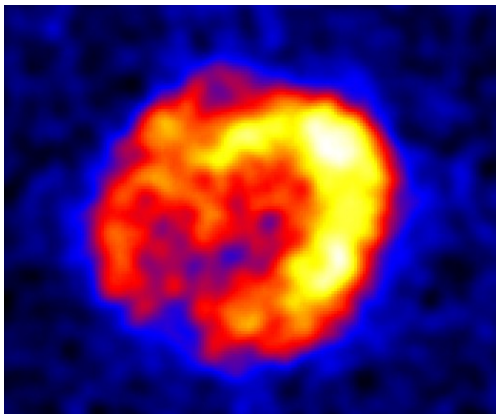
News on supernova remnants from IACT observations



Peter Eger

September 26th, 2013

AG 2013 splinter meeting:

"The High-Energy Universe"

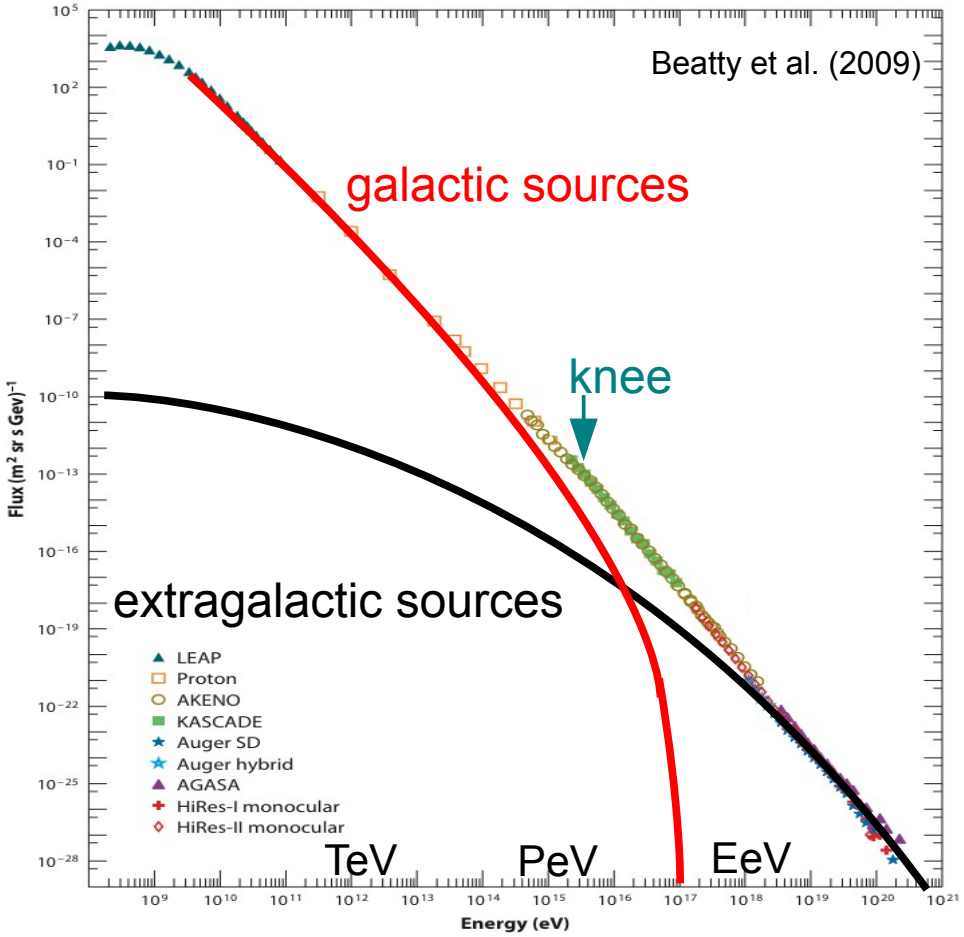
Tübingen

Goals:

1. Search for Galactic “PeVatrons”

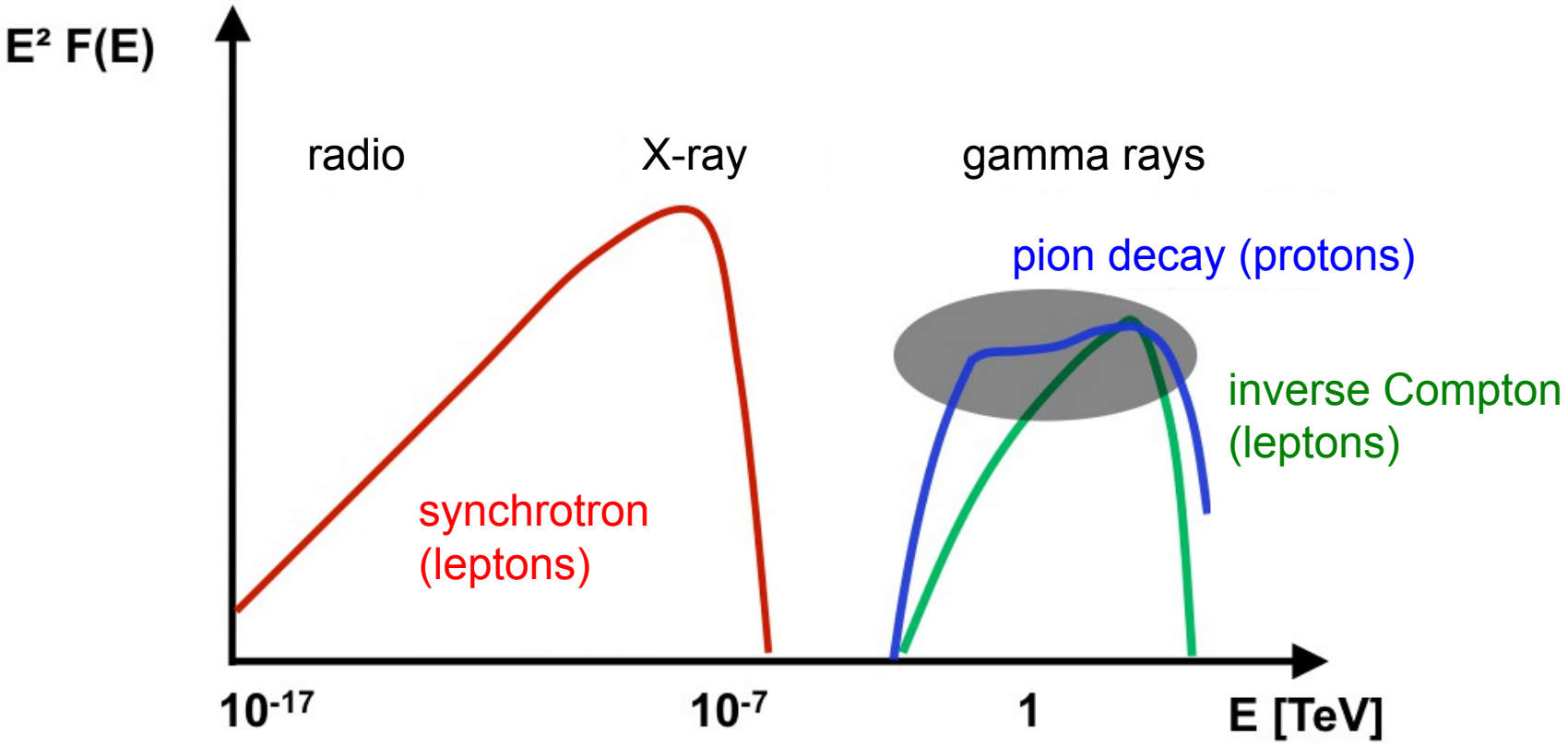
2. Understand particle acceleration mechanisms during the evolution of SNRs

Search for the most powerful Galactic CR accelerators

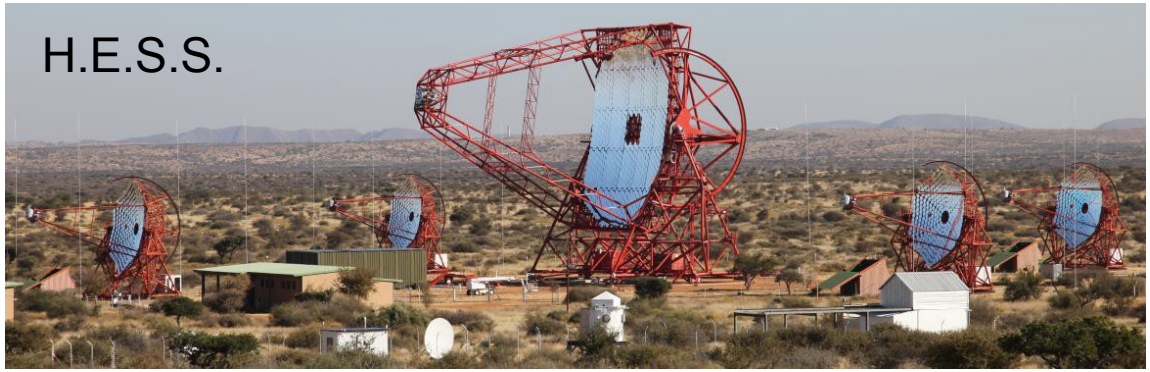


1 PeV protons
=
100 TeV gamma rays

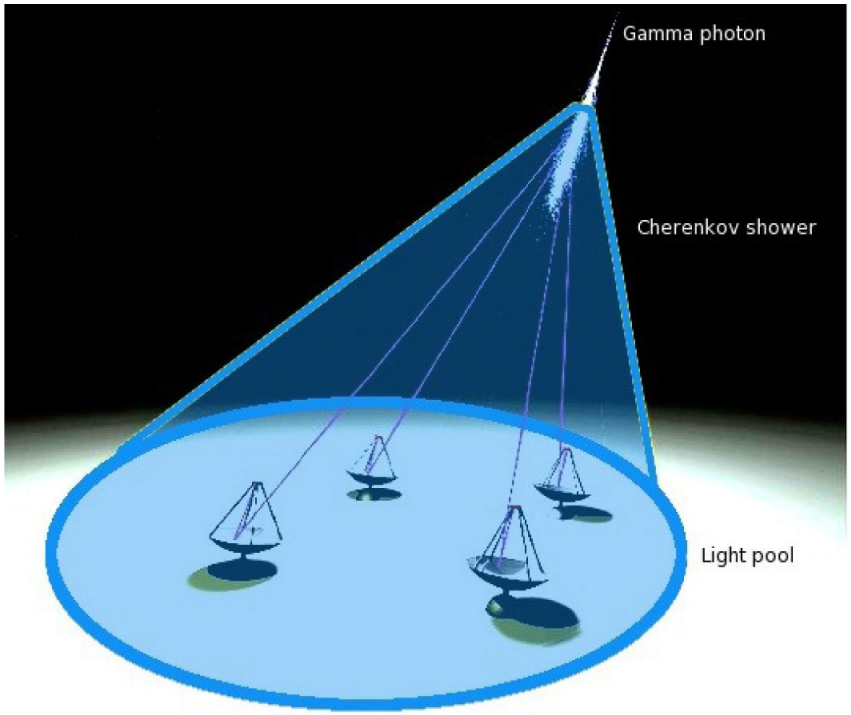
What signatures are we looking for in gamma-ray spectra?



The current generation of Imaging atmospheric Cherenkov telescopes (IACTs)



The IACT technique



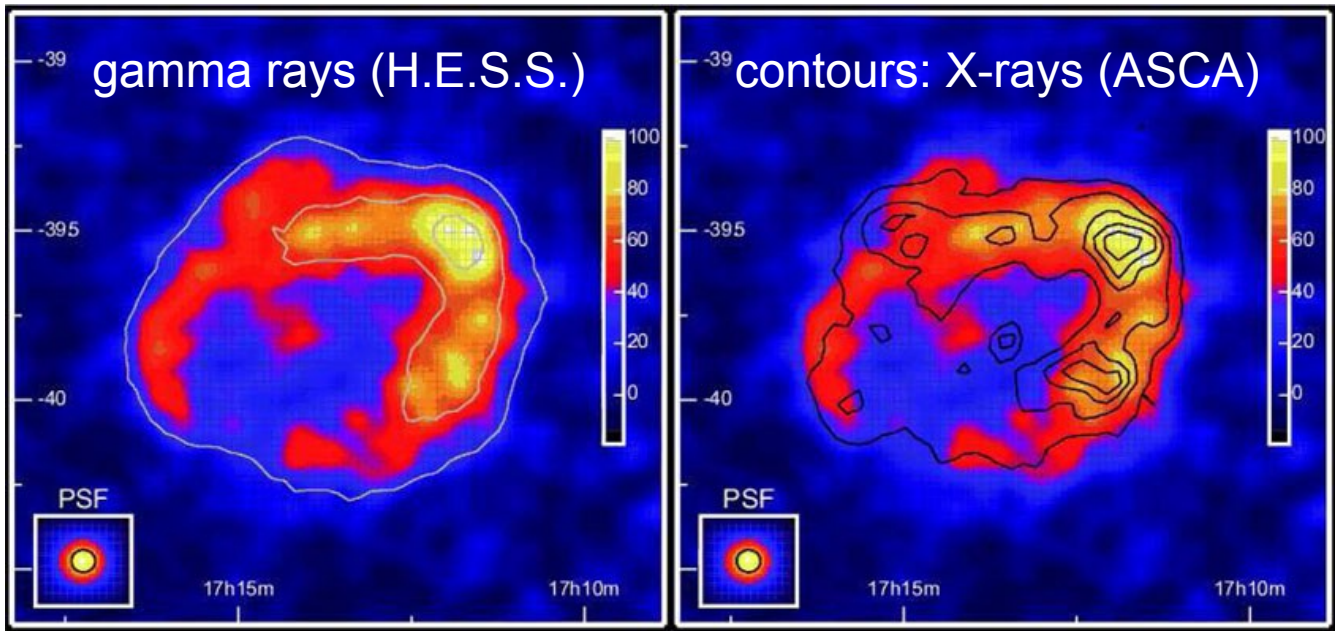
- Energy coverage:
  - ~100 GeV – 100 TeV
- Angular resolution:
  - ~0.07 degrees
- Effective area:
  - $>10^5$ m^2
- Field of view:
  - 3.5 – 5.0 degrees
- Sensitivity:
  - 10% crab flux with 5σ in 25 hours

3 types of TeV gamma-ray emitting SNRs

- Young, shell-type SNRs
- Middle-aged / old SNRs interacting with dense molecular gas
- Composite SNRs

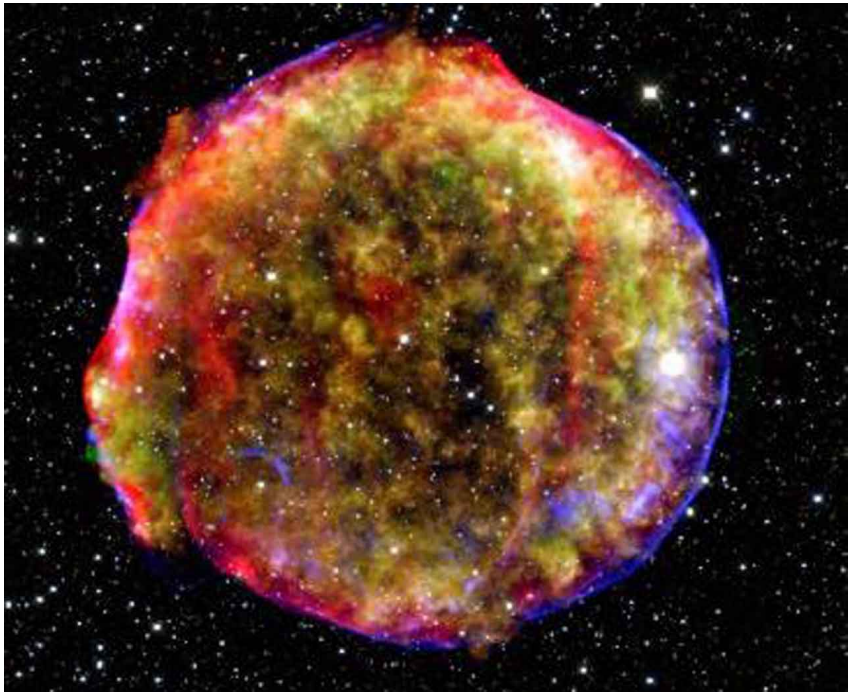
Young, shell-type SNRs

Protoype: RX J1713.7-3946



Aharonian et al., (2006)

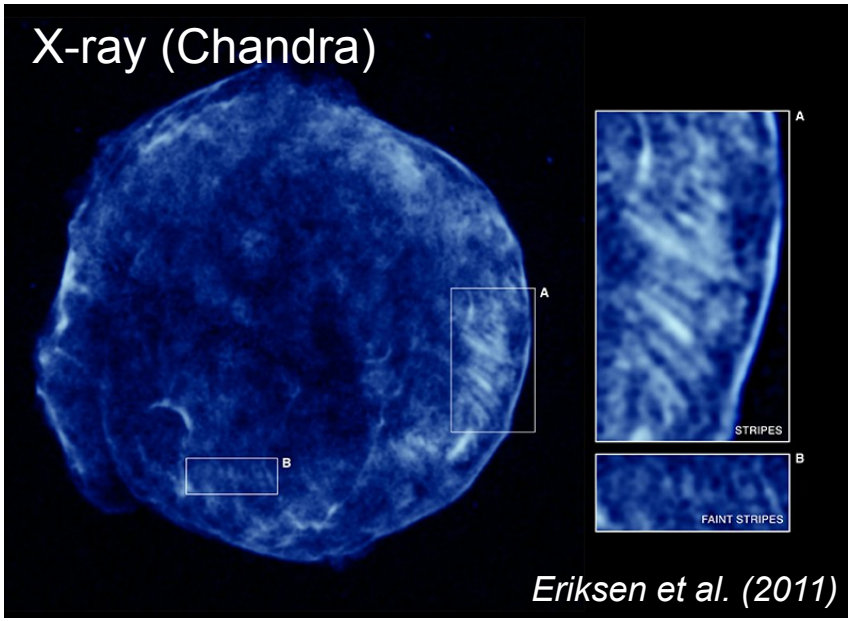
Young SNRs: Tycho's SNR



composite image: optical, IR, X-ray

- Type Ia remnant (441 years)
- Evolution into clean environement
- Not strongly interacting with molecular clouds

Young SNRs: Tycho's SNR



Evidence for hadronic CR acceleration:

- Thin X-ray filaments

  → high local B-field

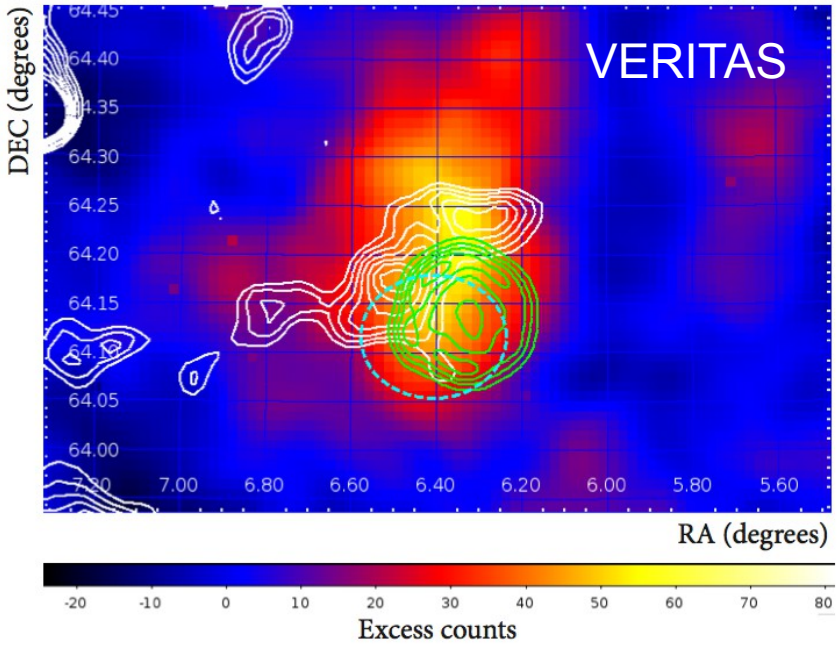
  → CR driven current instabilities?

- Thin Balmer filaments

  → CR induced shock precursor?

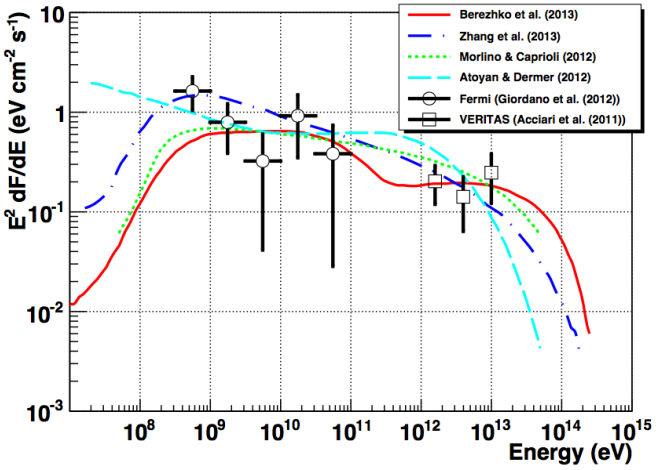
  (e.g. Lee et al., 2010)

Young SNRs: Tycho's SNR seen with VERITAS



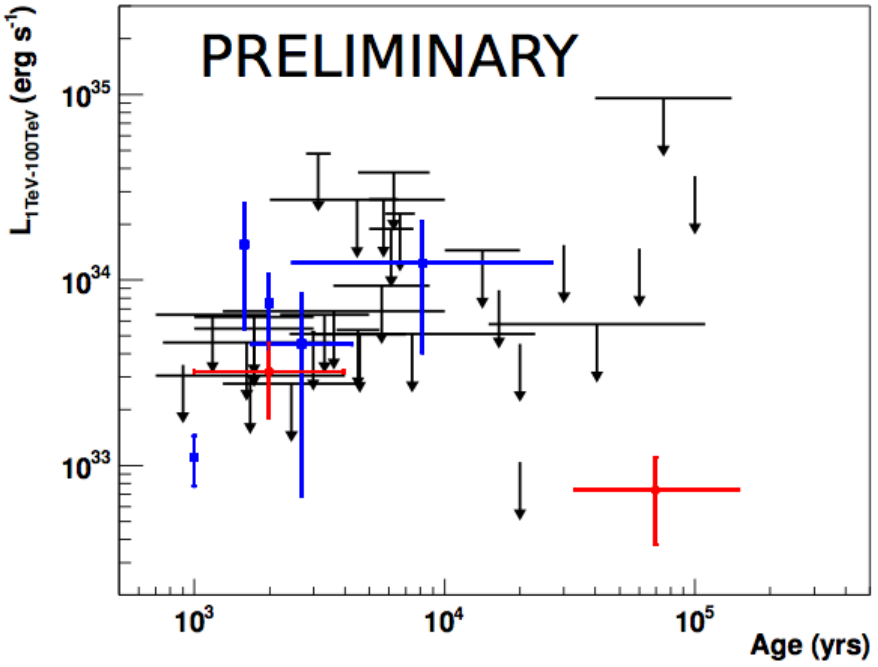
Park et al. (2013)

- 103 h of observation
- Detection: 800 GeV – few 10 TeV
- Very hard spectrum:
  - $\Gamma = 1.95 \pm 0.51_{stat} \pm 0.3_{sys}$
- Hadronic emission scenarios preferred:



Young SNRs: Population study of undetected SNRs with H.E.S.S.

- 220 of 300 known Galactic SNRs covered by the H.E.S.S. Galactic plane scan
- Systematic search for gamma-ray emission and upper limit extraction
- Comparison of upper limits with theoretical predictions

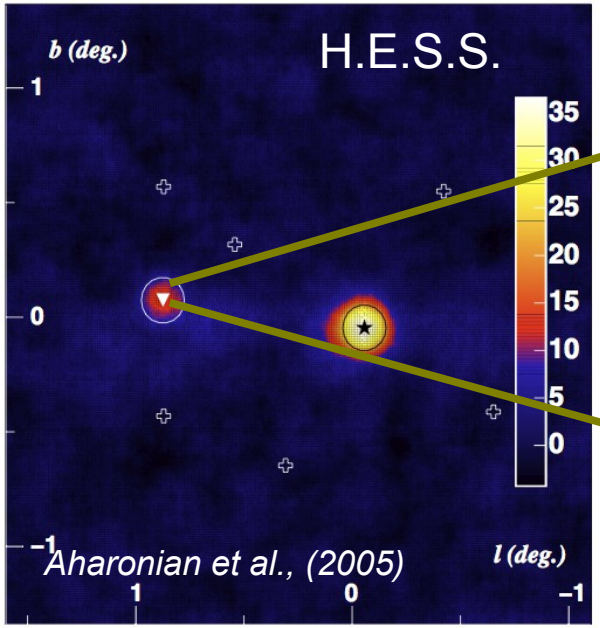


Fernandez et al. on behalf of H.E.S.S., ICRC (2013)

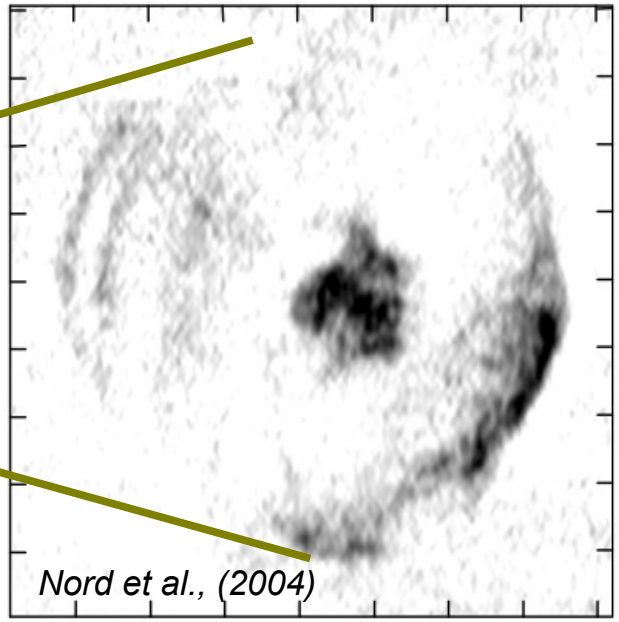
Composite SNRs

Protoype: SNR G0.9+0.1

TeV gamma-rays

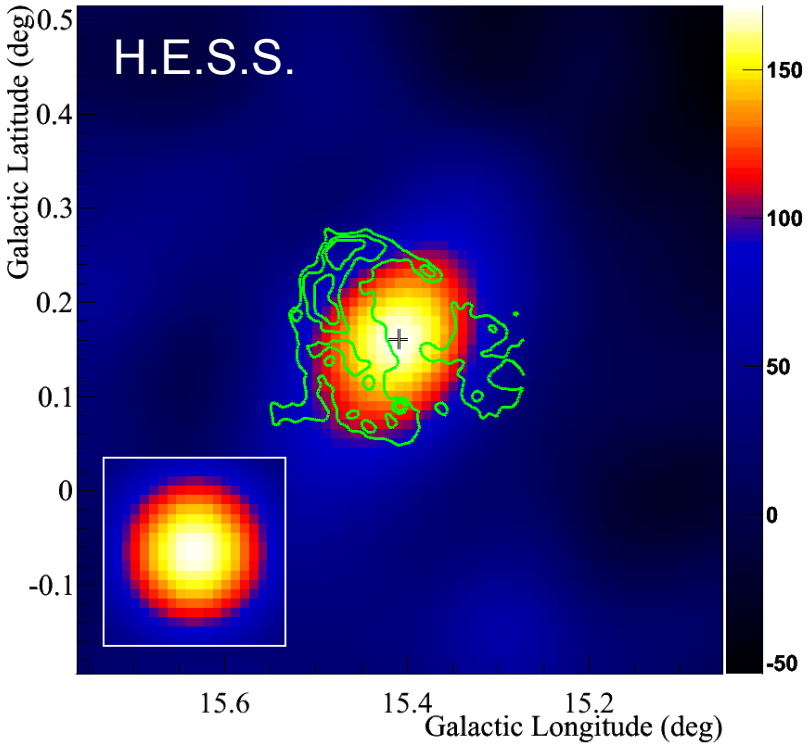


Radio (330 MHz)



Composite SNRs: HESS J1818-154

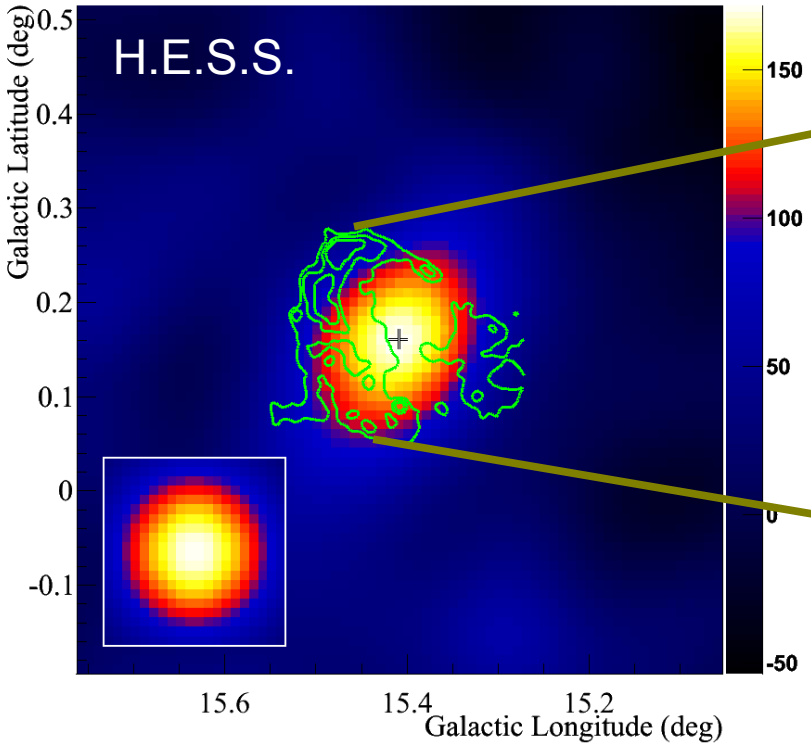
TeV gamma-rays



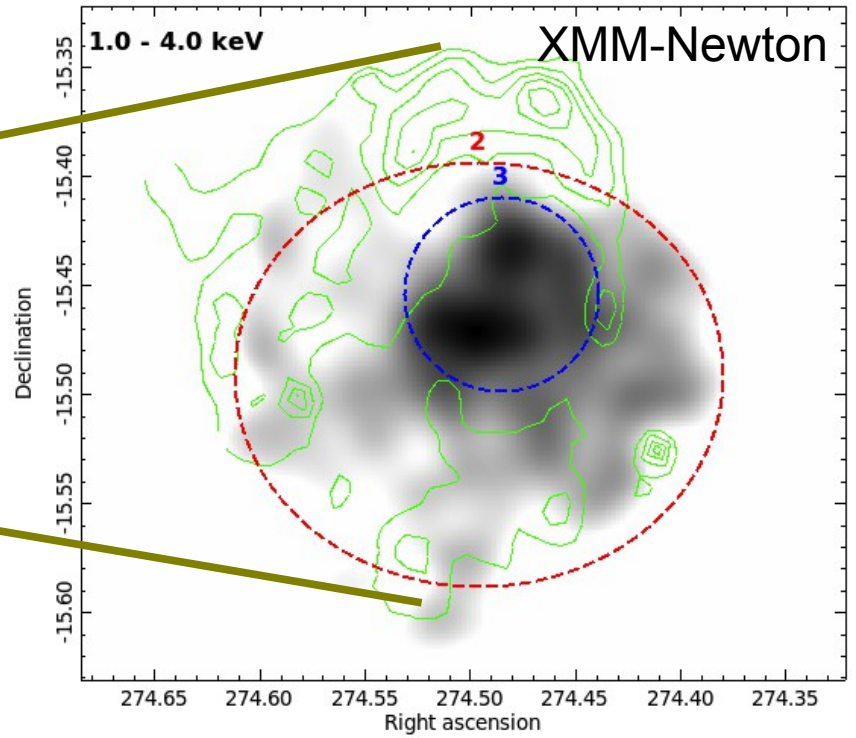
P. Hofverberg & PE, on behalf of H.E.S.S. in prep.

Composite SNRs: HESS J1818-154

TeV gamma-rays

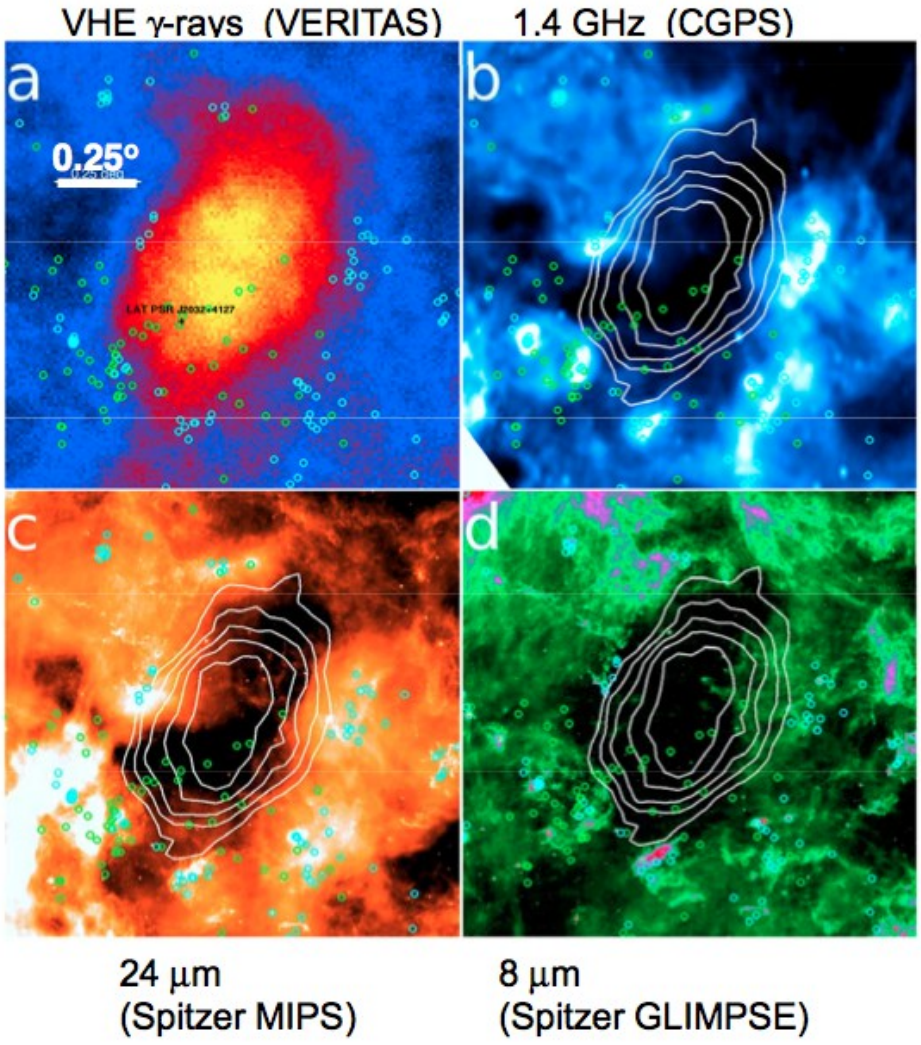


X-rays



P. Hofverberg & PE, on behalf of H.E.S.S. in prep.

Composite SNRs: VER J2032+415



Interpretation

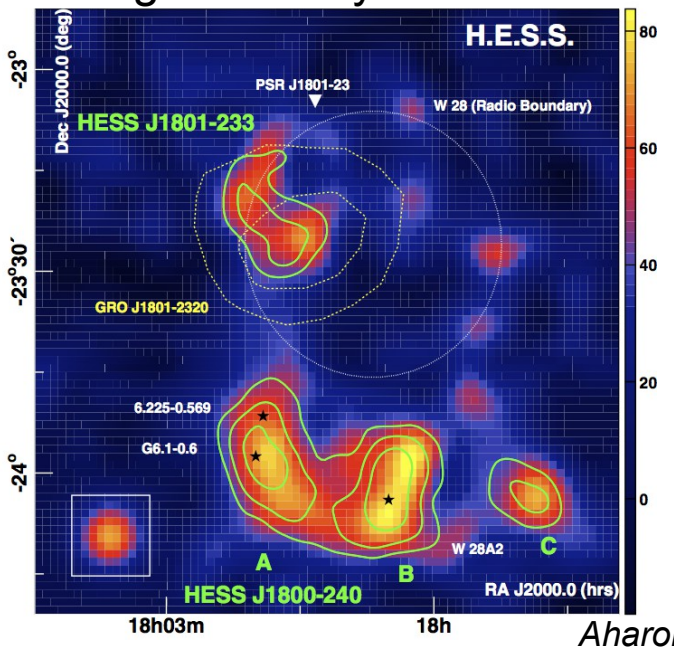
- PWN evolving inside gas cavity
- Cavity created by
  - SNR shock **and/or**
  - Stellar wind of progenitor star
- Pulsar detected by *Fermi*
- No SNR shell detected (yet?)

Aliu et al. (2013), in prep.

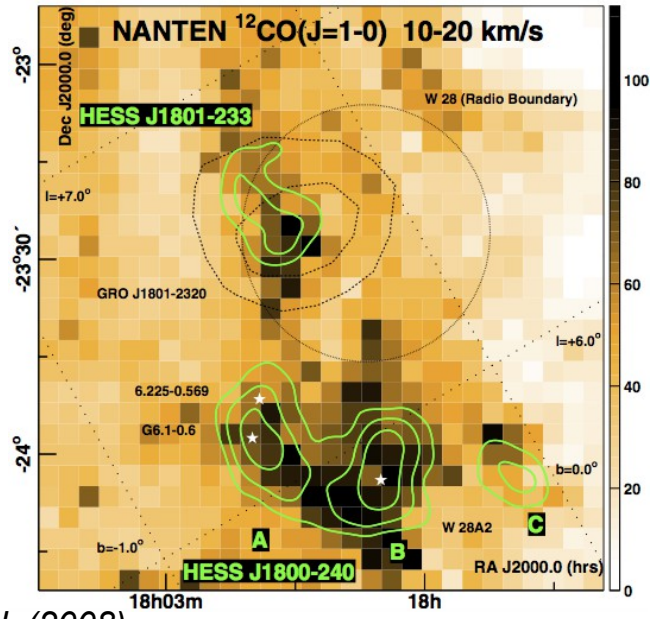
Interacting SNRs

Protoype: W 28 region

TeV gamma-rays



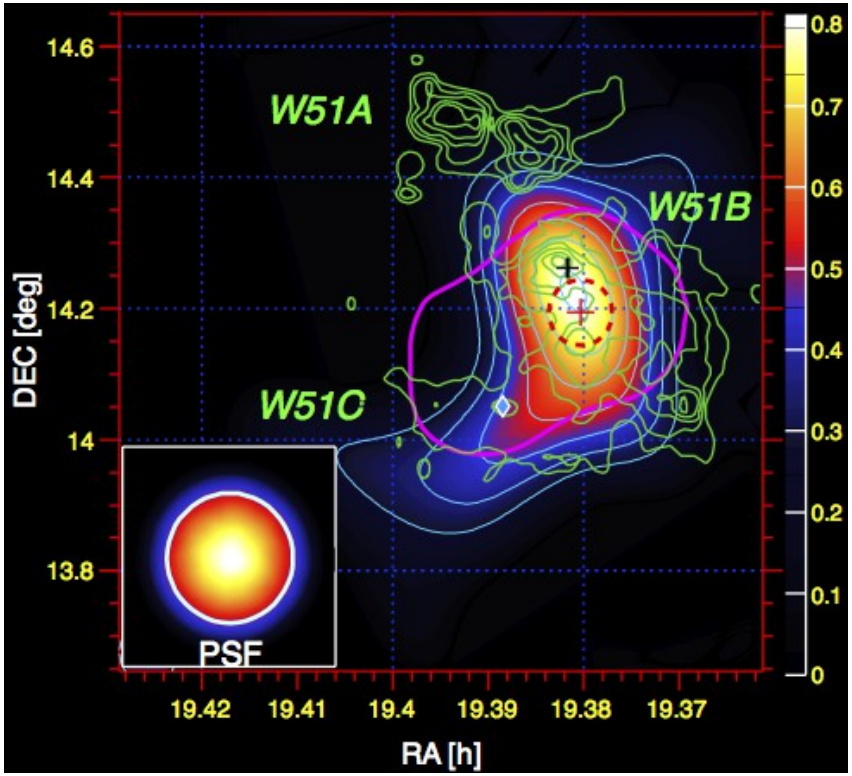
Molecular gas



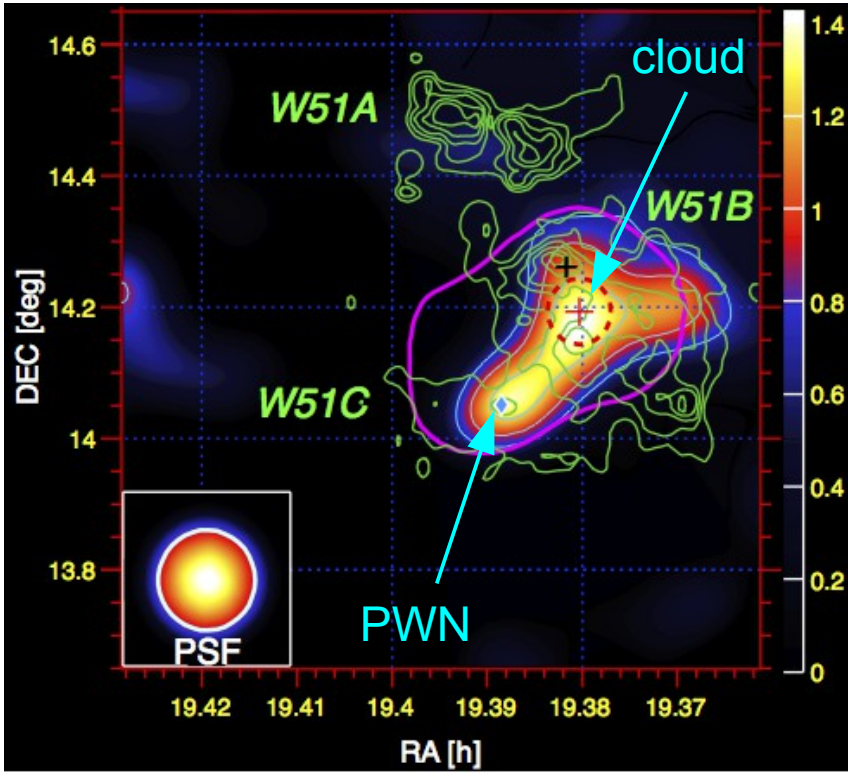
Aharonian et al. (2008)

Interacting SNRs: W49 region seen with MAGIC

300 – 1000 GeV



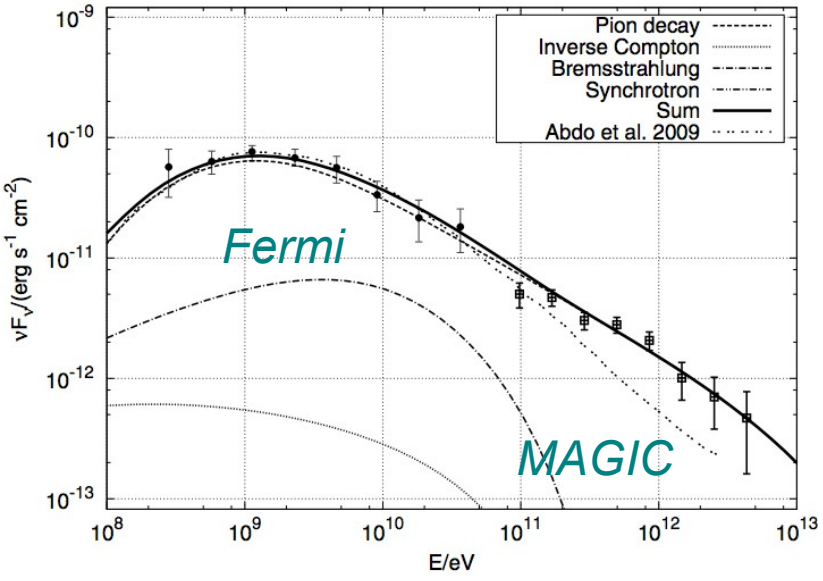
> 1000 GeV



MAGIC coll. (2012)

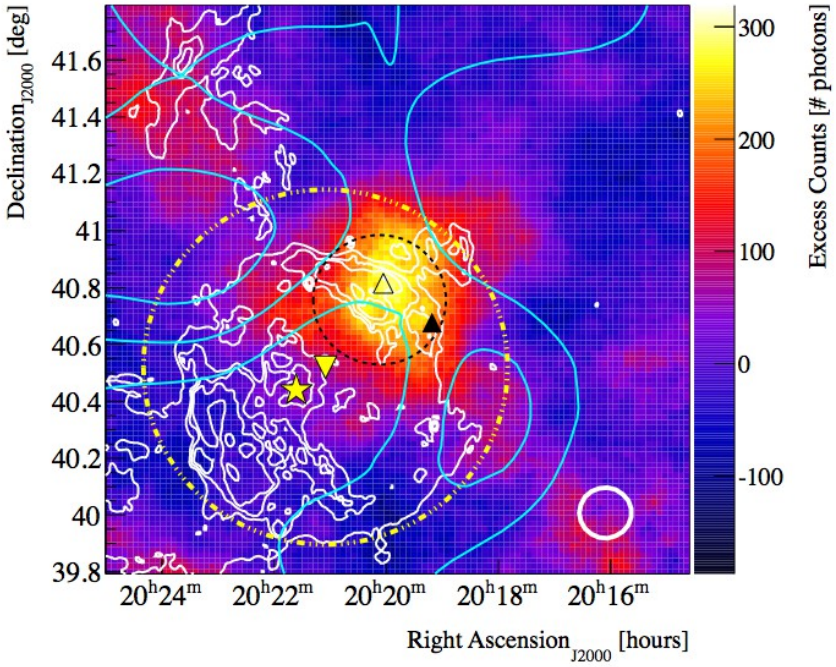
Interacting SNRs: W49 region seen with MAGIC

GeV – TeV spectrum



- Purely leptonic scenario does not fit the data
- Hadronic (pion decay) scenario preferred
  - SNR W51C as accelerator
  - 10 – 20% of total explosion energy in relativistic nuclei
  - Molecular cloud W51B provides target material

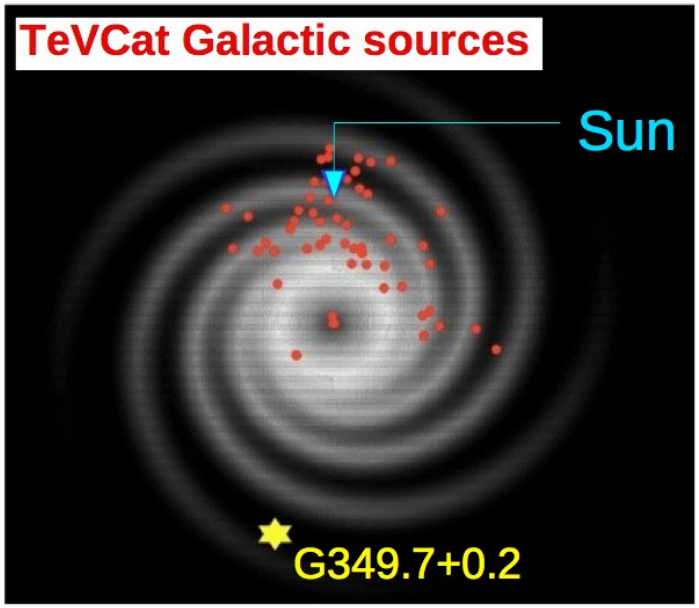
Interacting SNRs: SNR G78.2+2.1 seen with VERITAS

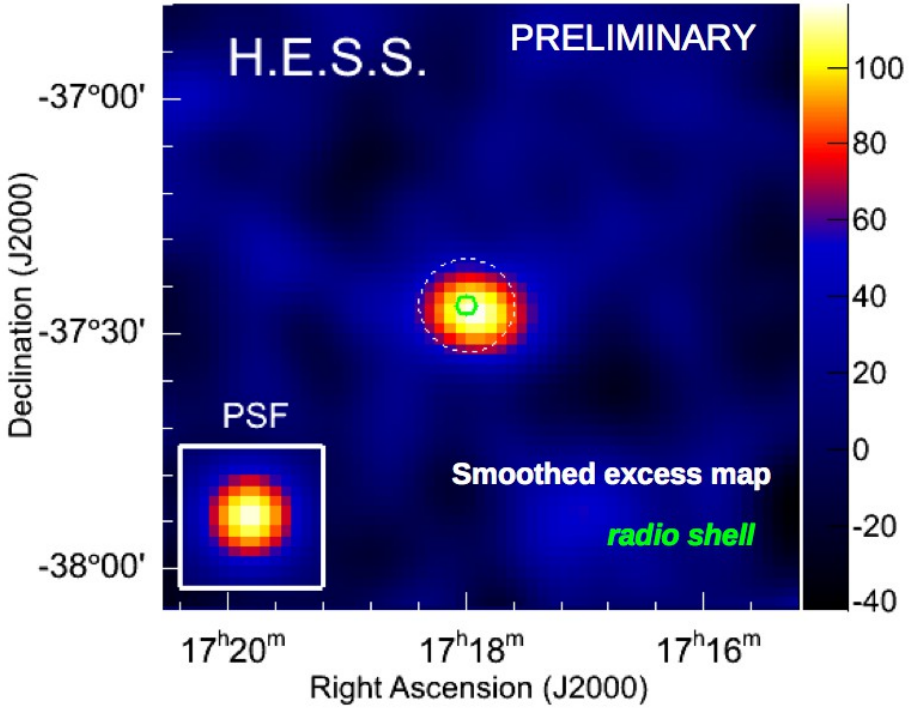


Aliu et al. VERITAS coll., (2013)

- SNR shock interacting with HI shell of wind-blown bubble
- TeV source consistent with shocked dense gas
- Emission scenario:
  - Leptonic and hadronic emission viable
  - Upper limit on non-thermal X-rays not strong enough to rule out leptonic scenario

Interacting SNRs: The most distant Galactic TeV gamma-ray source, SNR G349.7+0.2



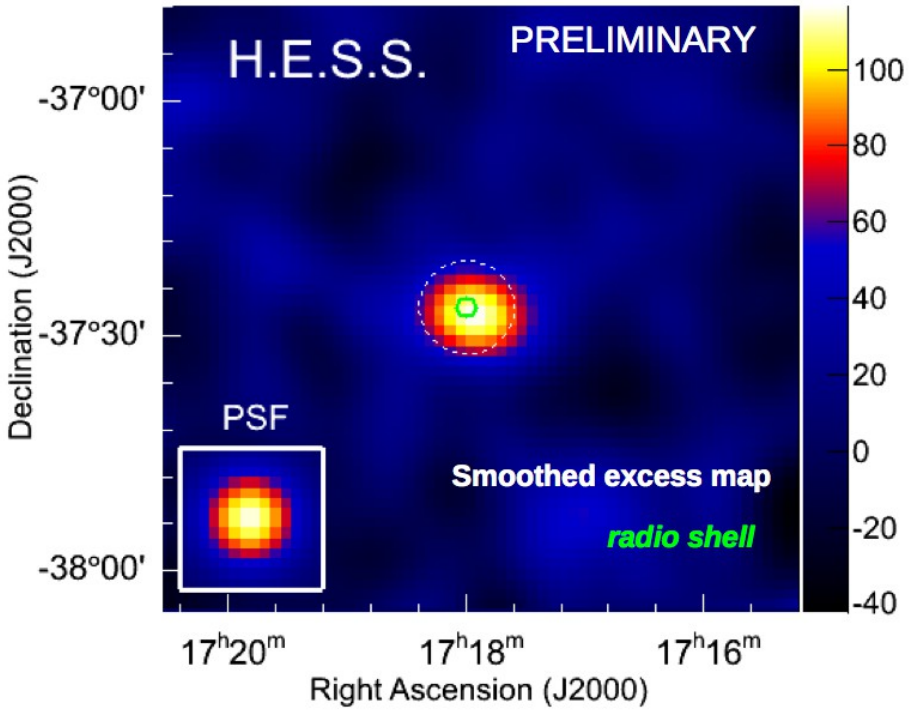


C. Trichard on behalf of H.E.S.S., ICRC (2013)

Interacting SNRs: The most distant Galactic TeV gamma-ray source, SNR G349.7+0.2

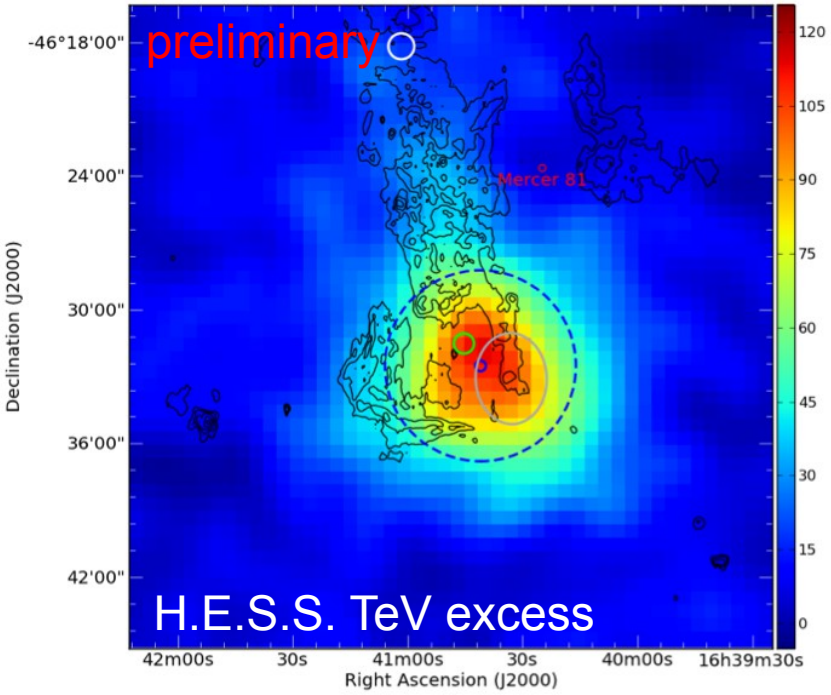
- Emission scenario:
  - Strong GeV and TeV emission
  - absence of non-thermal X-rays
  - Presence of dense molecular clouds

→ In favor of hadronic scenario

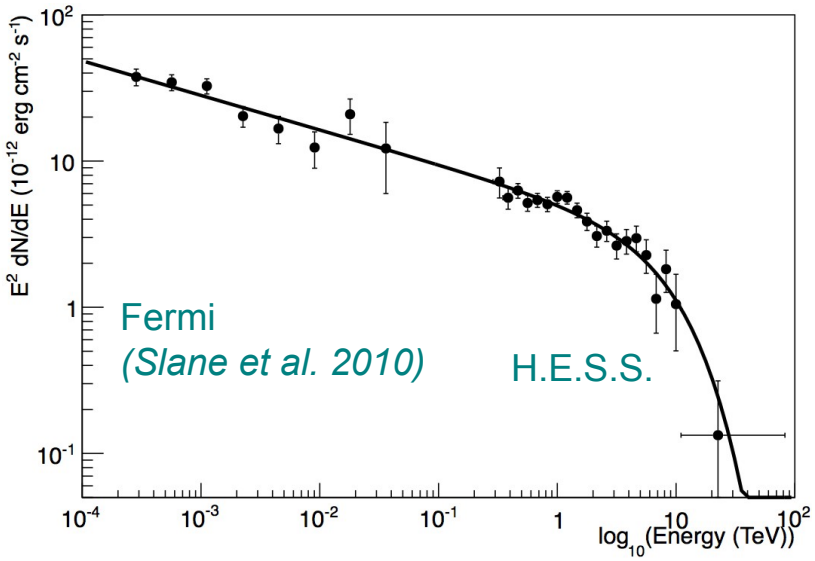


C. Trichard on behalf of H.E.S.S., ICRC (2013)

Interacting SNRs: The most luminous Galactic TeV gamma-ray source, HESS J1640-465

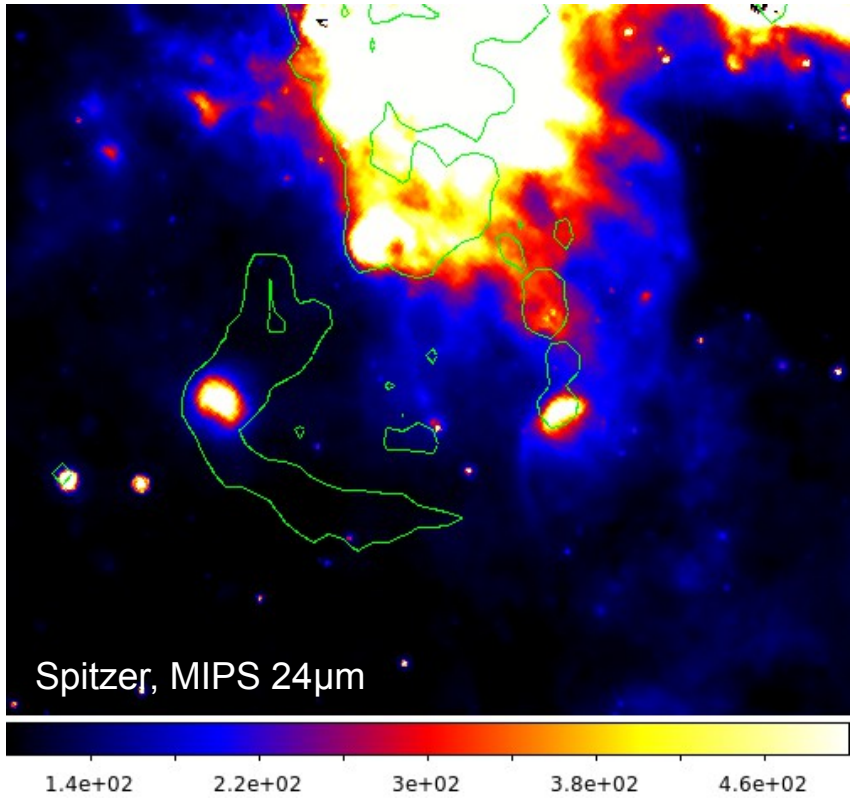


GeV – TeV spectrum

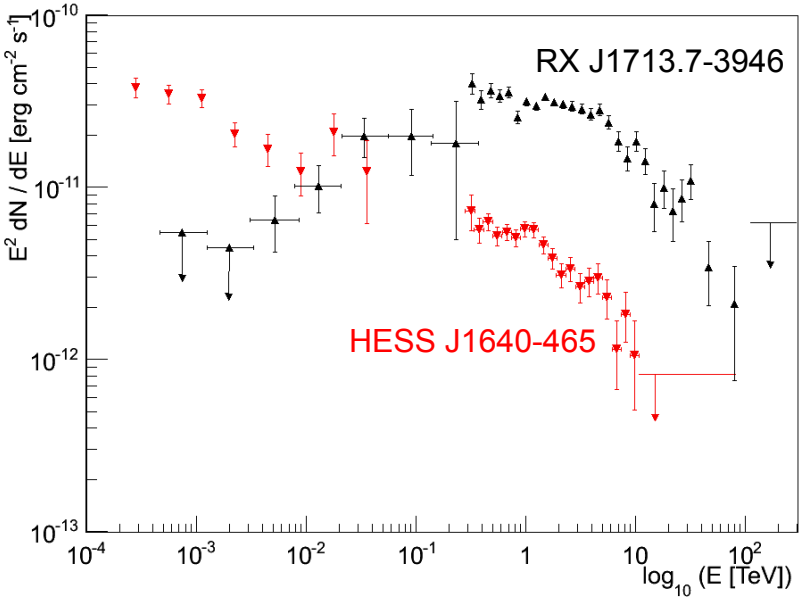


PE on behalf of H.E.S.S., ICRC (2013)

Interacting SNRs: The most luminous Galactic TeV gamma-ray source, HESS J1640-465



Comparison to RX J1713.7-3946



Final thoughts

- TeV emitting SNRs are a rich and diverse population of extreme astrophysical objects
- They might be the key to understanding the origin of Galactic cosmic rays
- Research with IACTs evolves rapidly; but still some fundamental questions lack definite answers

Thank you for your attention