cuSwift — a suite of numerical integration methods for modelling planetary systems implemented in C/CUDA

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Simulations of dynamical processes in planetary systems represent an important tool for studying the orbital evolution of the systems [1–3]. Using modern numerical integration methods, it is possible to model systems containing many thousands of objects over timescales of several hundred million years. However, in general, supercomputers are needed to get reasonable simulation results in acceptable execution times [3]. To exploit the ever-growing computation power of Graphics Processing Units (GPUs) in modern desktop computers, we implemented cuSwift, a library of numerical integration methods for studying long-term dynamical processes in planetary systems. cuSwift can be seen as a re-implementation of the famous SWIFT integrator package written by Hal Levison and Martin Duncan. cuSwift is written in C/CUDA and contains different integration methods for various purposes. So far, we have implemented three algorithms: a 15th-order Radau integrator [4], the Wisdom-Holman Mapping (WHM) integrator [5], and the Regularized Mixed Variable Symplectic (RMVS) Method [6]. These algorithms treat only the planets as mutually gravitationally interacting bodies whereas asteroids and comets (or other minor bodies of interest) are treated as massless test particles which are gravitationally influenced by the massive bodies but do not affect each other or the massive bodies. The main focus of this work is on the symplectic methods (WHM and RMVS) which use a larger time step and thus are capable of integrating many particles over a large time span. As an additional feature, we implemented the non-gravitational Yarkovsky effect as described by M. Brož [7].

With cuSwift, we show that the use of modern GPUs makes it possible to speed up these methods by more than one order of magnitude compared to the single-core CPU implementation, thereby enabling modest workstation computers to perform long-term dynamical simulations. We use these methods to study the influence of the Yarkovsky effect on resonant asteroids. We present first results and compare them with integrations done with the original algorithms implemented in SWIFT in order to assess the numerical precision of cuSwift and to demonstrate the speed-up we achieved using the GPU.

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