Dark Matter in Andromeda

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Abstract

Andromeda was studied in 2-year data (Fermi Collaboration – arXiv:1012.1952) and found to be a point source in gamma rays

This project searches for evidence of a spatially-extended M 31 in 4-year P202 Clean data as well as limits on dark matter annihilation therein

We find a point-source modeled Andromeda is still the most likely fit to data (TS=38.5), however a spatially-extended model is found to fit data nearly as well (TS=32.2)

No obvious dark matter signal is observed, and constraints are found (for both point and extended models) using DMFIT assuming an NFW density model

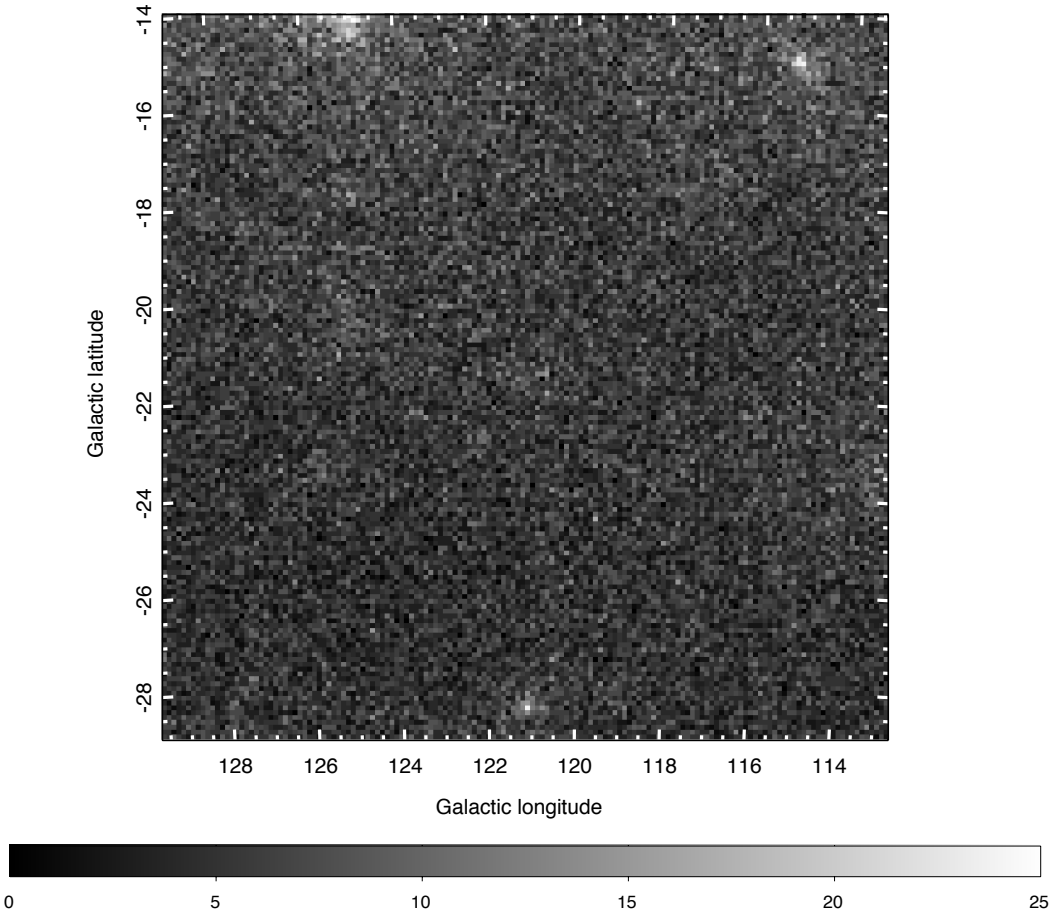
Existing work on M31

https://confluence.slac.stanford.edu/display/SCIGRPS/Constraints+on+dark+matter+in+M31

(Andrea Albert, Richard Hughes, Miguel A. Sánchez-Conde, Brian Winer, Zhaoyu Yang)

Data

15 x 15 deg ROI



Pass 7, P202 (base)

Centered on M 31:

RA: 10.68479
DEC: 41.26906

L: 121.174398
B: -21.573002

Time:

Min (MET): 239557417
Max (MET): 371262672

Min: 2008 Aug 04 at 15:43:36 UTC
Max: 2012 Oct 07 at 00:31:09 UTC
(50 months, or 4.2 years)

Energy:

Min: 100 MeV
Max: 300 GeV

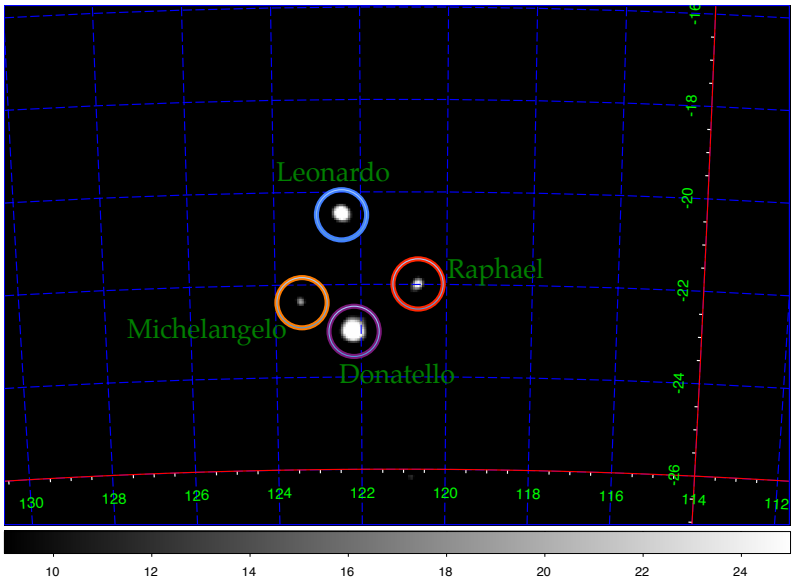
Other:

Radius:	15 degrees
Zenith:	< 100 degrees
Event Class:	Clean
Projection:	AIT
FT2 Files:	30-second
ROI-cut:	Yes
Quality filter:	DATA_QUAL==1 && LAT_CONFIG==1 && ABS(ROCK_ANGLE)<52

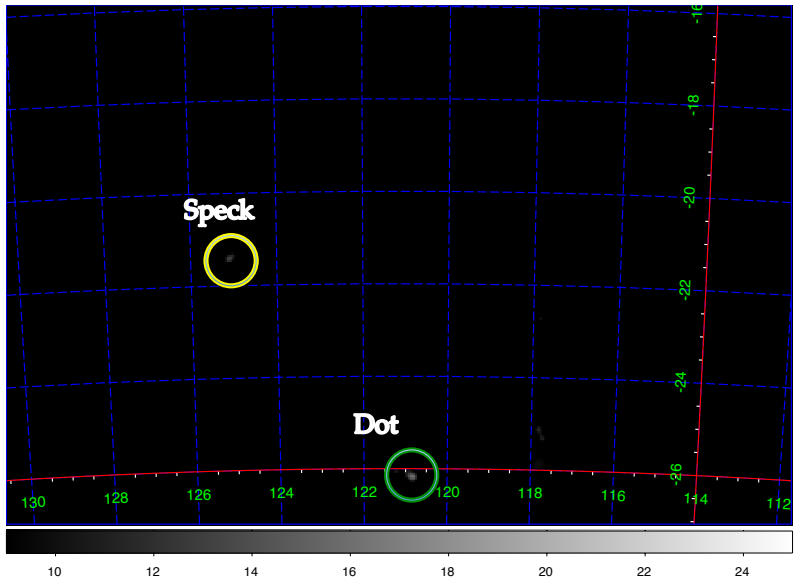
Models:

IRFS:	P7CLEAN_V6
Galactic Diffuse:	gal_2yearp7v6_v0.fits
Isotropic:	iso_p7v6clean.txt
Source Catalog:	Public 2FGL

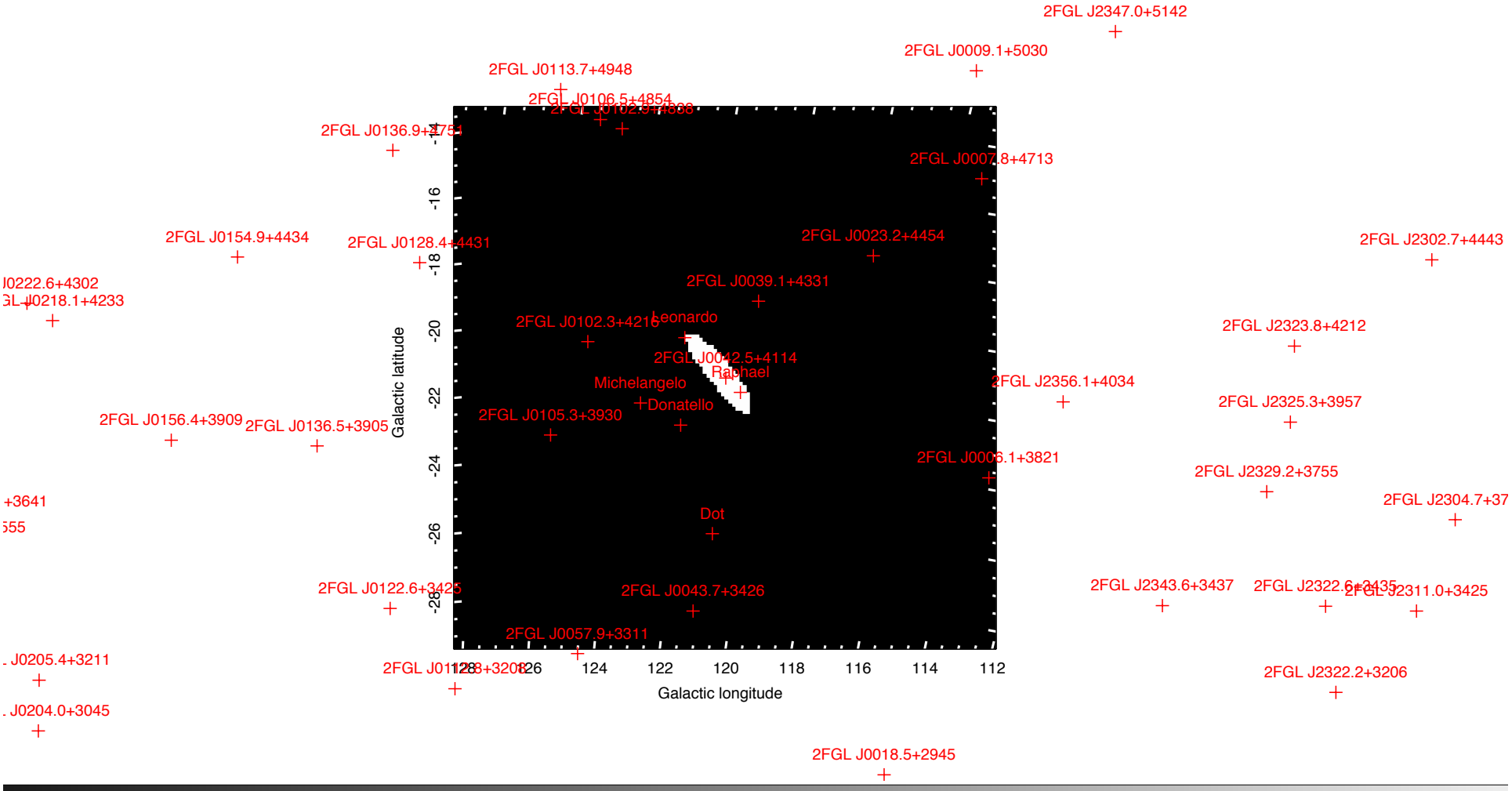
TS maps for 2FGL best fit model (Galactic Coordinates)



TS maps for “2FGL(14) + 4” best fit model (Galactic Coordinates)



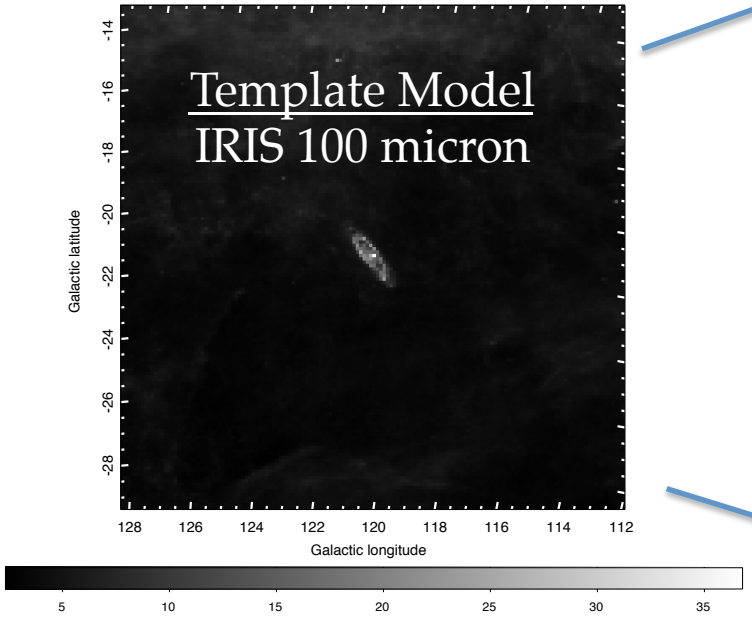
Final ROI Point Source Model – "2FGL(14)+5"

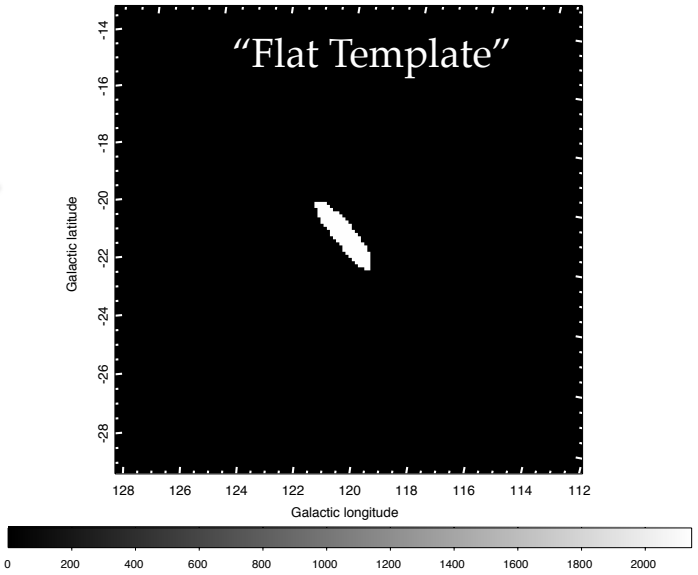


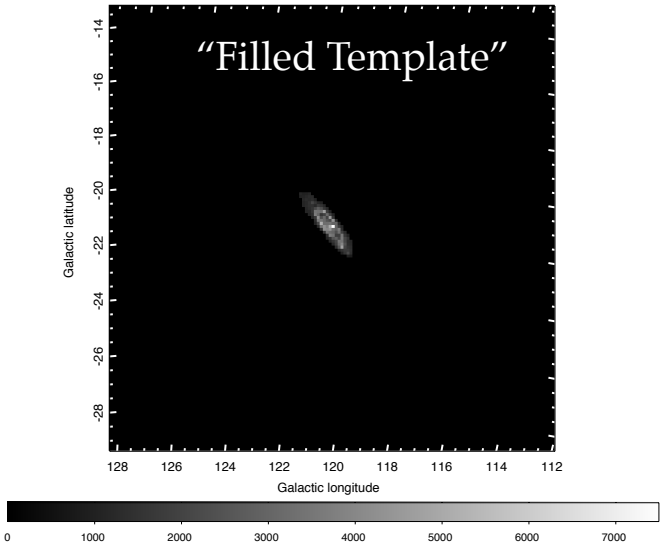
Location of sources inside (and near) the 15 x 15 deg ROI – Template based on IRIS 100 micron

(M 31 is 2FGLJ0042.5+4114, Raphael falls inside the expected area of an extended M 31)

Spatial Extension Templates







Summary of Template Model Fine-Tuning

Summary of M 31 point-source AND template analysis:

	Log Likelihood	Δ ln(L)
2FGL (14) + 5	-223988	-
2FGL (14I) + 5 ("Filled")	-223992	-4
2FGL (14L) + 5 ("Flat")	-223993	-1

Discovery of point-source AND template Andromeda:

	TS	Spectral Index	Photon Flux x 10^{-9} [# cm^{-2} s^{-1}]	Energy Flux x 10^{-6} [# cm^{-2} s^{-1} MeV^{-1}]
arXiv:1012.1952	28.8	-2.1 ± 0.3	11.0 ± 6.7	-
Albert et al (point-source)	55.5	-2.52 ± 0.12	13.6 ± 2.8	-
Albert et al (extended)	58.4	-2.19 ± 0.11	12.7 ± 2.8	-
2FGL (14) + 5	38.5	-2.69 ± 0.04	13.4 ± 1.2	3.26 ± 0.21
2FGL (14I) + 5	32.2	-2.49 ± 0.11	13.0 ± 2.3	3.88 ± 0.70
2FGL (14L) + 5	30.4	-2.45 ± 0.04	12.8 ± 0.9	4.00 ± 0.38

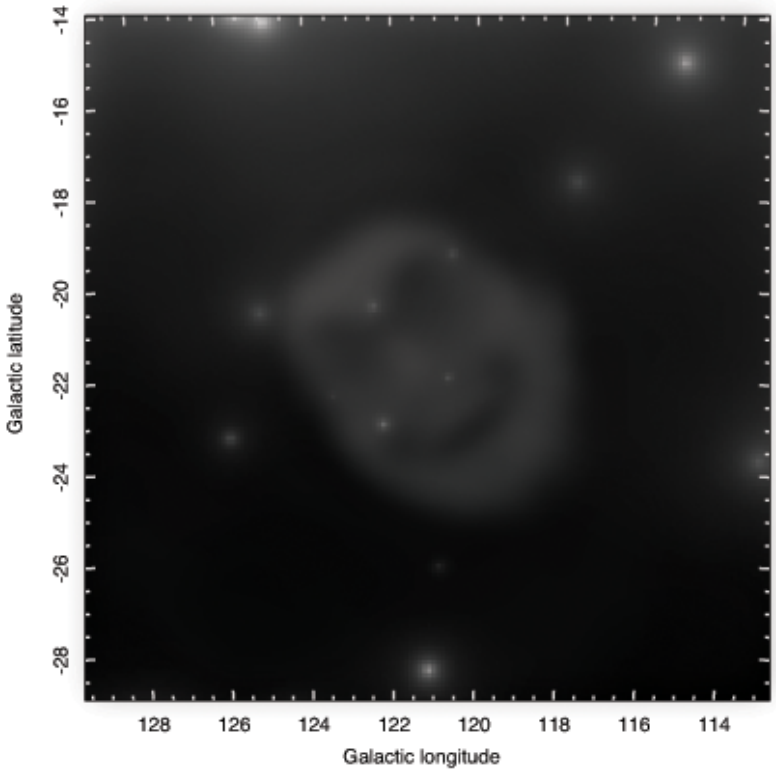
Also, this.

The hell is this about?

	TS	Spectral Index	Photon Flux x 10^{-9} [# cm^{-2} s^{-1}]	Energy Flux x 10^{-6} [# cm^{-2} s^{-1} MeV^{-1}]
2FGL (14I) + 5	32.2	-2.49 ± 0.11	13.0 ± 2.3	3.88 ± 0.70
2FGL (14L) + 5	30.4	-2.45 ± 0.04	12.8 ± 0.9	4.00 ± 0.38
Space Face	32.4	-2.22 ± 0.08	41.7 ± 6.3	19.1 ± 3.9

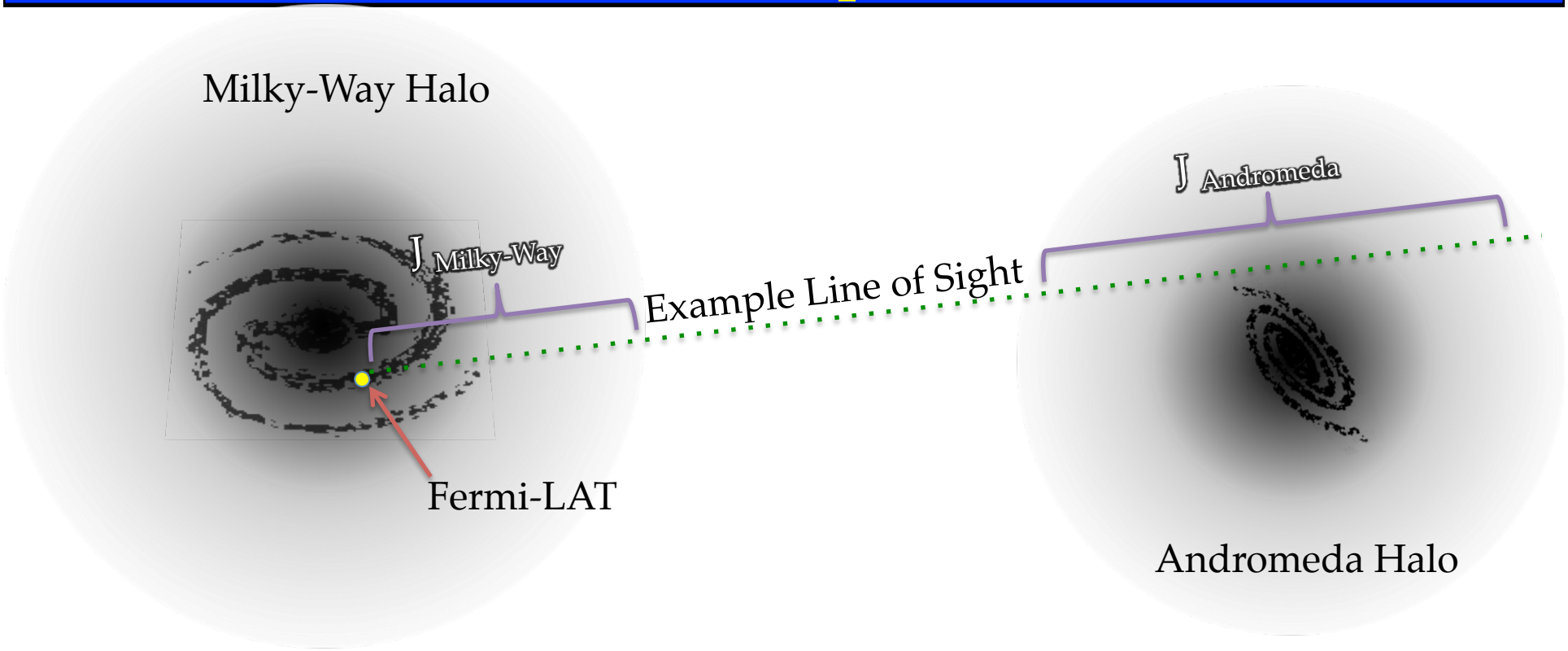
Also, this.

Infinite Statistics Model



	TS	Spectral Index
2FGL (14I) + 5	32.2	-2.49 ± 0.11
2FGL (14L) + 5	30.4	-2.45 ± 0.04
Space Face	32.4	-2.22 ± 0.08

J-Map

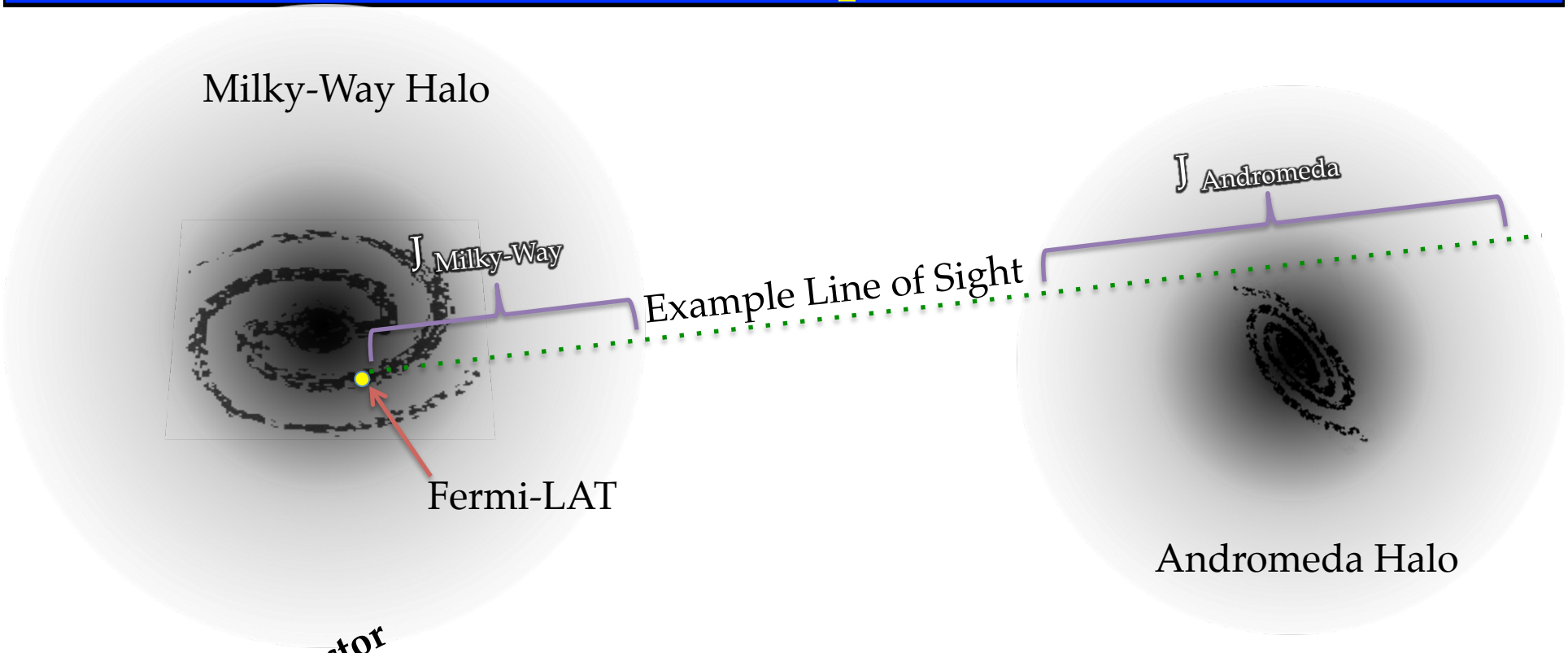


$$\text{J-Factor} = \int d\Omega \int \rho^2_{\text{Milky-Way}}\, dl + \int d\Omega \int \rho^2_{\text{Andromeda}}\, dl$$

$$\approx (\text{pixel-size})\left(\int_{\text{LAT}}^{\infty} \rho^2_{\text{Milky-Way}}\, dl + \int_{\text{LAT}}^{\infty} \rho^2_{\text{Andromeda}}\, dl\right)$$

(0.1 degrees square)

J-Map



Johnny Cash-Factor

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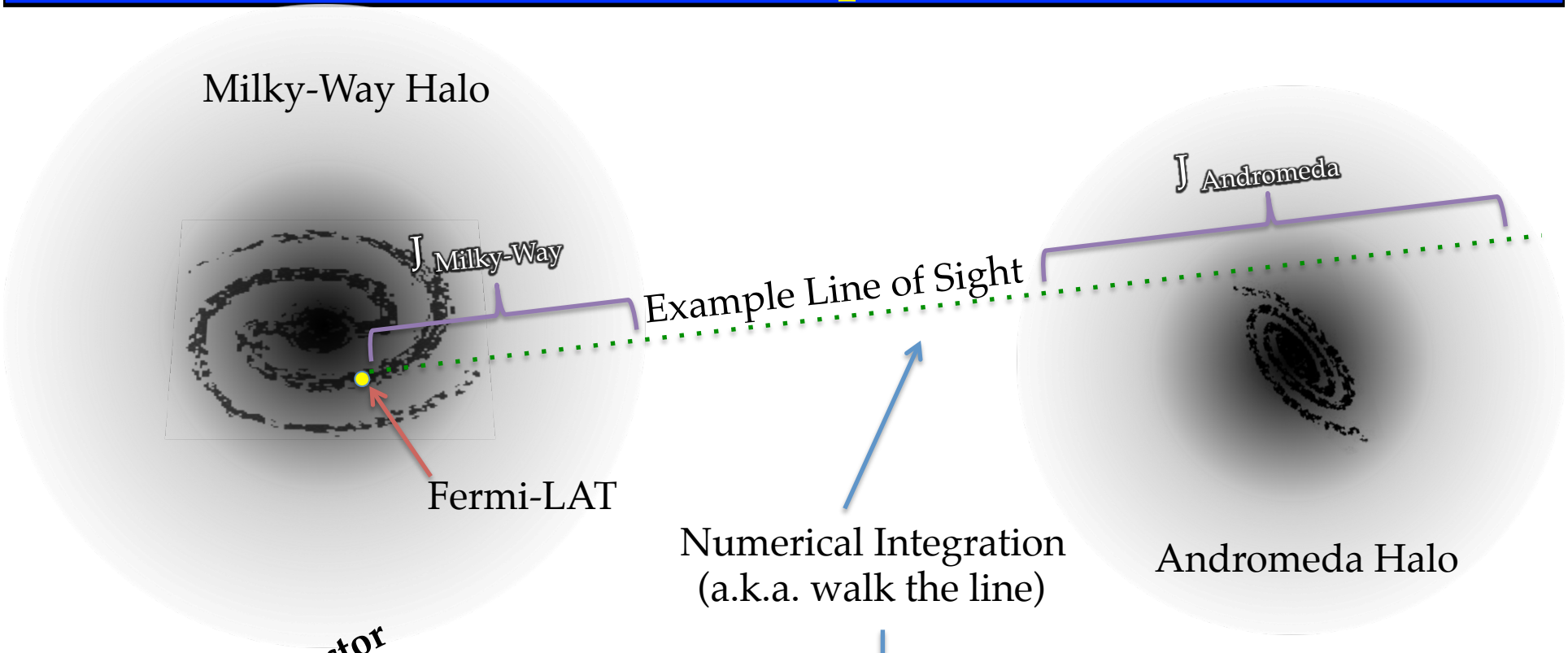
J-Map



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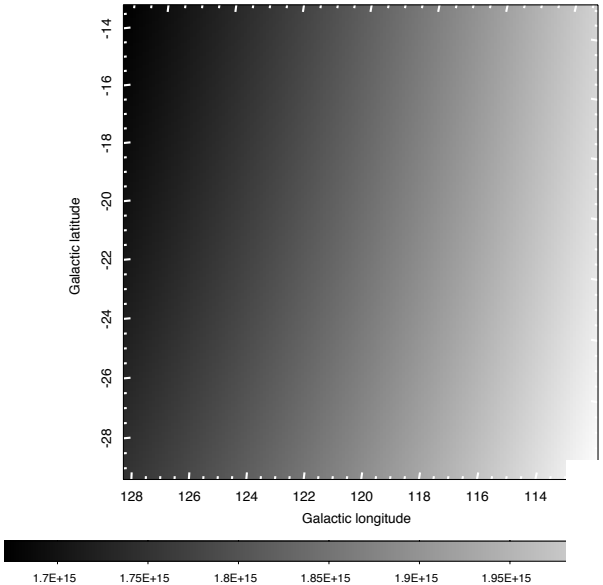
(0.1 degrees square)

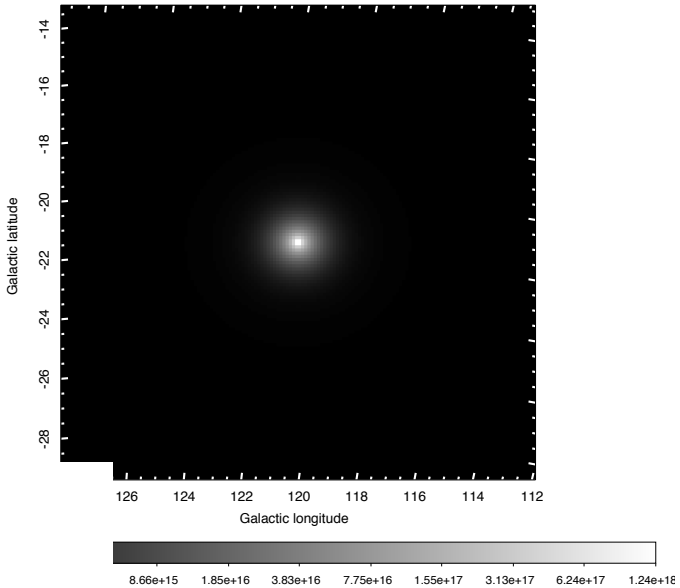
Template J Factor

J Factor as seen by Fermi-LAT for a spatially extended M 31

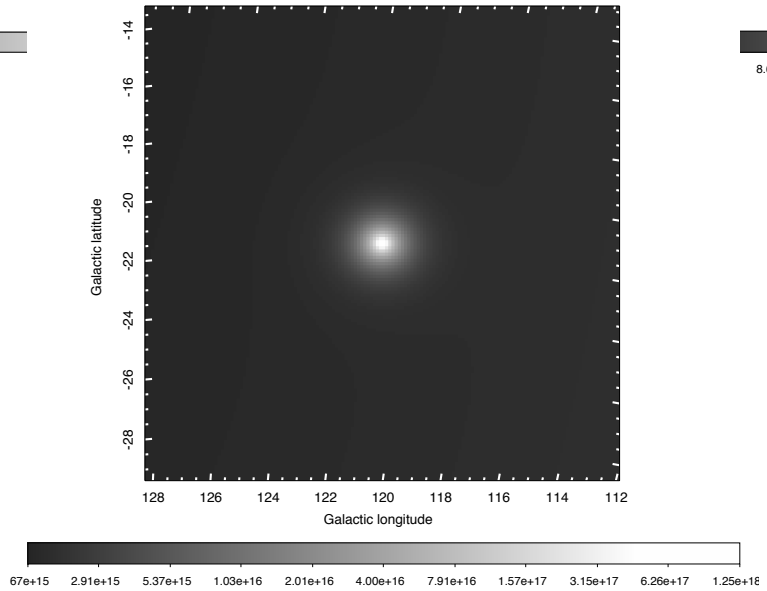
Milkyway



Andromeda (log scale)



Total Jmap (log scale)



DMFIT Limits