Exploring the Origin of Dark Matter Deficient Galaxies with Their Outskirts.

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Abstract Two dwarf galaxies, NGC1052-DF2 and NGC1052-DF4, have been discovered to lack dark matter. Previous studies suggest that they could have formed through tidal stripping, predicting they should exhibit corresponding tidal features. In this work, we use numerical simulations to investigated their tidal features through mock observations, identify these tidal features and analyze their evolution.

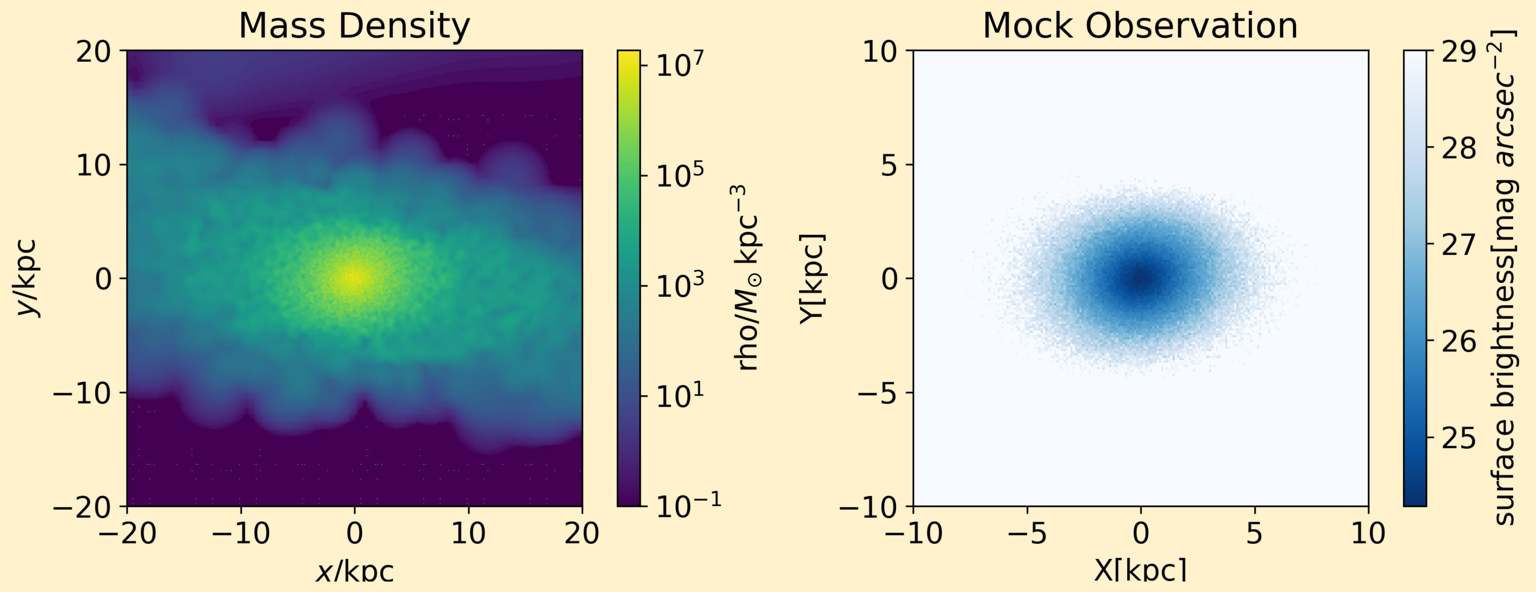
Introduction

Van Dokkum et al. (2018, 2019) reported that ultra diffuse galaxies NGC 1052-DF2 and –DF4 believed to be members of the NGC 1052 group, are dark matter (DM) deficient. Tidal stripping has been proposed as an explanation for NGC1052-DF2 and -DF4's missing dark matter (Ogiya et al. 2022). Such diffuse systems are expected to exhibit significant tidal features when subjected to tidal stripping. Such as distortions in the internal structure of the galaxy caused by tidal interaction (Keim et al. 2022), also suggested by numerical studies (Penarrubia et al. 2008). These distortions suggest the history of tidal interactions between the satellite galaxy and its host. Studying them can help us understand the origin of dark matter deficient galaxies.

Method

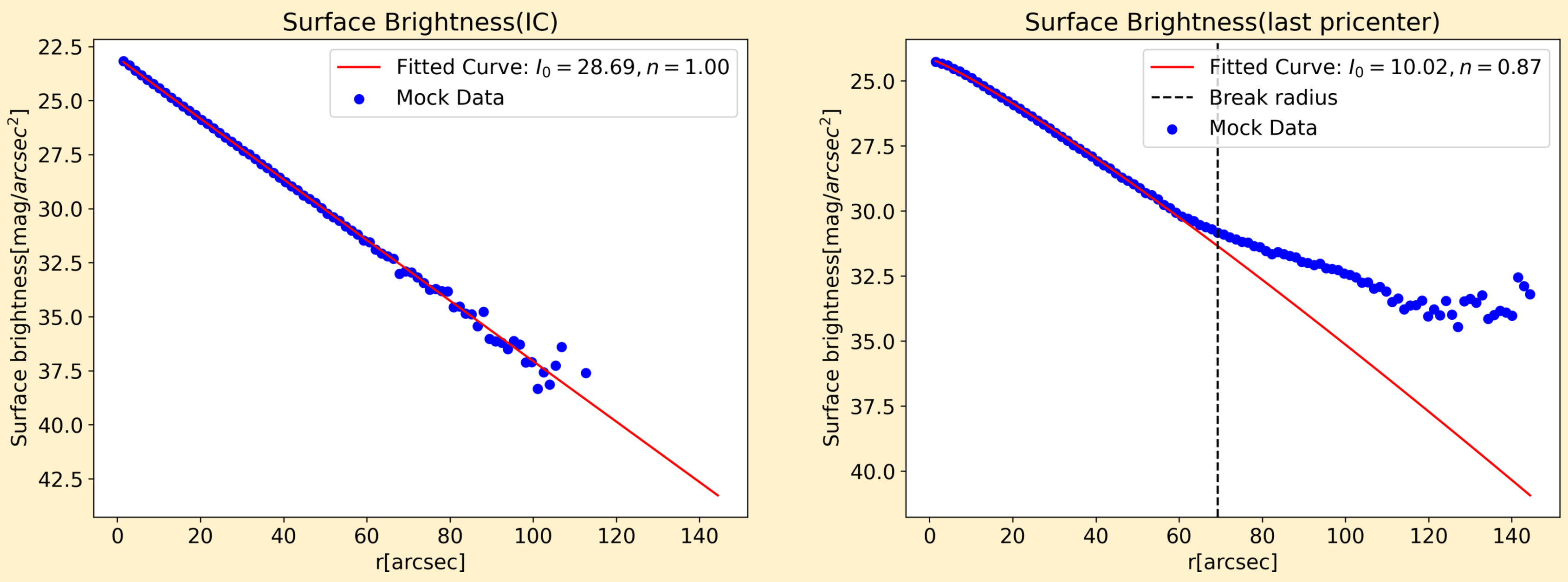
We use N-body simulation code GIZMO (Hopkins 2015) to simulate the dark matter deficient galaxies. We model the initial N-body system which eventually becomes dark matter deficient with two components: a stellar spheroid and a spherical DM halo. For stellar body, we use 3D radial density profile, whose 2D projected surface brightness corresponds to Sersic profile. For dark matter hallo, we use modified NFW profile (Read et al. 2016). We model the host halo, roughly representing the DM halo of the NGC 1052 group, using an analytical, time-varying NFW potential (Correa et al. 2015, Lodlow et al. 2016). The parameters are chosen based on observational data and empirical relations, for the satellite galaxy's orbit configuration, we use the same as Ogiya et al. (2022).

We obtained surface brightness data points for the simulated galaxy using mock observations, by projecting the distribution of star particles on to a plane along a randomly chosen orientation axis, which we register on a 2D rectangular grid with pixels that are 100 pc × 100 pc in size, and convert projected number density into a surface brightness in a mass-to-light ratio of $M/L = 2(M/L)_{\odot}$.

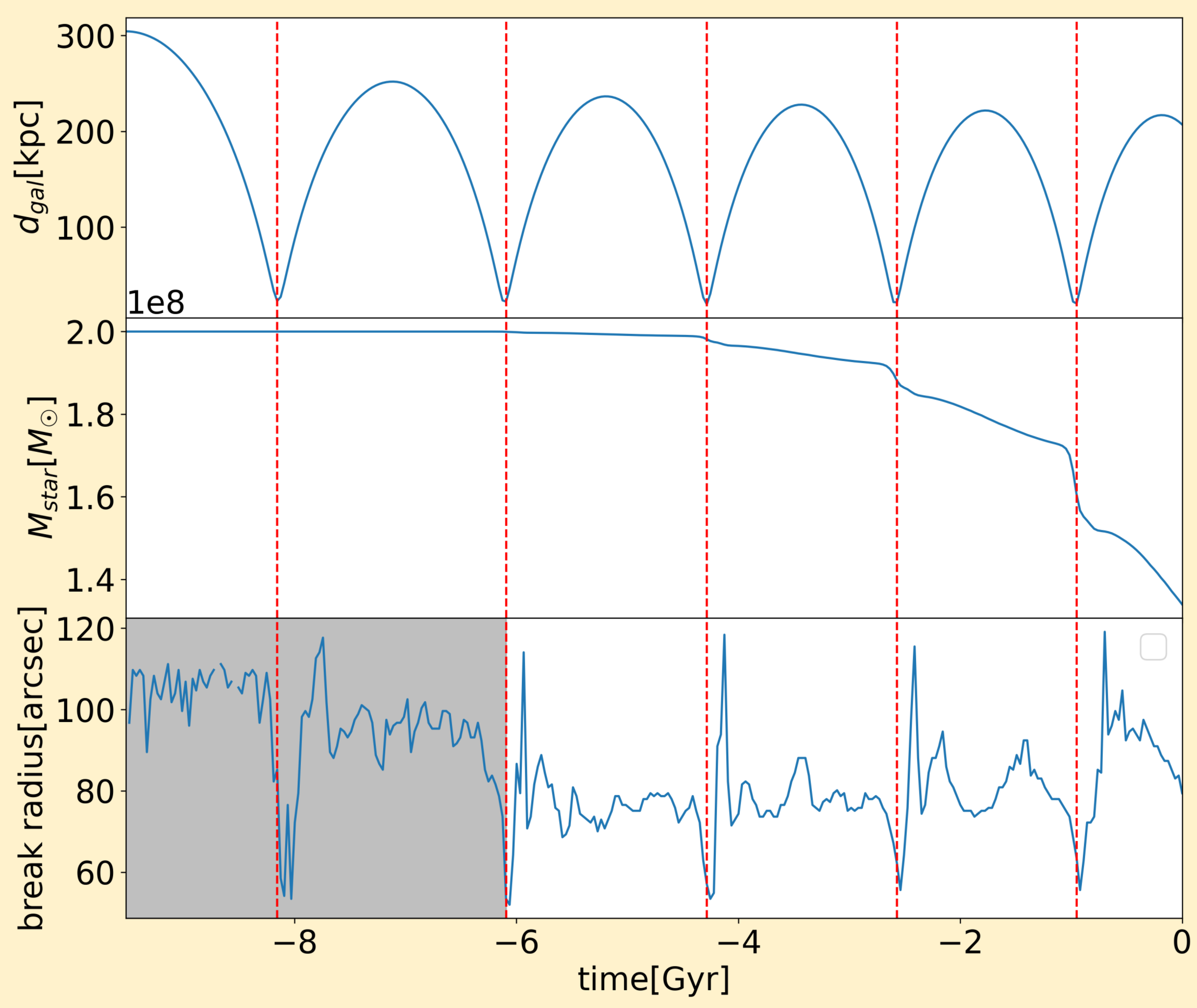


Results

By using the innermost data points and assuming they still follow a Sersic profile, we applied a least-squares method to fit new Sersic index and central luminosity. The effective radius was derived from the mock observation. Then we define the tidal break radius as the innermost radius that exceeds the Sersic fit by at least 0.5 $mag\ \mathrm{arcsec}^{-2}$.



Applying this analysis to all snapshots , we obtain the evolution of the break radius of the simulated galaxy over time. As shown in the figure below, from top to bottom are the evolution of the distance from the center of the satellite galaxy to the center of the host, the bound mass of the galaxy, and the break radius over time. In the last panel, since the satellite galaxy has not yet begun to experience tidal stripping before the first two pericenter passages, analyzing the break radius during this period is not meaningful. Therefore, this region is shaded in gray.



We found that the break radius responds to changes in tidal forces, rapidly decreasing at pericenter and then quickly increasing again. This behavior suggests the relaxation of the satellite galaxy after a tidal shock. Between subsequent pericenters, the break radius oscillates within a small range.

Using numerical simulations, identified tidal features comparable to those observed, specifically the break radius. We plan to further investigate this parameter and ultimately aim to predict its behavior from the perspective of the underlying physical processes.

Reference

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