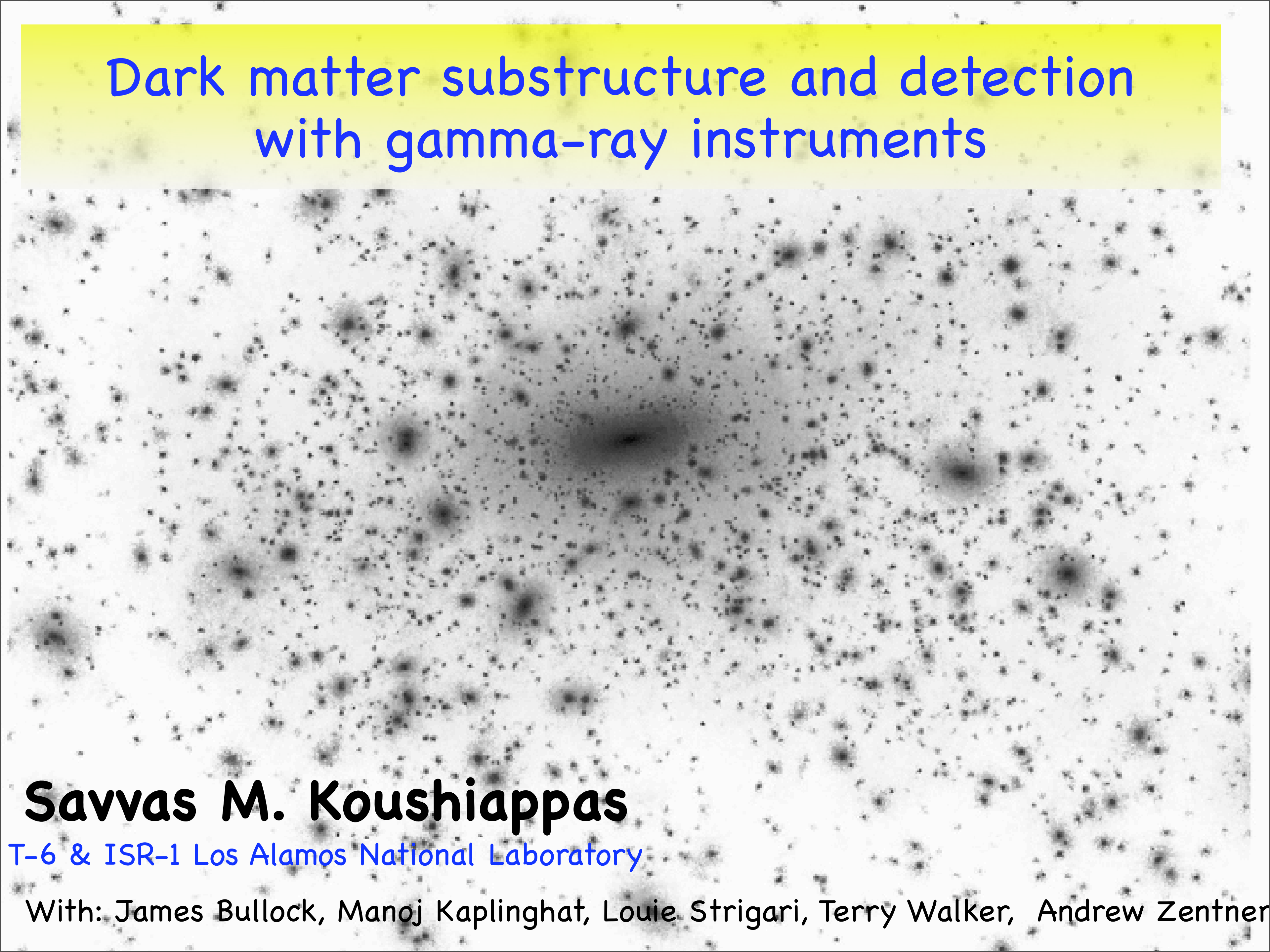
Dark matter substructure and detection with gamma-ray instruments



Savvas M. Koushiappas

T-6 & ISR-1 Los Alamos National Laboratory

With: James Bullock, Manoj Kaplinghat, Louie Strigari, Terry Walker, Andrew Zentner

Dark matter substructure and detection with gamma-ray instruments

I: Detecting dwarf spheroidals of the local group

II: Detecting the dark Milky Way substructure

III: Detecting hypothetical microhalos in the solar neighborhood

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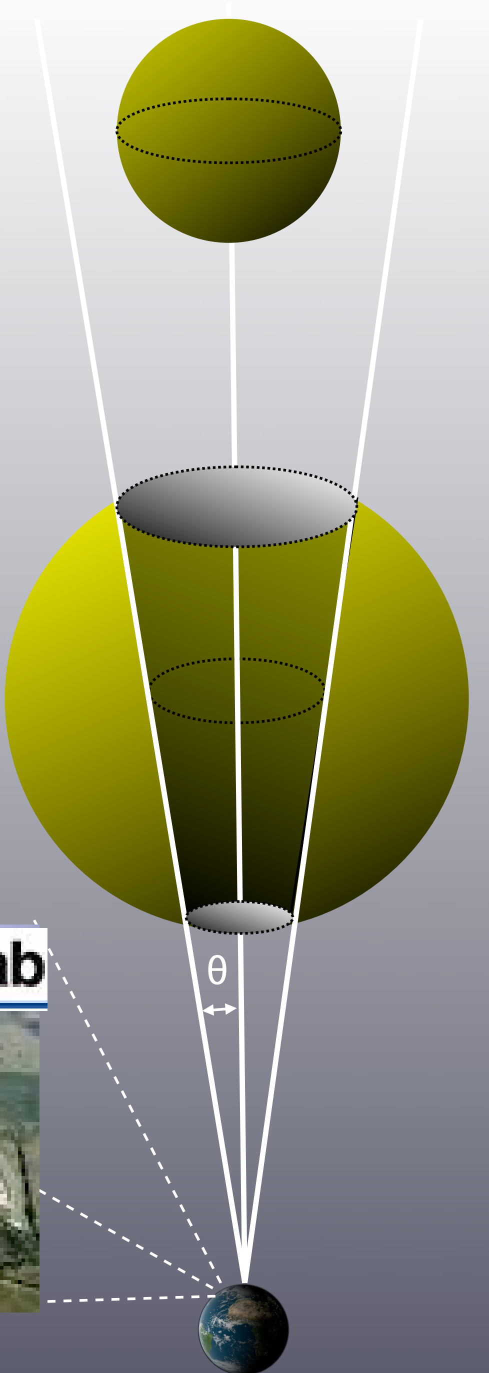
Structure formation

Particle Physics

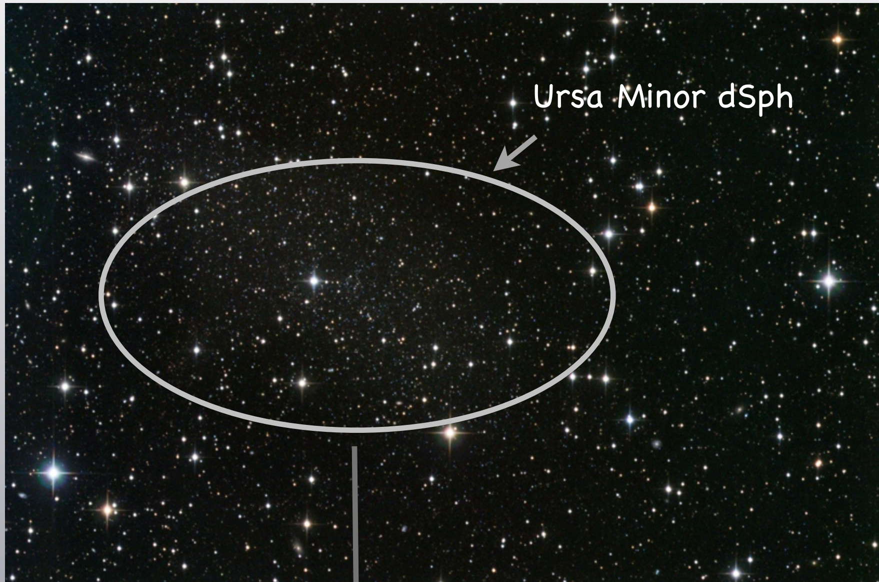
Gamma-ray detector

Number of photons

$$N_s = \frac{1}{4\pi} f[\langle \sigma v \rangle, M_\chi]\, g[\rho(r)]\, A_{eff} \tau_{exp}$$



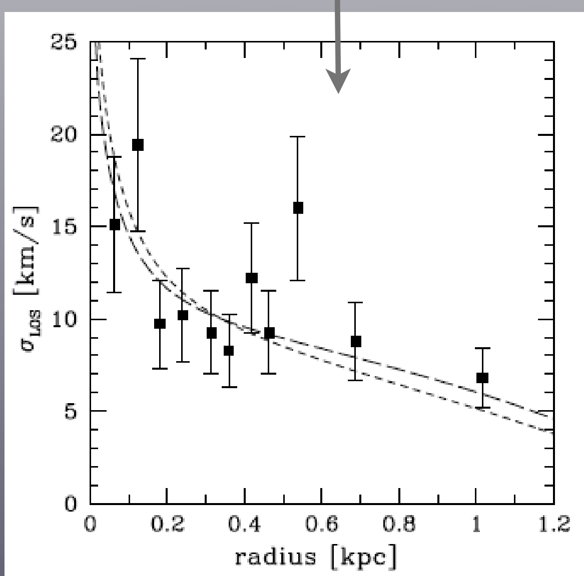
I: Dwarf satellites of the local group

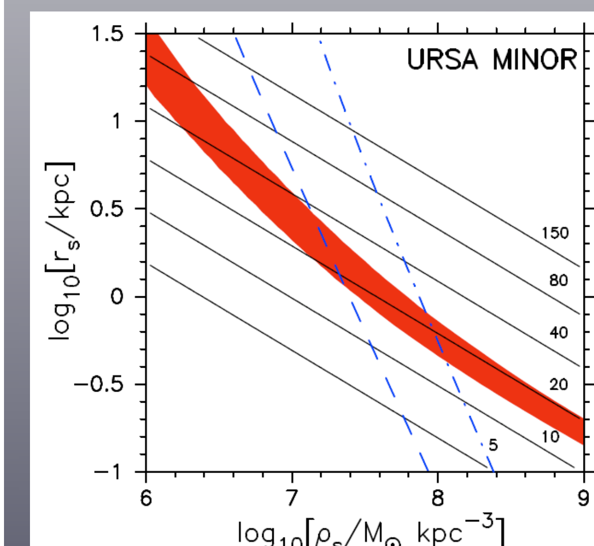


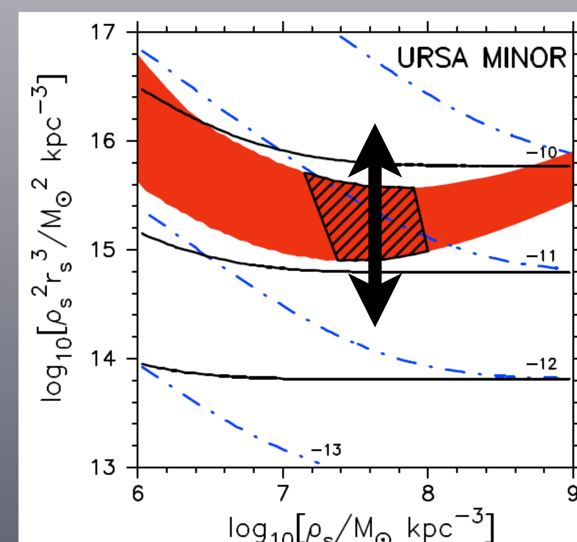
They are ideal laboratories for studying the distribution of dark matter:

- High mass-to-light ratios
- Astrophysical backgrounds relatively not present
- High galactic latitude thus better prospects for detection

Baltz et al., Phys. Rev. D 61, 023514 (2000), Stoehr et al., MNRAS 345, 1313 (2003), Tyler, Phys. Rev. D 66, 023509 (2002), Evans, Ferrer & Sarkar, Phys. Rev. D 69, 123501 (2004), Bergstrom & Hooper, Phys. Rev. D 73, 063510, Strigari, Koushiappas, Bullock & Kaplinghat, Phys. Rev. D 75, 083506 (2007)







Strigari, Koushiappas, Bullock & Kaplinghat, Phys. Rev. D 75, 083506 (2007)

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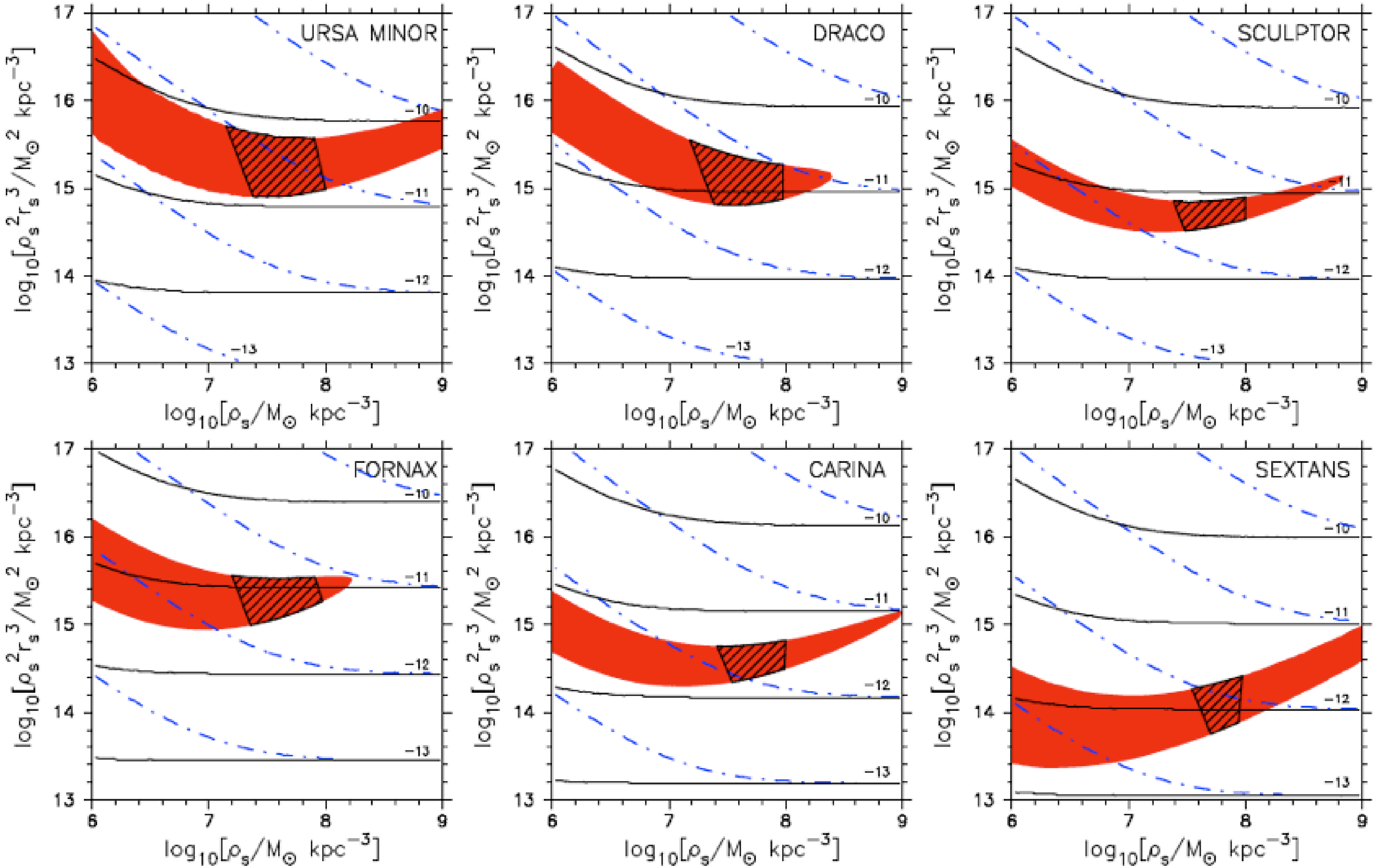
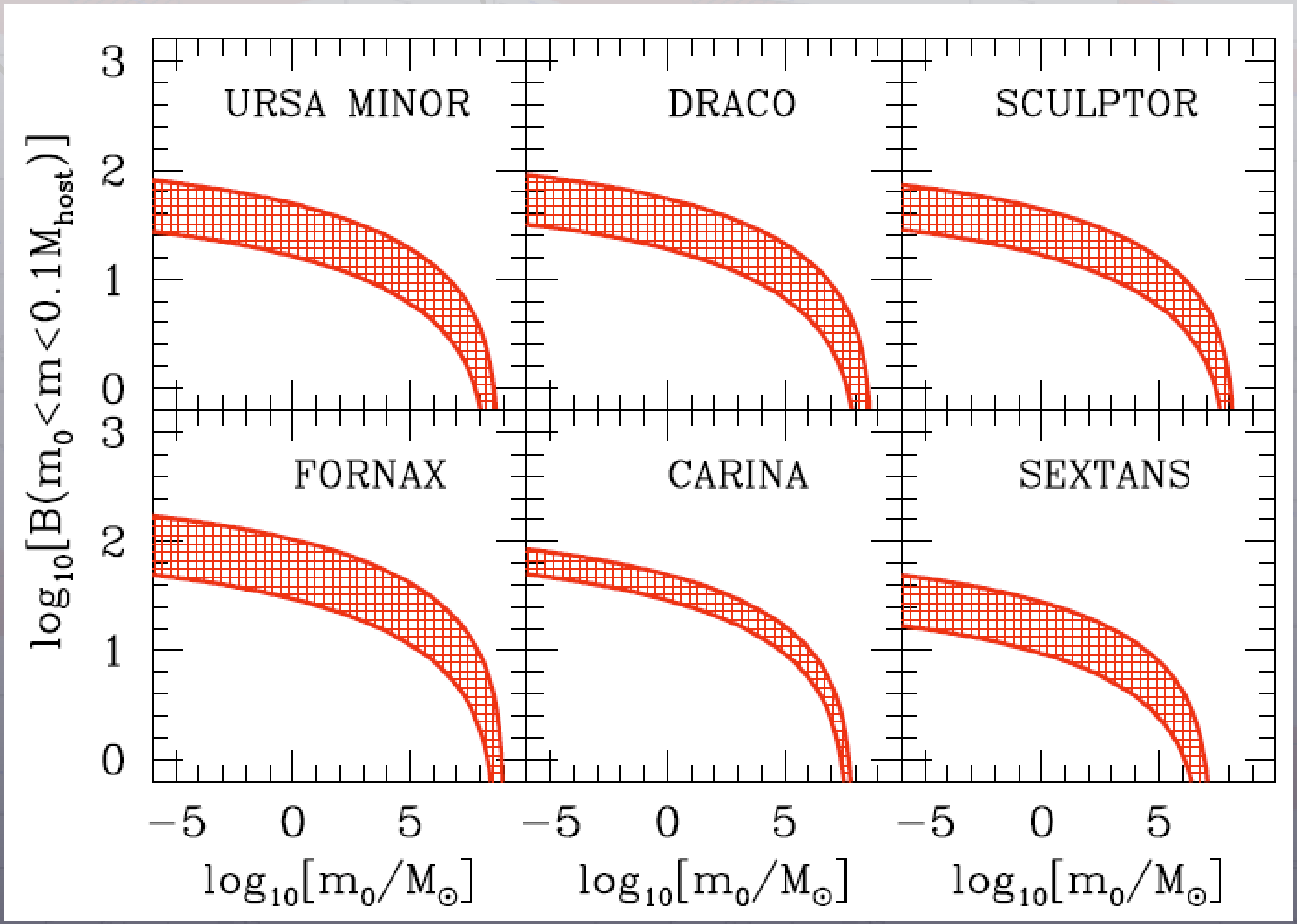


I: Dwarf satellites of the local group

Strigari, Koushiappas, Bullock & Kaplinghat, Phys. Rev. D 75, 083506 (2007)

Substructure can enhance the prospects for detection by increasing the flux by up-to a factor of ~ 100



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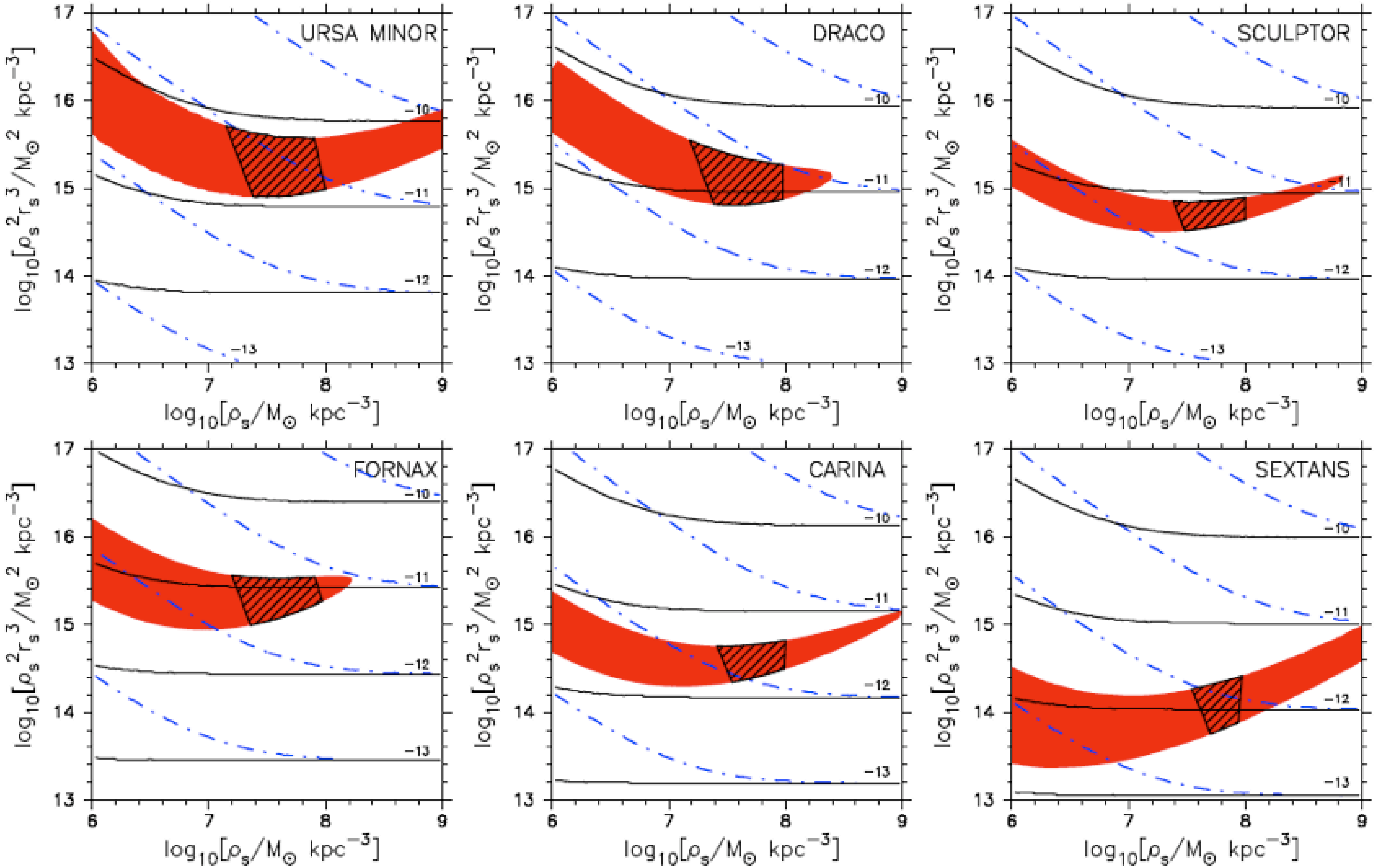


I: Dwarf satellites of the local group

Strigari, Koushiappas, Bullock & Kaplinghat, Phys. Rev. D 75, 083506 (2007)

dSph	within 0.1 deg	within 2 deg
Draco	0.1–3.2	0.1–2.8
Sculptor	0.07–1.6	0.05–0.7
Fornax	0.07–2.2	0.05–1.1
Carina	0.04–1.0	0.02–0.4
Sextans	0.02–0.5	0.007–0.02

TABLE II: The predicted flux ratios for dSphs relative to the γ-ray flux from Ursa Minor in CDM theory.

Flux ratios between the 6 dwarf spheroidals are not arbitrary!

We are able to direct gamma-ray experiments to the proper detection scheme

dSph	Radius of the area of 90% flux emission in degrees
Ursa Minor	0.4–2.7
Draco	0.3–1.8
Sculptor	0.2–0.9
Fornax	0.2–1.0
Carina	0.1–0.6
Sextans	0.1–0.4

TABLE III: The CDM-predicted angular extent in degrees where at least 90% of the γ-ray flux should originate for each dSph.

II: Dark substructure in the Milky Way

Calcaneo-Roldan & Moore, Phys. Rev. D 62, 123005 (2002), Tasitsiomi & Olinto, Phys. Rev. D 66, 083006 (2002), Koushiappas, Zentner & Walker, Phys. Rev. D 69, 043501 (2004) Baltz, Taylor & Wai, astro-ph/0610731,

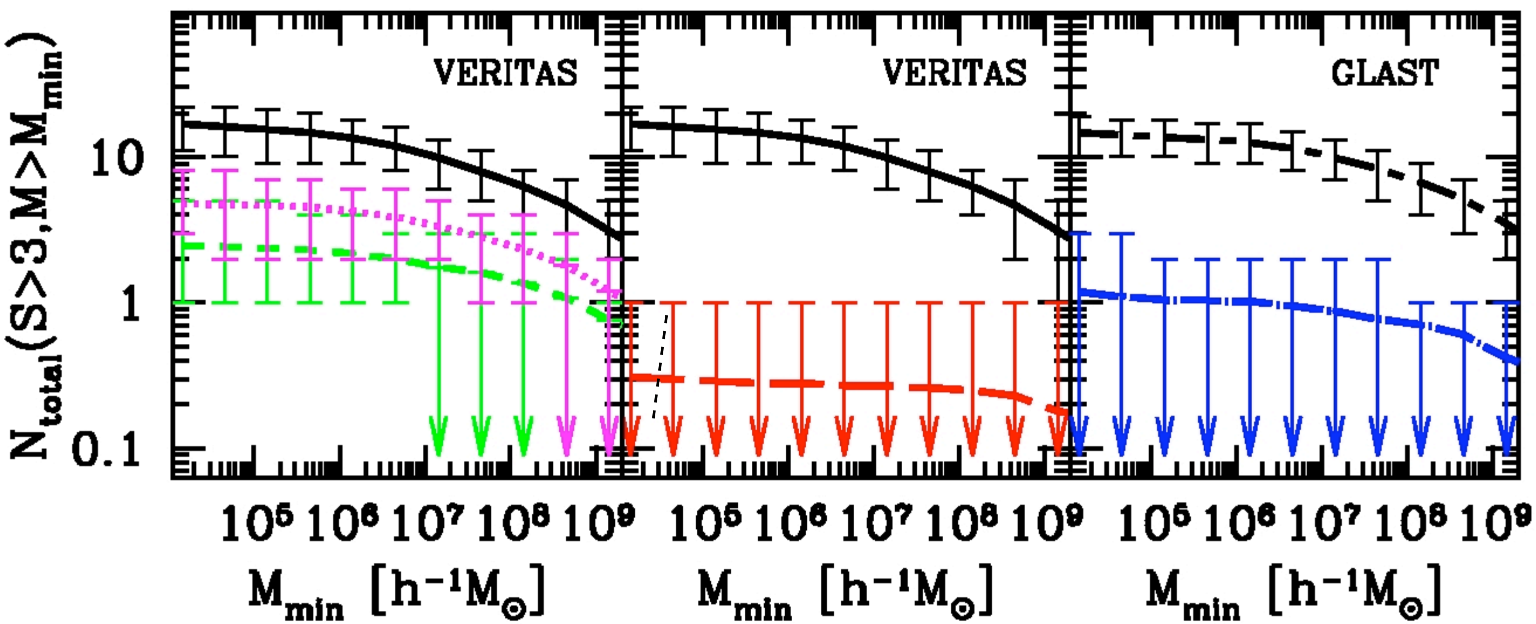
100 merger tree realizations of the Milky Way merger history

Monitor the interplay between:

- Accretion redshift
- Orbital evolution
- Tidal disruption

] ← **Set by cosmology**

Koushiappas, Zentner & Walker, Phys. Rev. D 69, 043501 (2004)



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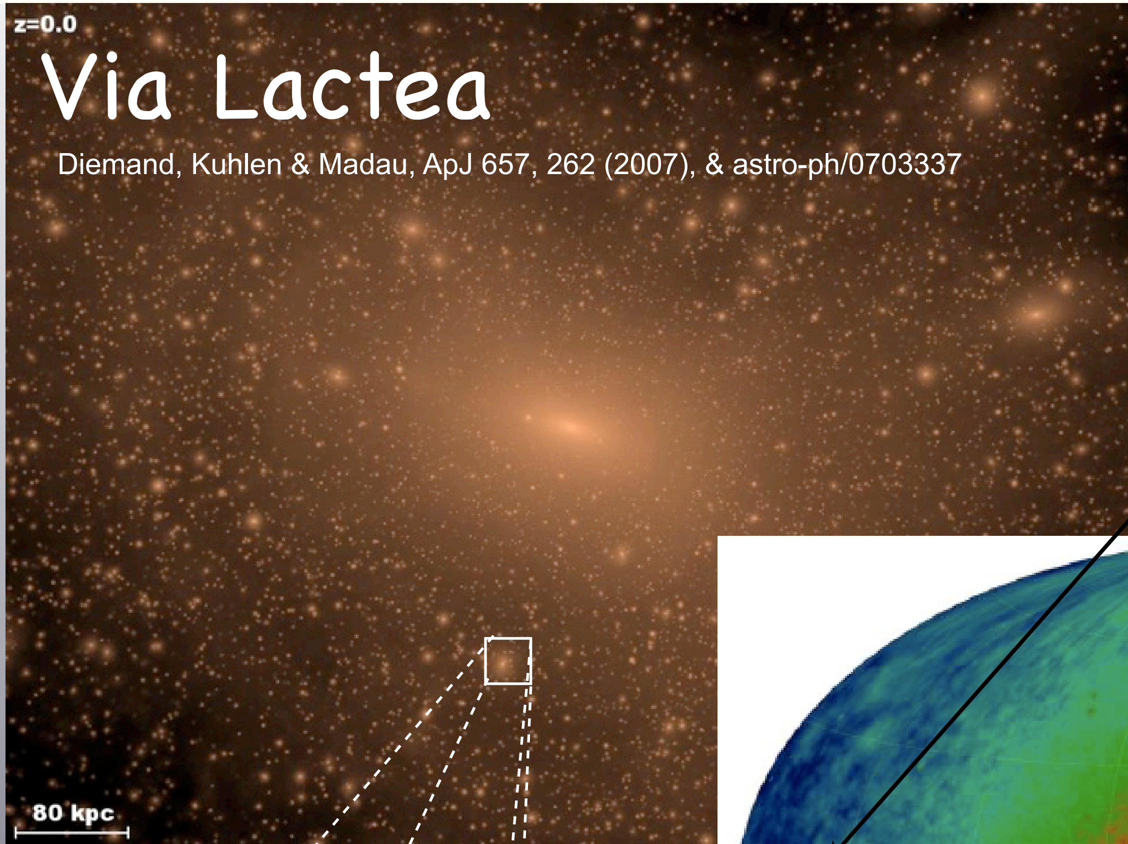
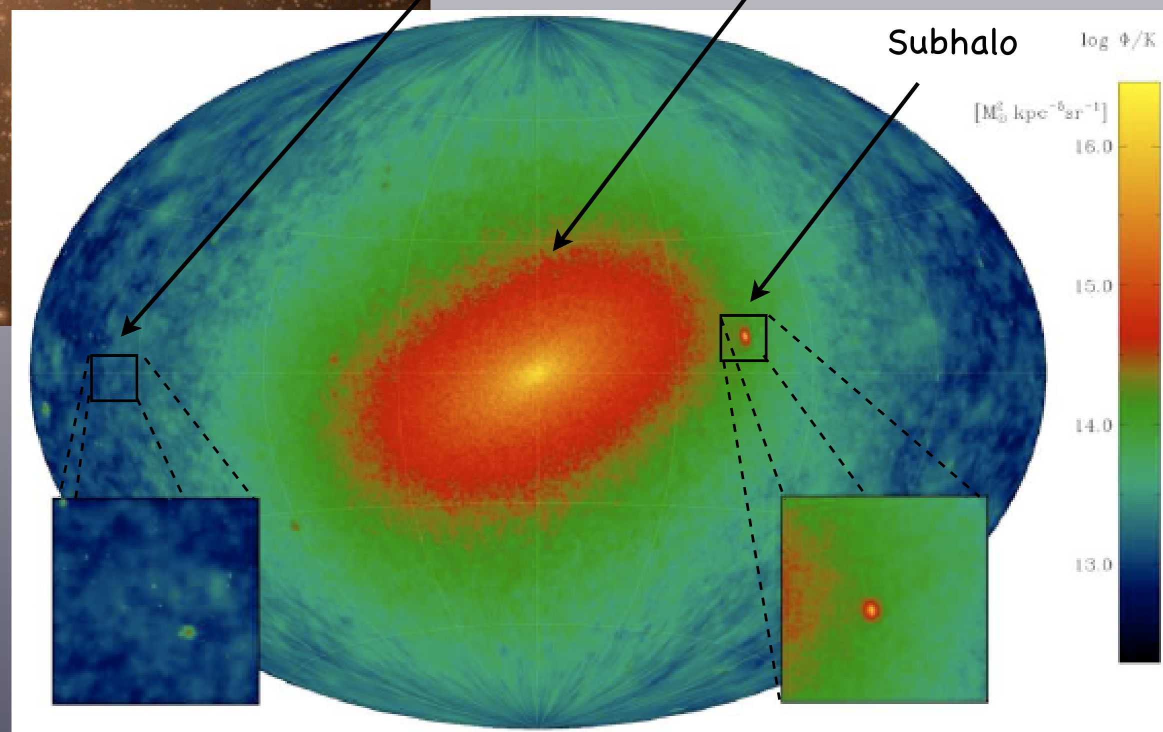


Diemand, Kuhlen & Madau ApJ 657, 262 (2007), Diemand, Kuhlen & Madau, astro-ph/0703337, see also past work, e.g. Calcaneo-Roldan & Moore, Phys. Rev. D 62, 123005 (2002), Stoehr et al., MNRAS 345, 1313 (2003)

Fluctuations in the dark matter distribution (Ando & Komatsu PRD 73, 023521)

The dark matter halo is not spherical (Hooper & Serpico, astro-ph/0702328)

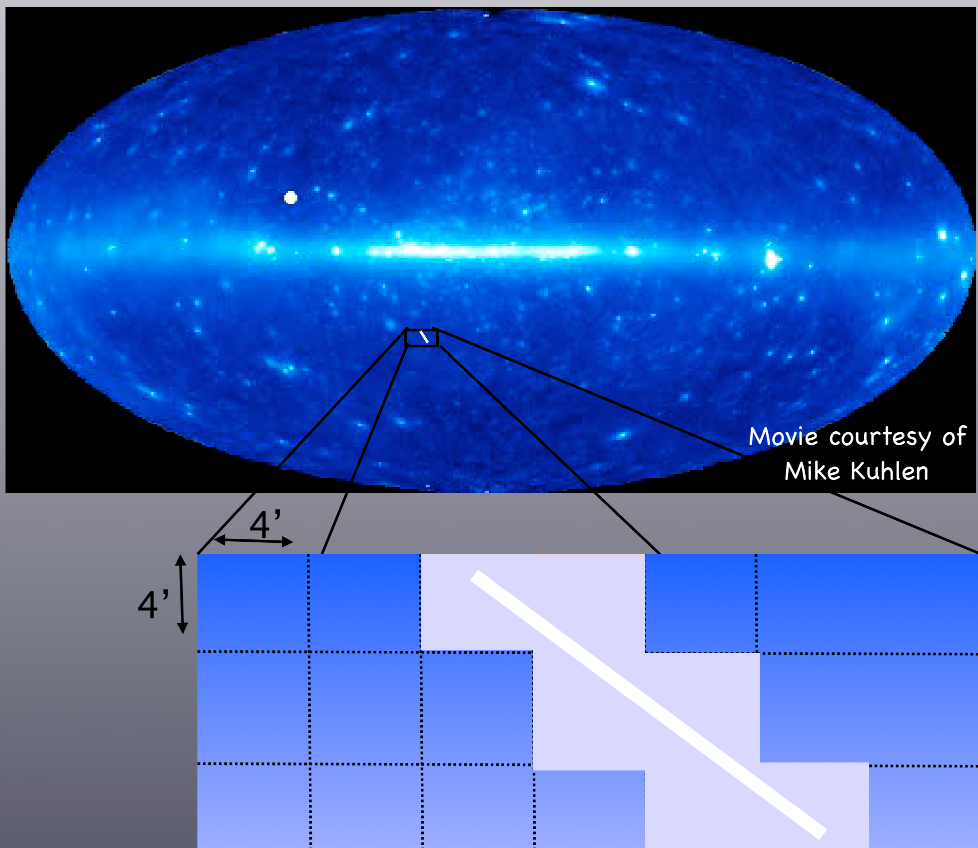


III: Microhalos present in the solar neighborhood

1. A possible detection can provide information about the particle physics properties of the dark matter particle.

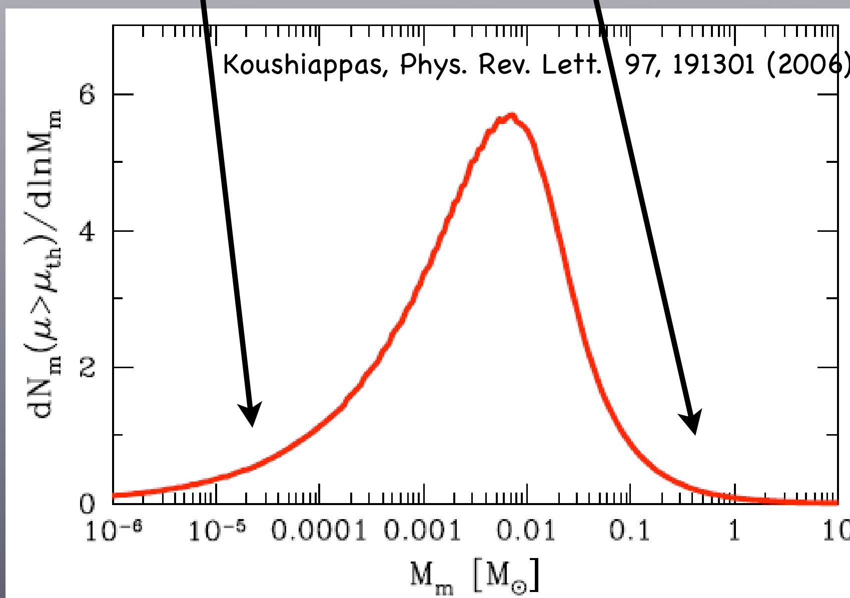
2. A measured abundance in the Milky Way halo contains information on the hierarchical assembly of dark matter halos at very early times (survival/disruption), a task unattainable by any other method.

See Schmid et al., Phys Rev. D 59, 043517 (1999), Hofmann et al., Phys. Rev. D 64, 083507 (2001), Chen et al., Phys Rev. D 64, 021302 (2001), Berezinsky et al, Phys. Rev. D 68, 103003 (2003), Green, Hoffmann,and Schwarz, MNRAS 353, L23 (2004),Green et al., JCAP 08, 003 (2005), Loeb & Zaldarriaga , Phys. Rev. D, 71, 103520 (2005) Profumo et al., Phys. Rev. Lett., 97, 031301 (2006), Koushiappas, Phys. Rev. Lett. 97, 191301 (2006)

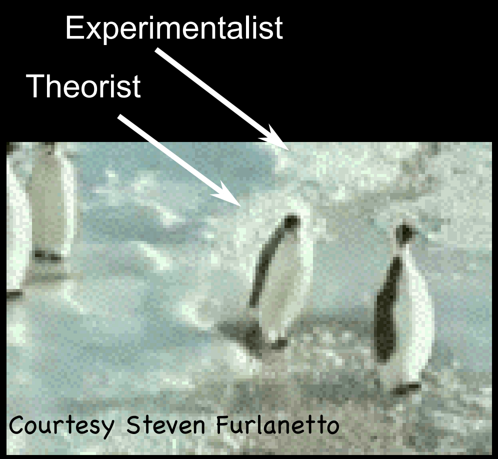


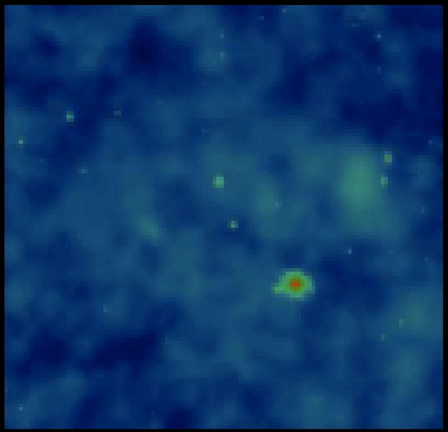
Limited by the **abundance** of detectable microhalos

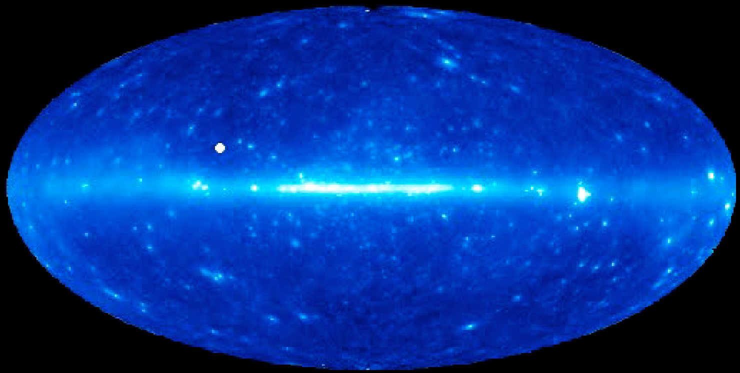
Limited by the amount of **proper motion** exhibited



Summary







- Microhalos that survive in the Milky Way halo could be observed via their proper motion signal measured in γ-rays - an extremely clean signature of dark matter - No other known object can mimic this potentially detectable phenomenon!
- Dwarf spheroidals of the local group are ideal laboratories for the detection of gamma-rays from dark matter annihilation
- It may be possible to detect the dark Milky Way substructure with future gamma-ray instruments