Indirect Searches for Dark Matter with IceCube

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Abstract.

The existence of dark matter can be inferred from a number of observations, among them rotational profiles of galaxies, large scale structures, and WMAP's anisotropy measurement on the cosmic microwave background. Weakly Interacting Massive Particles (WIMPs), 'cold' thermal relics of the Big Bang, are leading dark matter candidates. They are expected to be gravitationally trapped by massive bodies, such as the Sun and the Earth, or objects at the Galactic Center, where they could then annihilate and produce neutrinos, which could be detected by neutrino telescopes. We describe searches performed in AMANDA for these events and the prospects for IceCube.

1. Introduction

In the concordance model of cosmology, only about 4% of the universe's mass-energy content is described by standard model particles. The remaining fraction is predicted to be 23% non-baryonic cold dark matter (DM) and 73% dark energy. Understanding the dark sector of the universe is one of the most challenging problems in modern physics. Neutrino telescopes such as IceCube can search indirectly for DM by detecting neutrinos created in DM annihilation processes. IceCube will instrument a volume of 1 km$^3$ by 2011 with 80 strings, of which 22 have been deployed, each containing 60 Digital Optical Modules (DOMs). The AMANDA detector, which has been taking data in its final configuration since 2000 has been integrated into IceCube and is combinedly operated [1].

2. WIMP Searches with IceCube and AMANDA

Massive objects could gravitationally capture cold DM, resulting in an enhanced DM density at the center. Neutrinos could then be produced in annihilation processes and would escape from the source, providing a potential signal for kilometer scale neutrino telescopes. Indirect searches for such DM signals are competitive to direct searches for models with significant spin-dependent neutralino-proton couplings [2].

We have searched for such signals (from the Sun and center of the Earth) with AMANDA and upper limits were placed on the neutrino flux produced by neutralino annihilation processes.

In the search for solar WIMPs [3] the background was estimated from off-source data in the same declination band as the Sun. A 90% CL exclusion limit on the neutrino flux was set for a neutralino mass range from 100 GeV to 5 TeV as seen in Fig. 1. Two annihilation channels

1 IceCube web site at http://www.icecube.wisc.edu
were compared: $W^+W^-$, which produces a hard neutrino energy spectrum, and $b\bar{b}$ yielding a soft spectrum. The sensitivity for solar WIMPs has also been evaluated using the combined IceCube/AMANDA detector [1] and a considerable improvement compared to AMANDA was achieved. The improvement is due to a reduced trigger threshold, a larger effective volume, and the detector configuration, in which AMANDA forms a more densely instrumented subarray inside the IceCube detector, which is especially important for detection of sub-TeV neutrinos. Peripheral strings can be used as a veto region to more effectively reduce the atmospheric muon background. The detector configuration allows for an analysis of fully and partially contained events yielding additional sensitivity.

We have also searched for vertically up-going muon neutrinos as expected from neutralino annihilations in the Earth’s core using the AMANDA dataset and placed a 90% CL upper limit on the flux [3] as shown in Fig. 2 and compared to other experiments.

![Figure 1. 90% CL upper limit on the muon flux from neutralino annihilations in the Sun compared to other experiments.](image1)

![Figure 2. 90% CL upper limit on the muon flux from neutralino annihilations in the Earth compared to other experiments.](image2)

The region around the Galactic Center is another good potential candidate for sources of neutrinos from DM annihilations. Located in the Southern sky, it was so far inaccessible to AMANDA due to an irreducible down-going atmospheric muon background. However, the much larger IceCube detector might offer the potential to observe these neutrinos as fully or partially contained events. A dedicated filter for these contained events has been implemented [4].

3. Conclusions and Outlook
The combined IceCube/AMANDA detector provides a significant improvement in sensitivity for searches of DM. Dedicated filters for these events have been implemented and the analysis effort is ongoing. Extensions of IceCube to construct a more densely instrumented detector array near the bottom inside IceCube are also being studied. Such a configuration would further improve the sensitivity to sub-TeV neutrinos, as the deep ice is clearer, the deeper location provides an improved shielding from cosmic ray backgrounds, and surrounding IceCube strings can be used to reject down-going atmospheric muons.

References
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