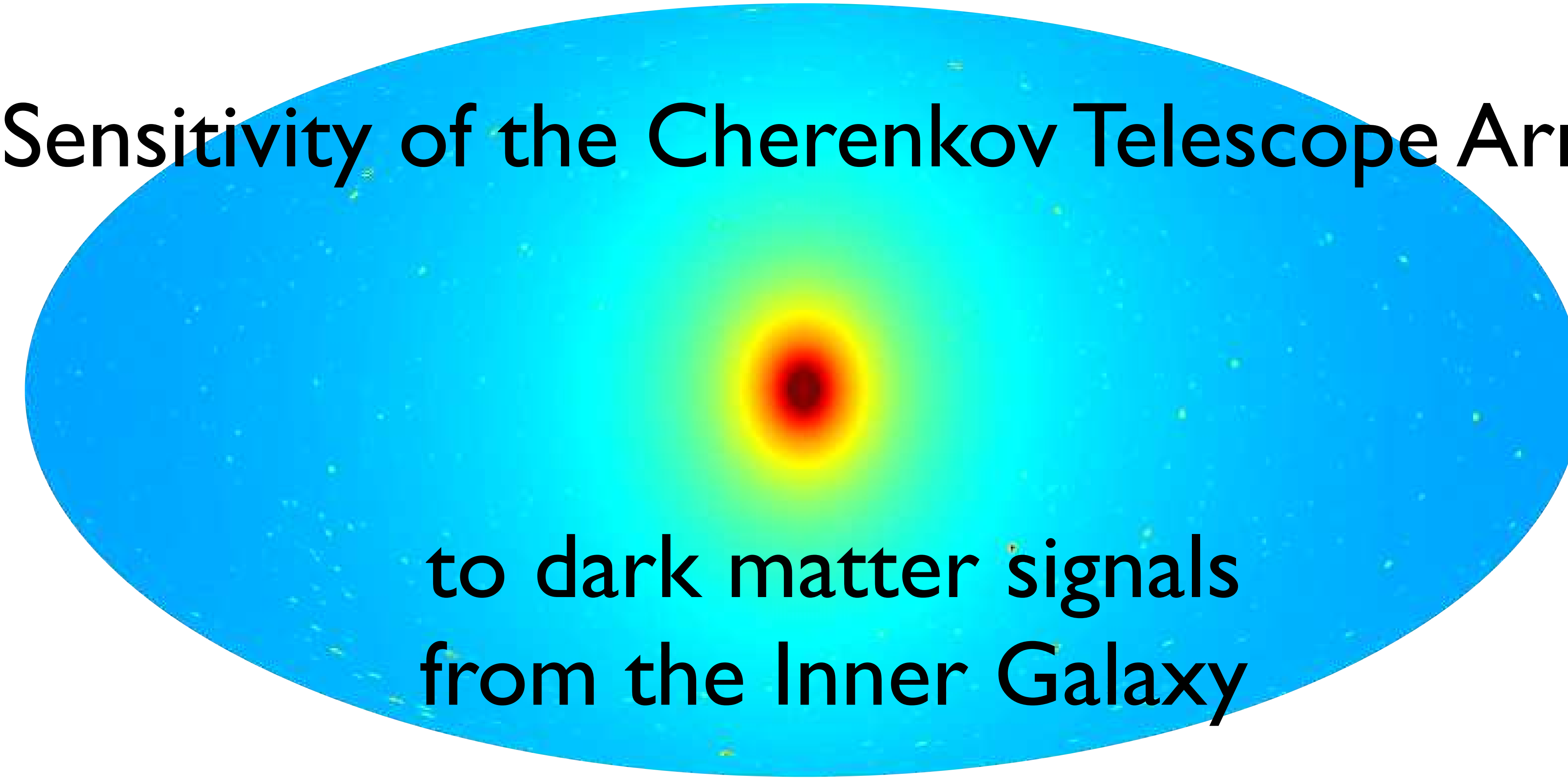
Sensitivity of the Cherenkov Telescope Array to dark matter signals from the Inner Galaxy



Jennifer Siegal-Gaskins

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Pat Scott (McGill)

Imaging Atmospheric Cherenkov Telescopes (IACTs)

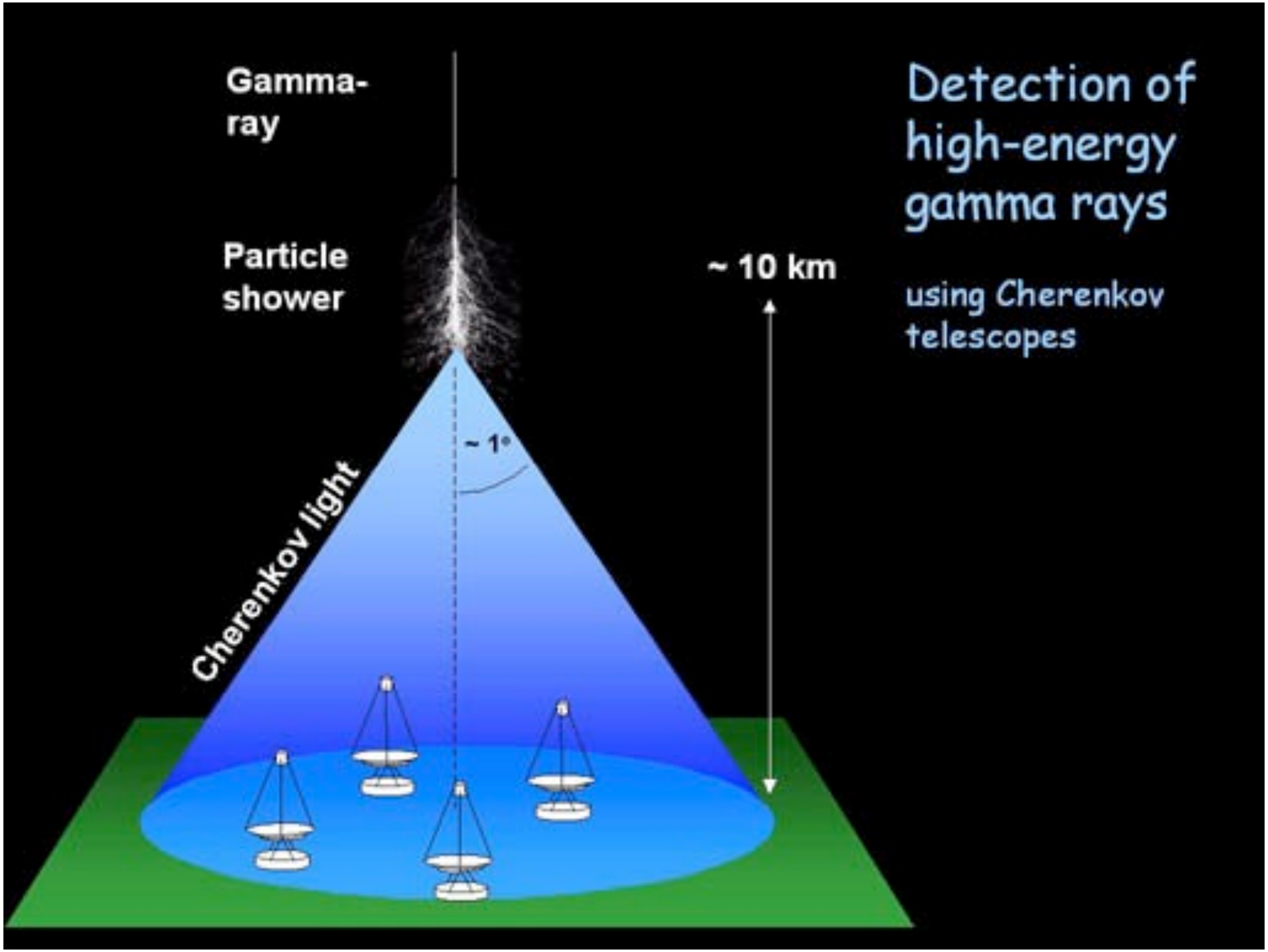


Image credit: H.E.S.S. Collaboration

The Cherenkov Telescope Array (CTA)

- array of many telescopes of various sizes to balance need for effective area while reducing energy threshold
- relatively large FOV ~ 10 deg (current ACTs ~ 5 deg)
- will trigger as low as ~ few tens of GeV (compared to ~ 100 GeV for current ACTs)

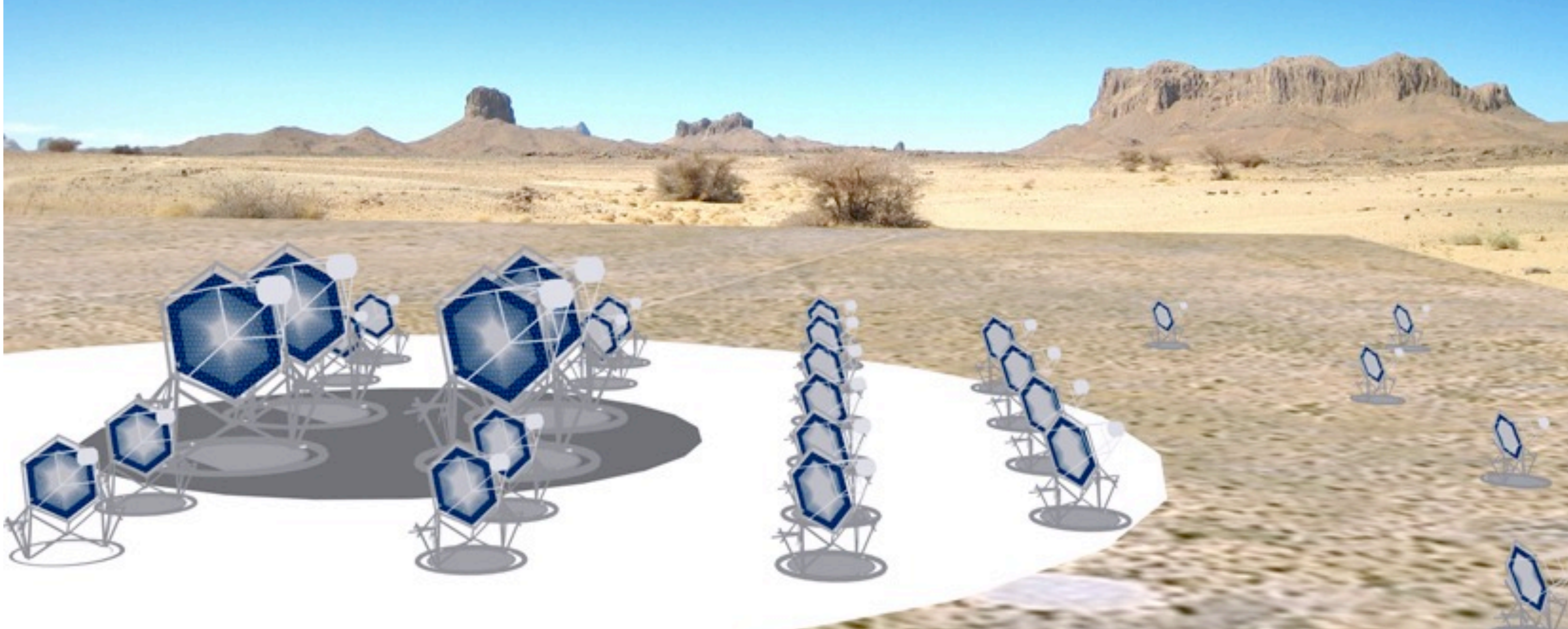
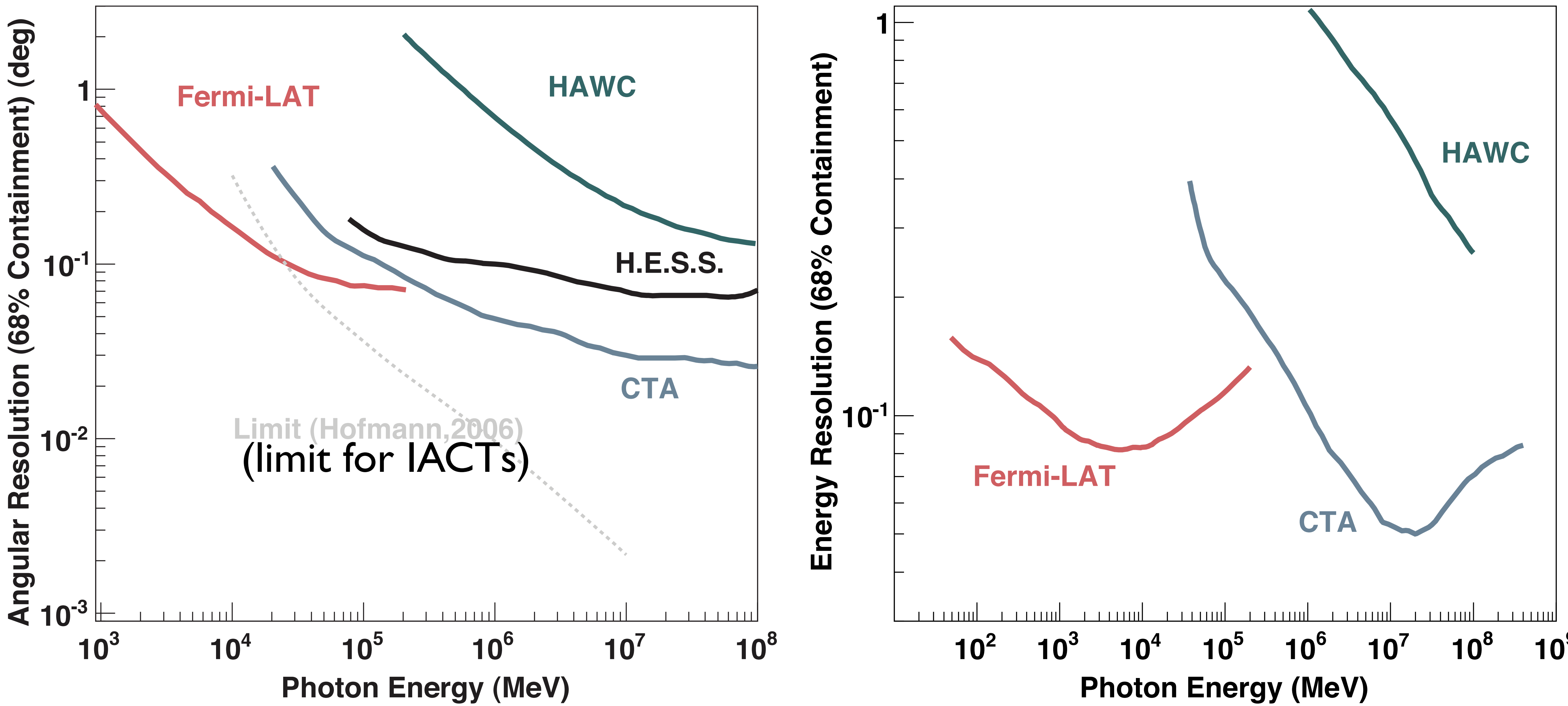


Image credit: CTA Collaboration

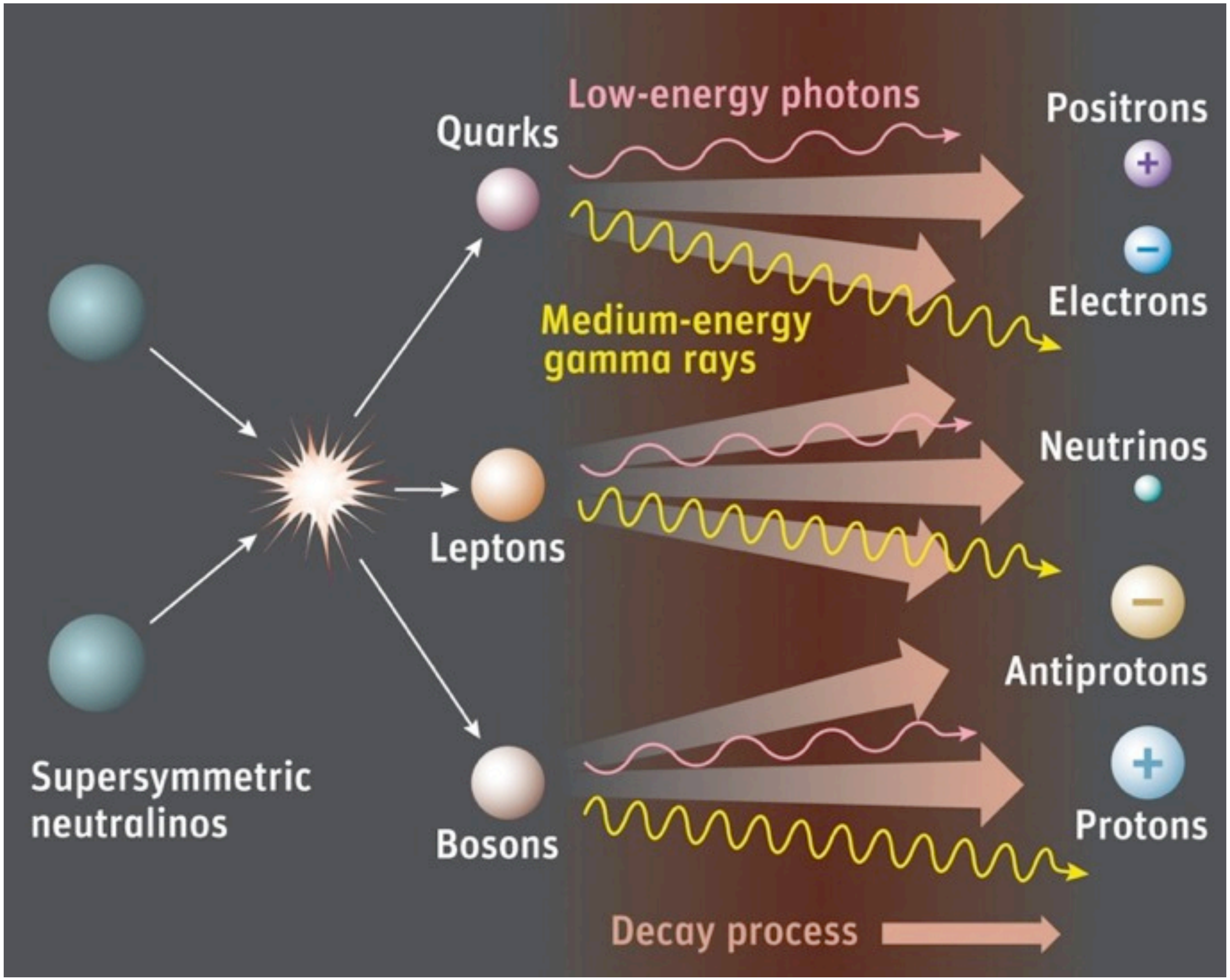
Current and future capabilities



Funk et al. 2012

NB: Fermi LAT effective area ~ 0.8 m^2 vs ~ 10^6 m^2 for CTA

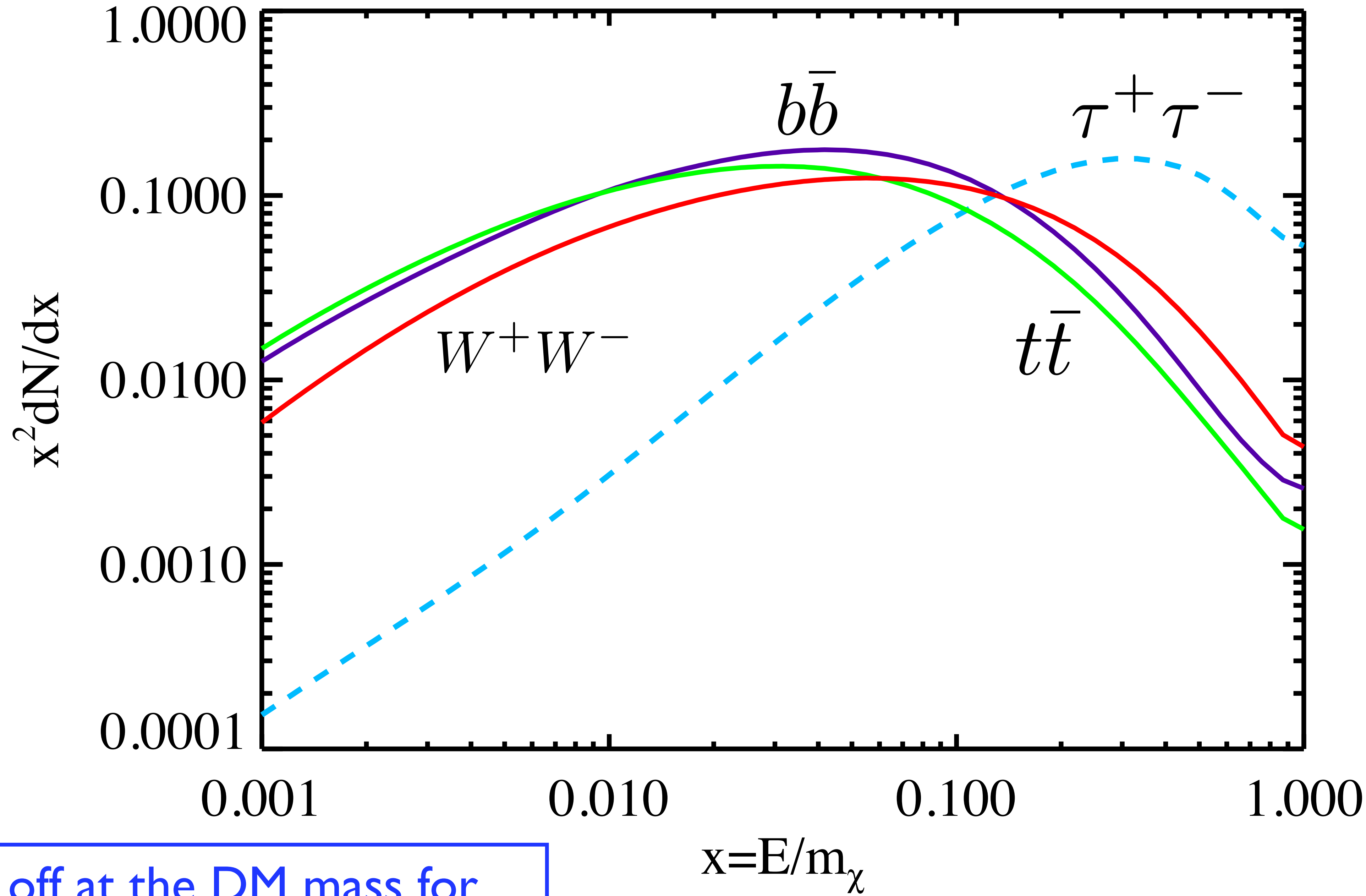
Indirect dark matter signals



Credit: Sky & Telescope / Gregg Dinderman

Dark matter photon spectra

- "soft" channels: produce a continuum gamma-ray spectrum primarily from decay of neutral pions
- "hard channels": include final state radiation (FSR) associated with charged leptons in the final states
- direct annihilation to photons = line emission (γγ, Zγ)



energy spectrum cuts off at the DM mass for annihilation, half the DM mass for decay

Spectra calculated with PPPC 4 DM ID [Cirelli et al. 2010]

Gamma-ray and neutrino indirect signals

(particles that propagate directly to the observer without deflection, attenuation, or secondary production)

differential intensity = particle physics term "K" • astrophysics term "J"

ANNIHILATION:

$$K_{\rm ann} = \frac{{\rm d}N}{{\rm d}E}\frac{\langle \sigma v\rangle}{2m_\chi^2}$$

$$J_{\rm ann}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho^2(s,\psi)$$

DECAY:

$$K_{\rm decay} = \frac{{\rm d}N}{{\rm d}E}\frac{1}{m_\chi \tau_\chi}$$

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spectrum of particles produced

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dark matter particle mass

DECAY:

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pair annihilation cross section times average relative velocity

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dark matter particle lifetime

Gamma-ray and neutrino indirect signals

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dark matter density

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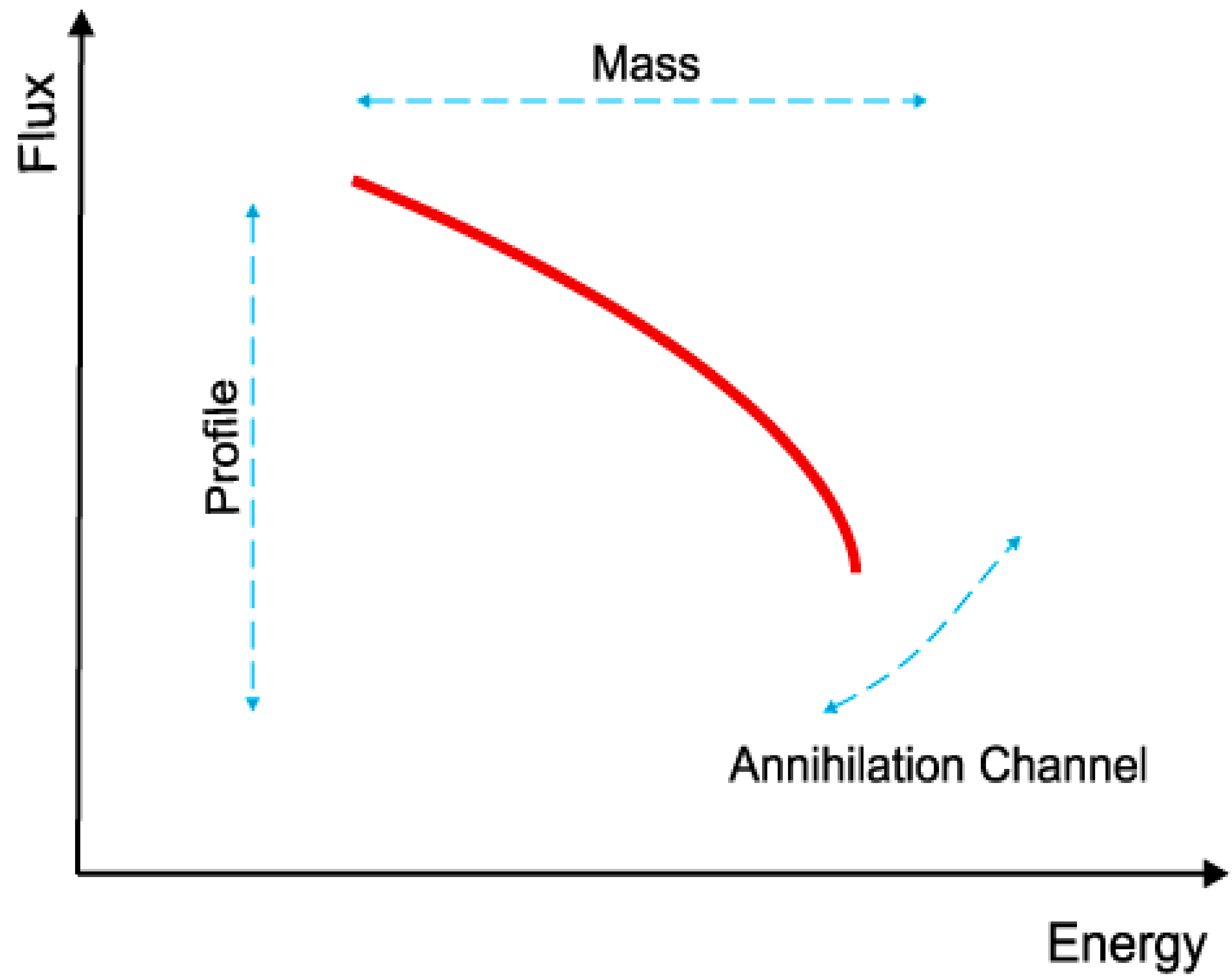
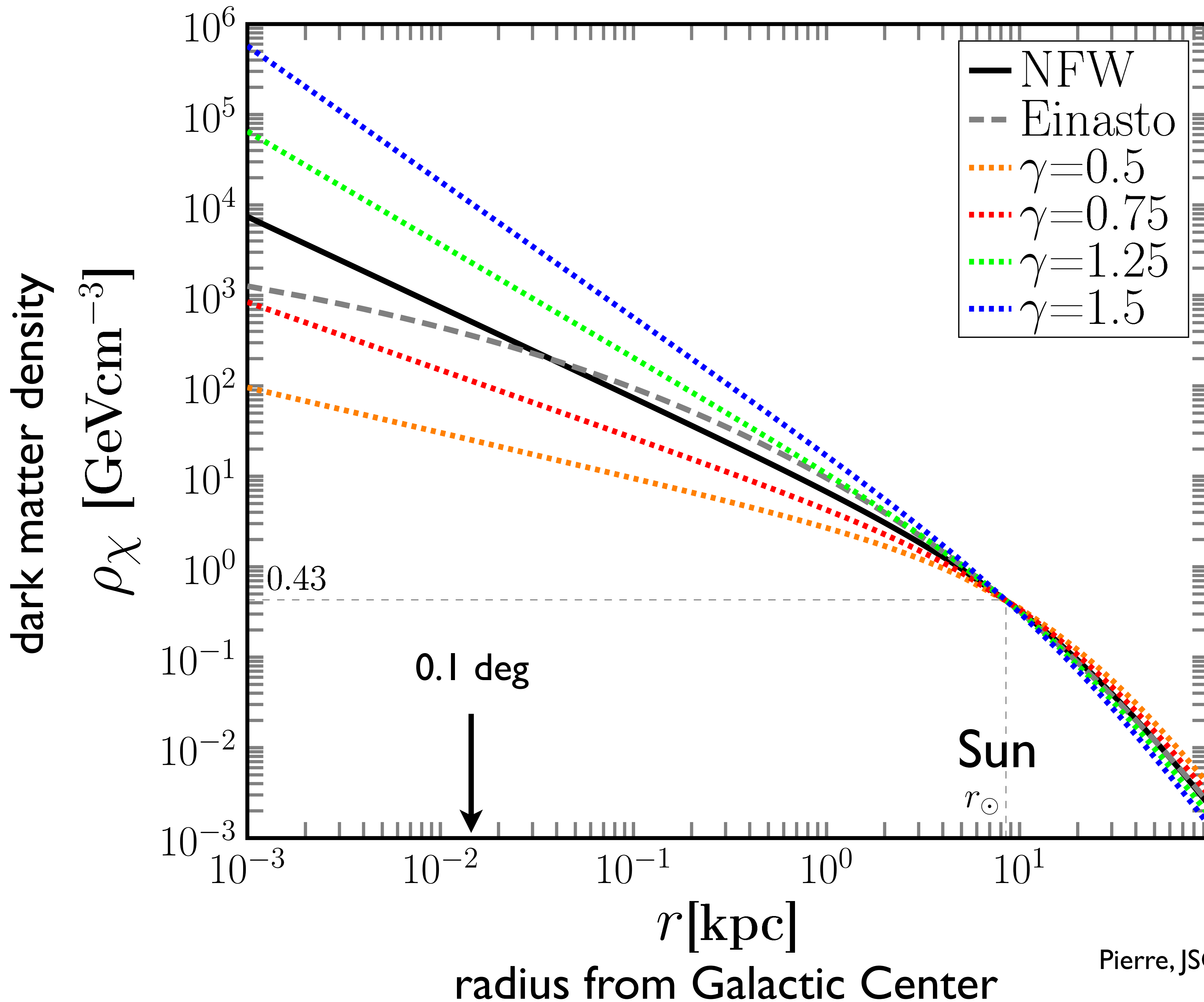
Indirect dark matter signals



Bertone 2007

Dark matter signals from the Inner Galaxy

dark matter density profiles

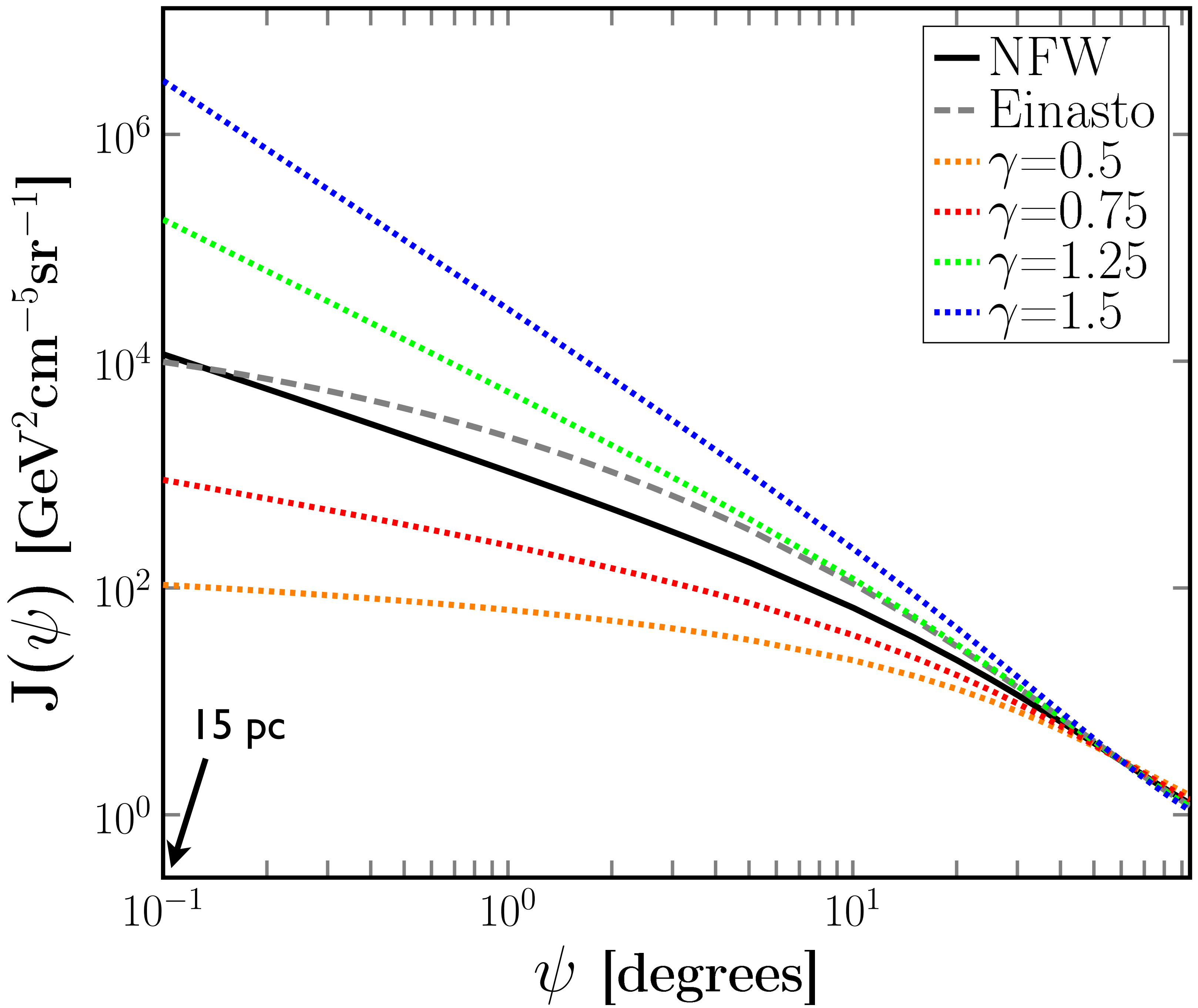


Pierre, JSG, & Scott, in prep

Dark matter signals from the Inner Galaxy

angular dependence of dark matter intensity

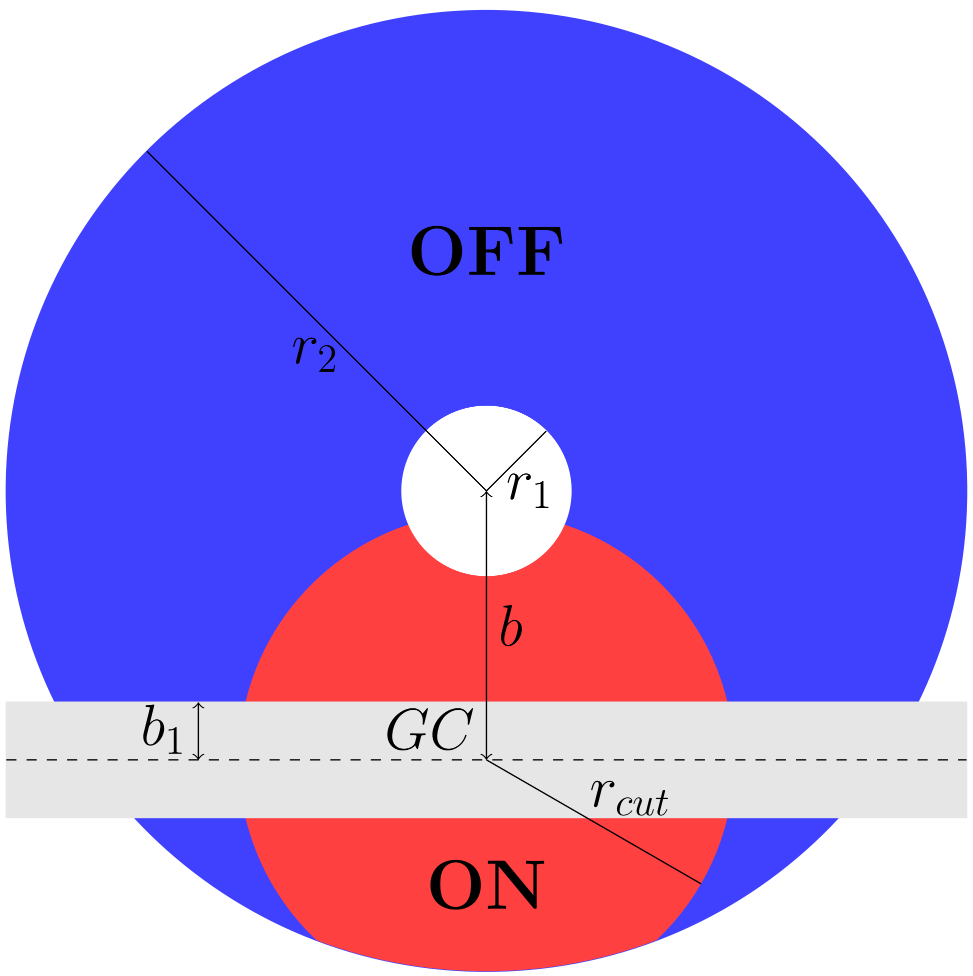
(proportional to intensity)



angle from Galactic Center

Pierre, JSG, & Scott, in prep

CTA search for dark matter signals



"Ring Method"

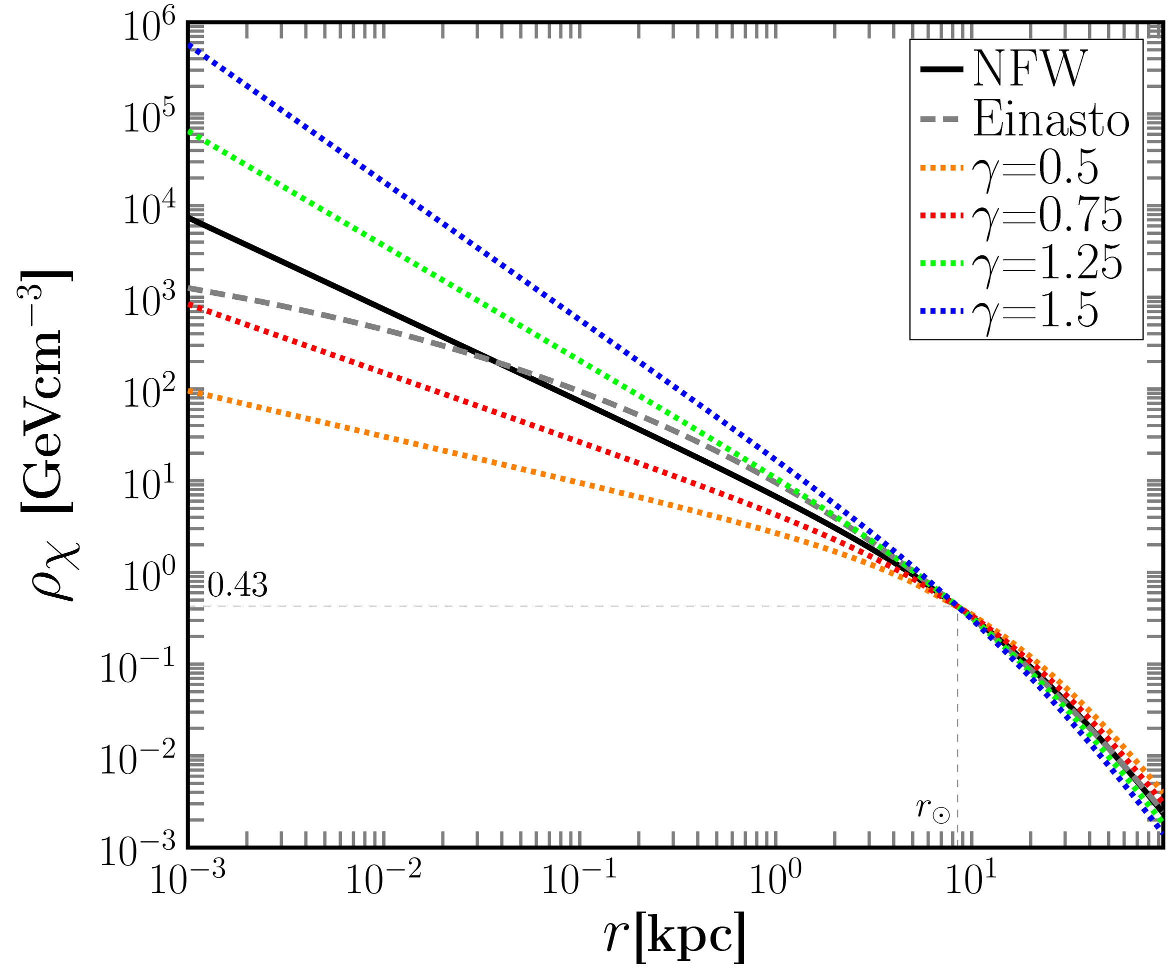
IACTs use "on-off" methods to search for signals due to large irreducible cosmic-ray electron background

The "Ring Method" limits systematics due to uncertainties in the effective area variation across the FOV

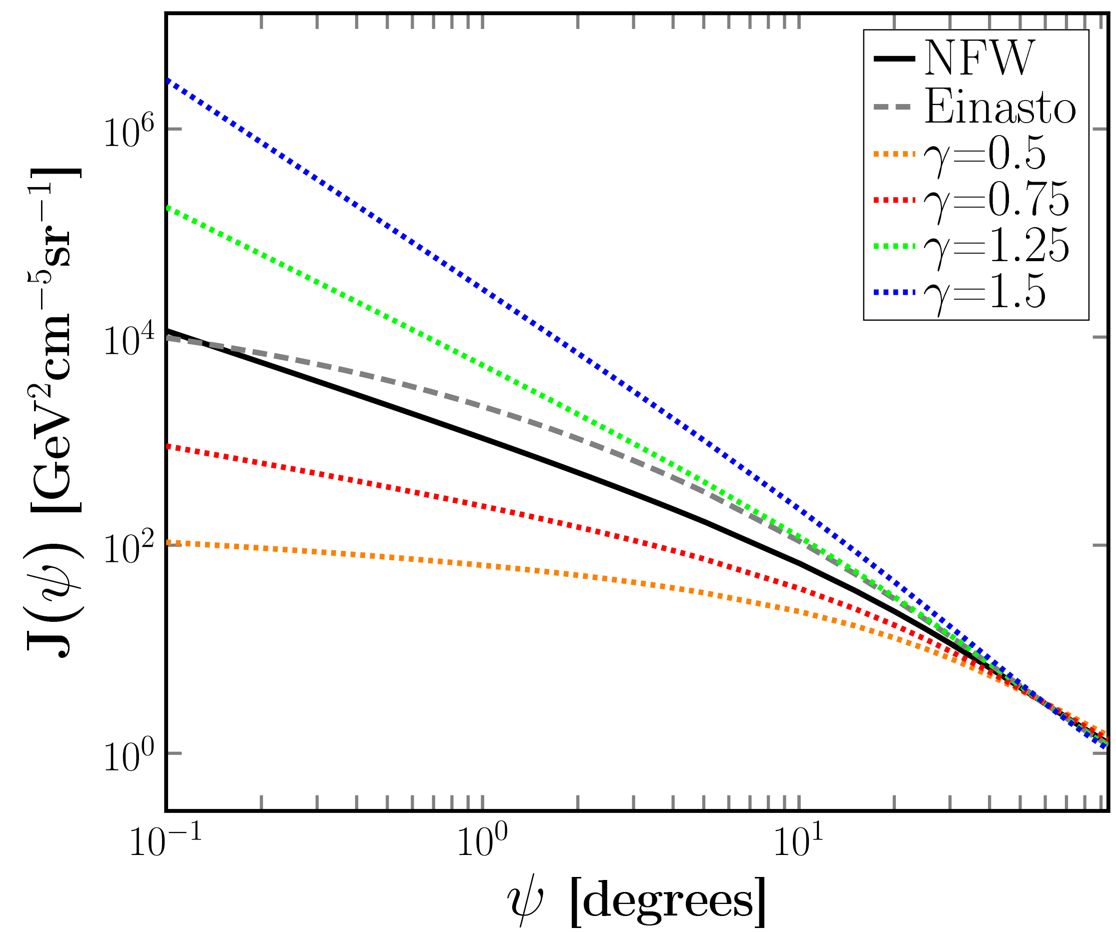
Pierre, JSG, & Scott, in prep

Detecting a Galactic Center DM signal with CTA

Density profile



Annihilation "J-factor"



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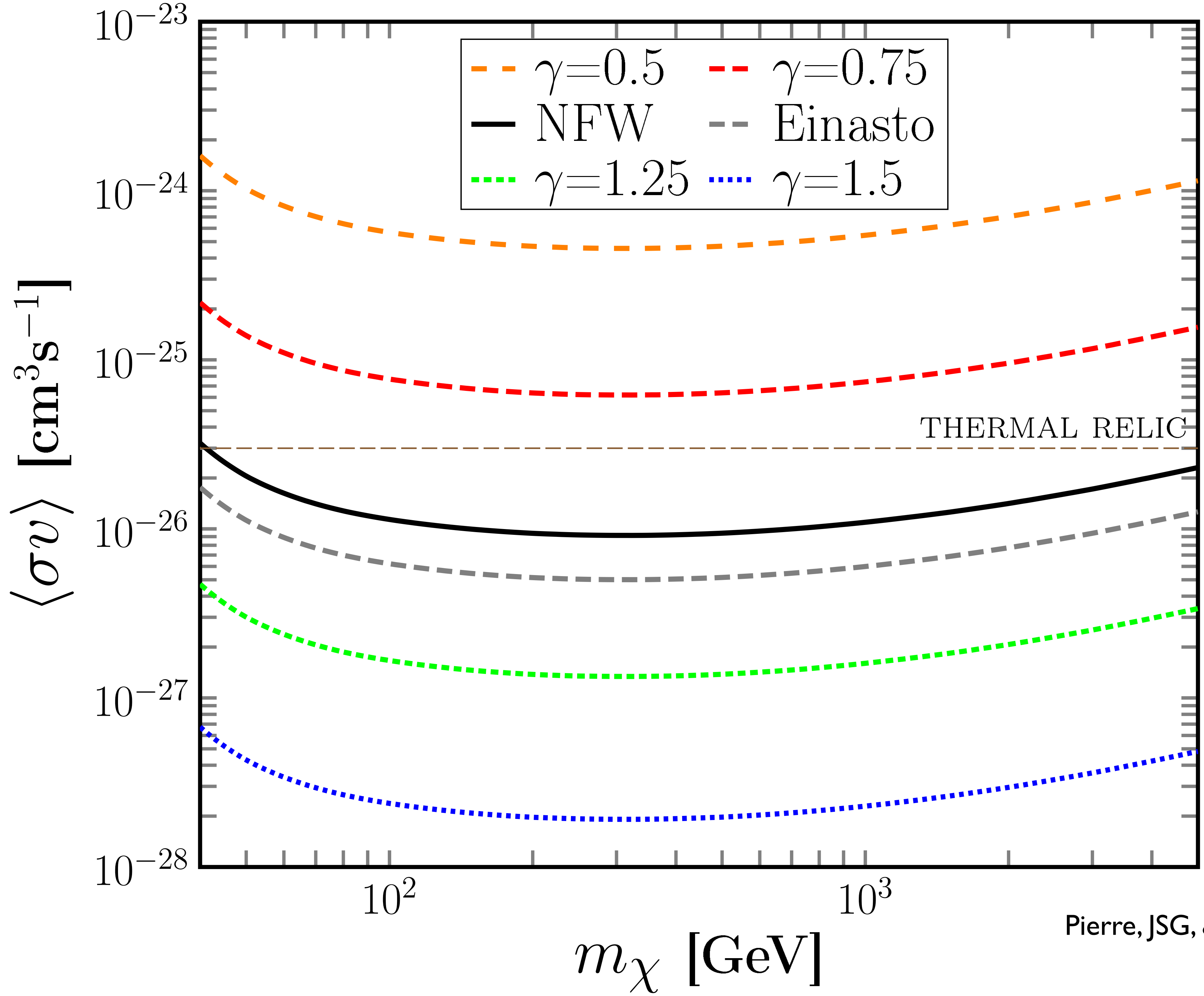
- flatter density profiles favored by some observational data and in some DM models (e.g., SIDM) could present a challenge for CTA
- Ring Method sensitive to the difference in the signal (per solid angle) in the ON vs OFF region -- flatter profiles harder to detect

Density profile dependence of sensitivity

500h, annihilation to $\tau^+\tau^-$



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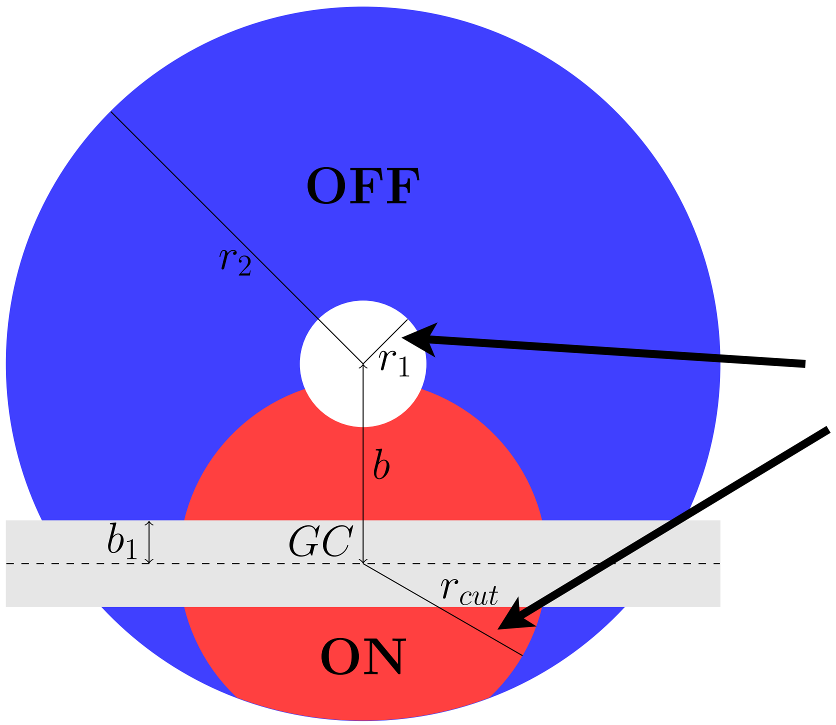
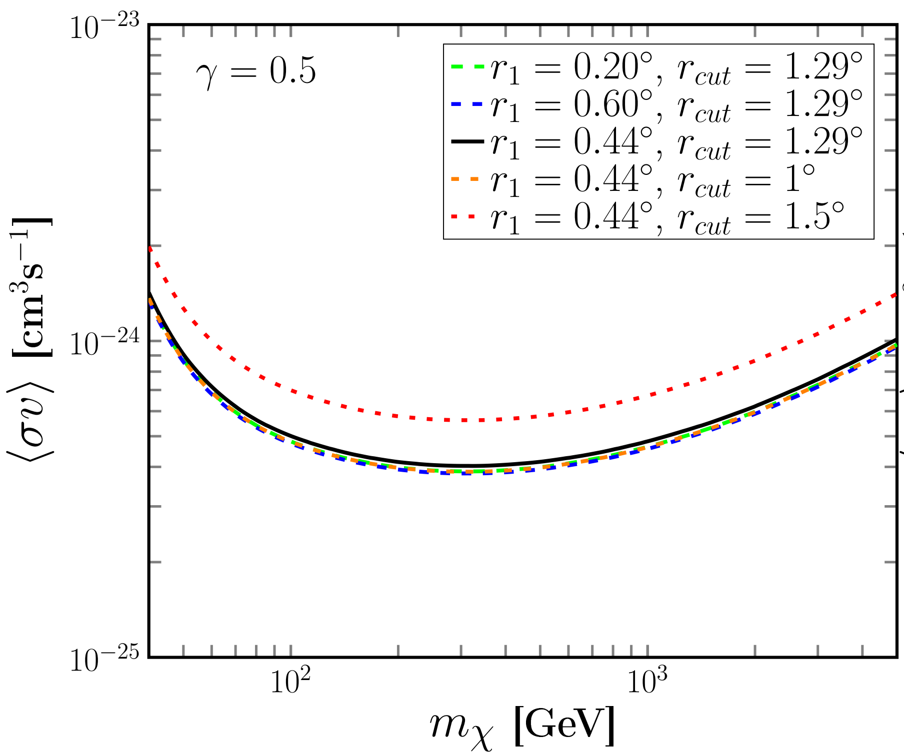
Optimizing the search regions



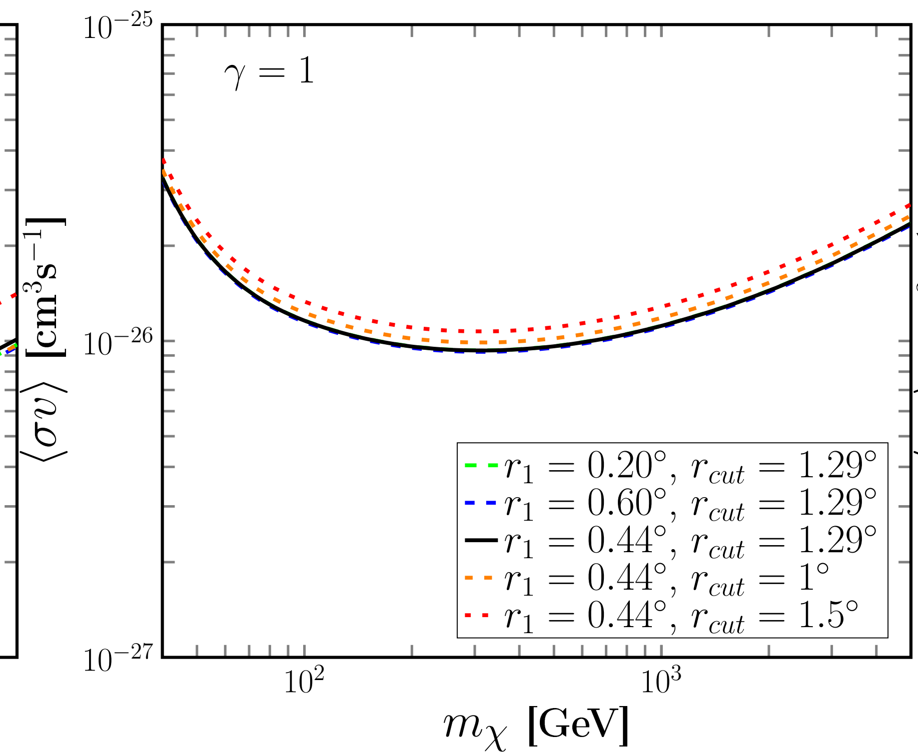
vary these parameters

sensitivity is not strongly dependent on search regions except for a very shallow profile

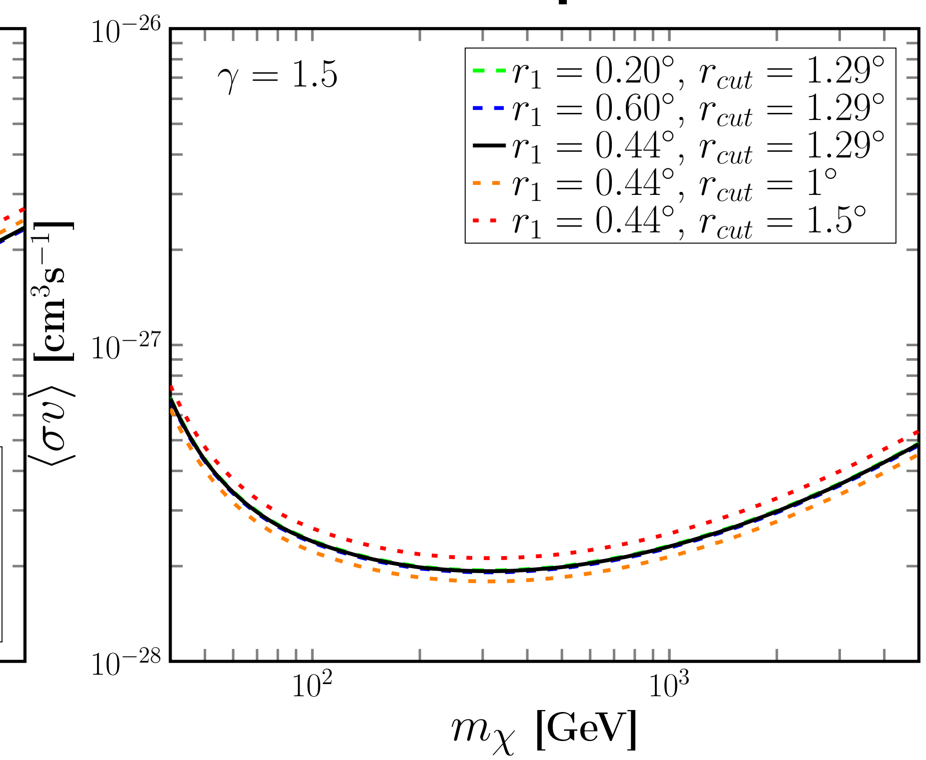
shallower



NFW



steeper



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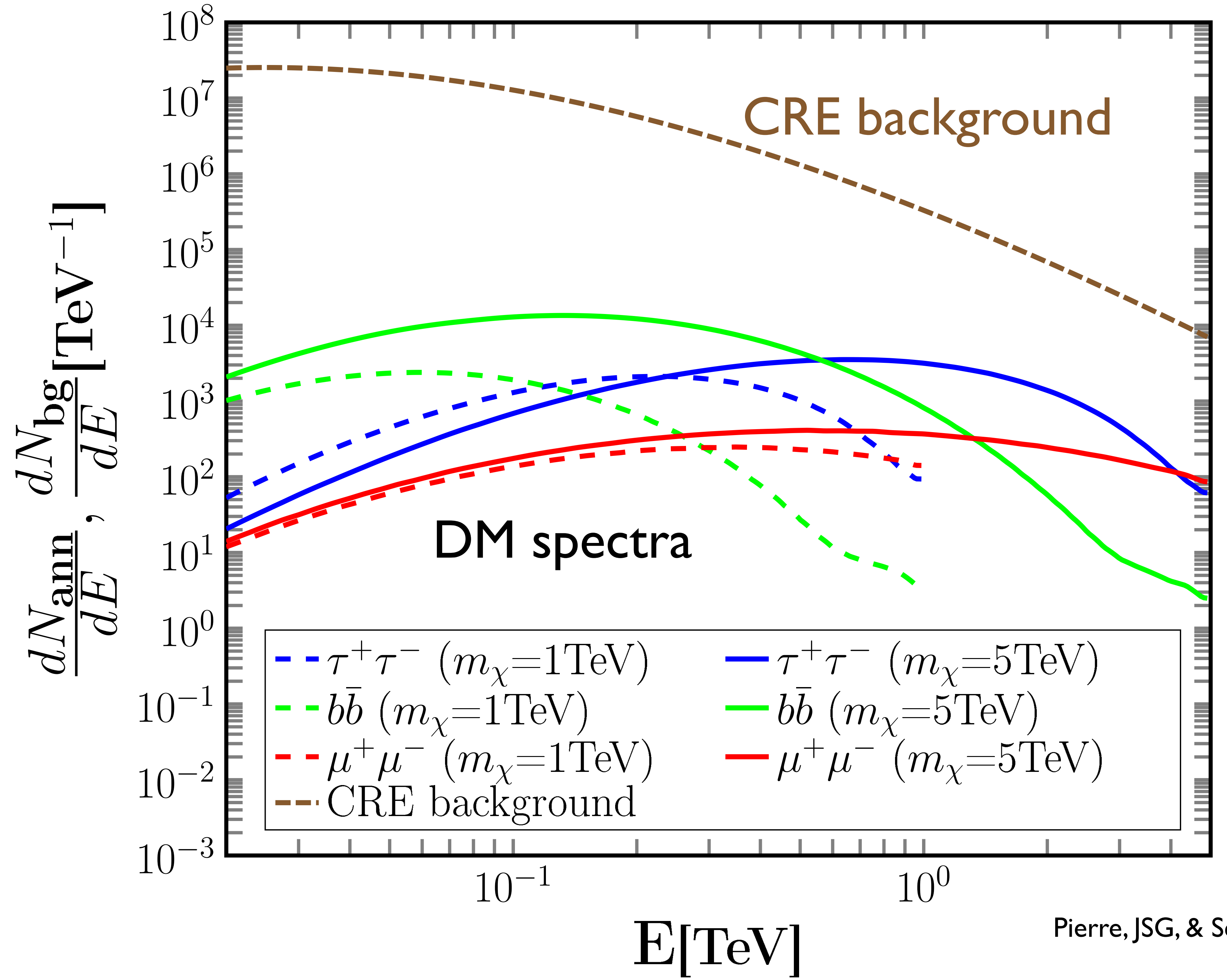
Taking advantage of spectral information

Differential observed counts spectrum



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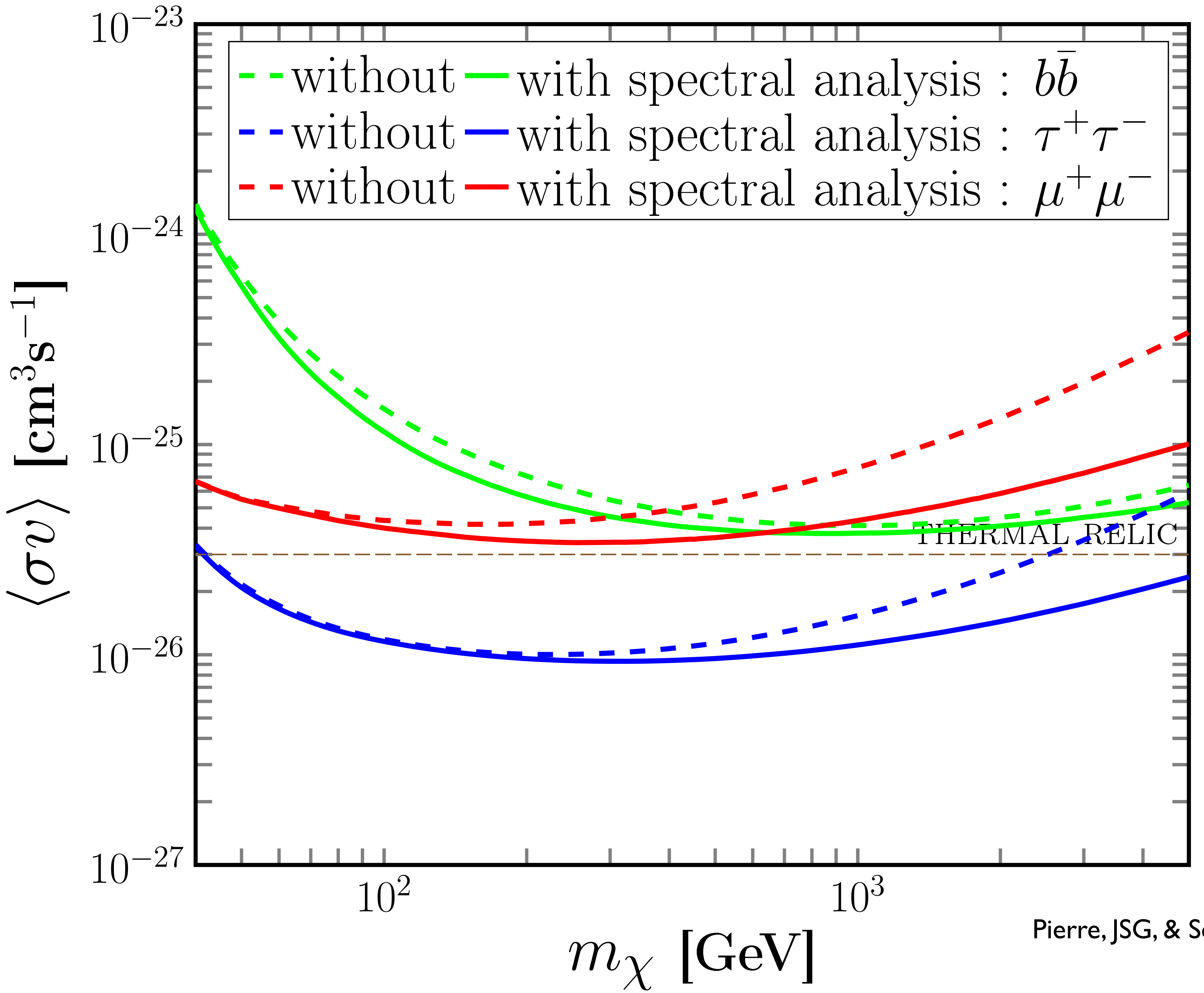
Improvement from spectral analysis

500h, NFW profile



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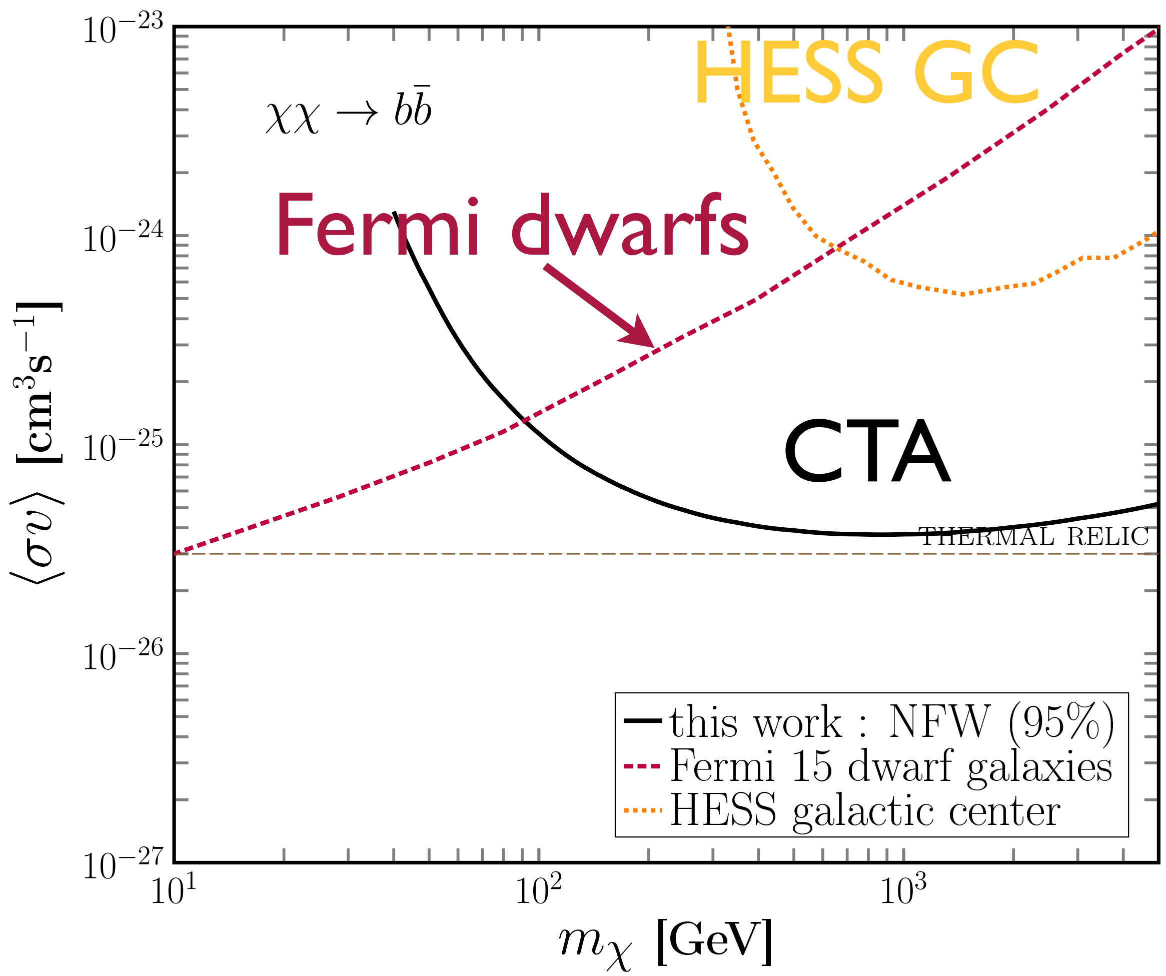
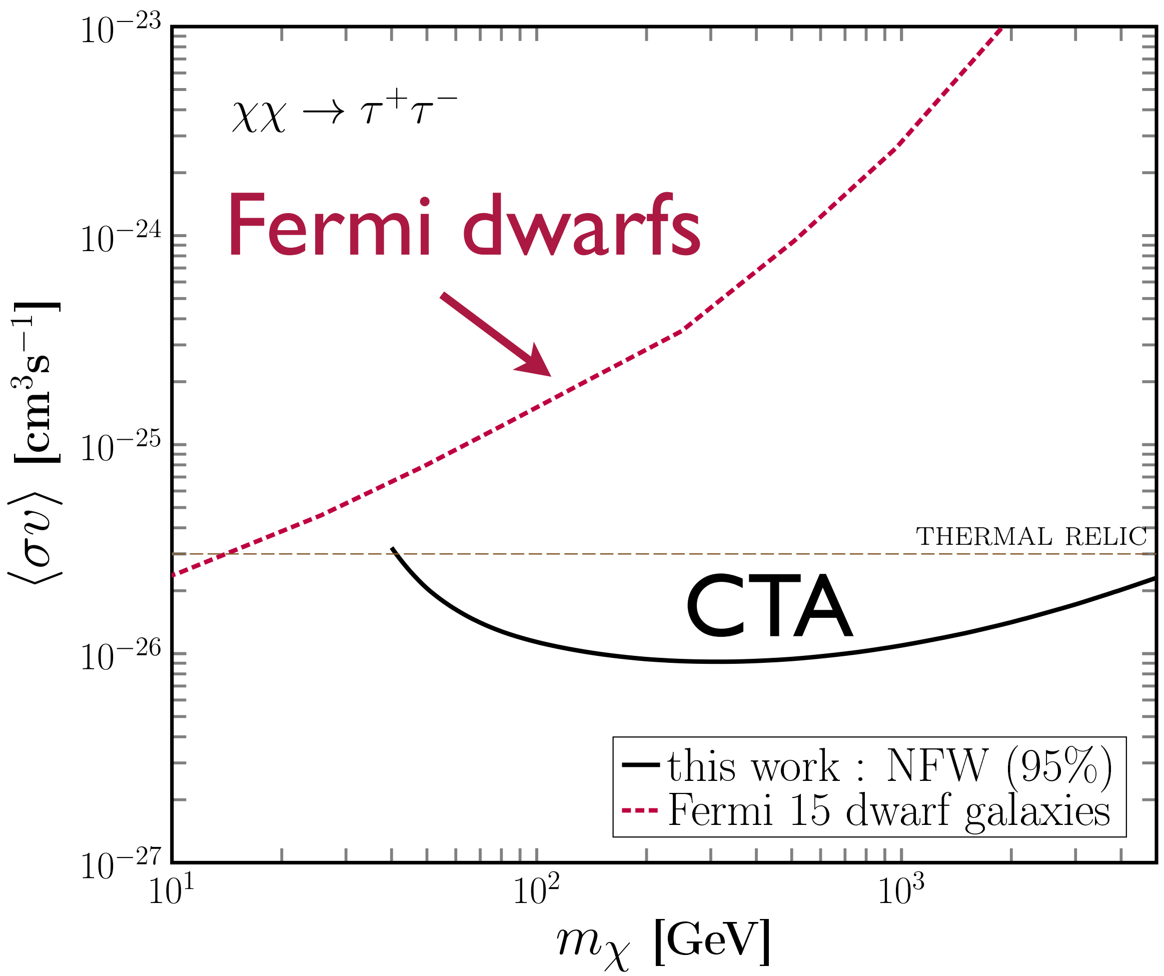
CTA sensitivity to dark matter annihilation

500h, NFW profile

annihilation to bb



annihilation to $\tau^+\tau^-$



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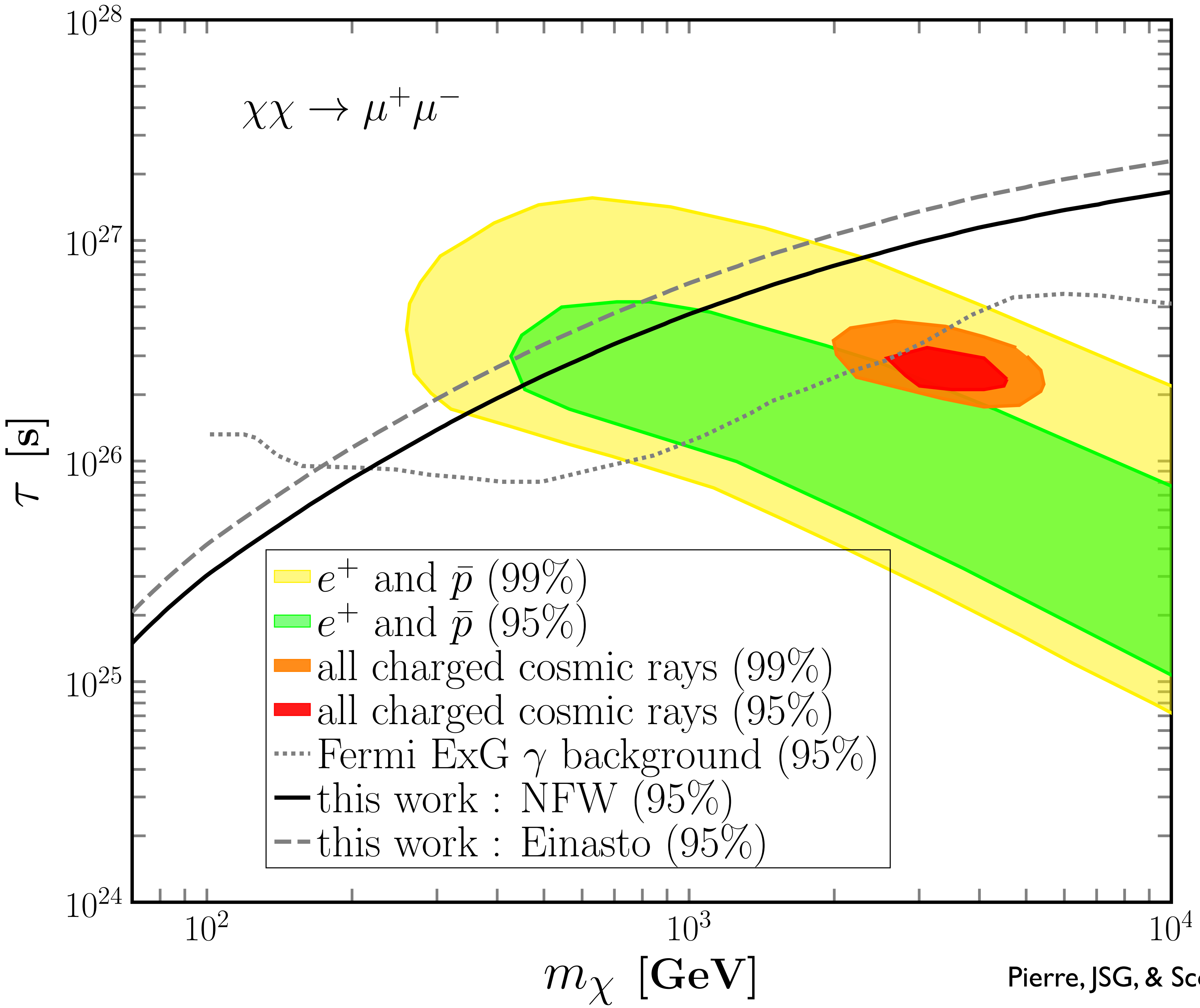
CTA sensitivity to dark matter decay

(parameter space BELOW the curves detectable)

500h, decay to $\mu^+\mu^-$

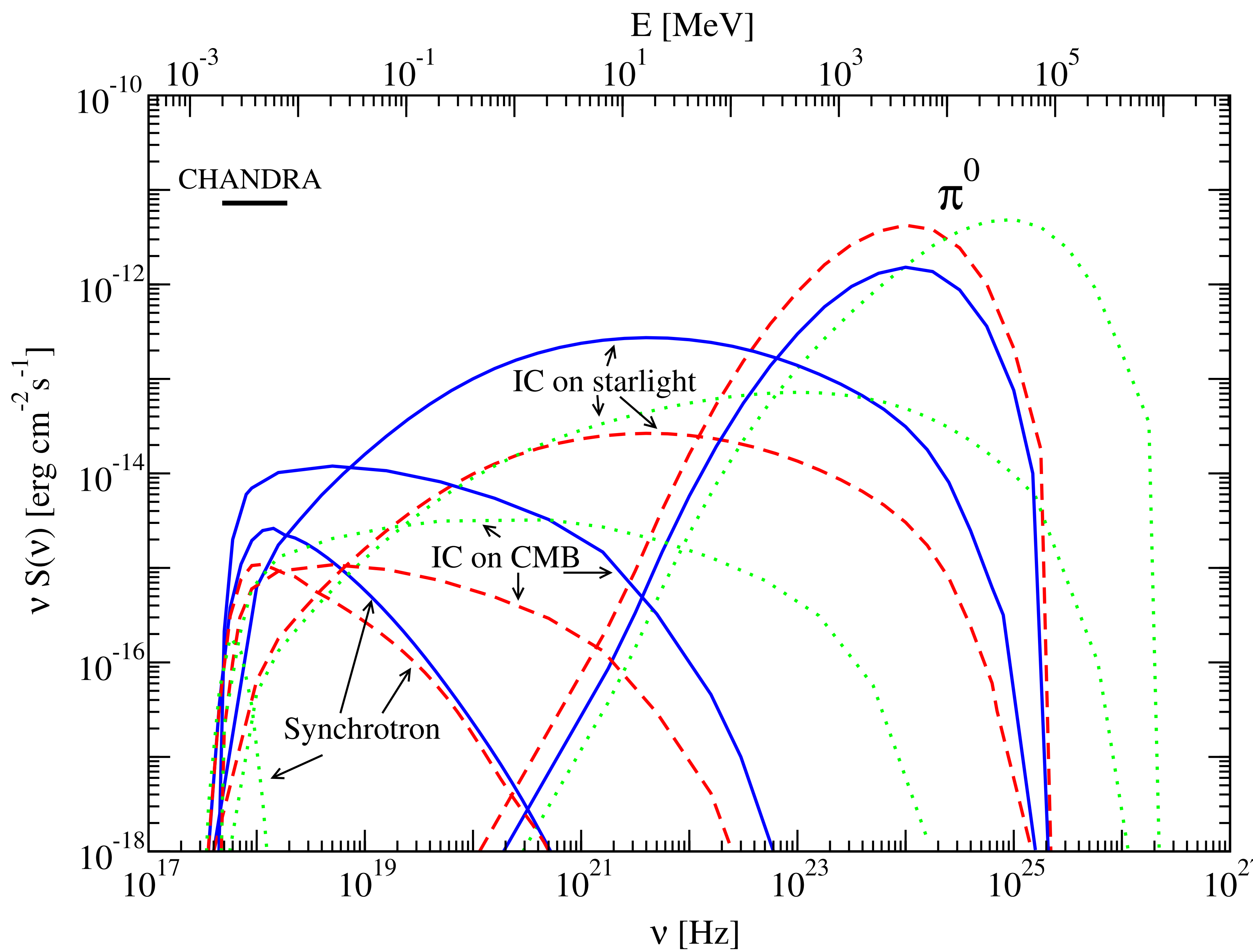


Pierre, JSG, & Scott, in prep

Multi-wavelength dark matter photon spectra

- secondary photon emission associated with charged particle final states:
  - inverse Compton scattering of starlight, CMB
  - synchrotron due to propagation in magnetic fields

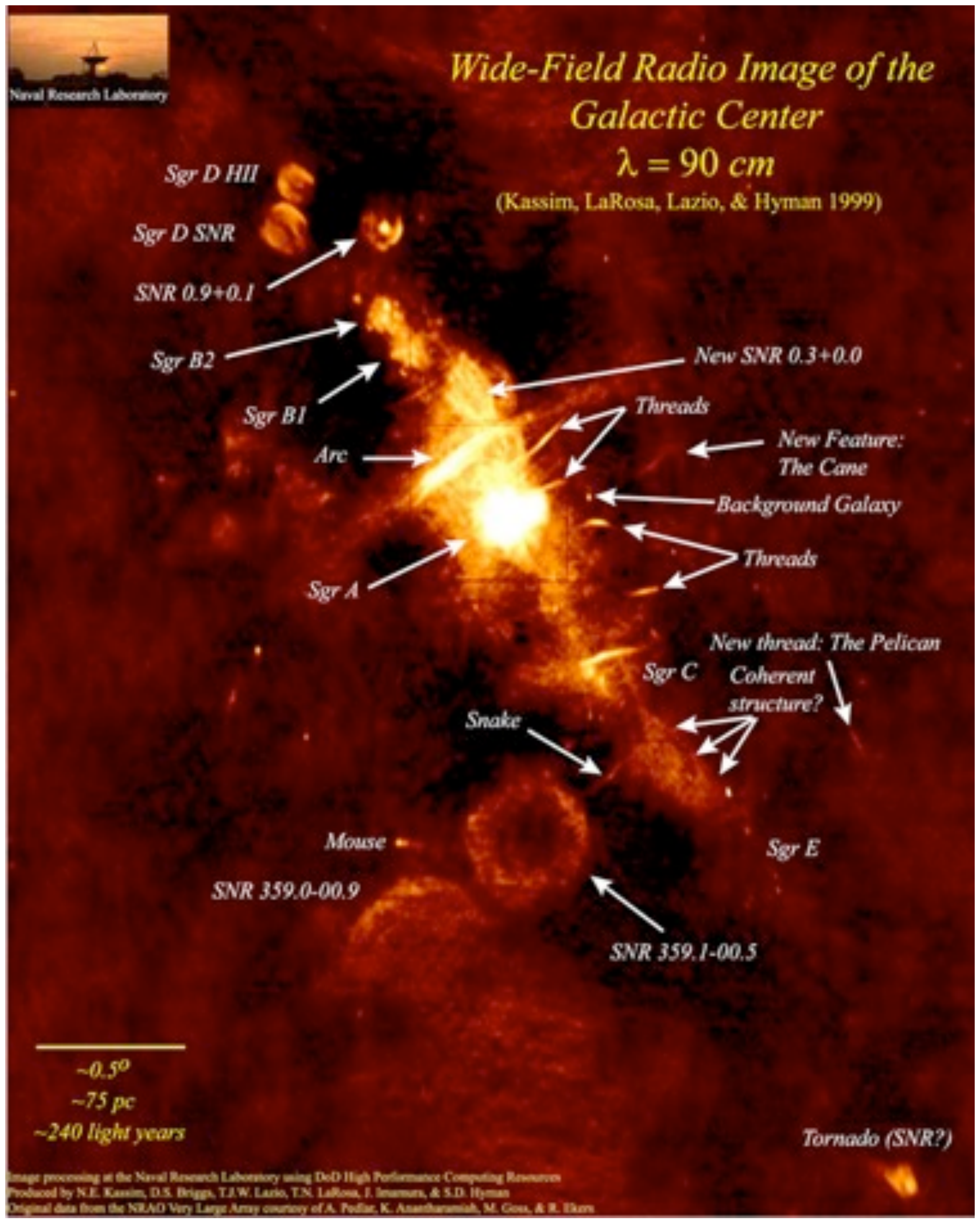
DM spectrum from the Galactic Center



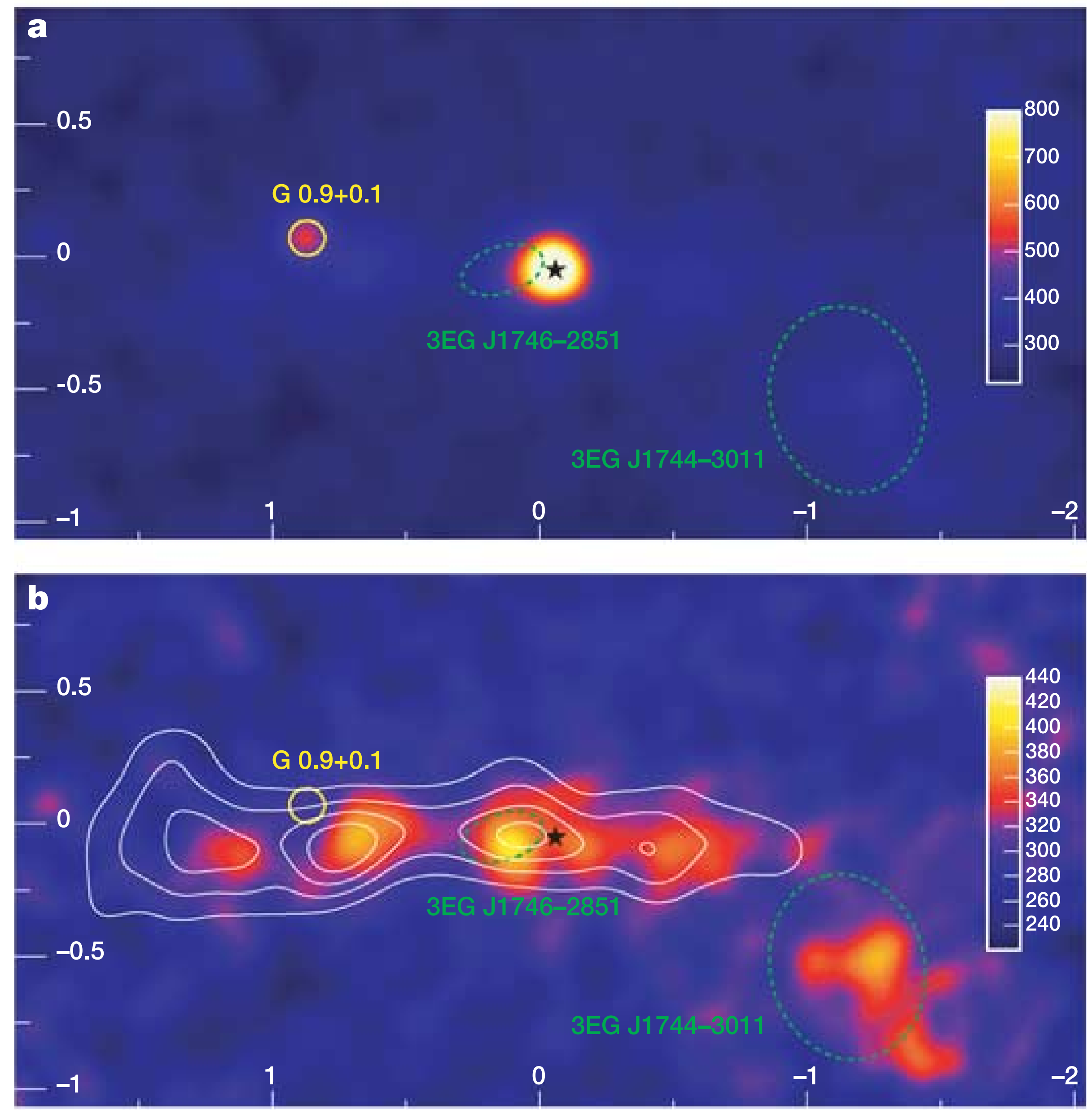
Regis & Ullio 2008

The multi-wavelength Inner Galaxy

VLA @ 330 MHz



HESS > 380 GeV



Aharonian et al. 2006

Looking forward

- CTA will provide new, strong sensitivity to dark matter signals, especially at high WIMP masses, for canonical DM density profiles
    - spectral analysis is important for improved sensitivity to channels with hard spectra
    - CTA will be able to test the DM interpretation of the cosmic-ray excesses
    - NB: for interpreting non-detections, need to better understand DM density profiles (e.g., using simulations, lensing, and kinematics)
- Multi-wavelength studies of DM, astrophysical populations, and diffuse emission from the Inner Galaxy will yield complementary information about possible DM signals