Dark matter searches with GLAST

Representing the GLAST LAT Collaboration
Dark Matter and New Physics working group
GLAST Large Area Telescope (LAT)  
20 MeV – 300 GeV

Anti-Coincidence Detector
- 4% R.L.
- 89 scintillating tiles
- Efficiency (>0.9997) for MIPs

Tracking detector
- 16 tungsten foils
  (12x3% R.L., 4x18% R.L.)
- 18 pairs of silicon strip arrays
- 884736 strips (228 micron pitch)

Calorimeter
- 8.5 radiation lengths
- 8 layers cesium iodide logs
- 1536 logs total (1200kg)
The LAT at SLAC
(October 2005)
GLAST LAT Collaboration

France
- IN2P3, CEA/Saclay

Italy
- INFN, ASI

Japan
- Hiroshima University
- ISAS, RIKEN

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Stanford University (SLAC and HEPL/Physics)
- University of Washington
- Washington University, St. Louis

Sweden
- Royal Institute of Technology (KTH)
- Stockholm University

Principal Investigator:
Peter Michelson (Stanford & SLAC)

~225 Members
(includes ~80 Affiliated Scientists, 23 Postdocs, and 32 Graduate Students)

Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

LAT Managed at
Stanford Linear Accelerator Center (SLAC)
GLAST is a NASA Mission
- Launch: September 2007
- Lifetime: 5-years (10-years goal)
- Orbit: 565 km, circular
- Inclination: 28.5°

Large Area Telescope (LAT)
20 MeV - 300 GeV

Observing modes:
- All sky survey
- Pointed observations

Re-pointing Capabilities:
- Autonomous
- Rapid slew speed (75° in < 10 minutes)

GLAST Burst Monitor (GBM)
5 keV - 25 MeV
Dark matter as particles!

WIMP pair annihilation to $W$, $Z$, or quark pairs

\[ \chi \chi \rightarrow W^-/Z/q \]

\[ W^+/Z/\bar{q} \]

\[ \pi^0 \rightarrow \gamma \gamma \]

\[ \pi^+ \rightarrow \nu_\mu \mu^+ e^+ \]

\[ \pi^- \rightarrow \nu_\mu \mu^- e^- \]

\[ \nu_\mu \nu_e \]
Gammas from lines

Branching fractions are in the range $10^{-2} - 10^{-4}$

- For $\gamma \gamma$ Line, energy = WIMP mass
- For WIMP masses $> M_Z /2$ can also have $\gamma Z^0$ line

- Measurement of line branching fractions would constrain particle theory
Where should we look for WIMPs with GLAST?

- Galactic center
- Galactic satellites
- Galactic halo
- Extra-galactic
Example A. dark matter satellite

Optimistic case: 70 counts signal, 43 counts background within 1.5 deg of clump center
Dark matter source spectrum

- Dark matter spectrum
- Diffuse background
- Molecular cloud spectrum

GLAST 55 days (10-sigma)
How many observable dark matter sources?


SUSY model definitions from Baltz, et.al. (2006); LCC2 and LCC4 are favorable to GLAST compared to LCC1 and LCC3.
Satellite mass distributions

All satellites (Taylor & Babul 2004, 2005)

Current simulation resolution limit

5-sigma (GLAST 5-yrs)
10-sigma (GLAST 5-yrs)
20-sigma (GLAST 5-yrs)

M=100 GeV

$\langle \sigma_A v \rangle = 2.3 \times 10^{-26}$ cm$^3$ s$^{-1}$
Example B. Milky Way dark matter halo

EGRET $E_\gamma > 1\,\text{GeV}$, point-source subtracted, Cillis & Hartman (2005)

High latitude Region

Disk Region

Center Region

High latitude Region

WIMP search “sweet spot” (Stoehr et.al. 2004)
EGRET diffuse “GeV excess”

Hunter et al (1997); similar “GeV excess” in all sky regions

\[ |b|<10\text{deg}, \ |l|<60\text{deg} \]

- Can be explained with astrophysical mechanisms; i.e. SMR (2004)
- De Boer has claimed WIMP annihilation; i.e. De Boer, et.al. (2005)

GLAST

“no backsplash”
Example C: Galactic Center

- EGRET point source

Spatial analysis
- 100MeV-300MeV (l ~ -0.75deg)
- 300MeV-1GeV (l ~ -0.30deg)
- > 1GeV (l ~ 0.05deg)
- > 5GeV (l ~ 0.20deg)

New diffuse component in the galactic center region, HESS (2006)
Galactic center mSUGRA sensitivity: small tan(\(\beta\)) regime

- See Baltz, et.al. (2006) for definition of LCC2.
- Note: position of this point is very sensitive to \(m_\chi\) and this placement estimates the equivalent LCC2.
- Accelerator limits are from H. Baer, et al. (2004)
Galactic center mSUGRA sensitivity: large tan(β) regime

See Baltz, et.al. (2006) for definition of LCC4.

Note: position of this point is very sensitive to m_t and this placement estimates the equivalent LCC4.

Accelerator limits are from H. Baer, et al. (2004)
Review

• The GLAST collaboration will search for WIMP annihilation gamma rays from 4 regions: galactic center, galactic satellites, galactic halo, and extragalactic

• If we locate a source consistent with WIMP annihilations, then we can constrain particle theory by measuring the line branching fractions (if not with GLAST, then perhaps with an IACT)
GLAST – a complementary way to observe dark matter signals!

GLAST:
- Large field of view allows imaging of dark matter
- Large fraction (16%) of WIMP mass converts to radiation in the GLAST energy range
- Cosmic ray shield allows us to achieve low cosmic ray background

Experiments by DM location:
- At the earth’s surface: direct detection (& colliders)
- In the earth’s/sun’s core: neutrino detectors
- In the galaxy: anti-matter & gamma ray detectors