master thesis status report

Dynamics of the Local Group

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Content of this talk

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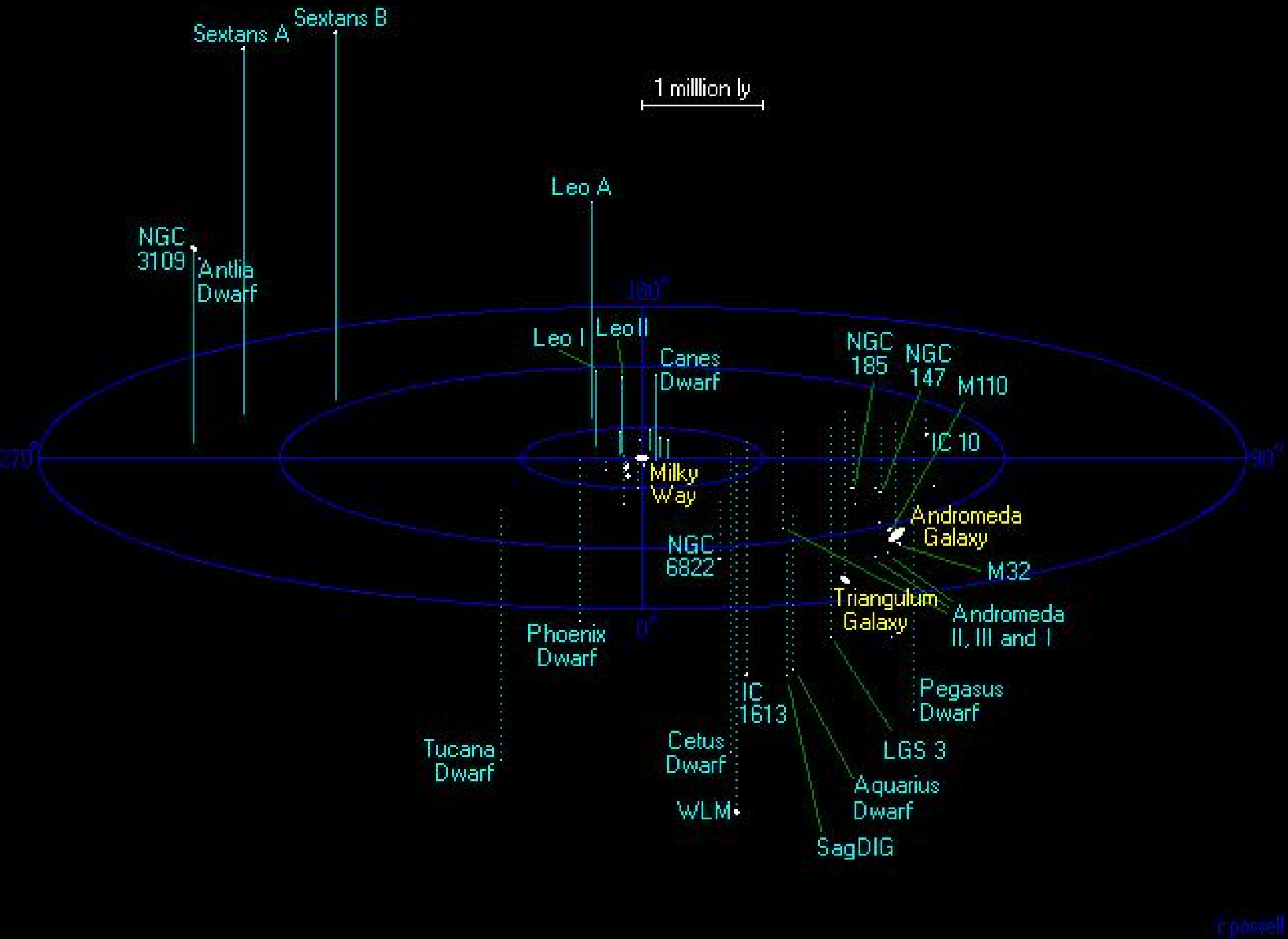
Local Group



members:

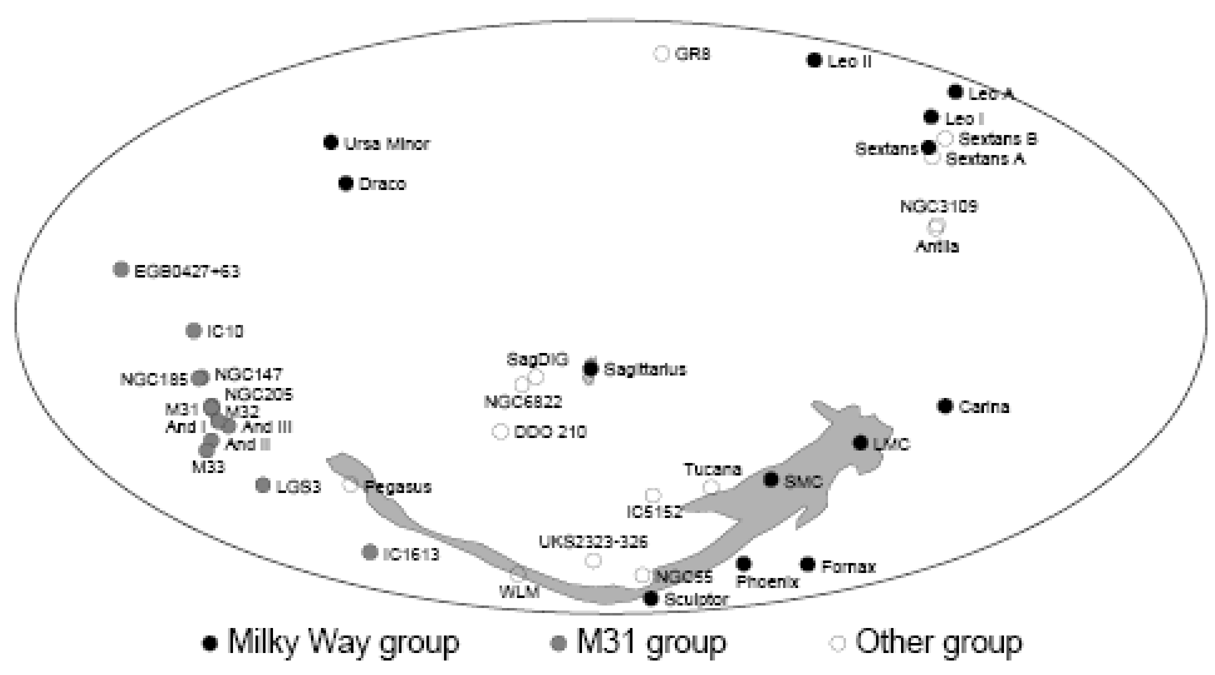
Milky Way
M31

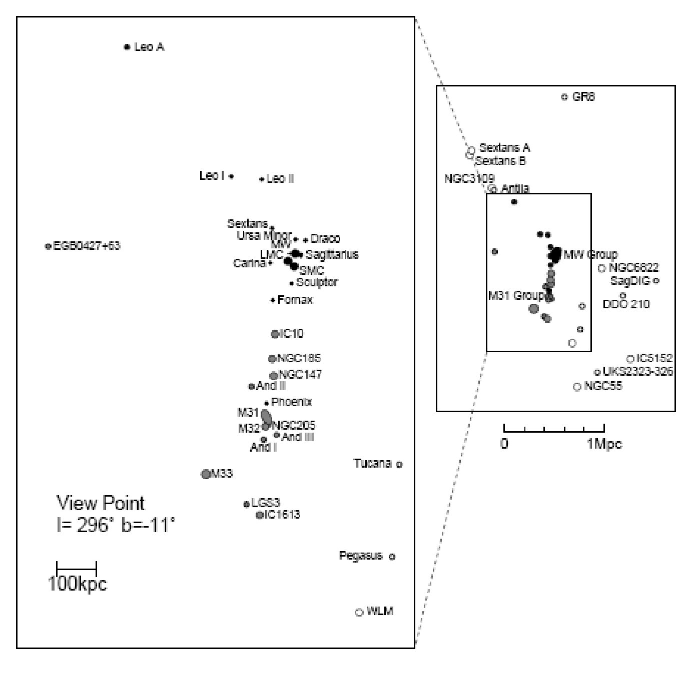
LMC
SMC
M33

+36 more known dwarf galaxies

A plane of galaxies

- Most galaxies in the local group a distributed in a thin plane (see Sawa & Fujimoto 2005)
- This plane doesn't correspond to a galactic plane of the spirals





➢ **Sawa & Fujimoto**	➢ **My own results**

❖ Normal vector in galactic coordinates

Sawa & Fujimoto	My own results
l=206°, b=-11° (Milky Way on plane)	l=200°, b=-20° (A) l=203°, b=-27° (2σ-clipping) l=200°, b=-20° (Milky Way and M31 on plane) (B)

❖ Thickness of the Local Group plane

Sawa & Fujimoto	My own results
About 50-100 kpc	21 galaxies within 100kpc (A) 28 galaxies within 100kpc (B)

Results basically similar but no perfect match

Origin of the Local Groups satellites

- Cosmological dark matter sub-halos

  - Problem: expected distribution would be spherical symmetric

- Infall and scattering of a filament

  - Problem: expected plane would be too thick

- Early interaction of extended gas-rich discs of Milky Way and M31

  - reproduces observed distribution very well

  - Problem: missing satellite problem, except in MOND, because no dark matter

Working hypothesis

- Most dwarf galaxies has been formed by an encounter of the gaseous discs of Milky Way and M31 more than 10 Billion years ago
- Scattered across the Local Group
- Orbits dominated by the two main galaxies
- Dwarfs are located now near the movement plane of Milky Way and Andromeda-galaxy

My model

- Milky Way and M31 on an elliptical orbit
- LMC, SMC and M33 are also massive
- All other dwarf galaxies are test particles
- Simulation starts about 10 Gyr in the past
- Test particles are located in the interacting outer edges of the two main spirals

NEMO

- Stellar Dynamics Toolbox by Teuben P.J.
- Contains many different models and codes
- Tools for analyzing and plotting results
- Easy input with Shell-commands

MOdified Newtonian Dynamics

- Alternative theory to explain observed rotations curves of galaxies
- Avoids dark matter (on galactic scales)
- First suggested by Milgrom in 1983
- Relativistic extension by Bekenstein in 2004

How does MOND work?

- Changes the law of gravitation for small accelerations.
- Introduces a new fundamental constant a_0
- By fitting of rotation curves
  $a_0 \sim 1.2\ 10^{-10}$ m/s² $\sim 1/6\ c\ H_0$
- Non-linear differential equations

- Modified Poisson-equation

$$\vec{\nabla}\left(\mu\left(\frac{a}{a_0}\right).\vec{\nabla}\Phi\left(\vec{r}\right)\right)=4\pi G.\rho\left(\vec{r}\right)$$

- Interpolating function μ(x)

$$\mu\left(x\right)=\frac{x}{\sqrt{1+x^2}}$$

alternative: $$\mu\left(x\right)=\frac{x}{1+x}$$

- No longer superposition of accelerations possible

- Force on particle depends on absolute acceleration

$$F = m.\mu\left(\frac{a}{a_0}\right).a$$

$$\frac{G.M}{r^2} = \mu\left(\frac{a}{a_0}\right).a$$

central potential

$a >> a_0 \quad \rightarrow \mu \sim 1$

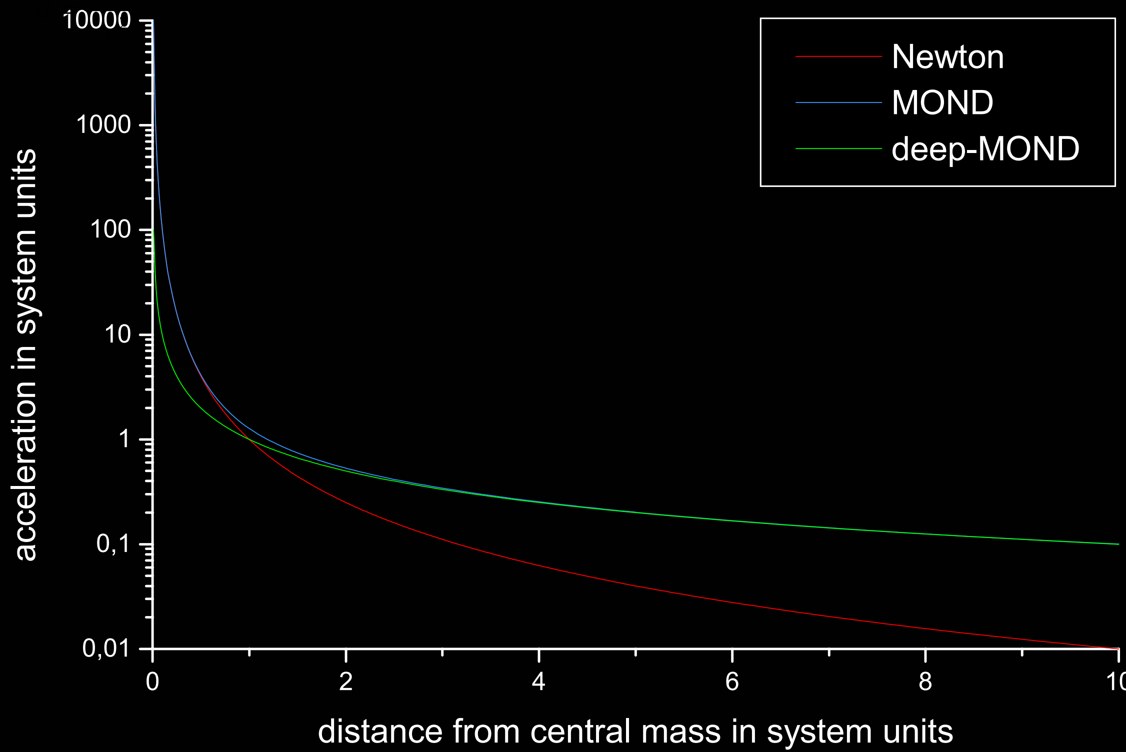
$$a = \frac{G.M}{r^2}$$

Newtonian limit

$a << a_0 \quad \rightarrow \mu \sim a/a_0$

$$a = \frac{\sqrt{G.M.a_0}}{r}$$

Deep-MOND limit



Problems

- merging is less likely in MOND but it also takes much longer → observed merging rate?
- Needs a new theory of general relativity (TeVeS), violation of strong equivalence principle → Lyman α forest problem
- Requires (hot) dark matter on cluster scale
- Bullet cluster

N-MODY

- Stellar dynamic n-body code for MOND written by Londrillo P. and Nipoti C.
- in Fortran 90
- (modified) Poisson-solver
- parallelized code (but also scalar version)

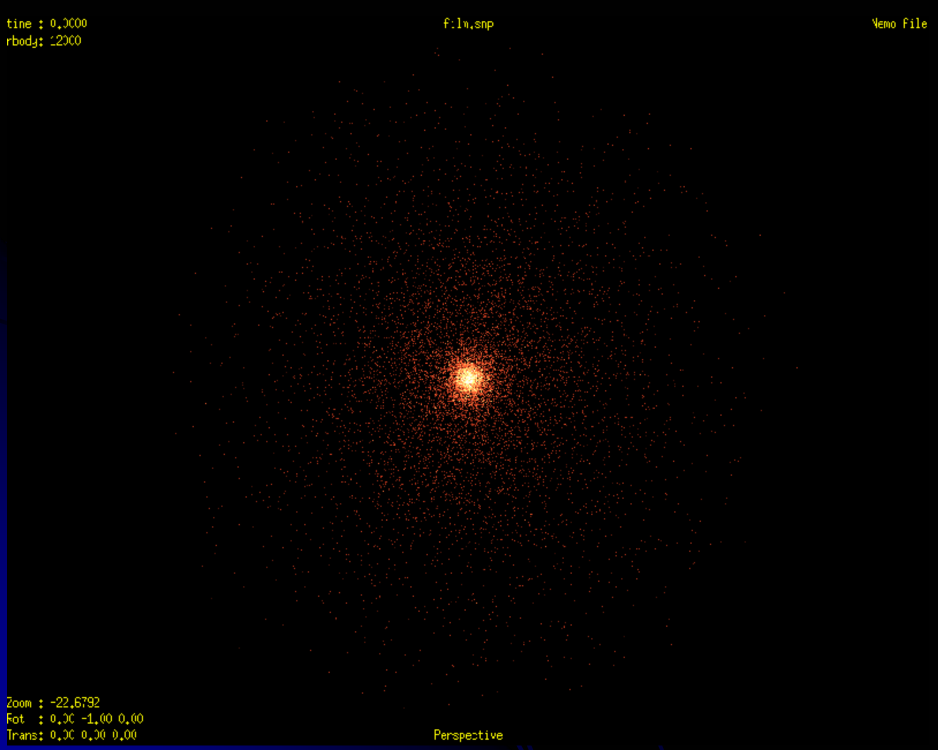
- N-MODY uses a particle-mesh scheme
- it creates a grid-based density-field from a given particle distribution
- calculates the MONDian acceleration on the grid and interpolates
- advances particles using a leap-frog scheme
- Output of particle-phase-space position, grid-data, potential-data and system parameters

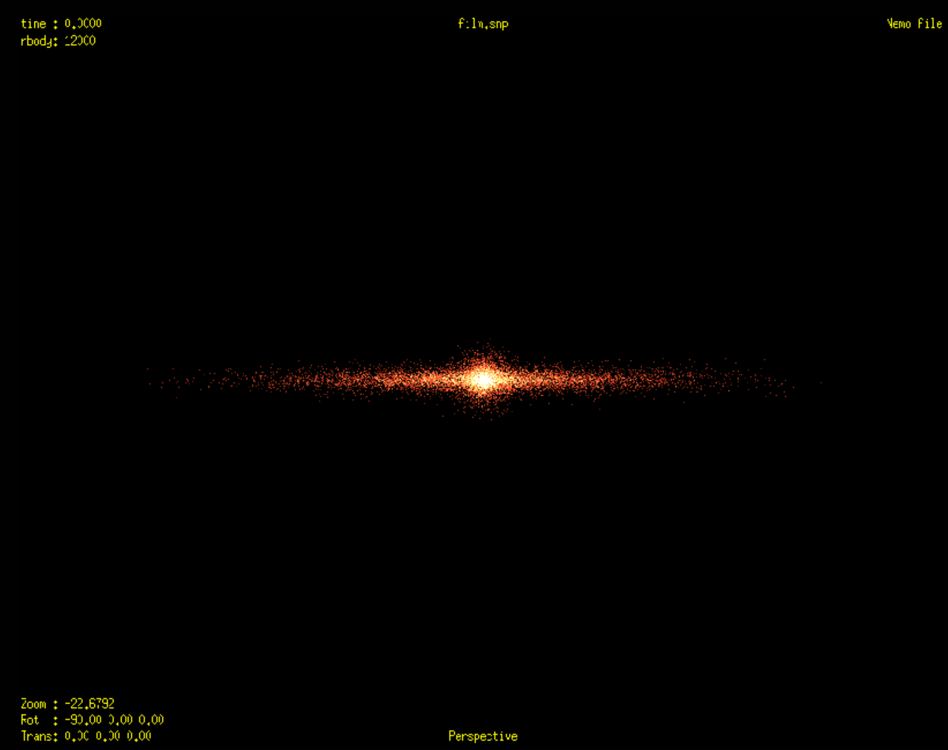
Problems with N-MODY

- Output and input in strange binary-format
  - translator program written √
- Only equal mass particles allowed
  - code modified √
- Maximal 100 output-files
  - code extended √

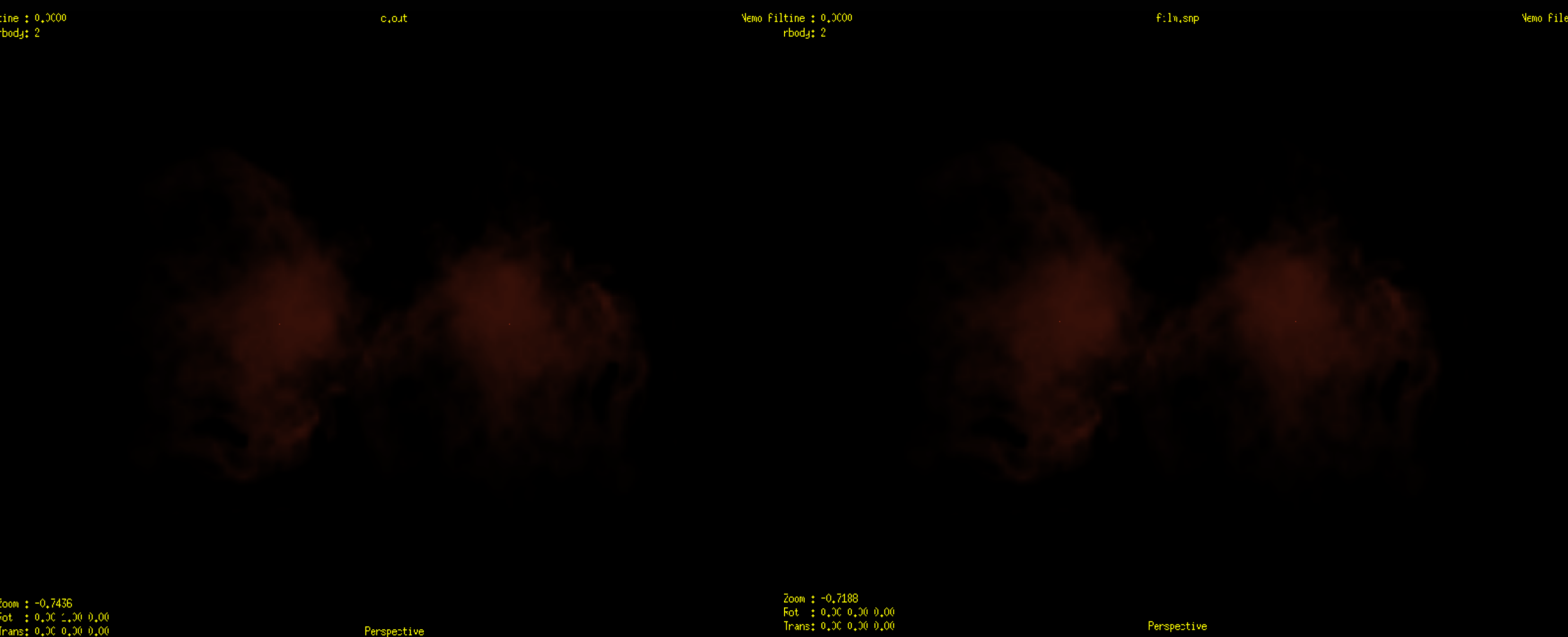
More problems

Kuijken & Dubinski 95 model (without halo) showed strange behavior of the disc in N-MODY



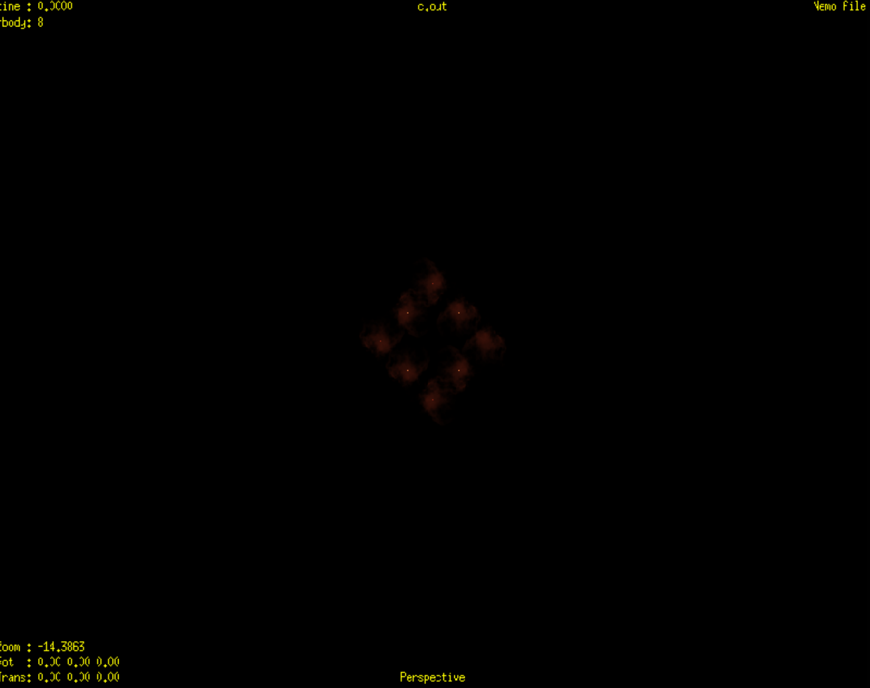


A BIG 2BODY-PROBLEM!!!

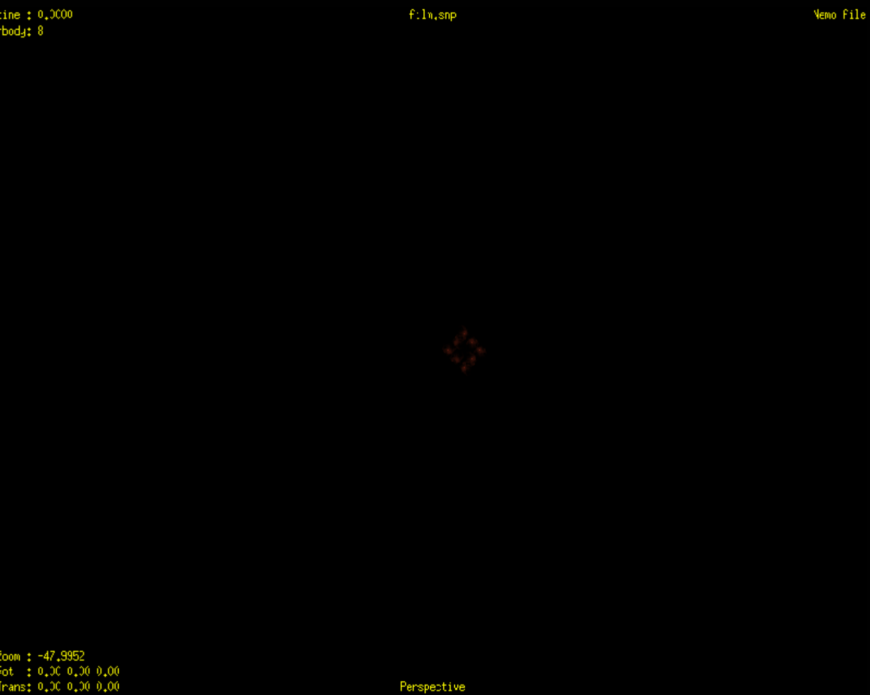


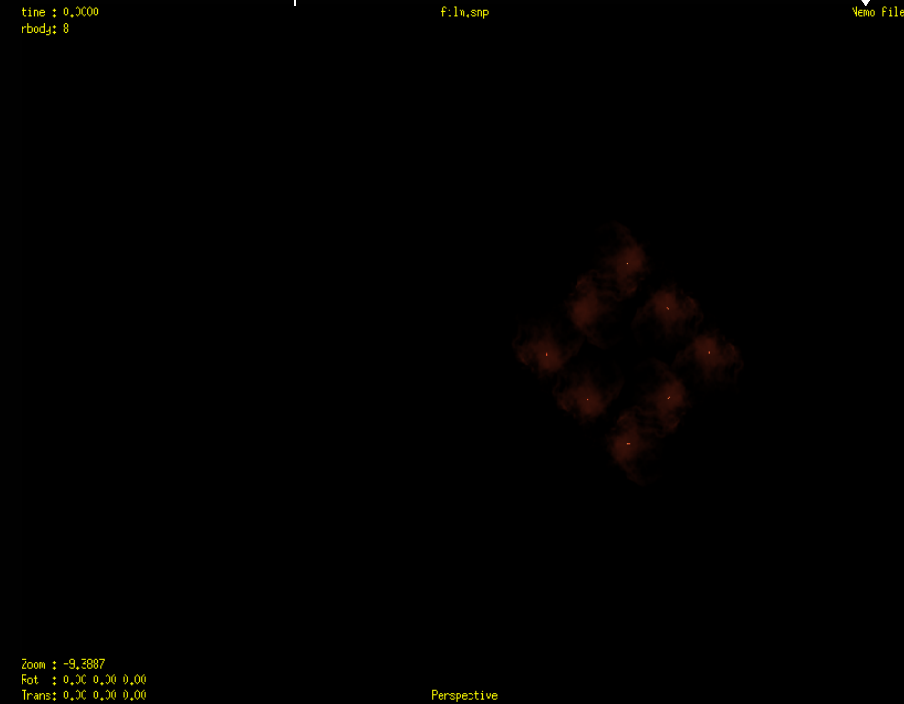
Newton with NEMO

MOND with N-MODY



Newton ↑ MOND out of center ↓ MOND centered ↑ MOND out of center ↓





next steps

- Find an alternative to N-MODY = do it yourself method
- Finish setup of my model
- Run simulations (Dark Matter and MOND)
- Analysis of results and writing everything down