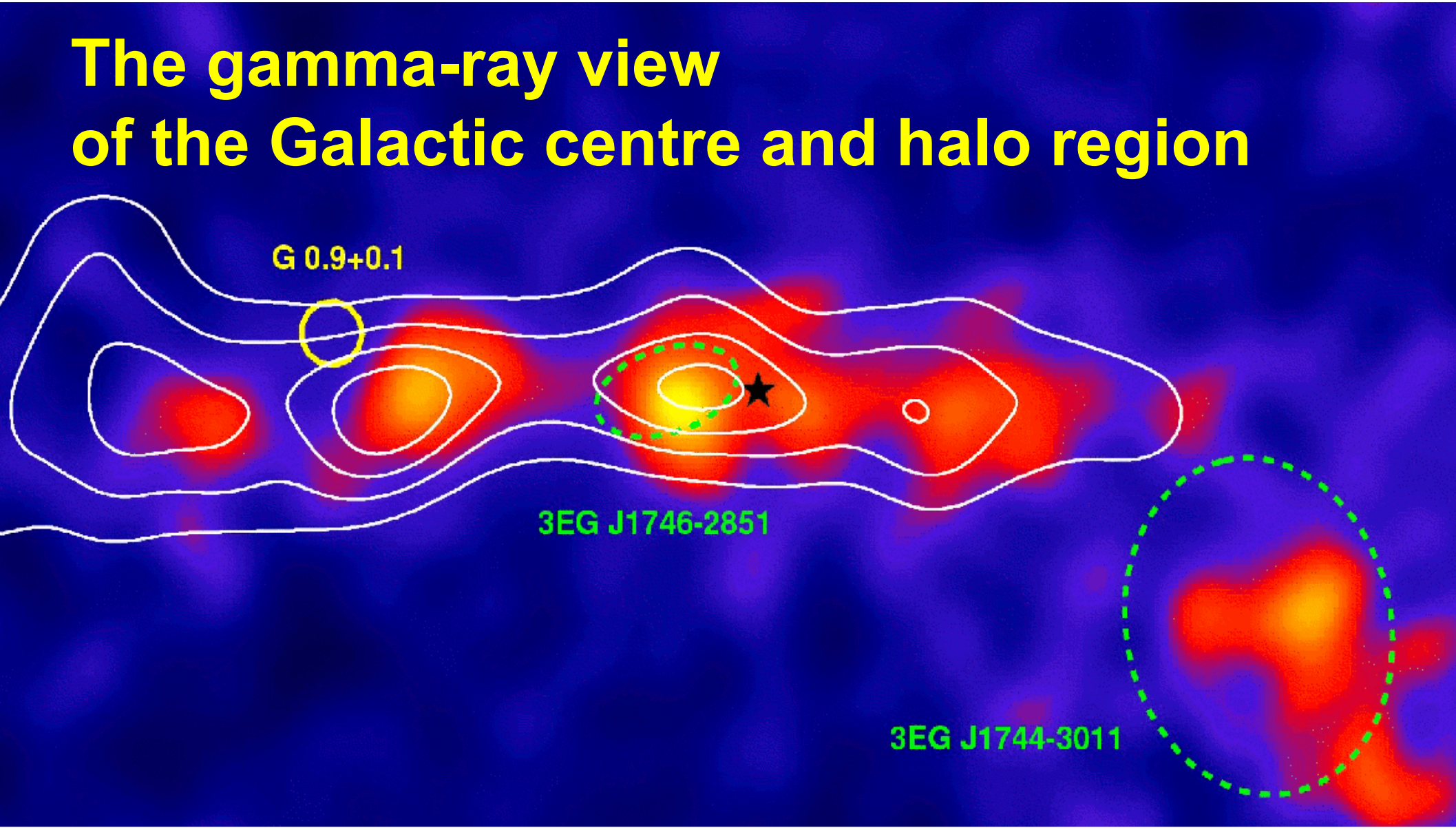
The gamma-ray view of the Galactic centre and halo region



Christopher van Eldik

Windows on the Universe
Aug 11-17, 2013

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE
FAKULTÄT

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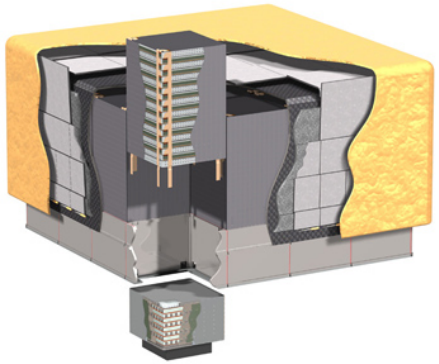
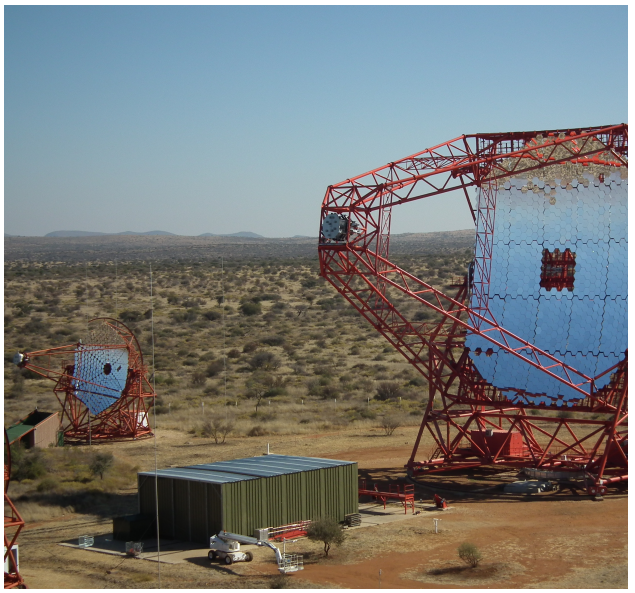
PHYSICS

Satellite vs. ground-based instruments





	Fermi-LAT	H.E.S.S. (phase 1)
Energy range	30 MeV - 300 GeV	100 GeV - 100 TeV
Energy resolution	10%	15%
Collection area	0.8 m^2 (1 GeV)	200.000 m^2 (1 TeV)
Field of view	2.4 sr / all sky	5° / pointed
Angular resolution	0.1° - 2.0°	0.05° - 0.1°
Duty Cycle	~8500 h/yr (24/7)	~1000 h/yr

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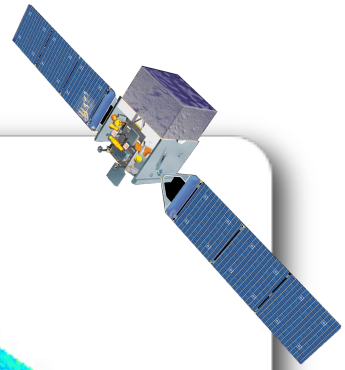
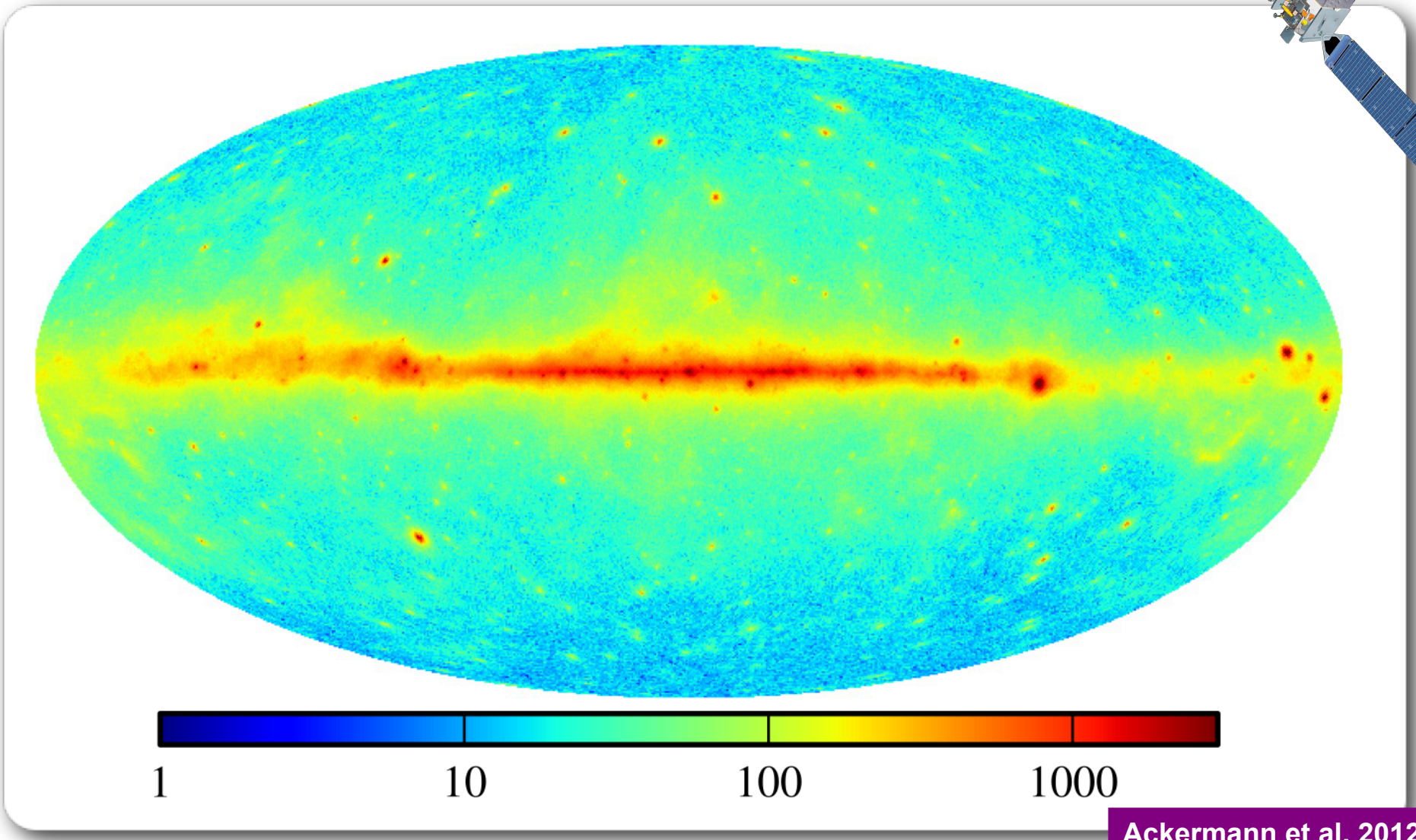
The Fermi-LAT all-sky survey





Ackermann et al. 2012

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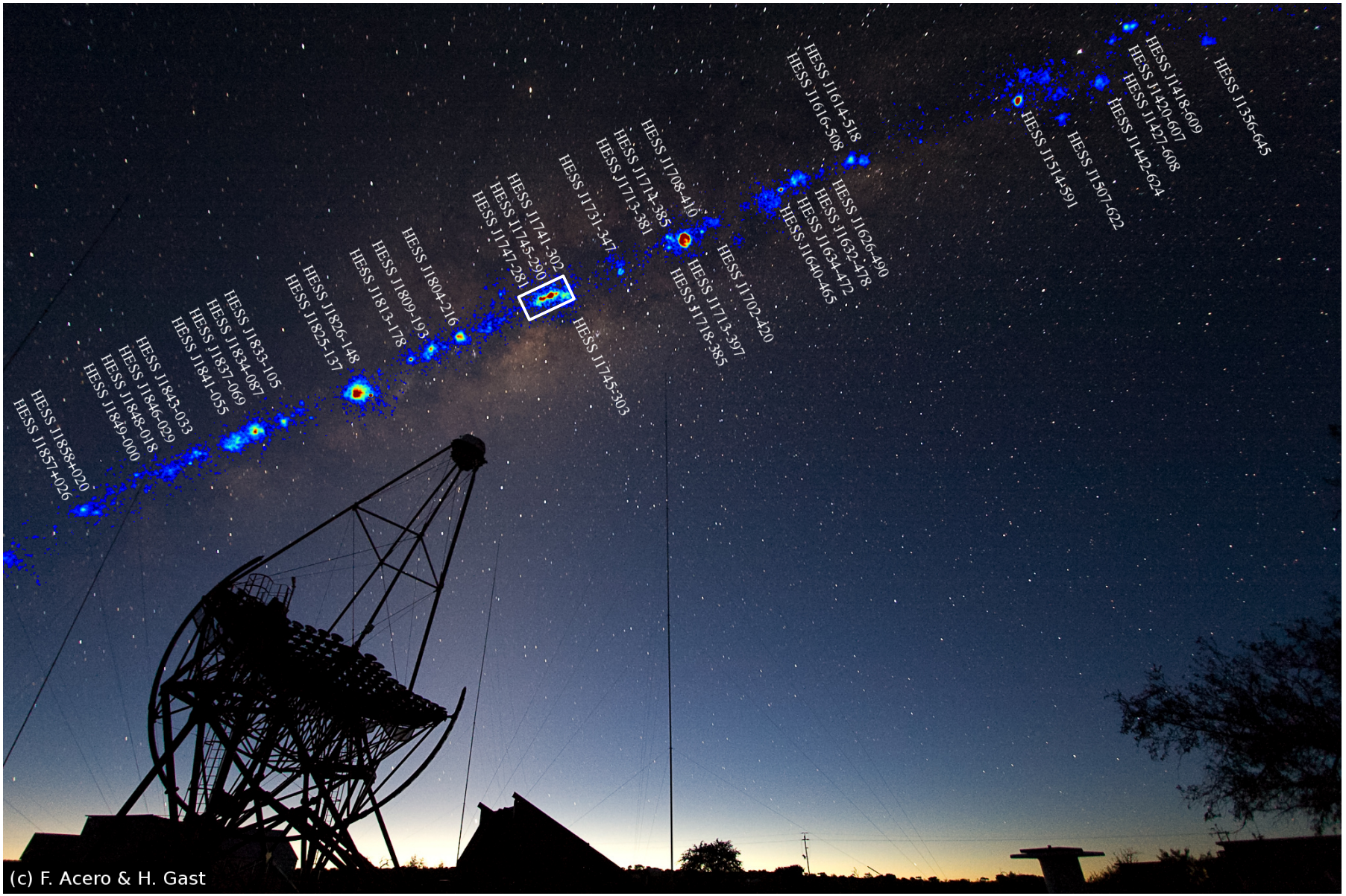
The H.E.S.S. Galactic Plane Scan



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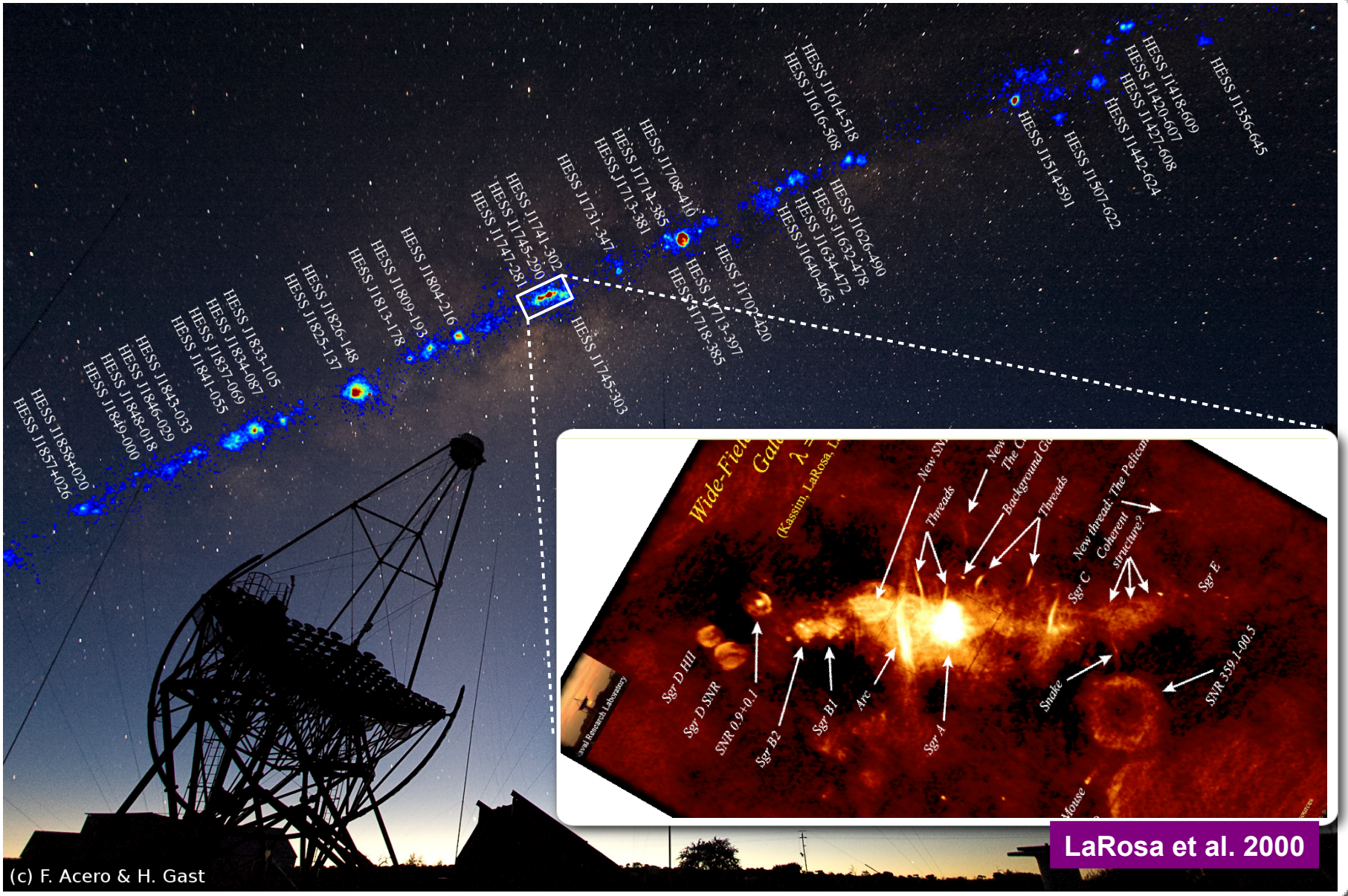
Galactic Centre: radio view



LaRosa et al. 2000

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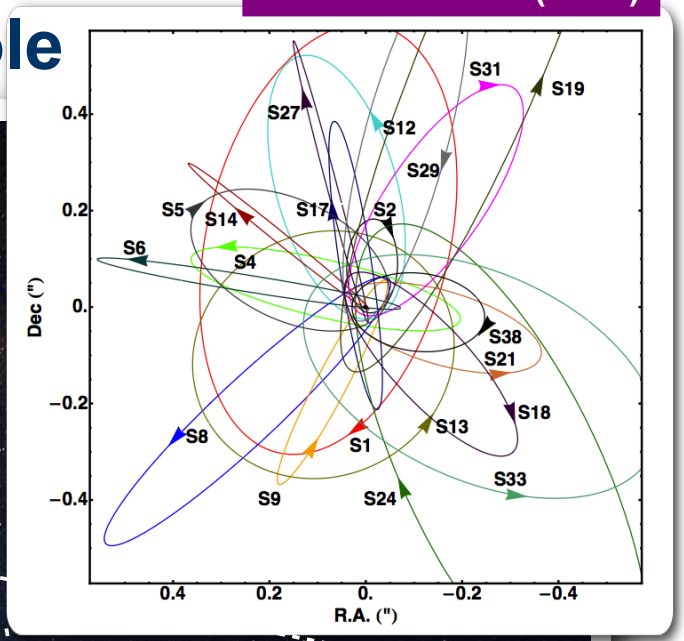
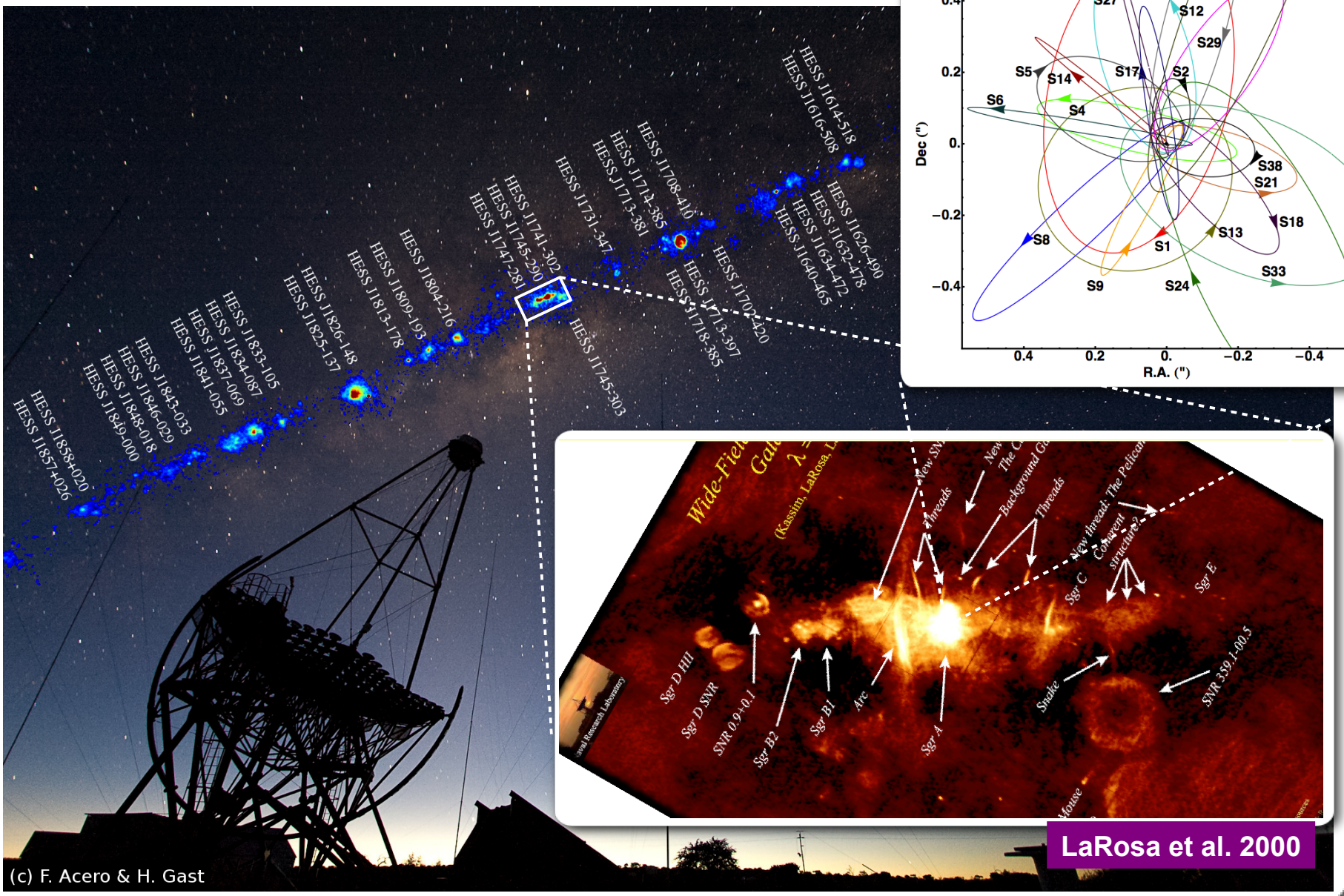
Sgr A* - a supermassive black hole

Gillessen et al. (2008)





LaRosa et al. 2000

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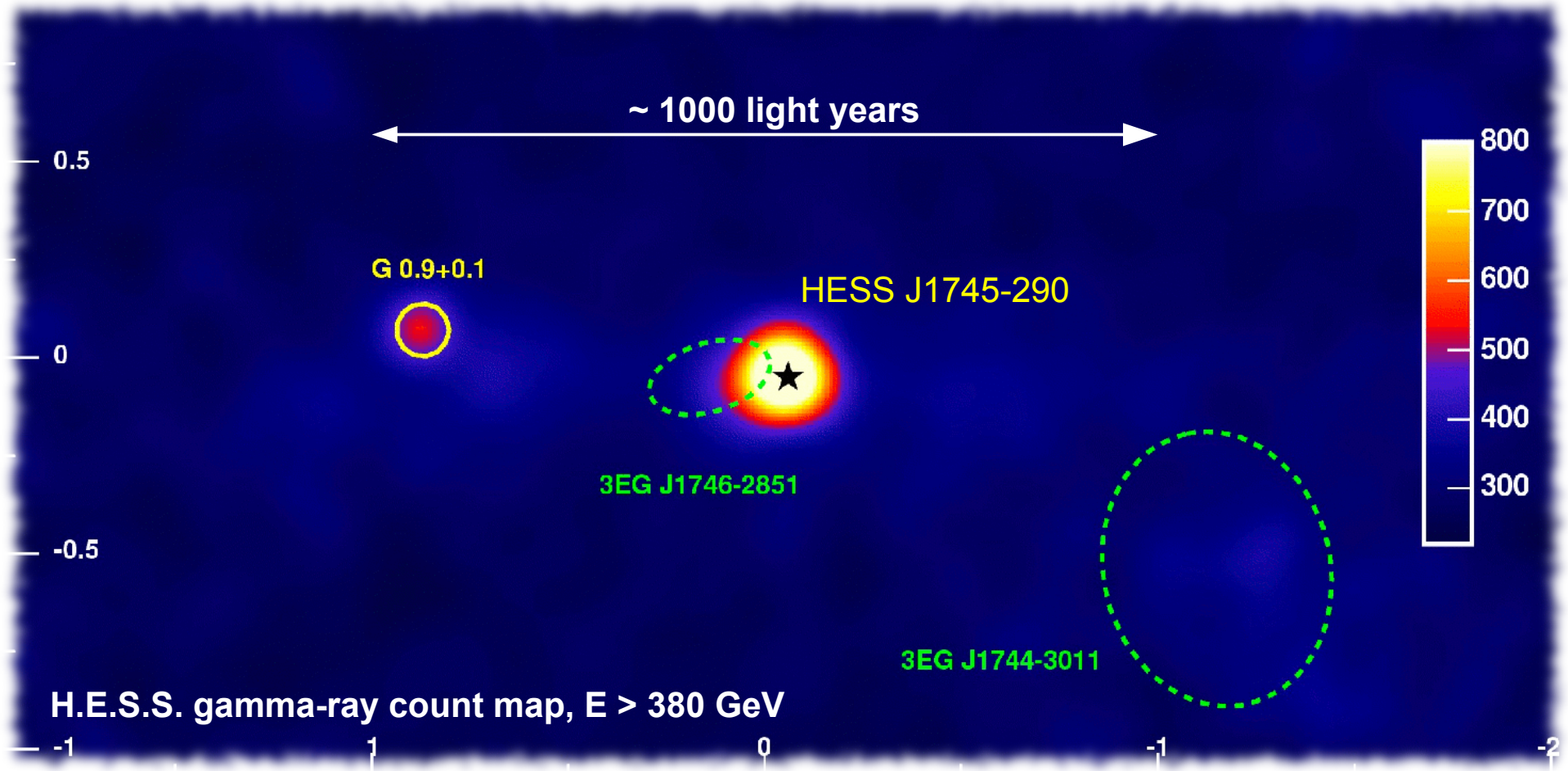
Astrophysical Sources

Nature of the central accelerator



HESS Coll. 2006

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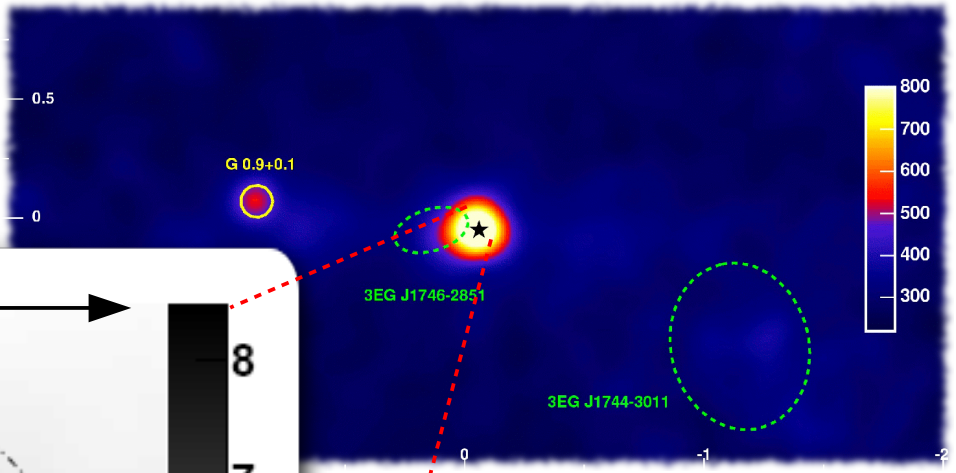
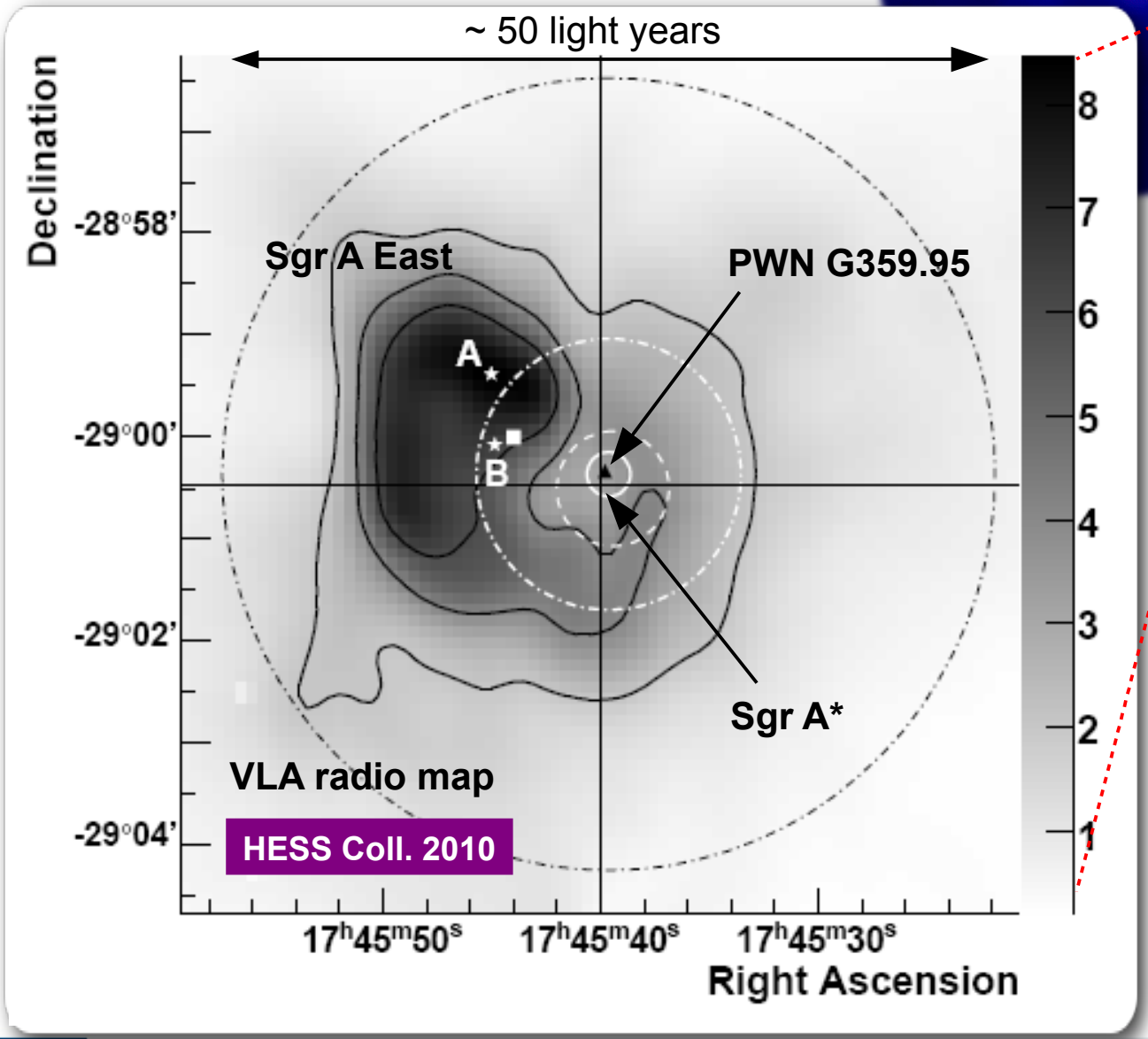
Nature of the central accelerator





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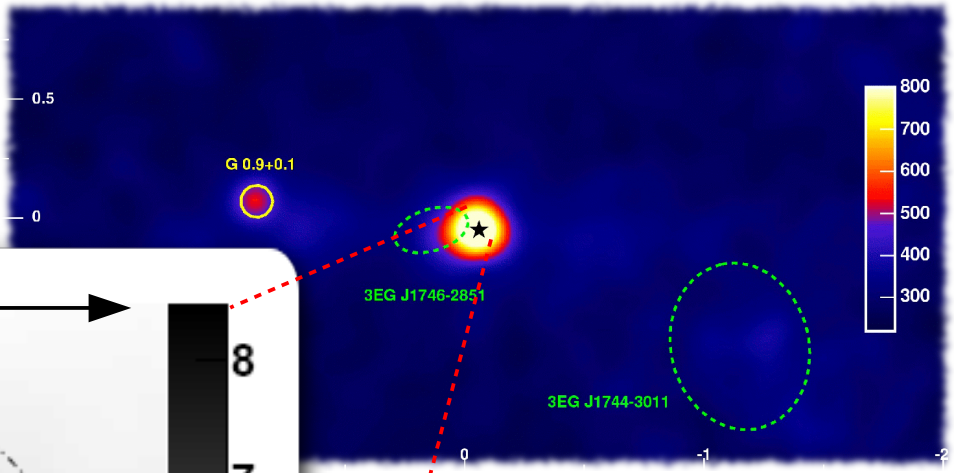
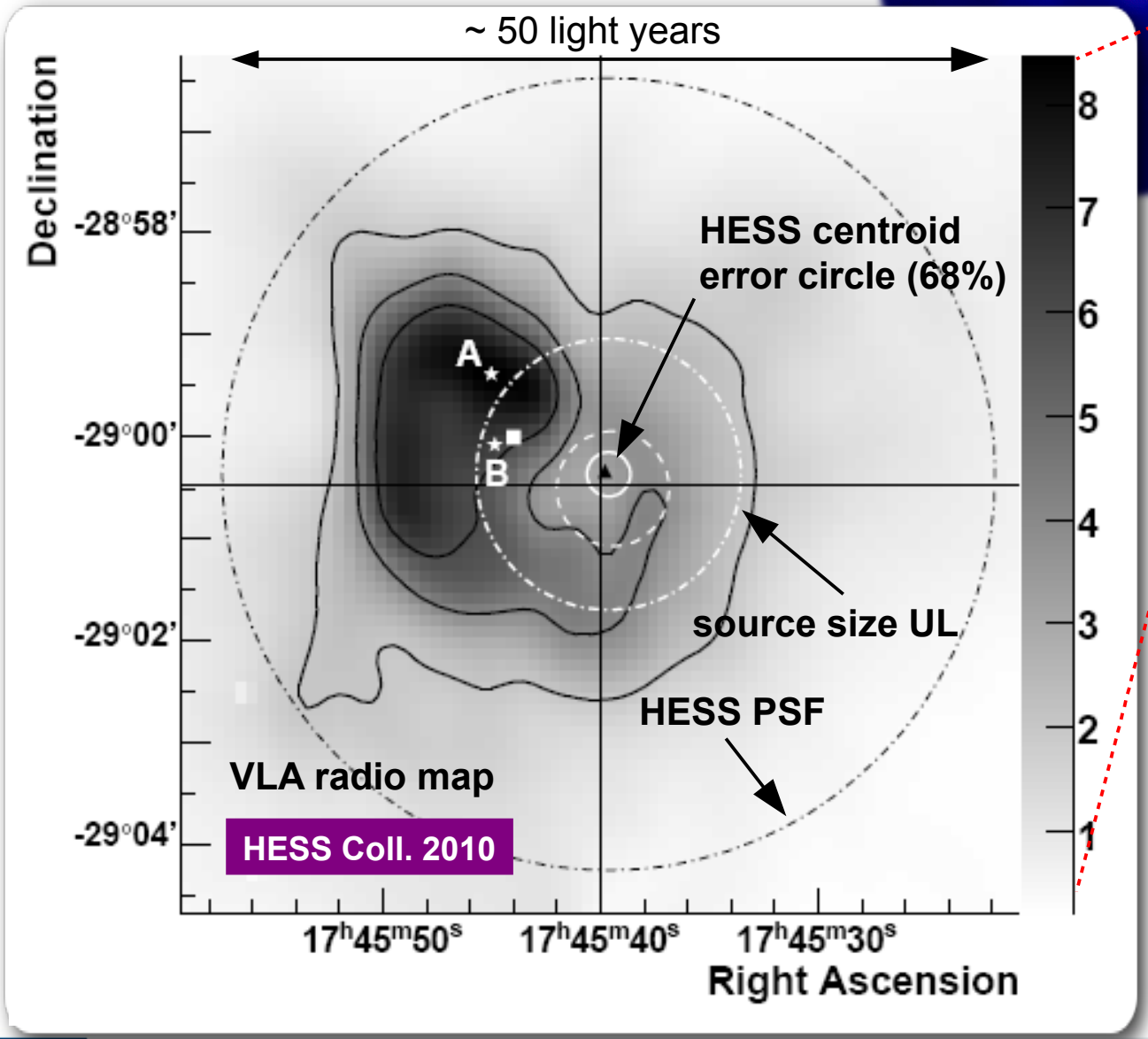
Nature of the central accelerator





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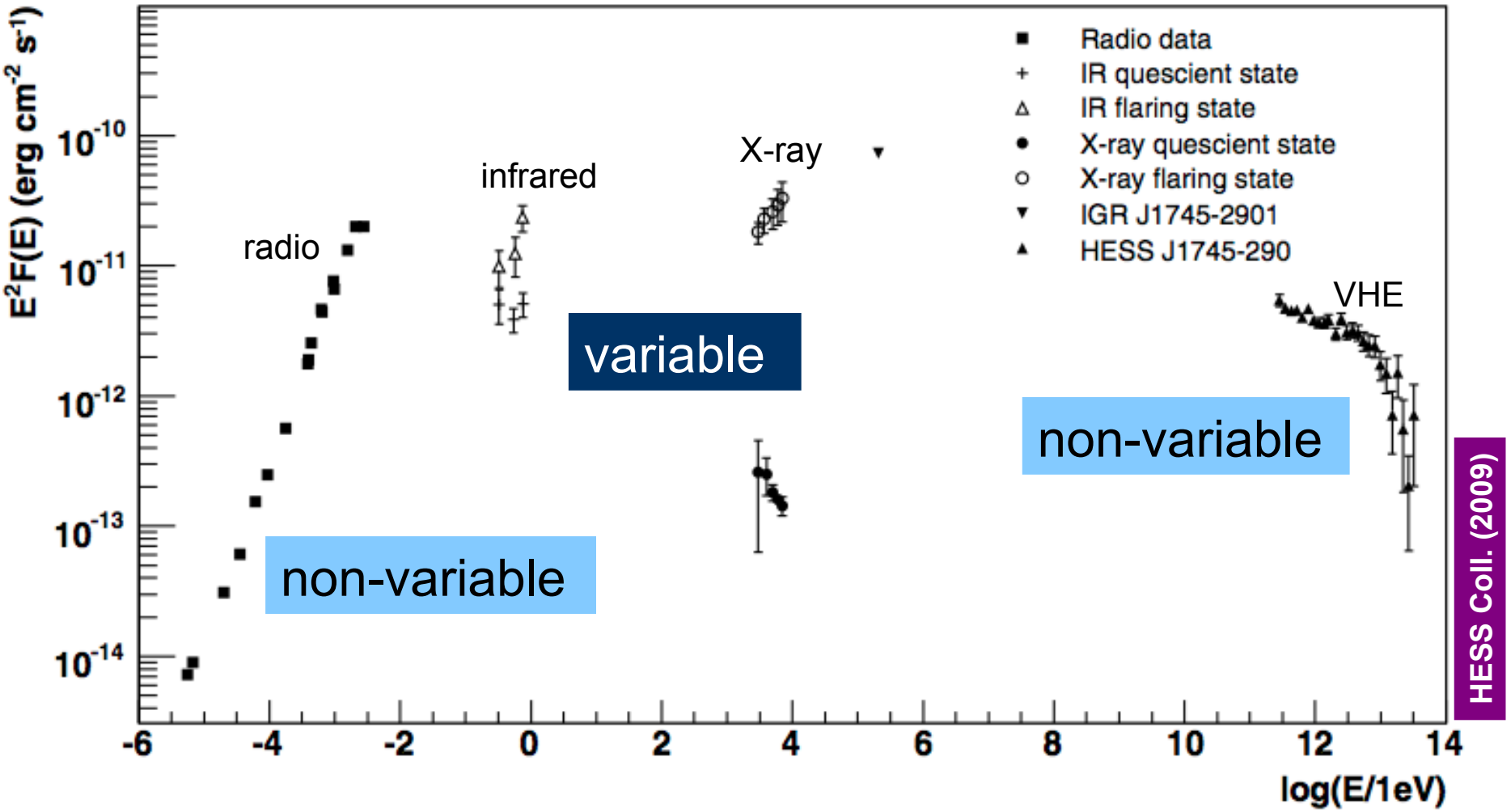
Association with Sgr A*?



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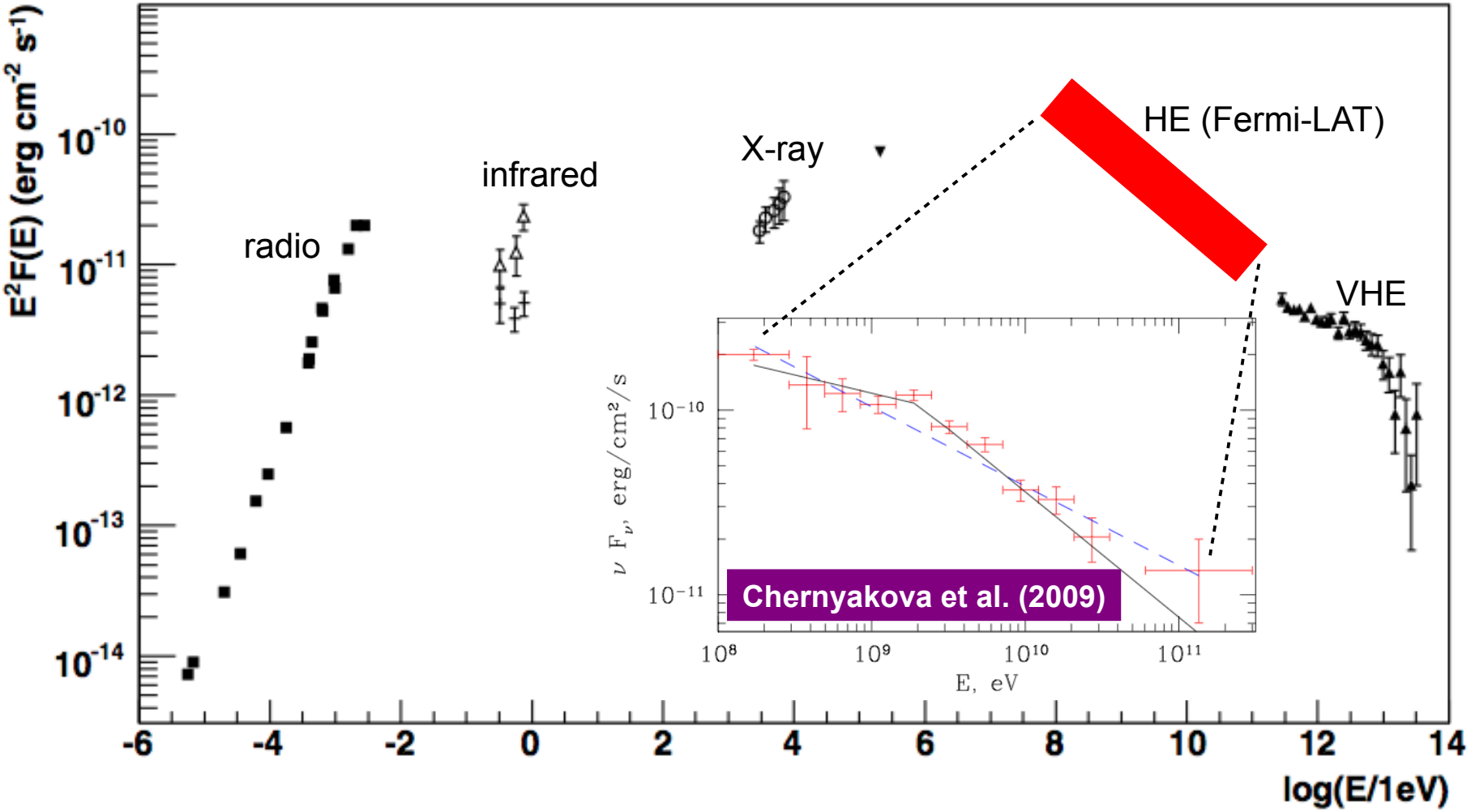
Association with Sgr A*?



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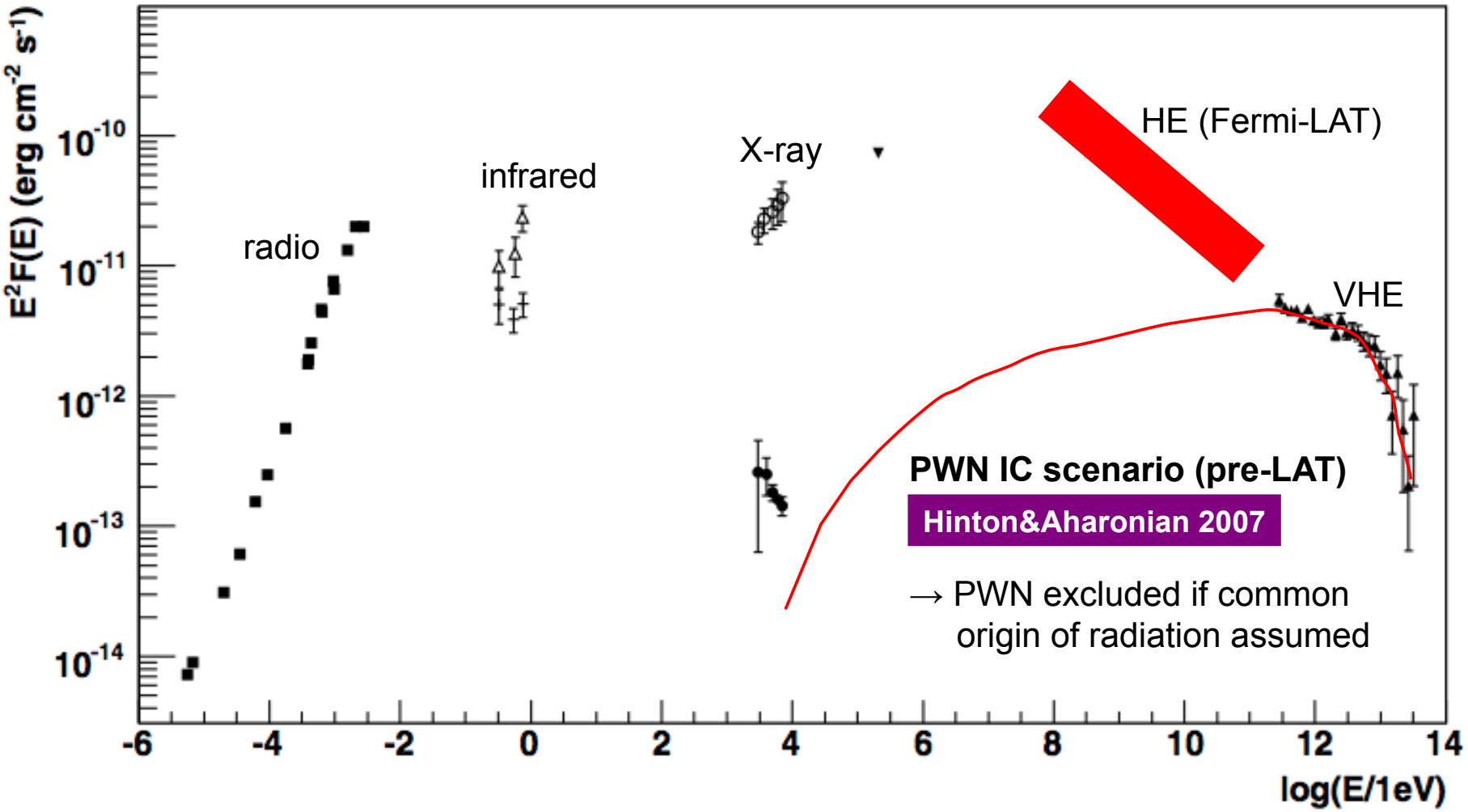
Association with Sgr A*?



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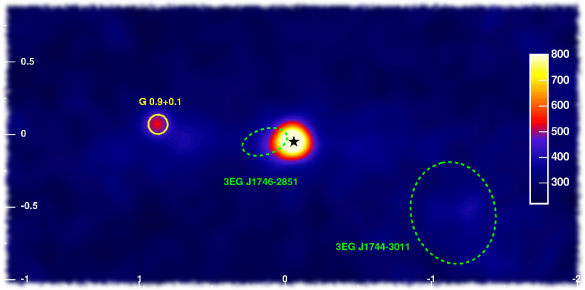
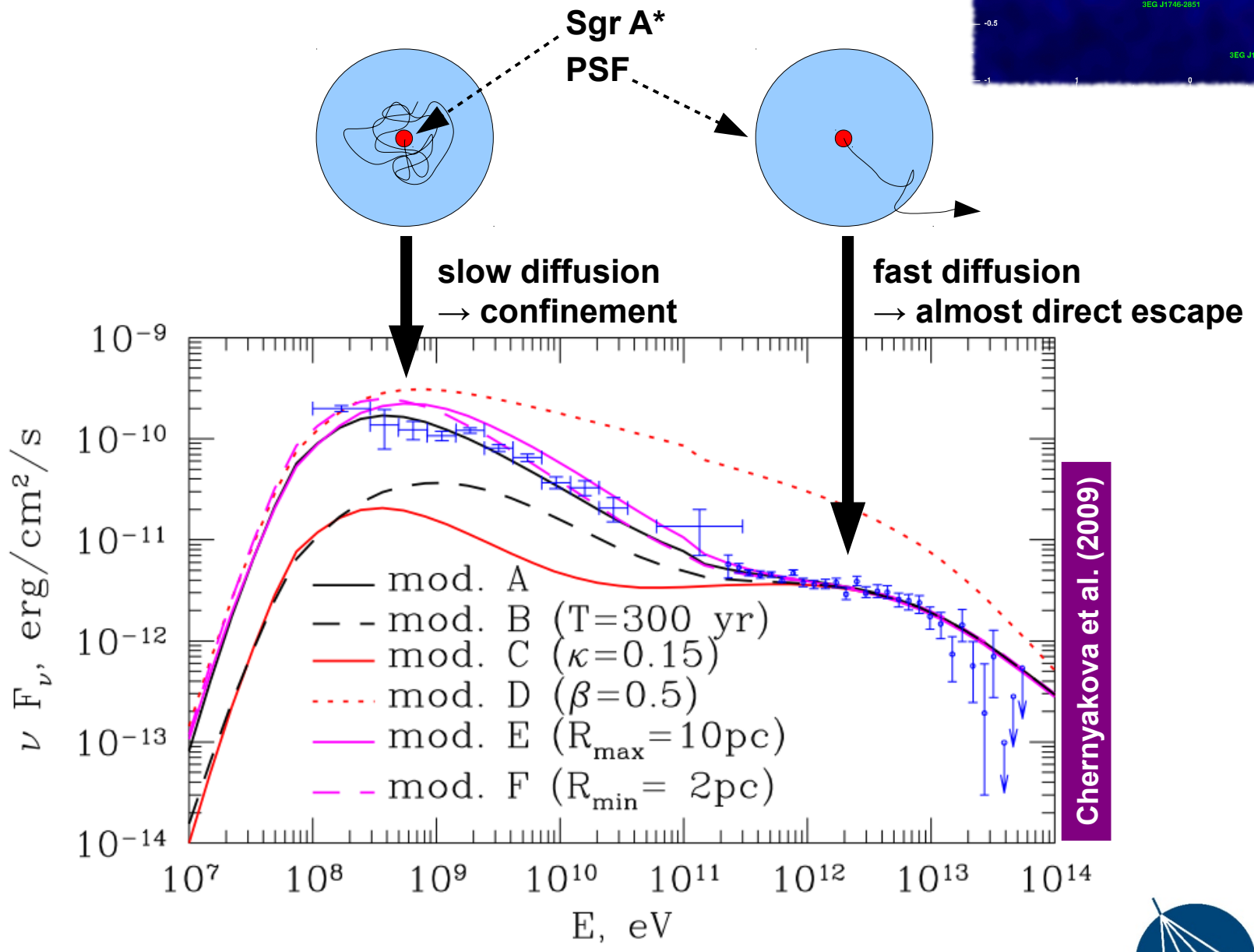
Proton diffusion from Sgr A*





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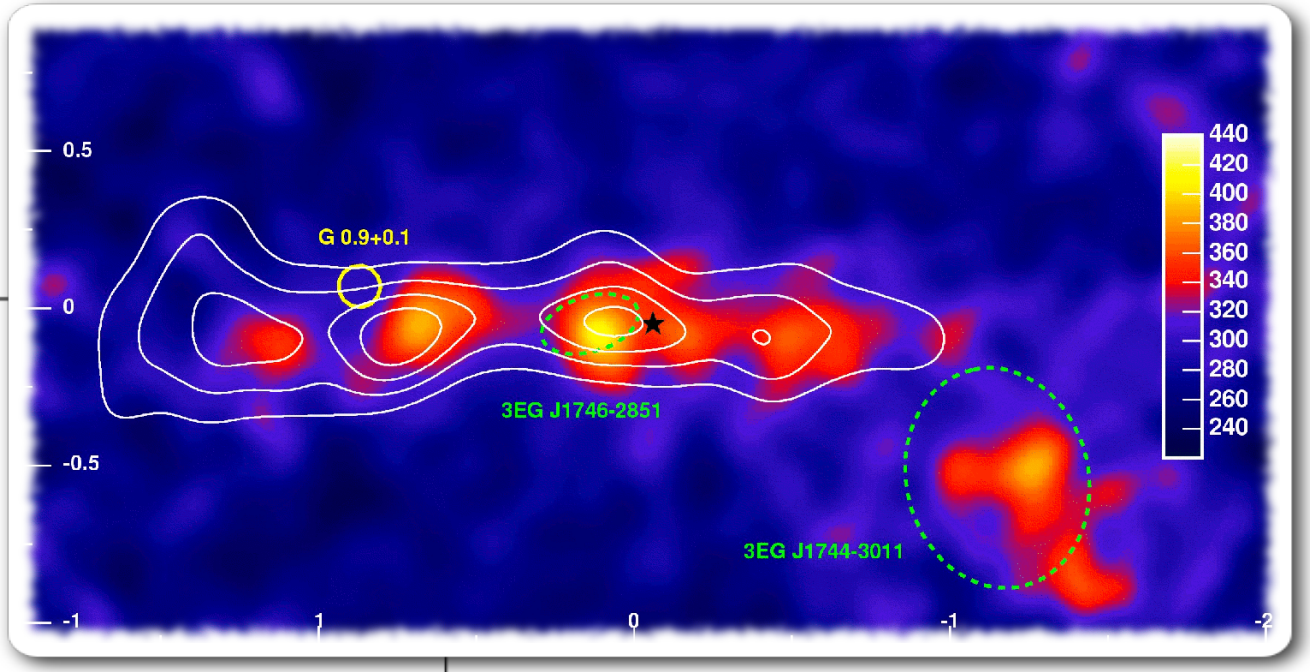
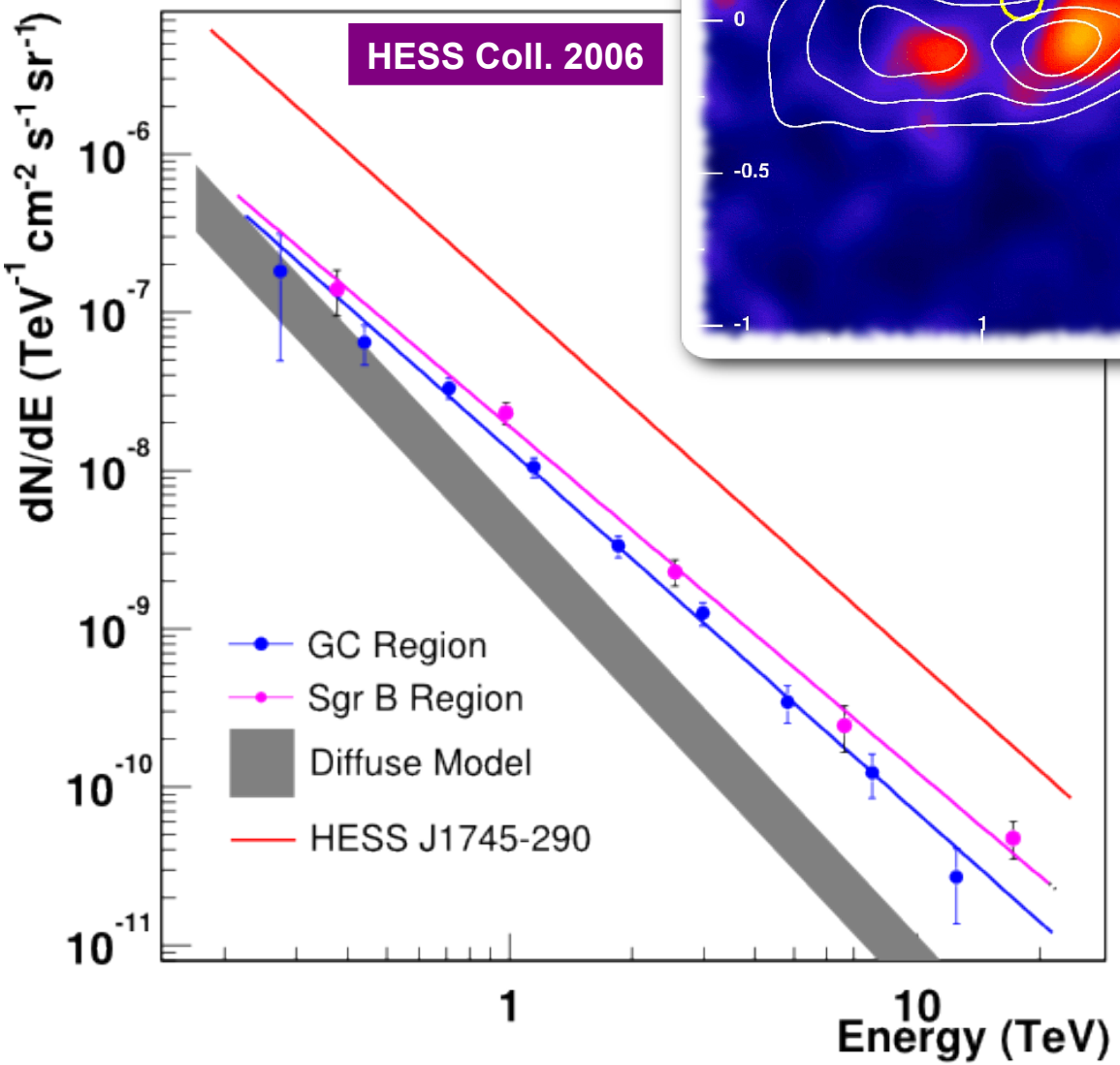
Diffuse emission





- Emission not explained by passive cosmic ray illumination
  → need local accelerator
- Photon index similar to central source
  → accelerator identified?
- Study cosmic ray diffusion in detail

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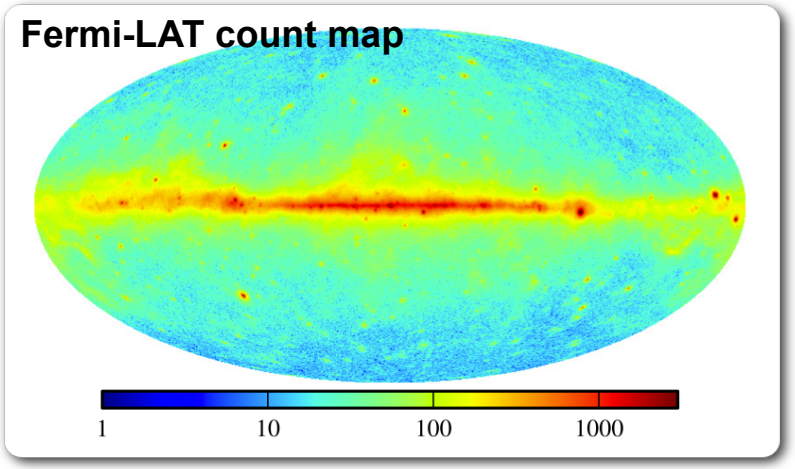
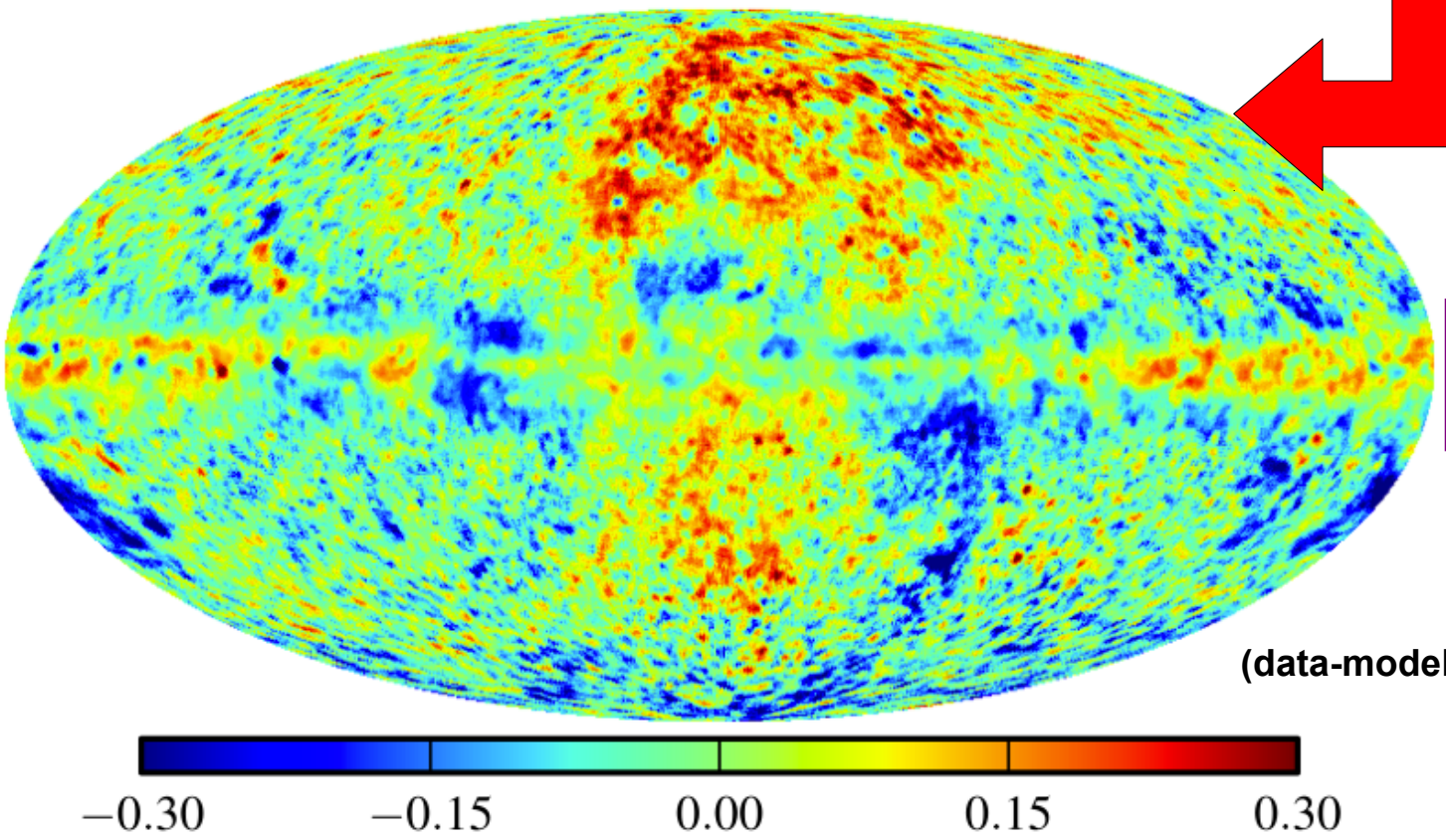
The Fermi bubbles

- Giant bipolar structure observed above/below Galactic Centre
- Coincident with WMAP/X-ray emission
  → synchrotron/IC of electrons?



Subtract standard diffuse model



(data-model)/model

Su et al. 2010
Dobler et al. 2010
Fermi-LAT Coll 2012

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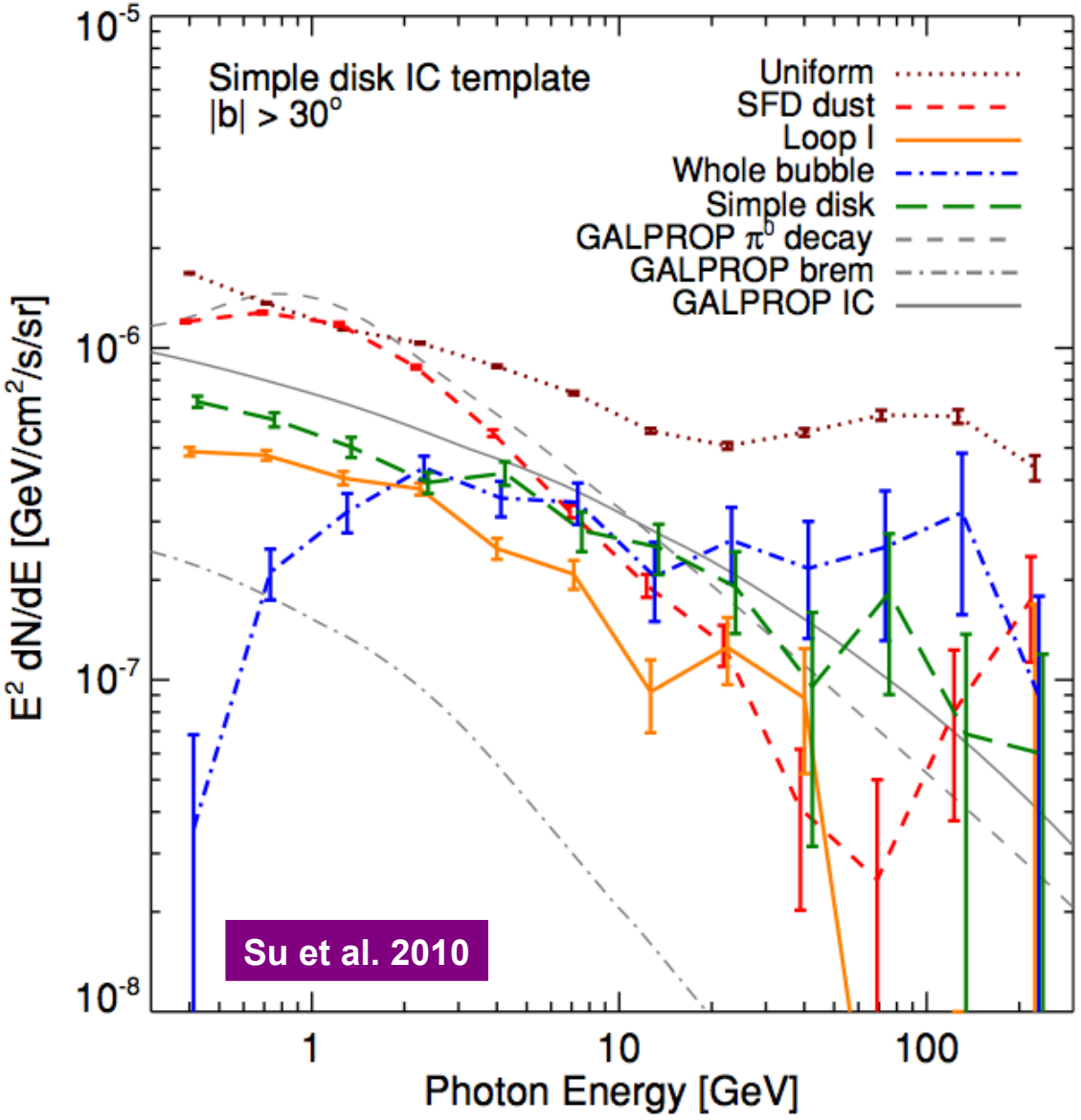
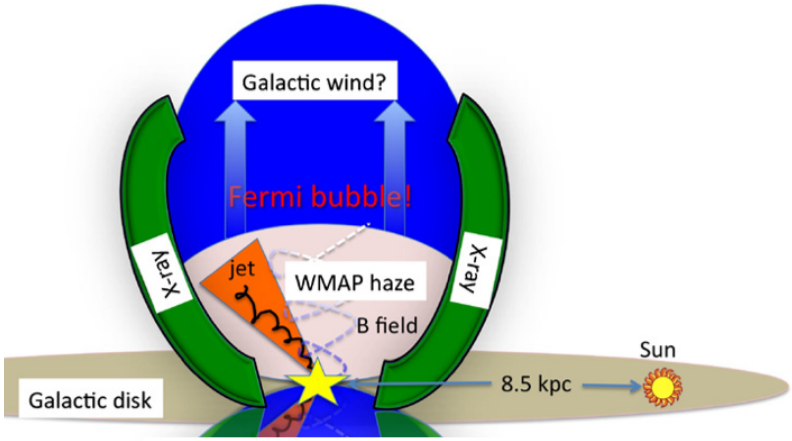
The Fermi bubbles





- Hard power-law spectrum ~E^{-2} → disk electrons unlikely
- Past jet-like activity in GC region?

Su&Finkbeiner 2012

- SNe from GC star forming region may provide constant proton wind → may even see pion cutoff

Crocker&Aharonian 2011

- Dark Matter?

Finkbeiner 2004
Hooper 2007
Dobler 2011

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Dark Matter Searches

Gamma-rays from WIMP annihilations

Observed flux **Annihilation cross section**

$$\frac{\mathrm{d}\Phi(\Delta\Omega, E_\gamma)}{\mathrm{d}E_\gamma} = \mathrm{B_F} \cdot \frac{1}{4\pi} \underbrace{\frac{(\sigma_{\mathrm{ann}} v)}{2m_\chi^2} \sum_i \mathrm{BR}_i \frac{\mathrm{d}N_\gamma^i}{\mathrm{d}E_\gamma}}_{\text{Particle physics}} \cdot \underbrace{\tilde{J}(\Delta\Omega)}_{\text{Astrophysics}}$$

$$\tilde{J} = \int_{\Delta\Omega} d\Omega \int_{\mathrm{los}} \mathrm{d}s\, \rho^2(s, \Omega)$$

Dark Matter energy density

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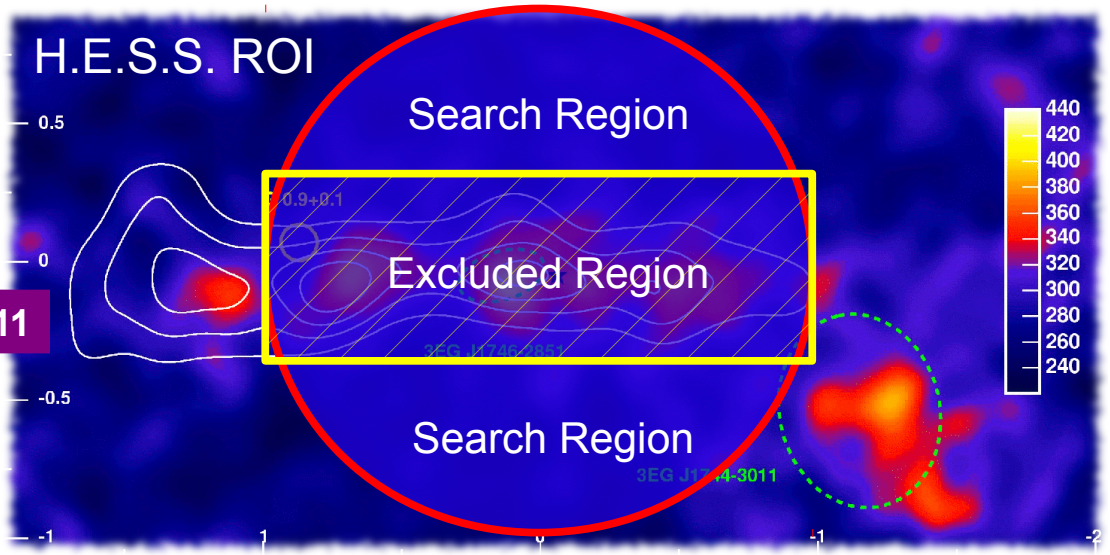
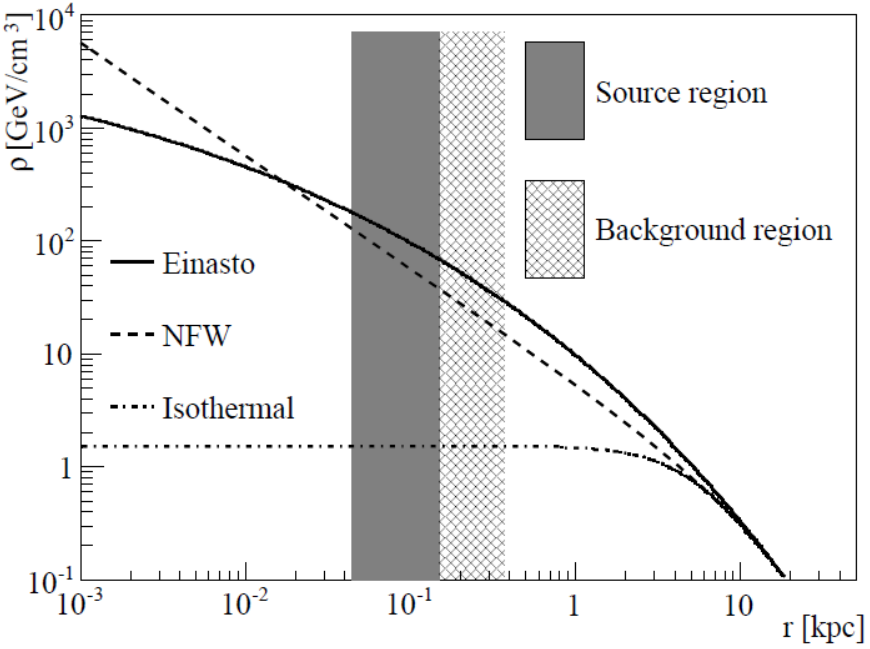
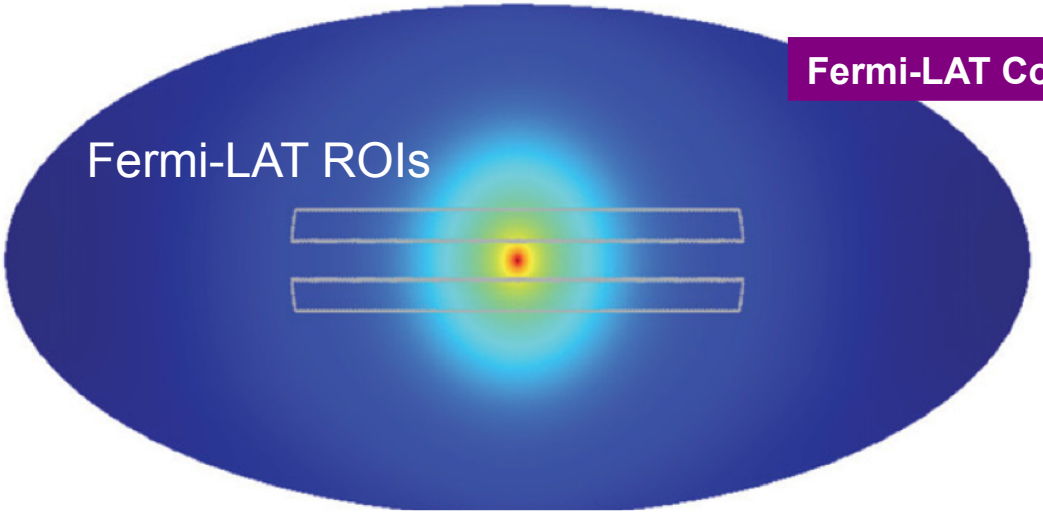
Dark Matter annihilations in the Galactic Halo?



HESS Coll 2011





Fermi-LAT Coll 2012

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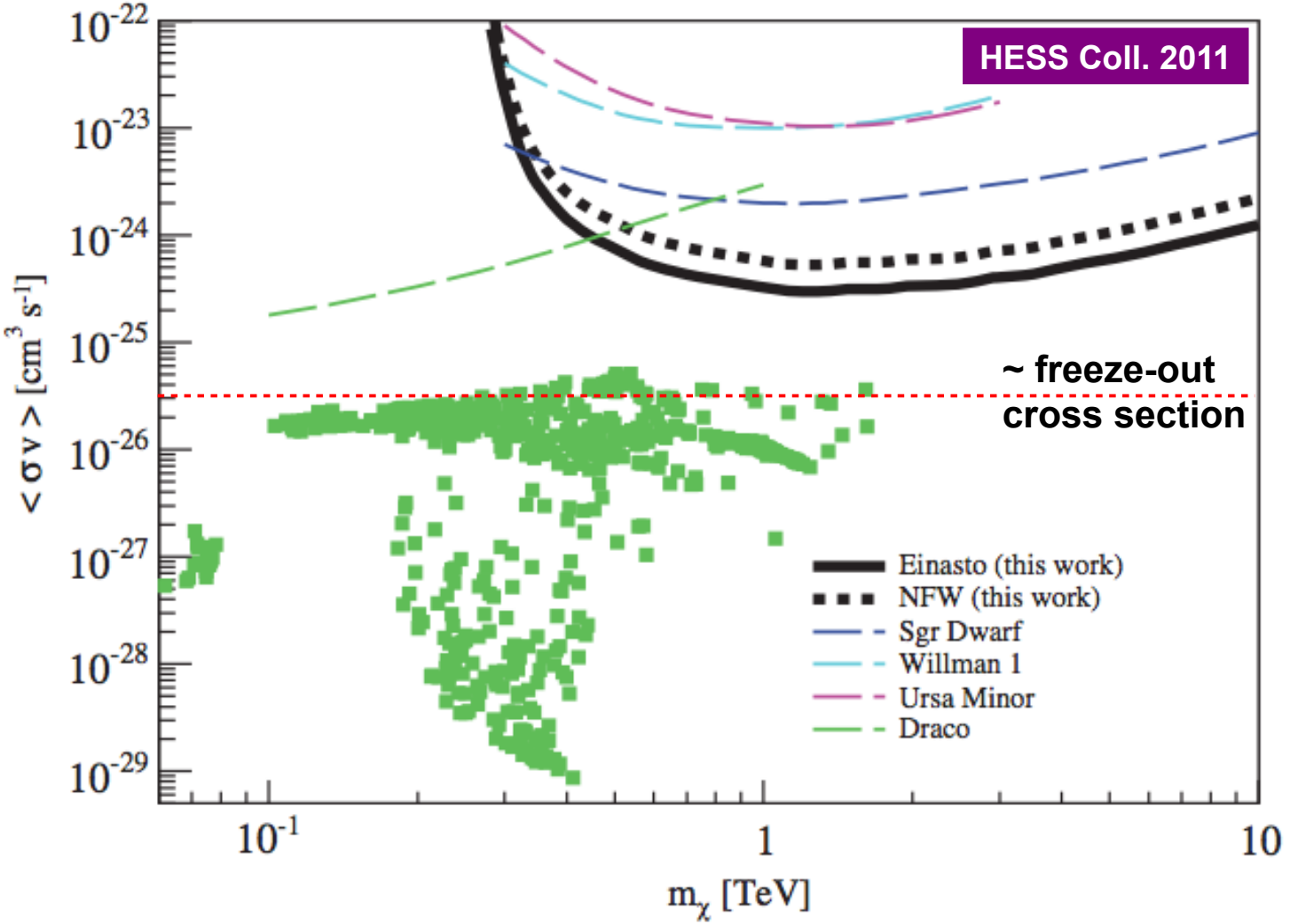
Limits for $\chi\chi \rightarrow q\bar{q}$



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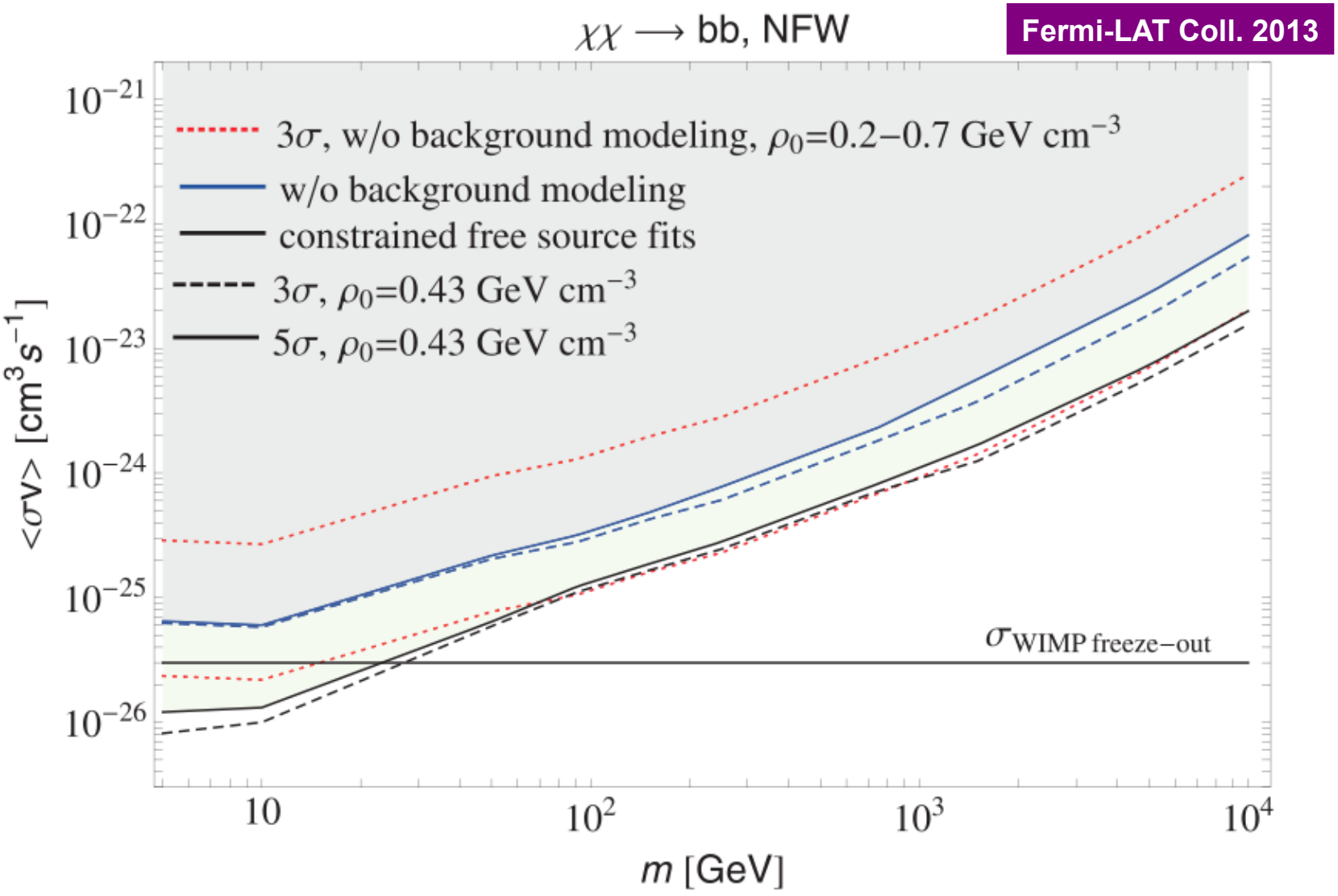
Limits for $\chi\chi \to b\bar{b}$



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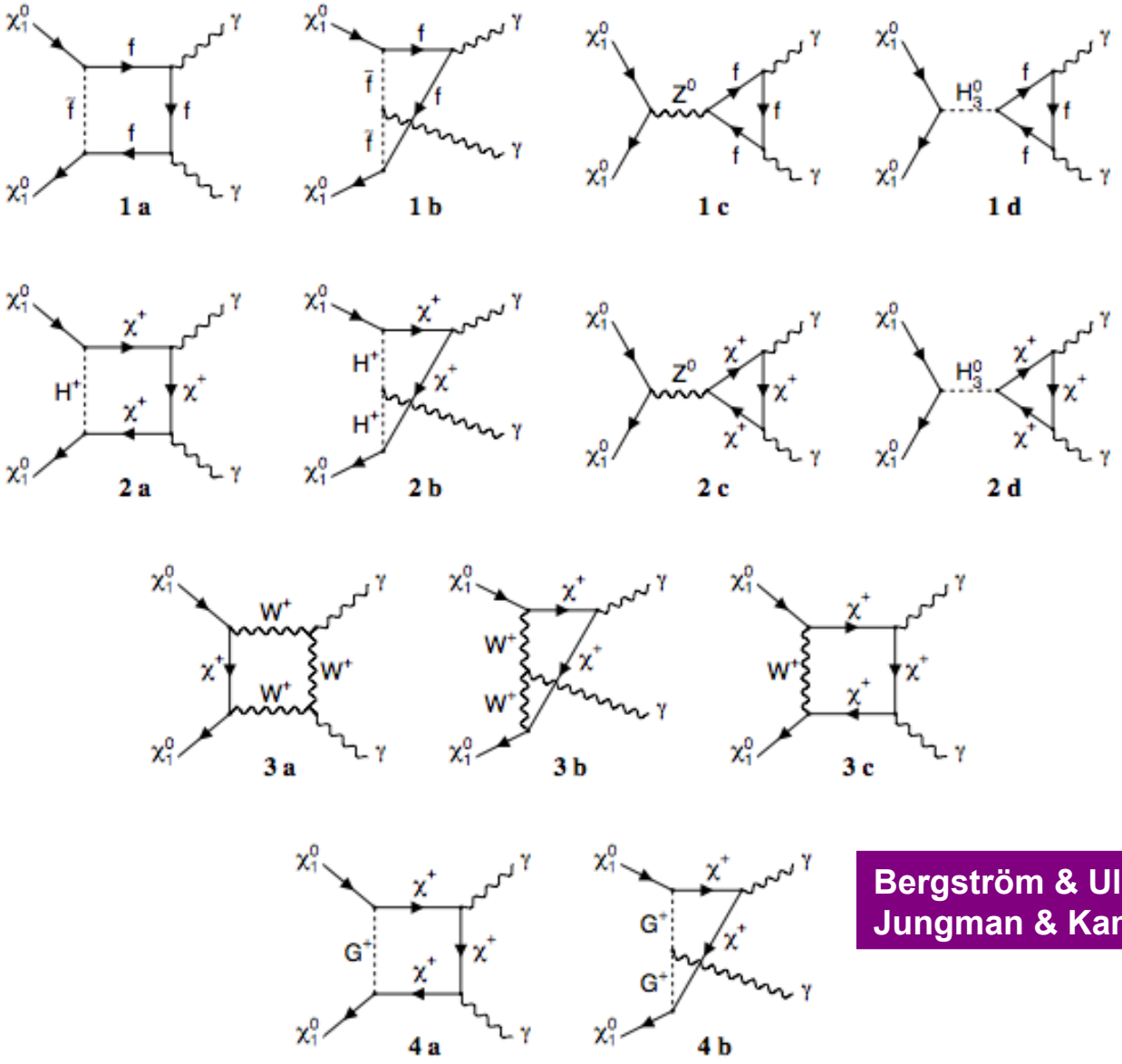
Gamma line searches



Bergström & Ullio 1997
Jungman & Kamionkowski 1995

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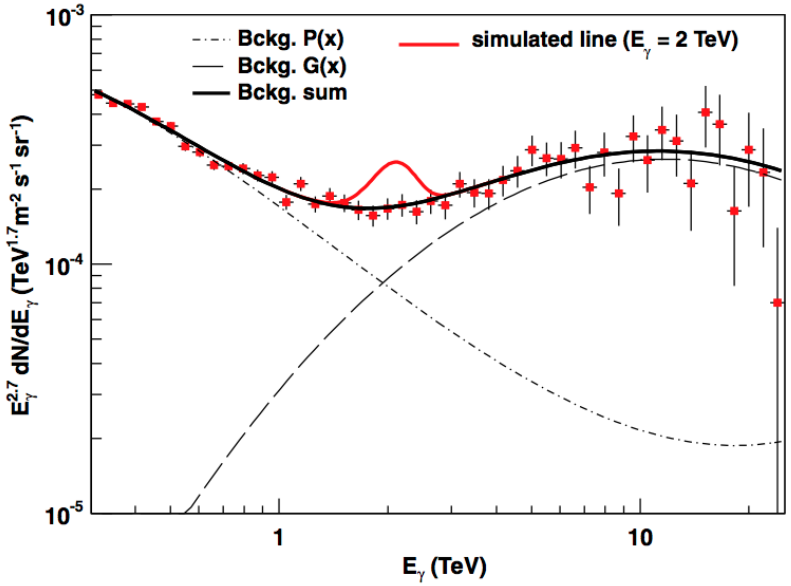
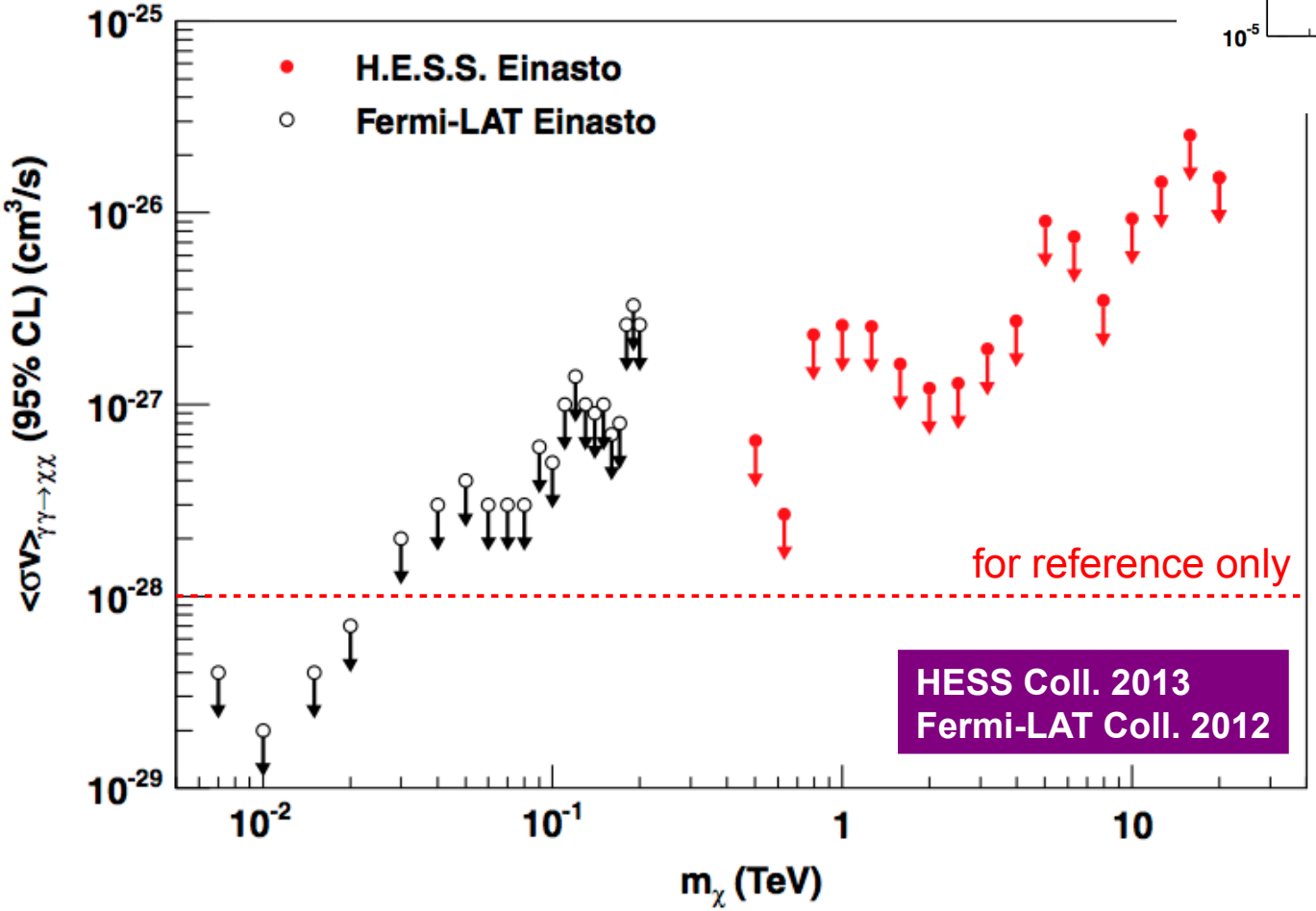
Galactic Halo limits for χχ→γγ





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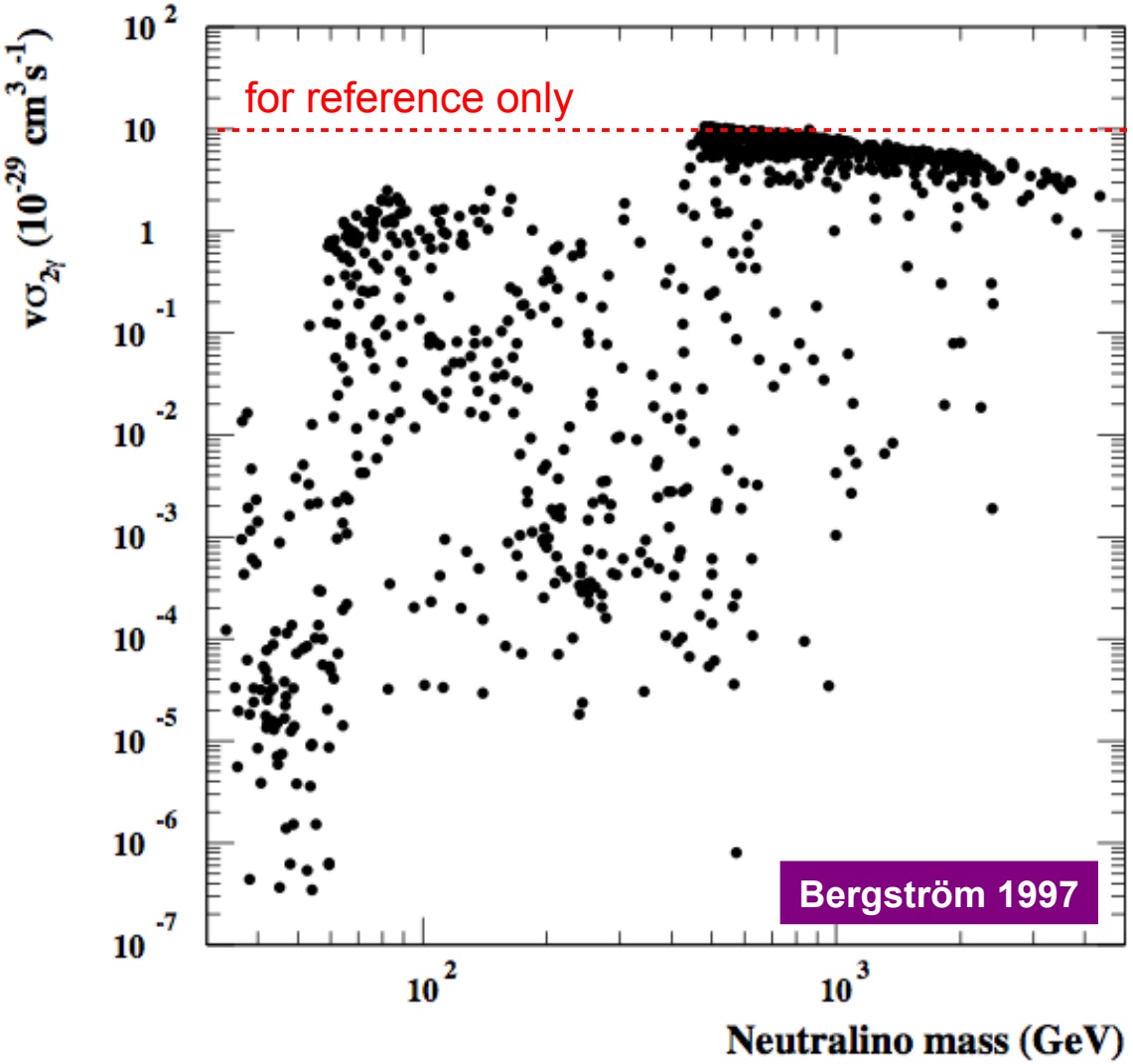
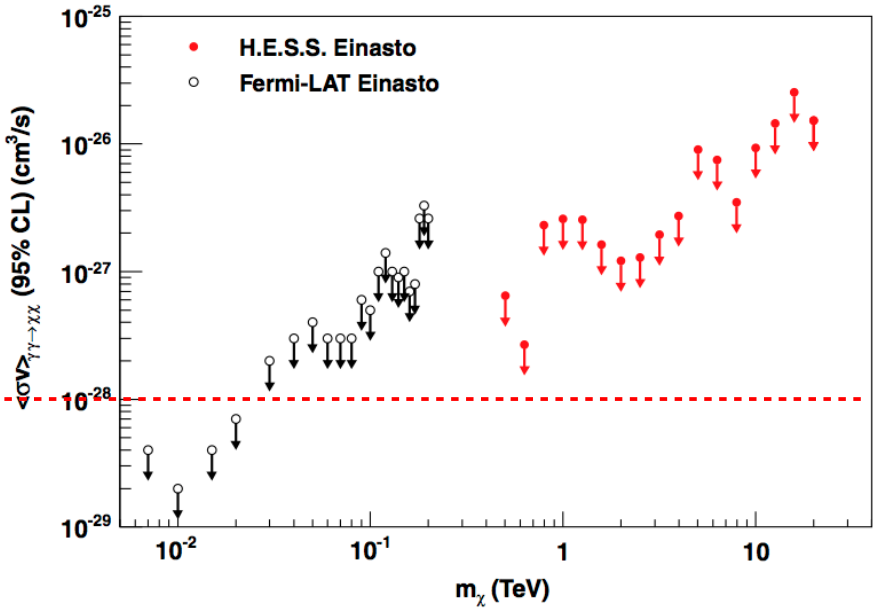
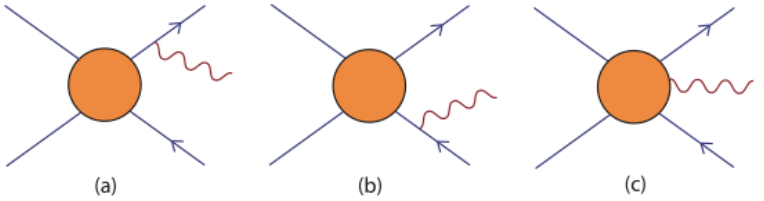
Galactic Halo limits for $\chi\chi \rightarrow \gamma\gamma$





- Limits still above bulk of conventional MSSM models
- Other line-like features accessible at tree level, e.g. FSR + VIB



Bringmann 2007

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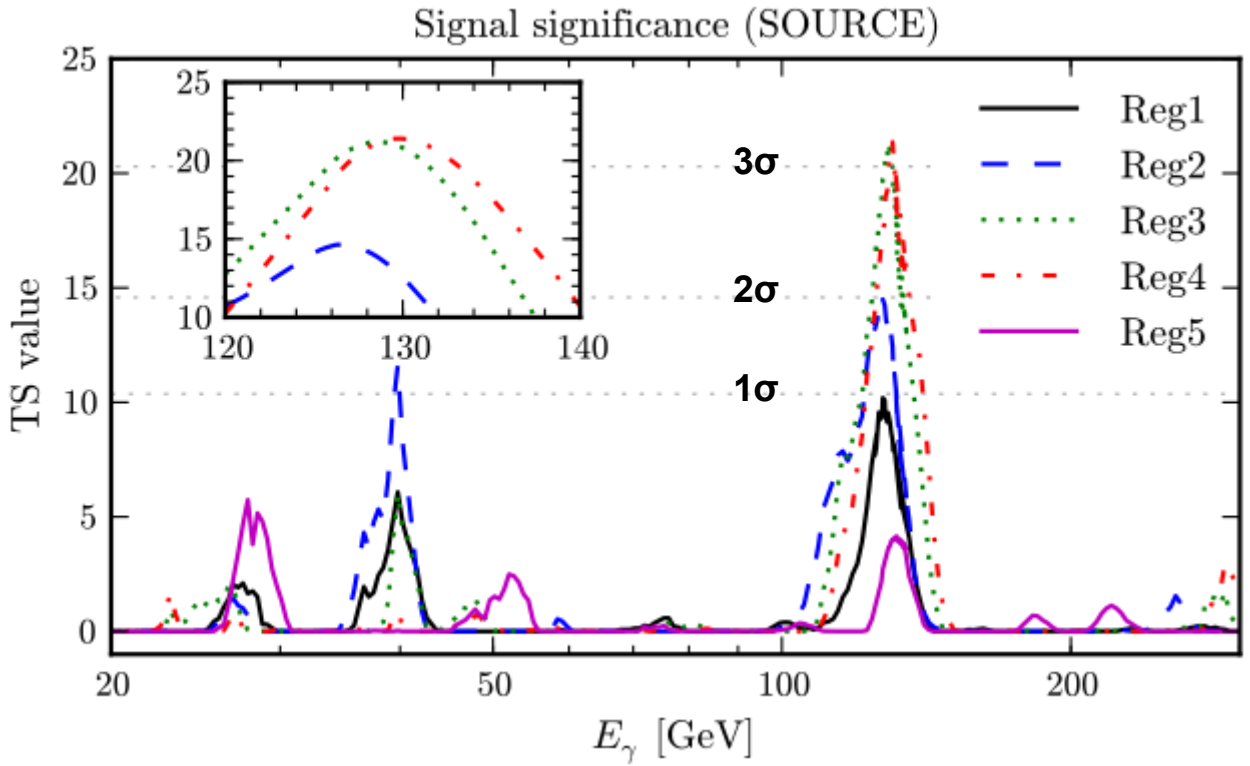
A line feature in the Galactic halo?

- Putative linie feature, 3.2σ post-trials (43 months Fermi-LAT data)
- ROI optimised on diffuse gamma-ray background at low energies
- $\langle\sigma v\rangle = 2.27 \times 10^{-27}$ cm^3/s for NFW profile



Weniger (2012)

Bringmann et al. (2012)

- Spatial shift of 150 pc w.r.t. Galactic Centre?
- Shift can be expected from cosmological simulations

Su&Finkbiner (2012)

Kuhlen et al. 2013

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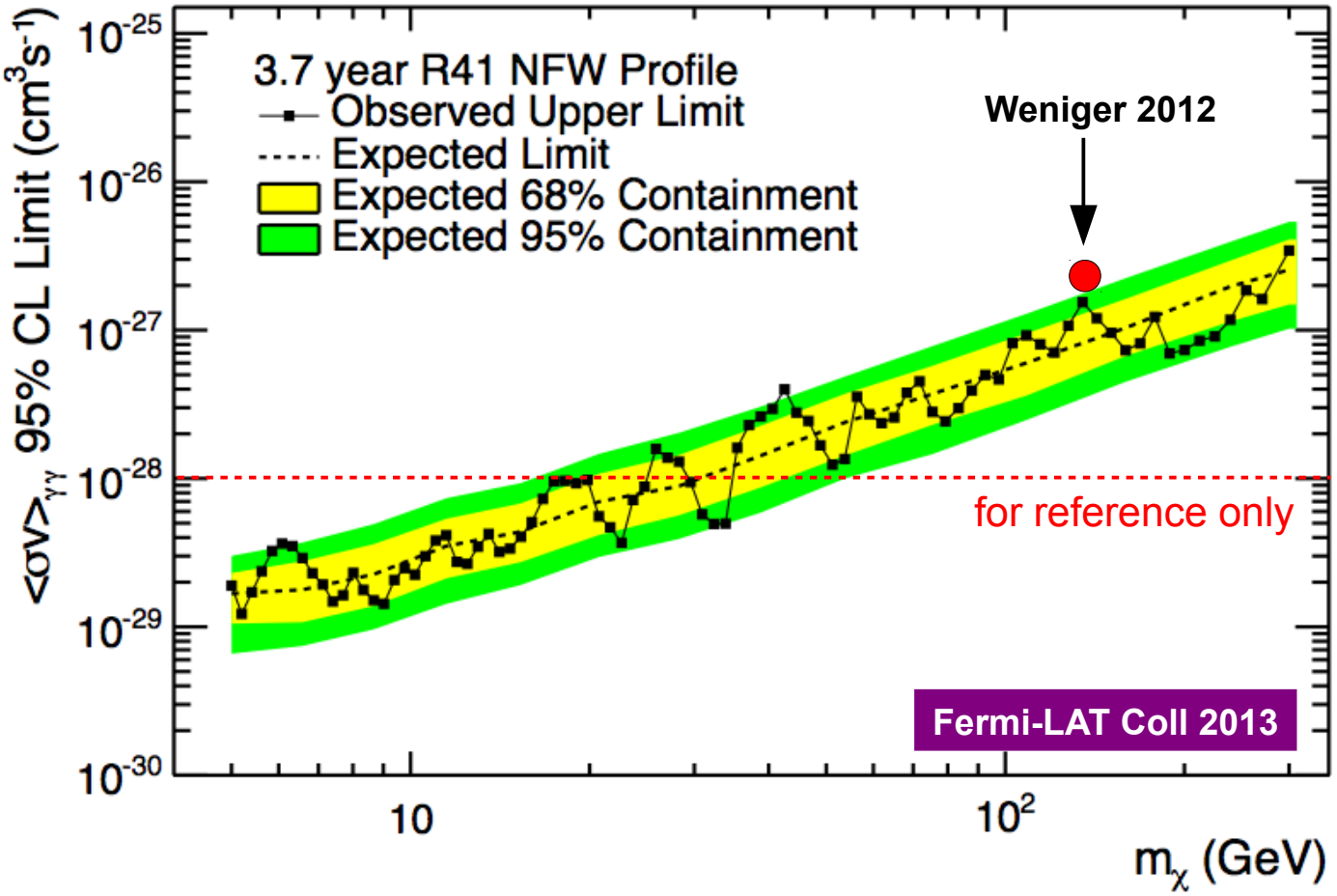
A line feature in the Galactic halo?

- LAT analysis using re-calibrated data (43 months)
- Circular ROI centred on GC (optimised on background simulations)



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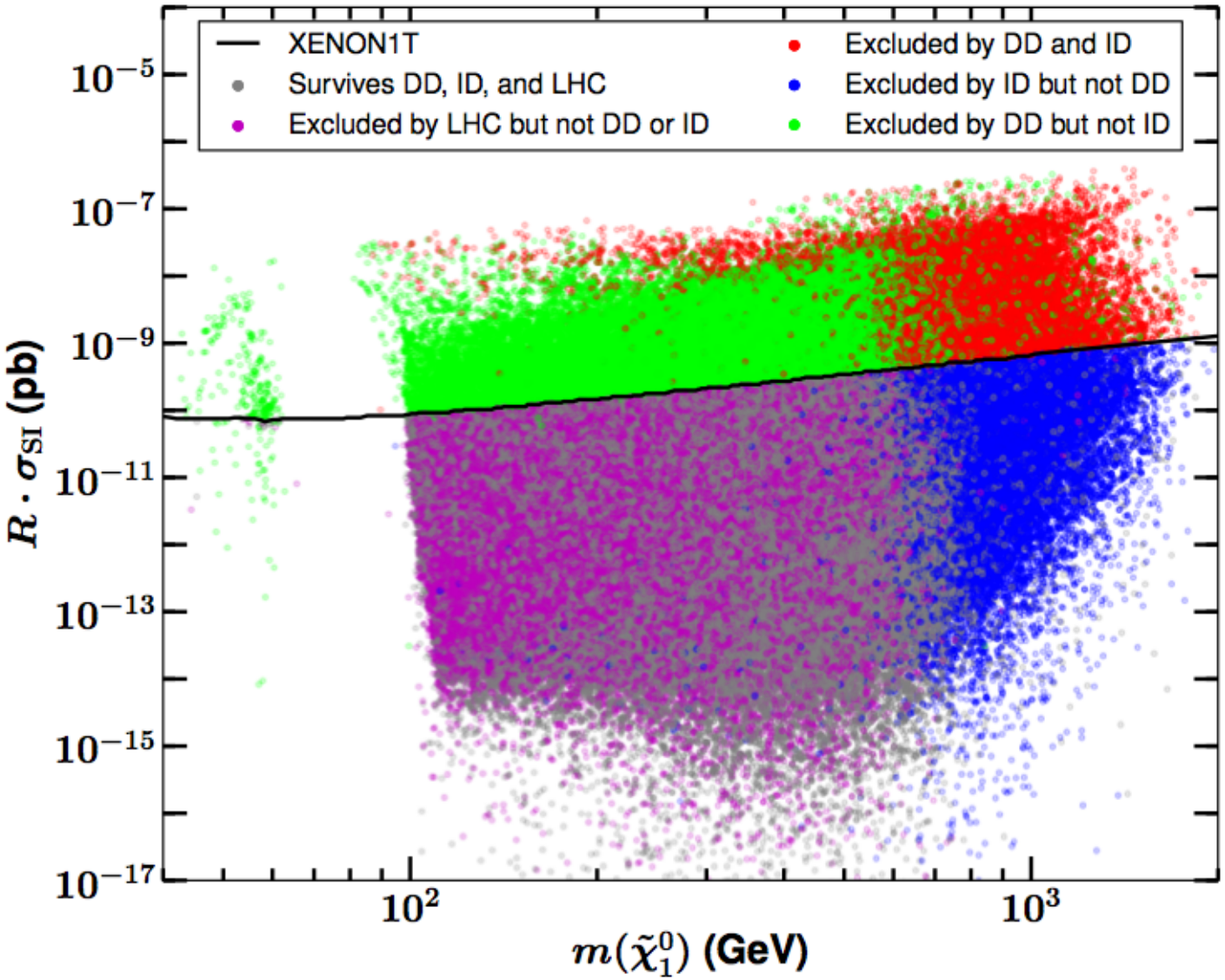
Complementarity: direct vs. indirect searches



Cahill-Rowley et al. 2013

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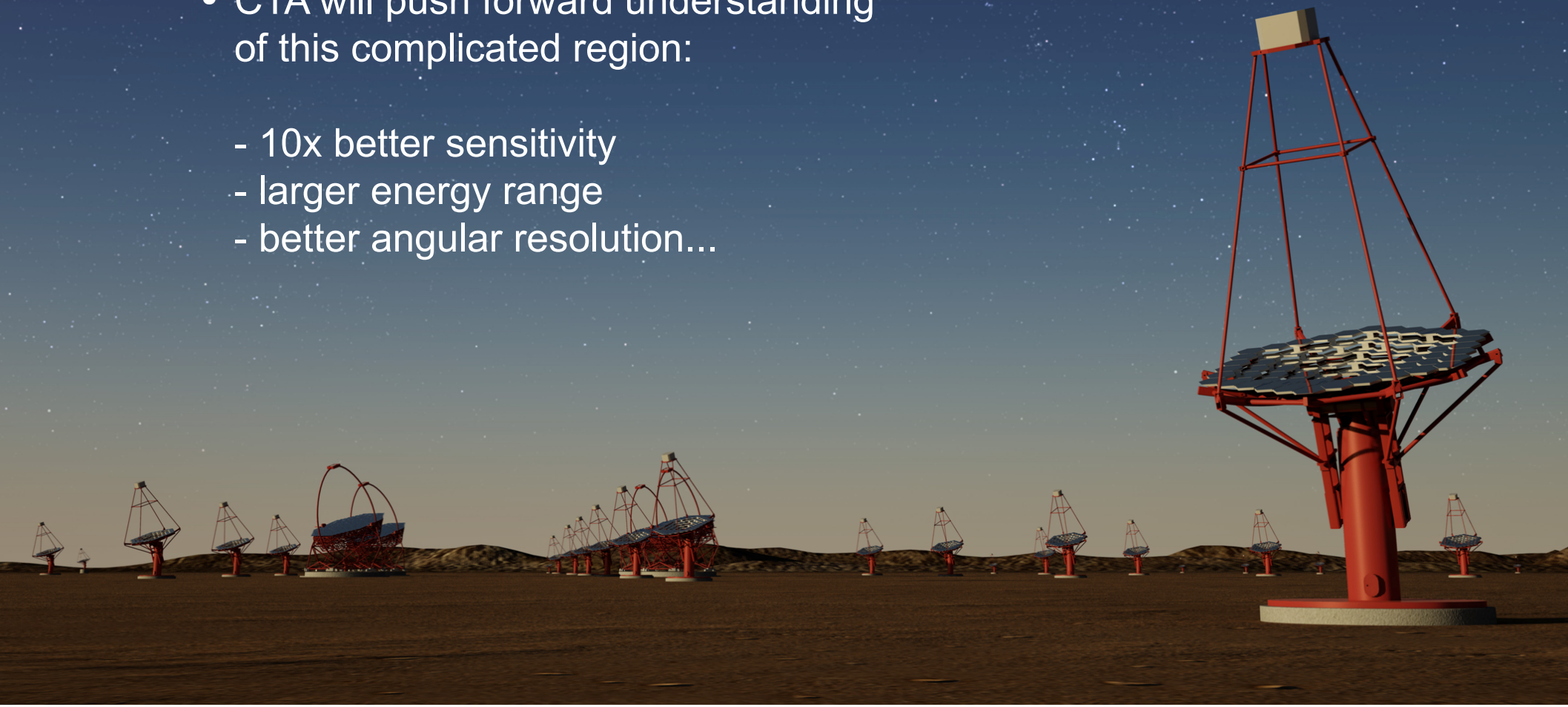
Instead of a summary

- CTA will push forward understanding of this complicated region:

  - 10x better sensitivity
  - larger energy range
  - better angular resolution...



HELMHOLTZ ASSOCIATION
Alliance for Astroparticle Physics

EMERGING FIELDS INITIATIVE

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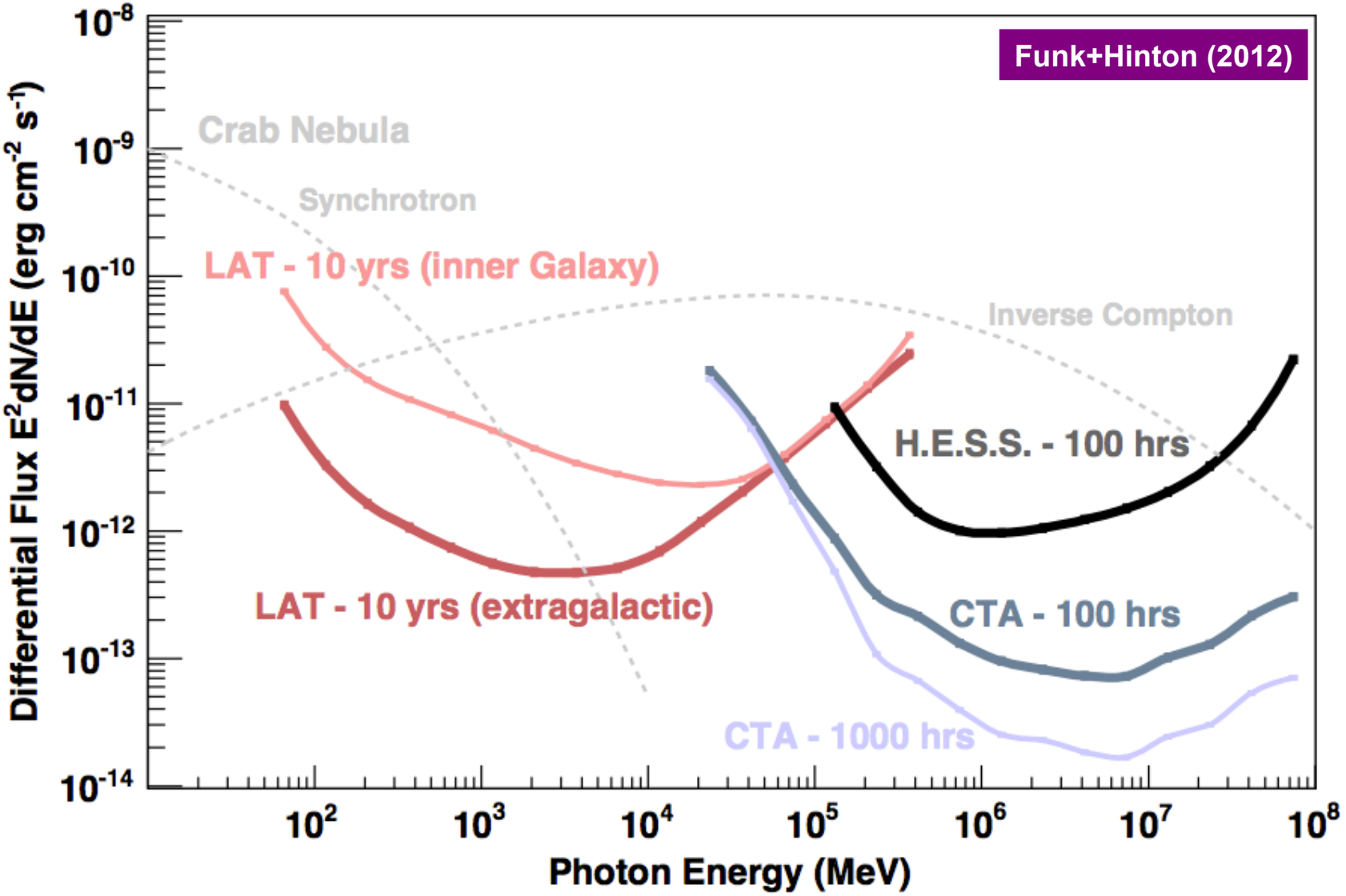
Flux sensitivity



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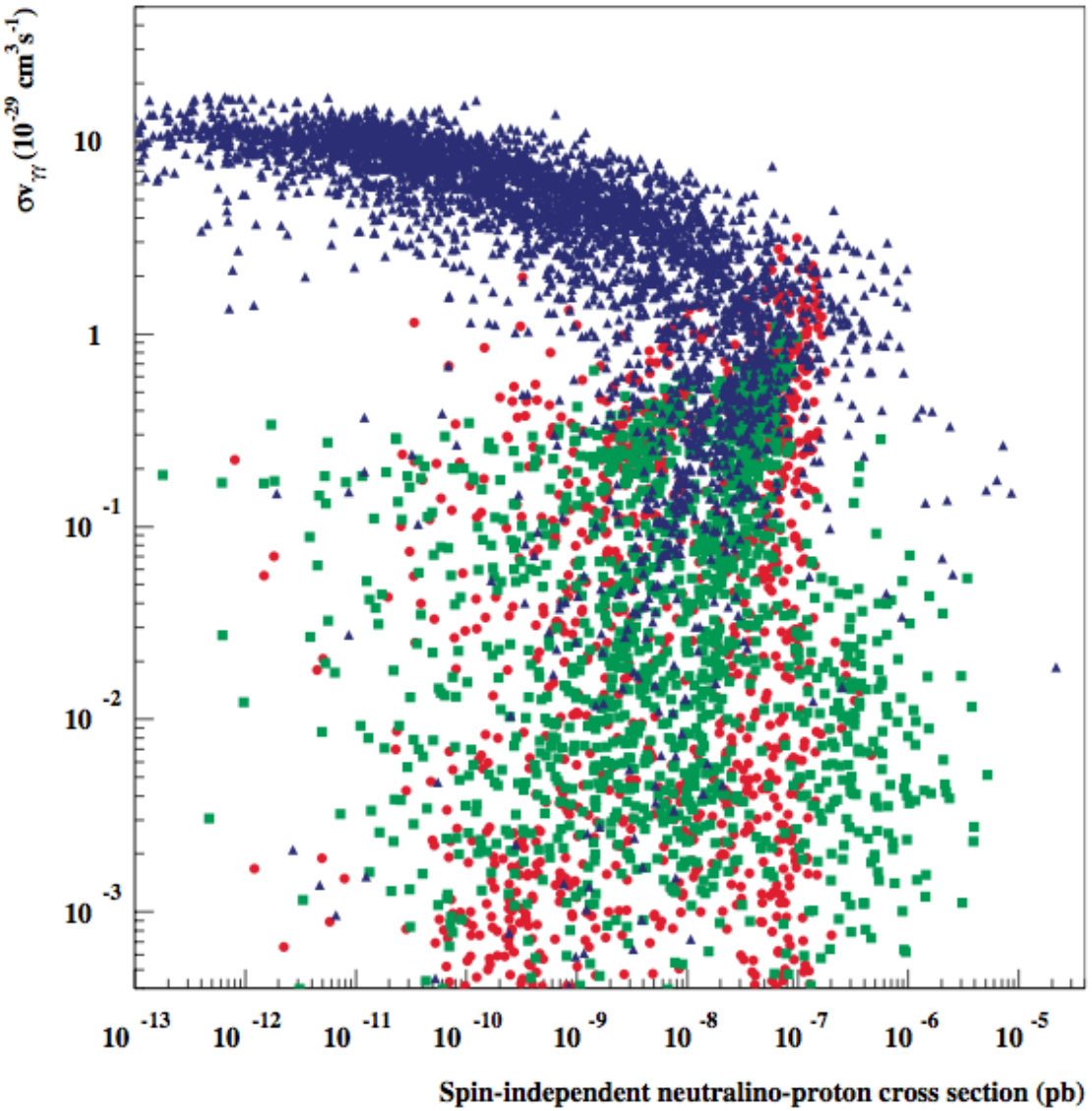
MSSM: gamma-line vs. spin independent



m < 100 GeV
100 GeV < m < 400 GeV
m > 400 GeV

Bergström 2000

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