Solving the cusp/core problem of galaxies and galactic clusters

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Why this is important

This is a novel solution to an outstanding discrepancy between predictions and observations of the inner density profiles of dark matter halos.

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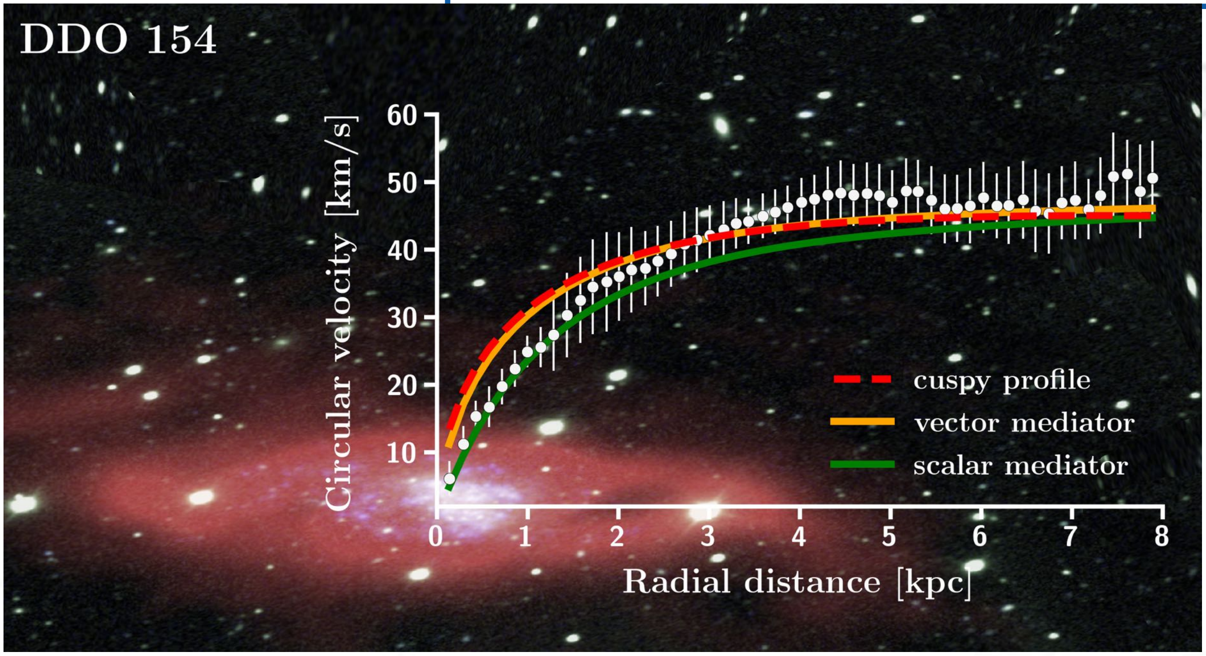
For many years, supercomputer simulations of structure formation in the early universe have predicted that galaxies and clusters of galaxies should have cuspy dark matter density profiles near their centres, whereas observations of stars' rotational velocities indicate a smooth (cored) behaviour. The discrepancy, known as "core-cusp problem" might be explained by complications from the ordinary visible matter, or self-interactions between the dark matter particles, but there is no consensus yet. We proposed a novel possibility: oscillations between dark matter and its antiparticle could become active at the time of structure formation, leading to enhanced annihilation between the two in the densest regions, and a consequent lowering of density in the centres of galaxies and galactic clusters. We showed that this could simultaneously explain both kinds of systems if the dark matter is light (around 65 MeV) and can annihilate into light scalar or vector particles.

The figure illustrates that annihilation of dark matter into scalar particles can explain the cored density profile of the smallest (dwarf spheroidal) galaxies and therefore their observed rotation curve, while annihilation into vector particles give a negligible contribution in such systems. We showed that the trend is opposite in the largest clusters of galaxies, where annihilations into vector particles dominate over those into scalar particles. The difference between these two annihilation channels arises because dark matter has larger velocities in galactic clusters than in small galaxies. As a consequence, a model in which dark matter can annihilate into either kind of particle can simultaneously solve the core/cusp problem in both kinds of systems. Improved future observations of rotation curves, with smaller errors, would be able to distinguish our proposal from the self-interacting dark matter scenario, which predicts somewhat different shapes for the density profiles.



Caption: Example of rotation curve (star circular velocity vs.radial distance) for the dwarf spheroidal galaxy DDO 154.The white dots with error bars represent observational data, the red dashed curve is the prediction from supercomputer simulations within the standard cosmological model, the orange and green lines are the result from dark matter annihilations into vector and scalar particles, respectively.