2nd master thesis status report

Dynamics of the Local Group

by Christoph Saulder

(supervised by Christian Theis)

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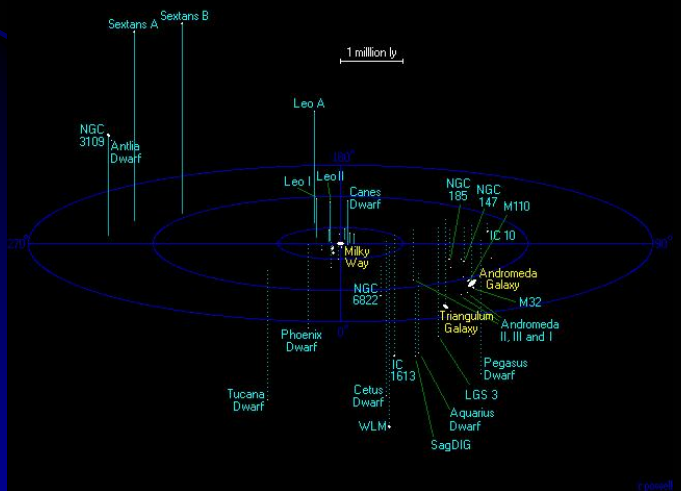
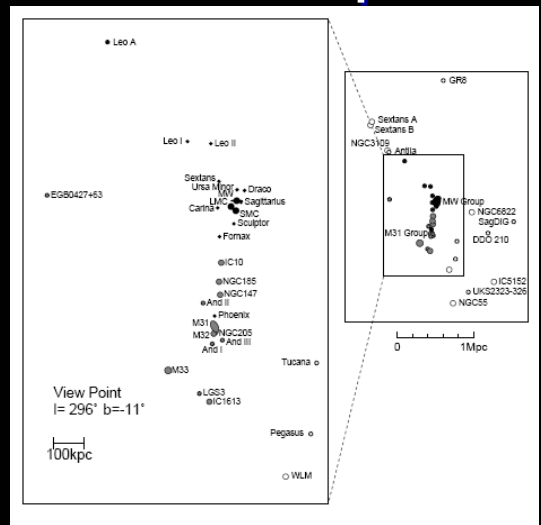
Content of this talk

- Summery of my last talk
- Programs
  - Mkinput & Mkmodel
  - NewHExI
  - DeMonI
  - Genetic algorithm
  - Interplay of my programs
- First results
- Remaining ToDo-list

Summery

- Local Group: Milky Way, M31, M33, LMC, SMC and 36+ dwarf galaxies
- Dynamics dominated by Milky Way and M31
- Planar distribution
- Scenario of origin of our dwarf galaxies: interaction of early gas rich MW and M31➔ scattering new dwarf galaxies in the orbital plane





- Testing dark matter and MOND
- MOdified Newtonian Dynamics

$$\vec{\nabla}\left(\mu\left(\frac{a}{a_0}\right).\vec{\nabla}\Phi(\vec{r})\right) = 4\pi G.\rho(\vec{r}) \qquad \mu(x) = \frac{x}{\sqrt{1+x^2}}$$

- new fundamental constant $a_0 \sim 1.2\ \ 10^{-10}$ m/s²
- deep-MOND limit $$a = \frac{\sqrt{G.M.a_0}}{r}$$
- MOND has several problems

N-MODY doesn‘t work

- Few body-simulations are not possible
- Mergers only work in a non-public modified version of N-MODY
- Tested different resolutions, scaling and step sizes
- Code can suddenly break down
- Disc galaxies (even in Newtonian limit) aren’t stable in THIS code
- Plummer models flatten in Newtonian case in this code, although code has spherical symmetry
- …

FORGET N-MODY!

Programs

- Written in Fortran90
- Using a NEMO-compatible file format
- Although all programs has been developed for a special problem, but most of them can be used for other problems as well (with some modifications).
- Controlled by a Shell-Script

Mkinput & Mkmodel

- Mkinput: creates a set of random parameter files containing all variable parameters (and some basic settings)
- Mkmodel: creates a ASCII Nemo snapshot file based on a parameter file
- My model:

  2 massive galaxies on elliptical orbit

  3 other massive galaxies around them

  36 massless dwarf galaxies
- Instead of single testparticles ➔ testparticle clouds

NewHExI

- Newtonian Hubble Expansion Integrator

- N-body code for massive particles and massless testbodies

- Newtonian gravity
- Dark matter halo
- Dynamical friction
- Hubble expansion

$$\vec{F}_{tot}(\vec{x},\vec{v},t) = \sum_{i=1}^{n_{massiv}} \vec{F}^{i}_{grav}(\vec{x}) + \sum_{i=1}^{n_{halo}} \vec{F}^{i}_{dynfrict}(\vec{x},\vec{v}) + \vec{F}_{Hubble}(\vec{x},\vec{v},t)$$

- Gravitational force

Outside halo : $\vec{a}_i = \frac{G.M_i}{\left|\vec{x}_i - \vec{x}\right|^3}\left(\vec{x}_i - \vec{x}\right)$

Inside halo $|x_i\text{-}x| < R_{Halo,i}$: $\vec{a}_i = \frac{G.M_i}{R_{Halo,i}\left|\vec{x}_i - \vec{x}\right|^2}\left(\vec{x}_i - \vec{x}\right)$

- Dynamical friction (only if $|x_i\text{-}x| < R_{Halo,I}$ and $10.m < M_i$)

$$\vec{a}_i = -\frac{M_i m \ln(\Lambda)}{R_{Halo,i}\left|\vec{x}_i - \vec{x}\right|^2\left|\vec{v} - \vec{v}_i\right|^3}\left(erf\left(\frac{\left|\vec{v} - \vec{v}_i\right|\sqrt{R_{Halo,i}}}{\sqrt{M_i}}\right) - \frac{2\left|\vec{v} - \vec{v}_i\right|\sqrt{R_{Halo,i}}}{\sqrt{\pi M_i}} e^{\frac{\left|\vec{v} - \vec{v}_i\right|\sqrt{R_{Halo,i}}}{\sqrt{M_i}}}\right)\left(\vec{v} - \vec{v}_i\right)$$

- Hubble flow (simulated by additional force)

$$\vec{a} = \frac{2\vec{x}}{3t^2} - \frac{2\vec{v}}{3t}$$

for an Einstein-deSitter universe

- Input Parameters: filename input, filename output, t_{stop}, t_{step}, softening, massless, t_{offset}, halo on, dynamical friction on, Hubble flow on
- Input file = ASCII NEMO snapshot file
- Integration with Runge-Kutta method
- Processing speed: 8 seconds

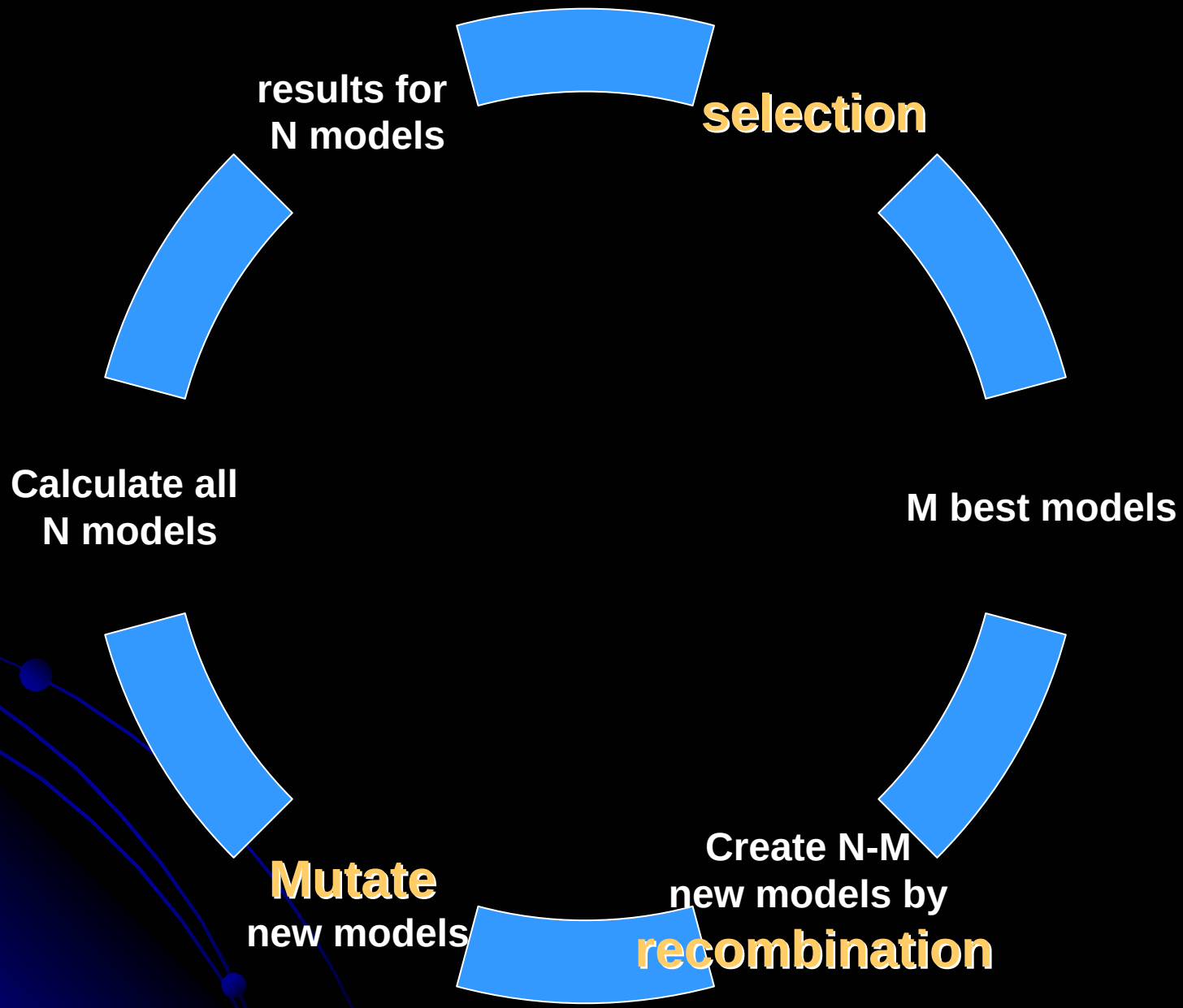
  (5 massive and 900 test particles for 1640 time steps(=12.7Gyrs))

DeMonI

- Deep MOND Integrator
- Outside the inner part of galaxies accelerations are small ➔ deep MOND limit
- Gravitation $$\vec{a} = \sum_{i=1}^{n_{massiv}} \frac{\sqrt{G.M_i.a_0}}{\left|\vec{x}_i - \vec{x}\right|^2}\left(\vec{x}_i - \vec{x}\right)$$
- Hubble Expansion also included
- Processing speed: 5.5 seconds

Genetic algorithm

- 237 variable starting parameters
- 158 fitting parameters
- Normal parameter scan unreasonable
- Fast alternative: genetic algorithm
- Possible problem: local minima


results for
N models
selection
M best models
Create N-M
new models by
recombination
Mutate
new models
Calculate all
N models

- For every model:
  - Calculate fitness parameter for massive galaxies: position and radial velocity
  - Find the best test particle for every massless galaxy ➔ origin of a new test particle cloud
  - Calculate total fitness of the model
- Create children by recombination of all parents (one child can have >2 parents)
- Choose mutating children randomly
- Mutate single parameters of a model within reasonable values

Interplay of my programs

makeinput

Loop for N generations (

makemodel

NewHExI or DeMonI

extracting required information after integration

Genetic algorithm)

tidy up the results

First Results

- It’s very difficult to reproduce the scenario.
- It’s only possible to analytically calculate the orbit of the two main galaxies if it is exactly a radial orbit.
- Including Hubble-Expansion is really necessary
- First runs indicate that the scenario might be valid for some dwarf galaxies but not for all.

Remaining ToDo-list

- Fix the last bugs
- Run long-time simulations for dark matter
- Run long-time simulations for MOND
- Compare results
- Write everything down

References

- Sawa & Fujimoto: 2005
- Nipoti, Londrillo et. al.: 2006, 2007
- Milgrom: 1983
- Bekenstein & Milgrom: 1984
- Li & White: 2007
- van der Marel & Guhathakurta: 2008
- Chandrasekhar: 1943
- Peacock: Cosmological Physics, 1999
- Binney & Tremaine: Galactic Dynamics, 2008

ANY QUESTIONS?