Simulating Star Clusters with AMUSE

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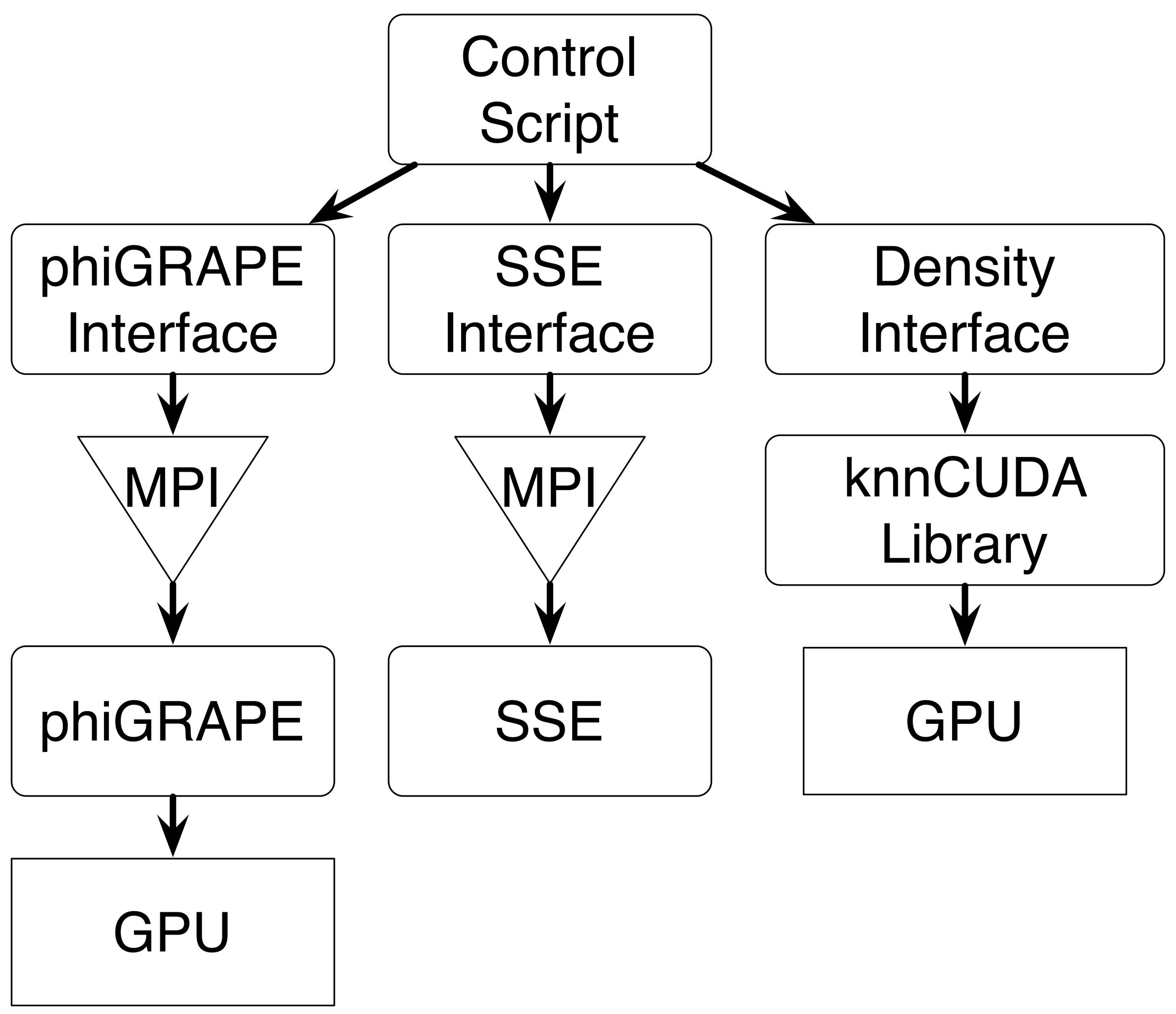
Introduction

Our goal is to demonstrate that the new AMUSE code framework is sufficiently developed to be useful for scientific work. This is done by attempting to reproduce well-known results from Chernoff & Weinberg (1990) [CW] and Takahashi & Portegies Zwart (2000) [TPZ] for clusters evolving under the combined influence of gravitational dynamics and stellar evolution.

The results survey the parameter space of King models in a highly idealized tidal field. We vary the concentration, mass function slope and tidal time scale. The parameters chosen specifically avoid core-collapse as the AMUSE multiple module is still in development.

AMUSE

The Astrophysical Multipurpose Science Environment (AMUSE) is a new code base growing out of the MUSE project [7]. The core idea behind AMUSE is that it links together codes specialized to a single physical problem in order to create a multi-physics simulation rather than combining all codes into a single monolithic program.

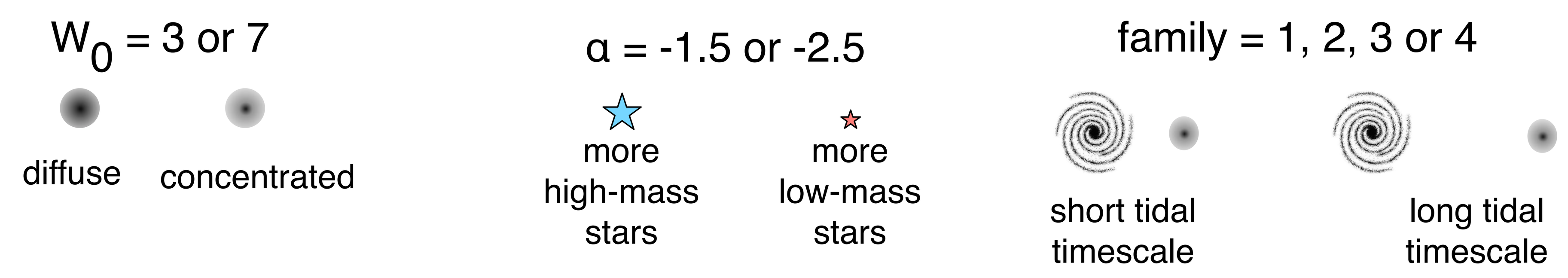


AMUSE uses MPI to allow each module to exist in its own process, possibly in parallel and on a different machine than the Python control script. The AMUSE framework provides an easy way to import new legacy codes.

phiGRAPE [4] provides N-Body dynamics using SAPPORO [2] for GPU acceleration. SSE [5] provides stellar evolution. knnCUDA [3] is used to compute densities (12th nearest neighbour) in a stand-alone code similar to [1], but separate from AMUSE. This code finds all nearest neighbours, regardlesss of distance.

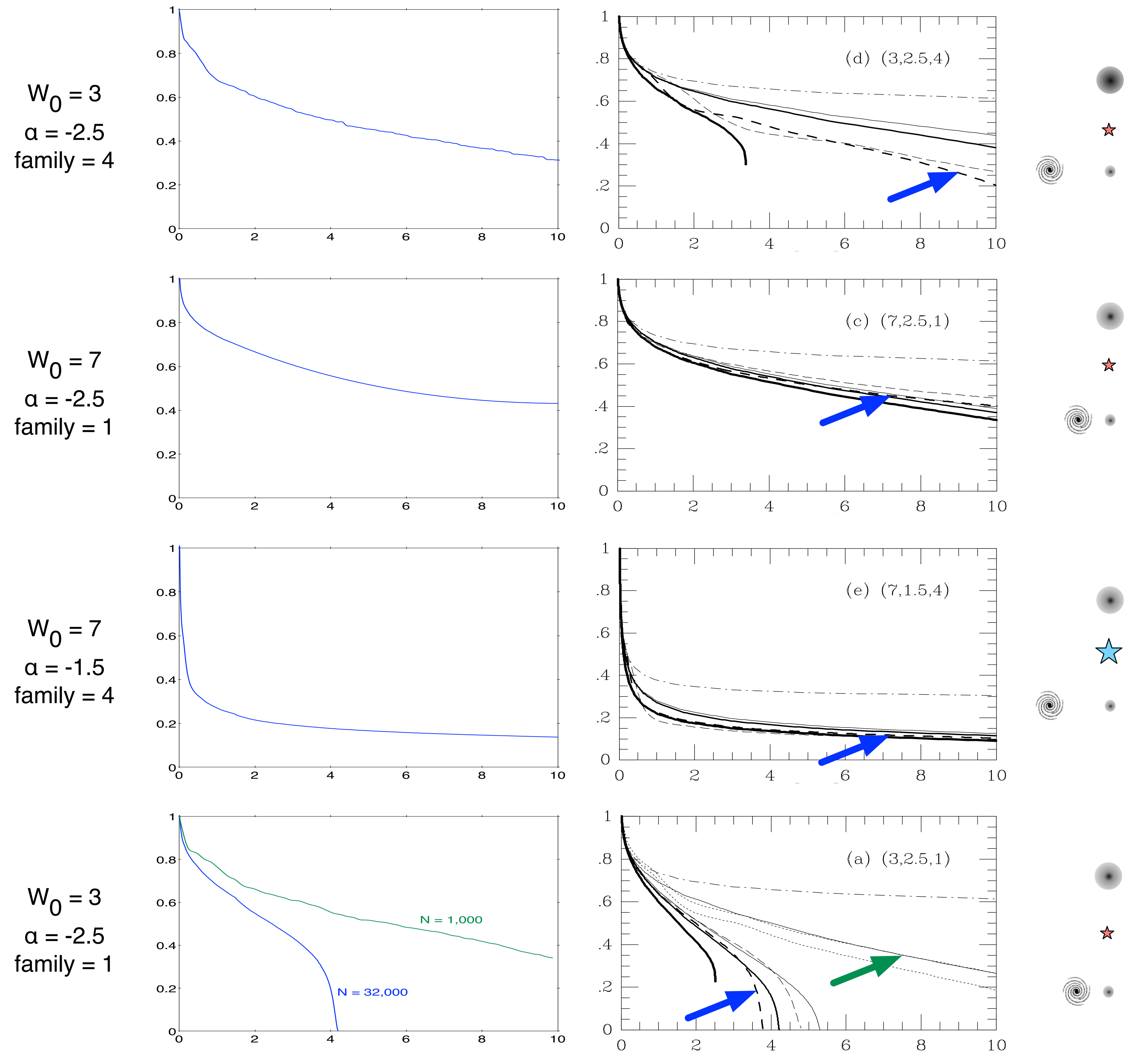
Models

King Models [5] of a star cluster:



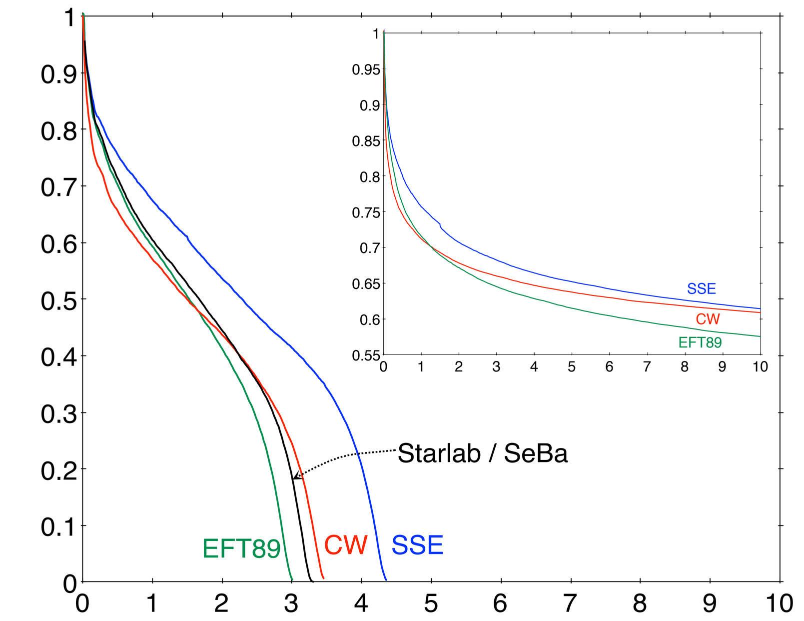
Tides are simulated using truncation at the Jacobi radius (= the King tidal radius). For all displayed runs, N = 32,000. Runs with N = 1,000 and N = 8,000 were also conducted.

Results



AMUSE runs are at left, [TPZ] at right. The plots are of mass (as a fraction of initial) versus time in Gyr. The thick dashed line (indicated) on the [TPZ] plots is the N=32k run.

Stellar Evolution Model Comparison



This plot shows the same N=16,000 model (W_0 = 3, α=-2.5, family=1) evolved using different stellar evolution models. AMUSE easily allows switching stellar evolution models in the same code. All curves used AMUSE, except for the Starlab comparison. The inset shows the population synthesis results for these models.

Conclusions

- Our AMUSE runs are in good agreement with [TPZ] and [CW], apart from small differences due the different stellar evolution models used, validating the use of AMUSE as a research tool.
- The modular structure of AMUSE facilitates comparison of physics modules and enables exploration of assumptions and approximations that is difficult or impossible with other simulation codes.
- Specifically, AMUSE allows direct comparison of the effect of differing stellar evolution models. The choice of model can change the computed lifetime of a cluster near disruption by up to ~25%.
- For the adopted parameters, AMUSE outperforms Starlab's kira by a factor of ~2.

References

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Further Information

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