Search for Dark Matter in Galactic and Extragalactic Halos with the IceCube Neutrino Observatory

The IceCube Collaboration

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Signal from Annihilating Dark Matter

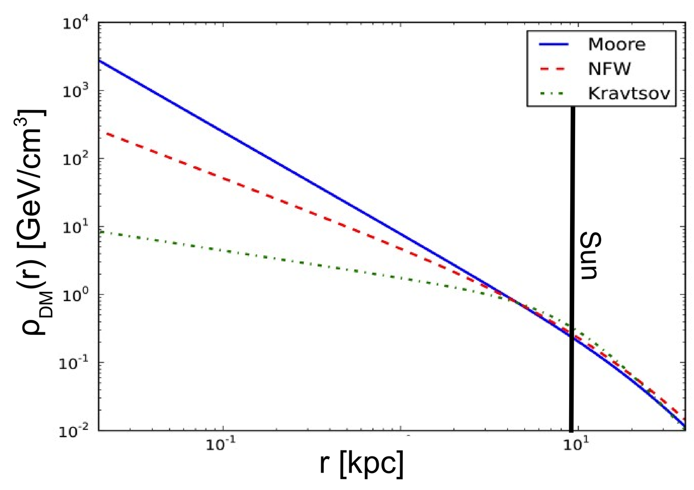
$$\frac{d\phi}{dE}=\frac{1}{4\pi}\frac{1}{2}\rho_{SC}^2\frac{<\sigma_A v>}{m_\chi^2}J(\psi)\frac{dN}{dE} \quad [1]$$

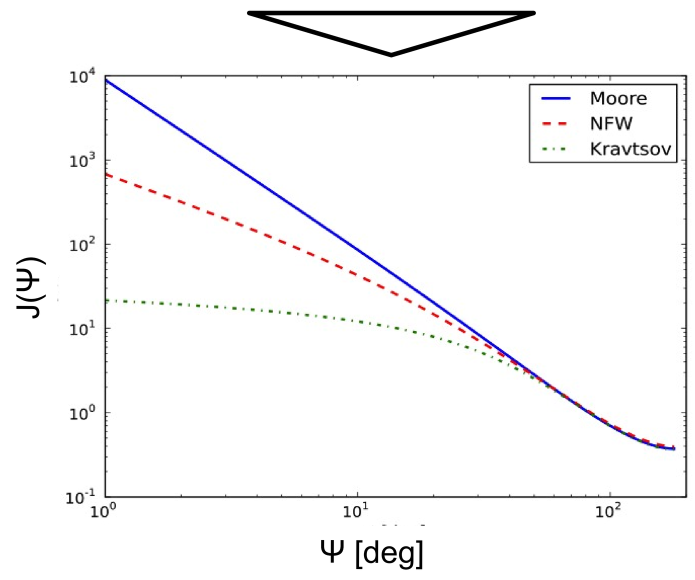
Self-annihilating dark matter can produce a flux of cosmic messenger particles (γ, e[±], p, ν ...). The flux depends on:

- Factors 1/(4π) from isotropic radiation, ½ from self-annihilation, ρ_{SC} is the local DM density
- Line-of-sight integral over the dark matter density profile

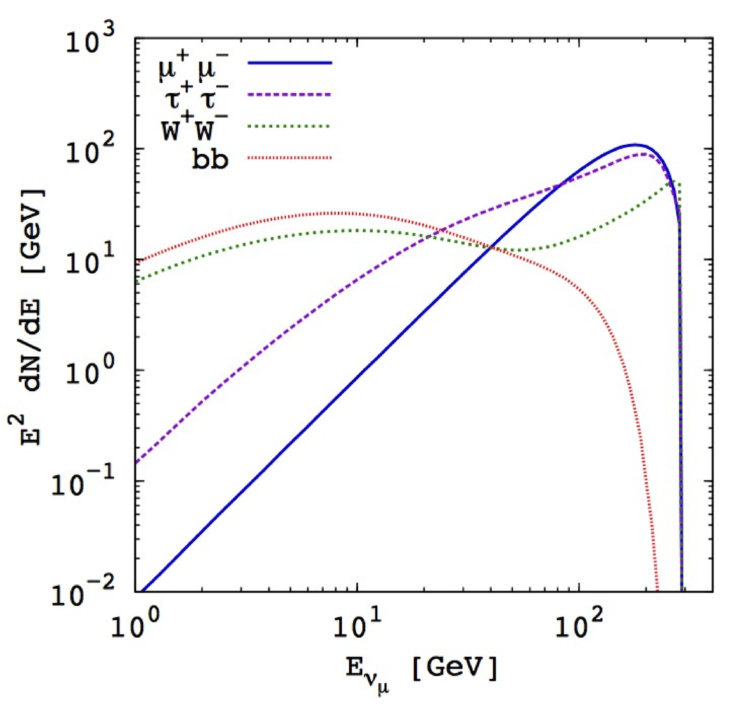
$$J(\psi)=\frac{1}{R_{SC}\rho_{SC}^2}\int_0^l \rho_{DM}^2(l(\psi))\,dl$$

$$l(\psi)=\sqrt{R_{SC}^2-2lR_{SC}\cos\psi+l^2}$$





- Velocity-averaged self-annihilation cross-section
- Neutrino energy spectrum



Dark Matter in the Galactic Center

The distribution of dark matter in the Milky Way may be described by a spherically symmetric density profile with the density increasing towards the Galactic Center. Thus, a flux of messenger particles, like gamma ray photons or neutrinos from the direction of the Galactic Center or a large-scale anisotropy in the Galactic halo, can be interpreted as indirect evidence of dark matter. The inherent advantage, and ensuing challenge, of neutrinos is the low interaction probability. Neutrinos can escape the production site unimpeded by potentially complex absorption processes but require large detectors.

Results from two searches for dark matter in the Galactic Center and halo are presented.

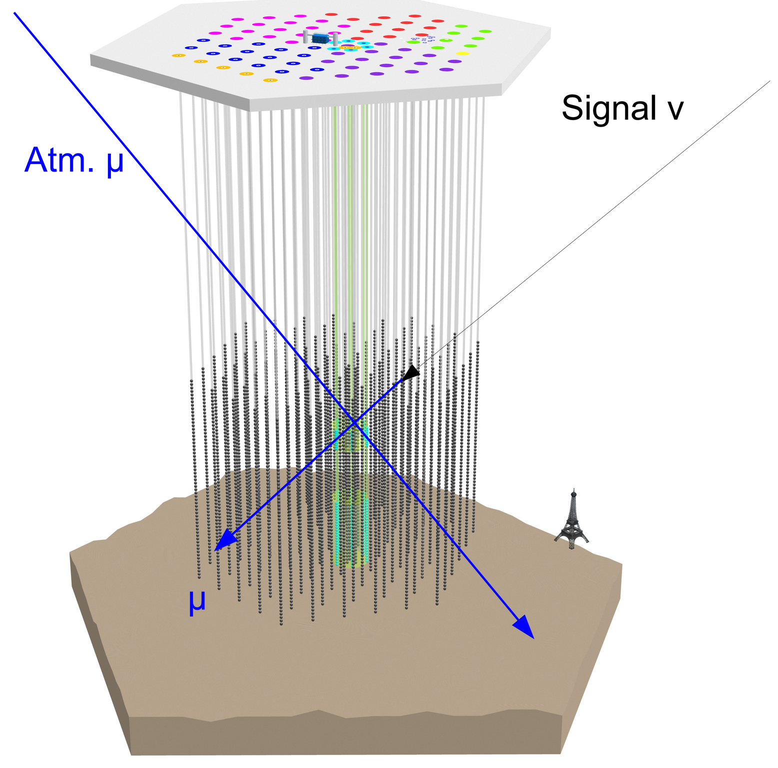
Dwarf Galaxies and Extragalactic Dark Matter Halos

The kinematics of dwarf galaxies imply that these objects have a large mass-to-light ratio and are thus considered to be strongly dark matter dominated. Other promising types of distant dark matter accumulations are large galaxies and galaxy clusters. A neutrino flux resulting from annihilating dark matter particles in these halos could be detected as an excess above the background of atmospheric neutrinos.

An analysis using data collected by IceCube in 2009/2010 with the 59-string configuration searching for a dark matter signal from five dwarf galaxies, two galaxy clusters, and the galaxy M31 is performed.

The IceCube Neutrino Observatory

- Located at the geographic South Pole
- Detects Cherenkov light from secondary charged leptons
- 5160 digital optical modules on 86 strings
- 15 strings form low-energy sub-array (DeepCore)
- 1.45 km – 2.45 km below the ice surface
- Instrumented volume of ~1km³
- During construction data was taken with 22, 40 and 59 strings (IC22, IC40, IC50)



Results

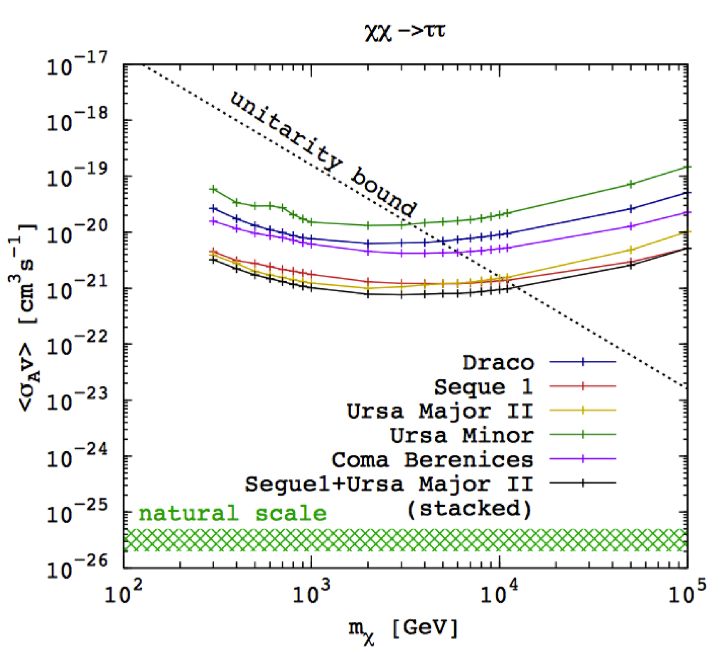
We present limits for:

- IceCube-22 (Galactic halo) [2]
- IceCube-40 (Galactic Center)

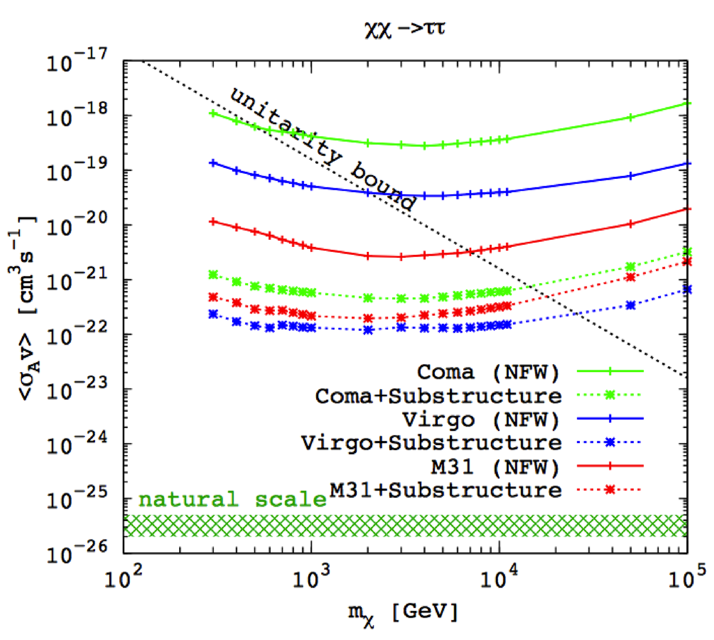
Further, we present sensitivities for:

- IceCube-59 (dwarf galaxies/clusters)

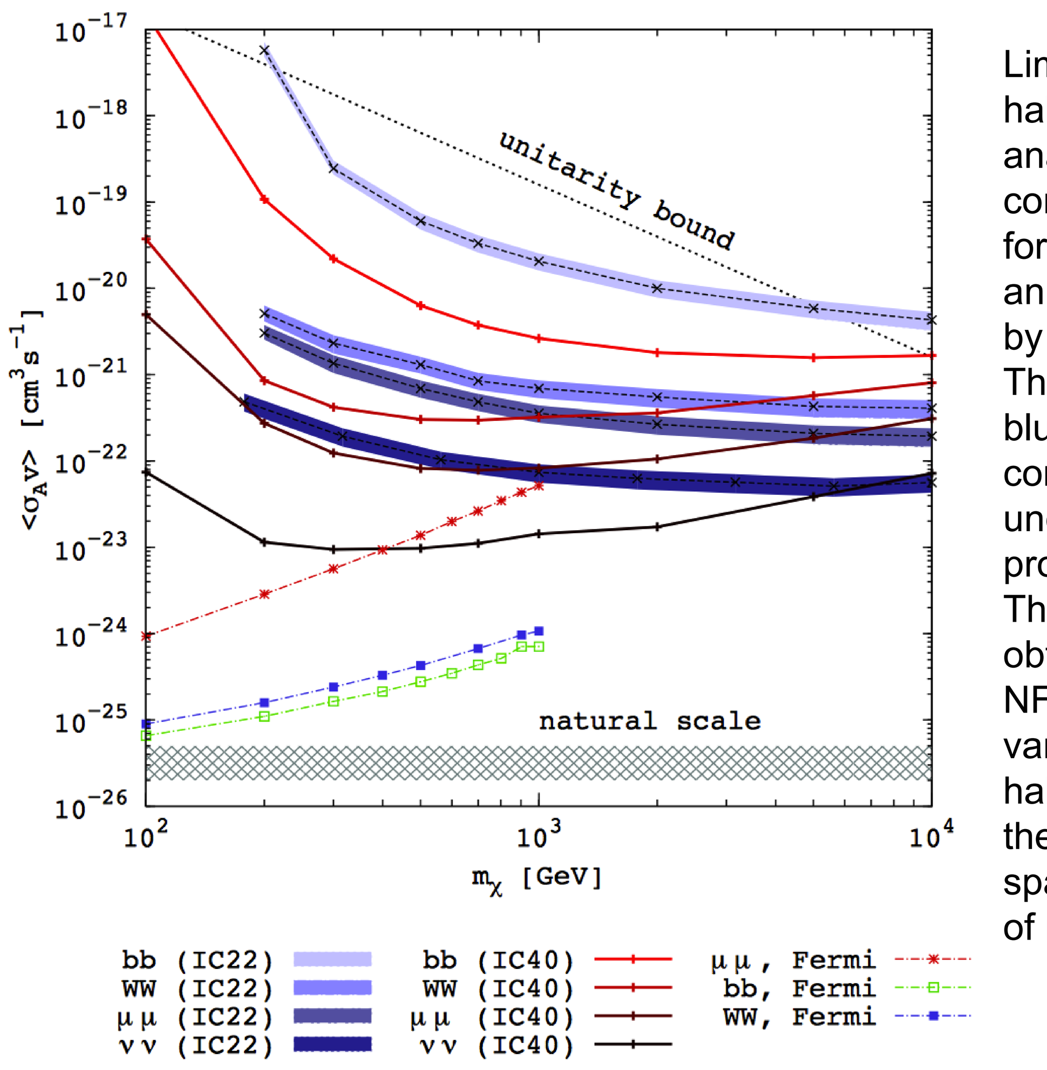
These are compared to phenomenological models based on DM-interpretations of the PAMELA/Fermi excess [3], as well as recent limits from Fermi, based on observation of dwarf galaxies [4].



Sensitivities for different dwarf spheroidal galaxies, as well as the sensitivity of a stacking analysis of Segue1 and Ursa Minor II.



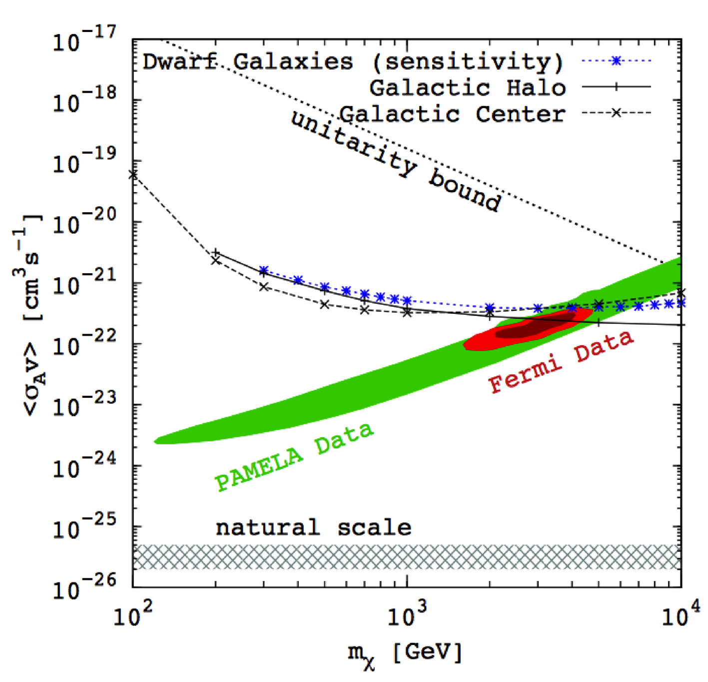
Sensitivities for the Andromeda galaxy and for the galaxy clusters Coma and Virgo for a smooth NFW profile (solid) and for a halo with substructure (dashed).



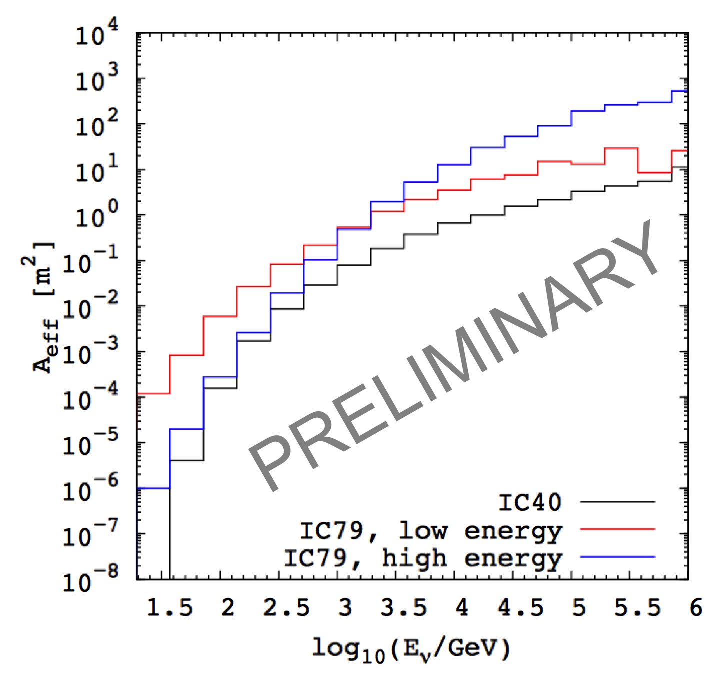
Limits from the Galactic halo and Center analyses (IceCube), compared to a search for gamma rays from annihilating dark matter by Fermi.

The thickness of the blue-shaded lines corresponds to the uncertainty on the halo profile.

The IC40 limits were obtained assuming the NFW profile. The variation of limits due to halo uncertainties for the Galactic Center spans up to two orders of magnitude.



Limits from the IC22 and IC40 analyses and the IC59 sensitivity compared to preferred regions for dark matter based on PAMELA/Fermi data (annihilation to tau leptons).



Comparison of the effective Area for the IC40 analysis to a Galactic Center Analysis with IC79 at online filter level.

References:

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