



An Overview of Galactic TeV Sources

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TeVPA, Sydney 2019

VERITAS



MAGIC II



HAWC



H.E.S.S.

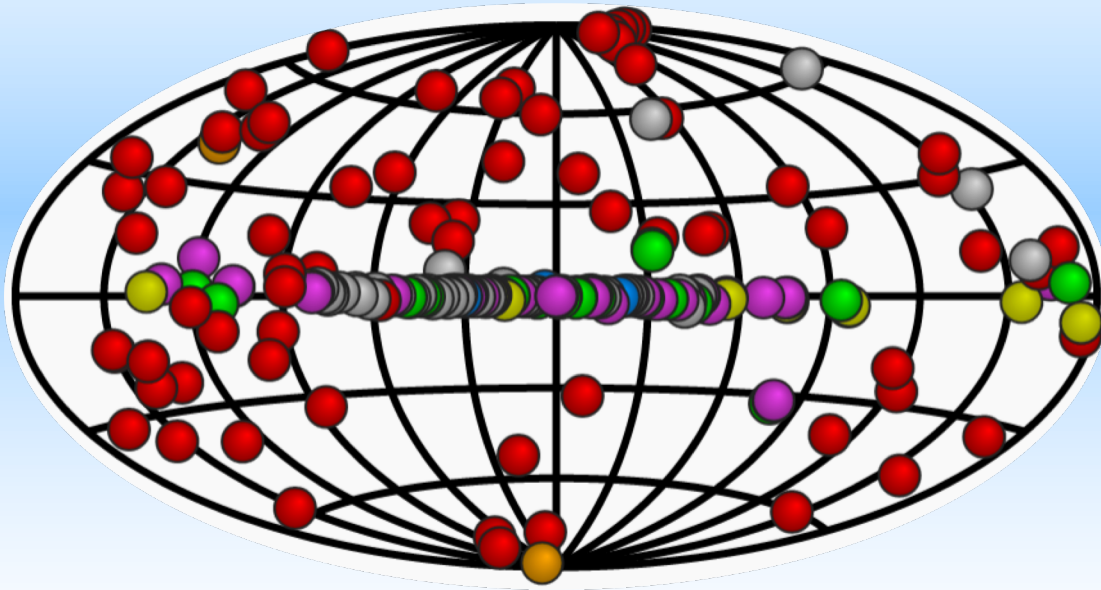


Galactic discovery instruments of the last decade



The TeV Gamma-ray Source Catalog

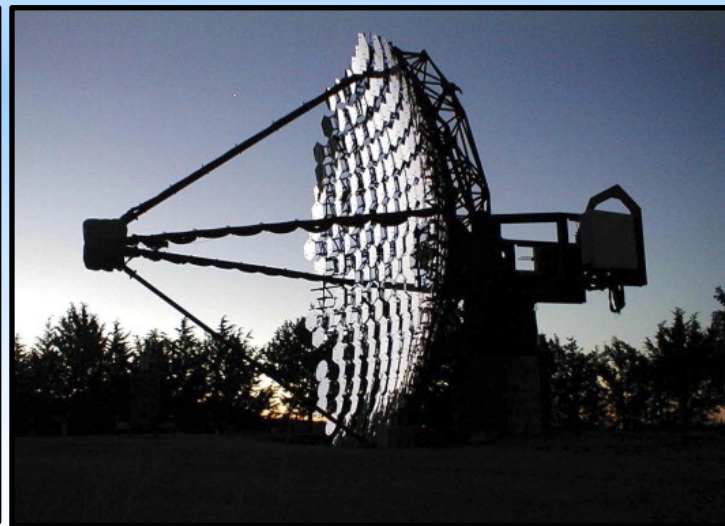
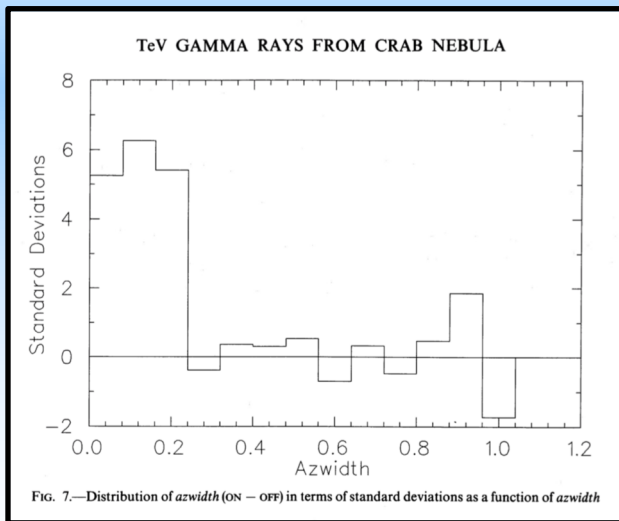
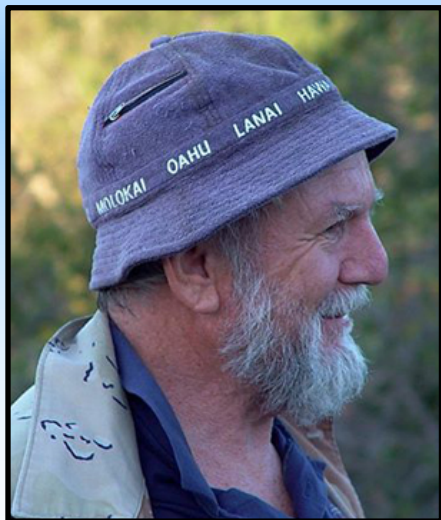
- 225 sources from many different source classes and sub-categories.
- One third are Galactic.



- Pulsar and/or Pulsar wind Nebula
- Active Galactic Nucleus
- Supernova Remnant
- Starburst Galaxy
- Unidentified
- Binary system
- Stellar Cluster

The Crab Nebula

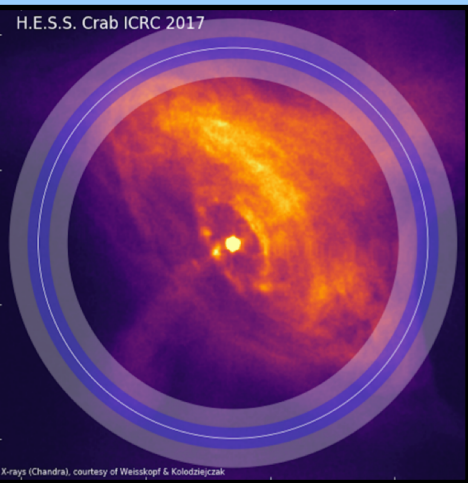
- First astrophysical TeV gamma-ray source detected (Whipple Collaboration, in 1989).
- Emission is SSC of leptons accelerated near the termination shock of the pulsar wind.



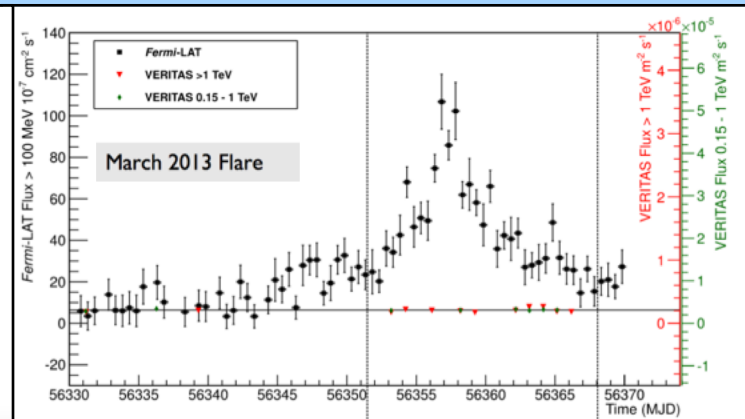
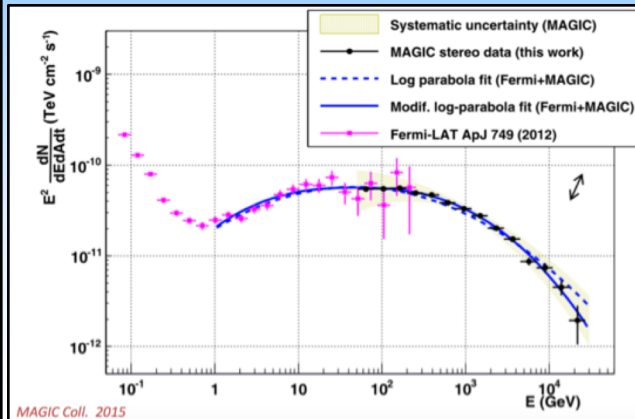
The Crab Nebula

- Current generation of IACTs have provided measurements of *exceptional* precision:
 - The Crab emission is *spatially resolved* at TeV energies.
 - The inverse Compton spectral peak is *flattened*.
 - Emission is *steady* to <12%. GeV Crab flares have *no counterpart* at TeV energies.

H.E.S.S. Crab ICRC 2017



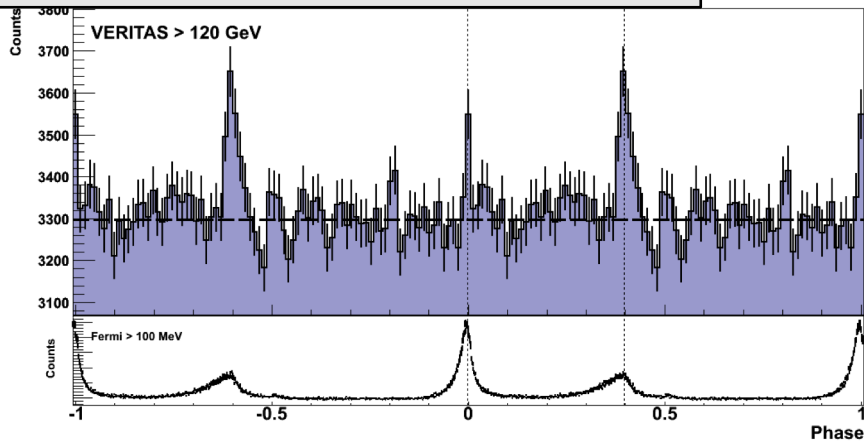
X-ray (Chandra, courtesy of Weisskopf & Kołodziejczak)



The Crab Pulsar

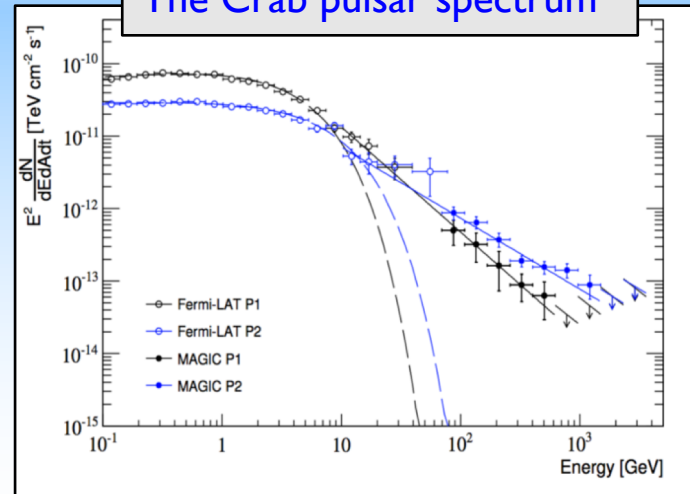
- Fermi-LAT measures a spectral break at **6 GeV**
- VERITAS measured power-law emission **above 100 GeV**
- Implies emission region > 10 stellar radii, curvature radiation unlikely.
- Latest MAGIC results extend to 1 TeV, and H.E.S.S. has now detected Vela pulsar up to 7 TeV.
 - **New component.**
 - **The Crab is not the only TeV pulsar.**
- What is the pulsar emission mechanism at the highest energies? What is the population?

The Crab pulsar lightcurve > 120 GeV



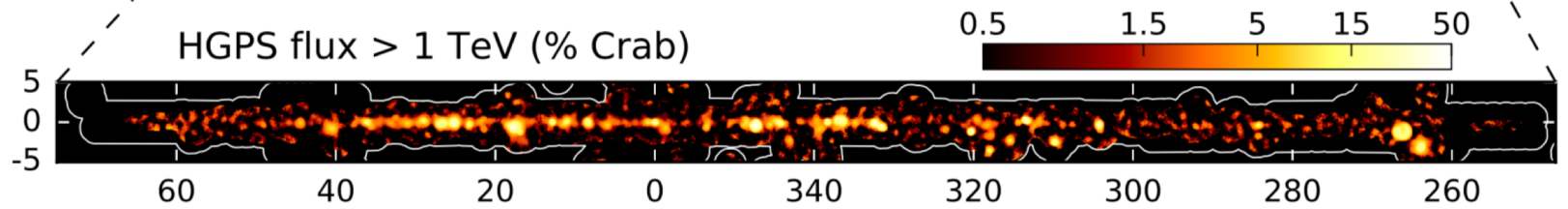
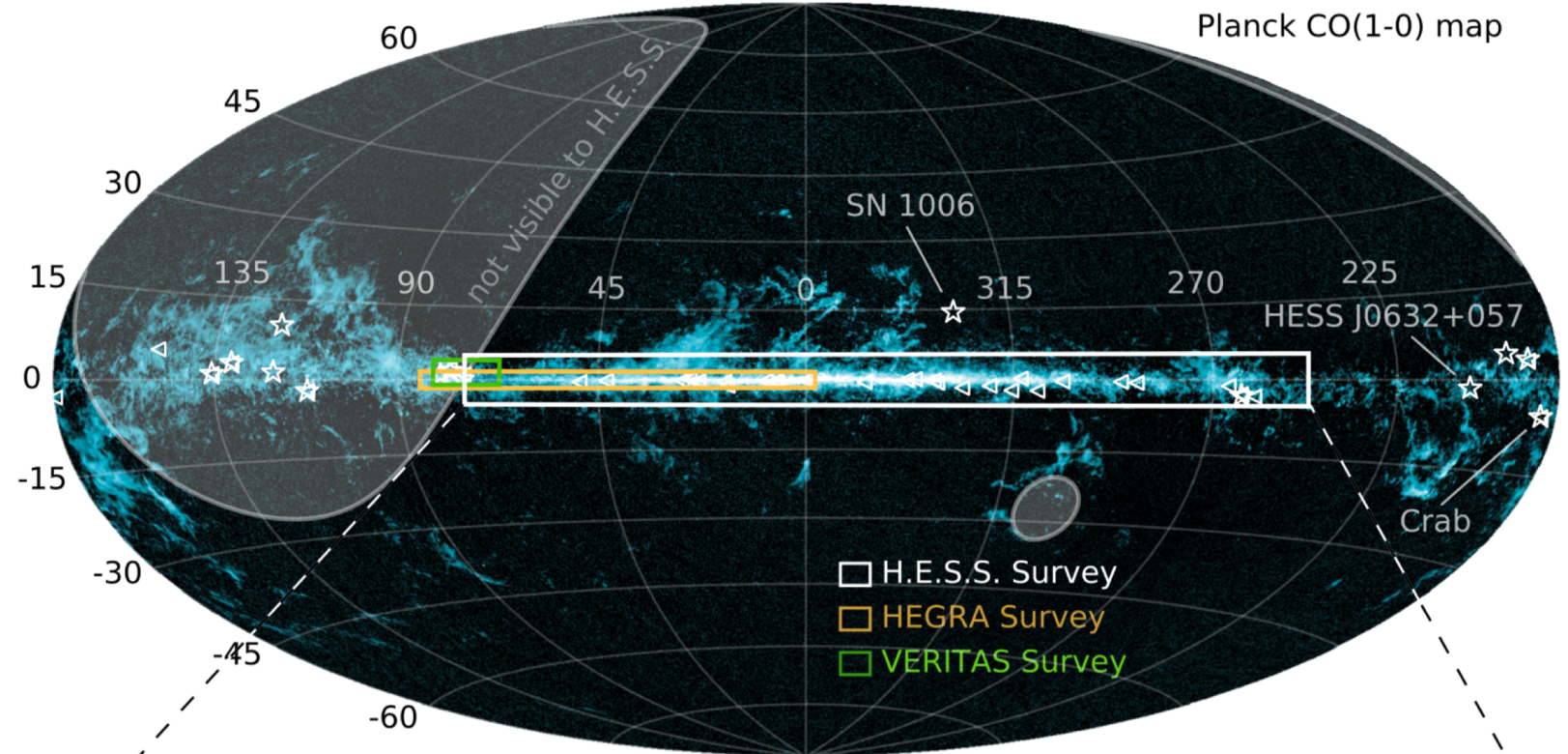
VERITAS Collaboration, Science, 334, 69, 2011.

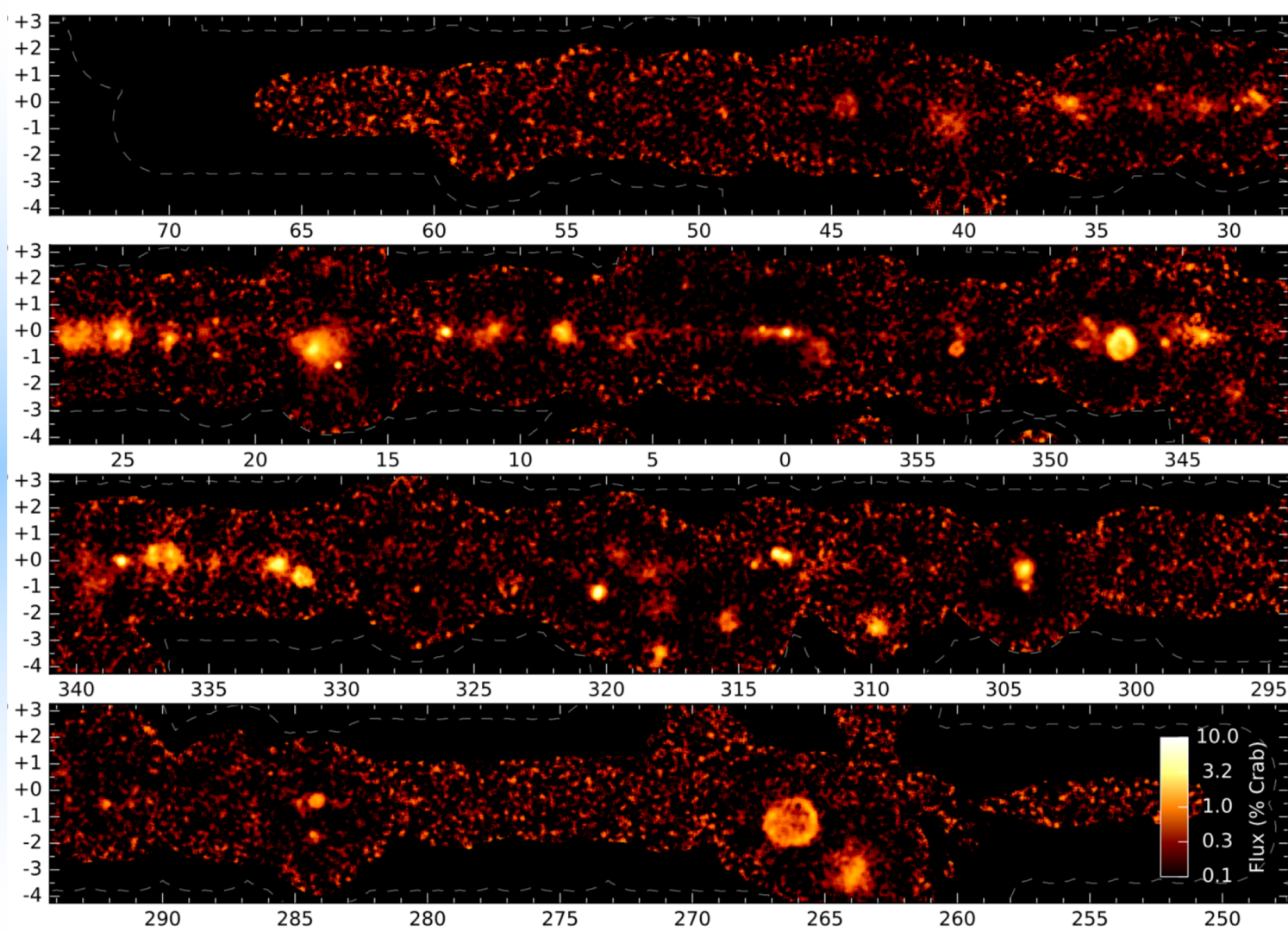
The Crab pulsar spectrum

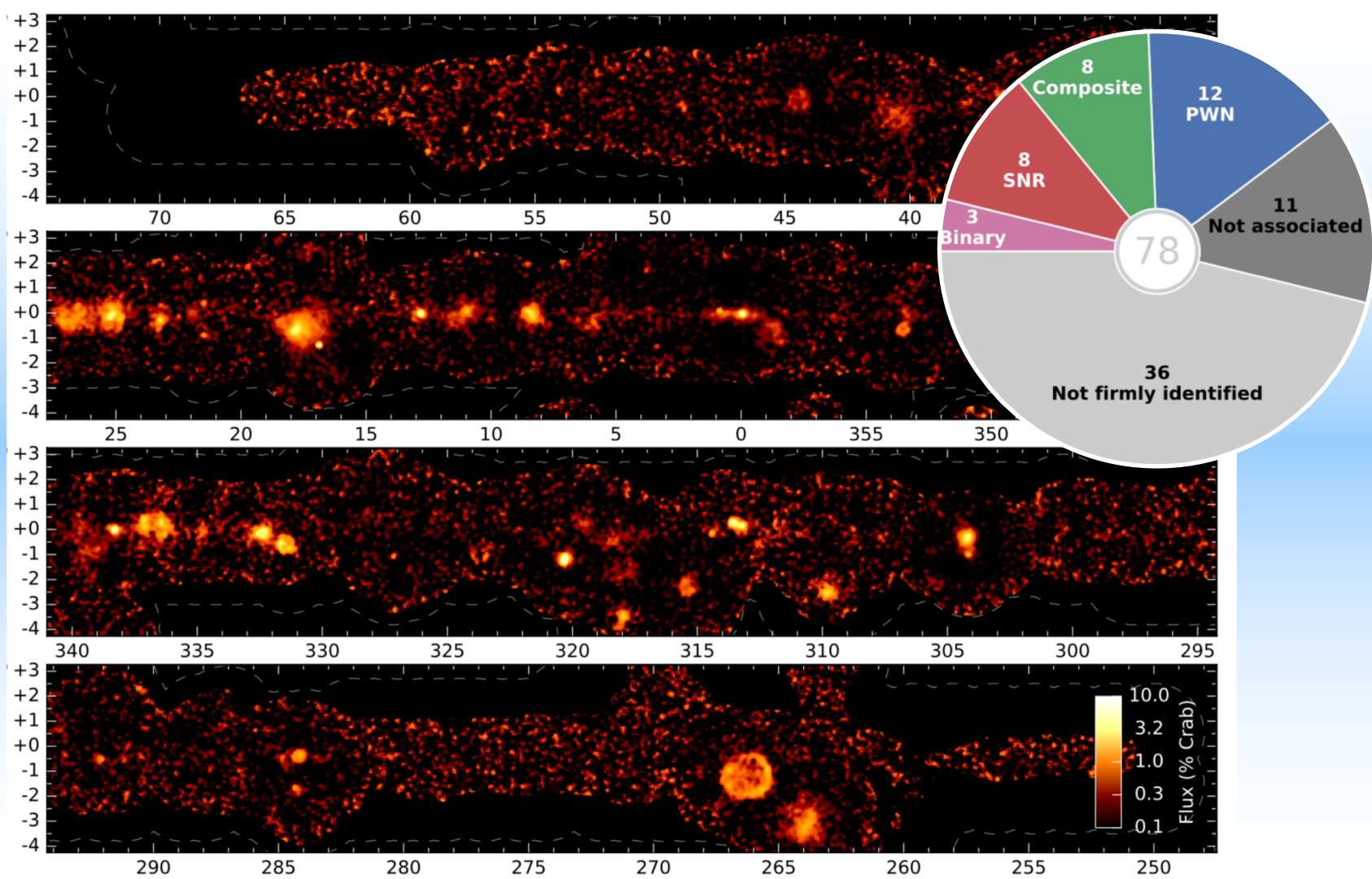


MAGIC Collaboration, A&A, 585, 133, 2016.

Planck CO(1-0) map

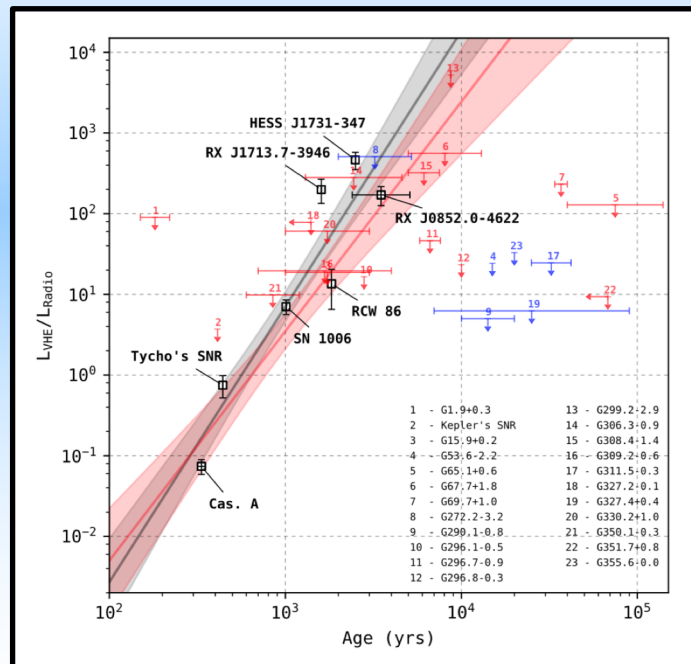
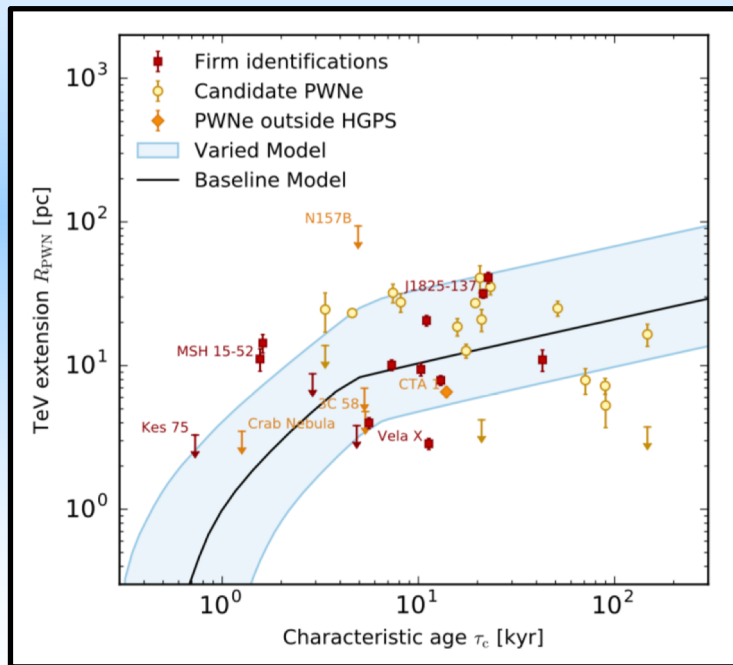






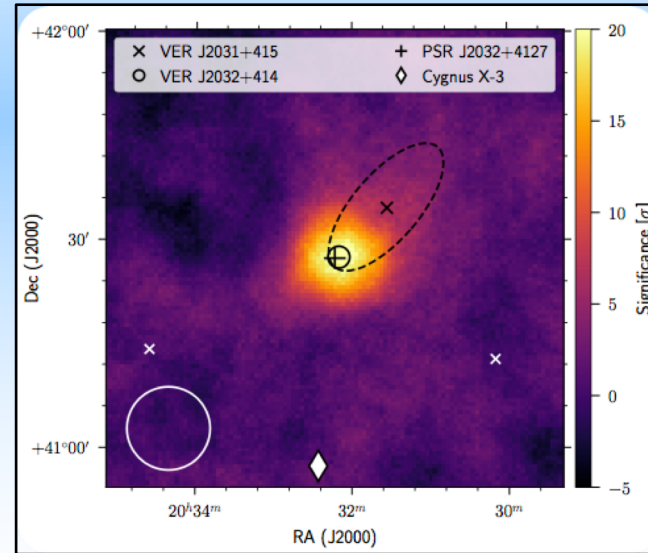
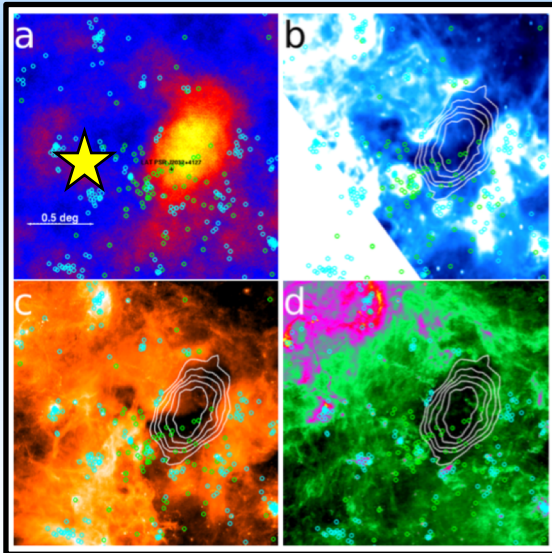
Galactic Population Studies

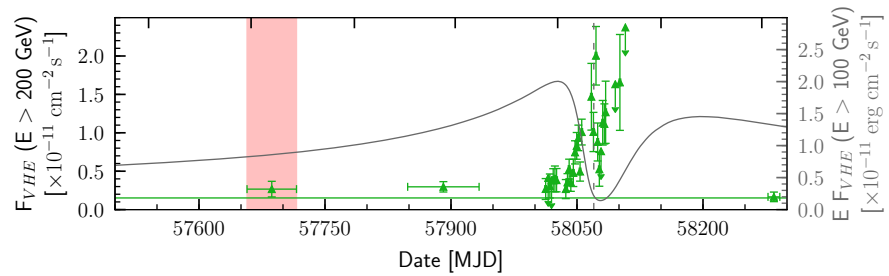
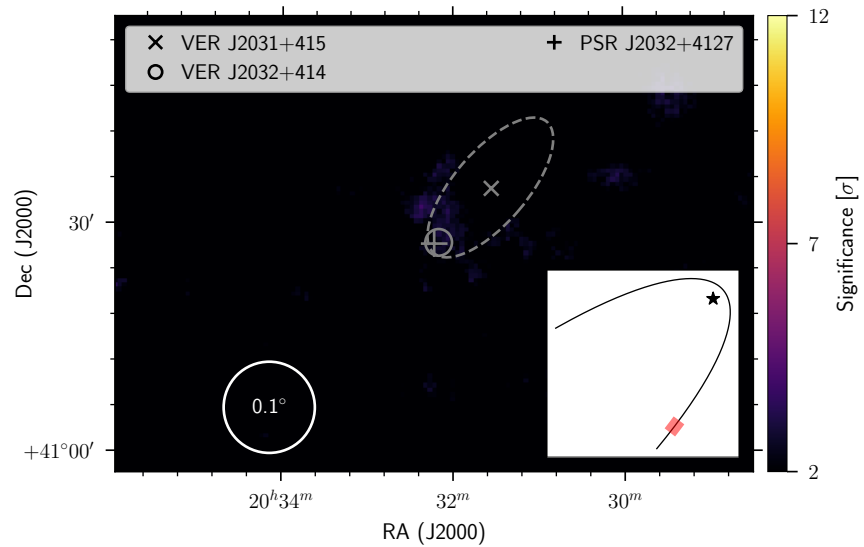
- The growing catalogue of Galactic TeV sources allows the first *population studies* of the properties and evolution of very high energy emission from pulsar wind nebulae and supernova remnants.

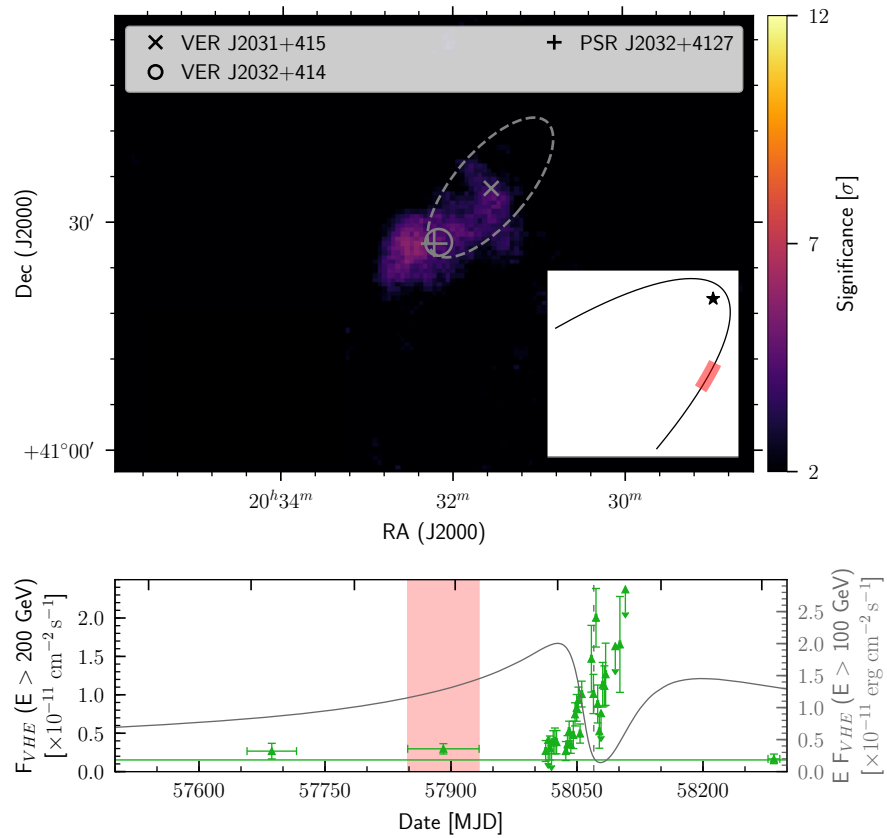


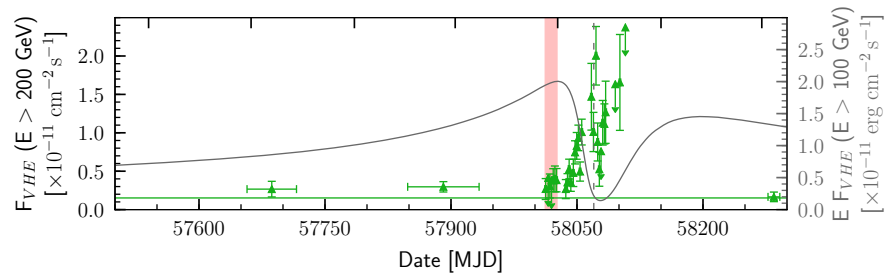
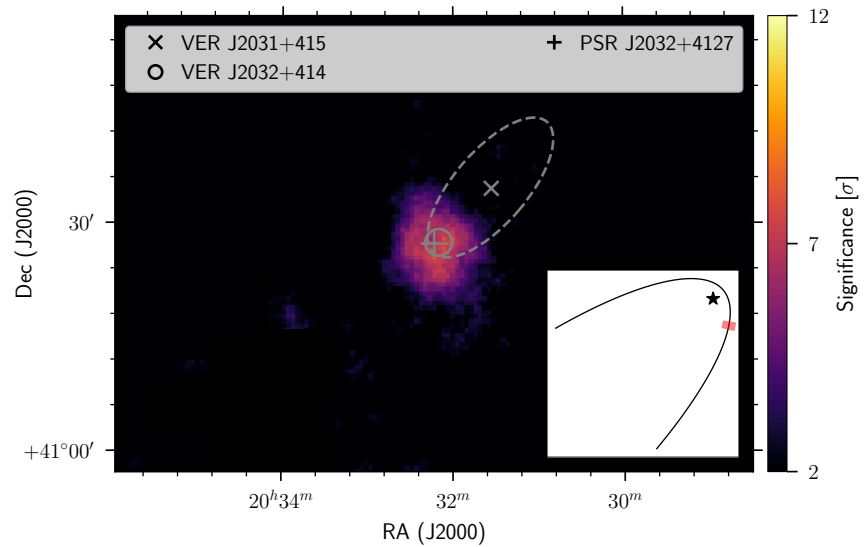
Two-for-one: a gamma-ray binary PWN

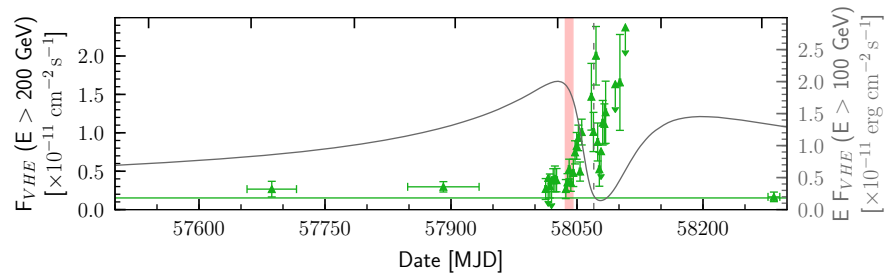
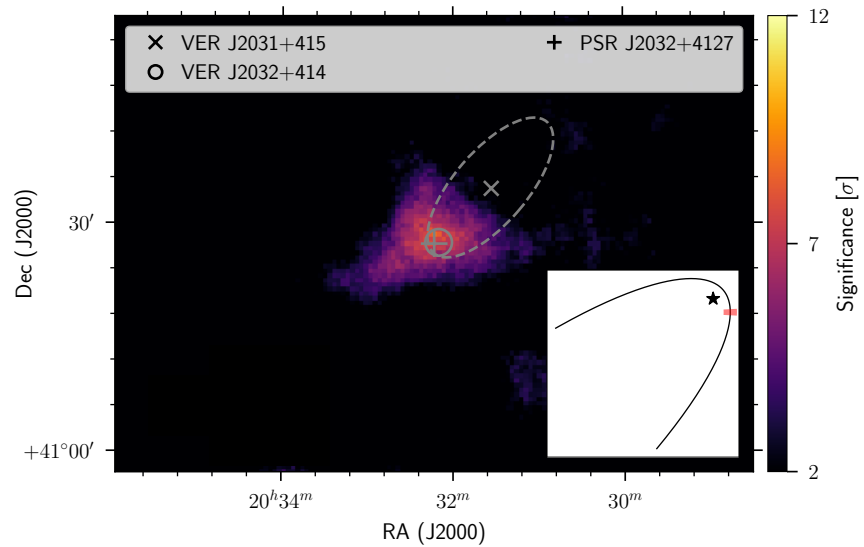
- TeV J2032+4127 was the first TeV source discovered (HEGRA) with no clear counterpart.
- VERITAS showed it to be an asymmetric, extended source, coincident with a radio/IR void.
- In 2009, Fermi discovered the likely power source: PSR J2032+4127 driving a PWN.
- In 2015, Lyne et al. showed that the pulsar is in 50-year period Be-star binary system.
- MAGIC and VERITAS monitored from 2016-2018, detecting bright flaring from the binary.

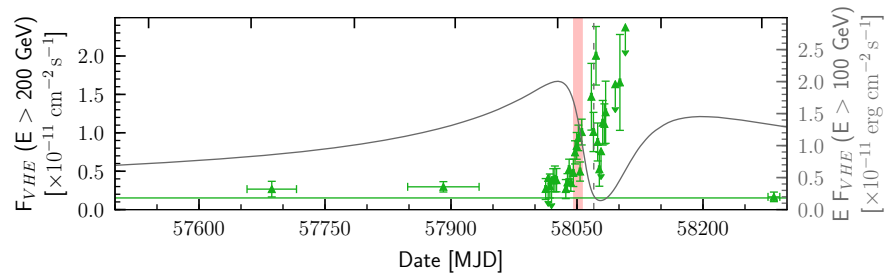
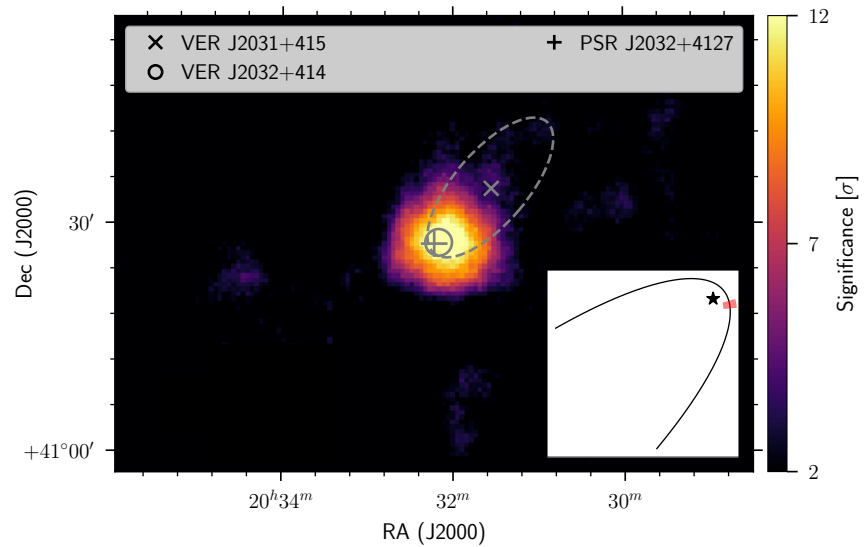


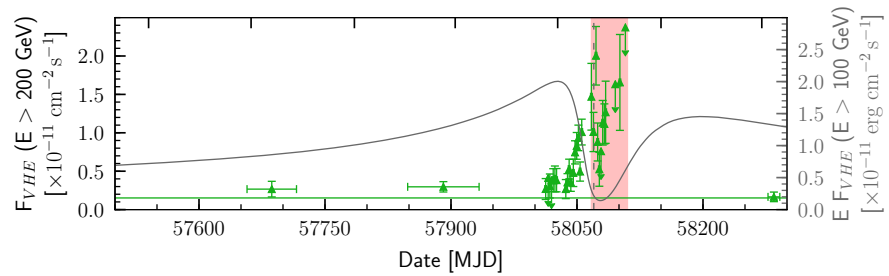
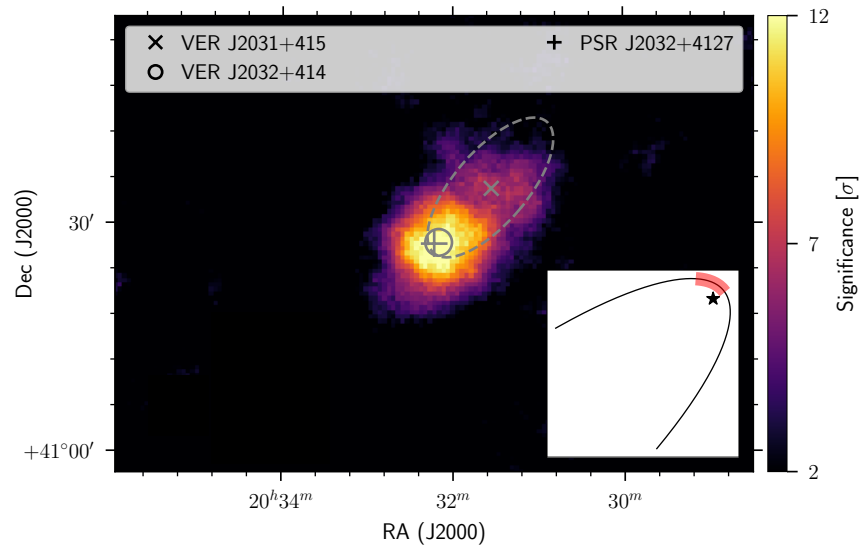


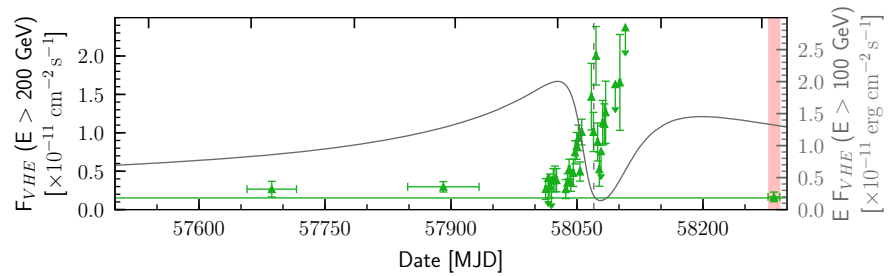
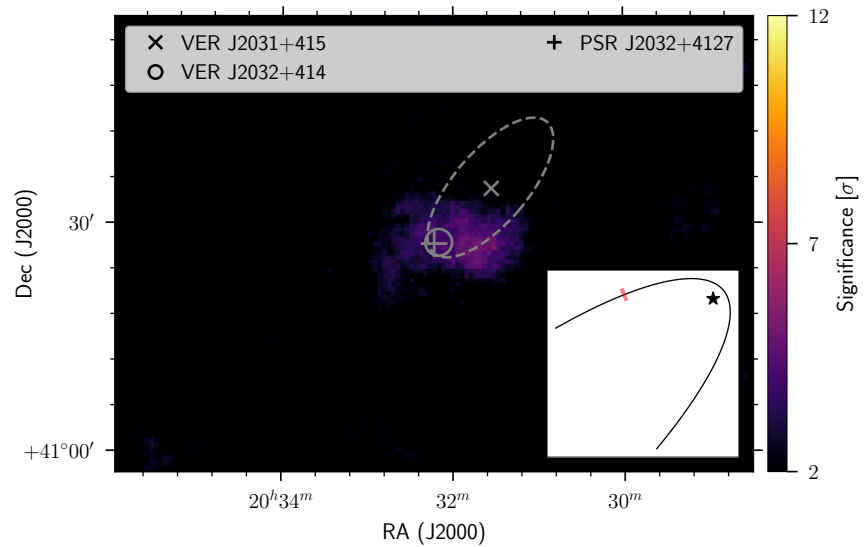








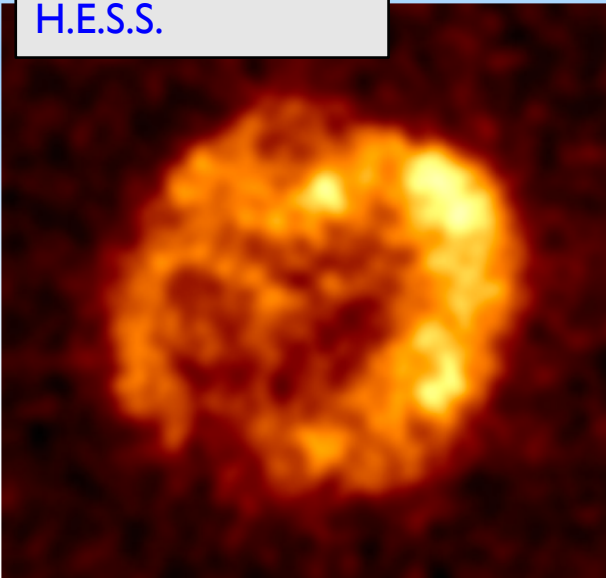




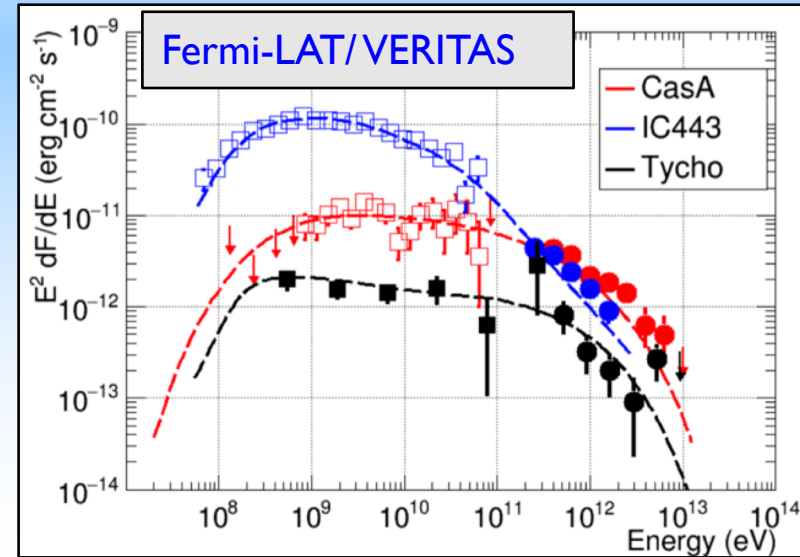
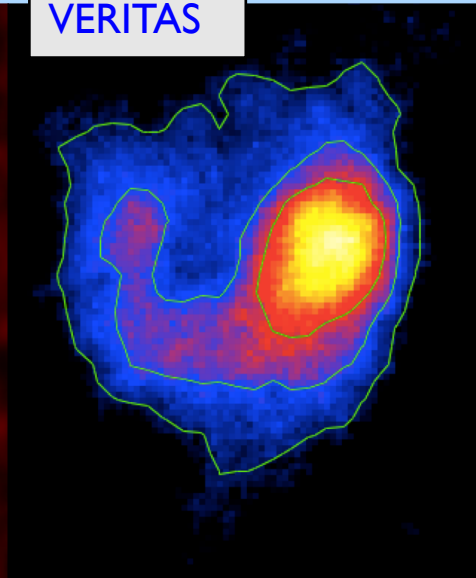
Shell-type Supernova Remnants

- Promising candidates to supply the majority of Galactic cosmic rays.
- A population which now includes a TeV-only detection (HESS J1912+101).
- Discrimination between leptonic and hadronic particle populations is often difficult.
- Even where hadrons are favored, the spectra do not extend to tens of TeV.

RX J 1713.7-3946
H.E.S.S.

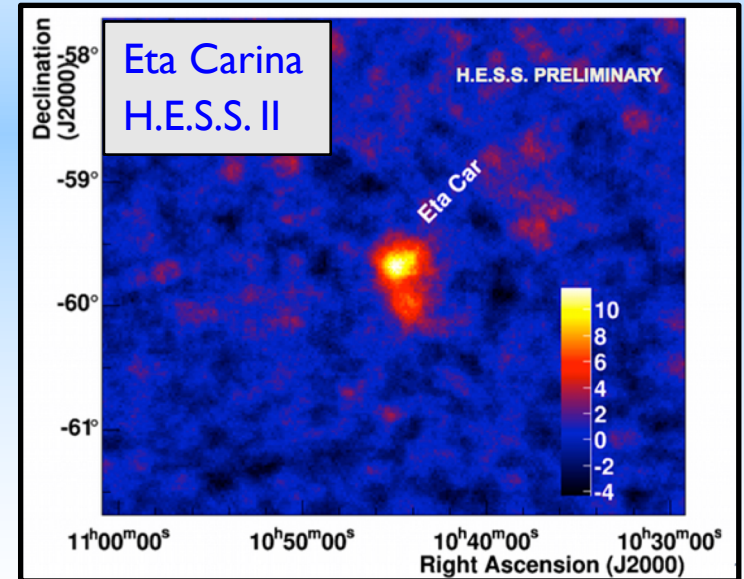
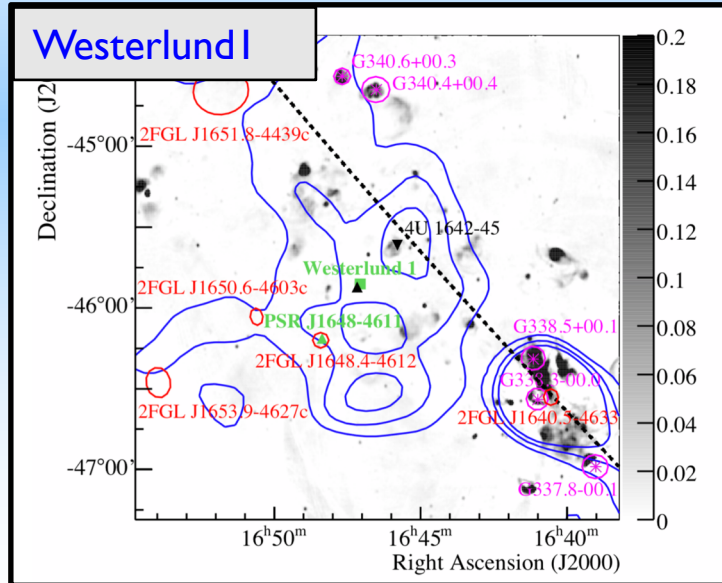


IC 443
VERITAS



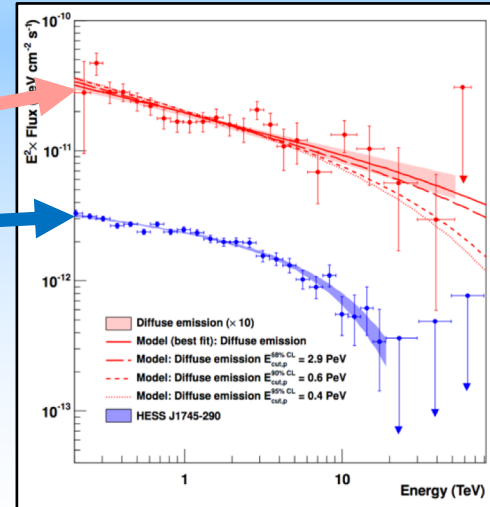
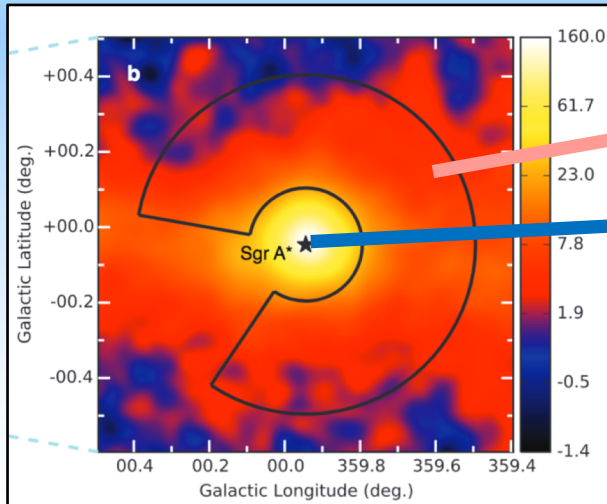
Star forming regions and wind interactions

- Westerlund I: most massive stellar cluster in the Galaxy
- Challenging observations and interpretation, due to source extent and confusion.
- Eta Carina provides first clear evidence of TeV emission from colliding winds.

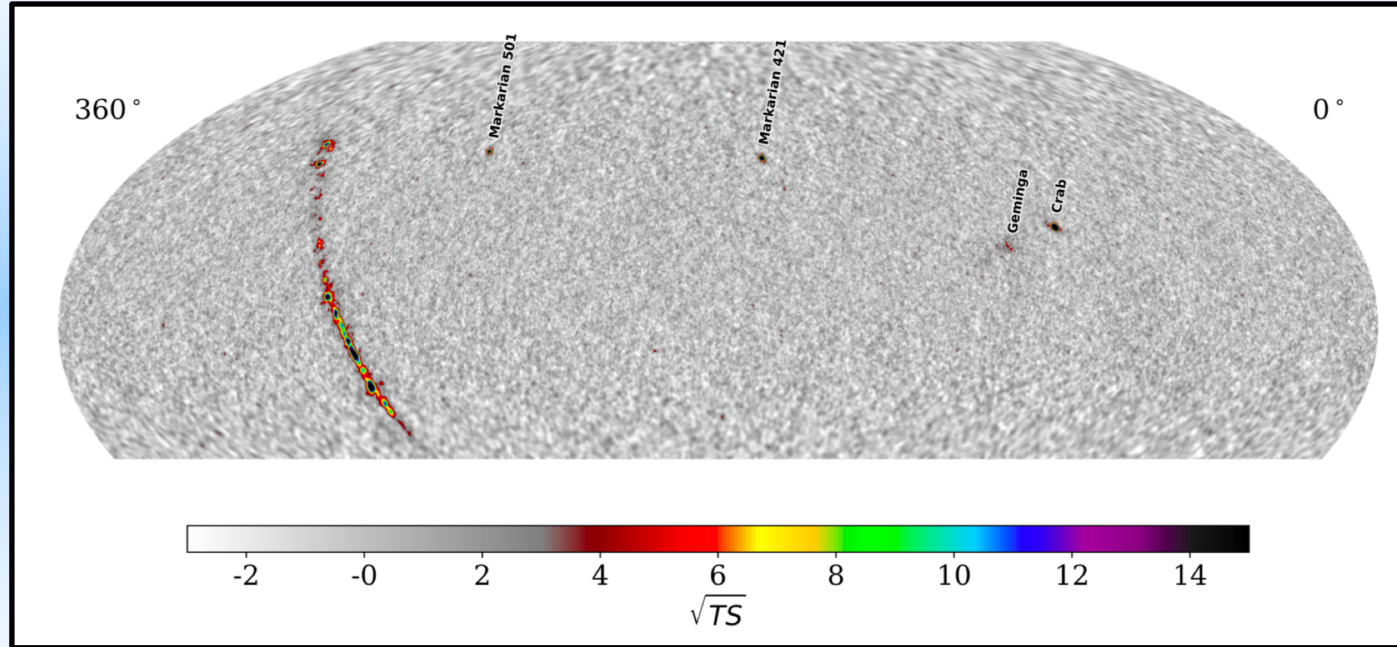


The Galactic Center Region.

- H.E.S.S. detected a bright, steady TeV source, spatially coincident with SgrA*
- Diffuse emission is observed along the plane, within a few degrees of the Galactic Center.
- The diffuse spectrum extends to 40 TeV with no cutoff.
- Indicates presence of PeV particles – but not sufficient to explain Galactic CR flux..
- Large zenith observations by northern instruments help to study highest energies.

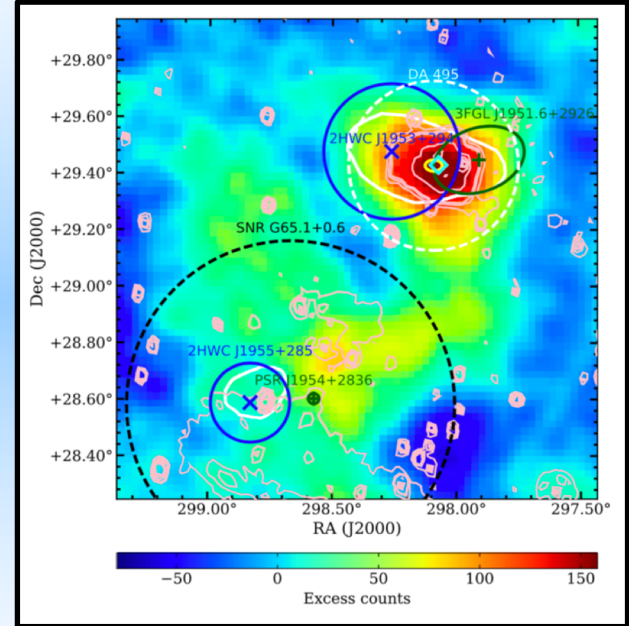
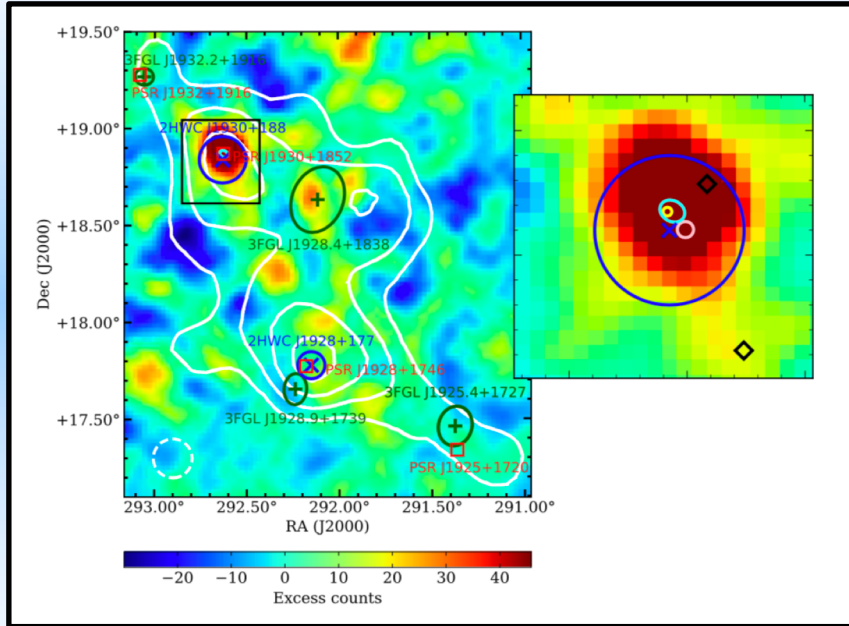


HAWC Survey

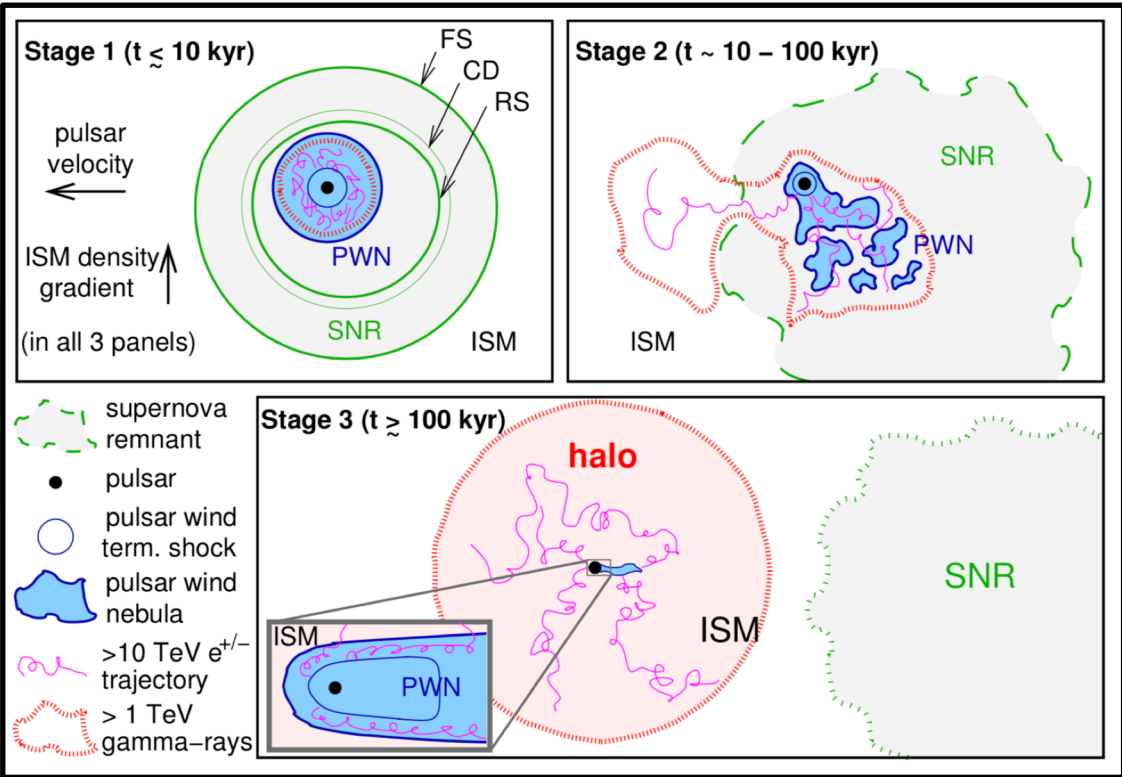
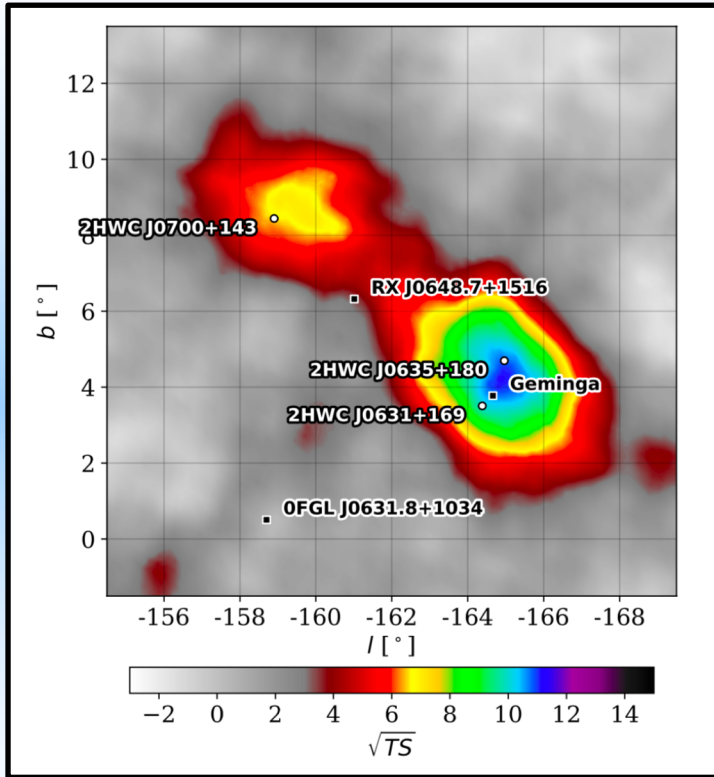


HAWC Collaboration, ApJ 843 (2017), 40.

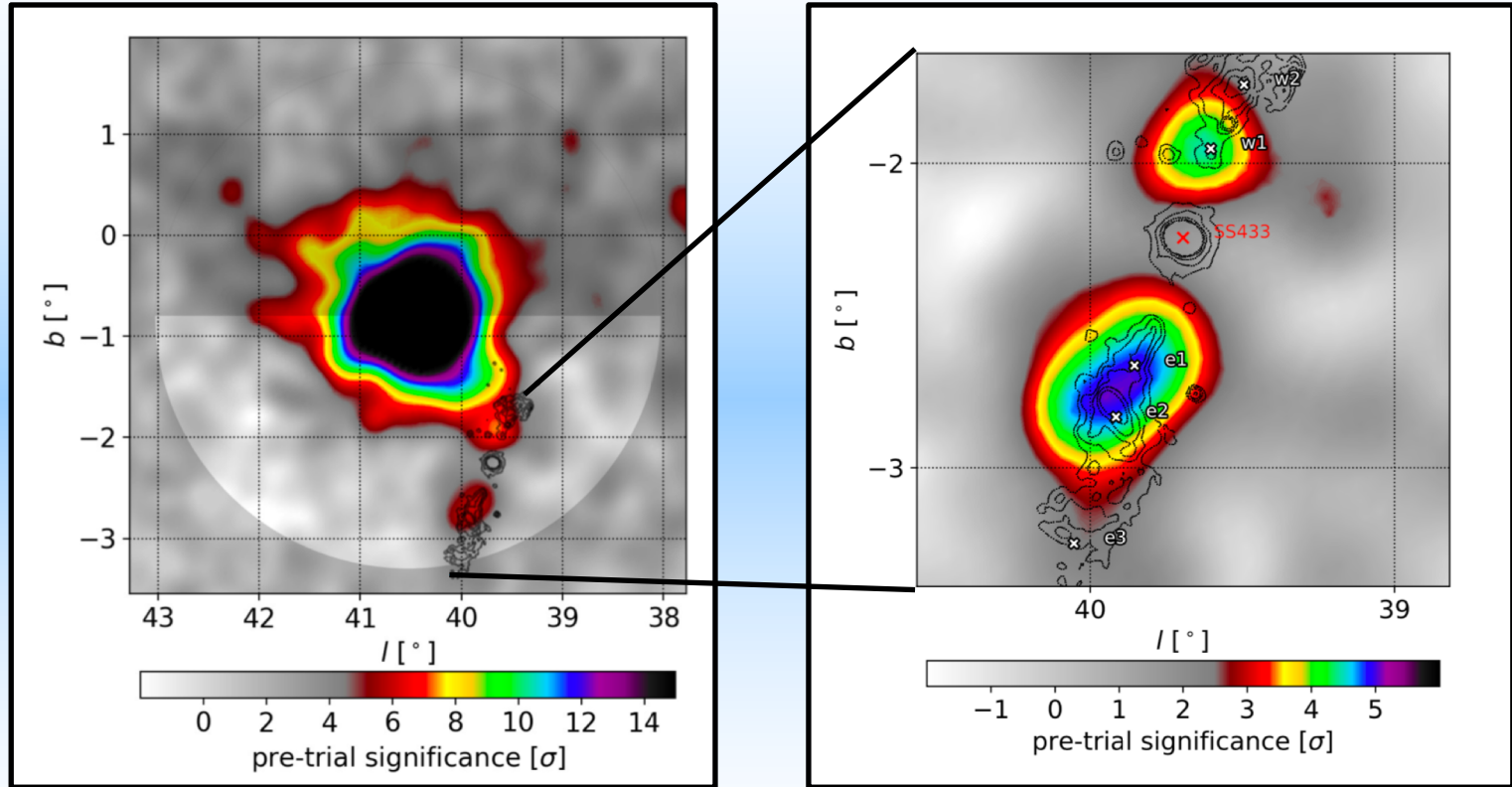
Complementarity



TeV Halos

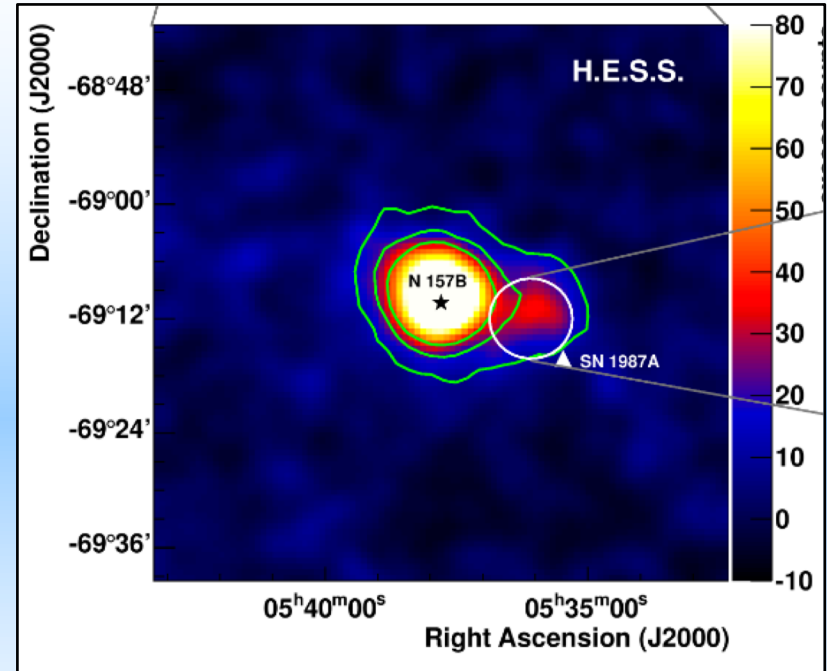


SS 433



“Galactic” sources in the Local Group

- The **LMC** hosts some exceptionally powerful TeV emitters:
 - **N157B**: PWN of the most energetic pulsar known.
 - **N132 D**: a radio-loud SNR.
 - **30 Dor C**: a wind-blown “superbubble”.
 - **LMC P3**: a 10-day gamma-ray binary.
 - But **SN1987a** is still not detected.



Conclusions

- Galactic TeV gamma-ray astronomy is still a young, and rapidly evolving field.
- As always, progress and new discoveries have opened more questions and opportunities.
- To address these requires better sensitivity and better spectral, spatial and temporal resolution.
- CTA is the tool to provide this.

