ABSTRACT

The aim of this thesis is to shed light on particulate dark matter (DM), and its non-gravitatinal interactions. We have provided some phenomenological implications on DM from direct detection, indirect detection and cosmological observations. The standard paradigm of Weakly Interacting Massive Particles (WIMPs) is being increasingly challenged by the null results of various terrestrial experiments. Also, the standard ΛCDM framework of cosmology is facing tensions from observations at the galactic scales. These call for an involved analysis into the astrophysical modeling of galaxies and its surrounding DM halo. In order to do so, we employ the legacy data from astrophysical observations of dwarf galaxies, Milky Way, Low Surface Brightness (LSB) galaxies, and galaxy clusters. During our analysis, we find cosmological N-body simulations to play a pivotal role in studies pertaining to DM searches and in explaining certain observations. We start by looking into the velocity and density distribution of DM at three different regions of a halo, first at the earth's position, secondly in the intermediary parts of the galaxy and finally at the galactic center.

We explore the fact that direct and indirect detection rates of DM are found to be highly correlated with the phase space distribution of DM, particularly in the galactic neighborhood. We systematically examine the implications of astrophysical uncertainties and non-standard velocity distributions on the electron recoil events in Xenon and semiconductor detectors. We find that the standard practice of taking the Maxwell-Boltzmann (MB) distribution as the default DM velocity distribution does not accurately take into account the number of DM particles which participate in scattering process, specially at the high velocity tail of the distribution. We find significant variations in the DM-electron scattering cross-section due to uncertainties in halo modeling and astrophysical measurements. Capture of DM within celestial objects is another important probe for constraining the DM-nucleon cross-section, and is argued to provide a useful blueprint in the indirect search for DM. We study the effects of different halo models on the DM capture rate within neutron stars, white dwarfs, brown dwarfs, exoplanets and the Sun. We take into account model independent DM interactions with nucleons, which slow down DM particles in order to get captured by the gravitational potential of the celestial object. Going beyond the MB distribution, we report deviations $\sim 200\%$, in the capture rate. This hints at significant variations on the heating, annihilation, neutrino and gamma ray signatures. Moving towards the center of the galactic halo, we encounter a long standing tension between observations that prefer a flat central density, to the prediction of a cusp-like over-density from N-body simulations. Self-interactions of DM may help thermalising these region and help in driving core formation. The radius of these thermalized regions are expectedly sensitive to the strength of DM self-interaction. We study the feasibility of constraining DM self-interactions from the distribution of core radius in isolated haloes.