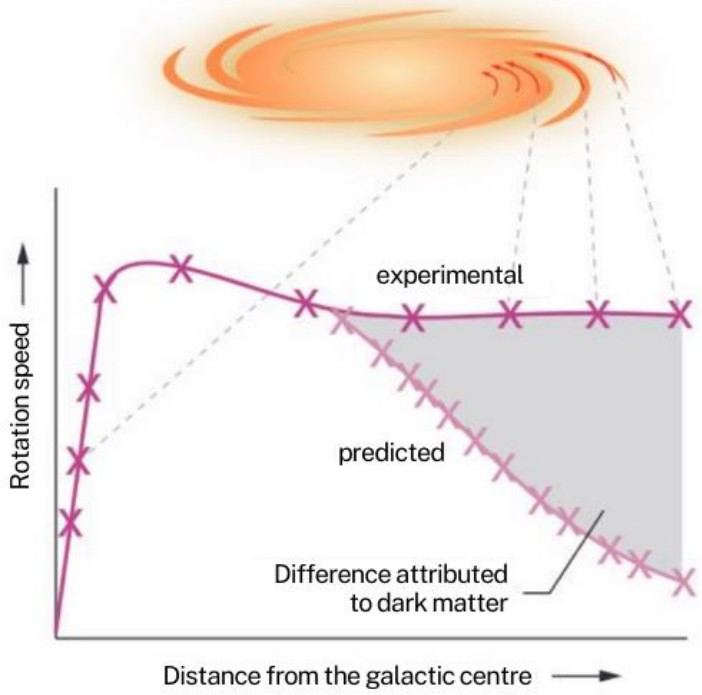
Dark Matter

All the stars and galaxies shining in the sky contain only a small fraction of the matter in the Universe. The rest is hypothetical matter, wrongly labelled dark matter on the grounds that it emits no light, and which puzzles particle physicists keen to uncover its true nature.

Rotation speed of the Milky Way

The dark pink curve and crosses show that the rotation speed of the Milky Way (the 'Galaxy') remains almost constant far from the centre; the bright pink curve and crosses show how the rotation speed would evolve if all the matter were packed in the stars.



Credit: N. Palanque-Delabrouille

How can we infer the existence of this dark matter, which eludes direct observation? Through the gravitational attraction it exerts! A first sign of the existence of dark matter is obtained by studying the rotation speed of galaxies. Whereas the light emitted by a galaxy's disc decreases with distance from the centre, which suggests that most of the luminous mass is found in the central areas, the rotation speed remains almost constant as far as can be measured. This anomaly can be explained by the presence of a massive halo of dark matter extending at least ten times further than the disc of stars.

Credit: NASA/A. Fruchter et al./WFPC2/HST

Galaxy cluster Abell 2218

Arcs produced by light rays coming from galaxies located in the background of galaxy cluster Abell 2218 and bent by the cluster's gravitational field.

Similarly, in galaxy clusters, the laws of gravitation state that the greater the total mass of the cluster, the greater the speed of each galaxy. By estimating the mass of clusters from the motion of their galaxies, we find that this estimate far exceeds that which can be deduced from the galaxies' luminosities, suggesting the presence of a large quantity of dark matter in the clusters.

These results are confirmed by the study of luminous arcs seen around certain galaxy clusters. The arcs are produced by light rays emanating from galaxies located behind the cluster and bent by the cluster's gravitational field. Through the study of the arcs, we can estimate the mass of the cluster in the foreground. Here again, the estimated mass turns out to be much greater than the mass derived from the luminosities of the galaxies making up the cluster.

What could be the nature of this ghost matter, which is five times more abundant in the Universe than the matter of which stars are made? Astrophysicists are convinced that ordinary matter (protons and neutrons) is not enough. So one has to turn to a yet unknown form of matter. This is where particle physicists step in, aiming to uncover this mysterious dark matter. One of their best candidates is the neutralino. The neutralino is a massive particle whose existence is predicted by some extensions of the Standard Model of particles and which interacts very faintly with ordinary matter. This is also why the neutralino, if it exists, has so far eluded detection. The best way to prove its existence would be to create it directly, through ultra-high-energy collisions of protons. This is one of the challenges of the LHC, the large particle accelerator located near Geneva. While the solution to the dark matter enigma has long been sought in the sky, it may actually be found underground!

Translated from 'La matière noire',* Passeport pour les deux infinis, *IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG