New insights towards the Galactic center from H.E.S.S.

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On behalf of the H.E.S.S. collaboration

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TeV emissions towards the Galactic center

- **First detection of sub-TeV gamma rays towards the Galactic center** by CANGAROO-II [Tsuchiya+2004], hint of TeV emission from Whipple (3.7 sigma) [Kosack+2004]

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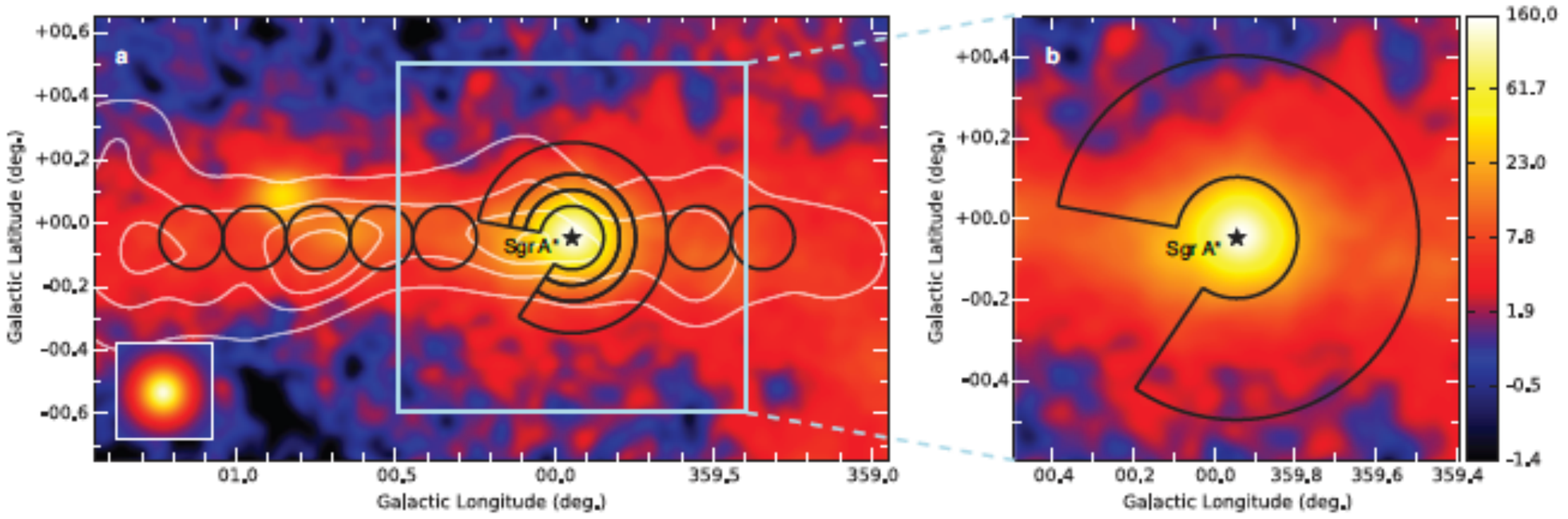
- Analysis of HESS J1745—290 and diffuse emission [H.E.S.S. collaboration 2016] with 226 hours of livetime



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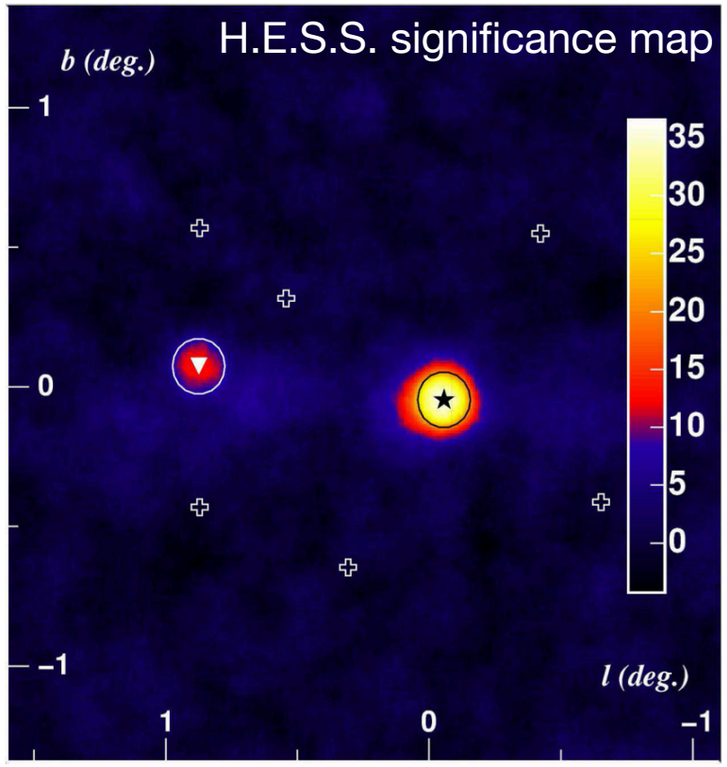
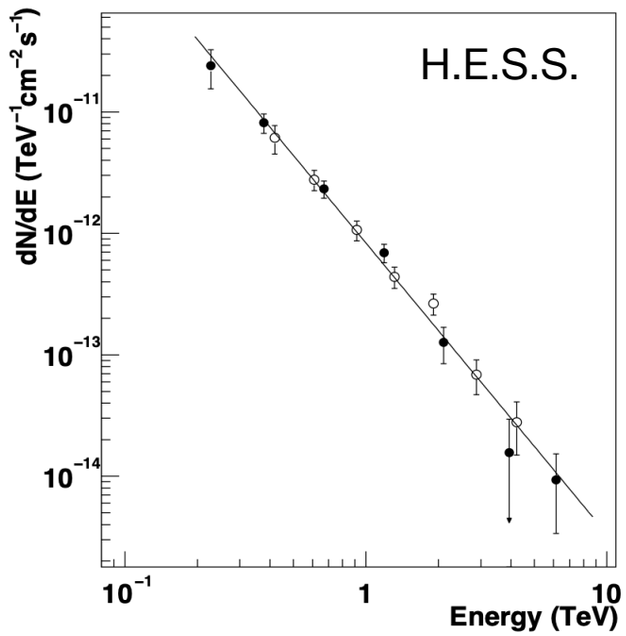
- **Detection of TeV emission from the pulsar wind nebula (PWN) G0.9+0.1: HESS J1747−281** [Aharonian+2005]



Power-law spectrum:



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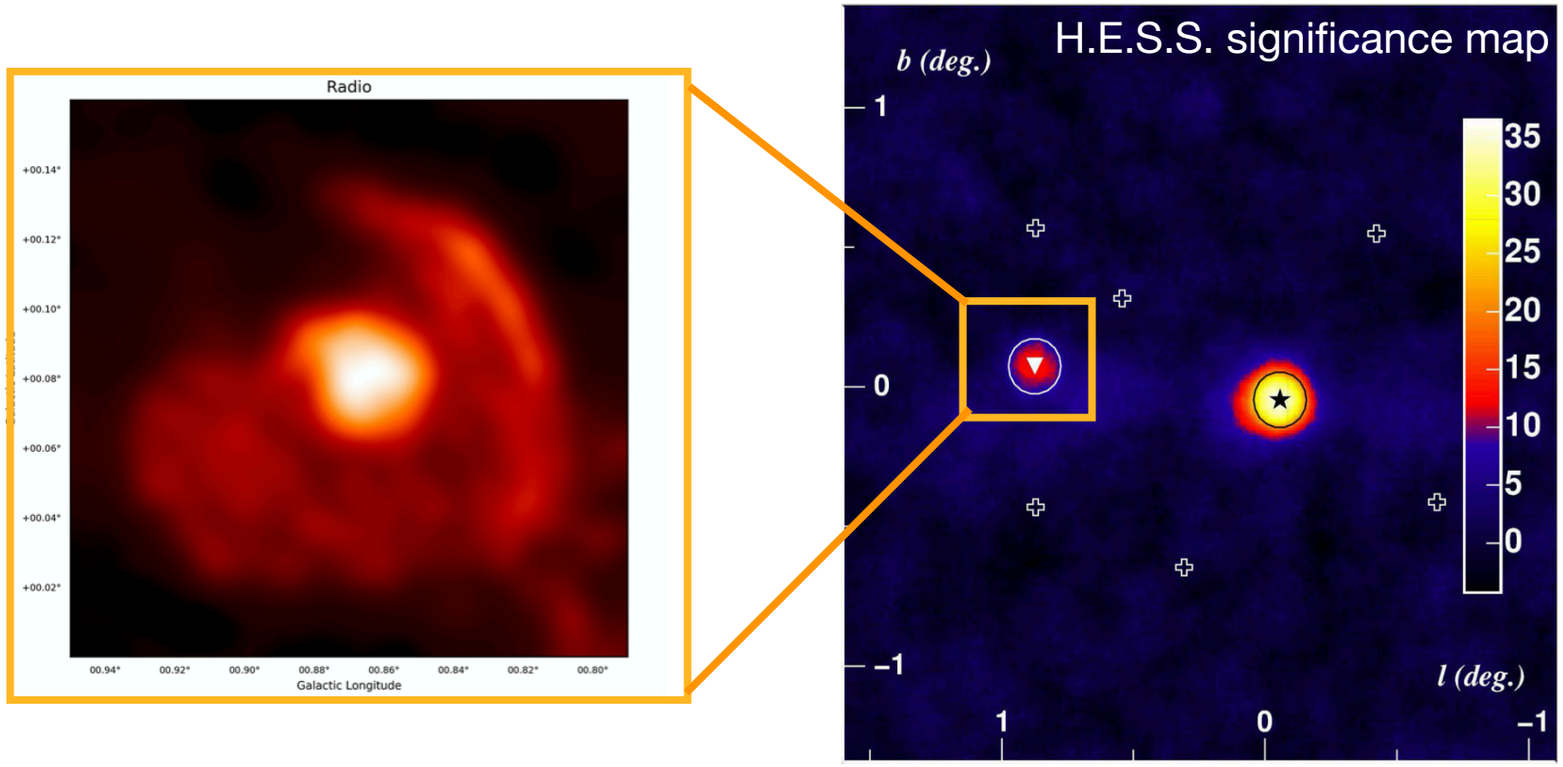
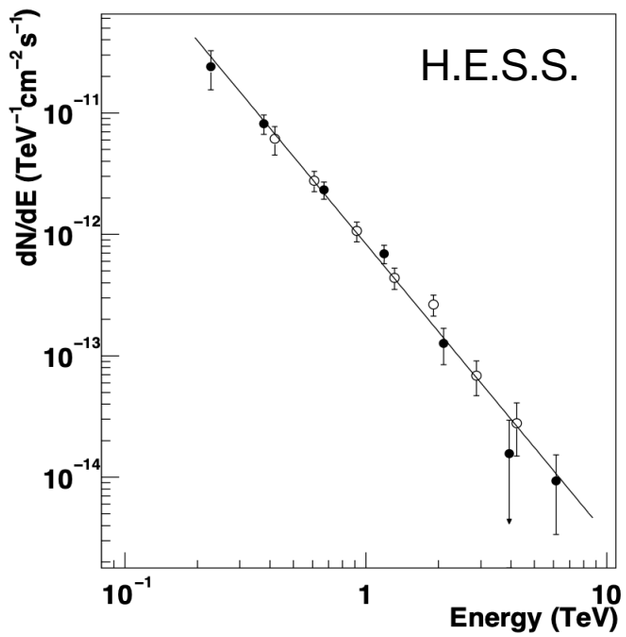


Composite supernova remnant

Power-law spectrum:



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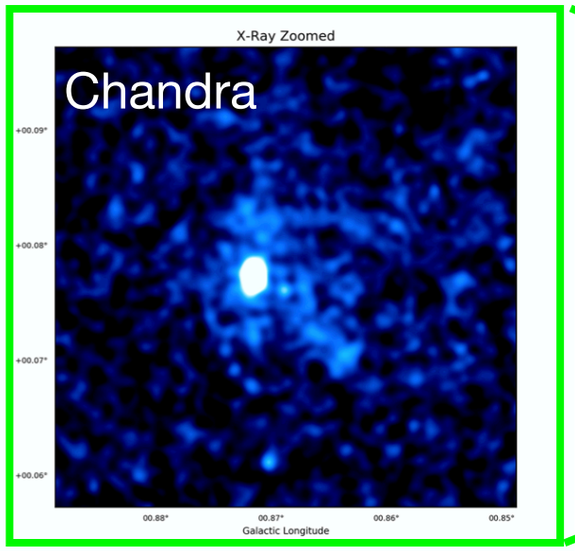

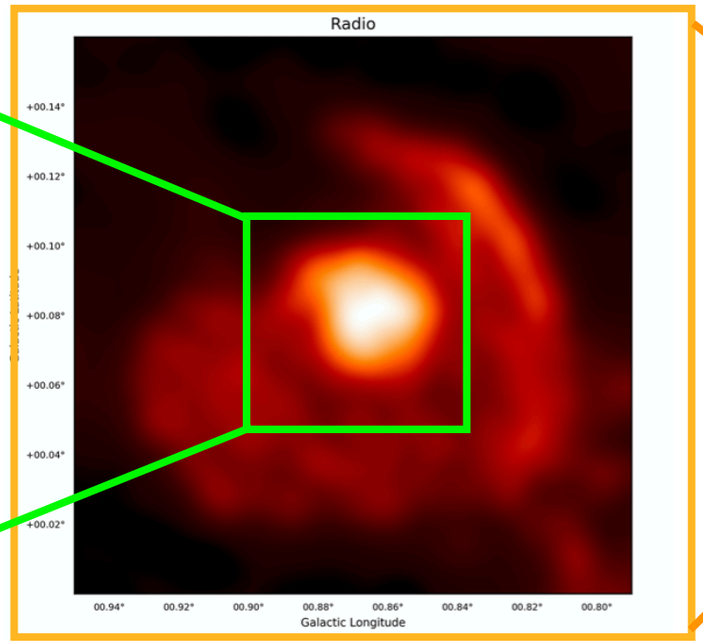

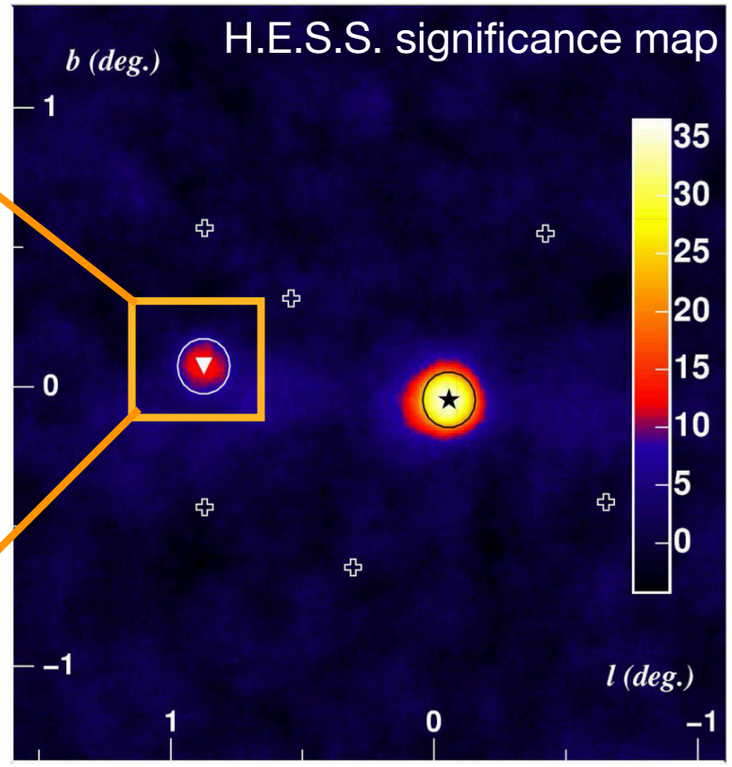

Extended nonthermal X-ray emission [Holler et al. 2012]

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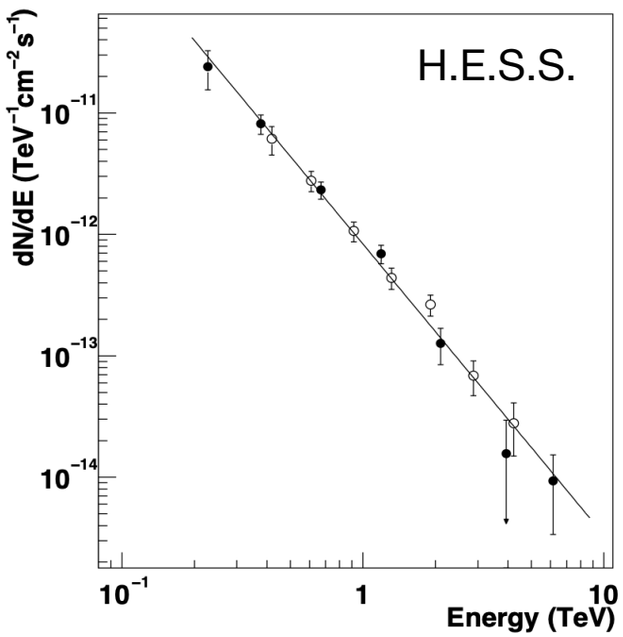
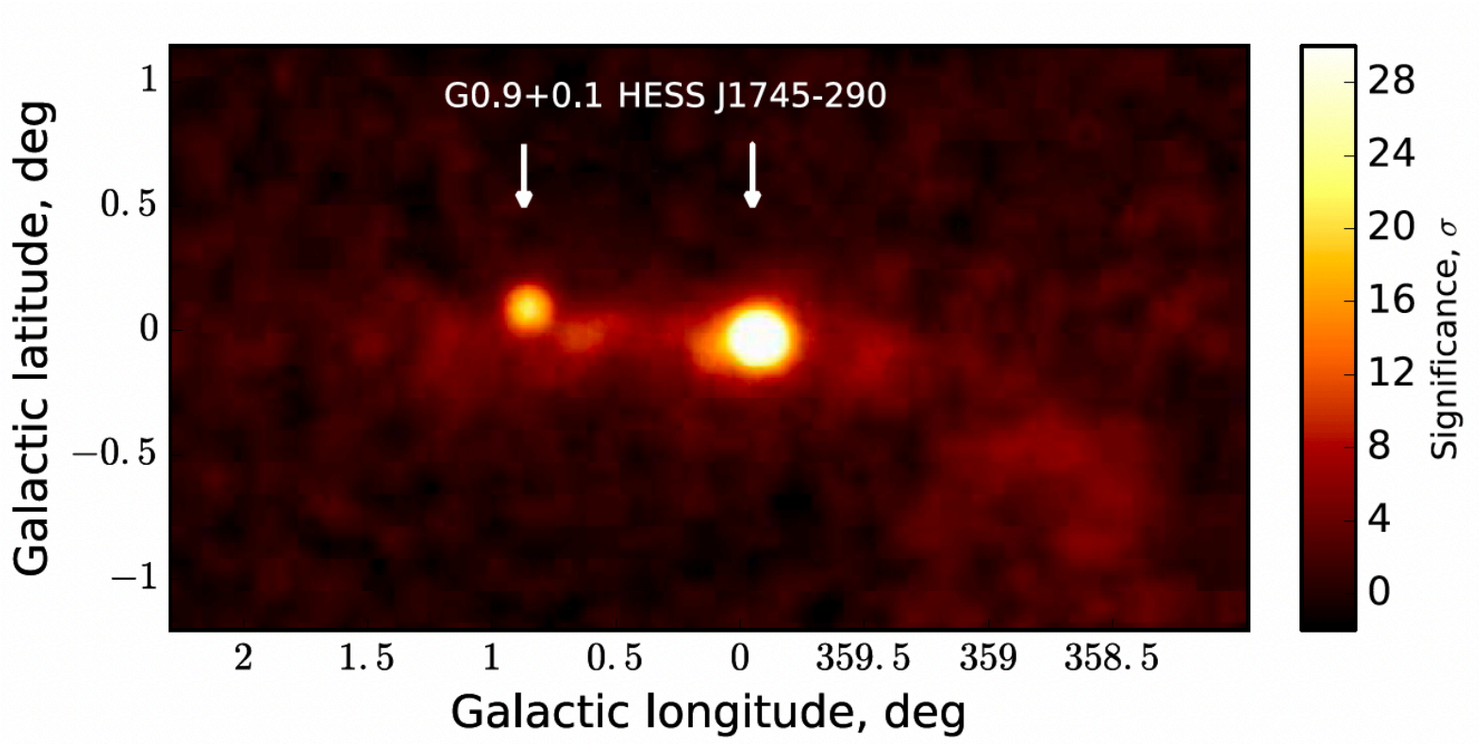


TeV emissions towards the Galactic center

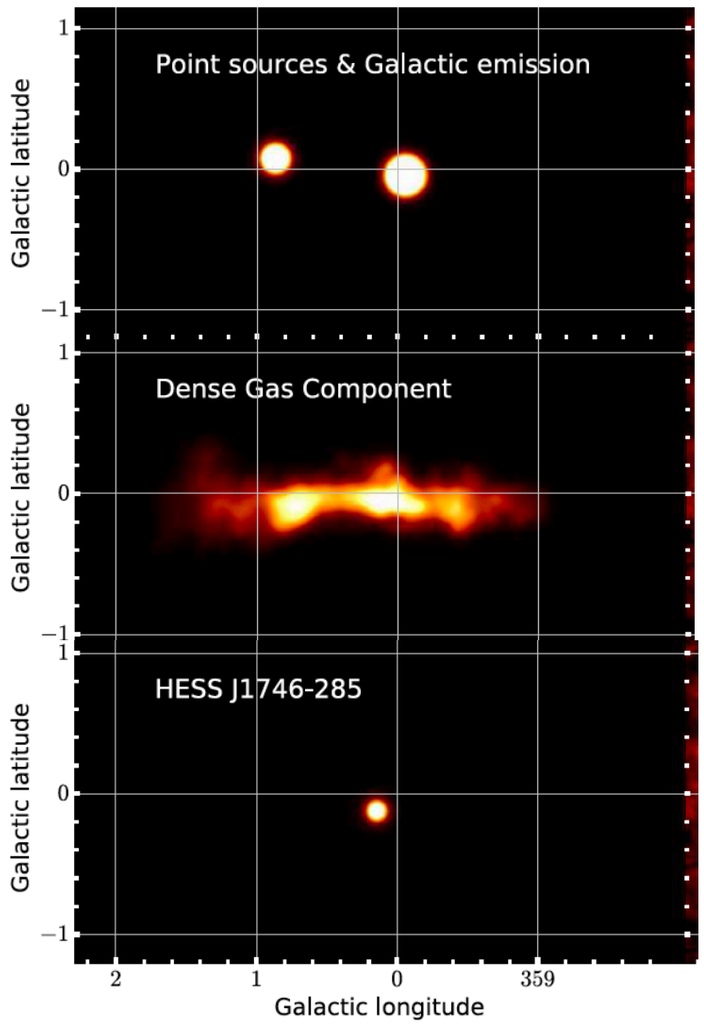
- Detailed morphological analysis using an iterating fitting procedure and a template-based approach with a total livetime of 259 hours [HESS collaboration 2018]

  ➡ **Detection of HESS J1746−285** spatially coincident with the radio arc and the PWN candidate G0.13–0.11 + **detection of an additional central component**



[HESS collaboration 2018]

Example of model components:



Aim

Revisit the Galactic center region with a spectro-morphological analysis:

- 12 years of H.E.S.S. data (CT1—4)
- Maximum zenith angle of 40° => 1161 runs (total livetime of ~ 540 hours, twice more than that in [HESS collaboration 2018])
- Fit of a 6° x 4° region from 0.4 TeV to 100 TeV
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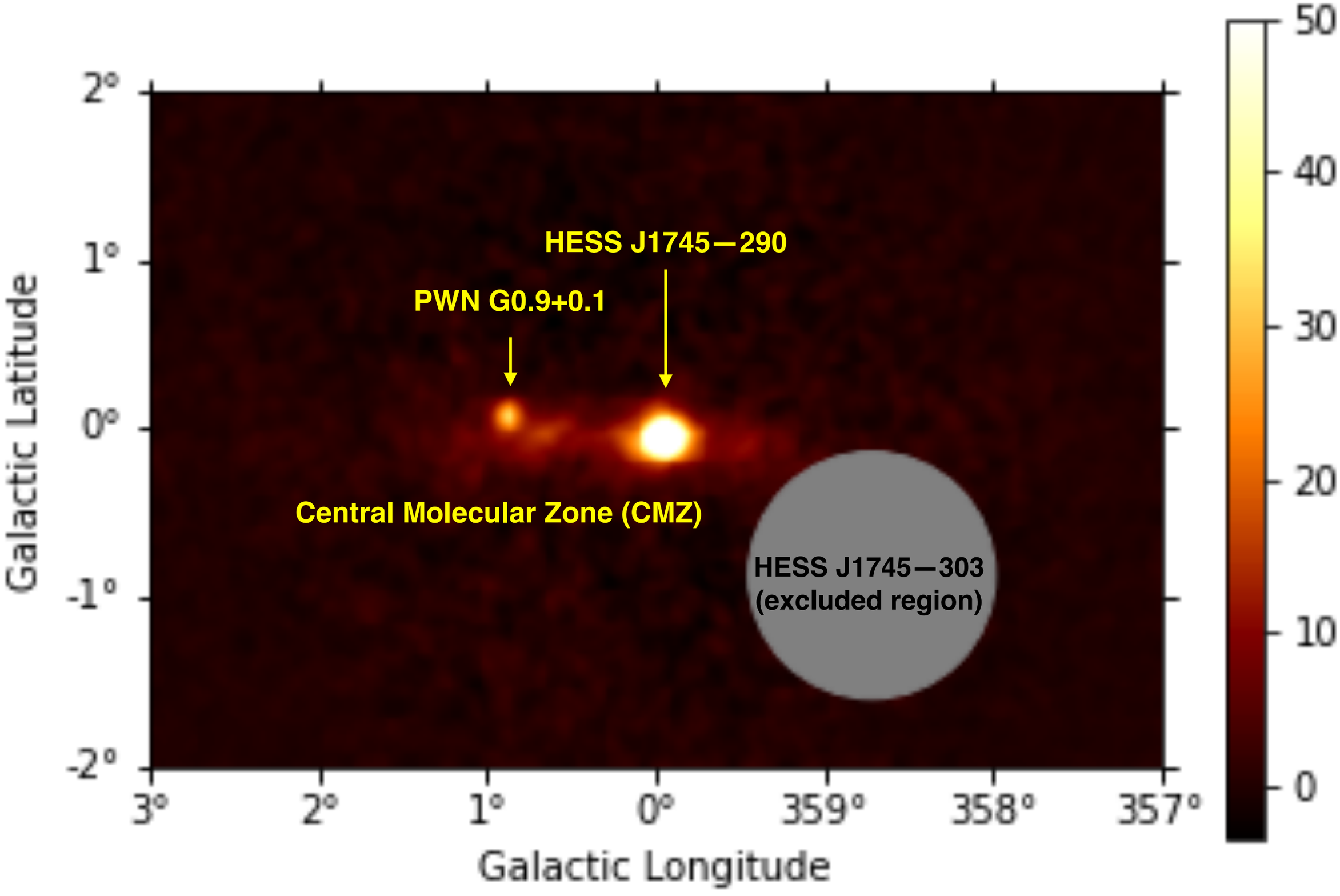
Spectro-morphological analysis using **gammapy:**

➡ Model components:

- known H.E.S.S. sources
- diffuse emissions
- residual hadronic background

H.E.S.S. excess map



Modeling the sources and the diffuse emissions

- **Starting with the H.E.S.S. Galactic plane survey:**

  - ➡ HESS J1745–290: spatially coincident with Sagittarius A*
  - ➡ HESS J1747–281: PWN G0.9+0.1
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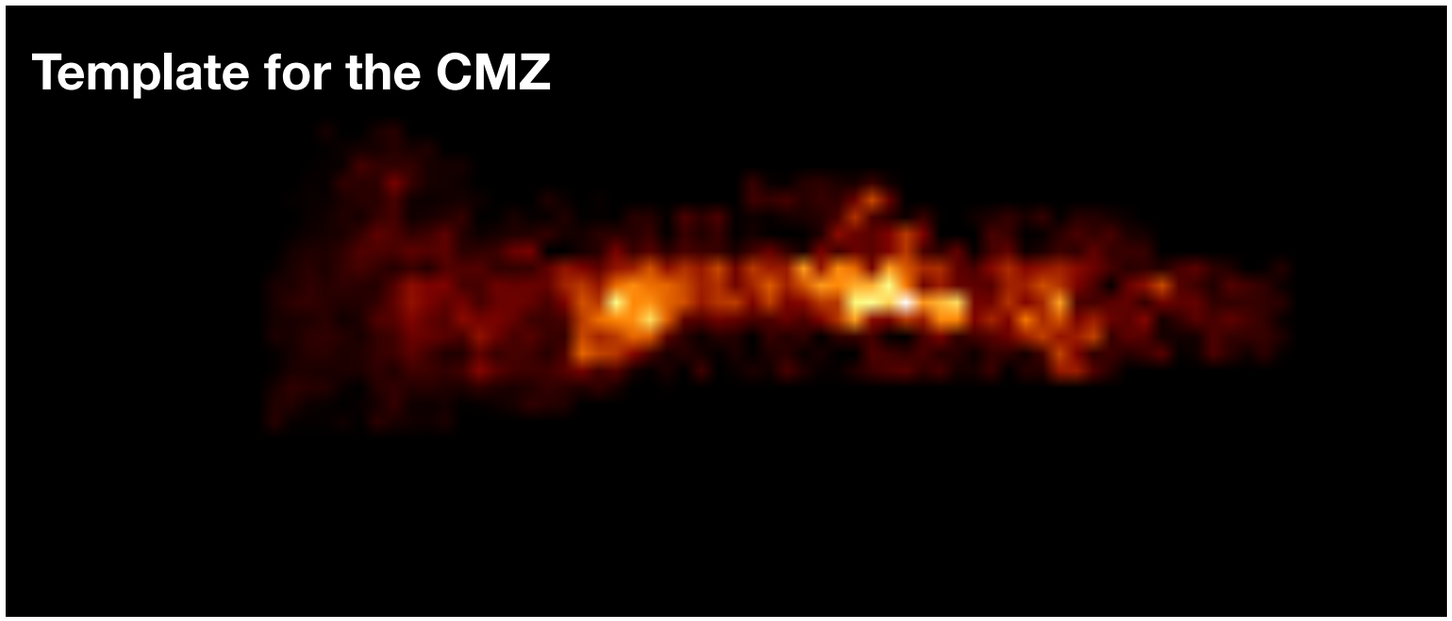
- **Diffuse emissions:**

  ➡ Central Molecular Zone (CMZ): described by the CS map [Tsuboi+1999, Sawada+2004]



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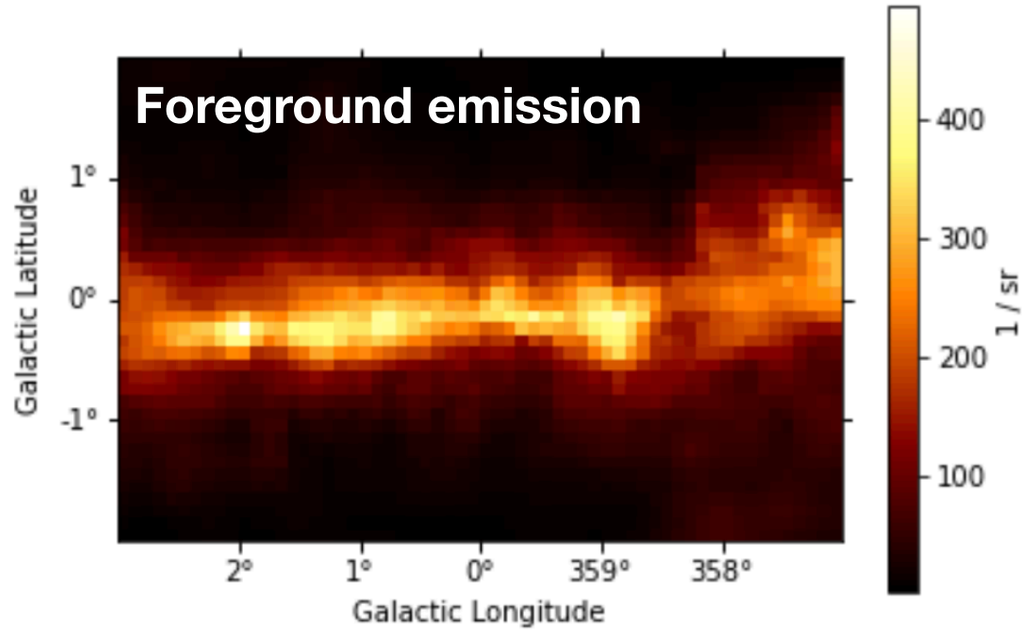
- **Diffuse emissions:**

  ➡ Central Molecular Zone (CMZ): described by the CS map

  ➡ Foreground galactic emission: modeled by the cosmic-ray sea interacting with the CO gas (excluding the region of the CMZ) [Fornieri+2020, Remy+2018]

2D template computed with the HERMES code [Dundovic+2021] using either a constant or an inhomogeneous cosmic-ray density

➡ emission modeled by a power law



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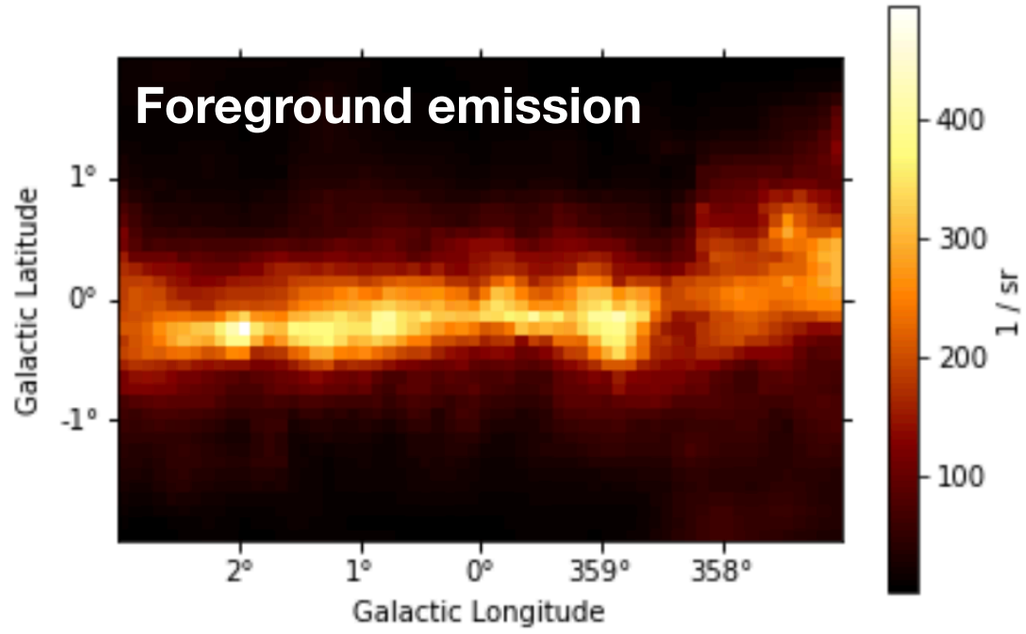

Large-scale emission model (not a measure of the Galactic diffuse emission) which encompasses also residual emission e.g. from unresolved sources, inverse Compton, etc.

Model components

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- **Diffuse emissions:**

  ➡ Central Molecular Zone (CMZ): described with the CS map

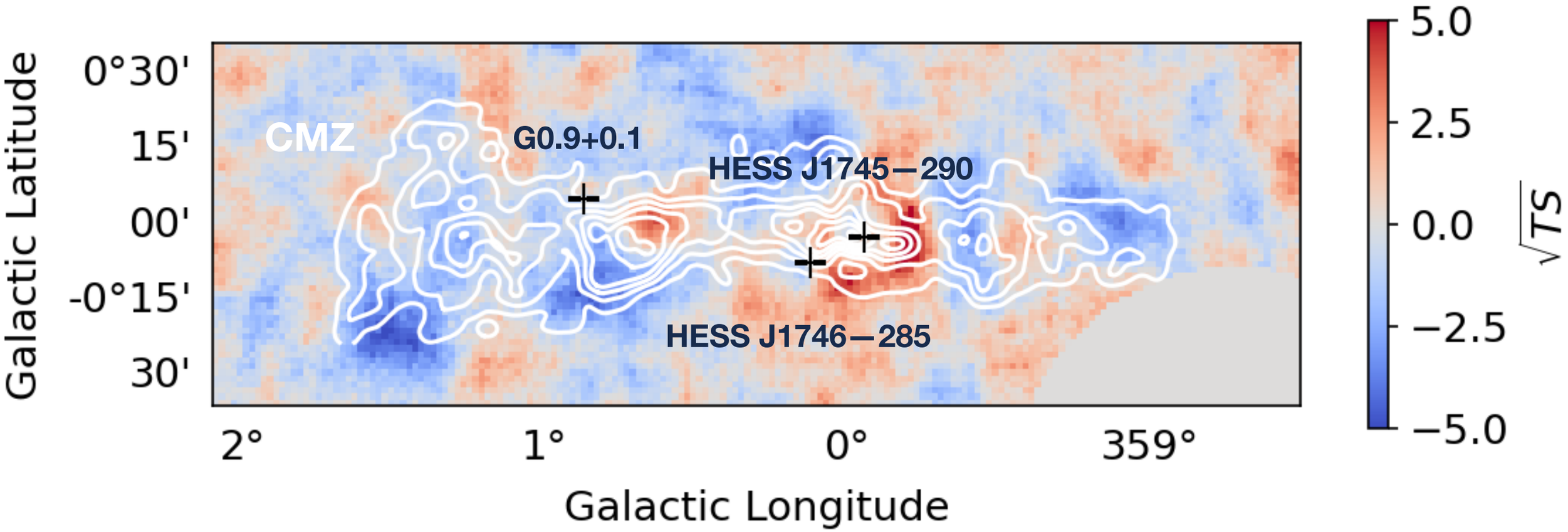
  ➡ Foreground galactic emission: modeled by the cosmic-ray sea interacting with the CO gas (excluding the region of the CMZ)

Consistent modeling of the entire region (6° x 4°) fitting simultaneously the morphological and spectral parameters of the components

Modeling the residual excess at the Galactic center

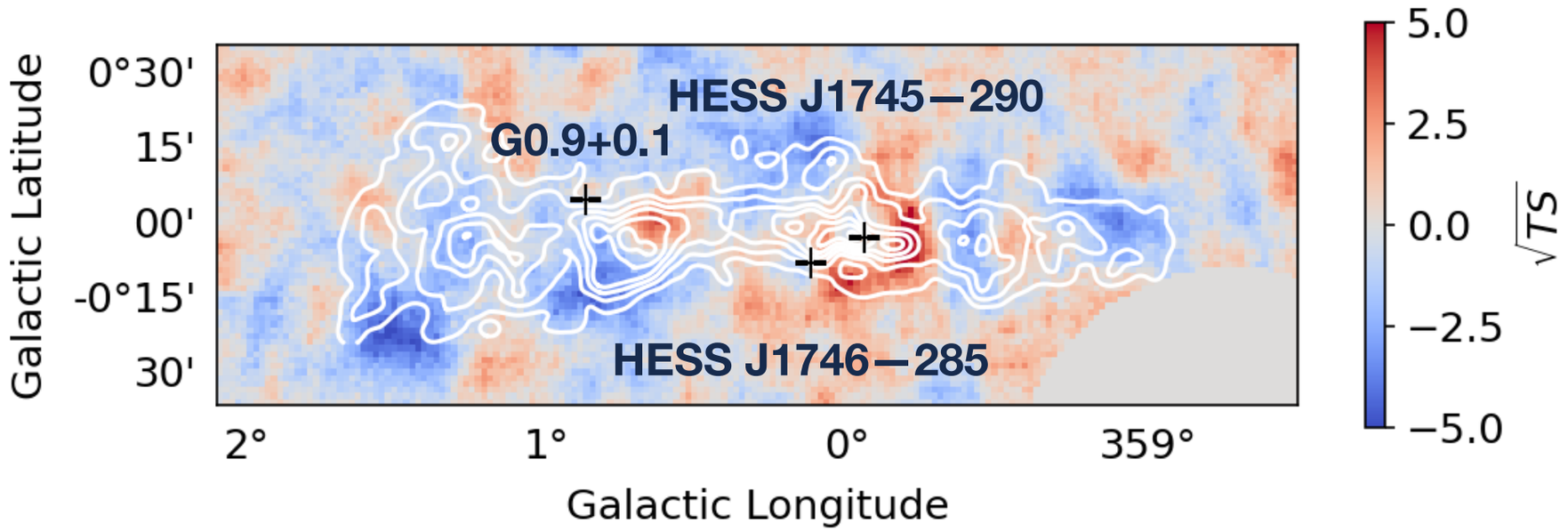
Simultaneous fit of the position and spectrum of the H.E.S.S. sources

Residual Test Statistic (TS) map:



A significant residual excess is seen at the Galactic center

Modeling the residual excess at the Galactic center



1. **Gaussian model for HESS J1745−290** (spatial and spectral parameters free): **Delta TS = 96.2**

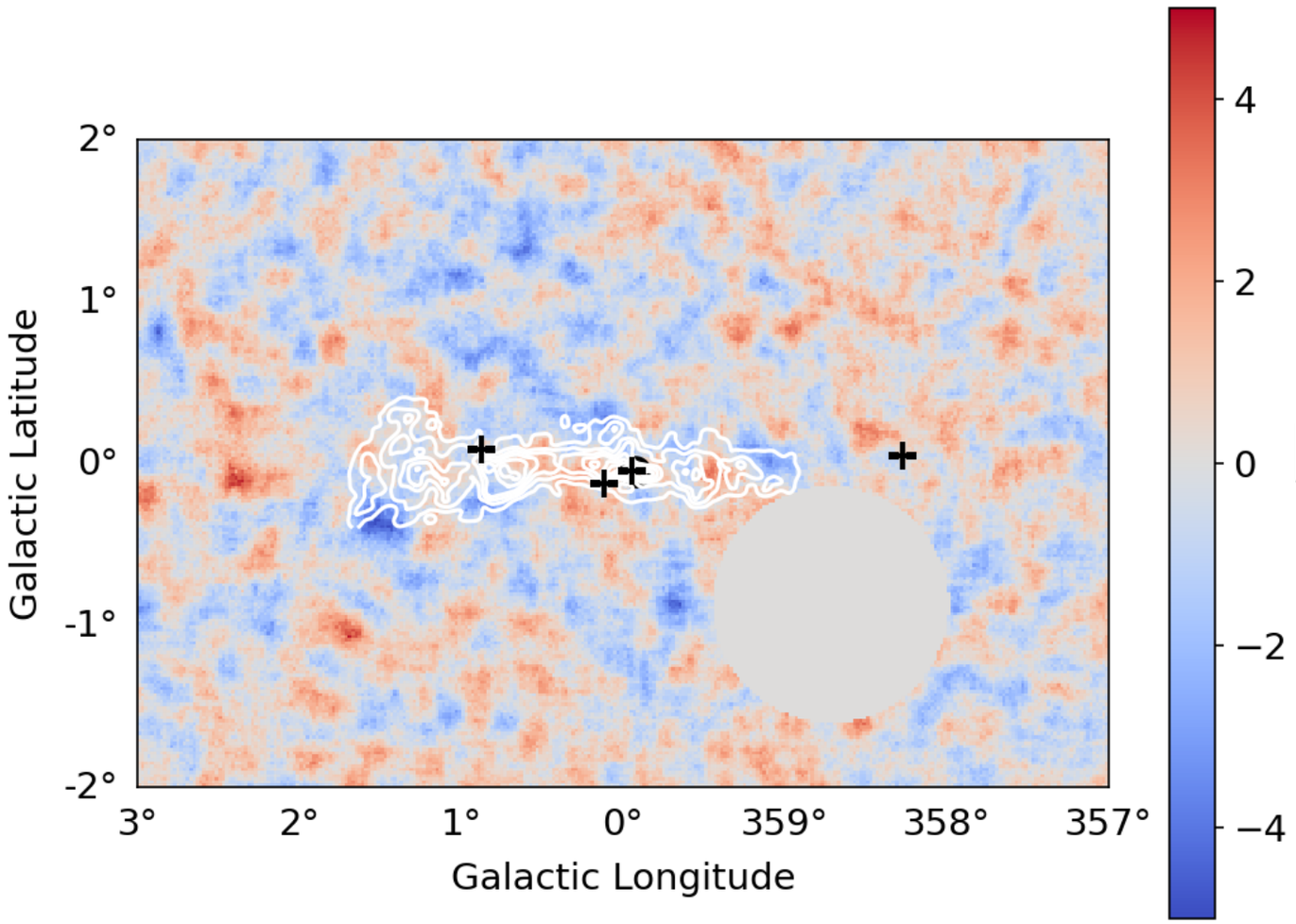
2. **Point-source model for HESS J1745−290 + additional Gaussian component with a power-law spectrum** (spatial and spectral parameters free for both sources): **Delta TS = 138.8**

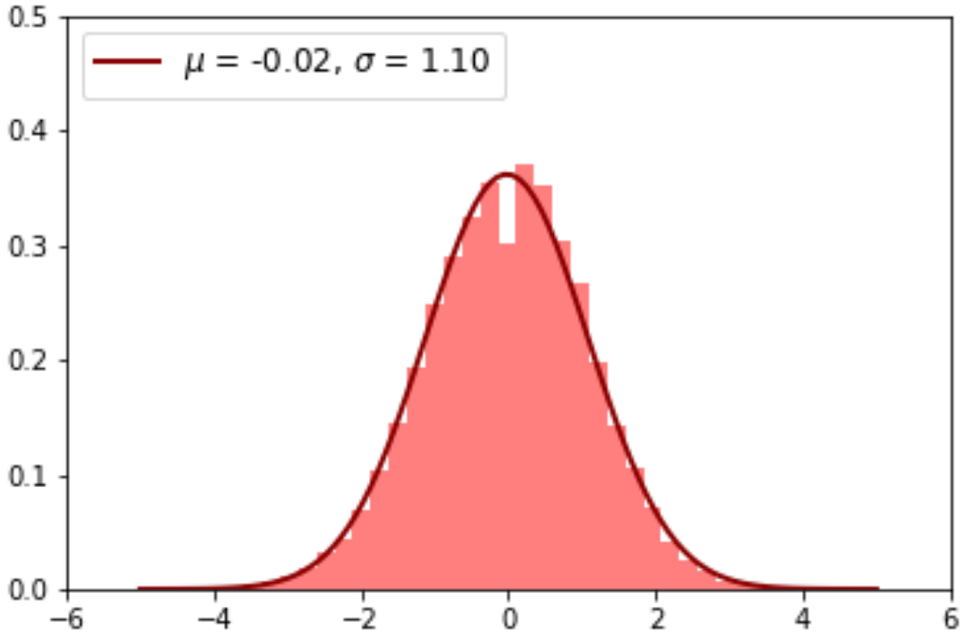
Confirmation of the need of an additional component near the Galactic center

as in [HESS collaboration 2018]

Residual TS map and distribution

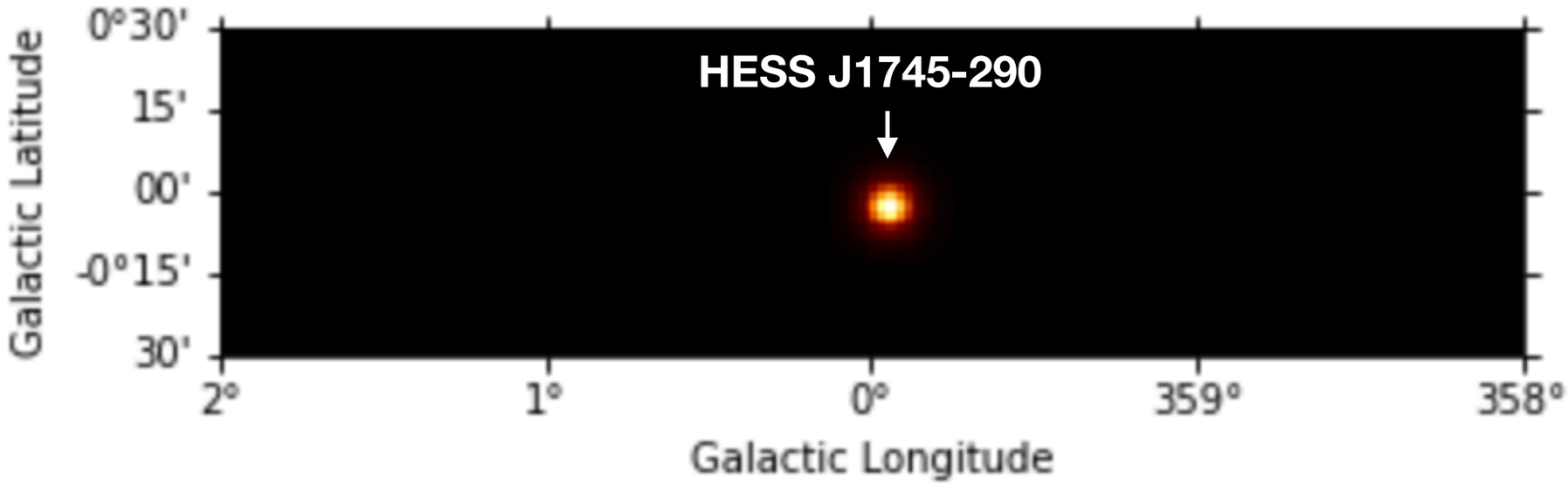
Final model includes **4 HESS sources**, **diffuse emissions** (CMZ and foreground) and the **additional extended component near the Galactic center**

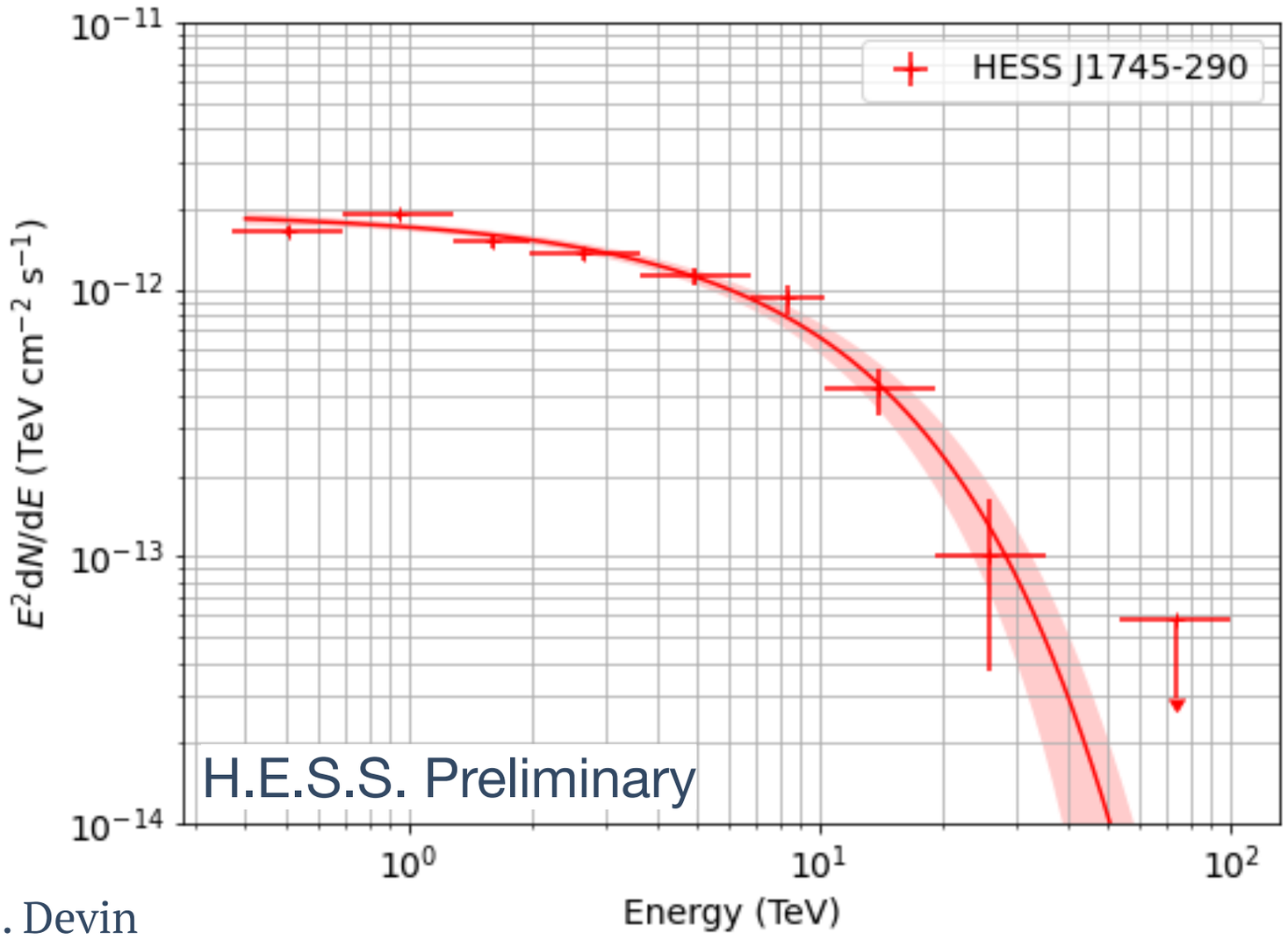




➡ The entire region is well modeled

Spectral analysis



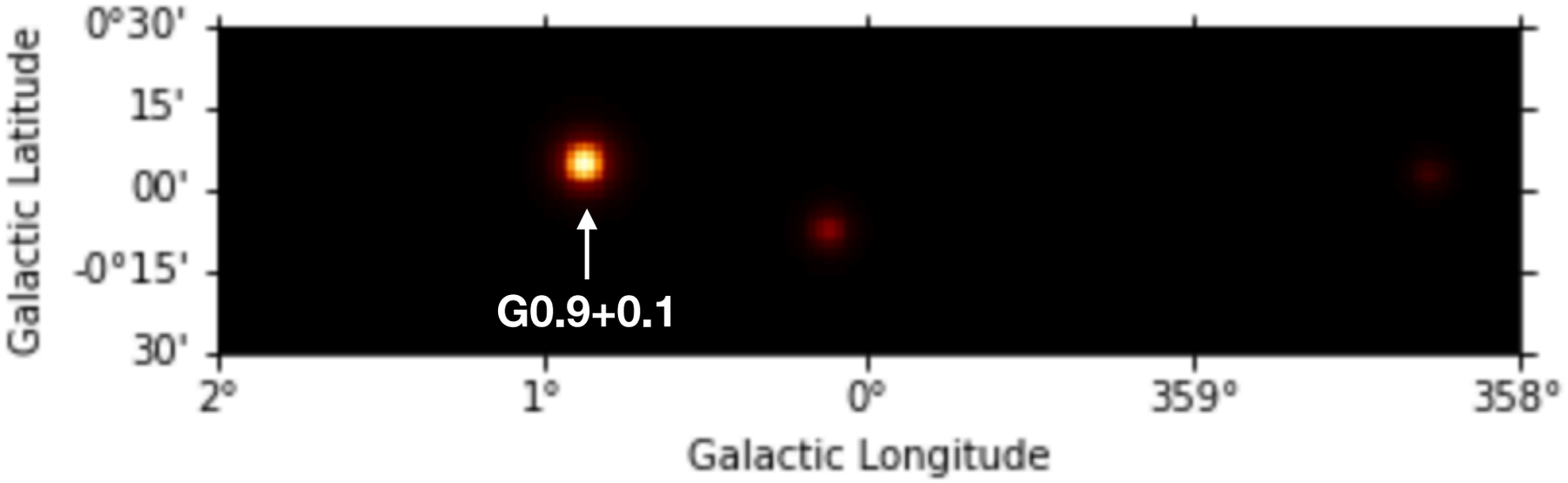


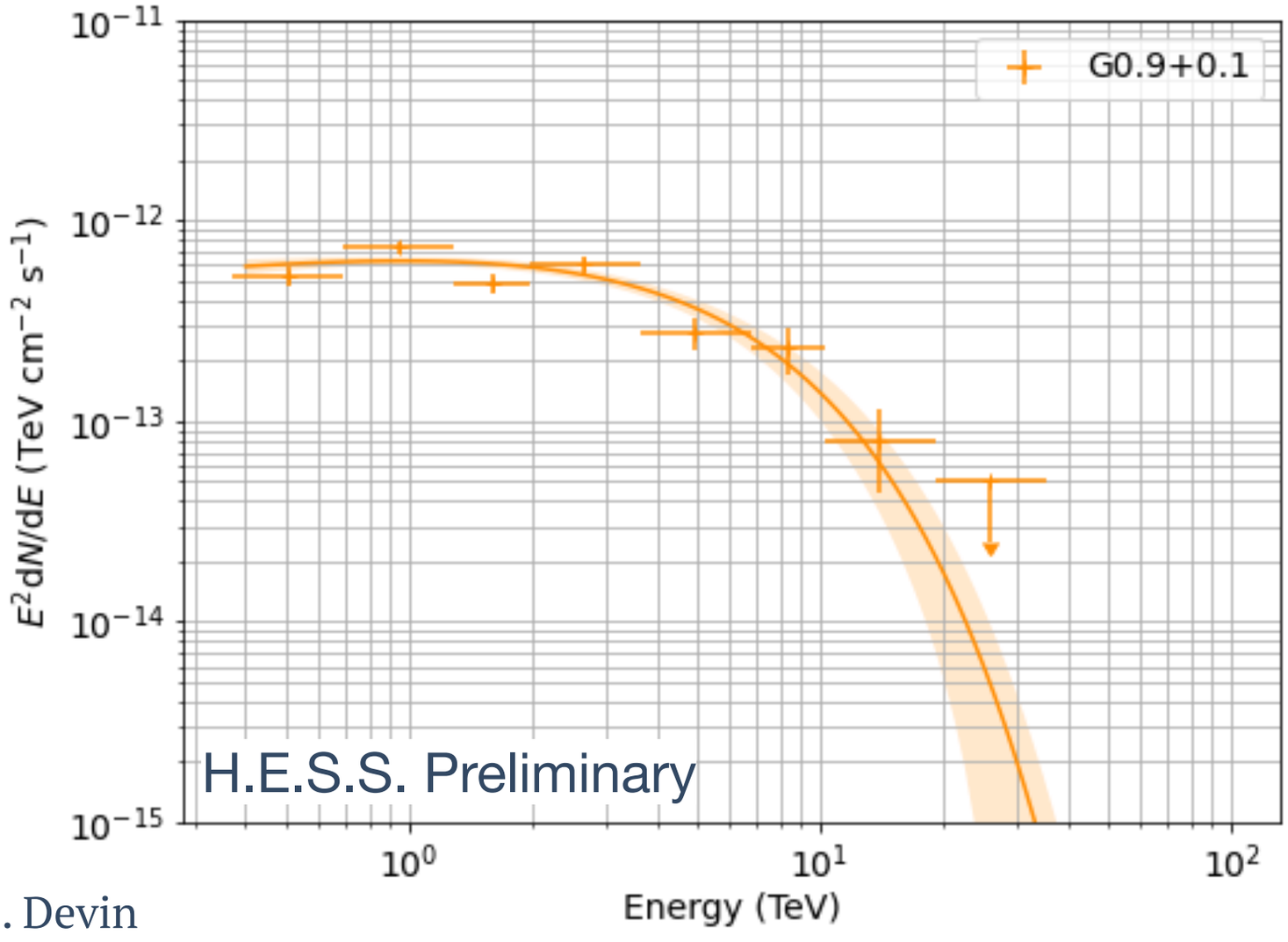
$$N_0(1\ \mathrm{TeV}) = (1.92 \pm 0.08) \times 10^{-12}$$
$$[\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

$$\Gamma = 2.01 \pm 0.05$$

$$E_{\mathrm{cut}} = 9.8 \pm 2.2\ \mathrm{TeV}$$

Spectral analysis





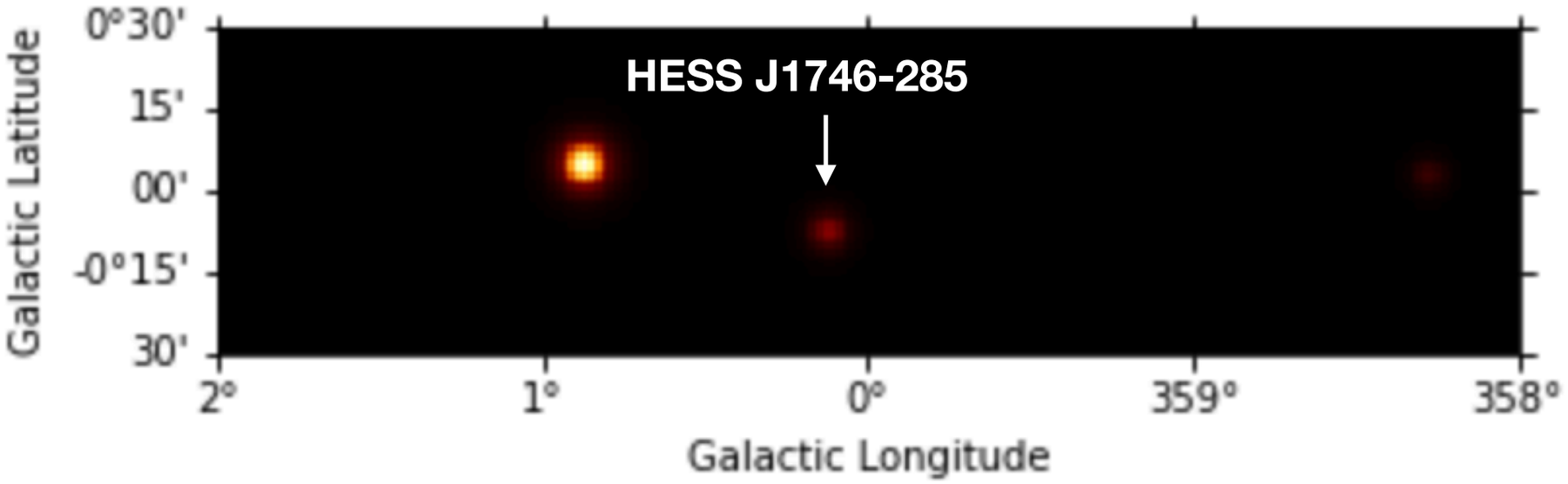
Exponential cutoff power law significantly preferred over a power-law model (> 5 sigma)

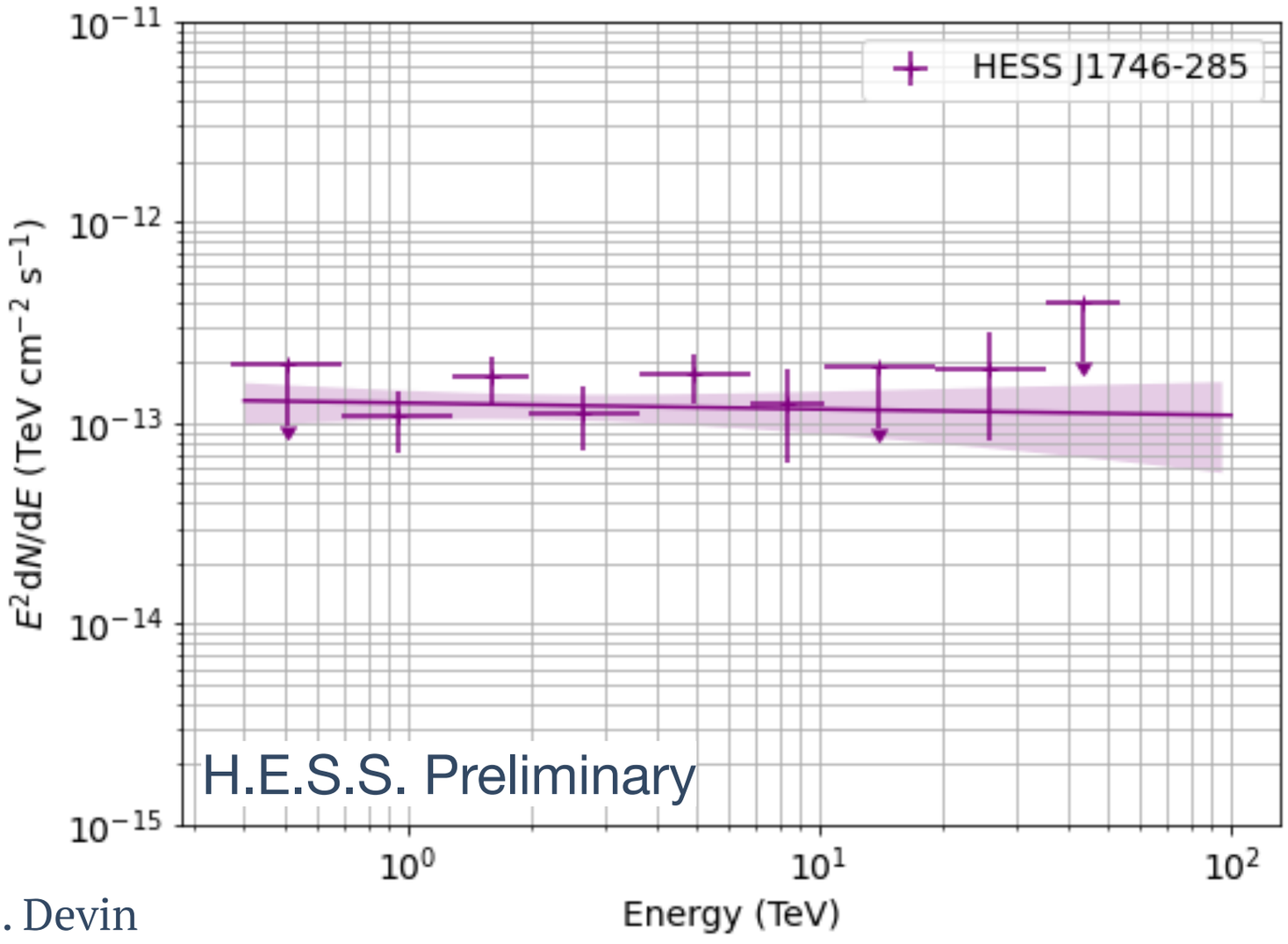
$$N_0(1\ \mathrm{TeV}) = (7.85 \pm 0.64) \times 10^{-13}\ [\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

$$\Gamma = 1.79 \pm 0.11$$

$$E_{\mathrm{cut}} = 4.5 \pm 1.1\ \mathrm{TeV}$$

Spectral analysis

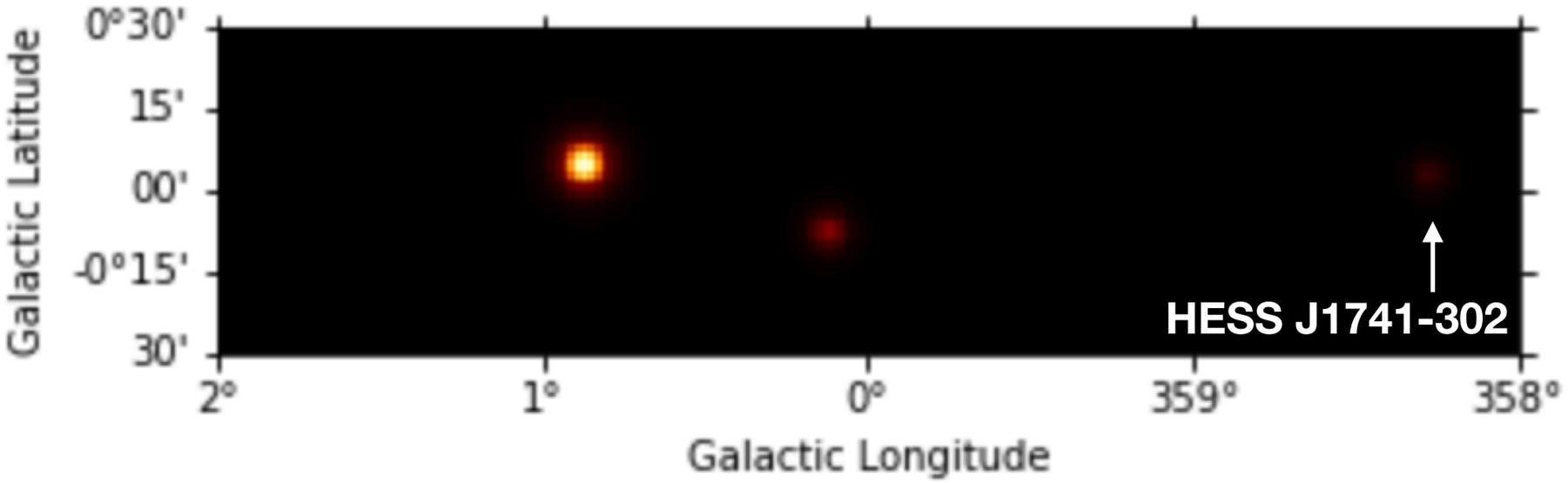


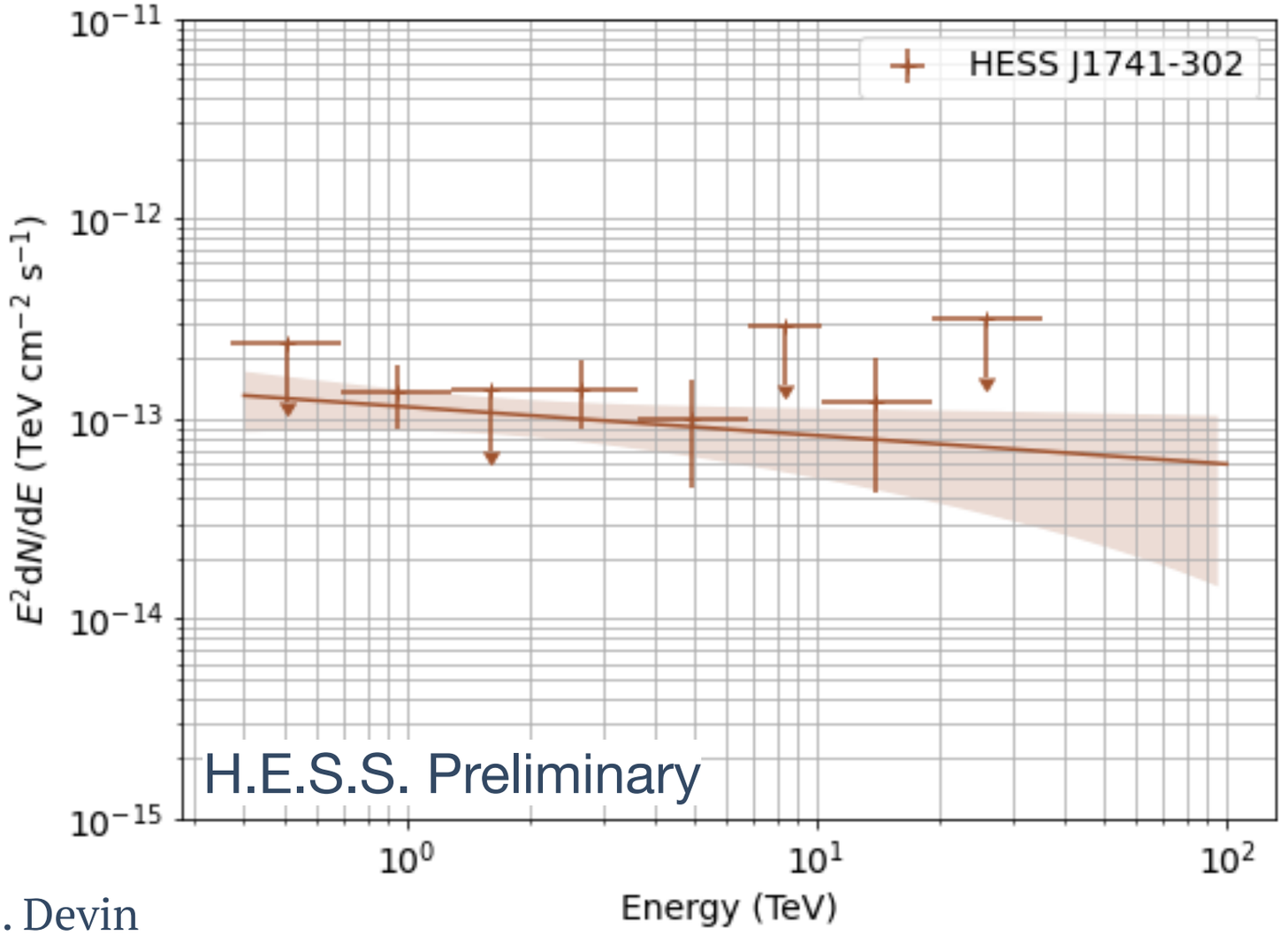


$$N_0(1\ \mathrm{TeV}) = (1.22 \pm 0.21) \times 10^{-13}$$
$$[\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

$$\Gamma = 2.03 \pm 0.12$$

Spectral analysis





$$N_0(1\ \mathrm{TeV}) = (1.14 \pm 0.26) \times 10^{-13}$$
$$[\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

$$\Gamma = 2.16 \pm 0.19$$

Conclusions

- **First spectro-morphological analysis** of the Galactic center region using 12 years of H.E.S.S. data

- **Consistent modeling** of the entire region (6° x 4°)

- First spectra of HESS J1745−290, G0.9+0.1, HESS J1746−285 and HESS J1741−302 **taking into account in space and energy the diffuse emissions**

- **Significant curvature** of the spectrum for G0.9+0.1

  ➡ Analysis ongoing to derive the intrinsic spectrum of the CMZ