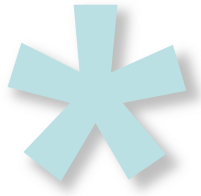


N-body simulation

- Available codes: <http://nbody.sourceforge.net/>
- MODEST: <http://www.manybody.org/modest/>
- Most often used for star cluster: AMUSE and NBODY6/7
- Moving stars around:
<http://www.artcompsci.org/kali/pub/msa/title.html>
- Dark Energy Universe (DEUS) Simulation
<http://www.deus-consortium.org/>
- **Complete overview:** Sverre J. Aarseth, 2003, *Gravitational N-Body Simulations*, Cambridge University Press

What is a N-body simulation?

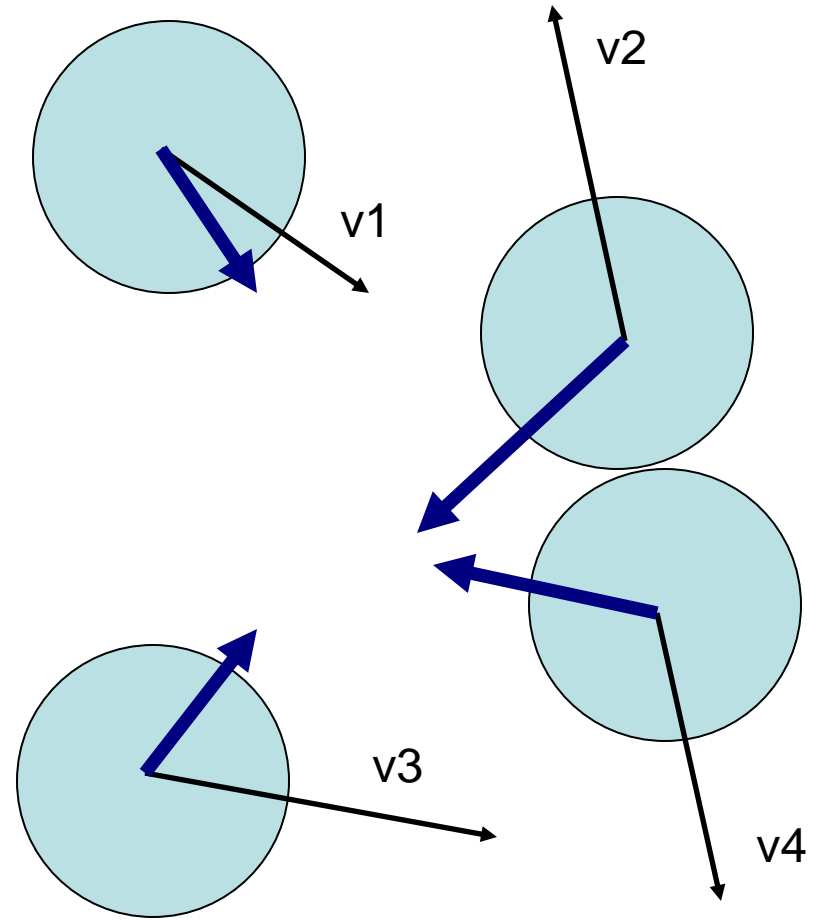
- Simulating the interaction of N objects in a system
- No limitation of interpretation
- Examples:
 - Movement of stars under the influence of gravity in a galaxy
 - Star cluster formation
 - Clusters of galaxies



Overview

N-body problem

- Masses
- Locations
- Velocities
- Geometries
- Other Properties



Basic N-body Simulation

- Start with the N bodies
- Initial position and velocity
- For each time step acceleration of each body is calculated, for example based on the influence of gravity
- Velocity is updated based on acceleration
- Position is updated based on velocity

How to update the position and velocity

- The simplest update step is a Forward Euler algorithm:

$$\mathbf{r}_{i+1} = \mathbf{r}_i + \mathbf{v}_i dt$$

$$\mathbf{v}_{i+1} = \mathbf{v}_i + \mathbf{a}_i dt$$

- Not very accurate
- For the time step dt , a body is moving in the \mathbf{v}_i direction
- Only correct at time i

Leap-Frog algorithm

- Position defined on integer time steps
- Velocity defined on integer + $\frac{1}{2}$ time steps
- Velocity updated by $(\mathbf{a}_i + \mathbf{a}_{i+1}) / 2$
- The approximate value of \mathbf{a} halfway between time steps i and $i + 1$.

$$\mathbf{r}_{i+1} = \mathbf{r}_i + \mathbf{v}_i dt + \mathbf{a}_i (dt)^2 / 2$$

$$\mathbf{v}_{i+1} = \mathbf{v}_i + (\mathbf{a}_i + \mathbf{a}_{i+1}) dt / 2$$

Parallel N-body methods

- **Barnes-Hut algorithm** (Barnes & Hut, 1986, Nature, 324, 446)
- **Fast Multipole Method**
(http://www.ics.uci.edu/~ihler/papers/ihler_area.pdf)
- **Parallel Multipole Tree algorithm**

