Dynamical evolution of the dark matter subhalos in the Milky Way

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Introduction

Although the existence of dark matter (DM) is a widely accepted idea, the nature of DM is yet unknown. One way to look for DM is the indirect detection method which aims to observe gamma-rays produced by annihilation of DM particles. The standard lambda cold dark matter cosmology predicts a hierarchical procedure for structure formation. As a consequence, there is a large number of low mass subhaloes inside larger haloes like our Galaxy, the Milky Way. These low mass subhaloes like dark satellites are known to be promising targets for gamma-ray DM searches since some of them may be close enough to yield large DM annihilation fluxes at Earth. Accurate prediction of annihilation signals requires multi-parameter space simulations of dark subhalos with high resolution to avoid artificial disruption (van den Bosch & Ogiya 2018).

Methods

1.N-body Simulation

We carry out a suite of idealized N-body simulations of subhaloes. As dynamical friction can be neglected for the low-mass subhaloes, the host is modelled with an evolving analytical potential which composed of a spherical DM host halo, stellar and gas discs and a spherical bulge (Aguirre-Santaella et al. 2022).

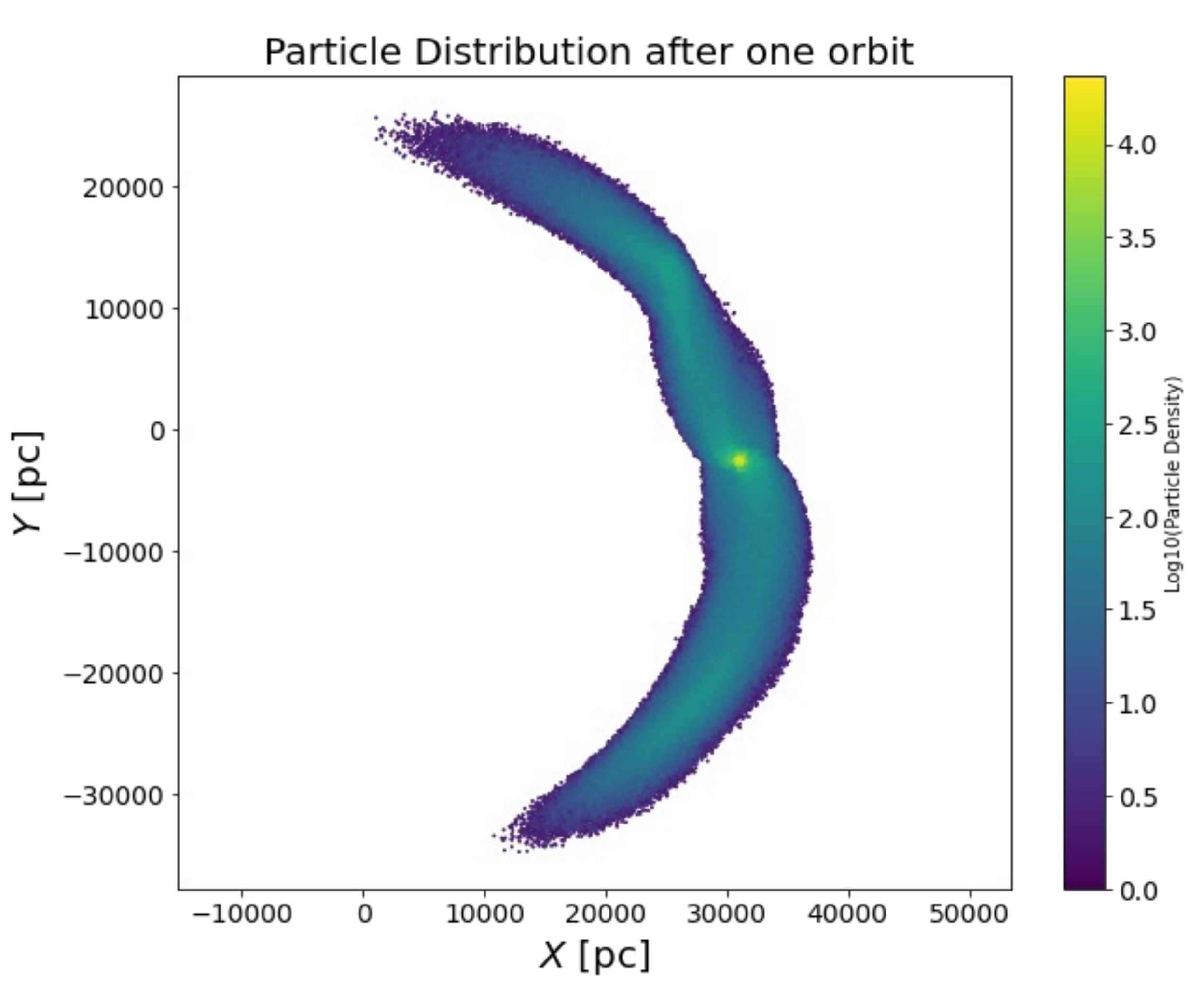
2.Orbital parameter

We put the subhalo at the viral radius of the host and use β to characterize the direction of the tangential velocity which has been overlooked in previous study.

$$V\theta = \beta Vt \ (-1 \le \beta \le 1)$$

Results

As the example figure shows, suffering tidal force, the subhalo is stripped and a tidal tail and leading arm appears.



Reference

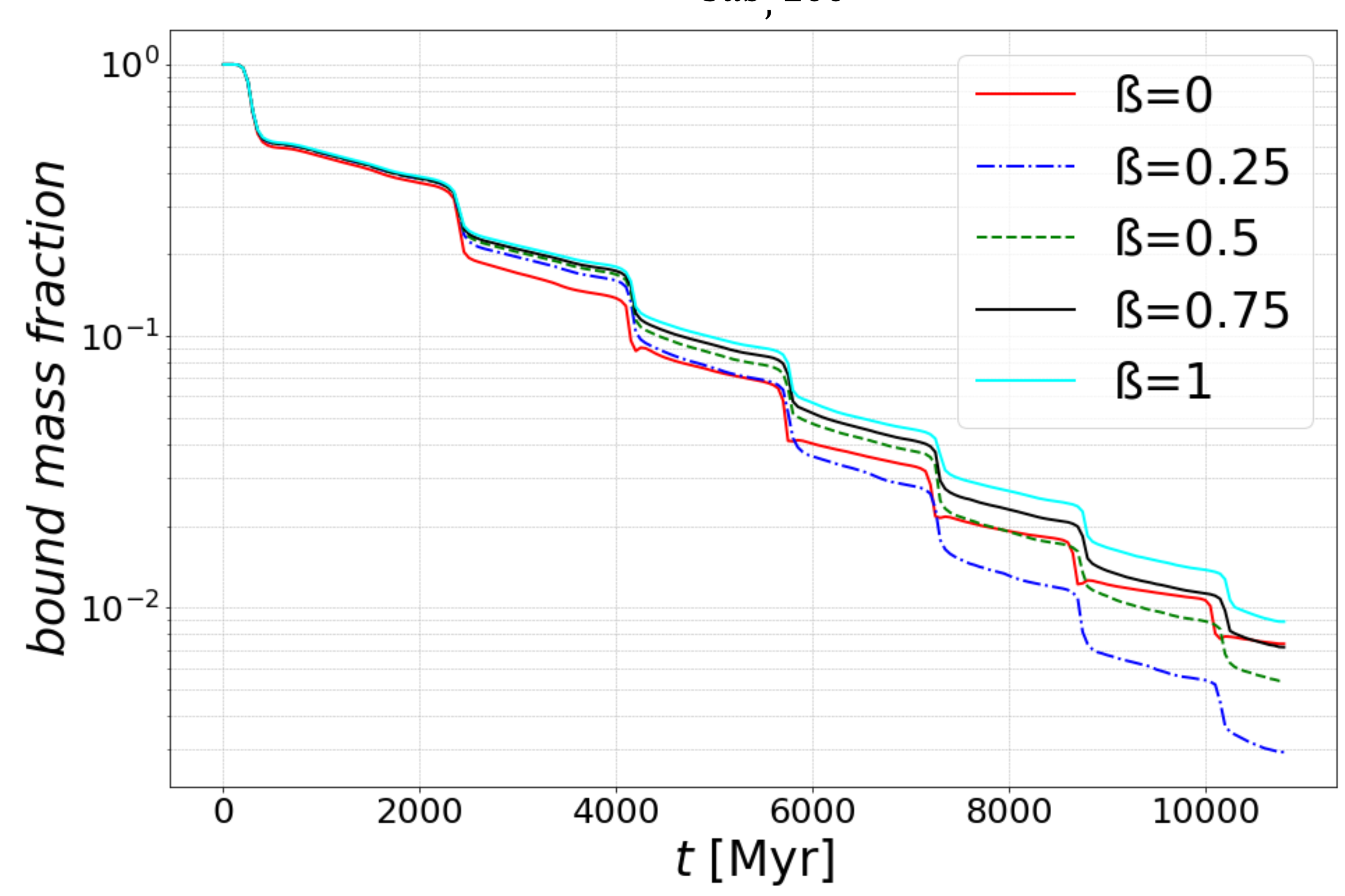
[1] Aguirre-Santaella A, Sánchez-Conde MA, Ogiya G, Stücker J, Angulo RE. 2022. Monthly Notices of the Royal Astronomical Society. 518(1):93–110

[2] van den Bosch FC, Ogiya G, Hahn O, Burkert A. 2018. Monthly Notices of the Royal Astronomical Society. 474(3):3043–66

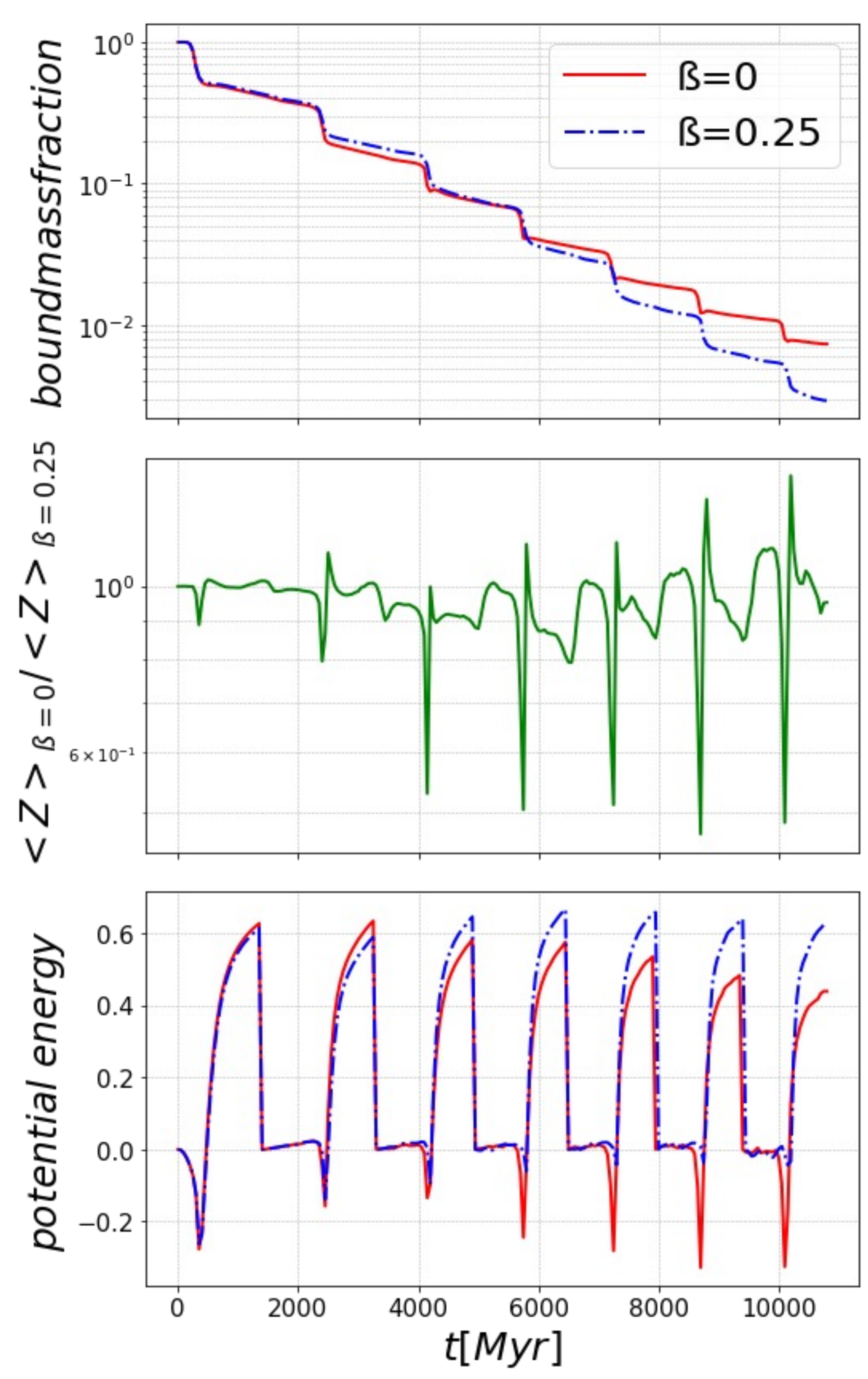
1.Bound mass fraction

The subhalos are put on the galatic disk plane with the radius of host viral radius and have same orbital energy and angular momentum. The bound mass fraction f_b decreases with decreasing β. Because β determines the angle between the orbit and the disk plane. Baryons induce a much greater mass-loss, especially when the subhalo orbit is more parallel to the Galactic disc. But the subhalo orbiting in the disk plane is an exception, its mass loss is relatively large at the beginning, and then it becomes smaller.

$$f_b = \frac{M(t)}{M_{sub,\,200}}$$



2.Engery injection through shock



The tidal force is stronger in the disk plane, and there is kinetic energy injection at the pericenter through shocking. As shown in the top panel, the subhalo on the disk plane (β=0) will suffer more mass loss at the beginning. As the host growing, the compression in the direction perpendicular to the disk plane becomes more apparent (middle). Compression makes the potential of the subhalo deeper (bottom). This process makes subhalo more compact and more resistant to tidal force later (top).

Summary

1. Orbital parameter β determines the inclination of the orbit to the disk plane, the more parallel the orbit is to the disk, the greater the mass loss.
2. The subhalo in the disk plane will become more compact due to the compression in the direction perpendicular to the disk, and the mass loss will be relatively small with evolving.
3. Future Work: We will simulate the subhalo in a multi-parameter space (angular momentum, concentration, orbital energy, accretion redshift, position, β) and use machine learning to predict the annihilation signal accurately.