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Cosmological structure formation with negative mass

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The possible existence of particles with negative mass has long been considered, starting from the seminal work of H. Bondi [1]. In a cosmological context, it was shown more recently that negative mass solutions are viable in a de Sitter universe [2]. Negative masses have also been considered in bi- and multi-metric extensions of General Relativity [3].

Besides, one cannot but note the peculiarity of the standard cosmological model, which - although impressively concordant on primordial nucleosynthesis, cosmic microwave background, baryonic acoustic oscillations, and supernovae luminosity distances - features an odd composition, with dark matter and dark energy, two unidentified components, supposedly representing approximately 96% of the mass/energy content of the Universe.

In this broad context, Benoit-Levy and Chardin [4] proposed a symmetric matter-antimatter universe where antimatter particles possess a negative gravitational mass. Such "Dirac-Milne" universe appears as gravitationally empty (or coasting) at large scales and is remarkably concordant without any adjustable parameter, in particular without the need for a dark energy component [5].

In order to explore such alternative cosmological scenarios, we constructed a family of Newtonian non-relativistic models with equal amounts of particles with negative and positive gravitational mass, which includes the Dirac-Milne scenario as a special case. We perform N-body numerical simulations of these negative-mass models for an expanding one-dimensional universe and study the associated formation of large-scale gravitational structures, focusing in particular on the Dirac-Milne case. The differences and analogies with a matter-dominated Einstein-deSitter universe and with the standard ΛCDM cosmological model are highlighted and discussed [6]. On a local scale, the Dirac-Milne model is shown to reproduce some of the features usually attributed to dark matter, or to modified Newtonian dynamics (MOND) theories [7].

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