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Hypervelocity stars and S-stars from eccentric stellar disc around SMBH

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Abstract. Recent observations of the Galactic halo revealed ≈ 20 B-type stars moving over the Galactic escape velocity (e.g., Brown, Geller, & Kenyon 2014). Proper motions of these unbound hypervelocity stars (HVSs) indicate their origin in the centre 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. In this work, we assume that the binaries were formed within an eccentric stellar disc around the SMBH (similar to that observed in the GC at distances 0.04 pc $\lesssim r \lesssim$ 0.4 pc; e.g., Paumard et al. 2006). We qualitatively discuss the key properties of the HVSs and S-stars formed by tidal breakups of such binaries brought towards the SMBH by the Kozai-Lidov dynamics in the potential of the disc itself (for more details of the dynamics, see Haas & Šubr 2016).

Key words. Galaxy: halo – Galaxy: nucleus – black hole physics – methods: numerical – stars: kinematics and dynamics – stars: early-type

1. Introduction

For the first time, we investigate this problem by means of direct N-body modelling. Our model contains two main constituents: (i) the SMBH treated as a single massive particle, and (ii) the stellar disc 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 GC (e.g., Do et al. 2013). We use N-body integrator NBODY6 (Aarseth 2003). Further details of our numerical setup can be found in Šubr & Haas (2016).

2. 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 disc in the GC). One of the most striking features of the observed HVSs is their anisotropic distribution on the sky shown in the upper 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 disc (lower panel). The

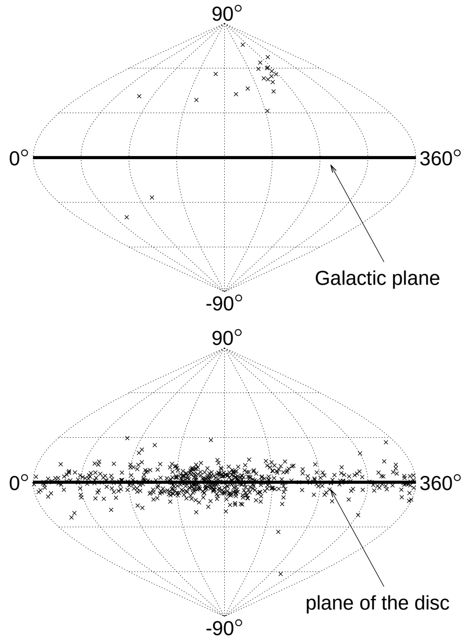

Fig. 1. Sinusoidal projection of positions of the HVSs observed on the sky (top; Galactic coordinates) and those produced in our model (bottom; disc plane defines zero latitude).

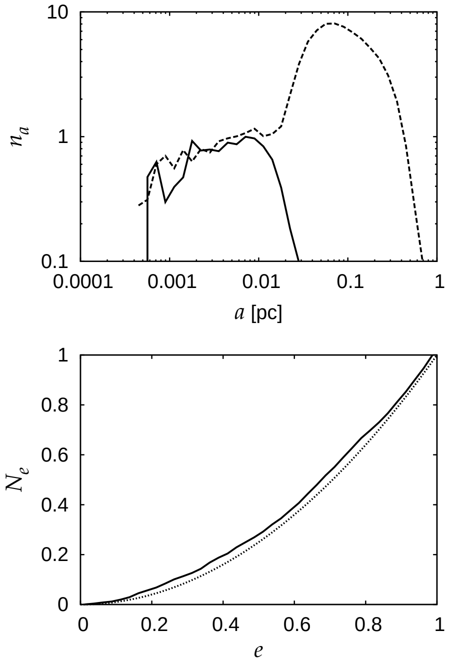

Fig. 2. Distribution functions of semimajor axes (top) and eccentricities (bottom) of the orbits of the S-stars produced in our model.

reason for such a choice is the unknown orientation of the parent stellar disc 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 our model. In the upper panel, we see that the S-stars (solid line) are found below the inner radius of the disc which is in accord with the observations (dashed line describes all stars in the disc). The lower panel displays the cumulative distribution function, N_e, of the orbital eccentricities of the S-stars (solid line) which appears to be close to thermal $N_e \propto e^2$ (dotted 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 Šubr & Haas 2016).

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