Gaia Data Release 3

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A first look at binary stars

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DR3 treats binary stars as such for the first time

A large fraction of stars live in binary or multiple systems.

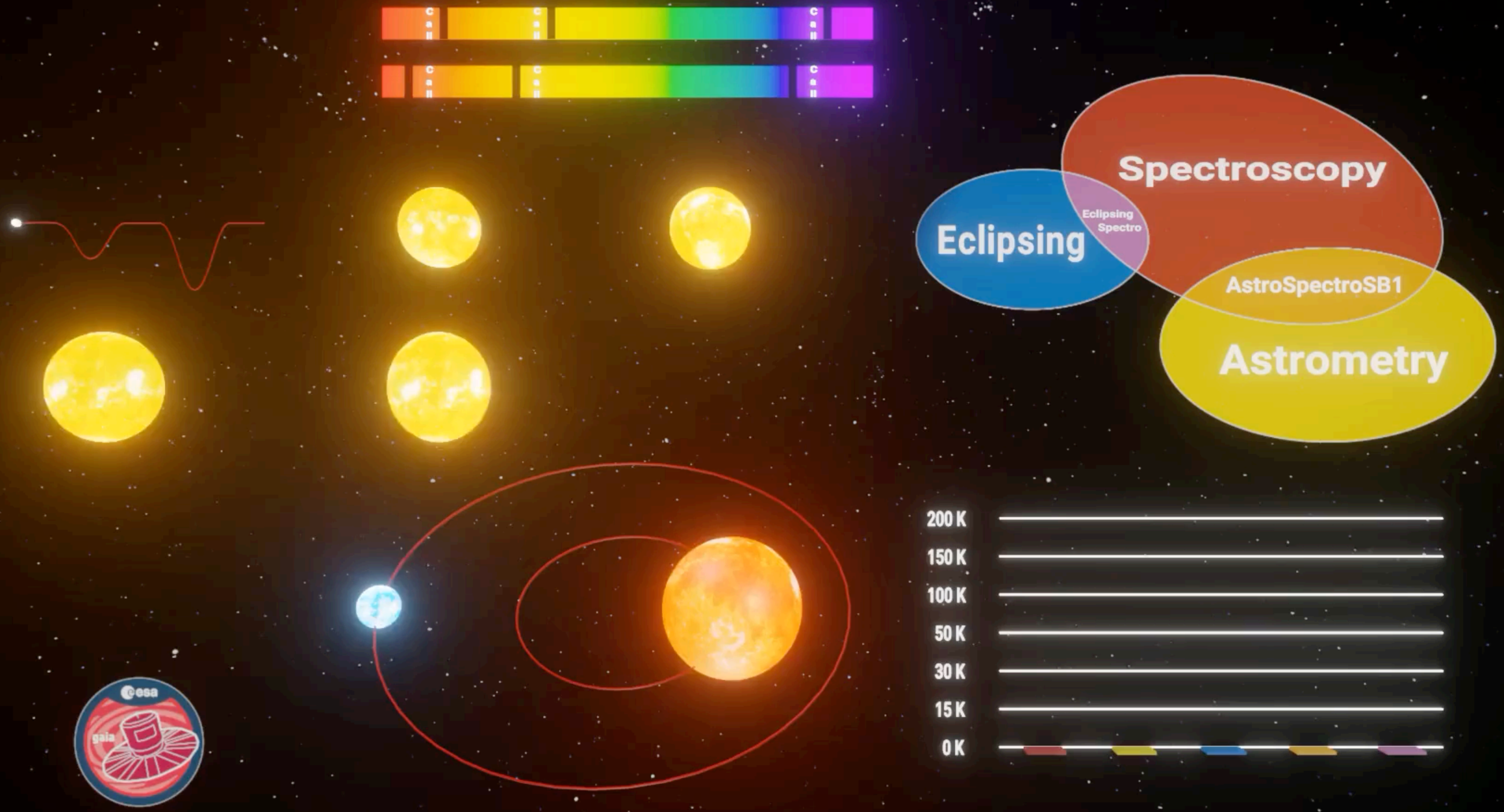
For DR1, DR2, and eDR3, the data processing has treated the Gaia measurements as if they corresponded to a single source.

In contrast, DR3 contains various flavours of "non-single star" (NSS) solutions

- Discovery of multiple systems
- Kepler's law -> component masses and the nature of the companion
- Eclipsing systems -> component sizes, luminosities, etc.
- Orbital configuration -> dynamical state and interactions with environment

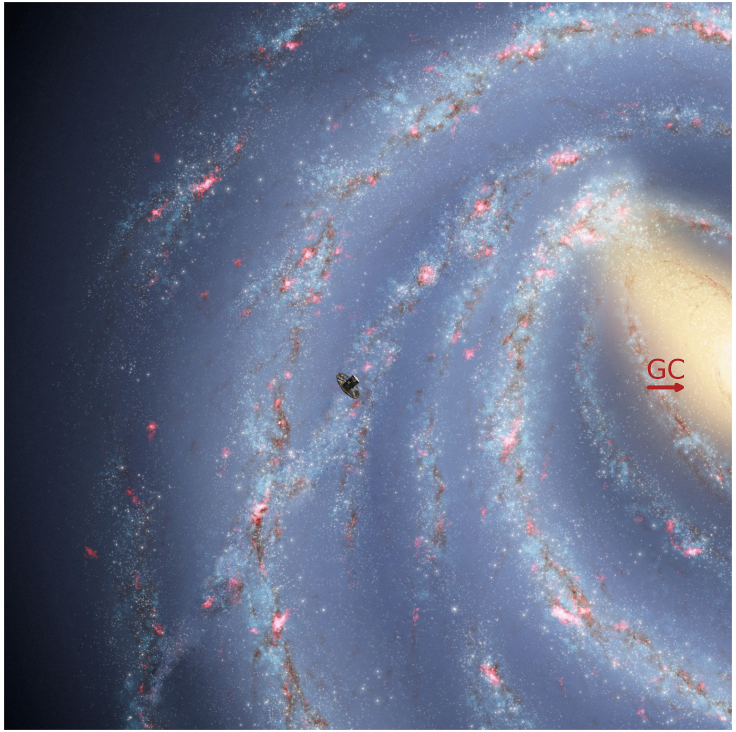
Paper: Gaia Collaboration, Arenou, et al., 2022, A&A: *Gaia Data Release 3: Stellar multiplicity, a teaser for the hidden treasure*

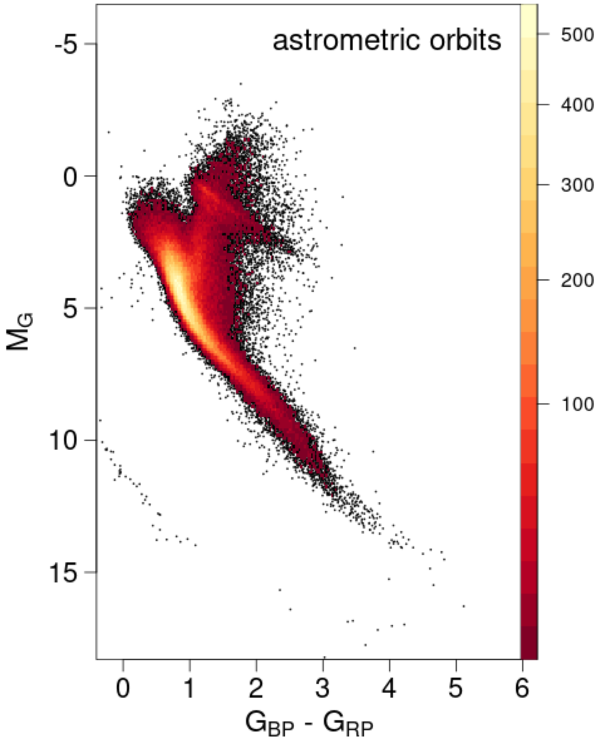
Processing papers: Damerdji at al. 2022; Gosset et al. 2022; Halbwachs et al. 2022; Holl et al. 2022; Siopis et al. 2022



Credits: ESA/Gaia/DPAC, Nathalie Bauchet

Gaia DR3 binaries are (almost) everywhere



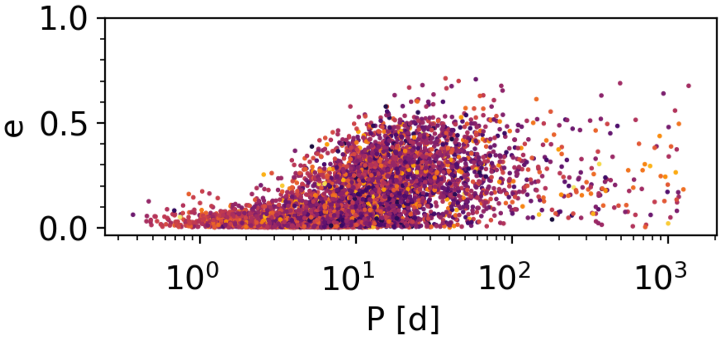


Credits: ESA/Gaia/DPAC, Nathalie Bauchet; Gaia Collaboration, Arenou et al. 2022

There are plenty of spectroscopic and eclipsing binaries in DR3

~ 185 000 spectroscopic binaries from radial-velocity variations

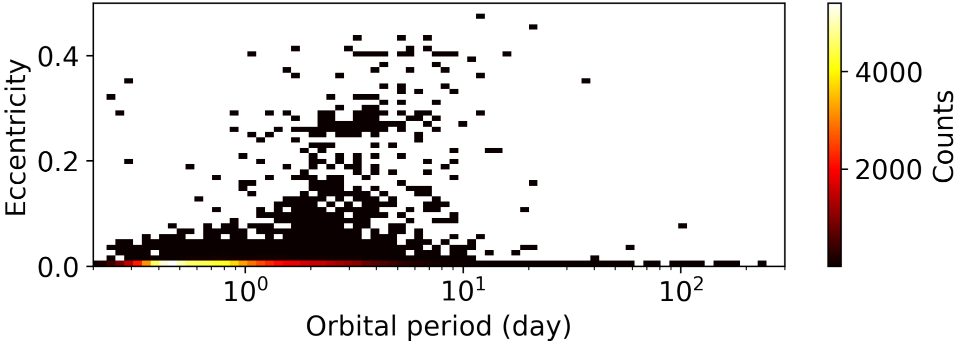
~45 times more orbits than in the SB9 Catalogue



Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022

~ 87 000 eclipsing binaries with orbital solutions from photometric variations

Example: Rare binaries where the companion is a young bloated white dwarf (EL CVn)

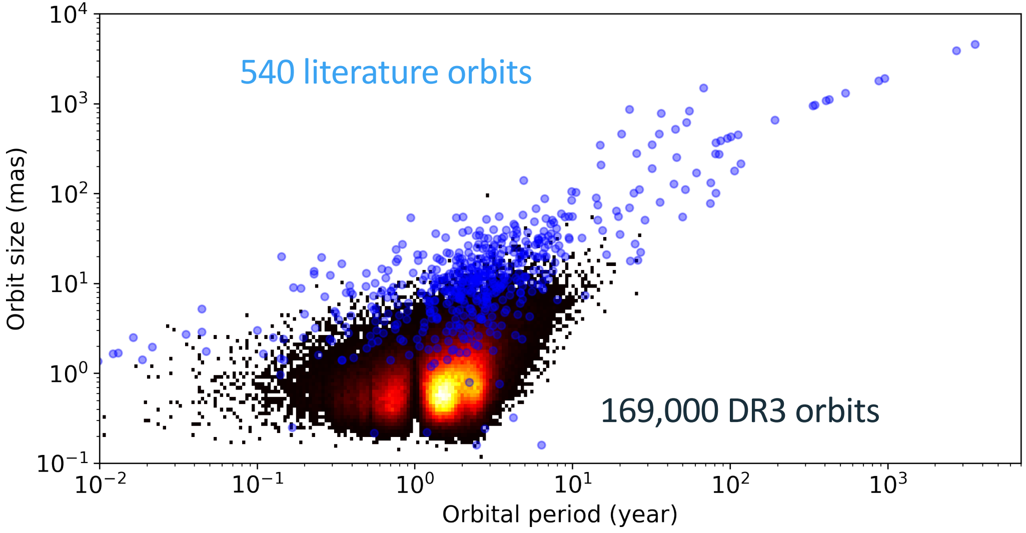


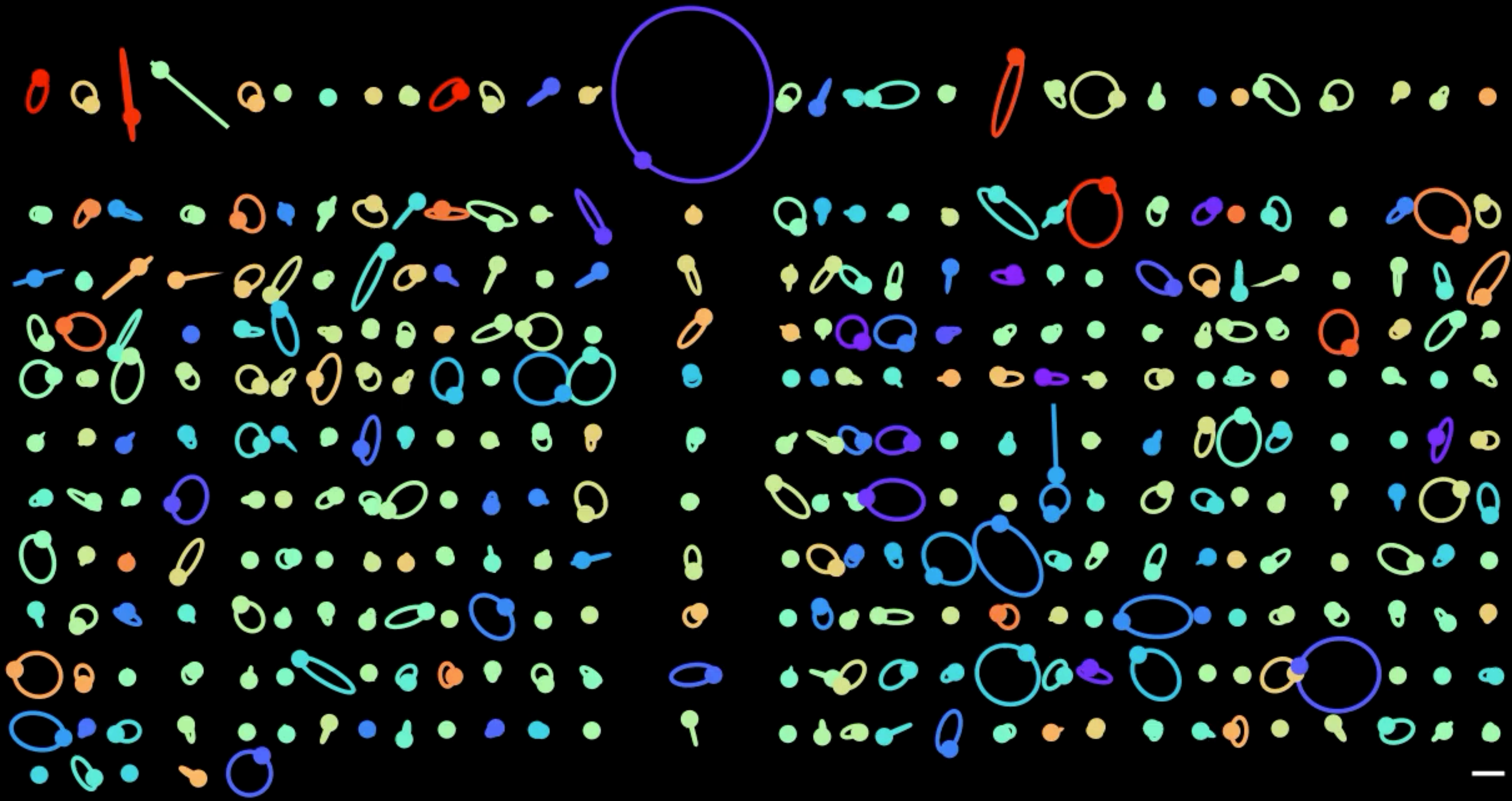
DR3 contains the first uniform and large-scale census of astrometric binaries

~169 000 astrometric orbit solutions, most correspond to unresolved "astrometric binaries".

The literature compilation (Washington Double Star Catalogue, WDS, "orb6") contains ~3400 orbits, of which most are resolved "visual binaries".

DR3 contains 50 times as many orbits as WDS and 300 times as many "astrometric binaries".





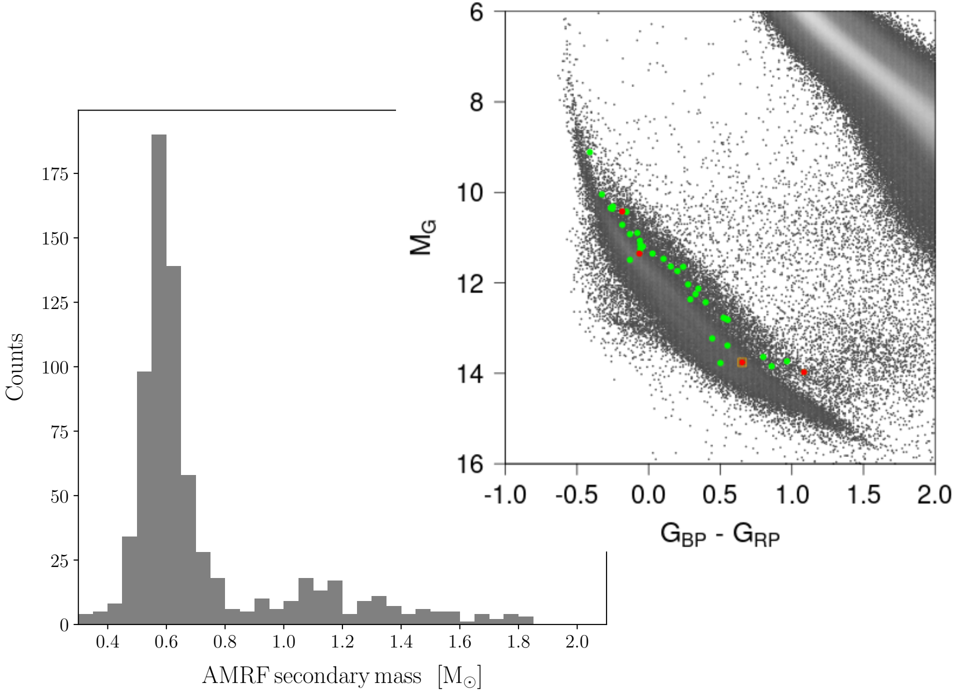
Credits: ESA/Gaia/DPAC, Johannes Sahlmann

Gaia discovers many white dwarf companions

Combined analyses of stellar and orbital parameters lead to companion-mass estimates.

The peak in the companion mass distribution corresponds to the typical value of field white dwarfs, e.g. Sirius-type systems.

A few dozen of double-degenerate white dwarf binaries were identified as well.



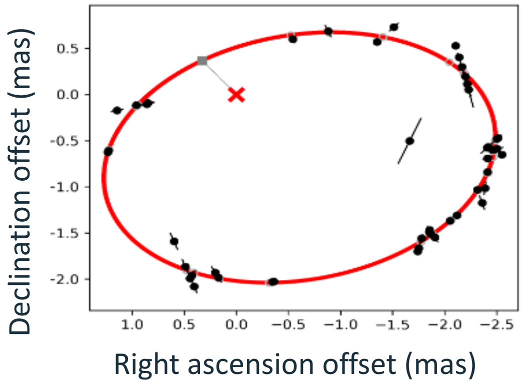
Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022

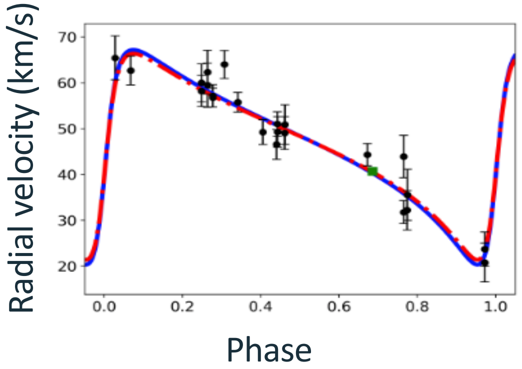
Gaia discovers a dormant neutron star (candidate)

Several spectroscopic orbits imply companions that are much dimmer but more massive than the primary star.

These companions can be neutron stars or even black holes.

Example: Gaia DR3 5136025521527939072; orbit detected both in radial velocity and astrometry; Period 546 d with inferred component masses of 1.2 $M_{\odot}$ + 1.5 $M_{\odot}$





Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022

DR3 contains exoplanet (re-)discoveries

Photometry:

first Gaia discoveries of transiting Gaia-1b & Gaia-2b (Panahi et al. 2022), several re-discoveries, and many candidates

Radial velocity:

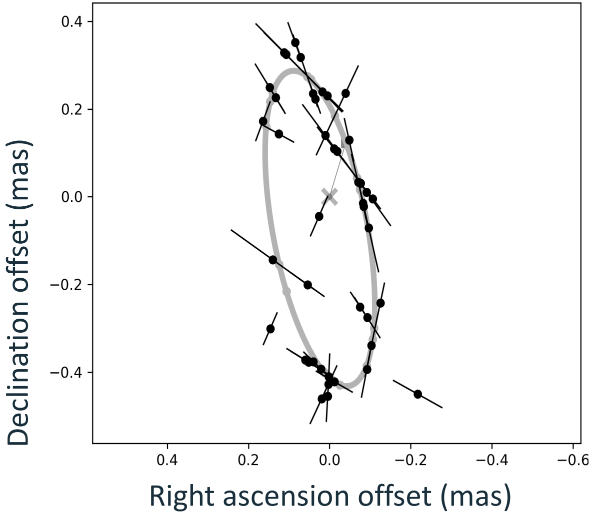
DR3 contains many candidates with some re-discoveries (e.g. WASP-18b)

Astrometry:

- Gaia astrometry unrivalled by other instruments -> a unique windows for discovery
- Astrometric orbits of known exoplanets, e.g. HD 81040 b
- Tens of new exoplanet candidates
- Confirmation usually necessitates additional analyses and/or data that are not part of DR3

List maintained at https://www.cosmos.esa.int/web/gaia/exoplanets

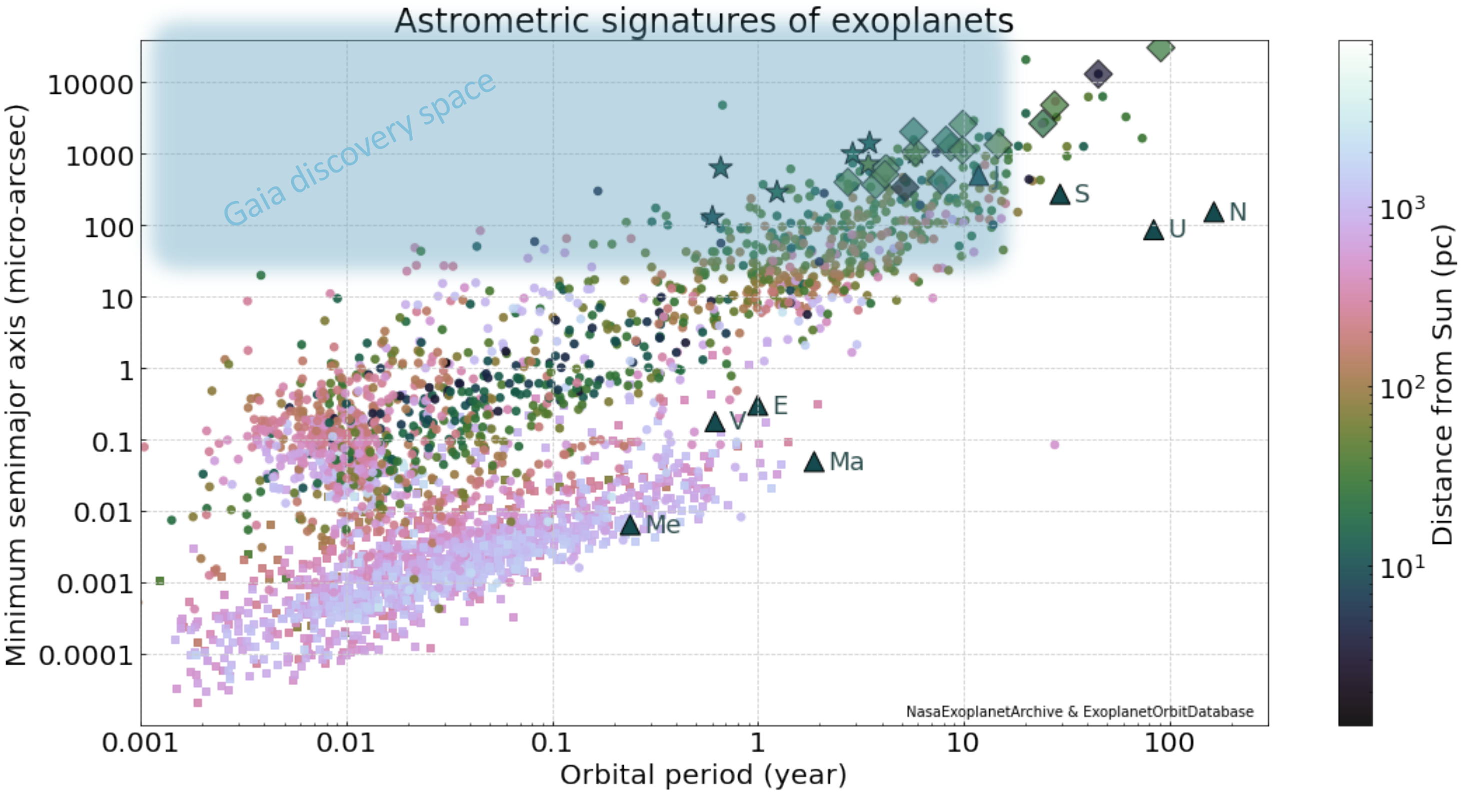
Astrometric orbit of HD 81040 hosting a 8 M_{Jup} planet



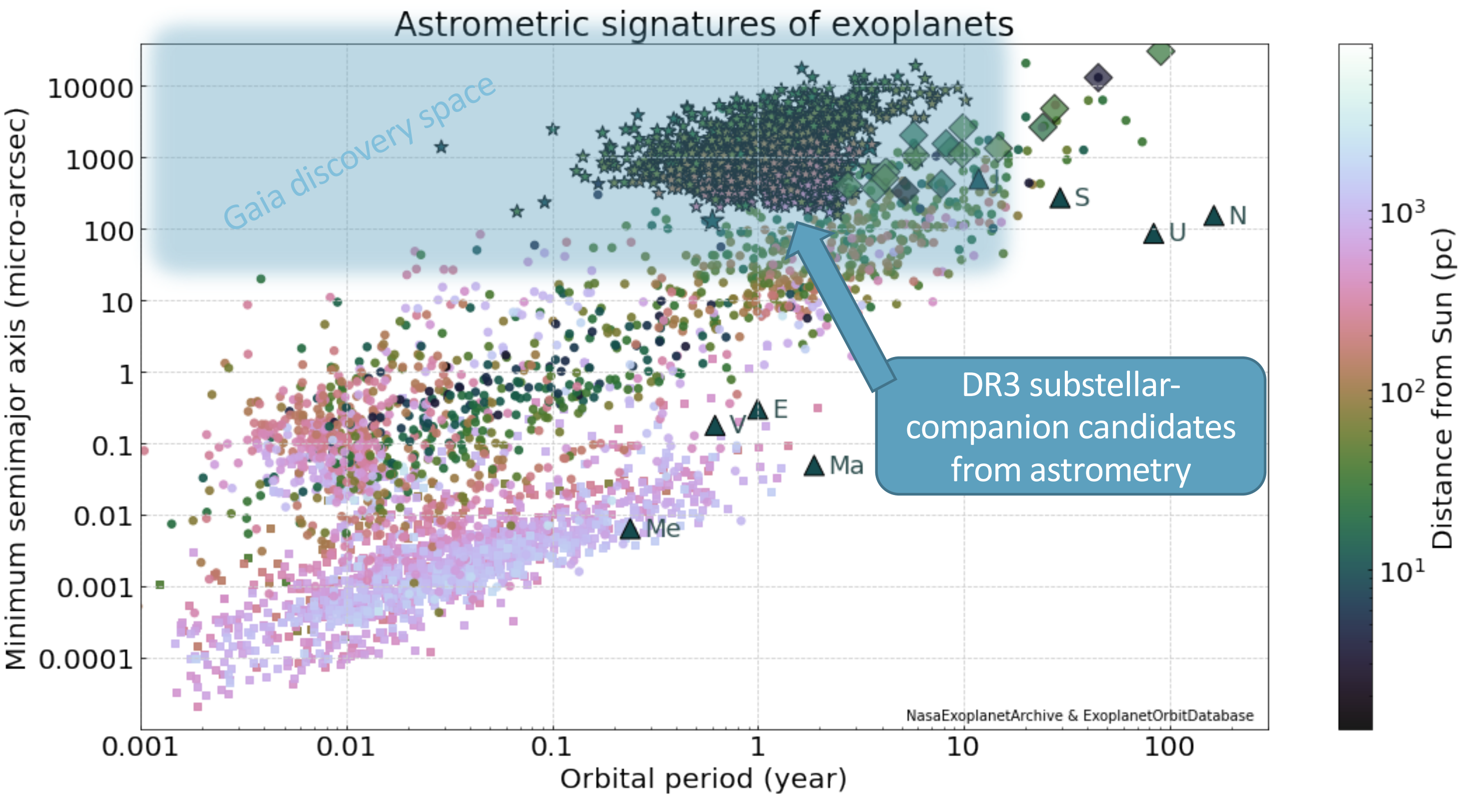
https://www.cosmos.esa.int/web/gaia/iow_20220131

Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022

Gaia starts harvesting exoplanet orbits

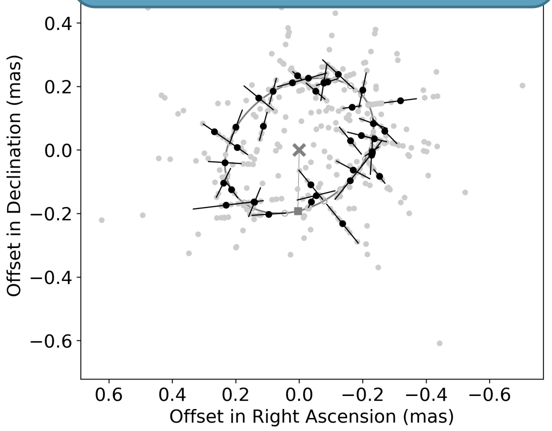


Gaia starts harvesting exoplanet orbits



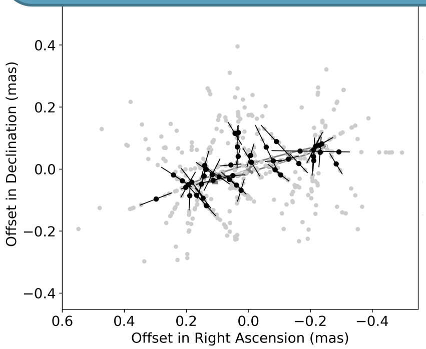
Gaia discovers new exoplanet candidates

Super-Jupiters around the main-sequence stars HIP 66074 and HIP 28193



Substellar companions to the young stars HD 3221 and 2MASS J02192210-3925225

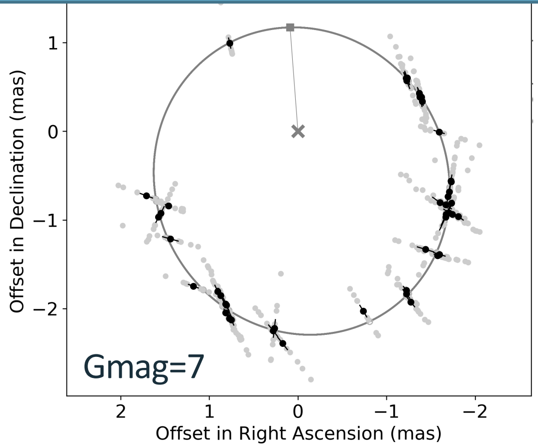
A super-Jupiter orbiting the nearby metal-polluted white dwarf WD 0141-675



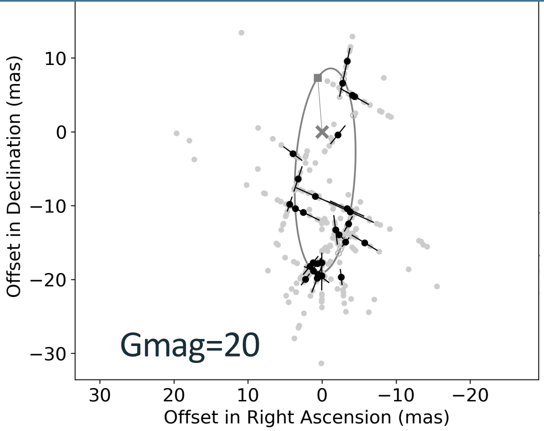
Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022; Holl et al. 2022

There is more substellar science candy in DR3

HD 114762 B: first substellar companion candidate around a solar-type star (Latham et al. 1989).
Gaia DR3 orbit firmly establishes this as a stellar binary.



Orbits and masses of brown dwarf binaries, e.g. 2M0805 (L4+T5).



Credits: ESA/Gaia/DPAC, Gaia Collaboration, Arenou et al. 2022; Holl et al. 2022

Conclusion: Gaia DR3 is awesome!

Several products and many results omitted for sake of time, e.g.

- Accelerations in astrometry and radial velocity -> binaries with long periods
- Catalog of masses (gaiadr3.binary_masses), including model-independent masses

Reminder: the epoch astrometry, photometry, spectroscopy is generally not part of DR3

The Gaia collaboration DR3 publications are shallow explorations of selected topics. They are potential entry points and inspirations for more thorough analyses.

Many exciting non-single star discoveries need to be confirmed and most remain to be made. This is a community effort. An enormous new dataset for the study of non-single stars is now just one archive query away.

Thank you