HYPERVELOCITY STAR

Candidates in Gaia DR1/TGAS

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1. Unbound velocity
2. GC origin

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)

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, ......)

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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

WE NEED MORE DATA!
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- 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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- **Golden sample** with average errors of 0.1% on proper motions and 15% on parallax

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- Estimates in Gaia DR1/TGAS: $\sim 0.1 / 1.5$ HVSs
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 ($\alpha, \delta, \omega, \mu_\alpha, \mu_\delta$) for training the algorithm.

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

- **DATA MINING ROUTINE**
  - SIMULATED DATA (stars + HVSs)
    - 5 parameters
  - **NEURAL NETWORK**
    - **TGAS STAR**
    - **CLASSIFICATION RULE**
    - **PREDICTED CLASSIFICATION**

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BLIND APPLICATION TO TGAS

- 2.057.050 stars (TGAS)

NN Probability > 0.5
BLIND APPLICATION TO TGAS

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BLIND APPLICATION TO TGAS

![Graph showing probability distribution with an 'X' marker indicating no HVS and HVS regions.](image_url)
BLIND APPLICATION TO TGAS

NO HVS

~1% CATALOGUE!

HVS

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BLIND APPLICATION TO TGAS

- 2.057.050 stars (TGAS)
  - NN Probability $> 0.5$
- 22.263 candidates (1% catalogue)
BLIND APPLICATION TO TGAS

• 2.057.050 stars (TGAS)

  ↓

  NN Probability > 0.5

• 22.263 candidates (1% catalogue)

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  \(|\Delta \omega/\omega| < 1\)

• 8.175 candidates (0.4% catalogue)
BLIND APPLICATION TO TGAS

• 2.057.050 stars (TGAS)
  \[ \text{NN Probability} > 0.5 \]

• 22.263 candidates (1% catalogue)
  \[ \left| \frac{\Delta \omega}{\omega} \right| < 1 \]

• 8.175 candidates (0.4% catalogue)
  \[ \text{MC over errors, mean – sigma} > 0.9 \]

• 80 candidates (0.004% catalogue)

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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

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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

ESCAPE SPEED from the MW (Williams+17)
HVS/BHVS CANDIDATES

Orbit Integration: Galpy (Bovy 2005)
HVS/BHVS CANDIDATES

Orbit Integration: Galpy (Bovy 2005)

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HVS/BHVS CANDIDATES

Orbit Integration: Galpy (Bovy 2005)
BHVS CANDIDATES

\[ v = 419^{+38}_{-35} \text{ km/s} \]
## HVS CANDIDATES

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<tr>
<th>TYC 2 ID</th>
<th>$v_{GC}$</th>
<th>$P_u$</th>
</tr>
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<tbody>
<tr>
<td>2298-66-1</td>
<td>$252^{+58}<em>{-38} / 523^{+448}</em>{-306}$</td>
<td>0.2% / 50.6%</td>
</tr>
<tr>
<td>8422-875-1</td>
<td>$446^{+186}_{-89}$</td>
<td>29.1%</td>
</tr>
<tr>
<td>2456-2178-1</td>
<td>$430^{+117}_{-68}$</td>
<td>22.7%</td>
</tr>
<tr>
<td>2348-333-1</td>
<td>$448^{+44}_{-32}$</td>
<td>7.6%</td>
</tr>
<tr>
<td>49-1326-1</td>
<td>$419^{+38}_{-35}$</td>
<td>1.2%</td>
</tr>
<tr>
<td>5890-971-1</td>
<td>$366^{+}_{-20}$</td>
<td>0.2%</td>
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<tr>
<td>7111-718-1</td>
<td>$776^{+576}<em>{-274} / 611^{+176}</em>{-172}$</td>
<td>82.2% / 70.7%</td>
</tr>
<tr>
<td>8374-757-1</td>
<td>$532^{+284}_{-147}$</td>
<td>50.4%</td>
</tr>
<tr>
<td>1071-404-1</td>
<td>$449^{+113}_{-78}$</td>
<td>23.7%</td>
</tr>
<tr>
<td>4515-1197-1</td>
<td>$423^{+135}<em>{-76} / 434^{+79}</em>{-76}$</td>
<td>23.3% / 15.8%</td>
</tr>
<tr>
<td>9404-1260-1</td>
<td>$402^{+4}_{-4}$</td>
<td>0.0%</td>
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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 succeeded 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 !