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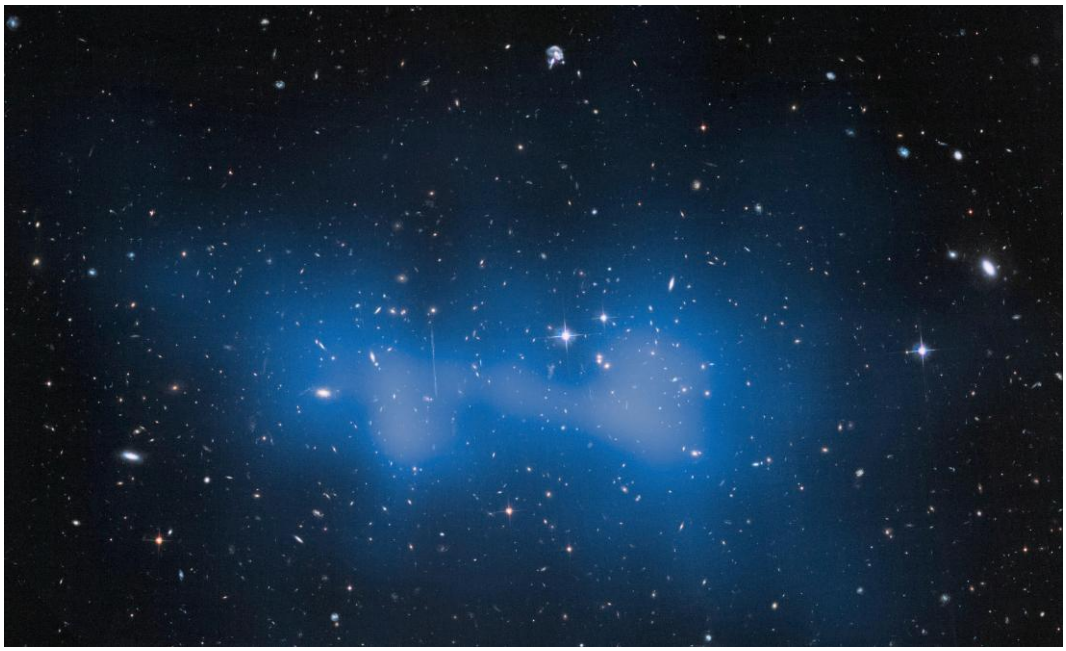
PRESS RELEASE

El Gordo: Dark Matter Could Be Self-Interacting

Simulations of a gigantic merging galaxy cluster indicate that dark matter may have self-interacting properties. The study, published in The Astrophysical Journal, was conducted by Riccardo Valdarnini, a former researcher in SISSA's Astrophysics and Cosmology group.



Trieste, 25 September 2026

Simulations of El Gordo, one of the most massive and distant galaxy clusters ever observed, provide strong indications that dark matter could interact with itself through collisions. The study, conducted by Riccardo Valdarnini, a former researcher in SISSA's Astrophysics and Cosmology group, shows that the observed properties of the cluster are particularly well reproduced by a two-state self-interacting dark matter model, in which particles can collide and exchange energy through both elastic and inelastic scattering channels. These findings, published in The Astrophysical Journal, offer new clues about the nature of one of the greatest mysteries in cosmology, although they will need to be tested through the study of other merging clusters.

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A cosmic laboratory for studying dark matter

Dark matter accounts for about 85% of the matter in the Universe, but its nature remains one of the major open questions in cosmology. The standard cosmological model assumes that it consists of “cold” particles with no significant interactions with one another, responding only to gravity. Known as Cold Dark Matter (CDM), this scenario has been remarkably successful in describing the formation and evolution of cosmic structures, but some tensions with observations have led scientists to explore alternative hypotheses.
As the study’s author Riccardo Valdarnini explains: “One possibility is that dark matter is self-interacting: its particles could collide with one another and exchange energy. In this case, during the collision of two galaxy clusters, dark matter could behave differently from the other components, leaving an observable signature in the distribution of mass.”
El Gordo, whose name means “the fat” in Spanish, is a particularly massive and distant galaxy cluster. It consists of two large substructures that are colliding at a speed of thousands of kilometers per second. “These characteristics make El Gordo a natural laboratory for studying dark matter,” Valdarnini says.

Clues from El Gordo

Observations of the cluster show some features that are difficult to explain within the standard CDM model. Valdarnini explains: “Specifically, the brightest X-ray emission peak of one of the subclusters is displaced ahead of its parent dark matter centroid. The relative velocity of the two subclusters along the line of sight is also significantly lower than expected from dynamical estimates.”
“These features can be interpreted as possible signatures of interactions between dark matter particles,” the researcher explains. To investigate this possibility, he carried out an extensive series of hydrodynamical simulations of the cluster, comparing the results with the available observations.
“The simulations show that the observed properties of El Gordo are particularly well reproduced by introducing a two-state dark matter model. In this scenario, particles can interact through both elastic and inelastic collisions in which part of their energy is transferred, causing the particle to change state.”
“These results indicate that the observed features of El Gordo are difficult to explain within a standard non-interacting CDM framework,” says Valdarnini. “Instead our simulations show that a model featuring self-interacting dark matter with multiple scattering channels can reproduce the observational constraints.”

A new way to search for dark matter

“The result does not yet provide definitive proof that dark matter is self-interacting. The model will need to be tested through the study of other merging clusters,” Valdarnini explains.
In this effort, gravitational lensing could play an important role. This phenomenon occurs when the gravity of matter in a cluster bends light coming from more distant objects. By using this effect to map the distribution of matter, scientists can compare the predictions of different dark matter models with observations.
Valdarnini concludes: “Merging galaxy clusters are particularly valuable cosmic laboratories. Future observations of massive systems undergoing high-velocity

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collisions could provide new clues as to whether dark matter particles actually interact with one another and, ultimately, what their true nature is."

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The paper

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