Hypervelocity Stars and S-Stars From Eccentric Stellar Disk Around SMBH

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Introduction

Recent observations of the Galactic halo revealed ≈ 20 B-type stars moving over the Galactic escape velocity (e.g. Brown et al. 2014). Proper motions of these unbound hypervelocity stars (HVSs) indicate their origin in the center of our Galaxy (GC). In the GC, another group of similar number of B-type stars known as S-stars is observed less than 0.04 pc from the central supermassive black hole (SMBH; e.g. Do et al. 2013). Long before their discovery, such two groups of stars were predicted by Hills (1988) as a natural result of breakups of binaries in the tidal field of the SMBH. The origin of these binaries and their transport to the vicinity of the SMBH, however, remain puzzling.

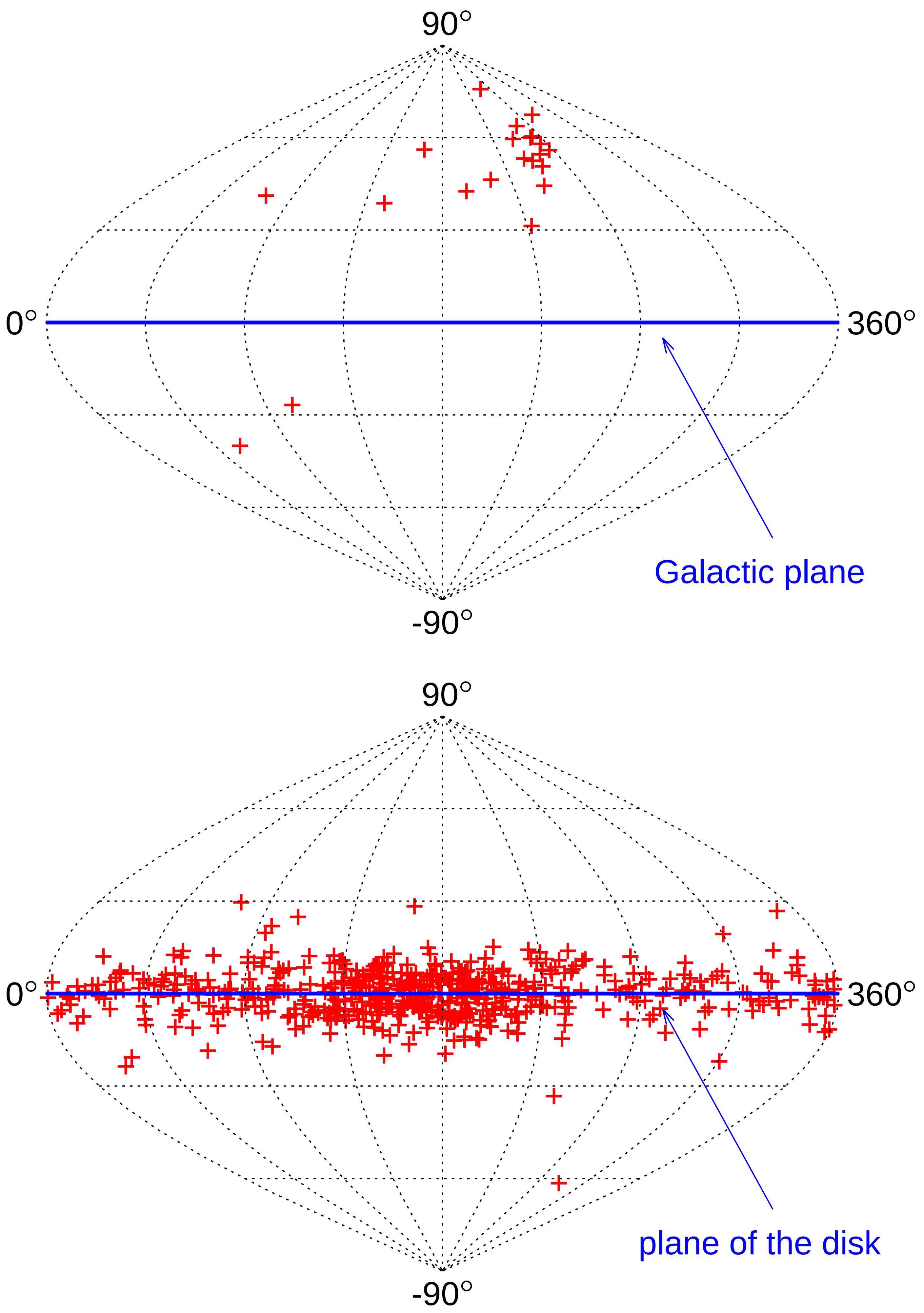

Figure 1: Sinusoidal projection of positions of the HVSs observed on the sky (top; Galactic coordinates) and produced in our model (bottom; disk plane defines zero latitude).

In this work, we assume that the binaries were formed within an eccentric stellar disk around the SMBH (similar to that observed in the GC at distances $0.04\ \mathrm{pc} \lesssim r \lesssim 0.4\ \mathrm{pc}$; e.g. Paumard et al. 2006). We qualitatively discuss the key properties of the HVSs and S-stars formed by the tidal breakups of such binaries brought towards the SMBH by the Kozai-Lidov dynamics in the potential of the disc itself (see the poster of Ladislav Šubr).

Model and Method

For the first time, we investigate this problem by means of direct N-body modeling. Our model contains two main constituents: (i) the SMBH modeled as a single massive particle, and (ii) the stellar disk represented by 2000 mutually gravitationally interacting stars that initially form 1000 binaries. The optional third component is a smooth spherical potential which emulates the old spherical cluster that is also observed in the Galactic center (e.g. Do et al. 2013). The N-body integrator is NBODY6 (Aarseth 2003).

Results

Our calculations show that, on average, 12 HVSs per realization are produced in our model within ≈ 8 Myr of evolution (if scaled to the dimensions of the stellar disk in the GC). One of the most striking features of the observed HVSs is their anisotropic distribution on the sky shown in the top panel of Fig. 1 in Galactic coordinates. In order to test whether this is reproduced in our model, we plot the positions of the HVSs from several tens of realizations of our model in analogous coordinates where, however, the plane of zero latitude is the plane of the stellar disk (bottom panel). The reason for such a choice is the unknown orientation of the parent stellar disk with respect to the Galactic plane. We see that the HVSs in our model are highly anisotropically distributed. Fig. 2 shows the key properties of the former companions of the HVSs, the S-stars. In the top panel, we see that the S-stars (red line) are found below the inner radius of the disk which is in accord with the observations (cyan line describes all stars in the disk). The bottom panel displays the cumulative distribution function, N_e, of the orbital eccentricities of the S-stars (red line) which appears to be close to thermal $N_e \propto e^2$ (green line) which is slightly flatter than indicated by the observations (e.g. Gillessen et al. 2009). Note, however, that the numbers and properties of the HVSs and S-stars obtained in our model strongly depend on various parameters of the system such as the properties of the original binaries and their orbits around the SMBH or the strength of the spherical potential of the old star cluster (see the poster of Ladislav Šubr).

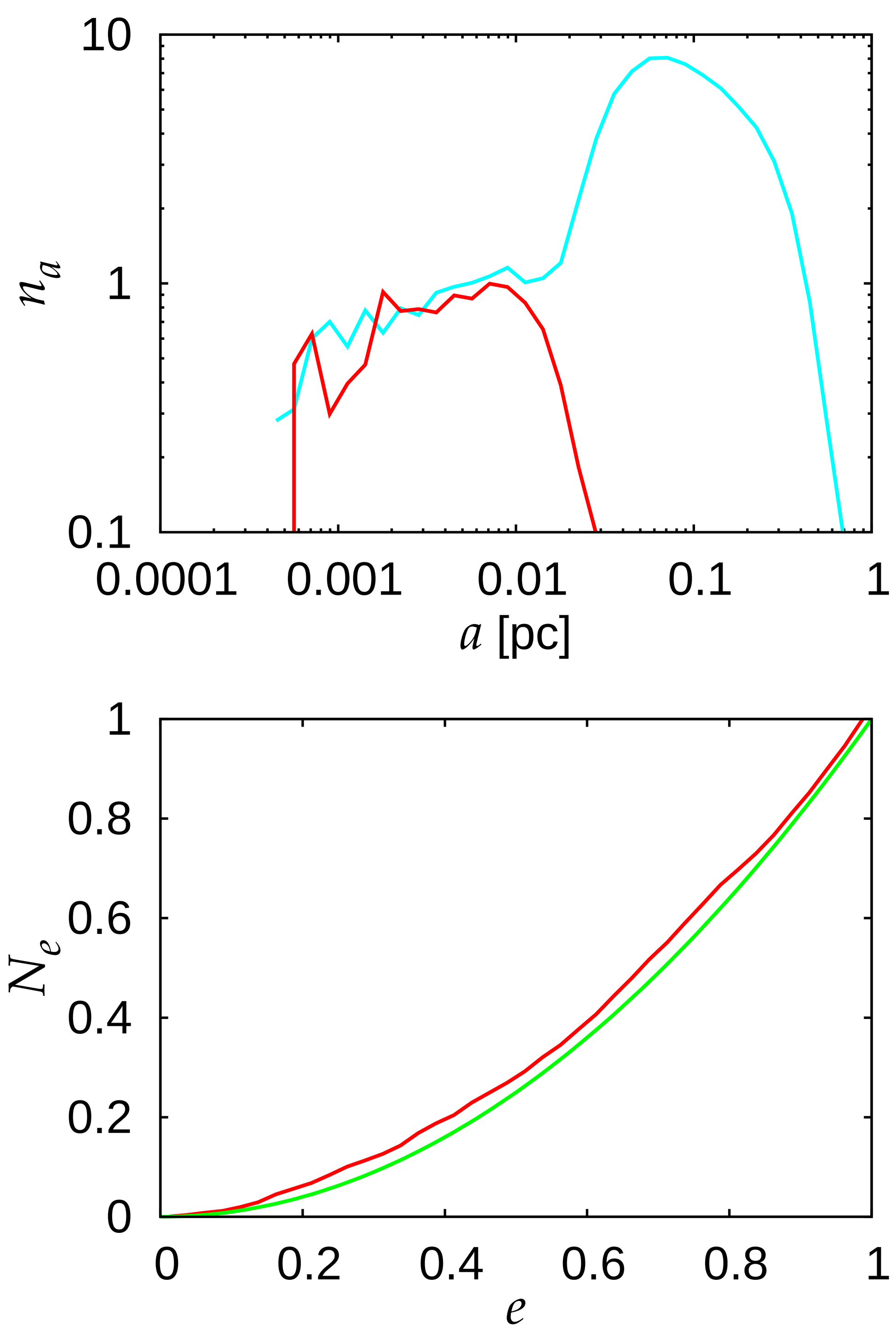

Figure 2: Distribution functions of semimajor axes (top) and eccentricities (bottom) of the orbits of the S-stars produced in our model.

References and Acknowledgments

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