



HYPERVELOCITY DISCOVERIES WITH GAIA DR2

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ESLAB 53

PREMISE

Hypervelocity star

- Any star travelling faster than the Milky Way's escape speed.

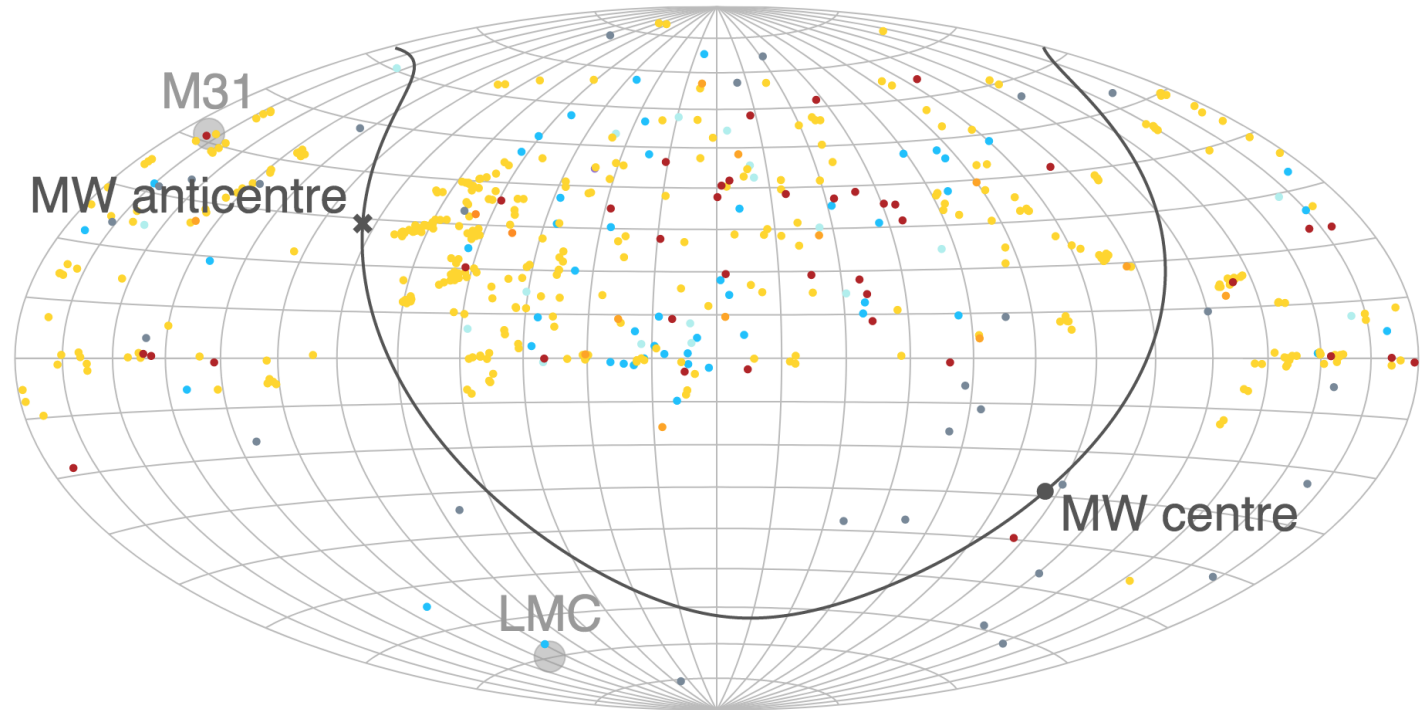
Hypervelocity stars can reveal either new astrophysics or errors in our methodology.

Gaia is great at finding both hypervelocity and “hypervelocity” stars.

CHARACTERISTICS OF THE POPULATION PRE-GAIA DR2

All over the sky

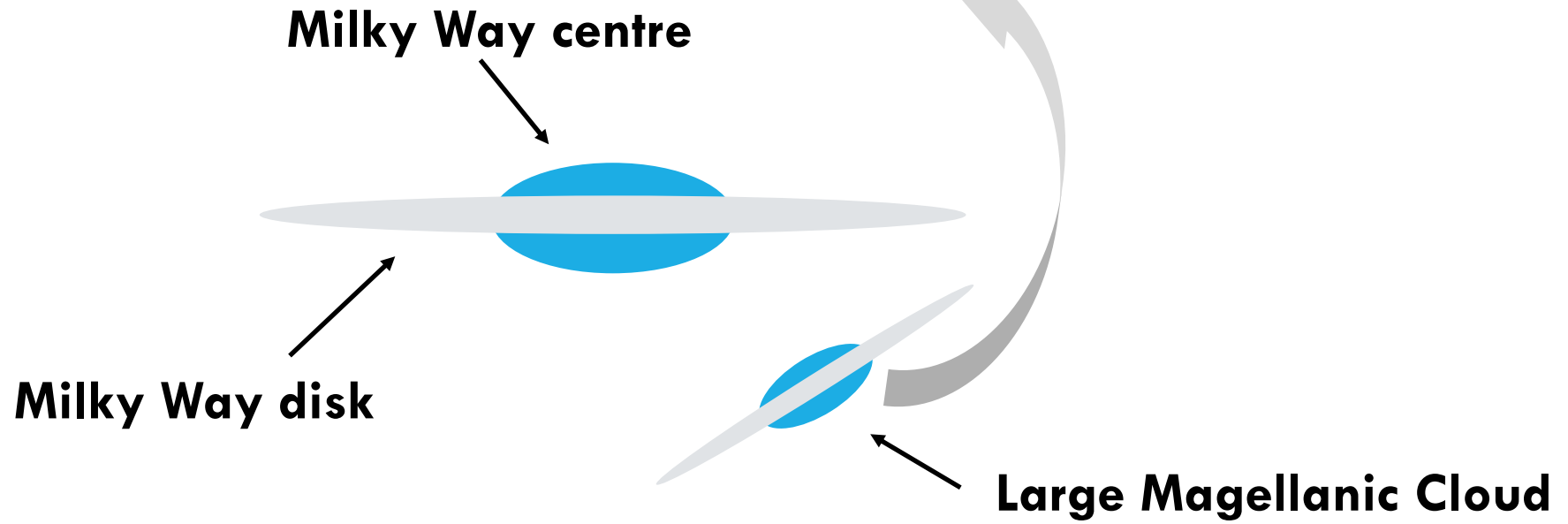
**Main sequence,
giants, WDs, SDs**



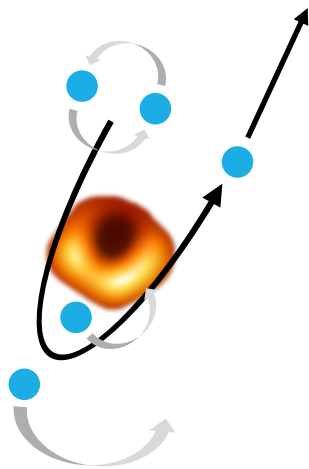
**Likely that many
are spurious**

100 pc to 100 kpc

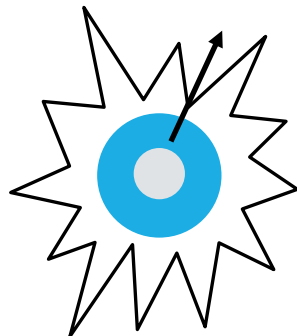
WHERE?



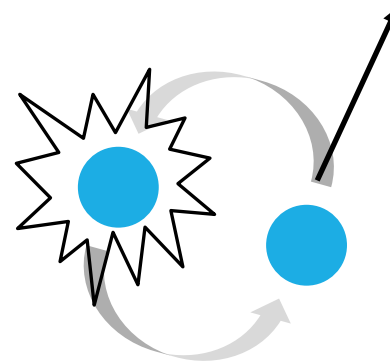
HOW?



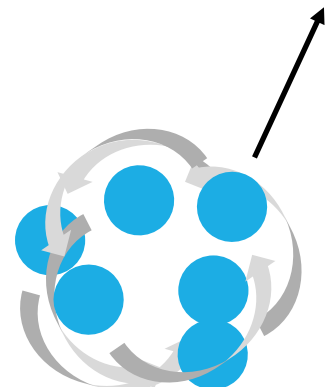
Hills



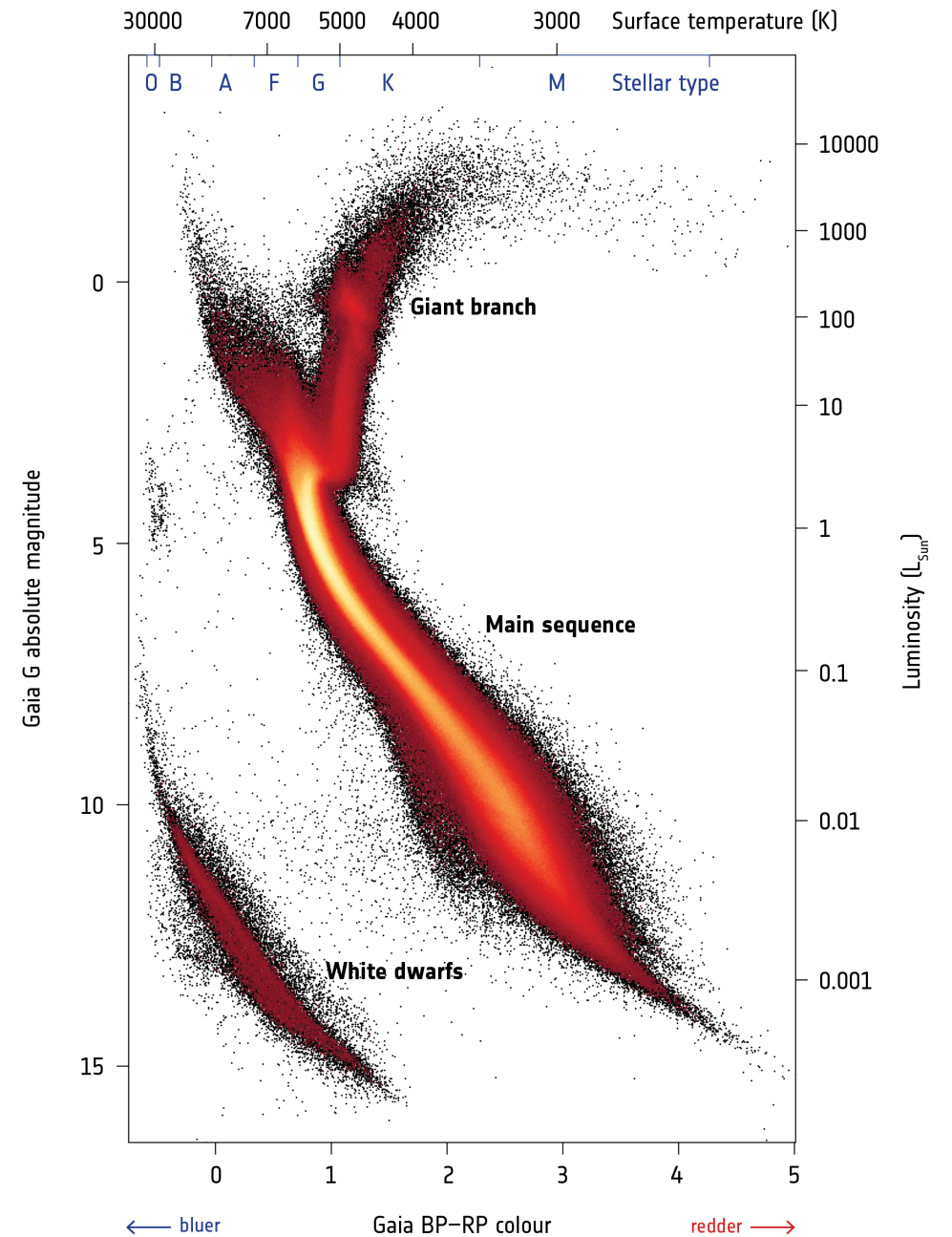
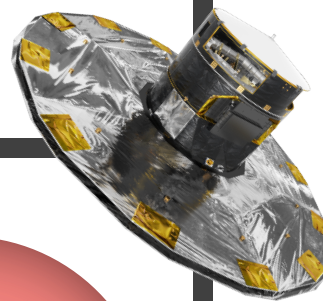
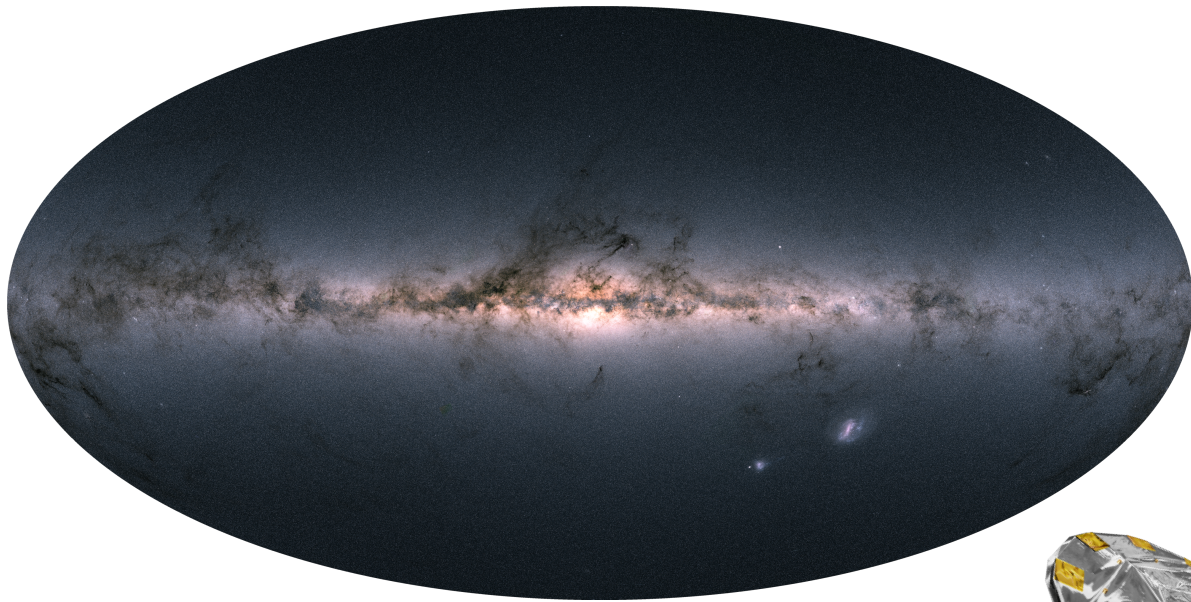
Supernova



Runaway



Cluster



1

Revisiting hypervelocity stars after Gaia DR2

Boubert et al. (2018, arXiv:1804.10179)

2

A hypervelocity star with a Magellanic origin

Erkal, Boubert et al. (2018, arXiv:1804.10197)

3

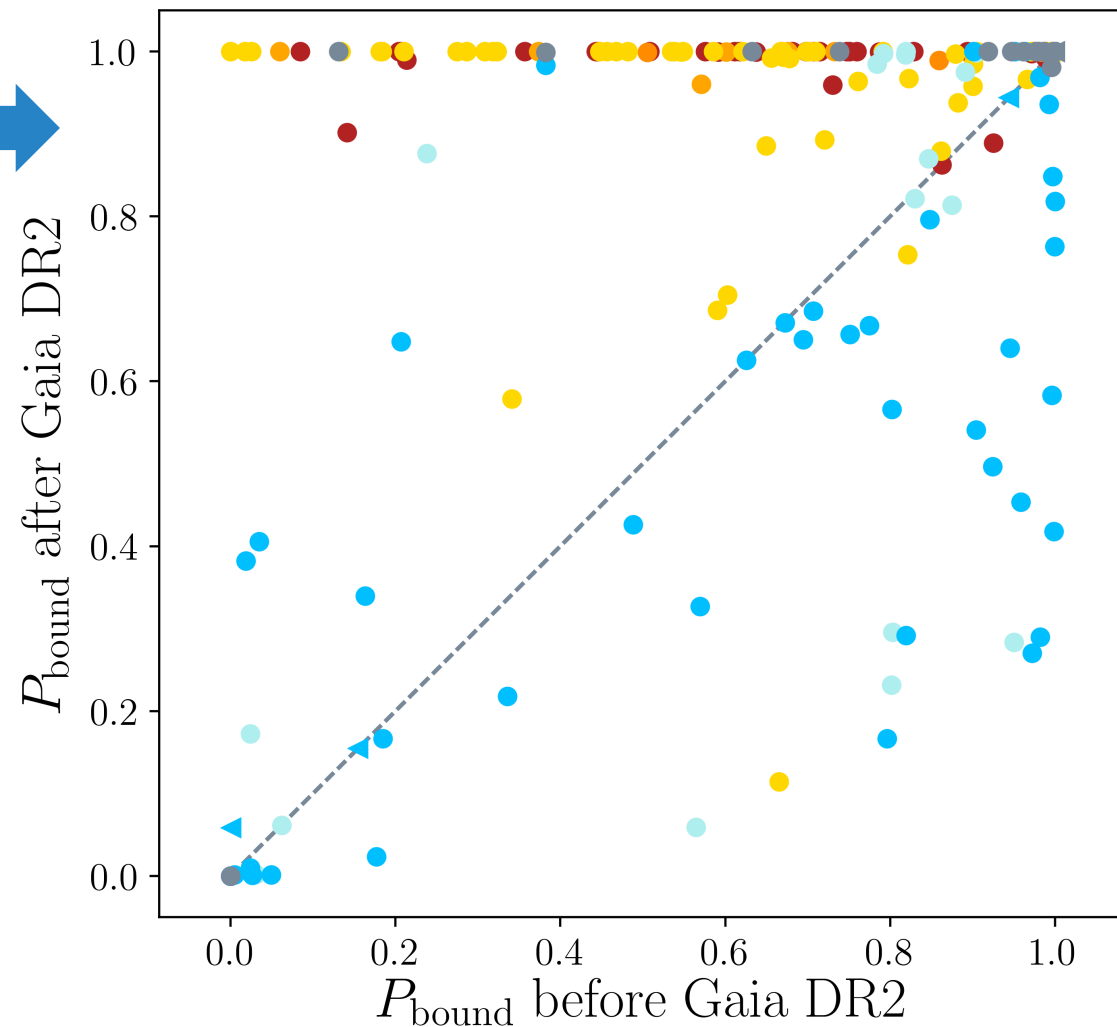
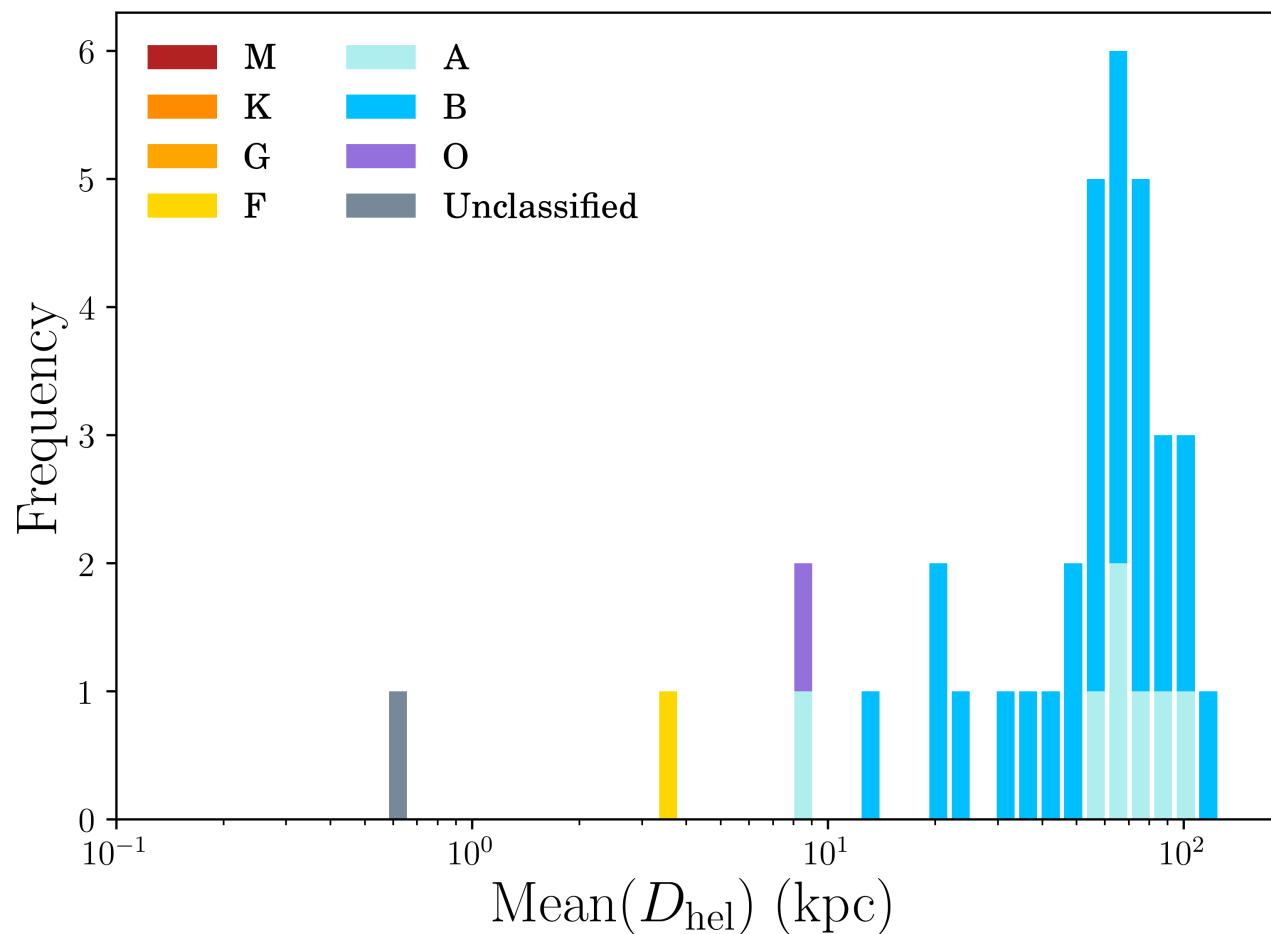
Three Hypervelocity White Dwarfs in Gaia DR2

Shen, Boubert et al. (2018, arXiv:1804.11163)

HYPERVELOCITY DISCOVERIES IN THREE PAPERS



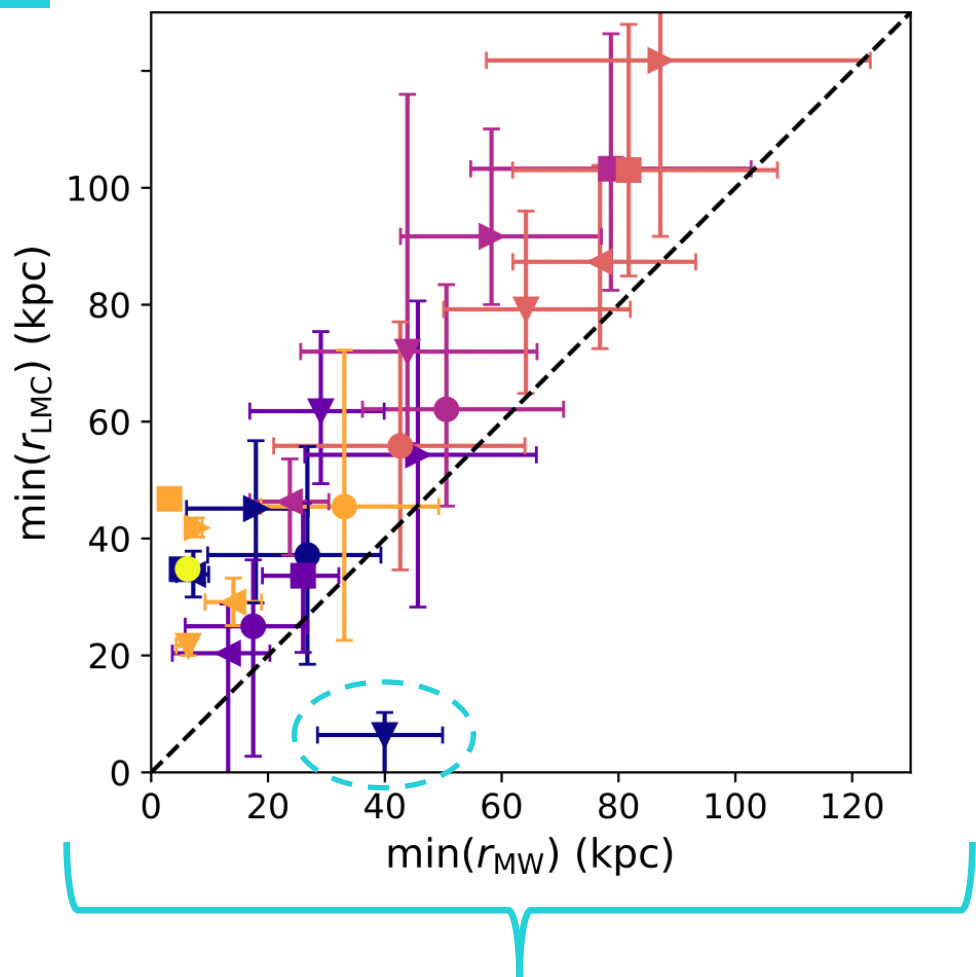
Nearby stars with very large tangential velocities were spurious



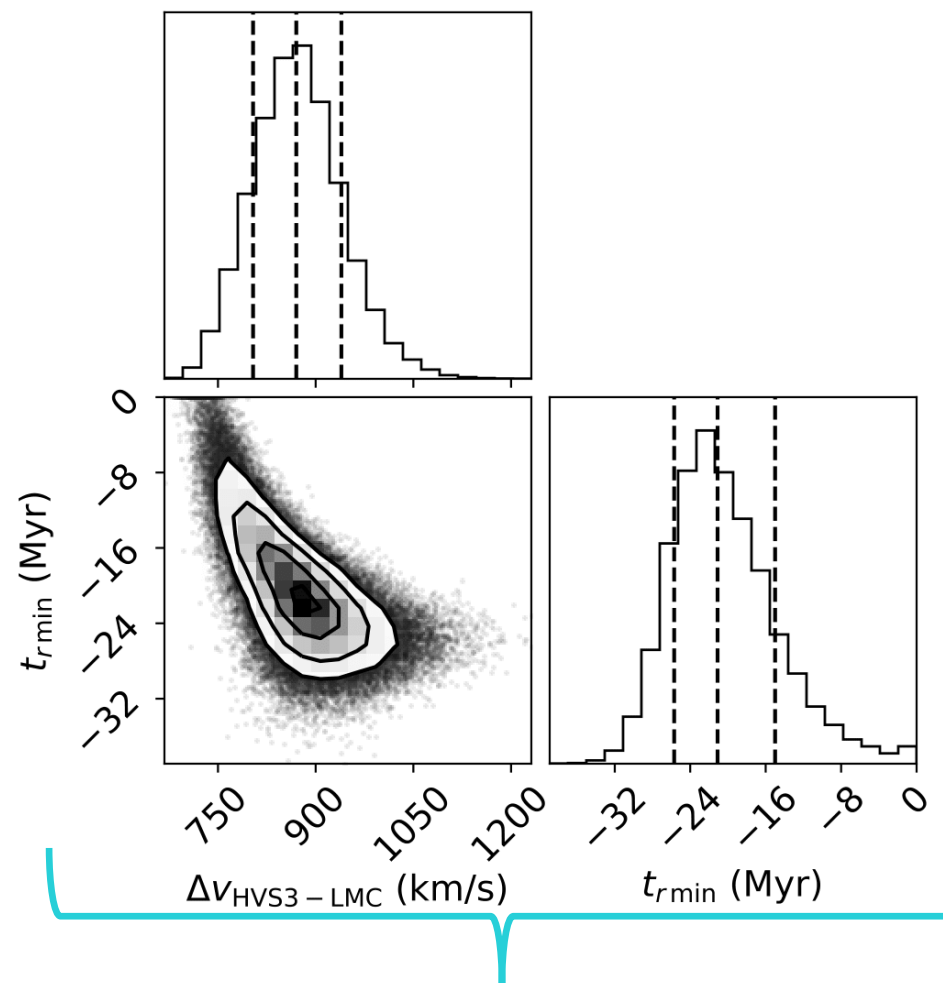
The average hypervelocity star is now as far away as the LMC.

2

Idea: Track the hypervelocity stars in the halo back to their origin



One star is definitely from the LMC.



It was ejected 21 Myr ago at 870 km/s.

2

A challenge for theory ...

... how do you kick an $8 M_{\odot}$ star at 870 km/s?

⇒ $> 10^3 M_{\odot}$ black hole in the LMC

3

Two white dwarfs in a mass-transferring binary.



The orbital velocity is ~ 1800 km/s.

If one explodes in a Type Ia, then the companion will fly away very quickly.

Idea: Are there any objects moving faster than 1000 km/s in Gaia DR2?

Yes.

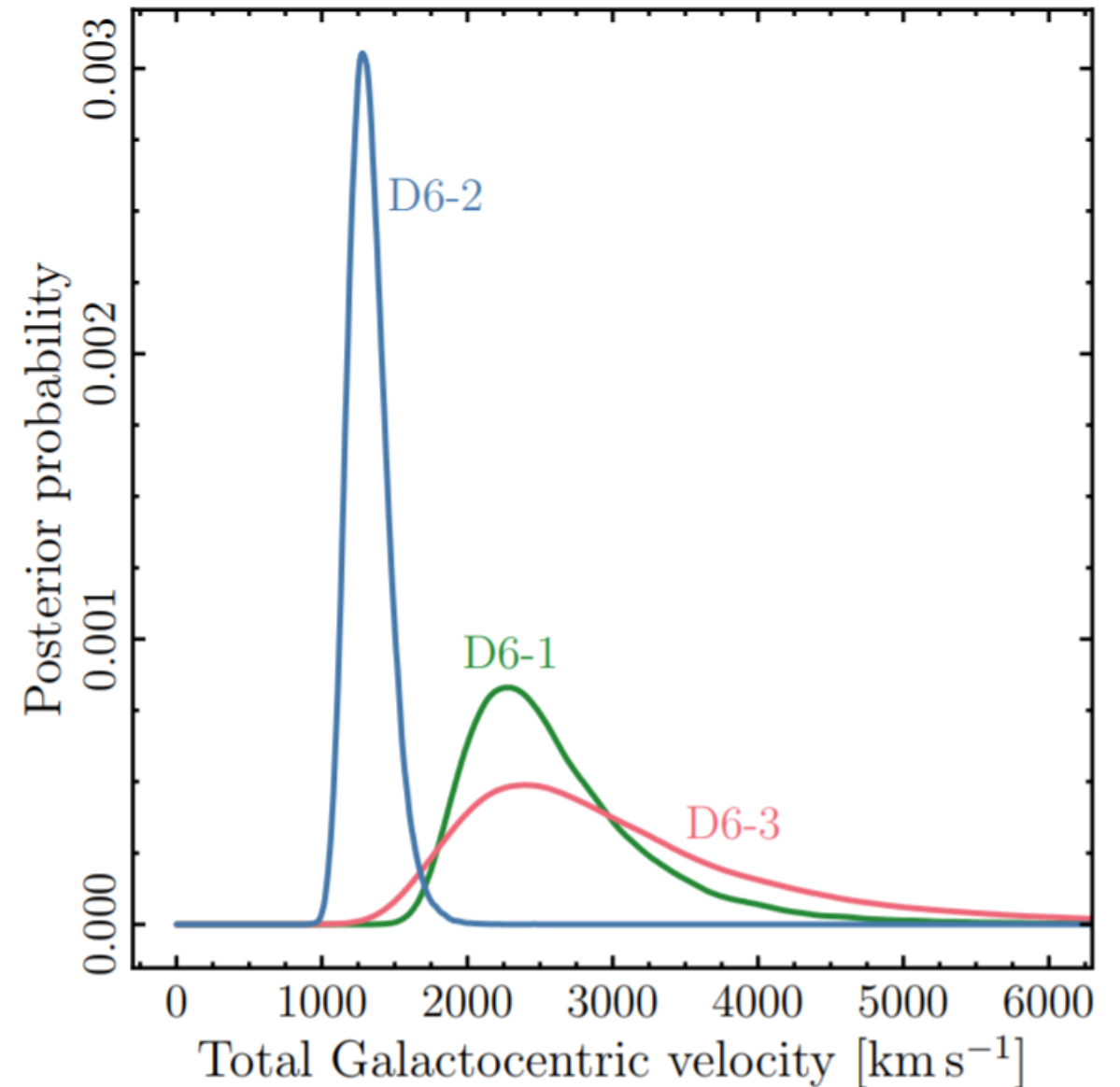
Table 3. Velocity information of the hypervelocity candidates

Nickname	RV_{helio}^a (km s^{-1})	$v_{\text{proper, helio}}^b$ (km s^{-1})	v_{Galacto}^c (km s^{-1})
D6-1	<u>1200 ± 40</u>	2200 [1400 – 6800]	2300 [1600 – 6600]
D6-2	20 ± 60	1200 [700 – 1500]	1300 [1000 – 1900]
D6-3	-20 ± 80	2400 [1700 – 11100]	2400 [1400 – 9000]

^a Heliocentric radial velocity, with 68.3% uncertainties.

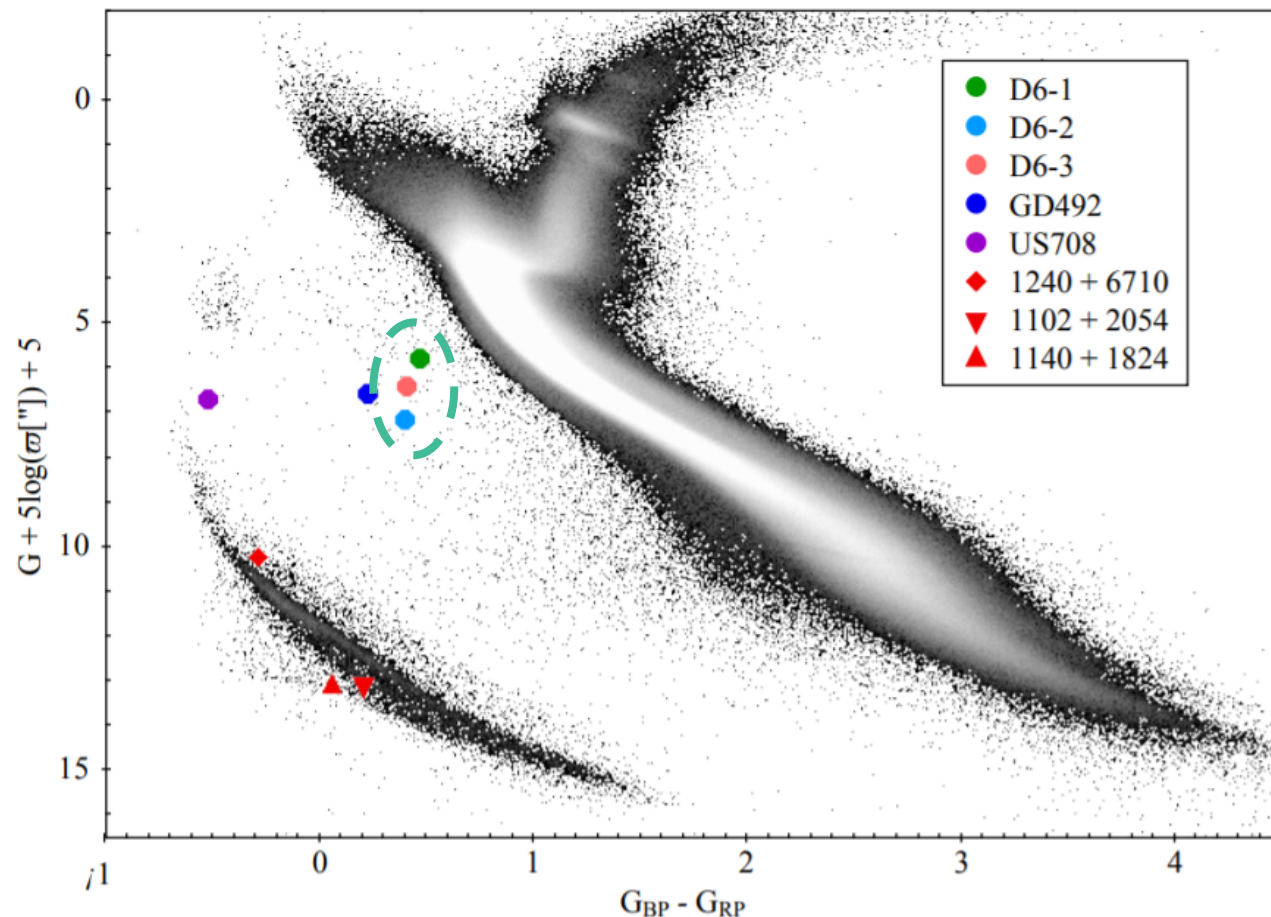
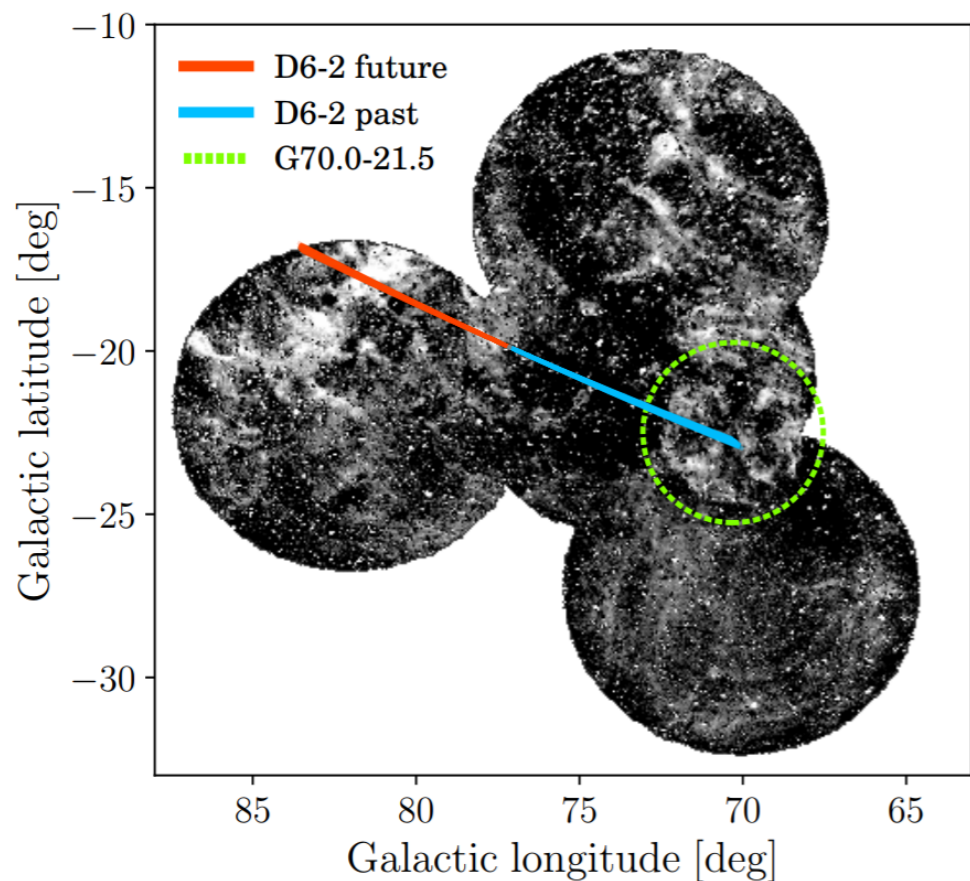
^b Heliocentric proper motion velocity, posterior maximum with 99.7% credible intervals.

^c Total Galactocentric velocity, posterior maximum with 99.7% credible intervals.



3

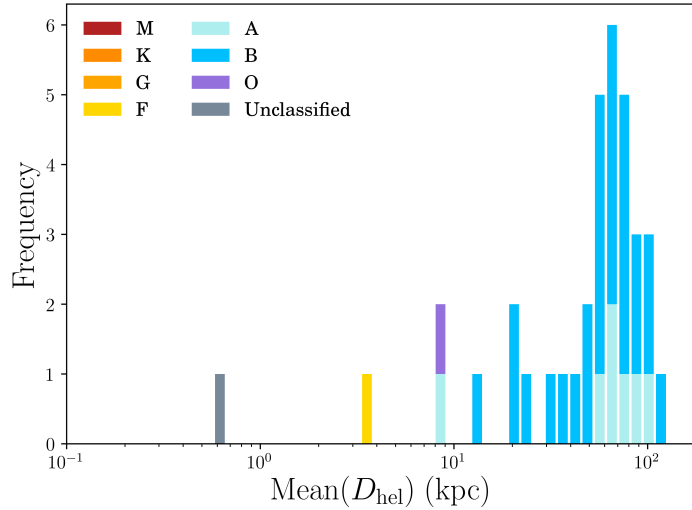
The double degenerate SN Ia channel can occur without a merger.



EVIDENCE:

1. D6-1 has a radial velocity of 1200 km/s.
2. They lie in one location in the HR diagram.
3. D6-2 tracks back to the centre of a SNR.

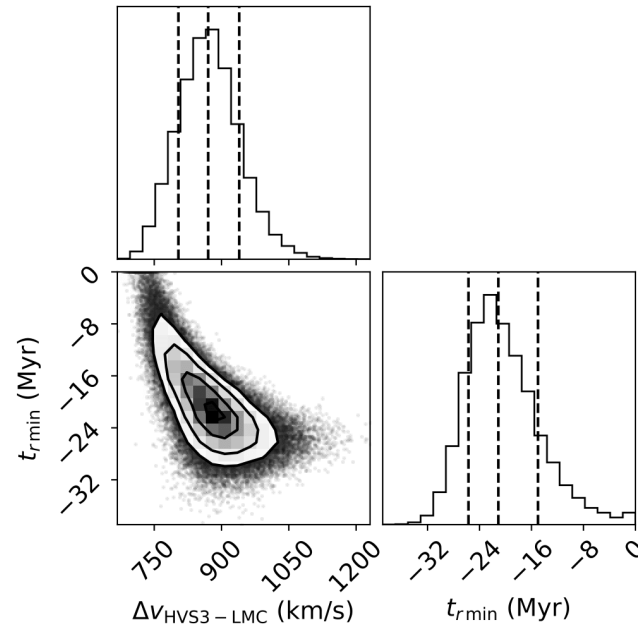
1



KEY IDEA:

Gaia DR2 has discovered
-500 hypervelocity stars.

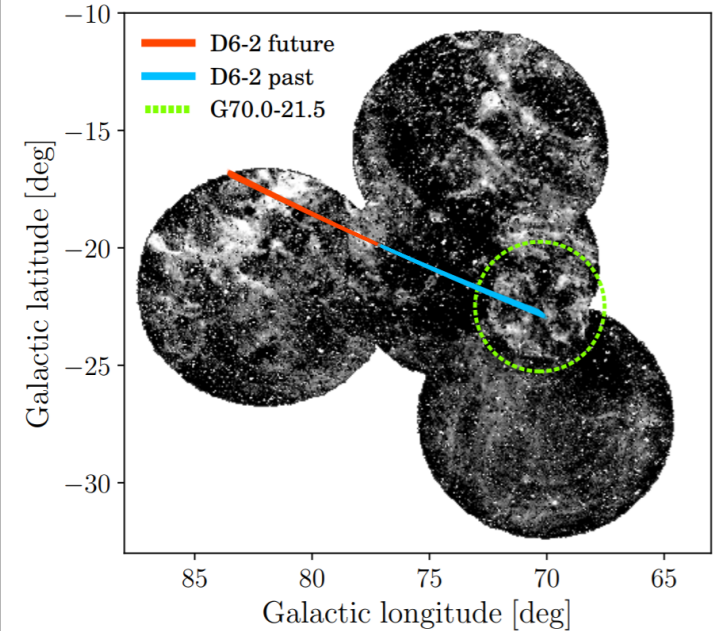
2



KEY IDEA:

At least one hypervelocity
star is from the Large
Magellanic Cloud.

3



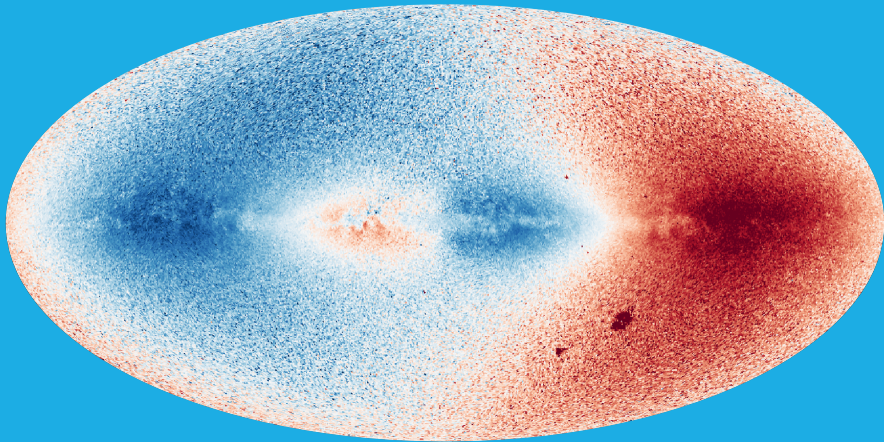
KEY IDEA:

Dynamical evidence of double-
degenerate Type Ia Sne
without a merger

MYSTERY OF THE FASTEST STAR IN GAIA DR2

THE RACE TO FIND HYPERVELOCITY STARS IN GAIA RVS

(The 7,224,631 stars with radial velocities.)



Easy to find hypervelocity stars if you have all 6 components.



Marchetti et al. (2018), Hattori et al. (2018) and Bromley et al. (2018) all searched in RVS.



Plenty of candidates but some are likely statistical astrometric outliers.

GAIA DR2 593...064: SURELY AN HVS(?)

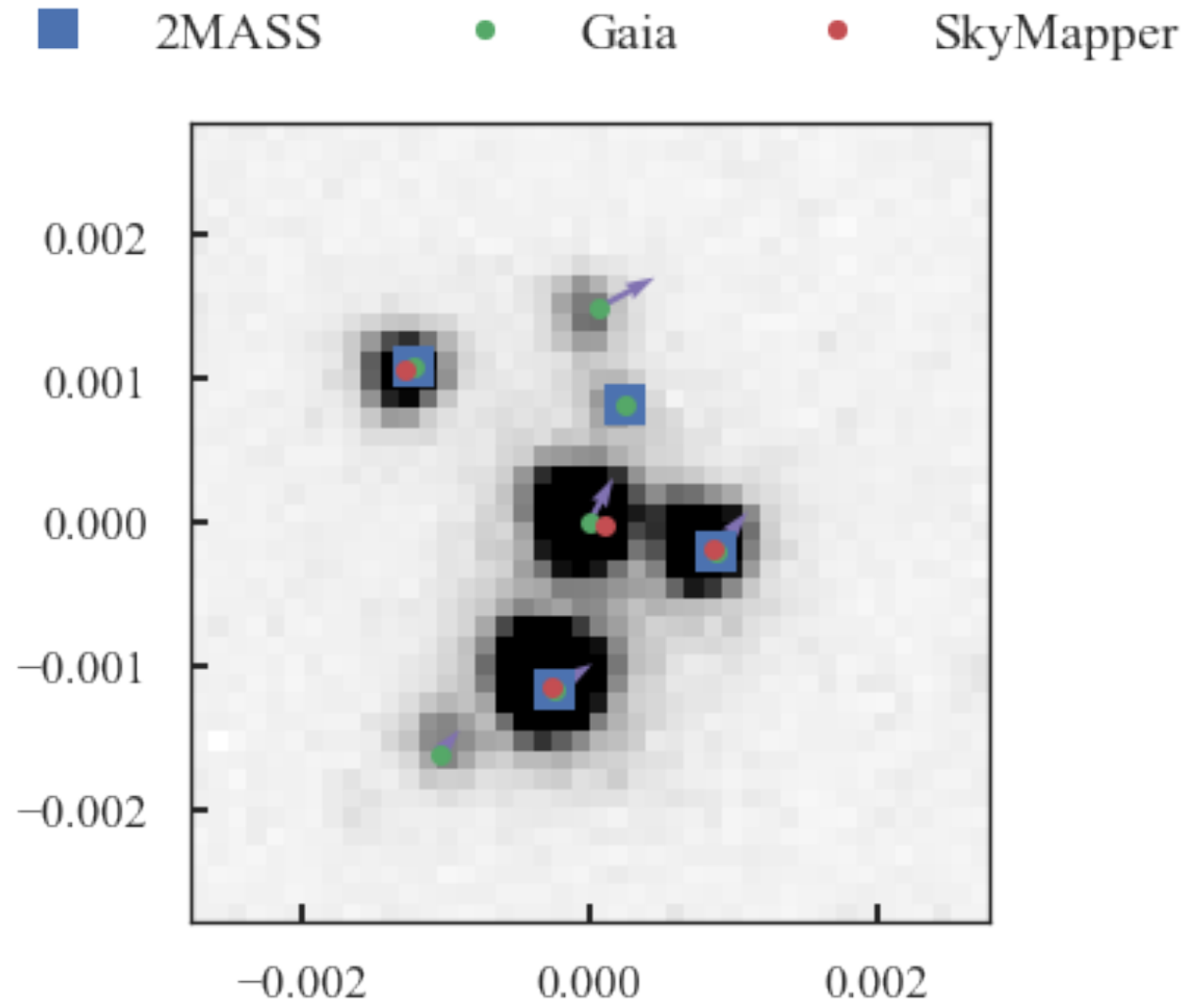
Property	Value
Radial velocity	-614.3 ± 2.5 km/s
Distance	2.1 ± 0.1 kpc
Total velocity	749.6 ± 6.8 km/s
(l, b)	(329.9°, -2.7°)
G	13.8



- RV alone is sufficient to make it an HVS.
- RV based on 7 measurements.



- Near Galactic plane and in crowded region.
- Proper motion is boring.



Identified by Marchetti et al. (2018) and Bromley et al. (2018).
Image from PanSTARRS and taken from Boubert et al. (2019).

Julian Date	Radial Velocity (km s ⁻¹)
2458243.76	-70.0 ± 9.8
2458278.58	-43.3 ± 10.0
2458288.50	-59.0 ± 9.6
2458289.46	-54.7 ± 9.0
2458309.58	-82.5 ± 8.2
2458322.45	-46.7 ± 8.2
2458372.51	-58.2 ± 8.5
2458377.50	-52.3 ± 3.9
Our median	-56.5 ± 5.3
<i>Gaia</i> median	-614.3 ± 2.5
Difference	557.8 ± 5.9



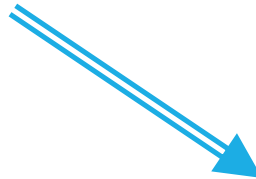
FOLLOW-UP WAS CONFUSING

- We measured eight radial velocities spread over 130 days.
- Our measurements are in tension with the *Gaia* measurement.
- The star is an A subgiant with $T_{\text{eff}} = 6600$ K, $\log g = 2.9$.

Two possibilities ...



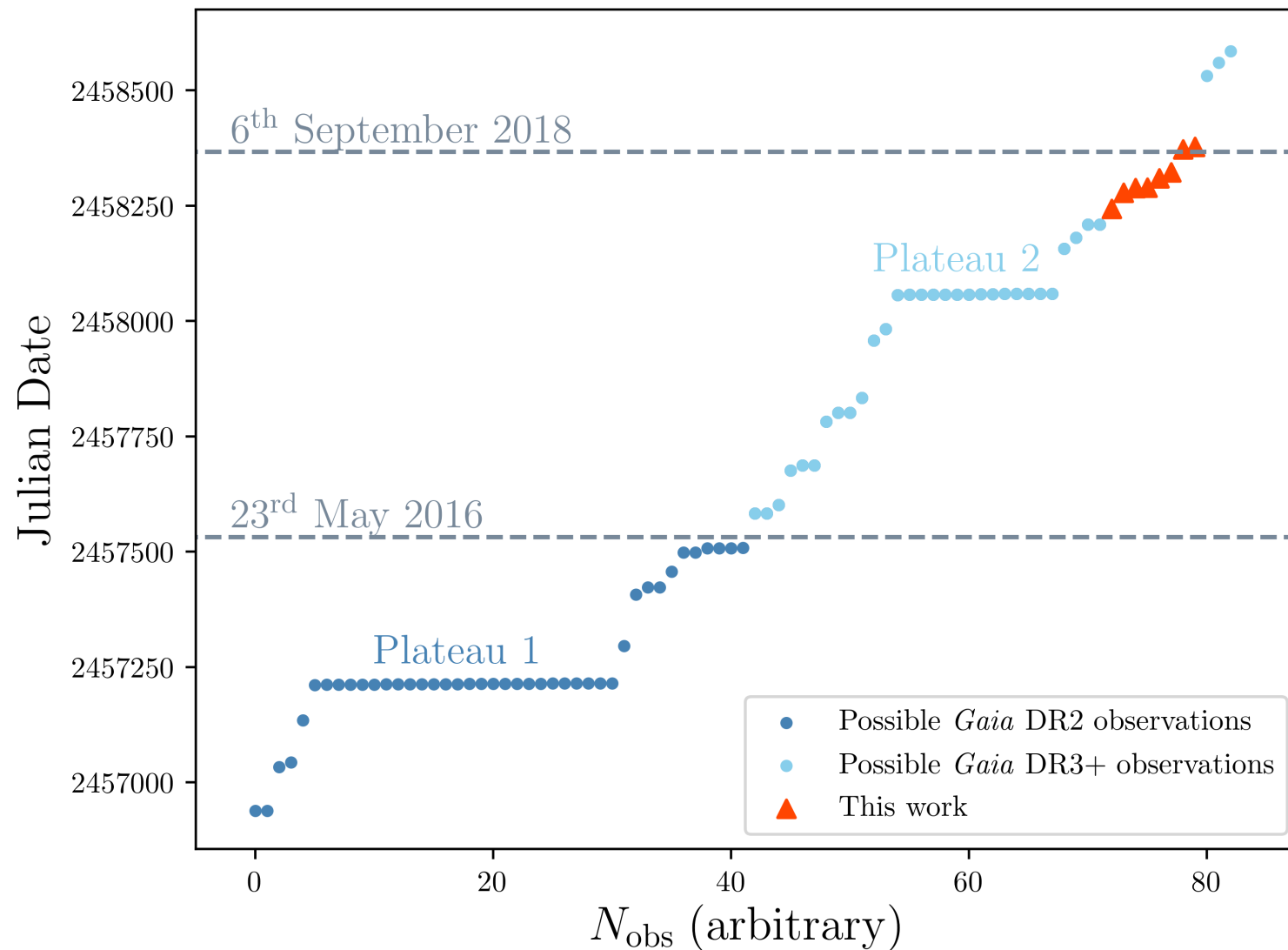
Gaia measurement is right



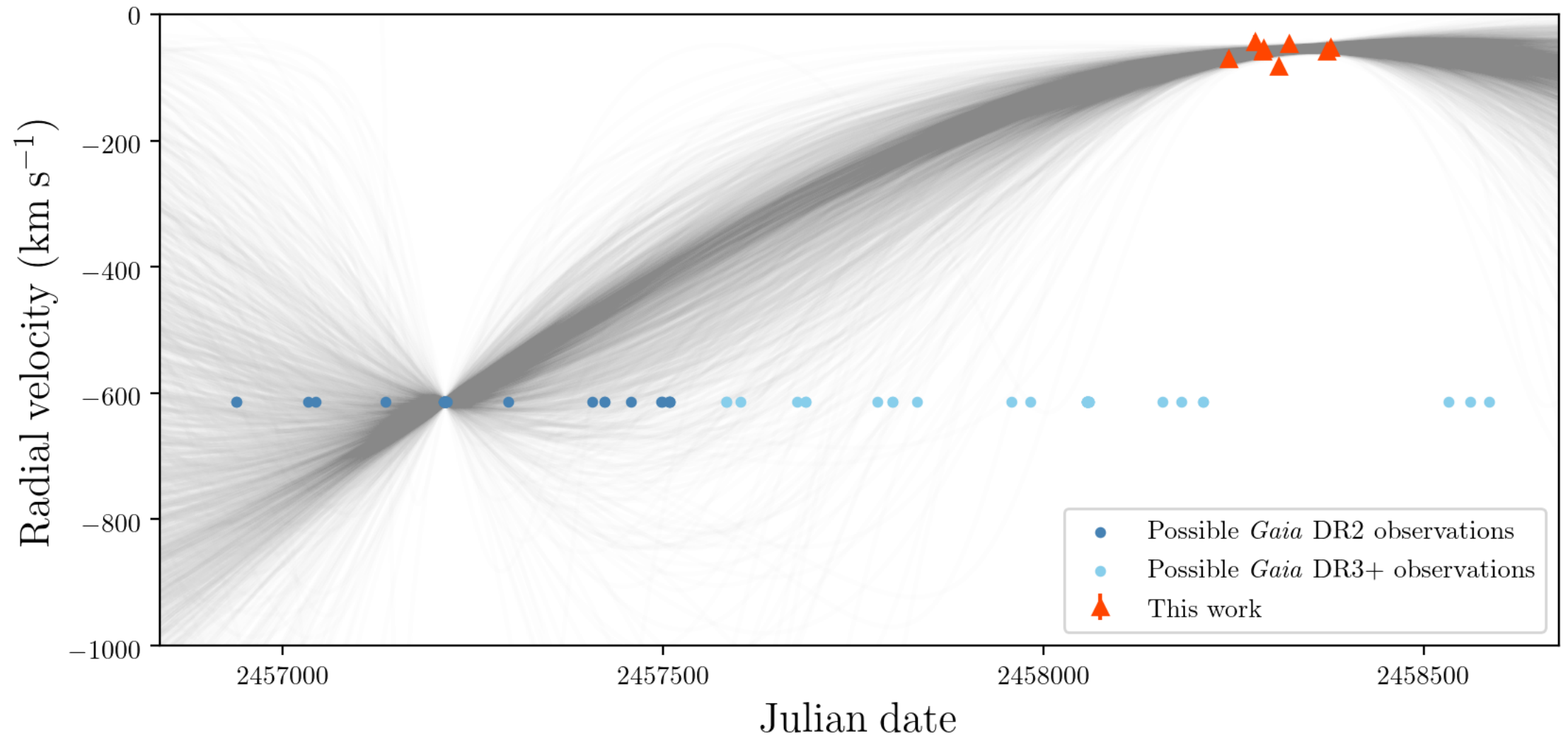
Gaia measurement is spurious

Conclusion: Gaia DR2 593...064 is not a hypervelocity star.

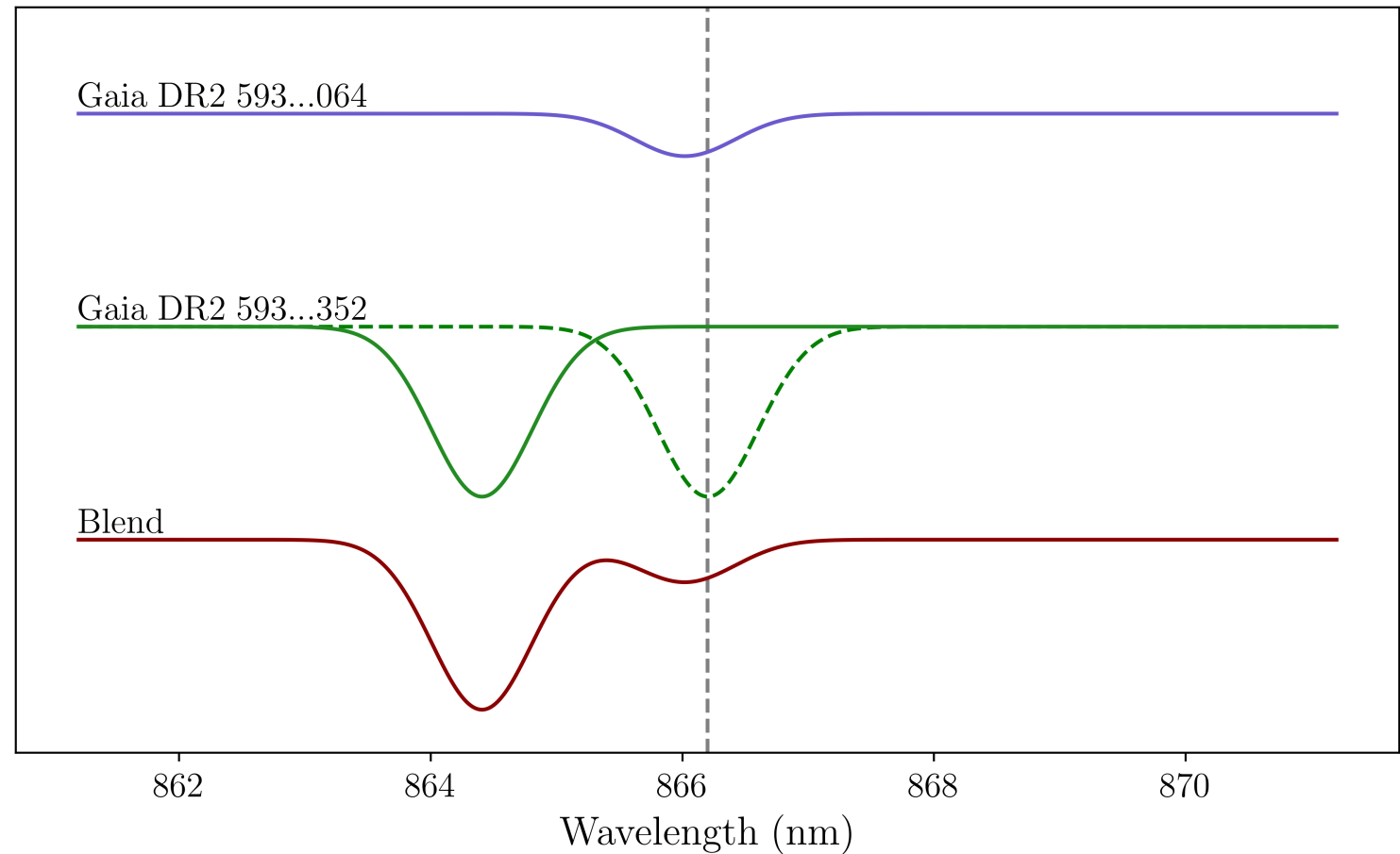
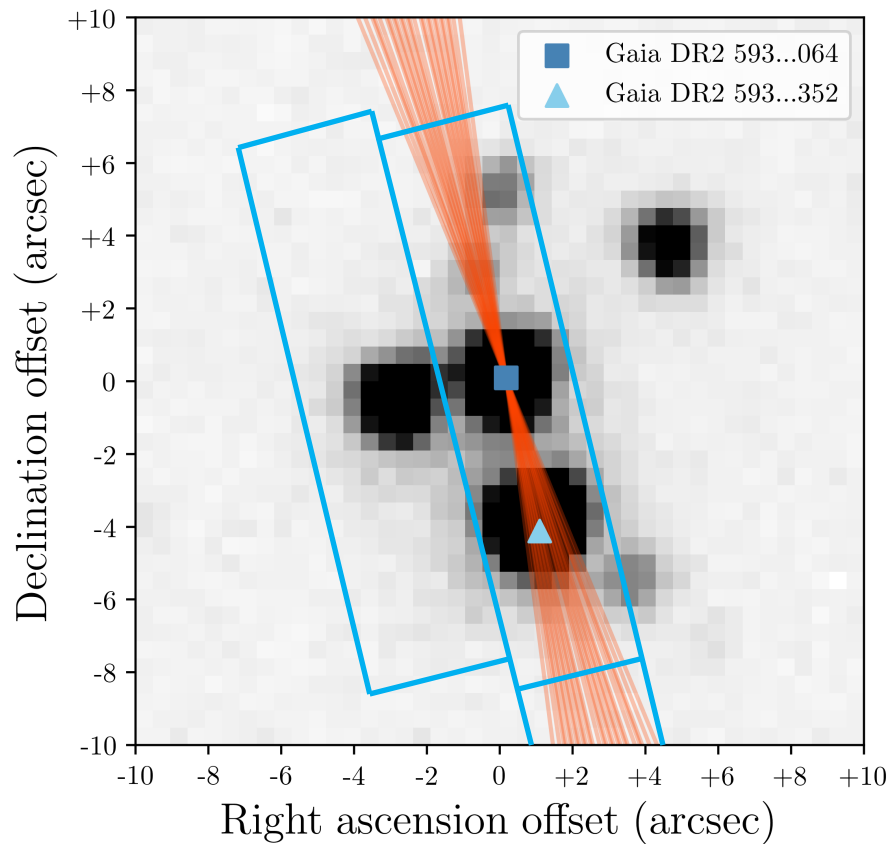
WHEN DID GAIA TAKE THE MEASUREMENTS?



The unseen companion must be at least $3 \times 10^3 M_{\odot}$.

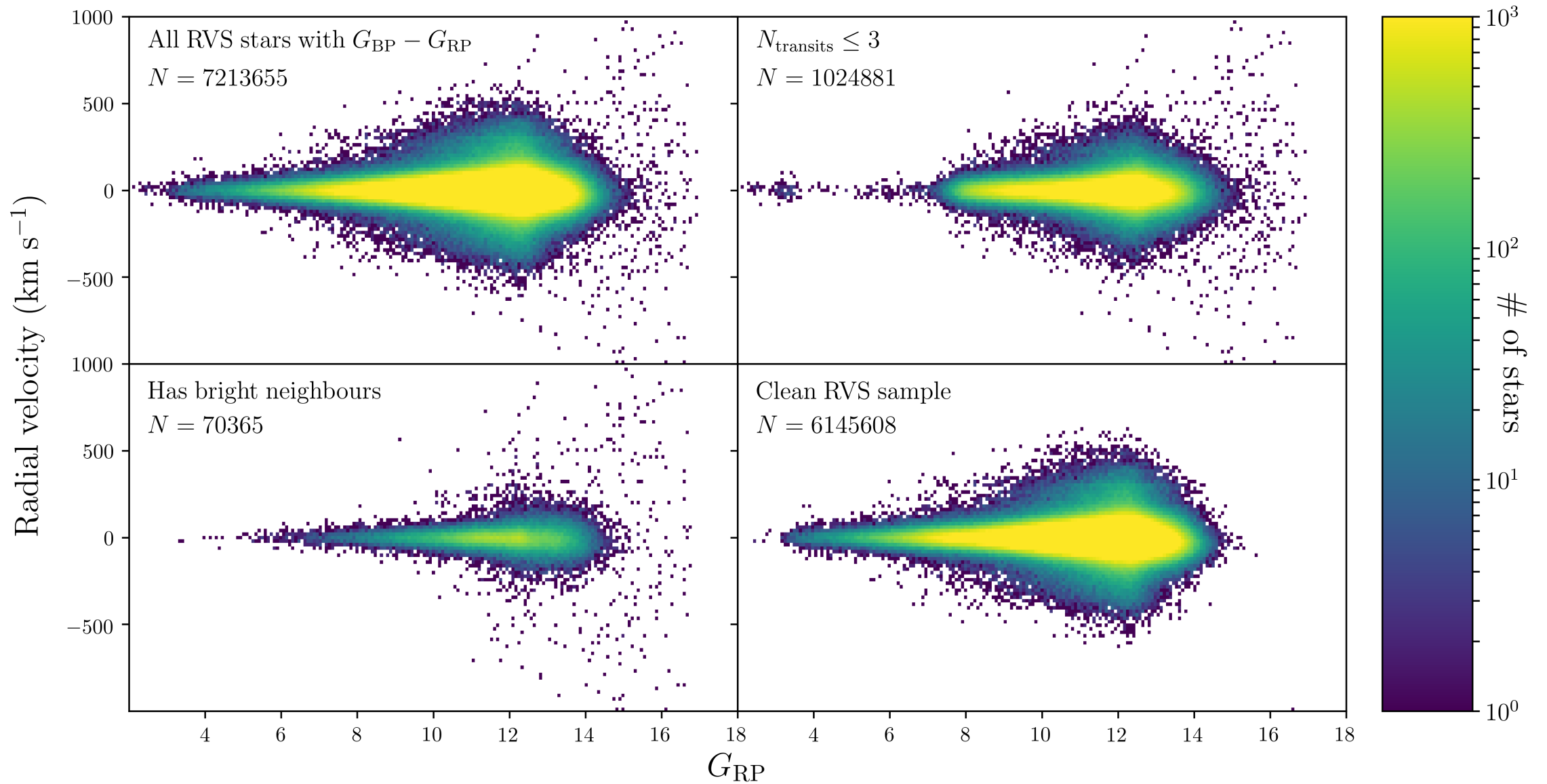


LIGHT FROM ANOTHER STAR



KEY IDEA:

“Angular offsets translate to radial velocity shifts at a rate of 145 km/s/arcsec.”



1

Investigated an almost certain hypervelocity star and disproved it.

2

Showed that Gaia spectra could blend to produce spurious RVs.

3

Identified a series of quality cuts to clean Gaia DR2.

KEY IDEA: Gaia DR3 isn't until 2021. To make progress in Galactic Dynamics, we need to understand the flaws of DR2.

CONCLUSION

Hypervelocity stars are the smoking guns of extreme stellar collisions and explosions ...

- Hypervelocity white dwarfs argue for D6 Ia supernovae
- B star ejected from LMC suggests IMBH in cluster

... but seeing a hypervelocity star just as often reveals a gap in our methodology as a new piece of astrophysics.

- Most candidates prior to DR2 were spurious
- Gaia DR2 593...064 highlighted an error in Gaia DR2