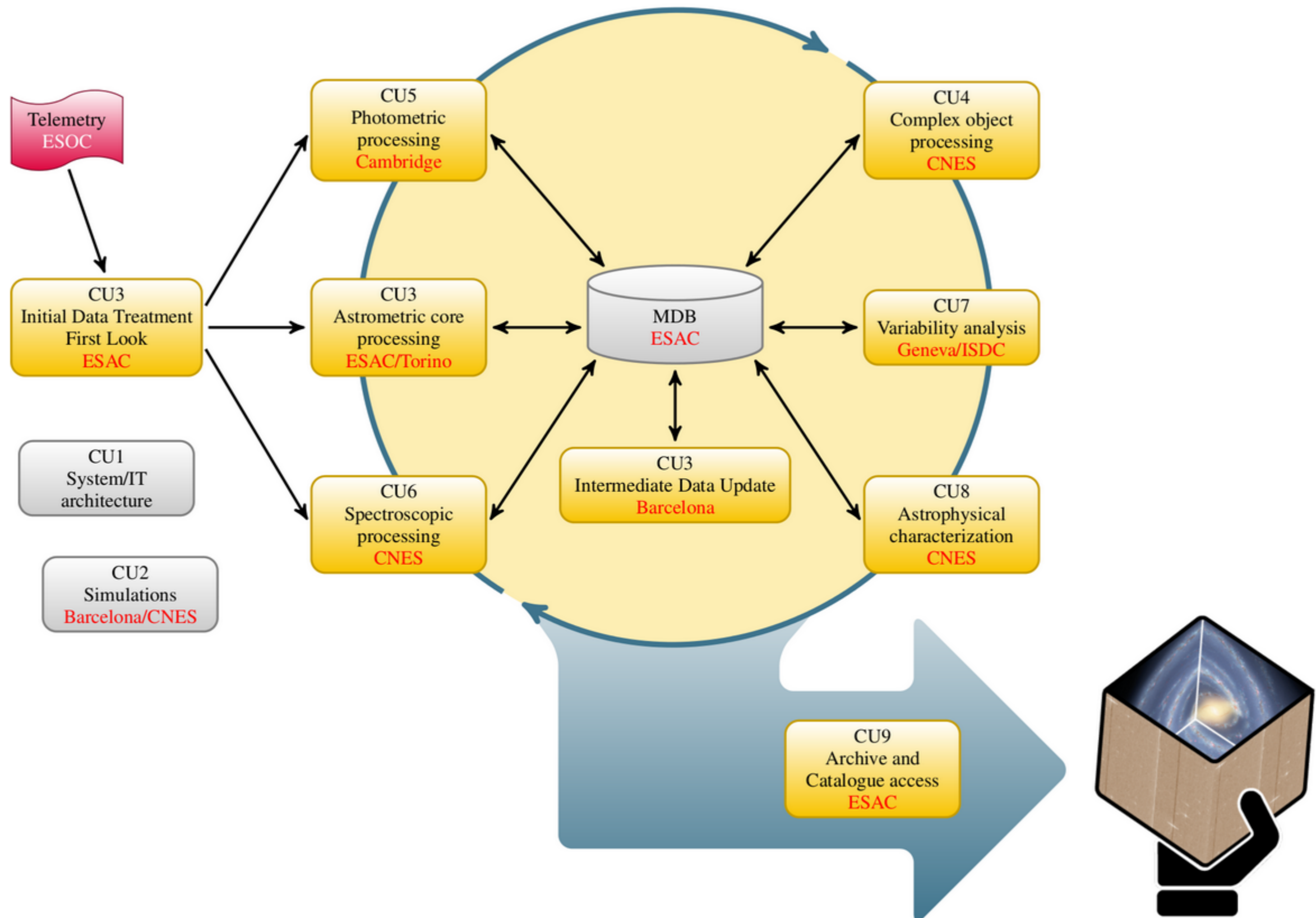


0 1 0 0 0 0 0 1 1 0 0 1 0 0 1 1 0 0 1 1 0 0 1 1 0 0 1 0 1 0



α δ ϖ μ α* Η δ G ...

Gaia data processing



The Gaia schedule

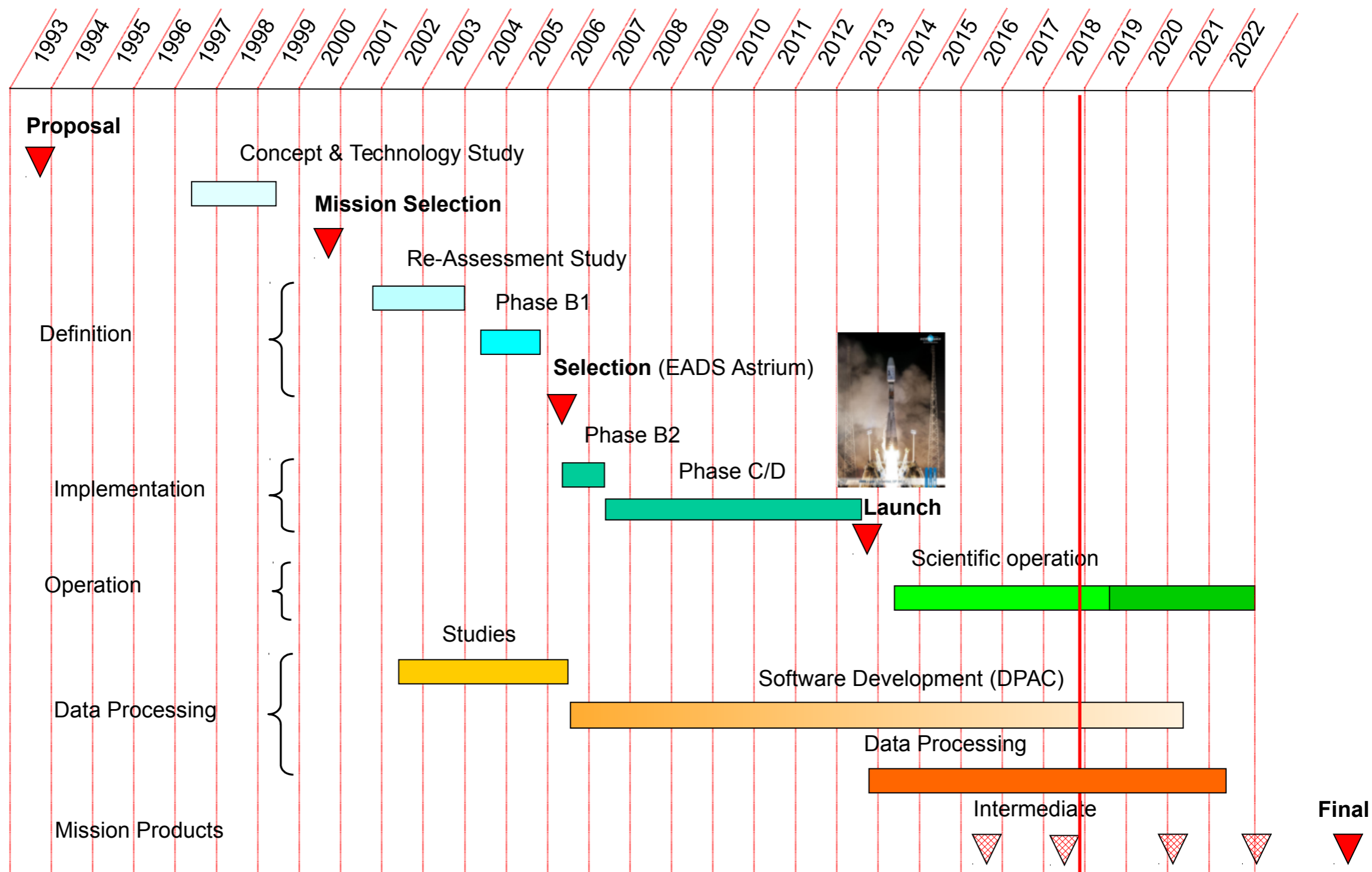
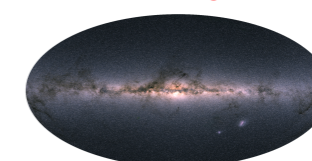


Figure adapted from Michael Perryman and François Mignard

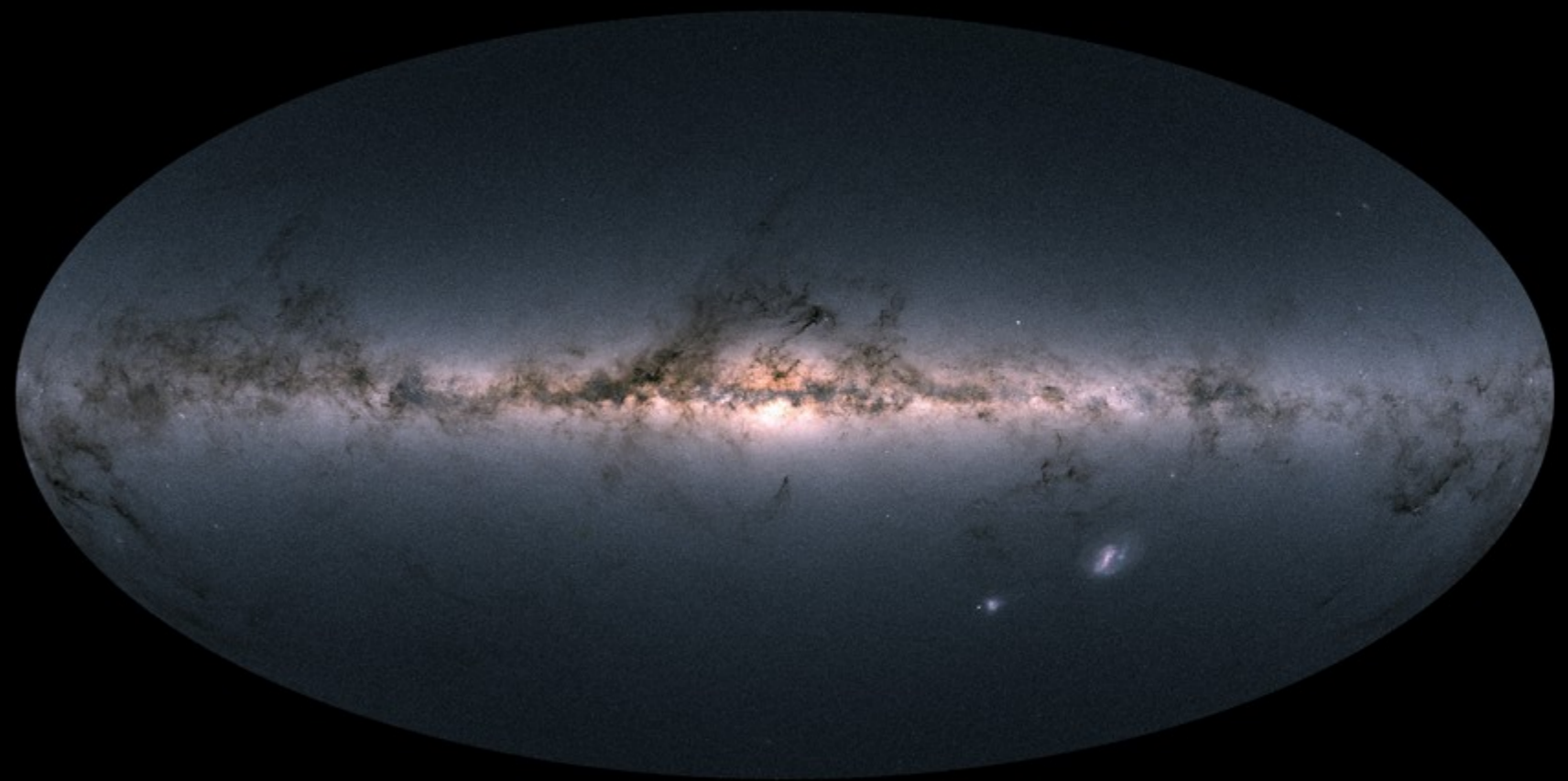
Today



Final

The second Gaia data release

- Gaia mission overview
- **Gaia DR2 content and limitations**
- A few (biased!) applications

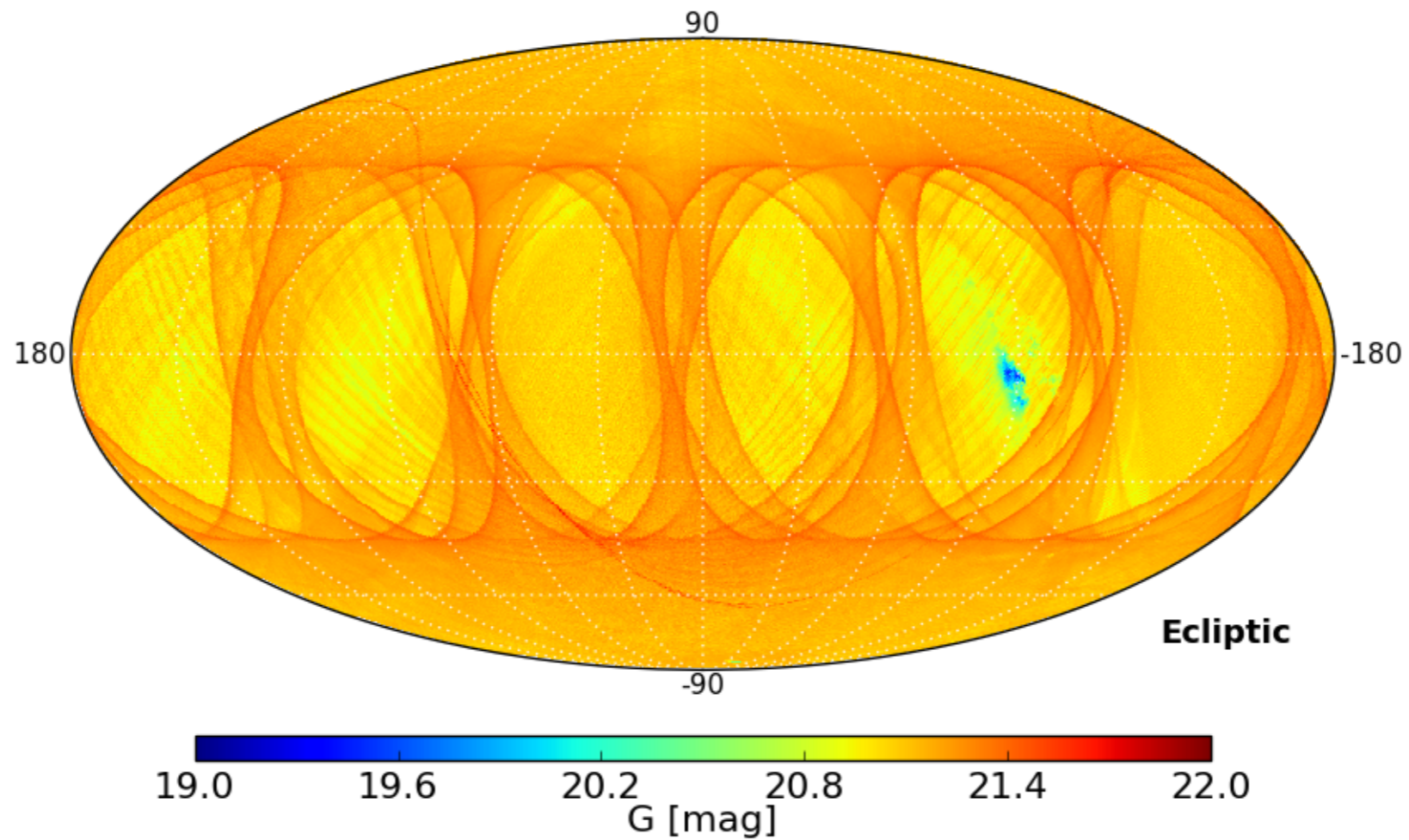


Gaia DR2 content

	DR1 (Sept 2016)	DR2 (25 April 2018)	DR3 (2021)	DR4 (TBD)
Parallaxes and proper motions	Hip/Tyc priors	Full Sample	++	++
Photometry	G	G, G _{BP} , G _{RP}	++	++
Variables	3 000	550 000	++	++
Radial velocities	-	RVs at G _{RVS} <12	++	++
SSOs	-	pre-selected asteroids	New SSOs	++
Astrophysical parameters	-	for G < 17 : T _{eff} , A _G Radii and luminosities <i>from integrated phot</i>	Classification + parameters from BP/RP + RVS spectra	++
Systems	-	-	Non-single catalogue Extended objects	Exoplanet list
Spectra	-	-	Mean BP/RP spectra Mean RVS spectra	++
Epoch data	-	-	-	All epoch data

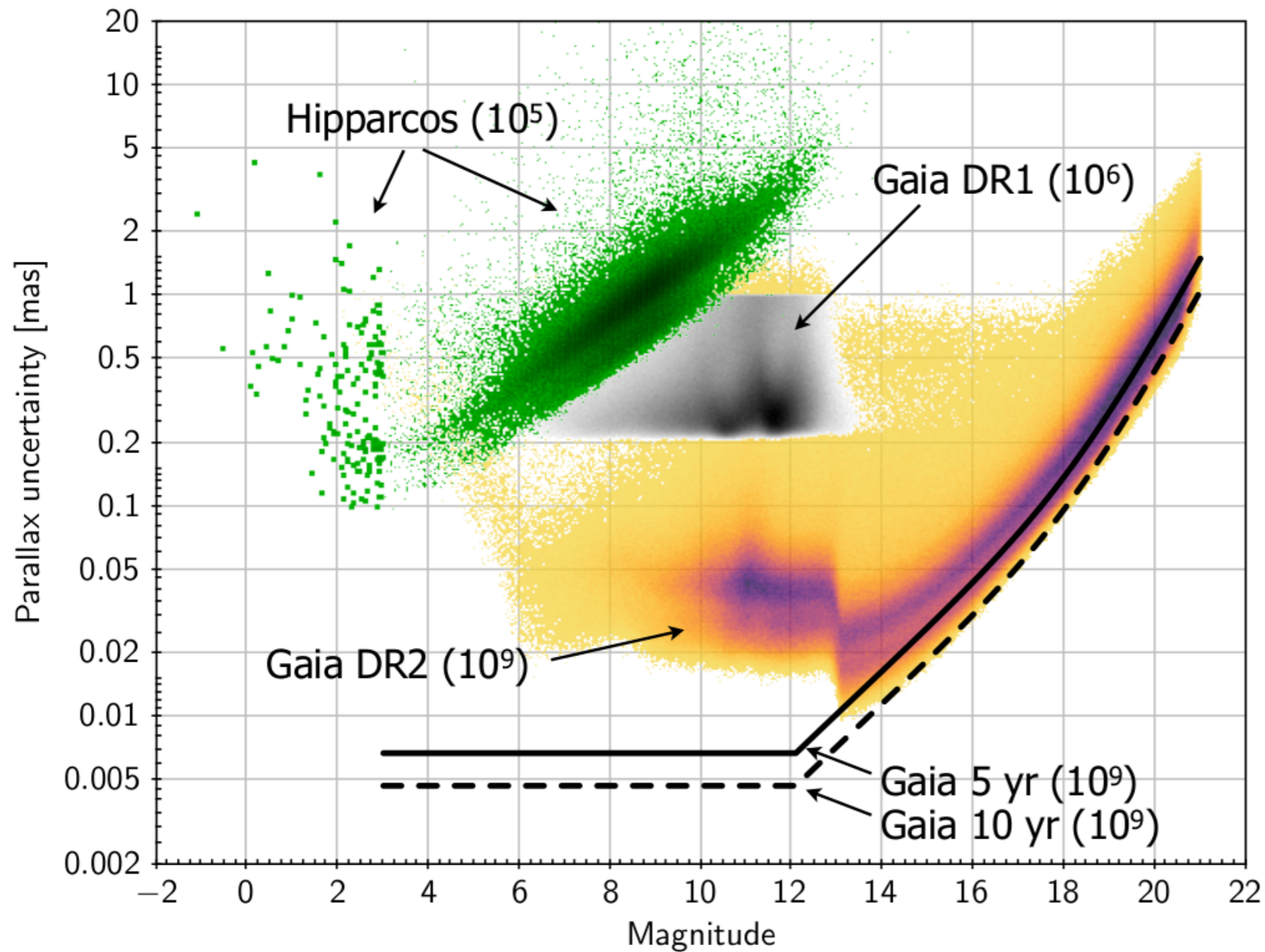
More DRs to be planned: mission extension !

DR2 completeness



Limiting magnitude: 99th percentile in G

DR2 astrometry



Typical parallax precision:

- G=15: 0.03 mas
- G=17: 0.1 mas
- G=20: 0.7 mas

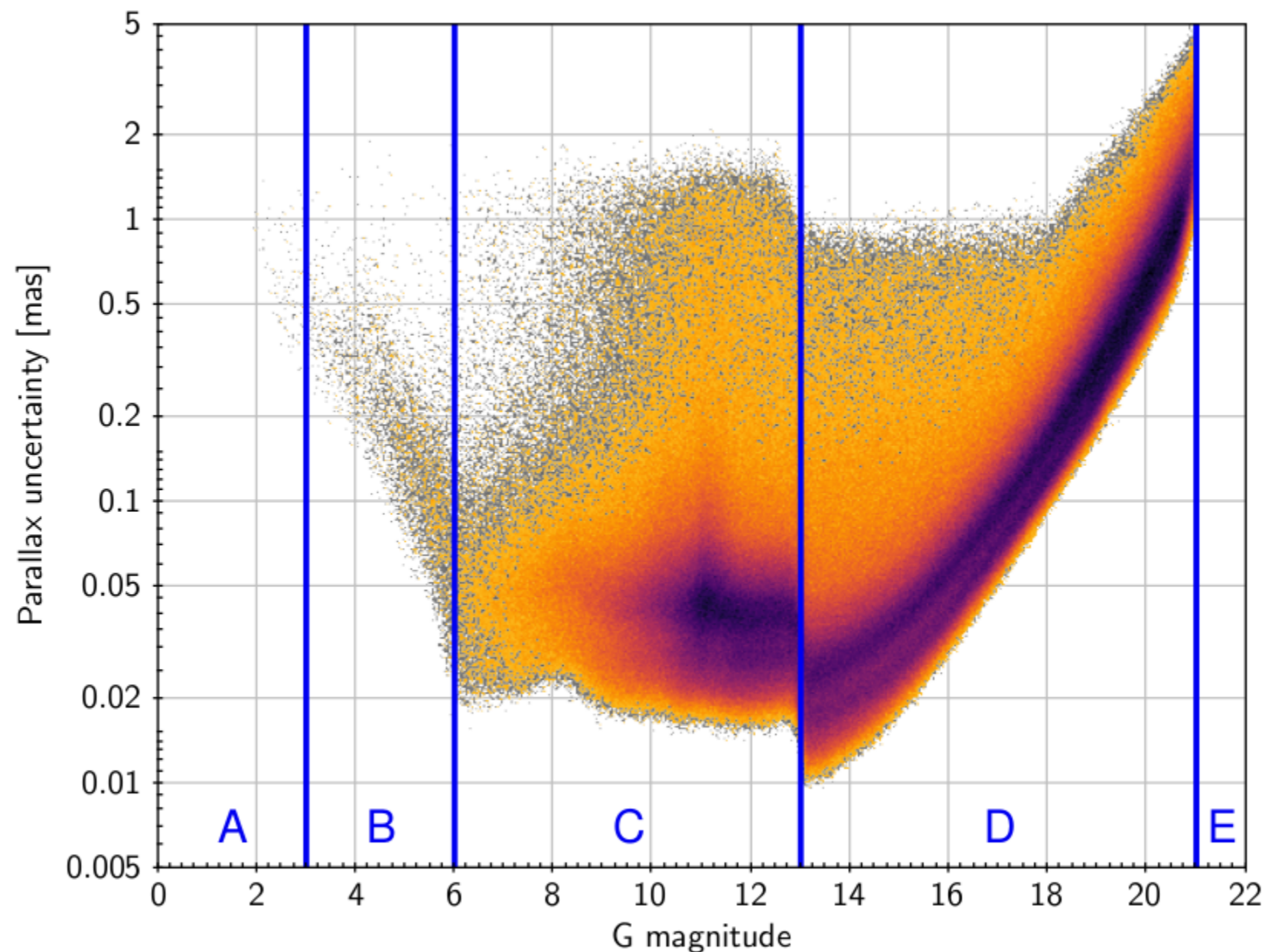
Still single-star solution

Systematics below 0.1 mas

Global zero point ~ -0.03 mas

Spatial correlations at ~ 1 and
 ~ 20 degree scales

DR2 astrometry : formal uncertainties



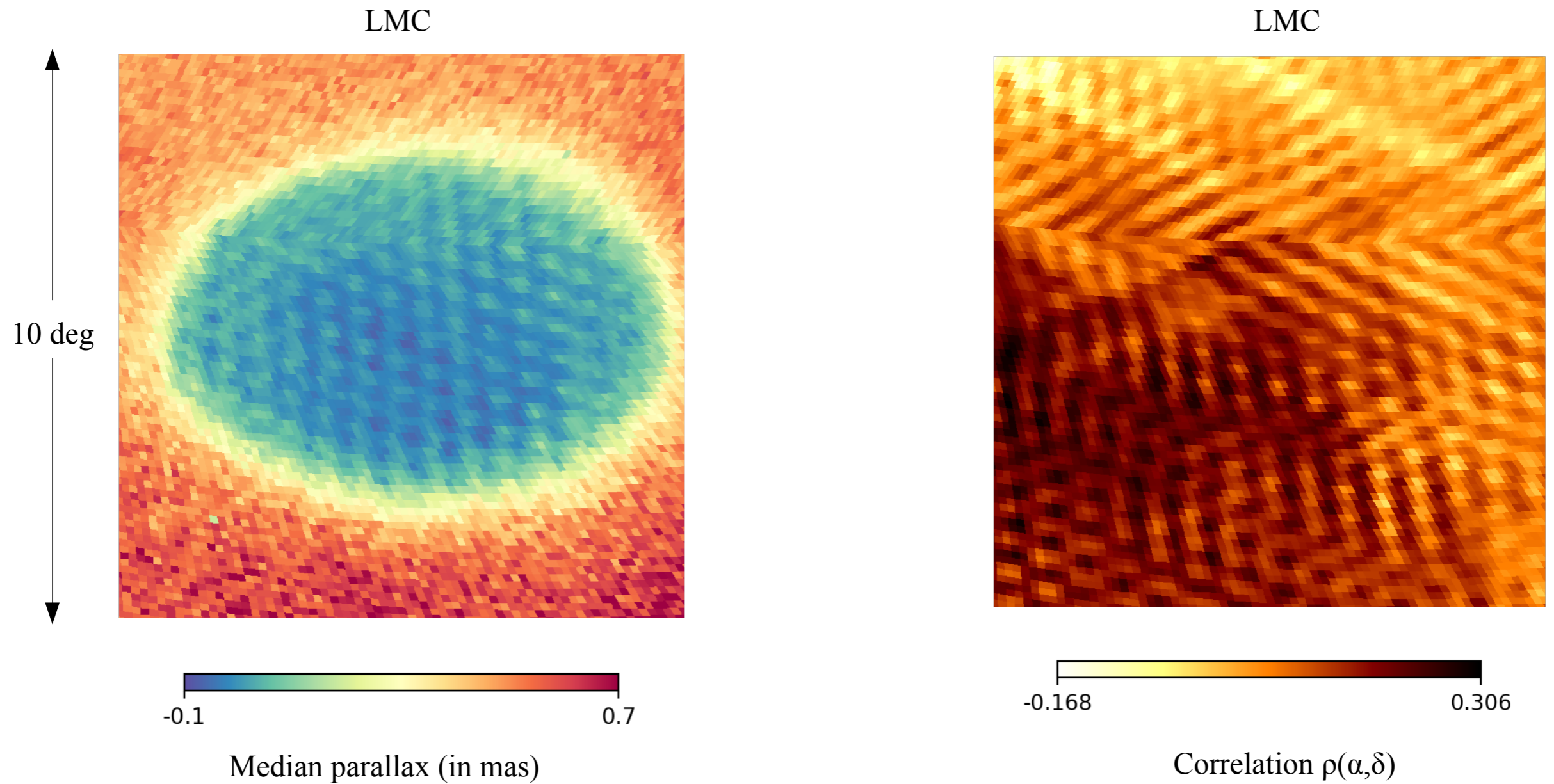
Regimes of G :

- A: Too bright
- B: Partly saturated (unreliable)
- C: Detector and calibration limited
- D: Photon limited
- E: Too faint (not published)

Provided: **formal uncertainties**
estimated from internal consistency of the measurements
do not represent the total error

DR2 astrometry : small scale systematics

Quasi-periodic patterns imprinted by the Gaia scanning law



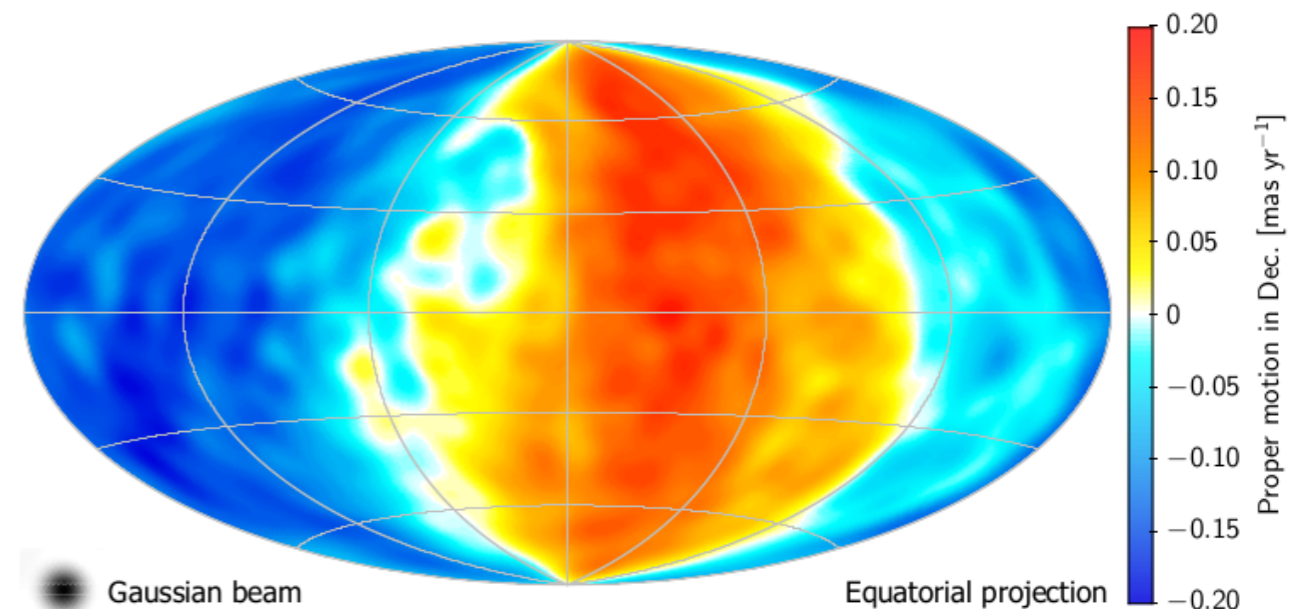
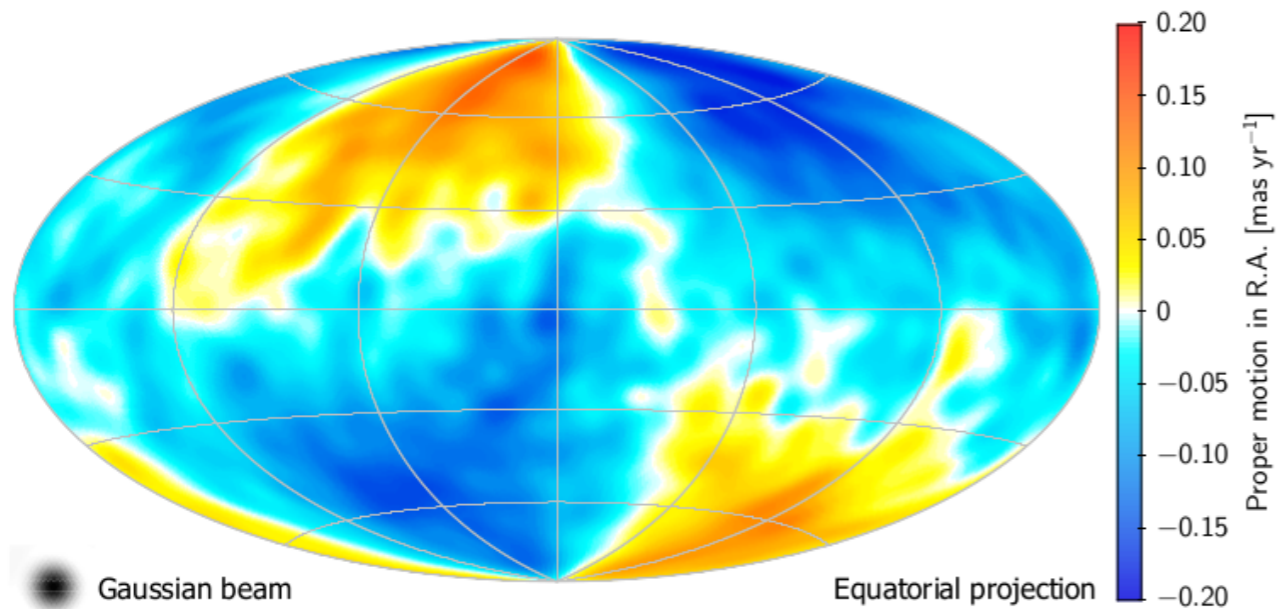
Characteristic period ~ 0.6 deg, RMS variation ~ 0.03 mas

DR2 astrometry : bright stars PM systematics

Proper motion difference versus Hipparcos

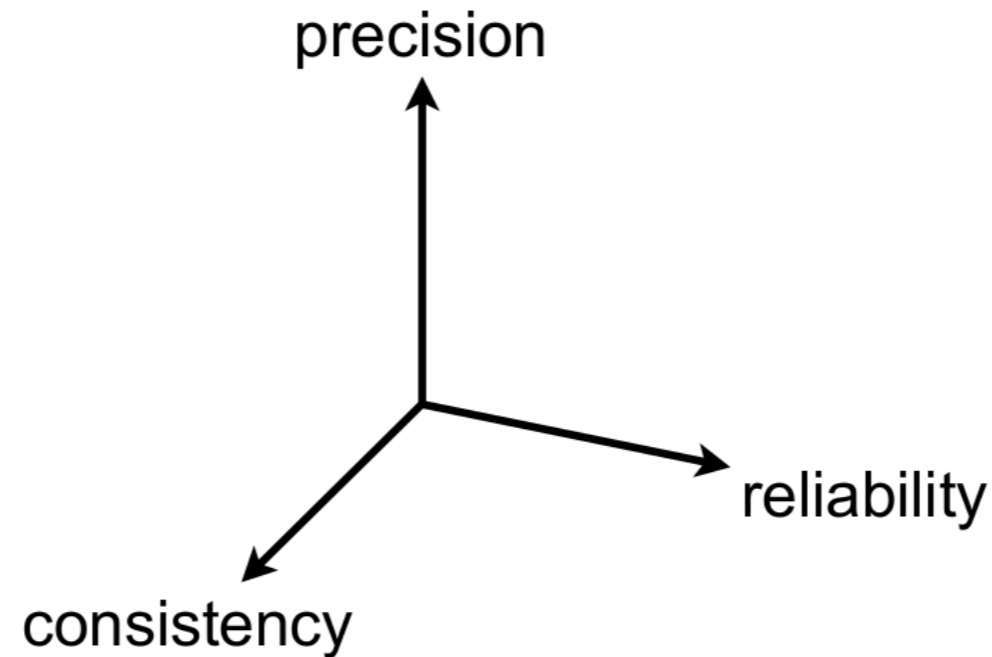
R.A.

Dec.



Global rotation $\sim 0.15 \text{ mas yr}^{-1}$

DR2 astrometry : quality indicators

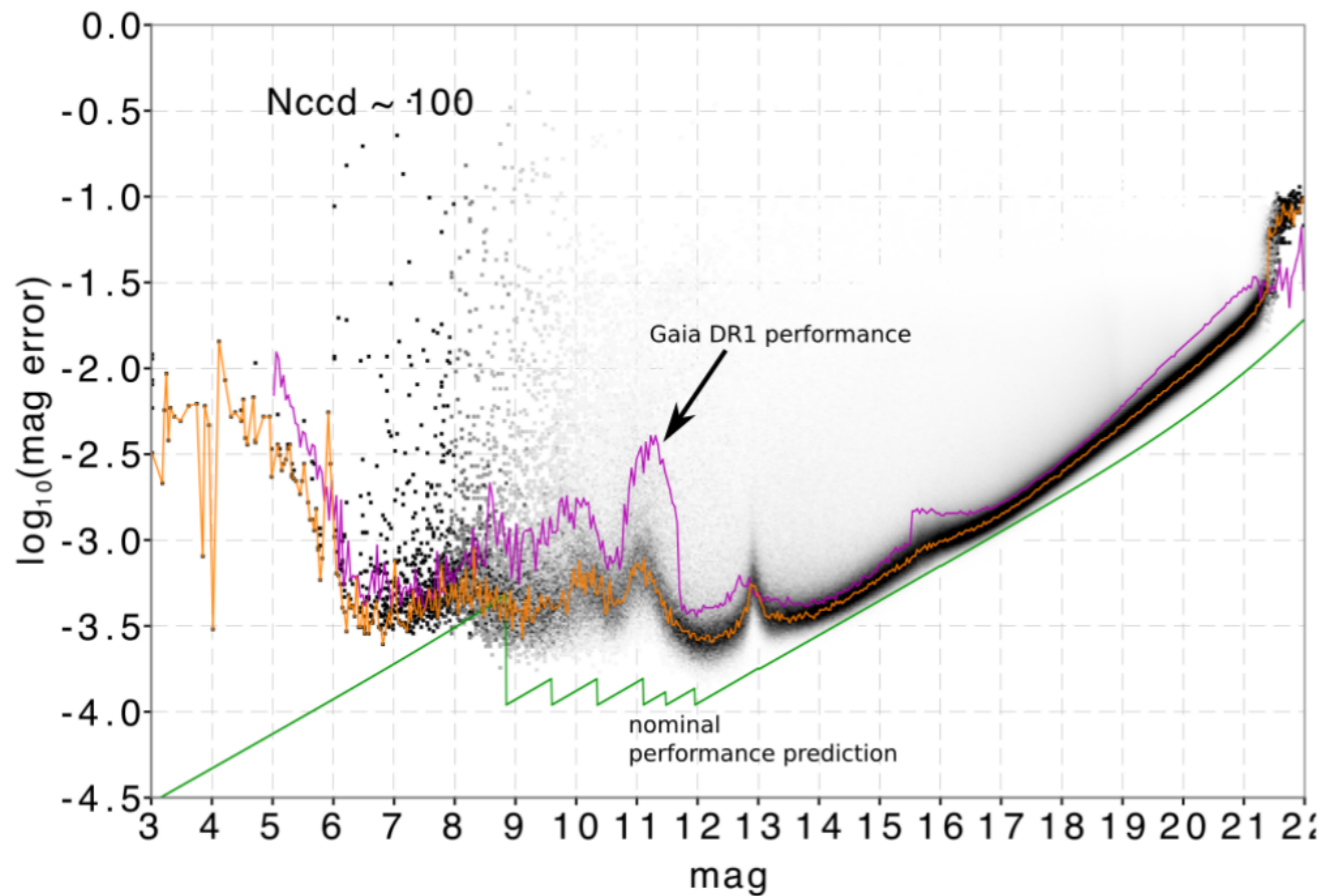


Precision: `parallax_error`, `pmra_error`, `pmdec_error` (internal!)

Reliability: `visibility_periods_used`

Consistency: Renormalised Unit Weight Error (see Gaia DR2 Known issue page)

DR2 photometry



~ 10 mmag level systematics

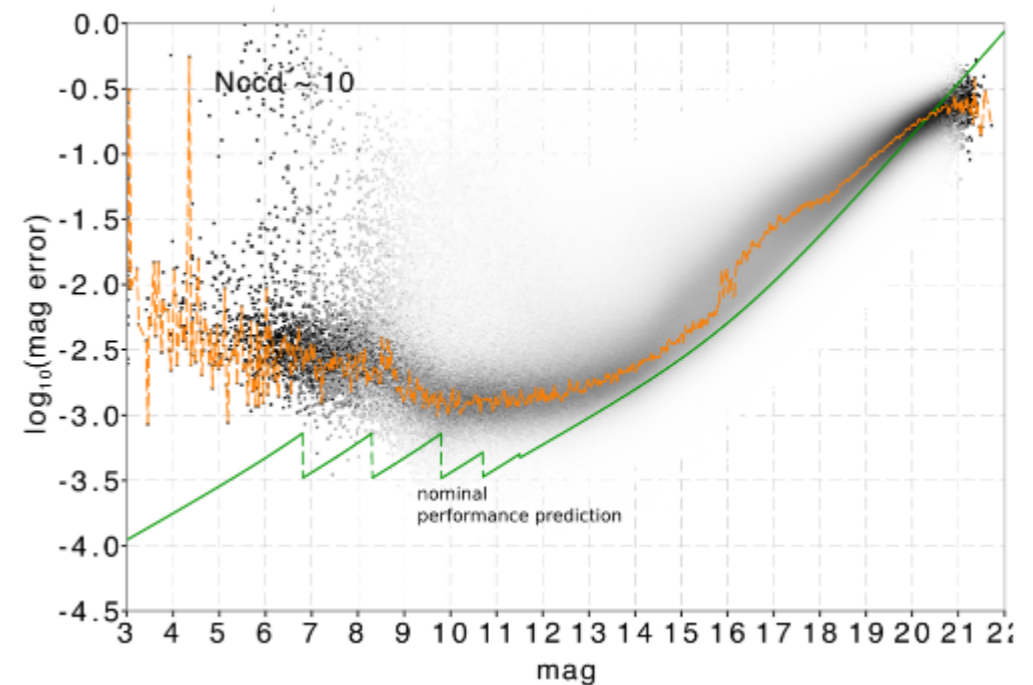
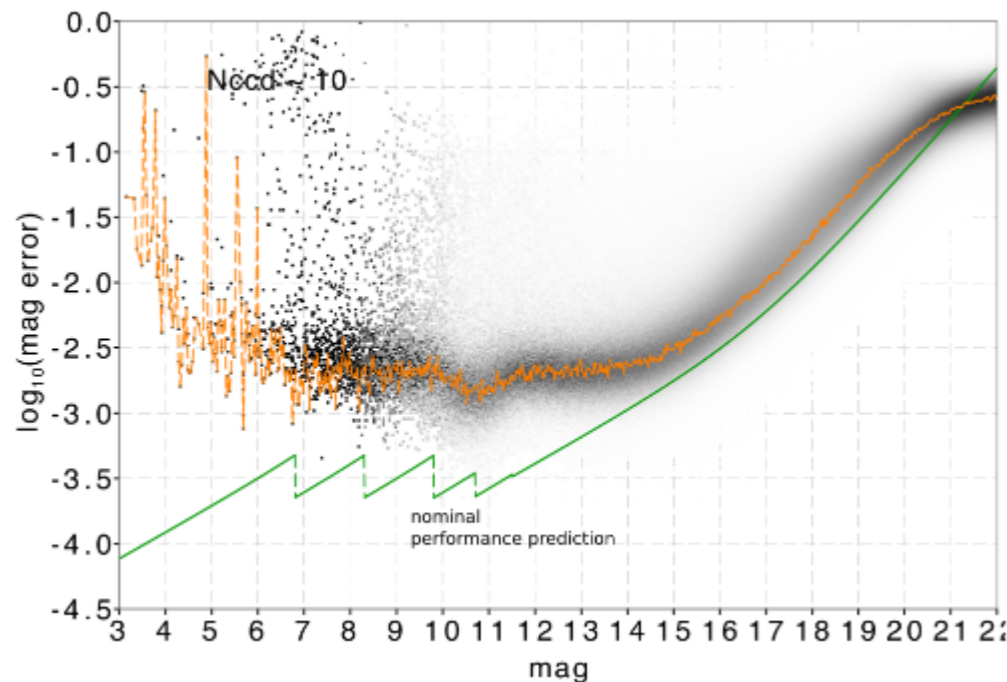
BP & RP integrated photometry

G=20: $\sigma_G \sim 0.02$ mag, $\sigma_{XP} \sim 0.2$ mag

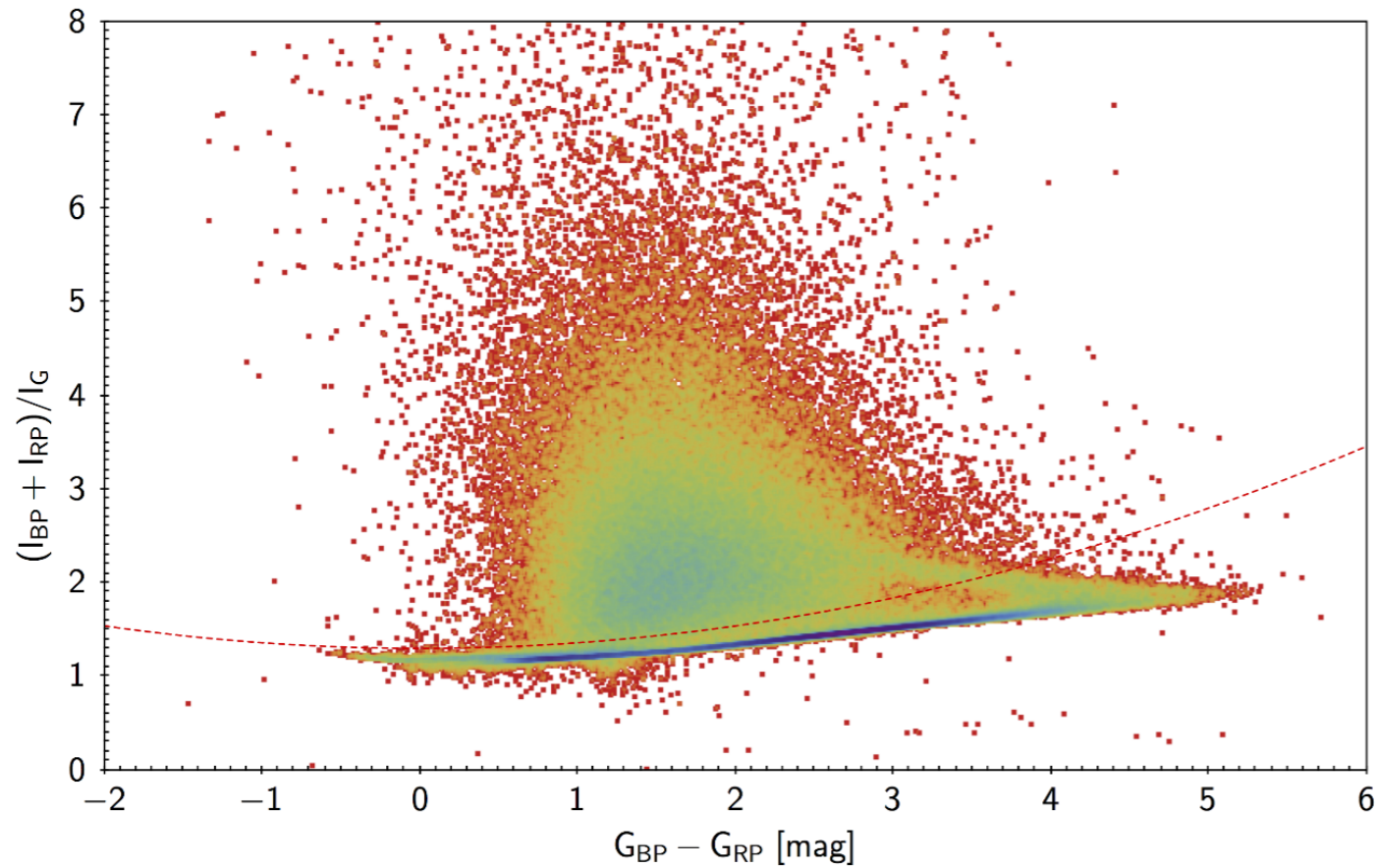
Passbands provided

! No deblending

! G band system different from DR1



DR2 photometry : main issues

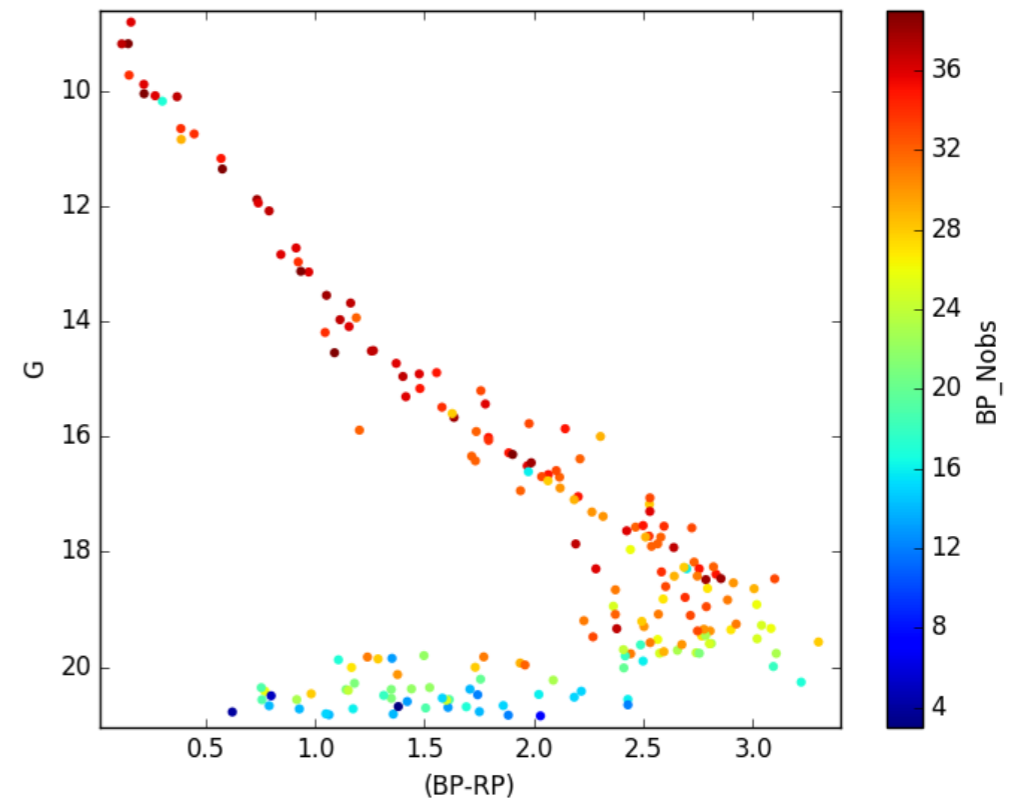


BP/RP excess flux

← crowded spectrophotometry

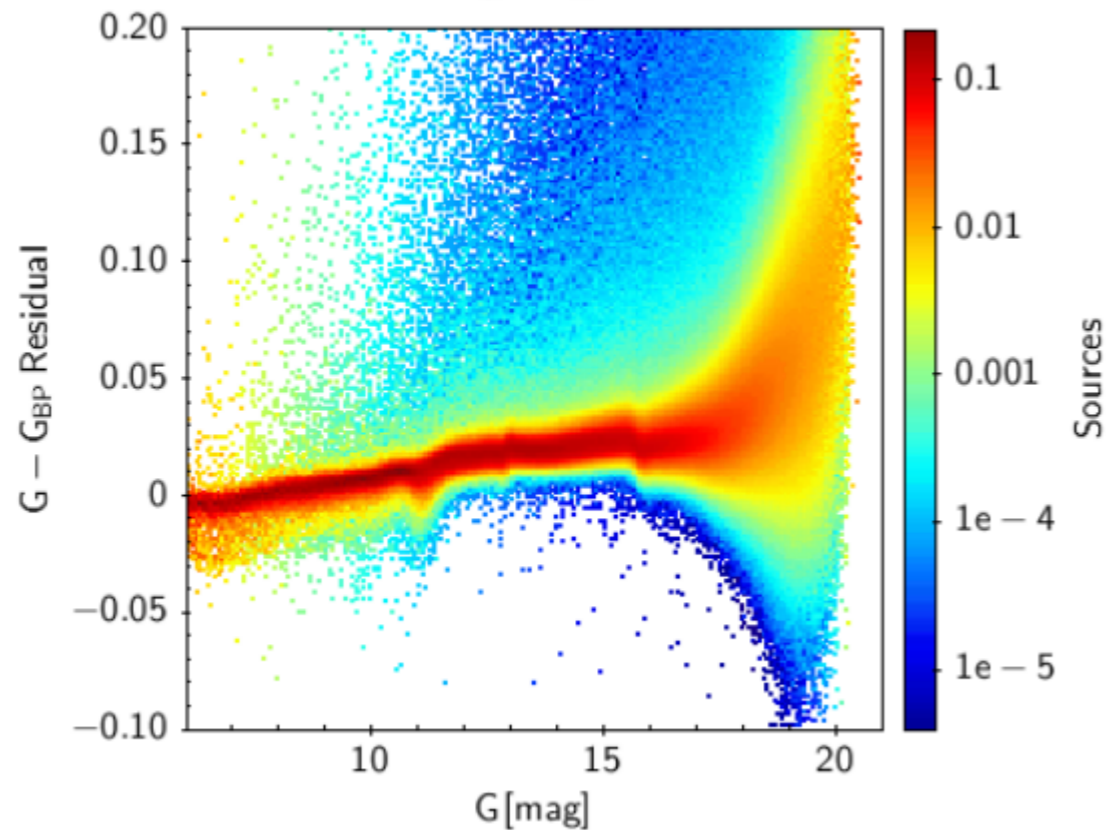
BP background under-estimation

CMD of Alessi 10



DR2 photometry : calibrations

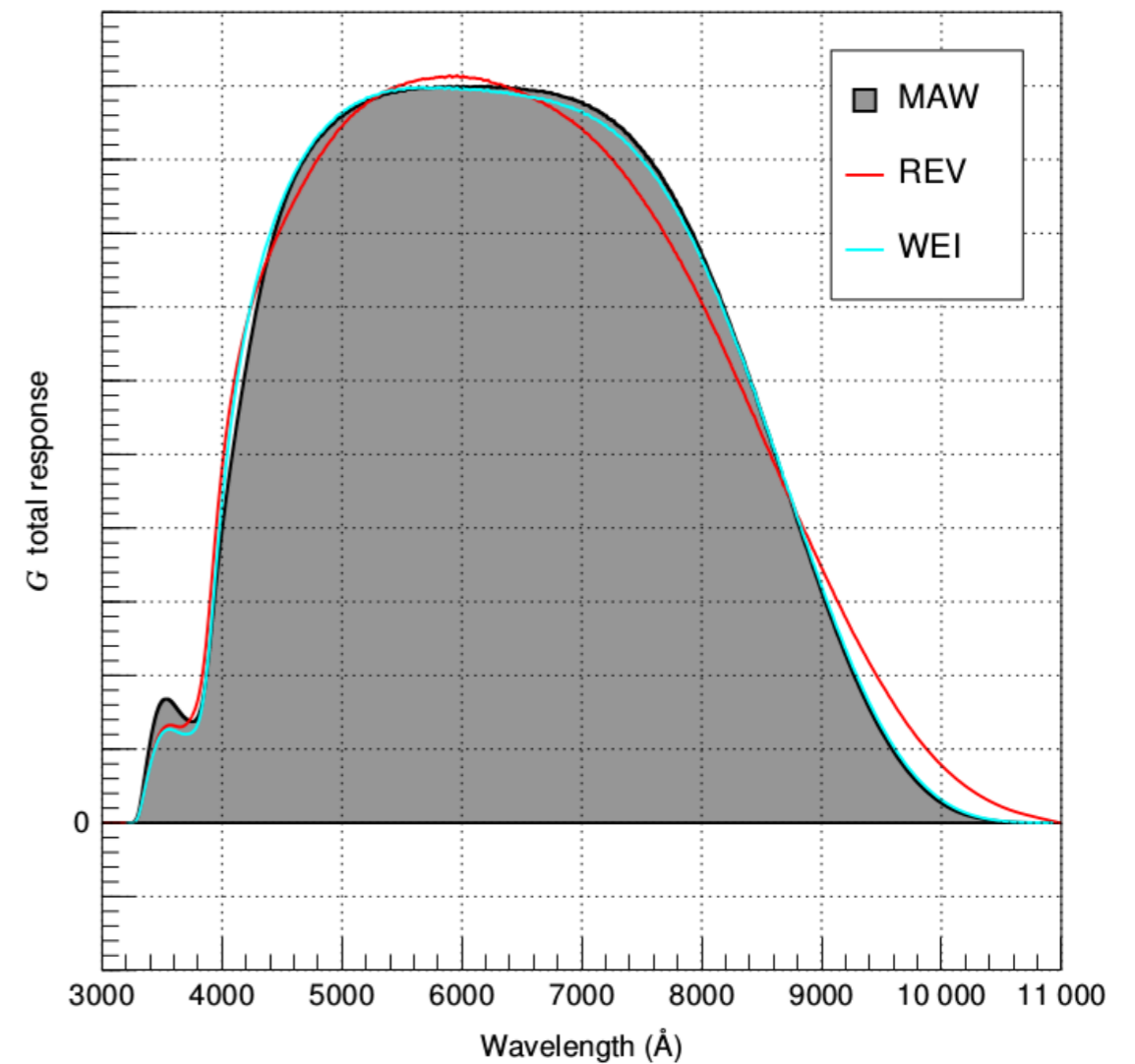
G fading of ~ 3 mmag / mag



Arenou et al. 2018

Weiler 2018

New calibrations of the Gaia photometric bands

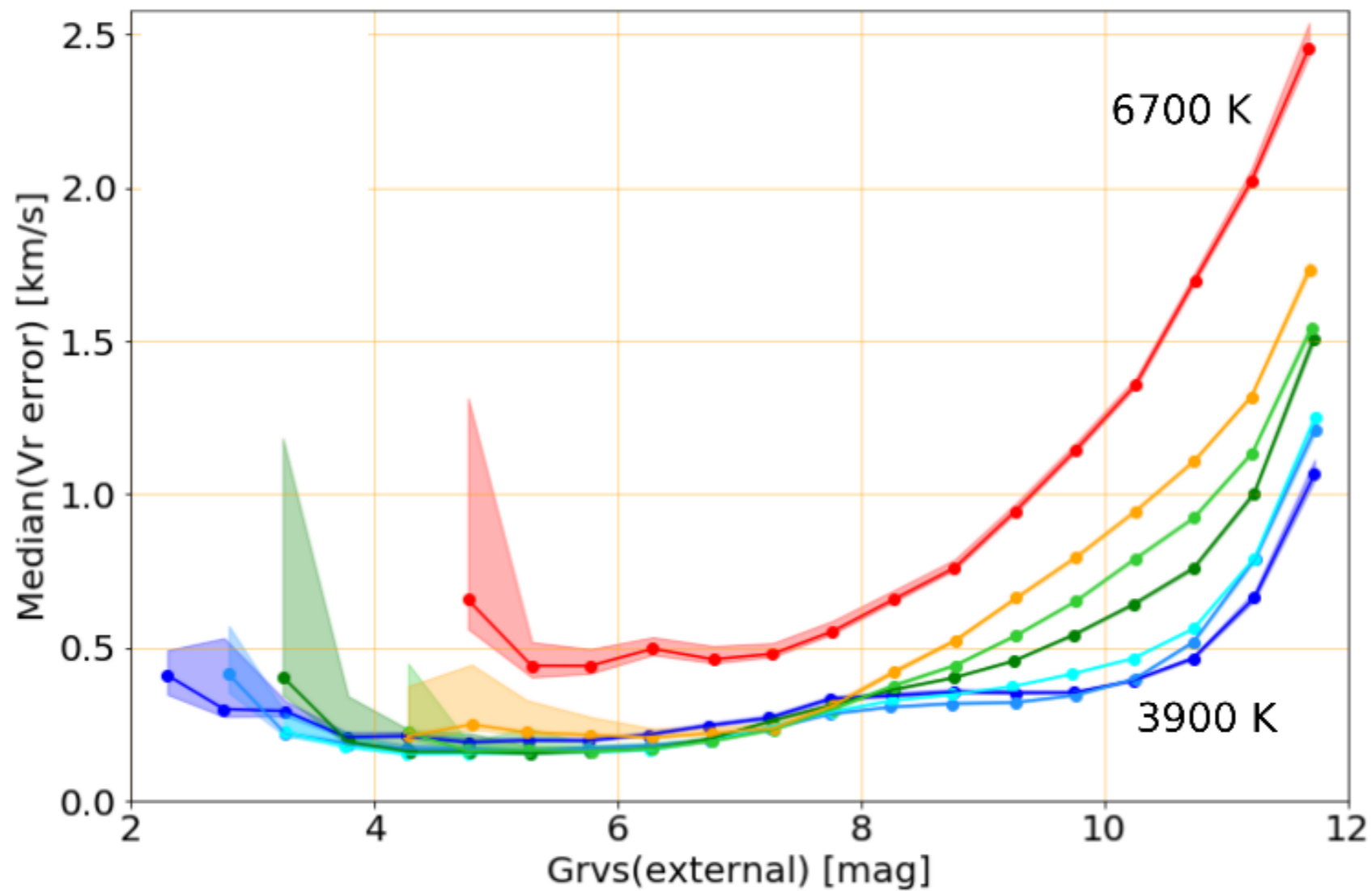


Evans et al. 2018

Weiler 2018

Maiz Apellaniz & Weiler 2018

DR2 radial velocities

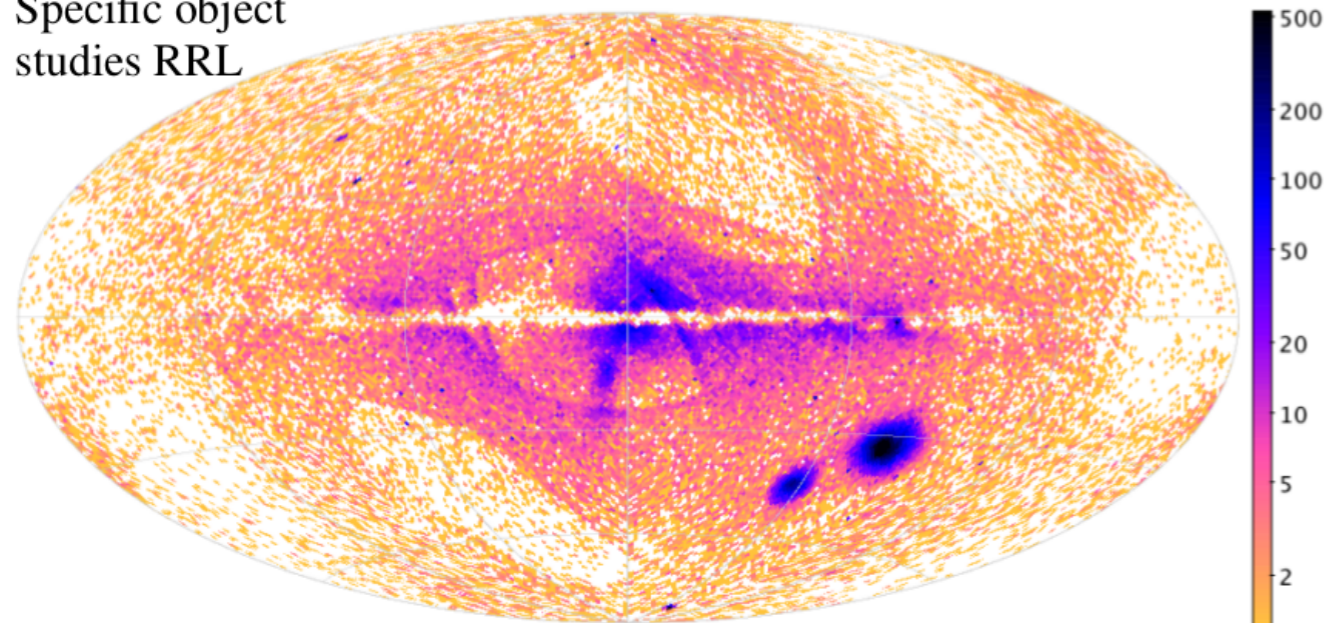


More than 7 million Vr

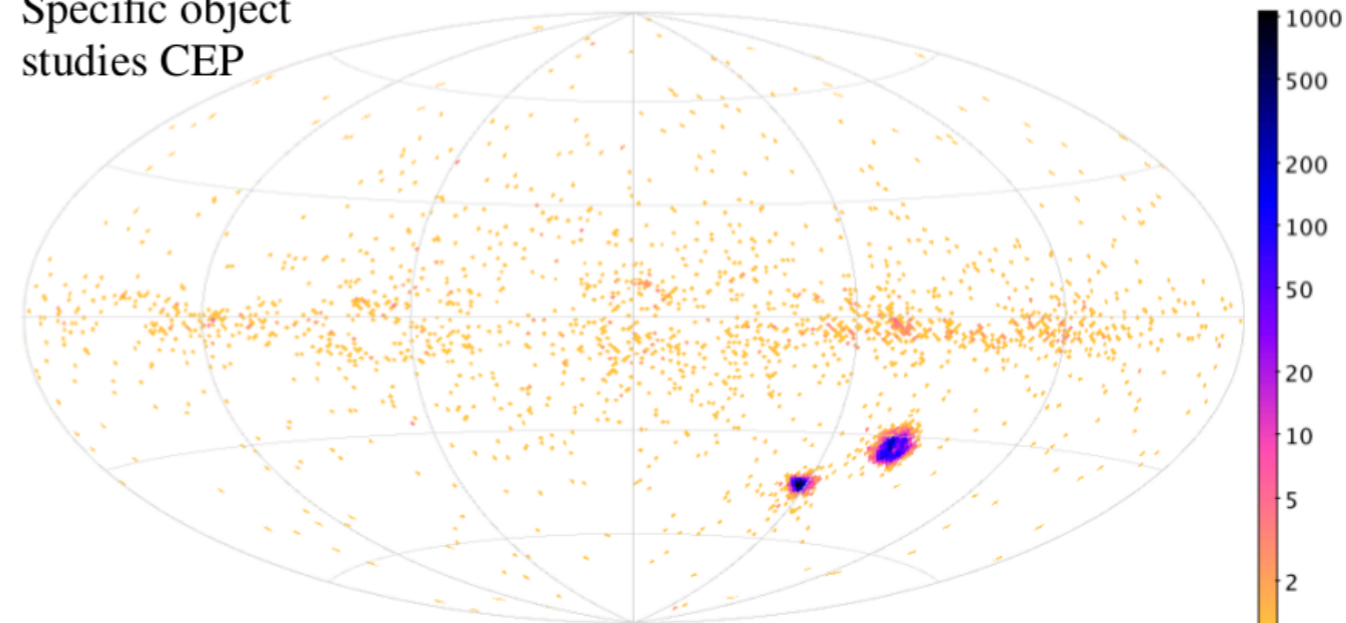
- Only for $\sim 3550 < T_{\text{eff}} < 6900$ K
- Zero point at ~ 0.1 km/s
- Systematics as a function of magnitude

DR2 variables

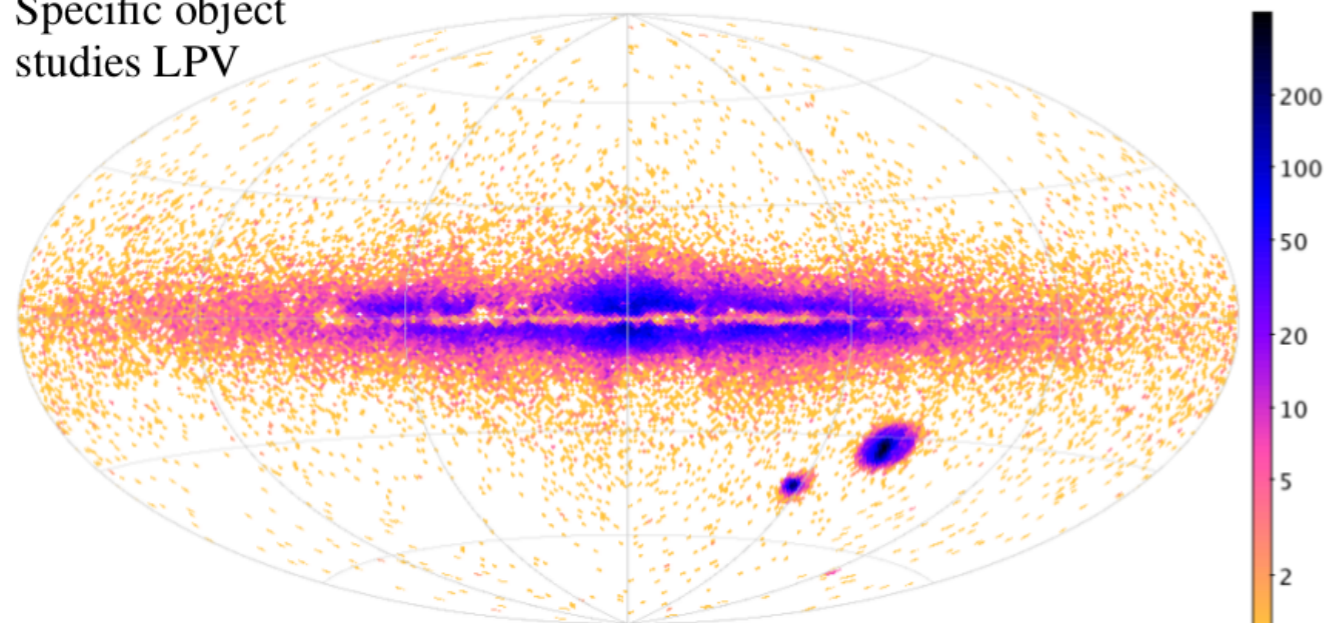
Specific object studies RRL



Specific object studies CEP

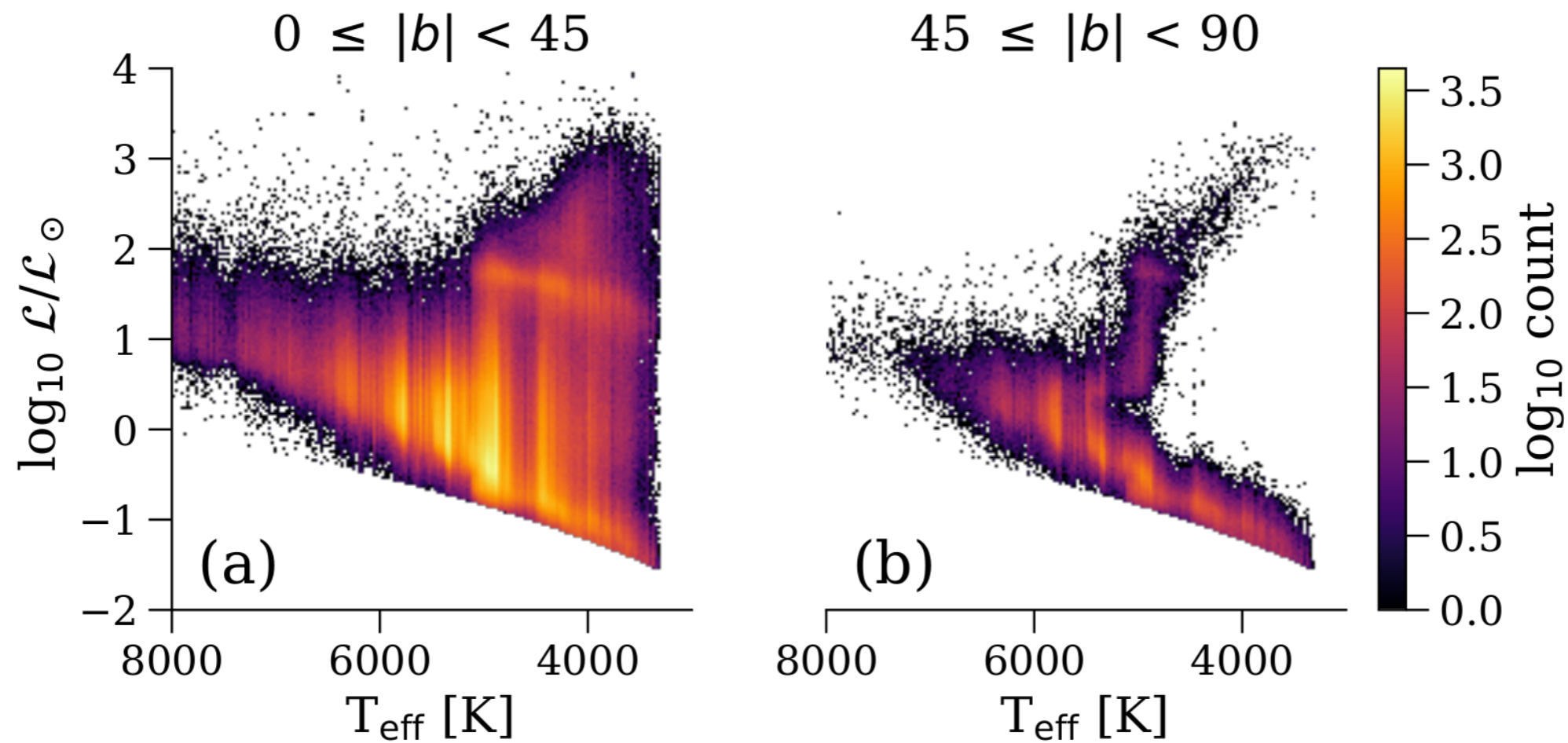


Specific object studies LPV



- 551 thousand variables identified
 - ▶ many more to come in future
- Subset classified by variability type
 - ▶ based on 2+ transits
- Overlapping subset studied in detail
 - ▶ based on 12+ transits

DR2 astrophysical parameters



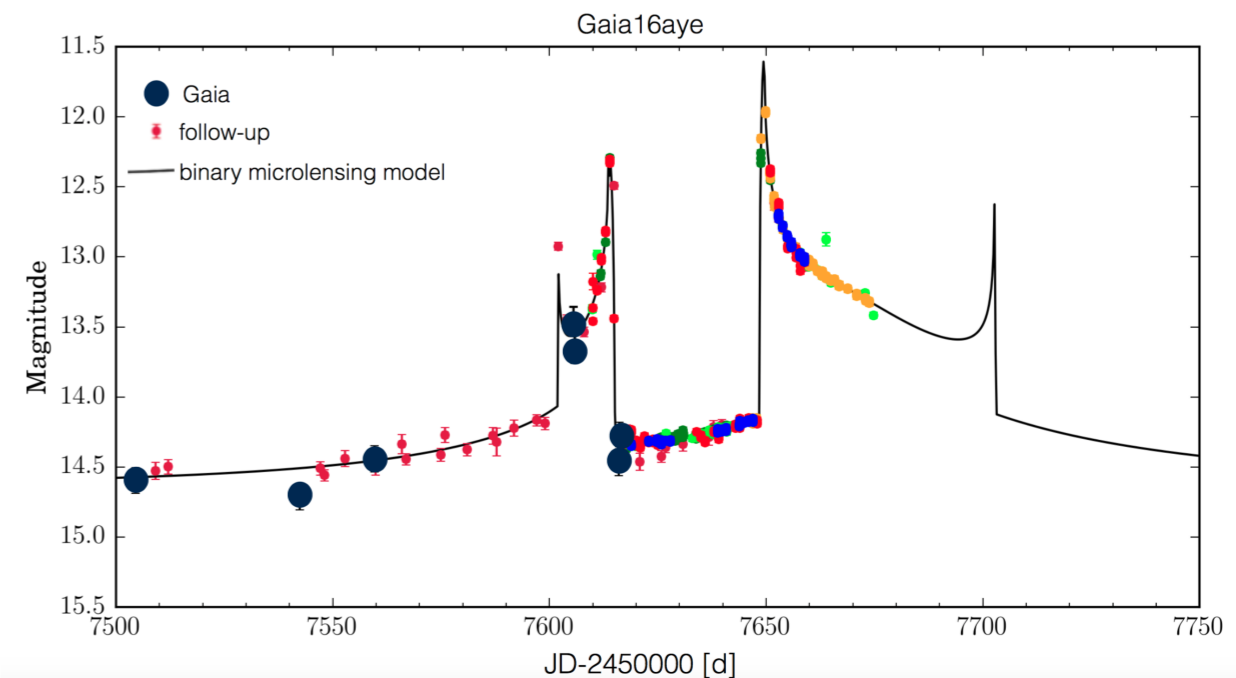
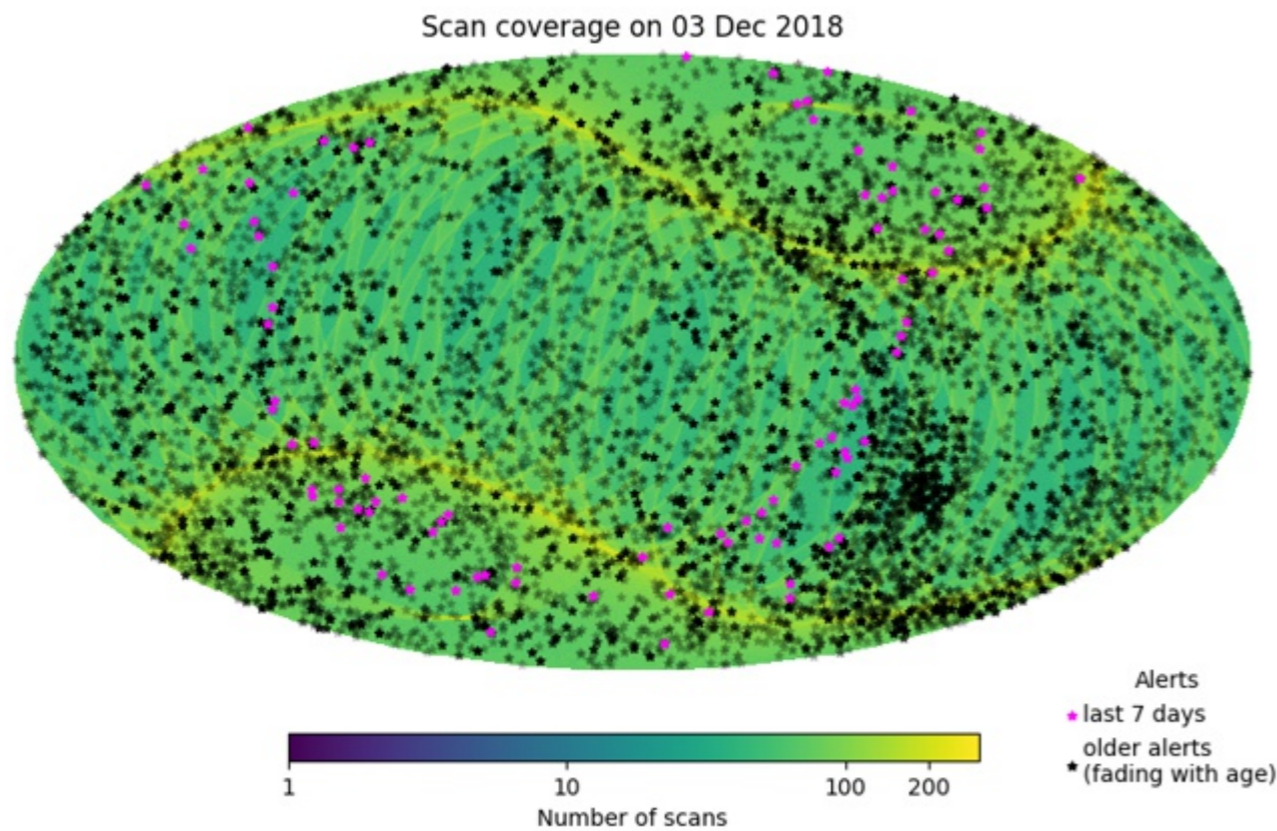
T_{eff} , A_G , $E(G_{\text{BP}}-G_{\text{RP}})$, luminosity, radius based only on G , G_{BP} , G_{RP} and parallax
→ strong degeneracies

Lots of documentation to read !

- Preliminary solution with associated limitations
single star solution, calibration issues, ...
- Complex selection function
scanning law, on-board limitations, pre & post processing filtering
- Uncertainties and covariance matrix
- Several systematics
parallax zero point, small and large scale systematics, ...
photometry in crowded fields, faint G_{BP} , G magnitude drift, ...
- Many artefacts
stars closer than proxima, excess flux

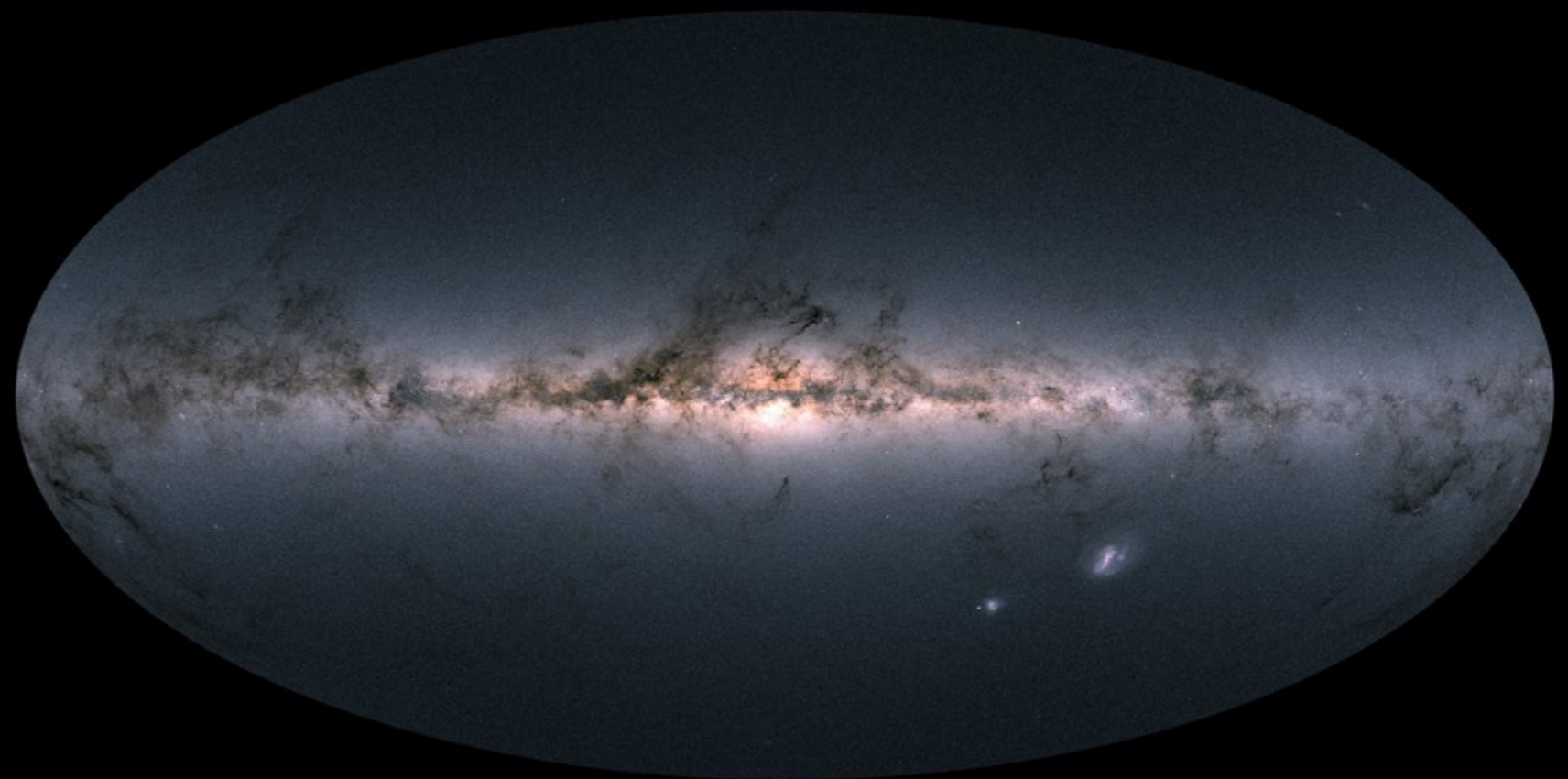
Gaia Photometric Science Alerts

started publishing alerts in July 2014



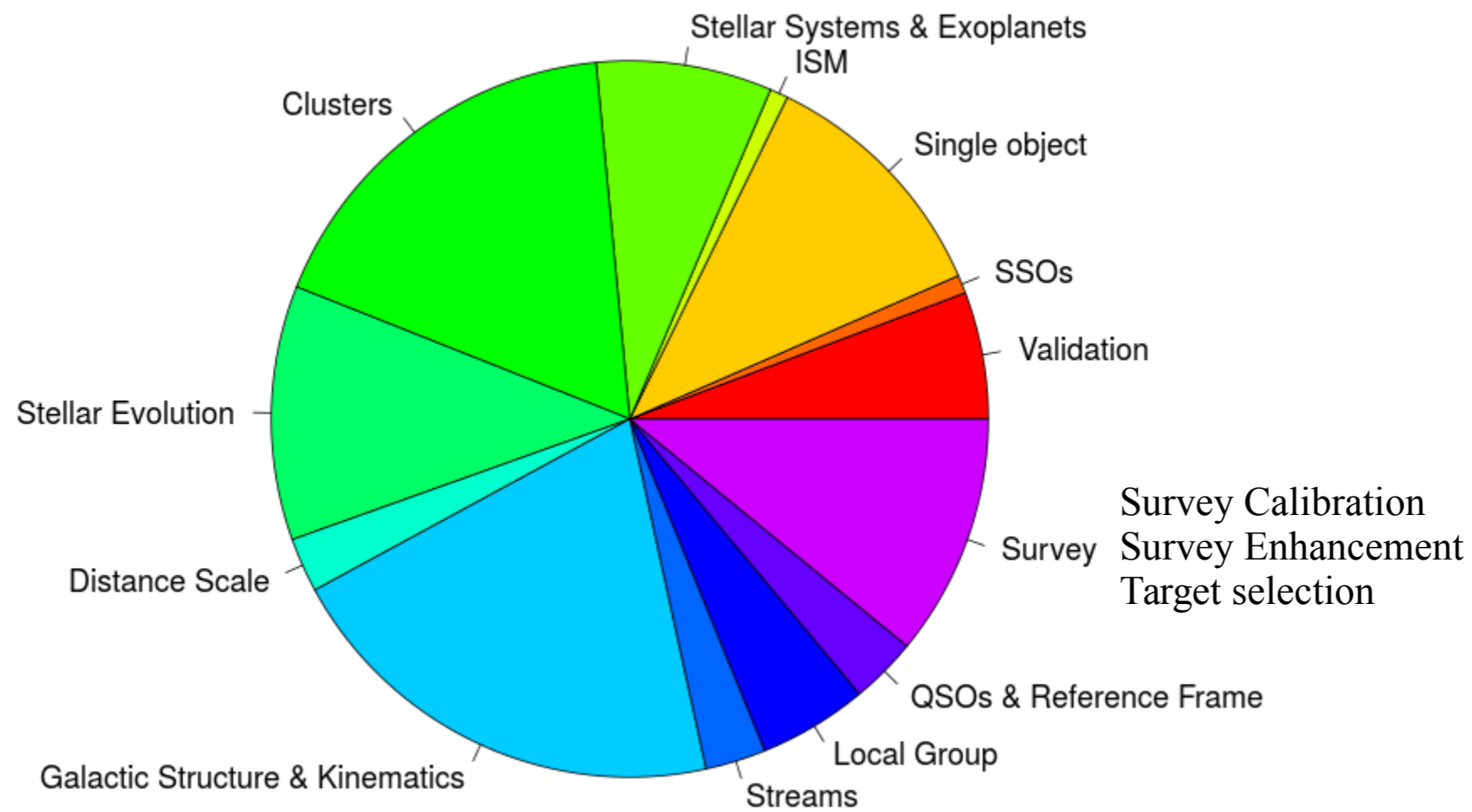
The second Gaia data release

- Gaia mission overview
- Gaia DR2 content and limitations
- **A few (biased!) applications**

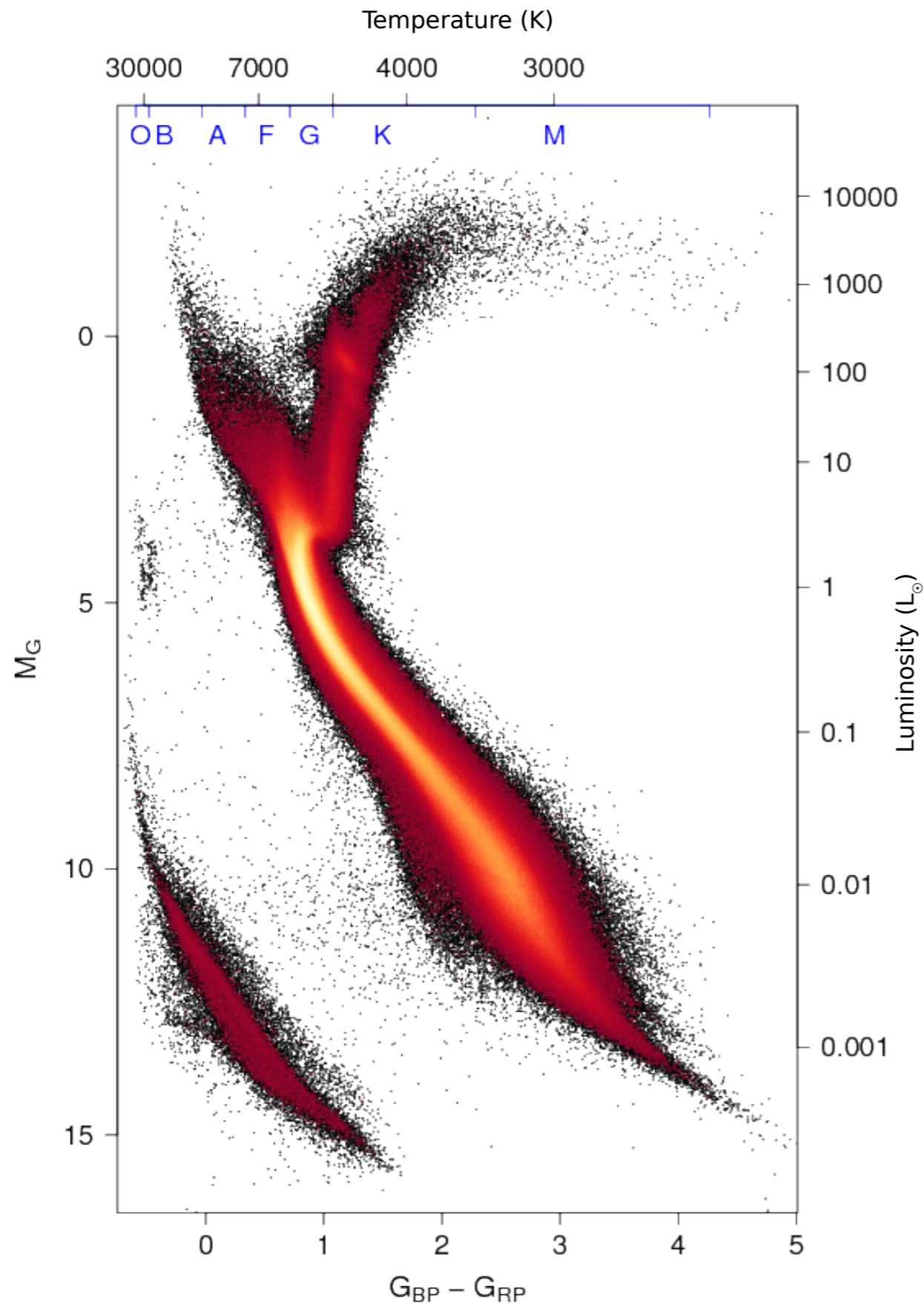


Gaia DR2 Science applications

> 410 papers on astro-ph using Gaia DR2 (~ 2/jours)

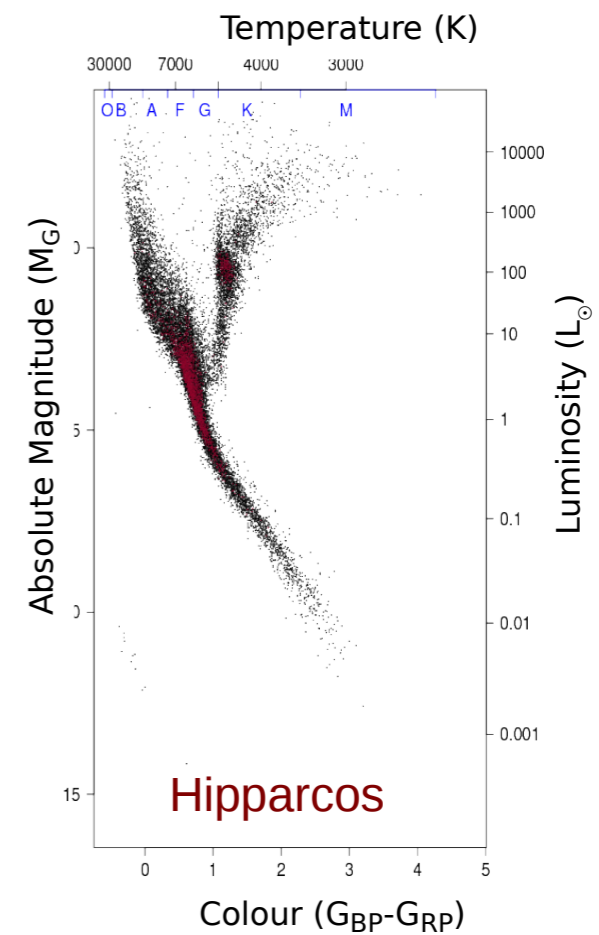


Gaia DR2 H-R diagram



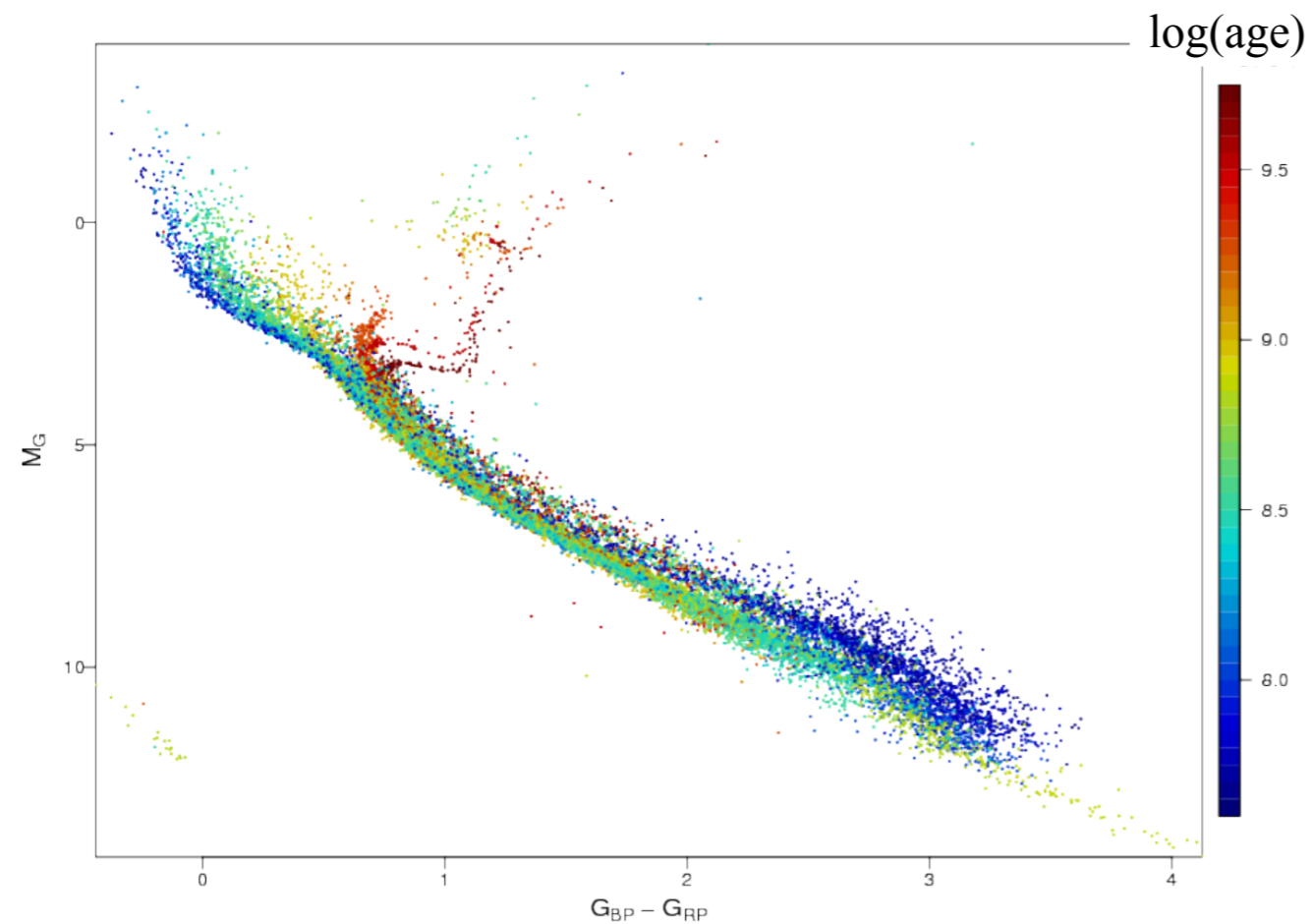
$$\sigma_{\pi}/\pi < 10\%, E(B-V) < 0.015$$

$\sim 4\,000\,000$ stars, < 2 kpc

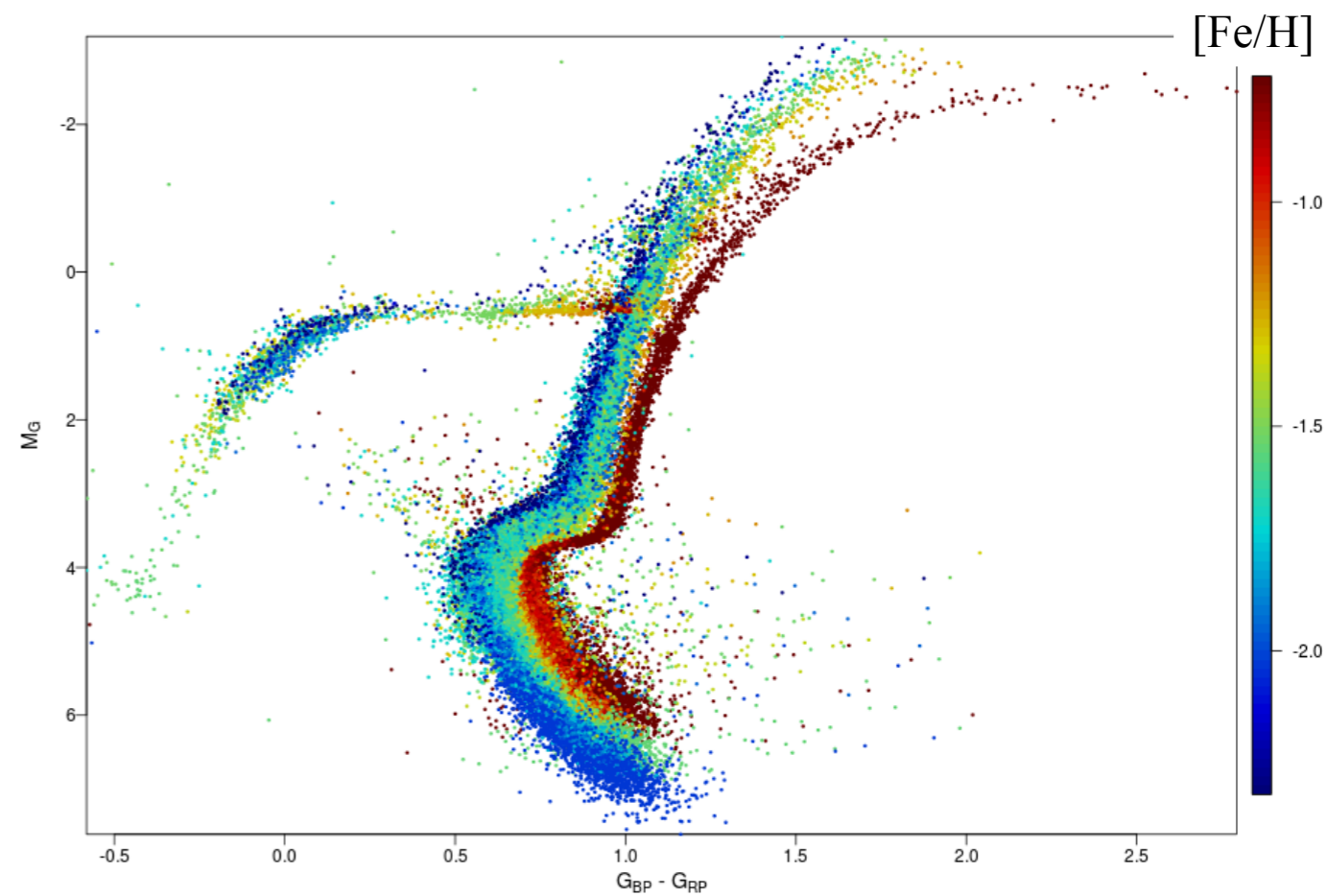


Clusters → empirical isochrones

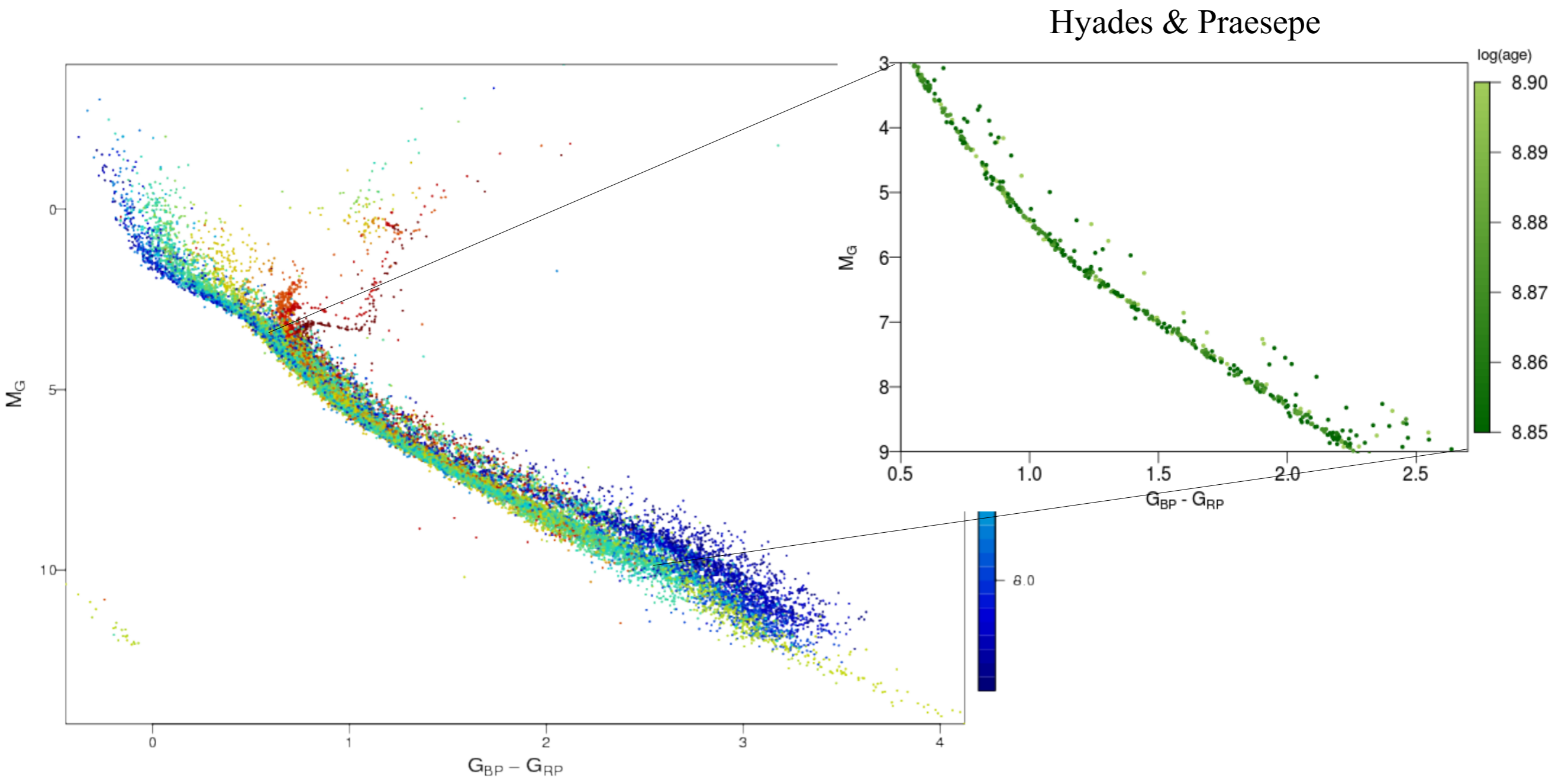
32 open clusters



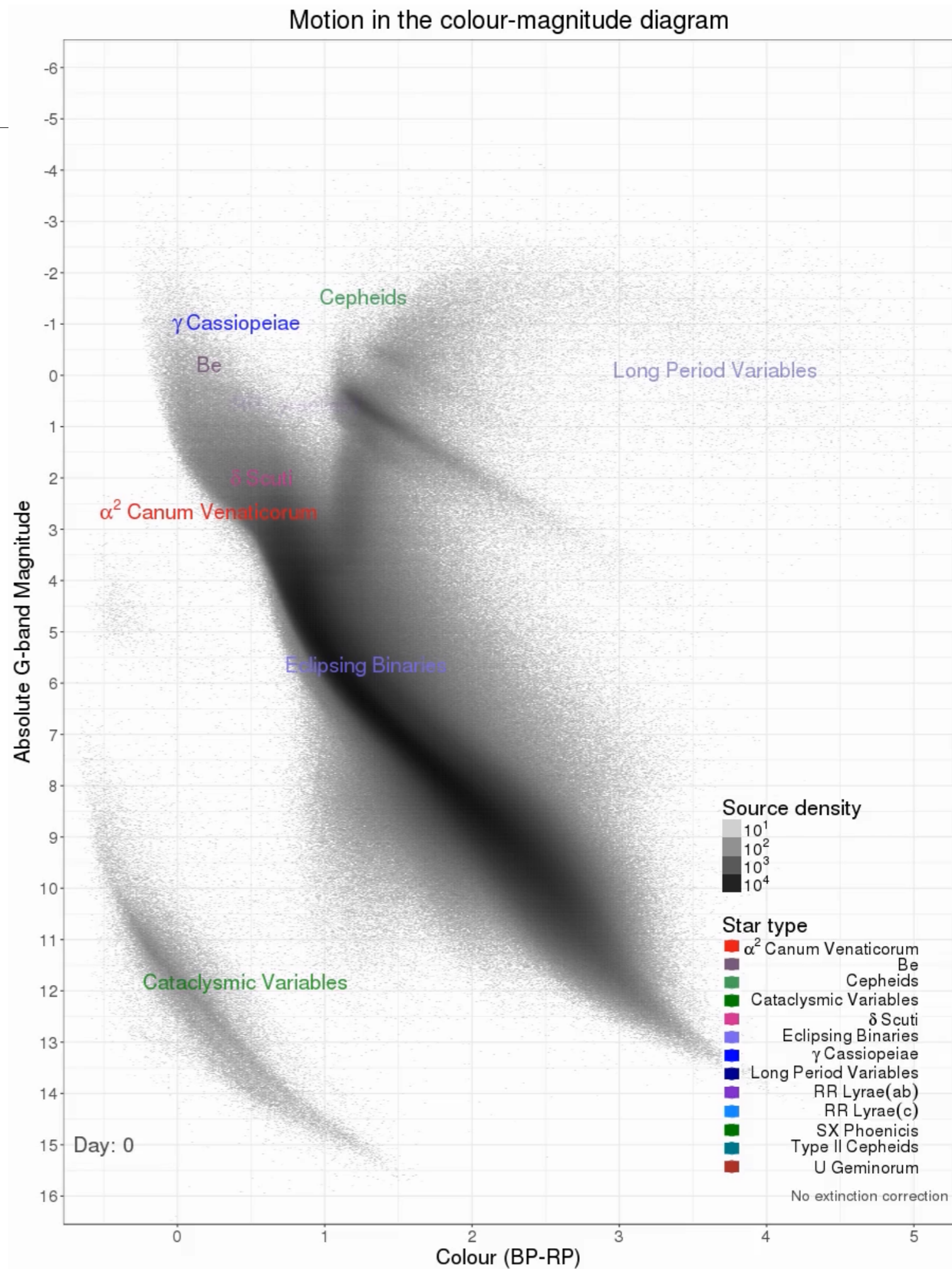
14 globular clusters



Clusters → empirical isochrones



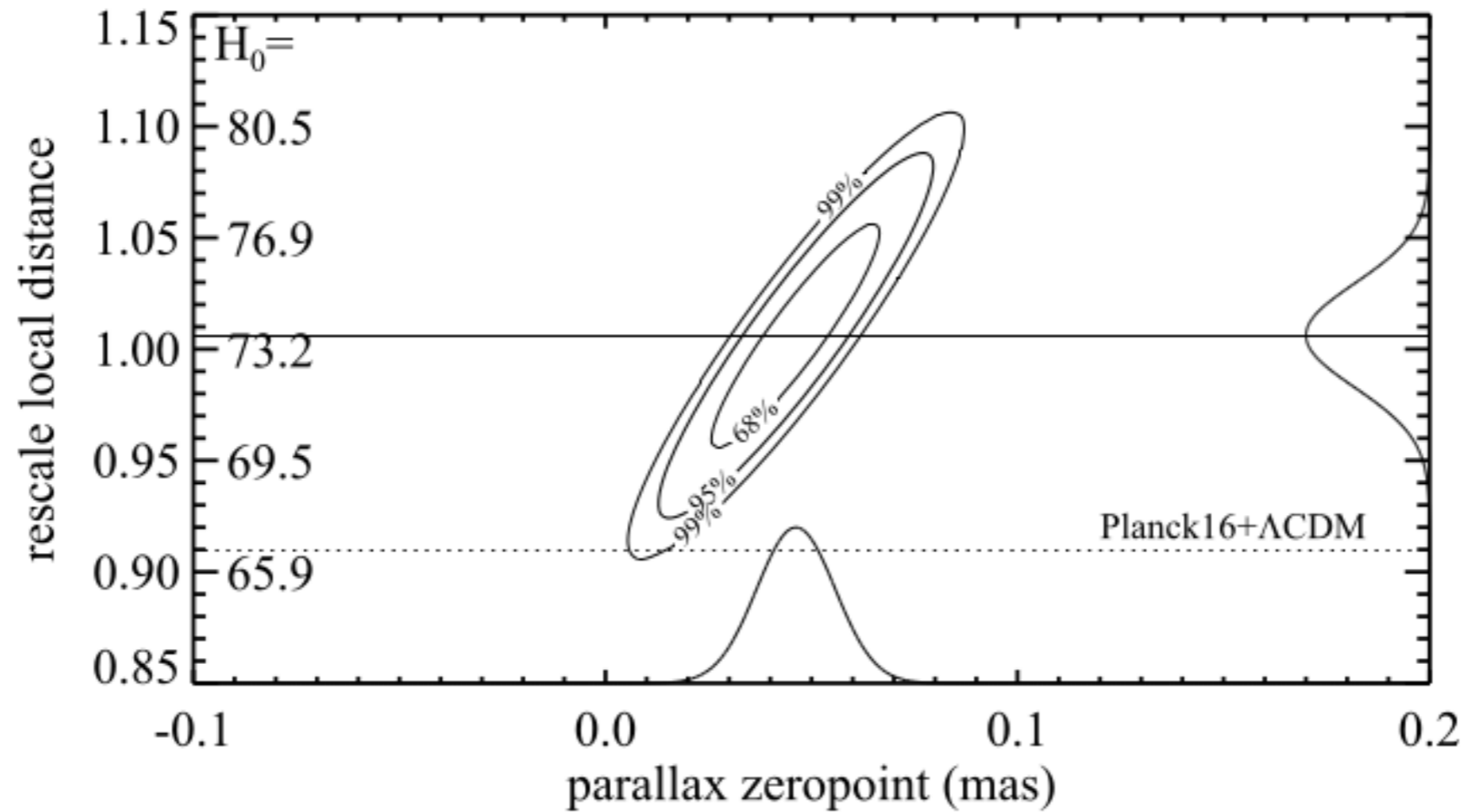
Variability in the HRD



Gaia Collaboration, Eyer et al. 2018

crédit ESA/Gaia/DPAC/CU7

Cepheids distance scale



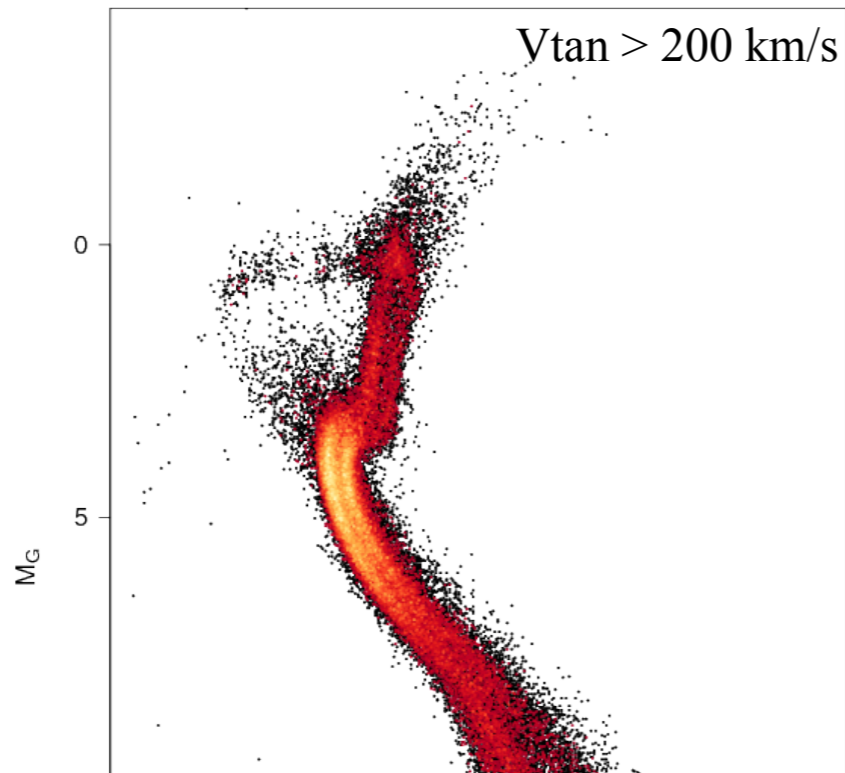
Reiss et al. 2018

See also Shanks et al. 2018 on this H_0 debate

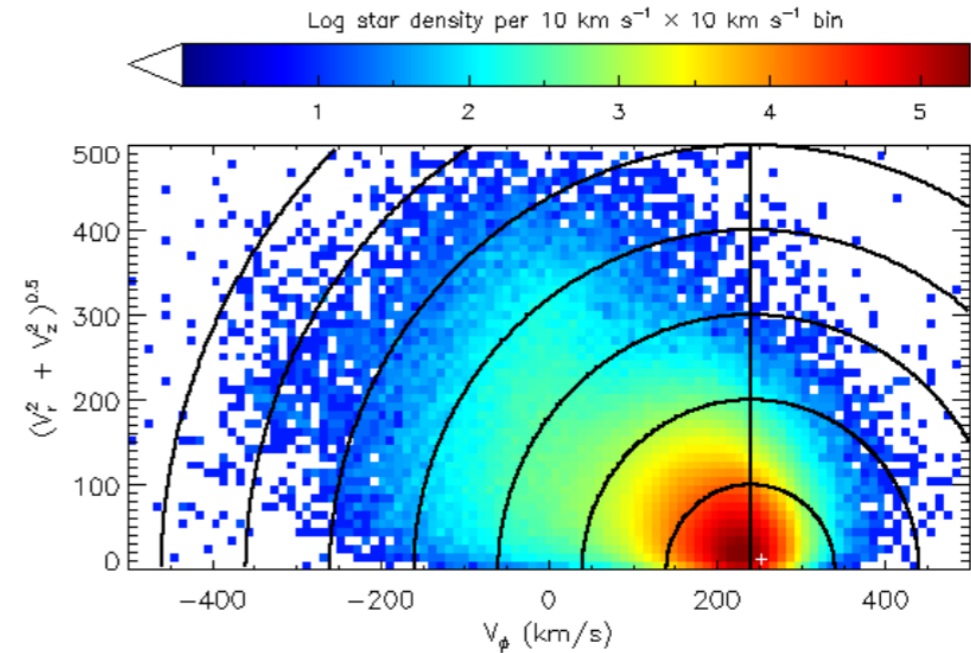
+ Groenewegen et al. 2018 on the Cepheids distance scale with Gaia DR2

Gaia-Enceladus the last big merger shaping both the halo and the thick disk?

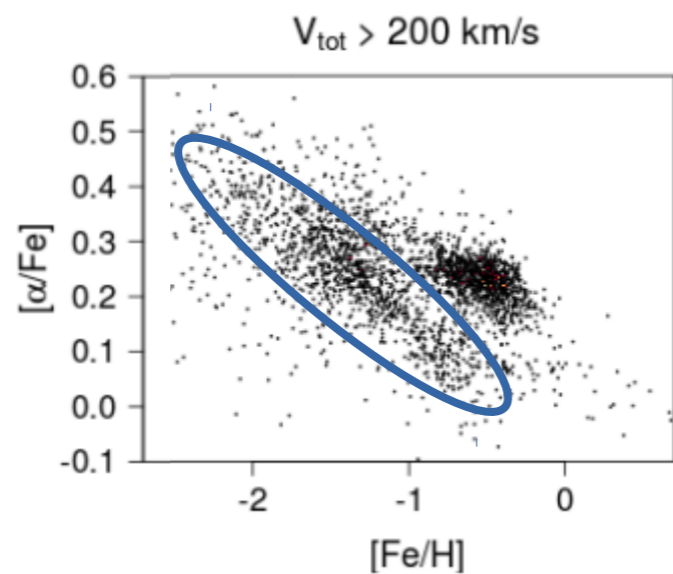
Gaia HR diagram



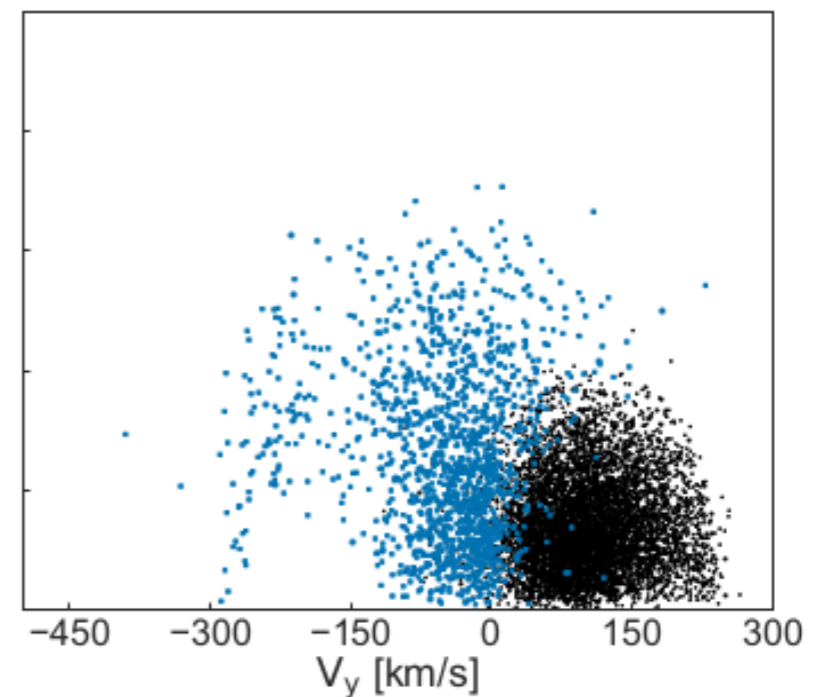
Gaia Toomre diagram



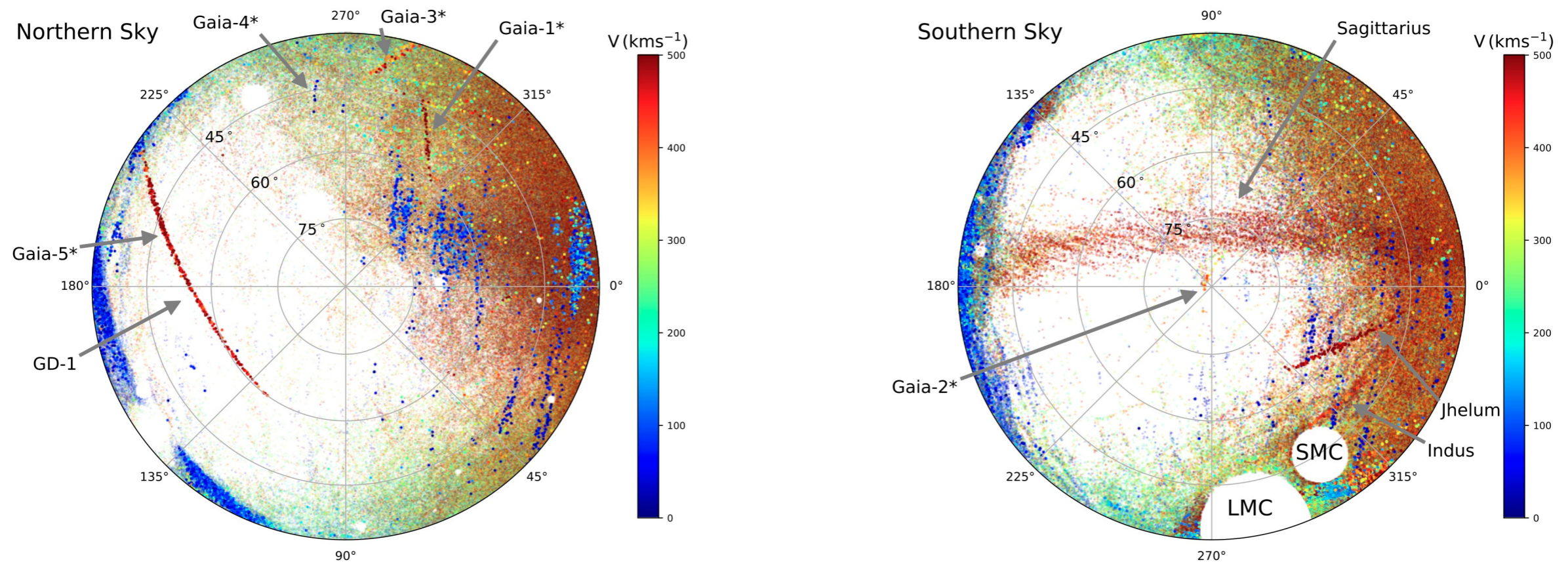
APOGEE spectroscopic data



Merger simulation



Stellar streams in the halo

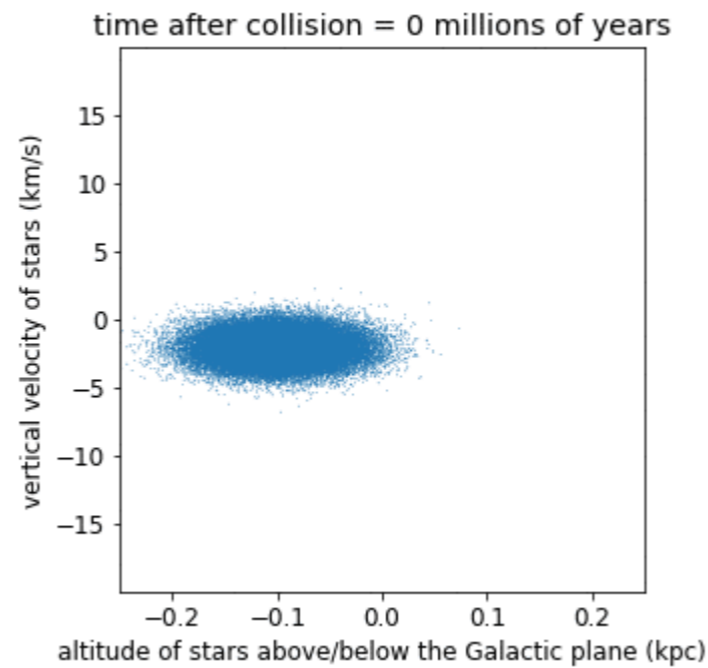
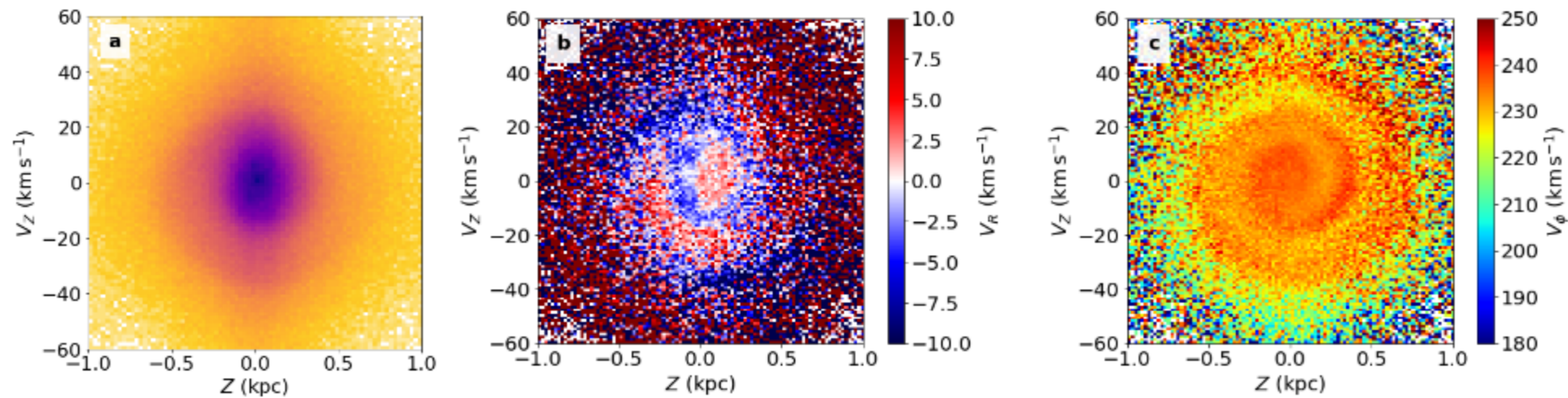


Malhan, Ibata, Martin 2018

Evans et al. : implications of Gaia-Enceladus / Sausage for the DM

Necib et al. : $42 \pm 25\%$ of the accreted DM is in kinematic substructure

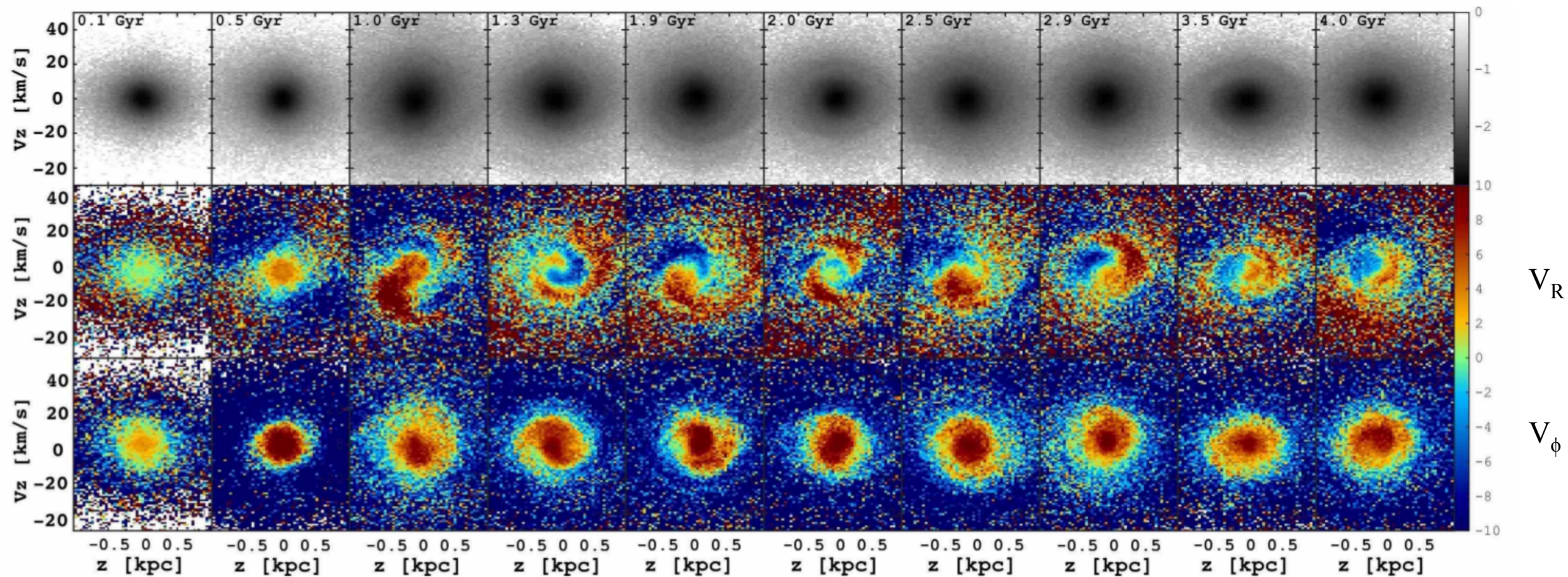
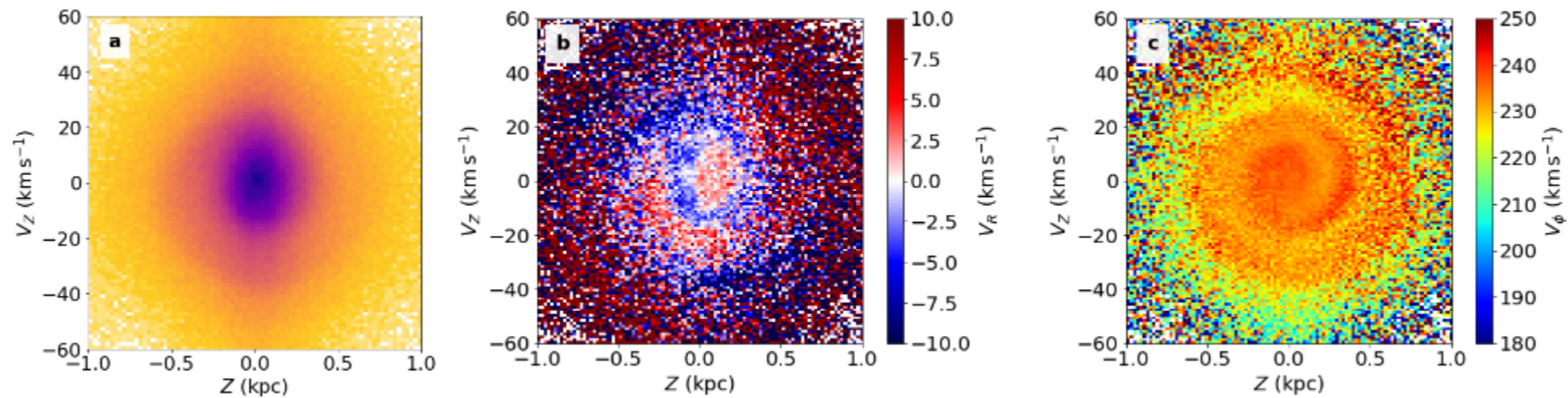
The perturbed Milky Way disk



Perturbation by the Sgr dwarf galaxy

Antoja et al. 2018

The perturbed Milky Way disk

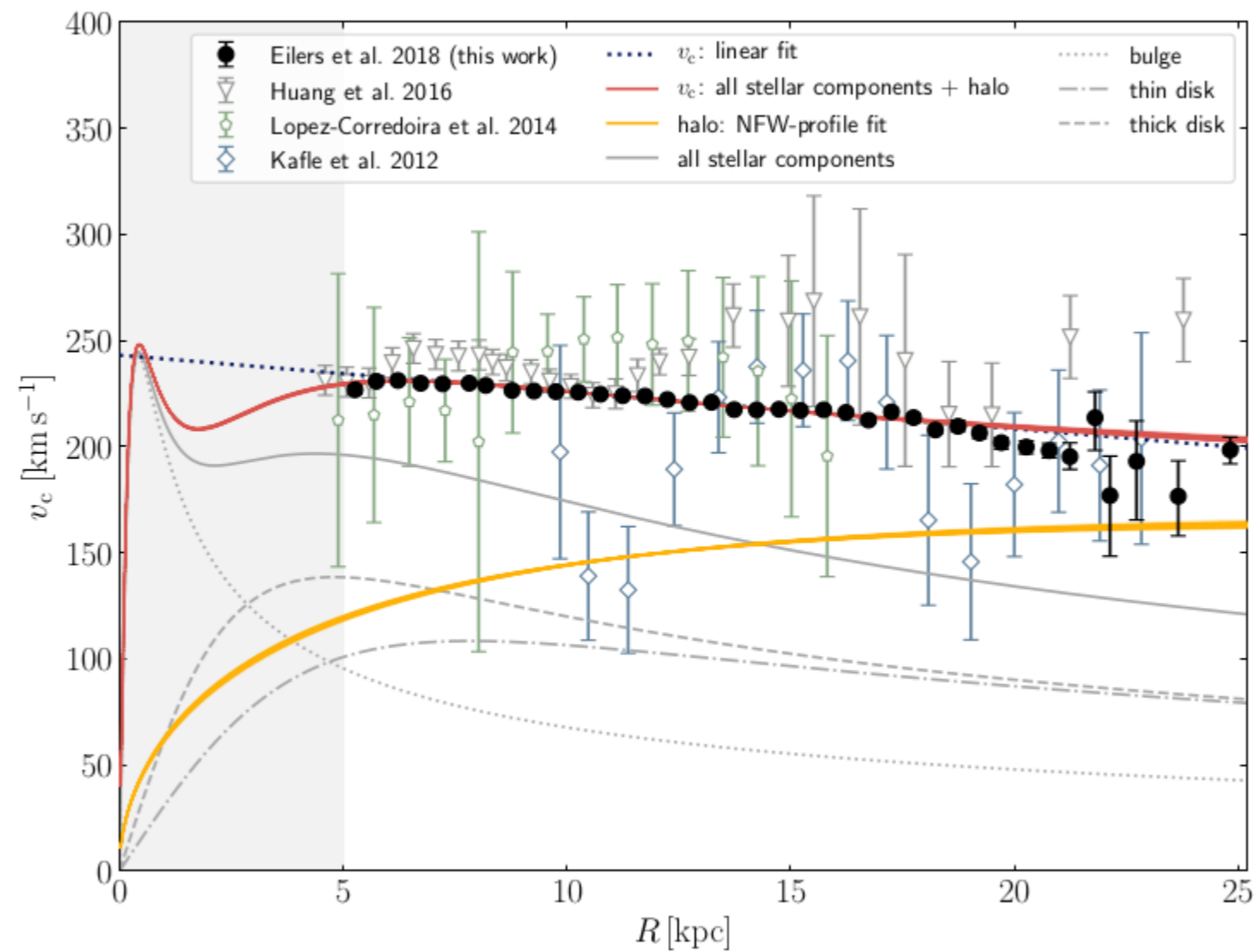


Perturbation by the bar buckling

Khoperskov et al. 2018

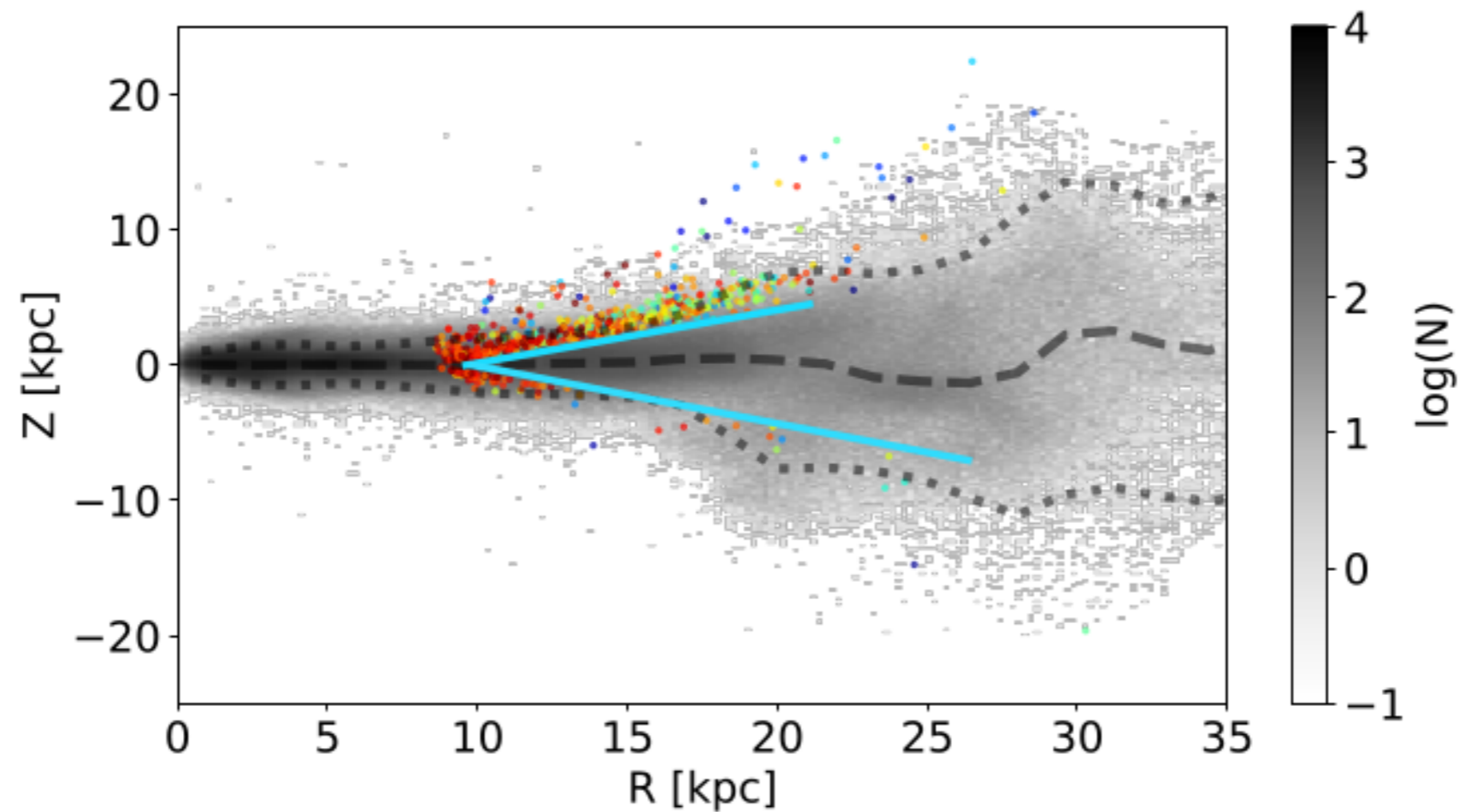
long-lived phase-space spirals 34

The Milky Way circular velocity curve

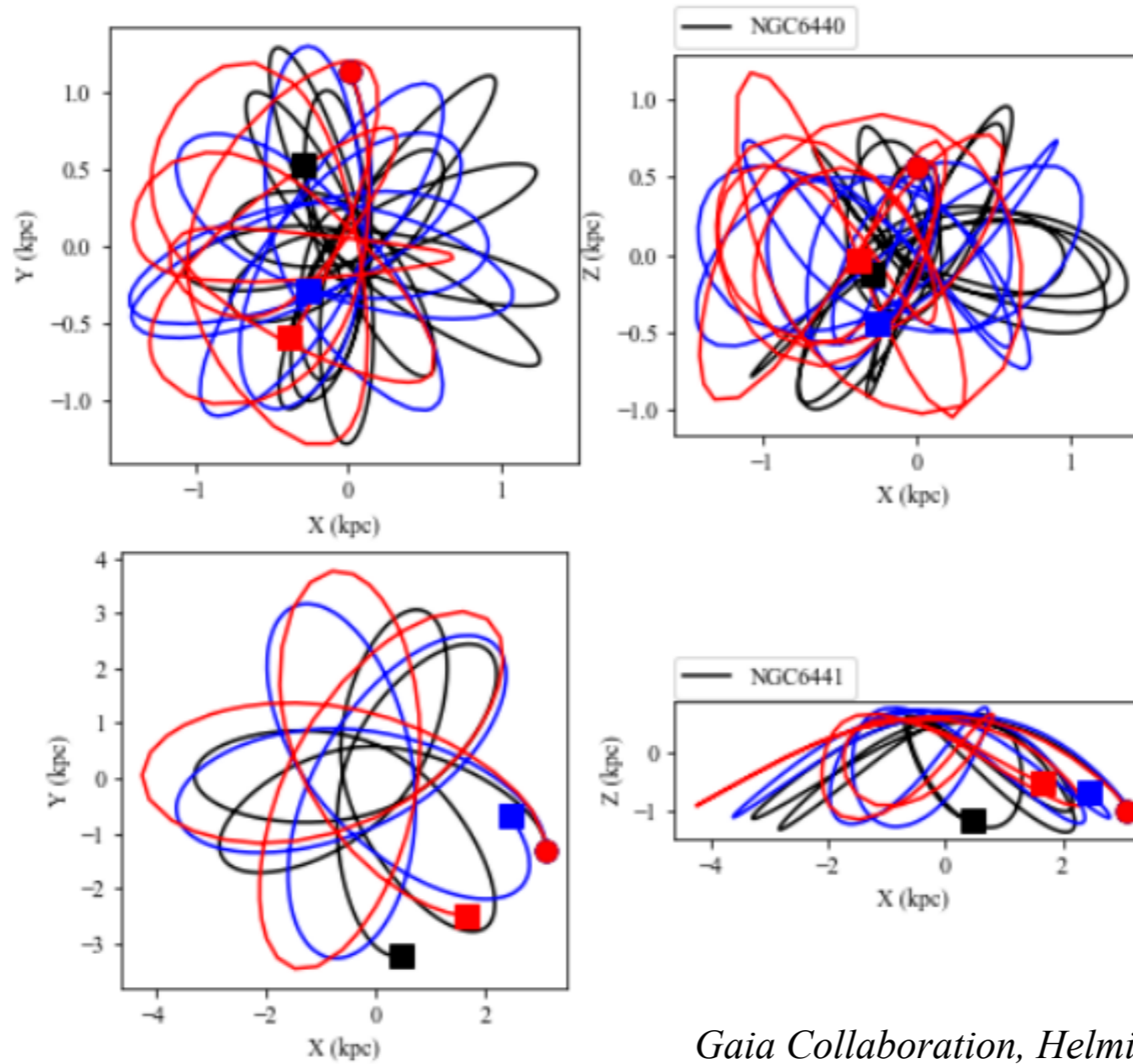


$$\rho_{\text{DM}}(R_{\odot}) = 0.30 \pm 0.03 \text{ GeV cm}^{-3}$$

The disc flare due to the Sgr dSph repeated passage ?



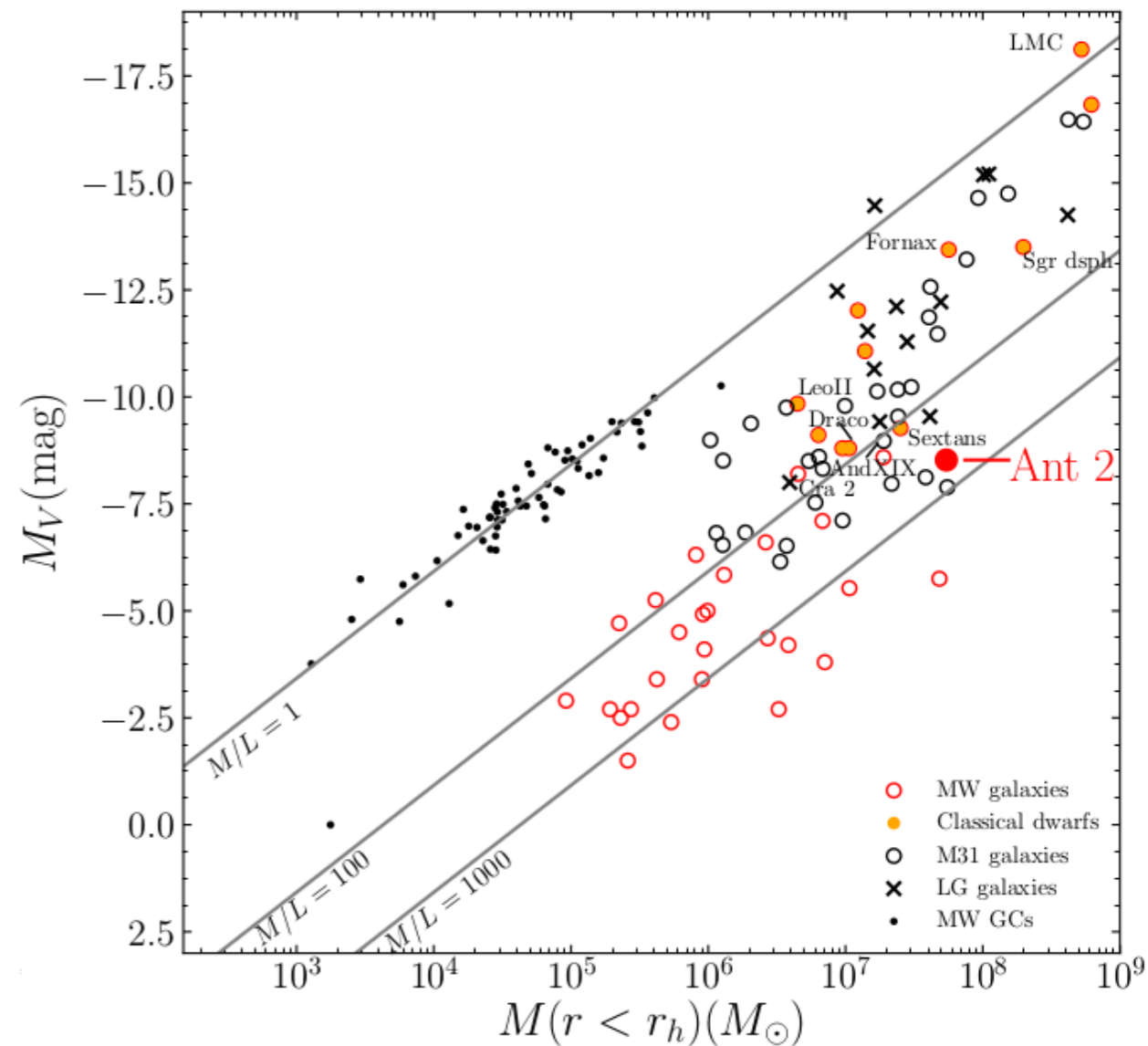
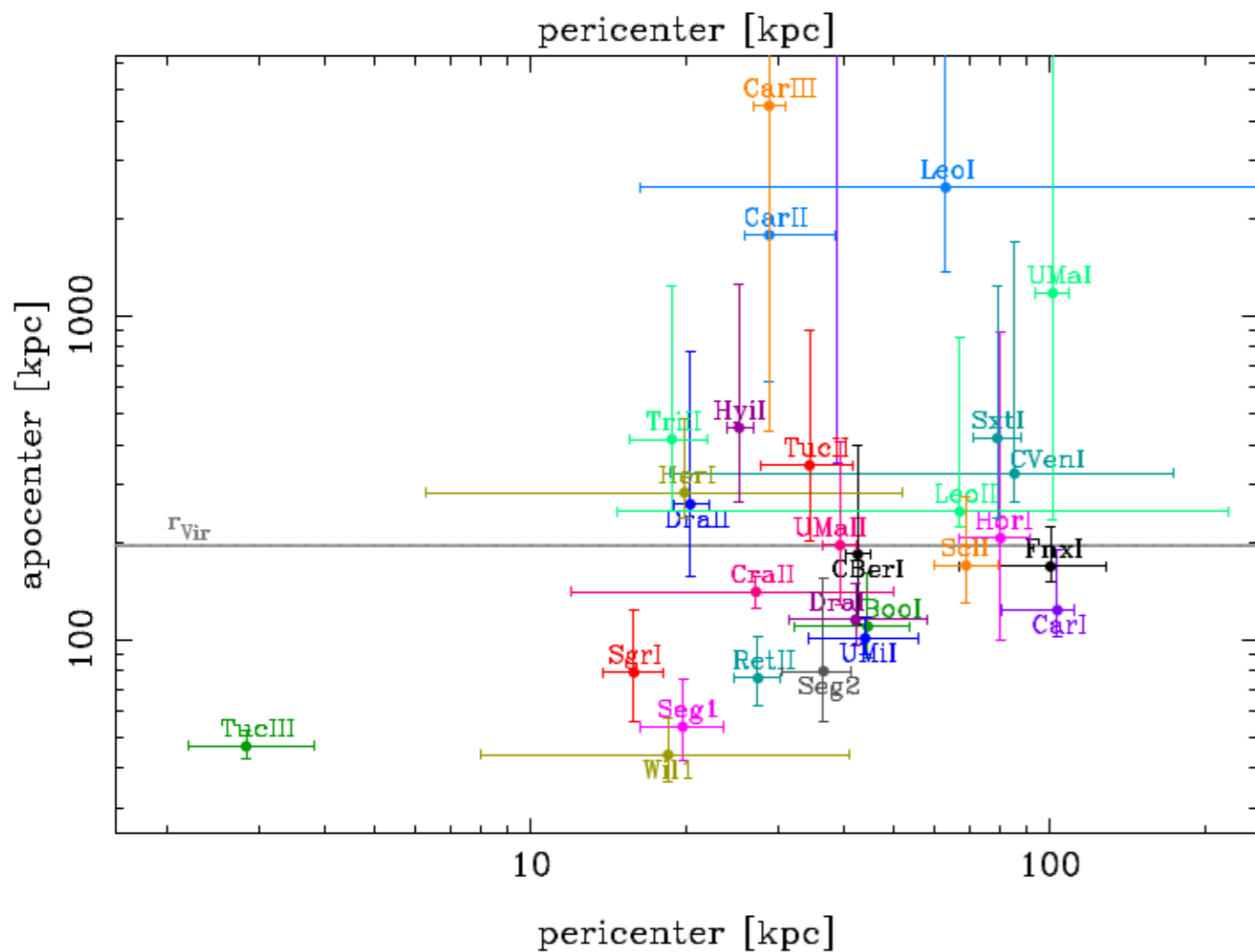
Globular Clusters



Gaia Collaboration, Helmi et al. 2018

Used to derive the mass of the MW + DM:
Watkins et al. 2018, Posti & Helmi 2018

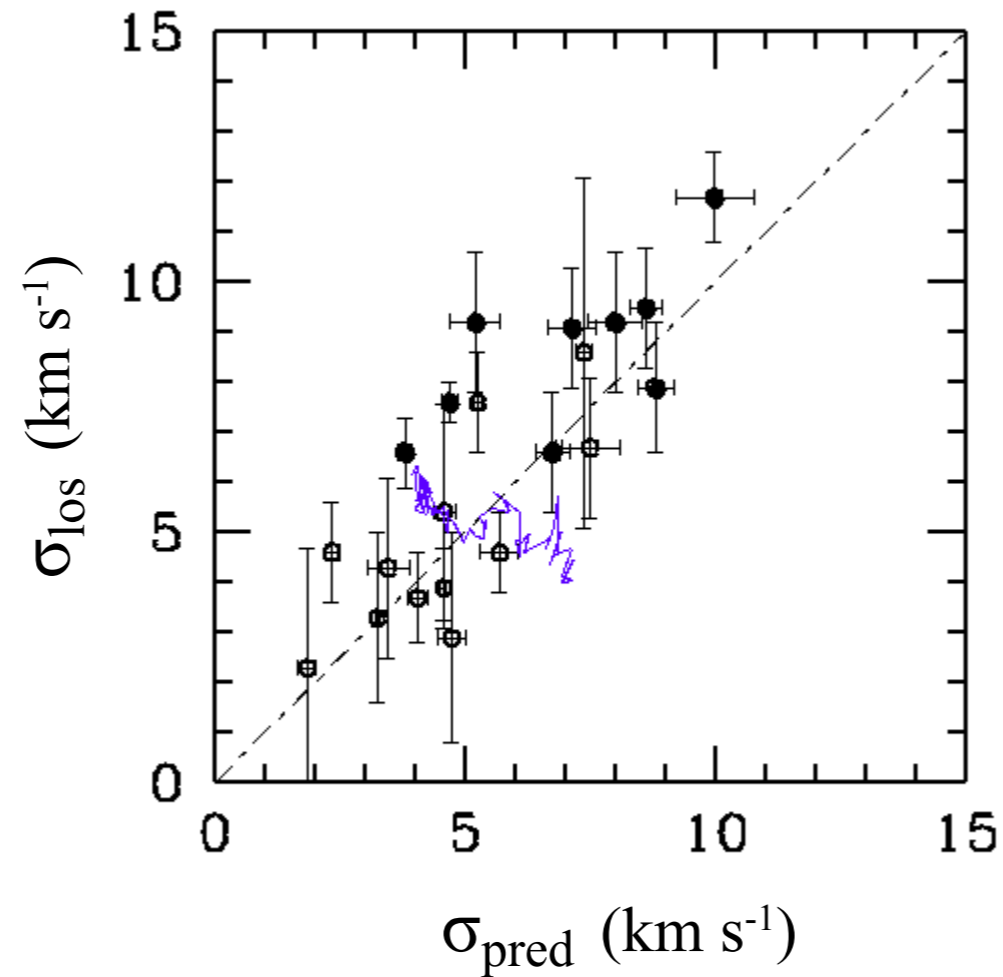
Dwarf spheroidals



Orbit determinations :
Gaia Collaboration, Helmi et al. 2018
Fritz et al. 2018

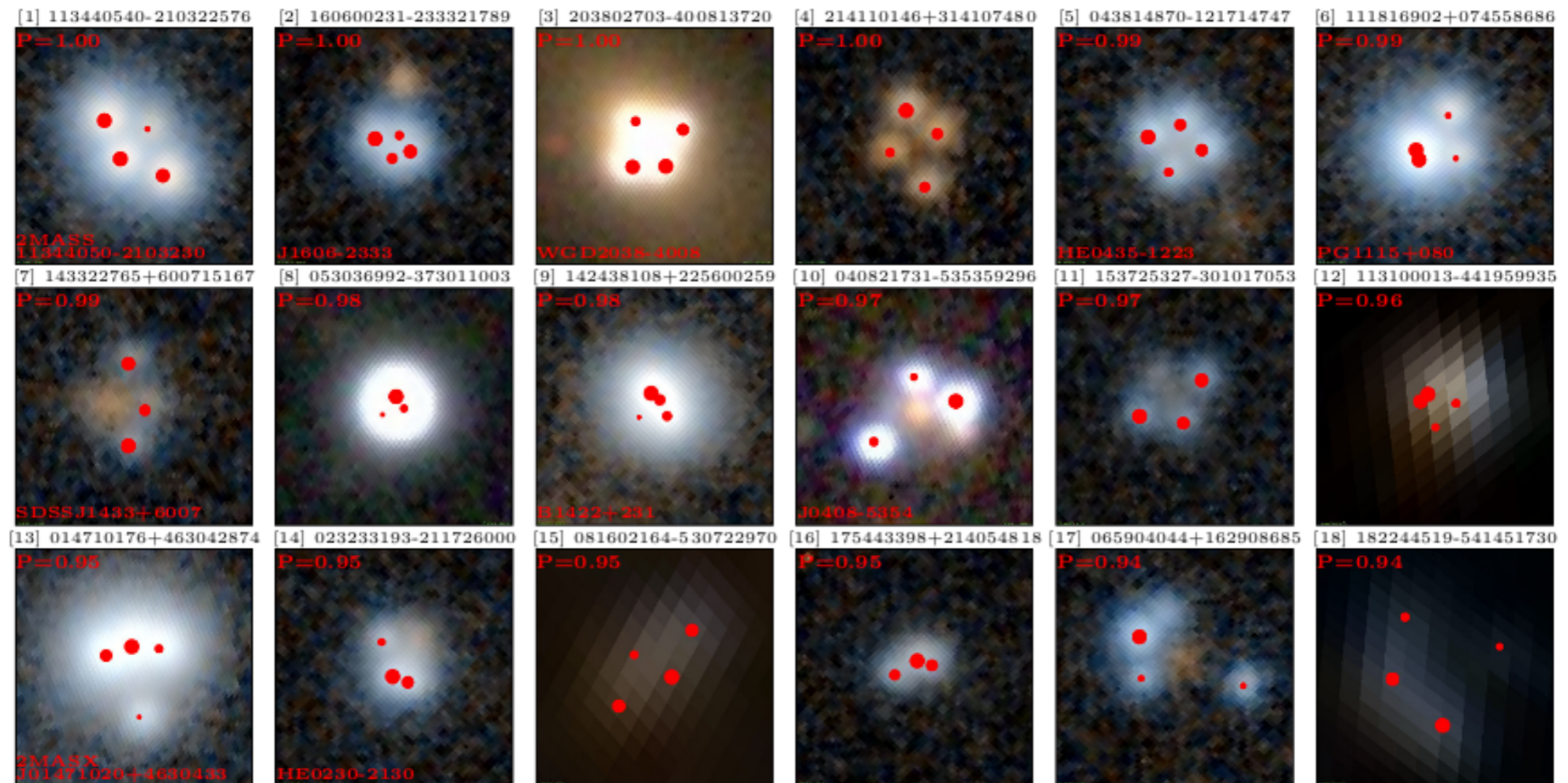
Torrealba et al. 2018
 Discovery of Antlia 2

No more need for DM in dSph ?



Velocity dispersion predicted by a model where dSph are at their first passage

Gravitational lenses



Search for gravitational lens systems in Gaia DR2

Delchambre et al. 2018

More than yesterday, less then tomorrow...

Hyades

	DR2 (25 April 2018)	DR3 (2021)	DR4 (TBD)
Parallaxes and proper motions	Full Sample	++	++
Photometry	G, G _{BP} , G _{RP}	++	++
Variables	550 000	++	++
Radial velocities	RVs at G _{RVS} <12	++	++
SSOs	pre-selected asteroids	New SSOs	++
Astrophysical parameters	for G < 17 : Teff, A _G Radii and luminosities <i>from integrated phot</i>	Classification + parameters from BP/RP + RVS spectra	++
Systems	-	Non-single catalogue Extended Objects	Exoplanet list
Spectra	-	Mean BP/RP spectra Mean RVS spectra	++
Epoch data	-	-	All epoch data

