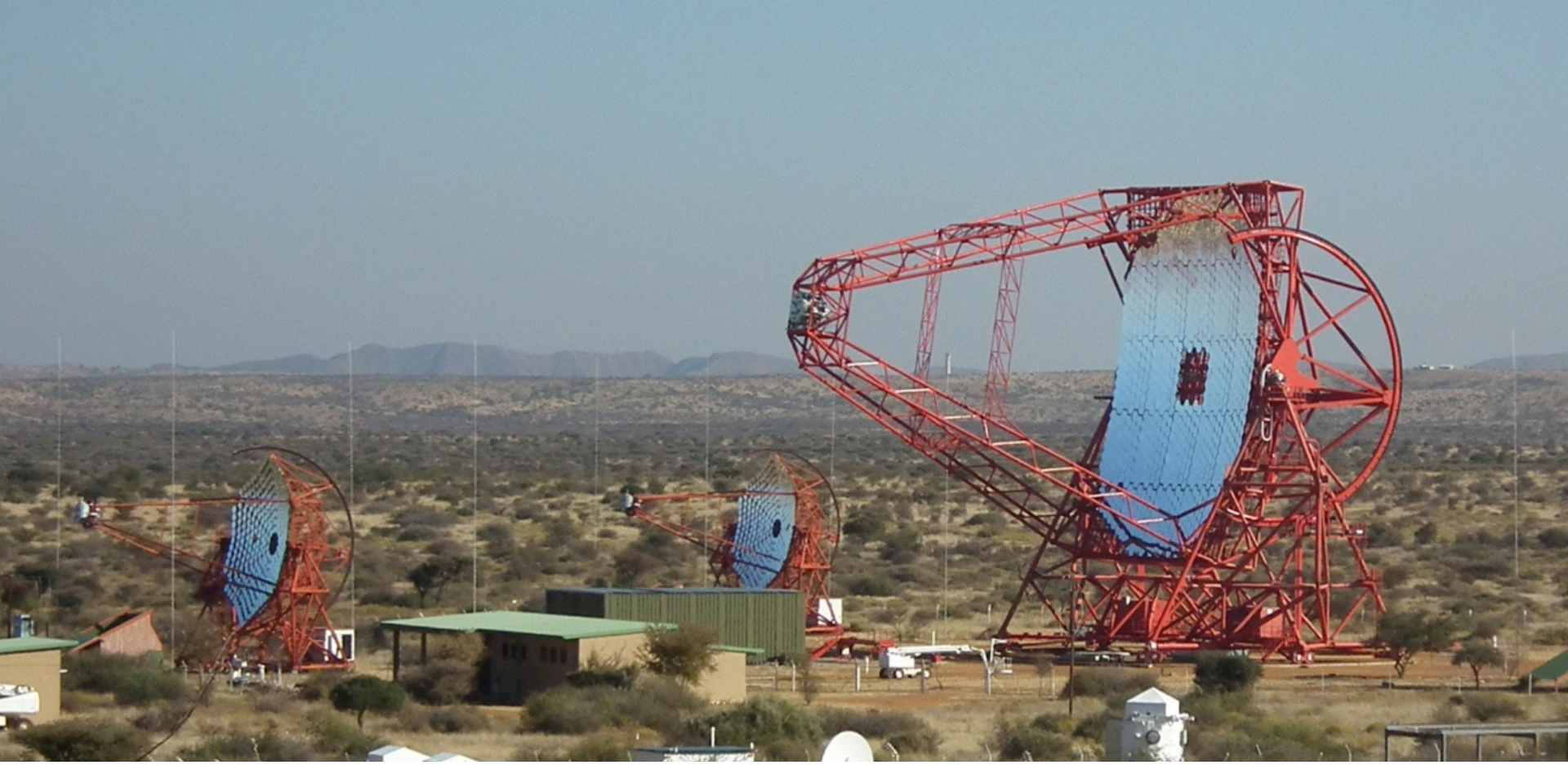


H.E.S.S.

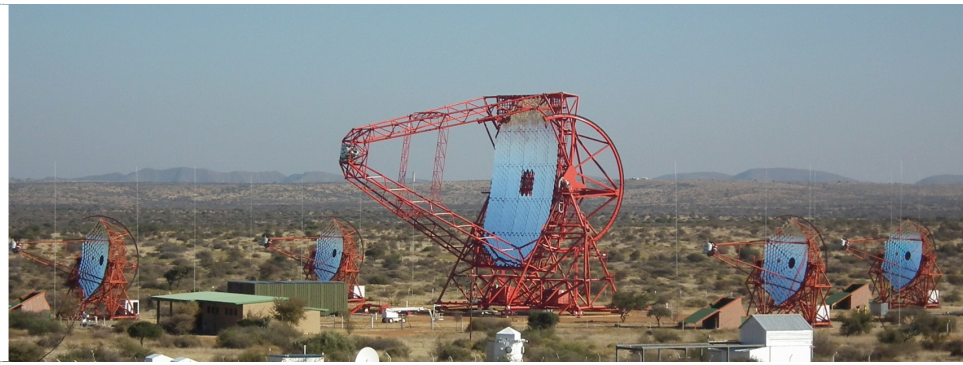
Christian Stegmann for the H.E.S.S. collaboration

Astrophysics and MAGIC
June 2018, La Palma

15 years MAGIC

- The H.E.S.S. Collaboration congratulates the MAGIC collaboration on 15 successful years of operation and many scientific breakthroughs.
- We thank the MAGIC Collaboration especially for leading us as a fair and demanding competitor to ever better results.
- Among other things, it is our (including VERITAS) joint success that ground-based gamma-ray astronomy is currently in a phase transition from closed experiments to an open observatory, which promises even more exciting results in the future.
- I personally hope for even more cooperation and less competition in the future in order to get the best out of the instruments in the coming years until the scientific operation of CTA starts.

The H.E.S.S. Experiment

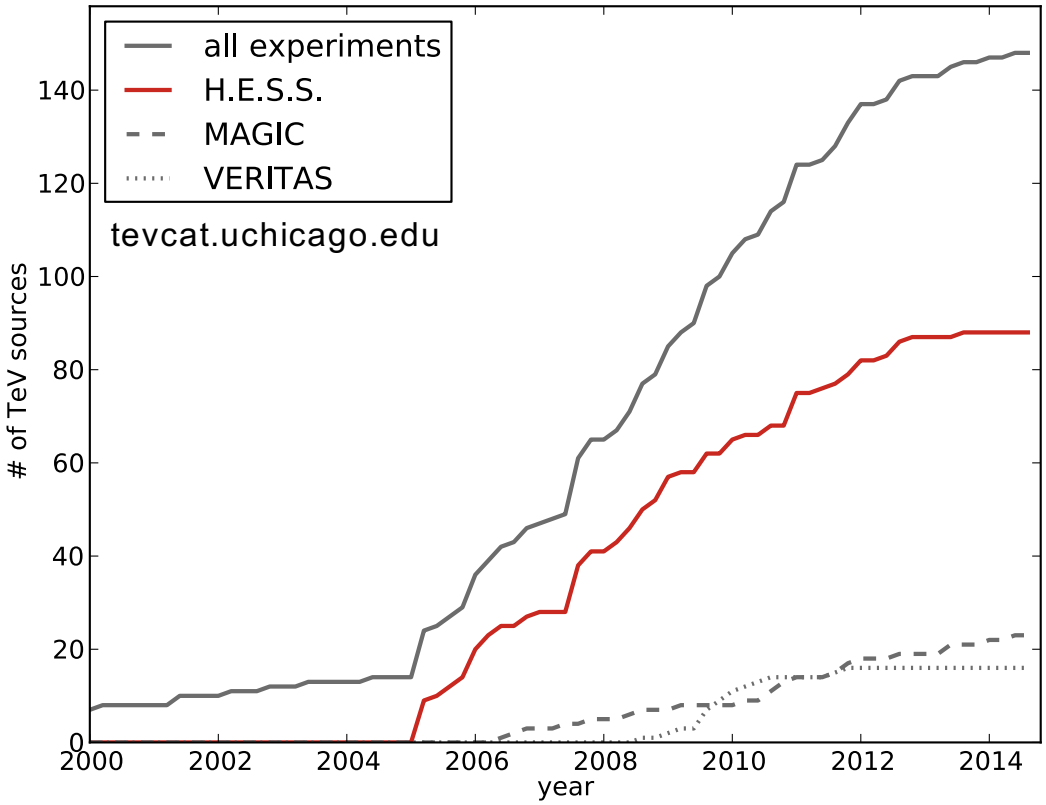


- H.E.S.S. phase I
  - four 12m telescopes
  - FoV 5 deg
  - energy threshold 100 GeV
  - angular resolution < 0.1 deg
- H.E.S.S. phase II
  - four 12m telescopes
  - one 28m telescope (FoV 3.5 deg)
  - energy threshold O(30 GeV)
  - angular resolution from 0.4 deg to less than 0.1 deg

H.E.S.S. phase I H.E.S.S. phase II

H.E.S.S.

The H.E.S.S. Experiment



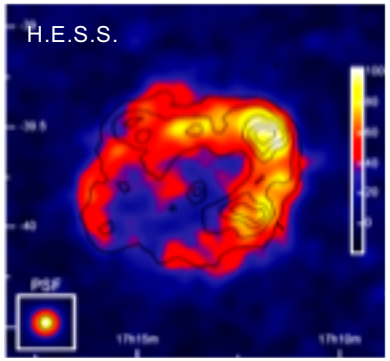
- H.E.S.S. phase I
  - more than 10000 hours of data
  - discovered over 80 new VHE gamma ray sources, published over 100 scientific papers
  - Continue with in-depth studies of deep observations
- H.E.S.S. phase II
  - towards lower threshold and transients

H.E.S.S. phase I H.E.S.S. phase II

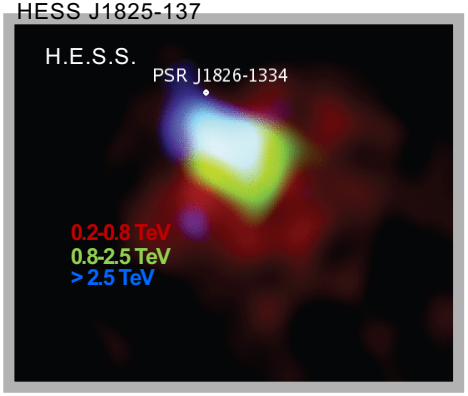
H.E.S.S. Data Quality

- Morphologies
  - spacial
  - energy-dependent
- Periodicities/Variability
  - from ms to years
- Energy-coverage
  - over several decades
- Source positions and extensions
  - on the arc-second level

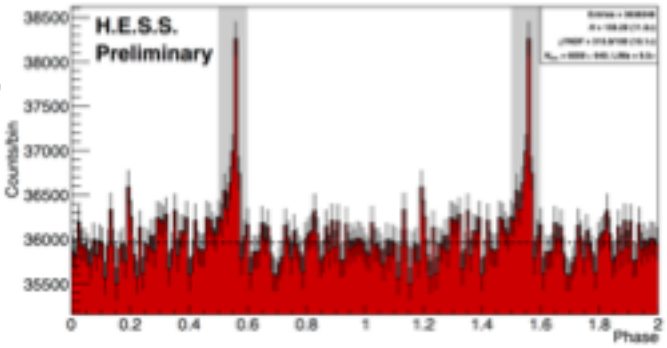
RX J1713-3946



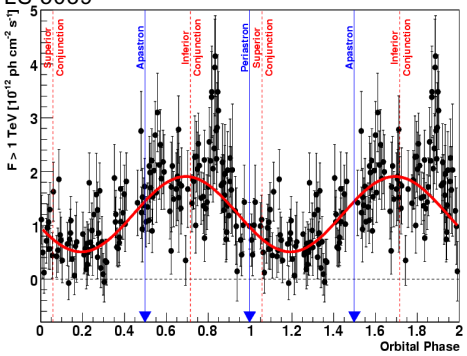
HESS J1825-137



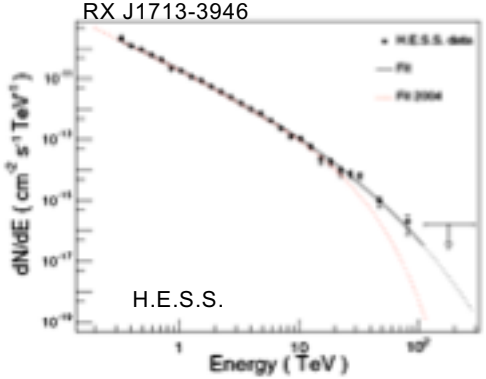
Vela pulsar



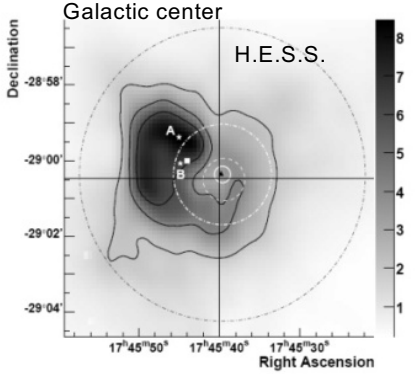
LS 5039



RX J1713-3946



Galactic center



H.E.S.S.

The Book of the Year 2018

A&A 612, E1 (2018)
https://doi.org/10.1051/0004-6361/201833049

H.E.S.S. phase-I observations of the plane of the Milky Way

Astronomy & Astrophysics
Special issue

Editorial

H.E.S.S. phase-I observations of the plane of the Milky Way

Of the three currently operating large Imaging Atmospheric Cherenkov Telescopes (IACT), the Namibia-based High Energy Stereoscopic System (H.E.S.S.) has the best access to the inner Galactic plane. Devoting 2700 hours to a survey of the Galactic plane, the H.E.S.S. Collaboration has covered the l = 250 deg to 65 deg longitude range for latitudes $|b| < 3$ deg, with 5 arcmin angular resolution.

In this issue, we publish a series of papers that presents the observations, analyzes many of the 78 detected compact sources, and makes the sky maps available in FITS format. By covering a wide range of objects, from pulsar wind nebulae to gamma-ray binaries through supernova remnants, these papers illustrate the great potential of IACTs to study the most energetic phenomena in the Galaxy and what can be expected from the planned multinational Cherenkov Telescope Array (CTA).

Thierry Forveille, Sergio Campana, and Steve Shore
Astronomy & Astrophysics Editors

- Our 15th anniversary – data for our first two scientific papers were recorded in the spring of 2003

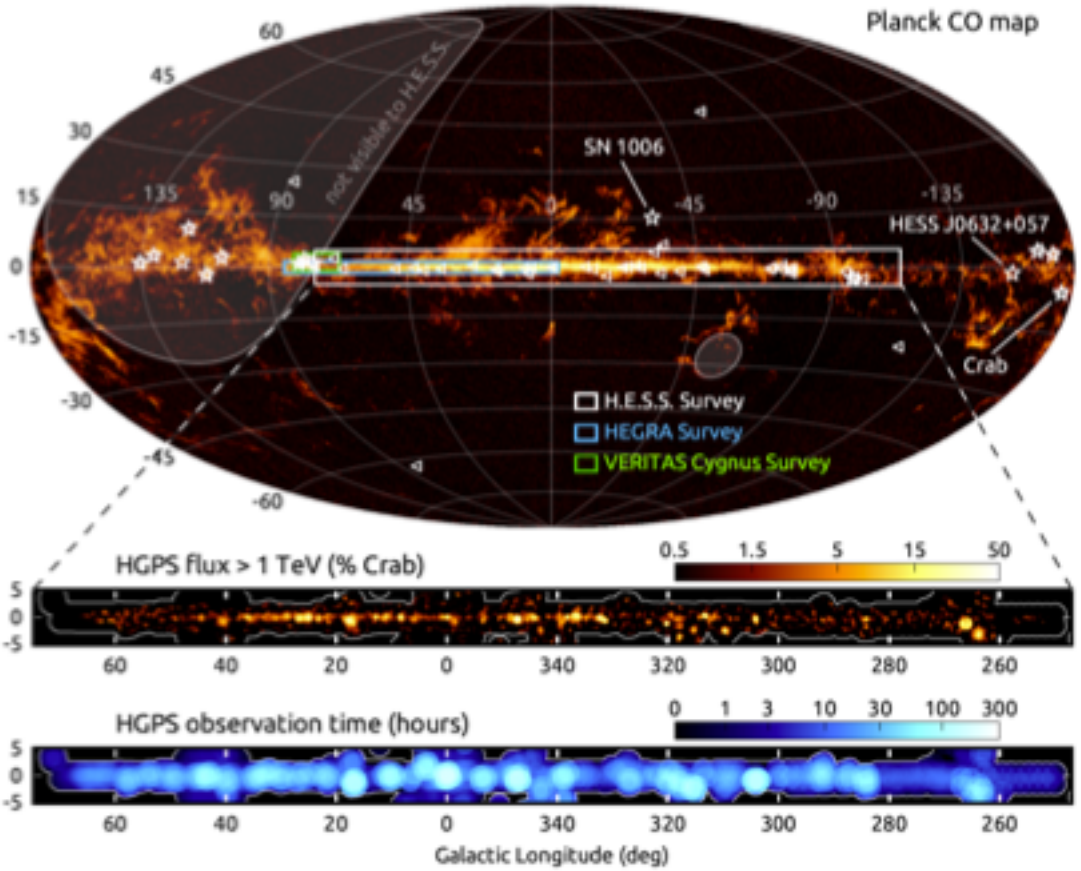
H.E.S.S.

The Book of the Year 2018: Content

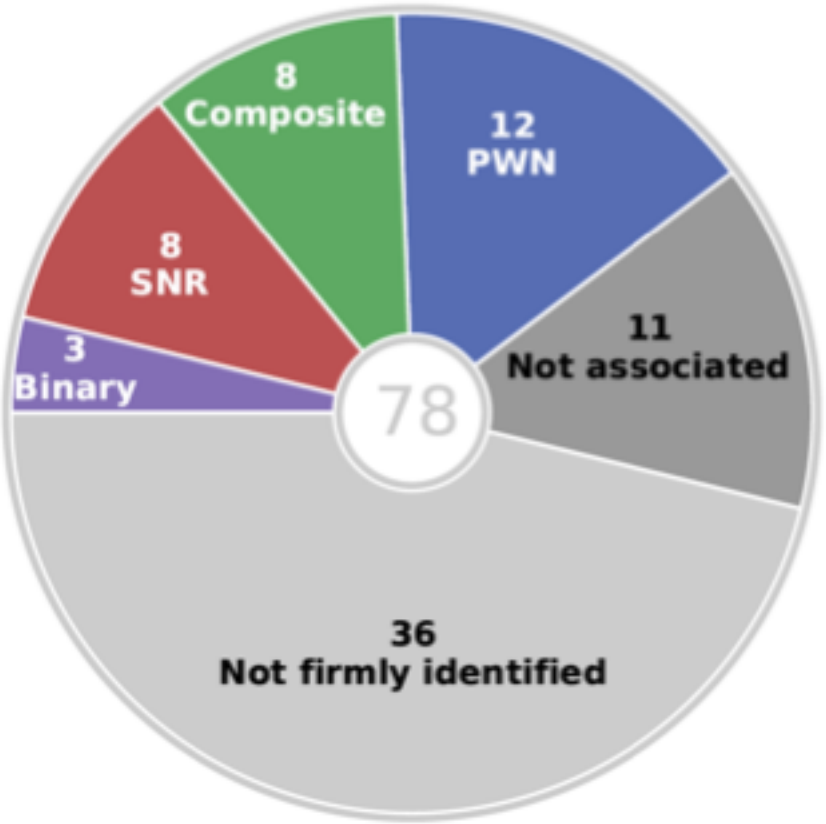
- **Population Studies:**
  - The population of TeV pulsar wind nebulae in the H.E.S.S. Galactic Plane Survey
  - Population Study of Galactic Supernova Remnants at Very High γ-Ray Energies with H.E.S.S.
  - Systematic search for very-high-energy gamma-ray emission from bow shocks of runaway stars
  - A search for new supernova remnant shells in the Galactic plane with H.E.S.S.
- **Galactic Centre Region:**
  - Characterising the VHE diffuse emission in the central 200 parsecs of our Galaxy with H.E.S.S
- **Precision studies of selected sources**
  - Detailed spectral and morphological analysis of the shell type SNR RCW 86
  - The supernova remnant W49B as seen with H.E.S.S. and Fermi-LAT
  - H.E.S.S. observations of RX J1713.7-3946 with improved angular and spectral resolution; evidence for gamma-ray emission extending beyond the X-ray emitting shell
  - Deeper H.E.S.S. Observations of Vela Junior (RX J0852.0-4622): Morphology Studies and Resolved Spectroscopy
  - A search for very high-energy flares from the microquasars GRS 1915+105, Circinus X-1, and V4641 Sgr using contemporaneous H.E.S.S. and RXTE observation
  - Extended VHE gamma-ray emission towards SGR1806-20, LBV1806-20, and stellar cluster Cl*1806-20
  - HESS J1741-302: a hidden accelerator in the Galactic plane
  - Constraints on particle acceleration in SS433/W50 from MAGIC and H.E.S.S. observations

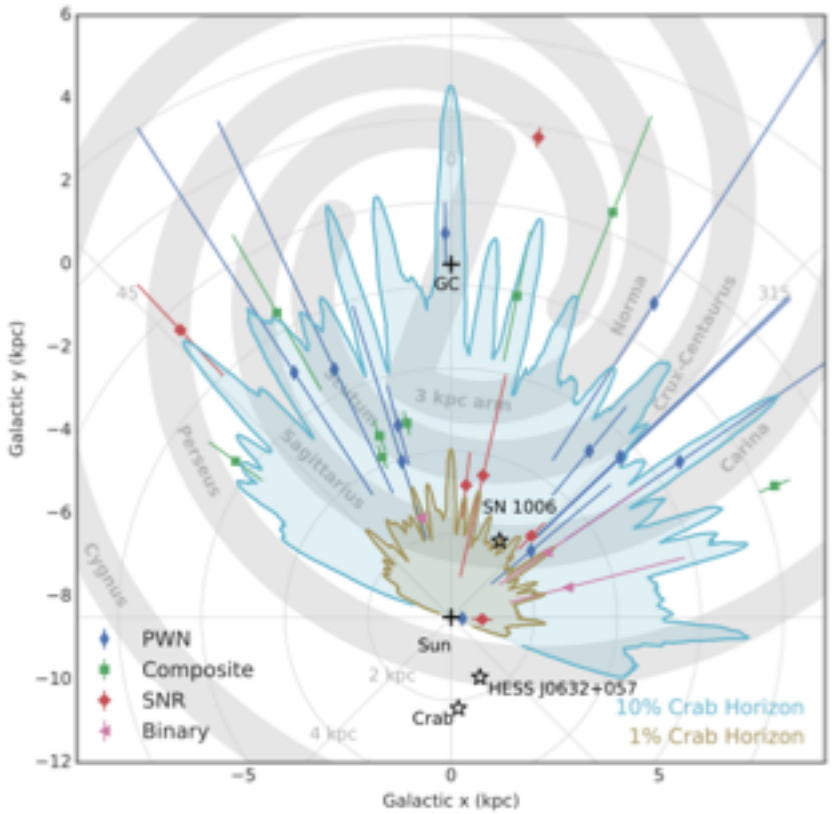
H.E.S.S. I Survey

- Major H.E.S.S. project
- Data collected 2004 – 2013
  - 2673 h after quality selection
  - l in [-110°, 70°]
  - b in [-5°, 5°]
  - Inhomogeneous exposure (sources of particular interest)
- Maps released in FITS format



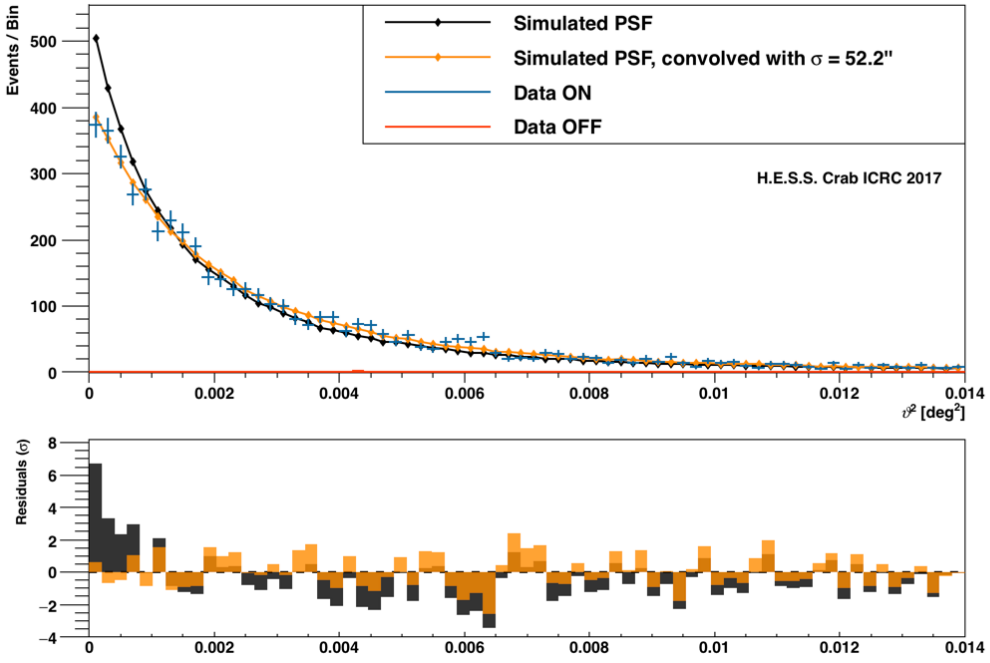
Associations and Identifications



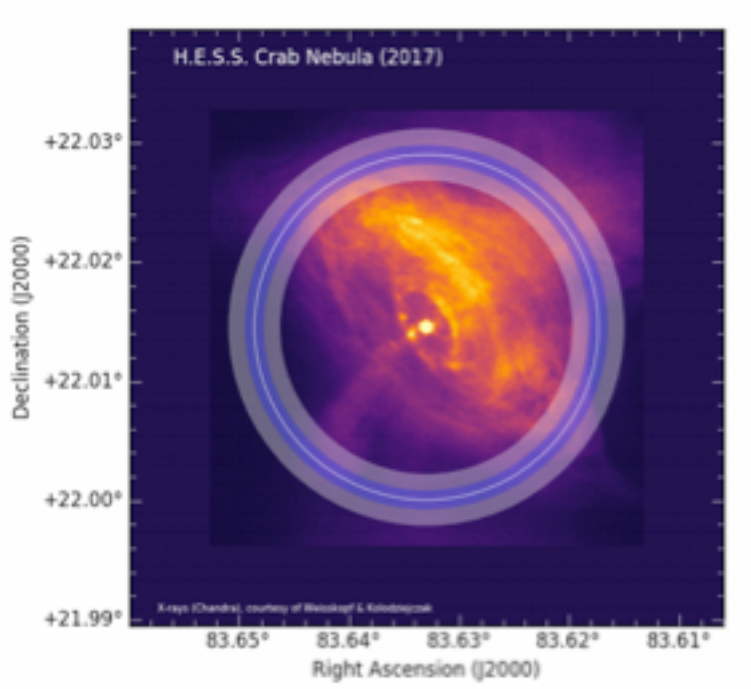


The Size of the Crab Nebula

- Improved simulation techniques „aka run-wise simulation“ allow to push the limits of ground-based gamma-astronomy
- Major step in data analysis, important for CTA



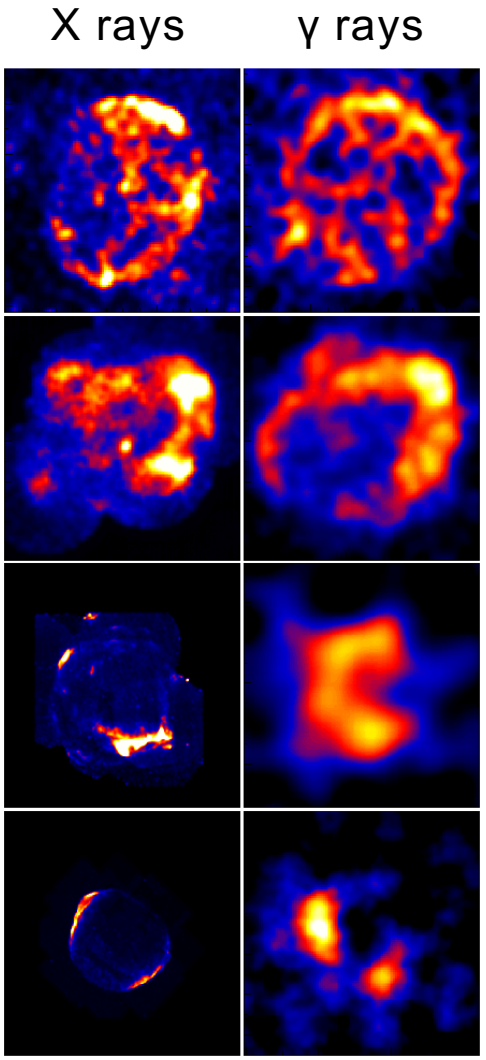
H.E.S.S. collaboration, ICRC 2017



$\sigma_{2D,G} = 52.2'' \pm 2.9'' \pm 6.6''$

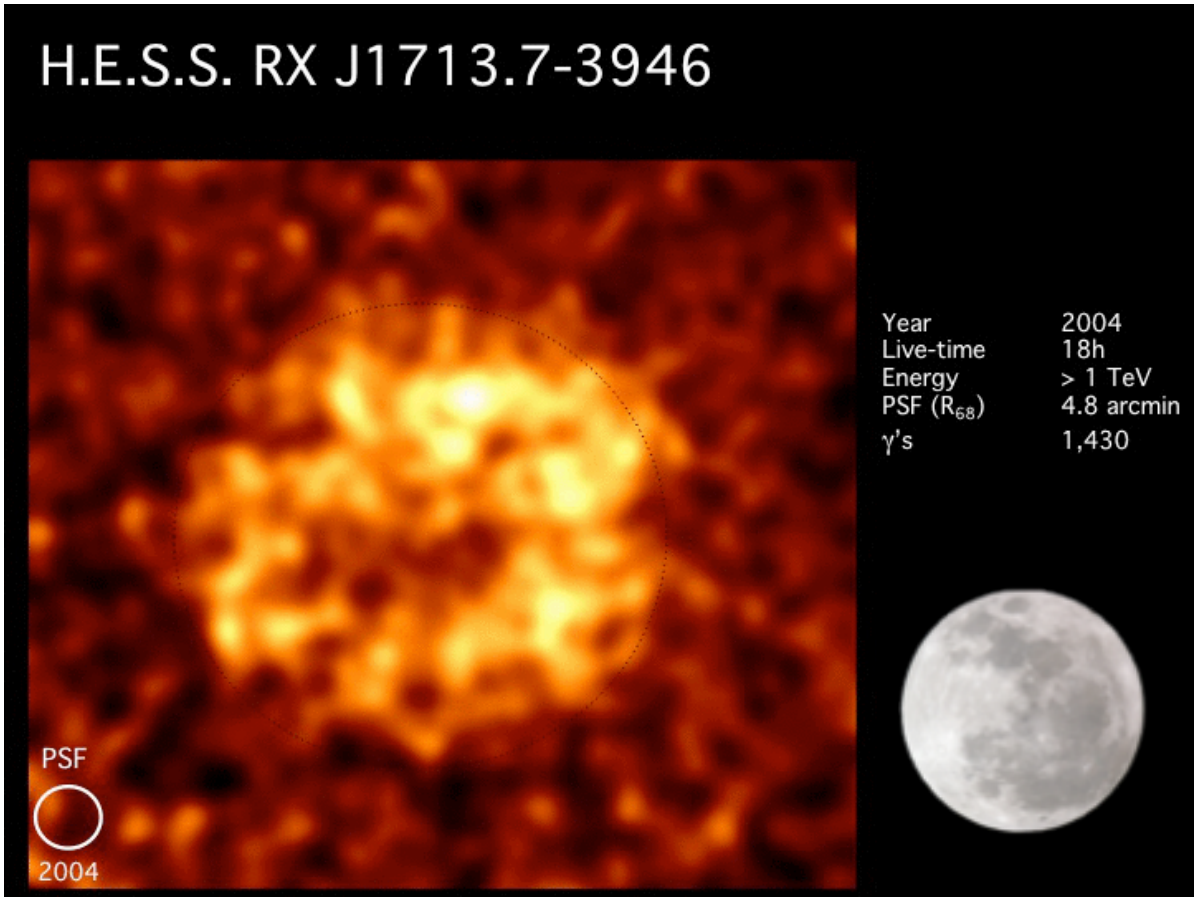
Supernova remnants

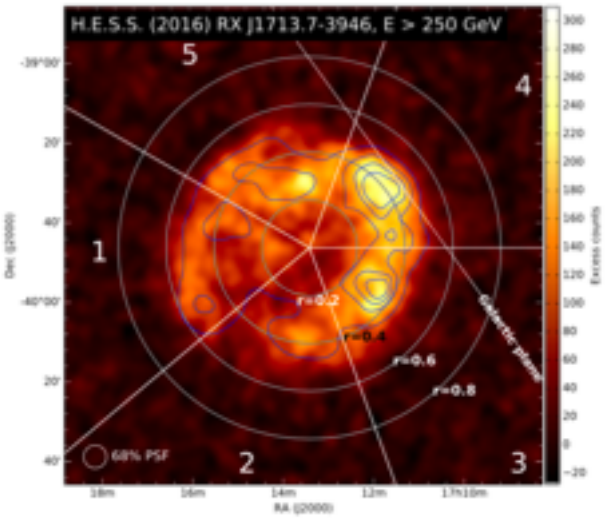
- Second largest population of VHE sources in Galaxy
- Young, historical supernova, in different evolution stages
  - High quality images, MWL data
- Older SNRs proven to accelerate protons
  - In interaction with molecular clouds (W28)
  - π^0 bump in Fermi LAT (IC 433, W49A, W51C, W44 …)
- High energy can be dominated by leptonic processes
  - Due to different efficiency of radiation mechanisms
  - $e^{\pm}$ cannot travel invisibly (IC unavoidable)
  - Hadrons need target to be revealed
- SNRs can be PeVatrons only during a (very) short time

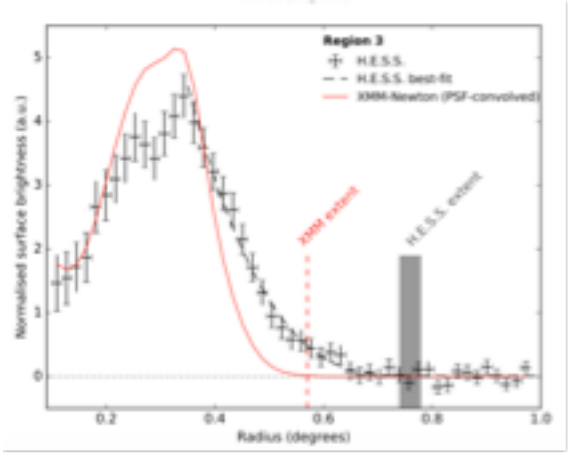


H.E.S.S.

Precision Measurements: RX J1713-3946







- First time: TeV beyond keV shell!

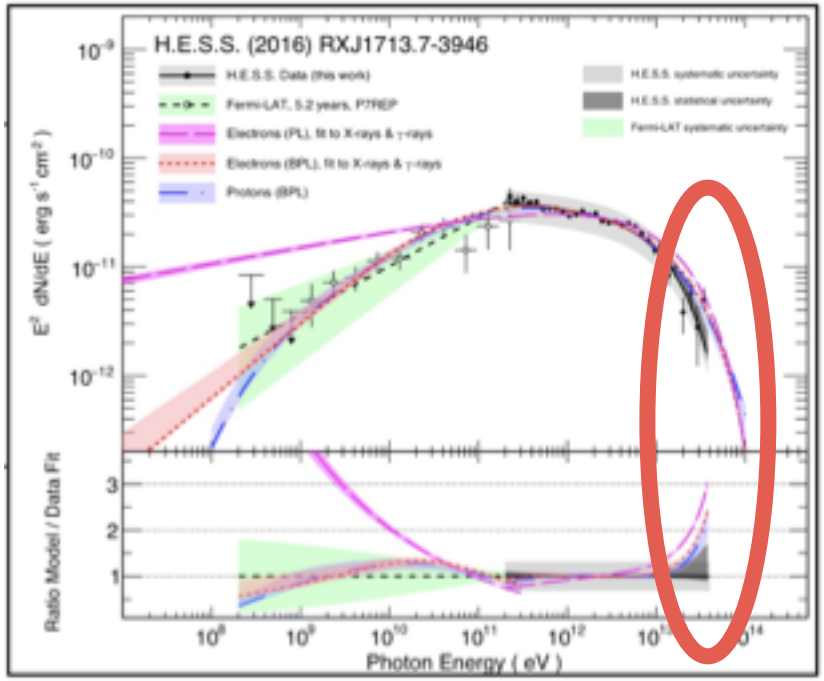
A&A 612 (2018), A6

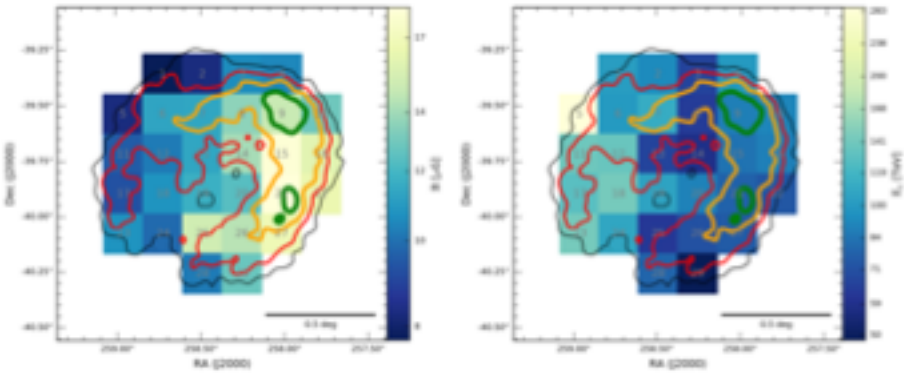
Precision Measurements: RX J1713.7-3946

- Spectrum best described by broken power-law + exponential cutoff
- Hadronic model
  - Break results from higher energy CRs diffusing faster into cold, dense MC clumps (e.g. Gabici & Aharonian 2014)
  - E_{break} depends on SNR age and density profile; E_c ~100 TeV
- Leptonic model
  - B ~ 10 – 15 μG, E_{break} ~2 TeV
  - Break requires 2nd electron population, or additional seed photon field
  - Detailed hydro-CR codes can reproduce observed emission

→ No clear case for either leptonic or hadronic accelerator

→ Improved 20 – 100 TeV coverage required

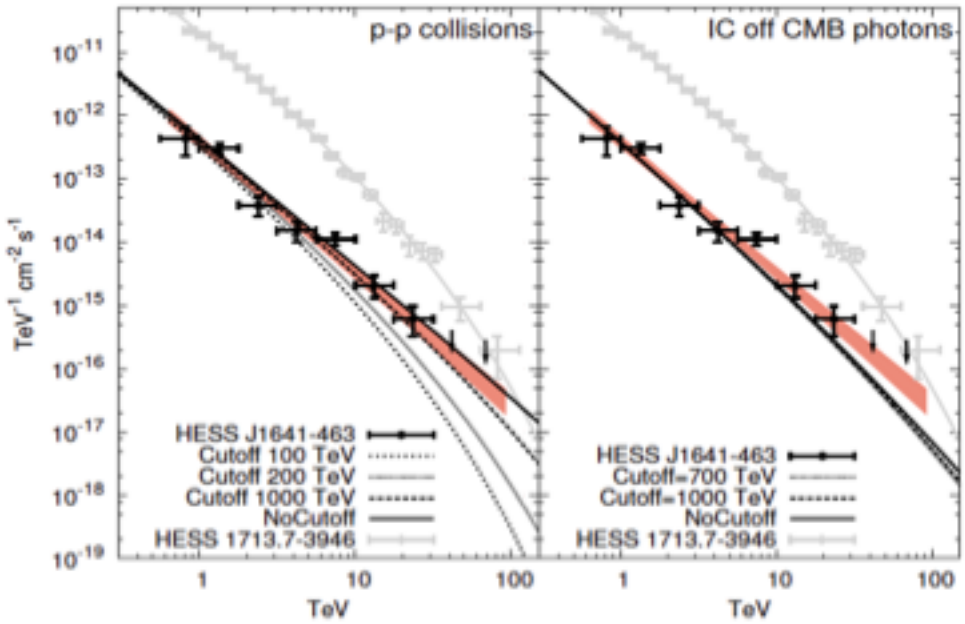


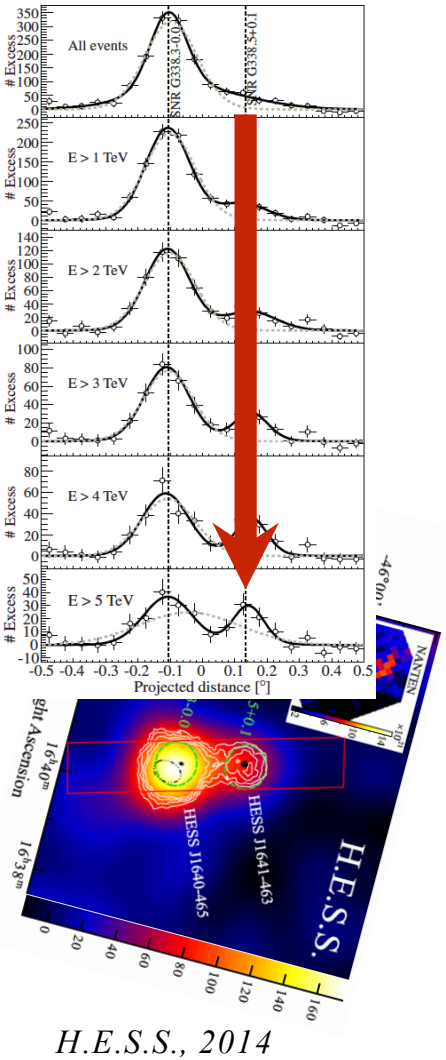


Potential PeVatrons amongst unidentified H.E.S.S. sources?

- HESS J1641-463
  - Very hard spectrum, index 2.07
  - Data points up to 20 TeV
  - Lower limit on cutoff energy: 100 TeV

→ a potential PeVatron?

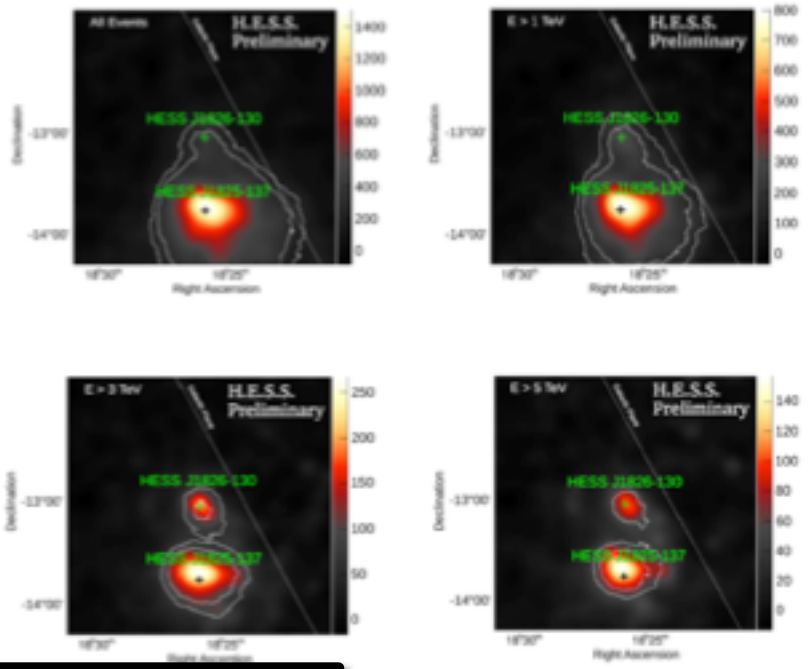




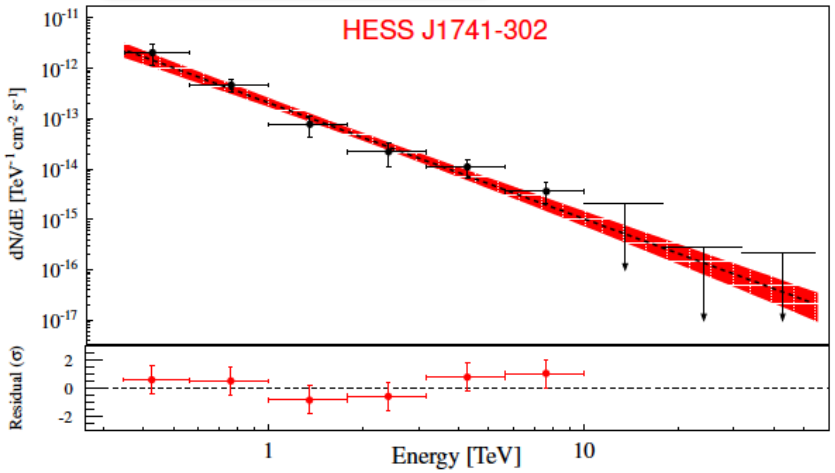
H.E.S.S., 2014

Further potential PeVatrons?

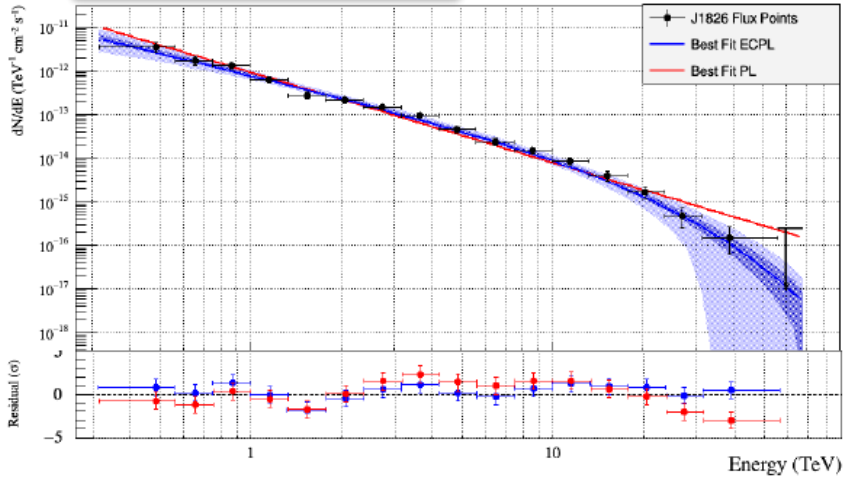
- Several sources in the HGPS exhibit hard spectra without apparent cutoff
- Deep exposure needed to investigate possible pevatron nature



HESS J1741-302

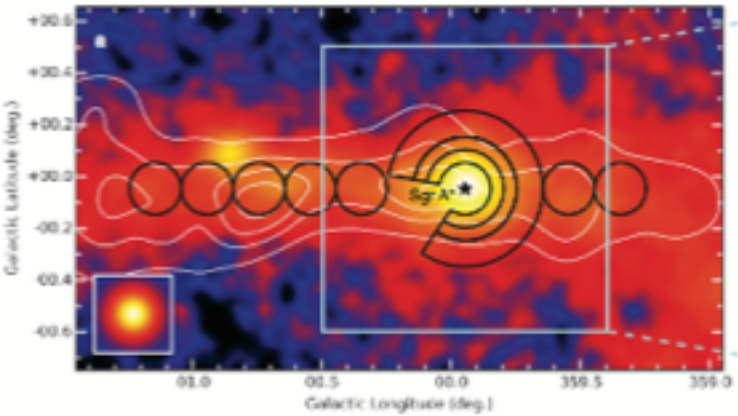


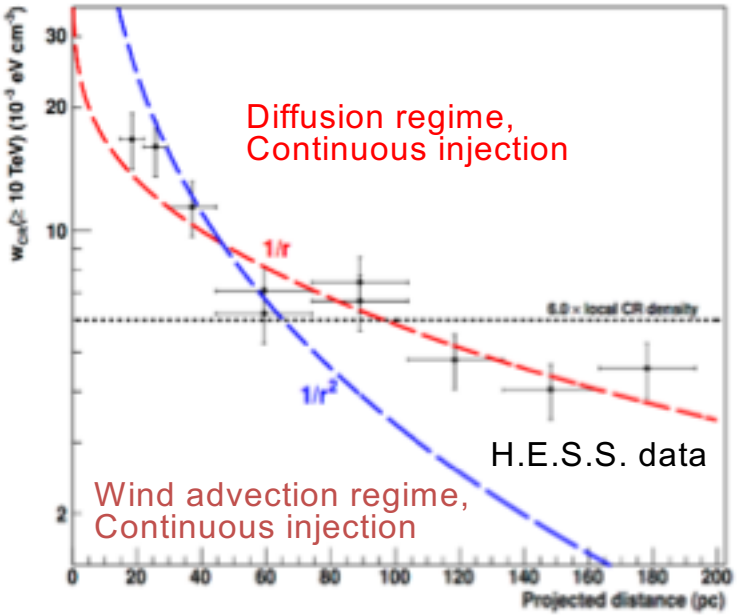
HESS J1826-130



The Galactic Centre region – a PeVatron

- Full dataset analyzed: 2004-2012, 220h obs. time
- Point like source > 100 σ, central source on top of extended (ridge) emission
- Diffuse emission up to > 50 TeV, attributed to protons accelerated around central black hole and diffusing away
- Parent proton population up to 1 PeV (2.9 PeV @ 68% CL)
- Central accelerator located within 10 pc and injecting CRs continuously for > 1 kyrs

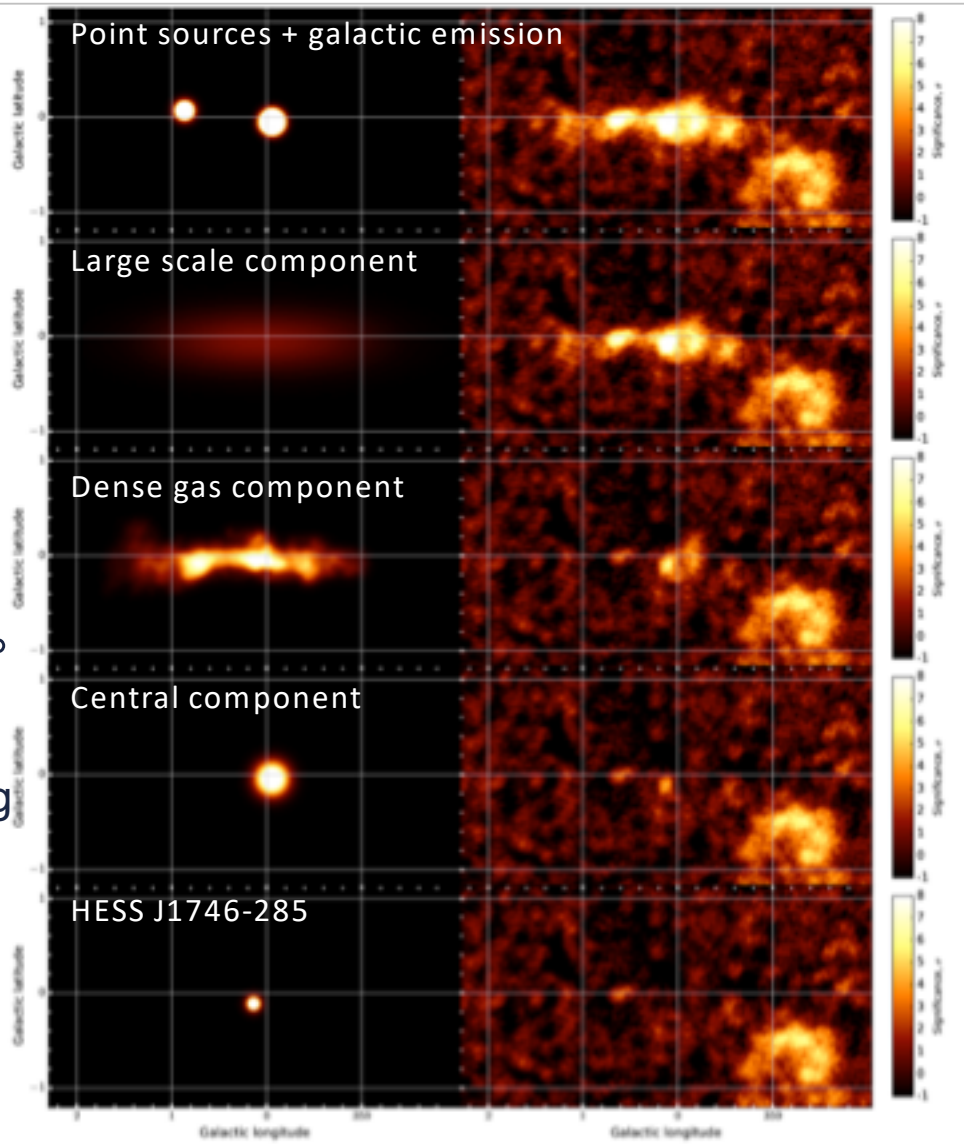




HESS Collaboration, Nature 531 (2016)

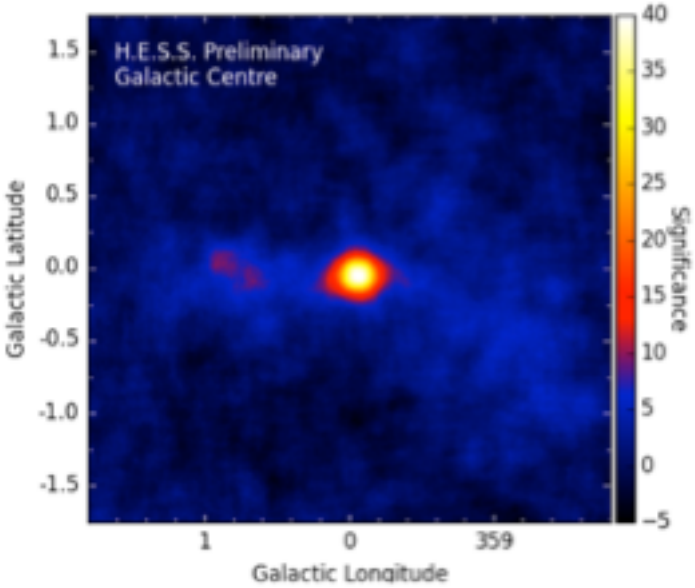
The Galactic Centre region

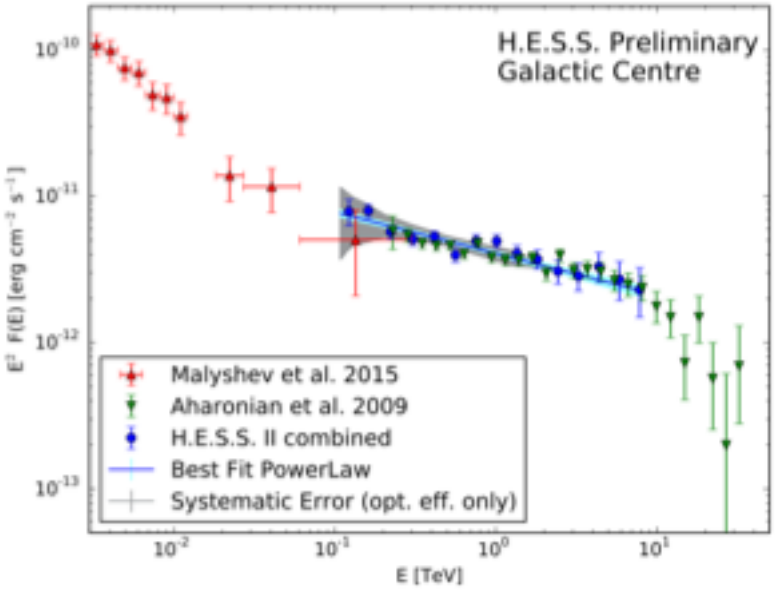
- Iterative fitting of different components
- Confirms central PeVatron
- CRs fill the entire CMZ
  - ~50% following dense has tracers
  - + Large scale component (dark gas? unresolved sources?)
- Additional central component of 0.1° (or 14pc extension)
  - CRs accelerated at the GC pervading the CMZ?
- Arc source HESS J1746-285
  - Non thermal filaments in the Radio Arc with high B field (>50μG)
  - Nearby molecular clouds



*H.E.S.S. Collaboration (**A&A Special Issue**)*

Closing the gap



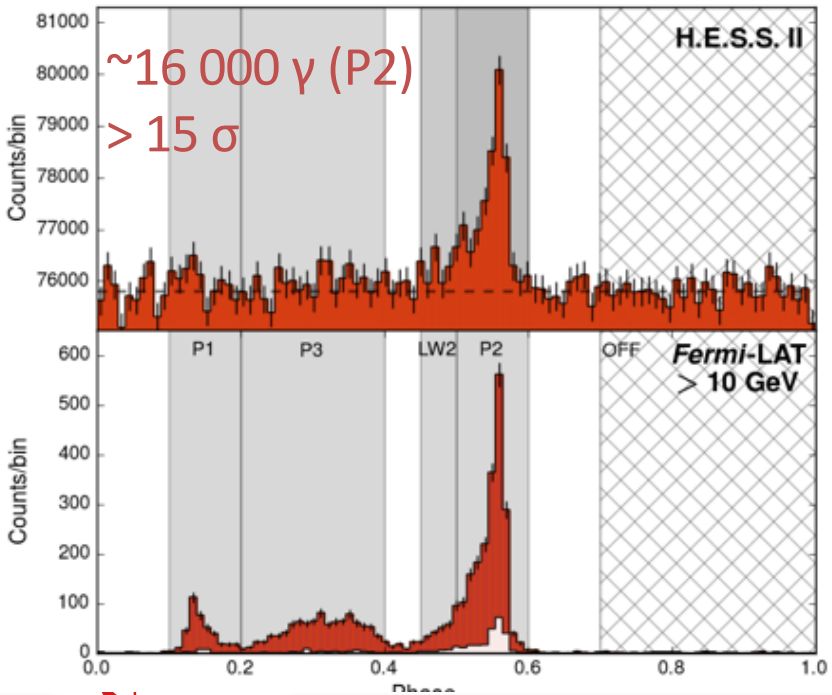


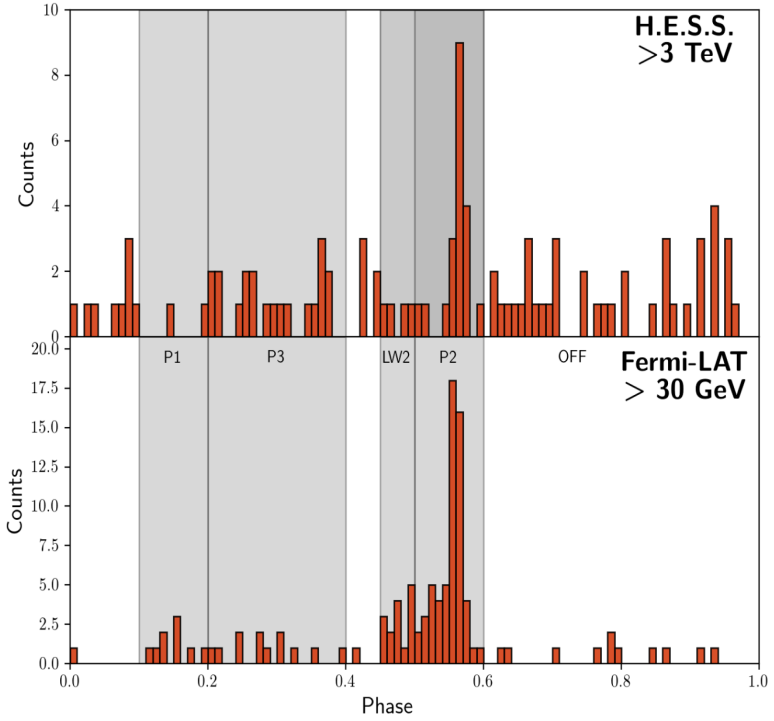
- Galactic Center with the H.E.S.S. II array down to ~100 GeV
- Detection of central source (40 σ), PWN G0.9+0.1, HESS J1745-303 + diffuse emission
- Smooth continuation from spectrum seen in H.E.S.S. I
- E-threshold not low-enough to fully describe Fermi-LAT - H.E.S.S. spectral break

H.E.S.S.

Vela Pulsar – H.E.S.S. II

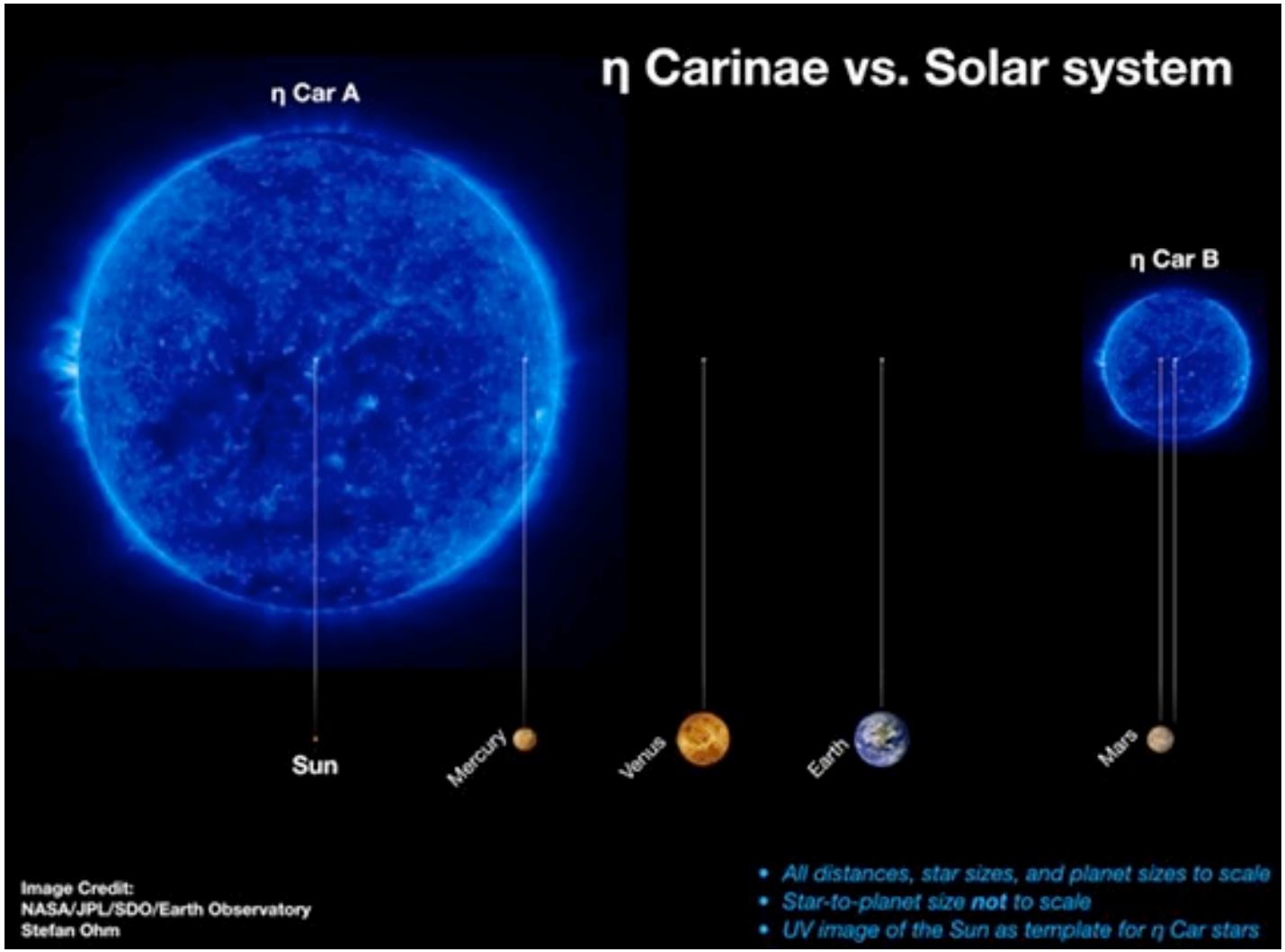
- Second VHE pulsar
  - Calibration source at the threshold in standard observation mode
  - Deep observation campaign needed to investigate maximum energy and variation of pulse profile with energy
  - Very different regime than Fermi-LAT: huge statistics over a huge background
  - First indication of VHE emission > 3 TeV → new component?



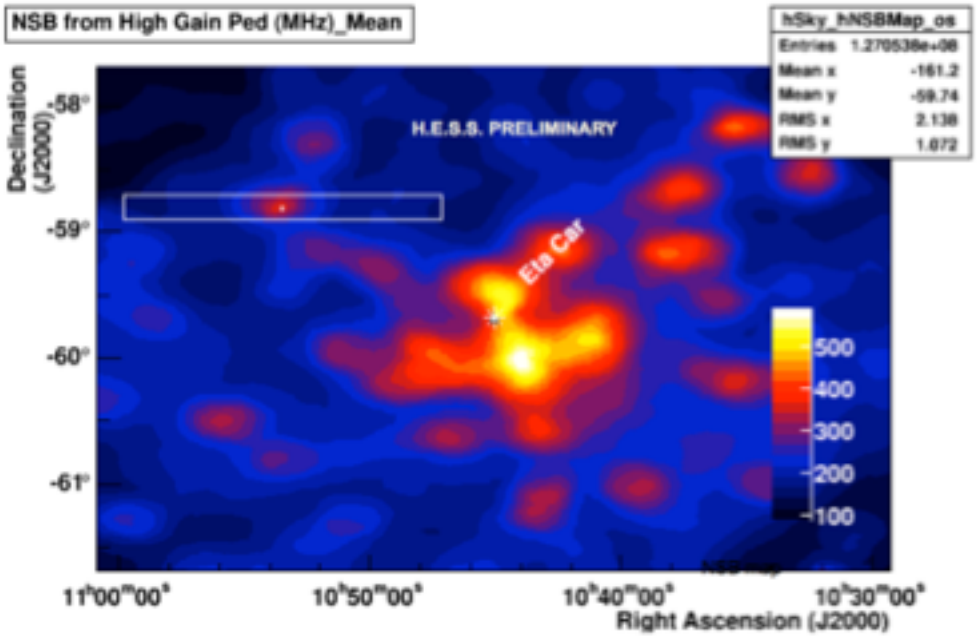


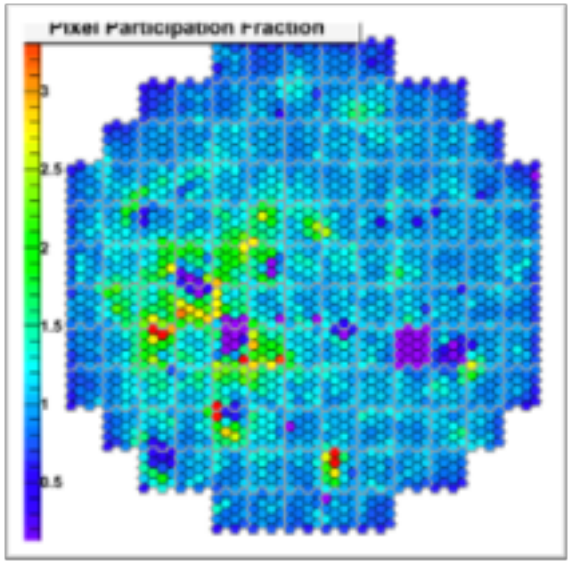
H.E.S.S. Collaboration (A&A, in prep.)

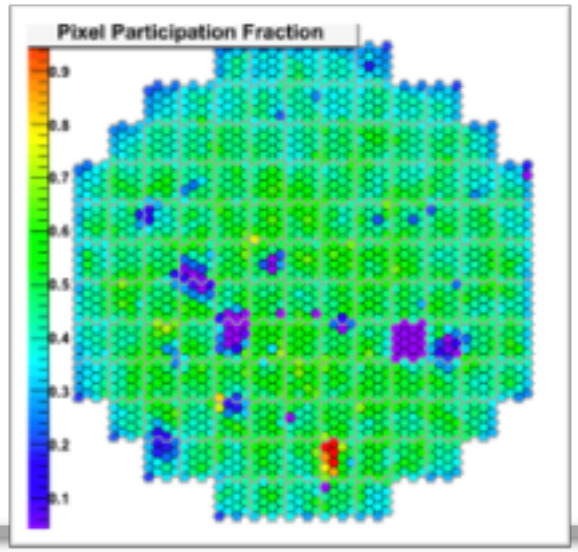
Eta Carinae


η Carinae vs. Solar system
η Car A
η Car B
Sun
Mercury
Venus
Earth
Mars
Image Credit:
NASA/JPL/SDO/Earth Observatory
Stefan Ohm
All distances, star sizes, and planet sizes to scale
Star-to-planet size not to scale
UV image of the Sun as template for η Car stars

Eta Carinae observations – a challenge for H.E.S.S.



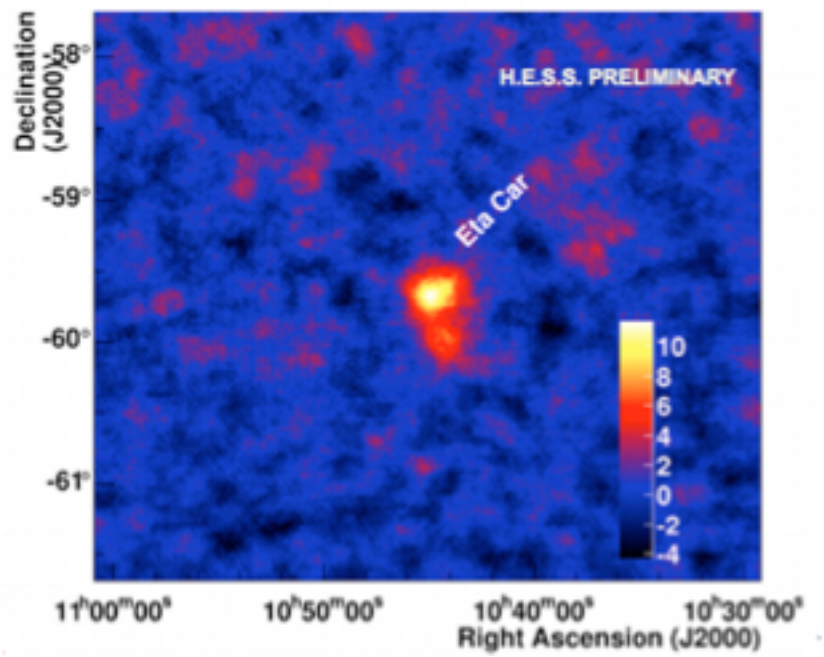


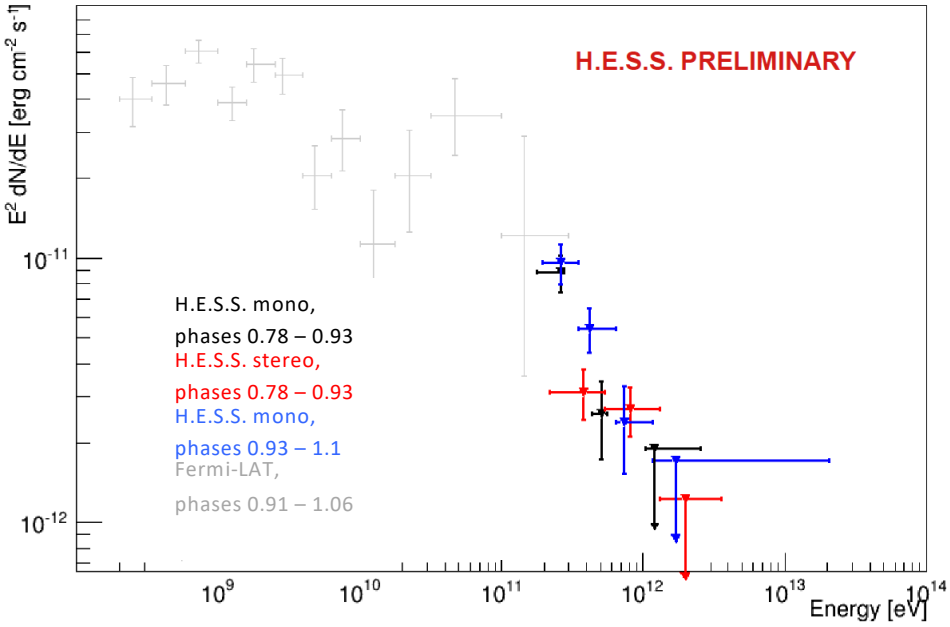


- Ran dedicated hardware campaign to find optimum settings for the camera trigger
- Adjustment of the analysis at all levels to reduce the number of NSB photons and to study the impact on the high-level analysis results

H.E.S.S.

Eta Car with H.E.S.S. II – a new TeV binary system

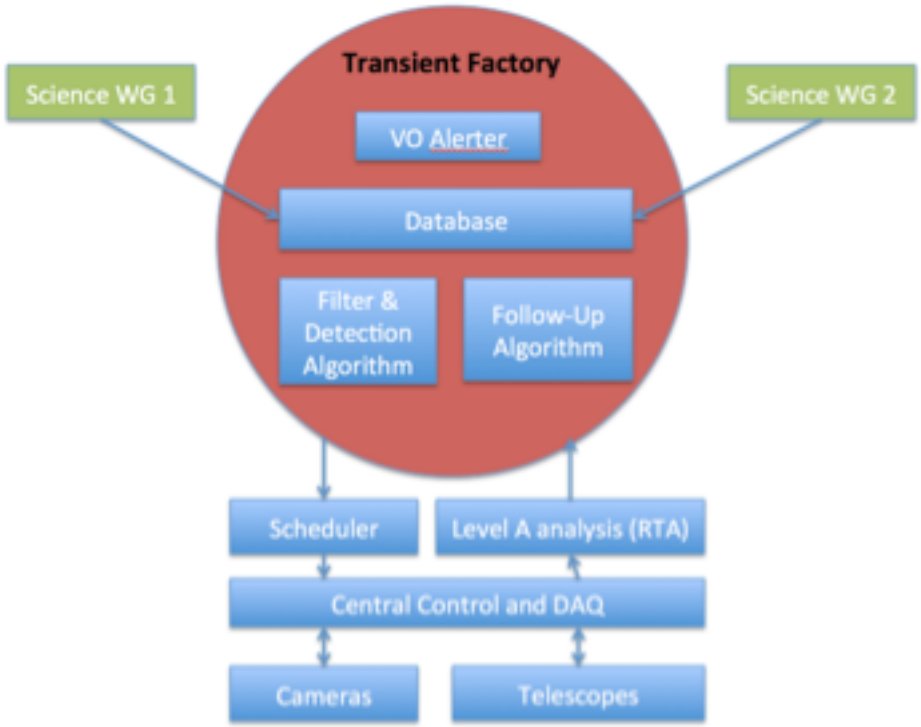




- Detected with H.E.S.S. II pre-periastron and around periastron (in total > 13 σ)
- Colliding wind binary system detected in very high energy gamma-rays

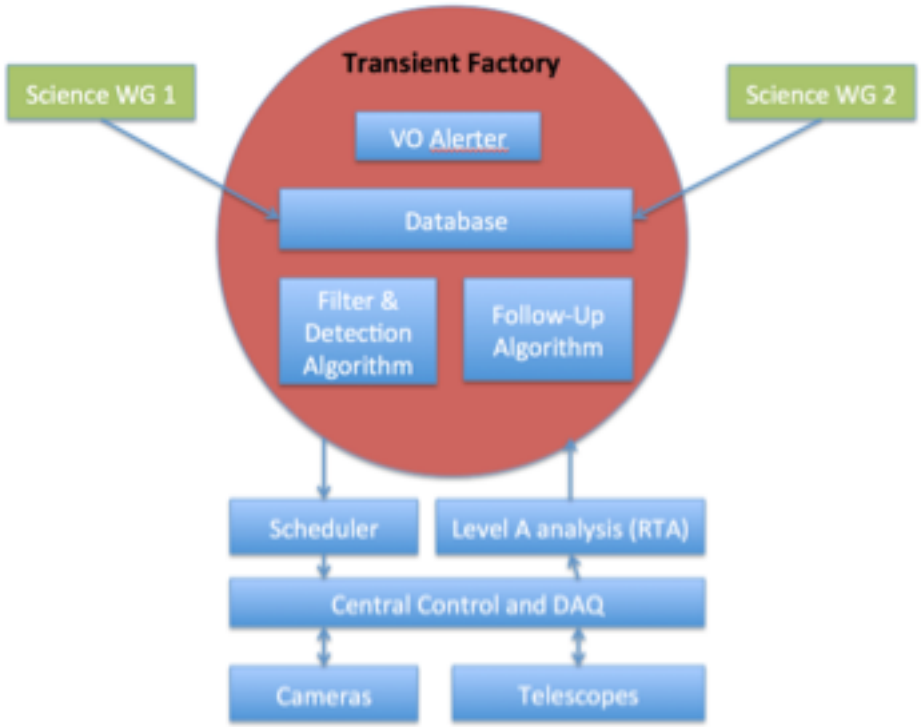
H.E.S.S.

Preparing H.E.S.S. for the multi-messenger era



- A performant transient system requires
  - Systemic approach
  - Flexibility (e.g. types of alerts)
  - Scalability (e.g. number of alerts)
  - Intelligent (e.g. combine info from channels)
  - Real-time feedback

Preparing H.E.S.S. for the multi-messenger era



2017 Scientific Exploitation

- GW/EM170817
- IC-EHE170922
- AGN ToOs
- Stellar superflares
- …

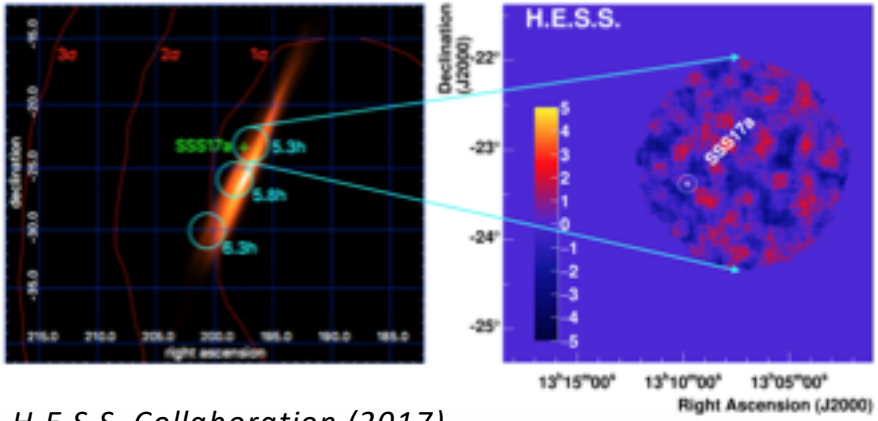
2016 Real-Time analysis ‚Transient Factory'

2015 Dedicated Transients TG

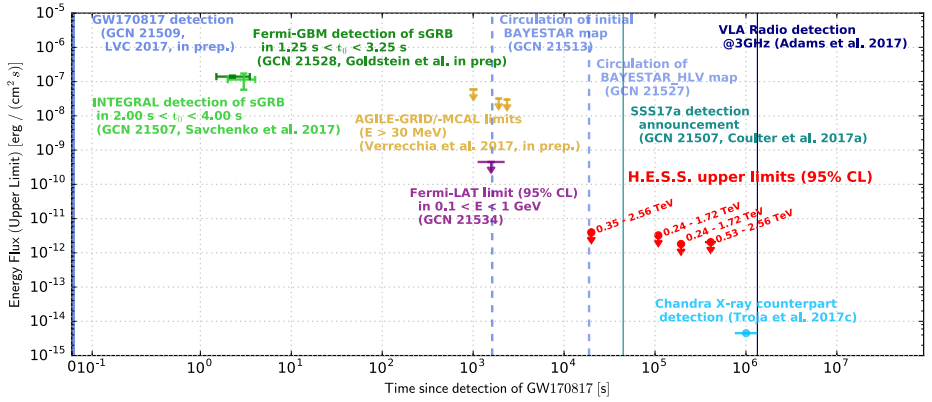
2013 Central Control & DAQ (Fully automatic follow-up)

The binary NS merger GW/EM170817 – the prompt H.E.S.S. follow-up

- 1st ground-based pointing telescope to observe GW170817
- Optimised follow-up algorithm
  Real-time analysis feedback within minutes
- Bottleneck: data transfer to Europe
  → solved now



H.E.S.S. Collaboration (2017)



Summary and Outlook

- H.E.S.S. is continuing to contribute to our understanding of the high-energy Universe
- Many many results not shown
  - Electrons: yes, the spectrum extents to 20 TeV
  - Dark Matter: yes, we do not see Dark Matter
  - AGN: yes, we observe flares and fill the gap to Fermi with high statistics
  - …
- The collaboration is preparing to extend the operation until 2023.