Friedrich-Alexander-Universität
Erlangen-Nürnberg

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H.E.S.S.

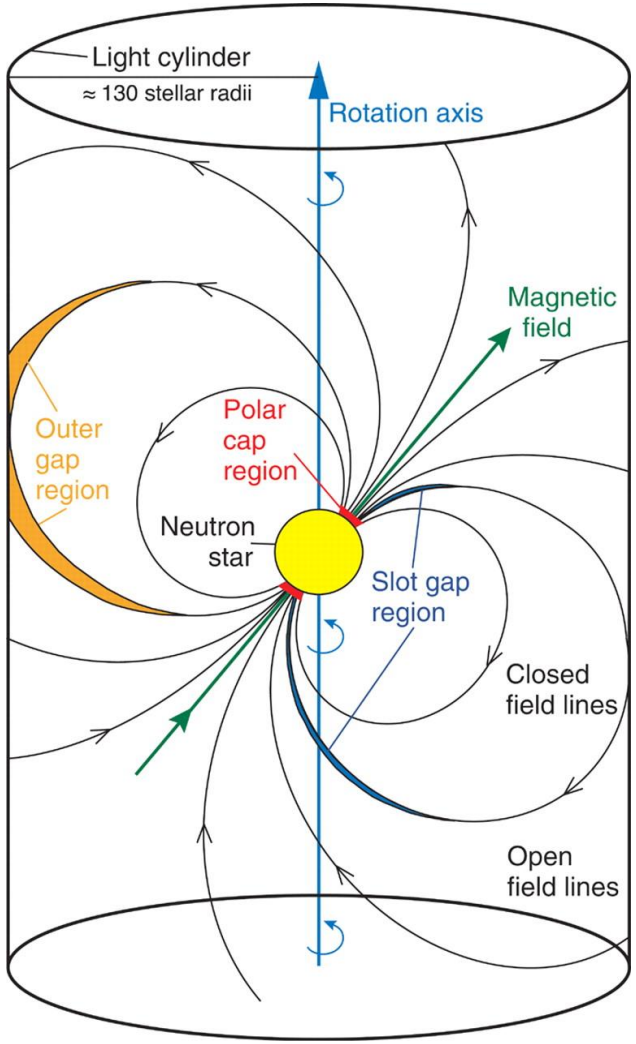
ECAP ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

FAU

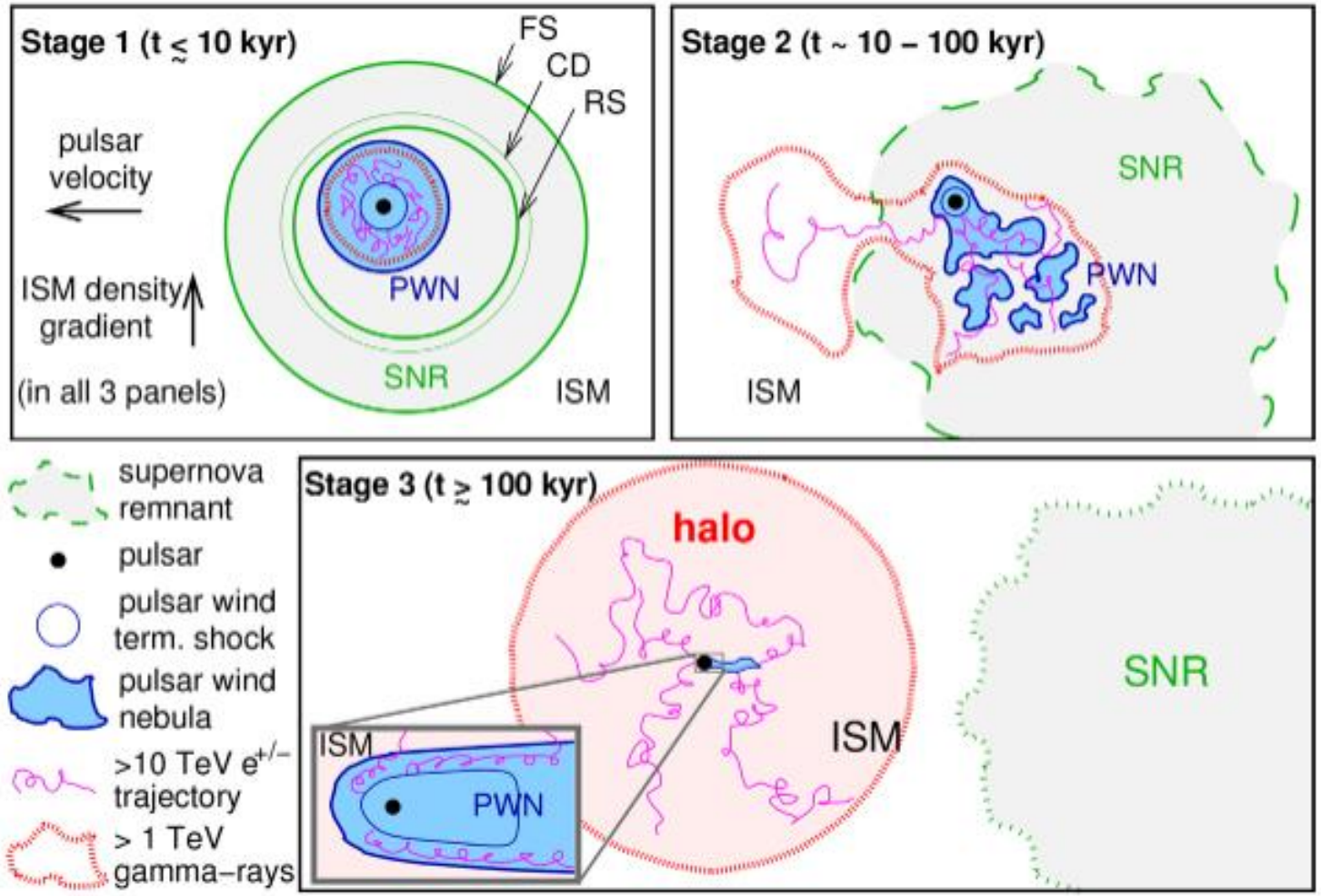
Detailed multi-instrument analysis of the very high energy γ-ray emission in the region of HESS J1813-178

Tina Wach, Alison Mitchell, Vikas Joshi
FRANCI Meeting
Bamberg, 01.08.22

Pulsar‘s and their Nebulae



Magic Collab. 2008



G. Giancinti. 2020

Supernova remnants and stellar cluster

- Hadronic cosmic ray sea
- Supernova remnants:
  - Acceleration of protons on the shock-front of SNR‘s
  - Cross section for proton proton interaction increases
  - Compact γ-ray signal visible due to decay of π^0
- Stellar cluster:
  - Group of massive stars in dense environment
  - Colliding wind binaries, collective stellar winds and SNR‘s inside the cluster
  - Proton acceleration on these shock-fronts

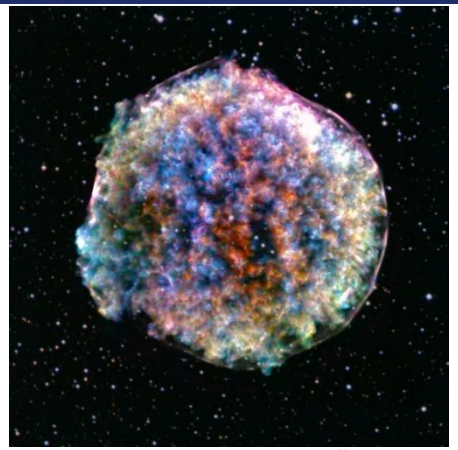
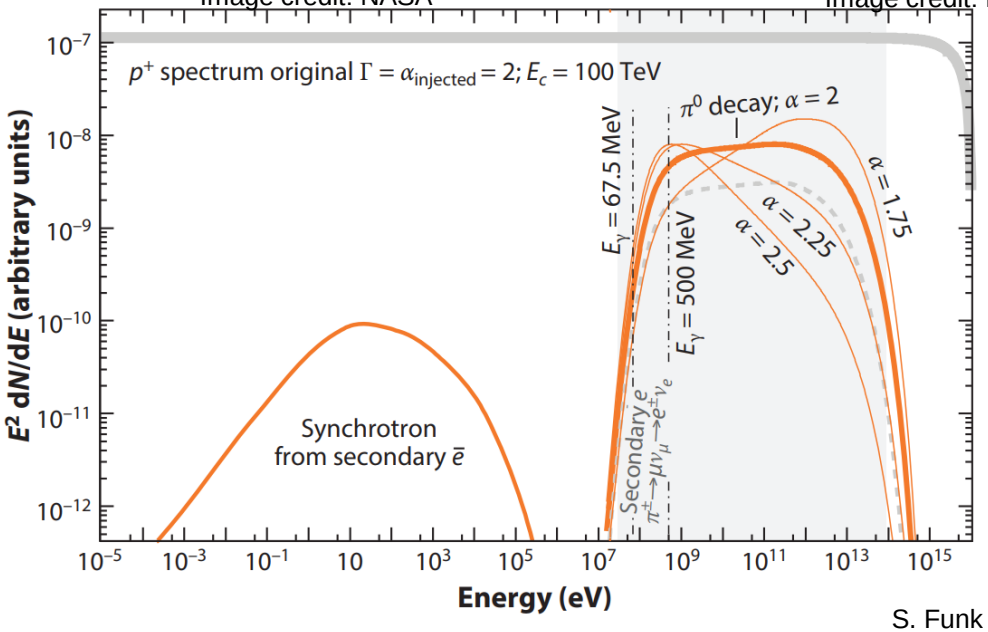


Image credit: NASA

Image credit: NASA



S. Funk 2015

H.E.S.S.

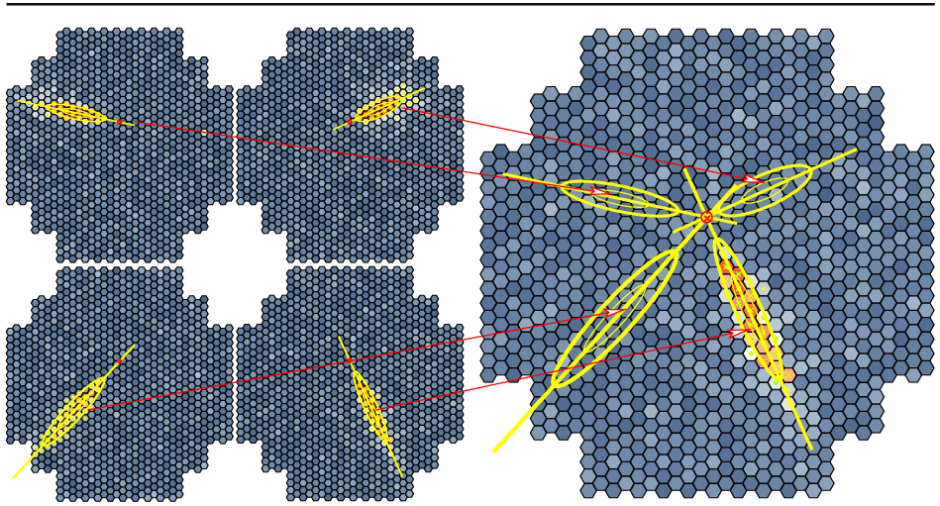


Image Credit: HESS Collab

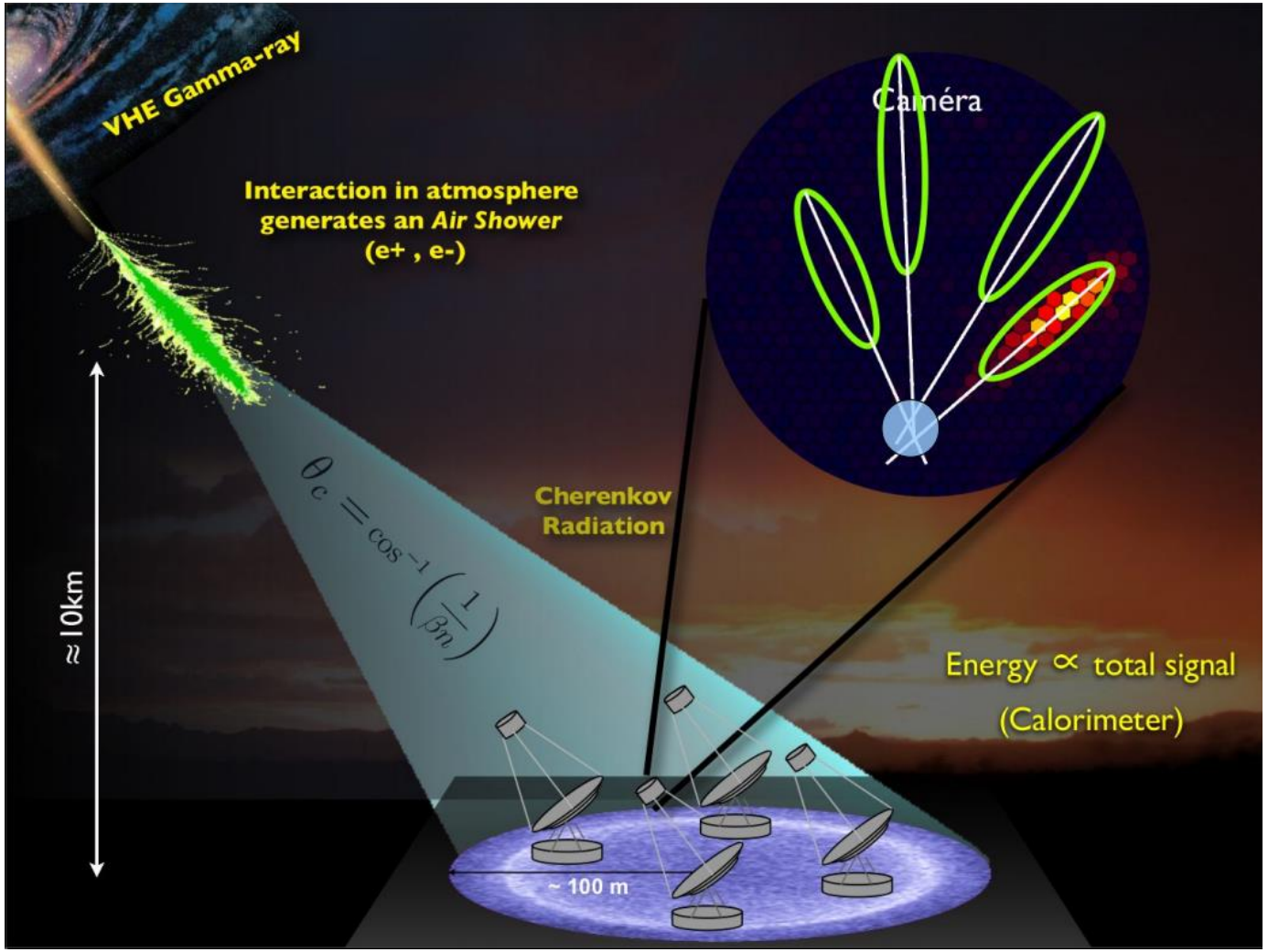
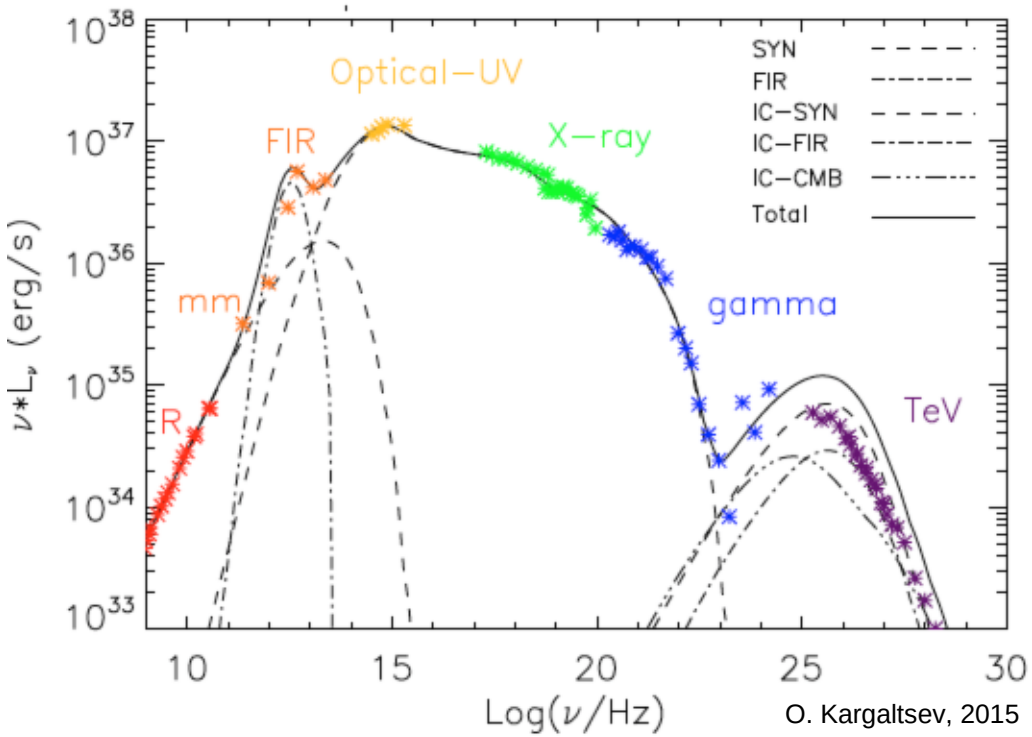
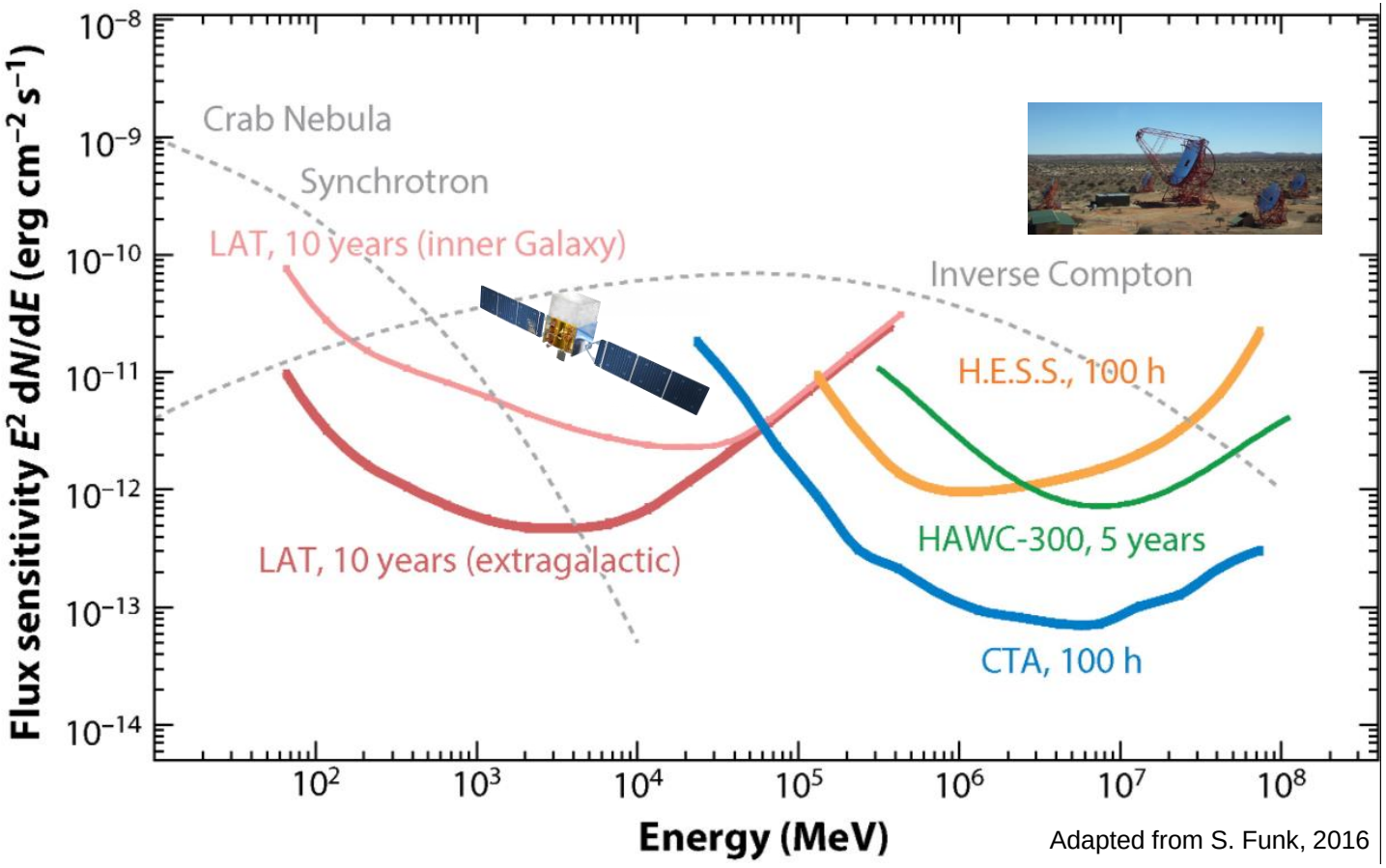


Image credit:K. Korsak

Why multi-instrument analysis?



O. Kargaltsev, 2015



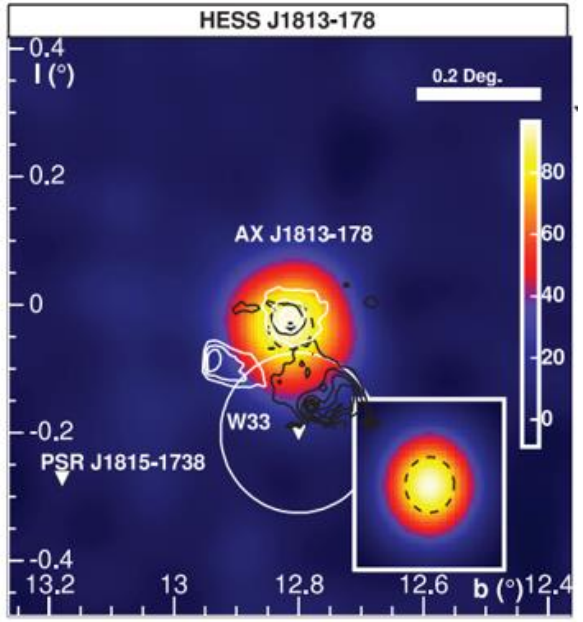
Adapted from S. Funk, 2016

Detection and Categorization of HESS J1813-178

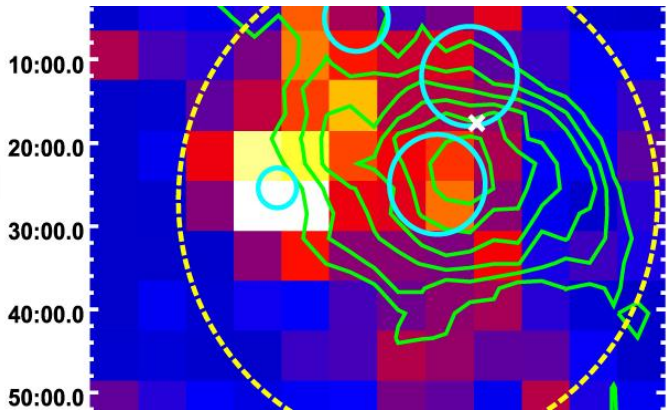
- Discovery: HGPS in 2005

→Compact source, extension of 0.04°

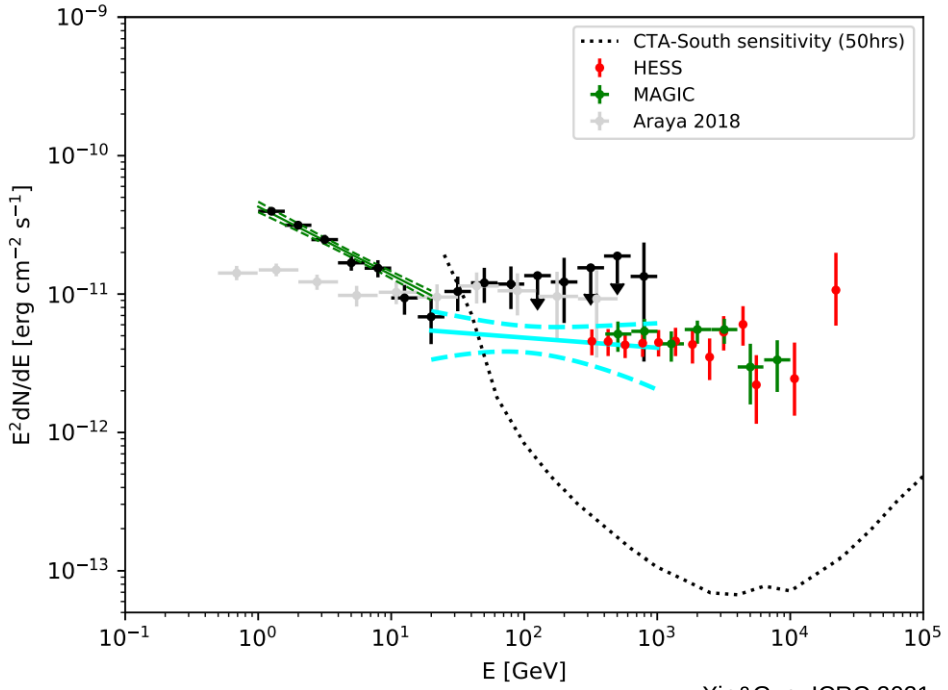
- Confirmation by MAGIC in 2006
- Positional coincidence with ASCA and INTEGRAL source
- Associated to young shell-like structure
- Detection of PSR J1813-1749 in 2009 indicates very young age
- Observation with Fermi-LAT reveal extended source of 0.6°



HESS Collab., 2006



Miguel Araya, 2018

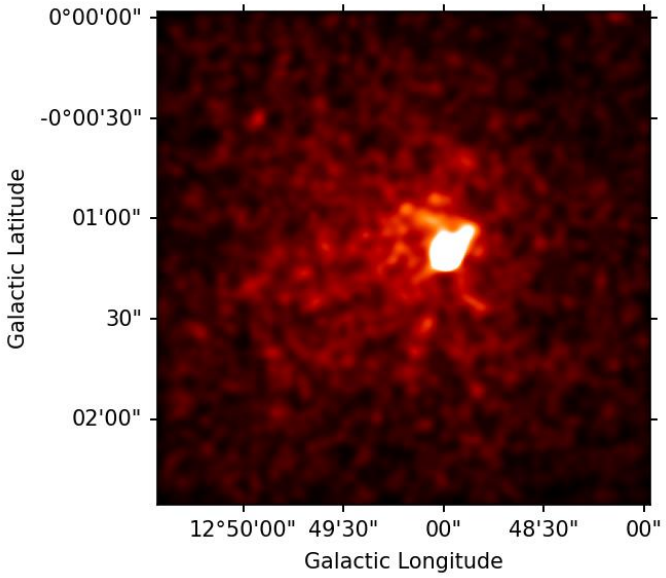


Xin&Guo, ICRC 2021

The region around HESS J1813-178

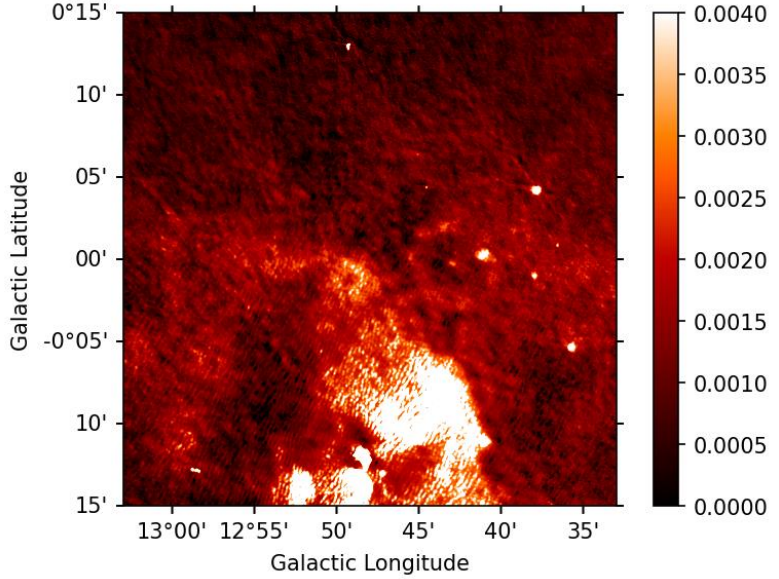
PSR J1813-1749:

- 44.7 ms pulsar
- $\dot{E}$ = 5.6e37 erg/s
- Characteristic age of 5.6 kyr
- True age estimated to 1.35 kyr
- Absorbing column density of 10e22 cm^{-2}
- Distance of 6.2 – 12 kpc

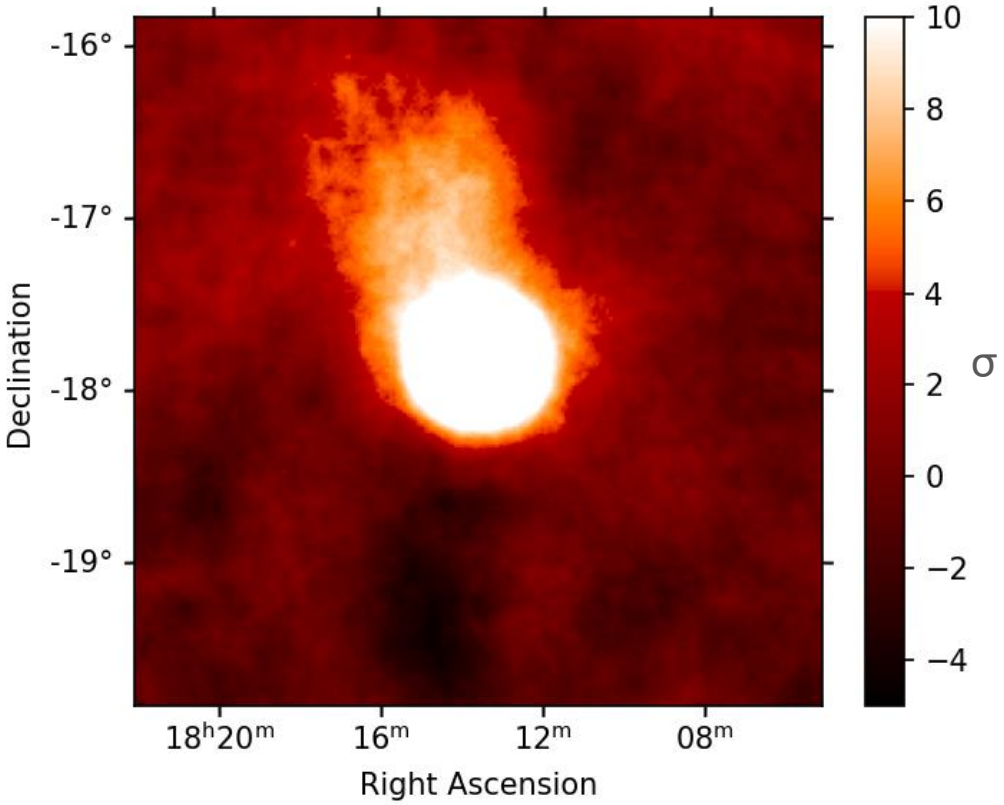


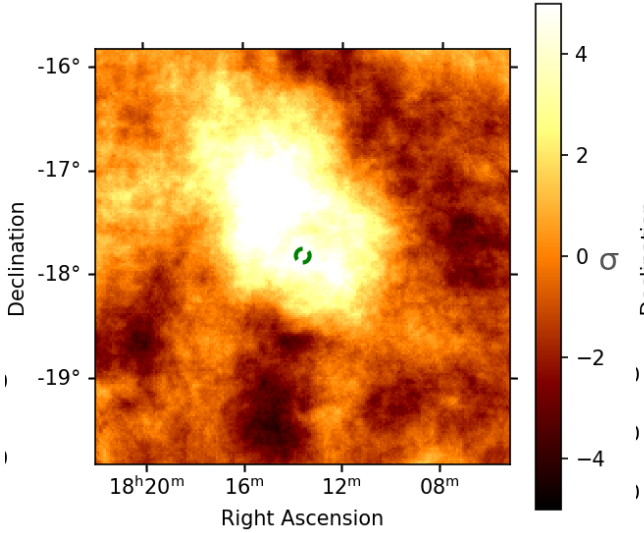
Cl J1813-178:

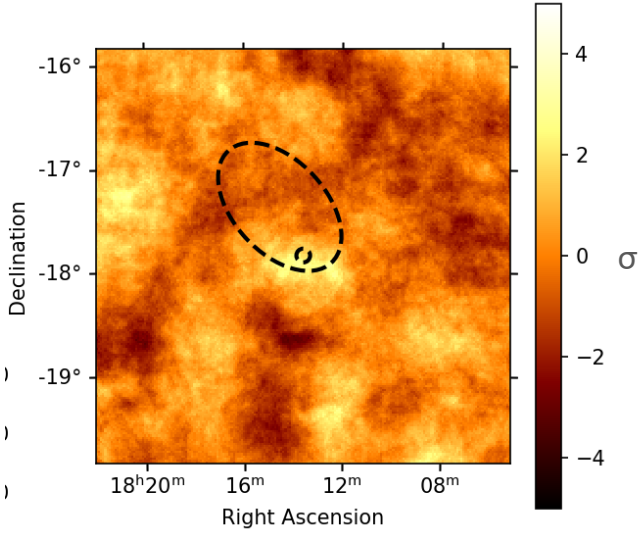
- Age estimated to 6-8 kyr
- Initial cluster mass 2000 solar masses
- Absorbing column density of 2e22 cm^{-2}
- Distance of 4.8 kpc
- Projected distance between HESS J1813-178 and cluster core 4.5‘

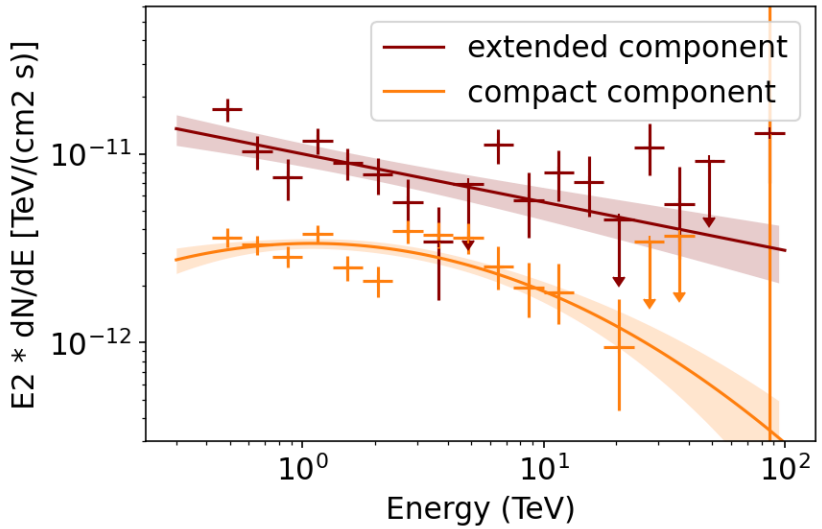


HESS J1813-178: Spectral and morphological analysis





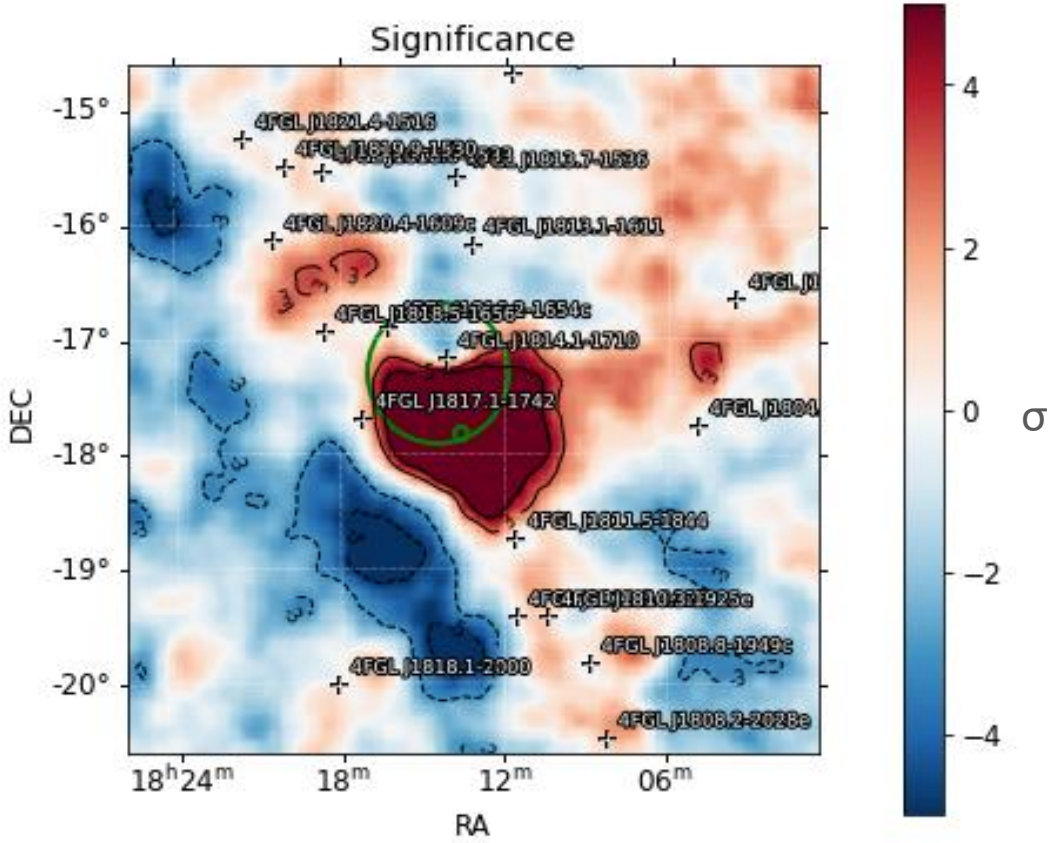


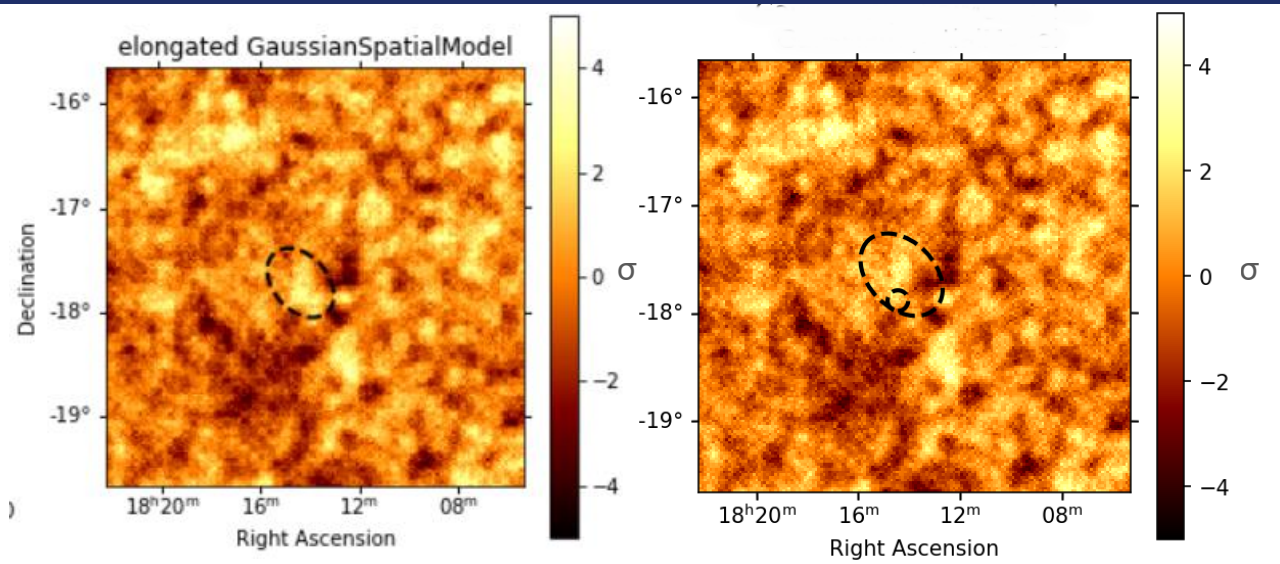


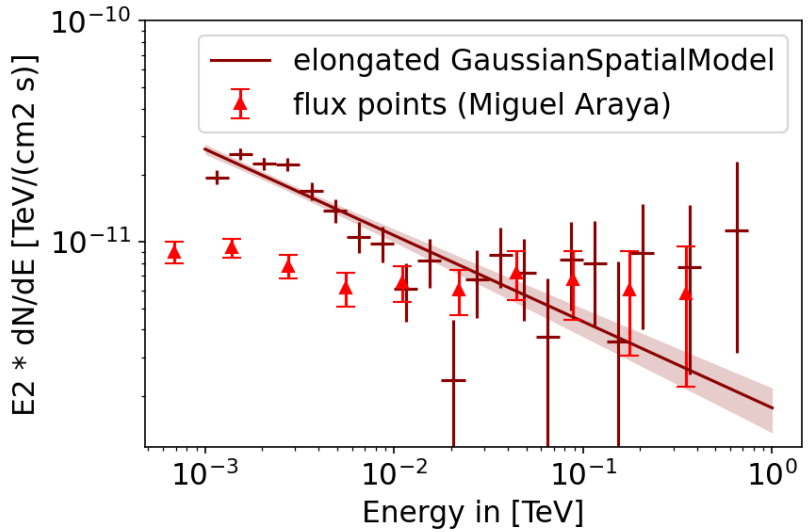
- Significance of the compact component: 35σ
- Significance of the extended component: 17σ
- Extension of the compact component: 0.06°
- Extension of the extended component: 0.7°

4FGL J1813.1-1737: Spectral and morphological analysis of Fermi-LAT data

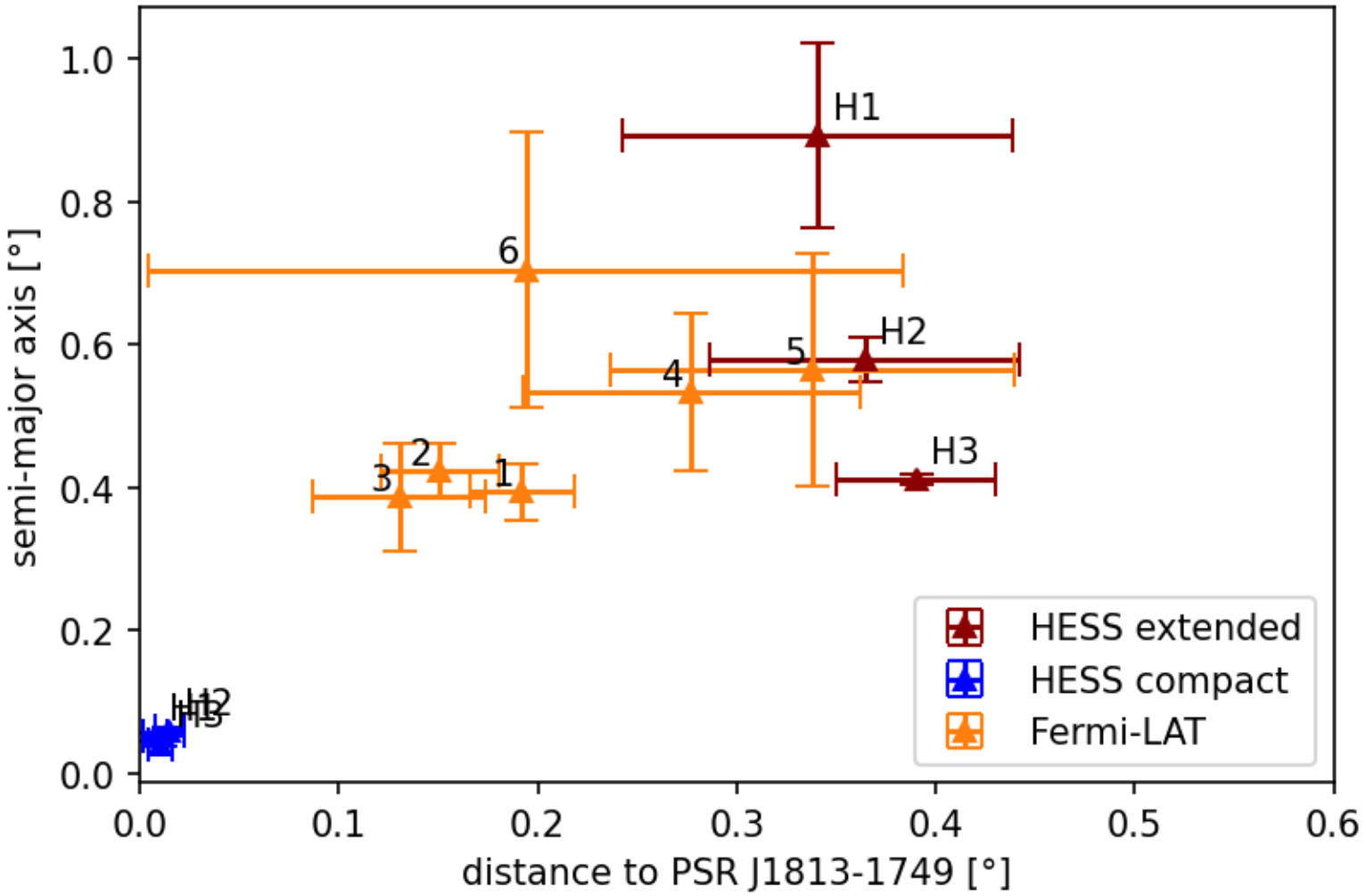
- Significance of the model: 15σ
- Extension of the component: 0.35°
- Significance of adding a second component: 4.6σ
- Extension of the second component: 0.06°

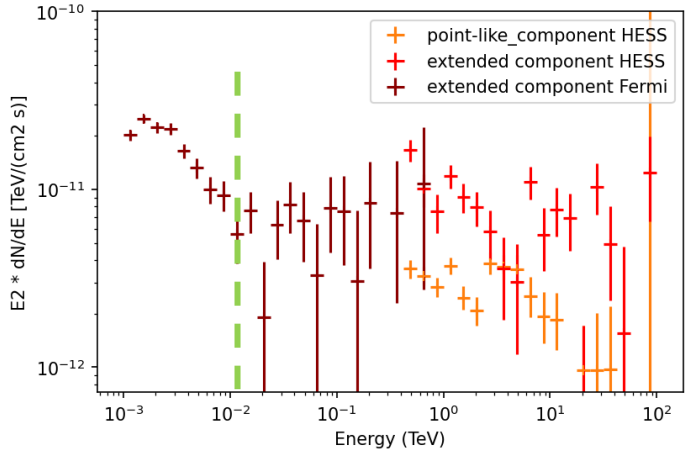






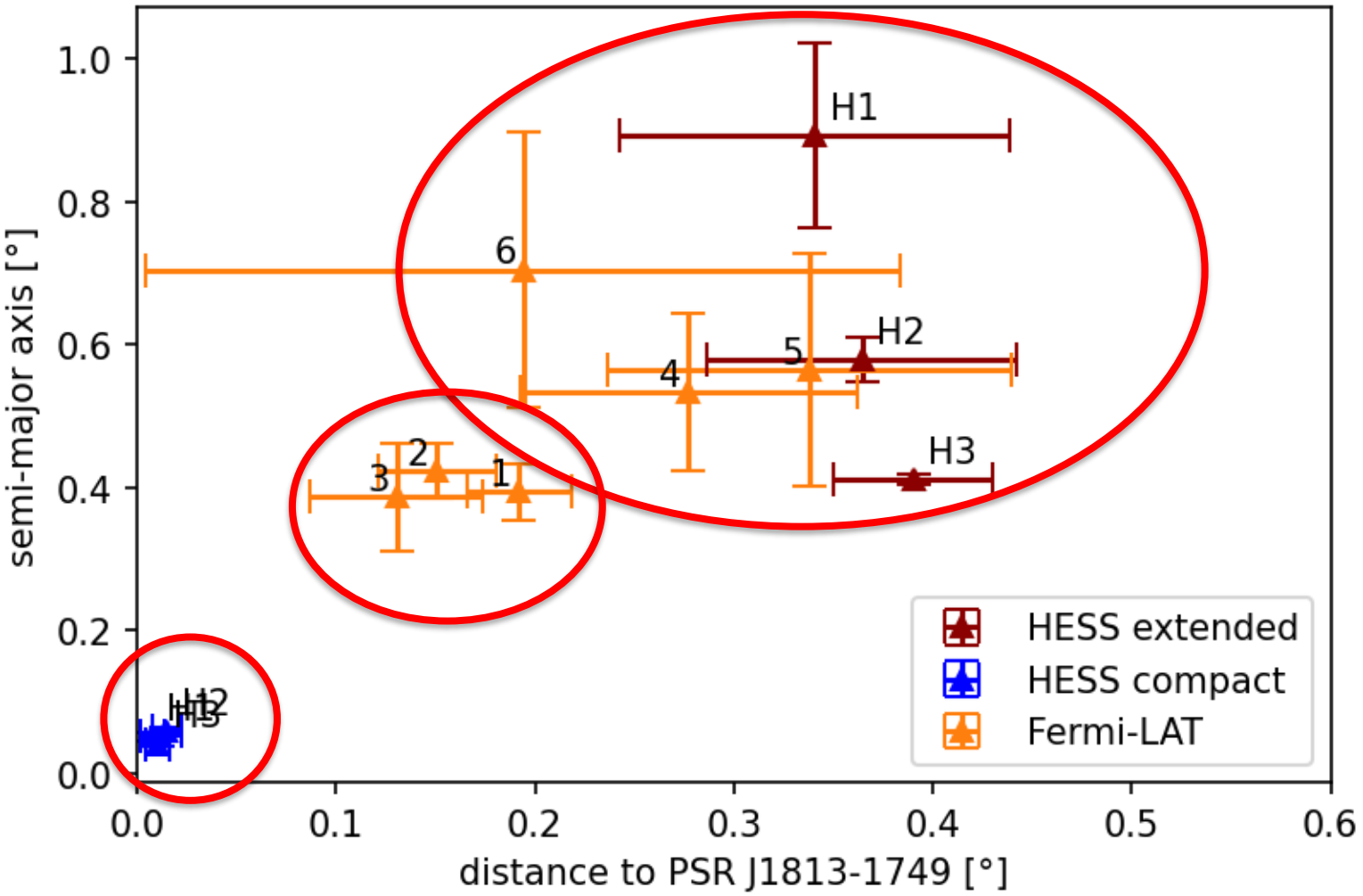
Energy dependence of the morphology

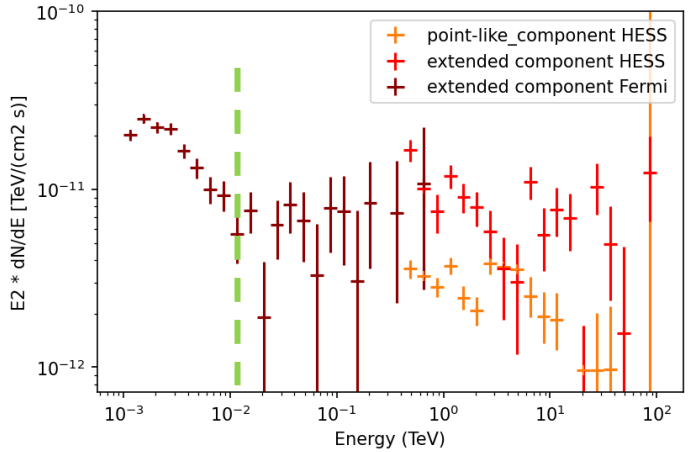




- Band 1: (1.0 - 2.0) GeV
- Band 2: (2.0 - 4.0) GeV
- Band 3: (4.0 – 7.5) GeV
- Band 4: (7.5 – 17.8) GeV
- Band 5: (17.8 – 56.0) GeV
- Band 6: (56.0 -1000) GeV
- Band H1: (0.4 – 1.0) TeV
- Band H2: (1.0 – 3.0) TeV
- Band H3: (3.0 – 100) TeV

Energy dependence of the morphology





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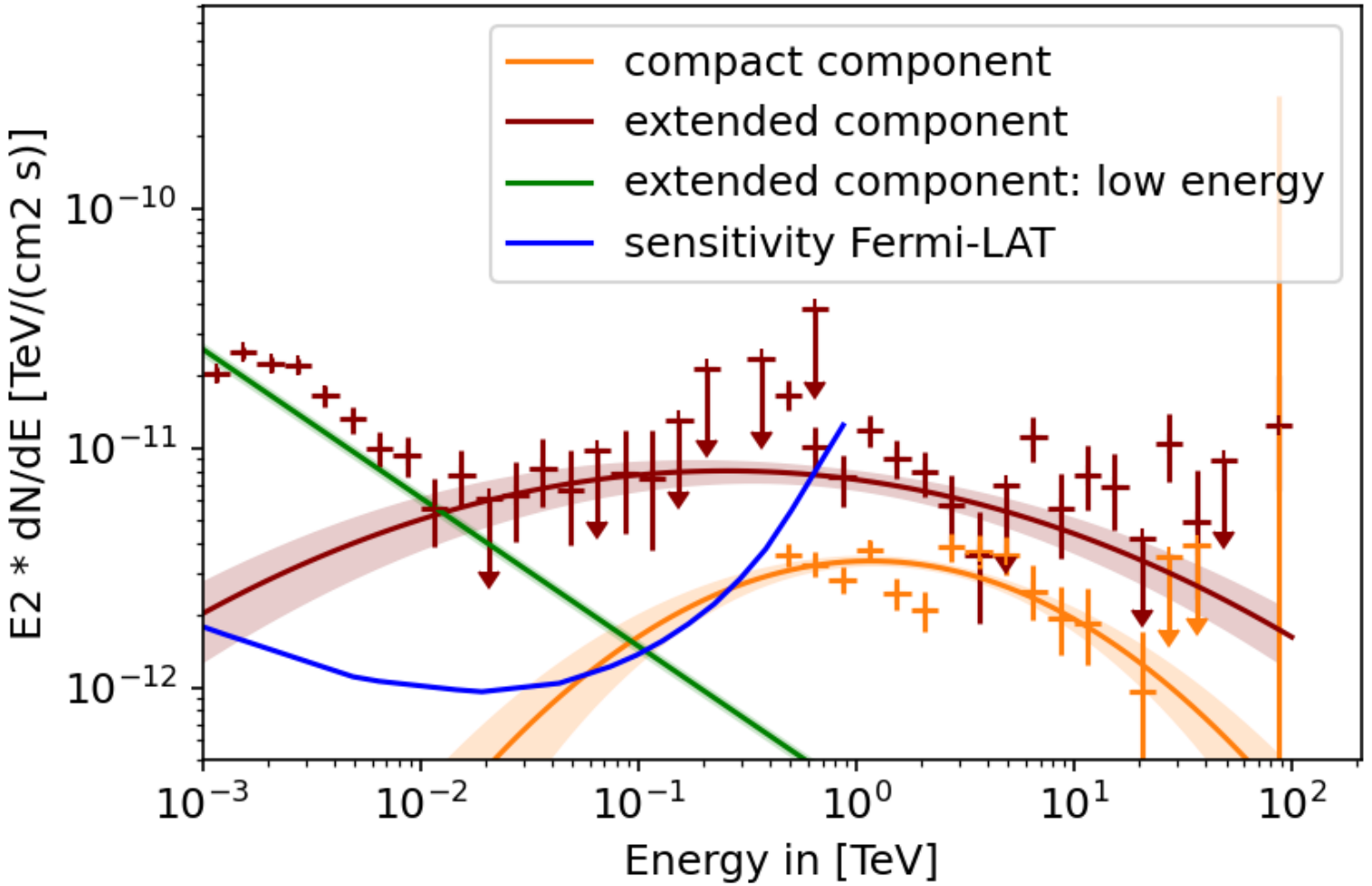
- Band 6: (56.0 -1000) GeV
- Band H1: (0.4 – 1.0) TeV
- Band H2: (1.0 – 3.0) TeV
- Band H3: (3.0 – 100) TeV

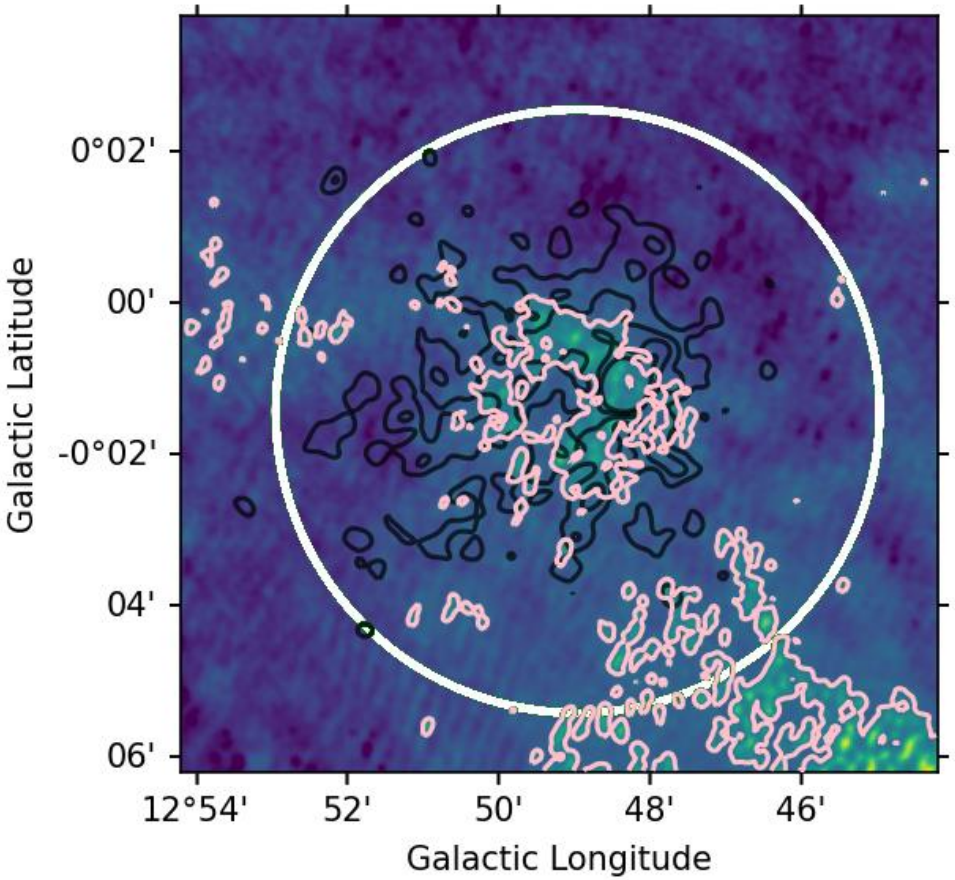
HESS/Fermi: Joint-Model

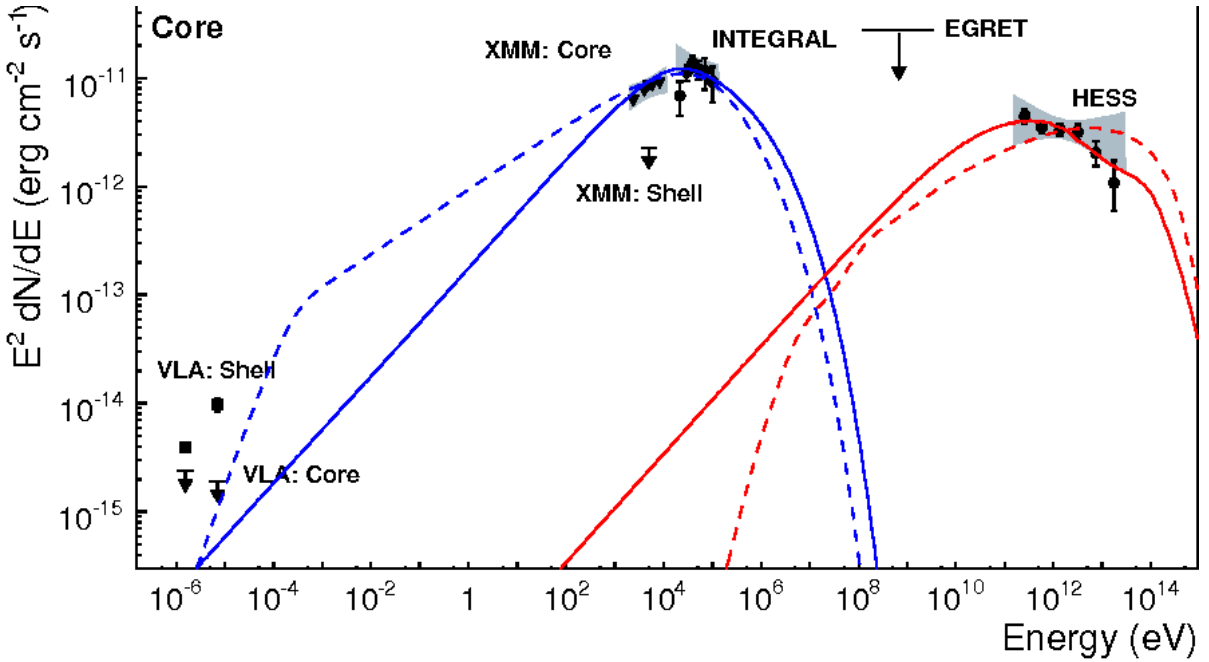
Compact component:
- Slightly extended (0.06deg)
- Only detected in HESS

Extended component:
- Two source models necassary
- PowerLaw with an extension of 0.3deg
- LogParabola with an extension of 0.7deg



Compact component HESS J1813-178



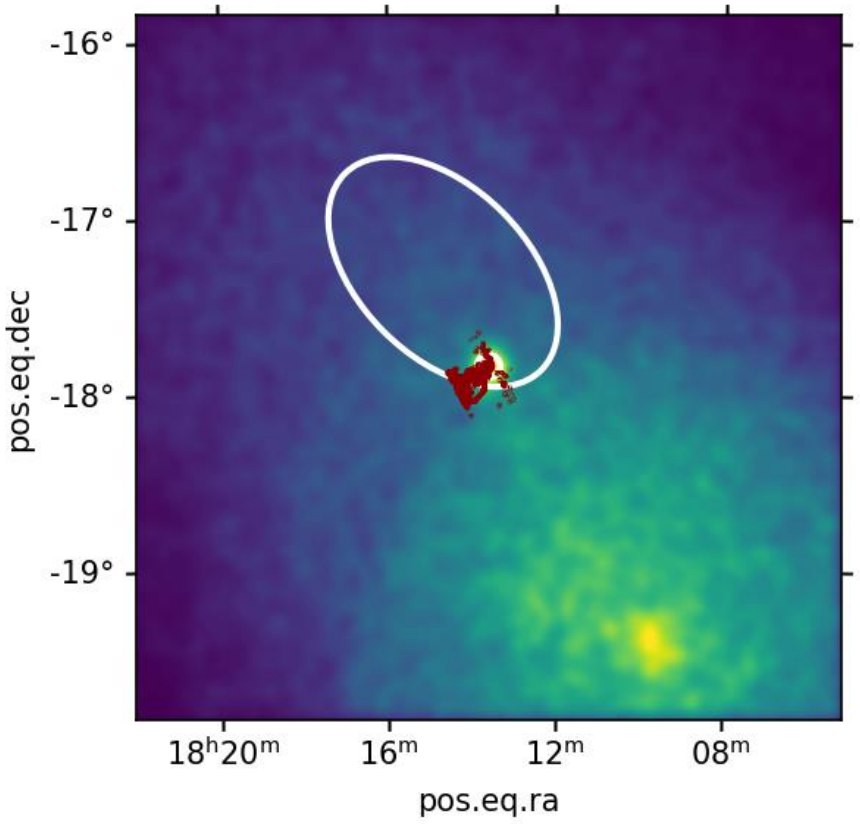


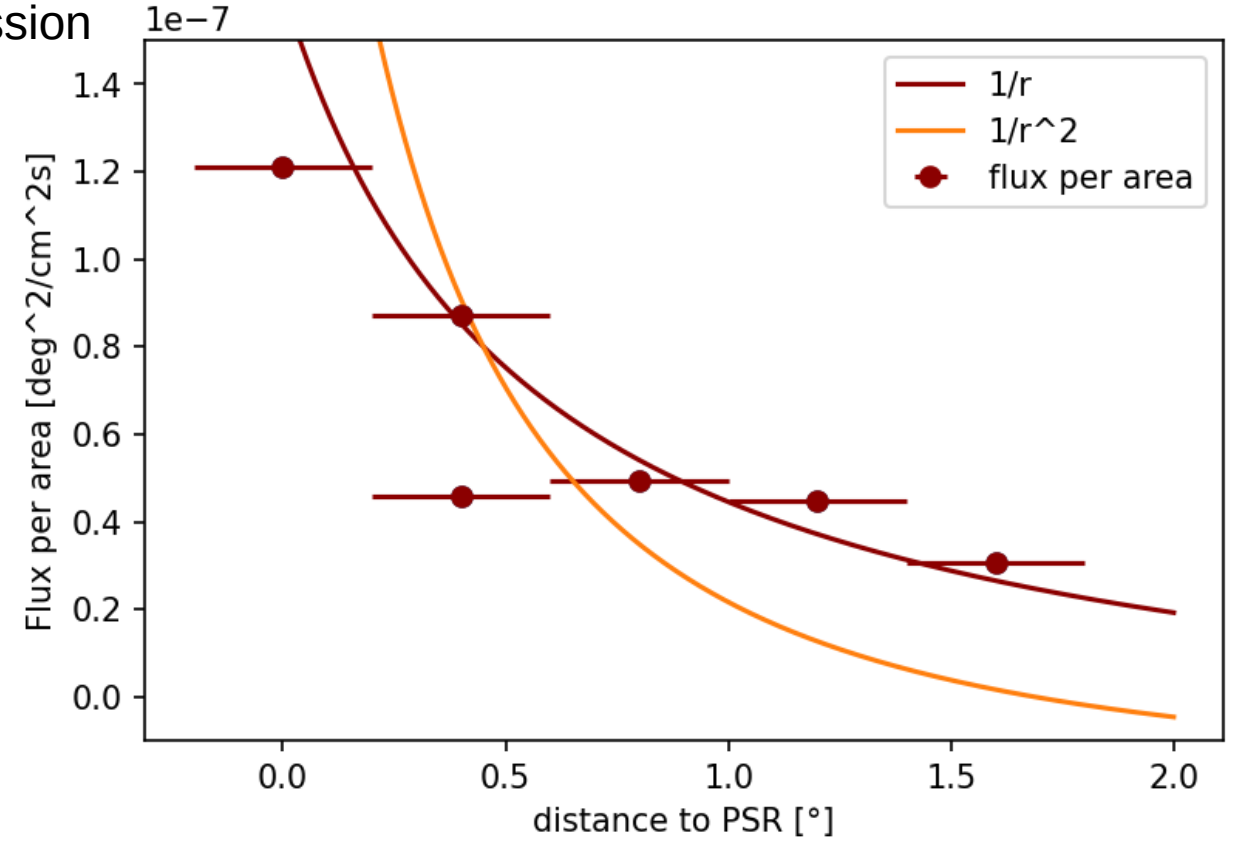
Adapted from S. Funk, 2007

- Soft spectral index
- No significant fluxpoint above 30 TeV
- Positional coincidence between TeV source, SNR and PSR
- Former analysis of the source with similar results
  → Pulsar wind nebula

Extended emission in the region of HESS J1813-178

- Energy dependent morphology indicates leptonic emission
- Hard spectral index indicates hadronic emission
- continous injection of particles into the region
- Spatial conincidence with pulsar and stellar cluster

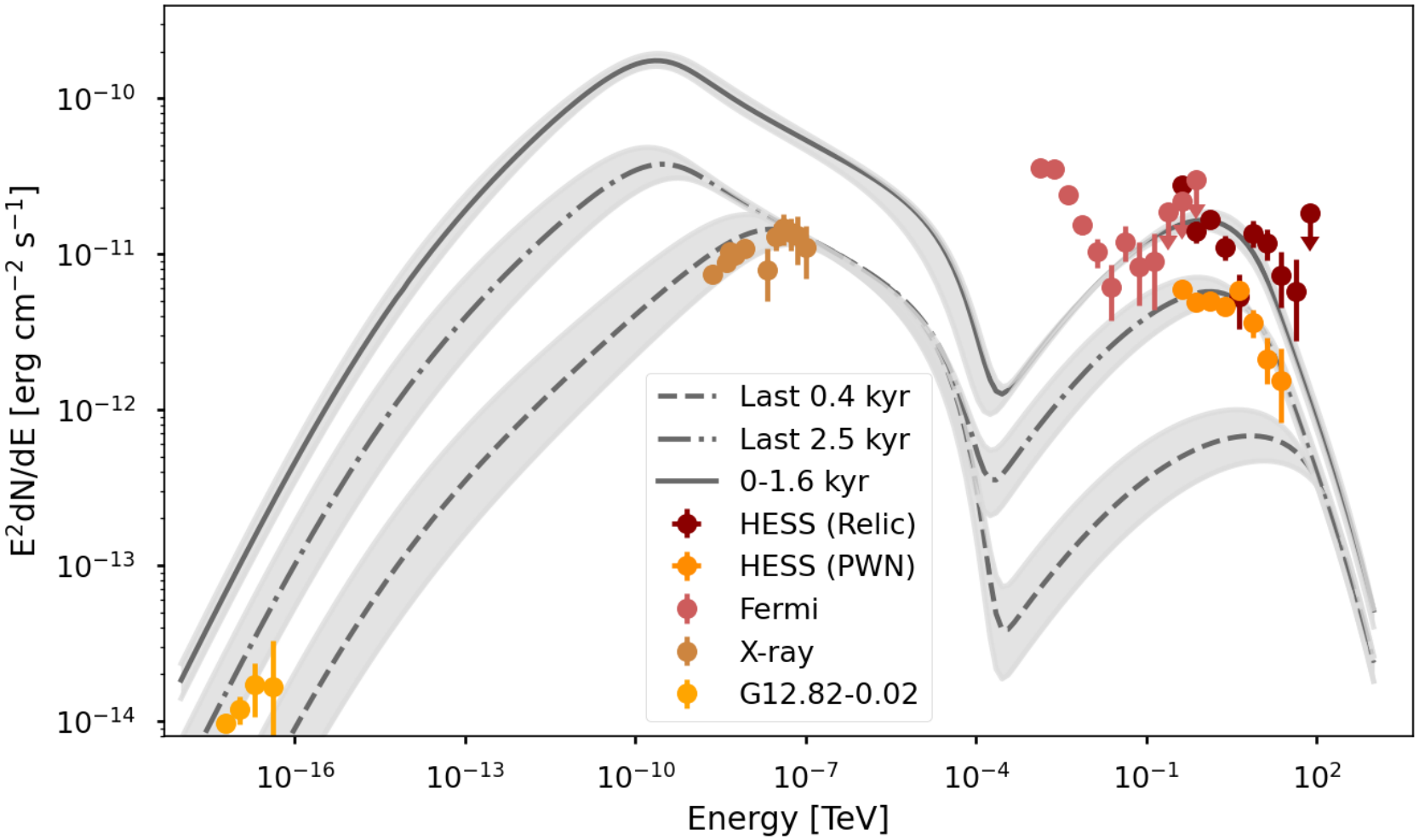




Two possible scenarios for extended emission:

1) **Association with PSR J1813-1749**
2) **Association with Cl J1813-178**

Leptonic Model



Assumptions:

- Distance: 6.2 kpc
- E_dot = 5.6e37 erg/s
- P = 44.7e-3 s
- P_dot = 1.26999e-13 s/s
- Braking index = 3.0
- Braking energy = 100 GeV
- Spectral index = 1.5

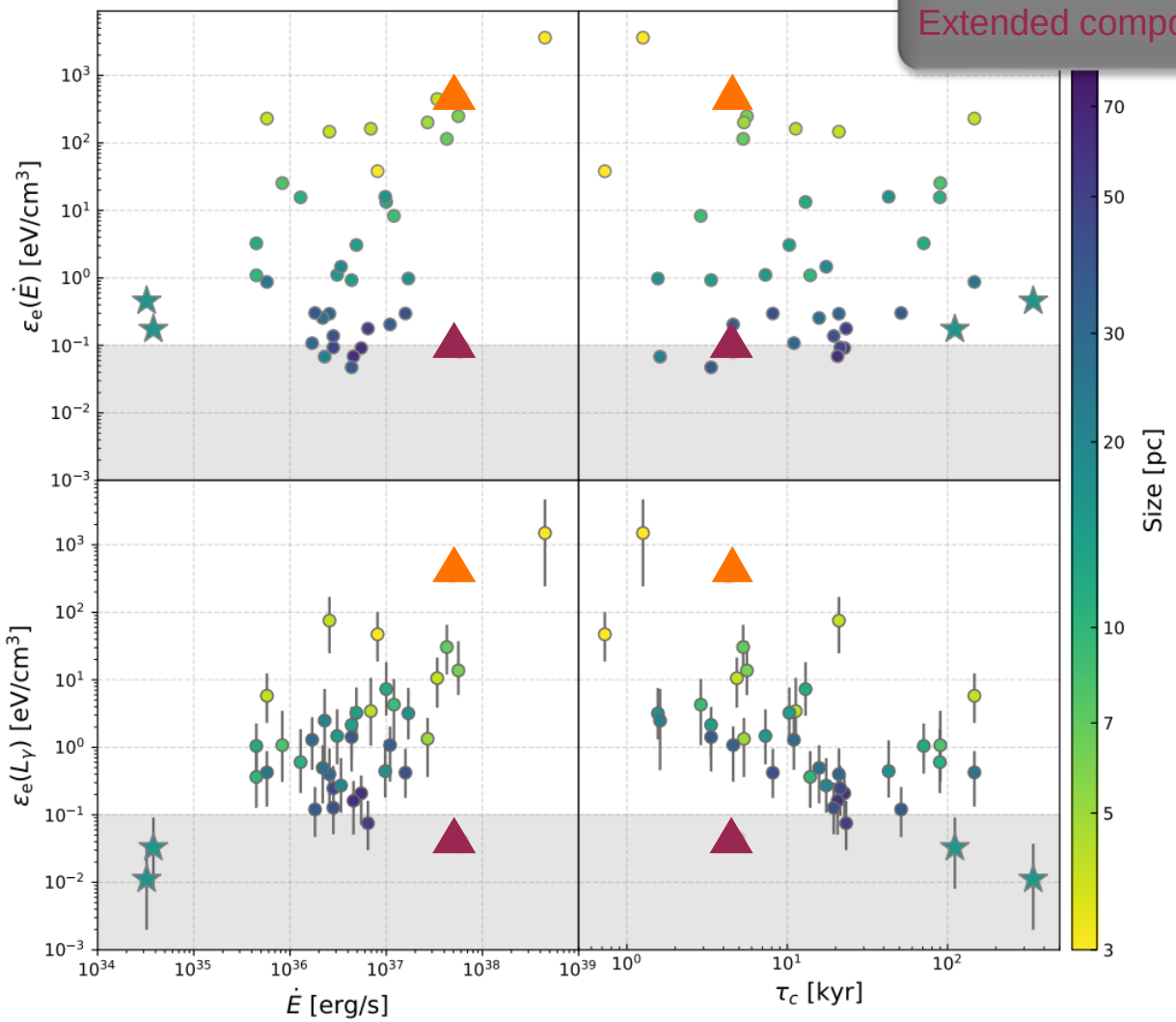
Fit parameters:

- B(now) = [10.4 – 12.6] μG
- P0 = [18.4 – 21.8] ms
- Theta = [0.12 – 0.26]
- Spectral index = [2.3 – 2.4]
- Time frac(X-ray) = [0.08 – 0.13]
- Time frac(pwn) = [0.57 – 0.69]

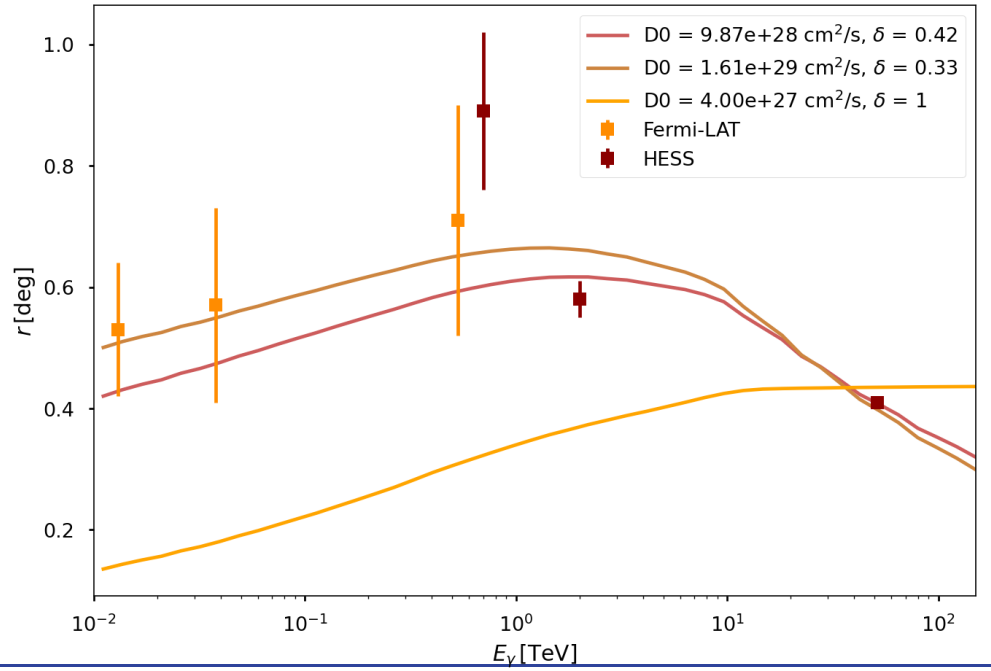
- True age estimated in this study: (5.7 - 6.5) krys

Leptonic Model

compact component
Extended compoment

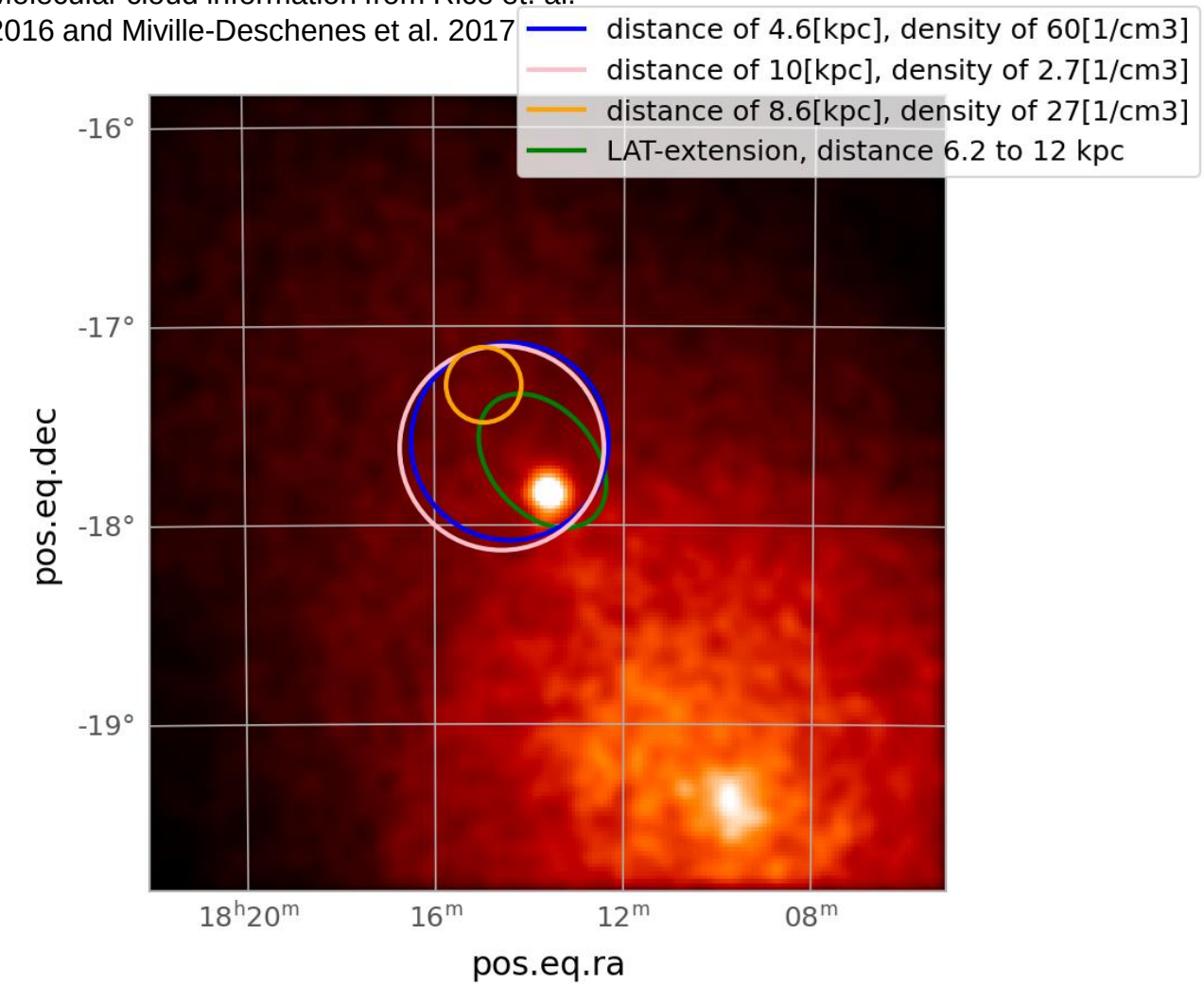


	Compact component	Extended component
ε_e(Edot) in eV/cm^3	707	0.09
$\varepsilon_e(L_\gamma)$ in eV/cm^3	351	0.04



Molecular clouds in the region

Molecular cloud information from Rice et. al. 2016 and Miville-Deschenes et al. 2017



Molecular clouds in the region

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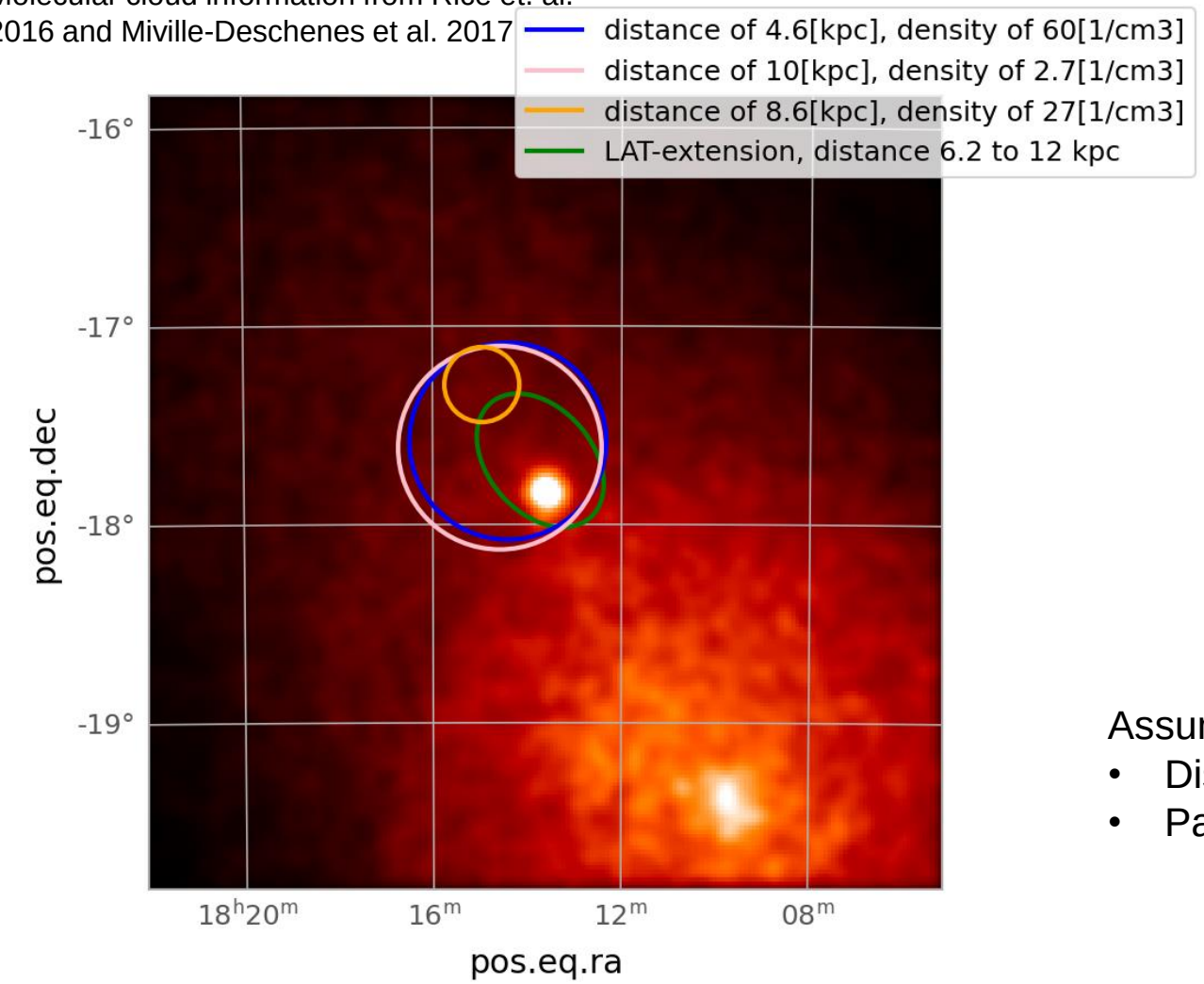
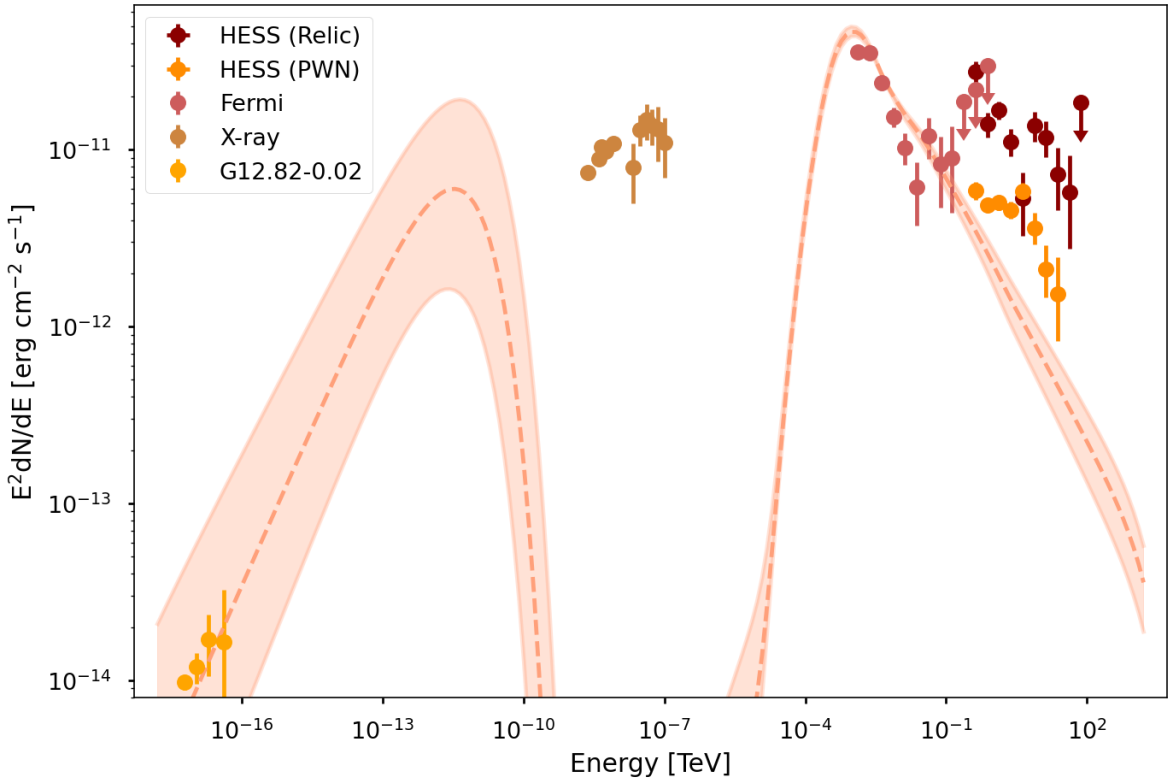




Assumptions:

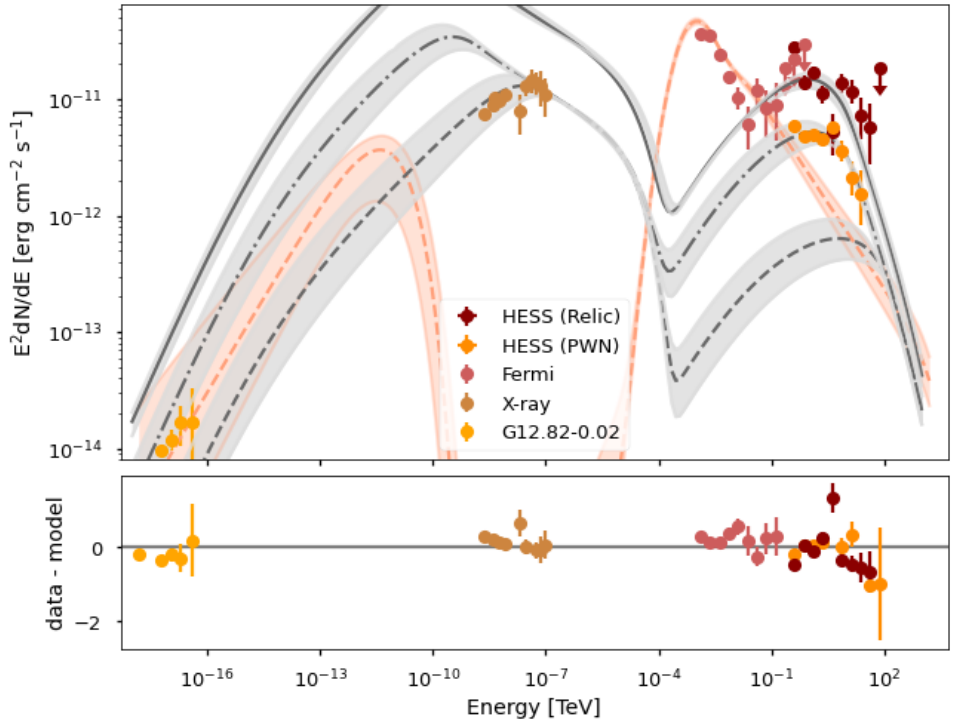
- Distance: 6.2kpc
- Particle density = 60 1/cm3

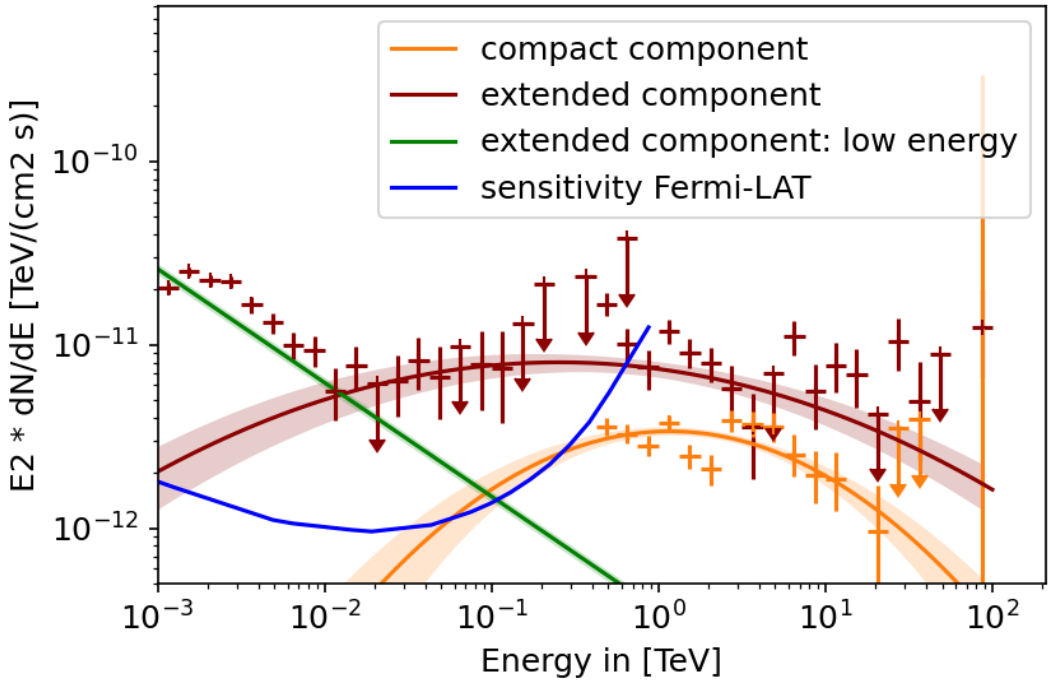
Fit parameters:

- Alpha_p = [2.52 – 2.63]
- Power_p = [1.06e50 – 0.95e50]
- Del_alpha = [-0.66 – -0.87]
- Log10(K_ep) = [-3.52 – -4.07]
- B_now_snr = [57 – 125] μG

Summary

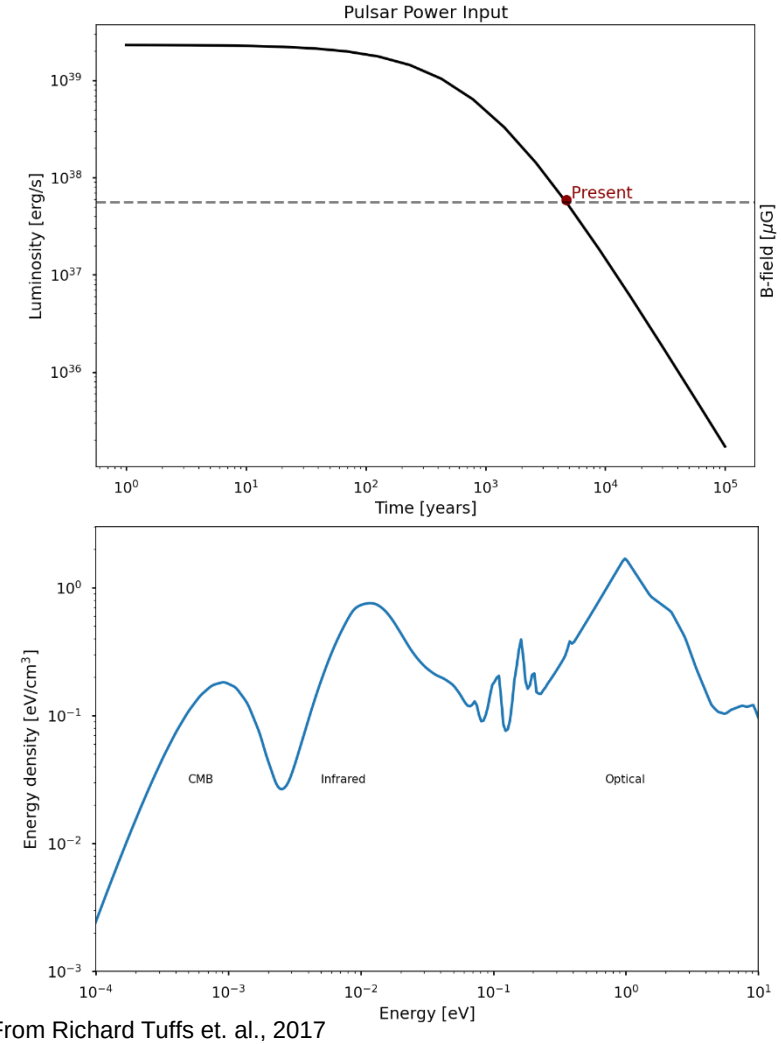
- Detection of an extended emission in the region of HESS J1813-178
- Continuous Model between Fermi-LAT and HESS
- Agreement of leptonic origin of compact component
- Extended emission in TeV energy can be explained by electrons that escaped the PWN
- Emission observed below 10 GeV can be explained by Protons interacting with a molecular cloud





Backup slides

Leptonic Model

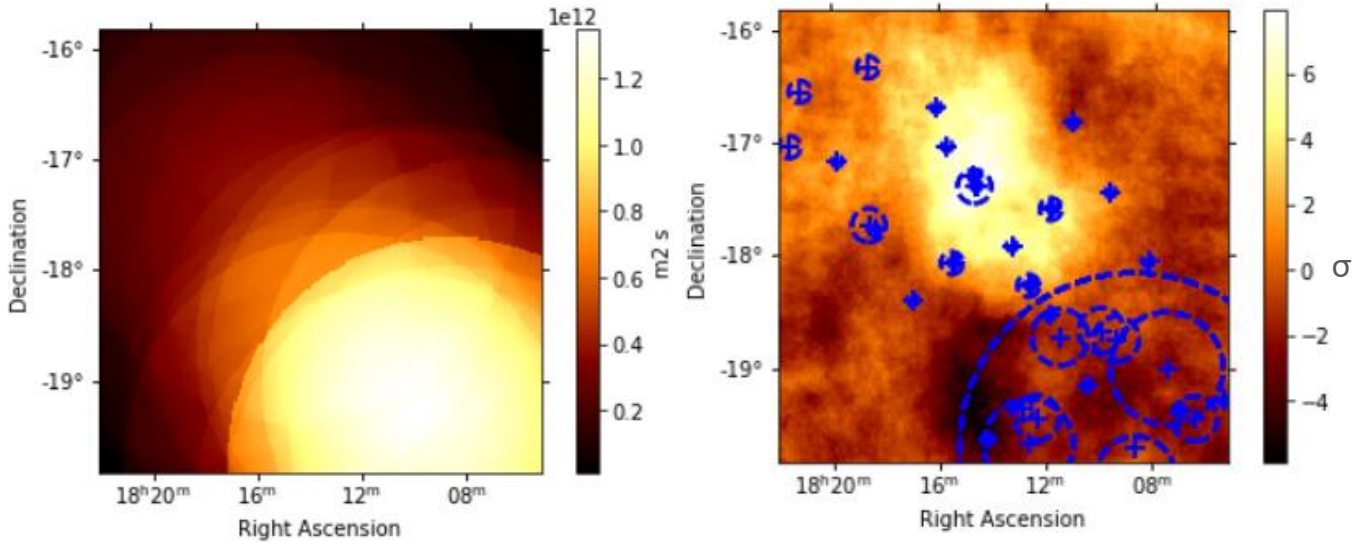


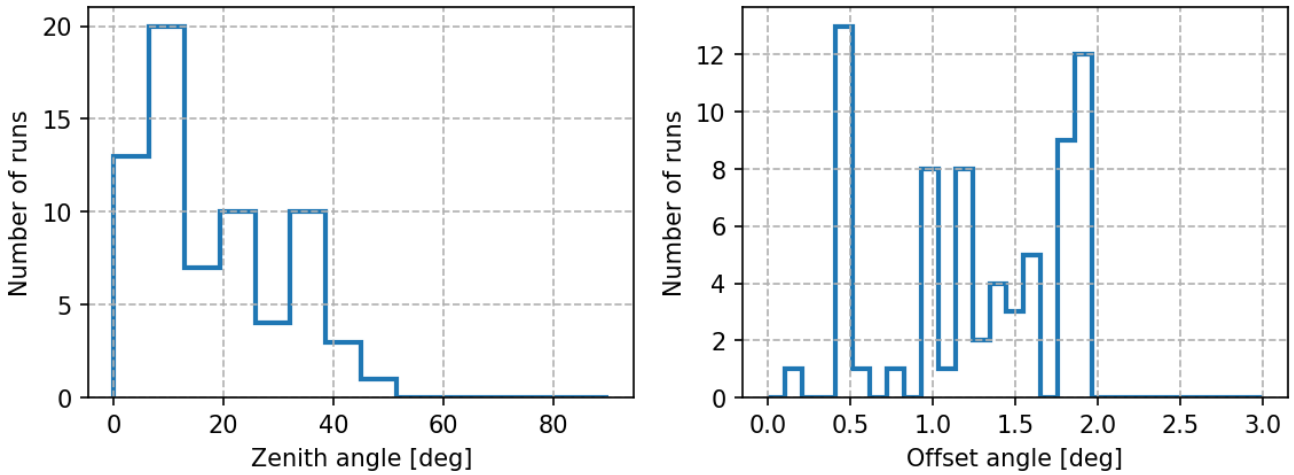
From Richard Tuffs et. al., 2017

	Compact component	Extended component
ε_e(Edot) in eV/cm^3	707	0.09
$\varepsilon_e(L_\gamma)$ in eV/cm^3	351	0.04

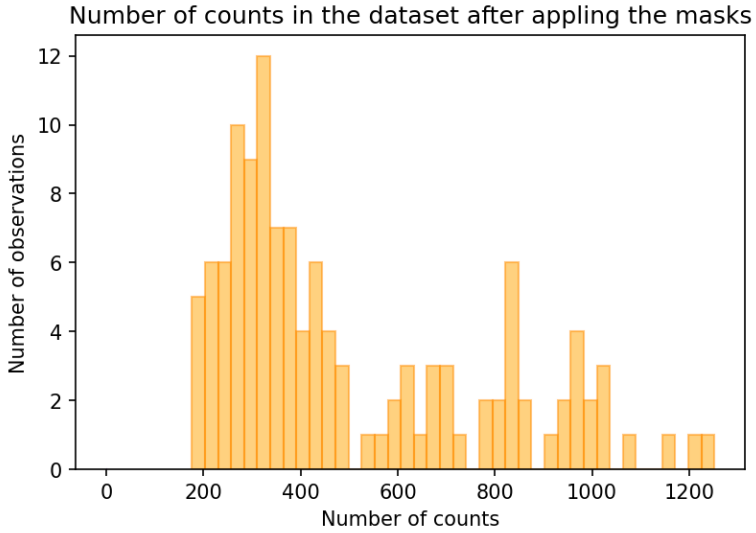
HESS Data

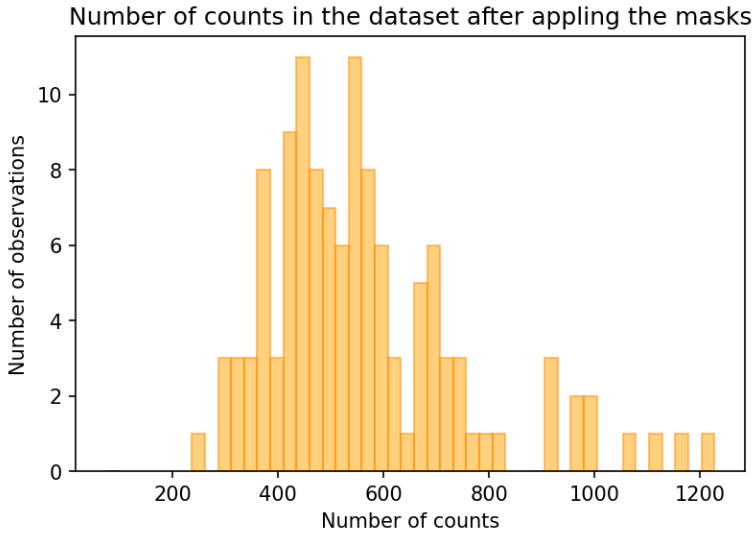
- Analysis tool: gammapy v0.18.2
- Analysis config: std_imPACT_fullEnclosure
- Maximum event offset: 2.0°
- Map pixel size: 0.02°
- Spectral quality cuts
- Standard Map-size: 4° x 4°
- Energy binning: 8 bins per decade
- Correlation radius for significance maps: 0.4°

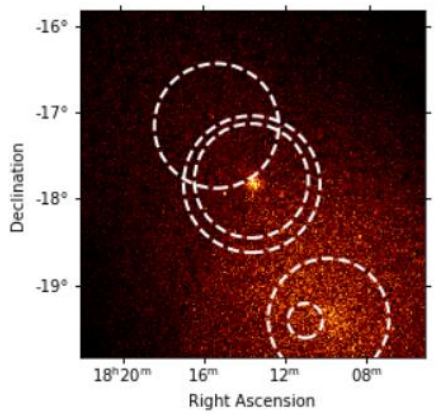


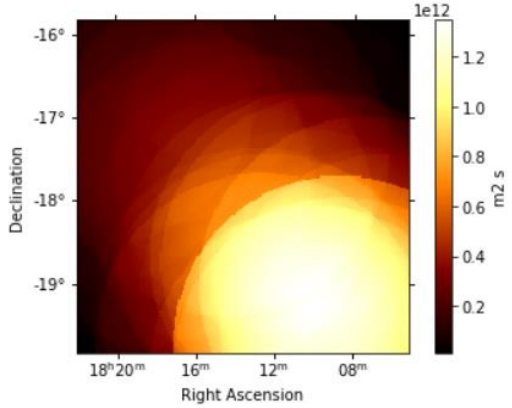


Background fit HESS Data

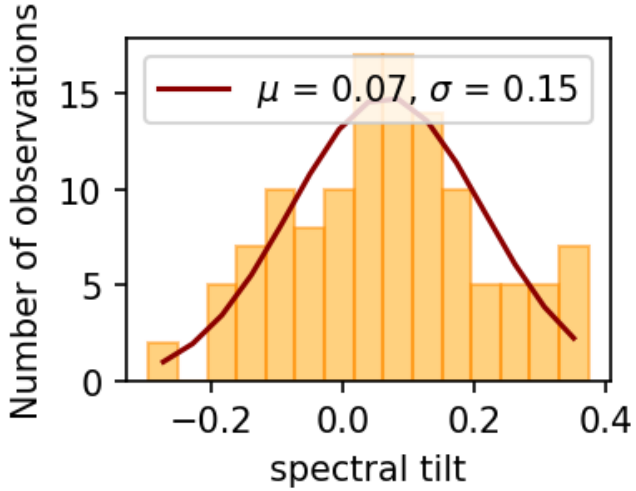


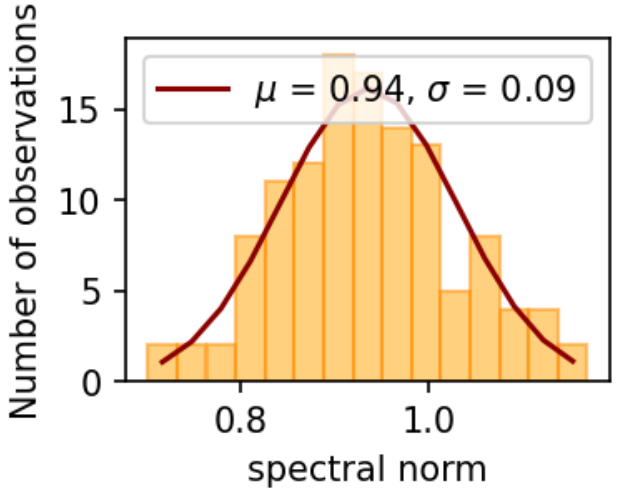




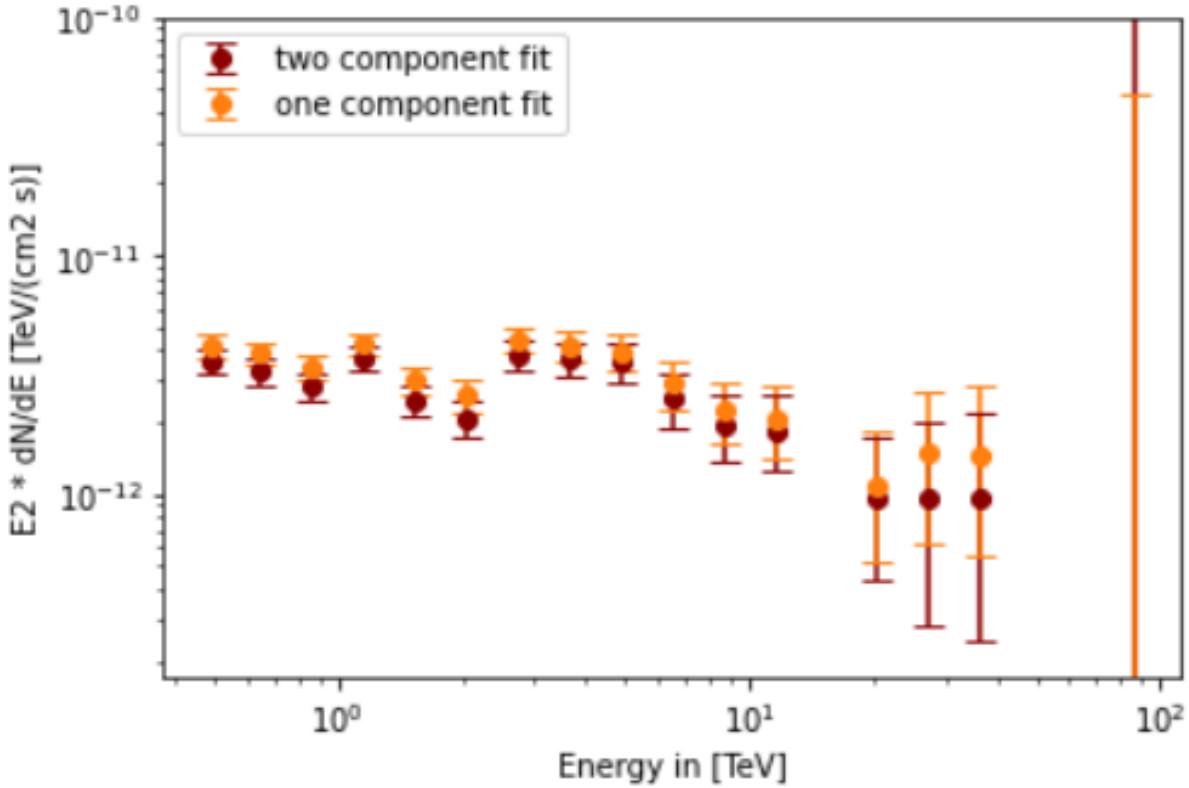


parameter of the bkg fit for fitting the whole data in the observation

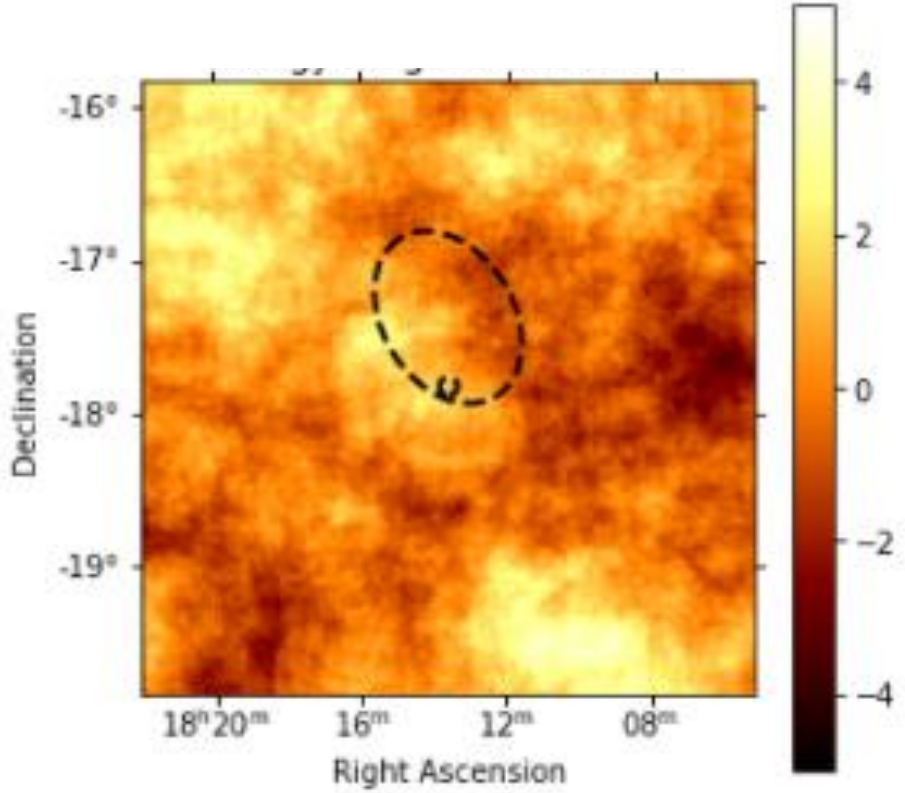


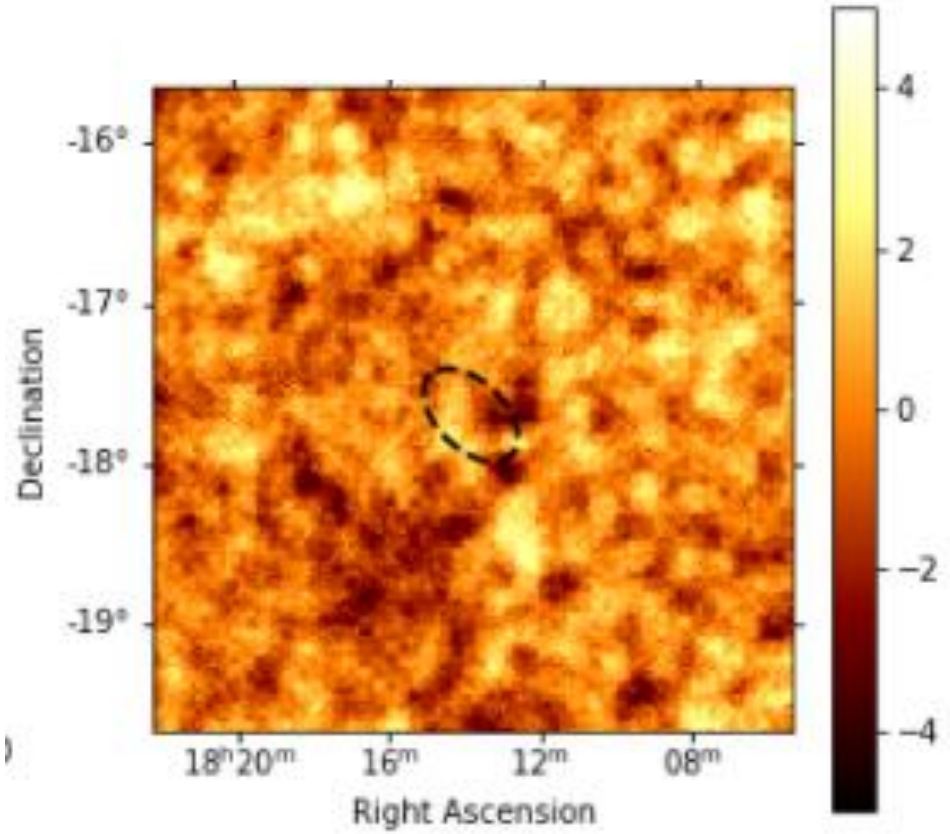


Influence of second component

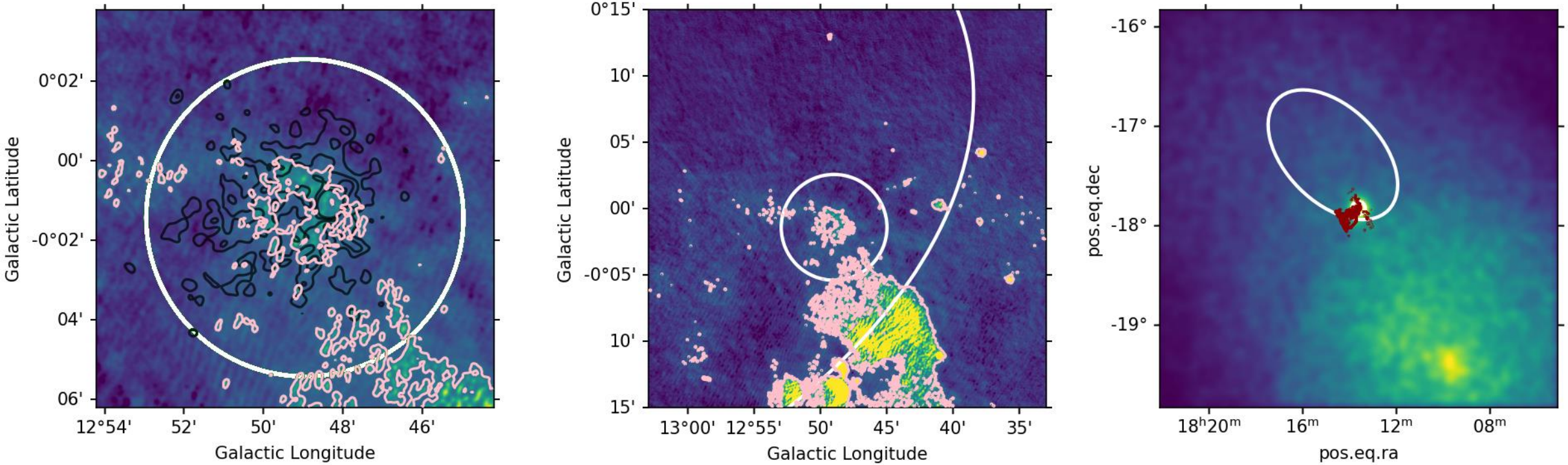


Joint-fit


-16°
-17°
-18°
-19°
Declination
18h20m
16m
12m
08m
Right Ascension
4
2
0
−2
−4

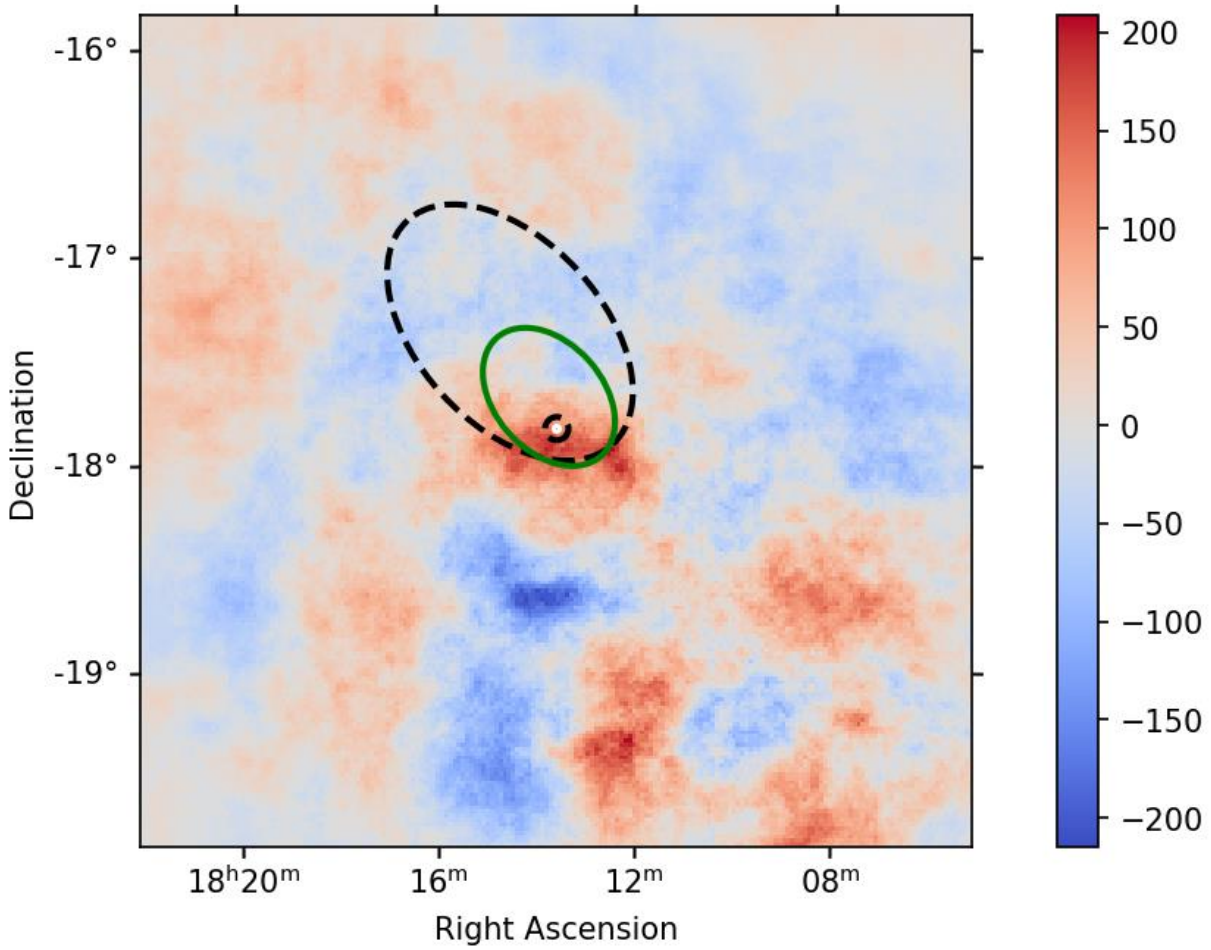

-16°
-17°
-18°
-19°
Declination
18h20m
16m
12m
08m
Right Ascension
4
2
0
−2
−4

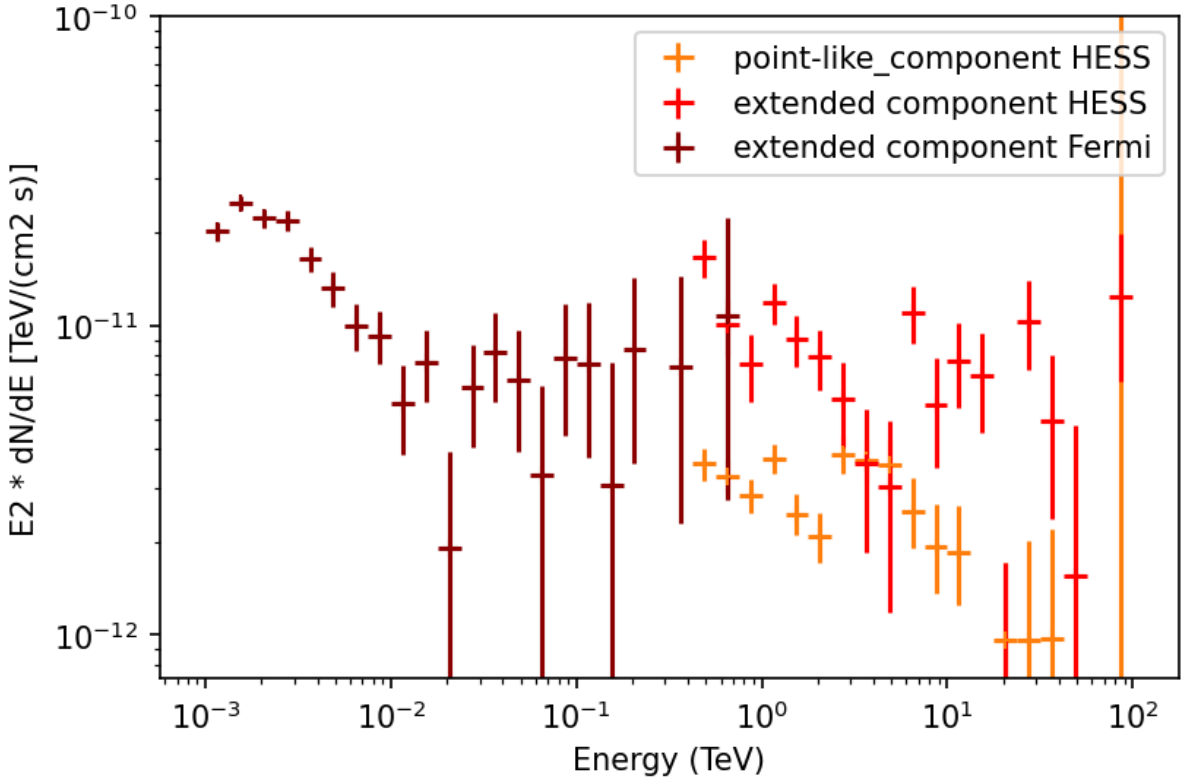
Multi-wavelength context



- Positional coincidence between PSR (XMM-Newton data in black) and SNR (pink/red)
- Positional coincidence between compact HESS source (white) and SNR
- Association between W33 and HESS emission possible

Comparison between HESS and Fermi-LAT best fit:





Alternative Models: