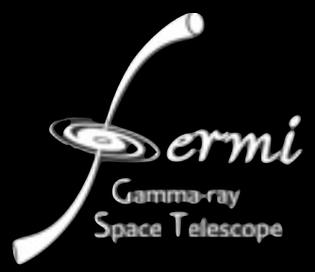
FERMI-LAT DM CONSTRAINTS FROM DWARF GALAXIES

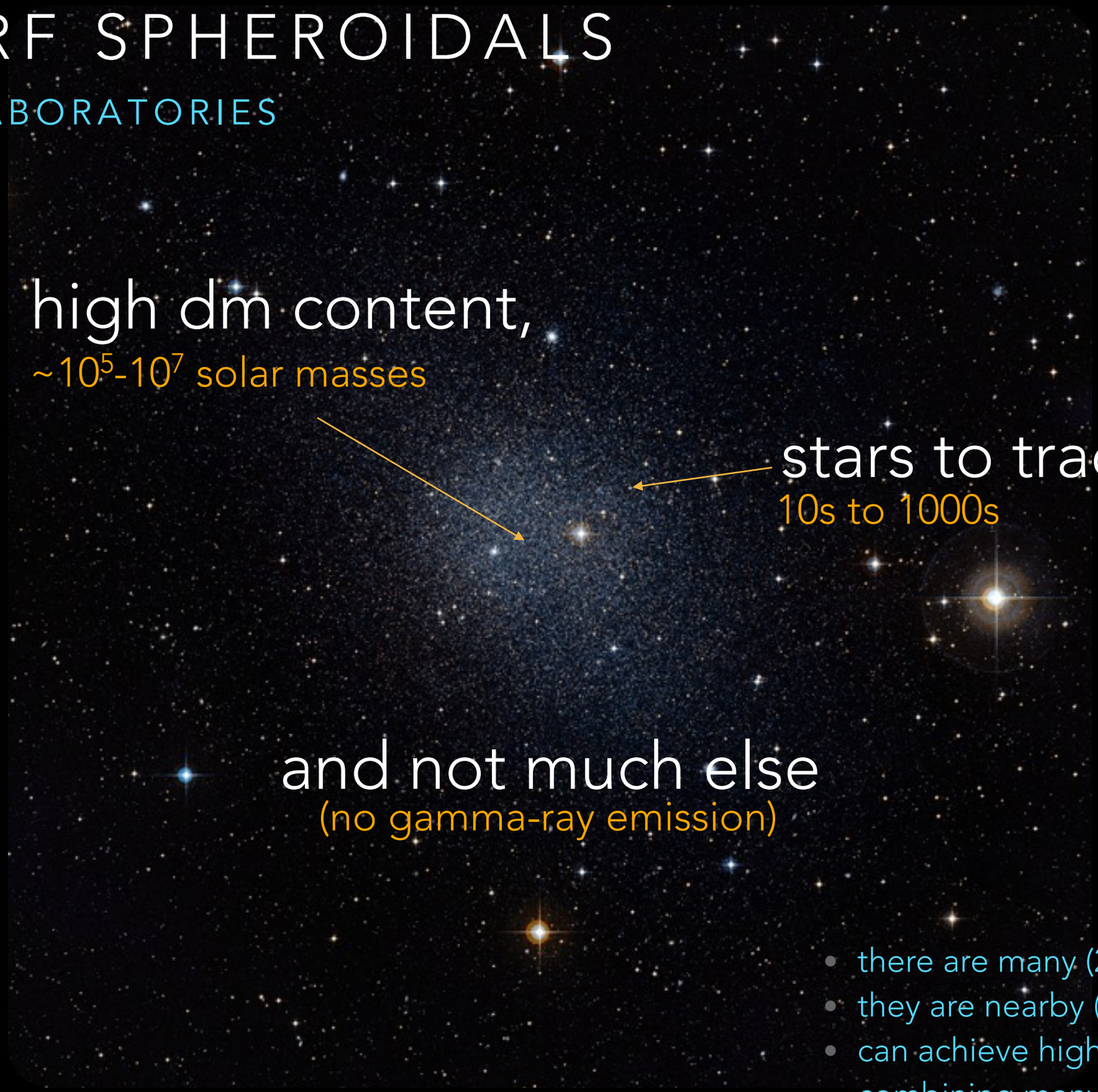


B. ANDERSON FOR THE FERMI-LAT COLLABORATION

WIN 2015
JUNE 12

DWARF SPHEROIDALS

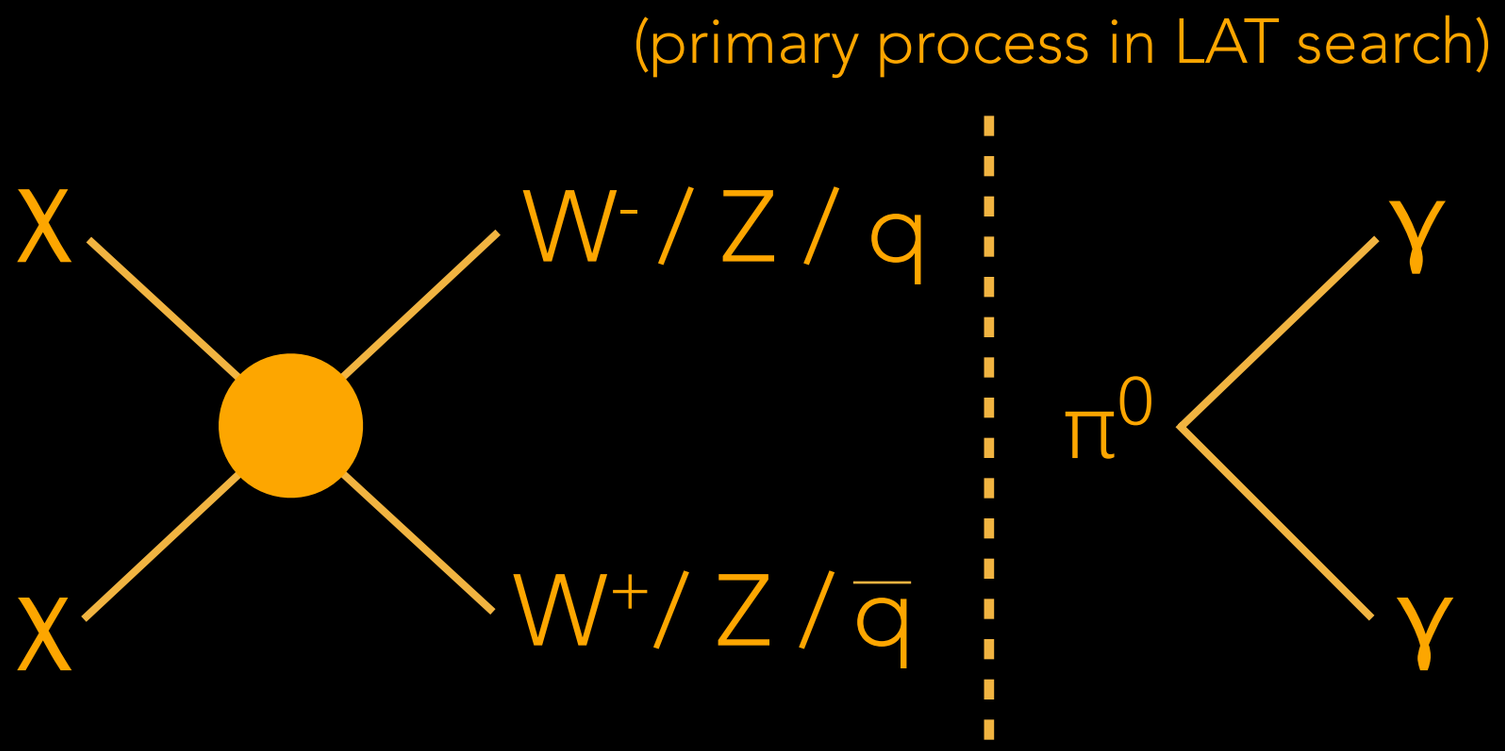
AS DM LABORATORIES



- there are many (20+ so far)
- they are nearby (<250 kpc)
- can achieve high sensitivity by combining many of them

WIMP PARADIGM

ABUNDANCE & OBSERVABILITY



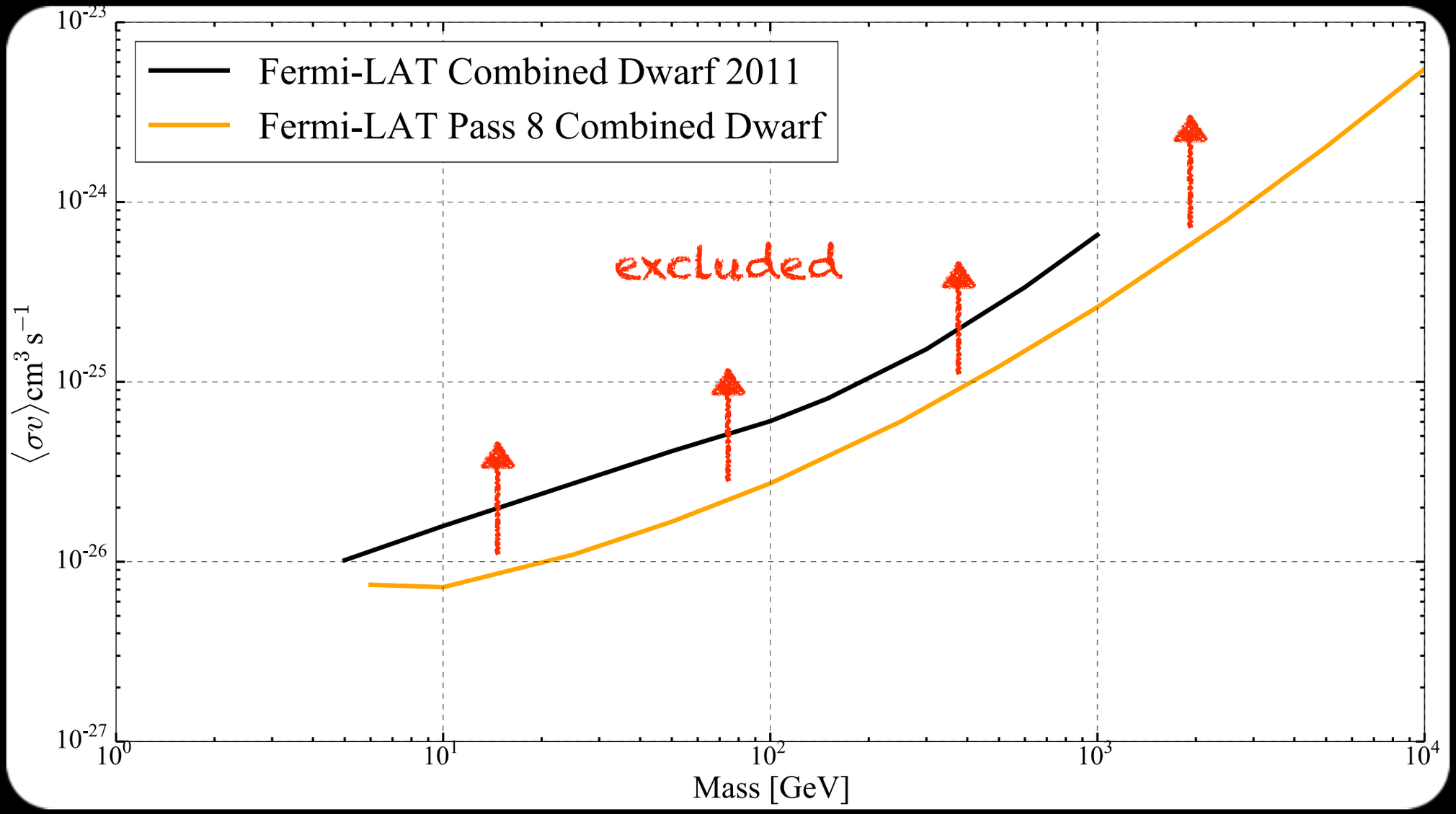
- annihilation with weak cross section (~2e-26 $cm^3\ s^{-1}$) gives Ω_{DM}
- same process would make it visible in high density areas today

$$\frac{d\Phi_\gamma}{dE_\gamma} = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\sum_f \frac{dN_\gamma^f}{dE_\gamma}B_f}_{\Phi_{PP}} \times \underbrace{\int_{\Delta\Omega}\int_{l.o.s.}\rho^2(r)dl\ d\Omega'}_{\mathrm{J-factor}}$$

MOTIVATION

WHAT KEEPS THIS INTERESTING?

arXiv:1111.0320
arXiv:1503.02641
b-quark channel



- no significant detections
- very low systematics —>
- factor of 2-3 drop in upper limits over the last years

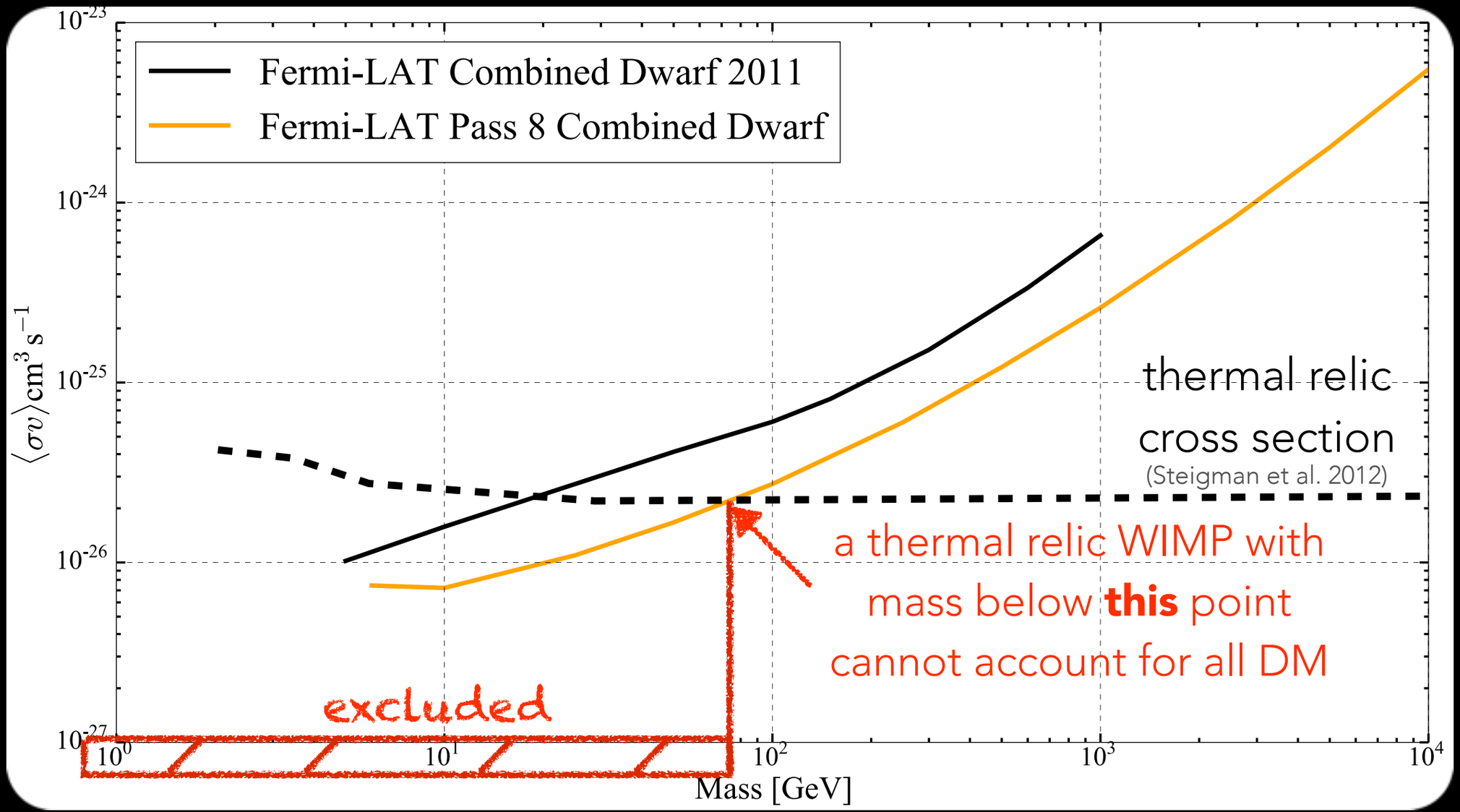
J-factor	Diffuse	IRFS
33%	8%	9%

@ 100 GeV
WIMP Mass

MOTIVATION

WHAT KEEPS THIS INTERESTING?

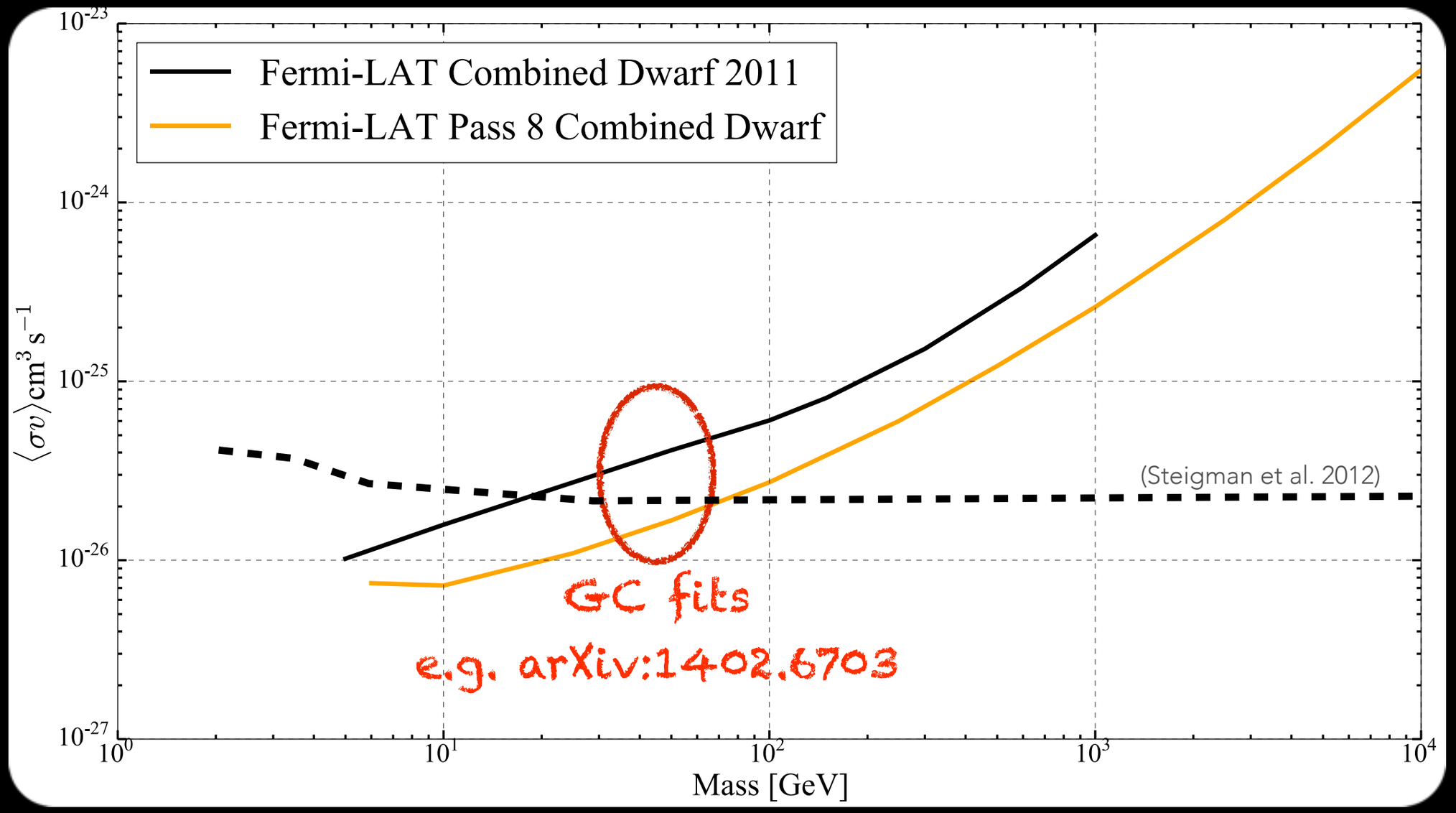
arXiv:1111.0320
arXiv:1503.02641
b-quark channel



MOTIVATION

WHAT KEEPS THIS INTERESTING?

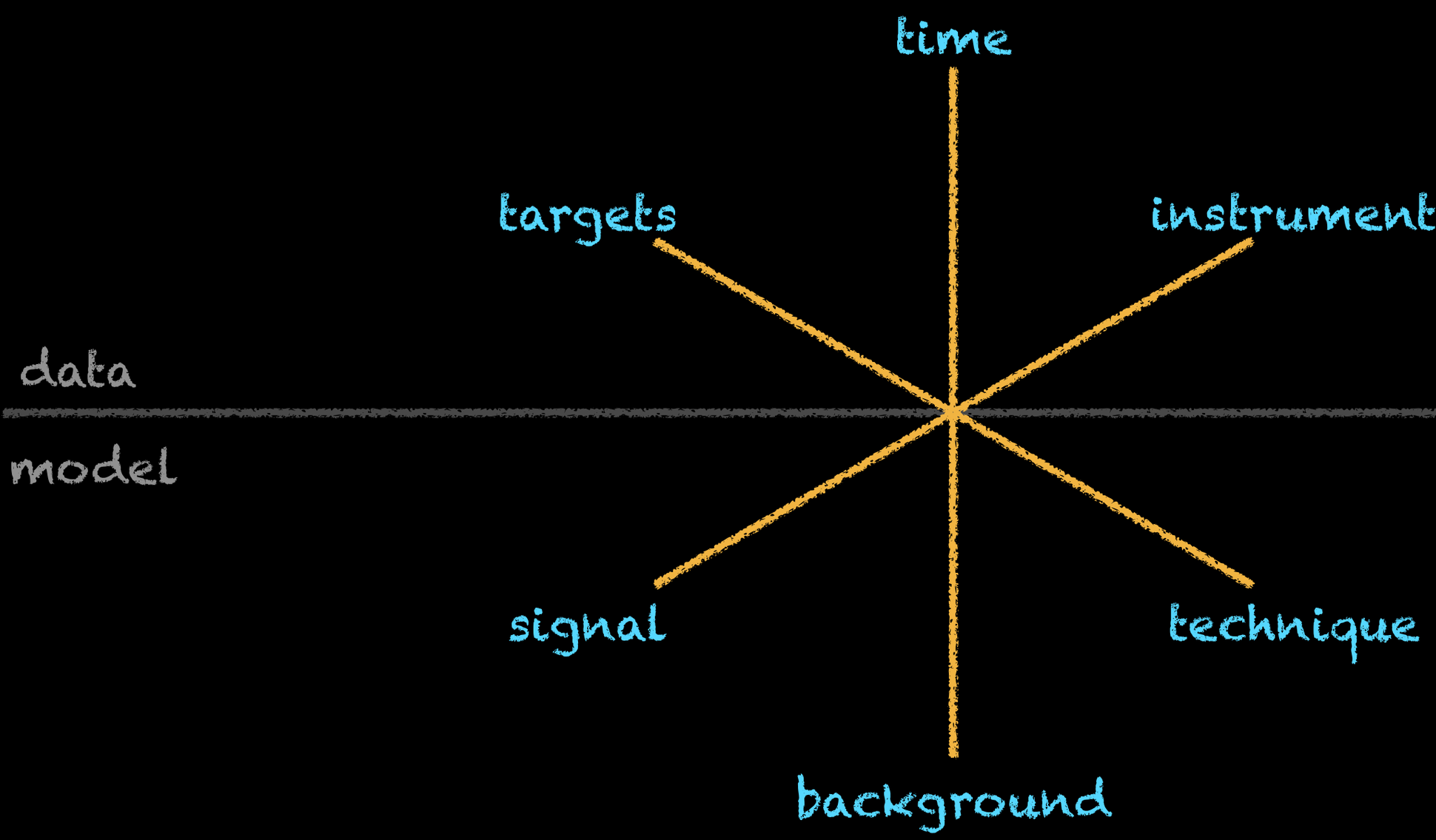
arXiv:1111.0320
arXiv:1503.02641
b-quark channel



(similar for τ)

IMPROVING

A FANCY DIAGRAM

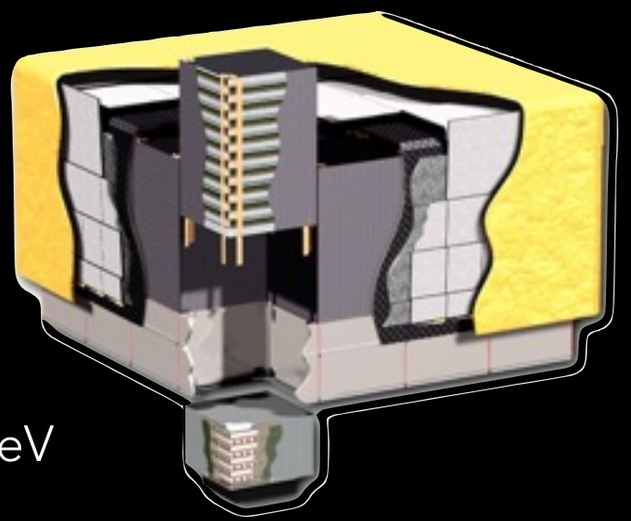


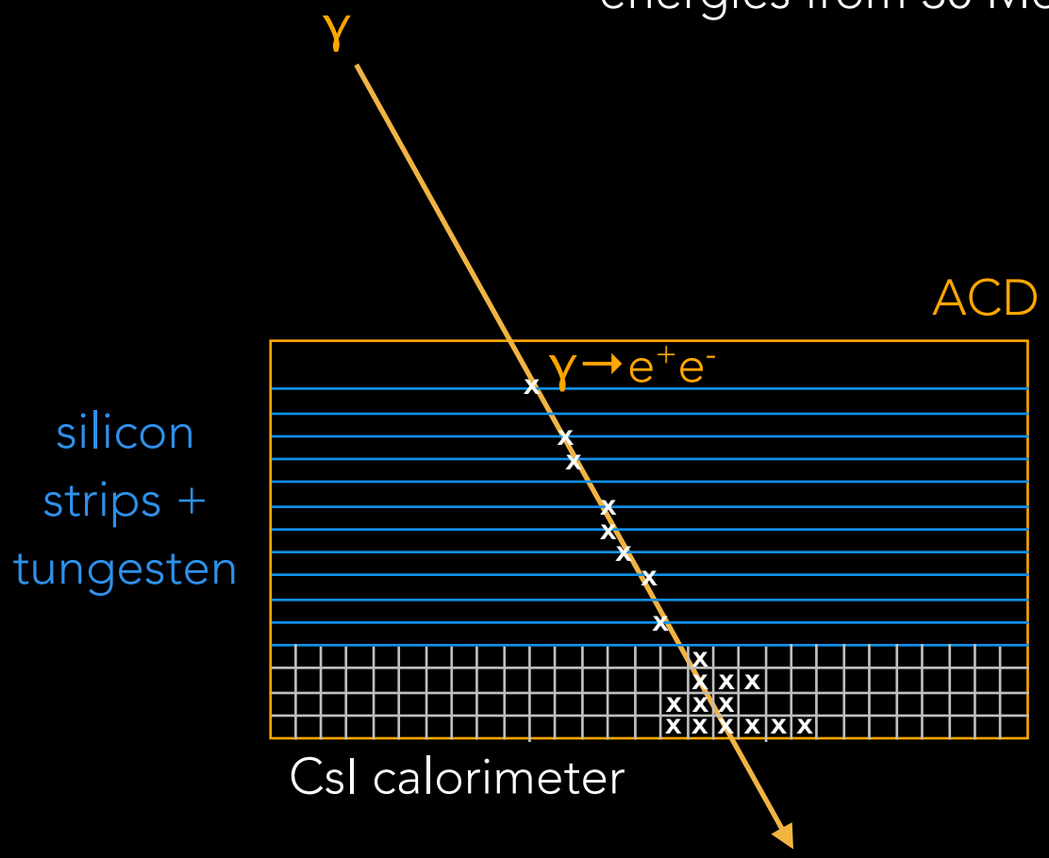
THE LAT
UPGRADED

*instrument

Fermi Large Area Telescope

- all-sky gamma-ray monitor
- public data
- ~1 m^2 effective area
- 6+ years of observation
- energies from 30 MeV to over 300 GeV





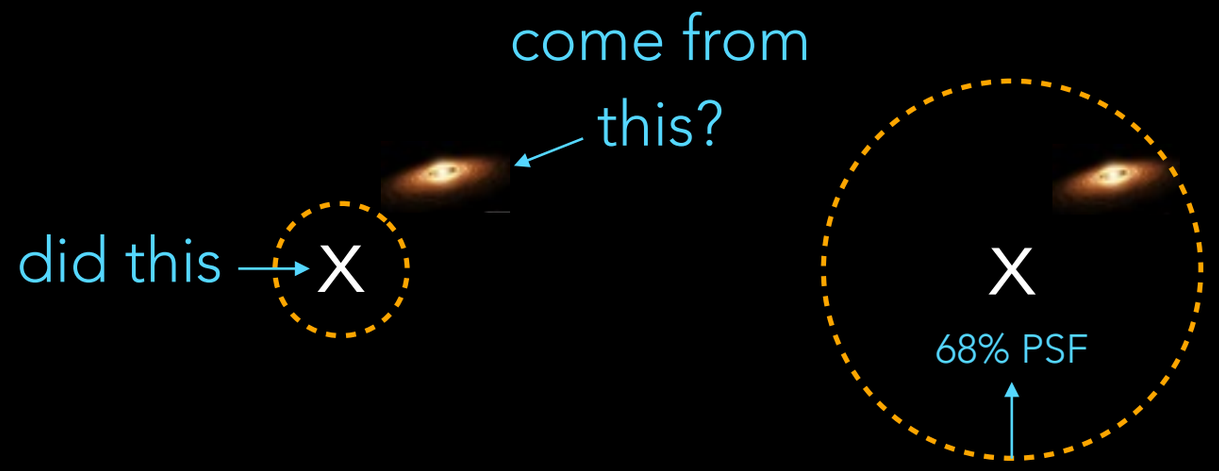
Pass 8

- complete event reconstruction
- applied to all prior data
- available this month!!

Effective Area	Angular Resolution	Point-Source Sensitivity
+25%	+10-15%	+40%
> 1 GEV	> 1 GEV	@ 1-10 GEV

PASS 8
EVENT TYPES

instrument



each event PSF is a parameterized function of

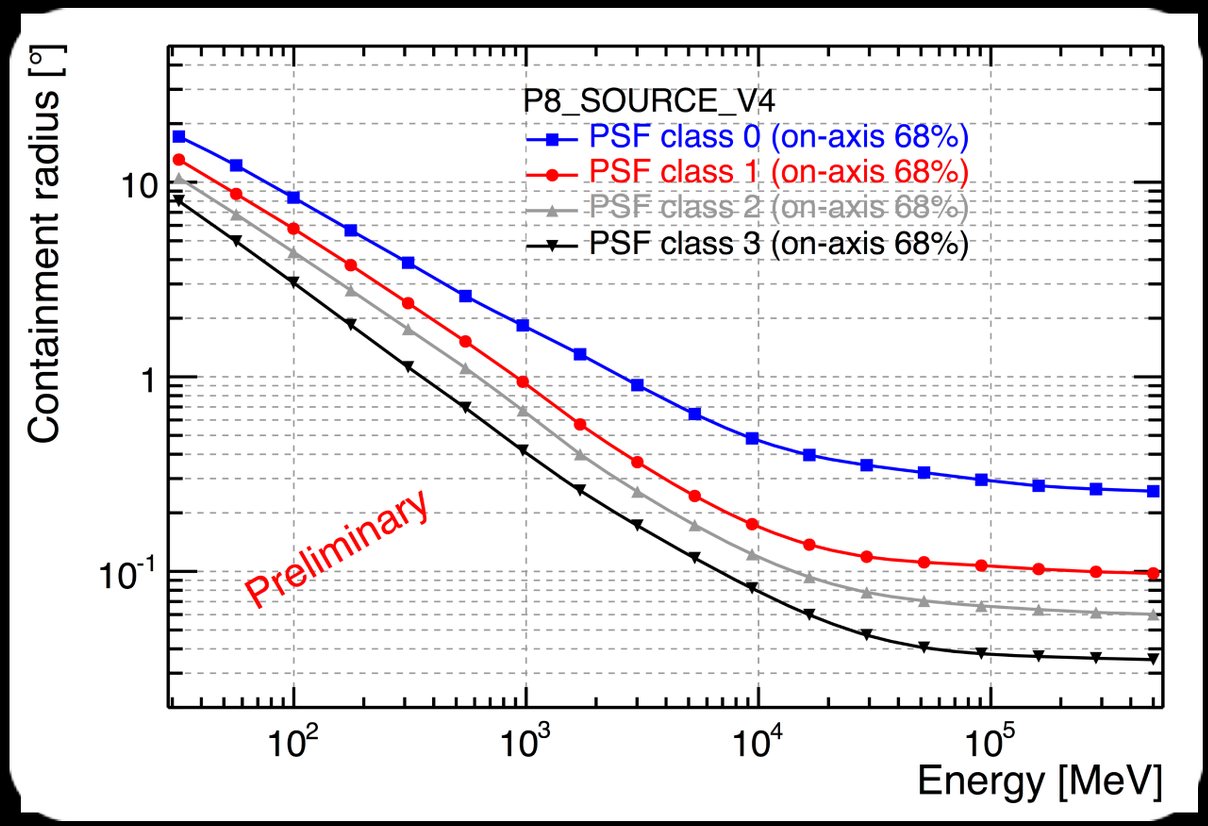
- energy
- incoming angle
- event class (probability to be a photon)

averaged over, e.g.

- what tracker layer it converted in
- if it passed through any gaps/cracks

new feature, PSF types

- uses deeper instrument info to subdivide events by angular uncertainty
- each set (4) gets its own PSF



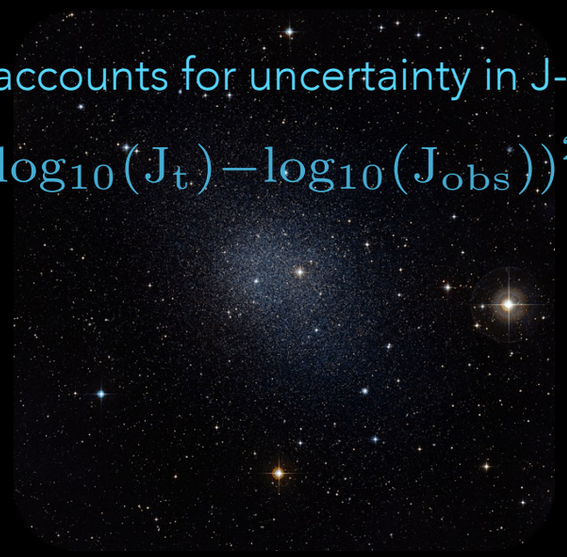
JOINT LIKELIHOOD

JOINT LIKELIHOOD

*technique

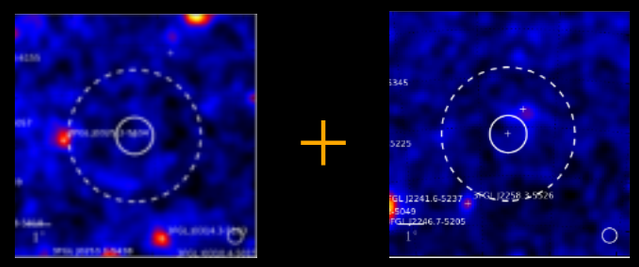
$$\mathcal{L}_2(\mathcal{D}|\boldsymbol{\mu}, \boldsymbol{\theta_t}) = \mathcal{L}_t^{\mathrm{LAT}}(\mathcal{D}_t|\boldsymbol{\mu}, \boldsymbol{\theta_t}) \times \frac{1}{\ln(10)\mathrm{J}_{\mathrm{obs}}\sqrt{2\pi}\sigma_{\mathrm{t}}} e^{-(\log_{10}(\mathrm{J_t})-\log_{10}(\mathrm{J_{obs}}))^2/2\sigma_{\mathrm{t}}^2}$$

(term accounts for uncertainty in J-factor)



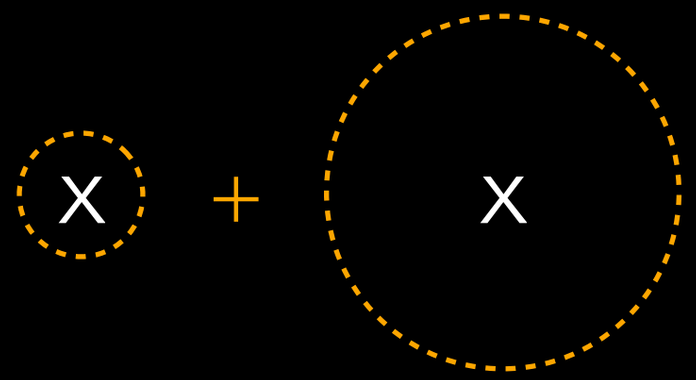
$$\mathcal{L}_3(\mathcal{D}|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\}) = \prod_{\mathrm{targets}} \mathcal{L}_2(\mathcal{D}|\boldsymbol{\mu}, \boldsymbol{\theta_t})$$

(combine information from all targets)



$$\mathcal{L}_4(\mathcal{D}|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\}) = \prod_{\mathrm{types}} \mathcal{L}_3(\mathcal{D}_c|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\})$$

(combine information from all PSF types)

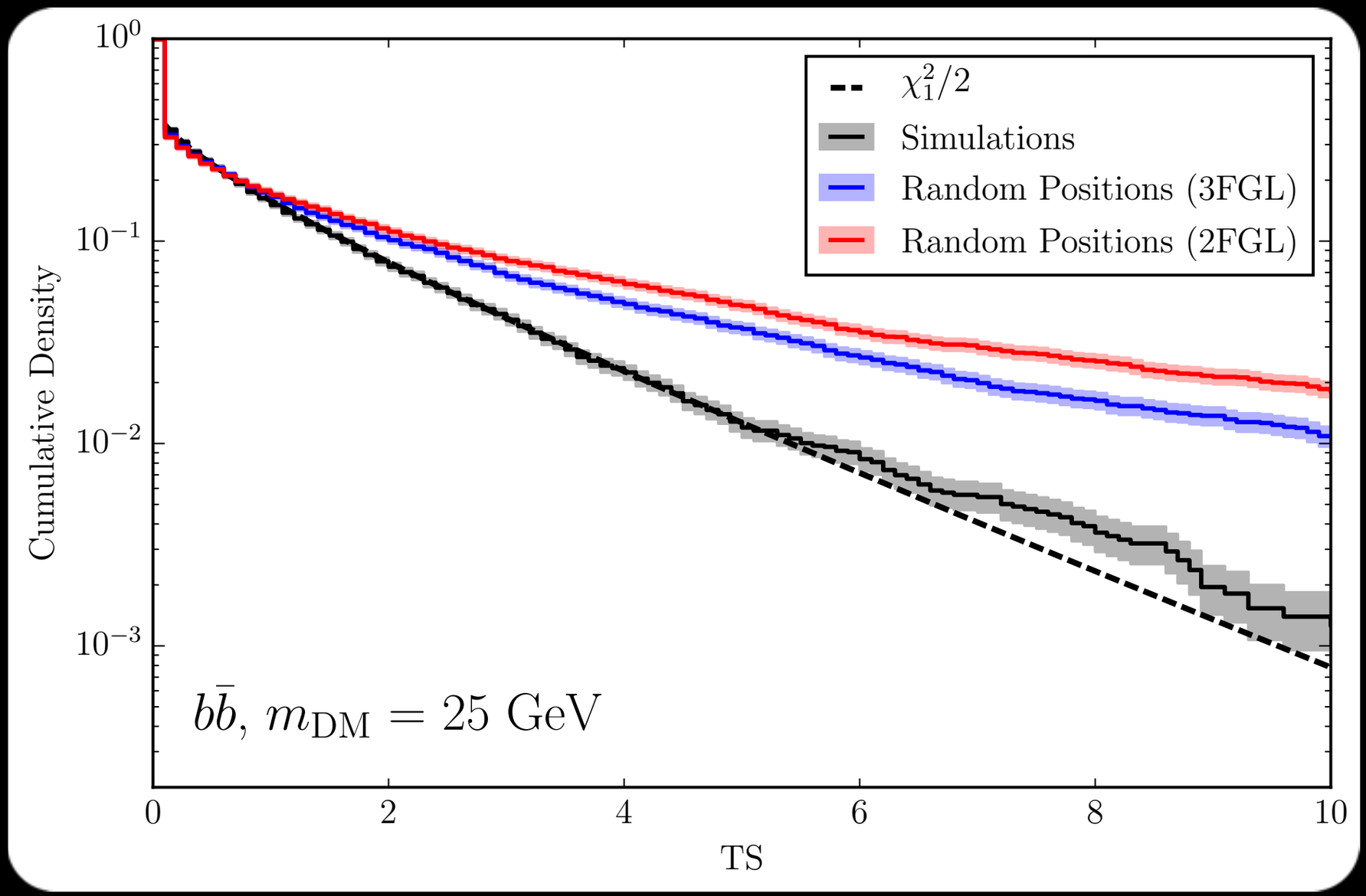


TYPE I ERRORS

SUB-THRESHOLD SOURCES

background

arXiv:1503.02641



- blank field analysis. number of type I errors decreases with updated catalog
- implies we had some un-modeled background (could still be more)
- direct increase in sensitivity

J-FACTORS

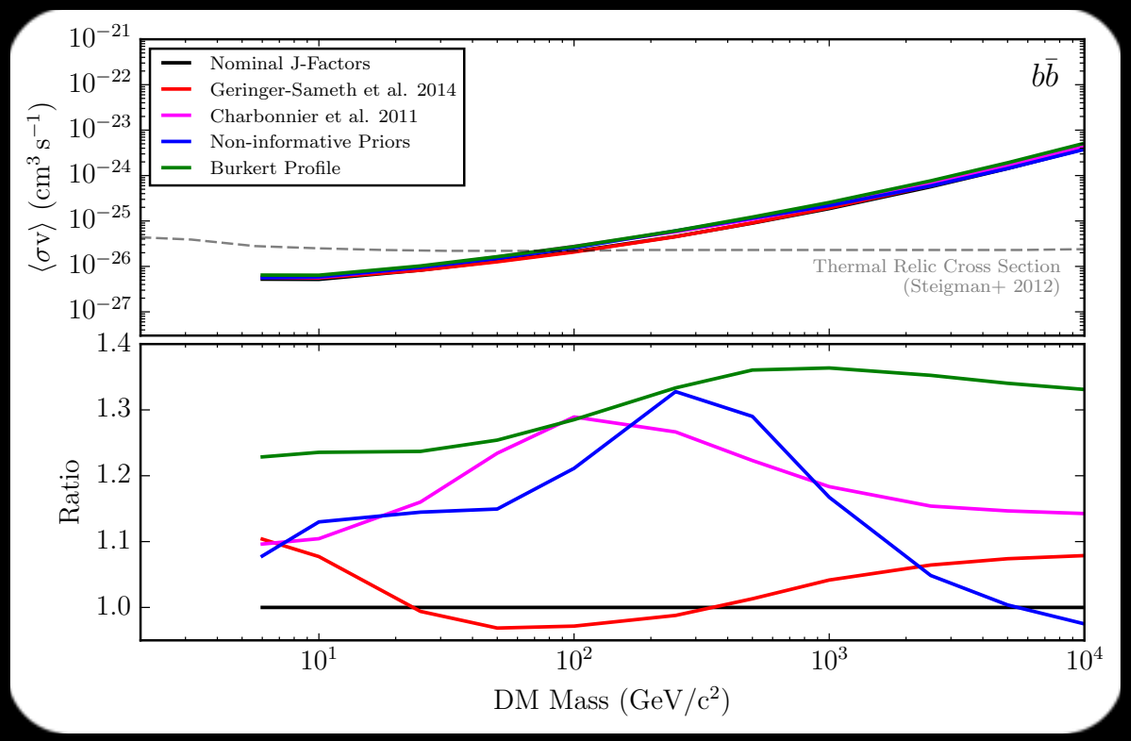
signal*

Determination

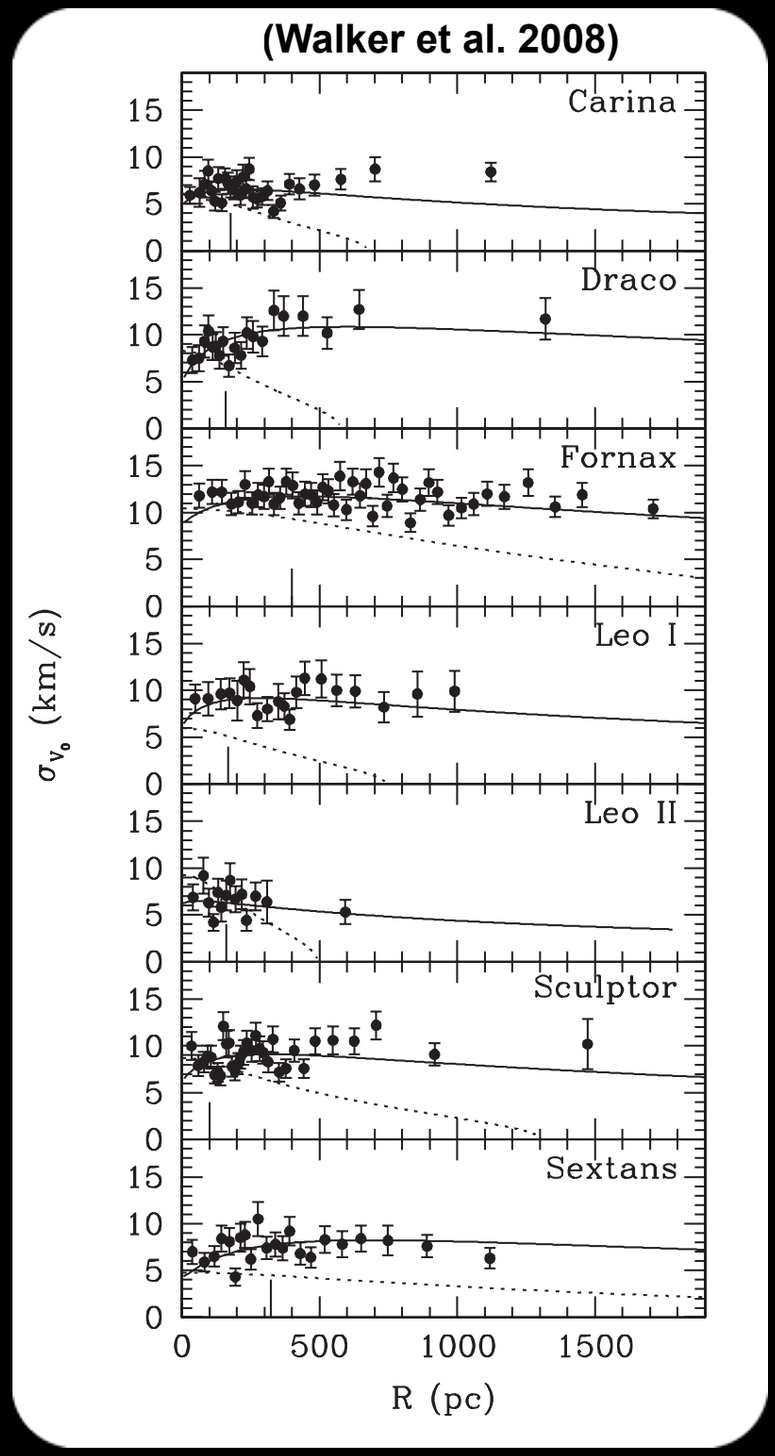
- spectroscopic velocity measurements
- fit mass distribution with NFW profile
- integrate to get J-factor

Uncertainty

- mass profile
- priors on parameters (scale radius, density, etc.)
- can we reduce the prior dependence?



arXiv:1503.02641



DARK ENERGY SURVEY

COMPARATIVELY

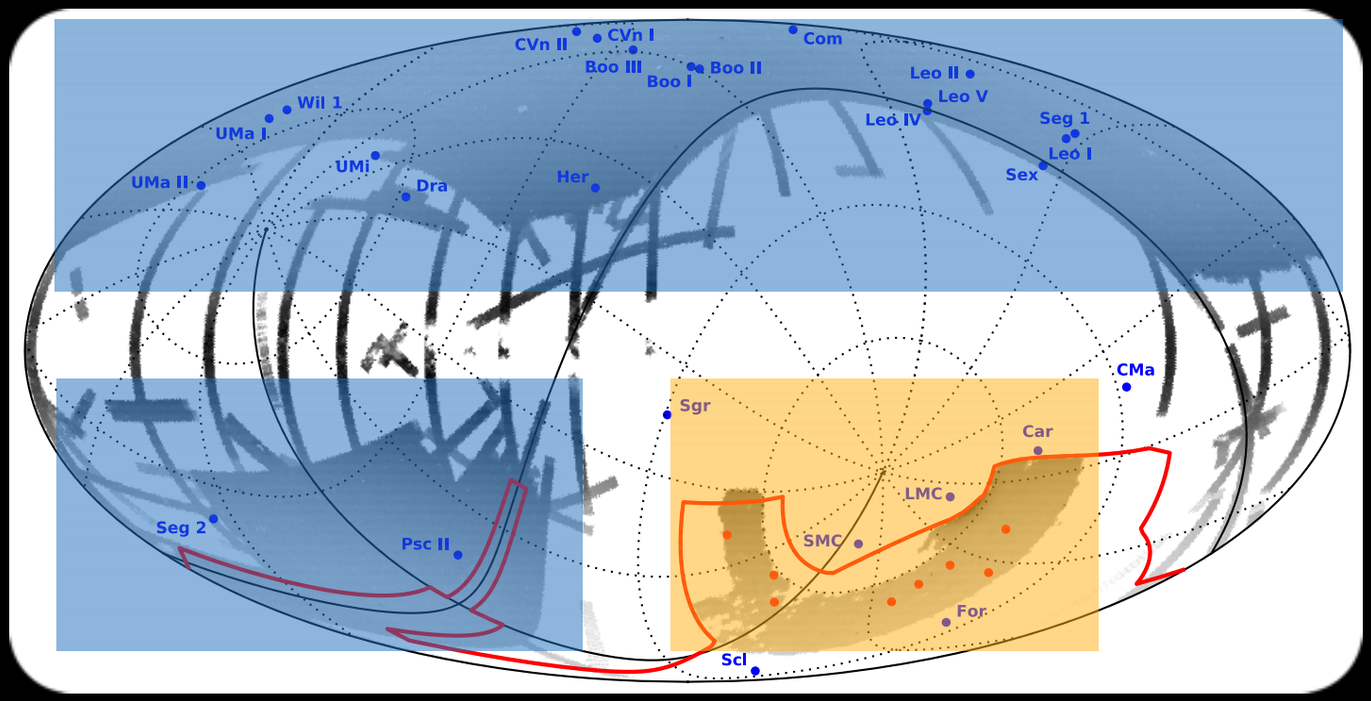
targets *

SDSS

- expanded on 12 ‘classical’ dsphs
- added 15 in a ~14,000 deg^2 patch
- 95% complete to r=22 mag
- can see faintest dsphs out to 50 kpc

DES

- will cover 5,000 deg^2
- sensitive to r=24 mag
- faintest to 120 kpc
- 1,600 deg^2 so far



arXiv:1503.02584v2

- expect 5+ from isotropy
- 20+ from N-body simulations and sensitivity

DARK ENERGY SURVEY

RETICULUM 2

targets

Location

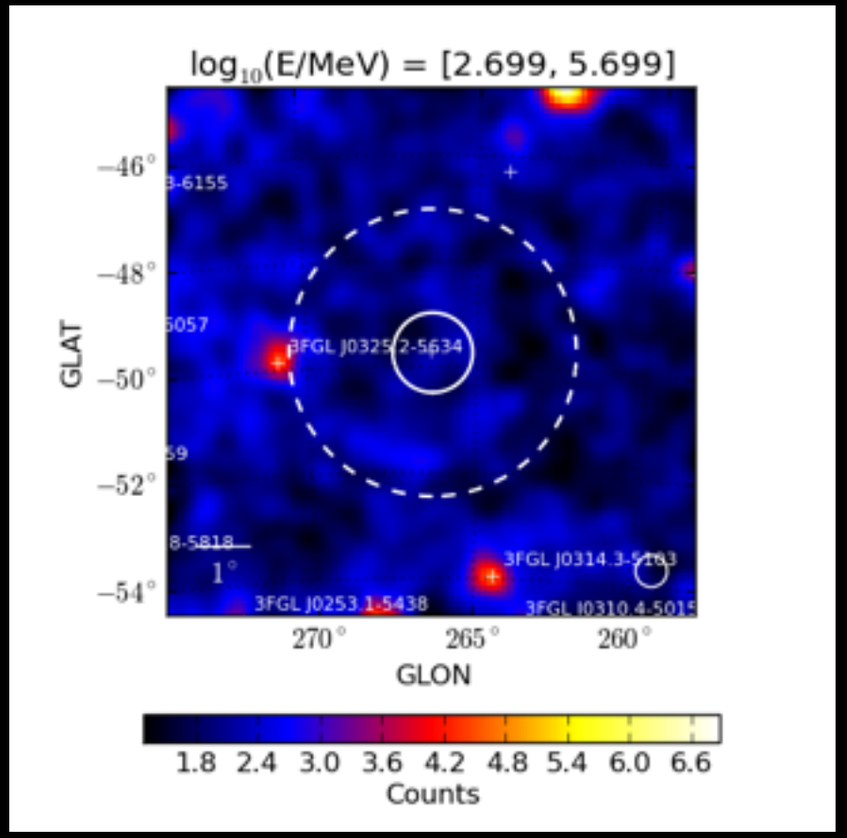
- nearby: 30 kpc (Segue I is 23)
- off-plane: -50 deg
- isolated: no nearby sources

LAT Observation

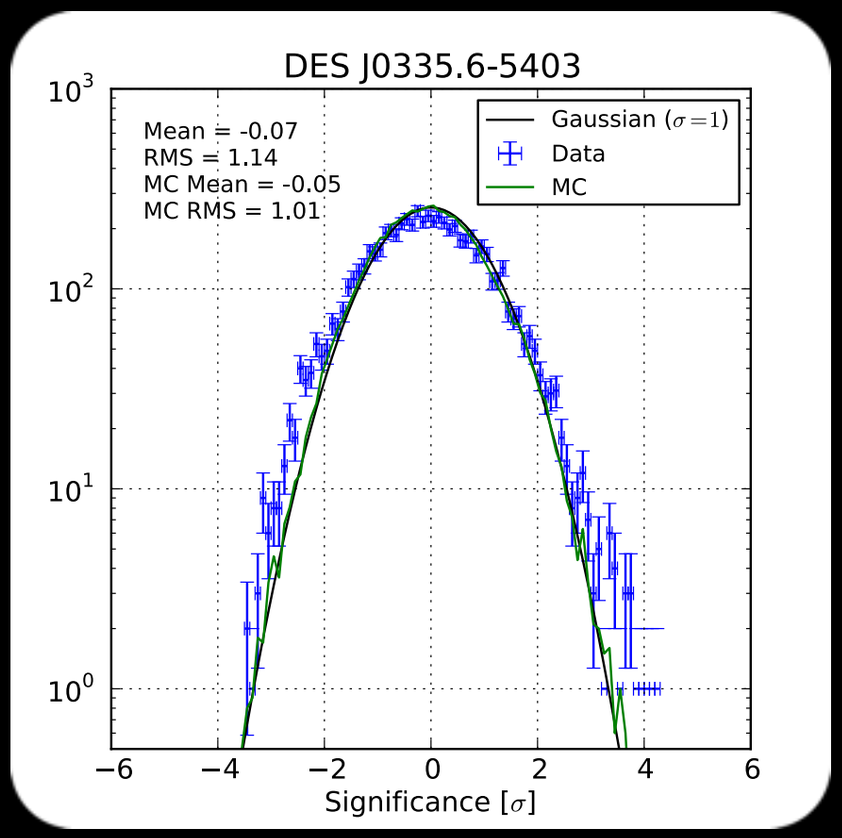
- 2.2σ local significance

DM content

- mass: $5.6 \pm 2.4 \times 10^5 M_\odot$
- one of the highest J-factors: (Segue I ~ 19.5)
  - log(J(0.5°)) = 19.5+1.0-0.6 arXiv:1504.03309v1
  - log(J(0.5°)) = 18.9±0.6 arXiv:1504.02889v1

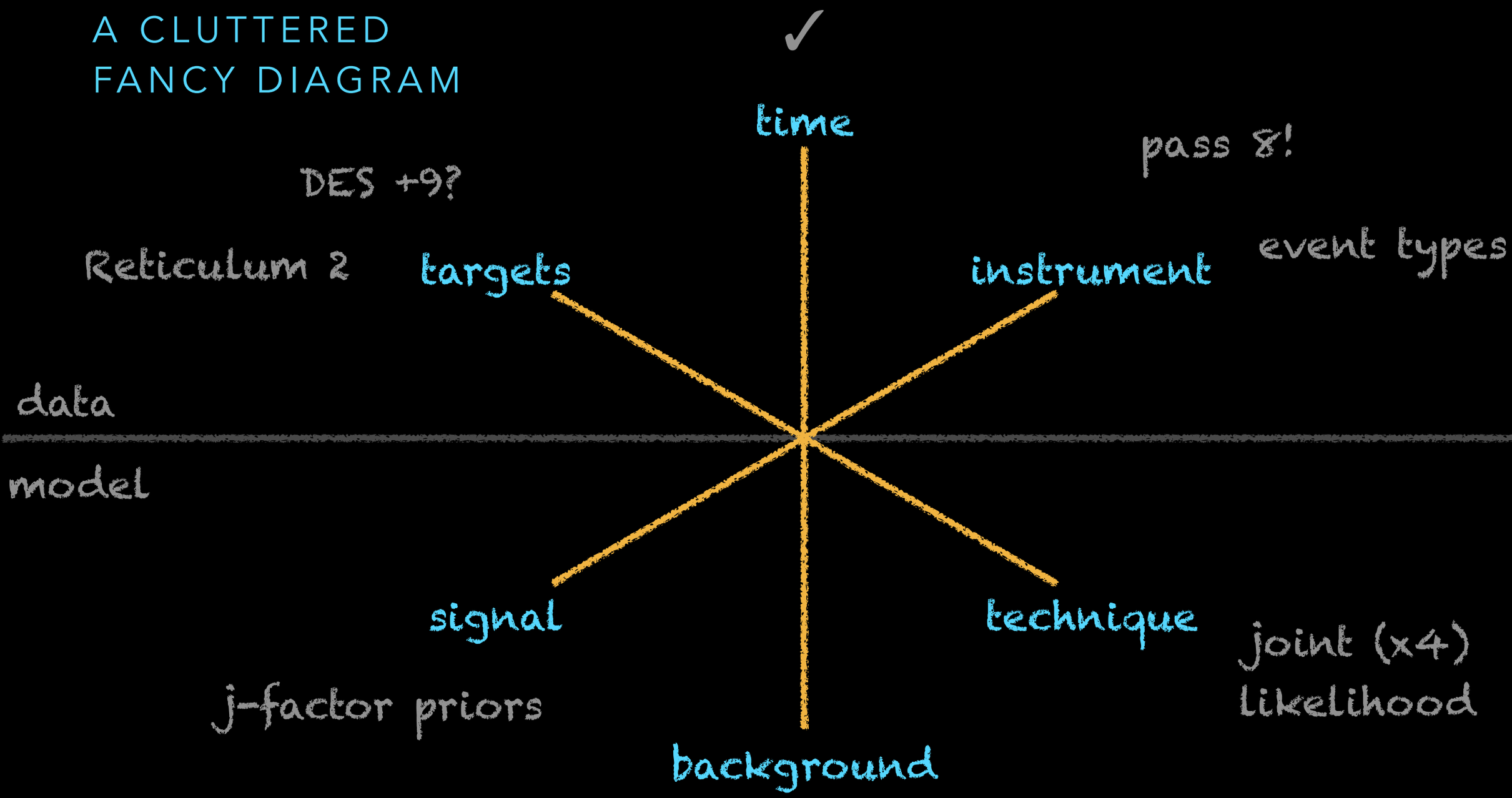


arXiv:1503.02632



SUMMARY

A CLUTTERED FANCY DIAGRAM



BACKUP

DARK ENERGY SURVEY

EFFECT ON CONSTRAINTS?

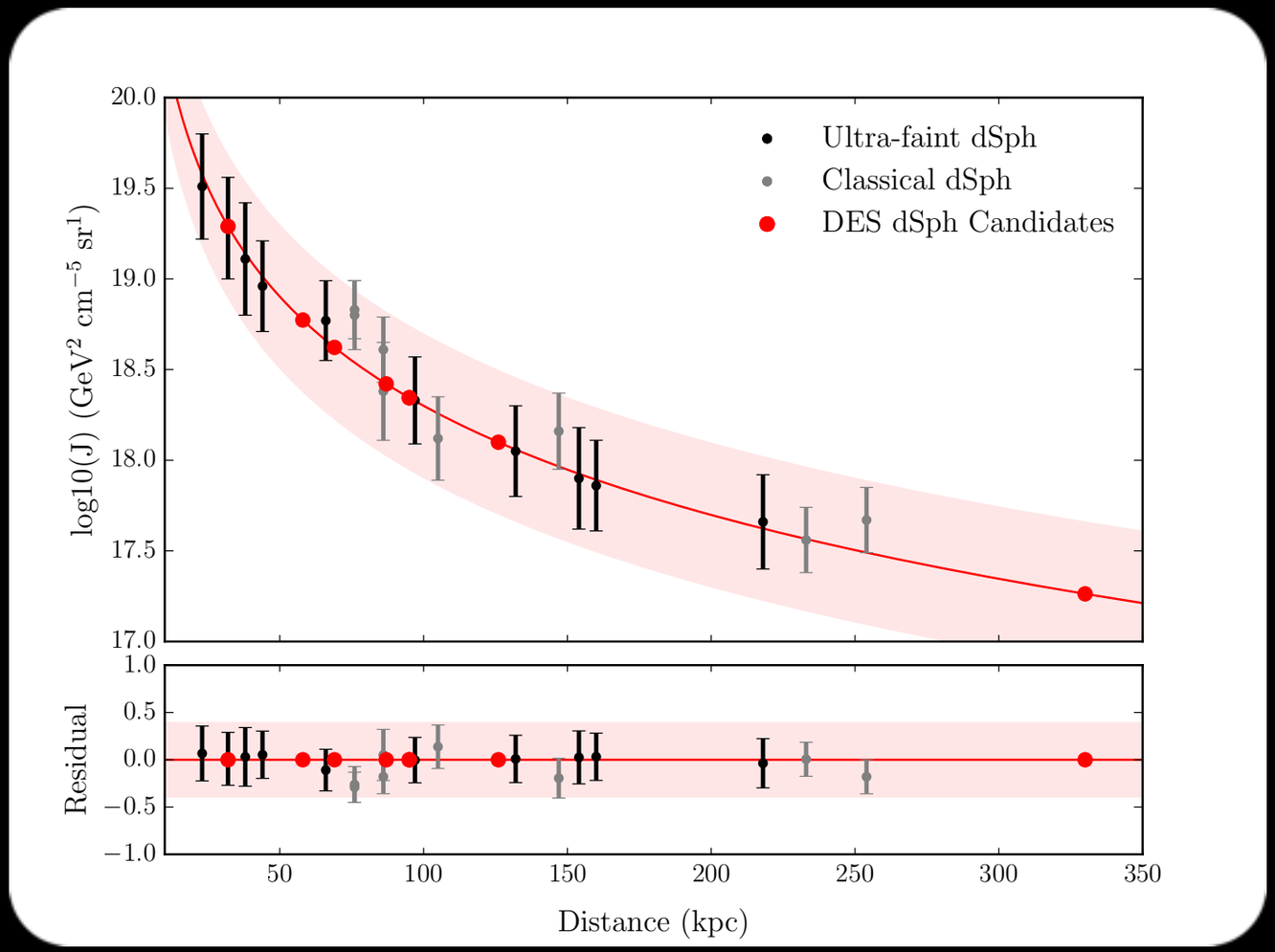
targets

J-factor estimates

- can we make a guess before spectroscopic follow-up?
- regardless of DM content, J-factor is proportional to 1/distance^2
- just assuming they all have the same content does okay

Caveats

- this doesn't fit so well to other analyses' J-factors
- no accounting for detection biases / distributions / etc.
- these might not even be bound objects

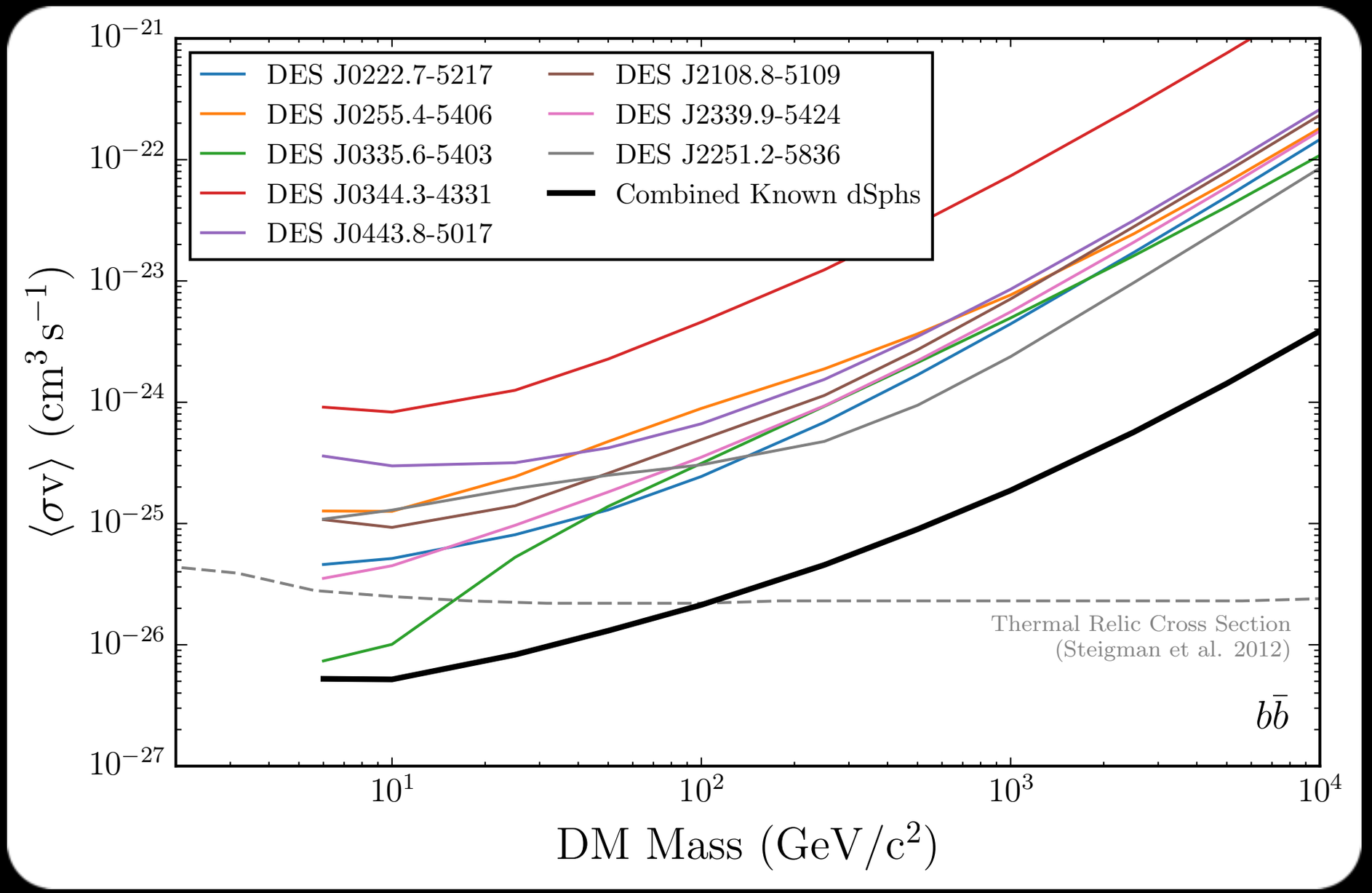


arXiv:1503.02632

DARK ENERGY SURVEY

EFFECT ON CONSTRAINTS?

targets

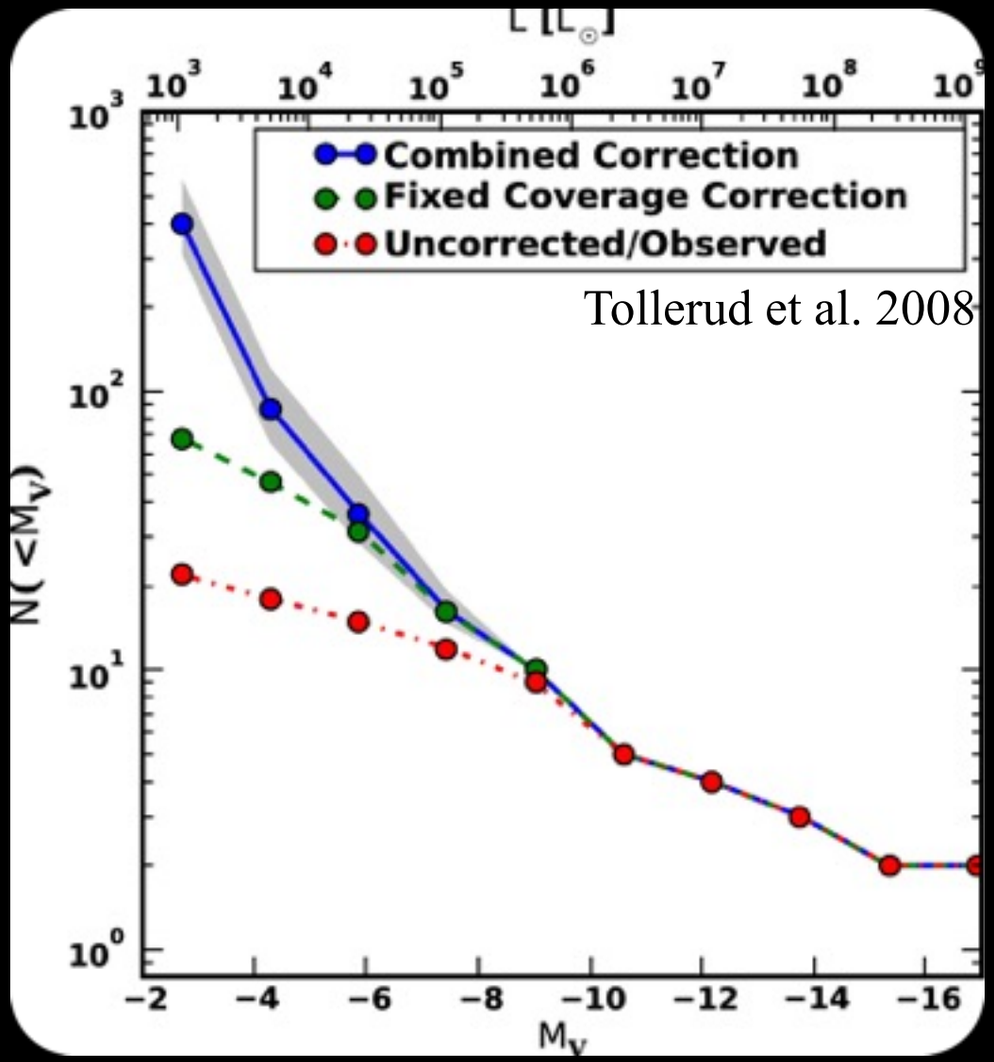


arXiv:1503.02632

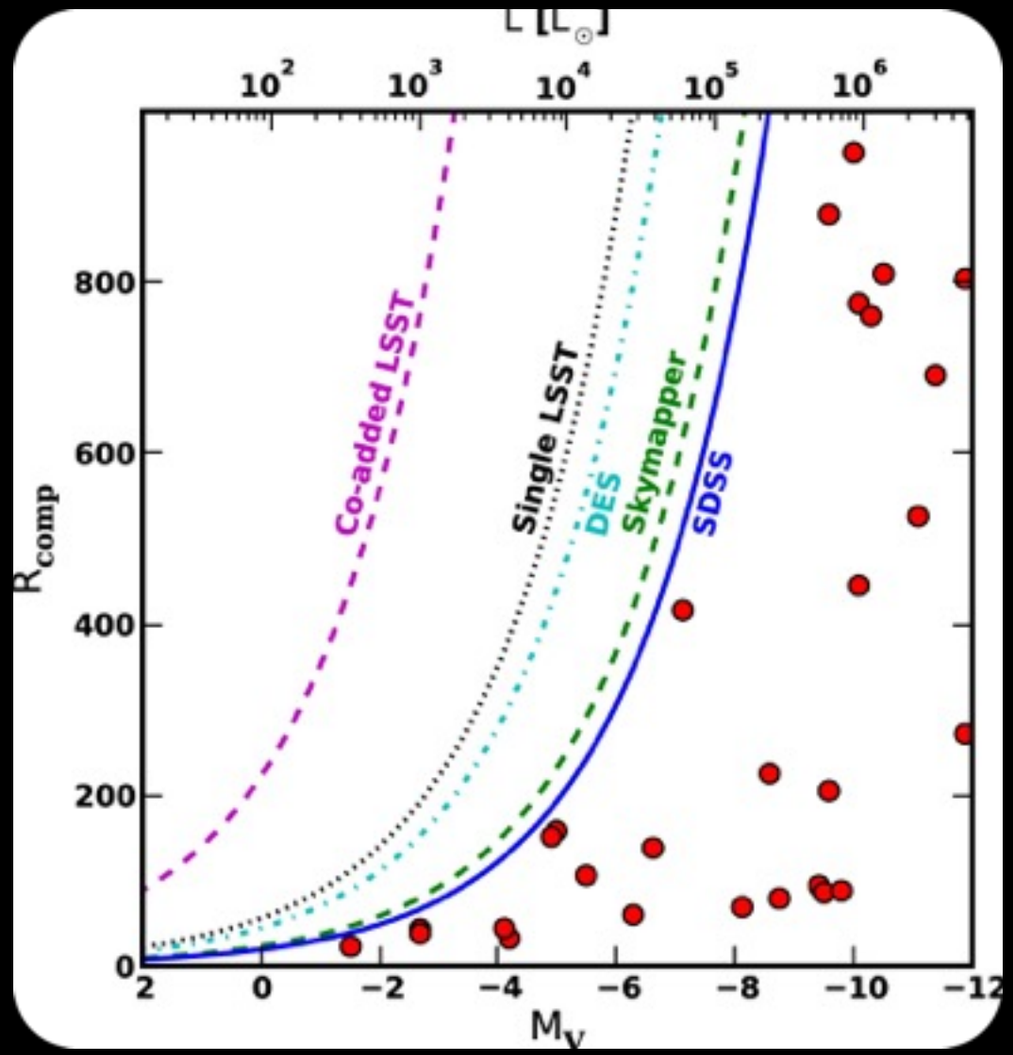
DSPH HUNTING

TOWARDS FULL SET

targets



Tollerud et al. 2008



Population Projection

- take an N-body (VLII)
- fit dsph mass threshold to observed radial distribution
- project total population

Upcoming Surveys

- DES running now
- LSST should see all dsphs (starting 2022)

LIMIT COMPARISON

arXiv:1503.02641