Binary Black Holes in Triaxial Galaxies

An approach to collisional and collisionless hardening

Oliver Porth (of MPIA Heidelberg) at RIT

Objectives

- Binary black hole coalescence is of great interest wrt. gravitational waves, merger history...
- Stellar dynamical simulations can help to:
  - Understand the contribution of relaxation & centrophilic orbits
  - Investigate the Core formation

Recipe for triaxiality

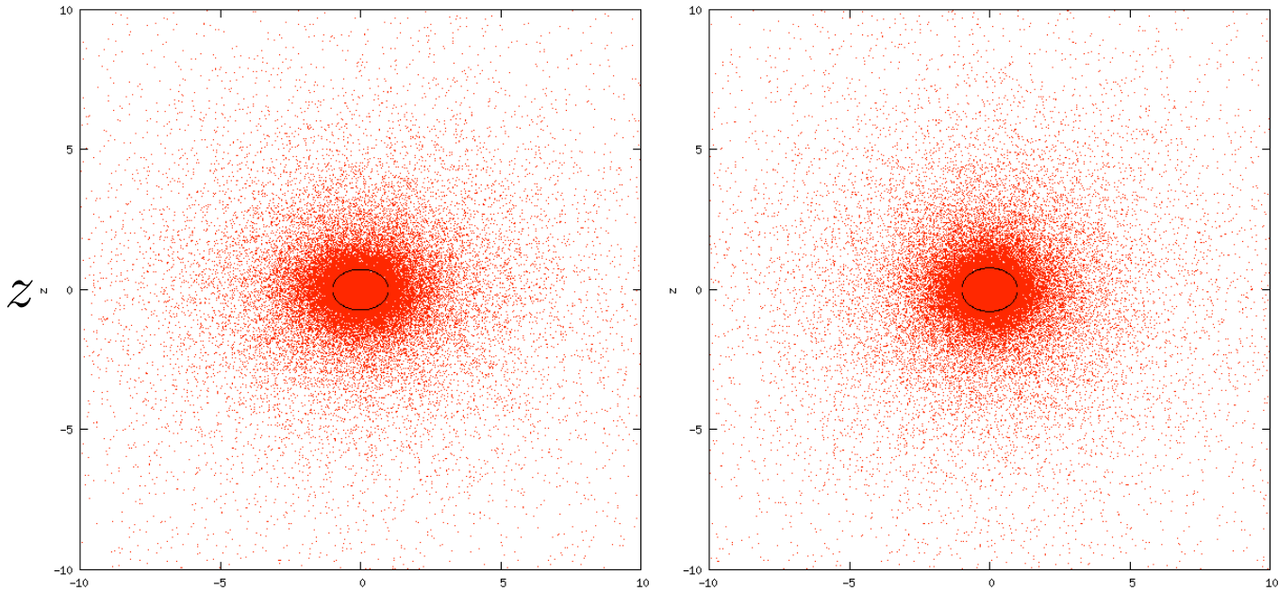
1. Take a spherical Dehnen $\gamma=1$ model with $M_{bh}=0.01\ M_{tot}$
2. Distort density and velocity tensor
3. Let the model "relax" for $t\approx 10 t_D$ using SCF[1]

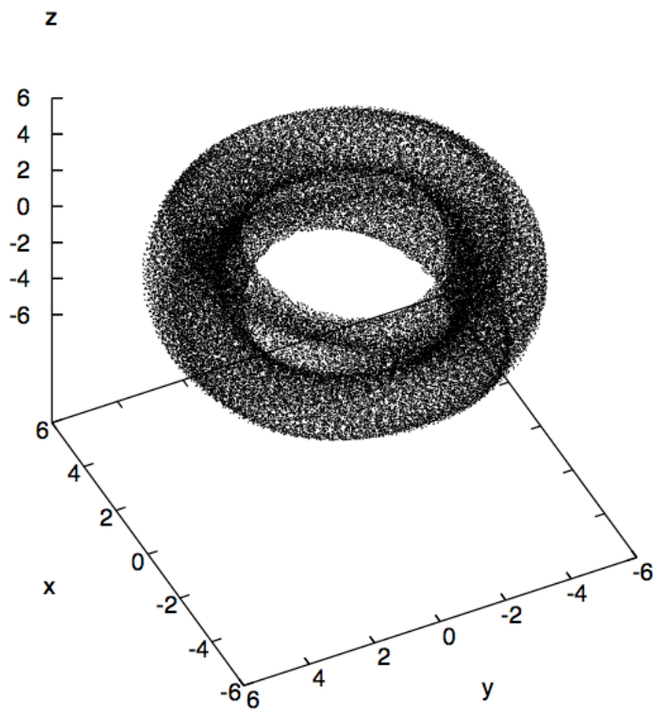
Pro	Con
Have a self consistent triaxial black hole model	Don't know exactly what you get stability is not guaranteed

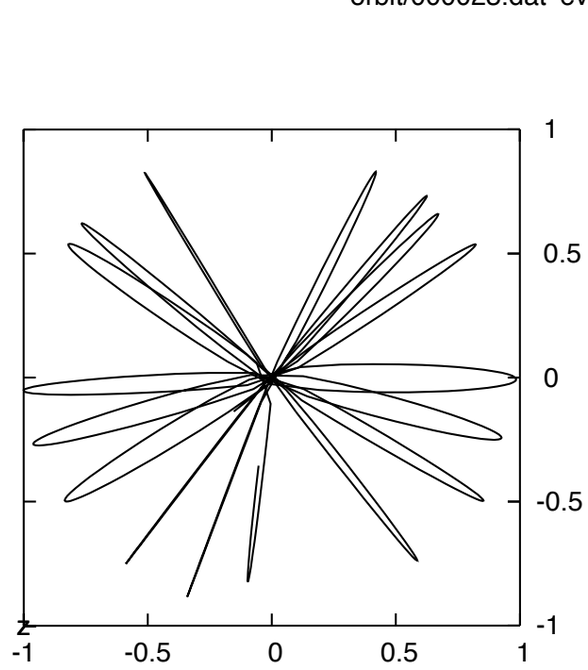
[1] Lars Hernquist and Jeremiah P. Ostriker, 1992

Oblate model

Integration of all 100K orbits in a fixed potential (each for 1000 periods)





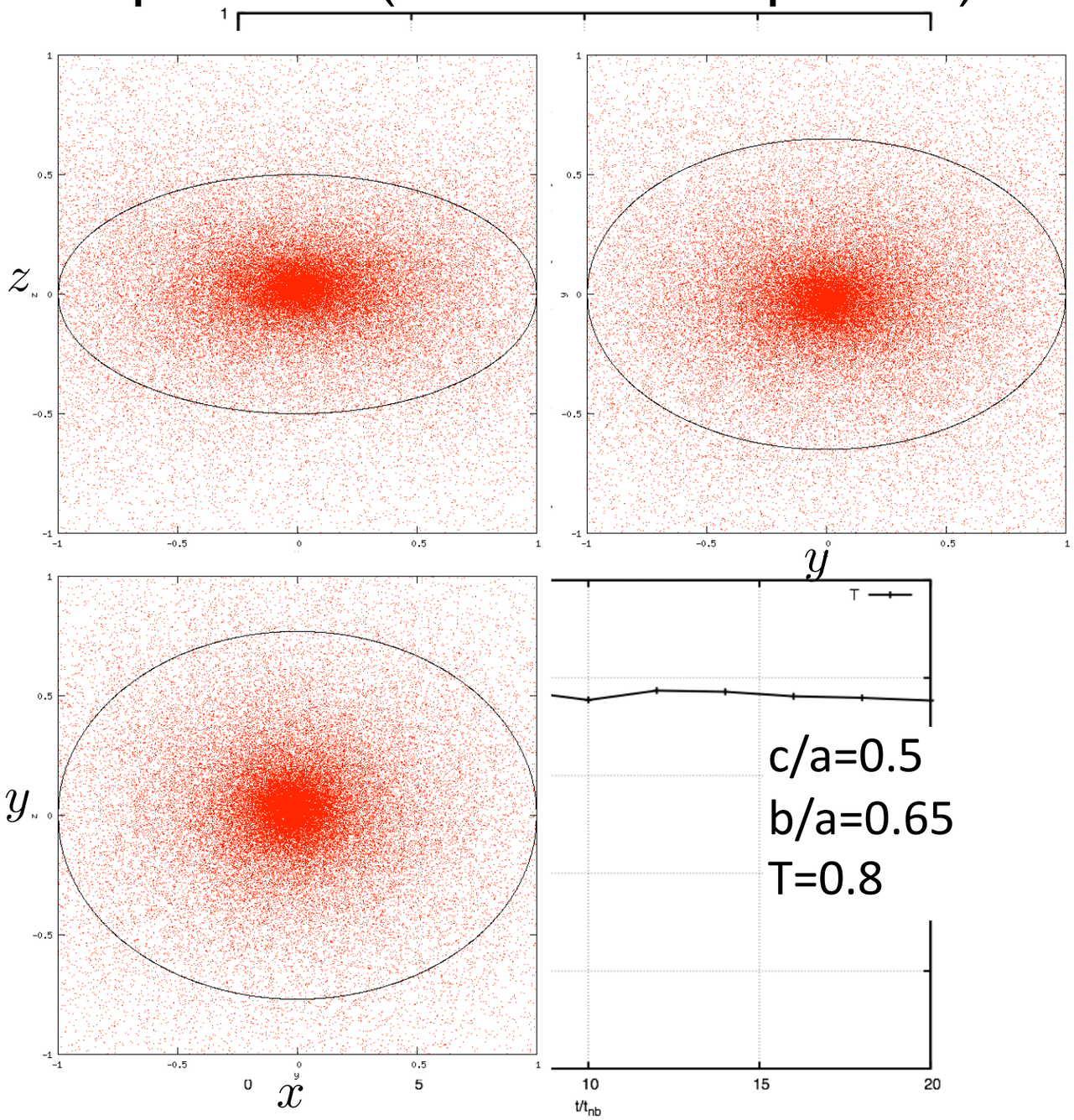


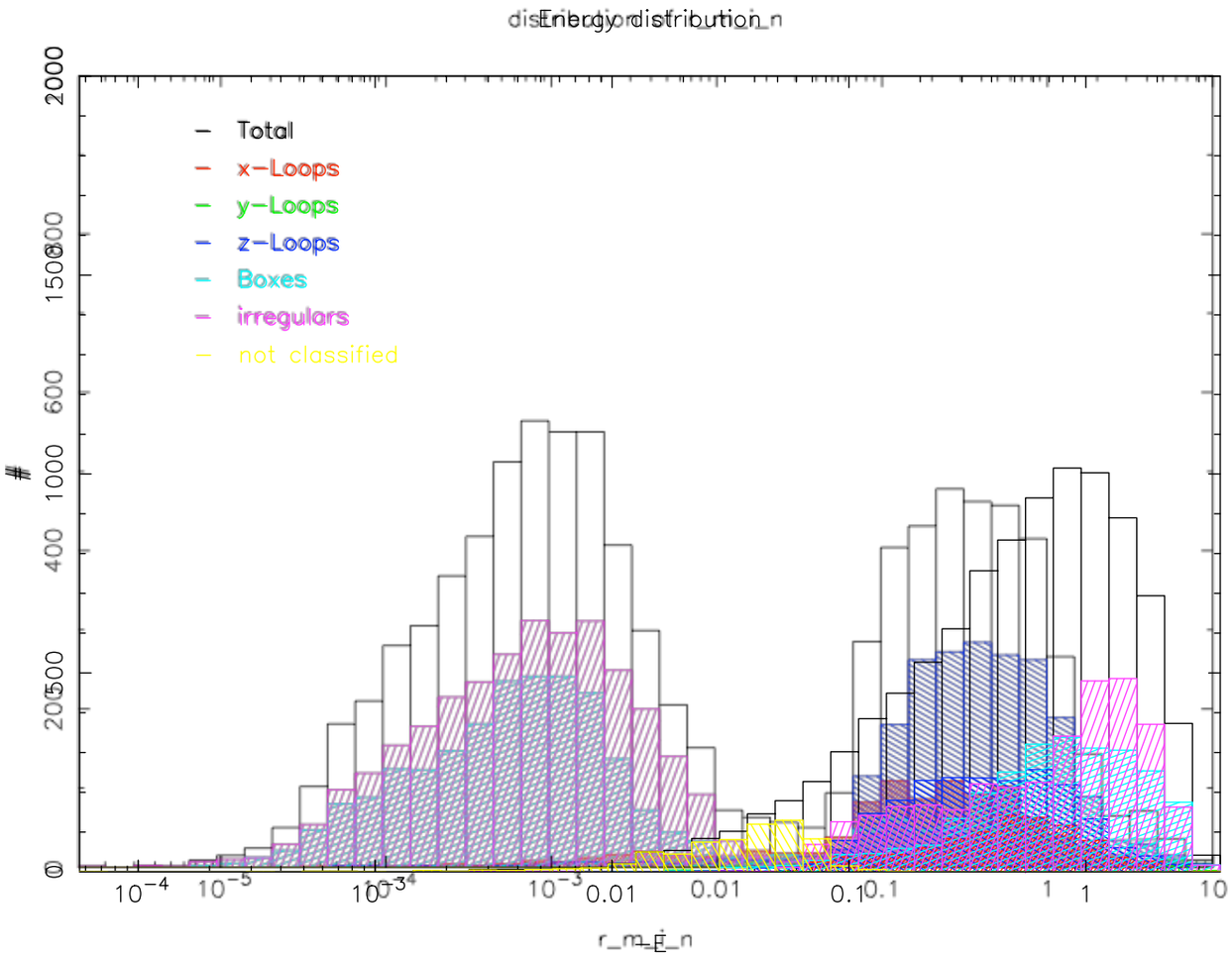
X-Tubes	Y-Tubes	Z-Tubes	Boxes	Irregular	Not Class.
13.4%	0.003%	61.5%	8.8%	8.0%	6.5%

Chaos classification by spectral dynamics

Prolate model

Integration of all 100K orbits in a fixed potential (each for 1000 periods)



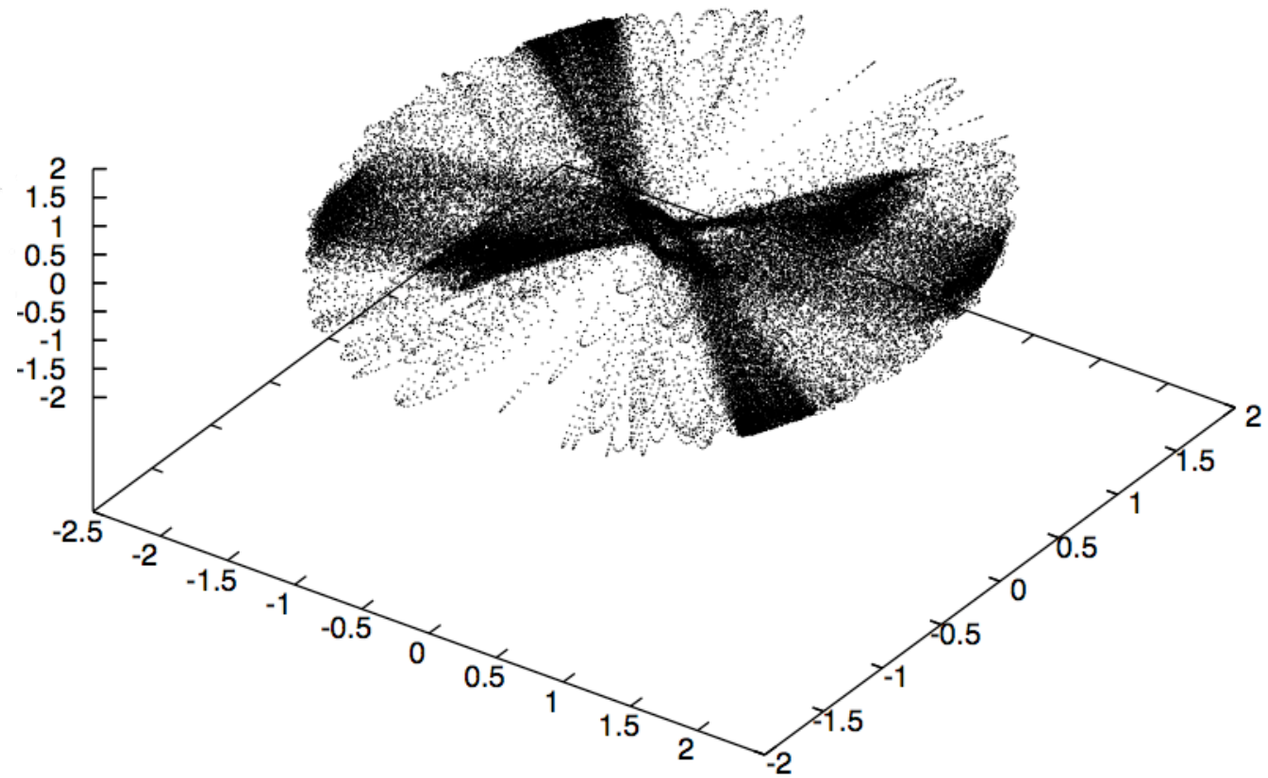


X-Tubes	Y-Tubes	Z-Tubes	Boxes	Irregular	Not Class.
9.4%	0.4%	21.2%	26.0%	33.7%	0.9%

Chaos classification by spectral dynamics

Thin orbits

- Do all Box orbits become chaotic?
- in 3D, resonant orbits are thin
- Thin orbits avoid the center, thus can stay in place
- How significant is this in nature?



Thin box orbit in a the prolate model

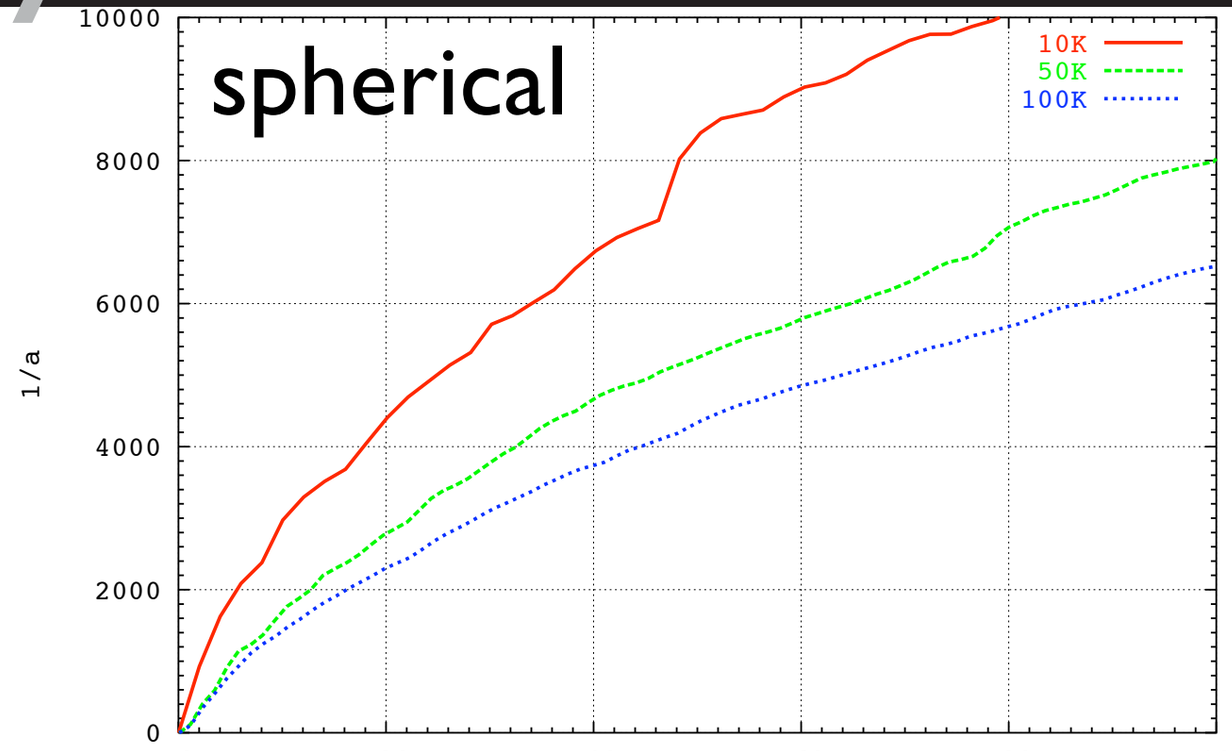
Merritt & Valluri, 1999

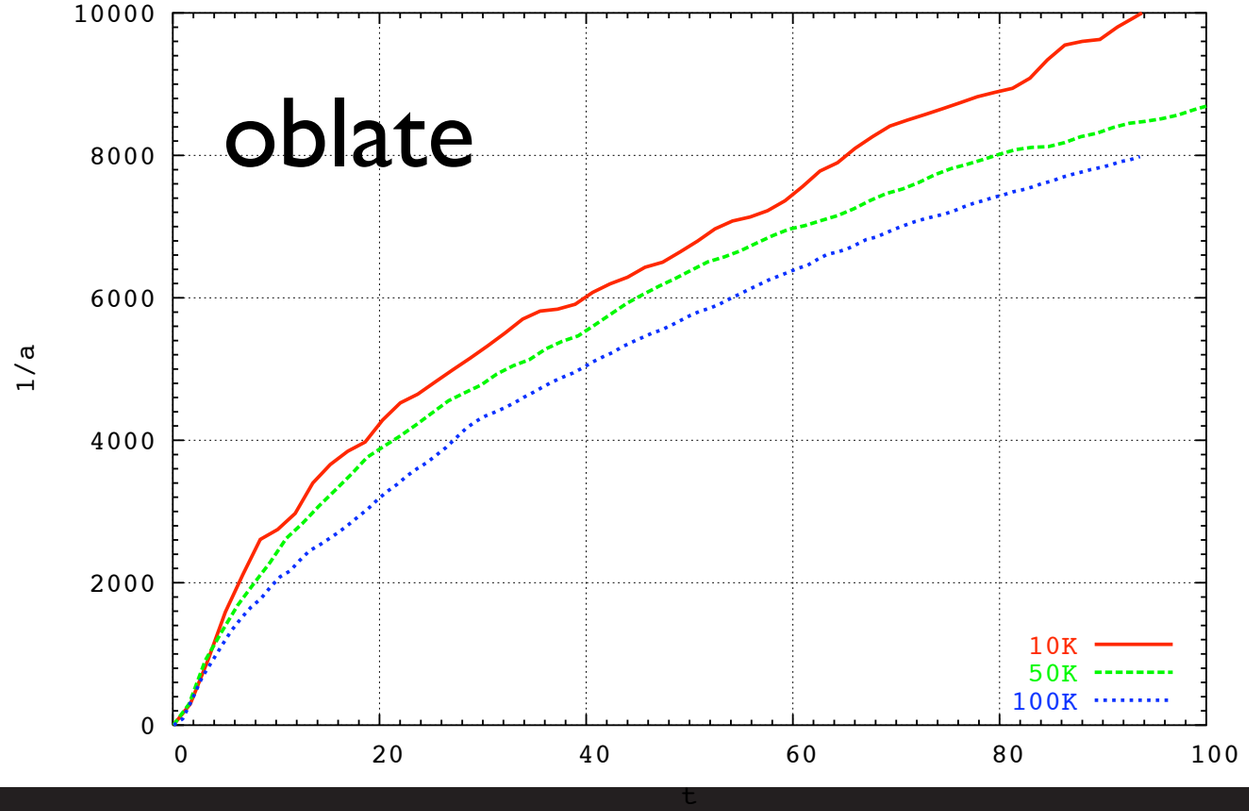
Direct Nbody realisation

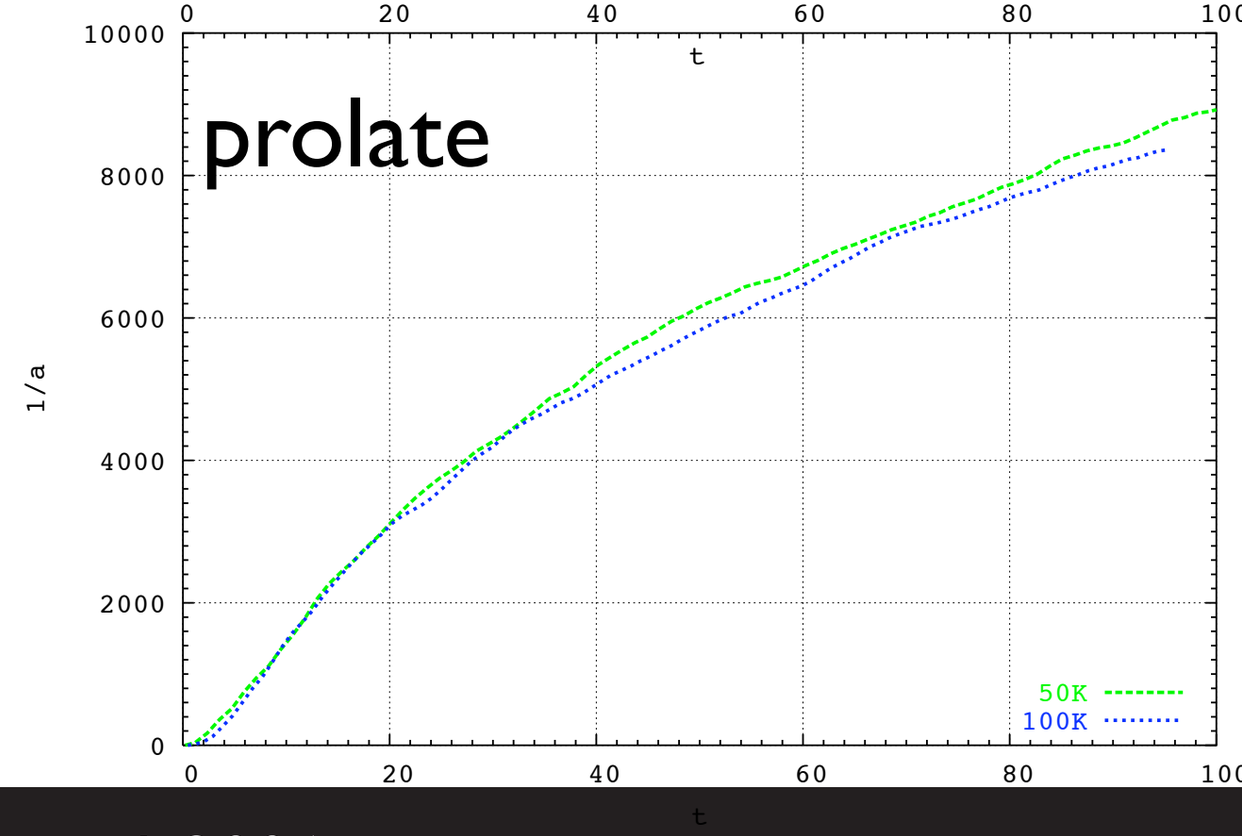
Binary black hole hardening in the aforementioned models

$M_{bh1}+M_{bh2} = 0.01\ M_{tot}$; $M_{bh1}=10\ M_{bh2}$

Circular orbit at 1% $r_{lagrange}$

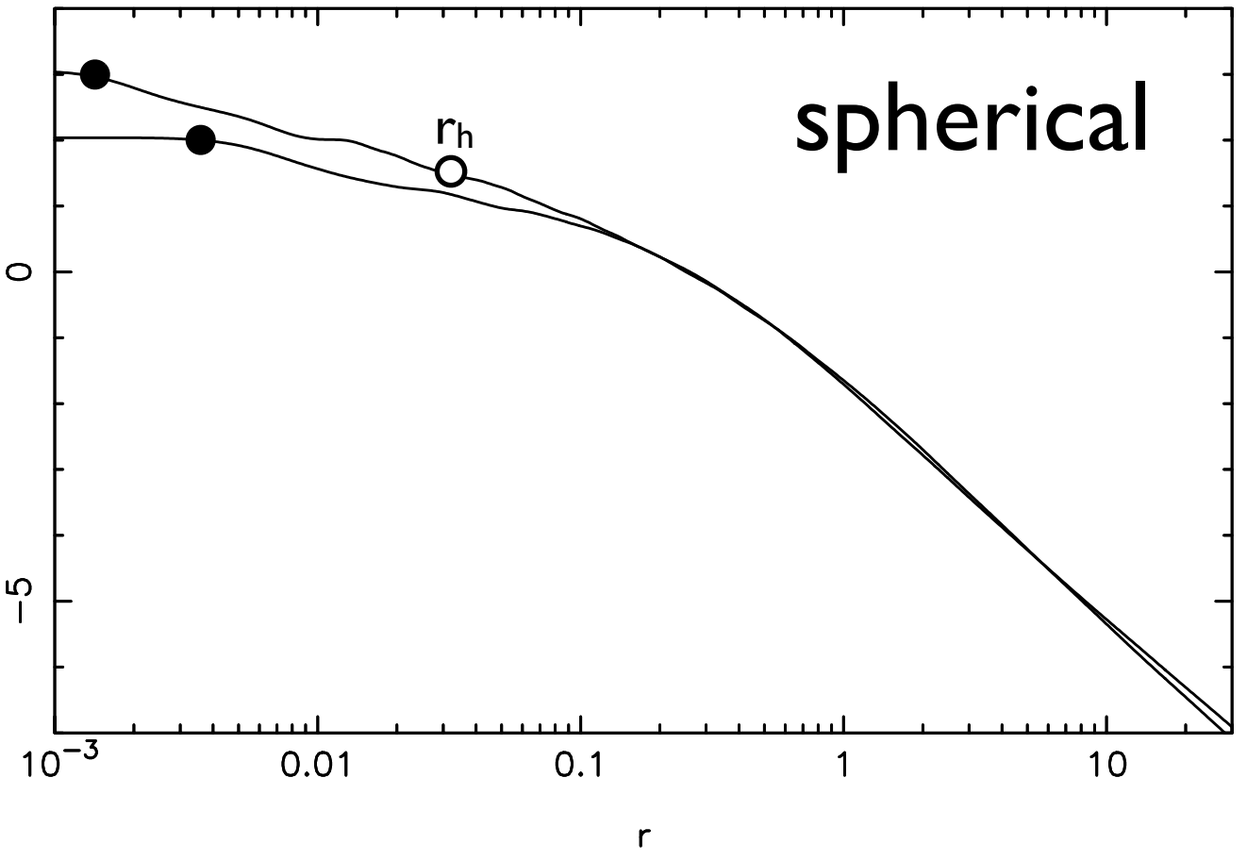






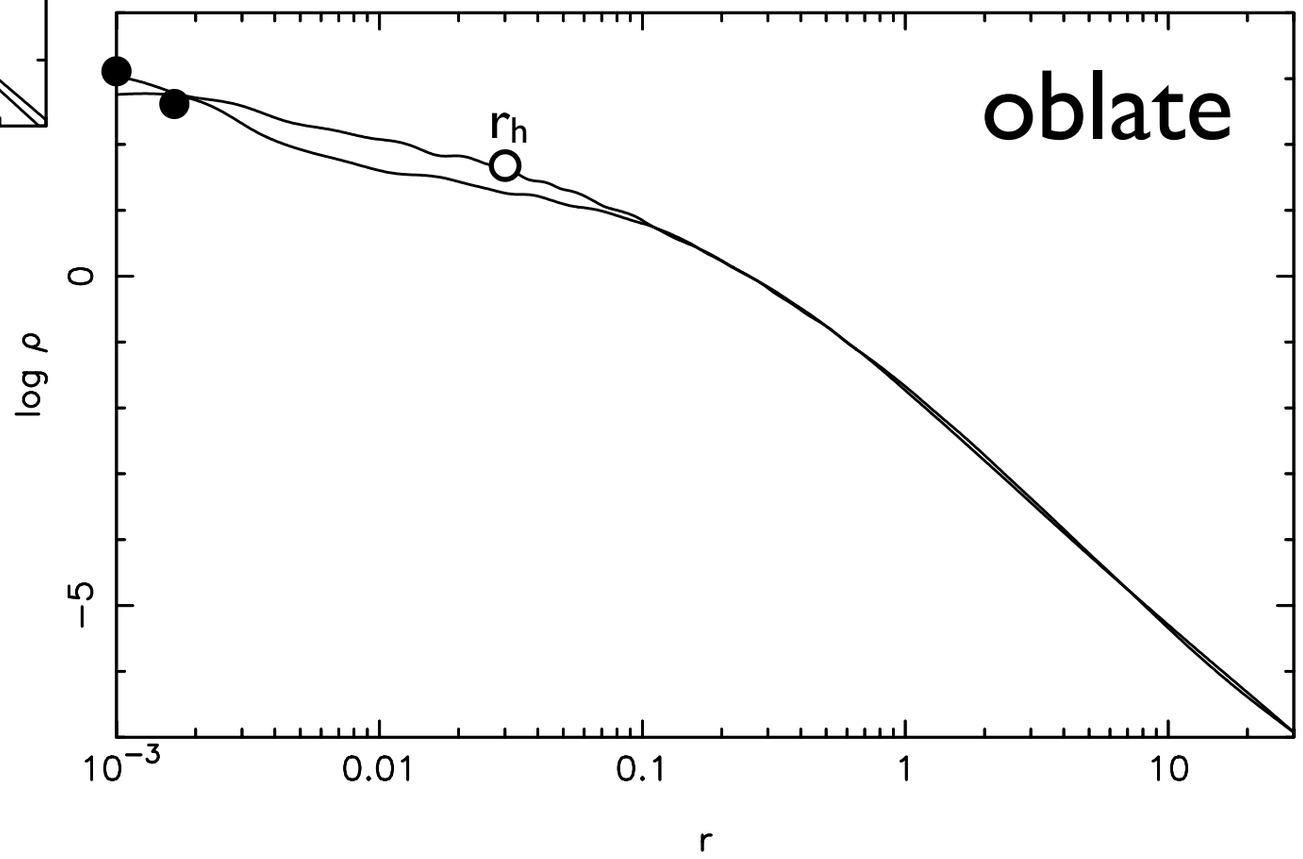
see also: Berczik et al. 2006

Carving of a Core I



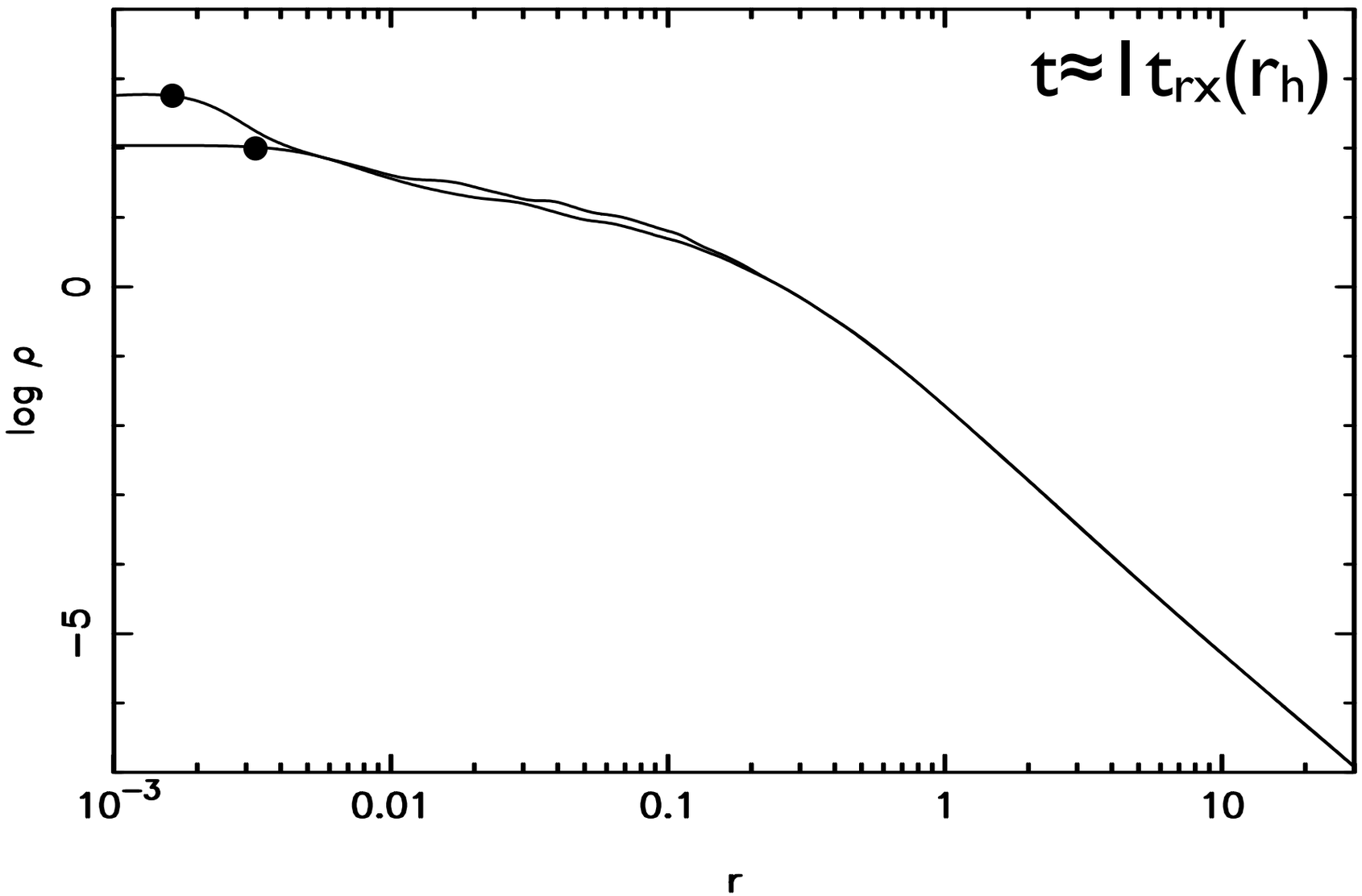
spherical density plots

- •: last star
- ∘ : influence radius



Density profiles
at t=0, 1/a=6250

Carving of a Core II



- Which is which?
- What happens inside?
- Only slight if any difference in the Core - could be “projection” effect

Conclusions and Outlook

- Centrophilic orbit dominated models circumvent the scaling problem
- Orbit analysis will be used to model the contribution of centrophilic orbits (Merrit & Poon, 2004)
- Significance of thin orbits?
- Evidence for lack of core in triax. models is not yet conclusive

Thank you!