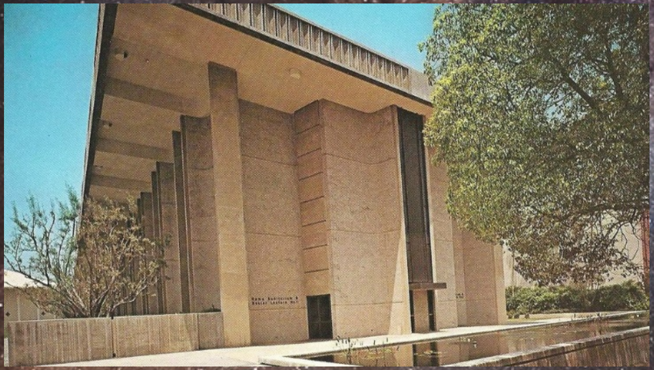
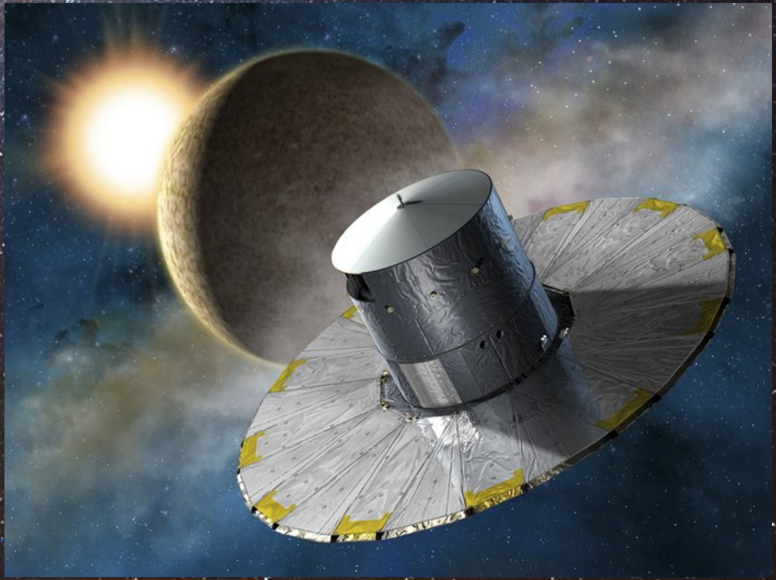
Gaia Exoplanet Survey: The (Start of the) Astrometry Revolution

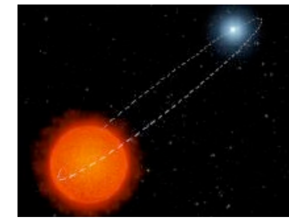


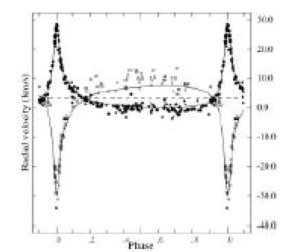


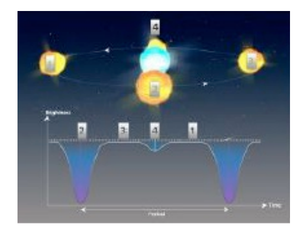
A. Sozzetti

INAF – Osservatorio Astrofisico di Torino

A colleague, and a friend…

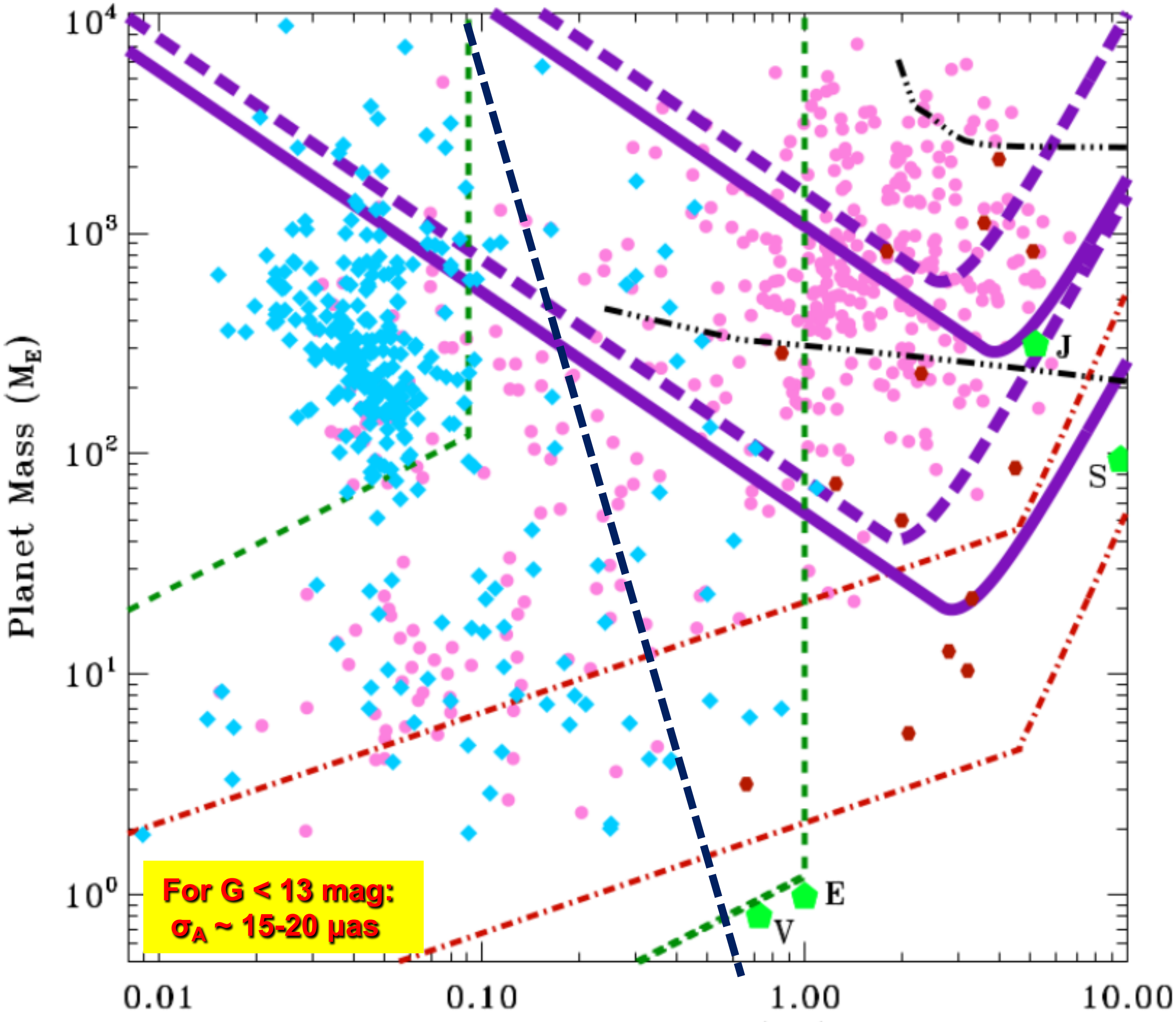






…Dimitri

Gaia Discovery Space



Sozzetti & de Bruijne 2018

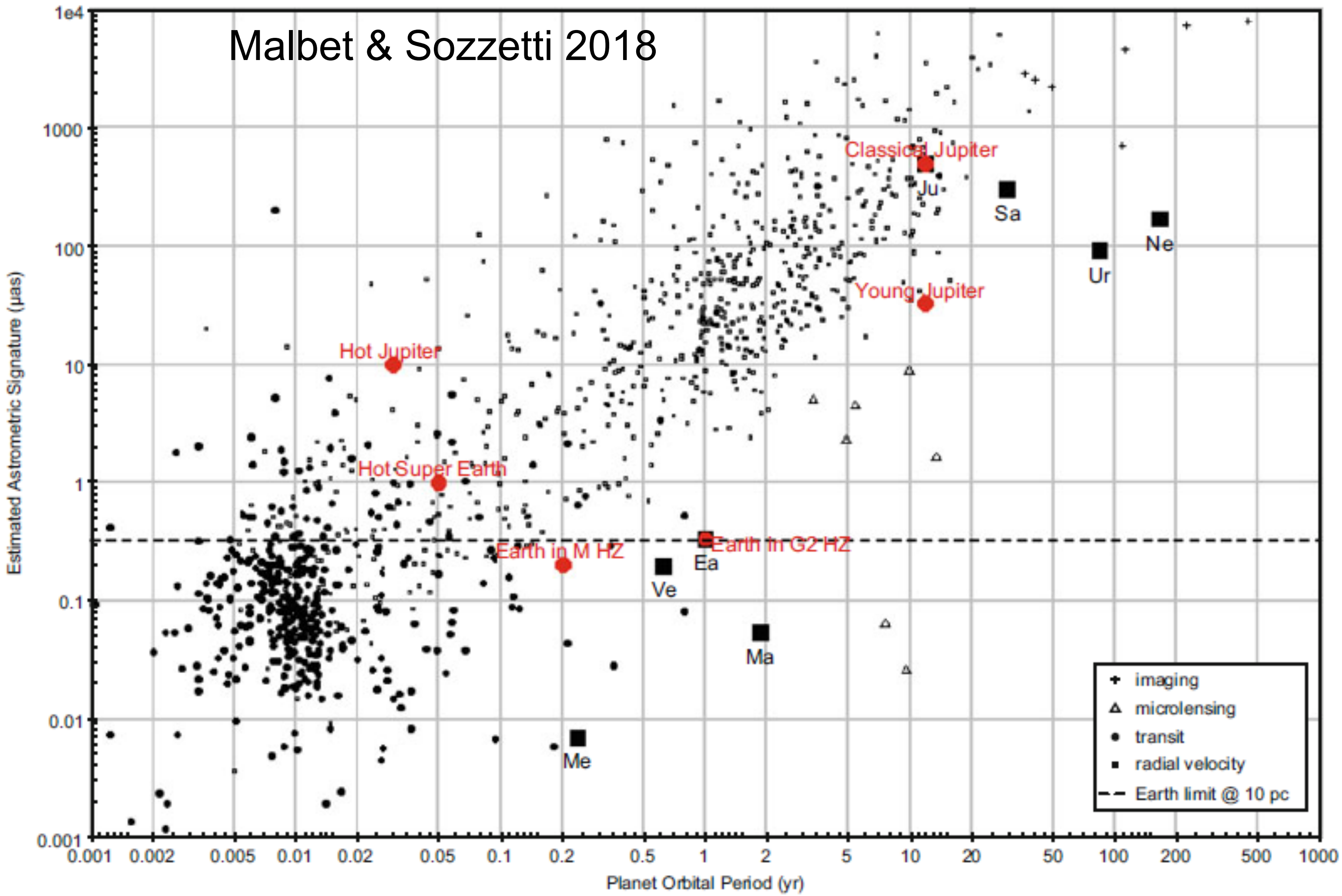
Unbiased, magnitude-limited planet census of maybe 10^6-10^7 stars

>10^4 NEW gas giants ($<$ 15 M_{JUP}) around A through M dwarfs
Numbers might as much as triple for a 10-yr mission

Lattanzi et al. 2000,
Sozzetti et al.2001
Casertano et al. 2008
Perryman et al. 2014
Sozzetti et al. 2014
Sahlmann et al. 2015

Gaia will test the fine structure of GP parameters distributions and frequencies (including the GP/BD transition), and investigate their changes as a function of stellar mass, metallicity, age, and multiplicity with unprecedented resolution

Gaia & Known Planets



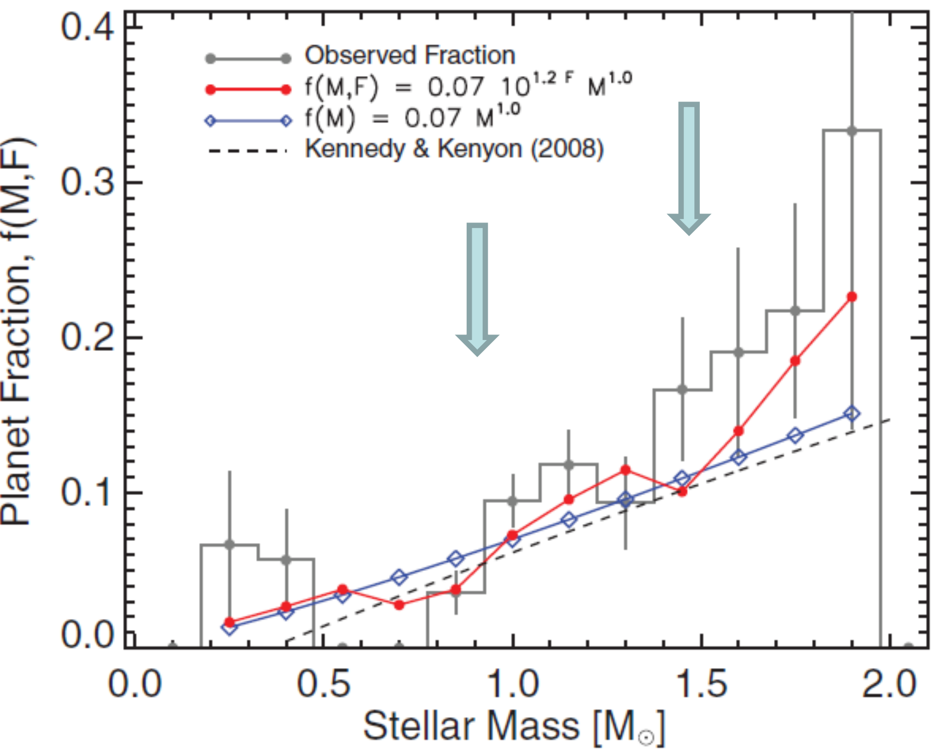
30 μas

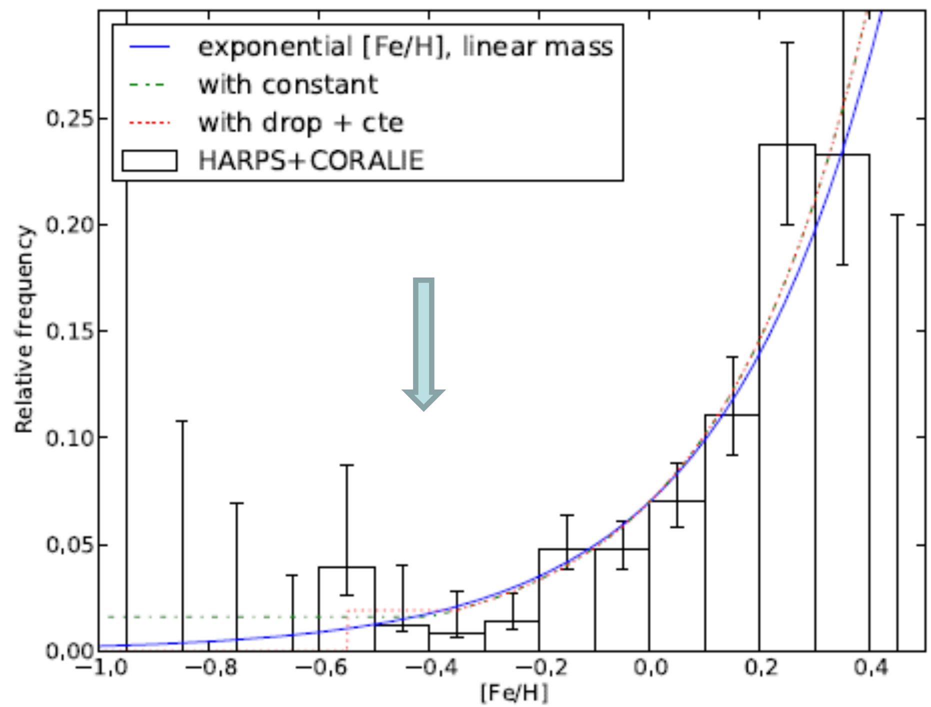
- Maybe 50% of known companions accessible to Gaia for true mass estimation
- MOST exoplanets found by Gaia around bright stars good for RV follow-up

GP Occurrence vs [Fe/H], M_*

Gaia: 10^4 stars in a bin!

Today: 10^2 stars in a bin!



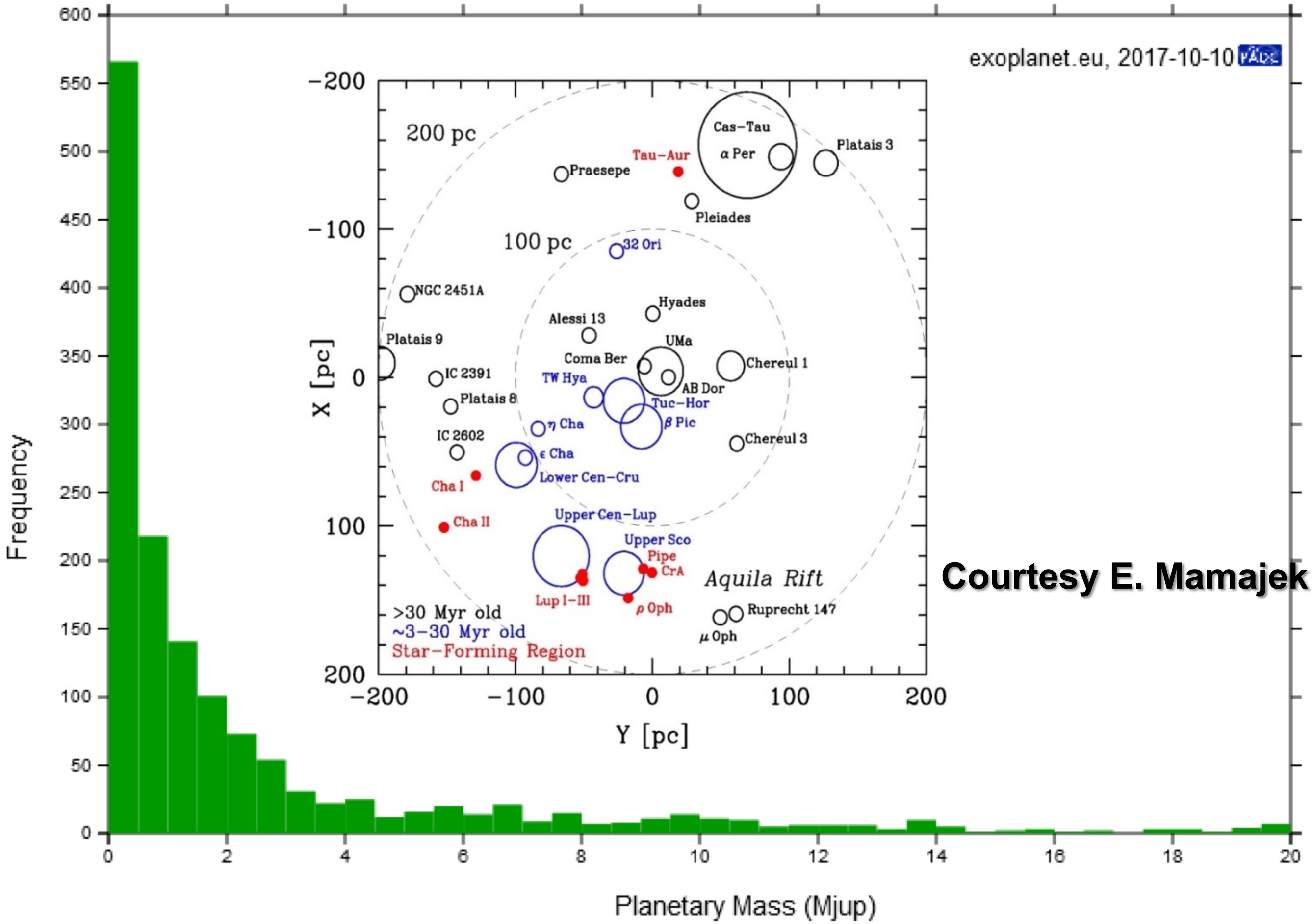


Mortier, Santos, Sozzetti et al. 2012

Johnson et al. 2010

How do giant planet frequencies, masses, orbits depend on the host stars' properties?

Gaia and Young Stars

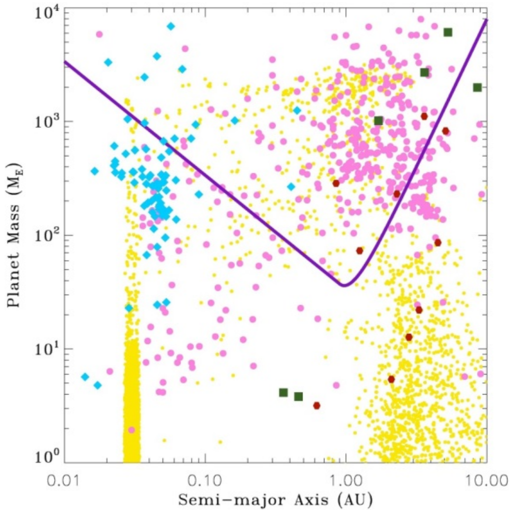


Courtesy E. Mamajek

1) Unique exploration of the GP/BD transition region of companions to (1000?) young stars (<200 pc) in a regime of separations mostly inaccesible to DI
2) Systematic improvement of DI-detected companions via detection of astrometric accelerations: that's another great synergy!

Gaia & UCD Planets

- Found so far only in microlensing events
- Gaia will see ~1000 UCDs of all ages, with sufficient astrometric sensitivity to giant planets within 2-3 AU
- A fundamental test of planet formation!



Sozzetti 2014

Gaia & Post-MS Stars

- Gaia might be sensitive to massive planet around thousands of bright White Dwarfs
- Gaia will perform THE observational test of theoretical predictions related to:

A) <u>post-MS planet evolution</u> &
B) <u>2nd generation planet formation</u>

	D<100 pc	D<200 pc
G<13	50	400
G<14	200	1600
G<15	800	6400

Silvotti, Sozzetti et al. 2015

gaia

Gaia DR2 & EDR3:

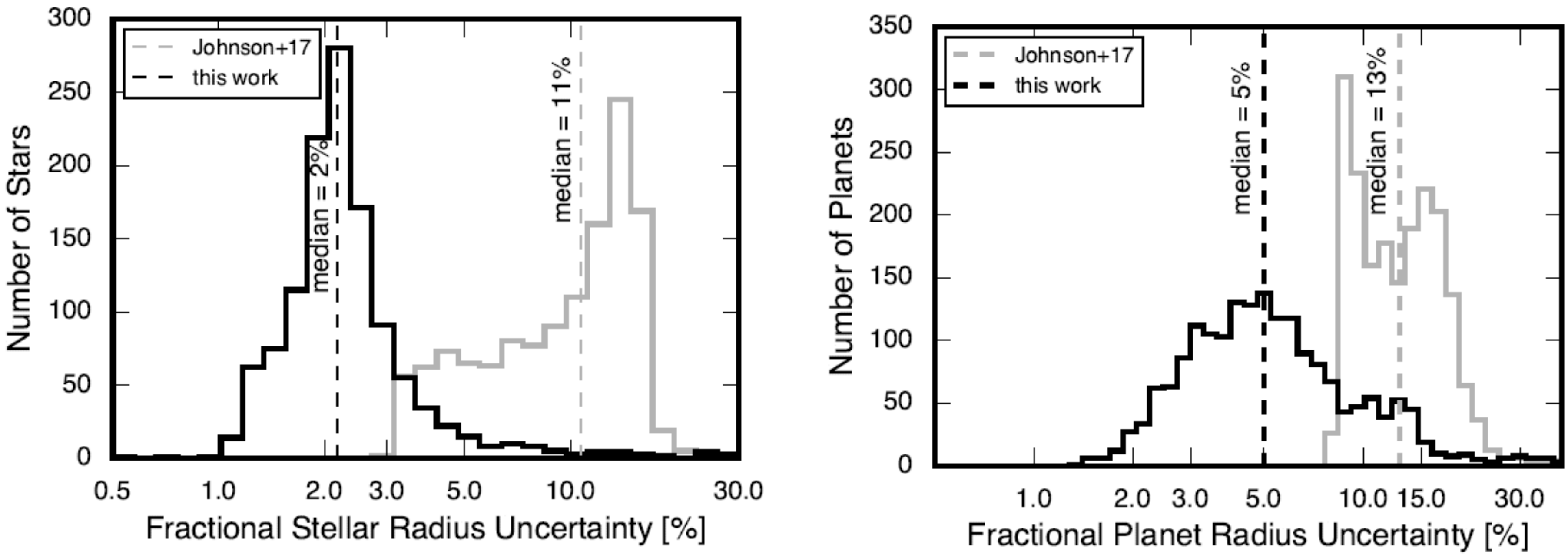
No direct binarity information

…Any Exoplanet Science with DR2/EDR3?

YES!

Calibration of the Hosts

Take Gaia parallaxes, and then do it your way!



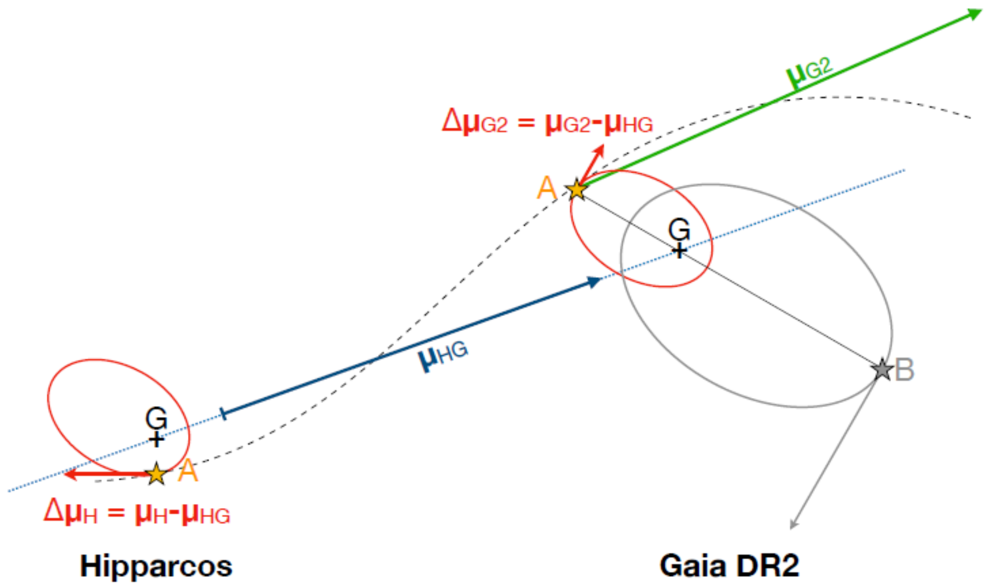
Fulton & Petigura 2018

See D. Huber, O. Creevey's, J. Christiansen's talks

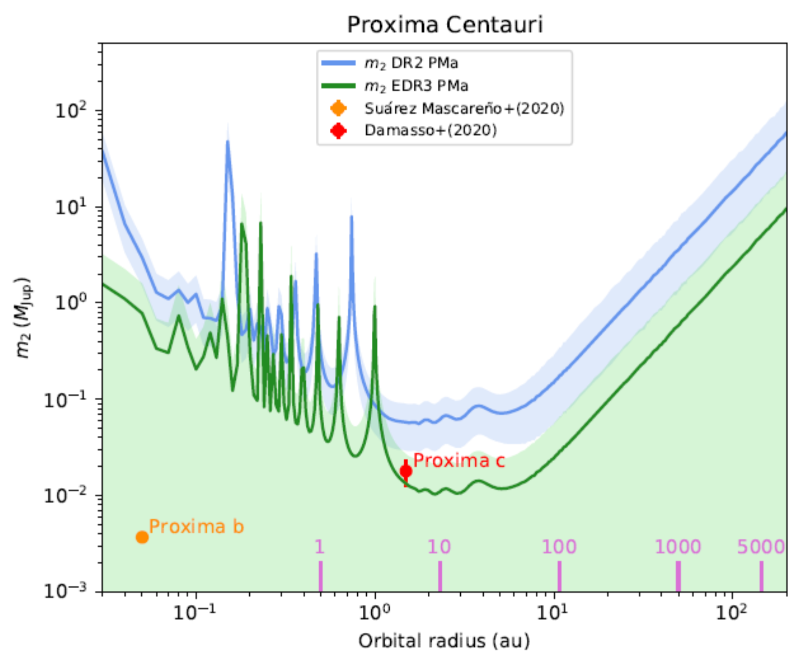
DR2/EDR3:
Bright (V<13) F-G-K stars (D<300-400 pc) and not very faint (V<16) M dwarfs (D<50-60 pc) have distances determined to 5%, or better

→ **Derive 'accurate' stellar (and planetary) radii to within 5% or better**
Much improved understanding of demographics (e.g., radius valley)

Constraints on Companions

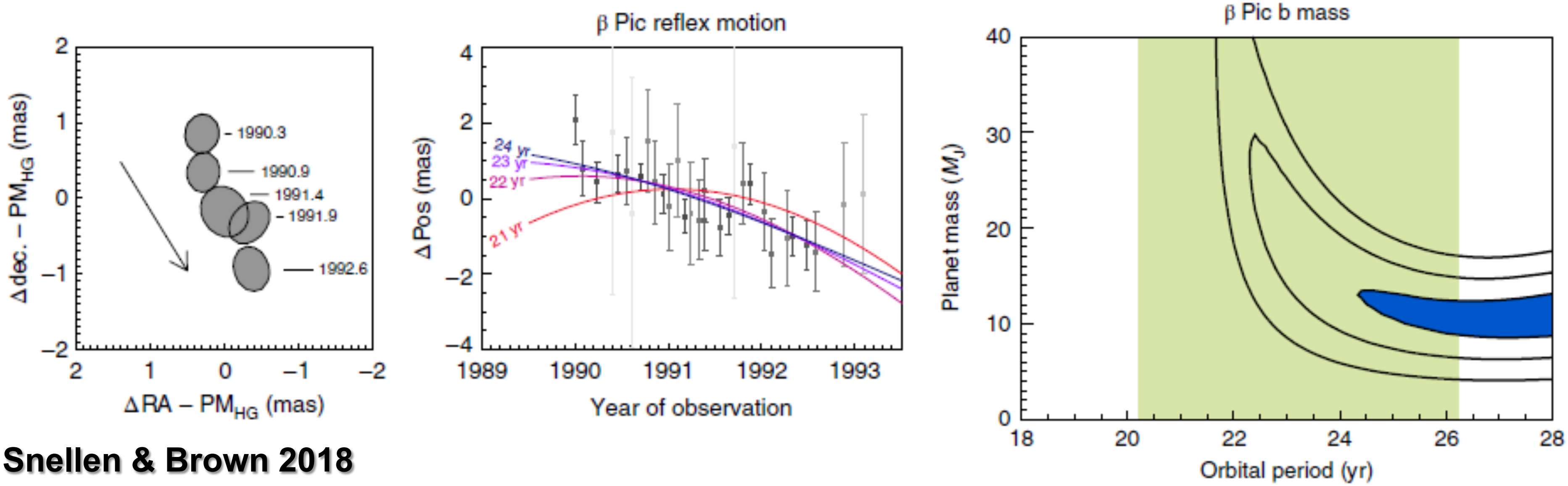


Kervella et al. 2019, 2022

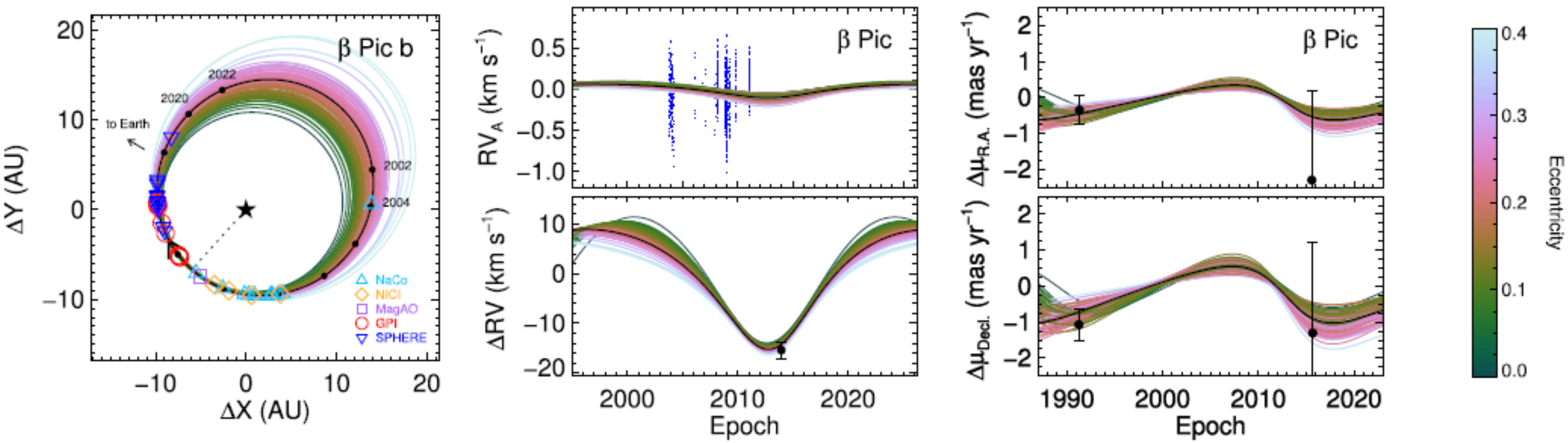


See P. Kervella's, T. Brandt's, M. Brandt's talks

Dynamical Masses



Snellen & Brown 2018

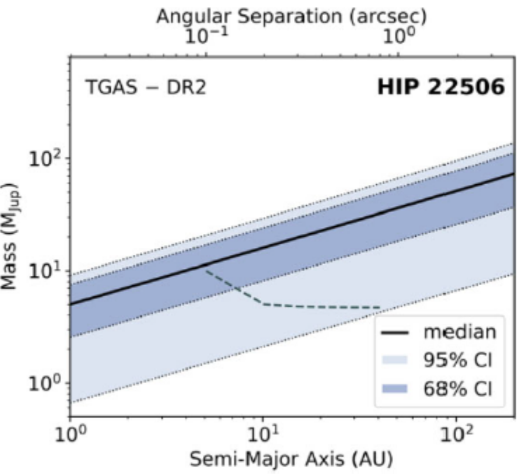


Young, luminous, directly-imaged companions

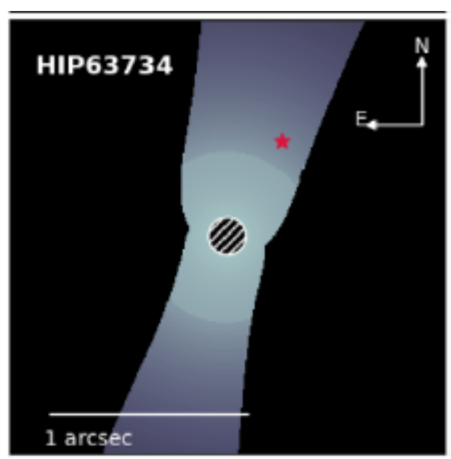
Dupuy et al. 2019

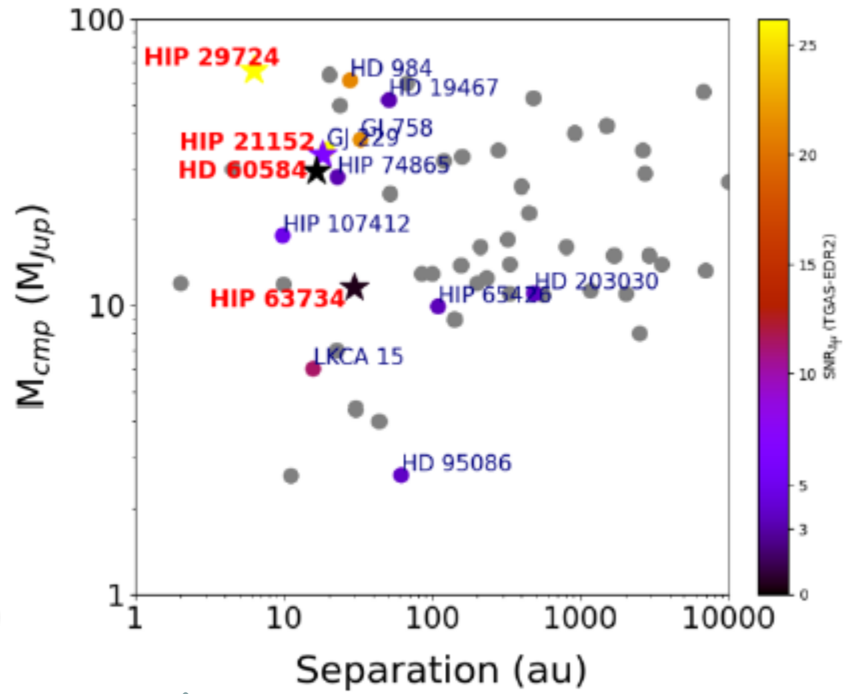
New Detections

Select accelerating stars for follow-up direct-imaging observations



Bonavita et al. 2022





Increasing efficiency of identification of wide-orbit substellar companions!

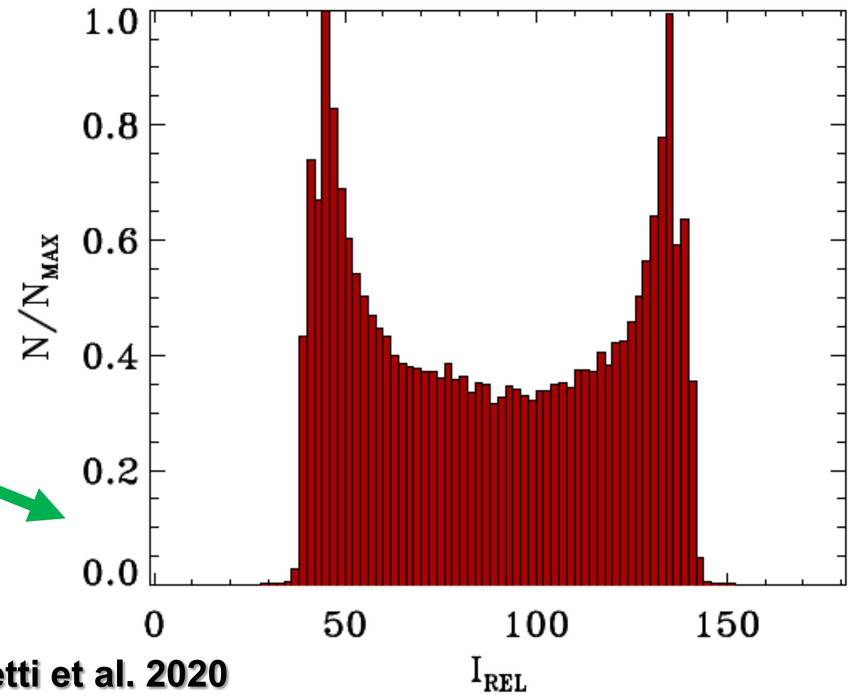
The π Mensae System

Star name	Epoch	$\Delta\mu_\alpha$ (mas yr^{-1})	$\Delta\mu_\delta$ (mas yr^{-1})
π Men	Hipparcos	0.768 ± 0.398	0.404 ± 0.445
π Men	Gaia	0.707 ± 0.246	-0.739 ± 0.263

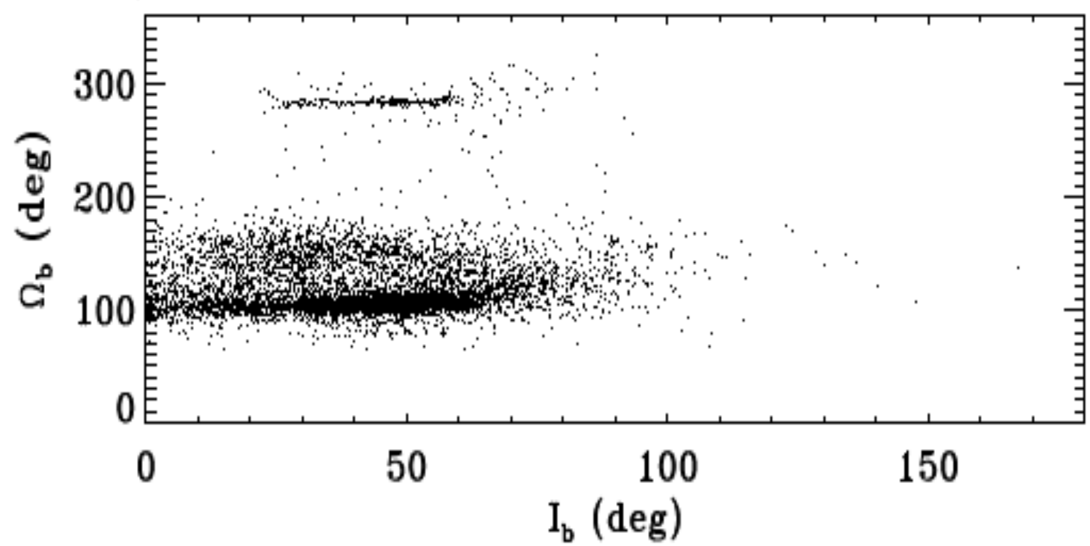
Jump parameter	Prior	Best-fit value
i_b [deg]	$\mathcal{U}(0.0,180.0)$	$47.9^{+1.1}_{-1.3}$
Ω_b [deg]	$\mathcal{U}(0.0,360.0)$	$104.1^{+0.6}_{-0.5}$
Mass, m_b [M_{Jup}]	(derived)	$13.4^{+0.3}_{-0.2}$

$$\cos i_{\rm rel} = \cos i_{\rm in} \cos i_{\rm out} + \sin i_{\rm in} \sin i_{\rm out} \cos(\Omega_{\rm out} - \Omega_{\rm in})$$

R_c/R_*	0.0165 ± 0.0001
a_c/R_*	12.5 ± 0.3
i_c [deg]	87.05 ± 0.15
Eccentricity, e_b	0.642 ± 0.001
Argument of periastron, $\omega_{\star,b}$ [deg]	-30.1 ± 0.3
$T_{b,\,periastron}$ [BJD-2 450 000]	8388.6 ± 2.2
Minimum mass, $m_b \sin i_b$ [M_{Jup}]	9.89 ± 0.25
Orbital semi-major axis, a_b [au]	3.28 ± 0.04
Eccentricity, e_c	0 (fixed)
Argument of periastron, $\omega_{\star,c}$ [deg]	90 (fixed)
Orbital semi-major axis, a_c [au]	0.0680 ± 0.0008
Mass, m_c [$M_\oplus$]	4.3 ± 0.7
Radius, R_c [$R_\oplus$]	2.11 ± 0.05
Average density, ρ_c [$g\ cm^{-3}$]	2.8 ± 0.5



Damasso, Sozzetti et al. 2020

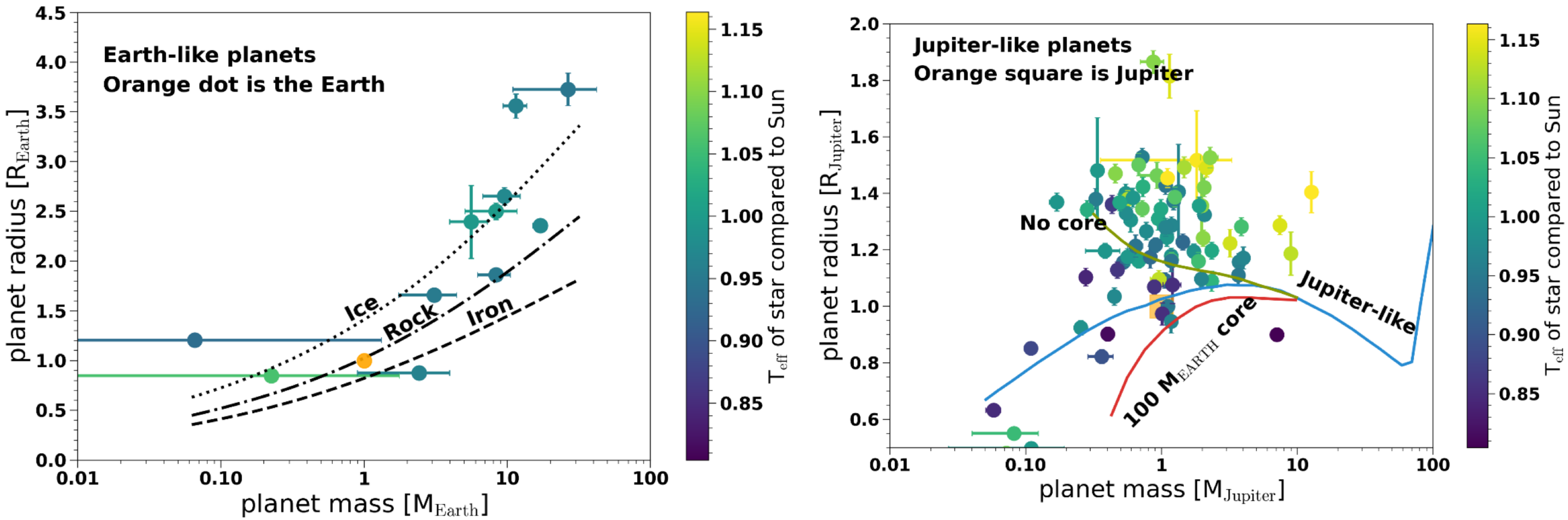


DR3: June 13th…

	# sources in Gaia DR3	# sources in Gaia DR2	# sources in Gaia DR1
Total number of sources	**1,811,709,771**	**1,692,919,135**	**1,142,679,769**
	Gaia Early Data Release 3		
Number of sources with full astrometry	1,467,744,818	1,331,909,727	2,057,050
Number of 5-parameter sources	585,416,709		
Number of 6-parameter sources	882,328,109		
Number of 2-parameter sources	343,964,953	361,009,408	1,140,622,719
Gaia-CRF sources	1,614,173	556,869	2191
Sources with mean G magnitude	1,806,254,432	1,692,919,135	1,142,679,769
Sources with mean G_{BP}-band photometry	1,542,033,472	1,381,964,755	-
Sources with mean G_{RP}-band photometry	1,554,997,939	1,383,551,713	-
	New in Gaia Data Release 3	Gaia DR2	Gaia DR1
Sources with radial velocities	33,812,183	7,224,631	-
Sources with mean G_{RVS}-band magnitudes	32,232,187	-	-
Sources with rotational velocities	3,524,677	-	-
Mean BP/RP spectra	219,197,643	-	-
Mean RVS spectra	999,645	-	-
Variable-source analysis	10,509,536	550,737	3,194
Variability types (supervised machine learning)	24	6	2
Supervised machine-learning classification for variables	9,976,881	390,449	3,194
Specific Object Studies – Cepheids	15,021	9,575	599
Specific Object Studies – Compact companions	6,306	-	-
Specific Object Studies – Eclipsing binaries	2,184,477	-	-
Specific Object Studies – Long-period variables	1,720,588	89,617	-
Specific Object Studies – Microlensing events	363	-	-
Specific Object Studies – Planetary transits	214	-	-
Specific Object Studies – RR Lyrae stars	271,779	140,784	2,595
Specific Object Studies – Short-timescale variables	471,679	3,018	-
Specific Object Studies – Solar-like rotational modulation variables	474,026	147,535	-
Specific Object Studies – Upper-main-sequence oscillators	54,476	-	-
Specific Object Studies – Active galactic nuclei	872,228	-	-
Photometrically-variable sources with radial-velocity time series	1,898	-	-
Sources with object classifications	1,590,760,469	-	-
Stars with emission-line classifications	57,511	-	-
Sources with astrophysical parameters from BP/RP spectra	470,759,263	161,497,595	-
Sources with astrophysical parameters assuming an unresolved binary	348,711,151	-	-
Sources with spectral types	217,982,837	-	-
Sources with evolutionary parameters (mass and age)	128,611,111	-	-
Hot stars with spectroscopic parameters	2,382,015	-	-
Ultra-cool stars	94,158	-	-
Cool stars with activity index	1,349,499	-	-
Sources with H-alpha emission measurements	235,384,119	-	-
Sources with astrophysical parameters from RVS spectra	5,591,594	-	-
Sources with chemical abundances from RVS spectra (up to 13 species)	2,513,593	-	-
Sources with a diffuse interstellar band (DIB) in their RVS spectrum	472,584	-	-
Non-single stars (astrometric, spectroscopic, eclipsing, orbits, trends)	813,687	-	-
Non-single stars - orbital astrometric solutions	169,227	-	-
Non-single stars - orbital spectroscopic solutions (SB1 / SB2)	186,905	-	-
Non-single stars - eclipsing binaries	87,073	-	-
QSO candidates	6,649,162	-	-
QSO candidates - redshifts	6,375,063	-	-
QSO candidates - host galaxy detected	64,498	-	-
QSO candidates - host galaxy surface brightness profiles	15,867	-	-
Galaxy candidates	4,842,342	-	-
Galaxy candidates - redshifts	1,367,153	-	-
Galaxy candidates - surface brightness profiles	914,837	-	-
Solar system objects	158,152	14,099	-
Solar system objects - epoch astrometry (CCD transits)	23,336,467	-	-
Solar system objects - orbits	154,787	-	-
Solar system objects - average BP/RP reflectance spectra	60,518	-	-
Solar system objects - planetary satellites	31	-	-
All-sky total galactic extinction maps at different spatial resolutions	HEALPix levels 6, 7, 8, and 9	-	-
Gaia Andromeda Photometric Survey (GAPS) with lightcurves for all objects	1,257,319	-	-

Transiting Planets Update

Creevey et al. 2022



- **A Golden Sample of sources with Gaia-based solid astrophysical parameters**
- **Transiting planets masses and radii are re-calibrated**

gaia

Courtesy: P.Panuzzo

DR3 CU4 NSS Products

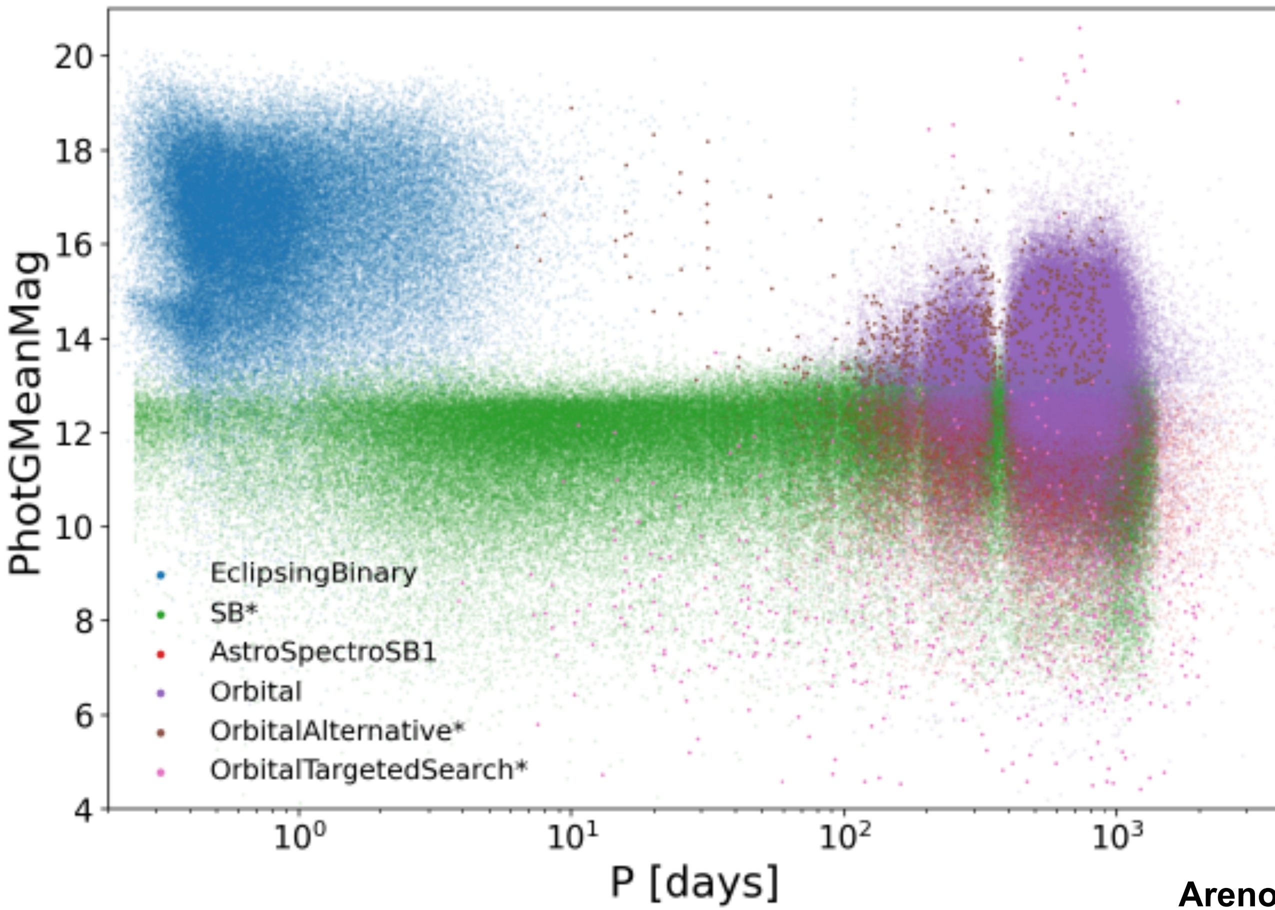
Gaia Collaboration (Arenou) et al. 2022

Table	Solution type	Solutions	Description
nss_acceleration_astro	Acceleration7	246 947	Second derivatives of position (acceleration)
	Acceleration9	91 268	Third derivatives of position (jerk)
nss_two_body_orbit	Orbital	134 598	Orbital astrometric solutions
	OrbitalAlternative*	629	Orbital astrometric, alternative solutions
	OrbitalTargetedSearch*	533	Orbital astrometric, supplementary external input list
	AstroSpectroSB1	33 467	Combined orbital astrometric + spectroscopic solutions
	SB1 or SB2	186 905	Orbital spectroscopic solutions
	EclipsingSpectro	155	Combined orbital spectroscopic + eclipsing solutions
	EclipsingBinary	86 918	Eclipsing binaries
nss_non_linear_spectro	FirstDegreeTrendSB1	24 083	First order derivatives of the radial velocity
	SecondDegreeTrendSB1	32 725	Second order derivatives of the radial velocity
nss_vim_fl	VIMF	870	Variable-induced movers fixed

* Gaia identifies and characterizes orbiting companions through all its observing channels: Astrometry, Spectroscopy, and Photometry
* As a consequence, many solution types are published in DR3
* No information on multiplicity (> 1 companion) in DR3

See also **processing papers**: Halbwachs et al. 2022, **Holl, Sozzetti et al. 2022**, Gosset et al. 2022, Damerdji et al. 2022, Siopis et al. 2022 and <u>on-line documentation</u>: https://gea.esac.esa.int/archive/documentation/GDR3/index.html

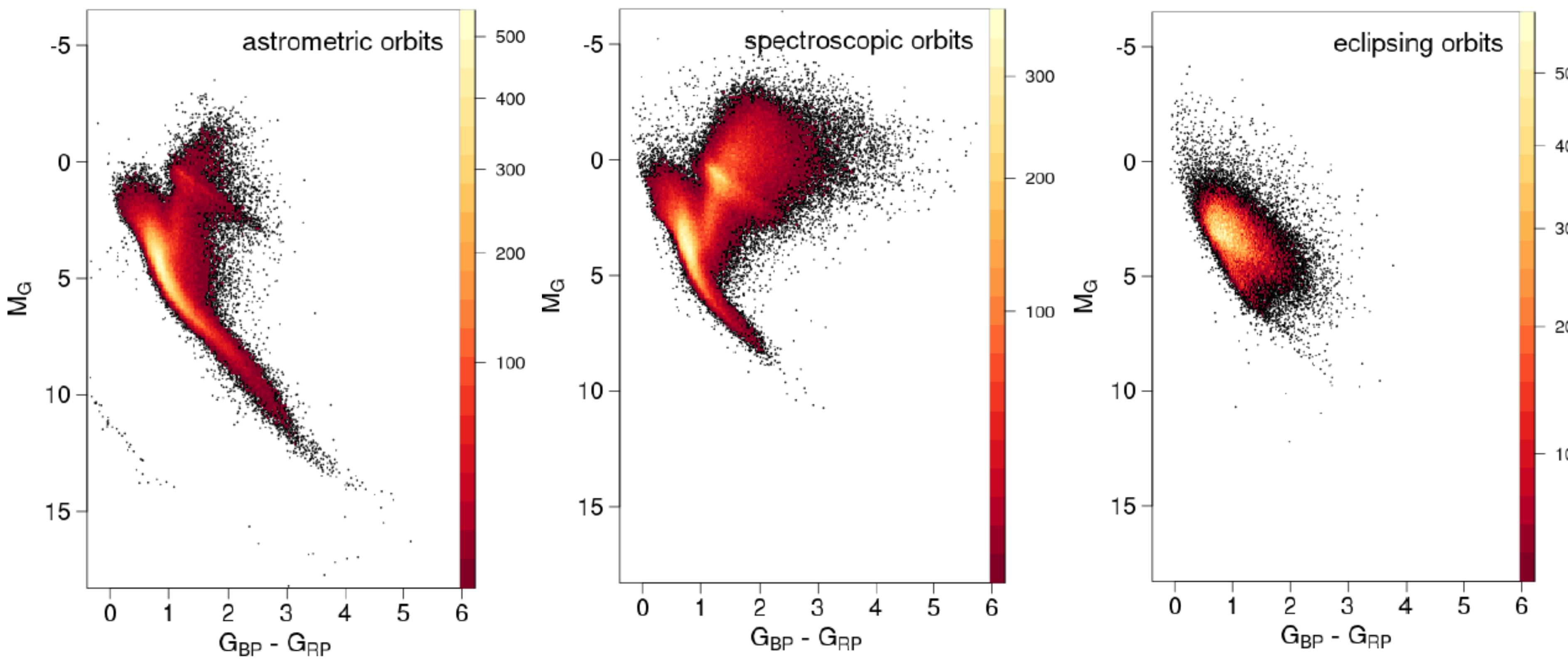
Statistics



Arenou et al. 2022

* 45 times more spectroscopic orbits than in the SB9 Catalogue
* 300 times more astrometric binaries than in Orb6 Catalogue

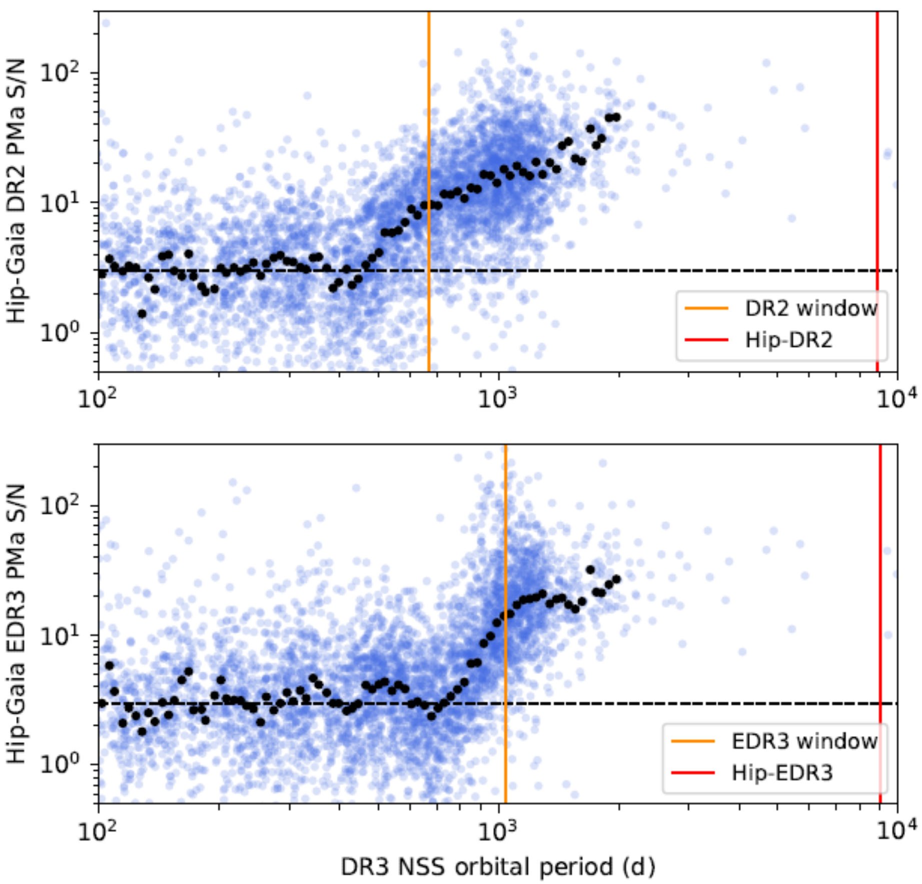
More Statistics

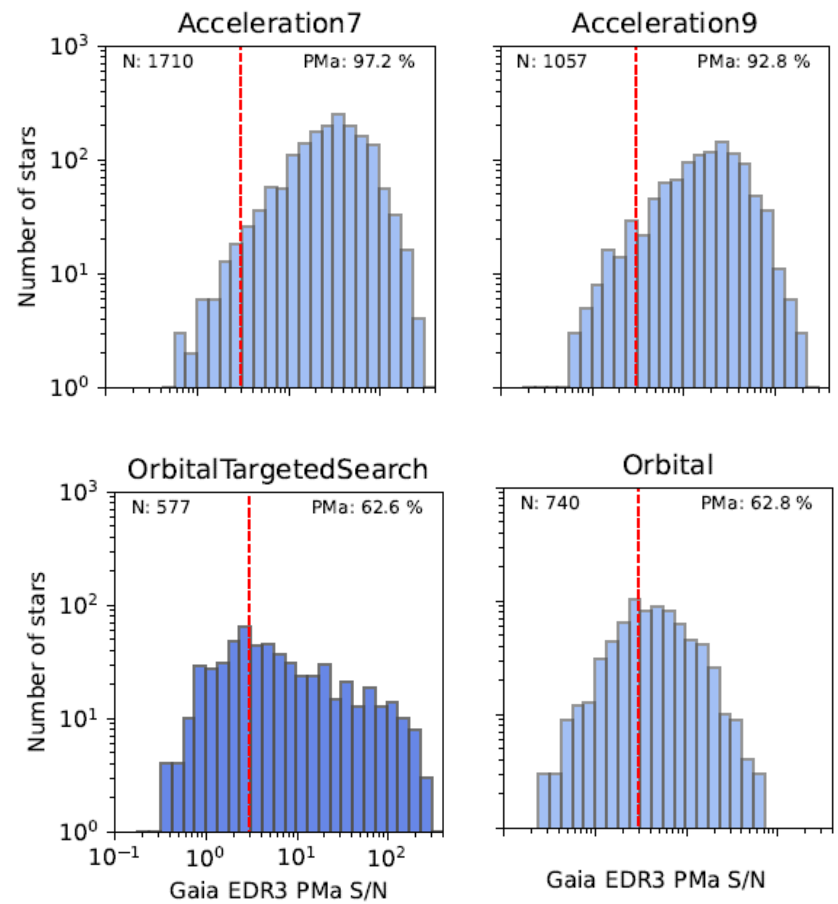


Arenou et al. 2022

* Covering the entire HR diagram, including the White Dwarf sequence

Some of the good…



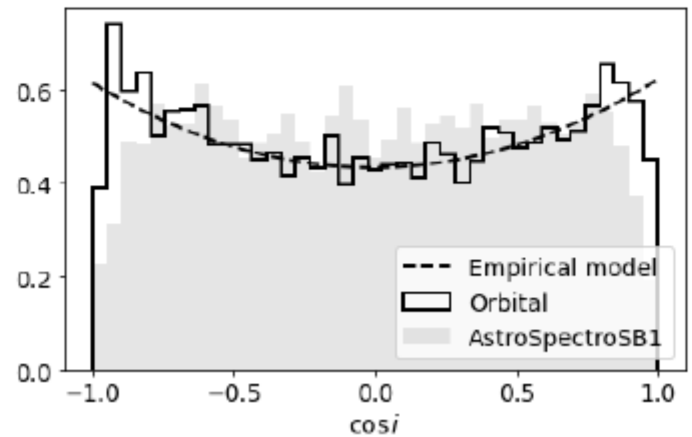


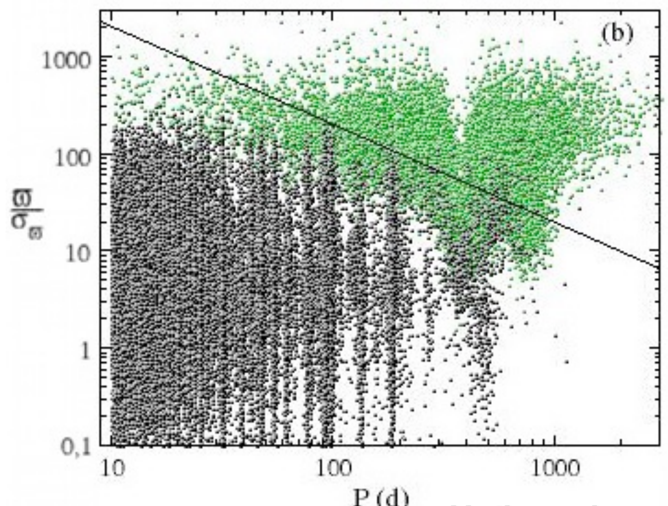
Arenou et al. 2022

Some of the bad…

- Huge validation effort necessary
- (In)Completeness and biases characterization
- Bad solutions identification:
  Some removed, some still present
- Caveats and recommendations for
  bad solutions filtering

Arenou et al. 2022

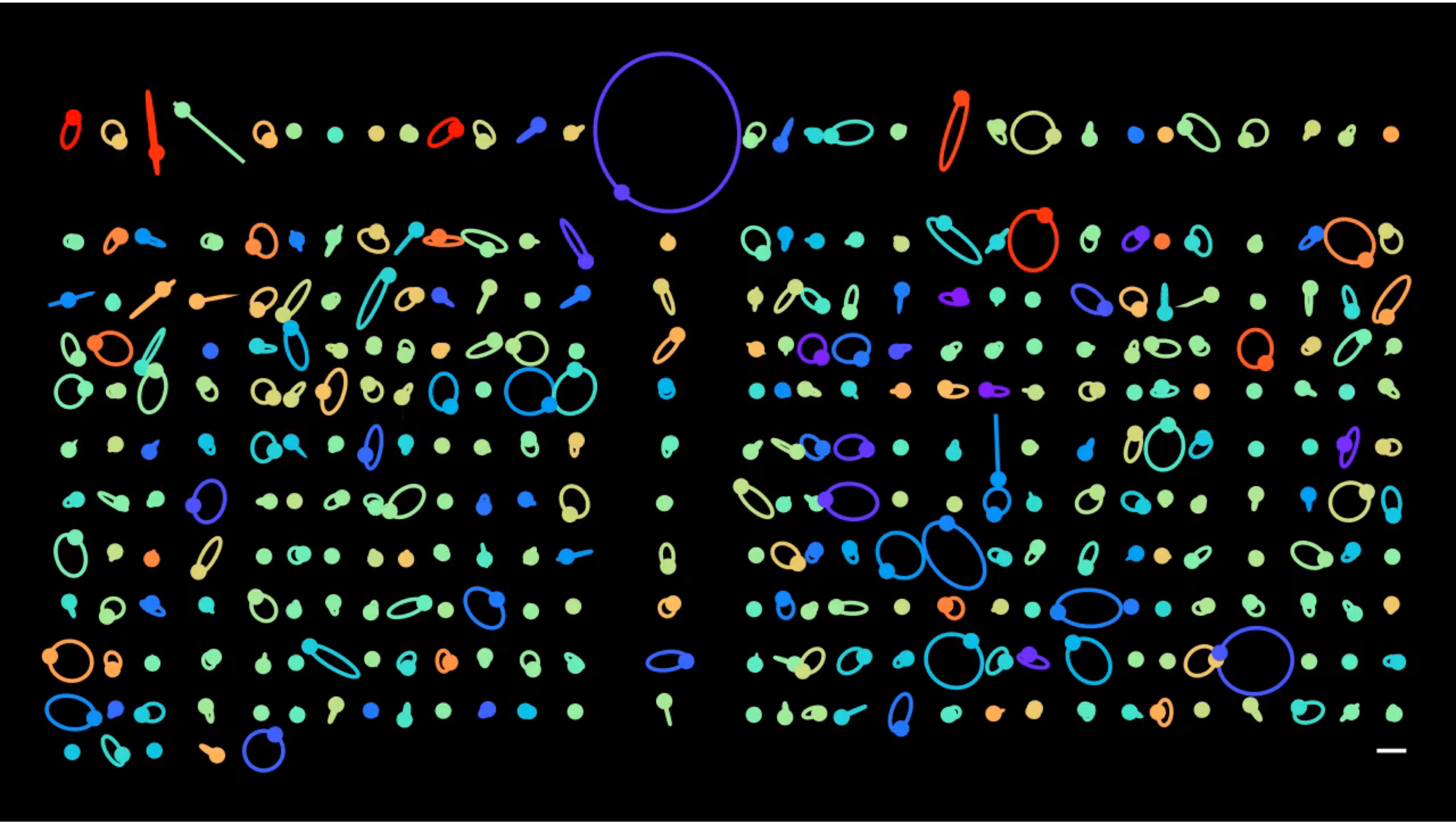




Halbwachs et al. 2022

An Orrery of (Astrometric) Orbits

Credits: J. Sahlmann



Substellar Companions

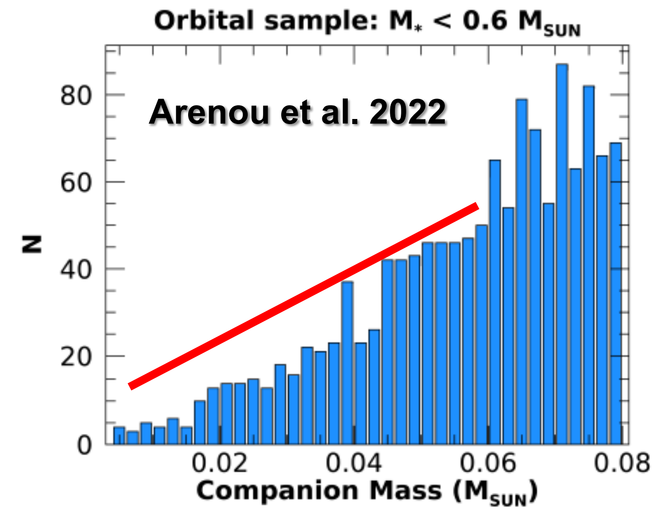
* Astrometry: 1843 BDs and 72 EPs candidates

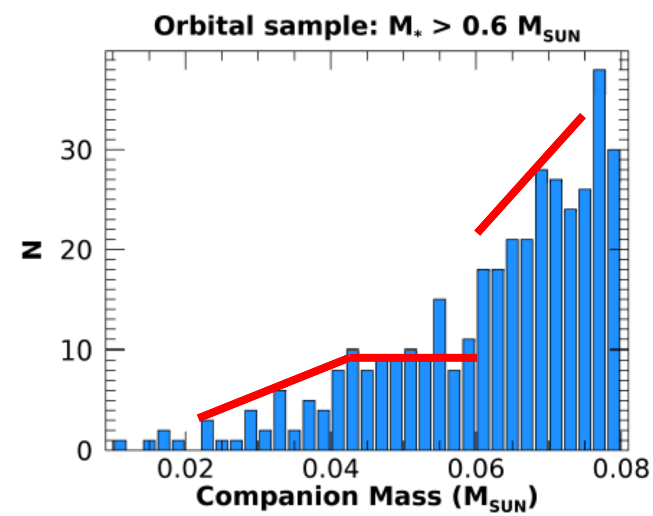
- 10 BDs and 9 EPs already known
- Some literature EPs found to be BDs/LMS
- 13 BD-BD binaries, 7 already known

* Spectroscopy: 6K SB1 with $M_2 \sin(i) < 0.08\ M_{SUN}$

- Many are probably aliases of longer periods
- 10 candidate Exoplanets
- One known transiting super-Jupiter correctly detected

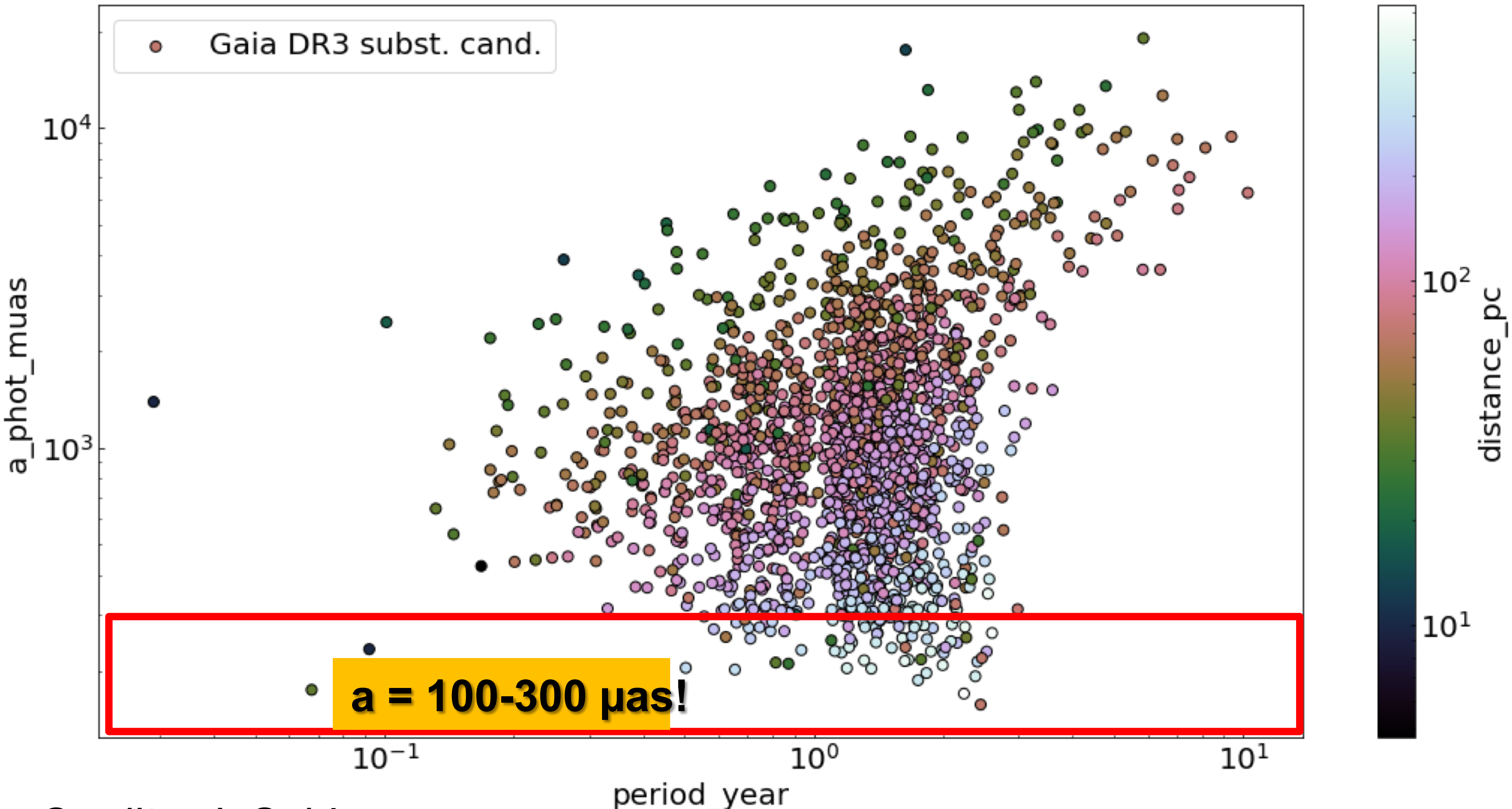
* Photometry: > 200 transiting exoplanet candidates, some 70 new.





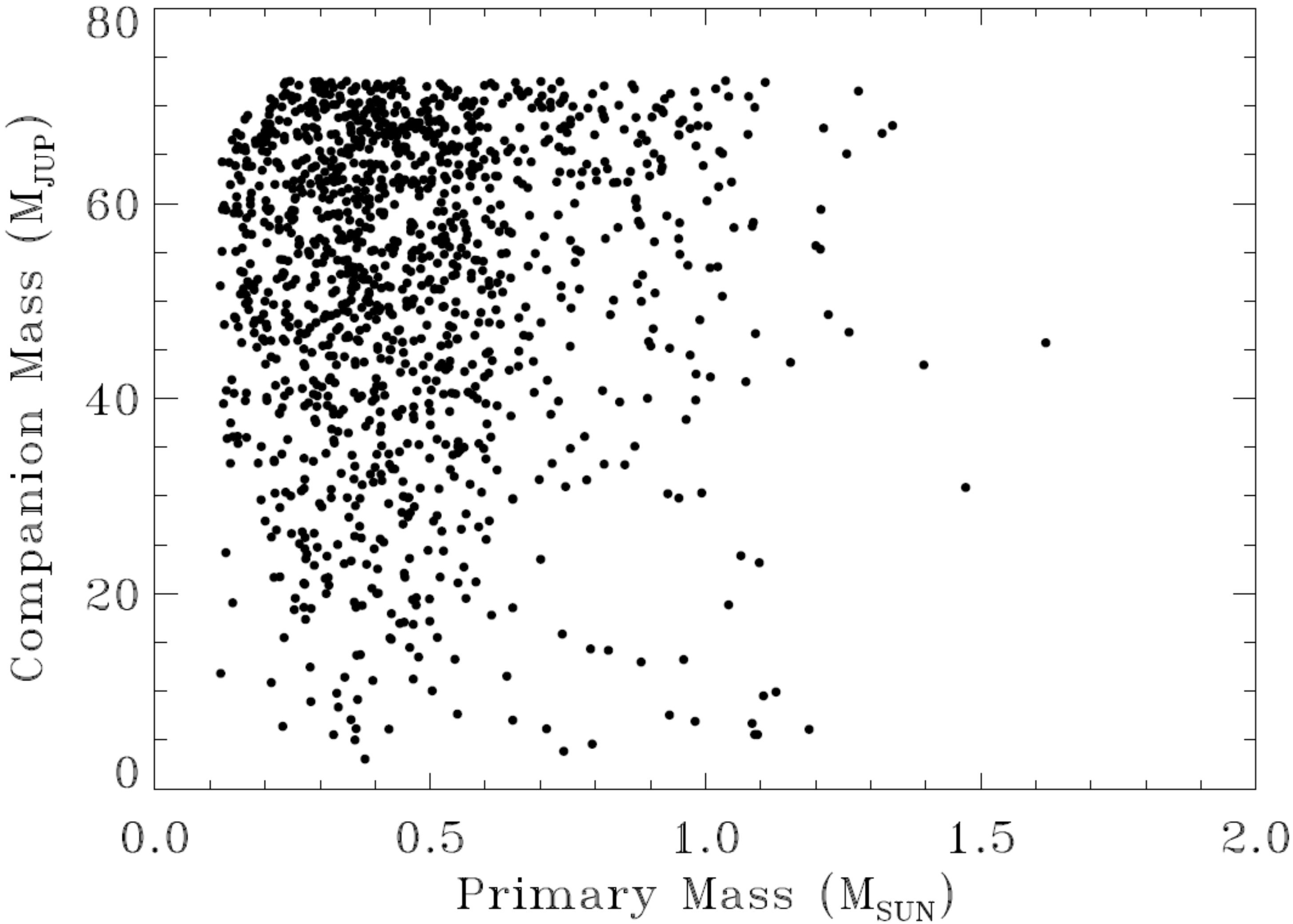
* Gaia candidate exoplanet list: https://www.cosmos.esa.int/web/gaia/exoplanets
* Gaia candidates now also in the Exoplanet Encyclopaedia: http://exoplanet.eu

Gaia DR3 astrometry: substellar mass companions



Credits: J. Sahlmann

Hosts of Substellar Companions



Primarily found around low-mass M dwarfs

BD Companion Occurrence

- Solar-type hosts of BDs have <[M/H]> = -0.02+/-0.29
- This value is right on estimates from RV surveys, with nearby field stars being more metal-poor, and planet hosts being more metal-rich
- Assuming 100% completeness and reliability, we infer *for the first time* a 0.3% occurrence rate of BDs around M dwarfs (likely underestimated, but it’s a first!)

Before you get too excited…

Hands-on session!

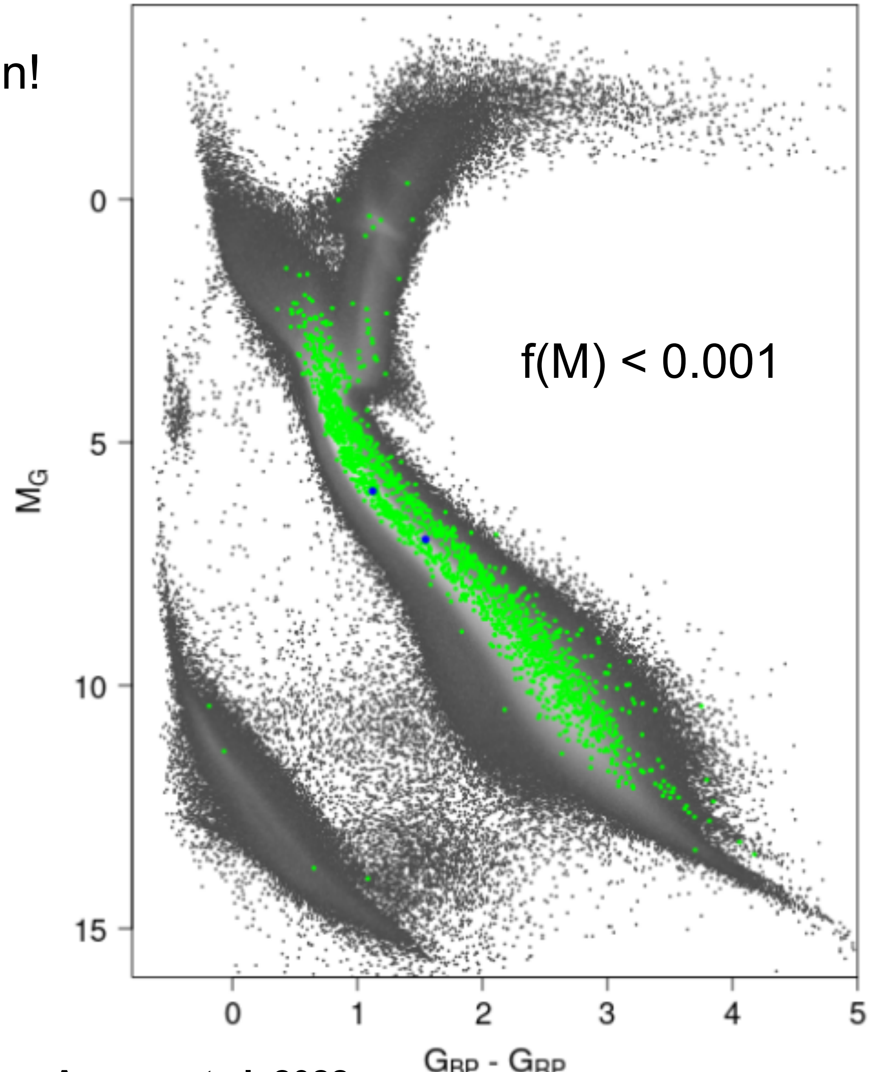
- Masses from f(M):

$$(\mathcal{M}_1 + \mathcal{M}_2)\left(\frac{\mathcal{M}_2}{\mathcal{M}_1 + \mathcal{M}_2} - \frac{F_2/F_1}{1 + F_2/F_1}\right)^3 = \frac{(a_0/\varpi)^3}{(P/365.25)^2}$$

- Small f(M) -> Small M_2?

- Impostors:

Binaries with $M_2/M_1 \approx F_2/F_1$



Arenou et al. 2022

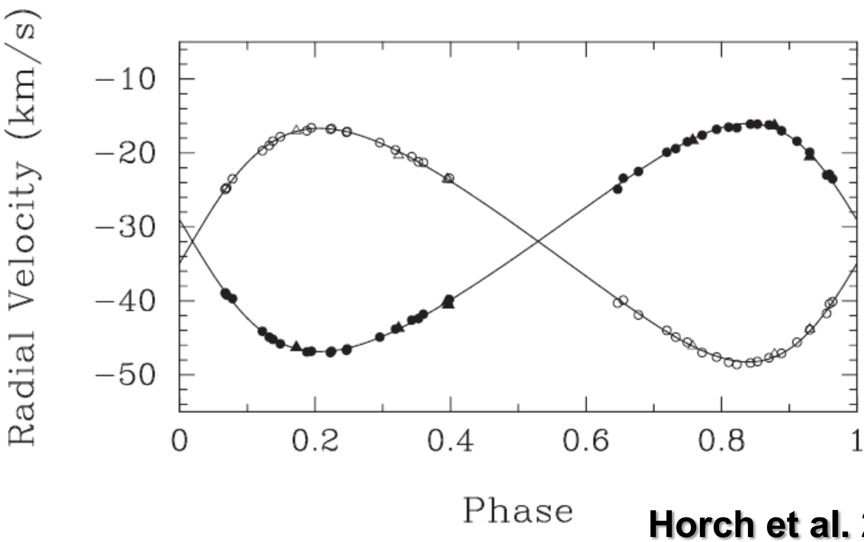
An instructive case: HD 185501

Gaia orbit:

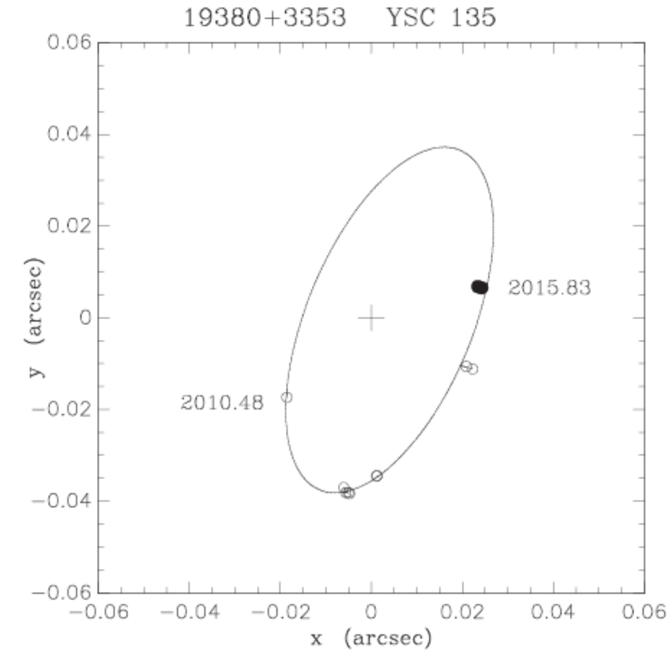
- P = 450 d
- a_1 = 480 μas

As d=32.7 pc, M_s = 0.90 M_{SUN}, M_2 could be a super-Jupiter or low-mass brown dwarf

Instead, it's an equal-mass binary with the same period!

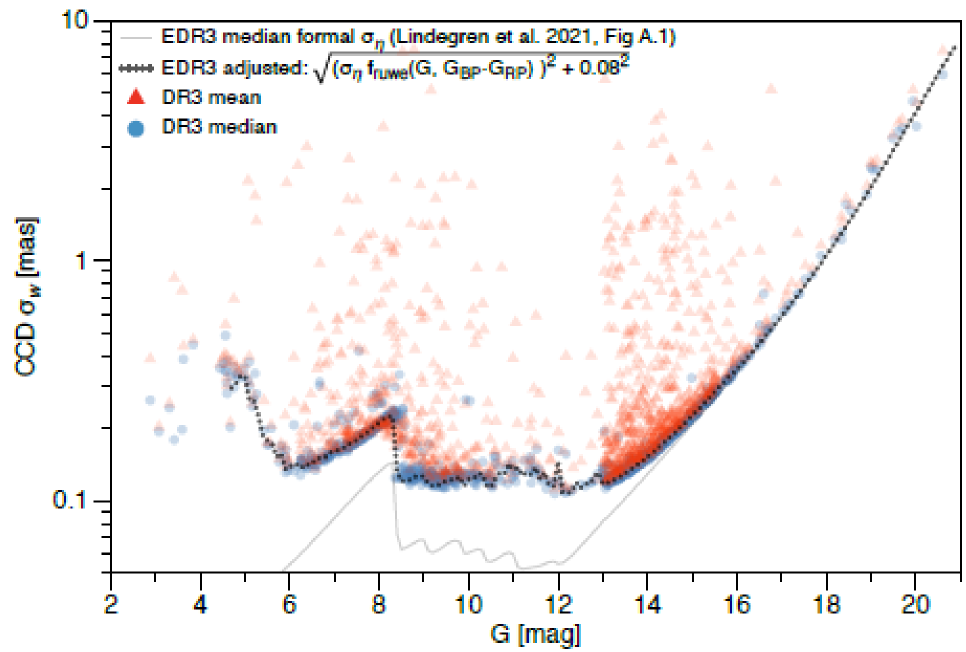


Horch et al. 2020



‘OrbitalTargetedSearch’: Special Processing

- ≈20k sources with known solutions, including all exoplanets
- DE-MCMC and Genetic Algorithms for astrometric orbit determination
- Aim to probe the low astrometric SNR regime



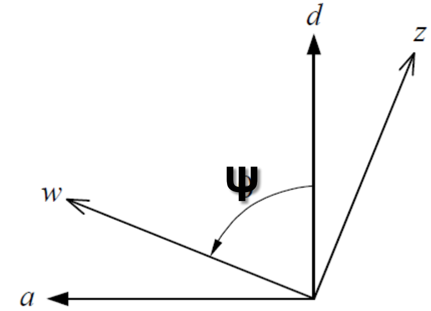
Holl, Sozzetti et al. 2022

Orbit Fitting with Gaia

(hands-on session)

Single-star Model (fully linear):

$$w_{ss} = (\Delta\alpha^{\star} + \mu_{\alpha^{\star}}\, t)\, \sin\psi + (\Delta\delta + \mu_{\delta}\, t)\, \cos\psi + \varpi\, f_{\varpi}$$



NOTE: z is not used (known with much lower accuracy)

Keplerian Model (partly linear):

$$w_{k1} = (B\,X + G\,Y)\sin\psi + (A\,X + F\,Y)\cos\psi$$

Linear component (Thiele-Innes elements):

$$\begin{aligned}
A &= a_0\,(\cos\omega\cos\Omega - \sin\omega\sin\Omega\cos i) \\
B &= a_0\,(\cos\omega\sin\Omega + \sin\omega\cos\Omega\cos i) \\
F &= -a_0\,(\sin\omega\cos\Omega + \cos\omega\sin\Omega\cos i) \\
G &= -a_0\,(\sin\omega\sin\Omega - \cos\omega\cos\Omega\cos i)
\end{aligned}$$

Non-linear component:

$$\begin{aligned}
E - e\sin E &= \frac{2\pi}{P}(t - T_0) \\
X &= \cos E - e \\
Y &= \sqrt{1-e^2}\,\sin E
\end{aligned}$$

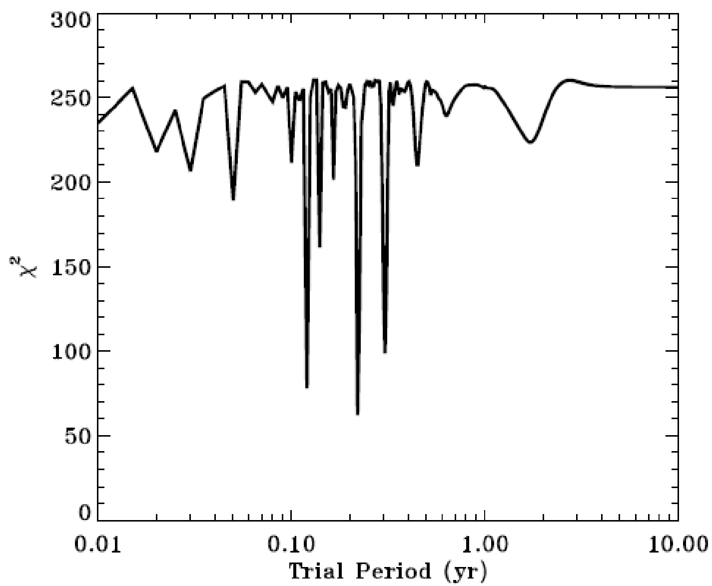
Full model: $w^{(\mathrm{model})} = w_{ss} + w_{k1}$

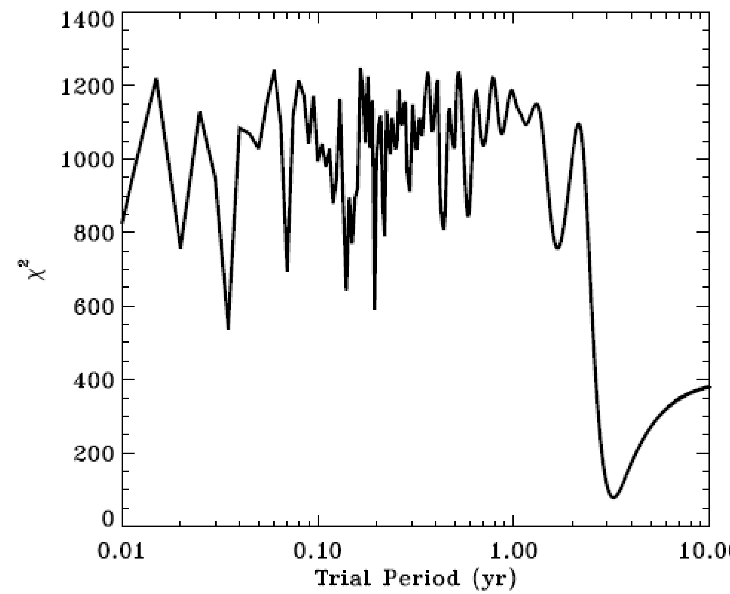
Figure of merit is the log-likelihood:

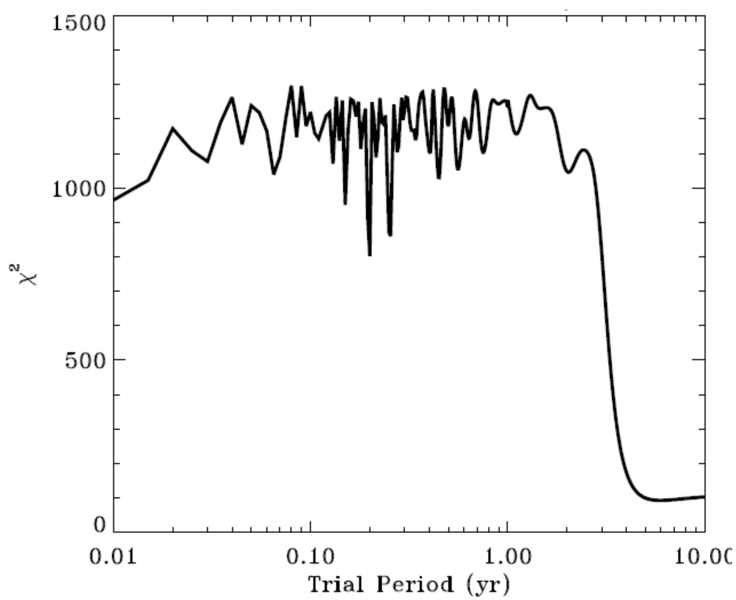
$$-\ln(\mathcal{L}) = \frac{1}{2}\sum_{j=1}^{N_{astr}} \frac{\left(w_j^{(obs)} - w_j^{(model)}\right)^2}{\sigma_{w,j}^2 + \sigma_{\mathrm{jit}}^2} + \frac{1}{2}\sum_{j=1}^{N_{astr}} \ln\left(\sigma_{w,j}^2 + \sigma_{\mathrm{jit}}^2\right)$$

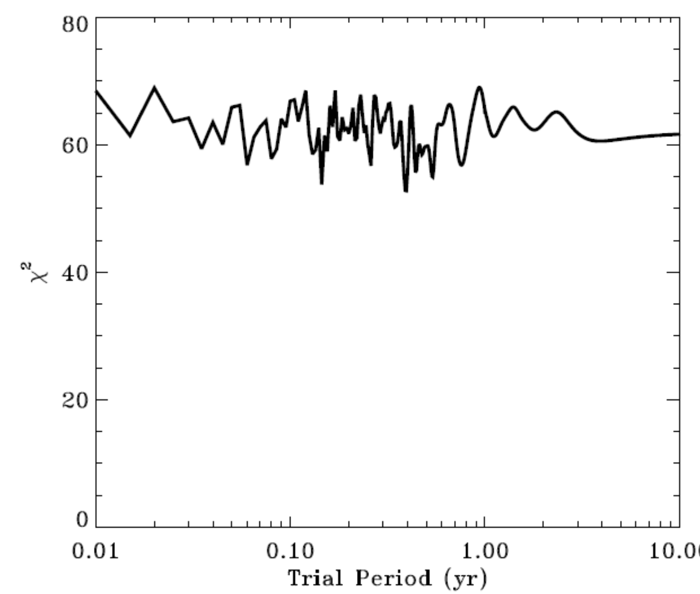
χ^2

Orbits with Gaia: Finding the Period

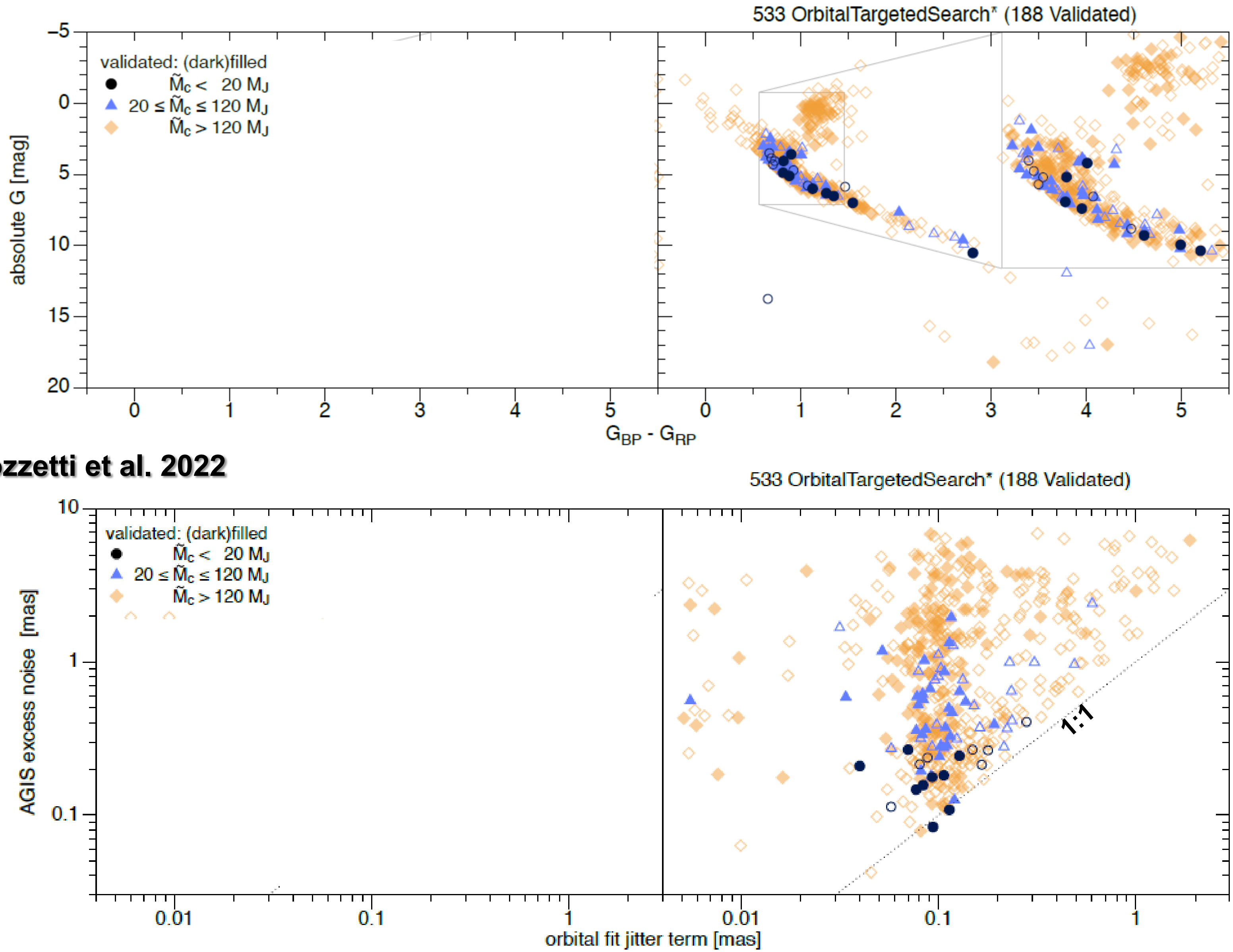






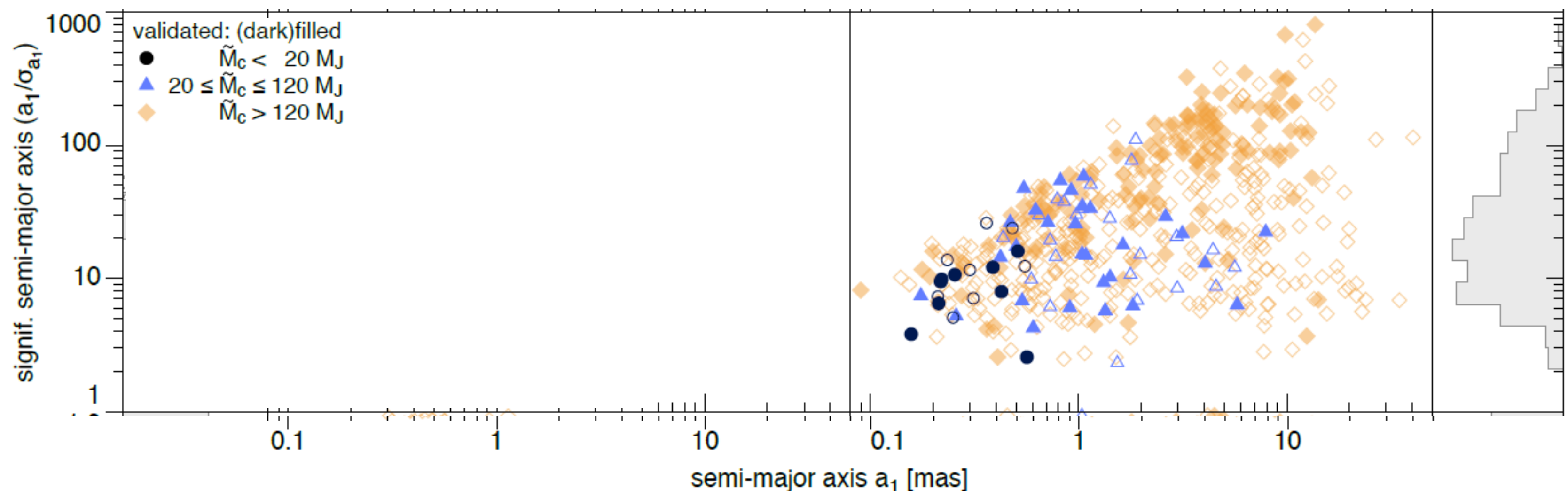


Verification: Internal checks (1)

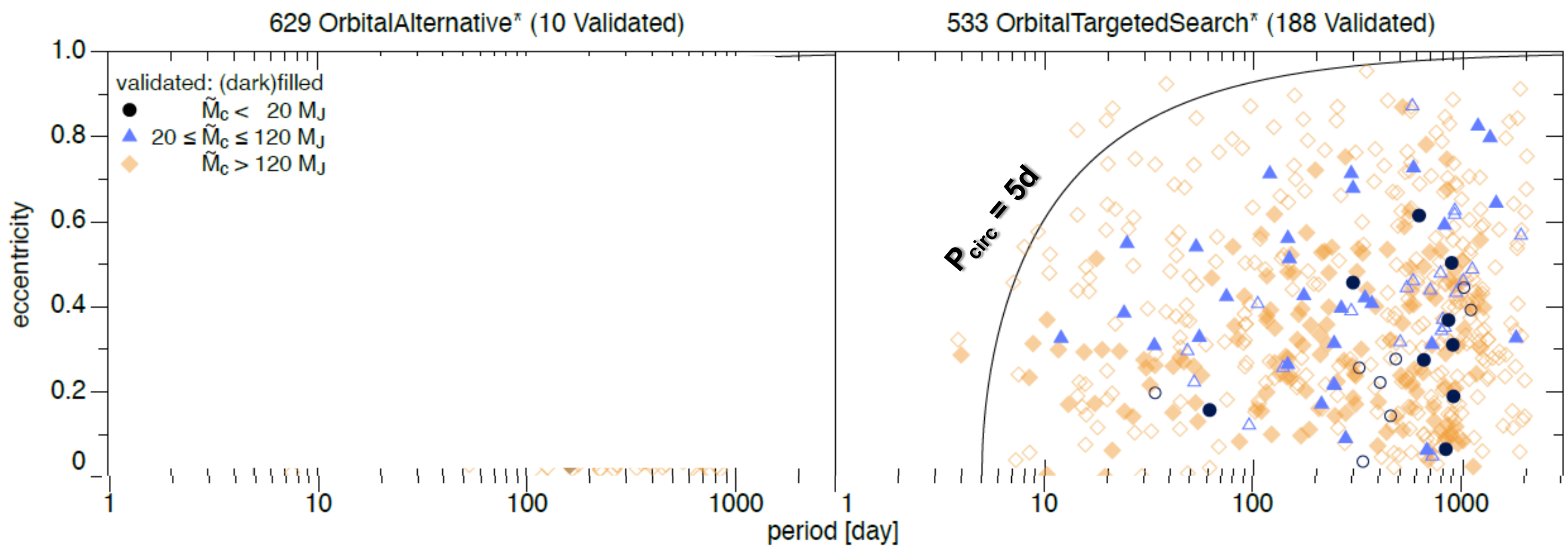


Holl, Sozzetti et al. 2022

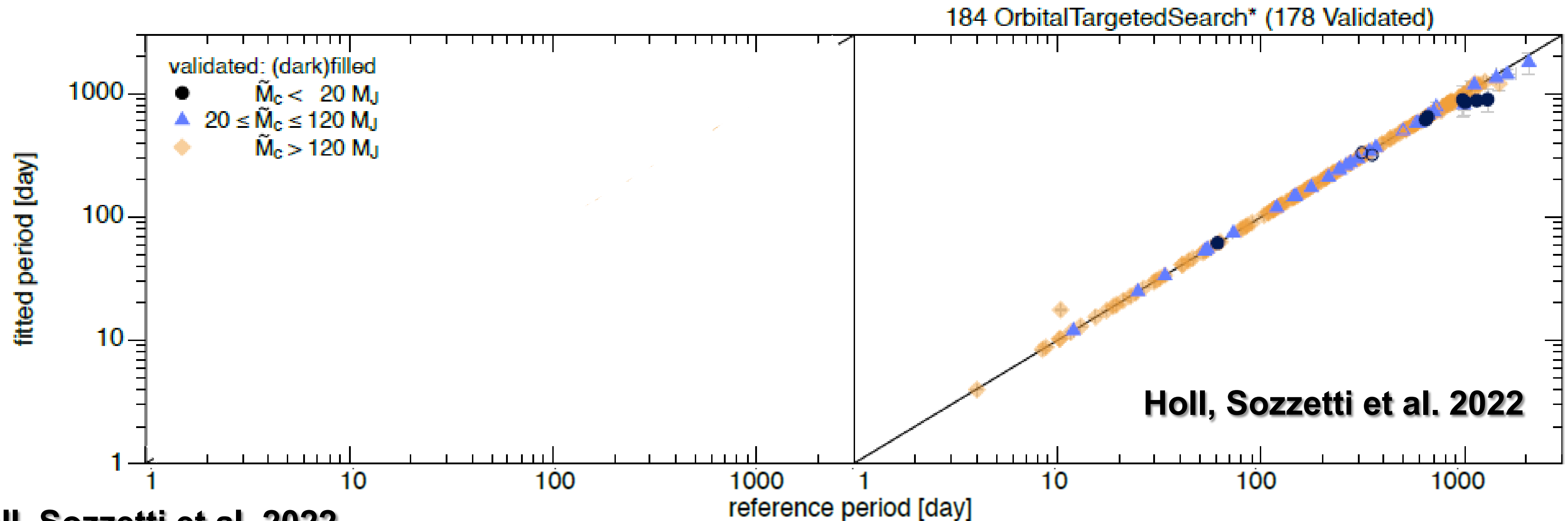
Verification: Internal checks (2)



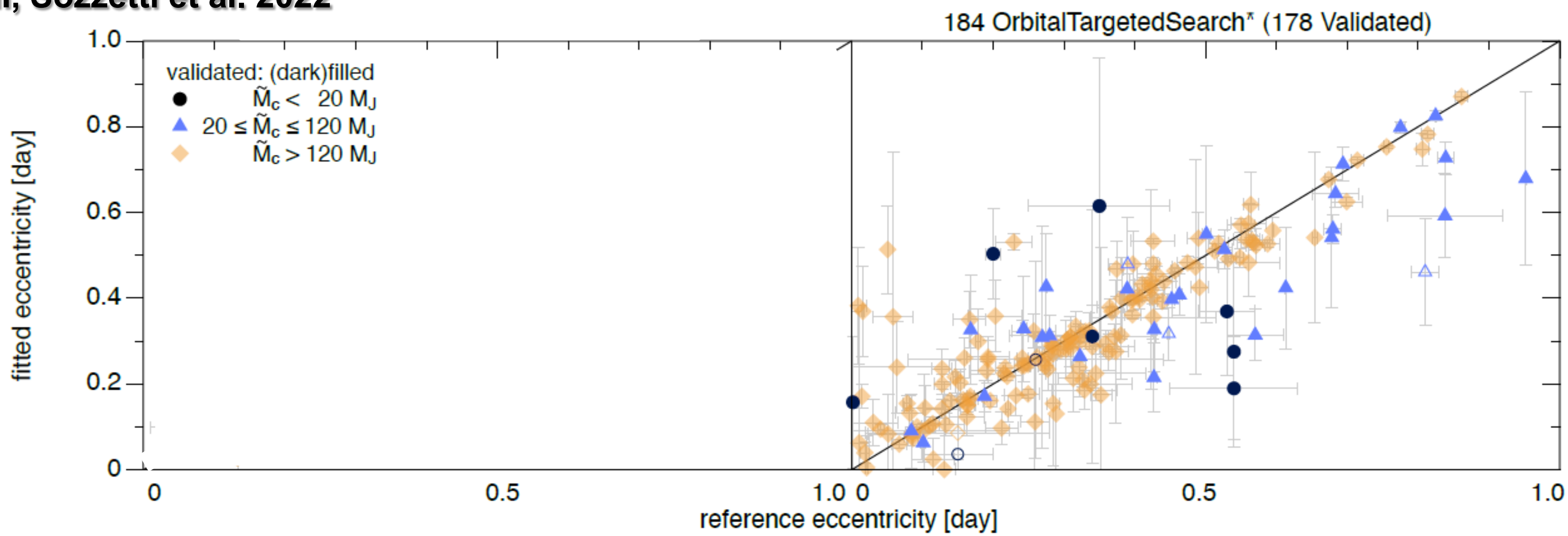
Holl, Sozzetti et al. 2022



Validation: Gaia vs. Literature



Holl, Sozzetti et al. 2022



Known Planets and BDs

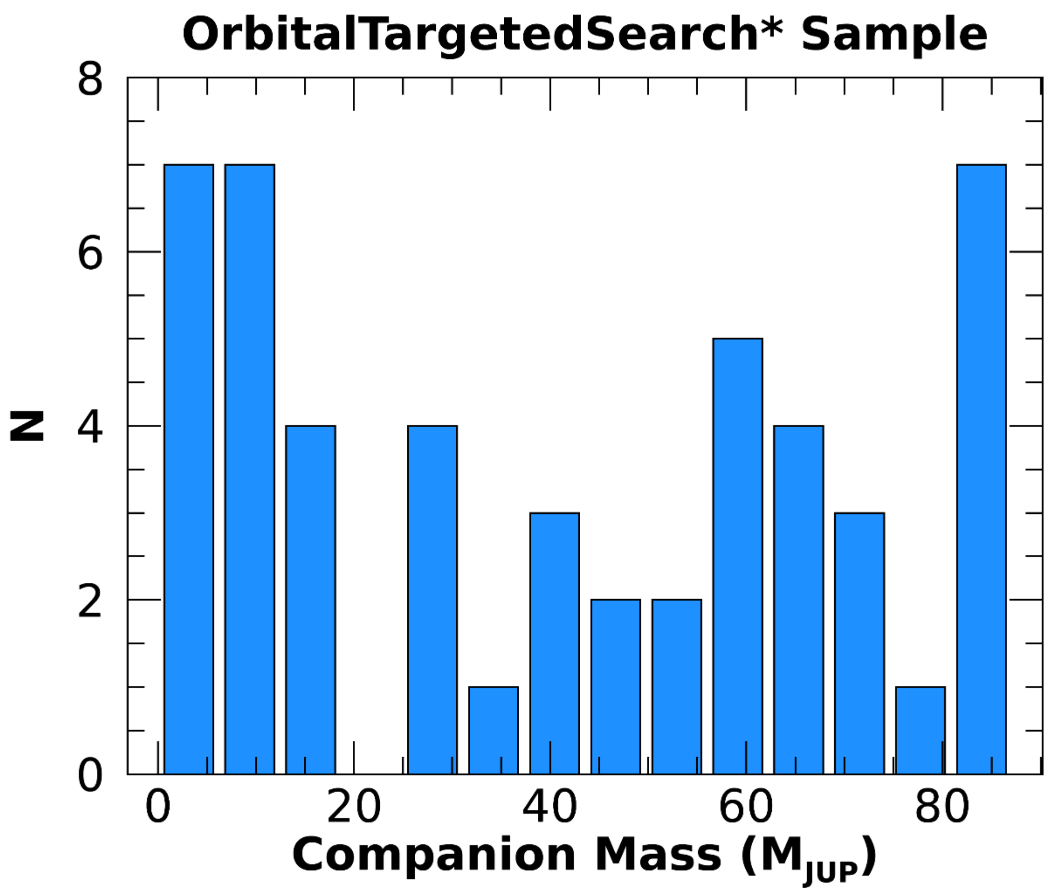
Table 11. Known substellar companions with a confirmed mass in the planetary and brown dwarf regime, respectively.

Gaia DR3	Name	$\mathcal{M}_c \sin i$ ($\mathcal{M}_{\rm Jup}$)	$\mathcal{M}_c$ ($\mathcal{M}_{\rm Jup}$)	i (deg)	$P_{\rm lit}$ (days)	$P_{\rm Gaia}$ (days)	$e_{\rm lit}$	$e_{\rm Gaia}$	a_0 (mas)	Refs.
6421118739093252224	HD 175167 b	7.8 ± 3.5	9.5 ± 0.9	28 ± 19	1290 ± 22	898 ± 198	0.54 ± 0.09	0.19 ± 0.12	0.22 ± 0.02	1
4062446910648807168	HD 164604 b	2.7 ± 1.3	14.3 ± 5.5	29 ± 19	606 ± 9	615 ± 12	0.24 ± 0.14	0.61 ± 0.34	0.56 ± 0.22	1,2
1594127865540229888	HD 132406 b	5.6	6.7 ± 2.1	122 ± 14	974 ± 39	893 ± 251	0.34 ± 0.09	0.31 ± 0.29	0.16 ± 0.04	3
4745373133284418816	HR 810 b	2.26 ± 0.18	6.2 ± 0.5	87 ± 6	312 ± 5	332 ± 6	0.15 ± 0.05	0.04 ± 0.2	0.30 ± 0.02	4,5
2367734656180397952	BD -17 0063 b	5.1 ± 0.12	4.3 ± 0.5	80 ± 6	656 ± 0.6	649 ± 36	0.54 ± 0.005	0.28 ± 0.22	0.22 ± 0.02	6
5855730584310531200	HD 111232 b	6.8	8.3 ± 0.6	97 ± 4	1143 ± 14	882 ± 34	0.20 ± 0.01	0.50 ± 0.10	0.51 ± 0.03	7
637329067477530368	HD 81040 b	6.8 ± 0.7	7.9 ± 0.9	108 ± 6	1002 ± 7	851 ± 113	0.53 ± 0.04	0.37 ± 0.15	0.39 ± 0.03	8
4976894960284258048	HD 142 b	1.3 ± 0.2	7.1 ± 1.0	59 ± 7	350 ± 4	319 ± 7	0.26 ± 0.18	0.26 ± 0.23	0.21 ± 0.03	5,9,10
2603090003484152064	GJ 876 b	2.1 ± 0.2	3.6 ± 0.4	101 ± 8	61.08 ± 0.01	61.4 ± 0.2	0.027 ± 0.002	0.16 ± 0.15	0.43 ± 0.05	11-18
2651390587219807744	BD -00 4475 b	25 ± 2	48.4 ± 7.6	129 ± 7	723.2 ± 0.7	780 ± 84	0.39 ± 0.01	0.48 ± 0.11	1.91 ± 0.28	19
2778298280881817984	HD 5433 b	49 ± 3	53.8 ± 1.7	12 ± 39	576.6 ± 1.6	576.7 ± 10.6	0.81 ± 0.02	0.46 ± 0.12	1.04 ± 0.03	19
3309006602007842048	HD 30246 b	55^{+20}_{-8}	40.6 ± 8.3	78 ± 2	990 ± 6	814 ± 141	0.84 ± 0.08	0.59 ± 0.10	1.34 ± 0.24	19
3750881083756656128	HD 91669 b	30.6 ± 2.1	43.2 ± 2.2	58 ± 3	497.5 ± 0.6	500.4 ± 6.9	0.448 ± 0.002	0.32 ± 0.06	0.73 ± 0.04	19
3751763647996317056	HD 89707 b	54^{+8}_{-7}	82.5 ± 12.7	54 ± 10	298.5 ± 0.1	297 ± 2	0.90 ± 0.04	0.68 ± 0.20	1.82 ± 0.30	19
685029558383335168	HD 77065 b	41 ± 2	64.2 ± 5.1	42 ± 3	119.113 ± 0.003	119.1 ± 0.2	0.694 ± 0.0004	0.70 ± 0.04	1.04 ± 0.07	20
855523714036230016	HD 92320 b	59.4 ± 4.0	70 ± 3.1	111 ± 2	145.4 ± 0.01	145.1 ± 0.3	0.323 ± 0.001	0.26 ± 0.05	0.82 ± 0.01	20
824461960796102528	HD 82460 b	73.2 ± 3.0	62.5 ± 6.4	66 ± 1	590.9 ± 0.2	579 ± 6	0.84 ± 0.01	0.73 ± 0.04	1.63 ± 0.09	21
873616860770228352	BD +29 1539 b	59.7 ± 2.0	60.7 ± 23.5	120 ± 9	175.87 ± 0.01	173 ± 3	0.275 ± 0.001	0.43 ± 0.12	0.61 ± 0.14	21
5563001178343925376	HD 52756 b	59.3 ± 2.0	61.2 ± 8.6	73 ± 4	52.8657 ± 0.0001	52.9 ± 0.1	0.678 ± 0.0003	0.54 ± 0.16	0.54 ± 0.08	22

References. (1) Arriagada et al. (2010); (2) Feng et al. (2019); (3) da Silva et al. (2007); (4) Kürster et al. (2000); (5) Butler et al. (2006); (6) Moutou et al. (2009); (7) Mayor et al. (2004); (8) Sozzetti et al. (2006); (9) Tinney et al. (2002); (10) Wittenmyer et al. (2012); (11) Trifonov et al. (2018); (12) Rivera et al. (2005); (13) Rivera et al. (2010); (14) Benedict et al. (2002); (15) Marcy et al. (1998); (16) Marcy et al. (2001); (17) Correia et al. (2010); (18) Nelson et al. (2016); (19) Dalal et al. (2021); (20) Wilson et al. (2016); (21) Kiefer et al. (2019); (22) Sahlmann et al. (2011).

Arenou et al. 2022

High-mass Planets and BDs



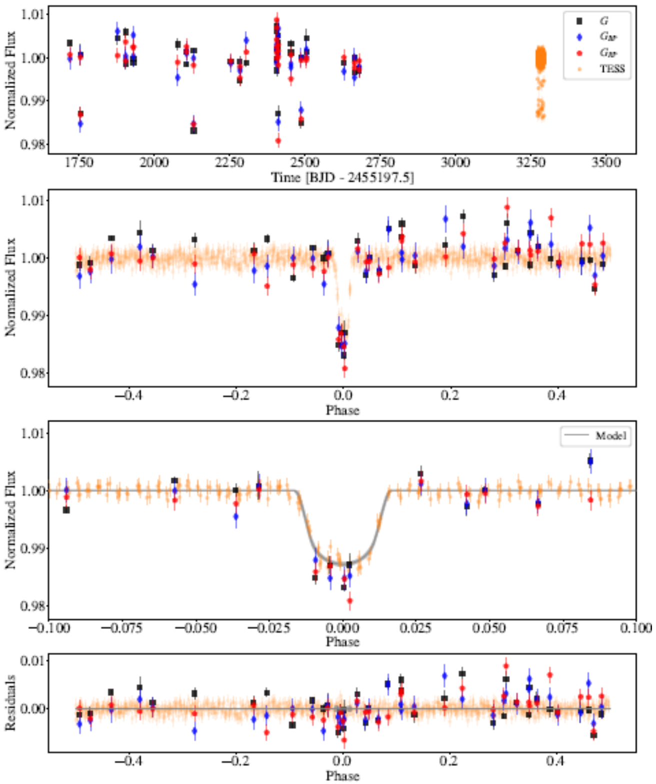
Arenou et al. 2022

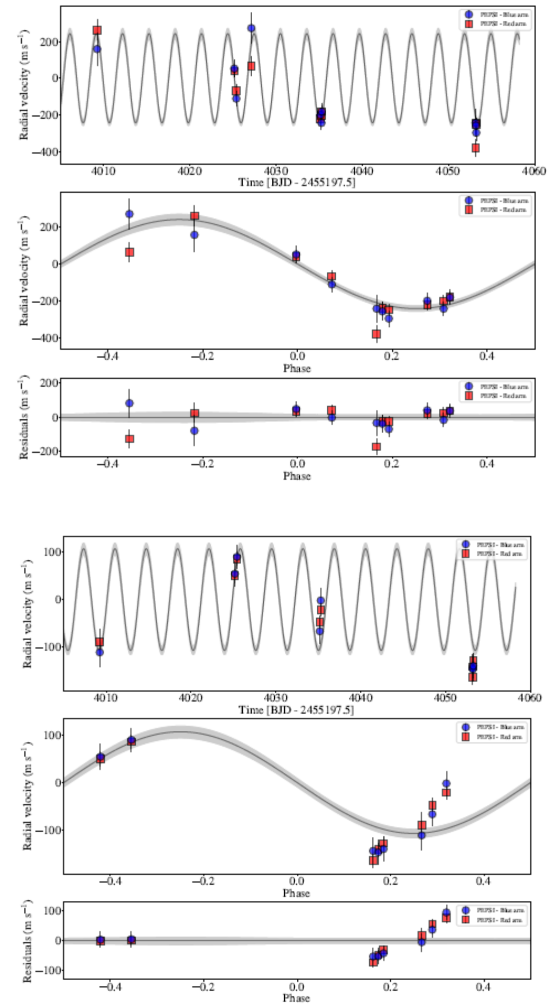
- A dip in the distribution in the 20-40 MJUP regime (but small-number statistics)

- First-time investigation of the BD desert with true masses available!

Gaia transiting planets

Panahi et al. 2022 (https://arxiv.org/abs/2205.10197)



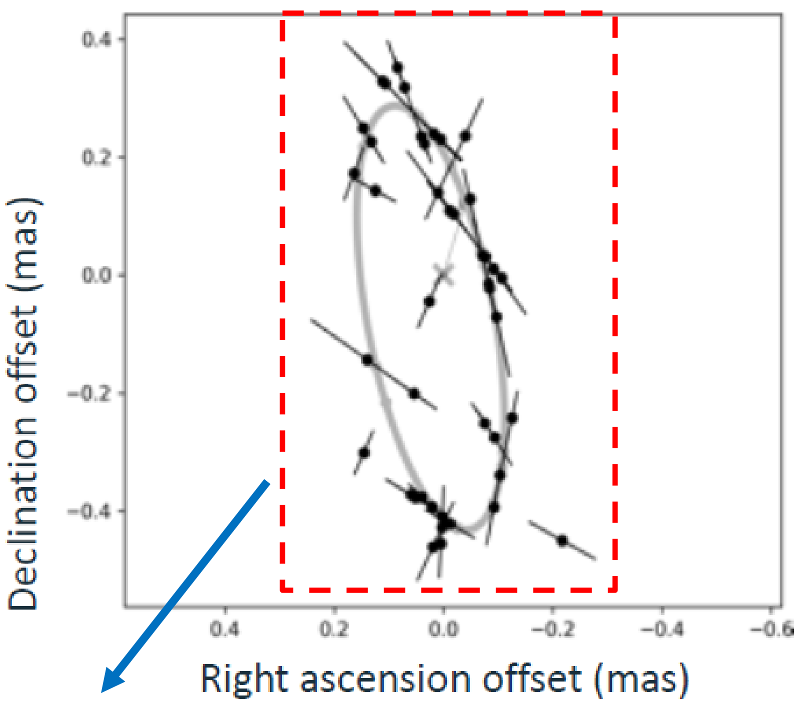


First Gaia detections around moderately bright Sun-type stars:

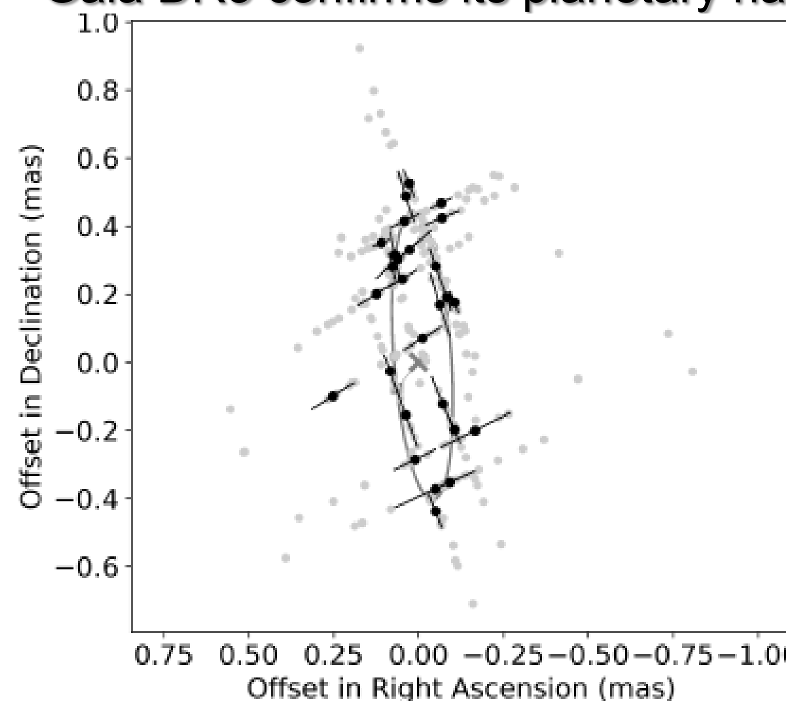
Gaia-1b: P 3.05d, M_p=1.78 M_J, R_p=1.23 R_J
Gaia-2b: P 3.69d, M_p=0.77 M_J, R_p=1.33 R_J

Gaia DR3 Astrometry: Known Exoplanets

HD 81040 b:
known RV planet (Sozzetti et al. 2006)
Gaia DR3 confirms it's a super-Jupiter



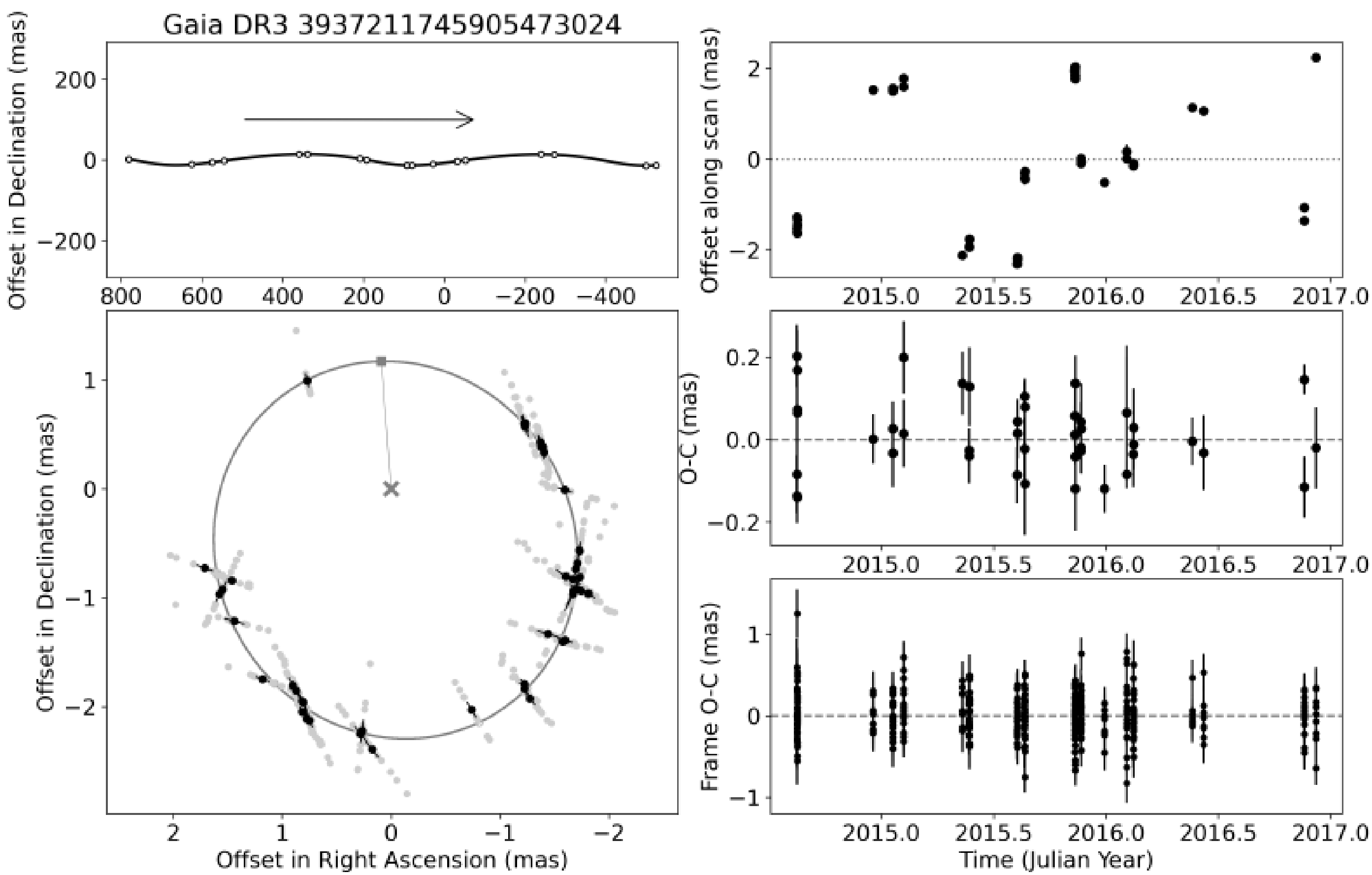
GJ 876 b:
A gas giant in a multiple system around an M dwarf at 4.7 pc (Marcy et al. 1998)
Gaia DR3 confirms its planetary nature



Hands-on session!

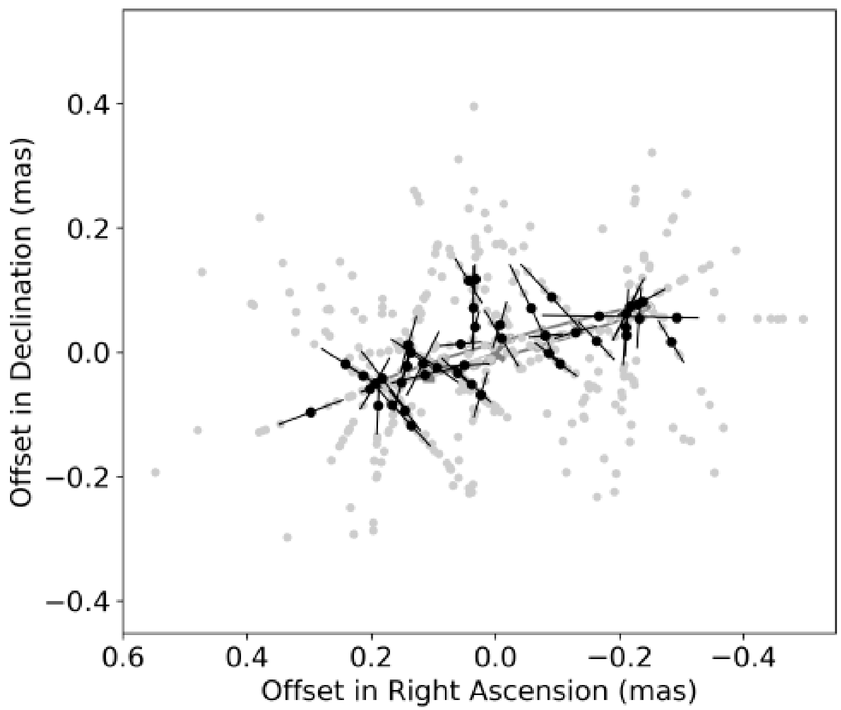
True masses for the first time!

A Famous Case

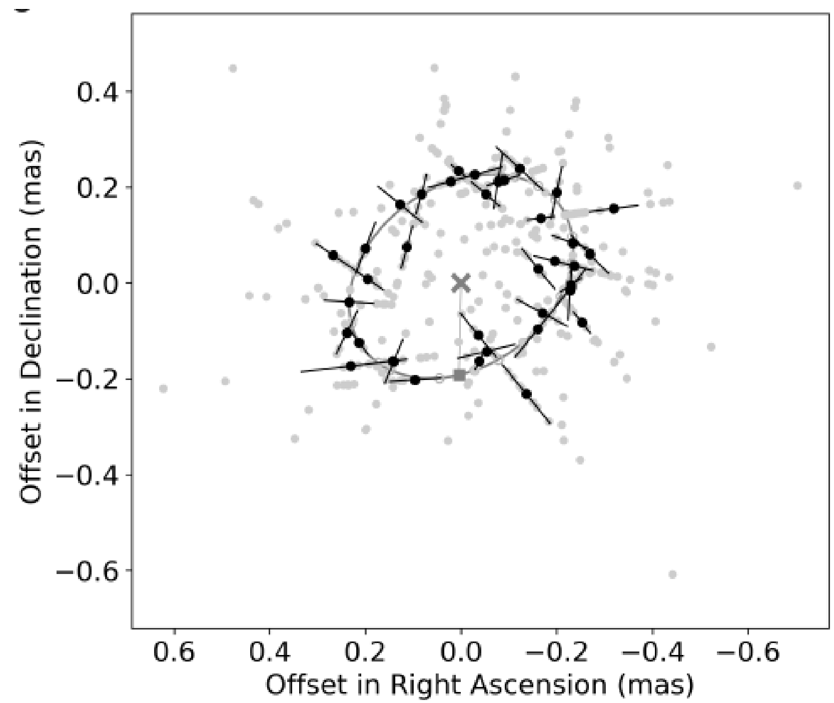


HD 114762 b:
- first substellar companion candidate around a solar-type star (Latham et al. 1989)
- Gaia DR3 orbit says it's a low-mass star

Gaia DR3 Astrometry: New Exoplanet Candidates



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

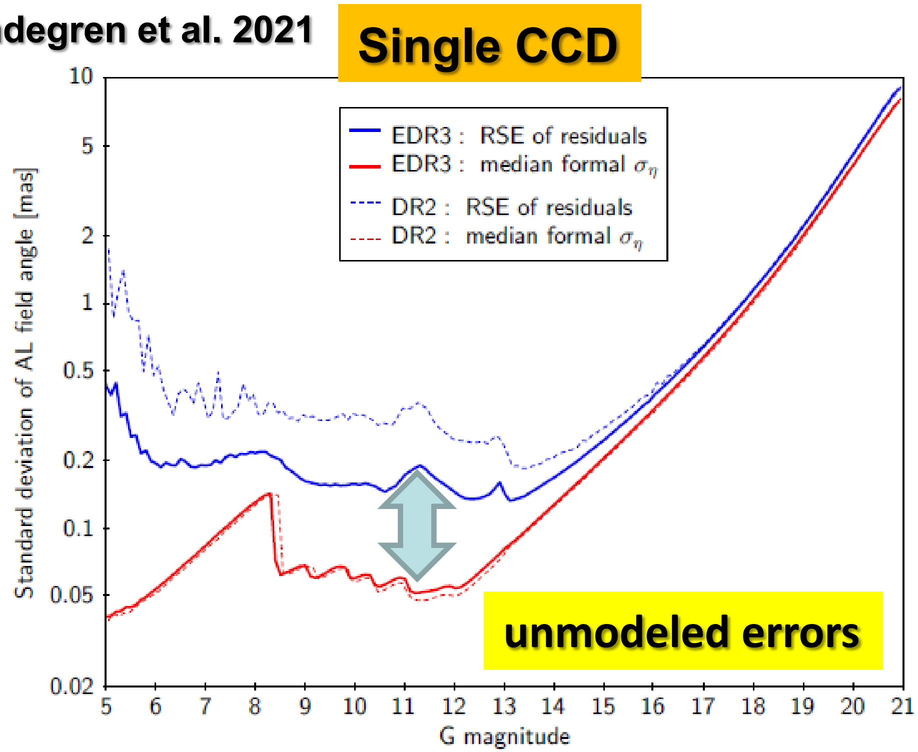


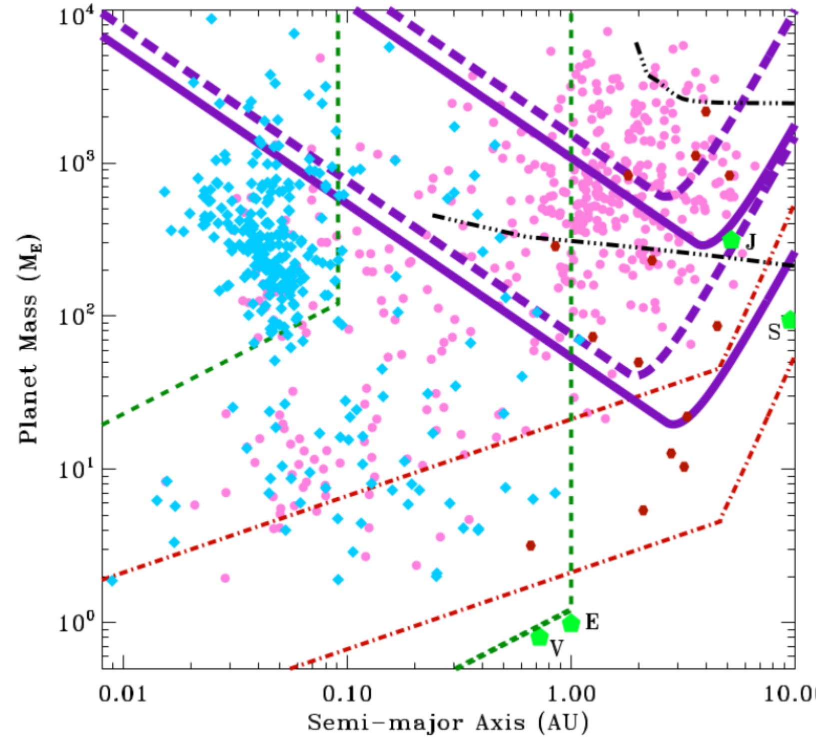
Super-Jupiters around solar-type stars HIP 66074 and HIP 28193 and the young star HD 3221

First sample from Astrometry ever!

A(nother) Word of Caution

Lindegren et al. 2021





*** G < 13 mag: typical σ_A ~ 50-60 μas**
*** DR3: systematic errors ~ 0.15-0.2 mas**
*** Calibration of bright stars still limited**

For Gaia, G < 13 mag:
σ_A ~ 15-20 μas (over 9 CCDs)

Critical to improve significantly the bright-star performance:

- At G < 13 mag exoplanet detections maximize the Gaia impact and synergy potential
- At G > 13 mag exoplanet detections will primarily have only a statistical value

Forecasting for DR4 and DR5…

Gaia will test the fine structure of GP parameters distributions and frequencies (including the GP/BD transition), and investigate their changes as a function of stellar mass, metallicity, age, and multiplicity with unprecedented resolution

No reason (yet) to doubt this will be the case!

SUMMARY

- Gaia DR2/EDR3 allowed to use a) parallaxes to improve accuracy and precision of stellar and planetary parameters, and b) proper motions in a clever way to improve knowledge of existing and find new substellar companions

- Gaia DR3 is wetting our appetite for exoplanet discoveries and is already a gold mine for BDs

- Not everything is hunky-dory, but we mostly know why

- We are beginning to work hard towards DR4

- The astrometry revolution has started!