Analysis methods for Milky Way dark matter satellite detection

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Abstract:
The LAT Dark Matter and New Physics Working group has been developing approaches for the indirect detection of dark matter satellites in the Milky Way. Our work has assumed that a significant component of dark matter is a new type of Weakly Interacting Massive Particle (WIMP). The annihilation of two WIMPs results in the production of a large number of high energy gamma rays (>1GeV) that can be well measured in the GLAST LAT. The spectra of these galactic satellites are considerably harder than most, if not all, astrophysical sources, have an endpoint at the mass of the WIMP, and are not power laws.

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WIMP annihilation: continuum spectrum

- Dominant mode for Majorana fermion WIMPs:
- Additional dominant modes for Dirac fermion or bosonic WIMPs:

\[
\begin{align*}
W^+ W^- & \rightarrow \ell^+ \ell^- + 2\,\text{hadrons} \\
W^+ W^- & \rightarrow 2\,\ell^+ \ell^- \\
WW & \rightarrow 4\,\ell^+ \ell^- + 2\,\text{hadrons} \\
WW & \rightarrow 2\,\ell^+ \ell^- + 8\,\text{hadrons}
\end{align*}
\]

Gamma ray yield per unit satellite flux

WIMP annihilation cross section at freeze-out versus the current time

- WIMP annihilation cross section can be written as \(\sigma \sim m^{-1/3}\)
- In the case of light WIMPs, the LHC and LCOE
- In the case of heavy WIMPs, the LHC

Confidence intervals on WIMP mass and ann. cross section

- Calculate the 95%, 99%, and 68.3% confidence regions on WIMP mass and ann. cross section jointly if this specific satellite is detected.

Analysis flow for dark matter satellites

SExtactor: source finding

- We generated 100 “300-day GLAST experiments” for the example satellite, by fixing the latitude, but shifting in longitude by 3 degrees. We use SExtractor to perform source finding for extended sources, and find out the detection efficiency and false detection rate.

Likelihood: energy spectrum

- Using the GLAST LAT sensitivity for 1 year, we calculated the significance of dark matter satellites in the Milky Way, by modeling the satellites using the semi-analytic method of Taylor & Babul and the SUSY LCOE benchmark of Baltz, et al. We used test statistics and profile likelihoods to extract the GLAST sensitivity versus WIMP mass.

We selected one example satellite to demonstrate statistical methods for distinguishing between satellite and diffuse background. In the future, we can use the same methods to distinguish satellite from other astrophysical sources.

Summary:
We estimated the significance of dark matter satellites in the Milky Way, by modeling the satellites using the semi-analytic method of Taylor & Babul and the SUSY LCOE benchmark of Baltz, et al. We used test statistics and profile likelihoods to extract the GLAST sensitivity versus WIMP mass.

We selected one example satellite to demonstrate statistical methods for distinguishing between satellite and diffuse background. In the future, we can use the same methods to distinguish satellite from other astrophysical sources.