Disentangling the hadronic from the leptonic emission in the composite SNR G326.3-1.8

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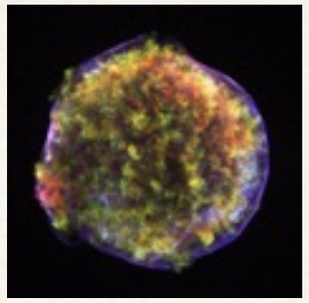
on behalf of the Fermi LAT collaboration

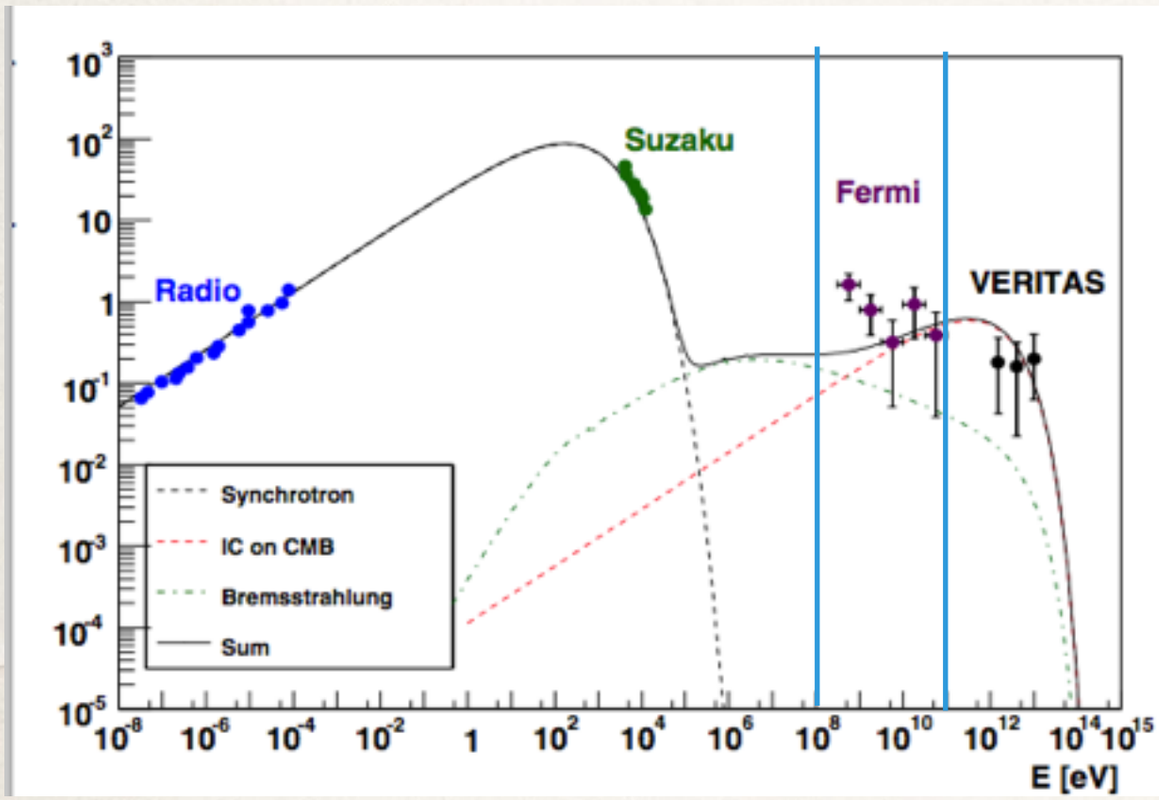
Workshop MODE
19th May 2016

Aim

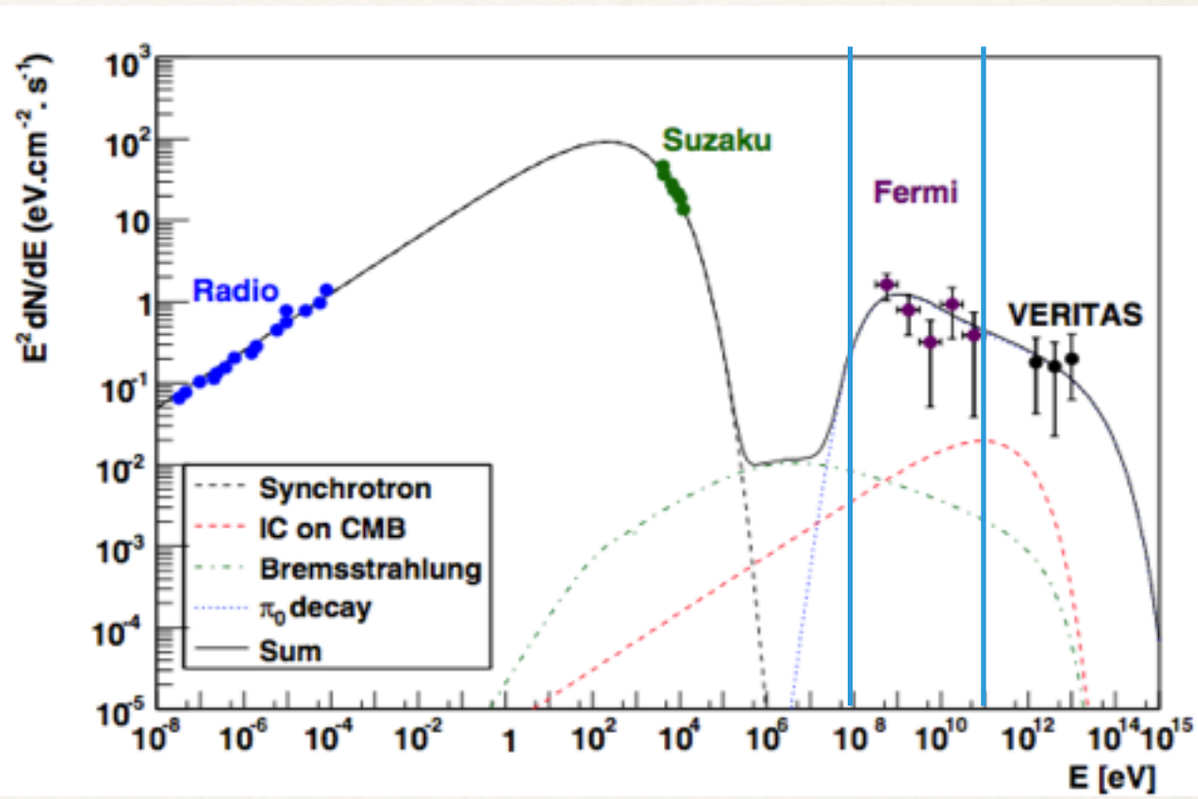
Study of the acceleration of cosmic rays by gamma-ray emission in supernova remnant and pulsar wind nebulae



Tycho spectrum (SN 1572)



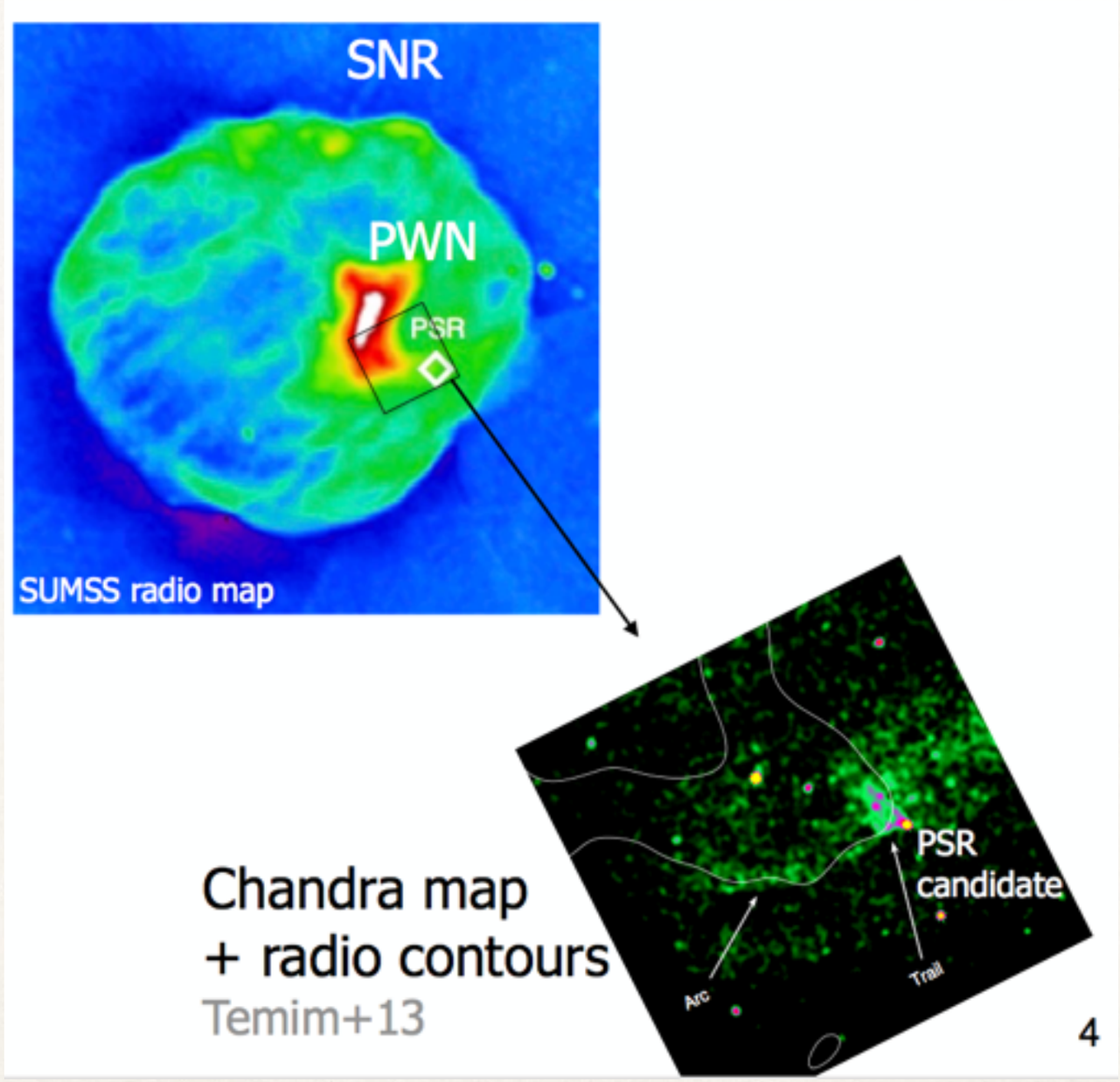
leptonic scenario



hadronic scenario

3 main processes : synchrotron, Inverse Compton, Π^0 decay

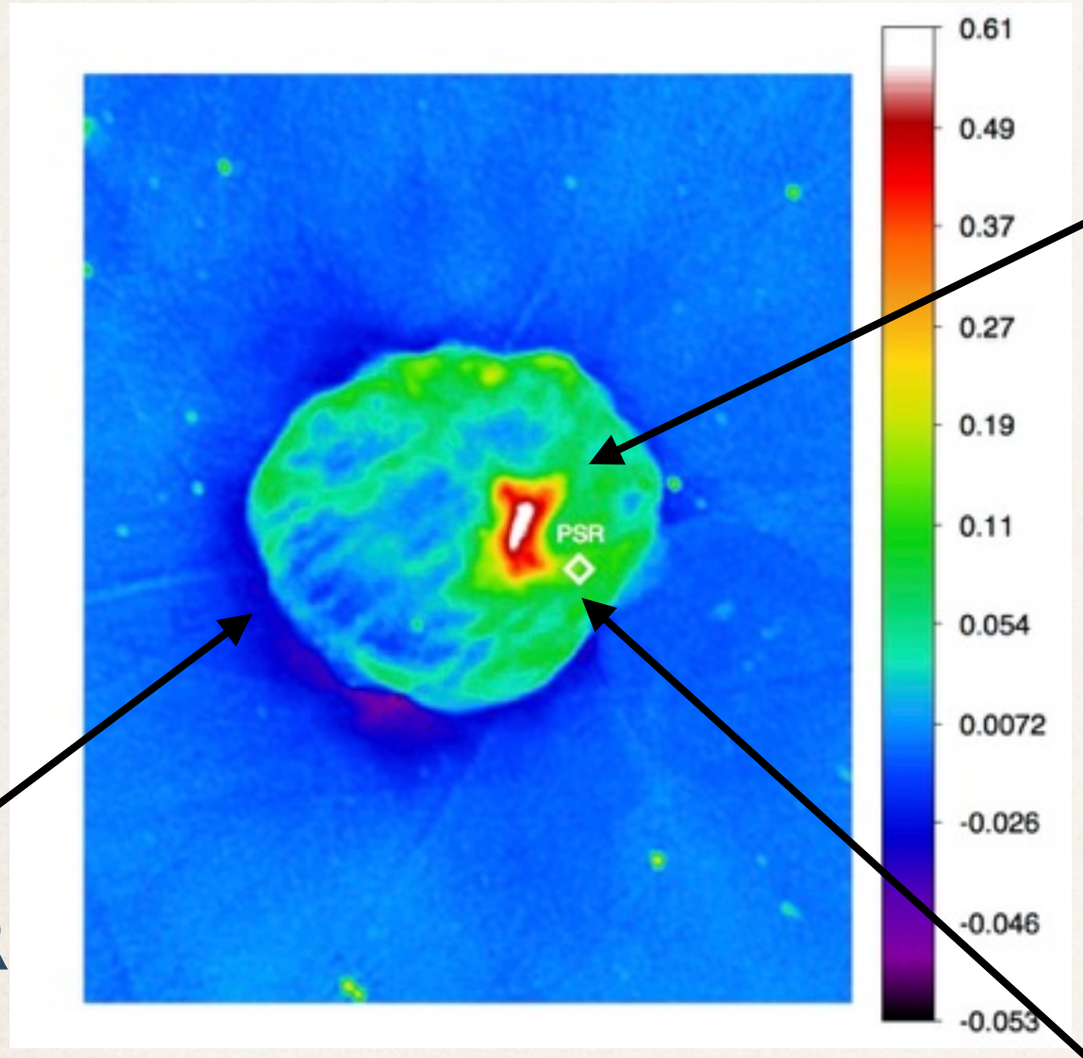
SNR G326.3-1.8



3 main processes : synchrotron, Inverse Compton, Π^0 decay

SNR G326.3-1.8

Composite supernova remnant



[Temim et al. 2013]

PWN

SNR

Pulsar

$$D \approx 4.1 kpc$$

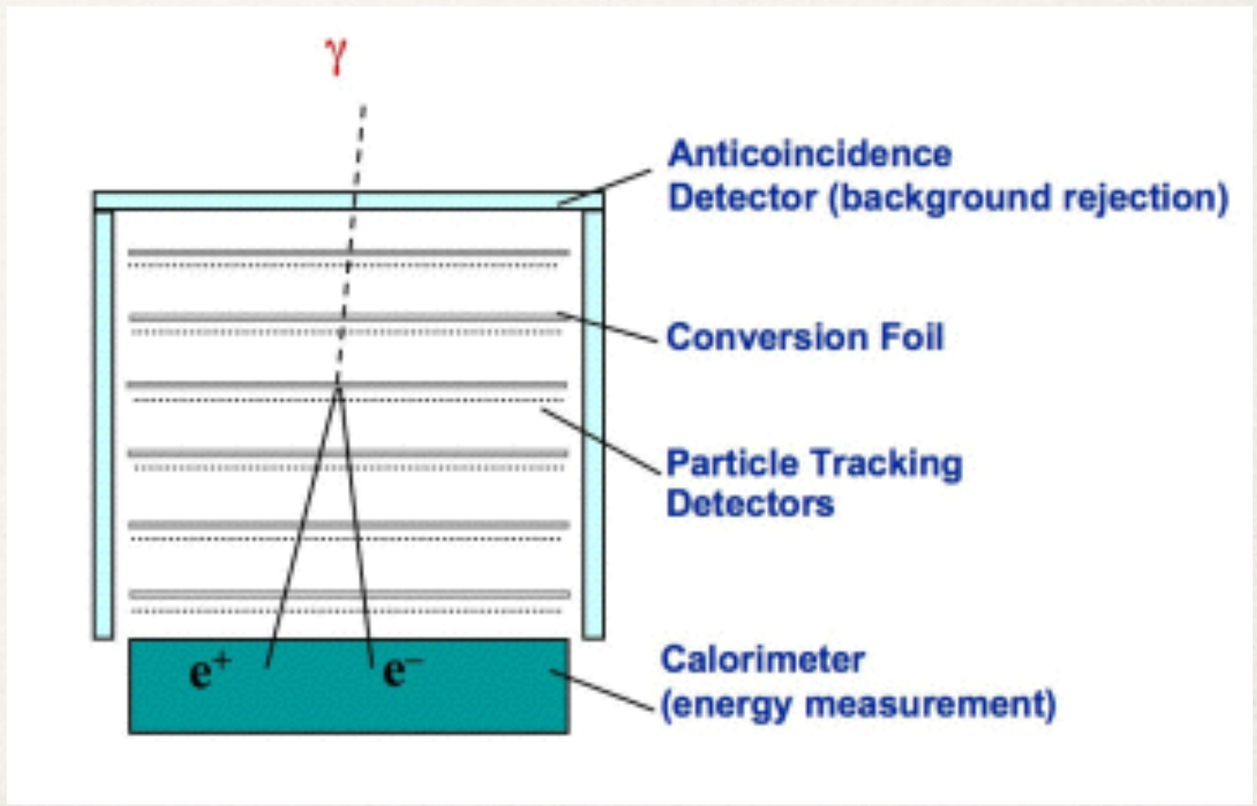
$$age \approx 16500 yrs$$

$$v_{pulsar} \approx 410 km.s^{-1}$$

$$v_{shock} = 500 km.s^{-1}$$

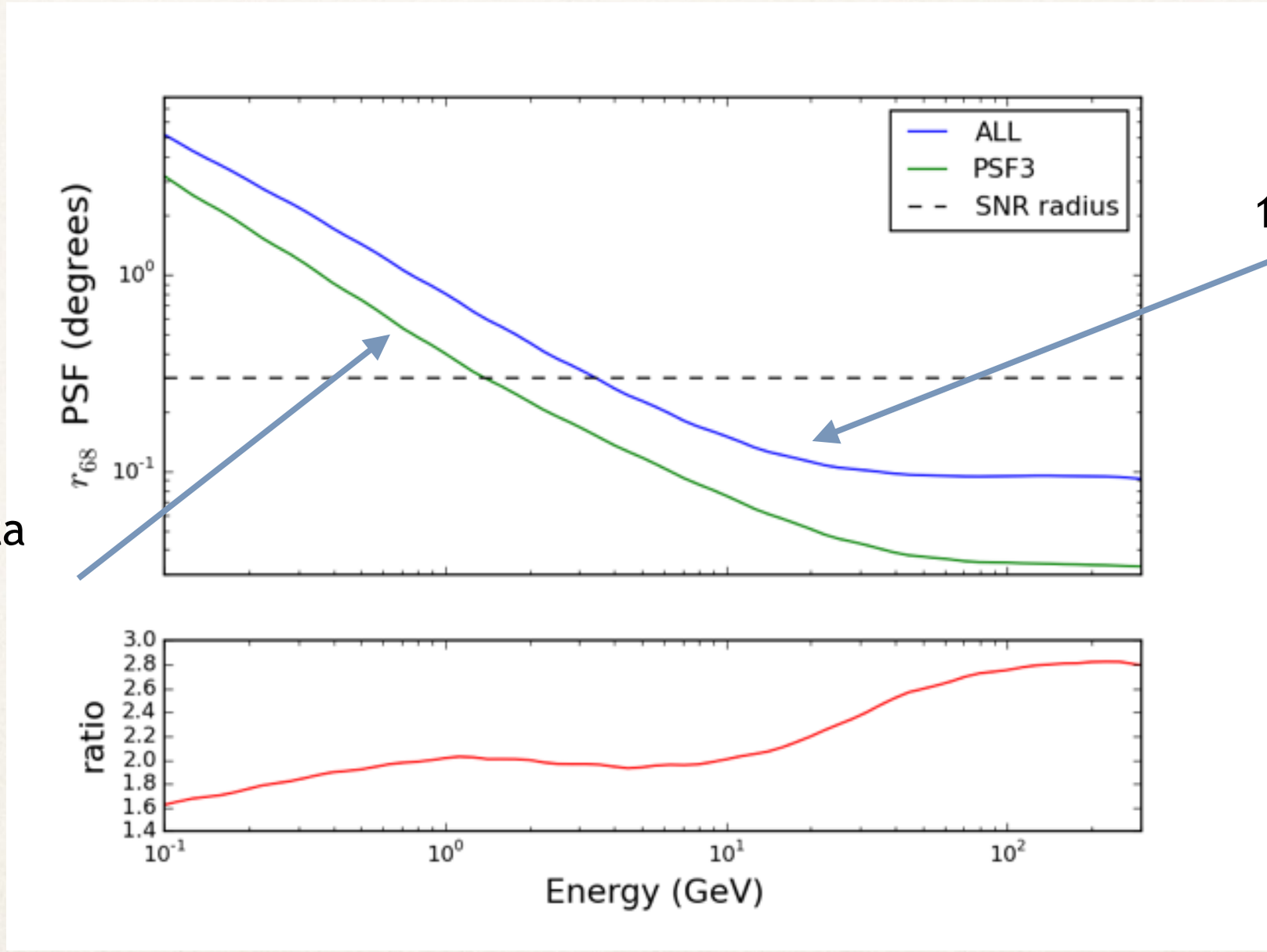
The gamma-ray satellite FERMI

- 11 Juin 2008
- 20 MeV – 300 GeV
- Whole scan each 3 hours
- See 20 % of the sky at any time



Pass 8 performances

Evolution of the PSF with energy



100% of the data

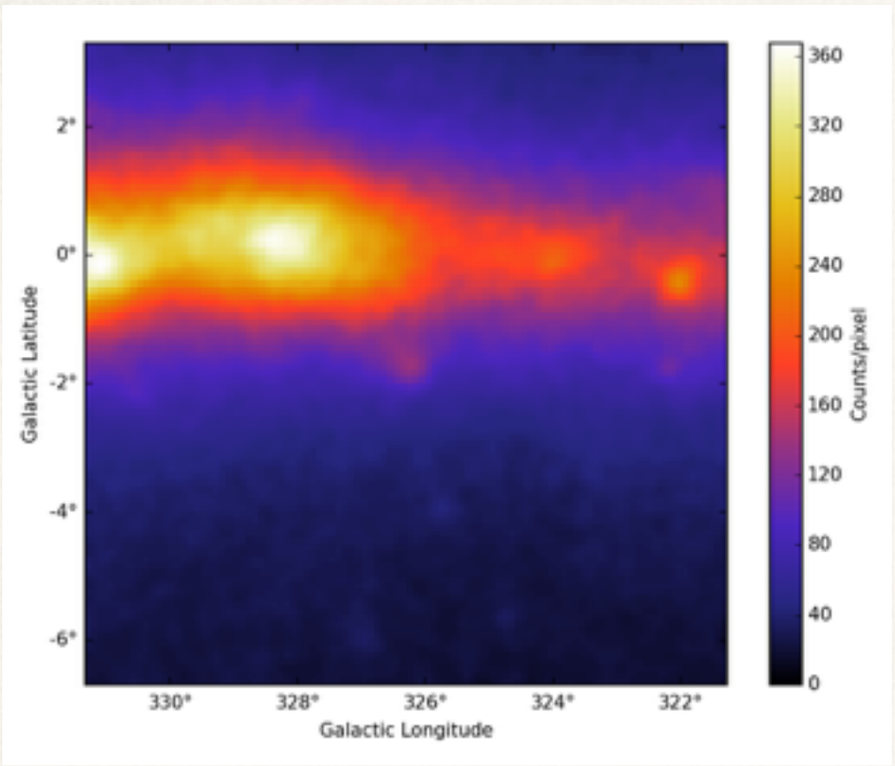
poor PSF

25% of the data

Best PSF

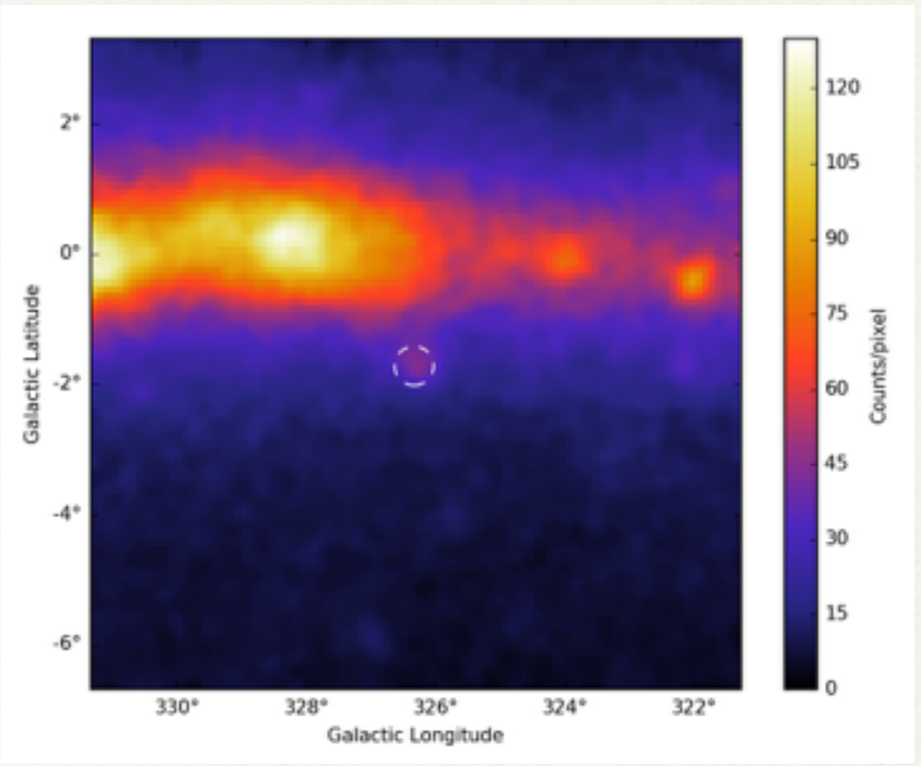
Description of the analysis

ALL events



Very bright SNR
TS ~ 1400
for ALL events

PSF3 events

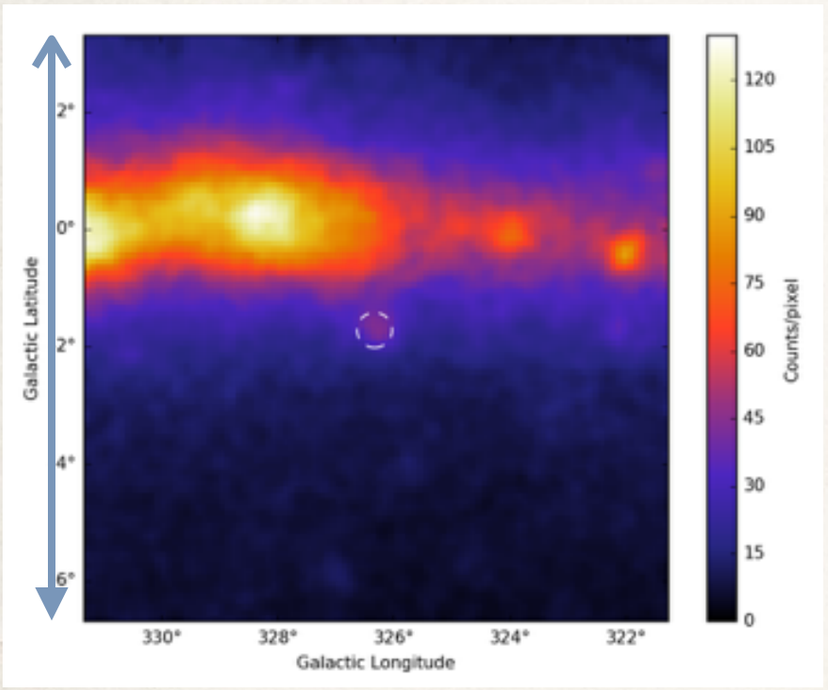


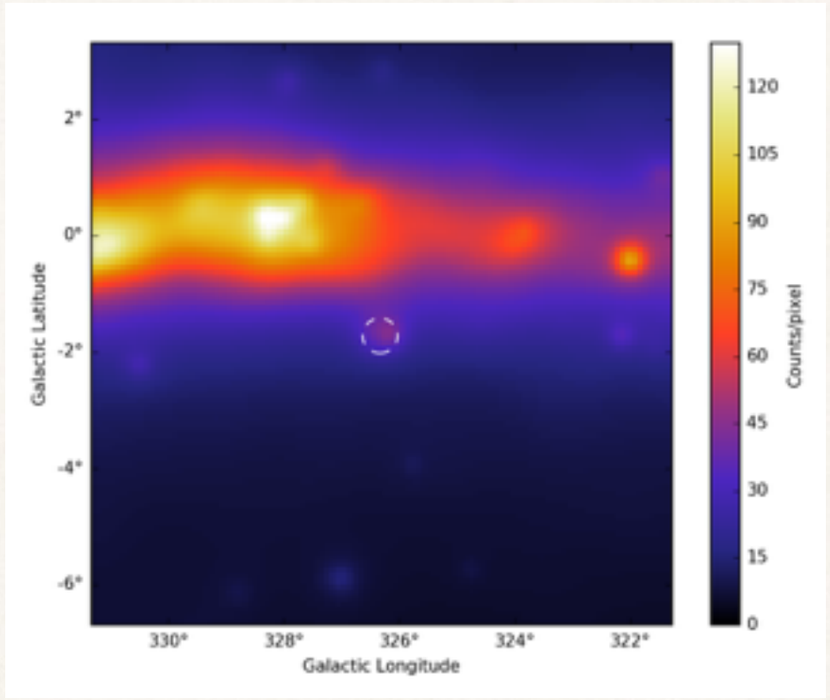
Still
TS ~ 700
for PSF3 events

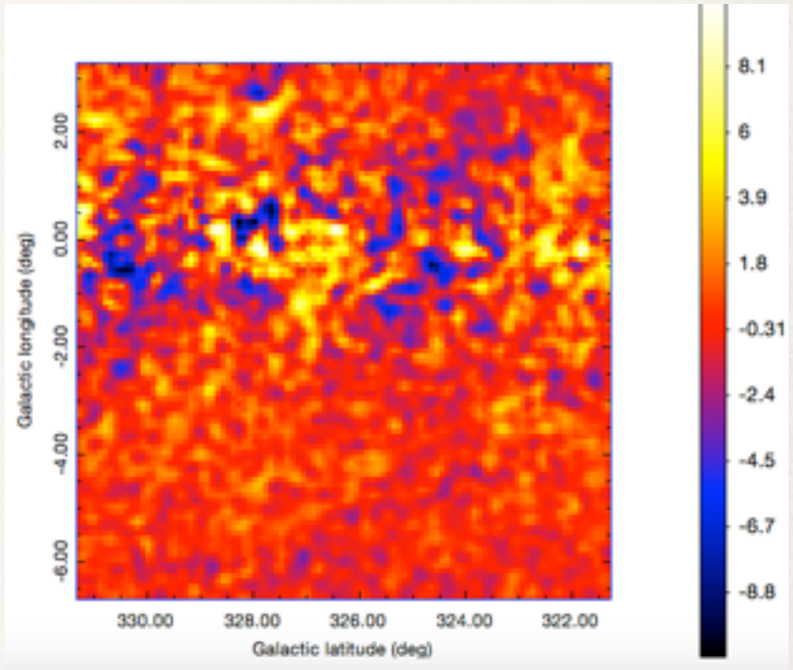
- Analysis on 10°x10° ROI for **0.3-300 GeV**
- 6.5 yrs of P8R2_SOURCE_V6 **with PSF3**
- Template_4years_P8_V2_scaled.fits diffuse
- Binned analysis
- Starting point : 3 FGL

Model of the ROI

10°x10°



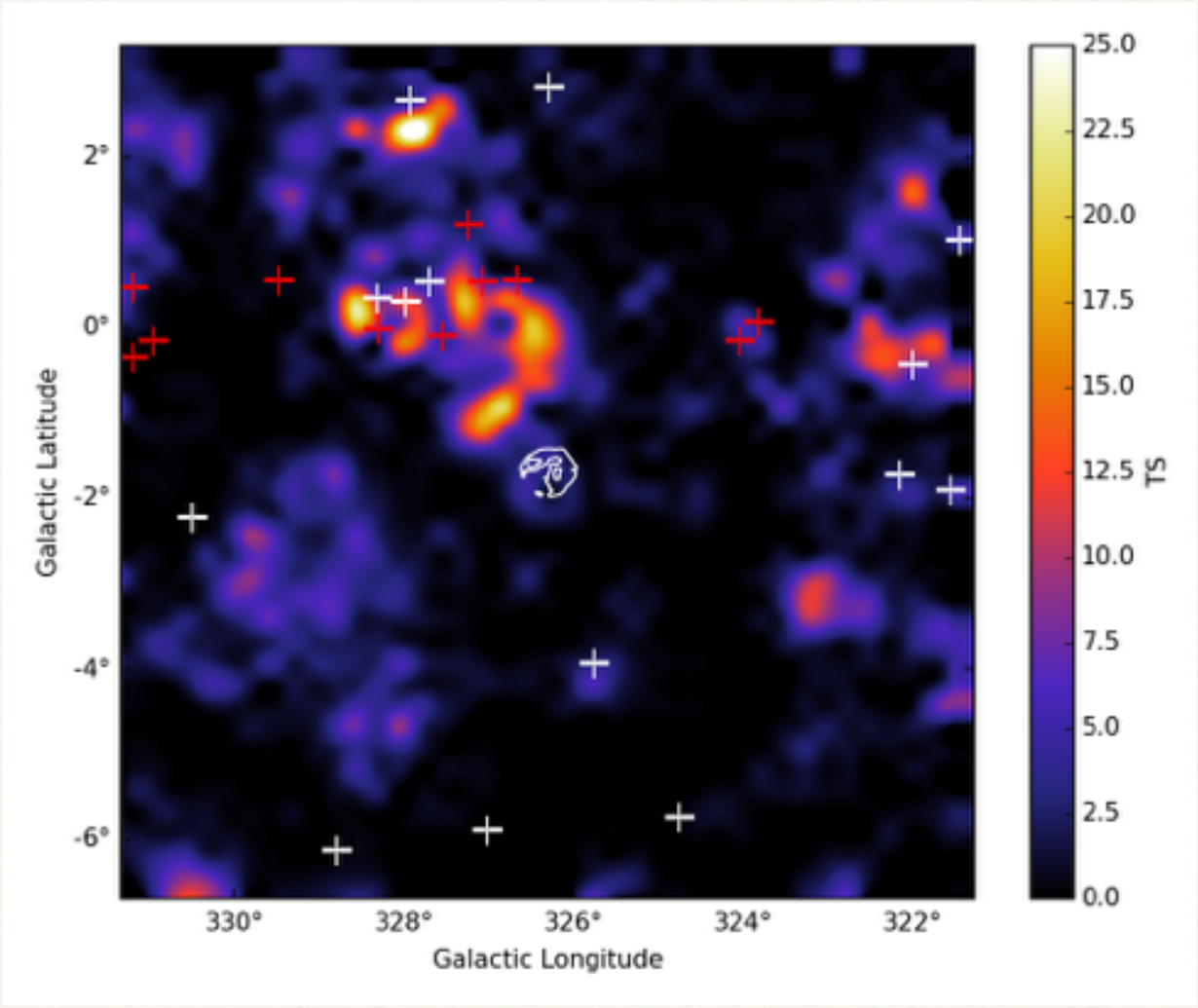




data - model = residues

Model of the ROI

Residual TS map



11 sources added
SNR is included

SNR G326.3-1.8

* Maximum likelihood method

Probability to obtain n_i photon when the model predicts λ_i

$$P_i = \frac{\lambda_i^{n_i}}{n_i!} e^{-\lambda_i}$$

Total probability to obtain the data :

$$L = \exp(-N_{pred}) \prod_i \frac{\lambda_i^{n_i}}{n_i!}$$

$$\boldsymbol{LL = \log(L)}$$

* Test Statistic

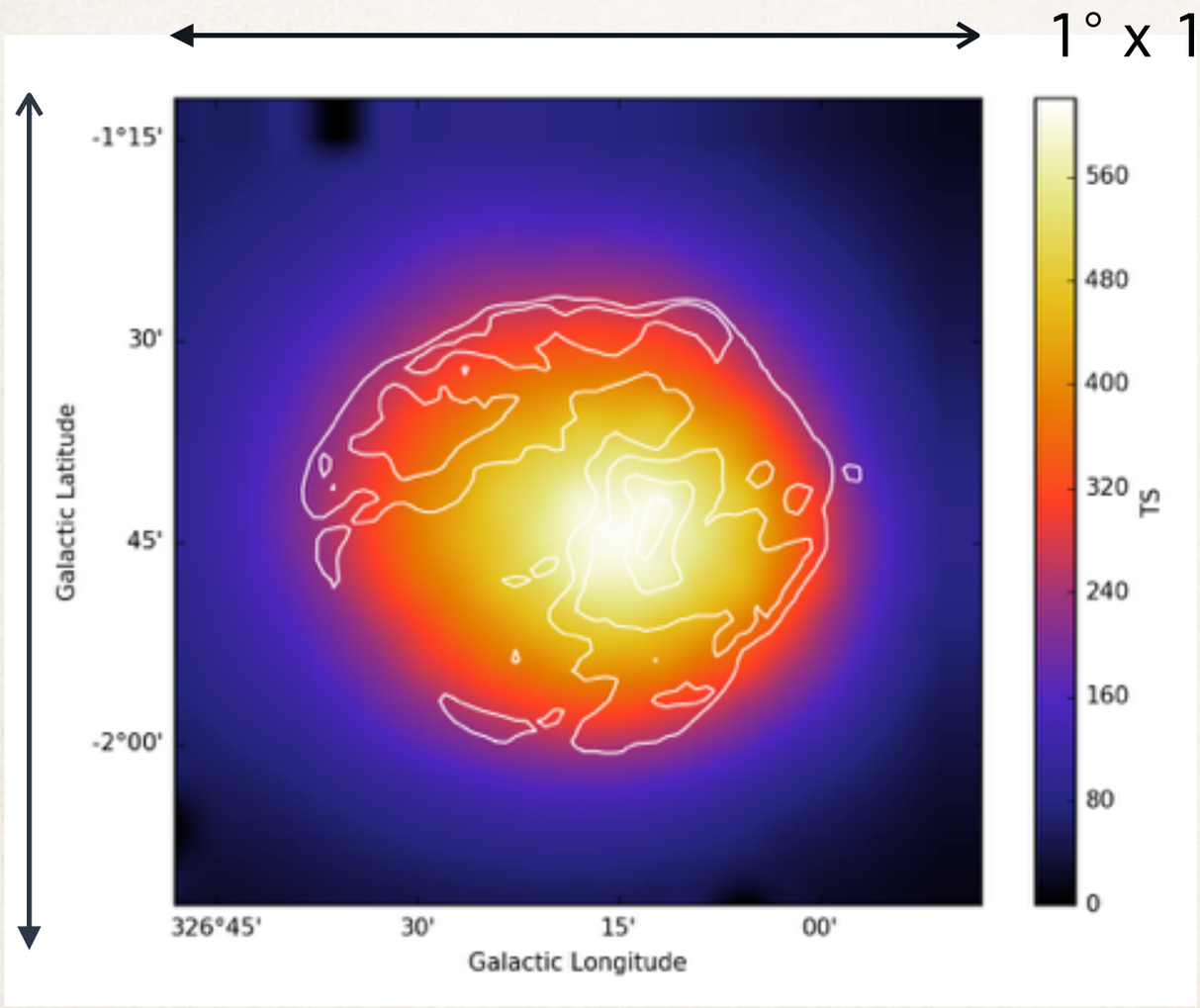
$$TS = 2(LL_1 - LL_0) > 25$$

The model with the source reproduces better the γ -ray emission

Morphological analysis

* Can we disentangle the PWN from the SNR component ?

Residual TS map (without source)

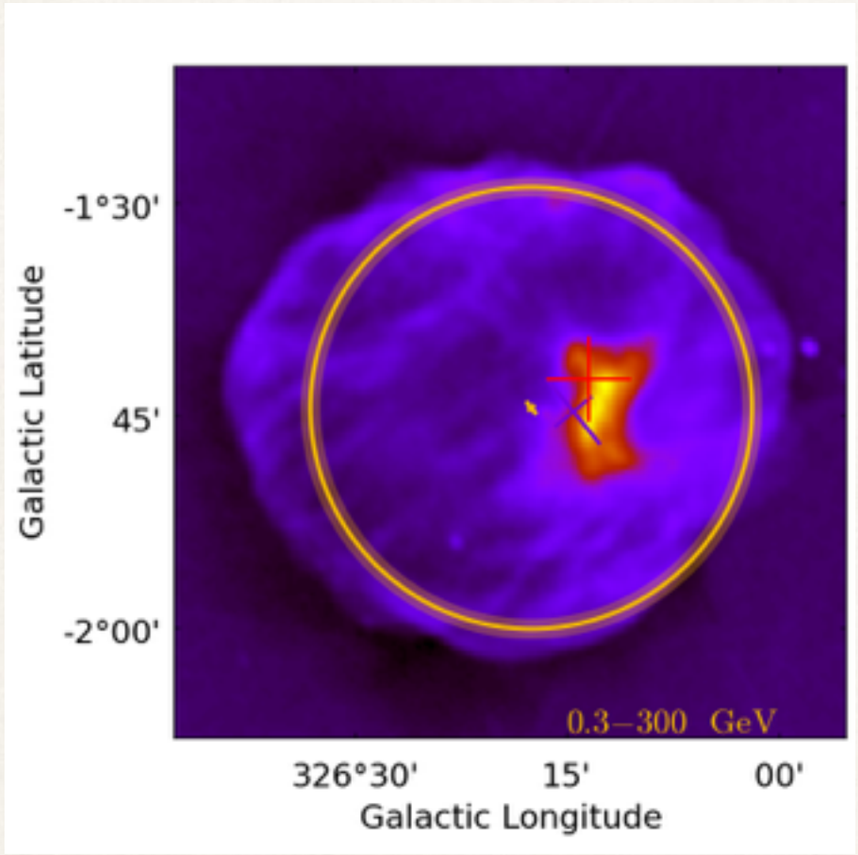


[500 MeV - 300 GeV]
with the cut PSF3

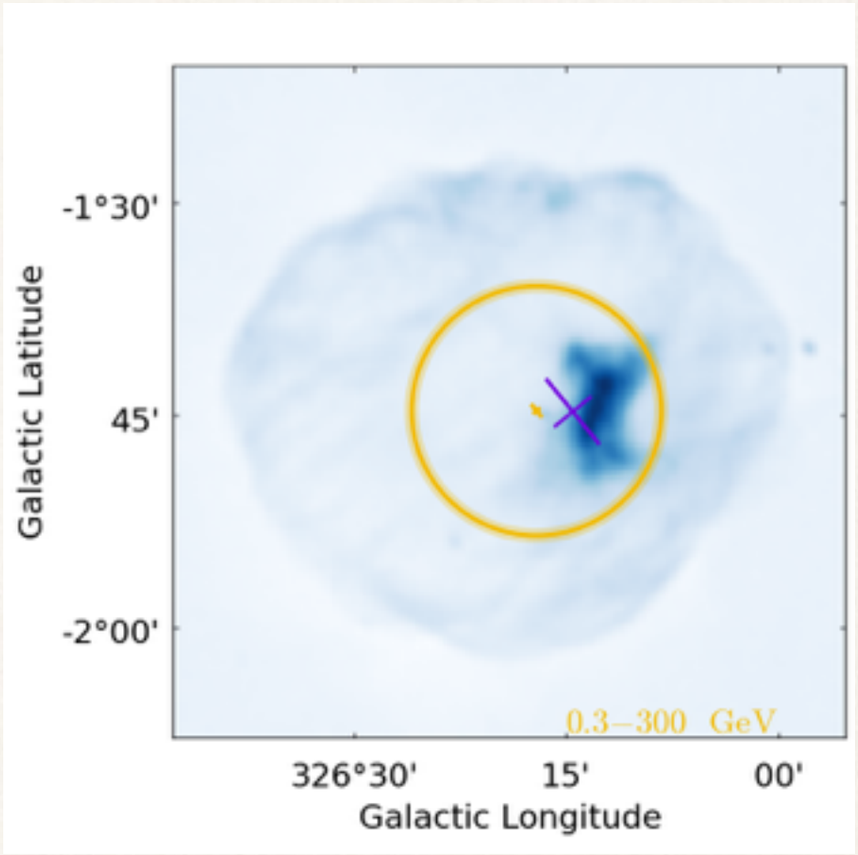
Extension

Point-like analysis (front events)

Uniform disk



Symmetric gaussian

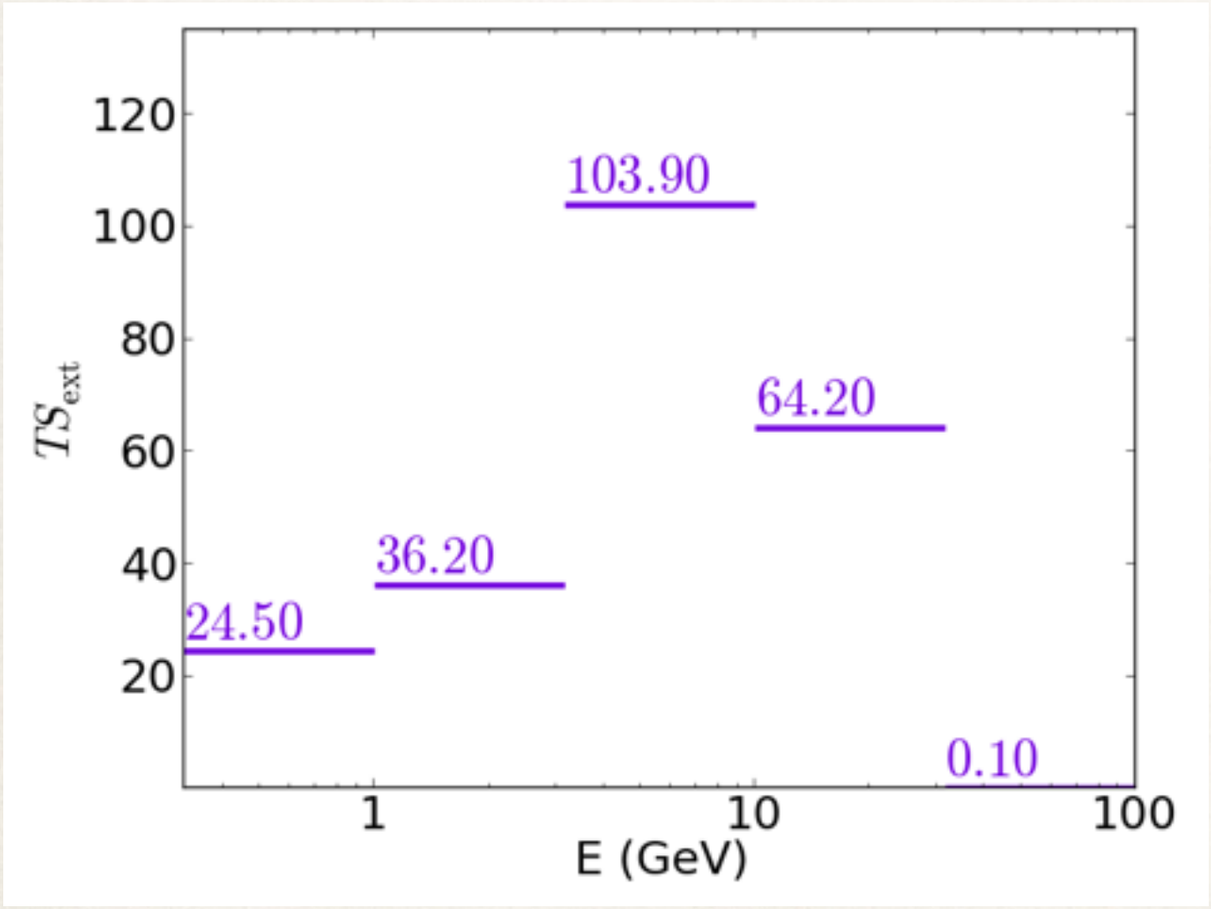


spatial model	RA	dec	size σ or r	$r_{68\%}$	$TS_{\text{ext}}^{\text{pointlike}}$	N_{DOF}
point source	238.157	-56.186	–	–	–	2
uniform disk	238.220	-56.151	0.260°	0.2132°	238.59	2
Gaussian	238.214	-56.158	0.147°	0.22197°	247.7	2

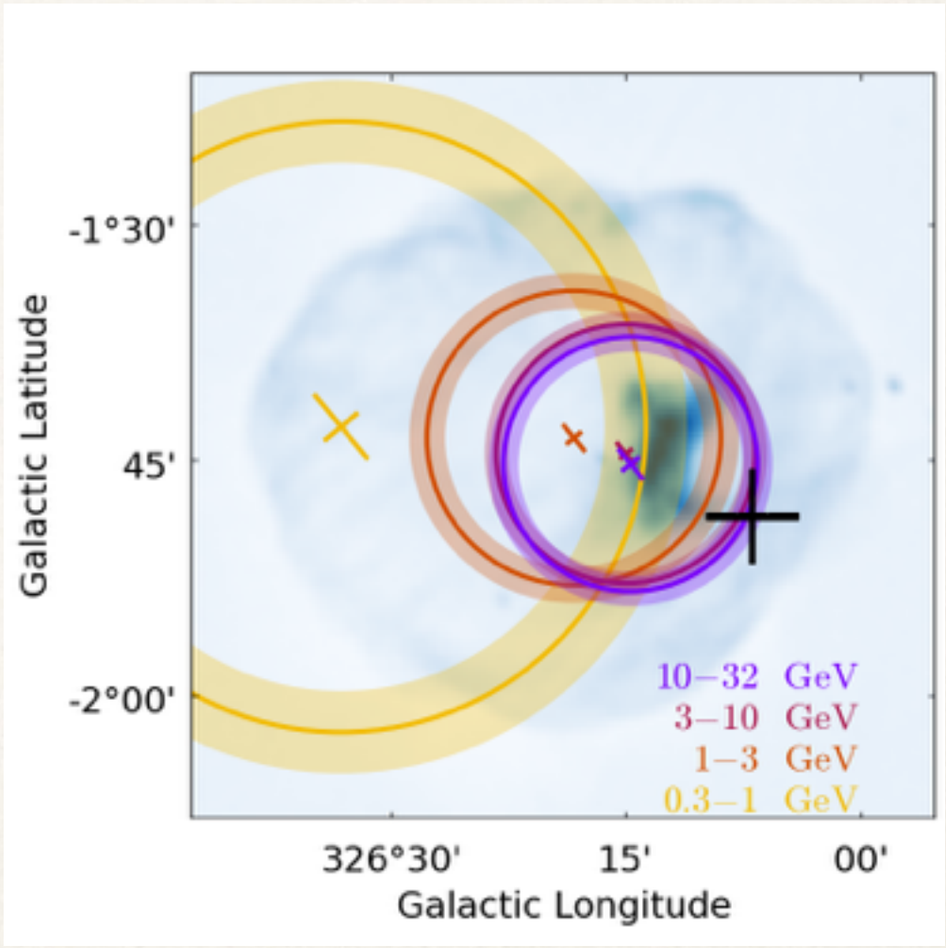
Energy-dependent morphology

Point-like analysis (front events)

Gaussian template :



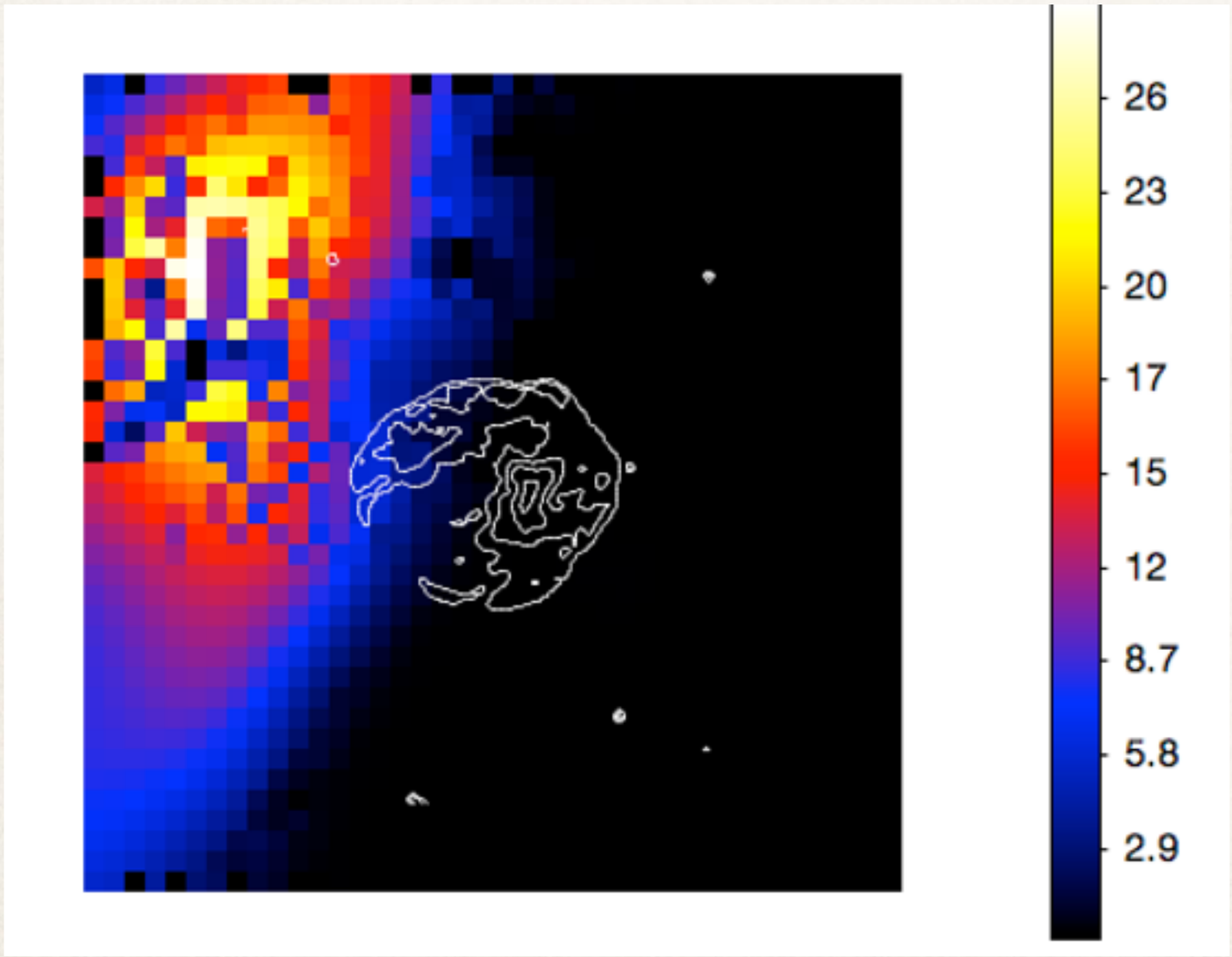
(1 sigma)



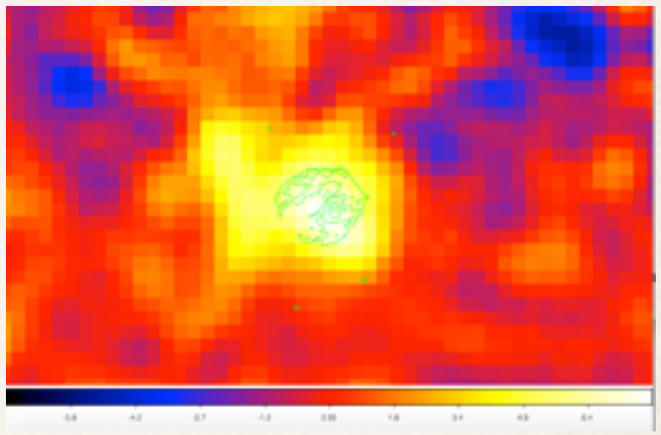
0.3 - 1 GeV / PSF3

Point source added to the model :

Residual TS map

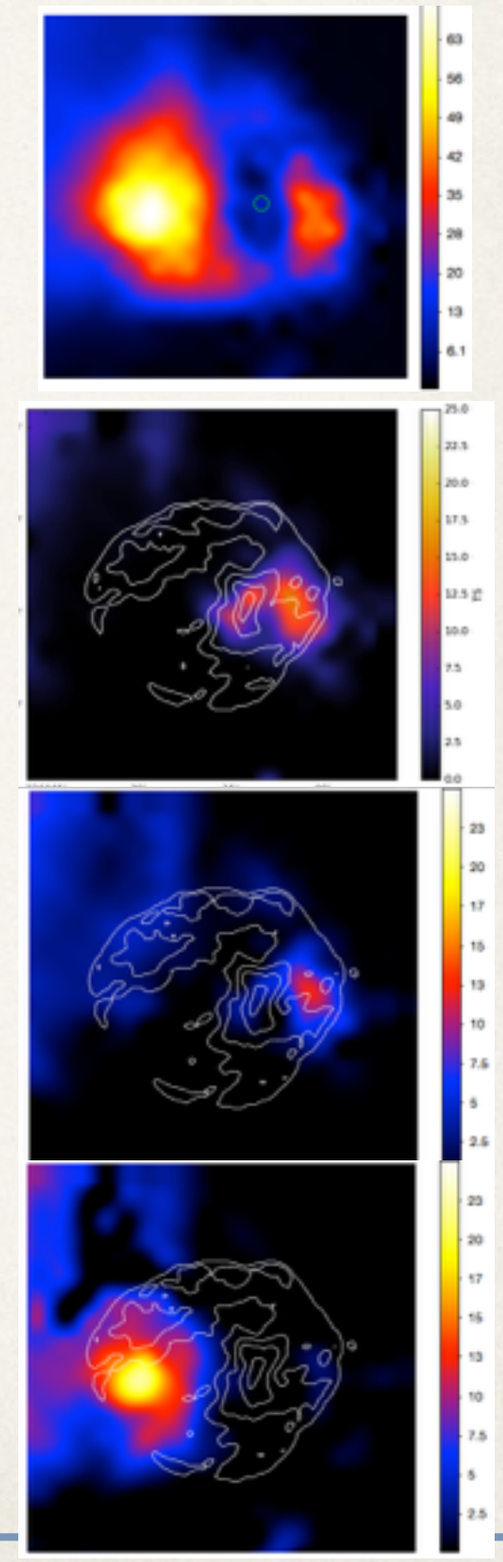


Count map

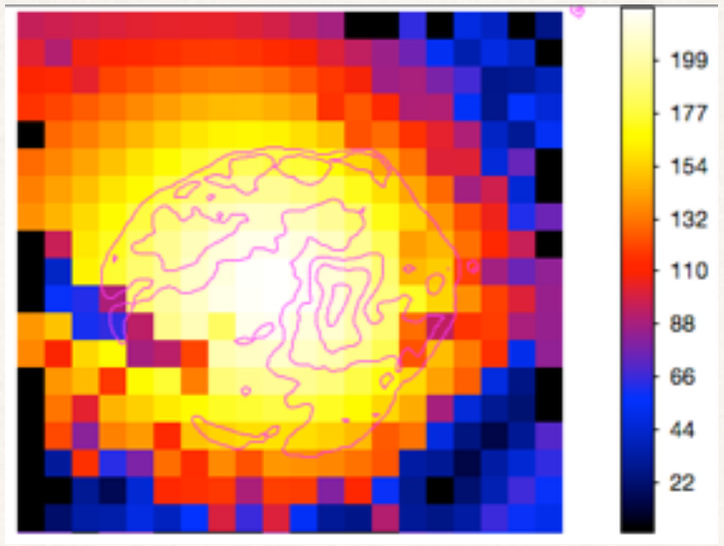


One component model - PSF3 events

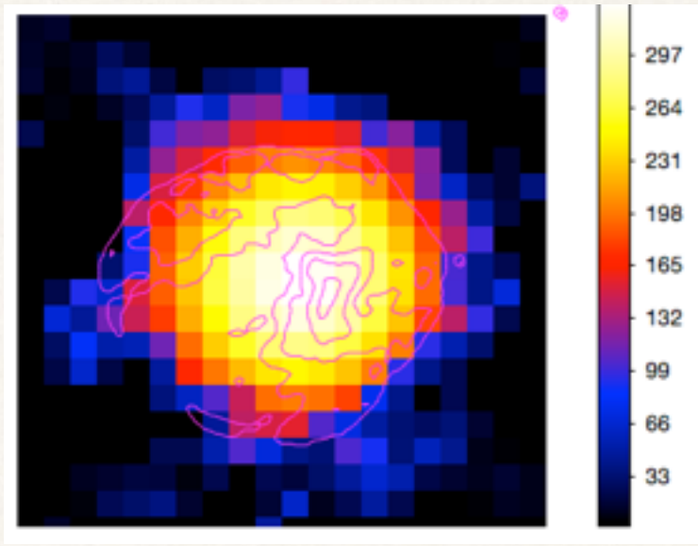
Template	ΔTS
Point Source	692.95
Uniform disk	837.66
Gaussian	835.96
Radio template	833.32



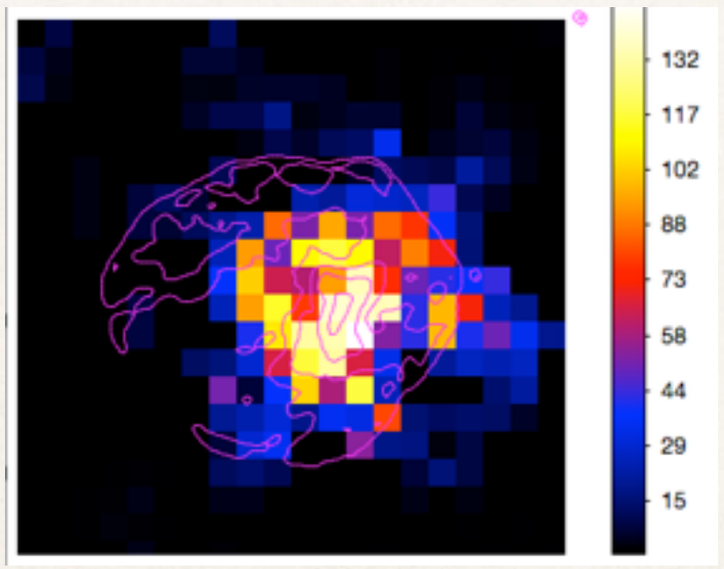
TS maps - PSF3 events



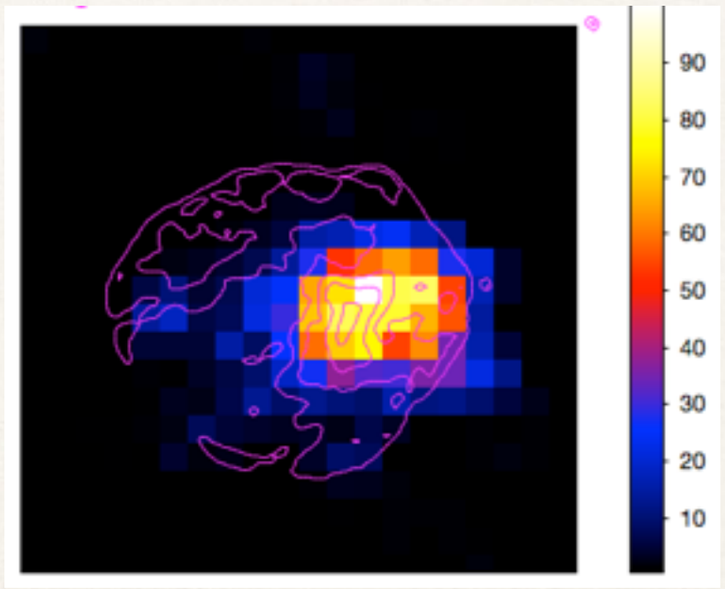
0.3 - 1 GeV



1 - 3 GeV



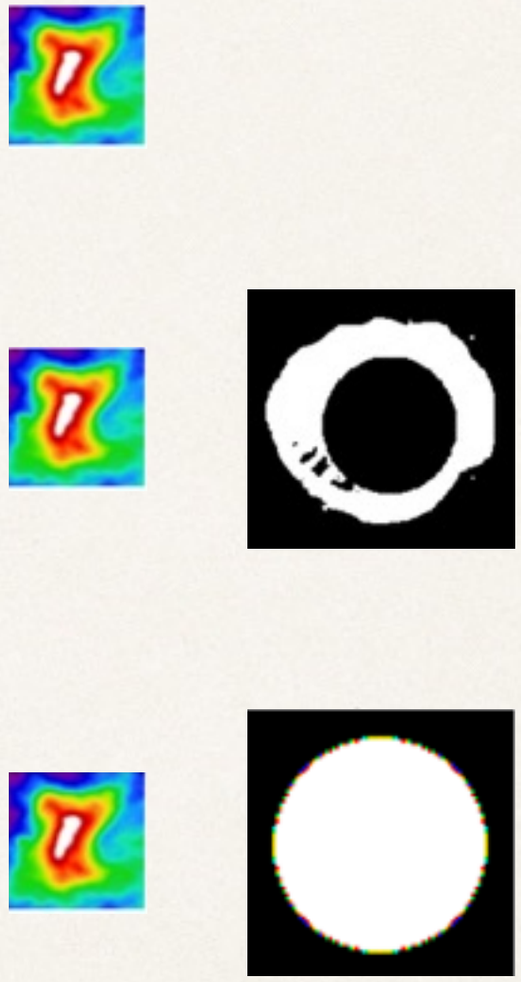
3 - 10 GeV



10 - 300 GeV

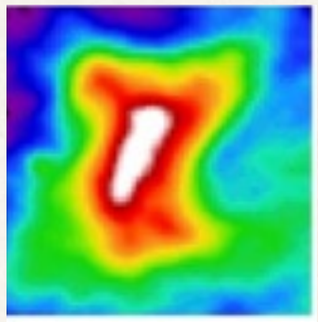
Two components model - PSF3 events

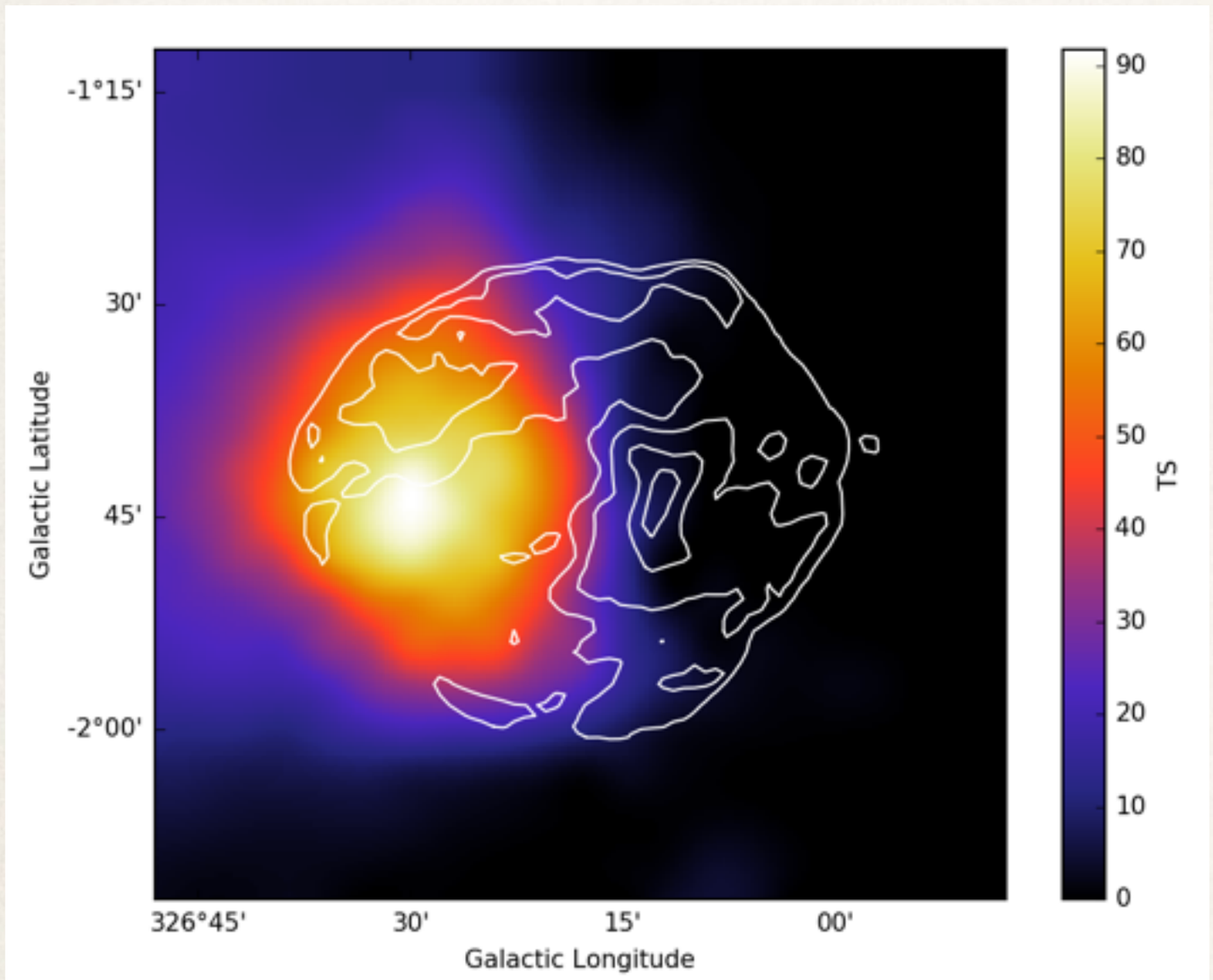
Template	ΔTS
PWN	742.64
PWN + SNR (ring)	851.26
PWN + Disk	851.67



Residual TS map

Residual TS map with the radio template of the PWN :

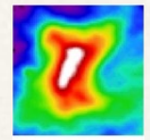


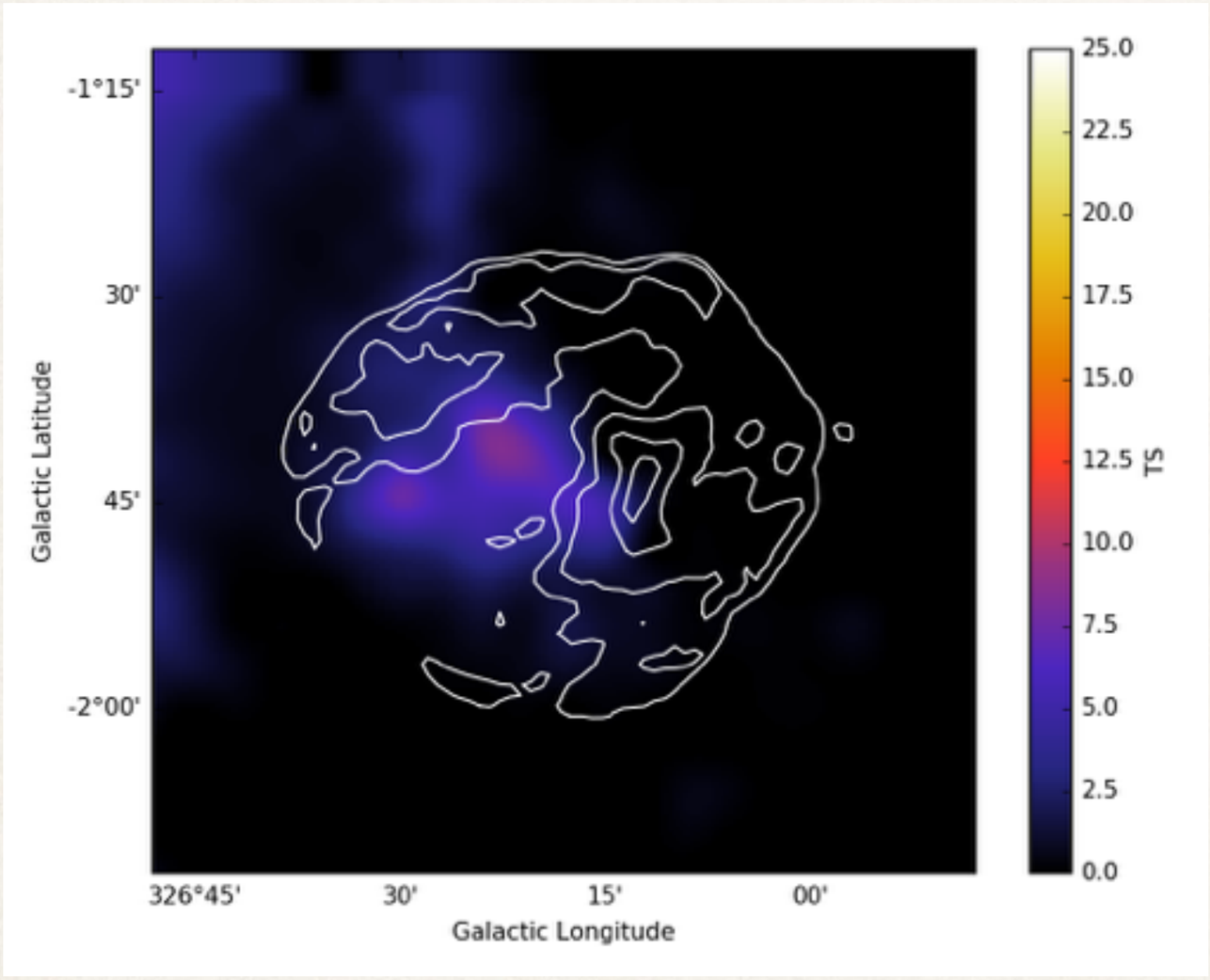


$$\Delta TS = 742.64$$

Residual TS map

Residual TS map with the radio template of the PWN and the ring modeling the SNR :





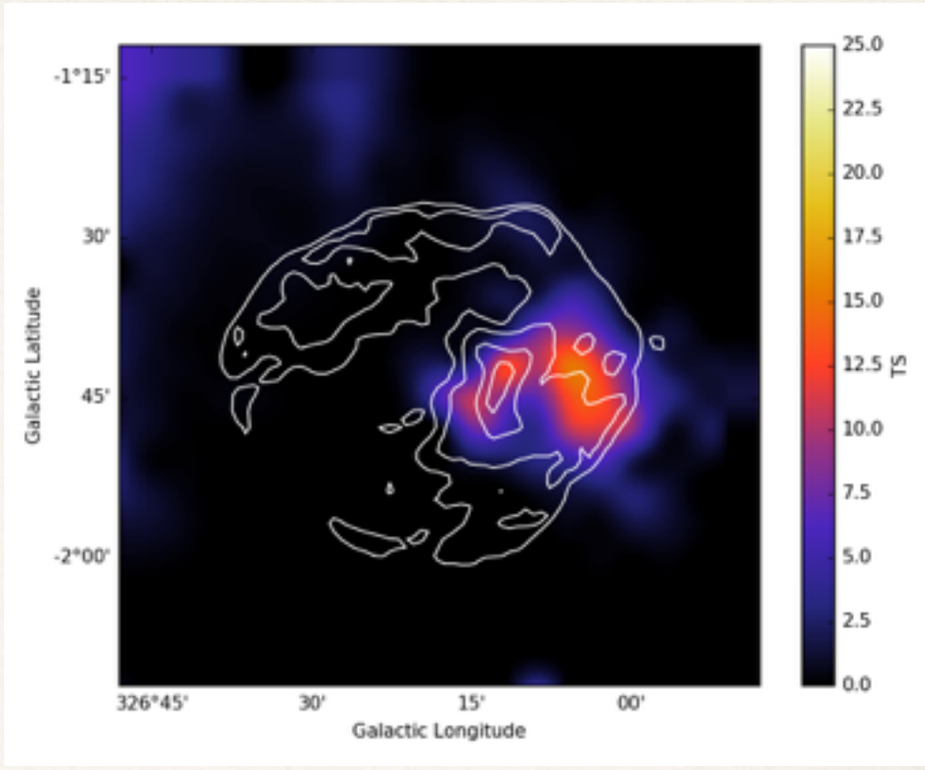
$$\Delta TS = 851.26$$

SNR G326.3-1.8

Residual TS maps

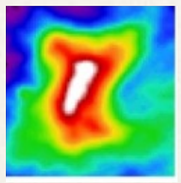
- Uniform disk

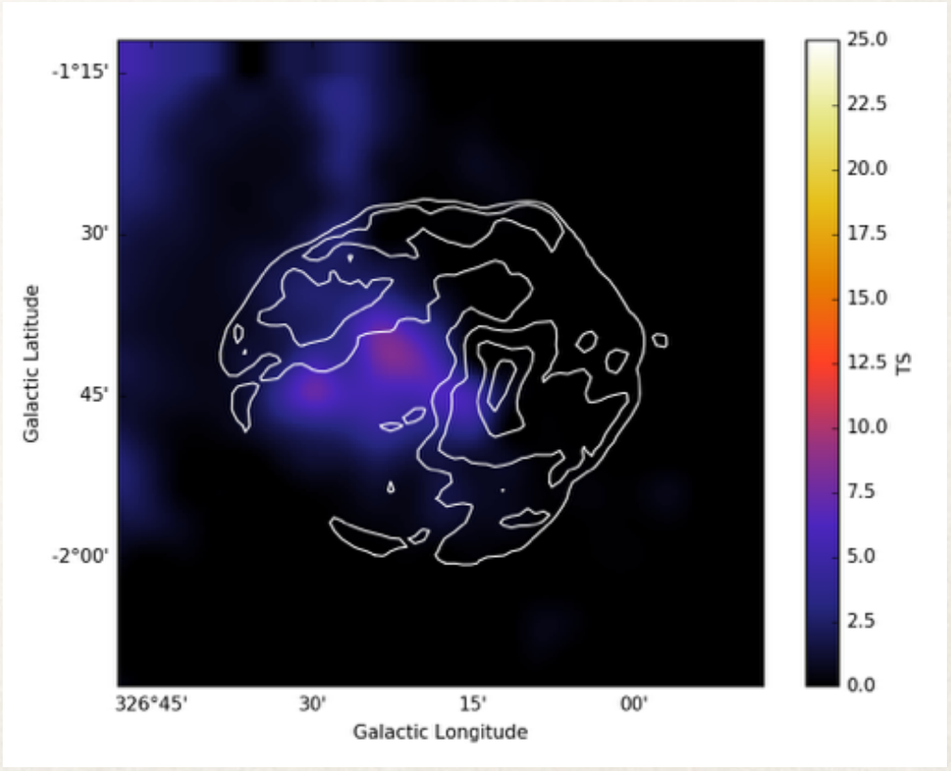
$$\Delta TS = 837.66$$



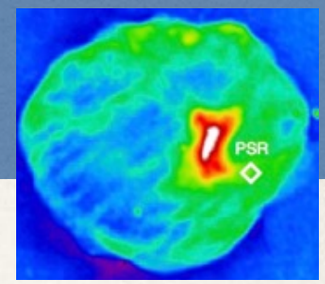
- PWN (radio) + SNR (ring)

$$\Delta TS = 851.26$$

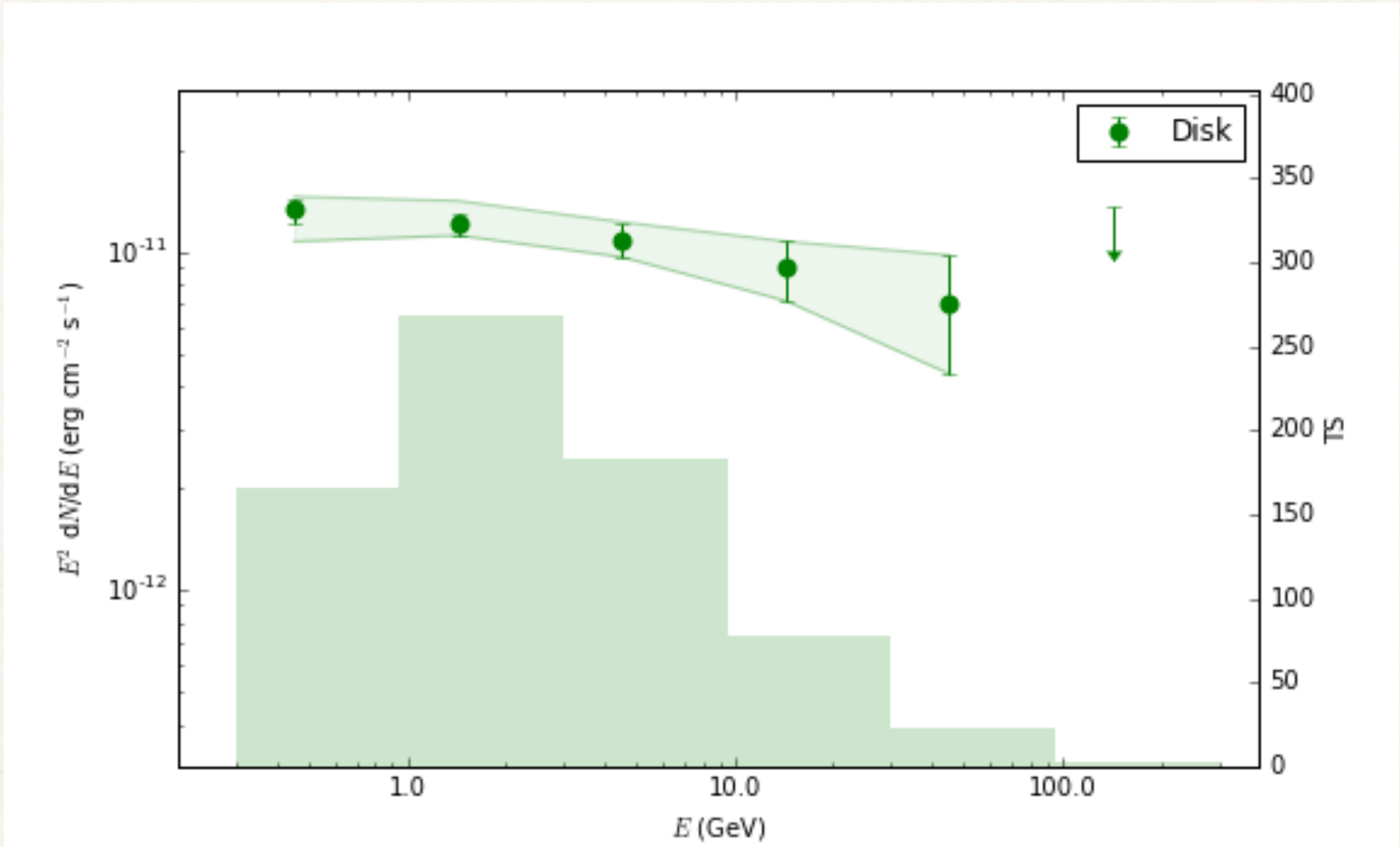




Spectral energy distribution

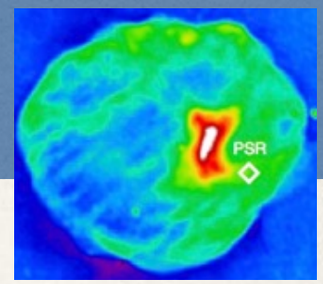


SEDs (Disk) :

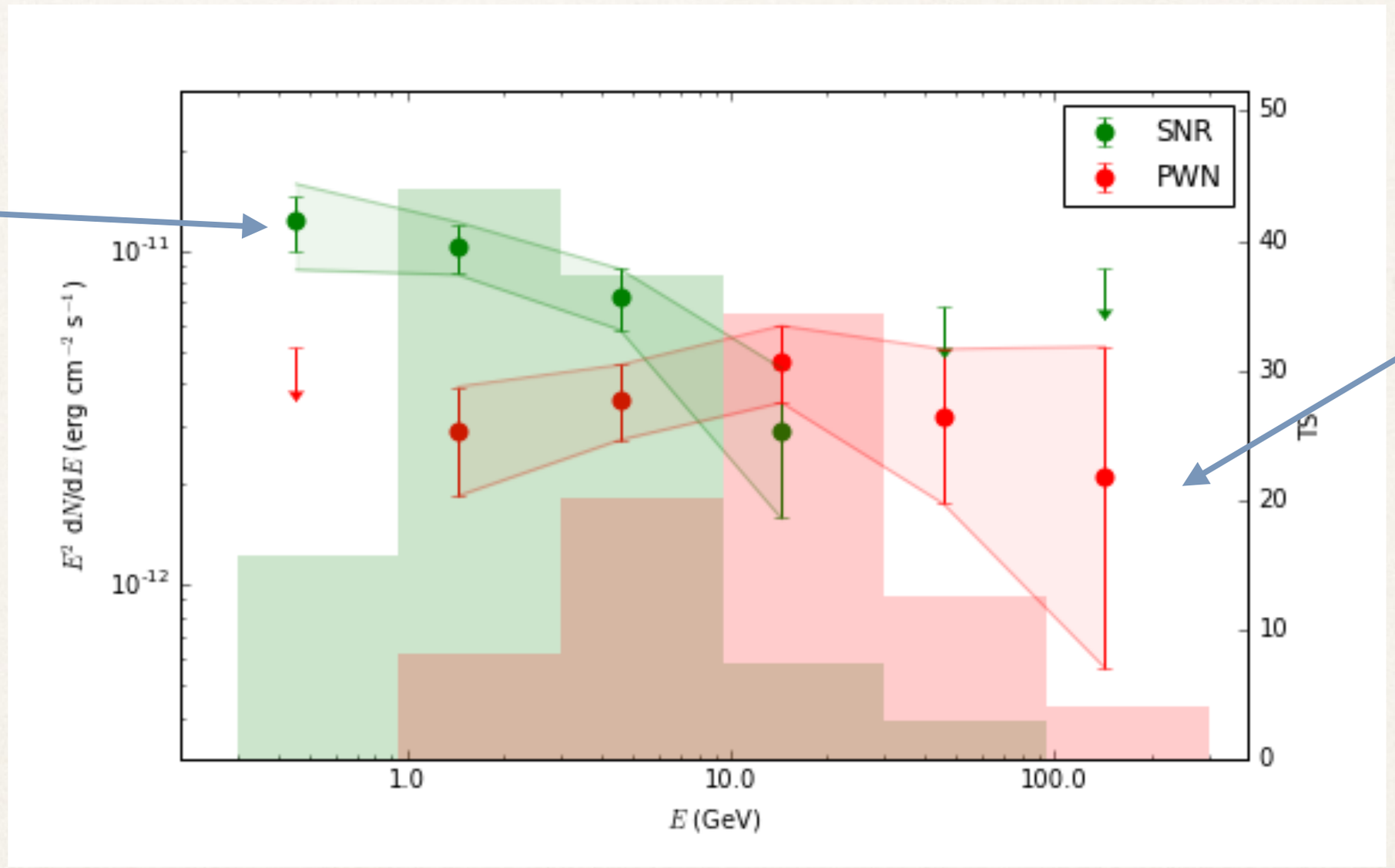


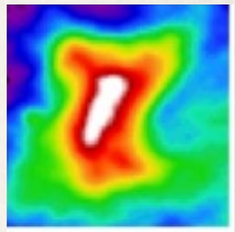
Index = 2.08 +/- 0.04

Spectral energy distribution



SEDs (PWN + SNR) :





Index = 2.24 +/- 0.07

Index = 1.86 +/- 0.09

Conclusions

Two complementary methods to investigate the different spatial constituents in the SNR G326.3-1.8

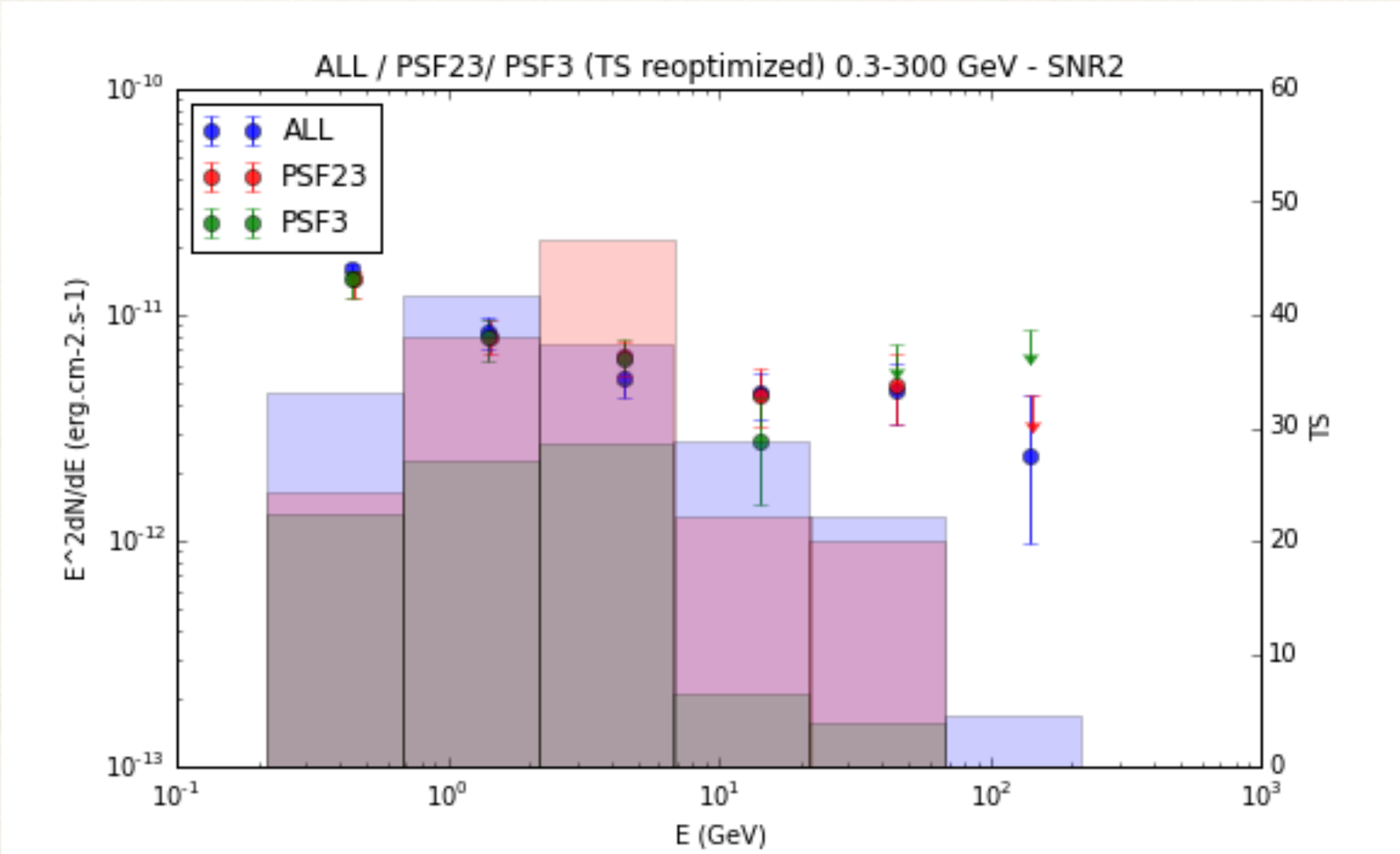
- spectral fitting using morphological templates
- fitting of the spatial morphology in a one-component model

The PSF3 selection can separate the contribution of 2 nested objects
-> the emission potentially refers to different origin of processes : leptonic (for the nebula) and hadronic (for the remnant)

THANK YOU FOR YOUR ATTENTION

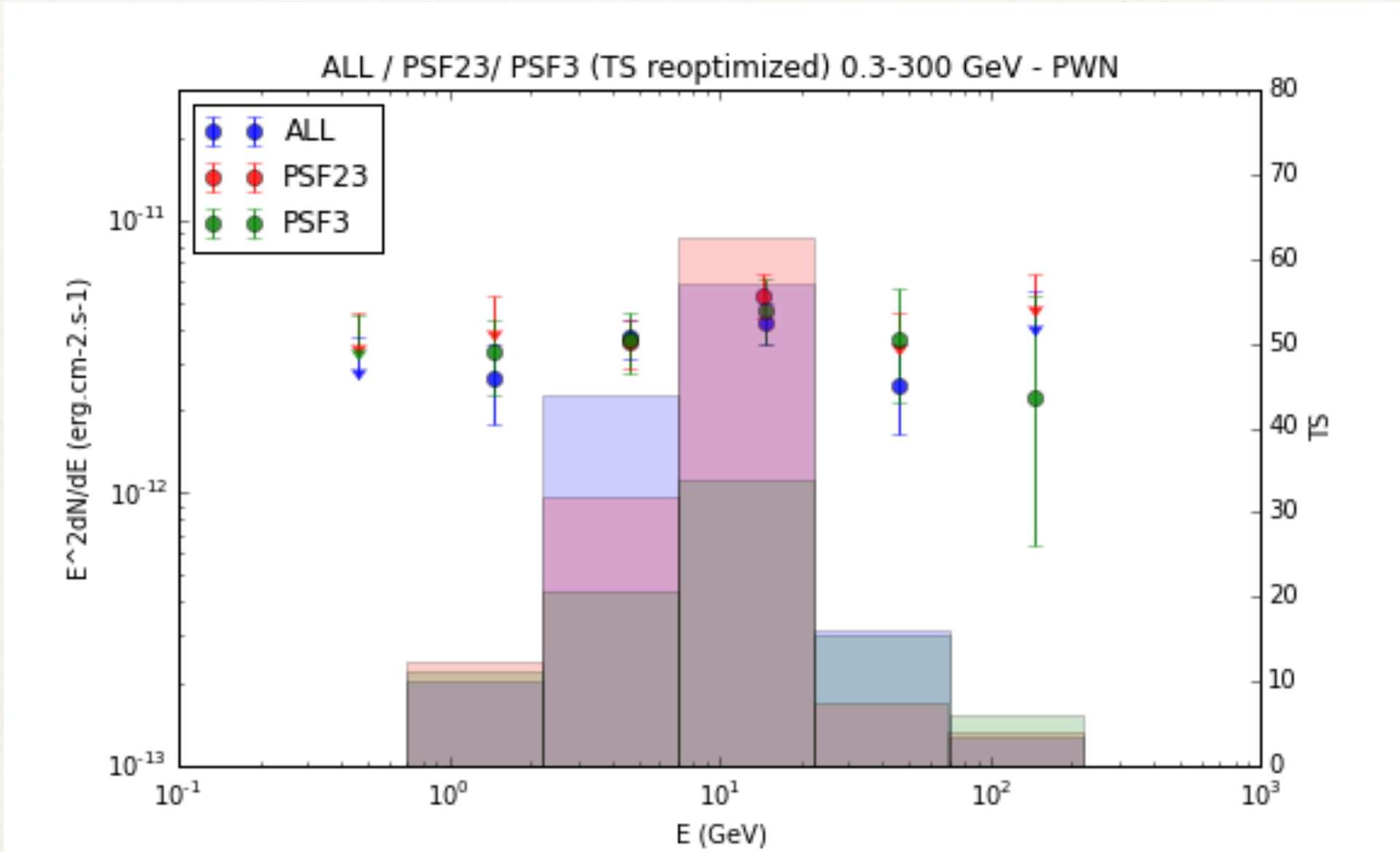
ALL / PSF2+3 / PSF3

SNR :

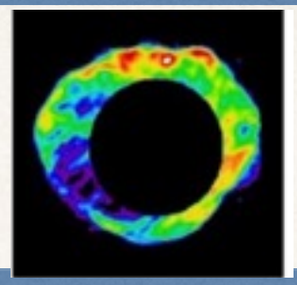


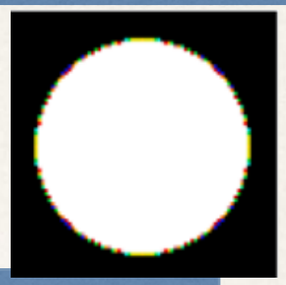
ALL / PSF2+3 / PSF3

PWN :



Two components model

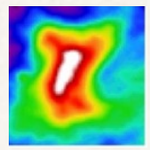


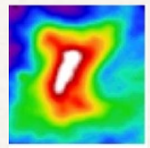
Contribution SNR	D(TS)
PWN + SNR (ring)	818.38
PWN + SNR (ring)	851.26
PWN + Disk	851.67

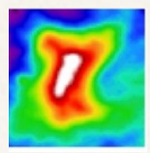
Contribution PWN	D(TS)
SNR (ring) + Point Source	841.12
SNR (ring) + Gaussian	852.56

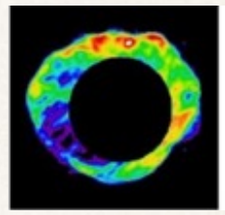
Two components model

Model	ΔTS
PWN	737.17
PWN + SNR (ring)	851.26
PWN + Disk	851.67
SNR (ring) + Point Source	841.12
SNR (ring)	759.36
SNR (template radio)	746.84
SNR (ring) + Gaussian	852.56









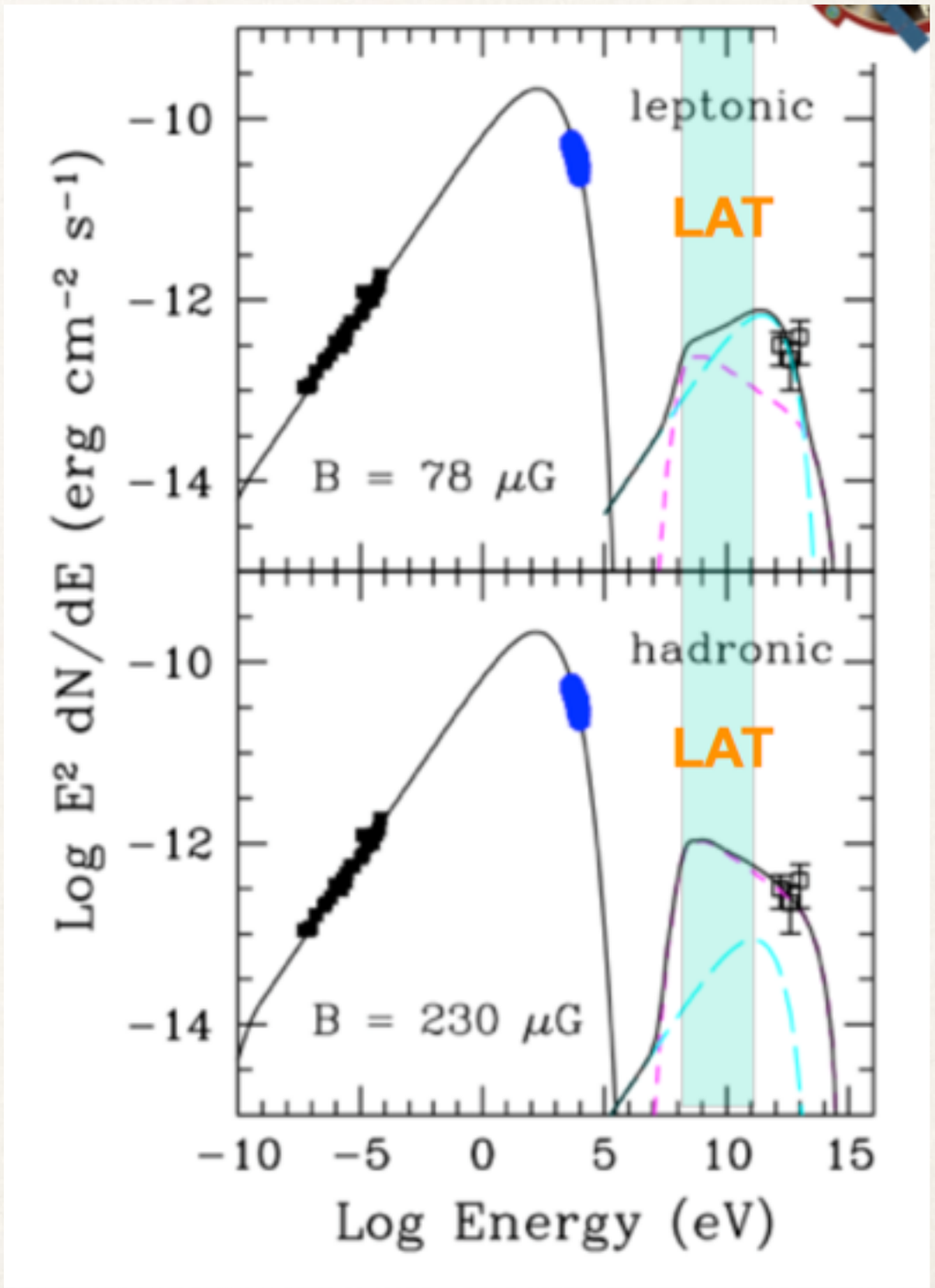
ACCELERATION DE PROTONS OU D'ELECTRONS ?

Scénario dominant :

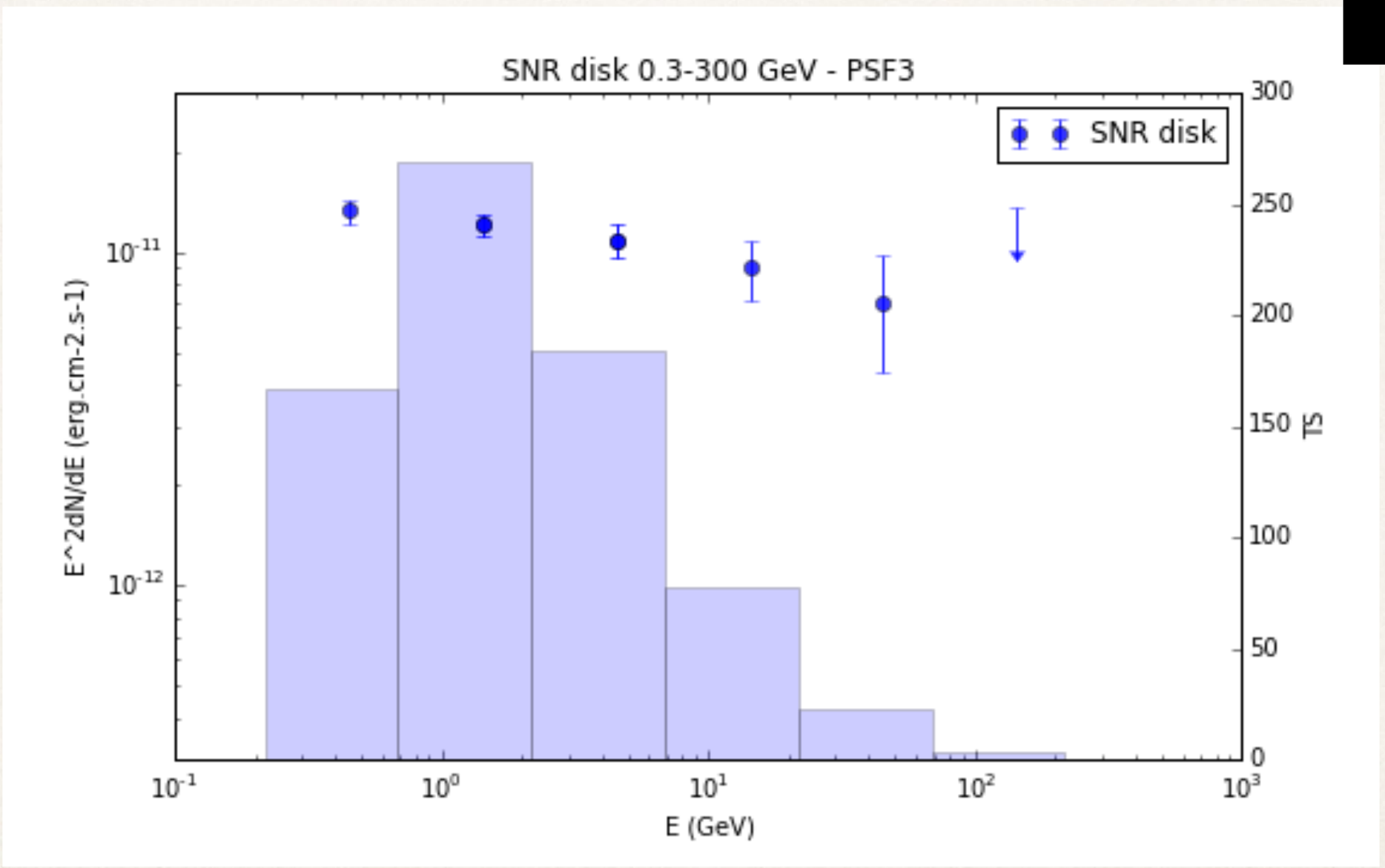
Leptonique

ou

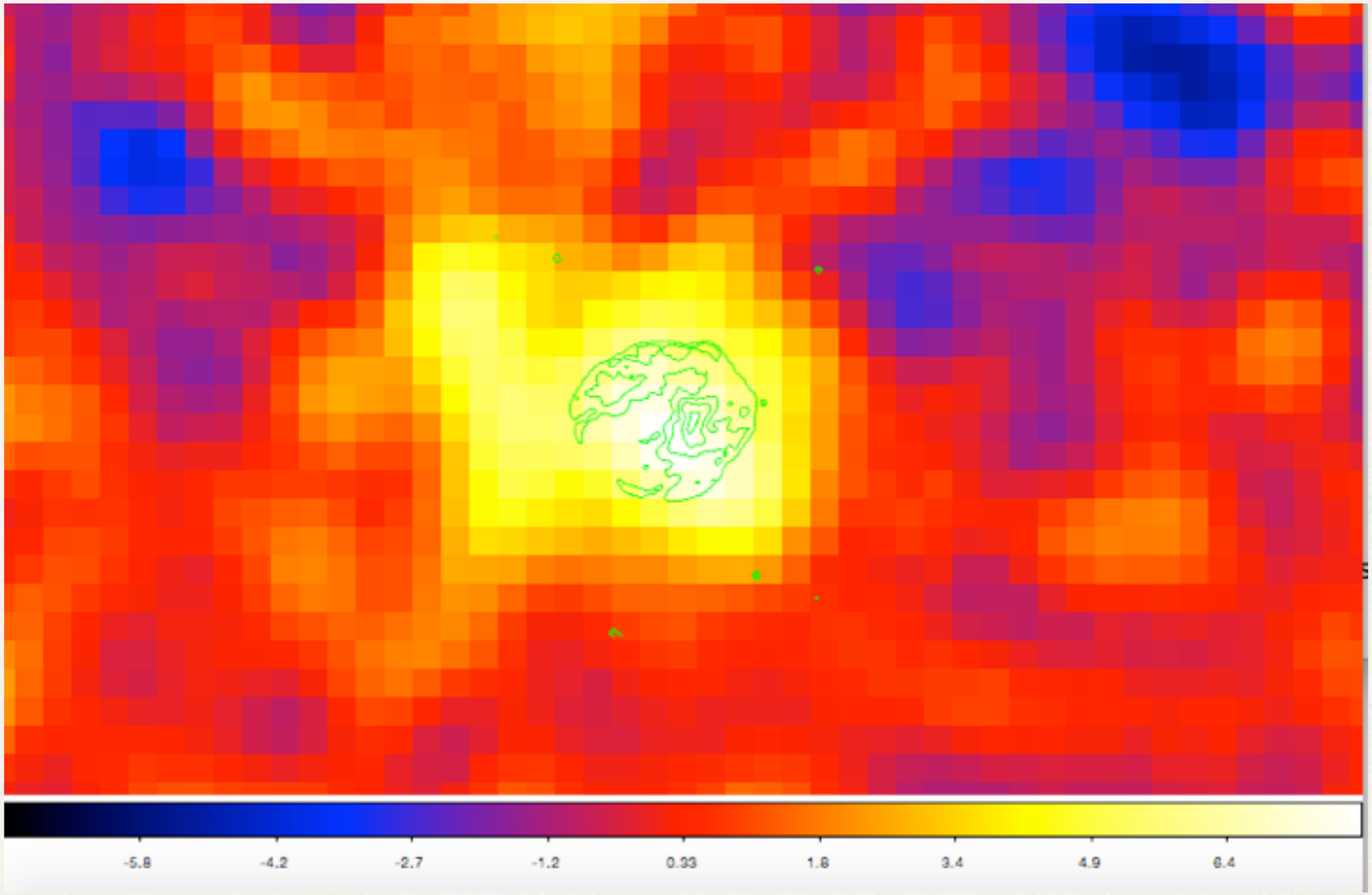
Hadronique



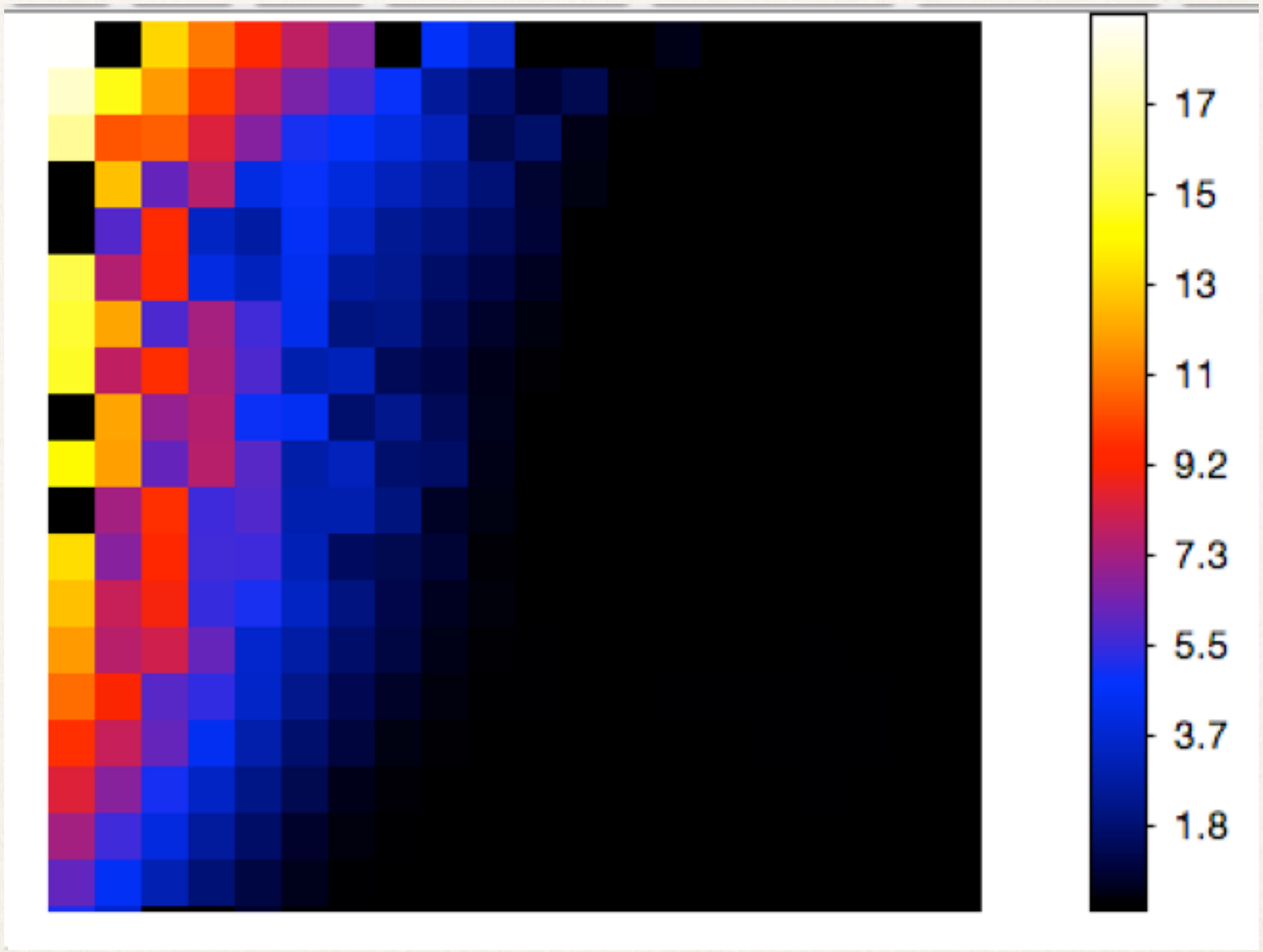
SED Disk


SNR disk 0.3-300 GeV - PSF3
SNR disk
E^2dN/dE (erg.cm-2.s-1)
10^{-11}
10^{-12}
TS
300
250
200
150
100
50
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
E (GeV)

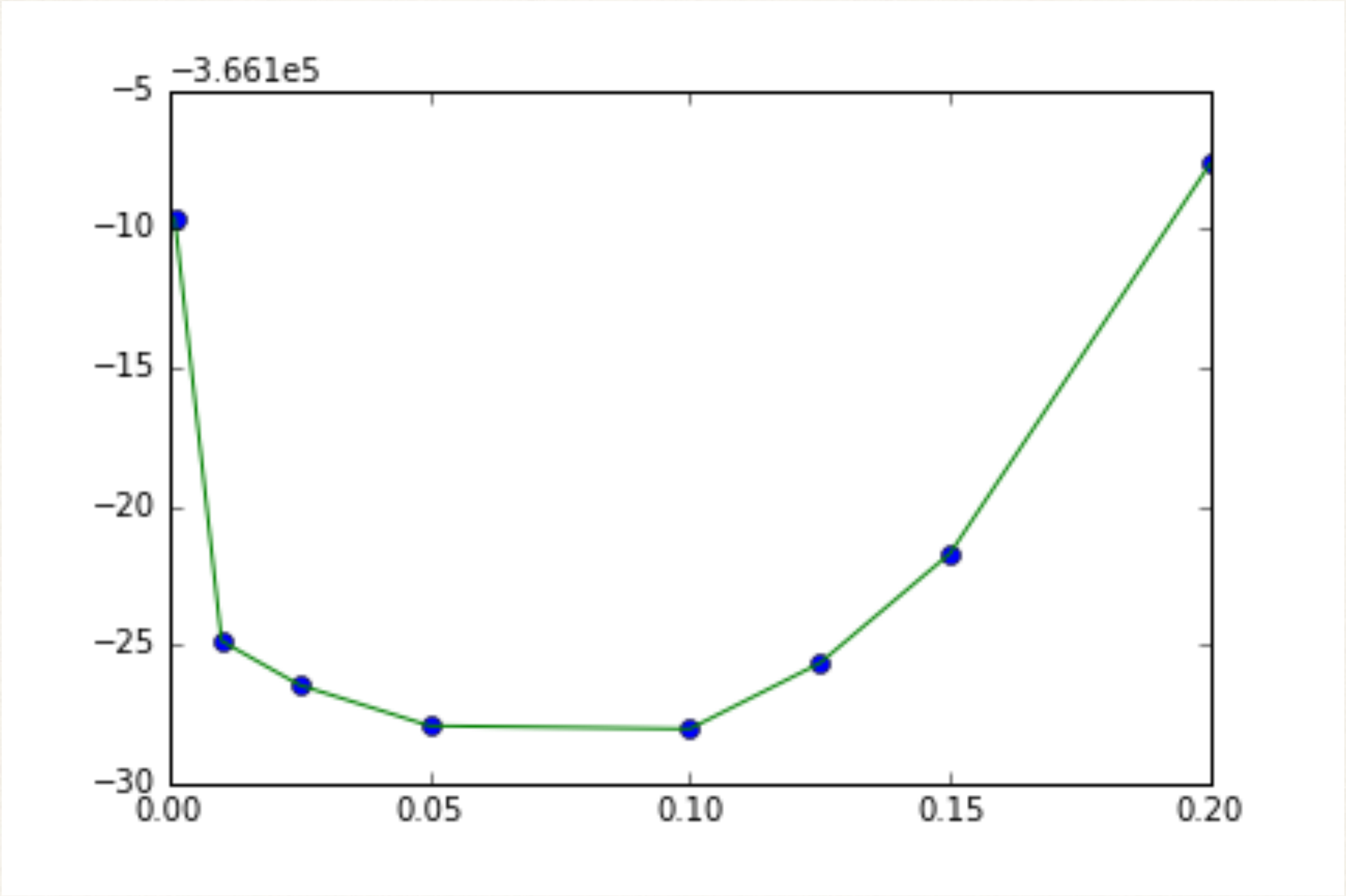
Count map (smoothed) 0.3 - 1GeV



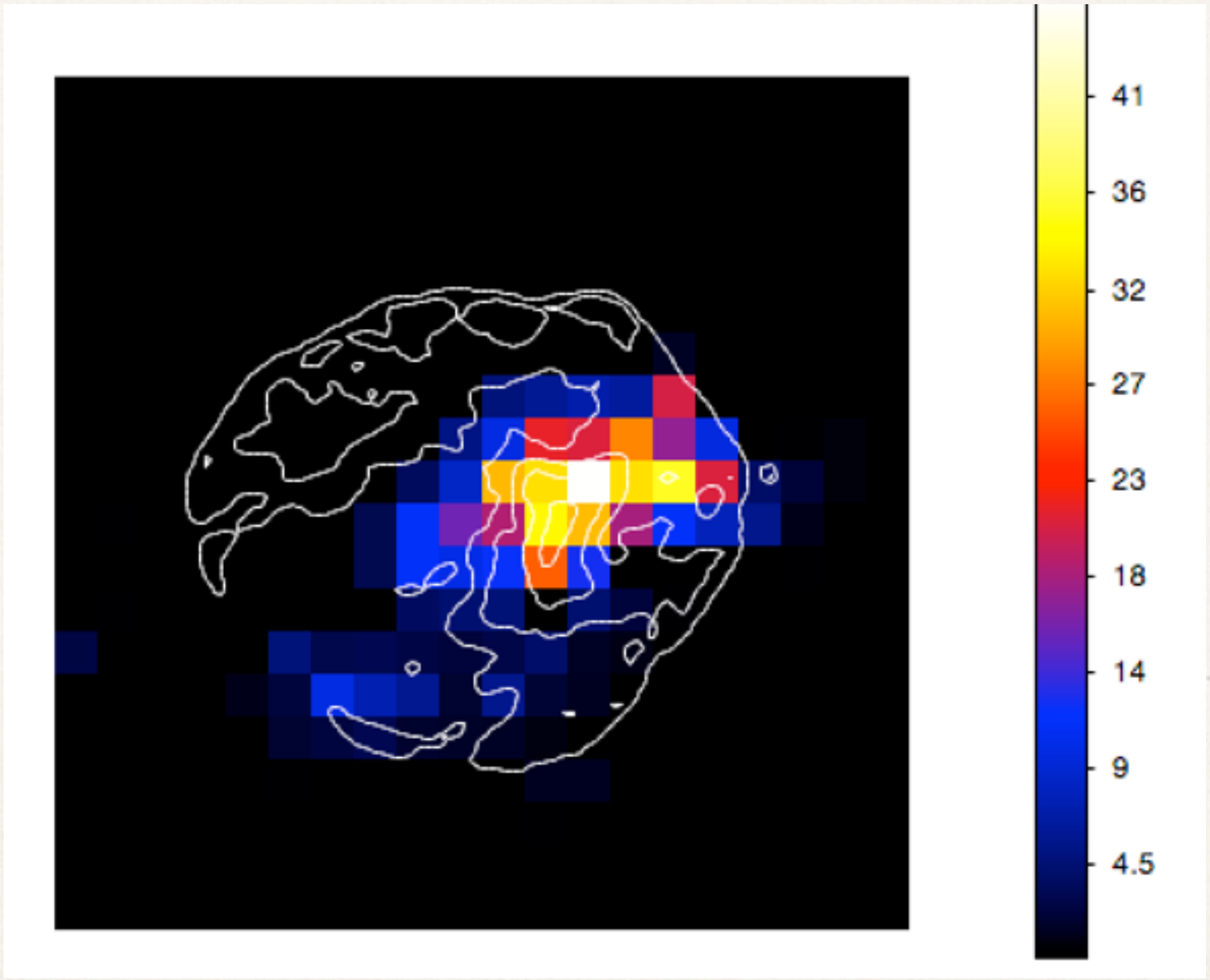
TS map with 1 point source added - 0.3 - 1GeV



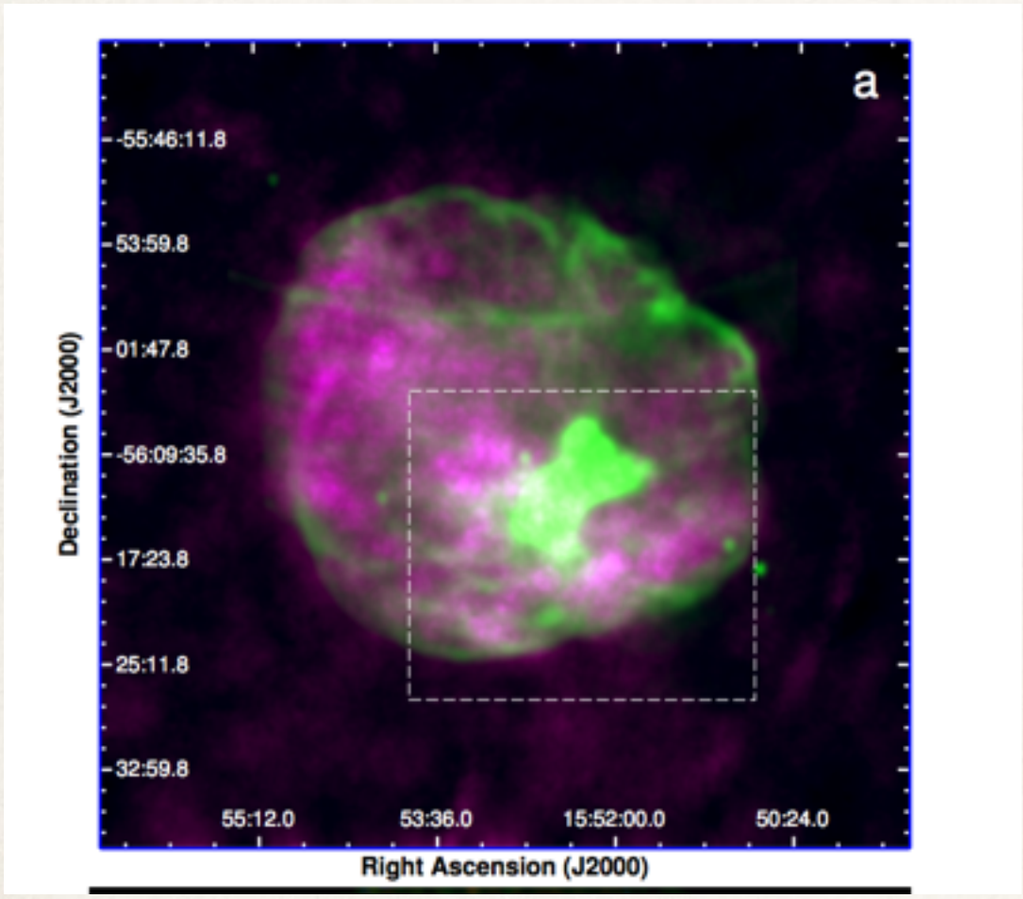
PWN extension

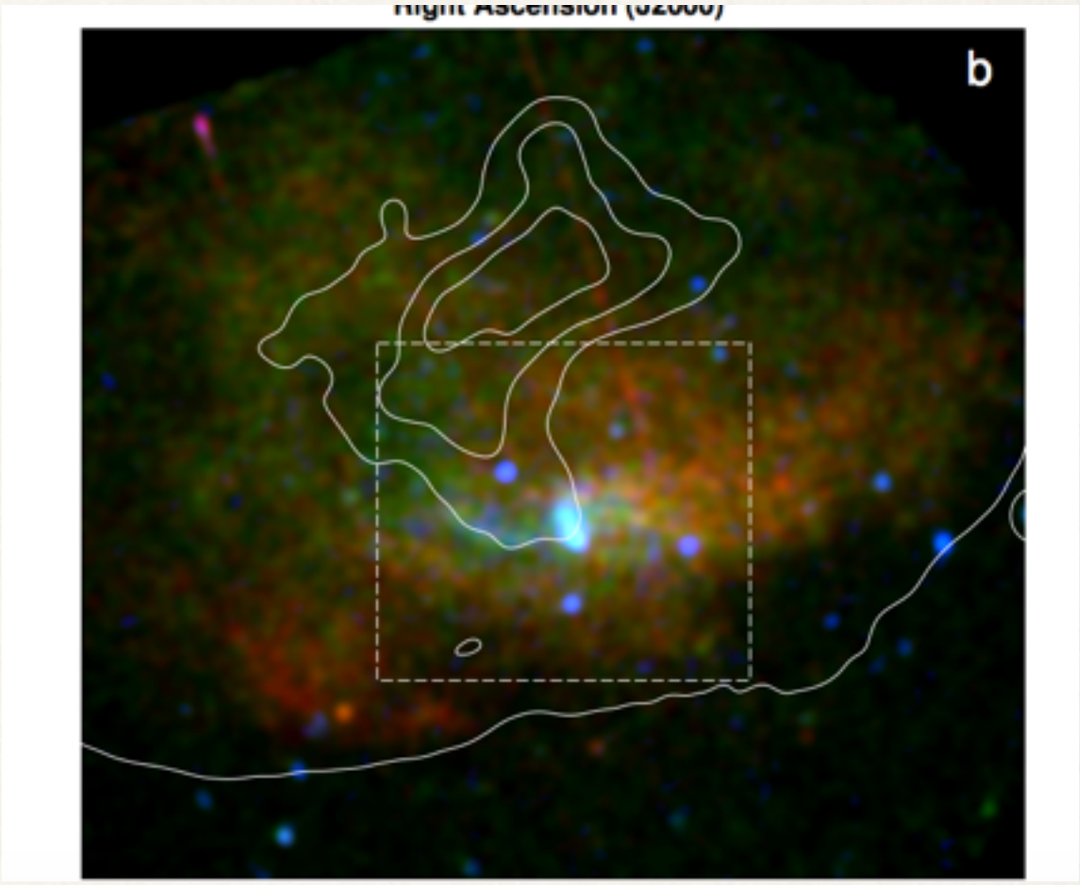


Above 20 GeV - TS map

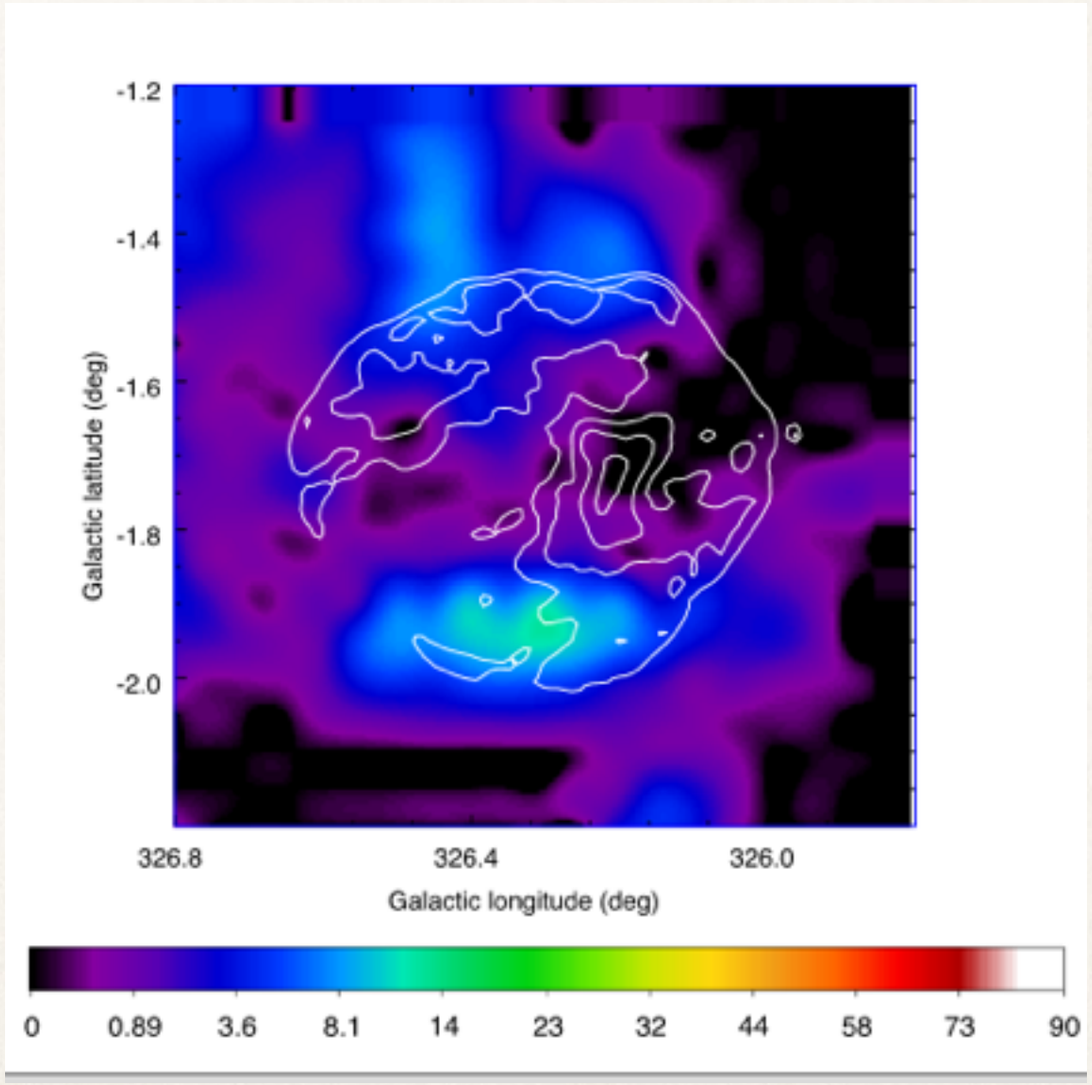


SNR G326.3-1.8


a
-55:46:11.8
53:59.8
01:47.8
-56:09:35.8
17:23.8
25:11.8
32:59.8
55:12.0
53:36.0
15:52:00.0
50:24.0
Declination (J2000)
Right Ascension (J2000)

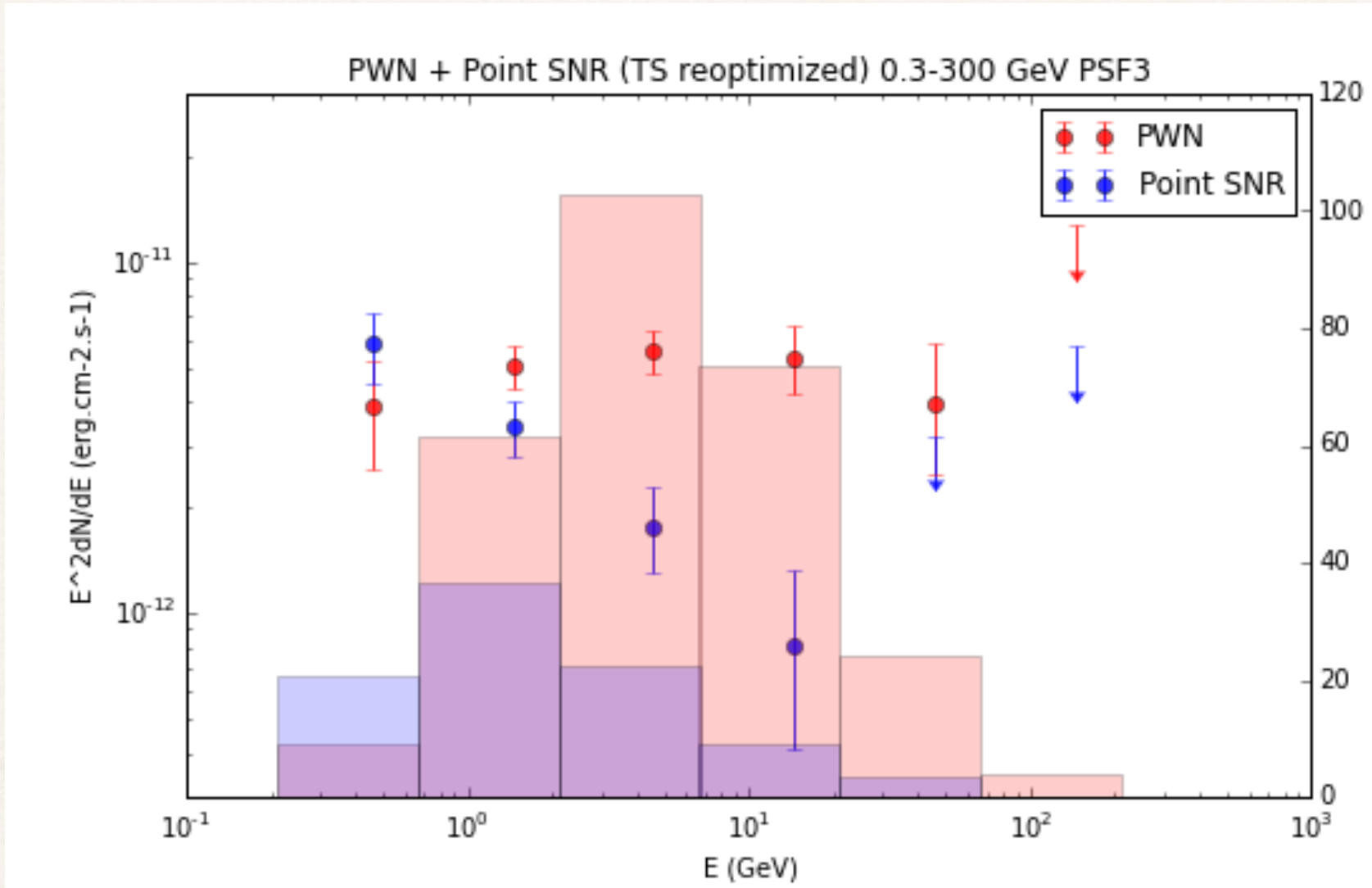

b

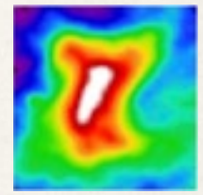
Residual TS map PWN + Point Source



SED PWN + Point Source

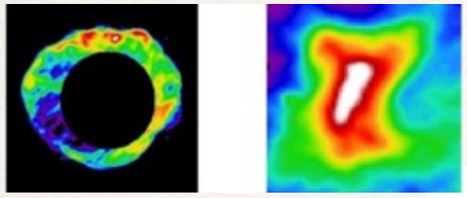
$\Gamma = 2.43 \pm 0.1$

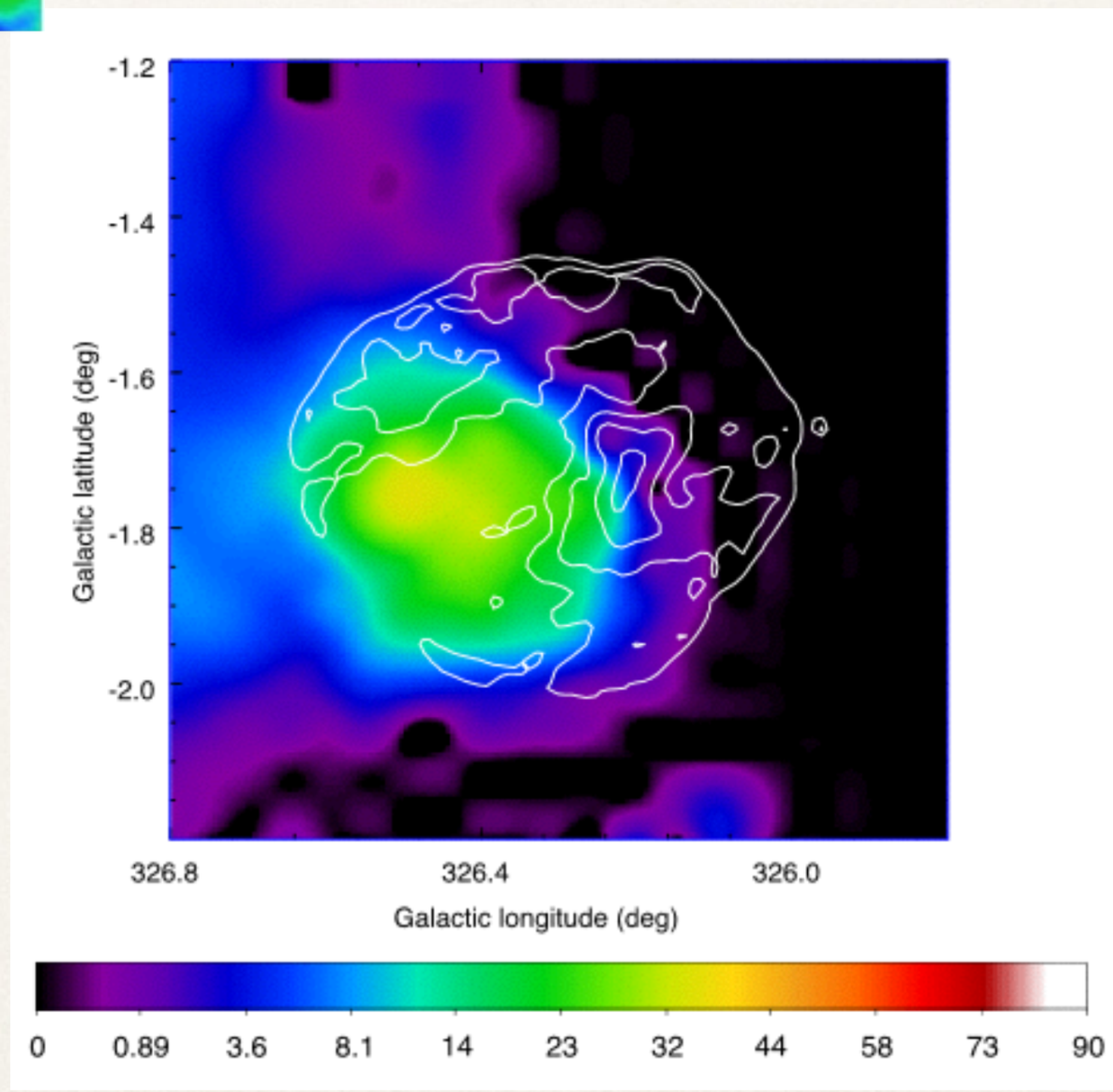




$\Gamma = 1.96 \pm 0.06$

SED PWN + Point Source





One component or two components ?

0.5 - 10 GeV :

TS (PWN) = 38.98 (80.83)
TS (SNR) = 103.11 (277.65)

LL = 51839.0652648

10 - 300 GeV :

TS (PWN) = 58.21 (73.69)
TS (SNR) = 12.18 (13.14)

LL = -8316.10752377

0.5 - 10 GeV :

TS (Disk) = 688.28 (689.31)

LL = 51839.36

10 - 300 GeV :

TS (Disk) = 109.07 (109.62)

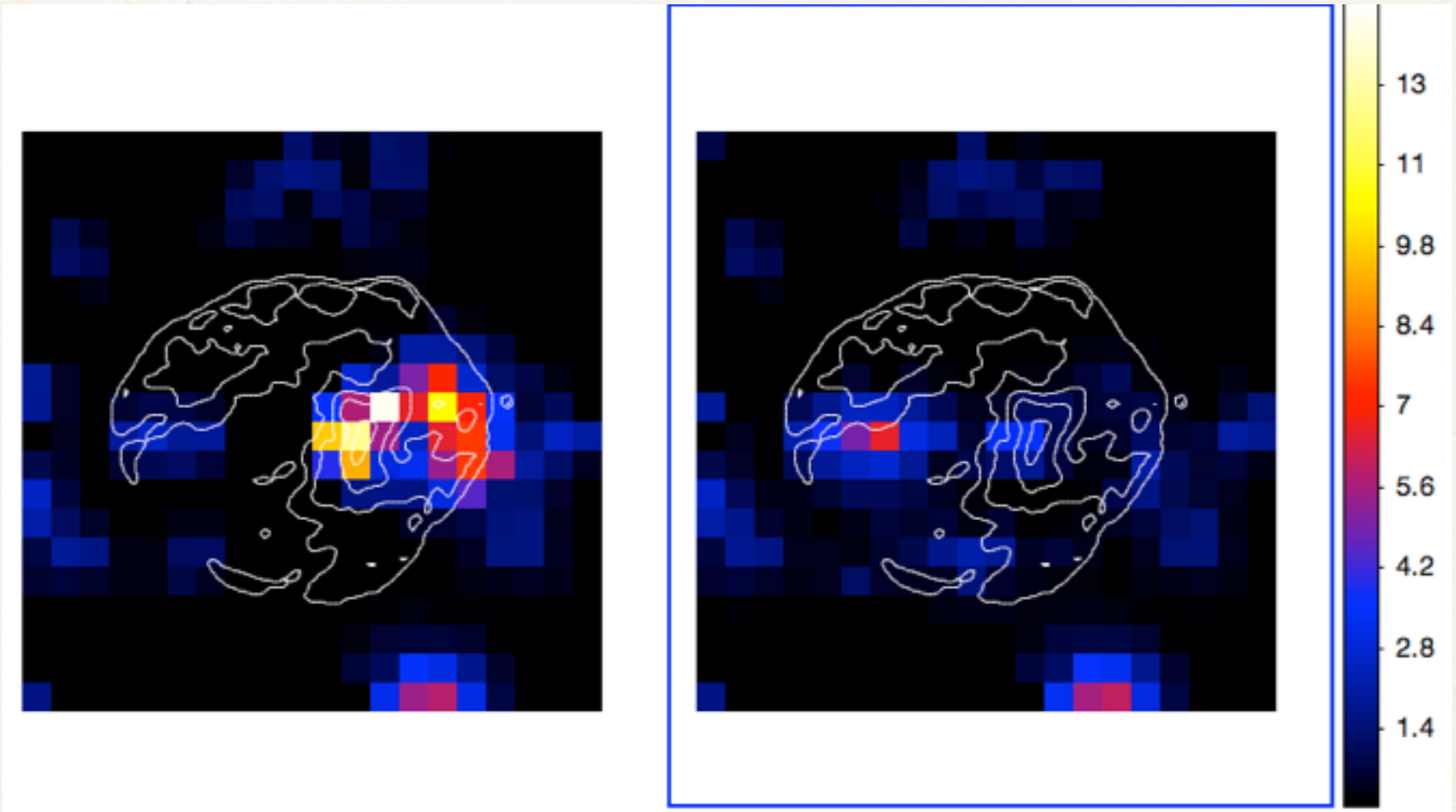
LL -8325.52

TS map

10 - 300 GeV :

Disk

PWN + SNR (ring)



TS map

1. PWN/Gaussian/PS
2. TS map Gaussian (only)
3. TS map PS (only)
4. Ts map Gaussian+ SNR2.5
5. SED G+SNR2.5
6. TS map PWN + PS (+ SED)