Fermi-LAT detection of γ-ray emission in the vicinity of Westerlund 2 and W43

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on behalf of
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CRISM
(Montpellier, 27 June 2011)

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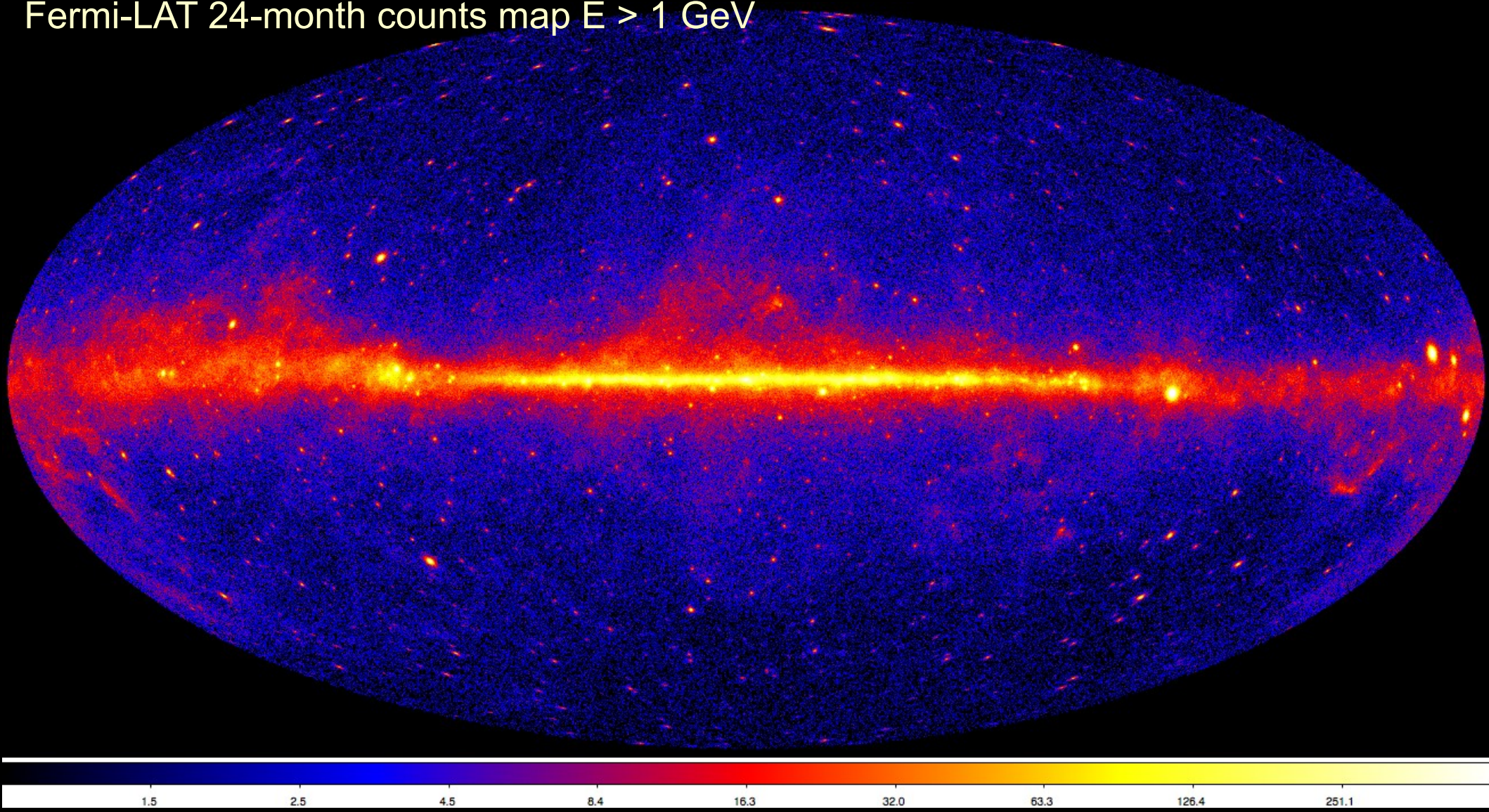
2 years of extensive GeV observations

1888 sources detected using 2 years of data !

Fermi-LAT 24-month counts map E > 1 GeV



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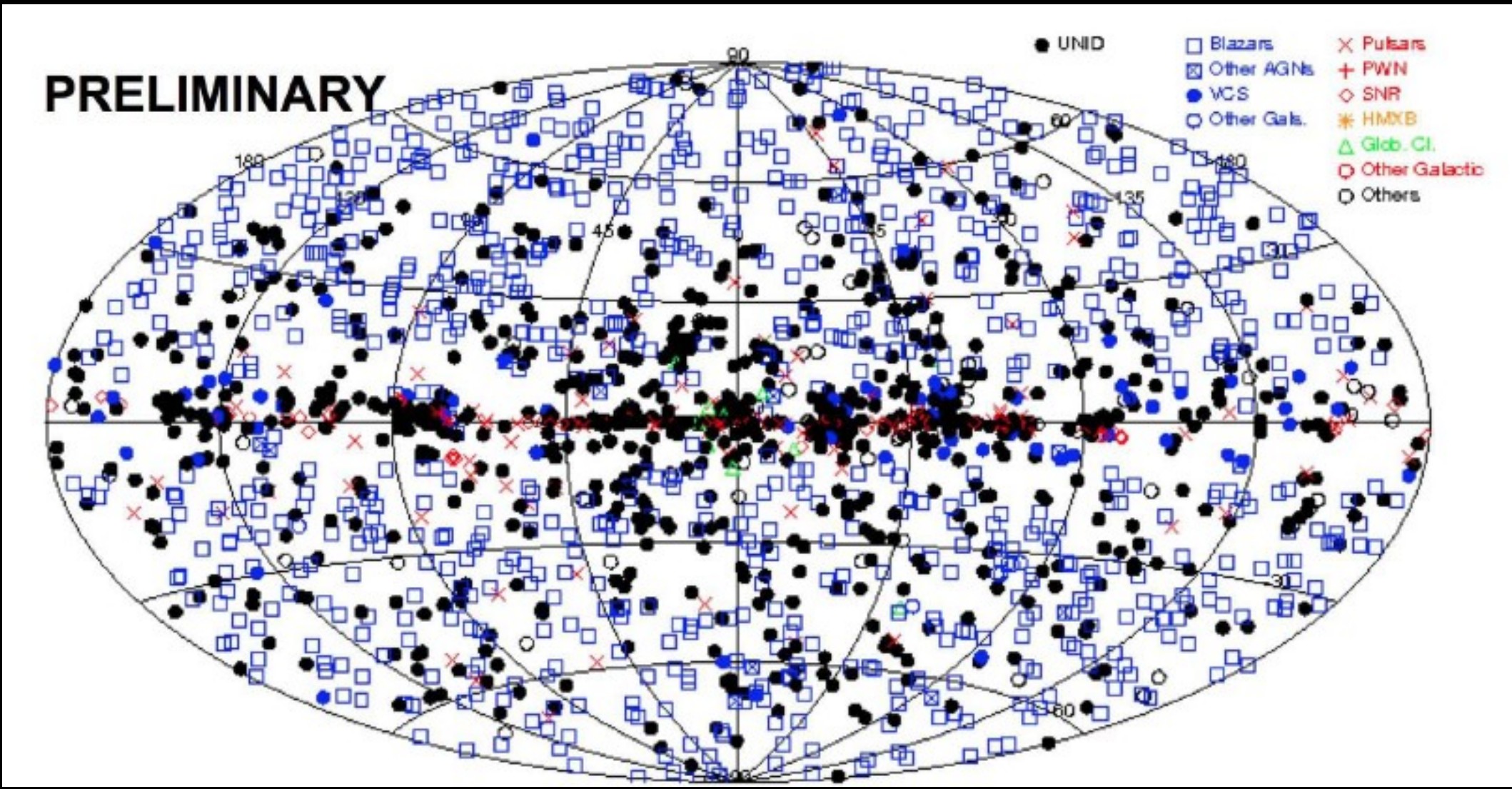


D. Thompson, Fermi Symposium 2011, Roma

What are the GeV sources detected by the LAT ?

Very Preliminary - Work Still In Progress

Type	Number	Percentage of total
Active Galactic Nuclei	832	44%
Candidate Active Galactic Nuclei	268	14%
Unassociated	594	32%
Pulsars (pulsed emission)	86	5%
Pulsars (no pulsations yet)	26	1%
Supernova Remnants/Pulsar Wind Nebulae	60	3%
Globular Clusters	11	< 1%
Other Galaxies	7	< 1%
Binary systems	4	< 1%
TOTAL	1888	100%

D. Thompson, Fermi Symposium 2011, Roma

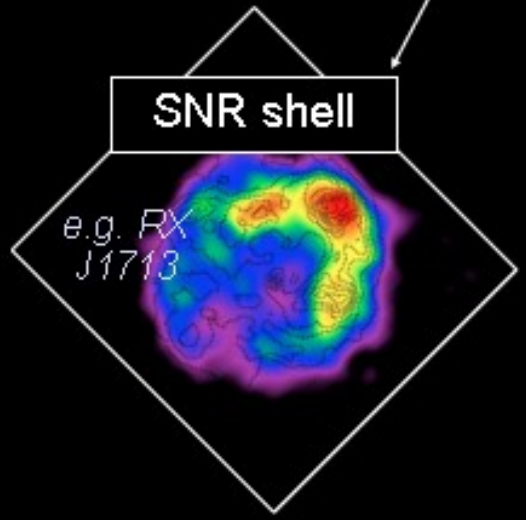
Molecular cloud

Massive star

No acceleration expected until…

Supernova

SNR shell



Molecular cloud

Nearby accelerator?

Yes

Active cloud

No

Passive cloud

(e.g. EGRET galactic clouds)

Massive star

In cluster?

No

Yes

Collective wind interactions

Binary?

No

No acceleration expected until…

Yes

Compact companion?

No

Yes

Supernova

Massive companion?

Neutron star companion?

Yes

Neutron star remains?

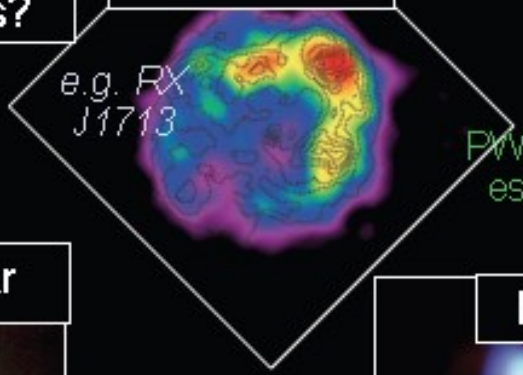
Binary PWN

No

Yes

SNR shell

Radio jets?



Yes

Composite SNR

PWN outlasts or escapes SNR

Colliding wind sys.

Microquasar

PWN

Molecular cloud

Nearby accelerator?

Yes

Active cloud

No

Passive cloud

(e.g. EGRET galactic clouds)

Massive star

In cluster?

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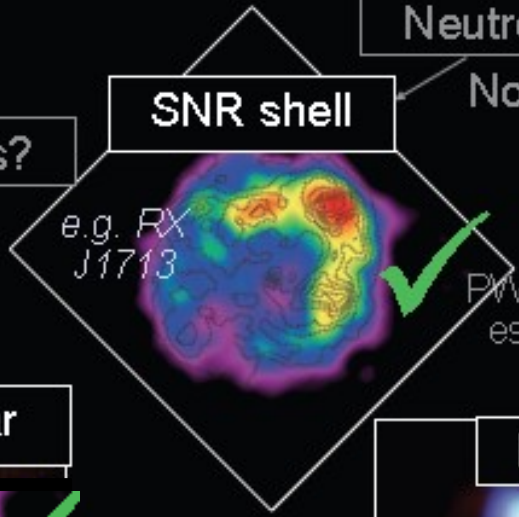

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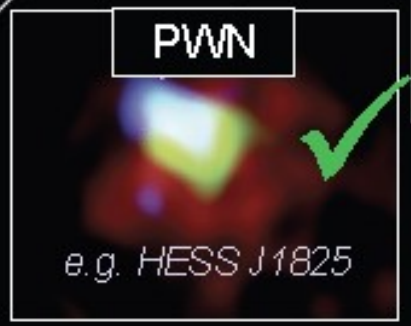


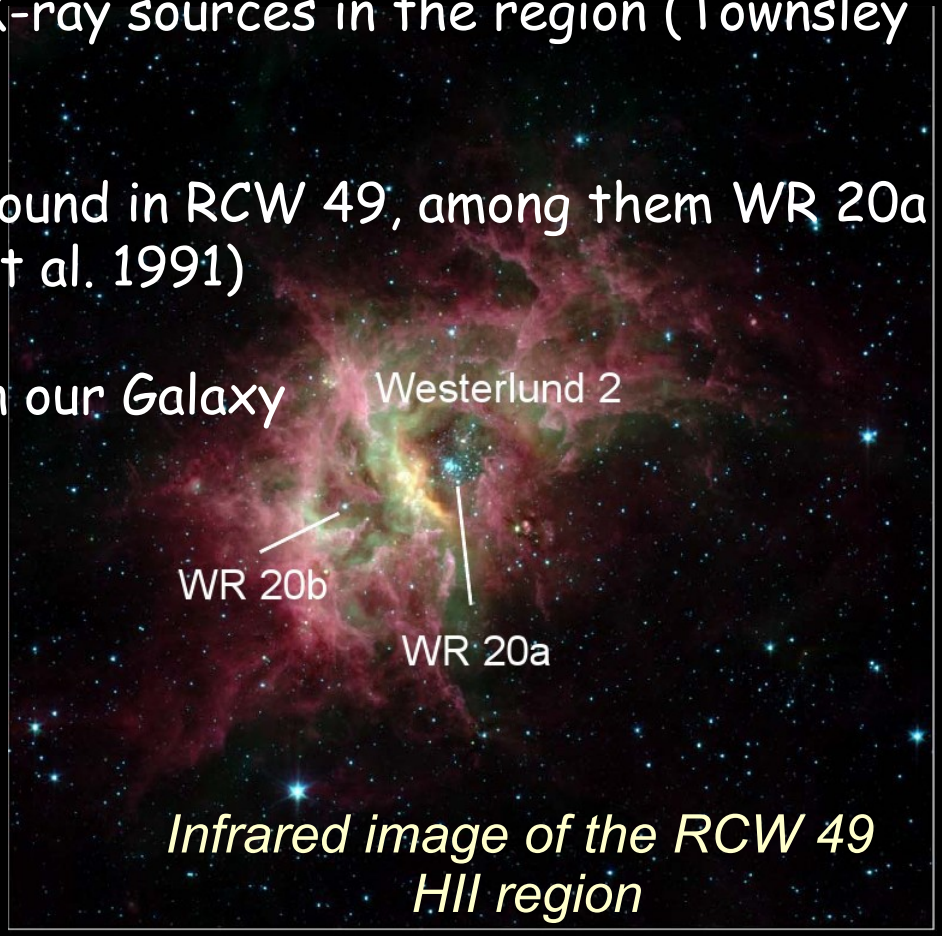
A brief introduction to Westerlund 2

RCW 49 is a giant HII region located towards the outer edge of the Carina arm (distance: 2-8 kpc)

Chandra observations uncovered about 500 X-ray sources in the region (Townsley et al. 2004)

Large number of massive Wolf-Rayet stars found in RCW 49, among them WR 20a and WR 20b (Van der Hucht 2001,Shara et al. 1991)

WR20a: most massive binary system known in our Galaxy



Infrared image of the RCW 49 HII region

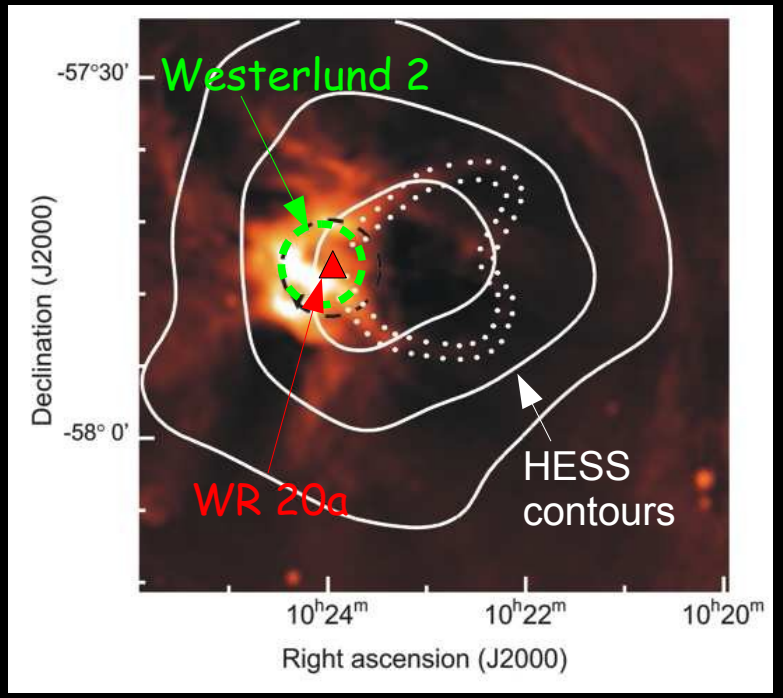
A TeV source in the vicinity of Westerlund 2

- An extended TeV source, HESS J1023-575, was detected *(Aharonian, F., et al. 2007, A&A, 467, 1075)* in the region of Westerlund 2

- Several scenarii to explain this VHE emission :
  - massive WR binary system WR 20a
  - young stellar cluster Westerlund 2
  - DSA in the wind blown bubble

- HESS emission slightly offset from WR 20a and WR 20b
  → disfavors the binary system hypothesis

Cosmic-rays accelerated in expanding stellar winds or supernova blast waves interacting with the boundaries of the blister/Interstellar radiation field are the only feasible scenarii



843 MHz image of the region of Westerlund 2

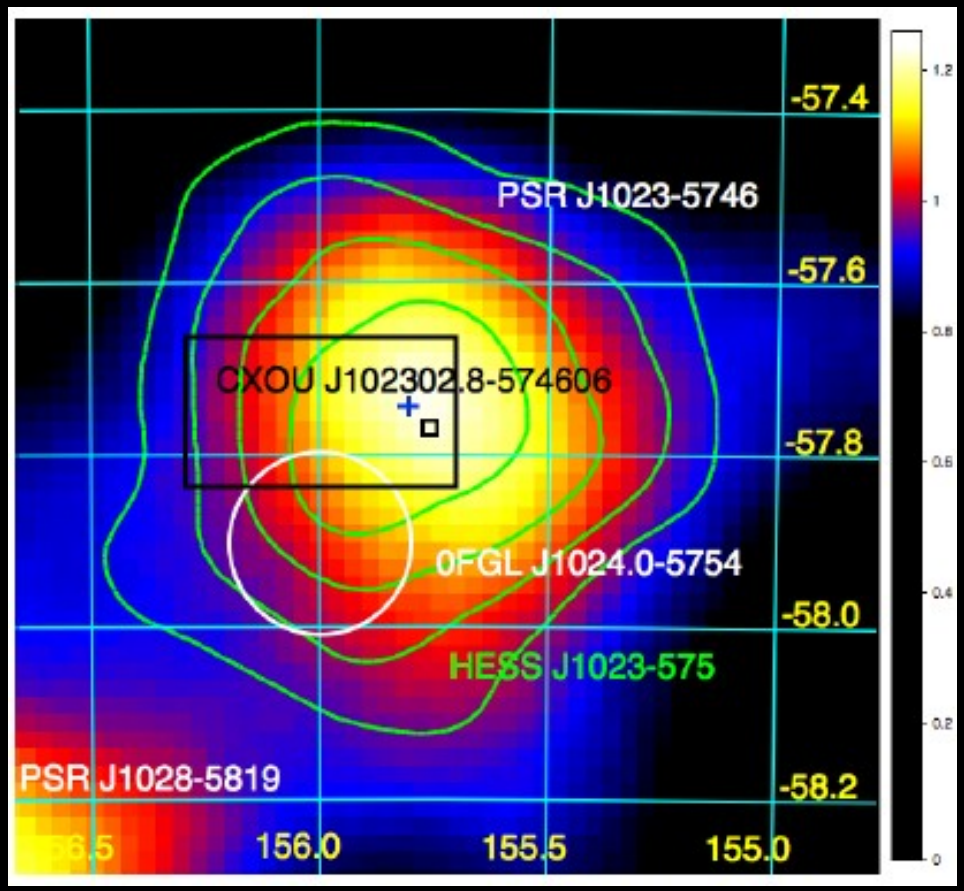
The answer is blowing in the wind

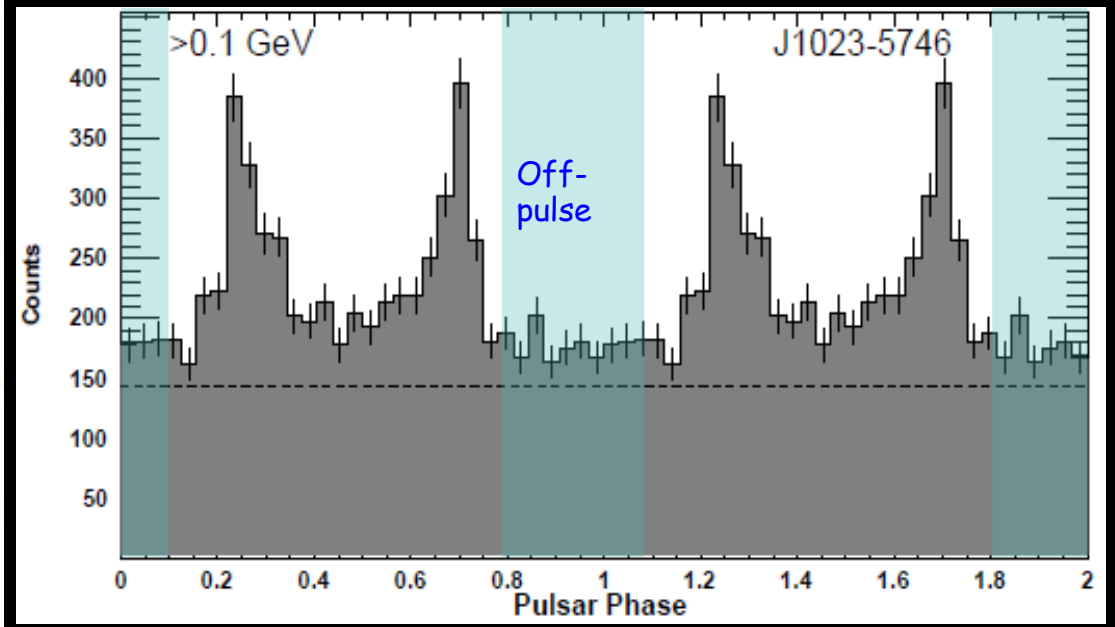
Yousaf M. Butt **Nature, Vol 446, Issue 7139**

A source of astoundingly energetic γ-rays associated with a star cluster might provide a clue to a century-old question: where do the cosmic rays that constantly bombard Earth come from?

Fermi-LAT blind search detection of a new Pulsar !

- Fermi Discovery of the pulsar PSR J1023-5746 (spin-down power of ~10^{37} erg/s) in blind frequency searches *(Saz Parkinson et al., 2010, ApJ, 725, 571)*
- Analysis of Chandra data (0.1 - 10 keV) revealed a faint source, CXOU J102302.8-574606, ~8' away from Westerlund 2 and coincident with the gamma-ray pulsar





A new PWN associated to PSR J1023-5746 ?

(Ackermann et al, 2011, ApJ, 726, 35)

- Analysis of the off-pulse windows of PSR J1023-5746 :
  → detection of a significant emission above 10 GeV (morphological studies are still waiting more statistics)

1. The LAT off-pulse emission is :
   - spatially coincident with the energetic pulsar PSR J1023-5746
   - spatially coincident with the source HESS J1023-575
   - characterized by a hard spectrum which links up with the HESS spectral points

2. The pulsar PSR J1023-5746 is young and energetic => only 0.4% efficiency needed to power the GeV-TeV PWN candidate

3. The HESS source is extended => disfavours emission close to the WR 20a and WR 20b

→ These elements point towards an identification of the off-pulse emission seen by the LAT and the HESS source as the PWN associated to the young pulsar PSR J1023-5746

.....BUT.....

A puzzling PWN candidate ....

X-ray Data (Fujita et al., 2009):

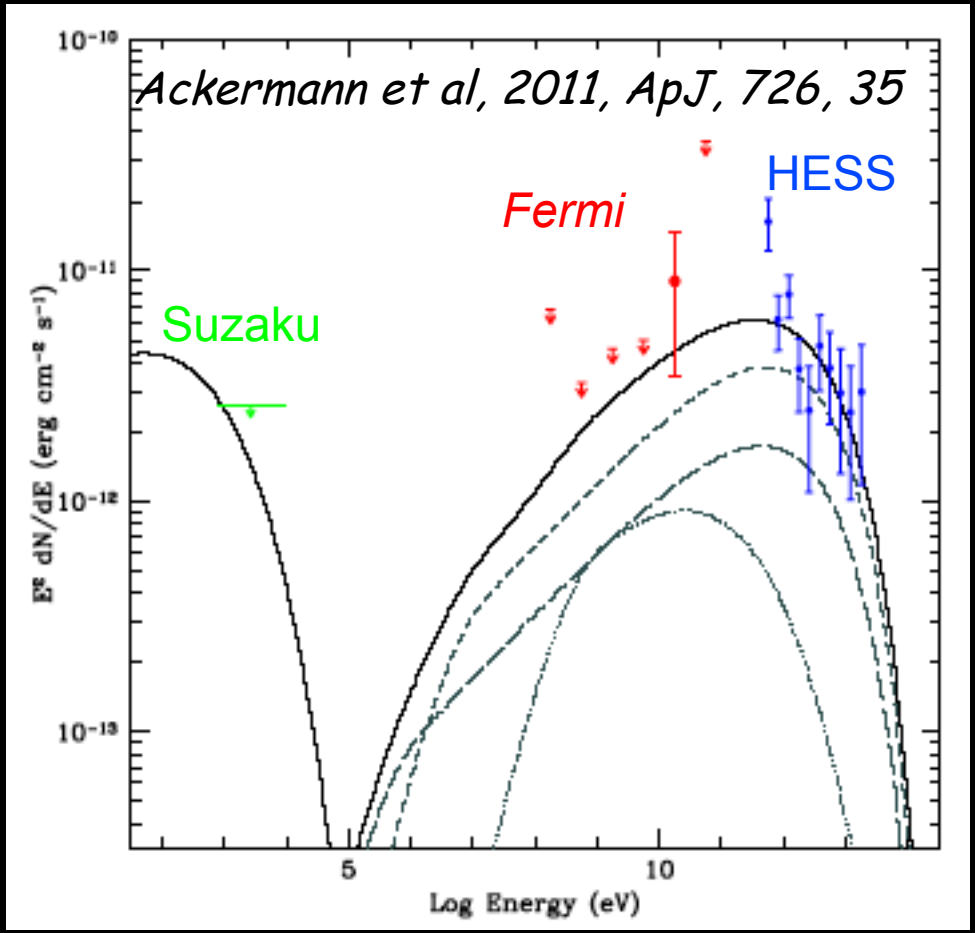
- Limits for X-ray diffuse emission => $\Phi_{NT} < 2.6 \times 10^{-12}$ erg cm^{-2} s^{-1}

Modeling of the MWL data:

B fixed at 5 μG (unconstrained due to X-ray Upper Limit)
Electron power-law index of 2.44 +/- 0.06 and energy cut-off at 60 +/- 45 TeV
Initial spin period of 63 +/- 17 ms

Independent of the origin of the γ-rays, the lack of X-rays is perplexing given its extremely high spin-down luminosity

=> This implies that the population of TeV emitting particles has already cooled and does not shine significantly in X-ray synchrotrons as is the case of most middle aged TeV nebulae



A brief introduction to W43

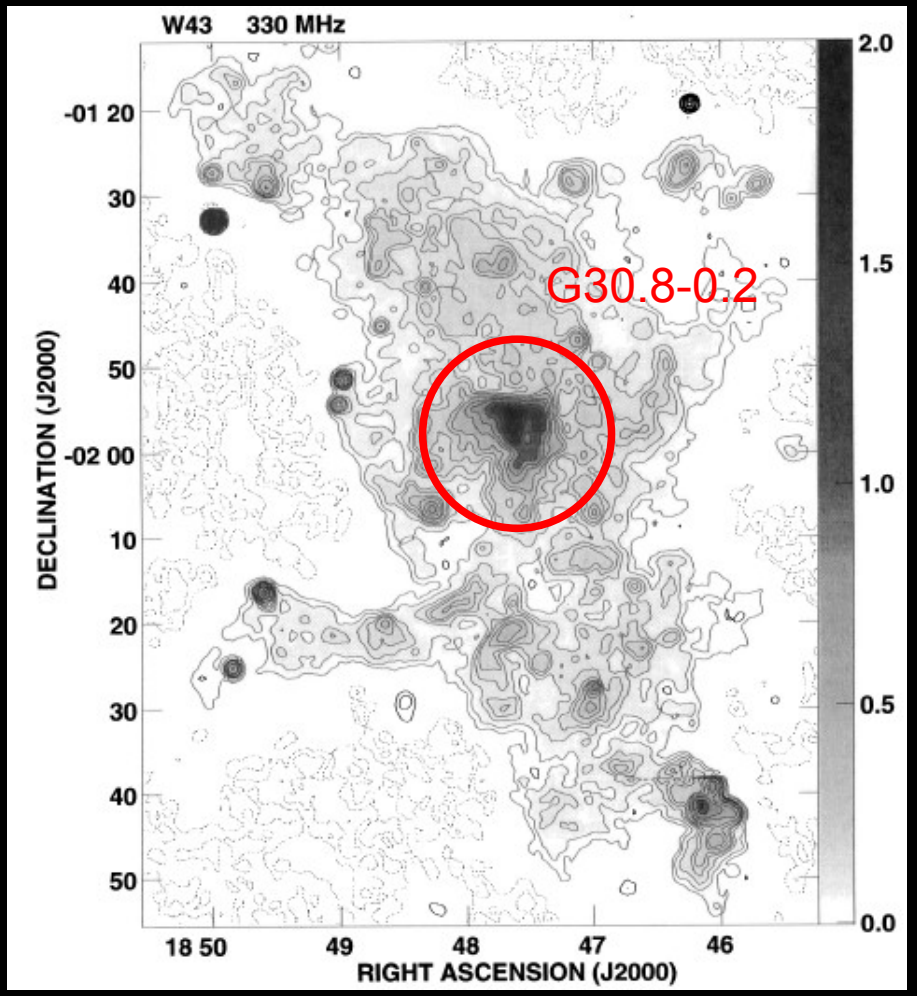
W43 aka G30.8-0.2

Massive star-forming region in the Scutum-Crux spiral arm tangent

Distance : 6 - 7 kpc

This region hosts :

- a giant H II region
- ~10^6 M_{sun} of molecular gas
- WR 121a (WN-type star, i.e. nitrogen dominant WR star)



330 MHz radio image of W43 (VLA, Subrahmanyan & Goss, 1996, MNRAS, 281, 239)

VHE γ-rays : HESS J1848-018

Detected during the HESS Galactic Plane survey:

- Significance : 5 σ (post-trials, ~50 h live-time)
- Significantly extended (rms of 0.32 ° ± 0.20° for a Gaussian)
- Soft spectrum (spectral index of 2.8 ± 0.2) and flux of 2% Crab
- Search for multi-wavelength counterparts (from radio to X-ray)

→ in the direction of (but slightly offset from) W 43, which hosts the giant HII region G30.8-0.2 and the Wolf-Rayet star WR 121a in the main stellar cluster

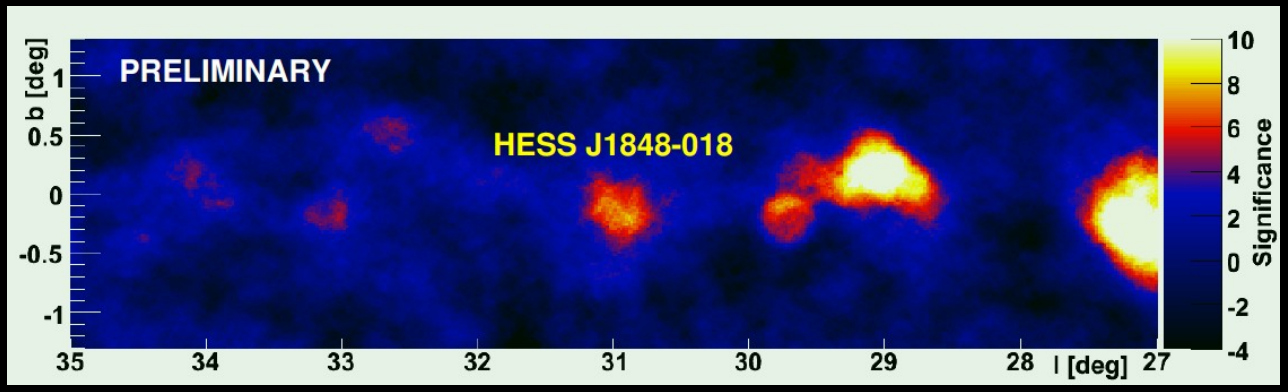
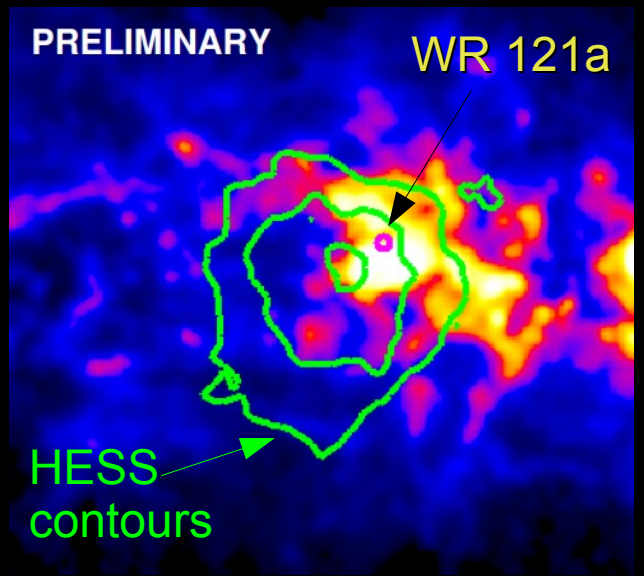


Image from the HESS extended Galactic Plane survey

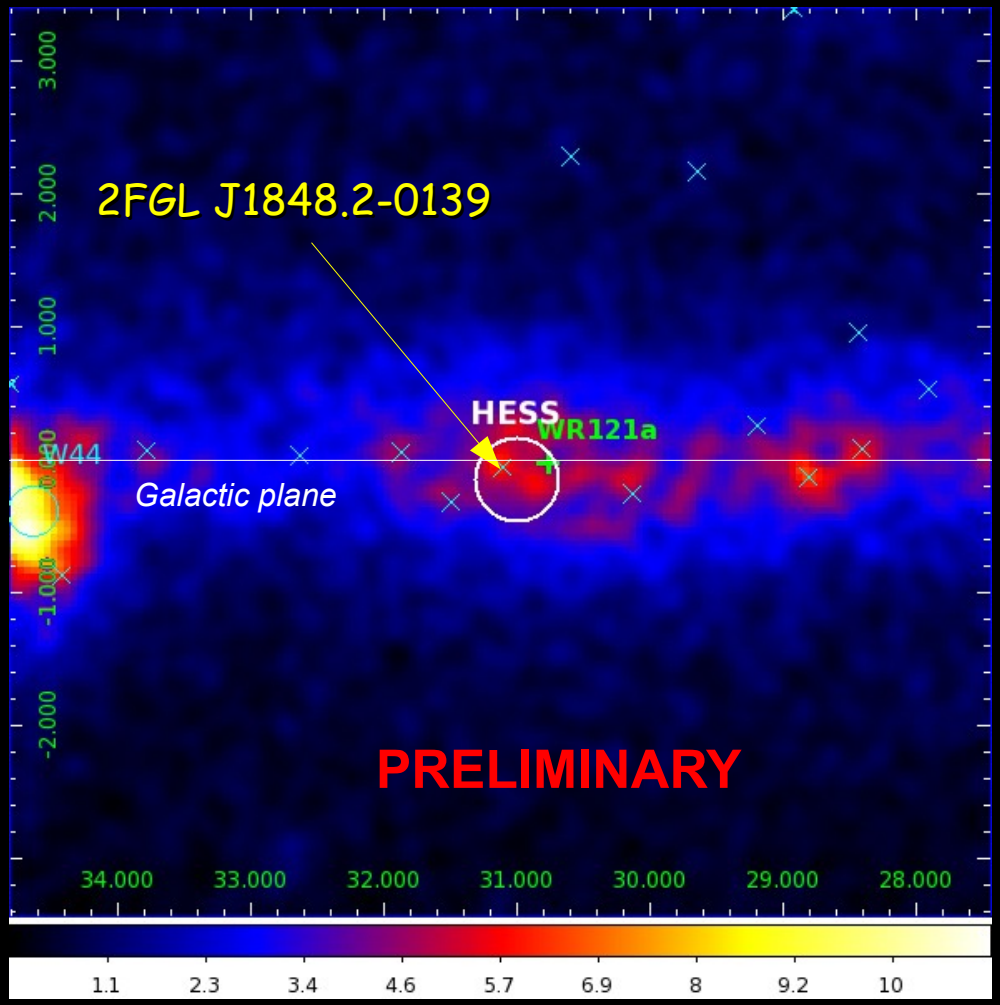


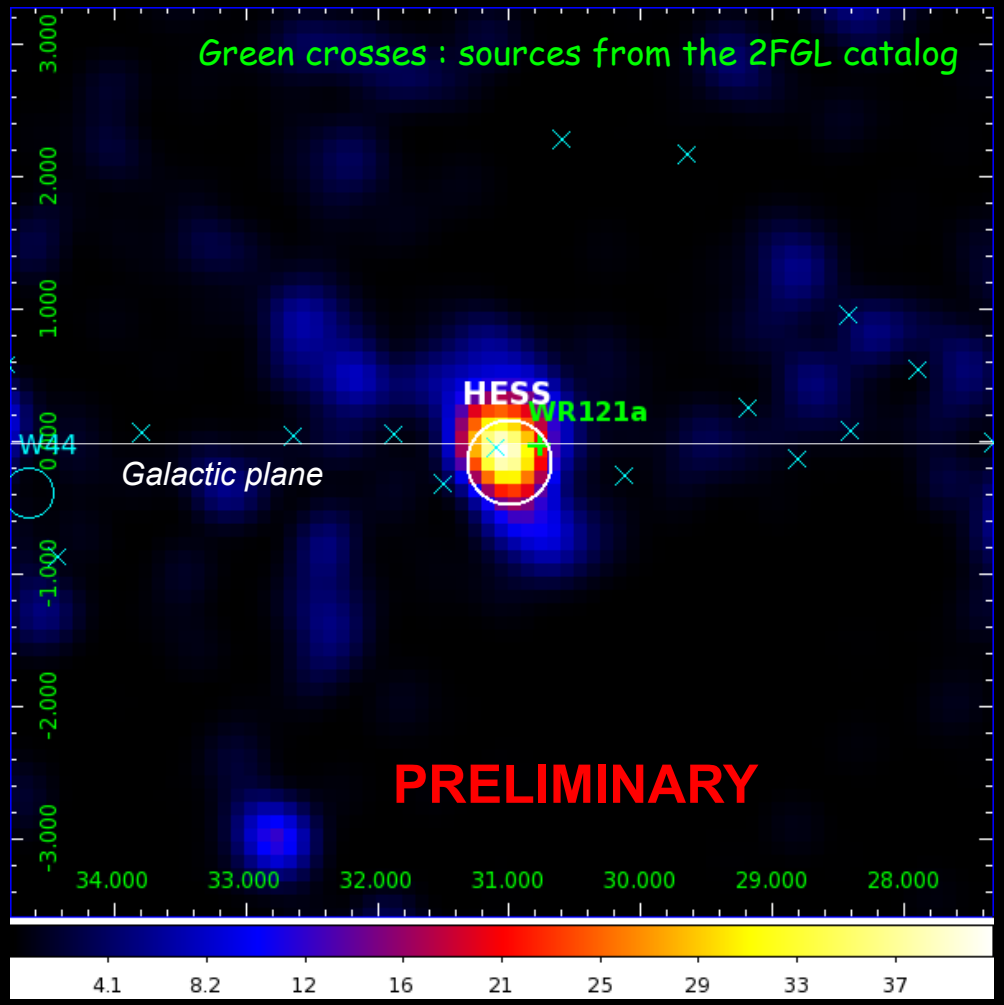
^{13}CO emission at a distance of 6-7 kpc

(Chaves, Renaud, Lemoine-Goumard & Goret, 2008, AIPC, 1085, 372)

Fermi-LAT observations above 2 GeV

Source located in the galactic plane (W43 : b = -0.11°)
Pointlike analysis using 31 months of data:
→ Significant emission located within the HESS contours and slightly offset from WR 121a detected above 1-2 GeV





Counts map (left) and TS map (right) of the region of W43 above 2 GeV

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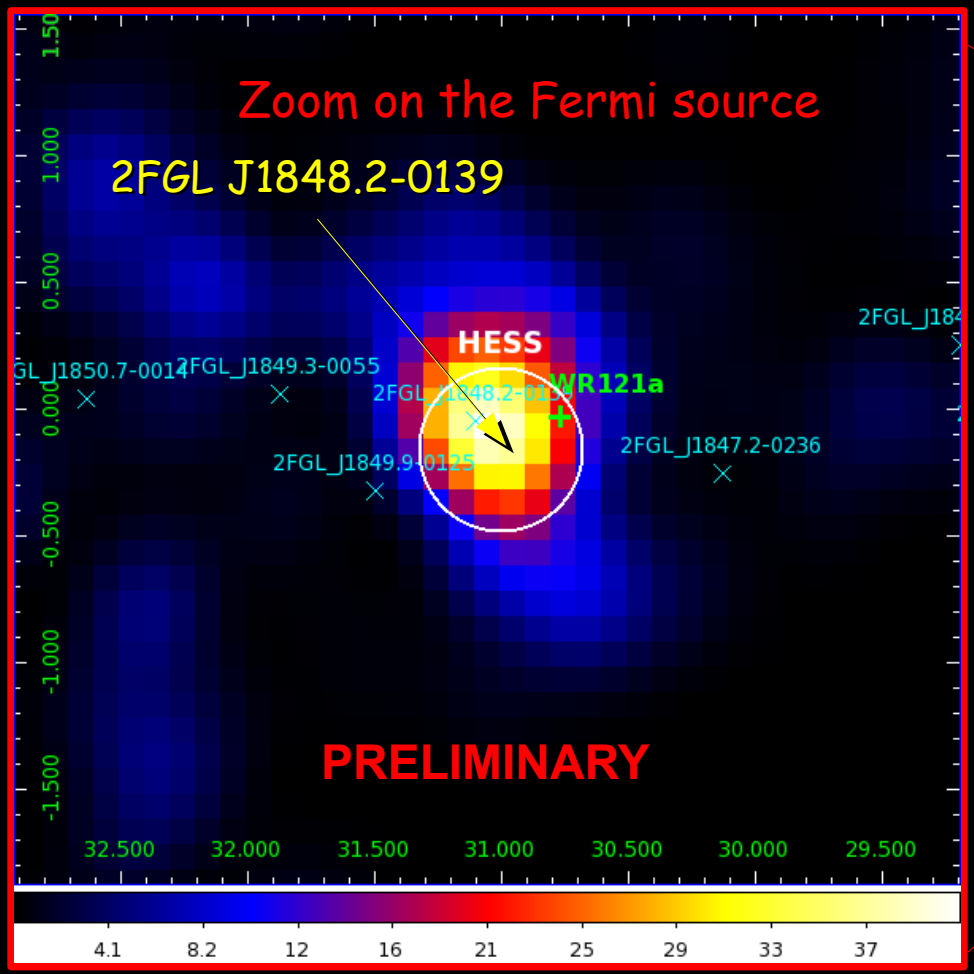
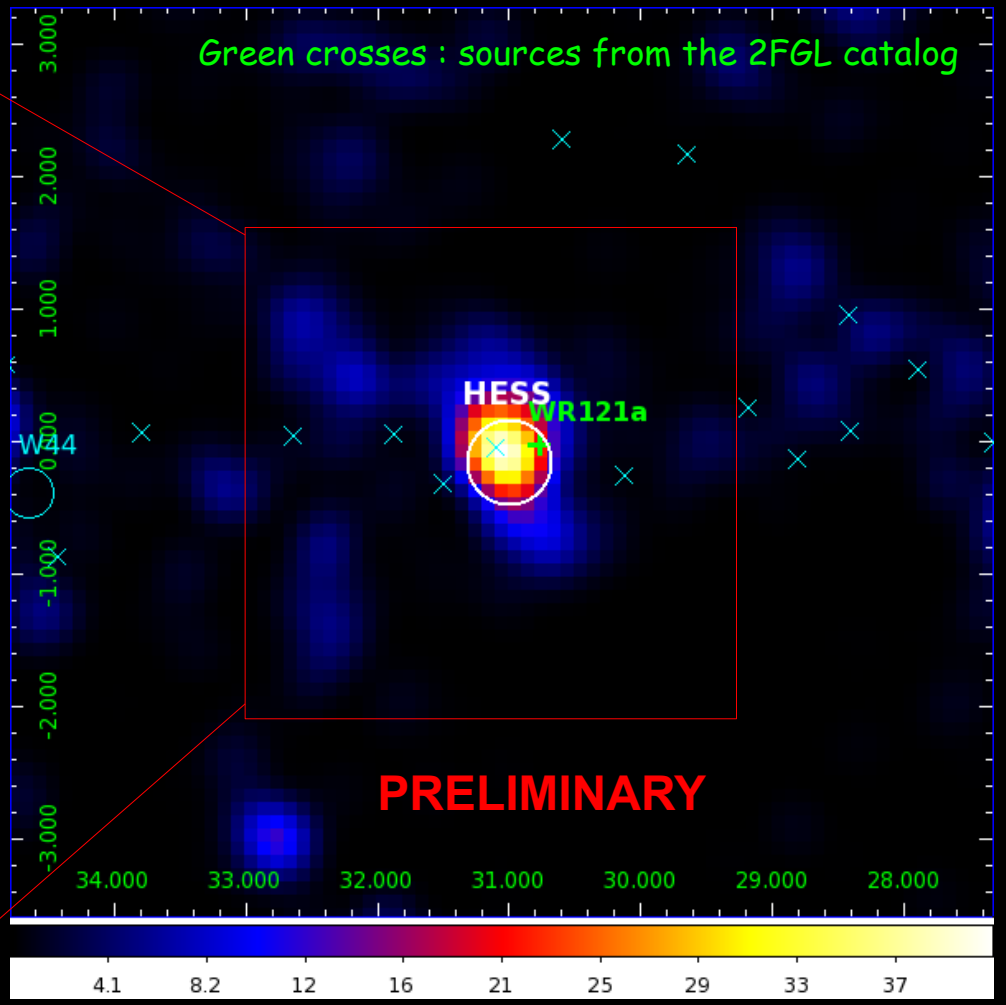




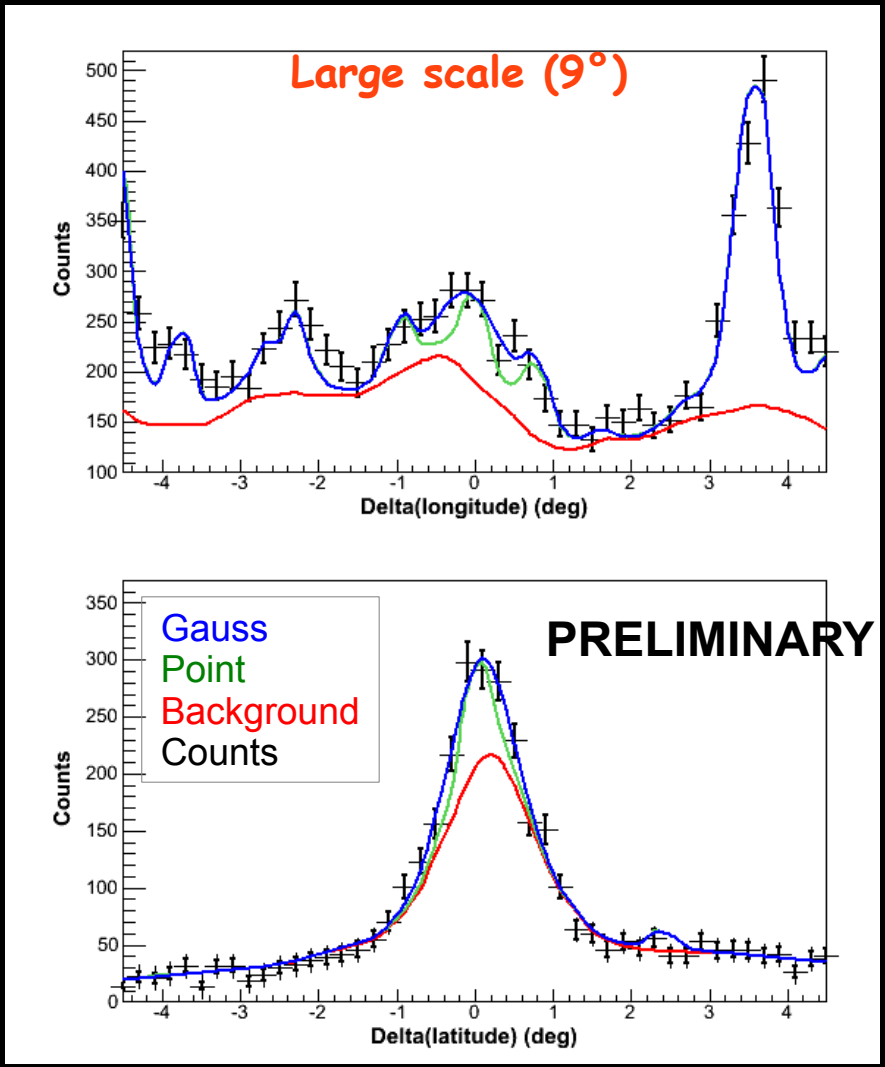
TS maps of the region of W43 above 2 GeV

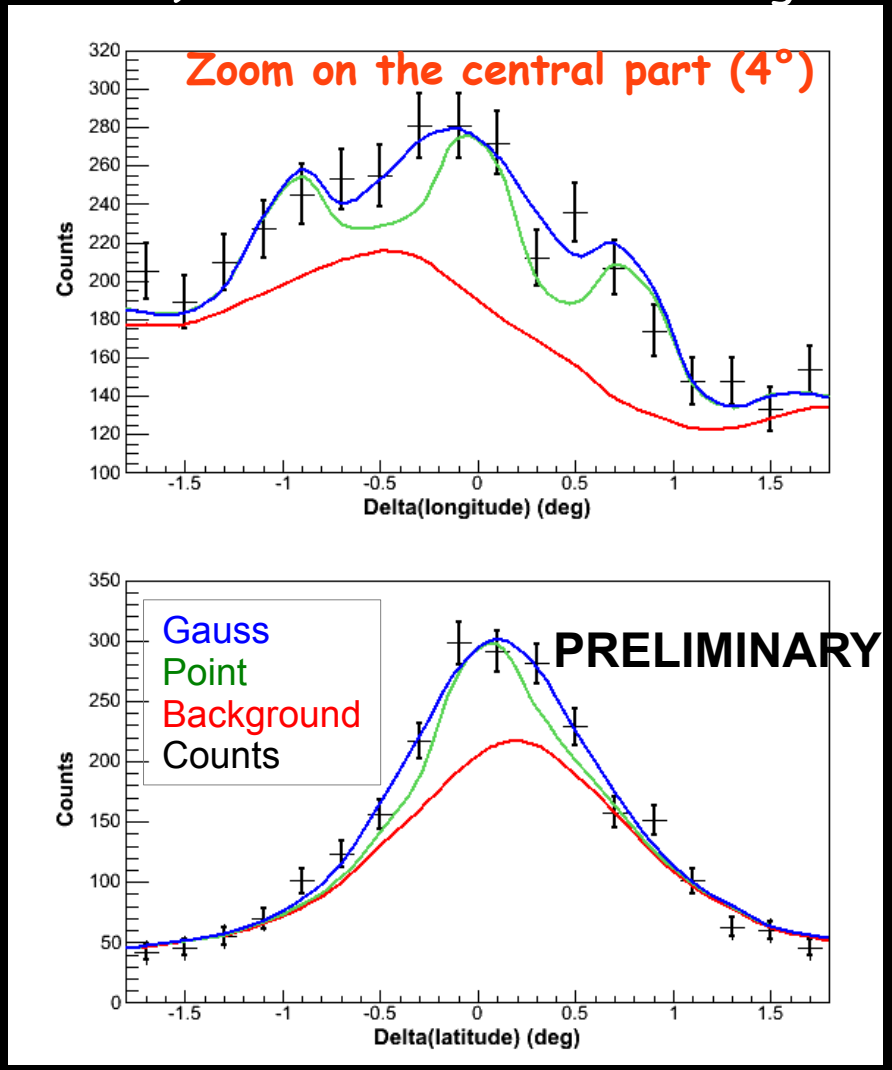
Fermi-LAT morphology (E > 2 GeV)

Evidence for extension at 3.7σ level (best fit with a Gaussian width of ~0.3°)

...But statistics not large enough to discriminate between 1 extended source and several point sources

Be careful: This source is noted as « c » (confused) in the Fermi-LAT catalog





Slices along galactic longitude and latitude, centered on the source; width of integration = 1°

Spectrum

Gaussian distribution :

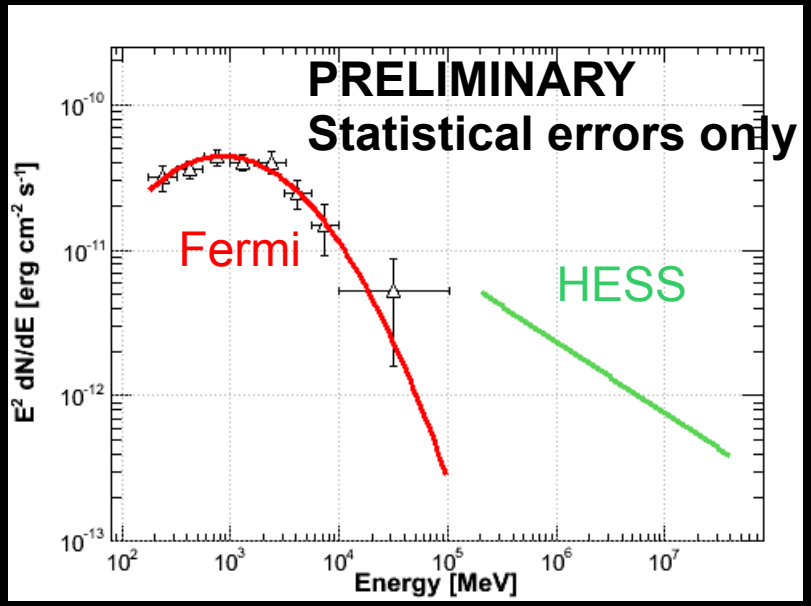
Spectrum : fitted with a Log Parabola

Flux = (1.77 ± 0.26)e-7 cm^{-2} s^{-1} above 100 MeV

Alpha = 2.07 ± 0.07

Beta = 0.22 ± 0.05

E_b = 1000 MeV



Fermi spectrum is obviously not connected to HESS result !

→ Contamination by 1 pulsar detected in the Fermi energy range and powering a PWN seen by HESS ?

(hypothesis supported by the Westerlund 2/PSR J1023-5746 case)

No pulsar with spin-down power higher than 10^{35} erg/s located in the vicinity of the GeV/TeV source => needs a radio-quiet one as for Westerlund 2

When the pulsar is off by only 1 arcmin it is hardly detectable by blind searches => With an extended source of 0.3° this is very tricky !

Conclusions

- Fermi-LAT significant detection of a source coincident with the massive stellar cluster Westerlund 2 ...but Fermi-LAT detection of a Pulsar using blind searches => this source might be a PWN
- Fermi-LAT detection of an extended source coincident with W43...but the spectrum looks like the one of a Pulsar and does not connect with HESS ! ....this source might be contaminated by pulsed emission
- Stellar clusters and massive star formation regions might be gamma-ray sources...but this identification requires a discrimination with the Pulsar/PWN (GeV/TeV) scenario

Our Galaxy contains hundred gamma-ray Pulsars and PWNe !

Already 88 pulsars reported at Fermi Symposium 2011 and more to come !
Pulsars and PWNe are the dominant sources at GeV and TeV respectively