Gamma-ray emission from star-forming complexes observed by MAGIC: W51 and HESS J1857+026

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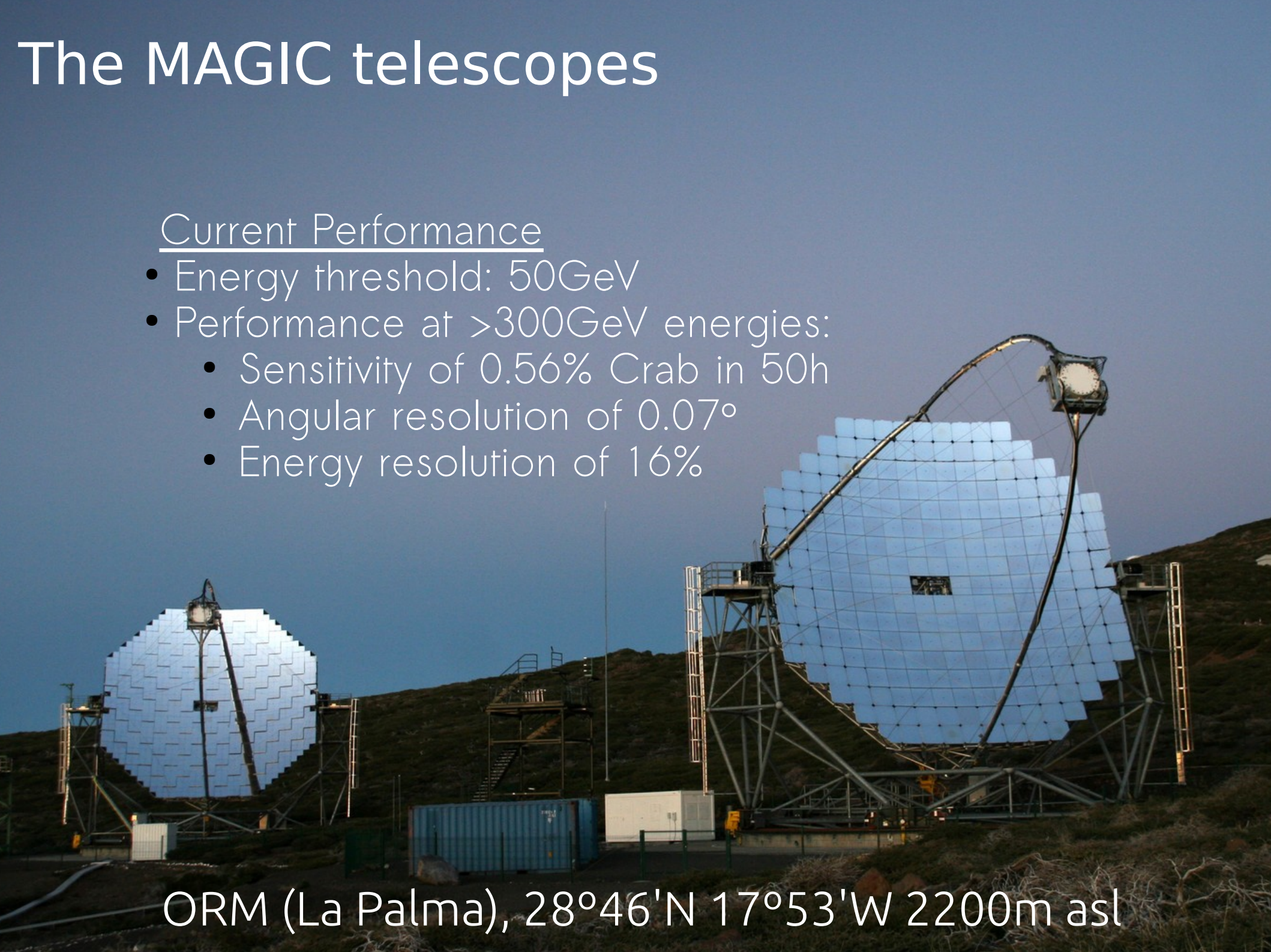
on behalf of the MAGIC Collaboration
Geneva, January 23rd 2015

Outline

- The MAGIC Telescopes
- W51C in W51 – An extreme SNR
- Substructure in HESS J1857+026
- Wrap up and conclusions

The MAGIC telescopes

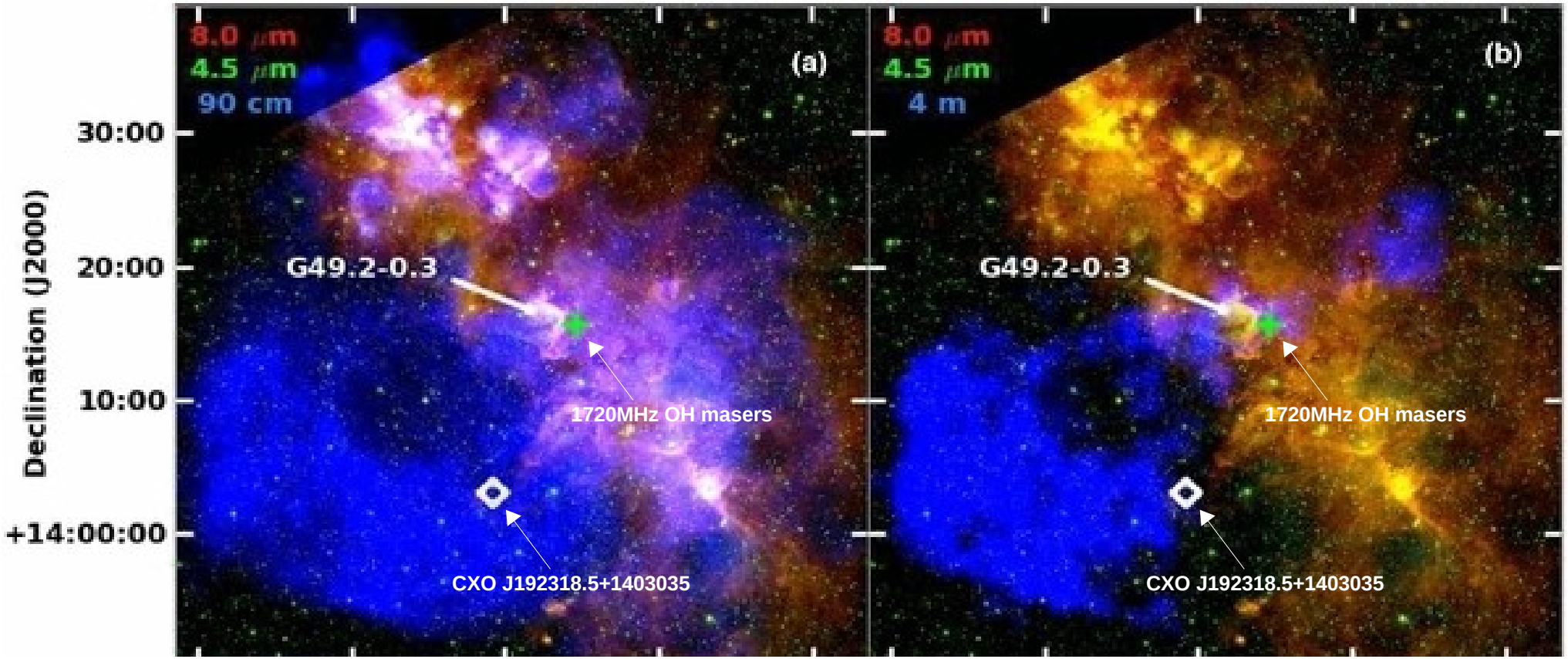


Current Performance

- Energy threshold: 50GeV
- Performance at >300GeV energies:
  - Sensitivity of 0.56% Crab in 50h
  - Angular resolution of 0.07°
  - Energy resolution of 16%

ORM (La Palma), 28°46'N 17°53'W 2200m asl

W51: a massive star-forming region



C. L. Brogan et al. 2013 ApJ 771 91

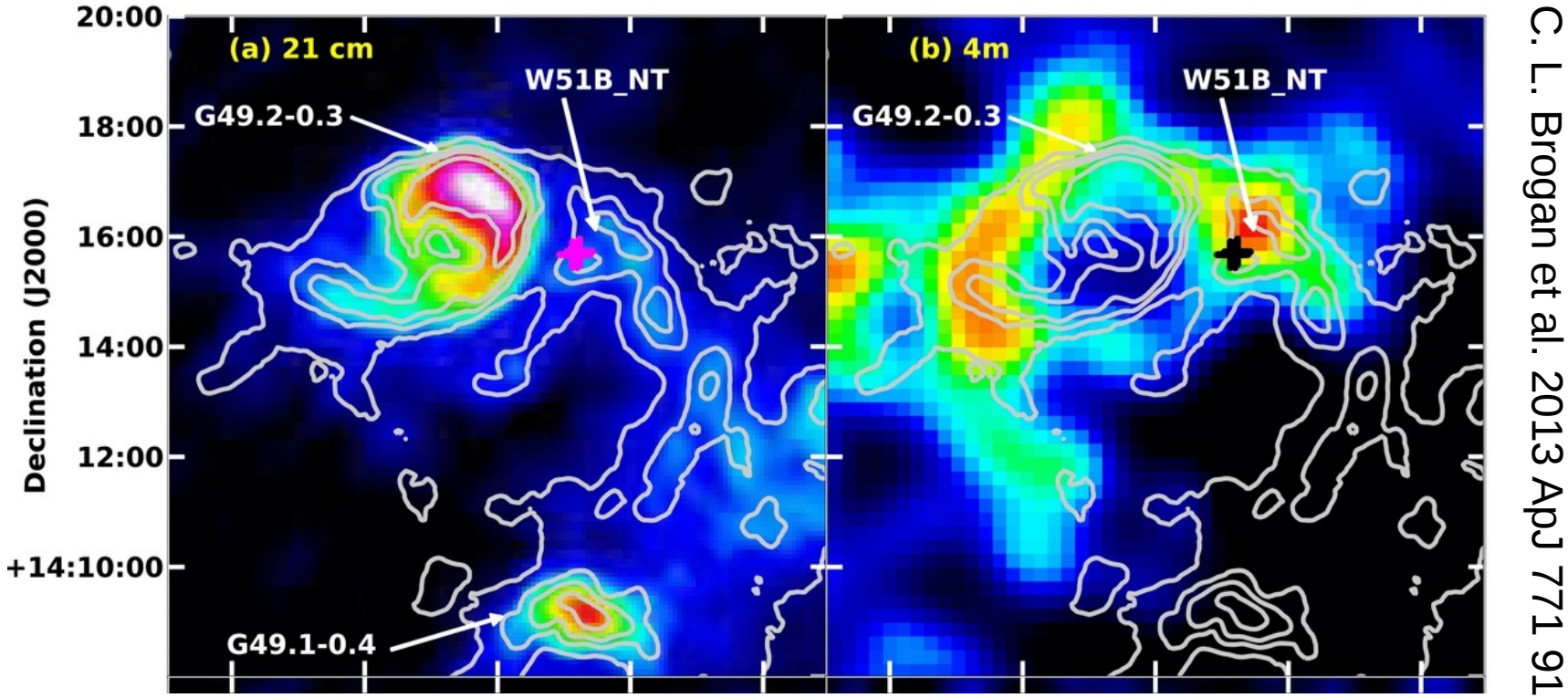
d = 5.5kpc

$n_{max} \sim 1 \times 10^5 cm^{-3}$

Includes SNR W51C (30kyr old)

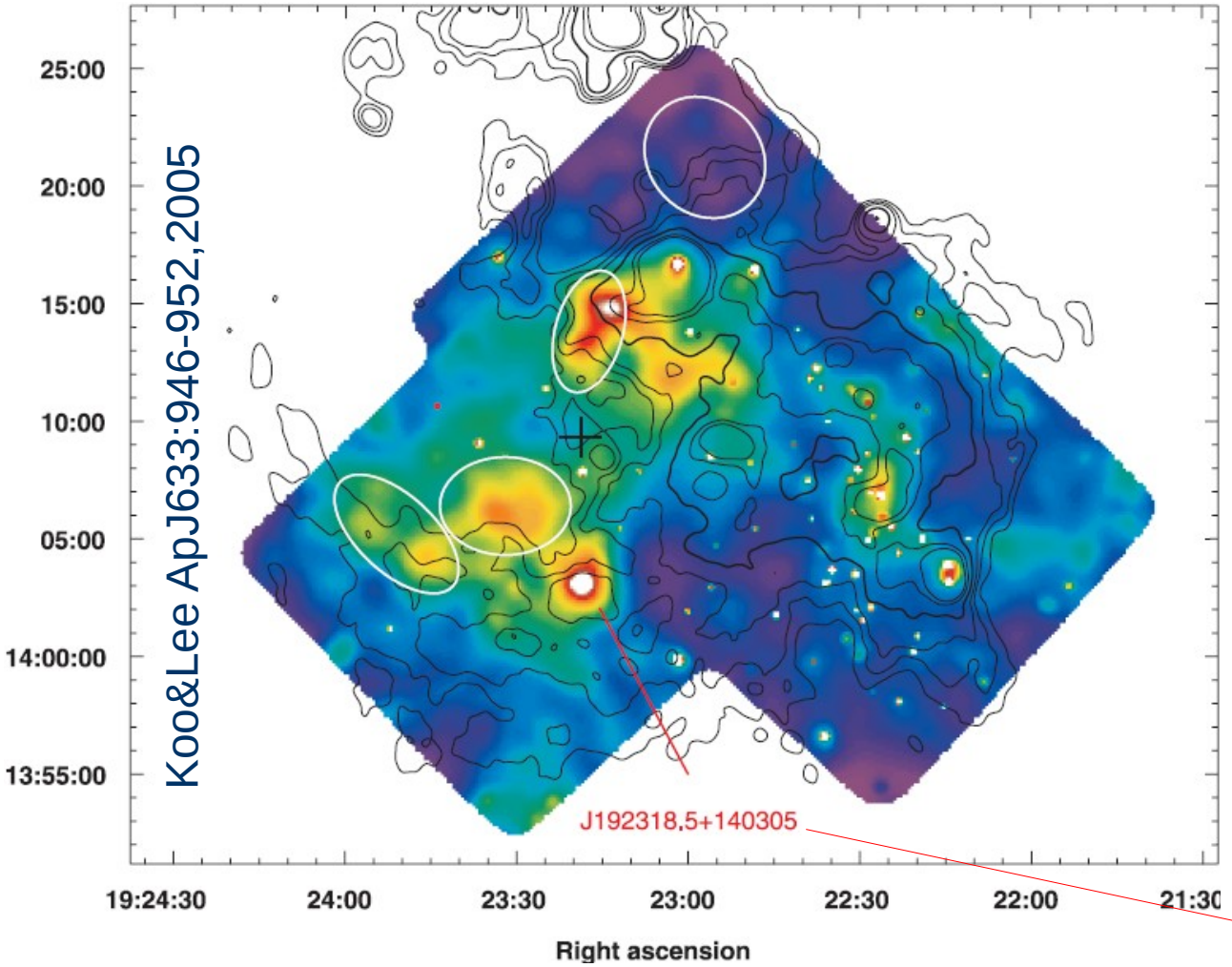
Some controversy:
Tian&Leahy 2013 ApJ 769 L17

Non-thermal emission around an HII region in W51B

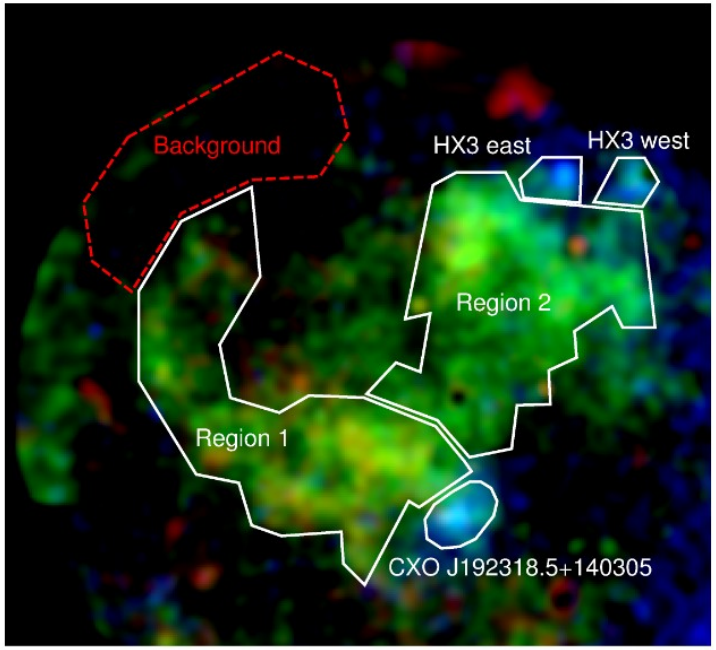


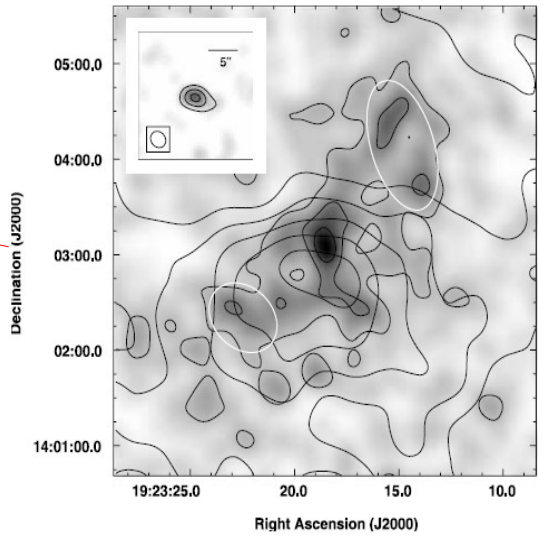
C. L. Brogan et al. 2013 ApJ 771 91

W51C/B in X-rays



Sasaki et al. A&A 563, A9 (2014)



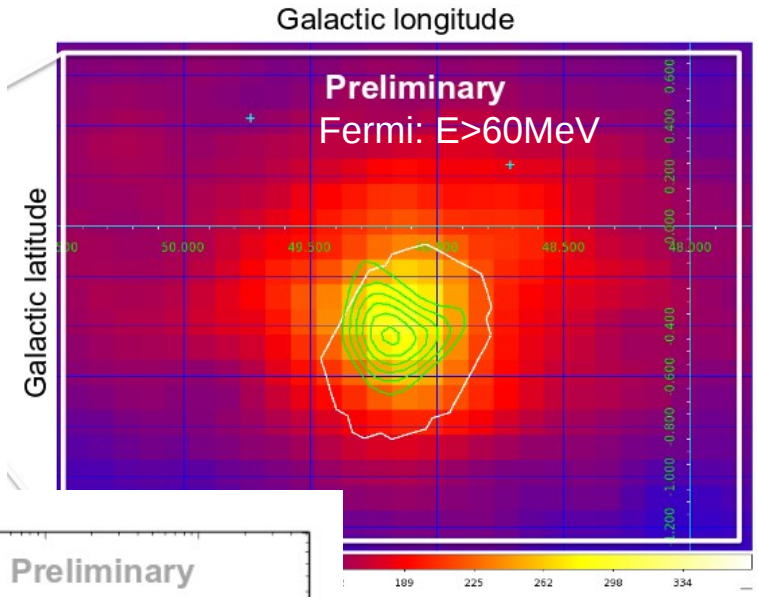


Two hard non-thermal sources:
PWNs? Winds from OB stars?
The SNR itself? (Hanabata et al. 2013)

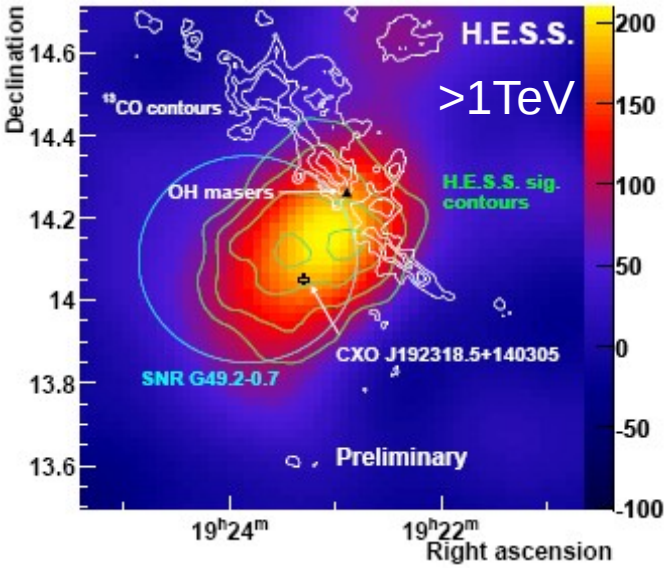
The W51 complex in gamma rays

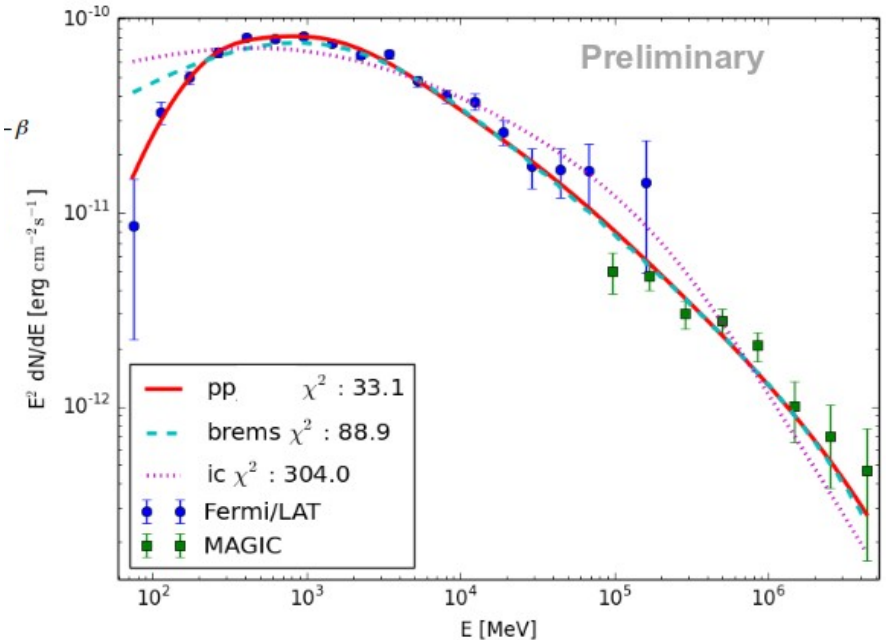
Breaking news!

T. Jogler's talk from yesterday

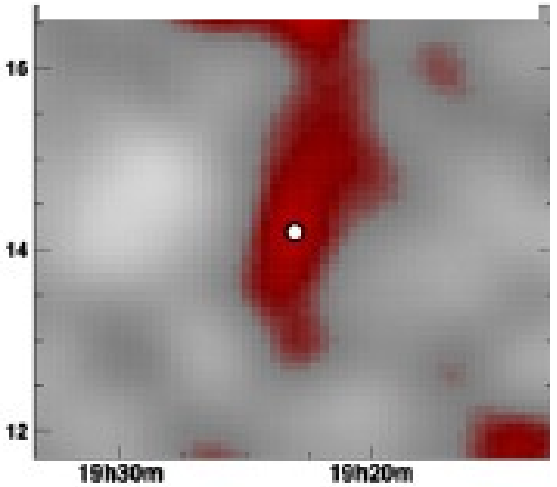


Fiasson et al. Proc 31st ICRC 2009





MILAGRO 1-100TeV



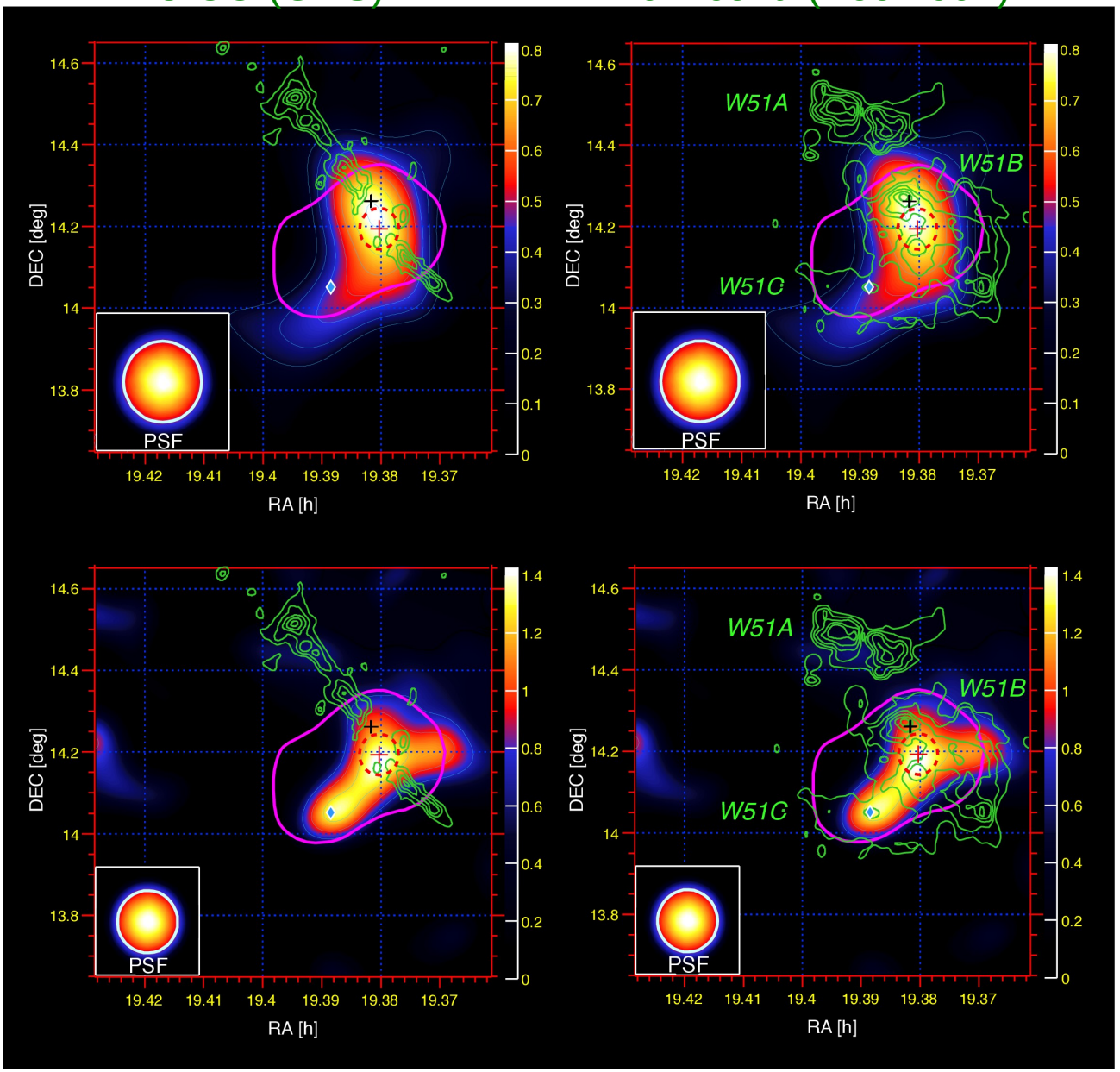
Abdo et al. ApJ700L,127A,2009

(3.4sigma)

W51 MAGIC Skymaps

Aleksić et al. 2012, A&A 541, A13 (2012)

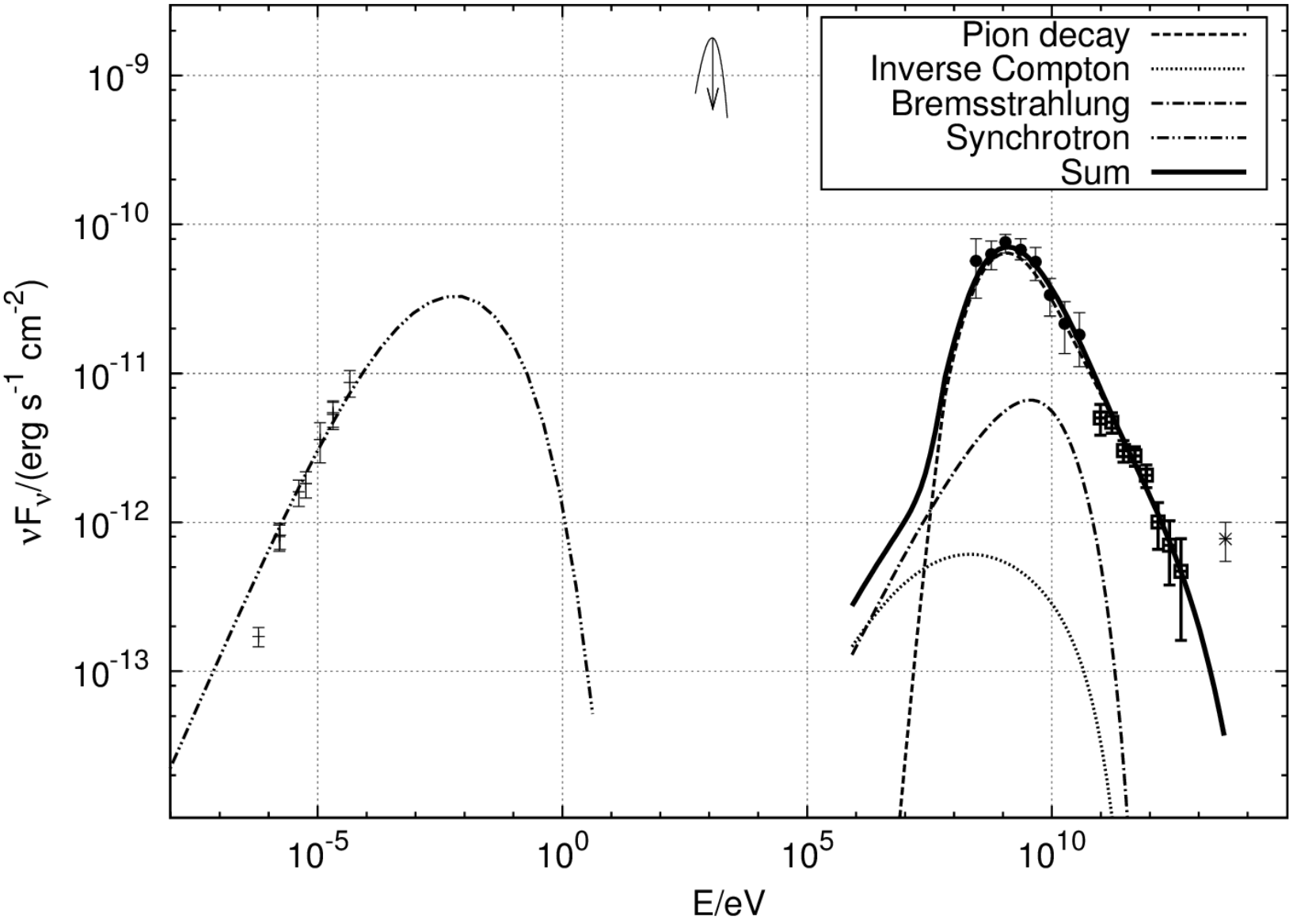
13-CO (GRS) | 21cm cont. (Koo 1997)



11.4 sigma detection
3% Crab (E > 1 TeV)
$\Gamma = 2.58 \pm 0.07_{stat} \pm 0.22_{syst}$

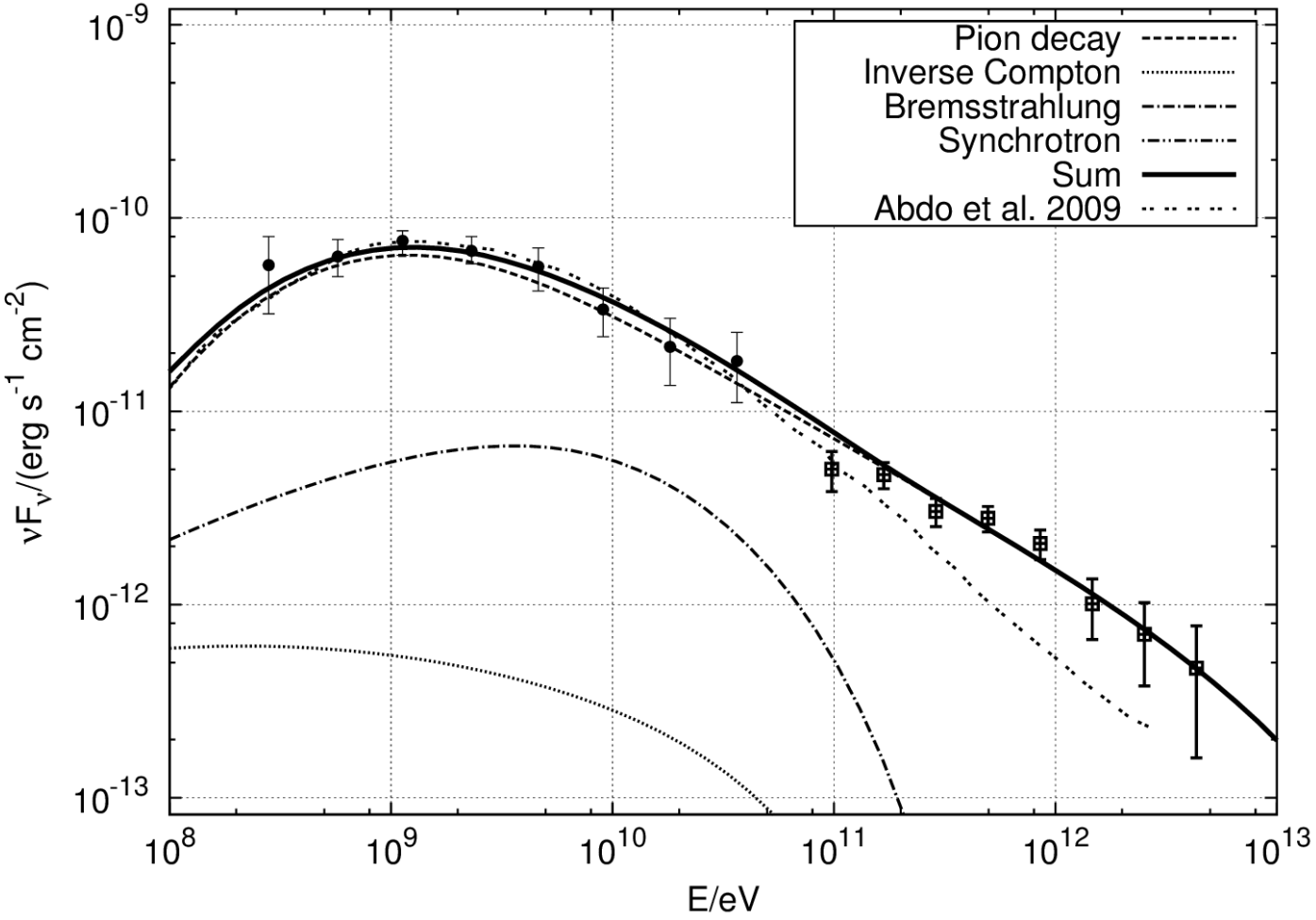
W51 SED model

Aleksić et al. 2012, A&A 541, A13 (2012)



W51 SED model (zoom)

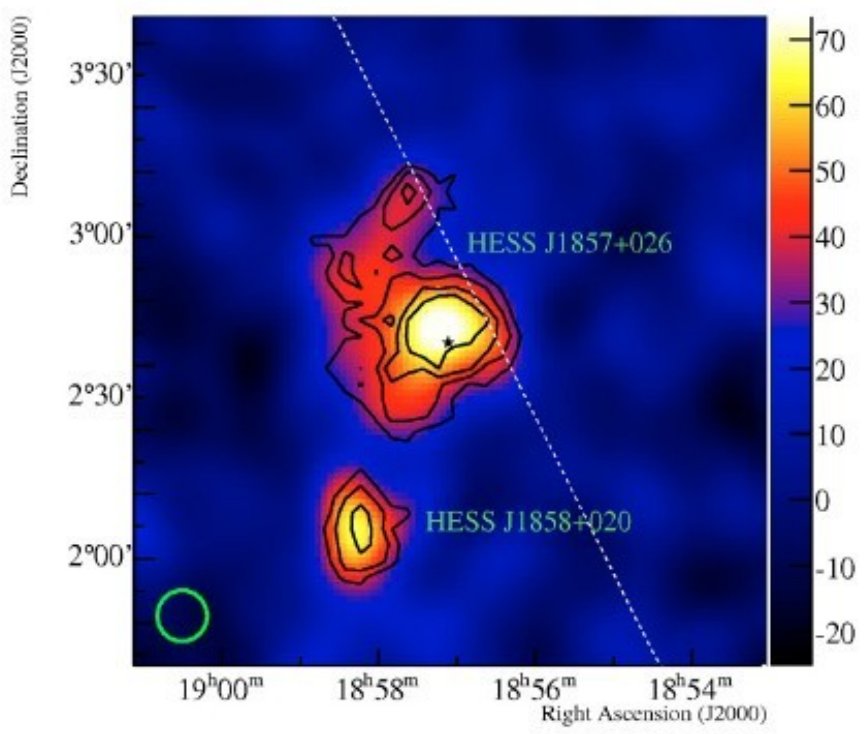
Aleksić et al. 2012, A&A 541, A13 (2012)



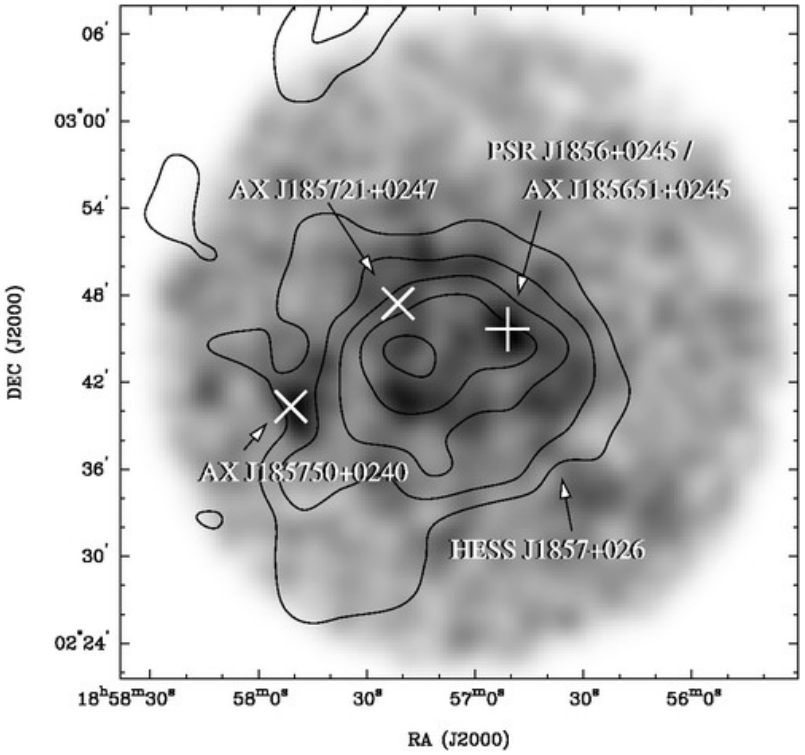
Parameter	Value
K_e/K_p	1/80
Δs	1.2
$E_{\rm br}$ [GeV]	10
$E_{{\rm cut},e}$ [TeV]	0.1
$E_{{\rm cut},p}$ [TeV]	120
B [μG]	53
n [cm^{-3}]	10.0
W_e [10^{50} erg]	0.069
W_p [10^{50} erg]	5.8

luminosity ~10^{36} erg/s, 16% efficiency

HESS J1857+026: not just a Galactic PWN

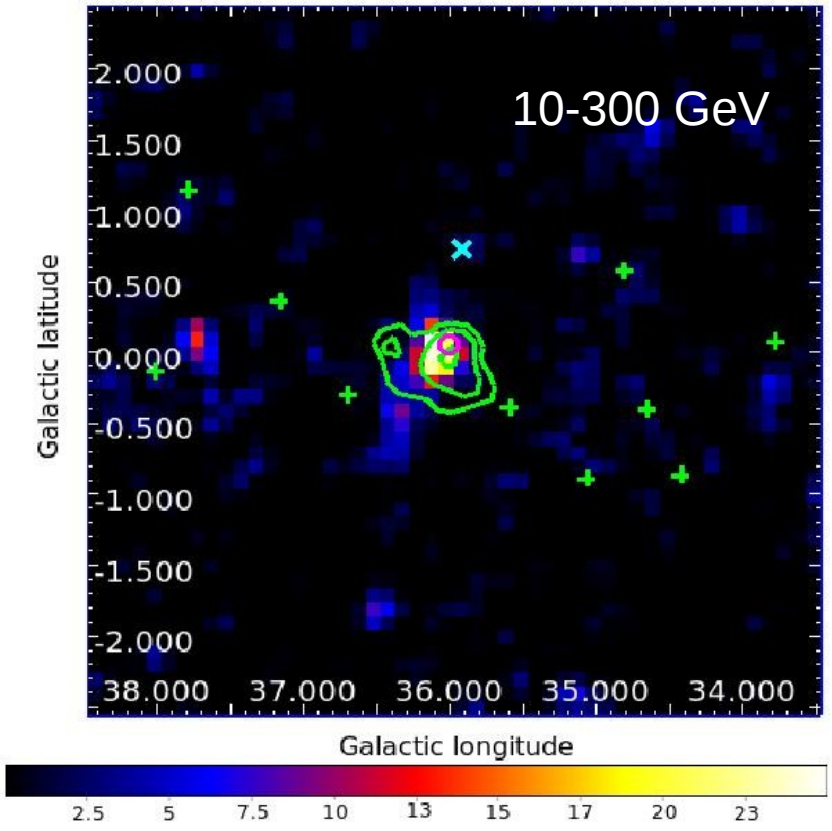


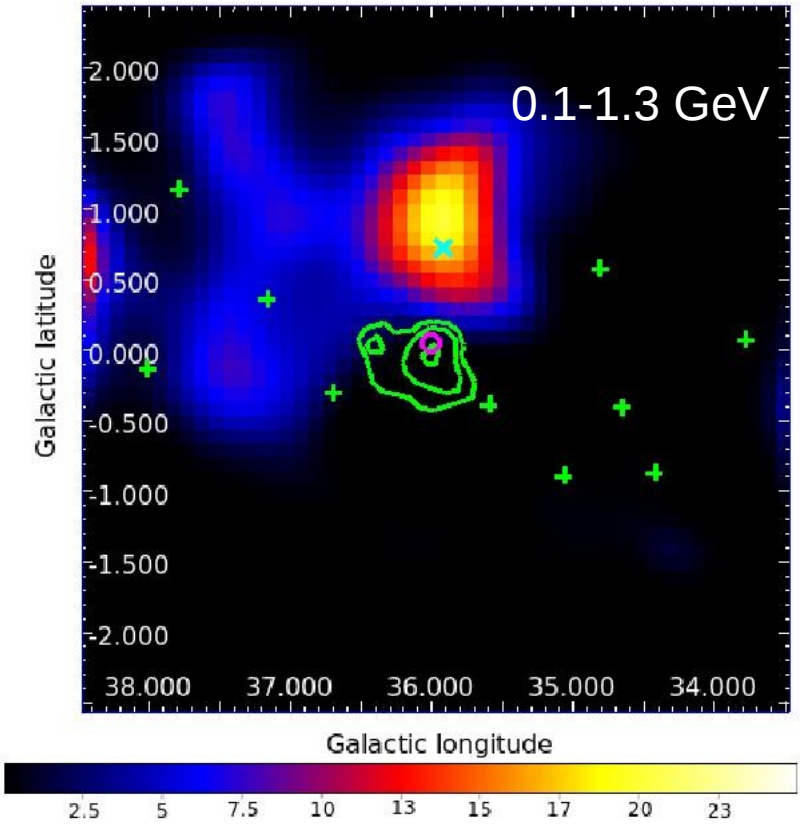
Aharonian et al. (2008)
A&A 477, 353-363



Hessels et al. (2008)
ApJ 682 L41

HESS J1857+026 in Fermi



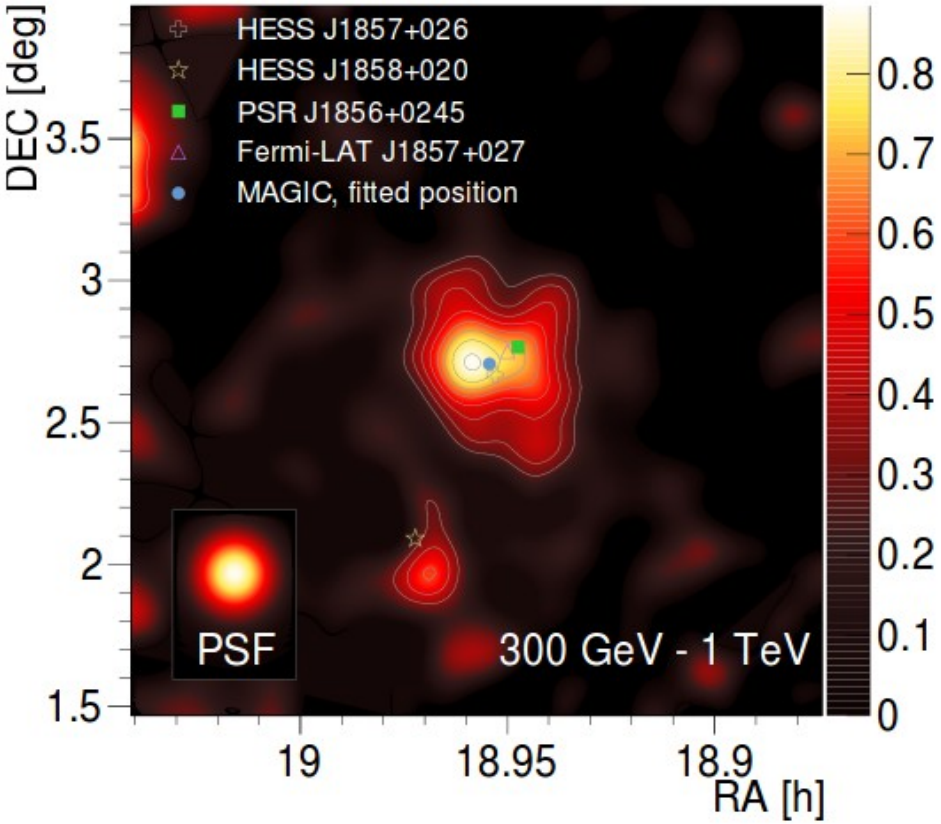


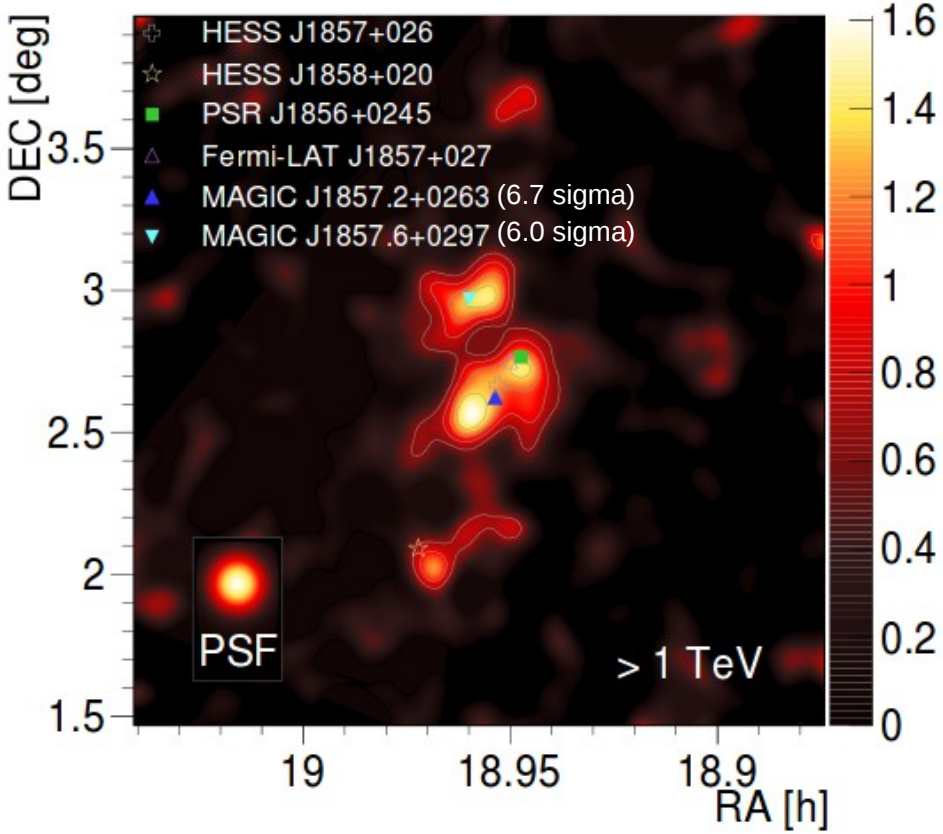
Rousseau et al. (2012)
A&A 544, A3

Already seen in
Neronov&Semikoz 2010
arXiv:1011.0210

HESS J1857+026 in MAGIC

Aleksić et al. 2014
A&A 571, A96

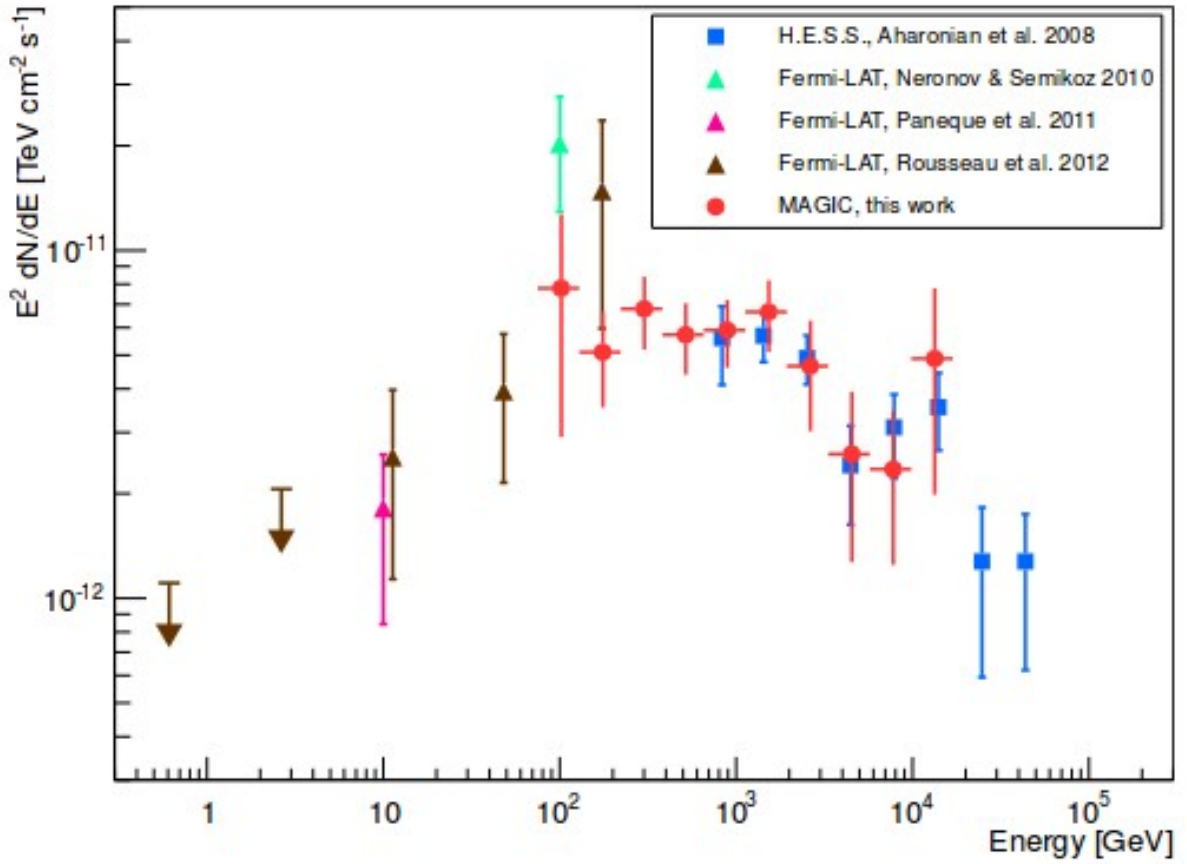




12 sigma detection
$\Gamma = 2.16 \pm 0.07_{stat} \pm 0.15_{syst}$

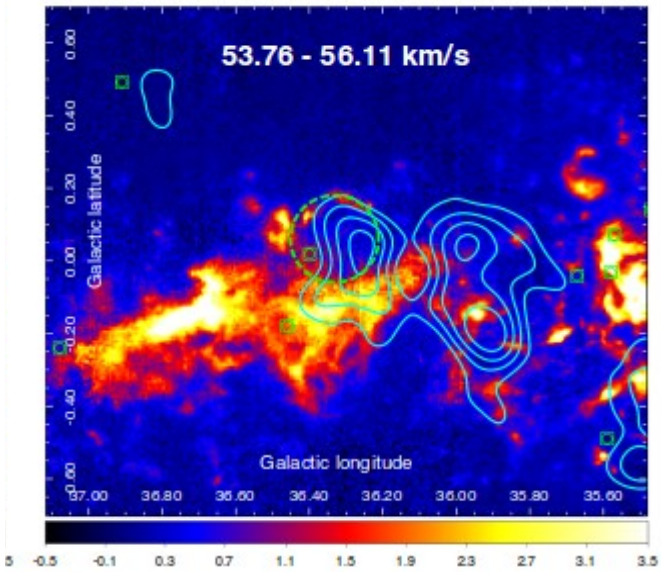
0.35deg separation between the peaks
(>4 x PSF)

HESS J1857+026 SED



Aleksić et al. 2014
A&A 571, A96

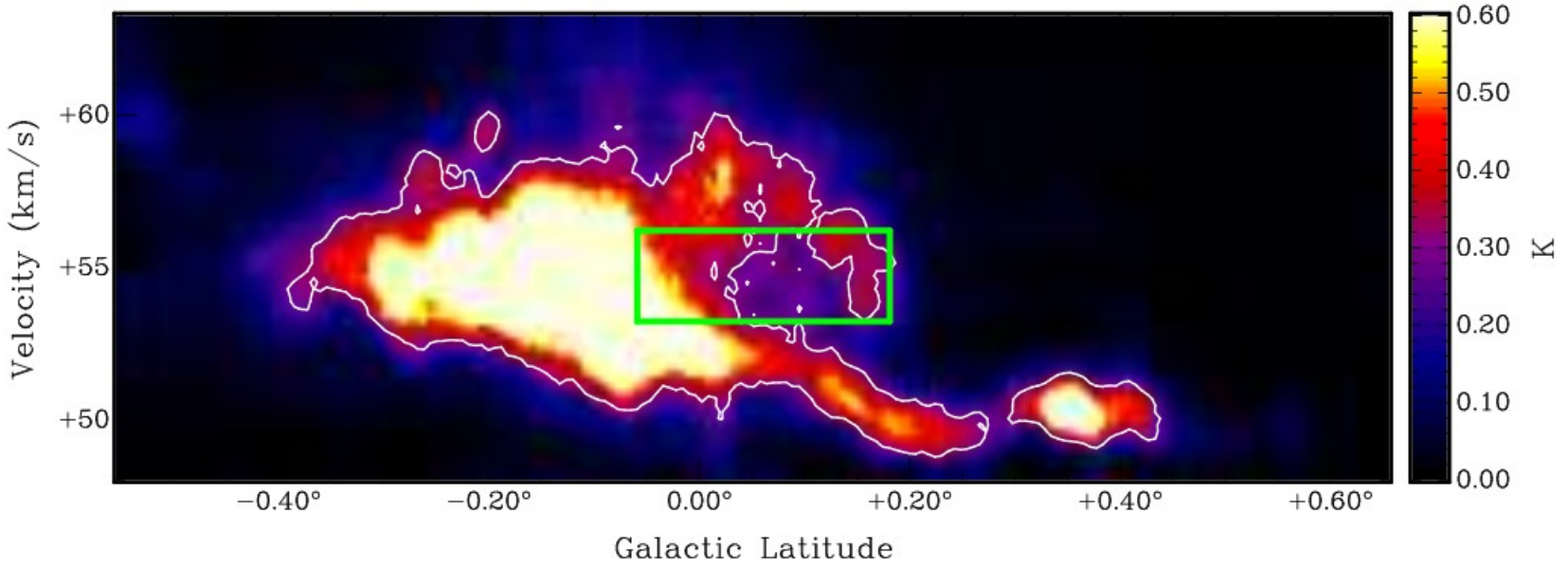
A cavity towards J1857.6+0297



Relic PWN in wind-blown bubble?
de Jager &Djannati-Ataï (2008)
Bock & Gvaramadze (2002)

Collective effects from OB/WR winds?
Absorbed! → Reimer et al. (2006)

Outflows of massive protostars?
Araudo et al. (2008)
Bosch-Ramon et al. (2010)



Aleksić et al. 2014 A&A 571, A96

Conclusions

- W51C is a powerful proton accelerator, not a typical SNR.

- Part of the emission from HESS J1857+026 is convincingly not associated to the PWN

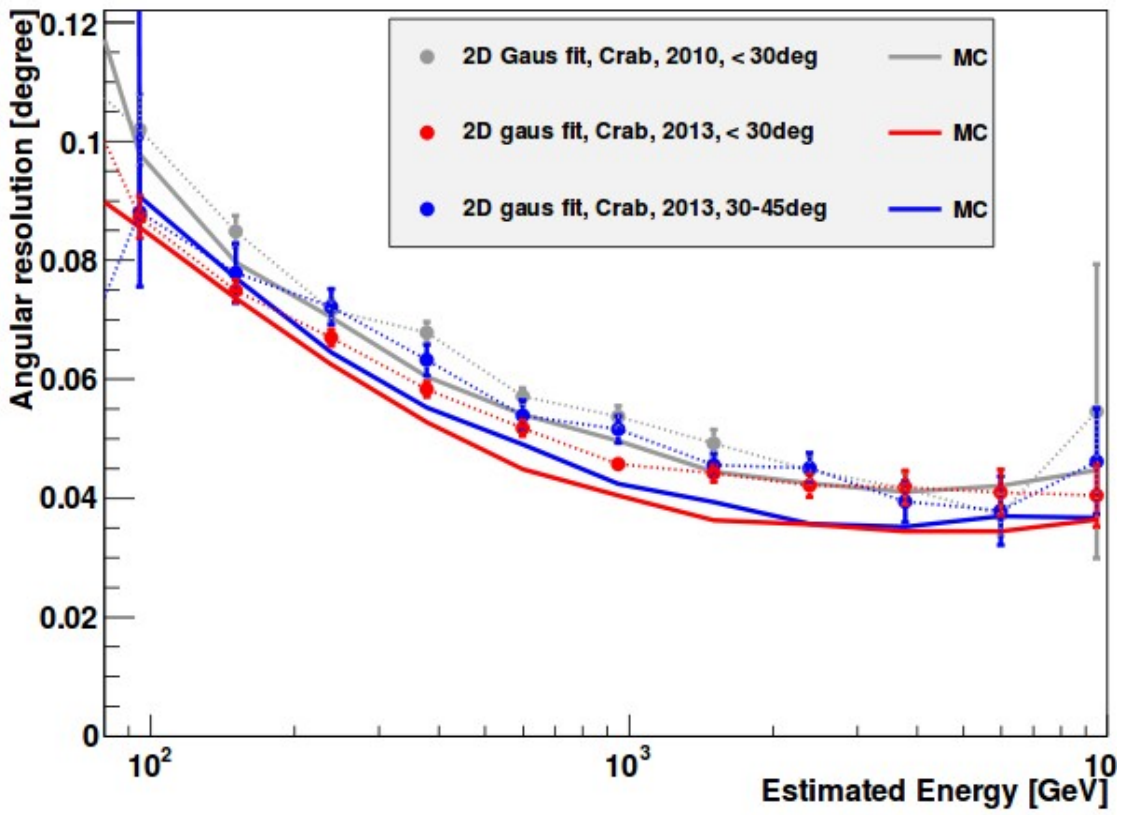
  → VHE gamma rays coinciding with a gas cavity

  → What is the contribution of these objects to other TeV sources? (and Un-IDs?)

- SFRs are challenging targets for gamma-ray telescopes, and so will remain for many years!

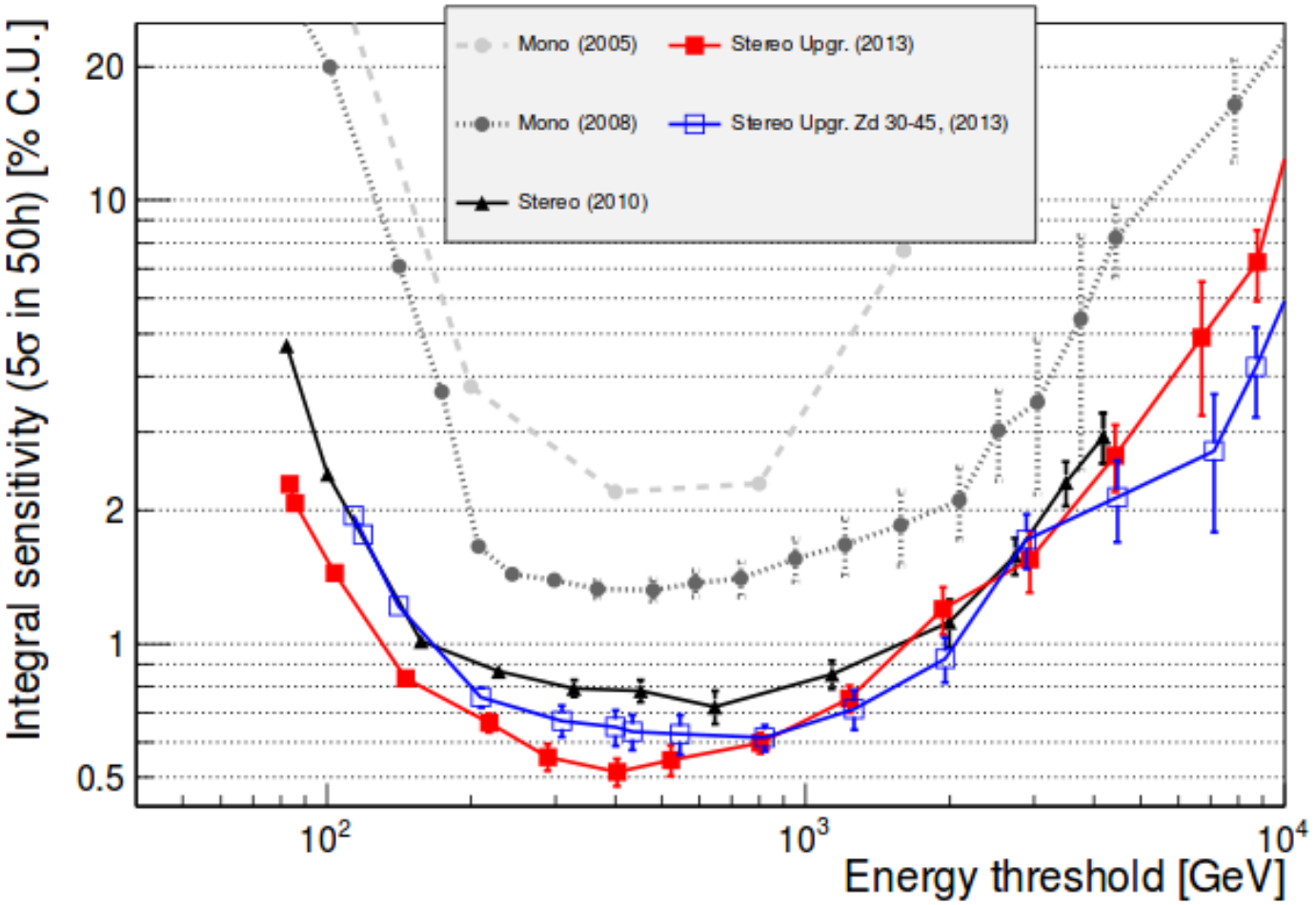
backup

Angular resolution of MAGIC



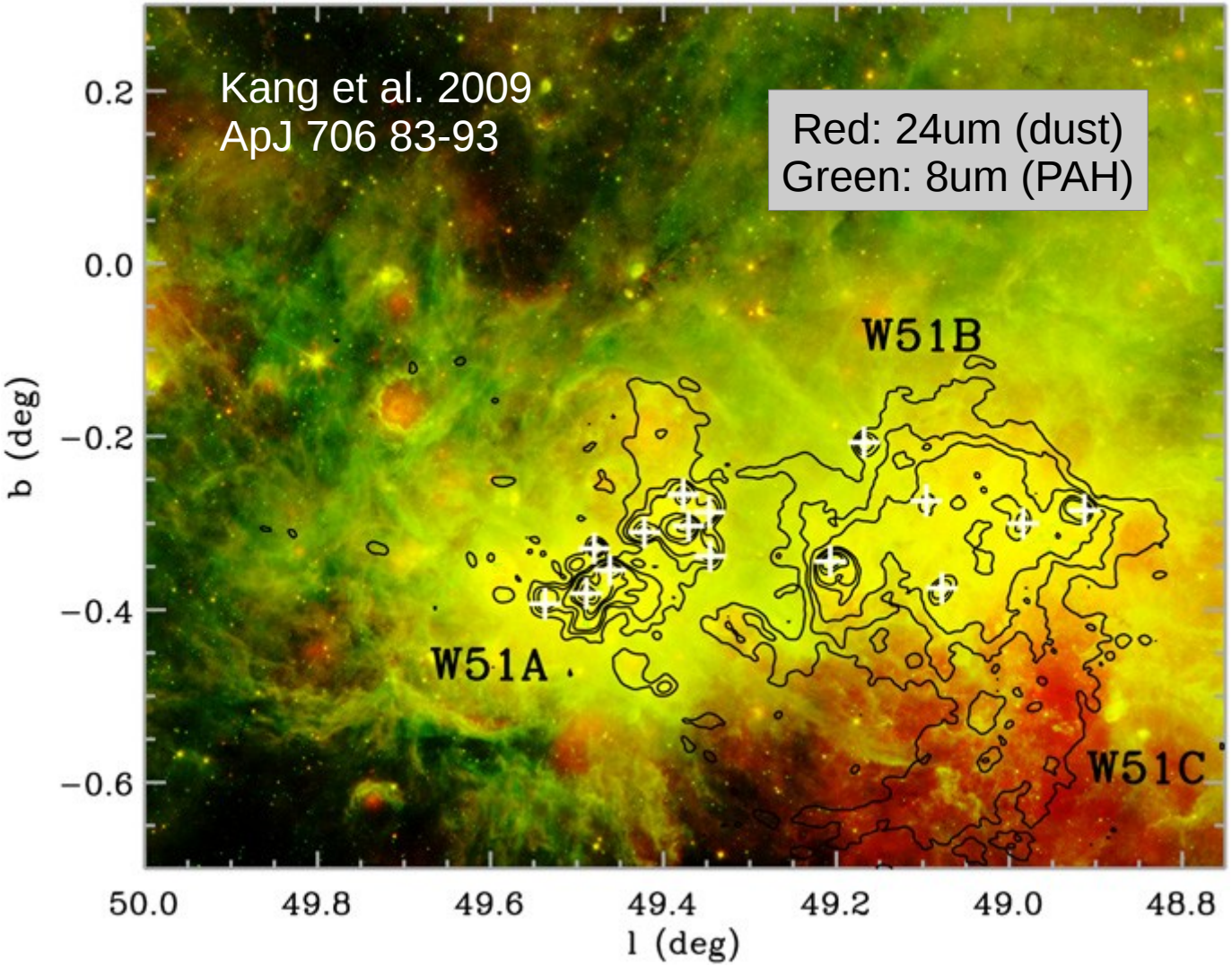
Aleksić et al. 2014 (arXiv:1409.5594)

Sensitivity of MAGIC

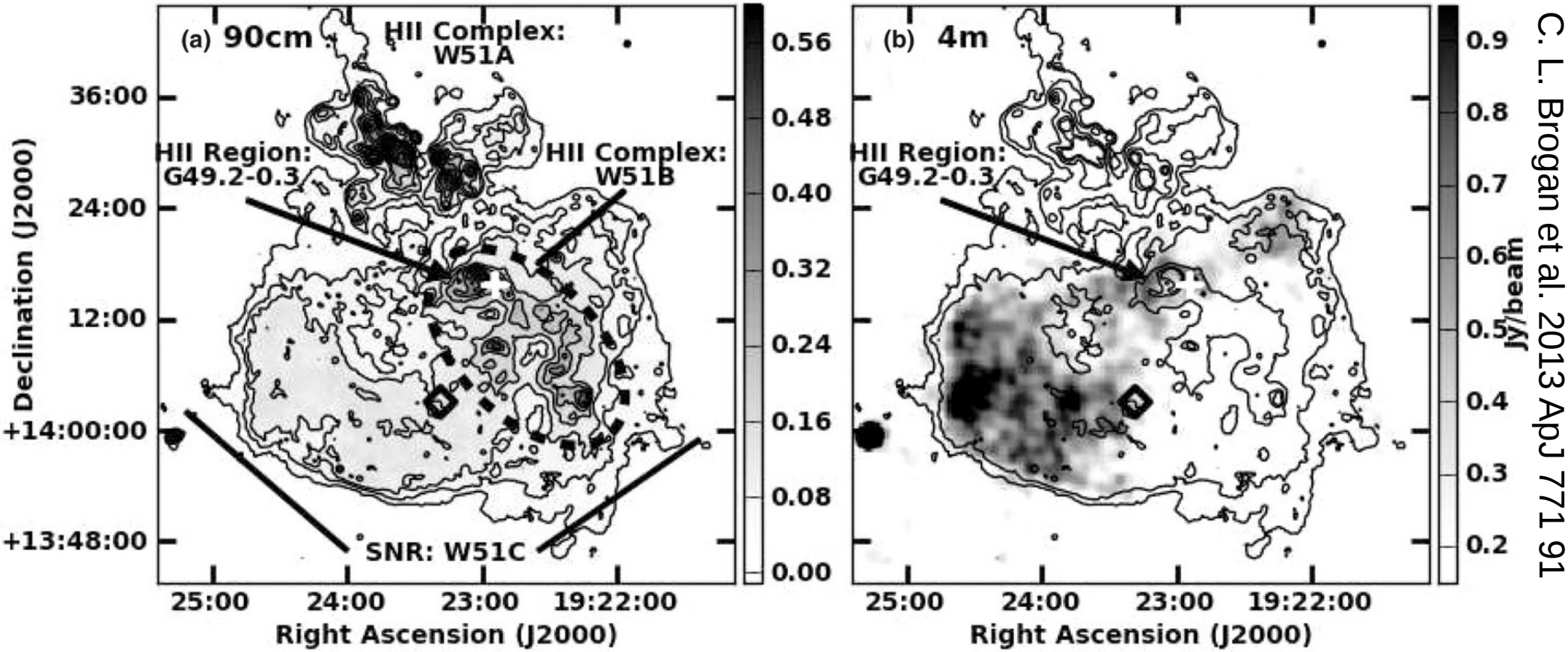


Aleksić et al. 2014 (arXiv:1409.5594)

W51 in the infrared



The W51 complex in radio continuum



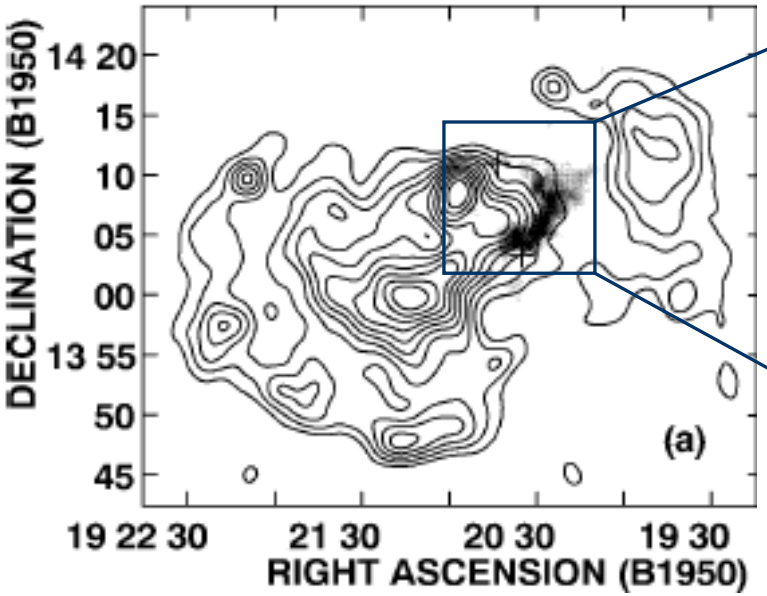
C. L. Brogan et al. 2013 ApJ 771 91

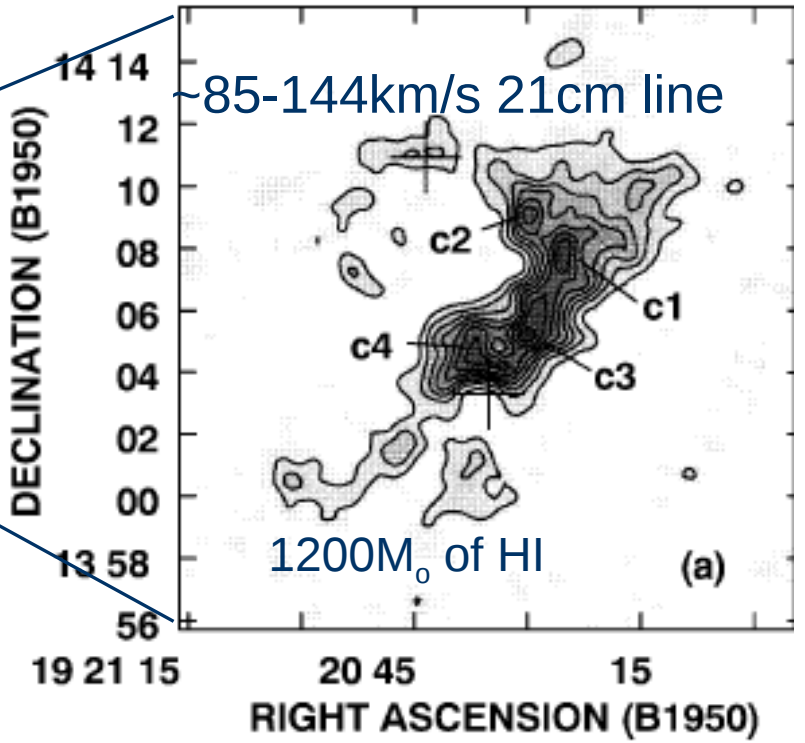
Interaction between W51C and W51B

High velocity neutral hydrogen:

NOTE: Galactic rotation at *l*=49º: ~60km/s (tangential point)

ROSAT&VLA 21cm



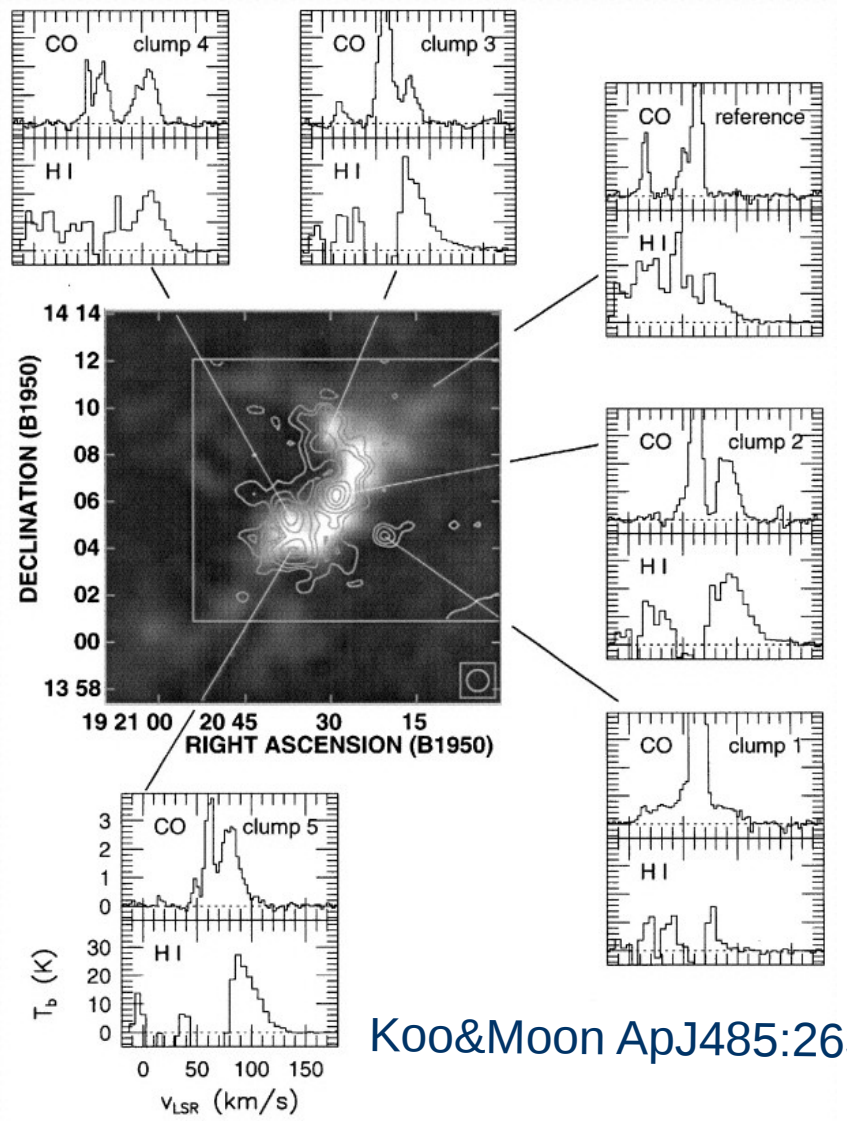


Koo&Moon ApJ 475:194-210, 1997

Alternative explanation & controversy available:
W. W. Tian and D. A. Leahy 2013 ApJ 769 L17

Interaction between W51C and W51B

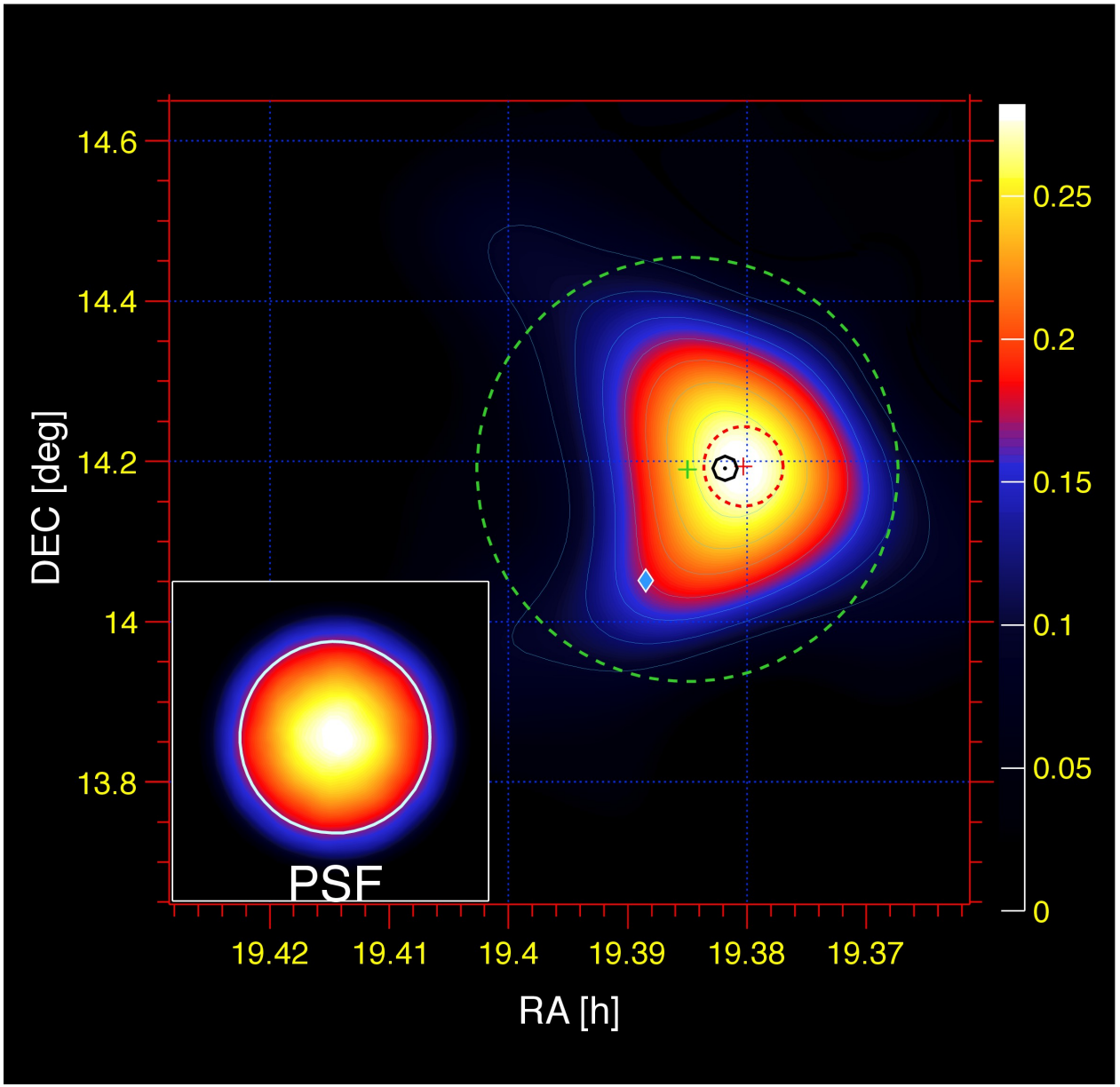
Coincidence with shocked molecular hydrogen:



Koo&Moon ApJ485:263-269,1997

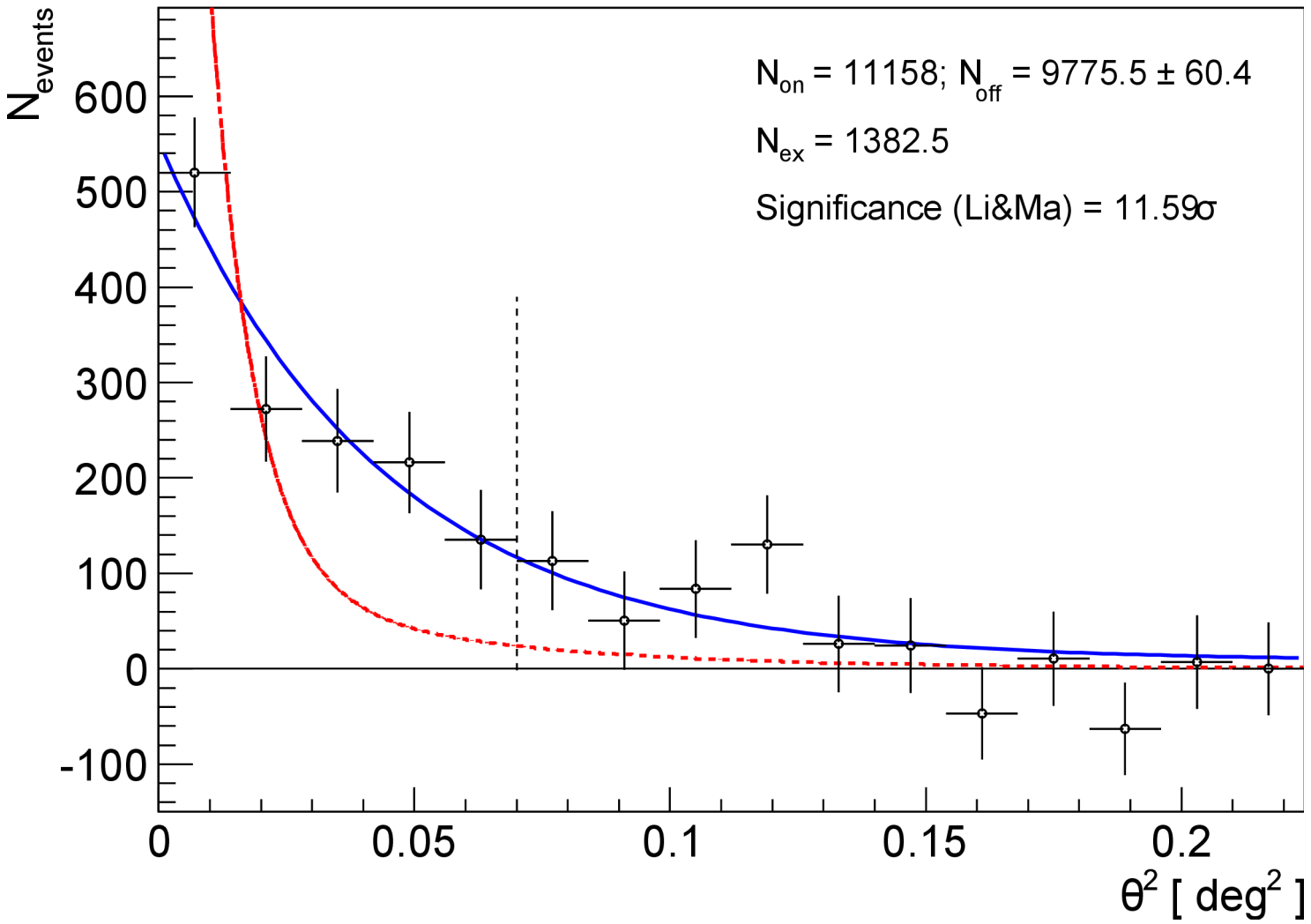
- $0.16M_o$ describing a 14pc long arc structure
- 20-50km/s velocities with respect to ambient medium

W51 Skymap >150GeV **Aleksić et al. 2012, A&A 541, A13 (2012)**



W51 Extension

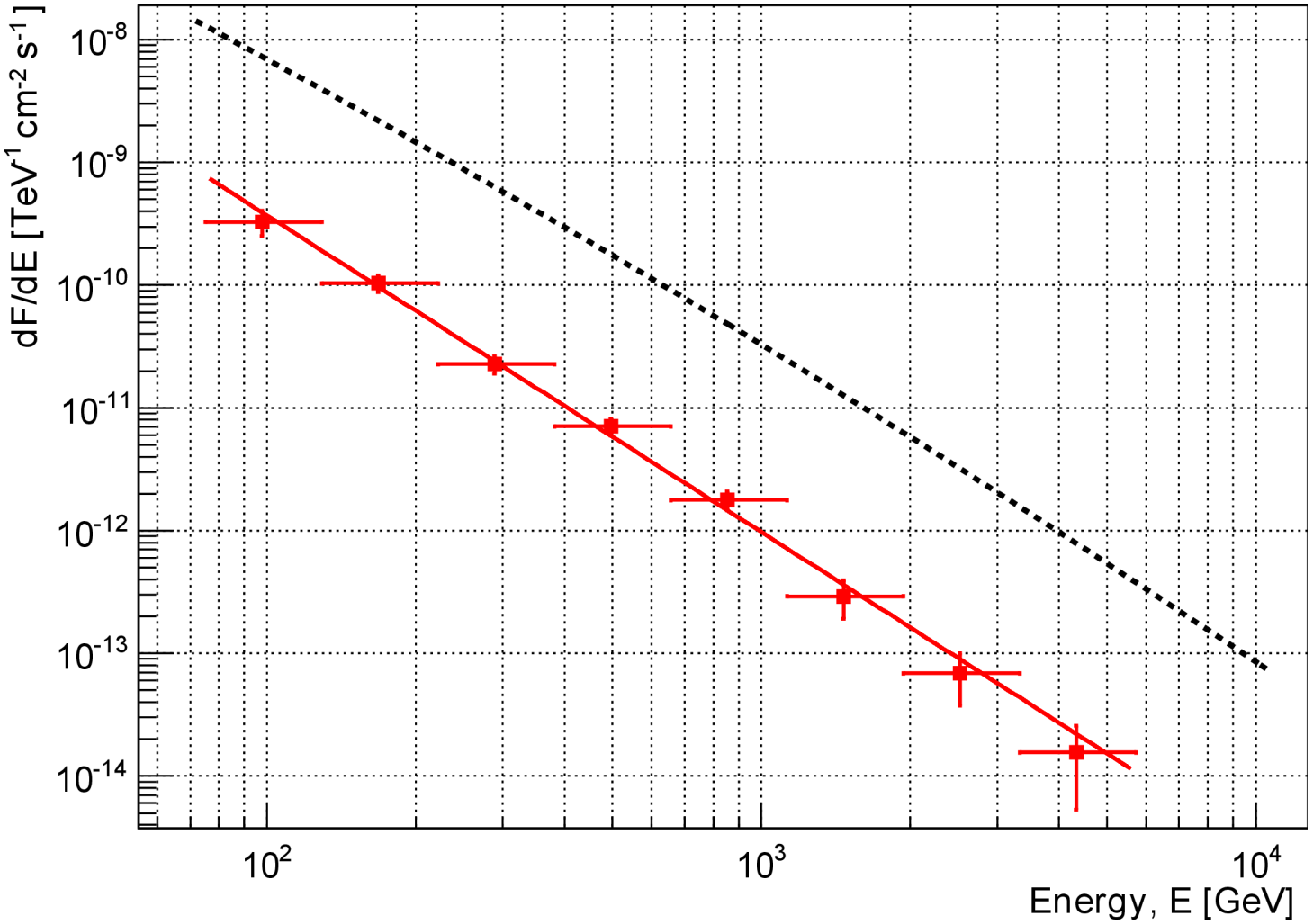
Aleksić et al. 2012, A&A 541, A13 (2012)



Extension: 0.12 +- 0.02(stat) +- 0.02(sys) deg

W51 Spectrum

Aleksić et al. 2012, A&A 541, A13 (2012)



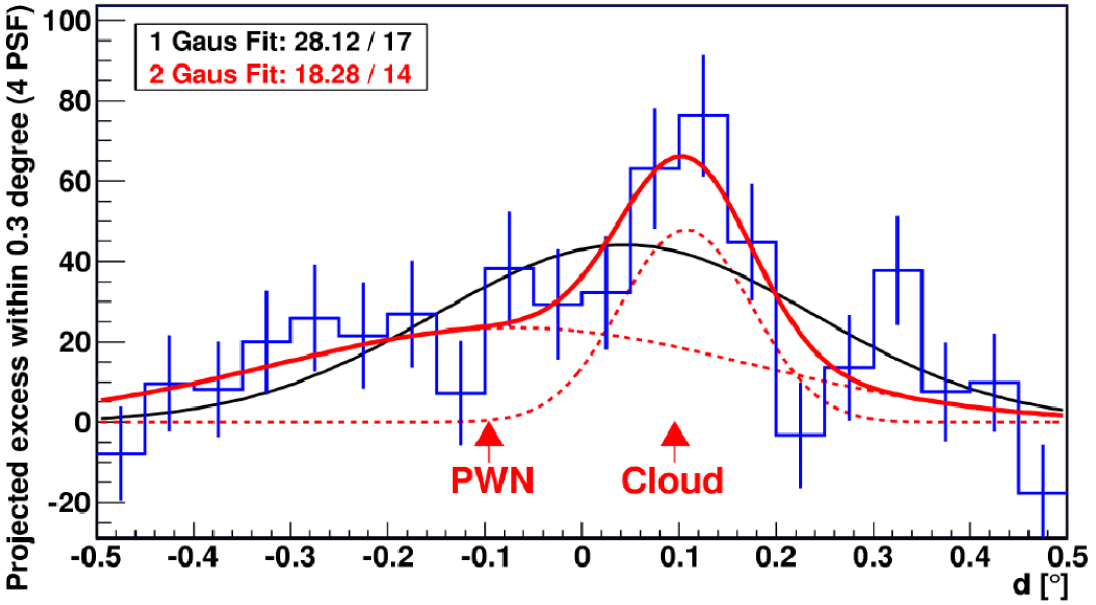
$$\frac{dN}{dE} = N_O \left(\frac{E}{1\,\mathrm{TeV}}\right)^{-\Gamma}$$

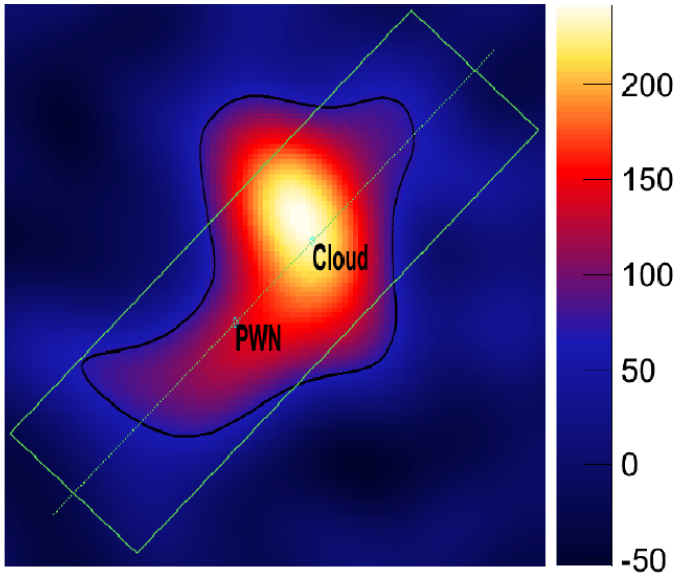
$$\Gamma = 2.58 \pm 0.07_{\mathrm{stat}}$$

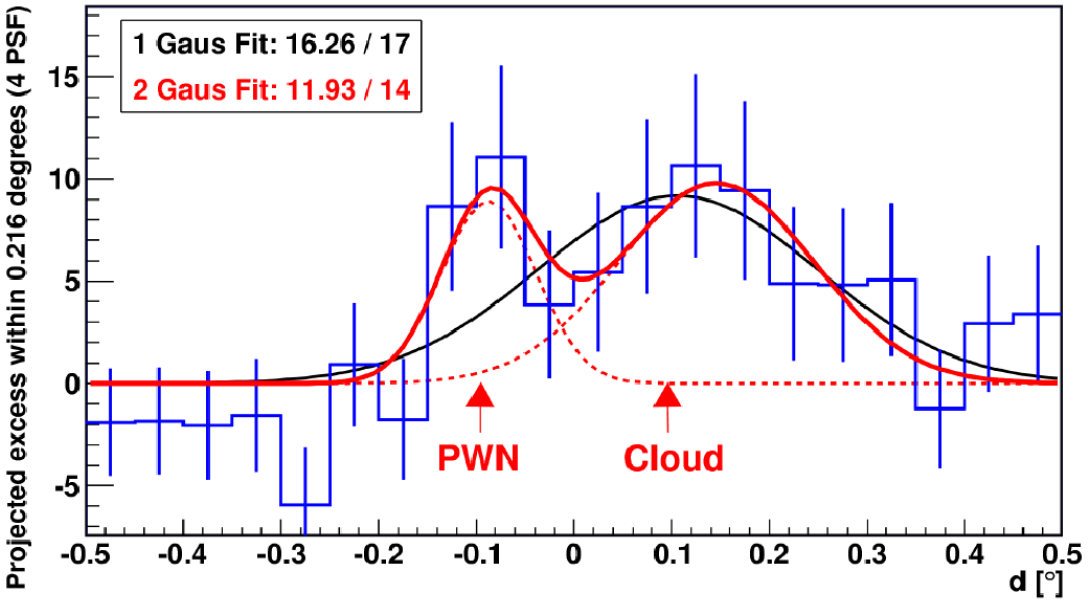
$$N_0 = (9.73 \pm 0.99_{\mathrm{stat}}) \times 10^{-13}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{TeV}^{-1}$$

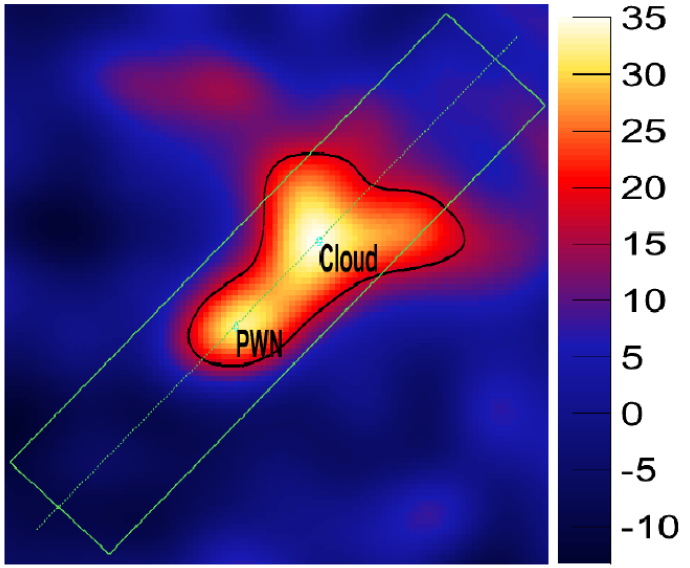
Substructure in W51

Aleksić et al. 2012, A&A 541, A13 (2012)







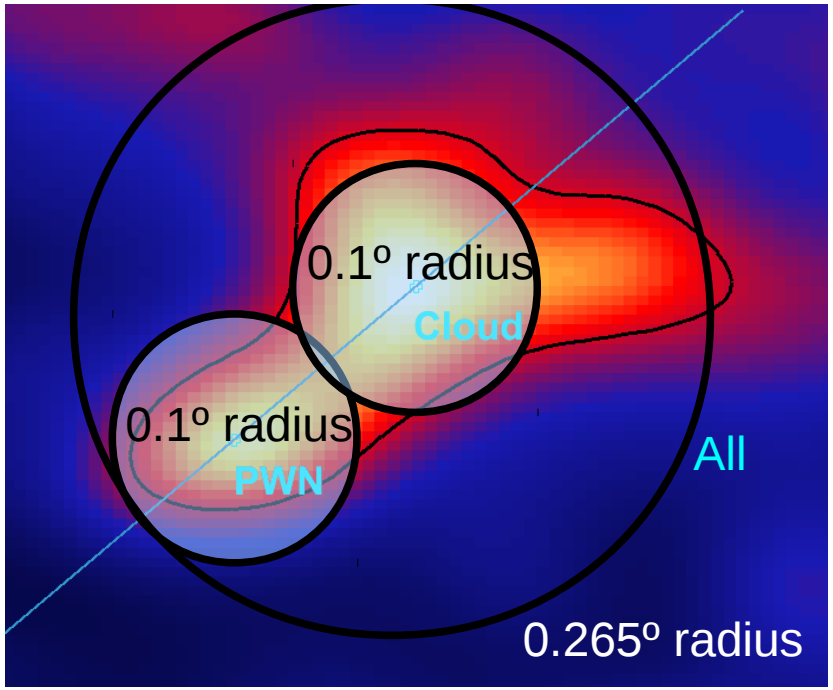


Events within 0.1deg: 25(PWN)/40(Cloud)

Spectral differences in W51

Aleksić et al. 2012, A&A 541, A13 (2012)

E [GeV]	*cloud*	*PWN*	*cloud*/all [%]	*PWN*/all [%]
> 300	200 ± 30	132 ± 25	30 ± 5	19 ± 4
> 500	116 ± 17	79 ± 17	32 ± 6	22 ± 5
> 1000	48 ± 10	27 ± 10	43 ± 12	24 ± 10



Part	Index	Flux
cloud	2.53 +- 0.10	1.2% Crab
PWN	2.66 +- 0.24	0.7% Crab

W51 SED model (input parameters)

Aleksić et al. 2012, A&A 541, A13 (2012)

- One-zone model
- Input particle spectrum:

$$\frac{dN_{e,p}}{dE_{e,p}} = K_{e,p}\left(\frac{E_{e,p}}{E_0}\right)^{-s}\left[1+\left(\frac{E_{e,p}}{E_{\rm br}}\right)^{\Delta s}\right]^{-1}\exp\left[-\left(\frac{E_{e,p}}{E_{{\rm cut},e,p}}\right)\right]$$

- Input parameters:

Parameter	Value	Reference
age	$\approx 30\,000$ yr	Koo et al. (1995b)
$E_{\rm SN}$	$\approx 3.6\times10^{51}$ erg	Koo et al. (1995b)
d	5.5 kpc	Sato et al. (2010)
		Moisés et al. (2011)
θ (radio)	$\approx 30'$	Moon & Koo (1994)
$B_{\parallel}$	$< 150\ \mu$G	Koo et al. (2010)
B (at masers)	1.5–1.9 mG	Brogan et al. (2000)
α_r	≈ -0.26	Moon & Koo (1994)
$m_{\rm cloud}$	1.9×10^5 M$_\odot$	Carpenter & Sanders (1998)