Recent H.E.S.S. highlights and status

RICAP 22

6–9 Sep. 2022
Physics Department, University "La Sapienza"
Roma, Italy

Emmanuel Moulin for the H.E.S.S. collaboration
CEA Saclay, Irfu, France

H.E.S.S.

CEA - Saclay

The H.E.S.S. observatory

- Located in the Khomas Highland of Namibia at 1800m asl
- H.E.S.S. phase I: four 12m IACTs
  - FoV 5°
  - first light 2002

- H.E.S.S. phase II: 28m telescope; FoV 3.5°; first light 2012

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  - Energy range: 30 GeV to 100 TeV
  - Energy resolution ~10% (68% cont.)
  - Angular resolution ~0.06° (68% cont.)

- H.E.S.S. collaboration: ~250 members, at 38 institutes, in 13 countries

H.E.S.S.

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- **Camera upgrade** in 2015-2016 (H.E.S.S. I) and in 2020-2021 (H.E.S.S. II)
  - Nectar-chip based HESS1U cameras and FlashCam-prototype
  - Changes to operational procedures and monitoring
- All telescopes, cameras, subsystems show high operational efficiency.
- Average losses due to technical failures <2%/telescope and <5% full array
- Low weather losses → >1200h darktime data

H.E.S.S.

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- H.E.S.S. 2nd extension from Oct. 2022 till Oct. 2024

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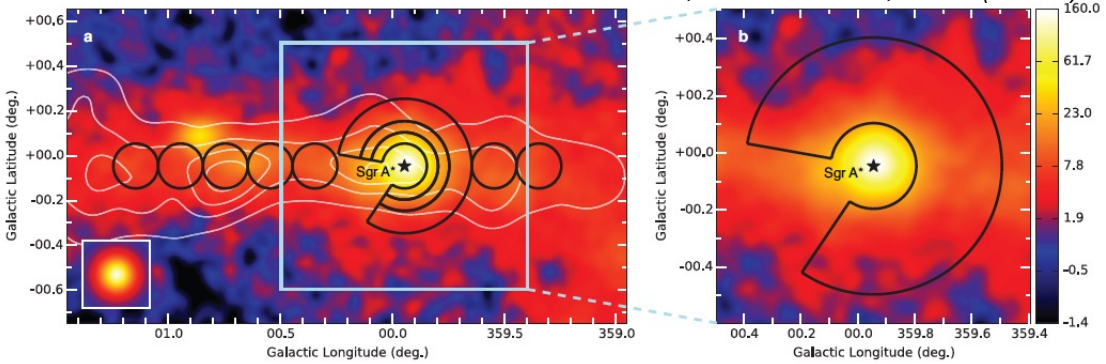
- COVID restrictions starting Feb 2020:
  - Observers not allowed to leave Namibia in March 2020.
    → Operations with local observers/telescope operators.
    → H.E.S.S. continued to take data throughout the entire pandemic
- Full integration of moonlight/twilight observations as of January 2021
  → ~1500h incl. conservative moonlight/twilight

Galactic science: Pevatrons and candidates

- Galactic centre region
  - Diffuse emission
  - Proton mostly responsible for the emission
  - First Galactic Pevatron detected

H.E.S.S. coll., Nature 531, 476 (2016)



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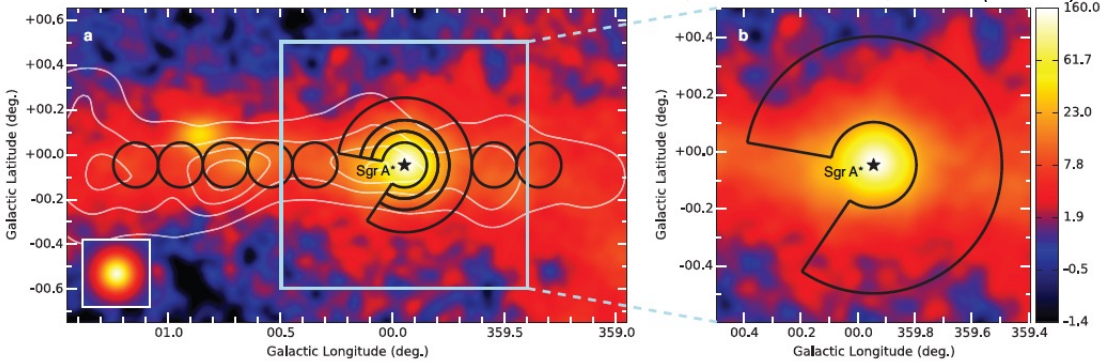
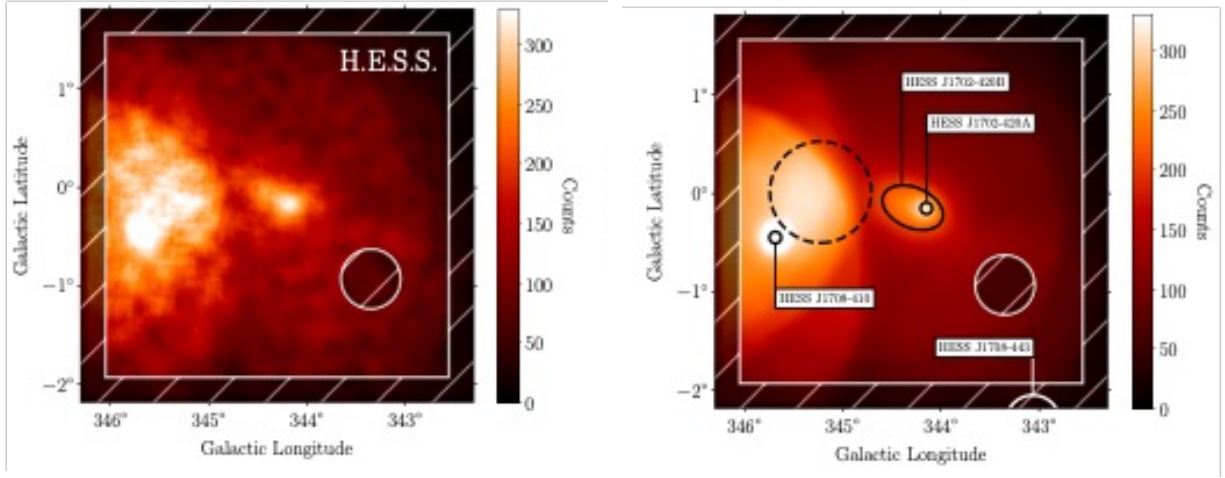
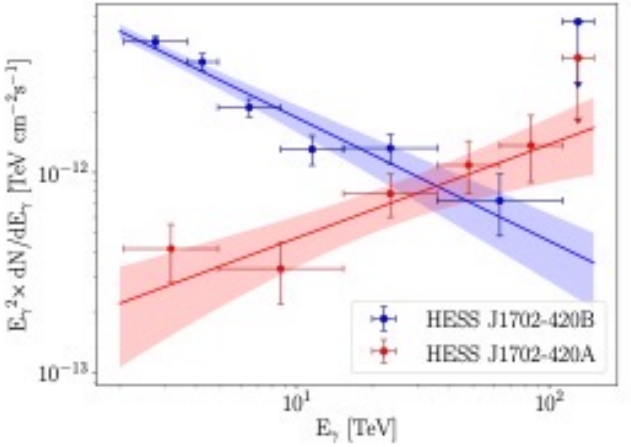


- HESS J1702-420

H.E.S.S. coll., A&A, 653, A152 (2021)

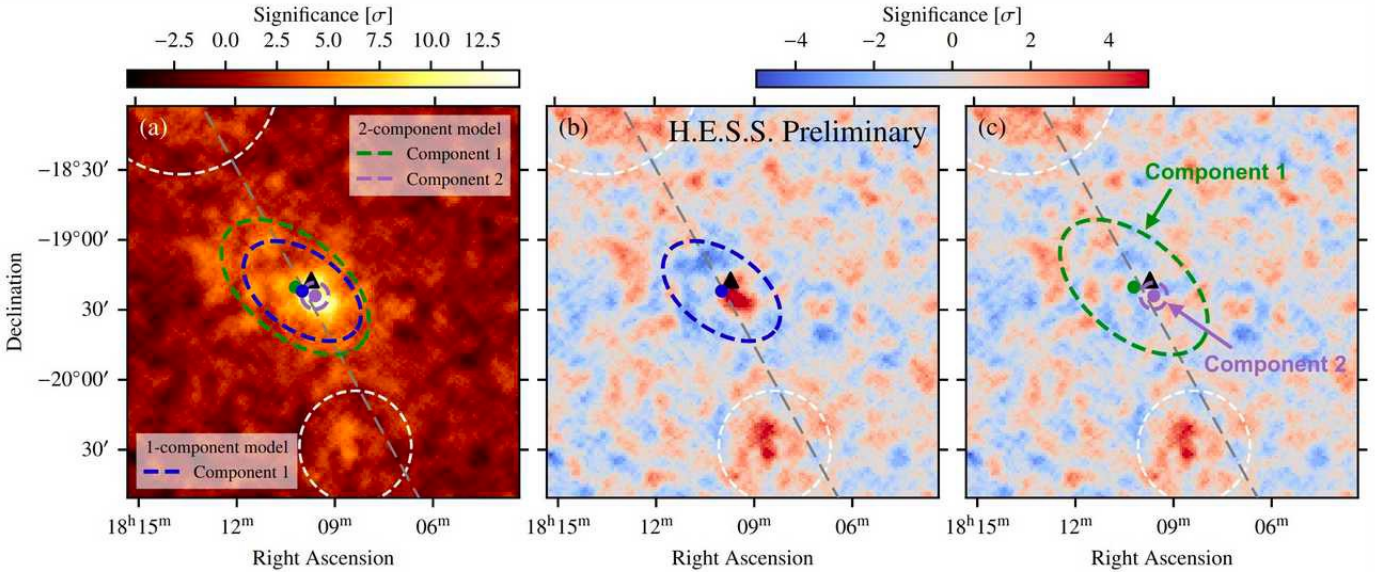


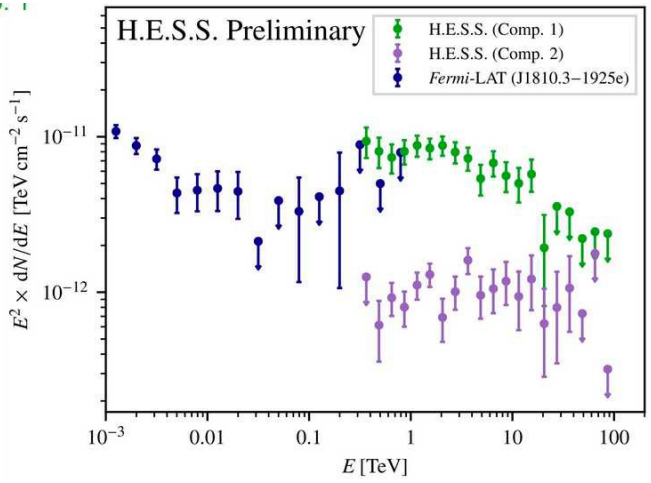


- Gamma rays up to 100 TeV from the component HESS J1702-420A
- Hadronic scenario: cut-off energy of the protons is higher than 0.5 PeV (95% CL)
- A leptonic origin of the observed TeV emission cannot be ruled out either.

Galactic science: Pevatrons and candidates

- HESS J1809-193
  - 2-component model Gaussian / power law preferred by 13σ





  - Origin of compact H.E.S.S. component & relation to Fermi-LAT emission unclear

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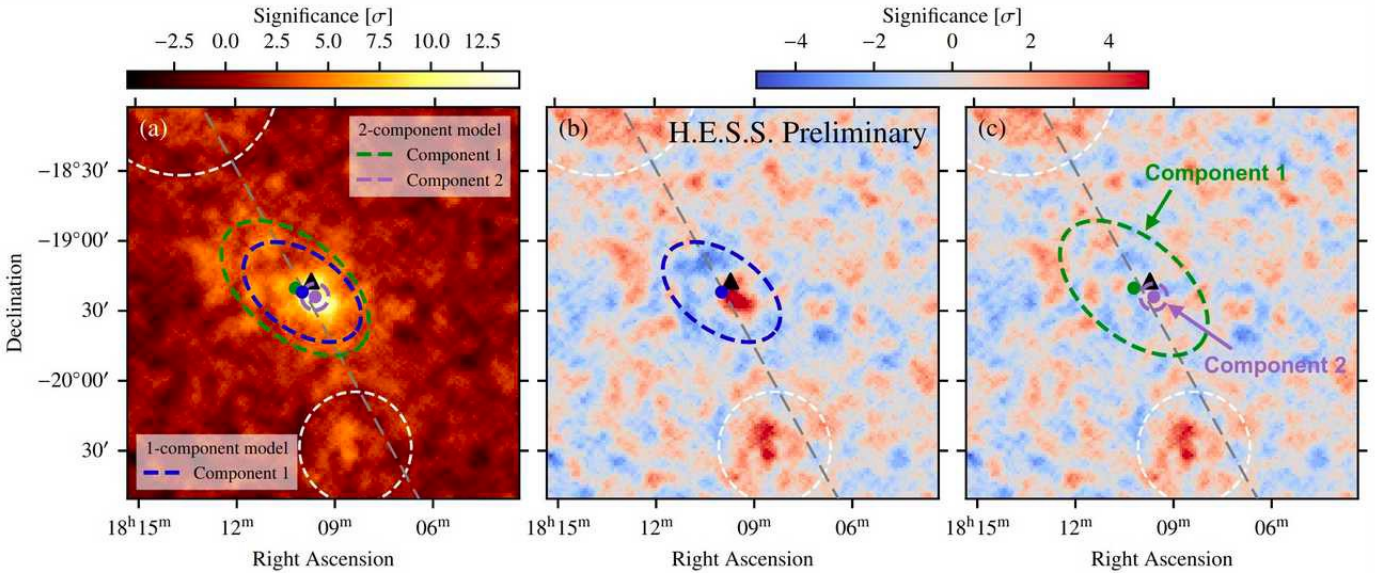
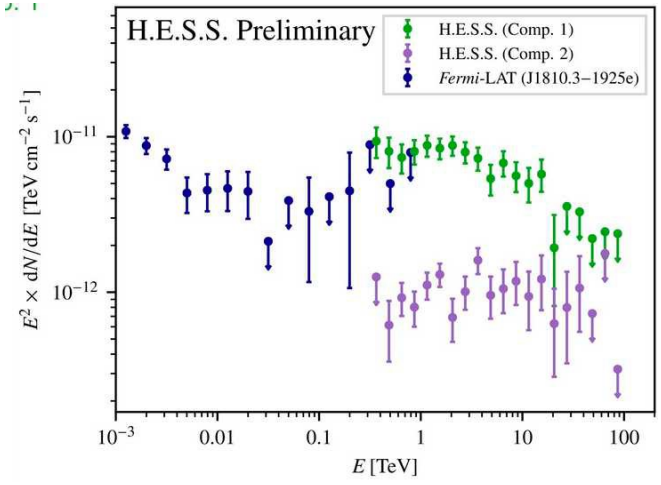
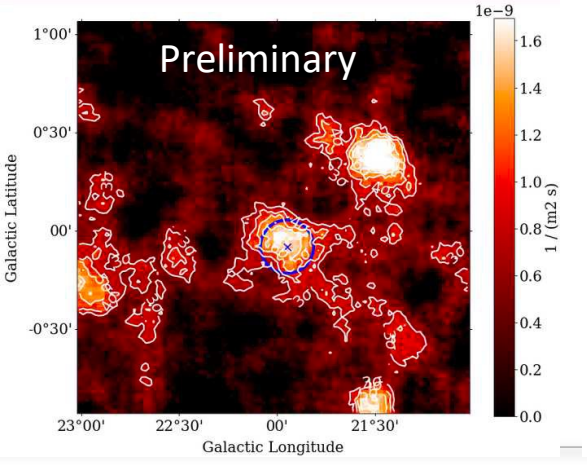
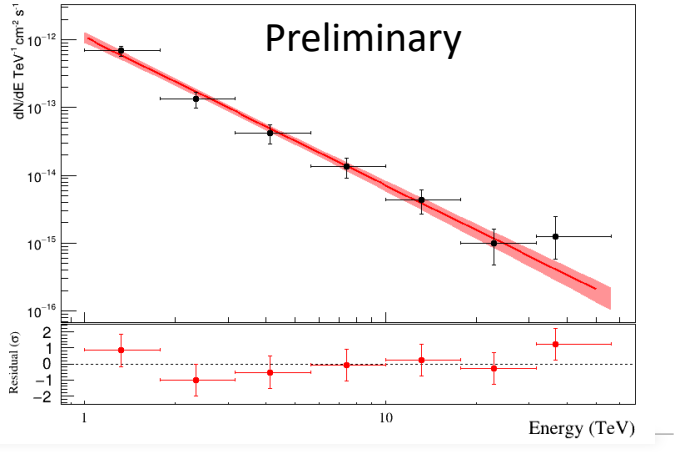




- HESS J1831-098
  - No indication for spectra cutoff
  - Extended morphology fit by a single component
  - Molecular cloud illuminated by nearby SNR or energetic pulsar wind nebula



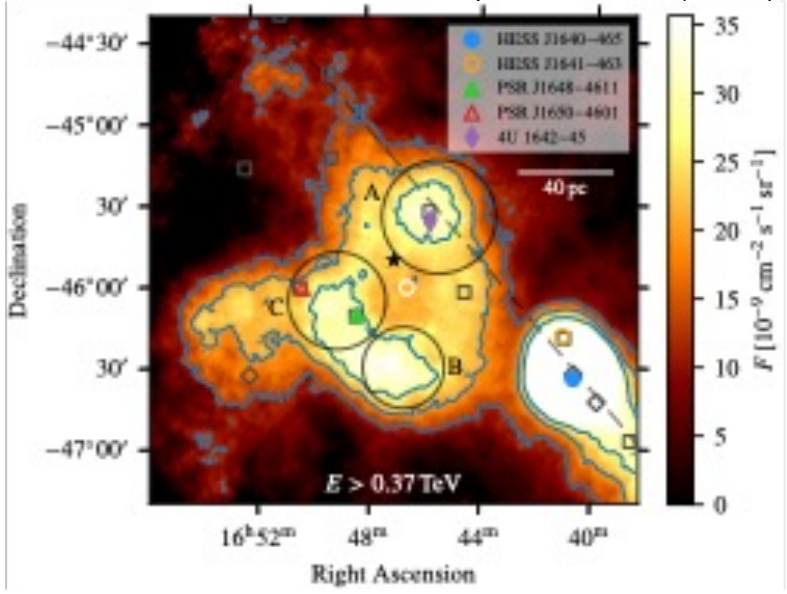


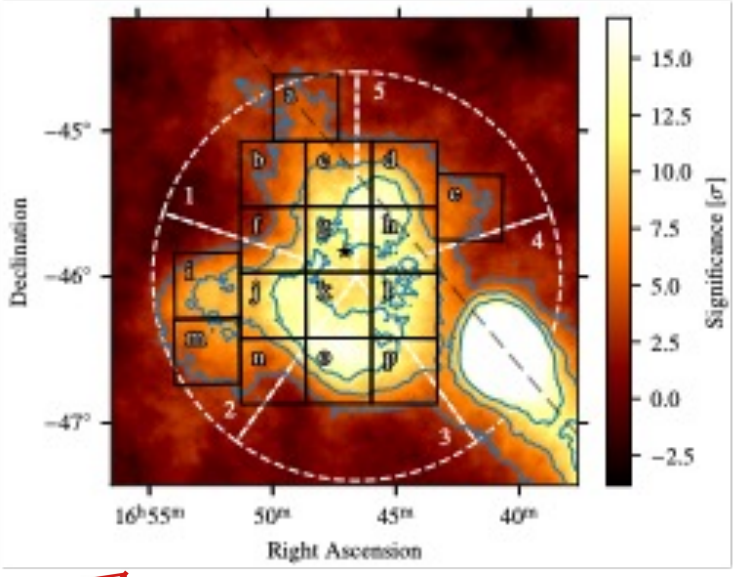
Galactic science: stellar cluster

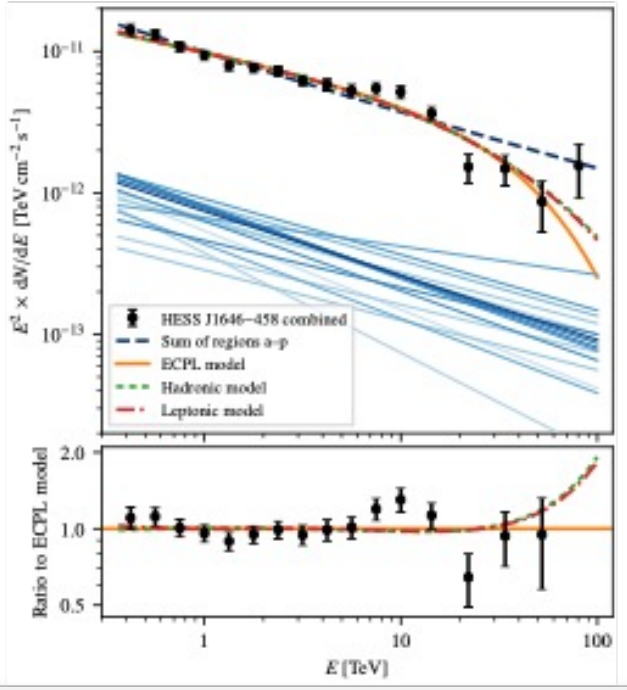
Westerlund 1: the most massive open cluster in the Galaxy

- Discovery of coincident, degree-scale source HESS J1646–458 centered on Wd1 in 2012
- New deep (164h) study reveals shell-like structure, centered on cluster and 4 sources on top of/adjacent to the shell
- The whole extended complex has remarkably homogeneous spectra

H.E.S.S. coll., accepted in A&A (2022)







- No clearcorrelation with neutral/molecular gas at 3.9 kpc (Wd1)
- While not unique, CR acceleration at the cluster wind termination shock

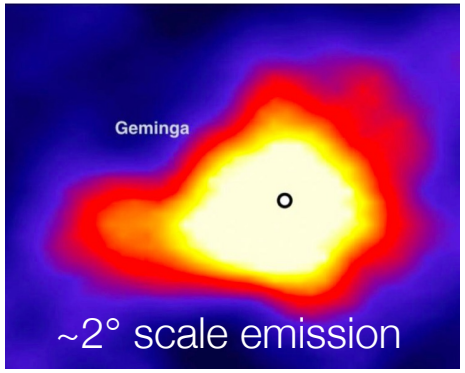
H.E.S.S.

See Andreas Specovius' talk on Thursday

Pulsar halos - Geminga

- **New source class:** Geminga and Monogem pulsars are surrounded by a spatially extended region (~20 pc) emitting multi-TeV gamma-rays
- Data implied the diffusion coefficient to be two orders of magnitude lower than the one in the Galaxy.

HAWC detection of extended TeV emission



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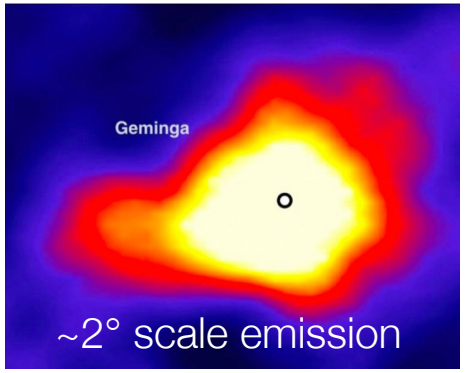

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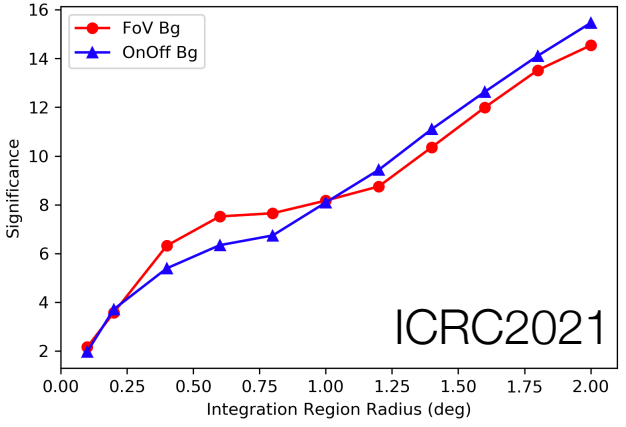
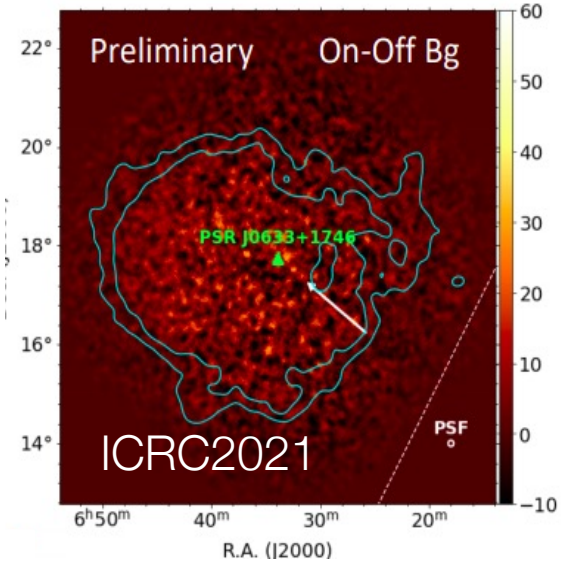
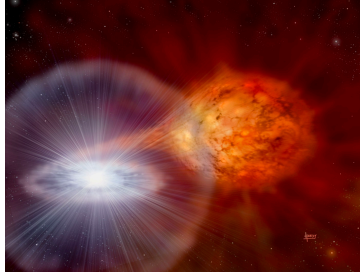
- **H.E.S.S observations of Geminga**
  - 2006-2008 dataset with 0.5° and 0.7° wobble offset, 14.2 hour livetime
  → No significant excess at the time
  - 2019: observations at large wobble offset ±1.6°

  - Detecting large, extended sources with IACTs is challenging, but possible
  - True emission extent likely larger than H.E.S.S. field-of-view





The recurrent Nova RS Ophiuchi



- Novae – outbursts from accreting binary systems of White Dwarf + massive donor
  - Detected in gamma rays, i.e., Fermi-LAT

- 1st Galactic transient source: RS Ophiuchi – 2021 flare
- Triggered by optical detection, VHE observations started with ~24h latency.

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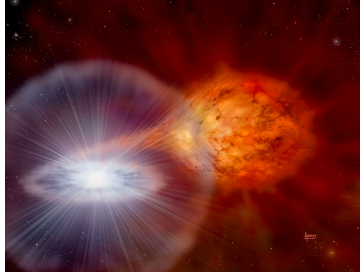

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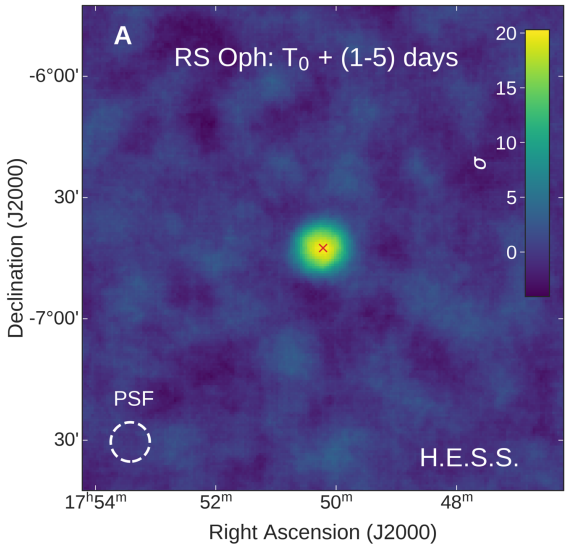
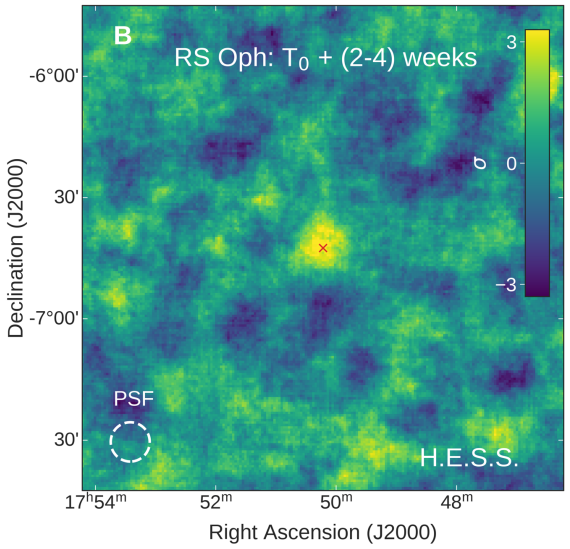
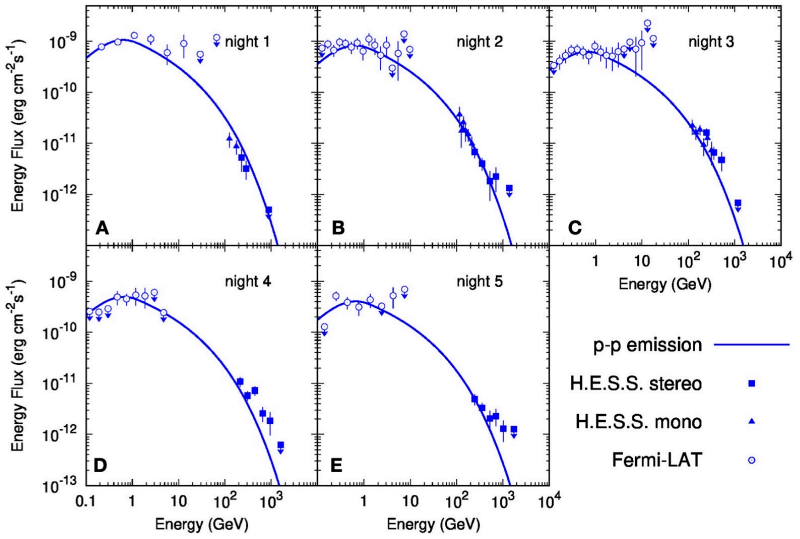
H.E.S.S. coll., Science 376 (2022) 6588







- Detection at > 6 sigma on each night of first five nights
- Hadronic acceleration scenario preferred

See Alison Mitchell's talk on Thursday

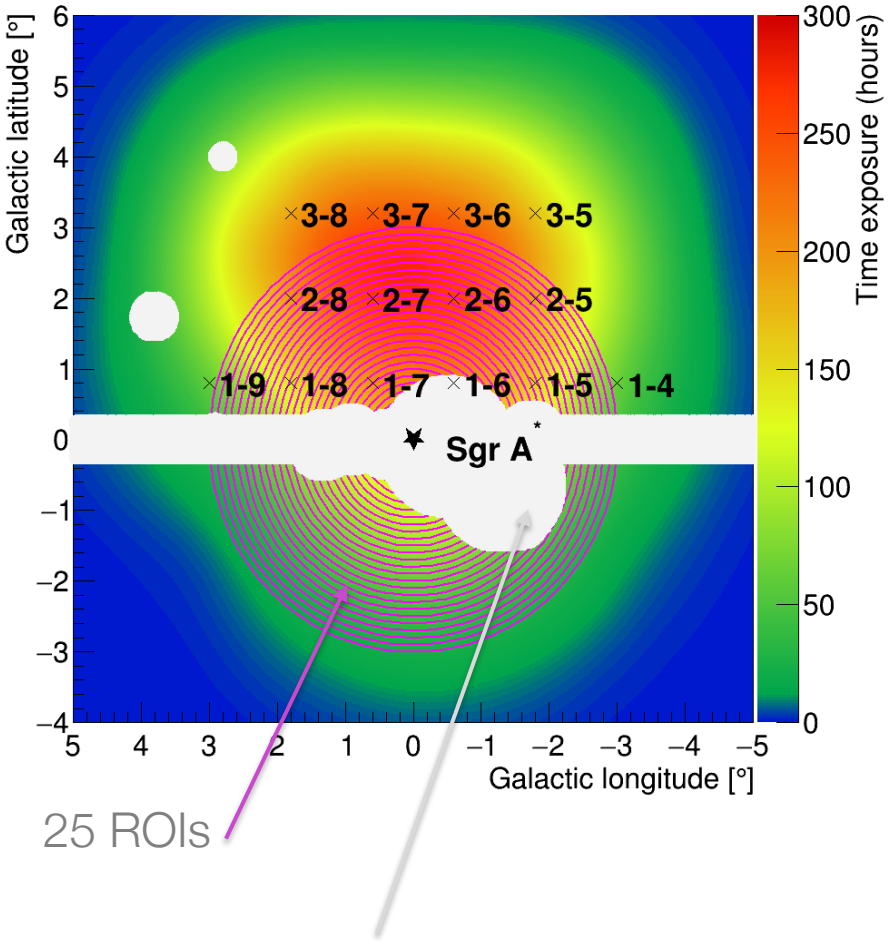
The Inner Galaxy Survey (IGS)

- H.E.S.S. is performing a survey of the inner few degrees of the Galactic Centre region since 2015
  - → provide unprecedented sensitivity to dark matter
  - → deeper study of the diffuse emission
  - → search for TeV outflows from the Galactic Centre

- The first ever conducted VHE gamma-ray survey of the Galactic Center (GC) region.

- 2014-2020 exposure map with IGS pointing positions: significant exposure up to b ≈ 6°

H.E.S.S. coll., accepted in Phys. Rev. Lett. (2022)



Set of exclusion regions for DM search to mask conventional gamma-ray emission

Dark matter search with IGS

- No significant DM signal found in any ROI
  → 95% C.L. upper limits on <σv>

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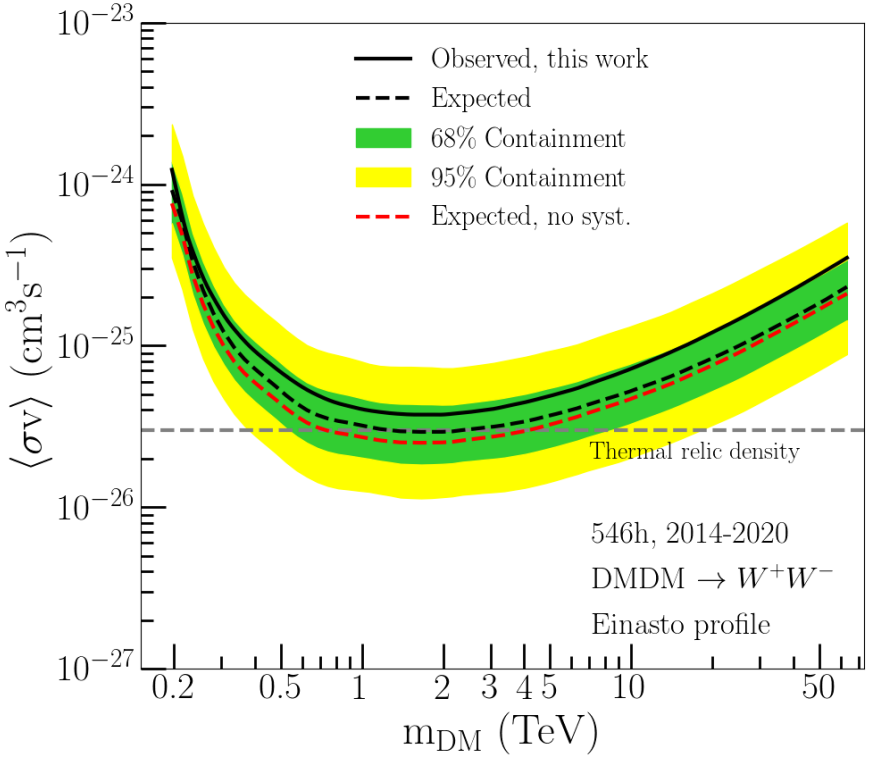

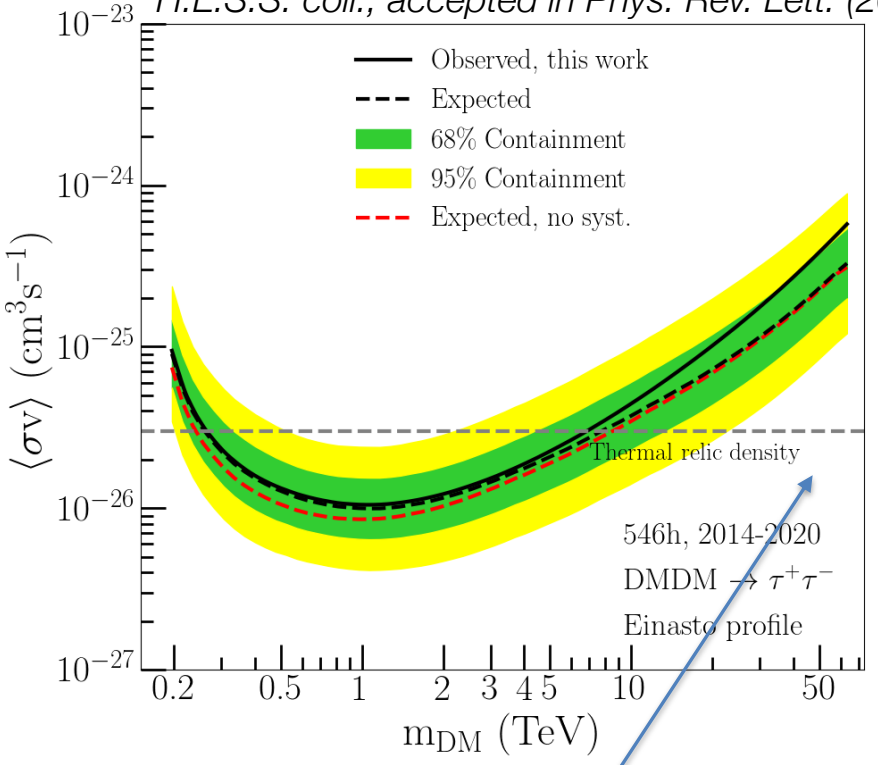

- Systematic uncertainty included in the limit computation

Thermal cross-section expected for vanilla (s-wave) annihilating WIMPs that account for 100% of DM

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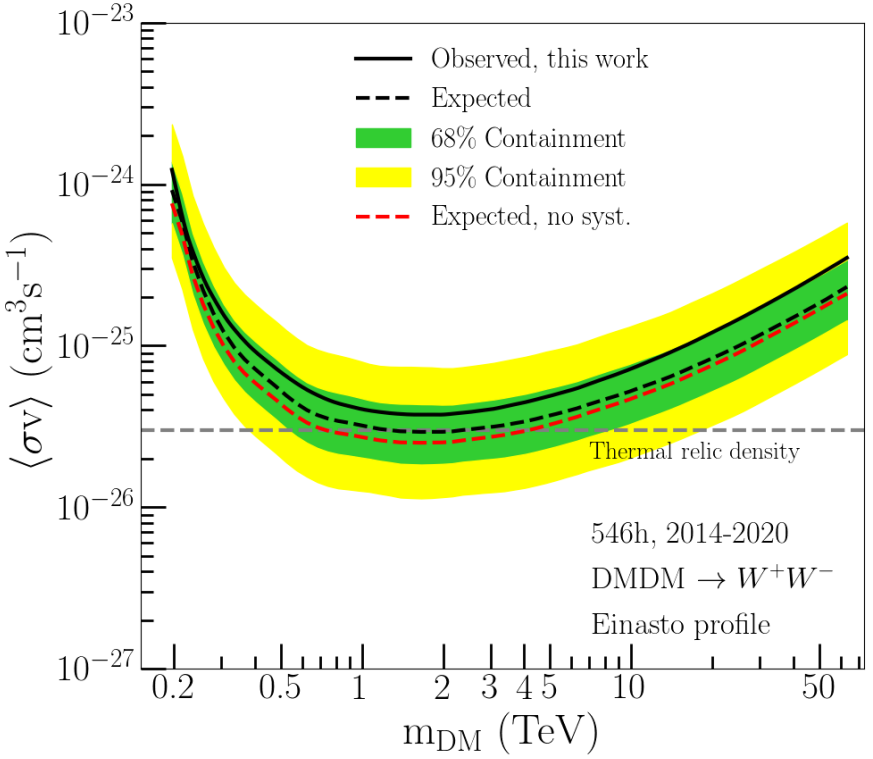

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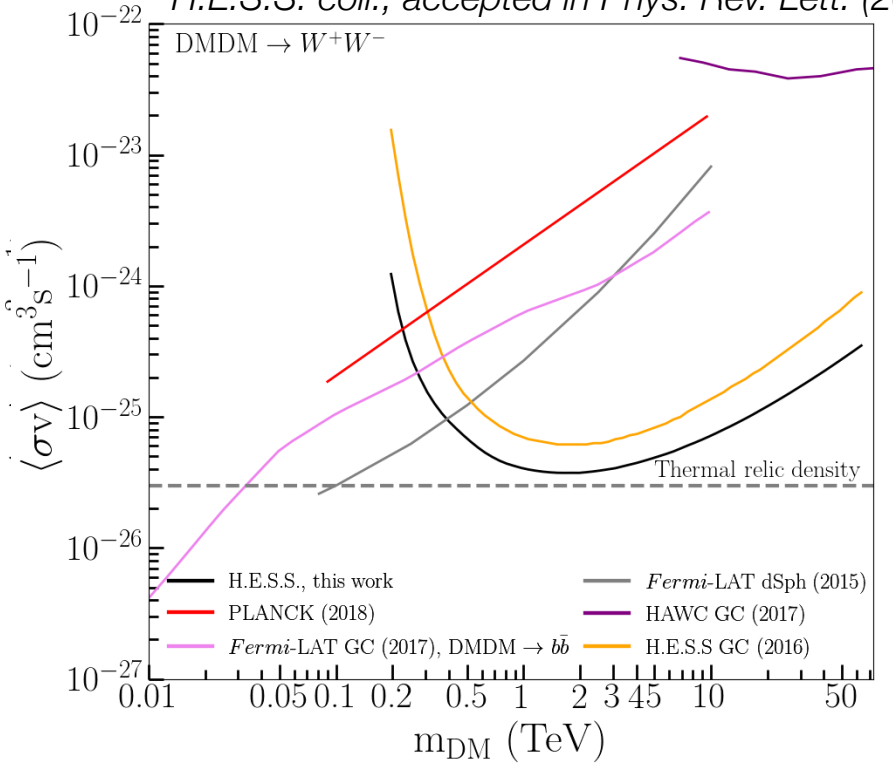

- Comparison with Fermi-LAT dSph and GC, HAWC dSph and GC, MAGIC Segue 1, PLANCK CMB, H.E.S.S. GC (2016) and this work.
  → Most constraining limits in the TeV-mass range

Selected Unidentified Fermi-LAT Objects as Dark matter subhalos

Dark Matter subhalos in the Galactic halo

- Lower signal than the GC region
- No astrophyiscal background
- Location not known …

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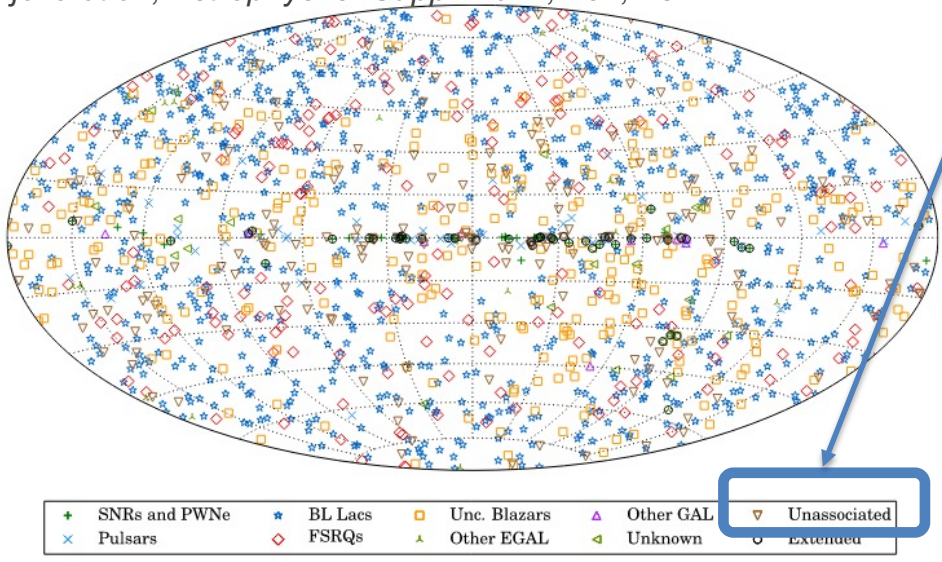
Ajello et al., Astrophys. J. Suppl. 2017, 232, 18



200 unassociated over 1556 sources in the catalogue;

→ these sources are classified as Unidentified Fermi Objects (UFOs);
→ Selection through the Third catalog of Hard *Fermi*-LAT sources (3FHL) to obtain the most promising UFOs for the IACT observations.

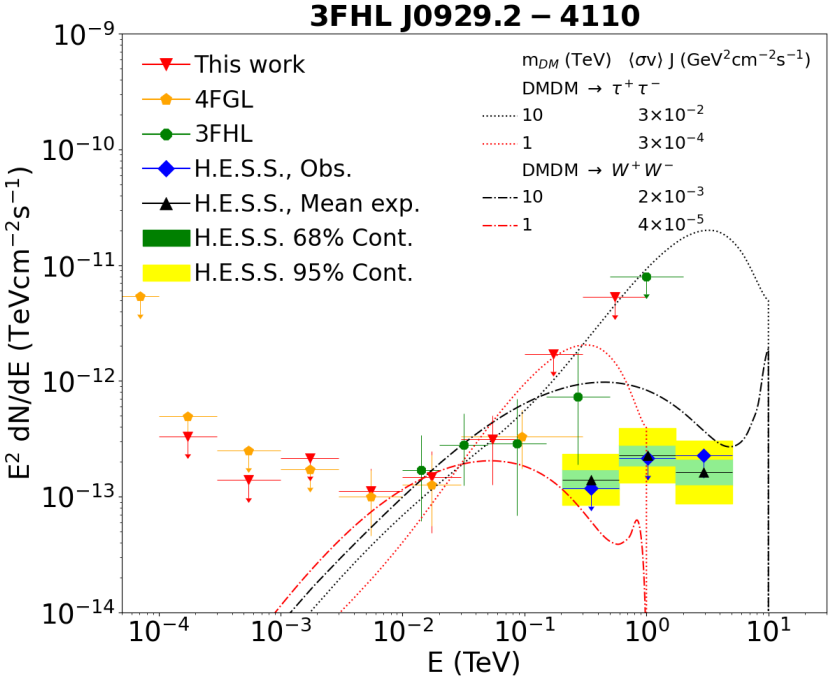
Selected Unidentified Fermi-LAT Objects as Dark matter subhalos

Criteria	Numbers of sources
Without association	178
Far enough from the Galactic plane, cut in Galactic latitude of $\|b\| > 5°$	126
Non-variable, cut in variability index (No. of Bayesian blocks in var. analysis) equal to 1	125
Maximum zenith angle at H.E.S.S. site of 45°	83
Follow a simple power law with significance for curvature $< 3\sigma$	83
Hard spectrum, cut in spectral index below 2	18
No MWL counterparts	6

→ 6 selected, 4 observed by H.E.S.S.

DM-induced emission models are viable according to *Fermi*-LAT measurements;

→ H.E.S.S. upper limits can constrain some viable DM-induced emission models that explain *Fermi*-LAT detection.



H.E.S.S. Coll. Astrophys.J., 918, 17 (2021)

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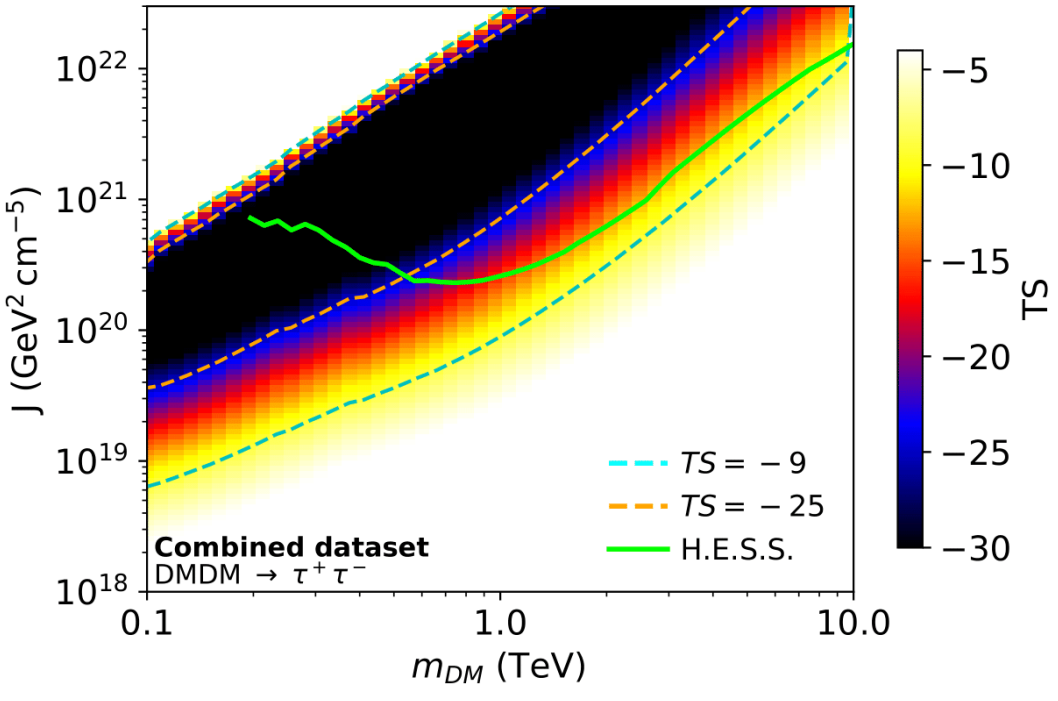
Assume thermally-produced WIMPs:
→ UFOs very unlikely DM subhalos

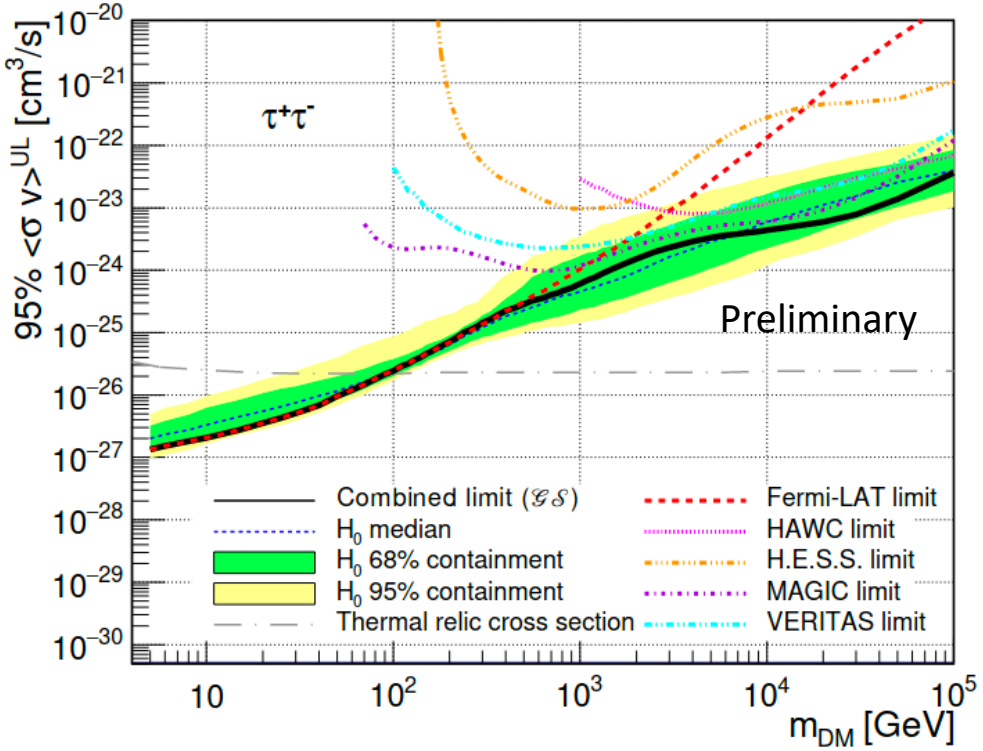
H.E.S.S. Coll. Astrophys.J., 918, 17 (2021)



Combining all dwarf galaxy observations

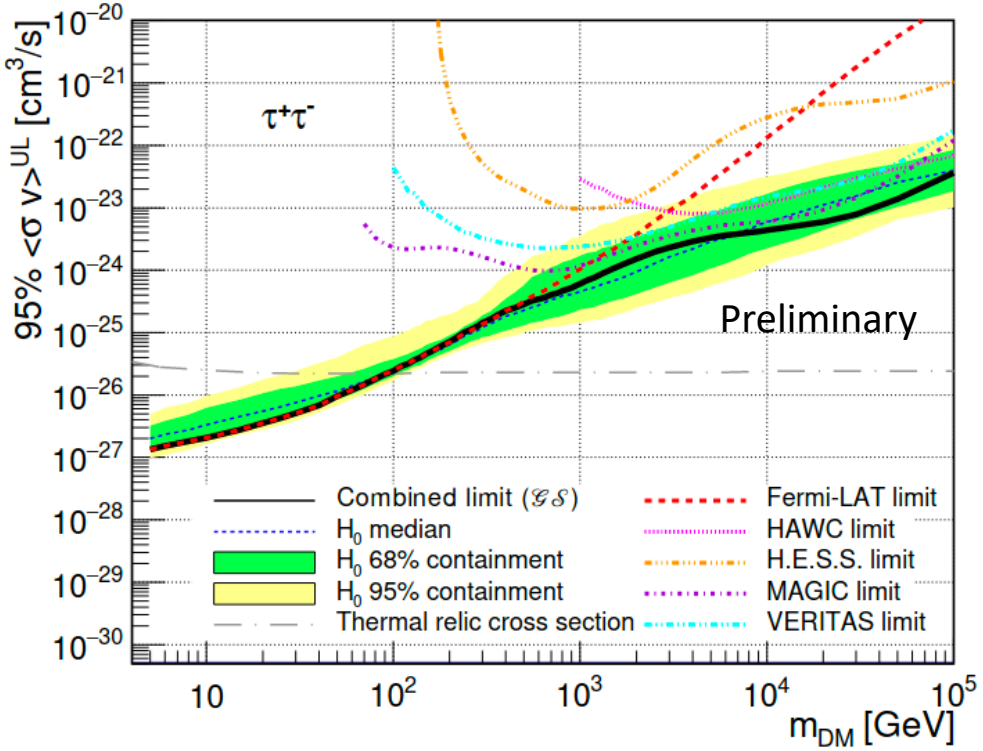
- Combination of the observation results towards 20 dSph galaxies
  - Significant increase of the statistics
    → Increase the sensitivity to potential DM signals
  - Cover the widest energy range ever investigated : 20 MeV – 80 TeV

- Common elements :
  - Agreed model parameters
  - Sharable likelihood table formats
  - Joint likelihood test statistic



Combining all dwarf galaxy observations

- This analysis framework allows us to perform multi-instrument and multi-target analysis
- No significant DM signal was observed
- Combined limits range from 5 GeV to 100 TeV and improve individual limits up to a factor 2 to 3
- Joint publication under preparation



New challenges

- Many studies combine very large data sets (+600 hours), obtained over many years with changing camera/telescope configurations, mapping extended structures beyond single fov and/or source confusion

- Challenges in treating systematics in large datasets, background estimation and –rejection as well as separation of sources
  → Extensive work improving calibration, background, and high-level analysis
  e.g. choice of gammapy as high-level tool (borne out of 1HGPS)

Summary

- H.E.S.S. is approaching its 20th anniversary
  - 1st telescope inauguration and start of stereoscopic observations in 2002
- The H.E.S.S. observatory still improves its operational performance and enables fascinating research

Thanks for your attention