SMBH Accreting Stars in Axisymmetric Galactic Nuclei

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Introduction

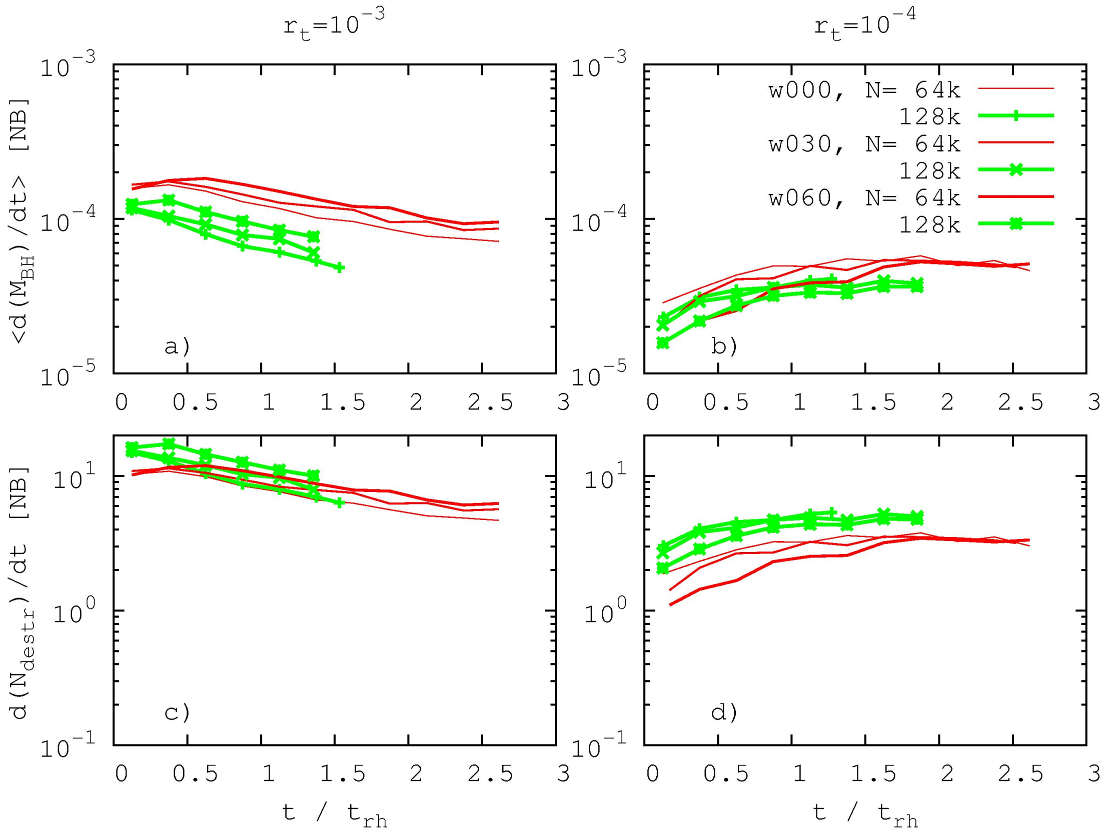
- SMBHs are found in most of the galactic centers, embedded in nuclear star cluster (NSC)
- NSC has bulk rotation, axisymmetric or triaxial shape. (Antonini et al., 2012; Feldmeier et al. 2014)
- BH can disrupt stars and accrete the gasous debris. (Frank & Rees, 1976)
- Tidal disruption of stars may play an important role in BH growth in non-spherical nuclei. (Merritt & Poon, 2004)
- We focus on the <u>tidal disruption rate (TDR), loss cone shape, and origin of TD stars</u> in axisymmetric potential.
- For this purpose, we use rotating King model (Ernst et al. 2008), perform N-body simulations utilizing φGPU code (Berczik et al. 2011; Spurzem et al. 2012), on GPU cluster `laohu` in NAOC.

Models

- Rotating King Model, with W=6.0, ω=0.3 (slow), 0.6 (fast)

  For comparison also ω=0.0 (non-rotating, standard King model)
- Units: G=M=1, E= -0.25 (Heggie & Mathieu, 1986)
- N=64, 128 K. Equal mass: m=1/N.
- BH mass 1% of the total mass. Initially put at origin with zero velocity. Free moving, tidal radius 10^{-3}, 10^{-4}
- We assume 100% mass accretion.

Tidal Disruption Rate



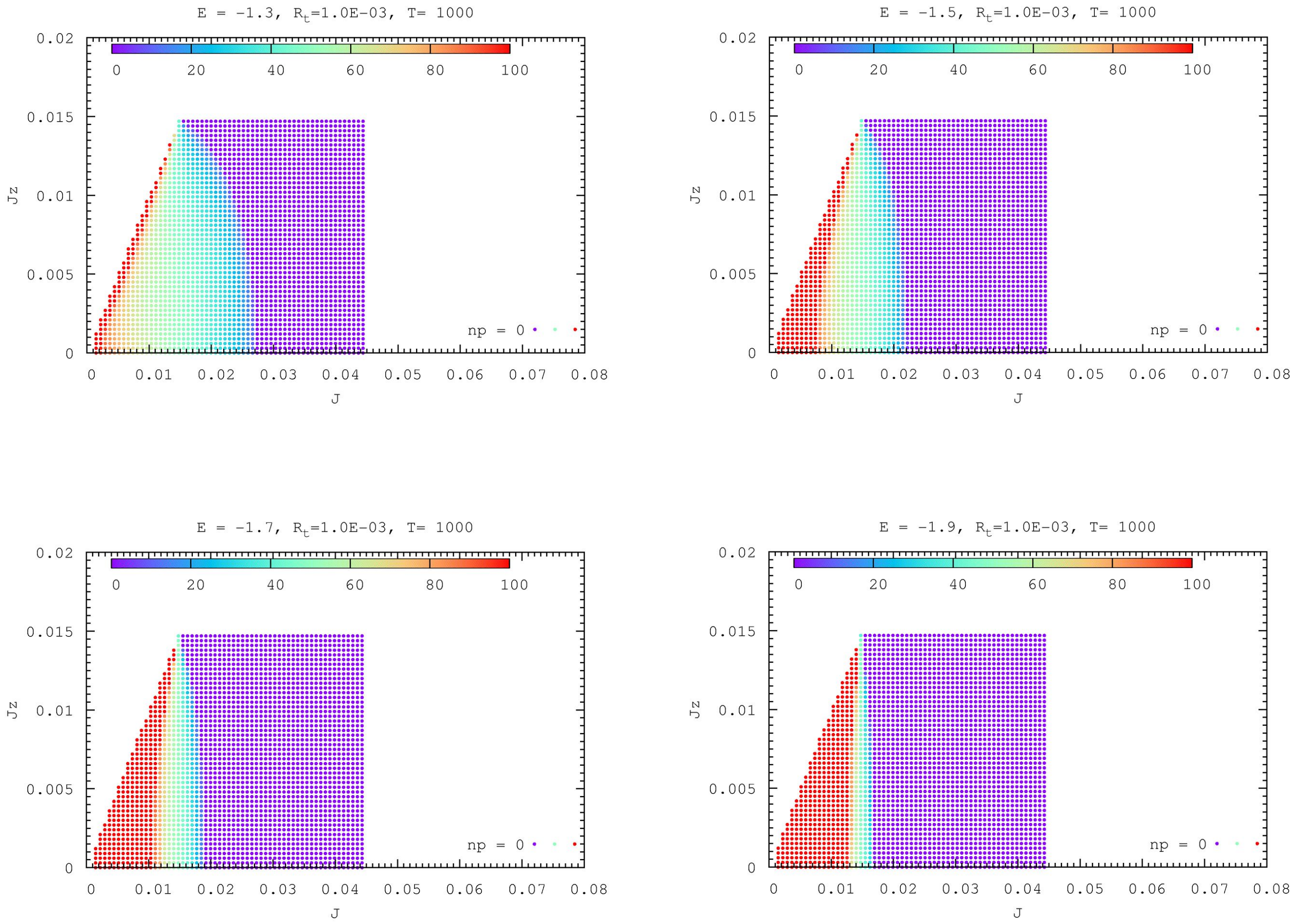
Loss cone status is affected by BH's Brownian motion. (Zhong et al. 2014)

Key point: empty loss cone regime, higher degree of rotation result in higher TDR

Final BH mass 10%~20% higher than non-rotating model.

Shape of loss cone

- Faster dynamical evolution? Enlarged loss cone?
- In spherical symmetric case, $J \leqslant J_{lc}$, $J_{lc} \approx \sqrt{2GMr_t}$ (Frank & Rees, 1976)
- In axisymmetric case, $J_z \leqslant J_{lc}$. Because J is not conserved, boundary in J dimension can be a few times larger than J_{lc}. (Magorrian & Tremaine, 1999)
- Particle experiment in (E,J,J_z) space
- Test particle start from apocenter, SCF realization of the potential based on simulation snapshot.
- Integrate for one orbital period.
- Results also depend on zenith angle θ of apocenter position. We incorperate this dependence into a parameter *P*. It means among all the orbits which have (E,J,Jz), only a fraction *P* of them are inside the loss cone.



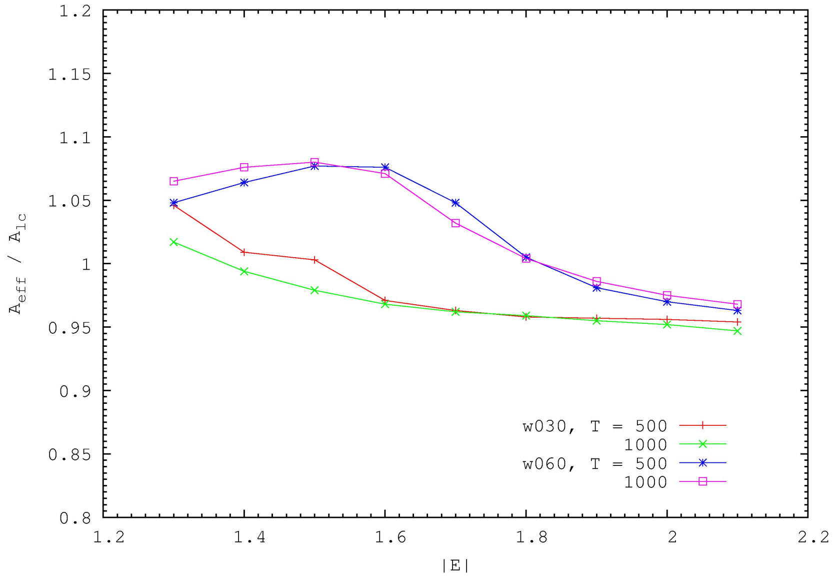
Energy of test particle decreases from top left to bottom right panel.

Red : stars with (E,J,Jz) in this region can reach the tidal radius

Purple : none of them can.

Region in between: a fraction of the stars can reach tidal radii

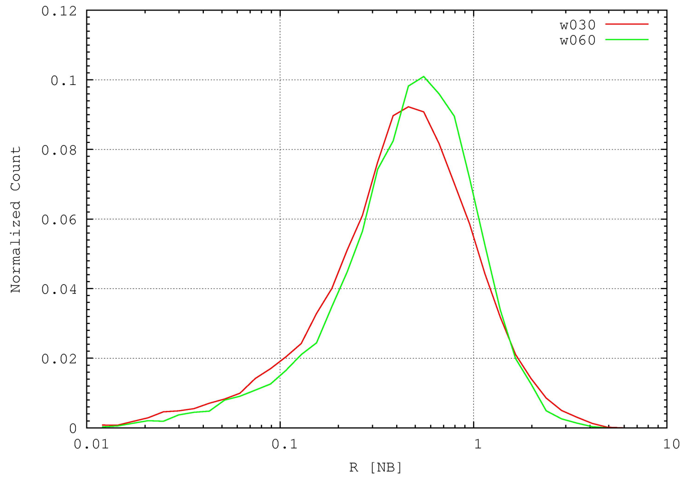
- Effective Area of Loss Cone $A_{eff} = \sum_i p_i$

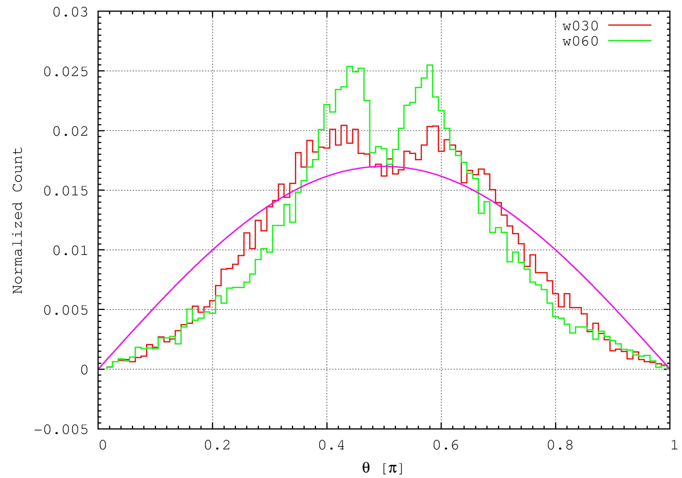


- Most of the disrupted stars have energy between -0.5 and -2.0, in this range effective area is larger in axisymmetric case.

Origin of TD stars

- Critical radius in loss cone theory
- We follow the disrupted stars' trajectory to find out their last apocenter position (*r*, θ).
- Binning procedure, we get their apocenter distribution in *r* and θ.

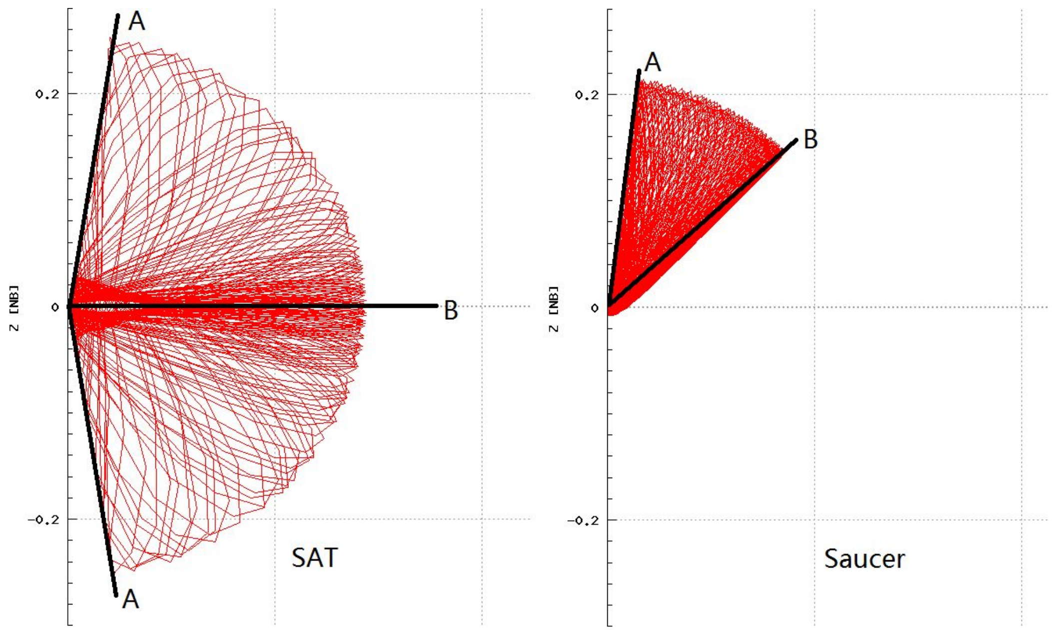




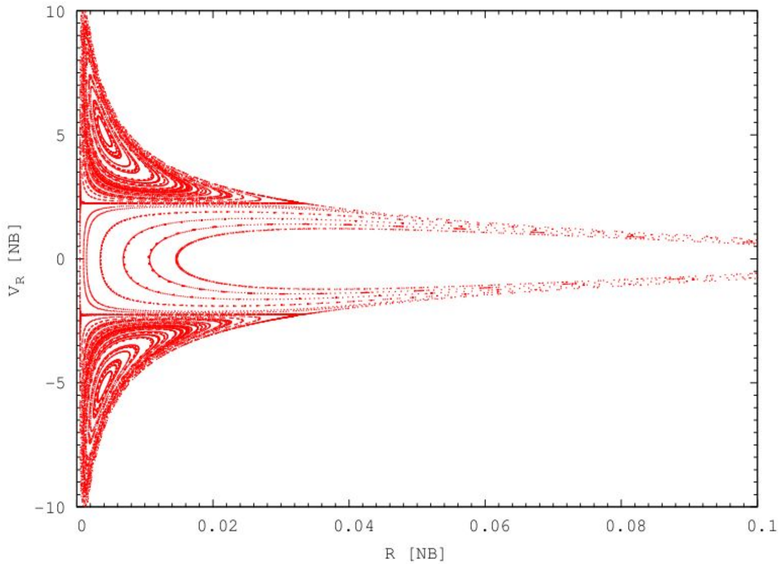
$$dN(\theta) = 2\pi r \cdot \Sigma(\theta) \cdot \sin\theta d\theta$$

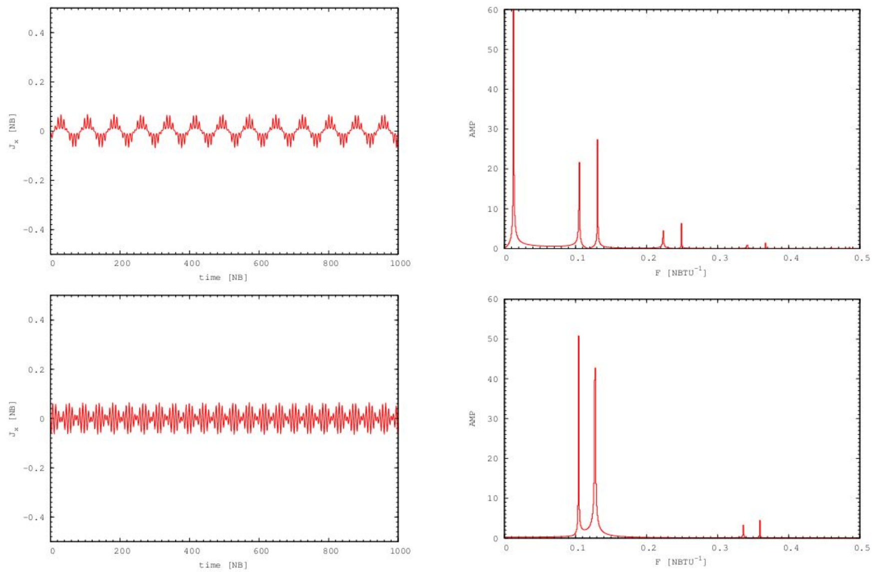
Orbit Family in Axisymmetric (+ BH) Potential

Inside BH's influence radius, 2 kinds of regular orbit: Short Axis Tube (SAT), saucer
Orbit plane coincide with A plane -> Maximum J
Orbit plane coincide with B plane -> Minimum J



Orbit Classification



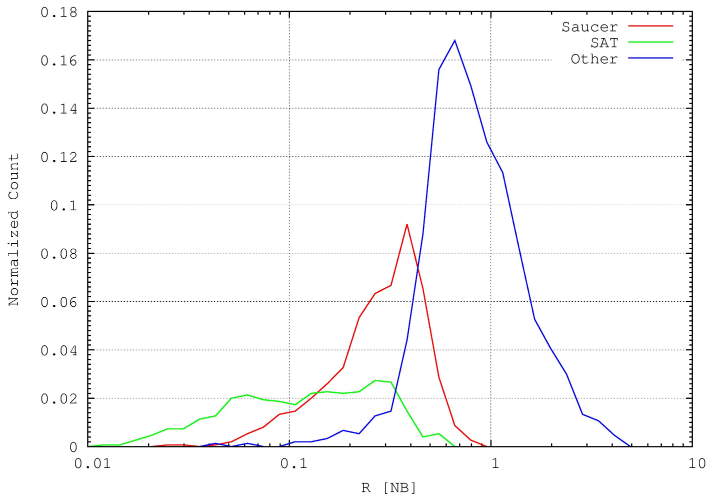


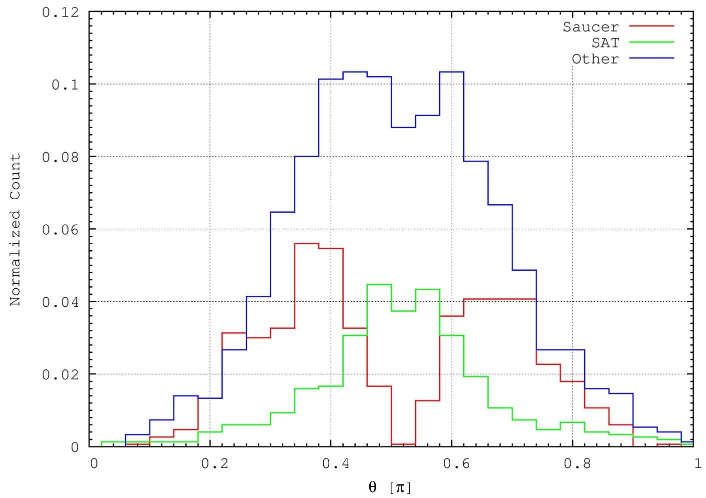
We select a set of disrupted stars (2943), find out which orbit family they belong to.

SAT: 467 (16%) Saucer: 757 (26%) Other: 1719 (58%)

And we know their last apocenter position from N-body data. Replot the *r* and θ distribution.

Results





The last apocenters for three types of orbit are also seperated in radial space.

Distribution in θ : SAT are well concentrated to equatorial plane. Saucer are double peaked. Other are just distributed as our first expectation.

Summary

- TDR is enhanced in rotating clusters.
- The loss cone in axisymmetric potential is enlarged.
- Distribution of last apocenter show double peak feature in θ, can be explained by orbit structure of the disrupted stars.