37th International Cosmic Ray Conference

Search for dark matter with metastable mediators with the IceCube observatory

Christoph Toennis[1,2] on behalf of the IceCube Collaboration[†]

[1]Department of Physics, Sungkyunkwan University, Suwon, 16419, South Korea;
[2]Institute of Basic Science, Sungkyunkwan University, Suwon 16419, Korea

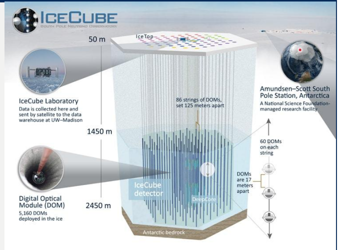
[†] http://icecube.wisc.edu/collaboration/authors/

Abstract

The IceCube neutrino observatory--installed in the Antarctic ice--is the largest neutrino telescope to date. It consists of 5,160 photomultiplier-tubes spread among 86 vertical strings making a total detector volume of more than a cubic kilometer. IceCube detects neutrinos via Cherenkov light emitted by charged relativistic particles produced when a neutrino interacts in or near the detector. The detector is particularly sensitive to high-energy neutrinos of due to its size and photosensor spacing. In this analysis we search for dark matter that annihilates into a metastable mediator that subsequently decays into Standard Model particles. These models yield an enhanced high-energy neutrino flux from dark matter annihilation inside the Sun compared to models without a mediator. Neutrino signals that are produced directly inside the Sun are strongly attenuated at higher energies due to interactions with the solar plasma. In the models considered here, the mediator can escape the Sun before producing any neutrinos, thereby avoiding attenuation. We present the results of an analysis of six years of IceCube data looking for dark matter in the Sun. We consider mediator lifetimes between 1 ms to 10 s and dark matter masses between 200 GeV and 75 TeV.

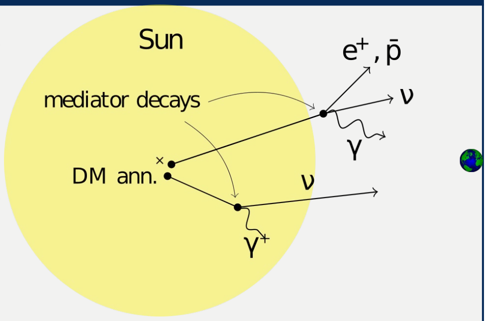
IceCube

- IceCube [1] is a cubic kilometer-scale Cherenkov detector deployed in the ice near the geographic South Pole
- Instrumented volume between 1,450 m and 2,450 m.
- Square kilometer cosmic ray air shower detector called IceTop at surface.
- 86 strings with 5160 optical module in total.
- Completed in 2011



Secluded dark matter

- Secluded dark matter [3] is a particle model for dark matter where the dark matter particle annihilates into a metastable mediator particle
- Mediator decays into pair of standard model particles.
- For DM in the Sun the mediator can be long-lived enough to escape the solar plasma before decay
- This yields an enhanced high energy neutrino signal.
- In other models signal is cut due to absorption at 1 TeV



- DM masses of 250 GeV to 75 TeV, mediator decay lengths from 0.01 to 10 solar radii and mediators decaying int W bosons and tauons have been considered.
- Since the simulation code WIMPSIM [3] that was used for this analysis does not include electroweak correction other decay channels were excluded

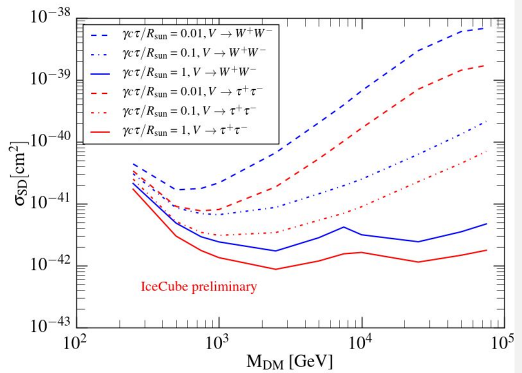
Analysis method

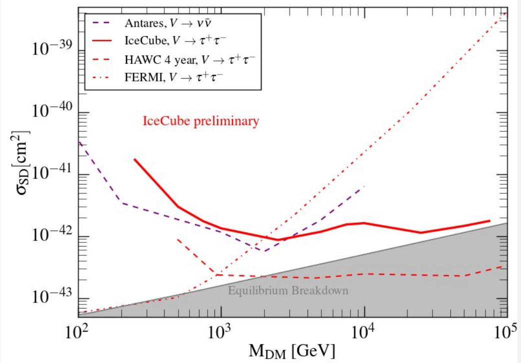
A dataset recorded between 2011 and 2016 with 1057.8 days of livetime was used. To analyse this dataset a unbinned likelihood method using the likelihood function

$$\mathcal{L}(n_s) = \prod_{i=1}^{N_{tot}} \left(\frac{n_s}{N_{tot}} S(\psi_i, E_i) + \frac{N_{tot} - n_s}{N_{tot}} B(\psi_i, E_i) \right)$$

was employed. The likelihood uses the angular distance of an event to the Sun ψ and the reconstructed event energy E to distinguish signal from background. Limits were set at a 90% confidence level using the Feldman-Cousins approach for confidence intervals Limits are then expressed in spin dependent scattering cross sections assuming an equilibrium between annihilation and accumulation of DM in the Sun [4].

Results





- No significant excess above the expected background was found in the examined dataset
- At dark matter masses between 7.5 and 10 TeV for long mediator decay lengths the signal part of the likelihood function S behaves particularly similar to the background distribution in reconstructed energy
- As a result a small and insignificant amount of events are misidentified as signal and an upwards kink can be seen in the limits in these cases.
- The limits for the tau channels are at a similar level as the results from ANTARES [5] for the neutrino channel and surpass them at higher masses.
- The limits are within an order of magnitude of those produced by the HAWC [6] and FERMI [7] collaborations.
- If direct decays into neutrinos were considered the results would surpass those of ANTARES.
- In a future analysis more data and a different signal simulation accounting for electroweak corrections will be used.

Proceeding

Link

References

1 IceCube Collaboration, M. G. Aartsenet al. JINST12no. 03, (2017) P03012.
2 A. R. Maxim Pospelov and M. B. Voloshin Phys.Lett.B662(2007) 53–61.
3 C. Niblaeus, A. Beniwal and J.EdsjöJCAP11(2019) 011.
4 . K. Gaisser, G. Steigman, and S. TilavPhys. Rev. D34(1986) 2206.
5 ANTARES Collaboration, S. A.-M. et al.JCAP05(2016) 016.
6 HAWC Collaboration, A. A. et al.Phys. Rev. D98(2018) 123012.
7 Fermi LATCollaboration, M. A. et al.Phys. Rev. D84(2007) 03.