“New results from the SNR Gamma Cygni”

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on behalf of the AGILE Team

11th AGILE Science Workshop:
“Gamma-rays and Galactic Cosmic Rays”
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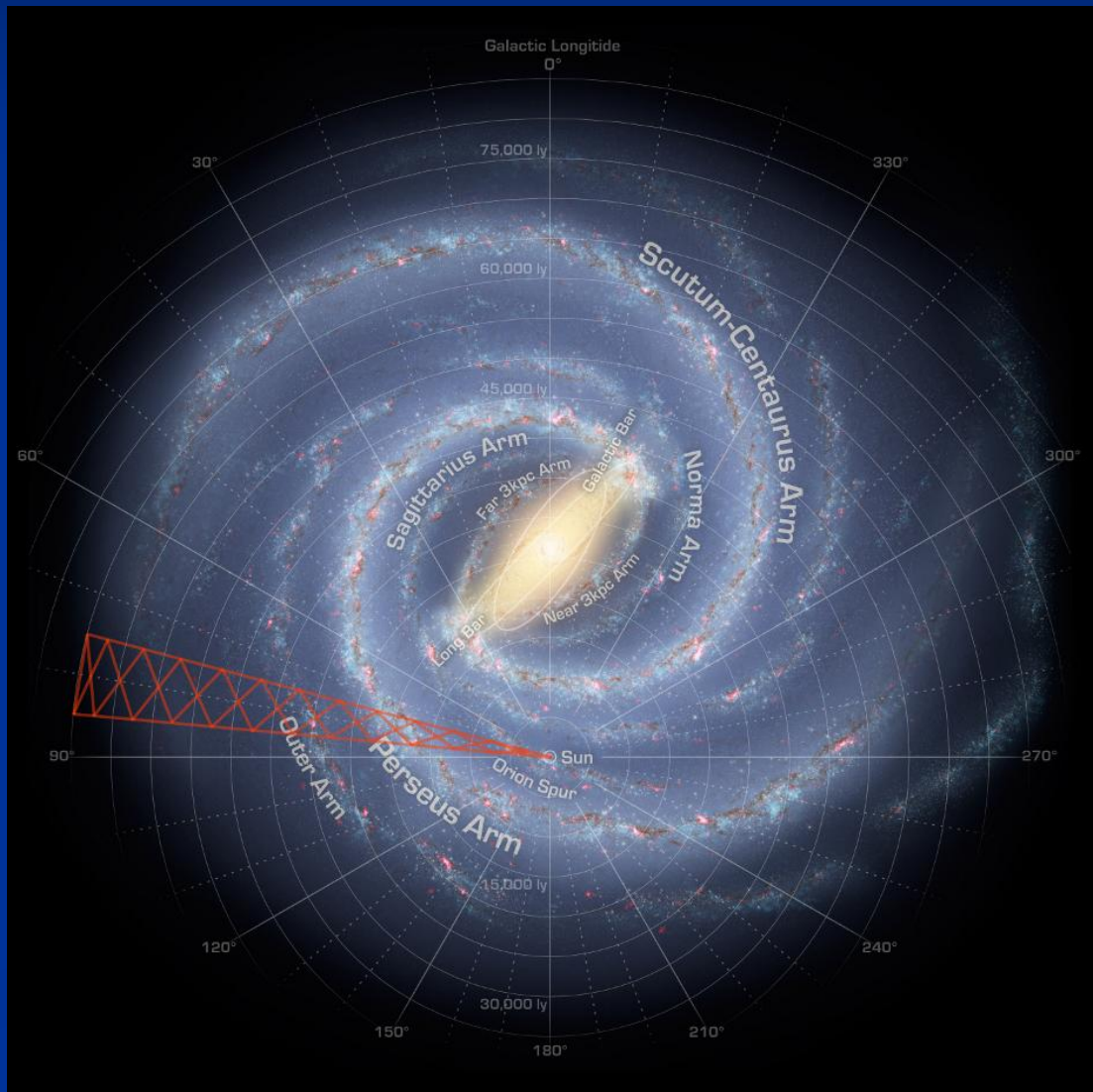
ASI Headquarters, Via del Politecnico, Rome

The Cygnus region



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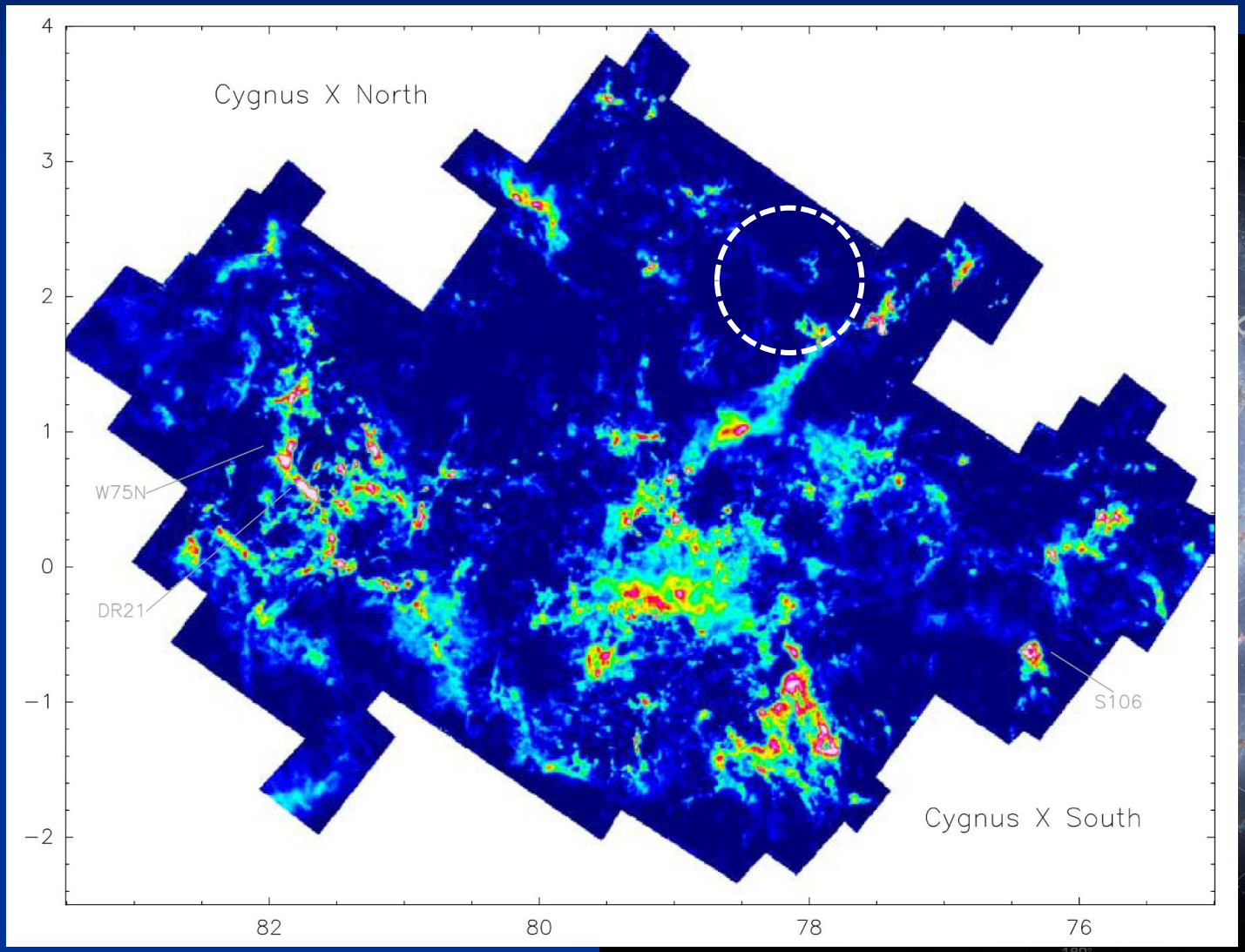

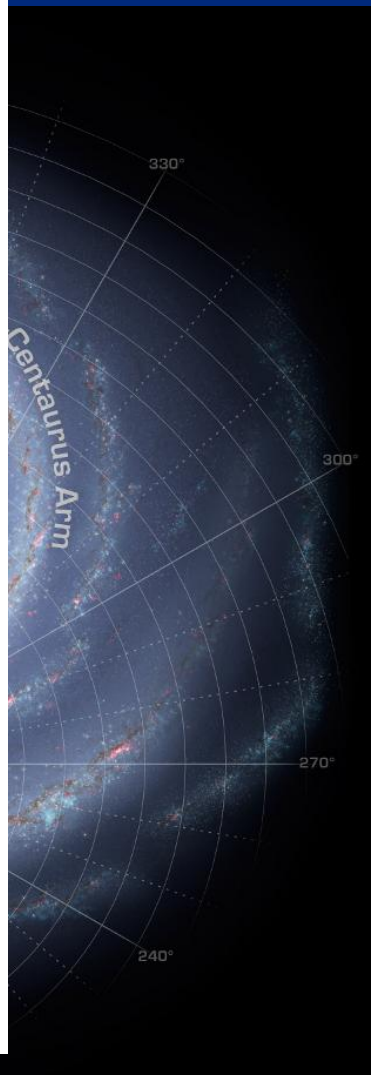

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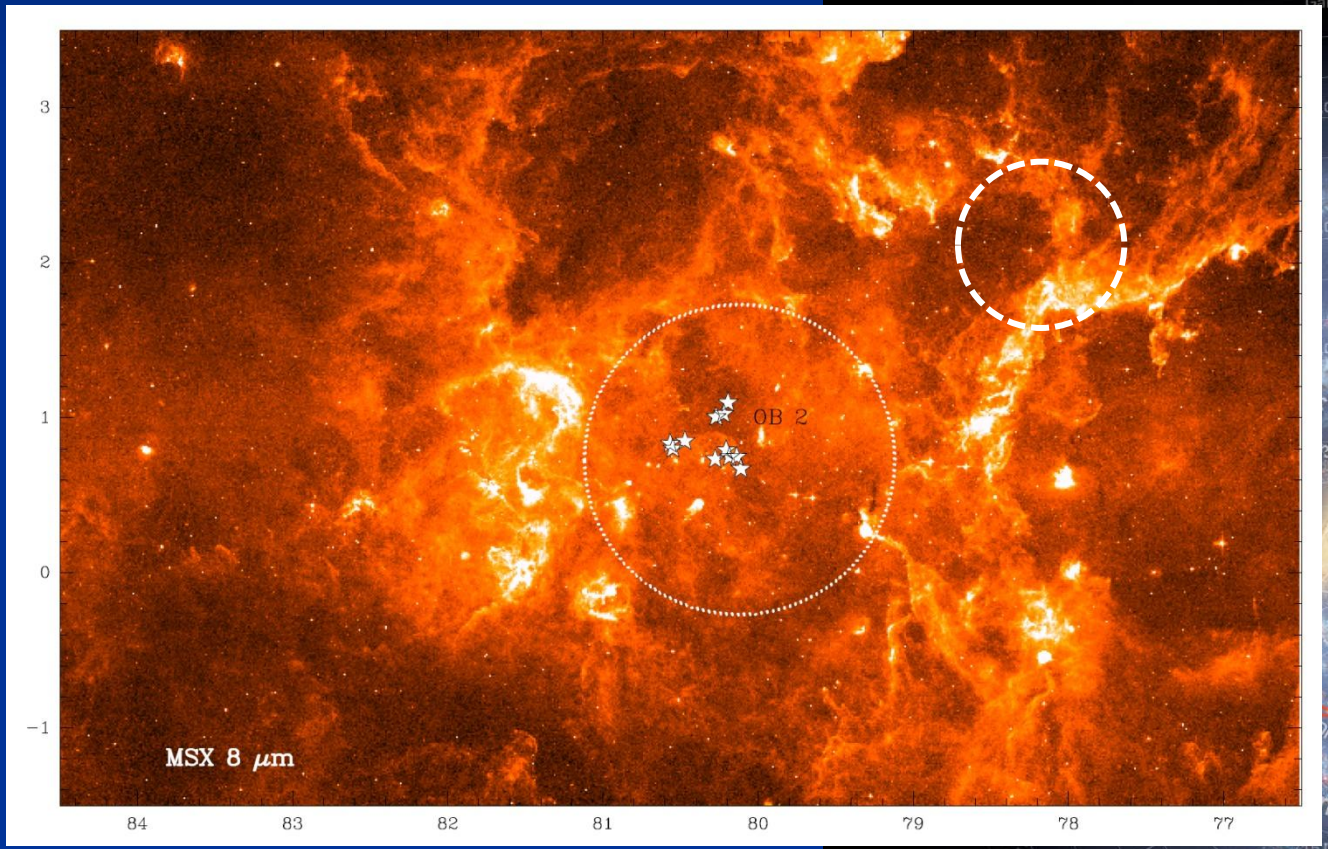

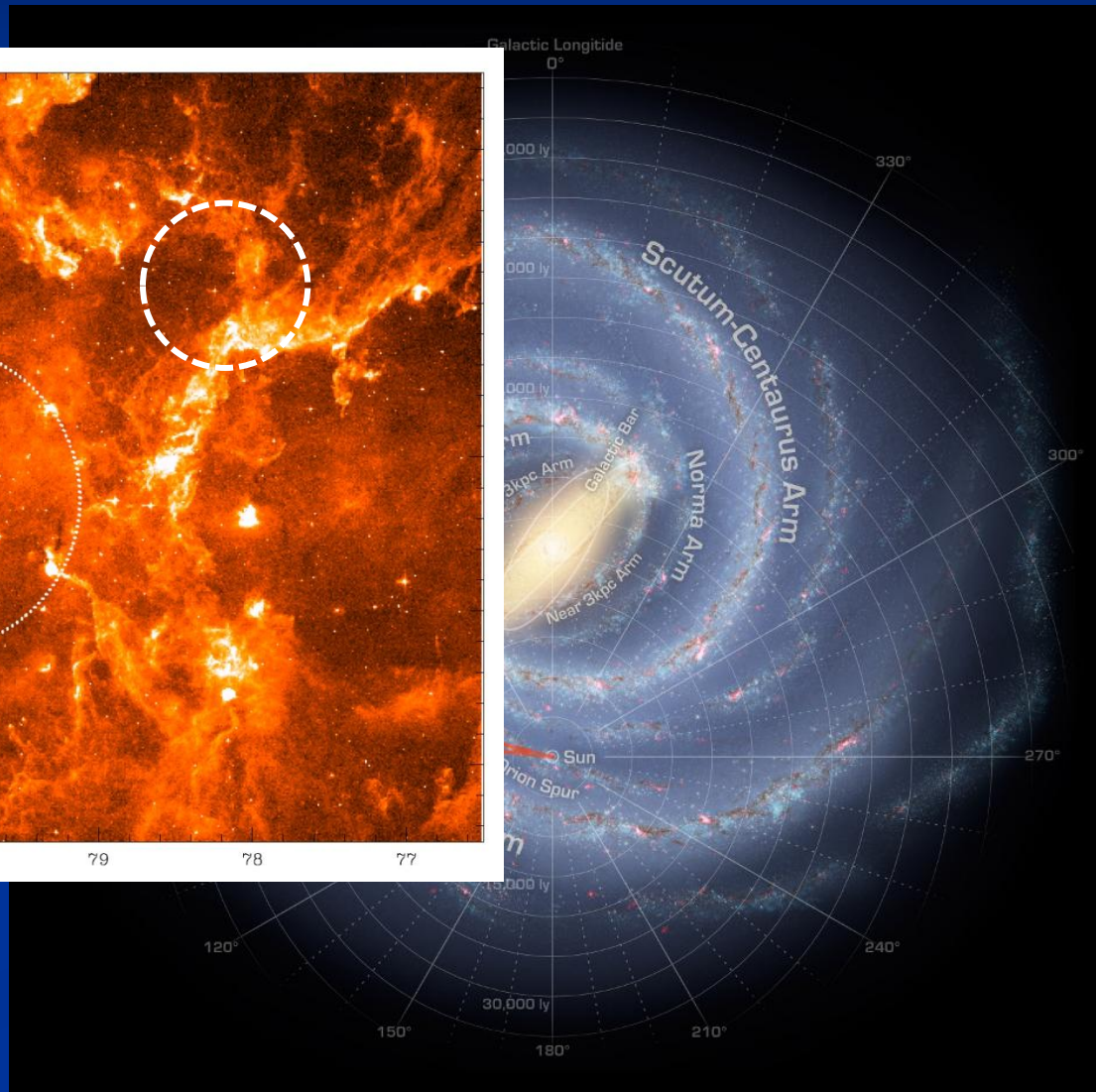

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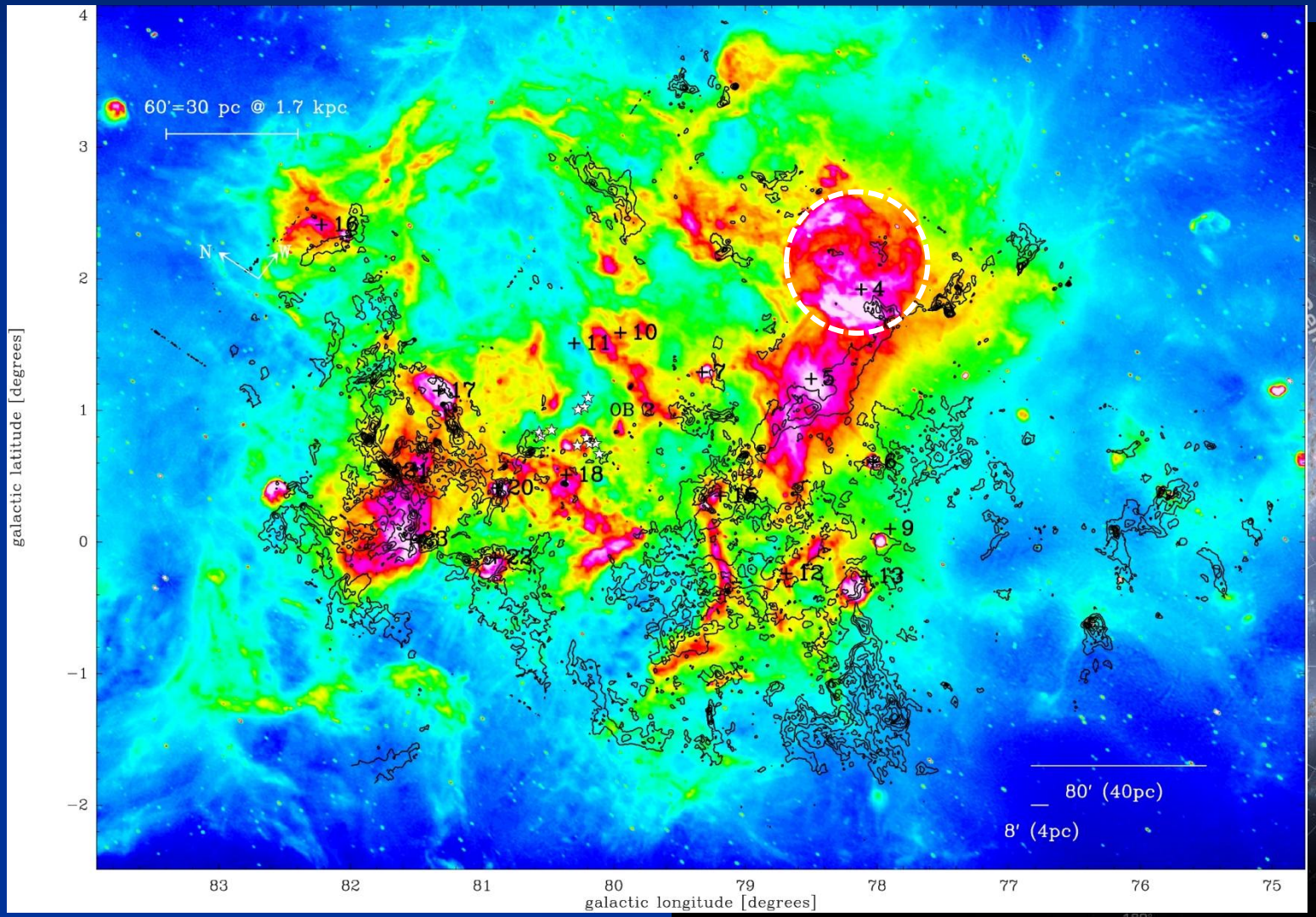
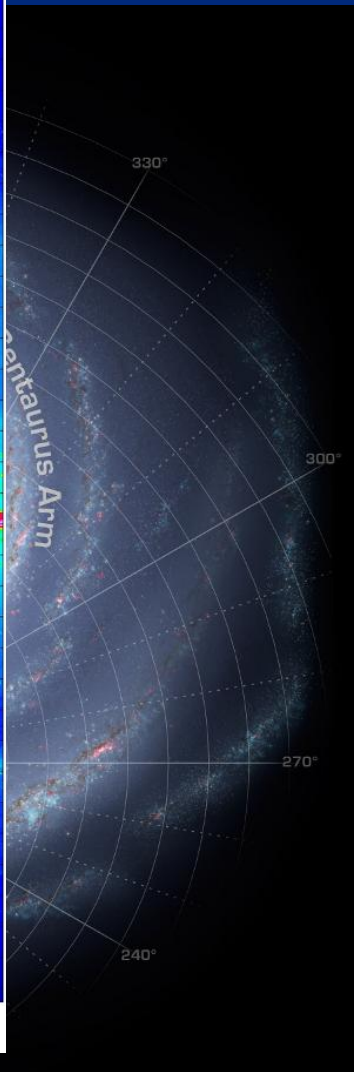
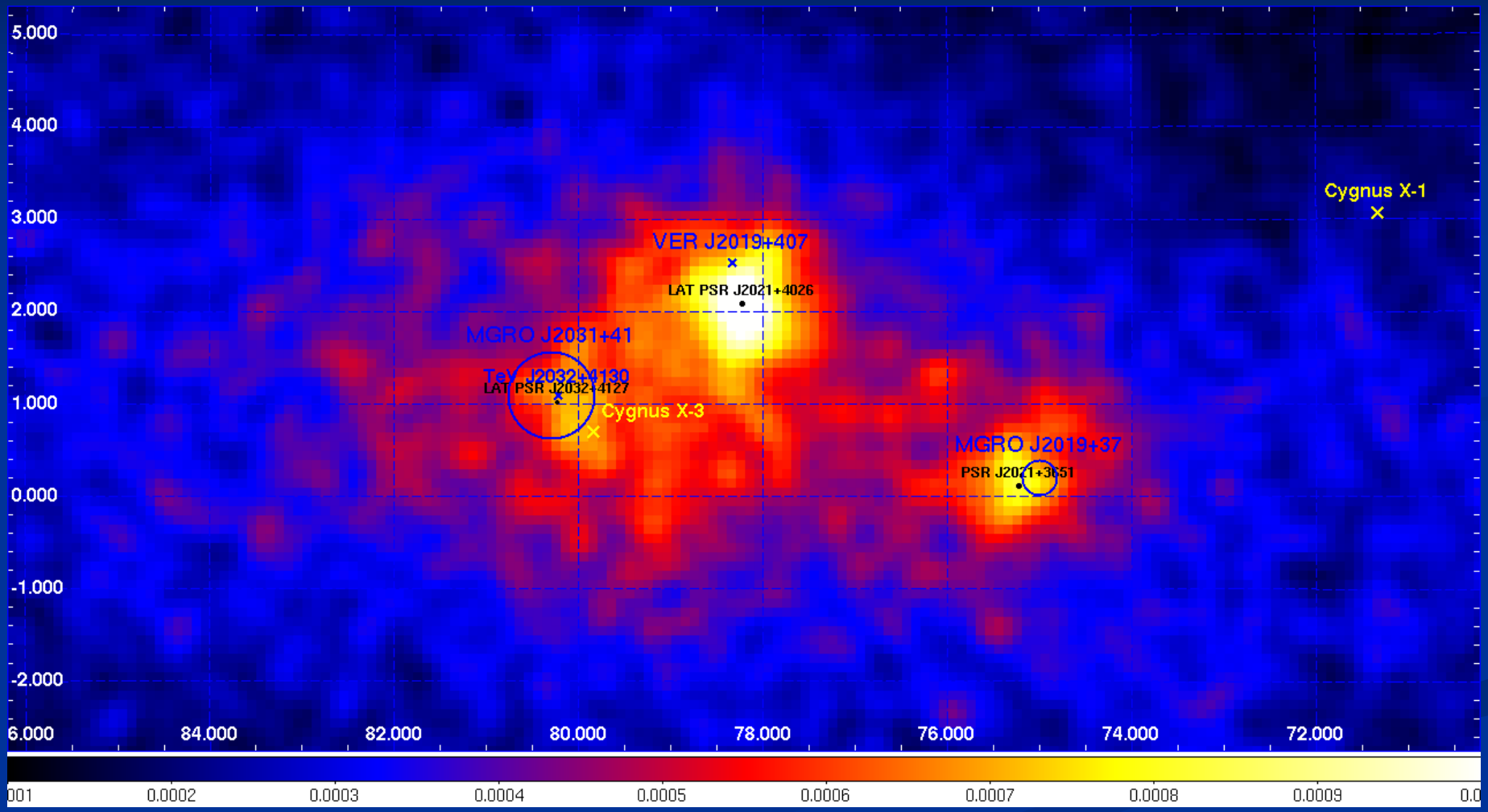




The Cygnus region in γ-rays:

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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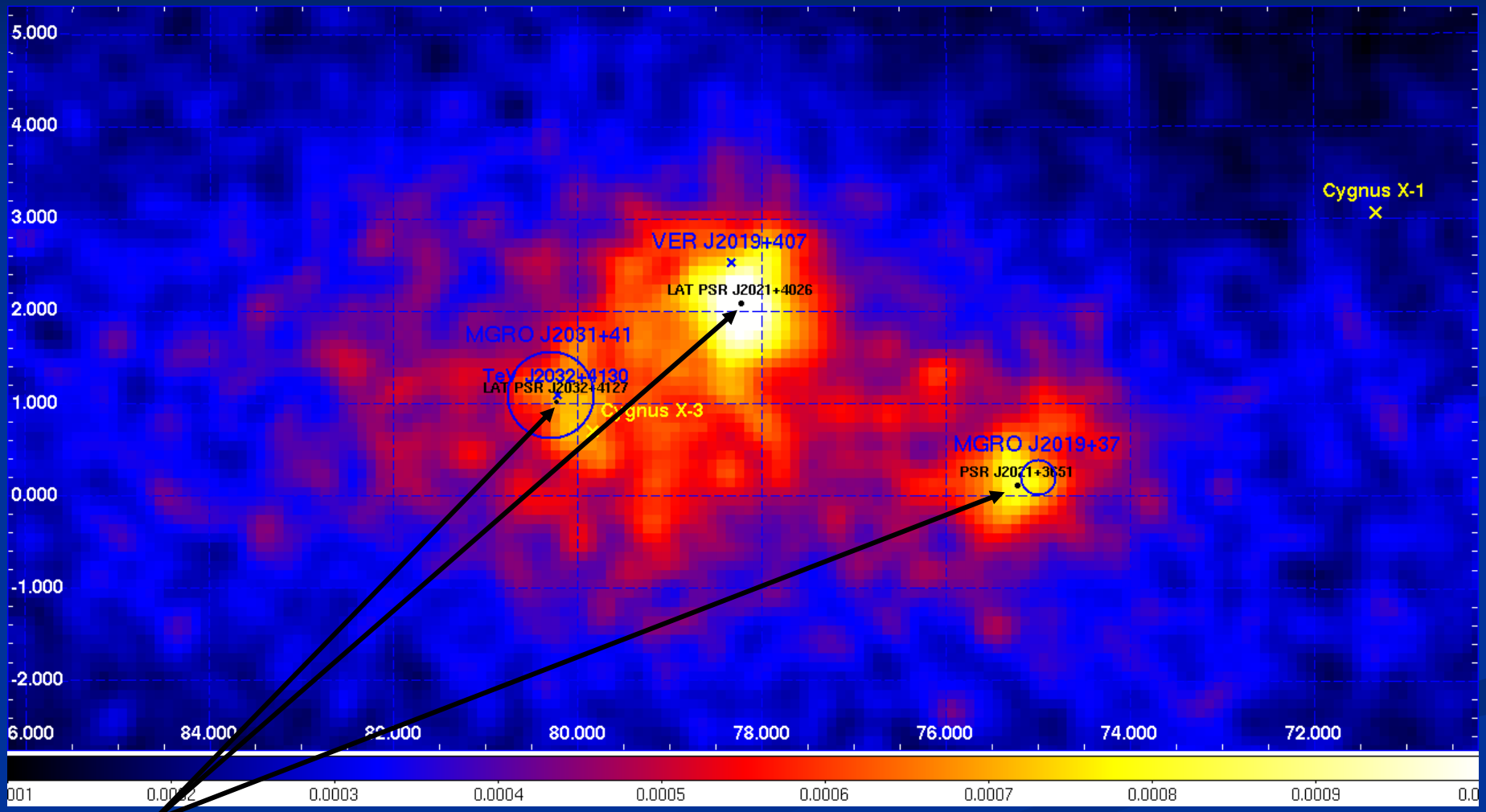

3 pulsars

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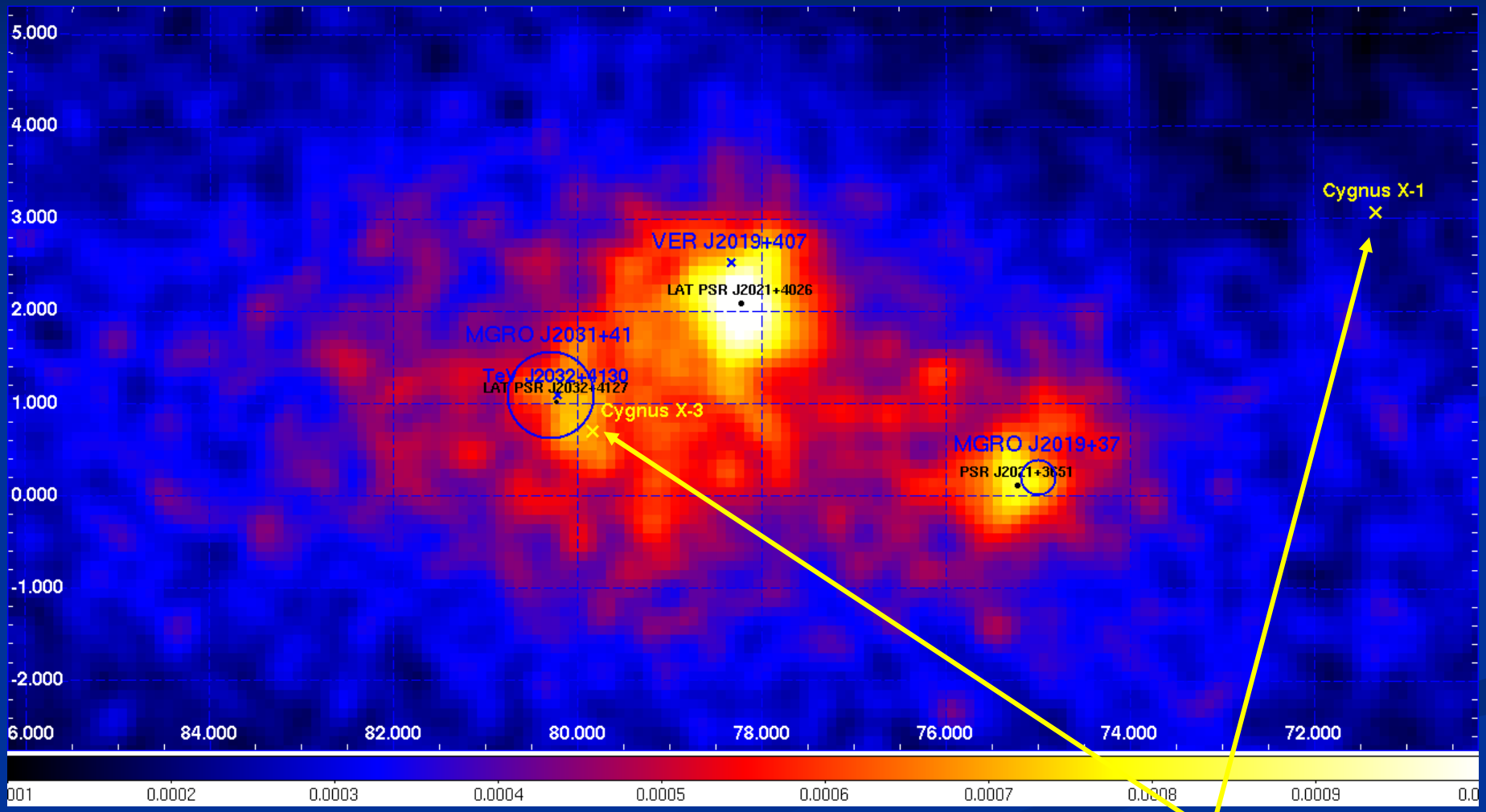

2 microquasars

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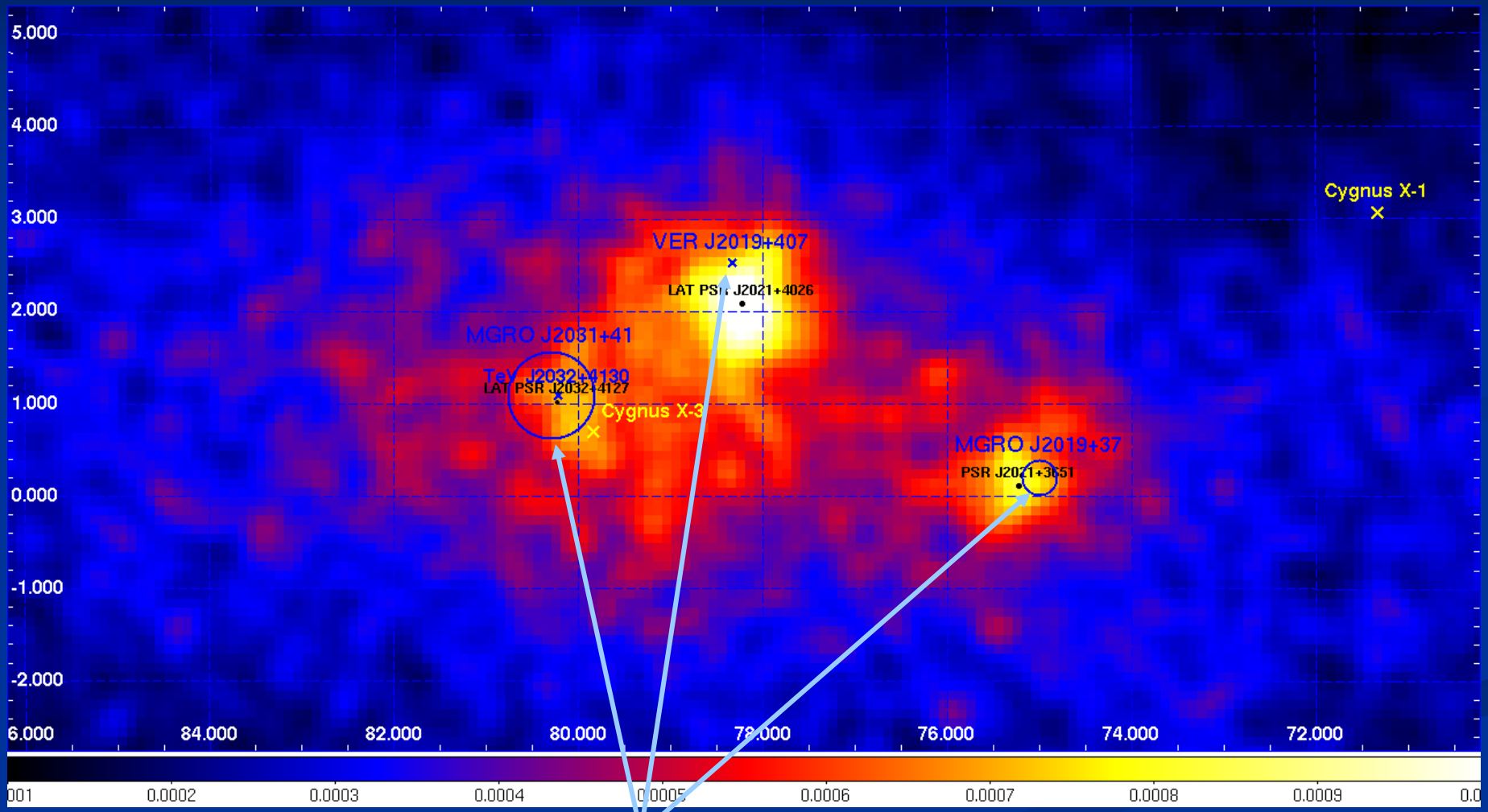

3 TeV sources

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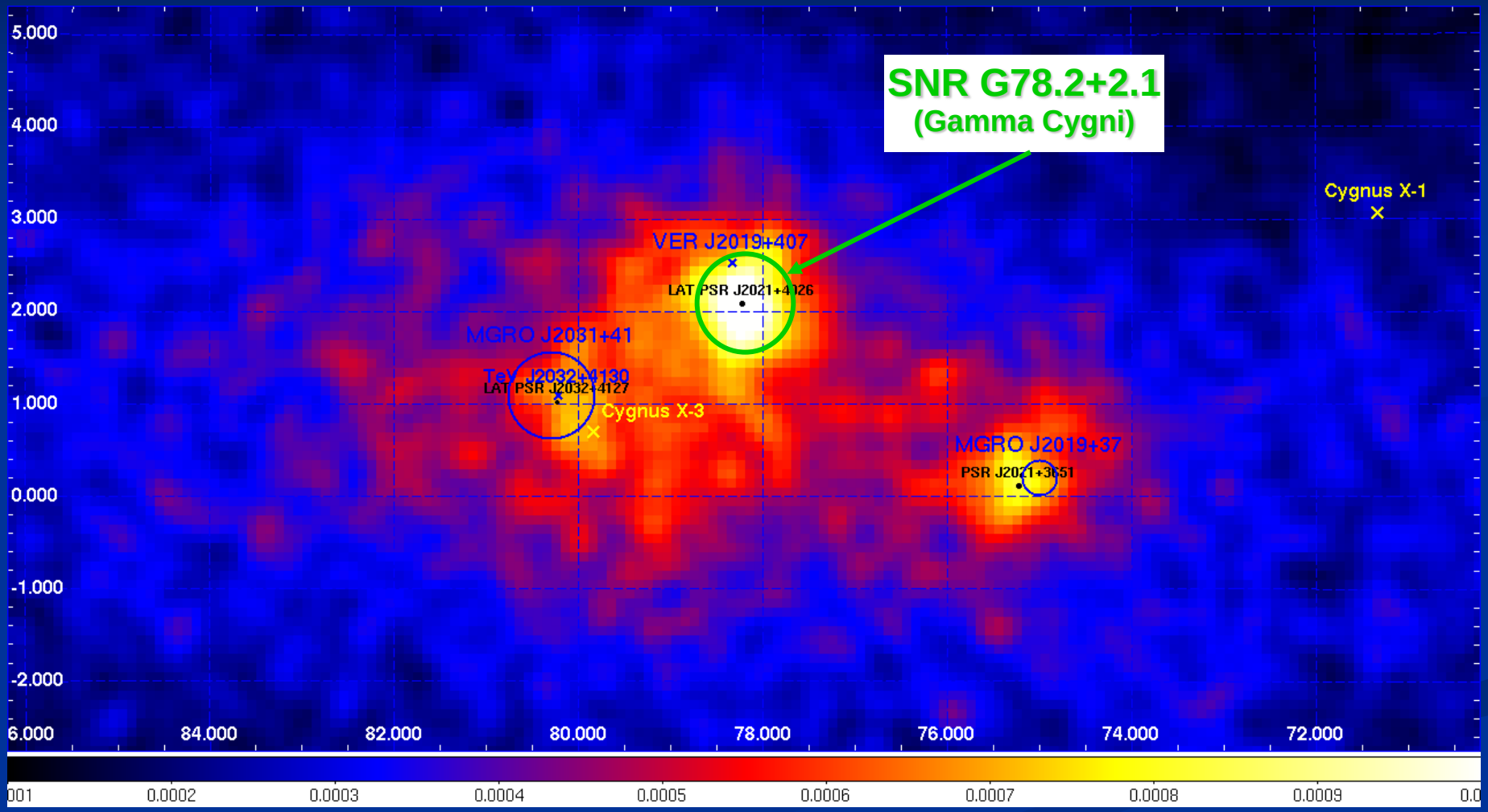
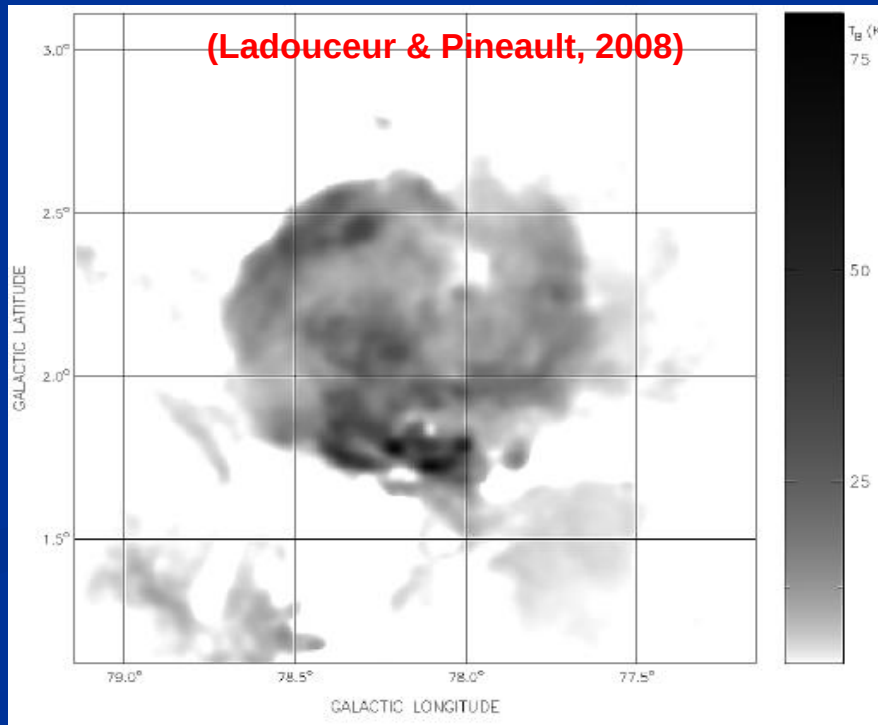


SNR Gamma Cygni (G78.2+2.1)

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



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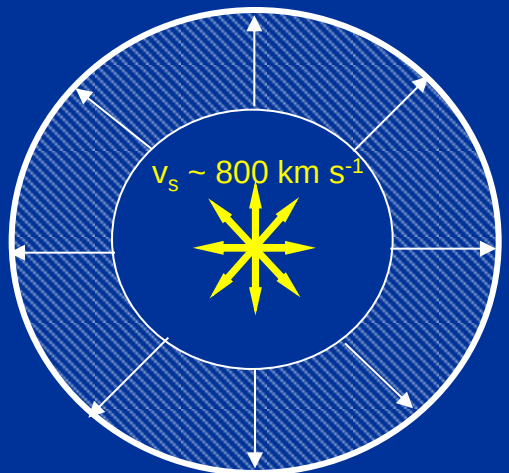
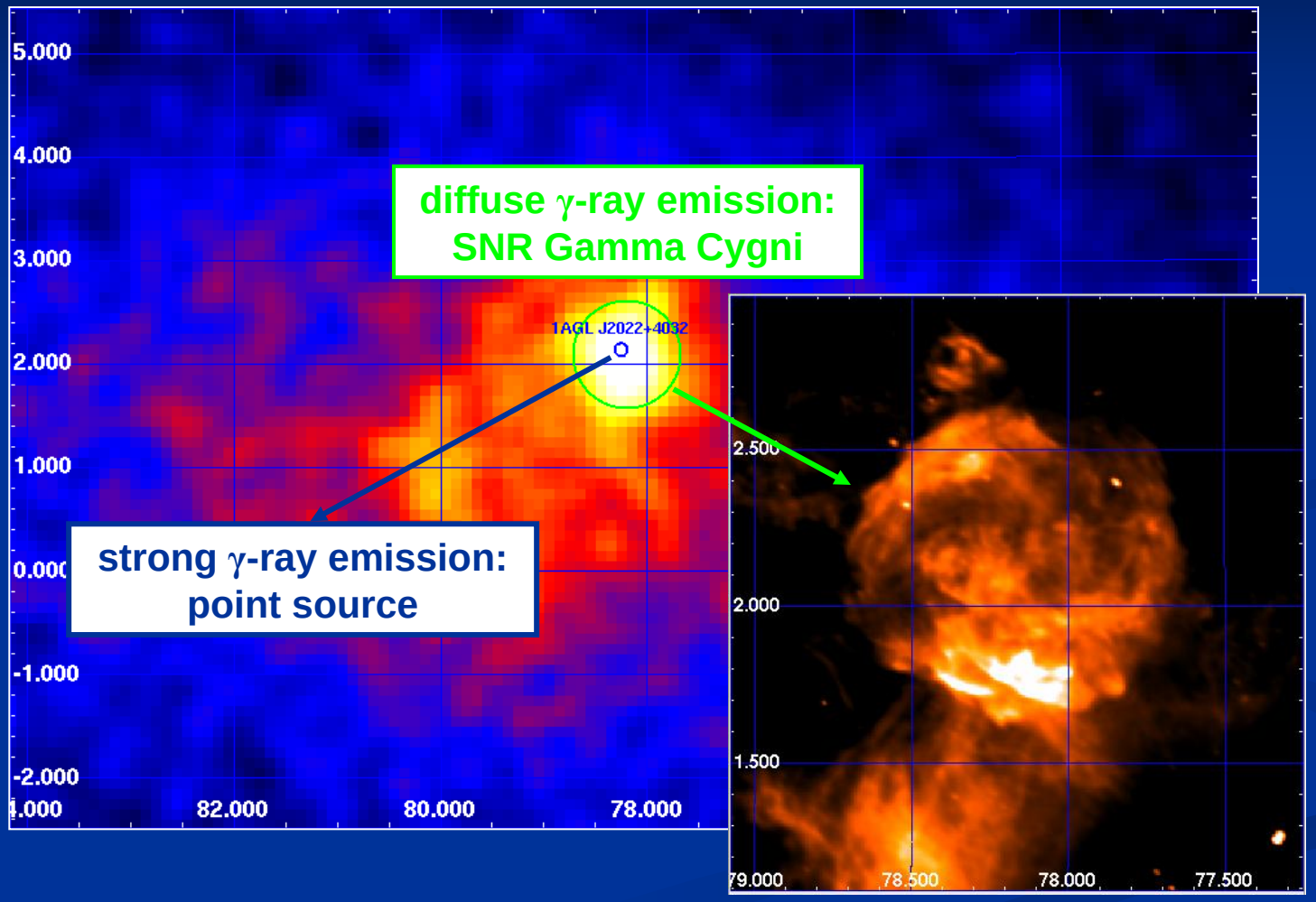
- The non-thermal synchrotron emission has a quasi perfect spherical symmetry
- The SN exploded in a cavity, evacuated by the strong wind of the progenitor star, surrounded by a denser shell of matter set in motion by the wind (Landecker, Roger & Higgs, 1980 – Ladouceur & Pineault, 2008)



shell expanding with
v ~10-20 km s^{-1}
(from H I kinematics)

The region of the Supernova Remnant Gamma Cygni (G78.2+2.1)



1AGL J2022+4032:

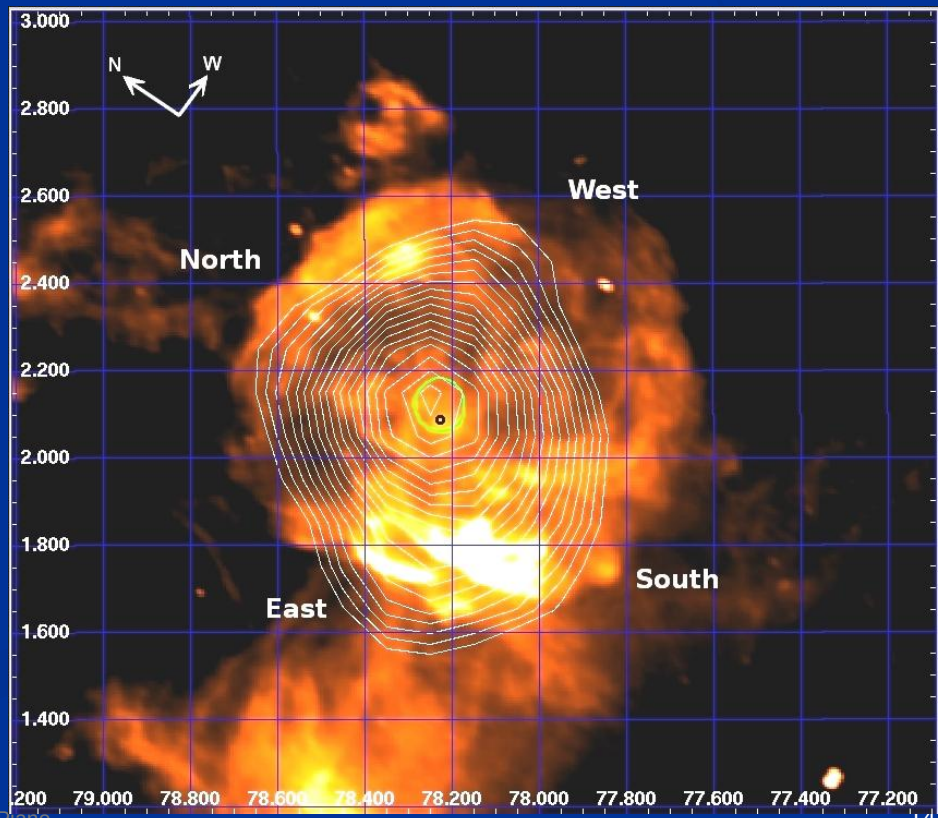
a bright γ-ray point source within the SNR Gamma Cygni (G78.2+2.1)

	galactic coordinates	significance	flux above 100 MeV [10^{-8} ph cm^{-2} s^{-1}]
1AGL J2022+4032	(l, b) = (78.23, 2.12) ± 0.06° (stat) ± 0.10° (syst)	39.64	131 ± 4 (stat) ± 10% (syst)

- **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 (?)

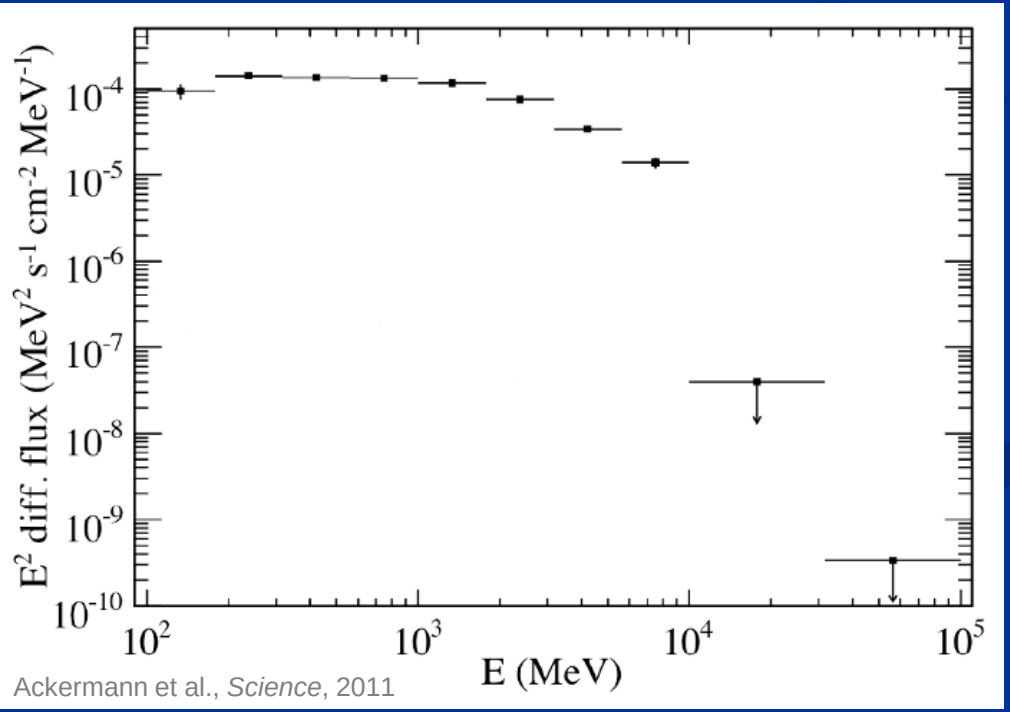
SNR G78.2+2.1

DRAO (21.1cm – 1.42 GHz)
+ AGILE-GRID contour levels
(emission above 100 MeV)



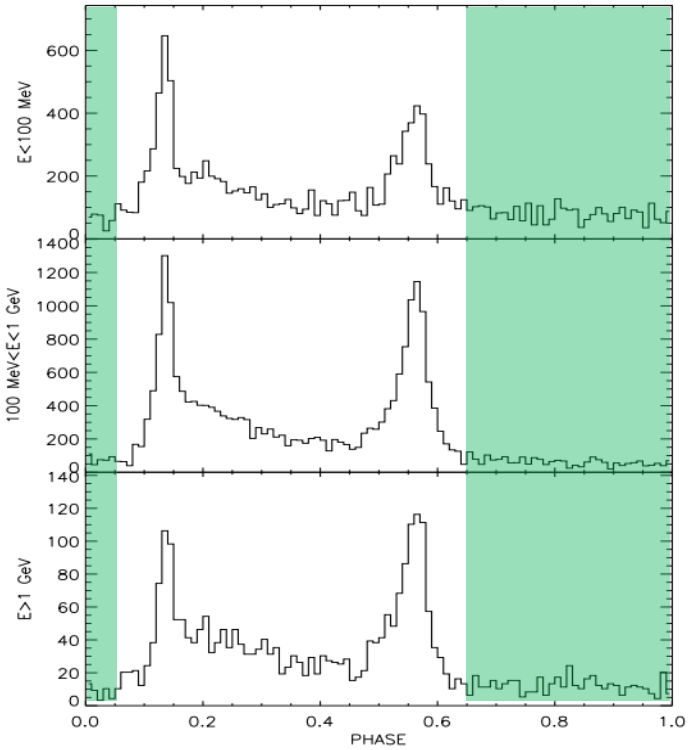
Detection issue:

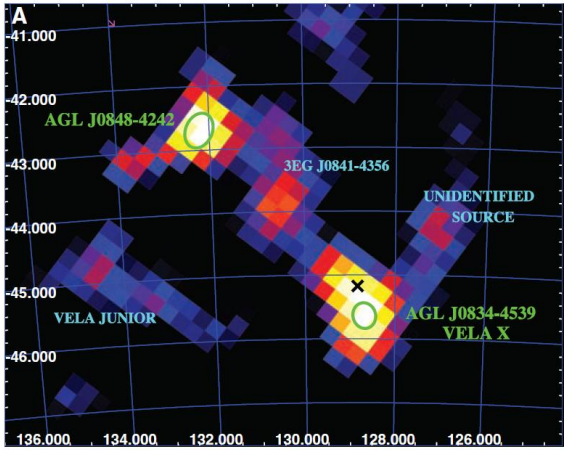
- γ-ray emission up to 10 GeV is dominated by the pulsar
- γ-rays from the SNR are probably "hidden"
- **necessity of "turning off" the PSR!**

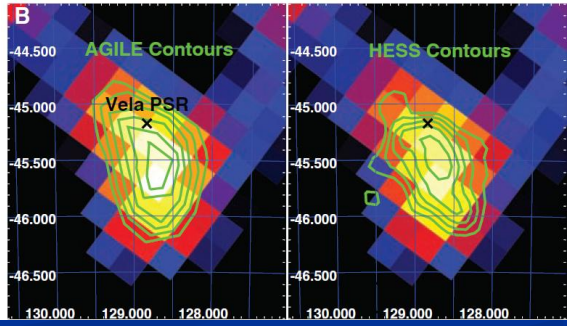


Ackermann et al., *Science*, 2011

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







Our approach to solve the problem:

- **“off-pulse” analysis**

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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

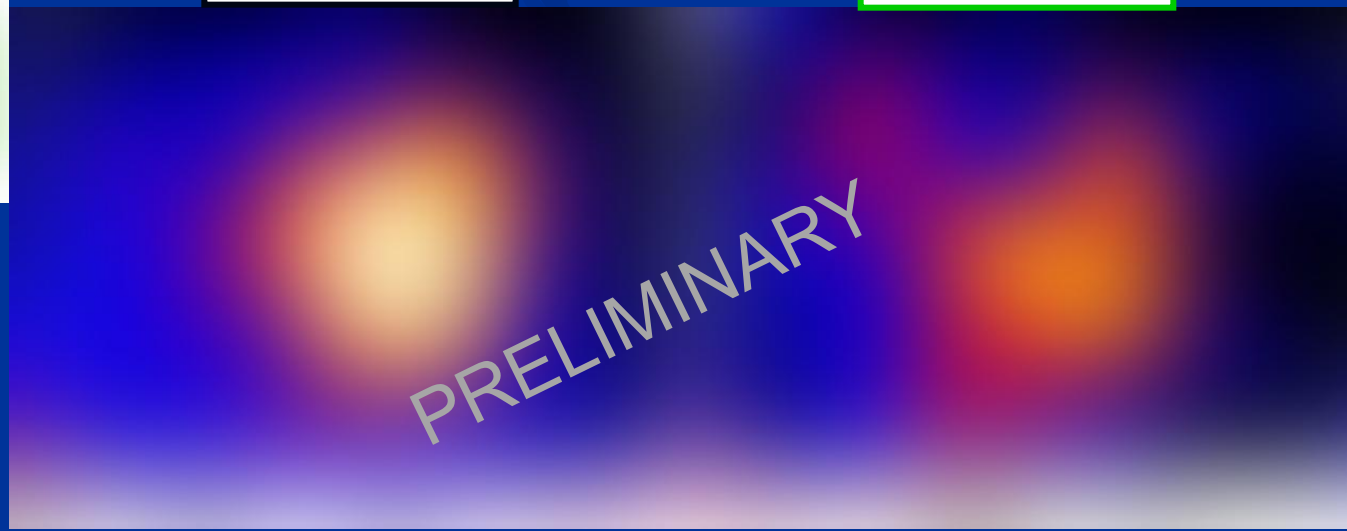
SNR Gamma Cygni (G78.2+2.1)

"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 ≥ 400 MeV

100% phase
(E ≥ 400 MeV)

off-pulse
20% phase
(E ≥ 400 MeV)



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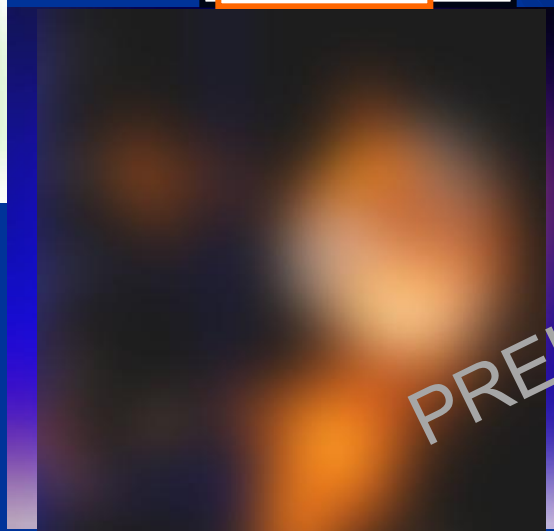
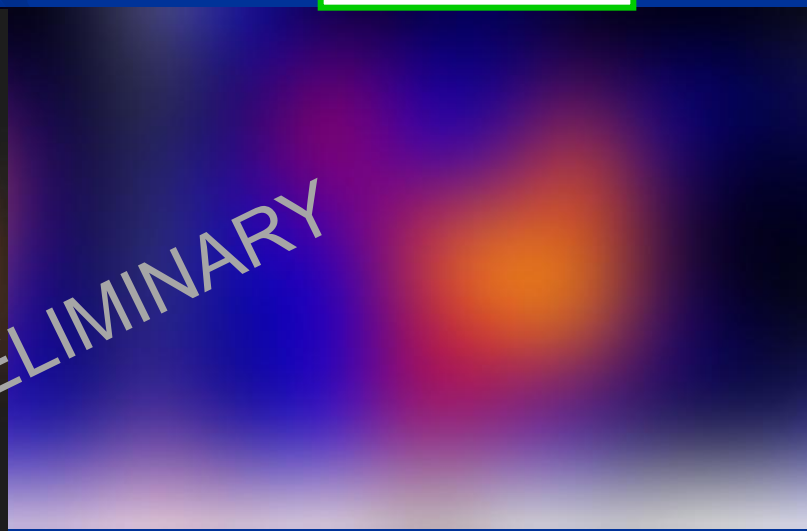
radio
(21.1 cm)



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”**

E ≥ 400 MeV

Photon Spectrum

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.

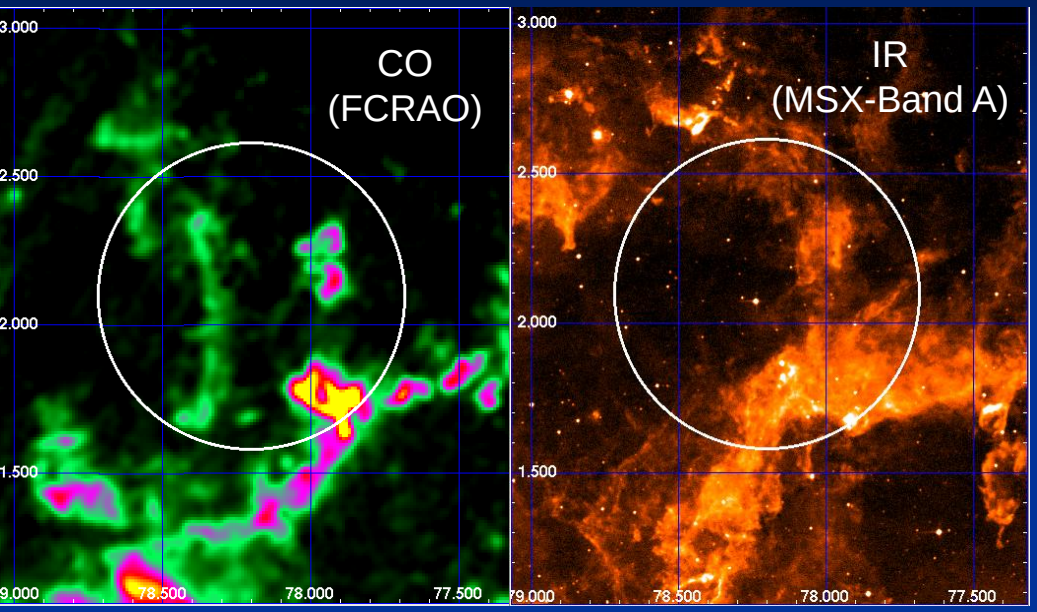
➢ accurate pattern of the gas distribution in the region of the SNR:
  ⇨ masses, relative distances of the main clouds with respect to the SNR

➢ characteristics of the accelerated particles (spectra, electron-proton ratio $\chi_{e,p}$, etc.) through multi-wavelength observations (radio, X-ray, HE & VHE γ-rays),

  ⇨ different contributions to the overall γ-ray emission:
    ✓ **hadronic** (π^0-decay);
    ✓ **leptonic** (Bremsstrahlung, IC)

SNR Gamma Cygni (G78.2+2.1)

gas distribution



^{13}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 γ-ray features

SNR G78.2+2.1 (Gamma Cygni)

X-rays, HE and VHE γ-rays

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 γ-ray SED of the AGILE source “A”

SNR G78.2+2.1 (Gamma Cygni)
ongoing analyses

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

- Extended source analysis of the γ-ray emission above 400 MeV
  - radio map (shell) of the SNR → 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) γ-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!