Computer Simulations of Planet Collisions Using a New Parallel Algorithm

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ABSTRACT

New deterministic computer simulations have been developed for studying the dynamics of large objects colliding. For various initial conditions the system may clump together forming a new object or may rotate, causing ejecta to leave the primary mass in a pattern sustaining only a short number of orbits, but promising of satellite formation. Bodies without a large central mass are not able to form a cohesive object, and fly apart upon impact. A rudimentary scaling study when the code is parallelized using a force-decomposition scheme suggests that the computational time scales inversely as the number of processors when less than four are involved and the gains are somewhat less pronounced as the number of processors increases.

I. INTRODUCTION

The formation of planets and solar systems has been a question in the scientific community for many centuries. A variety of analytical and numerical approaches have been put forth in an attempt to explain various aspects of the sun, moon, and planets within the last twenty years. Just recently, however, science has been able to apply numerical methods and conduct computational investigations into the actual dynamics and stochastic processes believed to be active in planetary formation and change. Ring and satellite systems are of particular interest: are they formed during various stages in the early history of a planet or can they be formed by trauma to an already formed body? Whether planet and solar system dynamics are modeled from a fluid-dynamical approach or a many-particle-system approach almost any study will contribute new insight and results to the field.

A fair amount of work has been done in an attempt to model the time evolution of the proto-solar system using hydrodynamic models with emphasis on circumstellar ring formation [1-7] and even ring formation using interacting gravitating particles [8,9]. Most closely related to the work presented here are the very interesting results of 36 smooth particle hydrodynamics (SPH) simulations of lunar formation by means of a large body impacting the Earth [10]. There were anywhere from 20,000 to 30,000 particles in the simulations and a wide range of initial conditions were examined. This work incorporates the Tilloston equation of state (EOS) originally developed to describe strong shock in condensed matter to model the various changes of phase that might occur throughout a collision between planets. The simulations incorporated a final angular momentum constrained to be within 10% of the current earth-moon angular momentum. Simulations with an object about the size of Mars colliding with an Earth close to the end of its formation (accretion process) yields an iron-poor moon with an appropriate earth-moon system mass and angular momentum.

The intent of this research was to understand how various initial conditions affect the outcomes of large bodies that collide. We also wished to clarify how the