Merger time scale of galaxies

Y.P. Jing, C. Y. Jiang, A. Faltenbacher, W. P. Lin, Cheng Li

Shanghai Astronomical Observatory, Nandan Road 80, Shanghai, China

Abstract. In this talk, we present our recent study of galaxy mergers in a high-resolution cosmological hydro/N-body simulation with star formation, and compare the measured merger timescales with theoretical predictions based on the Chandrasekhar formula. In contrast to Navarro et al., our numerical results indicate, that the commonly used equation for the merger timescale given by Lacey and Cole, systematically underestimates the merger timescales for minor mergers and overestimates those for major mergers. This behavior is partly explained by the poor performance of their expression for the Coulomb logarithm, $\ln(m_{\rm pri}/m_{\rm sat})$. The two alternative forms $\ln(1+m_{\rm pri}/m_{\rm sat})$ and $1/2\ln[1+(m_{\rm pri}/m_{\rm sat})^2]$ for the Coulomb logarithm can account for the mass dependence of merger timescale successfully, but both of them underestimate the merger time scale by a factor 2. Since $\ln(1+m_{\rm pri}/m_{\rm sat})$ represents the mass dependence slightly better we adopt this expression for the Coulomb logarithm. Furthermore, we find that the dependence of the merger timescale on the circularity parameter ε is much weaker than the widely adopted power-law $\varepsilon^{0.78}$, whereas $0.94*\varepsilon^{0.60}+0.60$ provides a good match to the data. Based on these findings, we present an accurate and convenient fitting formula for the merger timescale of galaxies in cold dark matter models.

Keywords: dark matter — galaxies: clusters: general — galaxies: kinematics and dynamics — methods: numerical
PACS: astrophysics

Dynamical friction plays a crucial role in the formation and evolution of galaxies. During the merger of two dark matter halos, galaxies in a less massive halo will become the satellite galaxies of the more massive one. These satellite galaxies gradually lose their energy and angular momentum under the action of dynamical friction and are predestined to sink to the center of the massive dark matter halo, if they are not disrupted by the tidal force.

The merger time scale is often estimated with the Chandrasekhar's formula, but no consensus has been reached on the accuracy of such applications. This is because a galaxy merger is a more complicated process than a pure motion of a rigid body through an uniform collisionless matter distribution as considered by Chandrasekhar. The primary halo has a density increasing inward to the halo center, which makes it nontrivial to choose the maximum impact parameter for the Coulomb logarithm. Because the satellites lose their mass due to the tidal interaction by the primary halo, one has to follow both the trajectory and the mass evolution of the satellites to derive their merger timescale. Unfortunately, there is still a considerable amount of uncertainties in modeling these processes. A further complication is that due to the similar orbits of the tidally stripped mass and the satellite itself the tidal debris will trail the satellite for a significant amount of time which in turn will exert a drag force on the satellite. Besides, the merger can alter the structure of the primary halo which is another complication for accurately computing the merger timescale.

Therefore, we analyse galaxy mergers in a SPH/N-body simulation and compare the merger time scale with the theoretical prediction based on the Chandrasekhar formula. We obtain the following main conclusions.

- In contrast with [1], we find that the widely used equation with the satellite's total mass at its first crossing of the host virial radius taken for $m_{\rm sat}$, systematically underestimates the merger timescale for minor mergers and overestimates it for major mergers;
- We show that the two alternative forms $\ln(1+m_{\rm pri}/m_{\rm sat})$ and $1/2\ln[1+(m_{\rm pri}/m_{\rm sat})^2]$ for the Coulomb logarithm, which also are widely used in literature, account for the mass dependence of merger timescale successfully. However, both of them underestimate the merger time scale by a factor 2 if the satellite's total mass at its first crossing of the host virial radius is used for $m_{\rm sat}$. Of these two forms, the former does slightly better in accounting for the mass dependence;
- With $\ln(1+m_{\rm pri}/m_{\rm sat})$ taken for the Coulomb logarithm, we find the dependence on circularity parameter ε is much weaker than $\varepsilon^{0.78}$, and can be accurately represented by $0.94*\varepsilon^{0.60}+0.60$;
- Combining our findings on the mass and circularity dependencies, we present an accurate fitting formula for the merger timescale. Together with the distribution functions, one can use this equation to predict for mergers of galaxies in LCDM models.

CP966, *Relative Astrophysics - 4th Italian-Sino Workshop,* edited by C. L. Bianco and S.-S. Xue

A very detailed version of our work can be found in Jiang et al. (2007).

Our results do not necessarily mean that Chandrasekar's theory is not applicable for mergers of galaxies. Instead our results do indicate that many previous applications of this theory led to incorrect results because some simplified assumptions were adopted. We believe that the mass loss of satellites and the steep density gradient of host halos are two of the key reasons that make the problem complicated. In a future paper, we will investigate if our simulation results can be reproduced with the Chandrasekhar theory by properly taking into account of these two factors.

ACKNOWLEDGMENTS

This work is supported by NSFC (10533030, 0742961001, 0742951001), by Shanghai Key Projects in Basic research (No. 04JC14079 and 05XD14019), and by the Knowledge Innovation Program of the Chinese Academy of Sciences, Grant No. KJCX2-YW-T05. AF is supported by the CAS Research Fellowship for International Young Researchers. The simulation was performed at the Shanghai Supercomputer Center.

REFERENCES

1. Navarro, J. F., Frenk, C. S., & White, S. D. M. 1995, MNRAS, 275, 56
2. Jiang, C.Y., Jing, Y.P., Faltenbacher, A., Lin, W.P., Li, C. 2007, ApJ, (in press); astro-ph/0707.2628