Friedrich-Alexander-Universität
Erlangen-Nürnberg

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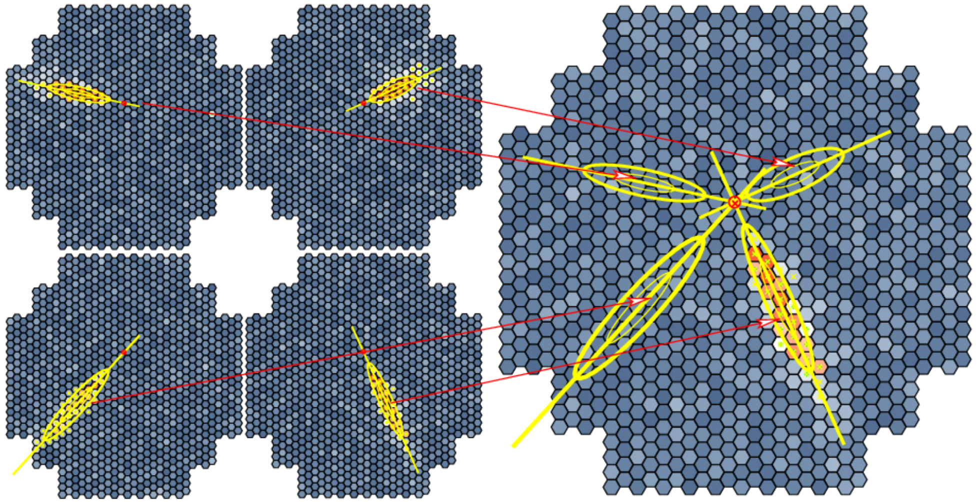
Muon tagging and multi-instrument analysis of the γ-ray emission in the region of Pulsars

Tina Wach
Astroparticle School 2022
Obertrubach

H.E.S.S.

Image credit: HESS collaboration



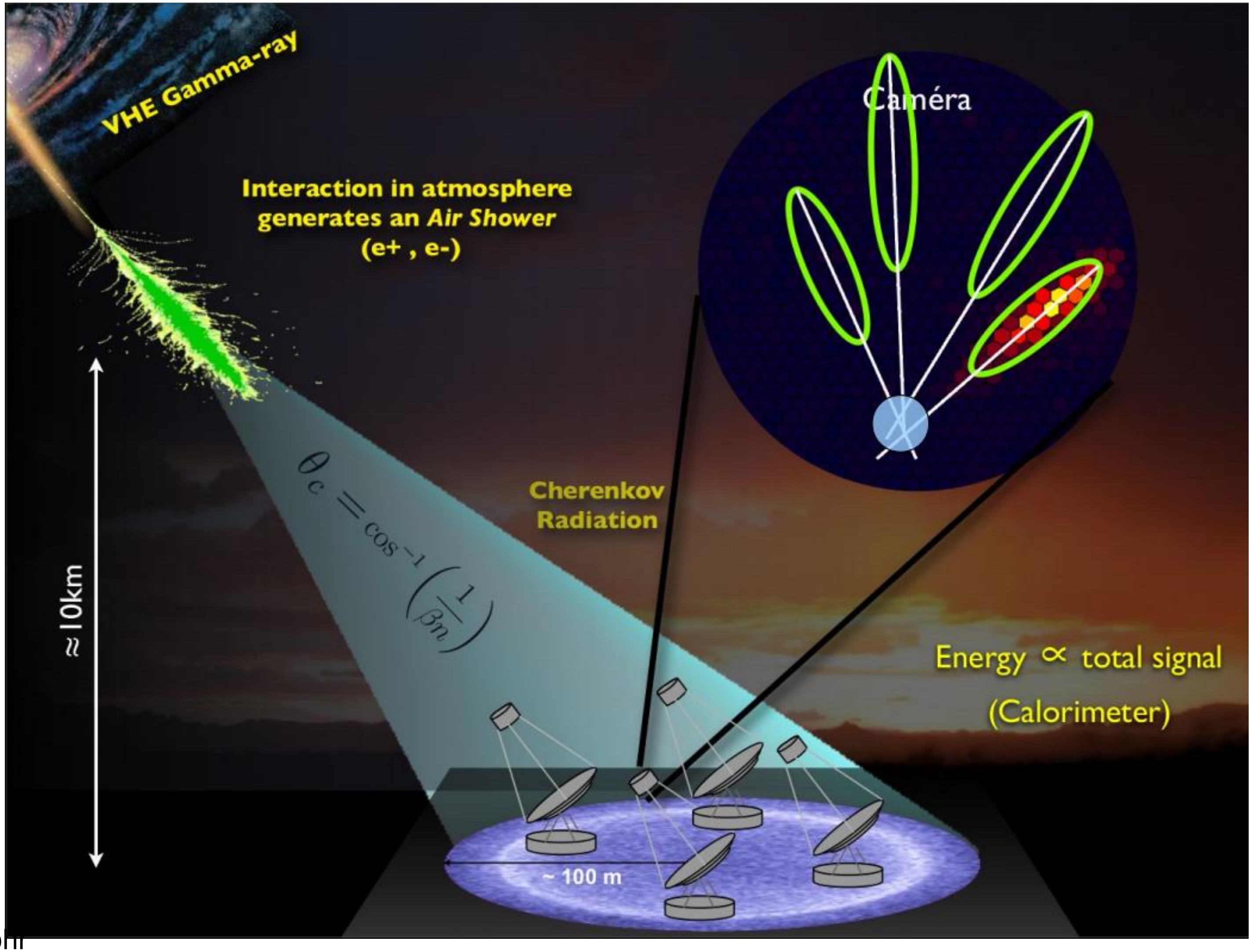
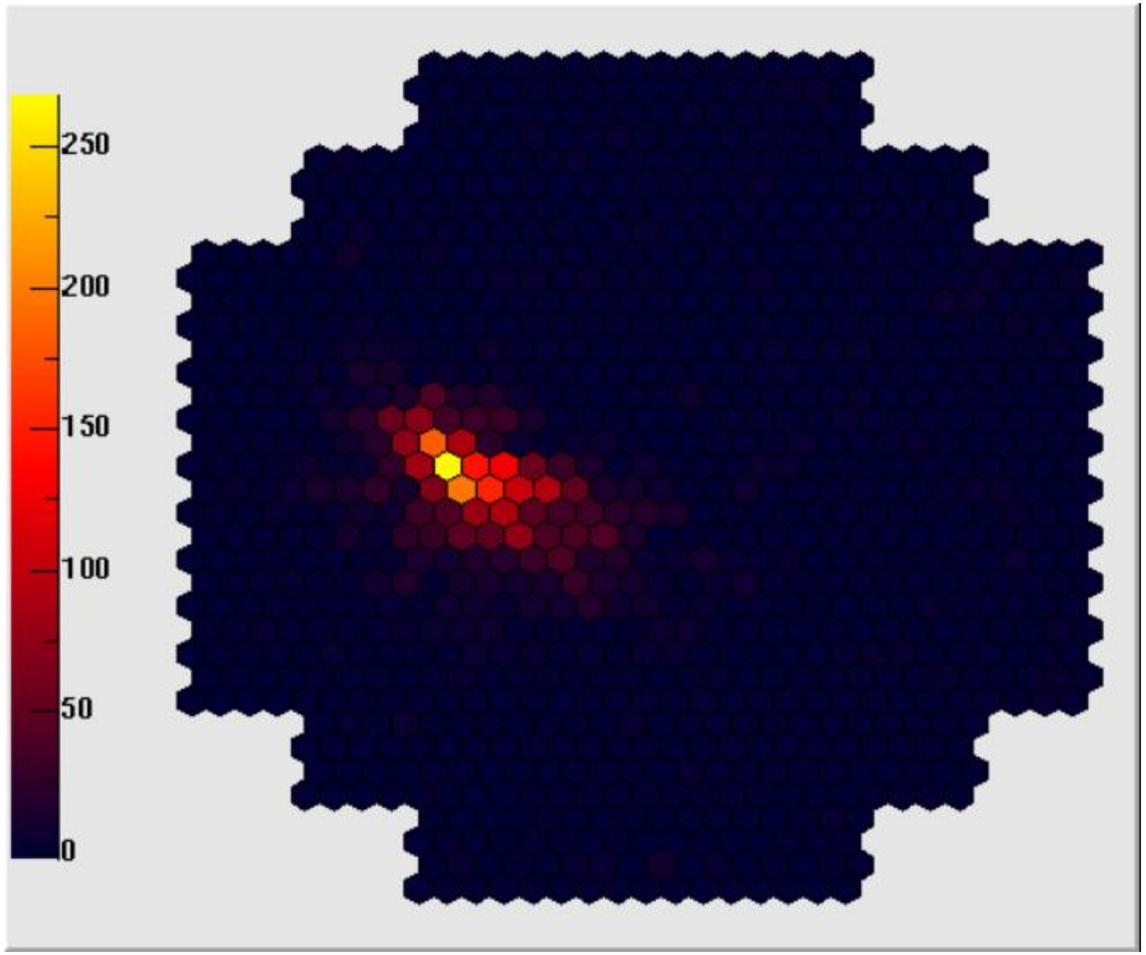
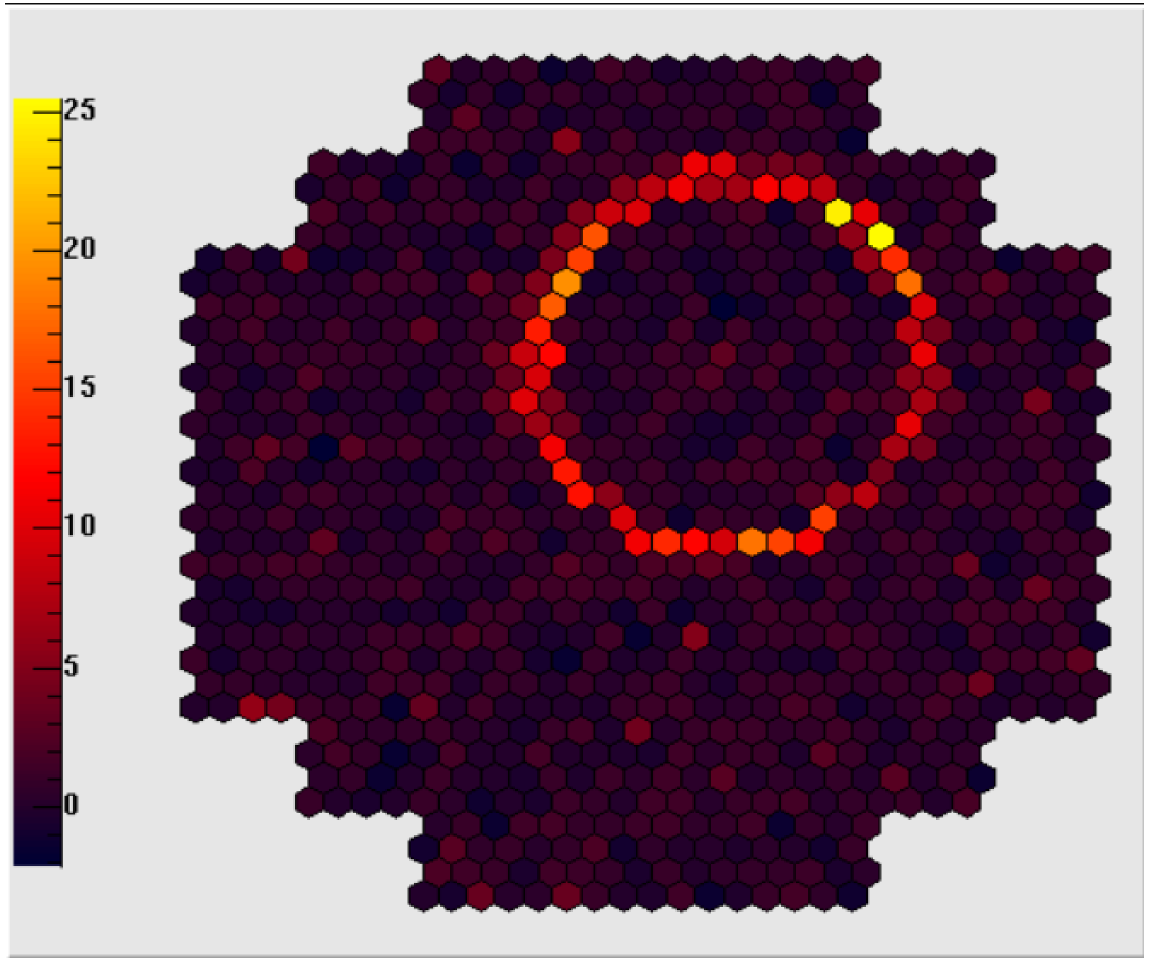


Image credit: K. Bernlöhr

Muon tagging using unsupervised machine learning algorithms

Signal reconstruction





Muon Tagging using unsupervised learning techniques

Muon Hunter project:
- VERITAS data
- Supervised learning
- Citizens labeling the training dataset

What will we gain?
- Increased background rejection
- Large dataset for calibration purposes

Muon tagging in H.E.S.S.

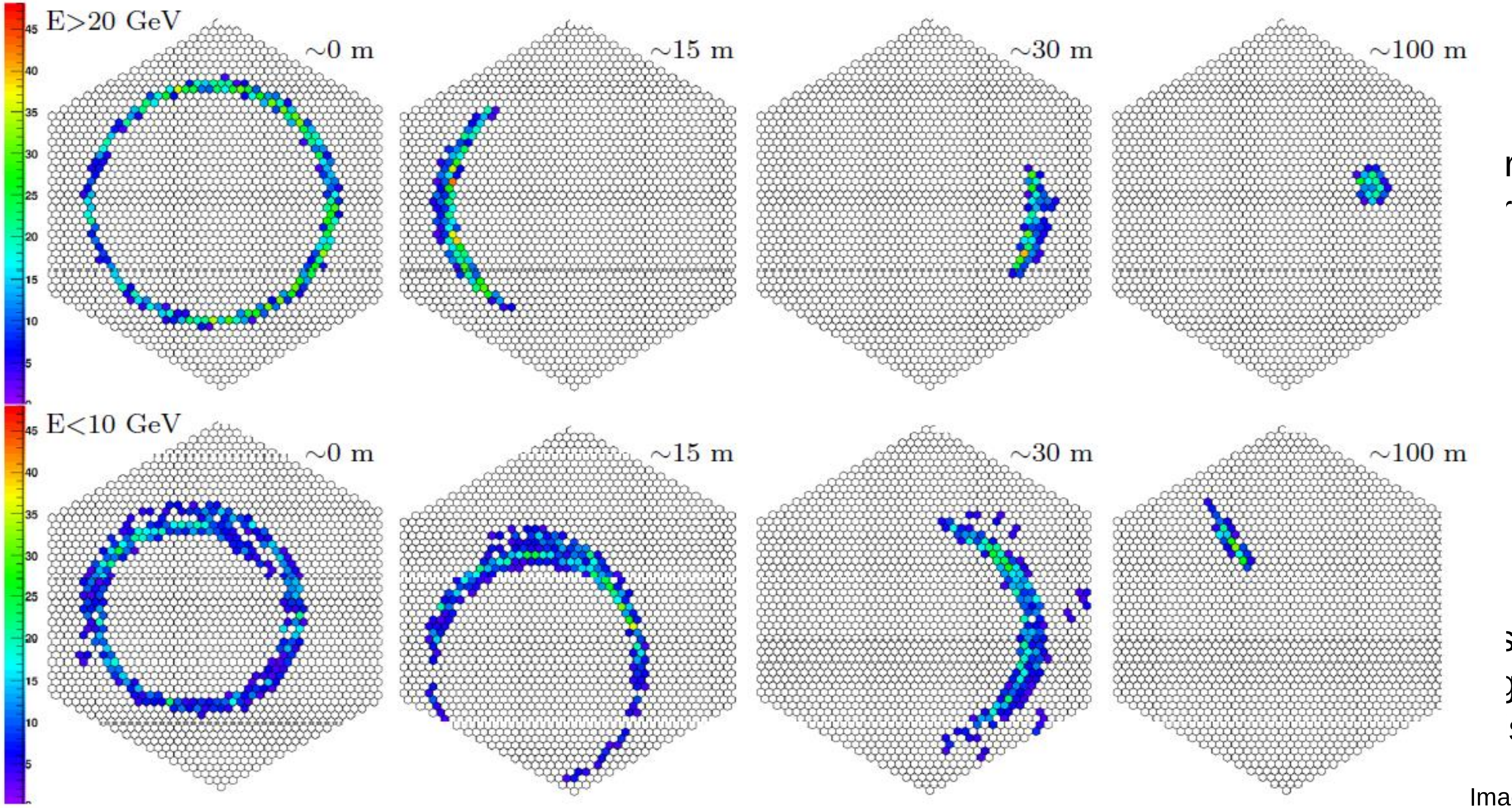
Why unsupervised?
- Less manpower required
- No human bias
- Improved results compared to labled test data shown

Possible Problems:
- Night sky background
- Large impact distance

Muon Tagging using unsupervised learning techniques

Muon
- VE
- Su
- Citi

round rejection
calibration



Why uns
- Less
- No h
- Impr
test c

s:
ground
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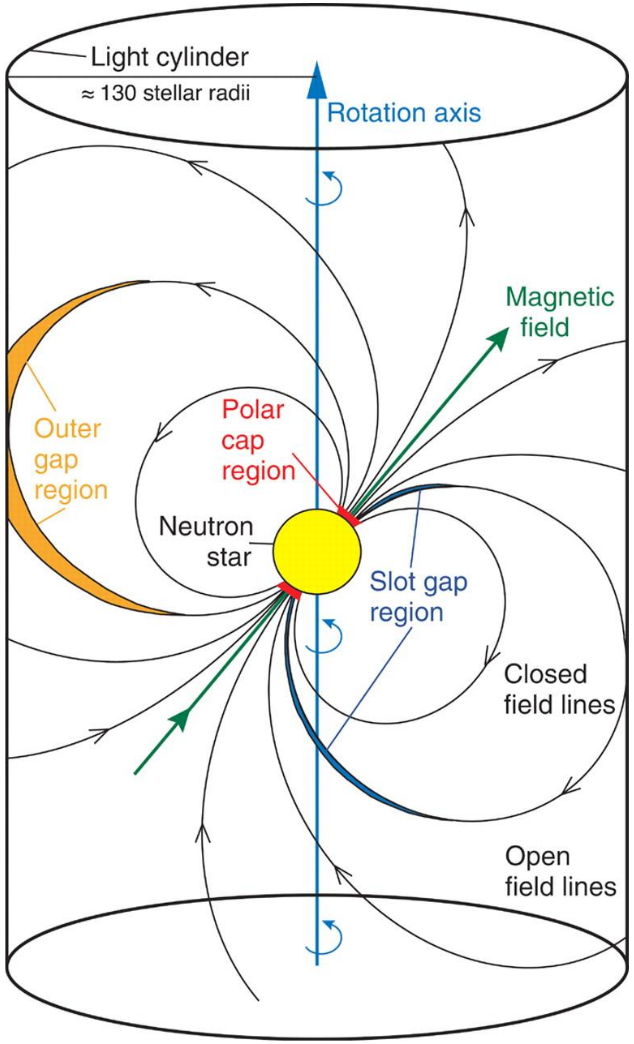
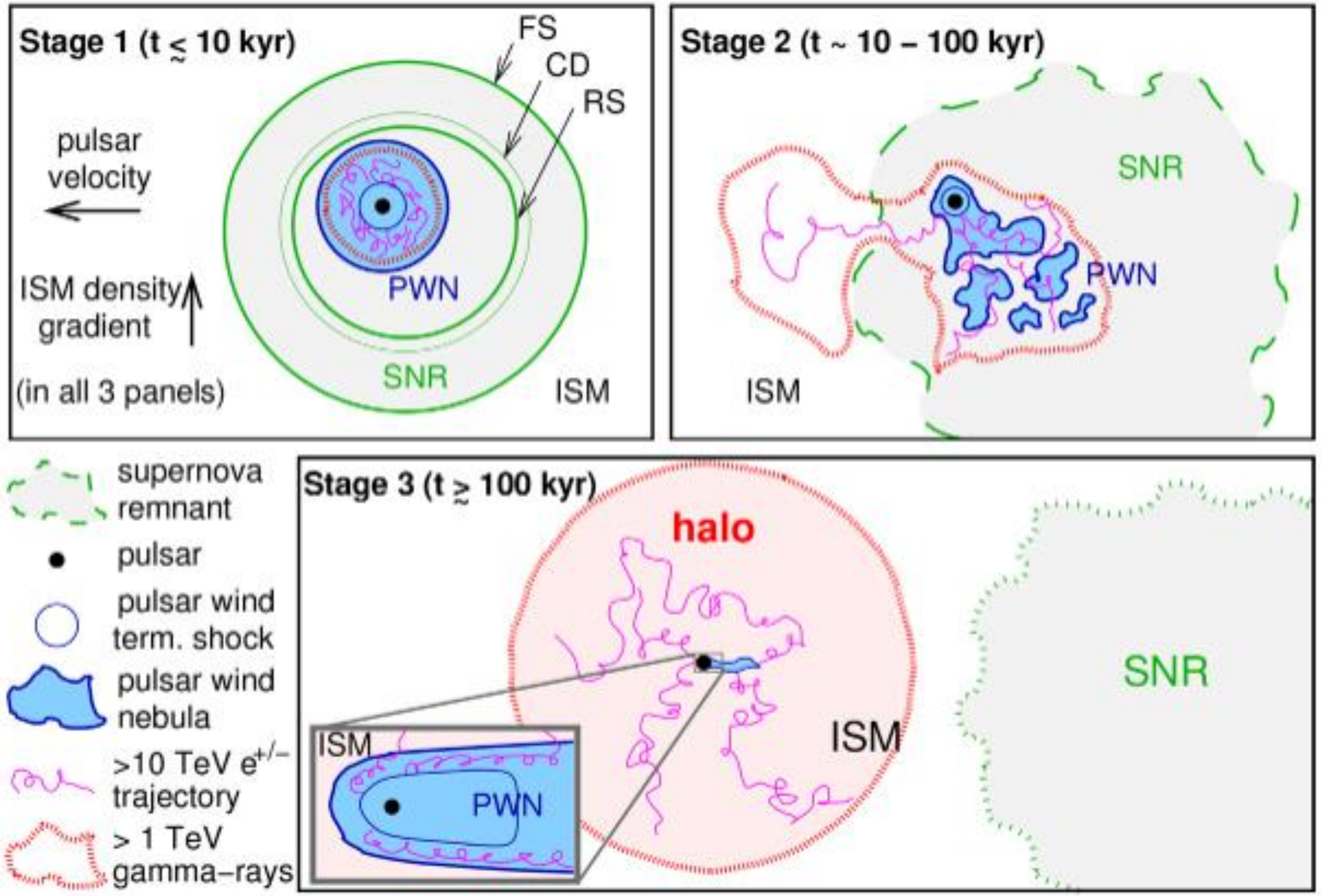
Image credit: L. Olivera-Nieto

Extended γ-ray sources in Pulsar environments: HESS J1813-178

Pulsars and their Nebulae

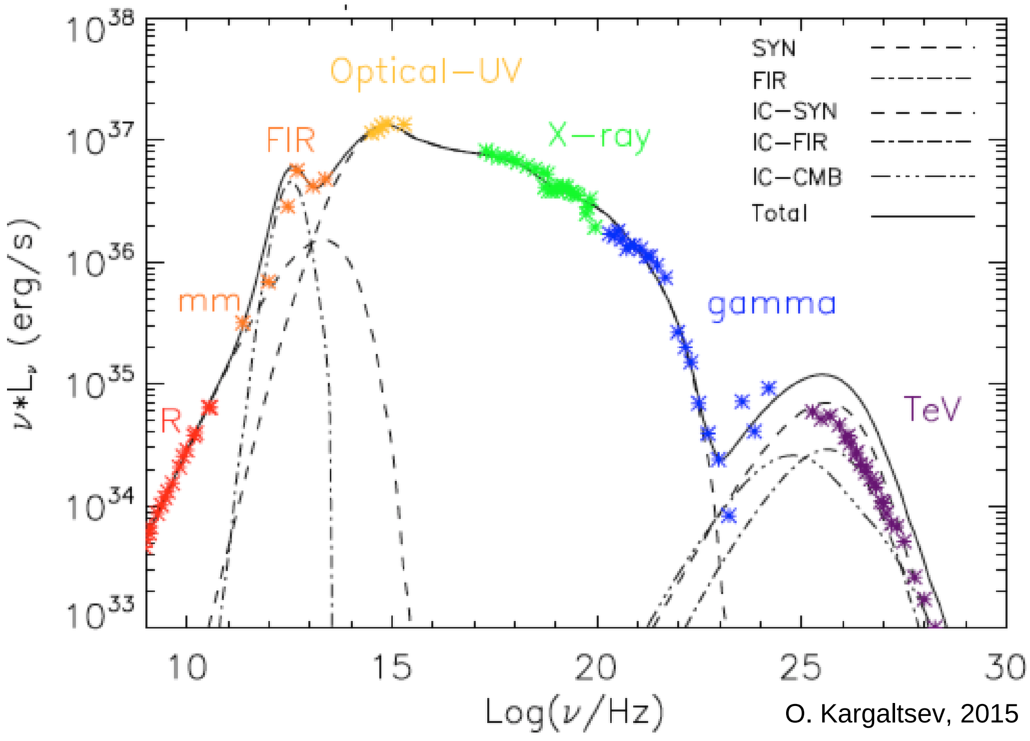


Magic Collab. 2008

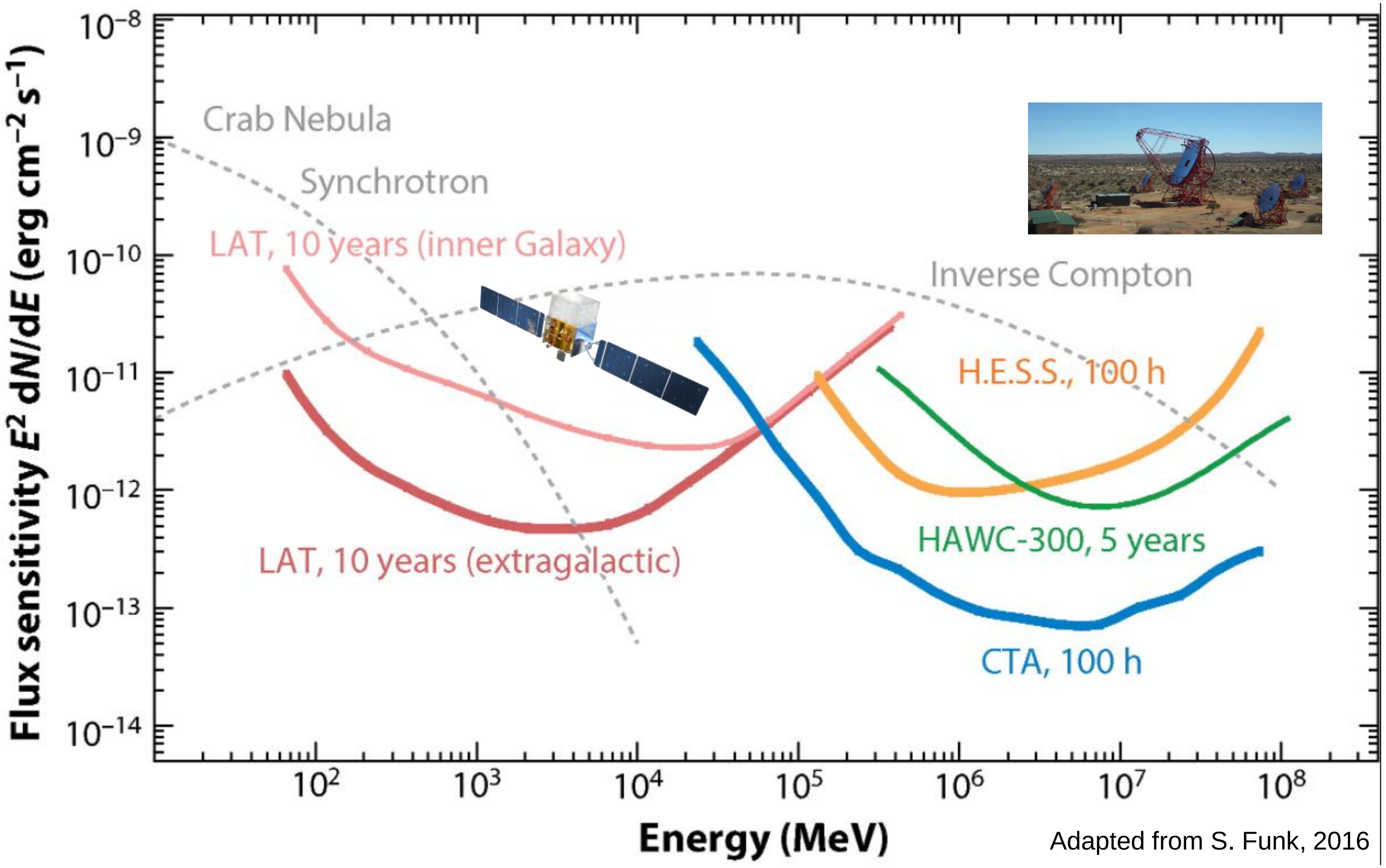


G. Giancinti. 2020

Why multi-instrument analysis?



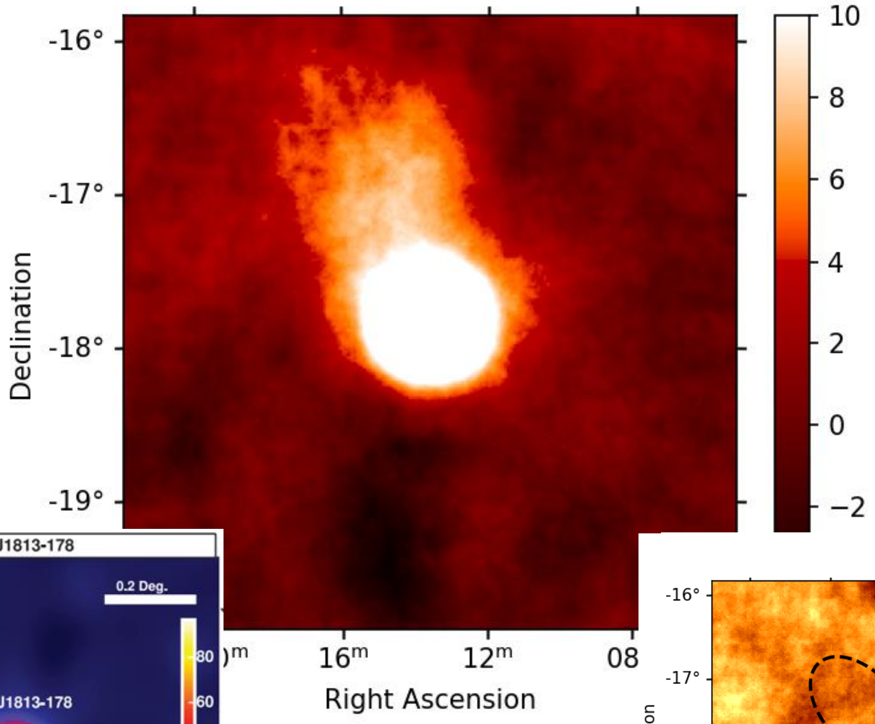
O. Kargaltsev, 2015

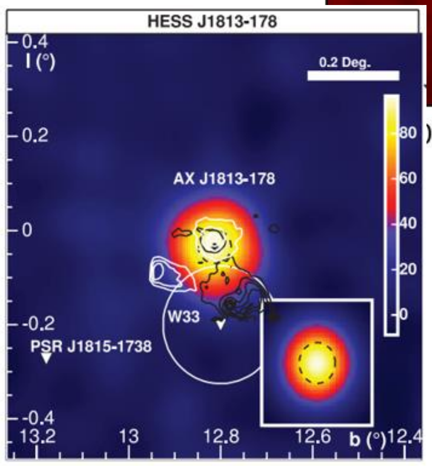


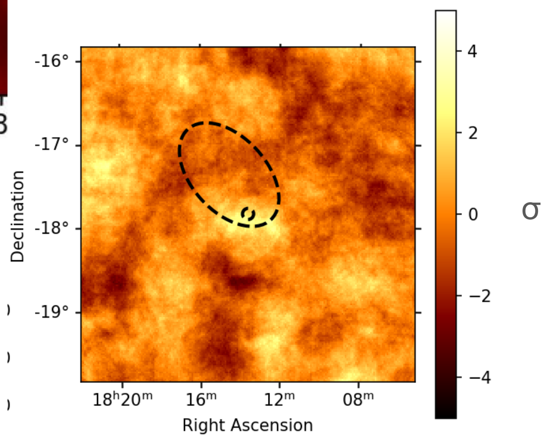
Adapted from S. Funk, 2016

HESS J1813-178: Spectral and morphological analysis

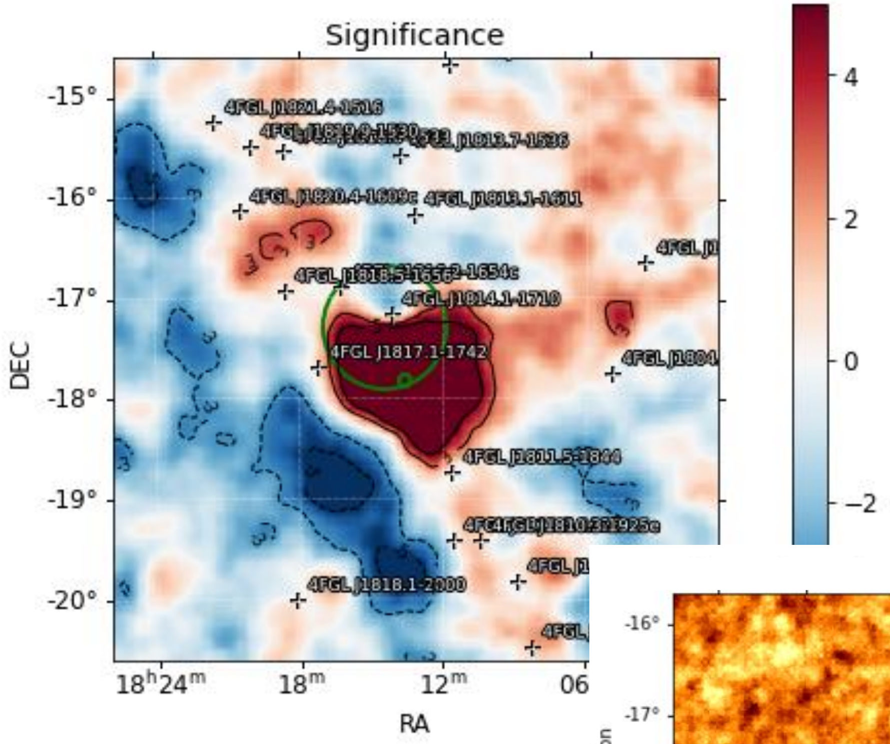
HESS Data:

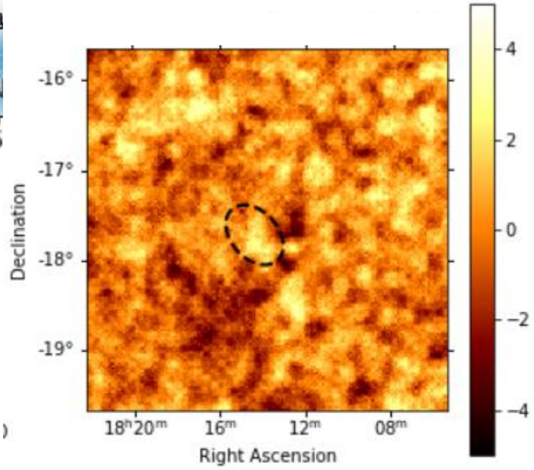






Fermi-Data:



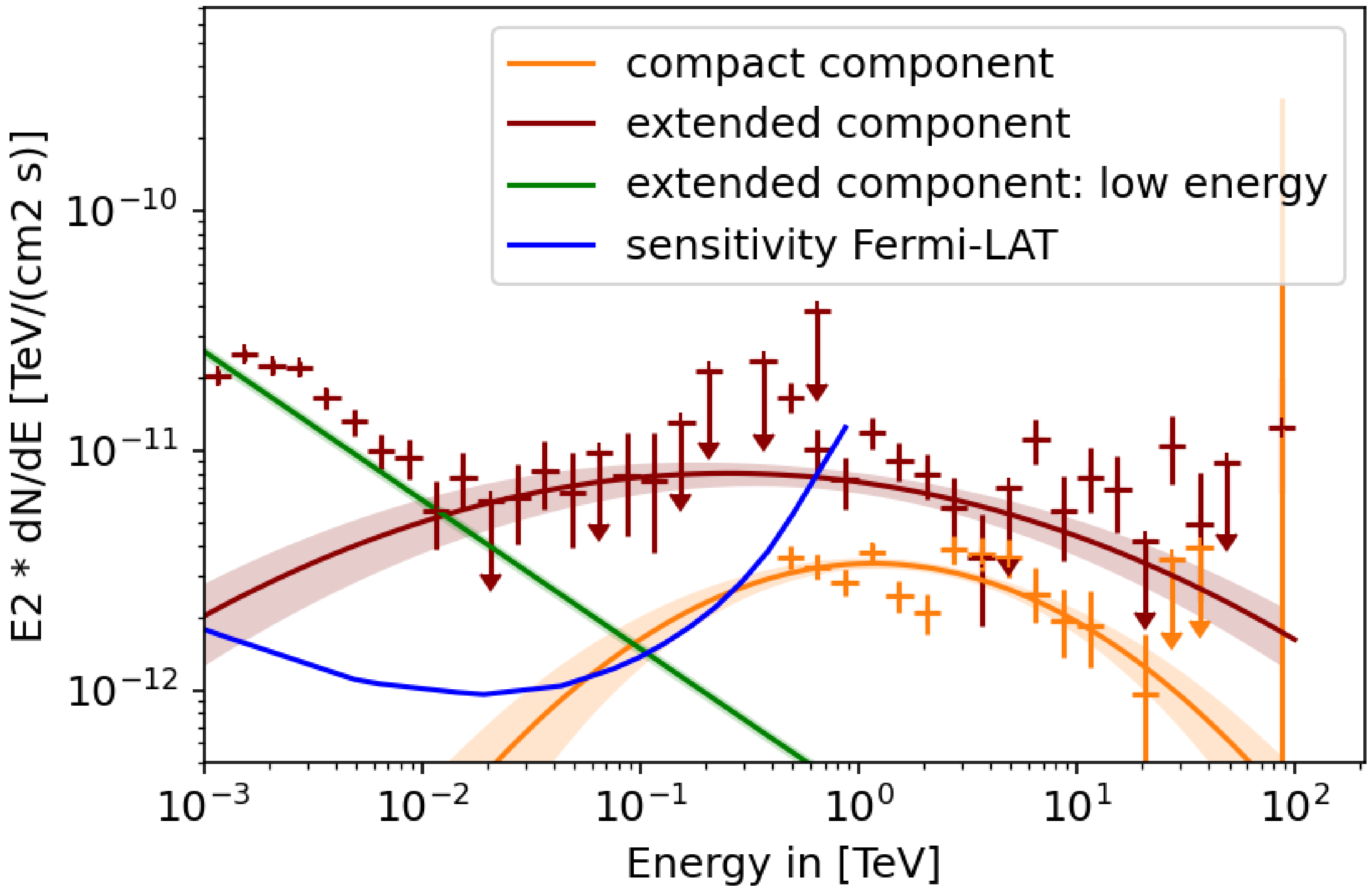


HESS Collab., 2006

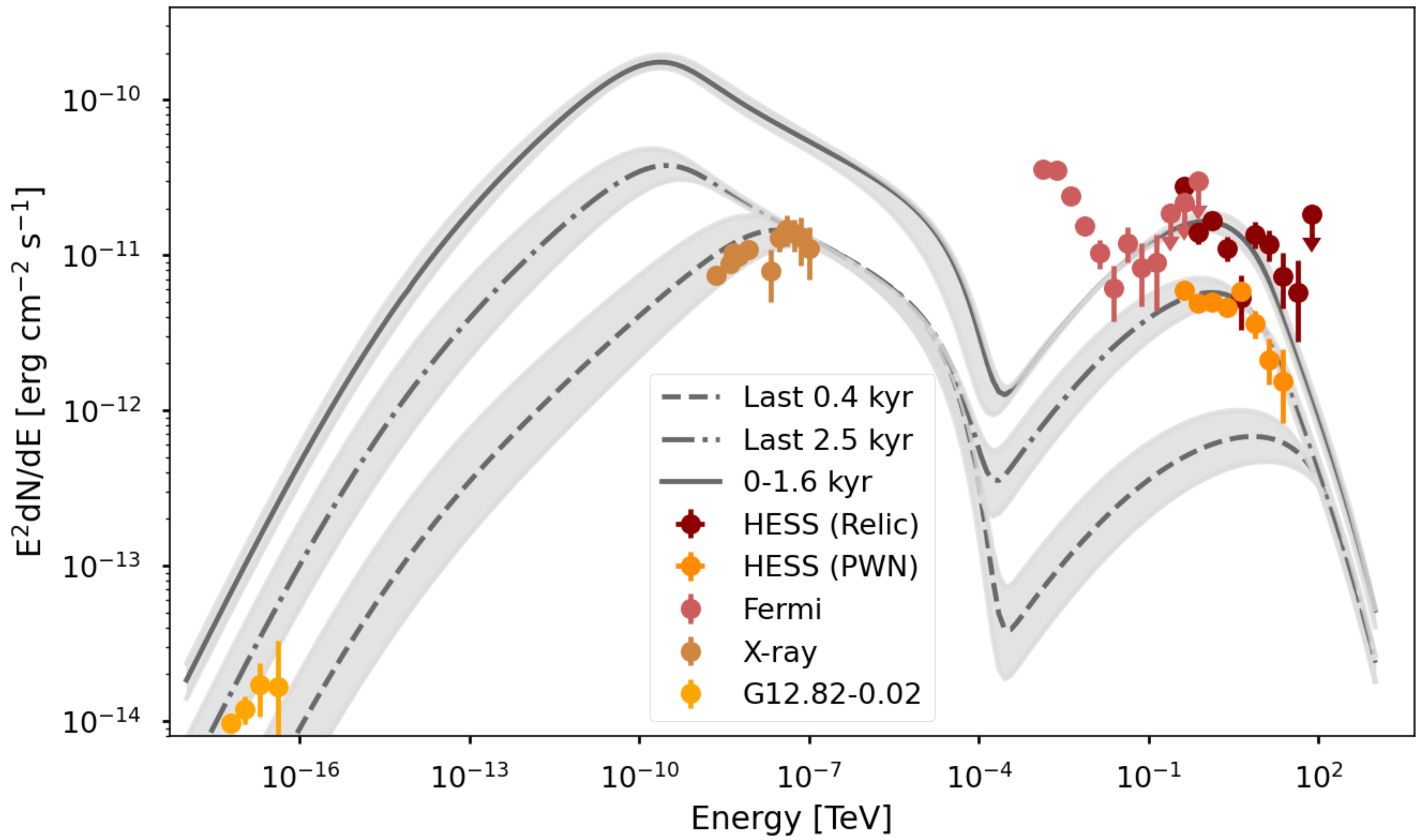
HESS/Fermi: Joint-Model

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



Leptonic Model



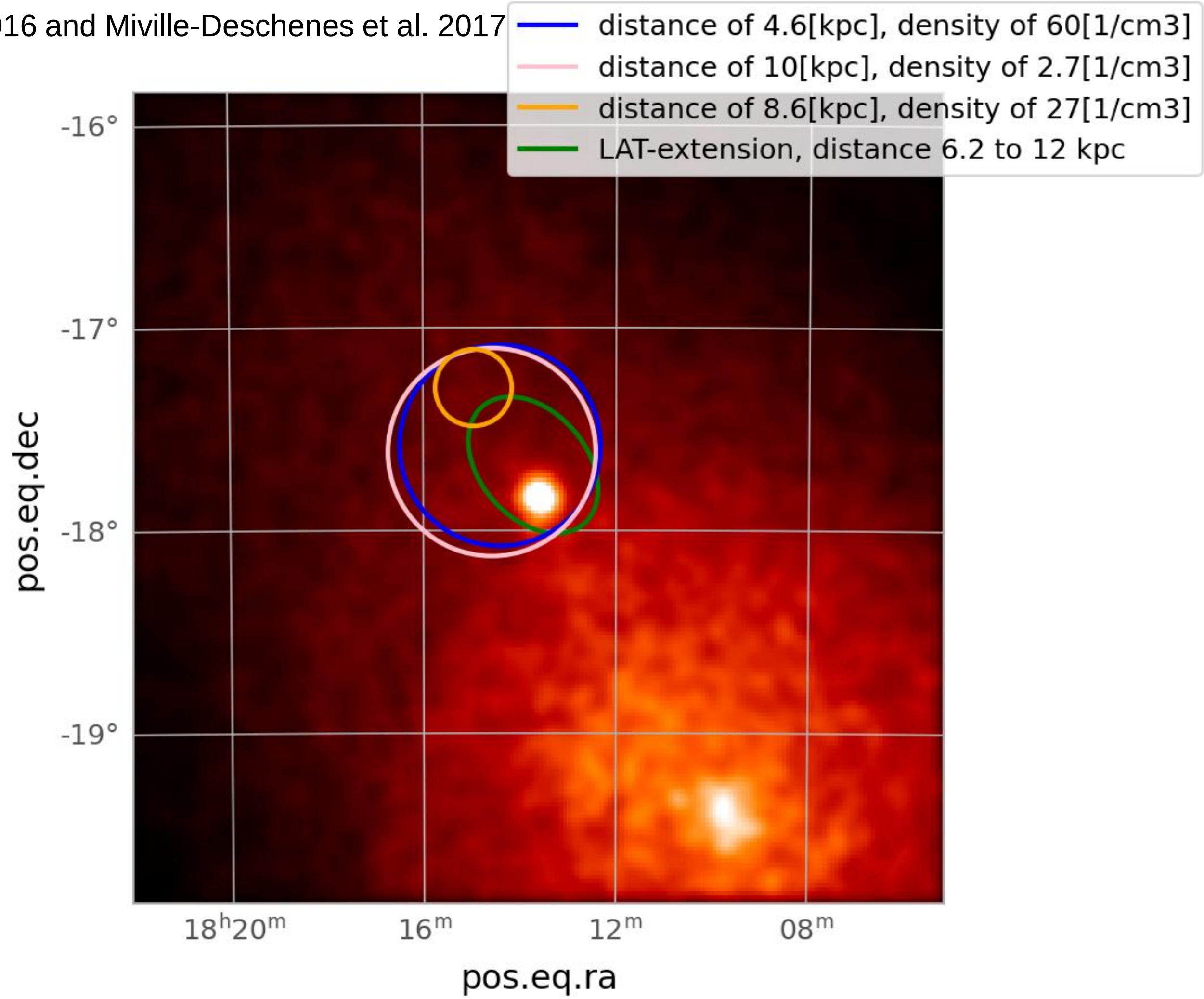
Assumptions:
- Distance: 6.2 kpc
- E_dot = 5.6e37 erg/s
- P = 44.7e-3 s
- P_dot = 1.26999e-13 s/s
- Braking index = 3.0
- Braking energy = 100 GeV
- Spectral index = 1.5

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

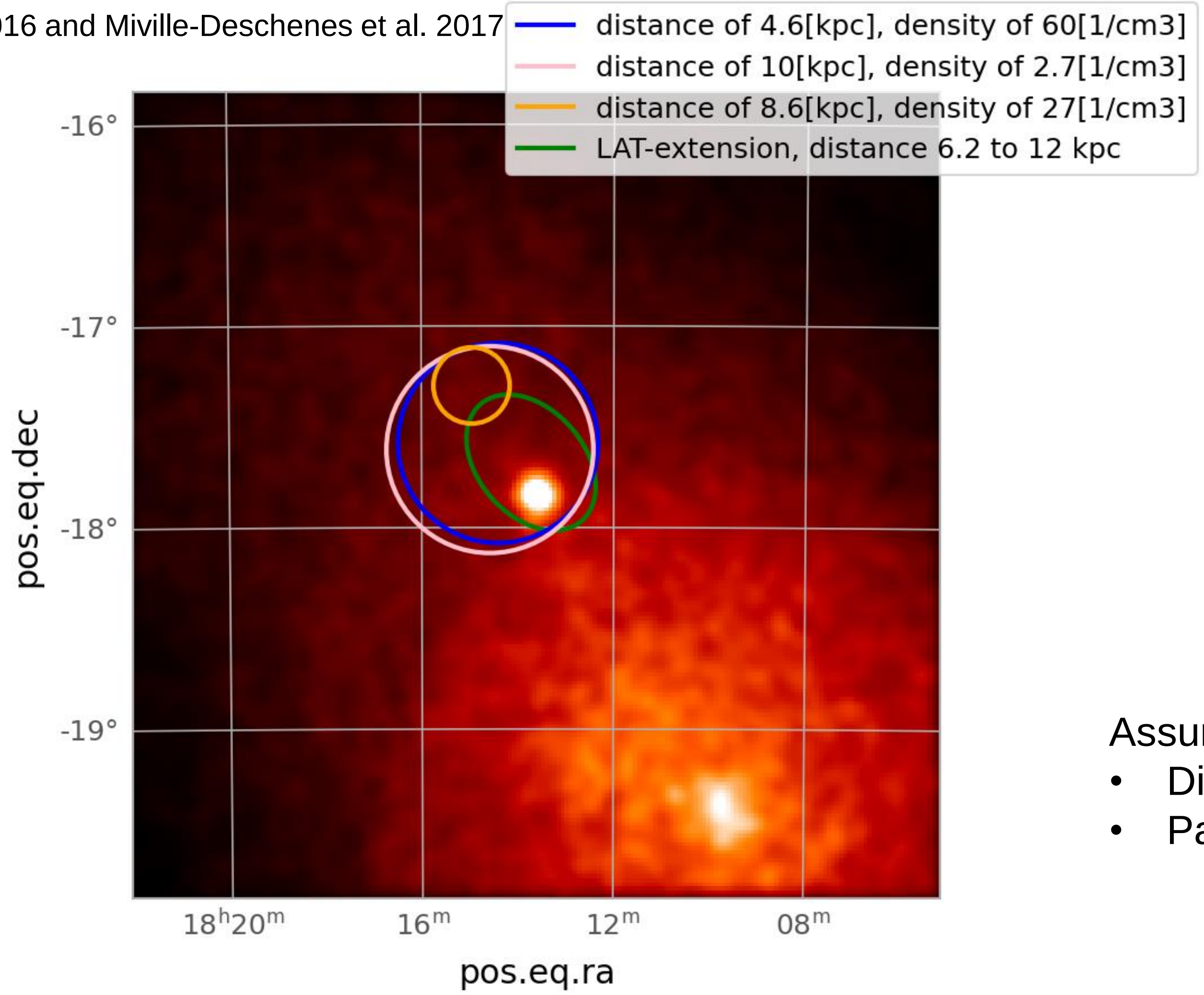
Molecular clouds in the region

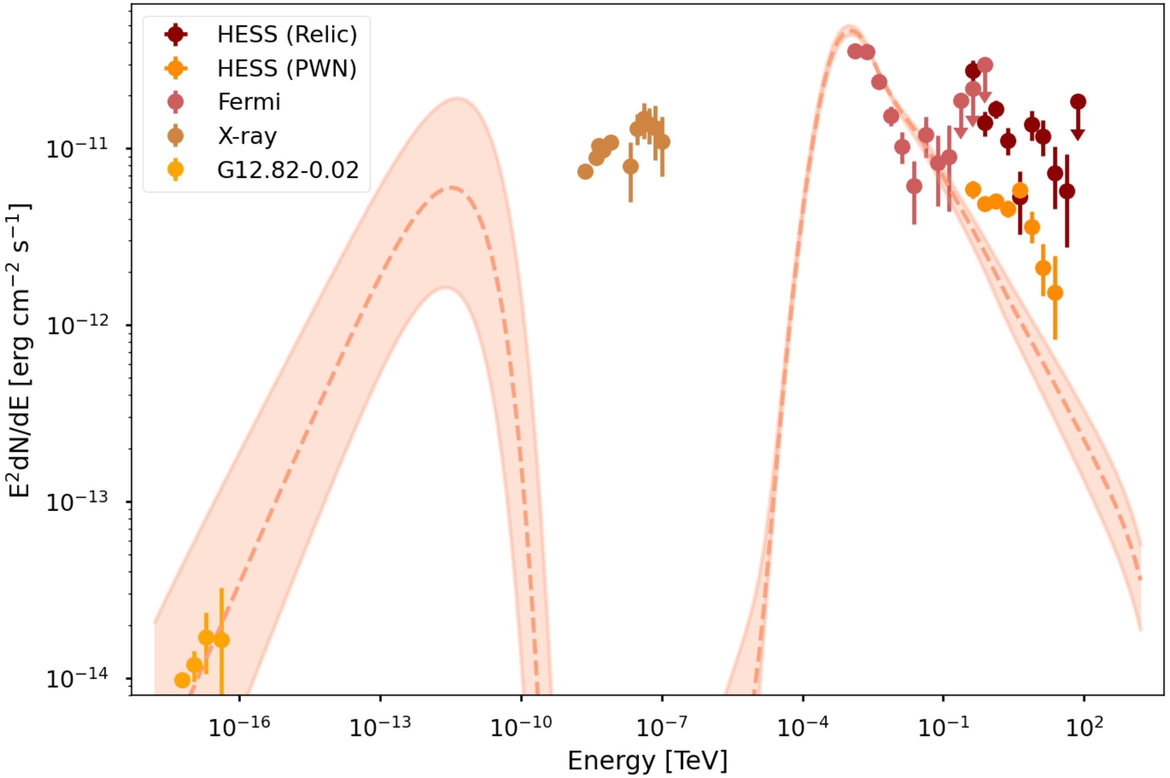
Molecular cloud information from Rice et. al. 2016 and Miville-Deschenes et al. 2017



Molecular clouds in the region

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





Assumptions:

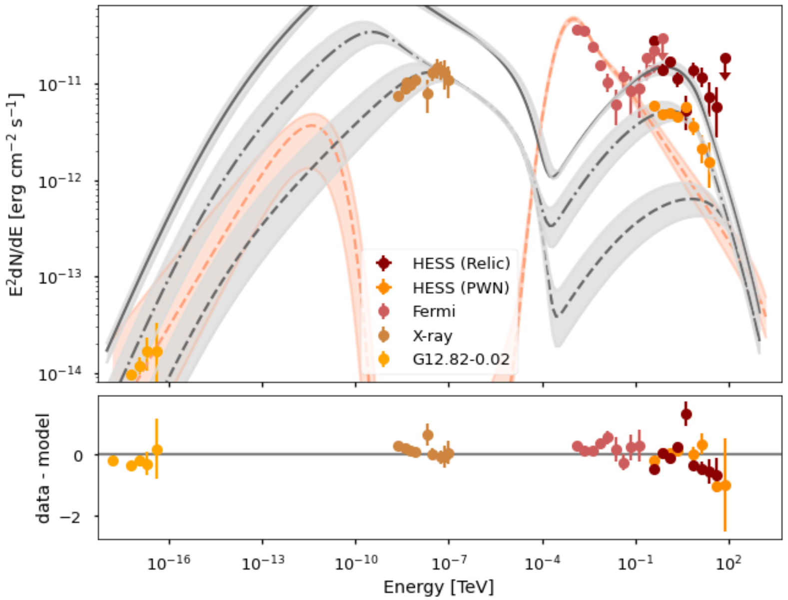
- Distance: 6.2kpc
- Particle density = 60 1/cm3

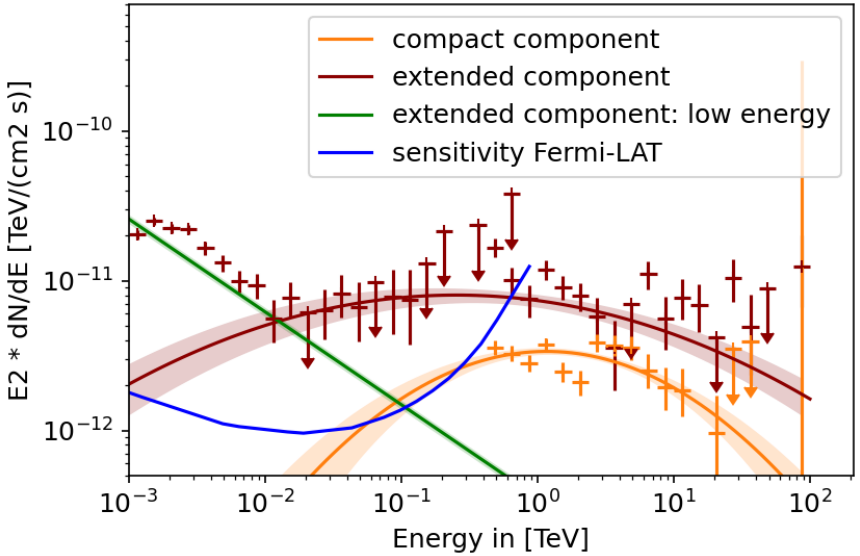
Fit parameters:

- 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

- Improvement of Muon tagging in IACT arrays
→ Improvement of background rejection
→ Improves the detectability of faint, diffuse sources
- Multi-Instrument Analysis of emission around Pulsars
- Example: HESS J1813-178
    - Detection of extended emission
    - Extended emission in TeV energy can be explained by electrons that escaped the PWN





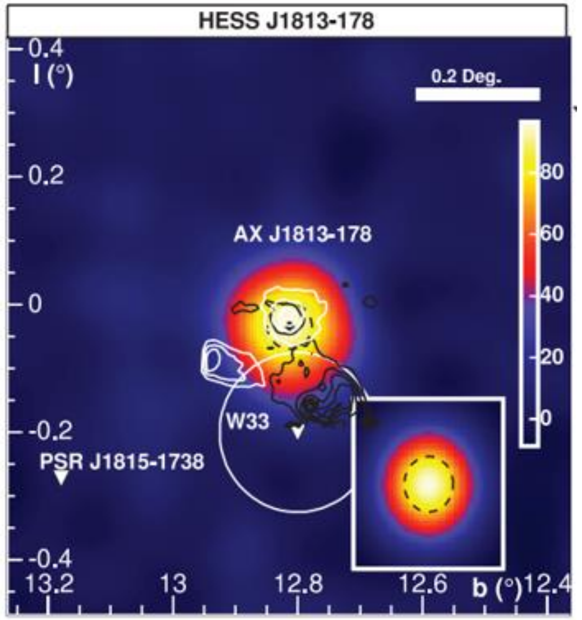
Backup slides

Detection and Categorization of HESS J1813-178

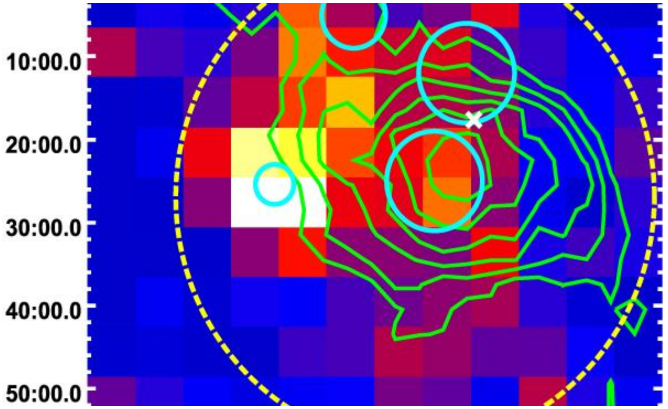
- Discovery: HGPS in 2005

→Compact source, extension of 0.04°

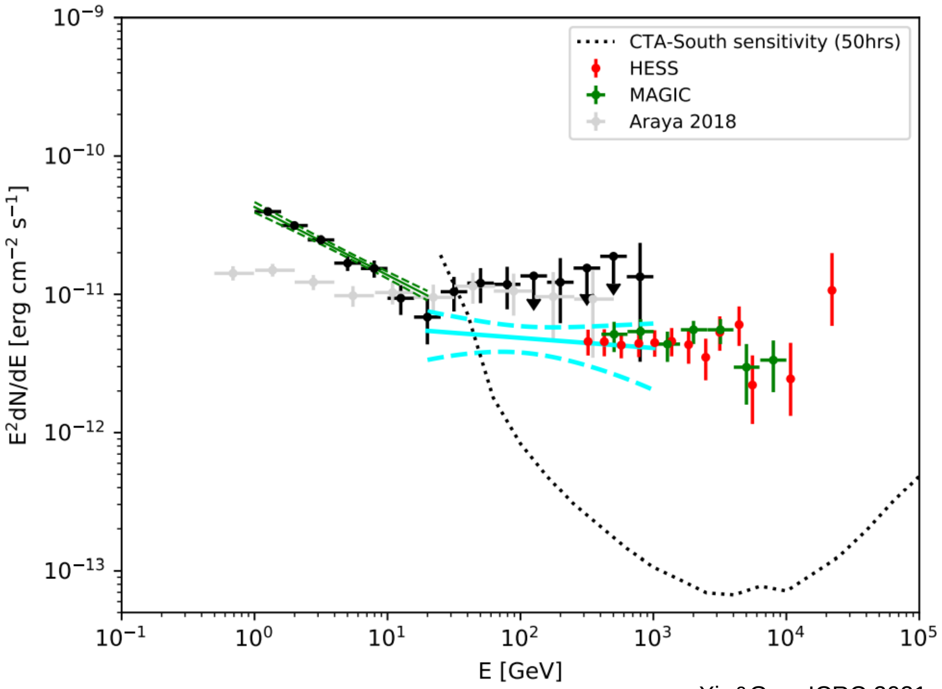
- Confirmation by MAGIC in 2006
- Positional coincidence with ASCA and INTEGRAL source
- Associated to young shell-like structure
- Detection of PSR J1813-1749 in 2009 indicates very young age
- Observation with Fermi-LAT reveal extended source of 0.6°



HESS Collab., 2006

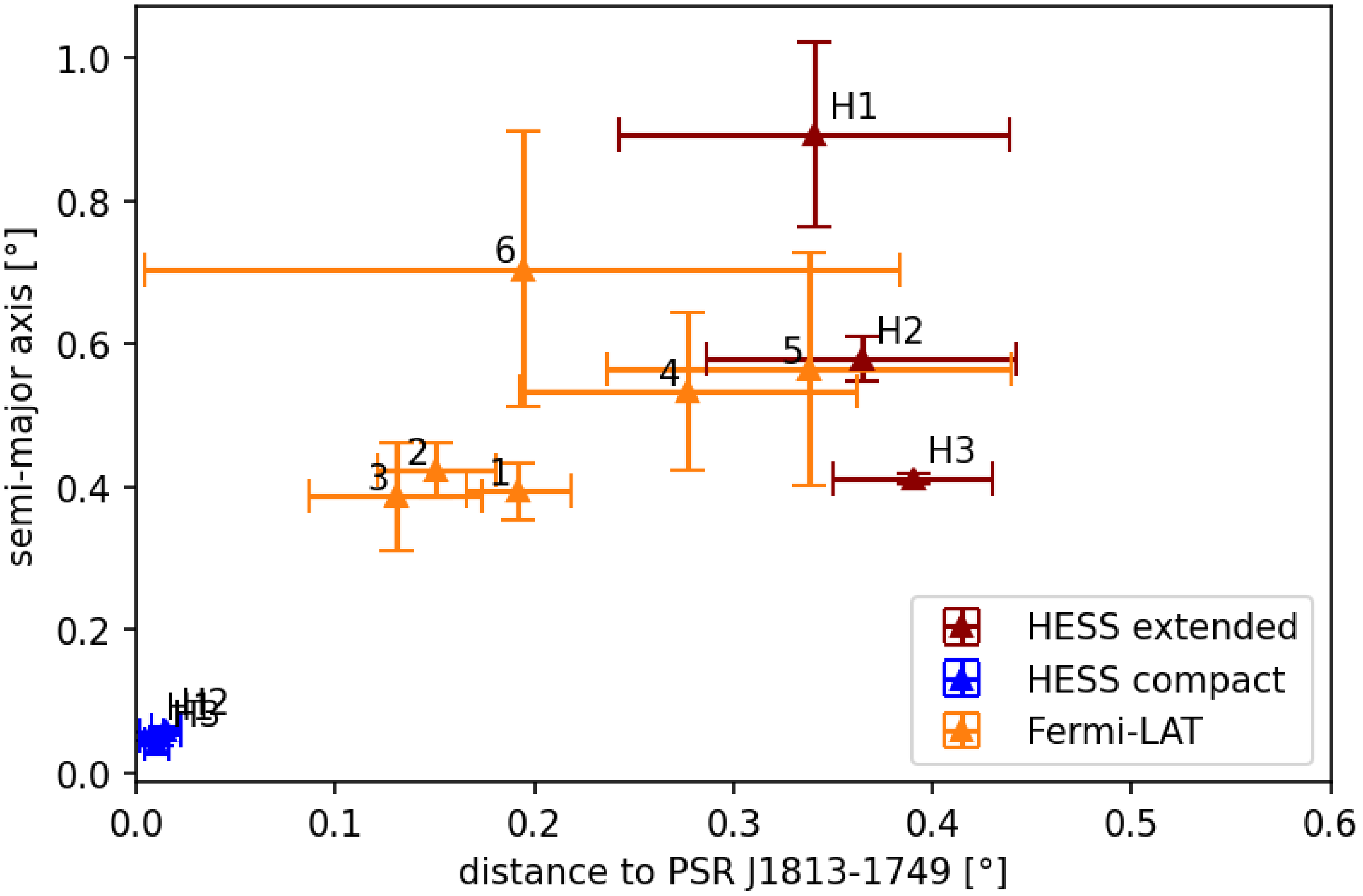


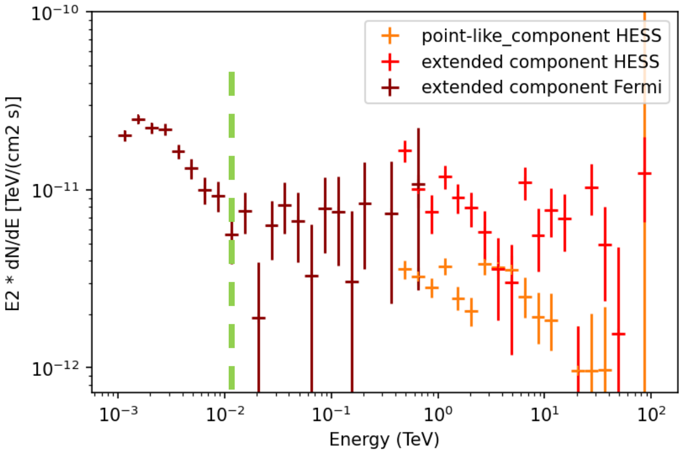
Miguel Araya, 2018



Xin&Guo, ICRC 2021

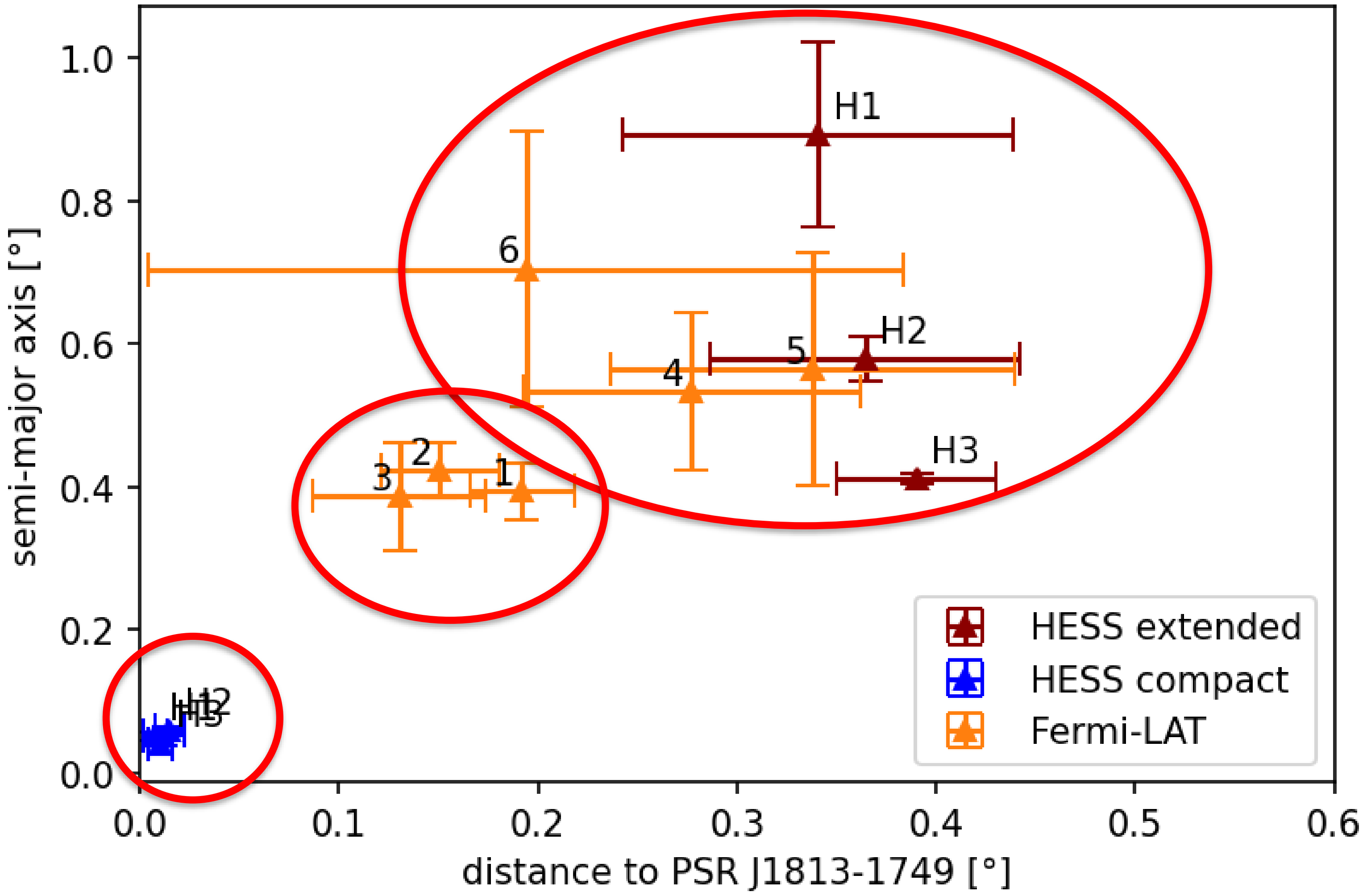
Energy dependence of the morphology

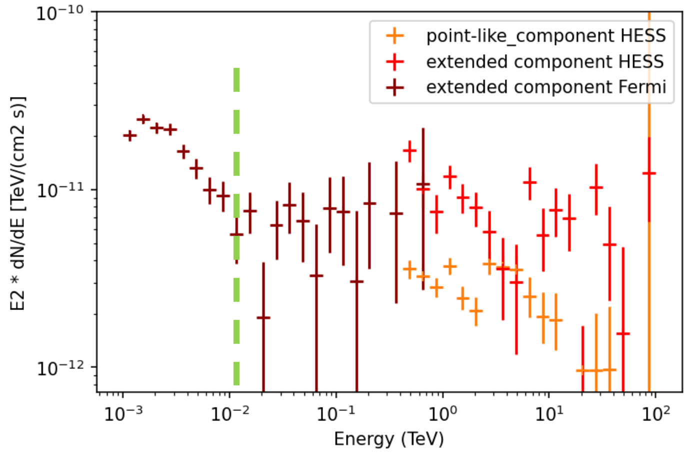




- Band 1: (1.0 - 2.0) GeV
- Band 2: (2.0 - 4.0) GeV
- Band 3: (4.0 – 7.5) GeV
- Band 4: (7.5 – 17.8) GeV
- Band 5: (17.8 – 56.0) GeV
- Band 6: (56.0 -1000) GeV
- Band H1: (0.4 – 1.0) TeV
- Band H2: (1.0 – 3.0) TeV
- Band H3: (3.0 – 100) TeV

Energy dependence of the morphology





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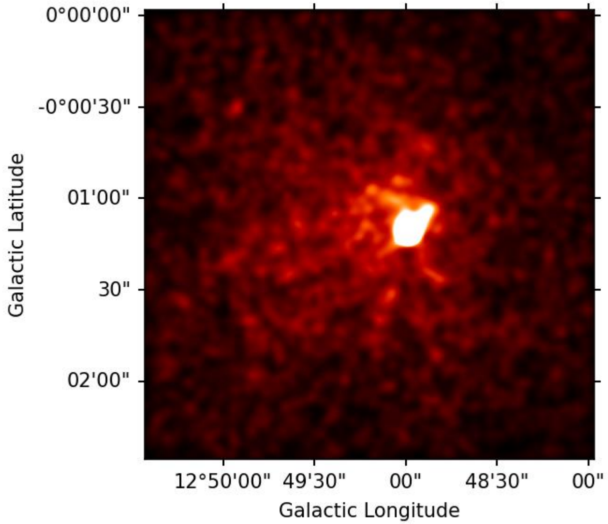
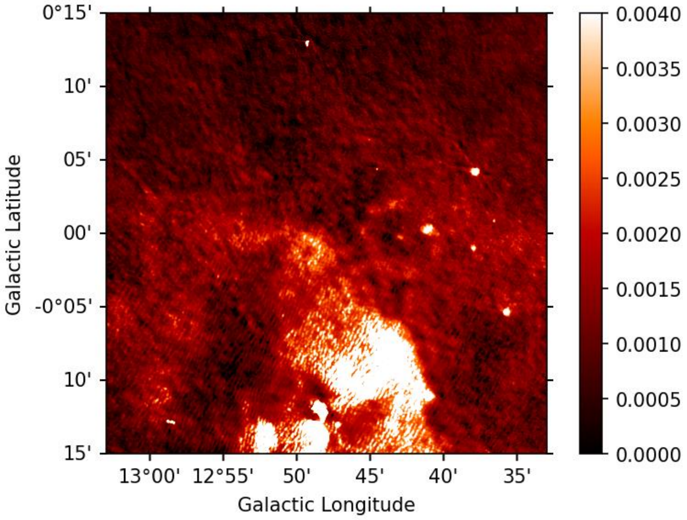
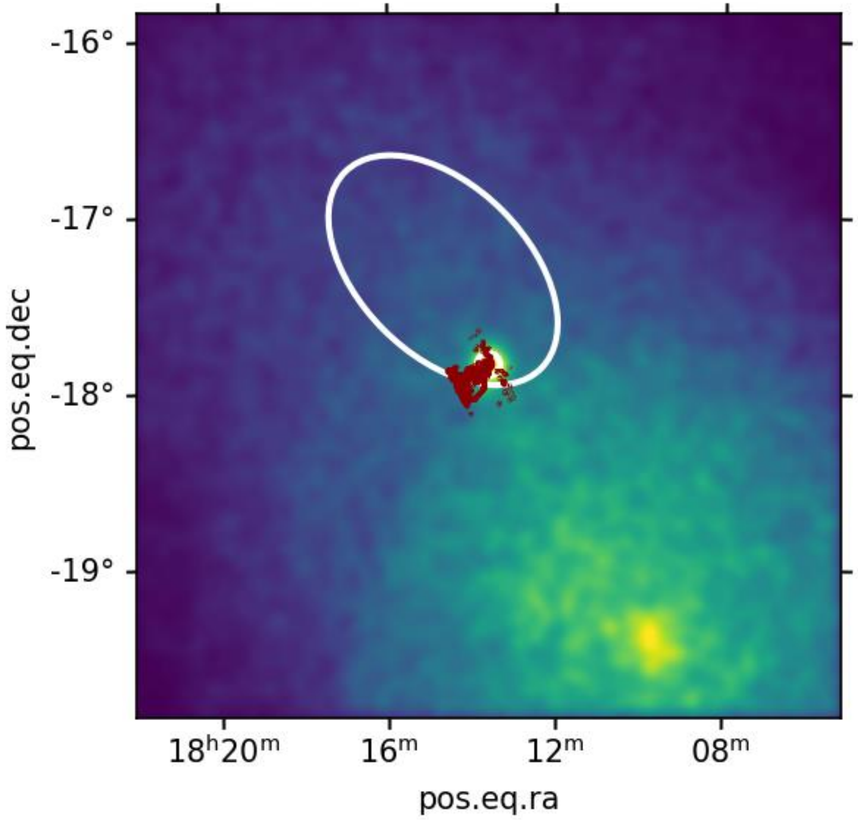
- Band 5: (17.8 – 56.0) GeV
- Band 6: (56.0 -1000) GeV
- Band H1: (0.4 – 1.0) TeV
- Band H2: (1.0 – 3.0) TeV
- Band H3: (3.0 – 100) TeV

Extended emission in the region of HESS J1813-178







PSR J1813-1749:

- 44.7 ms pulsar
- $\dot{E}$ = 5.6e37 erg/s
- True age estimated to 1.35 kyr
- Distance of 6.2 – 12 kpc

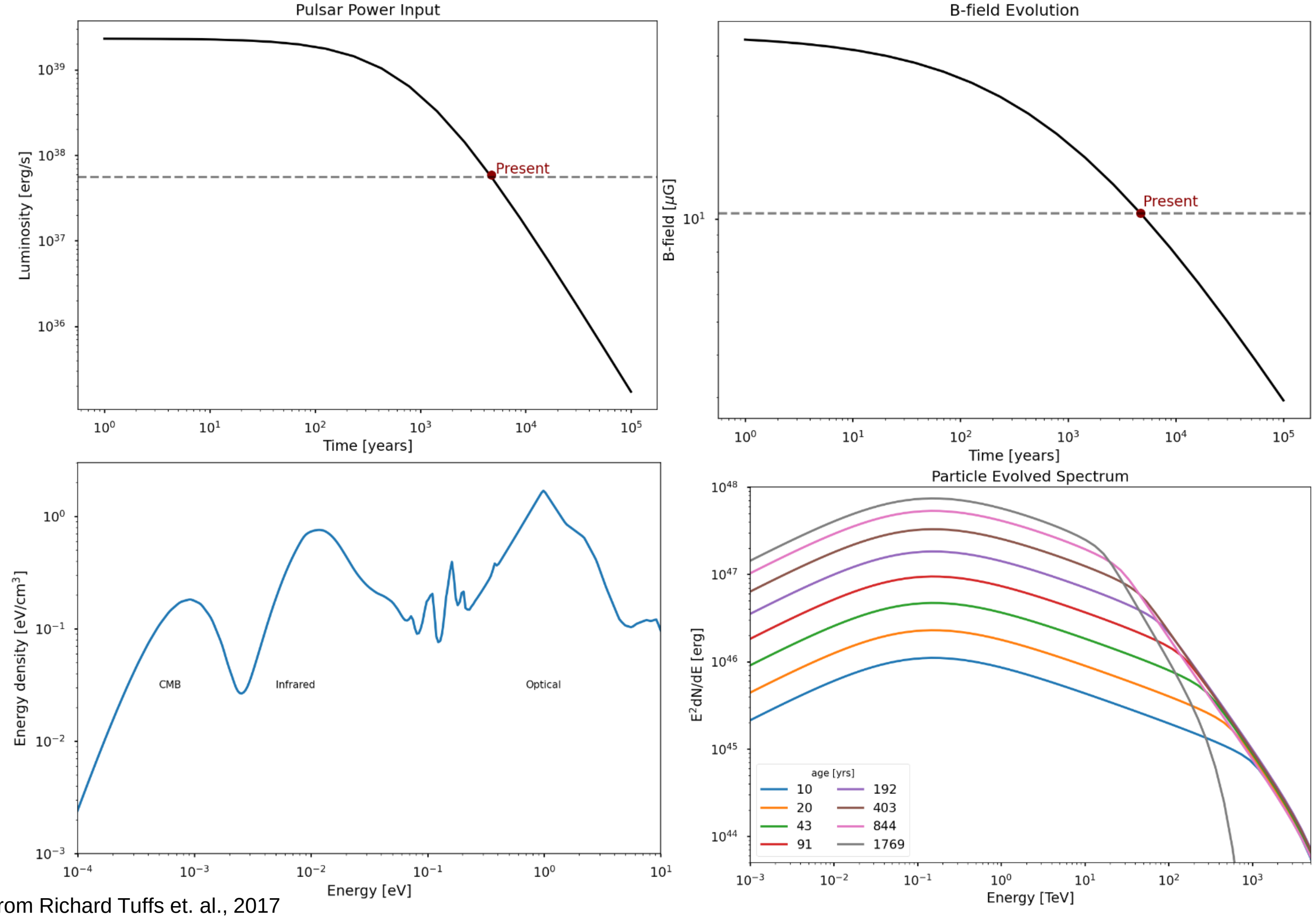
Cl J1813-178:

- Distance of 4.8 kpc
- Projected distance between HESS J1813-178 and cluster core 4.5‘

Two possible scenarios for extended emission:

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

Leptonic Model

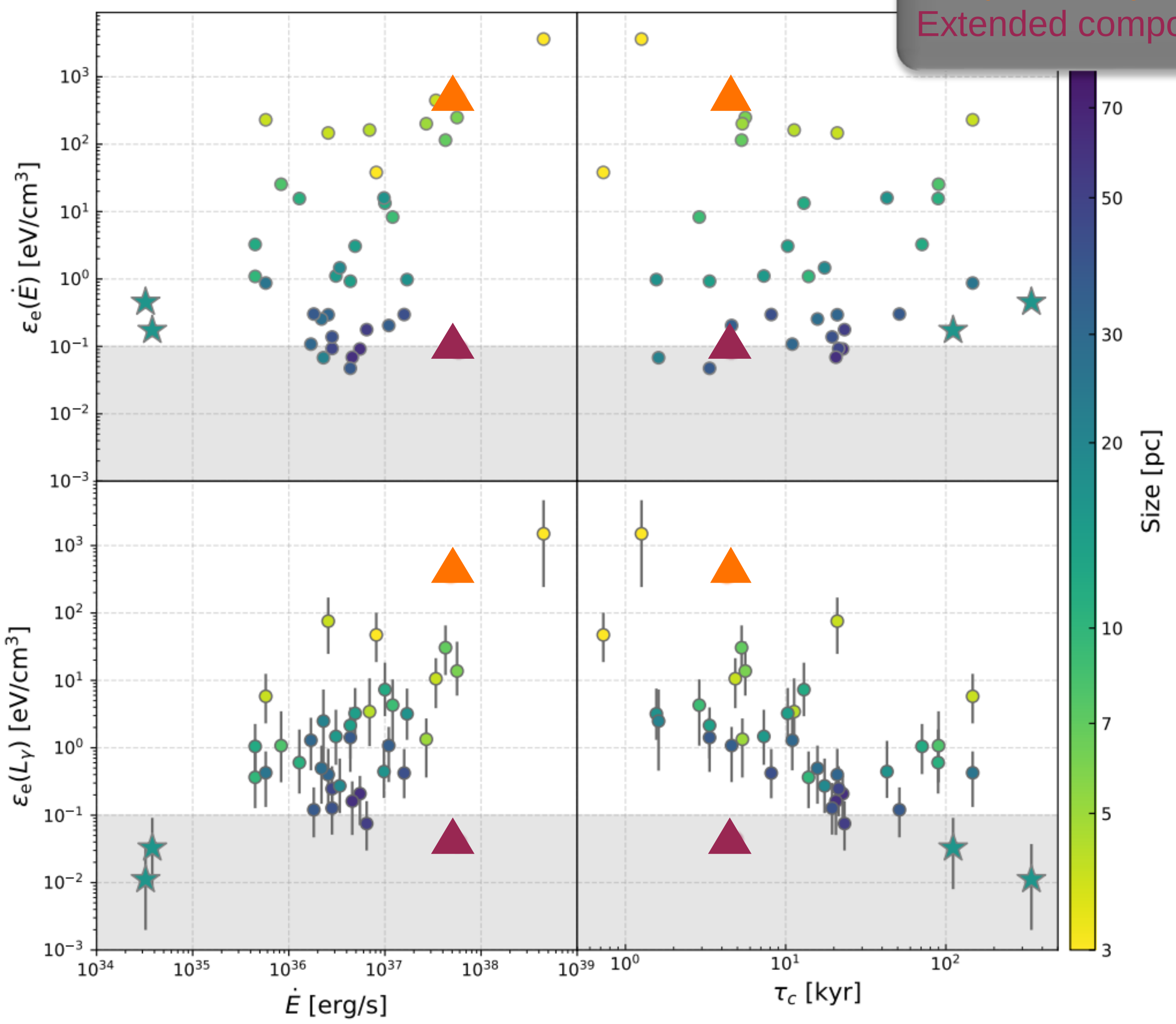


From Richard Tuffs et. al., 2017

	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

Leptonic Model

compact component
Extended compoment



	Compact component	Extended component
ε$_e$(Edot) in eV/cm^3	707	0.09
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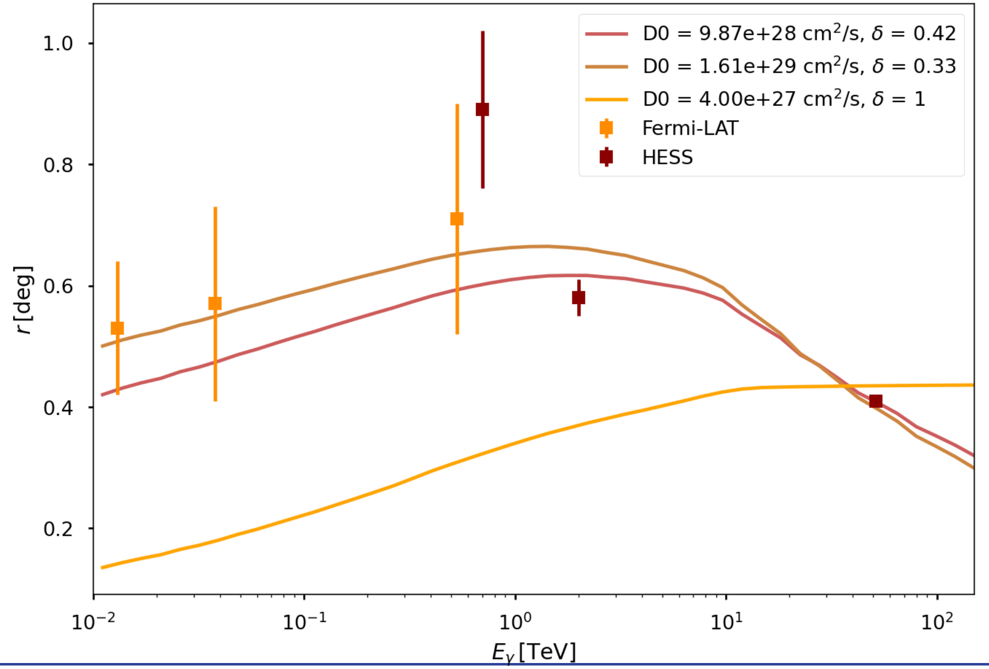
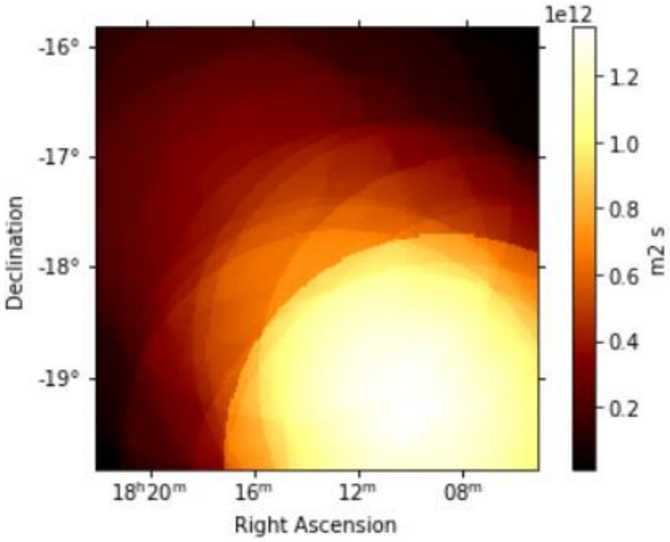
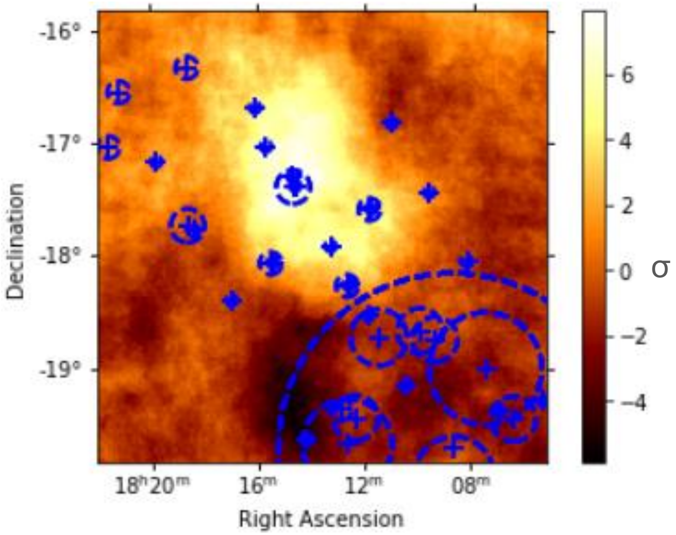
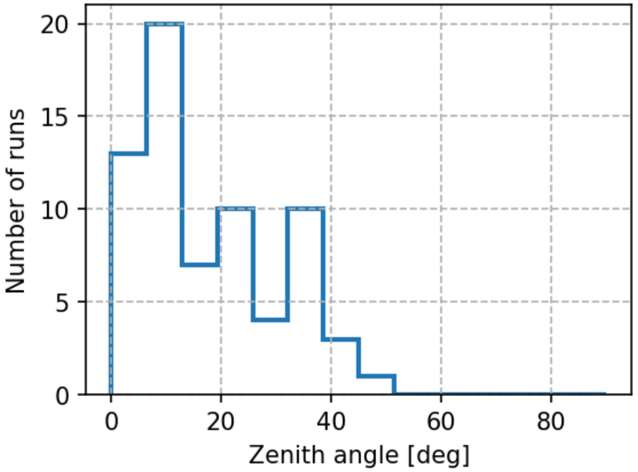


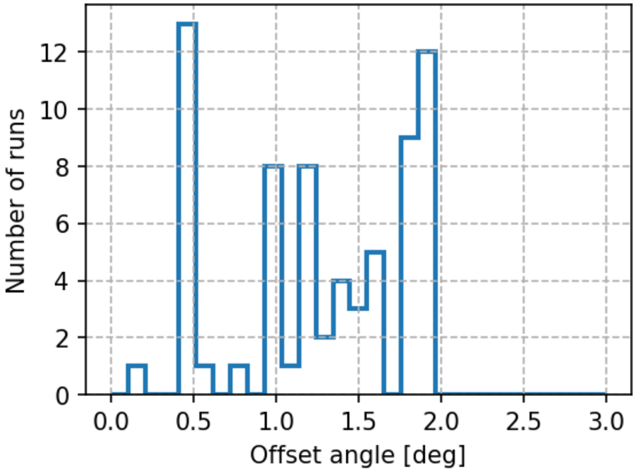
HESS Data

- 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°

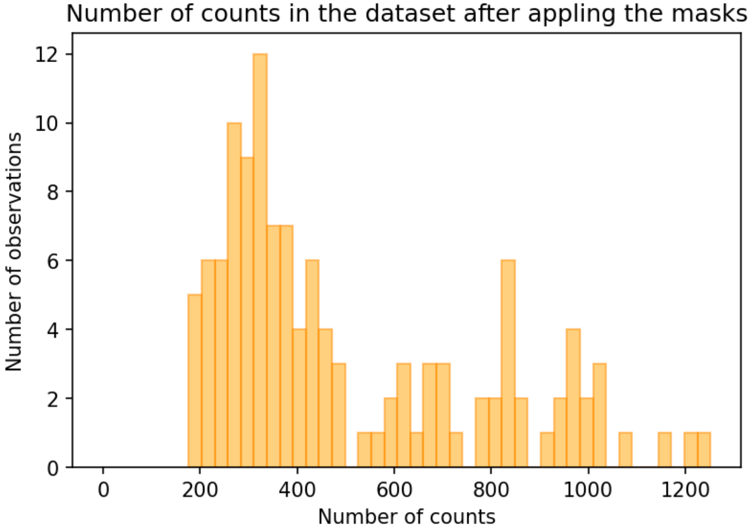


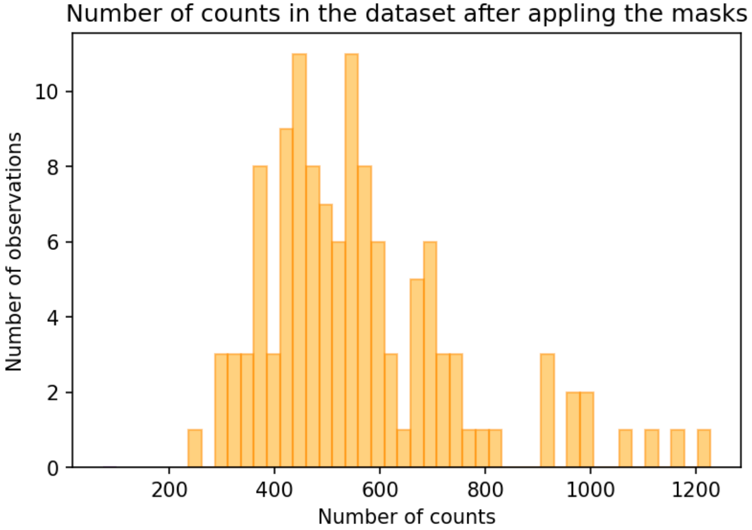


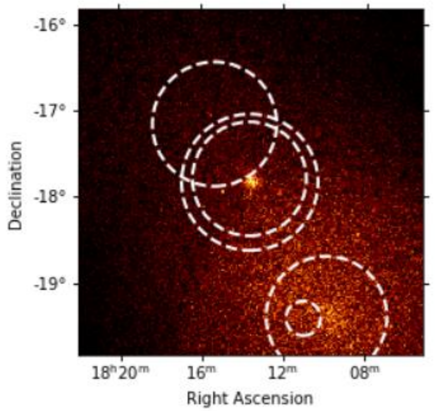


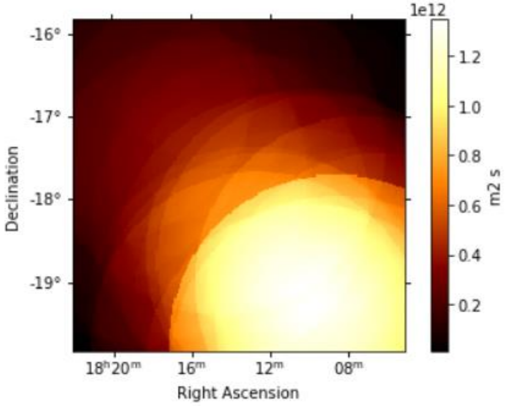


Background fit HESS Data

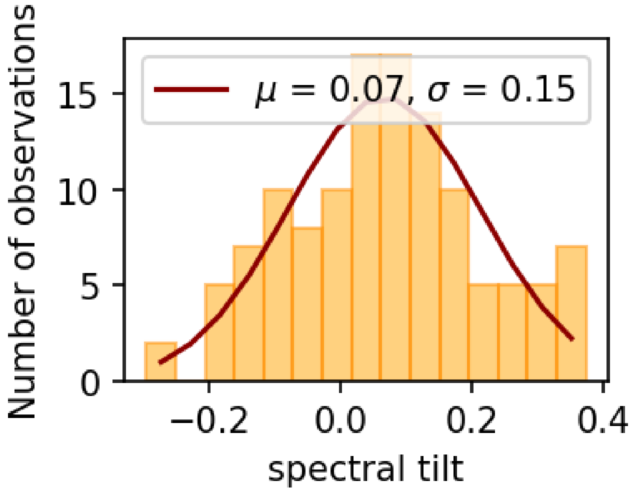


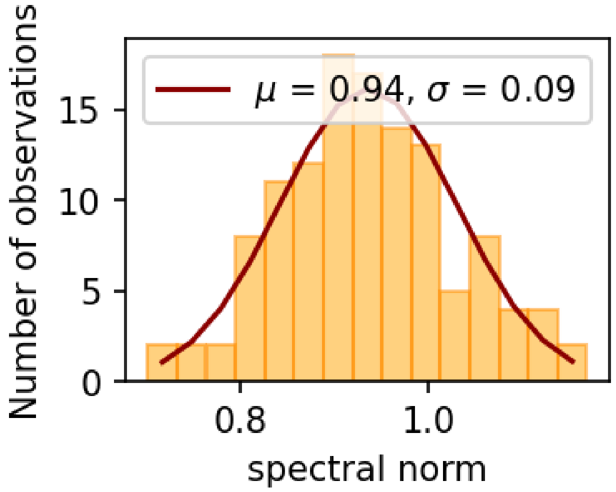




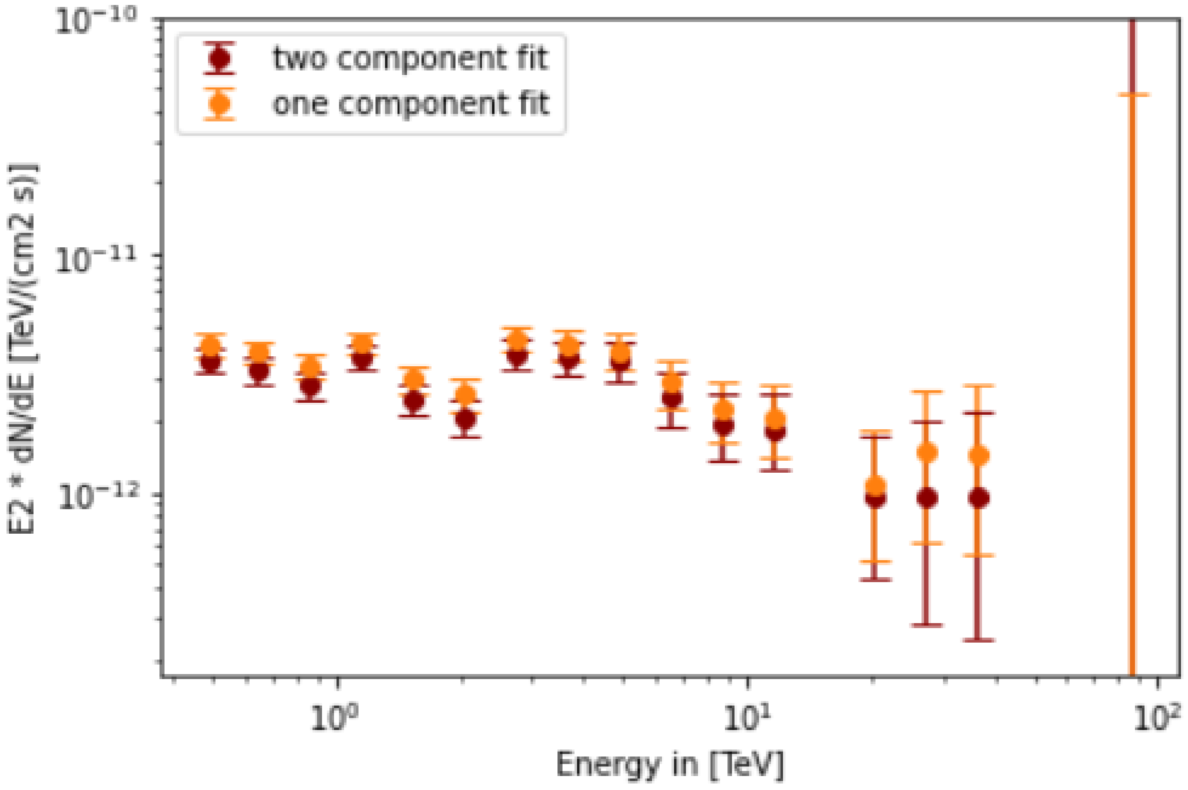


parameter of the bkg fit for fitting the whole data in the observation

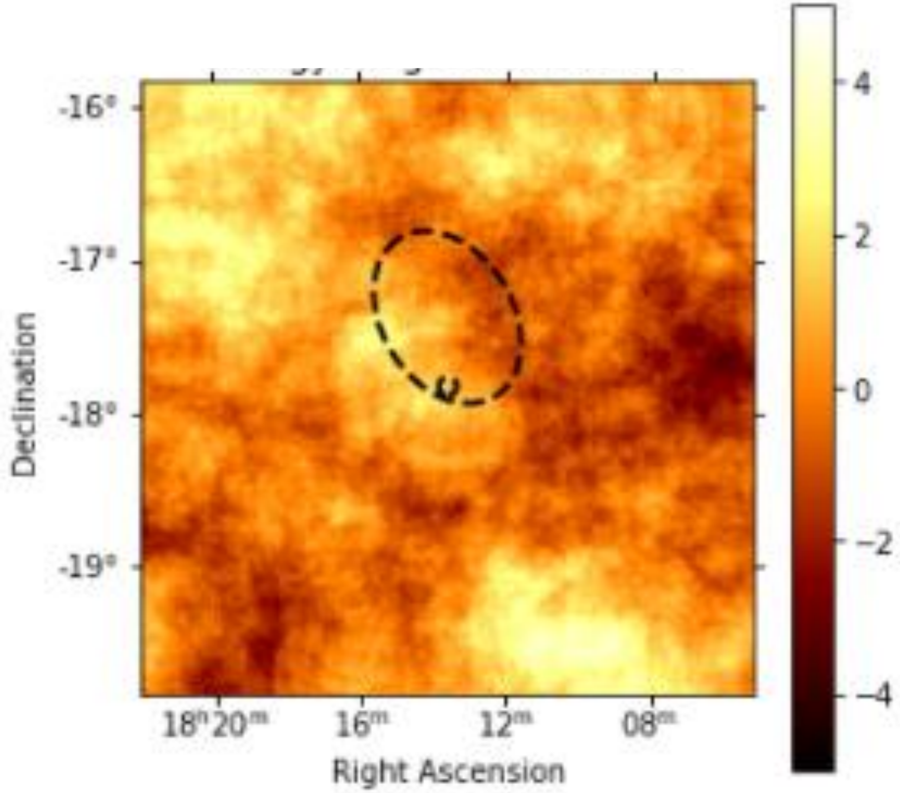




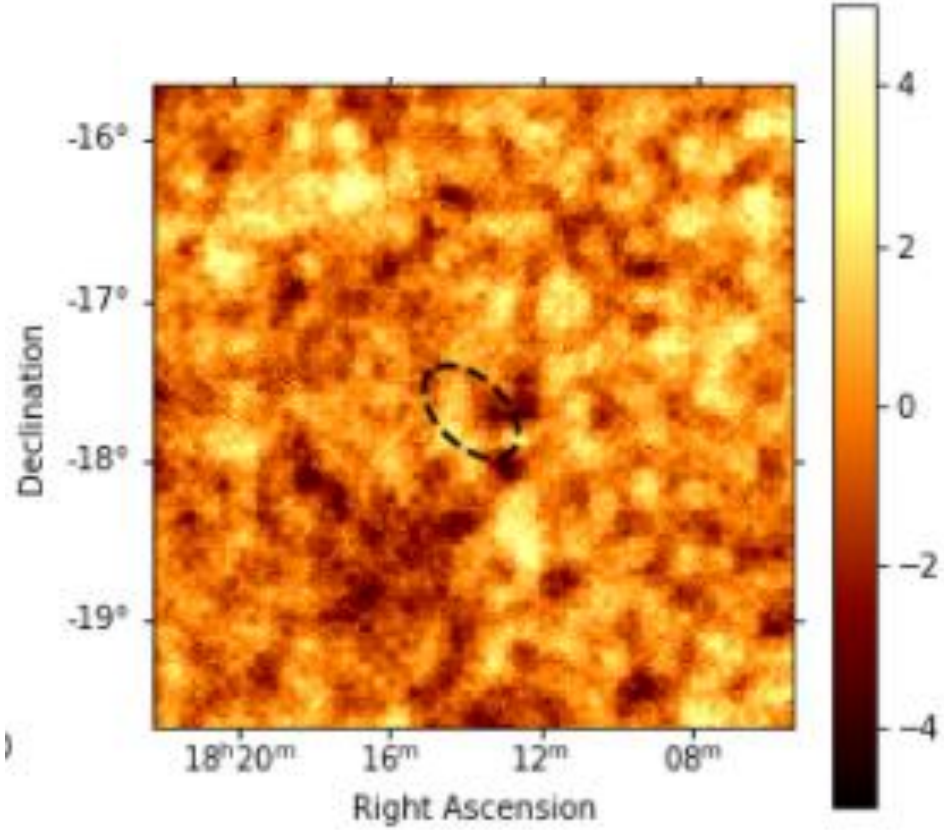
Influence of second component



Joint-fit

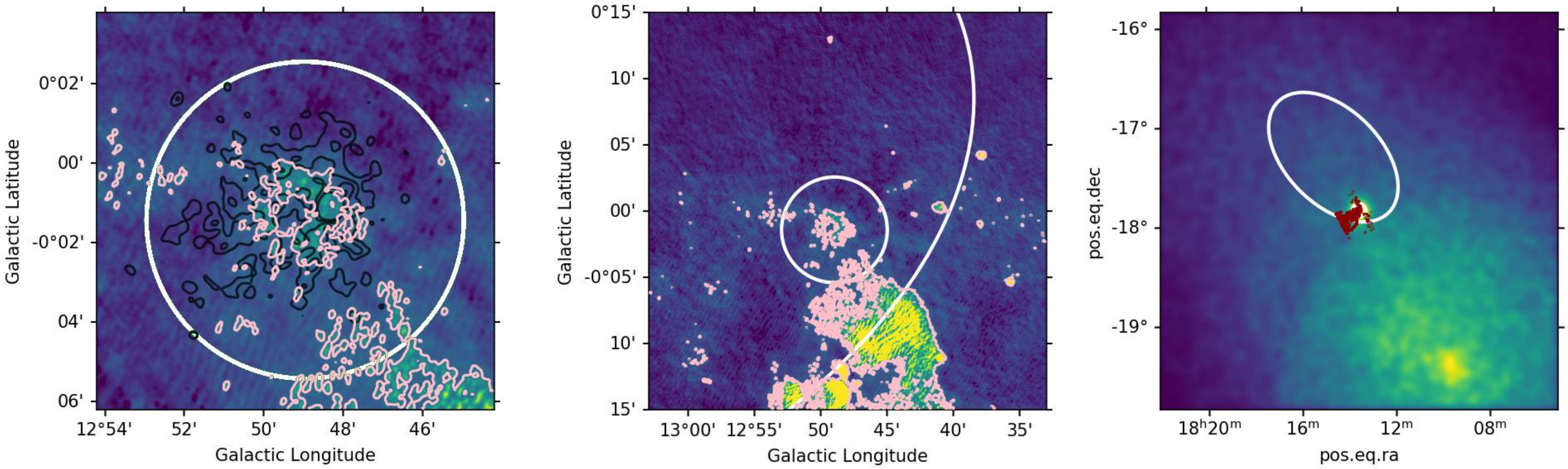


-16°
-17°
-18°
-19°
Declination
18h20m
16m
12m
08m
Right Ascension
4
2
0
−2
−4



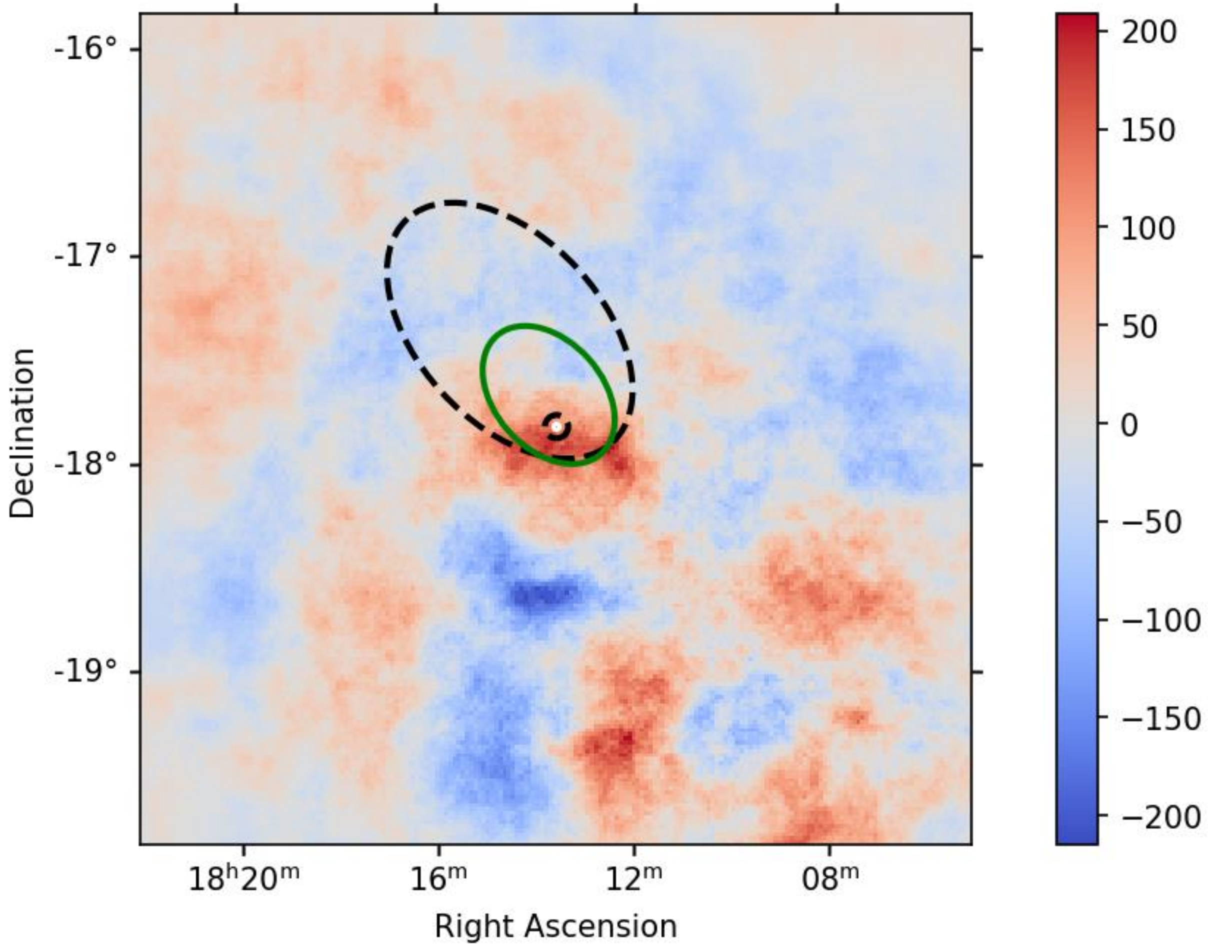
-16°
-17°
-18°
-19°
Declination
18h20m
16m
12m
08m
Right Ascension
4
2
0
−2
−4

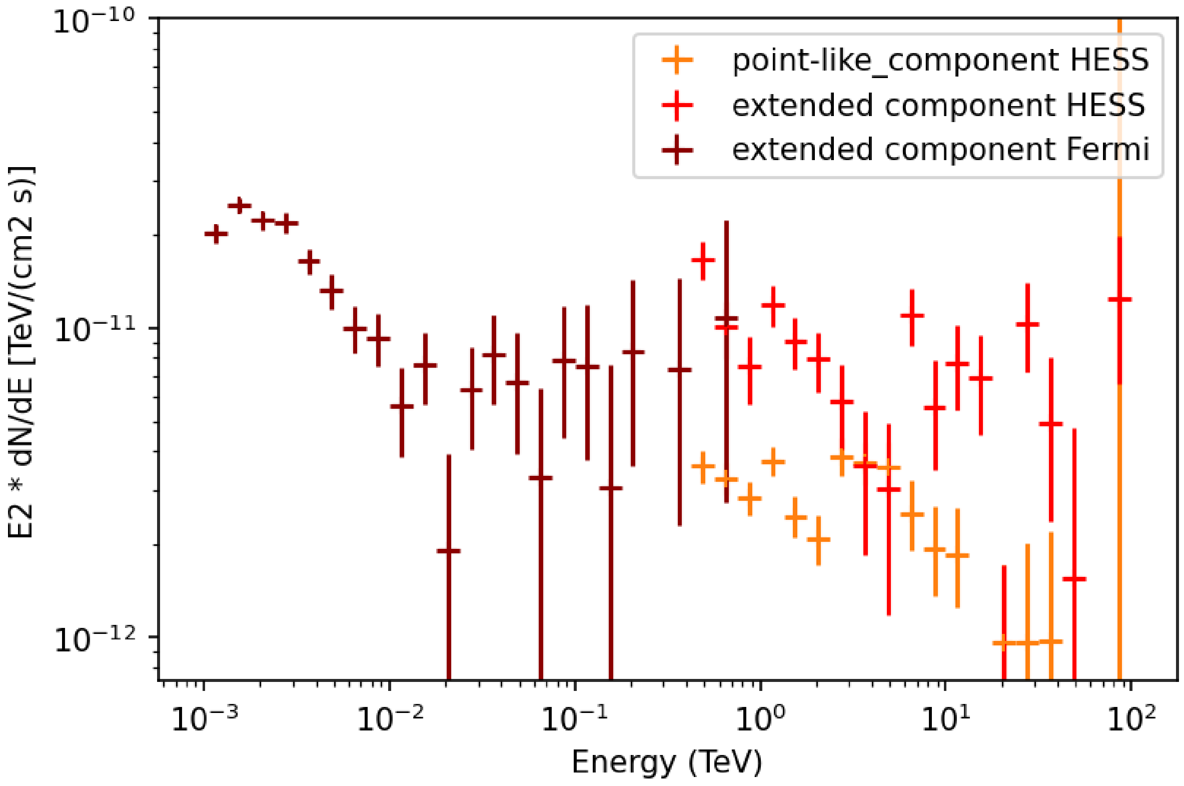
Multi-wavelength context



- 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: