

Nearly a century after the discovery, the physical nature of dark matter remains one of the most pressing open questions in physics. We know that this dark component makes up nearly one-third of the whole cosmic density and is more than five times more abundant than ordinary matter. Over the last several decades, an extensive research program has been brought forward, with the aim to determine the cosmological origin, fundamental constituents, and interaction mechanisms of dark matter. So far all Earth-based laboratory experiments had failed to catch and detect the elusive dark matter particles.

In this context, we need to remember that so far, all the information we have about the mysterious dark matter, comes from astrophysical and cosmological observations. The studies of the motion of galaxies in the Cosmic Web, the fast orbital velocities of stars in galaxies indicate the existence of a large amount of unseen matter. Without this matter, there would be not enough gravity produced by the visible stars and gas to explain observed motions and keep the galaxies and stars on orbits.

We see evidence for the dark matter's existence also on the large scales. On the vast distances between galaxies, the light from faraway galaxies gets distorted by the spacetime bending induced by the mass and gravity of the nearby galaxies. Here as well the amount of spacetime bending and distortions are far too great to be explained by the sole presence of the visible matter alone.

Finally, we see also the signatures of the extra gravity that compressed the hot plasma pervading the young Universe, some over 13 billion years ago. This is seen as a specific pattern of ripples in the Cosmic Microwave Background.

Whenever we look, we see traces and evidence of this mysterious agent at work. But what is the exact physical nature of the dark matter? The particle physicists have many ideas, but the main three models for dark matter consist of undetected exotic elementary particles that would be produced in vast amounts in the very early and hot Universe. These particles can either be very heavy they would make the so-called Cold Dark Matter (CDM) or can be relatively lighter to make-up the Warm Dark Matter (WDM). In addition, the Cold Dark Matter could have an exotic property of interacting with each other via quantum forces. This is the so-called Self-Interacting Dark Matter (SIDM).

For decades, the hunt for astrophysical and cosmological signals that would help to discriminate between the three competing dark matter candidates is on. This is a very hard problem due to tremendous variations of the galaxy population. The best objects to study the dark matter are small, dwarf galaxies, which would contain the largest amount of dark matter. Alas, these galaxies seem to be the most variable and unpredictable ones.

In the COLAB (COsmic Laboratory for Baryons and dark matter) project we will look into the Cosmic-Web, the grand-scale structure in which galaxies form and live. This Web creates a unique environment that can be segmented into cosmic nodes, filaments, thin walls, and vast and empty voids. By splitting the galaxies into different Cosmic Web elements we hope to better understand and thus reduce the intrinsic variability of the galaxy population. This will help us identify the best regions of the cosmic web and the most promising galaxy properties to study and highlight the nature of the elusive dark matter.