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The Evolution of Fundamental Galaxy Scaling Relations

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The purpose of this project is to investigate the structure of spiral galaxies using numerical simulations. We specifically explored the evolution of fundamental galaxy scaling relations, such as the Tully-Fisher relation (TFR), over the lifetime of a galaxy. The TFR is a linear relationship between the baryonic or stellar mass of spiral galaxies and their circular velocity. This project utilized two specific TFRs: the baryonic TFR (BTFR) which relates the baryonic mass of a galaxy to its circular velocity, and the stellar TFR (STFR) which compares the stellar mass of a galaxy to its circular velocity. While the TFR can provide valuable structural information about a galaxy (e.g., its distance), its underpinnings are still elusive and hold deep secrets about the way that baryons and dark matter impact each other. In order to examine how the TFR evolves with time, a hydrodynamical simulation of galaxy formation and cosmic structure was required. The Numerical Investigation of a Hundred Astrophysical Objects (NIHAO) simulation was used to the effect. The exact spatially-resolved definition of structural parameters also affects the final TFR and how it evolves with time. Therefore with NIHAO, we can better define TFR scaling parameters for fully-evolved systems (current time) and track their evolution with time. Four locations within a galaxy were tested for the measurement of TFR velocities at: 1) physical radii, 2) arbitrary (e.g. maximum) velocities, 3) percentages of the virial radius, and 4) isodensity levels. For each of these categories, four specific locations within the galaxy were tested, resulting in a total of sixteen test locations where to measure TFRs. After investigating the TFRs produced at these test locations for fully evolved ("redshift zero") galaxies, three locations were selected to track the TFRs: an isodensity level and two different velocities. The isodensity level chosen was $1\ M_{\odot} pc^{-2}$, and the velocities chosen were the velocity of the final data point for each galaxy and the median velocity between the effective radius of the galaxy and the last data point for each galaxy. Data analysis to track the evolution of the slopes and scatters of the TFRs at each of these three finalized locations is being applied over the full redshift range (0-3) of the NIHAO simulations. A project of this nature, to understand the detailed evolution of the TFR parameters and how it may be connected to the growth of the galaxy's stellar mass, dark matter mass, or both has never been presented before.

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