Gamma-ray emission from Puppis A with Fermi-LAT telescope evidence for proton acceleration

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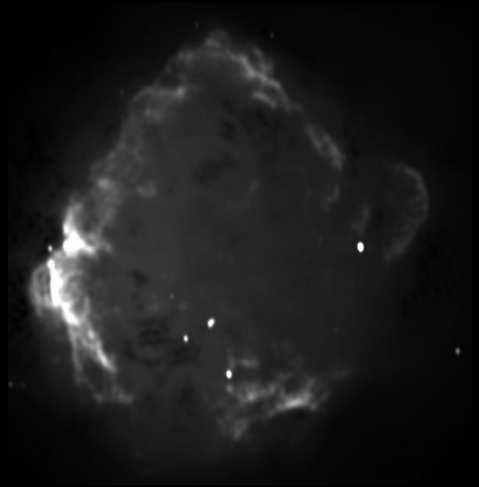
Introduction

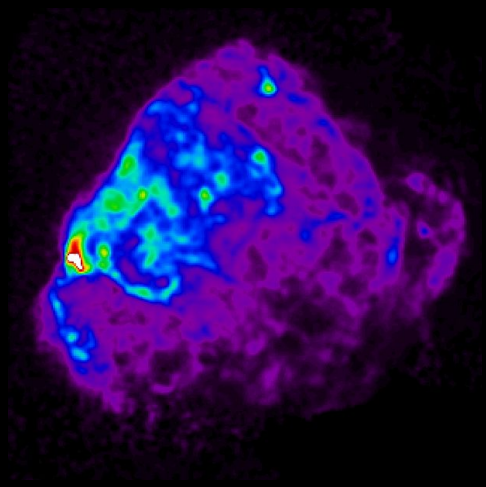
Puppis A (G260.4-3.4) is a well-defined SNR:

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

VLA



ROSAT



Introduction

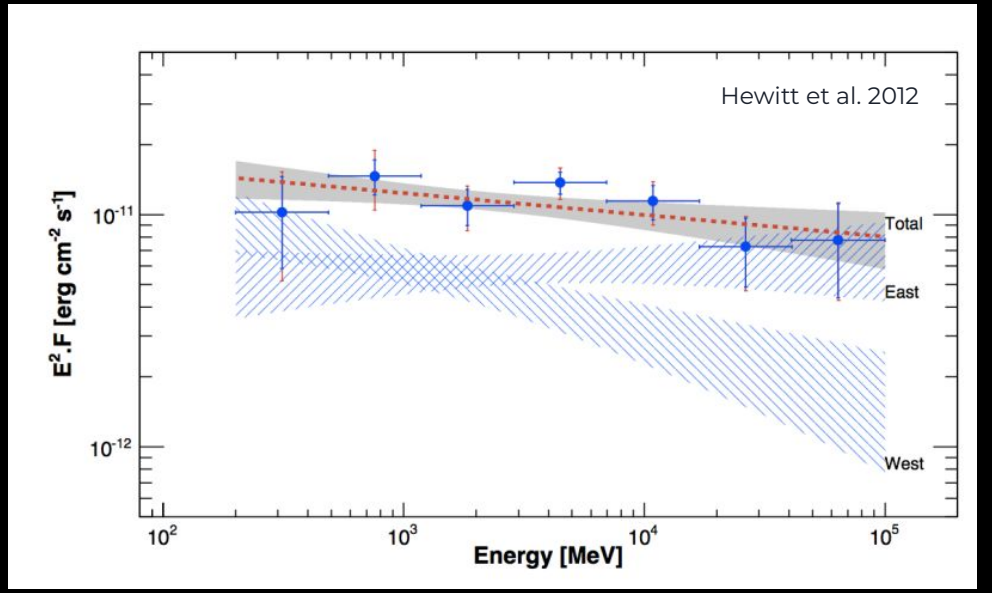
Cosmic-rays acceleration in Puppis A

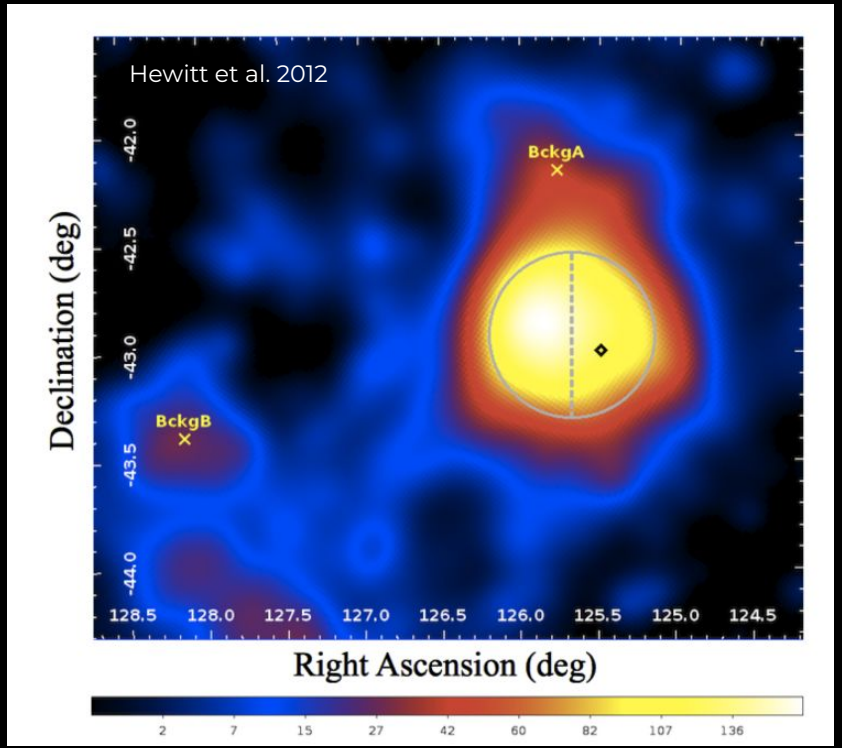
Previous works:

- Hewitt et al. 2012 (4 years of observation)
- Xin et al. 2017 (7 years of observation)

Spectral analysis (0.2-100 GeV)

Power law with index = 2





Introduction

Cosmic-ray acceleration in Puppis A
(Fermi observation Hewitt et al. 2012)

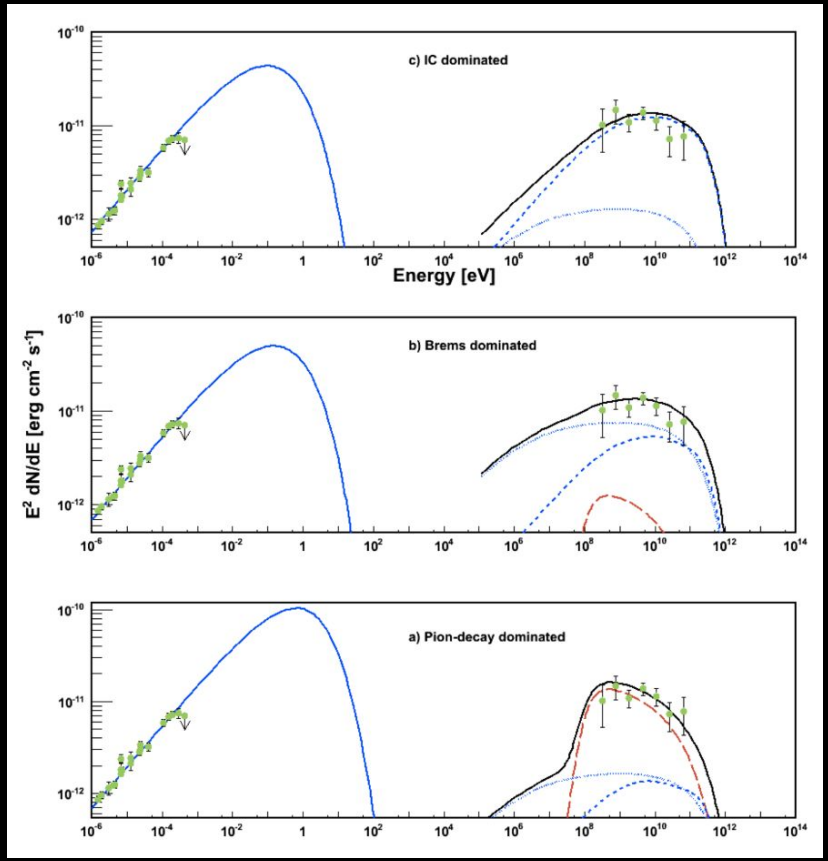
Nature of the gamma-ray emission

- Radio - synchrotron component
- π^0 -decay: long dashed, red
- Bremsstrahlung: dotted,blue
- IC emission: dashed, blue

Conclusion

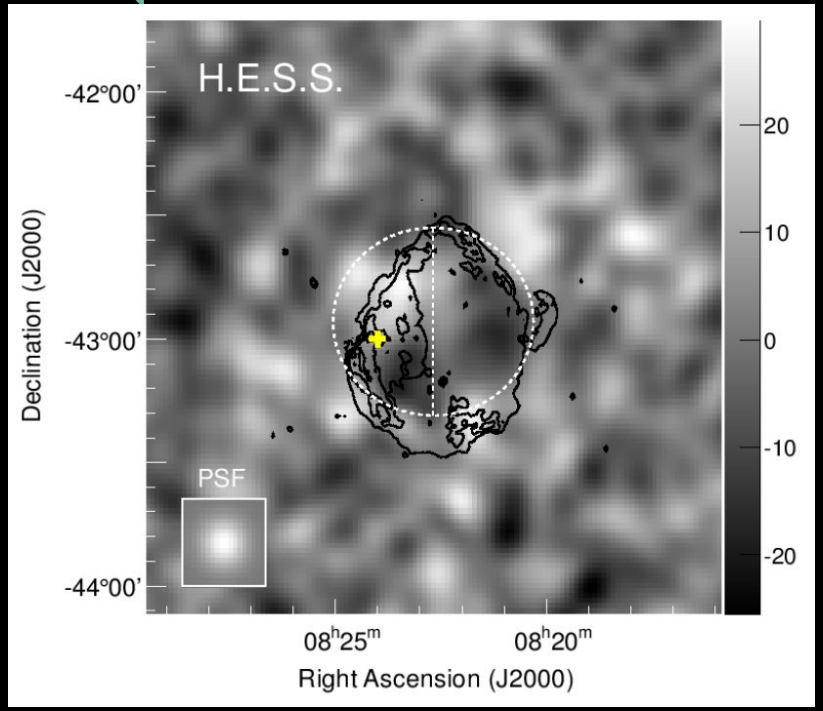
Hadronic models: a total energy in CR protons of ~4×10^{49} erg is needed

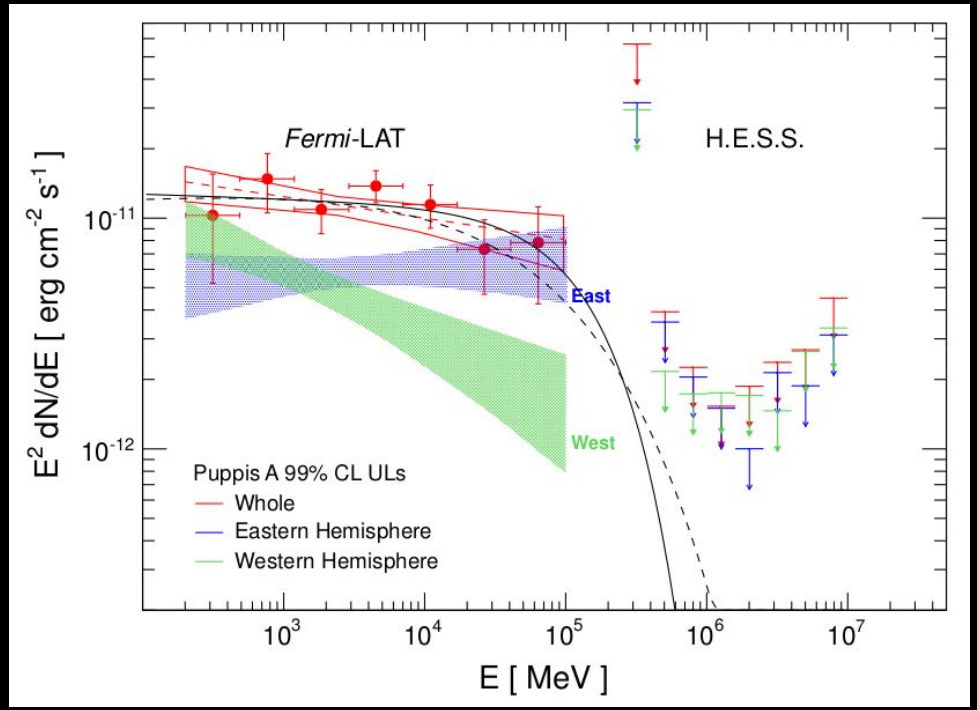
Leptonic models, at least $(1 - 3)\times10^{49}$ erg in relativistic electrons is required.



Introduction

Cosmic-ray acceleration in Puppis A (HESS observation, HESS collaboration 2015)





Fermi data analysis: 14 years of observation

Data selection:

- Pass 8
- Time intervals: 14 years
- IRF: P8R3_SOURCE_V3

Morphology:

- 1GeV - 1TeV
- zmax = 105°
- bin size = 0.03°

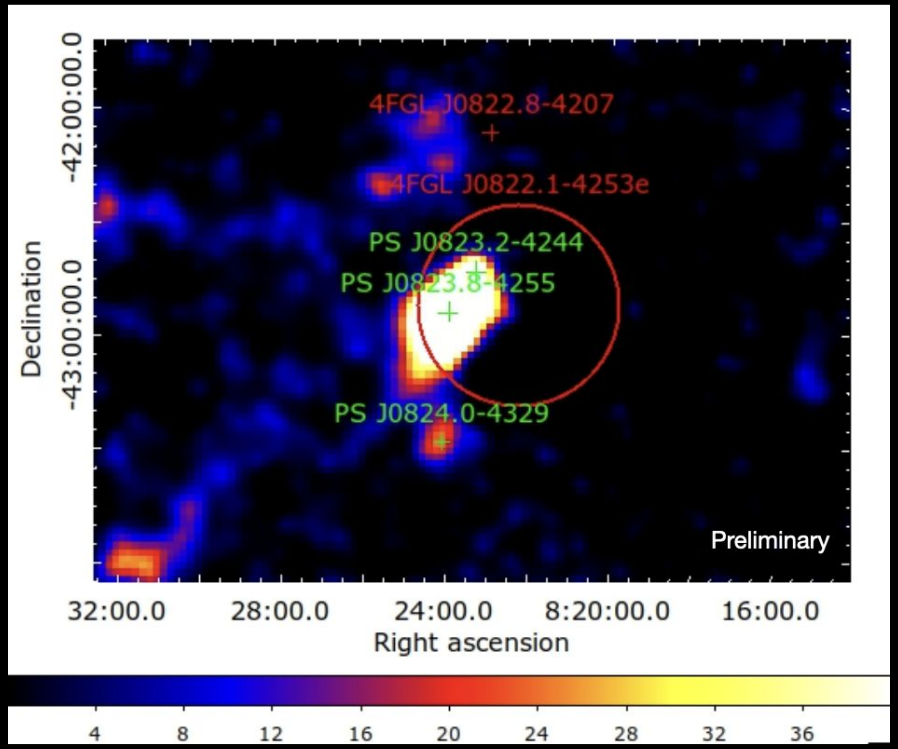
Spectra:

- 300 MeV - 1 TeV
- 4 components:
  - (PSF3, PSF2, PSF1, PSF0 (300 MeV – 1 GeV ; zmax=90° ; 0.05° bin size),
  - ALL (1 GeV – 1 TeV, zmax = 105° ; 0.03° bin size))

Fermi data analysis: 14 years of observation

Morphology of the source (1 GeV - 1 TeV)

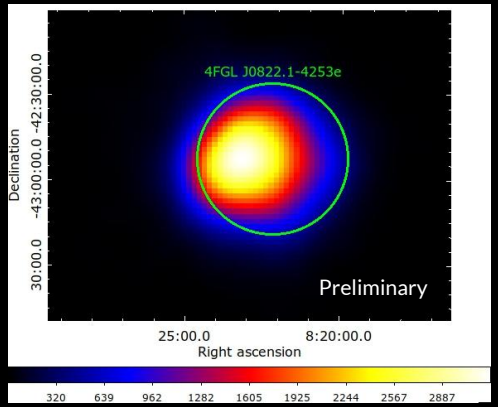
TS map - Background model: 4FGL-DR3 catalog (Abdollahi et al 2022)

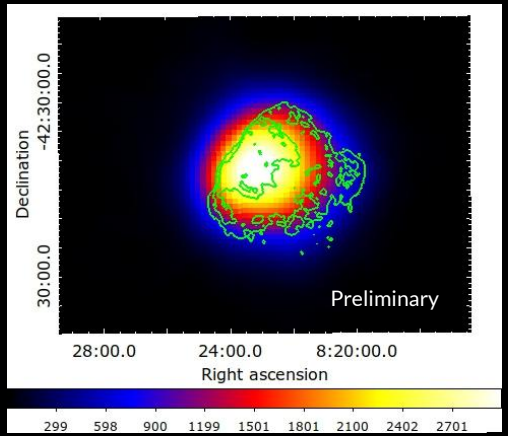


Puppis A TS value = 4697

Fermi data analysis: 14 years of observation

Morphology of the source (1 GeV - 1 TeV)

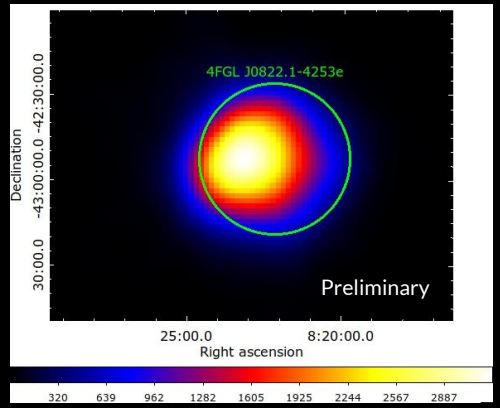


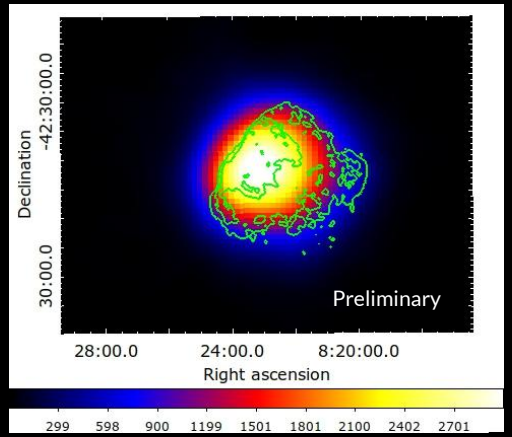


Fermi data analysis: 14 years of observation

Morphology of the source (1 GeV - 1 TeV)

Template	Log Likelihood	d.o.f.	Delta AIC
Catalog + 2pt sources	609.1	14	0
XMM-Newton (1.0-8.0 keV)	600.1	3	4
XMM-Newton (0.7-1.0 keV)	618.9	3	41





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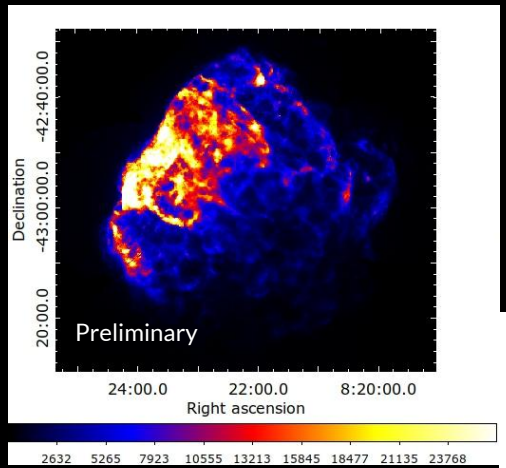
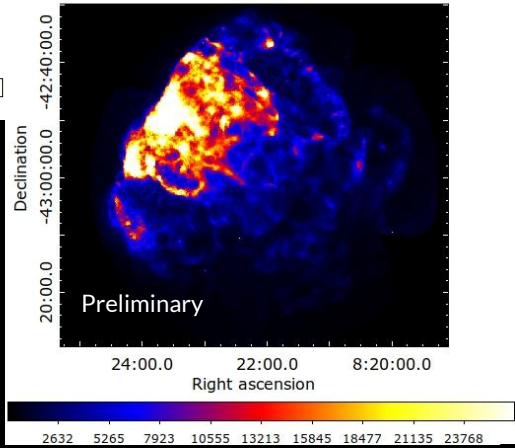
0.7-1.0 keV



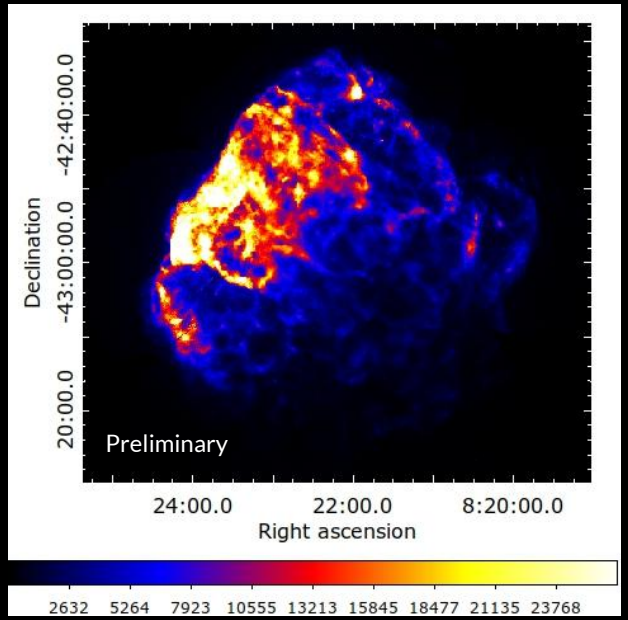
1.0-8.0 keV



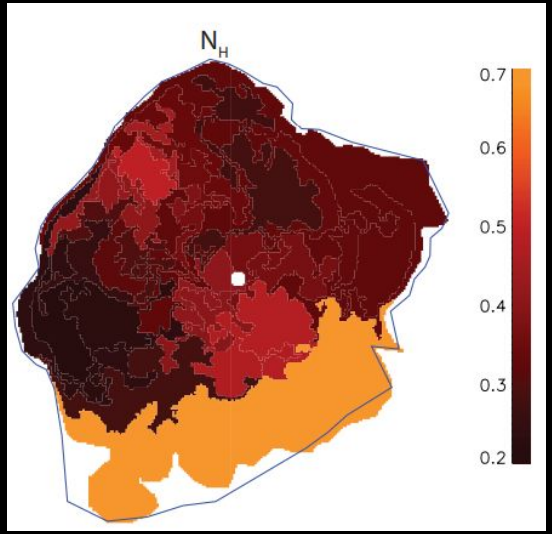
Fermi data analysis: 14 years of observation

Morphology of the source (1 GeV - 1 TeV)

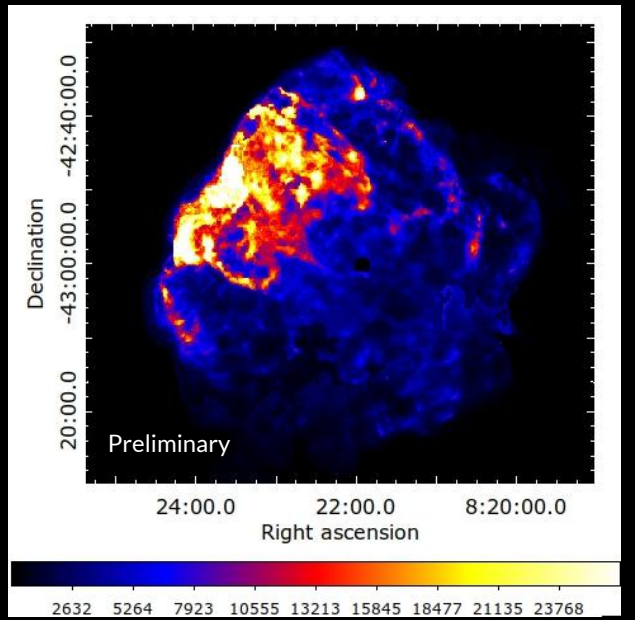
XMM- Newton (0.7-1 keV)



N_H map provided in Luna et al. 2016



XMM-Newton (0.7-1 keV) corrected for the N_H



Fermi data analysis: 14 years of observation

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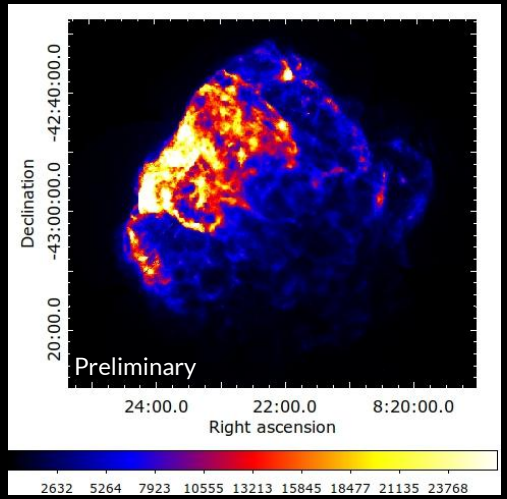
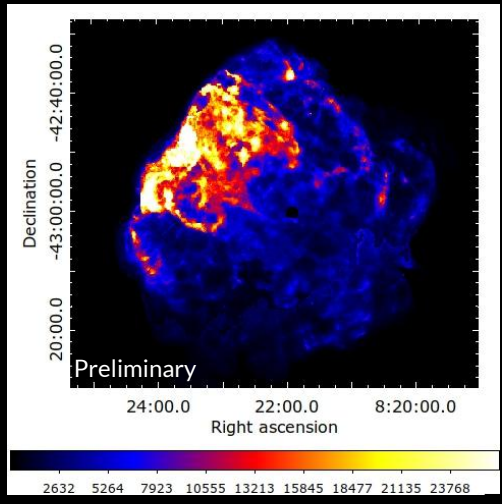
XMM-Newton (0.7-1.0 keV) - unabsorbed flux	624.0	3	52



XMM- Newton (0.7-1 keV)

XMM-Newton (0.7-1 keV) corrected for the N_H



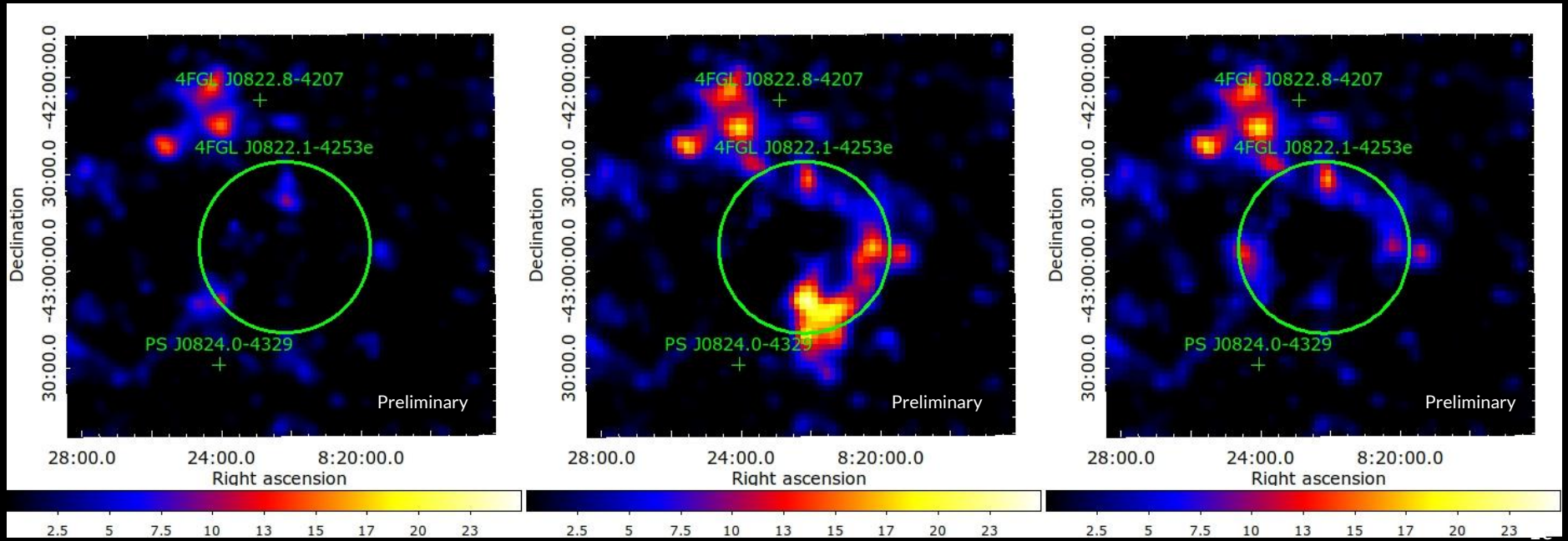
Fermi data analysis: 14 years of observation

Morphology of the source (1 GeV - 1 TeV)

uniform disk + 2 pt

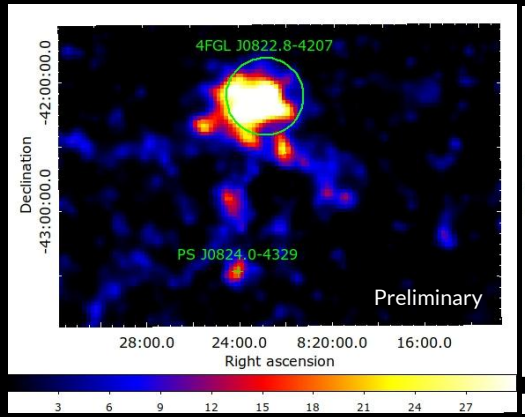
XMM- Newton (0.7-1 keV)

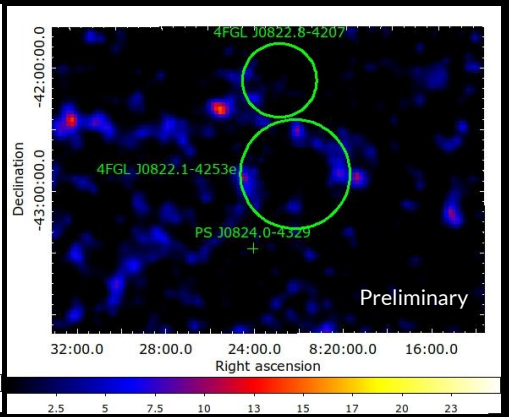
XMM-Newton (0.7-1 keV) corrected for the N_H



Fermi data analysis: 14 years of observation

Extension of 4FGL J0822.8-4207 (1 GeV - 1 TeV)





4FGL J0822.8-4207:
Gaussian function

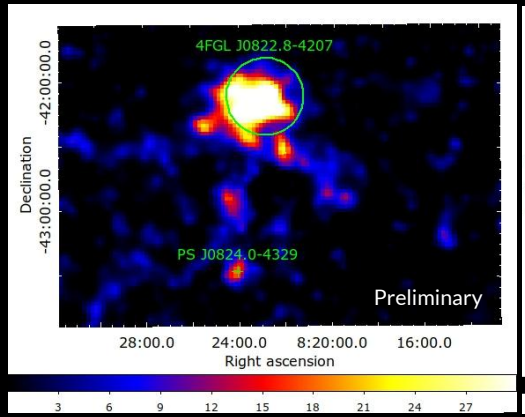
TS = 77
TS_{ext} = 22
sigma = 0.15 deg

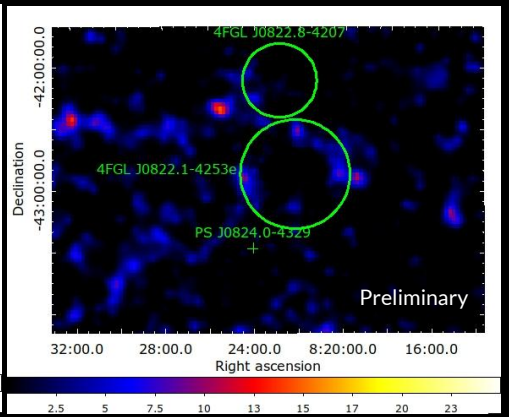
PS J0822.4-4329
Gaussian function

TS = 18.5
TS_{ext} < 16

Fermi data analysis: 14 years of observation

Extension of 4FGL J0822.8-4207 (1 GeV - 1 TeV)





4FGL J0822.8-4207:

New results with respect Araya et al. 2022

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PS J0822.4-4329
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Fermi data analysis: 14 years of observation

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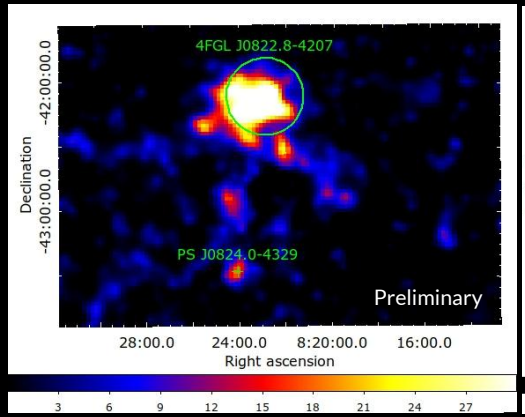
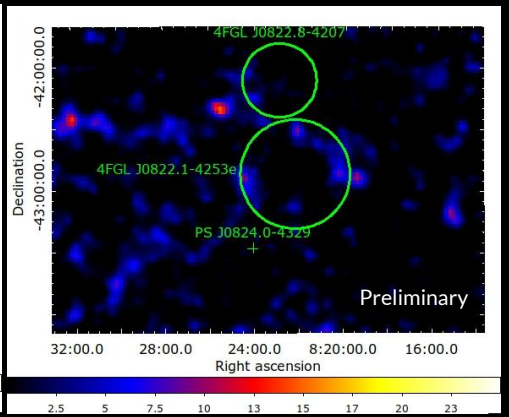
XMM-Newton (0.7-1.0 keV)	618.9	3	41
XMM-Newton (0.7-1.0 keV) - unabsorbed flux	624.0	3	52
XMM-Newton (0.7-1.0 keV) - unabsorbed flux Extended 4FGL J08422.8-4207	635.0	4	72





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TS = 77
TS_{ext} = 22
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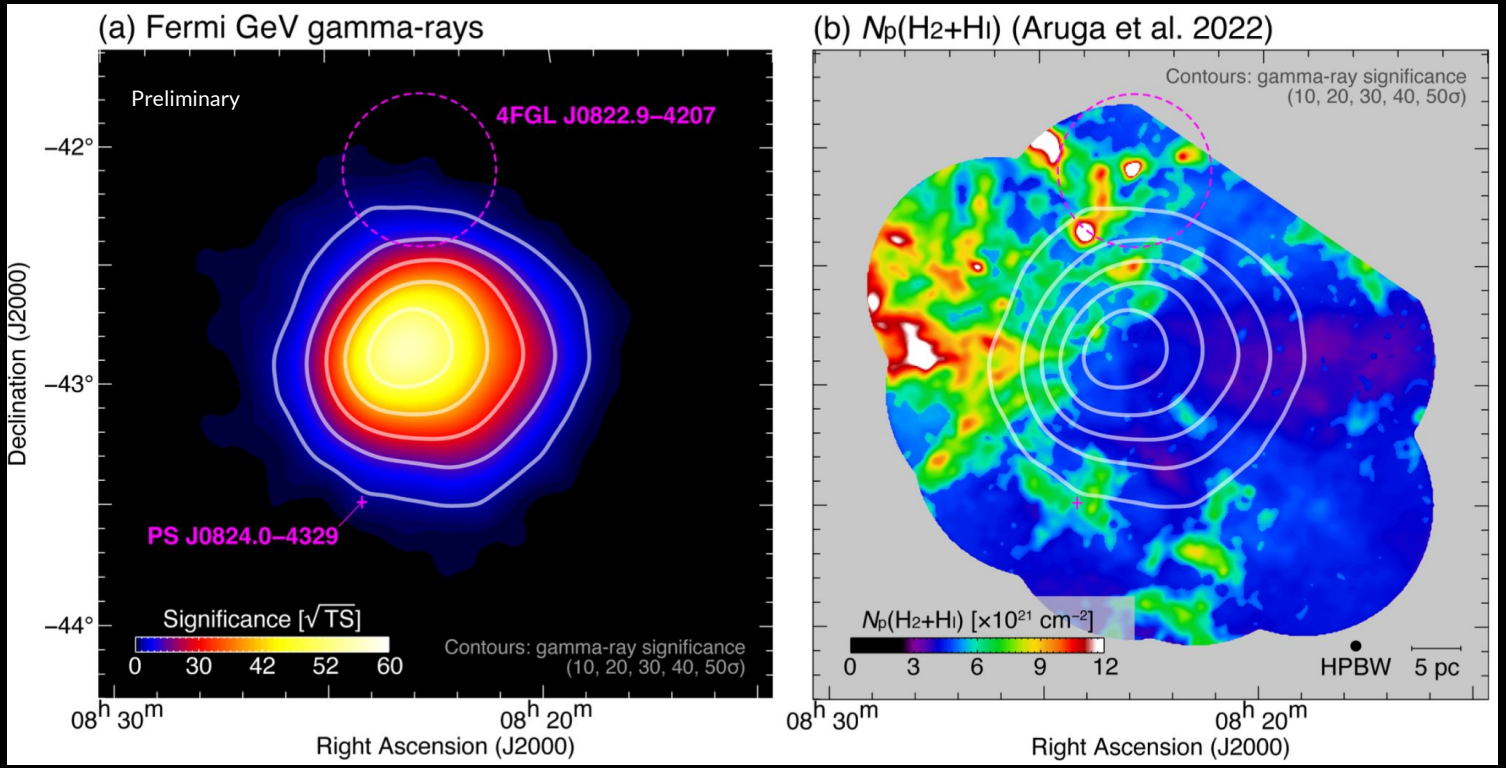
PS J0822.4-4329
Gaussian function

TS = 18.5
TS_{ext} < 16

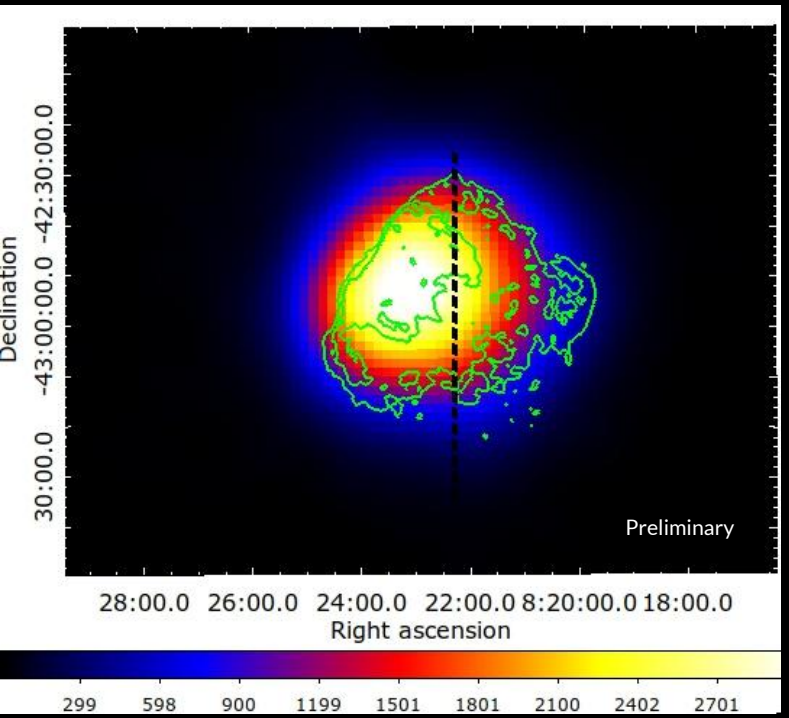
Fermi data analysis: 14 years of observation

Spectral analysis (300 MeV - 1 TeV)



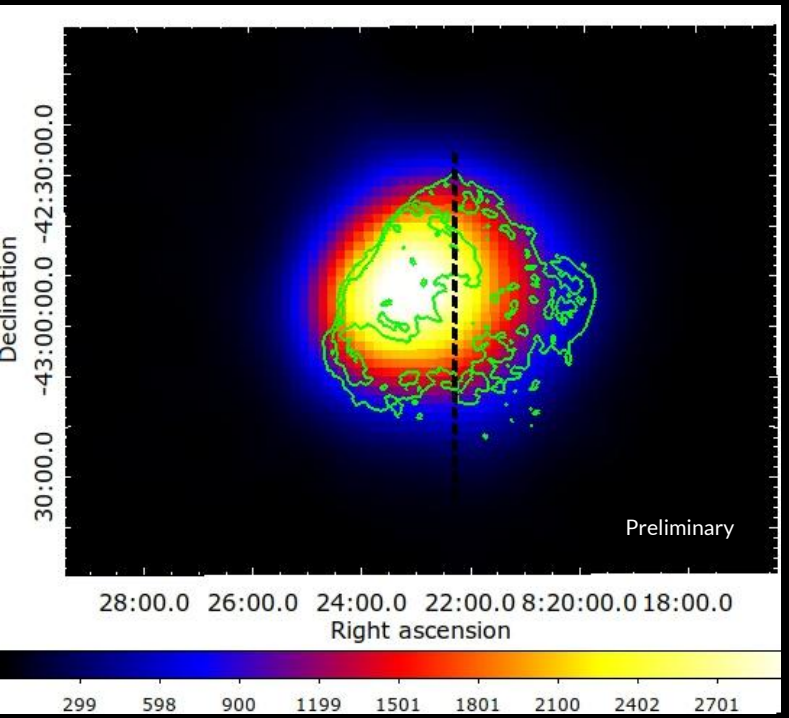
Fermi data analysis: 14 years of observation

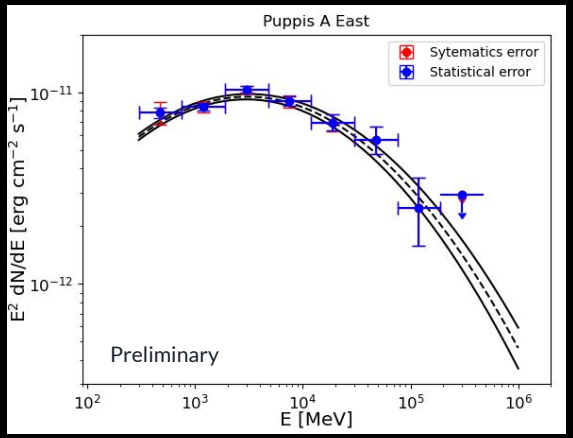
Spectral analysis (300 MeV - 1 TeV)

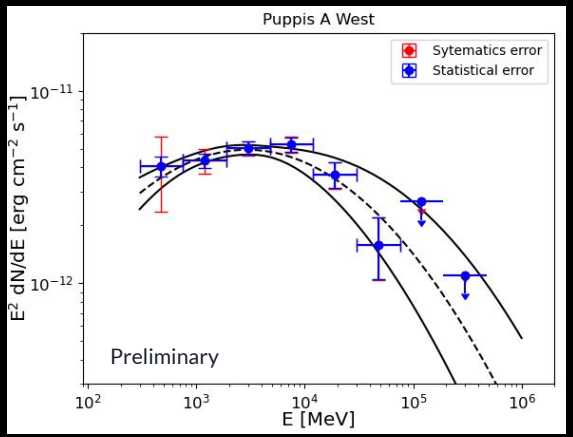


Fermi data analysis: 14 years of observation

Spectral analysis (300 MeV - 1 TeV)







Fermi data analysis: 14 years of observation

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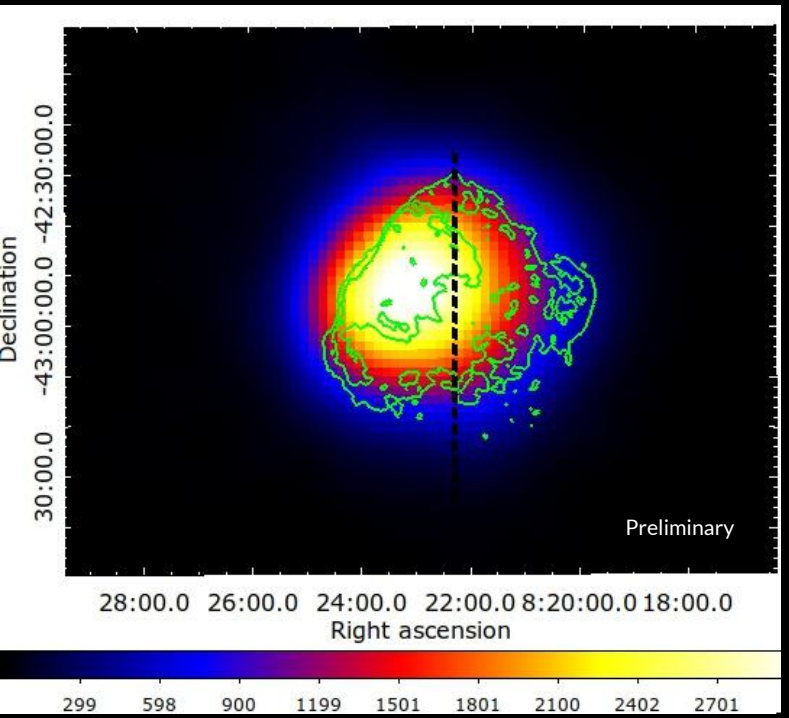
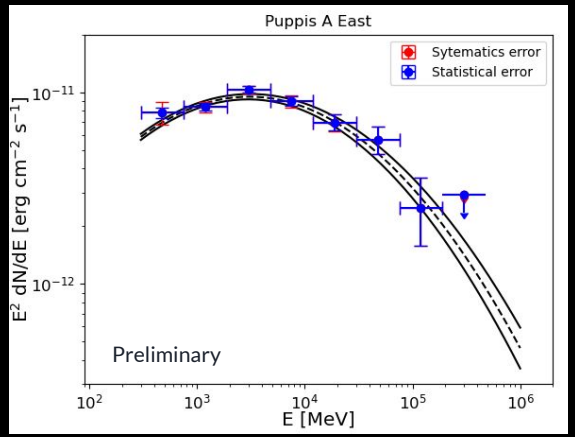
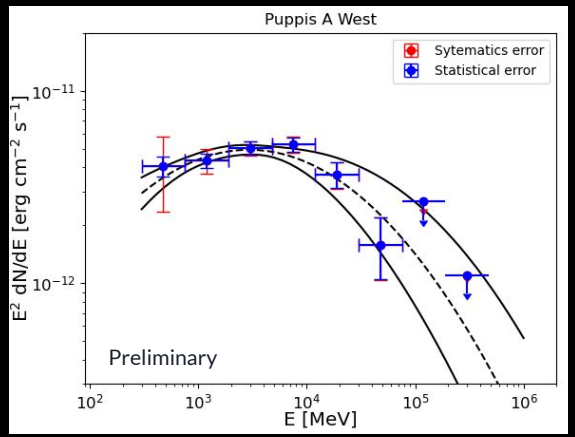


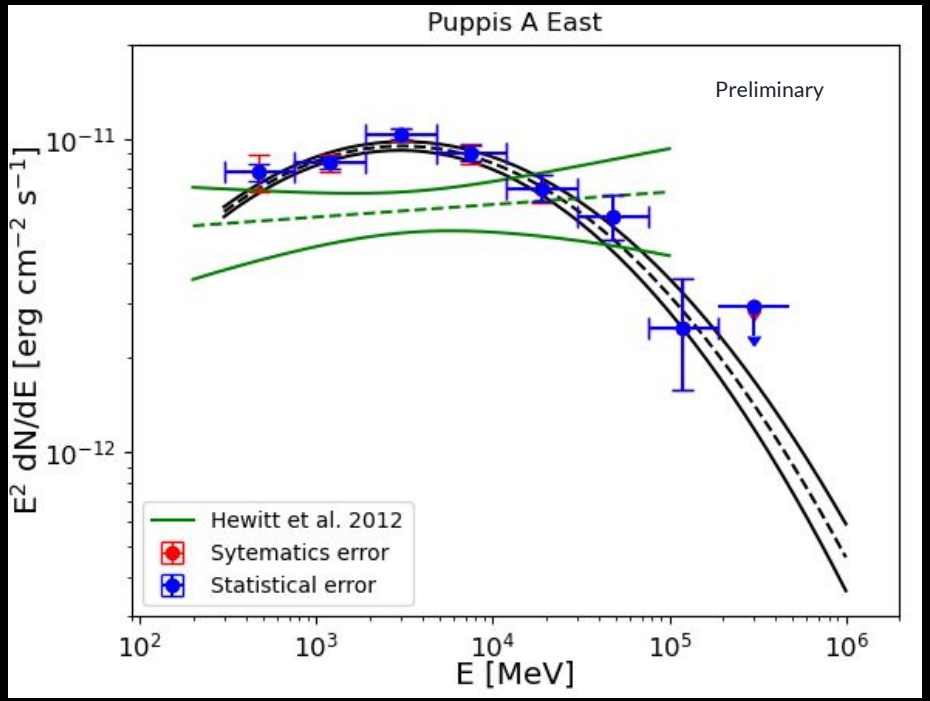
Log Parabola
$\frac{dN}{dE} = N_0 \frac{E}{E_b}^{-(\alpha+\beta ln(E/E_b))}$

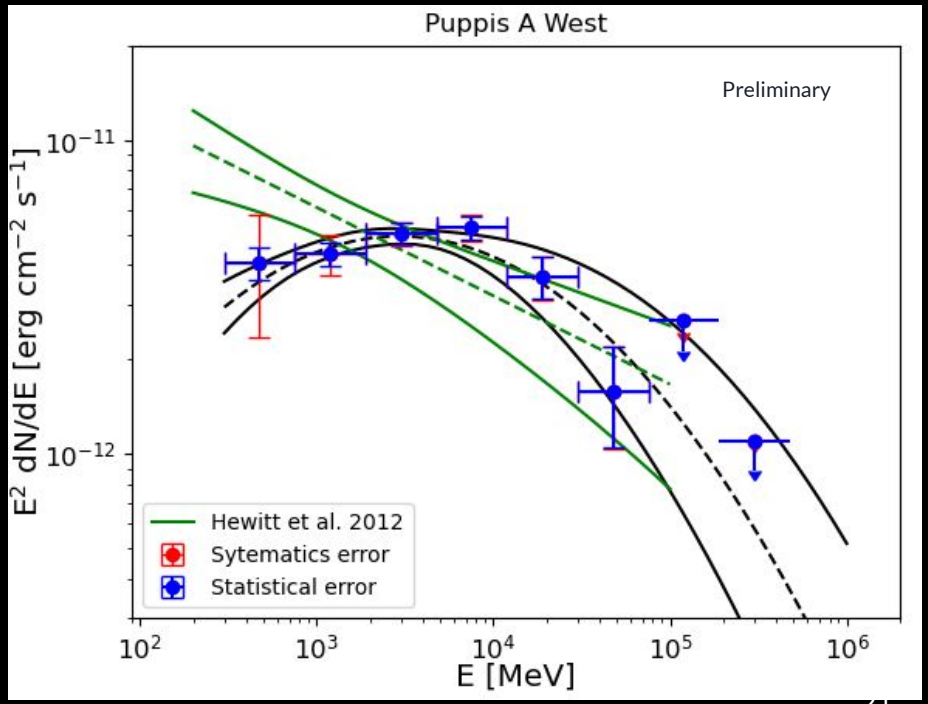
Composite likelihood	
Independent parameters	Tied alpha and beta, independent norms
LogLikelihood: 270	Loglikelihood: 271
Likelihood without the division: 269.6	





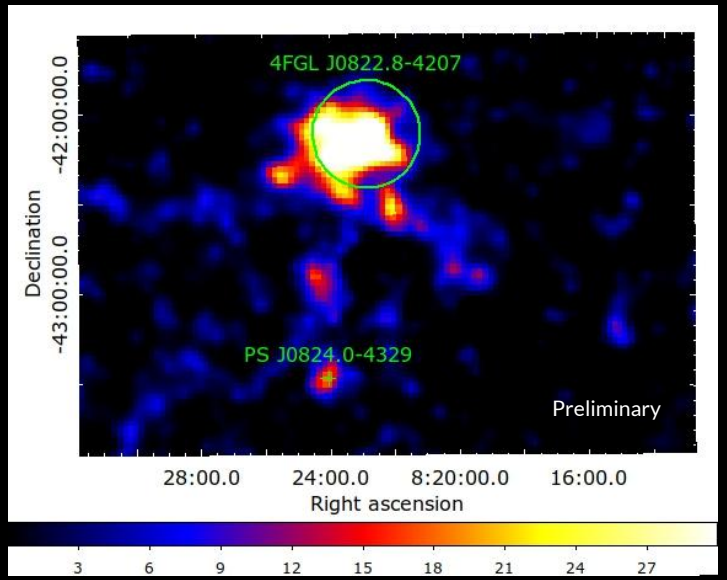
Comparison with Hewitt et al. 2012

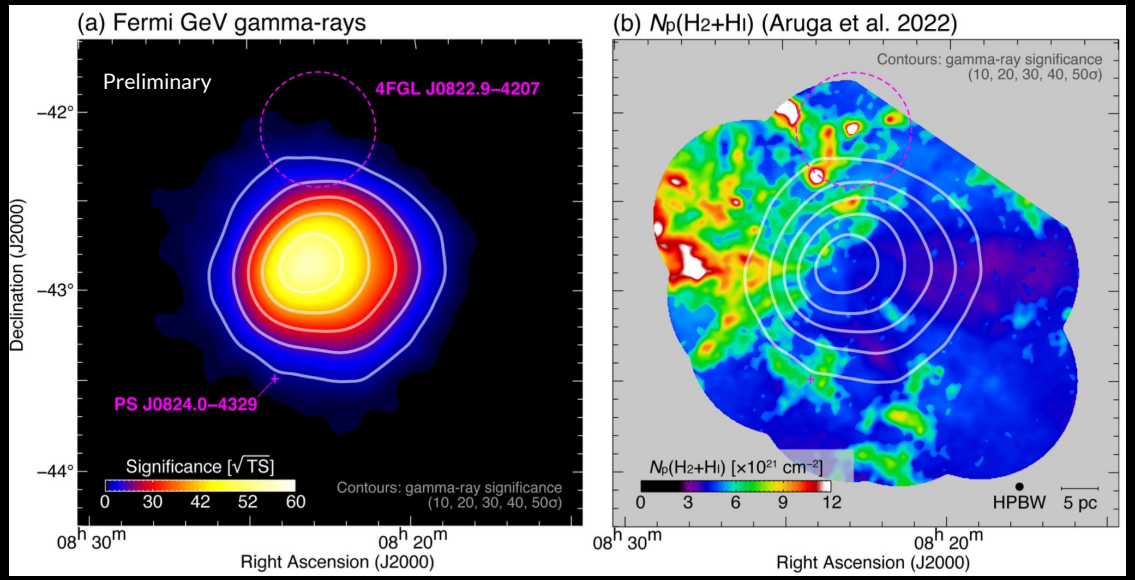




Fermi data analysis: 14 years of observation

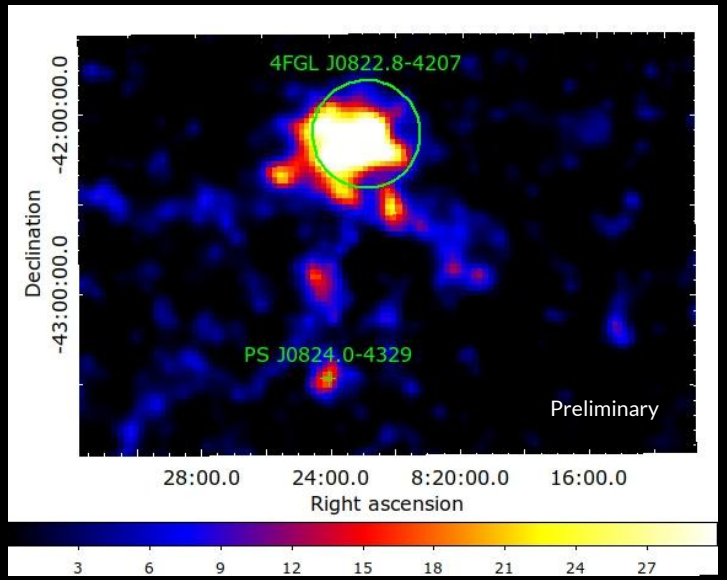
Spectral analysis (300 MeV - 1 TeV)

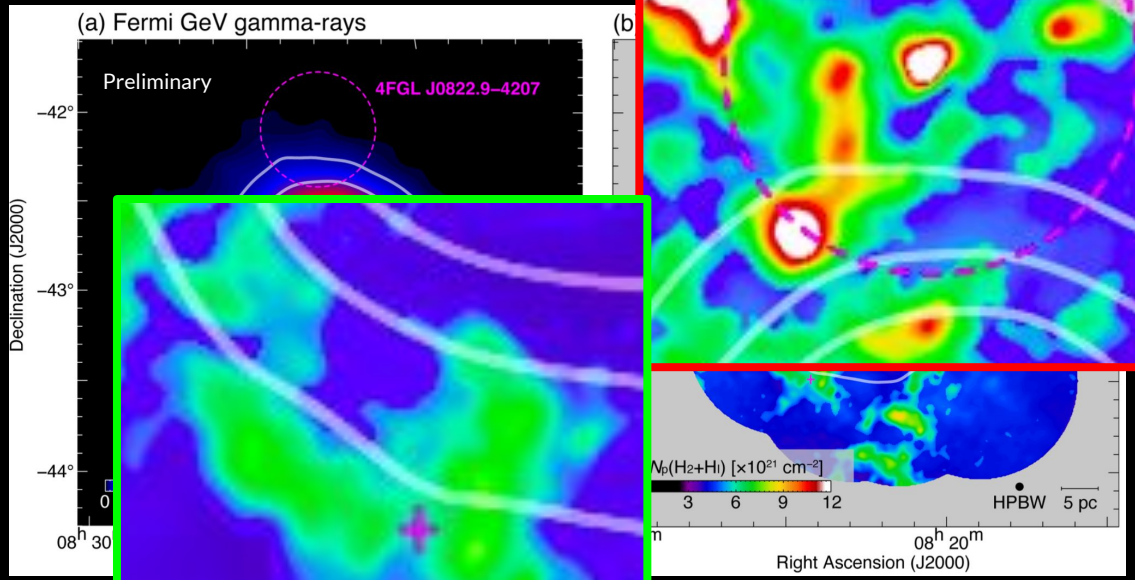




Fermi data analysis: 14 years of observation

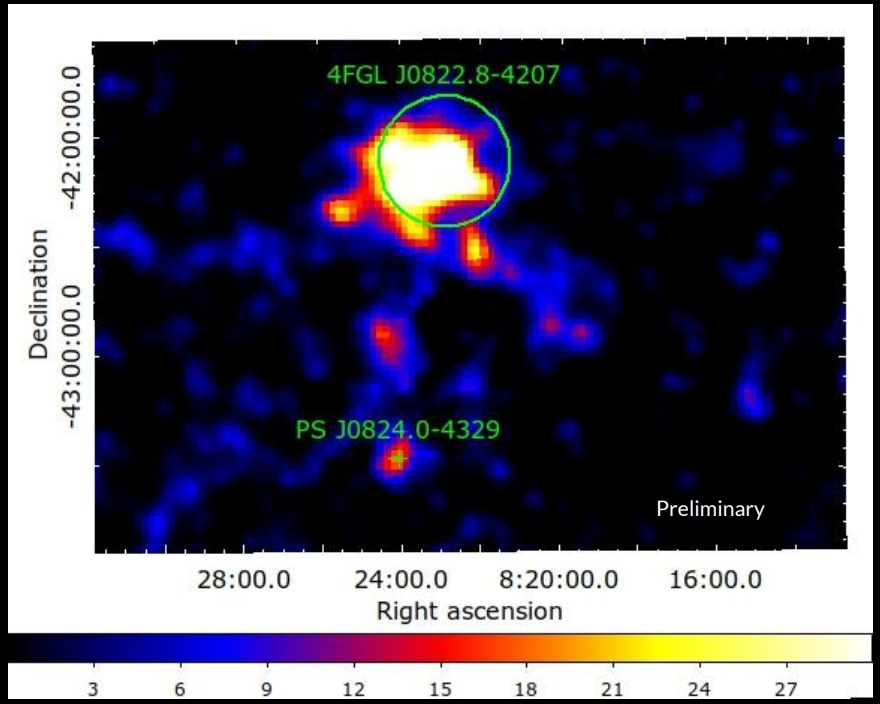
Spectral analysis (300 MeV - 1 TeV)





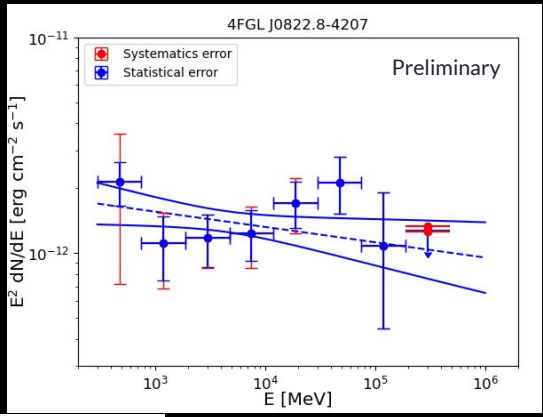
Fermi data analysis: 14 years of observation

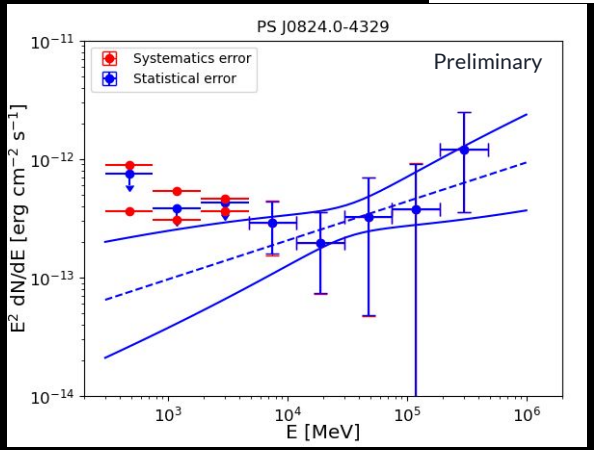
Spectral analysis (300 MeV - 1 TeV)



4FGL J0822.8-4207:

Prefactor:
Index: 2.02
TS: 77
TS ext: 22





PS J0824.0-4329

Prefactor:
Index: 1.7
TS: 18.5
TS ext < 16

Conclusion

Results

- Asymmetric gamma-ray emission. Both East and West side spectra show hadronic scenario despite the interaction with different ambient media
- Two different sources out of the remnant:
  - 4FGL J0822.8-4207 (north): well detected, extended, hard spectrum
  - PS J0824.0-4329 (south): not negligible, pointlike, hard spectrum

Future works

- We plan to investigate whether the bulk of the emission arises from re-accelerated particles
- Gamma-ray emission coming from the two sources may be due to particle escaped from the remnant interacting with molecular clouds.