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Advances in Galactic Dynamics: Classical Physics in the 21st Century

JOHN DUBINSKI, University of Toronto

During the past 2 decades, there have been tremendous advances in computational power and algorithmic efficiency in the numerical N-body problem. Despite the vast scale of the universe, the original Newtonian equations of motion along with the inverse-square law of gravity still provide an adequate physical framework for studying many of the complexities of the dynamic universe. The relativistic limit in the macroscopic universe is only reached on the extreme scales of the entire observable universe and the event horizons of black holes. Here I will review some of the recent advances in parallel computational algorithms for application to the collisionless N-body problem with the main applications to the problem of the dynamics of galaxies and cosmological structure formation. The cosmological paradigm of cold dark matter with a cosmological constant is now so well-constrained that in principle detailed predictions of the dynamical behavior of galaxies can be tested against observation. I will describe two recent studies that use realistic, self-consistent N-body models of disk galaxies to study the effects of two cosmological predictions: dark matter halo triaxiality and substructure. The reaction of a stellar disk to these dark matter characteristics leads to triggering of the bar instability at random times in a given galaxy's life history and so can help explain the observed fraction and incidence of bars in the spiral galaxy population. I will also present some recent work on high-resolution computer animation of galactic dynamics that originated as a way to illustrate and develop intuition about dynamical processes but has since developed into a means of artistic expression through the beauty of complex gravitating systems.