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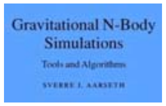
Adapting NBODY4 with a GRAPE-6a supercomputer for web access via NBodyLab

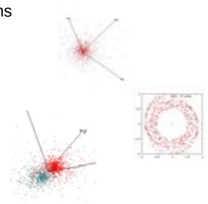
NBODY4 is an open-source N-body code for high-accuracy simulations of dense stellar systems.



For over 40 years, Sverre Aarseth has pioneered the field of direct N-body simulations. His 2003 book describes his codes and a history of N-body simulation techniques and scientific applications.

NBODY4 features include:

- GRAPE acceleration for high accuracy direct integration/summation
- Regularization of close encounters
- Stellar evolution with mass loss and collisions
- External tidal field
- Automatic error checking
- Over 40 options and 40,000 lines of code



Internally generated data models:

- Initial conditions for realistic stellar masses
- Two cluster models in specified binary orbit
- Standard cluster with primordial binaries
- Planetesimal disk and passing perturber

Applications and related N-body simulation software

The Cambridge GRAPE-6 has been used with NBODY4 for a variety of N-body simulations. Typical models of rich open clusters studied have 30,000 single stars. Such calculations may require a month's dedicated effort to model the evolution until complete dispersal. More realistic models with primordial binaries have also been investigated for observational comparison.

The widely-used NBODY6 is intended for standard N-body and realistic star cluster simulations on laptops and workstations without GRAPE hardware. The data structure and input parameters for NBODY4 and NBODY6 are similar. NBODY6 uses a neighbor scheme to speed up the integration while NBODY4 relies on the GRAPE to compute particle accelerations rapidly. NBODY6++ is a variant developed by R. Spurzem for massively parallel supercomputers. The NBodyLab website is a useful introduction to continued studies with NBODY6 on a personal workstation or local computing facilities.

For more information:

NBodyLab.com

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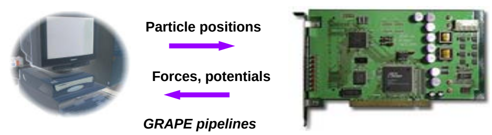
Vicki with Jun Makino

The GRAPE-6a is a new and affordable (~ $8,000) supercomputer card that accelerates direct N-body simulations. The card has a standard PCI interface and runs with Linux.



GRAPE-6a 125 Gflops

NBODY4+GRAPE-6a performance is ~10x faster than host-only NBODY6 for N < 10,000, and comparable to 50+ node Beowulf cluster for large N and single stellar systems.

International performance awards

The GRAPE-6a is the latest supercomputer created by astrophysicist Jun Makino and his team at the University of Tokyo. GRAPE (Gravity Pipeline) systems have received numerous international awards for peak supercomputer performance:

Numerical integration and GRAPE parallel pipelines

The basic integration employs the Hermite scheme. The GRAPE evaluates the force and first derivative for up to 48 particles at each cycle from the predicted coordinates and velocities. These values are used to construct the two next force derivatives whose contributions to the predicted quantities are added as a corrector on the host. Hierarchical time-steps are introduced so that many particles can be advanced as a group by the parallel pipelines. In general, there are few members at the smallest time-steps and about 12-15 different levels in the hierarchy, depending on N and the range in density.

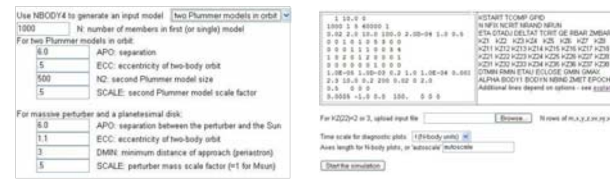
NBODY4 does not rely on softening of the force, and several powerful procedures are included on the host to deal with strong point-mass interactions of binaries and compact subsystems.

Selected References

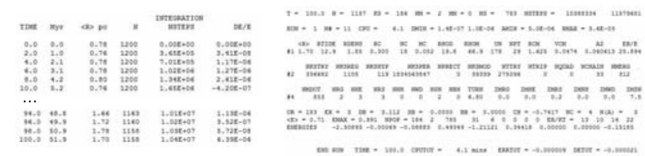
Aarseth, S. J., 1999, From NBODY1 to NBODY6: The Growth of an Industry, PASP, Volume 111, Issue 765, pp. 1333-1346
Aarseth, S. J., 2003, Gravitational N-Body Simulations, Cambridge University Press
Fukushige, T., Makino, J. & Kawai, A., 2004, GRAPE-6A: A single-card GRAPE-6 for parallel PC-GRAPE cluster, submitted
Johnson, V. L., et al., NBodyLab: A Testbed for Undergraduates, NEMO and MDGRAPE-2 Hardware, ADASS 2002 Proceedings
Johnson, V. L., & Ates, A., NBodyLab Simulations with GRAPE-6a and MD-GRAPE2 Acceleration, ADASS 2004 Proceedings
Makino, J., & Taiji, M. 1998, Scientific Simulations with Special-Purpose Computers–the GRAPE System, Wiley

NBodyLab enables short demonstration runs of NBODY4 to be made over the web. NBodyLab is a server-side framework that encapsulates the I/O and produces plots and animations.

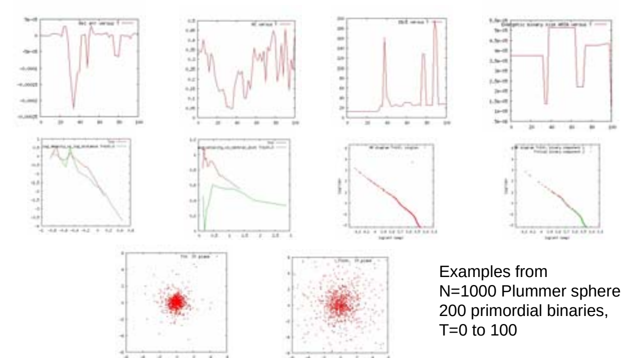
Simplified and concise NBODY4 parameter input



Summary progress indicators and full NBODY4 output



Plots and Java applet animations of N-body evolution



Examples from N=1000 Plummer sphere + 200 primordial binaries, T=0 to 100

Suggested experiments for students

- Two unequal Plummer models with higher mean density in the second
- Comparison of escape rate for equal masses versus general IMF
- Study the remnant bound core for positive total energy
- Time of significant binary formation as function of N
- Compare energy errors by varying random seed
- Plot radii of mass fractions for initial collapse
- Mass segregation (two specific mass groups in user-defined input model)