Search for extended gamma-ray emission around the Geminga pulsar with H.E.S.S.

A. Mitchell (UZH), S. Caroff (LPNHE)
for the H.E.S.S. Collaboration

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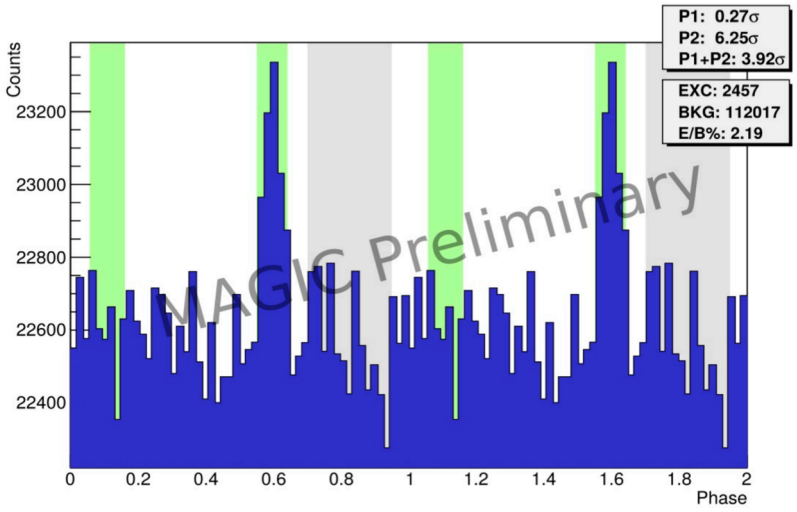
The Geminga Pulsar

- Radio quiet pulsar:
  strong gamma-ray and weak radio pulsed emission
- One of the first gamma-ray pulsars detected (EGRET)
- One of four pulsars with VHE pulsed emission detected by IACTs
  (Crab, Vela, PSR B1706-44)

- Nearby d ~ 250 pc
- Older and lower luminosity:
  age = 342 kyr,
  Edot = 3.26 x10^{34} erg /s

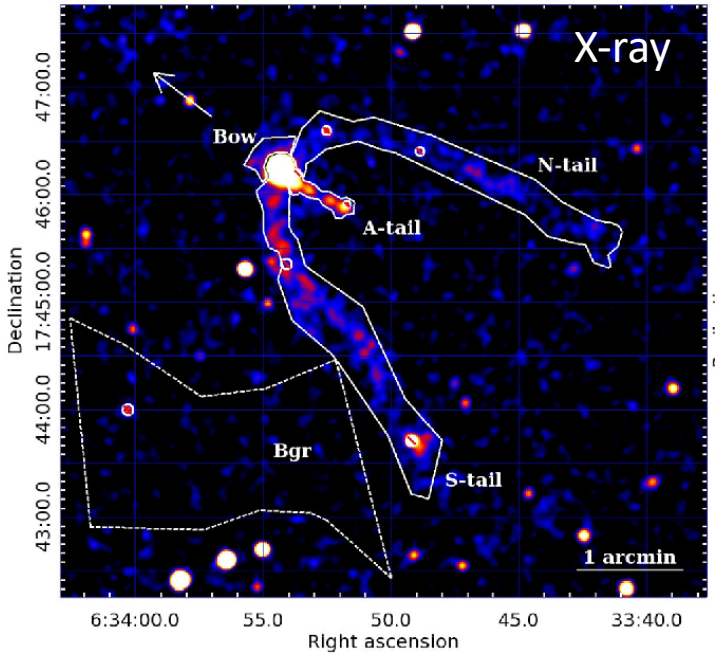
- Pulsars are copious lepton producers – nearby pulsars could help explain positron excess

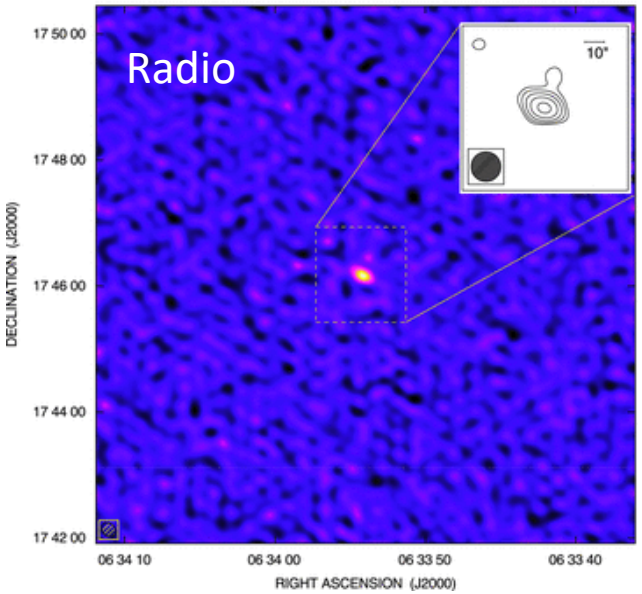
Lopez, MAGIC collaboration, ICRC 2019, PoS 728



Searches for extended emission

- Previous searches for extended emission in gamma-ray and radio
- X-ray and Radio PWN confirmed (on arcsecond – arcminute scales)
- Detection of extended gamma-ray emission around Geminga found by Milagro & HAWC
- Challenging for IACTs due to large scale emission

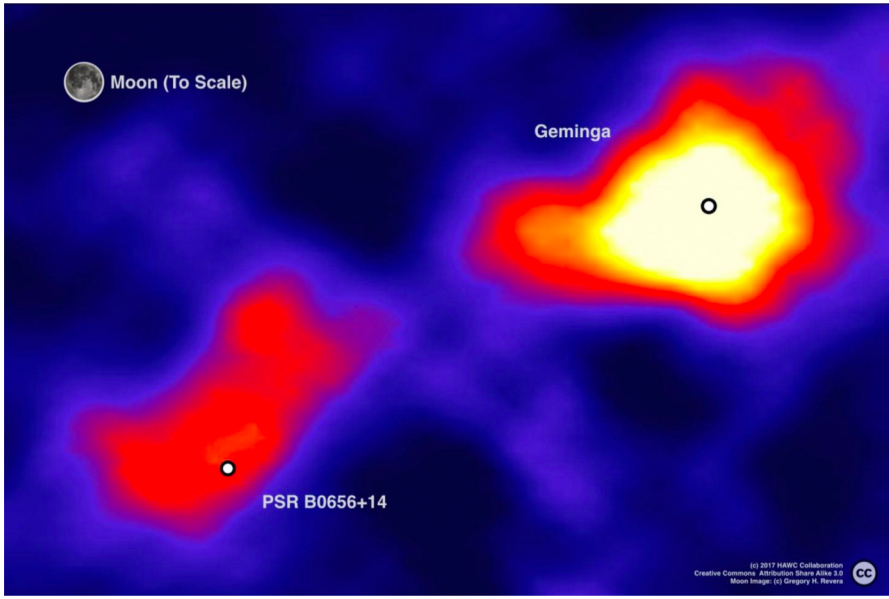




Posselt et al, ApJ 835, 66 (2017)
Pellizzoni et al, MNRAS Lett. 416, L45 (2011)

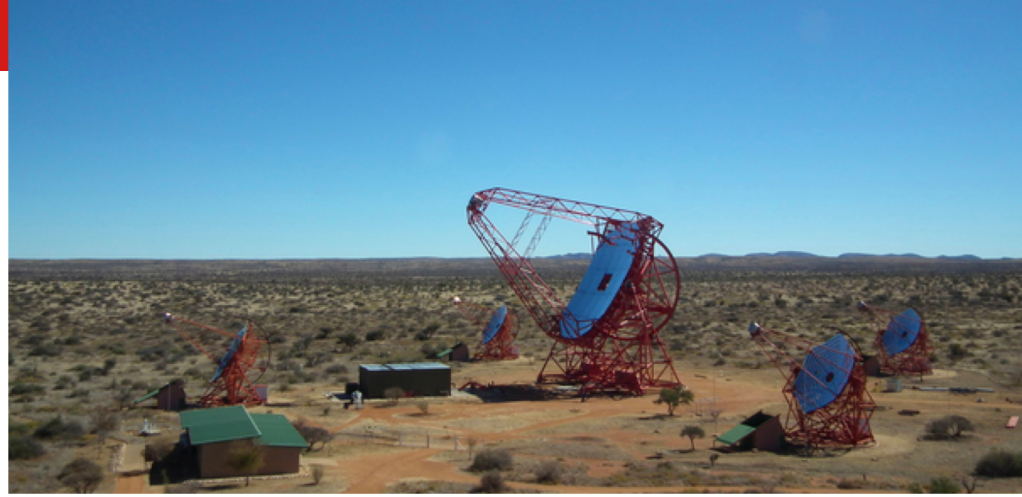
HAWC detection of extended TeV emission

- HAWC confirms Milagro excess
- Extended emission on ~2º scale
- Low diffusion coefficient inferred by HAWC from radial profile of emission
- Would imply Geminga is not local positron source if representative of intervening ISM
- Cool too quickly to reach Earth



RA-Dec, HAWC collaboration 2017

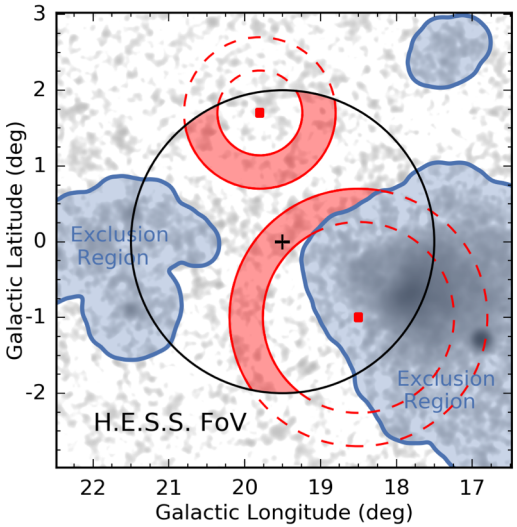
H.E.S.S.



- Array of five IACTs in Kohmas Highlands, Namibia
- CT1-4 108m^2 mirror area operational since 2004
- CT5 614m^2 mirror area, constructed in 2012
- Field-of-view: 5º (CT1-4)
- 50 GeV – 50 TeV range
  (c.f. HAWC ~ 1 – 100 TeV)
- ~0.1º angular resolution
  (c.f. HAWC ~0.2º - 1º)

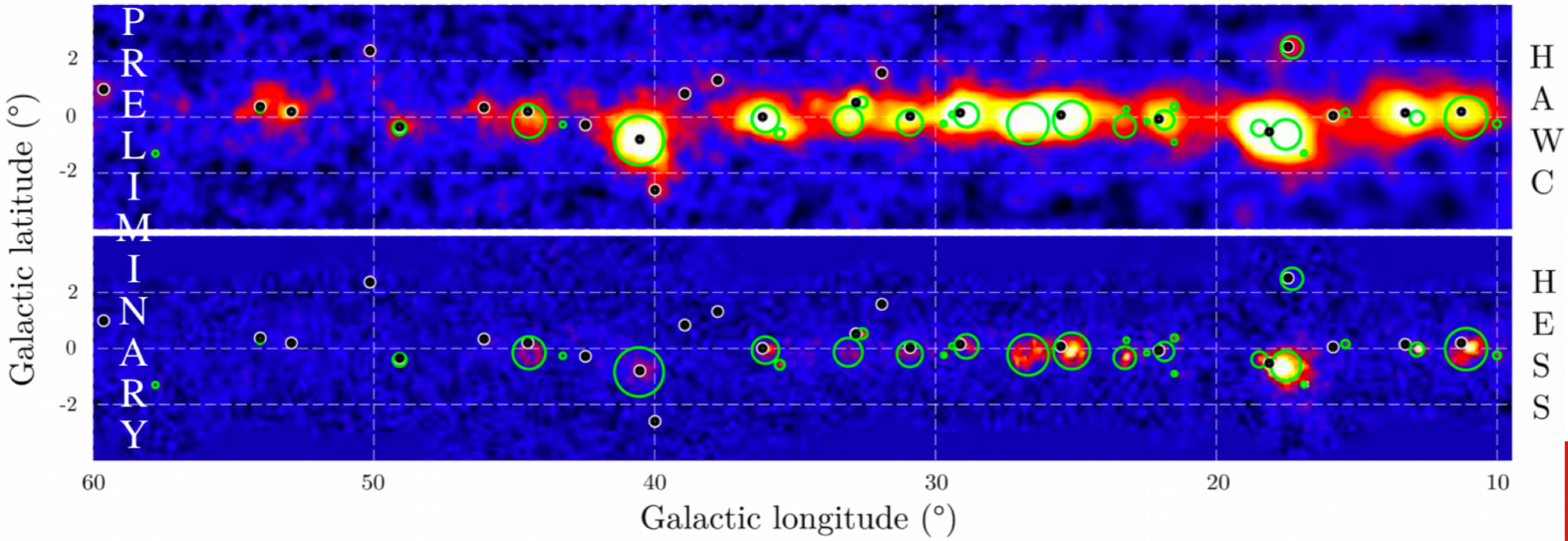
HAWC - H.E.S.S. analysis comparison study

- Recent dedicated effort in understanding analysis differences
- Tested in Galactic plane
- Ring Background:
  fixed offset from test position, estimate from data outside exclusion regions
- Field-of-View Background:
  use acceptance map for background estimation, assuming radial symmetry



H.E.S.S. Collaboration, A&A 612, (2018) A1

Jardin-Blicq ICRC 2019



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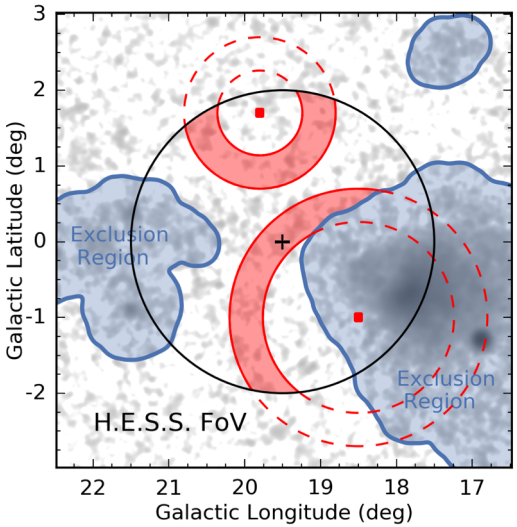

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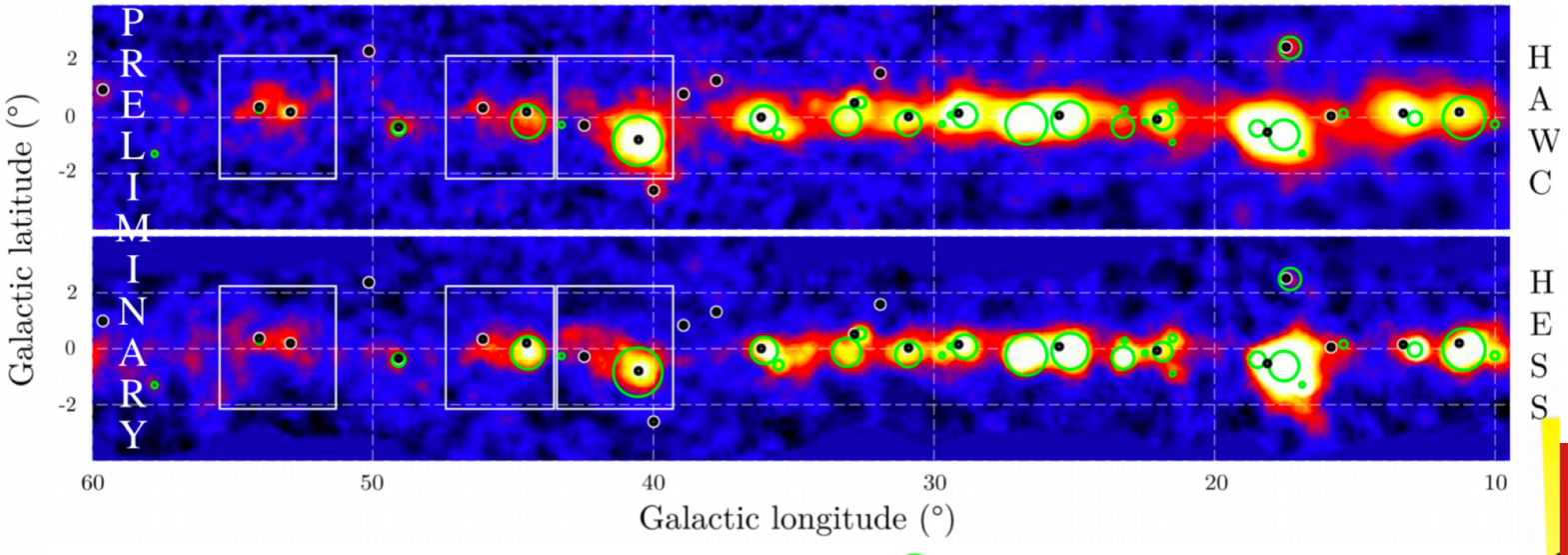


H.E.S.S. Observations 2006-2008

Time Period	Exposure	Zenith angle
Nov 2006	7.7 hours	42.2º
Jan-Feb 2008	6.5 hours	42.0º

- Data taken in 2006 and 2008
- Observations with H.E.S.S. I telescopes
- 0.5º and 0.7º wobble offset
- 14.2 hours total livetime

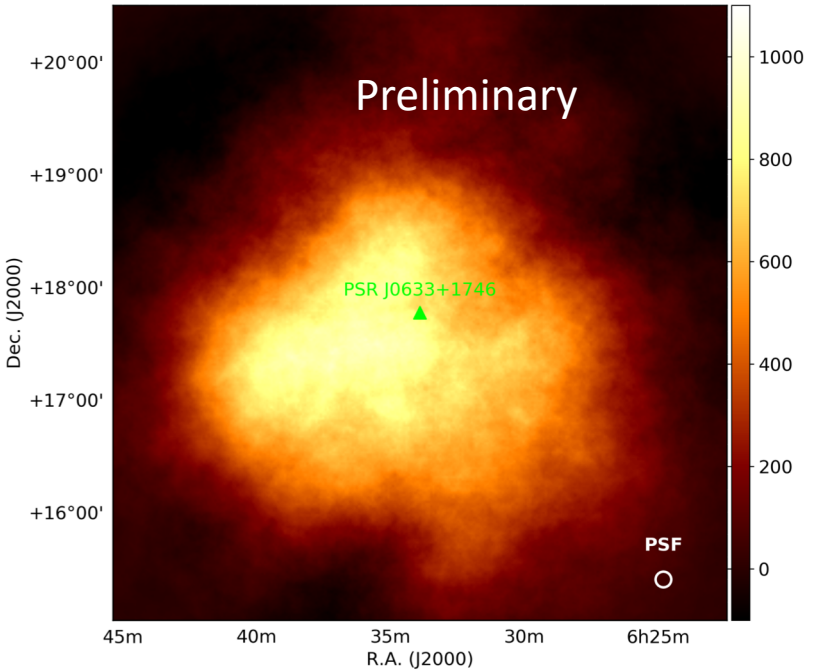
- No significant excess seen at the time

- From HAWC spectra, detection should be possible in ~10 hours

- Revisit data applying lessons learnt from HAWC-H.E.S.S. analysis comparison study

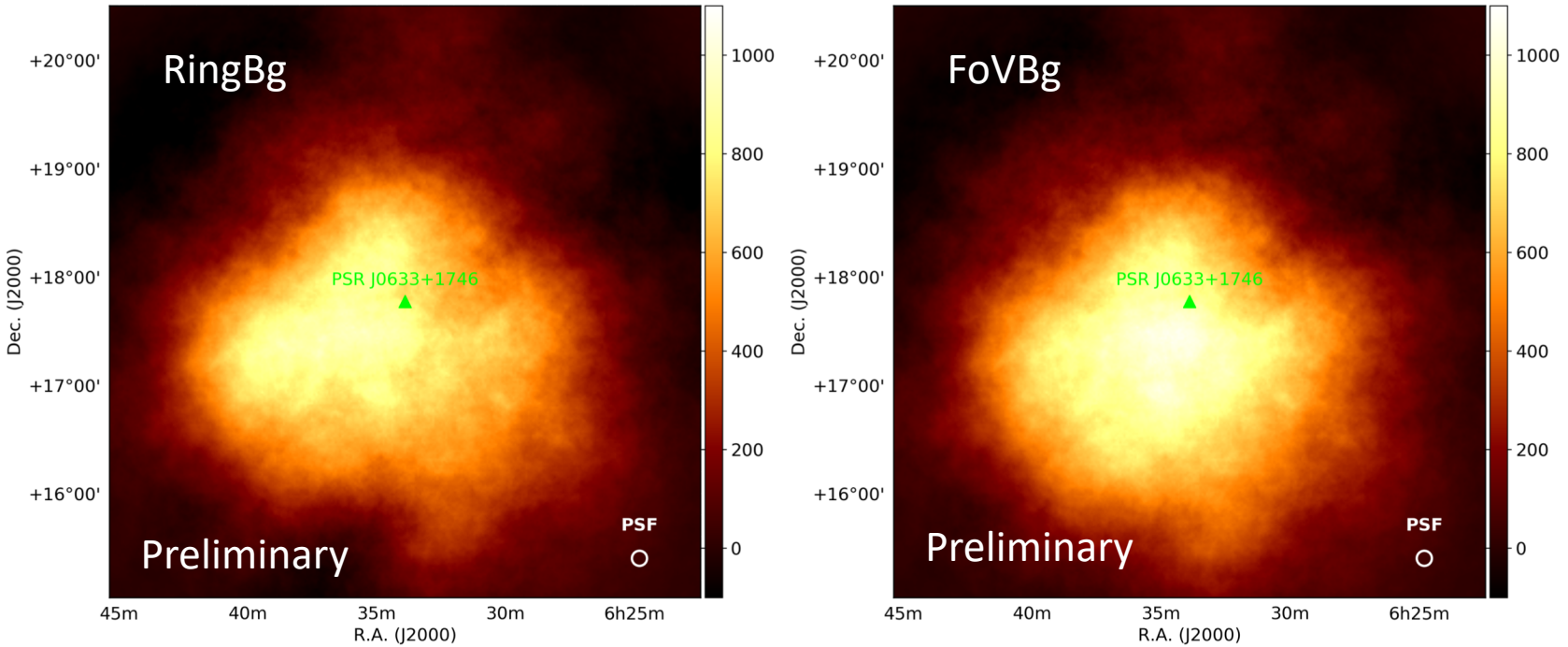
H.E.S.S. detection of extended TeV emission

- Ring background method
- Centred on pulsar:
- 2º radius exclusion region
- 1º radius integration region
- 0.5º width ring used for background estimation
  (N.B. background contains events from the source)
- 10.9 sigma detection



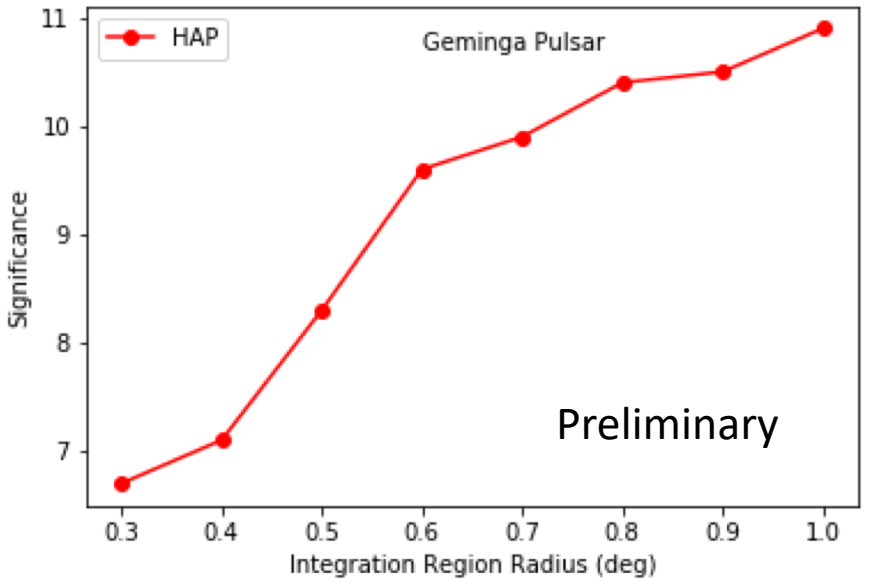
Background Methods

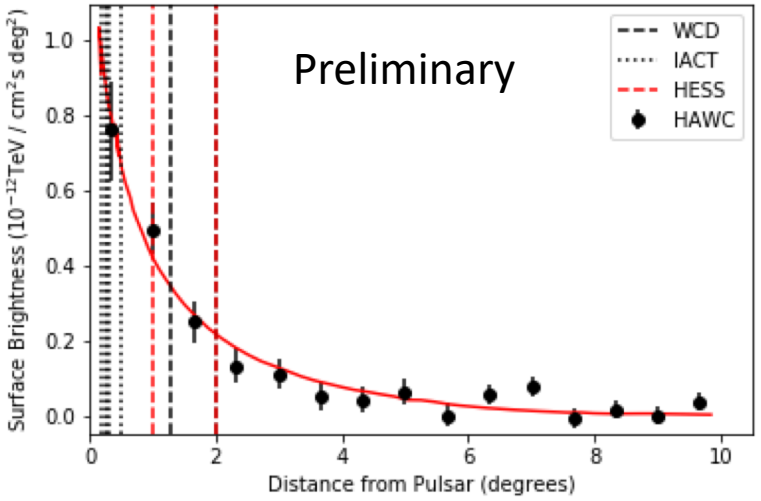
- Ring Background and Field of View Background
- Consistent morphology, different normalisation between background methods
- However, background estimation methods may bias apparent morphology



Integration region radius

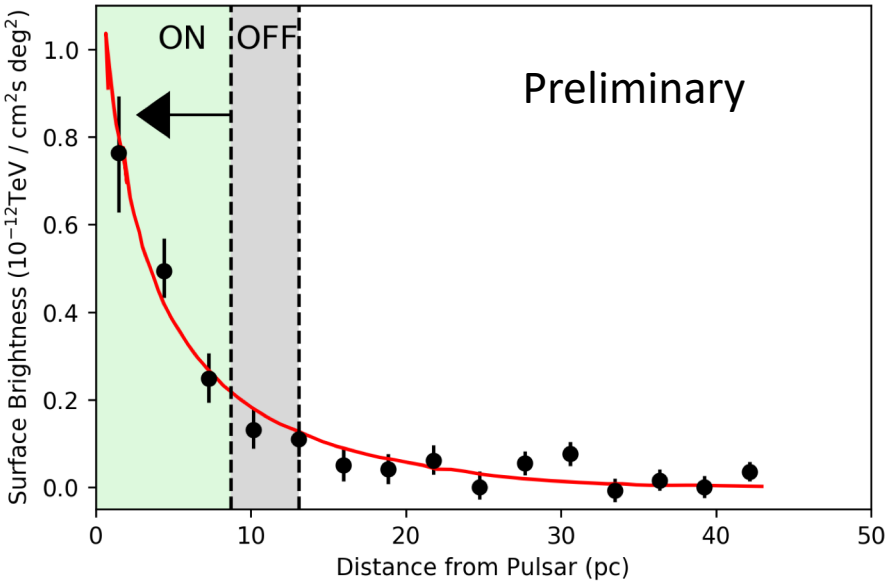
- Significance increases with increasing radius
- Curve does not flatten
- True extent > 1º radius
- Compared to previous searches with IACTs, H.E.S.S. now probes much larger angular scale





Angular Scale

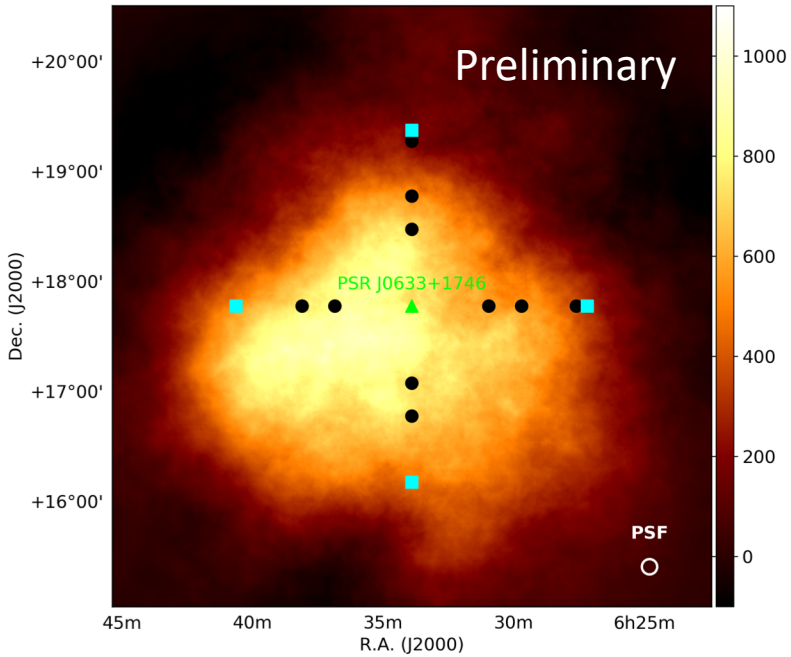
- PSF 0.08º
- Differential measurement with ring background
- Part of significant emission used to estimate background
- From HAWC profile; should see ~ 35% of the flux with this approach



See also HAWC collaboration, Science 358, 911-914 (2017)

Observations in 2019

- Another 30 hours of observations taken at large offset
- Intend to use OnOff background method
- Extragalactic runs as OFF data
- More suitable than Ring Background for large extended sources – reduce potential bias in morphology
- Challenges – good run matching selection, background normalisation



Black circles – 2006-2008 observation positions
Cyan squares – 2019 observation positions

Outlook

- Detecting large, extended sources with IACTs is challenging, but possible
- Good IACT angular resolution – investigate sub-structure and morphology
- Verify centroid location of gamma-ray emission
- Spectral analysis and search for energy dependent morphology pending
- Good IACT energy resolution – spectral analysis also from sub-regions
- Analysis results with the 2019 dataset will be presented in a forthcoming publication

Thank you for your attention

Any Questions?