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On a Downward Spiral: Understanding the Morphological Changes of M33 Under the Tidal Influence of M31

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1. INTRODUCTION

For my research project, I am interested in understanding the morphological evolution of M33's disk as it undergoes tidal interactions with M31. This topic is important to our current knowledge of galaxy evolution because by studying the effects of tidal interactions on a galaxy's morphology, we are able to understand how much a galaxy's shape is determined by both internal and external factors over time. Such an understanding is different from our knowledge of galaxy mergers (e.g. spirals merge into ellipticals) because it concerns the structure of a single galaxy rather than two or many galaxies combining into one.

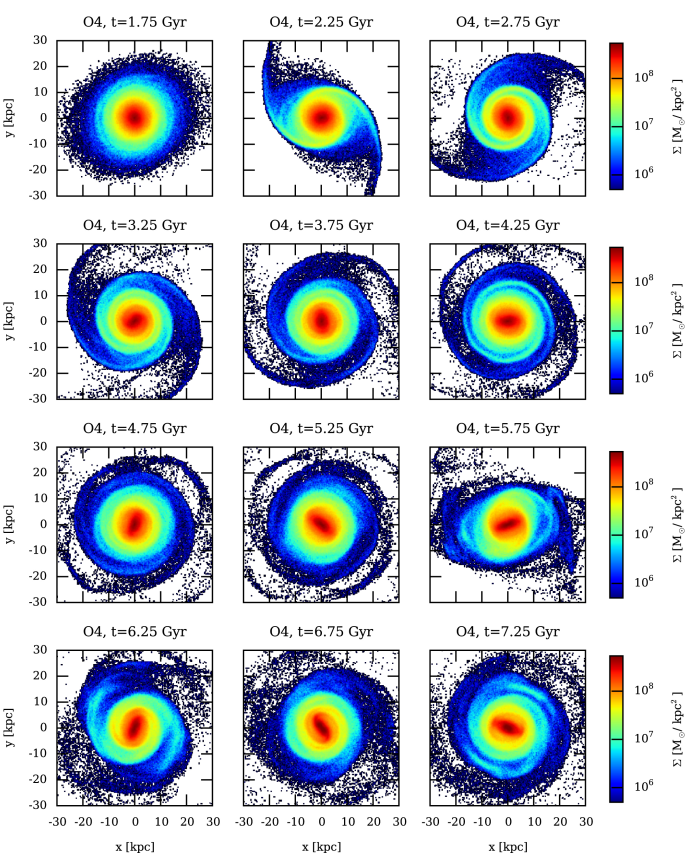

Figure 1. Face-on view of the surface density distribution of stars in the Milky Way-like galaxy from Semczuk et al. (2017), showing two distinct spiral arms.

Previous simulations have shown that tidal interactions can lead to changes in galactic morphology, specifically the formation of spiral arms. Hydrodynamic models of the grand spiral galaxy M51 by Dobbs et al. (2010) have shown that M51's spiral arms are most realistically the result of tidally-induced kinematic density waves that wind up over time. Similarly, Semczuk et al. (2017) found that when a Milky Way-like galaxy orbits a Virgo-like cluster, that galaxy can develop two temporary spiral arms during pericenter passages, as seen in Fig. 1. While M33 does not possess well-defined grand design spirals like M51 and is not similar in size to the Milky Way, it does have a two-armed spiral structure. Tracking M33 in simulations, Semczuk et al. (2018) noted that these arms were mostly likely excited by tides from its host galaxy, M31. This begs the question: what are the consequences that M33's tidally induced morphological changes would have on its disk? In my research project, I am hoping to answer this question, primarily by making density contours of M33 over time.

2. PROPOSAL

For my research, I will be looking at M33 in the simulation to answer the following questions: how and when do M33's spiral arms develop? Is it possible for these arms to wind up over time? If they reappear after winding up, what are the circumstances of the reappearance? Last but not least, how does M33's disk appear as these spiral arms are developing/winding up?

To answer these questions, I will analyze the simulation data. I will begin by making surface density contour plots of the stars in M33 in the xy, yz, and xz planes. An example of how these plots will look without contour lines can be found in Fig. 2, although I will not be categorizing the stellar material into old and young stars like that. On these contour plots, if I catch sight of any spiral structures, I will draw contour lines and assign values to these lines until they trace the outlines of the structures. By doing so, I hope to keep track of the evolution of these spiral arms over simulation snapshots. I will also be simultaneously drawing contour lines of M33's overall disk, so that I can look at the disk over cosmic time and describe qualitatively how it evolves, whether its shape has changed, etc.

I expect to find two spiral arms, just like other simulations and observations have noted. I also expect to find that the arms will exist temporarily at certain points along M33's orbit around M31. The reason is because the tidal force varies with distance, and the greater the distance, the less significant the tidal force. Other than these expectations, I also want to hypothesize that the spiral arms will be the most stable when M33 is far away from M31. I do not have enough knowledge on the literature to back this up, but my intuition is that when M33 gets close to M31, the tidal force will be so strong that M33 will be pulled apart in many directions, which will prevent it from maintaining well-defined spiral structures.

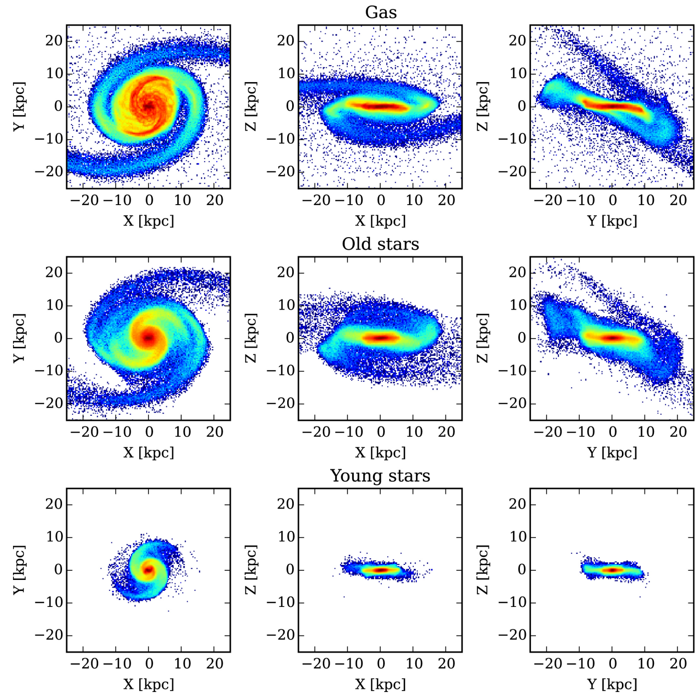

Figure 2. Surface density distributions of the gas, old stars and young stars in M33, as simulated by Semczuk et al. (2018).

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