Novel Searches for Dark Matter 2010

Center for Cosmology and Astroparticle Physics (CCAPP)
The Ohio State University
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CCAPP originated in July 2006 with a 5-year $5.5M Targeted Investment in Excellence (TIE) award from the Provost of The Ohio State University. The original proposal to establish CCAPP (Nov. 2005) set three objectives that are fundamentally linked to advancing the goals of the university’s Academic Plan and contributing to the overarching goal of becoming one of the world’s top public research and teaching universities: (1) to create a highly visible Postdoctoral/Visitor/Workshop Program that would mark CCAPP affiliation as a “badge of honor” in a young researcher’s career, (2) to initiate world-leading interdisciplinary research efforts in fields where OSU can make unique and fundamental contributions: dark energy, the origin of cosmic structure, and the highest energy particles of the Universe, and (3) to enhance the education of our graduate students and postdocs, and to enhance the science of our research efforts while increasing external research funding for CCAPP and its research initiatives. A central goal of CCAPP is providing an exceptional research environment for young researchers in the fields of cosmology and particle astrophysics.
What is CCAPP
Find your way

Astro Coffee takes place each morning at 10:30am in the Astronomy Conference Room (4054 McPherson)
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Why have this workshop now?

- Overwhelming evidence for the existence of Dark Matter
- ... but what is its nature?
- Fast progress on the experimental side, entering an exciting era of precision measurements in astroparticle physics
- Review new instrumentation, their performance and latest theoretical developments
- Develop an optimal analyses strategies to search for dark matter
Workshop Strategy

- Bring together experts from experimental and theoretical particle astrophysics (with a focus on Neutrino Telescopes)
- Provide an updated look at the neutrino/photon detection capabilities of Super-K / IceCube+DeepCore / Fermi and recent theoretical developments
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- Explore prospects for detection of dark matter annihilation / decay signals in the Milky Way
- Generate new ideas for how to best exploit dark matter signals
The Forum

- We will not keep time strictly
- Questions during talks are welcome
- Think tank atmosphere
- Discussions are encouraged
Deep Core

Configuration at the end of this year:

- 15 strings (8+7)
- large fraction of HQE DOMs
- threshold ~10GeV
- angular resolution <1deg

Taking data now:

- 13 strings (6+7)
- 3 layers of strings (extensive veto volume)
What will come out of this workshop?

- New collaborators
- Many new ideas!
- Publications
- Analyses
- White paper?

Importance of a precision neutrino detector in the search for dark matter
How large can the Dark Matter Self-Annihilation Cross Section be?

- **KKT**
  - cusp profiles

\[ \langle \sigma v \rangle_{KKT} \simeq 3 \times 10^{-19} \text{ cm}^3 \text{s} \frac{m_\chi}{\text{GeV}} \]

- **Unitarity**
  - Limit from Q.M.
  - The probabilities for elastic and inelastic scattering must sum to 1
  - Unitarity of the scattering matrix

\[ \langle \sigma v \rangle \leq 1.5 \times 10^{-13} \text{ cm}^3 \text{s} \left[ \frac{\text{GeV}}{m_\chi} \right]^2 \left[ \frac{300 \text{ km/s}}{v_{\text{rms}}} \right] \]

- “**Natural scale**” - WIMP is thermal relic
  - \( 3 \times 10^{-26} \text{ cm}^3\text{s} \)
How large can the Dark Matter Self-Annihilation Cross Section be?

- Assume DM annihilations only produce SM final states
- Stringent upper limit on total annihilation cross section can be obtained by assuming only neutrinos are produced in final states (worst case, least visible)
- Any other final state would be more visible

- "Natural scale" - WIMP is thermal relic
  - $3 \times 10^{-26}$ cm$^3$/s

[Beacom, Bell, Mack 2007]
How large can the Dark Matter Self-Annihilation Cross Section be?

- **“Natural scale”** - WIMP is thermal relic
  - $3 \times 10^{-26}$ cm$^3$/s

- Milky Way Halo provides a better way to test self-annihilation cross section

How large can the Dark Matter Self-Annihilation Cross Section be?

- **soft**(bb)
- **hard**(WW)
- **hard**(μμ)
- **line** (νν)

- "Natural scale" - WIMP is thermal relic
  - $3 \times 10^{-26}$ cm$^3$/s
How large can the Dark Matter Self-Annihilation Cross Section be?

- Status today!
Primary Sources: $e^-$ accelerated in supernova remnants
Secondary Sources: $e^+$ from collisions between cosmic rays & ISM protons

F. Aharonian et al., arXiv:0905.0105.


Primary Sources: e−-accelerated in supernova remnants
Secondary Sources: e± from collisions between cosmic rays & ISM protons

What's going on??

Moskalenko & Strong 1998

F. Aharonian et al., arXiv:0905.0105.

Where is the Dark Matter??
How large can the Dark Matter Self-Annihilation Cross Section be?

• What’s next and how do we get there?
  - Deep Core will extend IceCube’s reach to lower energies, new neutrino flavors and make the Galactic center more accessible (less background).
  - IceCube can perform a variety of Dark Matter Analyses to test the self-annihilation cross-section and lifetime
    - Galactic Center
    - Galactic Halo
    - Diffuse (extra galactic)
    - Stacking (Dwarf Spheroidals)
    - Lines / Bumps Search
    - Anisotropy

Mandal Buckley Freese Spolyar Murayama (2009)

Structure of the workshop

Today

- Bring everybody on the same page
- What’s new in theory
- Where is the dark matter
- What relevant anomalous signals exist and how what they could indicate?
- What can detectors do
- On-going searches and prospects

<table>
<thead>
<tr>
<th>Time</th>
<th>Discussion / Topic</th>
<th>Speaker</th>
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</thead>
<tbody>
<tr>
<td>8:10</td>
<td>Bus Departs from Crowne Plaza</td>
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<tr>
<td>8:30</td>
<td>Coffee + Breakfast</td>
<td></td>
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<tr>
<td>9:00</td>
<td>Welcome / Workshop Overview</td>
<td>C. Rott / S. Horiuchi</td>
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<tr>
<td>10:00</td>
<td>Dark Matter Models SUSY(30)</td>
<td>P. Sandick</td>
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<tr>
<td>10:30</td>
<td>Coffee Break</td>
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<tr>
<td>11:00</td>
<td>N-body simulations and Dark Matter distributions (30)</td>
<td>M. Vogelsberger</td>
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<tr>
<td>11:30</td>
<td>Dark Matter distributions and observations (30)</td>
<td>M. Kaplinghat</td>
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<tr>
<td>12:00</td>
<td>Phenomenological Interpretation of Observations (30)</td>
<td>M. Kistler</td>
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<tr>
<td>12:30</td>
<td>Lunch Break</td>
<td></td>
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<tr>
<td>14:00</td>
<td>IceCube/DeepCore Overview and DM Searches (30)</td>
<td>M. Danninger</td>
</tr>
<tr>
<td>14:30</td>
<td>DeepCore Reconstruction Status (20)</td>
<td>D. Grant</td>
</tr>
<tr>
<td>14:50</td>
<td>DeepCore Veto Methods (20)</td>
<td>S. Euler</td>
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<tr>
<td>15:10</td>
<td>PSU Workshop Summary (20)</td>
<td>D. Cowen</td>
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<tr>
<td>15:30</td>
<td>Coffee + Cookies</td>
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<tr>
<td>16:00</td>
<td>Super-K Status and DM Searches (30)</td>
<td>T. Tanaka</td>
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<tr>
<td>16:30</td>
<td>Fermi Status and DM Searches (30)</td>
<td>B. Winer</td>
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<tr>
<td>17:00</td>
<td>Discussions</td>
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<tr>
<td>18:00</td>
<td>Bus Departs from PRB to Crowne</td>
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<tr>
<td>19:30</td>
<td>Banquet Dinner at Gordon Biersch Brewery Restaurant (Google Map)</td>
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<td></td>
<td>(Arena District Map)</td>
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Structure of the workshop

Tomorrow

- Theoretical predictions and proposed searches
- New ideas
- Discussions
- (World Cup and during extended coffee break)
- White-paper and homework

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<tr>
<td>9:00</td>
<td>Uncovering DM and other unresolved source populations with anisotropies</td>
<td>J. Siegal-Gaskins</td>
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<tr>
<td>9:30</td>
<td>Photon Signals from DM and backgrounds (30)</td>
<td>K. Abazajian</td>
</tr>
<tr>
<td>10:00</td>
<td>Neutrino Signals from DM and backgrounds Halo (30)</td>
<td>H. Reno</td>
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<tr>
<td>10:30</td>
<td>Coffee Break</td>
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<tr>
<td>11:00</td>
<td>Neutrino Signals (30)</td>
<td>S. Mandal</td>
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<tr>
<td>11:30</td>
<td>Neutrino/Photon/CR comparison (30)</td>
<td>H. Yuksel</td>
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<tr>
<td>12:00</td>
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<td>Lunch Break</td>
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<tr>
<td>13:00</td>
<td>Neutrino Signals from DM and backgrounds Sun/Earth (30)</td>
<td>A. Peter</td>
</tr>
<tr>
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All meals provided

Institute of Medical and Biological Problems:

- Isolation facility

500-day six-person Mars mission simulation

New roommates: The Mars500 crew consists of (from left, front row): Alexei Sitev, Alexander Smoleyevsky, Mikhail Sinelnikov and (from left, back row) Sukhrob Kamolov, Romain Charles, Diego Urbina.

No daylight. No fresh air. No contact with the outside world for 18 months. On Thursday, six men in Moscow are cutting themselves off for 520 days in a simulated trip to Mars. The mission will reveal the effects of prolonged space flight on the human body -- and whether six people can live in a confined space for so long without coming to blows.
the northwest side of downtown. The Arena District has transformed into one of Columbus' most happening entertainment destinations.

The district used to be marked by the Ohio Penitentiary. Now Nationwide Arena is the centerpiece and home to Ohio's only National Hockey League team, the Columbus Blue Jackets, and the Columbus Clippers, Triple A affiliate of the Cleveland Indians, who play in Huntington Park, which just opened in April 2009.
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The open questions

- Can we correlate photons and neutrino signals ... combined search?
- Complementary search methods?
- Deep Core Capability paper ... theorists wish list
- Phenomenology papers ... experimentalists wish list
The open questions

- What's the impact of improved flavor id?
  - tracks vs. cascades
- What's the impact of (improved) energy resolution, angular resolution?
  - contained events
- How would the ideal detector look like?
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- What’s the impact of (improved) energy resolution, angular resolution?
- contained events
- How would the ideal detector look like?
The Open Questions

- What is the best way to discover dark matter?
- Which analyses are most valuable?
- Analysis priority list
- What is needed to understand it?
More details

Where is material posted?

Workshop website:

http://ccapp.osu.edu/workshops/DMsearch/program.html

Why do we need two projectors?

Agenda

Working document "Google document" (this is internal)

https://docs.google.com/document/edit?id=LvKHPd-XYtXHe85IeIFwOHSdaUjHhWnR3/JE6h9Ectlw&hl=en&authkey=CM-C07QK

Your favorite discussion topic

Working material