MNRAS **000**, 000–000 (0000) Preprint 18 March 2025 Compiled using MNRAS LATEX style file v3.3

Tidal Transformation of M33's Stellar Disk in the Future MW–M31–M33 Interaction

Animesh Garg[1]★
[1]*Department of Astronomy, University of Arizona, 933 N Cherry Ave, Tucson AZ*

18 March 2025

ABSTRACT
In this proposal, I will investigate the tidal transformation of the stellar disk of M33 in the future interaction of the Local Group system (MW, M31, M33). This study will focus on how tides from a massive host (particularly M31) lead to morphological and dynamical changes in M33's disk. The final goal is to quantify changes in mass loss rate, disk density profiles, and disk warping over time, using a suite of snapshots from the van der Marel & Besla (2012) simulation.

Key words: galaxies: dwarf – galaxies: interactions – galaxies: evolution – galaxies: spiral

1 INTRODUCTION

Topic & Relation to Galaxy Evolution.
The tidal transformation of satellite galaxies is a critical process in galaxy evolution. Repeated tidal encounters with massive hosts can drastically alter a satellite's morphology, kinematics, and star formation activity. In particular, M33 provides an excellent case study: it is a lower-mass spiral galaxy in the Local Group, destined to experience close interactions with the Milky Way (MW) and Andromeda (M31). Studying how tides affect M33's disk structure, including spiral arm evolution, bar formation (if any), and mass loss, offers insight into satellite survival, quenching of star formation, and the buildup of stellar halos.

Why It Matters.
Understanding tidal transformations is fundamental because it informs us about the broader morphological diversity of dwarfs, the build-up of diffuse stellar halos, and the orbital history of satellites. For instance, resonant tidal stripping can lead to rapid mass loss (Mayer et al. 2001; D'Onghia et al. 2010), while strong tidal shocks can thicken or warp the disk and possibly trigger episodes of star formation. By focusing on M33, we gain concrete evidence of how a lower-mass spiral evolves when subjected to strong external gravitational fields.

Current Understanding.
Recent work has shown that tidal encounters play a decisive role in reshaping the internal structure of satellites, especially if the orbit is prograde or has a small pericentric distance (Lokas et al. 2015; Pardy et al. 2016). Cosmological simulations of dwarfs also confirm that disk galaxies can form bars or develop strongly lopsided stellar distributions under repeated tidal shocks. However, the timescales and the severity of disk truncation versus warping remain an active area of research.

Open Questions.
Key open questions include the precise mass loss rate for M33 over future orbits, the evolution of the stellar disk density profile (e.g., does it remain exponential or become tidally truncated?), the emergence of any spiral arm pitch-angle evolution, and the role of orbital orientation (leading to warps vs. bars). Also, the extent to which M33's stellar disk might transition to a more pressure-supported system is unknown. These are the issues we will address using the van der Marel & Besla (2012) simulation data.

★ E-mail: animeshgarg@arizona.edu

[h]

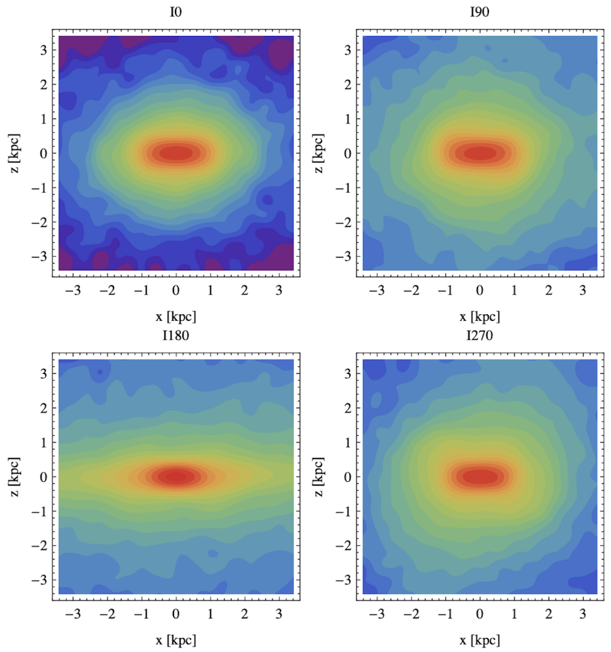

Figure 1. Surface density distributions of the stars in the dwarfs at the last apocenter (t = 8.65 Gyr) seen along the intermediate (y) axis of the stellar component. The surface density measurements were normalized to the maximum value $\Sigma_{max} = 4.8 \times 10^5$ stars kpc^{-2} occurring for I180. Contours are equally spaced in log Σ with $\Delta \log \Sigma = 0.05$

2 PROPOSAL

2.1 This Proposal

I will address the question: *How does M33's stellar disk evolve structurally (density profile, scale height, warping) and dynamically (mass loss, velocity dispersion) over the next* $\sim$ *5–10 Gyr under the repeated tidal influences of M31 and the MW*? I will focus on whether the disk develops signs of tidal truncation and measure the mass-loss rate of M33 as a function of time.

2.2 Methods

I will use the future MW–M31–M33 simulation data from van der Marel et al. (2012), specifically the snapshots from $t = 0$ to $t = 10$ Gyr at 1 Gyr intervals.

- *Particle selection*: Choose only M33 stellar particles (type=2 or 3) and ensure they lie within a fiducial radius of M33's center (e.g., $r < 30$ kpc).
- *Compute the Jacobi radius R_J* for M33 at each snapshot using $R_J \approx R \left(\frac{M_{\rm sat}}{2\,M_{\rm host}}\right)^{1/3}$ (e.g., Lokas et al. 2015).
- *Measure mass loss*: track total bound mass within R_J.
- *Stellar density profile*: fit to Sersic/exponential and check for tidal truncation.
- *Morphology*: create face-on/edge-on density maps, measure scale height over time, search for disk warps, pitch angles, or bar-like distortions.

All analyses will be done in Python, building on code from previous labs.

2.3 Hypothesis

I hypothesize that M33 will experience significant mass loss (10–20%) over the next 5 Gyr. Its outer disk will likely be tidally truncated, with a sharper density cutoff. The disk should become increasingly warped, especially after major pericentric passages near M31. Additionally, spiral arms may appear more flocculent or disrupted, and the overall scale height might grow due to tidal heating. These effects are expected because repeated resonant encounters can strip material and stir the disk (Mayer et al. 2001; D'Onghia et al. 2010).

DATA AVAILABILITY

No new data were generated. Simulation data from van der Marel et al. (2012) are publicly available via the authors.

REFERENCES

D'Onghia E., Besla G., Cox T. J., Hernquist L., 2010, Astrophysical Journal, 725, 353

Lokas E. L., Semczuk M., Gajda G., D'Onghia E., 2015, Astrophysical Journal, 810, 100

Mayer L., Governato F., Colpi M., et al., 2001, Astrophysical Journal, 559, 754

Pardy S., D'Onghia E., Athanassoula E., Wilcots E., Sheth K., 2016, Astrophysical Journal, 827, 149

van der Marel R. P., Besla G., et al., 2012, Astrophysical Journal, 753, 9