

# Ongoing cosmic ray acceleration in the supernova remnant W51C revealed with the MAGIC Telescopes

(Aleksic et al. 2012, A&A, Volume 541, id.A13)

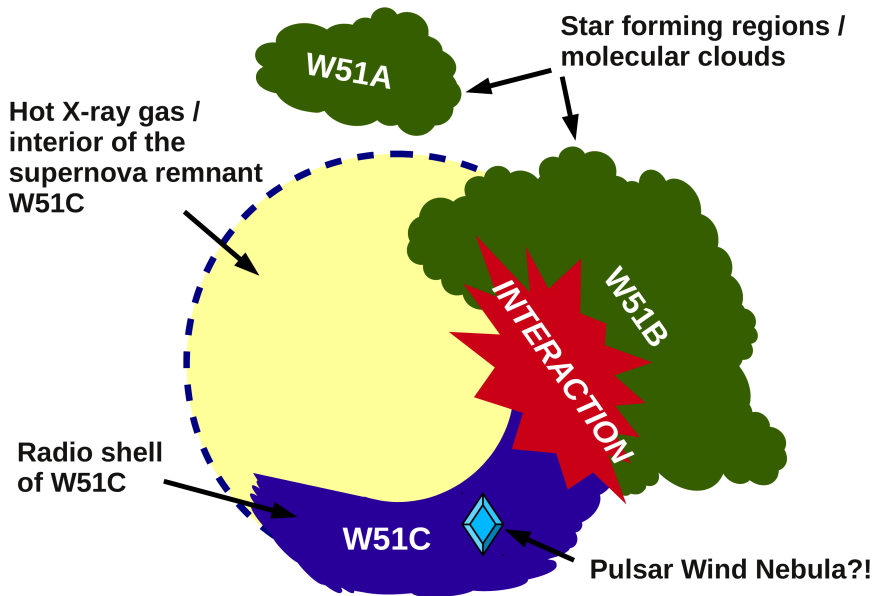
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on behalf of



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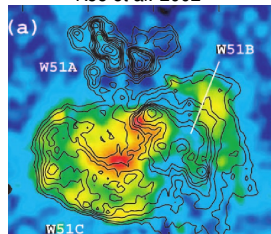
GAMMA 2012, July 9 – 13, 2012

# An illustration of the W51 complex

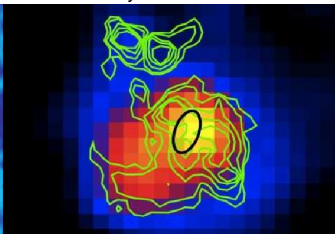


# Details about the W51 complex

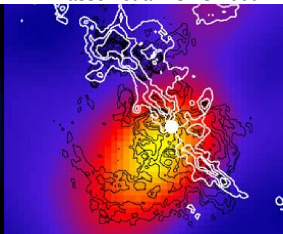
ROSAT 0.7-2.5 keV  
Koo et al. 2002



Fermi / LAT 2-10 GeV  
Uchiyama et al. 2011



H.E.S.S.  $>1$  TeV  
Fasson et al. ICRC 2009



- W51C ( $d \sim 5.5$  kpc) is a medium age ( $\sim 30$  kyr) supernova remnant [SNR]
- Possible Pulsar Wind Nebula associated to W51C (Koo et al. 2005)
- The SNR interacts with W51B (Koo et al. 1997a&b, Green et al. 1997)
- Discovered by *Fermi* / LAT ( $\sim$  GeV) and H.E.S.S. ( $4.4\sigma$ , flux  $> 1$  TeV)
- High CR ionization,  $\sim 100 \times$  ISM value (Ceccarelli et al. 2011)

**Promising candidate to test and study cosmic ray acceleration in SNR's**

# The MAGIC Telescopes



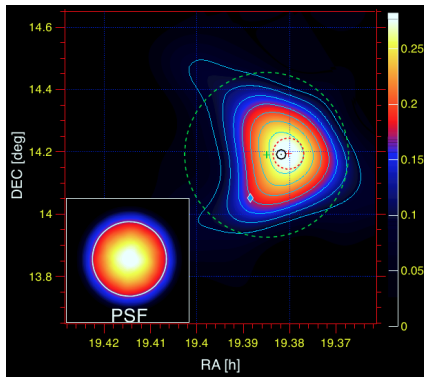
Located on La Palma (Canaries)  
Roque de los Muchachos  
2200 meter a.s.l.

Stereoscopic system of two  
imaging air Cherenkov telescopes

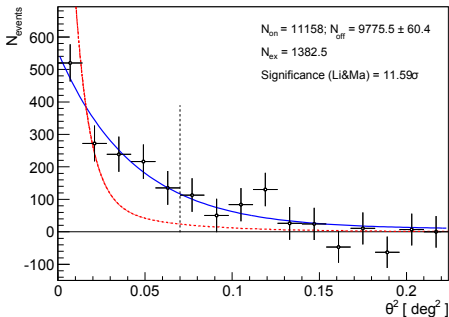
- Reflector diameter 17 m
- Energy threshold  $\sim 50$  GeV

| Performance                       | $> 0.3$ TeV       | $> 1$ TeV         |
|-----------------------------------|-------------------|-------------------|
| Sensitivity <sub>50h</sub> [crab] | $\sim 0.8\%$      | $\sim 0.9\%$      |
| Angular resolution                | $\sim 0.07^\circ$ | $\sim 0.05^\circ$ |
| Energy resolution                 | $\sim 17\%$       | $\sim 17\%$       |

# Detection of W51 with MAGIC ( $>150$ GeV)

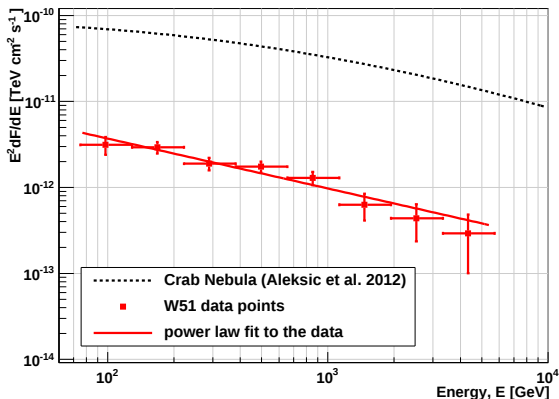


- data taken in 2010 & 2011
- 53 h effective time
- stereoscopic wobble data
- zenith range:  $14\text{--}35^\circ$



- $11\sigma$  detection  $>150$  GeV
- centroid:  
 $\text{RA} = 19.382 \pm 0.001\text{h}$   
 $\text{DEC} = 14.191 \pm 0.015^\circ$
- extension:  
 $0.12 \pm 0.02_{\text{stat}} \pm 0.02_{\text{syst}}^\circ$

# MAGIC high energy $\gamma$ -ray spectrum of W51



- ▶ integration radius 0.26 deg
- ▶ from 75 up to 5500 GeV
- ▶ well fitted by power law  
 $\chi^2/\text{d.o.f.} = 5.26/6$
- ▶ flux  $\sim 3\%$  crab  
compatible with H.E.S.S.
- ▶ spectral index compatible  
with *Fermi*/LAT  $> 10$  GeV

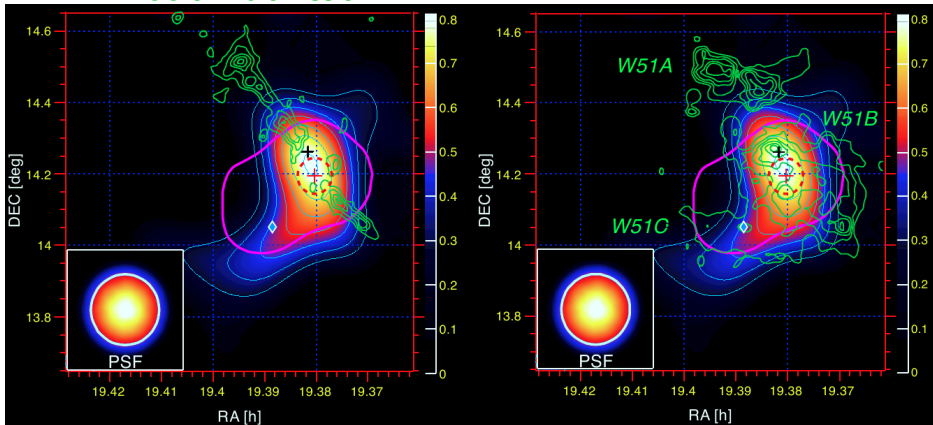
## Differential energy spectrum:

$$\frac{dF}{dE} = (9.7 \pm 1.0_{\text{stat}}) \times 10^{-13} \left( \frac{E}{\text{TeV}} \right)^{(-2.58 \pm 0.07_{\text{stat}})} [\text{TeV}^{-1} \text{cm}^{-2} \text{s}^{-1}]$$

# Morphology (300 – 1000 GeV)

–  $^{13}\text{CO}$  J=1-0 emission

– 21 cm continuum emission



+ OH Maser

◆ CXO J192318.5+140305 (possible PWN)

⊕ Shock cloud interaction region

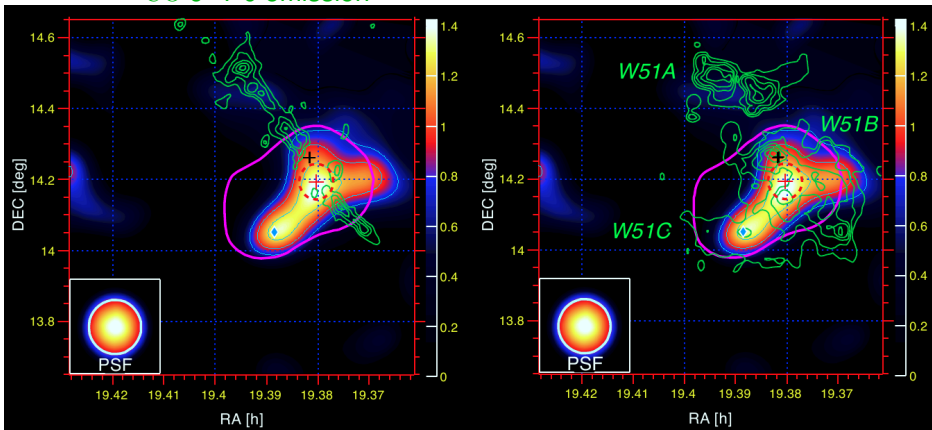
— *Fermi*/LAT 3 counts contour  $>1$  GeV

— MAGIC test statistics starting at 3 (+1 per contour)

# Morphology ( $> 1000$ GeV)

–  $^{13}\text{CO}$  J=1-0 emission

– 21 cm continuum emission



+ OH Maser

◆ CXO J192318.5+140305 (possible PWN)

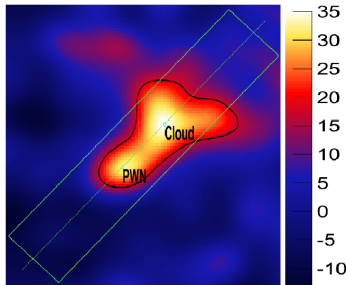
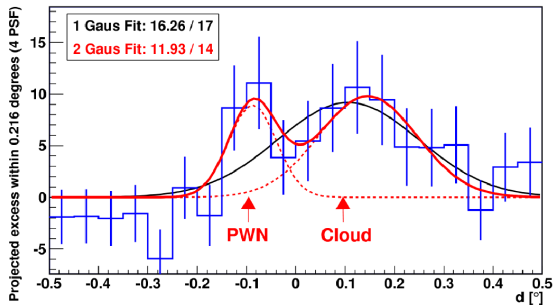
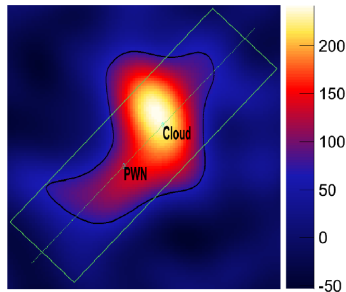
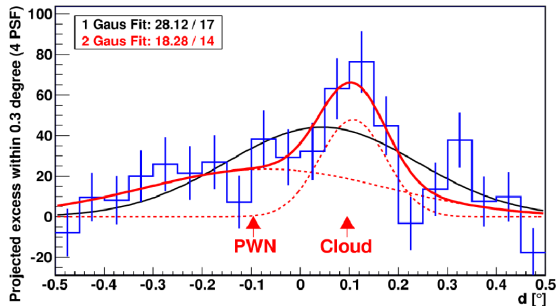
⊕ Shock cloud interaction region

— *Fermi*/LAT 3 counts contour  $> 1$  GeV

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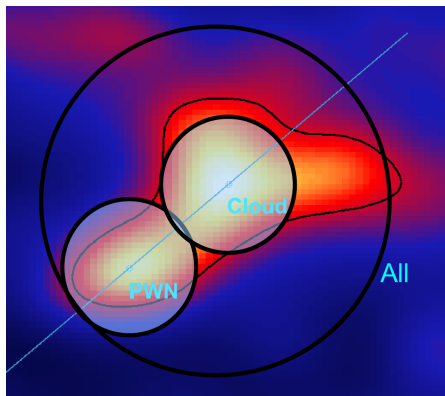
# Underlying structures?

(top: 300 – 1000 GeV, bottom: >1000 GeV)



# Excess contributions

| $E$ [GeV] | <i>cloud</i> | <i>PWN</i>   | <i>cloud/all</i> [%] | <i>PWN/all</i> [%] |
|-----------|--------------|--------------|----------------------|--------------------|
| $> 300$   | $200 \pm 30$ | $132 \pm 25$ | $30 \pm 5$           | $19 \pm 4$         |
| $> 500$   | $116 \pm 17$ | $79 \pm 17$  | $32 \pm 6$           | $22 \pm 5$         |
| $> 1000$  | $48 \pm 10$  | $27 \pm 10$  | $43 \pm 12$          | $24 \pm 10$        |



- Integration radius:  $0.1^\circ$
- Significance for the individual regions  $> 300$  GeV :
  - $10\sigma$  (All)
  - $7\sigma$  (Cloud)
  - $5\sigma$  (PWN)

- **No** energy dependence
- Flux (point-source):
  - PWN*  $\sim 0.7\%$  crab nebula
  - Cloud*  $\sim 1.2\%$  crab nebula

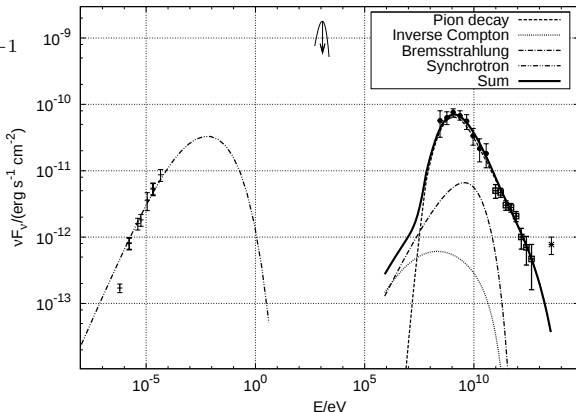
# Leptonic or Hadronic ?!

Cosmic ray spectrum

$$\propto \left( \frac{E_{e,p}}{E_0} \right)^{-s} \left[ 1 + \left( \frac{E_{e,p}}{E_{br}} \right)^{\Delta s} \right]^{-1}$$

## Best fit results:

- ▶  $s = 1.5$
- ▶  $E_{br} = 10 \text{ GeV}$
- ▶  $\Delta s = 1.2$
- ▶  $n = 10 \text{ cm}^{-3}$
- ▶  $B = 53 \text{ } \mu\text{G}$
- ▶  $K_e/K_p = 1/80$
- ▶  $W_p = 5.8 \times 10^{50} \text{ erg}$



- Simple 1-zone hadronic model explains the data  
~ 16% conversion of kinetic SNR energy to CR's
- No (1-zone) leptonic description matching the data could be found  
in agreement with the results of Abdo et al. 2009

# Summary & Conclusions

- **Spectral and morphological properties of W51**

- ▶ Flux  $\sim 3\%$  crab nebula
- ▶ Simple power law from  $\sim 10$  GeV to  $\sim 5$  TeV
- ▶ Centroid at shock cloud interaction
- ▶ Feature towards possible PWN ( $\sim 0.7\%$  crab nebula)
- ▶ Edges of W51B *dark* in VHE  $\gamma$  rays

- **Physical interpretation**

- ▶ Emission most probably hadronic
- ▶ VHE  $\gamma$  rays from (re-)acceleration zone
- ▶ Ongoing CR acceleration at least up to  $\sim 50$  TeV

