Smoothed Particle Hydrodynamics Simulations of Binaries and Disks

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In this proposal, we request a startup allocation via Teragrid consisting of 200,000 SUs on the TeraDRE cluster, and if possible under a startup, 100,000 SUs on Ranger (or Kraken if necessary). The PI, in association with collaborator E. Gaburov, has developed a GPU-enabled smoothed particle hydrodynamics (SPH) code that computes gravitational interactions between particles using the `CUNBODY` libraries that essentially replace calculations previously performed on specialized GRAPE hardware with GPU-based computations. The resulting code has been used to publish a number of papers over the past two years [1–3], and scaling results have been obtained indicating that the time per iteration scales like $2.1N_5^2 + 1.6N_5$s for calculations involving $10^5 N_5$ SPH particles. Faber and Lombardi have extensive experience with SPH codes, having released the `StarCrash` parallel SPH code in 2004 [4], with variants having been run at several platforms first at NCSA and then on Teragrid.

In this project, we propose to study two systems while refining our numerical methods for production runs on Teragrid architectures. On TeraDRE, we propose to use the GPU-enabled code to model the system v838 Monocerotis. This system, thought to contain an $8M_\odot$ primary, was observed in 2002 to undergo a quasi-periodic outburst with a period of roughly one month between luminosity spikes. One of the leading models to explain the observations involves a merger between the primary and a smaller secondary that was tidally disrupted after encountering it on a high-eccentricity orbit [5]. Such high-eccentricity events can occur via the Kozai mechanism, and there is a third star in the system that could have acted as a perturber. Using our SPH code, we plan to model the disruption of the secondary, the ejecta it produces, and the effect this has on the primary. Given the observed luminosities and outflow velocities, we hope to confirm or refute the merger model for the system, and if it is found to be plausible, constrain the properties of the original binary system. Assuming that a typical calculation will involve 10^6 SPH particles, we should be able to perform 15 timesteps per SU, with roughly 200,000-500,000 timesteps required for an average calculation ($13 - -33$kSU) that will span between 1-3 orbits as the secondary is gradually disrupted. Our goal is to consider at least two secondary stellar masses spanning the suggested possible range of values $M = 0.1,\ 0.3M_\odot$, and four impact parameters for each spanning the range between marginal Roche lobe overflow of the secondary and the onset of mass transfer and closer passages that lead to more immediate disruption of the secondary. These calculations should allow us to match the luminosity of each spike and velocity of the ejecta.

Should an additional allocation be possible via a startup, we request 100,000 SU on Ranger (with Kraken as an alternate choice) to investigate the properties of the SPH code on accretion disk systems in which self-gravity (and thus the GPU sector of the code) is ignored. As a first project, we will study models of disks around kicked post-merger black holes, motivated by a number of recent candidate observations (see, e.g., [6, 7]). We seek to model how the black hole kick angle affects the resulting disk evolution, as quantities like the kick velocity, BH mass, and disk mass can be used to define scaling relations in terms of a set of dimensionless quantities for the resulting Newtonian calculations.

We note that Faber, an assistant professor at RIT, and Ponce, a graduate student, currently have Teragrid accounts under allocation TG-PHY-060028 to support an unrelated set of numerical relativity calculations using a different set of codes.

References

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