SNR and molecular cloud associations as seen by H.E.S.S.

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on behalf of the H.E.S.S. Collaboration
H.E.S.S. experiment

- Most sensitive Cherenkov Telescopes
  - \( \sim 100 \text{ GeV} - 100 \text{ TeV} \)

- Performant strategy for CR acceleration site study:
  - Large Galactic observations
  - High number of detected sources (>80)
  - Angular resolution <0.1 deg
    => Very successful

- New phase HESS II since 2012
  - Lower threshold
SNR seen by H.E.S.S.

- SNRs are best candidates for Galactic cosmic rays accelerators
- VHE Gamma-rays detected from several SNR shells
  - Particles confined at shock
  - Evidence of >100 TeV accelerated particles
- What’s γ-rays origin?

\[ e^- + \gamma_{CMB} \rightarrow \gamma_{TeV} \]

\[ RC + p \rightarrow \pi^0 + \ldots \rightarrow \gamma_{TeV} \]
SNR seen by H.E.S.S.

- SNRs are best candidates for Galactic cosmic rays accelerators
- VHE Gamma-rays detected from several SNR shells
  - Particles confined at shock
  - Evidence of >100 TeV accelerated particles
- MWL measurements from RXJ1713 favor a leptonic origin
  - What about hadron acceleration?
  - Not enough dense ISM to detect them?

\[ e^{-} + \gamma_{CMB} \rightarrow \gamma_{TeV} \]

\[ RC + p \rightarrow \pi^{0} + \ldots \rightarrow \gamma_{TeV} \]
SNR/MC interest

- SNR shock propagating in dense medium:
  - Gamma-ray emission from hadronic collisions enhanced
  - Illuminated cloud away from the SNR may probe the highest CR energies

\[ RC + p \rightarrow \pi^0 + \ldots \rightarrow \gamma_{TeV} \]

- Massive stars originate inside massive dense coulds
  - Short life time => SNe close to the progenitor clouds
  - Frequent associations expected

- Large fraction of SNR show evidence of interaction such as
  - OH masers (1720 MHz)
  - Shocked molecular lines
  - Dust lines (SiO) heated by shock

Wardle, 2002

Require dense ISM
SNR/MC interest

W44

Ackermann et al. (2013)
Pending questions:

- Break between GeV/TeV (also for IC443) : systematic ?
- Are SNRs PEV accelerator?

TeV observations required
W 28

- D \sim 2-3 \text{kpc}
- Age \sim 35 - 150 \text{ kyr}
- CO coincident with TeV emission
- Two MC complexes North/South
- North cloud is shocked by W28 OH masers
- Brighest GeV emission from north cloud
Visible effect of accelerated particle diffusion away from the shock
• $E_{\text{Break}} \sim 1 \text{ GeV}$
**W 49B**

- **D ~ 8 - 12 kpc**
- **Age ~ 1 - 4 kyr**
- Evidences of SNR / dense medium interaction
  - Shocked molecular lines
- **TeV emission at the position of the SNR**
- **GeV coincident with the H.E.S.S source**

*Brun et al. 2010*

**Fermi position**

**NVSS radio contours**

**PRELIMINARY**
W 49B

- D ~ 8 - 12 kpc
- Age ~ 1 - 4 kyr
- Evidences of SNR / dense medium interaction
  - Shocked molecular lines
  - TeV emission at the position of the SNR
  - GeV coincident with the H.E.S.S source

Brun et al. 2010

- NVSS radio contours
- Fermi position

- Nice GeV/TeV spatial and spectral matching
- \( E_{\text{Break}} \sim 5 \text{ GeV} \)

\( \Gamma = 2.18 \pm 0.04 \)
\( \Gamma = 2.9 \pm 0.2 \)
\( \Gamma = 3.1 \pm 0.3 \)
G 349.7+0.2

- D ~ 11 - 12 kpc
- Age ~ 1.8 kyr
- Radio emission from the shell
- MC (~10^4 M☉) beyond the SNR
- Strong evidences of SNR/MC interaction
  - OH masers toward molecular clouds
  - Shocked molecular lines

VLA image

CO (2-1) contours v ~ 15 km/s
+ : OH Masers

Dubner et al. 2004

Tian & Leahy 2014
G 349.7+0.2

- Very nice correlation X-rays / Radio
- Two thermal X-rays component
  - Ejecta
  - Shocked gas
- No evidence of PWN
- No nonthermal X-rays detected
G 349.7+0.2

- Region covered by the Galactic plane survey + dedicated observations

- Close to:
  - RX J1713.7-3946
  - CTB37 A&B

- Point like TeV excess at the SNR position
G 349.7+0.2

- Reprocessed GeV data
- > 5 yr data analysed (with new IRFs)
- Very nice spatial agreement HESS/Fermi
G 349.7+0.2

- No significant spectral break in Fermi data
- $E_{\text{Break}} > 10$ GeV (under study)
**SNR/MC candidates**

- **W51, W41 & CTB37 A:**
  - Other scenario possible

- **Puppis A:**
  - GeV emission but no TeV detection

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- **Dubner et al. 2013**
  - X-rays

- **Fiasson et al. 2009**
  - CRISM 2014

- **Aharonian et al. 2008**
  - CTB 37A
  - H.E.S.S.
  - HESS Collab 2014 sub.
SNRs in dense medium

- HESS J1640-465
- HESS J1641-463
  - No tracer of physical interaction
  - Other scenario possible

- Kes 78, W30 :
  - Possible PWN emission

- ...

Oya et al. 2012
Aharonian et al. 2005

HESS Collab 2014
HESS J1640-465
CRISM 2014  C. Trichard  24.06.2014     Montpellier
### Common properties

<table>
<thead>
<tr>
<th>Source</th>
<th>Age (kyr)</th>
<th>Distance (kpc)</th>
<th>$E_{\text{Break}}$ (GeV)</th>
<th>$\Gamma_{E&lt;\text{Break}}$</th>
<th>$\Gamma_{E&gt;\text{Break}}$</th>
<th>$\Gamma_{\text{TeV}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 28N</td>
<td>~ 35 - 150</td>
<td>~ 2 - 3</td>
<td>1\pm0.2</td>
<td>2.09\pm0.08</td>
<td>2.74\pm0.06</td>
<td>2.66\pm0.27</td>
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<tr>
<td>W 49B</td>
<td>~ 1 - 4</td>
<td>~ 8 - 12</td>
<td>4.8\pm1.6</td>
<td>2.18\pm0.04</td>
<td>2.9\pm0.2</td>
<td>3.1\pm0.3</td>
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<tr>
<td>G349.7+0.2</td>
<td>~ 2</td>
<td>~ 11 - 12</td>
<td>&gt;10 (?)</td>
<td>2.19\pm0.04</td>
<td></td>
<td>2.8\pm0.3</td>
</tr>
<tr>
<td>CTB 37A</td>
<td>-</td>
<td>~ 6 - 10</td>
<td>-</td>
<td>LogParabola</td>
<td></td>
<td>2.3\pm0.13</td>
</tr>
<tr>
<td>W 51</td>
<td>~ 30</td>
<td>~ 6</td>
<td>-</td>
<td>LogParabola</td>
<td></td>
<td>detected</td>
</tr>
<tr>
<td>Puppis A</td>
<td>~ 4 - 8</td>
<td>~ 2</td>
<td>?</td>
<td>2.6\pm0.13</td>
<td></td>
<td>U.L.</td>
</tr>
<tr>
<td>W 41</td>
<td>~ 60 - 200</td>
<td>~ 4</td>
<td>?</td>
<td>2.15\pm0.12</td>
<td></td>
<td>2.64\pm0.13</td>
</tr>
<tr>
<td>W44</td>
<td>~ 10</td>
<td>~ 3</td>
<td>~ 2</td>
<td>2.36\pm0.05</td>
<td>3.5\pm0.3</td>
<td>-</td>
</tr>
<tr>
<td>IC 443</td>
<td>~ 10</td>
<td>~ 1 - 2</td>
<td>~ 20</td>
<td>2.36\pm0.02</td>
<td>3.1\pm0.1</td>
<td>3.1\pm0.3</td>
</tr>
</tbody>
</table>
What do we learn?

- TeV emission seemed related with SNR/Cloud interaction not from the shell

- Common features:
  - Spectral break GeV/TeV PowerLaw
  - Bright + "flat" GeV spectra
    Faint + soft TeV spectra
  - Hadronic origin of the γ-rays favored
    - $W_p < \sim 10 \% E_{SNR}$
    - No detection of VHE cutoff

- Evolution with age?
  - $E_{break}$  
    Strongly depend on environmental conditions
  - $\Gamma_{TeV}$
    Need bigger set of sources
• Fifth big telescope (2012):
  - Lower threshold: ~30 GeV

• Which interests for SNR/MC studies?
  - Overlap with Fermi
  - SNR/MC exhibit soft faint spectrum
  - More constraints on $E_{\text{Break}}$
Summary

- Number of SNR/MC detected at GeV and TeV increase steadily (new G349.7+0.2) + Large number of candidates

- Common spectral features appeared:
  - Spectral break GeV / TeV
    TeV observations needed
  - No signature of VHE cutoff

- Interesting objects for the whole CR community
  Acceleration/Diffusion/Propagation
  Cloud ionisation / ISM Chemistry
Thank you
W28 clouds

NANTEN $^{12}$CO(J=1-0) image of the W28 region

NANTEN $^{12}$CO(J=1-0) image of the W28 region
W 51

H.E.S.S.

\[ \text{\textsuperscript{13}CO contours} \]

\[ \text{OH masers} \]

\[ \text{H.E.S.S. sig. contours} \]

\[ \text{SNR G49.2-0.7} \]

\[ \text{CXO J192318.5+140305} \]

\[ \text{Preliminary} \]

\[ \text{Right ascension} \]

\[ \text{Declination} \]

\[ \text{CRISM 2014} \quad \text{C. Trichard} \quad 24.06.2014 \quad \text{Montpellier} \]
Unexpected lack of TeV emission from this young SNR