

Title: The Search for WIMP Dark Matter

Date: Feb 17, 2011 11:30 AM

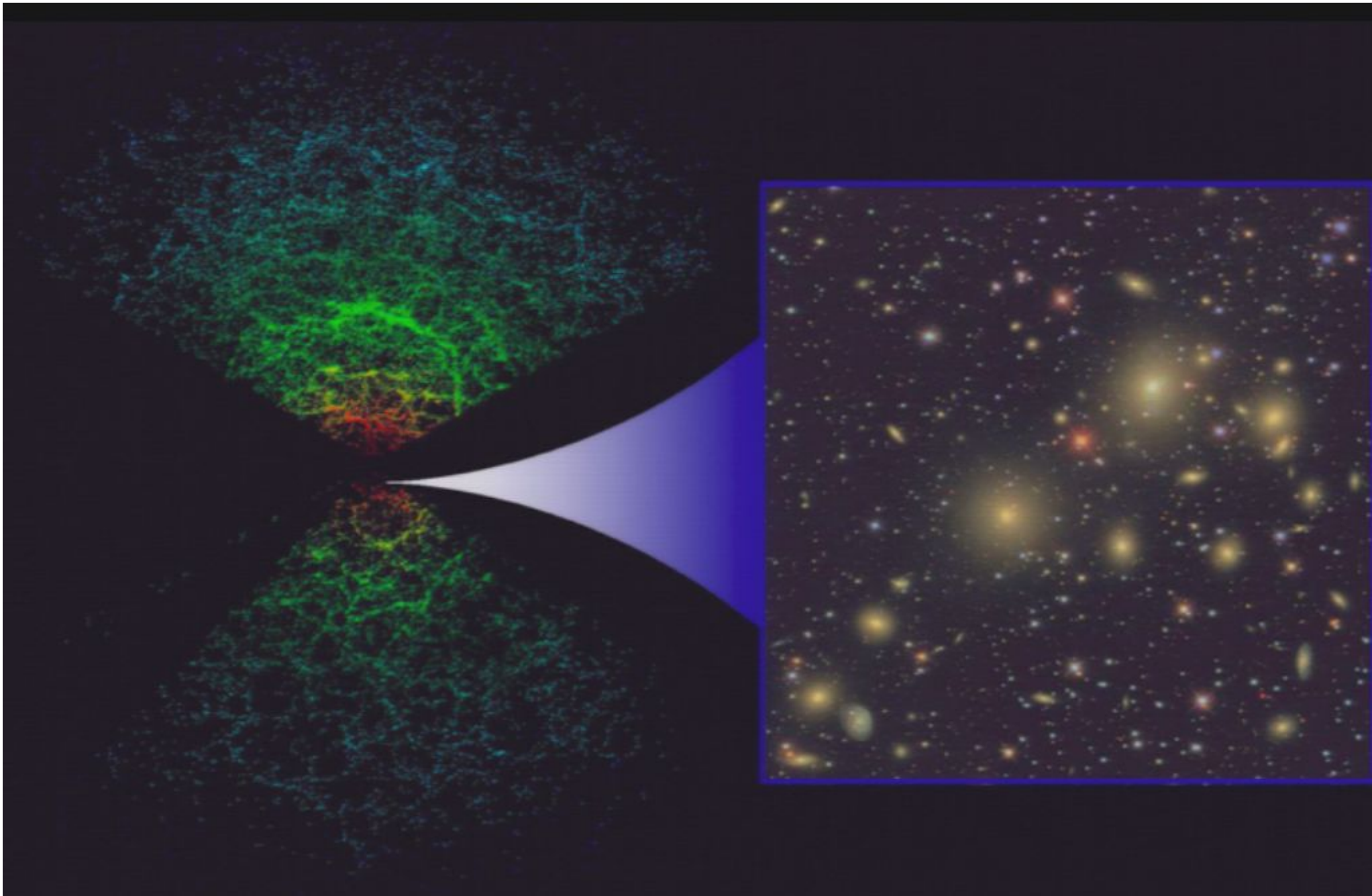
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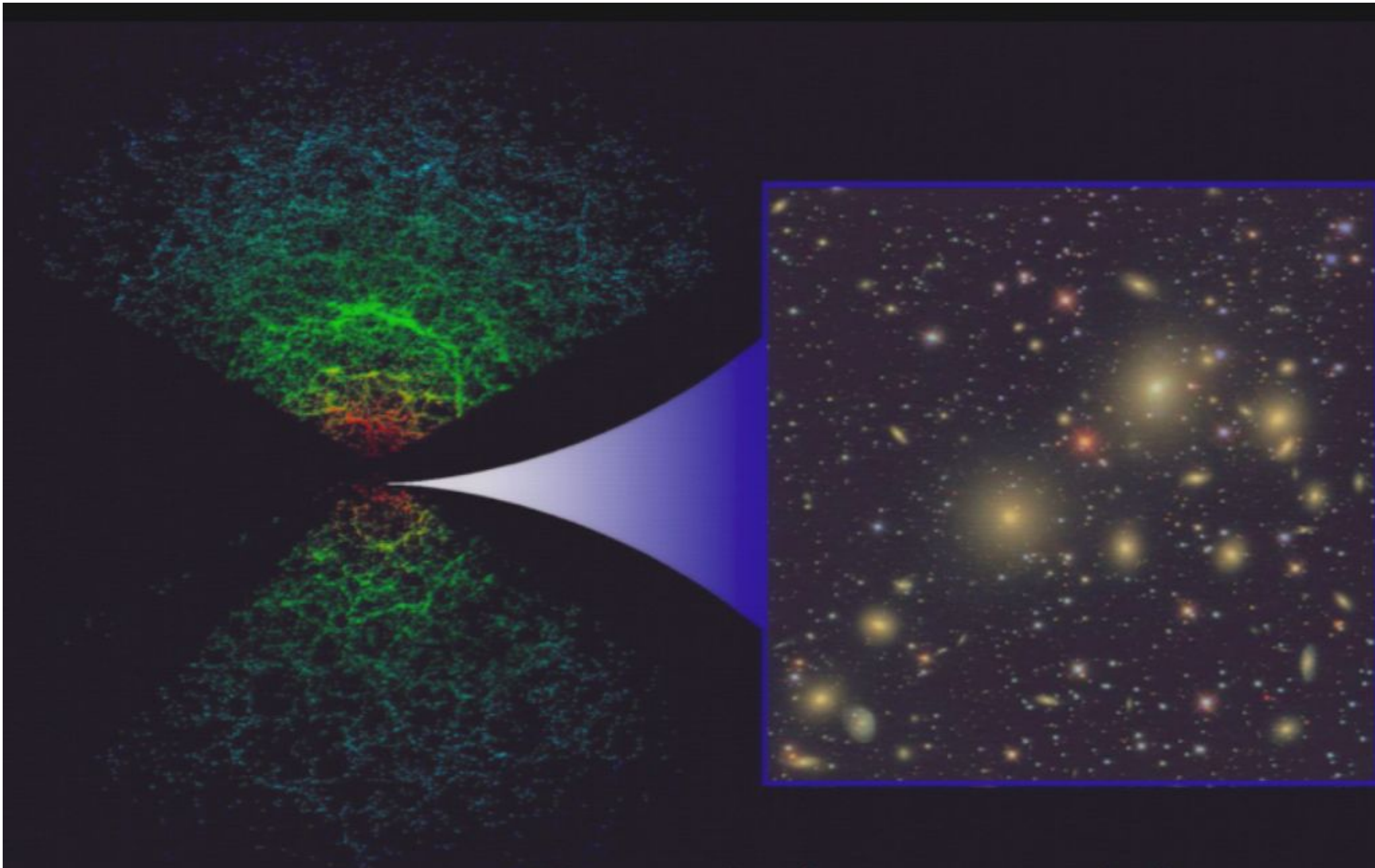
Abstract: For nearly the past century, the nature of dark matter in the Universe has puzzled astronomers and physicists. During the next decade, experiments will determine if a substantial amount of the dark matter is in the form of non-baryonic, Weakly-Interacting Massive Particles (WIMPs). In this talk I will discuss and interpret modern limits on WIMP dark matter from a variety of complementary methods. I will show that we are just now obtaining sensitivity to probe the parameter space of cosmologically-predicted WIMPs created during the earliest epoch in the Universe. I will discuss the science to extract from a positive signal in different experiments, and the prospects for an era of dark matter astrophysics.

# The Search for WIMP Dark Matter



Louis E. Strigari  
KIPAC-Stanford  
Cosmology & Gravitation Seminar  
Perimeter Institute

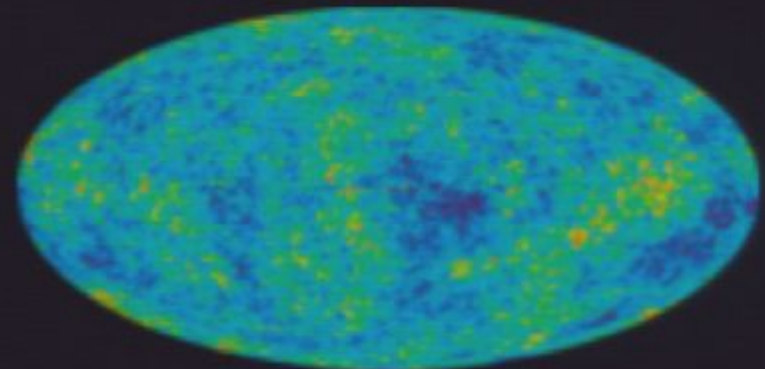




Observed galaxies trace dark matter distribution in the Universe

## LSS + CMB + SNIa + Clusters indicate:

- ▶ Scale-invariant and adiabatic spectrum of initial density fluctuations
- ▶ Universe is dominated by dark energy and **cold** dark matter

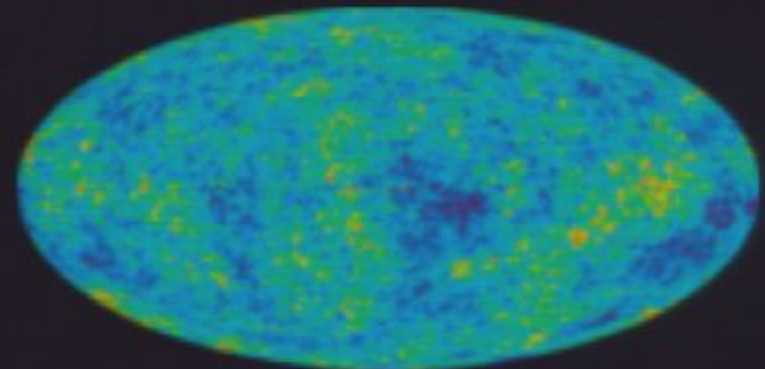


dark energy

dark matter

LSS + CMB + SNIa +  
Clusters indicate:

- ▶ Scale-invariant and adiabatic spectrum of initial density fluctuations
- ▶ Universe is dominated by dark energy and **cold** dark matter



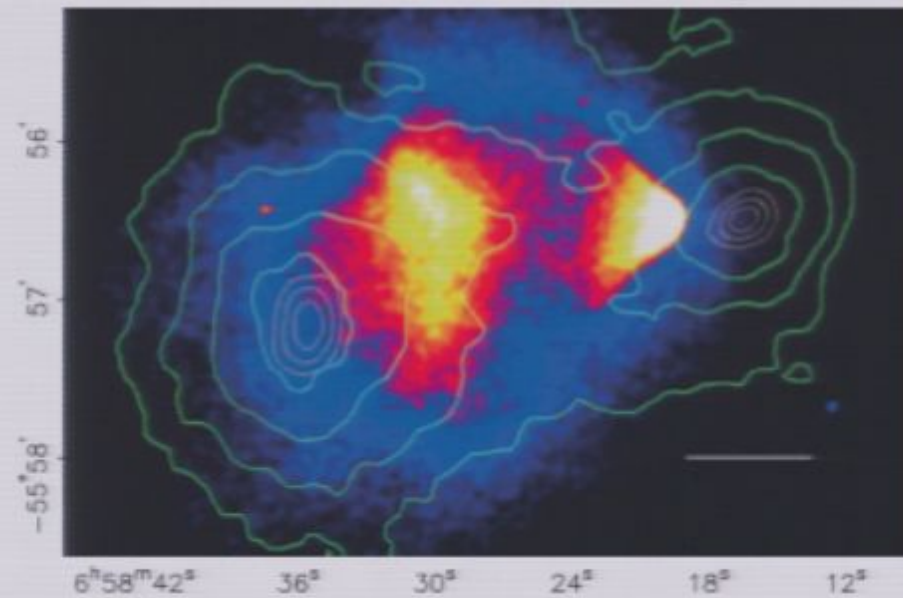
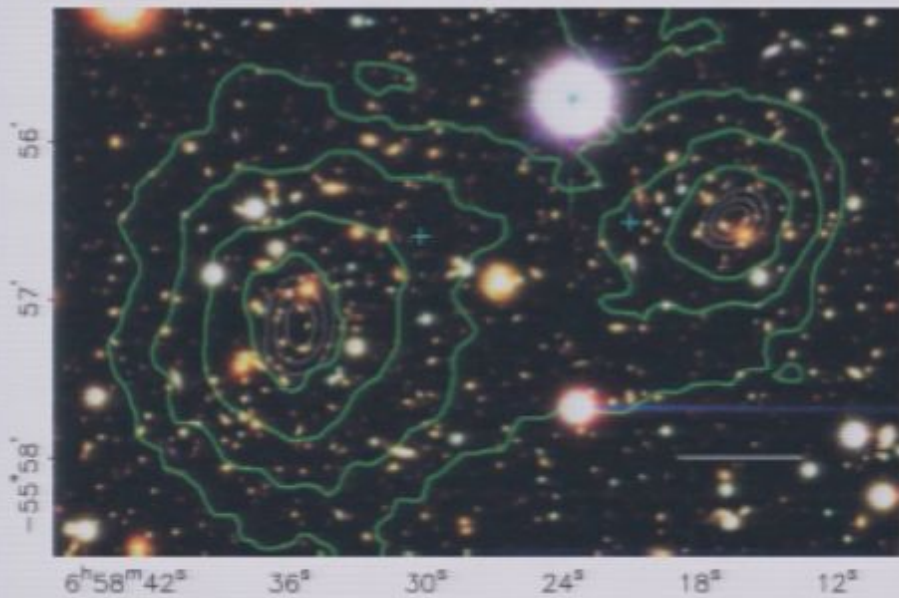
dark energy

dark matter

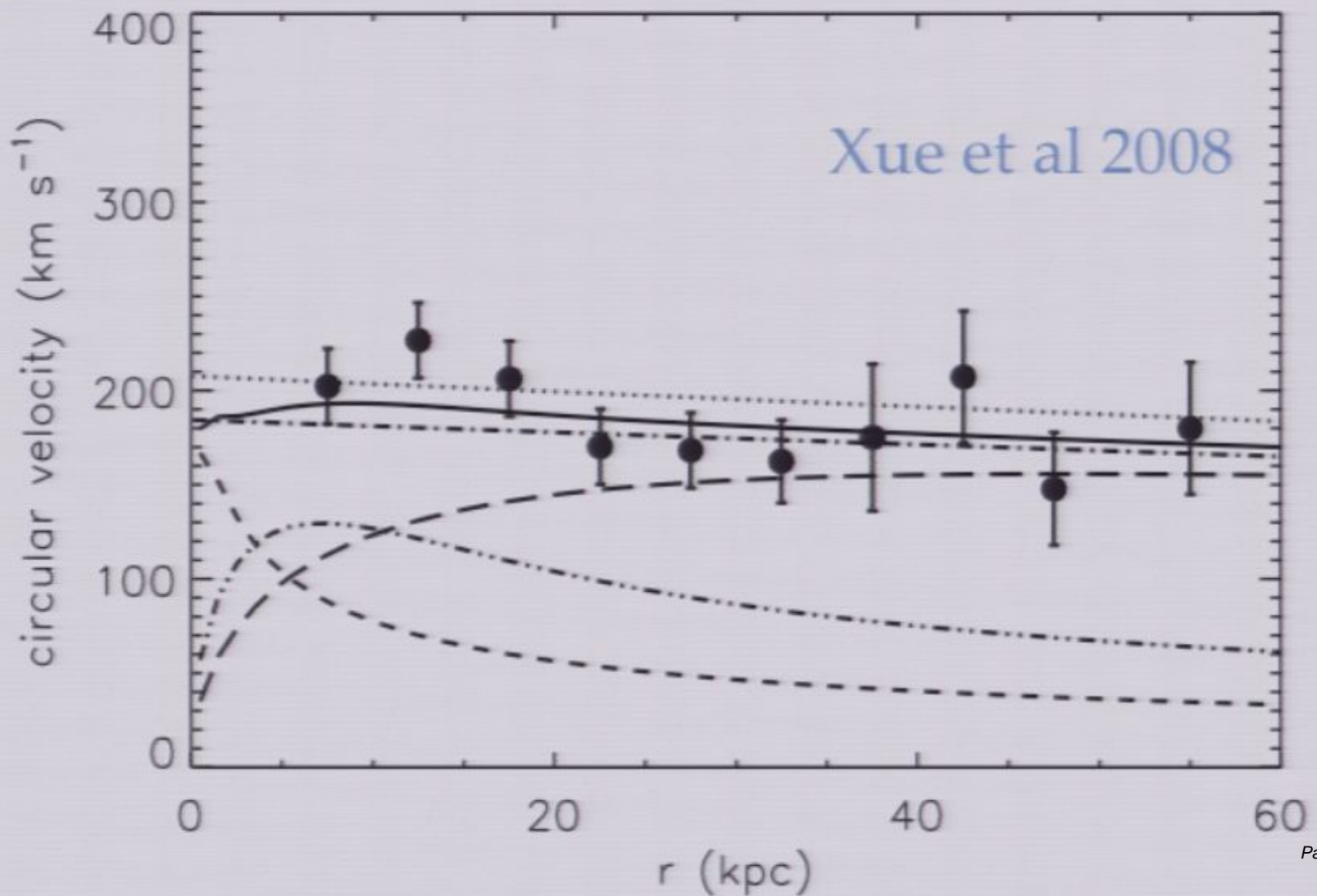
# A DIRECT EMPIRICAL PROOF OF THE EXISTENCE OF DARK MATTER<sup>1</sup>

DOUGLAS CLOWE,<sup>2</sup> MARUŠA BRADAČ,<sup>3</sup> ANTHONY H. GONZALEZ,<sup>4</sup> MAXIM MARKEVITCH,<sup>5,6</sup>  
SCOTT W. RANDALL,<sup>5</sup> CHRISTINE JONES,<sup>5</sup> AND DENNIS ZARITSKY<sup>2</sup>

*Received 2006 June 6; accepted 2006 August 3; published 2006 August 30*

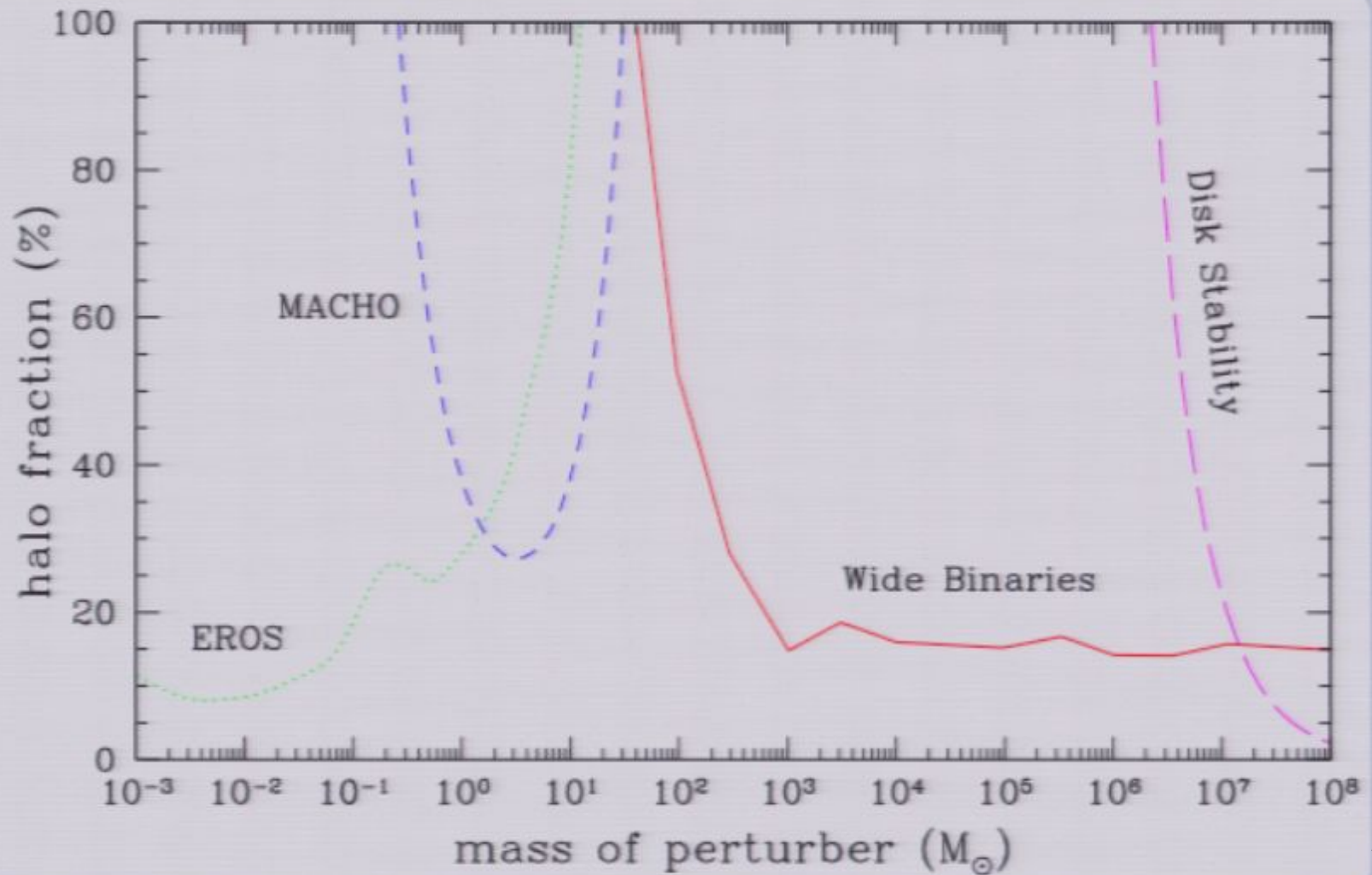


# Dark Matter In the Milky Way

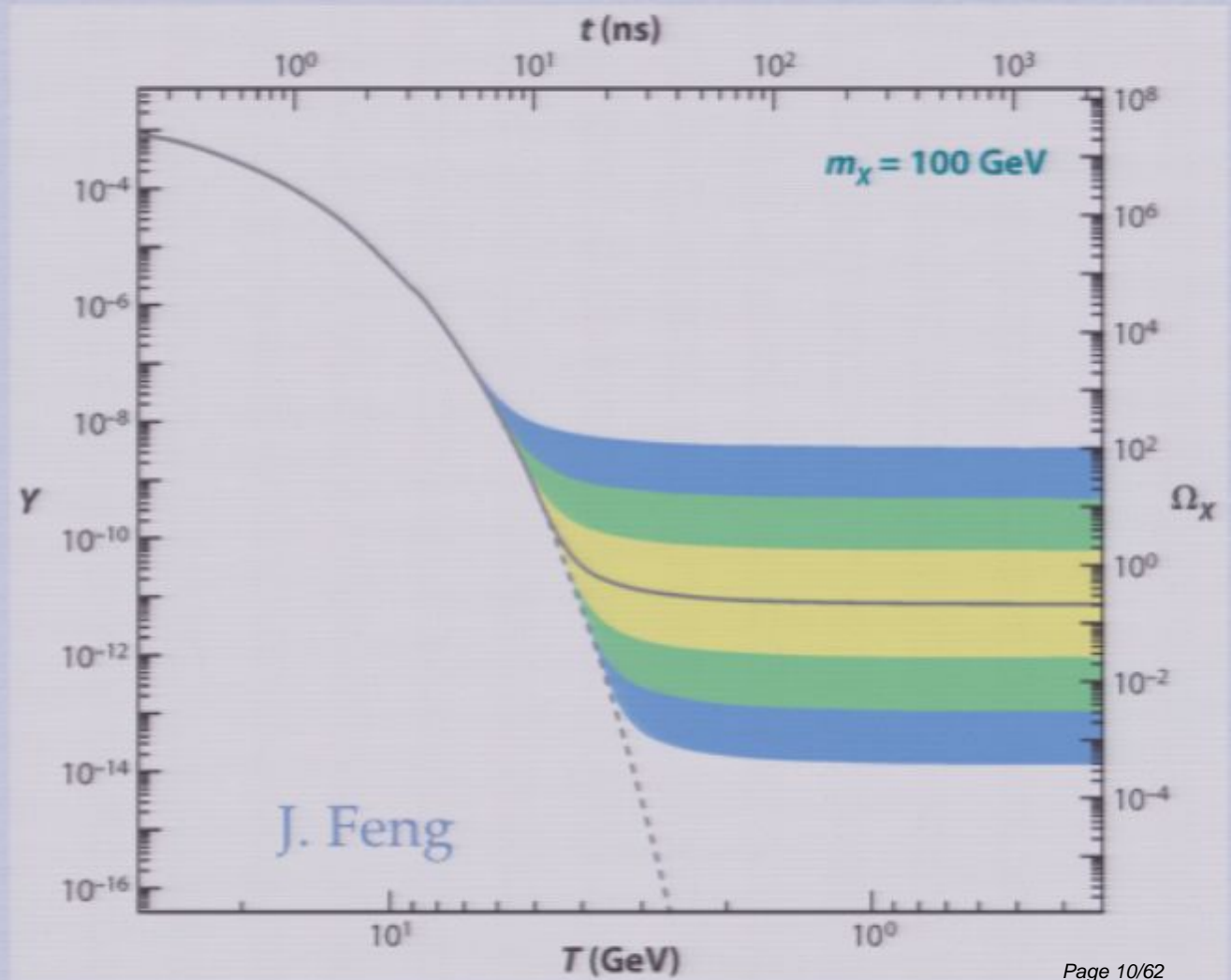
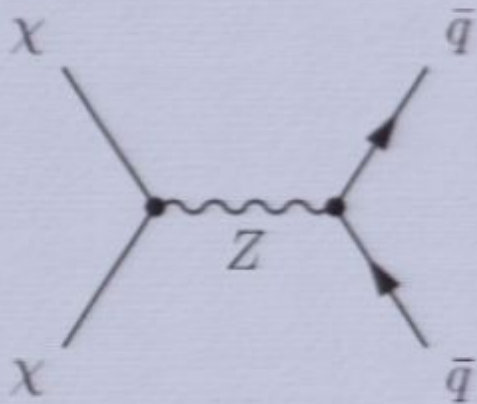




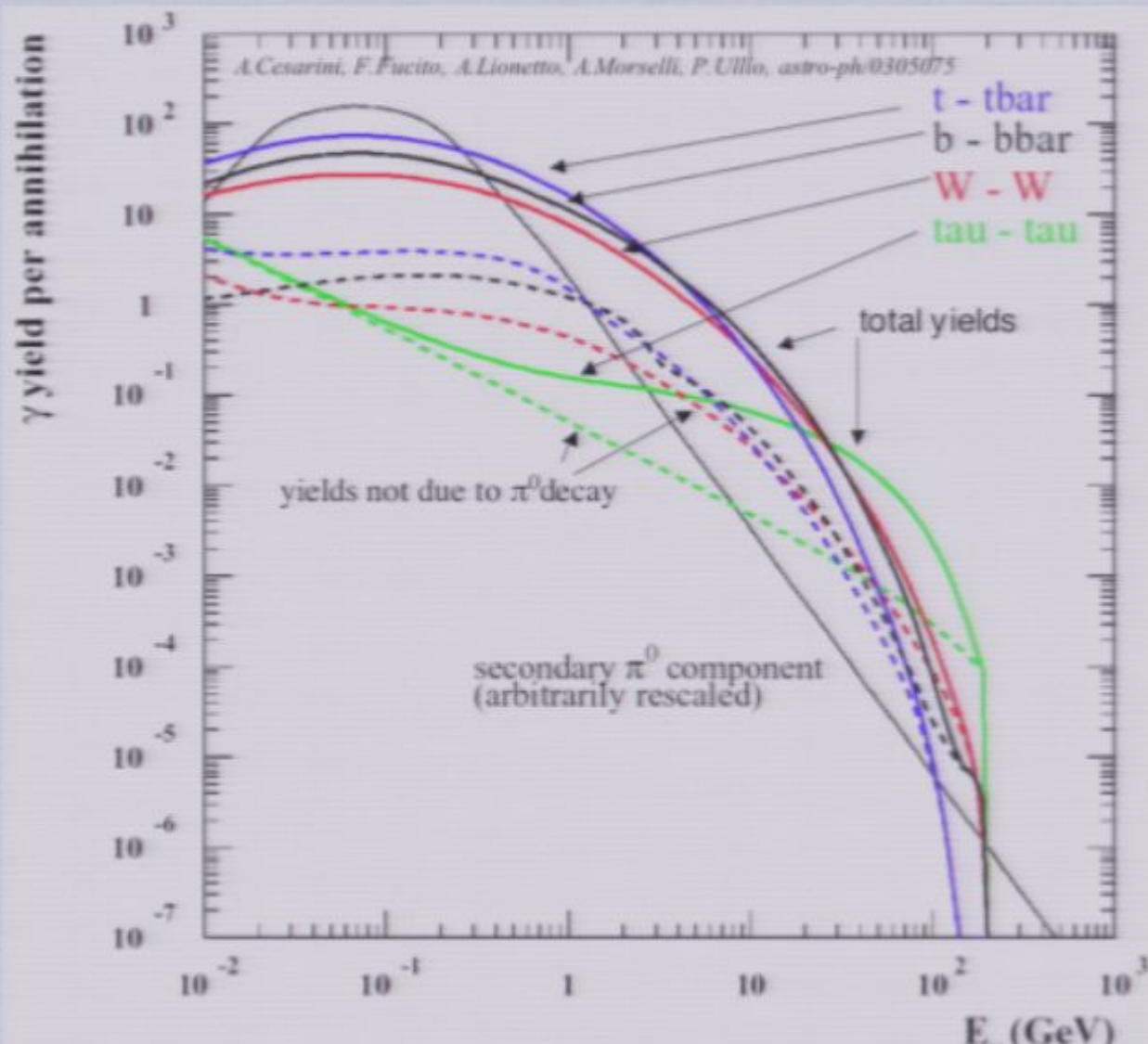
# Can dark matter be faint stars or planets?



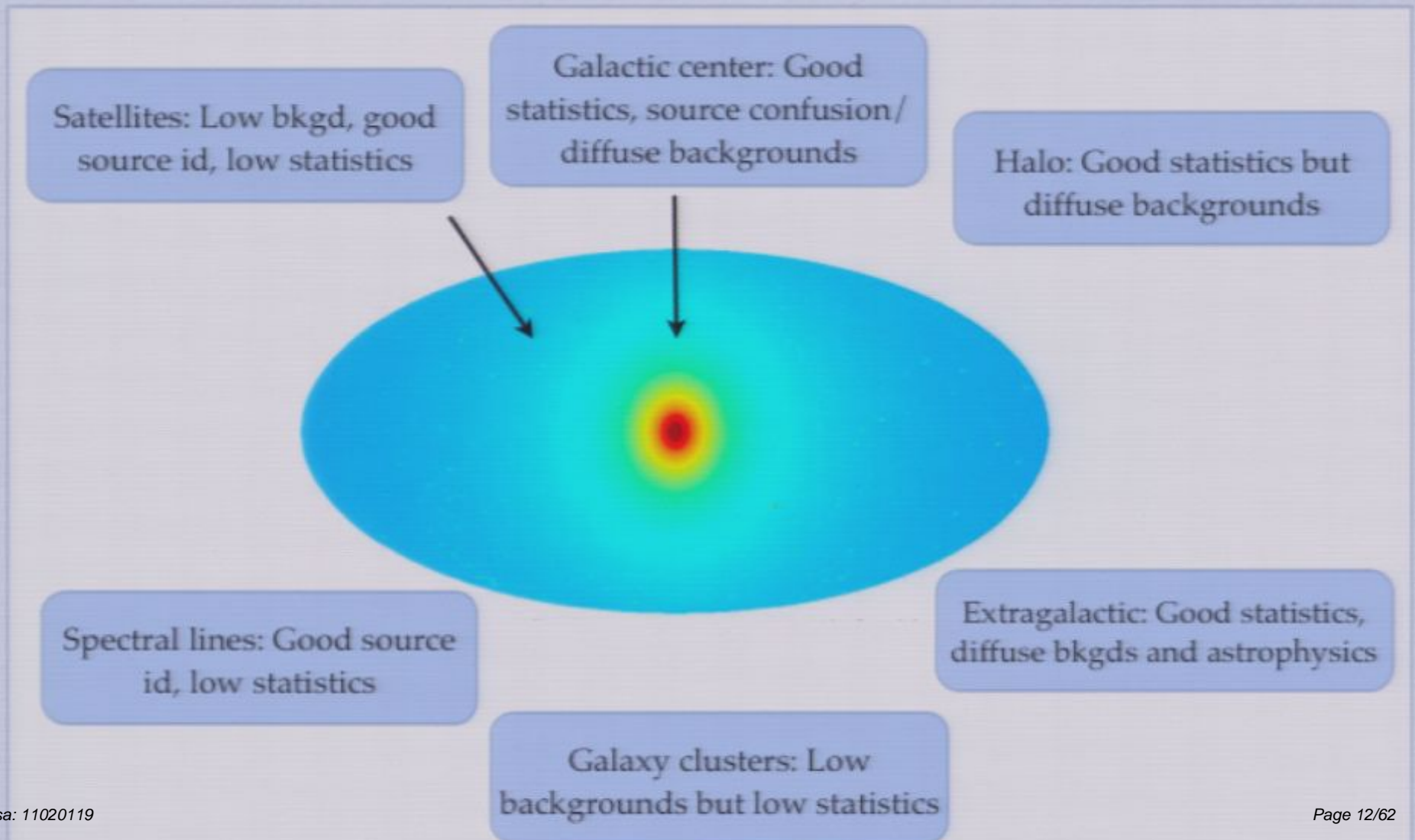
# Particle Dark Matter: WIMPs

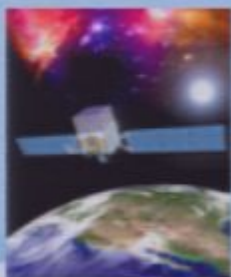


# WIMP annihilation

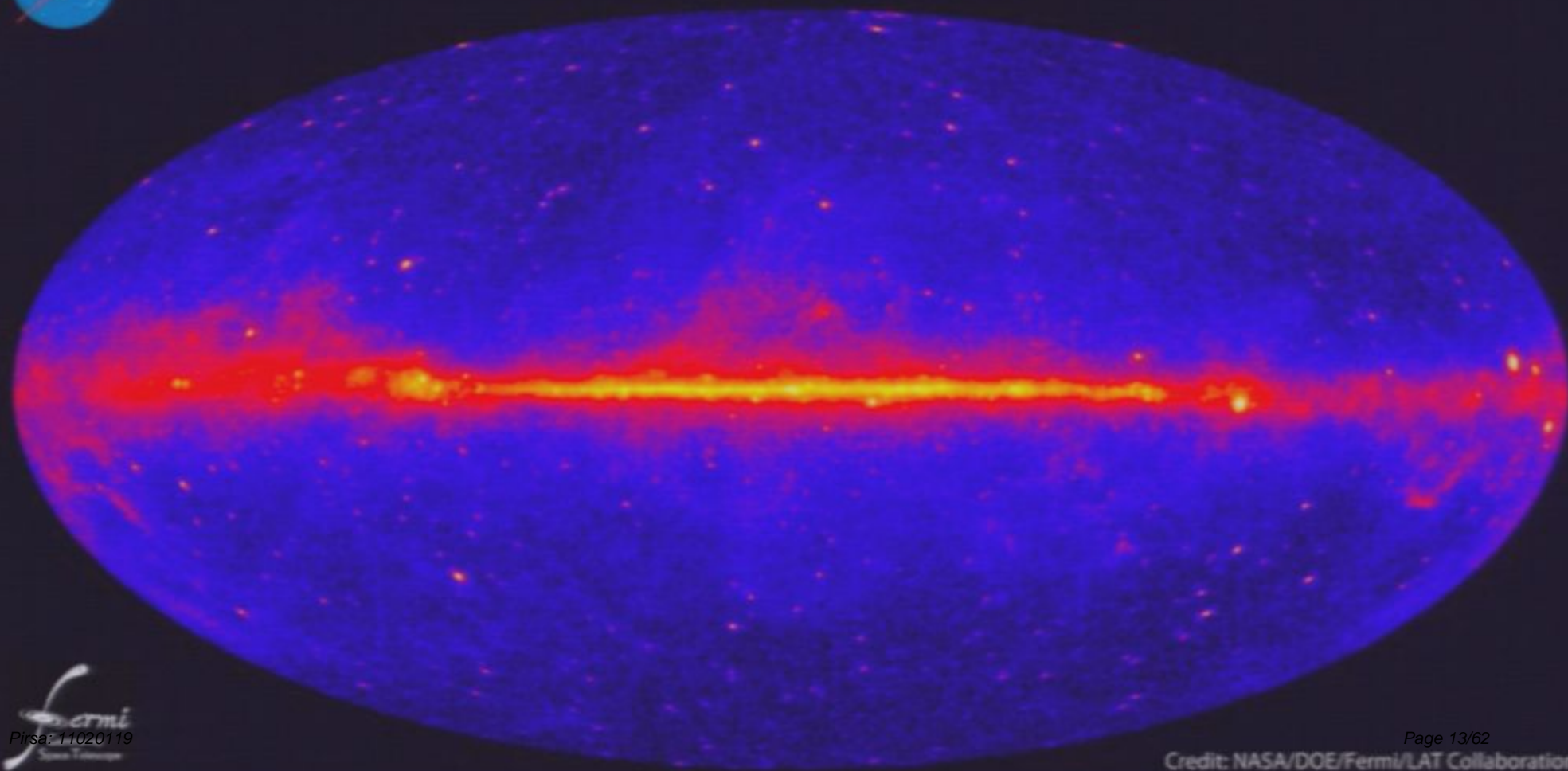


# WIMP annihilation: Search Strategies





# Fermi two-year all-sky map



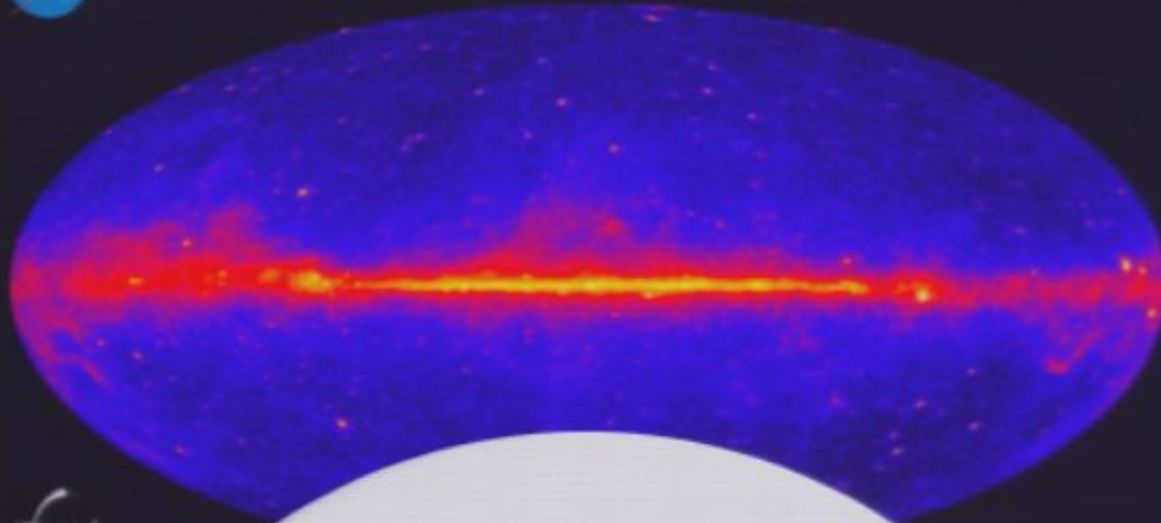
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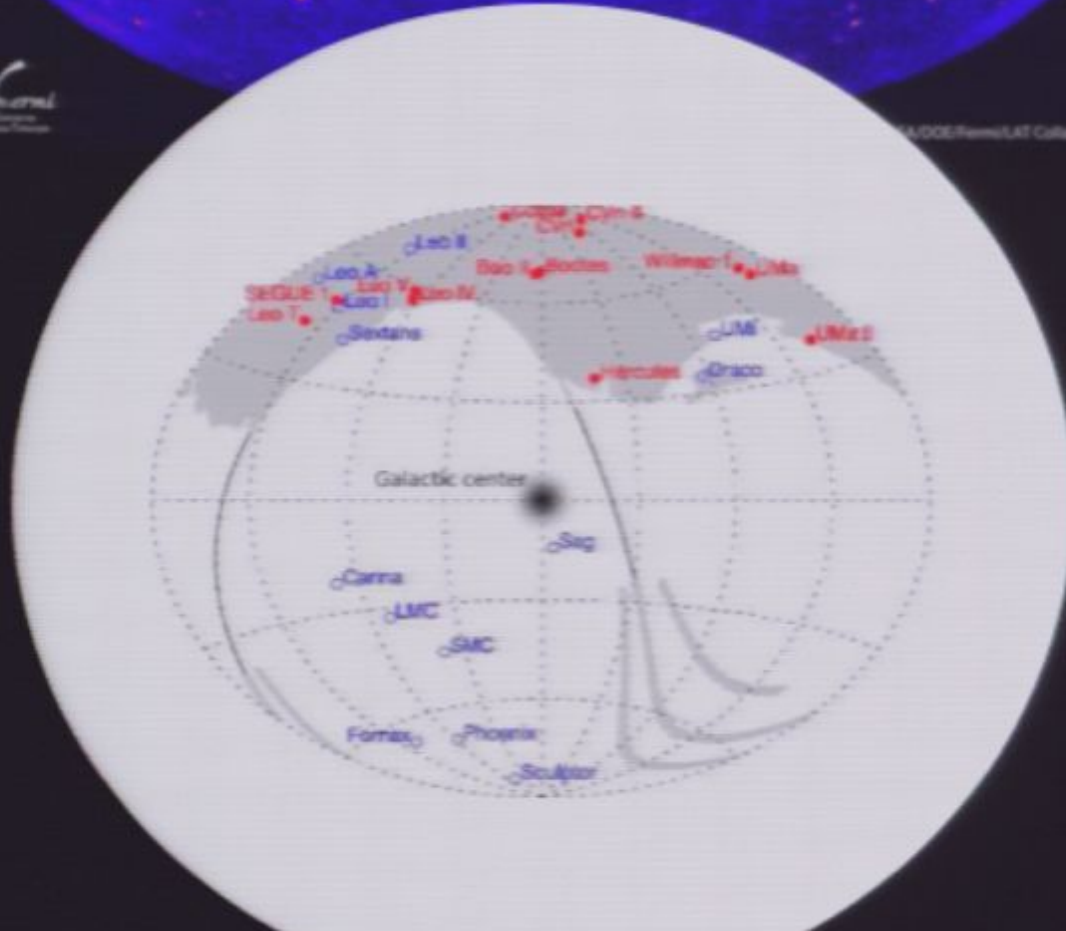
Credit: NASA/DOE/Fermi/LAT Collaboration



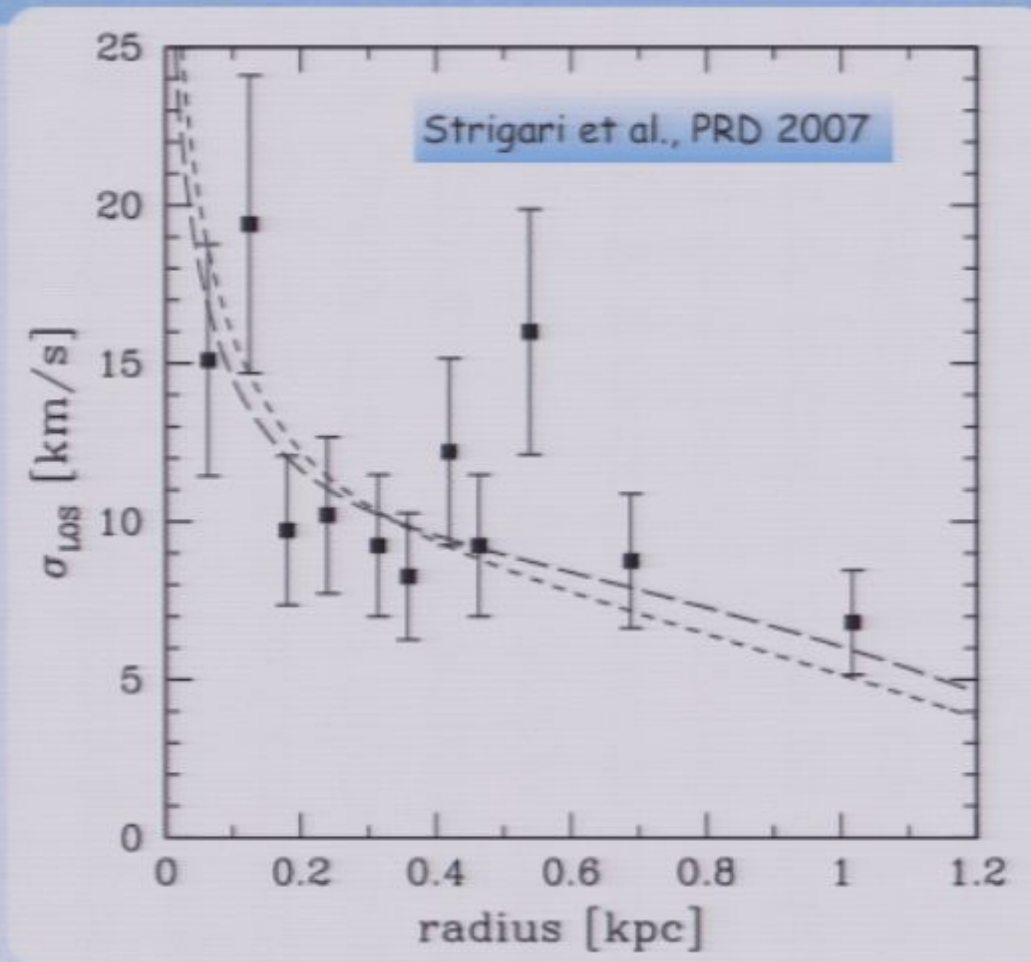
# Fermi two-year all-sky map



LAOEE/Fermi/LAT Collaboration

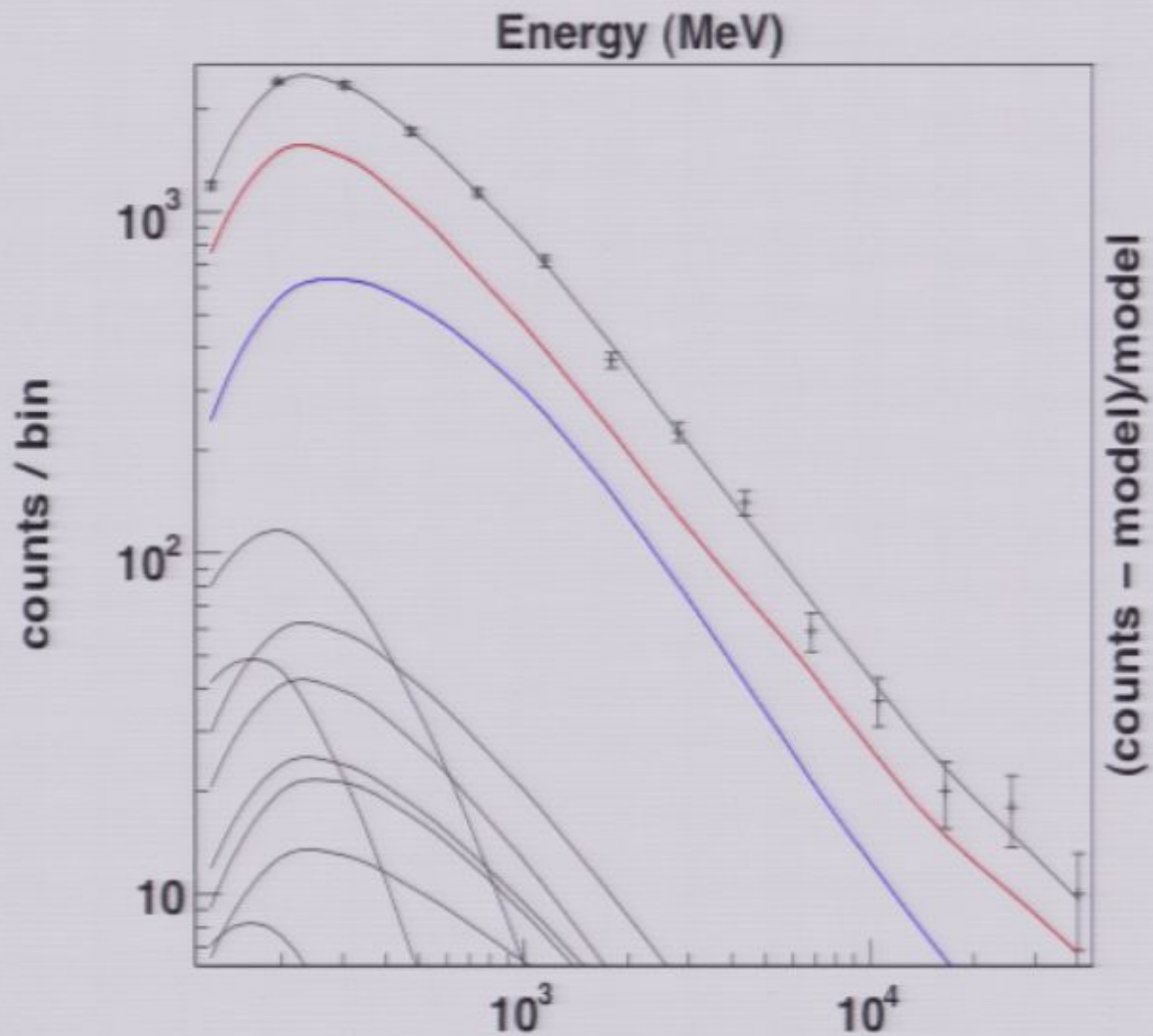


# WIMPs in nearby galaxies



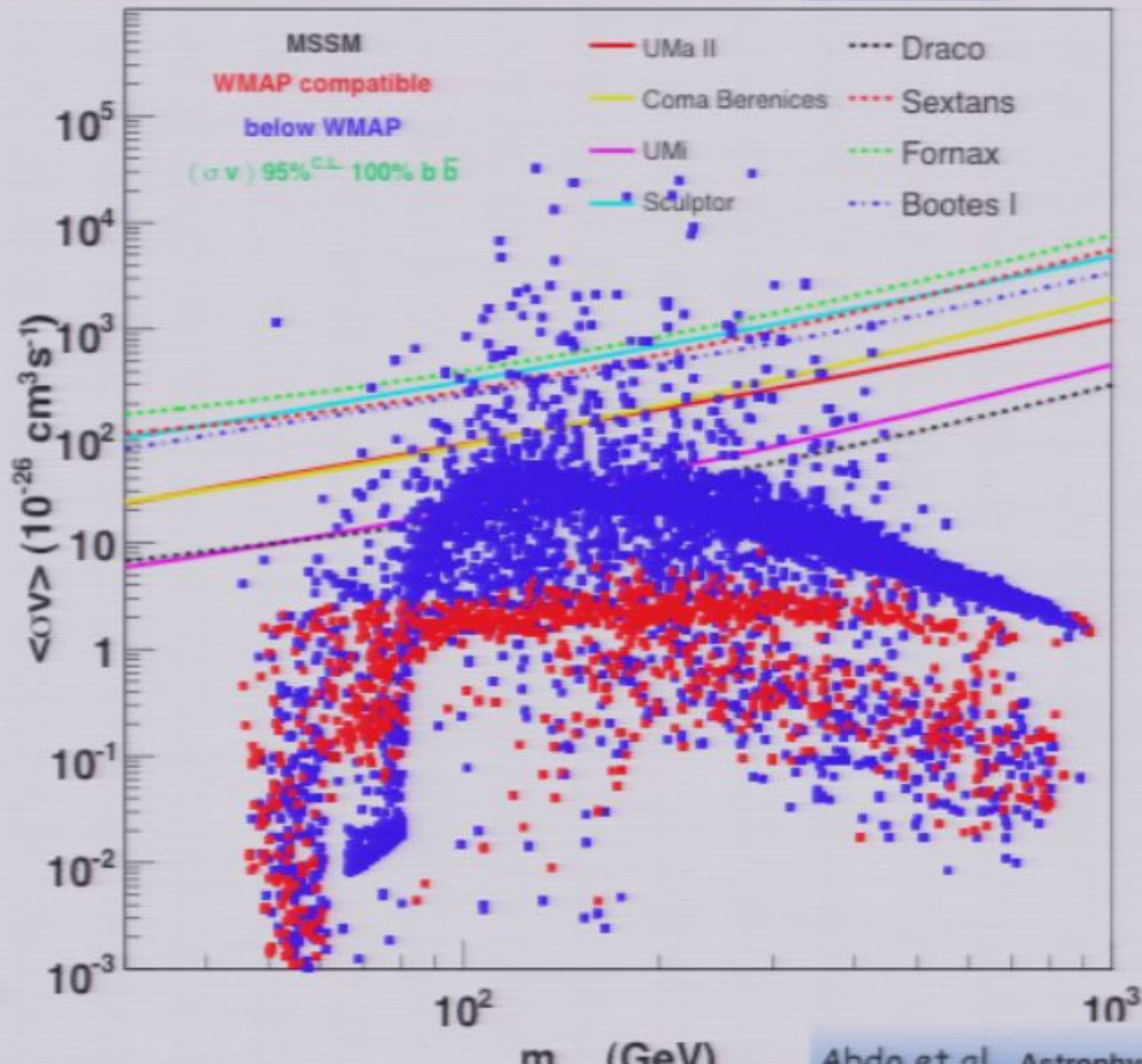
$$\text{Flux} = \left\{ \int_0^{\Delta\Omega} \left\{ \int_{\text{LOS}} \rho^2[r(\theta, \mathcal{D}, s)] ds \right\} d\Omega \right\} \left\{ \int_{E_{\text{th}}}^{M_\chi} \sum_i \frac{dN_{\gamma,i}}{dE} \frac{\langle \sigma v \rangle_i}{M_\chi^2} dE \right\}$$

# Gamma-ray modeling

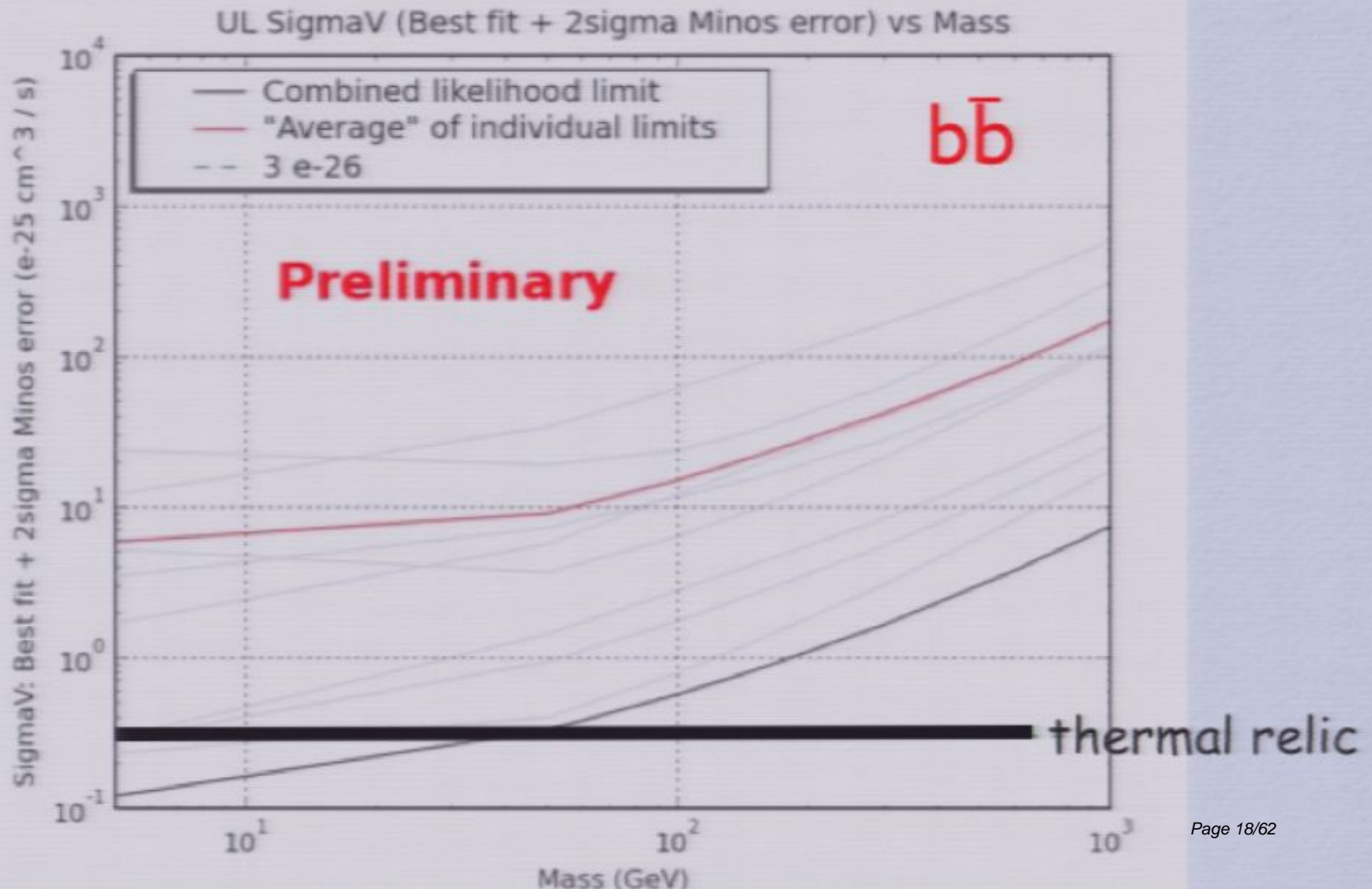




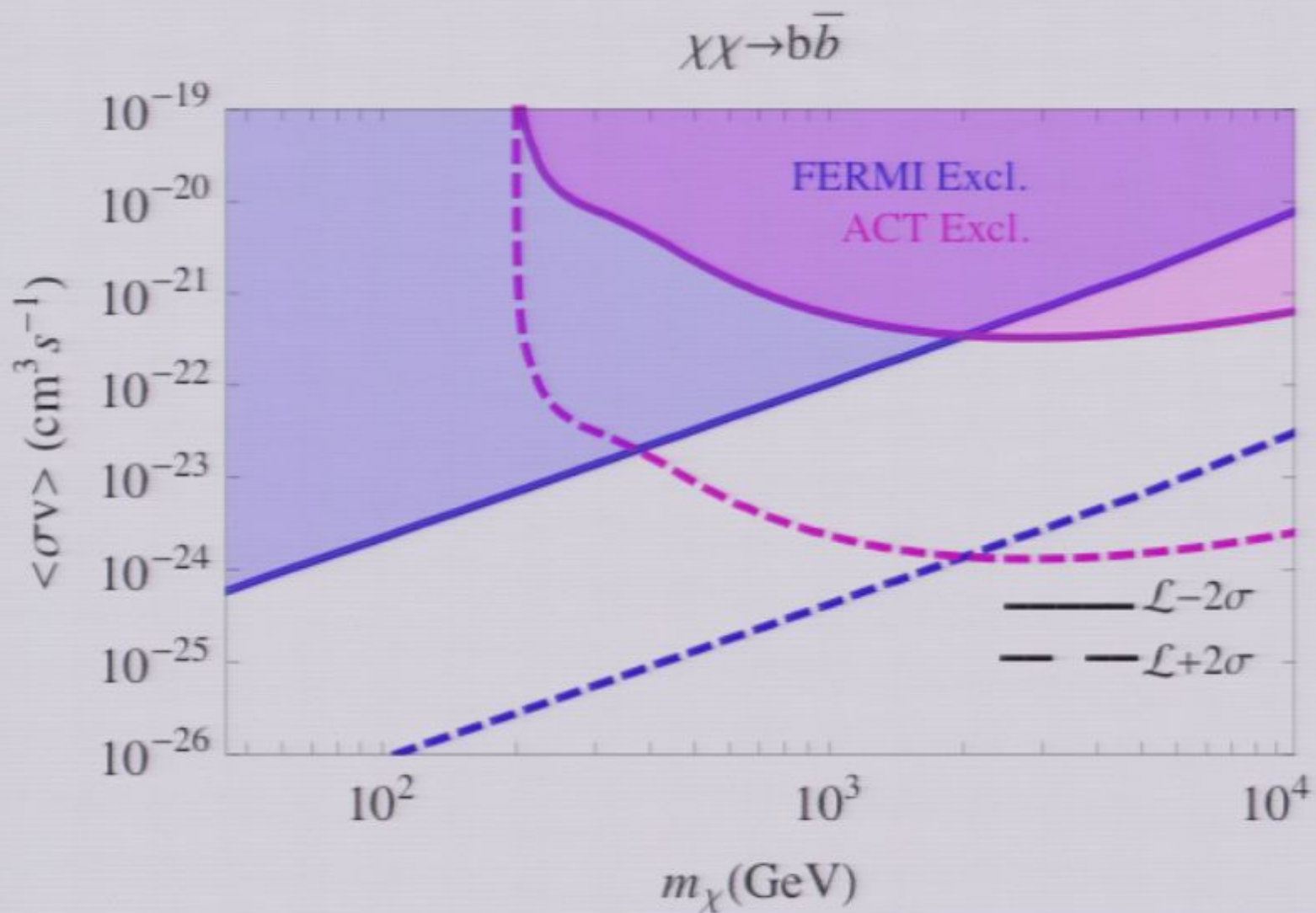
# FERMI



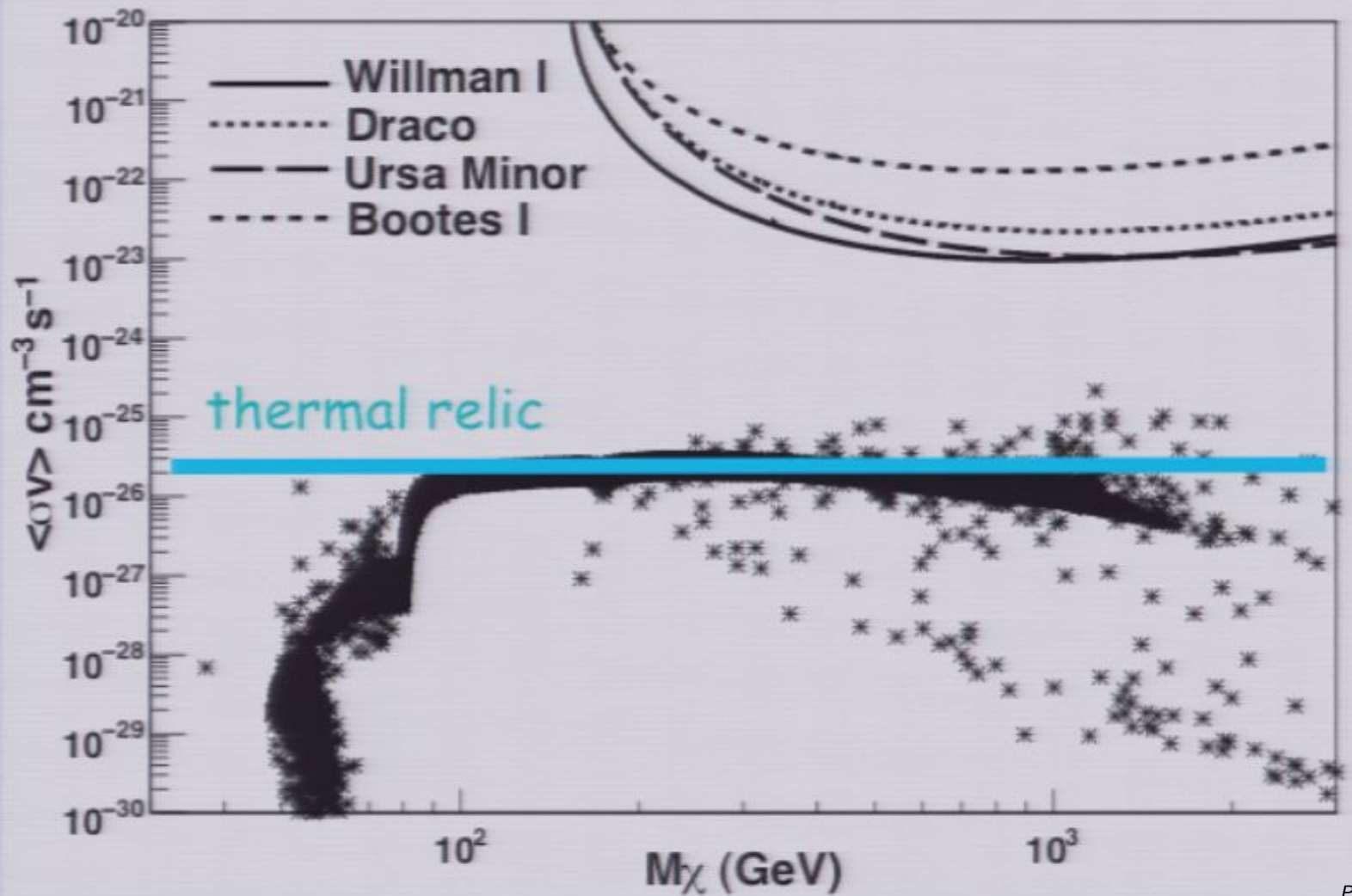
# Limits for Stacked Dwarfs



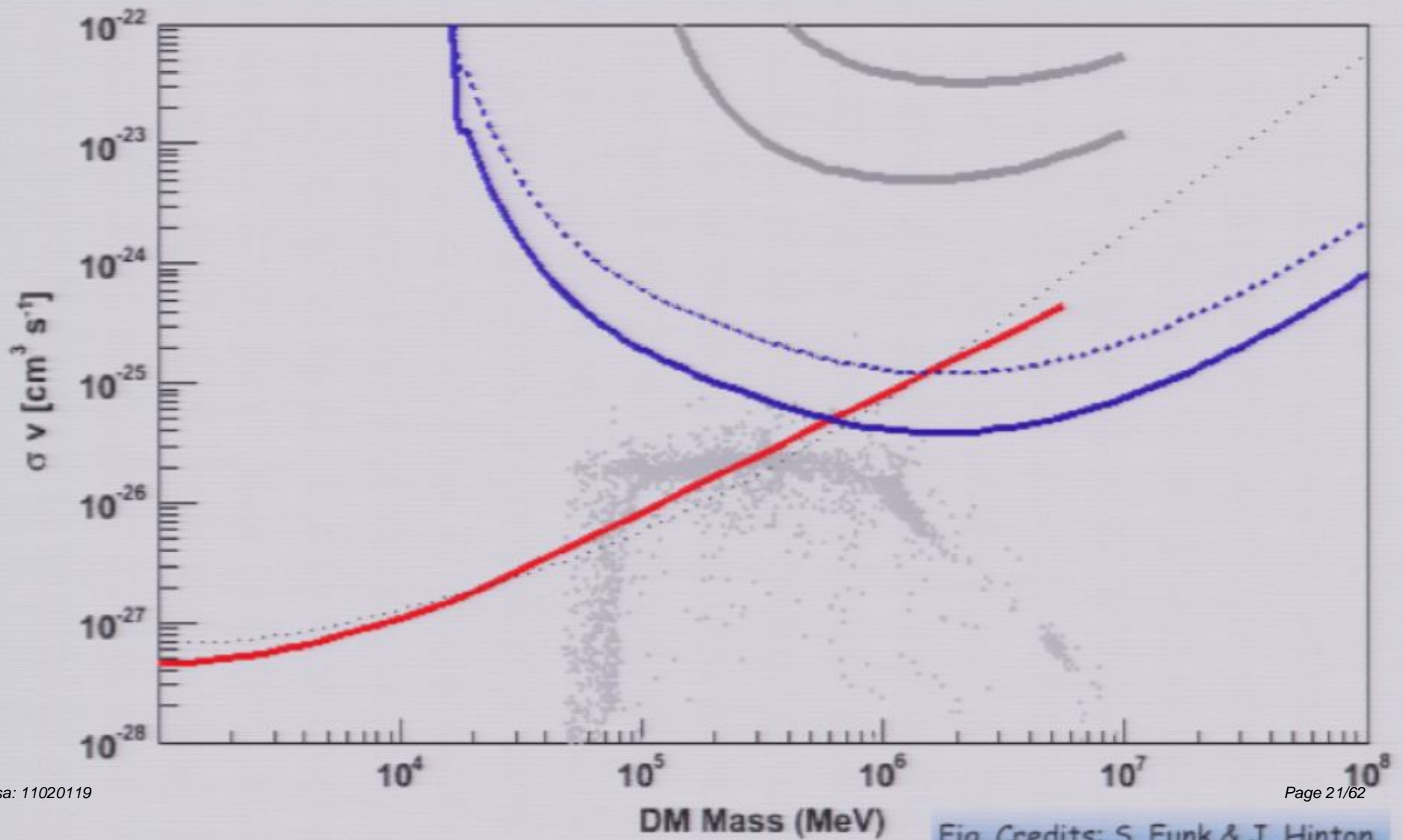
# Gamma-ray limits: Segue 1



# VERITAS

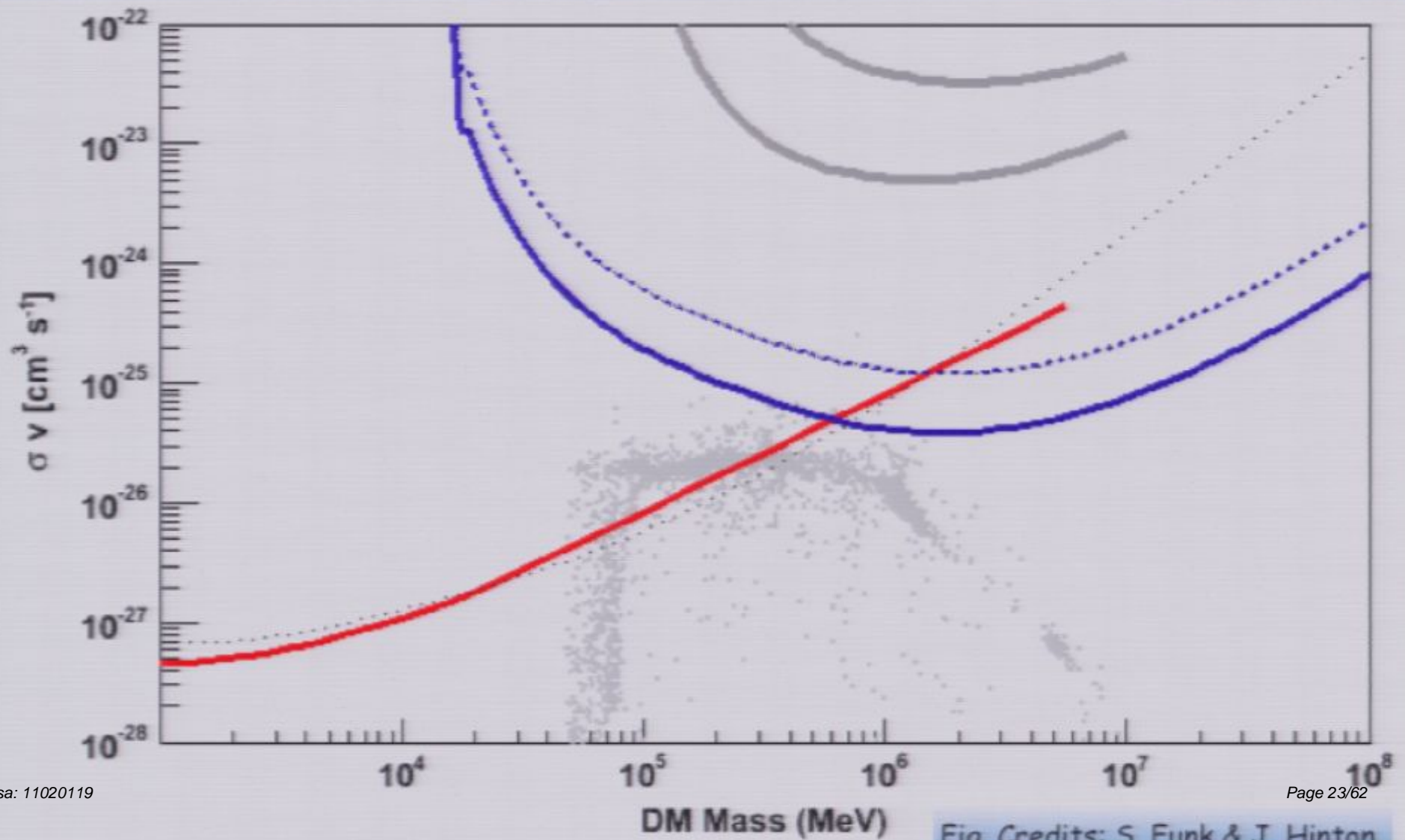


# Projected limits

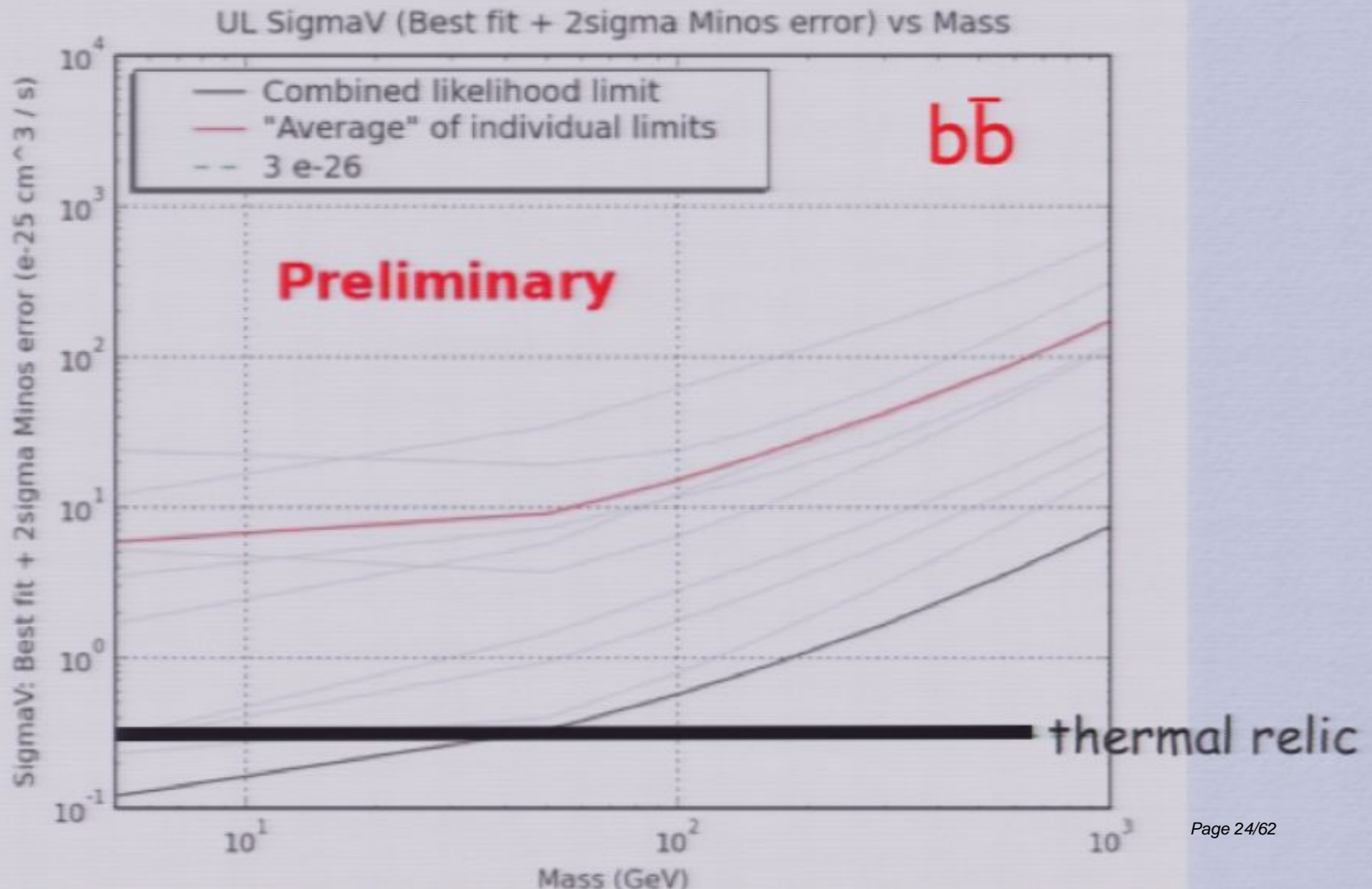


# Direct WIMP Detection

# Projected limits

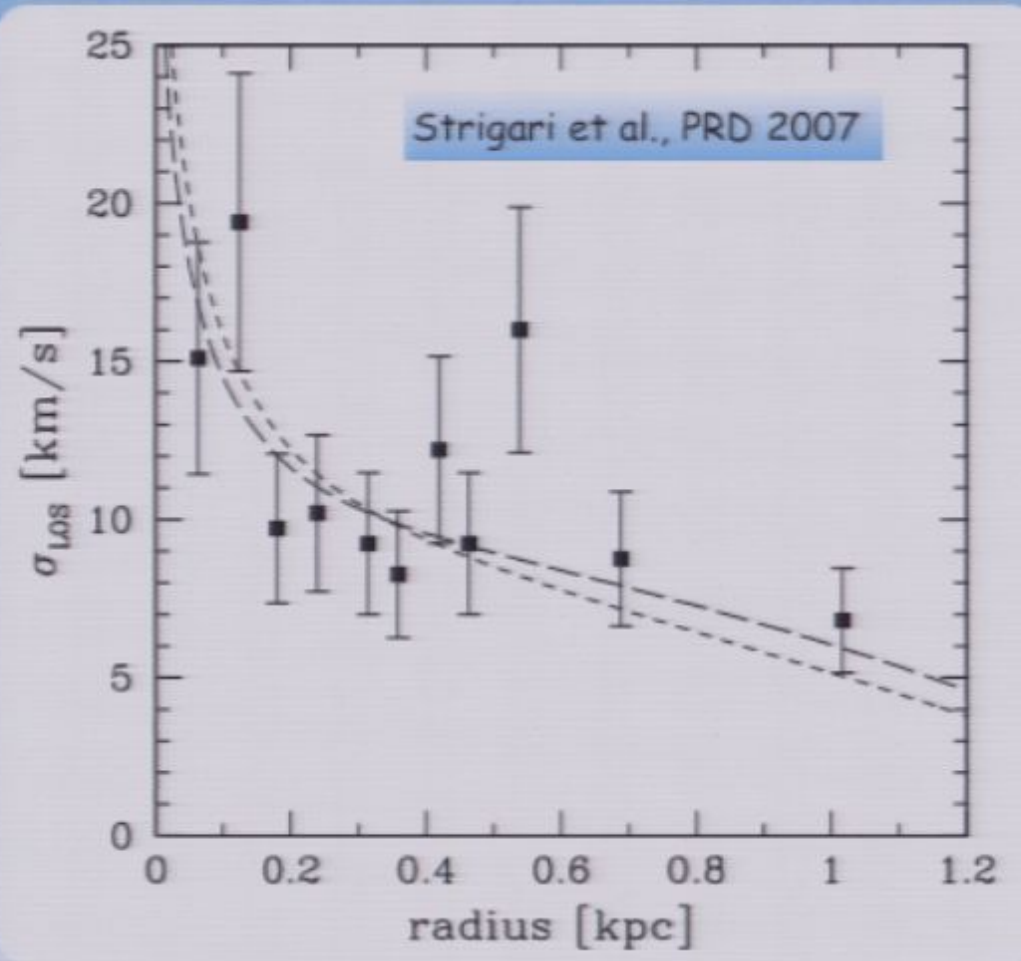


# Limits for Stacked Dwarfs



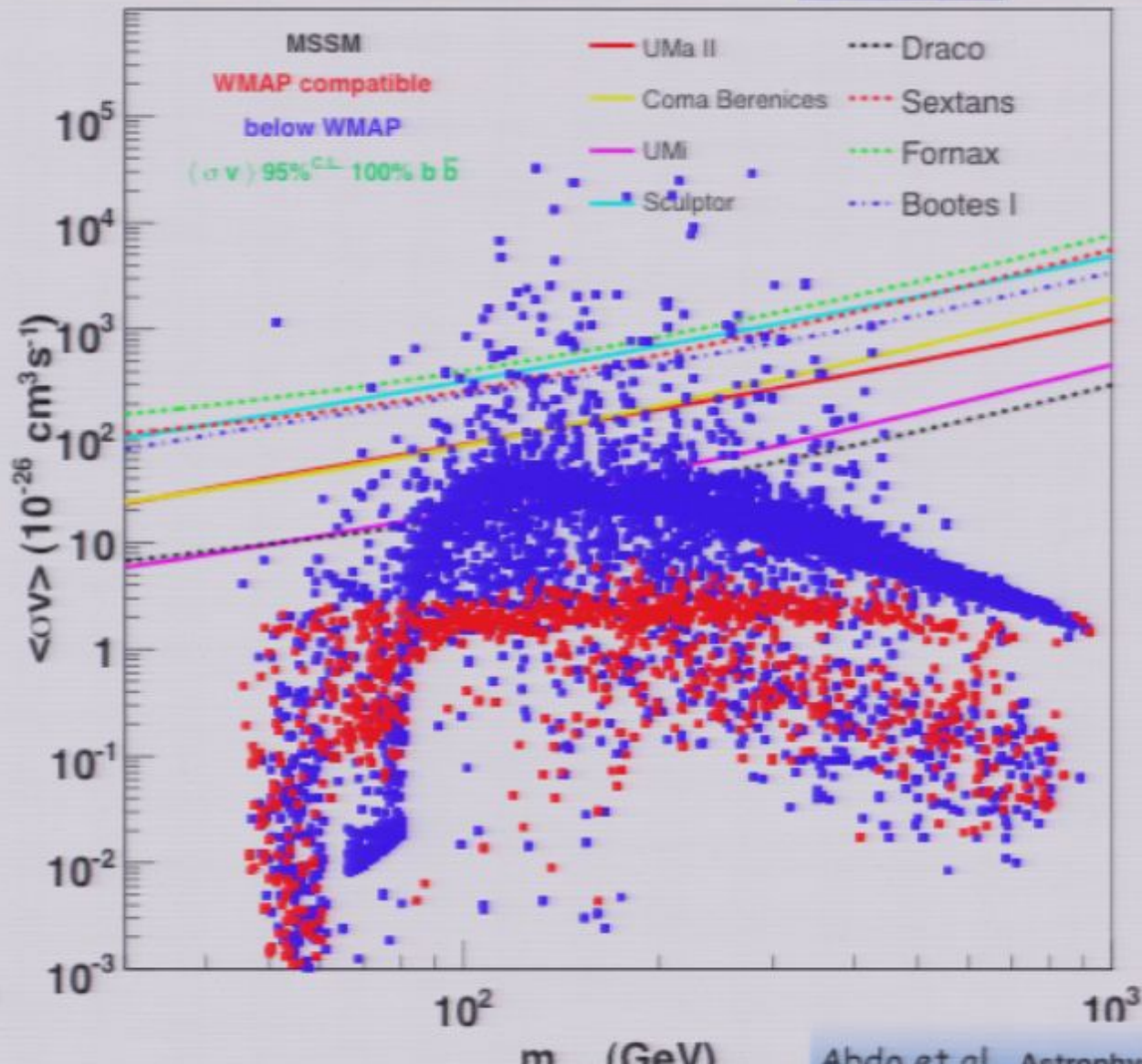


# WIMPs in nearby galaxies

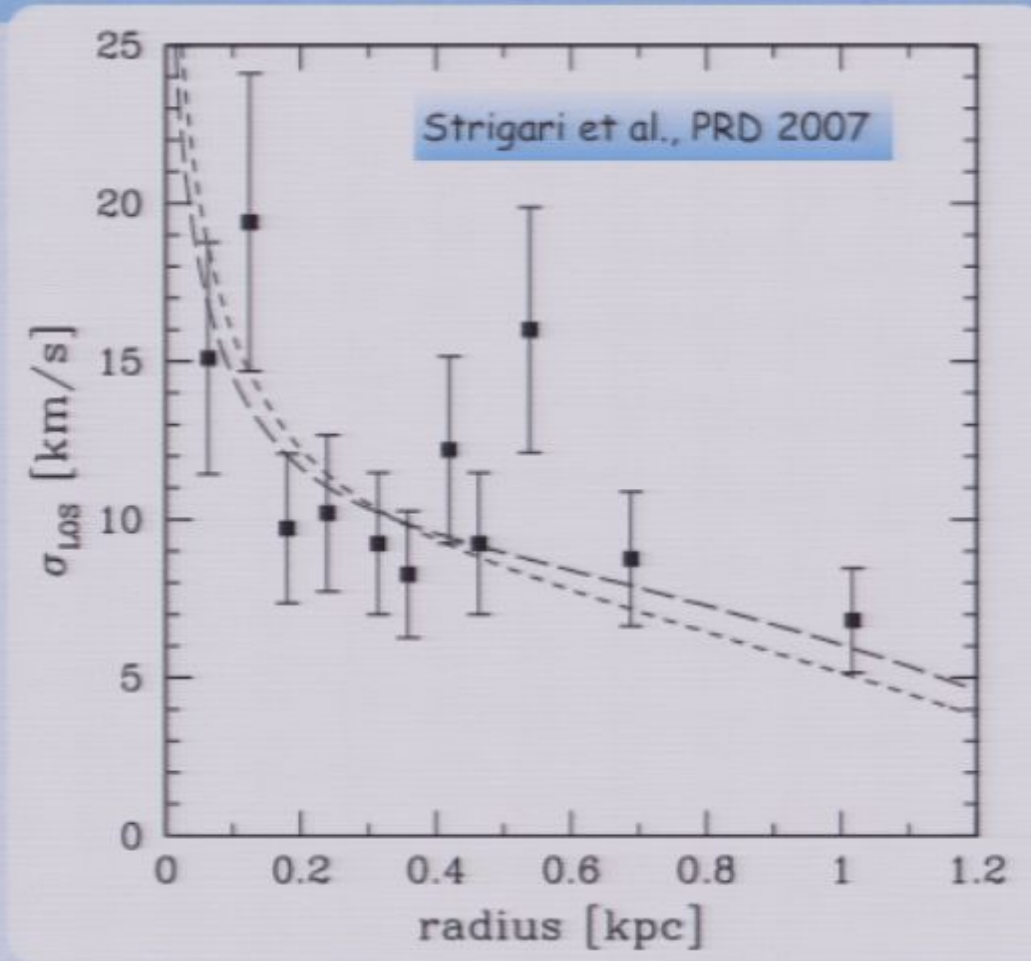


$$\text{Flux} = \left\{ \int_0^{\Delta\Omega} \left\{ \int_{\text{LOS}} \rho^2[r(\theta, \mathcal{D}, s)] ds \right\} d\Omega \right\} \left\{ \int_{E_{\text{th}}}^{M_\chi} \sum_i \frac{dN_{\gamma,i}}{dE} \frac{\langle \sigma v \rangle_i}{M_\chi^2} dE \right\}$$

# FERMI

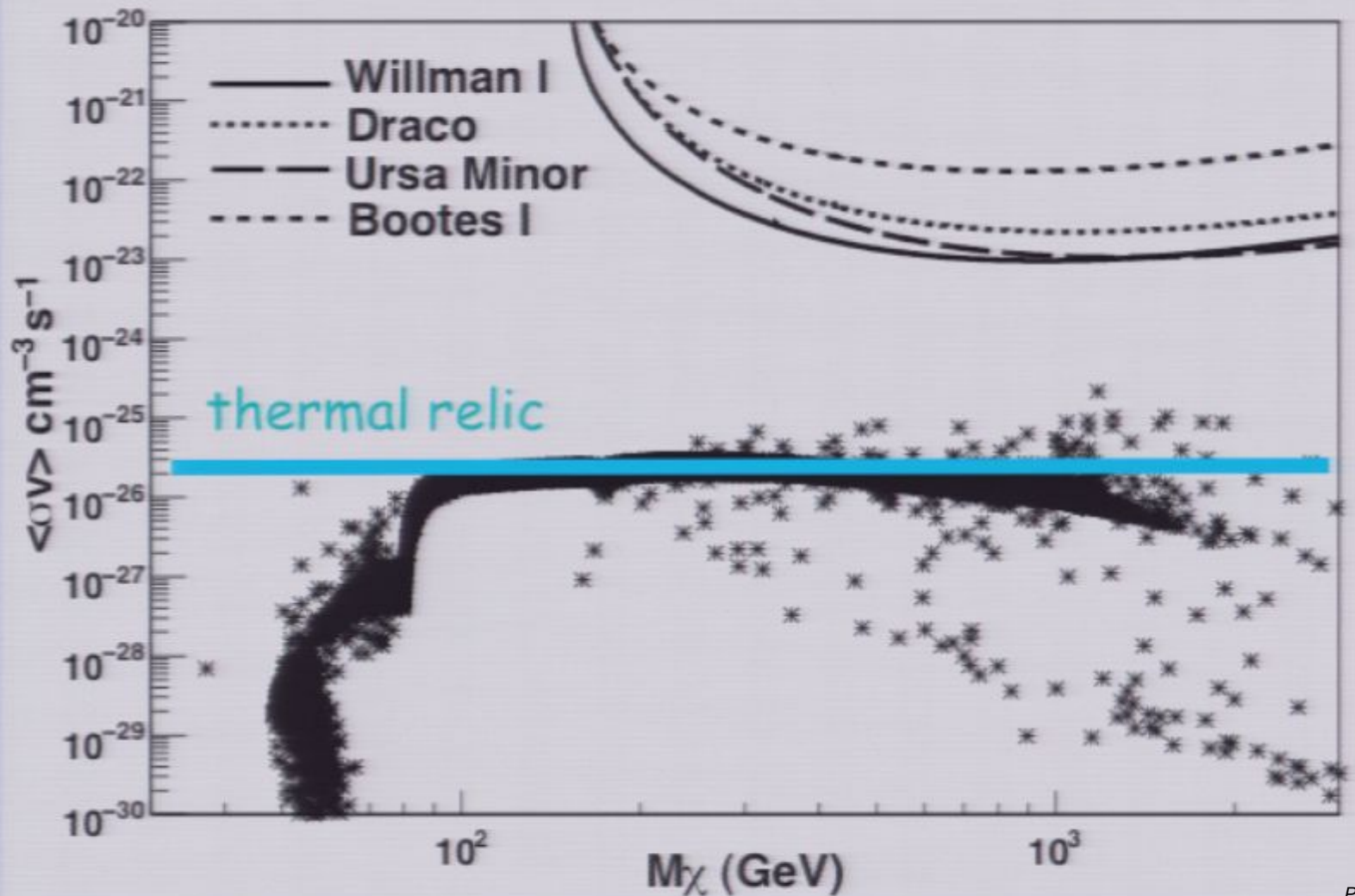


# WIMPs in nearby galaxies



$$\text{Flux} = \left\{ \int_0^{\Delta\Omega} \left\{ \int_{\text{LOS}} \rho^2[r(\theta, \mathcal{D}, s)] ds \right\} d\Omega \right\} \left\{ \int_{E_{\text{th}}}^{M_\chi} \sum_i \frac{dN_{\gamma,i}}{dE} \frac{\langle \sigma v \rangle_i}{M_\chi^2} dE \right\}$$

# VERITAS



# Direct WIMP Detection

# Dark matter in underground detectors

## Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten

*Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544*

(Received 7 January 1985)

We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses  $1-10^6$  GeV; particles with spin-dependent interactions of typical weak strength and masses  $1-10^2$  GeV; or strongly interacting particles of masses  $1-10^{13}$  GeV.

## Weak Scale Interactions

Spin-Independent: cross section  $\sim A^2$

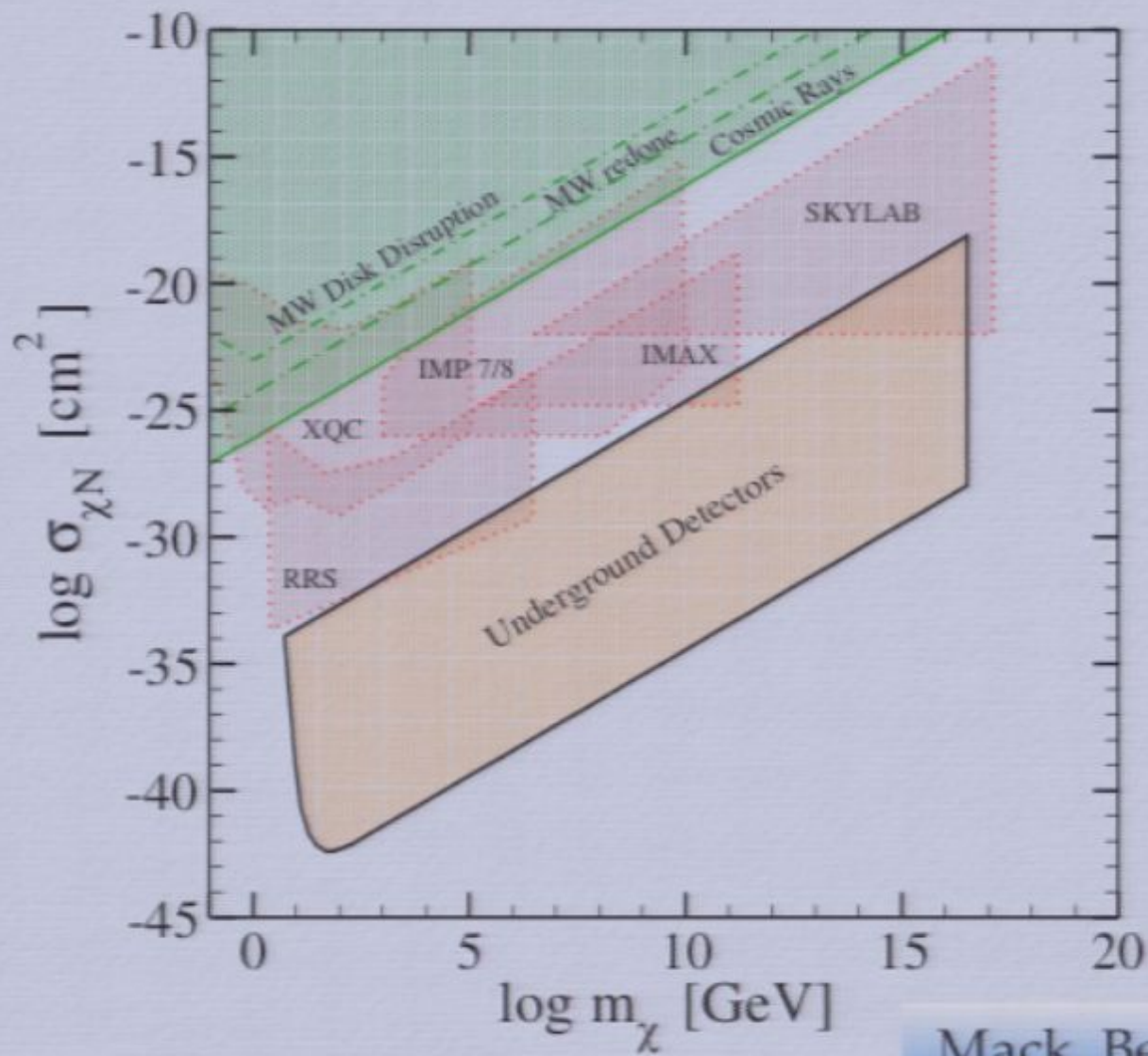
Spin-Dependent: cross section  $\sim J(J+1)$

## Strong Interactions

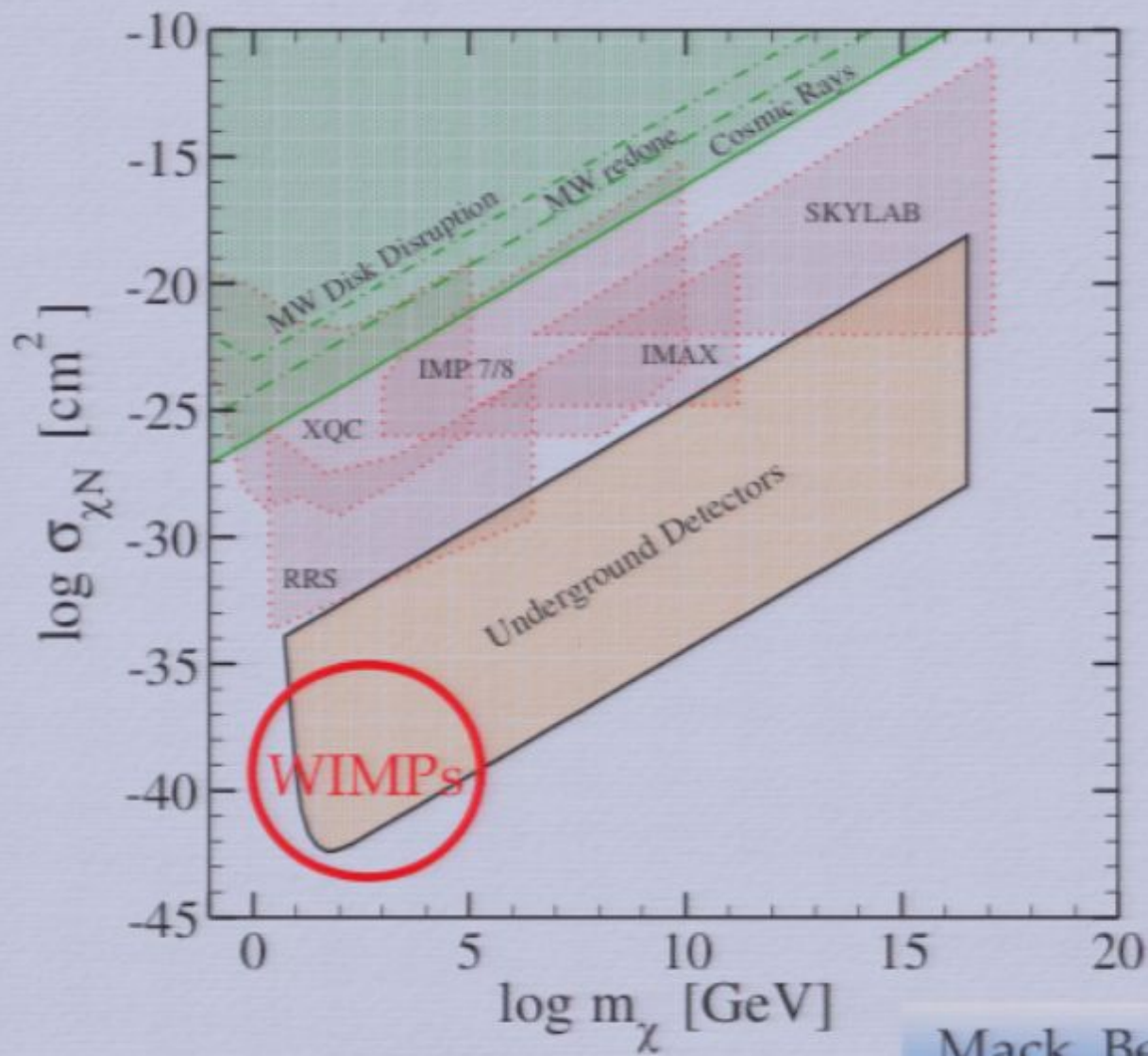
cross section  $\sim 4 \pi R^2$



# Dark matter interactions

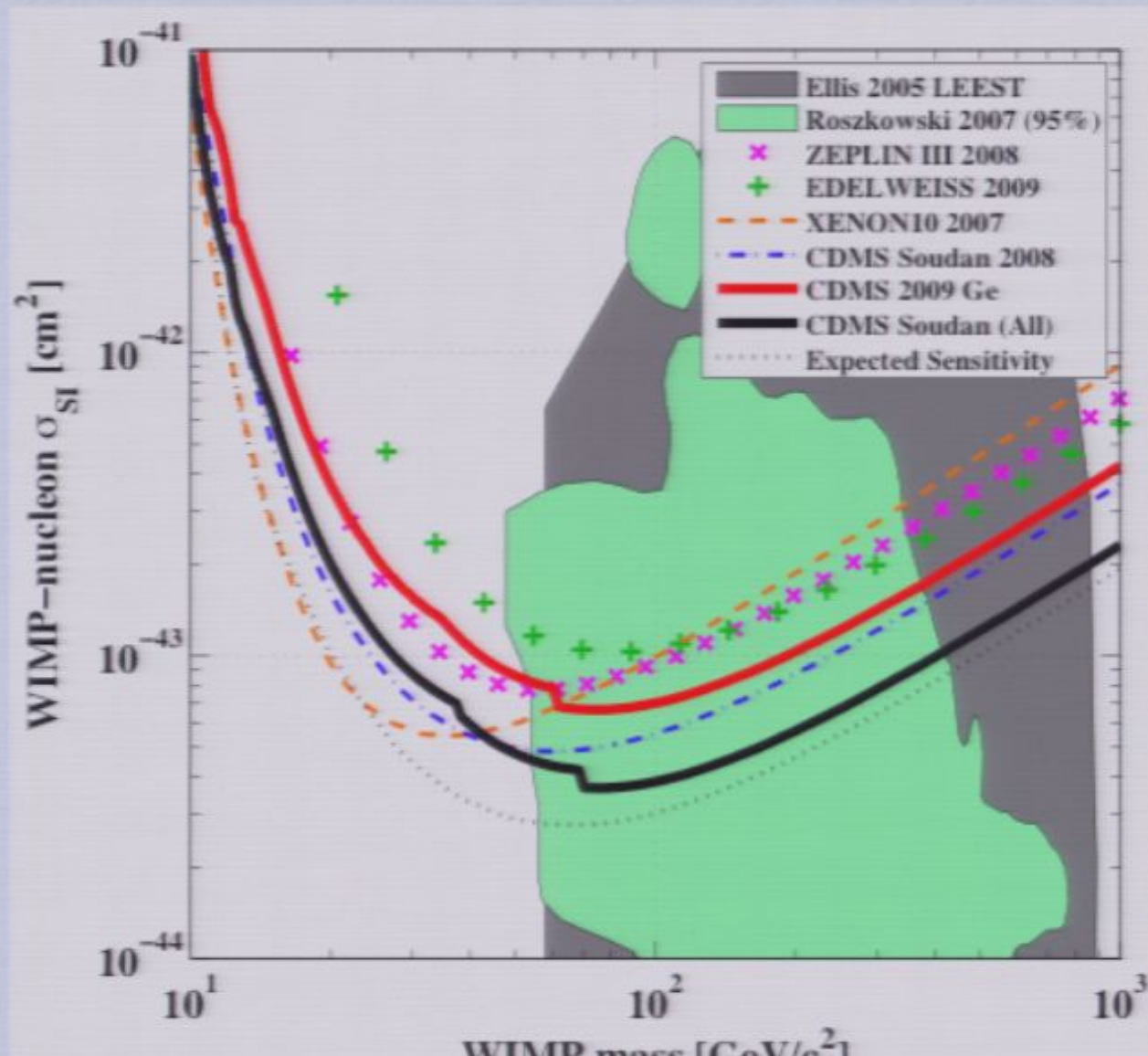


# Dark matter interactions

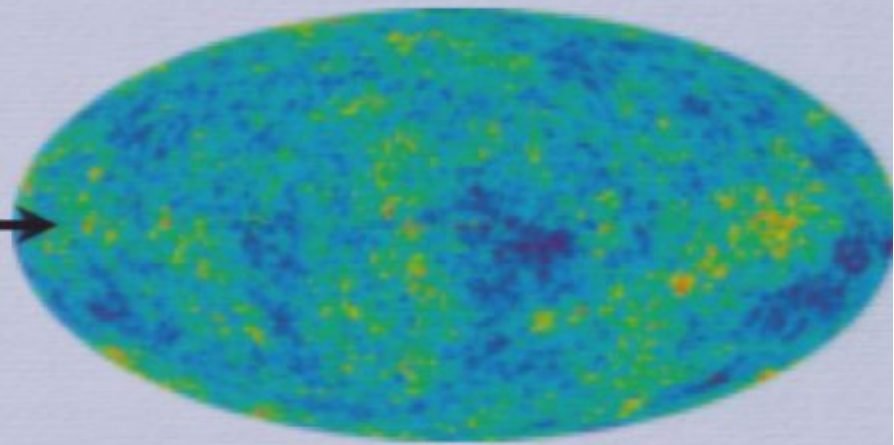
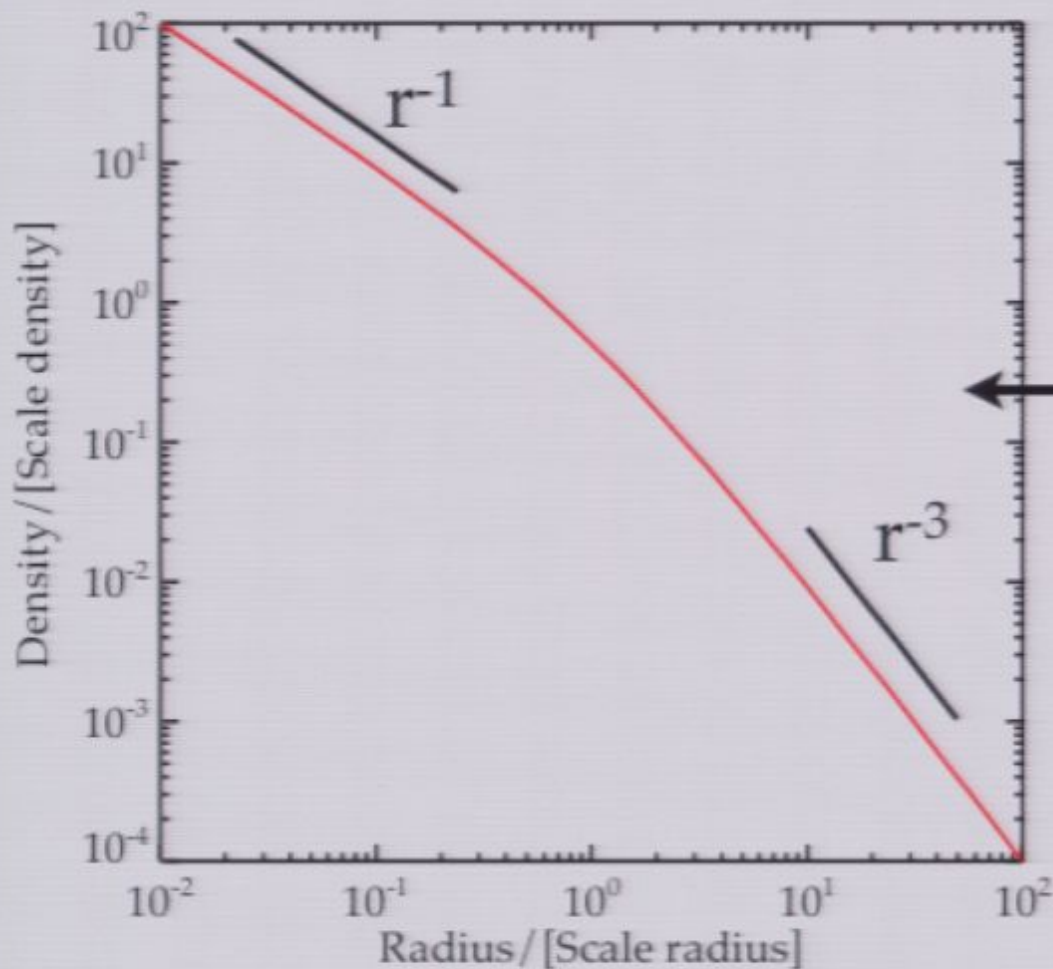




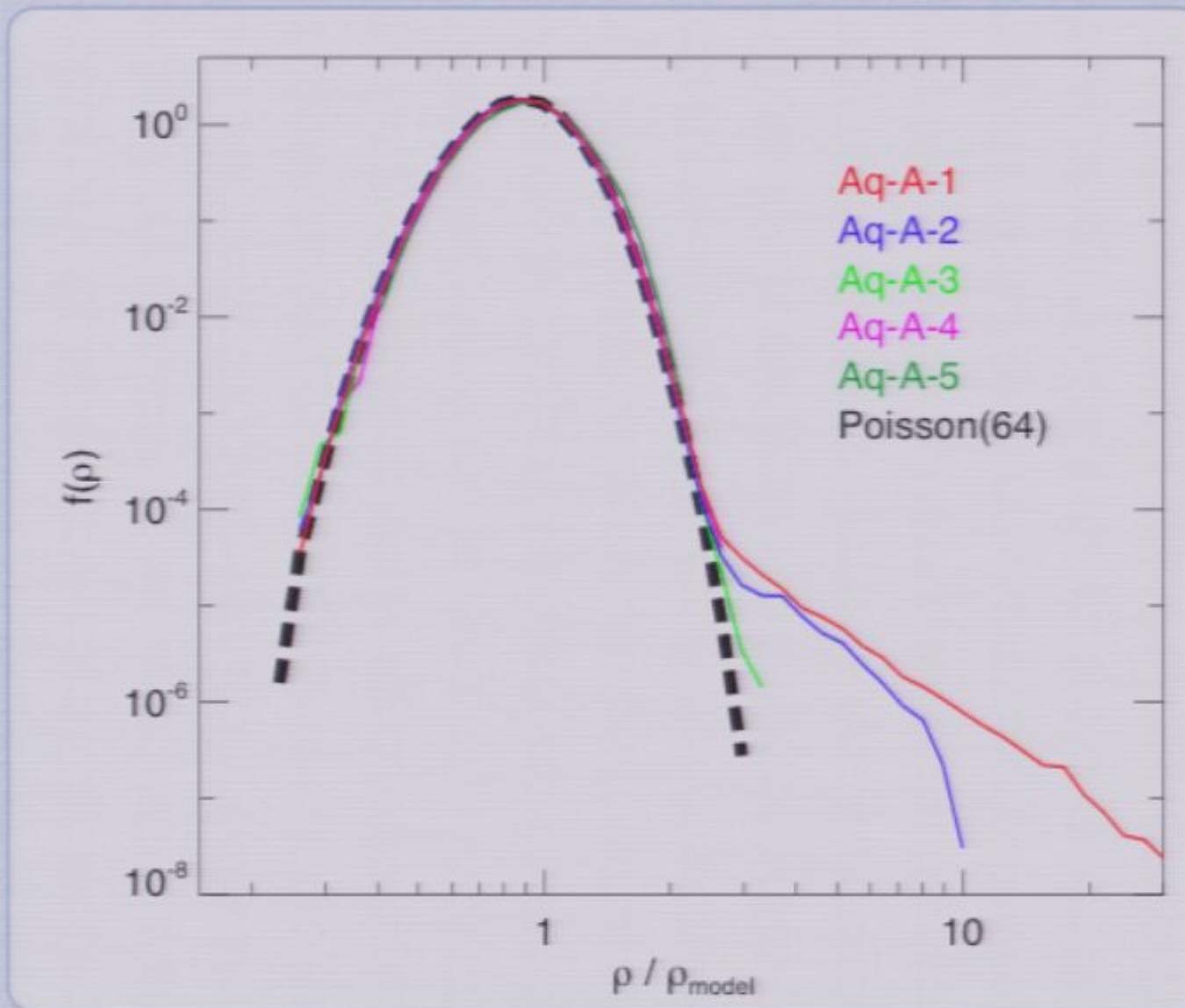
# Modern Dark Matter Limits



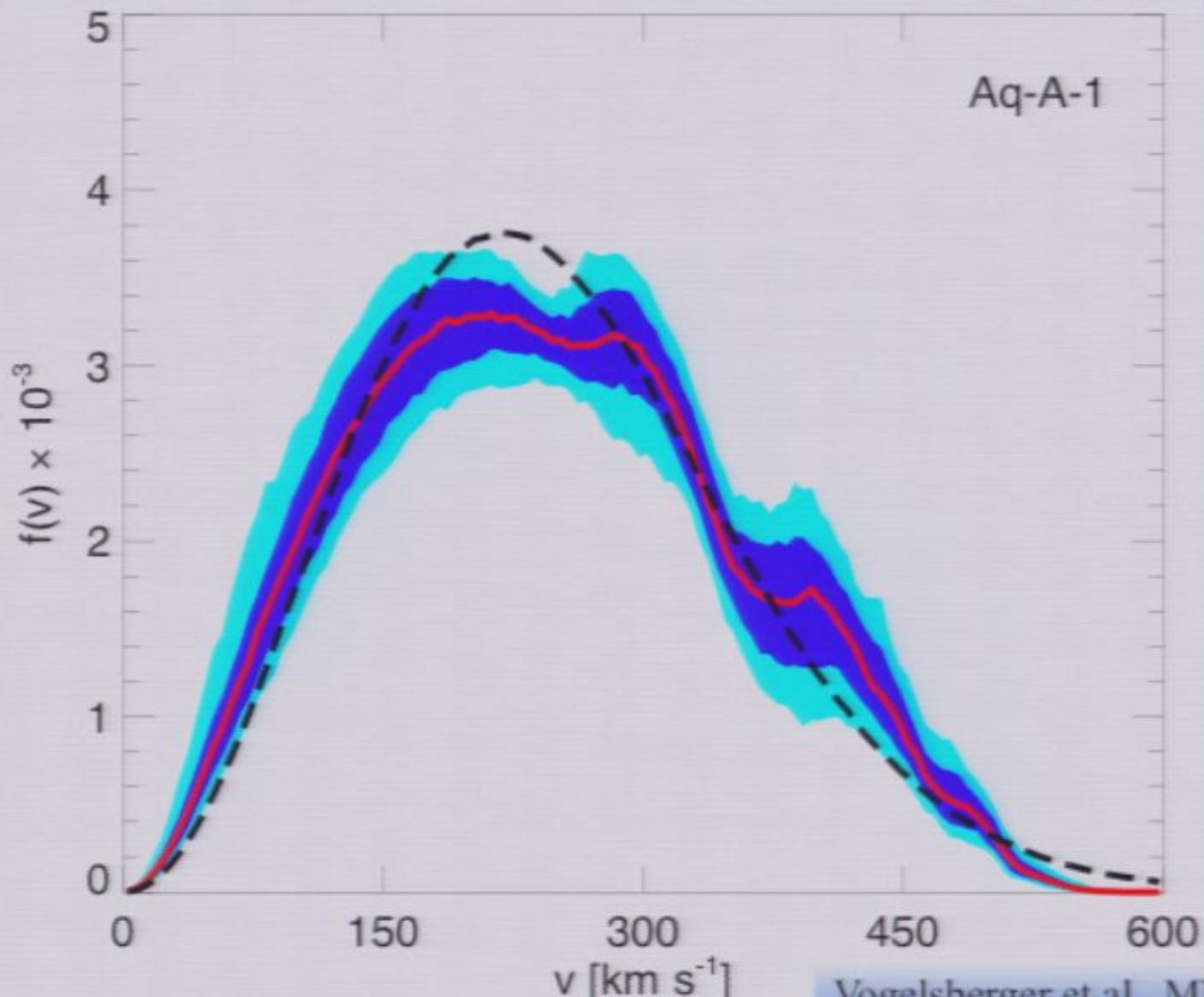
# Theory of Dark Matter Halos



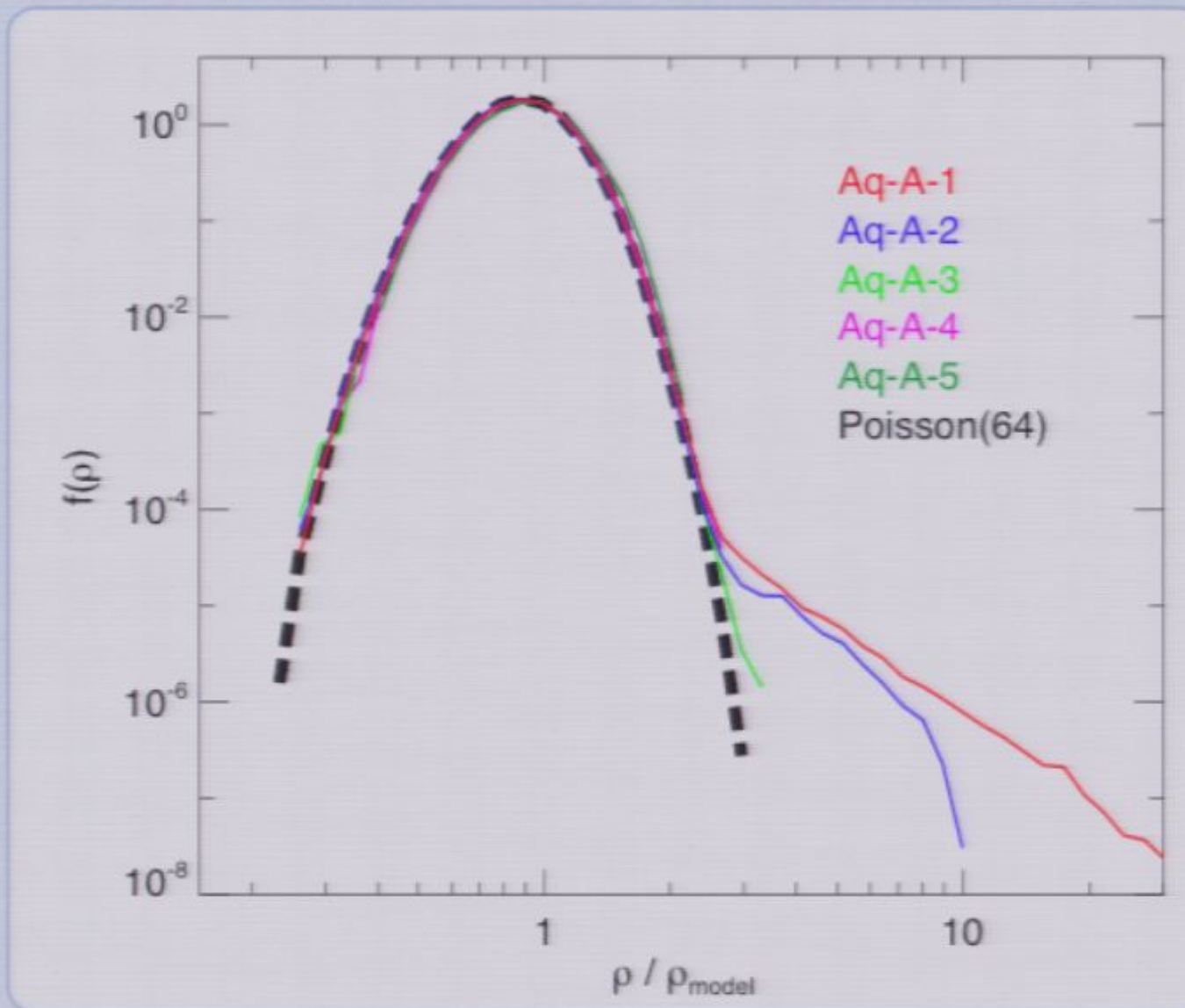
# Theory of Galactic halos



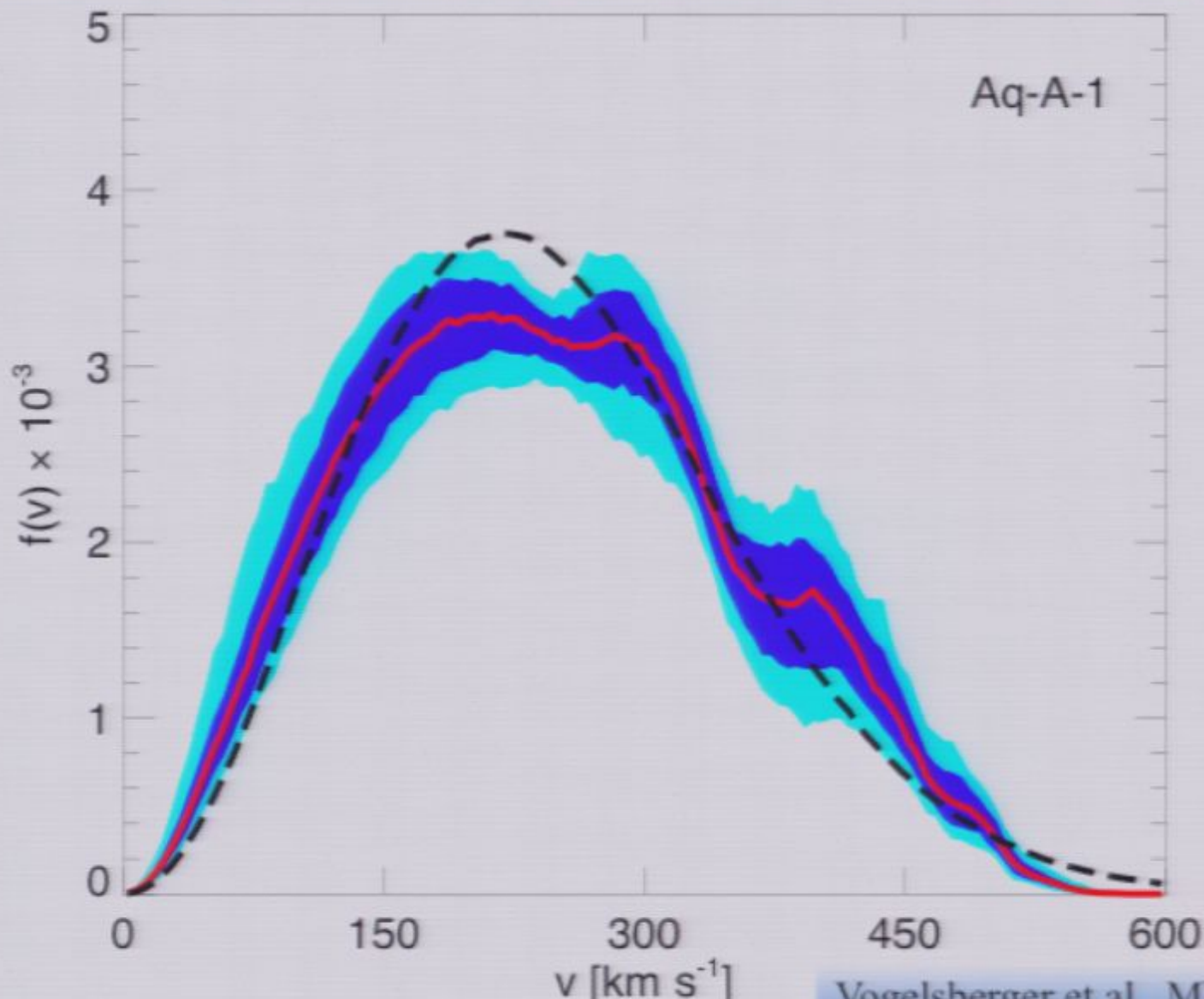
# Theory of Galactic halos



# Theory of Galactic halos

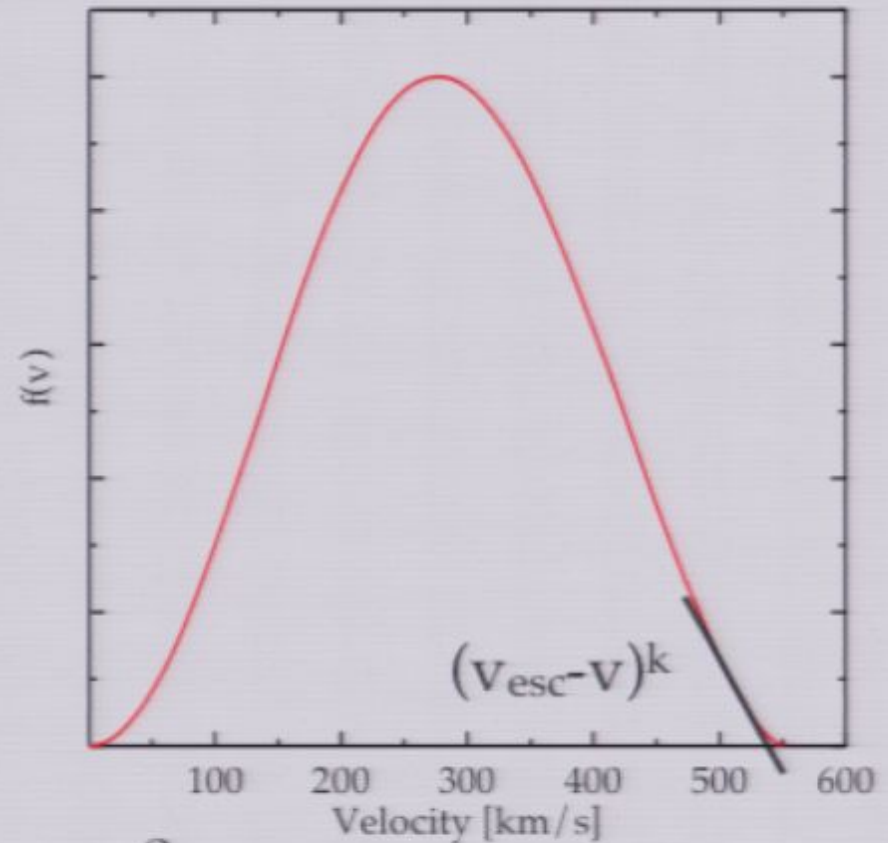
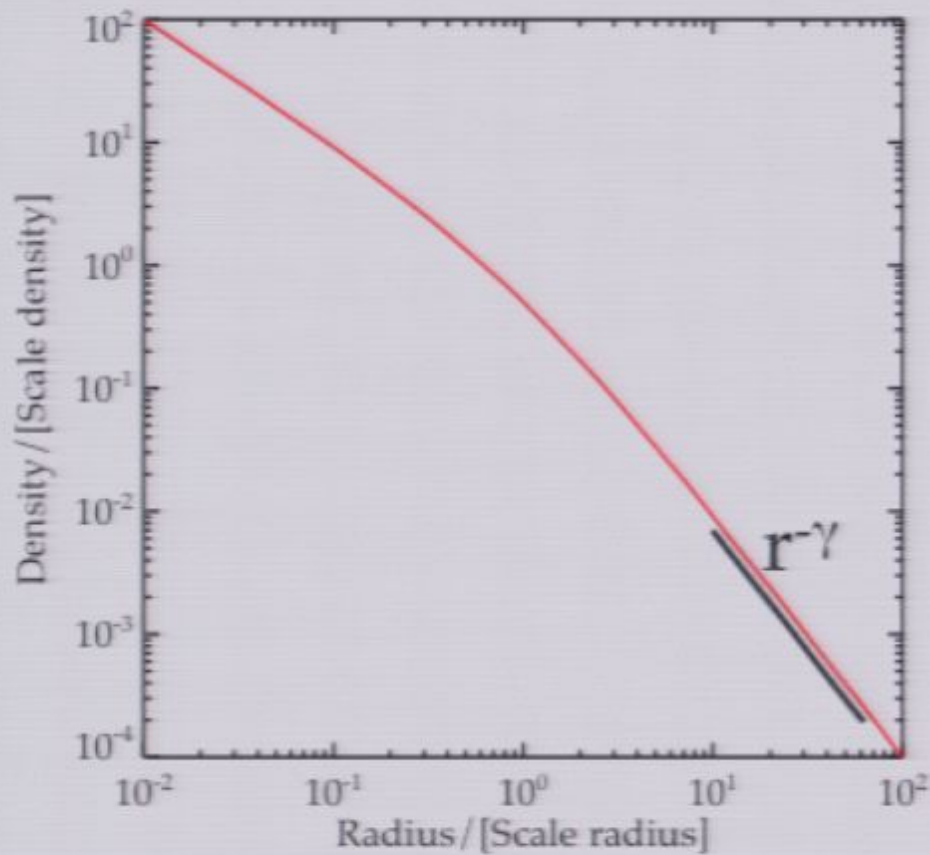


# Theory of Galactic halos



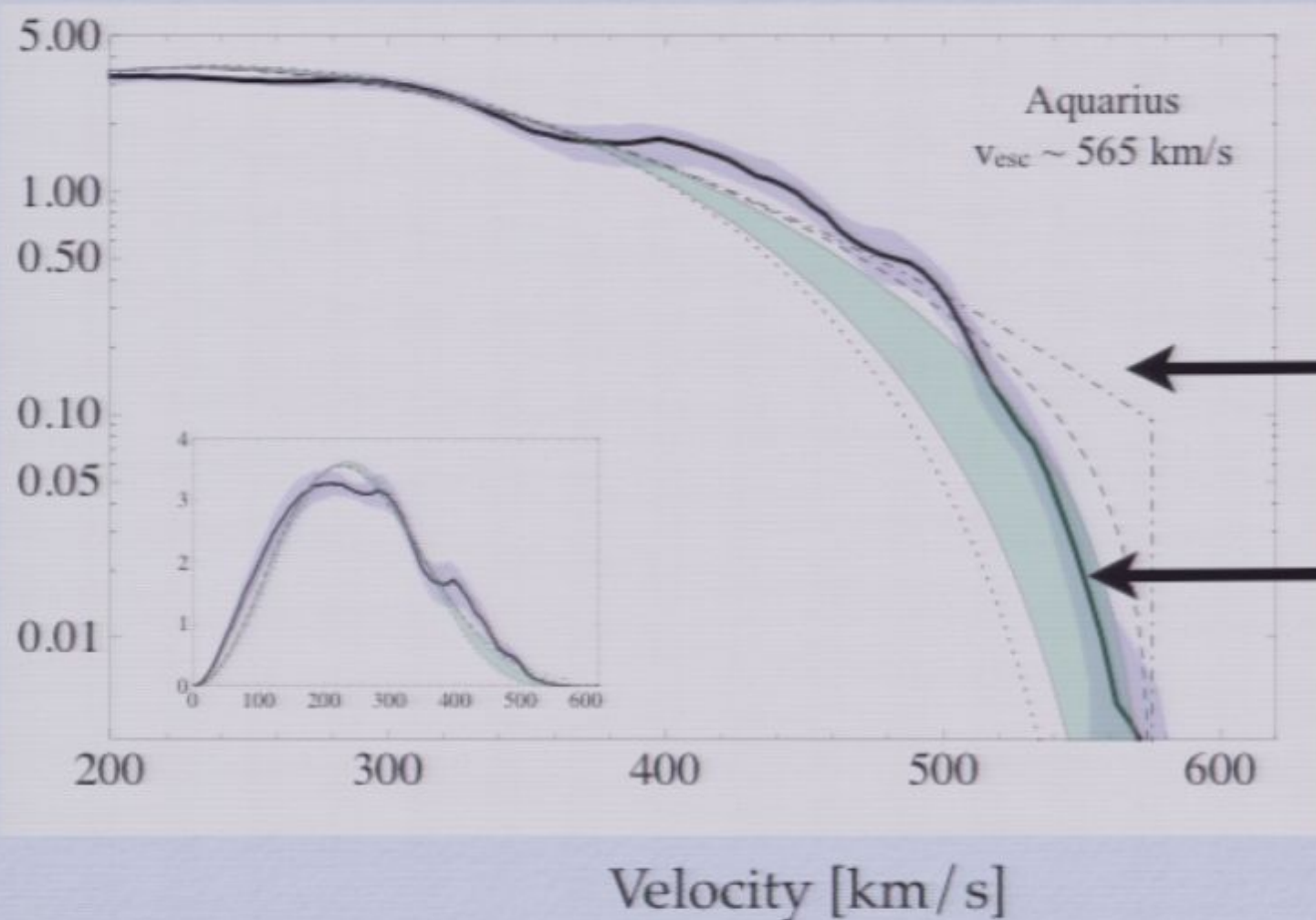
# Modeling Dark Matter Halos

$$\nabla^2 \psi = -4\pi G\rho = -4\pi GM \int f(v) d^3v$$



$$k = \gamma - \frac{3}{2}$$

# Dark Matter at End of Galaxy

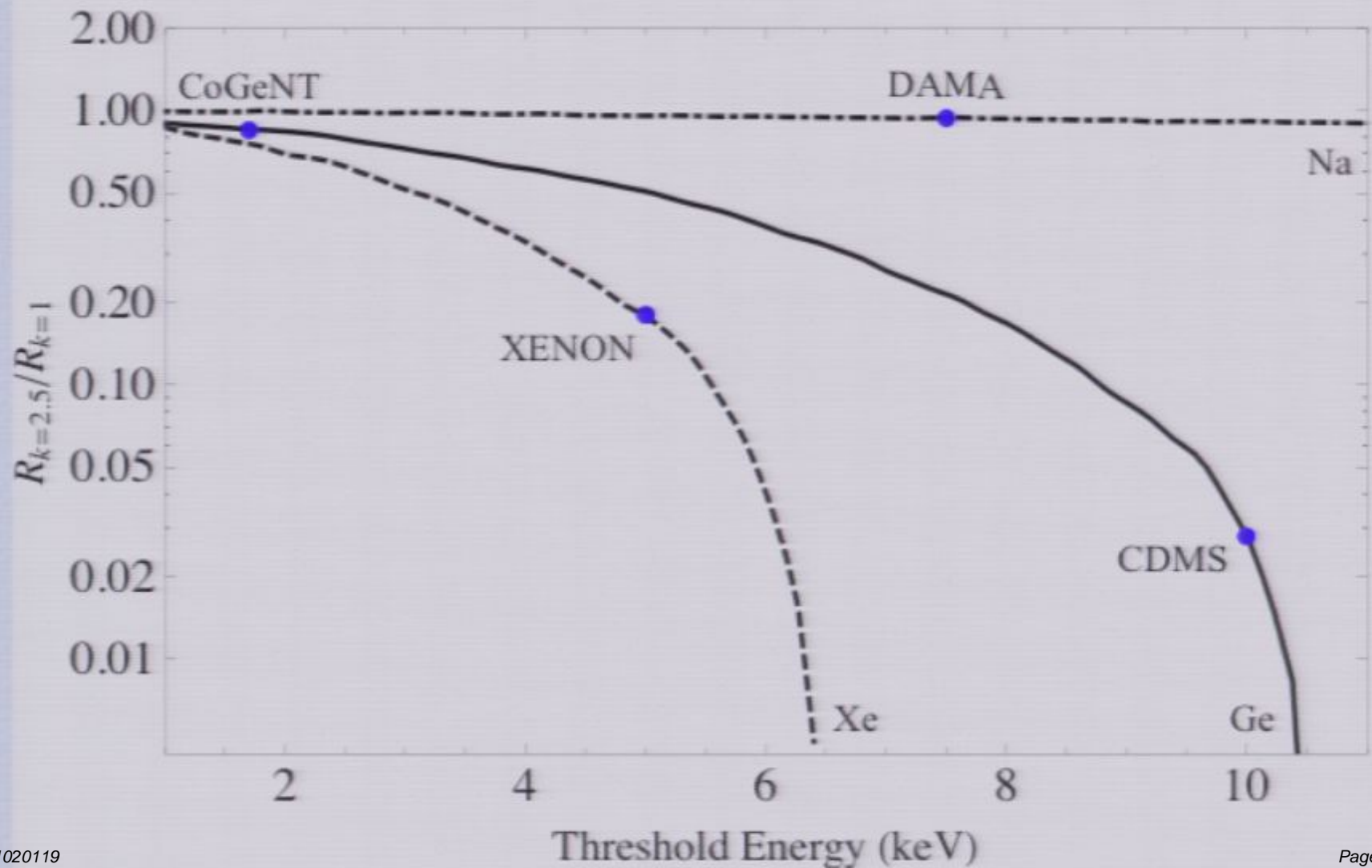


Standard  
Maxwellian  
Model

Analytic  
model

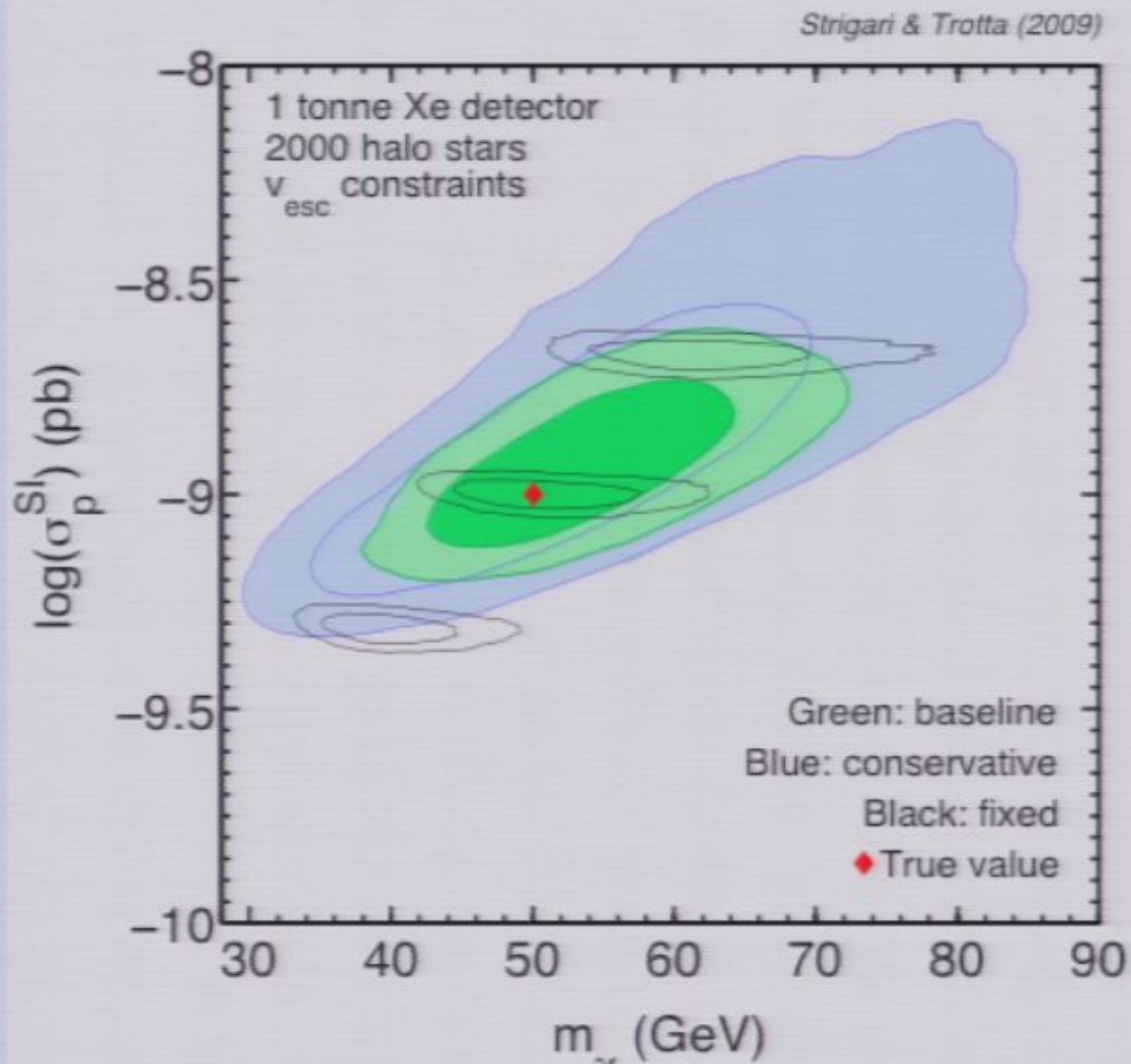


# Effects on measured rates

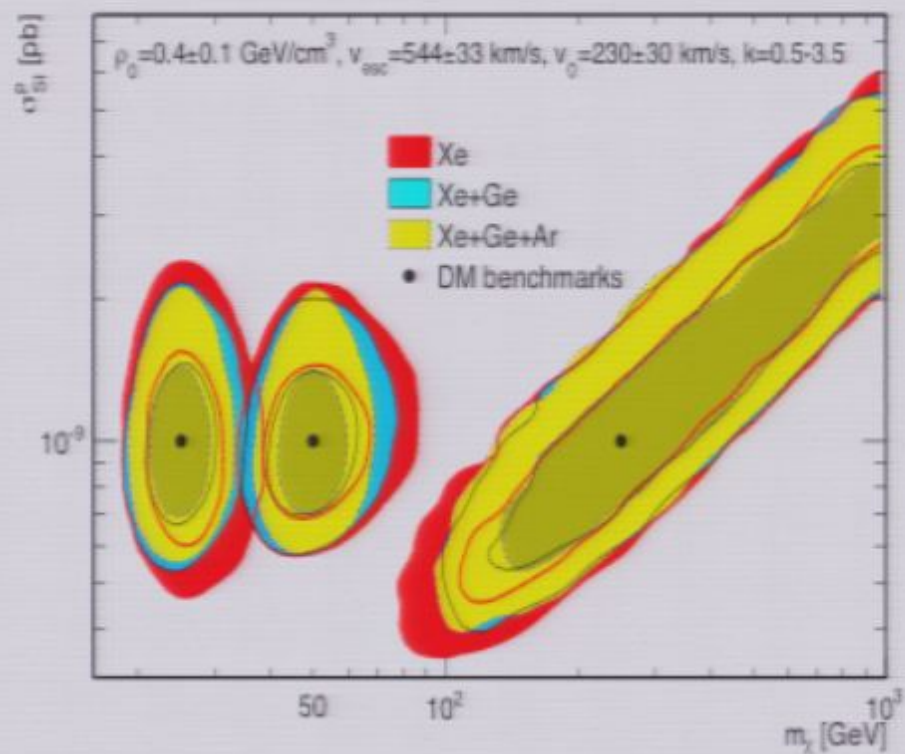
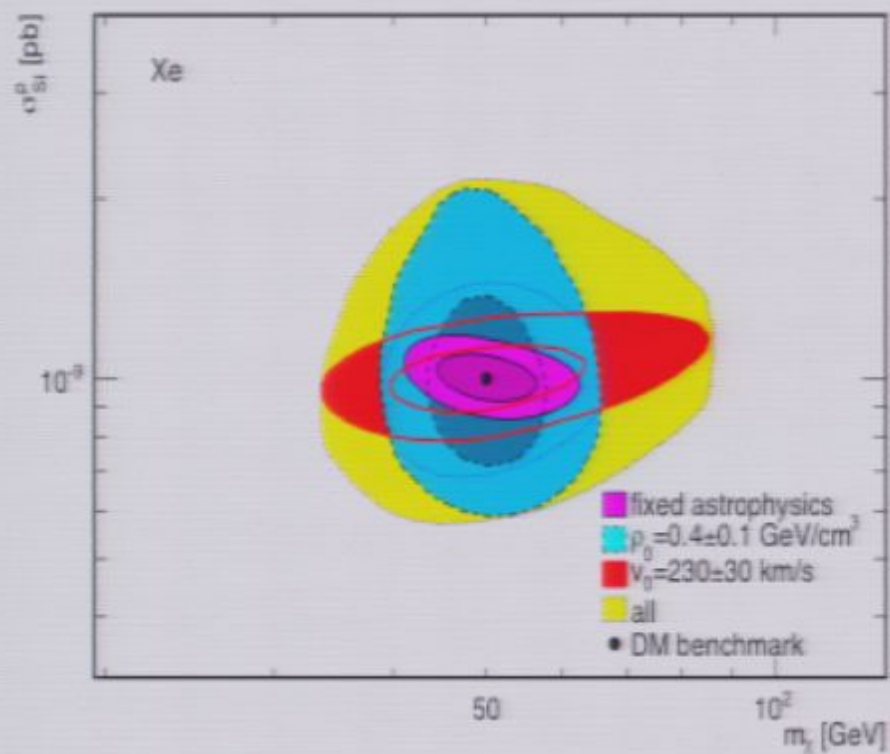


# Dark Matter Astrophysics

# Can WIMP properties be determined?



# Can WIMP properties be determined?



# Neutrinos underground

## Bolometric Detection of Neutrinos

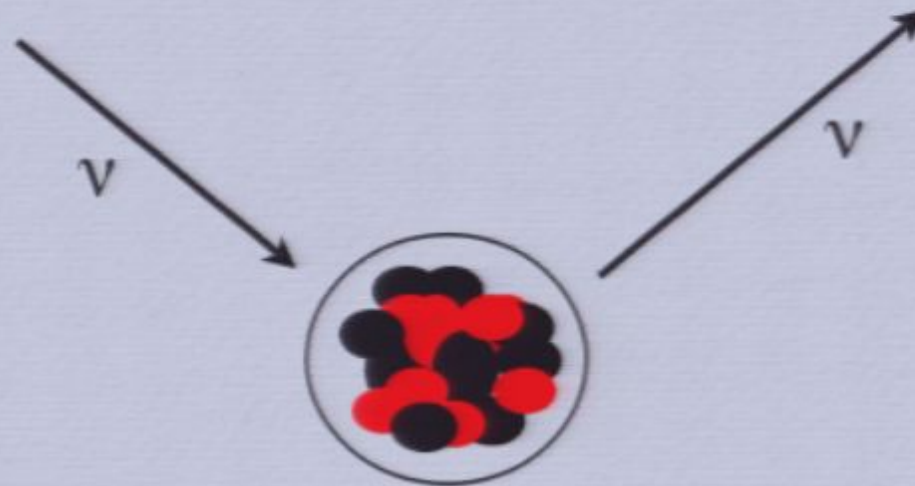
Blas Cabrera, Lawrence M. Krauss, and Frank Wilczek

*Department of Physics, Stanford University, Stanford, California 94305*

*Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 01238*

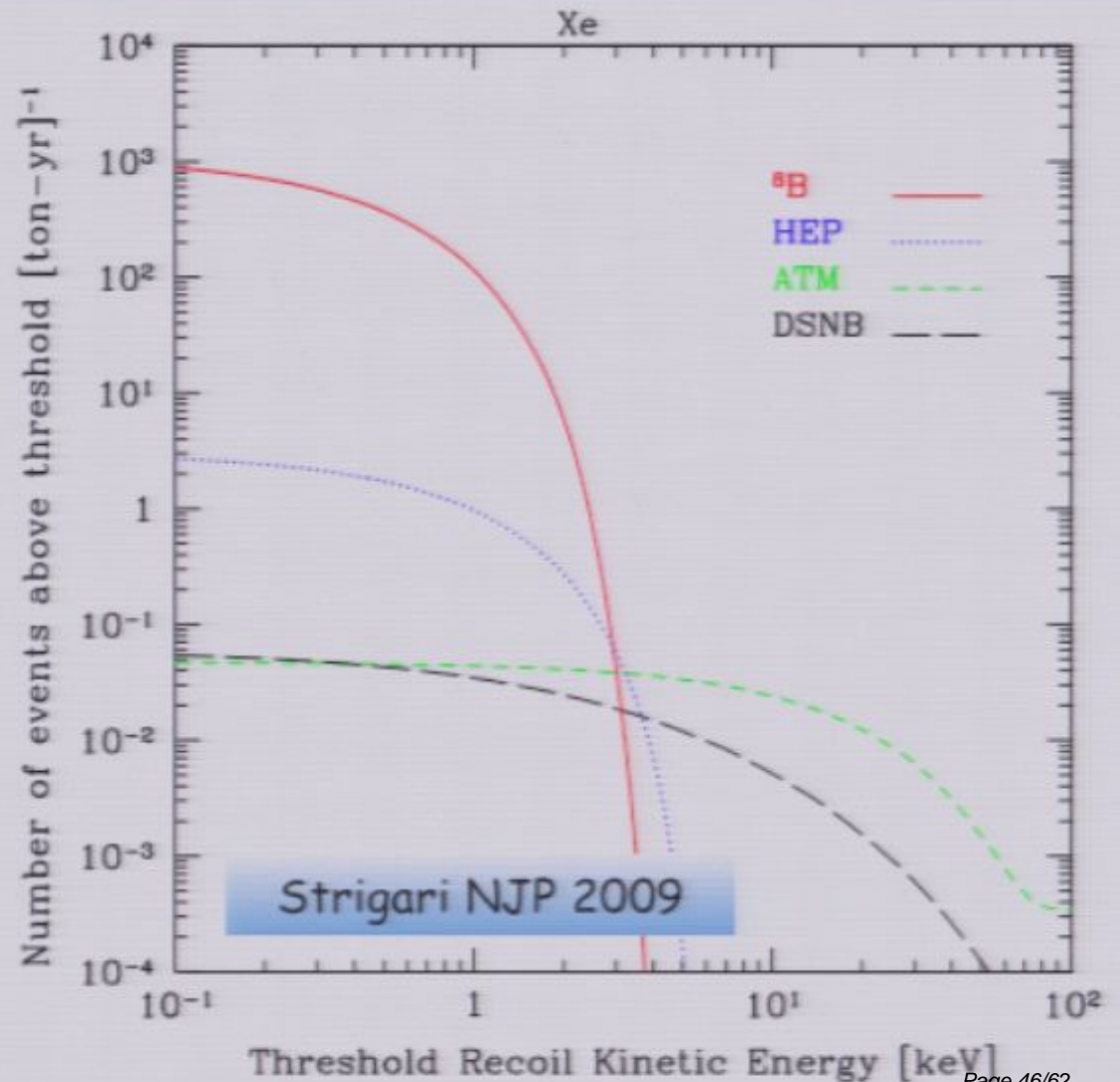
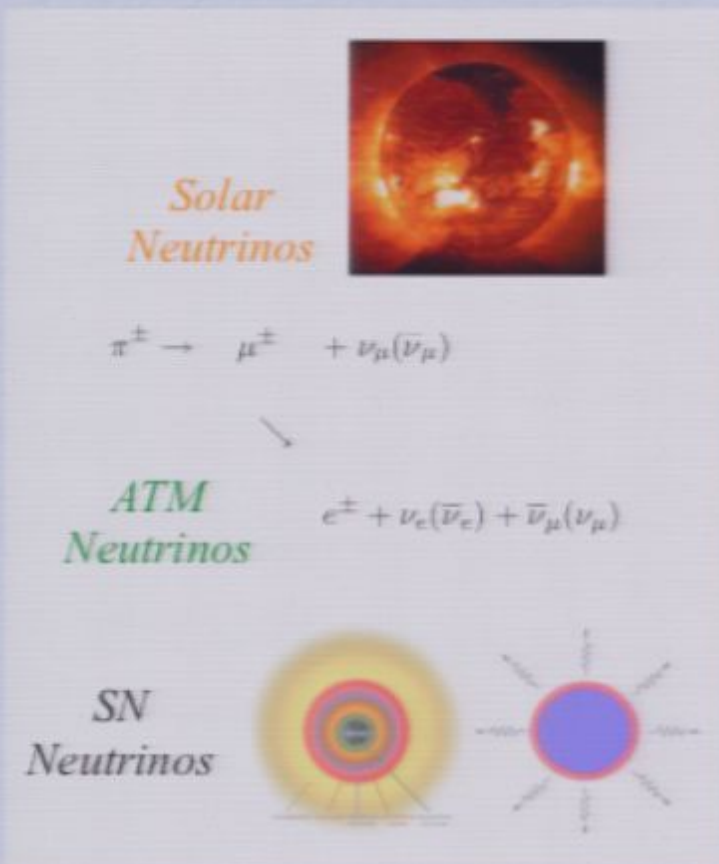
*Institute for Theoretical Physics, University of California, Santa Barbara, California 93106*

(Received 14 December 1984)

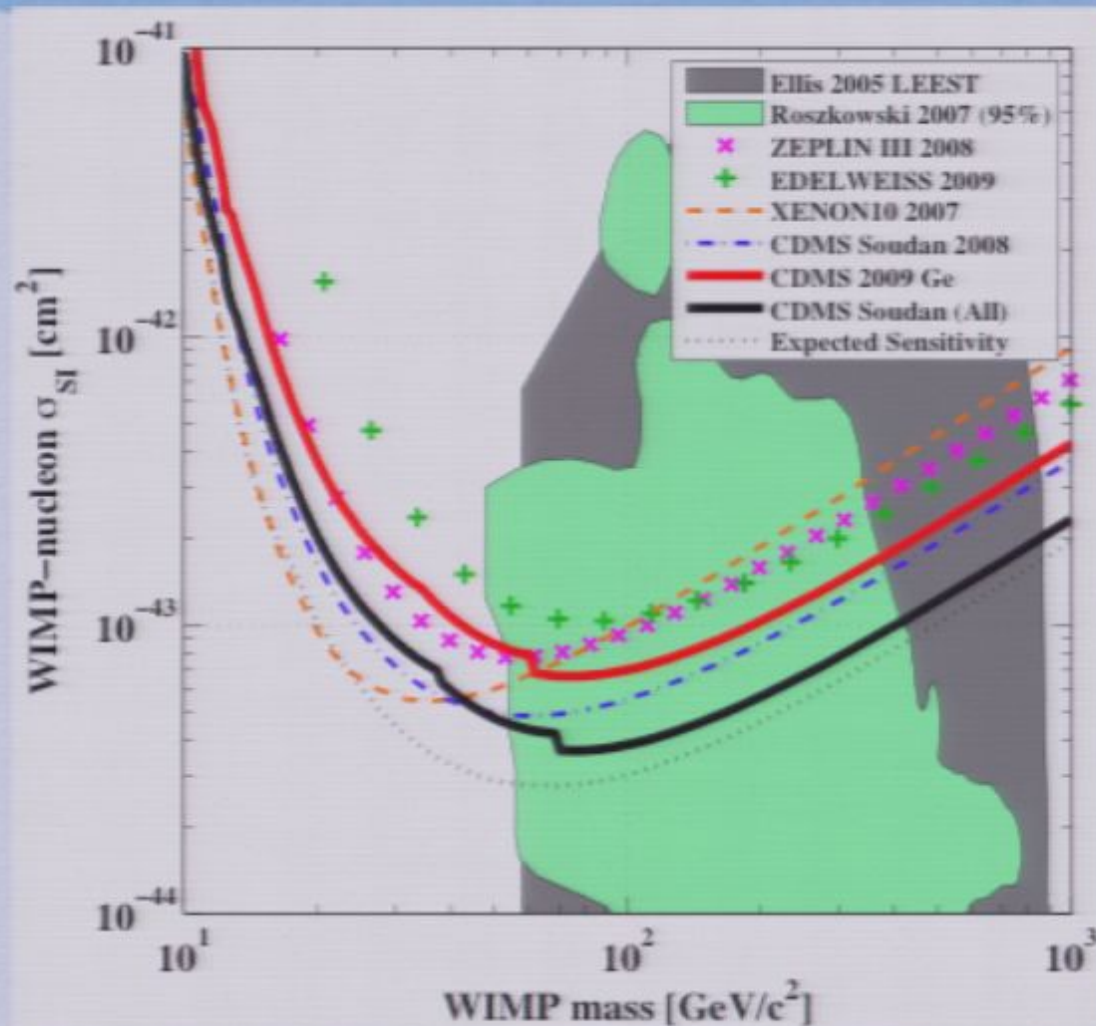


Fundamental prediction of the Standard Model, but not yet detected  
Freedman 1974 PRD, Tubbs & Schramm 1975

# Modern Predictions



# The End of Direct Detection

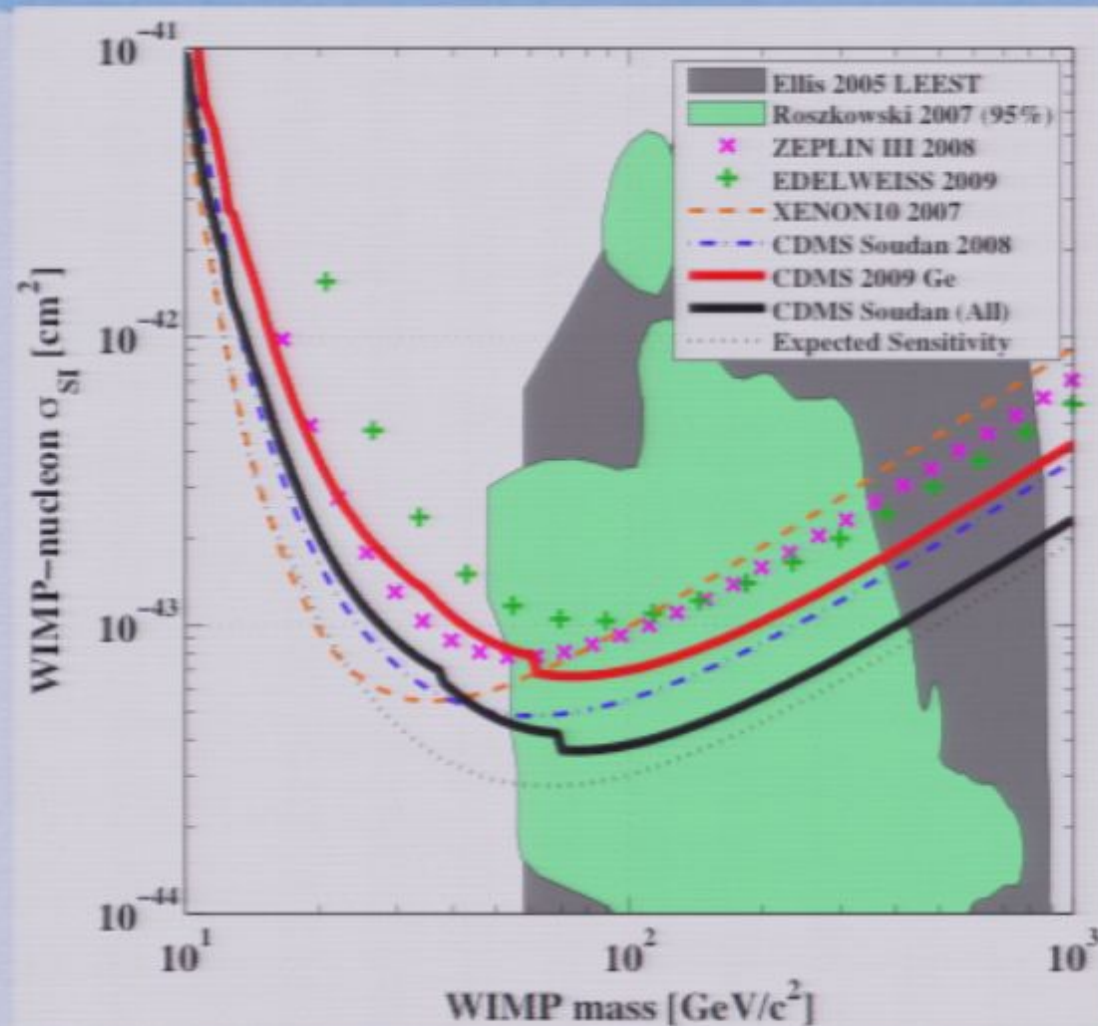


Neutrino backgrounds

# Outlook

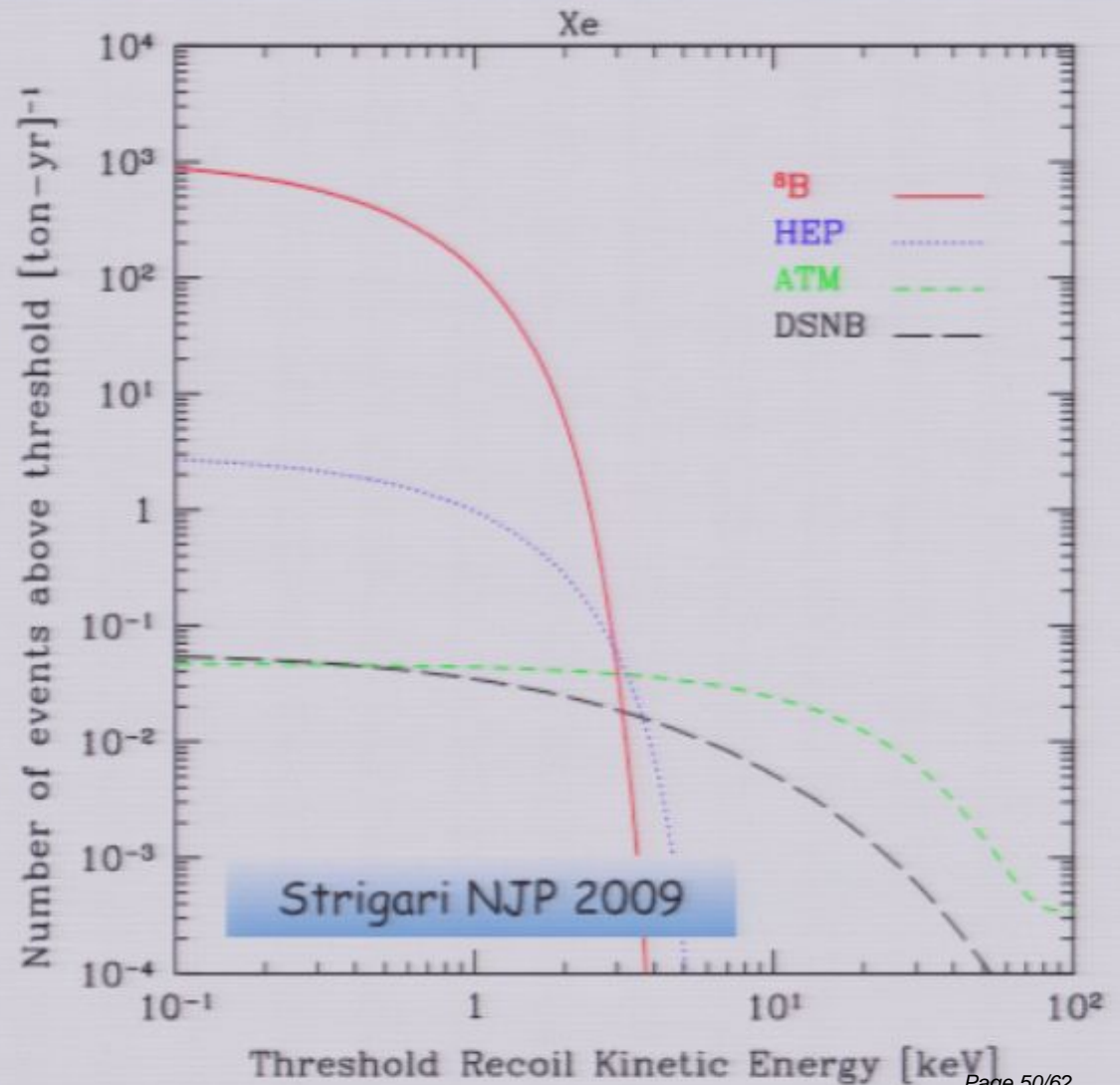
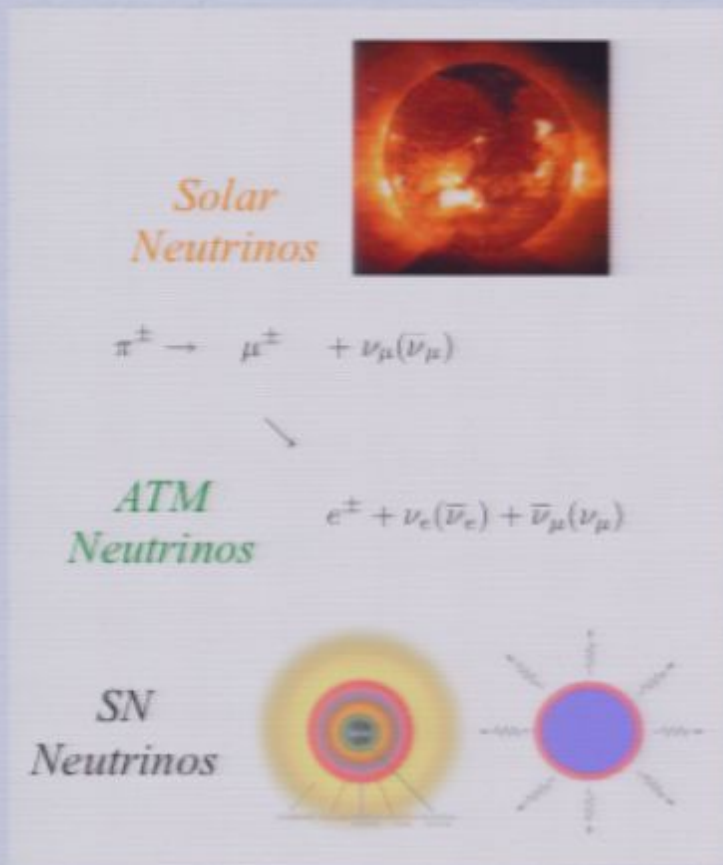


# The End of Direct Detection

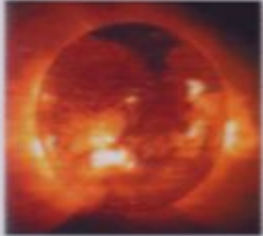


Neutrino backgrounds

# Modern Predictions

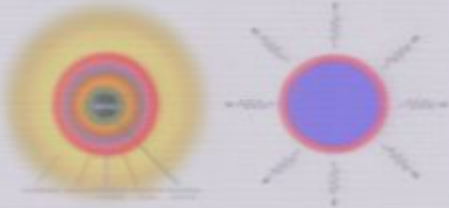


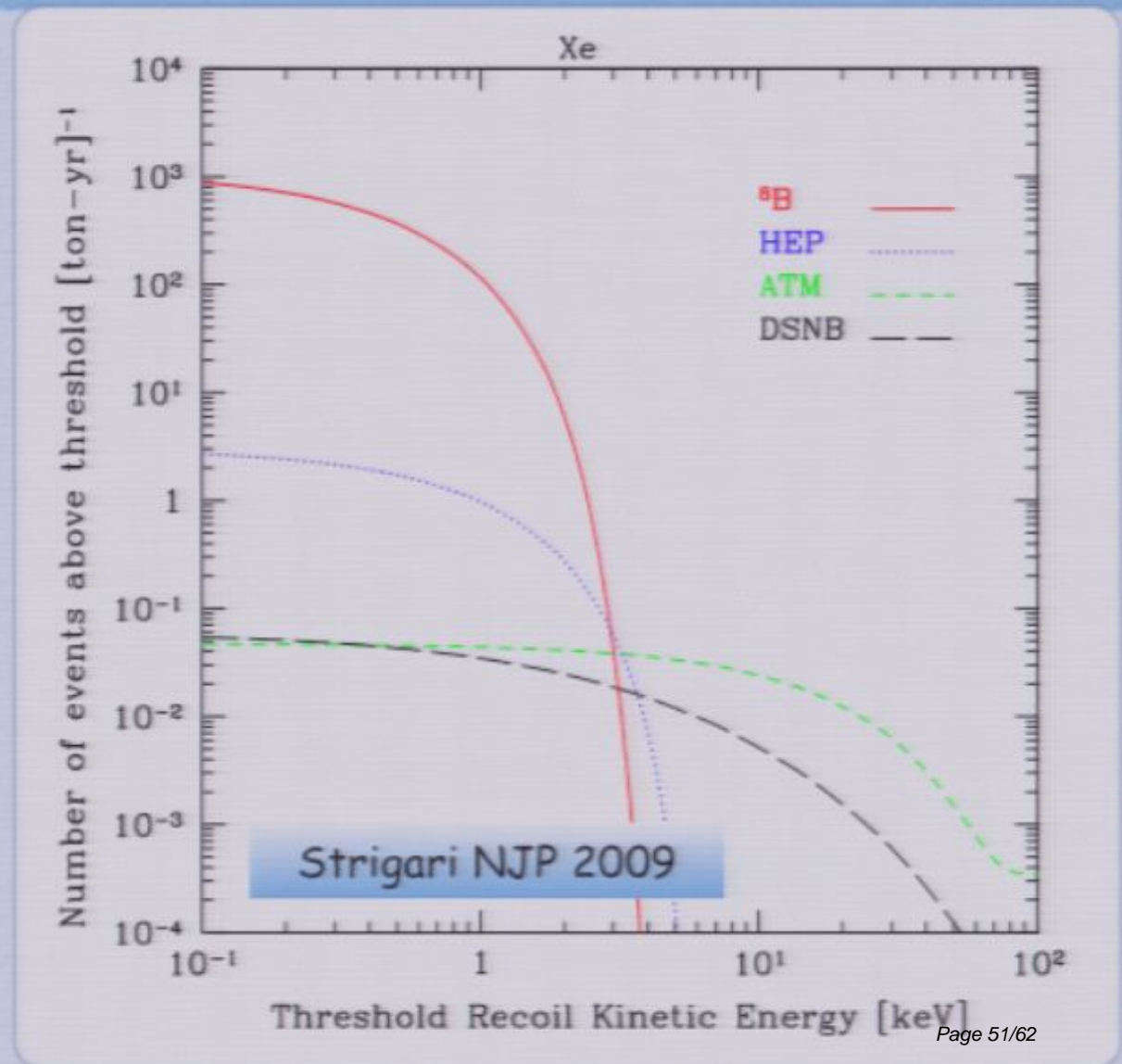
# Modern Predictions

*Solar Neutrinos* 

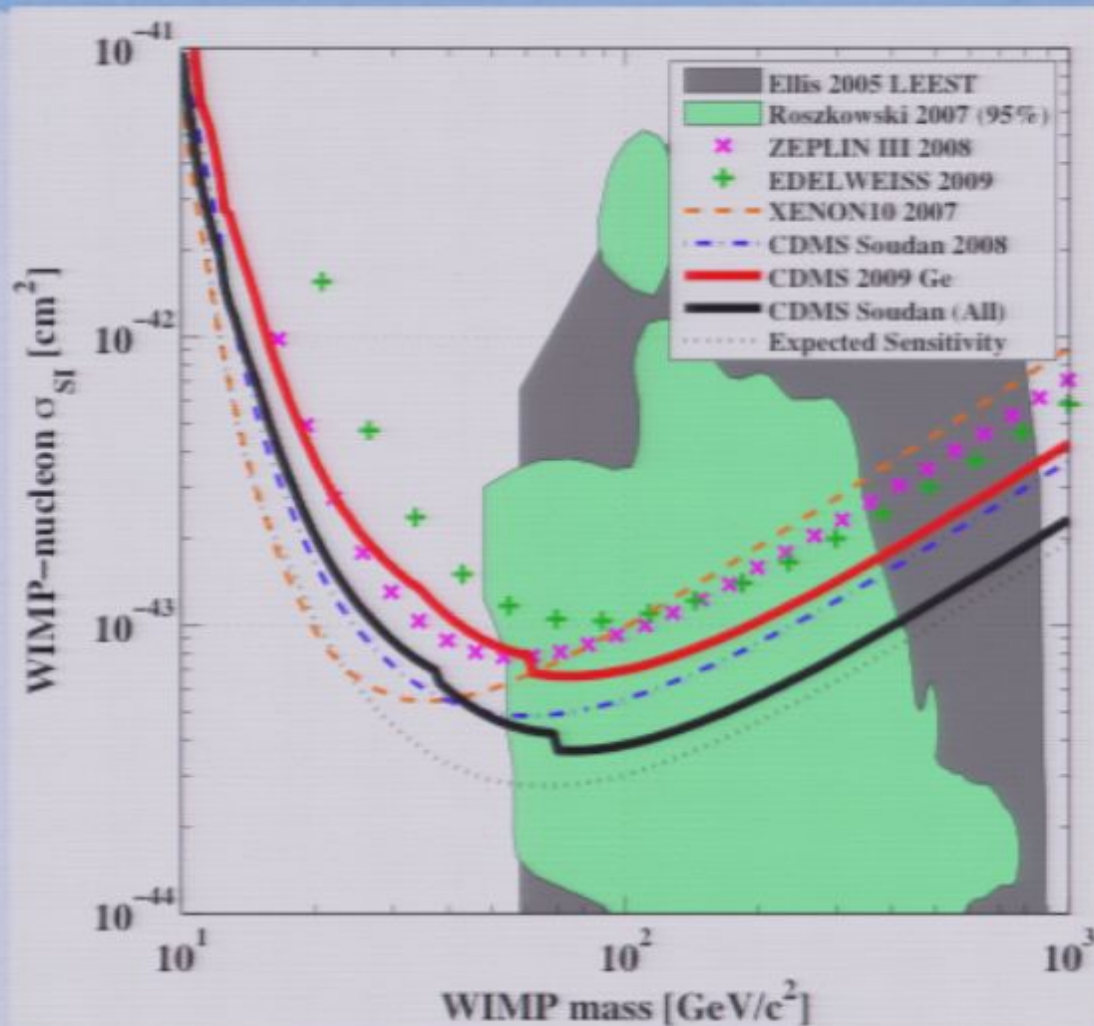
$$\pi^\pm \rightarrow \mu^\pm + \nu_\mu(\bar{\nu}_\mu)$$

*ATM Neutrinos*  $e^\pm + \nu_e(\bar{\nu}_e) + \bar{\nu}_\mu(\nu_\mu)$

*SN Neutrinos* 



# The End of Direct Detection



Neutrino backgrounds

# Outlook

- Search for WIMP dark matter is progressing rapidly
- Fermi dwarf limits getting very interesting.
  - Stacking analysis forthcoming

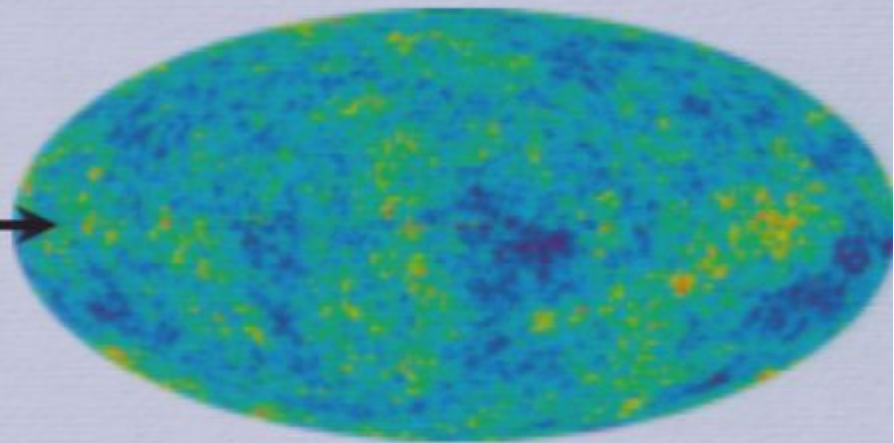
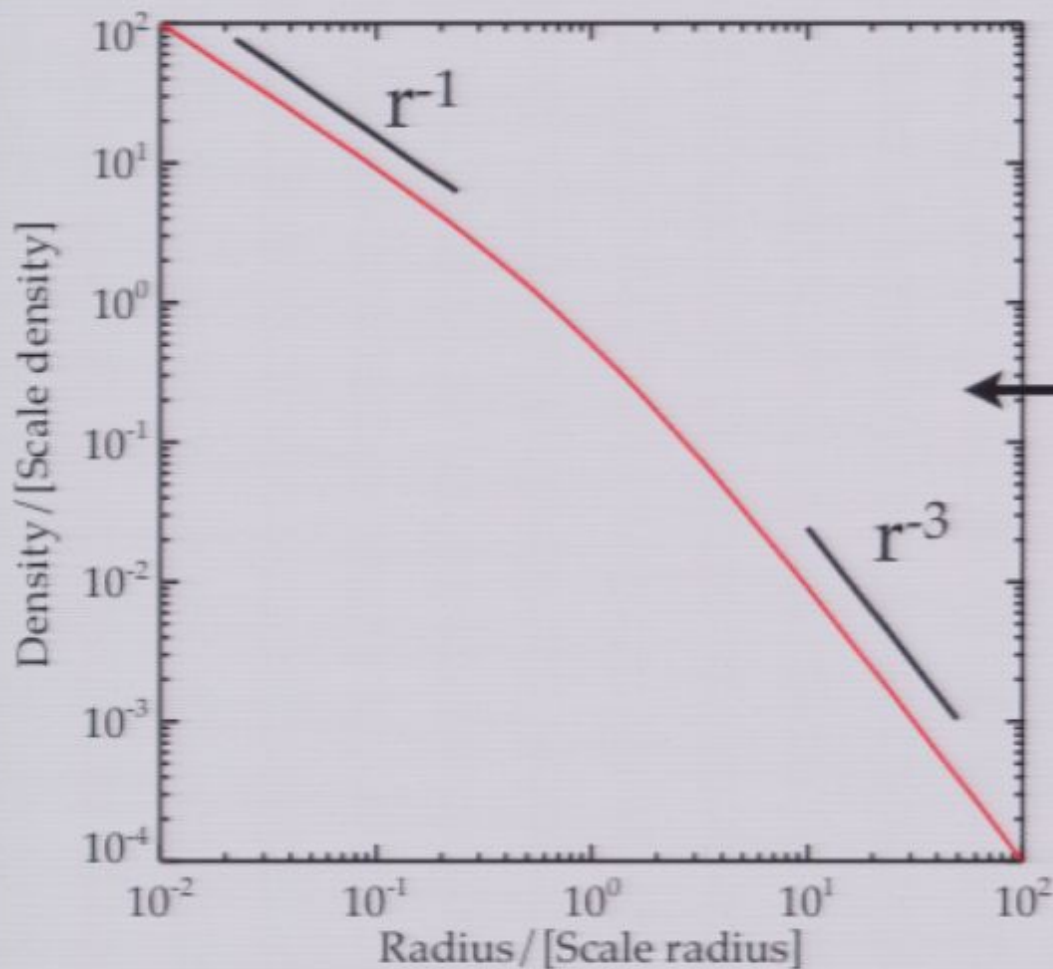
# Outlook

- Search for WIMP dark matter is progressing rapidly
- Fermi dwarf limits getting very interesting.
  - Stacking analysis forthcoming
  - New objects are being discovered
- WIMP direct detection limits becoming stringent
  - Interpretations important

# Outlook

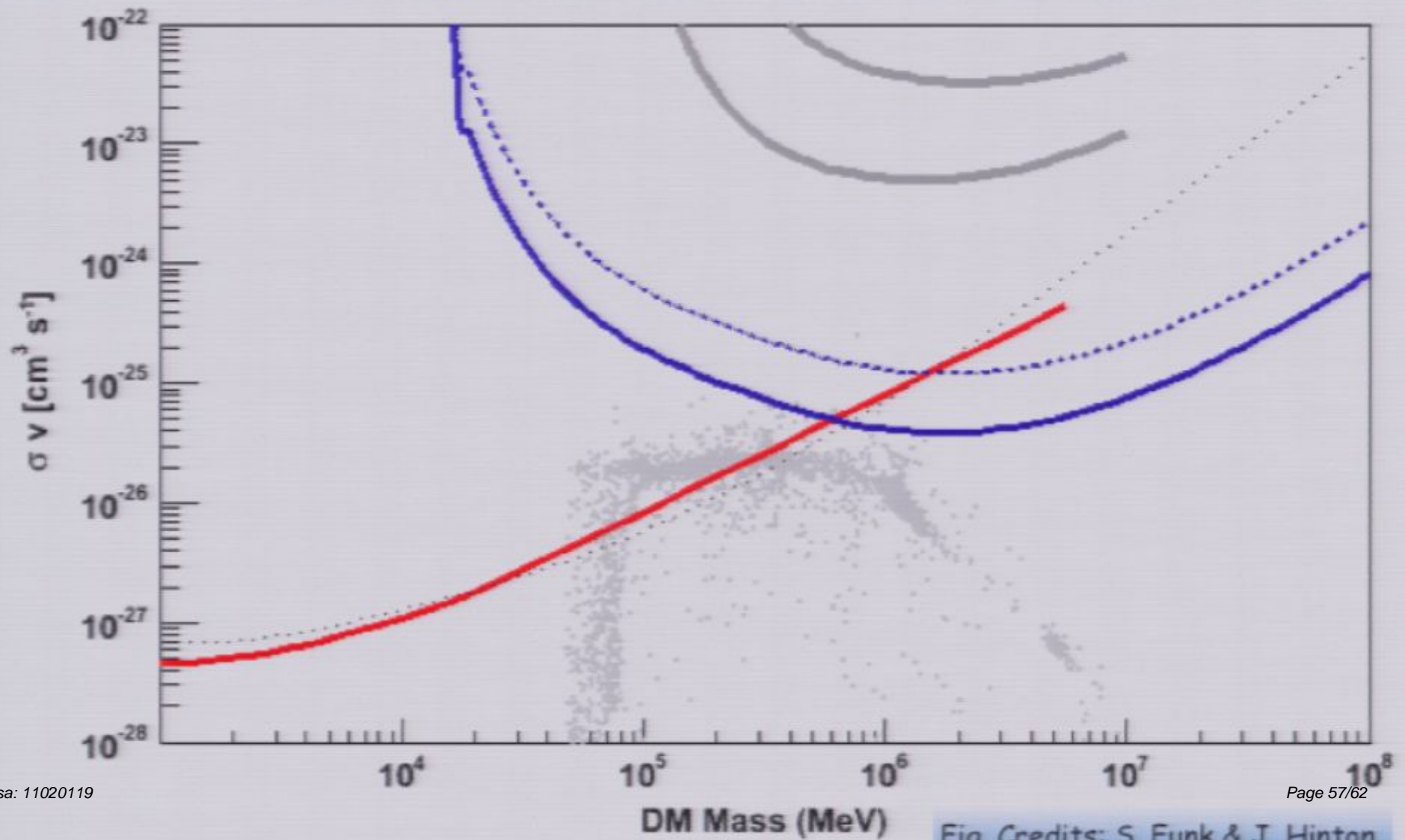
- Search for WIMP dark matter is progressing rapidly
- Fermi dwarf limits getting very interesting.
  - Stacking analysis forthcoming
  - New objects are being discovered
- WIMP direct detection limits becoming stringent
  - Interpretations important
  - Guaranteed signal

# Theory of Dark Matter Halos

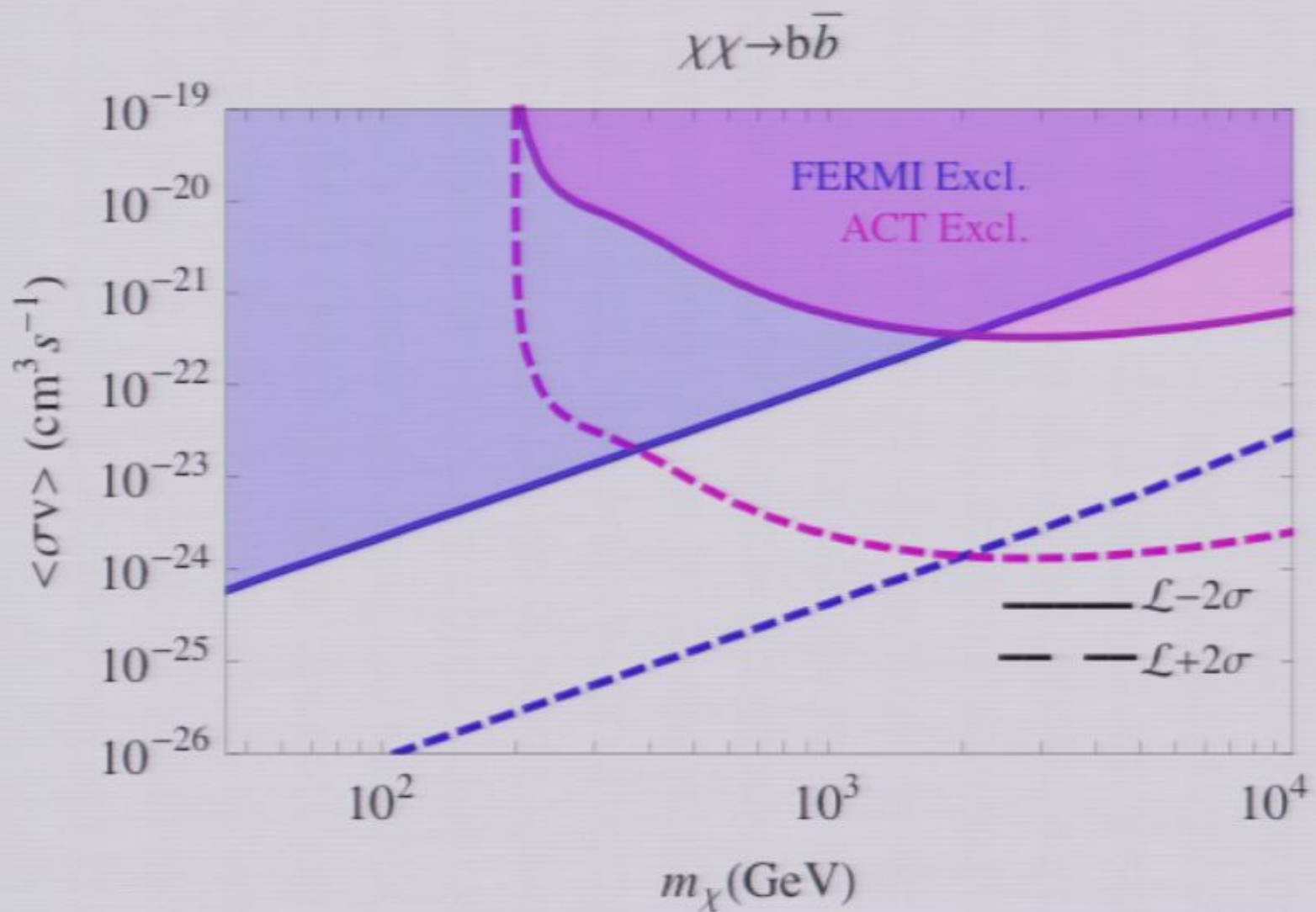




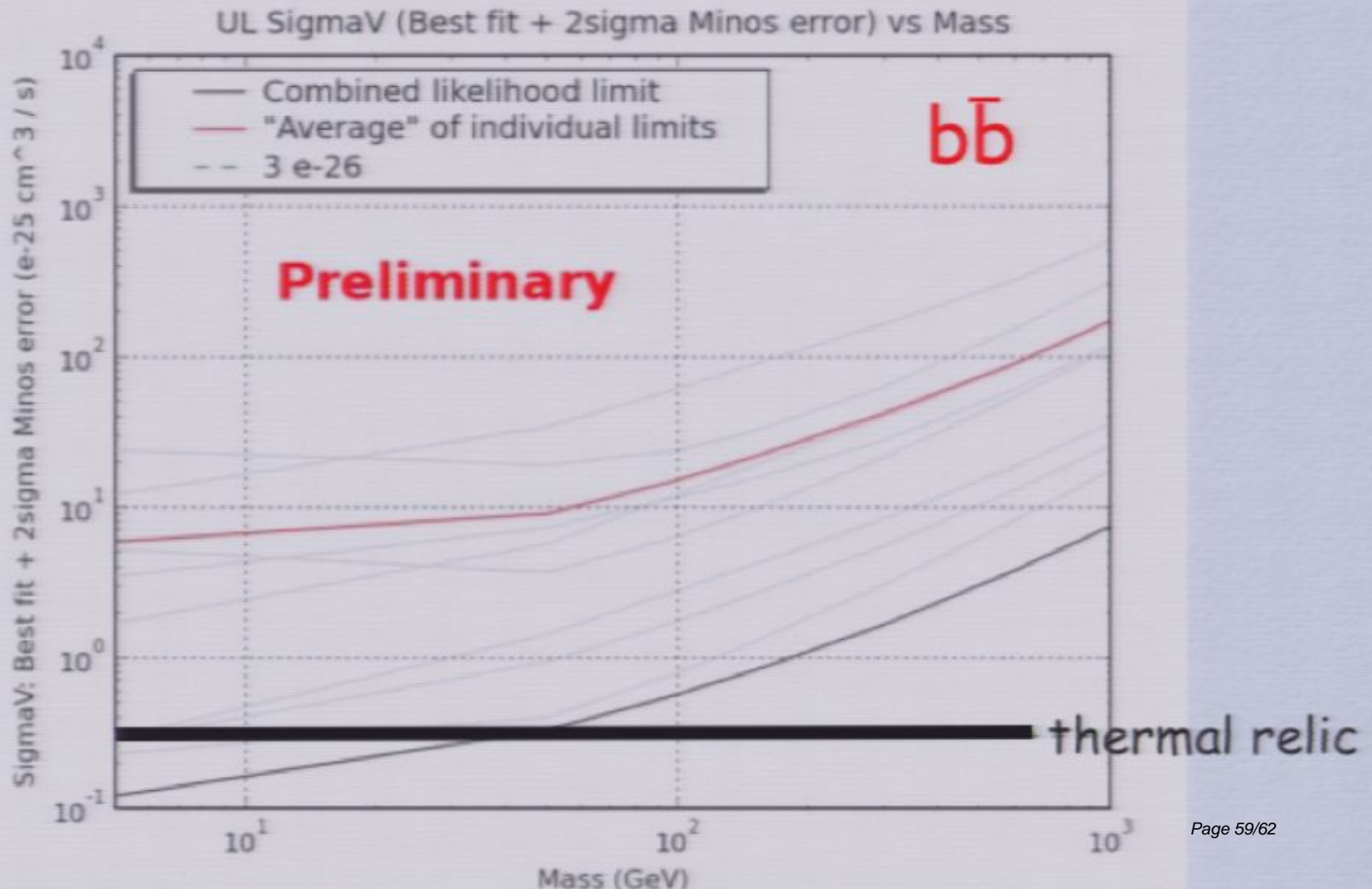
# Projected limits



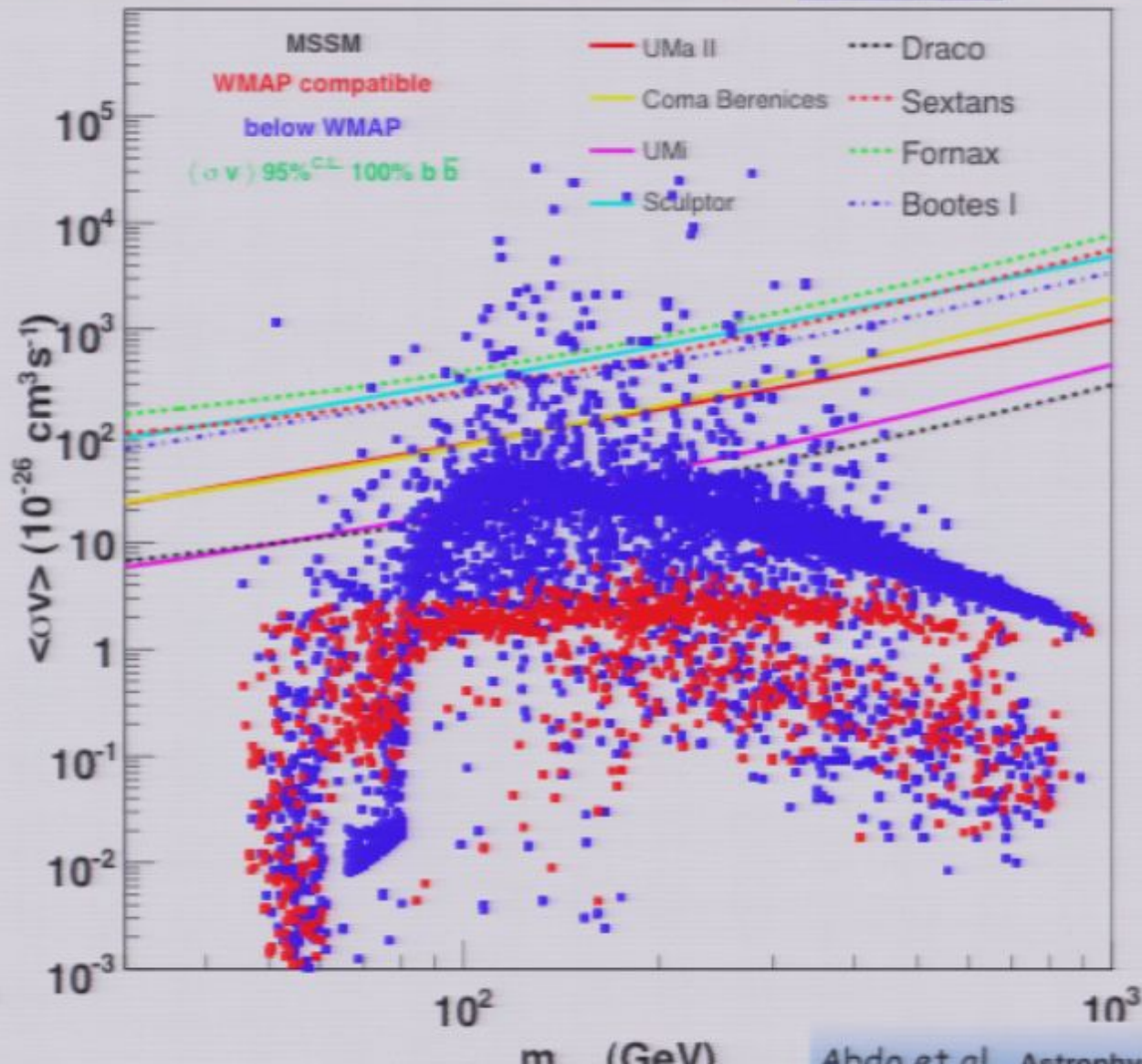
# Gamma-ray limits: Segue 1



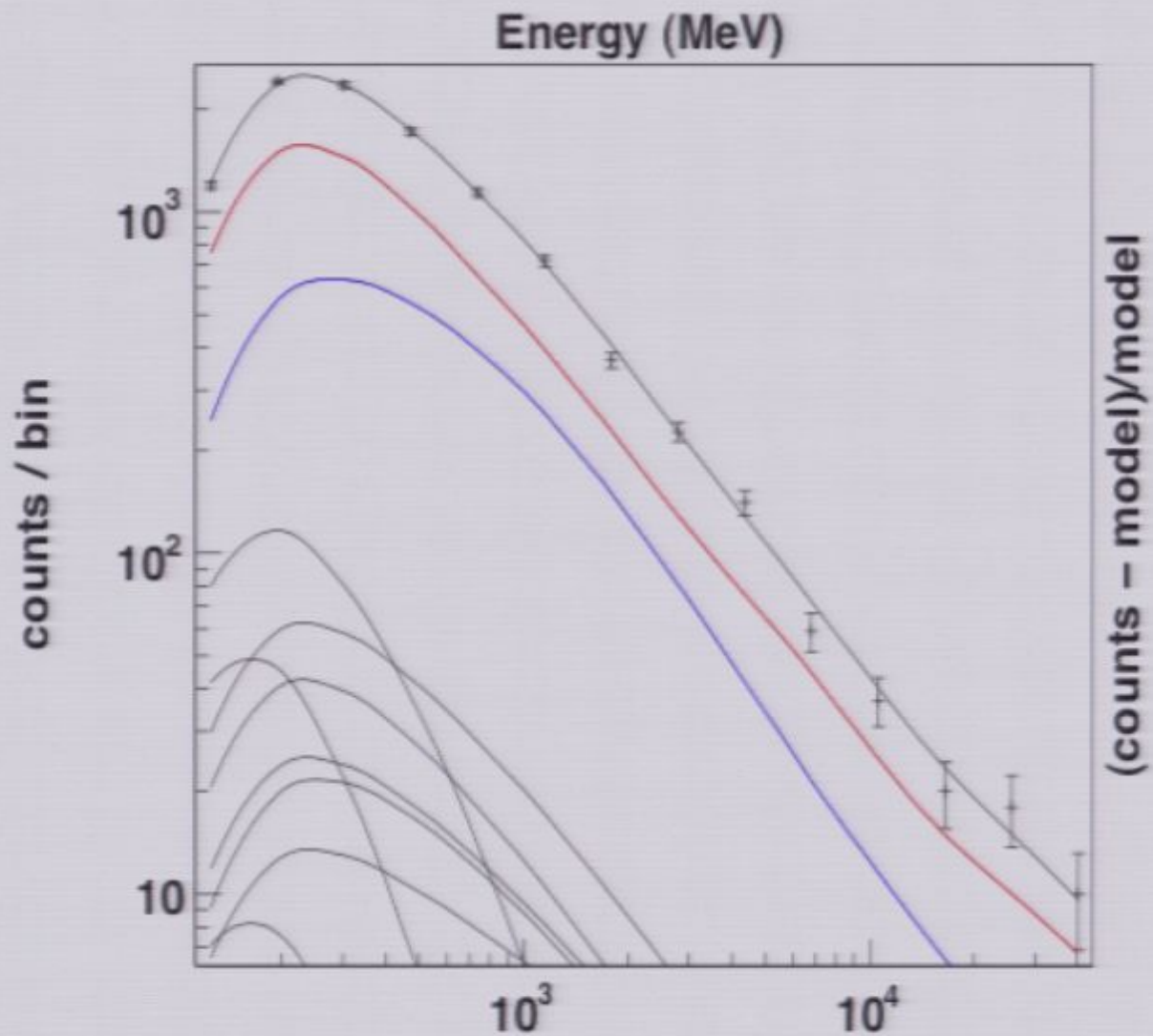
# Limits for Stacked Dwarfs



# FERMI



# Gamma-ray modeling



# FERMI

