Indirect Search for Dark Matter with the Neutrino Telescope ANTARES

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SUSY11, Fermilab, Batavia 28.08.2011
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Dark Matter

Experimental Hints

WMAP: $0.09 < \Omega_{DM} h^2 < 0.13$

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Dark Matter

Experimental Hints

Hot gas, baryonic matter

Dark Matter

DISTRIBUTION OF DARK MATTER IN NGC 3198
Search for Dark Matter

- Theories beyond the Standard Model (e.g. Kaluza-Klein, Supersymmetry) provide candidates for cold Dark Matter

- WIMPs: Weakly Interacting Massive Particles
  masses in the order of $O(100 \text{ GeV}) – O(1 \text{ TeV})$

- In SUSY models one of these WIMPs is the Neutralino $X$

- Indirect detection of Neutralinos with Neutrino Telescopes
Search for Dark Matter with Neutrino Telescopes

Principle of Detection:

- WIMPs from the galactic halo lose energy through scattering and accumulate in massive bodies, e.g. the Sun
- Self annihilation products (Neutrinos) can be detected with Neutrino Telescopes

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Supersymmetric WIMPs

Minimal Supersymmetric Standard Model (MSSM):

- Disadvantage: additional 105 free parameters
- Simplifying assumptions are necessary to reduce number of parameters
- mSUGRA (minimal SUperGRAvity): defined on scale of gauge coupling unification
  → only 5 free parameters left

\[ m_0, m_{1/2}, A_0, \tan(\beta), \text{sign}(\mu) \]
Regions of mSUGRA parameter space
(expected $\nu_\mu - \nu_\mu$ flux from the Sun)

- **Focus Point Region**
- **A-Annihilation Region**
- **Co-Annihilation Region**
- **Bulk Region**

- $0.09 < \Omega h^2 < 0.13$
- $\Omega h^2 < 0.09$
- $0.13 < \Omega h^2 < 1$

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The ANTARES Experiment

Collaboration:
8 Countries, 29 institutes
The ANTARES Experiment

Detector layout:

Fully operational since May 2008
The ANTARES Experiment

Detector layout:

Fully operational since May 2008
The ANTARES Experiment

Detector layout:

Fully operational since May 2008
Principle of Detection
Principle of Detection

**Graph**

- **Anglular resolution (degrees)**
  - $\mu_{\text{rec}} - \mu_{\text{true}}$
  - $\mu_{\text{rec}} - \nu$

**Logarithmic Scale**

- $\log_{10}[E_{\nu} \text{ (GeV)}]$
Background Rejection

![Diagram of Earth and cosmic particles]

Elevation

- data
- MC atm. μ
- MC atm. ν
- MC total

Number of events

\[
\text{Number of events} = \begin{cases} 
10^6 & \text{if } \sin \theta < 0.2 \\
10^5 & \text{if } 0.2 \leq \sin \theta < 0.6 \\
10^4 & \text{if } 0.6 \leq \sin \theta < 0.9 \\
10^3 & \text{if } 0.9 \leq \sin \theta < 1 \\
10^2 & \text{if } \sin \theta = 1 \\
10 & \text{if } \sin \theta = 0.8 \\
1 & \text{if } \sin \theta = 0.6 \\
0.1 & \text{if } \sin \theta = 0.2 \\
0.01 & \text{if } \sin \theta = 0 \\
0.001 & \text{if } \sin \theta = -0.2 \\
0.0001 & \text{if } \sin \theta = -0.4 \\
0.00001 & \text{if } \sin \theta = -0.6 \\
0.000001 & \text{if } \sin \theta = -0.8 \\
0.0000001 & \text{if } \sin \theta = -1 \\
\end{cases}
\]
ANTARES Effective Area

ANTARES Neutrino Effective Area in the low-energy regime

\[ A_{\text{eff}} \quad [m^2] \]

\[ E_{\nu} \quad [GeV] \]

- **Trigger3D, 60 kHz, 0% XOFFs**
  - Trigger level
  - Detection level

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ANTARES Effective Area

ANTARES Neutrino Effective Area in the low-energy regime

\( A_{\text{eff}} \) [m²]

\( E_\nu [\text{GeV}] \)

**Trigger3D, 60 kHz, 0% XOFFs**

- Trigger level
- Detection level
Expected Detection Rate from the Sun (Simulation)

- WMAP favoured, 90% CL. excludable by ANTARES
- WMAP disfavoured, 90% CL. excludable by ANTARES
- WMAP favoured, not excludable by ANTARES
- WMAP disfavoured, not excludable by ANTARES

- Search Cone: 3°
- 10% misreconstructed Events (assumed)
- Unified Approach of Feldman-Cousins
Limit on Neutrino Flux from the Sun (Data)
Summary and Future Prospects

- ANTARES operational and taking data
- First Limit derived from 5 Line period
- Complementary method of SUSY/Dark Matter search to direct detection and LHC
- Analysis of 10 and 12 Line data using dedicated Low Energy reconstruction algorithm in progress
- Search for annihilation signal from centre of Earth in progress
BackUp slides
Muon Flux limit

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Excludable regions of mSUGRA parameter space

Excludable in 3 years (90% C.L.): all  some  none