Gamma-ray detection of newly discovered Ancora SNR: G288.8–6.3

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in collaboration with R. Brose, J. Mackey, M. Filipović, E. Mestre, P. Goswami, E. de Oña Wilhelmi, I. Sushch

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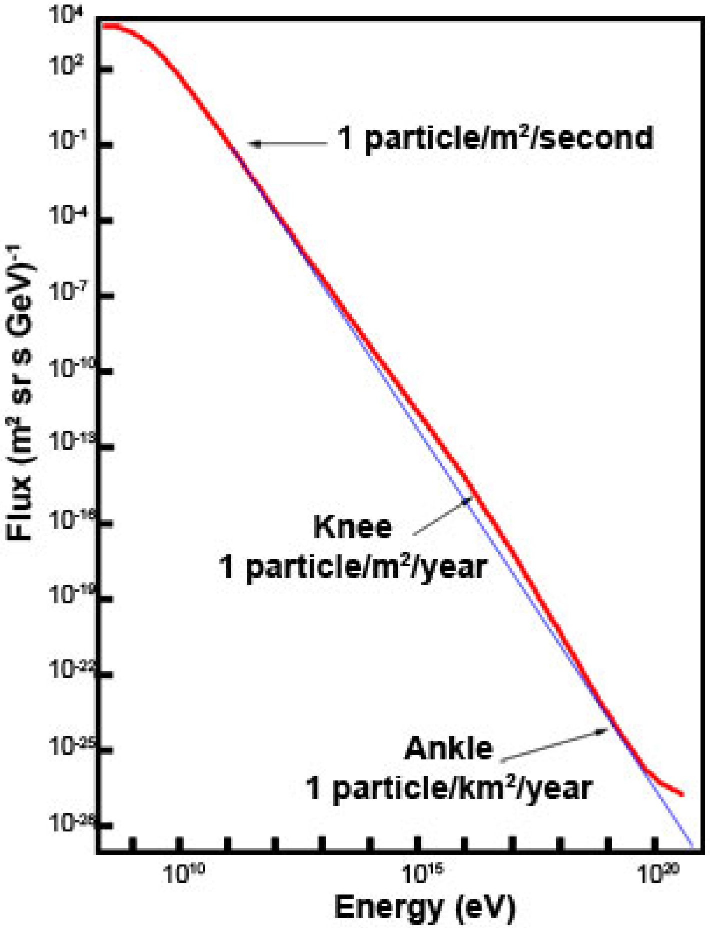
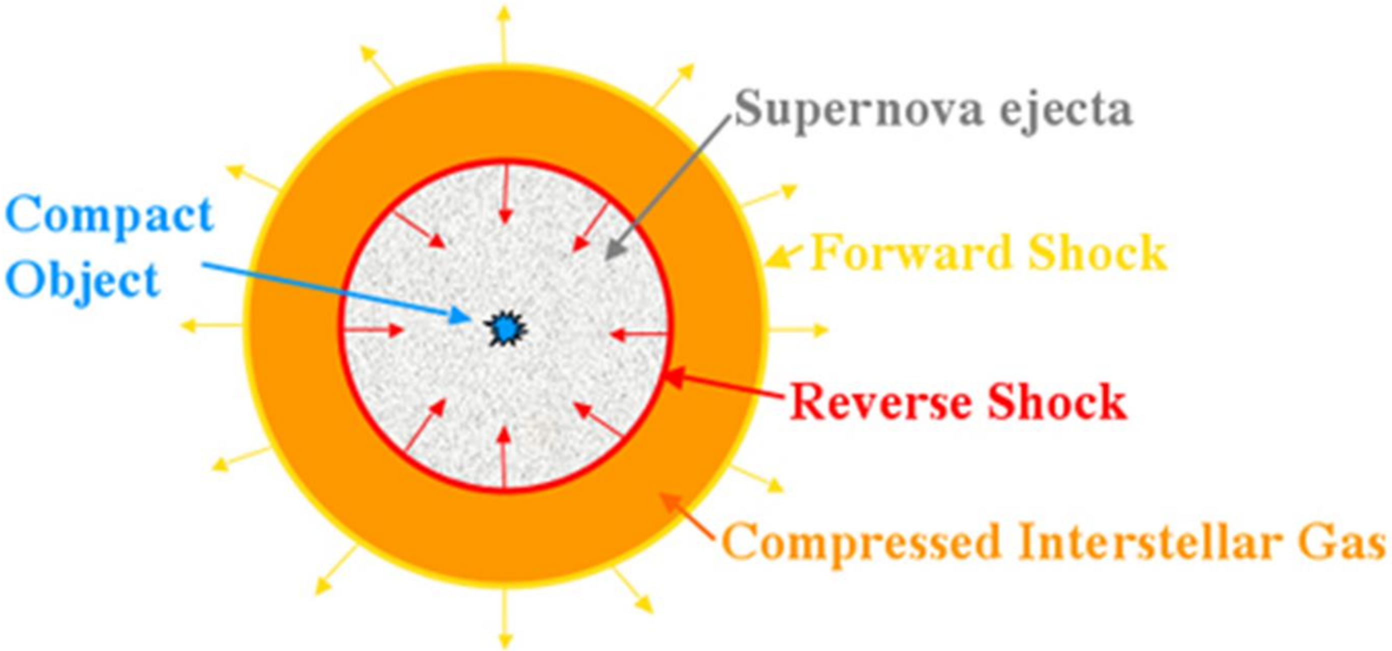
Cosmic rays (CRs)

Victor Hess 1914/15



Credit: Swinburne Centre for Astrophysics and Supercomputing

Supernova remnants



Credits: Swinburne Centre for Astrophysics and Supercomputing

- Hadronic
  - Pion decay
- Leptonic
  - Synchrotron radiation
  - Inverse Compton scattering

Research questions

- What energies can cosmic rays be accelerated up to in SNRs?
  (constrain models of CR acceleration)

- Can we resolve morphological features in these SNRs?
  (leptonic versus hadronic models)

- Can we build the SNR population to get more insight?
  (currently around 30 at HE (6 high-lat), 10 at VHE)

Ancora SNR: G288.8 – 6.3

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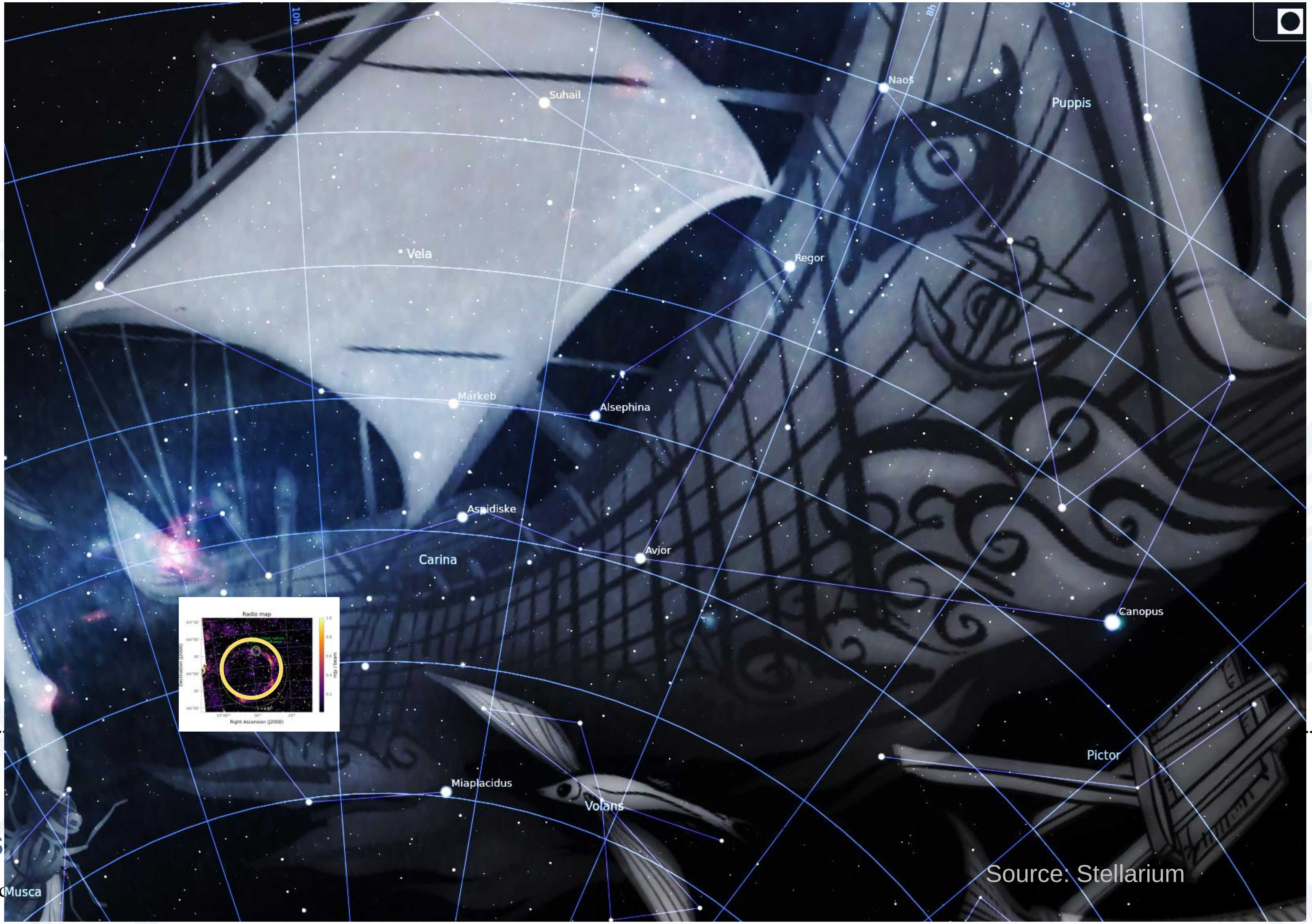
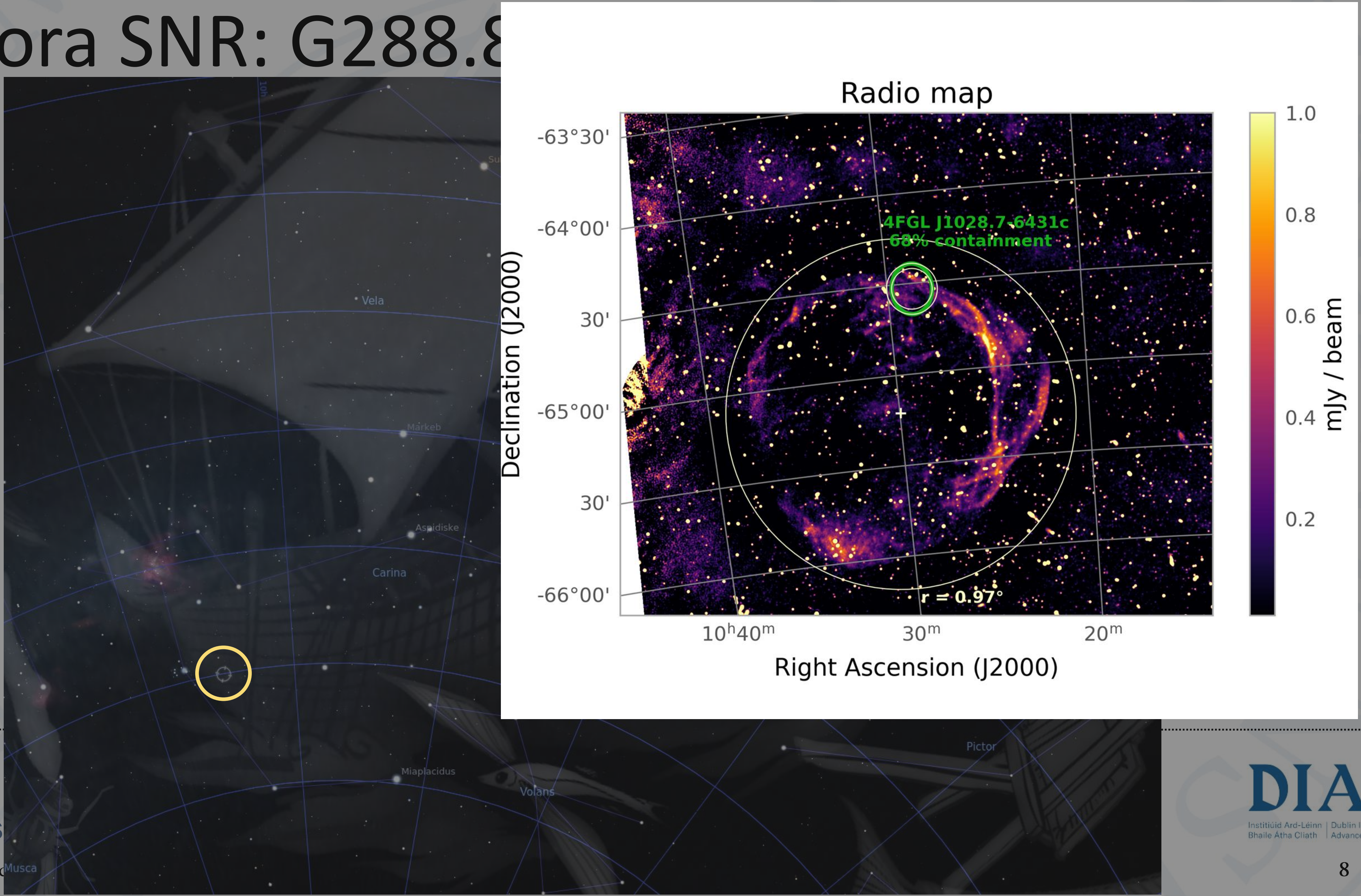


Ancora SNR: G288.8



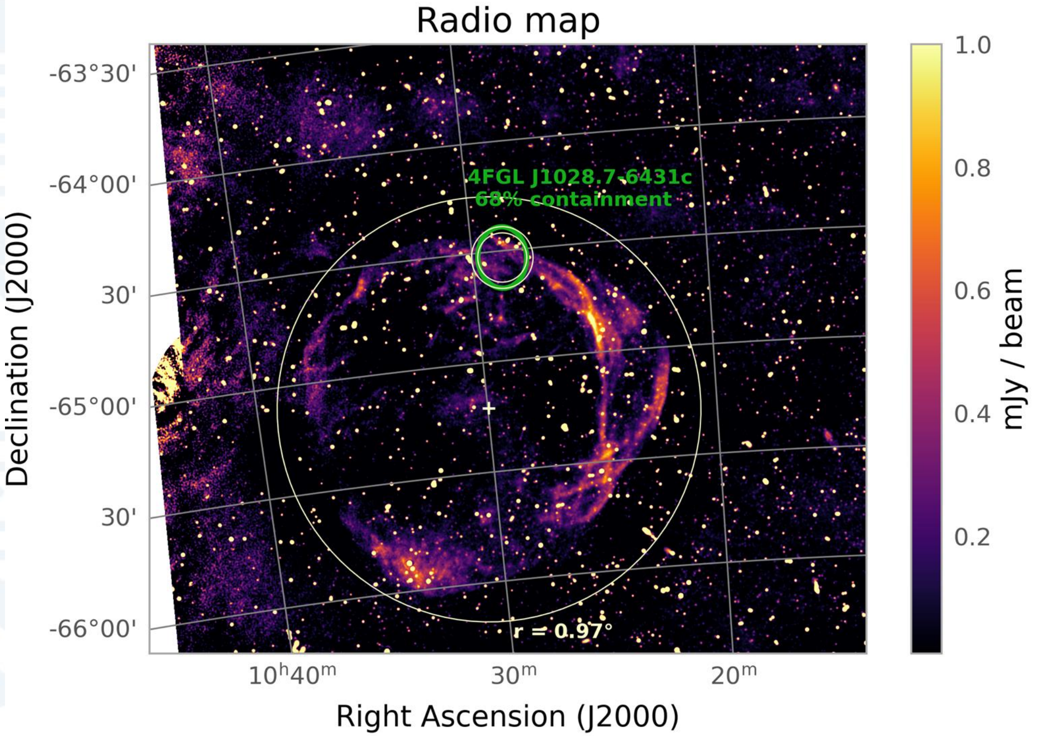
SNR G288.8 – 6.3

- Coordinates:
  GLON/GLAT: 288.8°/-6.3°
  R.A./ Dec: 157.488°/−65.214°

Distances:
  1.3 kpc
  ~140 pc from plane

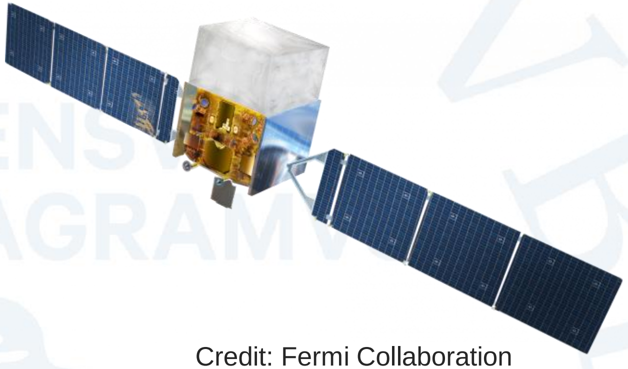
- Detection in radio (ASKAP at 943MHz)
- Extension in radio: ~0.8°

- Age (>13kyr?)



Filipović et al. (2023)
https://arxiv.org/abs/2308.08716v1

Fermi-LAT analysis



Credit: Fermi Collaboration

- Energy range (300 MeV – 1 TeV)
- FoV ~20% of whole sky

- Using Fermipy (v1.1.6) and Fermitools (v.2.2.0)
- 4FGL-DR3 Fermi catalogue (Abdollahi et al. 2022)

- 15 years of data (Aug 2008 – July 2023)
- Standard *binned maximum-likelihood analysis*

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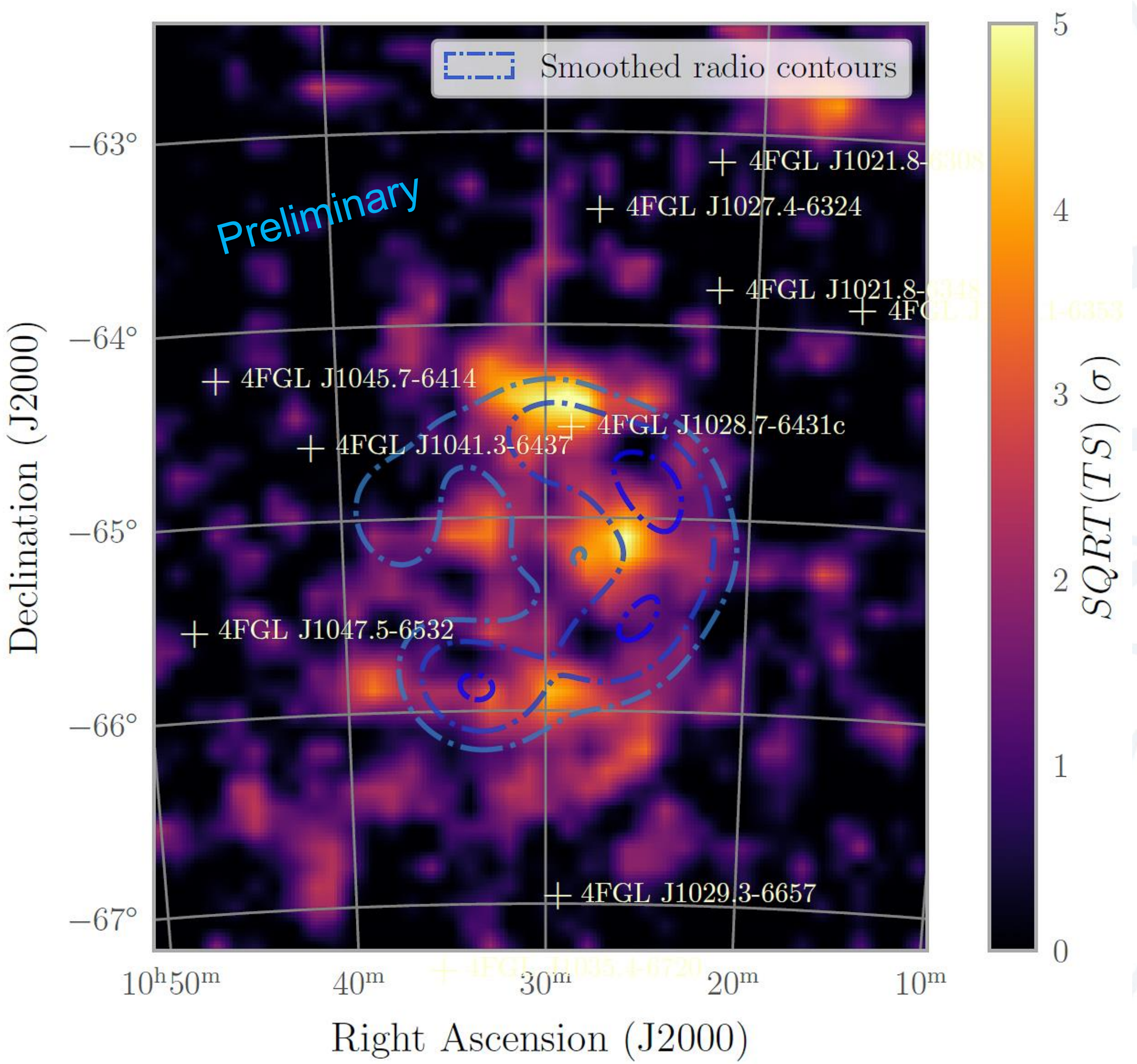
Fermi-LAT analysis

- Residual map with overlaid radio contours
- Several hotspots seen overlapping with radio



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Fermi-LAT analysis

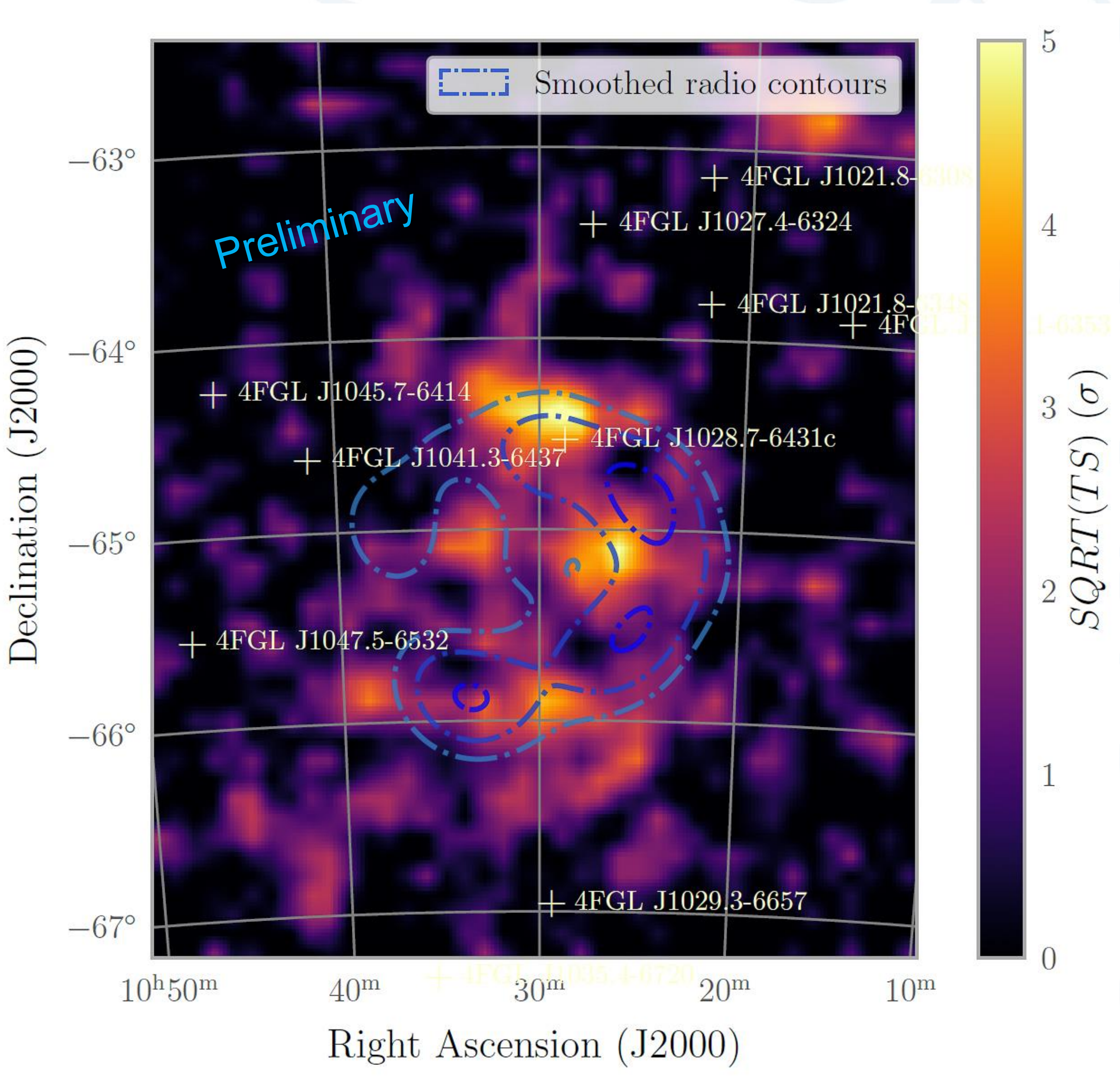
Model N°	J1028 incl.	Spatial model	Spectral model	$\Delta ln(\mathcal{L})$	Δk	ΔAIC
0	Y	—	—	0	0	0
1	N	—	—	-21.49	-7	29.00
2	Y	*RadialDisk*	*PowerLaw*	19.35	6	-28.71
3	N	*RadialDisk*	*PowerLaw*	-2.51	-1	3.03
4	N	*RadialDisk*	*LogParabola*	11.82*	0*	-23.64*
5	Y	*RadialGaussian*	*PowerLaw*	21.01	6	-30.01
6	N	*RadialGaussian*	*PowerLaw*	13.83	-1	-29.65
7	**N**	***RadialGaussian***	***LogParabola***	**15.24**	**0**	**-30.48**
8	N	Radio template	*PowerLaw*	9.34	-2	-22.68

* No extension fitting performed.

Preliminary

Fermi-LAT analysis

- Before modelling



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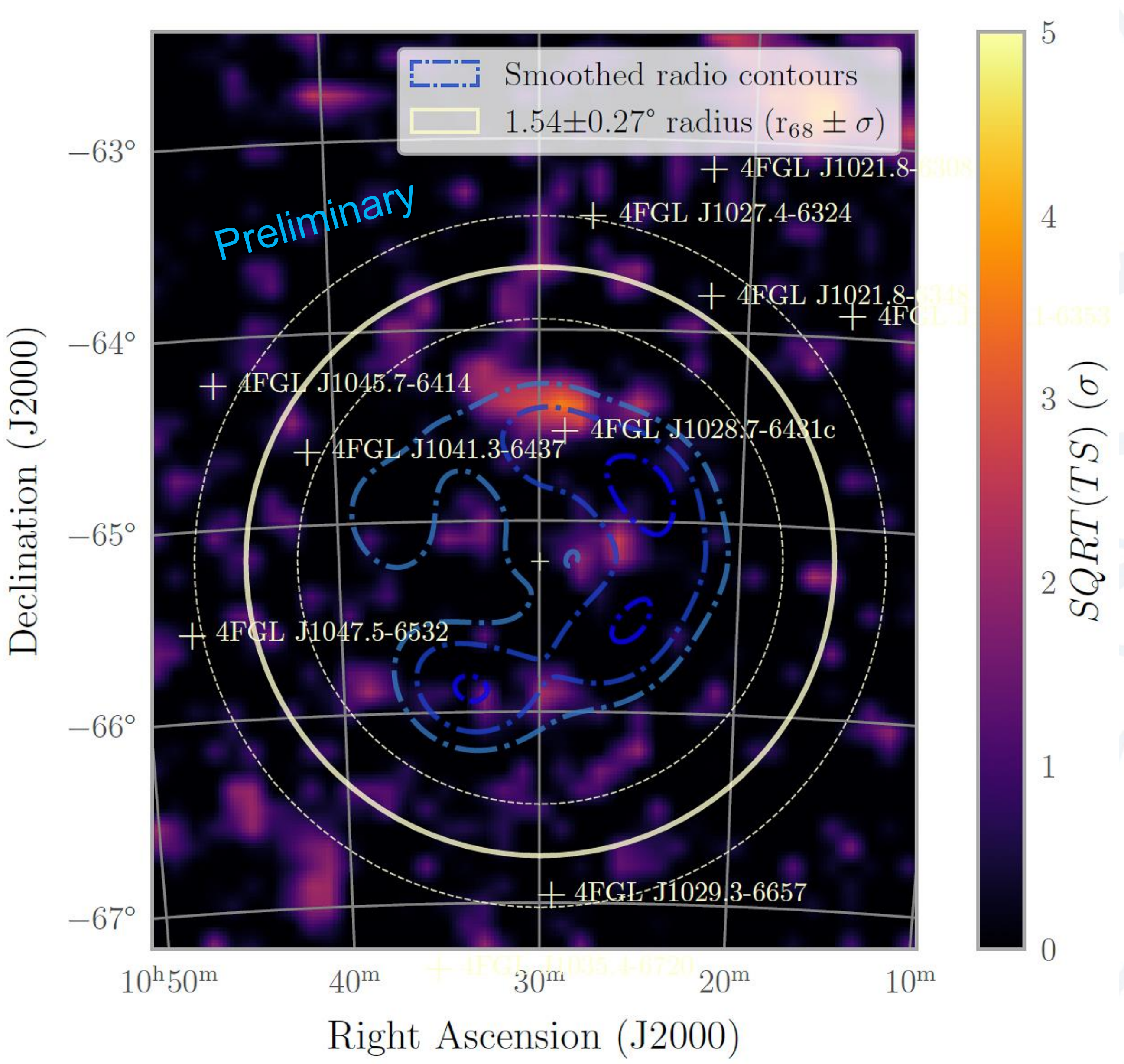
Fermi-LAT analysis

- After modelling with
  - RadialGaussian
  - LogParabola



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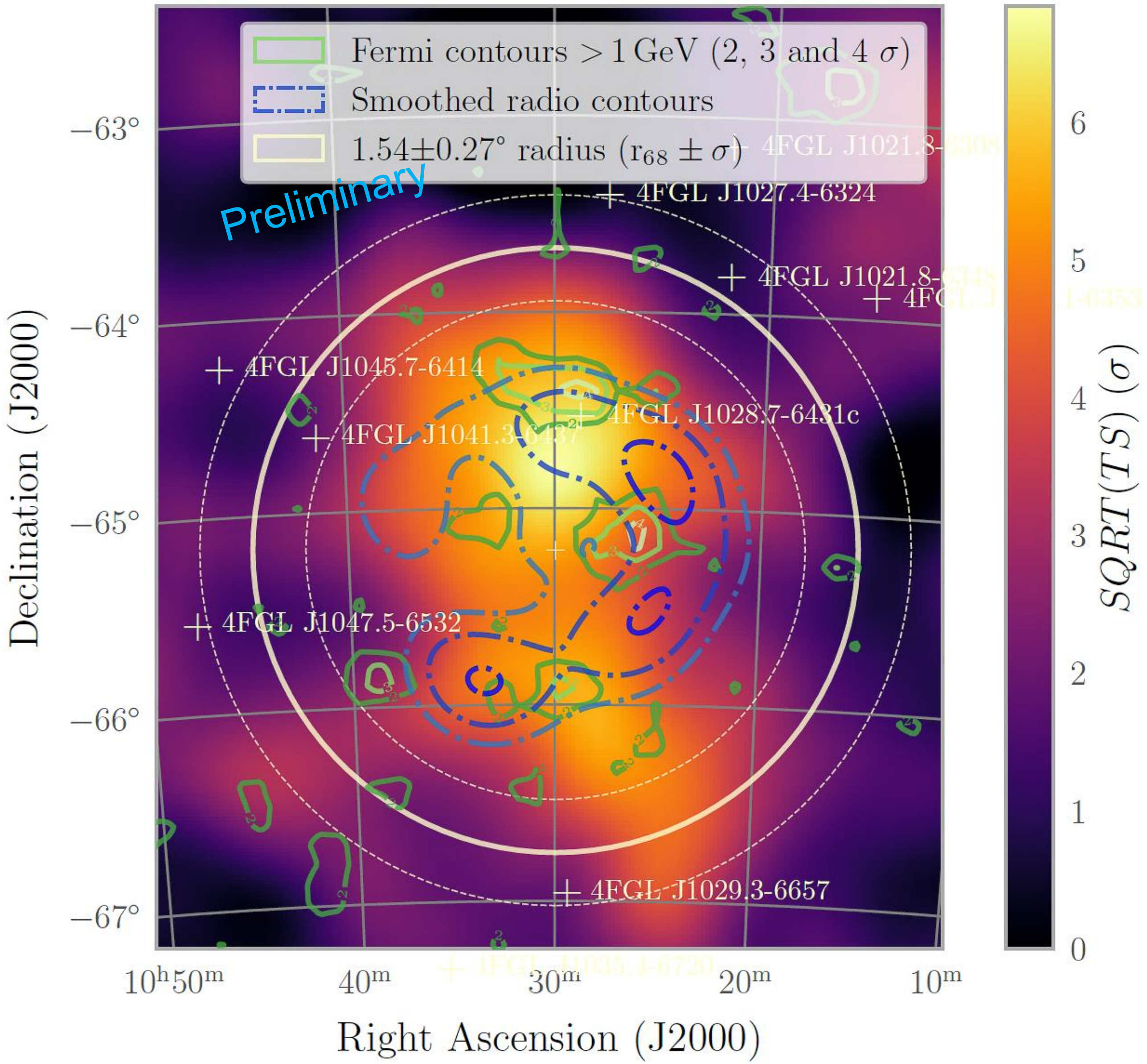
Fermi-LAT analysis

- Resulting map



Burger-Scheidlin et al. (in prep)

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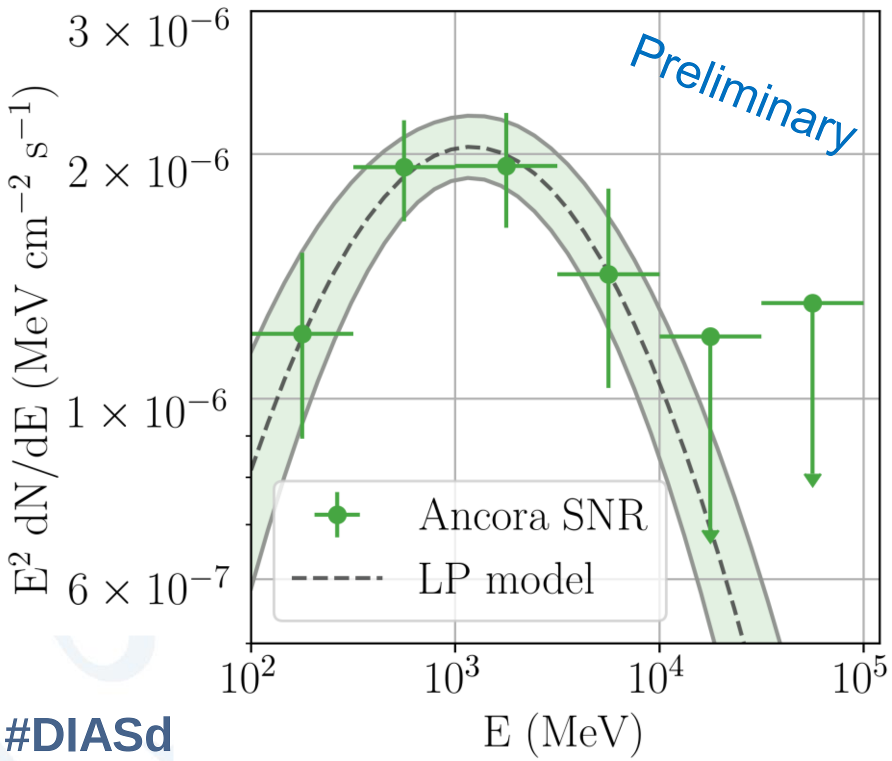
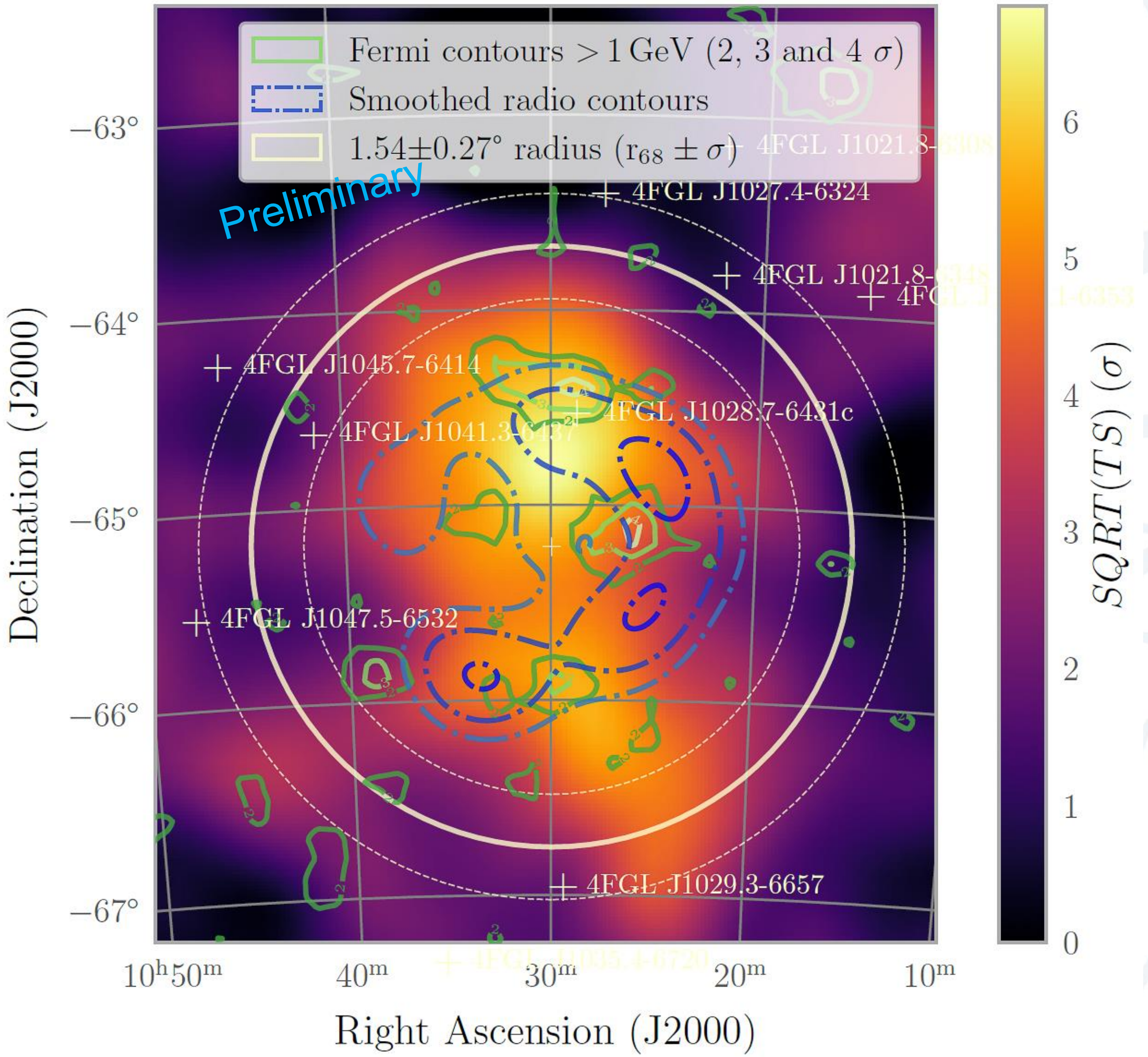
Fermi-LAT analysis

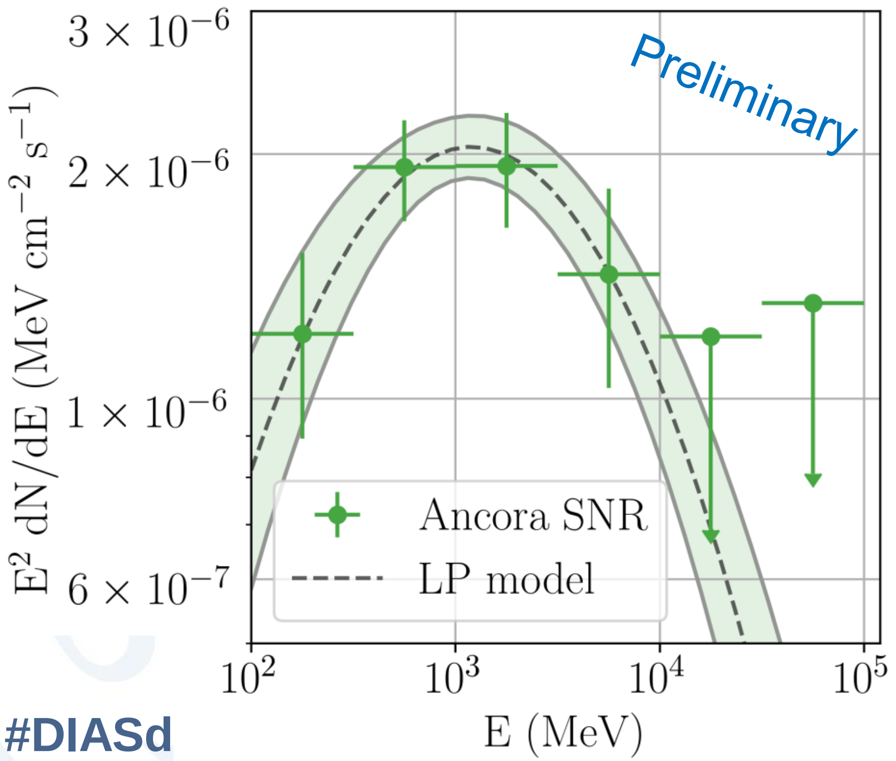
- Resulting map

  … and SED





Fermi-LAT analysis



Preliminary

Parameter	Unit	
Position		
R.A. / Dec	deg / deg	
GLON / GLAT	deg / deg	
Model N°		7
J1028 incl.		N
Spatial model		*RadialGaussian*
Spectral model		*LogParabola*
TS	—	105.67
N° of predicted photons	—	4703.2
Photon flux	ph cm^{-2} s^{-1}	$(1.33 \pm 0.57) \times 10^{-8}$
Energy flux	MeV cm^{-2} s^{-1}	$(8.57 \pm 1.70) \times 10^{-6}$
> 1 GeV (to 316 GeV)	MeV cm^{-2} s^{-1}	$(5.05 \pm 1.00) \times 10^{-6}$
Spectral parameters		
N_0	MeV^{-1} cm^{-2} s^{-1}	$(3.23 \pm 1.98) \times 10^{-13}$
Γ	—	—
E_0	MeV	—
α	—	2.21 ± 0.14
β	—	0.15 ± 0.10
E_b	MeV	2422 ± 673
Spatial parameters		
Radius (68 % containment)	deg	1.54 ± 0.27
TS extension	—	73.62

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MWL

- Naima modelling (computation of non-thermal radiation from relativistic particle populations)
- Probably only upper limits for X-rays
- Observations needed for good constraints:
  - VHE
  - hard X-ray

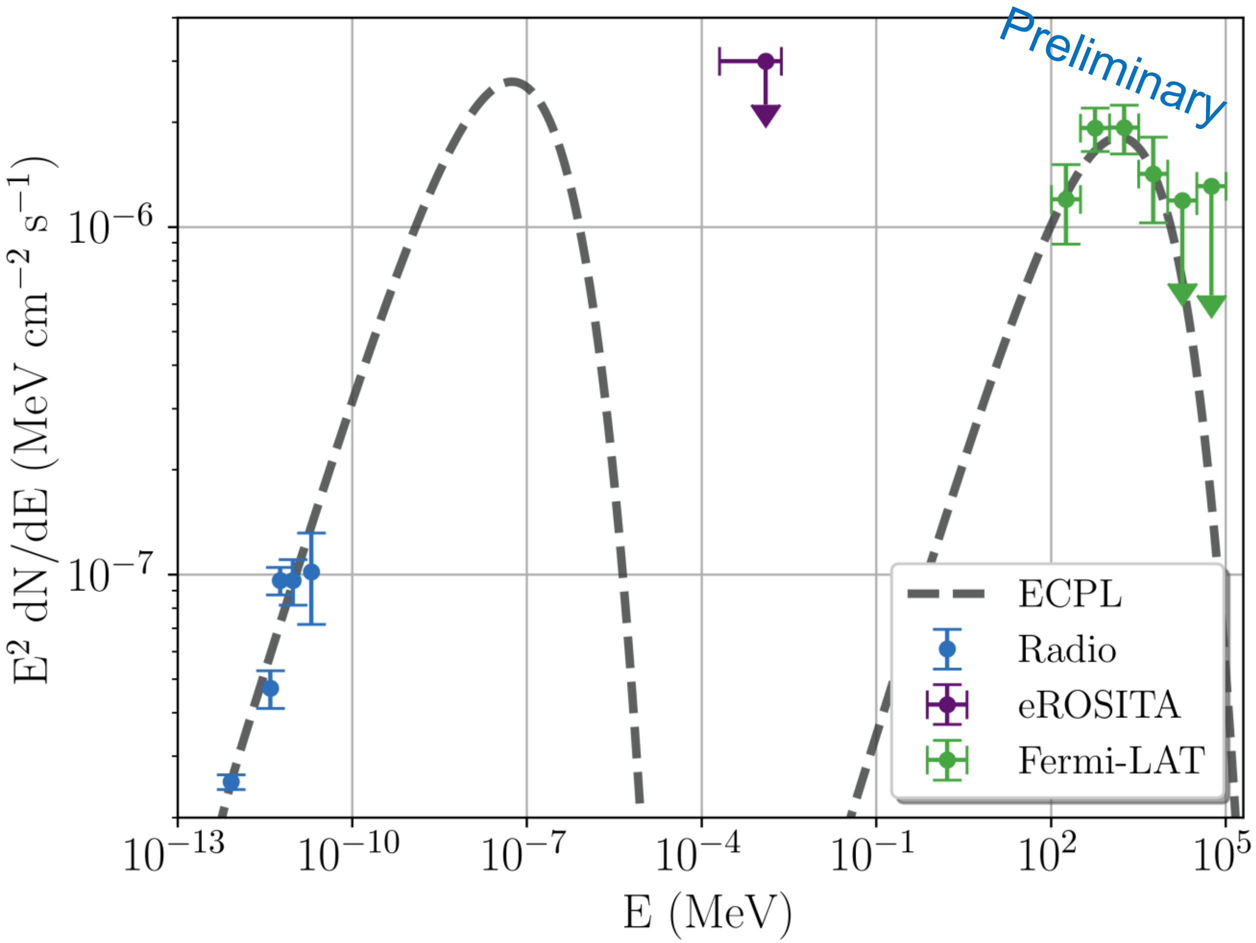

Table of high-latitude SNRs

Preliminary

Source Name	Energy Flux (MeV cm^{-2} s^{-1}) 1 GeV – 1 TeV	Spectral Index —	Reference
Ancora SNR / G288.8–6.3	$(5.05 \pm 1.00) \times 10^{-6}$	2.21 ± 0.14	This work
FHES J1741.6–3917	$(5.65 \pm 0.62) \times 10^{-5*}$	$1.80 \pm 0.04_{stat} \pm 0.06_{sys}$	Ackermann et al. (2018)
G166+4.3	$2.87 \times 10^{-6\dagger}$	2.7 ± 0.1	Araya (2013)
G296.5+10.0 / FHES J1208.7–5229	$8.17 \times 10^{-6\dagger}$ $(1.13 \pm 0.24) \times 10^{-5*}$	1.85 ± 0.13 $1.81 \pm 0.09_{stat} \pm 0.05_{sys}$	Araya (2013) Ackermann et al. (2018)
G150+4.5	$5.20 \times 10^{-5\nabla}$	$1.62 \pm 0.04_{stat} \pm 0.22_{sys}$ **	Devin et al. (2020)
G17.8+16.7 / FHES J1723.5–0501	 $(1.38 \pm 0.26) \times 10^{-5*}$	$1.83 \pm 0.02_{stat} \pm 0.05_{sys}$ $1.97 \pm 0.08_{stat} \pm 0.06_{sys}$	Araya et al. (2022) Ackermann et al. (2018)
Calvera SNR / G118.4+37.0	$3.06 \times 10^{-6\dagger\dagger}$	$1.66 \pm 0.10_{stat} \pm 0.03_{sys}$	Araya (2023)

* from FITS data provided with Ackermann et al. (2018)
† calculated using data from Table 2 in Araya (2013)
∇ calculated using data from Table 2 in Devin et al. (2020), and using results for the radial Gaussian model and log-parabola spectral model
** log-parabola model, α given in Table, $\beta = 0.07 \pm 0.02_{stat} \pm 0.02_{sys}$.
†† calculated using data from Araya (2023)

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Conclusions

- Clear detection of excess overlapping with the radio signal of the SNR (more extended than radio SNR)
- Leptonic scenario is good fit
- Energies up to 5 GeV, consistent spectral results and flux expected by this type of source
- Increase number of HE SNRs
- Paper in final stages

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