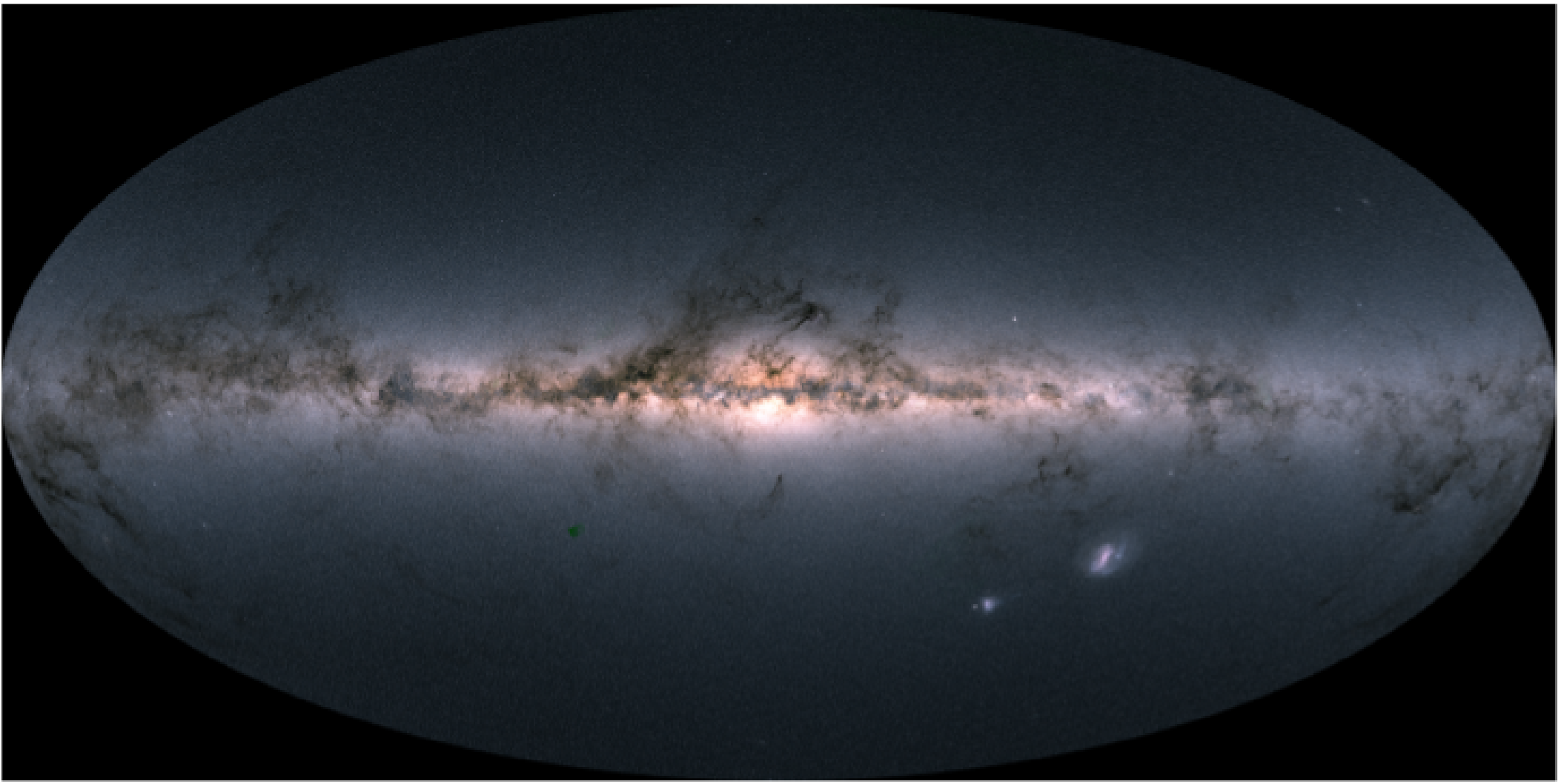
Status of the Gaia Mission and the Gaia DR2 Results



Observatoire de la CÔTE d'AZUR

Frédéric Thévenin

Gaia DPAC

Present status of the satellite

- In Space since 4 years and 7 months ago
- Degrading slower than expected:
- Solar panels & CCDs ok
- 2 decontaminations
- 3 safe modes, the last one is different and severe but ok.
- Gas for extension of the mission (max 5 years):
- 2 years extension accepted by ESA
- (discussion for optimization of the scanning law)

Data acquisition

- Ongoing mostly as expected
- Different events have lost data but nothing huge, it’s part of the life of the mission.
- Contamination is minimum, rising up again, but no plan of decontamination, focus ok for the 3 instruments
- Processing of the data OK by the different CUs
- Photometric spectra (BP/RP) a bit difficult

DR1 vs DR2

Important hypothesis : for DR2 stars are singles

- Source IDs : changes between DR1 & DR2 & DRx
- Photometry : differences between DR1 and DR2 (DR3 & DR4) filters
- Astrometry : complete (5 parameters) with Gaia-only data
- Radial velocities : as expected (data + treatments)
- Stellar Characterisation: Teff, R, L, A_G (E(B-R))

Gaia DR2:
3 catalogues (Main, Variables, Asteroids)
12 papers on the 25 April 2018

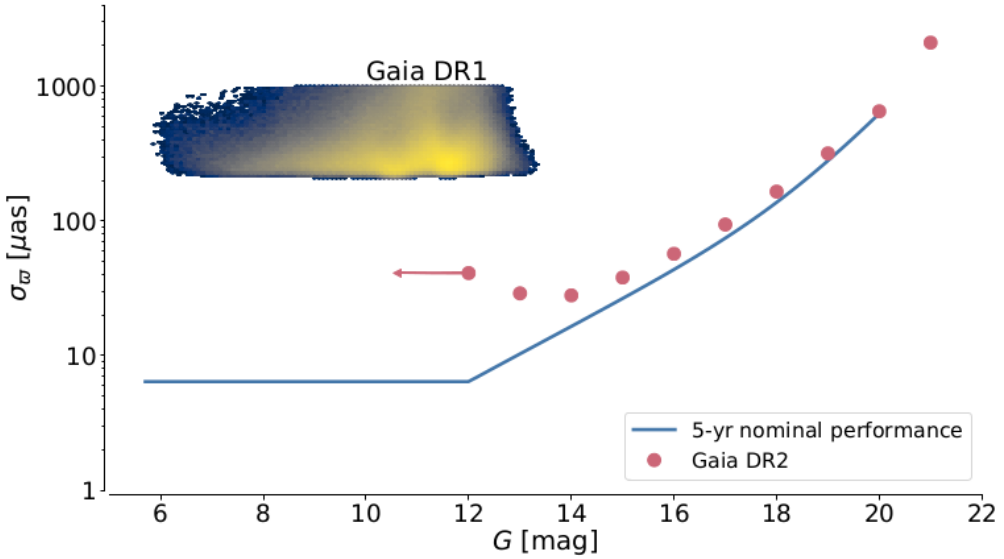
(Please read the papers)

- Gaia DR1: 14 months
- Gaia DR2: 22 months (25 July 2014 (10:30 UTC) and 23 May 2016 (11:35 UTC))
- Gaia DR3: 34 months (25 July 2014 (10:30 UTC) and 29 May 2017 (11:35 UTC))
- The reference epoch for Gaia DR2 is J2015.5 (J2015.0 epoch for Gaia DR1). The time coordinate for Gaia DR2 results is the barycentric coordinate time (TCB)
- Positions and proper motions are referred to the ICRS, to which the optical reference frame defined by Gaia DR2 is aligned.

A big step from Gaia DR1 to DR2

Data product	Gaia DR2	Gaia DR1
Total number of sources	$>$ 1.5 billion	1 142 679 769
Position, parallax, proper motion	$>$ 1.3 billion	2 057 050
Position only	$>$ 200 million	1 140 622 719
Mean G	$>$ 1.5 billion	1 142 679 769
Mean G, G_{BP}, G_{RP}	$>$ 1.1 billion	-
Median v_{rad} at $G_{RVS} < 12$	$>$ 6 million	-
Astrophysical parameters at $G < 17$	$>$ 150 million	-
Variable star light curves	$>$ 500 thousand	3 194
Epoch astrometry for a pre-selected list of asteroids	$>$ 13 000	-

More info: https://www.cosmos.esa.int/web/gaia/dr2



Typical parallax precision

$G = 15$	0.02–0.04 mas
$G = 17$	0.1 mas
$G = 20$	0.7 mas
$G = 21$	2.0 mas

- Systematic errors below 0.1 mas
- Spatial correlations at ~ 1 and ~ 20 degree scales
- Bright star performance calibration limited

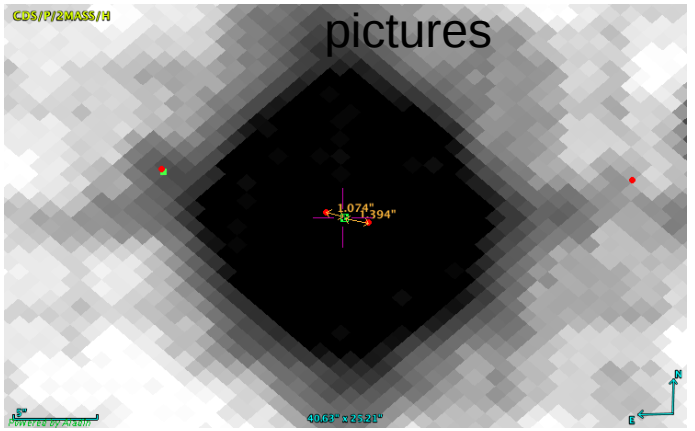
Observatoire de la CÔTE d'AZUR

Gaia DPAC

Cross-match catalogues can be difficult: example with a 2MASS star

- ASI tools (gaiaportal.asdc.asi.it) for the crossmatch catalogues
- Cross match catalogues with DR2 (epoch 2015.5)
- enlarged to 5” if object not found

2MASS pictures



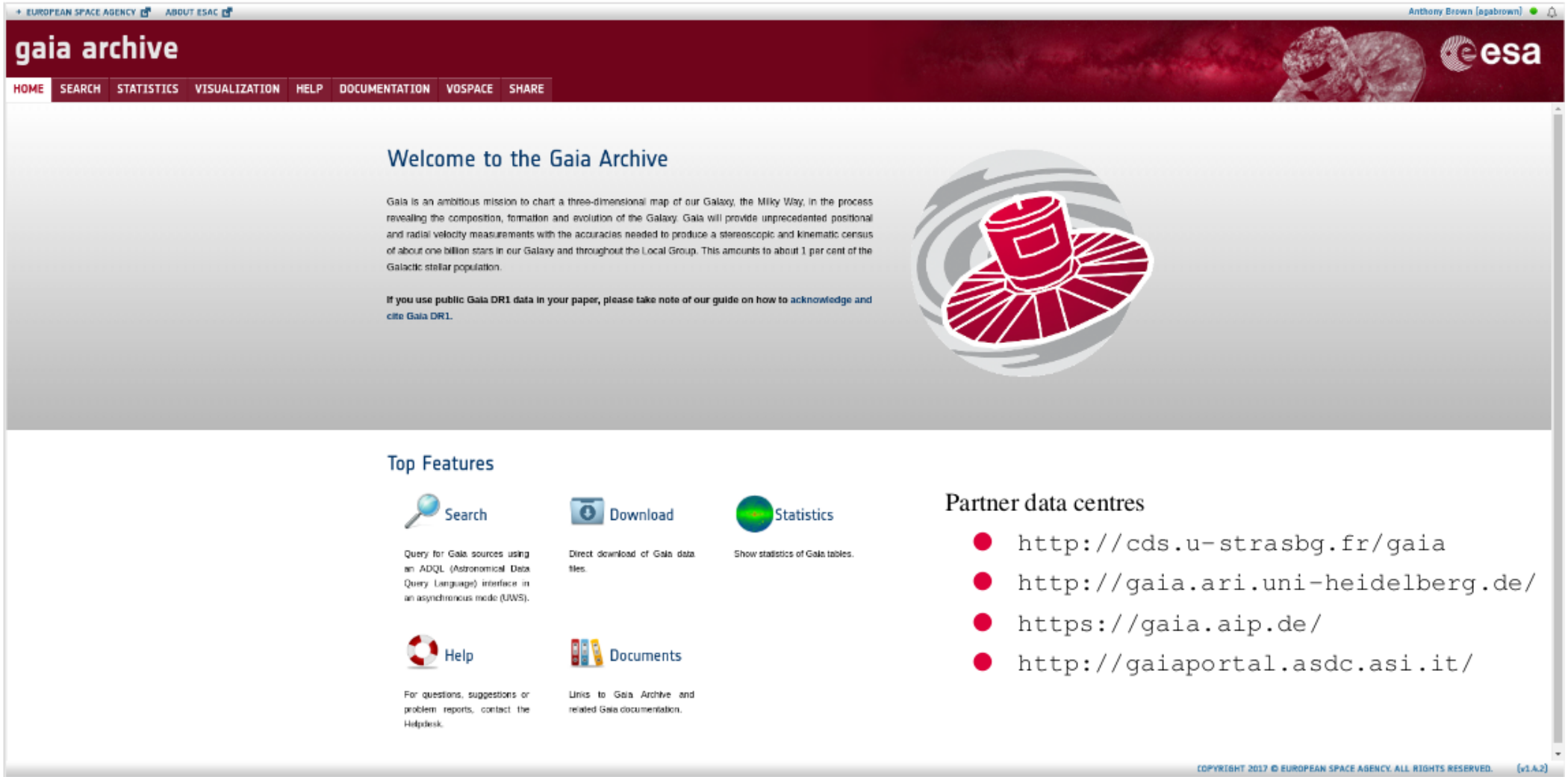
2mass coord 1999.0

Observatoire de la CÔTE d'AZUR

Gaia DPAC

ESA tools

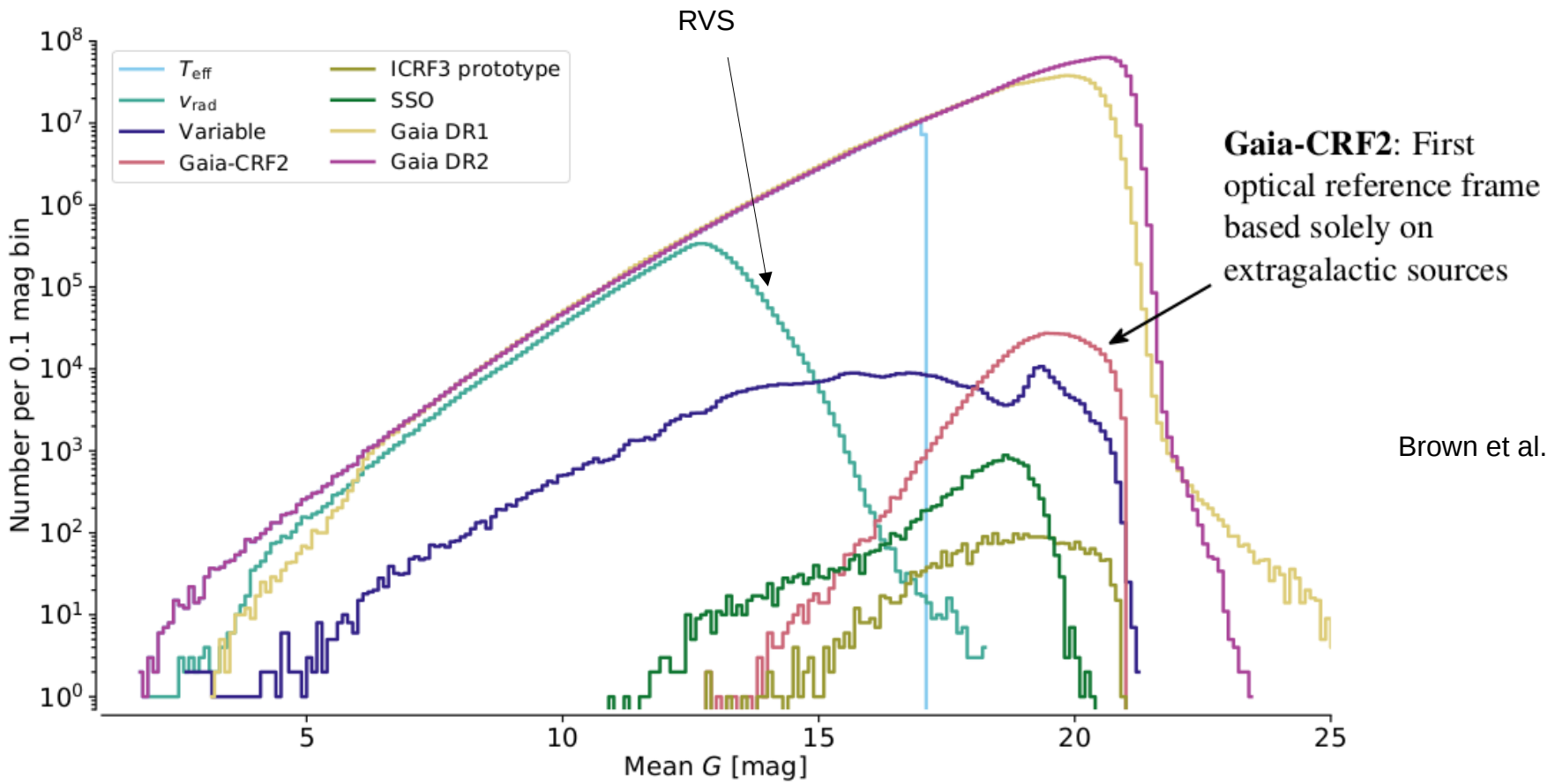
Gaia data archive (archives.esac.esa.int/gaia)



Gaia its own reference frame

- Gaia-CRF2 vs ICRF3

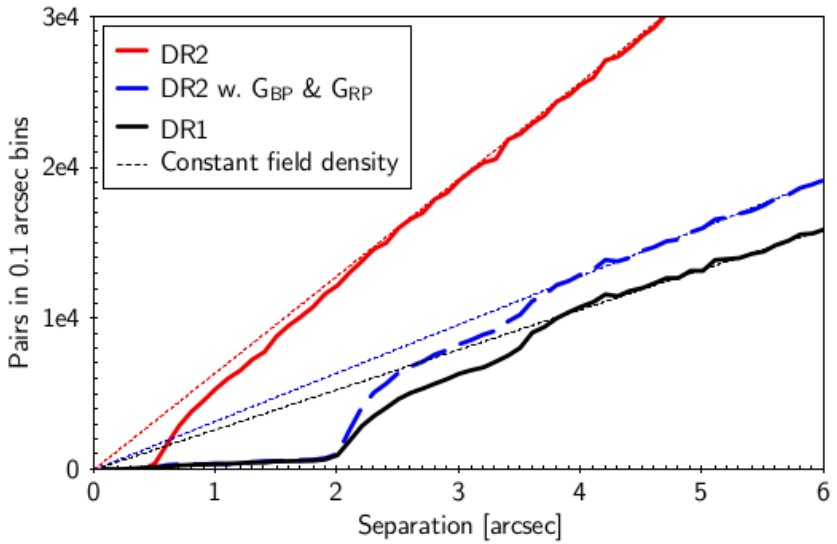
Source counts

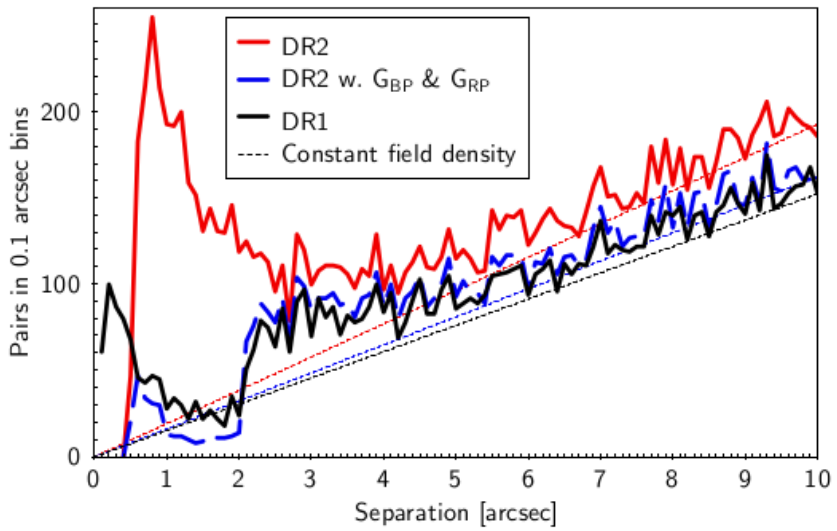


Brown et al.

Separation of sources: 0.1” DR4

Very important for example for Plato





Observatoire de la CÔTE d'AZUR

Gaia DPAC

Astrometric errors

- Negative parallaxes
- Systematics

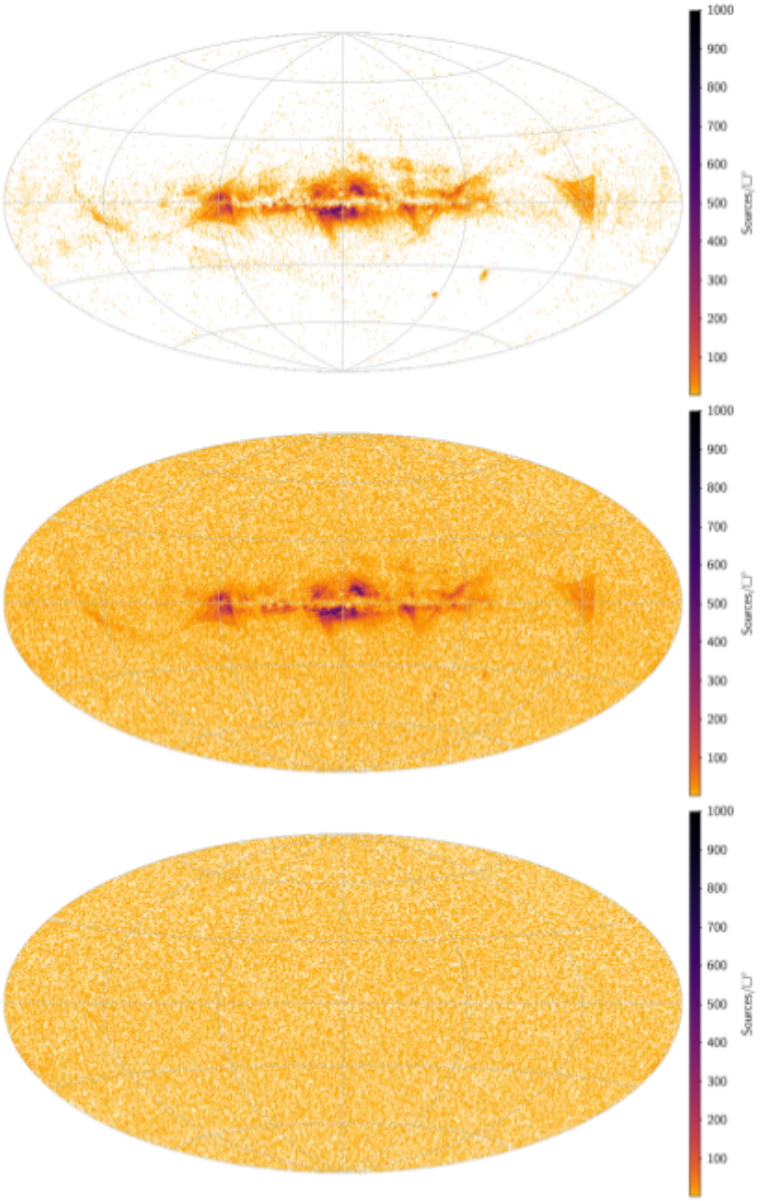


Fig. 10. Sky maps in Galactic coordinates showing sources with parallaxes with less than 10% error and significantly different from zero, *Top:* parallaxes below −10 mas; *Centre:* parallaxes larger than +10 mas; and *Bottom:* parallaxes larger than +10 mas after applying the quality filters in Eqs. 1 and 2.

-0.029 mas uniformely for faint objects, for the bright side of the catalogue systematics could be larger

Basic angle monitoring ?

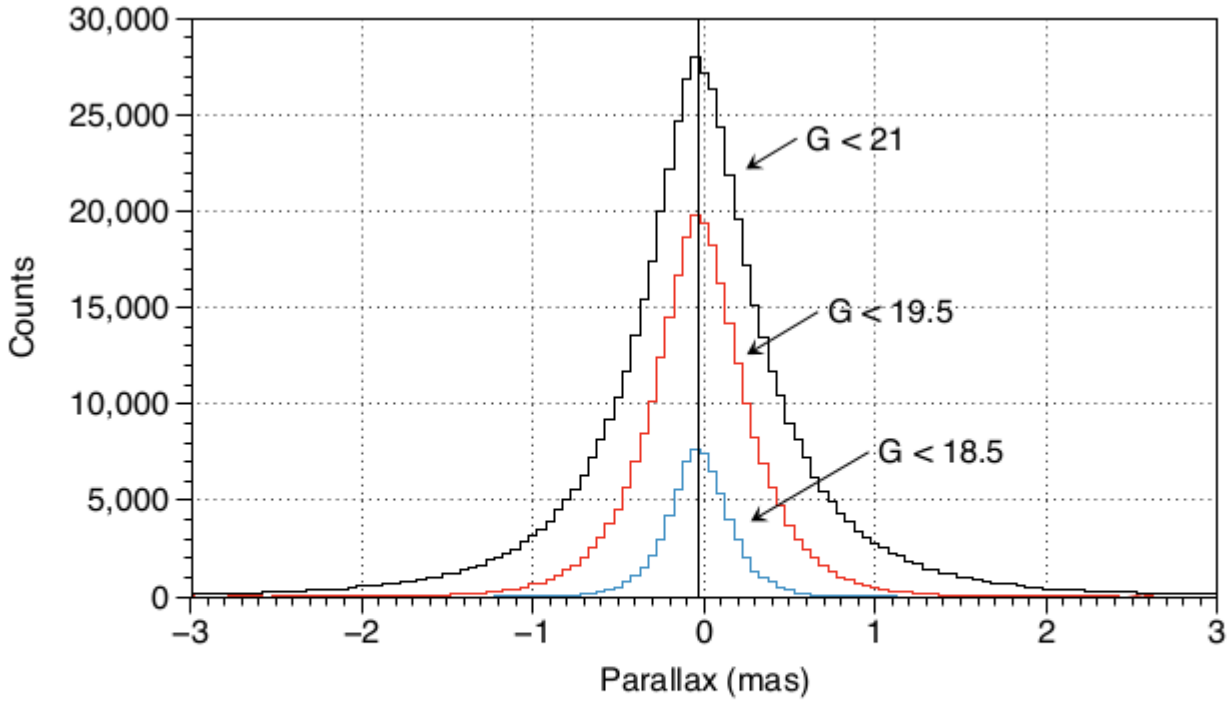


Fig. 8. Distribution of parallaxes in the *Gaia* Archive for the *Gaia*-CRF2 quasars, subdivided by the maximum magnitude. The line at $\varpi = -0.029$ mas shows the global zero-point offset.

Mignard+18

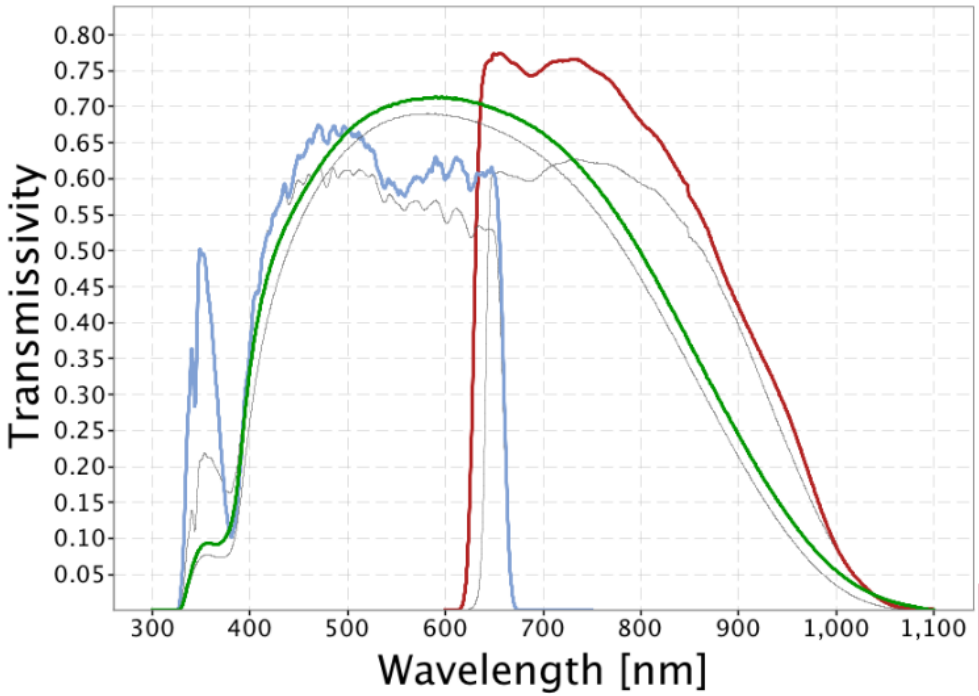
Important conclusions
on the parallaxes and the systematics

A systematic of 0.029 mas is detected (potentially a BAM calibration)
and probably more important systematics in particular for stars brighter than 13
(gating calibration, chromaticity)

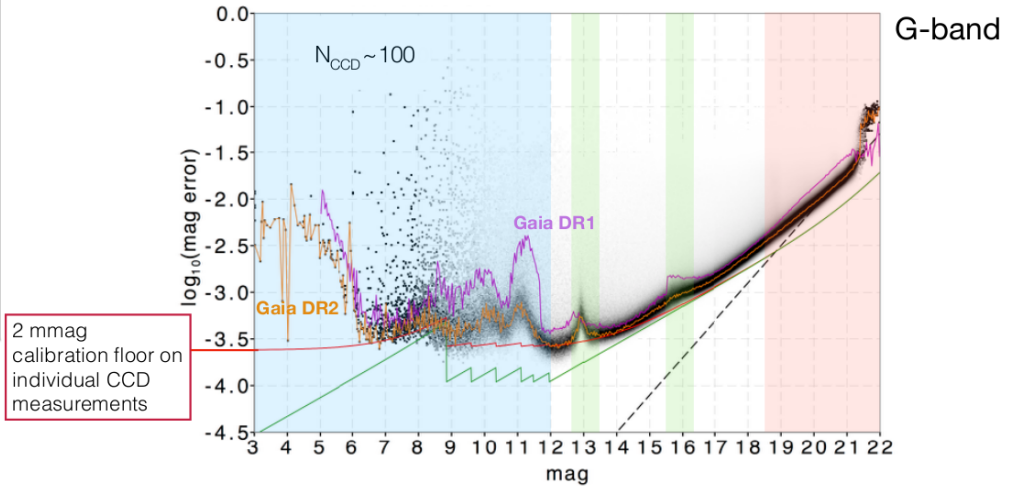
Structures exist in the AGIS solution : take car when regrouping star
in a common structure example for the LMC

DR3 will try to correct (at least understand) most of the systematics,
correlations

Photometry few difficulties
Calibration is hard (Gaia coll.+18)



Precision of the mean photometry



2 mmag calibration floor on individual CCD measurements

Saturation effects & problematic calibrations due to fewer calibrators

Change in windowing scheme, flux loss effects, photometric system inhomogeneities

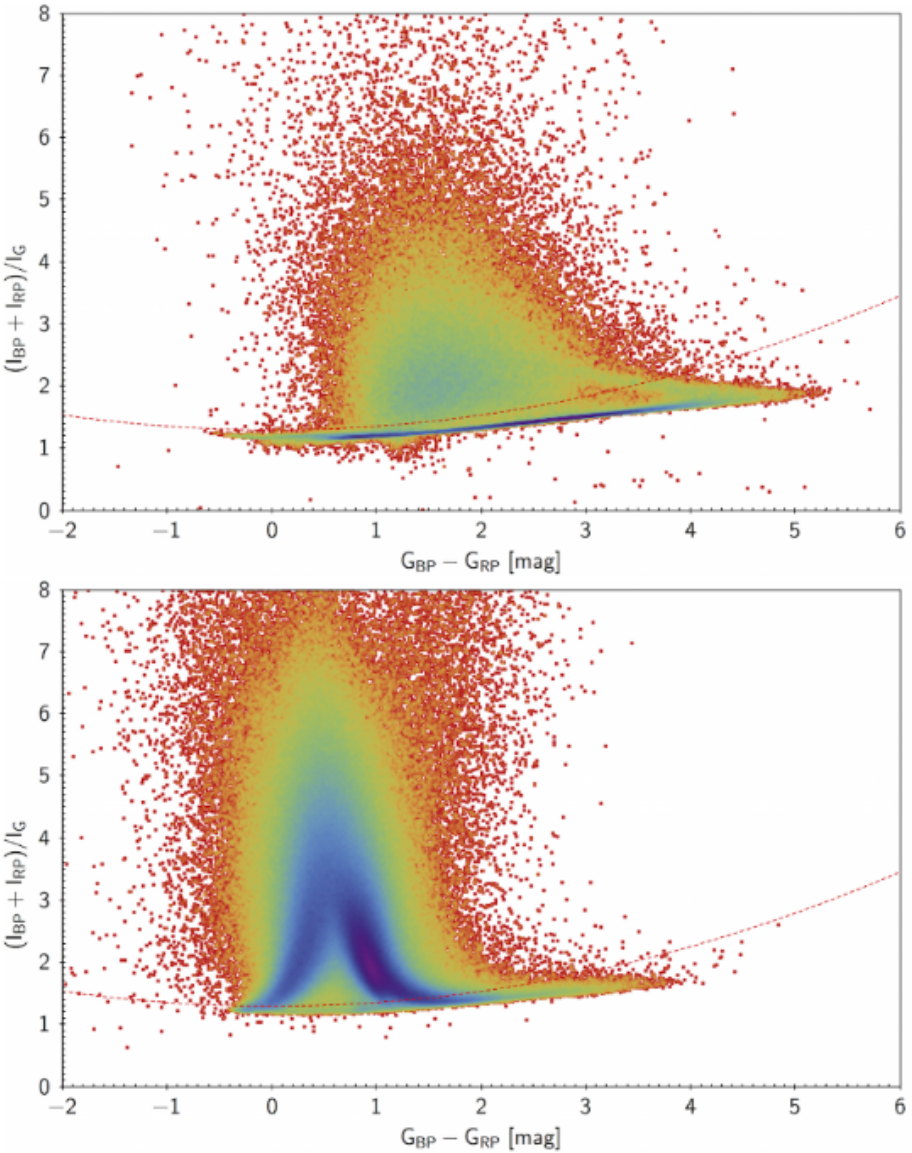
Increased background levels (stray-light) cause poorer performances for faint sources

Filters description:
https://www.cosmos.esa.int/web/gaia/iow_20180316

Important remark

(see Gaia coll. Paper photometry)

- There is an excess of color
- Possibly due to crowding, binarity
- (sky background modeling),
- extended objects
- Potential problem for the chromatism
- correction
- Difficulties for APs



Evans+18

Observatoire de la CÔTE d'AZUR

Gaia DPAC

Crowding, overlapping in BP/RP (Gaia coll.+18)

- LMC Bulge very affected: looks bluer
- Still background to improve in particular the Zodiacal light still visible in the distribution of the data

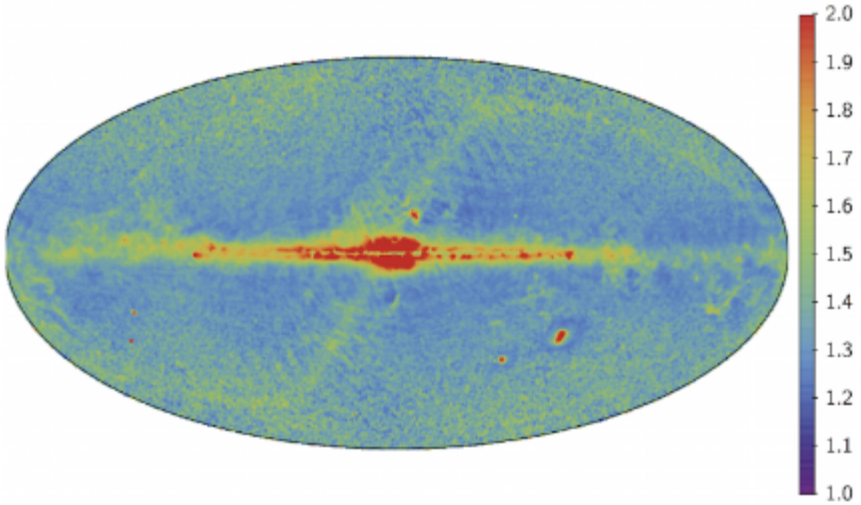
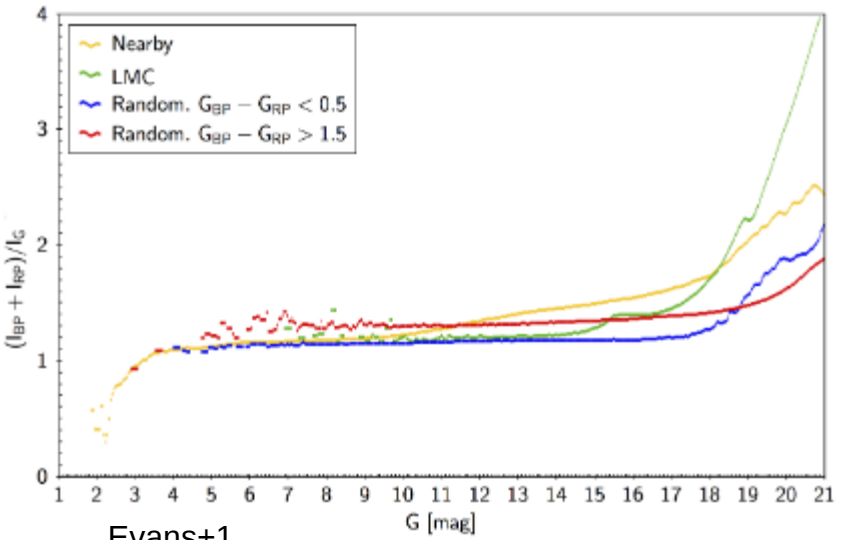


Fig. 18. Median flux excess in galactic coordinates for a random set of sources.



Evans+18

Observatoire de la CÔTE d'AZUR

Gaia DPAC

You can start a new science on clusters (Gaia coll.+18)

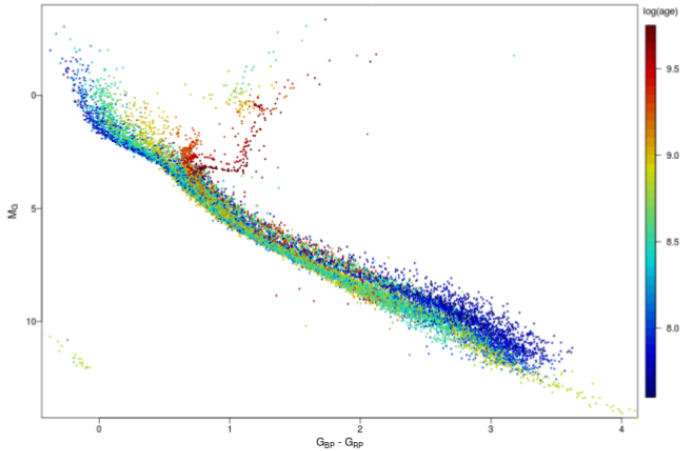


Fig. 2. The composite HRD for thirty two open clusters, coloured according to log(age), using the extinction and distance moduli as determined from the *Gaia* data (Table 2).

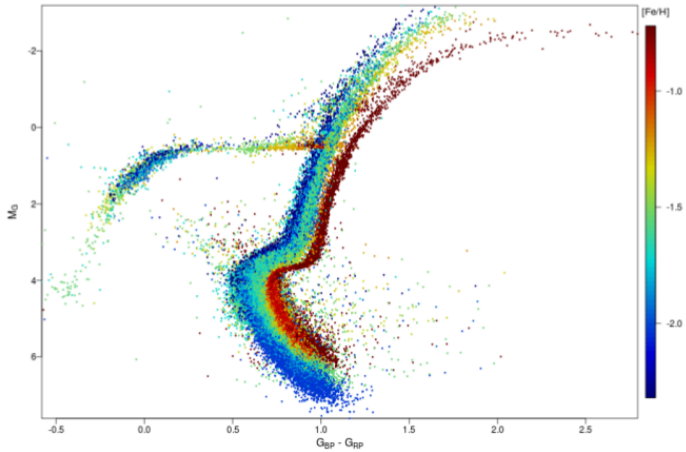


Fig. 3. The combined HRD for 14 globular clusters, coloured according to metallicity (Table 3).

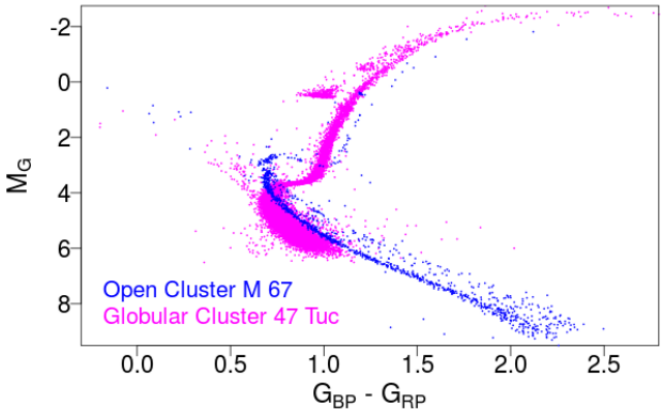


Fig. 4. Comparison between the HRDs of 47 Tuc (NGC 104, Age=12.75 Gyr, [Fe/H]=-0.72), one of the most metal rich globular clusters (magenta dots) and M 67 (NGC 2682, Age=3.47 Gyr, [Fe/H]=0.03), one of the oldest open clusters (blue dots).

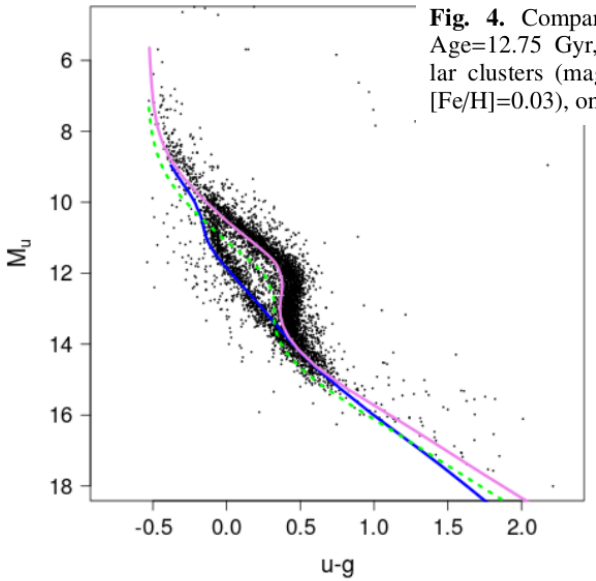


Fig. 15. SDSS white dwarfs (5,237 stars) with evolutionary models. M_u is computed using the SDSS *u* magnitude and the *Gaia* parallax. *Magenta* : 0.6 $M_\odot$ pure H; *Green dashed* : 0.8 $M_\odot$ pure H; *Blue* : 0.6 $M_\odot$ pure He.

Observatoire de la CÔTE d'AZUR

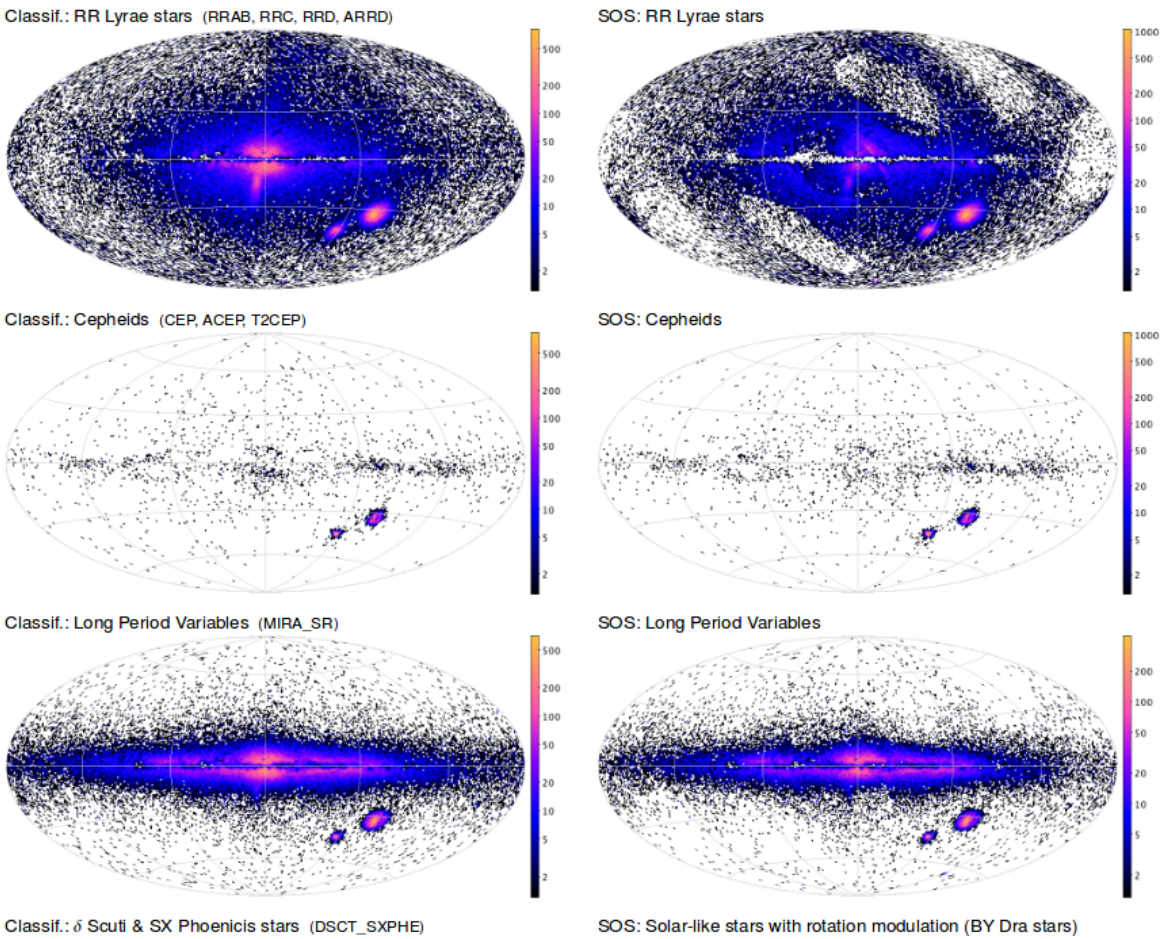
Gaia DPAC

Variability (Gaia coll.+18)

- A dedicated catalogue
- At minimum 2 observations
- using G

Vairiables are difficult for the astrometry and related calibrations!

Talk by A. Lanzafame on gyrochronology



Observatoire de la CÔTE d'AZUR

Gaia DPAC

Radial velocities

Gaia DR2 coll., 2018

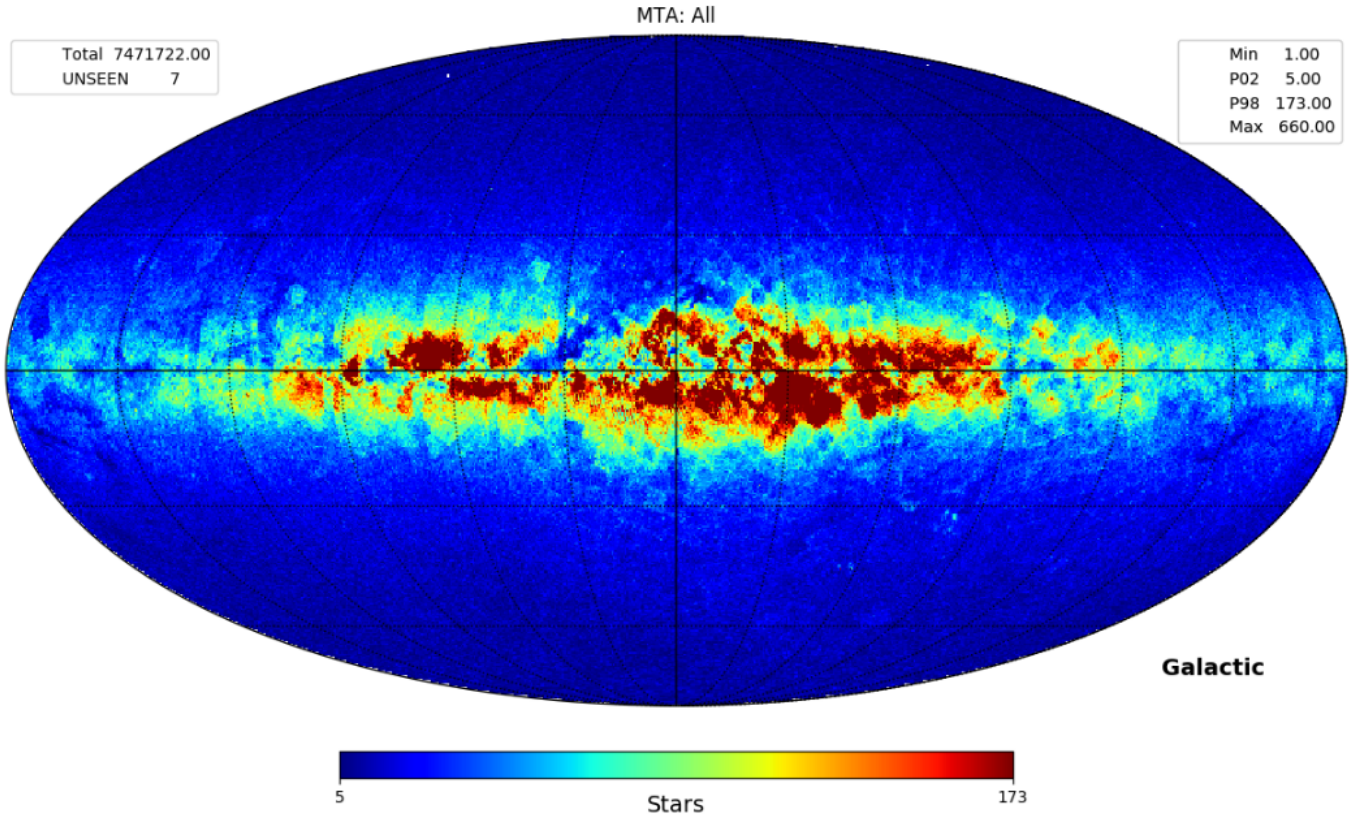
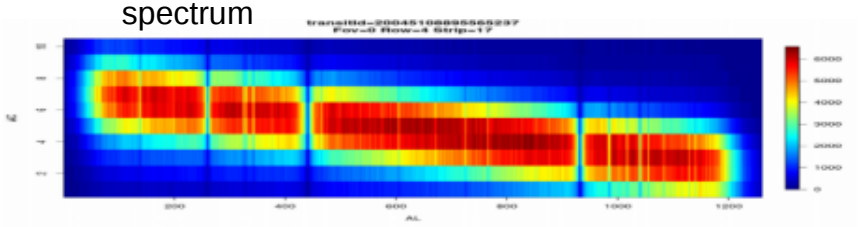


Fig. 2. Stellar density map (Galactic coordinates) of the stars for which a median velocity has been derived and which have passed the validation tests (so far). The area of the pixel is $\sim$0.2 deg^2.

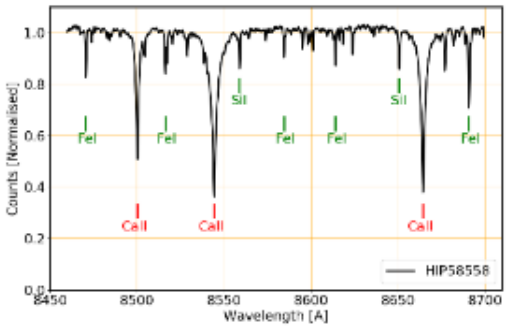
14 months of data!

RVS spectra

Extracted spectrum

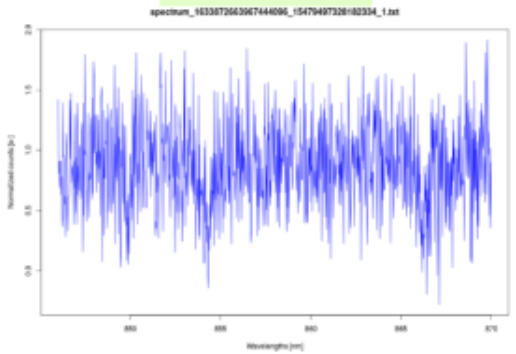


- Bright stars



- Exposure time: 4.42 s / spectrum
- Vr at Grvs = 16.2 mag → combine spectra over 5 years

- V = 12 mag

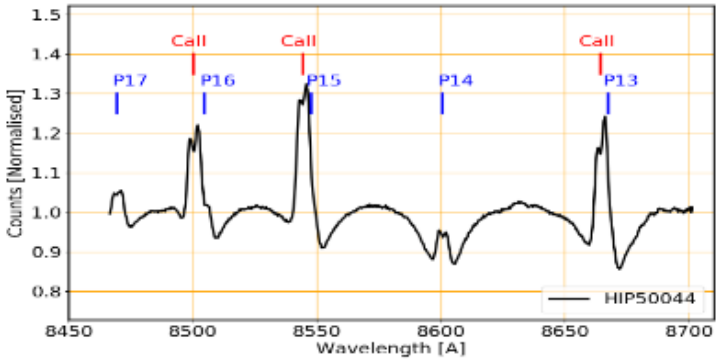


- Gaia DR2: **Grvs = 12 mag**
- Gaia DR2: **280 million spectra**

VR content

- Grvs ≤ 12 mag
- Vr in [-1000, +1000] km/s
- Teff in [3550, 6900] K

- No binaries (when detected)
- No emission-lines (when detected)
- No large amplitude variables (when detected)
- No non-rectangular windows processed



VR time series not published in DR2

Credit D. Katz

Observatoire de la CÔTE d'AZUR

Immersion of the VRs in ground based references (Gaia coll, Soubiran+18)

- Zero-point

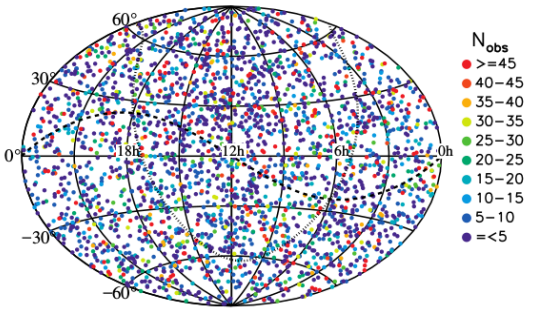


Fig. 6. Distribution of the RV-STDs on the celestial sphere in equatorial coordinates. A dashed line indicates the projection of the Ecliptic plane, a dotted line that of the Galactic plane. The colour code corresponds to the number of observations per star.

Data + Algos looks OK!

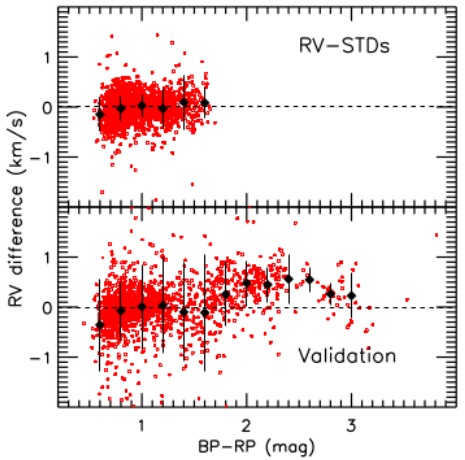
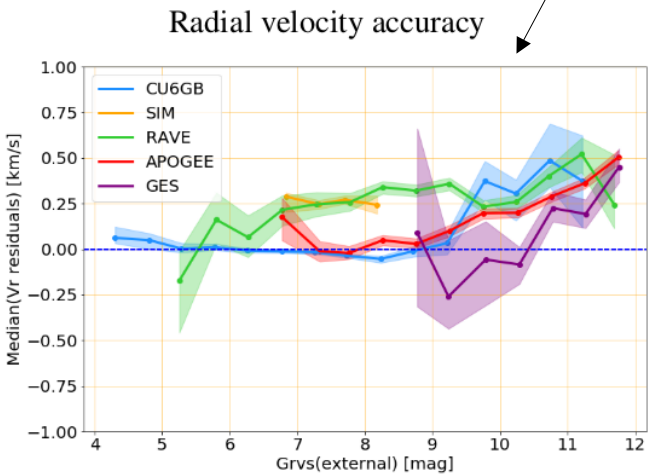
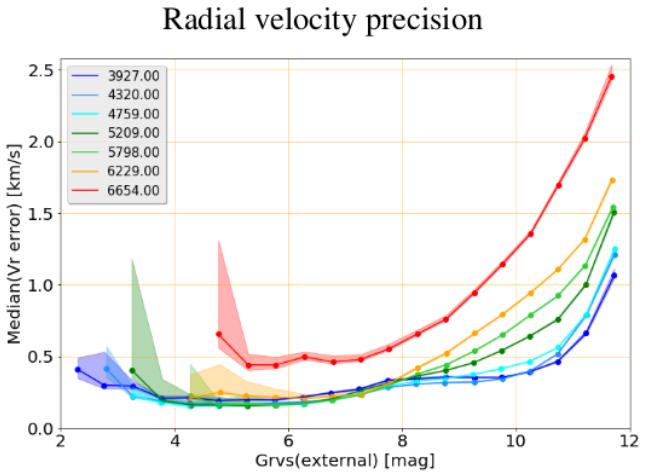


Fig. 10. RV difference (our catalogue – *RVS*) as a function of the $G_{BP} - G_{RP}$ colour for the RV-STDs and for the validation stars





Observatoire de la CÔTE d'AZUR

Gaia DPAC

From Gaia DR2 coll., Katz et al. 2018

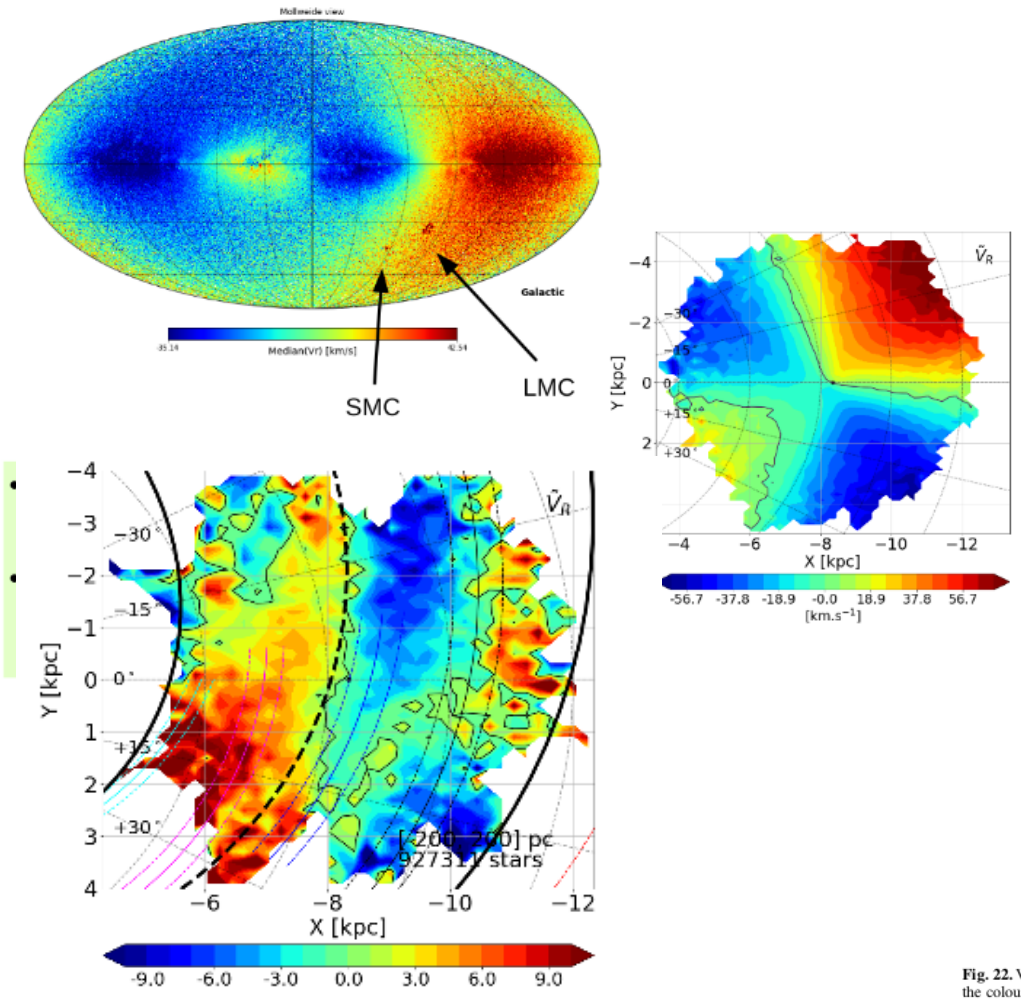


Fig. 19. Face-on map of the median radial velocity (in km s^{-1}) for the mid-plane layer ([−200, +200] pc), derived using the Giants Sample. The two arm model of Drimmel (2000), adjusted on near infra-red data, is over-plotted as thick black lines. The thick dashed line highlights the

See also talk by Eleonora Zari

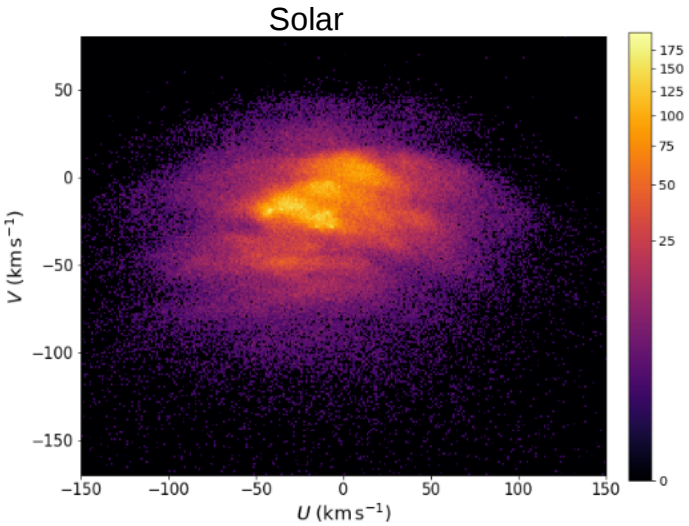


Fig. 22. Velocity plane of the stars of the solar neighbourhood. We show a two-dimensional histogram of the velocity with a bin of 1 km s^{-1}, thus, the colour scale indicates the number of stars per (km s^{-1})^2.

APs of stars (Gaia coll+18)

- Need BP/RP spectra, no yet available!
- Teff, A_G, L, R
- G<17
- 3000<Teff<10000K

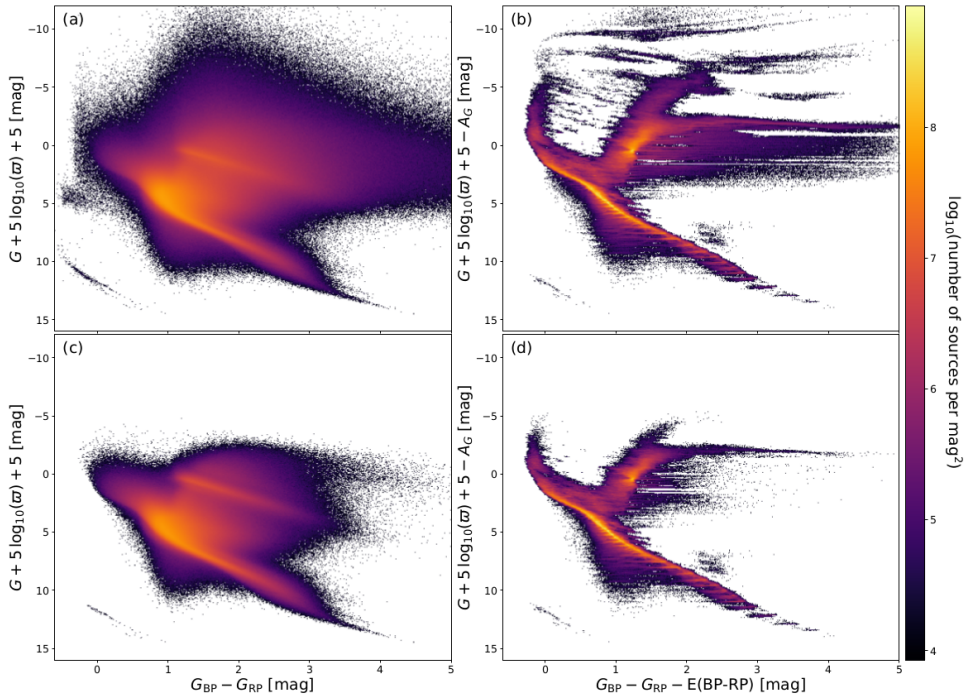


Fig. 19. Observed colour-magnitude diagrams (panels a and c) and dust-corrected colour-magnitude diagrams (panels b and d). Using our estimate of A_G, we obtain M_G from $M_G + A_G$ ($= G + 5\log_{10}\varpi + 5$). The upper panels a and b show all sources with $G \leq 17$ and $\varpi > 0$. The lower panels c and d restrict this further to sources with parallax uncertainties lower than 20%.

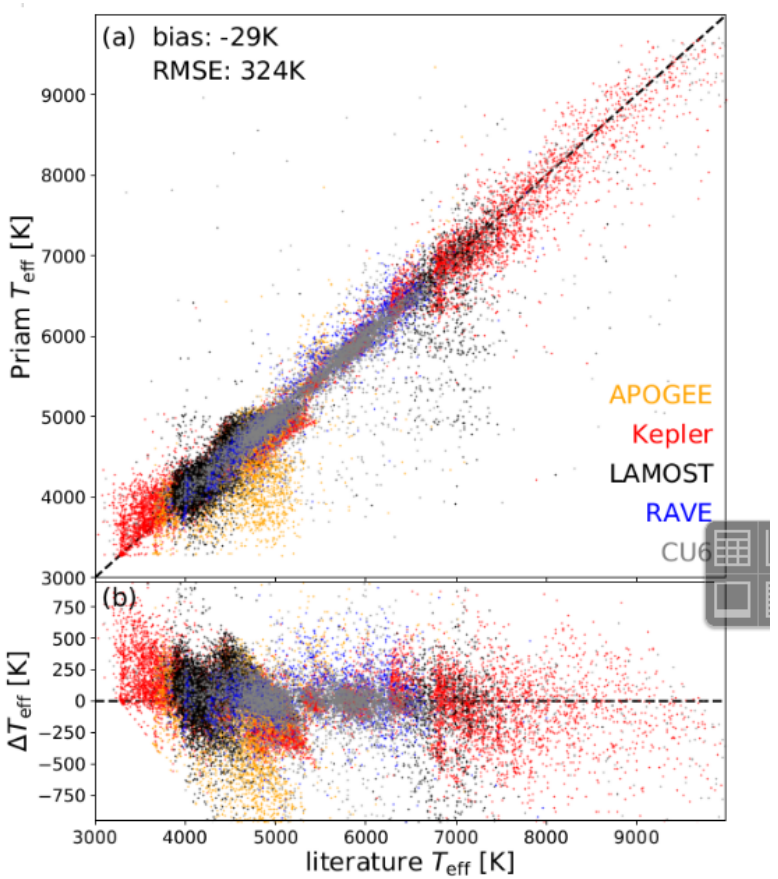


Fig. 10. Comparison of Priam $T_{\rm eff}$ estimates with literature values on the test data set for sources with clean flags, colour coded according to catalogue. The upper panel plots the Priam outputs; the lower panel plots the residuals $\Delta T_{\rm eff} = T_{\rm eff}^{\rm Priam} - T_{\rm eff}^{\rm literature}$.

Observatoire de la CÔTE d'AZUR

Gaia DPAC

Extinction map (Gaia coll.+18)

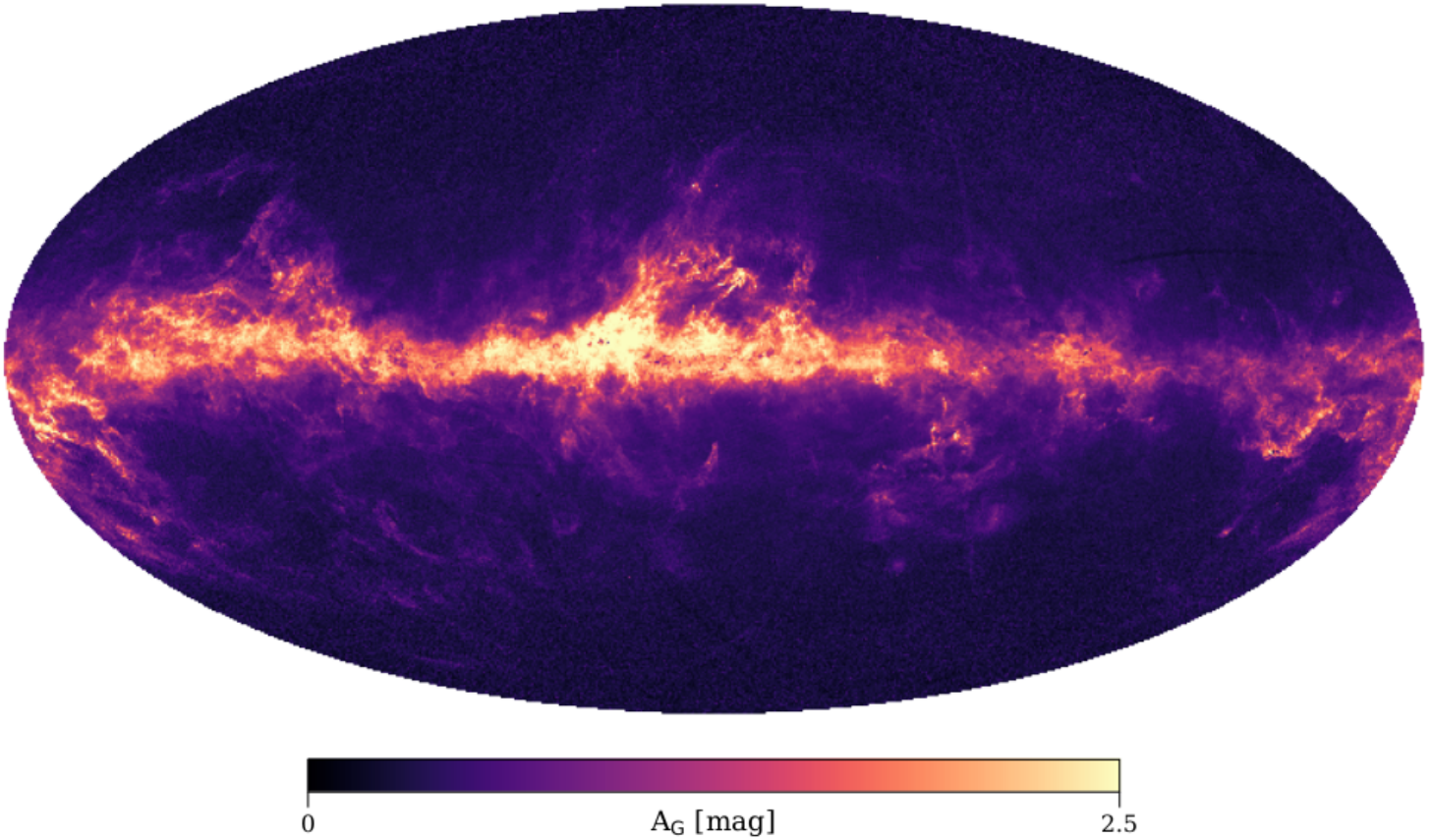


Fig. 21. Distribution of A_G (averaged over all parallaxes) in Galactic coordinates (Mollweide projection). The map is centered on the Galactic Center, with longitudes increasing towards the left.

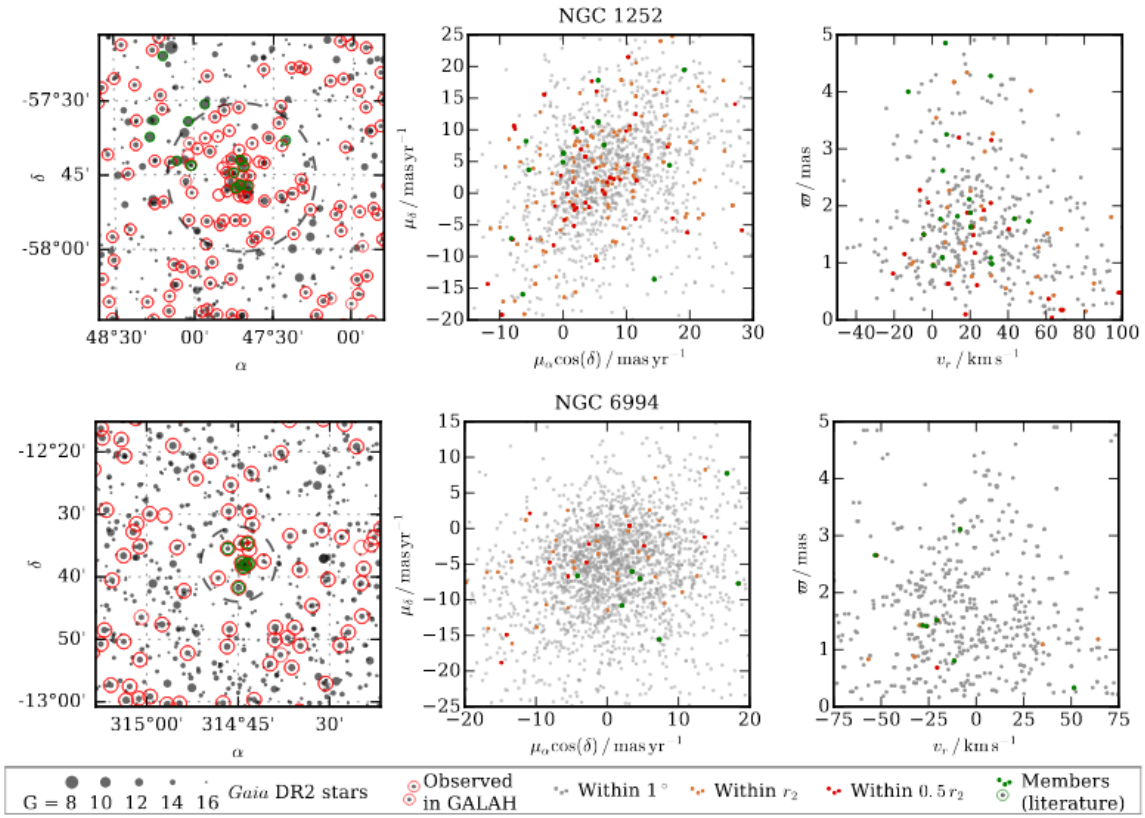
Future

- Today DR3 is still foreseen for end of 2020
  Mainly:
- 1) using 34 months of data (a gain of 20 % on uncertainties)
- 2) Refinement of the systematics on parallaxes and PMs
- 3) calibrated BP/RP spectra expected to be published (under discussion)
- 4) mean VRs at G=14, v.sini
- 5) Teff, logg, Fe/H (some Ti/H,...), AG, mass, radius, age
- 6) Duplicity of sources: list of **binary stars** detected by astrometry and VRs very **strong impact**
- 7) some RVS spectra will be published (under discussion)
- 8) solar system objects, list + orbital elements
- DR4 for 2022
- Nominal mission until mid-2019, extended for 2 years more (gas available, ESA OK).

Recent results using Gaia-DR2, few examples: Some open clusters not real

(see Kos+2018)

- 6 dimensions study of 5 high galactic latitude clusters
- (GALAH + DR2)



Gap at M_V=10 (M3V), Jao+2018

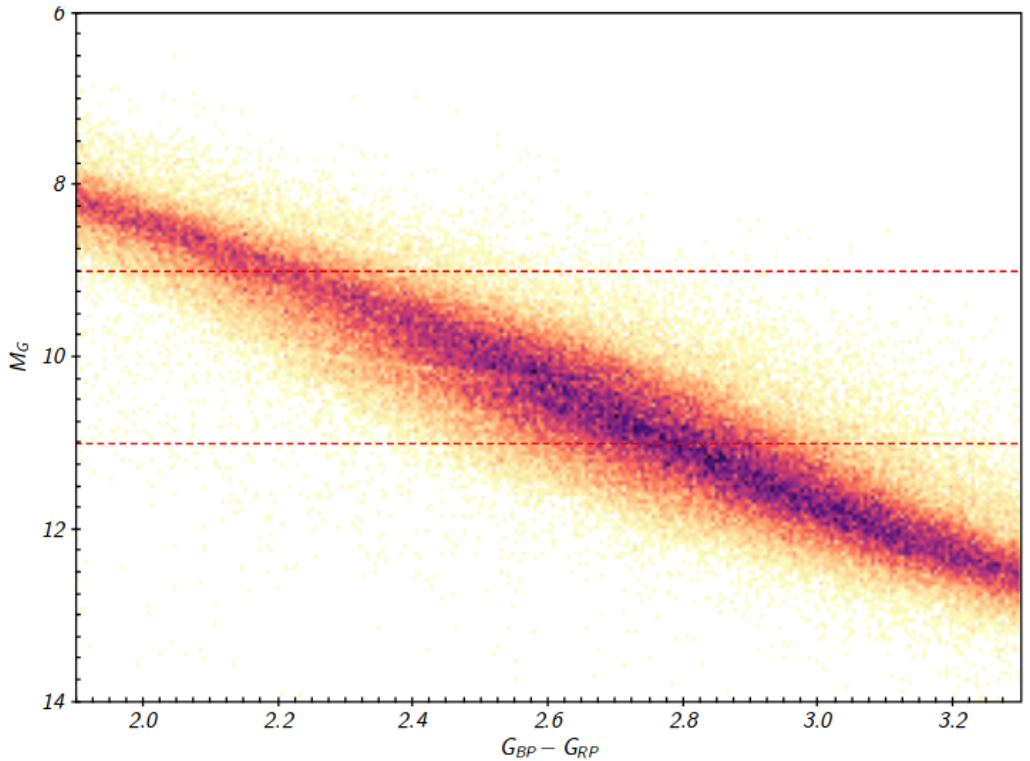


Figure 1. A portion of the observational HRD for stars within 100 pc in the *Gaia* DR2 dataset, using M_G and $G_{BP} - G_{RP}$. A thin, low density, gap is seen cutting through the main sequence. Two dashed lines ($M_G = 9$ and 11) represent a region selected for further discussion, and plotted in Figure 2.

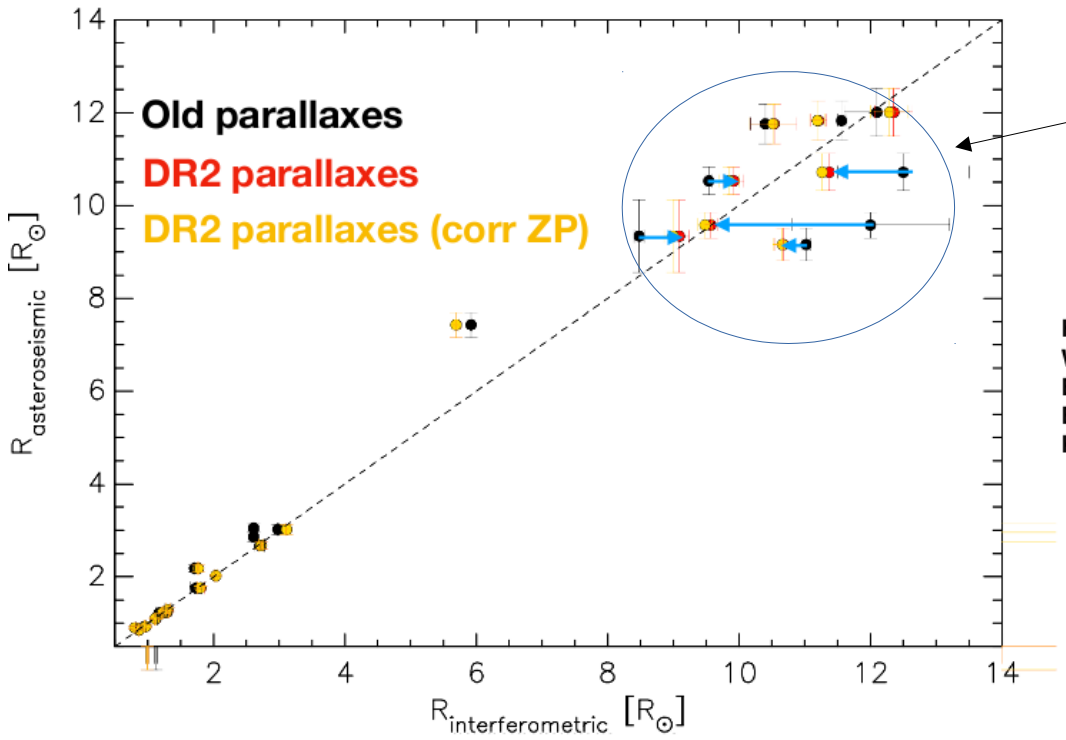
Observatoire de la CÔTE d'AZUR

Gaia DPAC

Linear diameter improved!

Credit : Bigot

Interferometric versus Asteroseismic Radii



Parallaxes LD ?

Data from

Huber + 2012 (PAVO)
White+ 2013 (PAVO)
Baines+ 2014 (NPOI)
Bigot+ (in prep) (VEGA)
Kervella+ 2017 (PIONIER)

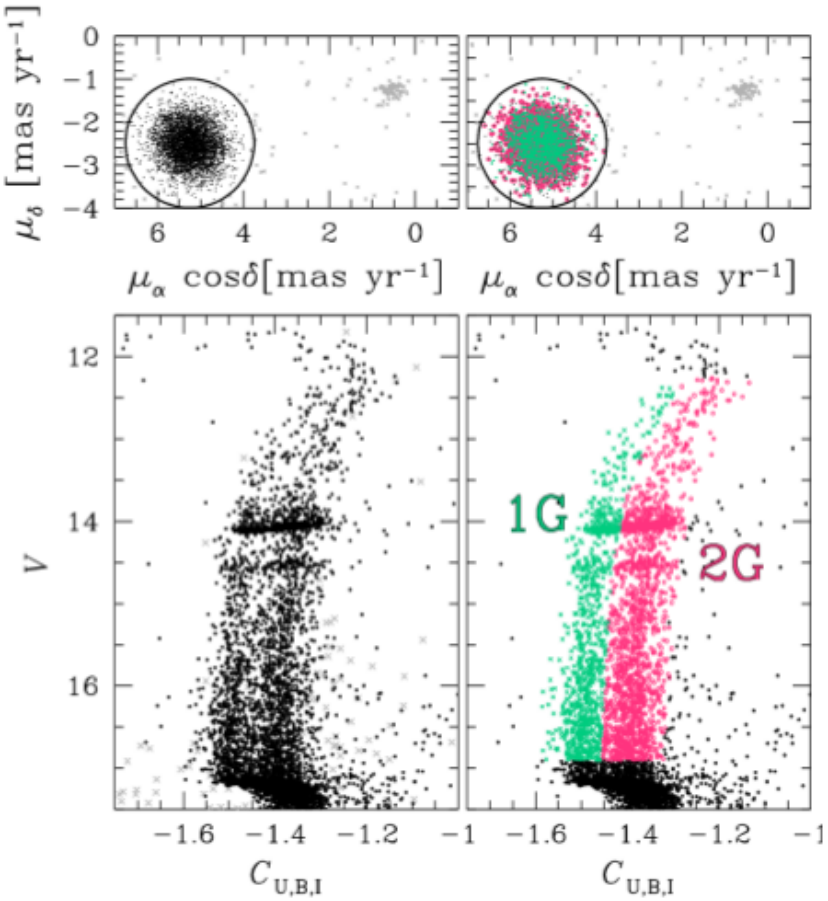
→Better agreement with new Gaia parallaxes (DR2, April 2018)

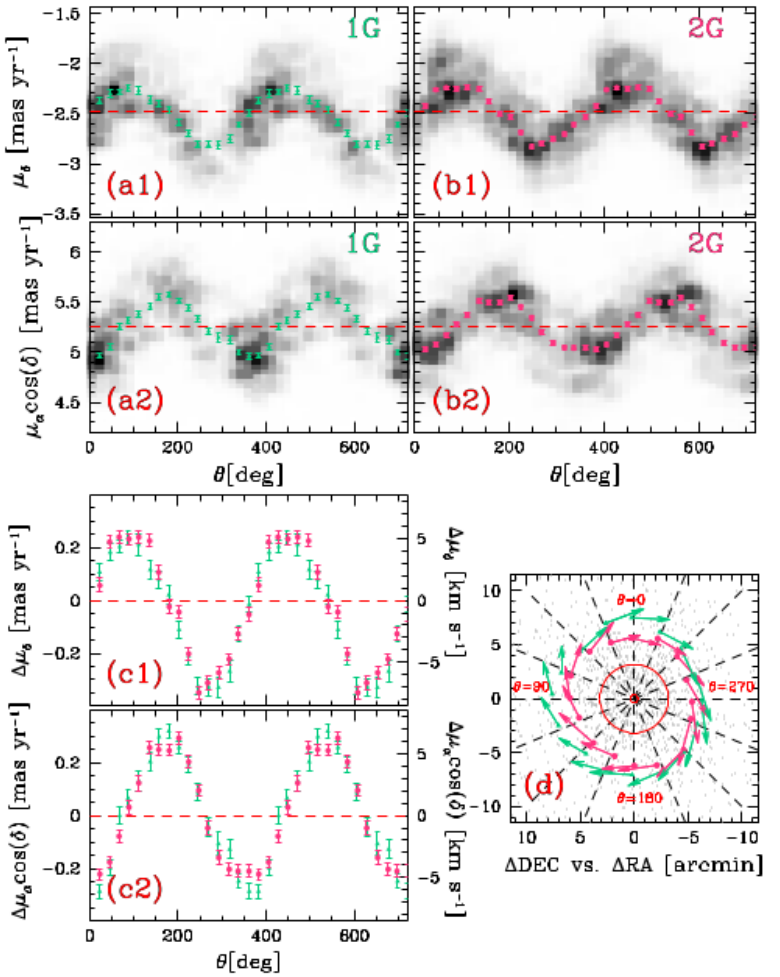
Observatoire de la CÔTE d'AZUR

Gaia DPAC

Some recent papers among many

- Gaia unveils the kinematics of multi stellar Pop in 47 Tuc (Milone+18)



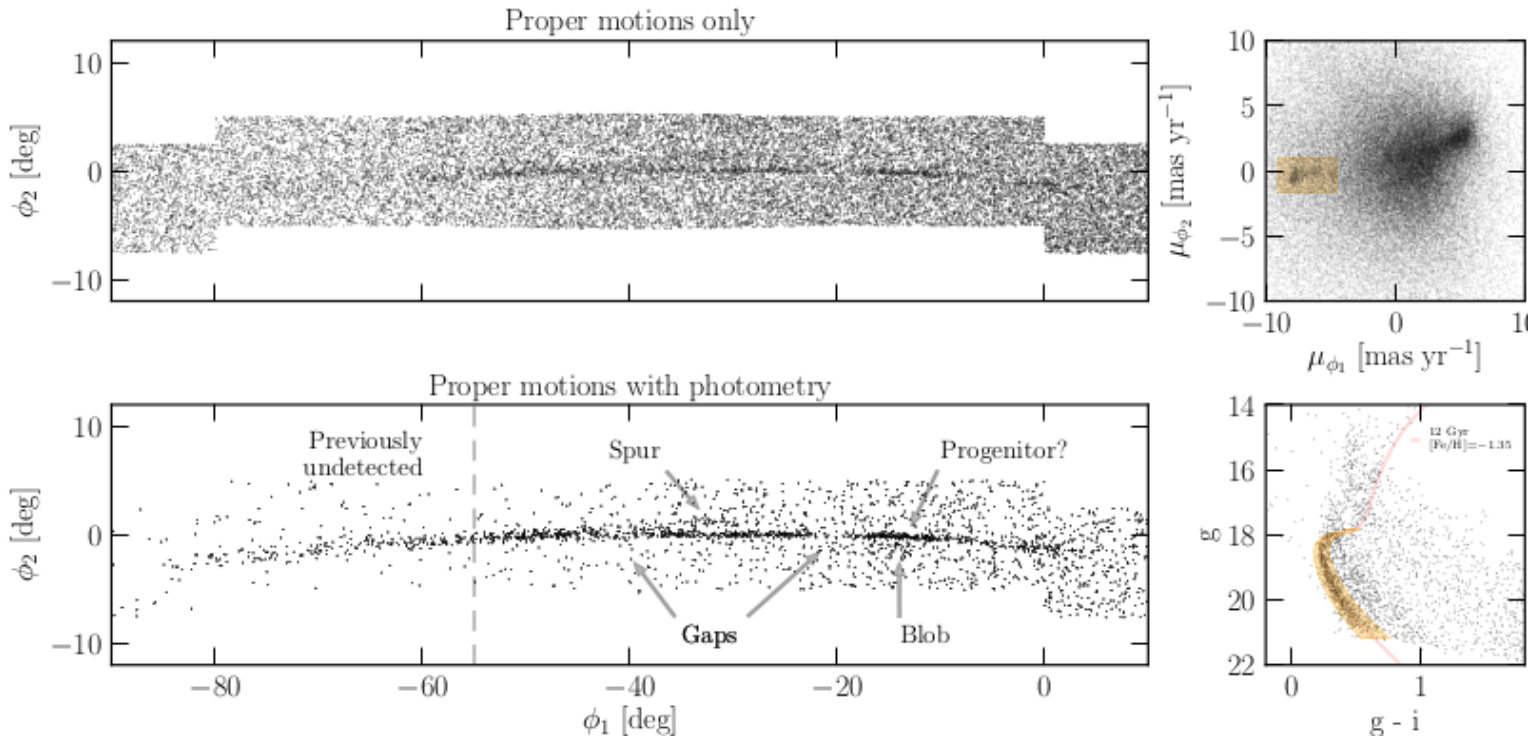


Observatoire de la CÔTE d'AZUR

Gaia DPAC

Some recent papers among many

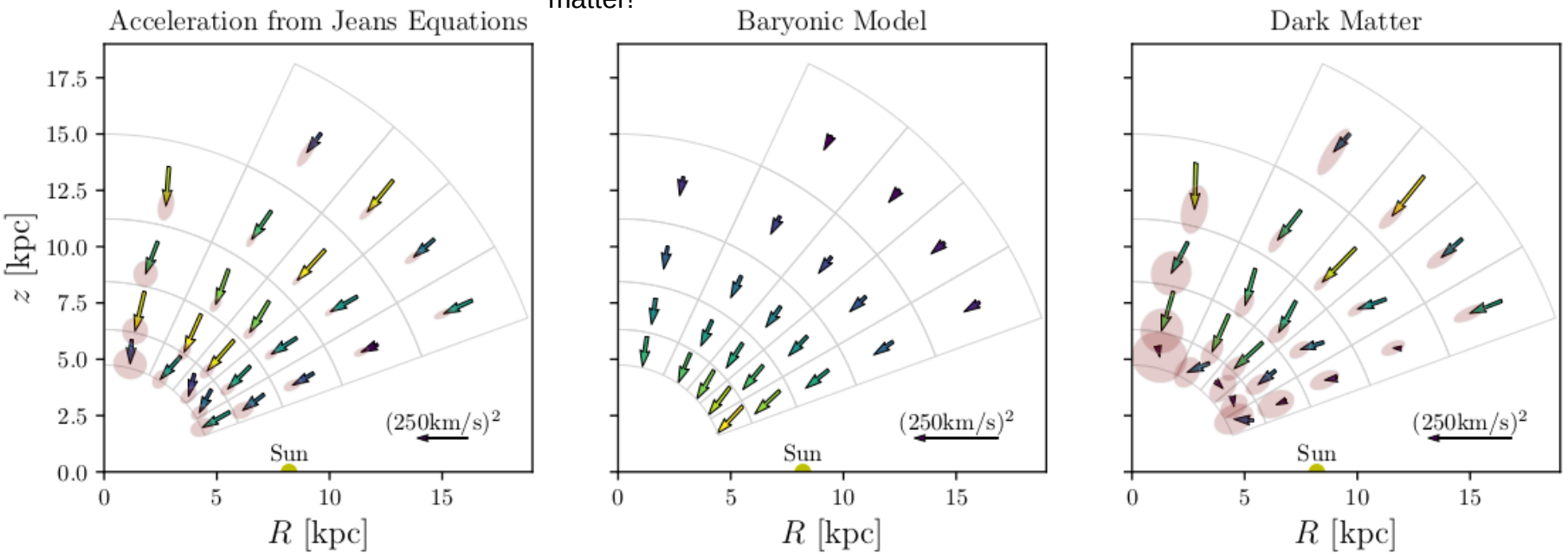
-
- Off the beaten path: Gaia reveals GD-1 stars ouside of the main stream (Price-Whelan+18)
- Gaia-DR2 + Pan-Starrs/Phot
-



Some recent papers among many

- The gravitational force field of the Galaxy Measured from the kinematics of RRL in Gaia (Wegg+18)

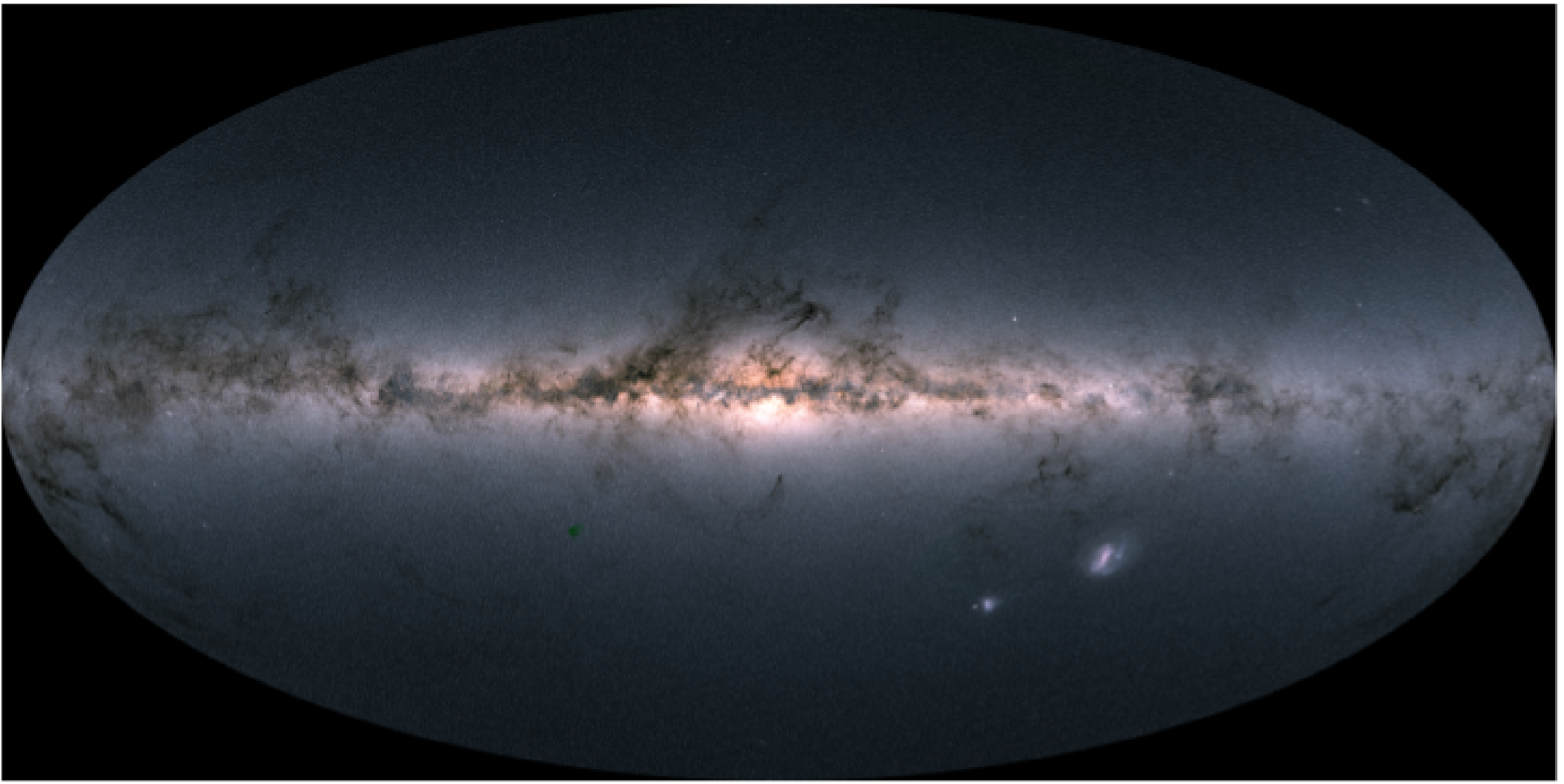
A search for dark matter!



Conclusions: some thougths for discussions

- Toward a fine description of CMDs. Better constraints on the physics of the interior (ex: **Mixing Length Theory**) (discussion in the talk by Laia Casamiquela)
- **Accurate diameters** from interferometry : VLTI (Gravity, PIONER), CHARA (Vega, PAVO), … important for PLATO
- Mixt of Gaia+Interferometry+asteroseismology: new characterisation of stars and the **ages** with better accuracies, important for **PLATO, TESS**
- **logg** from distances (or asteroseismology): very important for **metal-poor** for which NLTE is present in the atmospheres. Important consequences on **chemical abundances** (discussion with talks by Rodolfo Smiljanic, Rana Ezzedine)
- **3D** effects of the atmospheres of late-type: reachable with interferometry important for Gaia (RVS : kinematics velocities)
- Continue efforts on the **Gaia benchmark stars** (Heiter et al. 2015) to test the tools (models+inversion to Aps)
- 6 space dimensions : better understanding of the **Milky-Way**, origin and structure, ground based follow-up (see talks by Antonella Vallenari, Eleonora Zari and Marina Kounkel)

Thank You!



Observatoire de la CÔTE d'AZUR

Gaia DPAC