Research summary

In my thesis, my main research activities were focused on the understanding of the Dark Matter (DM) nature. In order to shed some light on this challenging topic, I used different approaches. In particular, a large effort was done in the theoretical side to understand how Cold Dark Matter (CDM) halos form and evolve within the ΛCDM paradigm. In particular, in [1], I studied the formation and evolution of CDM halos by means of the spherical infall model with shell-crossing. One of the main results we found is that the effect of shell-crossing plays a crucial role in the way the halo evolves and reaches the virial equilibrium and stabilization in radius. Indeed, the values currently adopted in the literature for the actual density contrast at the moment of virialization may not be accurate enough. This fact has important implications e.g. in the definition of a virial mass and a virial radius for the halo. However, our framework has some evident lacks at this moment; in a next step, I will include angular momentum and velocity dispersion to make this framework more robust and capable to show more consistent results. In addition, a detailed comparison with N-body cosmological simulations is needed.

I paid special attention to DM detectability as well. In [2], I performed an exhaustive study of the expected gamma-ray DM annihilation flux for the Fermi satellite and for a typical Imaging Atmospheric Cherenkov Telescope (IACT). The results helped to understand the real potential of Draco as a good DM candidate and the real capabilities of the current IACTs in DM searches. By the other side, as a member of the MAGIC Collaboration, I was involved in the observation of two dwarf galaxies in the context of DM searches: Draco [3] and Willman 1 [4]. In the case of Draco, my previous work [2] was the basis for the DM group to select the most likely DM density profile parameters, needed for a posterior comparison with the MAGIC data. For Willman 1, I was co-P.I. of the observational proposal and substantially contributed into the astrophysical background, being myself one of the two main authors of the final publication. Regarding the future of the field, I strongly believe that the inclusion of fundamental problems like the DM searches in the observational plans of gamma-ray experiments should certainly be a *must*. It is therefore essential to provide promising DM candidates or new strategies to search for DM. In a work in progress [5], for example, we will definitely elucidate which objects are, in average, the best places to look for DM in the Universe. Up to now, most of the attention has been devoted to nearby dwarf galaxies; however, massive galaxy clusters may yield a DM annihilation flux level of the same order of magnitude.

In an attempt to find and explore other plausible DM scenarios where the DM particle could be different from the neutralino, I investigated the possible role of axions in the DM problem as well. In [6] I presented the basis of a formalism to properly deal with the photon/axion mixing expected to occur in the magnetic fields of gamma-ray sources as well as in the presence of Intergalactic Magnetic Fields (IGMFs). This mechanism may represent an alternative explanation to those incongruities given by the most promising Extragalactic Background Light (EBL) models when applied to some distant AGNs recently discovered in gamma-rays ([7, 8]). In the future I will perform particular predictions for the expected photon flux from those controversial objects. Our studies also predict the existence of an universal feature in the spectrum of the sources, that only depends on the axion and IGMF properties. This will be studied in detail in order to propose the best observational strategy for Fermi and IACTs.

References

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