N-body simulations for MOND-gravity

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Are dark-matter models wrong?

The mass of the stars and gas in galaxies is insufficient to prevent the galaxies to fly apart: the observed velocities of the stars are much too high. The Newtonian force is strong enough to keep the galaxies together if there is six times as much mass as can be seen. This is why dark matter has been hypothesized. In 1983 Milgrom [1] invented an alternative. He supposed that Newton's gravity law changes for accelerations much less than a critical acceleration a_0 as

$$\ddot{\boldsymbol{r}} = -\hat{\boldsymbol{r}}\frac{GM}{r^2} \quad \longrightarrow \quad \ddot{\boldsymbol{r}} = -\hat{\boldsymbol{r}}\sqrt{\frac{GM}{r^2}a_0}$$

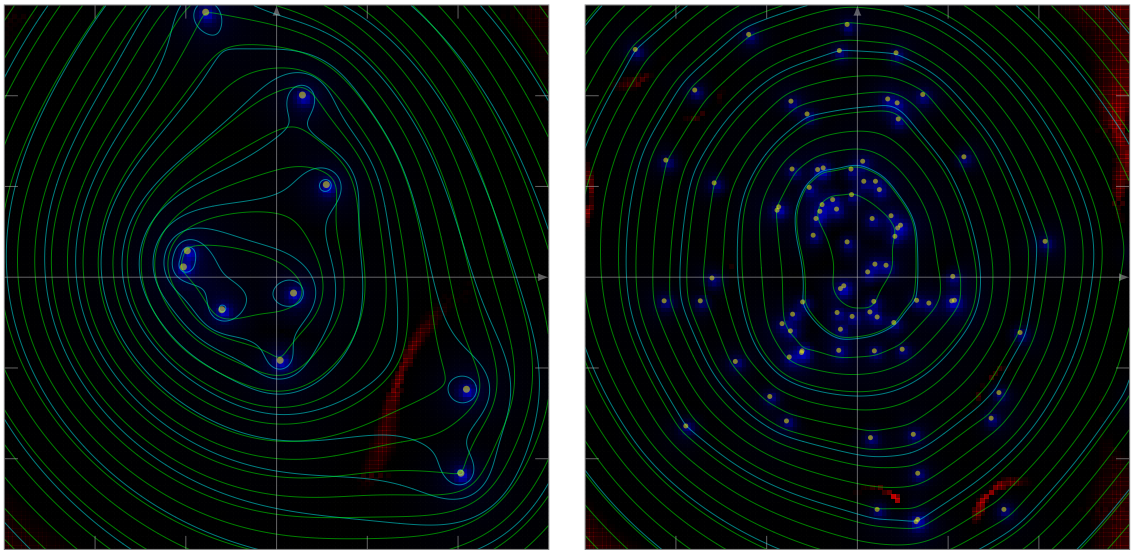
Then the observations not only agree, but can also explain why the velocities actually behave as $\propto M^{1/4}$, as described by the Tully-Fisher relation.

Particle-Mesh Code

A numerical code for simulations in Astronomy with the MOND-laws was written by Joost de Nijs [2]. The code solves the differential equation for the potential ϕ and calculates the motion of the stars which are located at the points $\boldsymbol{r}_i$. The system of equations is

$$\boldsymbol{\nabla} \bullet \mu\Big(\frac{|\boldsymbol{\nabla}\phi|}{a_0}\Big)\boldsymbol{\nabla}\phi = 4\pi G\rho(\boldsymbol{r}), \quad \rho(\boldsymbol{r}) = \sum\nolimits_{i=1}^{N} m_i\delta(\boldsymbol{r}-\boldsymbol{r}_i), \quad \dot{\boldsymbol{r}}_i = \boldsymbol{v}_i, \quad \dot{\boldsymbol{v}}_i = -\boldsymbol{\nabla}\phi.$$

where μ describes the transition from normal Newtonian dynamics to the MOND regime. This Particle-Mesh code is written in C and uses Fourier transform techniques on a large cubic grid. In principle, it can be parallelized, made to use GPUs instead of CPUs, with half-precision. This should make the code extremely fast [3]. (i) Can you speed-up or parallelize the code? (ii) Can you run it on the Super Computer Delft Blue? (iii) Can it beat the state-of-the art Simulators? (iv) What does your code predict for the orbits in wide-binary star systems?



References

[1] Mordehai Milgrom. "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis". In: *The Astrophysical Journal* 270 (1983), pp. 365–370.

[2] Joost V. de Nijs. "Developing a particle mesh code for Modified Newtonian Dynamics". Bachelor Thesis. Netherlands: TU Delft, 2023.

[3] P.M. Visser, S.W.H. Eijt, and J.V. de Nijs. "Fast particle-mesh code for Milgromian dynamics". In: *Astronomy & Astrophysics* (2023).