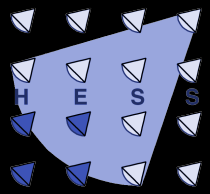


bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

Some H.E.S.S. MWL results

Observations of the Galactic Centre Region in Very High Energy Gamma-rays with H.E.S.S.

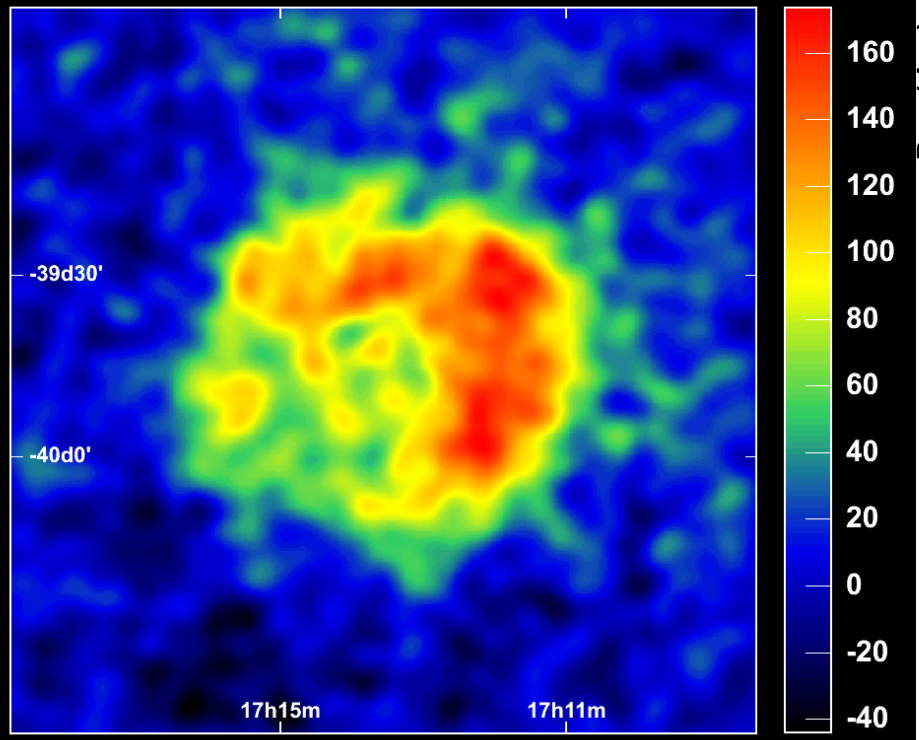
Gerd Pühlhofer (Landessternwarte Heidelberg) for the H.E.S.S. Collaboration

Why this topic here?

- **because**
  - complex region, well studied across all wavebands
  - MWL studies are essential for interpretation of the VHE data
  - results are fresh (first shown at ICRC '05)
  - studies are finished for the moment -> “MWL results”
- **caveats**
  - only archival MWL data used
  - no variability studies (except GC)
    -> no simultaneous observations in other wavebands

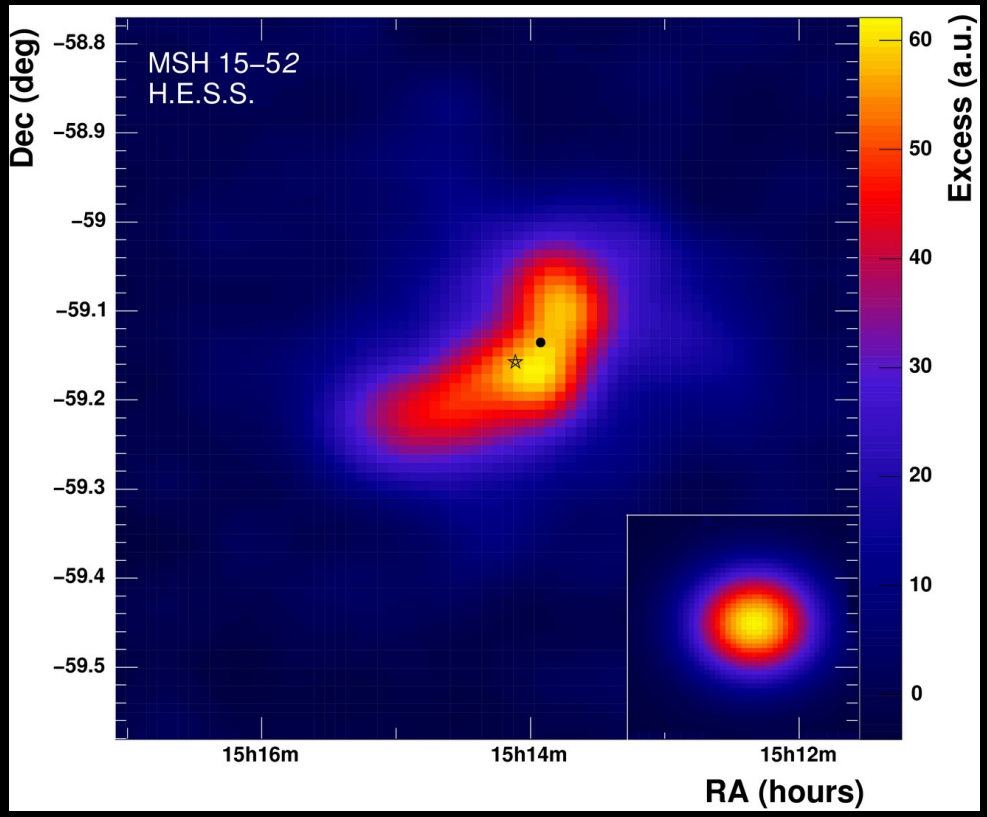
Preliminaries: some resolved VHE sources I

contours – X-ray: ASCA 1-3keV
colour map – HESS: TeV



RX J1713-3946:
shell-type SNR

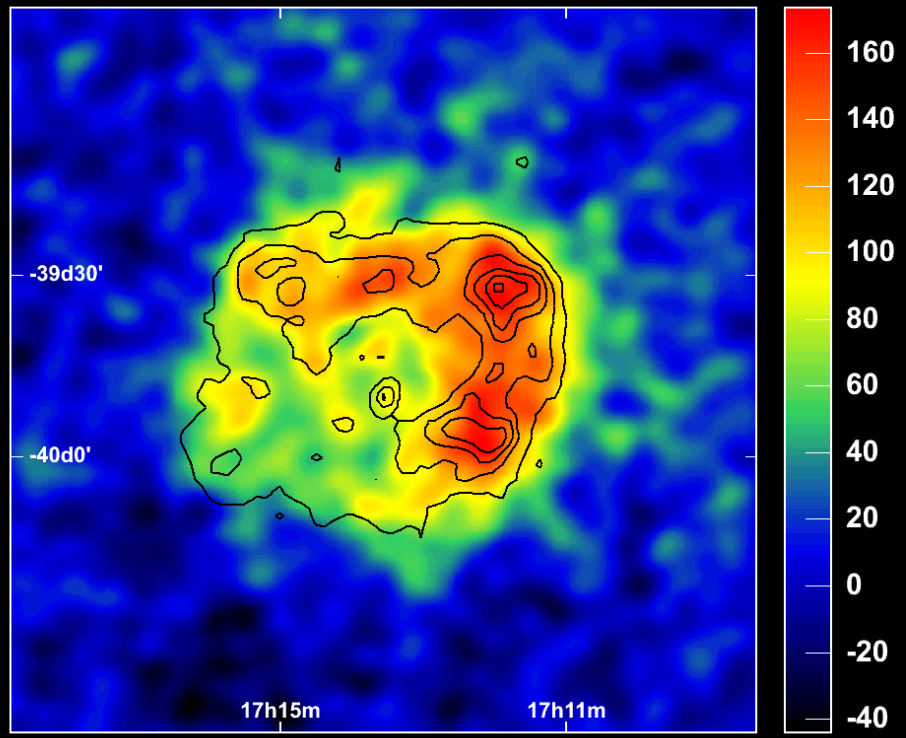
contours – X-ray: ROSAT 0.6-2.1keV
colour map – HESS: TeV



MS H15-52*:*
pulsar wind nebula

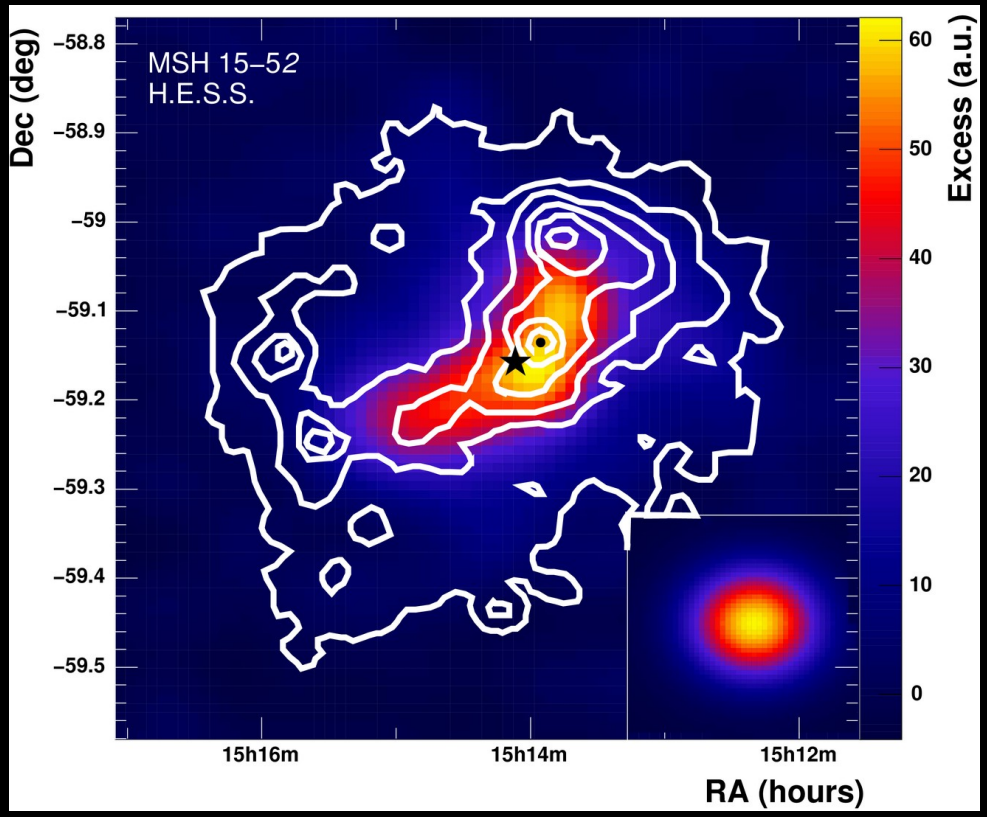
Preliminaries: some resolved VHE sources II

contours – X-ray: ASCA 1-3keV
colour map – HESS: TeV



- **close match**
  - same parent (e^-) distribution?
  - ✕ not neccessarily, spectral analysis prefers dominant π°-decay from p

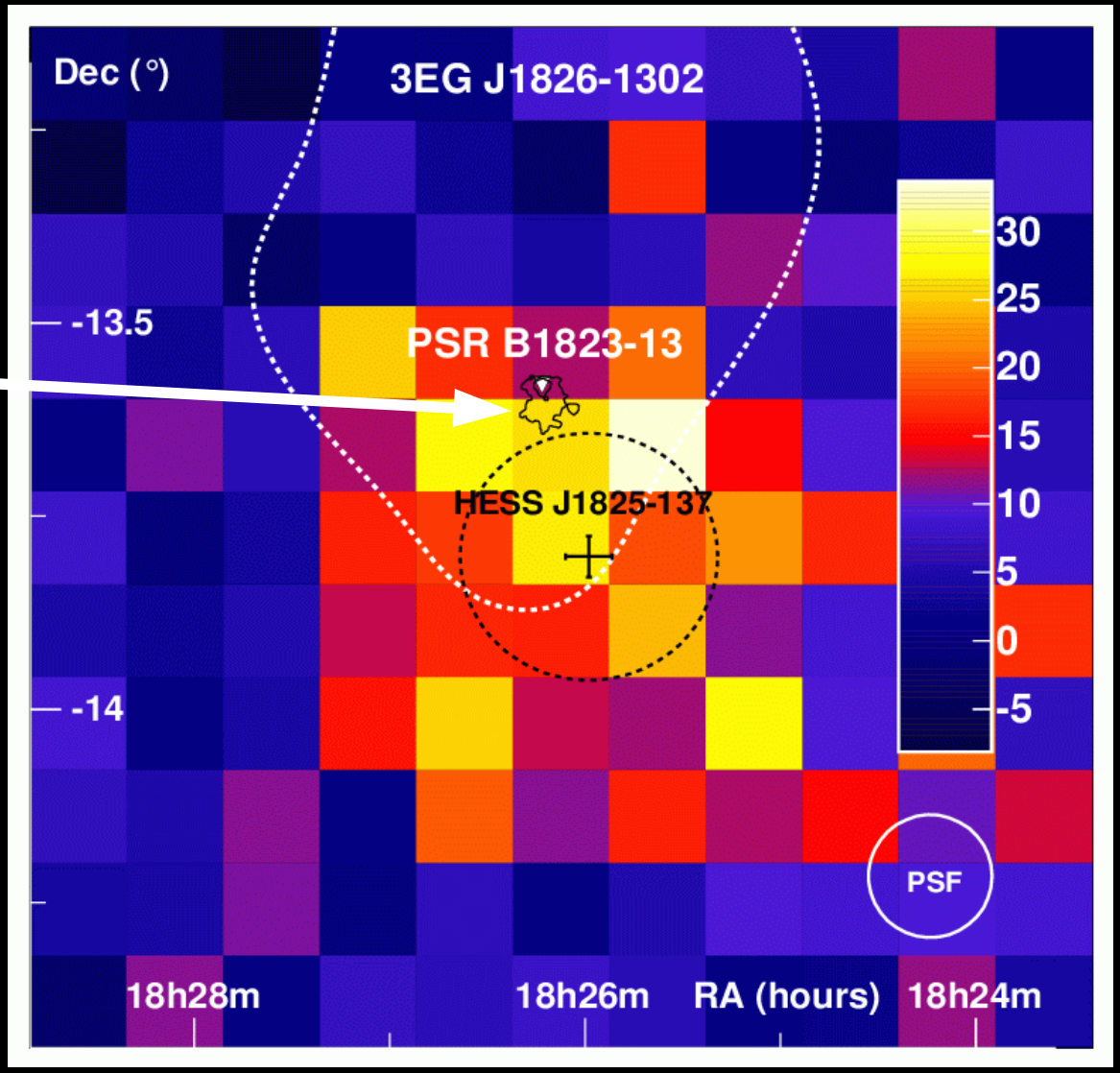
contours – X-ray: ROSAT 0.6-2.1keV
colour map – HESS: TeV



- same parent (e^-) distribution?
  - ✔ yes

Preliminaries: some resolved VHE sources III

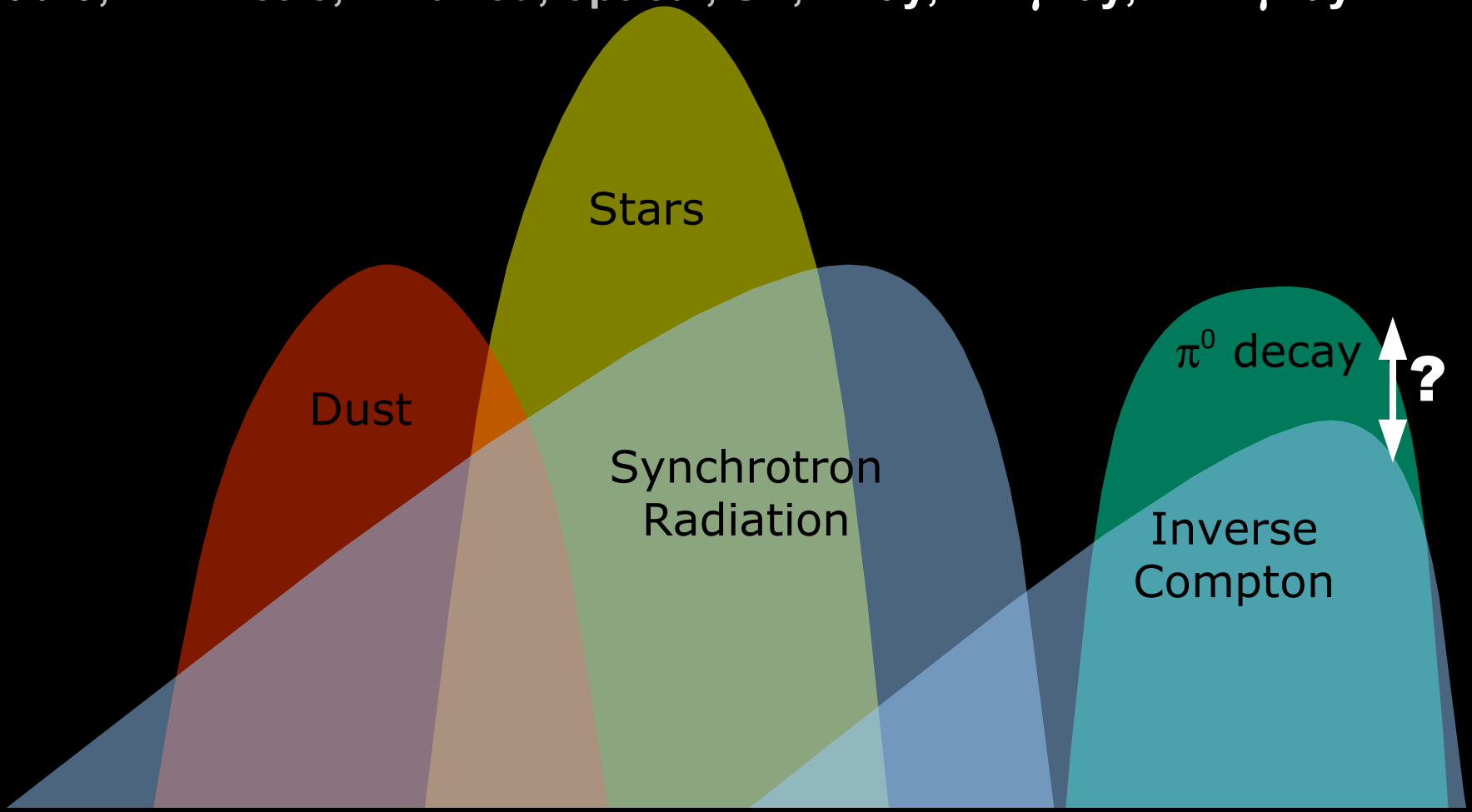
- HESS J1825-137
  - ~10% Crab Flux
  - $\Gamma = 2.4 \pm 0.1$
  - ~40' long
- X-ray nebula
  - is much smaller
  - has much lower (<10%) energy flux
  - but orientation is the same (North-South)
  - B ~ 10 μG
  - 1 keV synchrotron emission from 50 TeV electrons (if B = 10 μG)



Binned excess map

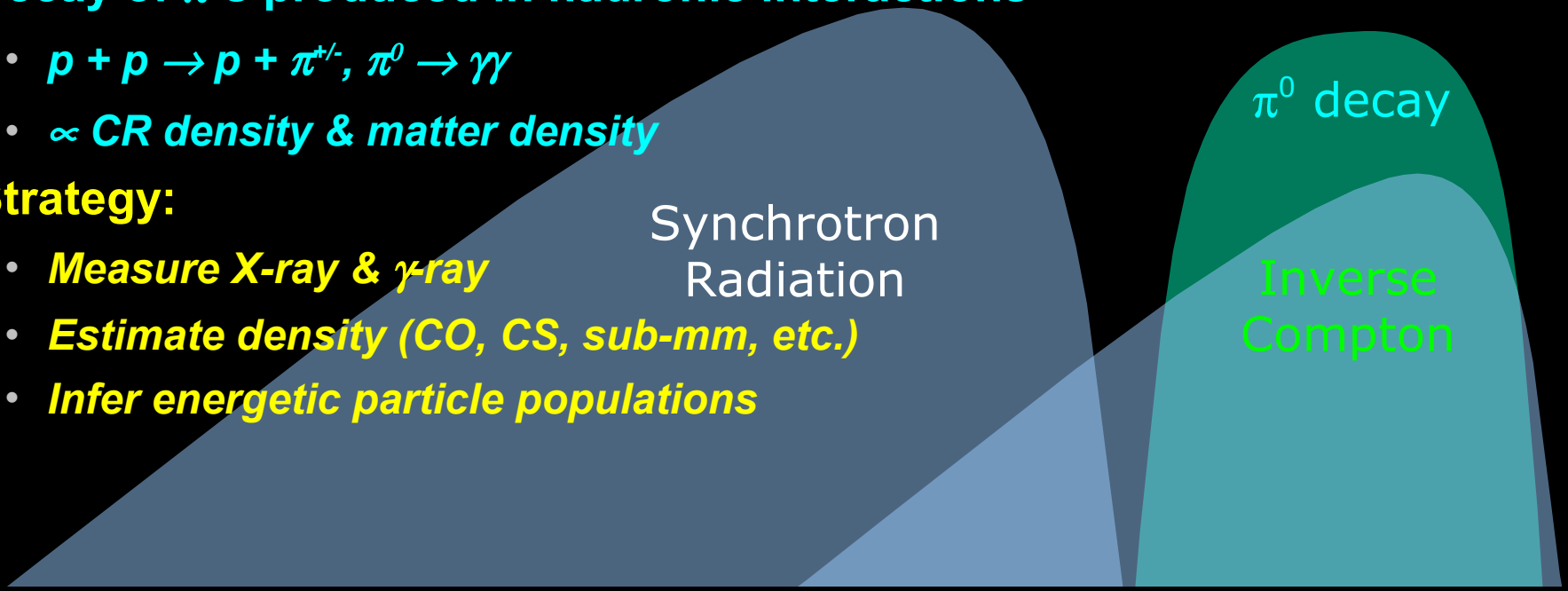
Generic Galactic 'SED': What about hadrons?

- **Radio**, millimetre, infra-red, optical, UV, **X-ray**, **HE γ-ray**, **VHE γ-ray**

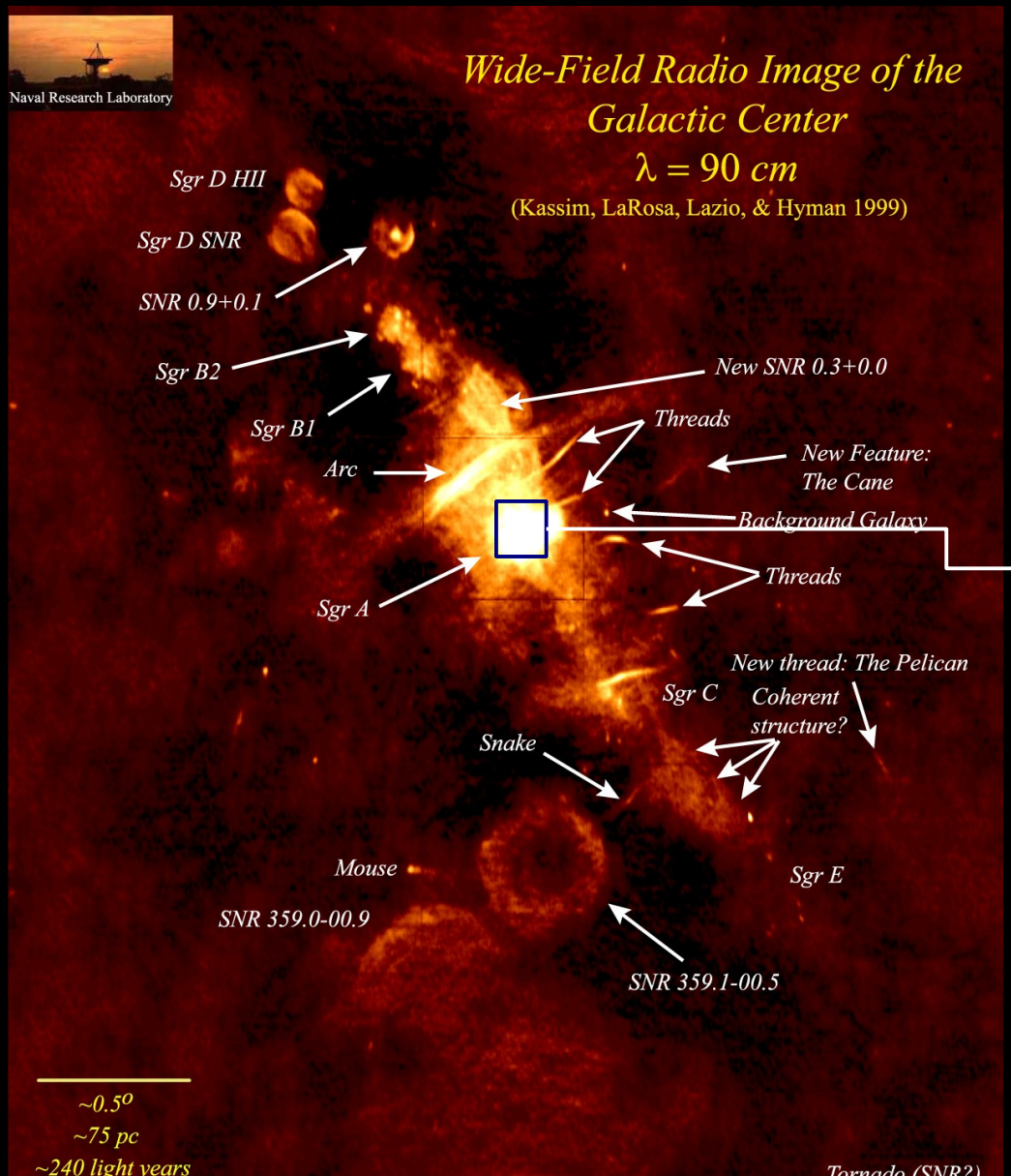


Non-thermal radiation

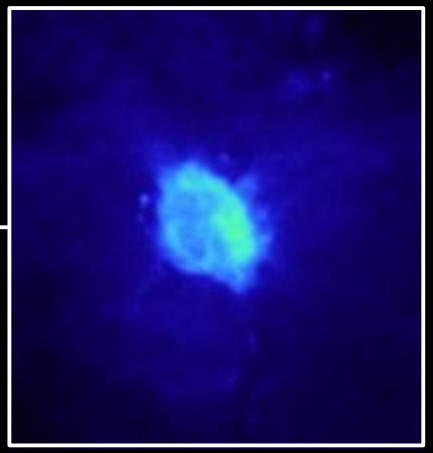
- Synchrotron emission dominated by electrons
  - $\propto$ *electron density and* B^2
- Inverse Compton scattering of electrons
  - $\propto$ *electron density and energy density of ambient photons*
- Decay of π^0s produced in hadronic interactions
  - $p + p \rightarrow p + \pi^{+/-}, \pi^0 \rightarrow \gamma\gamma$
  - $\propto$ *CR density & matter density*
- Strategy:
  - *Measure X-ray & γ-ray*
  - *Estimate density (CO, CS, sub-mm, etc.)*
  - *Infer energetic particle populations*



The Galactic Centre

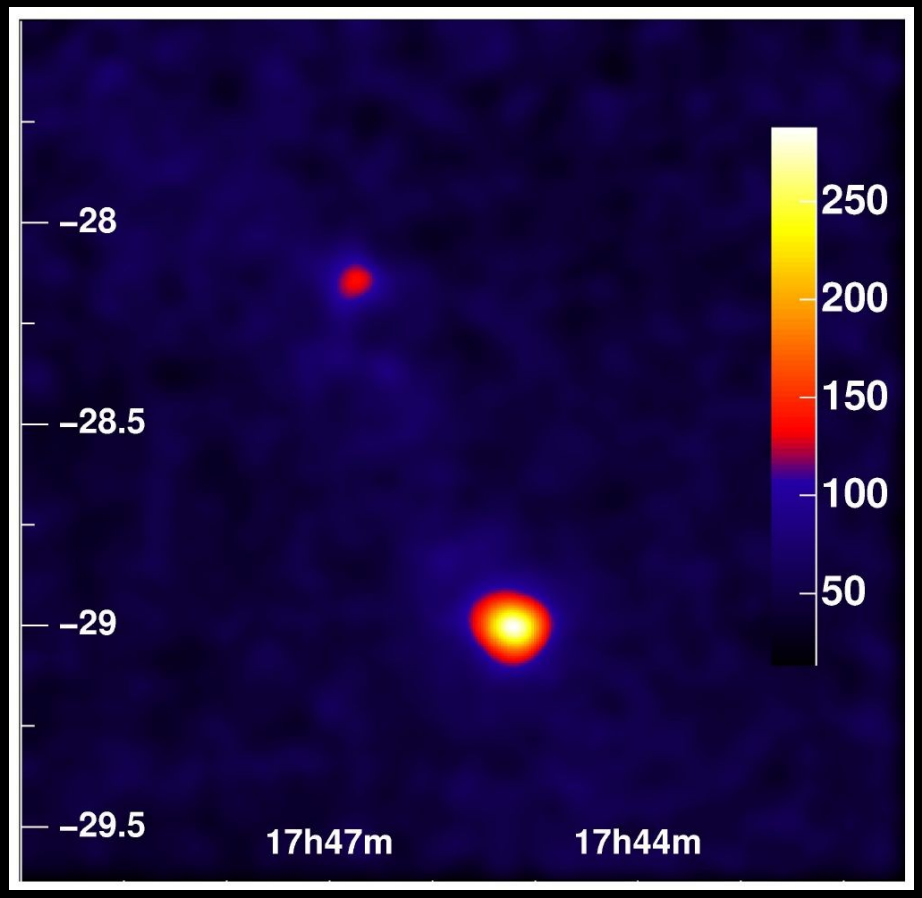


- **The central 2° = 300 pc**
  - GC Region
  - Central 50 pc = Sgr A

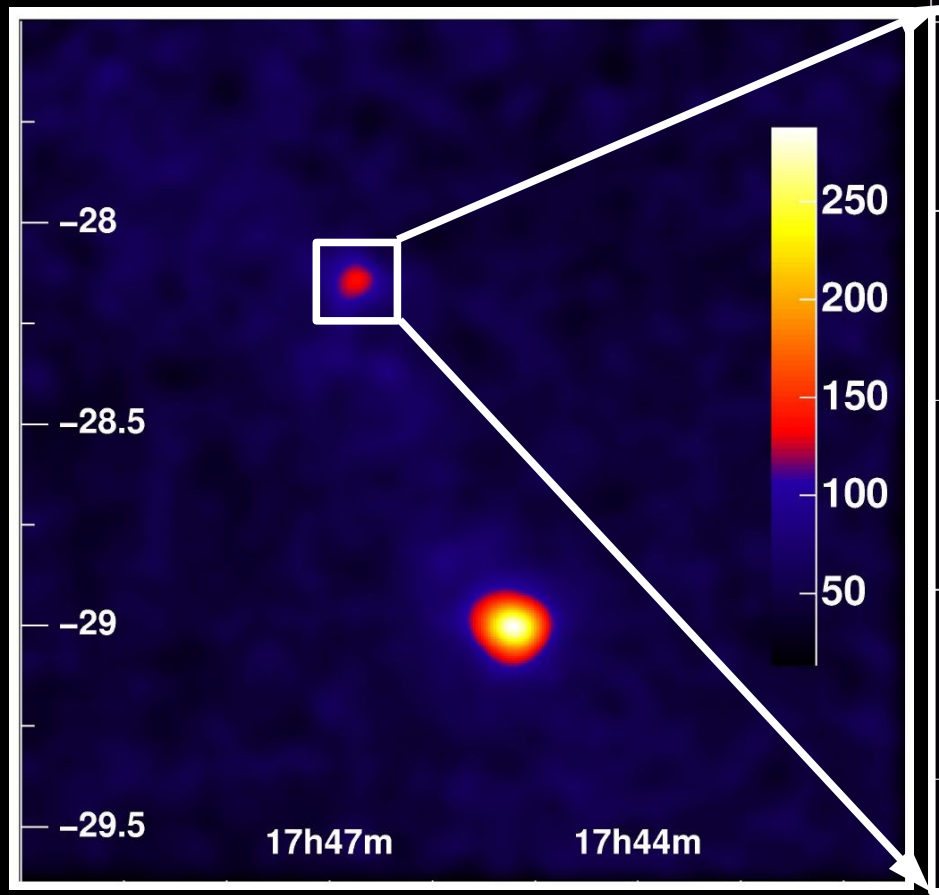


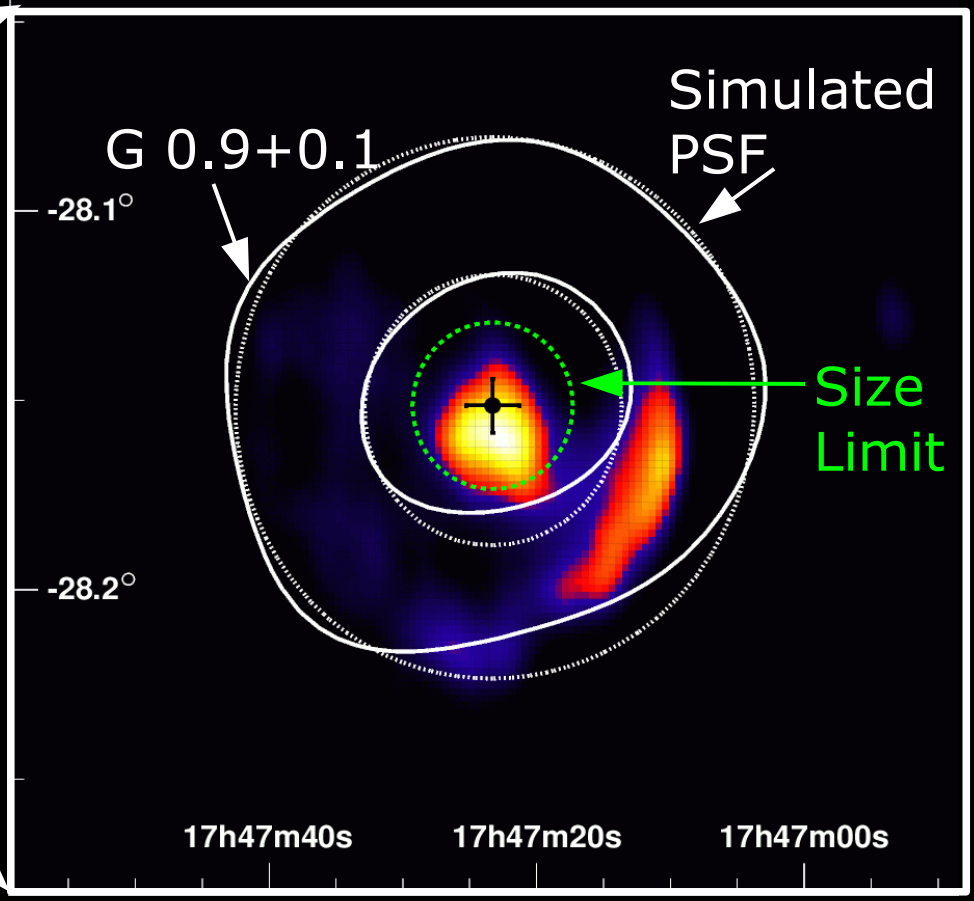
  - Radio emission of the Sgr A complex is dominated by the SNR Sgr A East

The GC region seen with H.E.S.S.

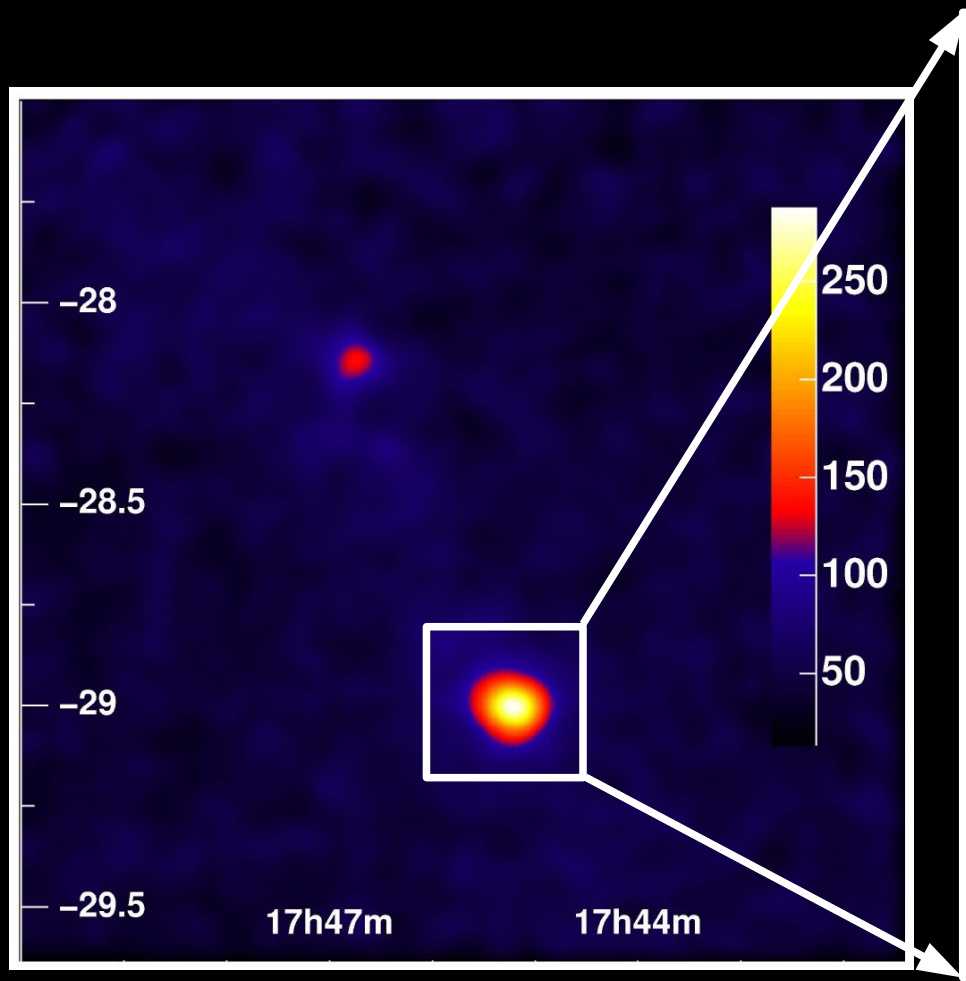


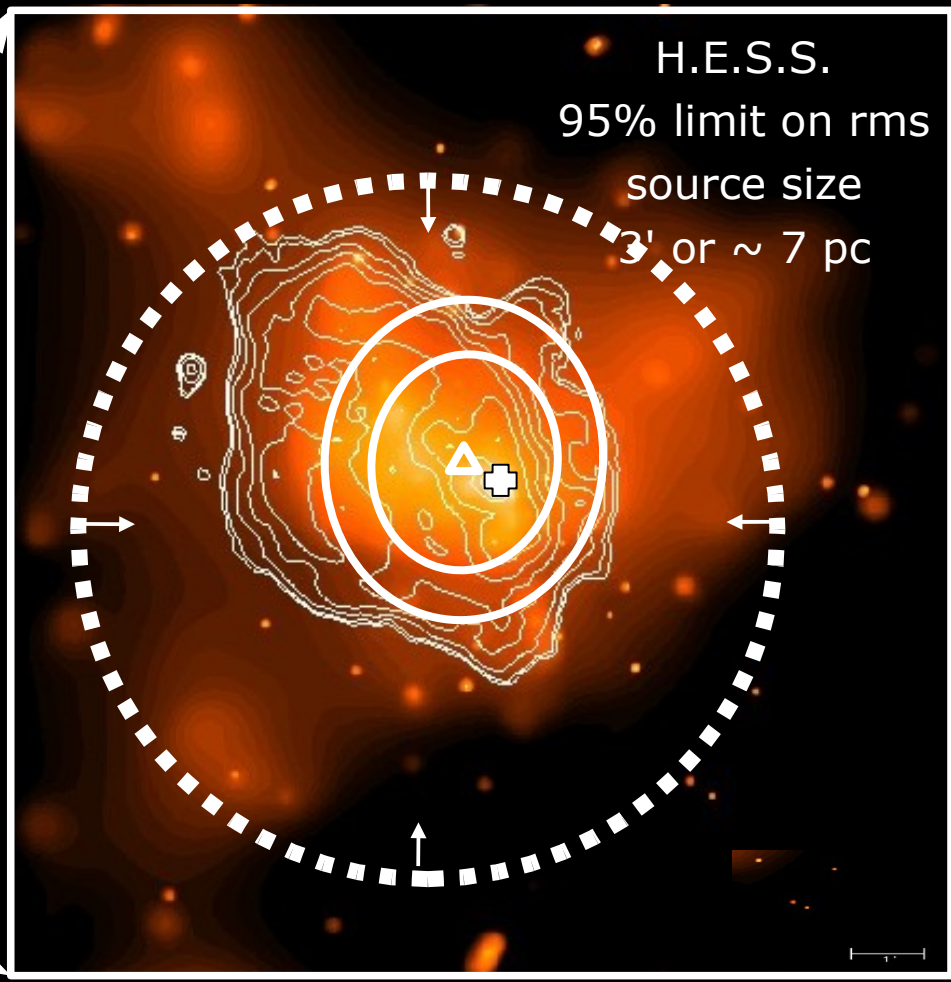
The GC region seen with H.E.S.S.





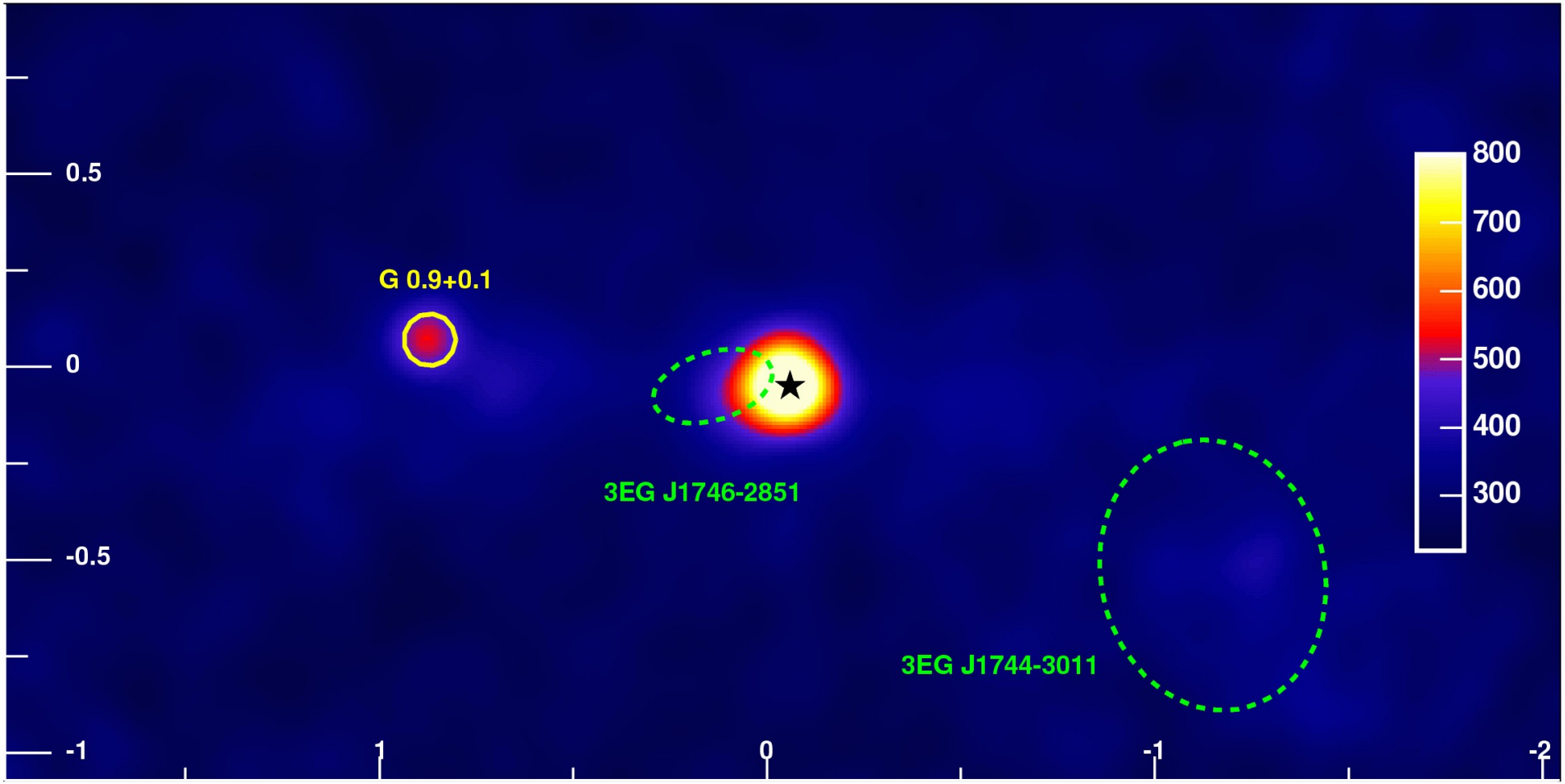
The GC region seen with H.E.S.S.





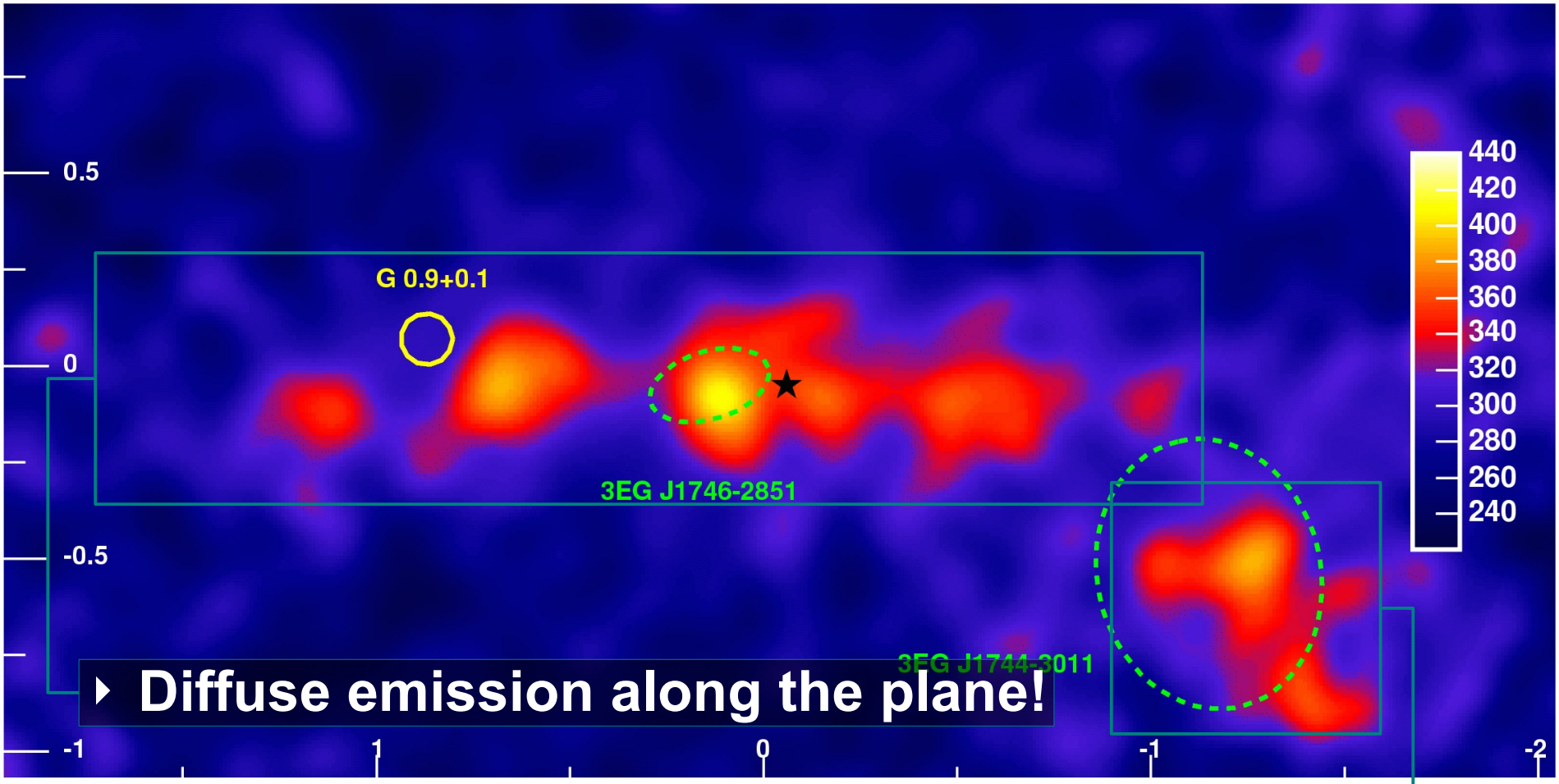
Sgr A East: Chandra & Radio Contours

Diffuse γs in H.E.S.S. data?



- 50 hour H.E.S.S. Observation of GC in 2005
- Need to subtract the two bright sources

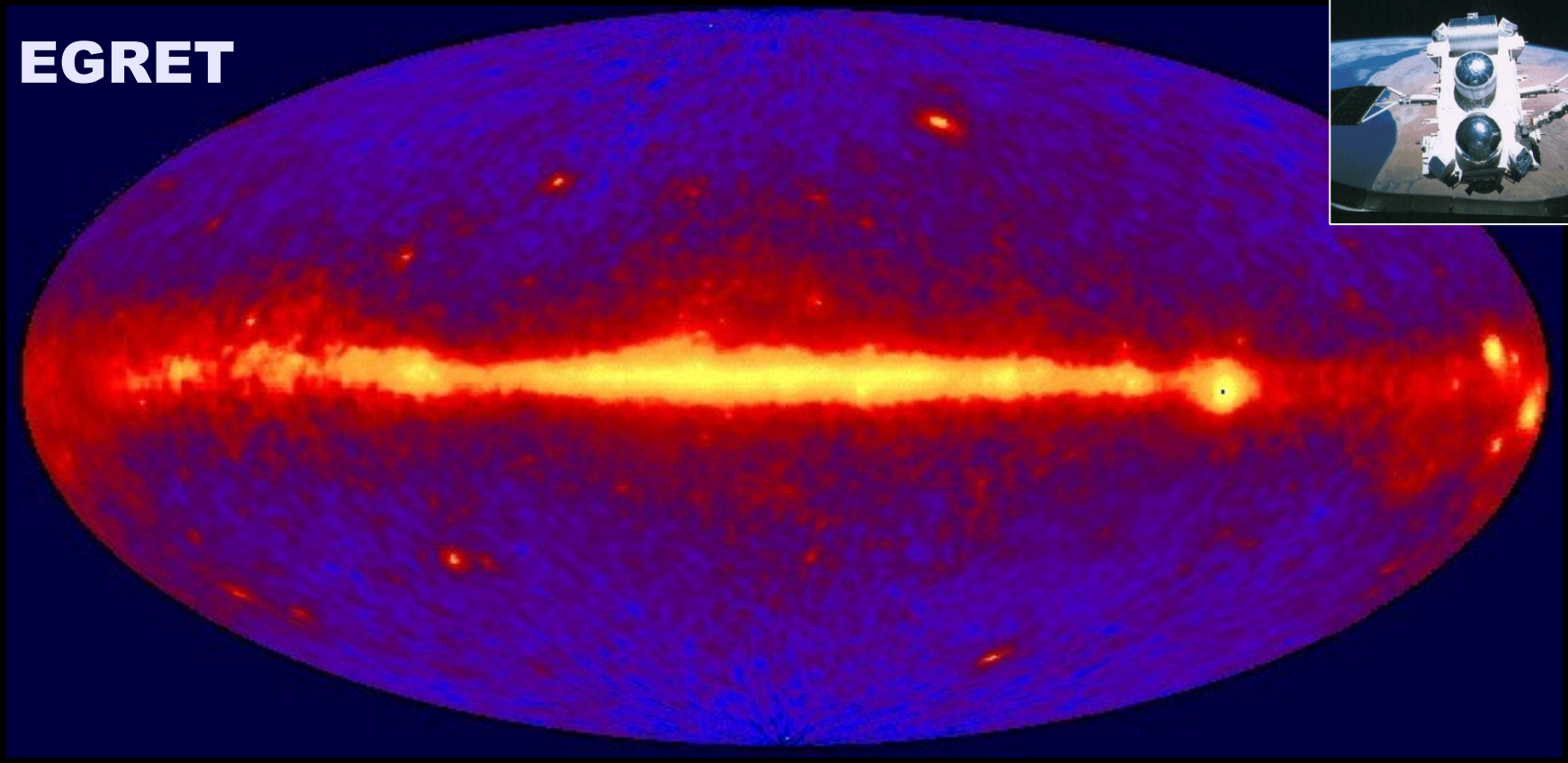
Residuals after source subtraction



- Diffuse emission along the plane!

new source
HESS J1745-303

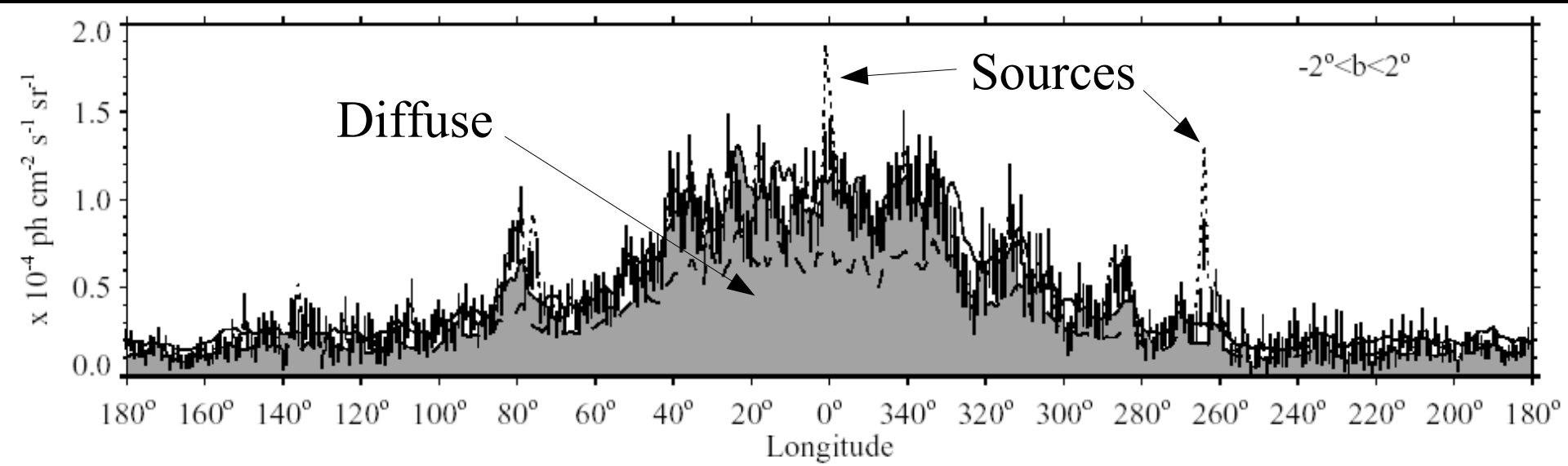
High Energy γ-Ray (~ 100 MeV)



- Diffuse emission along the plane
  - *CR interactions in the ISM*
- few identified sources – poor angular resolution

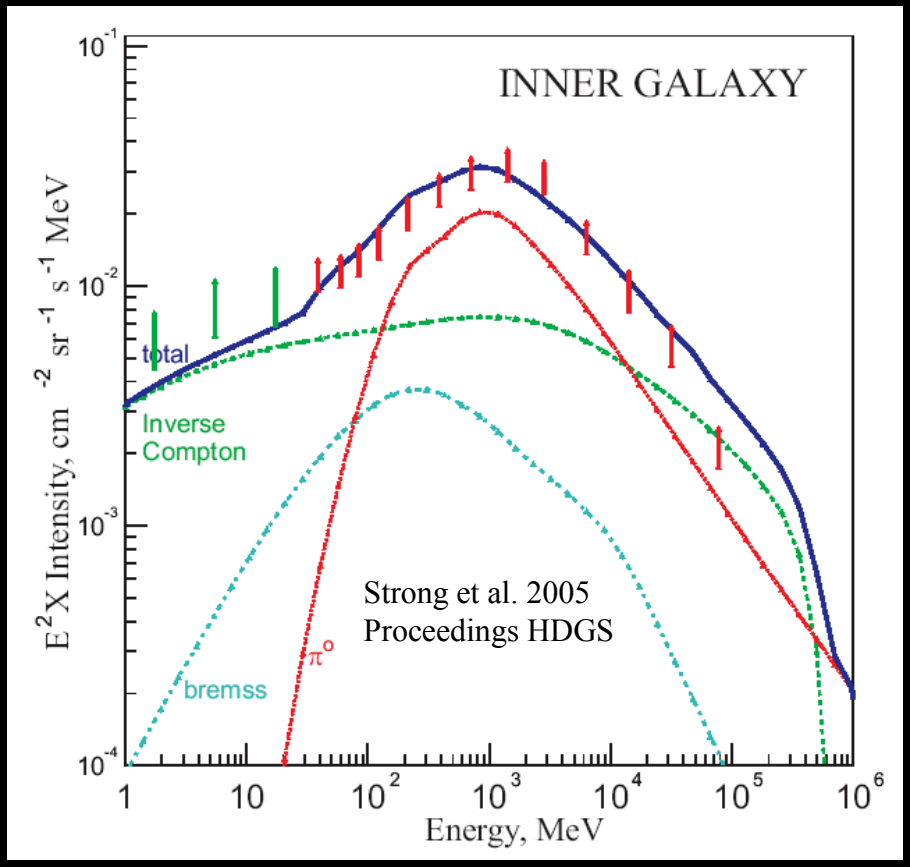
Diffuse γ-Rays from Cosmic Rays

- Cosmic ray interactions with the ISM medium lead to gamma-ray production via π^0 decay
  - eg EGRET (~ 100 MeV):

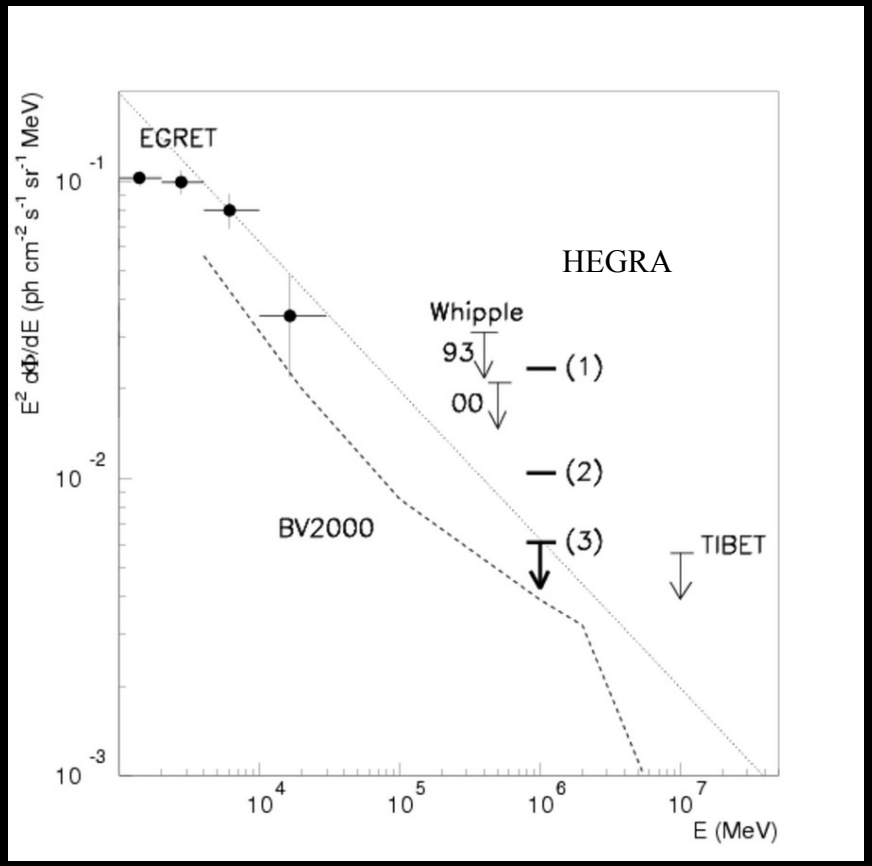


MeV – GeV – TeV extrapolation?

EGRET: MeV – GeV

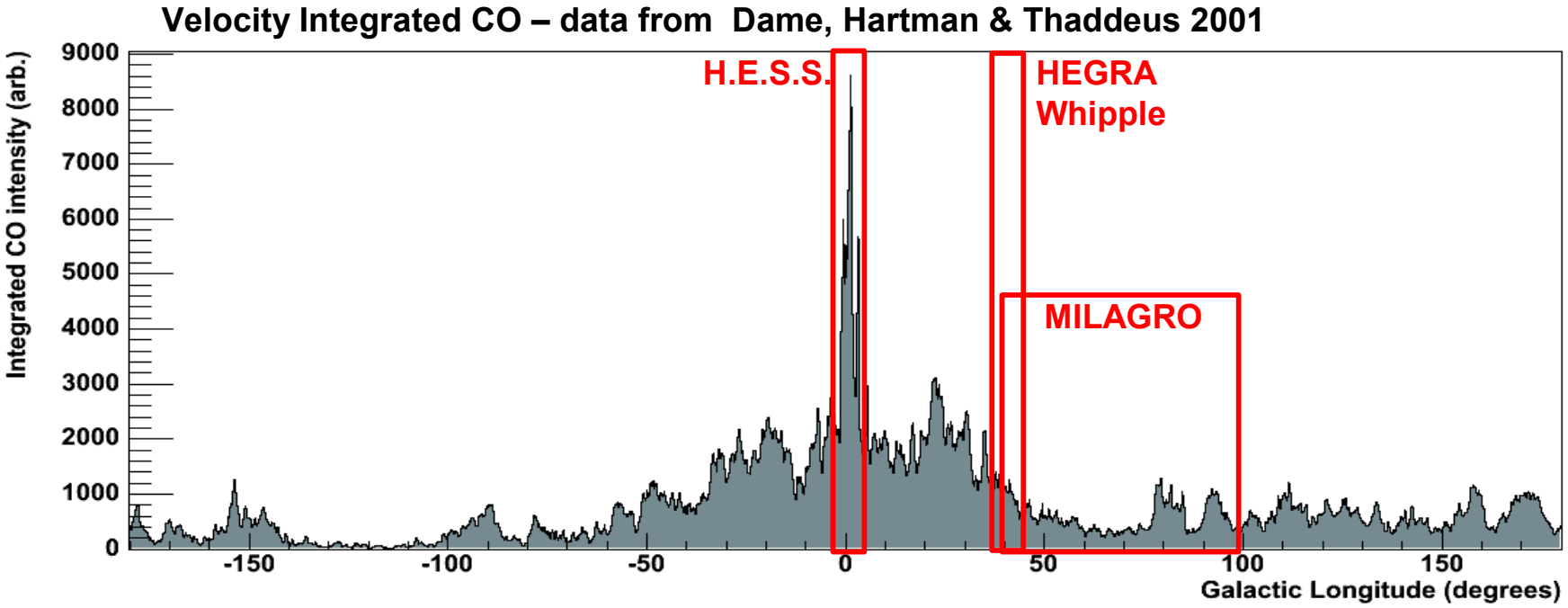


GeV – TeV



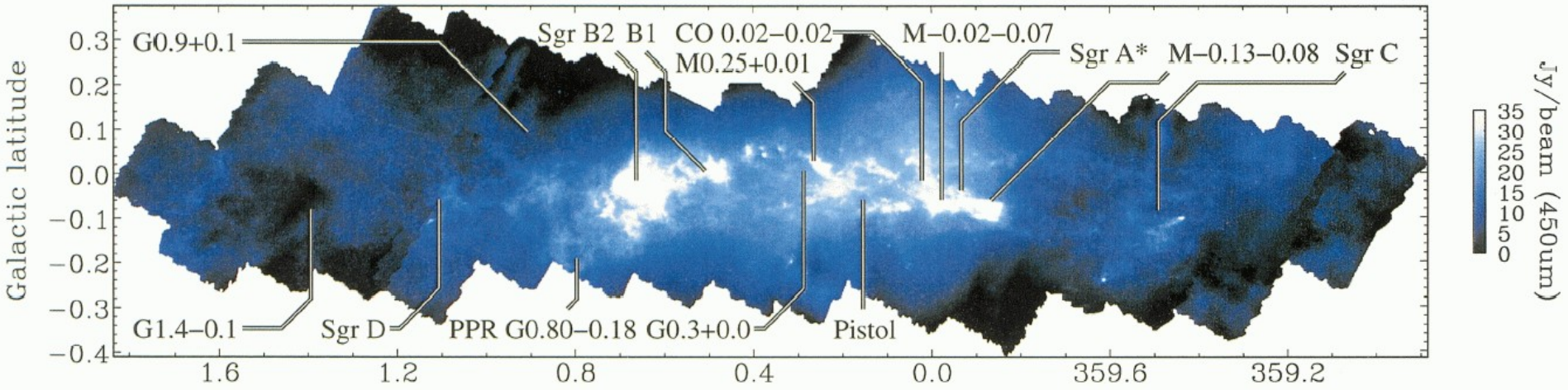
+ diffuse TeV emission from the plane claimed recently by Milagro

Molecular Material in the Galaxy



- Atomic component is rather uniform but
- Molecular part (traced by CO) is strongly peaked along the plane and in the GC region
- assume π°-decay @TeV: CR interaction with gas

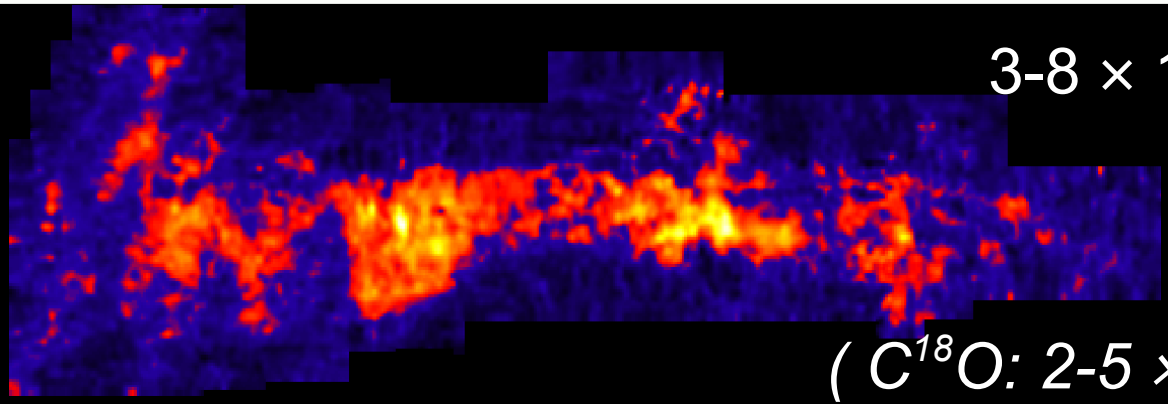
Dust and Molecules in the GC



SCUBA 0.45 mm

& T=20K → 4-6 × 10^7 M_{sun}

CS Line Emission

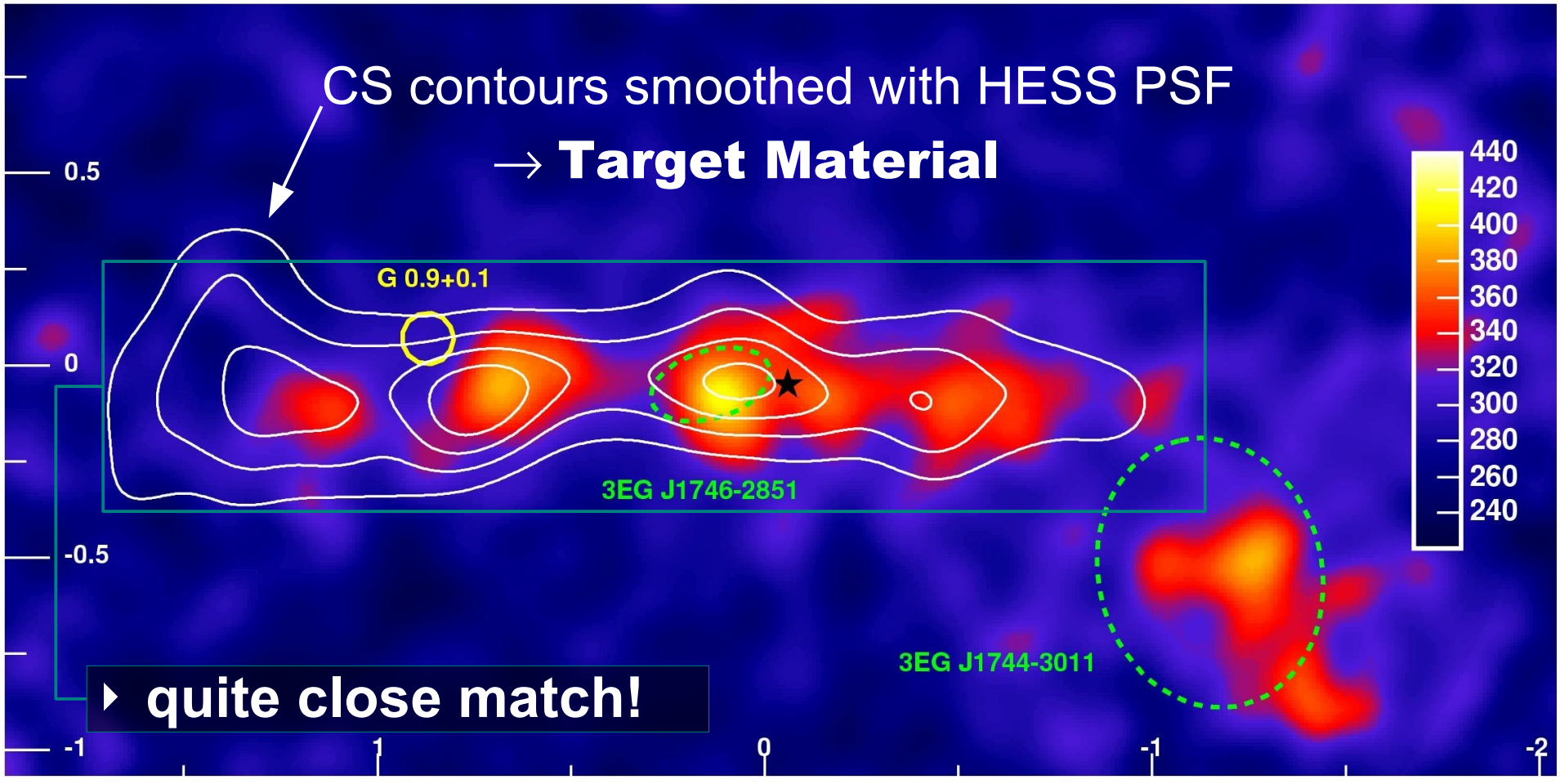


3-8 × 10^7 M_{sun}

($C^{18}O$: 2-5 × 10^7 M_{sun})

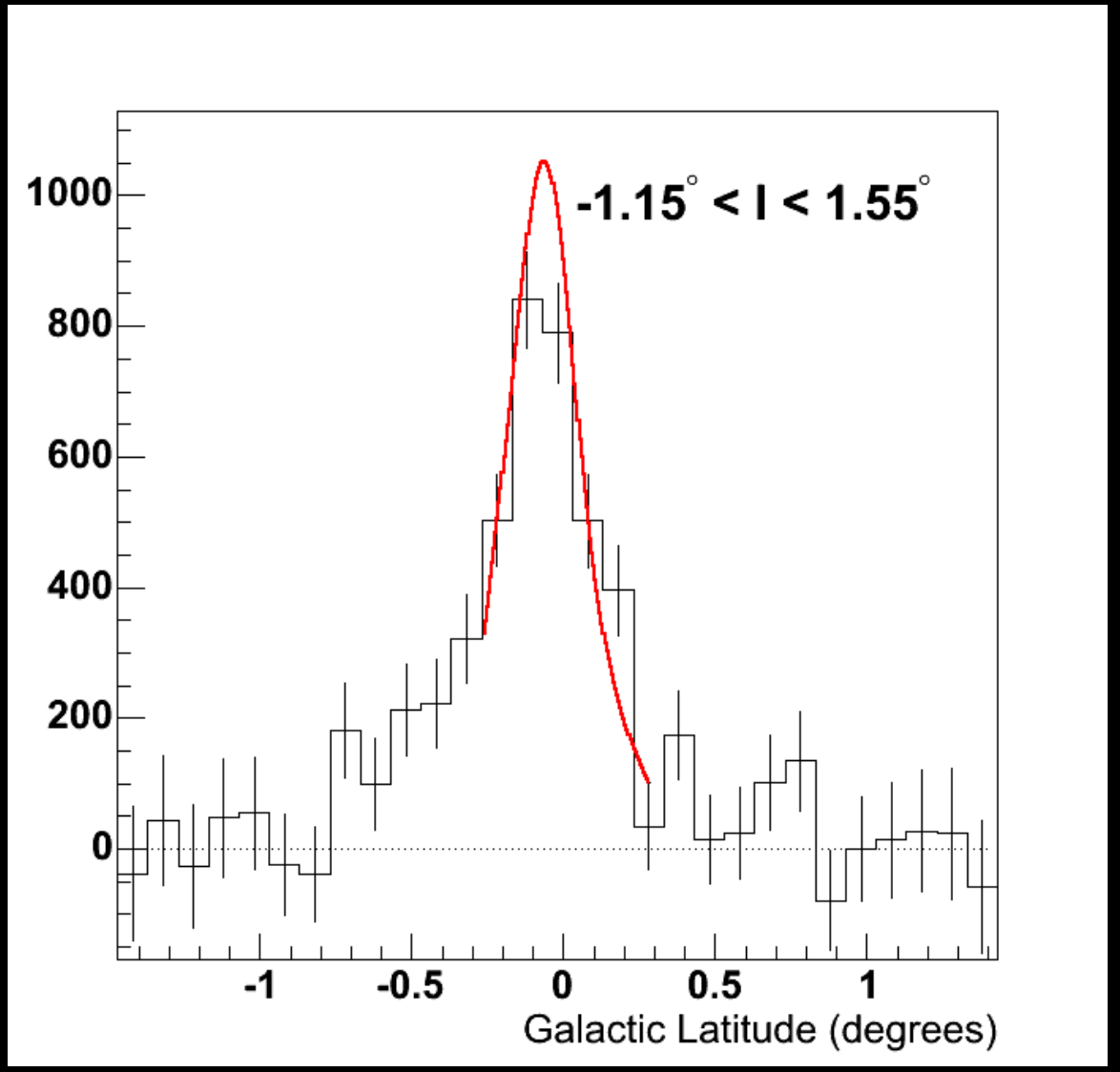
- **50 million solar masses in (dense) molecular clouds in the central 300 parsecs**

CS contours over H.E.S.S. map

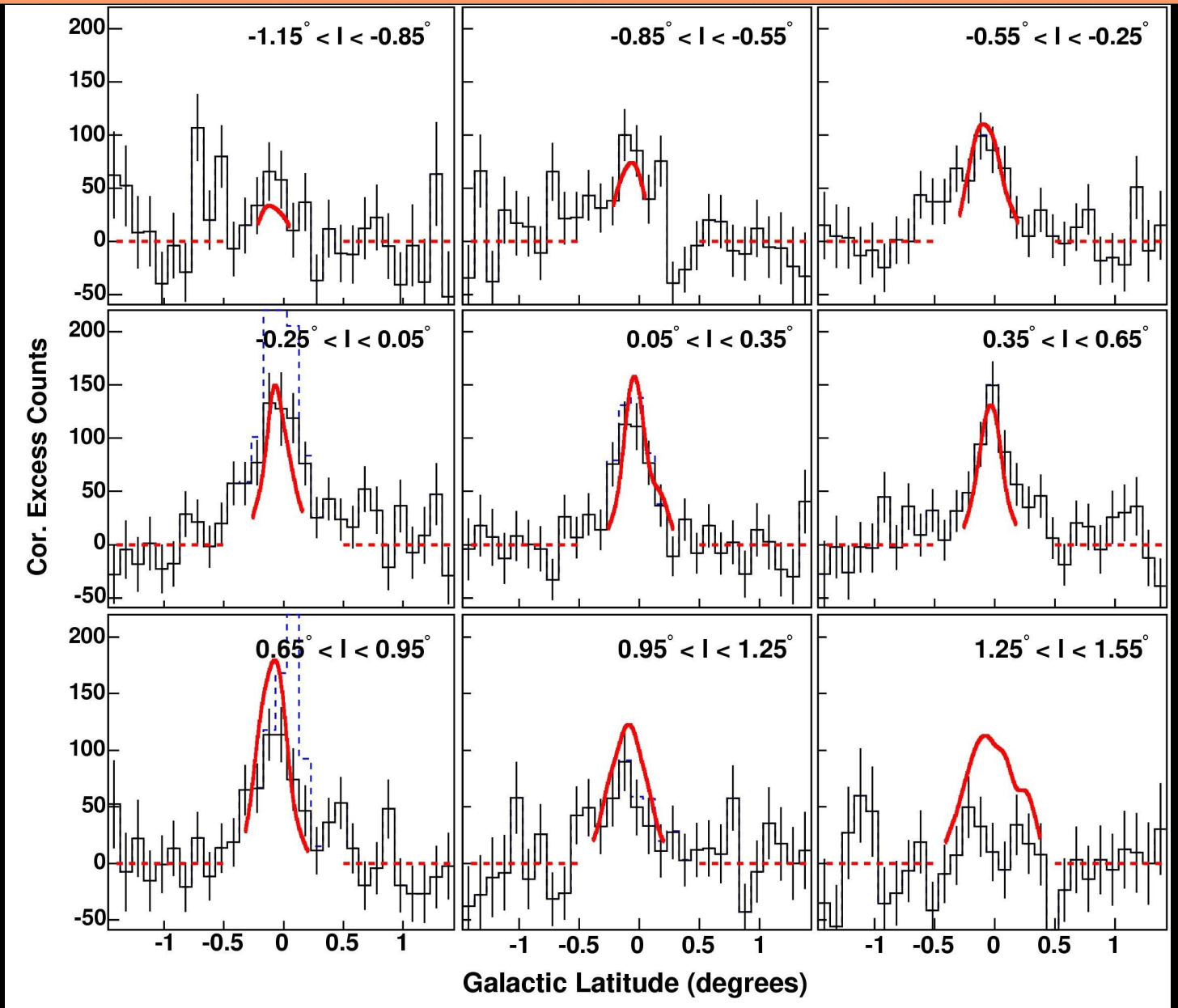


Integrated Latitude Slice

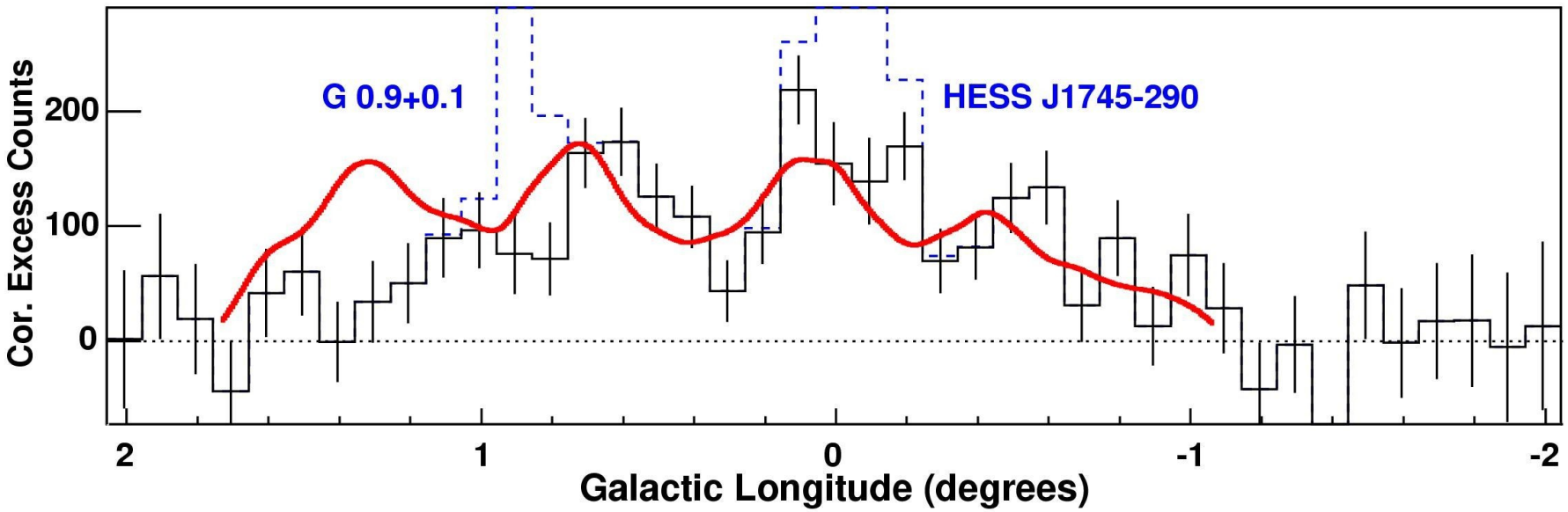
- Reasonable agreement in the region covered by CS measurements
- Close to a Gaussian with 0.2° RMS
  - CF PSF < 0.1°
  - Equivalent to ~30 parsecs
- 14.6 σ signal



...and In Longitude Bands



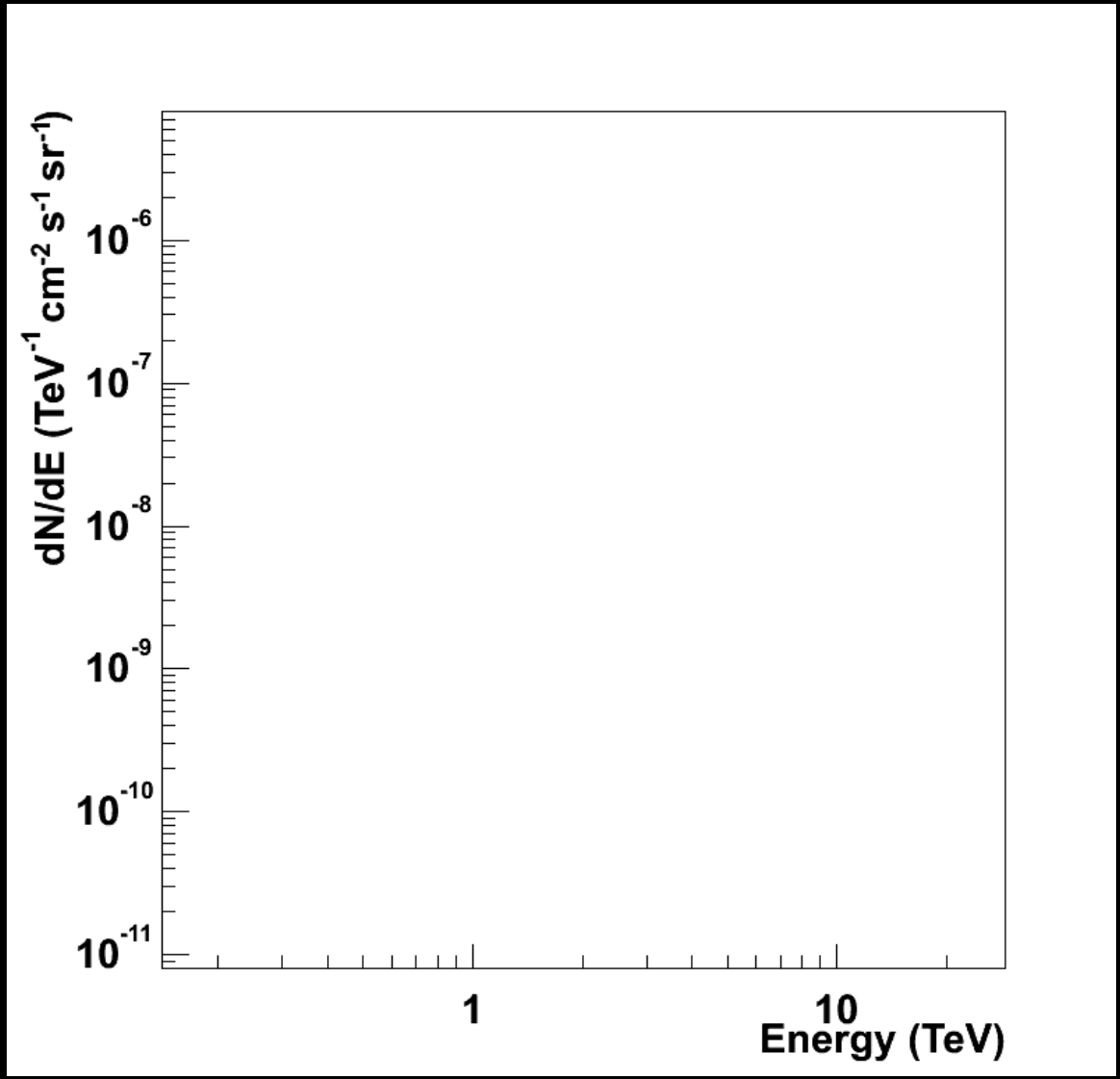
Longitudinal Slice



- Reasonable agreement overall but
  - Deficit around l = 1.3°

Energy Spectrum

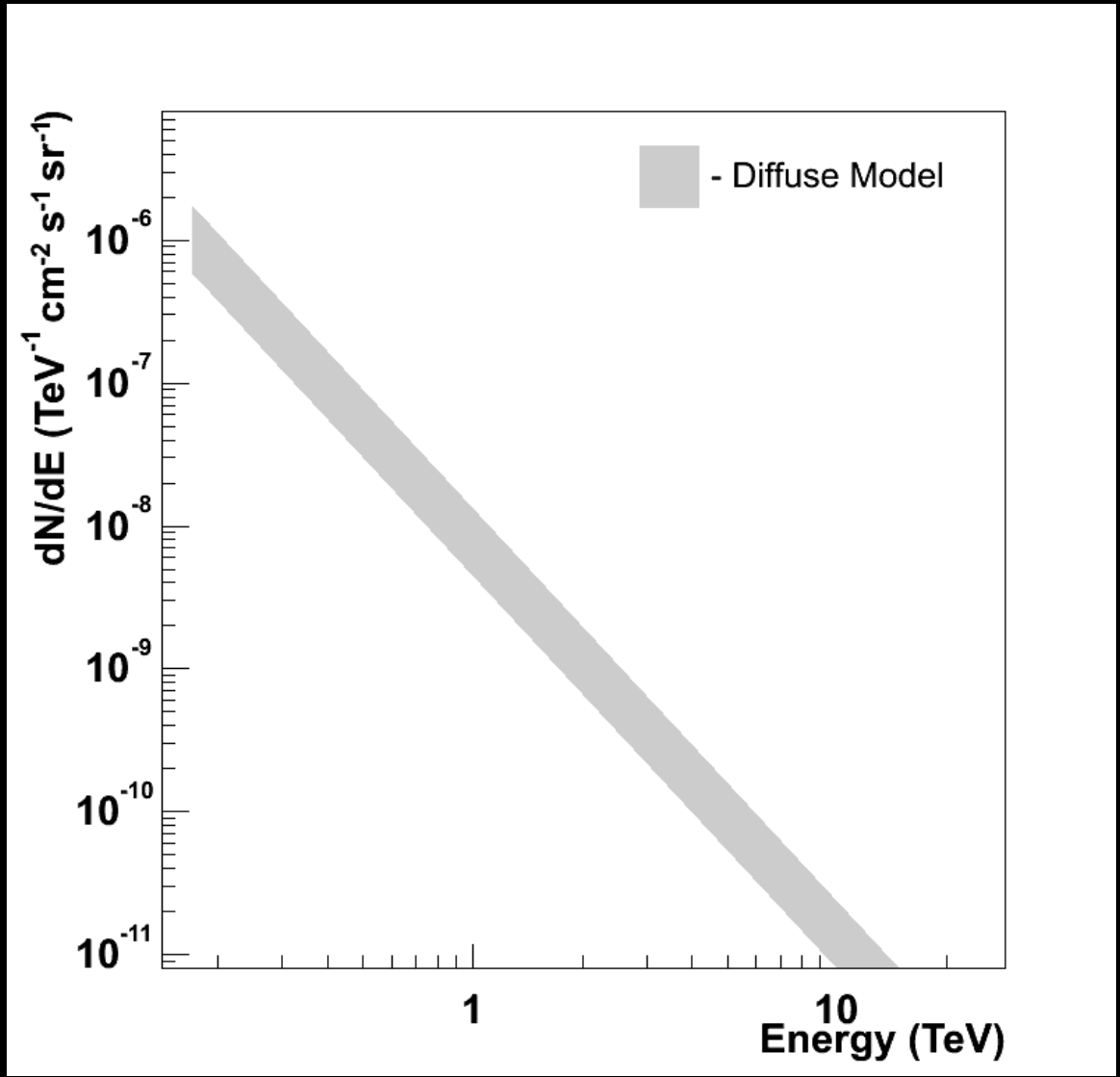
- Expectations
  - Molecular target material is 3-8 10^7 M_{sun} (Tsuboi – CS, SCUBA: 4-6 10^7 M_{sun})
  - Distance ~ 8.5 kpc
  - Cosmic Ray density?
    - *Assume Local*
- π^0 decay flux...



Energy Spectrum

- **Gamma Flux:**
  - $J(> E) \approx 1.5 \times 10^{-13}$ $(E/1\text{TeV})^{1.75}$ (M_5/d^2_{kpc}) photons $\text{cm}^{-2}\ \text{s}^{-1}$

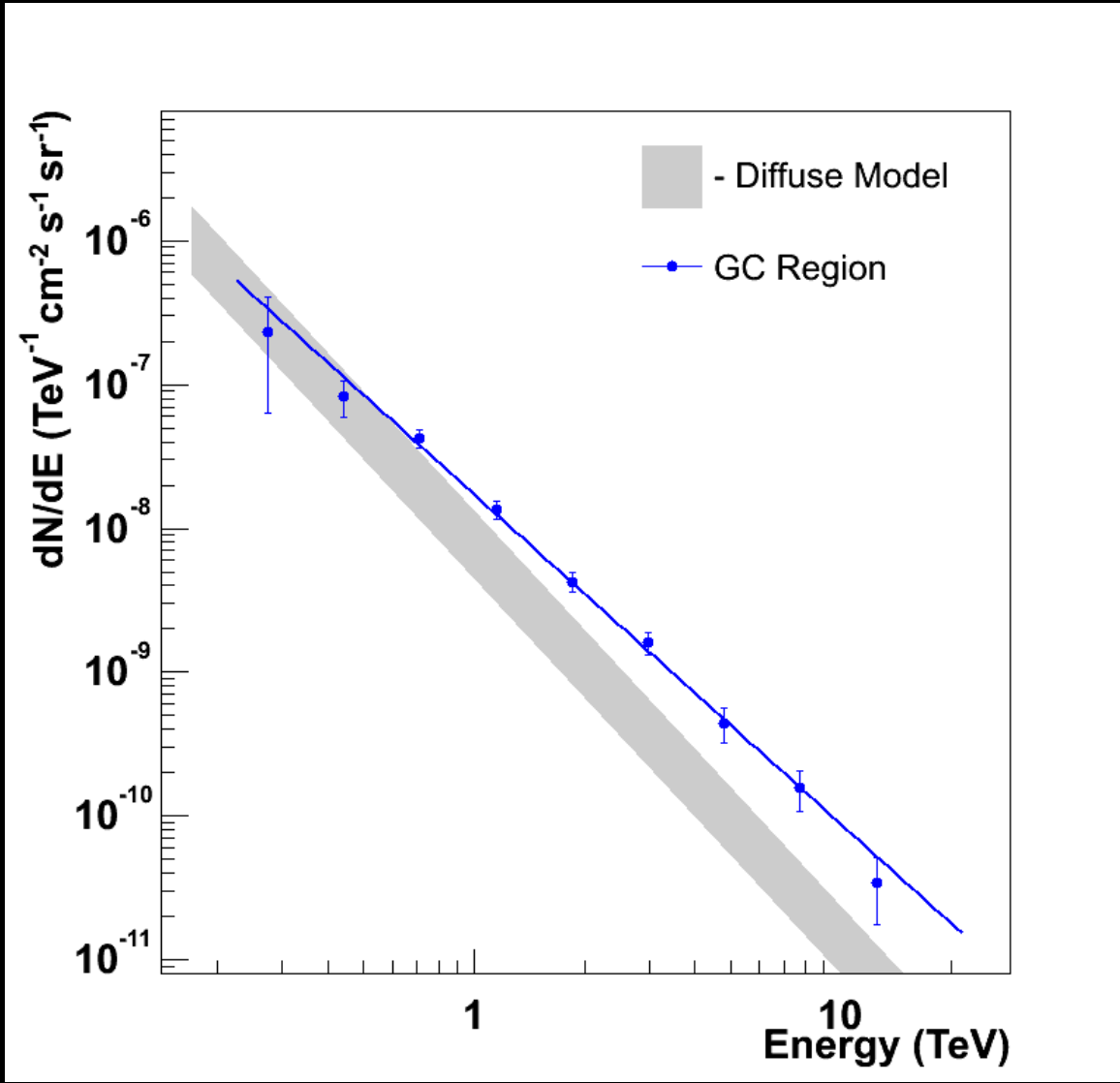
  (Aharonian 1991)
  - Index: $\Gamma_\gamma \sim \Gamma_{CR}$
- **For M_5 = 300 - 800**



Energy Spectrum

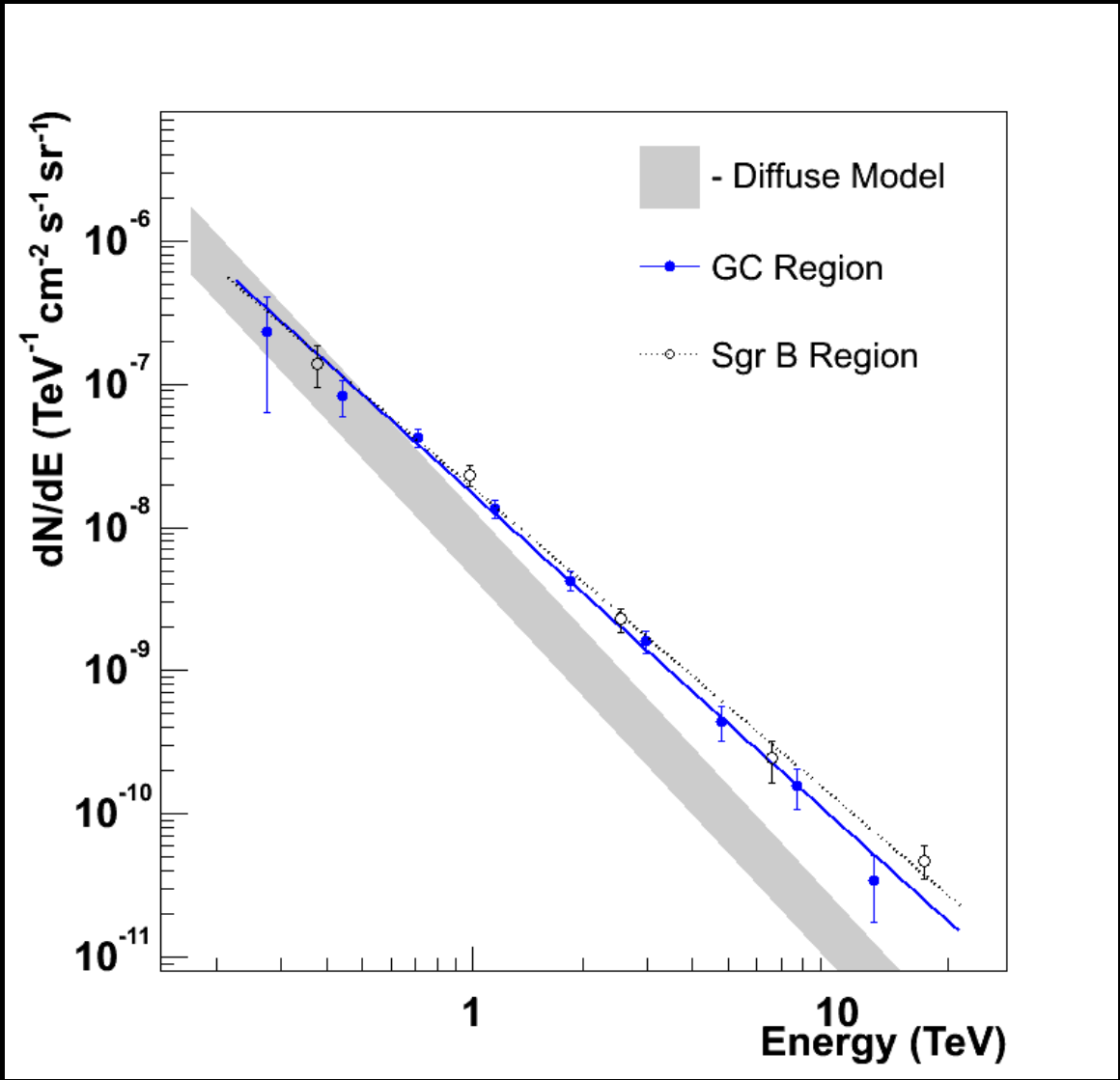
- **Measured Diffuse Spectrum**
  - $\Gamma_\gamma = 2.29 \pm 0.07_{stat} \pm 0.20_{sys}$
  - **Flux > 1 TeV:**

$3.1 \pm 0.3 \times 10^{12}$ cm^{-2} s^{-1} (13% Crab)



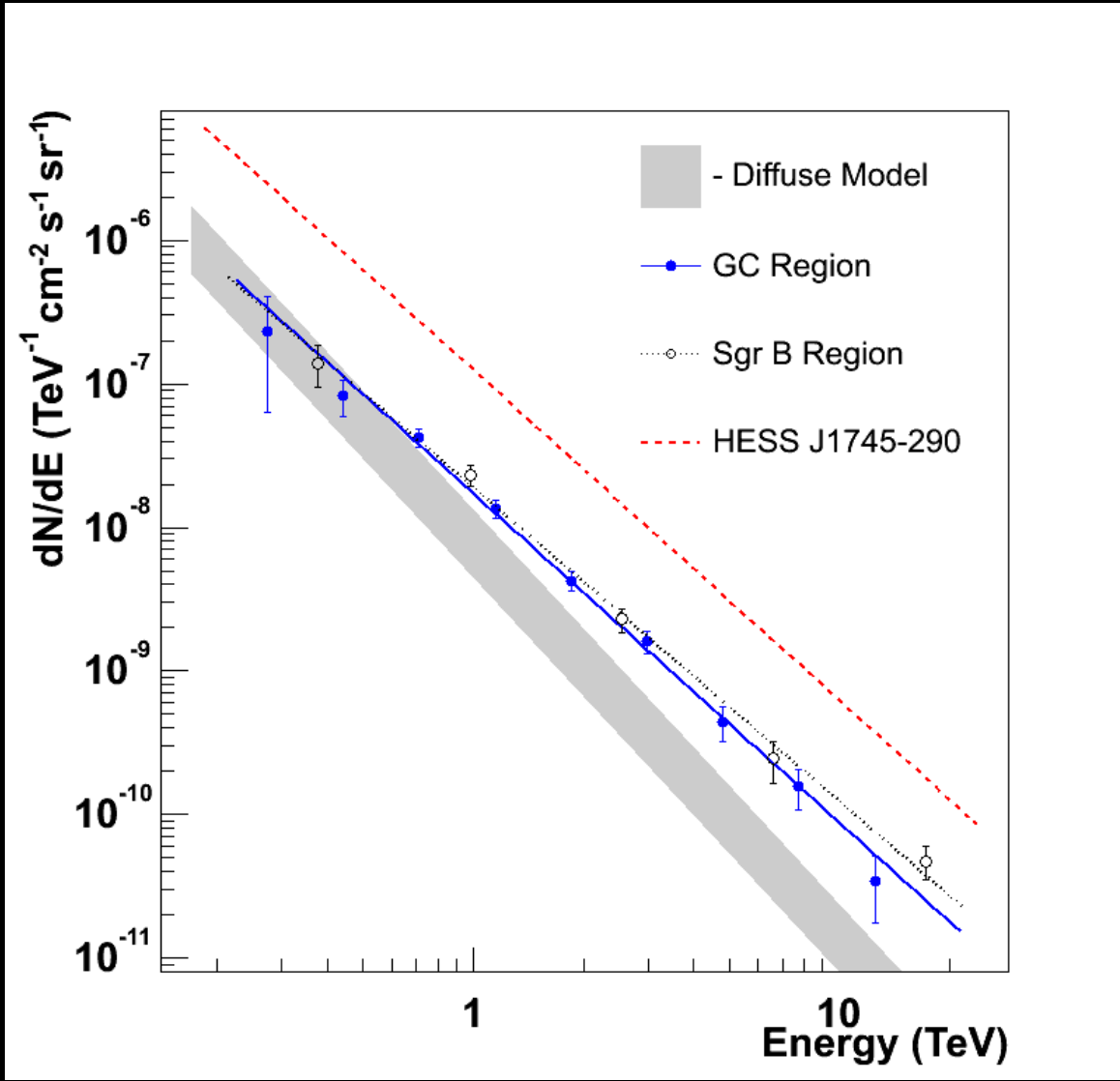
Energy Spectrum

- Sgr B region
  - $\Gamma_\gamma = 2.1 \pm 0.2_{stat} \pm 0.2_{sys}$
  - Flux > 1 TeV: $1.2 \pm 0.2 \times 10^{12}$ cm^{-2} s^{-1} (5% Crab)



Energy Spectrum

- The Galactic Centre Source: HESS J1745-290
  - (solid angle is integration radius used – source looks point-like)
- All emission in the GC has
  - $\Gamma_\gamma \approx 2.2$

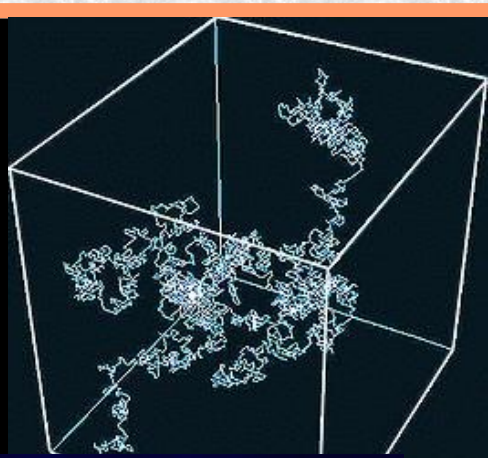


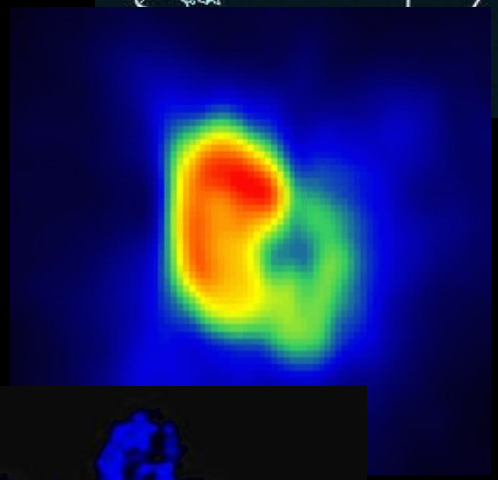
Interpretation

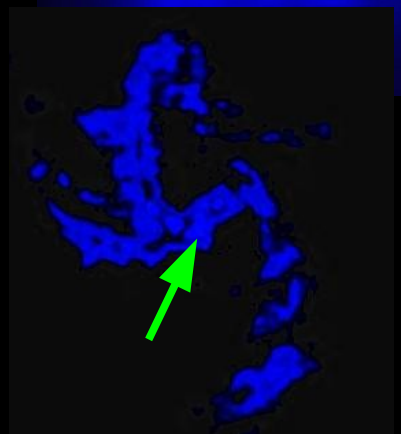
- **Several possibilities exist**
  - Emission is a superposition of many individual 'active' gamma-ray sources, but
    - ✗ *Close correlation with molecular material*
    - ✗ *Need many (~7) unknown sources, eg. SNRs and/or PWN*
  - Or diffuse emission, caused by CR interactions
    - *High energy CR density enhanced in the GC*
    - *1) Additional CRs are accelerated by a population of sources in the region*
    - *2) A single source (HESS J1745-290) accelerated most high energy (> 10 TeV) CRs in the central 200 parsecs*
    - ✔ *Same spectral index*
    - ✔ *Deficit in emission around l = 1.3°*

A central accelerator?

- **Diffusion timescale**
  - Say $D = \eta\ 10^{30}\ cm^2\ s^{-1}$, $\eta < 1$
  - $\eta = 1$ typical for TeV CRs in disc
  - $t_{kyr} = (\theta / 0.54°)^2 / \eta$
  - e.g. for $\theta = 1°$ and $\eta \sim 0.4$, t = 10 kyrs
- **SNR Sgr A East**
  - ~10,000 year old supernova explosion
  - unusually powerful - 4×10^{52} ergs...
- **Sgr A***
  - Hypothetical historical flare?
  - More recent flare suspected from X-ray observations of Sgr B2 (Compton Mirror)







Conclusions

- First measurement of gamma-ray emission from individual molecular clouds
- The Galactic Centre region seems to contain an excess of high energy cosmic rays
- MWL data are essential for the interpretation of this signal