

# The Galactic Center

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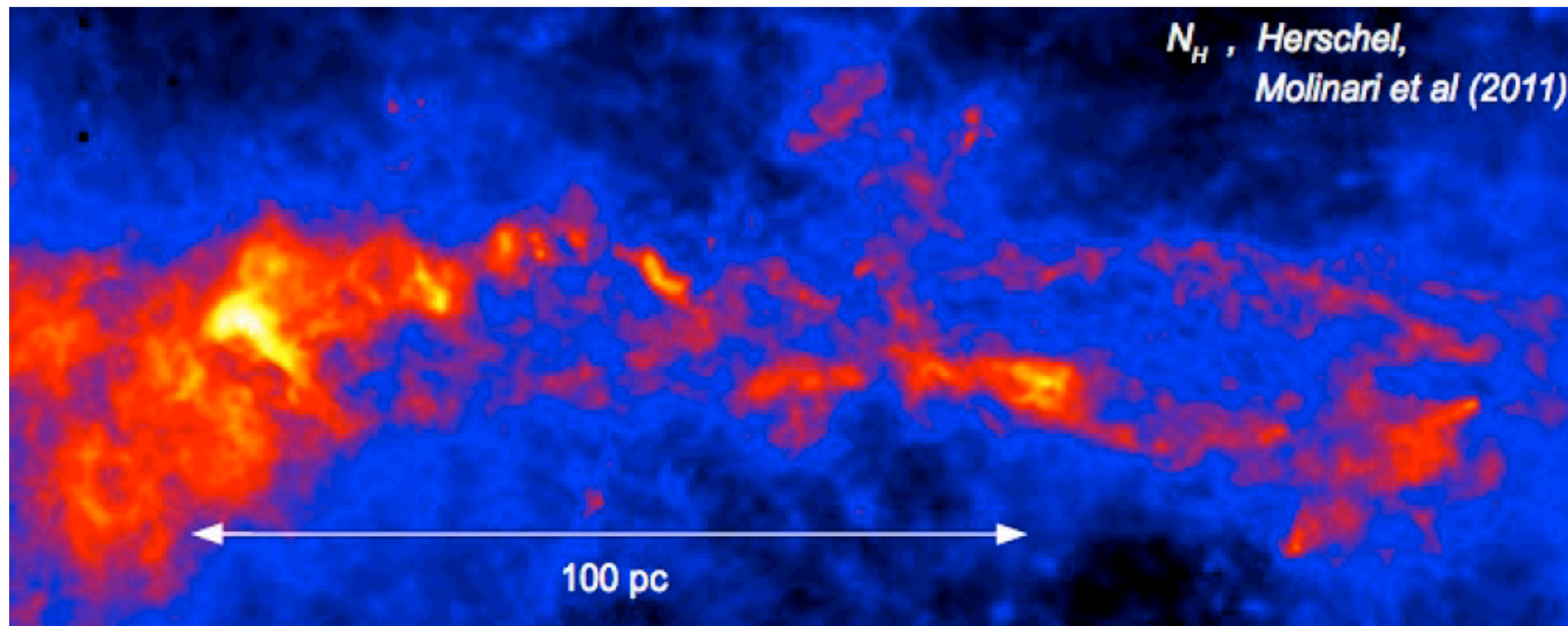


# The Galactic Center

Fruitful laboratory for astrophysics!

The Central Molecular Zone (CMZ) contains a large amount of molecular clouds;

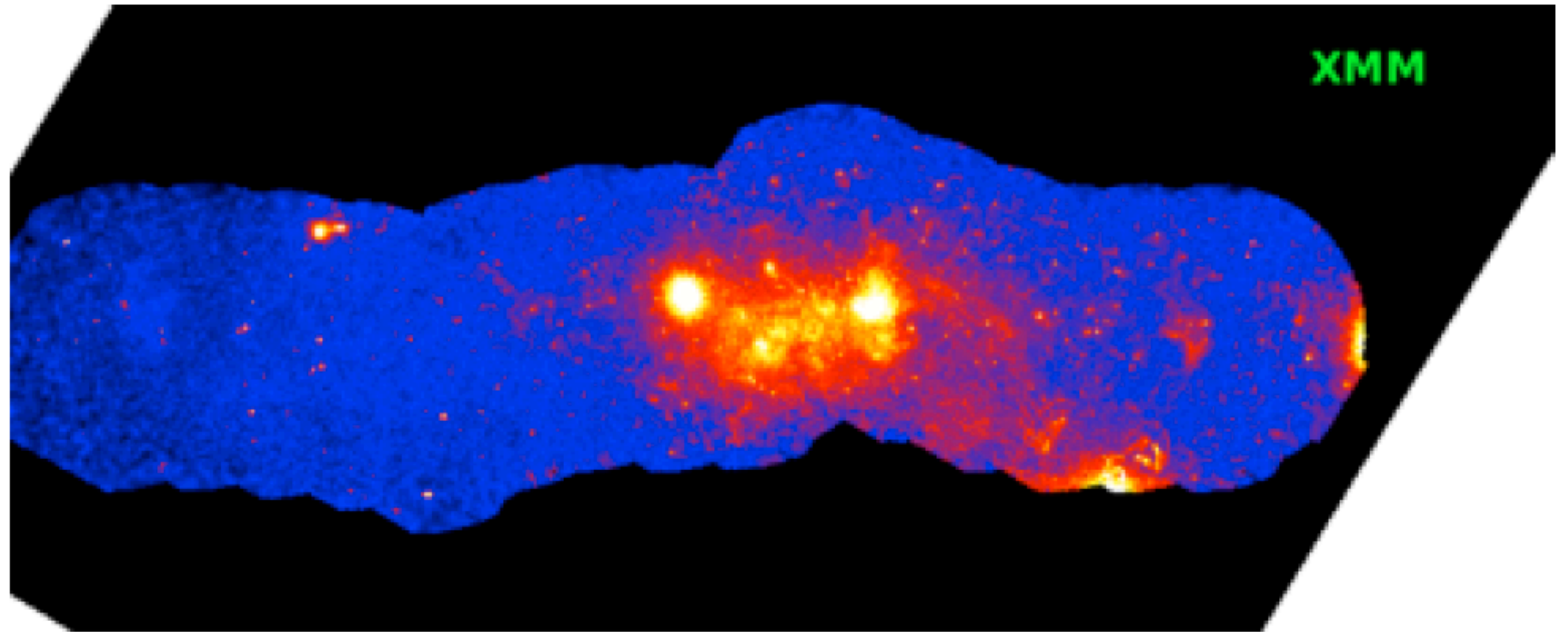
Large fraction of young massive star clusters





# The Galactic Center

Intense X-ray emission with short-term temporal variability (see Gabriele's talk!)



# The Galactic Center

Why do we need to study the GC in gamma-rays?

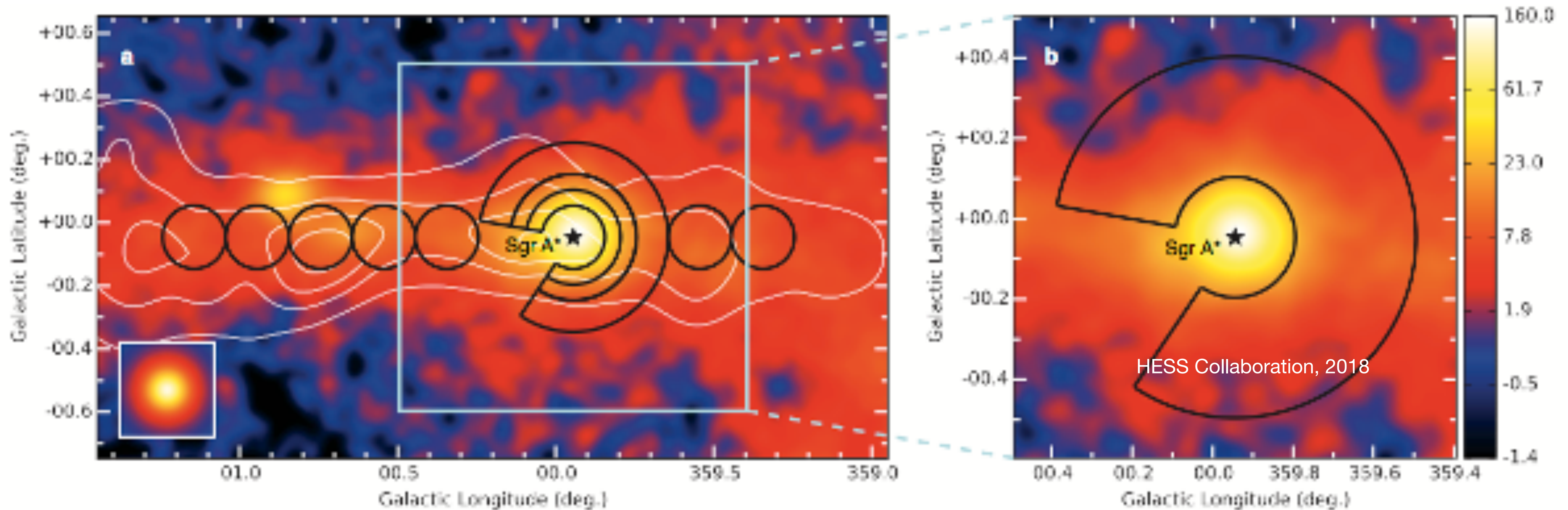
Extremely rich region, with a number of different source populations, Fermi bubbles, accretion processes, star formation bursts, possible place where to look for dark matter, feedback mechanisms and so on...

It is also an observational challenge due to the crowded region.



# The Galactic Center

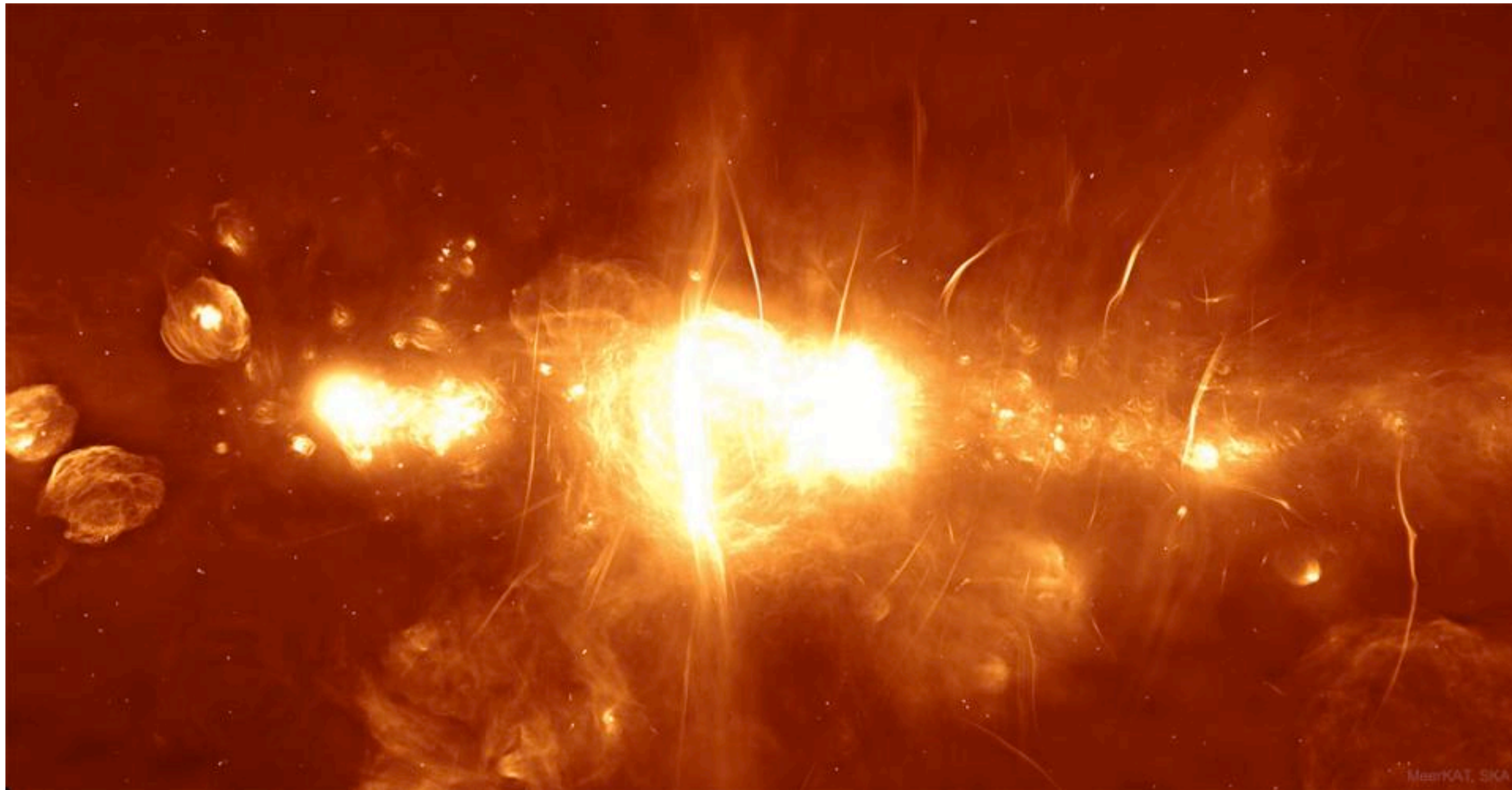
The Galactic Center is an extreme region where high energy photons are produced ( $> 100$  GeV) and host of a number of VHE sources





# The Galactic Center

The emission is thought to be hadronic in nature, i.e. inelastic scatterings of accelerated protons with protons of the surrounding molecular clouds



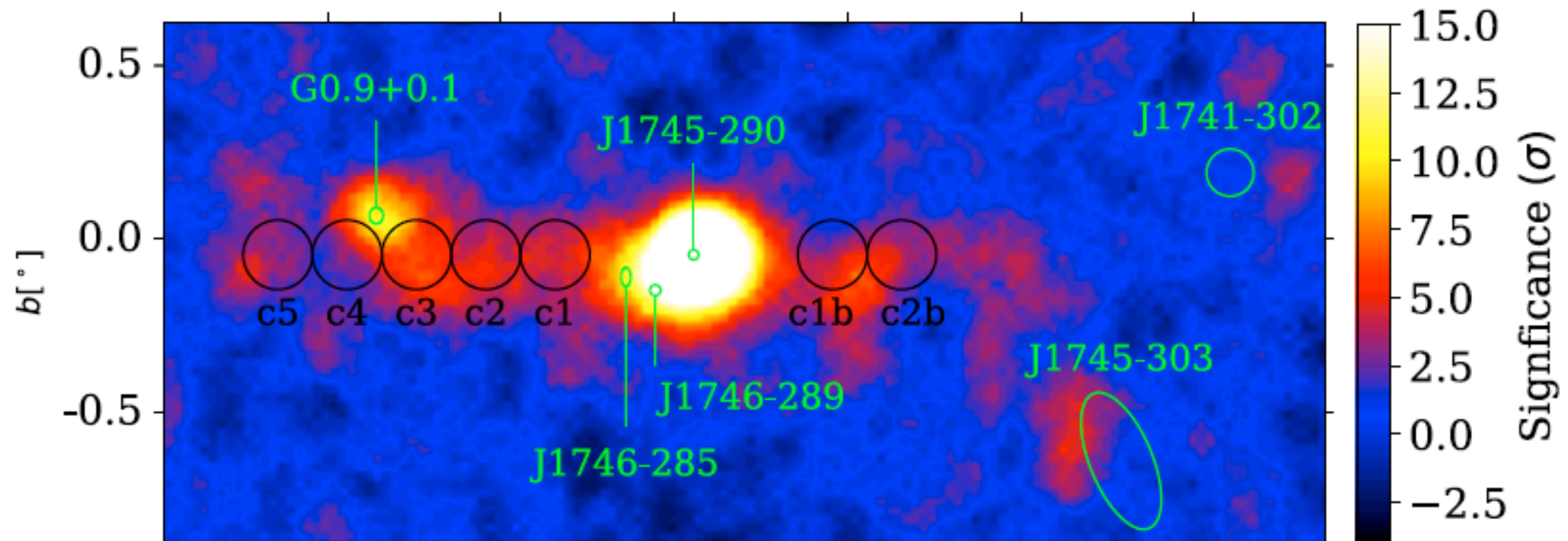
Gamma-ray emission is crucial to trace the injection of particles, their energy and their contribution to the cosmic rays (CR)



# The Galactic Center

Where does the emission come from?

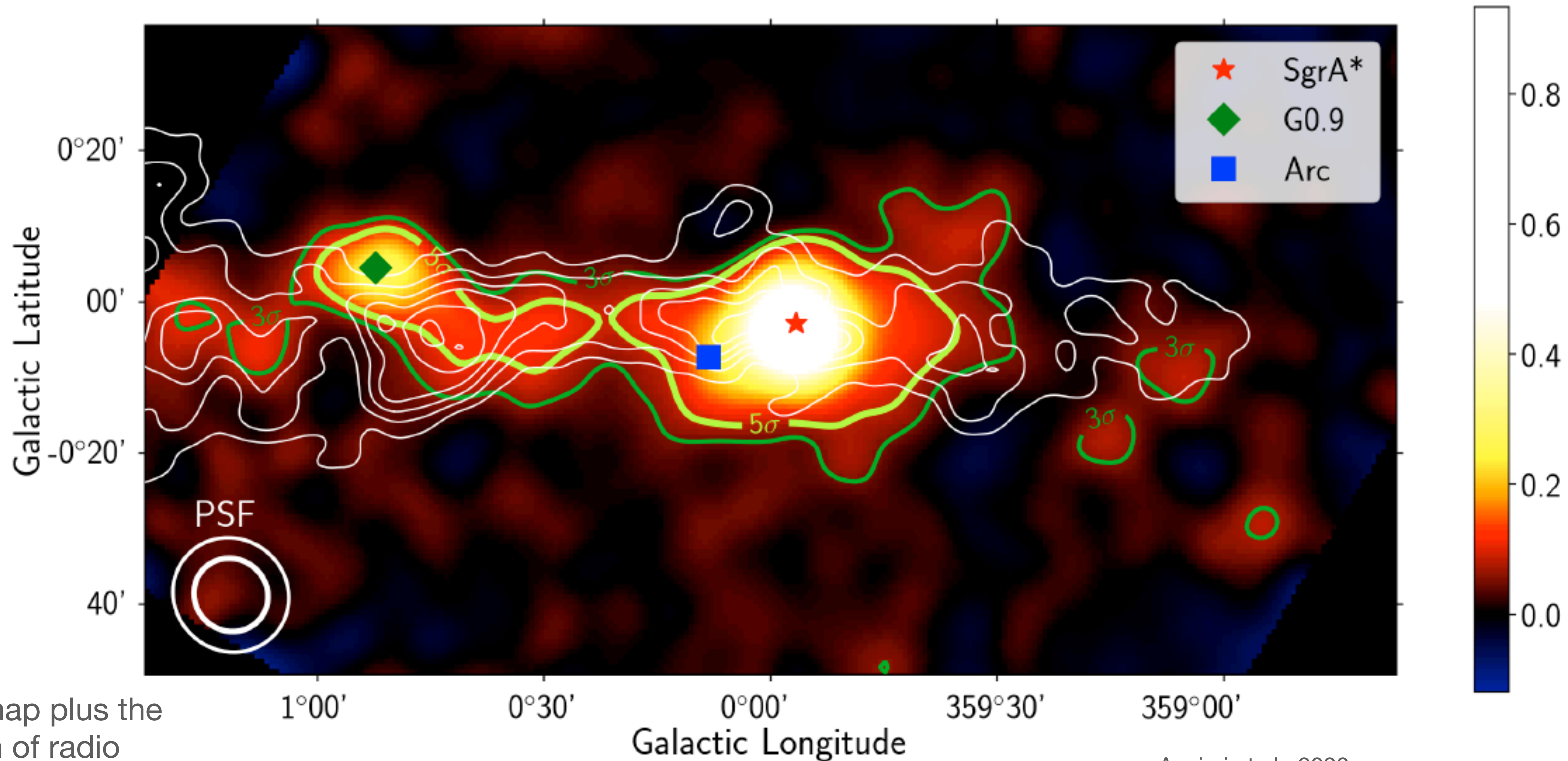
This is a hot topic as it may come from SGR A\*, winds from the central object, a diffuse emission, a number of not identified PWN, SNR or other kind of sources.





# The Galactic Center

The Galactic Center is considered the host of possible Pevatron candidate(s)

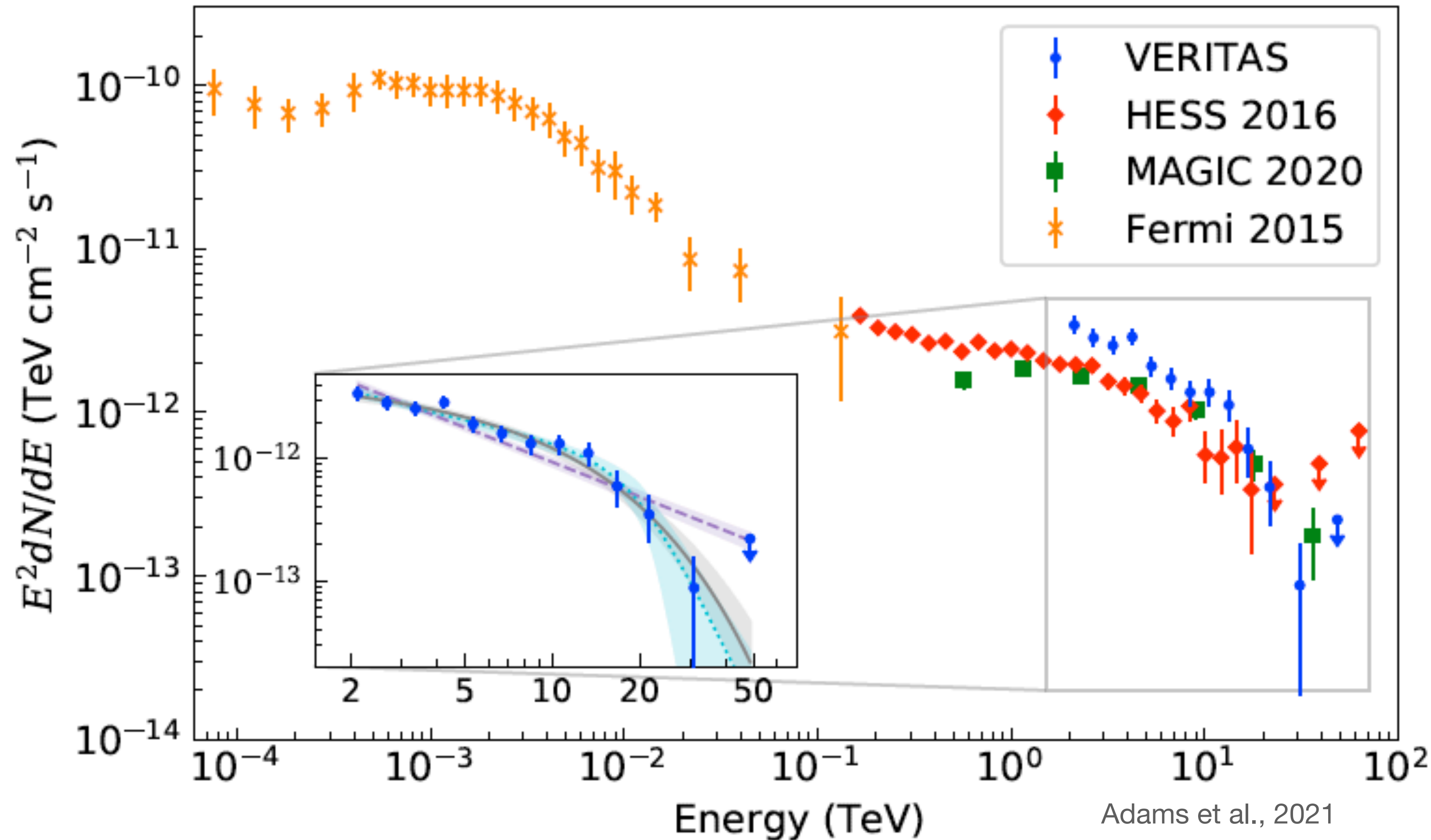


MAGIC excess map plus the super-position of radio emission from CS molecules



# The Galactic Center: SGR A\*

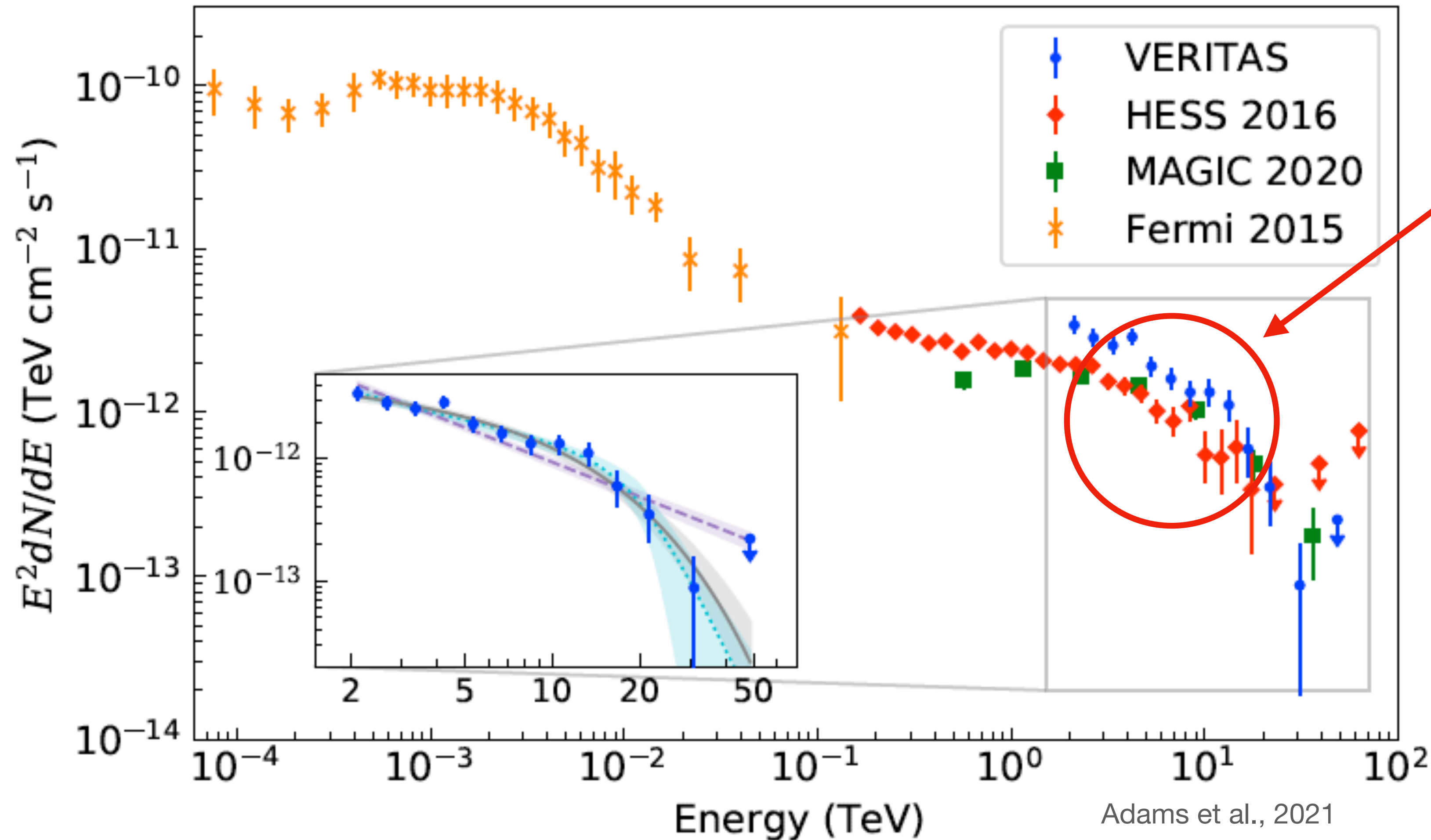
SGR A\* is observed in radio, IR and X-ray and it is considered as the best Pevatron candidate in the GC. No variability has been seen up to now in VHE energies (observational limits?).





# The Galactic Center: SGR A\*

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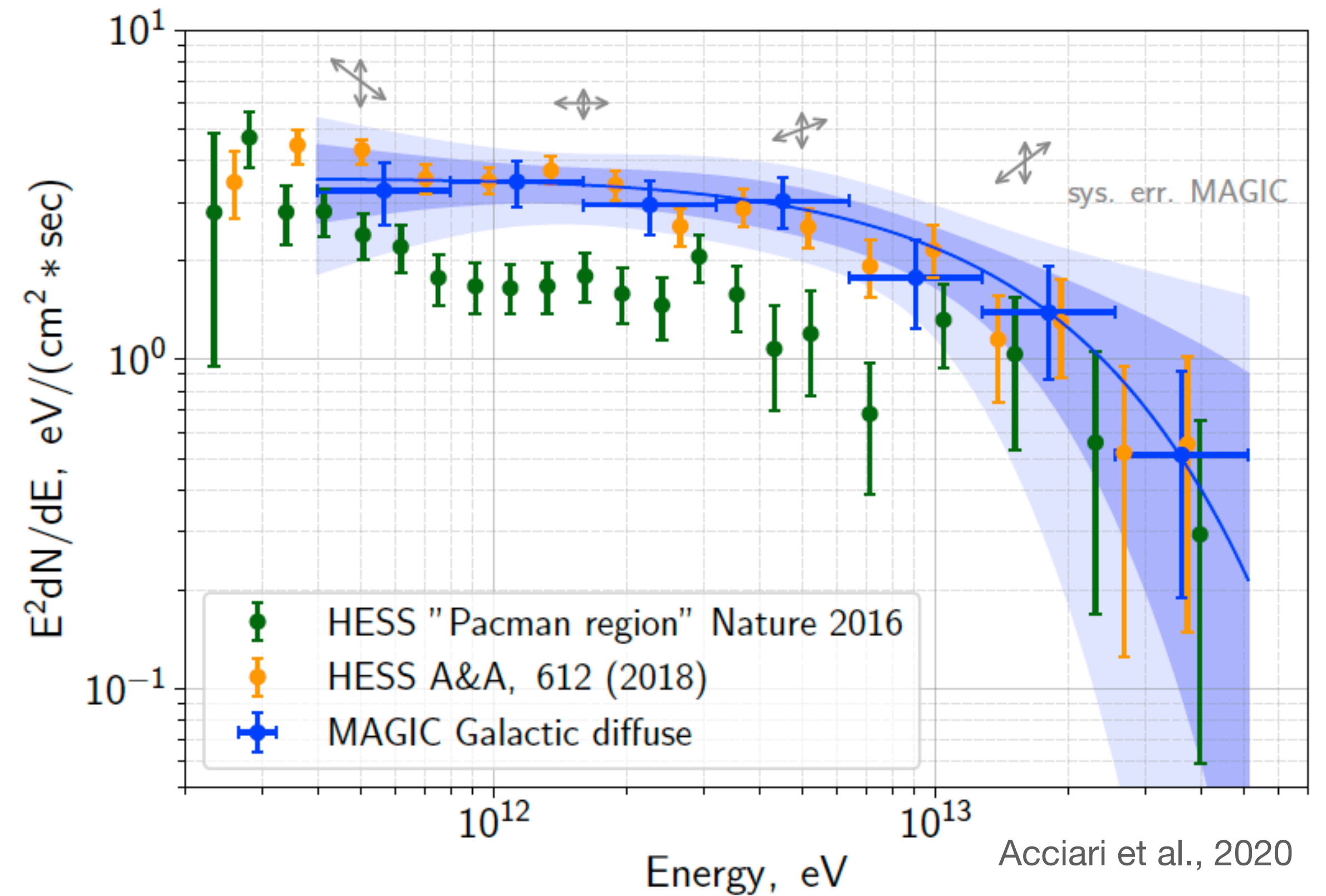
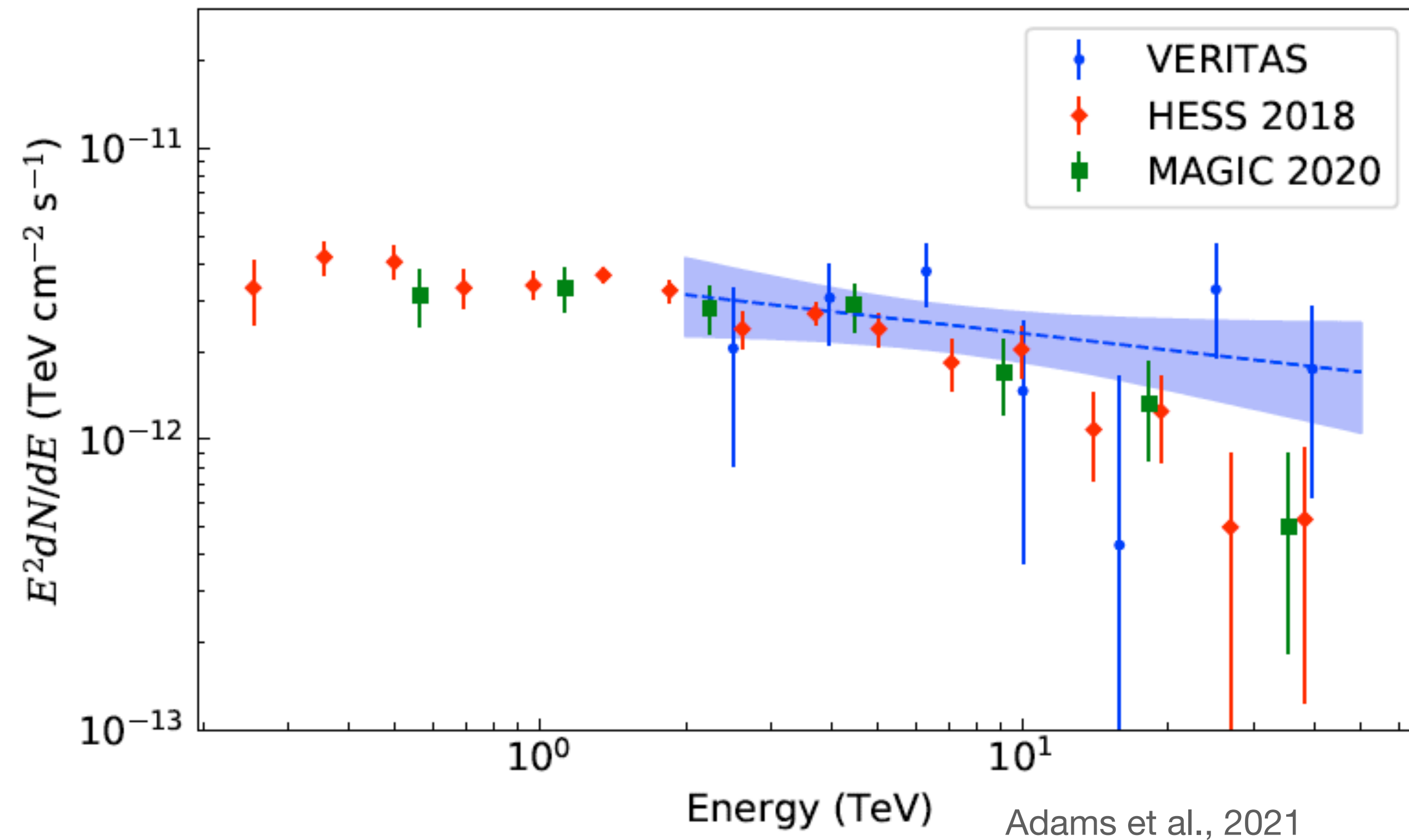


HESS, MAGIC and VERITAS show a spectrum for SGR A\* with an index of ~2.10 and a cut-off at ~10-20 TeV, although its significance is still marginal (~2sigma)



# The Galactic Center: diffuse emission

SGR A\* is surrounded by a diffuse gamma-ray emission with anisotropy to the east. The spectral index is compatible with the spectrum of SGR A\*.



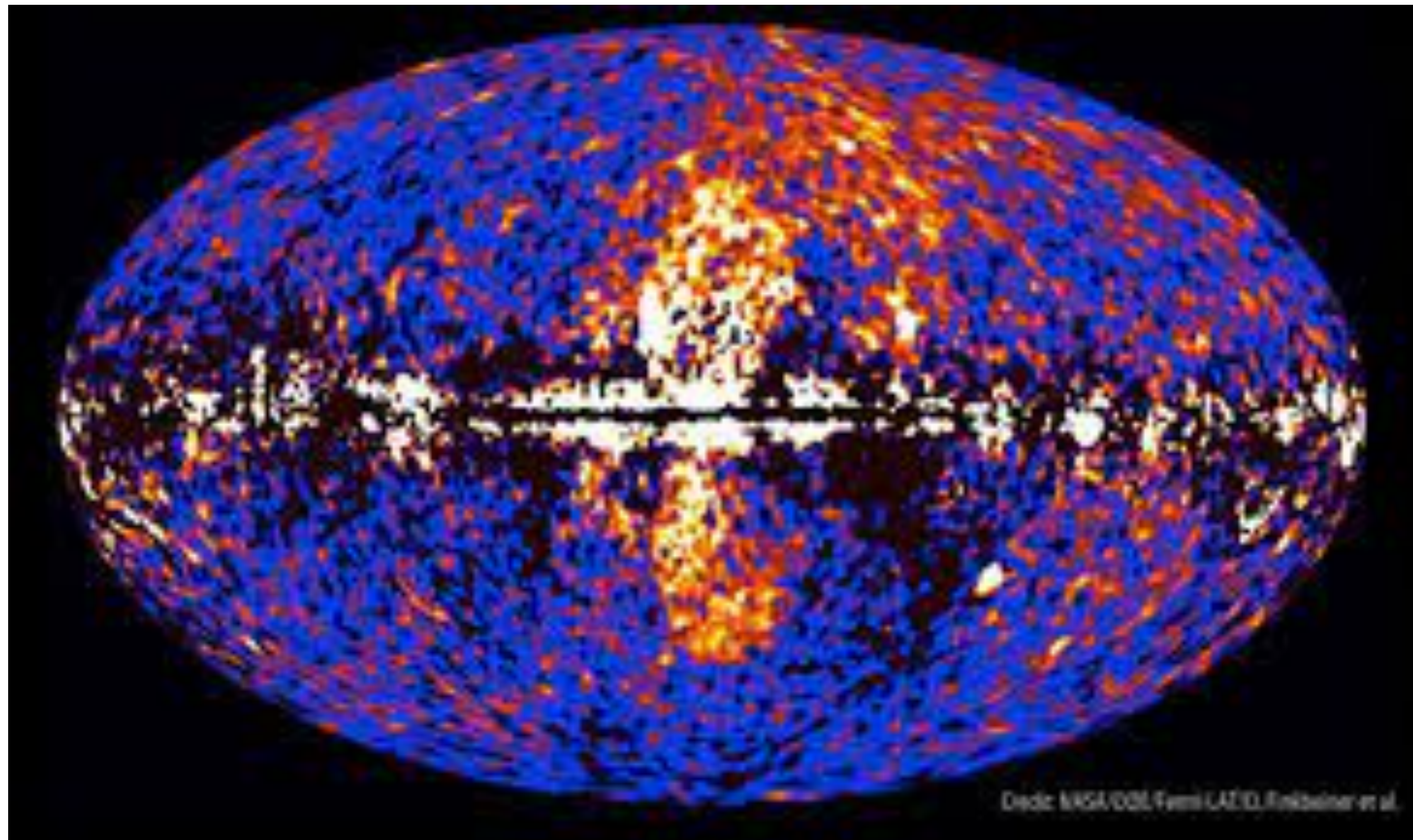
VERITAS does not find any cut-off, supporting the scenario of Pevatron candidate.

MAGIC and HESS found a possible cutoff instead



# The Galactic Center: Fermi bubbles

The central region hosts up to 10% of massive star in the Galaxy. However low star formation rate but with starbursts. Supernova explosions are therefore expected to have fed outflows and the Fermi bubbles

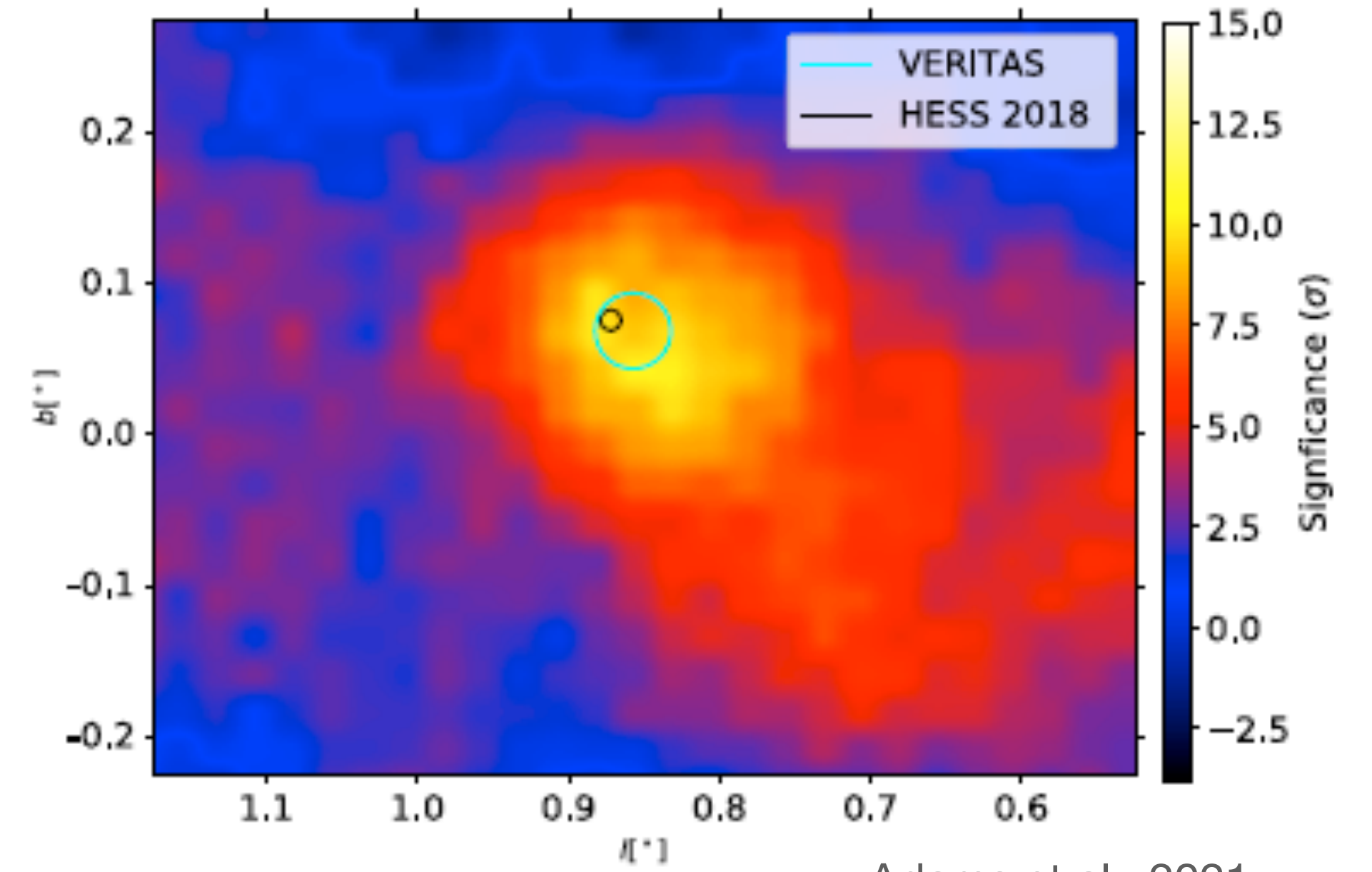


>2 GeV to ~100 GeV

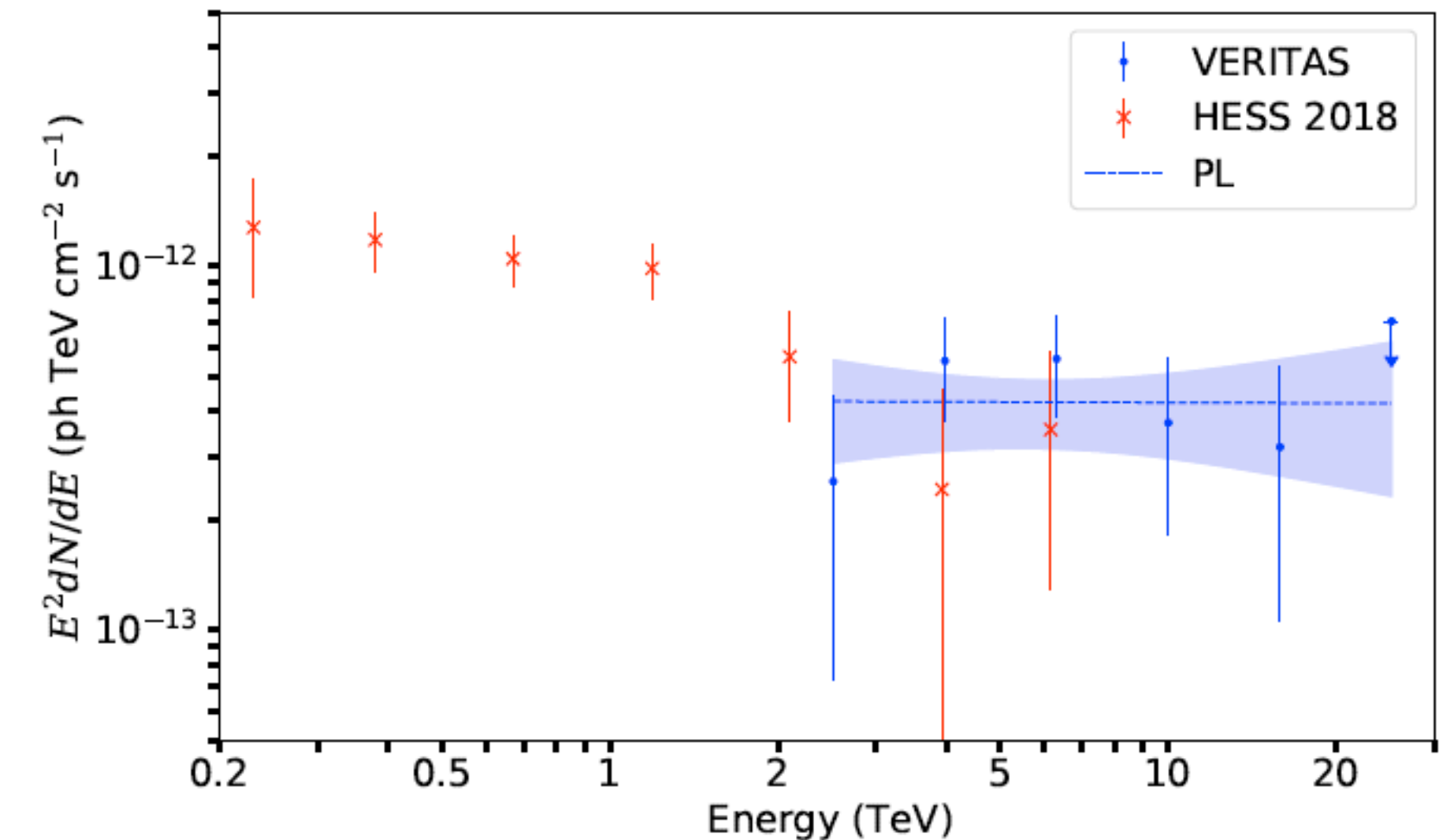
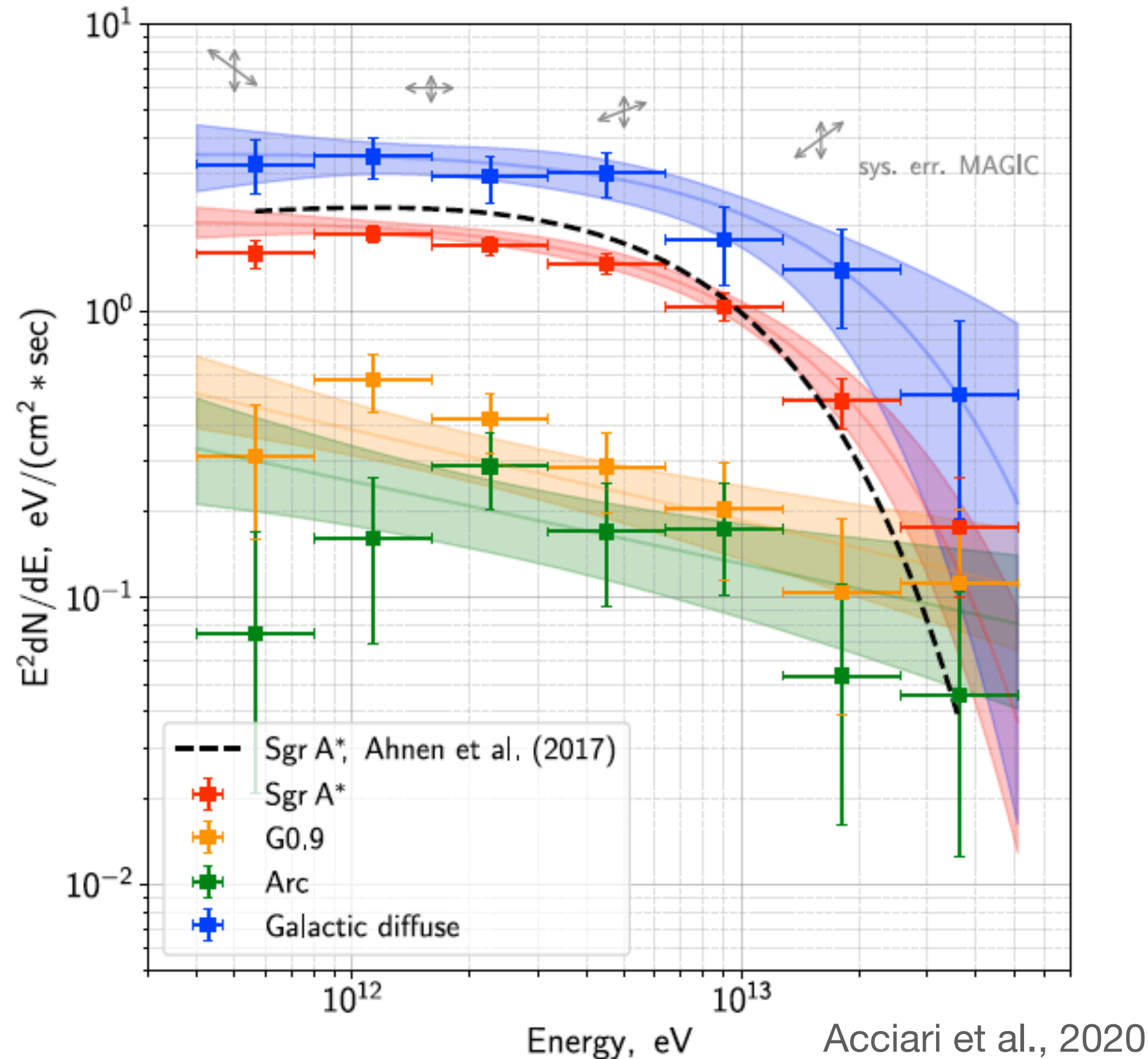


# The Galactic Center: G0.9+0.1

G0.9+0.1 (VER J1747-281) is a bright SNR, likely the youngest in our Galaxy. The source is clearly detected by Fermi, Magic, HESS and VERITAS



Adams et al., 2021





# The Galactic Center: X-ray filaments



Non-thermal X-ray filaments are observed along the Galactic Center.

The nature of such structures may be due to not resolved PWN and it is expected detectable TeV emission.

Contamination with the diffuse emission, hence there is the need of high resolution TeV observations to discriminate their properties.



# The Galactic Center and CTA

CTA will be the best facility to observe the GC

CTA will be crucial, thanks to its spatial resolution, to map the diffuse emission and constrain the position of the emission.

It will complete the information at other wavelengths, allowing to discriminate individual sources from clouds responsible for the gamma-ray emission and the propagation of the cosmic rays in the Central Molecular Zone

Revived activity in the last month in the CTA collaboration and a consortium paper is in preparation.

Currently activities of simulations of stellar winds, SNR and PWN populations



# Key questions to solve

- How cosmic rays propagate in the complex environment of the Central Molecular Zone?
- How magnetic field limits the diffusion of particles?
- Is the star formation enough to power the outflows and the Fermi bubbles?
- There exists only one Pevatron accelerator or more?
- Is the emission of SGR A\* due to cosmic rays interacting with the ring around the SMBH or an unresolved alternative source?
- Is there any TeV variability of SGR A\*?
- Any source energy-dependent morphology in the GC?
- How many sources are still undetected in the region?



# Key questions to solve

## Need of:

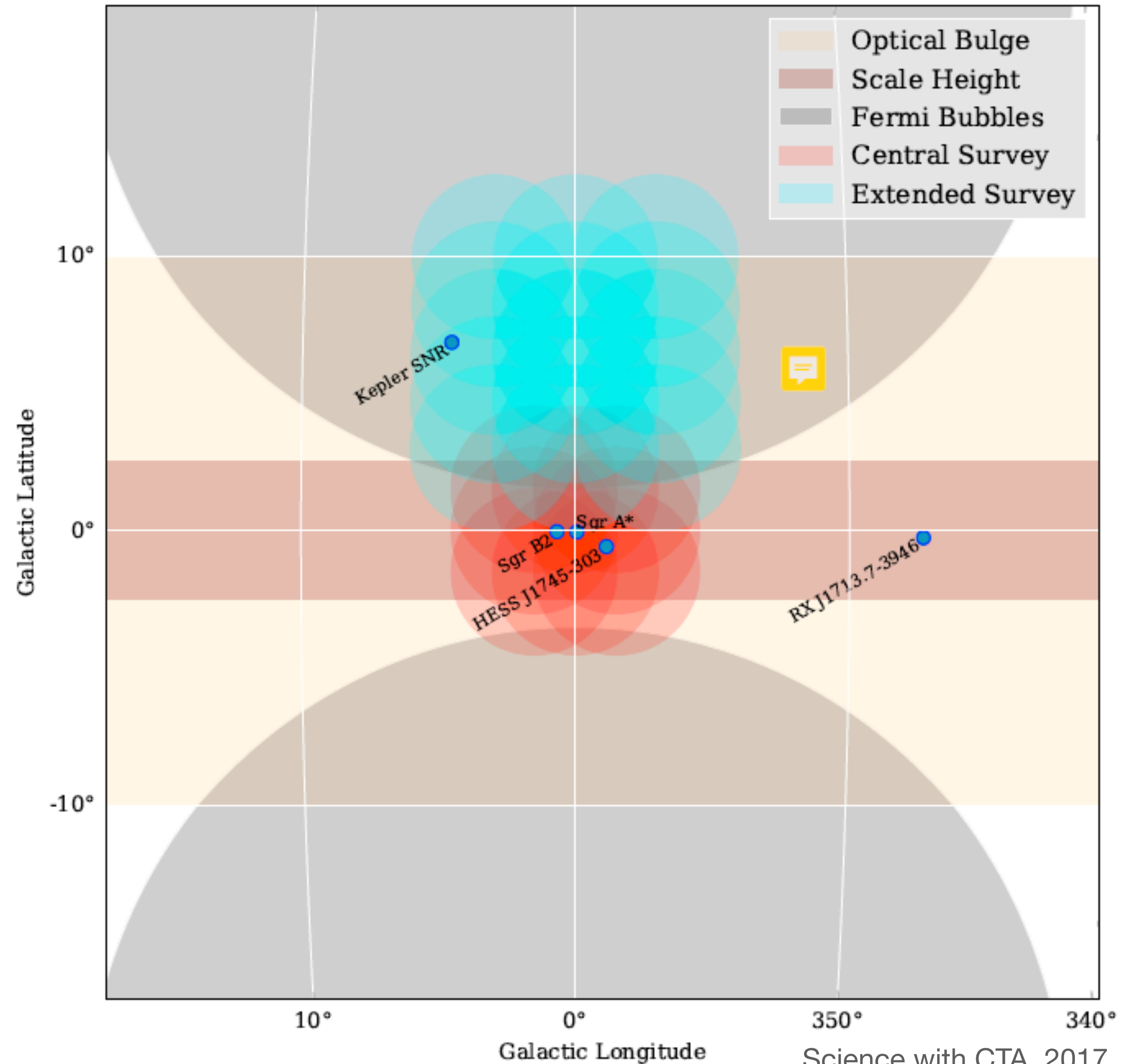
- High angular resolution (CTA will provide a few arcminutes)
- High photon statistics (long exposure)
- Excellent spectral sensitivity to probe emission at hundreds of TeV
- Time resolution fast enough to measure temporal variability



# Strategy in the CTA KSP

Southern array, with the full array and low zenith angles ( $< 40^\circ$ ).

- Central survey region:
  - SGR A\*
  - Diffuse emission
  - Diffuse sources
  - SNRs (G0.9+0.1, G1.9+0.3,...)
  - PWN
  - Dark matter?
  - Arc, filaments and radio lobes
- Extended survey region (symmetry of the paintings)
  - Base of the Fermi bubbles
  - Edge of Galactic bulge





# Italian community in the GC KSP

Strong connections with the KSP of the Galactic Plane Survey. The Italian community is involved in both KSP.

The current CTA activities of the GC are driven by Italians!

The GC is rich of different source populations: as for the Galactic Plane Survey, the Italian community has the expertise to take the leadership of this KSP.

The observational strategies in the KSP are old, need to be updated. We can give a contribution on that.

The ASTRI expertise the the Italian community can have with the Pevatrons can be spent within the GC KSP.