Dark Matter Detection from Milky Way Satellites

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### Census of Milky Way Satellites (Circa 2007)

<table>
<thead>
<tr>
<th>Name</th>
<th>Year Discovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMC</td>
<td>1519</td>
</tr>
<tr>
<td>SMC</td>
<td>1519</td>
</tr>
<tr>
<td>Sculptor</td>
<td>1937</td>
</tr>
<tr>
<td>Fornax</td>
<td>1938</td>
</tr>
<tr>
<td>Leo II</td>
<td>1950</td>
</tr>
<tr>
<td>Leo I</td>
<td>1950</td>
</tr>
<tr>
<td>Ursa Minor</td>
<td>1954</td>
</tr>
<tr>
<td>Draco</td>
<td>1954</td>
</tr>
<tr>
<td>Carina</td>
<td>1977</td>
</tr>
<tr>
<td>Sextans</td>
<td>1990</td>
</tr>
<tr>
<td>Sagittarius</td>
<td>1994</td>
</tr>
<tr>
<td>Canis Major</td>
<td>2003</td>
</tr>
<tr>
<td>Ursa Major I</td>
<td>2005</td>
</tr>
<tr>
<td>Willman I</td>
<td>2005</td>
</tr>
<tr>
<td>Ursa Major II</td>
<td>2006</td>
</tr>
<tr>
<td>Bootes</td>
<td>2006</td>
</tr>
<tr>
<td>Canes Venatici I</td>
<td>2006</td>
</tr>
<tr>
<td>Canes Venatici II</td>
<td>2006</td>
</tr>
<tr>
<td>Coma</td>
<td>2006</td>
</tr>
<tr>
<td>Leo IV</td>
<td>2006</td>
</tr>
<tr>
<td>Hercules</td>
<td>2006</td>
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<tr>
<td>Leo T</td>
<td>2007</td>
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</tbody>
</table>


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Assume galaxies are spherically-symmetric and in equilibrium

$$\sigma^2_{\text{los}}(R) = \frac{2}{I_*(R)} \int_R^\infty \left(1 - \beta \frac{R^2}{r^2}\right) \frac{\nu_* \sigma^2_r r dr}{\sqrt{r^2 - R^2}}$$
Line-of-sight velocity dispersion

Fornax


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Constraints on masses of satellites

Halo masses at about 600 pc are constrained to within 20%. Maximum circular velocities not constrained.

- Strigari, Bullock, Kaplinghat ApJL 2007

Strigari, Bullock, Kaplinghat, Diemand, Kuhlen, Madau 2007
Applications: Indirect Dark Matter Detection

Flux = Particle Physics x Astrophysics

$$\frac{dN_\gamma}{dAdt} = \frac{1}{4\pi} \mathcal{P}[(\sigma v), M_\chi, dN_\gamma/dE] \mathcal{L}(\rho_s, r_s, D).$$

$$\mathcal{L} = \int_0^{\Delta_\Omega} \left\{ \int_{\text{LOS}} \rho^2[r(\theta, D, s)] ds \right\} d\Omega,$$

- Galactic center: astrophysical issues, backgrounds [e.g. Bergstrom, Ullio, Buckley 1999; Hooper & Dingus 2004; Profumo 2005]
- Dark substructures [Savvas Koushiappas talk]

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Constraints on Astrophysical Parameters

LS, Koushiappas, Bullock, Kaplinghat PRD 2007

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Fluxes are ‘boosted’ with substructure

Two order of magnitude boost?

$\mathcal{L}(M) = [1 + B(M, m_0)] \tilde{\mathcal{L}}(M)$.

Boost factor

LS, Koushiappas, Bullock, Kaplinghat PRD 2007
Orders of magnitude more surviving dark substructures in simulations that satellites galaxies in the local group. The ‘missing satellites’ problem. [Kauffmann et al. 1993, Klypin et al. 1999, Moore et al. 1999]

Earliest forming halos
Largest before accretion

Earliest Forming
Largest Before Accretion
Dark subhalos
MW satellites

Mass < 0.6 kpc \([M_\odot]\)

LS, Bullock, Kaplinghat, Diemand, Kuhlen, Madau 2007

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Conclusions and Outlook

- Strong mass constraints on satellite galaxies from stellar kinematics
- Gamma ray fluxes may be ‘boosted’ by up to two orders of magnitude
- Fluxes from new dwarfs may be similar, or even larger
- New constraints on solutions to the missing satellites problem
- Further applications: Can distinguish between cores/cusps with astrometry [Strigari, Bullock, Kaplinghat ApJL 2007]

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