Search for Spatially Extended *fermi*-LAT Sources Using Two Years of Flight Data

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Overview

- Category II Paper
- Contact Authors: J. Lande, M. Ackermann, S. Funk
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- Target Journal: ApJ
- Currently submitted to internal referees
- Feedback welcome

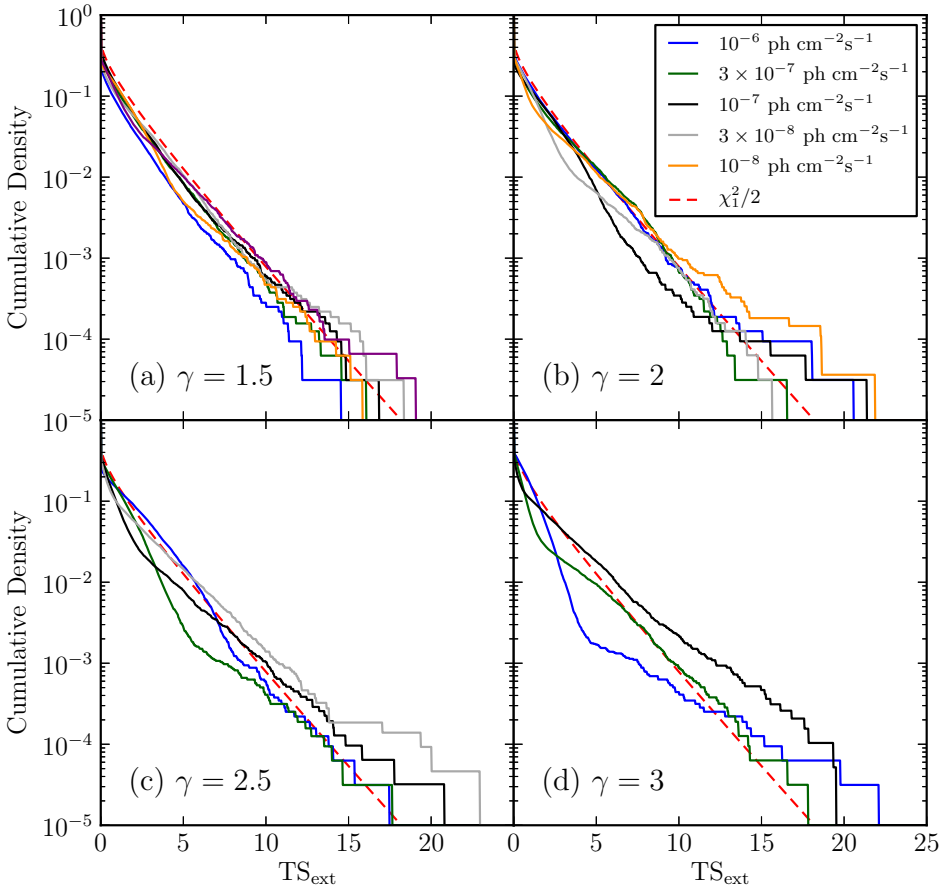
Paper Outline

- Description of a new method (`pointlike`) for analyzing extended sources.
- Monte Carlo calculation of false detection rate for extended sources.
- Calculation of the LAT's detection threshold to spatially extended sources
- Presentation of a new search for spatially extended sources:
  - Reanalyzing extension of 12 extended sources in 2FGL
  - Test AGN from 2LAC for extension to validate the analysis
  - Present 9 extended sources not in 2FGL

Topics relevant to catalog

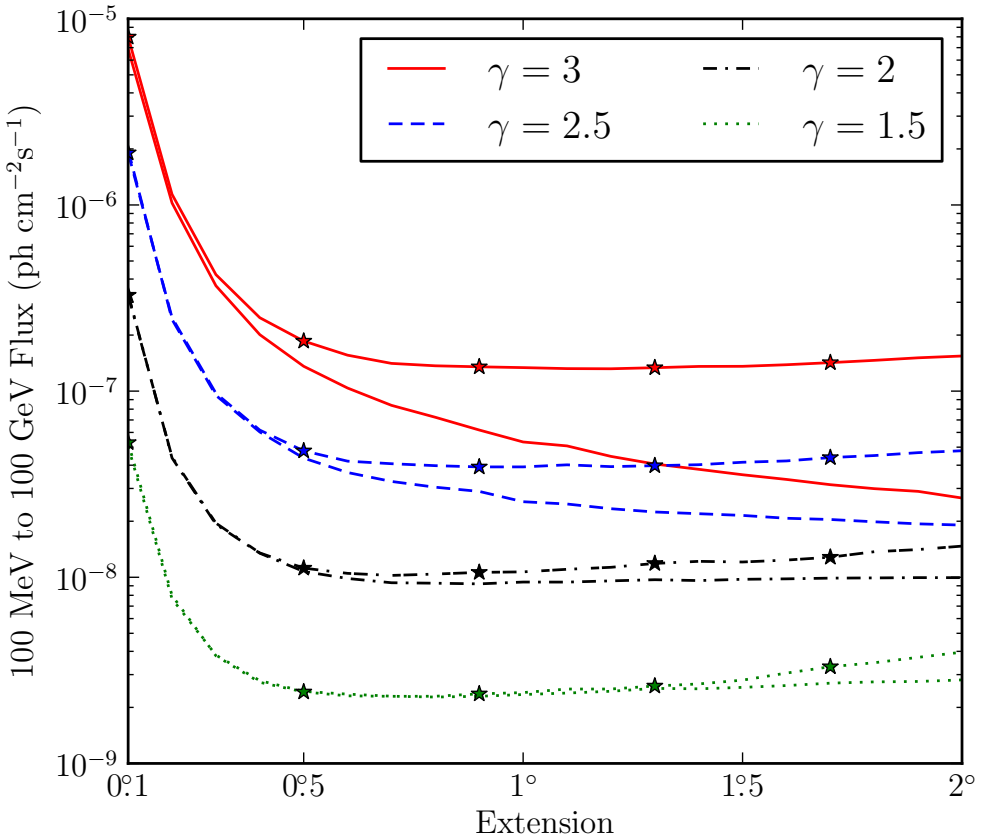
- Monte Carlo study of false detection rate
- LAT's detection threshold to extension
- Reanalysis of extended sources in 2FGL
- Testing AGN for extension
- (See presentation at Galactic splinter for rest of paper)

Fig. 3: Monte Carlo Study of false detection rate



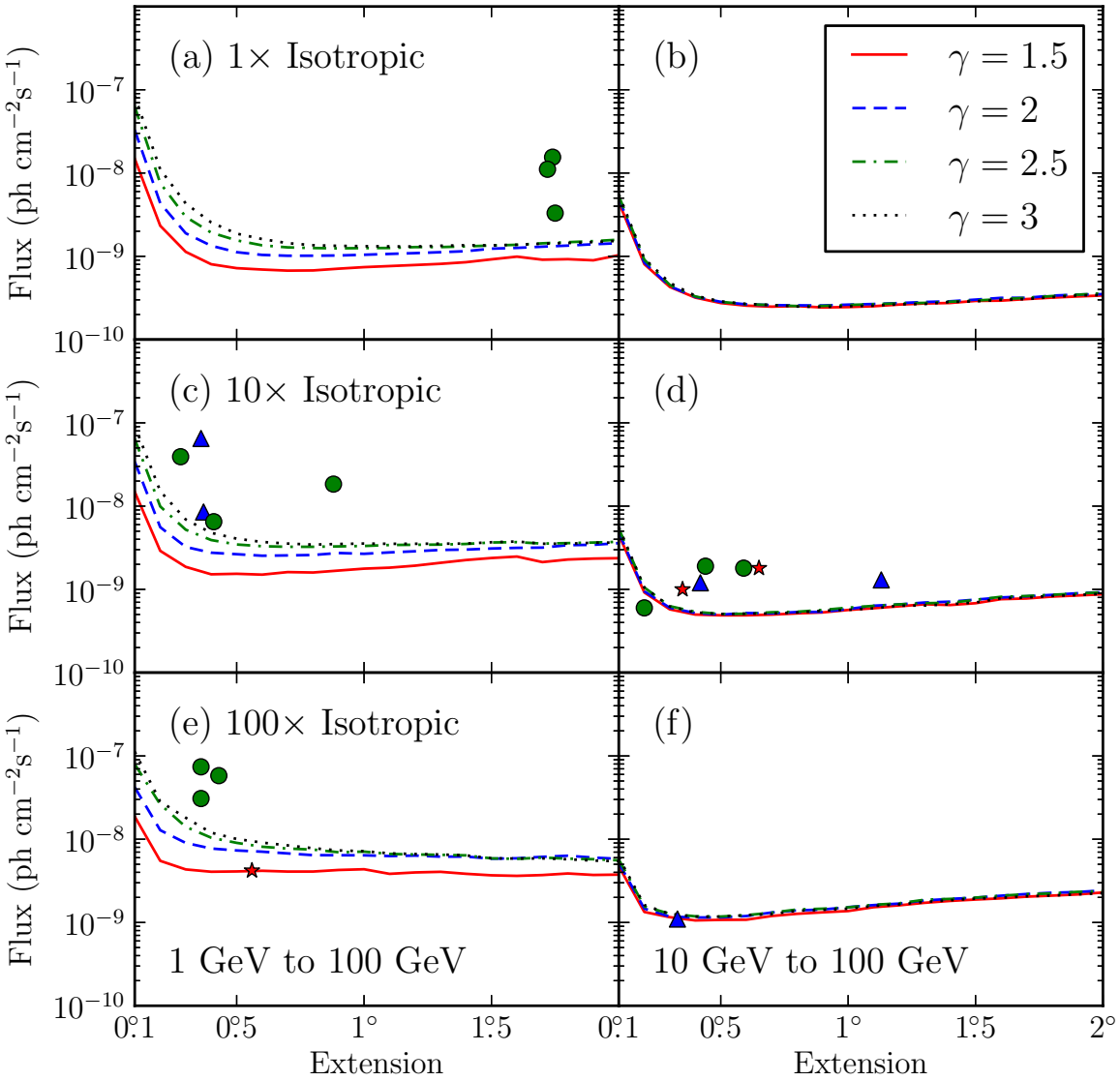
- Simulate point sources
- One year simulation
- Against EGRET isotropic BG
- Vary flux, spectral index
- $\sim$30,000 sims per spectral model
- Test for extension
- Compare CDF of TS$_{\rm ext}$ to $\chi^2_1/2$
- Good agreement with Wilks' Theorem

Fig. 4: Detection Threshold



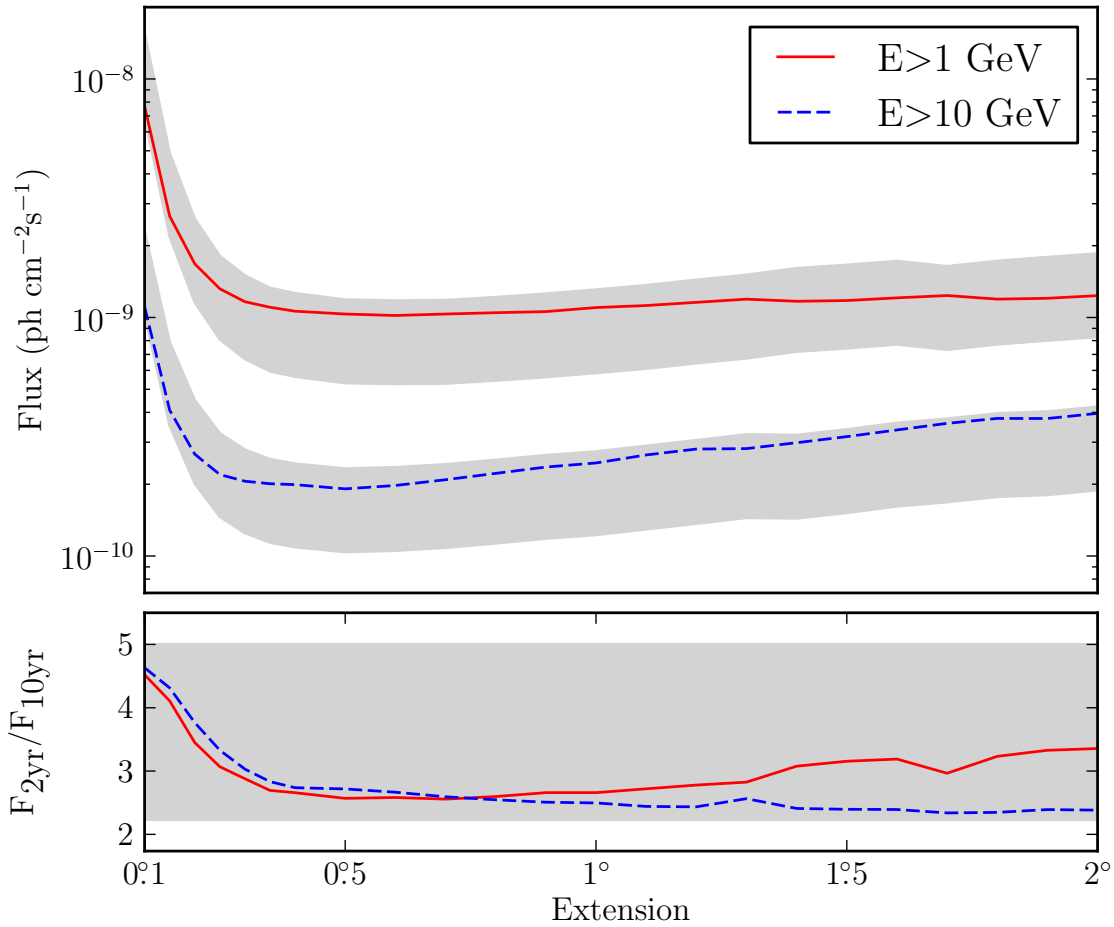
- Detetion threshold to extension
- 2 years + isotropic bg
- Definition: $\langle \mathrm{TS}_{\mathrm{ext}} \rangle = 16$
- Little sensitivity to small+soft sources
- Little improvement using 100 MeV to 1 GeV photons

Fig. 5: Threshold vs background



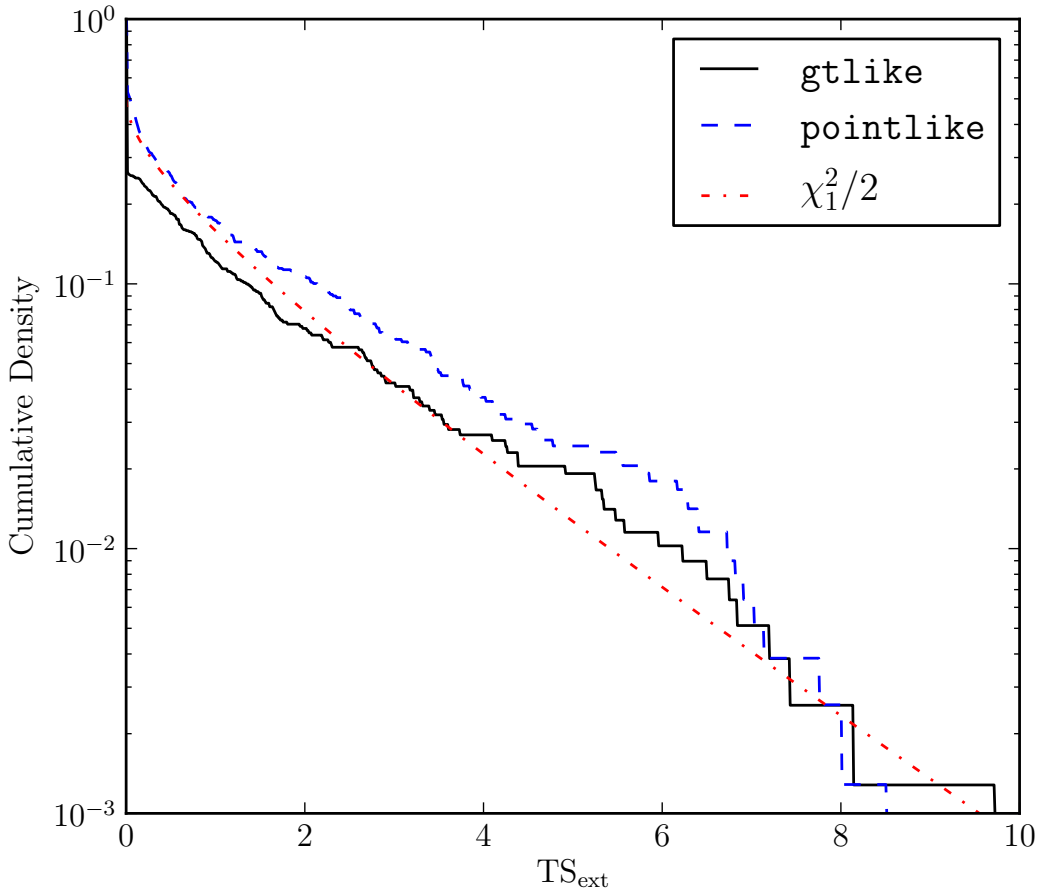
- Vary
  - spectral index,
  - diffuse normalization
  - energy range
- Overlay extended sources
- Reference for future publications

Fig. 6: Threshold vs time



- Calculate 10 year detection threshold
  - With MC simulationn
  - Projected from 2 years by $\sqrt{\text{time}}$ and time
- Sensitivity $> \sqrt{\text{time}}$ for small extended sources

Fig. 6: TS_{EXT} for 2LAC AGN



- 885 clean AGN in 2LAC
- Test 783 of these (with TS $>$ 25) for extension
- Compare CDF of TS_{ext} to $\chi^2_1/2$
- Don't find AGN to be extended

Table. 3: Reanalyze 12 sources in 2FGL

Name	GLON (deg.)	GLAT (deg.)	σ (deg.)	TS	TS_{ext}	Pos Err (deg.)	Flux[(a)] (ph cm^{-2} s^{-1})	Index
			E>1 GeV					
SMC	302.68	-44.81	$1.75 \pm 0.07 \pm 0.02$	94.8	67.4	0.12	3.3 ± 0.4	2.41 ± 0.17
LMC	279.10	-32.61	$1.74 \pm 0.05 \pm 0.13$	1101.3	860.5	0.05	15.5 ± 0.6	2.48 ± 0.06
IC443	189.05	3.04	$0.36 \pm 0.01 \pm 0.04$	10719.8	510.4	0.01	64.8 ± 1.2	2.23 ± 0.02
Vela X	263.34	-3.11	0.88					
Centarus A	309.52	19.42	~ 10					
W28	6.50	-0.27	$0.43 \pm 0.02 \pm 0.03$	1324.8	177.4	0.01	58.0 ± 1.8	2.63 ± 0.03
W30	8.61	-0.20	$0.36 \pm 0.02 \pm 0.02$	465.4	73.3	0.02	30.7 ± 1.6	2.59 ± 0.04
W44	34.69	-0.38	$0.36 \pm 0.01 \pm 0.02$	1903.3	217.7	0.01	73.6 ± 1.8	2.68 ± 0.02
W51C	49.13	-0.45	$0.28 \pm 0.02 \pm 0.05$	1819.5	115.7	0.01	39.3 ± 1.3	2.35 ± 0.03
Cygnus Loop	74.22	-8.46	$1.72 \pm 0.05 \pm 0.07$	356.5	356.5	0.06	11.1 ± 0.7	2.53 ± 0.11
			E>10 GeV					
MSH 15−52	320.38	-1.22	$0.20 \pm 0.04 \pm 0.03$	76.2	6.5	0.03	0.6 ± 0.7	2.27 ± 0.73
HESS J1825−137	17.56	-0.46	$0.65 \pm 0.03 \pm 0.01$	83.6	55.9	0.05	1.8 ± 0.2	1.74 ± 0.19

- Test 12 2FGL sources for extension
- Assume radially symmetric disk spatial model
- Improved models could be included in future catalog

Table. 4: 9 more extended sources

Name	GLON (deg.)	GLAT (deg.)	σ (deg.)	TS	TS_{ext}	Pos Err (deg.)	Flux$^{(a)}$ (ph cm^{-2} s^{-1})	Index	Counterpart
				E>1 GeV					
2FGL J0823.0−4246	260.32	-3.28	$0.37 \pm 0.03 \pm 0.02$	320.9	46.3	0.02	8.5 ± 0.7	2.20 ± 0.09	Puppis A
2FGL J1627.0−2425c	353.08	16.78	$0.41 \pm 0.05 \pm 0.02$	144.5	31.1	0.04	6.5 ± 0.6	2.49 ± 0.14	Ophiuchus
2FGL J1712.4−3941	347.25	-0.54	$0.56 \pm 0.04 \pm 0.01$	75.0	39.6	0.05	4.2 ± 0.9	1.47 ± 0.12	RX J1713.7−3946
				E>10 GeV					
2FGL J0851.7−4635	266.29	-1.43	$1.13 \pm 0.08 \pm 0.05$	116.1	87.2	0.07	1.3 ± 0.2	1.76 ± 0.21	Vela Jr.
2FGL J1615.0−5051	332.38	-0.14	$0.33 \pm 0.04 \pm 0.01$	53.4	16.3	0.04	1.1 ± 0.2	2.24 ± 0.28	HESS J1616−508
2FGL J1615.2−5138	331.66	-0.66	$0.42 \pm 0.03 \pm 0.01$	76.6	48.0	0.05	1.2 ± 0.2	1.77 ± 0.24	HESS J1614−518
2FGL J1632.4−4753c	336.41	0.22	$0.44 \pm 0.04 \pm 0.03$	127.8	64.5	0.04	1.9 ± 0.2	2.29 ± 0.21	HESS J1632−478
2FGL J1837.3−0700c	25.08	0.13	$0.35 \pm 0.08 \pm 0.03$	46.2	18.8	0.07	1.0 ± 0.2	1.63 ± 0.29	HESS J1837−069
2FGL J2021.5+4026	78.18	2.19	$0.59 \pm 0.03 \pm 0.02$	222.2	116.4	0.04	1.8 ± 0.2	2.31 ± 0.19	γ-Cygni

Extended sources could be included in future catalog