Morphological and Spectral Studies on SS 433 Region with HAWC

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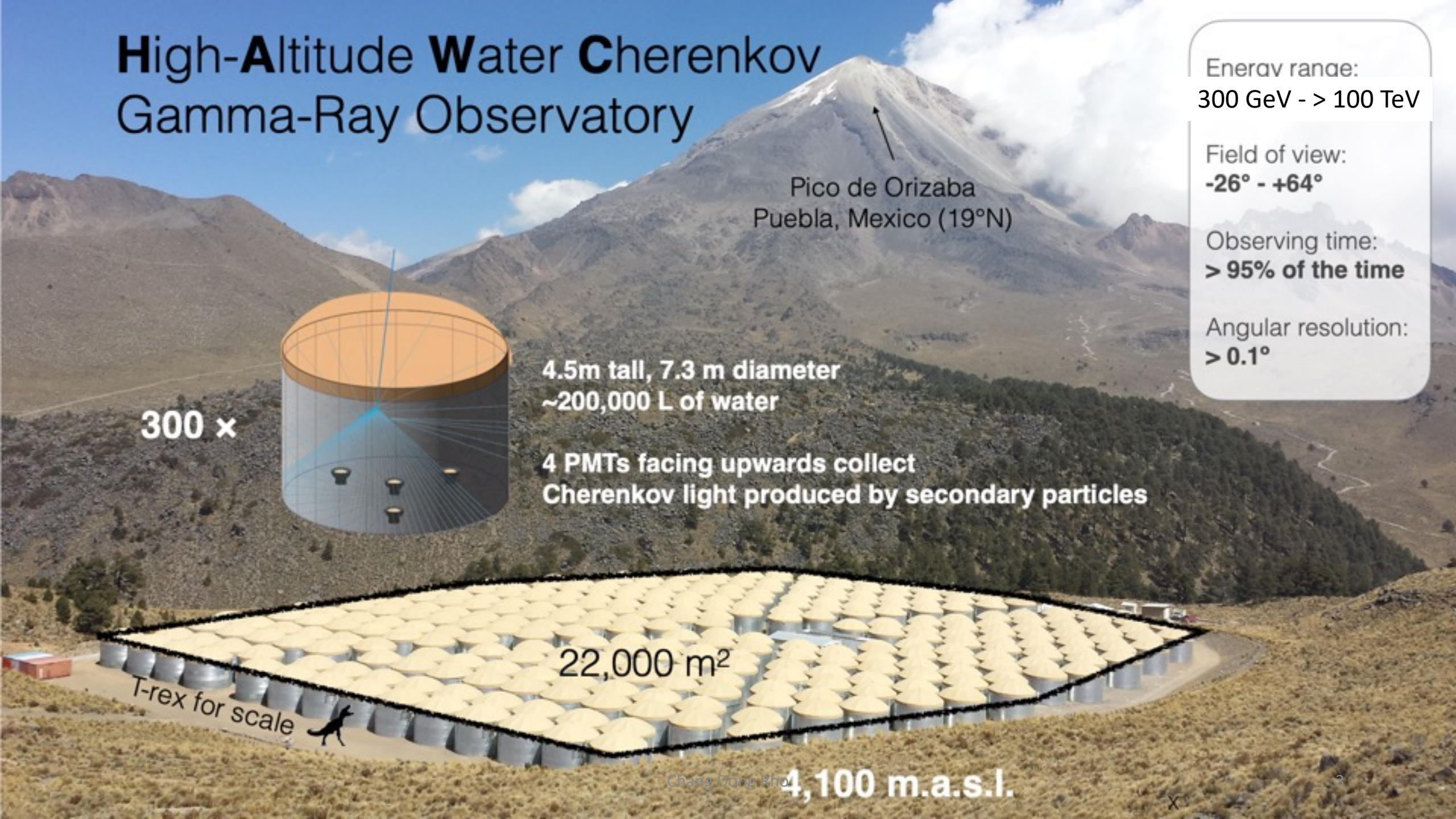
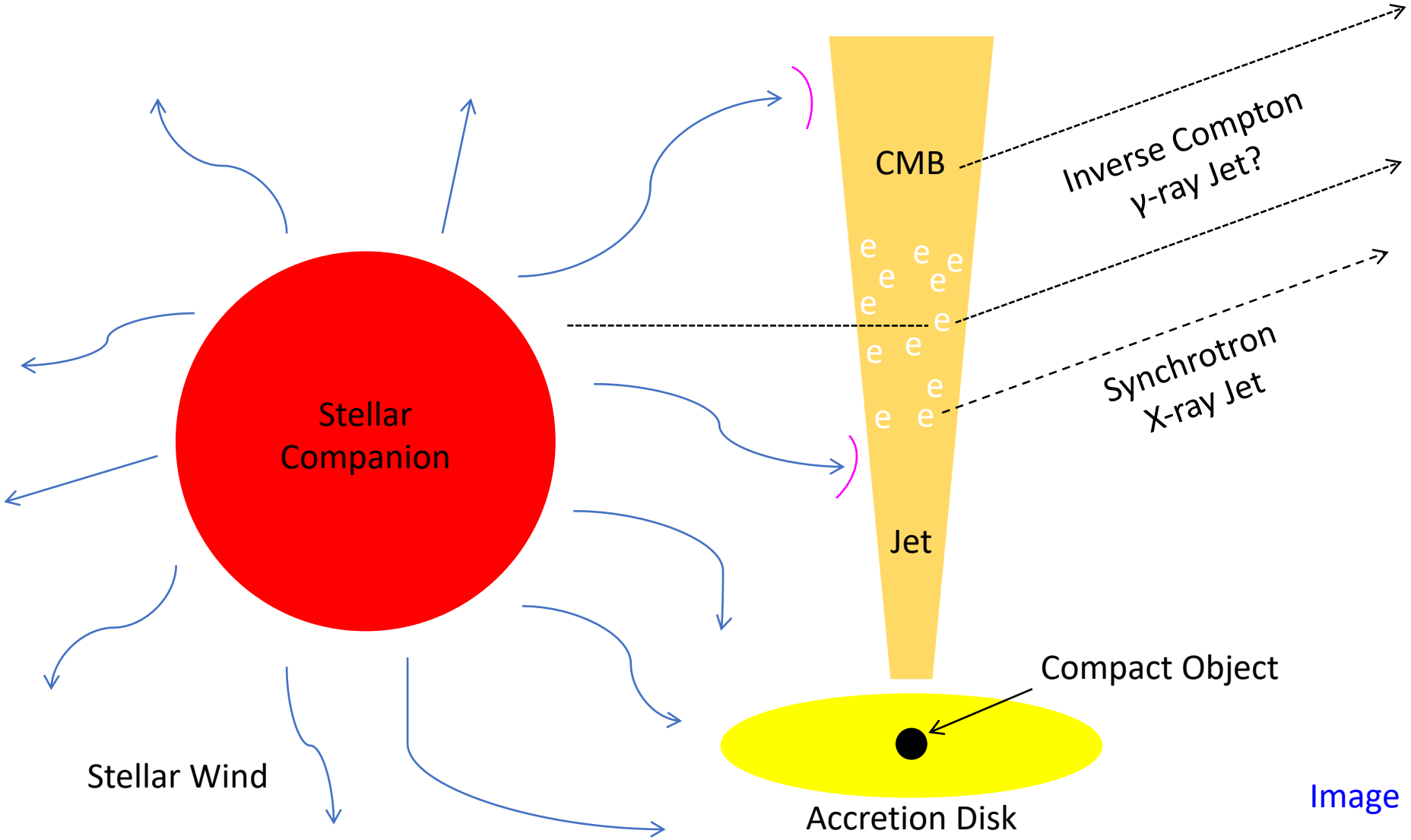
Overview

- HAWC observatory
- Gamma-ray microquasars – why SS 433?
- Analysis results on SS 433 / W50 with HAWC data


High-Altitude Water Cherenkov
Gamma-Ray Observatory
Pico de Orizaba
Puebla, Mexico (19°N)
Energy range:
300 GeV - > 100 TeV
Field of view:
-26° - +64°
Observing time:
> 95% of the time
Angular resolution:
> 0.1°
300 ×
4.5m tall, 7.3 m diameter
~200,000 L of water
4 PMTs facing upwards collect
Cherenkov light produced by secondary particles
22,000 m²
T-rex for scale
4,100 m.a.s.l.

Gamma-Ray Microquasars



SS 433 – Properties

Image Credit: VLA

- First microquasar
- Composed of compact object and massive companion star
- Encapsulated by a supernova remnant W50
- Distance of ~ 5.5 kpc
- Orbital period of ~ 13.1 days; jet precession of ~ 162.5 days

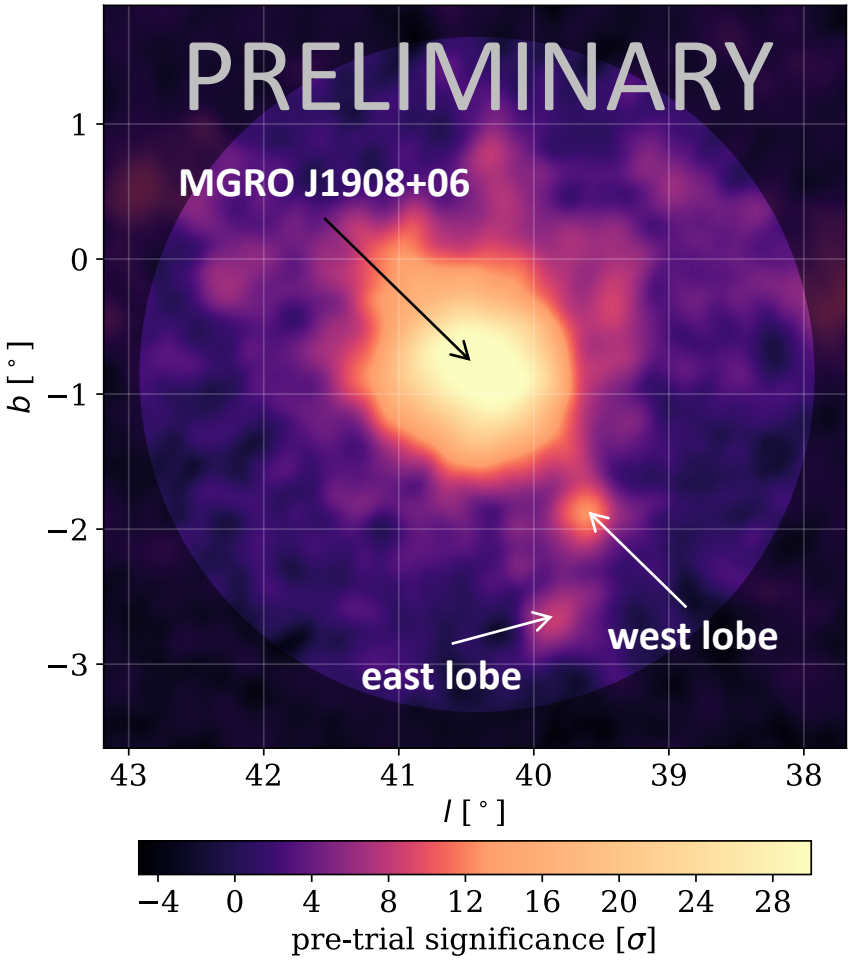
SS 433 as Gamma-Ray Source

- First observation of TeV gamma-ray microquasar jets (HAWC; 2018)
  Abeysekara, A.U. *et al.* SS 433. *Nature* **562**, 82–85 (2018)

- Observation of jet precession in gamma rays (Fermi-LAT; 2020)
  Li, J., Torres, D.F., Liu, RY. *et al. Nat Astron* **4**, 1177–1184 (2020)

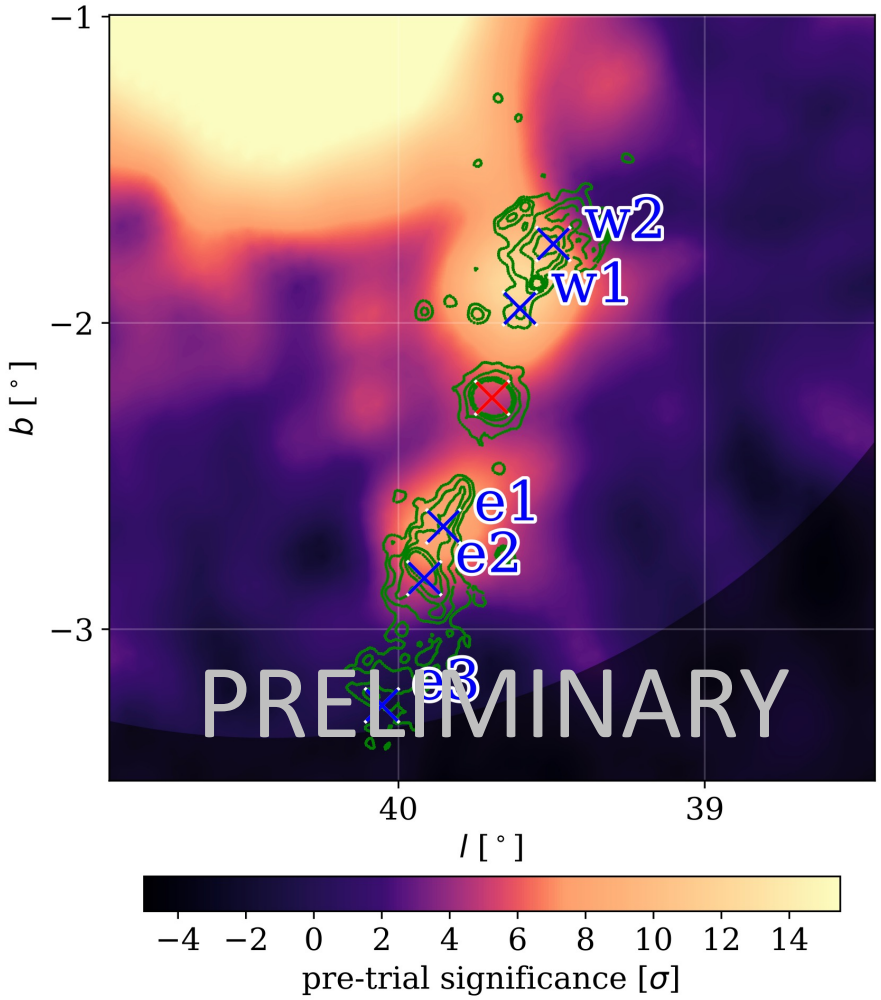
- Observation of energy dependent shift of gamma-ray jets (H.E.S.S.; 2024)
  H.E.S.S. Collaboration. Science 383, 402-406 (2024)

Follow-Up Analysis on SS 433 – 2565 days



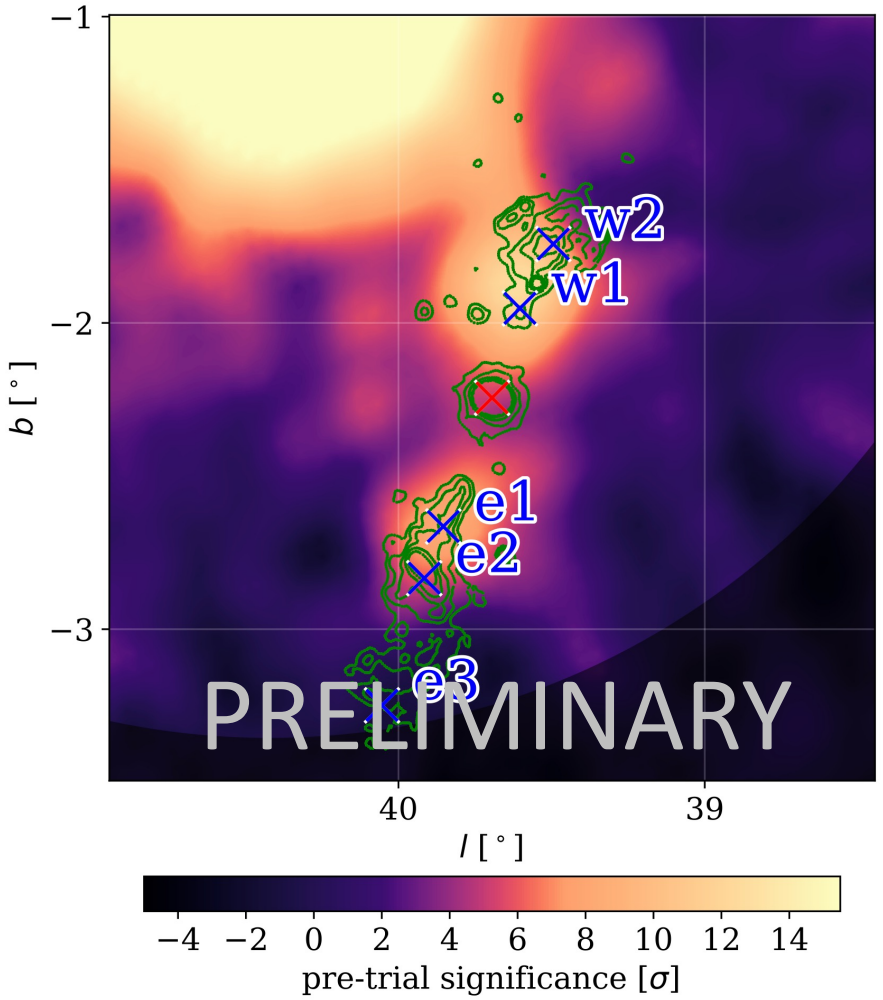
- Brighter lobes, more evident separation from J1908
- Jet lobes now significant enough for individual analyses including spectral studies
- No significant emission from central binary

Follow-Up Analysis on SS 433 – 2565 days

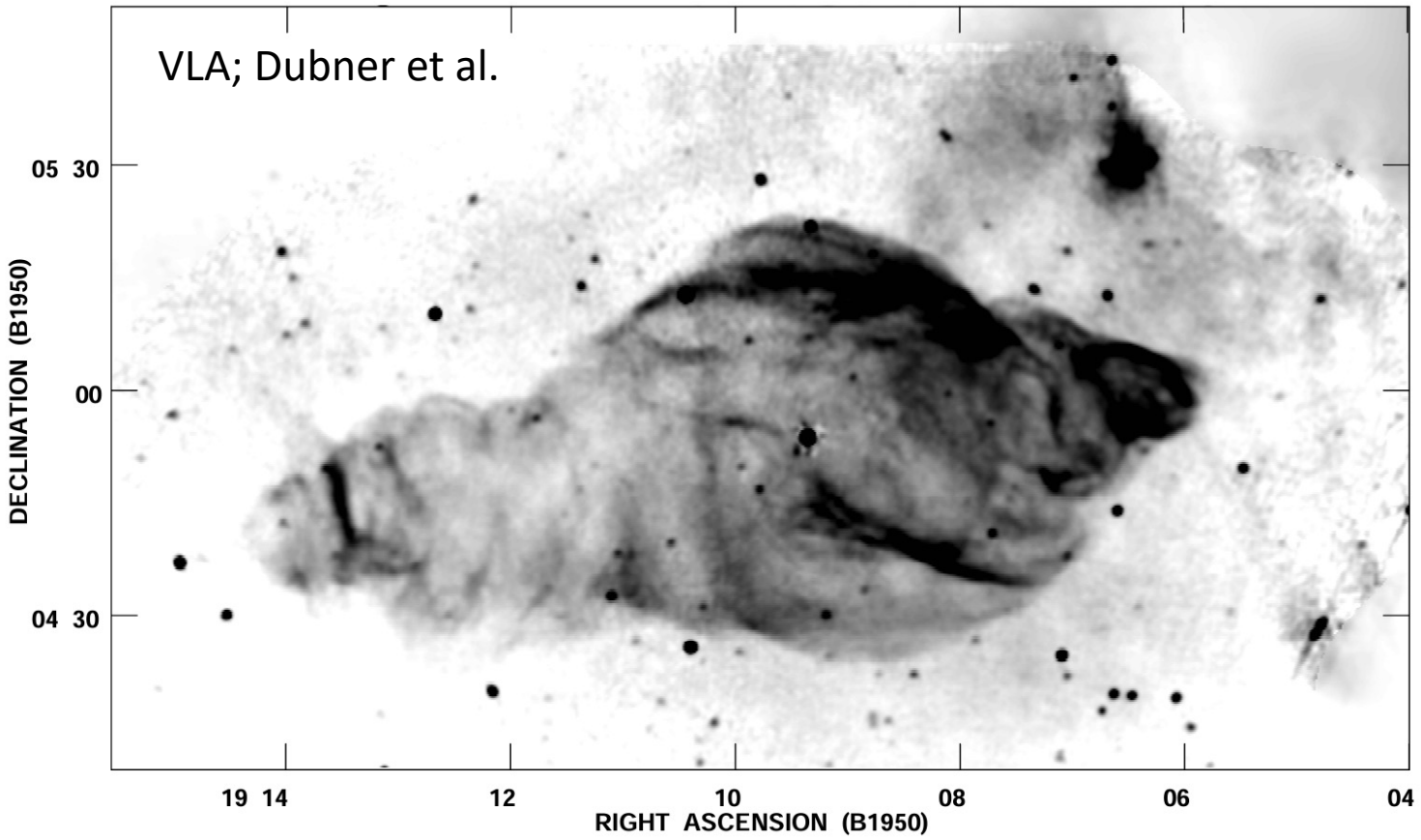


- Lobes still in spatial agreement with X-ray observation
- Best fit locations (after multi-source modeling) match with e1 and w1 for east lobe and west lobe, respectively

SNR W50

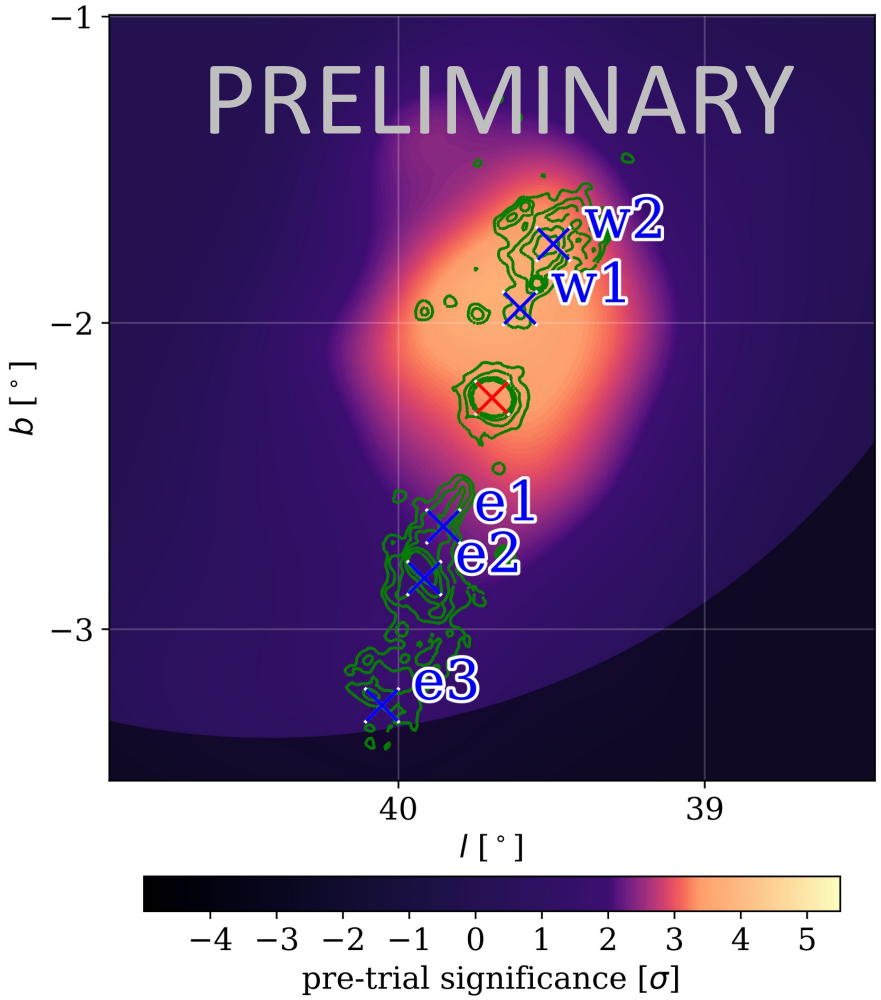


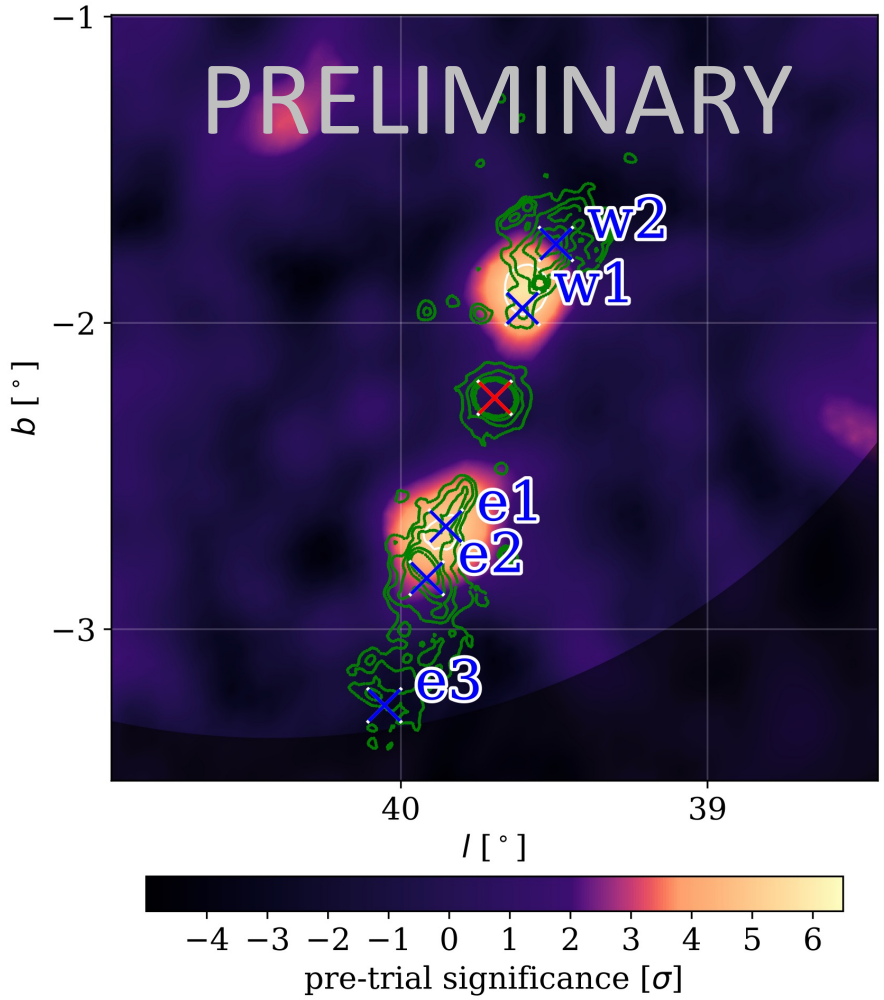
Source confused region!



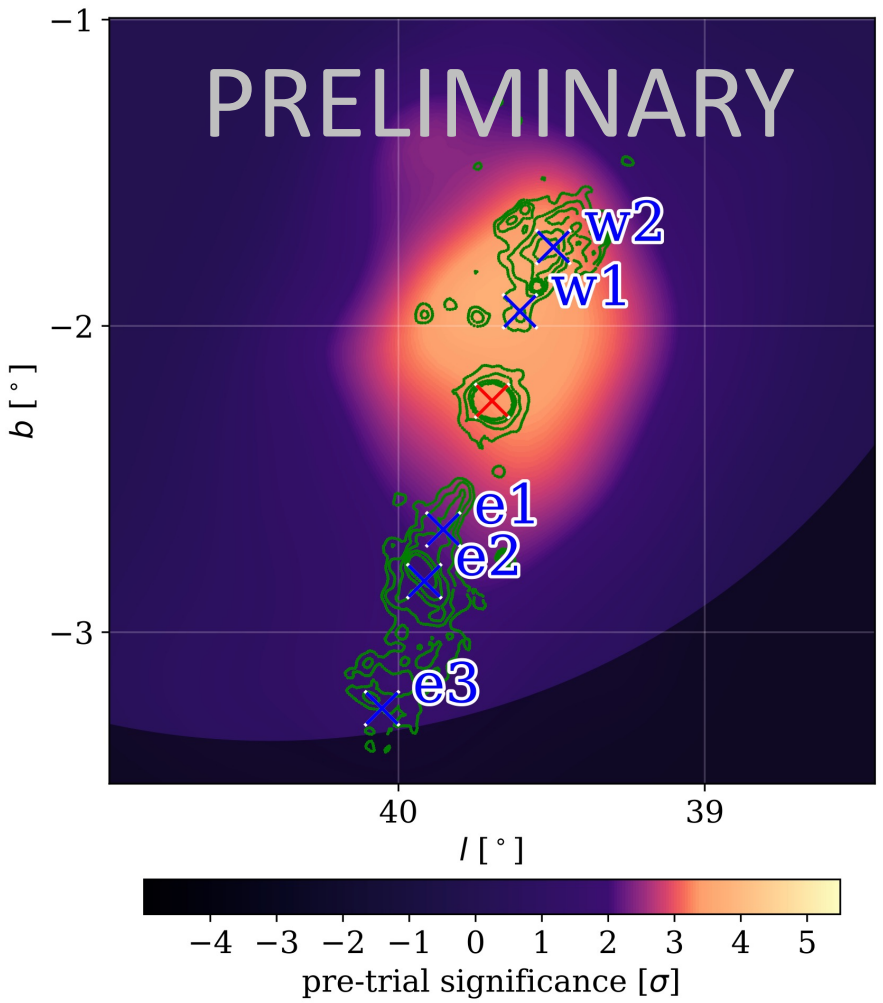
- Though not strong, the cumulative HAWC data suggest that we are getting emission around the lobes

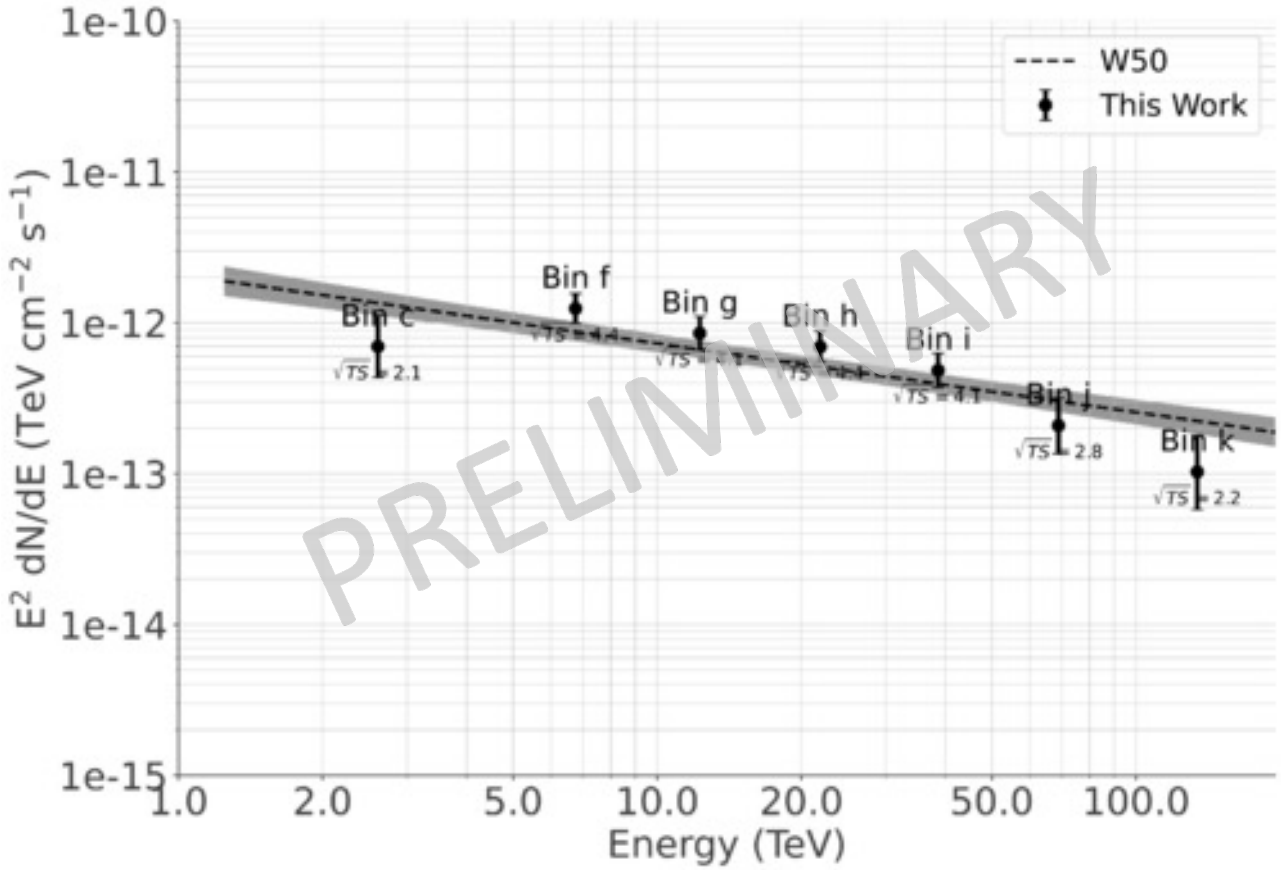
Analysis on W50 – 2565 days



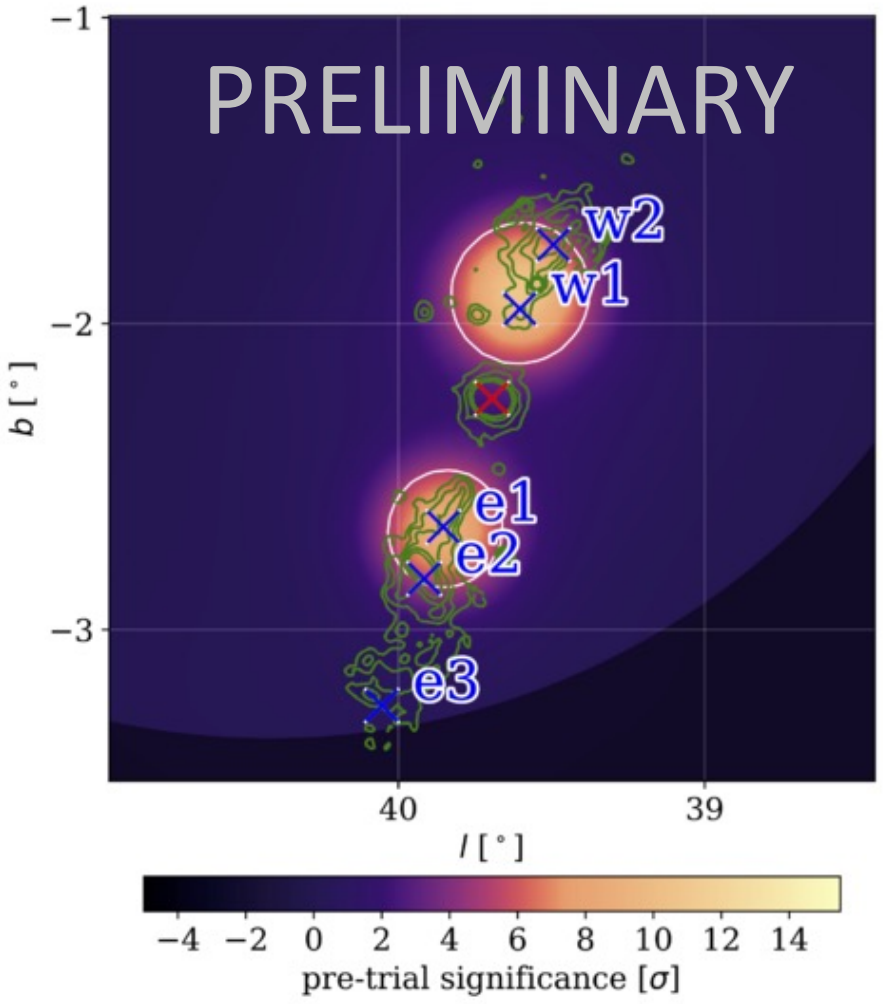


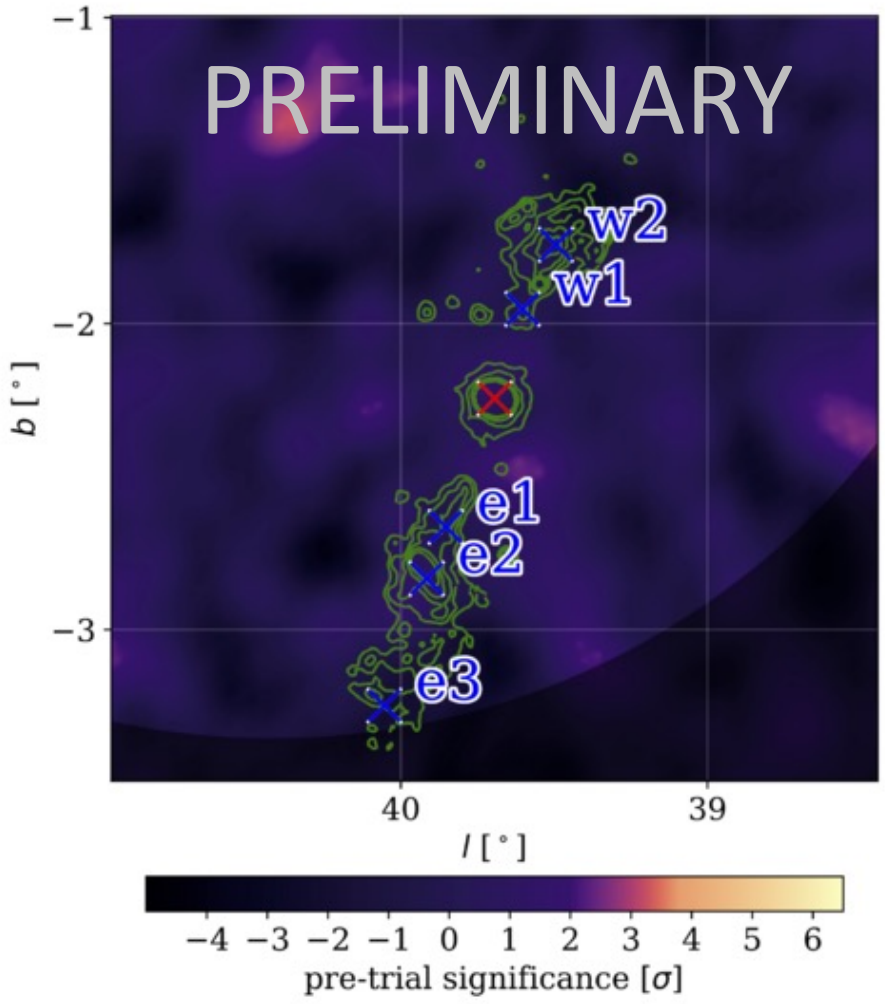
Analysis on W50 – 2565 days



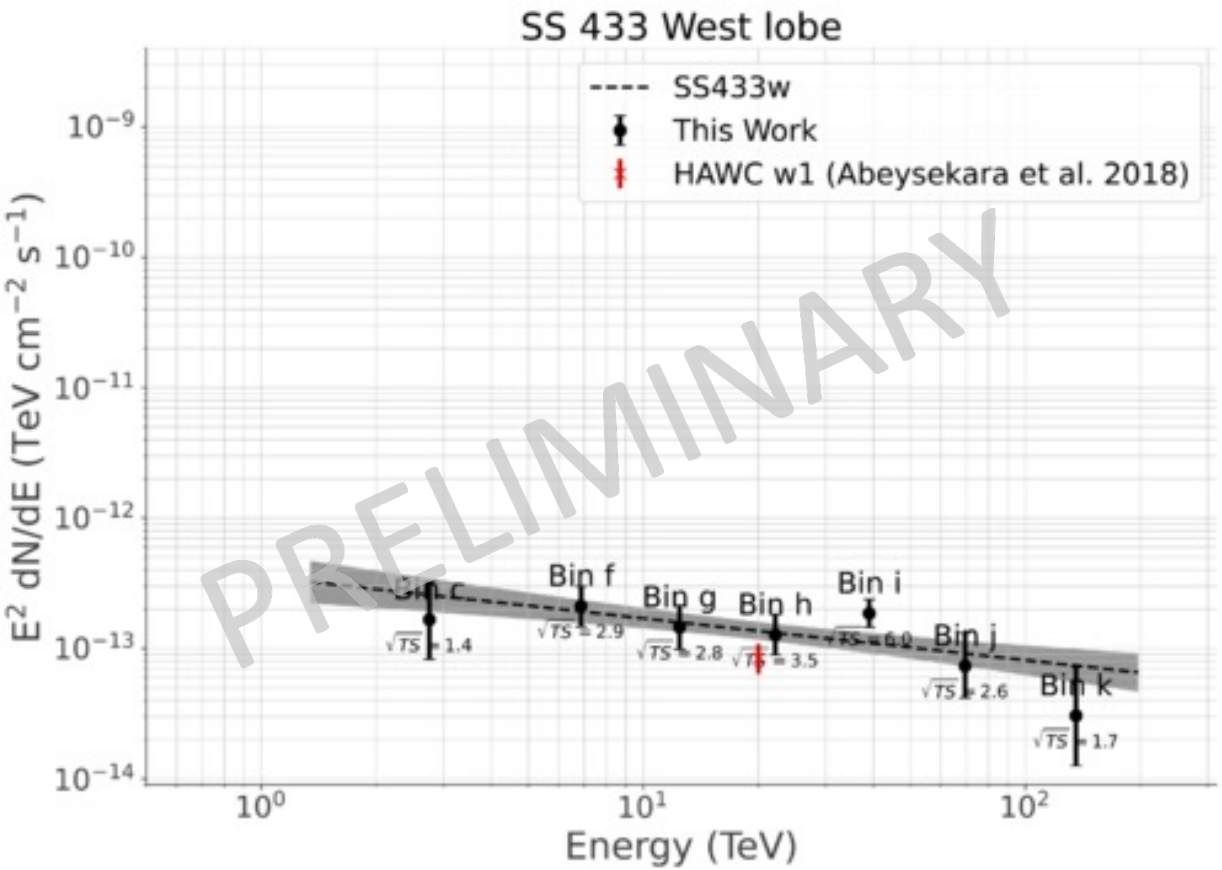


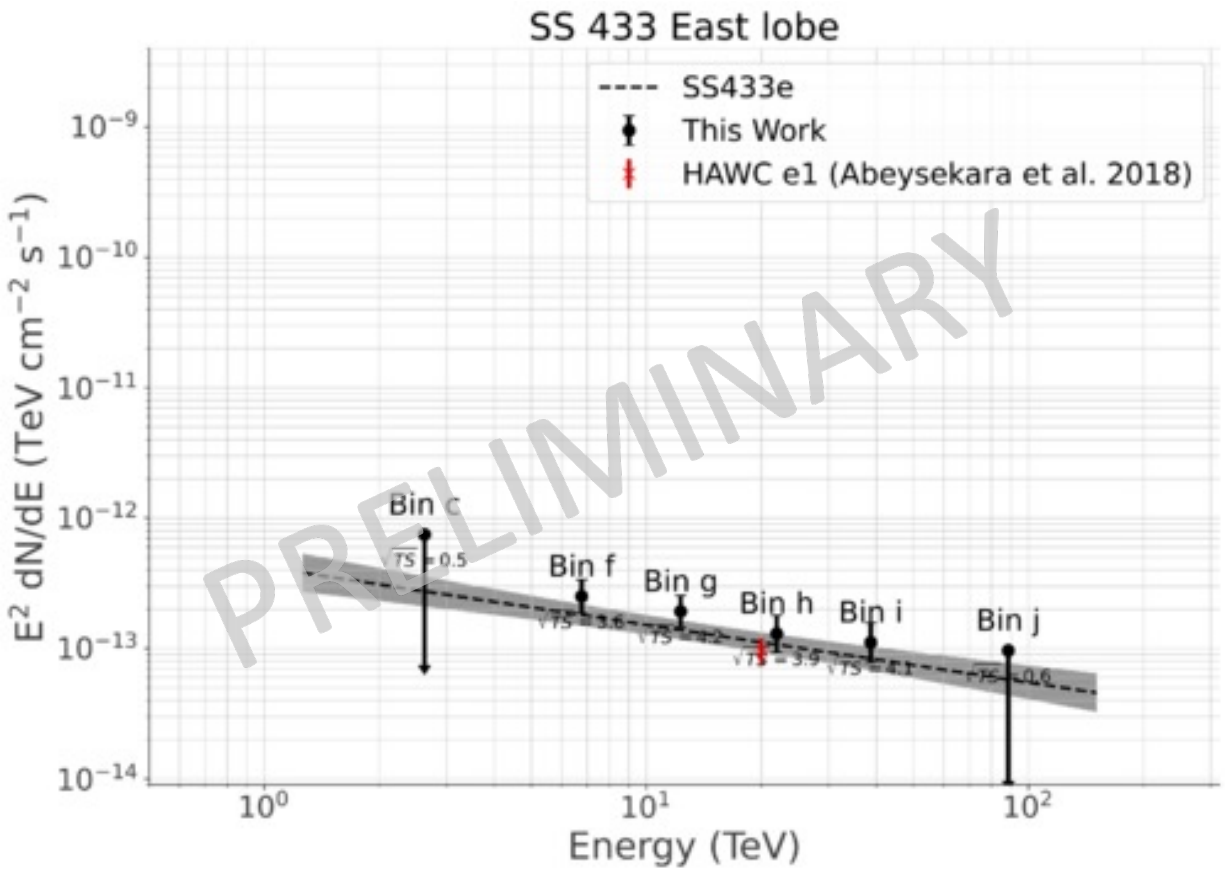
Analysis on W50 – 2565 days





Analysis on SS 433 Jet Lobes – 2565 days



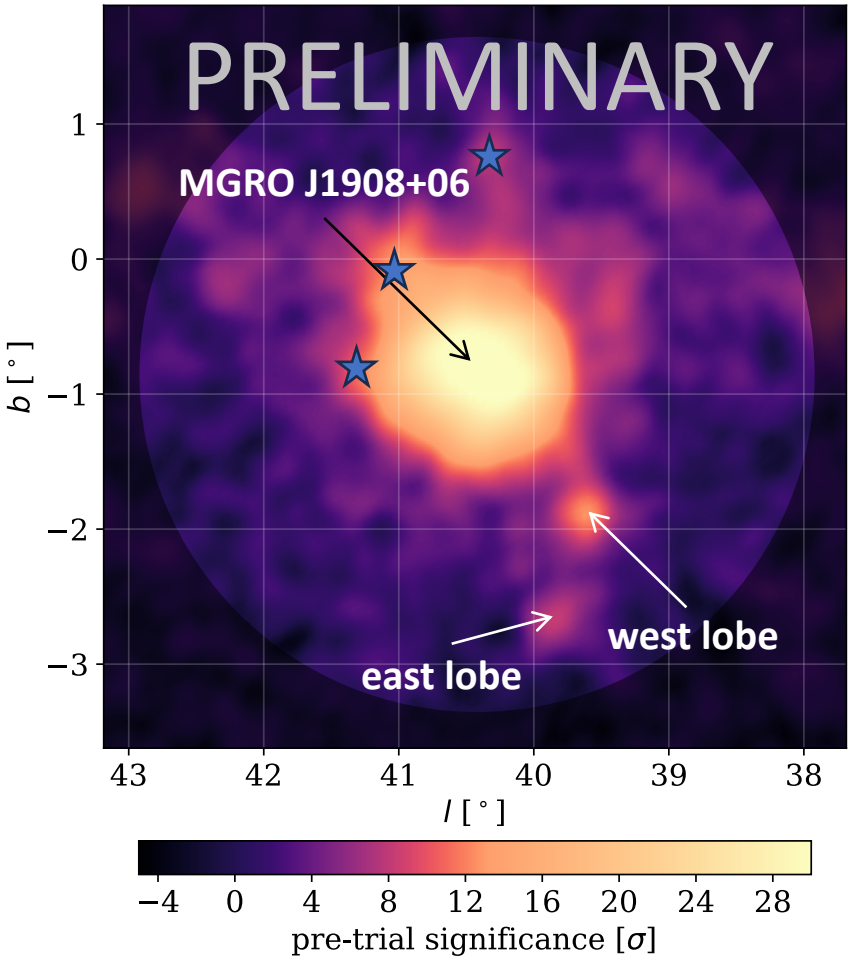


Summary and Future Plans

- HAWC's wide F.O.V. makes it well-suited to study SS 433 and separate its emission from the background sources within a source-confused region
- With increased amount of accumulated data, HAWC can now perform more sophisticated analyses on each jet lobe of SS 433
- Studying W50 and SS 433 may unveil the formation of SS 433 + W50 system
- Using the VLA observational results as a template, HAWC data suggest that we do not see significant emission from W50
- However, the results may still narrow down the power that goes into the explosion or the age / shock properties in the nebula

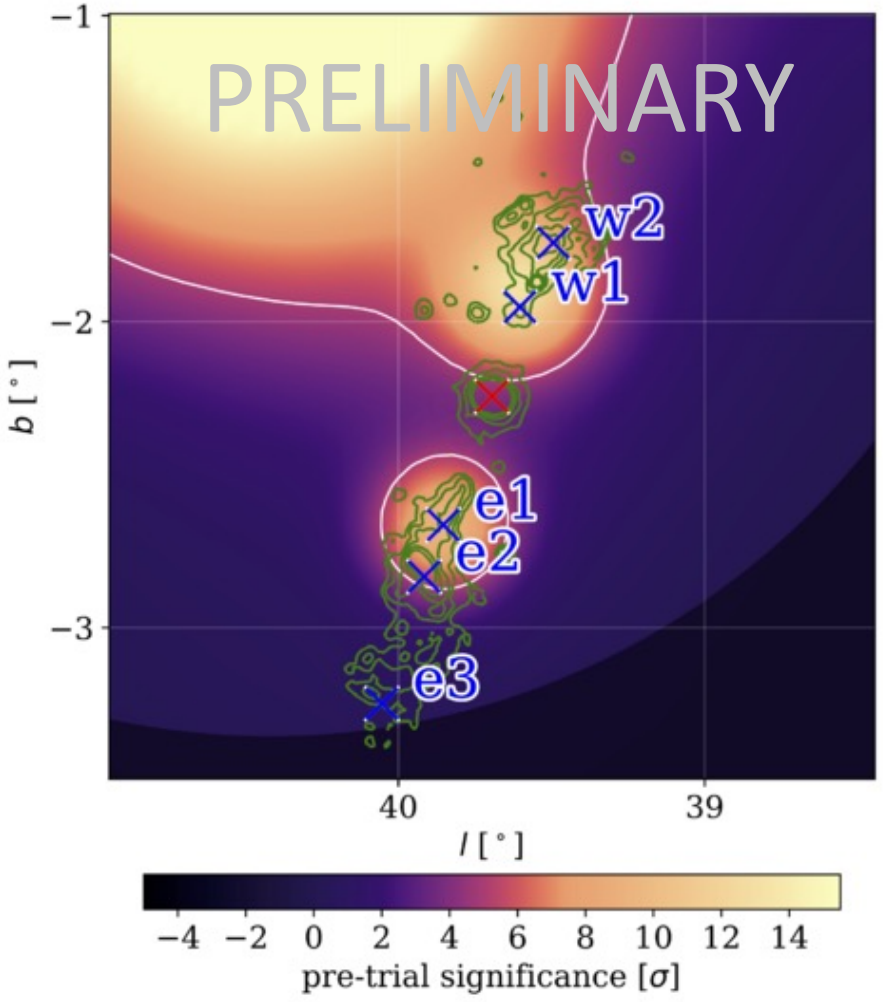
Back Up

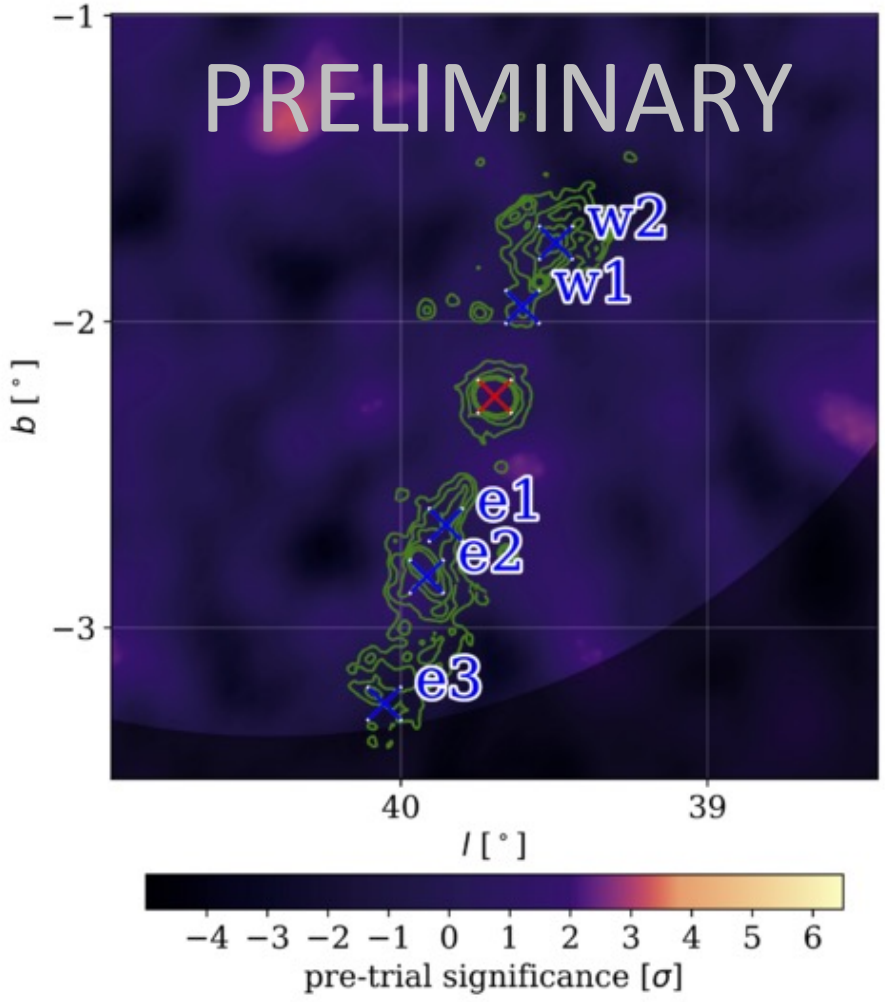
Follow-Up Analysis on SS 433 – 2565 days



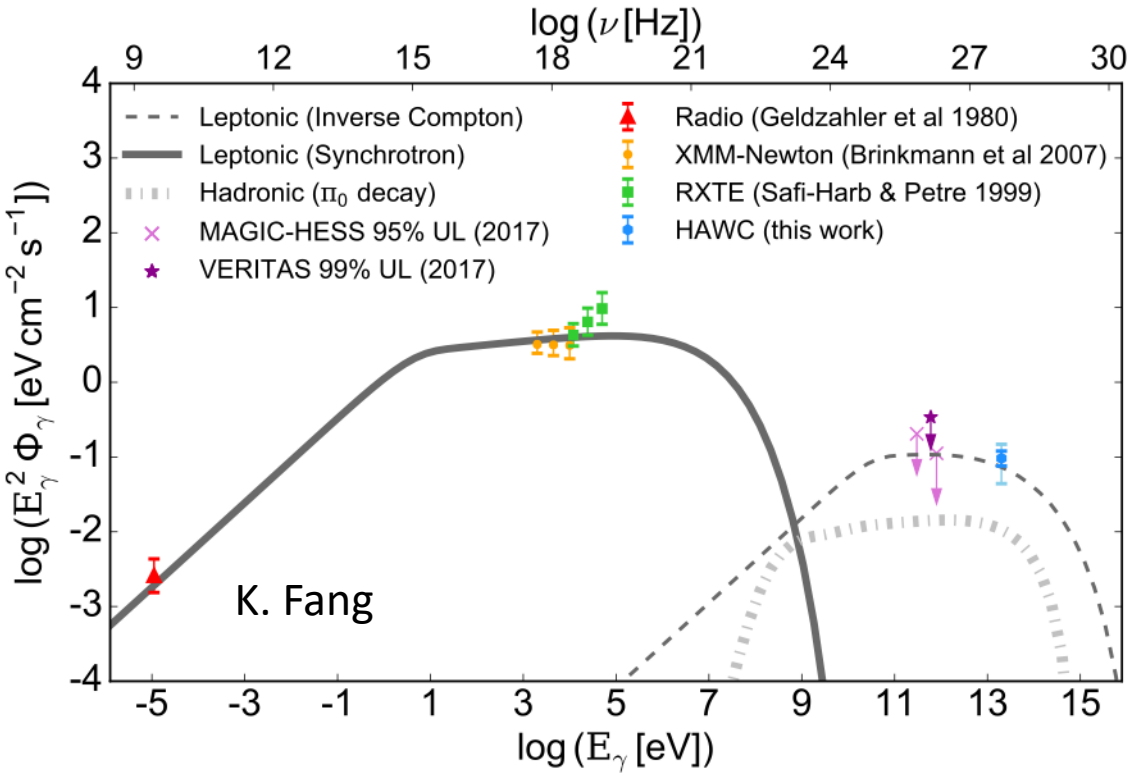
- Systematic source search in the disk ROI
- No *a priori* assumptions on the number of sources + positions of the sources
- Found six sources (1 extd, 5 pnt) within the region
- Three of the sources consistent with MGRO J1908+06 (extd), east jet lobe (pnt), west jet lobe (pnt)
- No significant emission from central binary

Analysis on W50 – 2565 days





Broadband S.E.D. at e1 (2018)



- Leptonic: radio + X-ray photons are produced via synchrotron emission in a magnetic field. TeV γ rays observed by HAWC are produced via IC of CMB by the same population of e^-.