Study of Gamma-Ray Emission at the Cygnus Cocoon Region

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For the HAWC Collaboration

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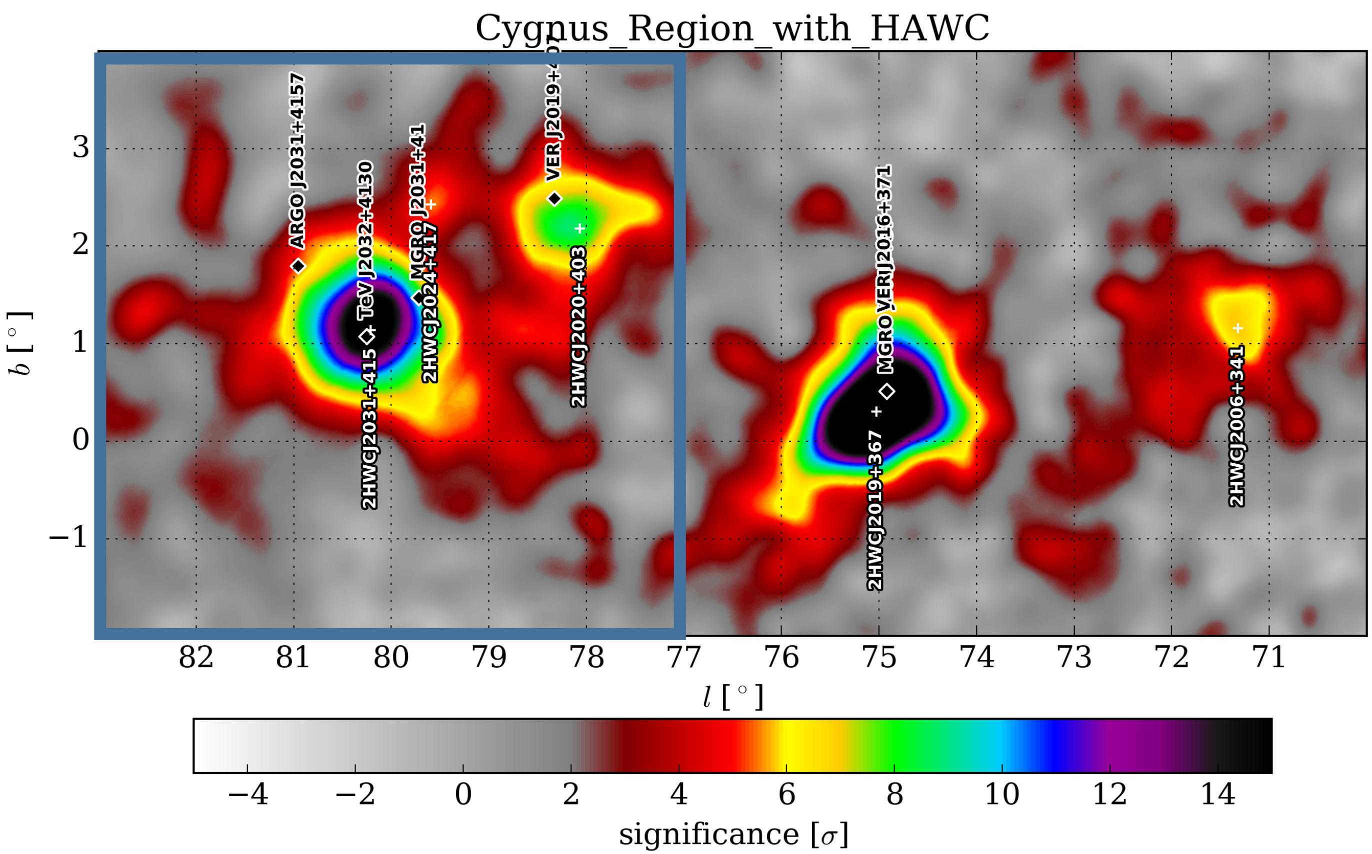
Cygnus Region with HAWC



Significance Map of the Cygnus Region with 760 days of HAWC data

Sources in the Cocoon Region

2HWC J2031 + 415 overlaps with two sources:

1) Fermi Cocoon
2) PWN TeV J2032+4130

TeV J2032+4130 powered by the pulsar PSR J2032+4127 [*Abdo, A. A., et al. 2012, ApJ, 753, 159*]

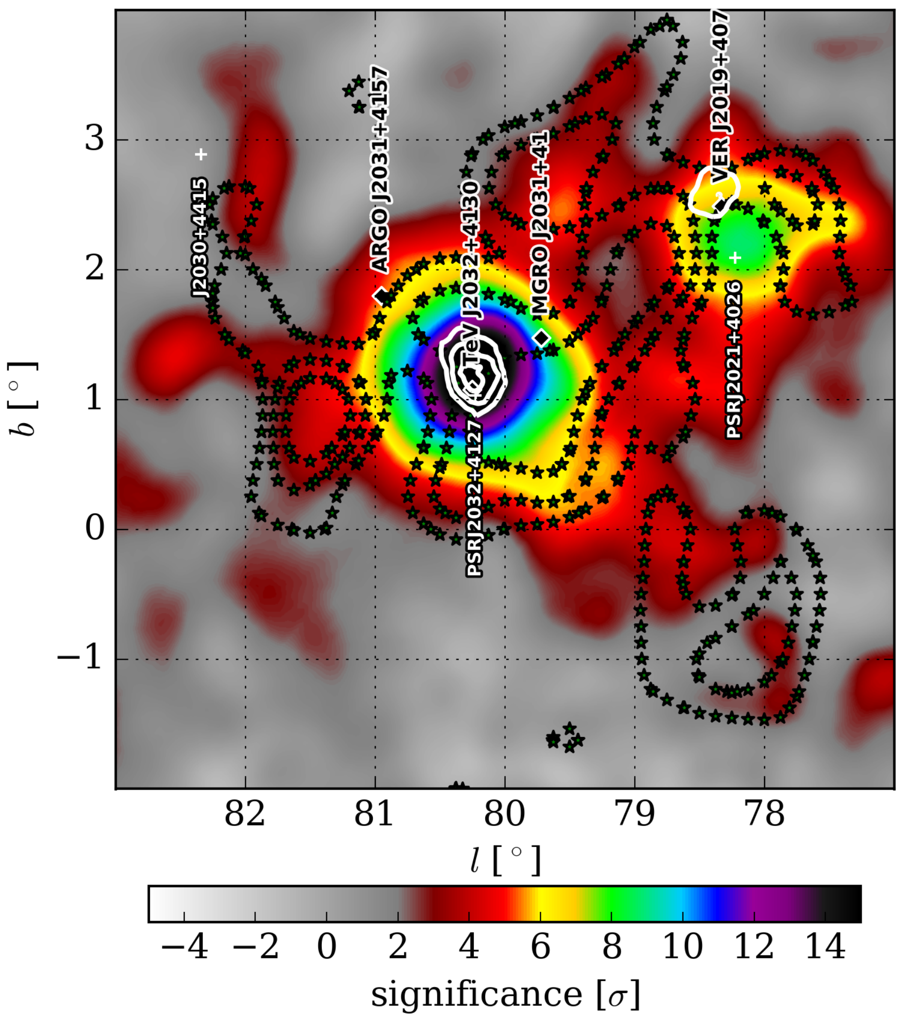
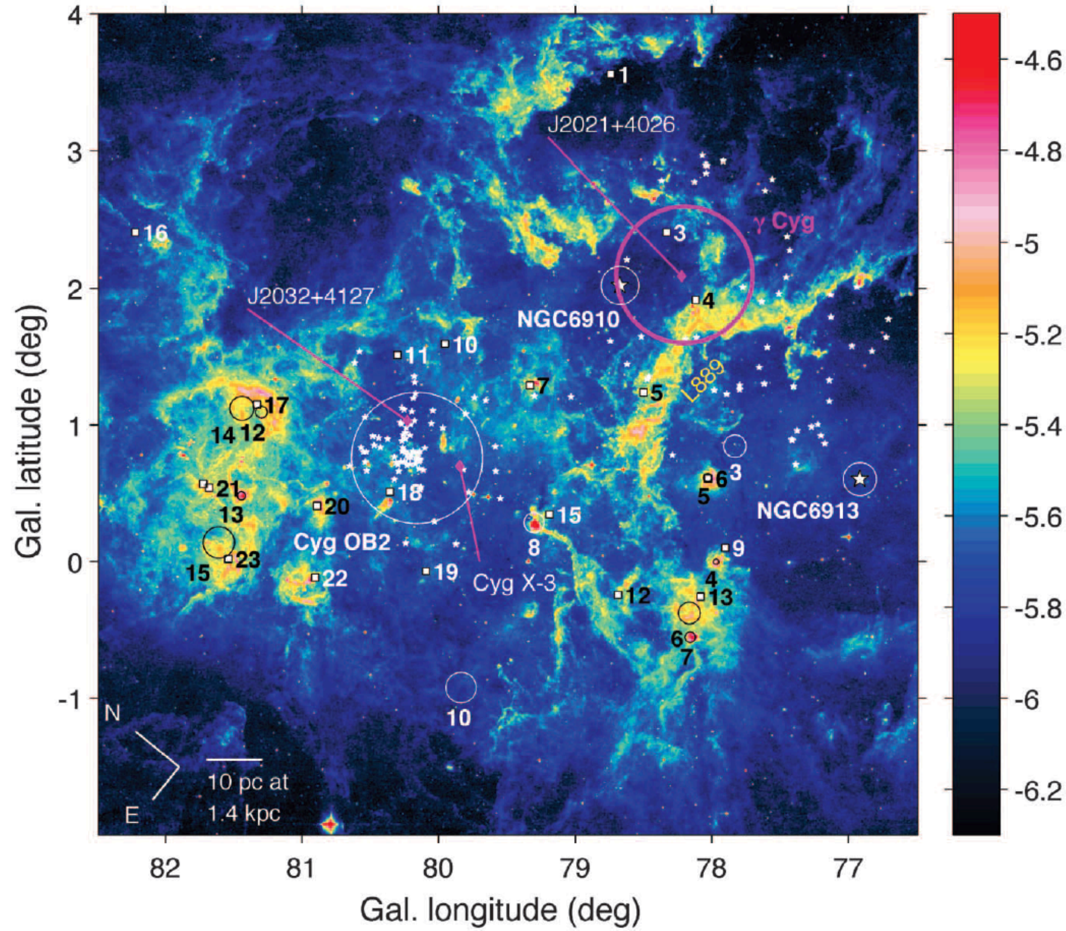


Fig.
White contours: VERITAS contours (5, 7, 9, 11 sigma) using extended source analysis (0.23deg) [*R. Bird et al, ICRC 2017*]
White plus signs: Pulsars from ATNF catalog [*http://www.atnf.csiro.au/people/pulsar/psrcat*]
Black stars: Fermi Cocoon contours [*Ackermann, M., et al. 2011, Science, 334, 1103*]

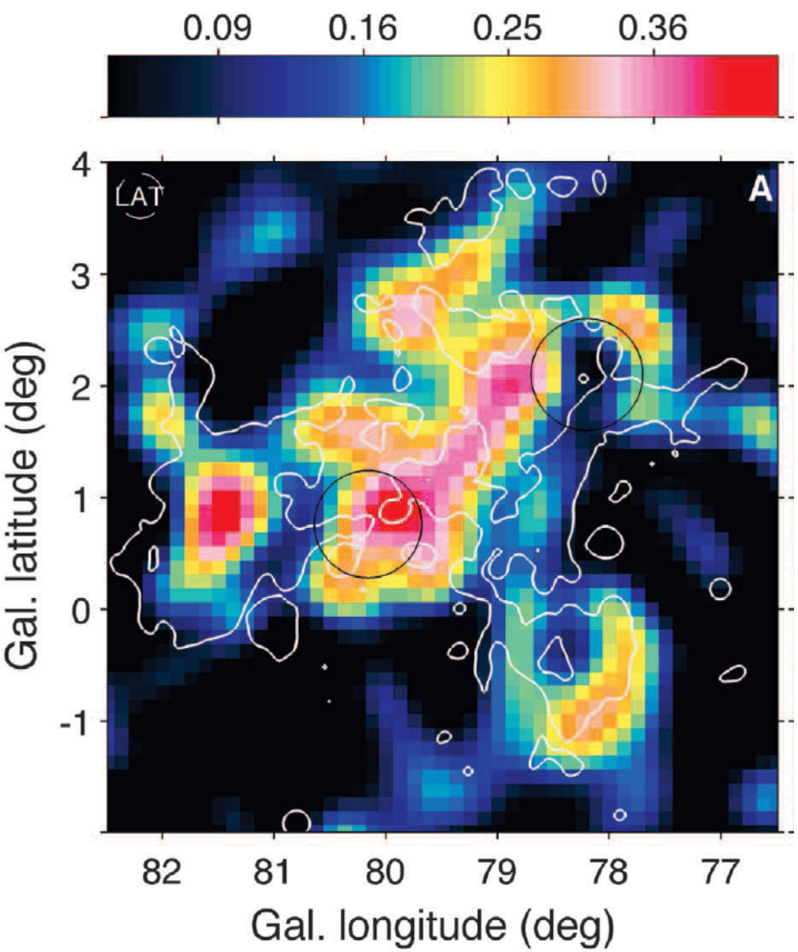
Cygnus Cocoon

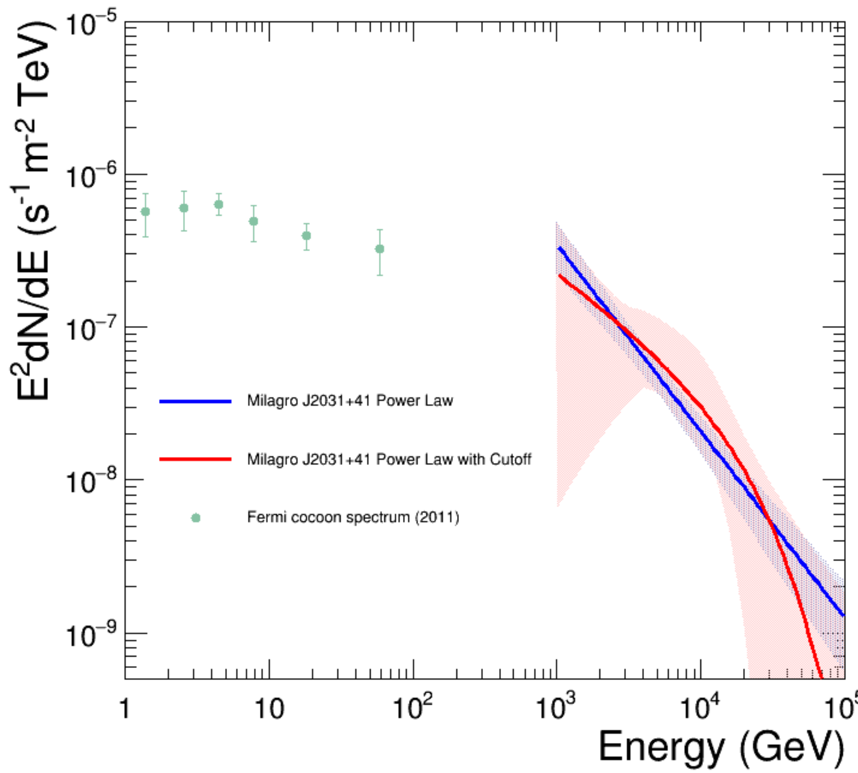
- Fermi-LAT detection of hard and extended GeV gamma-ray emission in Cygnus
- “Cocoon” of freshly accelerated cosmic rays
- Extent ~ 50 pc between OB2 and SNR Gamma Cygni
- Origin possibly attributed to Gamma Cygni or/and OB2?



Ackermann, M., et al. 2011, Science, 334, 1103

Cygnus Cocoon





Ackermann, M., et al. 2011, Science, 334, 1103

Cocoon Region with FermiLAT data

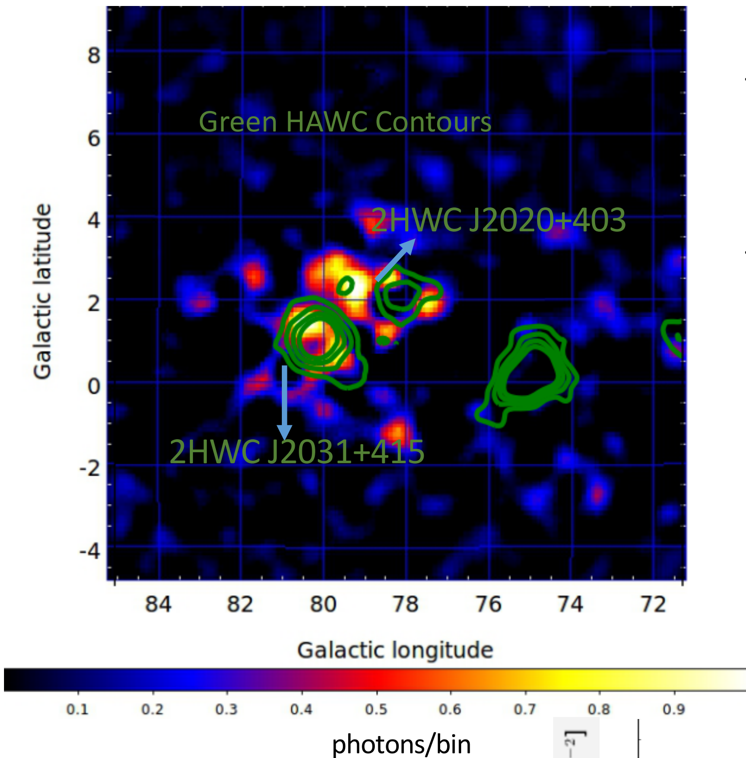
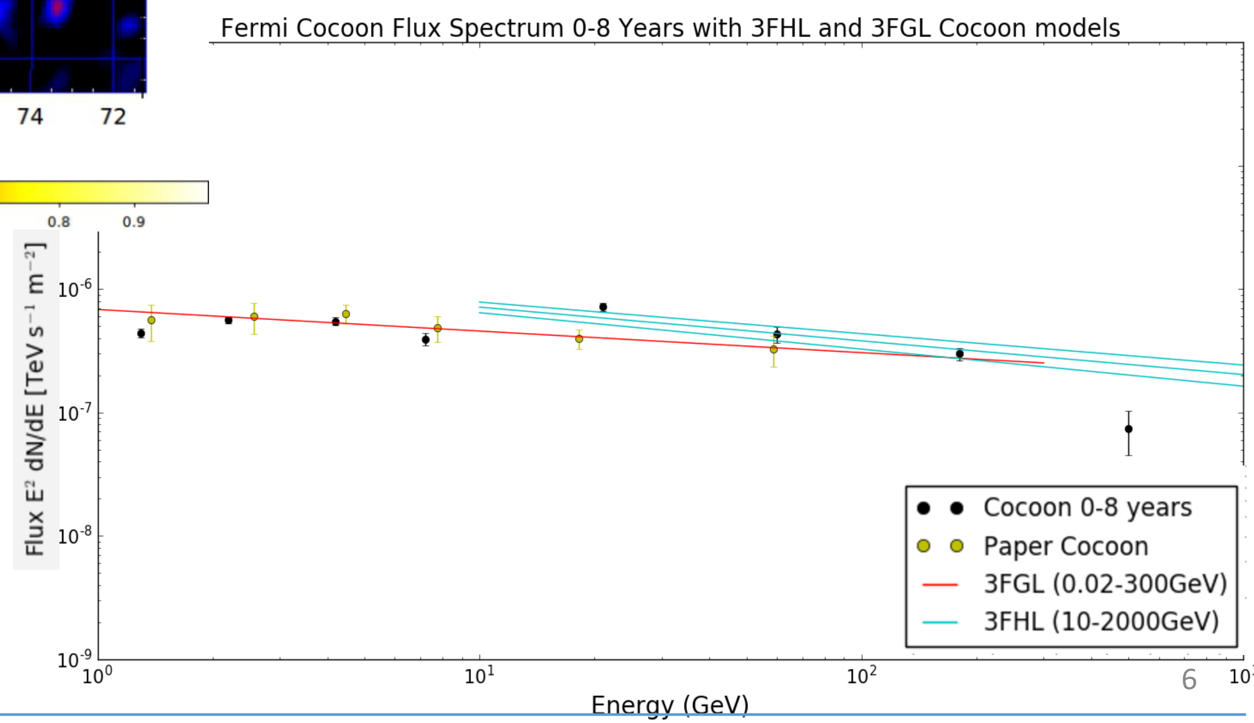


Fig. left: Residual count map of the Cocoon region (Fermi Science tools, pass 8 data, clean) with 5σ, 8σ & 11σ contours from HAWC significance map

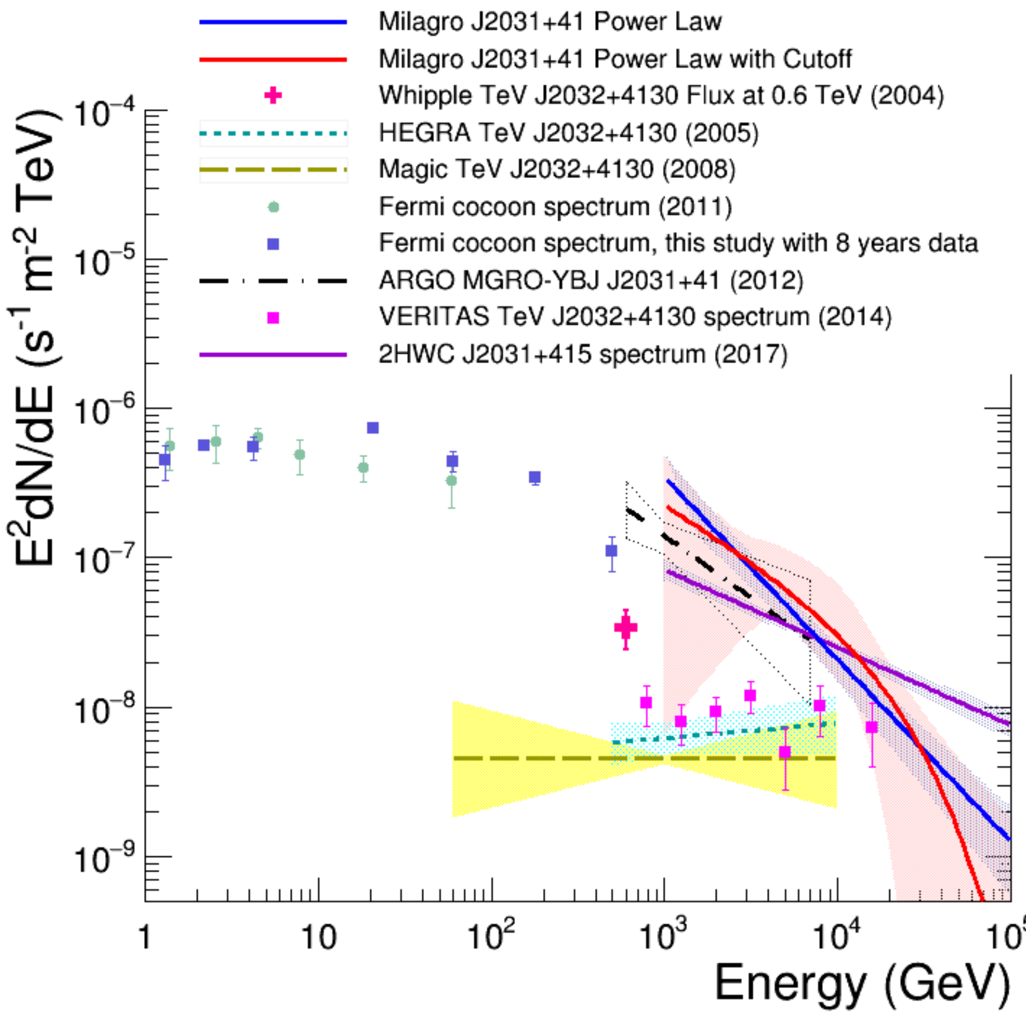
Fig. bottom right: Published 2 year cocoon spectrum by Fermi and the spectrum obtained with Fermi tools

Caveat: Used publicly available isotropic and diffuse background. For 2011 paper, a specific diffuse emission background template used by Fermi



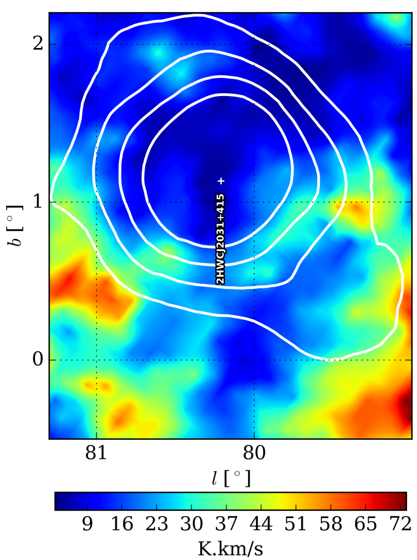
Comparison between different observations

- Detected higher flux by wide field TeV observatories
- Extrapolation of the HAWC spectrum at GeV energies consistent with the extension of the Fermi Cocoon spectrum
- ARGO J2031+41 possible counterpart of Cocoon at TeV energies [*Bartoli, B., et al. 2014, ApJ, 790, 152*]
- Relation between TeV sources and GeV emission needs further studies



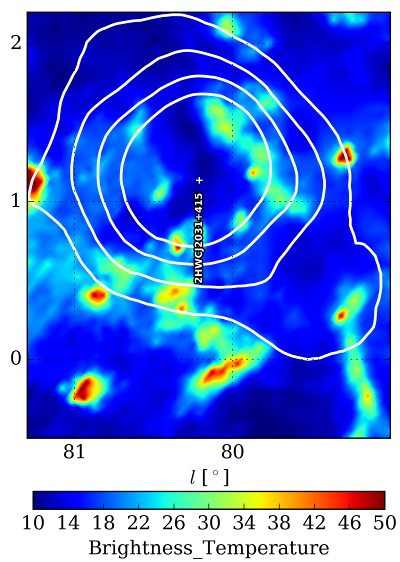
J2031 region at different wavelength

25 months HAWC contours (5, 7, 9, 11) overlaid on top of CO gas distribution map by DAME survey



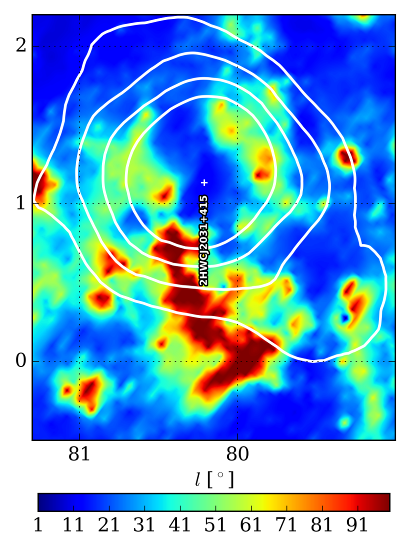
https://www.cfa.harvard.edu/rtdc/CO/NumberedRegions/DHT10/index.html

25 months HAWC contours (5, 7, 9, 11) overlaid on top of atomic hydrogen gas distribution map by CGPS survey

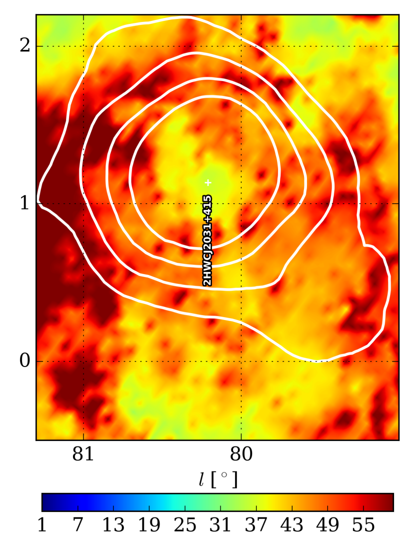


http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/cgps/

25 months HAWC contours (5, 7, 9, 11) overlaid on top of Spitzer MIPS 24 μm image from the MIPSGAL survey



25 months HAWC contours (5, 7, 9, 11) overlaid on top of Spitzer IRAC 8 μm image



http://irsa.ipac.caltech.edu/data/SPITZER/Cygnus-X/

Morphological Studies

- Source Spectrum $$\frac{dN}{dE} = I_0 \frac{E}{E_0}^{-\Gamma}$$

- Morphological shapes used to model 2HWC J2031+415
  1) A Simple Gaussian Shape
  2) A Pulsar Diffusion Model

  - Based on the morphological studies of Geminga & PSR B0656+14
  - Electrons and Positrons diffused off from the PWN TeV J2032+4130
  - TeV Gamma-Ray emission via Inverse Compton scattering
  - PSR J2032+4127 closer to Geminga and PSR B0656+14 in age

Name	Age (kyr)	Distance (pc)	$\dot{E}$ (erg/s)
PSR J2032+4127	181	1700	1.7e35
Geminga	342	250	3.2e34
PSR B0656+14	111	288	3.8e34

http://www.atnf.csiro.au/people/pulsar/psrcat/

- Multi-Mission Maximum Likelihood (3ML) *[Vianello, G., et al. 2015, 34th ICRC, PoS, 1042]*

Comparison between the Morphologies Studied

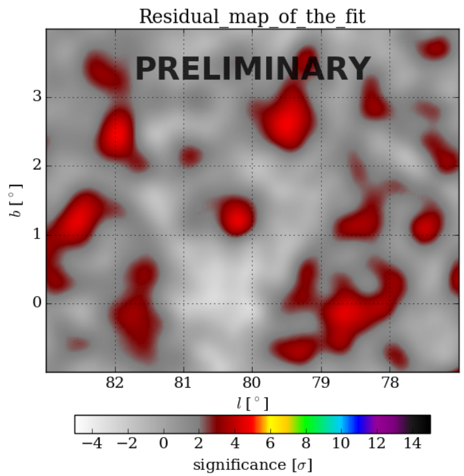


Fig. 1. (left): Residual map of the multisource fit with a simple Gaussian at 2HWC J2031 location and a point source at 2HWC J2020 location

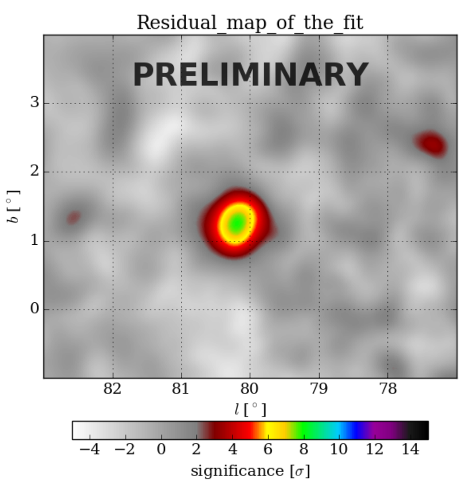
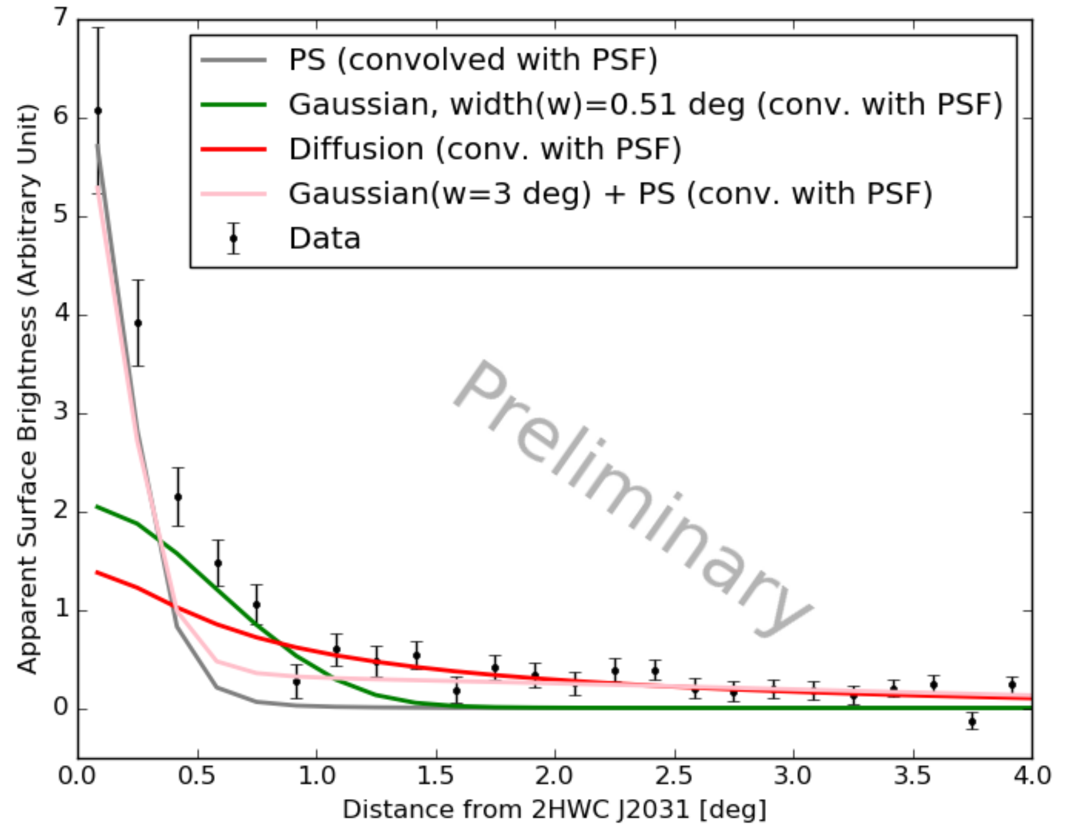


Fig. 2. (left): Residual map for the multisource fit with a pulsar diffusion model at 2HWC J2031 location and a point source at 2HWC J2020 location



Summary

- Contribution from overlapping sources to TeV emission at the cocoon region unclear
- First study of morphology in Cygnus Region with HAWC data (including multi-source fit, physics modelling)
- Next: Joint analysis with Fermi-LAT, VERITAS and HAWC data (including new HAWC energy estimator, in preparation)