Evidence of proton accelerated and escaped from the Puppis A region using Fermi-LAT observations

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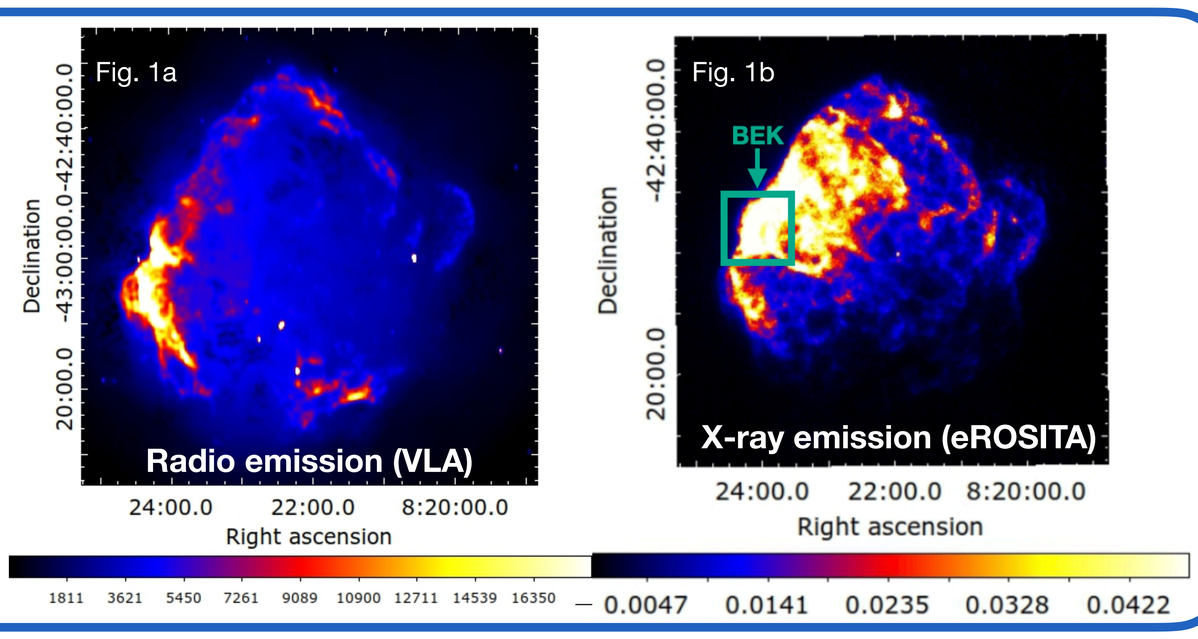
On behalf of the Fermi collaboration

INTRODUCTION

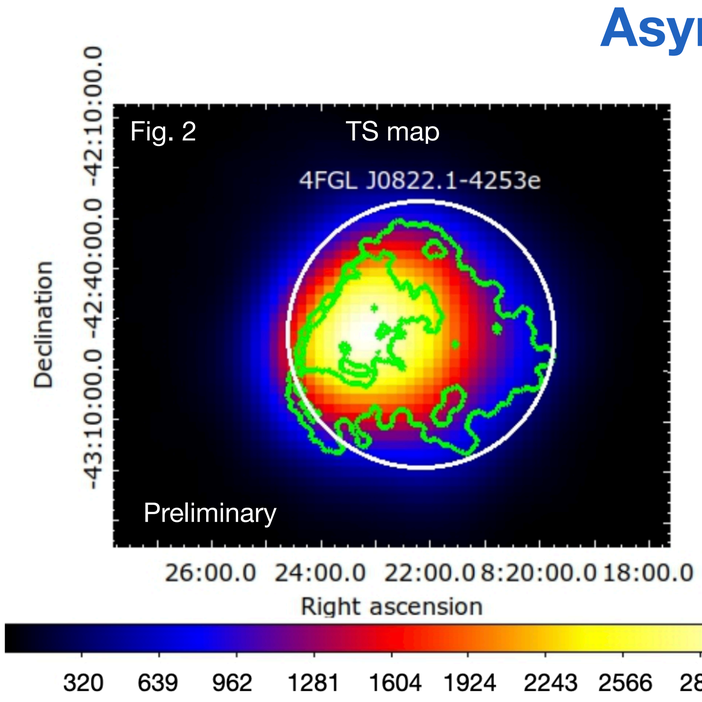
Puppis A (G260.4-3.4) is an interesting core-collapse SNR:

- Distance: 1.3 kpc (Reynoso et al. 2017)
- Age: 4 kyr (Winkler & Kirshner 1985, Blair et al. 2003, Becker et al. 2012)
- Central Compact Object: RX J0822-4300
- Interacting with molecular clouds
- Radio, X-ray, Gamma-ray emission (BEK: Bright Easter Knot)

We present a new analysis using 14 years observations with Fermi-LAT telescope



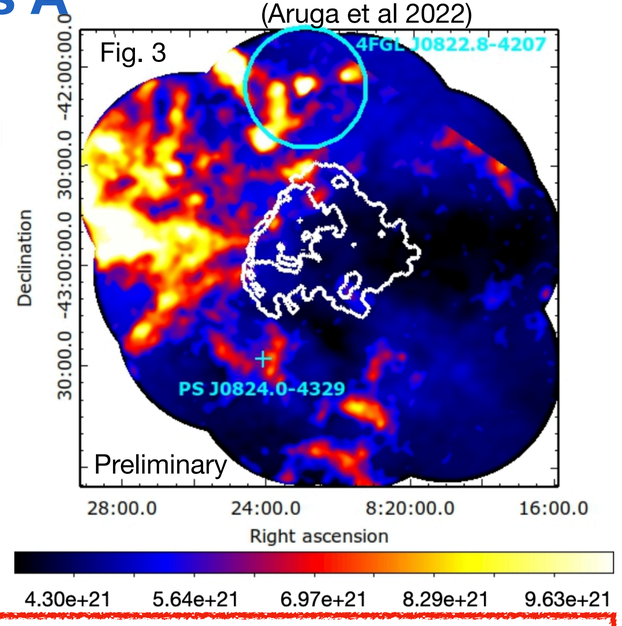
Asymmetry of the gamma-ray emission of Puppis A



Morphological analysis (1 GeV - 1 TeV)

Asymmetric gamma-ray emission (Hewitt et al. 2012), characterized by high surface brightness at northeast, where Puppis A is interacting with a dense molecular cloud (Aruga et al. 2022).
The gamma-ray morphology is well modelled by the unabsorbed X-ray (*eROSITA*) map in the 0.7-1 keV band.
Green and white contours: contour levels at the 1% and 10% of the maximum of the *eROSITA* map (Fig. 1b).

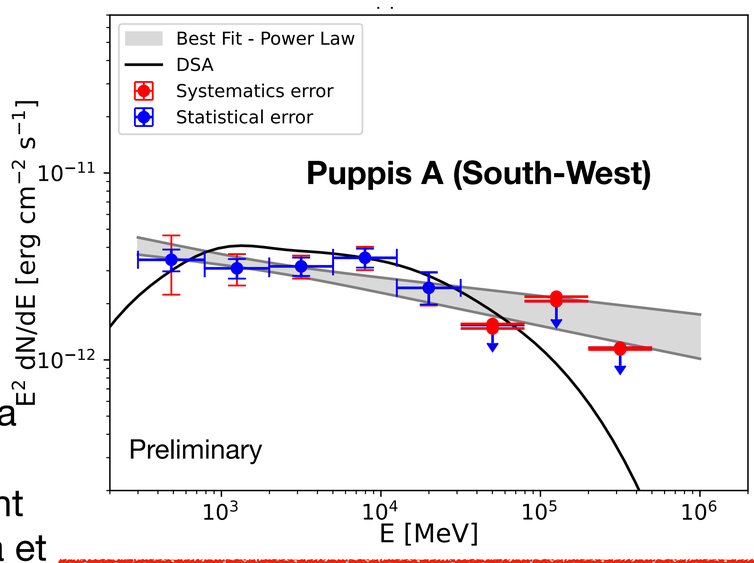
ISM proton column density (v = 8-20 km/s) (Aruga et al 2022)



Spectral analysis (300 MeV - 1 TeV)

Two scenarios:

1. Different spectral shape at 3 sigma level (fermipy analysis)
   South-West: power law - cosmic-rays accelerated via DSA in a low density environment (Mayer et al. 2022).
   North-East: Log Parabola - re-acceleration of ambient cosmic rays in the crushed cloud scenario (Uchiyama et al. 2010). The interaction with the molecular cloud (n ~ 250 cm^{-3}) decelerates the shock and makes it radiative.
   Caveat: similar cutoff energy at 1 TeV for both sides.
2. **South-West**: cosmic-rays accelerated via DSA.
   North-East: cosmic-rays accelerated via DSA.
   Caveat: to explain F_{NE}/F_{SW} ~ 3 in 300 MeV - 1TeV energy band we need n_{NE}/n_{SW} ~ 3 in disagreement with Aruga et al. 2022.



South-West: TS = 382

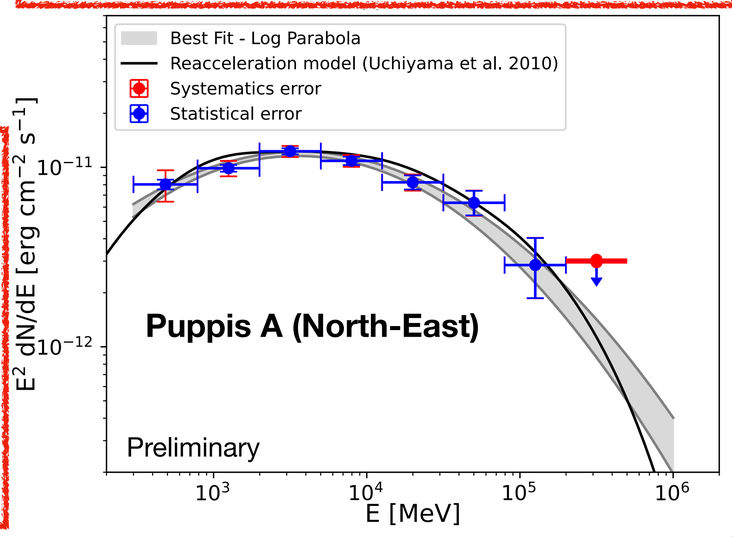
Power law (300 MeV - 1 TeV):

- Norm: (1.6 ± 0.2 ± 0.1) x 10^{-12} erg cm^{-2} s^{-1}
- index: 2.14 ± 0.05 ± 0.05

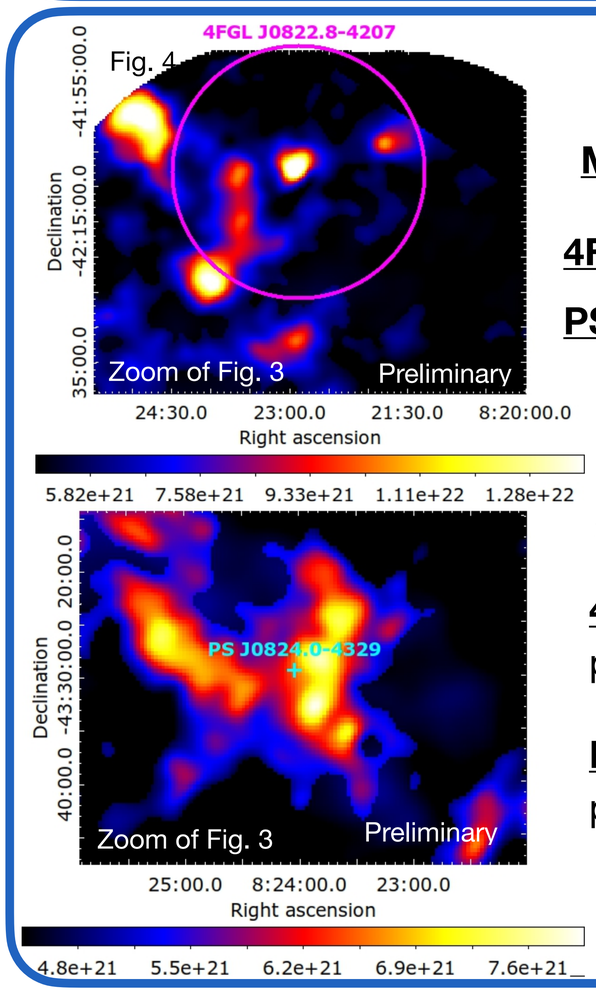
North-East: TS = 3788

Log Parabola (300 MeV - 1 TeV):

- Norm: (6.1 ± 0.2 ± 0.7) x 10^{-12} erg cm^{-2} s^{-1}
- alpha: 1.72 ± 0.03 ± 0.07
- beta: 0.12 ± 0.01± 0.02
- Eb = 1GeV



Detection of two gamma-ray excesses out from the remnant



Morphological analysis (1 GeV - 1 TeV)

4FGL J0822.8-4207: TS = 74, TS_{ext} = 20.5

PS J0824.0-4329: TS = 22, TS_{ext} < 16

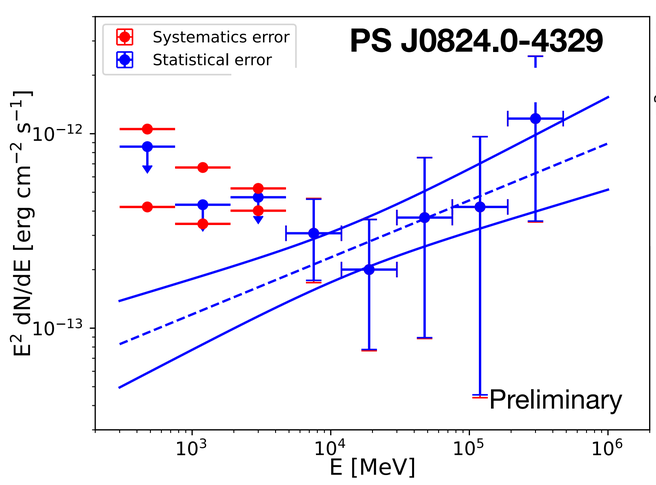
Pointlike source

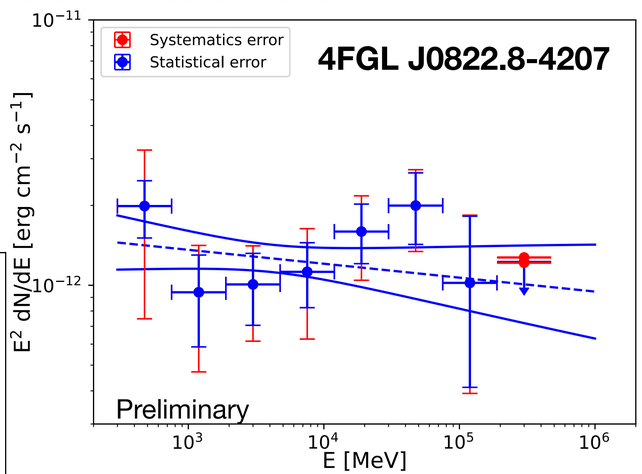
Extended source
Gaussian, sigma = 0.15 ± 0.03 deg

Spectral analysis (300 MeV - 1 TeV)

4FGL J0822.8-4207: power law with photon index: 2.05 ± 0.08 ± 0.09

PS J0824.0-4329: power law with photon index: 1.8 ± 0.2 ± 0.1





From the luminosity and the ambient density of the two sources (calculated integrating the column density over some solid angle, Fig. 4) we obtain the CR energy density (w_{CR}). Assuming a sphere with radius of 22 pc (which is the CRs diffusion length at 10 GeV in a B~3μG), including both the sources we calculated the energy provided from the SNR to accelerate particles (E_{CR}).

For both sources: w_{CR} = 7 eV/cm^{-3}, E_{CR} = 1.5 x 10^{49} erg