Astrophysicists unwind 'Cold Dark Matter Catastrophe' conundrum

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For nearly twenty years scientists have been trying to resolve the discrepancy in the cold dark matter paradigm - the so-called "Cold Dark Matter catastrophe". Recently an international research group including physics professor Lucio Mayer from the University of Zurich has succeeded in unraveling this paradox in a simulation of bulgeless dwarf galaxy formation.

Cold Dark Matter - present day science is still in pursuit of a proof of its existence. Numerous astrophysical phenomena are only explainable by assuming its existence: the Cold Dark Matter (CDM) paradigm accounts, for instance, for the distribution of galaxies and of standard matter in the universe on large scales, i.e. on the order of billions of light years, and including the nature of the relic microwave background radiation from the Big Bang.

However, when applied to individual galaxies - dimensions of hundreds to ten thousand light years - the model breaks down, leading to inconsistencies with the observations of astronomers.

Predictions by the model suggest that the central regions of galaxies should rotate at greater speed than is effectively indicated by astronomical measurements. As a result, the model implies a significantly higher density of CDM at the galactic core than allowed by measurements. For nearly two decades astrophysicists, particle physicists and astronomers have struggled to resolve this «Cold Dark Matter catastrophe», as this discrepancy is called among specialists, and to propose an convincing explanation for the varying behavior of DM at different scales. To date all attempts at explanation have fallen short or led to further irresolvable discrepancies. An international research group including Professor Lucio Mayer of the University of Zurich as one of three project leaders has now succeeded in unraveling this conundrum using a highly sophisticated supercomputer simulation.

Simulation of standard matter

Mayer and his colleagues simulated the formation of disc dwarf galaxies, for which the "Cold Dark Matter catastrophe" is particularly severe. In contrast to their predecessors, for the first time they modeled not only the behavior of CDM as influenced solely by gravitation, but also the highly complex behavior of baryonic matter, as normal, visible matter is also called, down to the scale at which star clusters form. At 83 percent, DM composes the vast majority of a galaxy, but is nevertheless also influenced by baryonic matter, as the researchers could now demonstrate in their publication in *Nature*.

Thanks to the high resolution simulations, which required the use of various supercomputers including one from NASA, Mayer and his colleagues could show with their model that during supernova explosions not only the interstellar gas but also CDM is pushed away from the core of a galaxy. In explosions of supernovae large quantities of normal, visible matter are removed from the galactic core in one blast: DM responds to the sudden change of the gravitational field by expanding away from the center and its density decreases. As a result the rotational velocity of the dwarf galaxy declines. Thus for the first time the simulated CDM paradigm and the nature of dwarf galaxies are in harmony - the apparent paradigmatic discrepancy is thereby resolved and the "Cold Dark Matter catastrophe" disappears.

Consequences for astrophysics and particle physics

These new findings bear consequences for particle physics and some of the methods employed for detecting DM particles. Among others the approach for demonstrating the presence of DM particles by means of their disintegration into gamma radiation is based on the density of DM in the core of galaxies. The simulation now predicts a significantly lower density of CDM than previously assumed at the core of dwarf galaxies, one of the targets of dark matter detection experiments. The anticipated radiation signals would therefore have to be weaker than formerly expected, requiring detectors of correspondingly greater sensitivity.

Lucio Mayer, who holds an assistant professorship at the University of Zurich endowed by the Swiss National Science Foundation, will continue to work on the topic of "The Formation of Galaxies" in the future: one of his doctoral candidates, Simone Callegari, is already occupied with modeling the formation of massive disc galaxies resembling our own Milky Way galaxy.

More information: F. Governato, C. Brook, L. Mayer, A. Brooks, G. Rhee, J. Wadsley, P. Jonsson, B. Willman, G. Stinson, T. Quinn and P. Madau: Bulgeless dwarf galaxies and dark matter cores from supernova-driven outflows, *Nature*, 14. January 2010

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