

NBodyLab: A Testbed for Undergraduates Utilizing a Web Interface to NEMO and MDGRAPE-2 Hardware

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Scientific: Simulate stellar dynamics

- dynamics of single galaxies
relaxation, scattering and collapse
- interacting galaxies
collisions and mergers
- interesting structures like tidal tails

Technical: Web interface to NEMO, MDGRAPE-2

- aid students who can't program or use Unix
- simplify use of NEMO, an advanced stellar dynamics toolbox
- achieve 10-100x better performance using MD-GRAPE2
- open-source, extensible framework

Educational: Motivate students

- to use Unix and NEMO
and other Unix astro packages
- learn scientific programming
- extend and improve components

Objectives:

Input Parameters

- Models and data sets
- Transforms
- Analyses and displays

Model Generation Or Data Selection

- Generate models with NEMO
- N-body format translations

N-body Evolution

- Integration options
- Optional MD-GRAPE2 Hardware Acceleration

Analyses and Displays on Web

- Generate analyses with NEMO
- Visualization
- Diagnostics

The screenshot shows a web form with two sections for 'Galaxy model 1' and 'Galaxy model 2'. Each section includes fields for 'Model' (Plummer NEMO model), 'Number of particles for NEMO models (<= 50000)' (set to 200), 'Scale factor' (none), 'Rotation about axes' (e.g. 0, 90, 0) (none), 'Order' (e.g. xyz) (none), 'Shaft' (e.g. 0, 5, 0) position (none), 'Velocity' (none), and 'Z-spin angular frequency' (none). The 'Integration' section has 'Type' (NEMO hackcode1 integrator without MD-GRAPE acceleration), 'Number of iterations (<= 5000)' (1500), 'Output state every nth iteration, n=' (50), and 'dt (<= 1)' (0.01). The 'Display' section has 'Plot observation plane' (xy), 'Plot range (-x,x) for all axes' (8), 'Animated GIF of evolution' (yes), 'Image and velocity maps' (yes), 'Radial profiles' (yes), 'Slit spectrogram simulation' (yes), 'position angle' (90), 'origin (x,y)' (0,0), and 'width' (1). A 'Start the simulation' button is at the bottom left. A dropdown menu on the right lists various models like 'plummer NEMO model', 'dareidisk NEMO model', 'expdisk NEMO model', etc.



The diagram shows a 'Host Server' (a computer monitor) connected to an 'MDGRAPE-2 PCI interface' (a circuit board). Arrows indicate the flow of 'Particle positions' and 'Forces, potentials' between them. Below the diagram, text reads: 'Host Server: NEMO, Apache, CGIPerl, Linux, Integration of equations of motion'. A paragraph describes the hardware: 'Each of the four MD-GRAPE chips runs at 16 Gflops peak and has four pipelines that stream calculations independently, following a 100MHz clock signal. Each pipeline holds 6 particle positions. The MD-GRAPE board has memory for one million particle positions. Logic on the board streams all of the board particles past the pipeline particles. The pipelines automatically calculate the particle separations and then evaluate and sum the forces $F = -(GMm/r^3)r$. When this streaming is finished, the force sums return to the host and another six particles are assigned to each pipeline. After all of the particles on the board have streamed by all of the pipelines on the pipeline list, operation is returned to the host computer.' A graph titled 'Processing Time, secs' shows 'Time' (0 to 700) vs 'Number of particles' (0 to 12000). Two lines are shown: 'With MD-GRAPE' (a steep line reaching ~650s at 10000 particles) and 'With MD-GRAPE2' (a much flatter line reaching ~100s at 10000 particles).



The collage includes: 'Evolution' (a 3x3 grid of particle positions over time), 'Animation' (a 3D visualization of a galaxy), 'Windows OpenGL viewer for initial, final states' (a 3D view of a galaxy with a grid), 'Integration diagnostics' (a plot of force vs position), 'Maps of intensity, velocity' (a 2D map of a galaxy), 'Density versus radius' (a plot of density vs radius), 'Circular velocity versus radius' (a plot of velocity vs radius), and 'Simulation of slit spectrogram' (a plot of intensity vs wavelength).

Framework (perl) presents form with CGI.pm, invokes NEMO programs and integrator calling MD-GRAPE2 libraries/linux kernel module for force calculation

Examples of student exercises: **Single galaxy:** How does a Plummer model evolve with time? What are the central mass distributions and velocity dispersions? Experiment with an exponential disk – what does its rotation curve look like? Comment on the effects of the addition of angular momentum. **Dynamics of two galaxies:** Make two Plummer spheres interact by colliding and merging. How does the new equilibrium configuration compare in shape and size to the original? Try “glancing” blows where the spheres are sent at various impact parameters and constant velocity. Try to create a polar ring galaxy by dropping a compact dense galaxy normal to a disk galaxy in a path perpendicular to the disk. www.nbodylab.com