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The Evolution of Stellar Disk/Bulge Morphology after a Major Merger

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ABSTRACT

1. INTRODUCTION

For this paper, we aim to investigate how well the remnant of the mergers can be described as a classical elliptical galaxy based on its surface density profile, with a specific focus on determining the best-fit Sérsic profile of the remnant galaxy post-merger. We will only focus on dry mergers, which are mergers between gas-poor galaxies (L. Lin et al. 2008). The classification of galaxies based on morphology has been one of the earliest approaches to understanding galaxy structure, particularly based on the relative prominence of their two main components, i.e. the (spheroidal) bulge and the (exponential) disc. This particular scheme was originally proposed by E. P. Hubble (1926) and later refined by G. De Vaucouleurs (1959).

The morphological framework has sparked a fundamental question in the field of galaxy formation and evolution: What is the relationship between a galaxy's shape and its evolutionary history? By examining this, we can inform our understanding of the role of various astrophysical processes, including mergers, star formation, and black hole growth, in driving galaxy evolution (J. E. Barnes & L. Hernquist 1992).

Our current understanding of galaxy evolution suggests that mergers play a crucial role in shaping the structure and morphology of galaxies. One of the primary ways that mergers can be identified is through their effect on galaxy structure, with merging galaxies often exhibiting peculiar or distorted morphologies (e.g. A. Toomre & J. Toomre (1972); C. J. Conselice (1997)). Various methods have been developed to quantify the merger fraction, including the CAS approach (C. J. Conselice 2003), the Gini / M20 parameters (J. M. Lotz et al. 2004) and the multi-mode statistics (P. E. Freeman et al. 2013). These methods can be used to calculate the merger fraction, which is the number of mergers within a given population of galaxies, and to study the role of mergers in shaping galaxy evolution (e.g. R. De Propris et al. (2007)).

Despite the importance of galaxy mergers in understanding galaxy evolution, there are still many open questions surrounding the galaxy-galaxy merger rate and its consequences. Theoretical and observational studies have yielded inconsistent results, with different groups and simulations producing varying estimates of the merger rate as a function of galaxy mass and merger mass ratio (e.g. S. Gottlober et al. (2001); T. Weinzirl et al. (2008)). Furthermore, the role of minor mergers versus major mergers in bulge formation remains a topic of debate, with some studies suggesting that minor mergers can be just as effective as major mergers in building bulge mass (T. J. Cox et al. 2008). The merger history of galaxies and how it affects their evolution is also not well understood, with many questions remaining about the typical merger history through which most of the bulge mass in the universe was assembled.

2. PROPOSAL

2.1. *Proposal*

We determine how well is the remnant described as a classical elliptical galaxy based on its surface density profile? What is the best fit sersic profile of these galaxies post merger?

2.2. *Methods*

We will utilize the simulation data (R. P. Van Der Marel et al. 2012) from the merger, which occurs between 6.3 (snap 441) and 6.7 (snap 469) Gyr, and focus on the data from snap 469, as it represents a time shortly after the merger (a few Myr) when the system has had a chance to relax and become more stable. We will combine the particles from the disk and bulge of both the MW and M31 using the high-resolution version of particle data (VHighRes), and calculate the surface density profile of the remnant galaxy using the surface mass density code from Lab 6. We will then assume that the remnant galaxy can be described by a Sérsic profile for an elliptical galaxy, given by the equation

$I(r) = I_e\, e^{-7.67((r/R_e)^{1/n}-1)}$, and use the `scipy.optimize` module to fit the Sérsic profile to the surface density profile, estimating the best-fit parameters, including the effective radius R_e, the Sérsic index n, and the intensity I_e.

We expect to see a surface density profile as shown in Figure 1 and will fit the Sérsic index to the density profile.

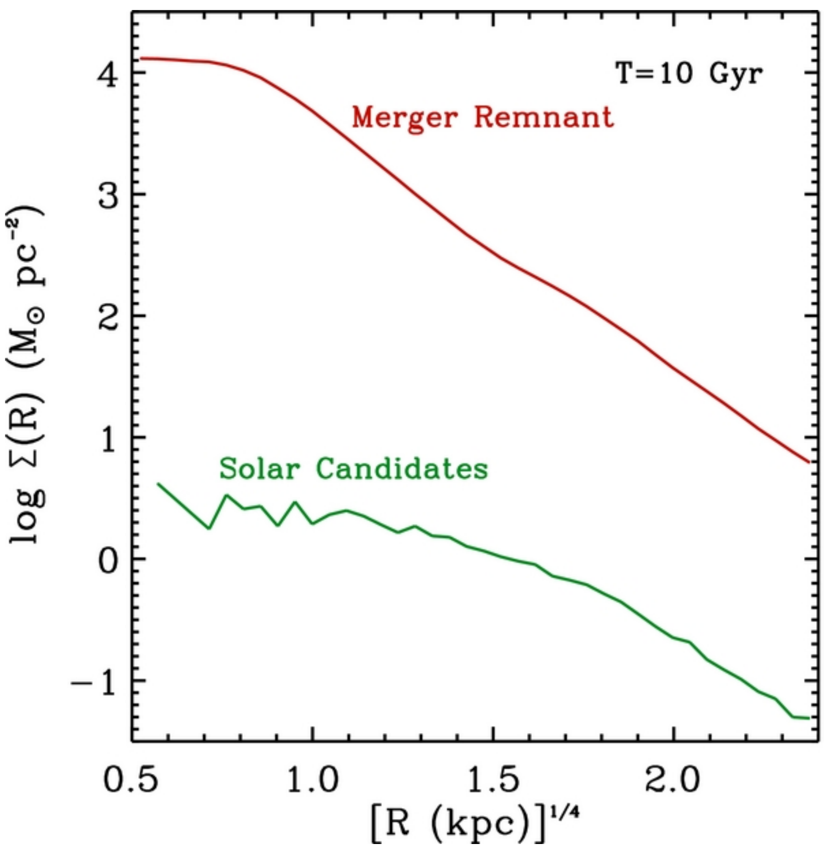

Figure 1. Adapted from R. P. Van Der Marel et al. (2012), this figure shows the projected surface-density profile (red) of luminous MW and M31 particles in the merger remnant at the end of the N-body simulation.

2.3. *Hypothesis*

Based on our understanding of galaxy mergers and the formation of elliptical galaxies, we hypothesize that the remnant of the MW-M31 merger would be an elliptical galaxy and will be well-described by a Sérsic profile with a high Sérsic index ($n = 4$) following the de Vaucouleurs profile. Additionally, the simulated remnant galaxy is expected to have more radially extended than its progenitor galaxies. We predict that the effective radius (R_e) of the remnant galaxy will be larger than that of the individual progenitor galaxies, due to the increased size and scale of the merged system. Overall, our hypothesis is that the remnant galaxy will exhibit a density profile that is consistent with that of a classical elliptical galaxy, with a high Sérsic index, a large effective radius, and a surface-density profile that follows a de Vaucouleurs $R^{1/4}$ law.

REFERENCES

Barnes, J. E., & Hernquist, L. 1992, Annual Review of Astronomy and Astrophysics, 30, 705, doi: 10.1146/annurev.aa.30.090192.003421

Conselice, C. J. 1997, Publications of the Astronomical Society of the Pacific, 109, 1251, doi: 10.1086/134004

Conselice, C. J. 2003, The Astrophysical Journal Supplement Series, 147, 1, doi: 10.1086/375001

Cox, T. J., Jonsson, P., Somerville, R. S., Primack, J. R., & Dekel, A. 2008, Monthly Notices of the Royal Astronomical Society, 384, 386, doi: 10.1111/j.1365-2966.2007.12730.x

De Propris, R., Conselice, C. J., Liske, J., et al. 2007, The Astrophysical Journal, 666, 212, doi: 10.1086/520488

De Vaucouleurs, G. 1959, in Astrophysik IV: Sternsysteme / Astrophysics IV: Stellar Systems, ed. S. Flügge & S. Flügge, Vol. 11 / 53 (Berlin, Heidelberg: Springer Berlin Heidelberg), 275–310, doi: 10.1007/978-3-642-45932-0_7

Freeman, P. E., Izbicki, R., Lee, A. B., et al. 2013, Monthly Notices of the Royal Astronomical Society, 434, 282, doi: 10.1093/mnras/stt1016

Gottlober, S., Klypin, A., & Kravtsov, A. V. 2001, The Astrophysical Journal, 546, 223, doi: 10.1086/318248

Hubble, E. P. 1926, The Astrophysical Journal, 64, 321, doi: 10.1086/143018

Lin, L., Patton, D. R., Koo, D. C., et al. 2008, doi: 10.48550/ARXIV.0802.3004

Lotz, J. M., Primack, J., & Madau, P. 2004, The Astronomical Journal, 128, 163, doi: 10.1086/421849

Toomre, A., & Toomre, J. 1972, The Astrophysical Journal, 178, 623, doi: 10.1086/151823

Van Der Marel, R. P., Besla, G., Cox, T. J., Sohn, S. T., & Anderson, J. 2012, The Astrophysical Journal, 753, 9, doi: 10.1088/0004-637X/753/1/9

Weinzirl, T., Jogee, S., Khochfar, S., Burkert, A., & Kormendy, J. 2008, doi: 10.48550/ARXIV.0807.0040