Hypervelocity stars in the Gaia era

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Hypervelocity stars

- 2005 discovery in SDSS catalogue (Brow et al.)

- dedicated spectroscopic survey, targeting B stars in outer Halo with MMT telescope

- found around around 20 unbound HVSs

- trajectory and energy points towards an origin close to SgA*

Galactic Rest frame velocity versus Galacto-centric distance

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Modelling HVS ejection

1. *star* binary tidally disrupted  2. *black hole* binary scatters stars

Hills 1988

Yu & Tremaine 2003

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One explanation for 2 mysteries

1. *star* binary tidally disrupted
   
   \[ S\text{-}stars \text{~cluster<} 0.04 \text{~pc from } SgrA^* \]

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Hills 1988

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Star trajectories: *new* method

- simplify equations of motion exploiting large discrepancy in mass
- very precise, fast and allow large parameter space investigation
- different from direct 3-body (e.g. Kenyon, Bromley)

Sari et al 2010

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Sari, Kobayashi & EMR 10, Kobayashi et al 12, EMR et al. 14

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Ejection velocity

geometry of encounter

Ejection velocity

\[ v = K \sqrt{2Gm_c/a_b} \left( \frac{M}{m_t} \right)^{1/6} \]

binary separation

Analytical description of the ejection velocity

Sari et al 2010
Velocity distribution

below peak: galactic deceleration

around peak: separation distribution

above peak: no influence of GP

dependence on mass distribution

$N_v$ depends on binary properties at GC (mass and separation “a”) and on Galactic potential

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what can we learn?

- Binary population in the galactic centre do not have flat distribution in logP. There are more wider binaries: e.g. $f_\alpha \propto \alpha^3$

Rossi et al. 2014
Importance of HVS study

but we need more and better data (and modelling) to

• Distinguish formation models, informing stellar dynamical models around SMBHs

• Determine stellar binary properties at Galactic Centre: mass and separation distribution

• Study the shape and depth of Galactic Potential and its components (bulge, disc, halo)
need more data: Gaia!

- **Great Opportunity**: select HVSs not spectroscopically but astrometrically exploiting their peculiar radial trajectory ==> larger (~a few 100) and less biased sample

- **Challenge**: sieve through $10^9$ star catalogue to find ~a few 100 HVSs
The HVS project in Leiden

Running simulations, using Gaia mock catalogue to:
• determine best part of sky to discover HVS w Gaia
• determine # HVS with given mass and precision
• identify contaminants
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Known HVSs: too far for Gaia

proper motion expected < 0.5 mas/yr, smaller or equal to Gaia detection errors

work by Master Student Joshua Albert

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High accuracy below 30 kpc

& Radial velocity below 16 kpc

Relative errors for a B5V star with $v = v_{\text{esc}}$, A. Brown’s pyGaia package

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Conclusions

• An unprecedented large sample of HVSs can be built with Gaia

• This requires an efficient way to extract HVSs candidates from catalogue

• A large sample may allow for unprecedented measurements of Galactic properties, like the shape and depth of the Galactic potential at different scales