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A self-consistent numerical model of the Milky Way with the N-body software GADGET-4

The use of N-body simulation is a commonly applied approach to explain, reproduce and predict phenomena in extragalactic astronomy. A model of the Milky Way self-consistent with the current reference values of its physical parameters is particularly valuable for analyzing phenomena within our galaxy, such as the distribution of star properties within the stellar disk. This study aimed to present a numerical model of an isolated galaxy that accurately reproduces multiple physical features of the Milky Way. Parameters proposed in the initial condition and assessed in the resulting simulation included: star formation rate, gas fraction, morphological aspects of the disk, aspects of the dark matter halo, disk metallicity and properties of the galaxy bar. This work utilized the GALSTEP software to generate initial conditions that satisfy recent observational constraints. Simulations were carried out using the N-body simulation software, GADGET-4, which includes gas cooling and star formation modules, used to calculate gravitational interactions. We obtained a numerical model of the Milky Way ($\sim N \times 10^6$ particles) with best fit benchmark values that simultaneously features a star formation rate ($\sim 2.5\,\mathrm{M_\odot yr^{-1}}$) and gas fraction ($\sim 10\%$). As an application of the numerical model, we developed an algorithm to estimate the length of the galaxy bar by fitting ellipses. This algorithm obtained a bar length of $\sim 3.5\,\mathrm{kpc}$ and a bar ellipticity of ~ 0.4, values also consistent with the Milky Way's reference values.

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