# Dark Matter Searches with the ANTARES Neutrino Telescope

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## Abstract

The ANTARES Neutrino Telescope is currently under construction in the Mediterranean Sea. An important part of the ANTARES scientific programme is the search for cold, non-baryonic dark matter in the form of neutralinos. This paper describes how this search can be made, summarises the expected ANTARES sensitivity to this particular type of dark matter and compares the predicted ANTARES sensitivity with that expected from direct detection methods.


## 1. Introduction

The need for dark matter in the Universe is well established. The analysis of galactic rotation curves indicate a significant difference between the implied mass from the doppler shifts of stars rotating about the centre of the galaxy and the observed mass of stars in the galaxy. In recent years, precise measurements of cosmologically-relevant parameters as diverse as anisotropies in the Cosmic Microwave Background (CMB) and the Hubble expansion rate have placed increasingly stringent limits on the differing components of the matter budget in the Universe. Most recently, results from analysis of the CMB using WMAP [13] when coupled with data on high-redshift Type Ia supernovae [12] indicate a flat Universe with $\Omega = 1$ which is comprised of 27% matter (dominated by cold dark matter) and 73% dark energy. With a density of $\Omega_{CDM}h^2 = 0.1126^{+0.0161}_{-0.0181}$ [7], the cold dark matter may exist in one or more of several forms which include axions, neutrinos, supersymmetric dark matter and superheavy dark matter in the form of cryptons, wimpzillas which remain today as relics of the early Universe. Of these, by far the most compelling candidate is the *neutralino*, the lightest supersymmetric particle which is an admixture of gauginos and higgsinos - the counterparts of the Higgs and gauge bosons in the supersymmetric extension to the Standard Model of particle physics (SUSY).

## 2. The ANTARES Neutrino Telescope

The ANTARES neutrino telescope is currently under construction [11]. Recently two instrumented lines, a sector line and a mini instrumentation line have

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been deployed and operated at the ANTARES site [4]. The detector will consist of 900 phototubes distributed over 12 autonomous mooring lines or "strings". Muon neutrinos undergo charged current weak interactions which produce relativistic charged muons which are detected via the Cherenkov light that they liberate as they pass through sea water. Interstring distances are typically of the order of 65m which permits a muon threshold well below 50 GeV to be attained, this is particularly relevant for dark matter searches.

## 3. Neutralino Detection Technique

Neutralinos, the best candidates for cold dark matter, can become gravitationally captured in massive astrophysical objects such as the Sun and the Earth when the neutralino is scattered as it passes through the body and loses momentum. Once captured, over time, the neutralino will scatter further causing it to fall to the core of the object. The number density of neutralinos at the core subsequently increases. The neutralinos, being Majorana particles, can self-annihilate to pairs of fermions or bosons including quarks, gauge bosons and Higgs bosons, the decay products of which often include neutrinos. The observation of a flux of high energy neutrinos from the centre of the Sun or Earth therefore is indicative of a population of non-baryonic dark matter particles at the core of that object.

The latitude of the ANTARES site is particularly advantageous for a detailed study of Galactic Centre which may also be a source of high energy neutrinos from neutralino self-annihilations from the expected increased number density around the black hole at the centre of the Galaxy.

## 4. ANTARES Sensitivity to Neutralinos

The sensitivity of ANTARES to neutralinos is assessed in the following way. First the effective volume (which is the detector sensitive volume including reconstruction efficency) is calculated as a function of neutralino energy. This effective volume is calculated within a certain cone angle around the source and is also a function of the position of the source on the sky (averaged over one year). The cone angle size is optimized as a function of the neutralino mass. For any assumed neutralino mass, the expected background inside the cone is calculated and the 90% confidence level limit set using the Feldman and Cousins technique [8] to yield a neutrino flux limit. This is converted to a muon flux limit using the muon yield per neutrino from the DarkSUSY [6] program. Two specific cases called "hard" and "soft" are considered where the neutralino annihilates solely to products that yield a hard (soft) neutrino spectrum respectively.

The resulting ANTARES muon flux limit in the case of neutralinos from the centre of the Sun assuming a "hard" neutrino spectrum is presented in Fig. 1. Here, the sensitivity corresponds to a slightly different detector configuration than the final one. The sensitivity is compared to published limits from MACRO, Super-Kamiokande and BAKSAN [9,10,14]. The fall-off in sensitivity at low energies arises from using a reconstruction package optimised for higher energies. Dedicated studies to improve low energy reconstruction efficiencies are underway.

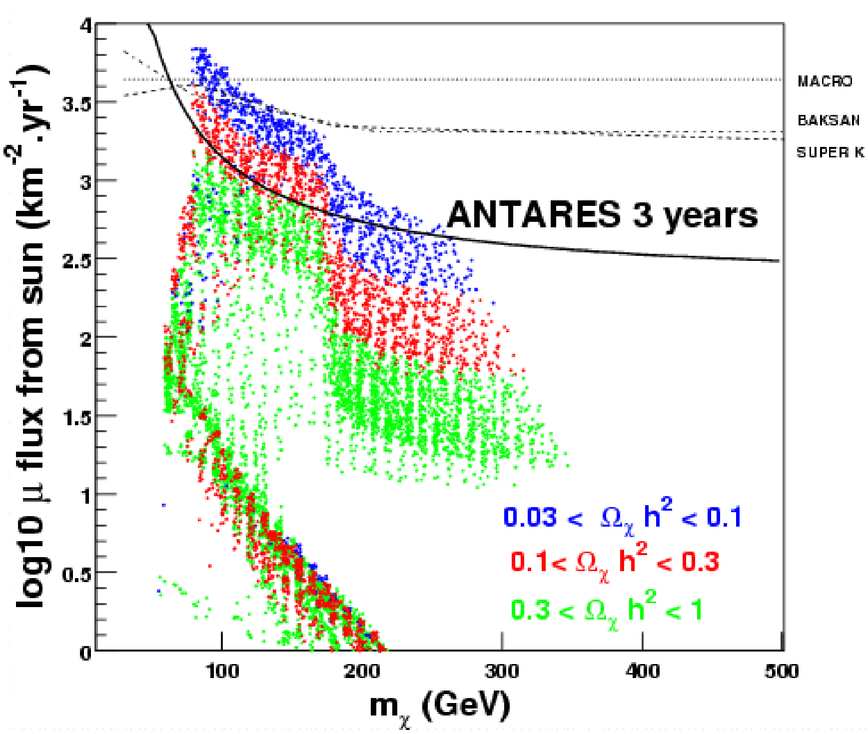


**Fig. 1.** ANTARES sensitivity to a muon flux from neutralinos in the Sun.

Superimposed on Fig. 1 are a number of points which correspond to theoretical predictions within the so-called mSUGRA [2] framework (where the number of free SUSY parameters is reduced by equating certain sparticle masses and couplings). A scan over a wide range of mSUGRA parameter space was performed [1] using the SUSPECT and DarkSUSY [5,6] software packages. The mSUGRA predictions are colour-coded according to the relic density, the cosmologically interesting region corresponds to the red (mid-grey) points. it should be noted that with 3 years of data taking ANTARES will have the capability of rejecting certain models within this mSUGRA parameter space.

## 5. Comparison with Direct Detection Techniques

It is interesting to compare the sensitivity from indirect detection techniques for identifying neutralinos, as presented here, with those from direct detection techniques. A comparison between the ANTARES sensitivity to neutralinos from the Sun as depicted in Fig. 1 with that expected after 3 years of data-taking with the Edelweiss-II low temperature detector [3] is presented in Fig. 2 for models within the mSUGRA framework. This figure illustrates that there is a promising complementarity between the two approaches that will enable more of the SUSY parameter space to be explored than with one technique alone.

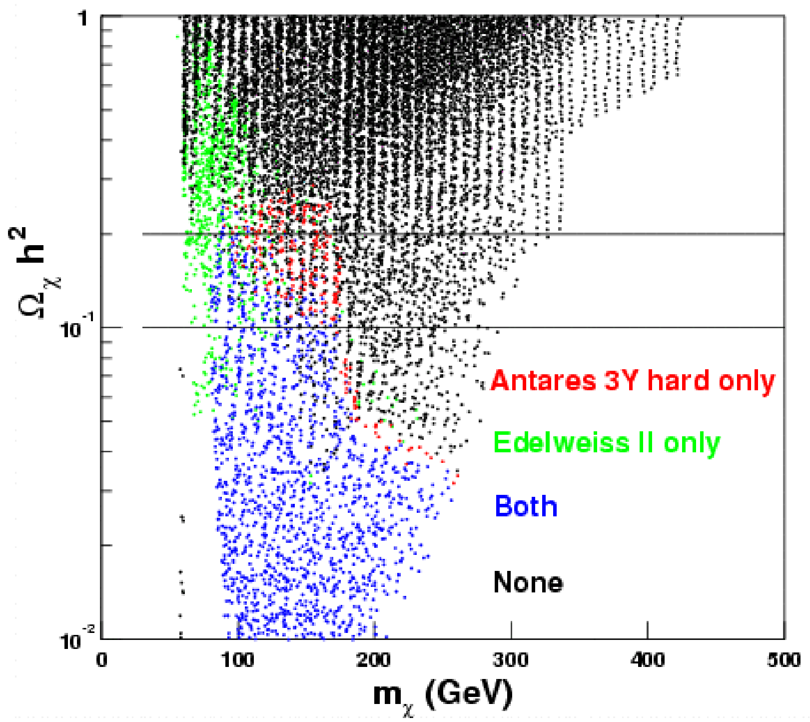


**Fig. 2.** Comparison of ANTARES and EDELWEISS-II neutralino sensitivities, Horizontal lines delimit the area of cosmological interest.

## 6. References


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