Fermi-LAT detection of the massive star forming region W49A in high-energy gamma rays

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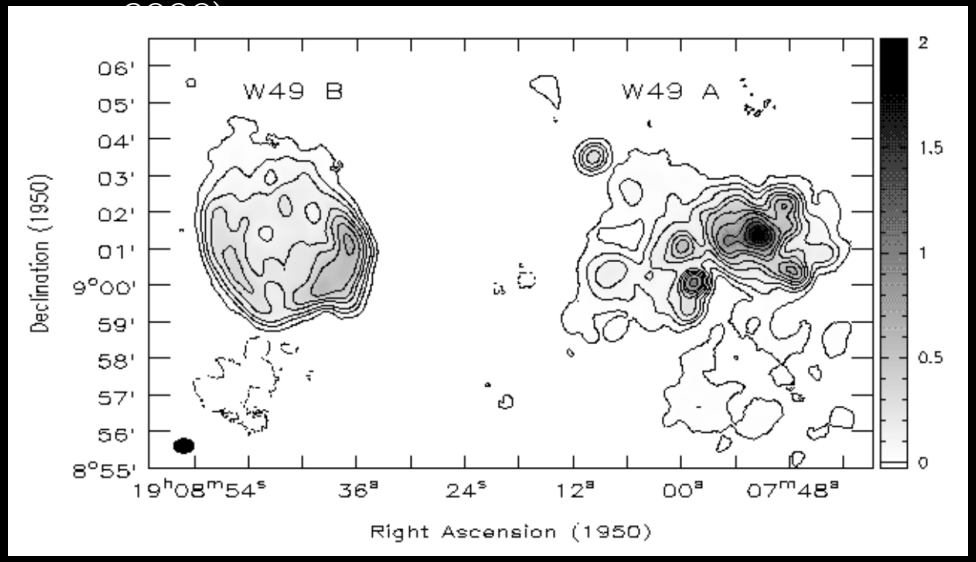
The W49 region

VLA (21 cm) observations (Brogan & Troland,

SNR W49B



Star forming region W49A

- Mixed-morphology SNR (radio shell of ~ 3' x 4', centrally filled with thermal X rays)
- Age ~ 1 – 4 kyr (Moffett & Reynolds 1994)
- D ~ 10 kpc (Zhu et al. 2014)
- Interacting with dense MC

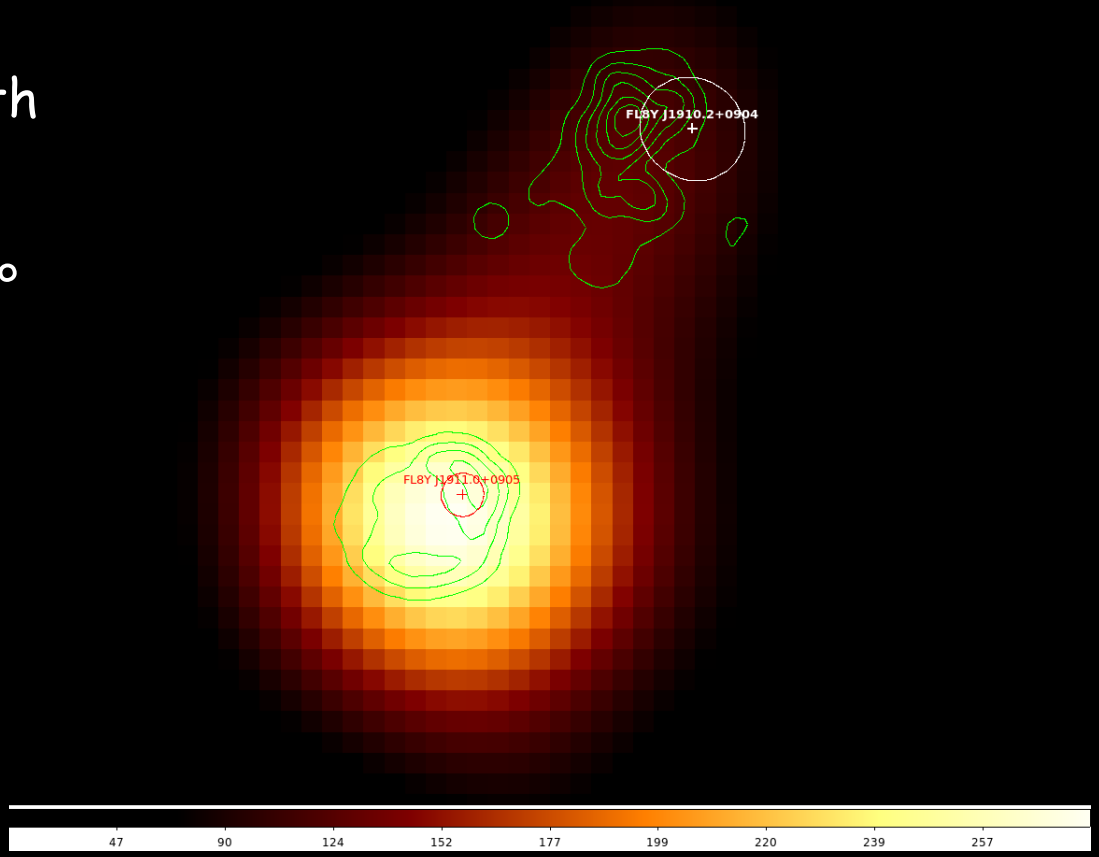
- D = 11.1 +- 0.7 kpc (Zhang et al. 2013)
- Located in the densest 15 pc of a 10^6 $M_\odot$ GMC of ~ 100 pc
- Powered by the equivalent of ~100 O7 Stars (Vacca 1994) and contains numerous UC HII regions (De Pree et al. 1997)
- One of the most massive star forming regions outside the Galactic centre

Recent Fermi + HESS paper : Abdalla et al. 2018, A&A, 612, A5

The W49 region & FL8Y

- FL8Y J1910.2+0904 coincident with the massive star forming region W49A
  - RA = 287.5535°, Dec = 9.0756°
  - Signif_Avg = 10.321

- FL8Y J1911.0+0905 coincident with the SNR W49B (see Fermi+H.E.S.S. paper)



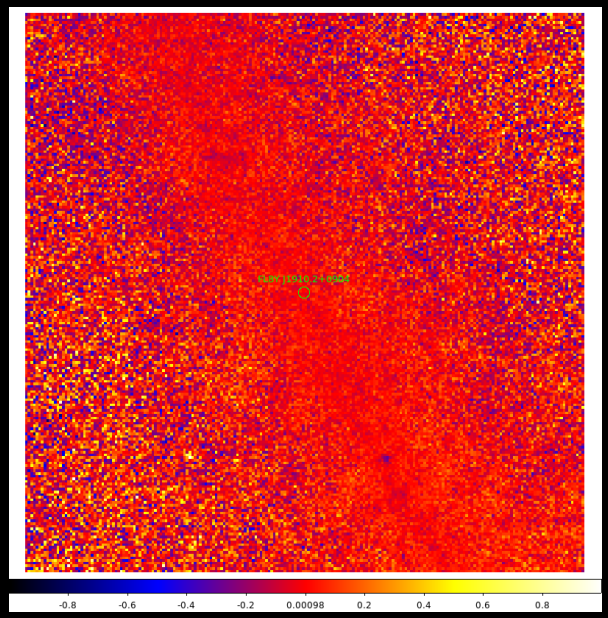
H.E.S.S. excess map (from the paper) + Radio contours (NVSS) + FL8Y sources

W49A analysis

- Fermi re-analysis (with the Enrico package) :
  - XML Model
    - From FL8Y list of sources :
      - → ROI of 15°
      - → Fix params if more than 5° away from the source or Signif_Avg < 5
- Data
  - Dates : 05/08/2008 → 05/01/2018
  - Energy range : 300 MeV – 300 GeV
- Analysis
  - P8R2_SOURCE_V6, Evclass = 128, Evtype = 56 (PSF1,2,3)

W49A analysis : Results

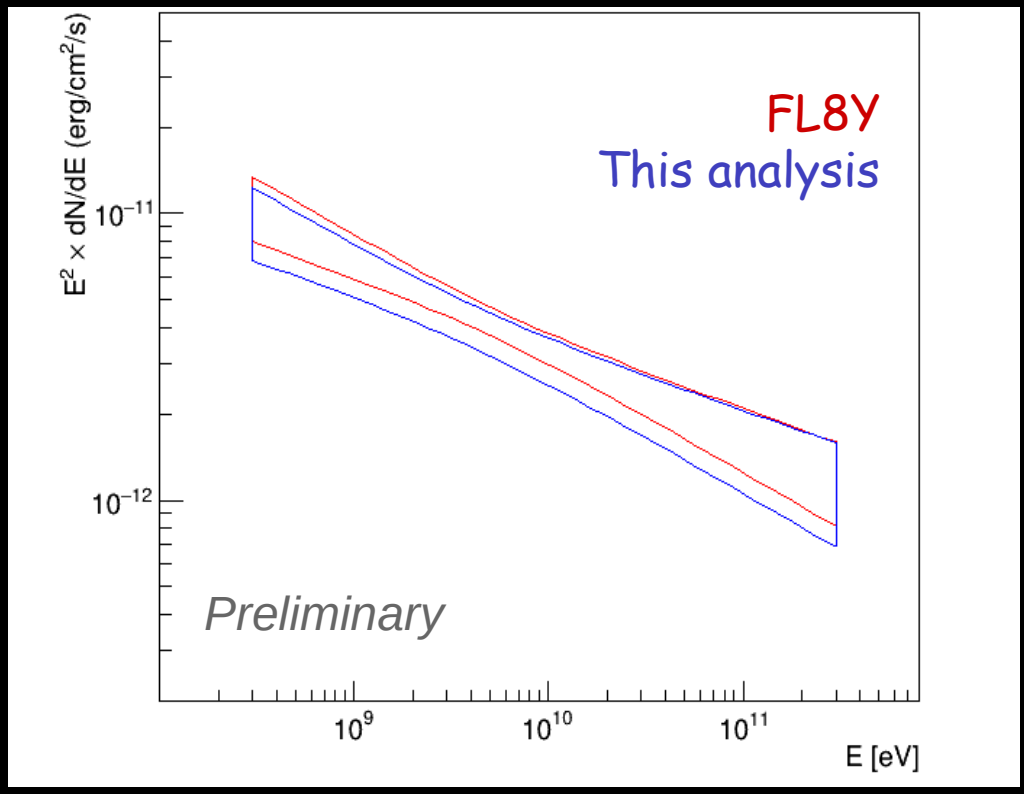
- Nice residuals map

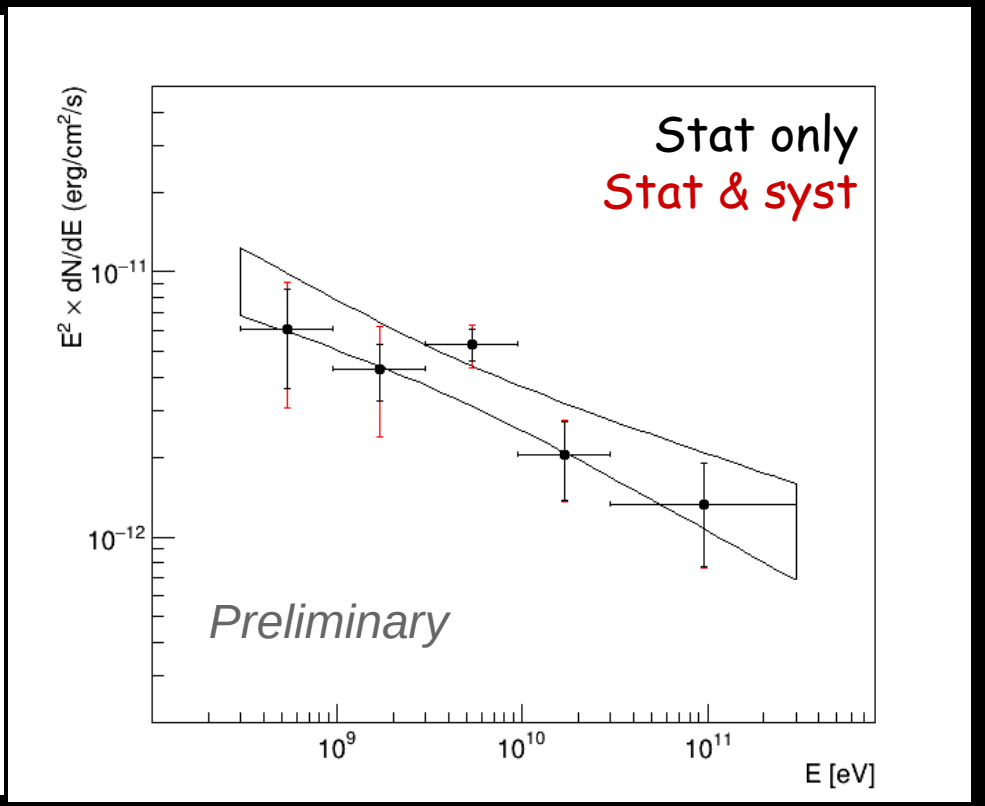


- Source parameters :
  - TS = 213.8
  - Index = $2.32 \pm 0.05_{stat} \pm 0.09_{syst}$
  - E_p = 4204.31 MeV
  - Prefactor = $(14.16 \pm 0.99_{stat} \pm 2.43_{syst}) \times 10^{-14}$ $cm^{-2}s^{-1}MeV^{-1}$
  - Systematics estimation :
    - → Re-fit and fix the scale of the obtained galactic diffuse to 0.94 and 1.06

W49A analysis : SED

- Nice agreement with FL8Y spectrum



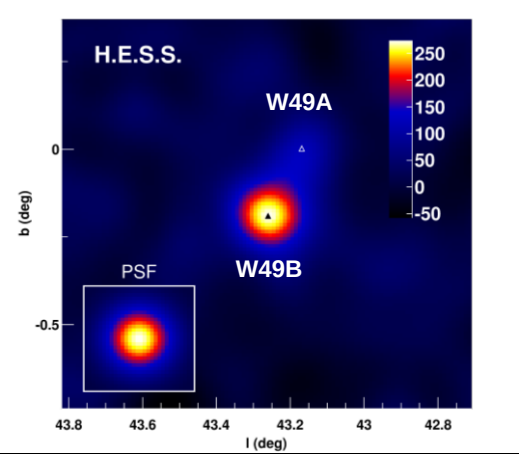


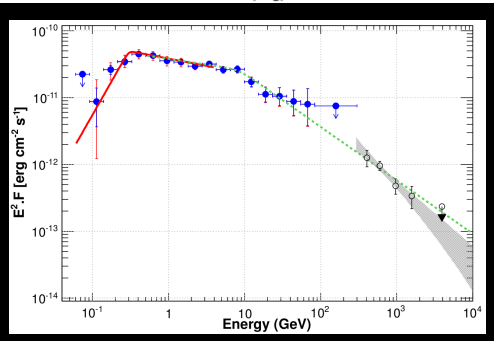
Nice agreement with the spectrum obtained in FL8Y !

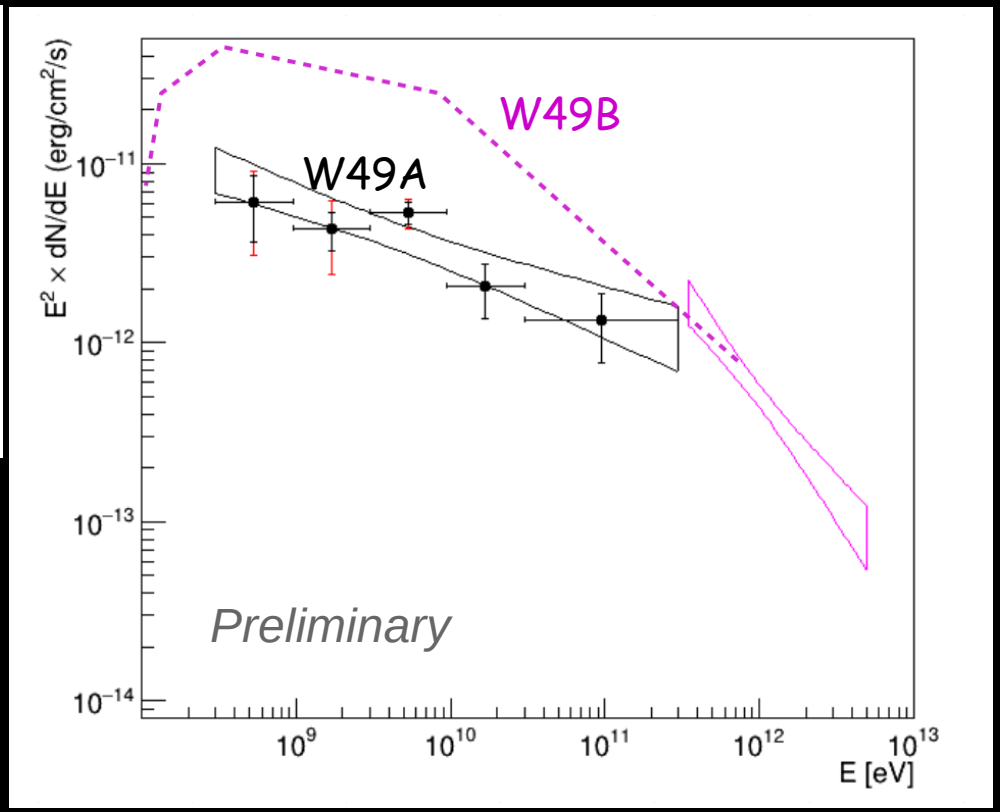
W49A analysis : comparison with TeV data

- SED : Comparison with TeV data
  - No detection at TeV with H.E.S.S.

VHE γ-ray emission is observed towards W49A with the primary analysis but it could not be confirmed (above 5σ) with the cross-check analysis. Therefore, only the VHE emission coincident with W49B is discussed in the following.







W49B stats :
(ON,OFF,alpha) = (1141, 16017, 0.047) → N_γ = 388.2

With the same background estimation, to get 5σ N_{ON} = 897. This corresponds to N_γ = 145.2

Scaling the W49B spectrum by the ratio (assuming same index)...

W49A analysis : comparison with TeV data

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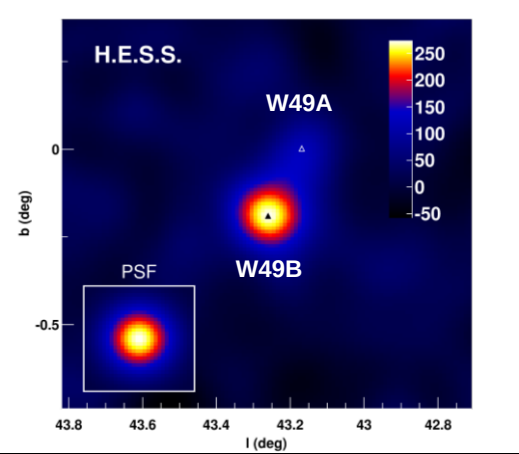
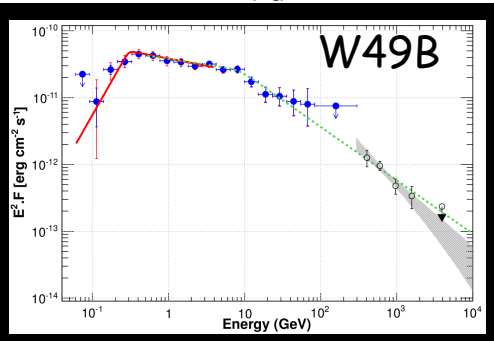
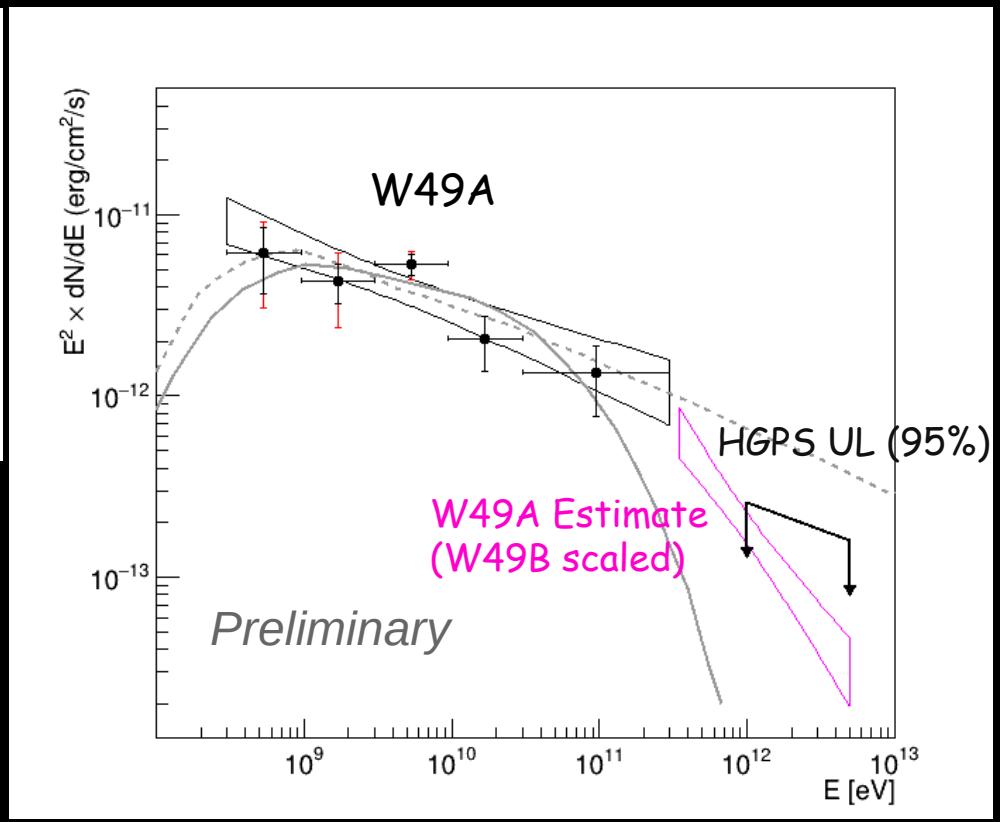


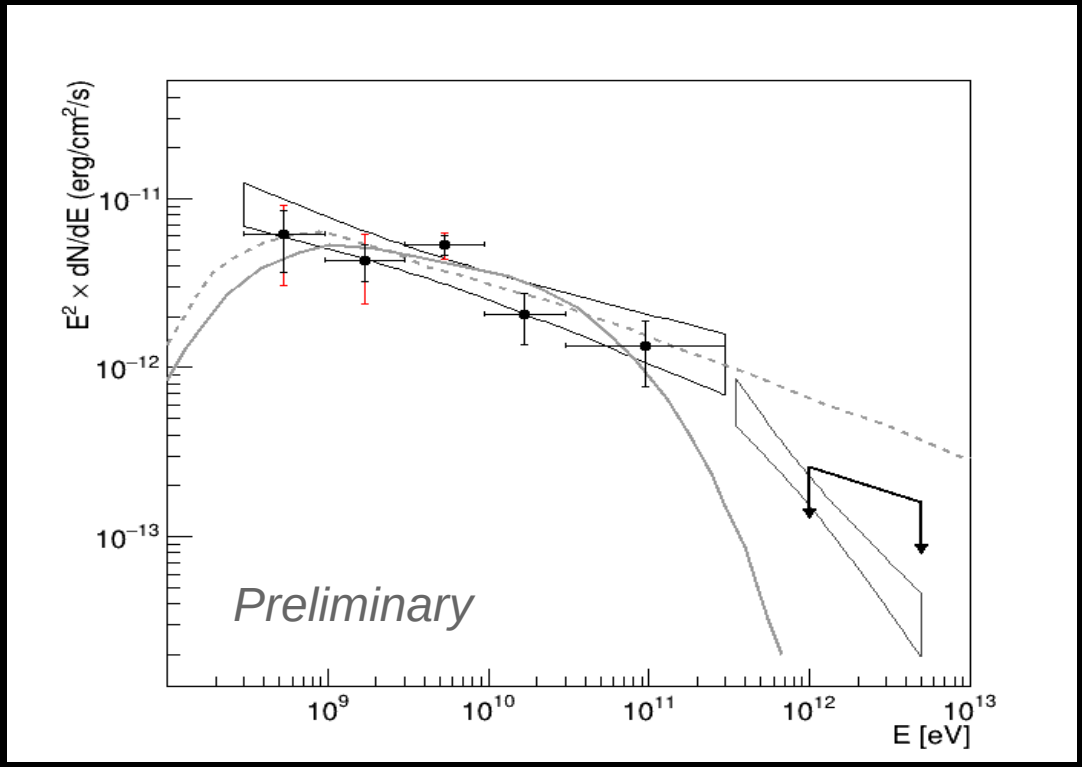




Break around 300 GeV in the gamma-ray spectrum ?

Hadronic model fits using naima

- MCMC fitting routines of naima (Zabalza, 2015)
- 2.5σ improvement with an exponential cut-off
- Low cut-off energy in proton spectrum = 500 (+600 / -200) GeV
- Exp PL index = 2.1 ± 0.1
- PL index = 2.4 ± 0.1
- Wp (E > 1 GeV) = 2.5 (± 0.6) x10^{51} erg/cm^3 for Exp PL ; 3.5 (± 0.4) x10^{51} erg/cm^3 for simple PL



A major factory of Galactic cosmic-rays ?

- Similar differential luminosities

- Gamma-ray spectral index ~ 2.3 in all cases

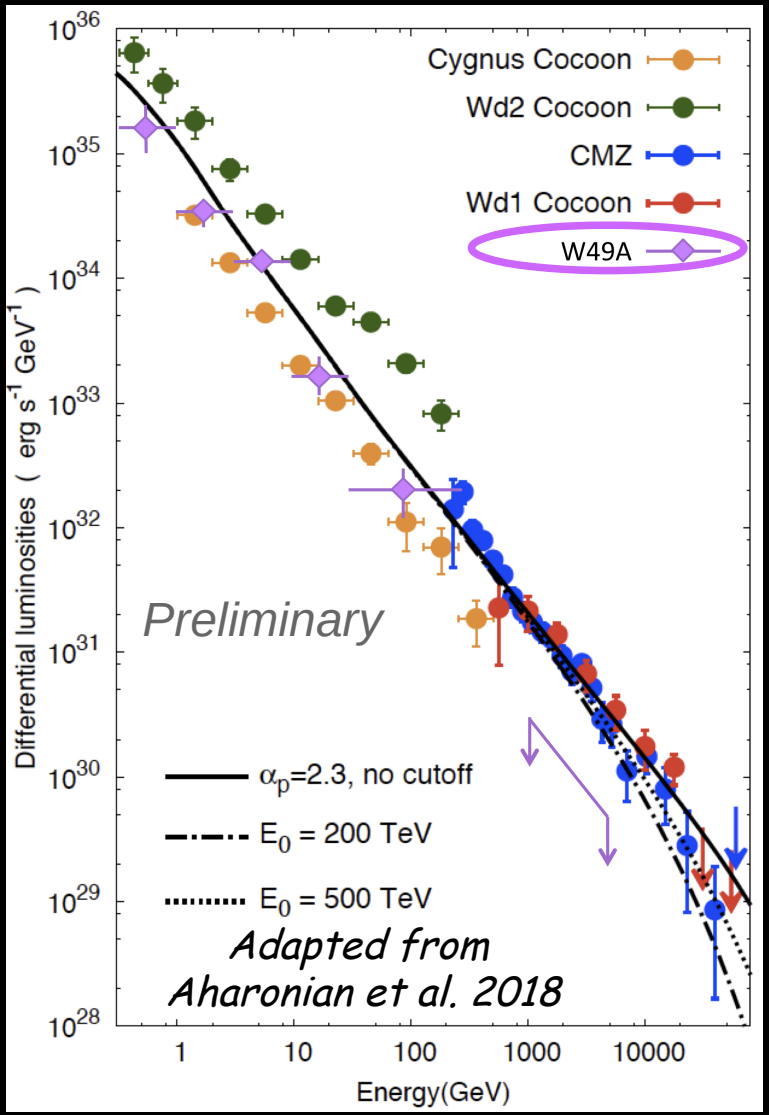
- Points towards same acceleration mechanism : interacting winds of massive stars

- Using a catalog of O stars (Wu et al. 2016), one can estimate Ekin > 7×10^{37} erg/s in W49A vs Ekin = 2×10^{38} erg/s for Cygnus Cocoon

- This difference cannot explain the apparent high energy break in W49A

Would be due to lack of SNRs in W49A ?

Wind interactions are less efficient than SNR shocks ?



Summary & Outlook

- SFR are cosmic-ray factories and shine at gamma-rays
- Cygnus cocoon was the only confirmed case, a few candidates
- Are SFR PeVatrons ?

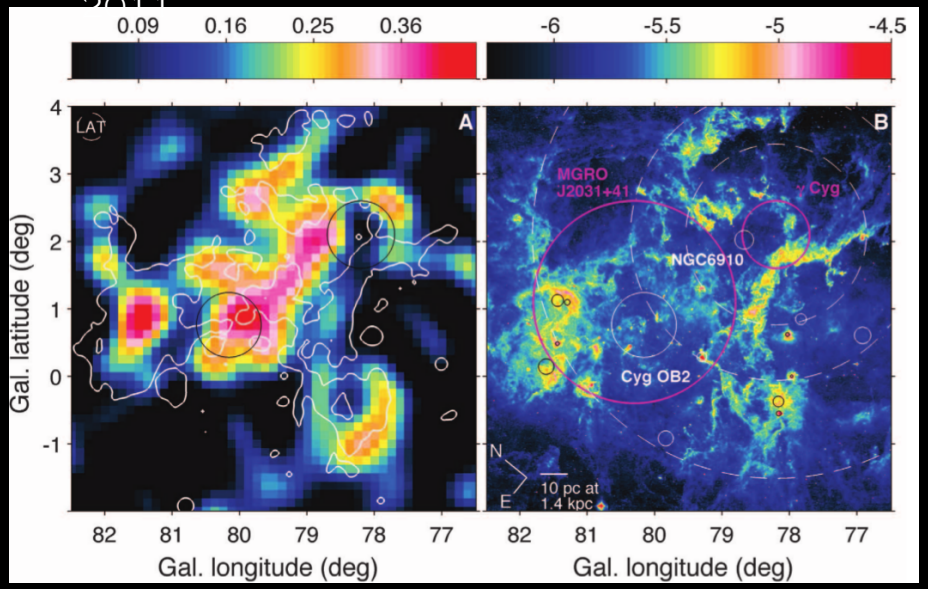
- W49A is in the FL8Y source list, re-analysed in this work
- Comparison with TeV data : energy break at rather low energies (~300 GeV → $E_{max,p}$ <10 TeV)
- Potentially showing that collective effects of stellar winds are less efficient than a SNR shockwave

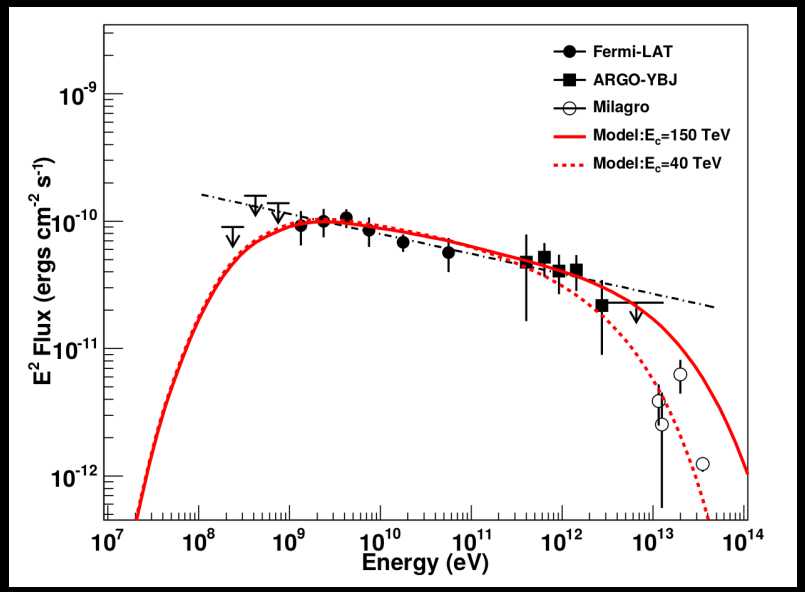
- Prime sources for CTA !

Additionnal slides

The Cygnus cocoon

ACKERMANN ET AL.
2011





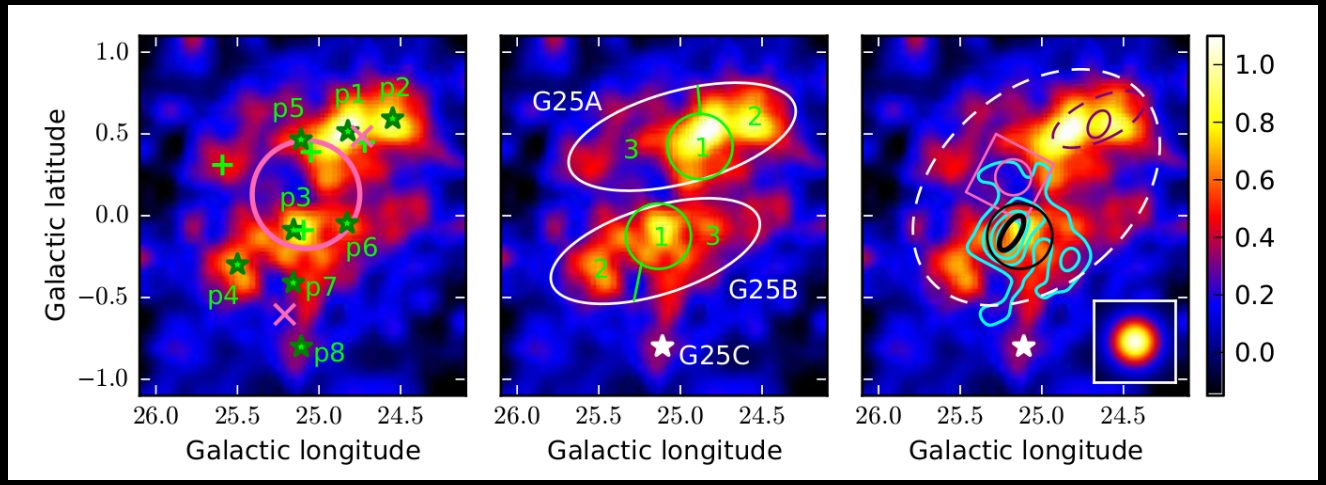
- Extended gamma-ray emission from the Cygnus region detected by the Fermi-LAT
- Freshly accelerated CRs fill a cavity probably created by Cyg OB2 & NGC 6910
- First evidence of CR acceleration from collective effect of of the winds of massive stars

  → SFRs can be CR factories

  → ARGO results : $E_{max,p}$ = 150 TeV

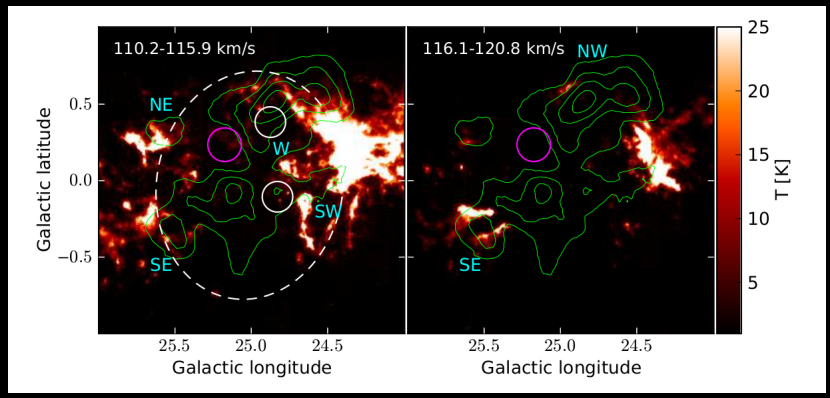
G25.0+0.0

- Fermi-LAT detection of extended gamma-ray emission in the G25 region (Katsuta et al. 2017)



G25A 1,2,3 + G25B 2,3 : Hard spectrum (Γ = 2.1)

- Likely association with a massive SFR
  - As in Cygnus X : a « cocoon » scenario is favored (but PWNe are present)



Other candidates ?

- NGC 3603 (Yang & Aharonian, 2017)
  - Extended (~ 1° radius) HE gamma-ray emission coincident with the most massive HII region in the Galaxy

    … but crowded region with possible counterparts (SNRs/PWNe)
- Westerlund 1 (HESS Collaboration, 2012)
  - Same as above
- Westerlund 2 (HESS 2007 & 2011, Lemoine-Goumard et al. 2011)
  - TeV and GeV emission detected by HESS and the Fermi-LAT

    … but the LAT also detected a very young and energetic pulsar (PSR J1023–5746). The emission is most probably a PWN.

Other candidates ?

- W43 (Lemoine-Goumard et al. 2011, HESS 2018)
  - GeV and TeV detection of a source coincident with W43 but the GeV spectrum has a Pulsar-like spectrum, contamination ?
- FHES J2129.9+5833 (Ackermann et al. 2018)
  - Extended off-plane source partially overlaping IC 1396 but the association remains to be confirmed
- HESS J1808-204 and HOTS J1907+091 (HESS 2018)
  - Coincident with stellar clusters

    … but also with magnetars (and the part of a SNR shell for HOTS J1907+091)
  - New FL8Y source coincident with HOTS J1907+091