Probing Extreme Universe with Gamma-Ray, Kashiwa, January 13th

INDIRECT SEARCH FOR DM

CROSS-CORRELATION OF GALAXIES WITH EXTRA GALACTIC GAMMA-RAY

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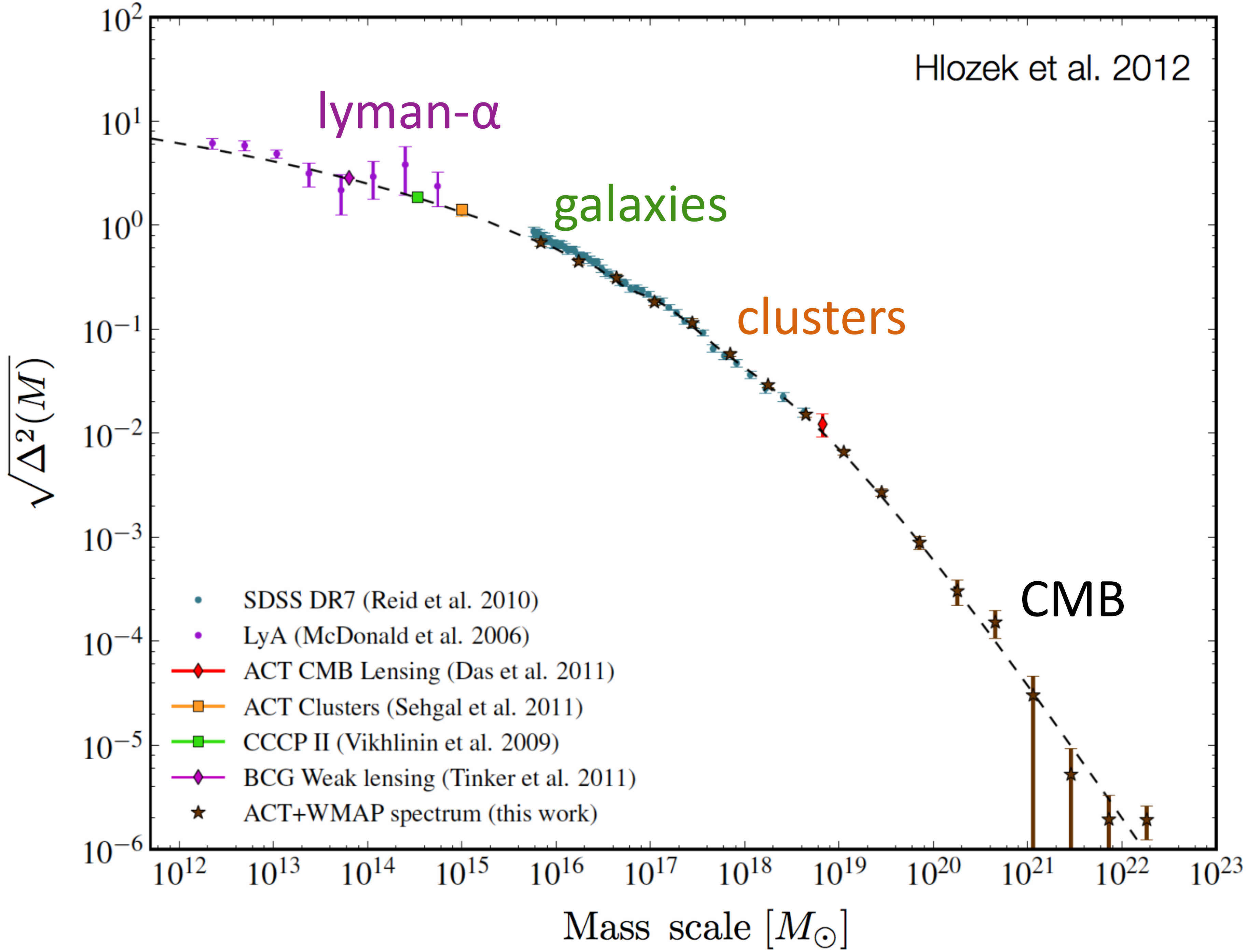
References:

Shirasaki, Horiuchi, NY, 2014, PRD 90 35020   Cosmic shear - EGB
Shirasaki, Horiuchi, NY, 2015, PRD 92 12354   LRG - EGB

The success of ΛCDM continues...



The nature of dark matter

- Elementary particles ?
- Particle mass, charge, velocity dispersion

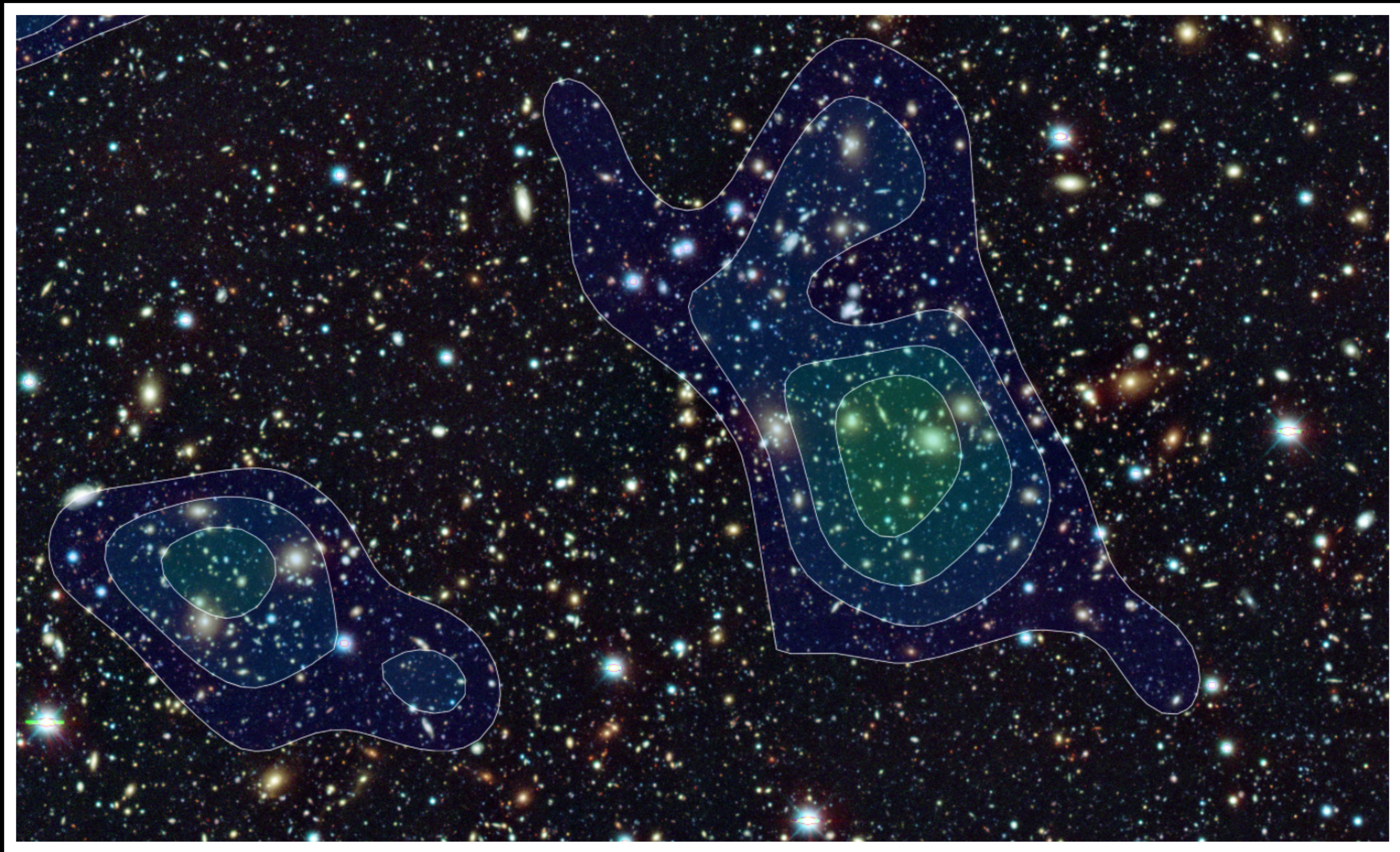
- Cross section of (elastic) scattering
- Cross section of self-annihilation
- Decay life time

The key is non-gravitational signature,
possibly electro-magnetic one,
of dark matter.

Indirect search
for
dark matter

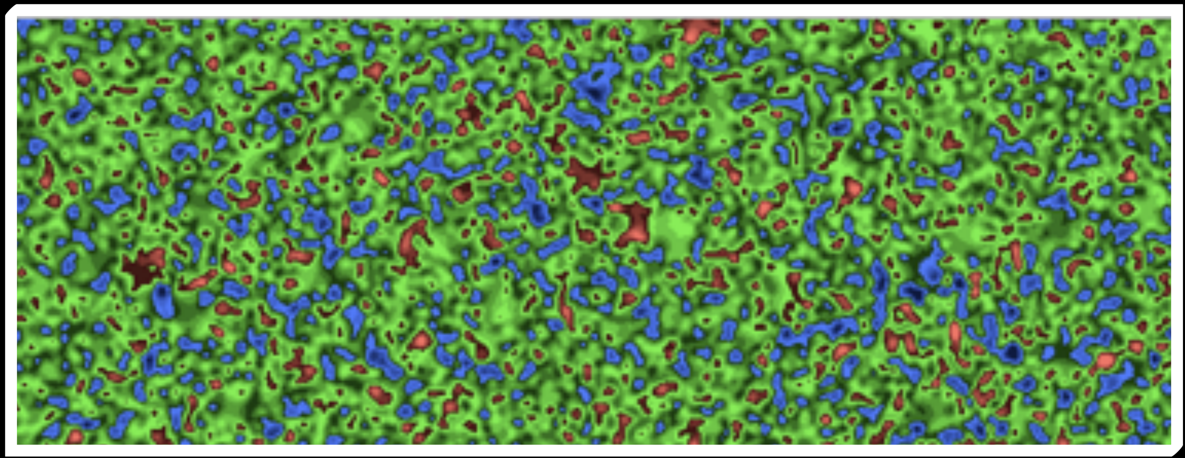
Direct mapping of dark matter

Small distortion of galaxy shapes → Grav. potential



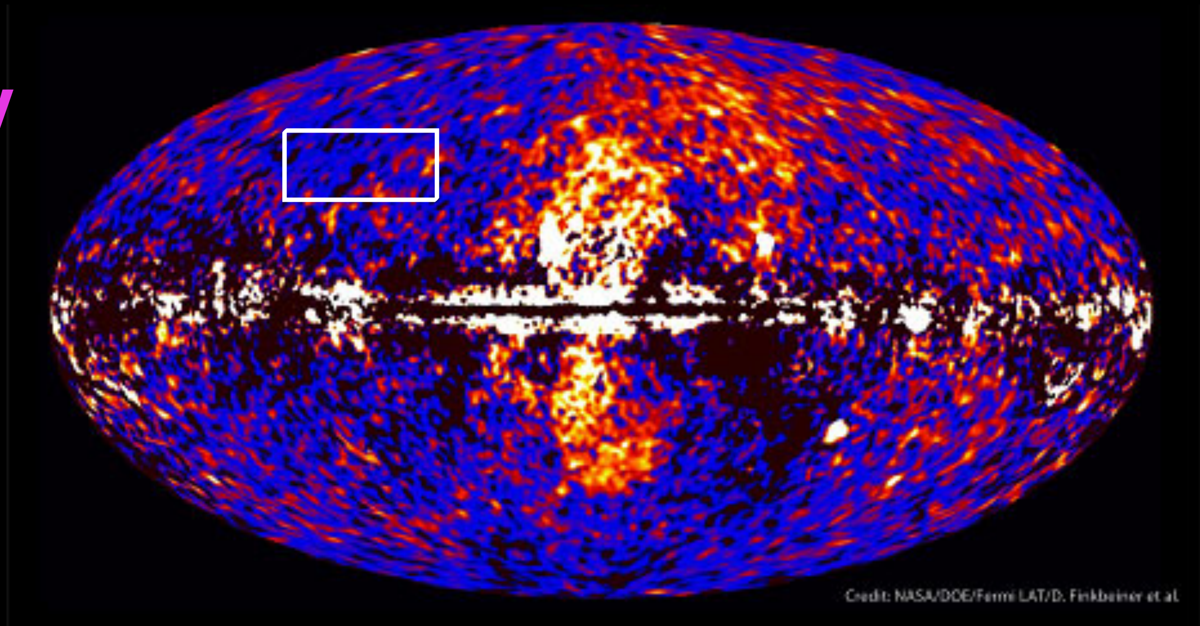
Recent snapshot from HSC survey

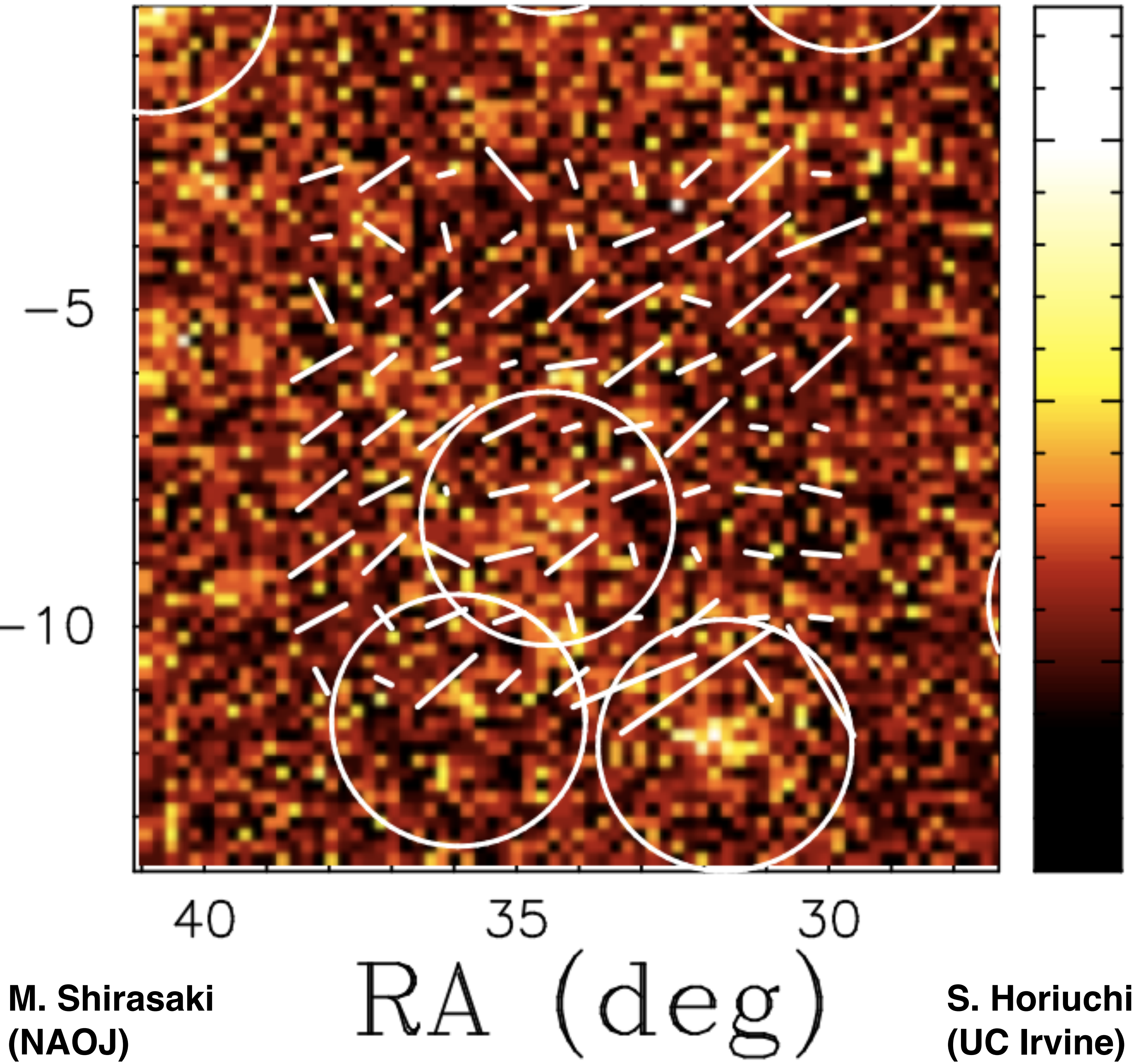
When we have two maps…



Dark matter distribution from CFHTLenS survey

Fermi all-sky γ-ray





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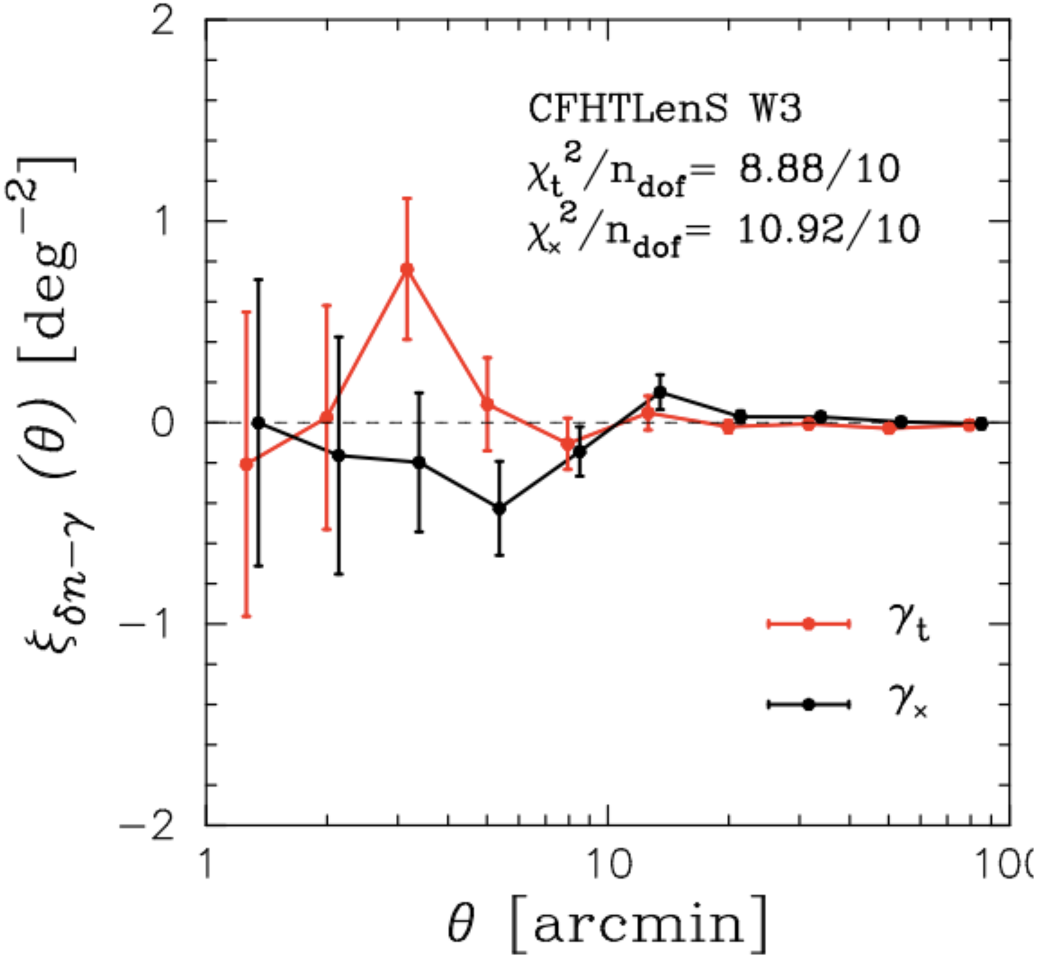
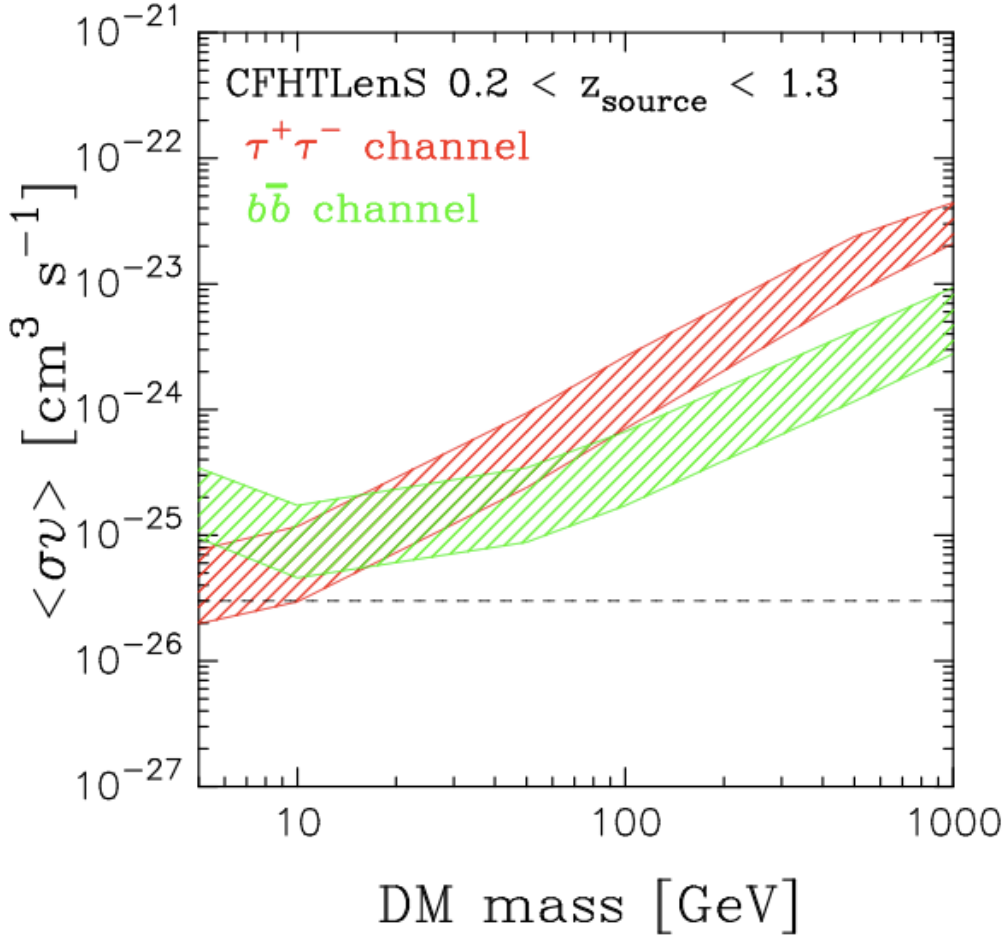
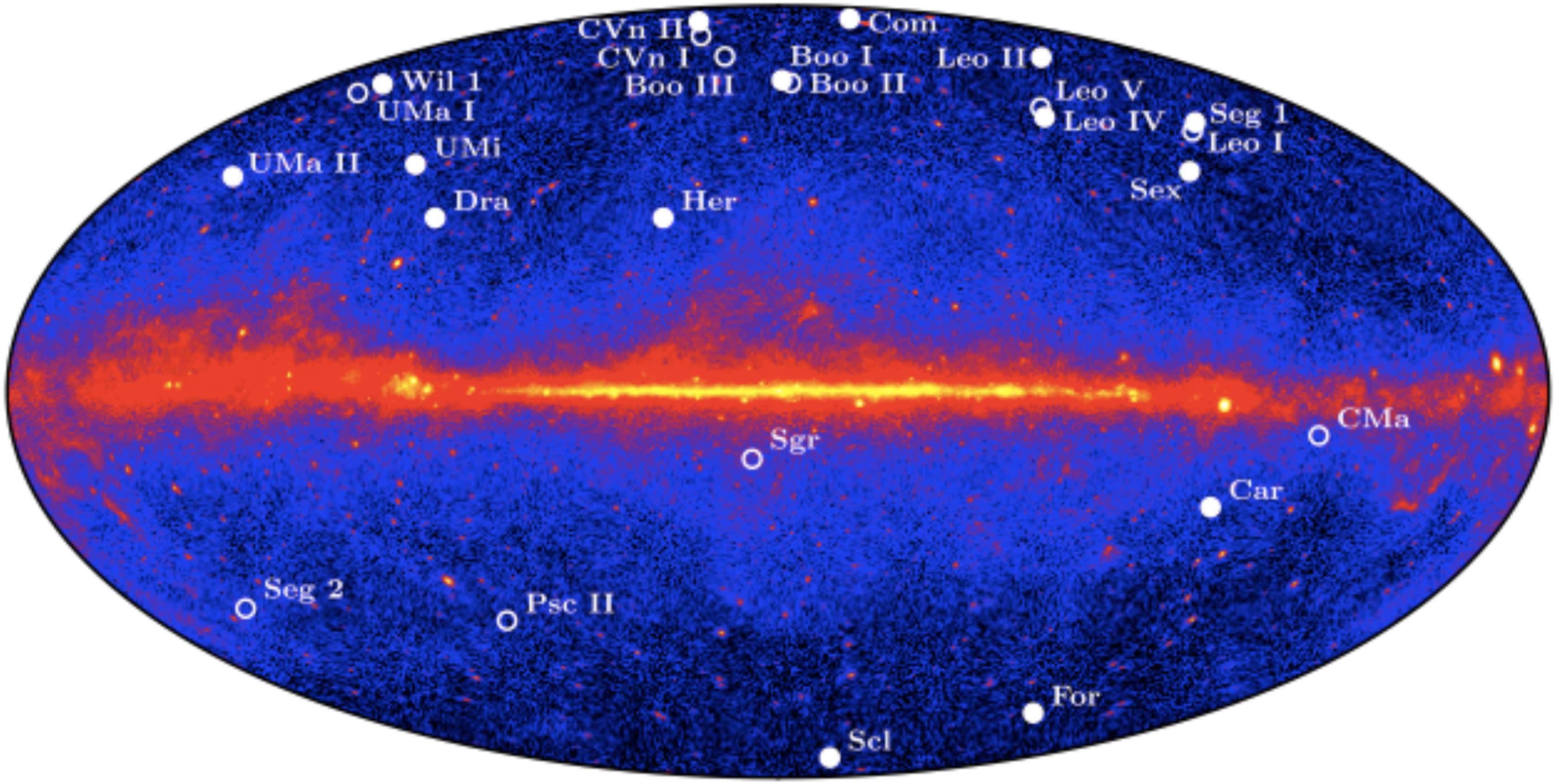
The first "cosmological" constraints on the annihilation cross-section



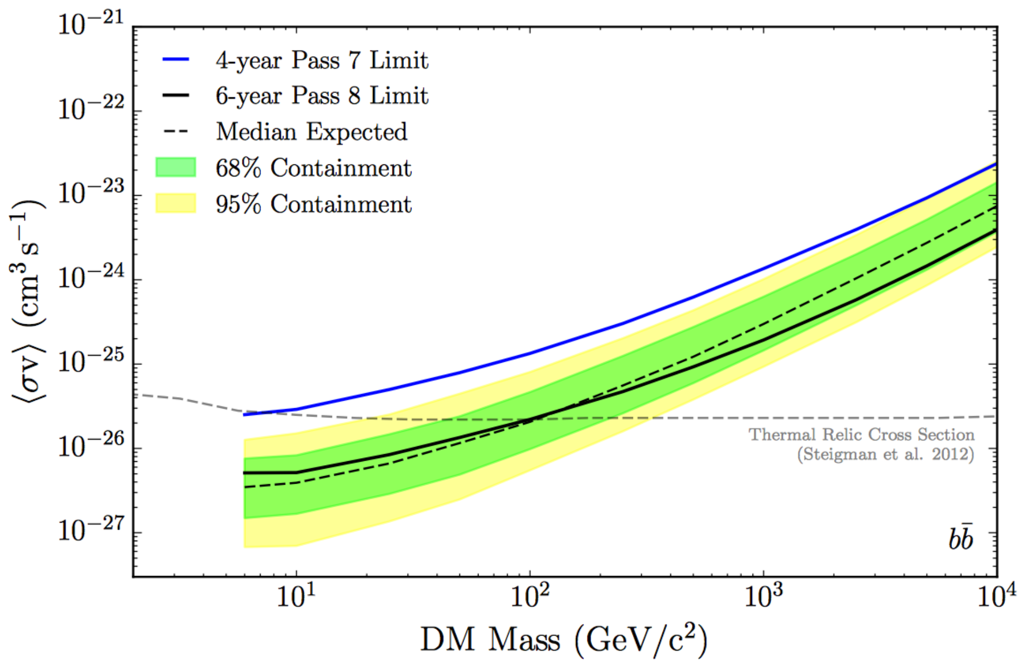


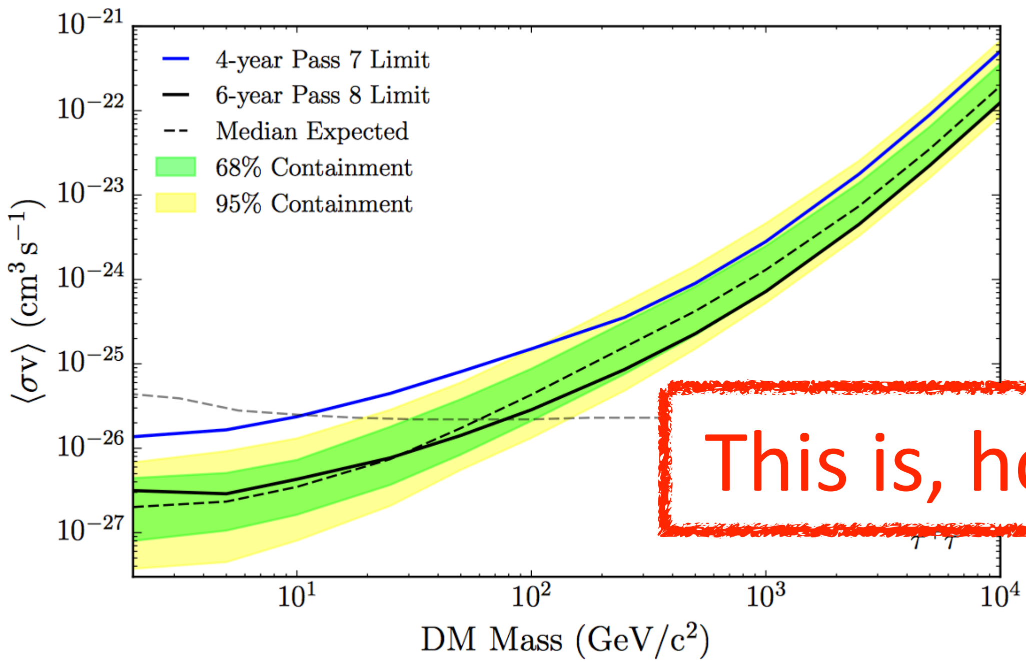
All-sky gamma-ray map



Fermi sat.
Ackermann et al. 2014
Circles indicate the locations of 25 Milky Way satellite galaxies

Annihilation cross-section





Fermi 6-year data
Search for excess γ-emission from dwarf galaxies

↓

No detection of excess

↓

Modeling of DM contents

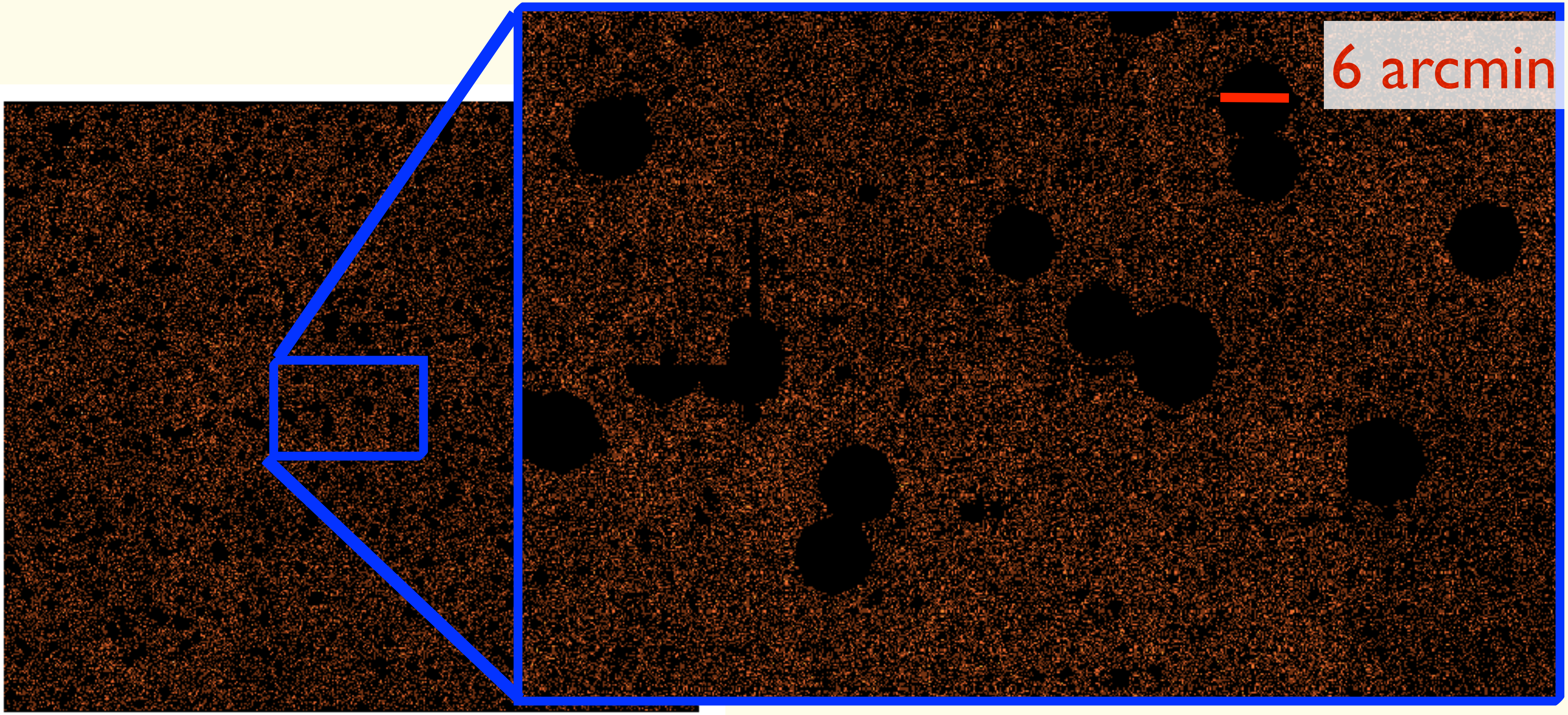
↓

Constraints on the DM annihilation cross-section

←

This is, however, a “local” constraint.

Dark matter distribution in a CFHT field



Colored by the number of source galaxies per grid
(grid size=0.15 arcmin)

Lensing analysis

Observation

inhomogeneous shear map

Ray-tracing simulation

homogeneous shear map

add noise

$$\mathcal{K}(\boldsymbol{\theta}) = \int \mathrm{d}^2\phi \; \gamma_t(\boldsymbol{\phi}:\boldsymbol{\theta}) Q_t(\boldsymbol{\phi}),$$

continuous WL mass map — NOT directly compared! — continuous WL mass map

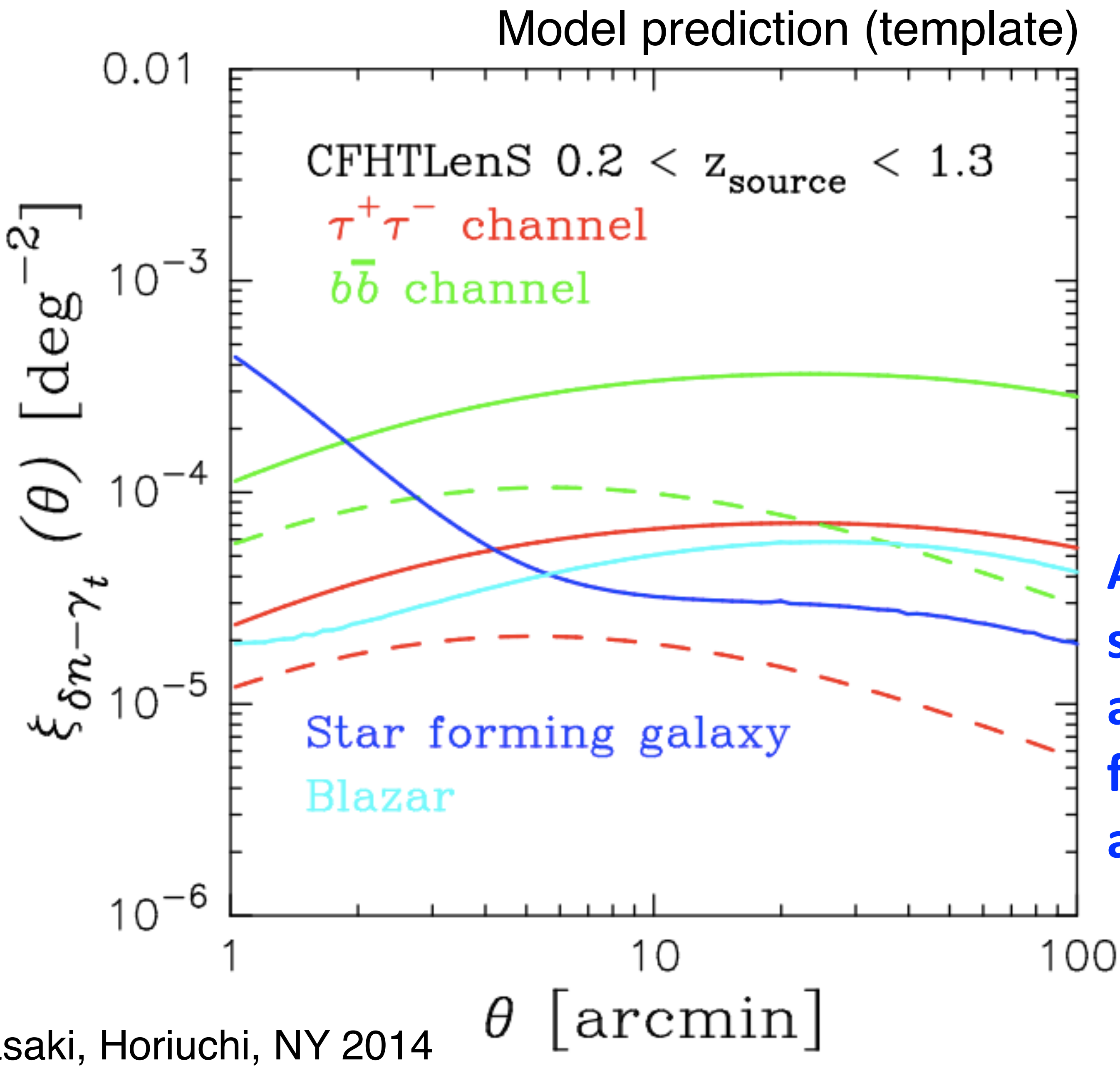
take up inhomogeneity

discard some pixels = paste mask field

$$\mathcal{K}(\boldsymbol{\theta}) = \int \mathrm{d}^2\phi \; \gamma_t(\boldsymbol{\phi}:\boldsymbol{\theta}) Q_t(\boldsymbol{\phi}),$$

masked WL map — statistics — masked WL map

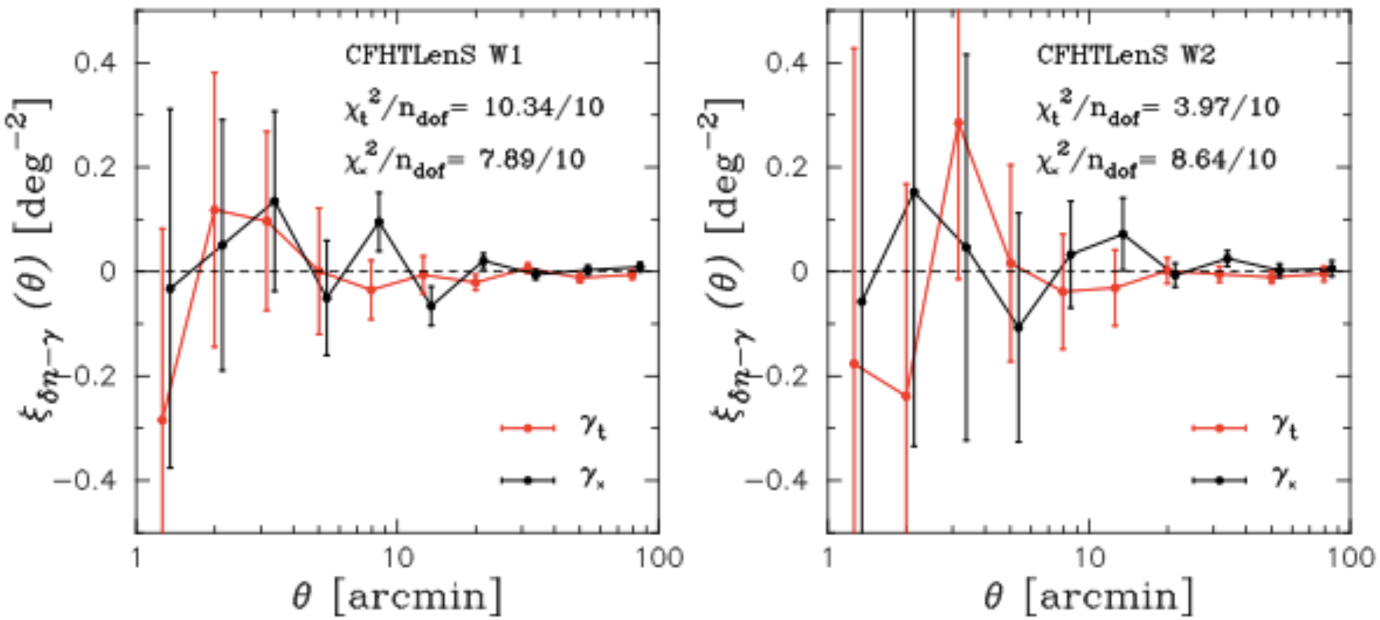
Shear -γ cross-correlation



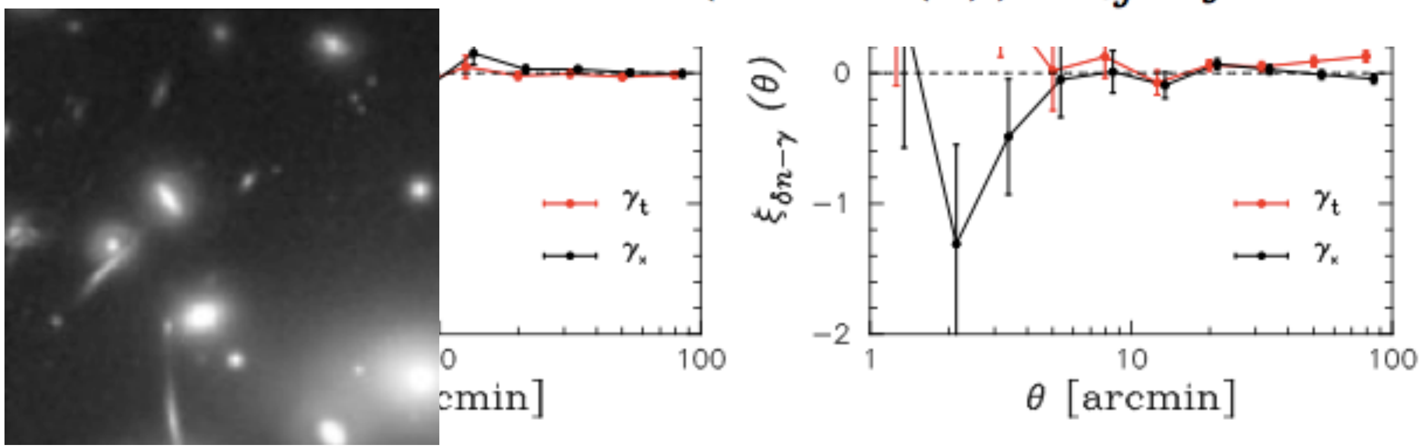
Astrophysical sources sub-dominant at large-angular scales for a canomical ann. cross-section

Shirasaki, Horiuchi, NY 2014

4 fields: 154 deg^2

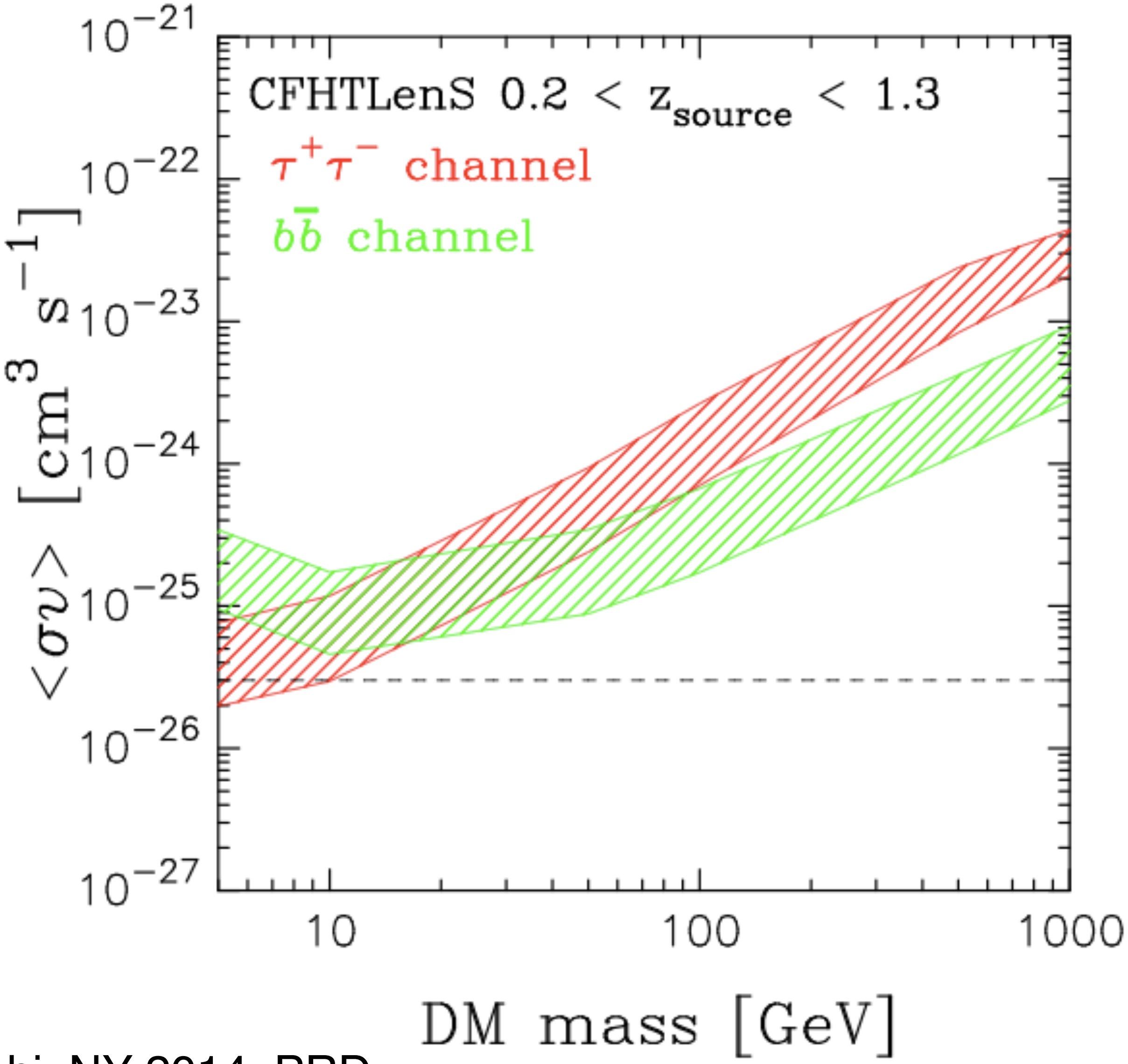


$$\xi_{\delta n-\gamma_t}(\theta) = \frac{\sum_{ij}(n_i^{\rm obs}(\boldsymbol{\phi}_i) - n_i^{\rm gm}(\boldsymbol{\phi}_i))w_j\epsilon_{t,j}(\boldsymbol{\phi}_i + \boldsymbol{\theta}_j)}{(1+K(\theta))\sum_{ij} w_j}$$



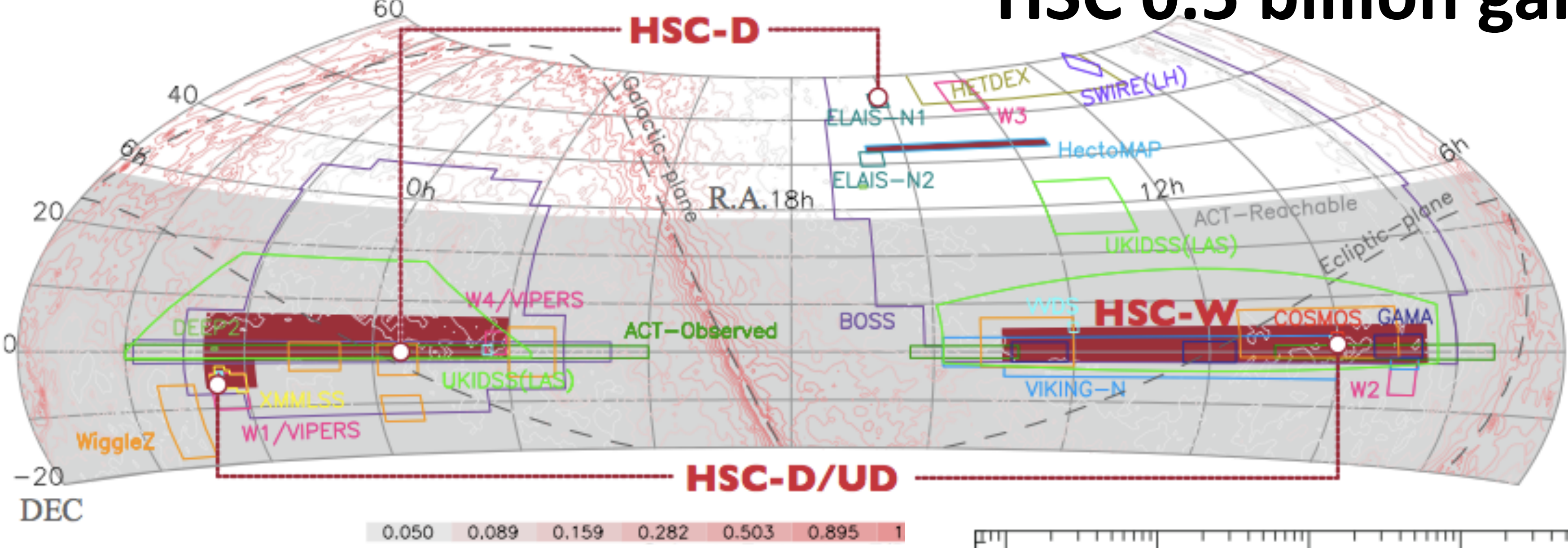
CFHT-Fermi cross-correlation

$$\langle \sigma v \rangle$$

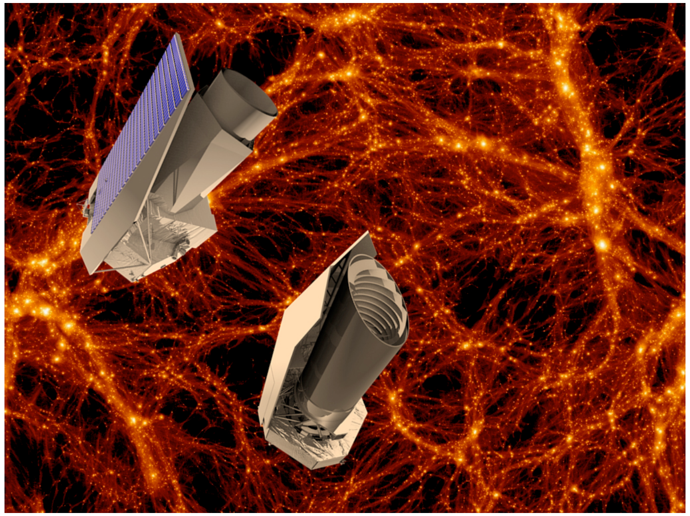


Shirasaki, Horiuchi, NY 2014, PRD

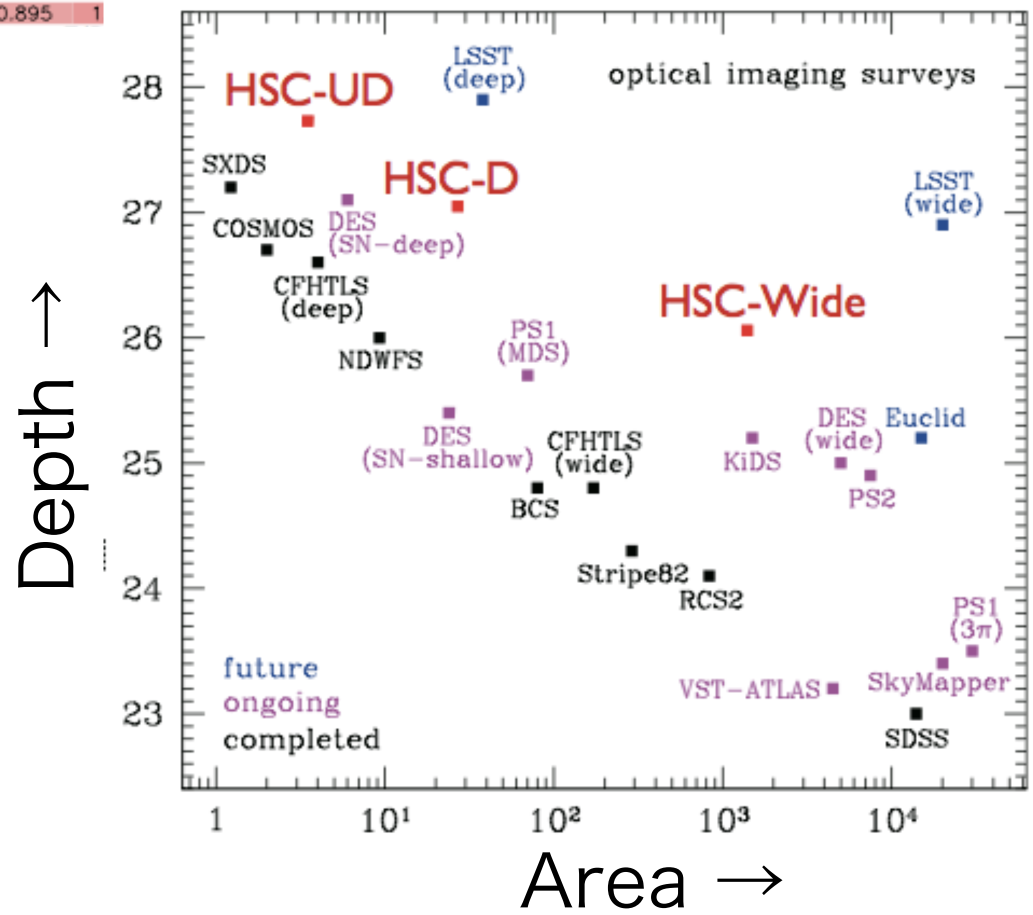
HSC 0.5 billion galaxies



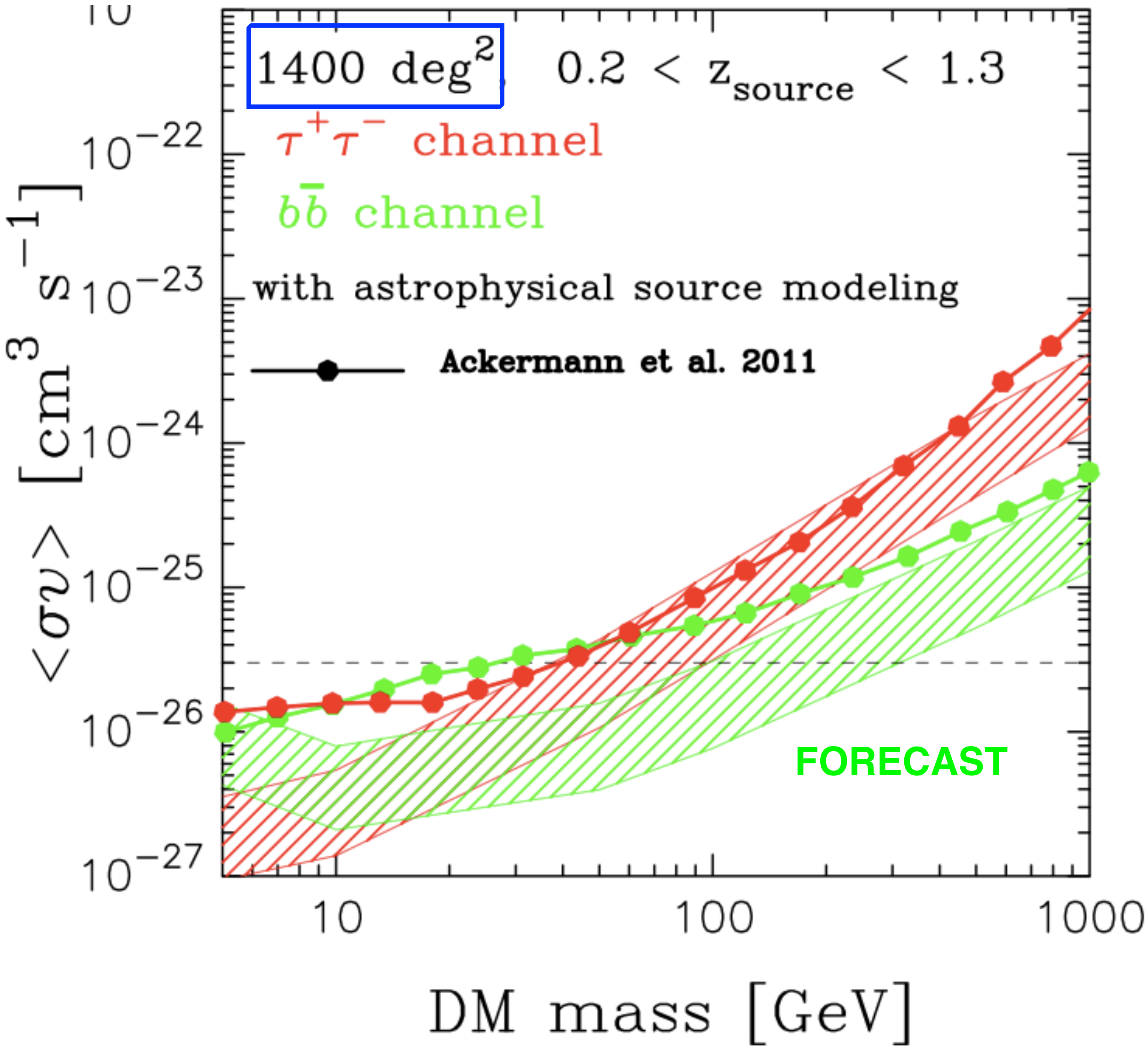
Euclid (2020-)



Dark matter, dark energy, test of gravity

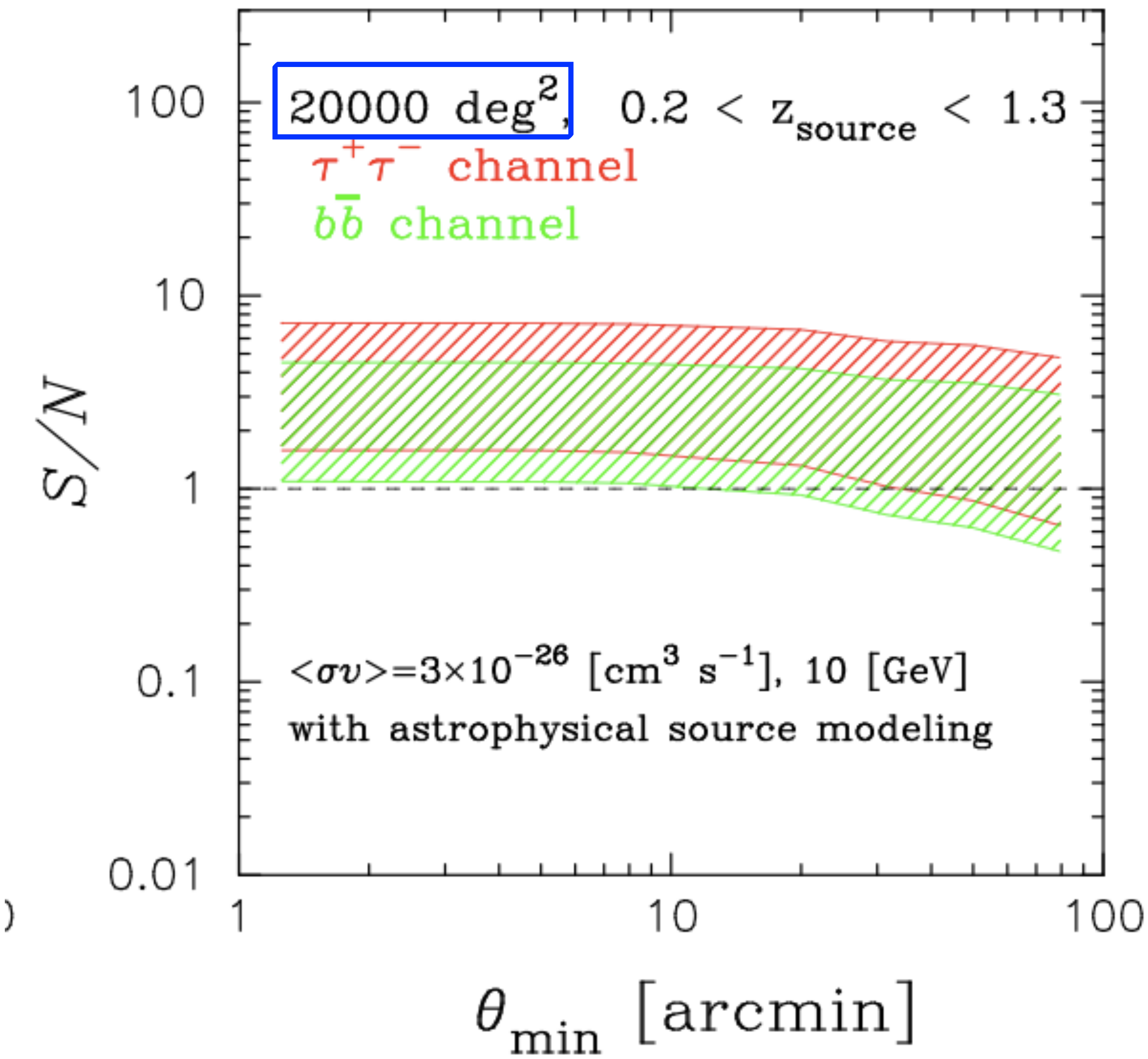


We'll use HSC!!!


1400 deg^2, 0.2 < z_{source} < 1.3
$\tau^+\tau^-$ channel
$b\bar{b}$ channel
with astrophysical source modeling
Ackermann et al. 2011
FORECAST
$\langle\sigma v\rangle$ [cm^3 s^{-1}]
DM mass [GeV]
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10
100
1000

With LSST…

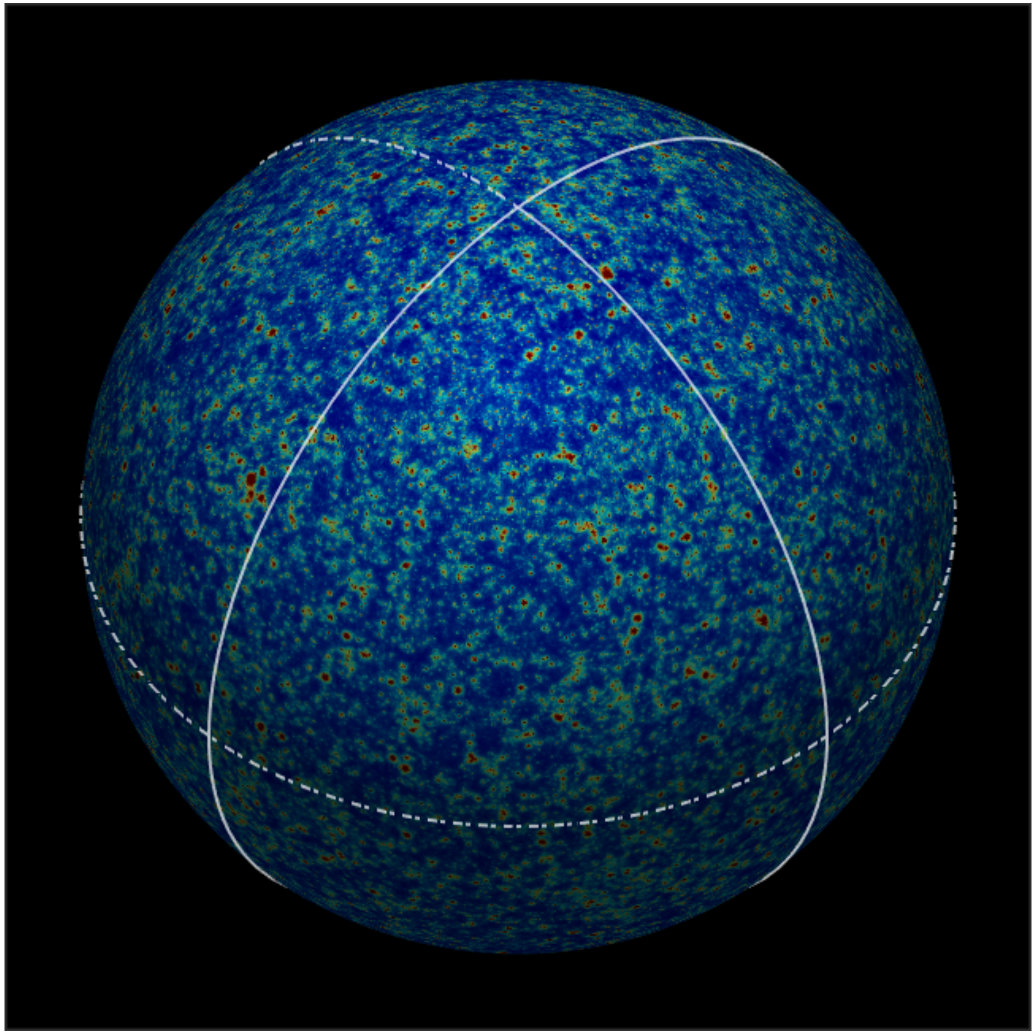
DETECTION with 3-5σ confidence is possible！！！



← This estimate is derived from the 4-yr Fermi data and the current SFG/blazer model. Both can be improved.

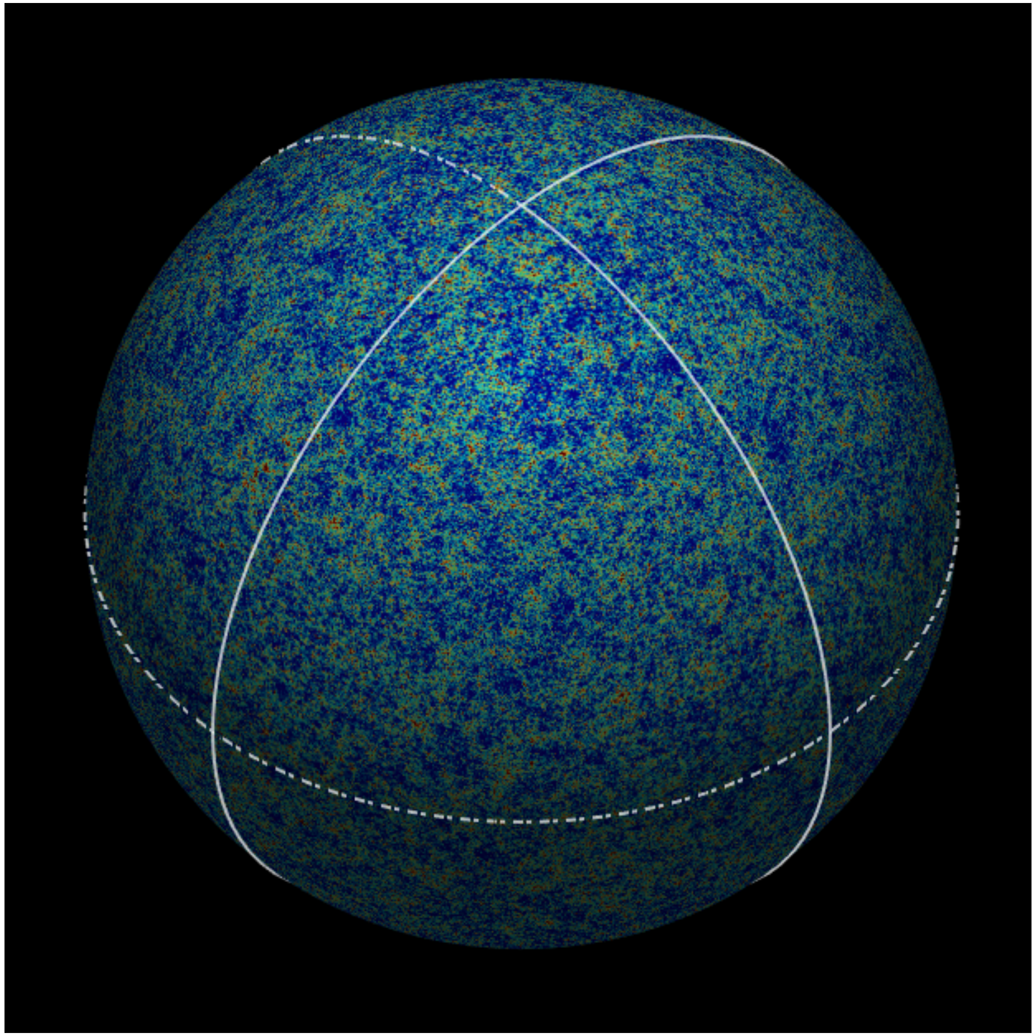
All-sky simulation

Extra-galactic γ-ray (θ_{pix} ~ 0.2 deg)



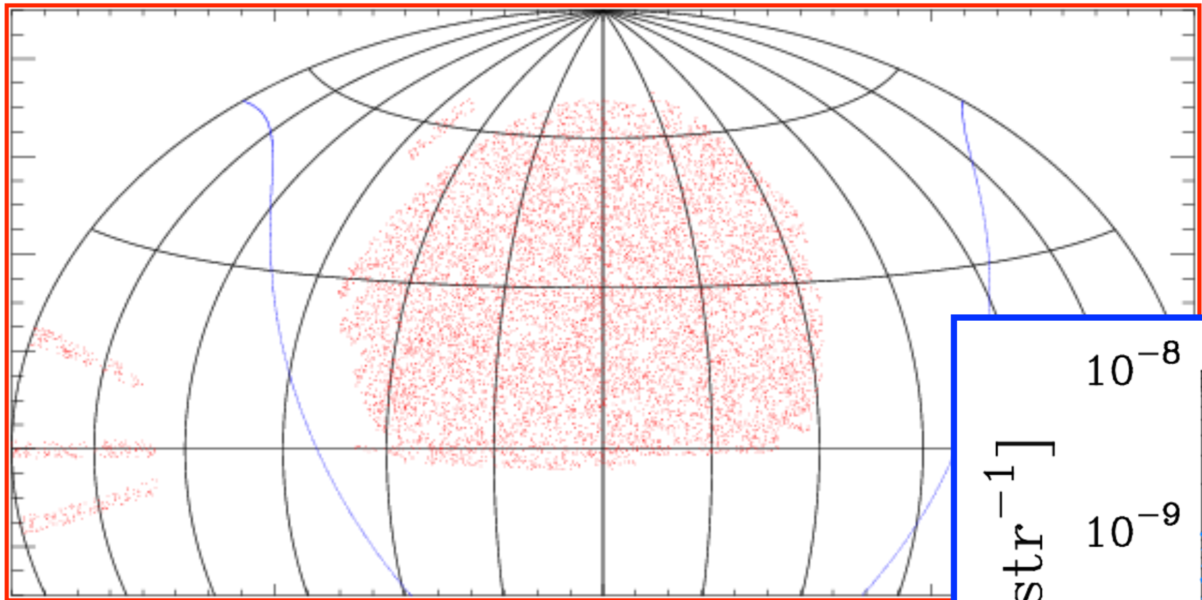
100 GeV, thermal cross section bb channel

Weak lensing(θ_{pix} ~ 1 arcmin)



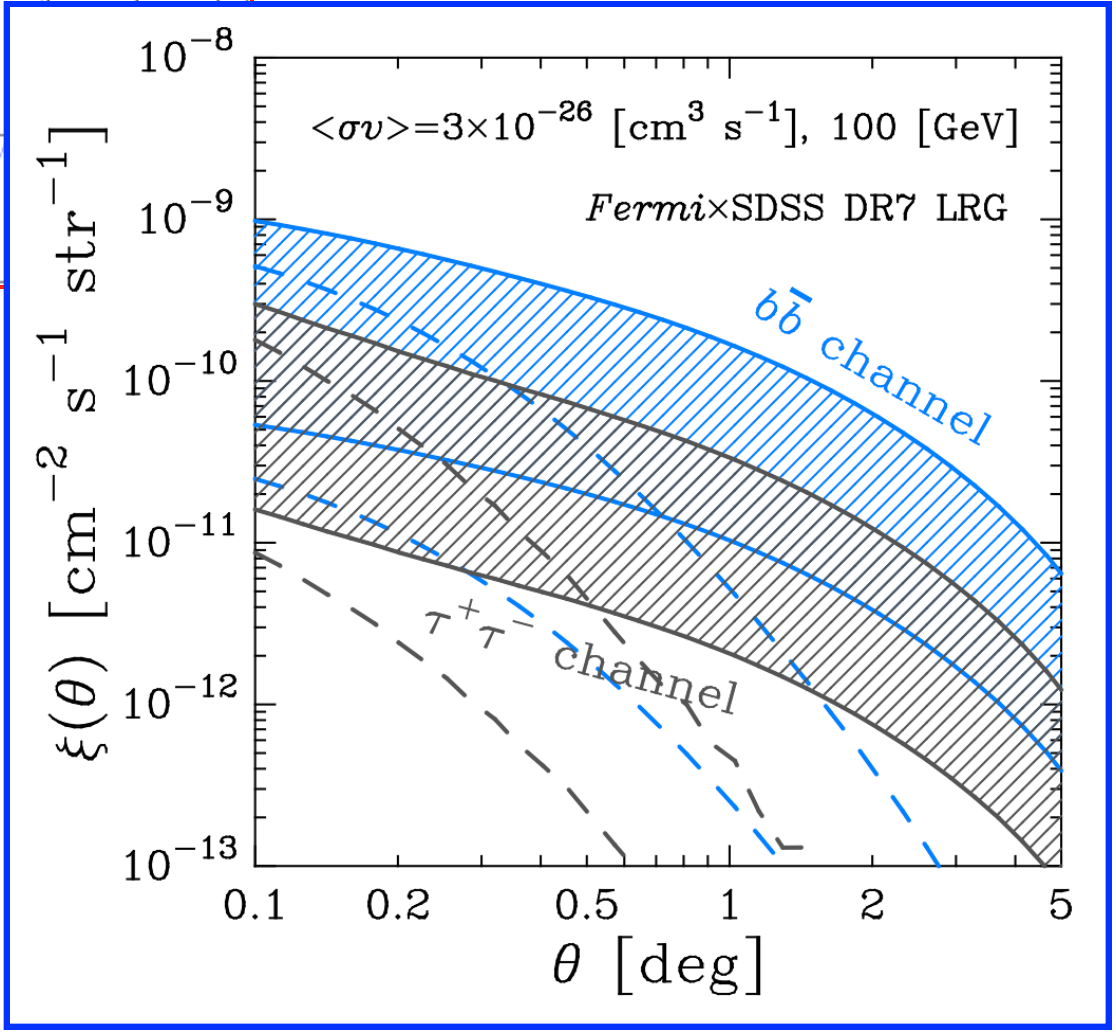
Many mock catalogues for Hyper-Suprime Cam

X-correlation with LRGs

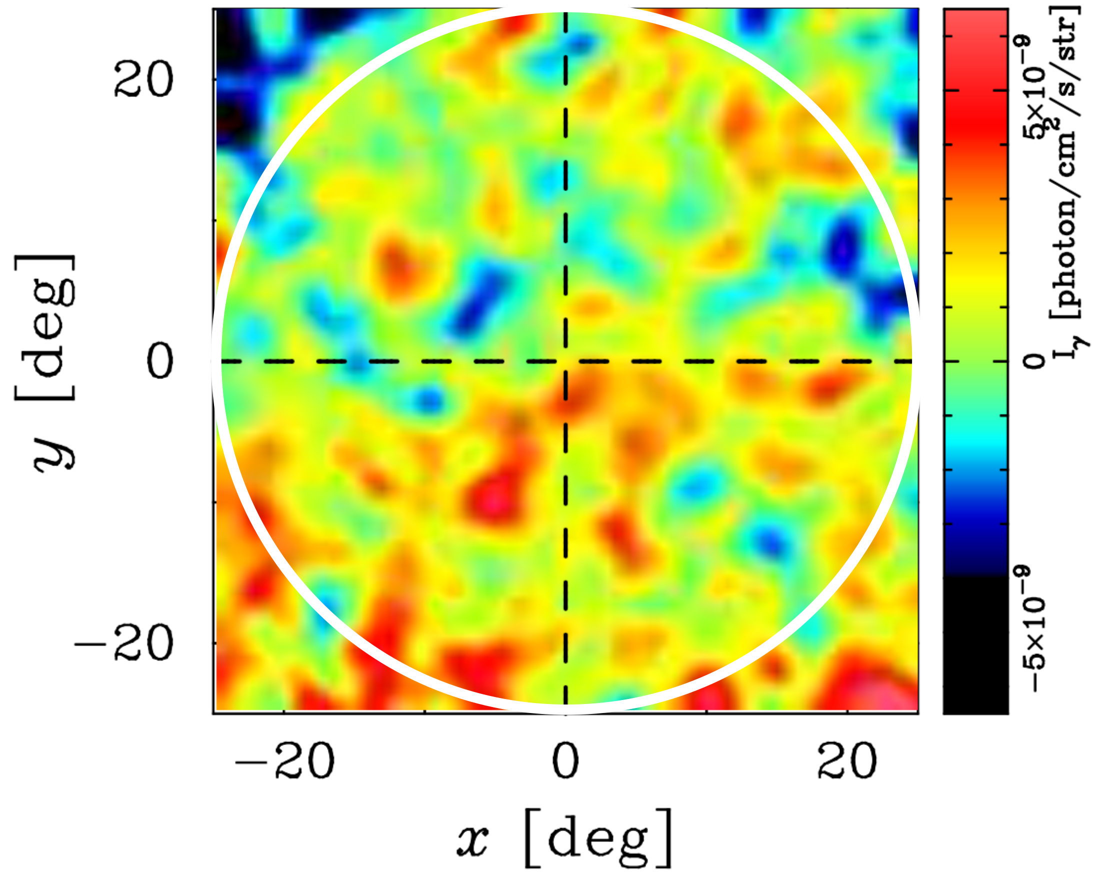


Distribution of SDSS luminous red galaxies. 30,272 LRGs with spectroscopic redshift. Well determined HOD with gal-gal lensing info. Plus many mock catalogues.

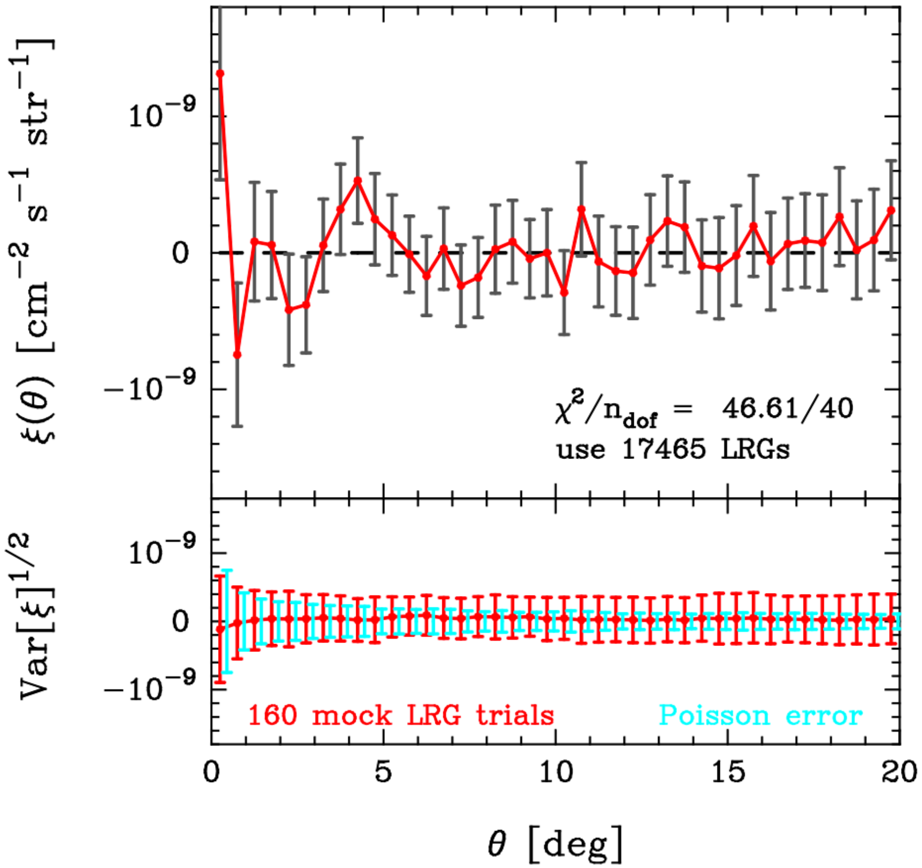
Expected signal from DM annihilation



X-correlation with LRGs



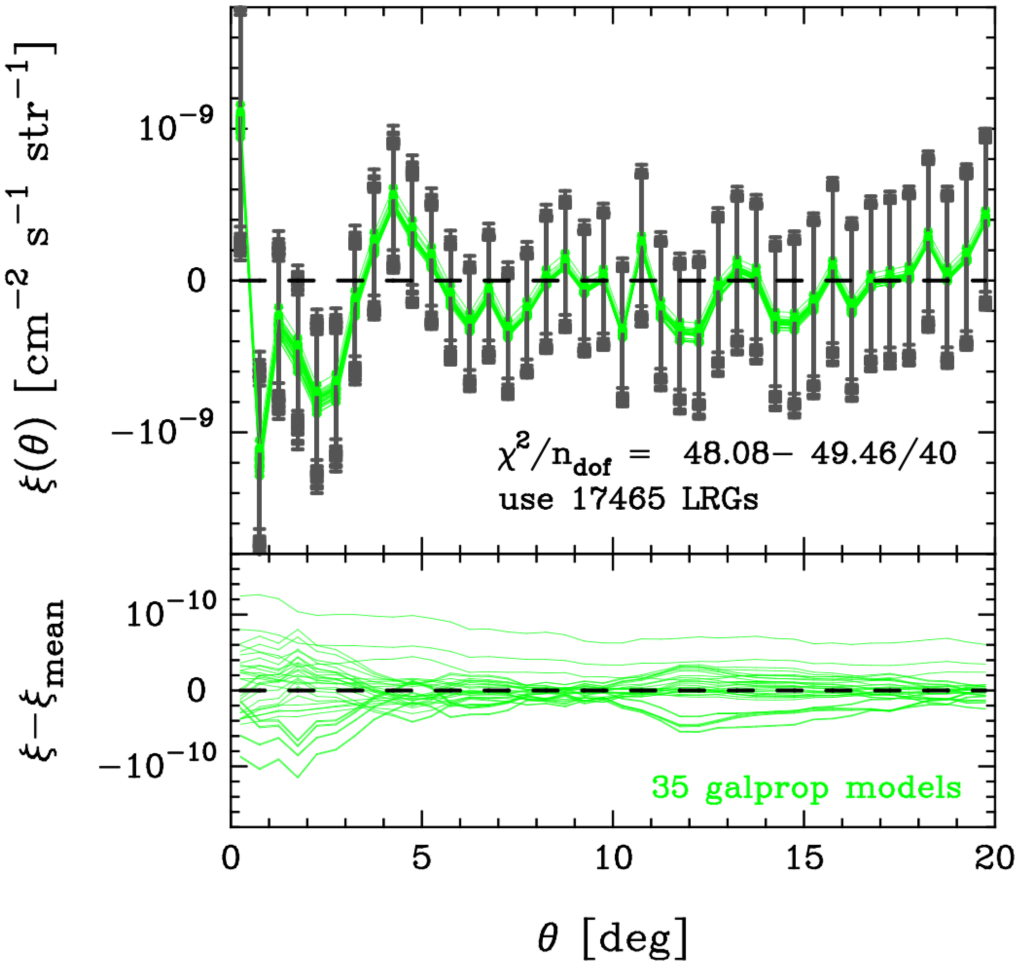
Stacked γ-image centered at the position of the LRGs



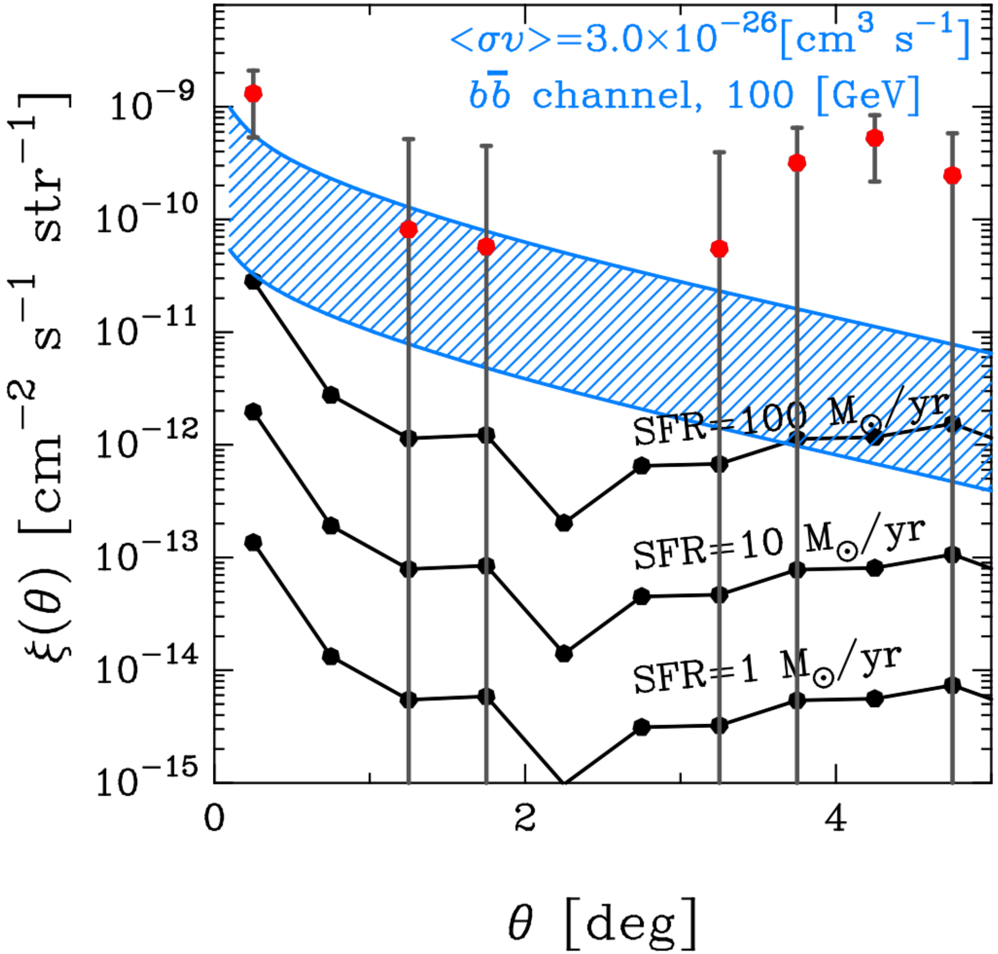
Consistent with null-correlation (～ No DM contribution)

Foreground and astrophysical sources

Galactic model uncertainties are unimportant

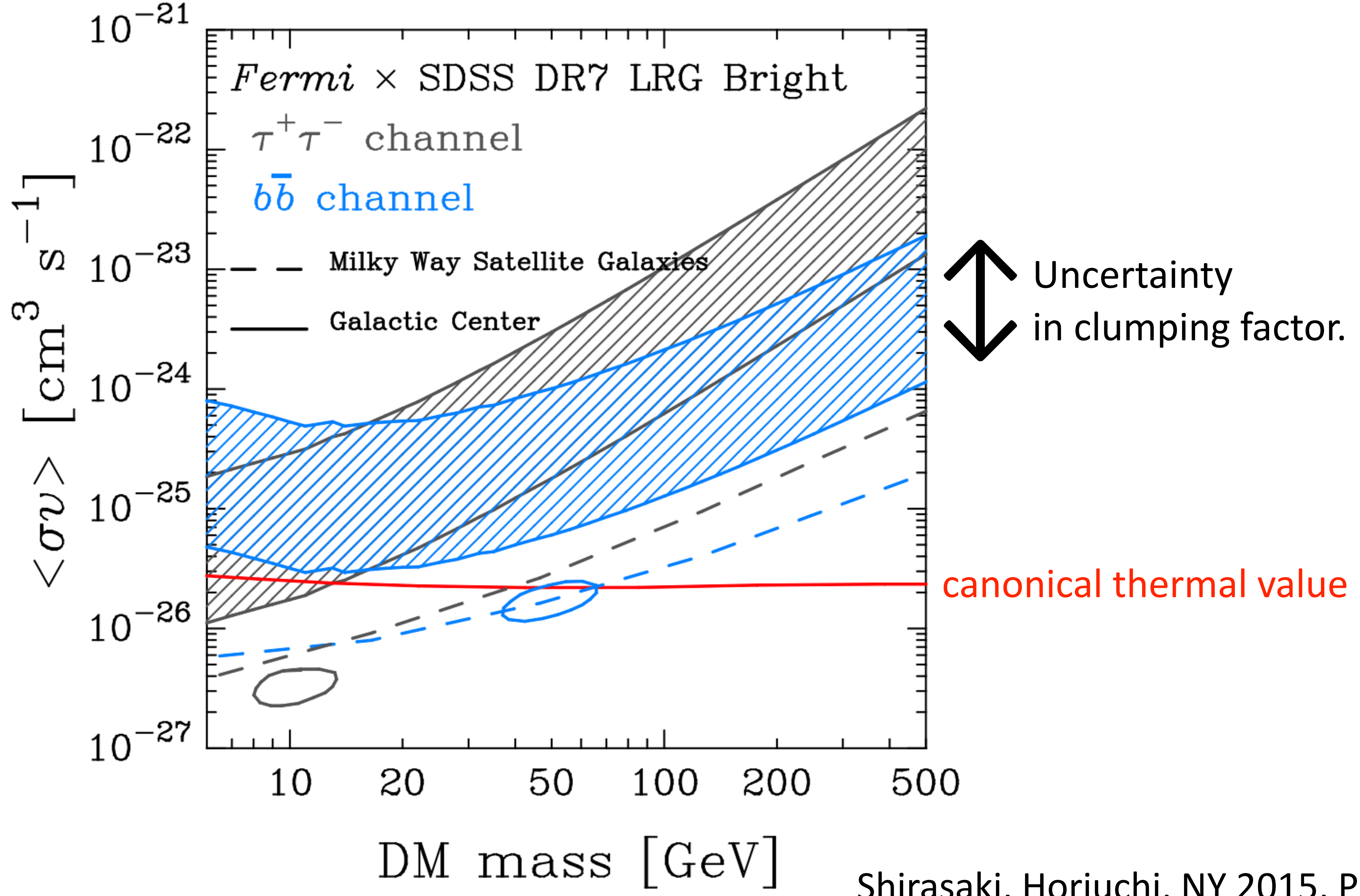


γ-ray from star formation in LRGs is unimportant



35 models of pulsar/O-star dist., CR-confinement etc (galprop2012) + CR-ray spectrum

Cross-section constraint



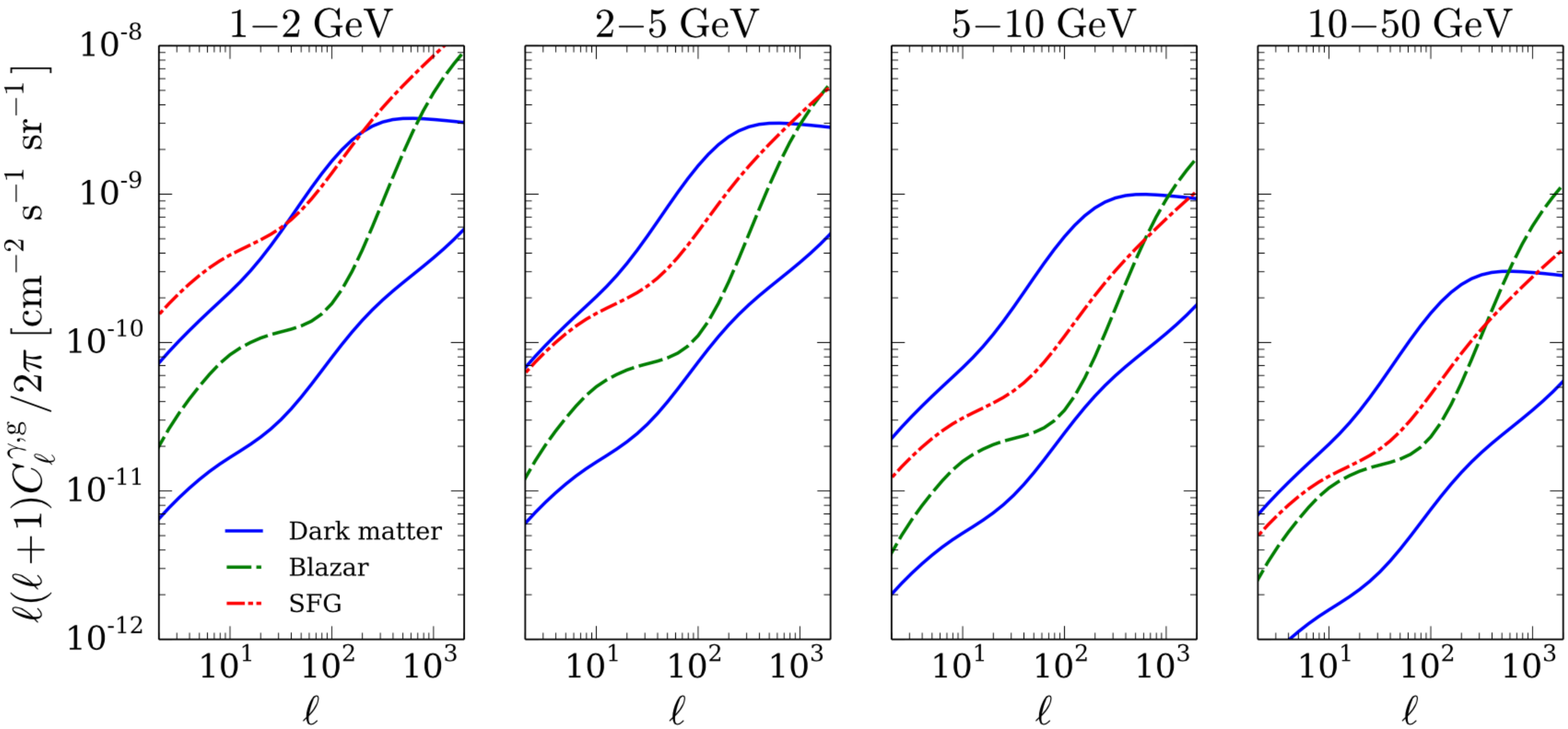
Shirasaki, Horiuchi, NY 2015, PRD

So, with CTA…

Would it be feasible to do a "survey" with enough sensitivity (@100GeV), wide-field (tens of deg^2), and with good angular resolution ?
If yes, we (I mean I) start thinking seriously about astrophysical sources.

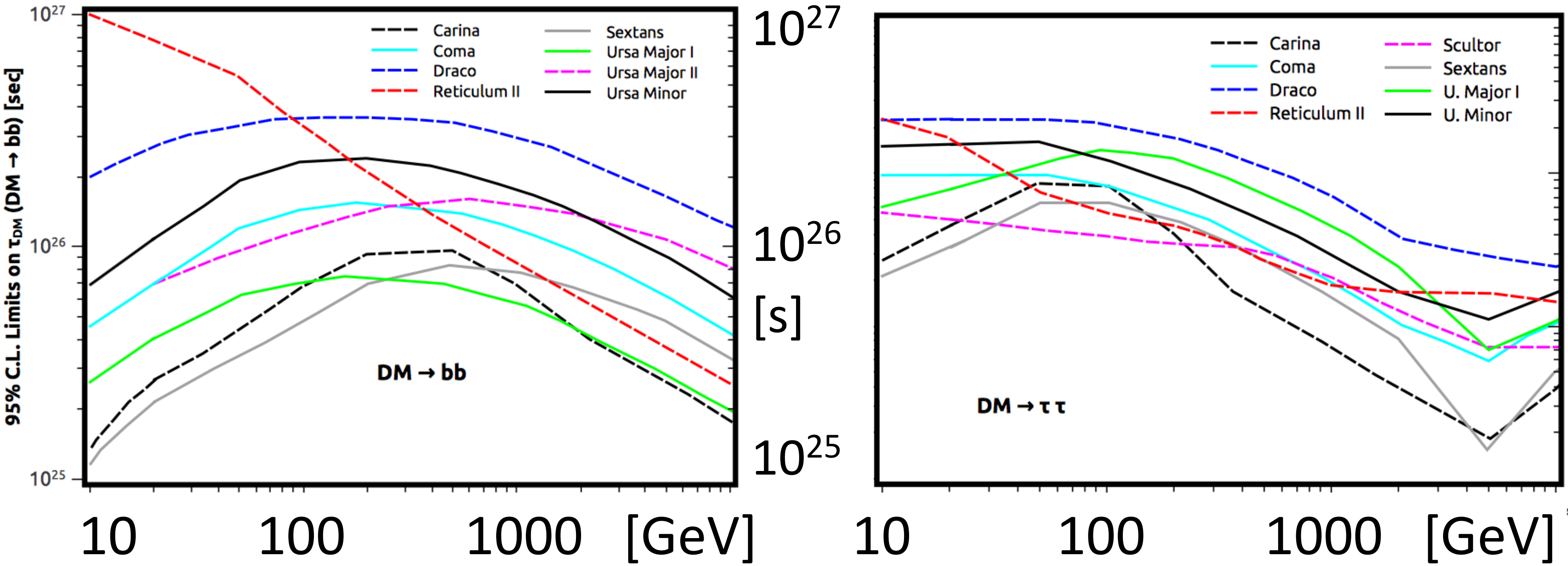
(We can also do similar analysis to DM decay, by the way.
Very heavy DM decay might be a good target for CTA.)

Energy Tomography



Cross-Power spectrum with 2MASS galaxies (Ando 2014 JCAP)

DM decay lifetime



Baring et al. 2015