MAGIC observations of HESS J1809-193 using the Very Large Zenith Angle technique at energies above TeV

Darko Zaric*, D. Green, M. Strzys, I. Vovk
for the MAGIC Collaboration

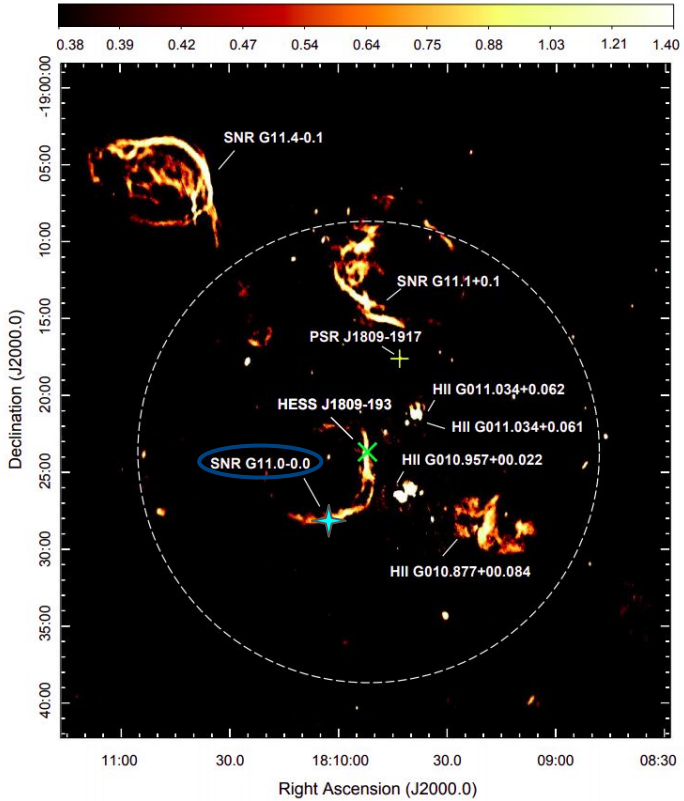
Online - July 2021 ICRC 2021

Motivation

- SNRs - a primary candidate for the source of Galactic CRs
    - Their environments are known to efficiently accelerate CRs to hundreds of TeV
- VHE gamma rays provide a unique probe into these extreme environments around potential PeVatron candidate sources by tracing signatures of particle acceleration through the morphology and spectrum features
- Domain above several tens of TeV has not been deeply studied by IACTs
    - Perform spectral measurements in that domain

HESS J1809-193

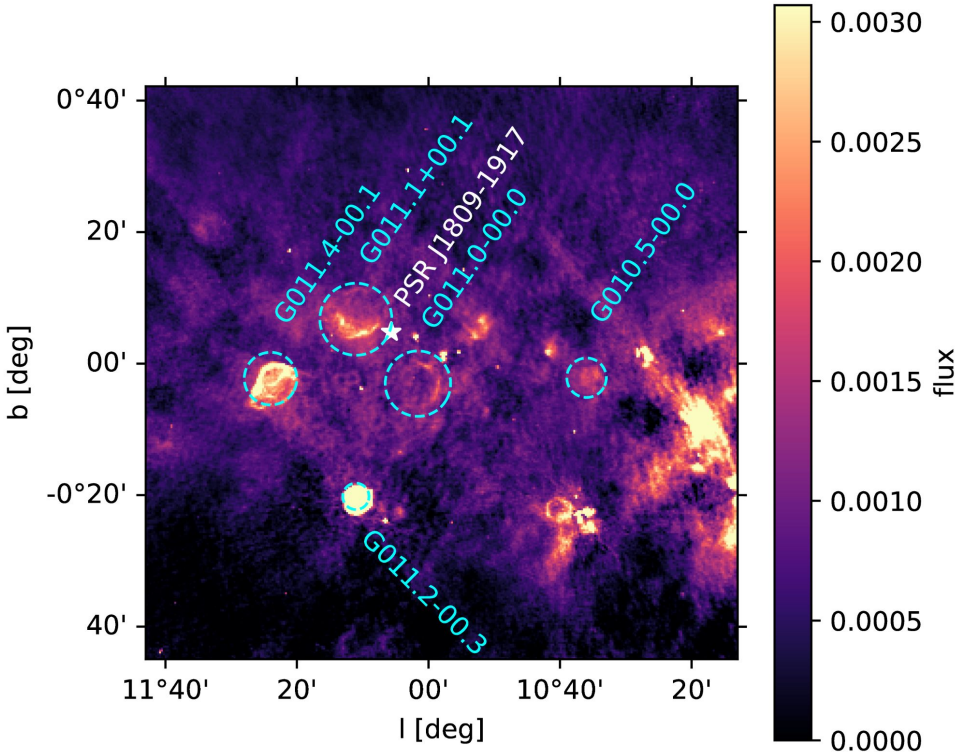
- It is an unidentified extended Galactic source
- Number of known astrophysical sources nearby
    - one of them being SNR G11.0-0.00 coincident with the peak of the TeV emission
- Potential association with the young and energetic pulsar PSR J1809-1917
    - located around 0.1° from this peak
- Spectrum difficult to explain with IC emission from high-energy electrons alone
- Deep measurements at tens of TeV needed to confirm its hadronic nature



Radio continuum image at 1.4 GHz
Image from [Castelletti et al (2016).]

Multiwavelength view

- Suzaku X-ray observations confirmed the existence of diffuse hard X-ray emission
  - No signs of cooling via synchrotron emission along this distance were seen
  - contrary to expectations for a young PWN
- Using radio observations from the Karl G. Jansky Very large Array Castelletti et al. (2016) found no counterpart to the proposed PWN
  - Study of the interstellar medium revealed several molecular clouds at the shock front of the SNR G11.0-0.00
  - Evidence for interaction between the SNR and the clouds
  - Hadronic interactions proposed to explain the origin of the gamma-ray emission



MAGPIS 20cm radio emission

MAGIC Telescopes

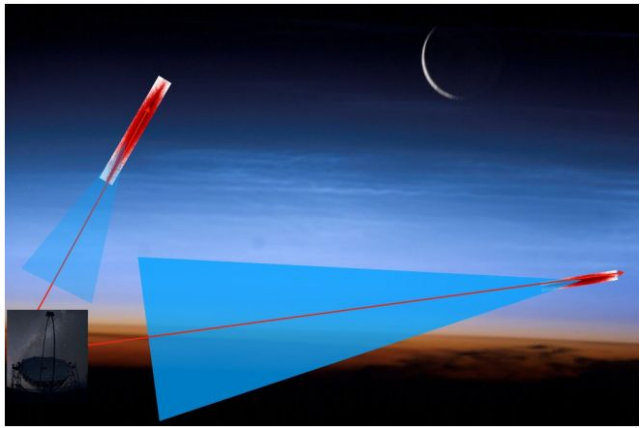
- System of two Imaging Atmospheric Cherenkov Telescopes
- Located at La Palma, Canary islands
- Observing the Very High Energy gamma-ray sky
- Energy range:
  ~30 GeV to ~100 TeV
- Field of view 3.5°

	HESS (HGPS)	**MAGIC VLZA (this work)**
Observation period	2004 - 2013	2019 - 2021
Livetime - map	83 h	64 h
Livetime - spectrum	10 h	64 h
Analysis threshold	0.38 TeV	2.5 TeV
$PSF_{68\%}$	0.08° - 0.15°	0.15°

Credit: Giovanni Ceribella

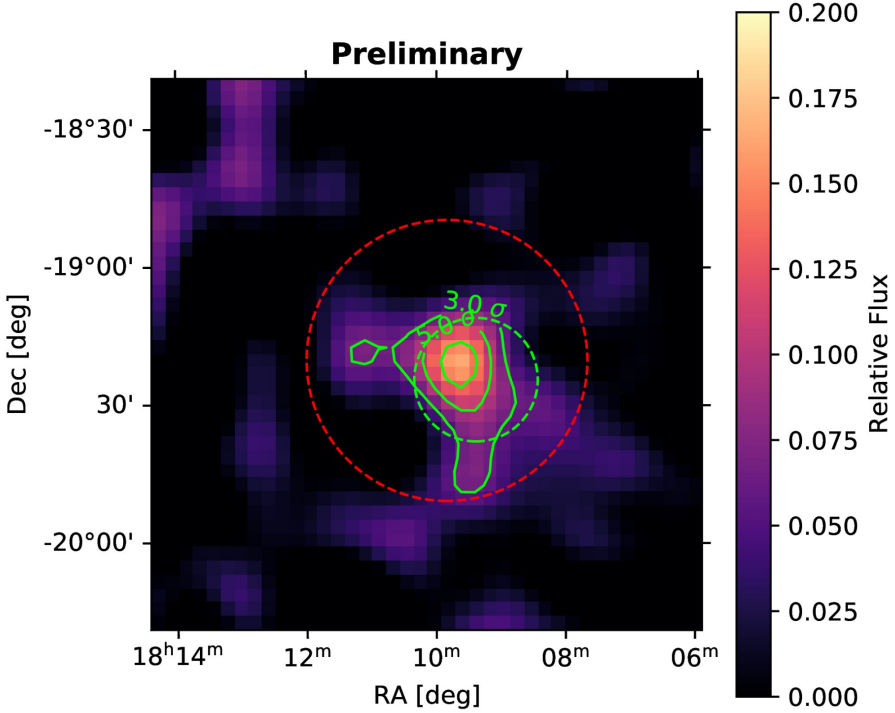
Very Large Zenith Angle Observations

- Observations of very-high-energy gamma rays
  - Flux decreases rapidly → low count rates
- Solution: increase observation time or increase the collection area
- To increase collection area:
  - Build bigger telescope arrays
  - Observing with Very Large Zenith Angles
- Observations above ~60° zenith
- Increase in collection area ~km2
- Energy threshold ~TeV



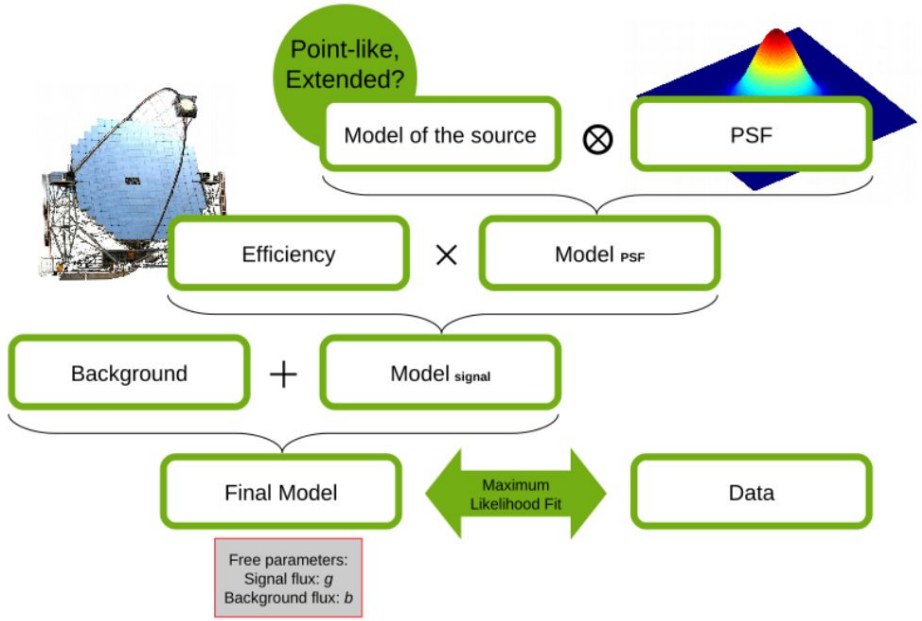
Skymap

- Relative flux map as seen by MAGIC above 3 TeV
- Green solid lines represent the MAGIC 3, 5 and 7 σ contours
- Green dashed line represents R_{68} of this study
- Red dashed line represents R_{68} of eHWC J1809-193 [Abeysekara et al. (2020)]



Source modeling

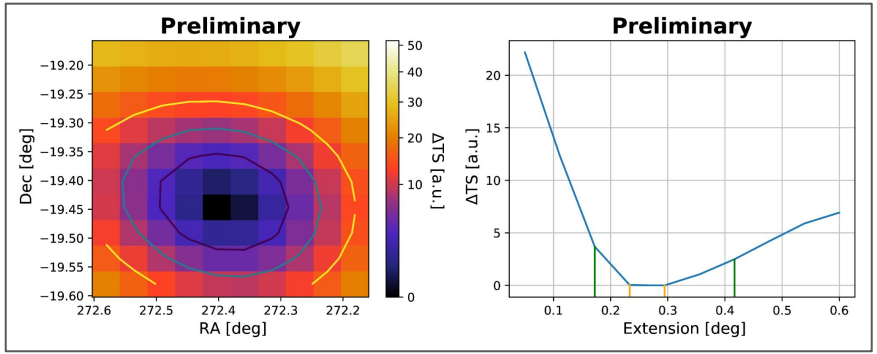
- Standard IACT analysis uses source and background control region to extract spectral parameters
  - Usually only suitable for point like sources
- Special analysis tool in MAGIC: Maximum likelihood fit of the source model to the sky image



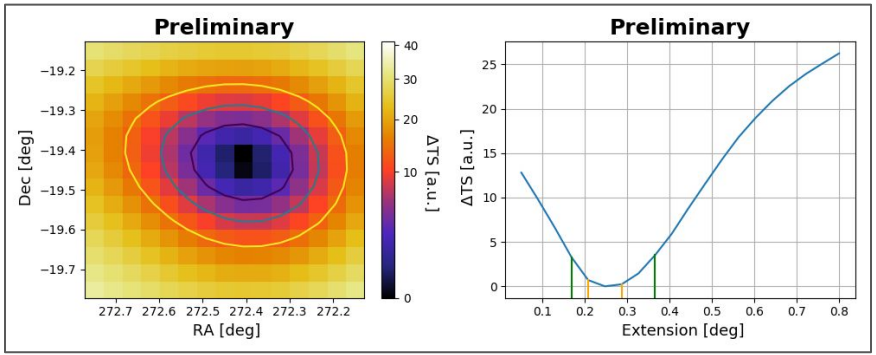
Vovk et al., A&A 619, A7 (2018)

Likelihood scan

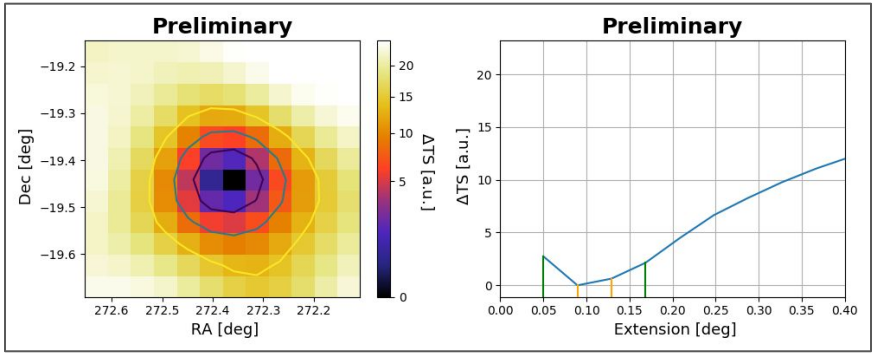
- Maximum likelihood scan performed to obtain the source location and extension
- 2D symmetric Gaussian preferred over Point Source and Disk spatial model
- Contours for the 2D plot represent the 1 σ(purple), 2 σ (blue), 3 σ(yellow) errors
- 1D plots the vertical lines represent the 1 σ(yellow) and 2 σ(green) errors



3-400 TeV



3-25 TeV

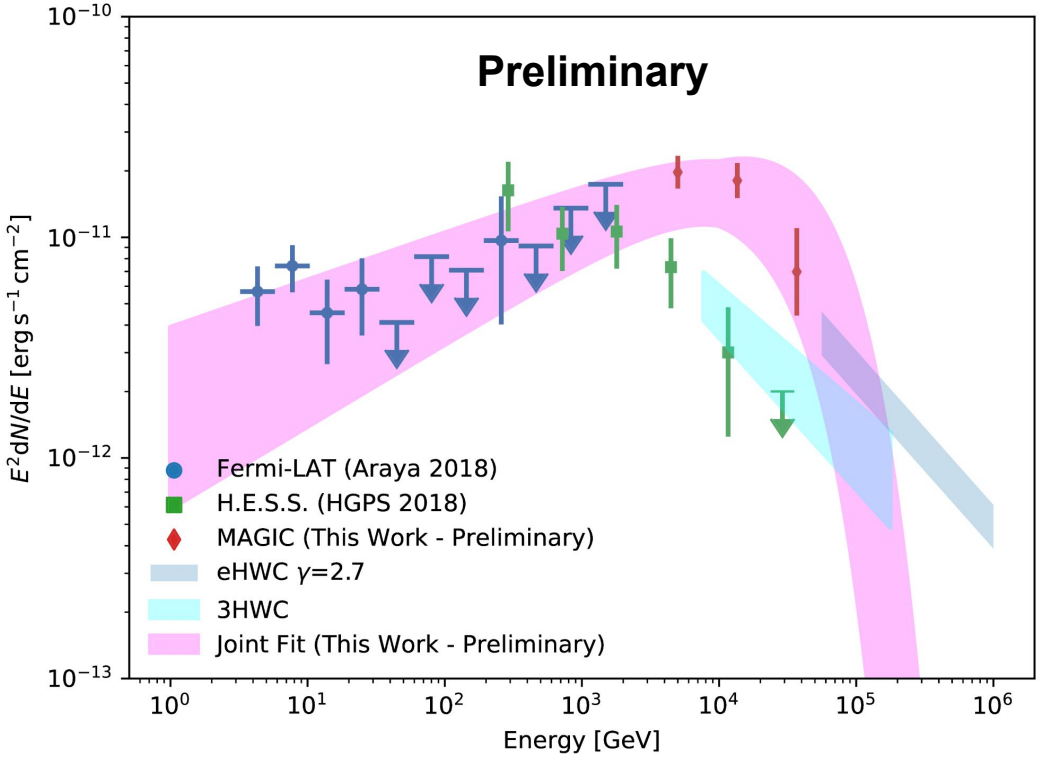


25-400 TeV

Spectrum

- Used location and extension measurements results of the 2D symmetric Gaussian spatial source model
- Joint forward-folding fit performed using the Fermi-LAT data
- Power Law with Exponential Cutoff and Log Parabola were preferred over the Power Law model
  - ~2.3 sigma preference of PLEC over PL
- Results more in line with the eHWC measurements
  - Also agrees best in terms of the extraction region
- IACTs crucial as the energy turnover occurs in that energy range

Joint Fit with Fermi data - Power Law with Exponential Cutoff



Resulting fit parameters

$$E_0 = 10\ TeV\ ;\ f_0 = 1.51^{+0.25}_{-0.37} \cdot 10^{-13}\ cm^{-2} s^{-1} TeV^{-1}$$
$$\Gamma = 1.70^{+0.08}_{-0.07}\ ;\ E_{cut} = 28.30^{+12.36}_{-7.41}\ TeV$$

Summary

- MAGIC observations on HESS J1809 for about 60h
- Observed with Very Large Zenith Angles to increase the collection area in the multi-TeV range
- Current spectrum most in line with eHWC measurements
- Stay tuned for the paper and interpretation