Prospects for Observation of Galactic Sources of Cosmic Neutrinos

Ali Kheirandish & Francis Halzen

IceCube Particle Astrophysics Symposium
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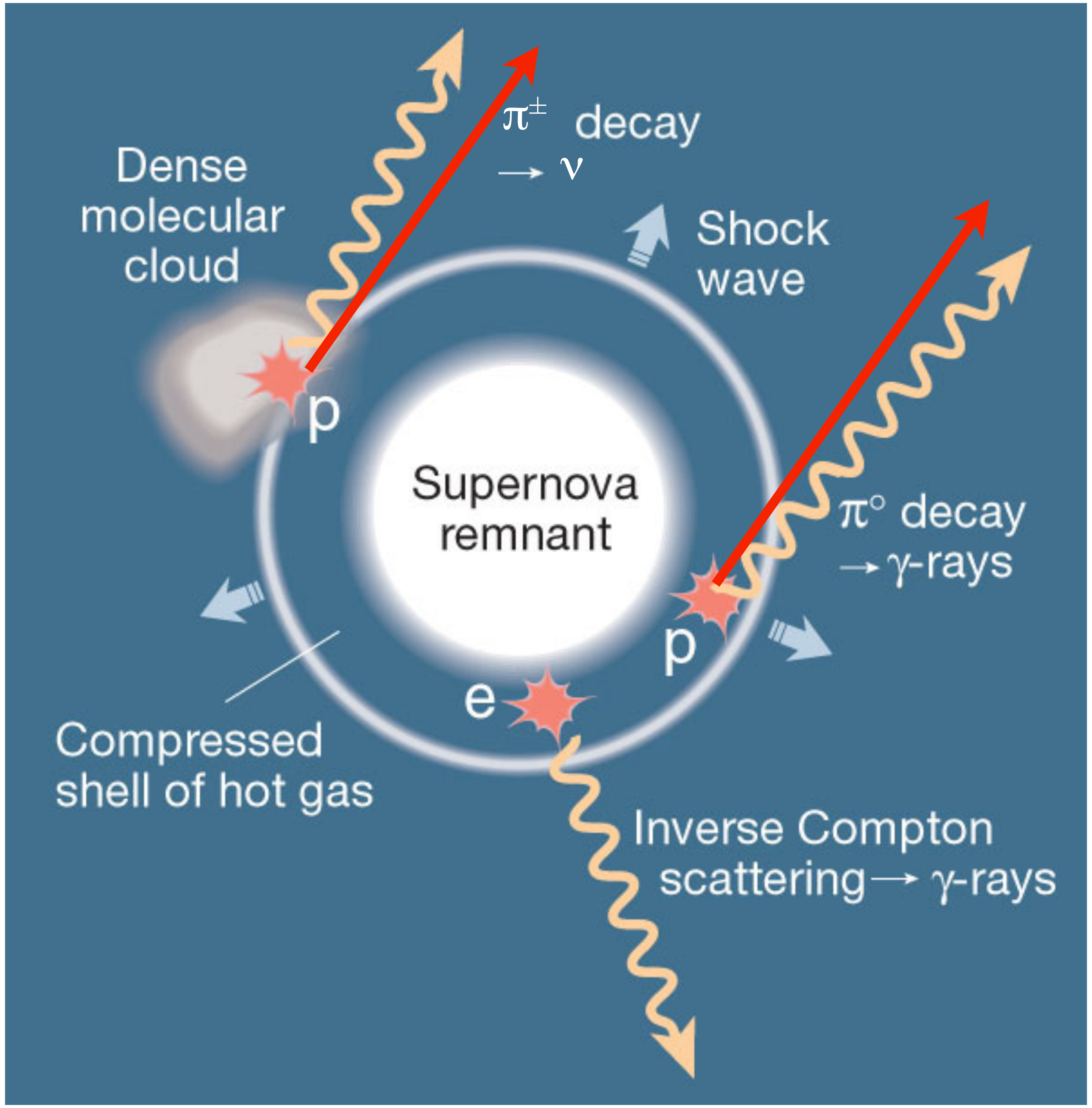
WIPAC
Wisconsin IceCube Particle Astrophysics Center

Galactic Cosmic Ray Accelerators

- The search for Galactic cosmic neutrino sources concentrates on the search for "Pevatrons" which have the required energetics to produce cosmic rays up to the knee in the spectrum.
- Pevatrons will produce pionic gamma rays whose spectrum extends to several hundred TeV without cut off.
- Supernova remnant meet such condition.
- TeV gamma rays should be accompanied by TeV neutrinos, observable at IceCube.



Milagro TeV Sky

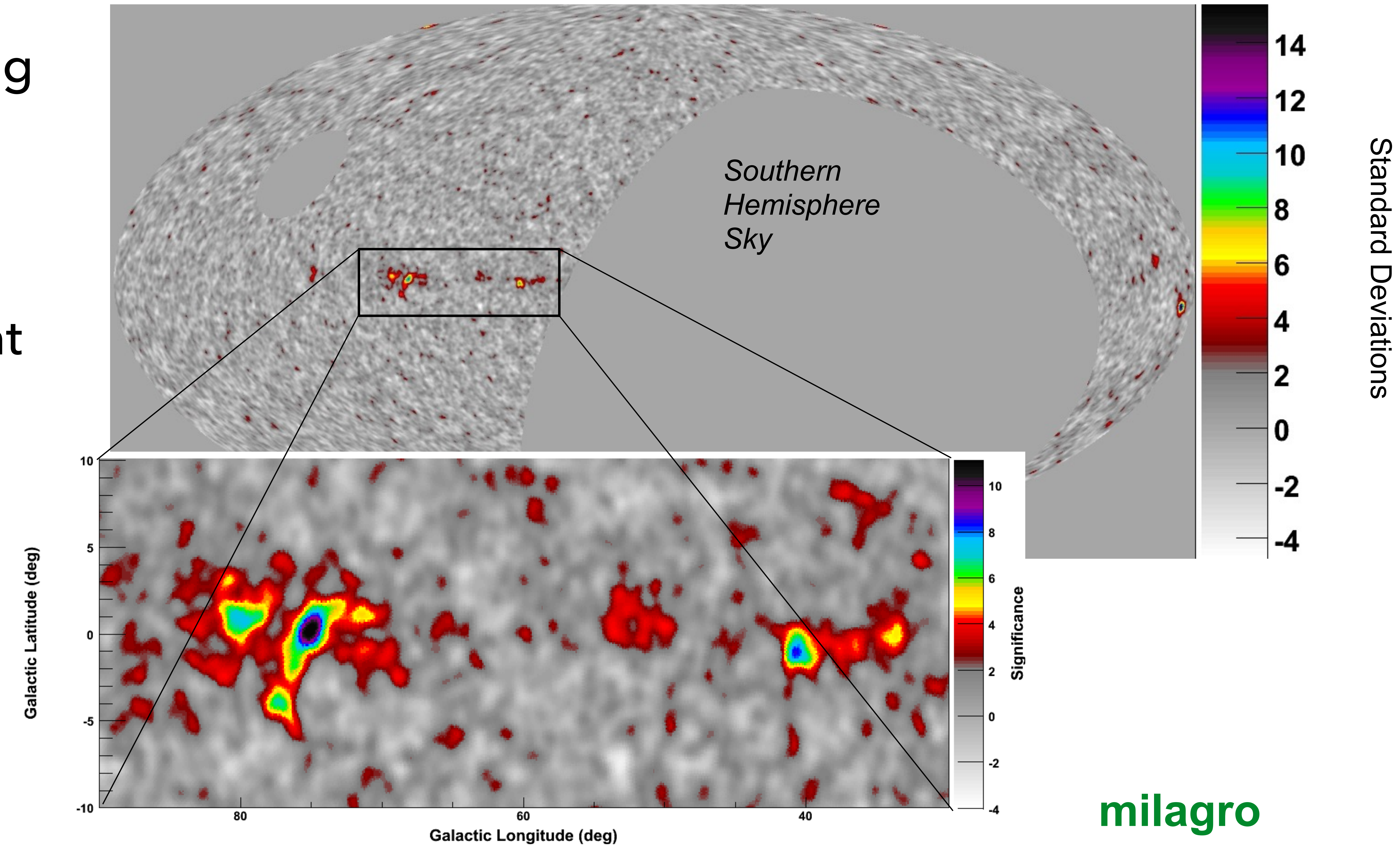
- 6 Sources were identified in the initial map of Milagro. The idea was to look for supernova remnants in star forming regions.

- MGRO J1908+06, MGRO 2019+37, and MGRO J2031+41 were significant (The most significant after Crab)

- MGRO J2043+36 (C1) and MGRO J2032+37 (C2): Candidate sources

- MGRO J1852: below threshold

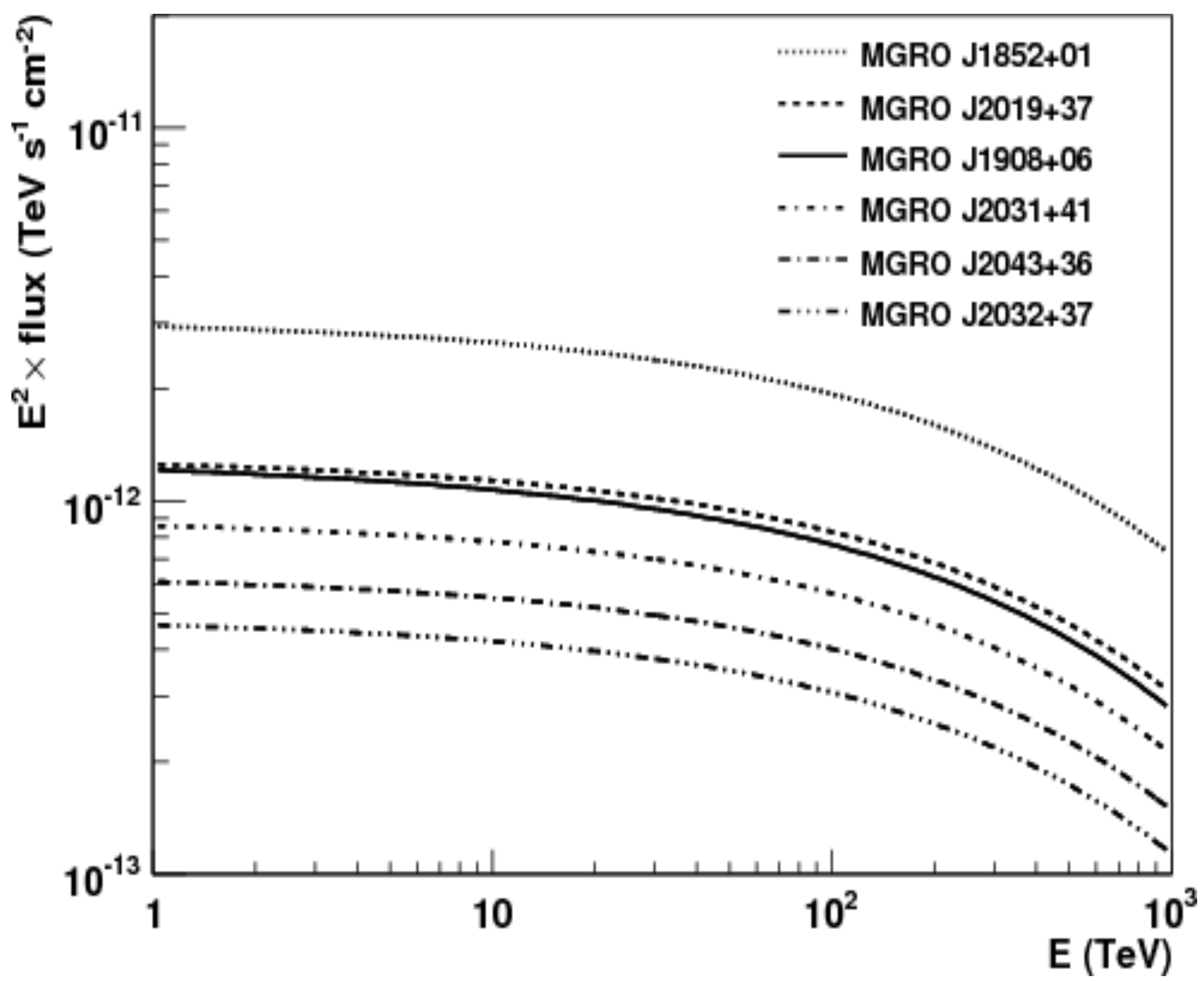
Galactic plane in 10 TeV gamma rays:



Halzen, Kappes, & O'Murchadha, 2008
Gonzalez-Garcia, Halzen & Mohapatra 2009

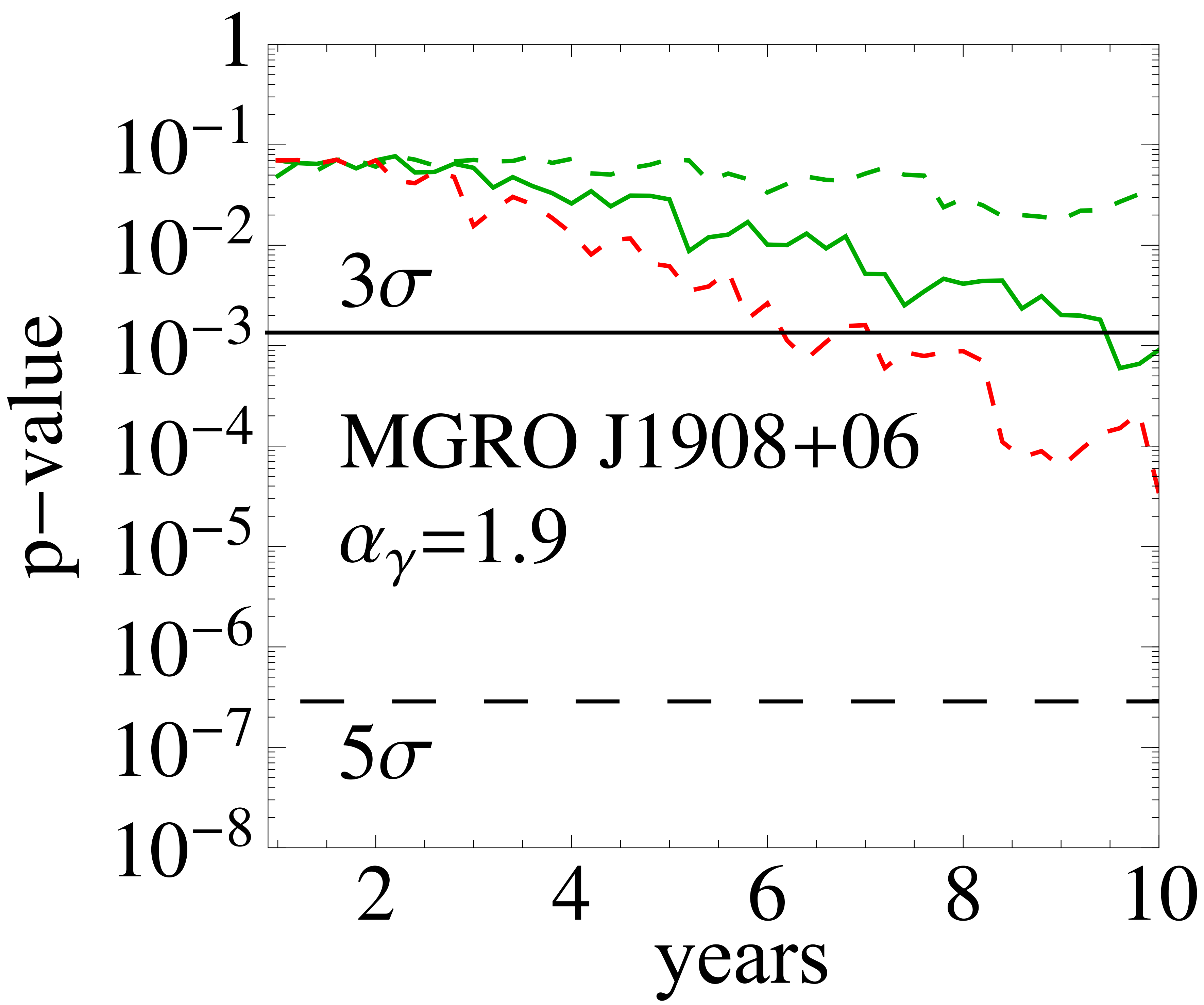
Early predictions for IceCube

Neutrino spectra for all sources



- Studies based on hard spectra reported from Milagro claimed that IceCube should observe them after 5 years of run.

Halzen, Kappes, & O'Murchadha, 2008
Gonzalez-Garcia, Halzen & Mohapatra 2009



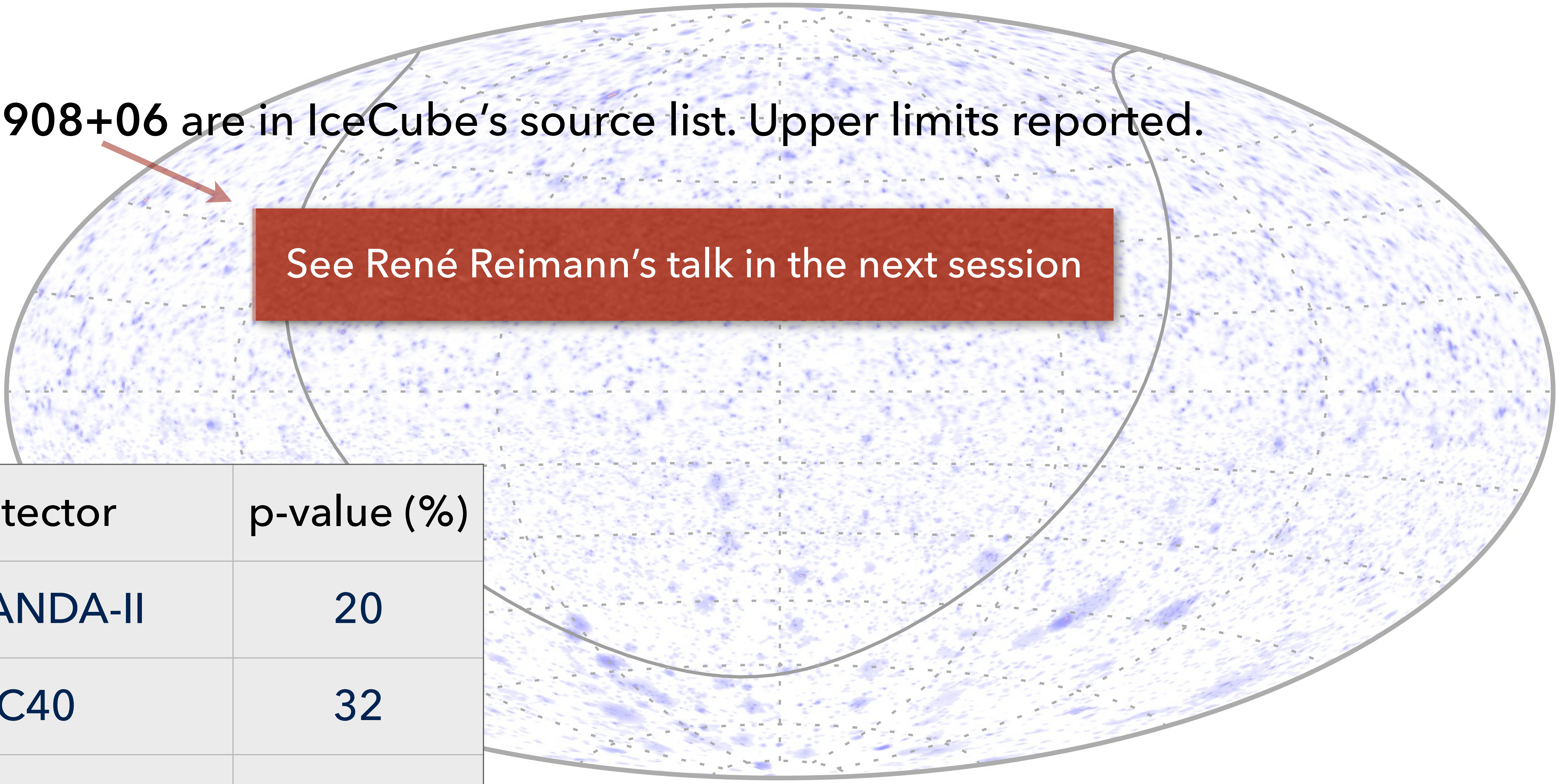
- Updated flux measurements from Milagro and ARGO-YBJ reported cut-off at low energies.
- Only MGRO J1908+06 observation seemed likely.

Gonzalez-Garcia, Halzen & Niro 2013

IceCube Searches

Point source searches:

MGRO 2019+37 and **MGRO J1908+06** are in IceCube's source list. Upper limits reported.



See René Reimann's talk in the next session

Stacked Searches:

Detector	p-value (%)
AMANDA-II	20
IC40	32
IC40+59+79	20
IC40+59+79+86-I	2

IceCube Collaboration, Phys.Rev. D79 (2009) 062001, Astrophys.J. 732 (2011) 18, Astrophys.J. 779 (2013) 132, & Astrophys.J. 796 (2014) no.2, 109

Prospects for observation in IceCube

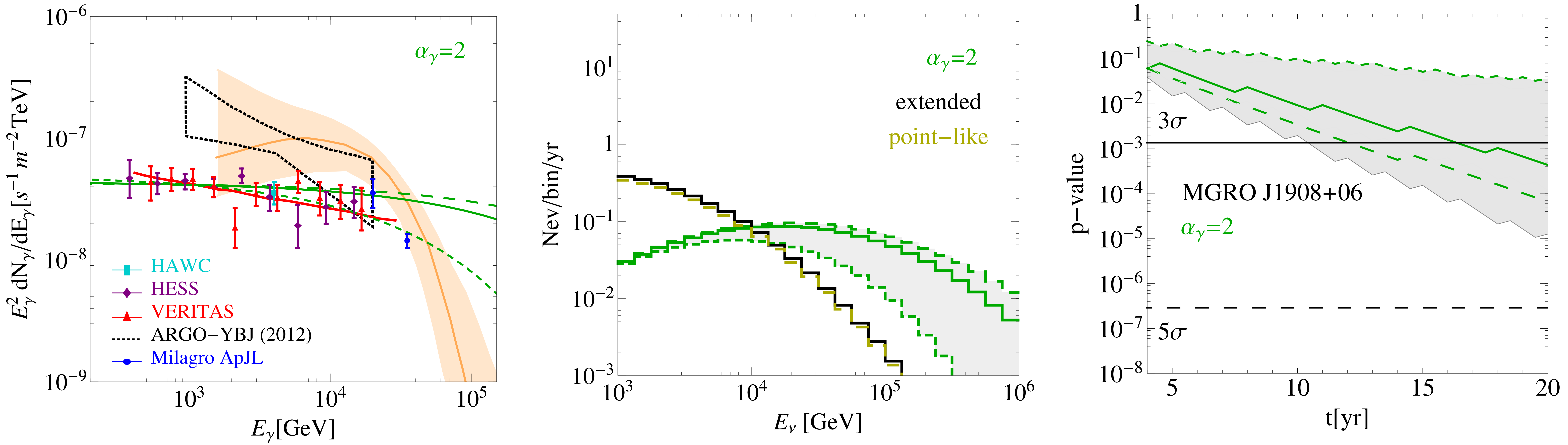
In light of:

- Confirmation of MGRO J1852+01 in HAWC.
- Observation of MGRO J1908+06 flux and extension in H.E.S.S
- Observation of MGRO J12031+41 flux and extension in ARGO-YBJ & Fermi
- Observation of MGRO J12019+37 flux and extension in VERITAS

We updated the neutrino spectrum as single power-law with cut-off where the flux normalization and cut-off are related to new gamma ray flux measurements.

Neutrinos from MGRO J1908+06

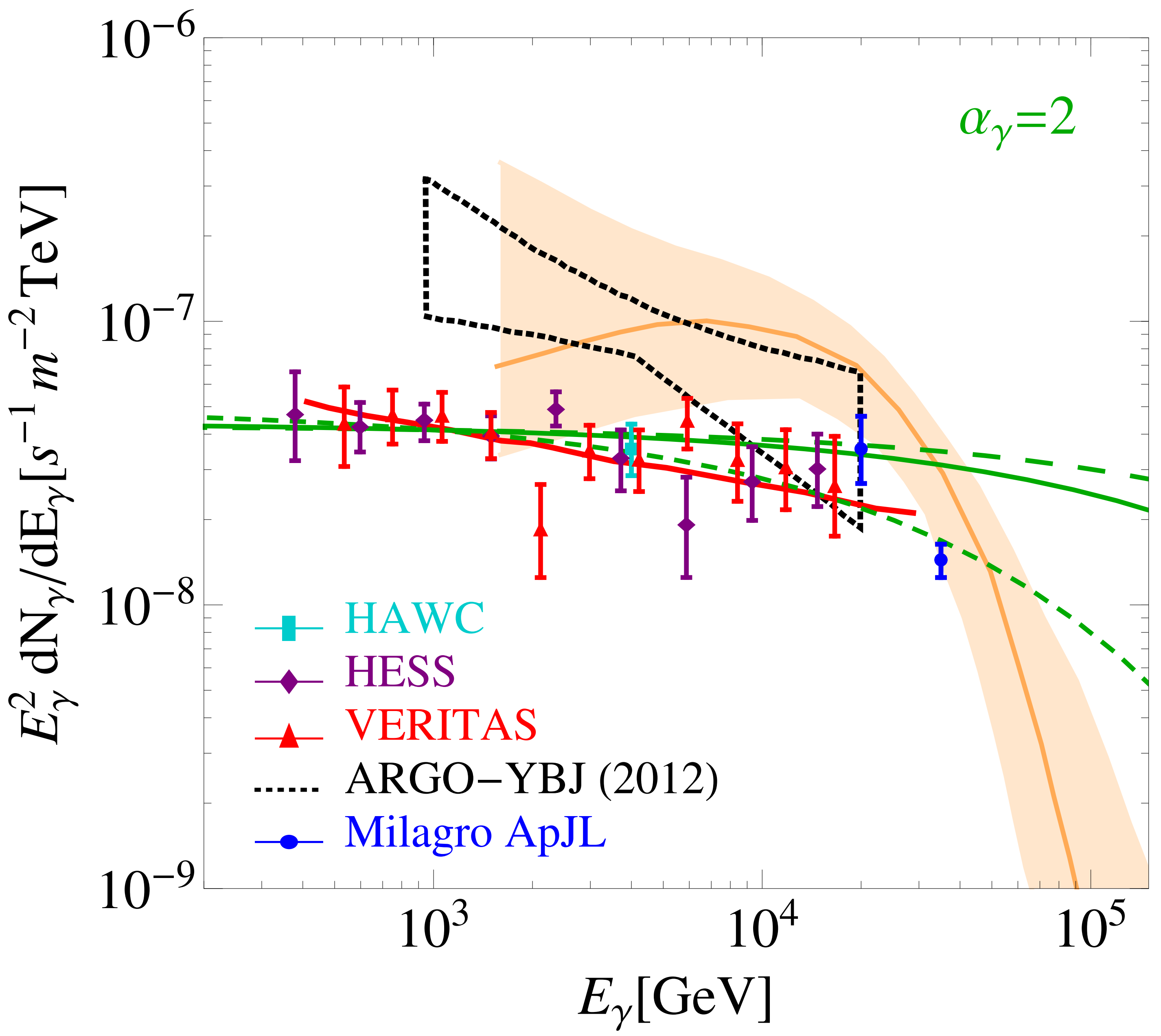
- High-energy gamma ray source Observed in different experiments
- Unidentified extended source: *discrepancy in measurements*
- Expected to be observed in less than 10 years of IceCube operation

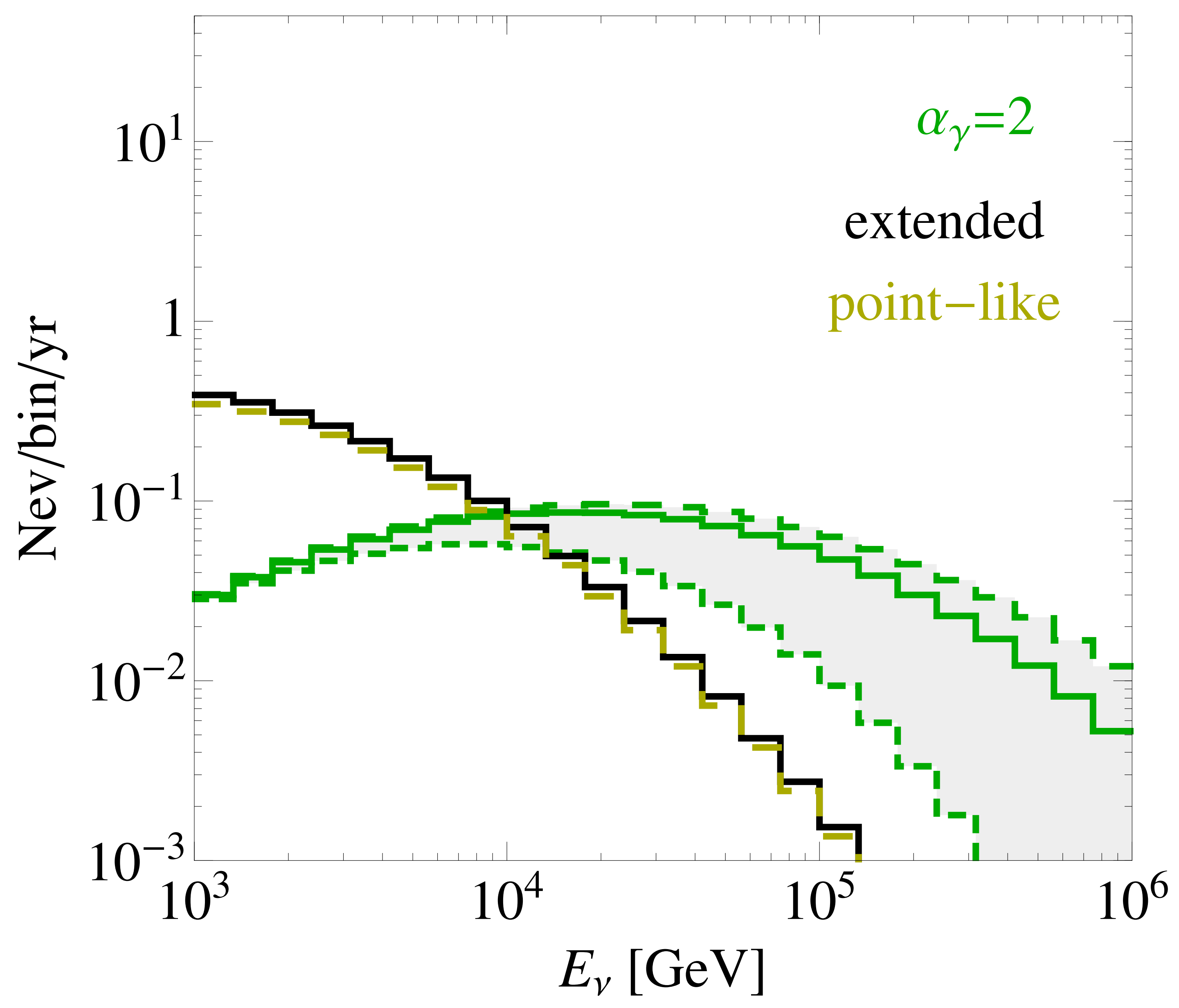


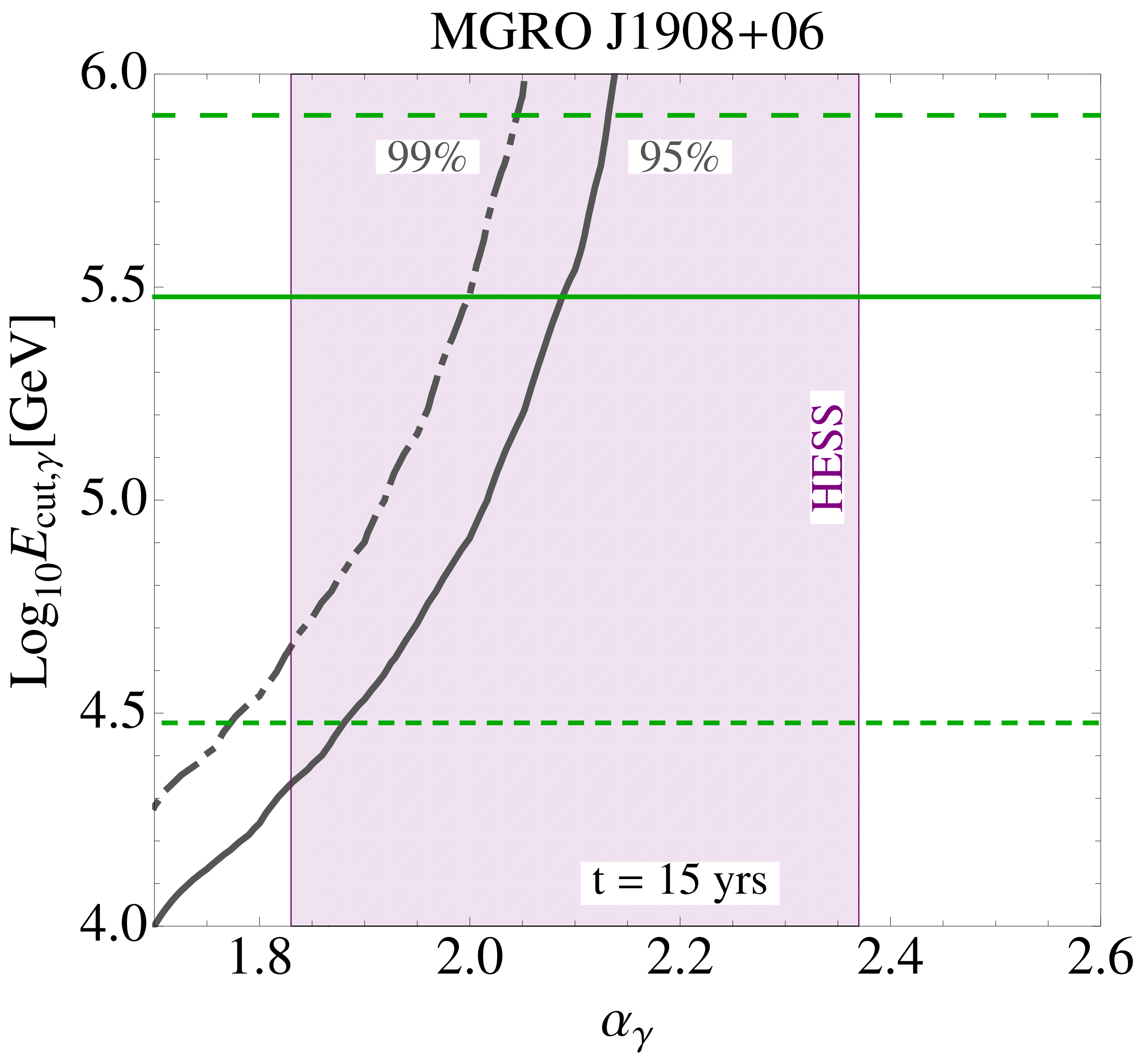
F. Halzen, AK, V. Niro, Astropart.Phys. 86 (2016) 46-56

Neutrinos from MGRO J1908+06

- High-energy gamma ray source Observed in different experiments
- Unidentified extended source: *discrepancy in measurements*
- *Non-observation* : Constraining the spectrum parameter space







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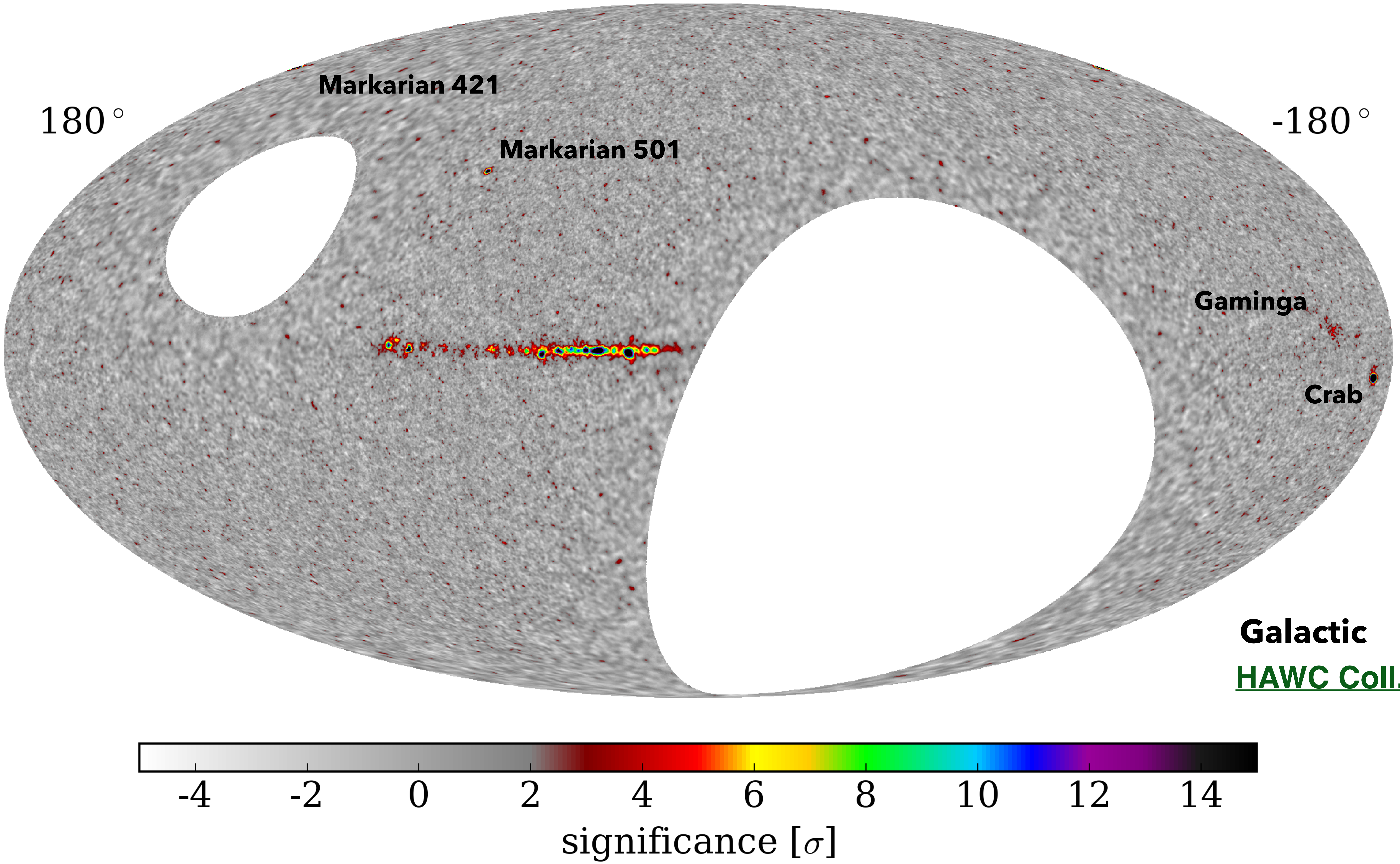
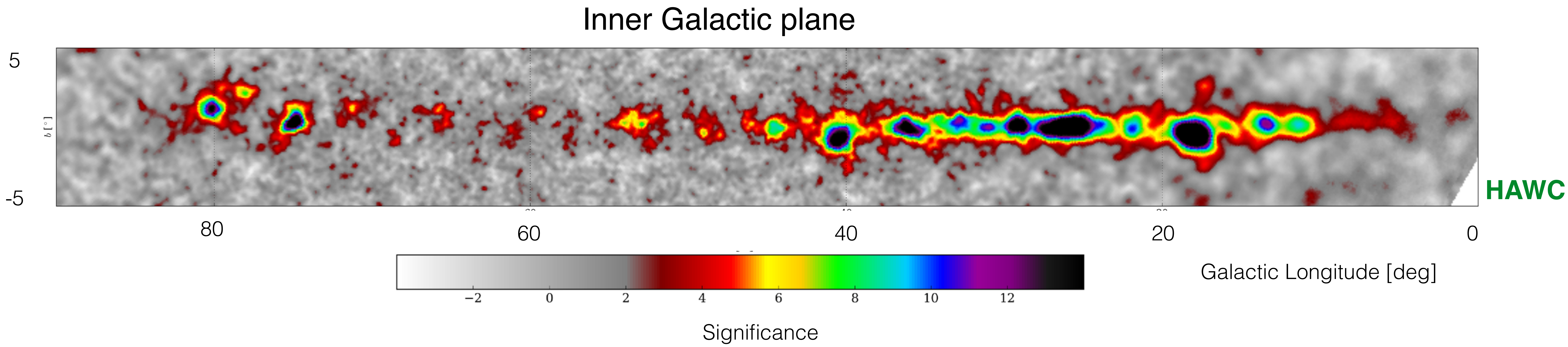
HAWC 2HWC Catalog (17 Month)



HAWC Coll. 2017

IceCube⊕HAWC

AK, R. Hussain, & J. Wood

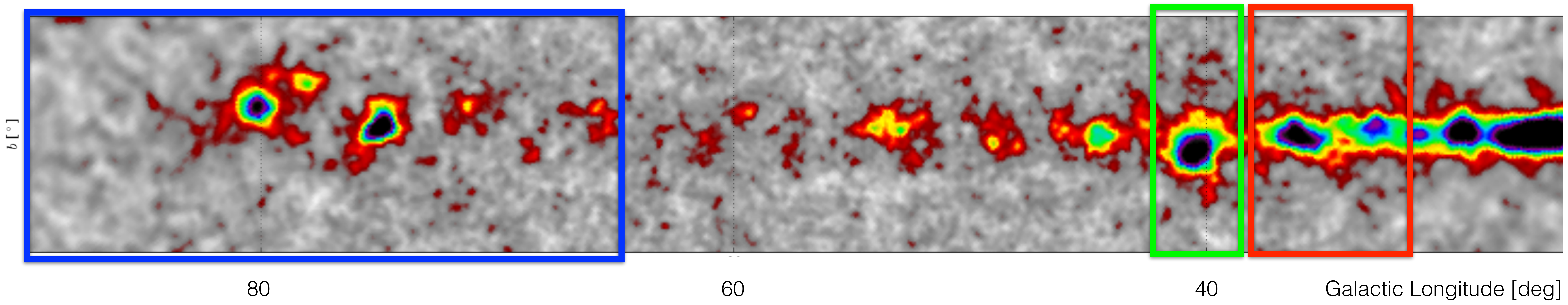


- **Joint** analysis between IceCube and HAWC collaborations using 17 month observation of HAWC and 7 years of IceCube.

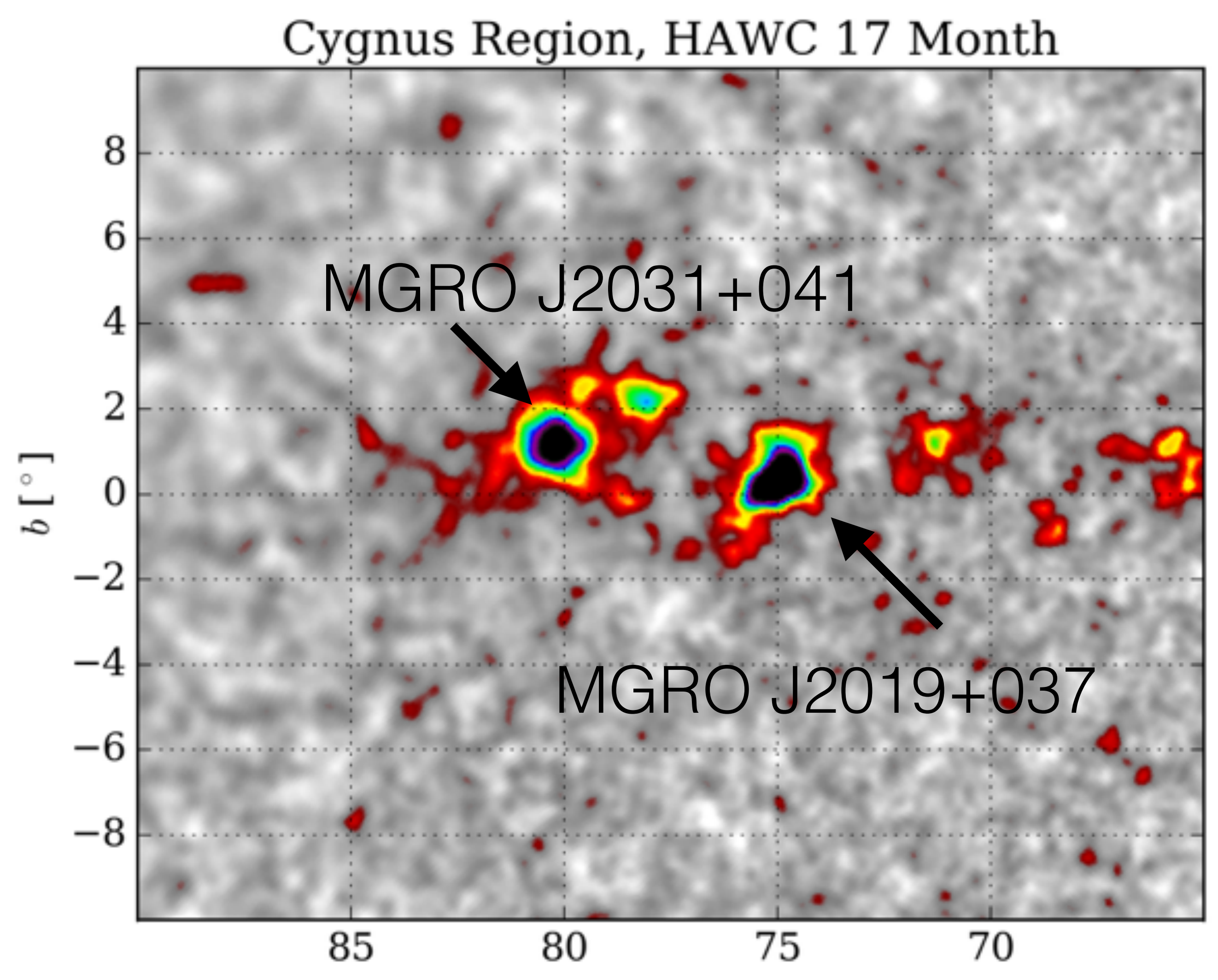
- Looking for
    - Correlation study for selected sources in 2HWC
    - Correlation to the Galactic emission
    - Correlation to Cygnus region and other interesting regions in the Galaxy

Special Regions Search

AK, R. Hussain, & J. Wood



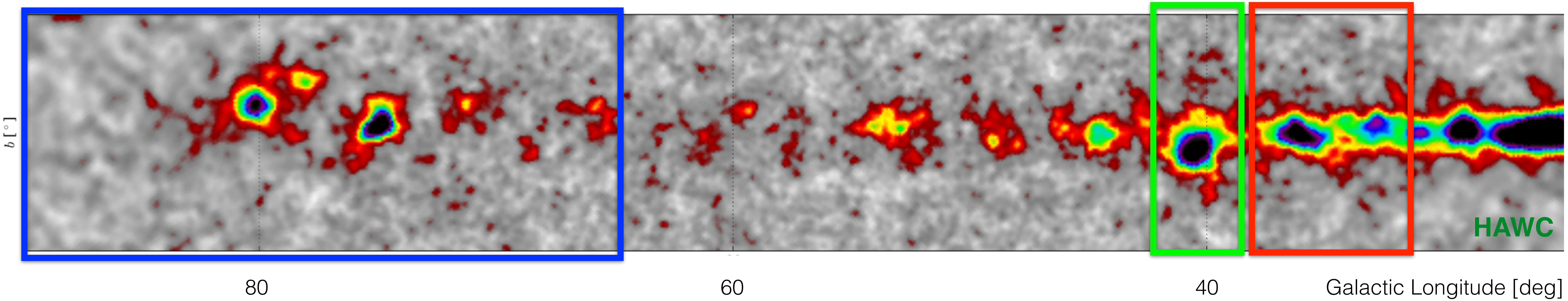
Cygnus Region



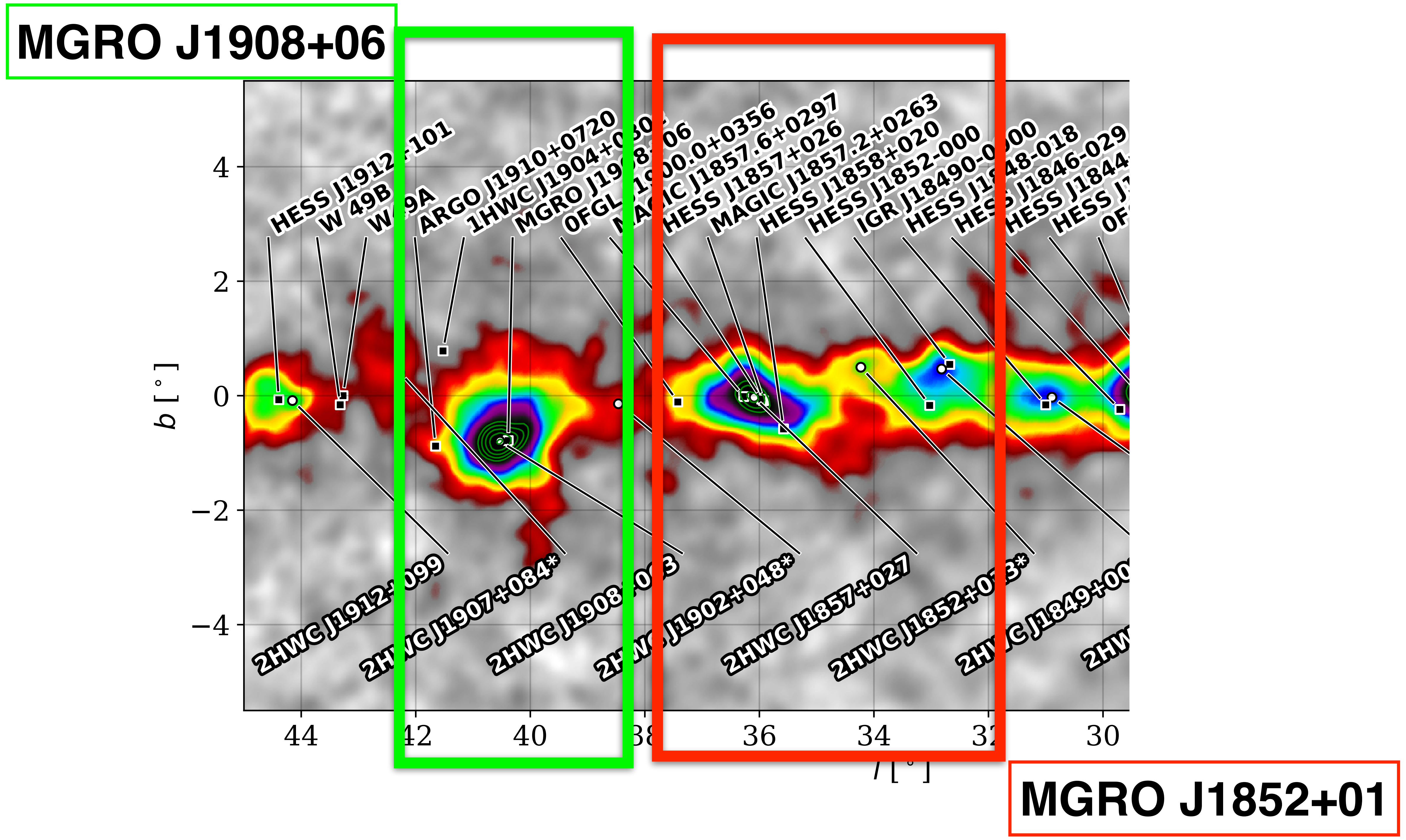
- Starforming region with a high level of gamma ray activity and young stars
- Very high-energy diffuse gamma ray emission claimed by Milagro
- Gamma ray emission from the cocoon
- Large uncertainties regarding the resolved sources and their extension

Special Regions Search

AK, R. Hussain, & J. Wood



- Regions containing previously identified sources with spectra consistent with PeVatron scenarios
- Located at the best place for IceCube (near horizon)
- Gamma ray emission nature not well understood



Special Regions Search

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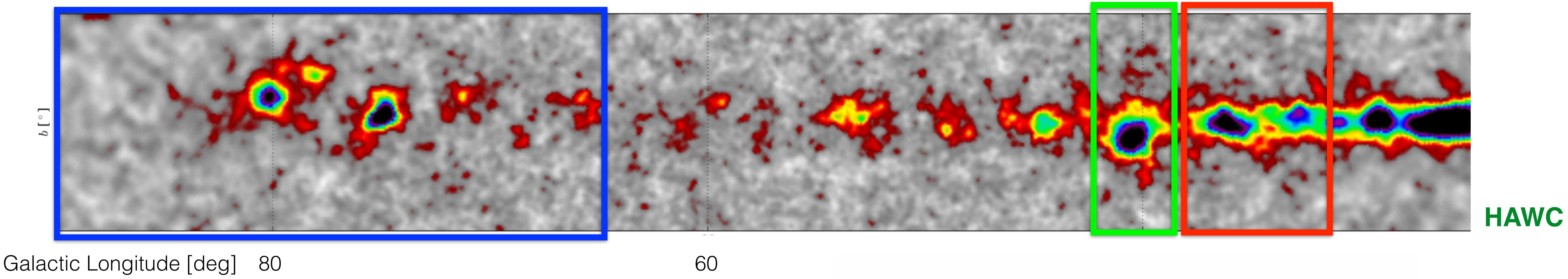

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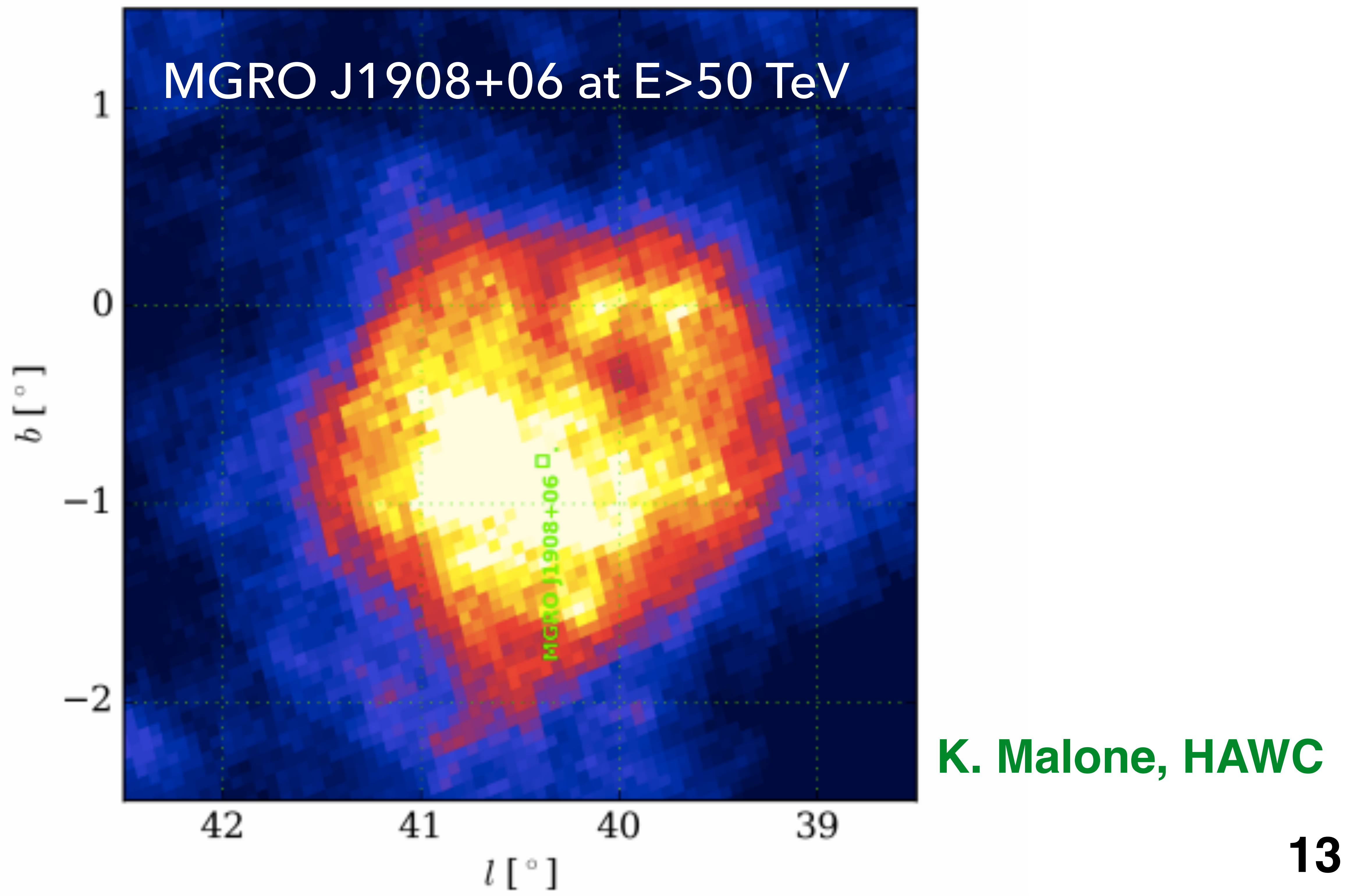
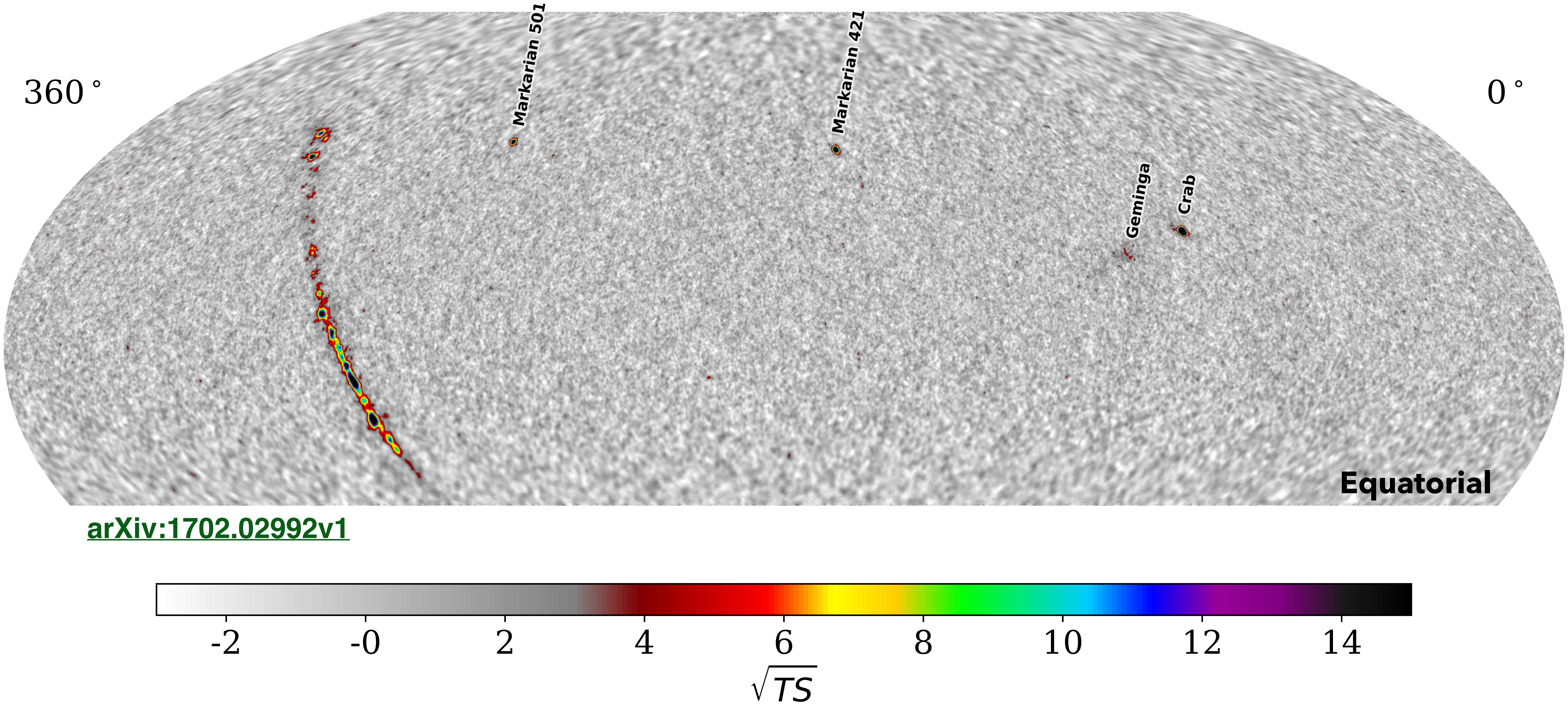


Summary

- The prospects of identifying Galactic sources of cosmic neutrinos are highly entangled with the discrepancy in gamma ray flux measurements.
- The discrepancy may come from different resolution of IACT experiments and Milagro.
- Any evidence of astrophysical neutrinos from any of Galactic sources will provide valuable information about the nature and spectrum of the sources.
- Considering fluxes measured, MGRO J1908+06 observation is likely in less than10 years of IceCube.
- IceCube's current study of the high-energy gamma ray emission from HAWC will help in identifying Galactic sources of cosmic neutrinos.

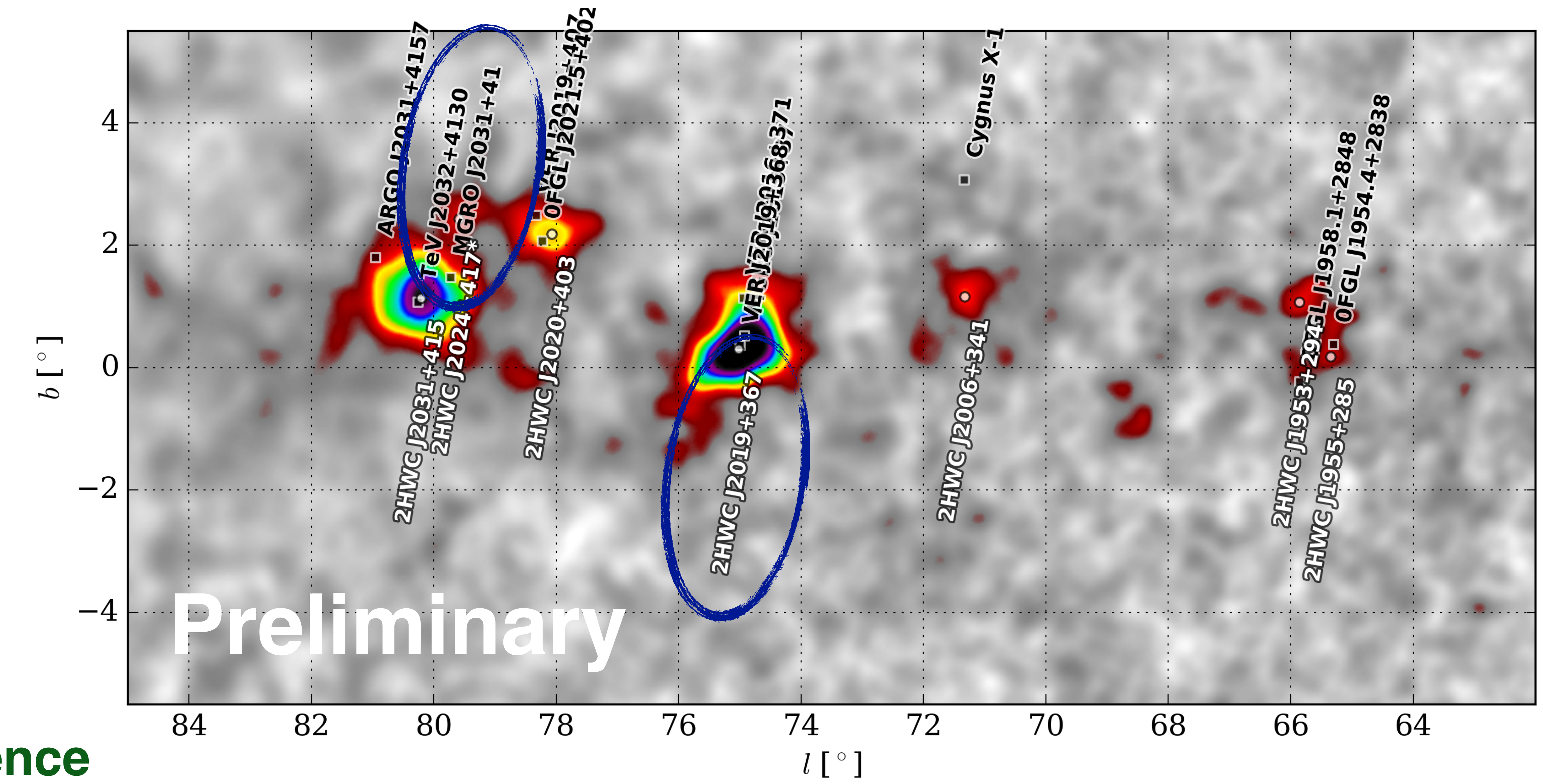
Back up Slides

HAWC 1st Year Catalog

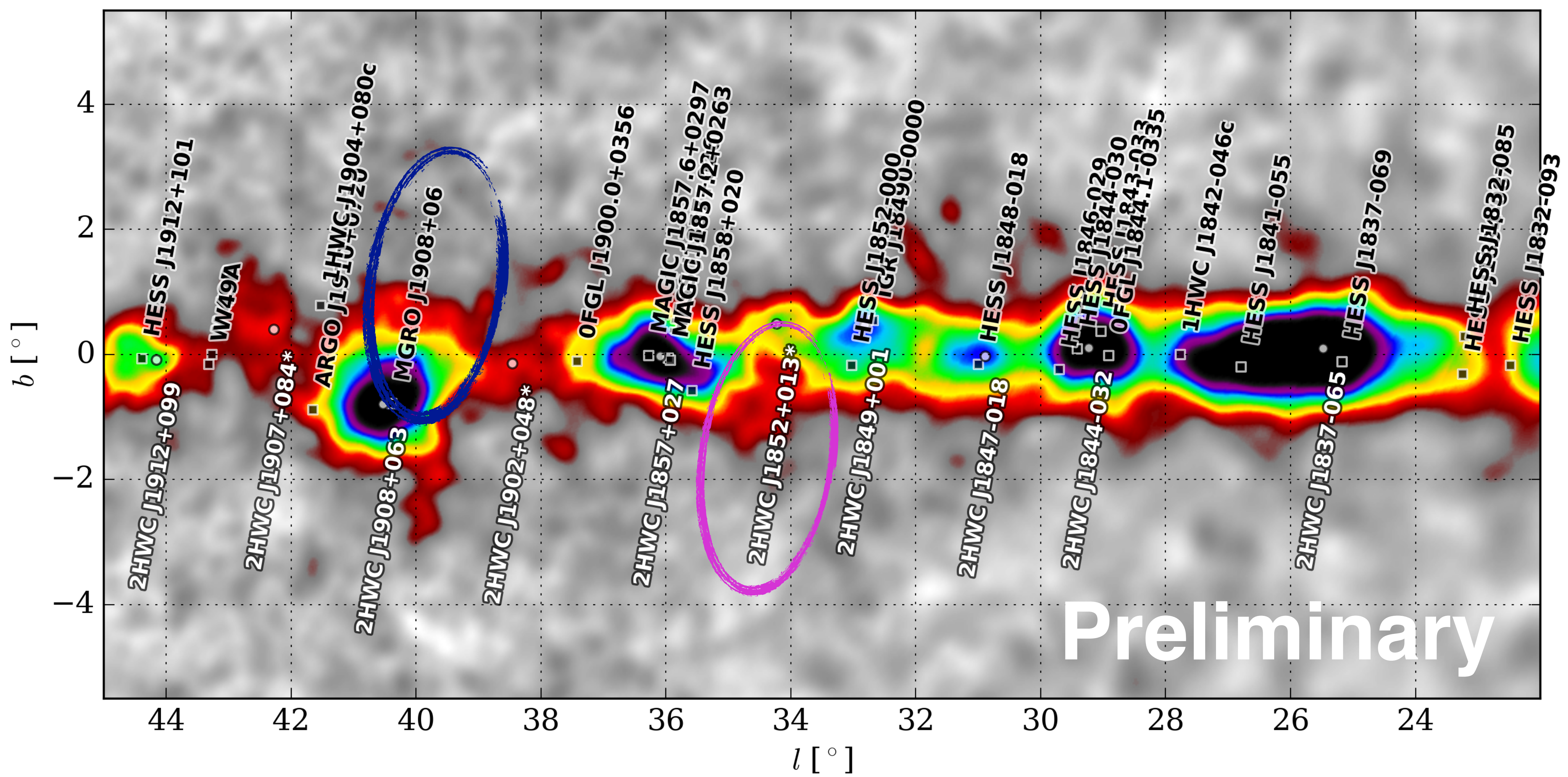


arXiv:1702.02992v1

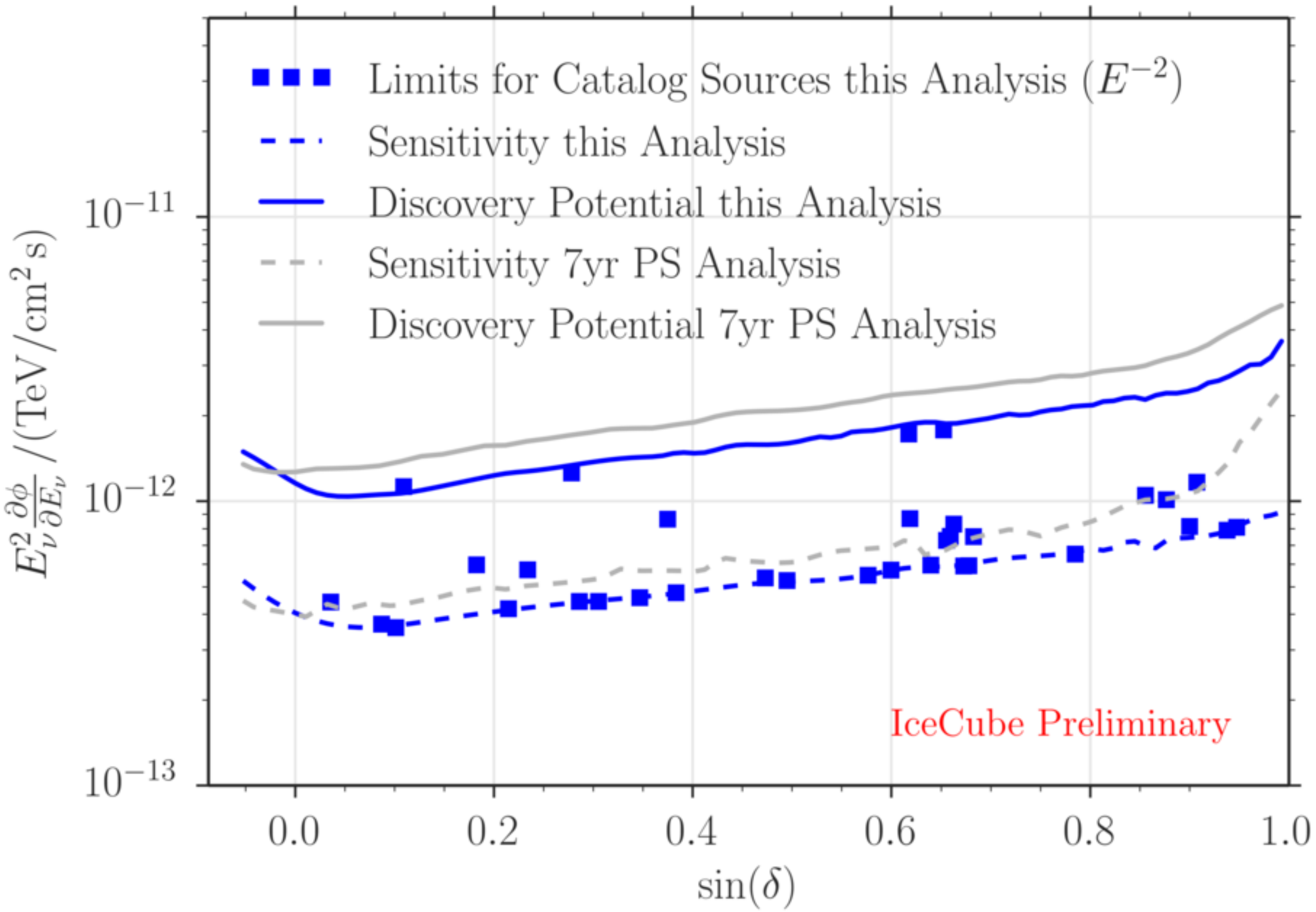
HAWC:



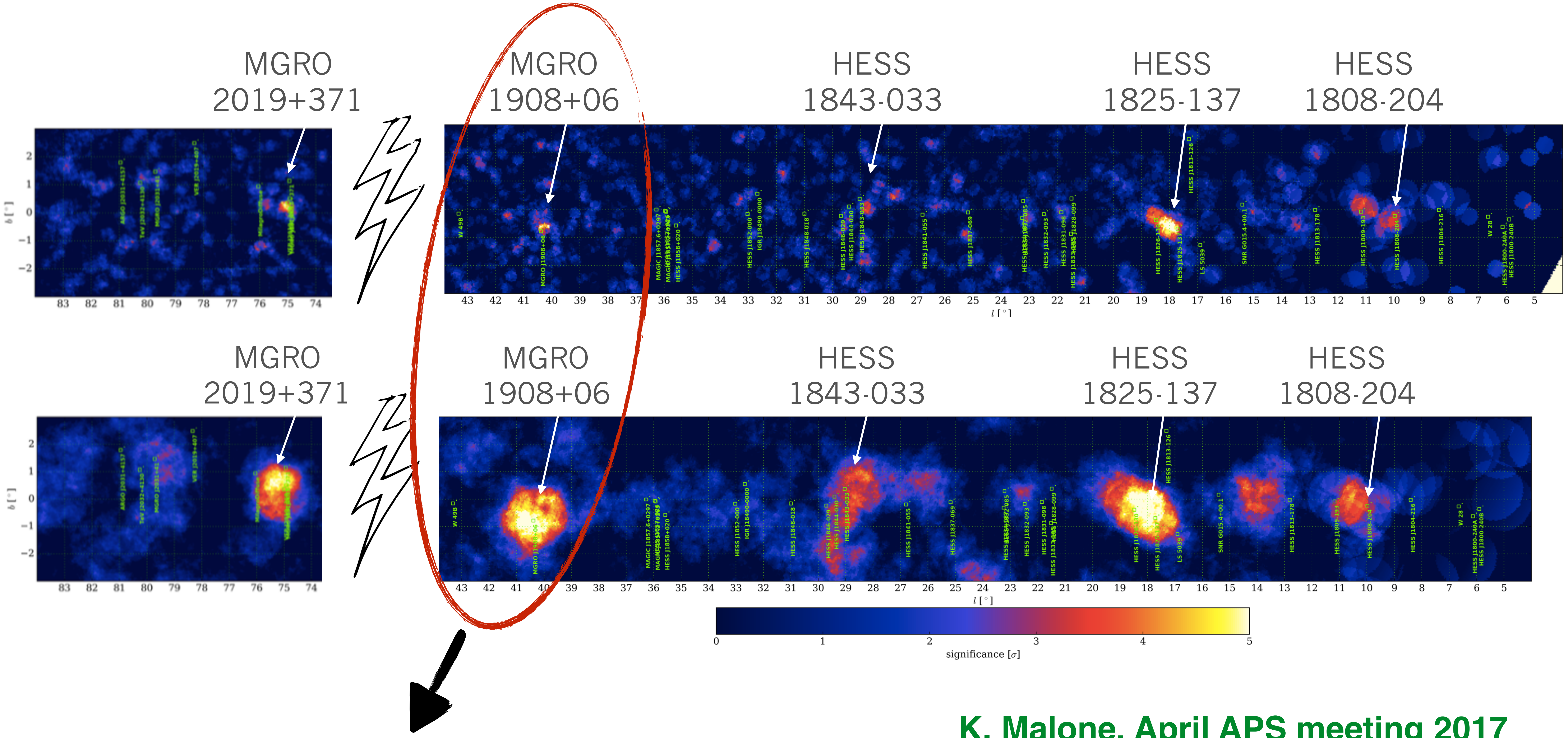
HAWC, Gamma2016 Conference



IceCube Point Source Search Sensitivity



Galactic Plane at E> 50 TeV in HAWC



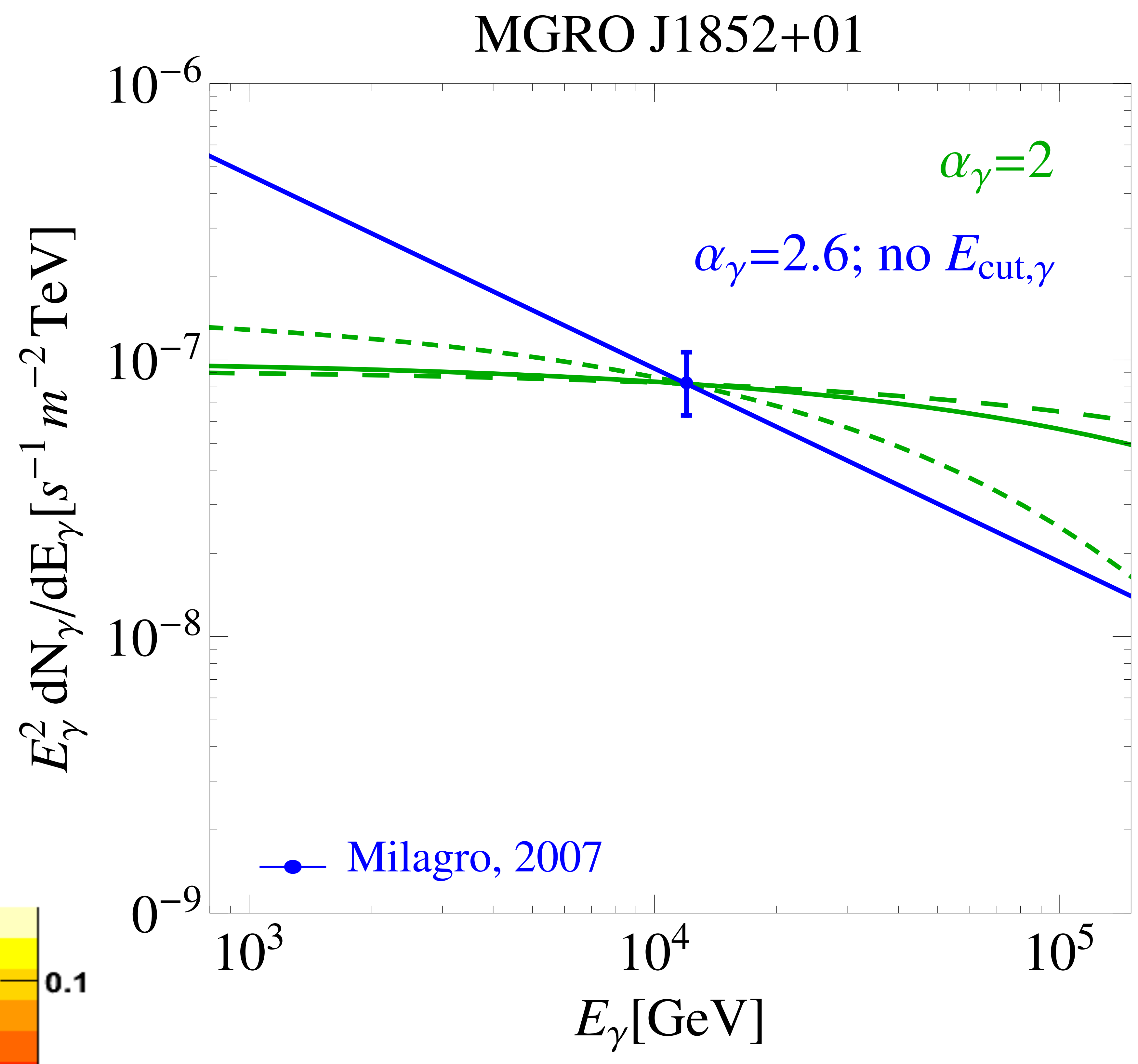
incompatible with the low-energy cut-off reported by Milagro+ARGO

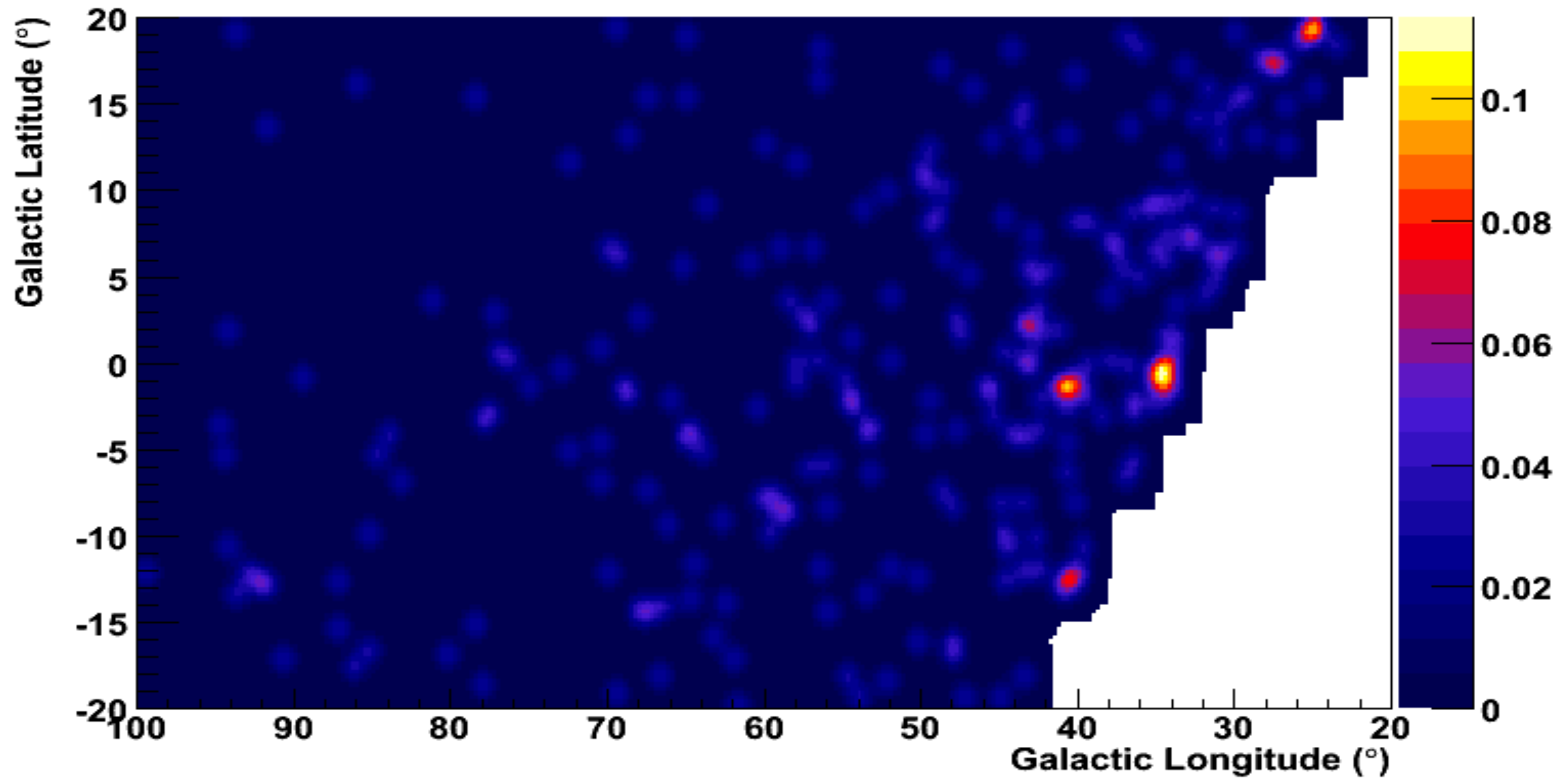
K. Malone, April APS meeting 2017

MGRO J1852+01

Milagro: This source fell below the threshold for Milagro. A relatively high flux was reported for a region of 3x3 deg.

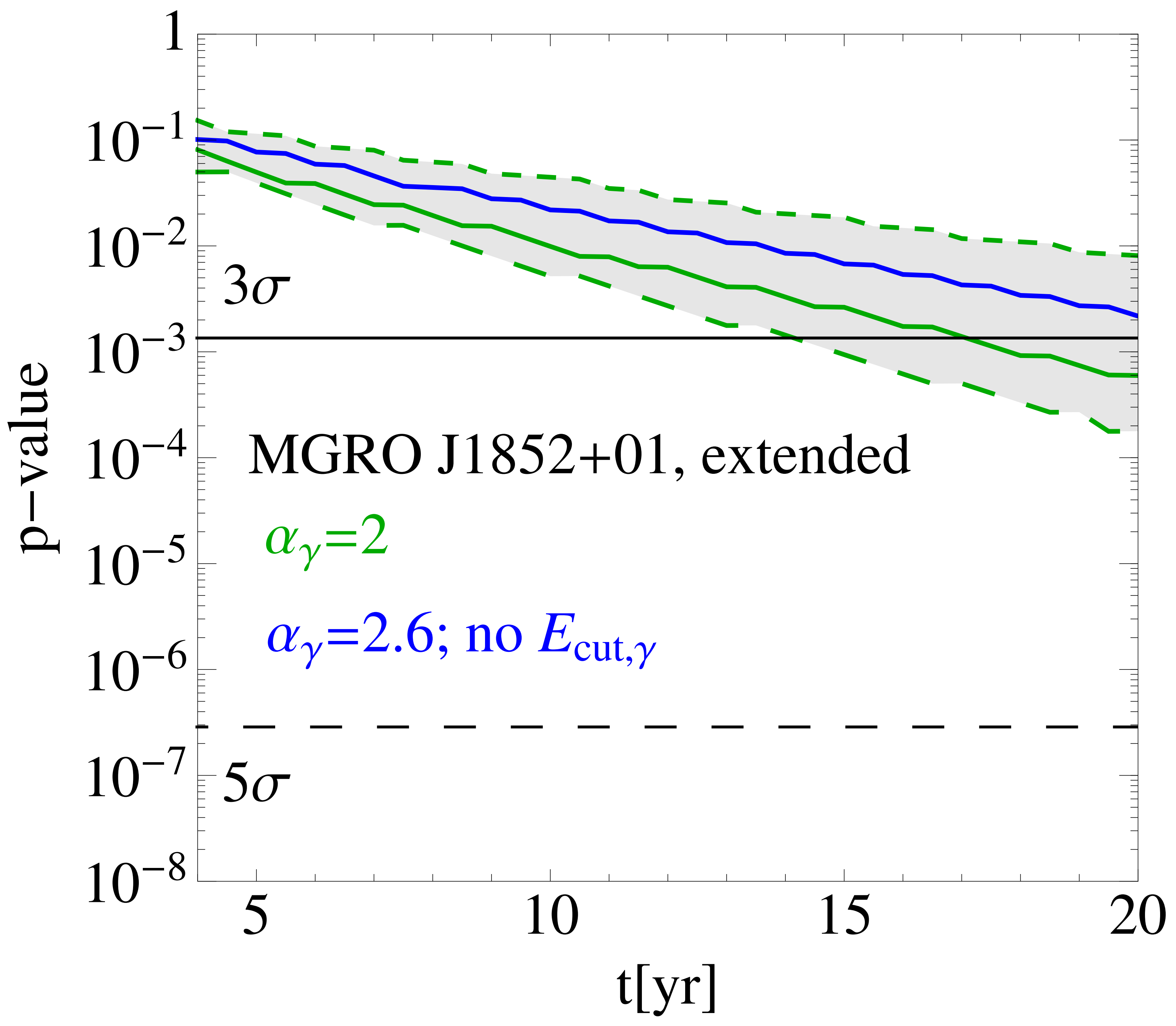
HAWC: The source is observed in HAWC 2nd catalog of TeV sources. The flux and extension estimation needs further studies.

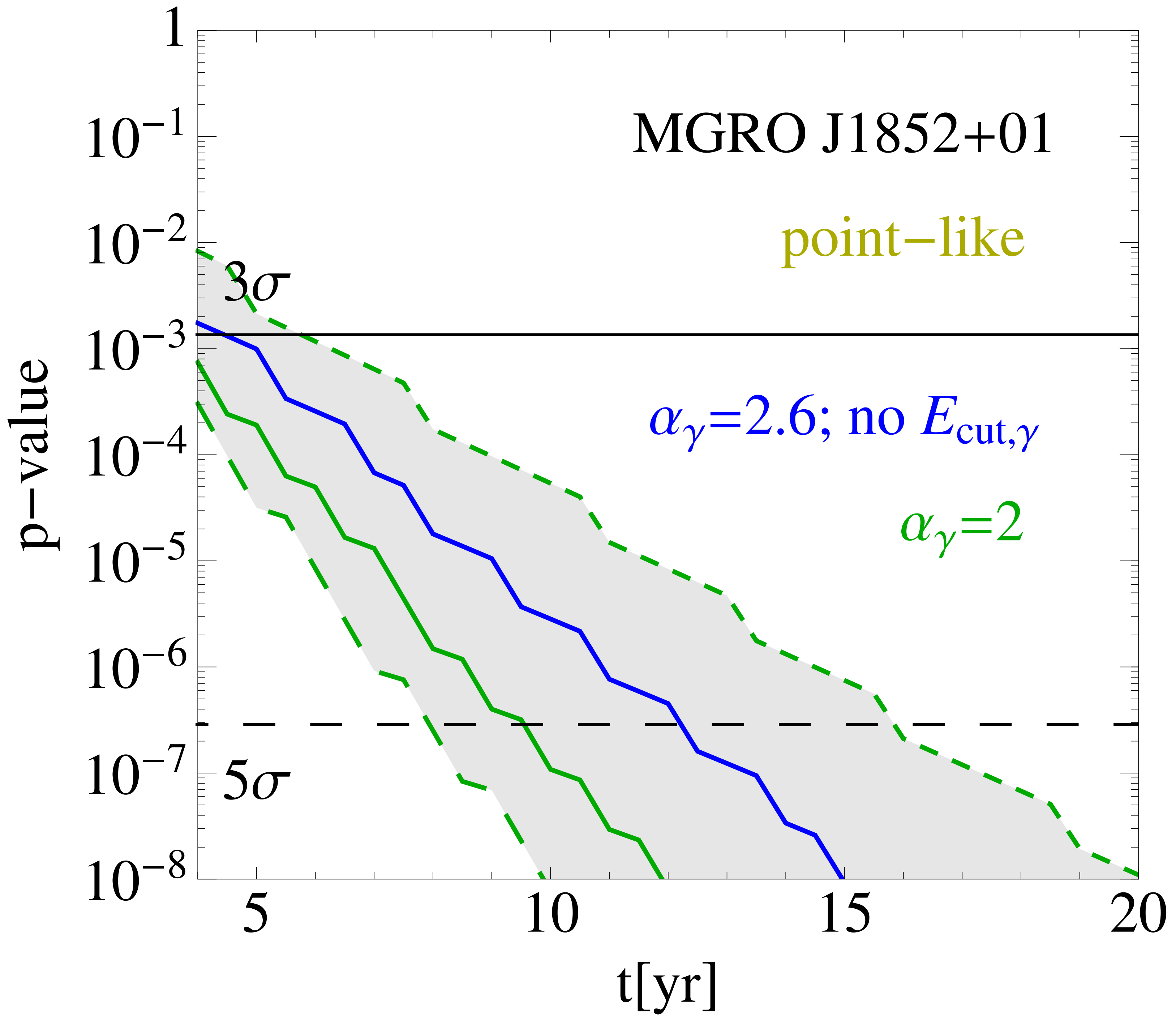




Simulated sky map of IceCube in galactic coordinates

Neutrinos from MGRO J1852+01
Milagro flux





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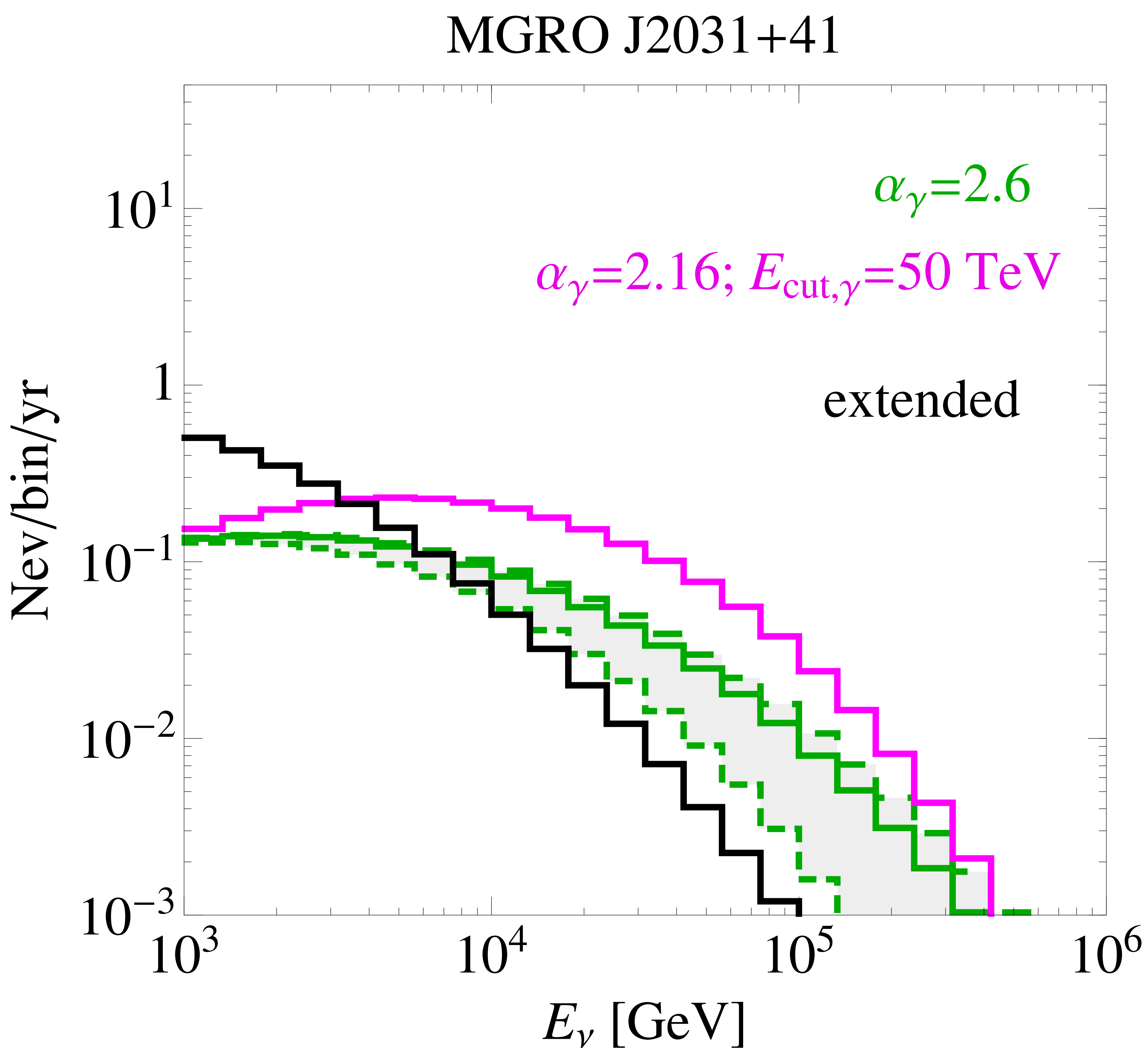
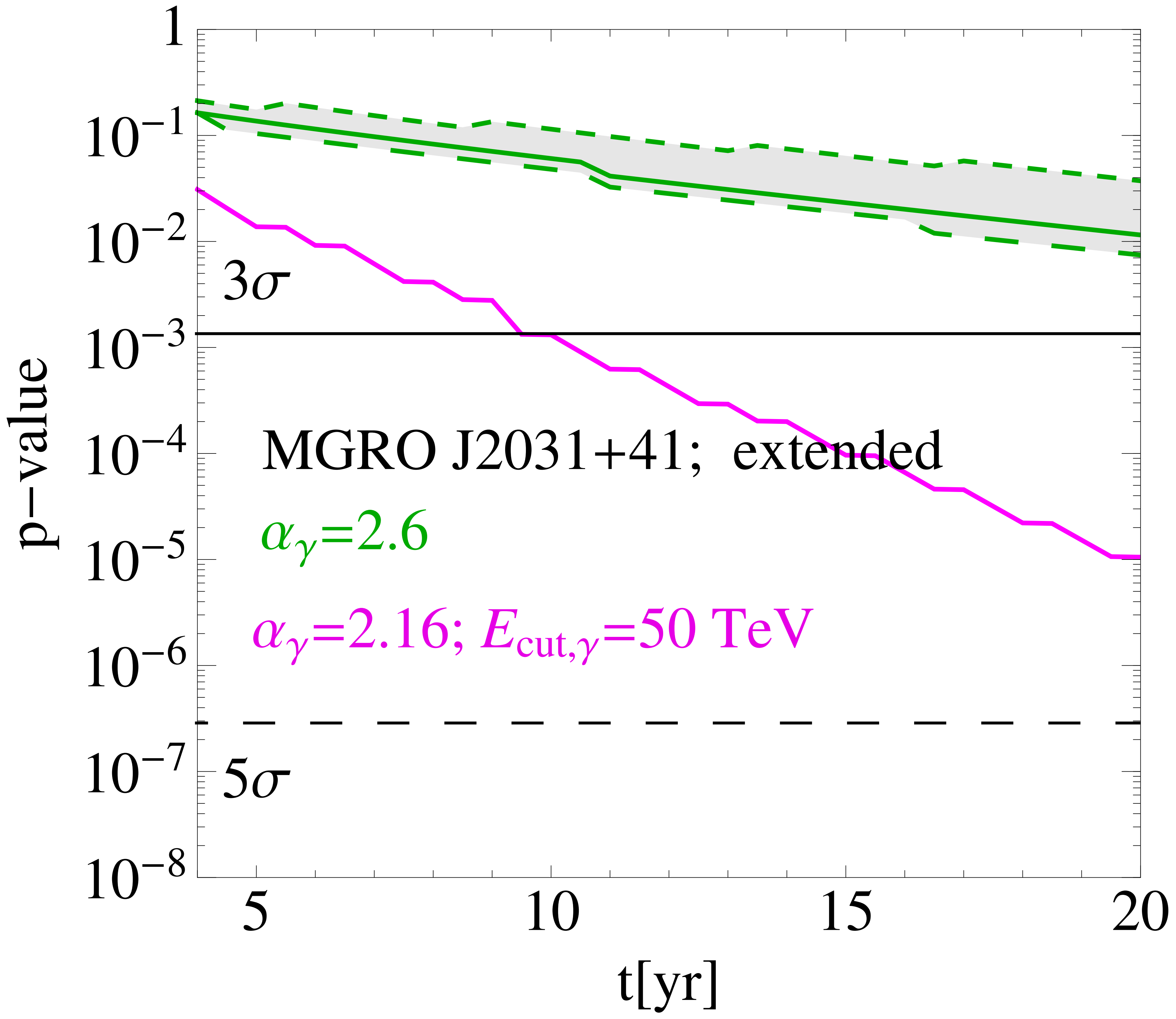
Neutrinos from MGRO J2031+43
ARGO-YJB and Fermi flux





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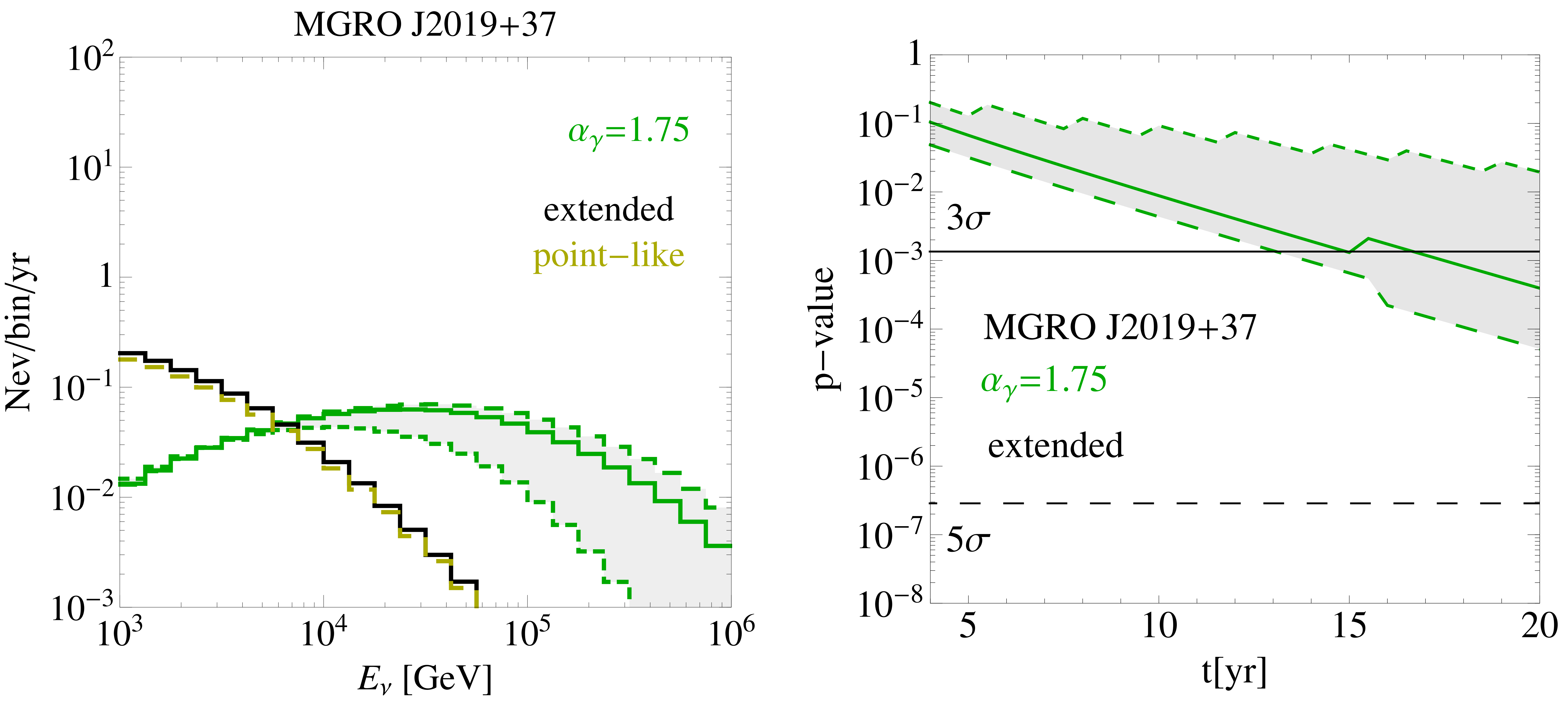
Neutrinos from MGRO J2019+37
VERITAS flux



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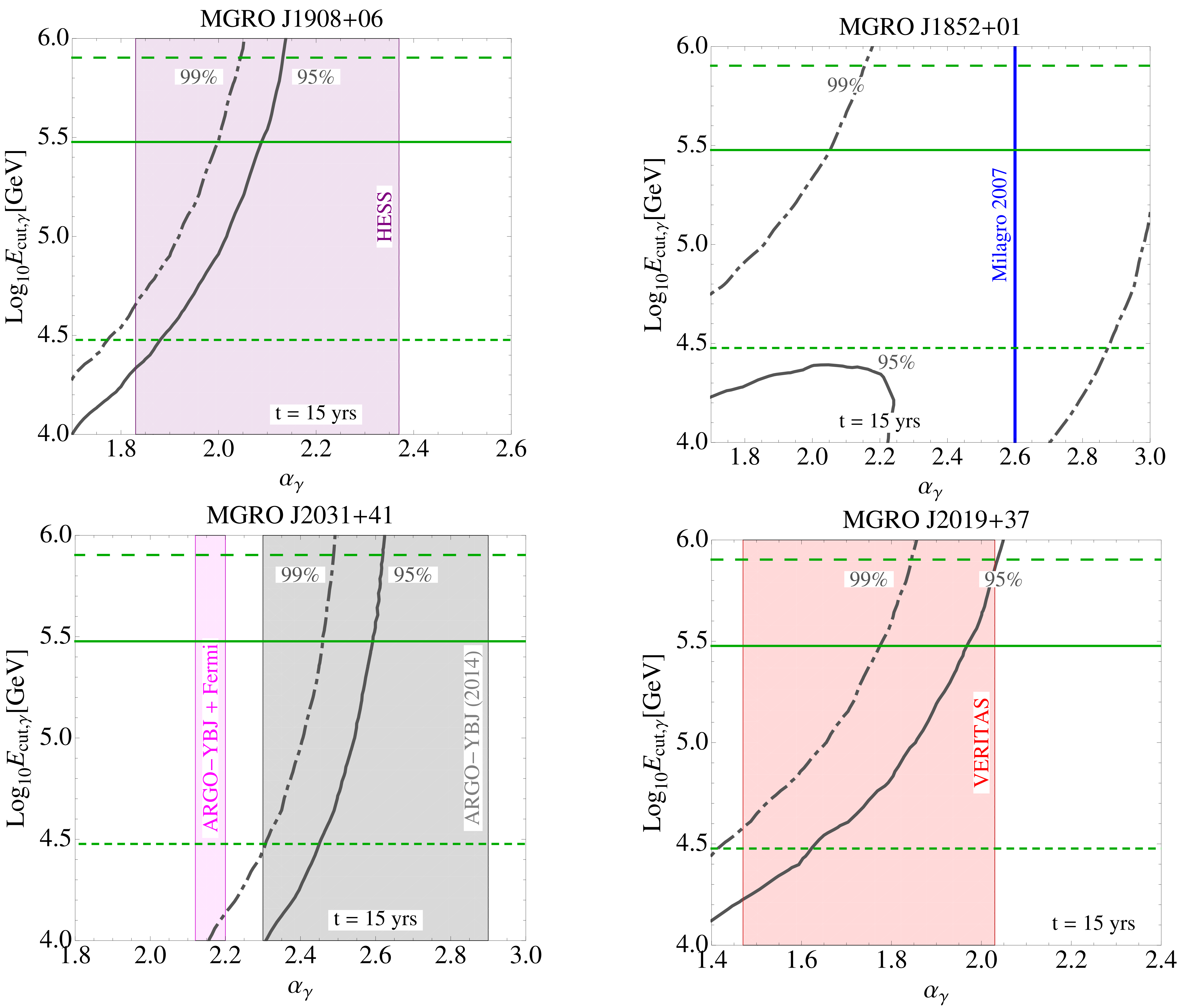
Non-Observation Constrains on Spectrum



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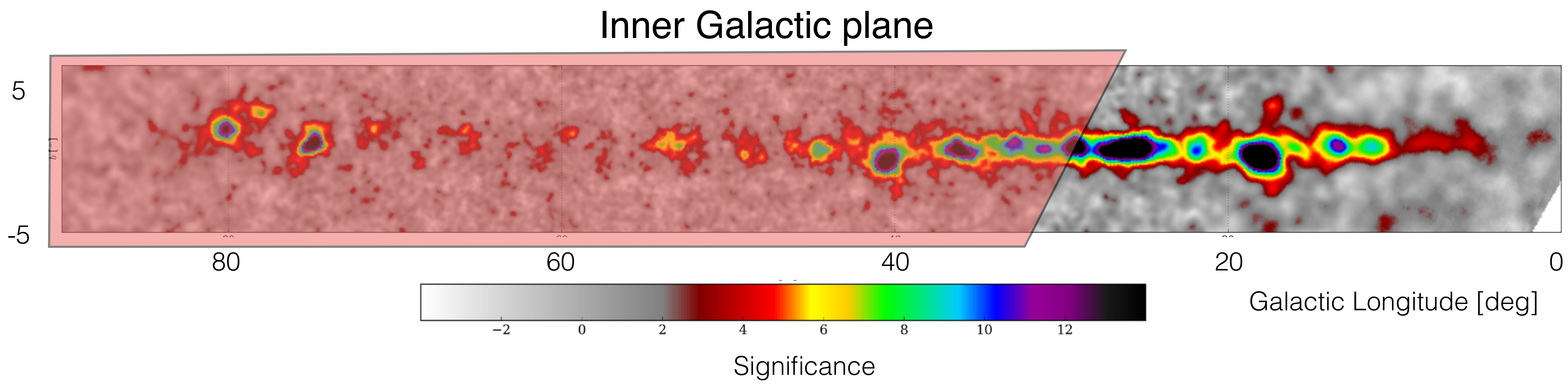
Stacked Analysis

- Stacked point source analysis with identified 2HWC
- Sources identified as pulsar wind nebula (PWN) are removed from the list: remaining Shells, Molecular clouds, Supernova remnants, and Unidentified sources, plus sources observed in HAWC for the first time
- Flux of the sources are used to do a weighted stacking:
  - -- refitting the sources spectrum as power-law with a energy cut-off at 300 TeV

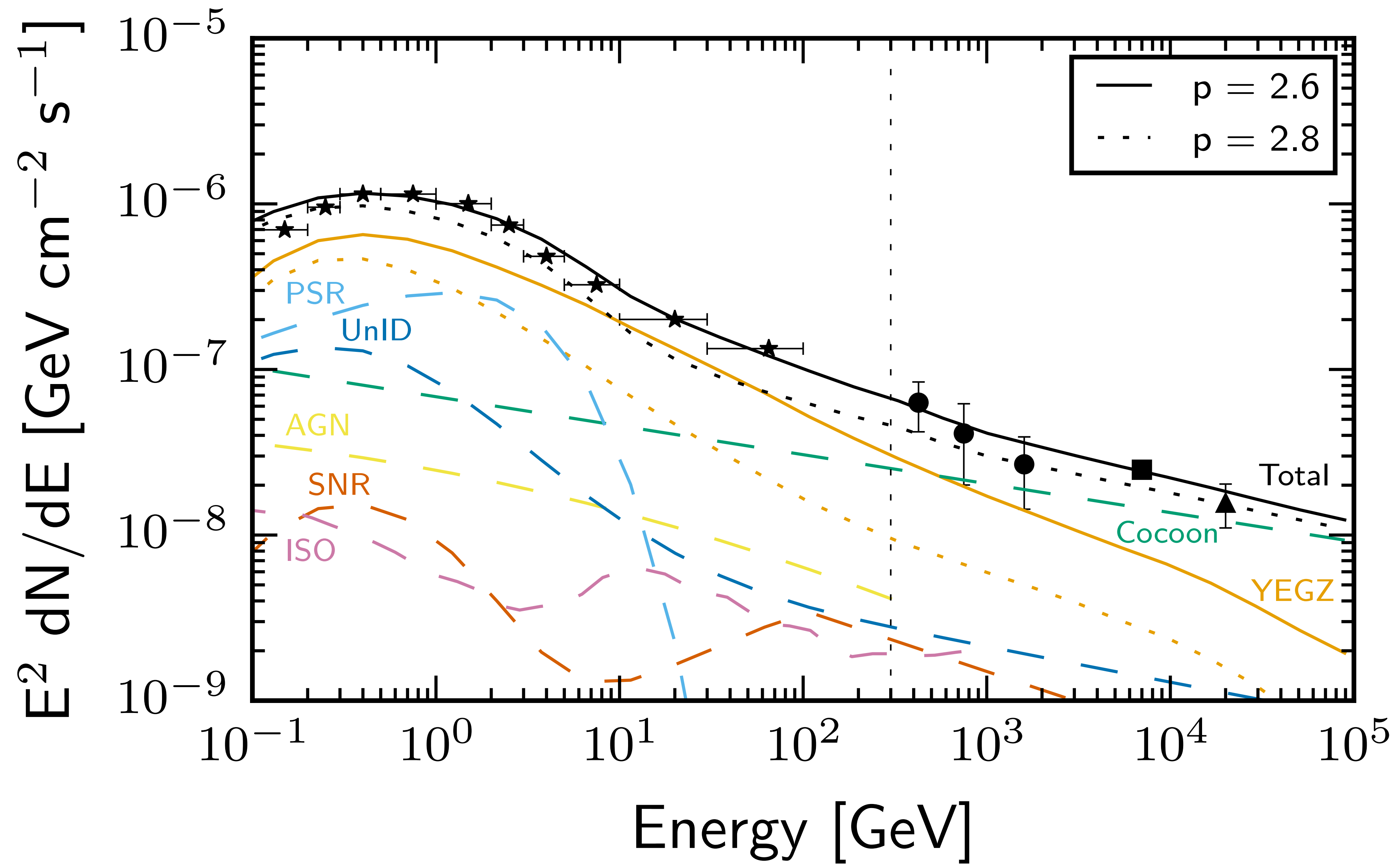
Name	Search	TS	RA [°]	Dec [°]	l [°]	b [°]	1σ stat. unc. [°]	Nearest TeVCat source: Dist. [°]	Nearest TeVCat source: Name
~~2HWC J0534+220~~	PS	1.1E+4	83.63	22.02	184.55	-5.78	0.06	0.01	Crab
~~2HWC J0631+169~~	PS	29.6	98.00	17.00	195.61	3.51	0.11	0.39	Geminga
~~2HWC J0635+180~~	PS	27.4	98.83	18.05	195.04	4.70	0.13	0.97	Geminga
~~2HWC J0700+143~~	1.0°	29	105.12	14.32	201.10	8.44	0.80	2.98	-
2HWC J0819+157	0.5°	30.7	124.98	15.79	208.00	26.52	0.17	7.86	-
2HWC J1040+308	0.5°	26.3	160.22	30.87	197.59	61.31	0.22	8.77	-
~~2HWC J1104+381~~	PS	1.15E+3	166.11	38.16	179.95	65.05	0.06	0.04	Markarian 421
~~2HWC J1309-054~~	PS	25.3	197.31	-5.49	311.11	57.10	0.22	3.27	-
~~2HWC J1653+397~~	PS	556	253.48	39.79	63.64	38.85	0.07	0.03	Markarian 501
~~2HWC J1809-190~~	PS	85.5	272.46	-19.04	11.33	0.18	0.17	0.31	HESS J1809-193
~~2HWC J1812-126~~	PS	26.8	273.21	-12.64	17.29	2.63	0.19	0.14	HESS J1813-126
~~2HWC J1814-173~~	PS	141	273.52	-17.31	13.33	0.13	0.18	0.54	HESS J1813-178
~~2HWC J1819-150*~~	PS	62.9	274.83	-15.06	15.91	0.09	0.16	0.51	SNR G015.4+00.1
~~2HWC J1825-134~~	PS	767	276.46	-13.40	18.12	-0.53	0.09	0.39	HESS J1826-130
~~2HWC J1829+070~~	PS	25.3	277.34	7.03	36.72	8.09	0.10	8.12	-
~~2HWC J1831-098~~	PS	107	277.87	-9.90	21.86	-0.12	0.17	0.01	HESS J1831-098
~~2HWC J1837-065~~	PS	549	279.36	-6.58	25.48	0.10	0.06	0.37	HESS J1837-069
2HWC J1844-032	PS	309	281.07	-3.25	29.23	0.11	0.10	0.18	HESS J1844-030
2HWC J1847-018	PS	132	281.95	-1.83	30.89	-0.03	0.11	0.17	HESS J1848-018
~~2HWC J1849+001~~	PS	134	282.39	0.11	32.82	0.47	0.10	0.16	IGR J18490-0000
2HWC J1852+013*	PS	71.4	283.01	1.38	34.23	0.50	0.13	1.37	-
2HWC J1857+027	PS	303	284.33	2.80	36.09	-0.03	0.06	0.14	HESS J1857+026
2HWC J1902+048*	PS	31.7	285.51	4.86	38.46	-0.14	0.18	2.03	-
2HWC J1907+084*	PS	33.1	286.79	8.50	42.28	0.41	0.27	1.15	-
2HWC J1908+063	PS	367	287.05	6.39	40.53	-0.80	0.06	0.14	MGRO J1908+06
2HWC J1912+099	PS	83.2	288.11	9.93	44.15	-0.08	0.10	0.24	HESS J1912+101
2HWC J1914+117*	PS	33	288.68	11.72	46.00	0.25	0.13	1.64	-
2HWC J1921+131	PS	30.1	290.30	13.13	47.99	-0.50	0.12	1.14	-
2HWC J1922+140	PS	49	290.70	14.09	49.01	-0.38	0.11	0.10	W 51
2HWC J1928+177	PS	65.7	292.15	17.78	52.92	0.14	0.07	1.18	-
2HWC J1930+188	PS	51.8	292.63	18.84	54.07	0.24	0.12	0.03	SNR G054.1+00.3
2HWC J1938+238	PS	30.5	294.74	23.81	59.37	0.94	0.13	2.75	-
2HWC J1949+244	1.0°	34.9	297.42	24.46	61.16	-0.85	0.71	3.43	-
2HWC J1953+294	PS	30.1	298.26	29.48	65.86	1.07	0.24	8.44	-
2HWC J1955+285	PS	25.4	298.83	28.59	65.35	0.18	0.14	7.73	-
2HWC J2006+341	PS	36.9	301.55	34.18	71.33	1.16	0.13	3.61	-
~~2HWC J2019+367~~	PS	390	304.94	36.80	75.02	0.30	0.09	0.07	VER J2019+368
2HWC J2020+403	PS	59.7	305.16	40.37	78.07	2.19	0.11	0.40	VER J2019+407
2HWC J2024+417*	PS	28.4	306.04	41.76	79.59	2.43	0.20	0.97	MGRO J2031+41
2HWC J2031+415	PS	209	307.93	41.51	80.21	1.14	0.09	0.08	TeV J2032+4130

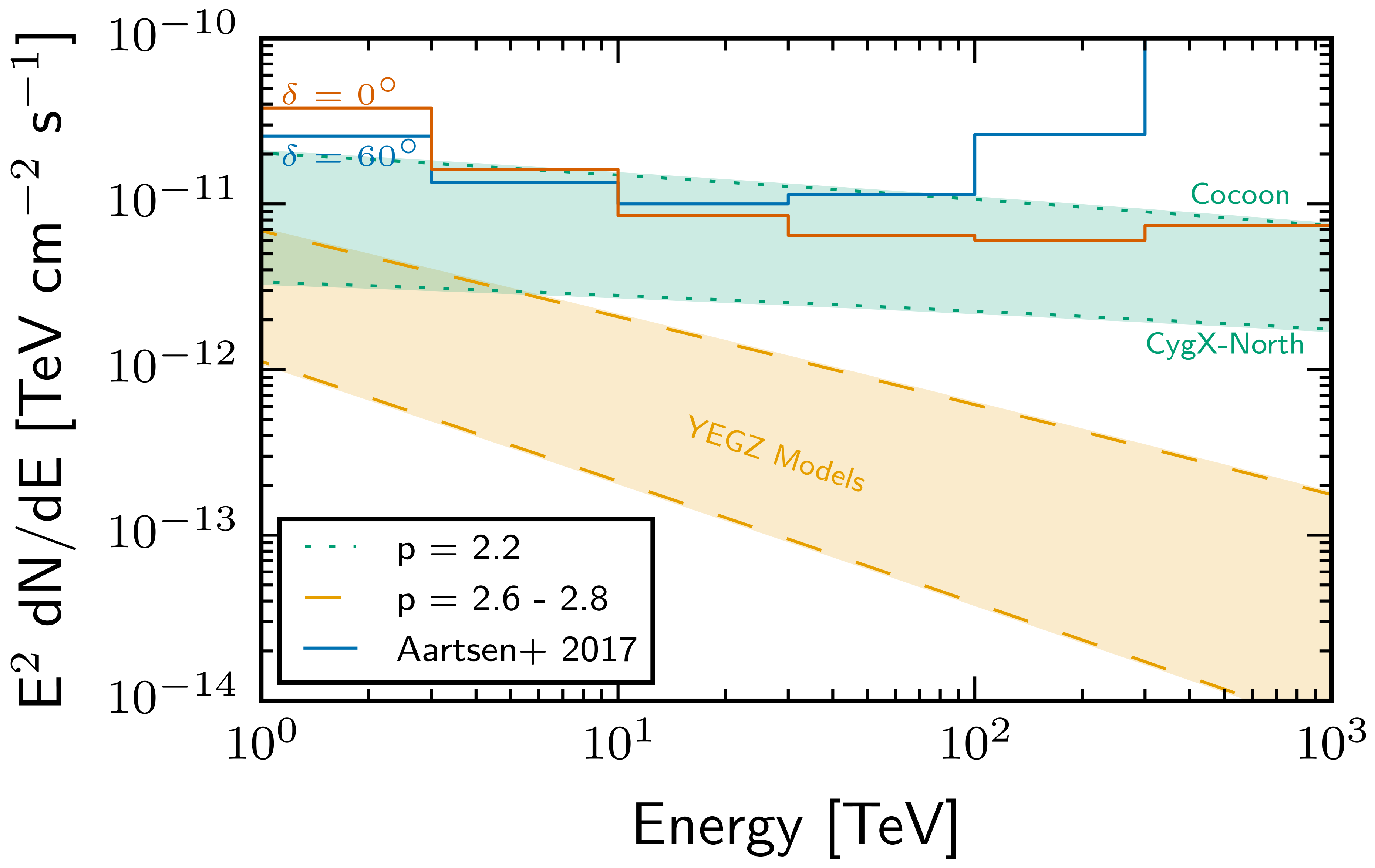
Galactic Plane Template Search



- Stacked Search using the observed gamma ray template by HAWC
- Using the observed TS as the weight
- Using Skylab and platform provided by Zach Griffiths.

Modeling the flux





- With addition of Fermi sources and emission from the cocoon, the gamma ray emission could be modeled.

- If the cocoon emission is hadronic, and extends to higher energies, it should be observed by IceCube.

T. Yoast-Hull, J. Gallagher, F. Halzen, AK,E. Zweibel, arXiv:1703.02590