Stellar and exoplanetary systems from Hipparcos and Gaia

Pierre Kervella, Frédéric Arenou, Frédéric Thévenin

Image: NASA, ESA and G. Bacon (STScI)

Principle

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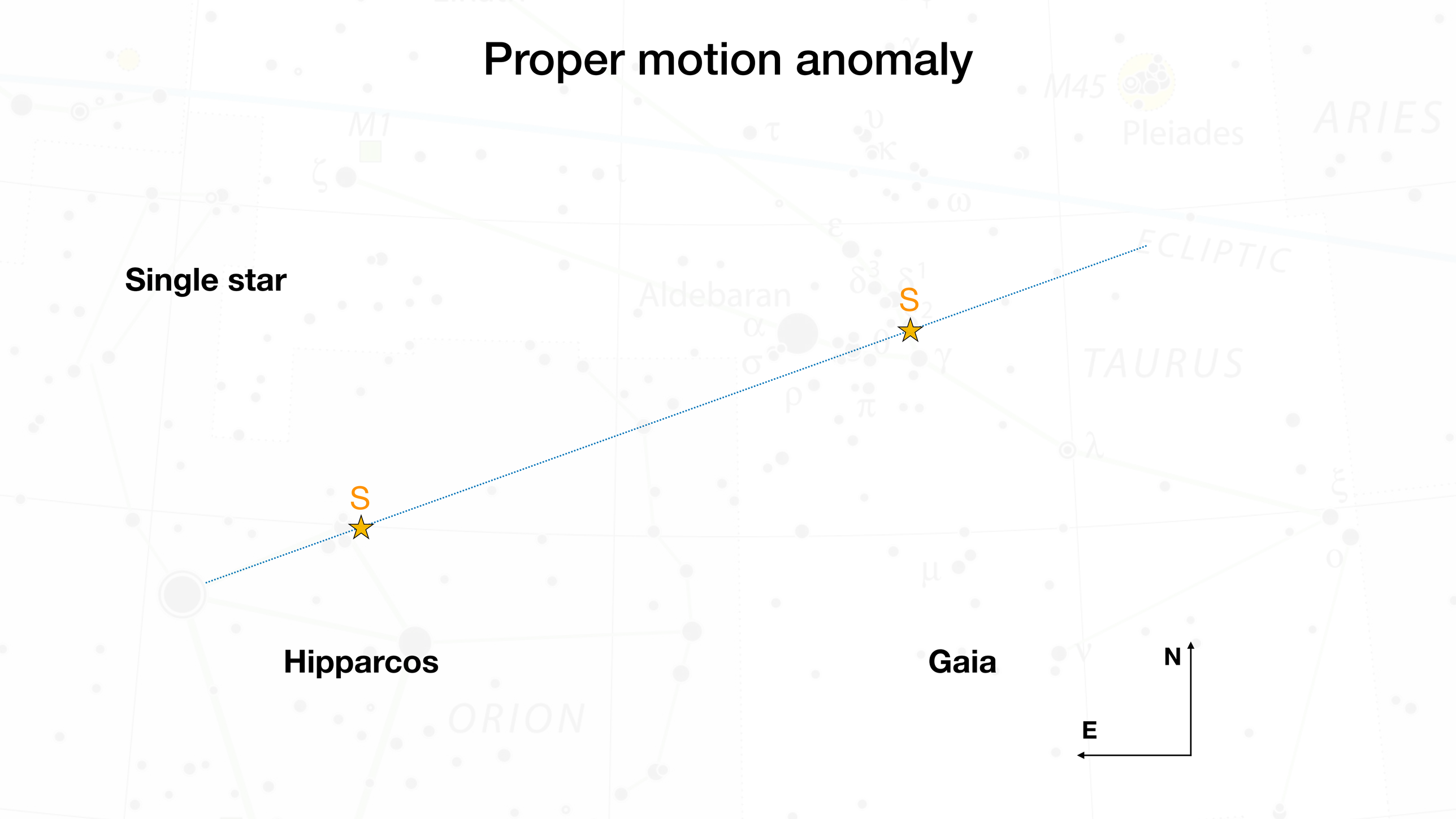
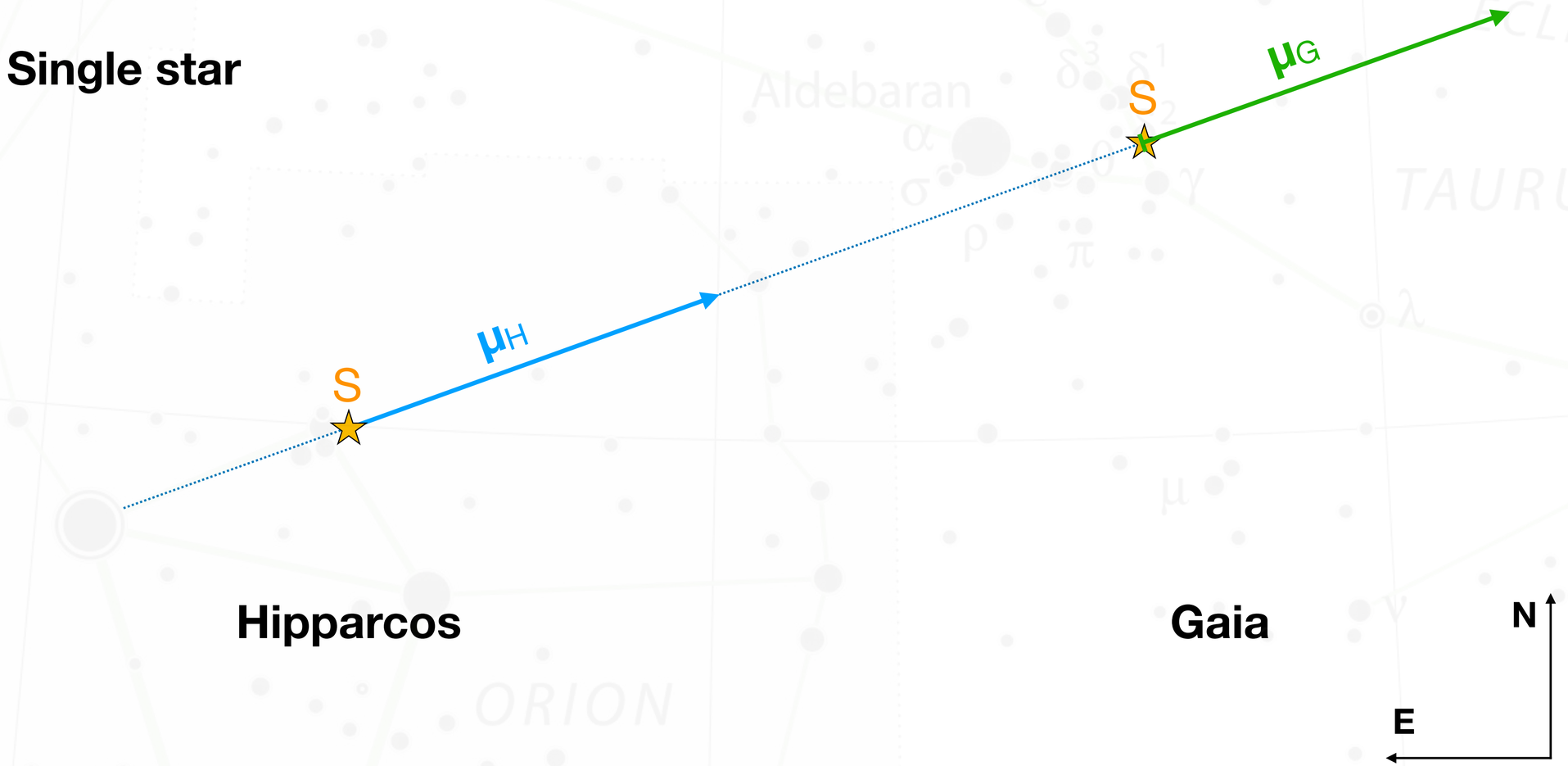
1. The **long-term** proper motion computed from the Hipparcos and Gaia positions (baseline 2016.0 - 1991.25 = 24.75 years)

2. The **short-term** Gaia (E)DR3 proper motions (epoch 2016.0, average over 34 months)

Proper motion anomaly



Proper motion anomaly



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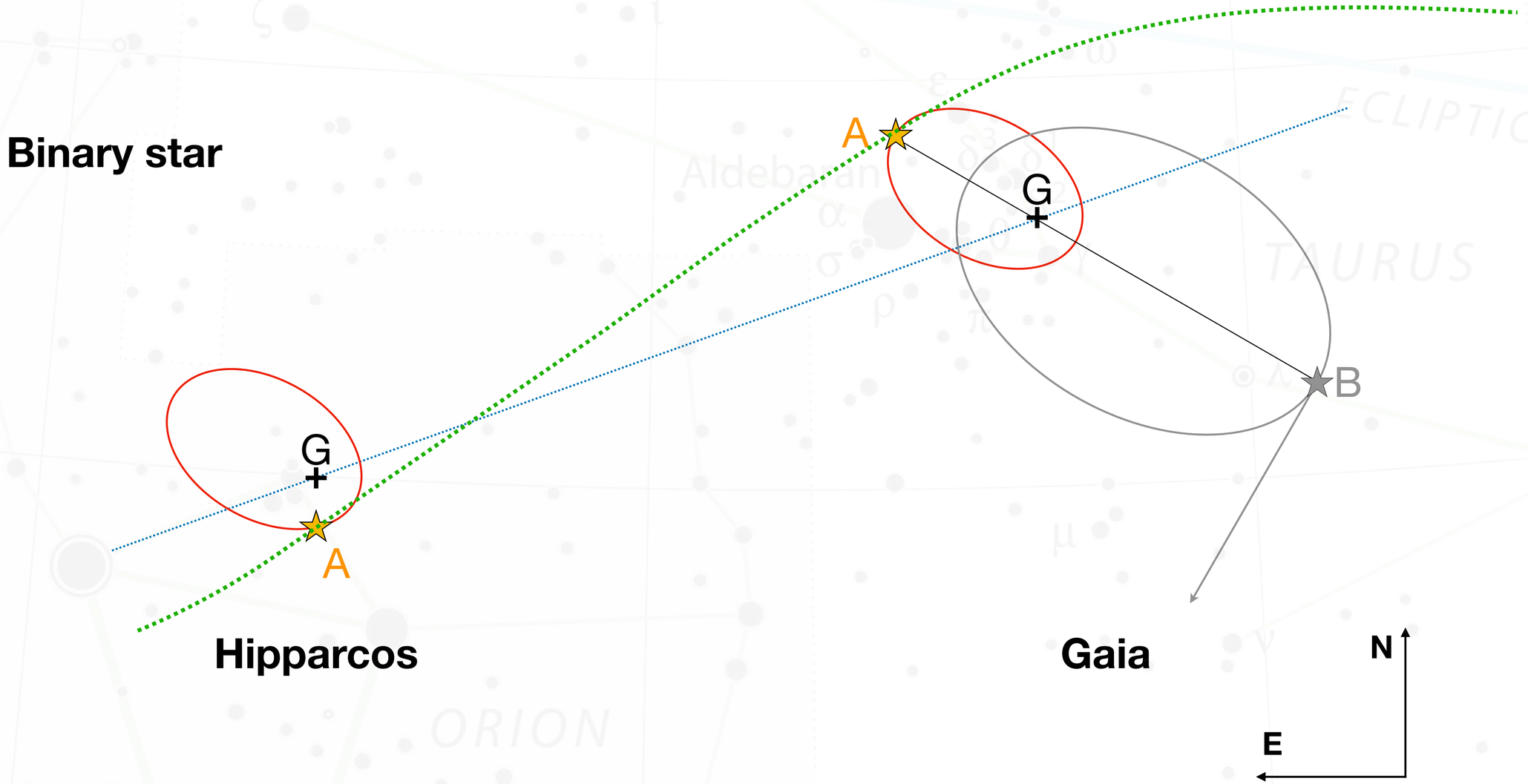
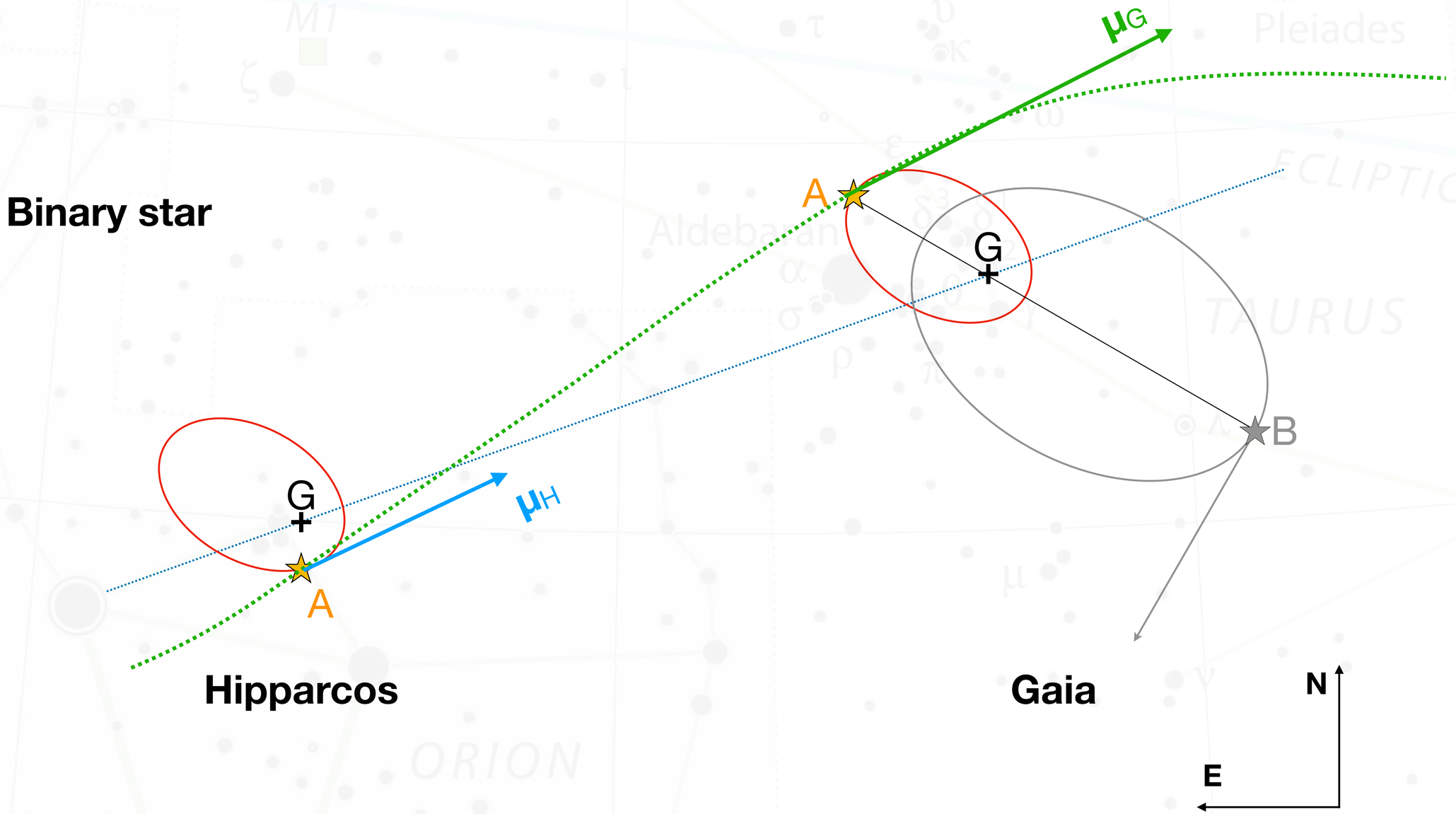
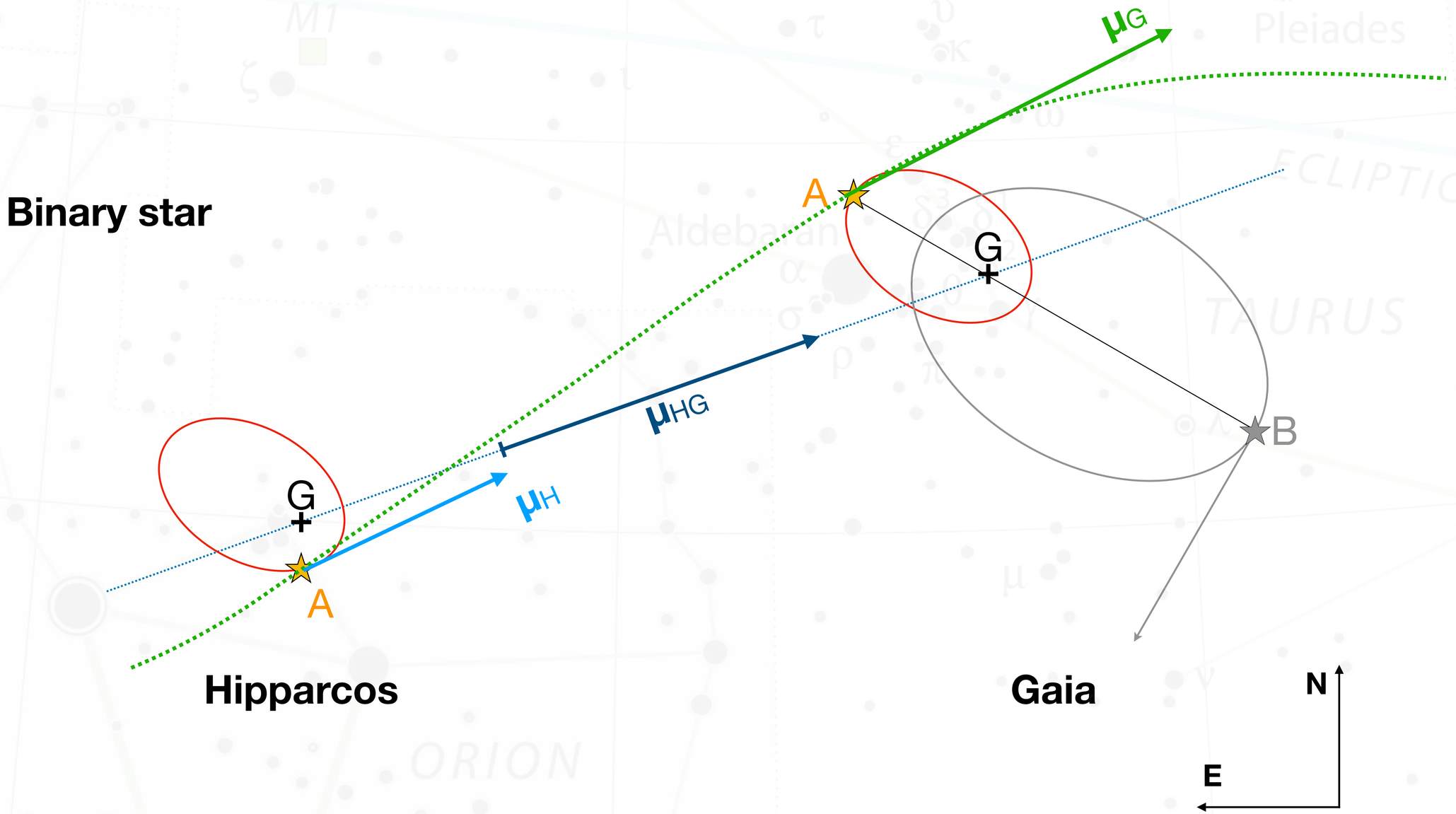


Proper motion anomaly



Proper motion anomaly



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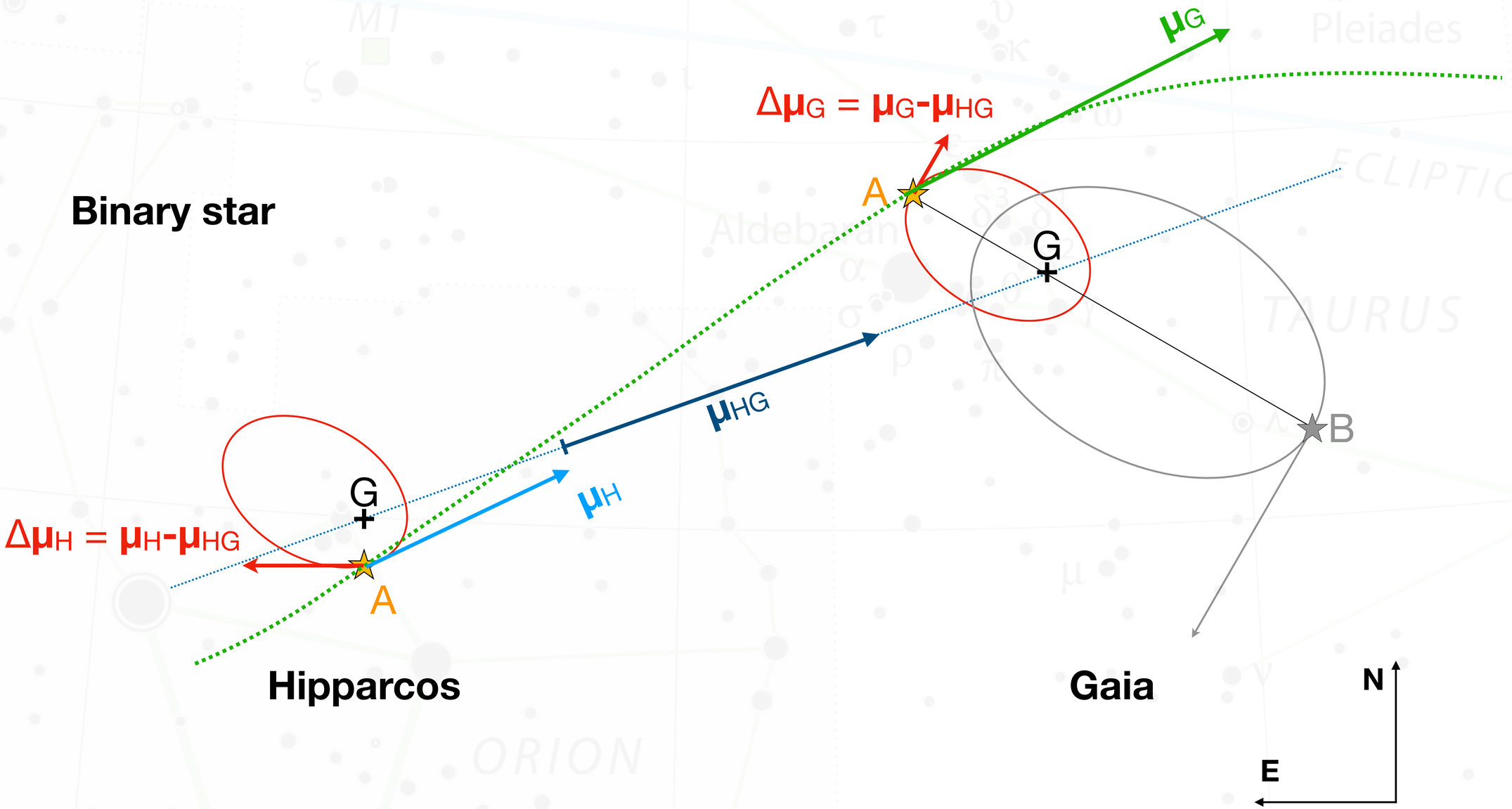


- Sensitivity in companion mass:

$$\frac{m_2}{\sqrt{r}} = \sqrt{\frac{m_1}{G}}\, v_1 = \sqrt{\frac{m_1}{G}} \left(\frac{\Delta\mu[\mathrm{mas\,a^{-1}}]}{\varpi[\mathrm{mas\,au^{-1}}]} \times 4740.470 \right)$$

Gaia DR2

$$\sigma(\Delta\mu_{\mathrm{G2}}) = 234\ \mu\mathrm{as\,a^{-1}}$$

$$\sigma(\Delta v_{\mathrm{tan,G2}}) = 1.1\ \mathrm{m\,s^{-1}\,pc^{-1}}$$

$$\sigma(m_2^{5\,\mathrm{au}})_{m_1=M_\odot} = 40\ \mathrm{M_\oplus\,pc^{-1}}$$

Gaia (E)DR3

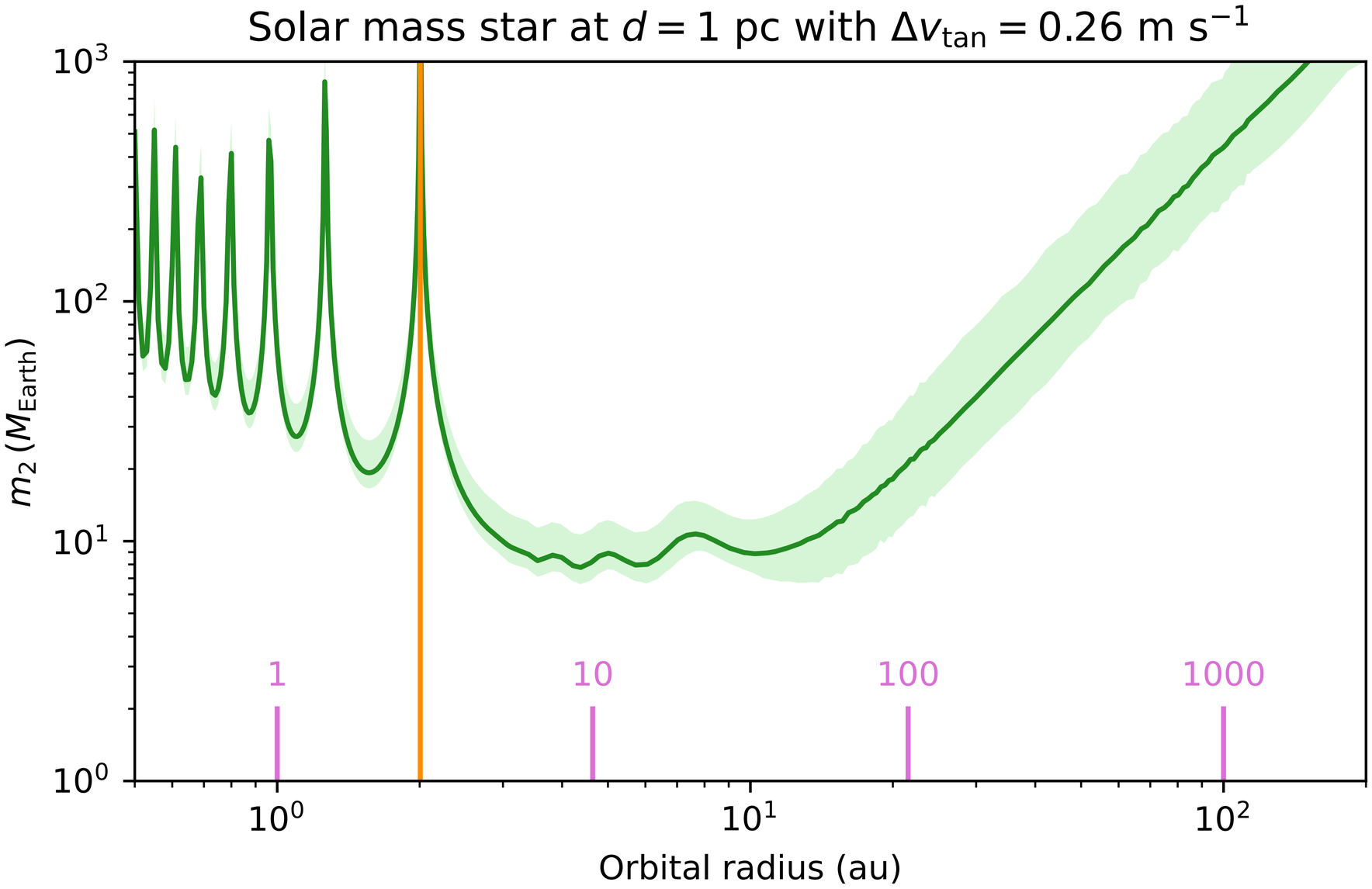
$$\sigma(\Delta\mu_{\mathrm{G3}}) = 56\ \mu\mathrm{as\,a^{-1}}$$

$$\sigma(\Delta v_{\mathrm{tan,G3}}) = 0.26\ \mathrm{m\,s^{-1}\,pc^{-1}}$$

$$\sigma(m_2^{5\,\mathrm{au}})_{m_1=M_\odot} = 10\ \mathrm{M_\oplus\,pc^{-1}}$$

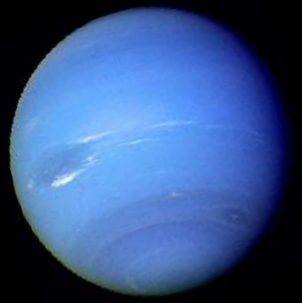
- The sensitivity of the PMa technique decreases with the distance to the target

PMa sensitivity curve

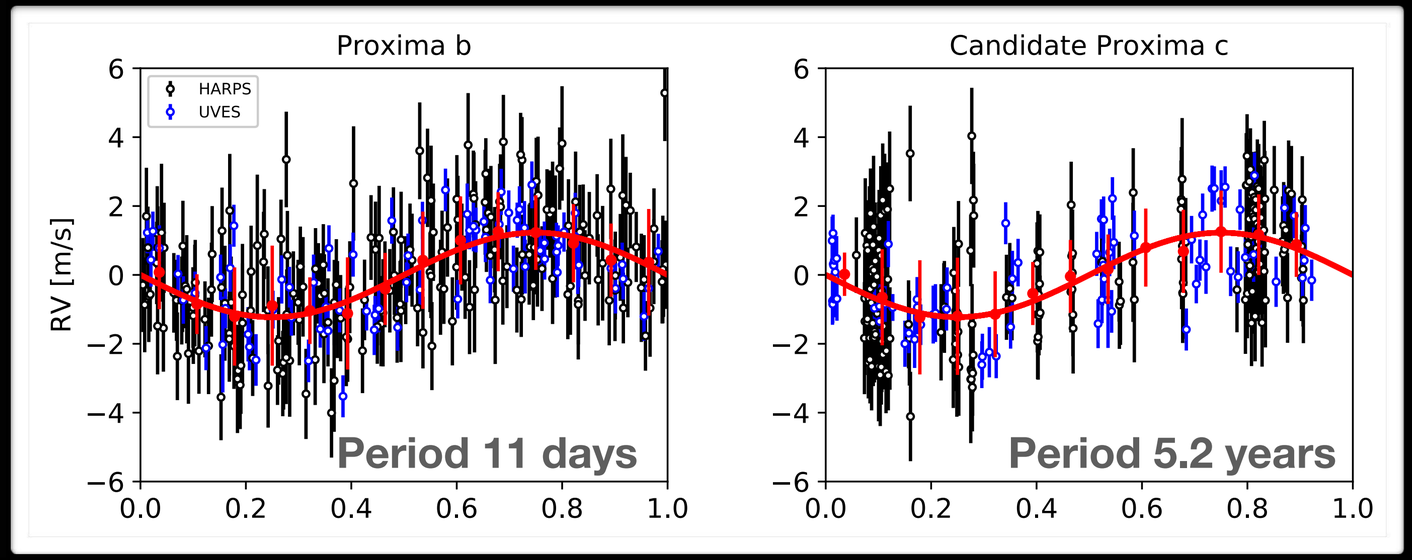


A long-period planet for Proxima ?

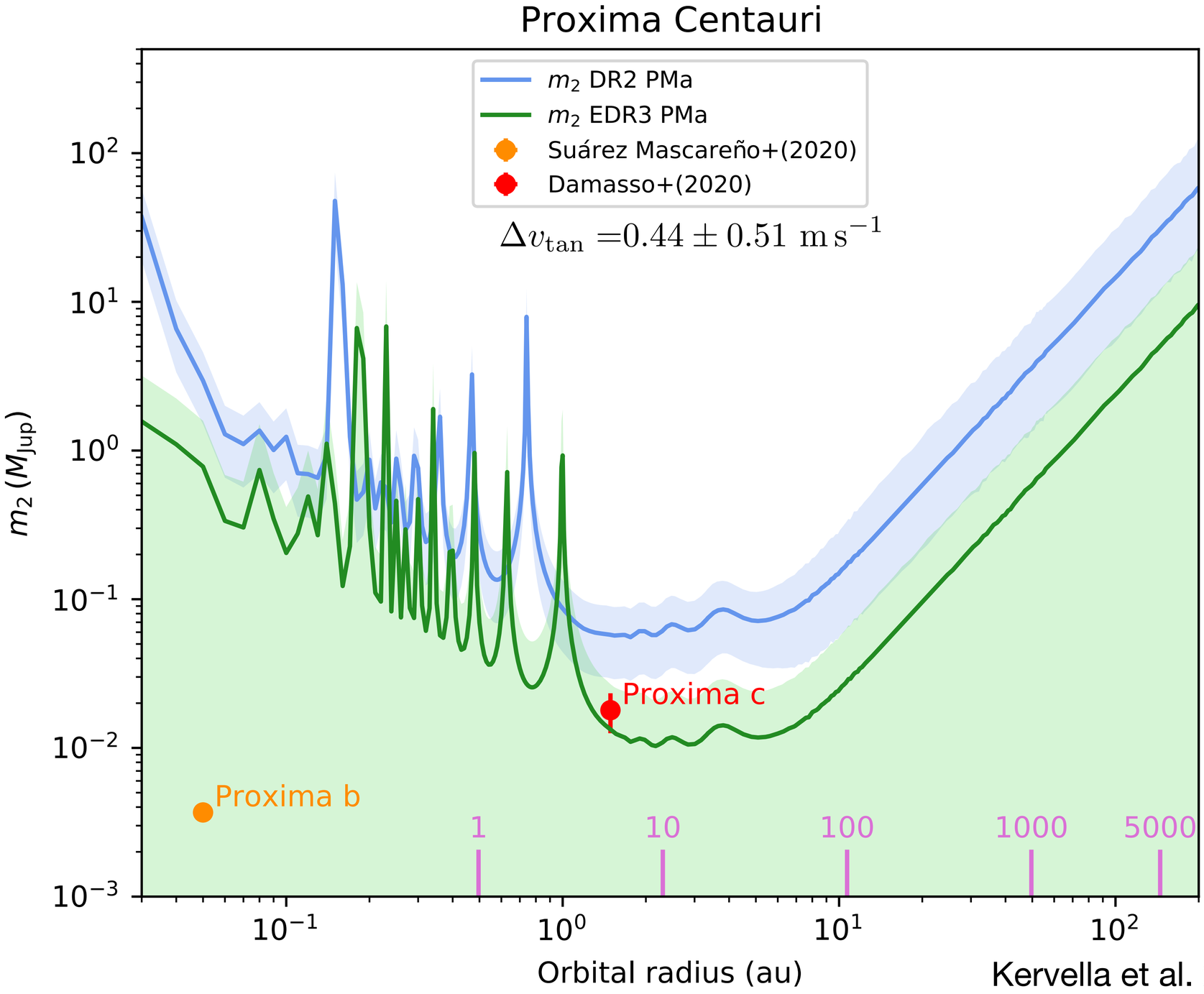
Proxima b



Proxima c

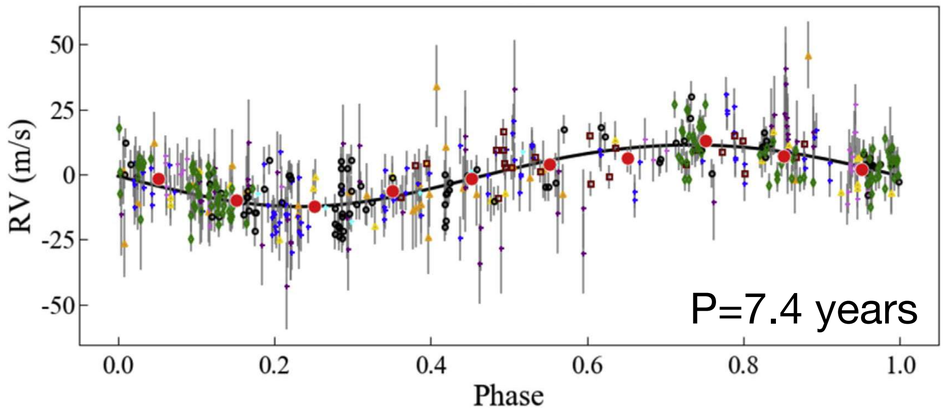


Damasso et al. 2020, Science Advances, 6, 3

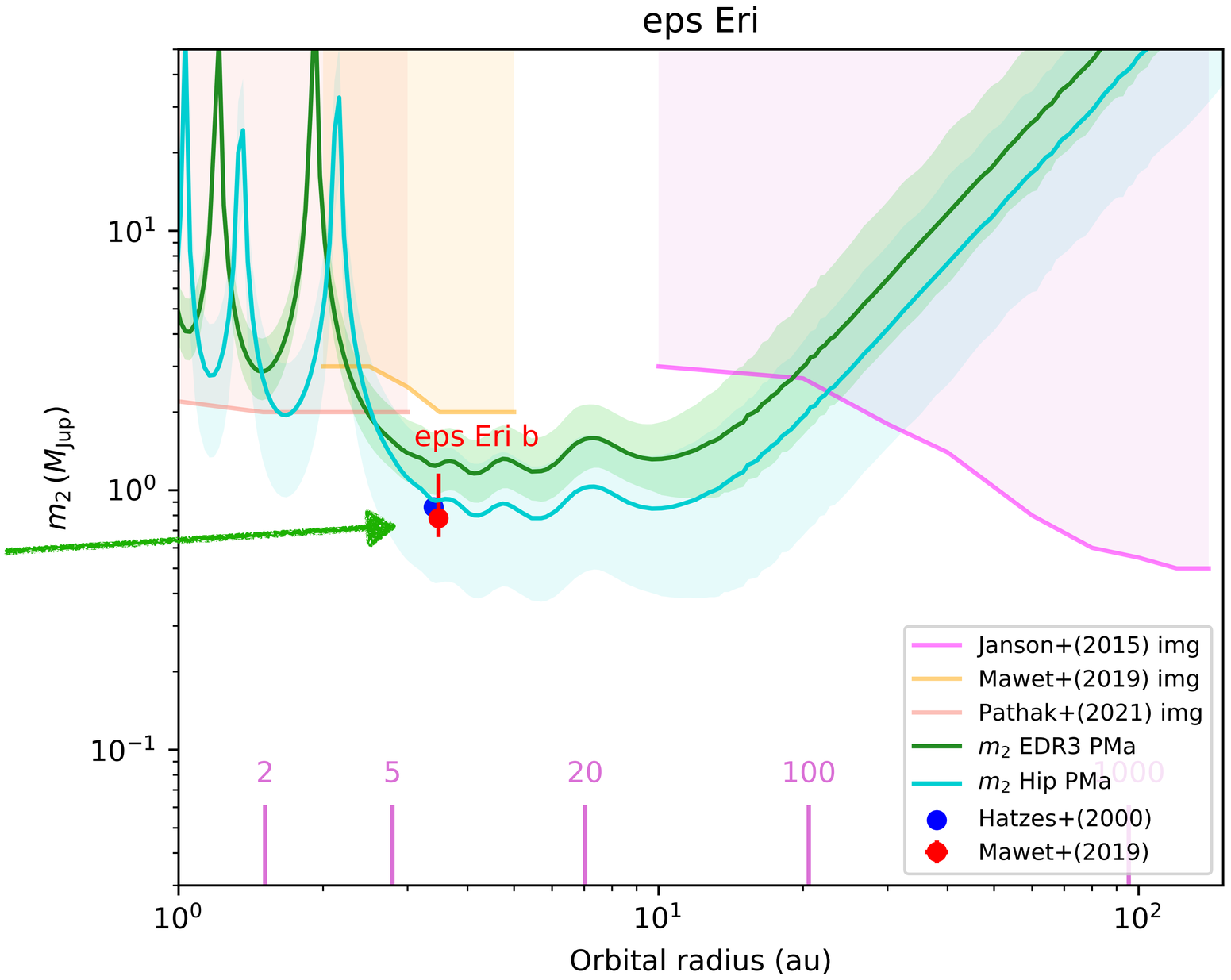


Kervella et al. 2022, A&A, 657, A7

ε Eridani



Mawet et al. 2019, AJ, 157, 33



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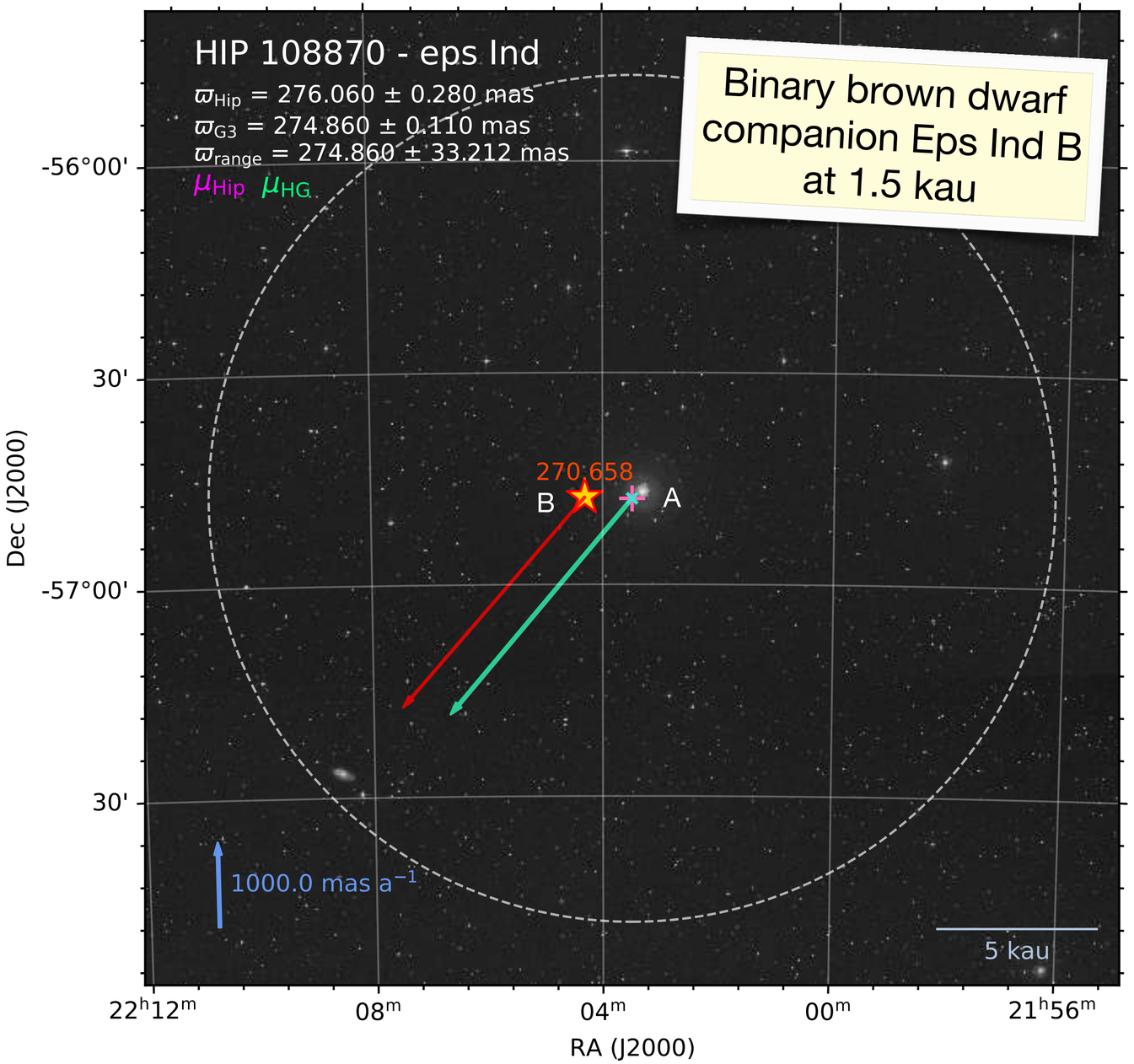
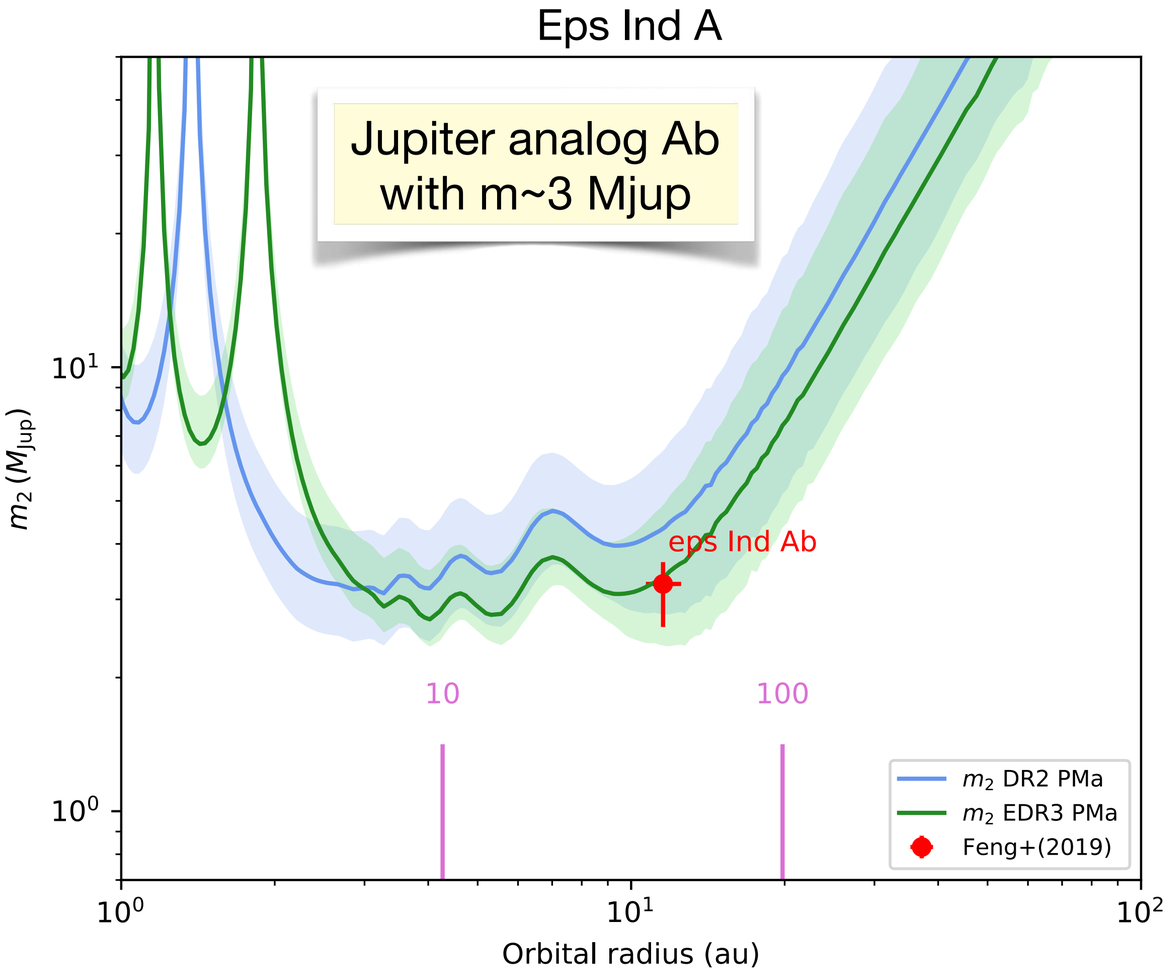
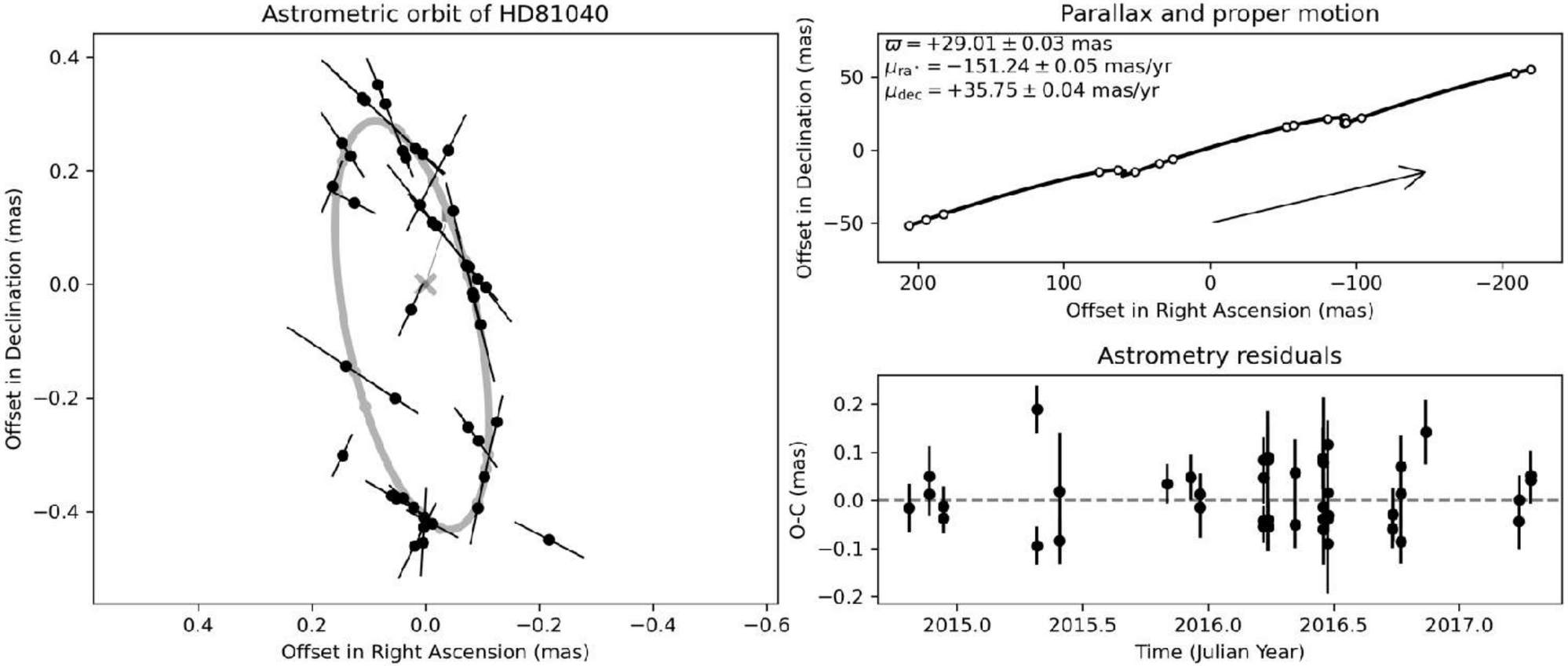
Epsilon Ind


HIP 108870 - eps Ind
ϖ_{Hip} = 276.060 ± 0.280 mas
ϖ_{G3} = 274.860 ± 0.110 mas
ϖ_{range} = 274.860 ± 33.212 mas
μ_{Hip} μ_{HG}
Binary brown dwarf companion Eps Ind B at 1.5 kau
270.658
B
A
1000.0 mas a^{-1}
5 kau
-56°00'
30'
-57°00'
30'
Dec (J2000)
22^{h}12^m
08^m
04^m
00^m
21^{h}56^m
RA (J2000)


Eps Ind A
Jupiter analog Ab with m~3 Mjup
eps Ind Ab
10
100
m_2 DR2 PMa
m_2 EDR3 PMa
Feng+(2019)
m_2 (M_{Jup})
10^1
10^0
10^0
10^1
10^2
Orbital radius (au)

Gaia DR3 NSS exoplanet detection

$P = 850.84 \pm 112.53$ d
$e = 0.37 \pm 0.15$
$T_P = 145.68 \pm 68.64$ d
$\alpha = 0.40^{+0.03}_{-0.03}$ mas
$\omega = 63.22^{+13.91}_{-14.84}$ deg
$\Omega = 12.46^{+5.79}_{-5.38}$ deg
$i = 107.40^{+5.51}_{-5.58}$ deg



- Astrometric wobble of the star due to its 8 M_J companion (Sozetti+ 2006; Stassun+ 2017; Li+ 2021) on a 1000 days orbit.

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

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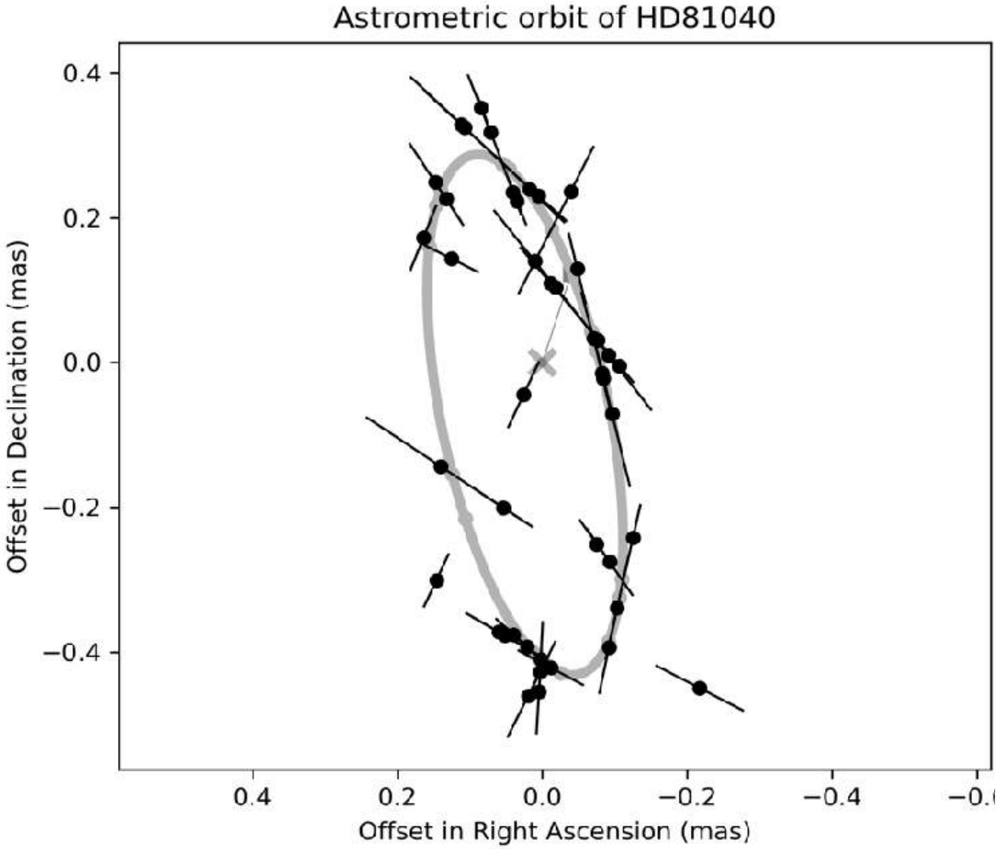

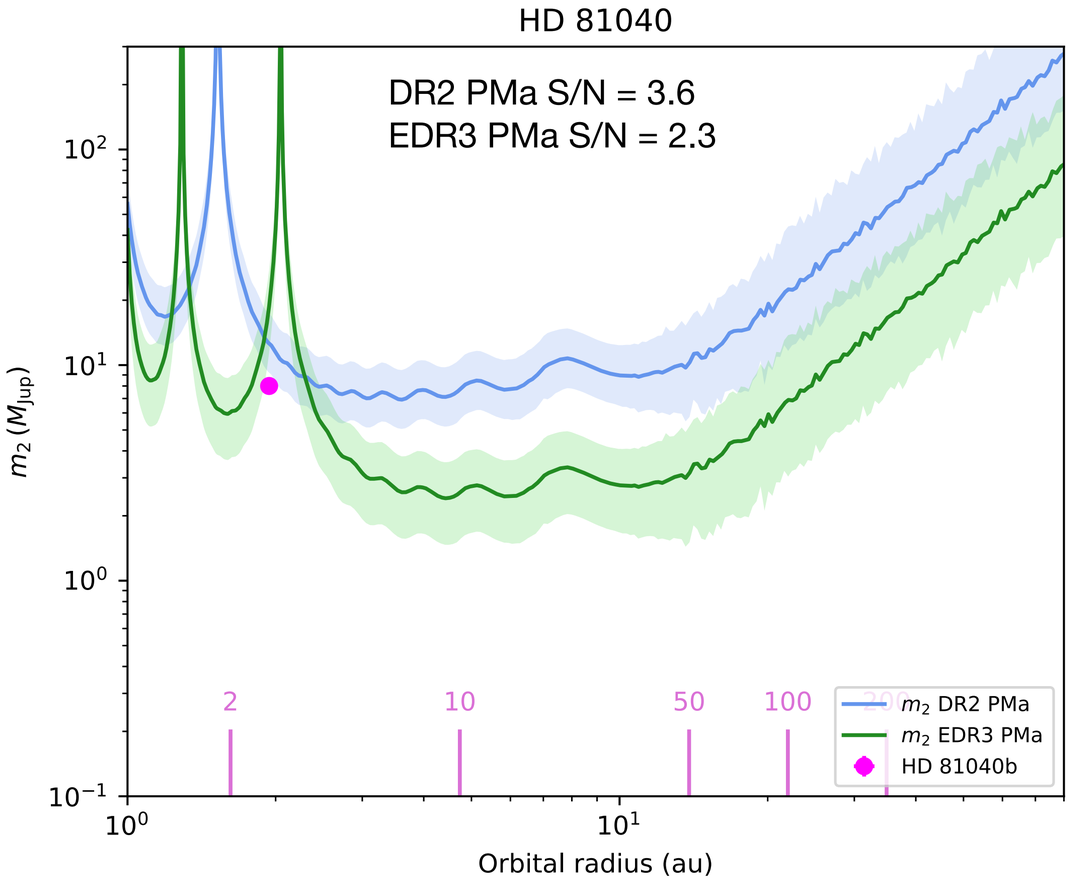

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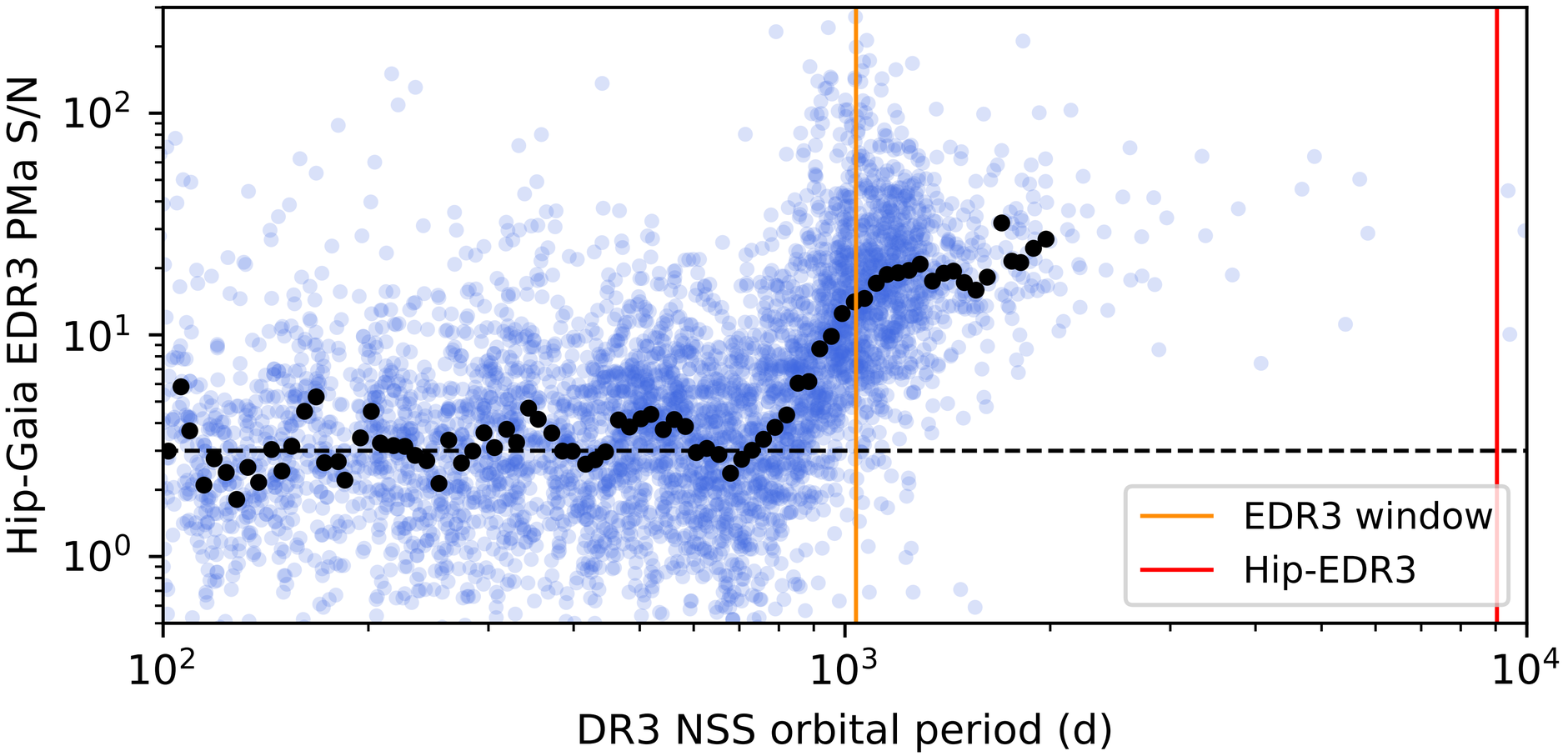
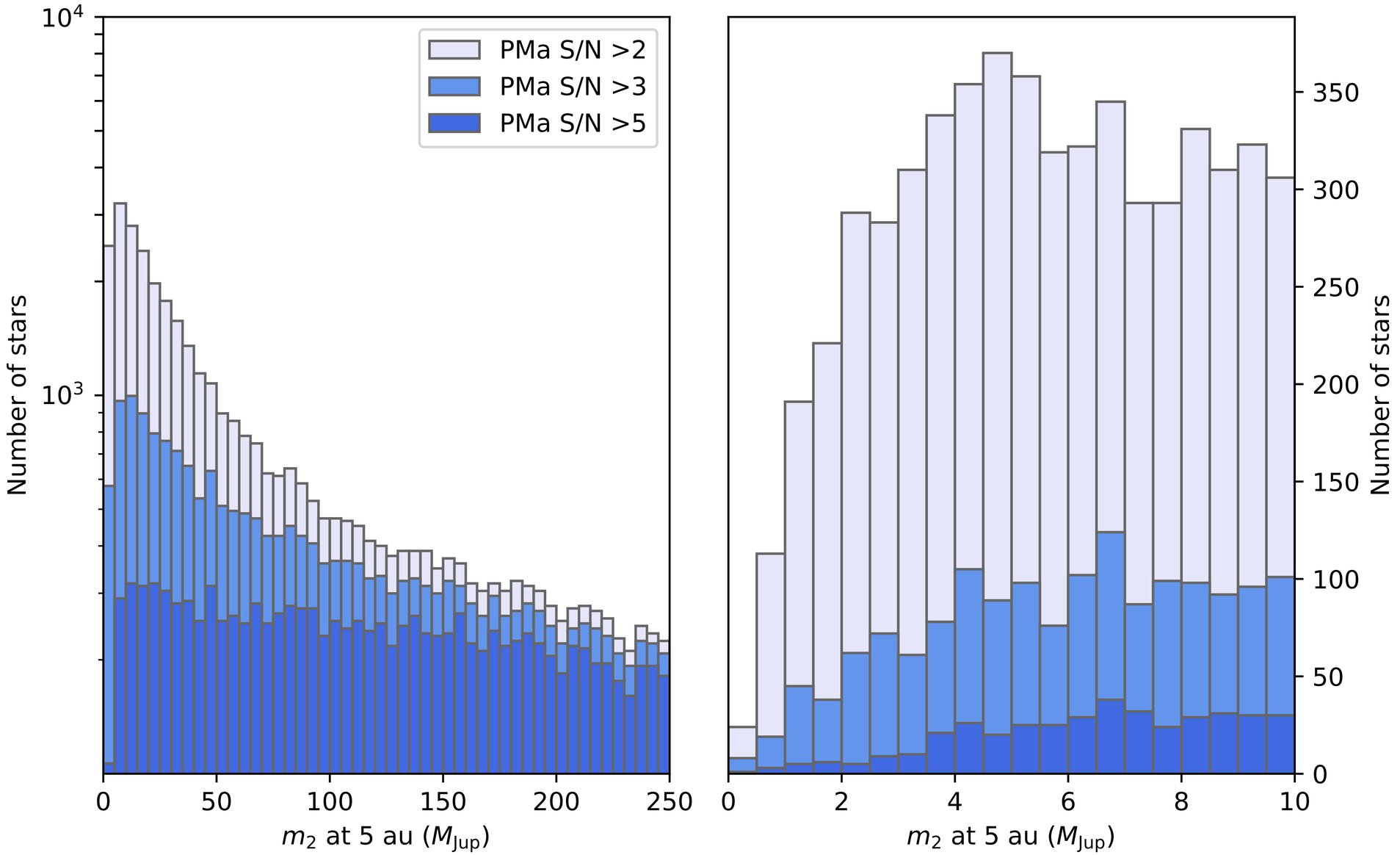
Short and long orbital periods
Gaia DR3 NSS orbits & PMa



Gaia Collaboration, Arenou et al. 2022, A&A, in press

PMa secondary mass @5au histogram



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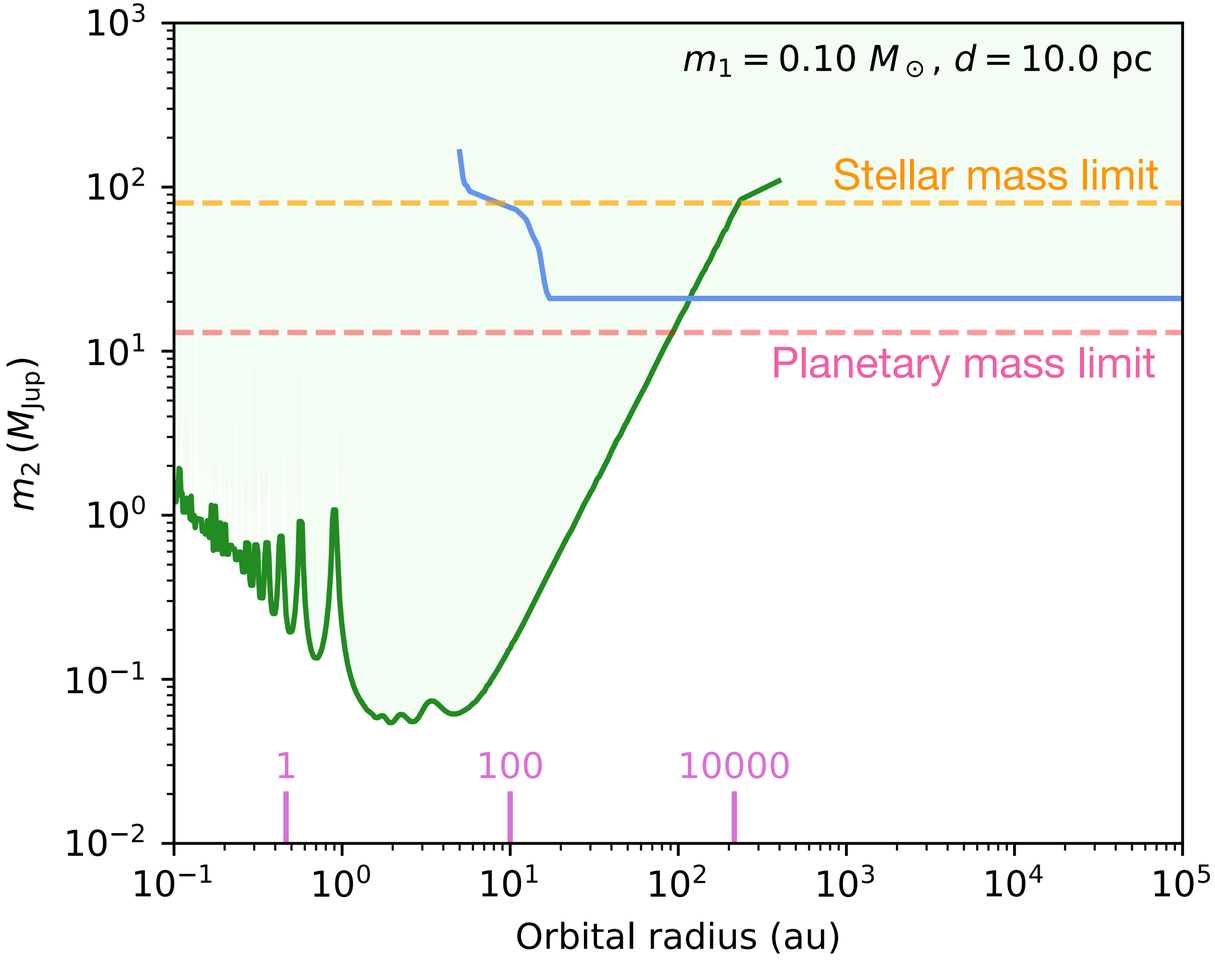
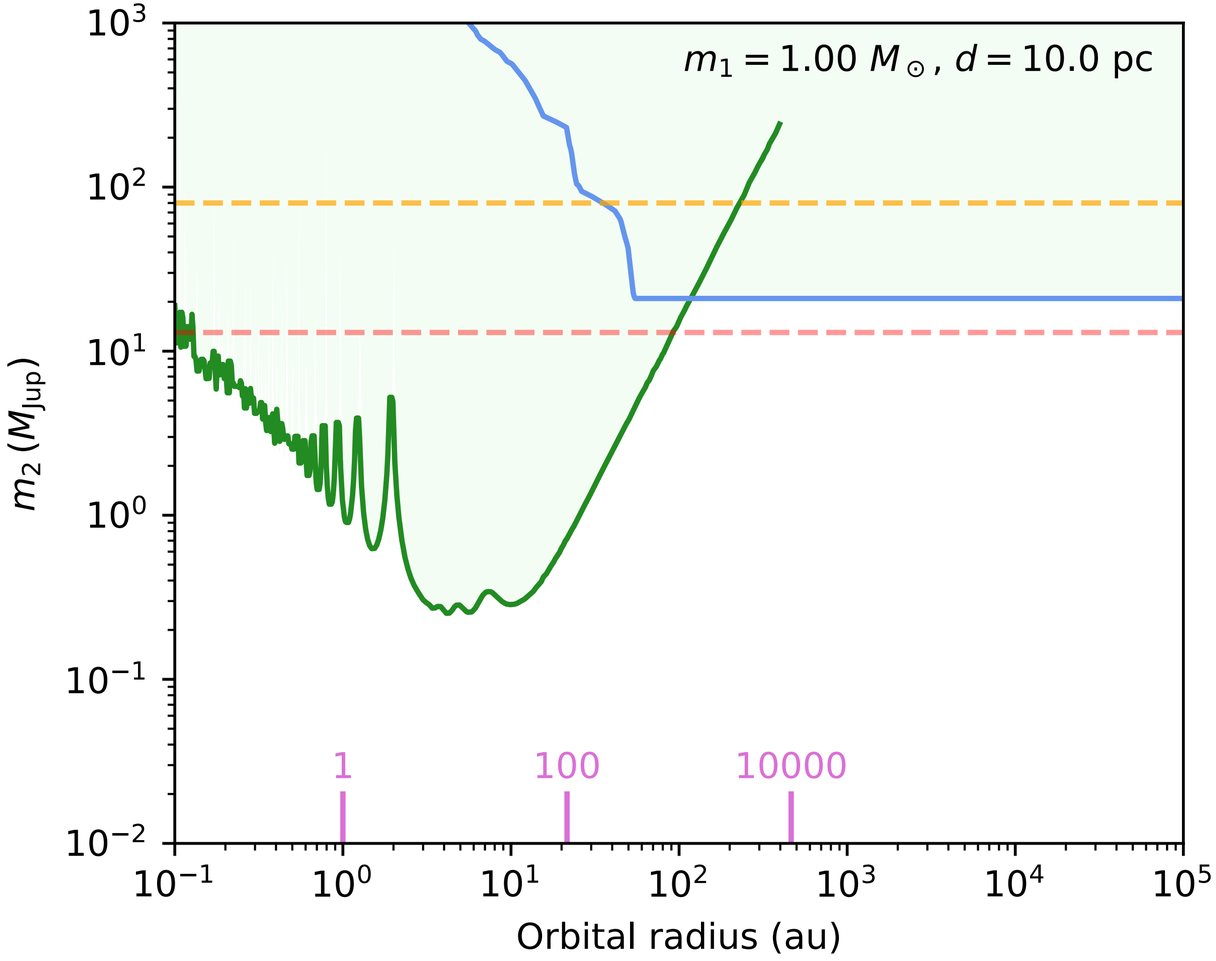
Combined PMa + common proper motion





Overall statistics for Hipparcos stars

Method	Number of stars	Fraction
Full catalog	117 955	100%
PMa $S/N > 3$	37 347	32%
CPM bound candidates	12 914	11%
RUWE > 1.4	25 067	21%
PMa or CPM	37 347	32%
PMa or CPM or RUWE	50 720	43%

Conclusion

- **43%** of the 117,000 Hipparcos stars exhibit at least one signature of binarity (PMa, RUWE, CPM)
- Many **low mass companion** signatures in PMa, including of planetary mass
- Tangential velocity anomaly accuracy: **Δv_{tan} ~ 0.26 m/s/pc** with the (E)DR3
- The DR3 includes a **wonderful catalog** of non-single stars !

https://www.cosmos.esa.int/web/gaia/dr3-papers