The 10 parsec sample in the *Gaia* era

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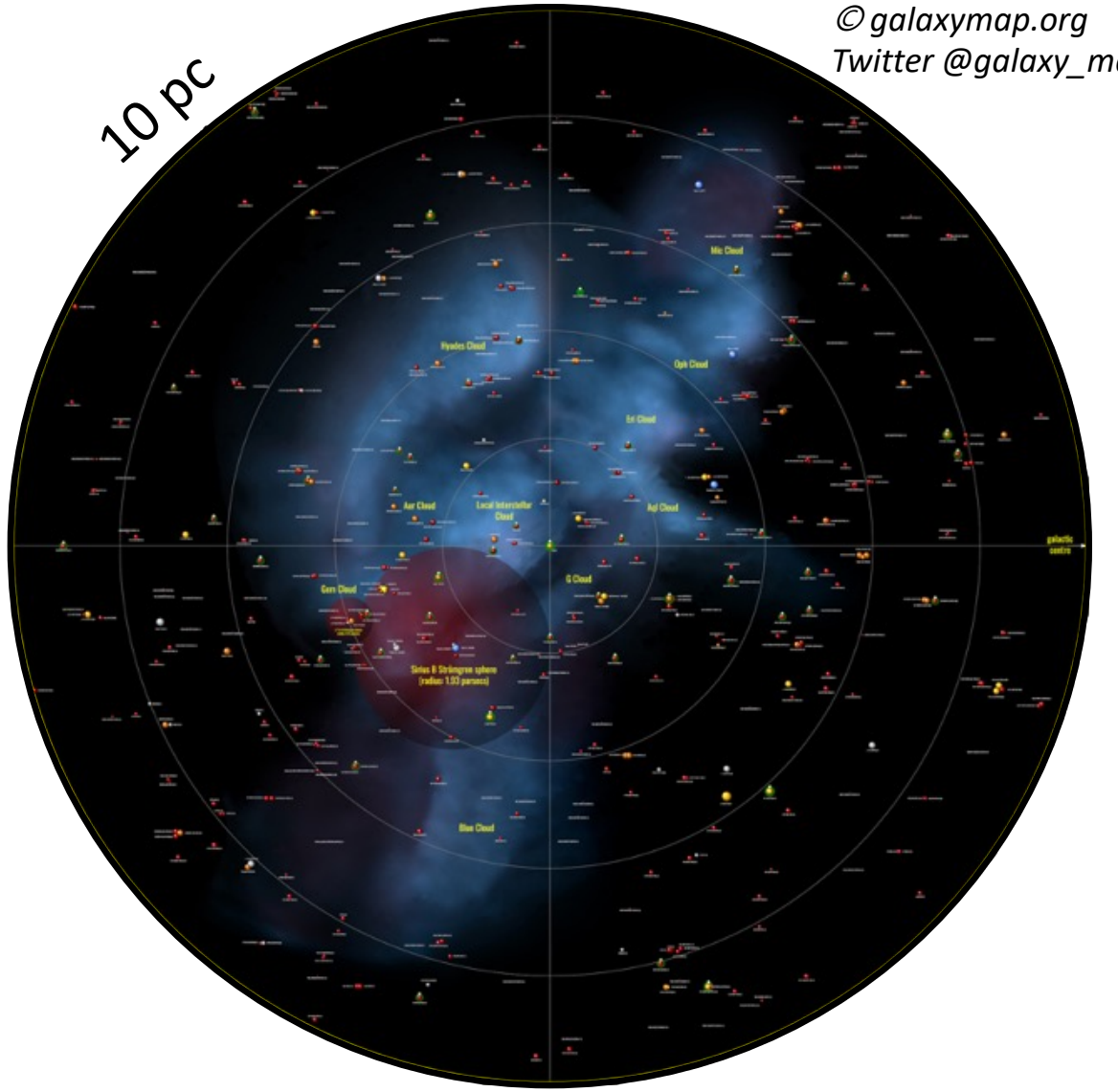
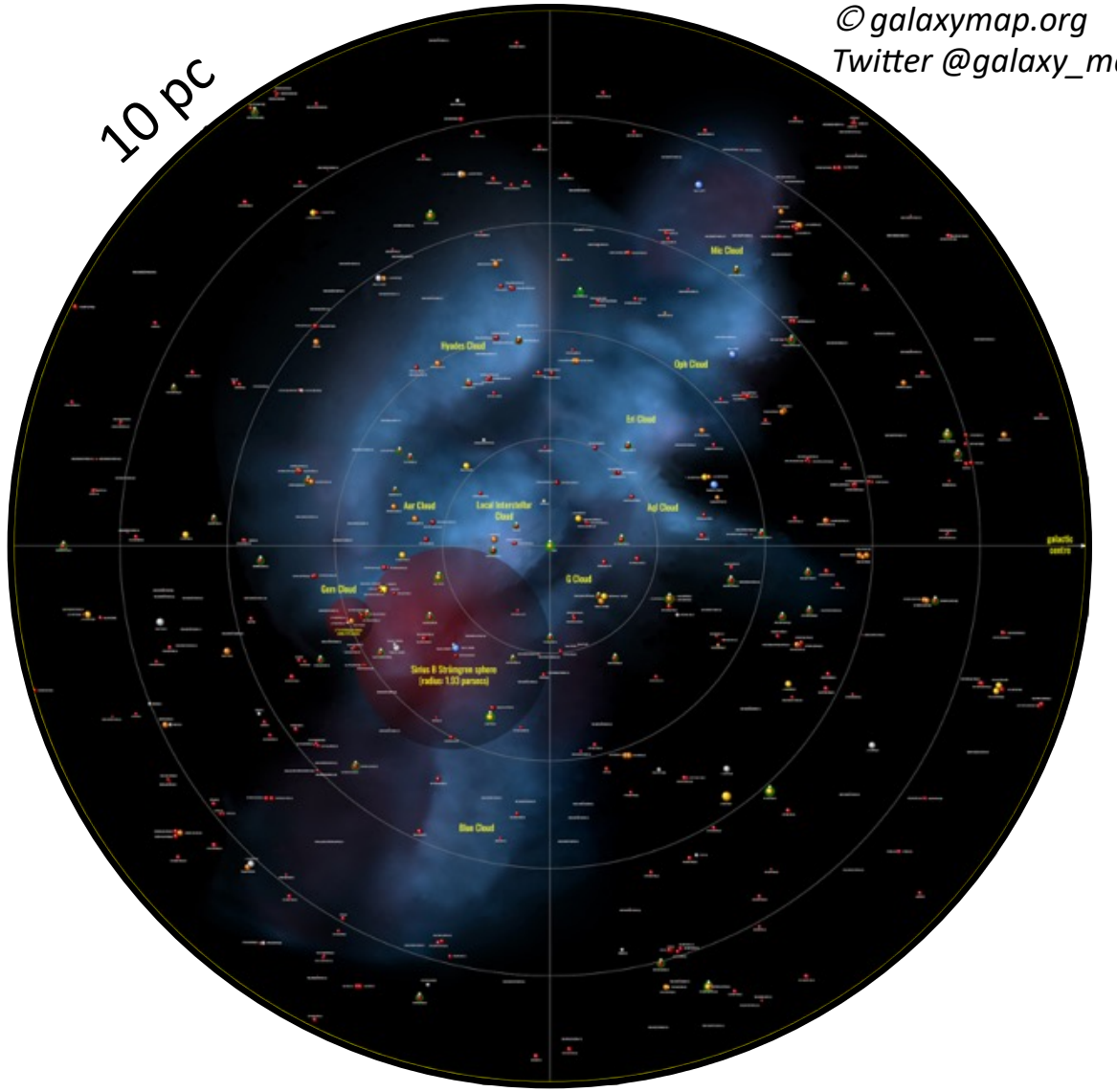
with Kevin Jardine, Pascal Fouqué, José Caballero, Richard Smart & Alessandro Sozzetti



Outline

- Motivation, method
- The 10 pc content
- Expected updates
- Digging into Gaia DR3



Motivation

Nearby sample ≡ anchor

- all objects can be seen and studied with precise data;
- fundamental constraint to understand stellar physics and the Galaxy;

Magnitude-limited sample biased against intrinsically faint objects *(Malmquist 1925).* Low-mass stars (<0.5$M_{\odot}$) are dominant in the Galaxy, but the brightest one (AX Mic) is invisible to the naked eye.

Long-term efforts to get volume-limited catalogues *(e.g. Jenkins 1937; van Biesbroeck 1961; Reid et al. 2004; Gliese & Jahreiß 1991 CNS3; Golovin et al 2023 CNS5; Henry et al. 2018 & REsearch Consortium On Nearby Stars)*

Motivation

Use of the unprecedent high precision parallaxes of *Gaia* EDR3 to review the census of objects within 10 pc.

- First compilation focused on objects observable by *Gaia*, as a quality assurance test for the 100 pc *Gaia* Catalogue of Nearby Stars *(Gaia coll. Smart et al 2021)*.
- Complemented to get a full 10 pc census, including bright stars, close binaries, brown dwarfs, and exoplanets.

Method

Query in SIMBAD database to retrieve all objects with parallax ≥100 mas

✓ components in very close astrometric binaries and spectroscopic binaries *(Catalog of Components of Double and Multiple Stars, Washington Double Star catalog)*

✓ brown dwarfs from recent parallax programmes *(Best et al 2020; Kirkpatrick et al 2019, 2021)*

✓ exoplanets *(Extrasolar Planets Encyclopædia, NASA Exoplanet Archive)* reviewing their status to add only confirmed discoveries

X objects with recent parallaxes <100 mas

X objects with refuted binarity (from *Gaia* parallax, from confusion with activity)

The 10 pc content

A&A 650, A201 (2021)
https://doi.org/10.1051/0004-6361/202140985

Astronomy & Astrophysics

The 10 parsec sample in the *Gaia* era★,★★

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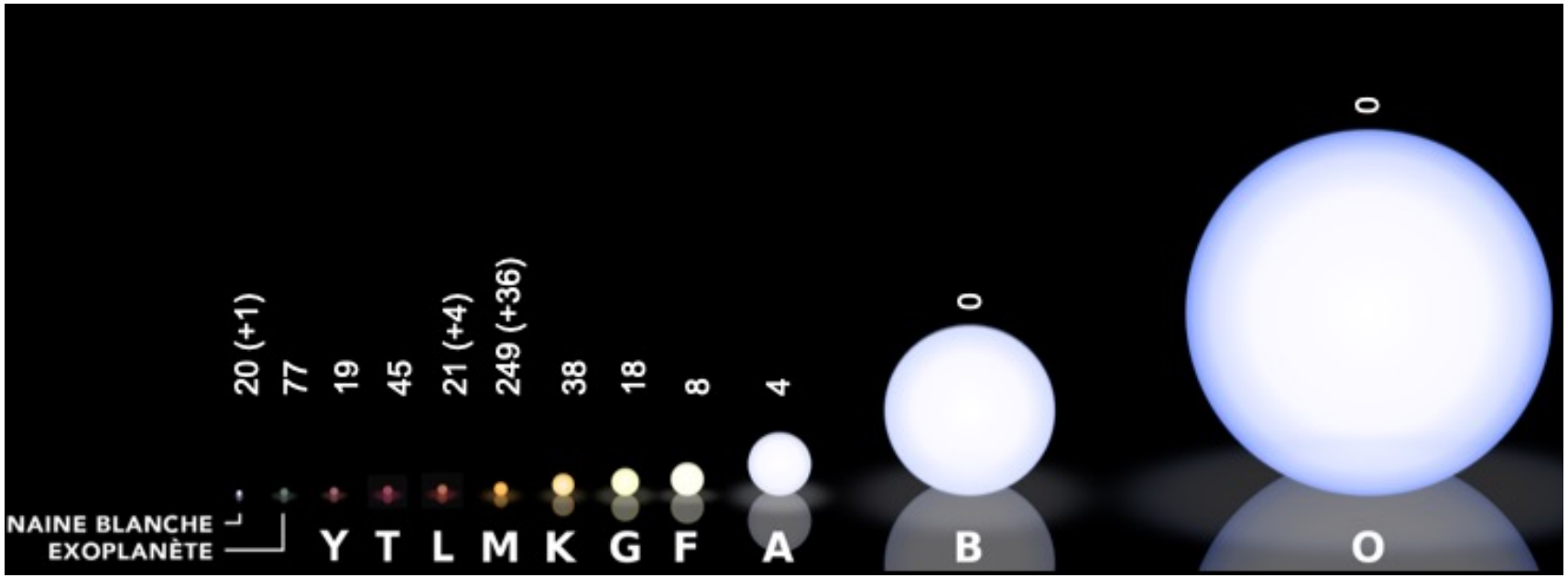
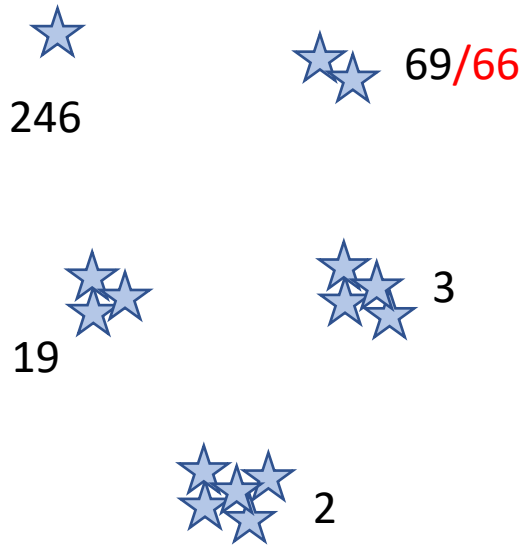
540/541 stars, brown dwarfs, exoplanets (77/85) in 339/336 systems *(Reylé et al, 2021, 2022)*



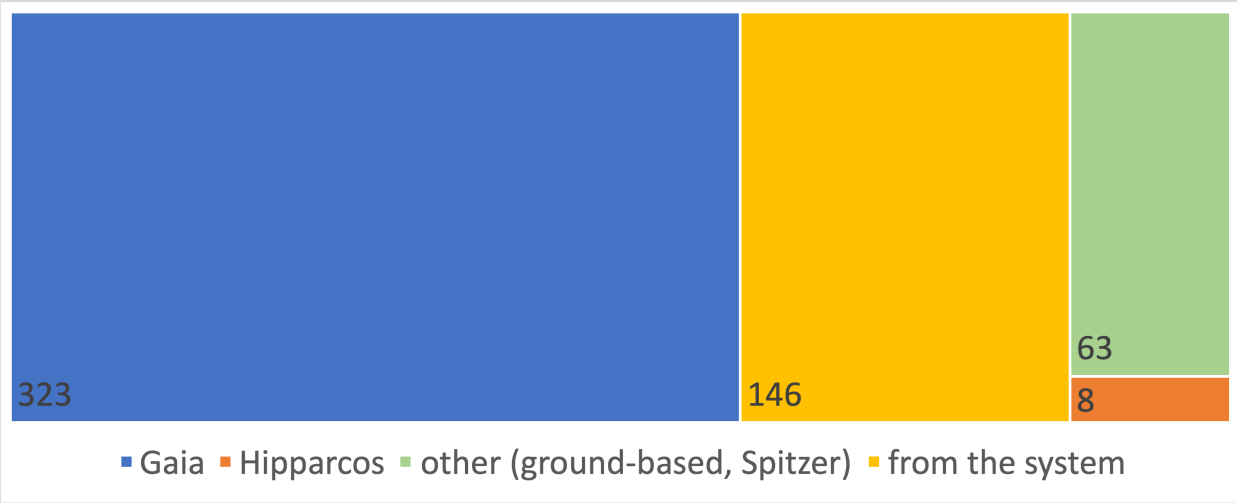


4 subgiants, 5 PMS

The 10 pc content

- Astrometry

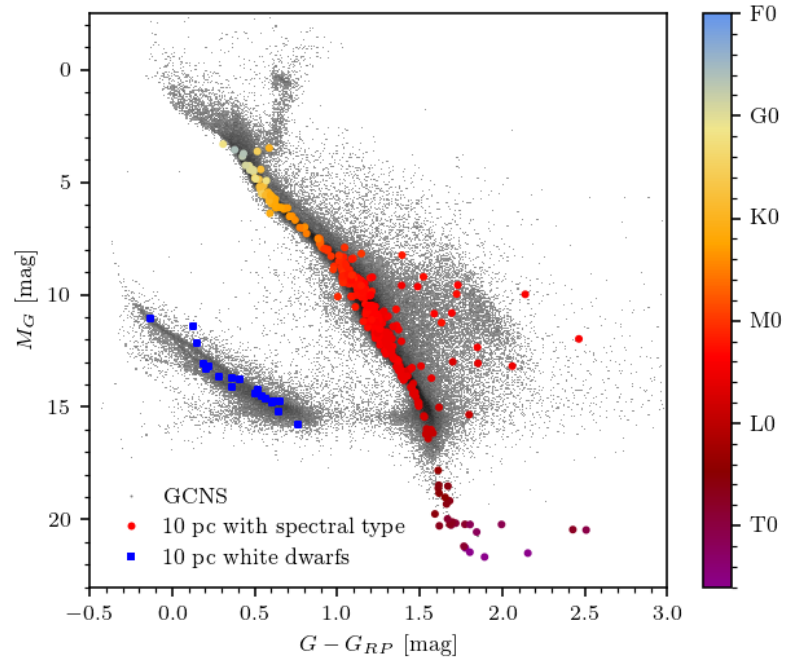
(positions, parallax, proper motions)

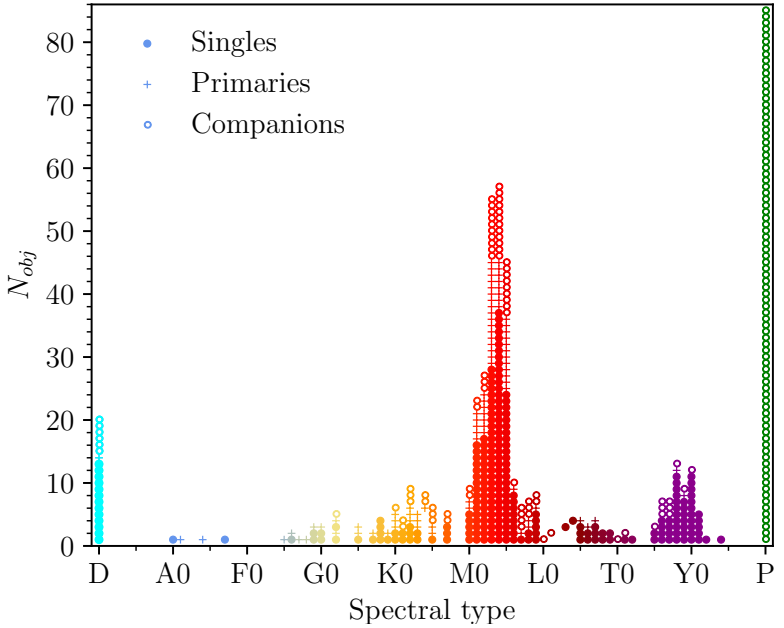


- Photometry (U, B, V, R, I, G, G_{BP}, G_{RP}, J, H, K)
- Radial velocities for 287 objects
- Spectral types for 423 objects

The 10 pc content

- Peak at M3-M4, around the partly to fully convective transition in the main sequence
- ~60% are M-dwarfs, smaller than previous studies *(~70%, eg Henry et al. 2006; Bochanski et al. 2010*) because of the more complete brown dwarf sample
- Stars/brown dwarfs ~4.4, dominated by late-T and Y
- Multiplicity frequency ~27% (22% for the 15 pc mid-to-late M sample, Winters et al 2022)





Expected updates

- current and future spectroscopic surveys, adaptive optics and interferometric observations will probably resolve some of the single stars into multiple components *(eg Baroch et al 2018; Fouqué et al 2018; Winters et al 2019; Vrijmoet et al 2022)*
- faint white dwarfs, in particular in unresolved systems. 2 candidates: G 203–47, spectroscopic binaries with a $M>0.5M_{\odot}$ companion *(Reid & Gizis 1997; Delfosse et al 1999)*, CD–32 5613 unresolved double white dwarf *(Toonen et al. 2017)*
- extremely cool objects probably hiding in the Milky Way plane *(eg Beamín et al. 2013; Scholz 2014; Scholz & Bell 2018; Faherty et al. 2018, Lodieu et al 2022)*
- exoplanets: ~2.5 small and close-by planets per M star predicted from Kepler's results *(Dressing & Charbonneau 2015).* Global astrometry with *Gaia* might unveil ∼10-20 new cold giant planets *(Sozzetti & de Bruijne 2018)*

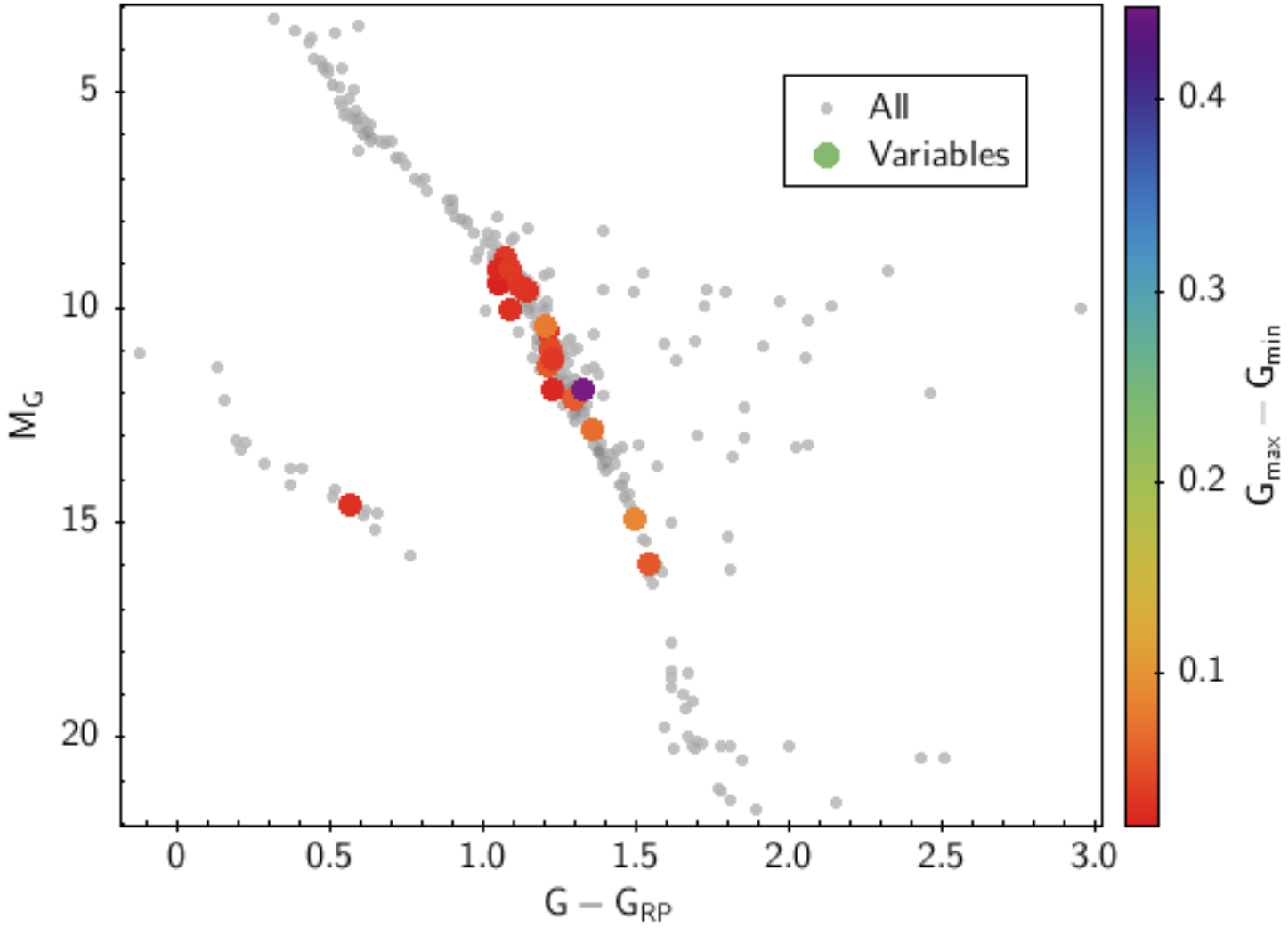
Digging into *Gaia* DR3

- Variablility

19 objects with variability parameters

7 with short timescale variability

9 solar-like type (spots, rotation modulation)



See also *Gaia coll. Eyer et al 2022*

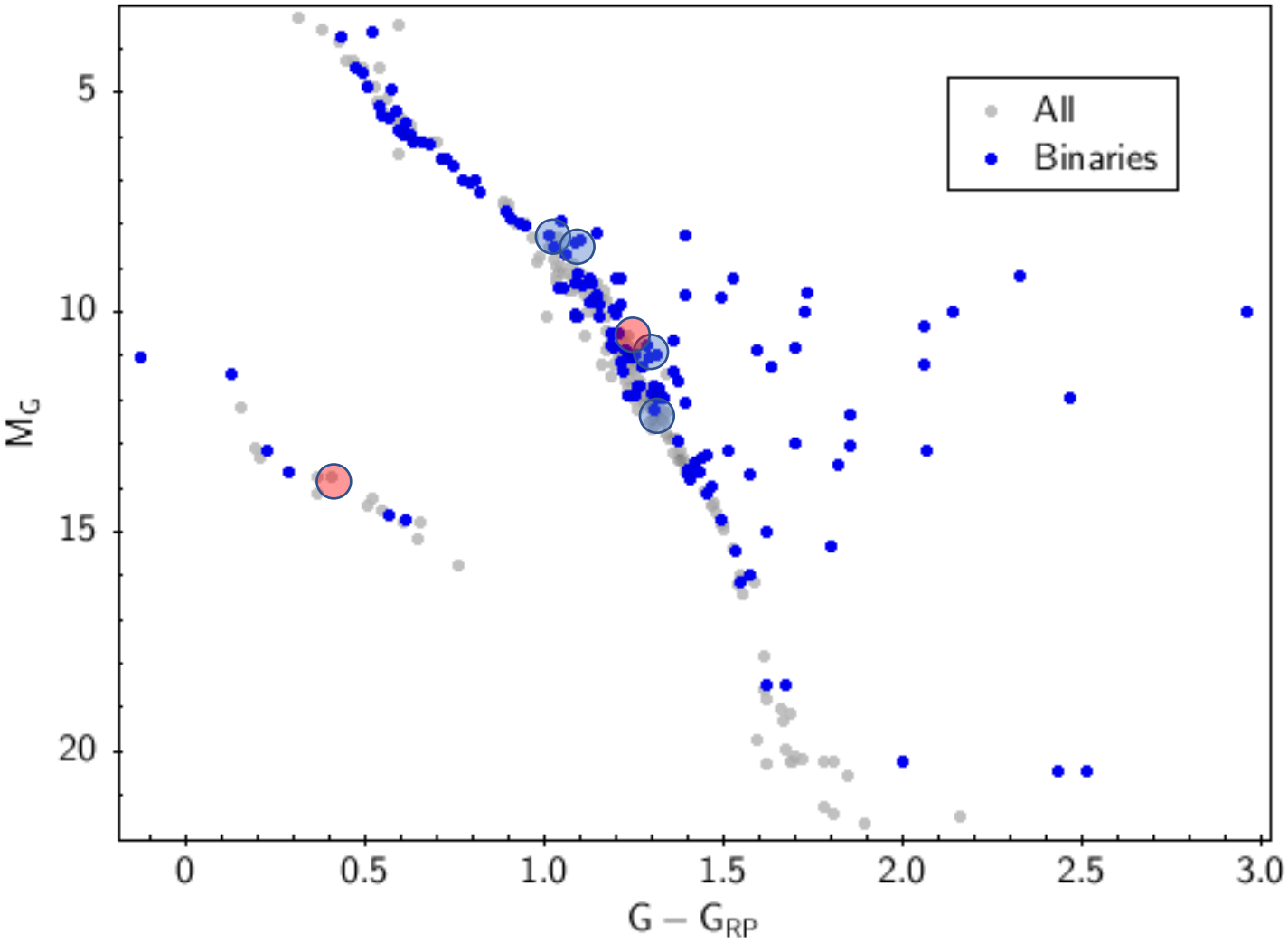
Digging into *Gaia* DR3

- Non single stars

Period, eccentricity, inclination, dynamical masses, flux ratio, …

spectroscopic or close binaries: 41 Ara Bab, Wolf 227 AB, GJ 867 AC, GJ 1230 AC

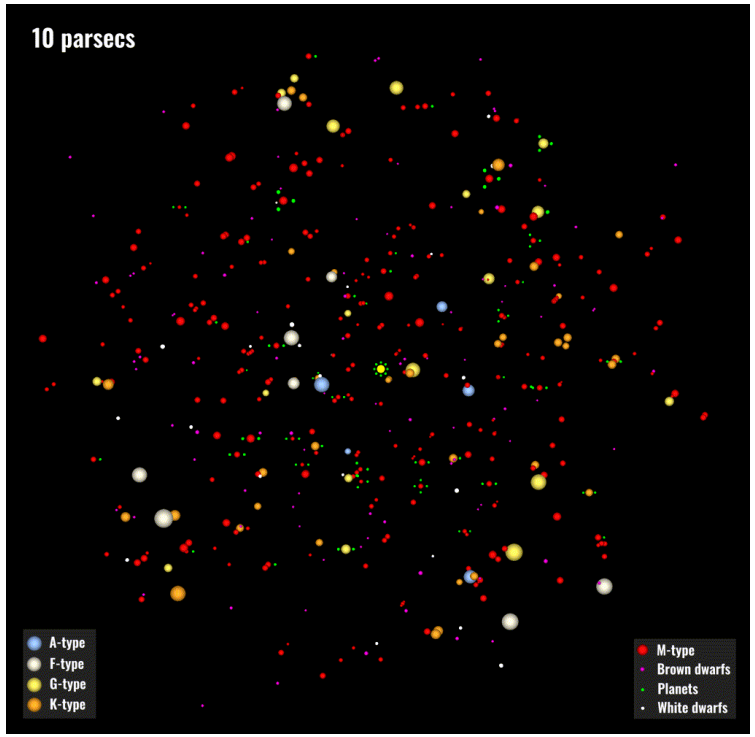
planet Gl 876b with mass estimate 3.6 M_{jup} and planet candidate around the WD L 88-59



dedicated list of exoplanets (mostly candidates) maintained by A. Sozzetti: https://cosmos.esa.int/web/gaia/exoplanets
See also *Gaia coll. Arenou et al 2022*

Discussion

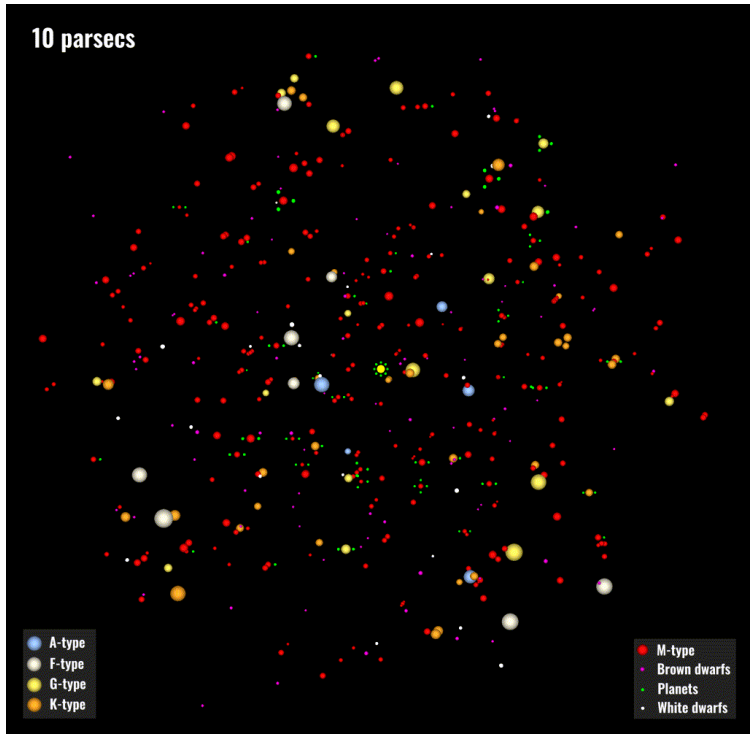
- High variety of objects in the 10 pc sample
- Still not complete (unresolved binaries, ultra-cool brown dwarfs) Gaia > 0.4 arcsec
- Number of stars and brown dwarfs should be superseeded by exoplanets
- High precision, homogeneous, and large diversity of parameters in *Gaia* DR3 and more to come in *Gaia* DR4 (~end of 2025) and DR5 (~2030)



https://gruze.org/10pc/resources/

Discussion

- Observer toutes les étoiles suffisamment brillantes avec une haute résolution spatiale <1 arcsec pour imposer des restrictions sur la présence de compagnons supplémentaires jusqu'à ~0,2 arcsec ;
- obtenir une nouvelle astrométrie d'époque des systèmes binaires proches connus (utile pour les masses dynamiques) et confirmer des candidats ou des systèmes douteux et même trouver de nouveaux compagnons peu lumineux entre 8 pc et 10 pc, où les recherches d'optique adaptative sont incomplètes ;
- Vérifier la photométrie Gaia des étoiles décalées par rapport à la séquence principale.



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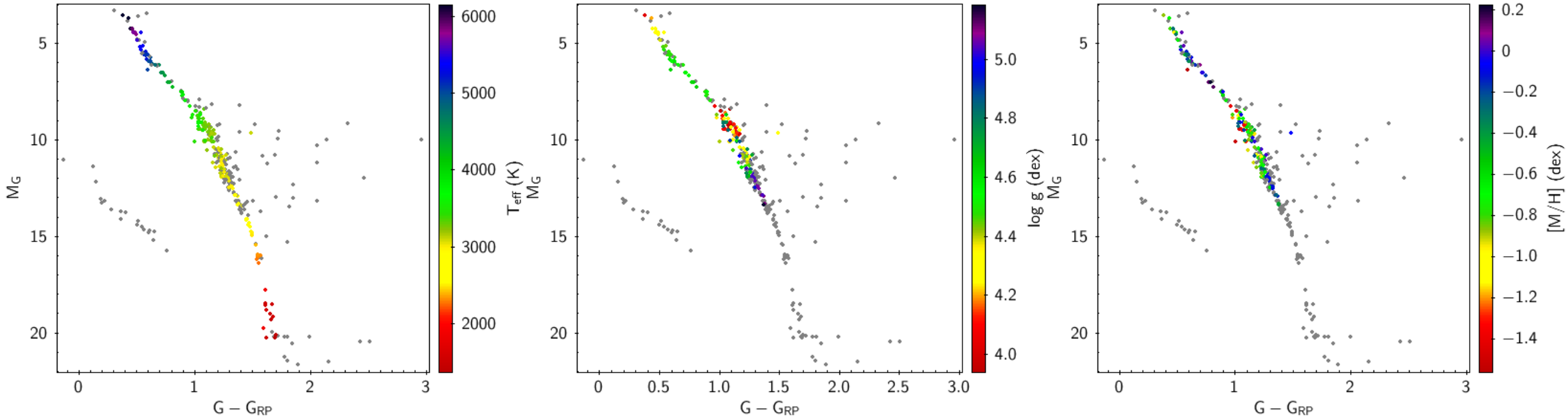
Digging into *Gaia* DR3

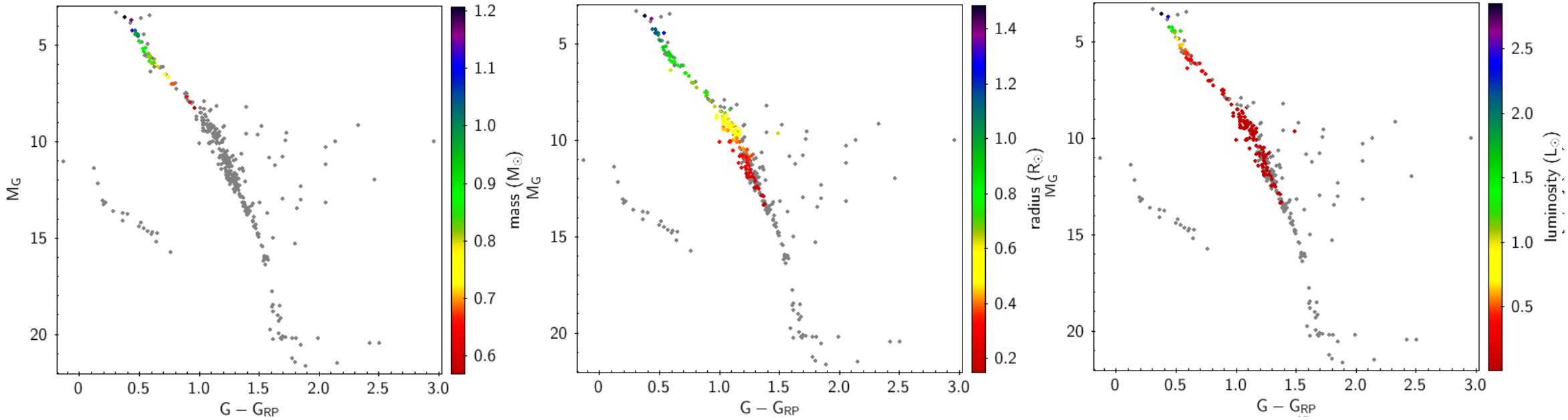
- Astrophysical parameters: T_{eff}, log g, [M/H]



See also *Gaia coll. Recio-Blanco et al 2022*

Digging into *Gaia* DR3

- Astrophysical parameters: mass, radius, luminosity



See also *Gaia coll. Creveey et al 2022*

Updates

X 6 low-mass or brown dwarfs removed assuming better parallax measurements *(eg GJ 748 more accurate and robust HST parallax of 98.4+-0.3 mas taking into acount the effects of binary, Benedict et al 2016)* + UPM J0815-2344 B a close visual companion was wrongly attributed by 2018AJ....155..265H + GJ 424B

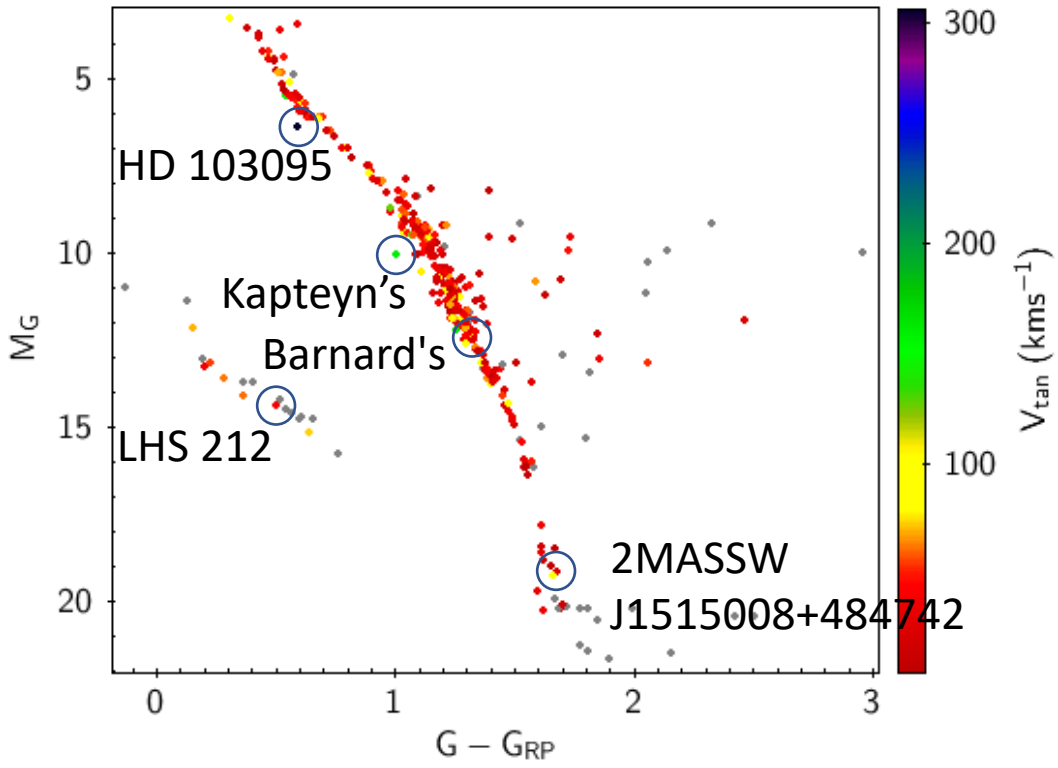
✓ metal-poor ultra-cool WISE J181005.5−101002.3, 112.5±8 mas, l=19° b=4° *(Lodieu et al 2022 and poster #166)* + CWISEP J225628.97+400227.3 oubli dans Kirkpatrick21

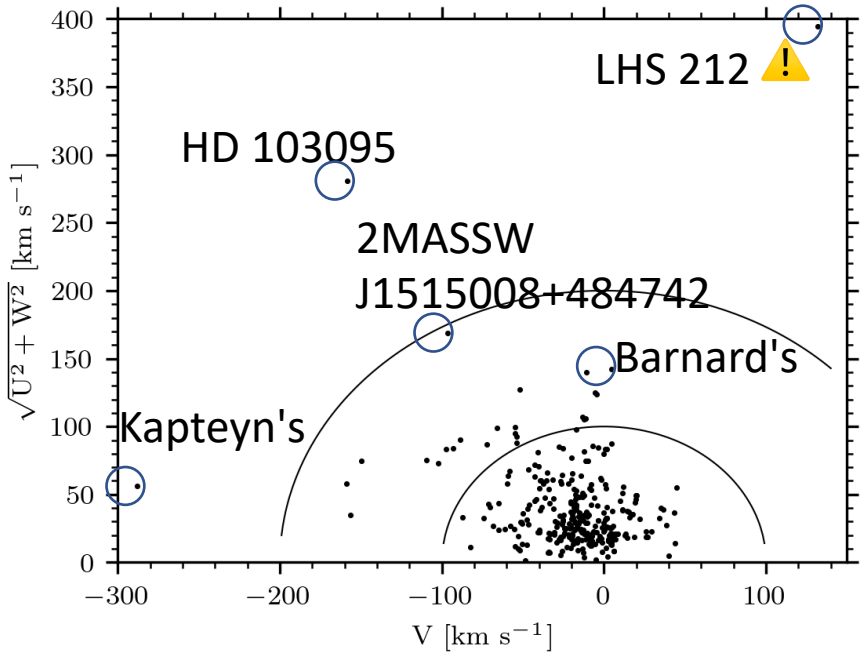
✓ 6 exoplanets LTT 1445 A c, GJ 367 b, GJ 393 b, GJ 411 c, HD 260655 b and c *(Winters et al 2022; Lam et al 2021; Amado et al 2021; Rosenthal et al 2021; Luque et al 2022)* *+ GJ 514 b* 2022A&A...666A.187D

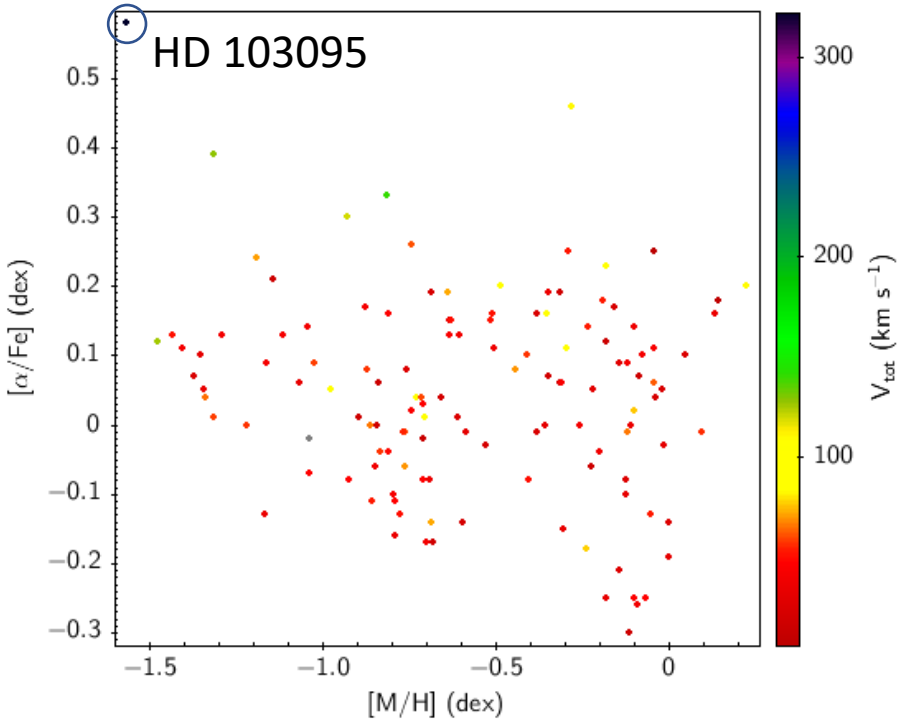
+ 3 candidates GJ 411 d, LTT 1445 A d, Proxima Cen d *(Hurt et al 2022;Lavie et al 2022; Faria et al 2022)*

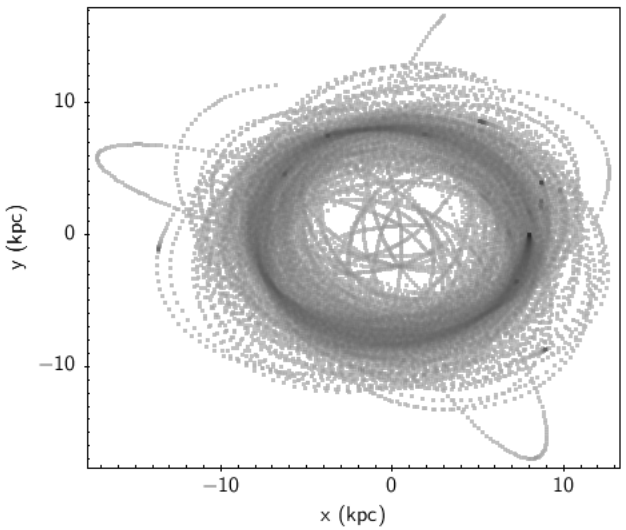
Digging into *Gaia* DR3

- Kinematics, stellar populations





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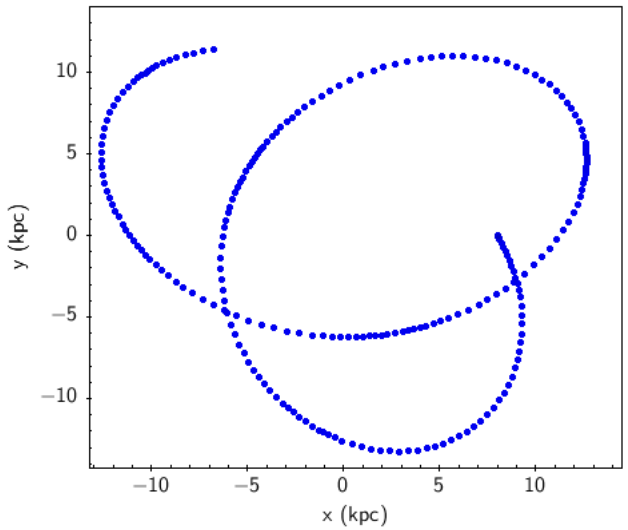
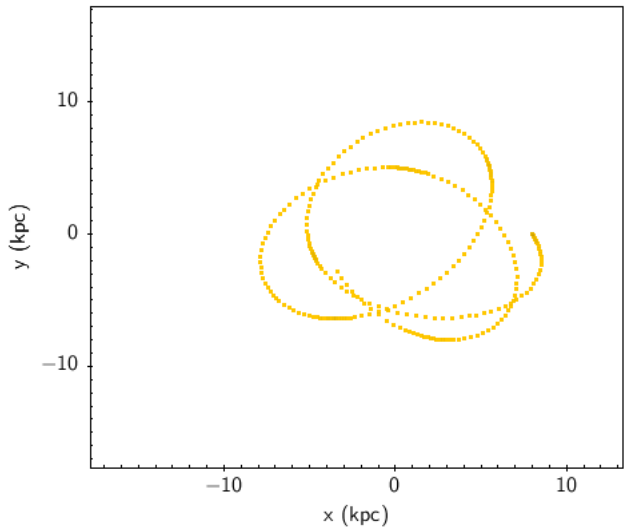
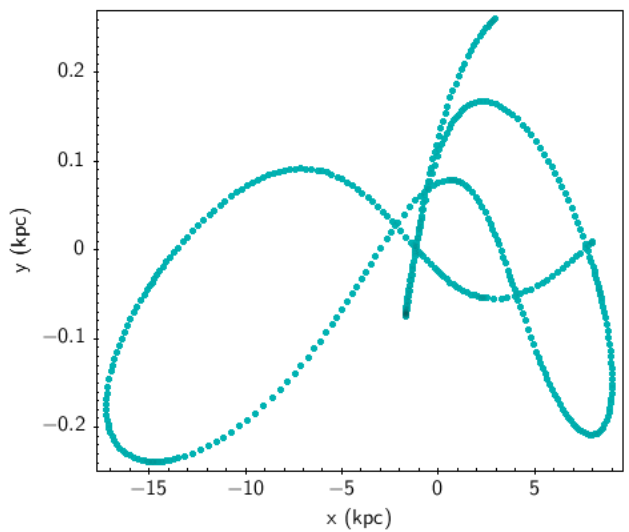
x (kpc)
10
0
−10
−10
0
10


y (kpc)
x (kpc)
10
5
0
−5
−10
−10
−5
0
5
10


y (kpc)
x (kpc)
10
0
−10
−10
0
10


y (kpc)
x (kpc)
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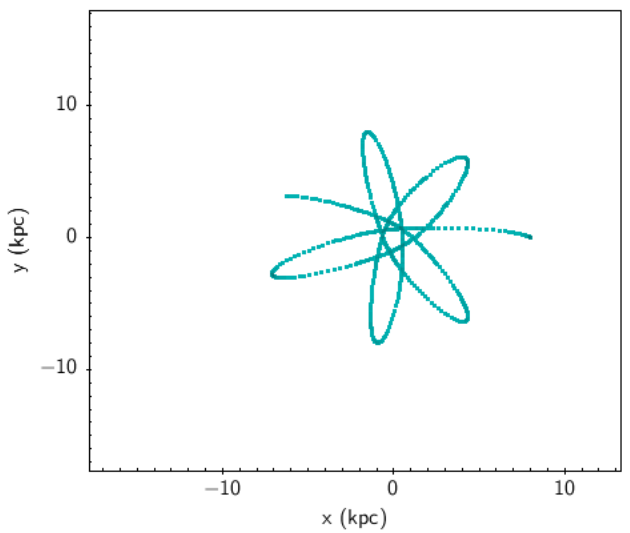
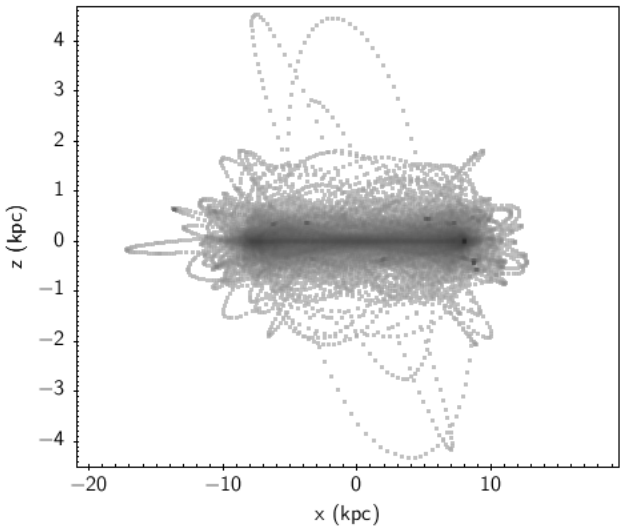
0.1
0
−0.1
−0.2
−15
−10
−5
0
5


y (kpc)
x (kpc)
10
0
−10
−10
0
10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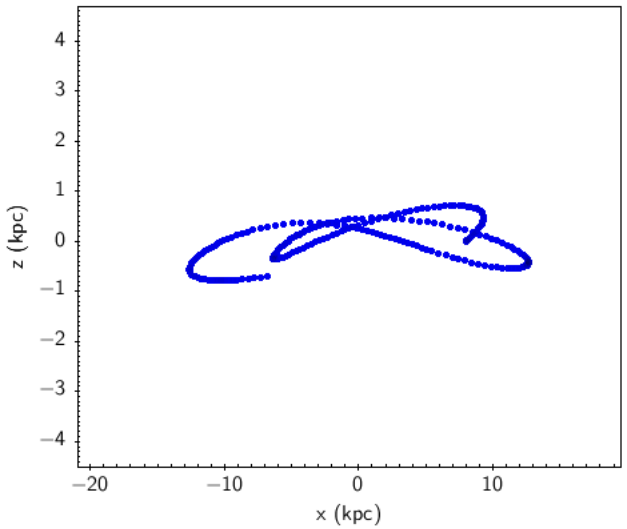
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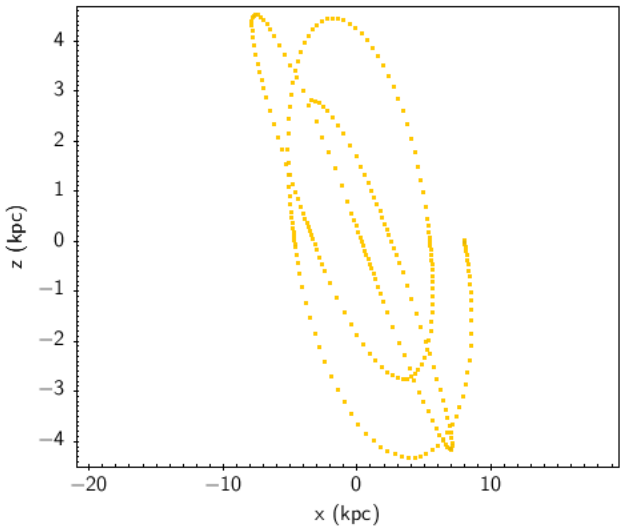
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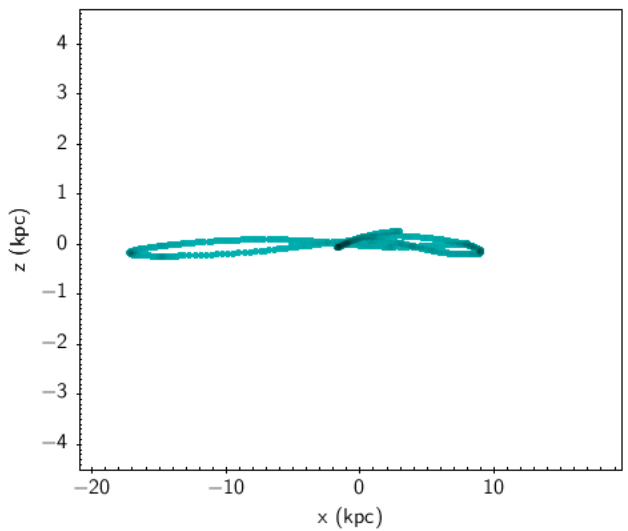
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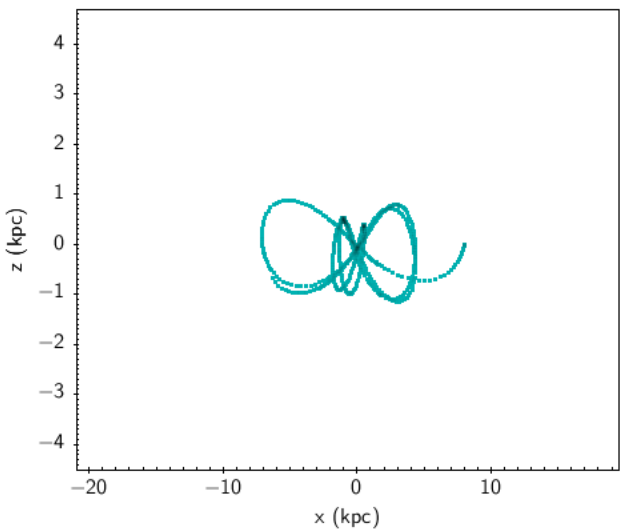
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