“New results from the SNR Gamma Cygni”

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on behalf of the AGILE Team

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The Cygnus region
The Cygnus region

Cygnus X North

Cygnus X South

W75N

DR21

S106
The Cygnus region
The Cygnus region
The Cygnus region in $\gamma$-rays:
AGILE-GRID data INTENSITY MAP (100 MeV-10 GeV)

Pointing Mode: ~2 years of data (November 2007 – October 2009), ~315 days, ~13 Ms net exposure time
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 highlighting the Cygnus region with 3 pulsars noted.
The Cygnus region in $\gamma$-rays:

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2 microquasars
The Cygnus region in $\gamma$-rays:

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3 TeV sources
The Cygnus region in $\gamma$-rays:
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SNR G78.2+2.1 (Gamma Cygni)
SNR Gamma Cygni (G78.2+2.1)

- Shell-type SNR with a diameter of ~62' (Higgs, Landecker & Roger, 1977)
- Inferred distance: \( d \sim 1.5 \text{ kpc} \pm 30\% \) (Landecker, Roger & Higgs, 1980)
- Estimated age: \( \tau_{\text{age}} \sim 6600 \text{ years} \) (Uchiyama et al., 2002)
- Shock velocity: \( v_s \sim 800 \text{ km s}^{-1} \) (Uchiyama et al., 2002)
- The non-thermal synchrotron emission has a quasi perfect spherical symmetry

(Ladouceur & Pineault, 2008)
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- The non-thermal synchrotron emission has a quasi perfect spherical symmetry
- The SN exploded in a cavity, evacuated by the strong wind of the progenitor star, surrounded by a denser shell of matter set in motion by the wind (Landecker, Roger & Higgs, 1980 – Ladouceur & Pineault, 2008)

Shell expanding with \(v \sim 10-20\) km s\(^{-1}\)
(from H I kinematics)
The region of the Supernova Remnant Gamma Cygni (G78.2+2.1)

diffuse $\gamma$-ray emission: SNR Gamma Cygni

strong $\gamma$-ray emission: point source
**1AGL J2022+4032:** a bright γ-ray point source within the SNR Gamma Cygni (G78.2+2.1)

<table>
<thead>
<tr>
<th>galactic coordinates</th>
<th>significance</th>
<th>flux above 100 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1AGL J2022+4032</td>
<td>(l, b) = (78.23, 2.12) ± 0.06° (stat) ± 0.10° (syst)</td>
<td>39.64</td>
</tr>
</tbody>
</table>

- **Bright γ-ray source:**
  - the brightest γ-ray source in the Cygnus region
  - associated to the brightest EGRET unidentified source: 3EG J2020+4017

- Identified as a γ-ray pulsar by *Fermi*-LAT (PSR J2021+4026)

- AGILE-GRID observations (~2 years) show strong evidence of **flux variability** (probability of variability >99%, *(Chen, Piano et al., 2011)*) at temporal scale of ~6.5 days in the 100-400 MeV energy band:
  - a variable pulsar (?)
  - multiple objects along the same line-of-sight
    - background blazar (?)
    - X-ray quiet microquasar (?)

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**SNR G78.2+2.1**
DRAO (21.1 cm – 1.42 GHz) + AGILE-GRID contour levels (emission above 100 MeV)
Detection issue:

- $\gamma$-ray emission up to 10 GeV is dominated by the pulsar
- $\gamma$-rays from the SNR are probably “hidden”
- Necessity of “turning off” the PSR!

Ackermann et al., Science, 2011
Our approach to solve the problem:

- “off-pulse” analysis

Vela X PWN
(Pellizzoni et al., *Science*, 2010)
Detection issue:

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- necessity of “turning off” the PSR!

Our approach to solve the problem:

- “off-pulse” analysis
- AGILE-GRID study:
  - 2-years of data (November, 2007 → July, 2009)
  - We “turned off” the strong emission from the pulsar
SNR Gamma Cygni (G78.2+2.1)
“subtracting” the pulsar → “off-pulse” analysis

- PSR → peculiar light curve (high unpulsed fraction, not sharp separation between on-peak and off-peak phases)
- several cuts for the off-pulse phase (45%, 20%, 10%)
- better-defined off-pulse phase: $0.95 \leq \Delta \varphi_{\text{off-phase}} \leq 1.15$ (20%)
- AGILE-GRID imaging for $E \geq 400$ MeV

100% phase
(E $\geq 400$ MeV)

off-pulse
20% phase
(E $\geq 400$ MeV)
SNR Gamma Cygni (G78.2+2.1) “subtracting” the pulsar → “off-pulse” analysis

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**radio** (21.1 cm) **pulse** (E MeV) **off-pulse** 20% phase (E ≥ 400 MeV)
SNR Gamma Cygni (G78.2+2.1)
analysis of the “off-pulsed” map above 400 MeV

Multi-source analysis: 3 γ-ray “sources”
SNR Gamma Cygni (G78.2+2.1) data interpretation hypothesis

- Is the “off-pulsed” emission related to cosmic-ray acceleration in the SNR?
- Natural hypothesis: shock-cloud interaction.

- Accurate pattern of the gas distribution in the region of the SNR:
  - masses, relative distances of the main clouds with respect to the SNR

- Characteristics of the accelerated particles (spectra, electron-proton ratio $\chi_{e,p}$, etc.) through multi-wavelength observations (radio, X-ray, HE & VHE $\gamma$-rays),
  - different contributions to the overall $\gamma$-ray emission:
    - hadronic ($\pi^0$-decay);
    - leptonic (Bremsstrahlung, IC)
SNR Gamma Cygni (G78.2+2.1)
gas distribution

$^{13}\text{CO}$ [J: 1→0, -20 to 0 km s$^{-1}$], FCRAO:

→ MOLECULAR CLOUDS

8.23 μm, MSX (band A):

→ DUST at ~400 K

Hints of dense gas consistent with several $\gamma$-ray features
Hints of non-thermal emission (probably) related to shock-cloud interactions in the North-Western part of the shell

- **X-rays** (Uchiyama et al., 2002):
  ASCA [4-7 keV] clumps (C1, C2, C3) → non-thermal Bremsstrahlung (electrons on dense clouds)

- **HE γ-rays:**
  AGILE-GRID Source A,
  Fermi-LAT 2FGL J2019.1+4040

- **VHE γ-rays:**
  VERITAS VER J2019+407
Modeling the $\gamma$-ray SED of the AGILE source “A”
SNR G78.2+2.1 (Gamma Cygni) 
going analyses

• Mass density estimation of the gas clouds in the SNR region

• **Extended source analysis** of the $\gamma$-ray emission above 400 MeV
  - radio map (shell) of the SNR $\rightarrow$ template of the likelihood analysis
  - significance of the shell-shape in the AGILE “off-pulsed” map

• **Multi-wavelength SED**
  - radio, X-ray, HE (AGILE, Fermi) and VHE (VERITAS) $\gamma$-ray spectra
  - hadronic/leptonic scenario?
SNR G78.2+2.1 (Gamma Cygni) (preliminary) conclusions

• “Turning off” the pulsar, a complex pattern of residual γ-ray emission is detected with a distinct morphology, partially overlapping the boundary of the synchrotron radio shell.

• Hints of shock-cloud interactions in the North-Western side of the shell (X-ray, MeV-GeV-TeV γ-rays).

• Preliminary tests → the AGILE γ-ray SED (source A) consistent with both hadronic and leptonic models.

• If the ongoing tests firmly confirm these preliminary results: FIRST DETECTION of γ-ray emission below 10 GeV associated with the SNR Gamma Cygni.
Thanks!