

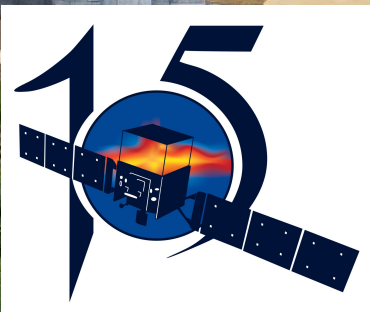


HAWC J1813-178 and its potential counterpart



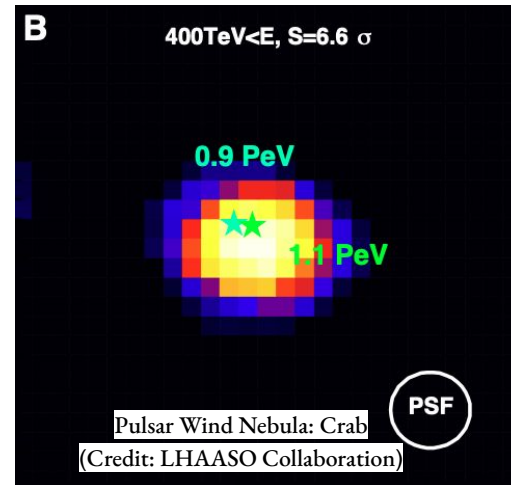
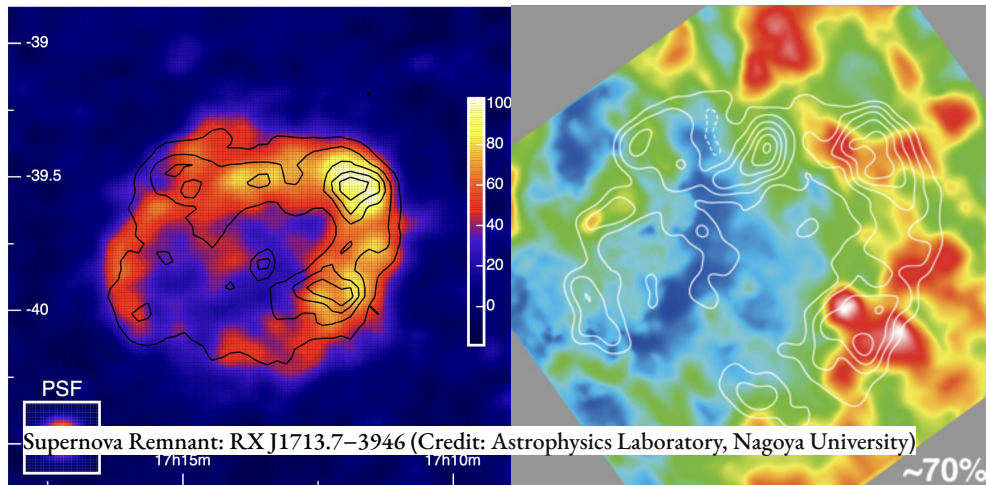
Rishi Babu (rbabu@icecube.wisc.edu)
Michigan State University
for the HAWC Collaboration

11th International Fermi Symposium
Sept 9-13, 2024



Motivation: Search for PeVatron Accelerators using γ -rays

- Observations by TeV instruments over the years indicate multiple PeV accelerators in our galaxy
- Nature of these PeVatrons are still not understood despite having several counterparts in their vicinity!
- Supernova Remnants are capable of accelerating Cosmic rays to PeV energies
- Detection of Crab Nebula at PeV energies by LHAASO Collaboration indicates presence of a leptonic PeV accelerator



HESS J1813-178

- Observed by H.E.S.S. Collaboration in 2006 as a point source
- Located at ~ 4.5 kpc away
- Detected in radio, X-rays and γ -rays
- Lies $10'$ from W33 Star forming region
- INTEGRAL(2006): Soft γ -ray source
- Originally thought to be the PWN of PSR J1813-1749: one of the most energetic pulsar known
 - PSR J1813-1749: highly energetic young pulsar
 - SNR G12.8-0.0 : young shell type SNR
 - SNR G12.7-0.0
 - W33 Star Forming Region
- Classified as a PeVatron candidate

HESS
J1813-178

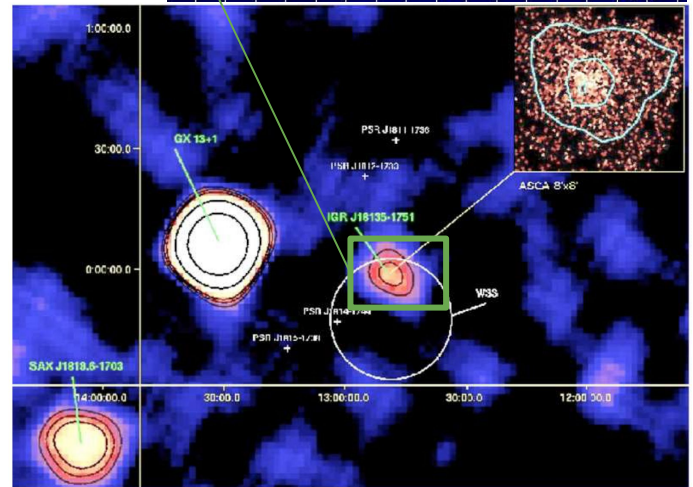
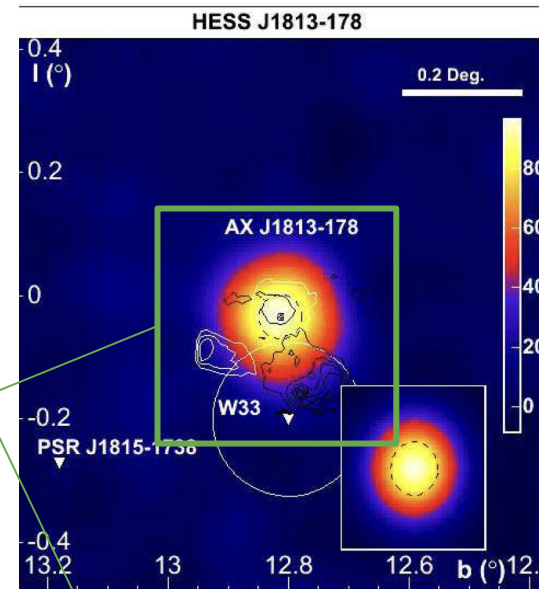
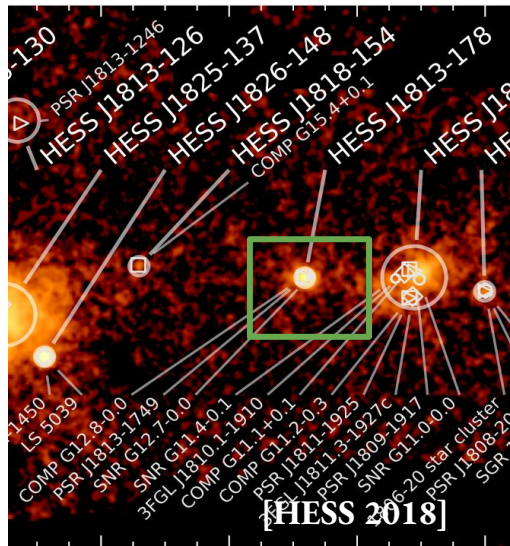


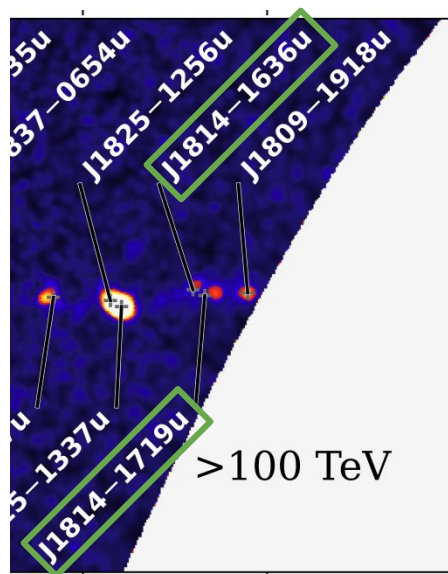
Fig: H.E.S.S. Collaboration, Abdalla, H. et al "The H.E.S.S. Survey of the Inner Galaxy in Very High Energy Gamma Rays " (2006)

Fig: The IBIS/ISGRI 20-40 keV significance map showing the location of PSR J1813-1749 and relative significance contours

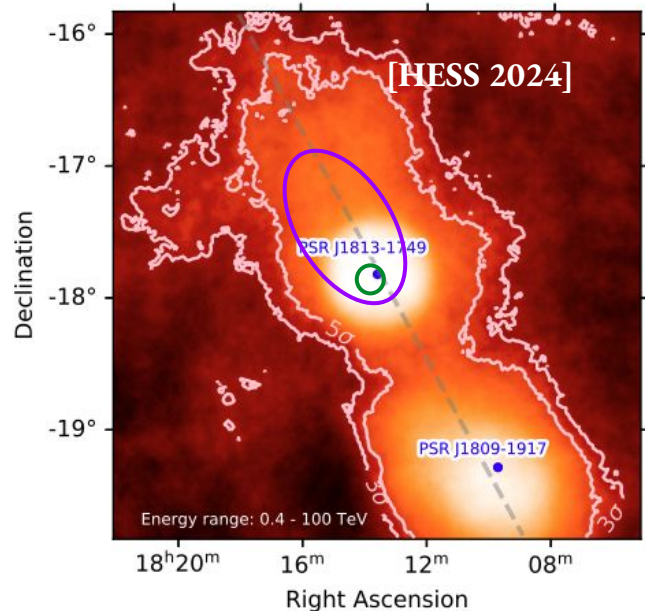
HESS J1813-178 over the years



H.E.S.S. Galactic Plane Survey: a point source at the location of HESS J1813-178



LHAASO catalog: 2 separate sources in the region at the highest energies



Latest results from H.E.S.S.: an extended tail: electrons diffusing into ISM

What can HAWC say about the extended emission?
Do we see the similar extension at higher energies?

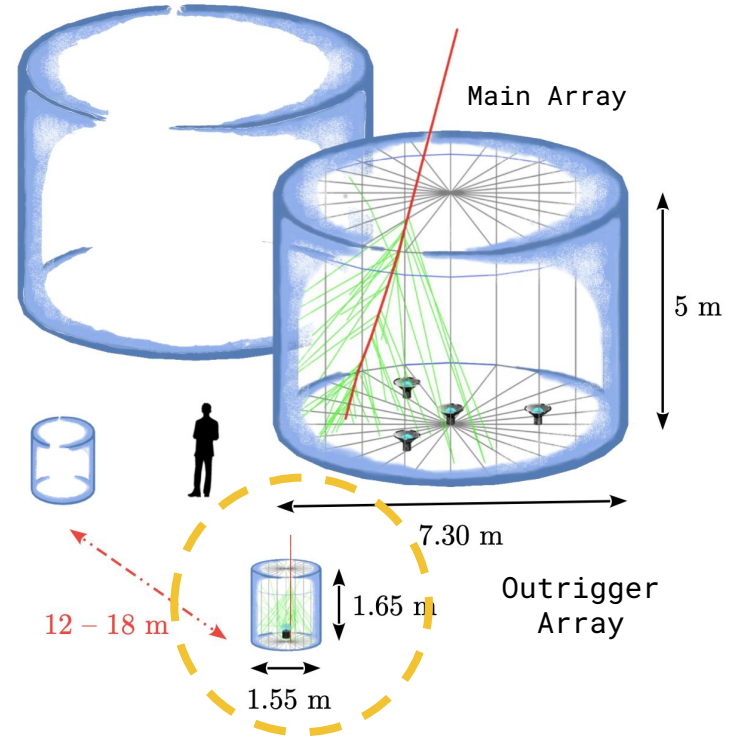
High Altitude Water Cherenkov Observatory



Main Array

Outrigger Array

Credit: V. Joshi, ICRC 2017



Main Array

5 m

7.30 m

Outrigger Array

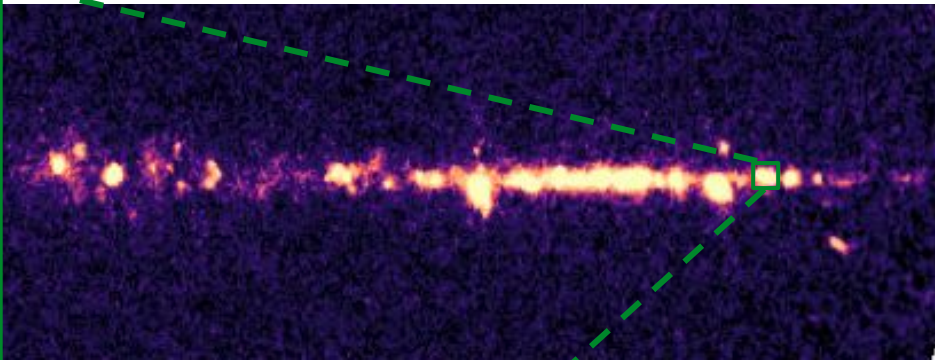
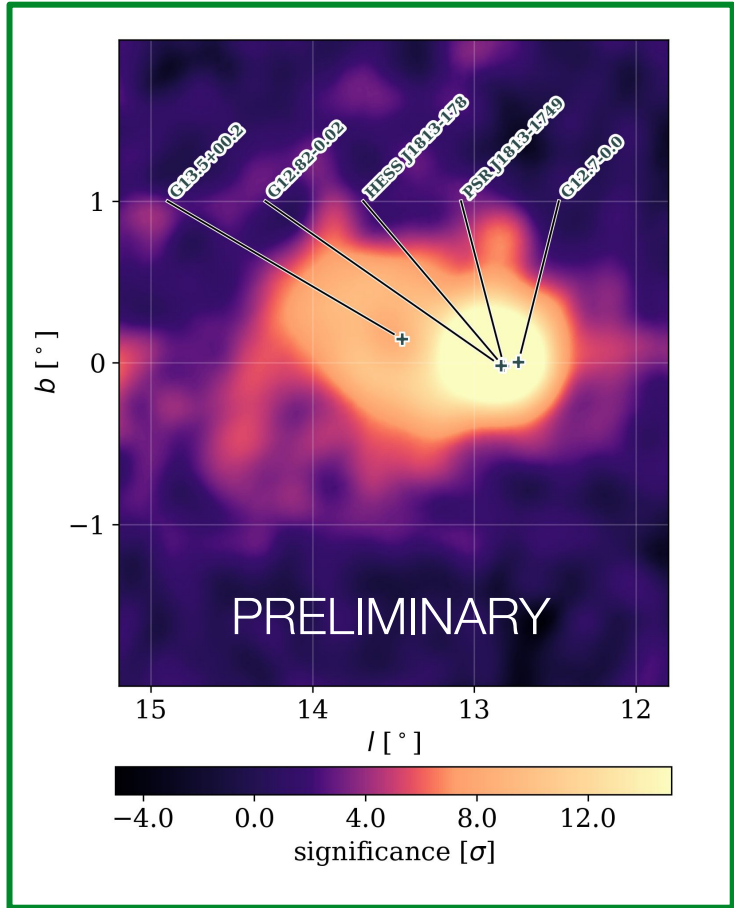
1.65 m

1.55 m

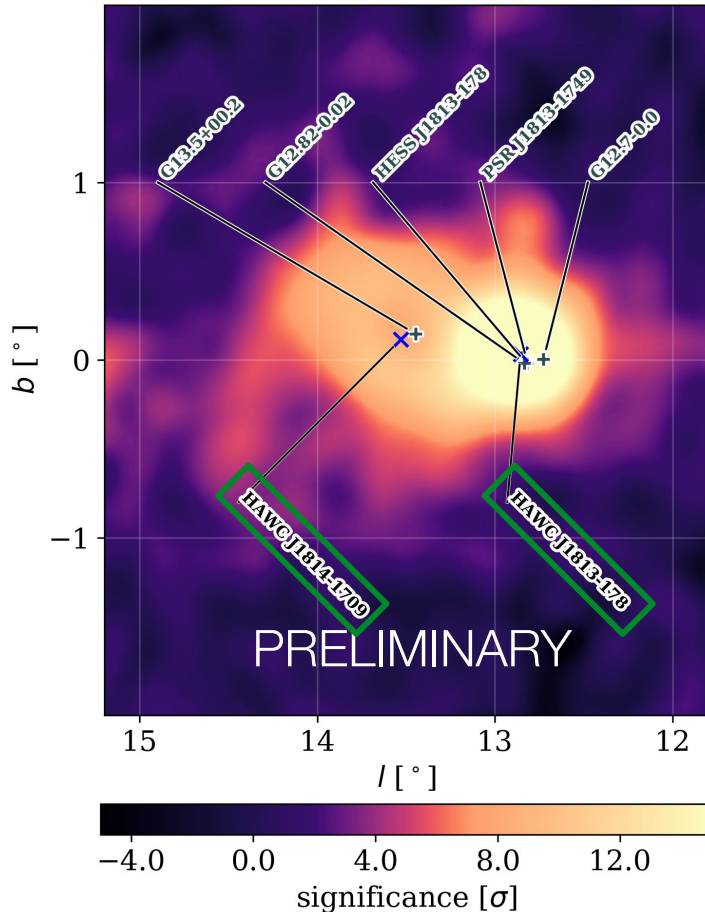
12 - 18 m

- 300 Main Array + 345 Outrigger Array ($\sim 10000 \text{ m}^2$)
- $\sim 2\text{sr}$ Instantaneous FOV
- High duty cycle $> 95\%$
- Energy range: $\sim 300 \text{ GeV}$ to $>100 \text{ TeV}$
- Angular resolution: $\sim 0.2^\circ$

HAWC Observations of the HESS J1813-178 region

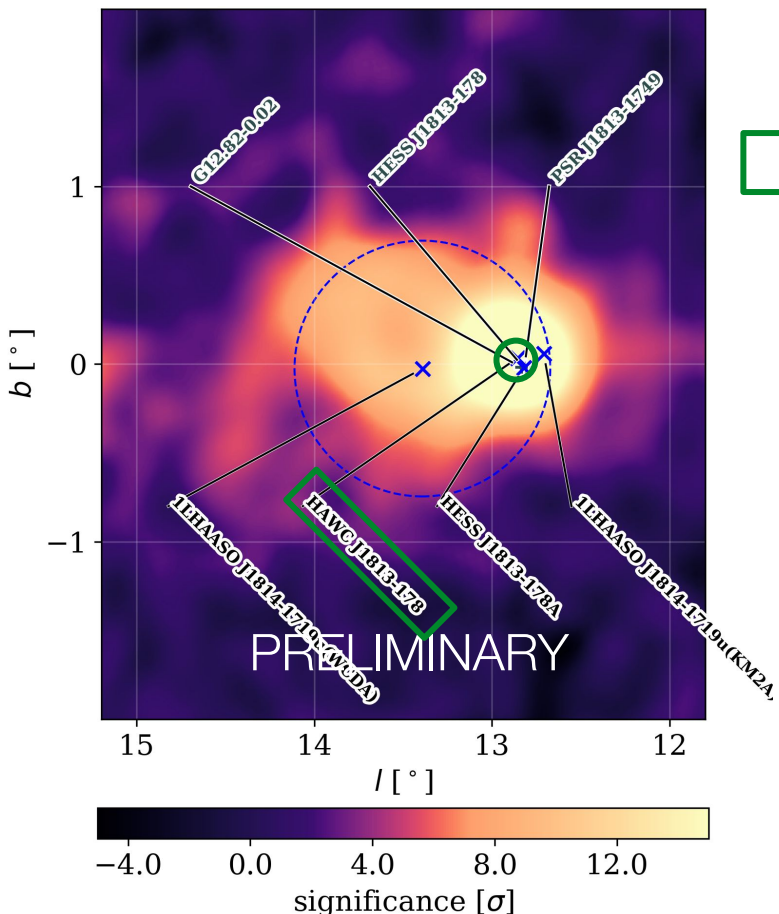


HAWC Analysis of the region



- Maximum Likelihood method (3ML, Vianello et al. 2015; Abeysekara et al. 2022)
- Use a systematic source search method inspired from Fermi's source search pipeline (M. Ackermann et al. 2017)
- Find morphology and Spectrum for the source that best describes the data in the region
- Best model:
 - 1 point source with Log-Parabola spectrum
 - 1 extended Gaussian source with Cutoff-Powerlaw spectrum
 - Galactic Diffuse Emission based on Hermes Model (Dundovic et al. 2021)

Preliminary Results: HAWC J1813-178

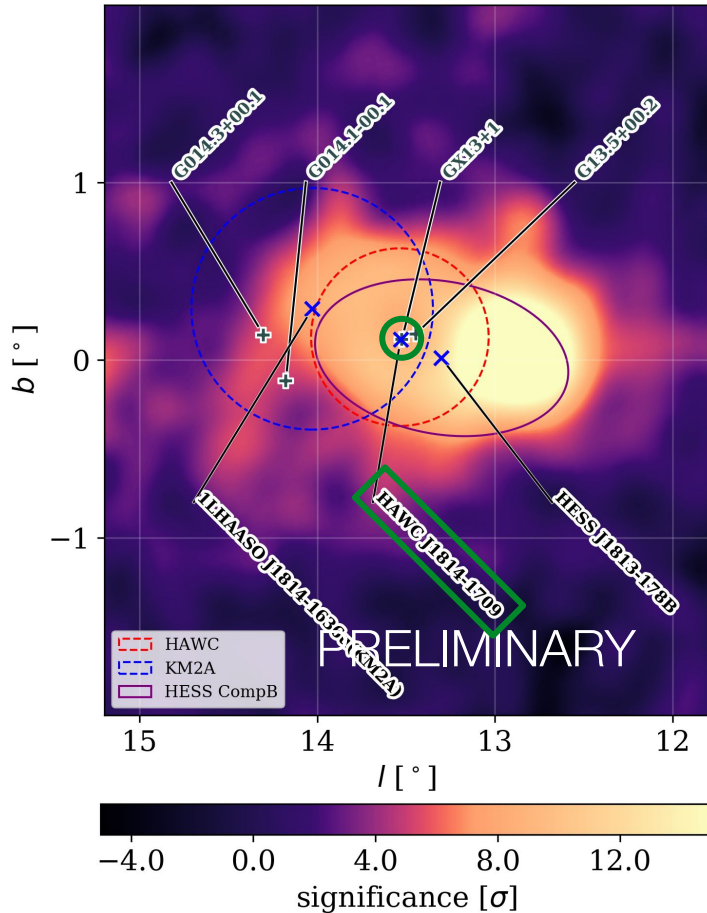


HAWC J1813-178

- A point source with Log-Parabola spectrum
- Almost at the same location as that of HESS J1813-178 and almost spatially coincident with PSR J1813-1749 and SNR G12.8-0.00
- Spatially coincident with HESS J1813-178A(2024) and 1LHAASO J1814-1719u (KM2A)
- LHAASO WCDA source is 0.71° 1σ width and is offset by more than 0.7° away from the KM2A counterpart (“dubiously merged sources”)

Most likely association:
PWN of PSR J1813-1749

Preliminary Results: HAWC J1814-1709

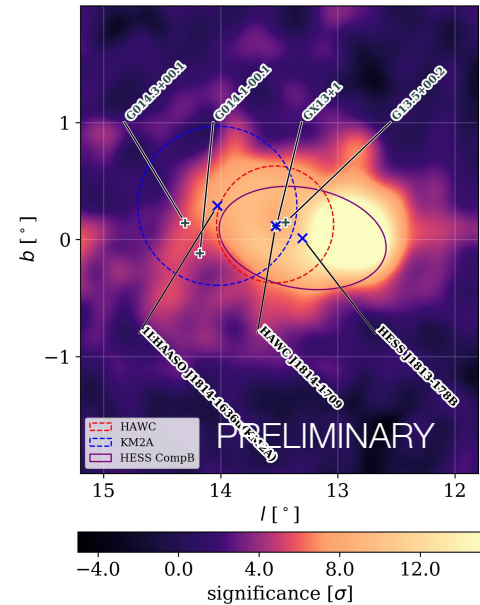


HAWC J1814-1709:

- Extended source with 0.5° 1σ width
- Cutoff-Powerlaw spectrum
 $\alpha = -1.44 \pm 0.28$, $E(\text{cutoff}) = 24 \text{ TeV}$
- 0.4° away from HESS J1813-178B (2024)
- 0.7° away from 1LHAASO J1814-1636u

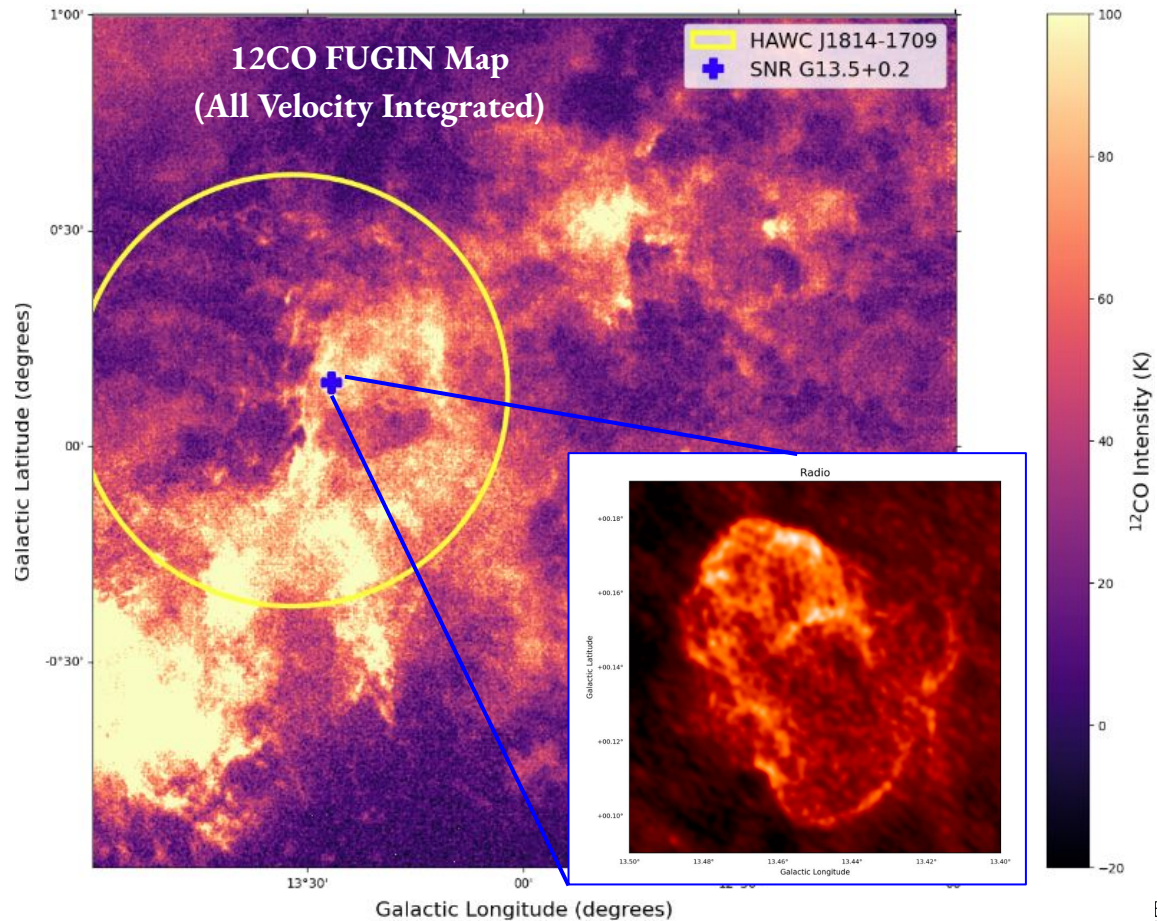
Most likely association: ?
 Not a lot of counterparts in the region!

Extended Source Counterparts: A potential SNR?

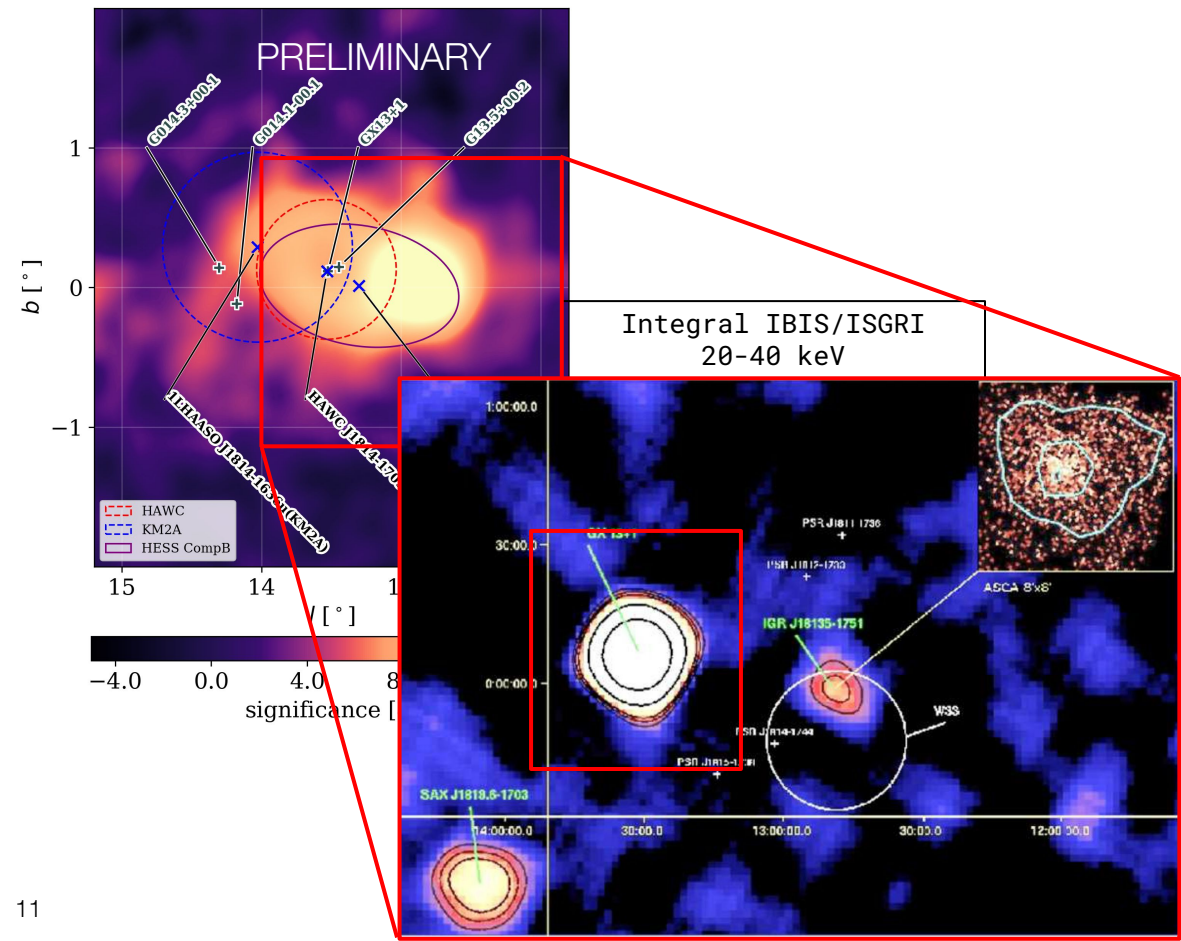


SNR G13.5+0.2

- Elongated, incomplete shell
- Distance 13 +/- 7 kpc (Lee et al. 2020)
- 3.6 arcminutes wide
- Not detected in Fermi's SNR search



Extended Source Counterparts: A potential Binary?

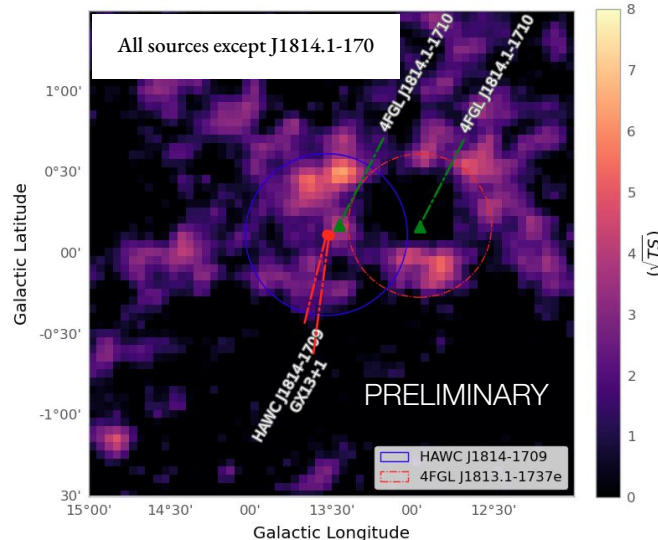
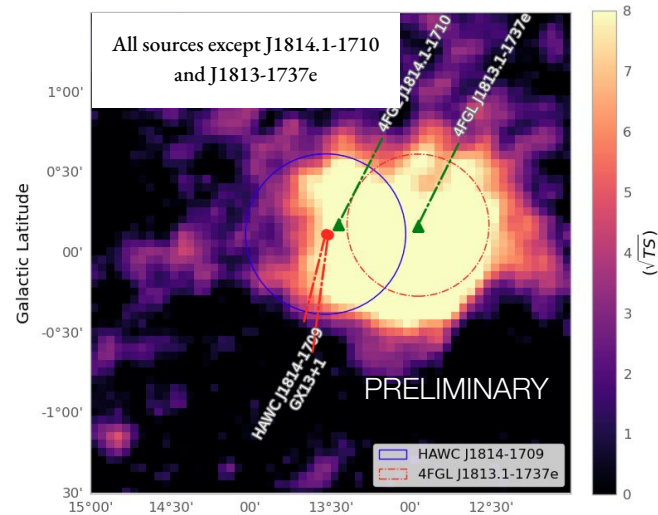
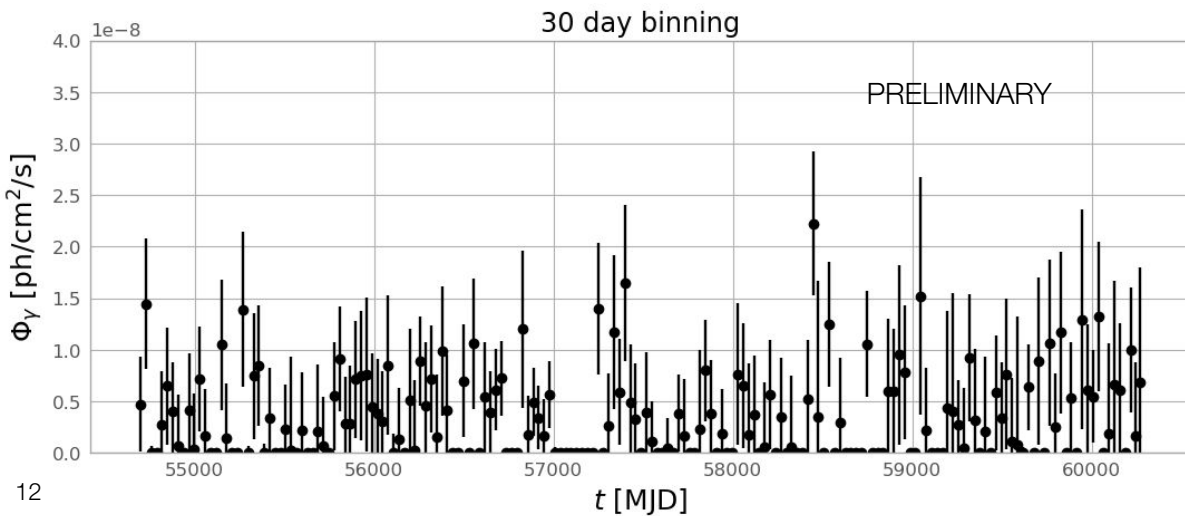


- GX13+1/V5512 Sgr
 - Low-mass X-ray binary system
 - Most luminous “atoll” source
 - X-ray burst during 1985 and 1995 suggest that the accreting object - neutron star
 - The spectral type of the companion star is K5 III (~ 0.8 M_{\odot})
 - Distance to the system is 7 kpc
 - Period is around 25 days
 - Only other LMXB to be detected in gamma-ray
 - XSS J12270-4859 (Fermi-LAT association)



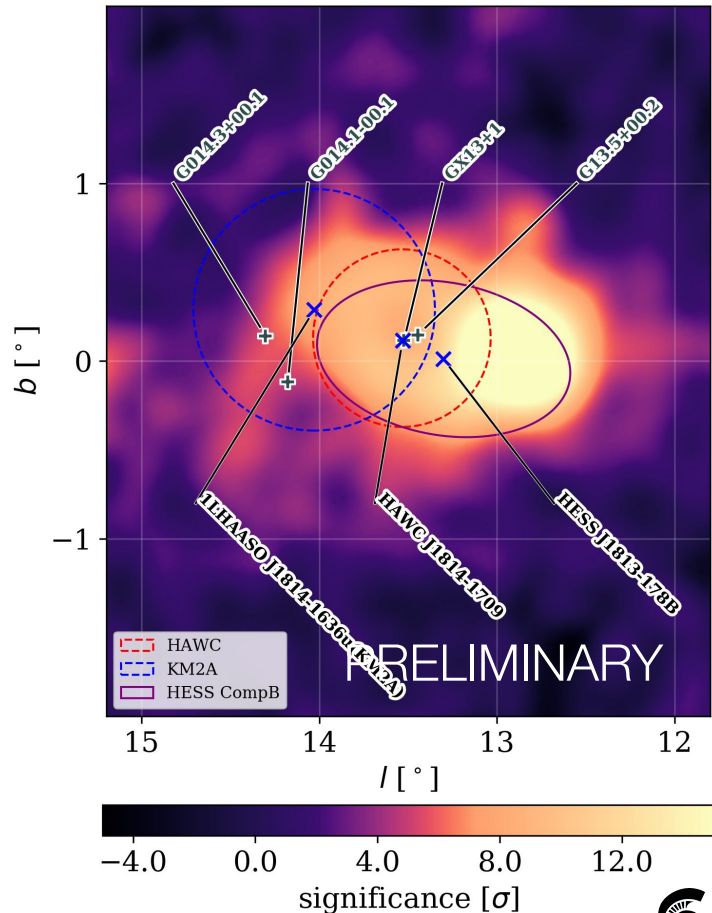
Fermi-LAT Analysis Results

- Analysed 14 years of Pass 8 Data using P8R3_SOURCE_V2 IRFs
 - Found 2 sources in the region
 - 4FGL J1813-1737e (0.38° extended)
 - 4FGL J1814.1-1710 (point source): closer to GX13+1
- Calculated the light curve from 4FGL J1814.1-1710 with a 30 day binning period
- No significant variability in the flux found in the 30 day LC



Summary

- HAWC Observations of HESS J1813-178
 - Observed 2 different sources in the region
- HAWC J1813-178 - consistent with other observations
 - Spatial association with the PWN around the pulsar
- HAWC J1814-1709 - Extended source with 2 counterparts
 - Spatial association with a far-away SNR
 - Spatial association with a LMXB
- Fermi analysis show no flux modulation in the light curve
- Emission from HAWC J1814-1709 is still a mystery!
- Work in progress. Stay tuned!

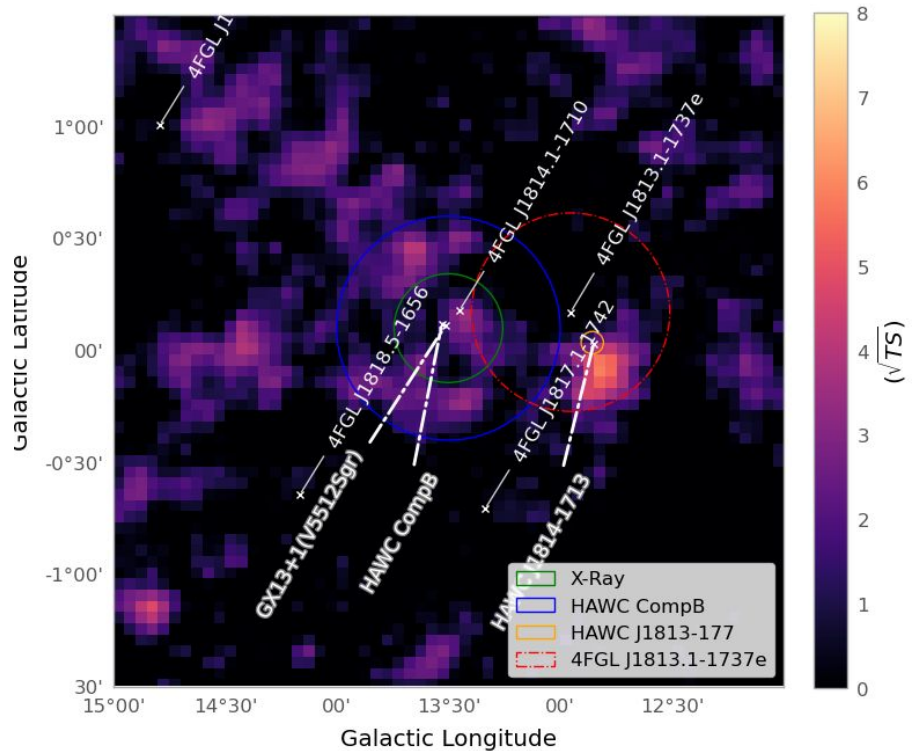




Thank you



Fermi Fit Results

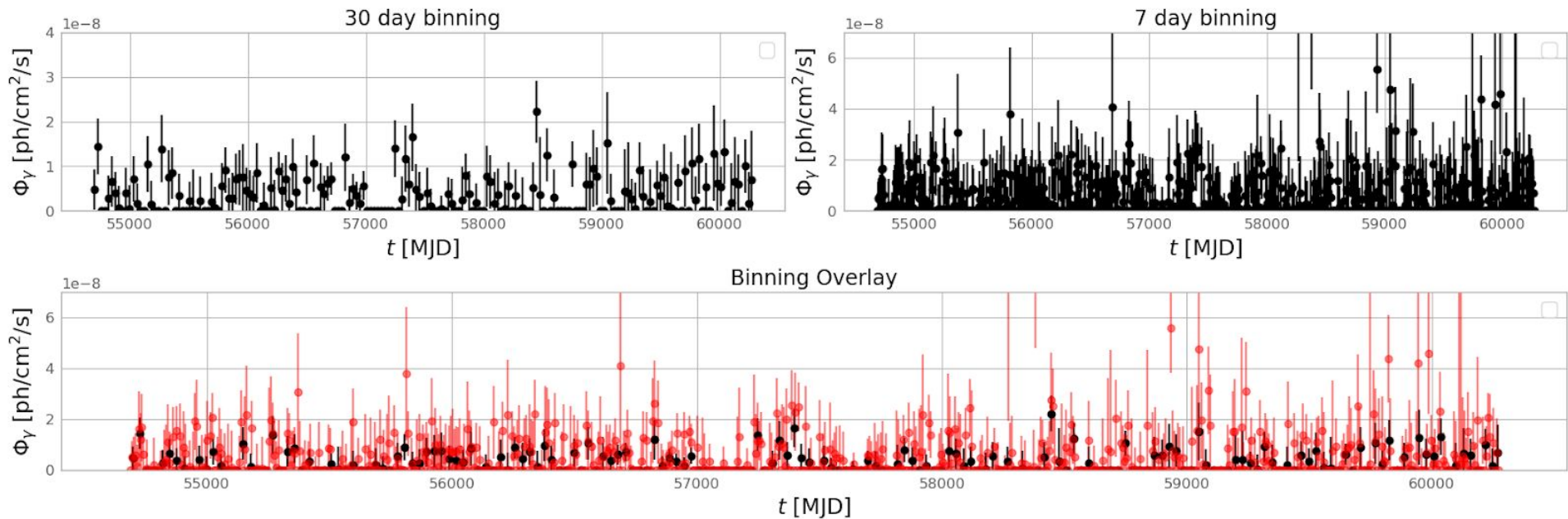


- 4FGL J1813.1-1737e: Extended source and Log-P spectra
 - $\alpha=2.41$, $\beta=0.01$
 - $r=0.46$ degrees
- 4FGL J1814.1-1710 : Point source and PL spectra
 - $\text{index}=3.23$ (soft spectrum)

Significance map of HESS J1813-178 region after refit with source localization and source search

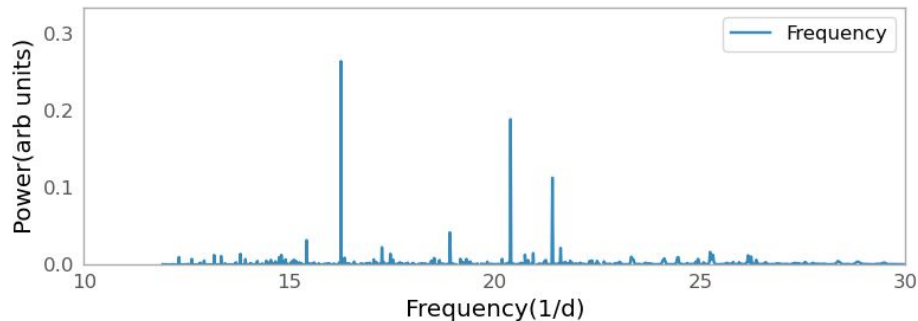


Light curve analysis for 4FGL J1814.1-1710



- Light curves are binned in 1 week and 1 month respectively
- Weak source so a lot of data is almost zero flux

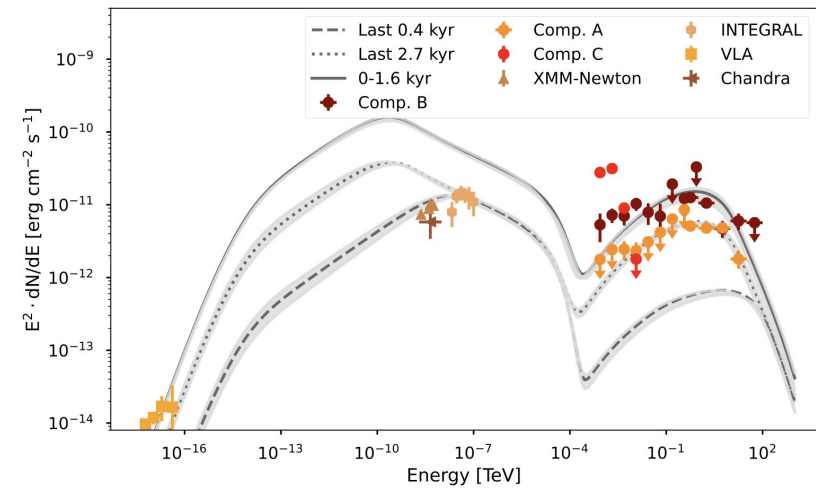
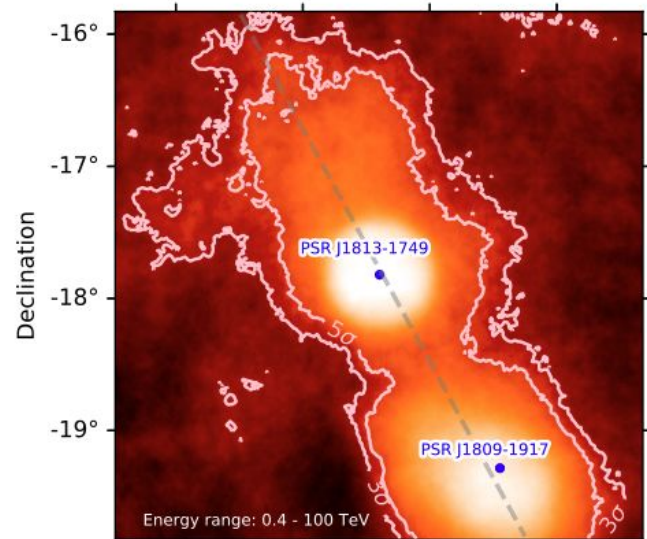
Light curve analysis for 4FGL J1814.1-1710



Lomb Scargle power periodogram for
30 day binning

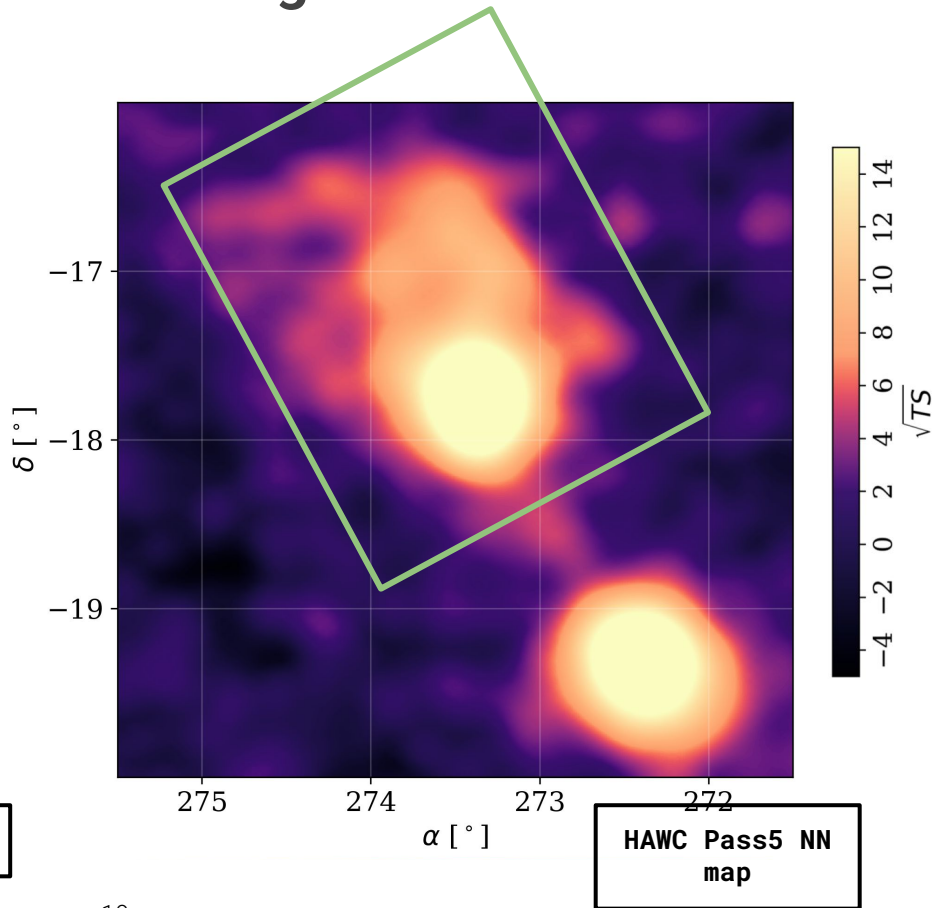
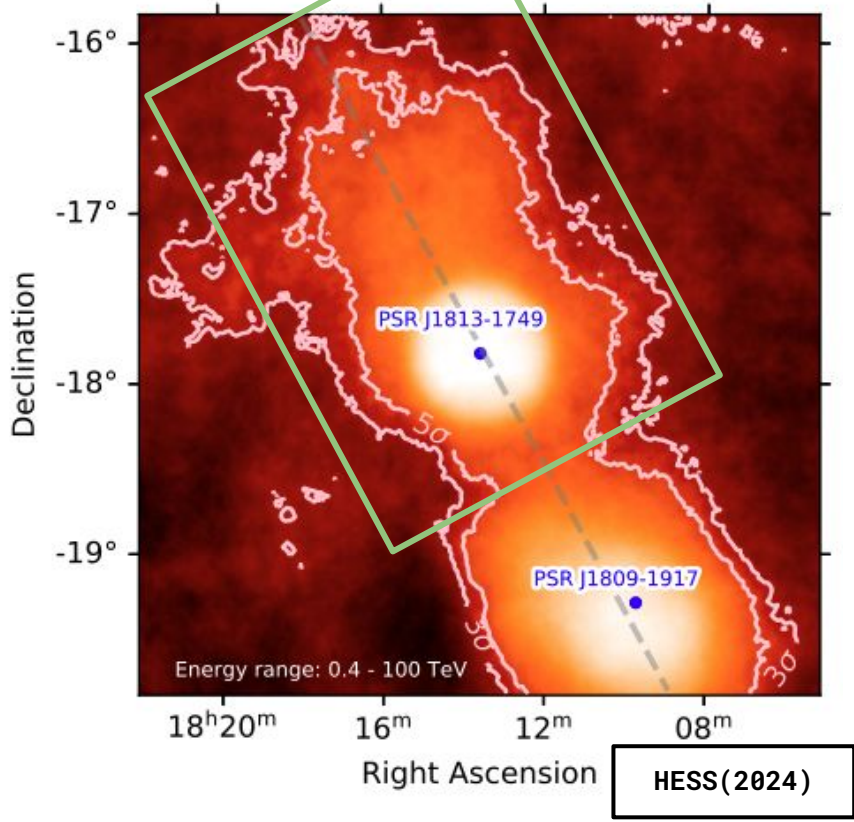
Lomb Scargle periodogram indicates a frequency range between 16-23 days(30 day binning) and 15-28 days(7 day binning)
The orbital period of the system is 24 day

HESS Results 2024

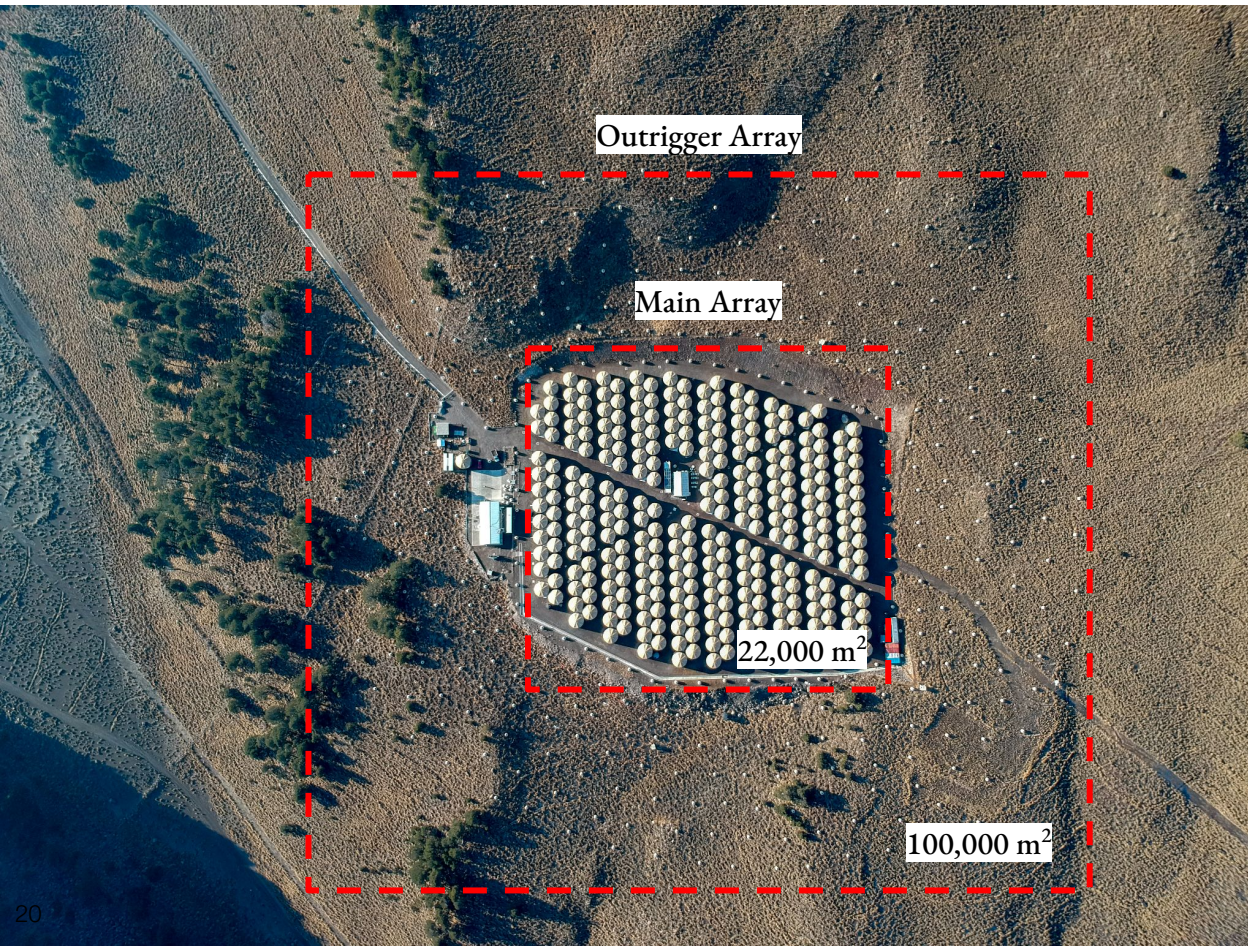


- Extended emission is caused by electrons and positrons escaping the confines of the PWN and diffusing into the ISM
- Diffuse leptonic emission around a pulsar is usually only observed in systems older than ~10 kyr
- The true age of the system is < 5kyr
- Diffusion coefficient is below that observed in the ISM
- Energy density comparable to that of TeV halos
- Non-uniform diffusion coefficient
- Maybe possible
- No conclusive result

Map of the region



High Altitude Water Cherenkov Observatory



- 4100m elevation on the flanks of Sierra Negra, Mexico
- Energy range: ~300 GeV to >100 TeV
- Angular resolution: ~0.2°
- ~ 2 sr Field of View
- > 95% Duty Cycle