

Hypervelocity stars in the tidal debris of a disrupted dwarf galaxy

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Hypervelocity stars (HVS)

- Are stars with unusually high radial velocities.
- Thought to be unbound to the Milky Way.
- Postulated by Hills (1988), originating from the gravitational interaction of stellar systems with the supermassive black hole at the Galactic center.
- First HVS found by Brown et al. (2005).
- In the latest HVS compilation (Brown et al. 2006, 2007a,b) the **anisotropic distribution of HVS on the sky** raised doubts on the interpretations as being propelled out by the black hole-ejection mechanism.
- Abadi et al. (2009) proposed an **alternative origin** for some of the HVS in the compilation: the tidal debris of a passing (or disrupted) satellite having a fraction of its stars in the 'outer' tidal arm gaining enough speed during a pericentric passage and eventually become unbound.

Energy distribution of the tidal debris

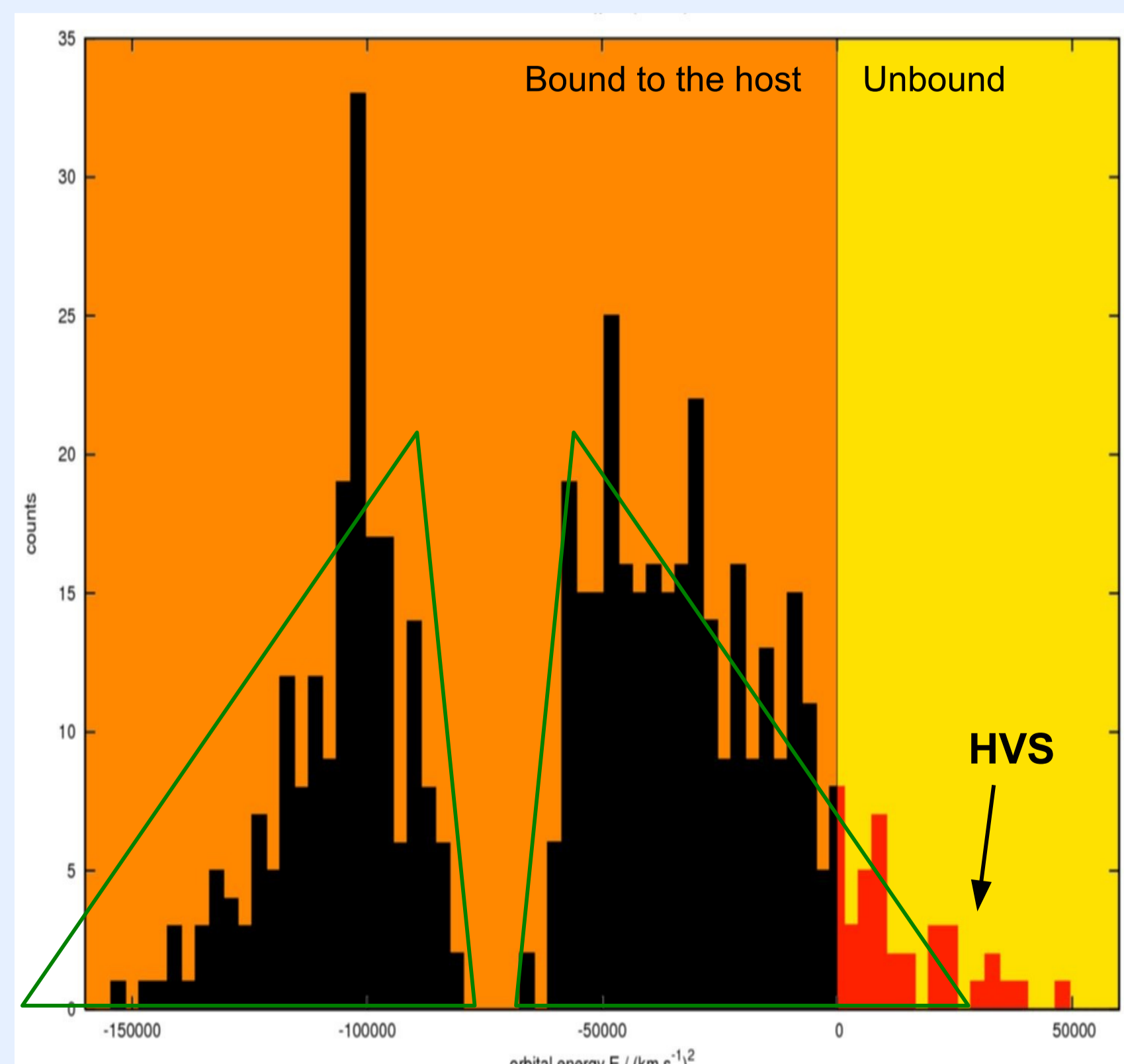
Johnston (1998) developed a rough semianalytic model for the energy distribution of the stars in the tidal debris of a disrupted satellite galaxy:

- Developed with rigid host systems.
- Simple bi-triangular form of the distribution (see figure below)
- Characteristic scale of the spread in energy of the debris stars depending on satellite and host potential and satellite orbit.
- For the fraction of stripped-off mass a fit had to be made for each individual simulation.

We attempt to

- check if the model is still valid for live halos
- improve this model by finding dependencies on the initial conditions of the interactions.

In this way the model gains predictive power. By focusing on the high energy tail of the distribution we can thereby estimate the fraction of HVS generated.



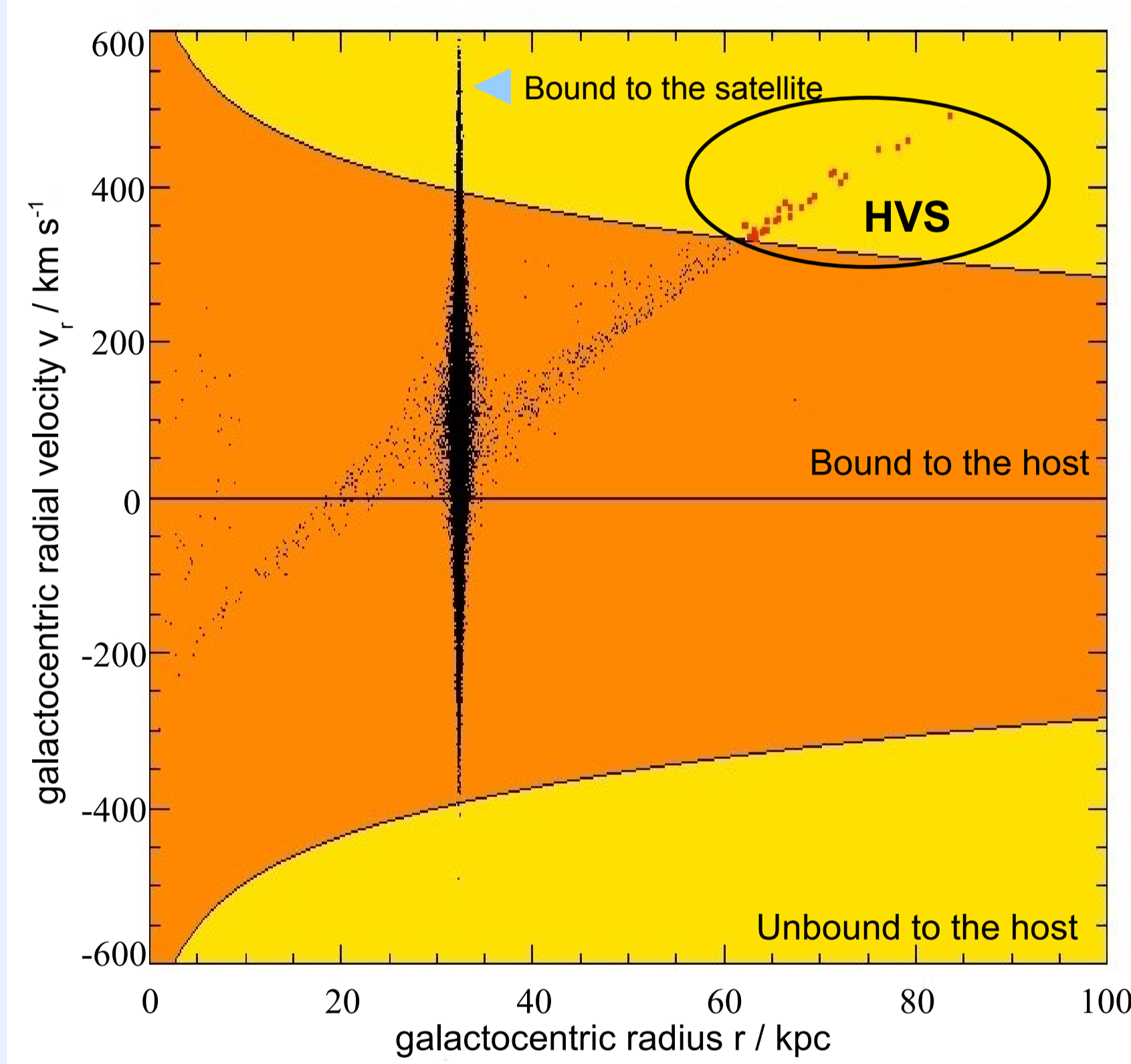
Energy distribution of stripped-off stars after the first pericentric passage. The middle of the gap between the two peaks marks the orbital energy of the satellite. Stars with positive energy are also unbound to the host system. The green triangles visualize the rough approximation of the energy distribution of Johnston (1998).

Motivations and Aims

If the accreted satellite mechanism provides a significant number of HVS, these unbound stars could be used as tracers for past accretion events.

Our work aims to further explore this scenario by means of *N*-body simulations to

- show that HVS can be produced by this process.
- determine the efficiency and the critical parameters of producing HVS via the accreted satellite mechanism.



Snapshot of a simulation shortly after the first pericentric passage of the satellite galaxy in radial velocity versus galactocentric distance (host galaxy not plotted). 'Bound' and 'Unbound' area are separated by the local escape speed of the host. The two tidal arms are clearly visible left and right to the satellite core.

N-body simulations

The simulations are modeling collisions of a low-mass satellite galaxy with its much more massive host system.

For the *N*-body code we use GADGET-2. To synthesize the effect of the initial conditions of the satellite the host galaxy we use:

- Only *N*-body dynamics with stars and dark matter.
- Newtonian space with vacuum boundary conditions.
- A host galaxy with as little intrinsic evolution as possible. For its representation we use two approaches:
 - An implementation of a time-independent rigid potential into the simulation code.
 - A so-called live halo, where the host galaxy is also represented by an *N*-body system in equilibrium (initialization routine taken from Springel & White (1999)).
- The host is designed to resemble our own Galaxy with halo, disk and bulge component.
- For the satellite galaxy a Plummer sphere is used with core radius $r_{\text{core}} = 0.1 - 1.0$ kpc.
- Satellite masses were 0.1 - 3 % of the mass of the host system.

For the initial coverage of the parameter space relatively low numbers of particles are used:

- 5×10^4 in the satellite.
- 2.6×10^5 in the live halo.

Follow-up simulations with larger particle numbers are planned.

Initial results

By simulating isolated host-satellite pairs of galaxies over a variety of different initial conditions we will determine the efficiency and the critical parameters of producing HVS via the accreted satellite mechanism:

- Presently only polar orbits had been studied to exclude the effect of prograde and retrograde encounters.
- Orbits with high eccentricity ($e > 0.9$).

For these conditions we find:

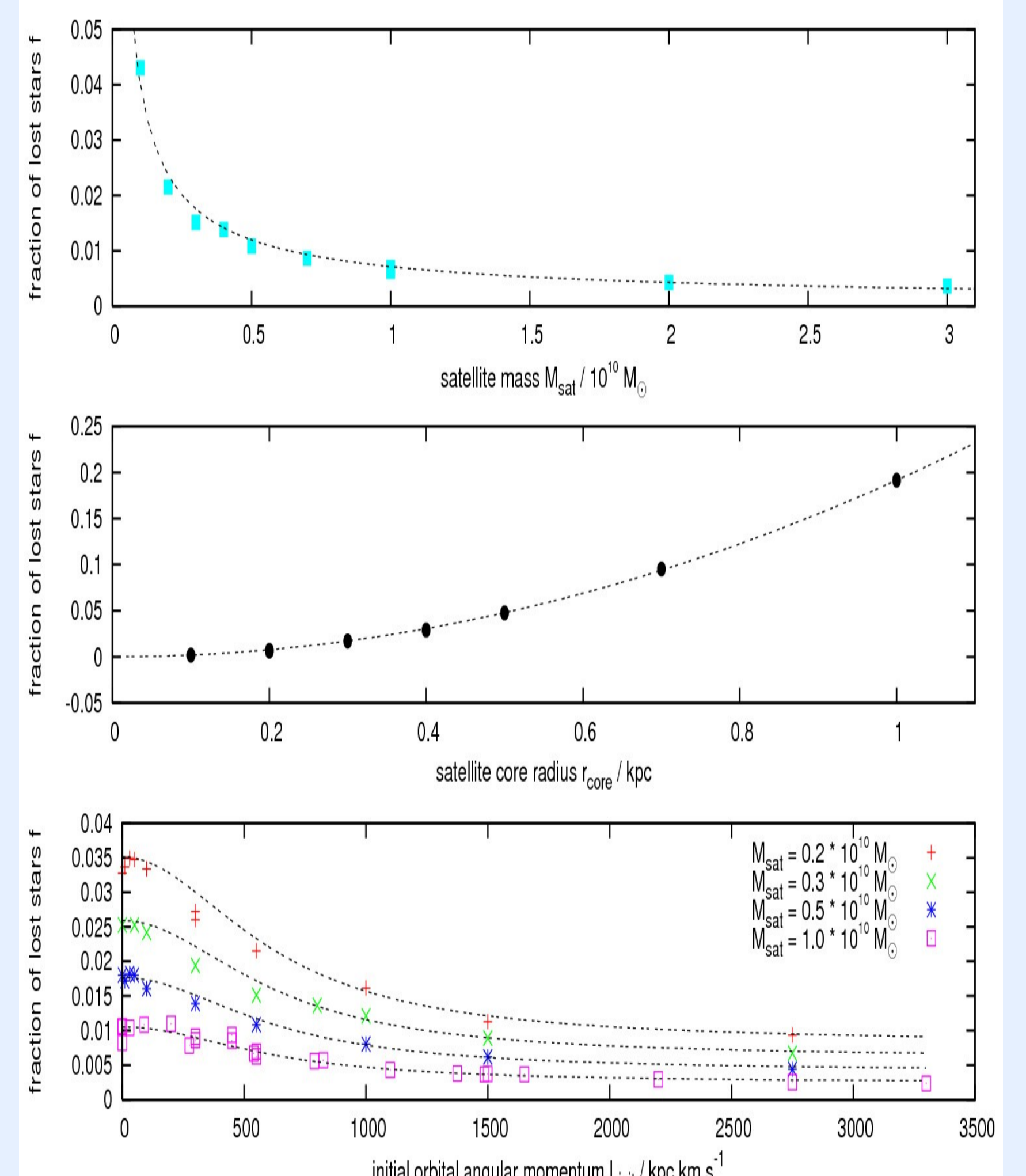
- Tight relations between stripped-off mass fraction f and initial conditions (see figure below):

$$f \propto M_{\text{sat}}^{-\alpha}$$

$$f \propto r_{\text{core}}^2$$

$$f \propto (\lambda^2 + L_{\text{init}}^{-2})^{-1}$$

- In almost all of the runs performed in this work unbound stars were generated.



Initial results of our parameter space study with a live halo. The fraction of stripped-off satellite stars after one pericentric passage for varying initial conditions. Top panel: initial mass of the satellite, middle panel: Plummer core radius of the satellite, bottom panel: initial angular momentum of the satellite. All other parameters were kept constant, respectively. The dotted lines indicate the curve progression of our fitting formula given the relations above.

Conclusions

- HVS can be produced during a merger event.
- We have promising initial results of our parameter space study. Tied back to the Johnston semianalytic model these results will be used to extract a formula for the HVS production as a function of the initial conditions of the approaching satellite and the host properties.
- The coverage of the parameter space has to be extended to other orbital parameters as for different host systems.
- The next step in our study will be to compare our models to the observational data from the RAVE and SDSS/SEGUE surveys, focusing on the high-velocity end of the distributions.

References

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