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Neutrino Point Source Searches for Dark Matter

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About the Study

Any dark matter spikes surrounding black holes in our Galaxy are sites of significant dark matter annihilation, leading to a potentially detectable neutrino signal. The nature of dark matter (DM) is one of the most interesting open questions in particle physics, and the discovery of a DM signal could offer the first hints of physics beyond the Standard Model (SM). While the existence of DM has been well established by its gravitational interactions at a variety of scales over several different epochs, the detection of DM interactions with the SM have remained elusive in an increasingly broad experimental program. One of the best-motivated DM candidates is the weakly interacting massive particle (WIMP), signatures of which can potentially be detected when produced at collider experiments or when recoiling off SM particles at direct detection experiments. In addition, the SM products of WIMP annihilation in the Milky Way halo can be searched for in terrestrial or space-based indirect detection (ID) experiments.

The WIMP signal at ID experiments depends on both the annihilation rate and the particular composition of the SM annihilation products arising from a variety of potential annihilation channels. Charged particles such as electrons, positrons and (anti)protons produced by WIMP annihilation can be detected in cosmic rays incident on Earth after propagating through the galaxy and the solar system. ID searches for gamma-rays originating from the products of WIMP annihilation can be especially sensitive since experiments such as H.E.S.S and Fermi-LAT are sensitive to photons originating in parts of the galaxy with either a large potential DM signal (e.g. galactic center) or a small SM background. Neutrino detection experiments such as ANTARES (AN) and Ice Cube (IC) are also sensitive to WIMP annihilation in the galaxy, as well as to the annihilation of DM that is gravitationally captured in the Earth and Sun. While ID of both gamma-rays and neutrinos is not subject to most of the uncertainties associated with cosmic ray propagation, the relative sensitivity of the respective experiments to WIMP annihilation is largely determined by whether the WIMPs annihilate through channels that primarily yield hadronic or leptonic annihilation products.

In addition to signatures of dark matter interacting with the SM at direct detection and collider experiments, we can also probe the nature of dark matter through the indirect detection of the SM particles produced in dark matter annihilation. Signals of dark matter annihilating in our galaxy can potentially be enhanced if dark matter spikes form around the black hole remnants that remain after the collapse of Pop III.1 stars within dark matter minihalos. The largely unconstrained history of Pop III.1 star formation, in particular the redshift zf after which such stars cease to form, impacts both the distribution of dark matter spikes in the galaxy and the density profiles of individual spikes. The dark matter annihilation signal from an individual spike can vary depending on the annihilation cross section, final state, and dark matter mass, as well as the density profile associated with a central black hole of a given mass. While previous studies have mainly focused on gamma-ray signals from WIMP annihilation, in this paper we investigate the sensitivity of neutrino point source searches to dark matter spikes.

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