Dark Matter Annihilation from the Milky Way's halo

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Small-scale structure in $\Lambda$CDM halos

A rich galaxy cluster halo
Springel et al 2001

A 'Milky Way' halo
Power et al 2002
CDM galaxy halos (without galaxies!)

- Halos extend to \( \sim 10 \) times the 'visible' radius of galaxies and contain \( \sim 10 \) times the mass in the visible regions.

- Equidensity surfaces approximate triaxial ellipsoids
  - more prolate than oblate
  - axial ratios greater than two are common

- "Cuspy" density profiles with outwardly increasing slopes
  - \( \frac{d \ln \rho}{d \ln r} = \gamma \) with \( \gamma < -2.5 \) at large \( r \)
  - \( \gamma > -1.2 \) at small \( r \)

- Substantial numbers of self-bound substructures containing \( \sim 10\% \) of the mass and with \( \frac{d N}{d M} \sim M^{-1.8} \)

  Most substructure mass is in most massive subhaloes
Dark Matter Annihilation

If the dark matter WIMP's are Majorana particles

Self-annihilation is possible
Annihilation products will typically include $\gamma$-rays

The luminosity density of annihilation emission is

$$L(x) \propto n_{DM}(x)^2 \langle \sigma \ v \rangle$$

Thus the $\gamma$-ray luminosity of an object is

$$L \propto \langle \sigma \ v \rangle \int \rho^2 \ dV \propto \langle \sigma \ v \rangle \int \rho^2 \ r^2 \ dr$$

critical density exponent for convergence is $\rho \propto r^{-1.5}$
Inner density structure of a Milky Way halo

- Four simulations from the same initial conditions but with differing resolution $N_{200} = 14,000, 130,000, 1,200,000, 10,100,000$

- Inner structure converges down to about 1 kpc

- Slope is $\rho \propto r^{-1.5}$ at 7 kpc
Image of a 'Milky Way' halo in annihilation radiation

$S(\theta) \propto \int \rho^2 \, dl$
Substructure luminosity

- $J = \sum \rho_i m_i$ is proportional to the annihilation luminosity of an object.

- $J$ appears to have converged for the higher resolution models.

- $J \propto M$ for subhaloes total subhalo luminosity dominated by most massive objects.
Cumulative radial distributions of mass and light

- Half mass/light radii of the diffuse halo component are 90 kpc and 7 kpc
- Half mass/light radii of the subhalo component are both 130 kpc
- Total light from subhalo component is 25% that from the diffuse component
- The Sun is much closer to the peak of the diffuse emissivity than to a subhalo

Observed flux dominated by diffuse emission from inner Galaxy
Surface brightness of the simulated Milky Way as seen from the Sun's position

- Hatched area is scatter in circularly averaged surface brightness profiles for 8 artificial skies constructed directly from the simulation.

- Heavy lines are from analytic fits to the density profile.

- Vertical line is resolution limit of simulation at Galactic Centre.
Signal-to-noise of the simulated Milky Way as seen from the Sun's position

- Hatched area is scatter in circularly averaged signal-to-noise profiles for wide beam observation of 8 artificial skies assuming uniform background.
- Heavy lines from analytic fits to the density profile.
- Best S/N is achieved about at a radius of 10 degrees.
- At this radius simulation is secure and backgr'd is lower.
Could GLAST or VERITAS see the Signal?

- For VERITAS (a Cerenkov detector with 1.75° FOV) the detectability of the G.C. depends on poorly resolved regions of the simulation and is marginal.

- For GLAST (a satellite with 3 sterad. FOV) detection should be possible 20° to 30° from the G.C. in a very long integration and for most MSSM parameters. This does not depend on poorly resolved regions of the simulation.

Possible MSSM params from Darksusy