HYPERVELOCITY STAR Candidates in Gaia DR1/TGAS

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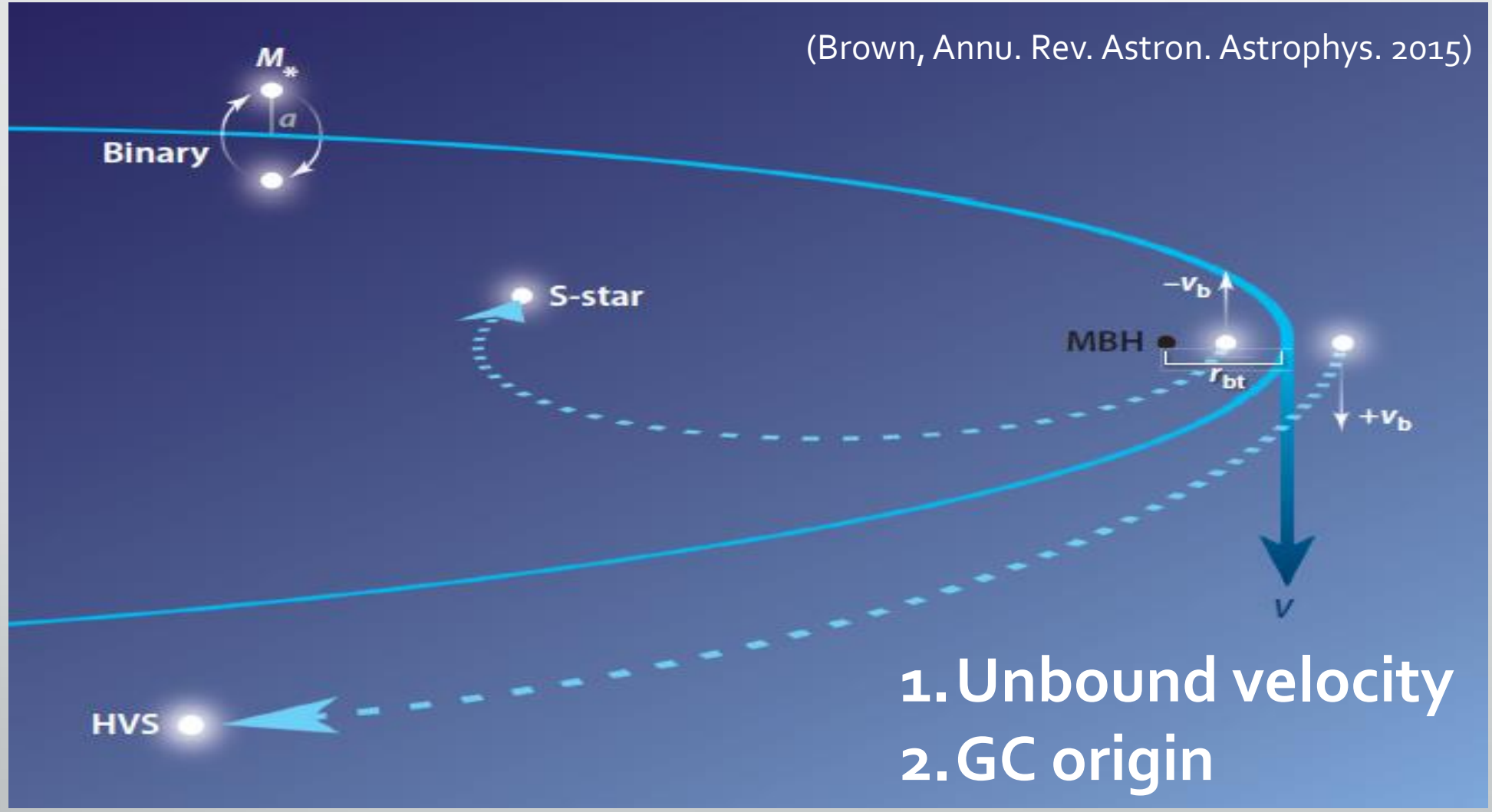
- T. Marchetti, E. M. Rossi, G. Kordopatis, A. G. A. Brown, A. Rimoldi, E. Starkenburg, K. Youakim, R. Ashley

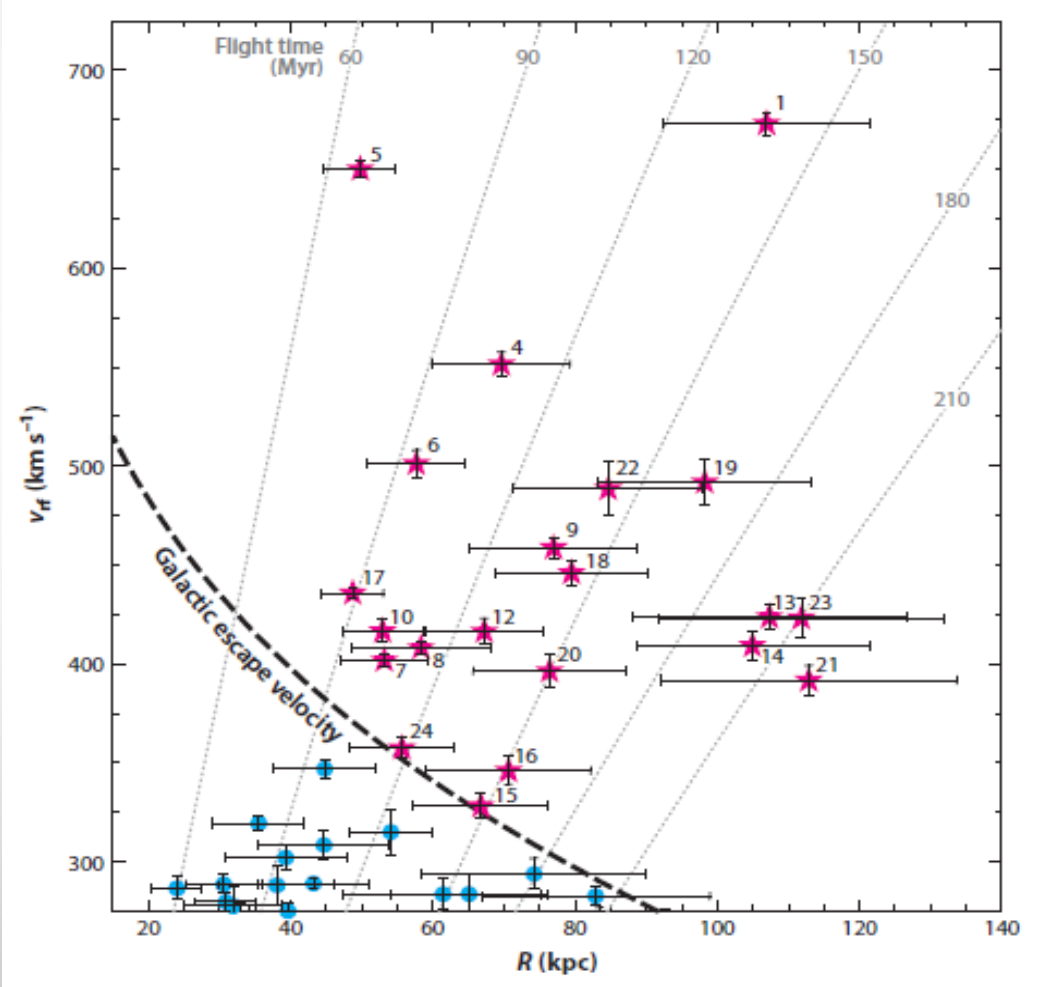
Sterrewacht Leiden

HVSs: THE HILLS MECHANISM



CURRENT OBSERVATIONS

- **MMT Hypervelocity Star Survey** (Brown et al. 2014): complete survey over 29% of sky
- 21 unbound late B-type HVSs detected in the outer halo (observational bias).
- 10'000 HVSs estimated of all masses within ~ 100 kpc (Brown et al. 2007)



(Brown, Annu. Rev. Astron. Astrophys. 2015)

HYPERVELOCITY STARS… A TOOL FOR:

- Linking the outer part of the Milky Way to the Galactic Center (difficult to observe…)
- Probing of the mass function and binary population of the Galactic Center, to understand its history and formation
- Providing important information on the shape and orientation of the Galaxy's mass distribution

(Gnedin et al. 05; Yu & Madau 07; Perets et al. 09; Rossi, TM et al. 17, ……)

WE NEED MORE DATA!

- But we need a larger sample of HVSs, not biased as the few late B-type stars known up to now, to break the degeneracy between halo and binary parameters

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GAIA SATELLITE

HVS NUMBER ESTIMATES

	relative error $< 1\%$	relative error $< 10\%$	Rmax [kpc]	Mean Mass $[M_\odot]$
Proper motion	$200 - 900$	$700 - 4000$	~ 35	~ 1
Parallax		a few tens	~ 10	$\sim 1 - 2$
Radial Velocity	$100/150$		~ 25	~ 3

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- ***Golden sample*** with average errors of 0.1% on proper motions and 15% on parallax

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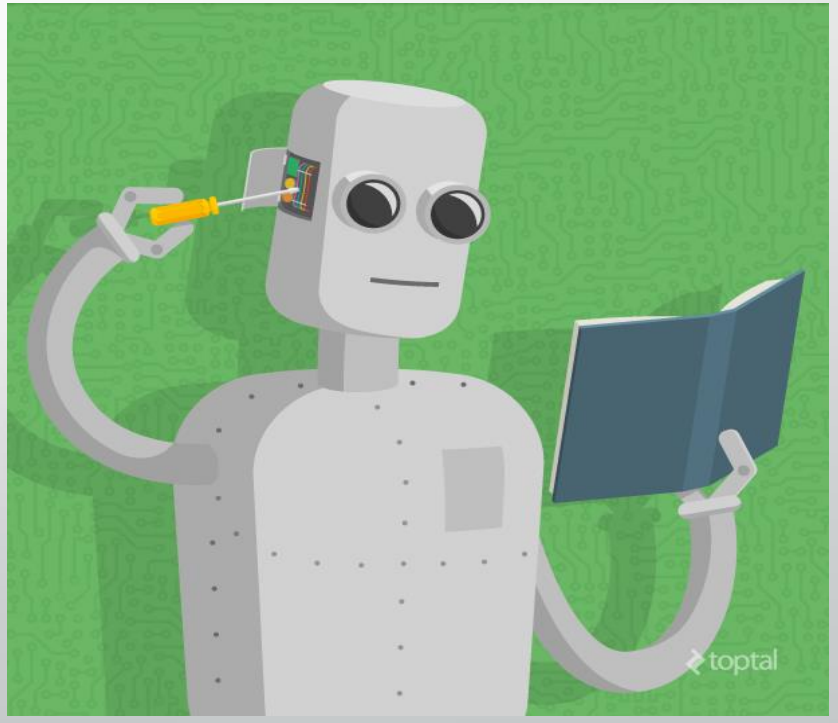
- Estimates in Gaia DR1/TGAS: ~0,1 /1,5 HVSs

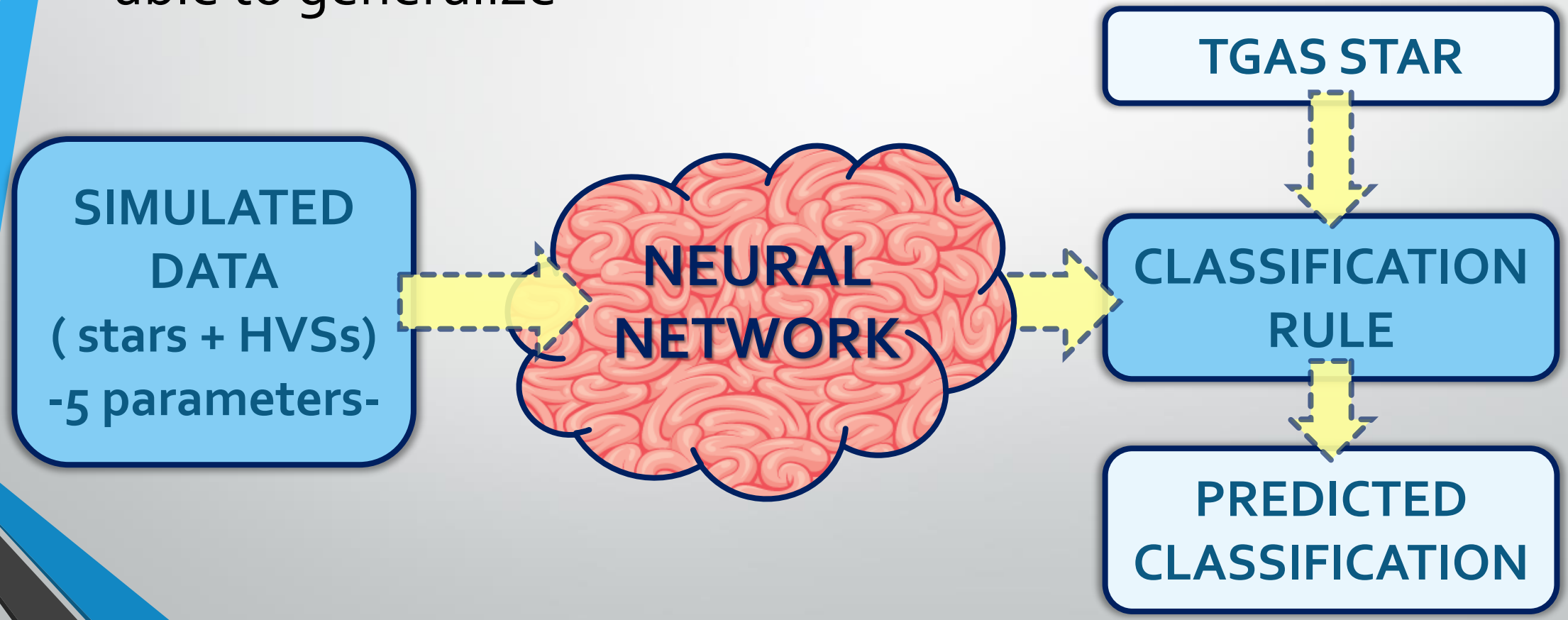
MACHINE LEARNING!

- ***SUPERVISED LEARNING:*** The algorithm is presented with example units and their desired outputs, in order to **learn** a general rule that maps inputs to outputs.
- ***OUR APPROACH:*** Training the algorithm on HVSs mock populations (1) and on «normal» stars from the Gaia mock catalogue (GUMS) (0) (Robin et al. 2012).
- Choice of the 5 parameters $(\alpha, \delta, \varpi, \mu_\alpha, \mu_\delta)$ for training the algorithm.



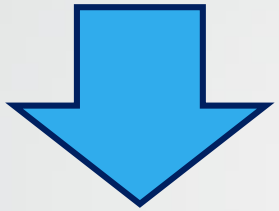
DATA MINING ROUTINE

- Training a **NEURAL NETWORK**: nonlinear algorithm, able to generalize



BLIND APPLICATION TO TGAS

- 2.057.050 stars (TGAS)



NN Probability > 0,5

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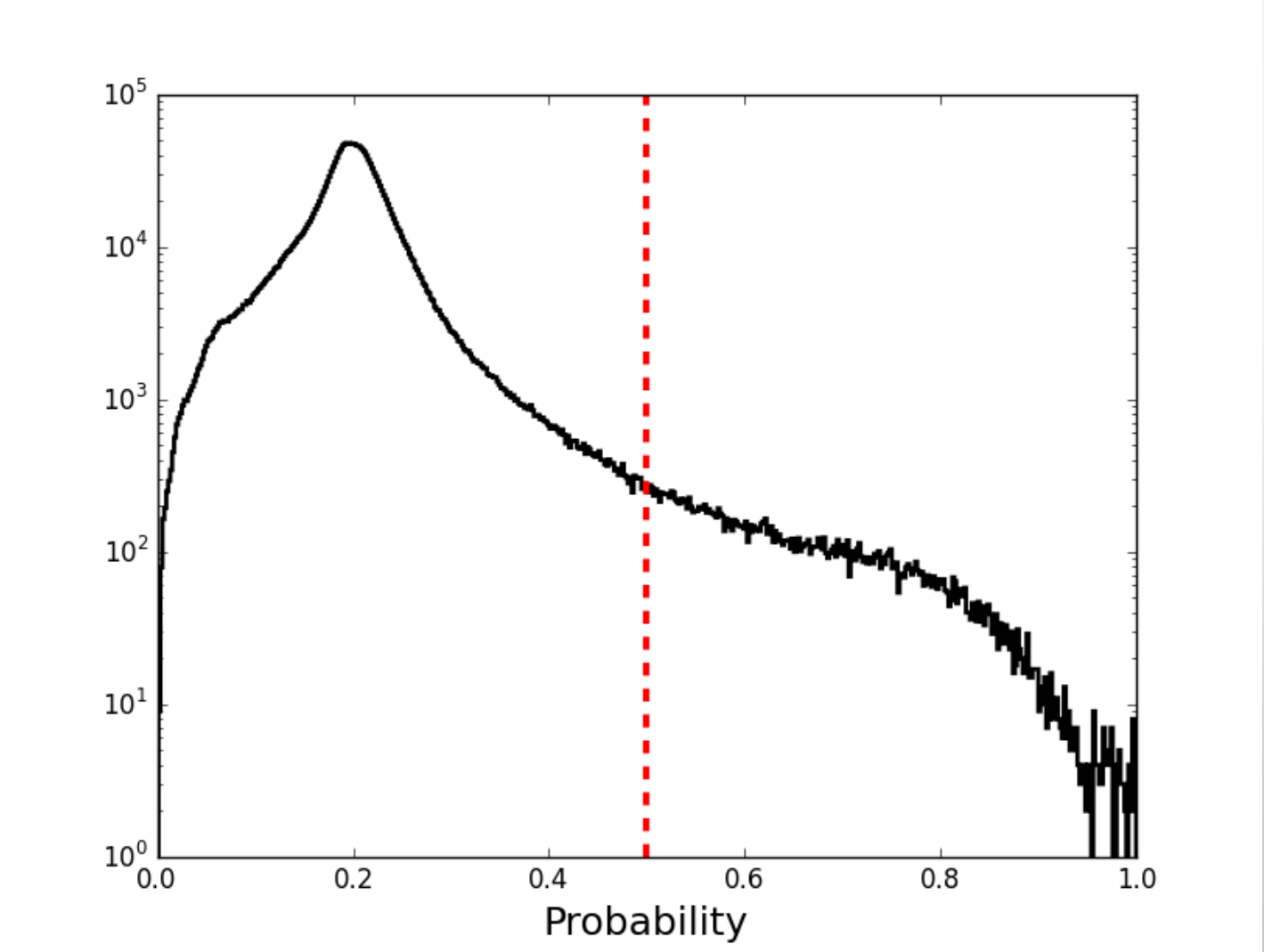

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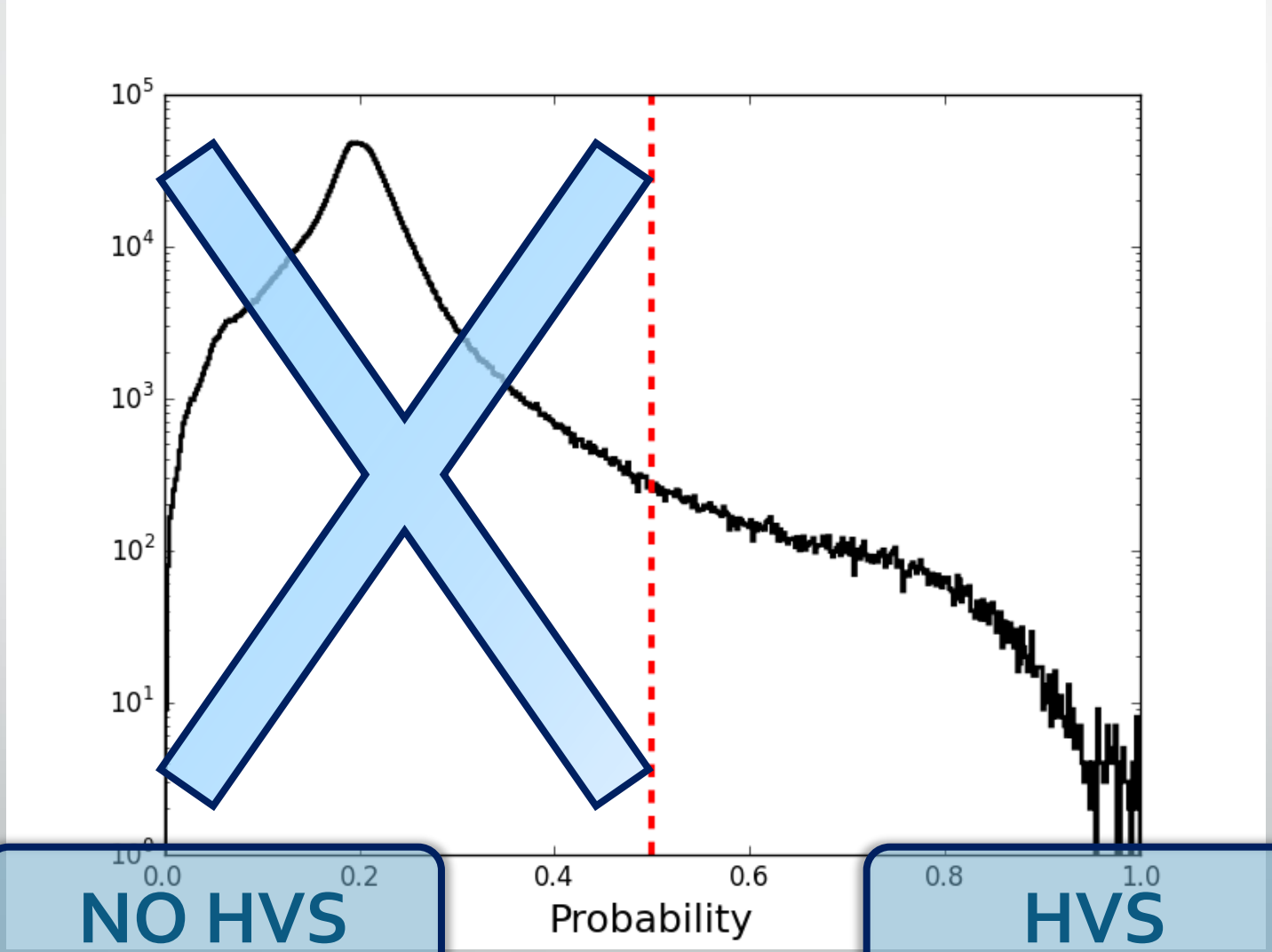

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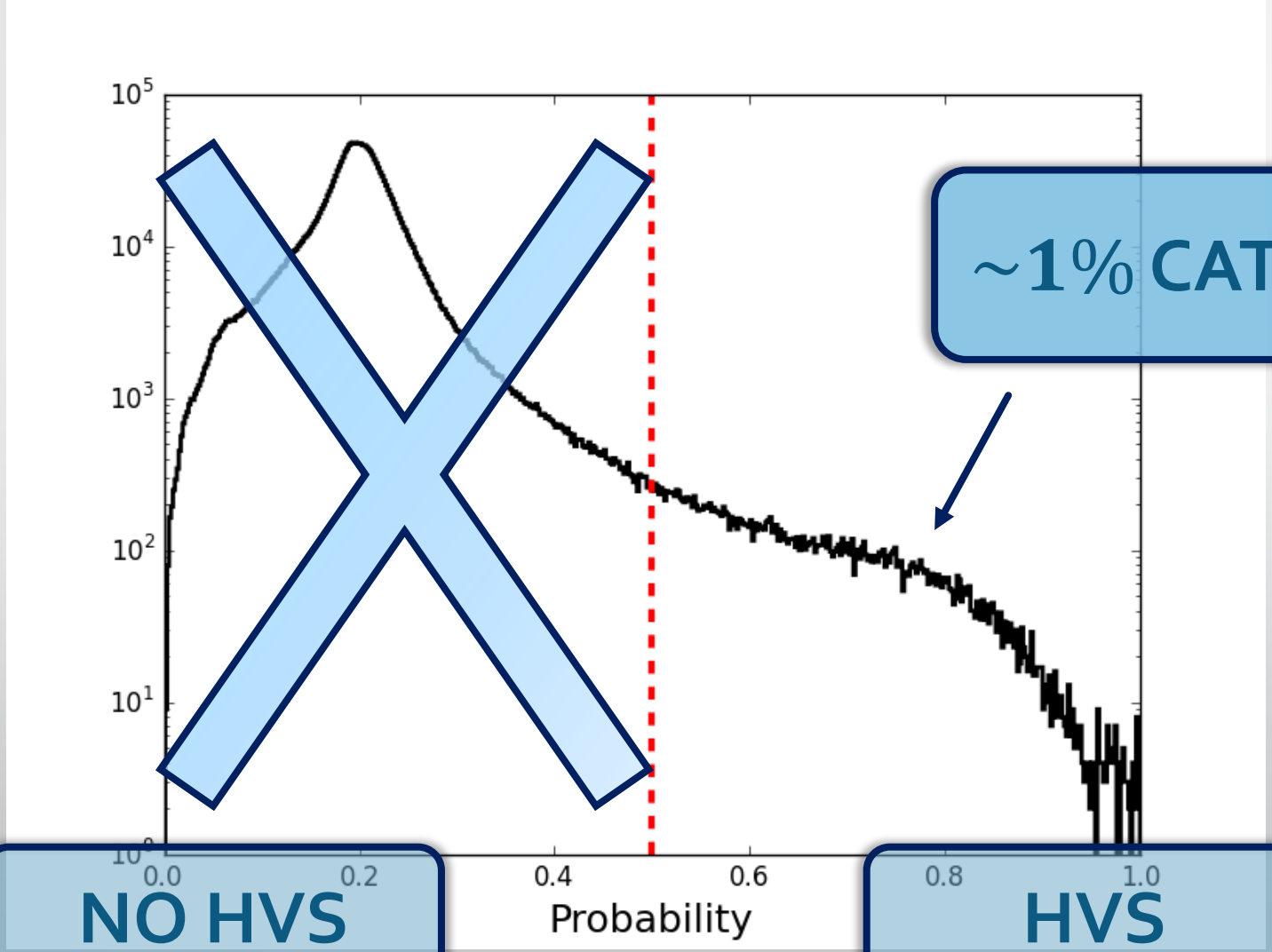

~1% CATALOGUE!

NO HVS

HVS

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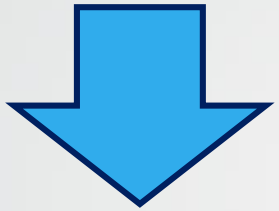

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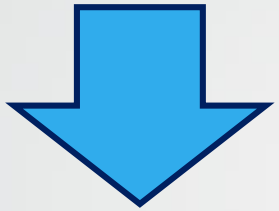

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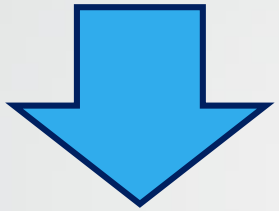

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MC over errors, mean – sigma $>$ 0,9

- **80 candidates** (0,004% catalogue)

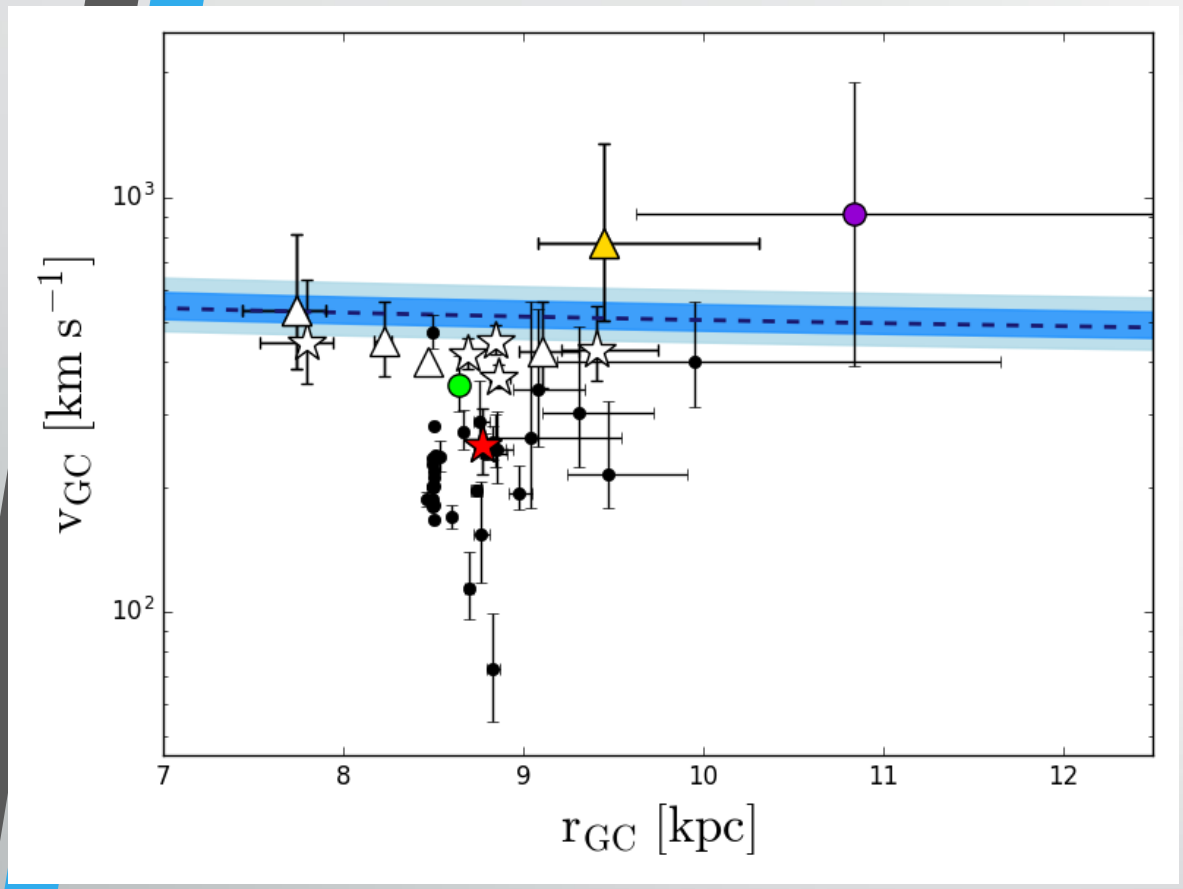
RADIAL VELOCITY ACQUISITION

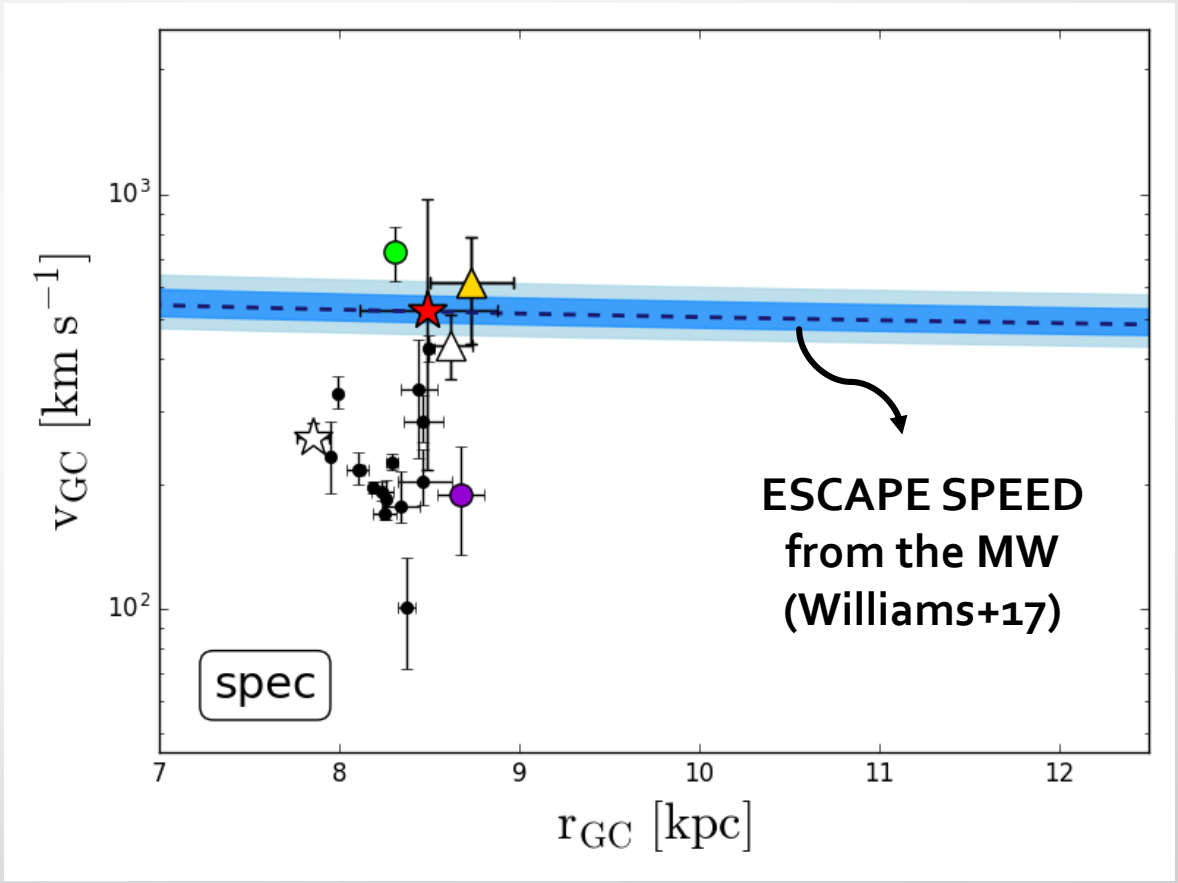
- Time at Isaac Newton Telescope for 22 candidates

- Cross-match with spectroscopic surveys of the Milky Way: RAVE, LAMOST, APOGEE, Gaia-ESO
- Parallax-inferred distances for 47 stars (Bailer-Jones 05, Astraatmadja & Bailer-Jones 16 a,b)
- Spectroscopic distances for 22 stars

→ 2 different velocity estimates

CANDIDATES

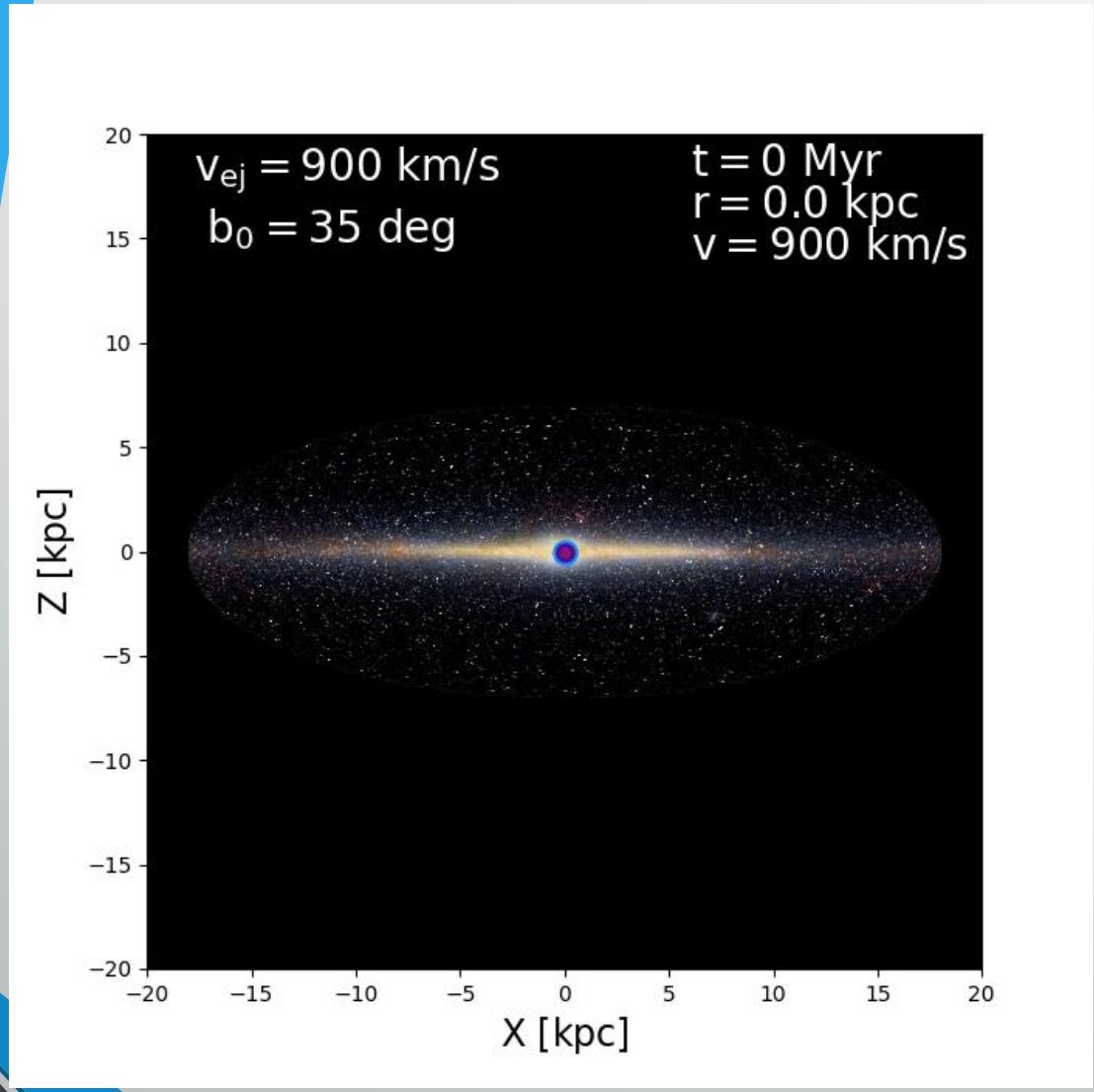




- 45 stars with $v > 150$ km/s
- 14 stars with $v > 400$ km/s

- 11 (3) stars are consistent with being unbound in the 1° (2°) panel

HVS/BHVS CANDIDATES



Orbit Integration: Galpy (Bovy 2005)

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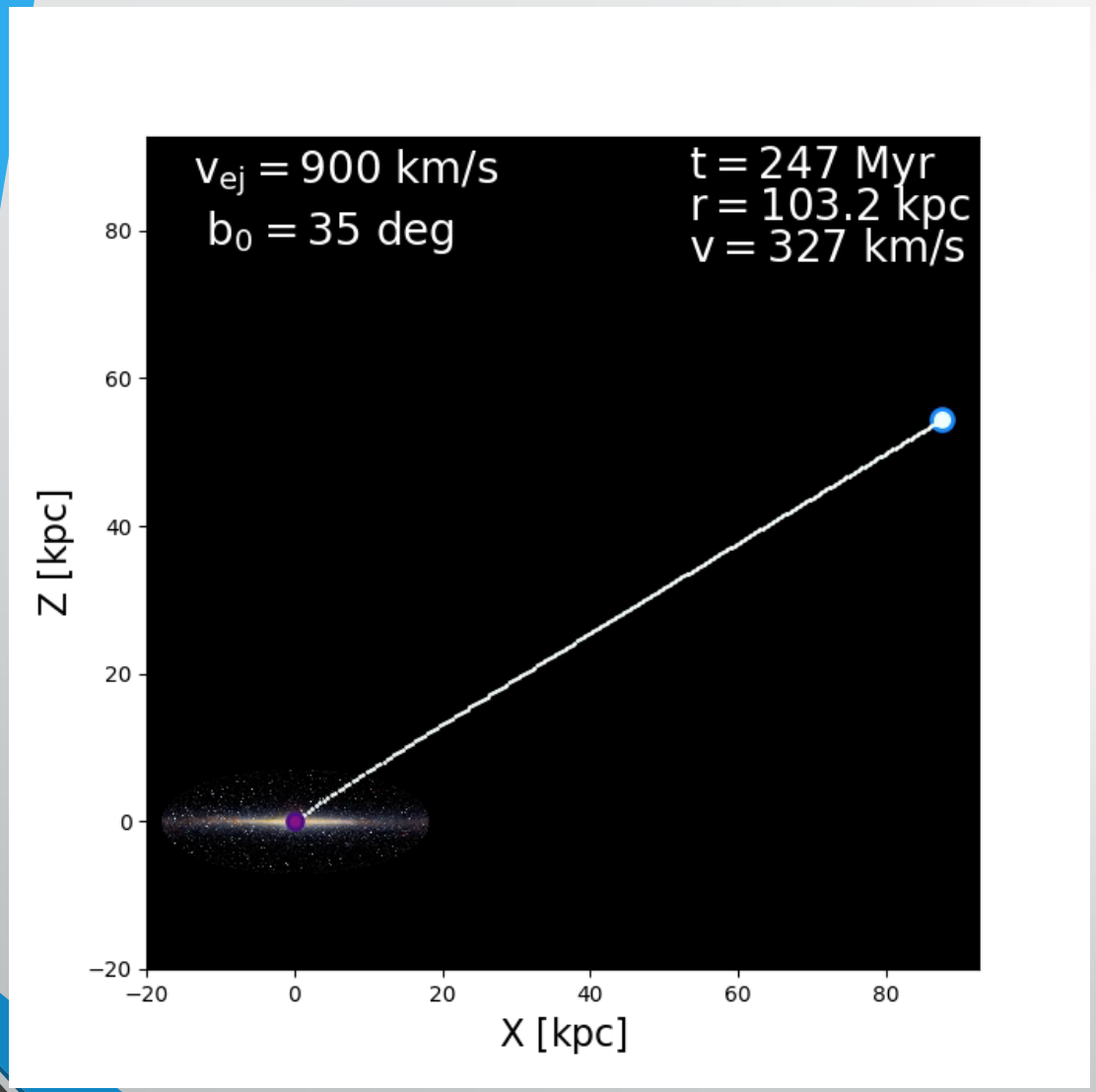

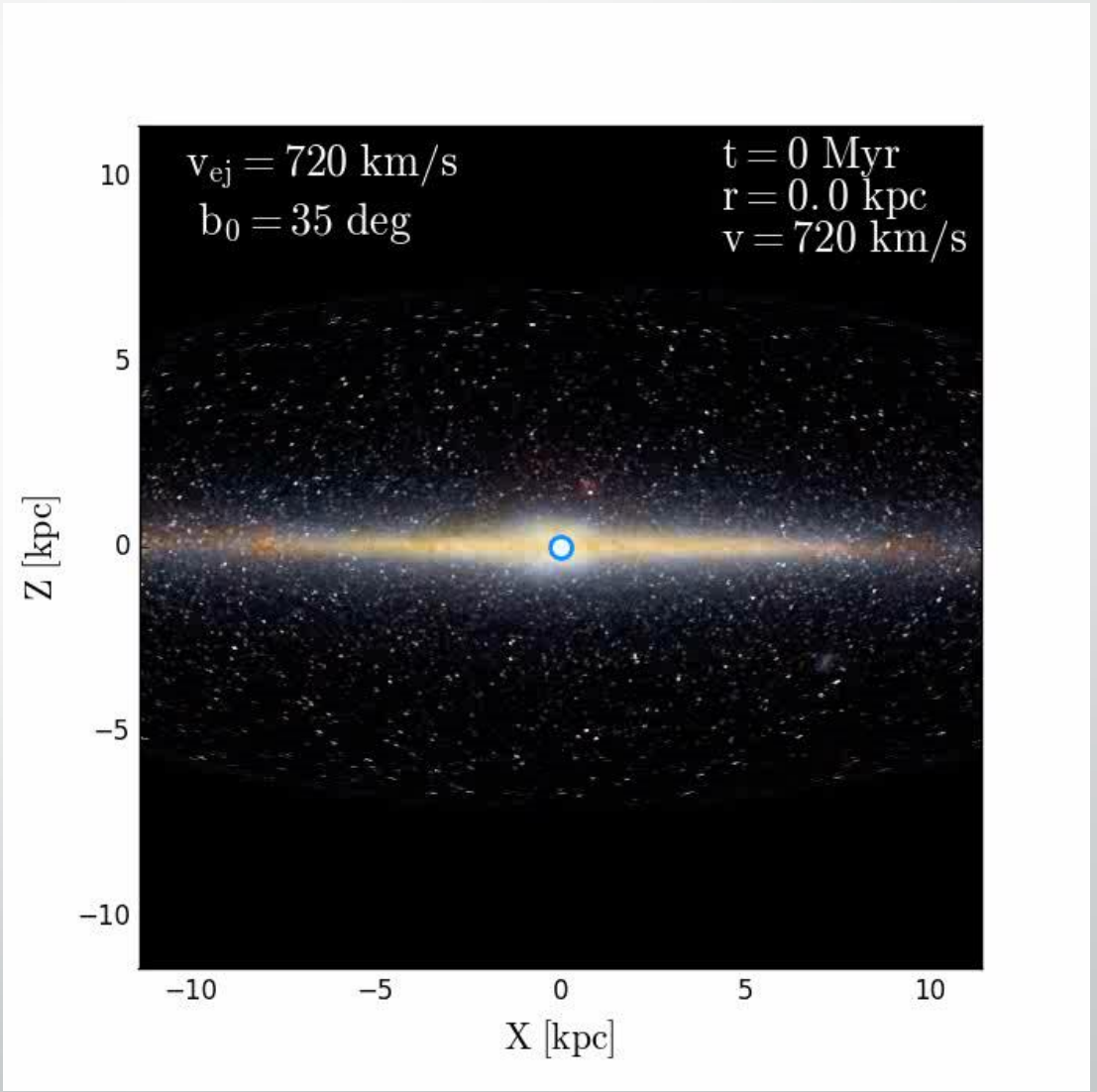

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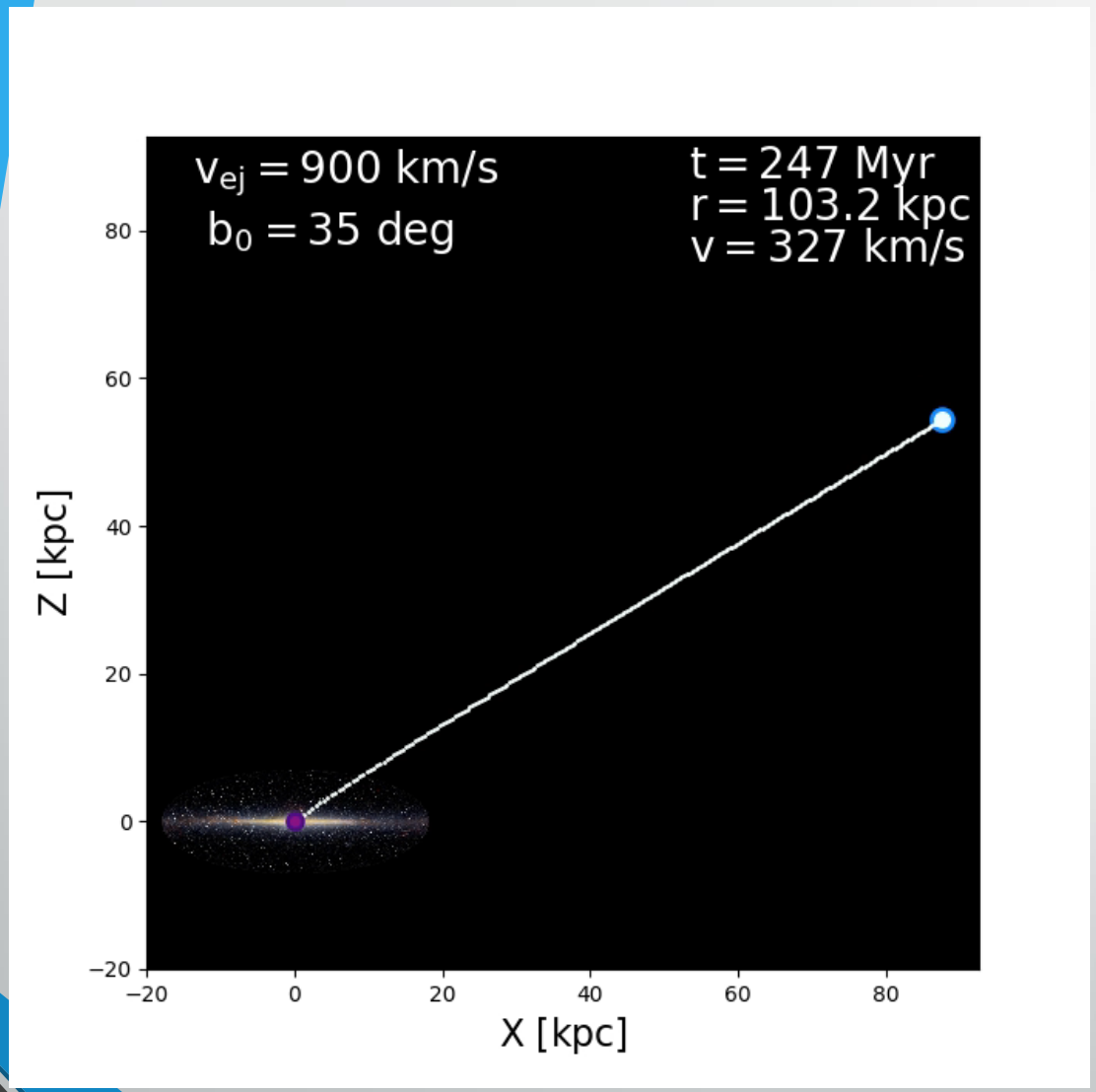

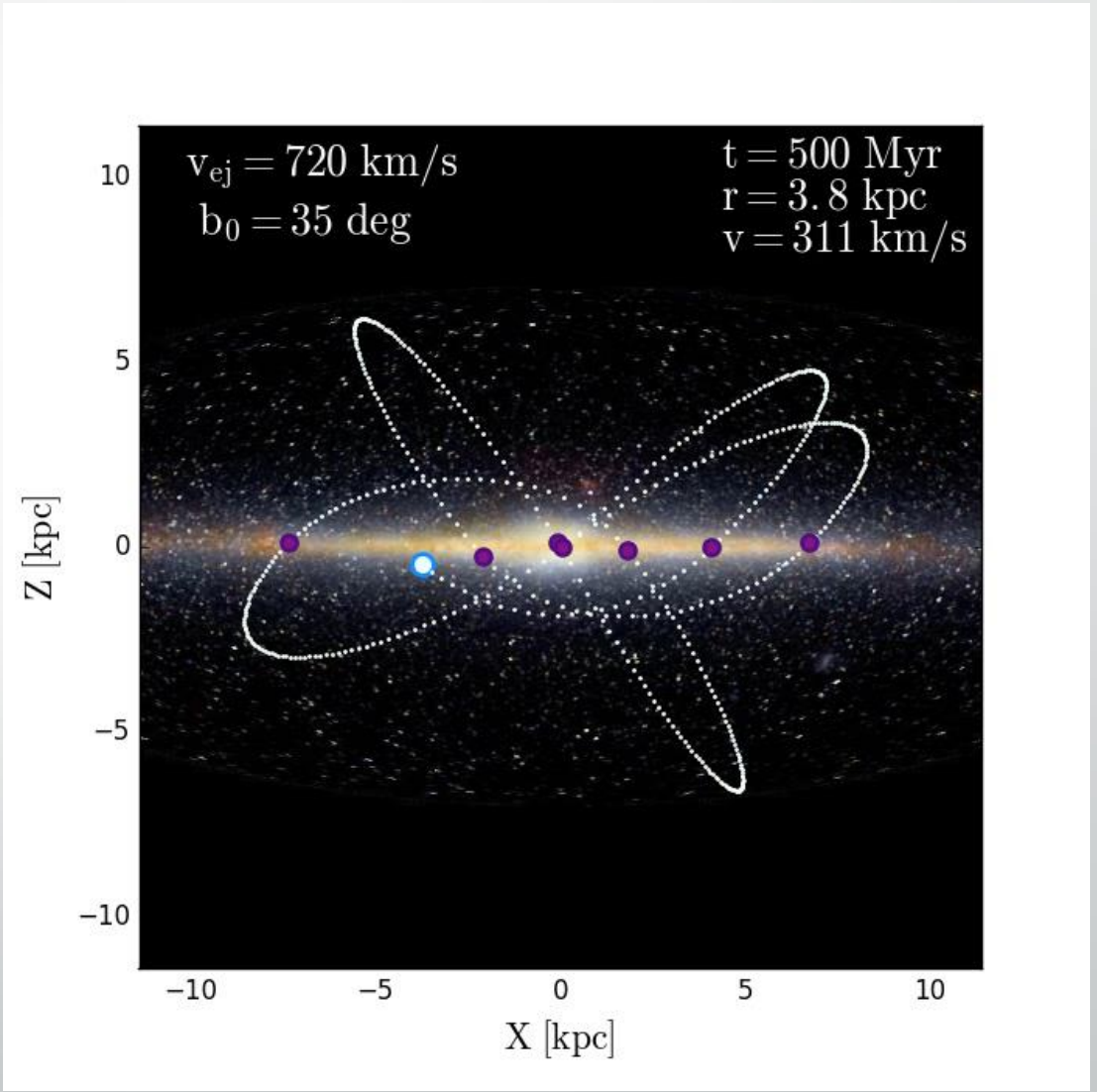

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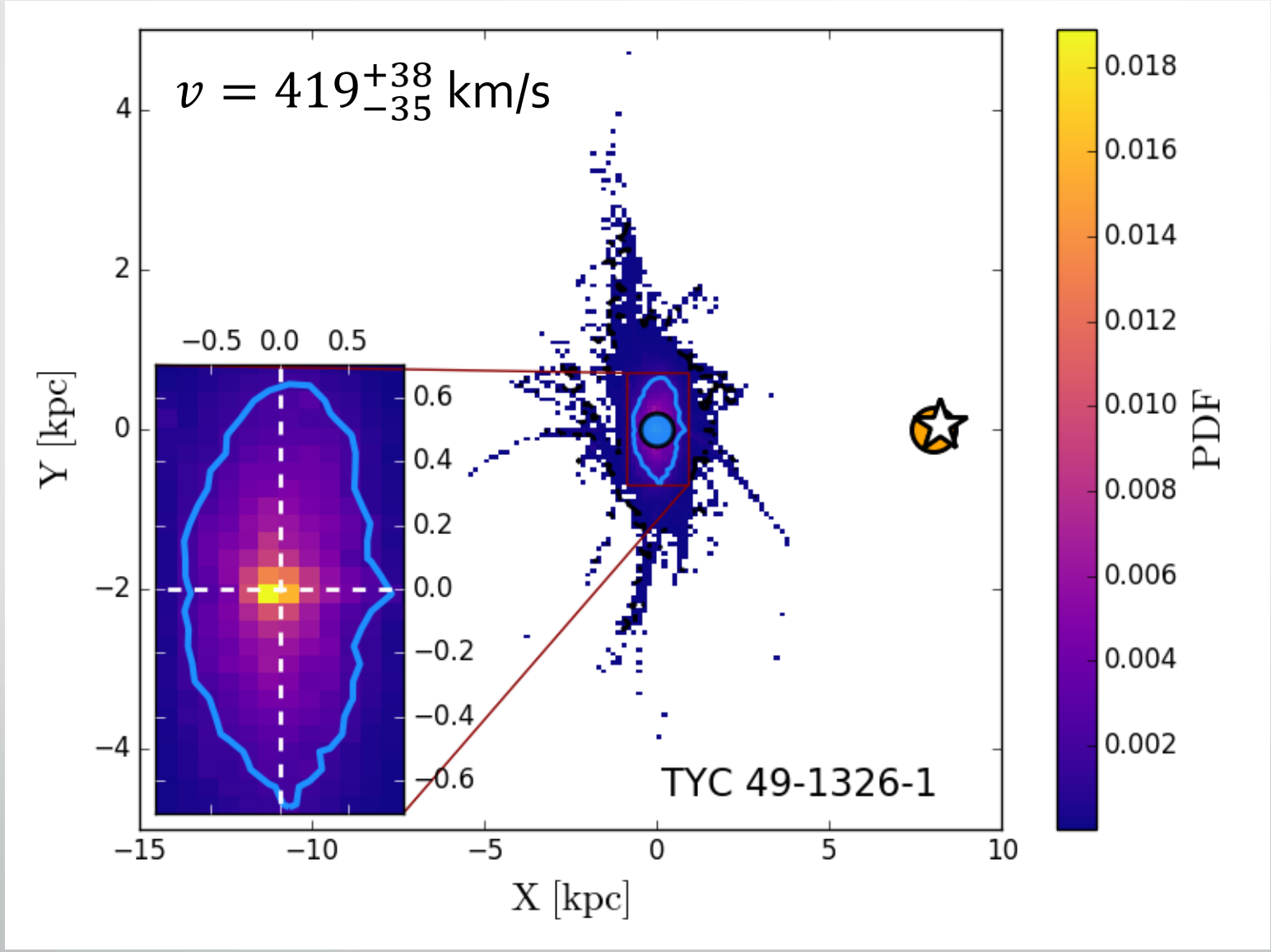
BHVS CANDIDATES



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HVS CANDIDATES

TYC 2 ID	v_{GC}	P_u
2298-66-1	252^{+58}_{-38} / 523^{+448}_{-306}	0.2% / 50.6%
8422-875-1	446^{+186}_{-89}	29.1%
2456-2178-1	430^{+117}_{-68}	22.7%
2348-333-1	448^{+44}_{-32}	7.6%
49-1326-1	419^{+38}_{-35}	1.2%
5890-971-1	366^{+}_{-20}	0.2%

RUNAWAY STAR CANDIDATES

TYC 2 ID	v_{GC}	P_u
7111-718-1	776^{+576}_{-274} / 611^{+176}_{-172}	82.2% / 70.7%
8374-757-1	532^{+284}_{-147}	50.4%
1071-404-1	449^{+113}_{-78}	23.7%
4515-1197-1	423^{+135}_{-76} / 434^{+79}_{-76}	23.3% / 15.8%
9404-1260-1	402^{+4}_{-4}	0.0%

CONCLUSIONS

- We are expecting hundreds/thousands of HVSs in the Gaia catalogue;
- The data mining routine has been optimized for the very unbalanced search of rare objects in a large dataset, and succeded in finding high velocity stars
- 5 stars with probability > 50% of being unbound
- 1 HVS candidate, 5 bound HVSs, and 5 runaway stars (2 hyper-runaway stars)
- Waiting for DR2 !