MAGIC Observations of the enigmatic γ-Cygni supernova remnant

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G078.2+02.1 – the shell type SNR in the Cygnus region

- Shell-type radio SNR
- Changing radio spectral index over shell: $0.4 - 0.8$ [Ladouceur+'08]
- Distance: $1.7 - 2.6$ kpc (H I) [Leahy+'13]
  $\sim 1.7$ kpc ($\Sigma(D)$) [Lozinskaya+'00]
- Extent: $\sim 0.56^\circ$ ($\sim 17$ pc)
- Age: $\sim 4,800 - 10,000$ years
Indication of a cavity wall in H I

- Hint for a HI shell surrounding the SNR [Ladouceur+’08]
- Supposed to be compressed ISM by the wind of the progenitor star
- The region is complex and existence of wind-blown bubble not yet established, feature might be due to absorption [Leahy+’13]
The puzzling X-ray morphology

- In soft X-ray strong emission in north- and south-west; in north even beyond shell
  - Thermal emission from shock heated gas in non-equilibrium state [Leahy+'13]
  - Chandra observation of centre suggest: reverse shock just recently shocked centre [Hui+'15]
- Part of the north X-ray emission may come from stellar wind of B3 star (V1685Cyg) [Leahy+'13]
- A few hard non-thermal hard X-ray emission regions of which C2 might be associated with SNR [Leahy+'13]
The Fermi high energy view – discovery of a peculiar pulsar

- Emission dominated by PSR J2021+4026, emits all its non-thermal energy in gamma-rays: $\dot{E} \approx L_\gamma$
- The only known pulsar variable in $\gamma$-rays
- $>10$ GeV (Pulsar less significant) Emission all over the shell
Towards the highest energies– the VERITAS observation

- VERITAS observations found extended emission ($\sigma = 0.23^\circ$) towards north-west edge of the SNR
- Observations were preformed in 2009 and observation time was 21.6 h
- Spectrum found is single power-law with index of $2.37\pm0.14$ and a level of 3.7% Crab ($>320$ GeV)

[Aliu+'13]
Hint for an energy dependent morphology in gamma-rays

- VERITAS emission towards north-west edge of the SNR, structure not clearly resolved
- Towards higher energies Fermi emission seen more towards north-west shell (counts are quite low)
A kind of magic – the MAGIC telescopes on Canary island La Palma

- Situated at the Observatorio del Roque de los Muchachos @ 2200 m a.s.l.
- Stereo system of 2 x 17m dish telescopes
- Energy range of 50 GeV - 50 TeV

[Aleksić+'16]
The MAGIC image of γ-Cygni – the TeV emission resolved

- Effective observation time of 48.3 h after quality selection (light transmission >80% – measured with LIDAR system)
- Emission detected coincides with the radio shell, but just in north-west region
- Substructures visible
- Pulsar not visible (at least not above the steady emission)
- Star affects analysis at low energies in the south-east

**Red star**  – PSRJ 2021+4026

**White star** – Sadr mag. 2.2

**Orange**  – 408 MHz contours from CGPS

**White Cont.** - MAGIC Significance contours (3.,5.,7.σ)
The MAGIC image of γ-Cygni – Comparison with VERITAS/Fermi

- MAGIC contours extend beyond VERITAS count map contours, major/brightest part overlaps
- Fermi detects emission inside radio shell, MAGIC emission extends to outside the radio shell
The energy dependent morphology at very high energies

- In the Fermi-LAT energy range emission is situated inside shell
- Towards higher energies, emission seems to be stretched to outside the shell
Spectra – to be handled with care

- Spectrum of VERITAS (red integration region) and the main source in MAGIC (white integration region) agree within error bars; MAGIC spectral index: -2.44
- Extraction of spectra from extended region requires likelihood analysis → currently ongoing
- Comparison between the different energy bands is complicated as the emission regions differ
  ➔ More sophisticated analysis and SNR modelling needed
Some possible scenarios

MAGIC observations identify the region around the north-west shock as the region of TeV emission

- hadronic particles interacting with the ambient medium (cavity wall, no OH maser found)?
- or inverse Compton emission?

Puzzling energy dependent morphology

- CR escaping ahead of shock front?
- different components?
- particular magnetic field structure?
- What is the role of the peculiar pulsar?
Summary

- MAGIC observations identify the region around the shock as the region of TeV emission
- Puzzling energy dependent morphology
- Currently explanation not clear, but work in progress

→ Stay tuned for further excitements from the Gamma-Cygni SNR

Thank you very much for your attention!
BackUp – CO Map

- CO emission not coinciding with TeV emission
  - target not visible in CO
  - or TeV emission from electrons

[Torres+’03]