Orbits of black holes in triaxial potentials

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Objectives

Study the effect of different triaxial potentials, and initial speeds ~~and numerical integrators~~ on the times required by a supermassive black hole to return to its initial position, after experiencing a recoil, as well as to quantify how chaotic its trajectory is.

- Obtain probability distributions for the return times based on each of the free parameters of the triaxial potential, the magnitude and direction of the initial velocity
- Quantify how chaotic is the trajectory of the black hole in each simulation, using exponents of Lyapunov
- Evaluate the performance of the ~~numerical integrators~~ LeapFrog scheme, using the information of the simulations

Galactic setup

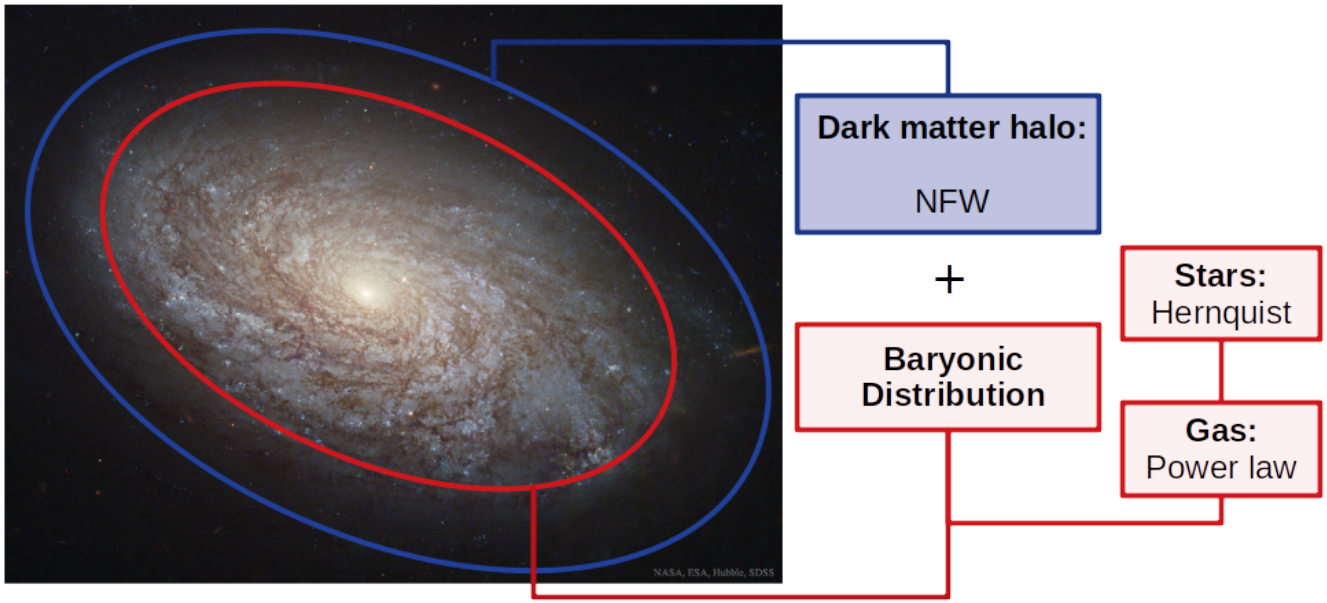


Figure: NGC4414 galaxy as seen by the Hubble telescope.

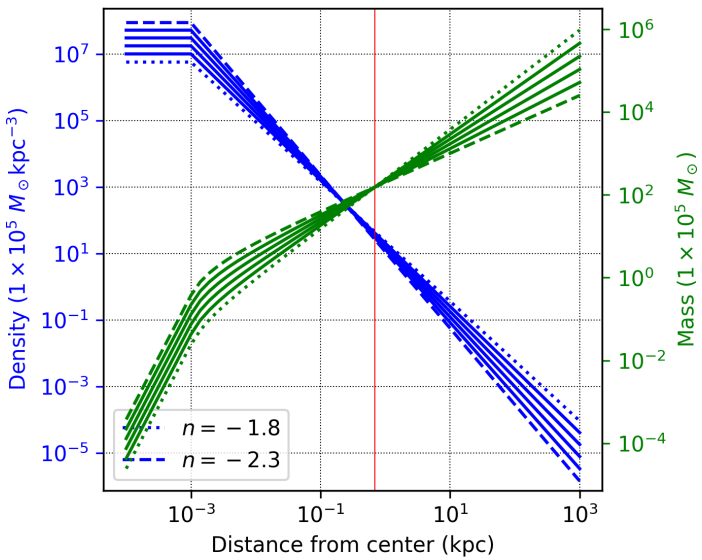
1. Gas density (Power law):

$$\rho_{\text{gas}}(r) = \begin{cases} \rho_0^{\text{gas}} & \text{if } r < r_0 \\ \rho_0^{\text{gas}} \left(\frac{r_0}{r}\right)^{-n} & \text{if } r \geq r_0 \end{cases} \tag{1}$$

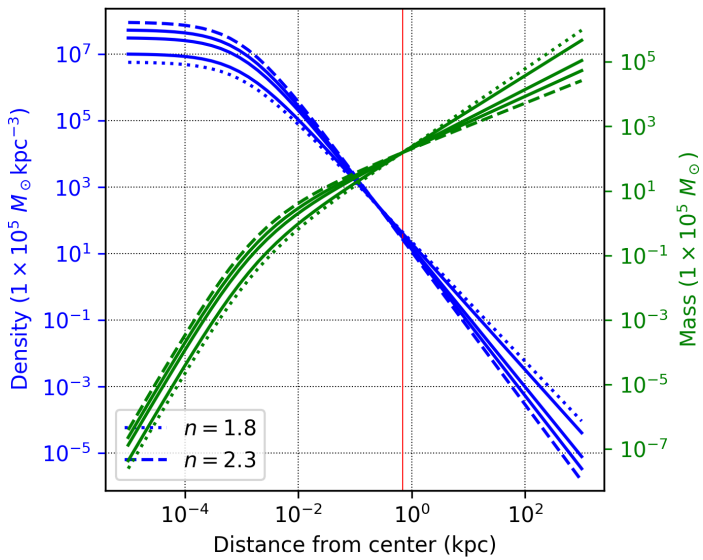
2. Gas density (Double power law)

$$\rho_{\text{gas}}(r) = \frac{\rho_0^{\text{gas}}}{\left(1 + \frac{r}{r_0}\right)^n} \tag{2}$$

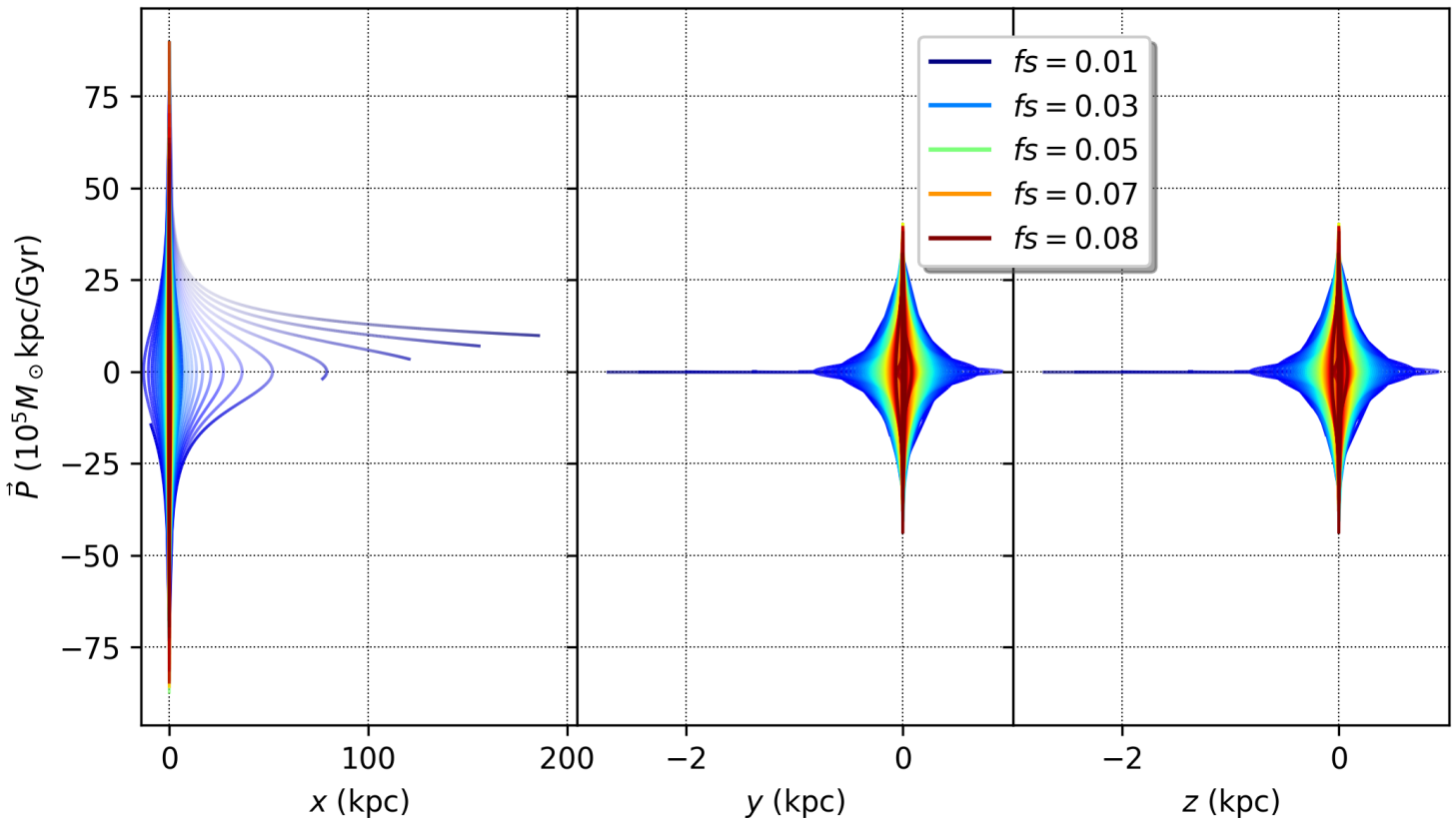
1 Gas density (Power law)



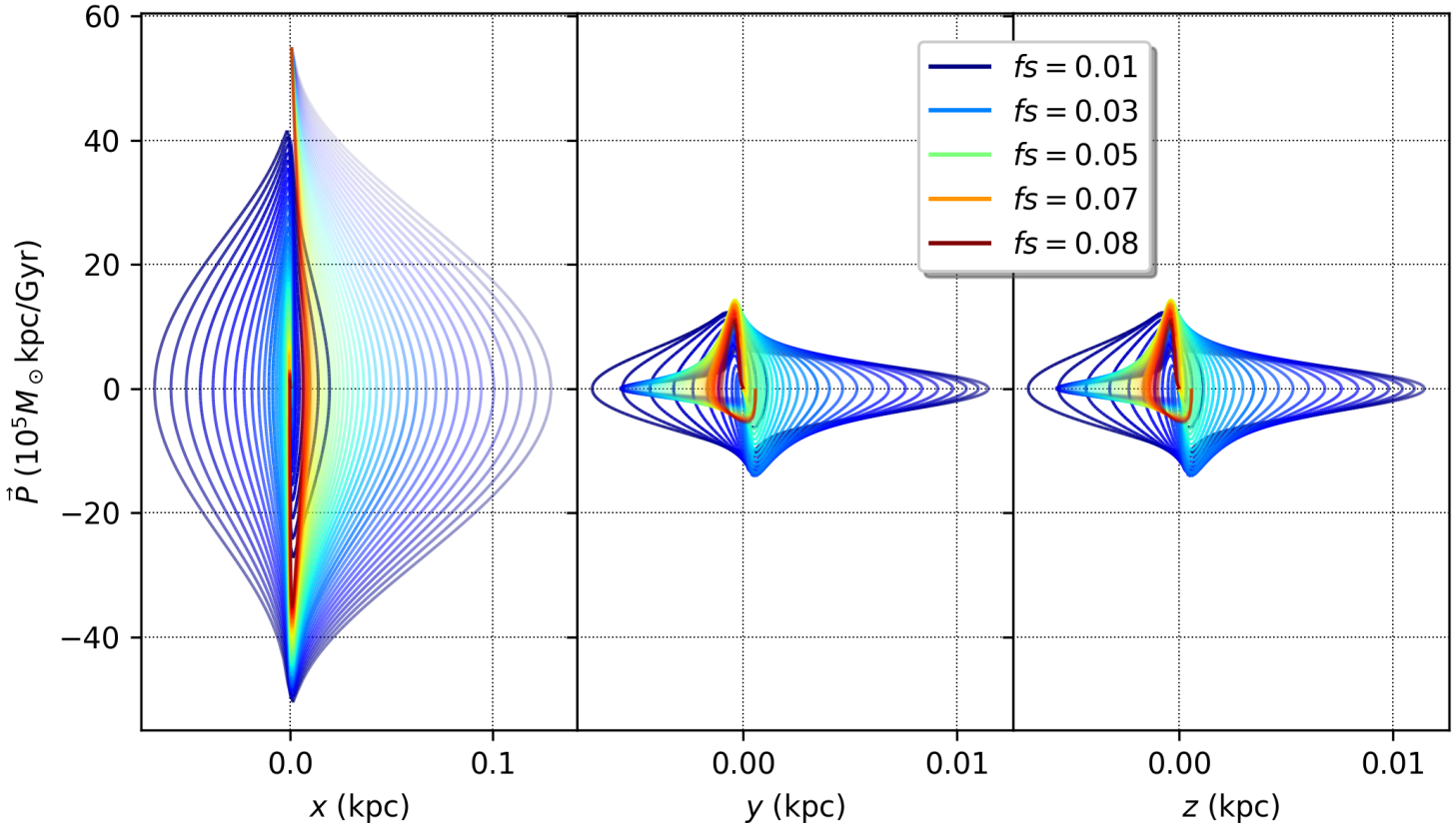
2 Gas density (Double power law)



Effect of the stellar fraction



Effect of the stellar fraction



Effect of the stellar fraction

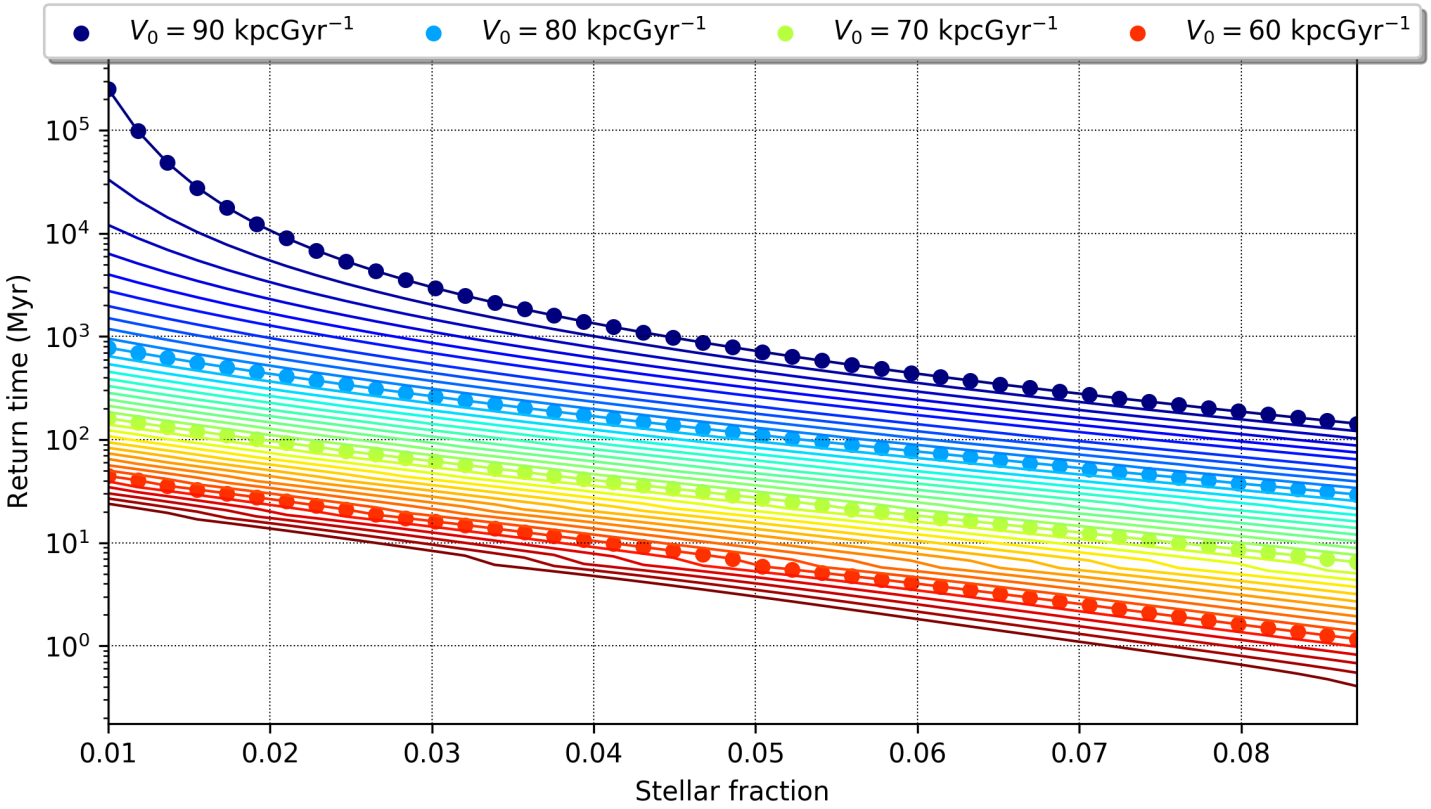
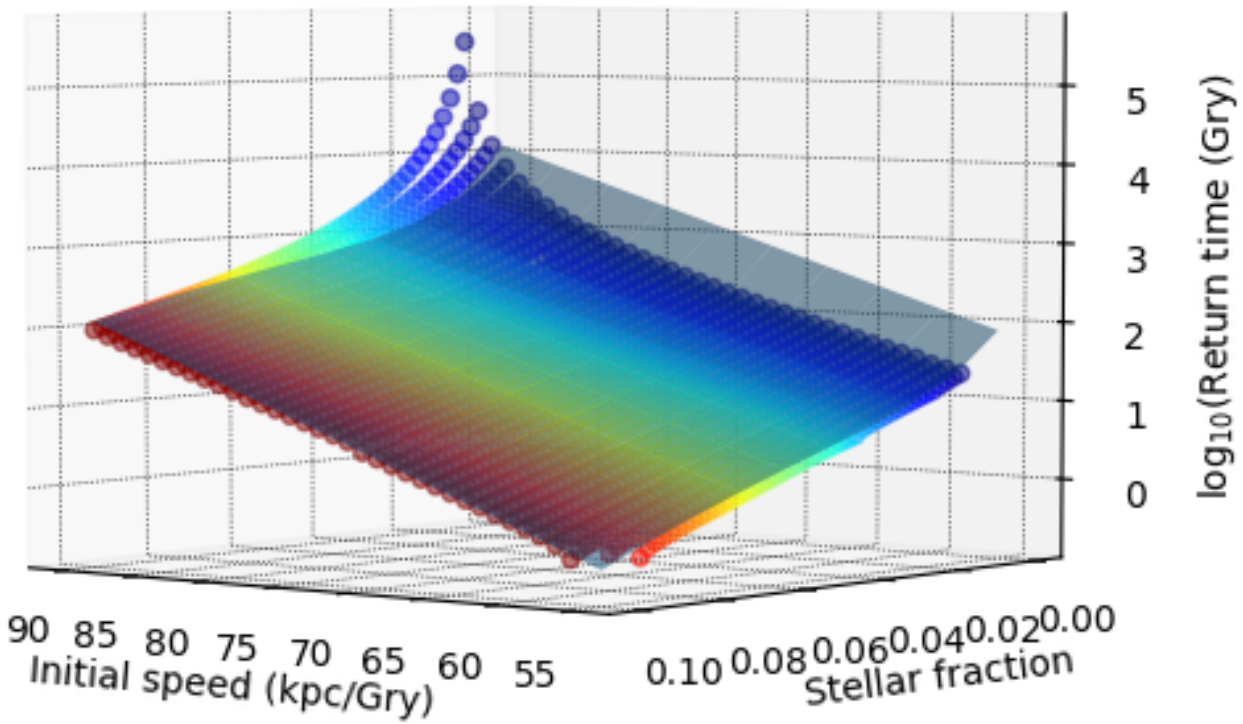
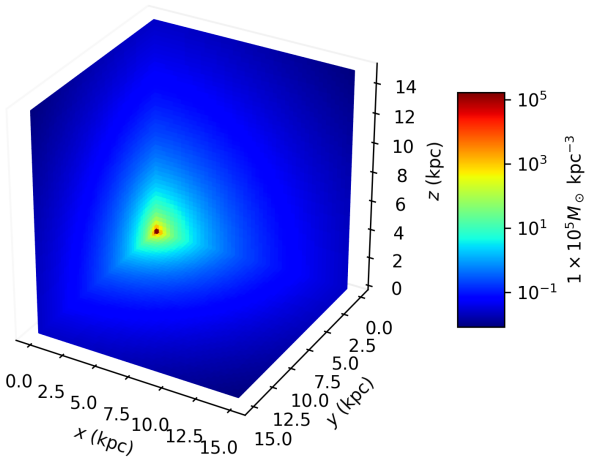


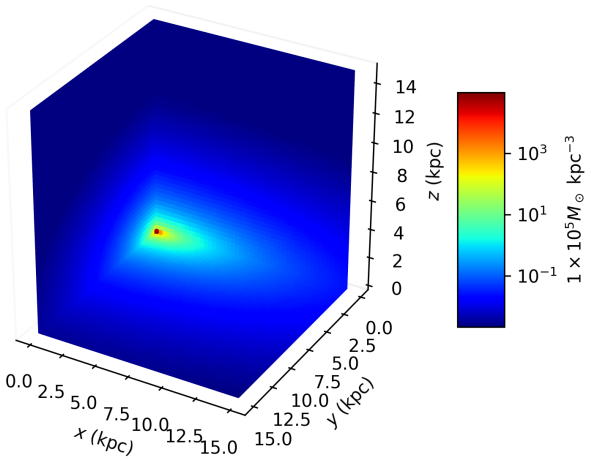
Figure: Return time for different stellar densities.

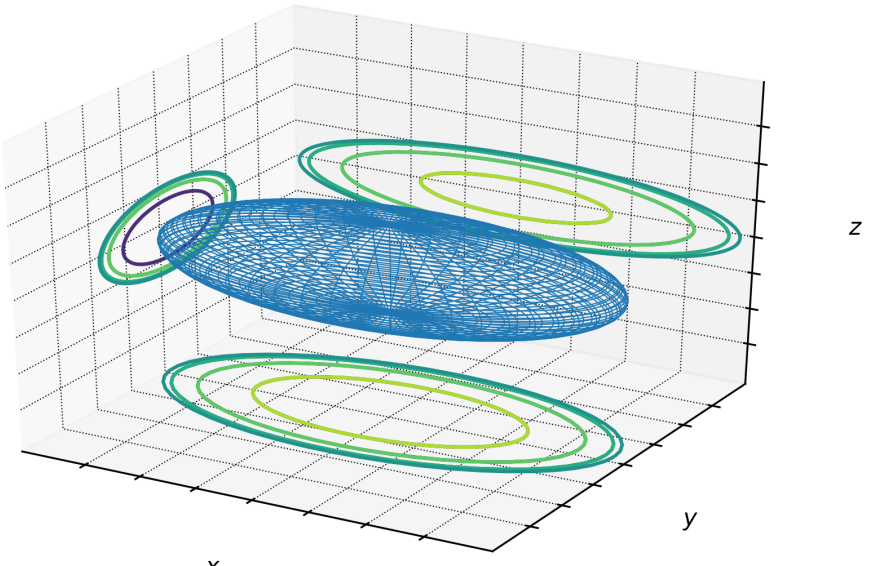
Effect of the stellar fraction

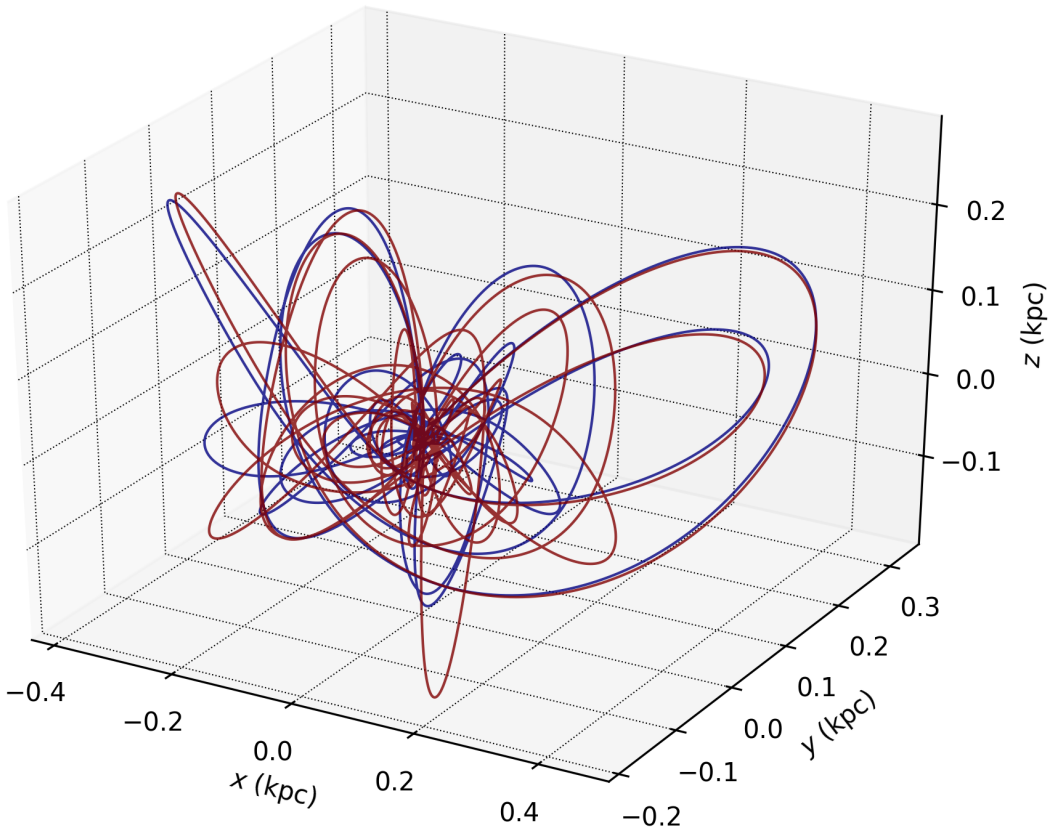


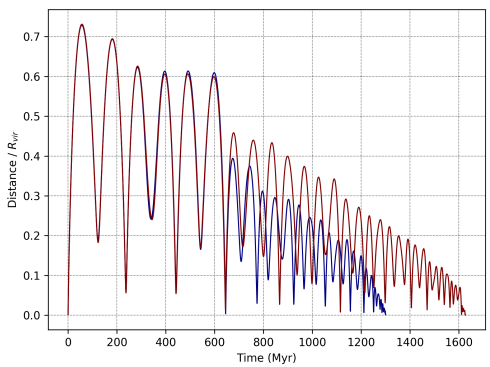
Triaxial

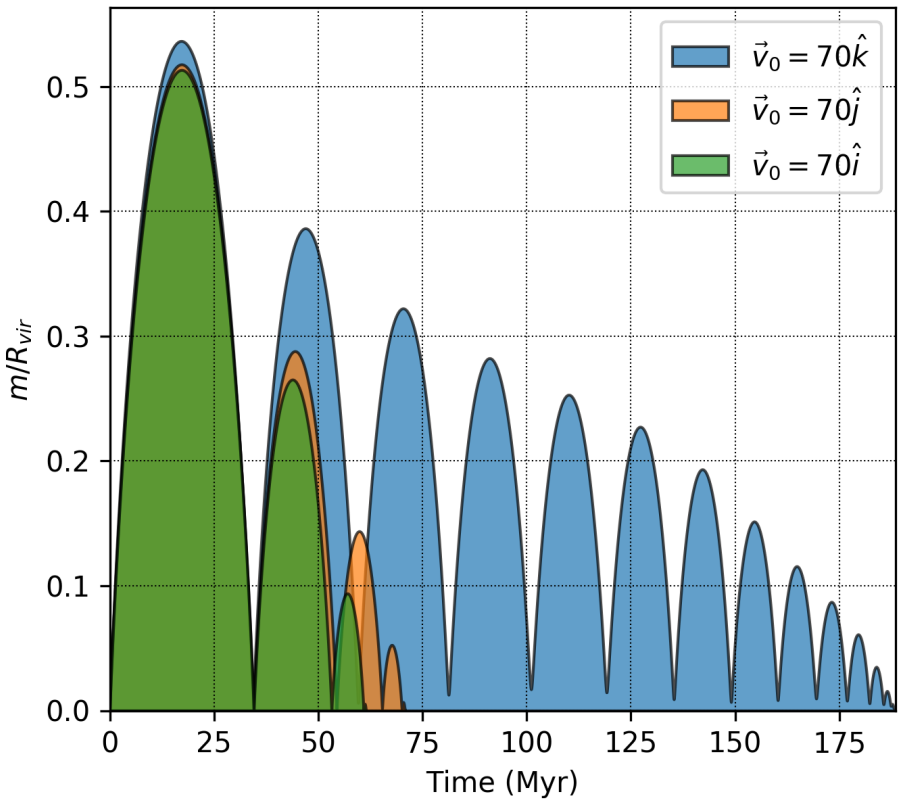

z (kpc)
x (kpc)
y (kpc)
$1 \times 10^5 M_\odot$ kpc^{-3}


z (kpc)
x (kpc)
y (kpc)
$1 \times 10^5 M_\odot$ kpc^{-3}


z
y
x


0.2
0.1
0.0
−0.1
z (kpc)
−0.4
−0.2
0.0
0.2
0.4
x (kpc)
−0.2
−0.1
0.0
0.1
0.2
0.3
y (kpc)


Distance / R_{vir}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
200
400
600
800
1000
1200
1400
1600
Time (Myr)



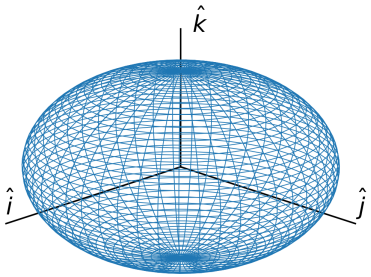
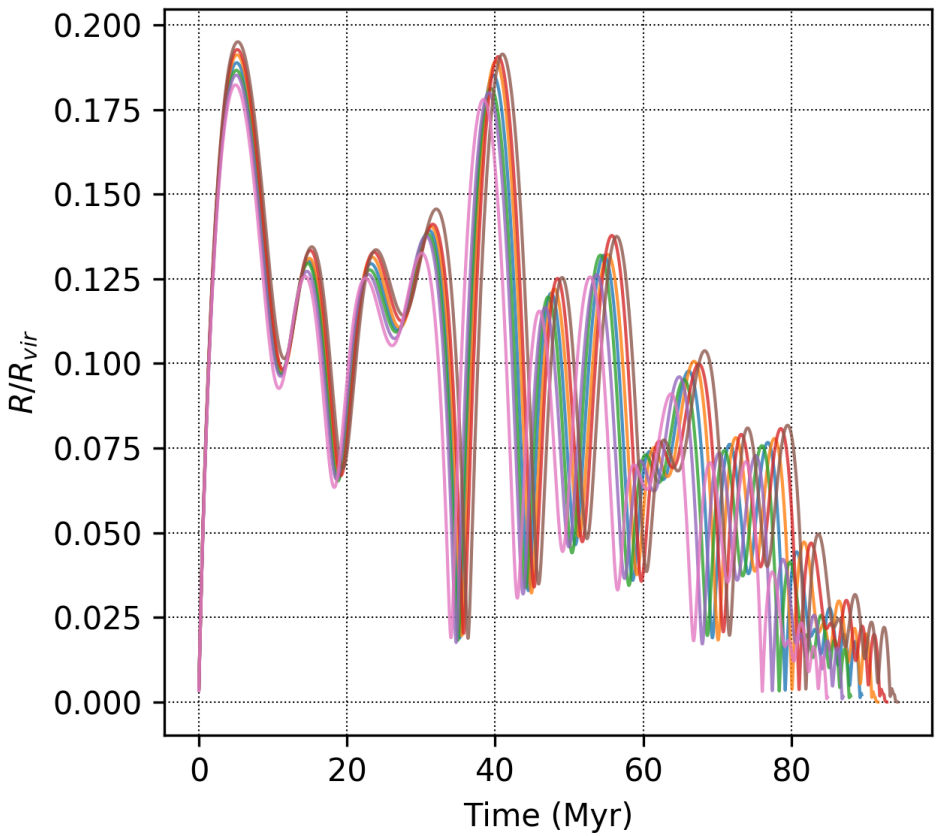
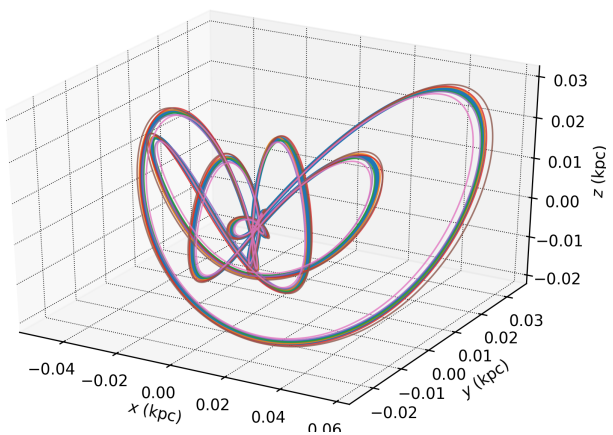


Figure: Orthogonal launches for a triaxial profile with semi-axis $(a_1{:}a_2{:}a_3) = (1 : 0.99 : 0.95)$


0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
R/R_{vir}
0
20
40
60
80
Time (Myr)


0.03
0.02
0.01
0.00
−0.01
−0.02
z (kpc)
−0.04
−0.02
0.00
0.02
0.04
0.06
x (kpc)
0.03
0.02
0.01
0.00
−0.01
−0.02
y (kpc)

Thank You