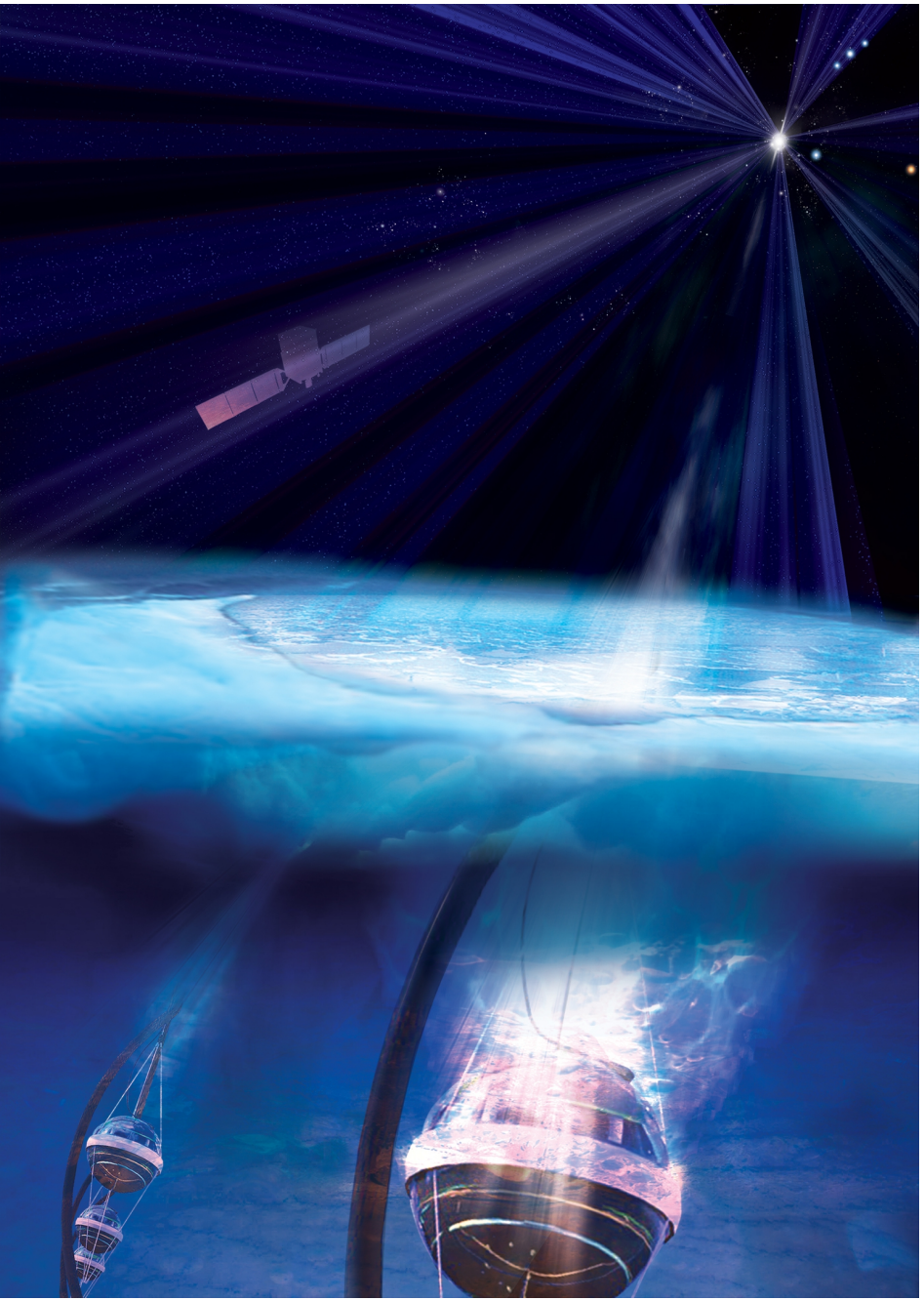


Why We Need MeV Observations

- A Neutrino Perspective -

Naoko Kurahashi Neilson
(Drexel University)

AAS2021 MeV Astronomy Splinter Meeting
January 11, 2021

This is from the perspective of <u>experimental</u> neutrino astronomy

Many great theoretical arguments exist such as:

Gao, S., Pohl, M., & Winter, W. 2017, ApJ, 843, 109

Keivani, A., Murase, K., Petropoulou, M., et al. 2018, ApJ, 864, 84

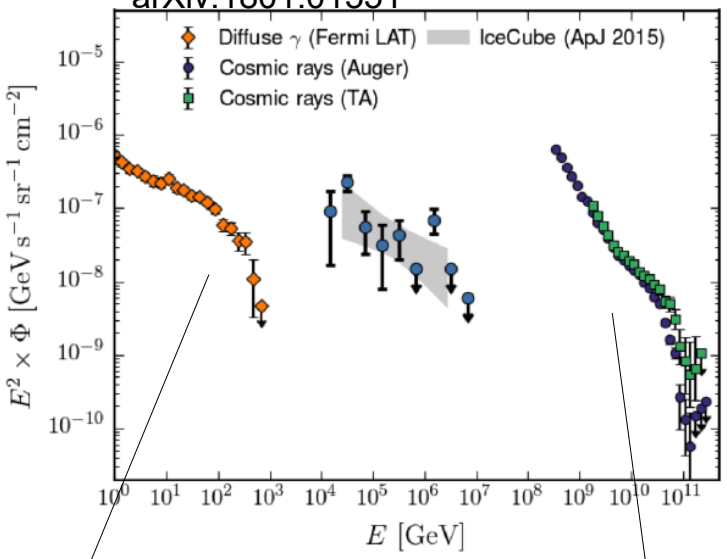
Murase, K., Oikonomou, F., & Petropoulou, M. 2018, ApJ, 865, 124

Murase, K., Kimura, S. S., & Mészáros, P., 2020, Phys. Rev. Lett. 125, 011101

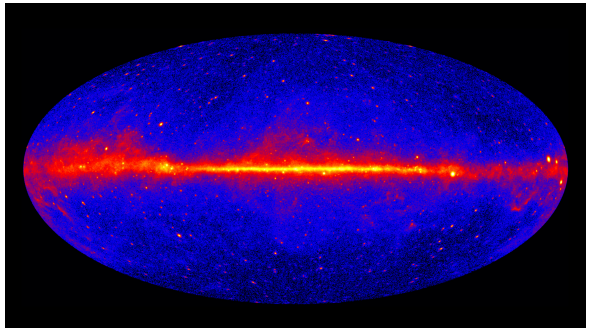
Why neutrinos for MMA?

Neutrinos only choice to bridge the gap between gamma rays and ultra-high-energy cosmic-rays

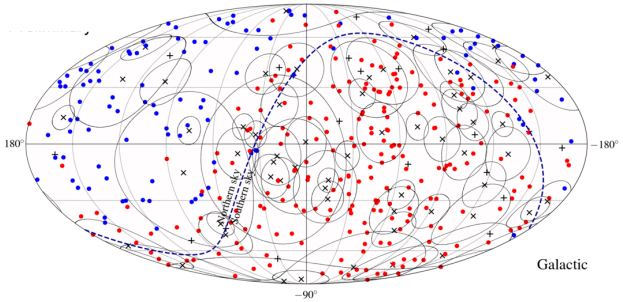
arXiv:1801.01551



1. Energy gap between gamma rays and UHECR (gamma-ray absorption on IR background)



svs.gsfc.nasa.gov



JCAP01(2016)037

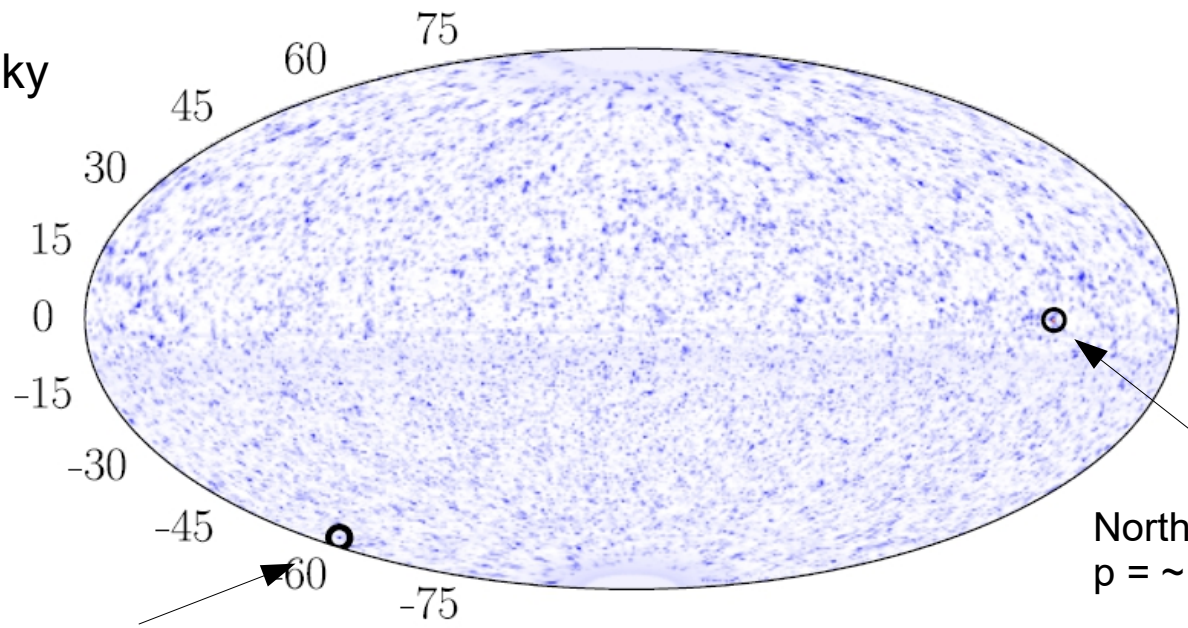
2. Cover gap between resolved universe in EM and unresolved in CR (deflects in magnetic field)

We haven't discovered neutrino sources yet*

*3 caveats coming

IceCube: Phys. Rev. Lett. 124 (2020) 051103
ANTARES: Astrophys. J. 786 (2014) L5

IceCube Neutrino Sky



Northern Sky Hottest Spot
p = ~10%

Southern Sky Hottest Spot
p = ~75%

We don't know what source population makes the neutrinos flux

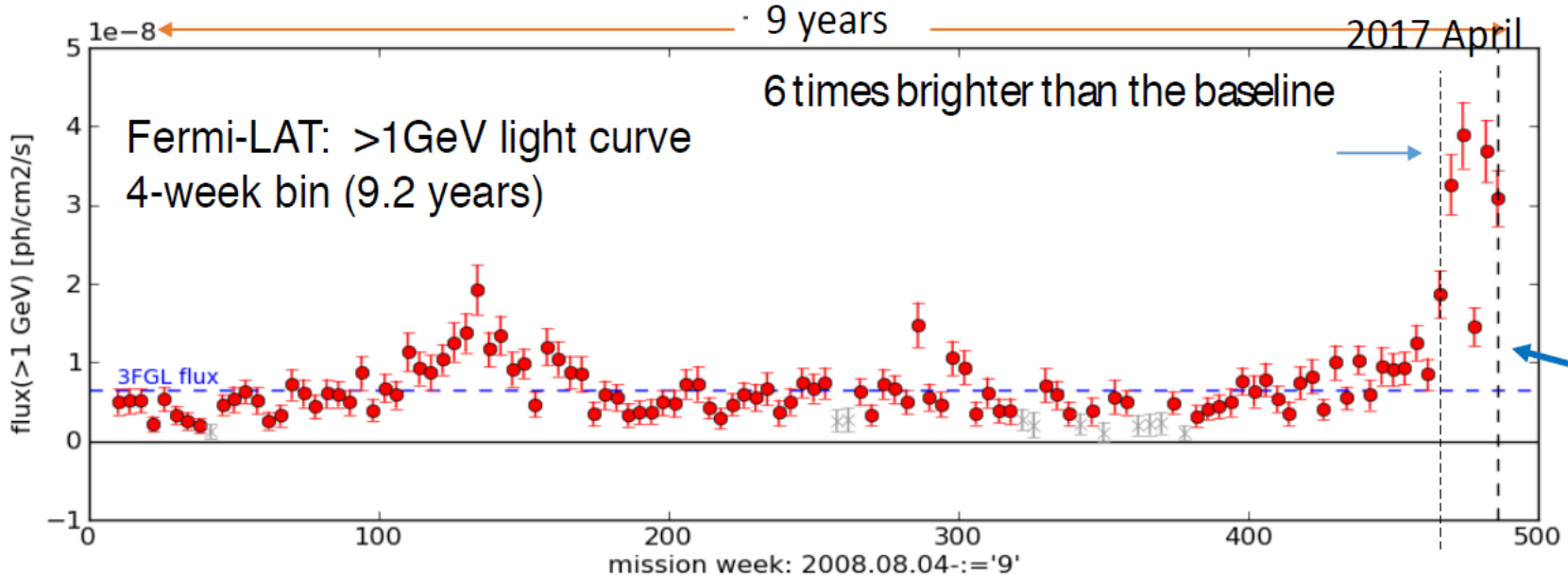
limits in terms of % of neutrino diffuse flux

		Upper limit in diffuse flux	notes
Blazars		~ 17%	862 from Fermi 2nd AGN cat. Spectral index = -2.5
Nearby Starburst Galaxies		~ 8%	127 nearby Spectral index = -2
Galactic Sources	Young SNR	~ 5%	30 with no PWN or MC Spectral index = -2
	Young PWN	~ 3%	10 with no MC Spectral index = -2
Galactic Plane		~14%	Fermi Diffuse γ Spatial template Spectral index = -2.5 to -2.7
GRBs		~1%	506 bursts observed Spectral index = -2 to -2.7

Astrophys.J. 796:10 (2014), ApJ, 805, L5 (2015)

Caveat 1: TXS 0506+056

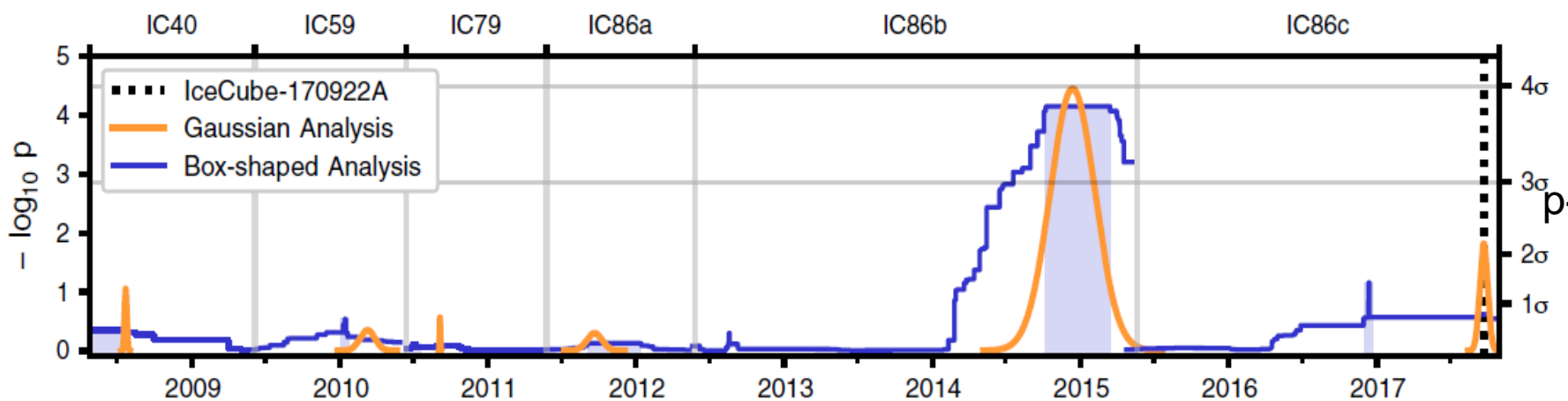
a) Multi-messenger Coincidence (Science 361 (2018) eaat1378)



p-value = 3σ

IceCube 170922A

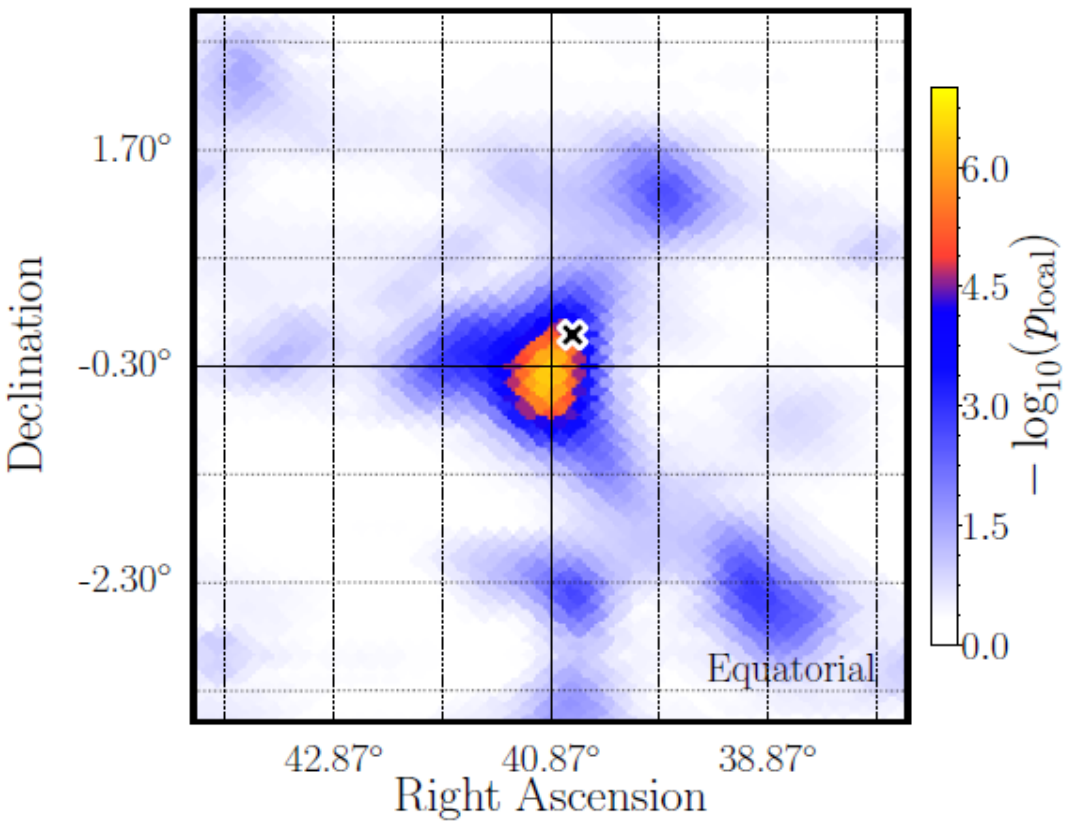
b) Archival neutrino search (Science 361 (2018) 147-151)



p-value = 3.5σ

Caveat 2: NGC 1068

IceCube: Phys. Rev. Lett. 124 (2020) 051103

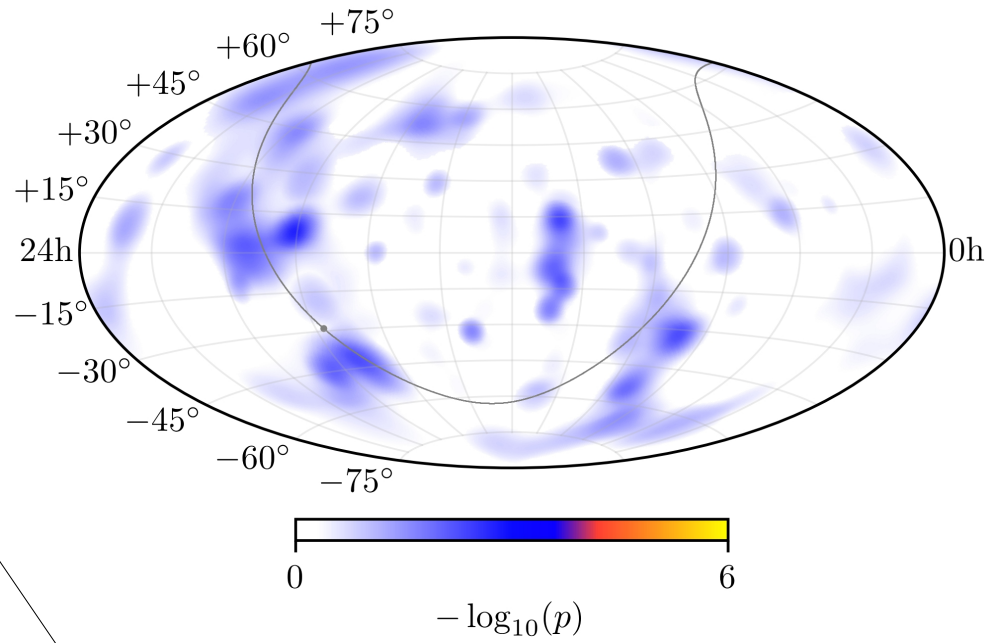


- Starburst Galaxy
- Seyfert II
- 14 Mpc
- AGN-driven particle accelerator
  (A. Lamastra, et al, Astr. & Astrop. 596 (2016))

p-value = 0.2% (~2.9 σ)

weak Caveat 3: Diffuse Galactic Plane

Astrophys. J. 886 (2019) 12



2.1%

Template	7yr Cascades p-value	7yr Cascades Sensitivity	7yr Cascades Fitted Flux	7yr Cascades UL	Previous Work p-value	Previous Work Sensitivity	Previous Work Fitted Flux	Previous Work UL
KRA_γ^5	0.021	0.58	0.85	1.7	0.29	0.81	0.47	1.19
KRA_γ^{50}	0.022	0.35	0.65	0.97	0.26	0.57	0.37	0.90
Fermi-LAT π^0	0.030	2.5	3.3	6.6	0.37	2.97	1.28	3.83

Gaggero, D., Grasso, D., Marinelli, A., Taoso, M., & Urbano, A. Phys. Rev. Lett., (2017) 119

Ackermann, M., Ajello, M., Atwood, W. B., et al. ApJ (2012) 750

IceCube Cascades
Astrophys. J. 886 (2019) 12

IceCube Tracks + ANTARES Tracks and Cascades
Astrophys. J. 868 (2018) L20

Notice all 3 caveat analyses rely on Fermi-LAT observations!

IceCube publications from point source working group, 2018-2020

IceCube Search for Neutrinos Coincident with Compact Binary Mergers from LIGO-Virgo's First Gravitational-wave Transient Catalog
Astrophys.J.Lett. 898 (2020) 1, L10, Astrophys.J. 898 (2020) 1, L10

IceCube Search for High-Energy Neutrino Emission from TeV Pulsar Wind Nebulae.
Astrophys.J. 898 (2020) 2, 117

ANTARES and IceCube Combined Search for Neutrino Point-like and Extended Sources in the Southern Sky
Astrophys.J. 892 (2020), 92

A search for IceCube events in the direction of ANITA neutrino candidates
Astrophys. J., 892 (2020), 1

Constraints on neutrino emission from nearby galaxies using the 2MASS redshift survey and IceCube
JCAP 07 (2020), 042

Time-Integrated Neutrino Source Searches with 10 Years of IceCube Data
Phys.Rev.Lett. 124 (2020) 5, 051103

A Search for Neutrino Point-source Populations in 7 yr of IceCube Data with Neutrino-count Statistics
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Astrophys.J. 890 (2020) 2, 111

Search for Sources of Astrophysical Neutrinos Using Seven Years of IceCube Cascade Events
Astrophys.J. 886 (2019), 12

Neutrinos below 100 TeV from the southern sky employing refined veto techniques to IceCube data
Astropart.Phys. 116 (2020), 102392

Investigation of two Fermi-LAT gamma-ray blazars coincident with high-energy neutrinos detected by IceCube
Astrophys.J. 880 (2019) 2, 880:103

Search for transient optical counterparts to high-energy IceCube neutrinos with Pan-STARRS1
Astron.Astrophys. 626 (2019), A117

Search for steady point-like sources in the astrophysical muon neutrino flux with 8 years of IceCube data
Eur.Phys.J.C 79 (2019) 3, 234

Search for Multimessenger Sources of Gravitational Waves and High-energy Neutrinos with Advanced LIGO during Its First Observing Run, ANTARES, and IceCube
Astrophys.J. 870 (2019) 2, 134

Joint Constraints on Galactic Diffuse Neutrino Emission from the ANTARES and IceCube Neutrino Telescopes
Astrophys.J.Lett. 868 (2018) 2, L20, Astrophys.J. 868 (2018) 2, L20

Constraints on minute-scale transient astrophysical neutrino sources
Phys.Rev.Lett. 122 (2019) 5, 051102

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A
Science 361 (2018) no.6398, eaat1378

Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert
Science 361 (2018) no.6398, 147-151.

A Search for Neutrino Emission from Fast Radio Bursts with Six Years of IceCube Data
Astrophys.J. 857 (2018) no.2, 117..

IceCube publications from point source working group, 2018-2020 that uses Fermi-LAT data

IceCube Search for Neutrinos Coincident with Compact Binary Mergers from LIGO-Virgo's First Gravitational-wave Transient Catalog
Astrophys.J.Lett. 898 (2020) 1, L10, Astrophys.J. 898 (2020) 1, L10

IceCube Search for High-Energy Neutrino Emission from TeV Pulsar Wind Nebulae.
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Astrophys.J. 857 (2018) no.2, 117..

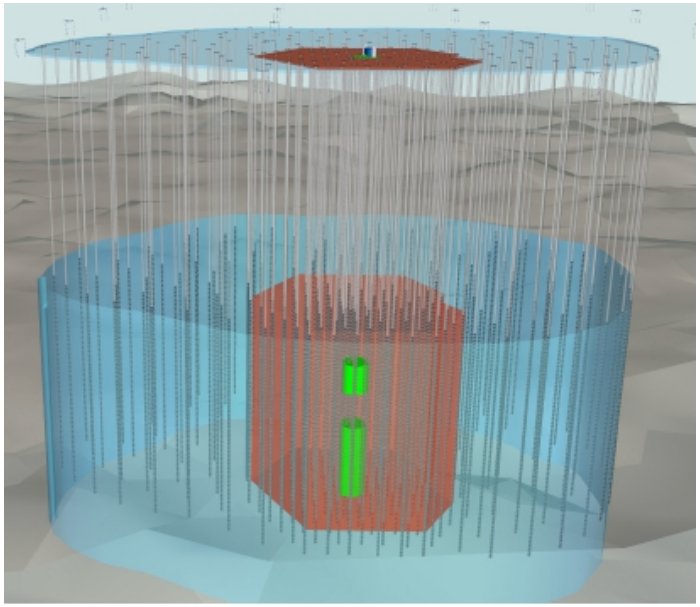
Takeaways here:

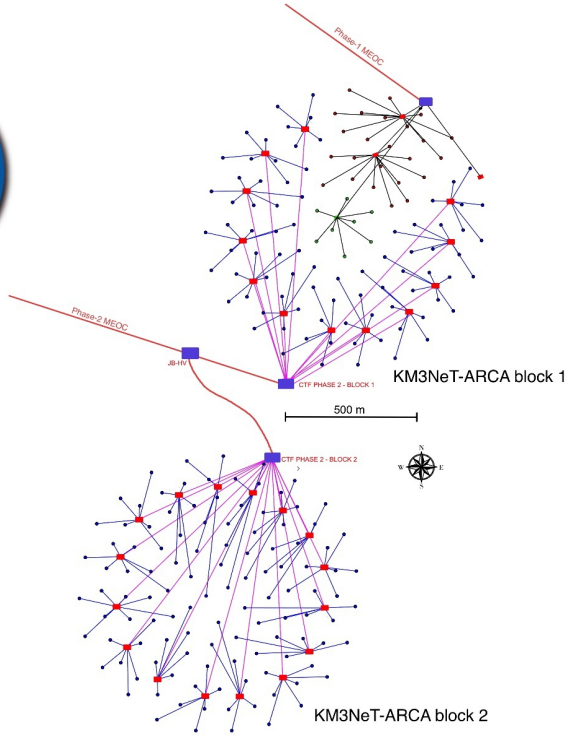
1. Neutrino telescopes need Fermi-LAT (or another all-sky gamma-ray telescope)

2. Maybe GeV gamma not the right/only energy band for neutrino counterparts?

* For a non-hand-wavy argument, see Murase, Guetta, & Ahlers, 2016, Phys.Rev.Lett. 116, 071101

The Future of Neutrino Astronomy is Already Being Built





IceCube Gen2
Upgrade currently being built
Full Gen2 ~2026-2033 deployment?

KM3NeT
Strings being deployed since 2015
~2026 completion?

There needs to be gamma-ray observatories while neutrino telescopes are running

- Track record shows...
  - Most of IceCube's point source analyses use Fermi-LAT input
  - Interesting near-discoveries needed Fermi-LAT input
- Because Fermi is
  - An (almost) all-sky instrument that is
  - On all the time

- What about IACTs? (great but insufficient)
  What about what source type it is? You seem to have glossed over that entirely? (I would argue it doesn't matter)
  What's the best energy for this gamma observatory (MeV-GeV)
  What's the best time scale? (5-10 years to overlap with future neutrino telescopes)

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