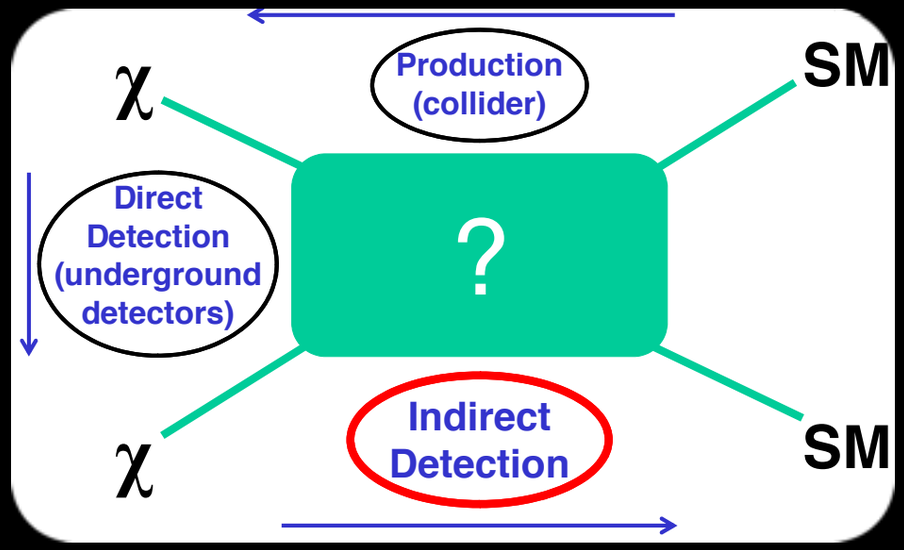
INDIRECT DM DETECTION
FERMI-LAT

BRANDON ANDERSON

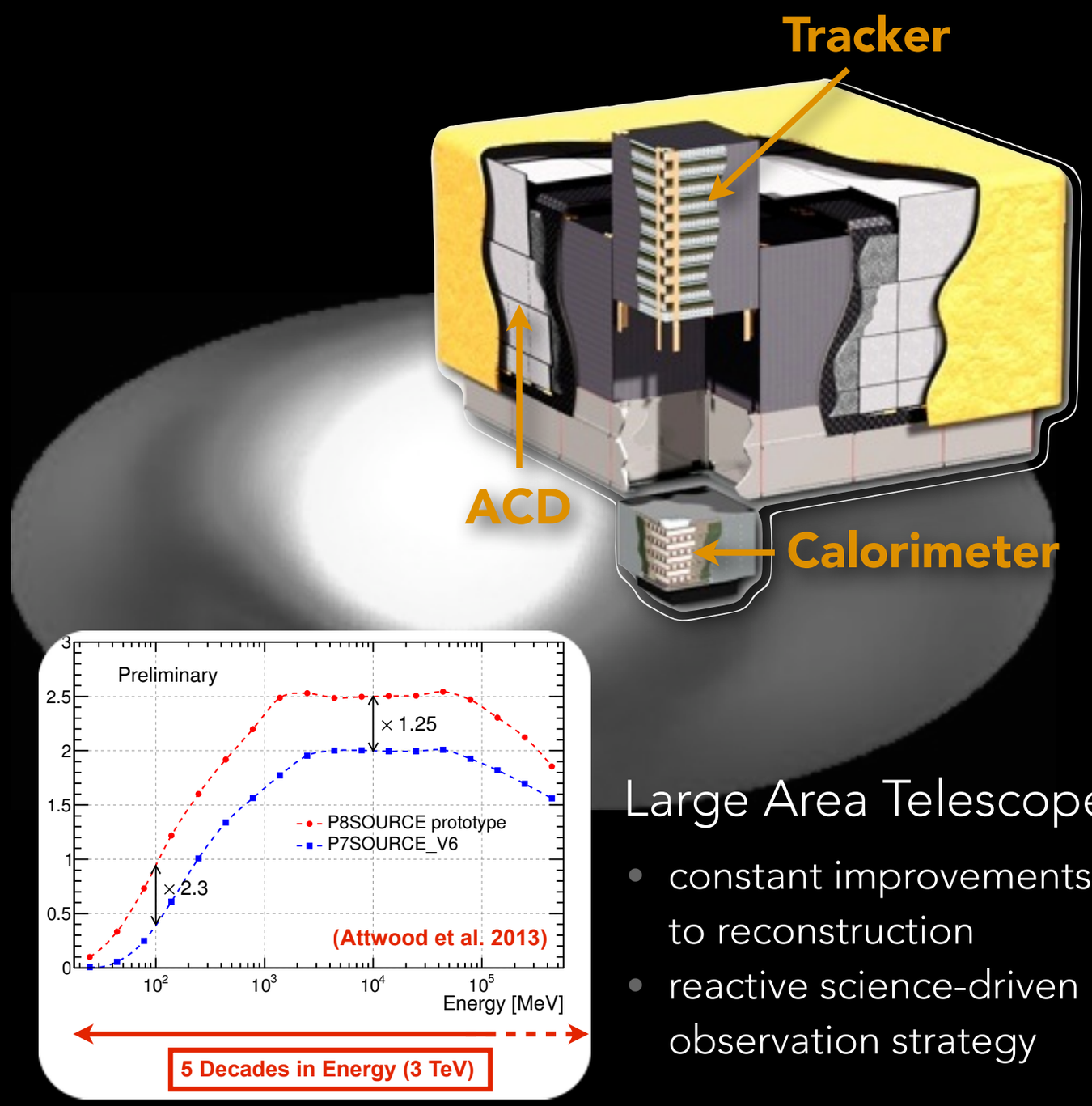
WHAT IS THE DARK MATTER?

MAY 12, 2014

INTRO



- gamma rays let us use the universe as a lab, relating information about highly concentrated DM regions

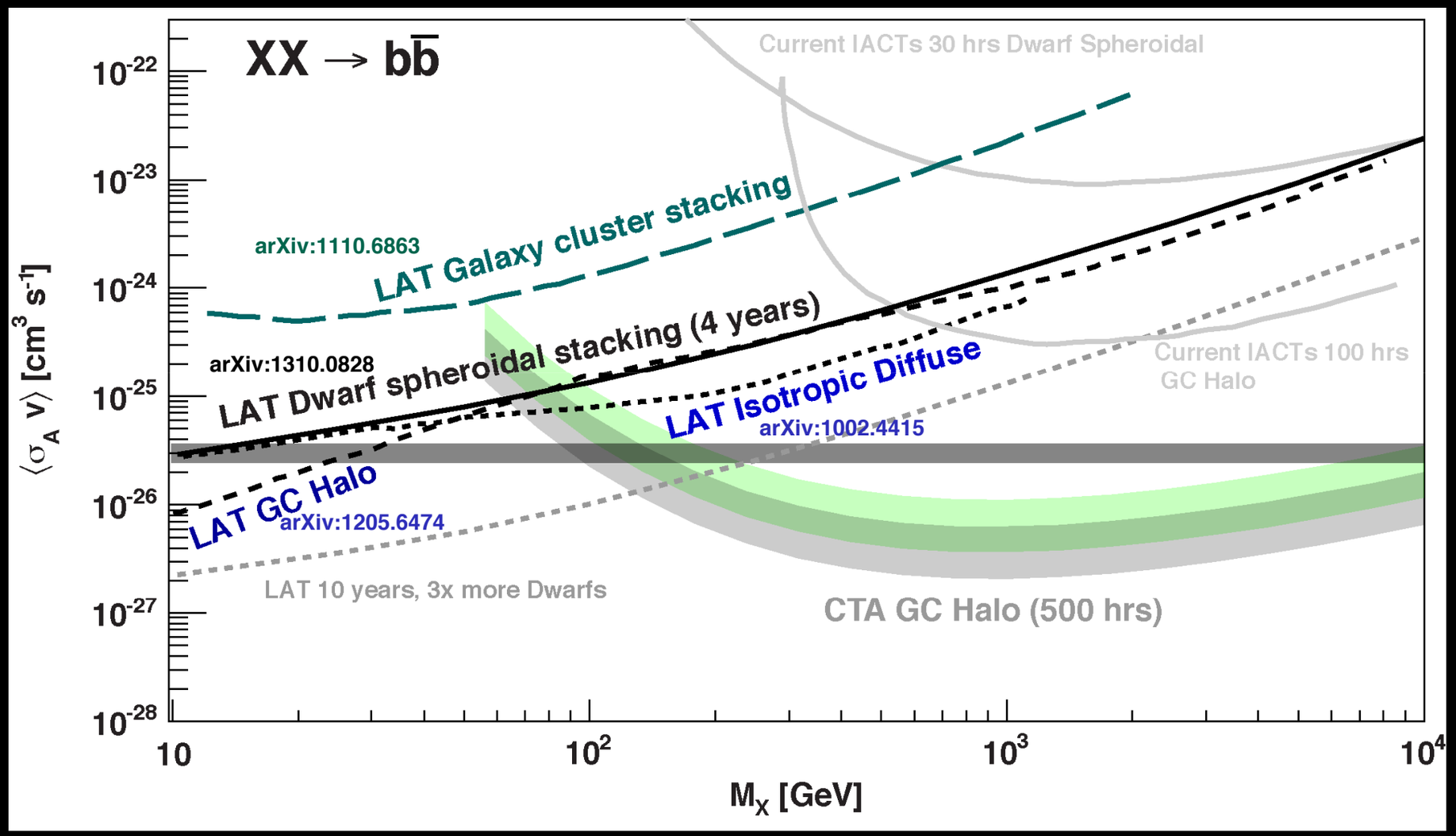


Large Area Telescope

- constant improvements to reconstruction
- reactive science-driven observation strategy

$$\frac{d\Phi_\gamma}{dE_\gamma} = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\sum_f \frac{dN_\gamma^f}{dE_\gamma}B_f}_{\texttt{particle}} \underbrace{\int_{\Delta\Omega} d\Omega \int_{los} \rho^2(l)\; dl(\psi)\; d\Omega}_{\texttt{astro}}$$

INTRO



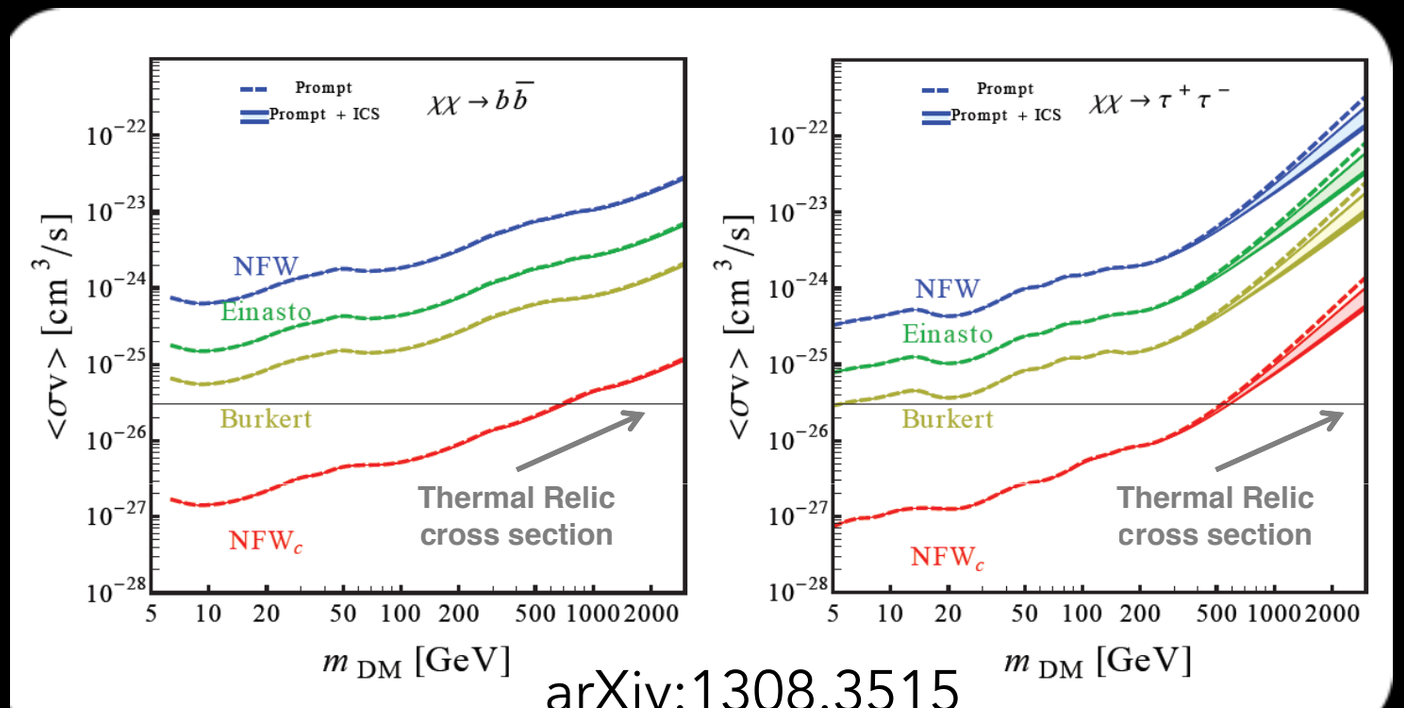
- no solid detections, but great progress with varied approaches!

EVERYTHING IS DARK

MATTER!

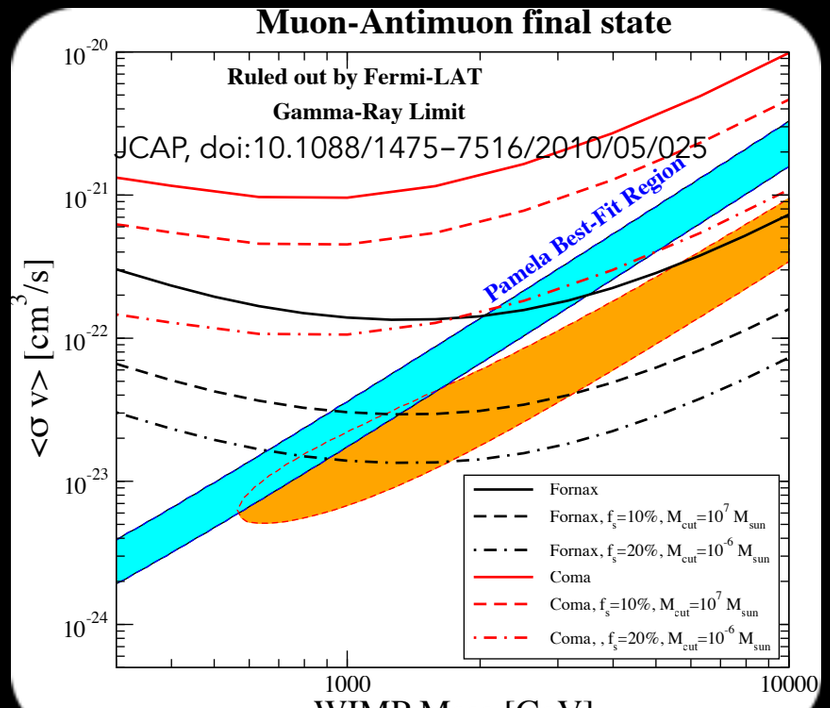
DARK MATTER *ONLY*

Inner Galaxy



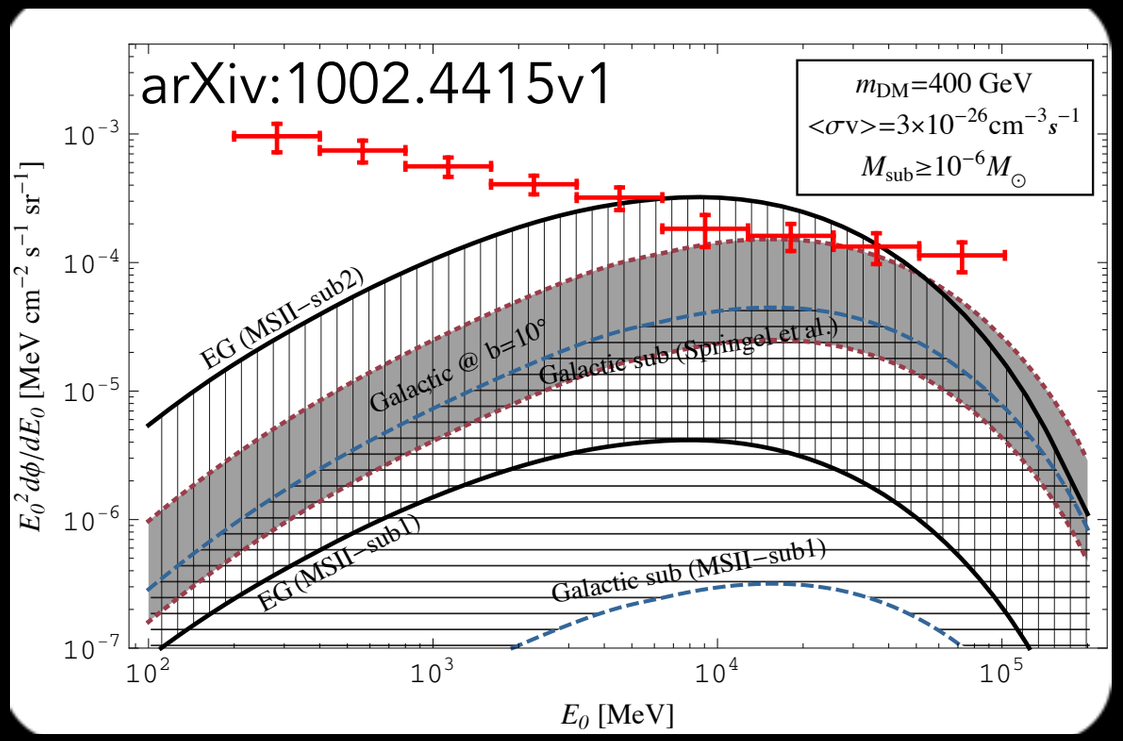
arXiv:1308.3515

Galaxy Clusters



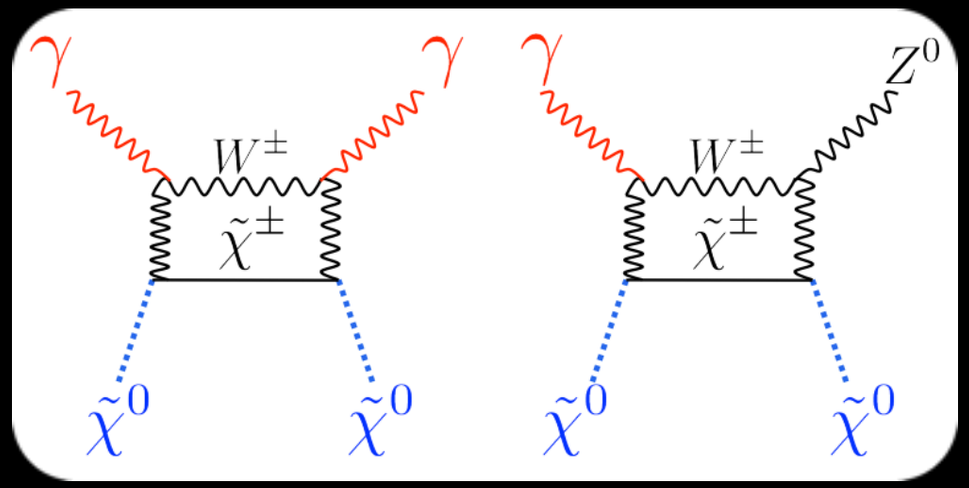
- general strategy: assume dark matter does not overproduce entire observation
- pick regions with high signal-to-noise, don't model anything
- ask Stephan Zimmer for more on clusters!

Isotropic



NO ASTROPHYSICAL BACKGROUND

LINE SEARCH

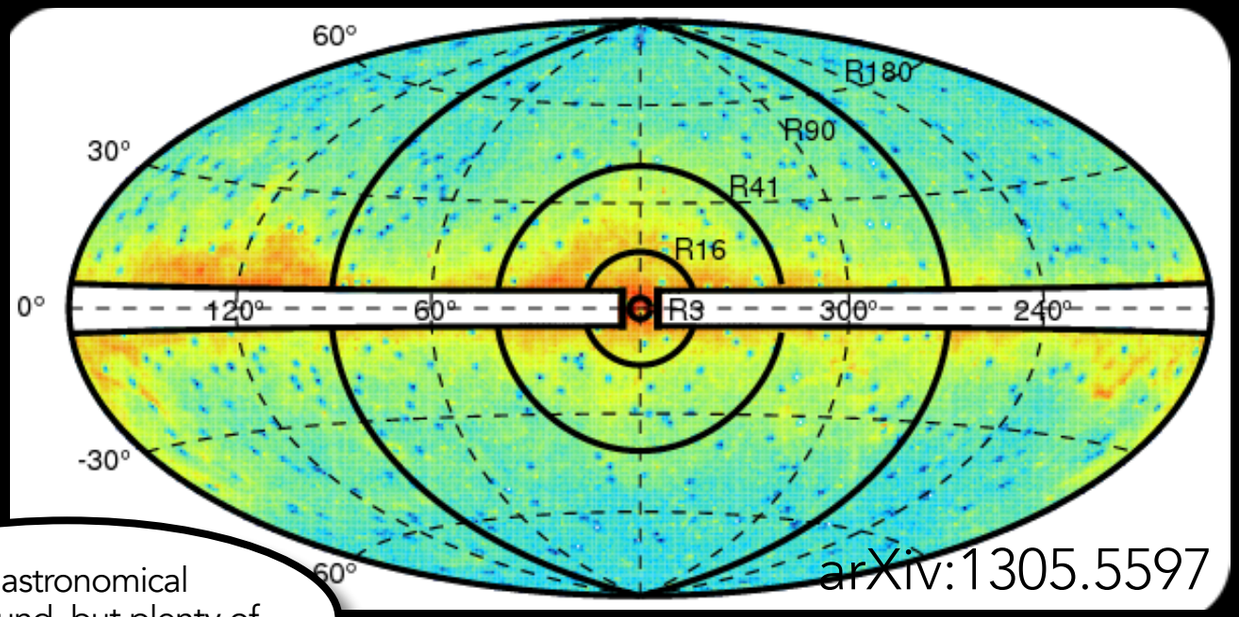


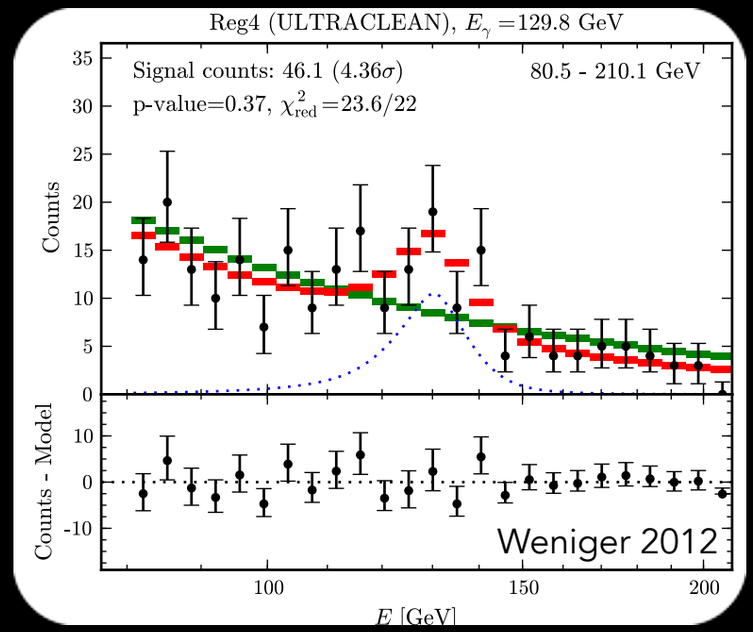
NOTHING ELSE MAKES THIS!

- means we don’t have to model competing processes
- loop-suppressed, however, so requires a high j-factor region

LINE SEARCH

GALACTIC CENTER





No astronomical background, but plenty of systematics.

Predicted Spectrum — Signal Model — Background Model

$$C(E', P_{\rm E}|\vec{\alpha}) = n_{\rm sig} D_{\rm eff}(E', P_{\rm E}|E_\gamma) w_{\rm sig}(P_{\rm E}) + \frac{n_{\rm bkg}}{c_{\rm bkg}} \left(\frac{E'}{E_0}\right)^{-\Gamma_{\rm bkg}} \eta(E') w_{\rm bkg}(P_{\rm E})$$

$$D_{\rm eff}(E'; E_\gamma) = \int^{FoV} \int^{ROI} D(E'; \theta|E_\gamma) \frac{I_{\rm sig}(\hat{p}) \mathcal{E}(\hat{p}, \theta, E_\gamma)}{n_{\rm sig}} d\Omega d\Omega_{\hat{v}}$$

Effective Energy Dispersion

Incorporates energy reconstruction quality (P_E)

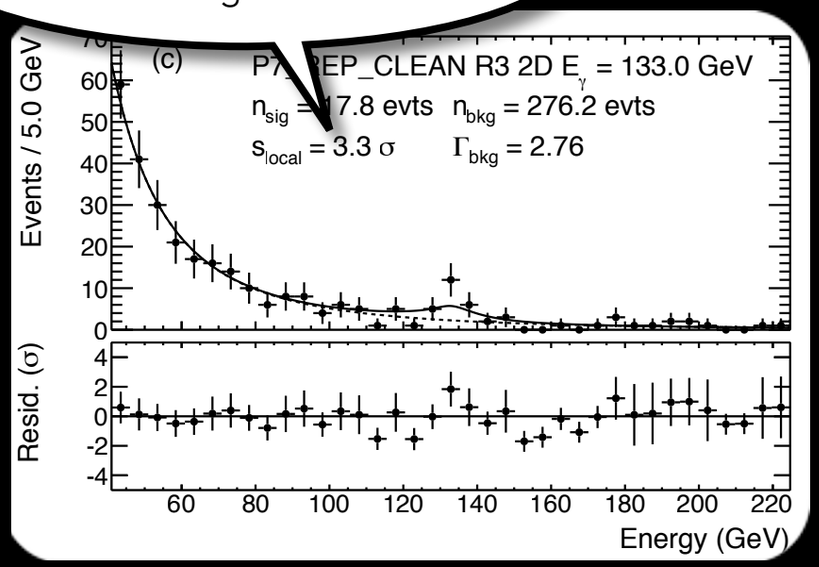
$$\eta(E') = \int^{FoV} \int^{ROI} \frac{I_{\rm bkg}(\hat{p}) \mathcal{E}(\hat{p}, \theta, E_\gamma)}{n_{\rm bkg}} d\Omega d\Omega_{\hat{v}}$$

Effective Area Corrections

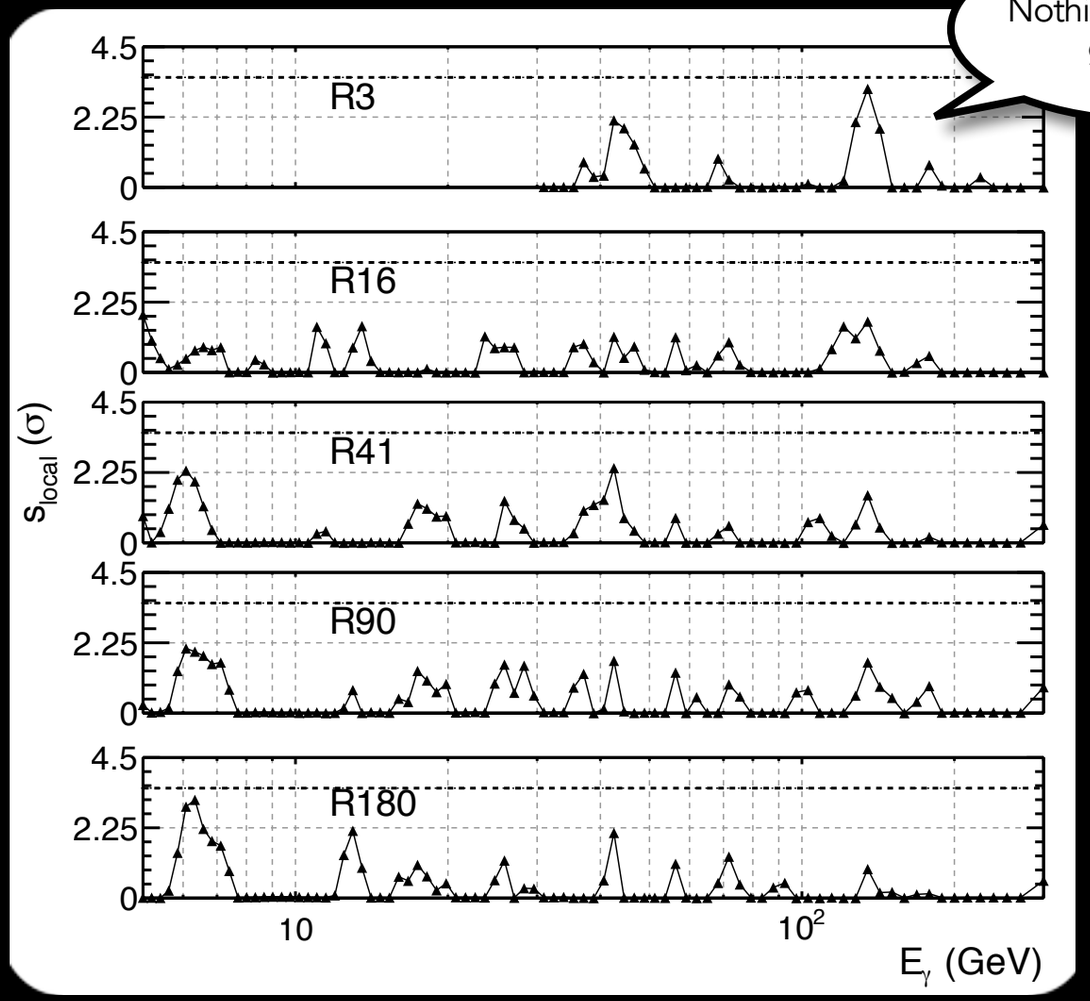
LINE SEARCH

GALACTIC CENTER

Using 2-D point spread function, highest significance is 3.3 sigma.

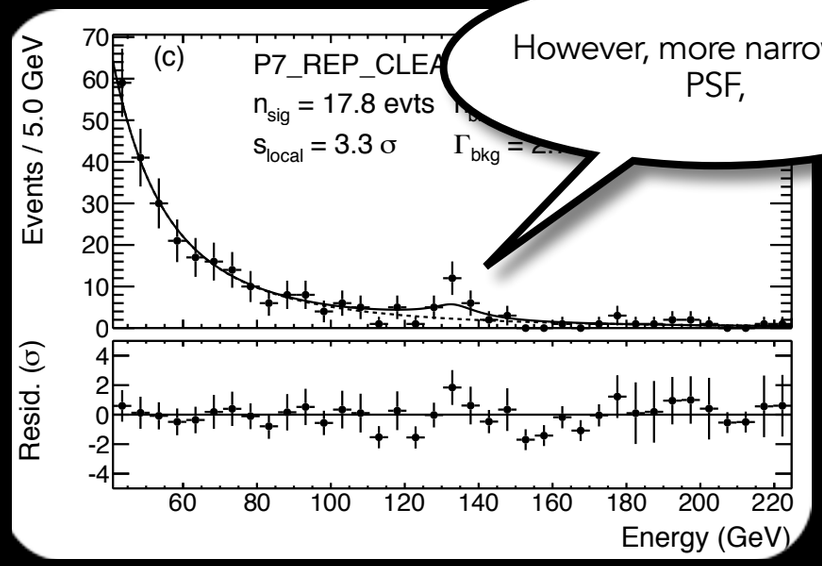


Nothing stands out globally.

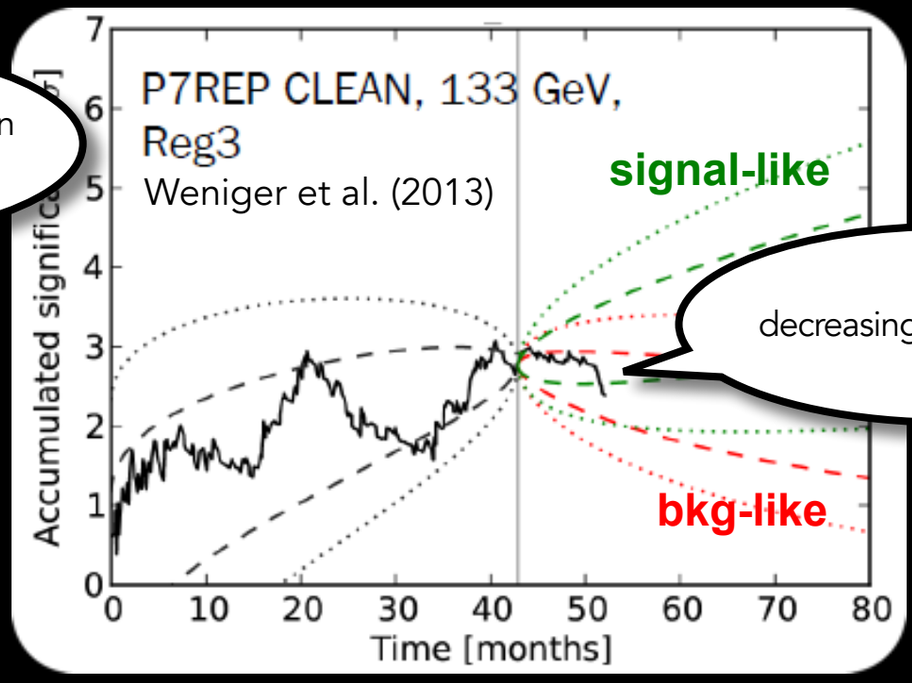


LINE SEARCH

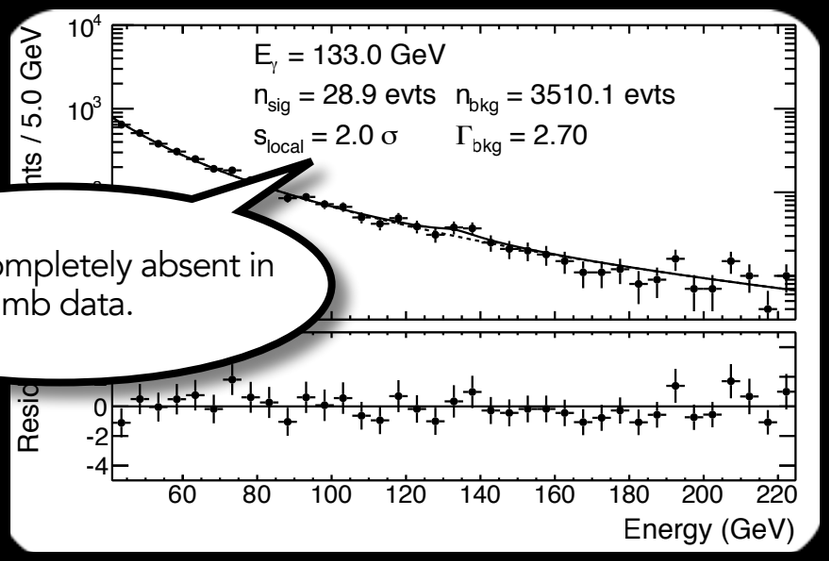
GALACTIC CENTER



However, more narrow than PSF,



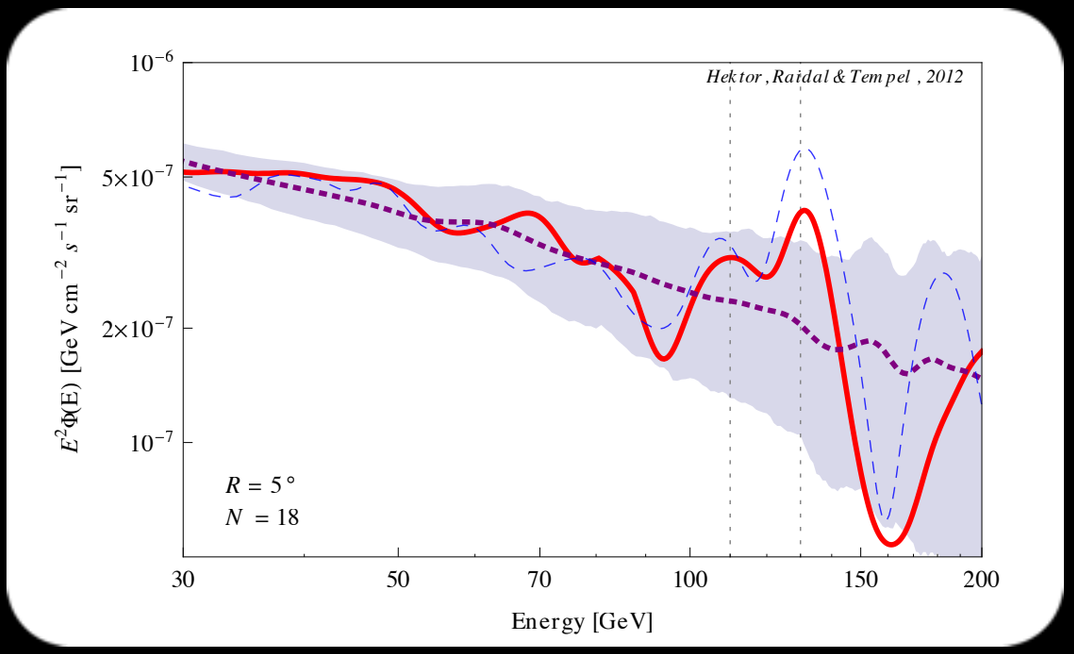
decreasing in significance,

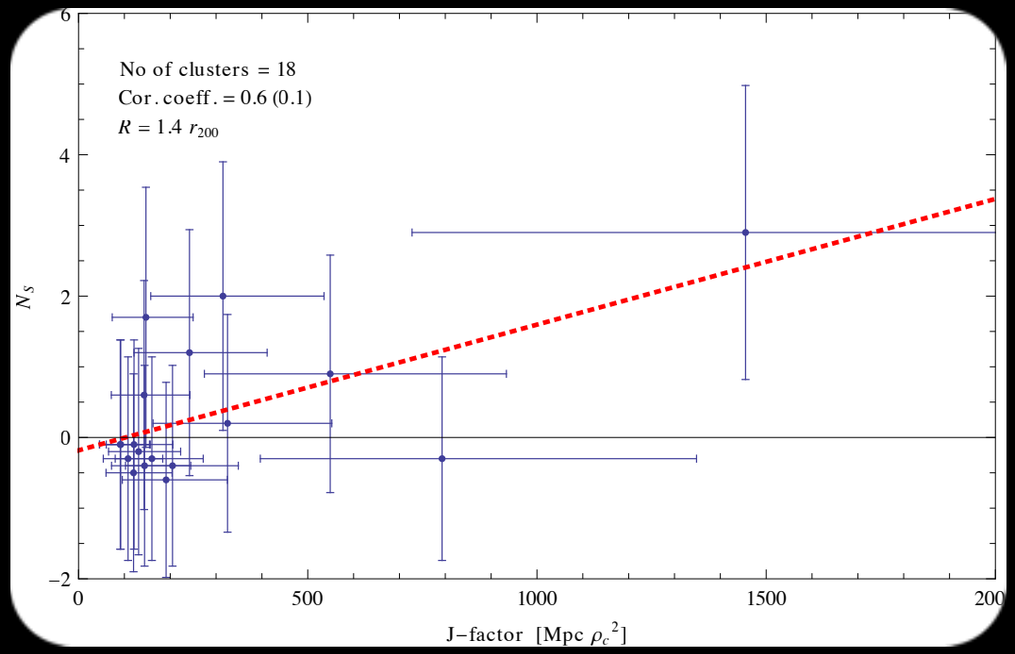


and not completely absent in limb data.

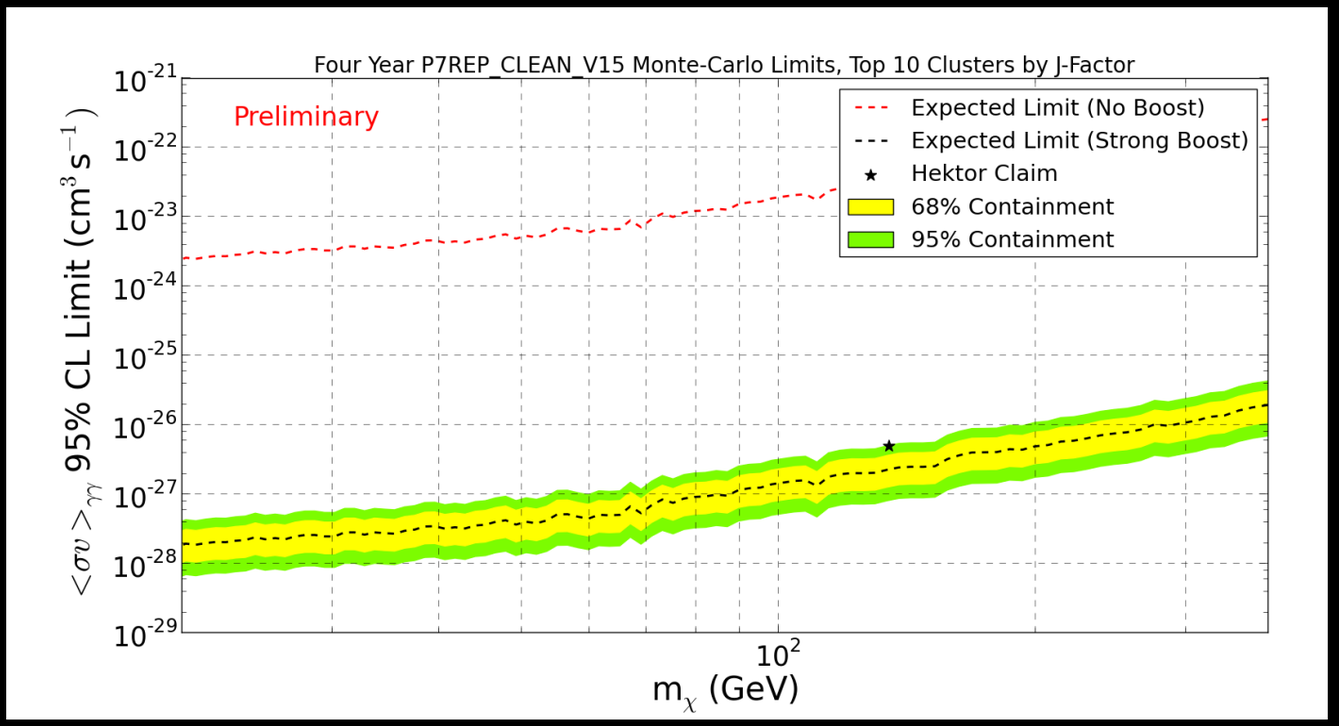
LINE SEARCH

GALAXY CLUSTERS



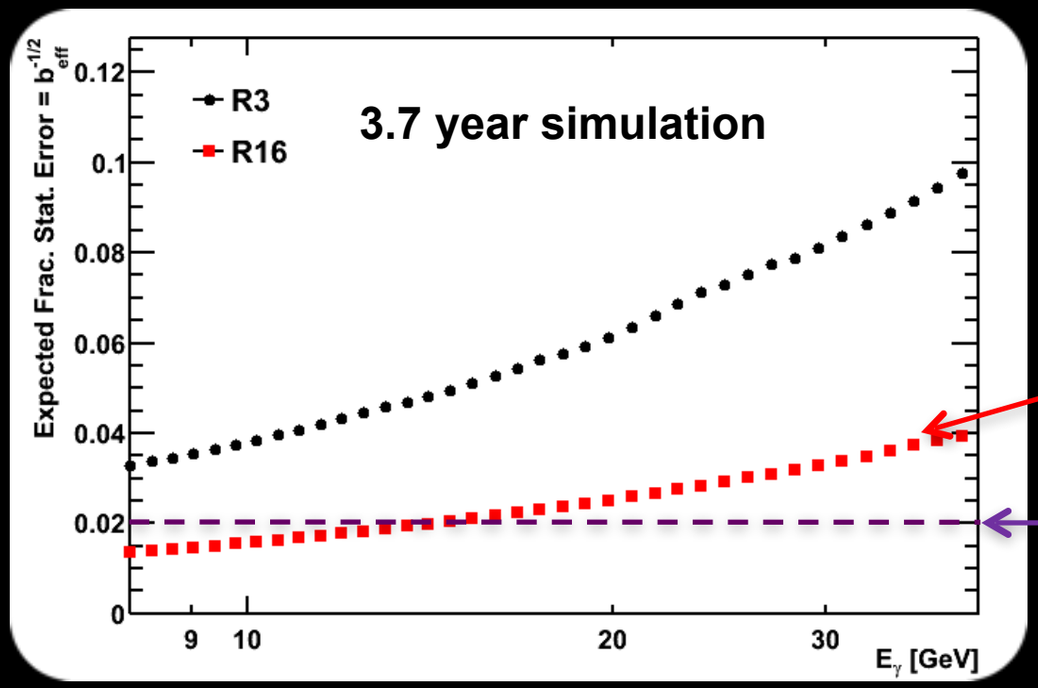


- claim for 3.6 sigma detection in 18 cluster set
- Fermi follow-up joint-likelihood analysis should be sensitive, results very soon



LINE SEARCH

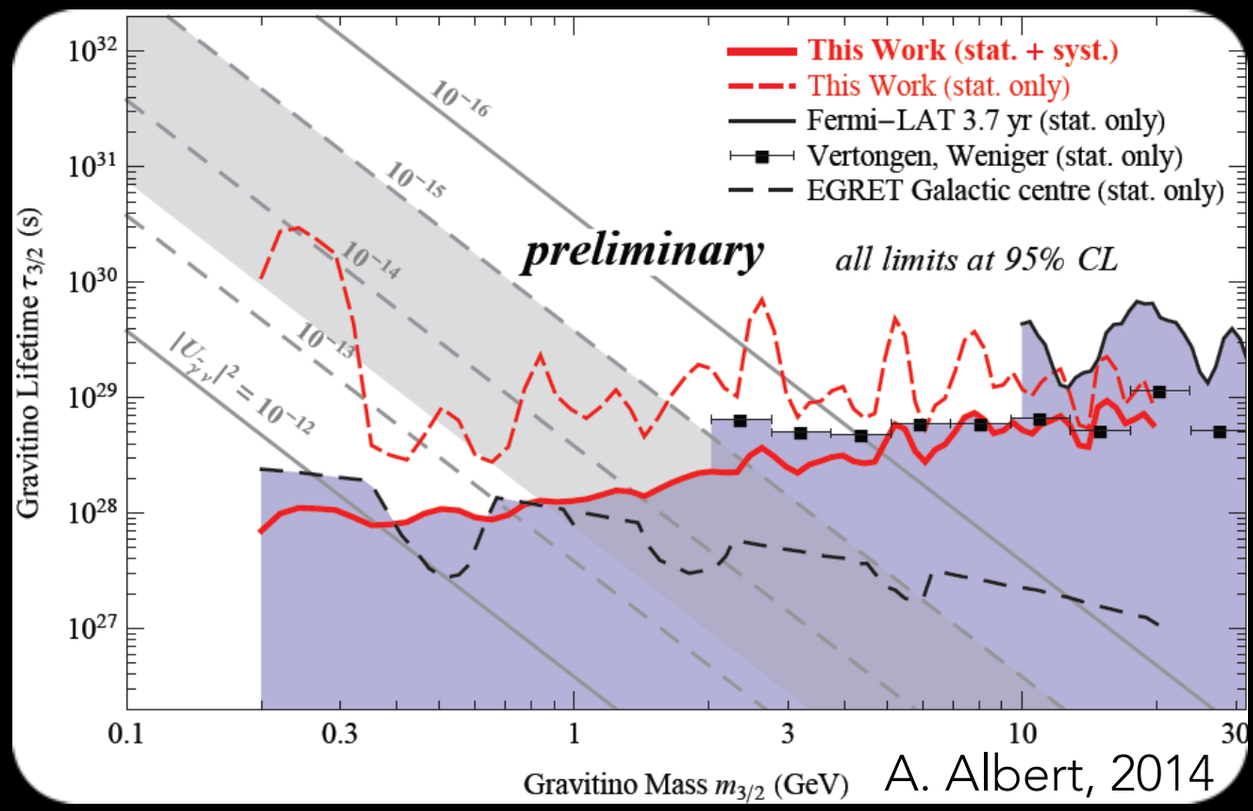
LOW ENERGY



Stat uncertainty

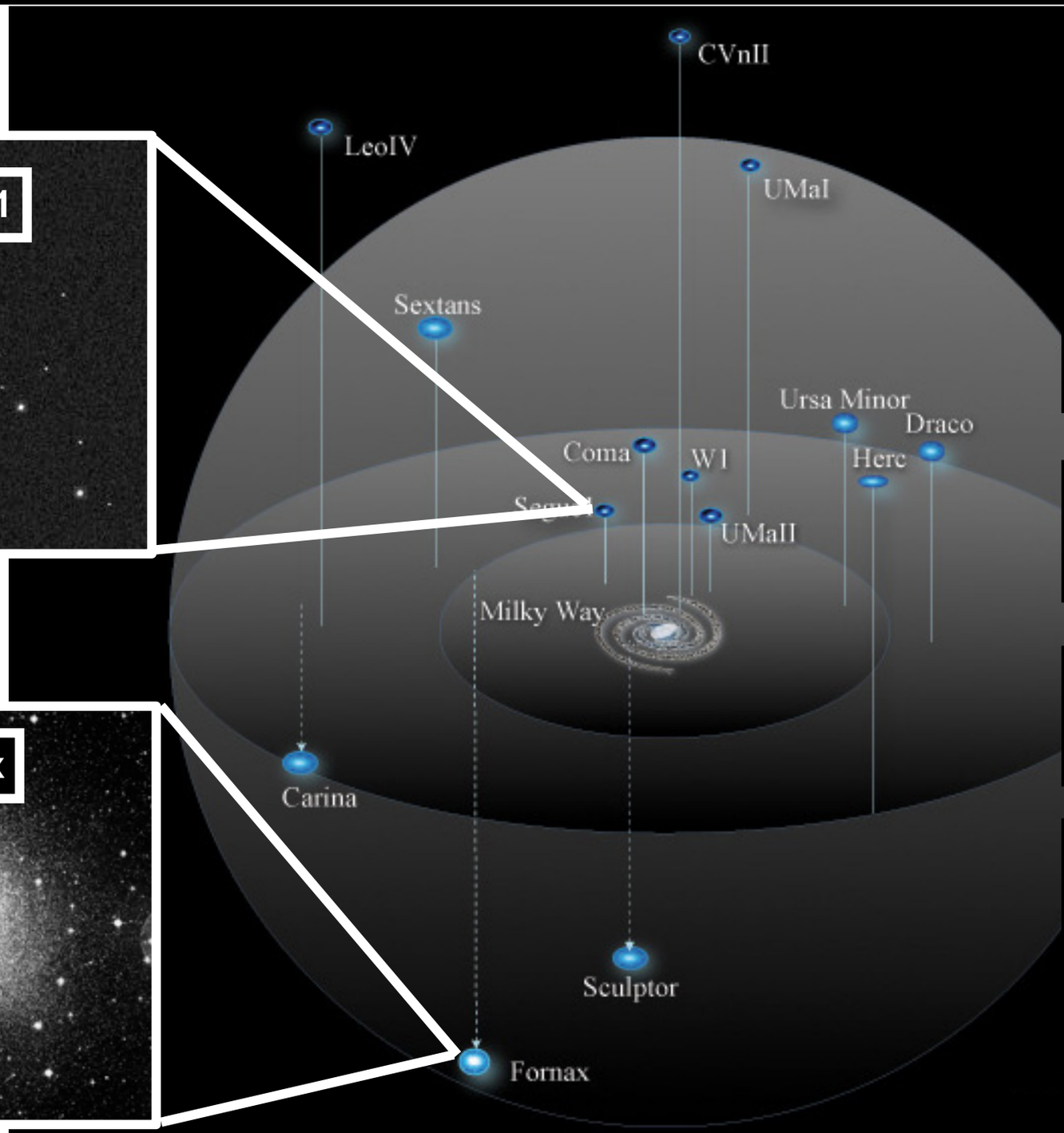
Syst uncertainty

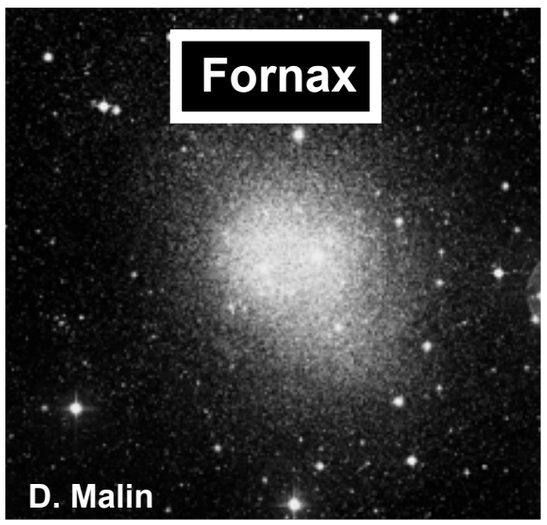
- look from 0.1 to 10 GeV. possible gravitino decay
- here we are systematics-dominated (CR contamination, point sources & complex background, effective area . . .)
- use off-regions to calibrate sensitivity
- dramatic effect: 9.2 sigma -> 0.2



A. Albert, 2014

DWARF GALAXIES





(Bullock, Geha, Powell)

The Milky Way is surrounded by small satellite galaxies

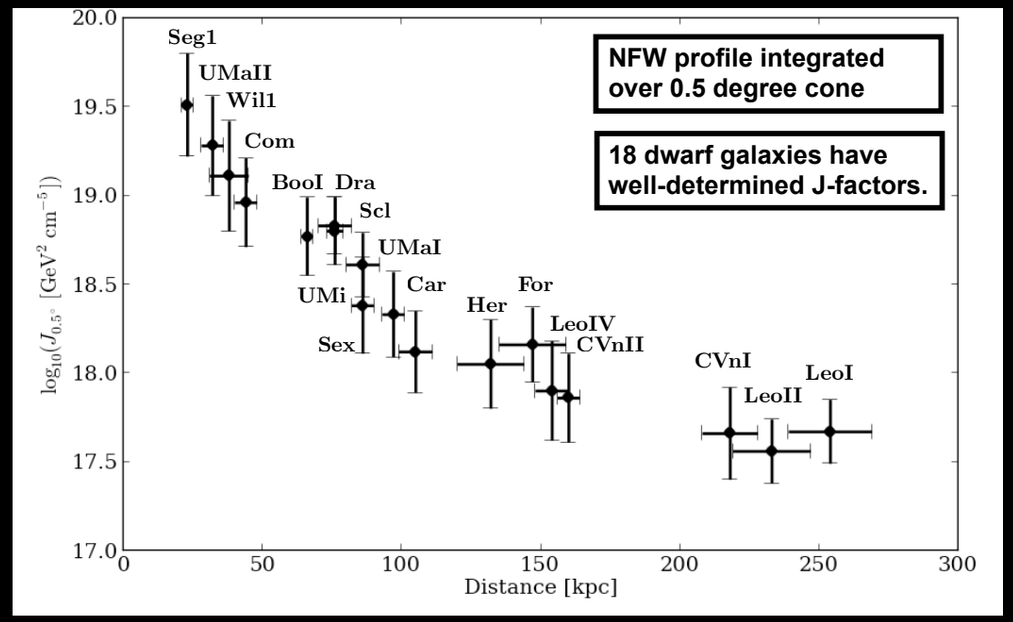
Close to Earth (25 kpc to 250 kpc)

Luminosities range from 10^7 $L_\odot$ to 10^3 $L_\odot$

Astrophysically inactive

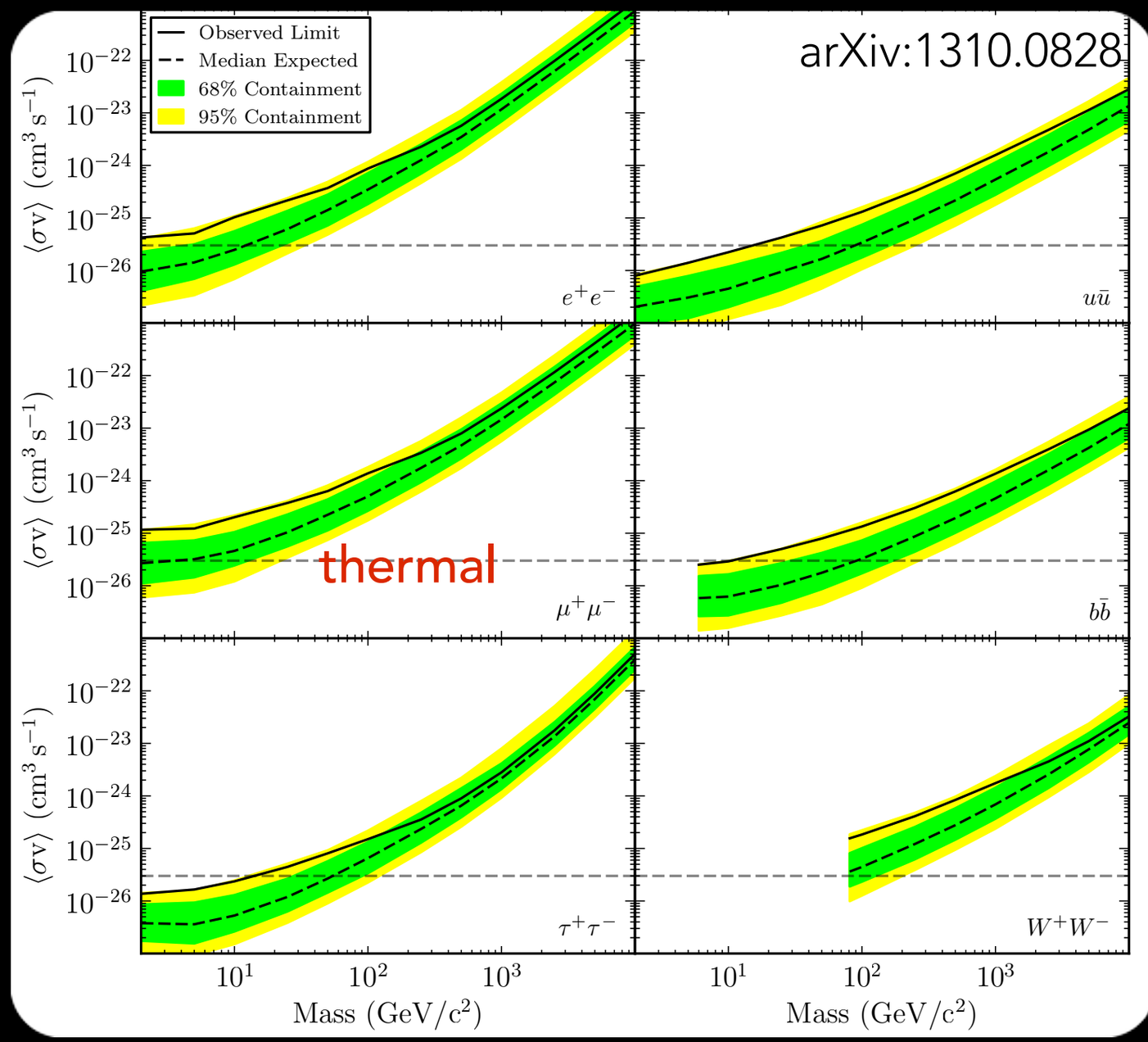
Most dark matter dominated objects known

DWARF GALAXIES

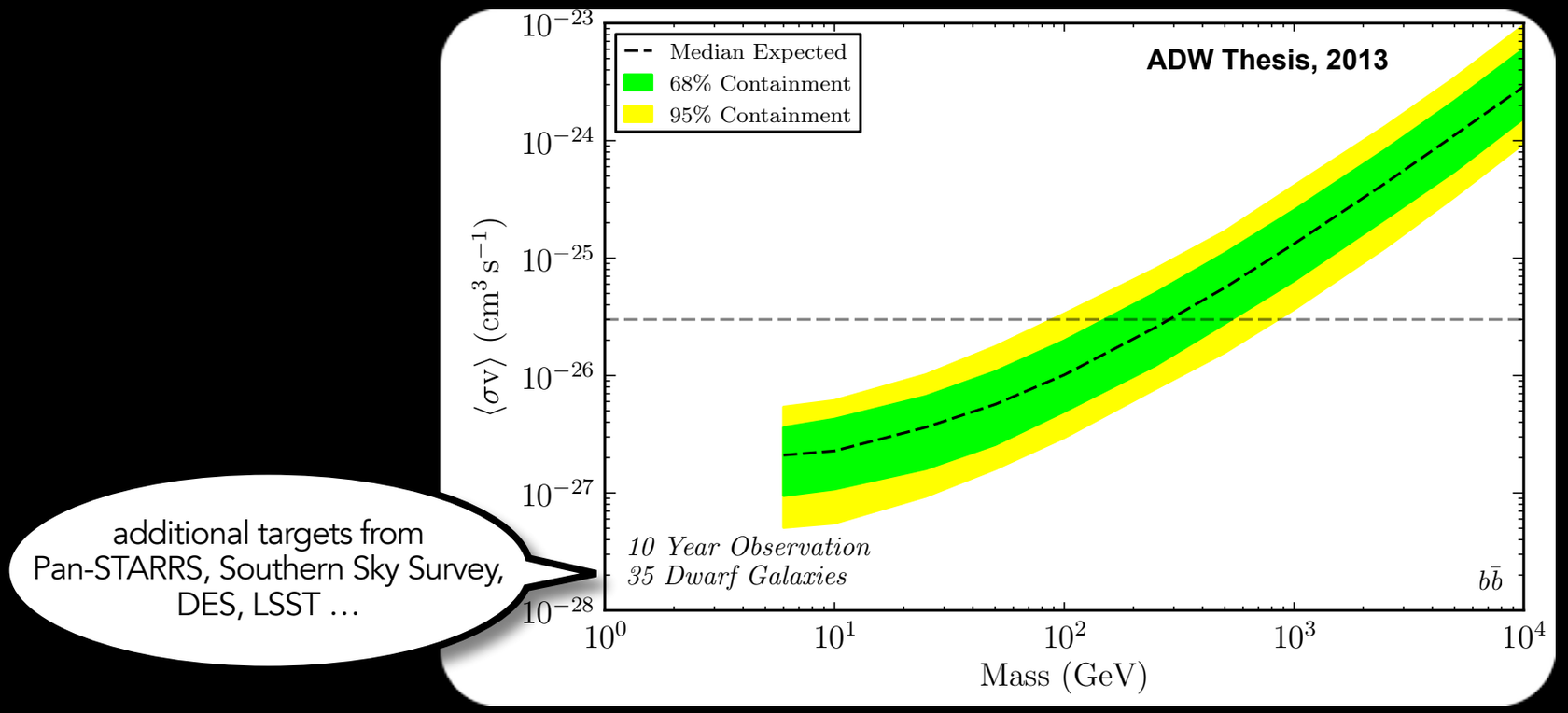


WHERE WE STAND:

- j-factors derived from nested bayesian analysis of velocity dispersions
- joint likelihood limits are very strong
- largest excess has TS=8.7 for 25 GeV b-bbar



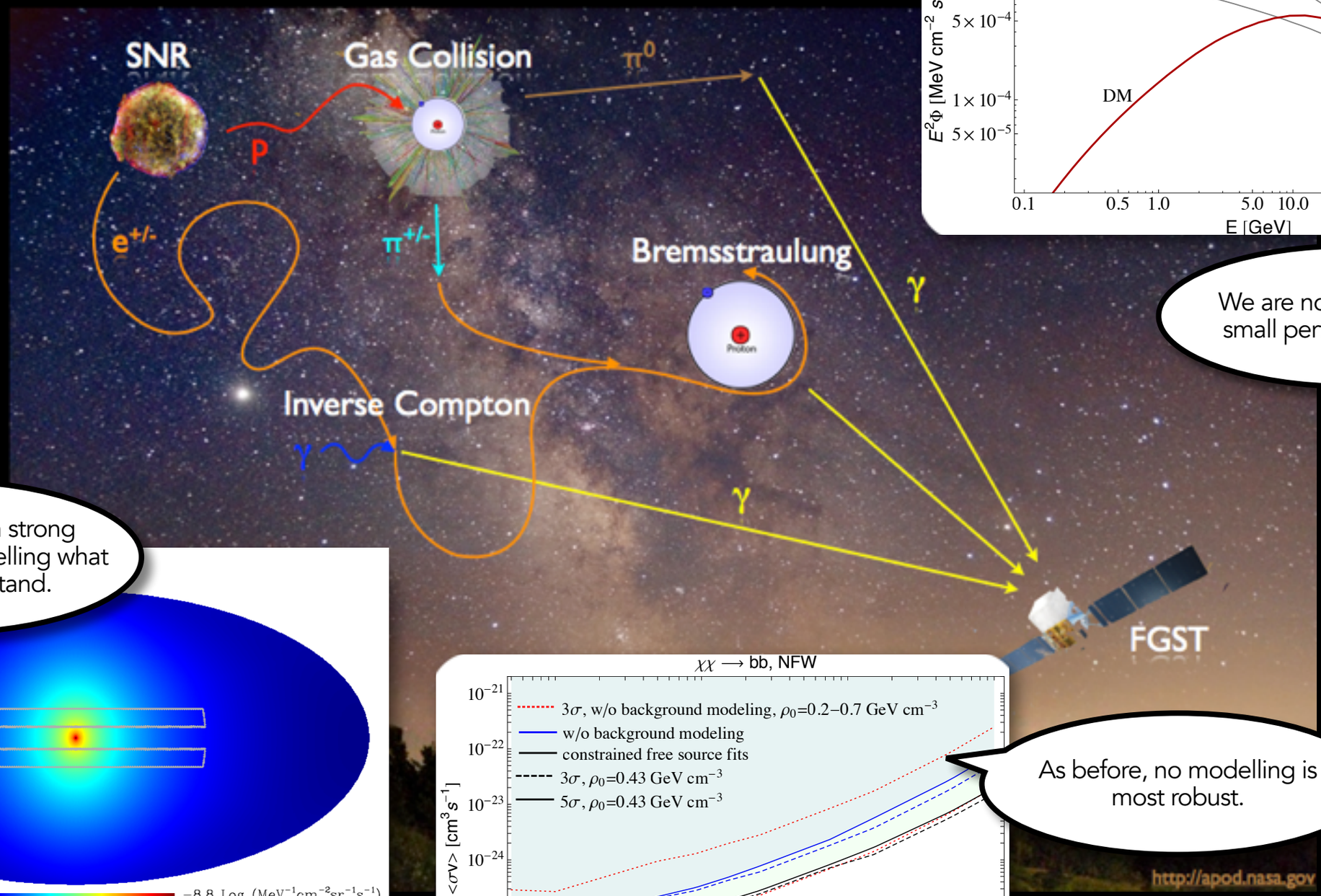
DWARF GALAXIES

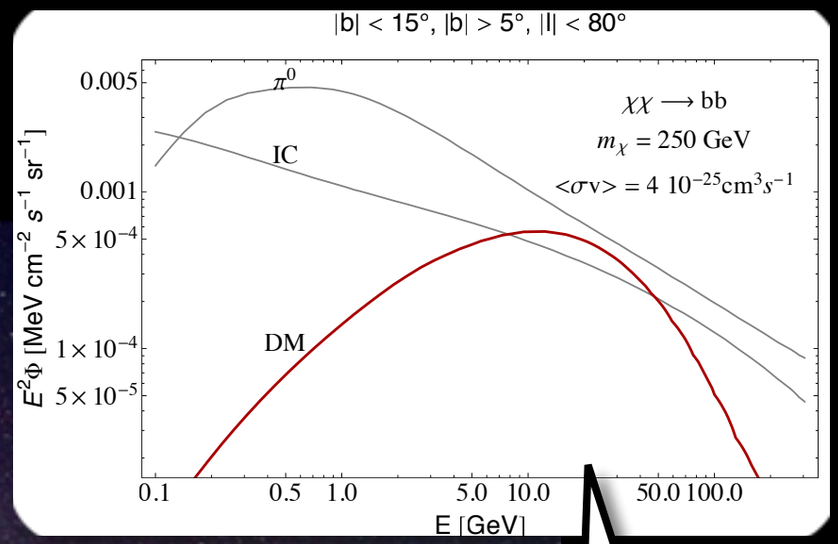


- expected improvement, not including pass8!

COMPLEX
SMALL SIGNAL
BACKGROUND

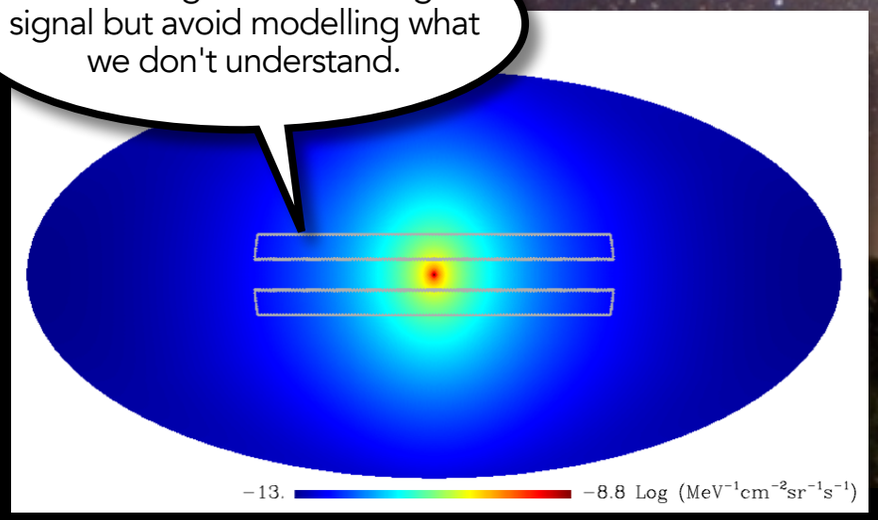
GALACTIC HALO

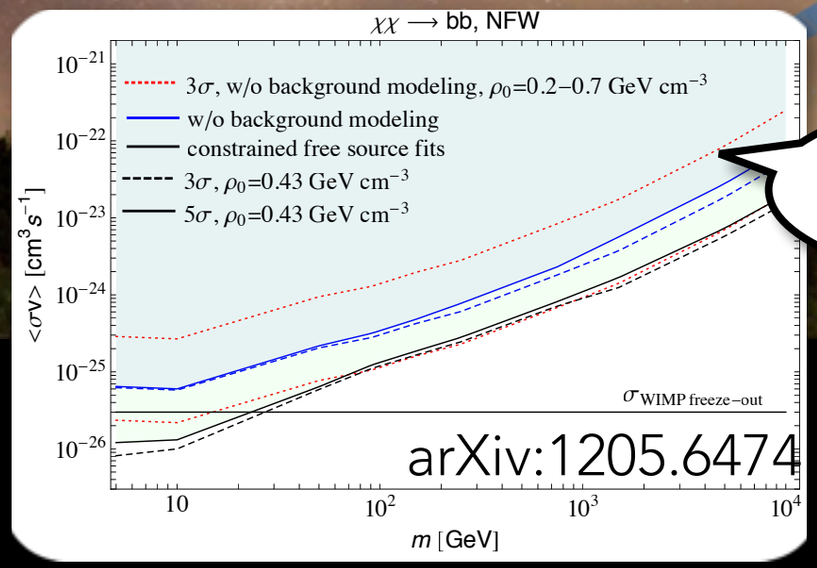




We are now talking about small perturbative signal.

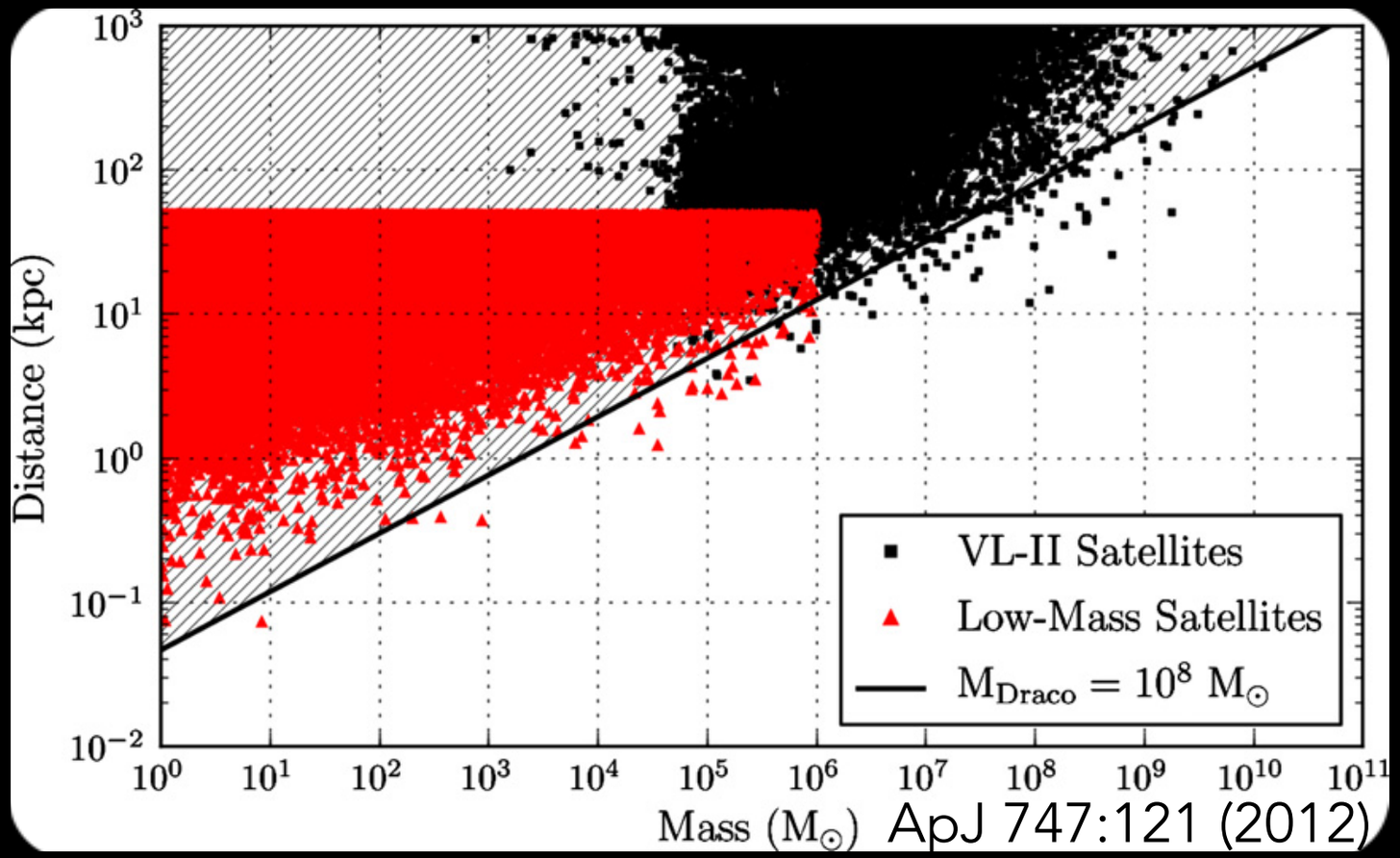
Select regions with strong signal but avoid modelling what we don't understand.





As before, no modelling is most robust.

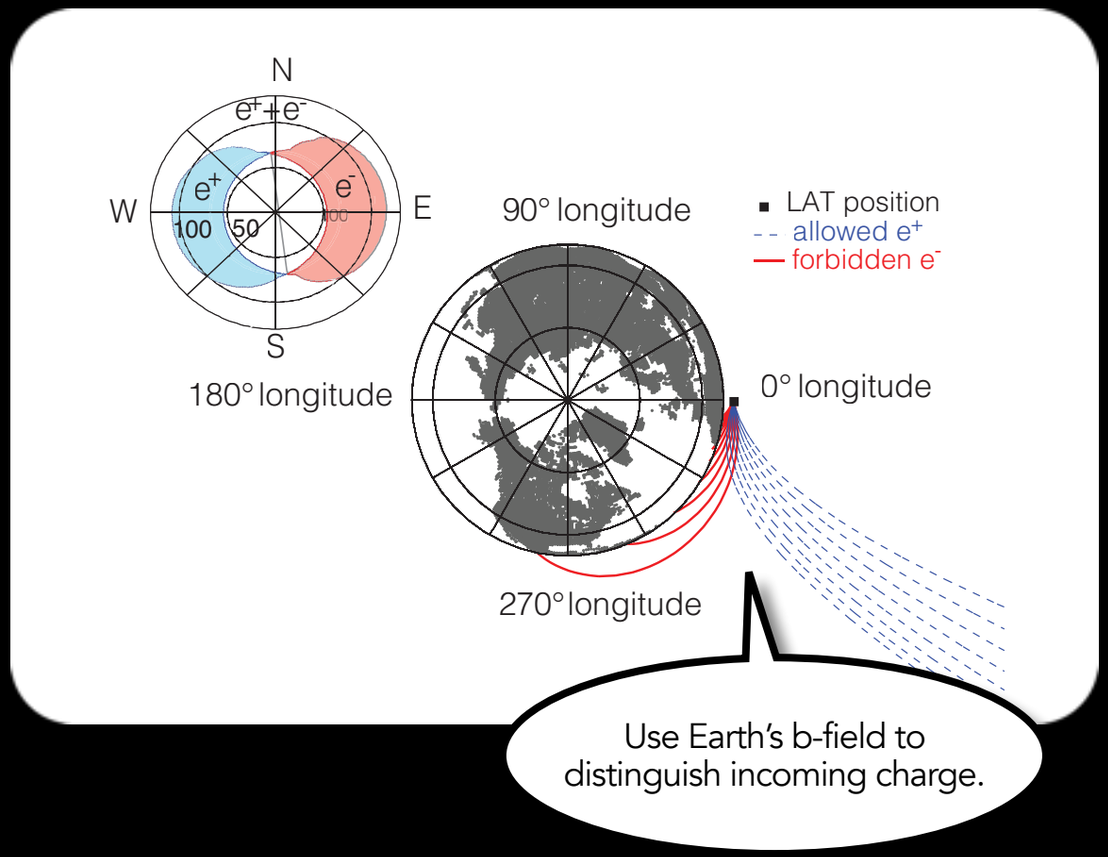
UNIDENTIFIED SOURCES

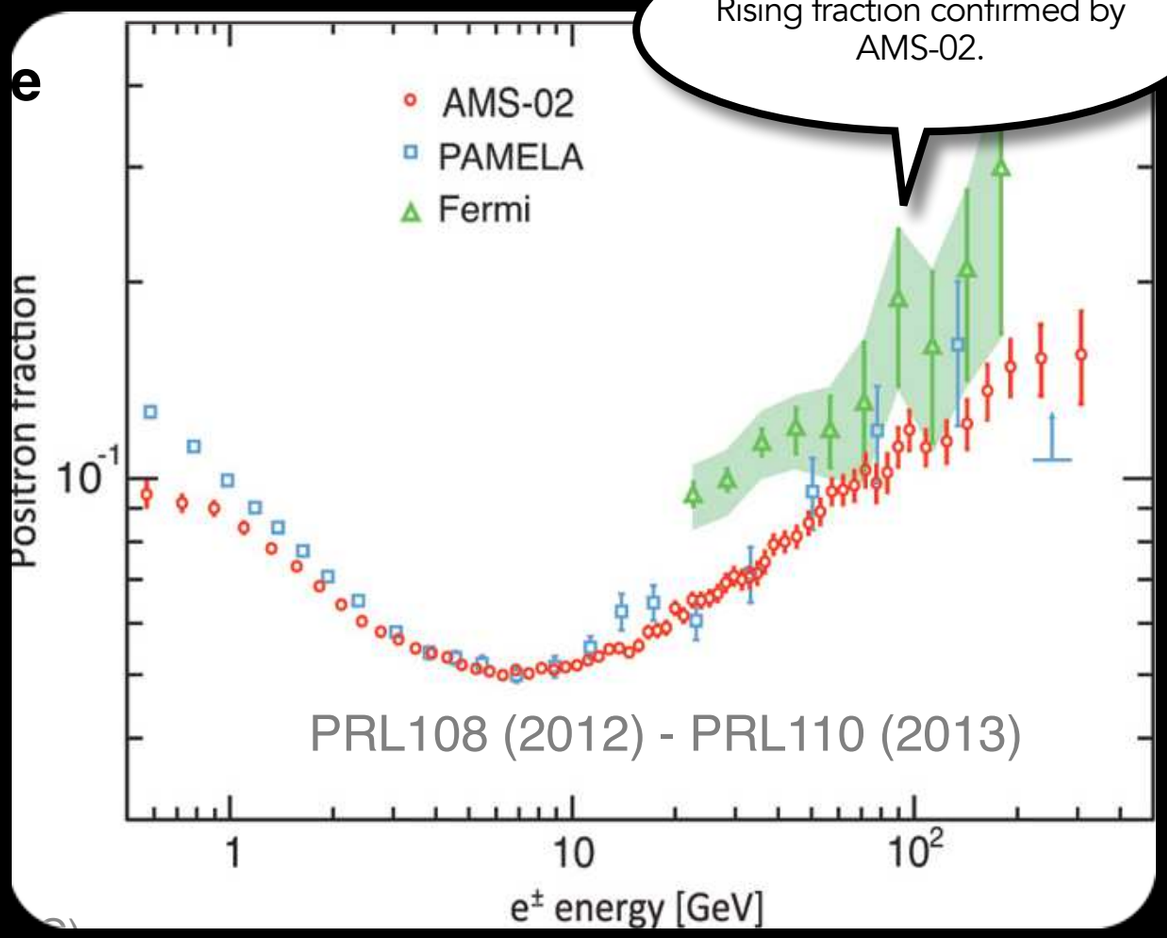


ApJ 747:121 (2012)

- expect many dark subhalos to exist beyond n-body resolution.
- search for unassociated, time-invariant, extended, hard spectrum sources.
- no real candidates so far . . . but catalogues are never complete!

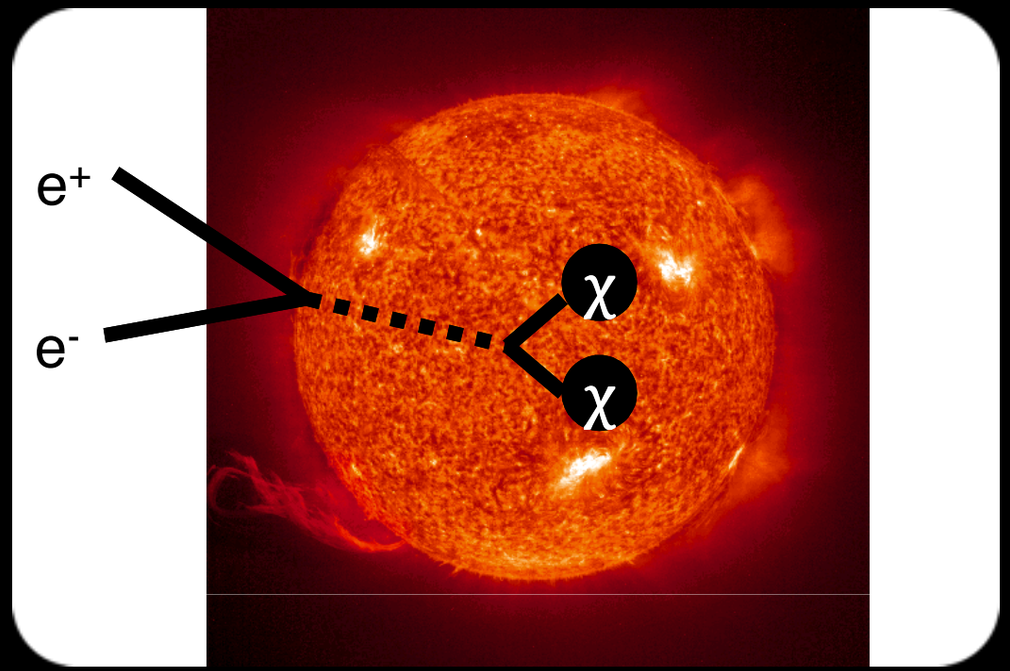
ELECTRONS & POSITRONS



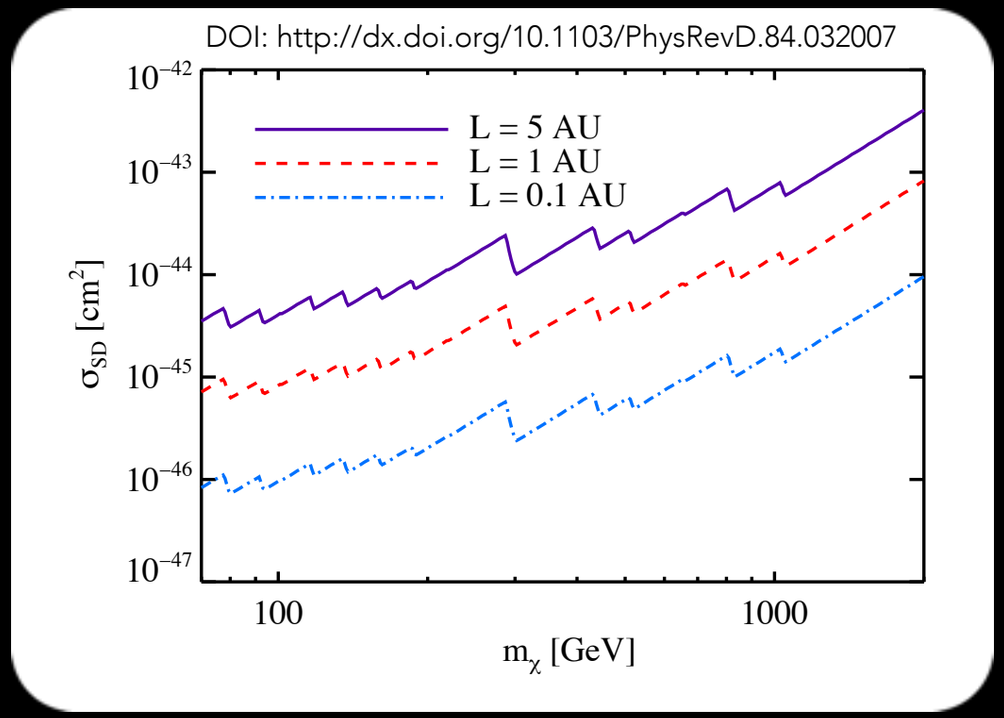


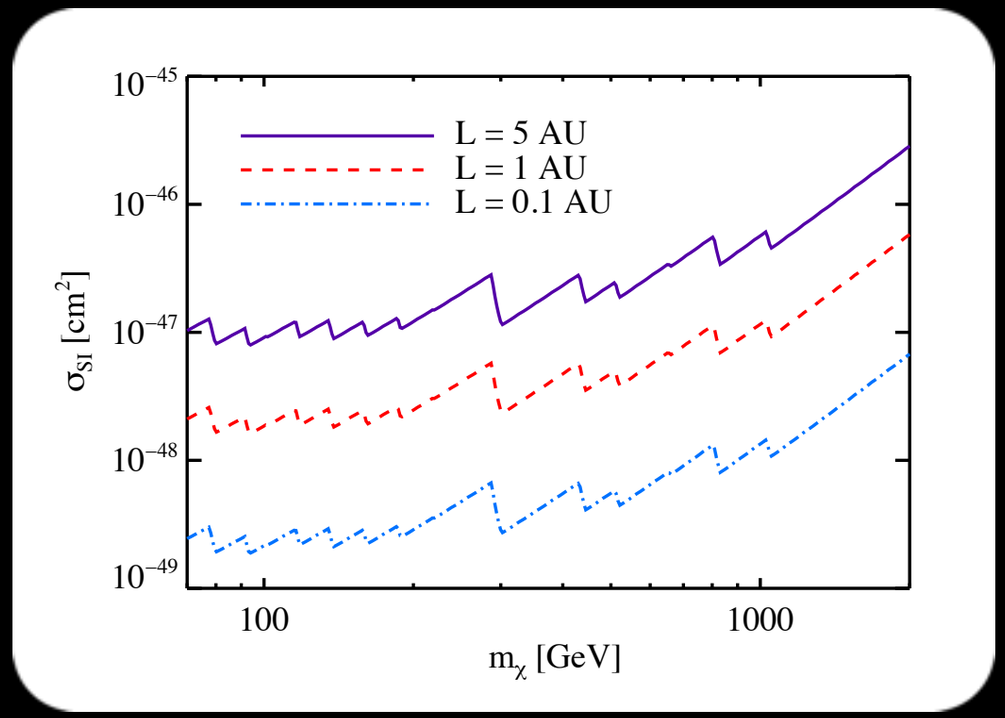
- possible nearby source? pulsar(s)? secondaries? DM?

SOLAR CAPTURE

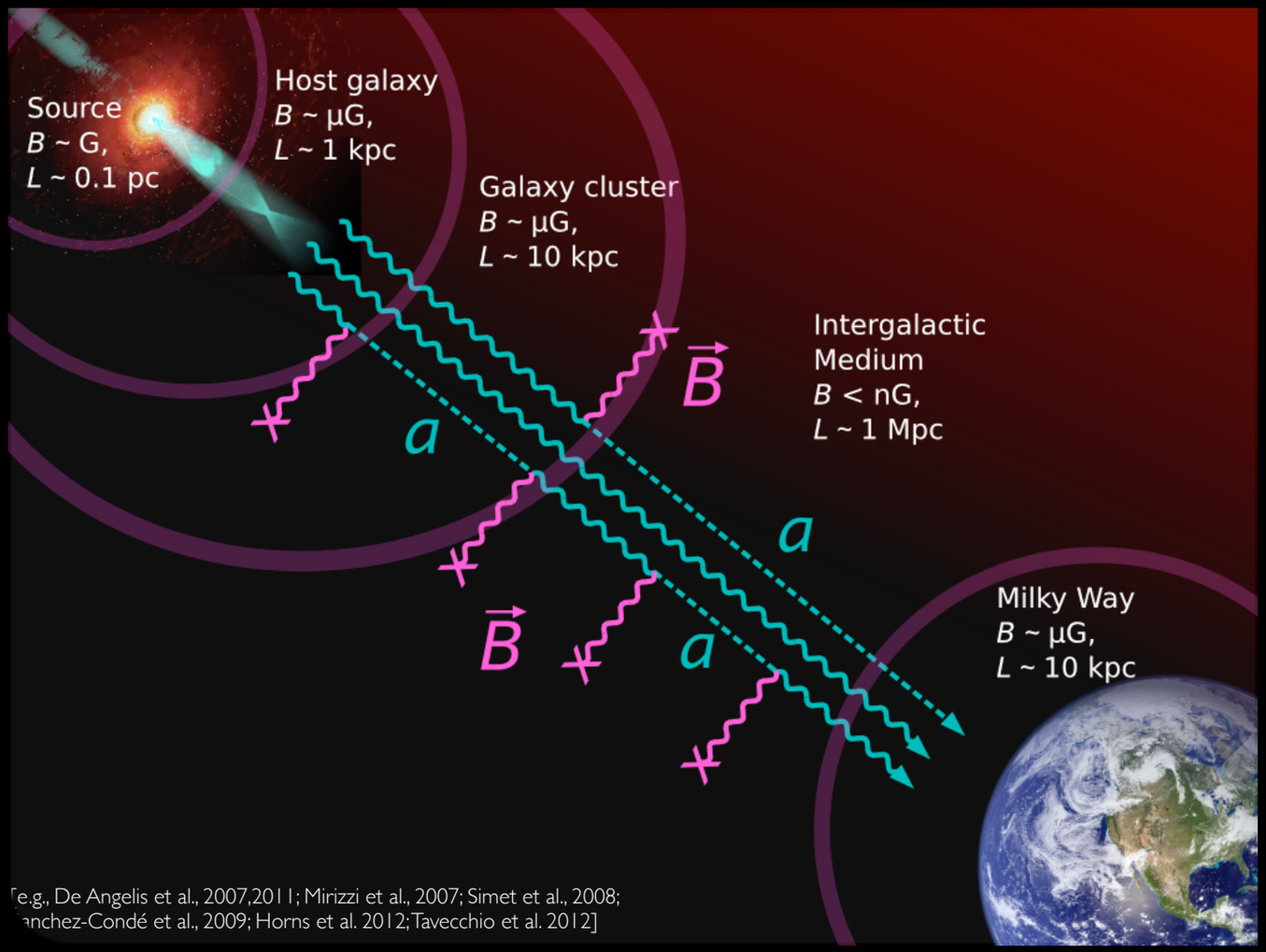


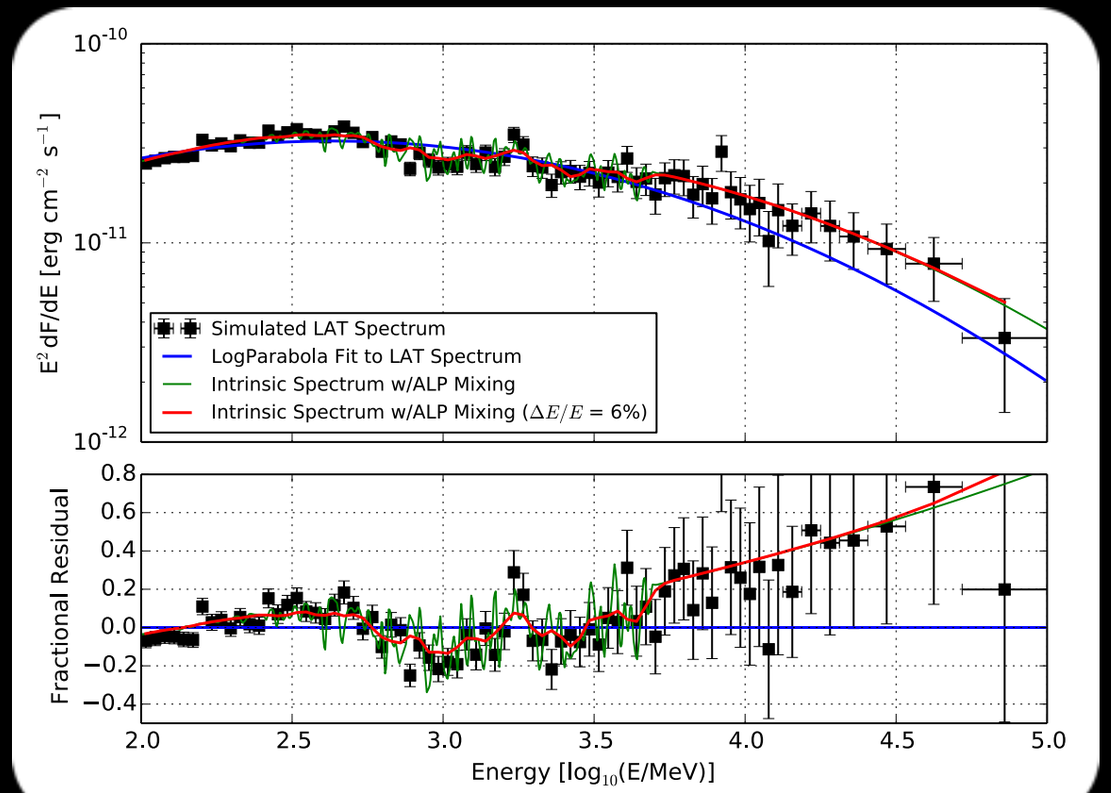
- WIMPS can scatter directly to get stuck in the sun's potential well
- if they annihilate through a sun-permeable intermediary, we can have decays that reach earth
- use the LAT as a charged particle detector

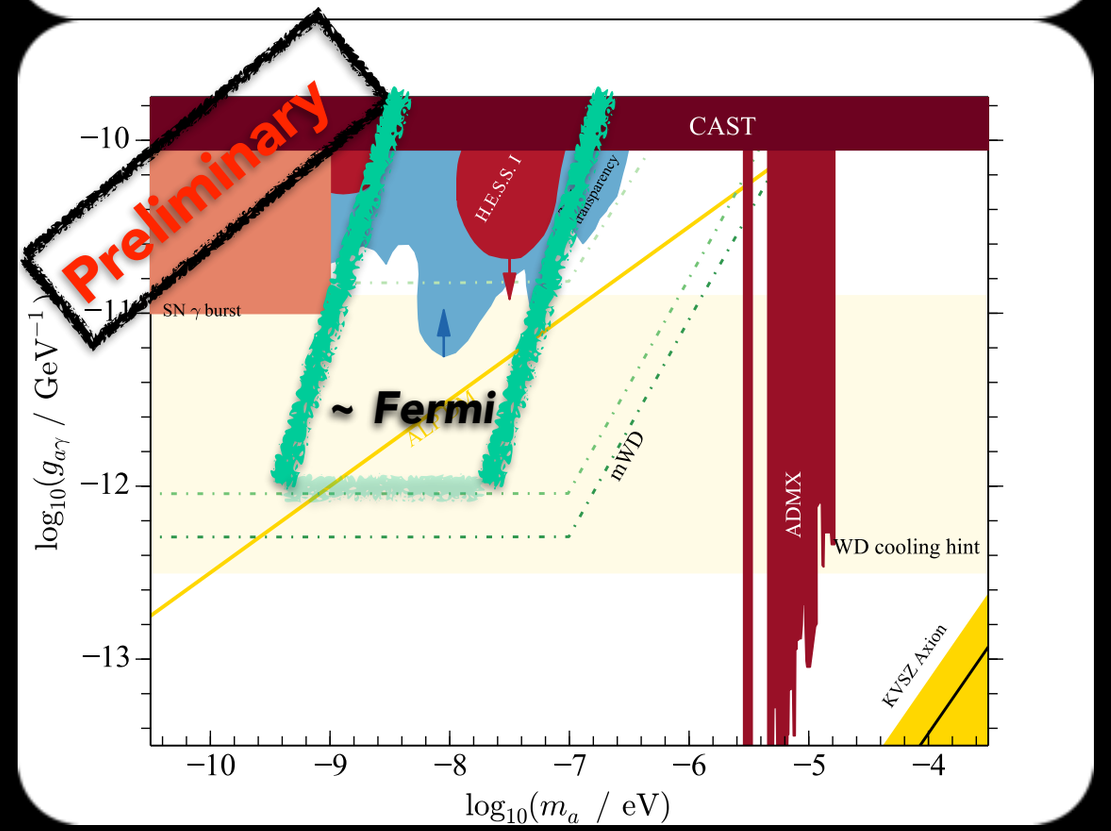




AXION CONVERSIONS







- photon-axion conversions protect emissions from pair production
- introduces spectral features to distant AGN (Wouters & Brun, 2012)
- ongoing work - ask Manuel Meyer