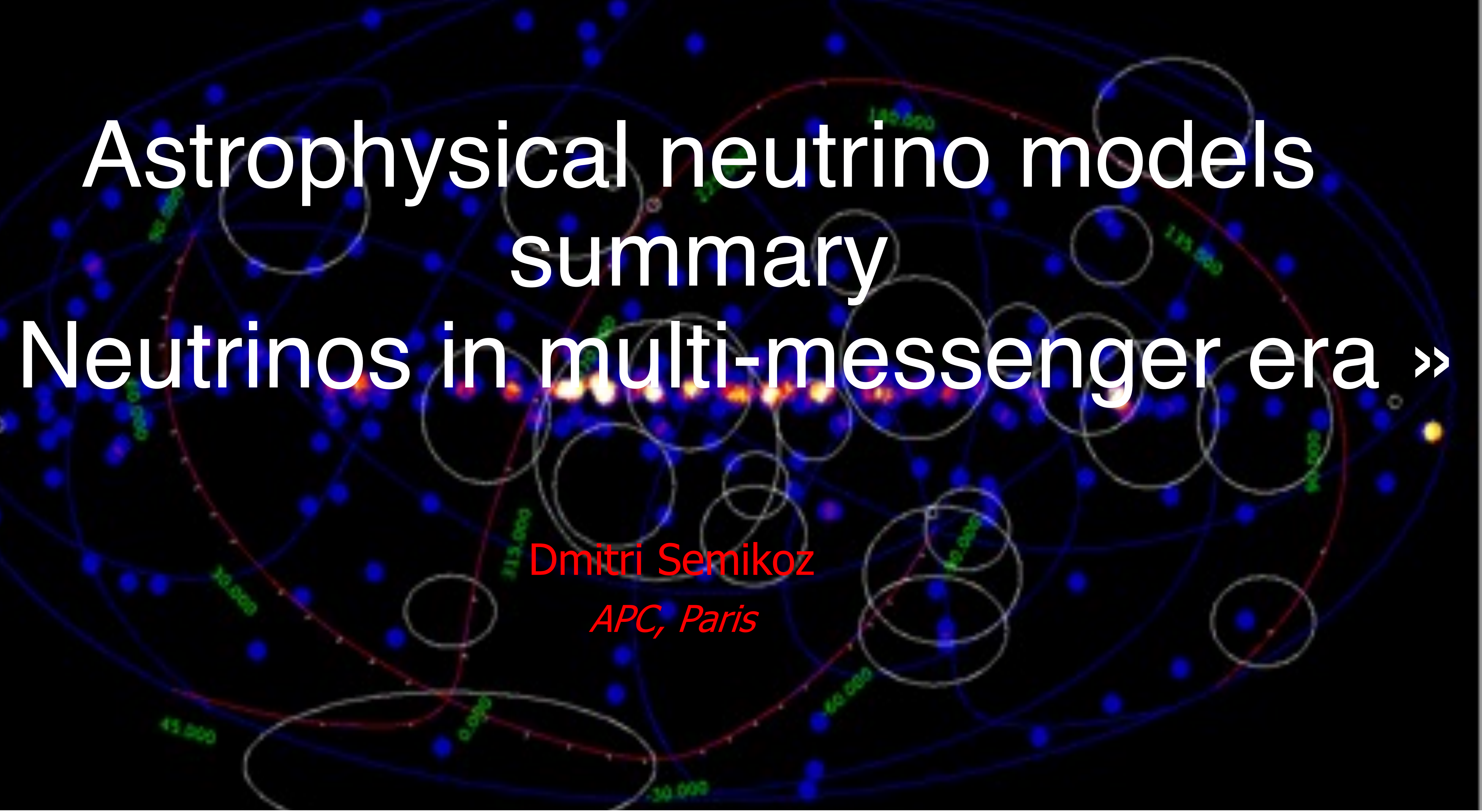


Astrophysical neutrino models summary

Neutrinos in multi-messenger era »

Dmitri Semikoz

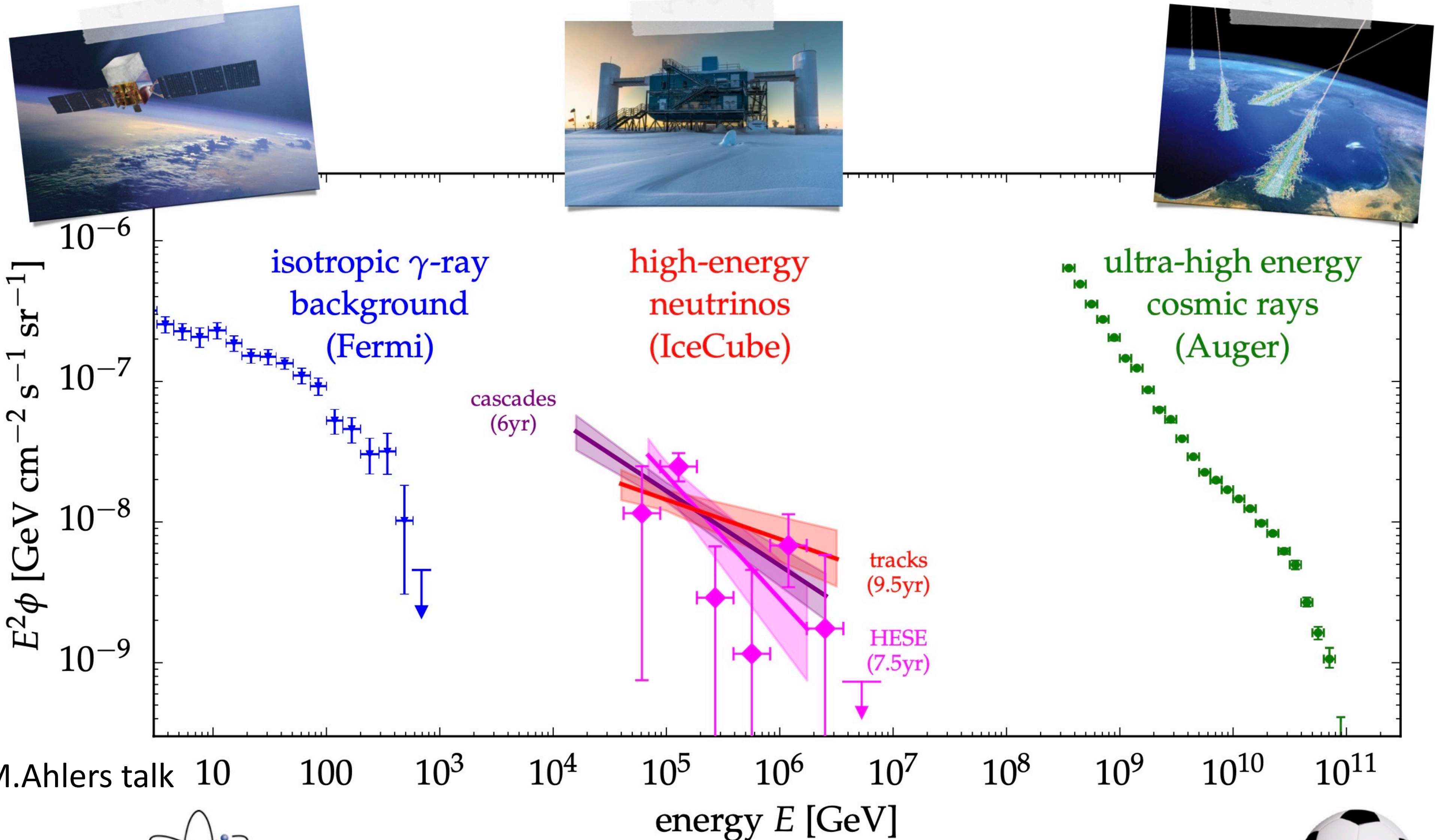
APC, Paris

Plan

- Extragalactic diffuse neutrino flux
- Blazar sources: TXS 0506+056: 270 TeV 1/E^2
- AGN core, NGC 1068 TeV flux 1/E^3
- Transient: TDE, SN
- GRB models
- Diffuse flux galactic: Galactic ridge
- Cyg region
- Binaries
- Beyond Standard Model
- Conclusions

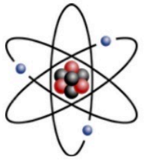
Extragalactic Diffuse neutrino flux

Diffuse TeV-PeV Neutrinos



Blasars
TDE events
SN
Star burst galaxies
Gamma-ray bursts
UHECR sources
Milky Way Galaxy

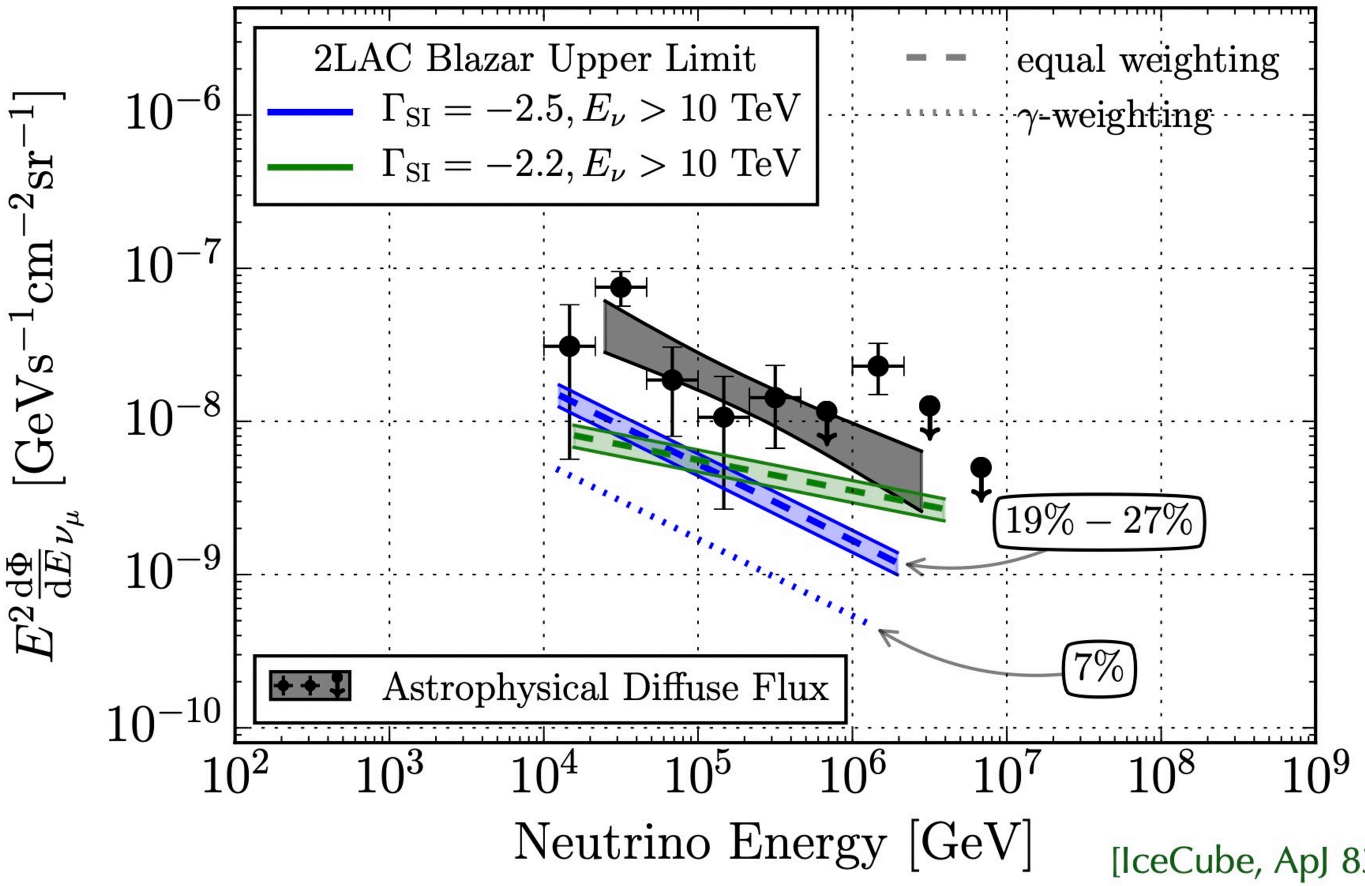
M.Ahlers talk



[IceCube, PRL 125 (2020) 12; PoS (ICRC2019) 1017; arXiv:2011.03545]

Neutrinos from blazars

Fermi-LAT Blazar Stacking



[IceCube, ApJ 835 (2017) 45]

Combined contribution of Fermi-LAT blazars (2LAC) **below 30%** of the isotropic TeV-PeV neutrino observation.

M.Ahlers talk

Neutrino from active galaxies

Looking for the population

2020: we associated neutrinos with radio blazars, Plavin+20

Before 2020: searches for gamma-ray correlation, negative results


ANTARES and IceCube Combined Search for Neutrino Point-like and Extended Sources in the Southern Sky

ANTARES Collaboration*: A. Albert[1,2], M. André[3], M. Anghinolfi[4], G. Anton[5],

Abstract

A search for point-like and extended sources of cosmic neutrinos using data collected by the ANTARES and IceCube neutrino telescopes is presented. The data set consists of all the track-like and shower-like events pointing in the direction of the Southern Sky included in the nine-year ANTARES point-source analysis, combined with the through-going track-like events used in the seven-year IceCube point-source search. The advantageous field of view of ANTARES and the large size of IceCube are exploited to improve the sensitivity in the Southern Sky by a factor ~2 compared to both individual analyses. In this work, the Southern Sky is scanned for possible excesses of spatial clustering, and the positions

AGN outflows as neutrino sources: an observational test

P. Padovani,[1,2★] A. Turcati[3] and E. Resconi[3]

A multiwavelength view of BL Lac neutrino candidates

C. Righi,[1,2,3★] F. Tavecchio[2] and L. Pacciani[4]

Accepted 2018 November 6. Received 2018 October 22; in original form 2018 July 10

ABSTRACT

The discovery of high-energy astrophysical neutrinos by IceCube kicked off a new line of research to identify the electromagnetic counterparts producing these neutrinos. Among the extragalactic sources, blazars are promising candidate neutrino emitters. Their structure, with a relativistic jet pointing to the Earth, offers a natural accelerator of particles and for this reason

AGN outflows as neutrino sources: an observational test

P. Padovani,[1,2★] A. Turcati[3] and E. Resconi[3]

Fermi/LAT counterparts of IceCube neutrinos above 100 TeV

F. Krauß[1,2], K. Deoskar[3,4,5], C. Baxter[1,5], M. Kadler[6], M. Kreter[7,6], M. Langejahn[6], K. Mannheim[6], P. Polko[8], B. Wang

Received 3 September 2018 / Accepted 17 October 2018

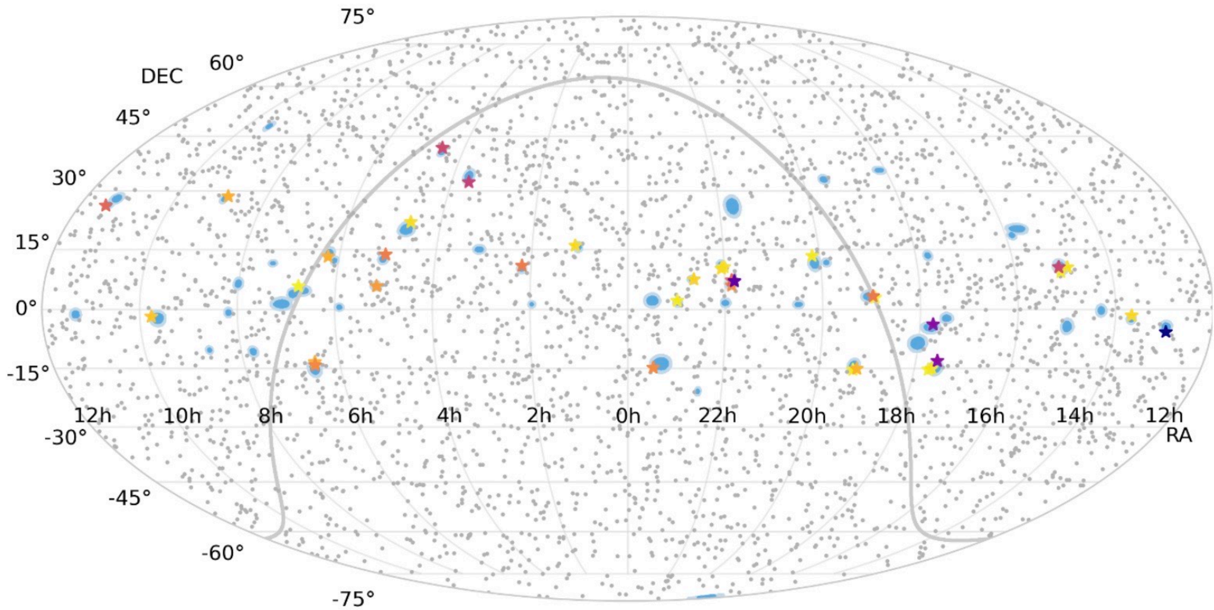
Searches for steady neutrino emission from 3FHL blazars using eight years of IceCube data from the Northern hemisphere

The IceCube Collaboration*

http://icecube.wisc.edu/collaboration/authors/icrc19_icecube

E-mail: mhuber@icecube.wisc.edu

Located at the South Pole, the IceCube Neutrino Observatory is the world largest neutrino telescope, instrumenting one cubic kilometre of Antarctic ice at a depth between 1450 m to 2450 m. In 2013 IceCube reported the first observations of a diffuse astrophysical high-energy neutrino flux. Although the IceCube Collaboration has identified more than 100 high-energy neutrino events, the origin of this neutrino flux is still not known. Blazars, a subclass of Active Galactic Nuclei and one of the most powerful classes of objects in the Universe, have long been considered promising sources of high energy neutrinos. A blazar origin of this high-energy neutrino flux can be examined using stacking methods testing the correlation between IceCube neutrinos and catalogs of hypothesized sources. Here we present the results of a stacking analysis for 1301 blazars from the third catalog of hard *Fermi*-LAT sources (3FHL). The analysis is performed on 8 years of through-going muon data from the Northern Hemisphere, recorded by

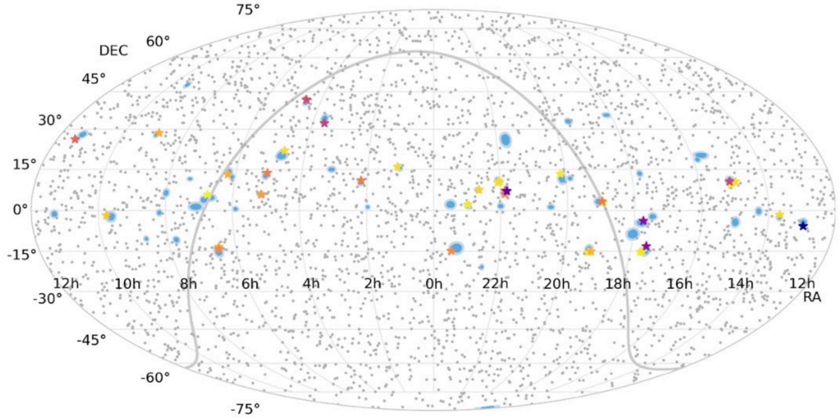


A.Plavin talk

Neutrino from active galaxies

Looking for the population

2020: we associated neutrinos with radio blazars, Plavin+20



Before 2020: searches for gamma-ray correlation, negative results

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After 2020: multiple works that connect neutrinos with various bright blazar samples

Eg: Giommi+20, Plavin+21, Hovatta+21, Aublin+22, Buson+22

Not every analysis detects a correlation: Zhou+21, Desai+21

A.Plavin talk

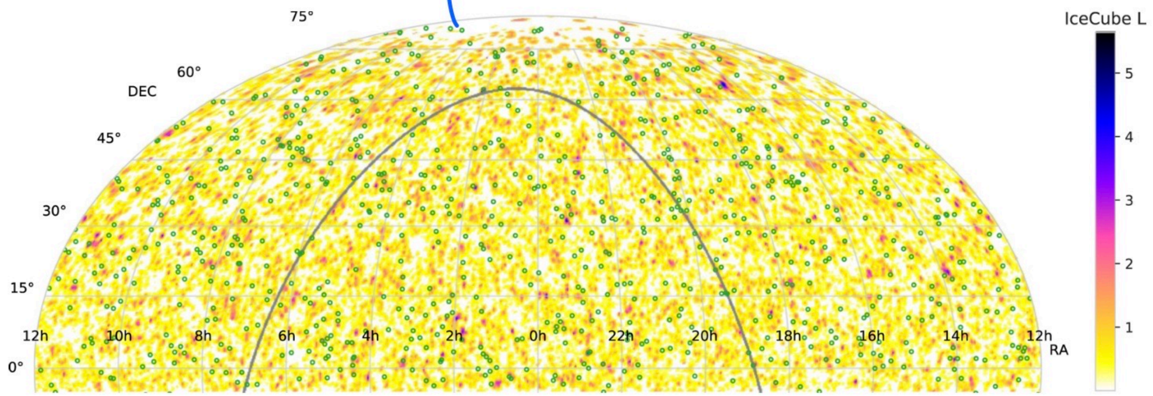
Radio blazar – neutrino association

Ver. 2022

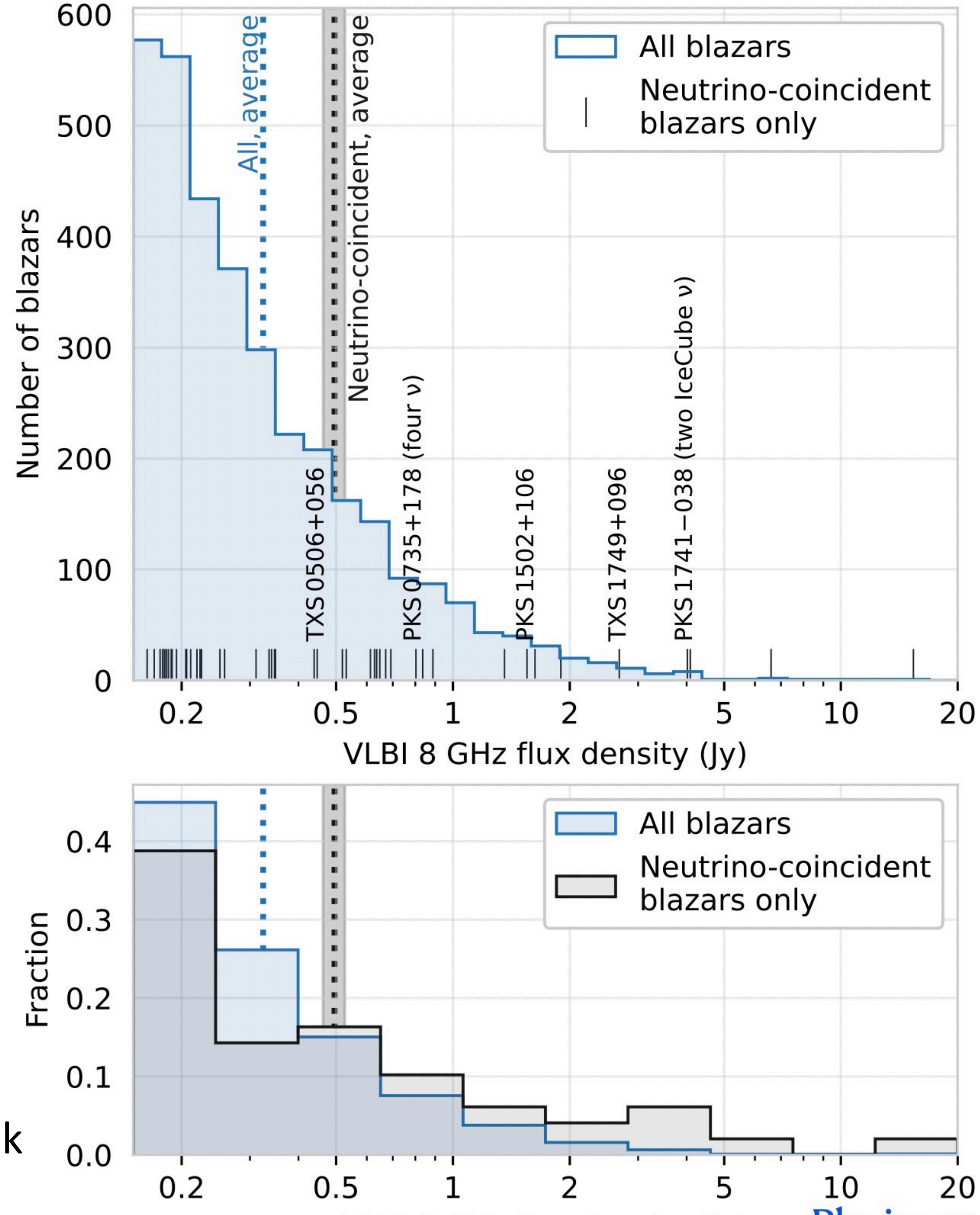
Result: average radio flux is higher for blazars around neutrinos!
$p=3\cdot10^{-4}$ (3.6 σ)

For comparison, in 2020 (56 evts): $p=2\cdot10^{-3}$

Together with independent TeV+ analysis (Plavin+21): $p=2\cdot10^{-5}$ (4.3 σ)



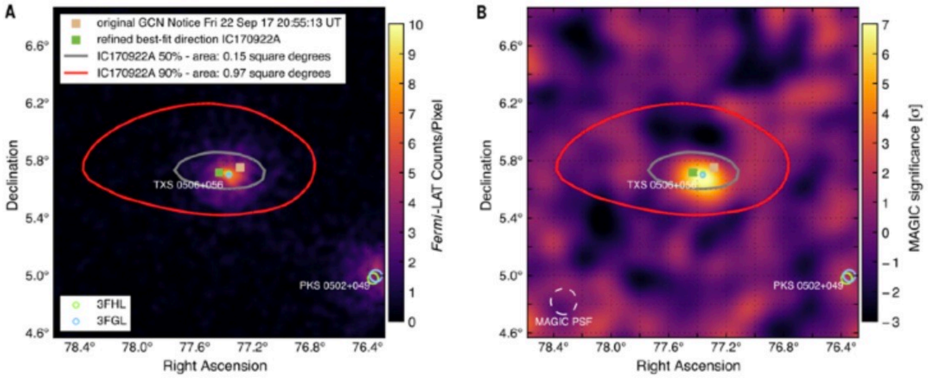
A.Plavin talk

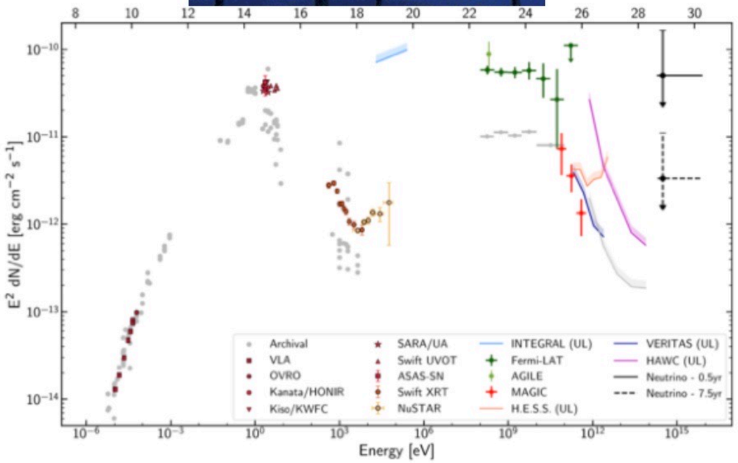


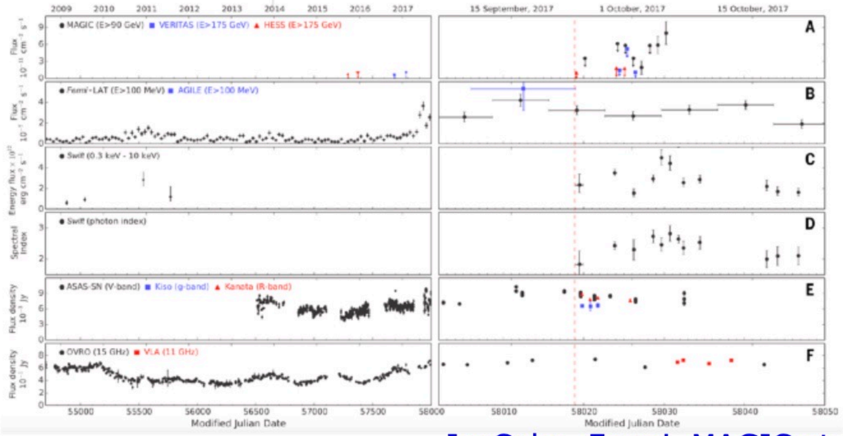
Plavin+22

IceCube-170922A / TXS 0506+056

Most significant association (3σ)
of a high-energy (290 TeV) neutrino with an astrophysical source

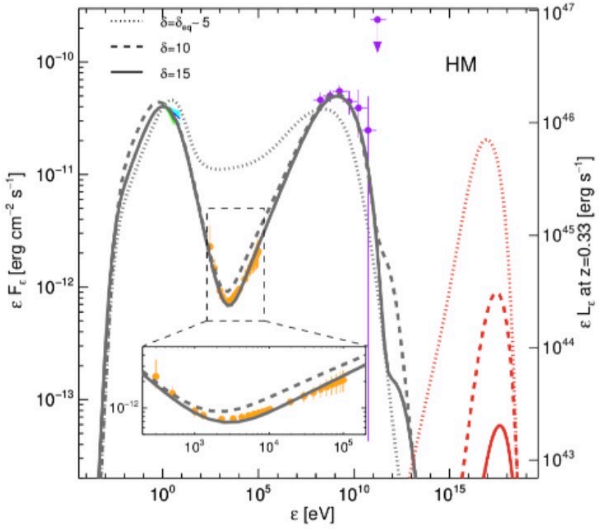






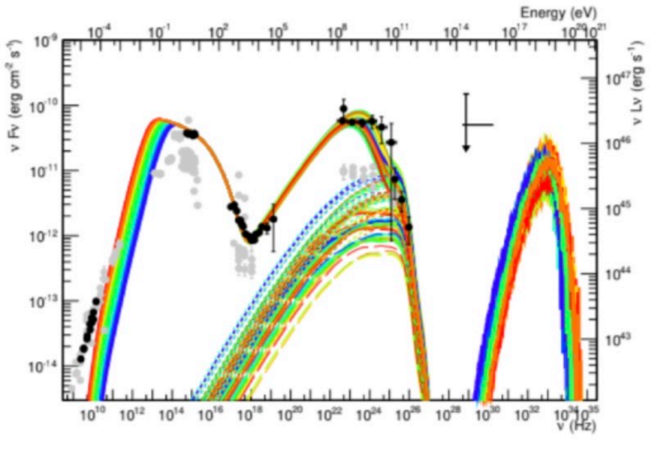
[IceCube, Fermi, MAGIC et al. 2018]

TXS 0506+056: the 2017 flare



[Keivani et al. 2018](#)

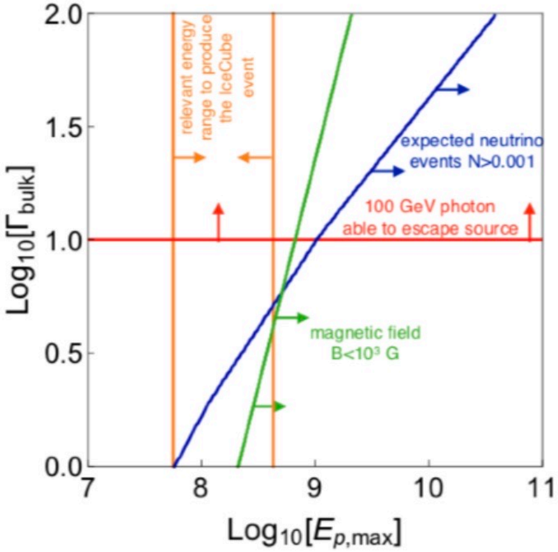
$\nu \simeq 10^{-5}\ yr^{-1}$



(a) Proton synchrotron modeling of TXS 0506+056

[Cerruti et al. 2019](#)

$\nu = 10^{-5} - 10^{-3}\ yr^{-1}$

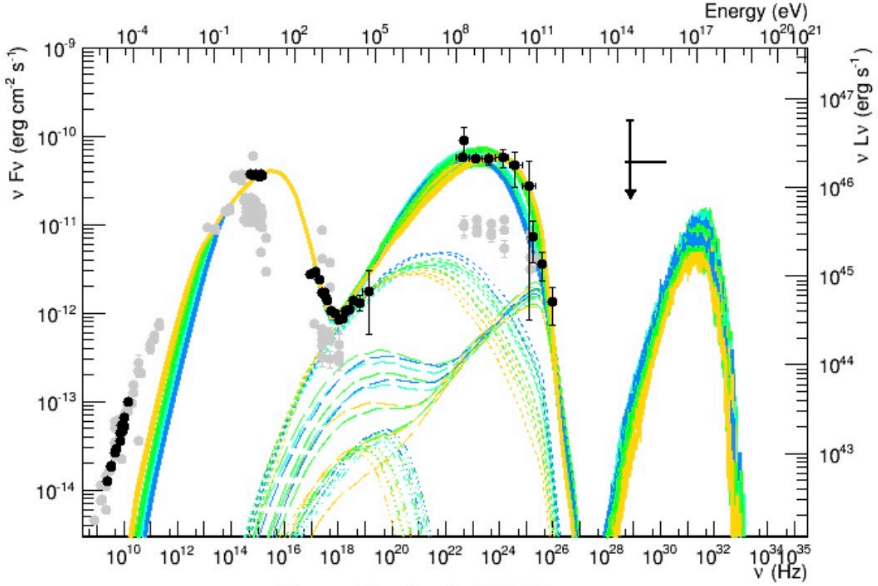


[Gao et al. 2018](#)

Proton synchrotron solutions exist,
but the expected neutrino rate is very low

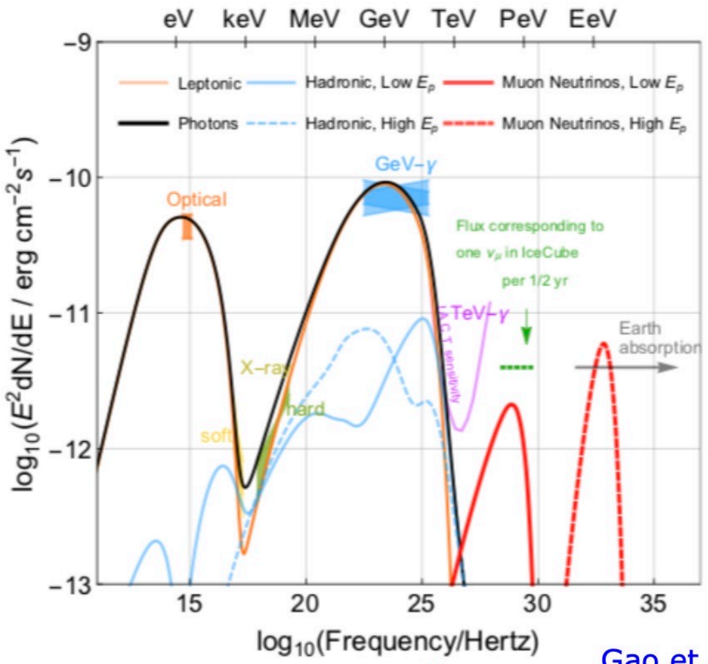
TXS 0506+056: the 2017 flare

Lepto-hadronic solutions



[Cerruti et al. 2019]

$L_{jet} = (9 - 60) \times 10^{47} erg/s$
$\nu = 0.01 - 0.06\ yr^{-1}$



[Gao et al. 2018]

$L_{jet} \simeq \times 10^{50} erg/s$
$\nu = 0.3\ yr^{-1}$

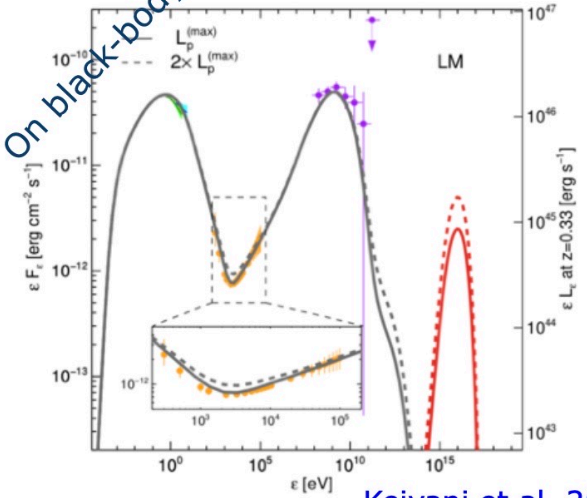
They can work: neutrino rates of the order of 0.1 / yr

But rather high energetic requirement : $L_{jet} \gg L_{Edd} \simeq \times 10^{46-47}\ erg/s$

TXS 0506+056: the 2017 flare

Proton-photon interaction on external photon fields

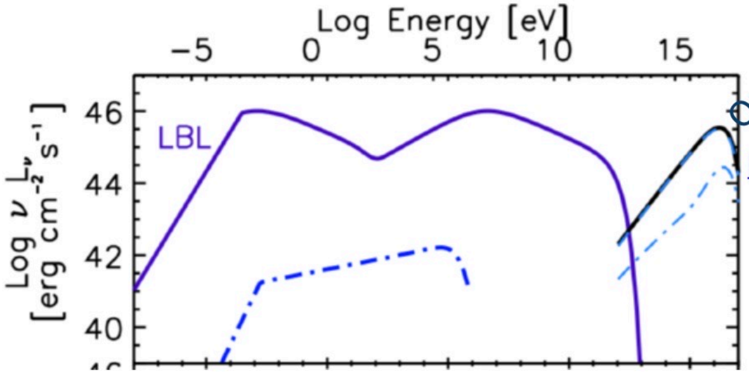
On black-body



Keivani et al. 2018

$L_{jet} = (4 - 150) \times 10^{45} erg/s$

$\nu_{max} = 0.02\ yr^{-1}$



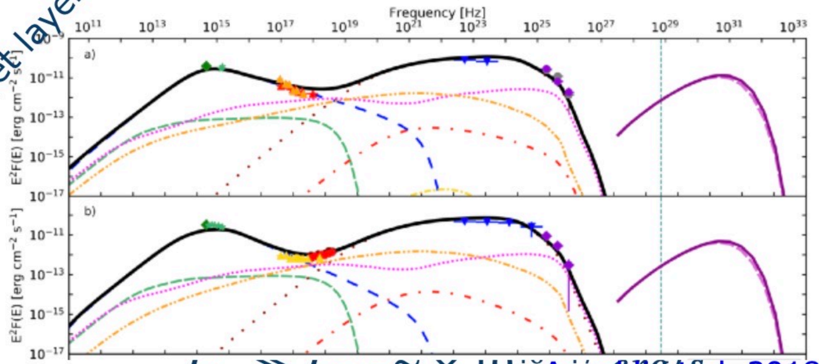
On RIAF

Righi et al. 2019

$L_{jet} = 6.3 \times 10^{45} erg/s$

$\nu = 0.14\ yr^{-1}$

On jet layer



$L_{jet} = (3 - 8) \times 10^{45} erg/s$

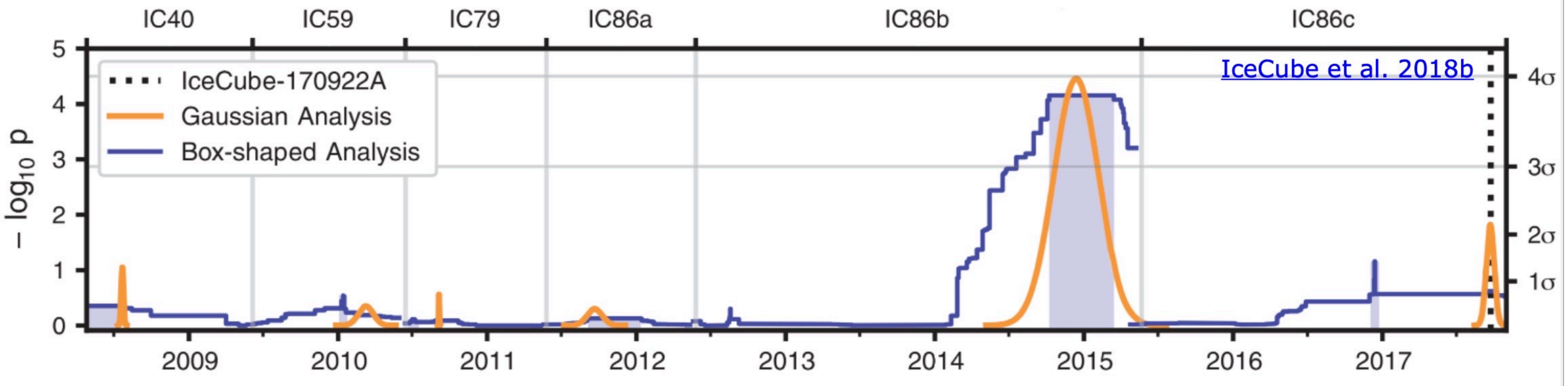
$\nu = 0.12 - 0.34\ yr^{-1}$

$L_{jet} \gg L_{Edd} \simeq \times 10$ erg/s

Ansoldi et al. 2018

TXS 0506+056: the 2014/15 flare

Detection of a second neutrino flare in 2014-2015
(without a gamma-ray counterpart)



3.5σ evidence for neutrino emission in 2014-2015 independent from the 2017 event

TXS 0506+056: the 2014/15 flare

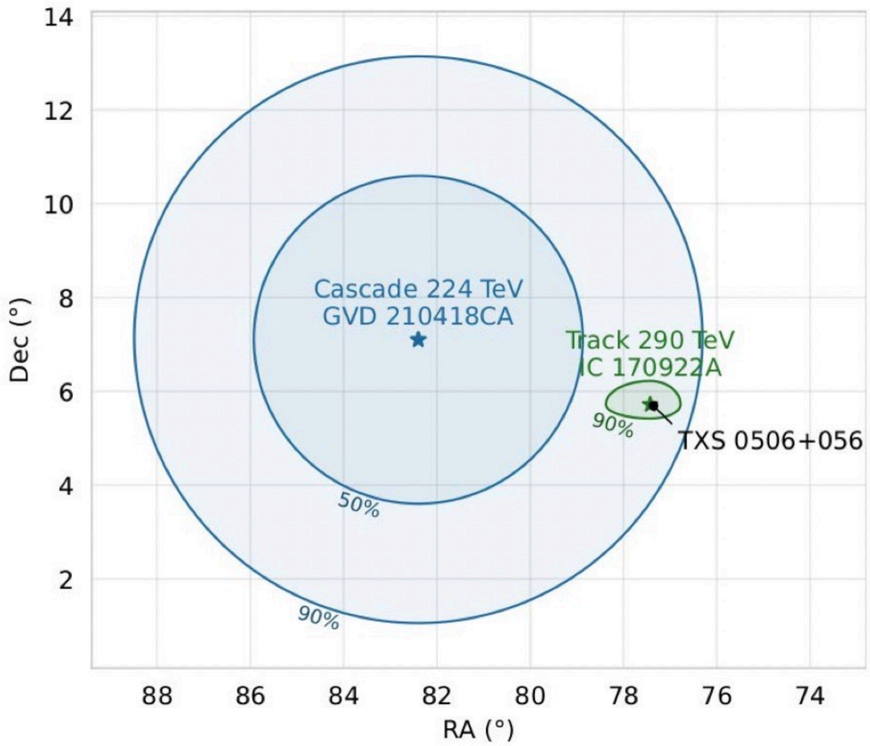
What did we learn?

- Single zone models are disfavored : very difficult to get no photons with the neutrino flare
(although there may be some room in the MeV band)

- A possible solution could be a two-zone models:
the ν and the γ-ray emitting region are not the same

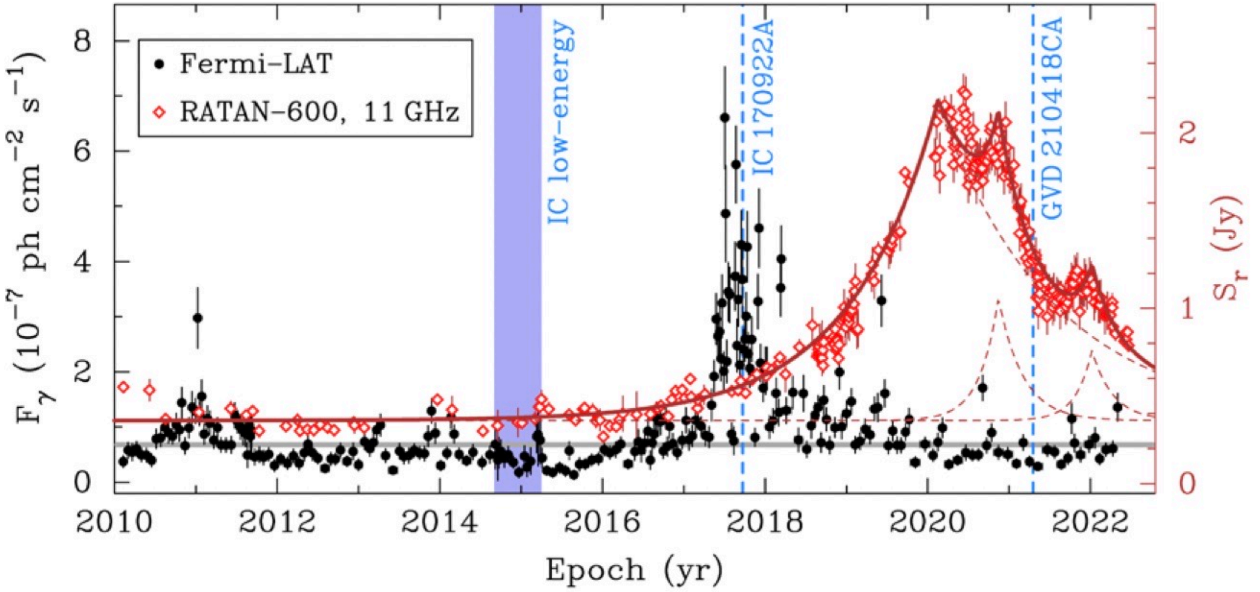
A high energy neutrino from the direction of TXS 0506+056

GVD210418CA (97% signalness) lies within 90% error circle from TXS 0506+056



The chance probability for such an association to occur randomly due to the background is p = 0.0074

Radio and gamma-ray light curves of TXS 0506+056.



Analysis of RATAN-600 radiotelescope data (11GHz) showed increased activity

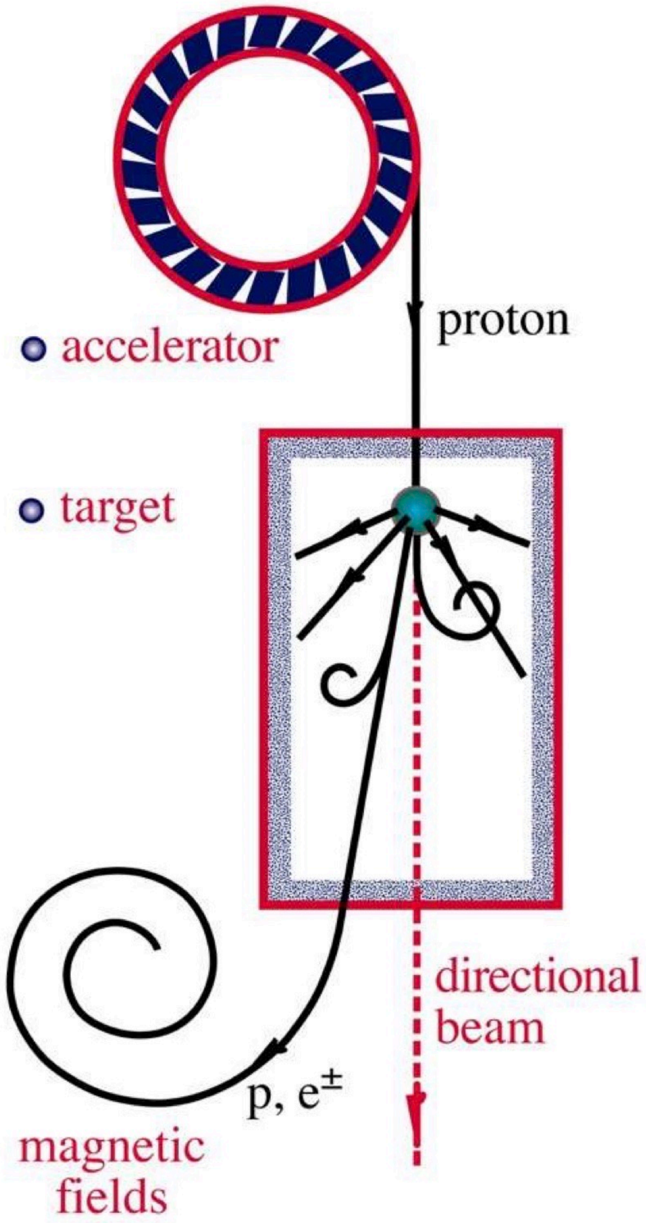
- IC event registered during γ flare and radio activity
- Baikal-GVD event during radio activity
- Probability of IC non-observation: 11%

Zh.Dzhilkibaev talk

arXiv:2210.01650

Neutrinos from AGN core

NEUTRINO BEAMS



the pγ efficiency dilemma

- efficiency for producing the neutrinos in the photon target:

$$\tau_{\mathrm{p}\gamma} \simeq \frac{\kappa_{\mathrm{p}\gamma} \mathrm{R}_{\mathrm{escape}}}{\lambda_{\mathrm{p}\gamma}} \simeq \mathrm{R}_{\mathrm{escape}}\, \sigma_{\mathrm{p}\gamma}\, \mathrm{n}_{\mathrm{photons}}$$

- likelihood of the multimessenger photons to be absorbed in target

$$\tau_{\gamma\gamma} \simeq \mathrm{R}_{\mathrm{target}}\, \sigma_{\gamma\gamma}\, \mathrm{n}_{\mathrm{photons}}$$

→ therefore, with $\mathrm{R}_{\mathrm{escape}} \sim \mathrm{R}_{\mathrm{target}}$

$$\tau_{\gamma\gamma} \sim \frac{\sigma_{\gamma\gamma}}{\sigma_{p\gamma}} \tau_{p\gamma} \sim 300\, \tau_{p\gamma}$$

→ do not expect high energy gamma rays to accompany cosmic neutrinos

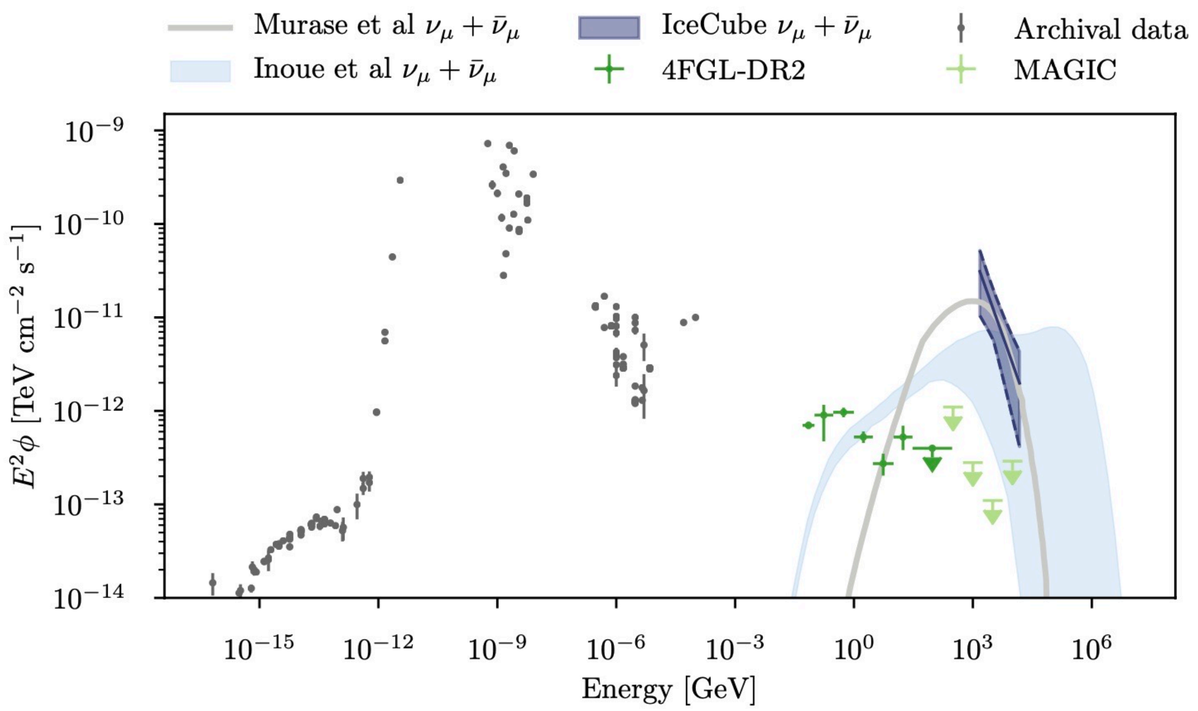
→ blazar jets are out

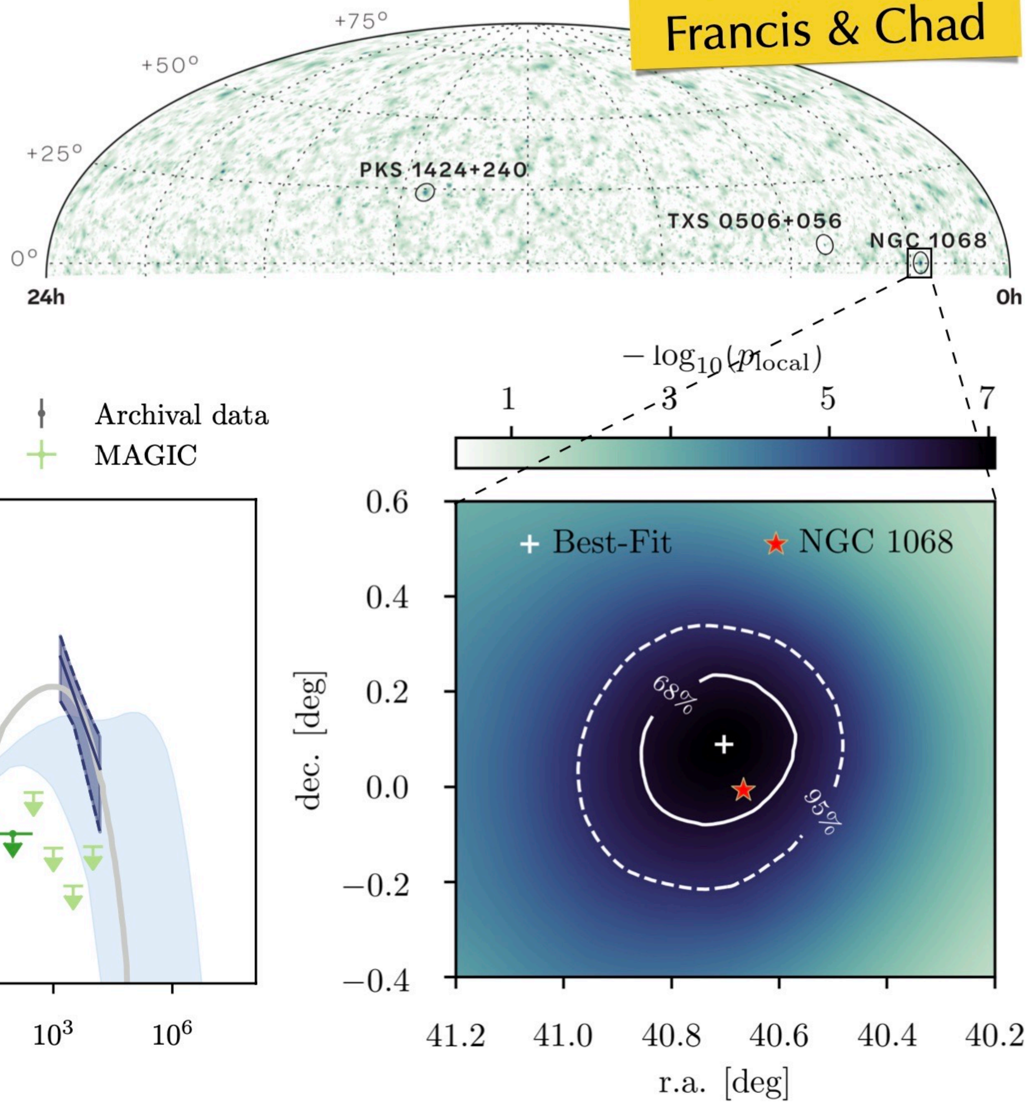
F.Halzen talk

Excess from NGC 1068

see talks by
Francis & Chad

Northern hot spot in the vicinity of Seyfert II galaxy **NGC 1068** has now a **significance of 4.2σ** *(trial-corrected for 110 sources)*.

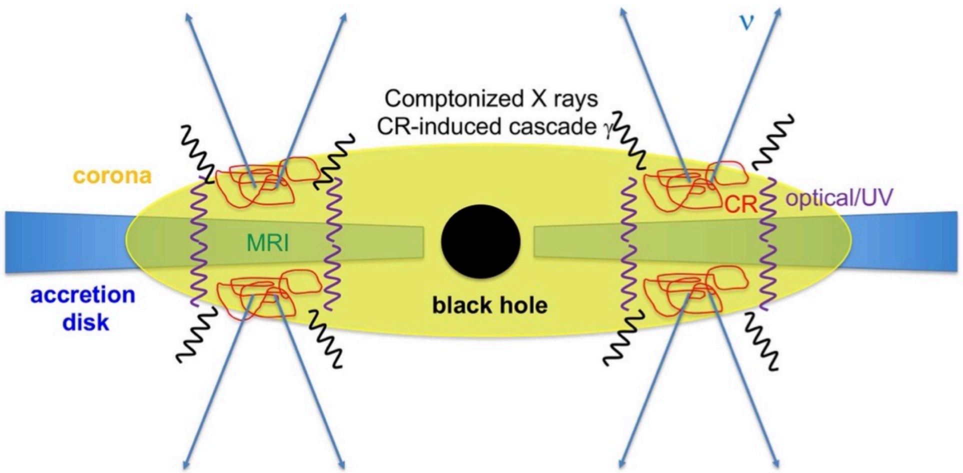




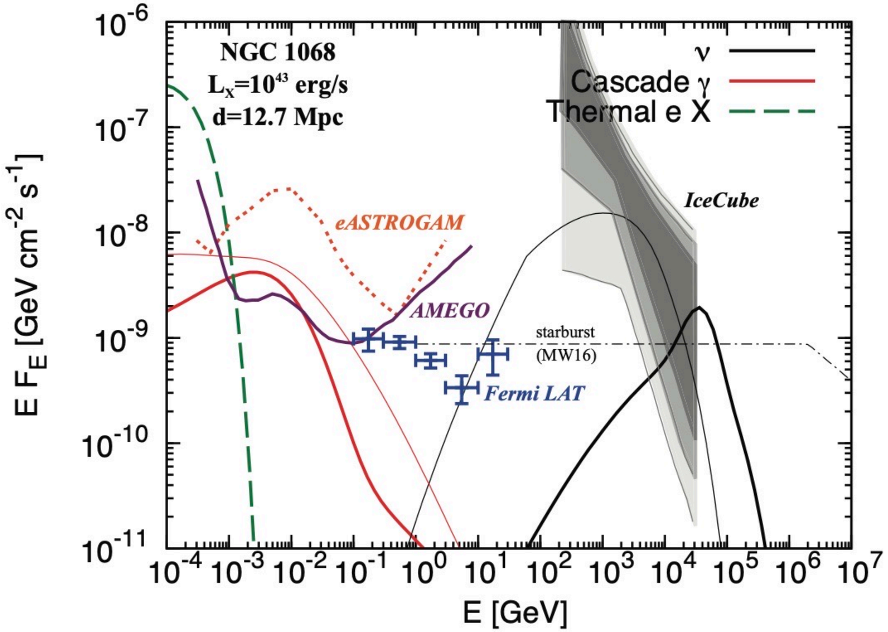
M.Ahlers talk

[IceCube, PRL 124 (2020) 5 **(2.9σ post-trial)**; Science 378 (2022) 6619 **(4.2σ post-trial)**]

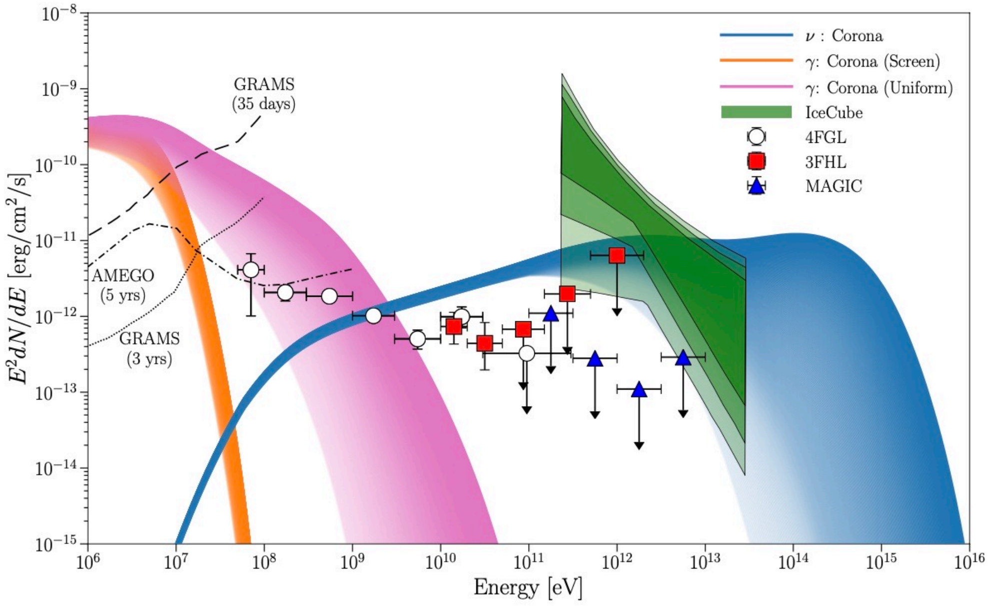
Excess from NGC 1068



- **Soft spectrum** ($\gamma = 3.2 \pm 0.2$) within 1.5-15 TeV indicates peak or cutoff in ν emission.
- Effective **absorption** of accompanying γ-rays in X-ray photons of **AGN corona.**



[Murase, Kimura & Meszaros '20]

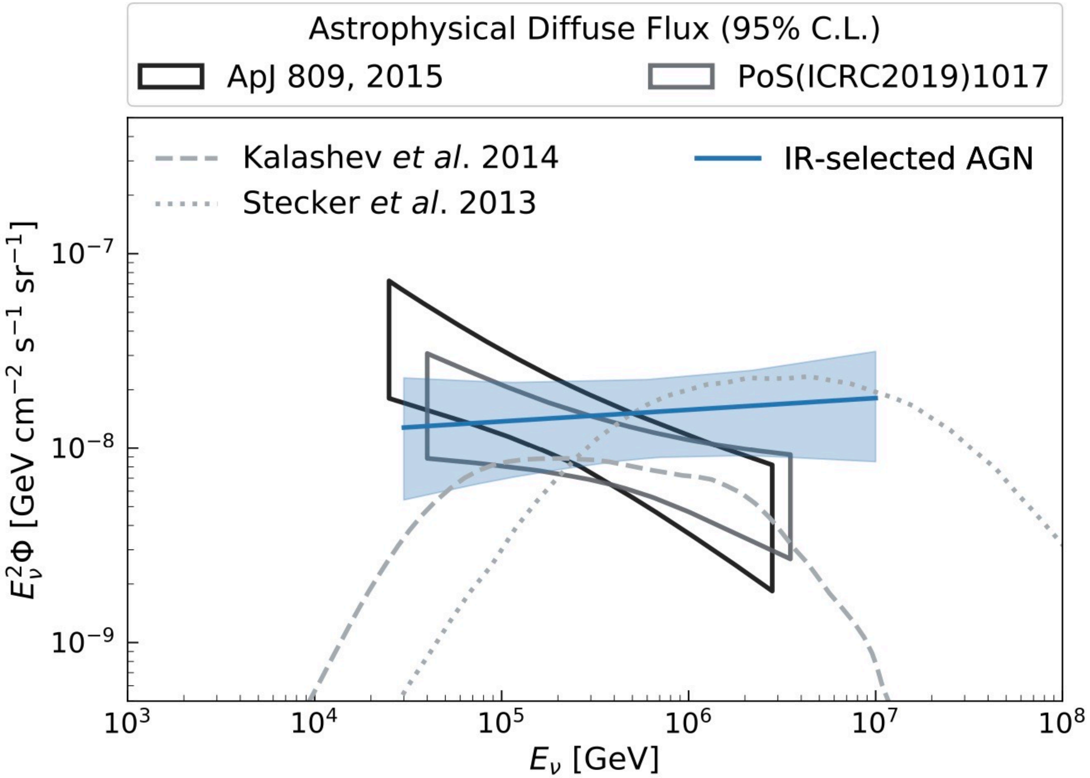


[Inoue, Khangulyan & Doi '20]

M.Ahlers talk

AGN Core Stacking

- Hadronic γ-rays in **cores of AGNs** are suppressed due to pair production in X-ray background.
- IceCube finds a **2.6σ excess** for 32,249 AGN selected by their IR emission.



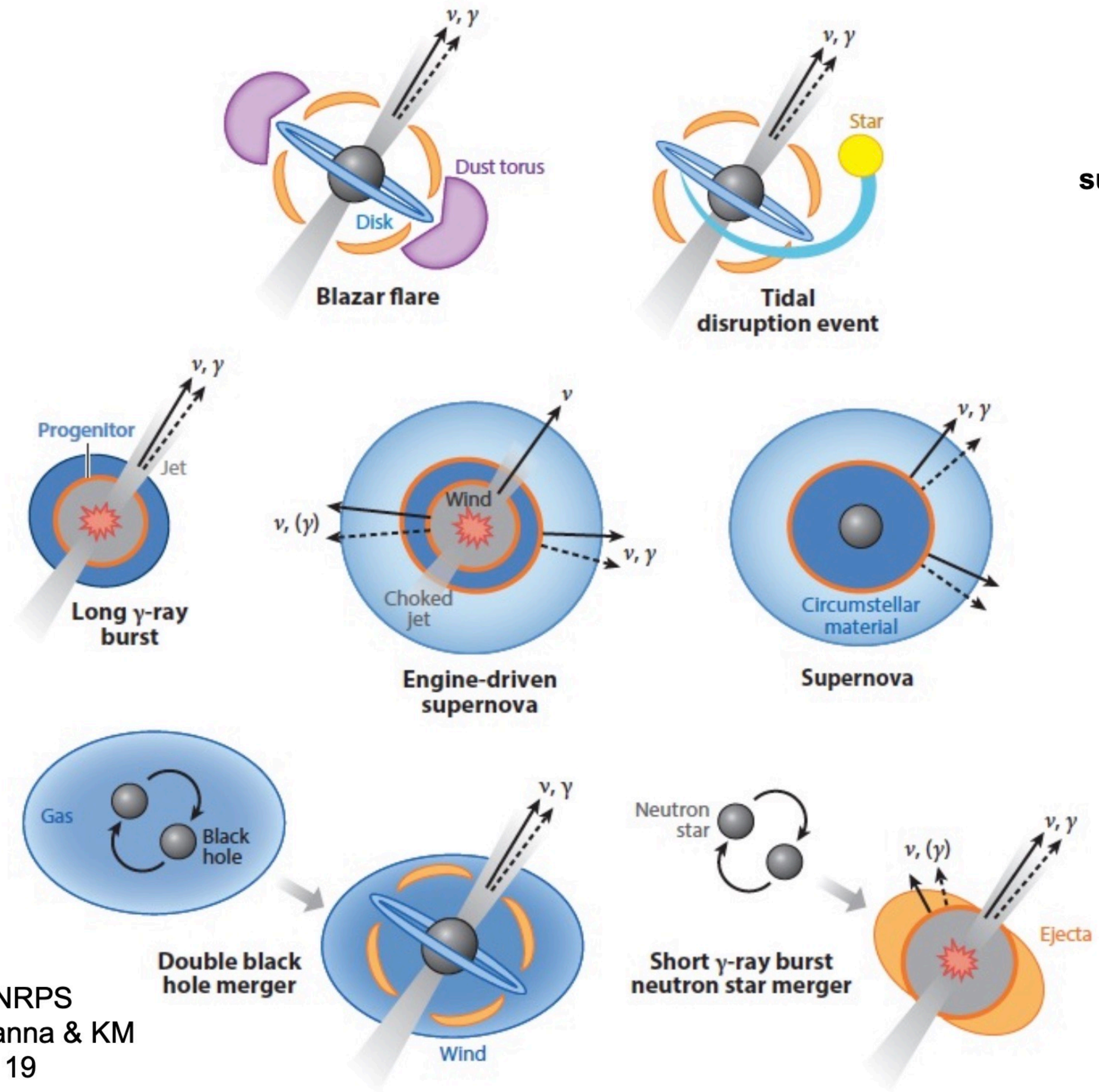
[IceCube, PRD 106 (2022) 2]

TABLE I. Properties of the AGN samples created for the analysis. The surveys used for the cross-match to derive each sample, the final number of selected sources, cumulative X-ray flux in the 0.5-2 keV energy range from the selected sources [44] and the completeness (fraction of total X-ray flux from all AGN in the Universe contained in the sample) are listed.

	Radio–selected AGN	IR–selected AGN	LLAGN
Matched catalogues	NVSS + 2RXS + XMMSL2	ALLWISE + 2RXS + XMMSL2	ALLWISE + 2RXS
Nr. of sources	9749	32249	15887
Cumulative X-ray flux [erg cm^{-2} s^{-1}]	7.71×10^{-9}	1.43×10^{-8}	7.26×10^{-9}
Completeness	$5^{+5}_{-3}\%$	$11^{+12}_{-7}\%$	$6^{+7}_{-4}\%$

M.Ahlers talk

Diversity of High-Energy Transients



supermassive black holes

massive stellar deaths

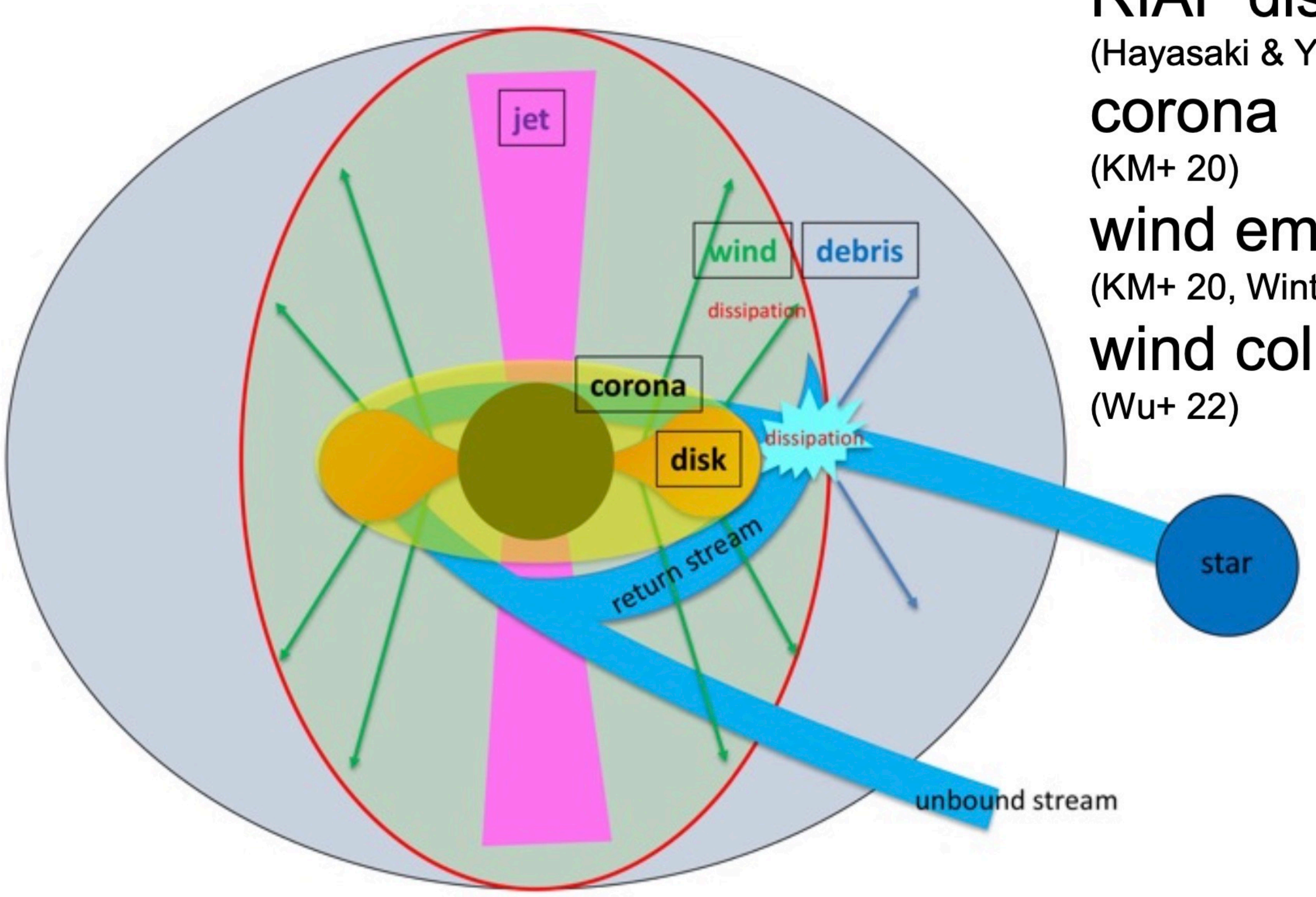
compact mergers (promising GW sources)

KM & Bartos 19 ANRPS
Meszaros, Fox, Hanna & KM
Nature Rev. Phys. 19

K.Murase talk

Tidal Disruption Events

HE Neutrinos from TDEs



successful/hidden jets
(Wang+16, Senno, KM & Meszaros 17
KM+ 20, Lunardini & Winter 17, 21)

RIAF disk
(Hayasaki & Yamazaki 19, KM+ 20)

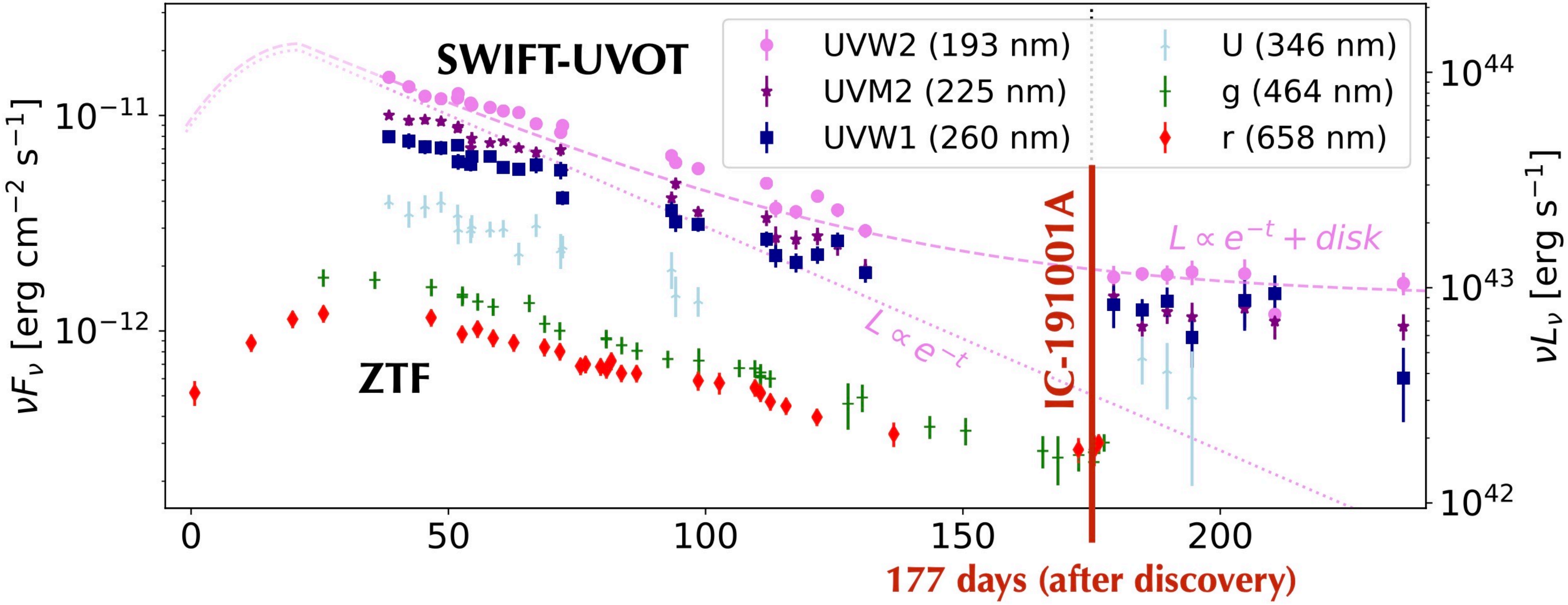
corona
(KM+ 20)

wind embedded in debris
(KM+ 20, Winter & Lunardini 22)

wind colliding w. clouds
(Wu+ 22)

K.Murase talk

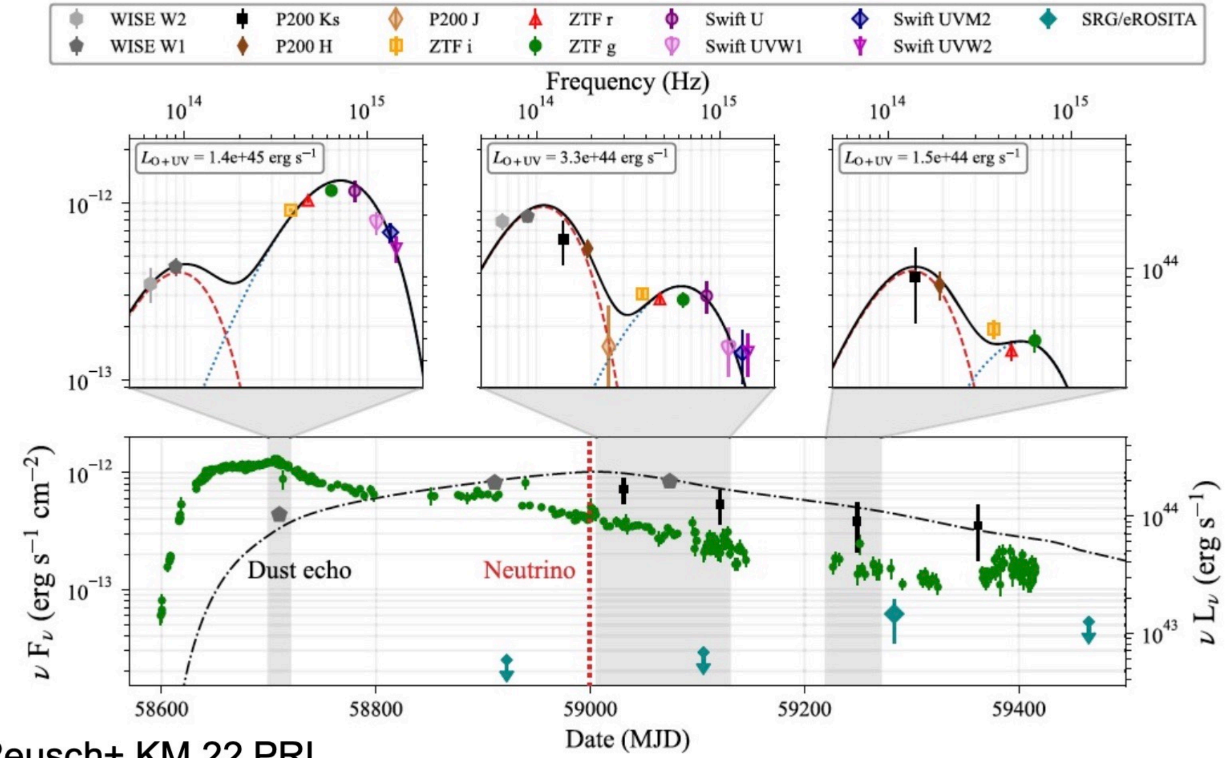
Tidal Disruption Events



[Stein et al. Nature Astronomy 5 (2021) 5]

- Association of alert IC-191001A with radio-emitting TDE AT2019dsg
- Plot shows data from Zwicky-Transient Facility and SWIFT-UVOT.
- Chance for random correlation of TDEs and IceCube alerts is 0.5%.

M.Ahlers talk



Reusch+ KM 22 PRL

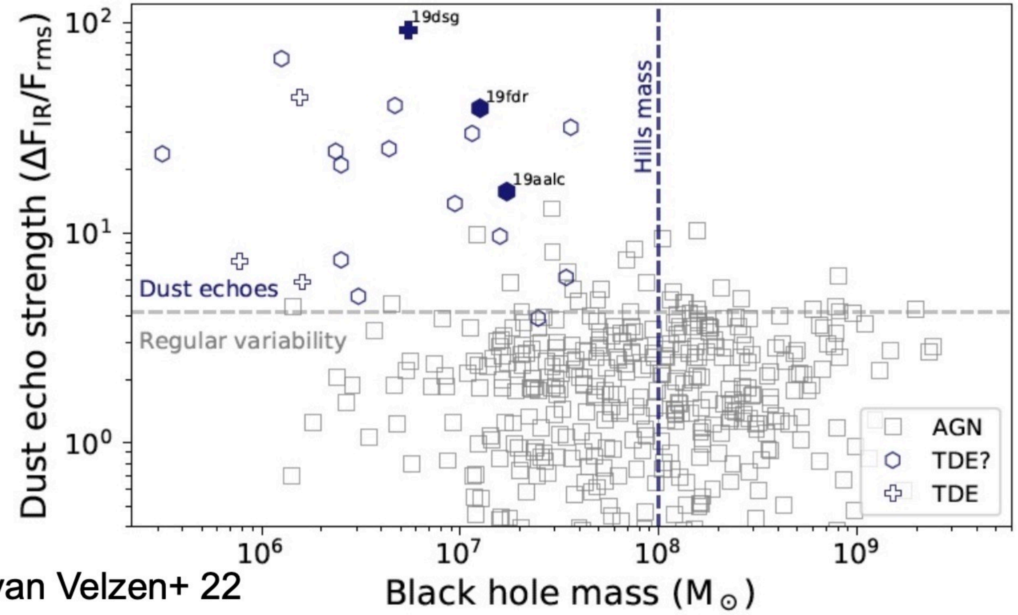
AT 2019fdr

E_{OUV}=3.4x10^{52} erg

E_ν < 10^{53} erg

Commonalities

- Brightest TDEs
- Dust echoes
- Radio
- Soft x-rays



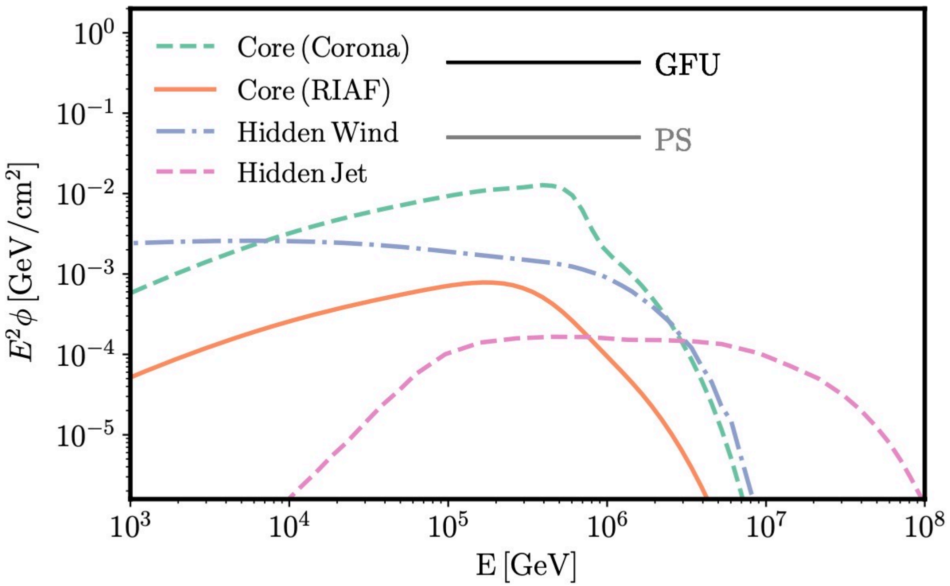
van Velzen+ 22

- Correlation w. dust echoes (63 samples; ~3.7σ)
- One more candidate found **AT 2019aalc** (highest IR flux)
- Controversial interpretations

K.Murase talk

Implications for AT2019dsg & AT2019fdr

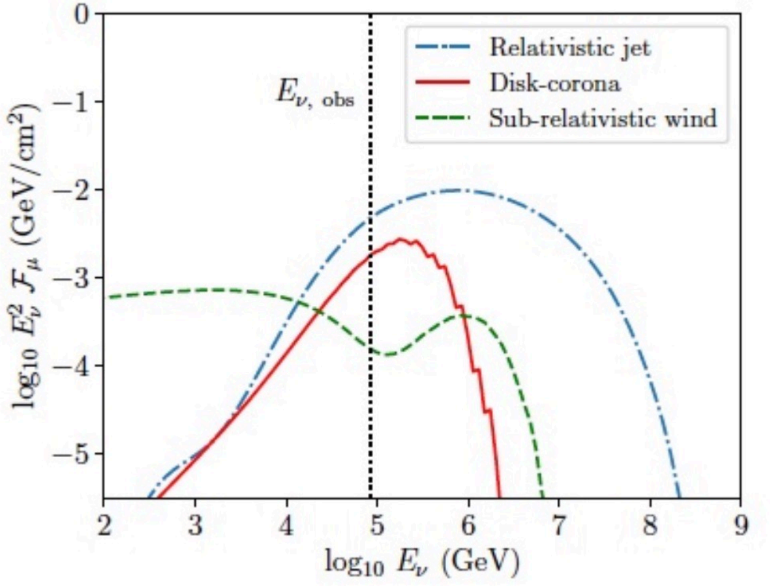
AT 2019dsg



KM+ 20 ApJ

Model	$\mathcal{N}_{\nu_\mu}(> 100\,\mathrm{TeV})$ Point Source	GFU
Core (Corona)	9×10^{-2}	1×10^{-2}
Core (RIAF)	3×10^{-3}	3×10^{-4}
Hidden Wind	9×10^{-3}	1×10^{-3}
Hidden Jet	1×10^{-3}	3×10^{-4}

AT 2019fdr



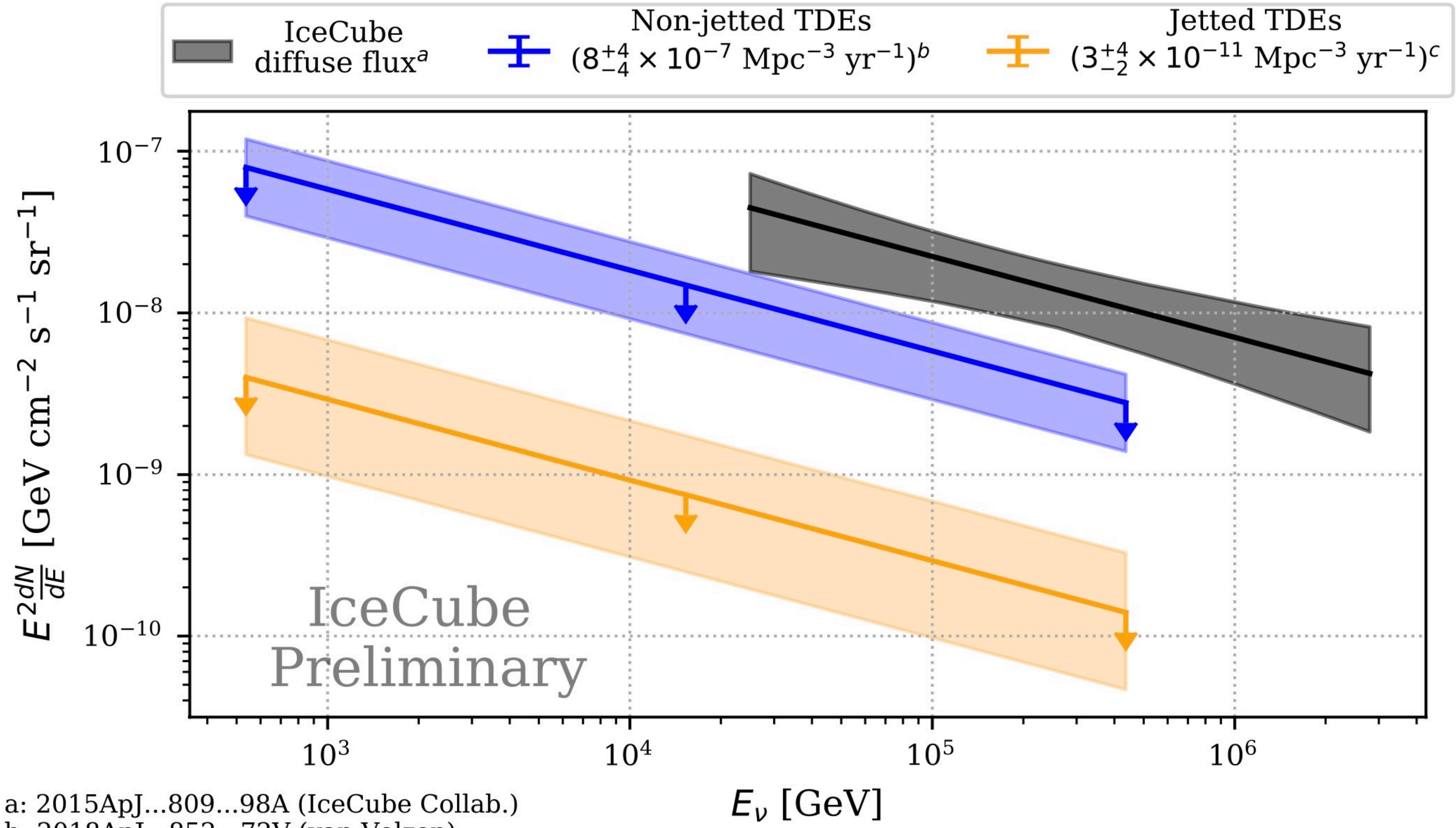
Reusch+ KM 22 PRL

N_ν ~ 0.01-0.1 events (alert)

no evidence of jets

K.Murase talk

TDE Limits



a: 2015ApJ...809...98A (IceCube Collab.)
b: 2018ApJ...852...72V (van Velzen)
c: 2015ApJ...812...33S (Sun et al.)

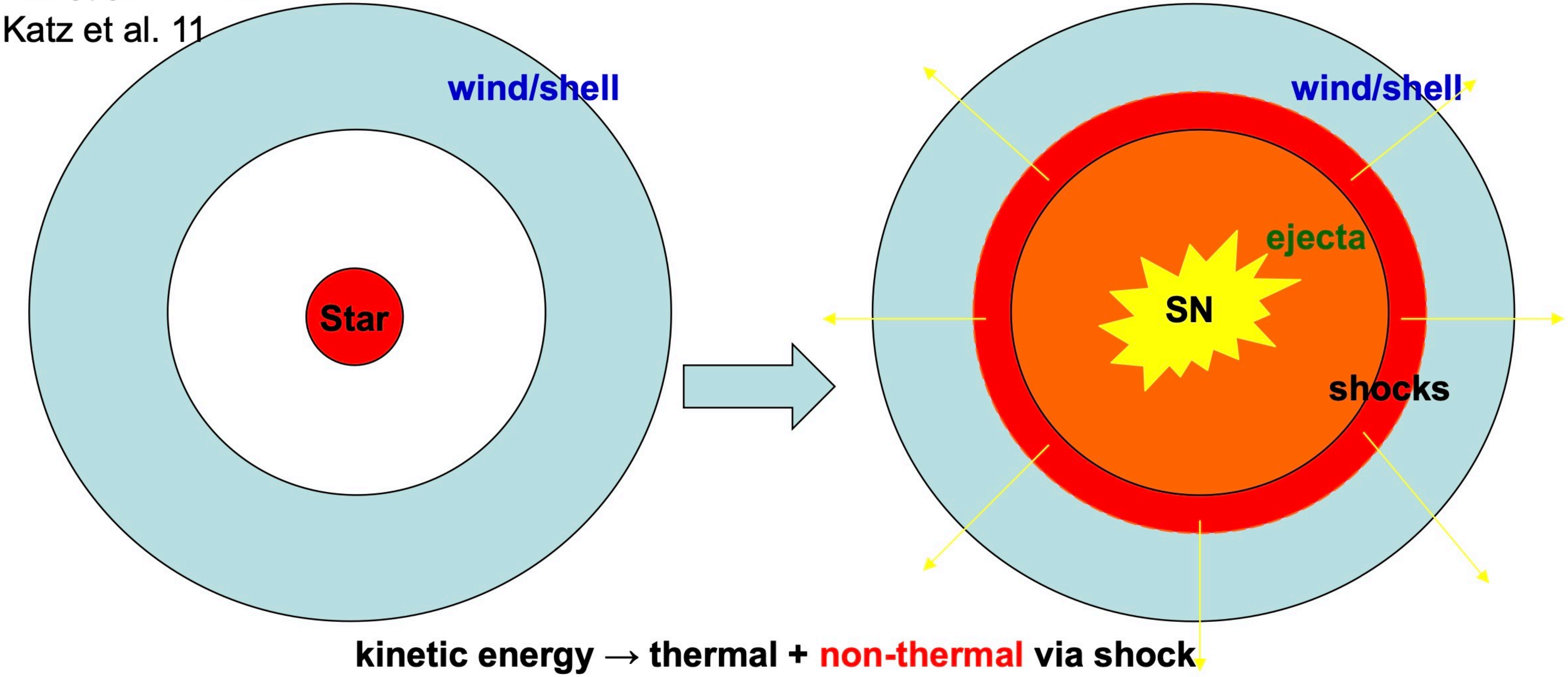
[IceCube, PoS (ICRC2019) 1016]

M.Ahlers talk

Limits derived based on stacking of 3 jetted and 13 non-jetted TDEs.
Correspond to <1.3% and <26% of diffuse flux.

Interacting Supernovae

KM et al. 11 PRD
Katz et al. 11



kinetic energy → thermal + non-thermal via shock

$$p + p \rightarrow N\pi + X$$

$$\pi^{\pm} \rightarrow \nu_{\mu} + \bar{\nu}_{\mu} + \nu_{e}(\bar{\nu}_{e}) + e^{\pm}$$

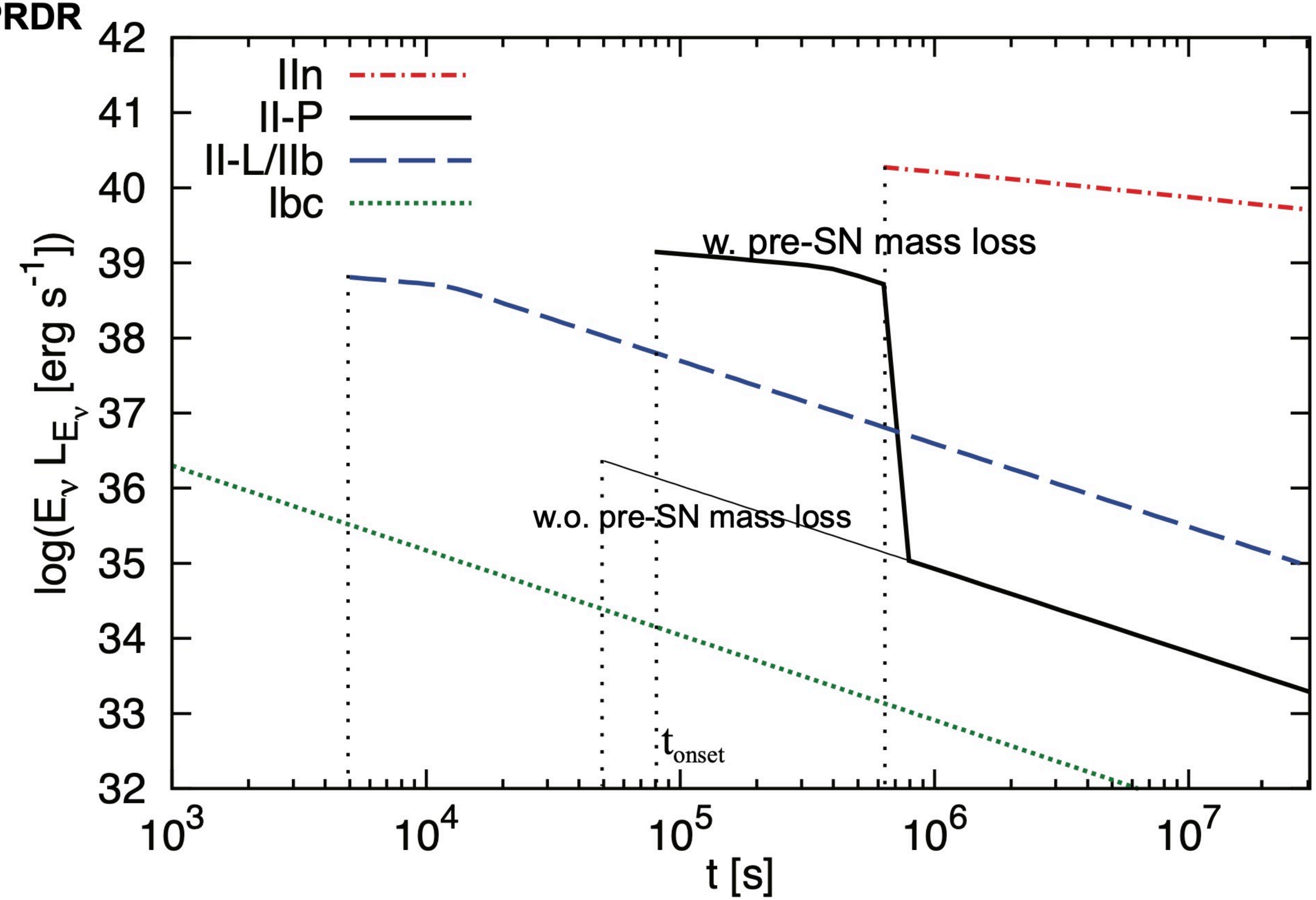
$$\pi^{0} \rightarrow \gamma + \gamma$$

dense environments = efficient ν emitters (calorimeters)

K.Murase talk

Neutrino Light Curve

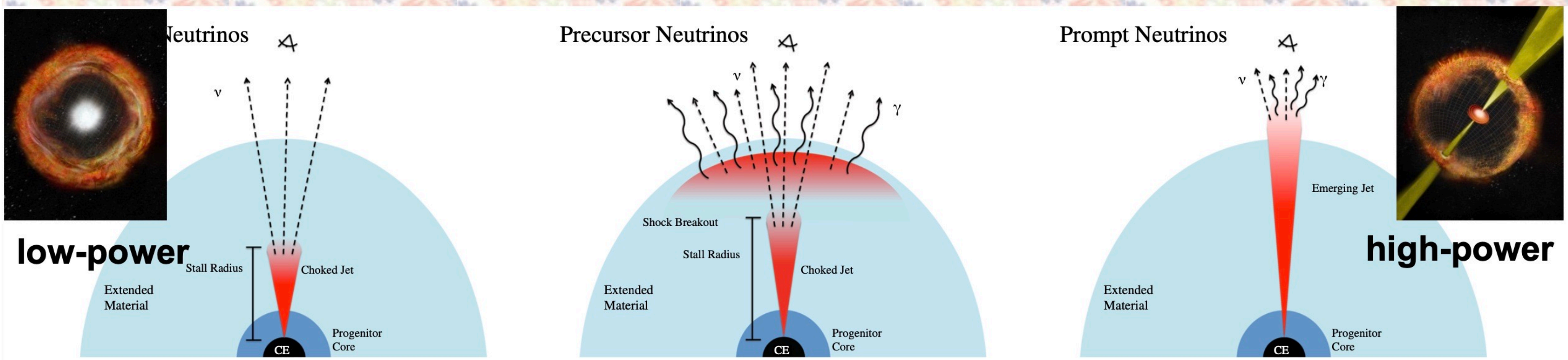
KM 18 PRDR



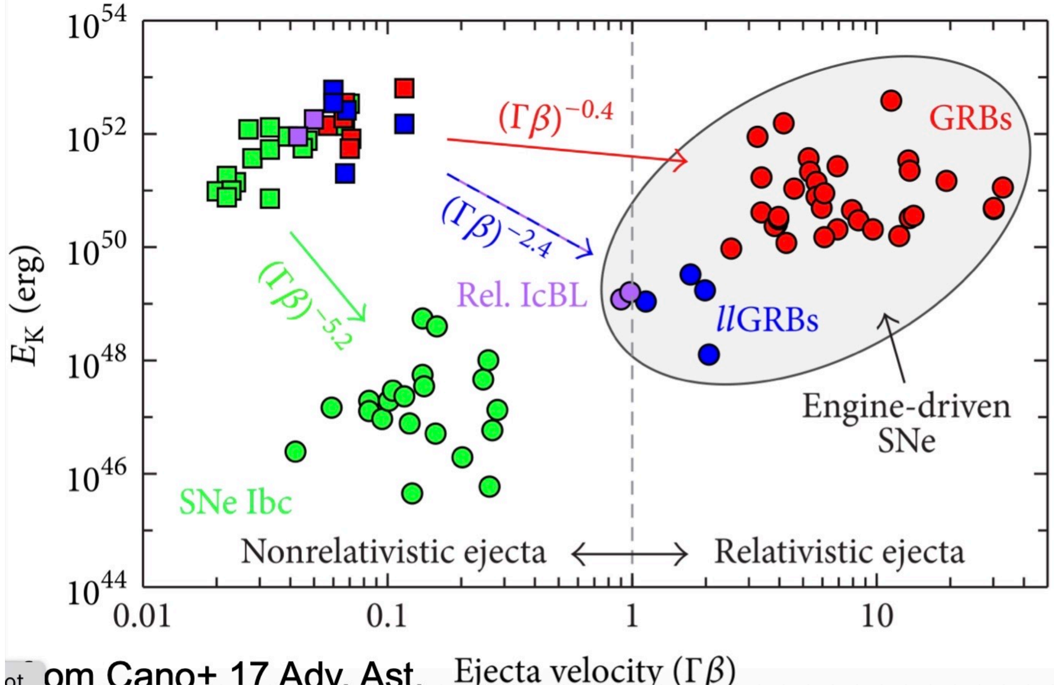
K.Murase talk

slowly declining light curves while pion production efficiency ~ 1

HE Neutrinos from Choked Jets in Type Ibc SNe



from Senno, KM & Meszaros 16 PRD



…om Cano+ 17 Adv. Ast.

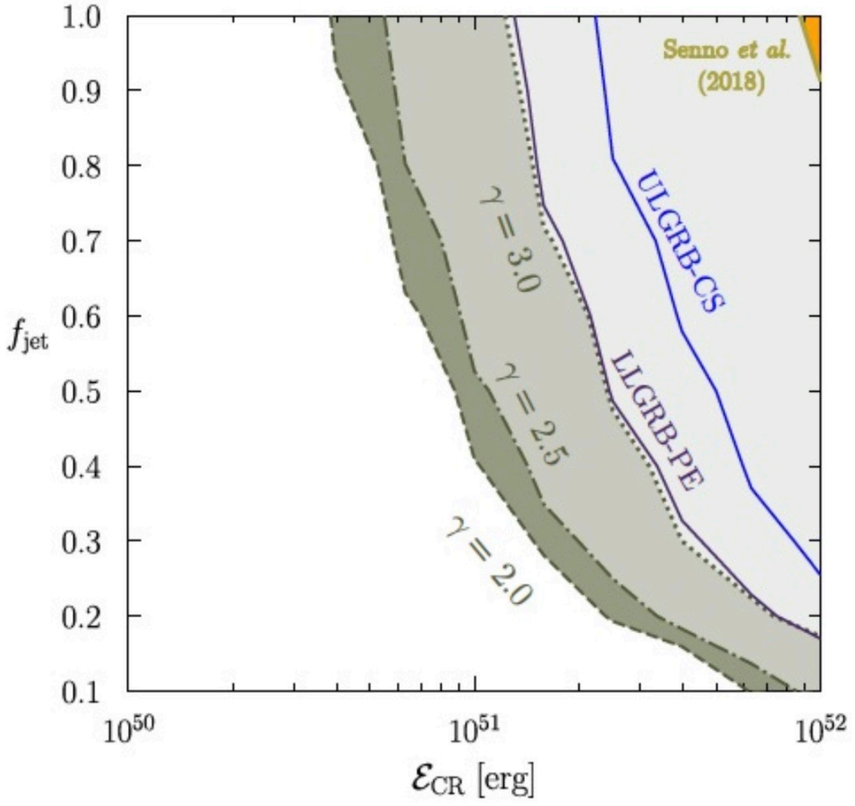
- Marginally choked jets: trans-relativistic SNe & low-luminosity (LL) GRBs
  (Toma+07, Nakar 15, Irwin & Chevalier 16)

- Low-power choked jets may contribute to the IceCube flux with GRB stacking limits evaded
  (KM+ 06 ApJL, Gupta & Zhang 07 APh, KM & Ioka 13 PRL, Denton & Tamborra 18 ApJ Carpio & KM 20 PRD)

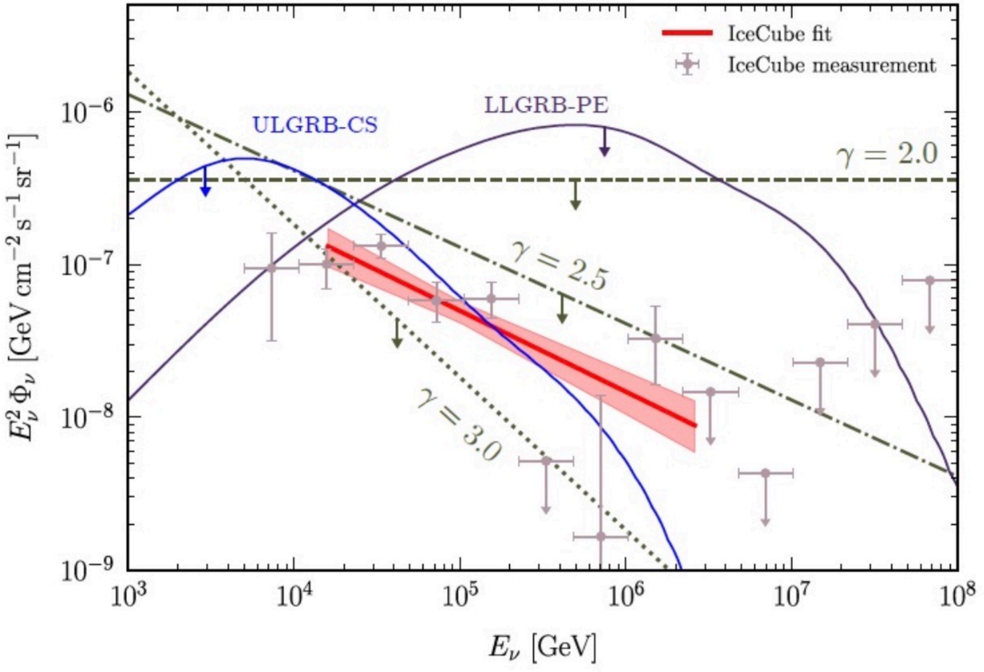
K.Murase talk

Powerful Stacking Searches

Stacking analyses on 386 SNe Ibc w. 10 yr IceCube data



Chang, Zhou, Km & Kamionkowski 22
see also Senno, KM & Meszaros 18 JCAP
Esmaili & KM 18 JCAP

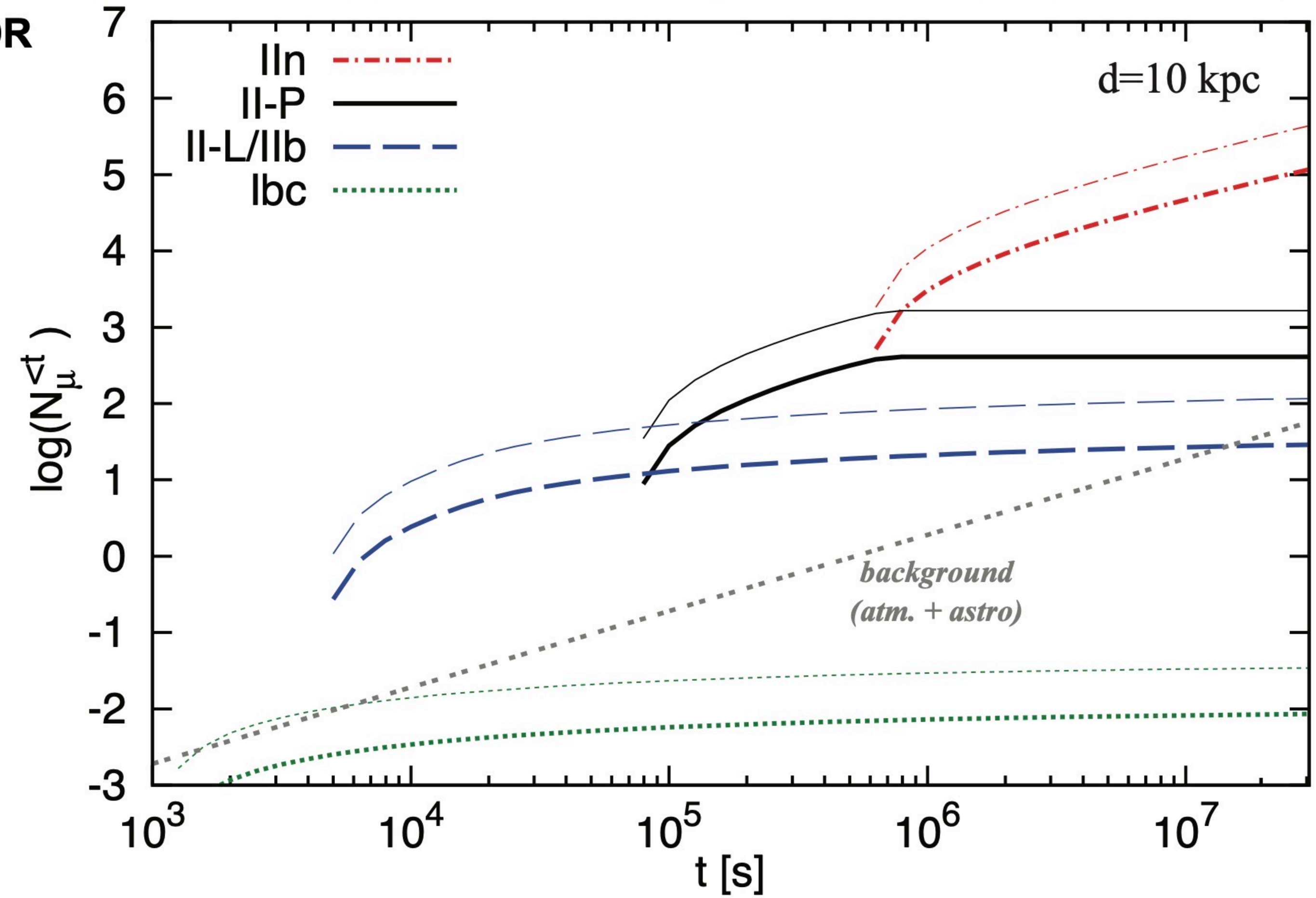


- Present constraints: $E_{cr}<10^{51}$-10^{52} erg (if all SNe emit νs)
- Future: readily improved w. more SNe (especially w. Rubin)
- Be careful about the completeness of representative population

K.Murase talk

Next Galactic Supernova?

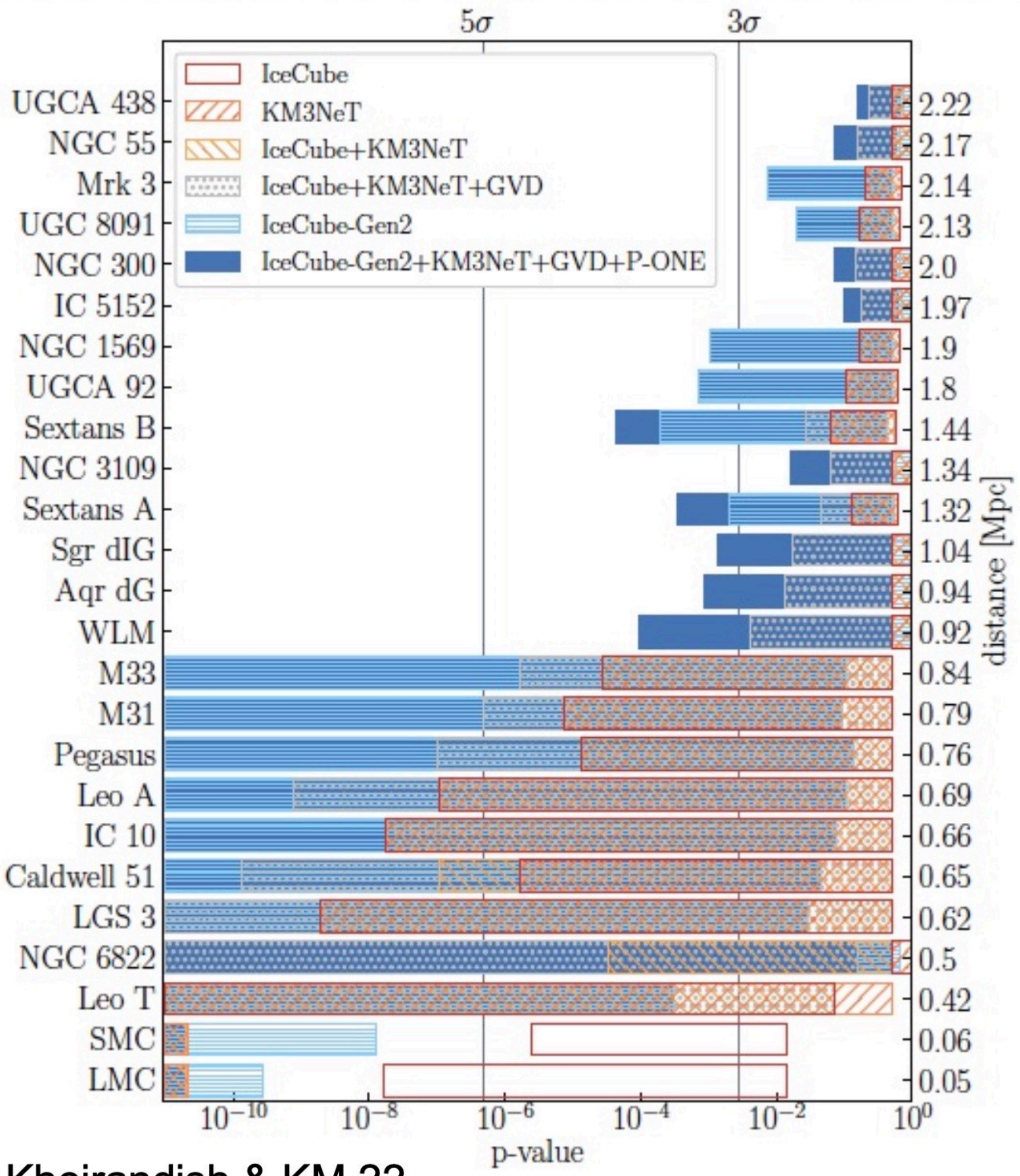
KM 18 PRDR



- Type II: ~100-1000 events of TeV ν from the next Galactic SN
  ex. Betelgeuse: ~10^3-$3x10^6$ events, Eta Carinae: ~10^5-$3x10^6$ events
- SNe as "multi-messenger" & "multi-energy" neutrino source
- "Real-time" detection of CR acceleration, testing Pevatrons, neutrino physics

K.Murase talk

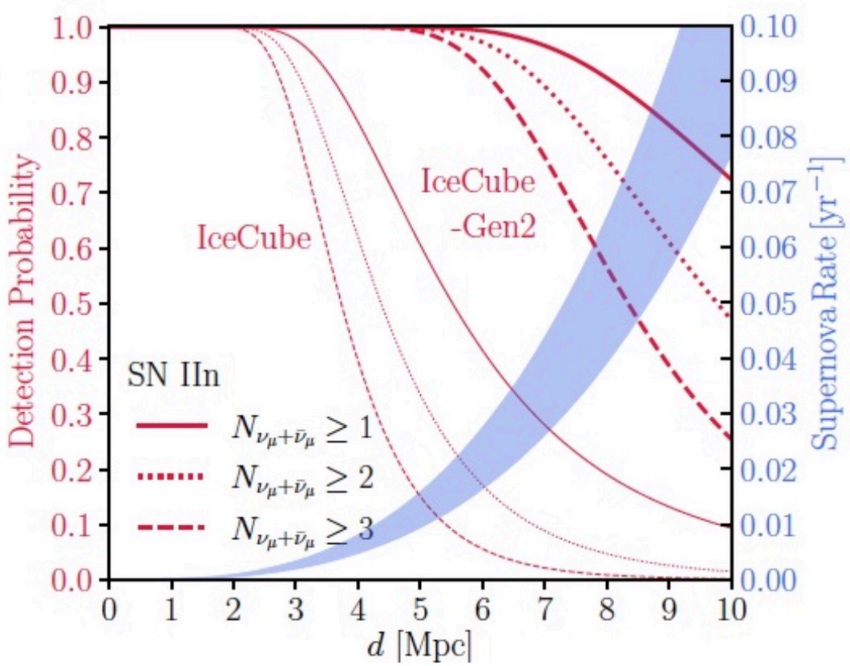
Detectability of Minibursts



Kheirandish & KM 22

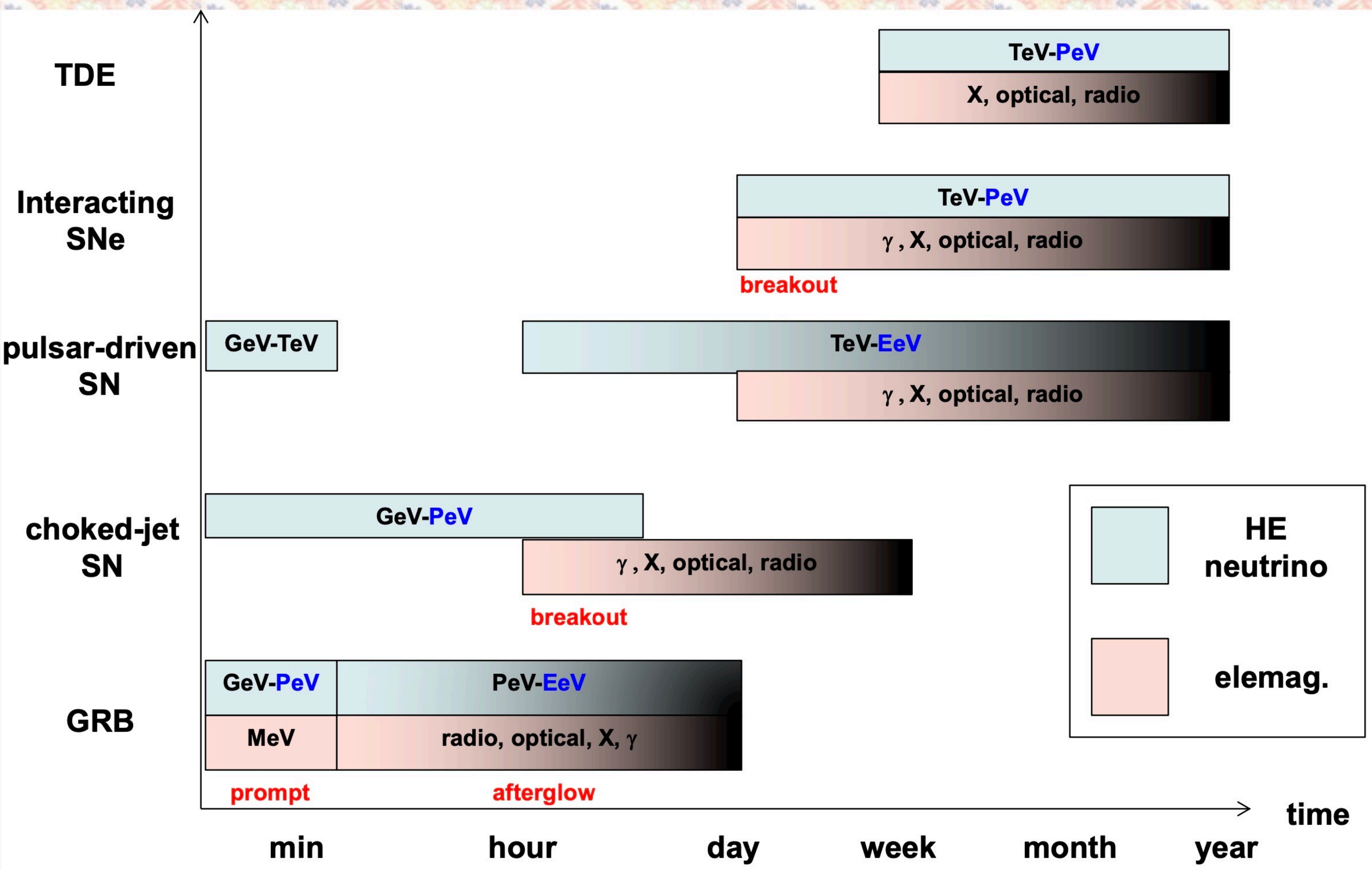
- CCSN rate enhancement in local galaxies (ex. Ando+ 05 PRL)
- Neutrino telescope networks are beneficial for nearby SNe at Mpc
- II-P: detectable up to ~3-4 Mpc
  IIn: detectable up to ~10 Mpc

see also Erin's talk



K.Murase talk

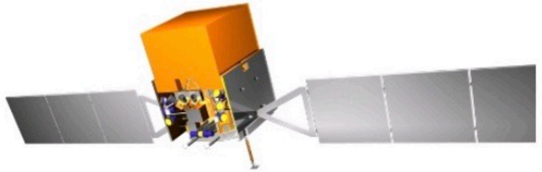
Long-Duration TeV-EeV vs Short-Duration GeV-TeV



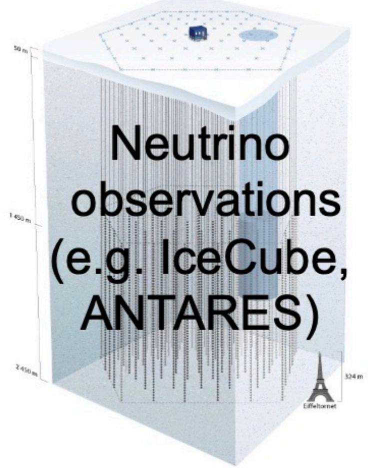
K.Murase talk

Multimessenger stacking bounds

Gamma-ray observations (e.g. Fermi, Swift, etc)

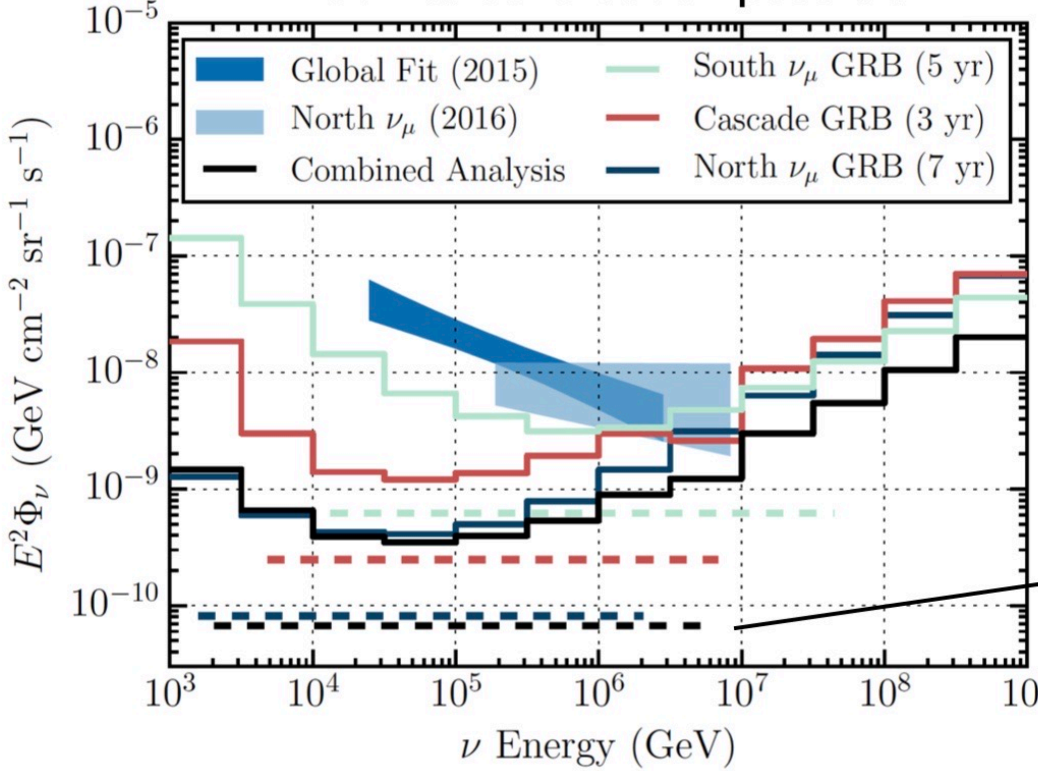


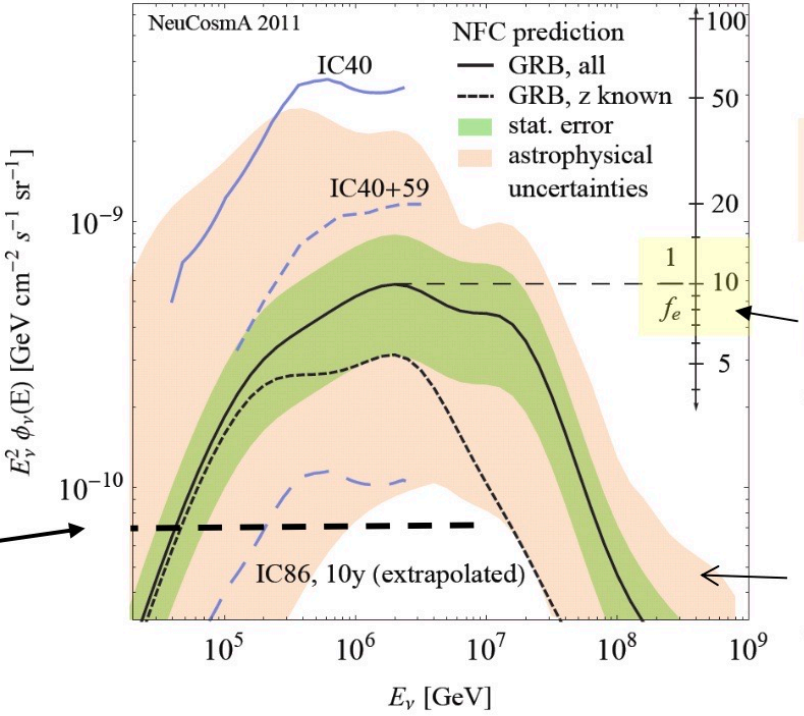
Coincidence?



Use timing, directional and energy information to reduce backgrounds

Cannot power observed diffuse flux!
But: 1% contribution possible





Neutrino production
$E_\nu \sim E_\gamma \times 1/f_e \times f_\pi$

Baryonic loading:
Ad hoc assumption
(estimate from UHECRs)

Uncertainty from geometry estimators
(→ pion prod. efficiency f_π)

IceCube, Nature 484 (2012) 351;
Fig. from update: ApJ 843 (2017) 112

Hümmer et al PRL 108 (2012) 231101;
Waxman, Bahcall, 1997; Guetta et al, 2003; He et al, 2012

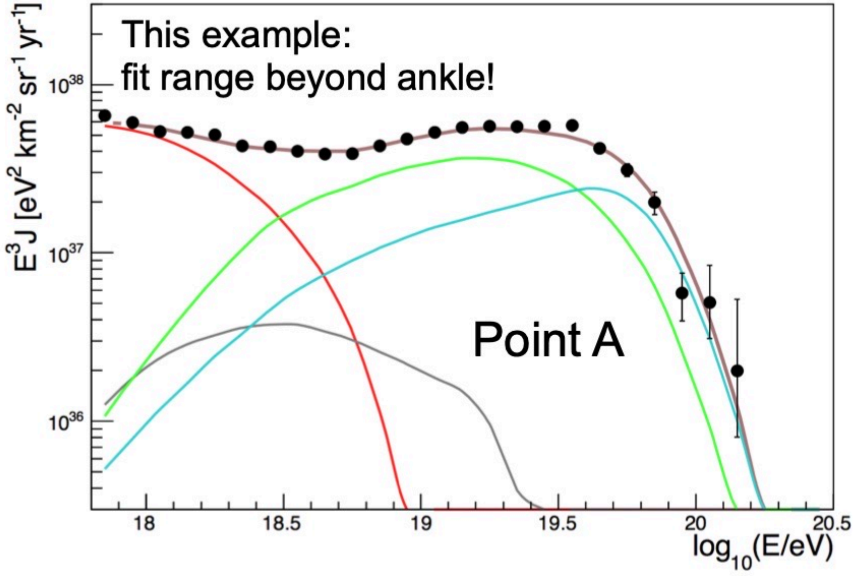
The vanilla one-zone prompt model

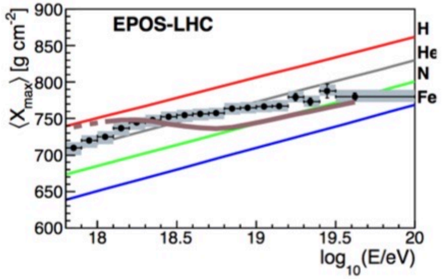
Neutrino and cosmic ray emission at same collision radius R

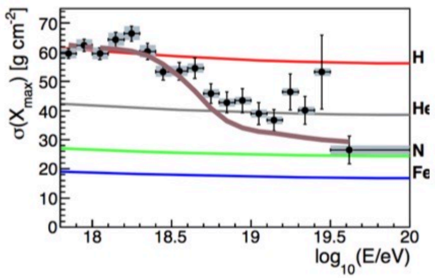
- Can describe UHECR data, roughly
- Scenario is constrained by neutrino non-observatons

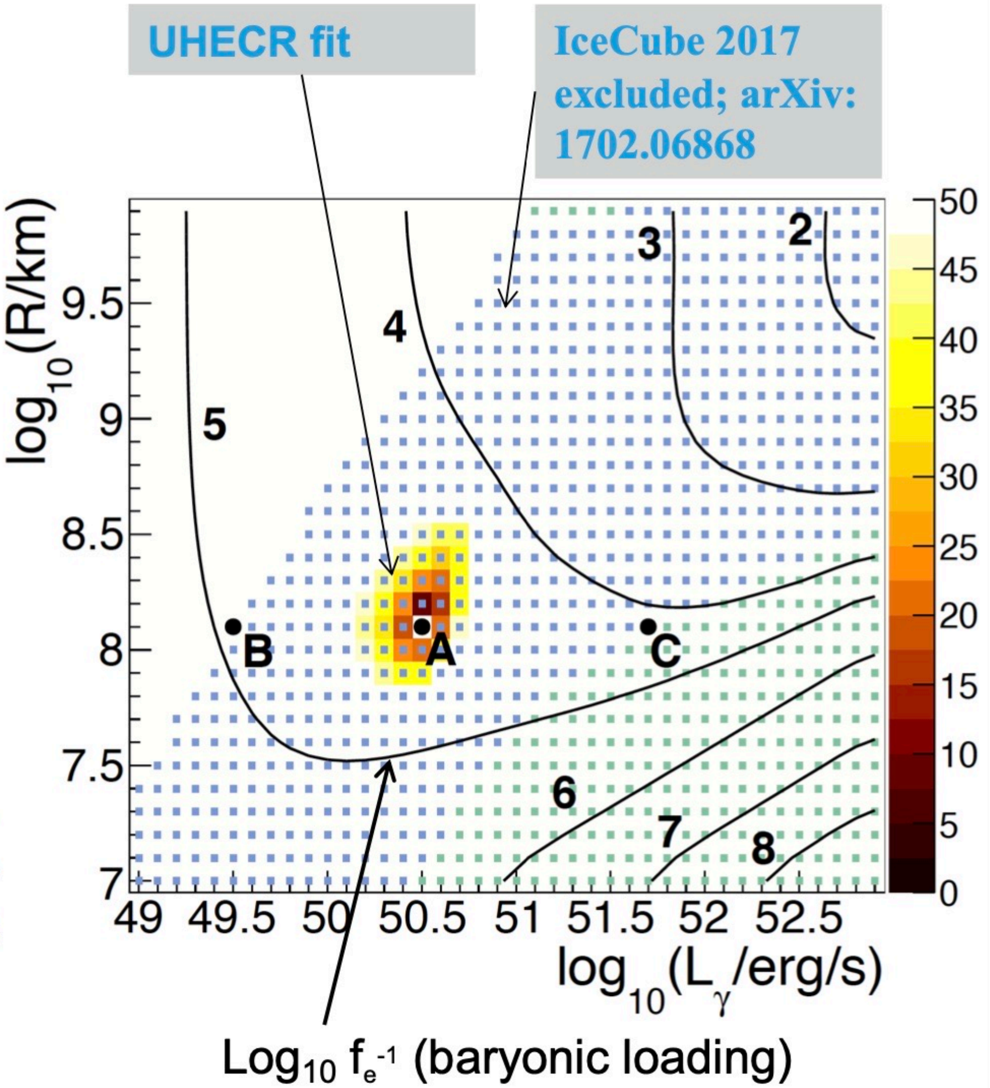
Recipe:

- Fit UHECR data, then compute predicted neutrino fluxes
- Here only one example; extensive parameter space studies have been performed
- Conclusion relatively robust for parameters typically expected for HL-GRBs





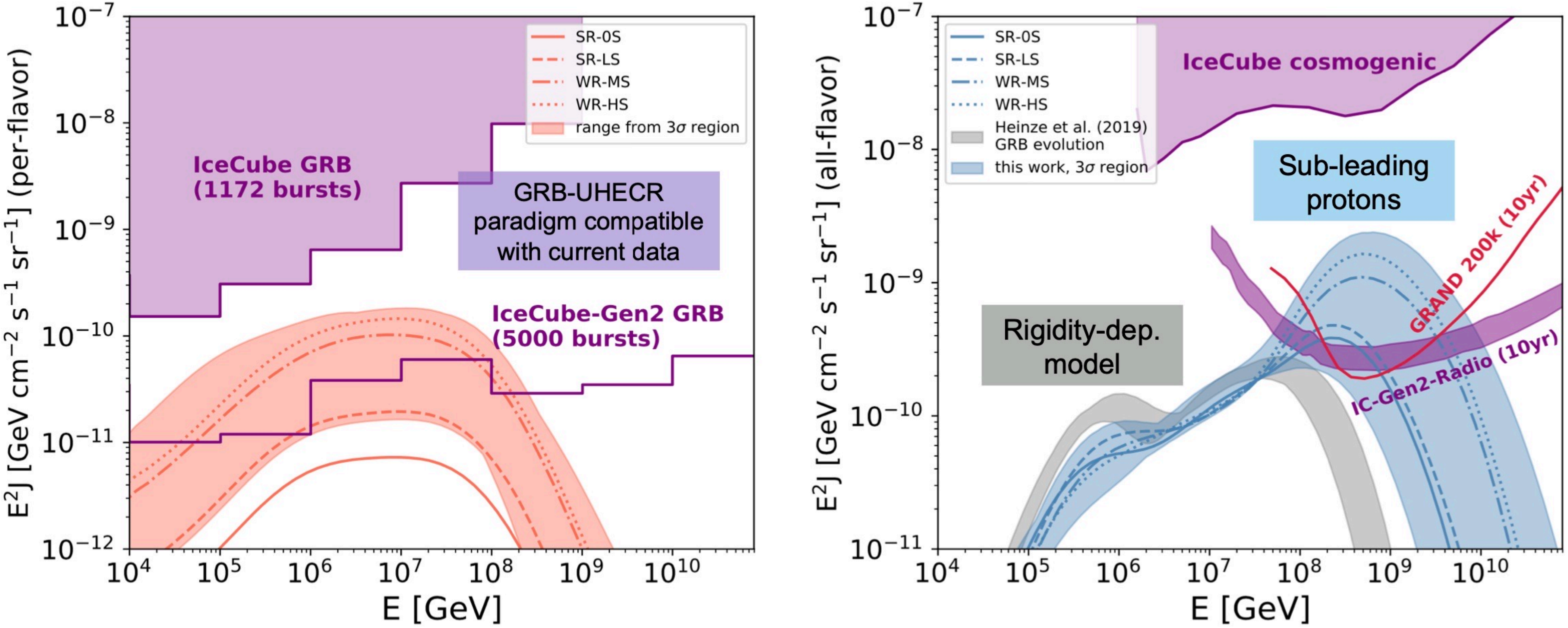




Biehl, Boncioli, Fedynitch, Winter, arXiv:1705.08909
Astron. Astrophys. 611 (2018) A101;
Baerwald, Bustamante, Winter, Astropart. Phys. 62 (2015) 66

Inferred neutrino fluxes from the parameter space scan

Prompt neutrino flux possibly testable with IceCube-Gen2, cosmogenic one in future radio instruments



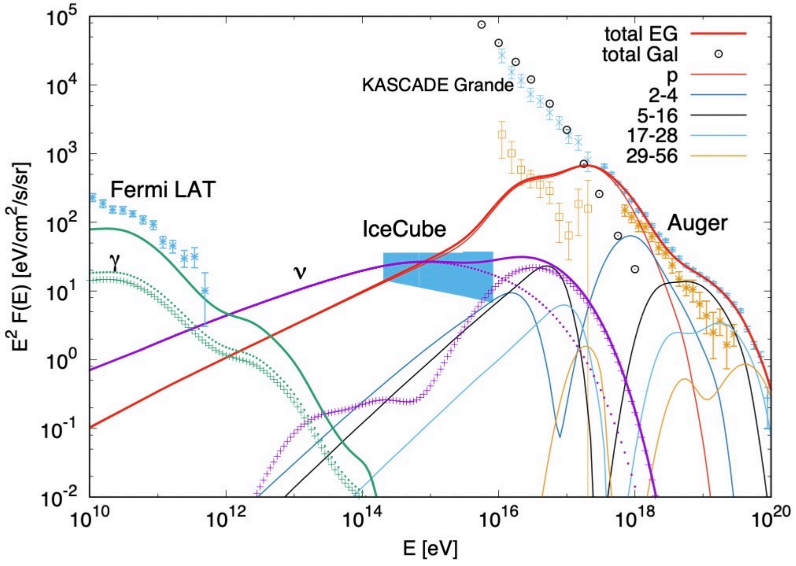
Heinze, Biehl, Fedynitch, Boncioli, Rudolph, Winter, MNRAS 498 (2020) 4, 5990, arXiv:2006.14301

Cosmic Ray Calorimeters

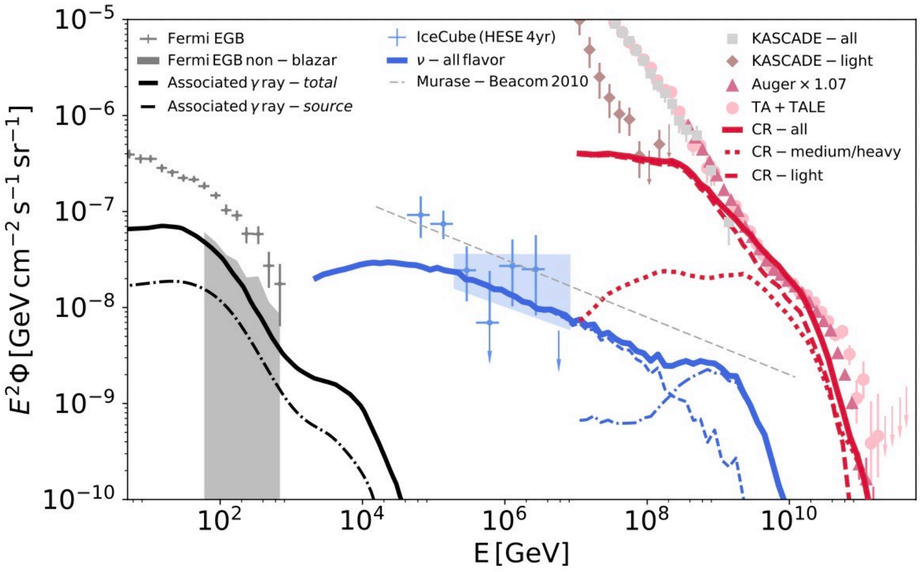
- Competing requirements for efficient CR acceleration and subsequent interaction can be accommodated in **multi-zone models**.
- Magnetic confinement in CR calorimeters, such as **starburst galaxies**, could provide a unified origin of UHE CRs and TeV–PeV neutrinos.

[Loeb & Waxman '06]

- "*Grand Unification*" of UHE CRs, γ-rays and neutrinos?



[Kachelriess, Kalashev, Ostapchenko & Semikoz'17]

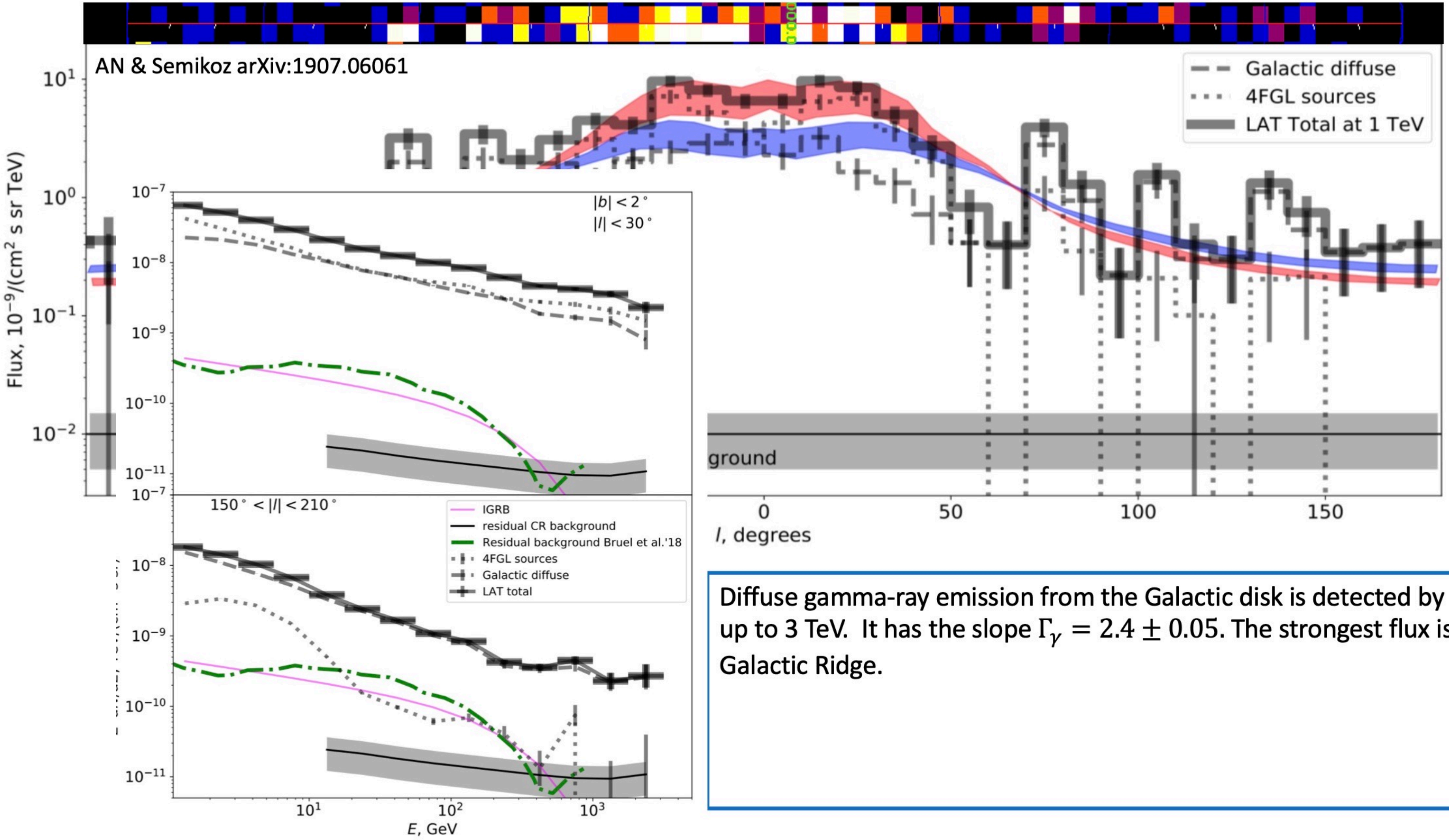


[Fang & Murase'17]

M.Ahlers talk

Galactic sources

Diffuse emission from the interstellar medium



A.Neronov talk

Diffuse gamma-ray emission from the Galactic disk is detected by Fermi/LAT up to 3 TeV. It has the slope $\Gamma_\gamma = 2.4 \pm 0.05$. The strongest flux is from the Galactic Ridge.

Hint in latest ANTARES Search !

M. Lamoureux's poster

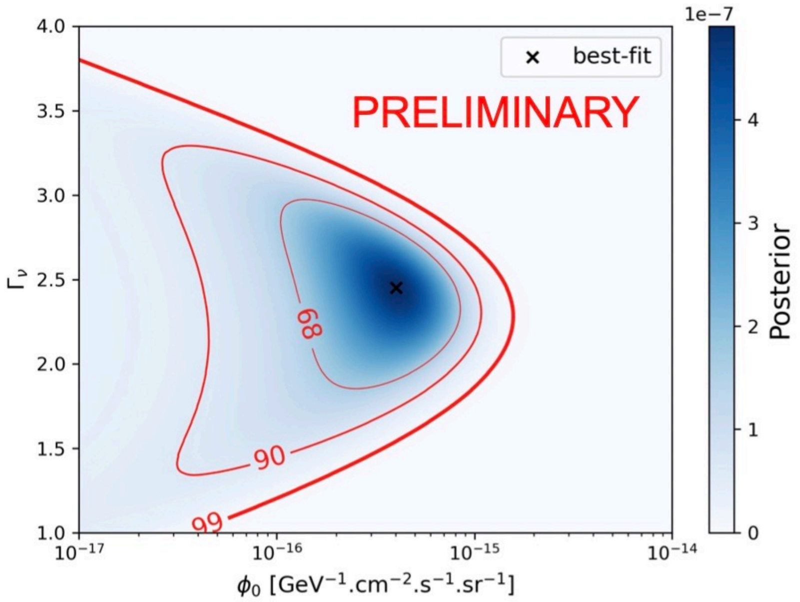
CAUTION HOT

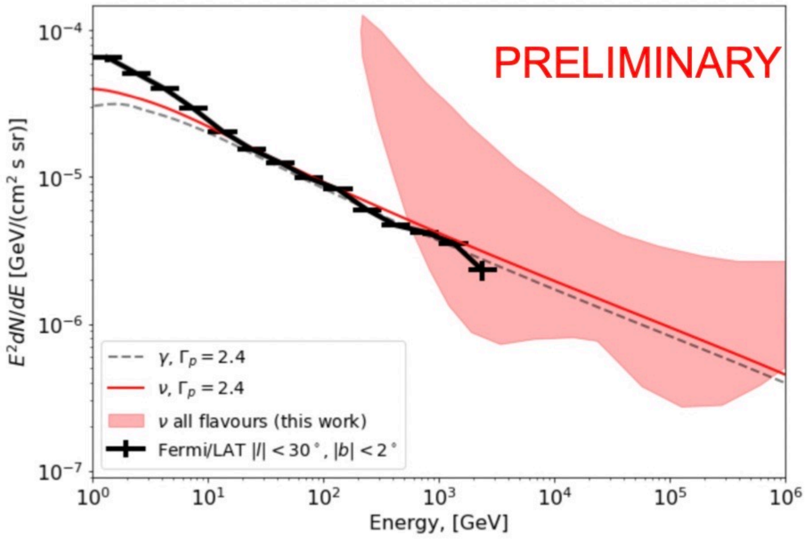
PRELIMINARY

- **Data period:** 2007–2020
- **Events:** tracks + showers, using existing diffuse neutrino selections
- **Signal hypothesis:** looking for signal in the region $|\ell| < 30^\circ$ and $|b| < 2^\circ$ assuming a simple power-law

$$\frac{dN}{dEdtd\Omega} = \phi_0 \times \left(\frac{E}{40\,\mathrm{TeV}}\right)^{-\gamma} \text{ in } [\mathrm{GeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}] \quad \text{per flavor}$$

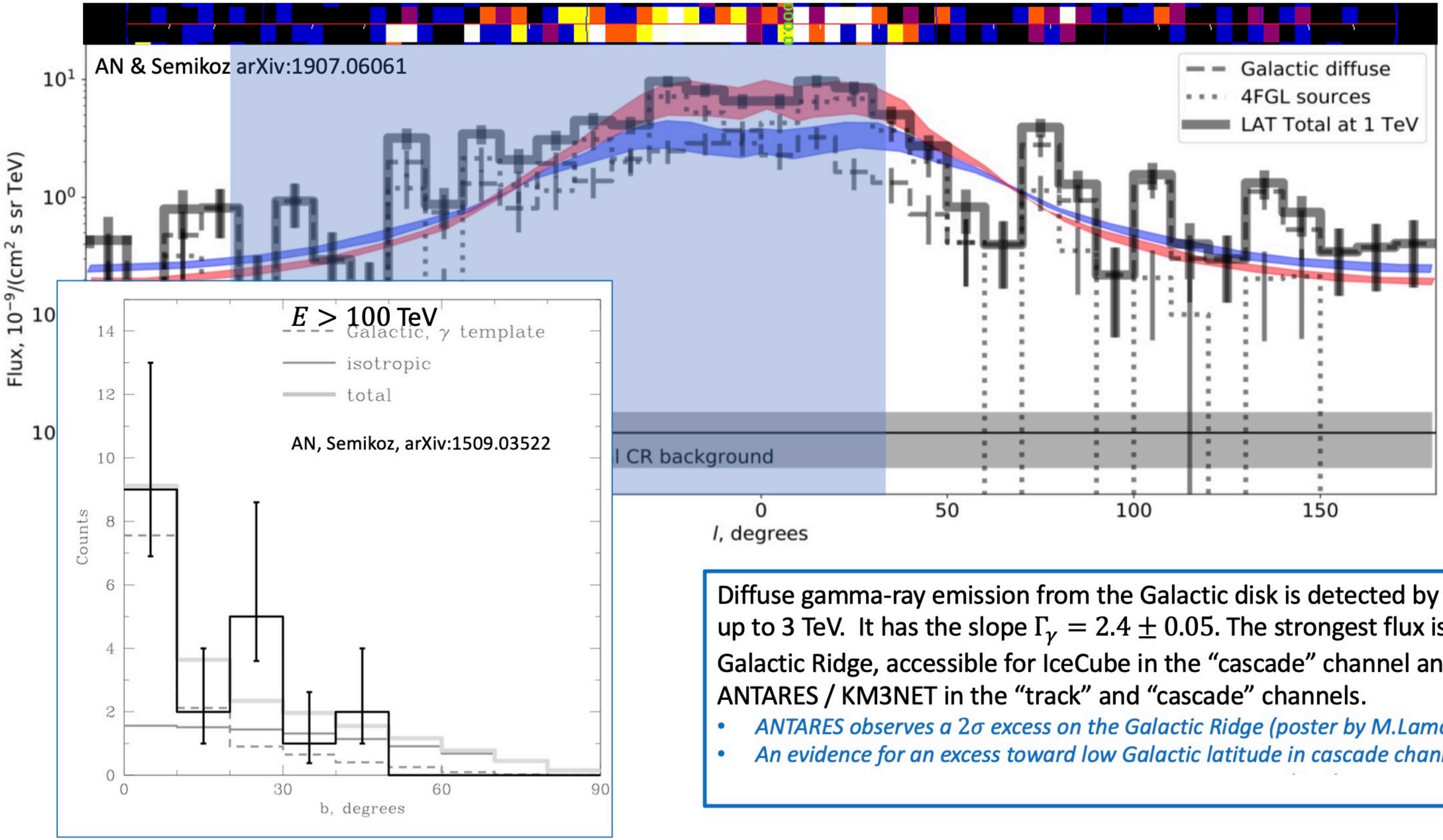
Best-fit: γ =2.45, ϕ_0(40 TeV)=4.0e-16





A.Kouchner talk

Diffuse emission from the interstellar medium

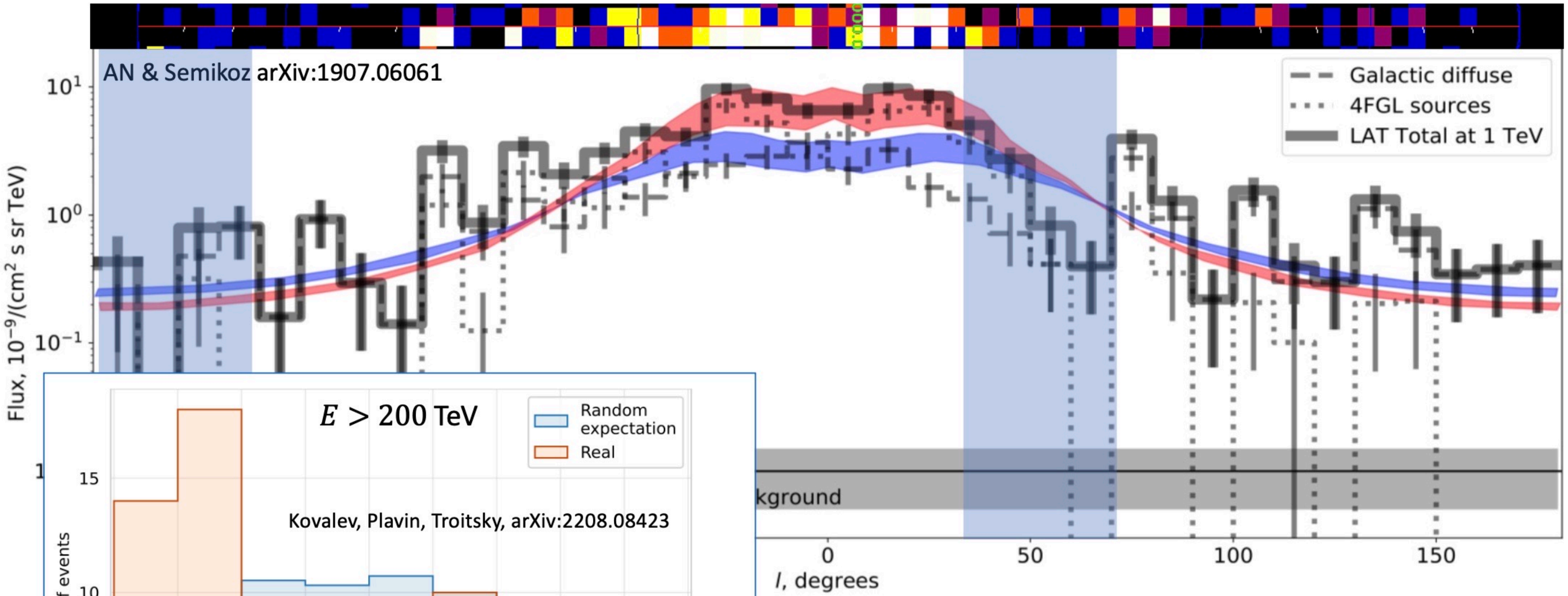


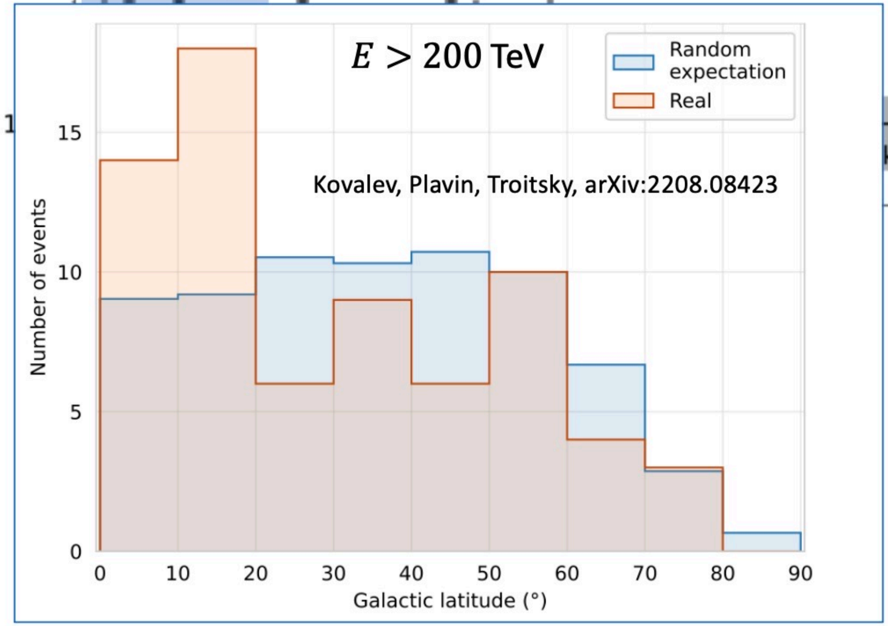
Neronov talk

Diffuse gamma-ray emission from the Galactic disk is detected by Fermi/LAT up to 3 TeV. It has the slope $\Gamma_\gamma = 2.4 \pm 0.05$. The strongest flux is from the Galactic Ridge, accessible for IceCube in the "cascade" channel and to ANTARES / KM3NET in the "track" and "cascade" channels.

- *ANTARES observes a 2σ excess on the Galactic Ridge (poster by M.Lamoureux).*
- *An evidence for an excess toward low Galactic latitude in cascade channel in IceCube*

Diffuse emission from the interstellar medium





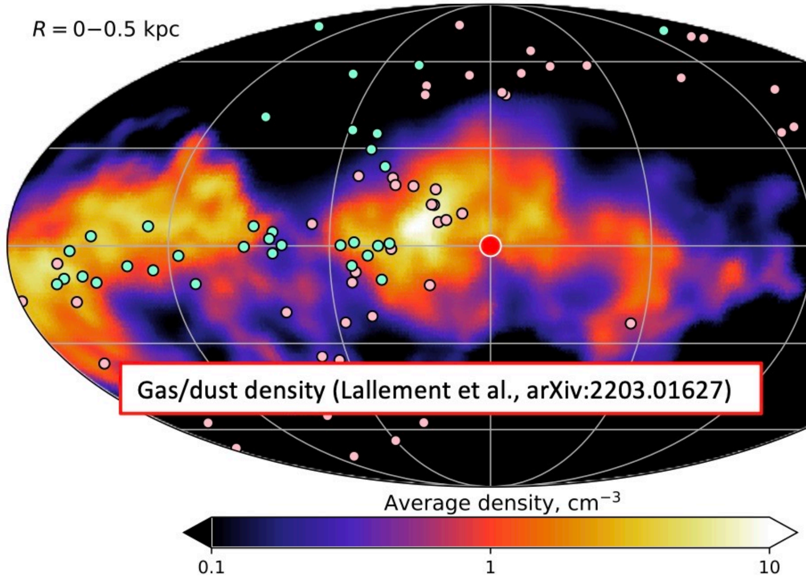
A.Neronov talk

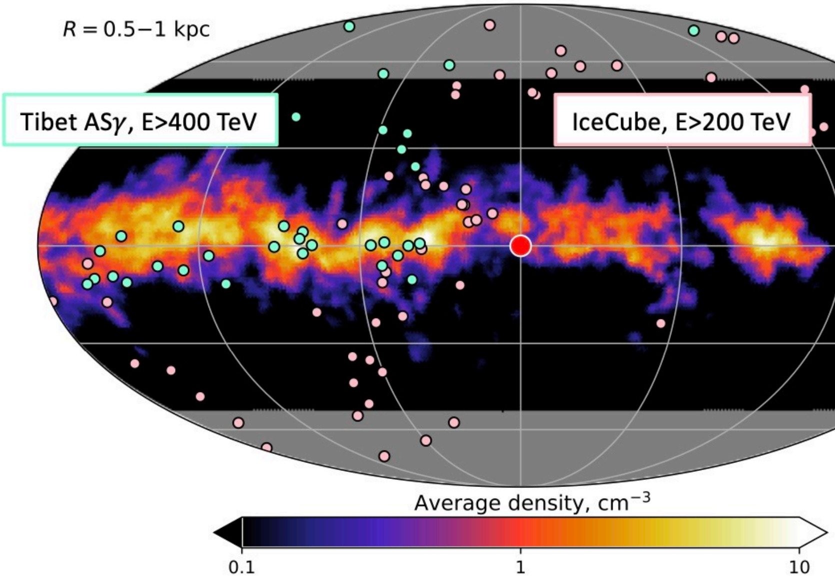
Diffuse gamma-ray emission from the Galactic disk is detected by Fermi/LAT up to 3 TeV. It has the slope $\Gamma_\gamma = 2.4 \pm 0.05$. The strongest flux is from the Galactic Ridge, accessible for IceCube in the "cascade" channel and to ANTARES / KM3NET in the "track" and "cascade" channels.

- *ANTARES observes a 2σ excess on the Galactic Ridge.*
- *An evidence for an excess toward low Galactic latitude in cascade channel in IceCube*
- *---and in the muon neutrino channel*

See talk S.Koldobsky

Diffuse emission from the interstellar medium



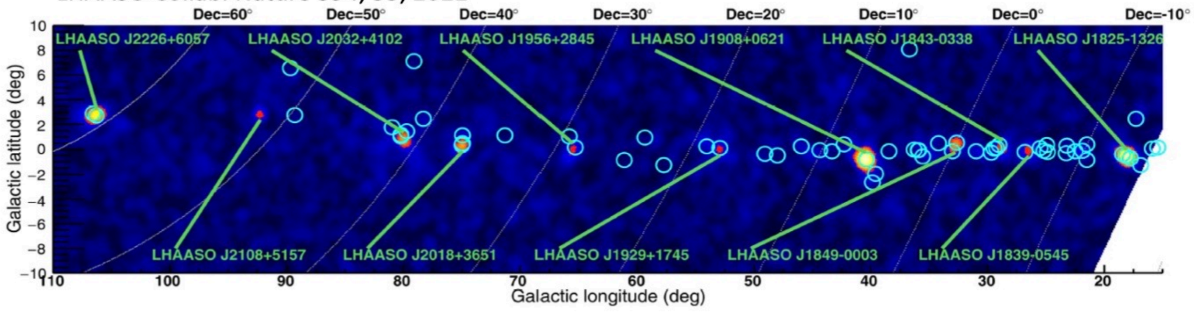


Excess in 20° Galactic latitude may indicate that the signal is coming from our "Galactic neighborhood", rather than from the entire Galactic disk (that would be expected to give the signal within several degrees Galactic latitude).

Kovalev, Plavin, Troitsky, arXiv:2208.08423
Amenomori et al. arXiv:2104.05181
Koldobskiy, Semikoz, AN (in preparation)

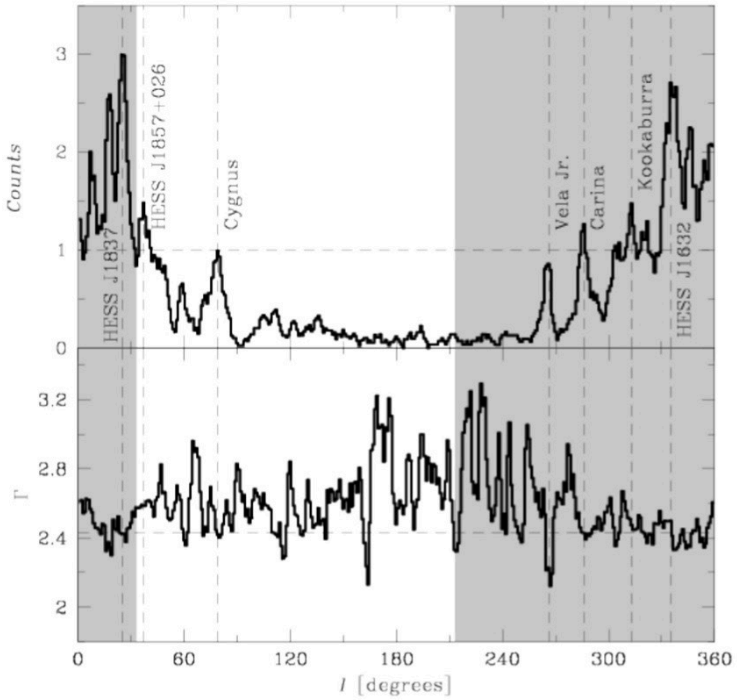
Isolated Galactic sources

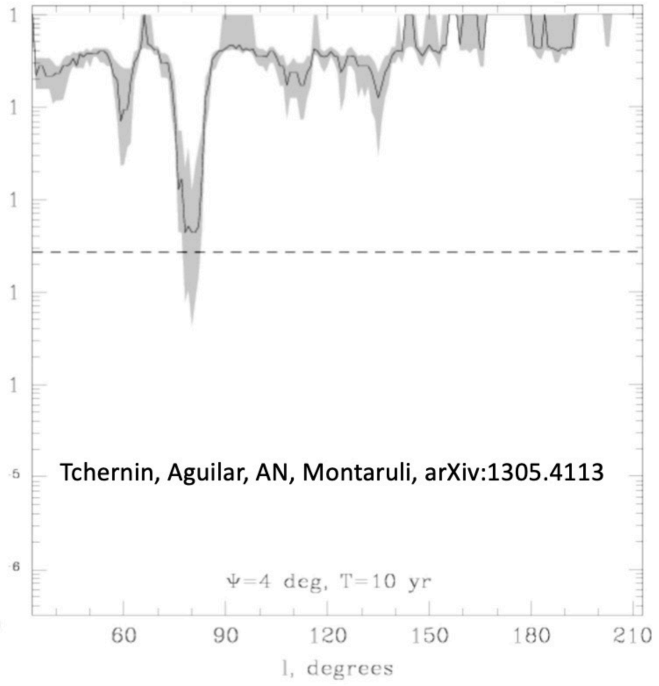
LHAASO Collab. Nature 594, 33, 2021



Gamma-ray observations in the TeV-PeV band limit the neutrino flux from isolated sources.

Cygnus X region appears to be the best candidate in the Northern sky.



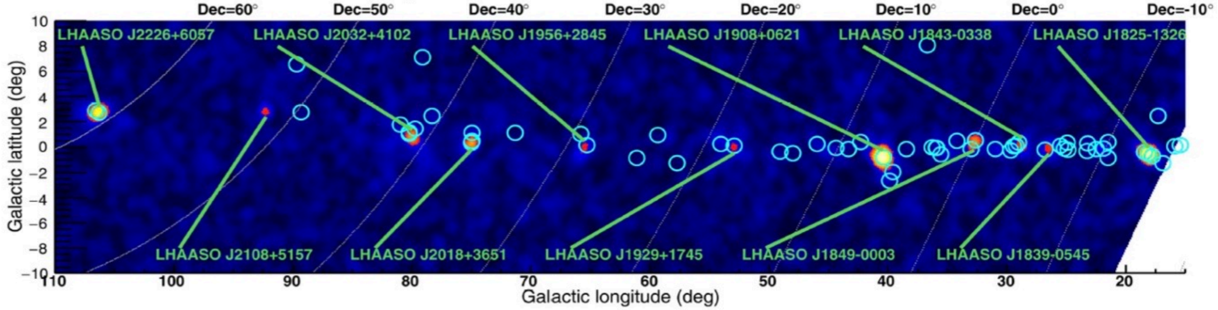


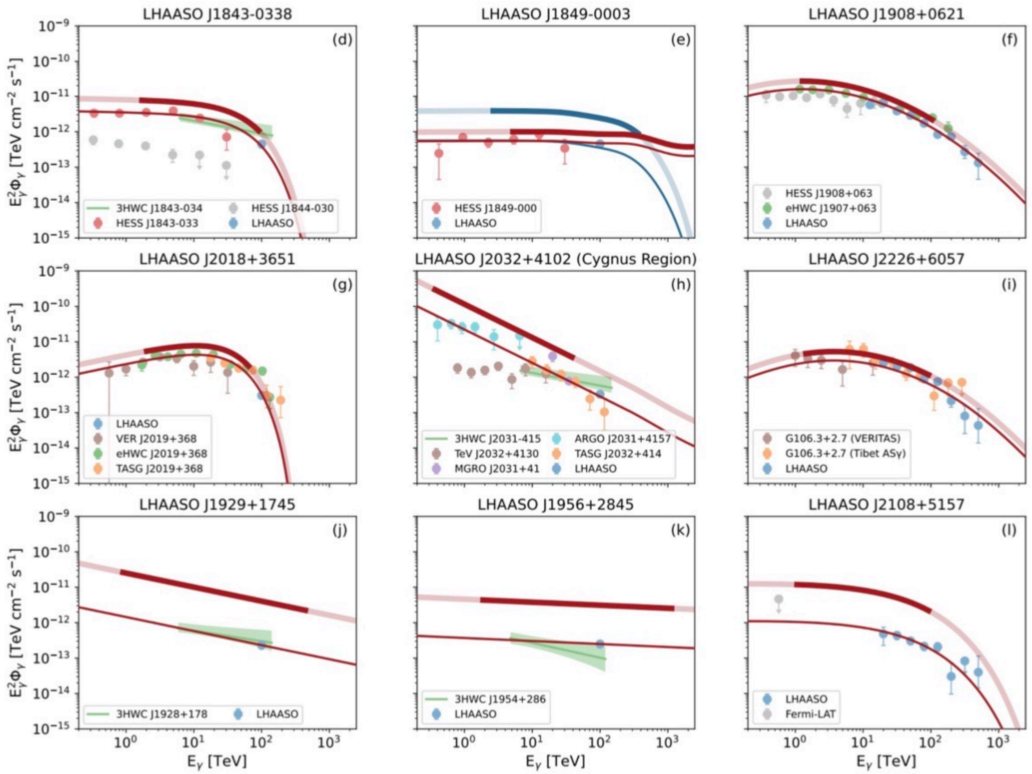
Tchernin, Aguilar, AN, Montaruli, arXiv:1305.4113

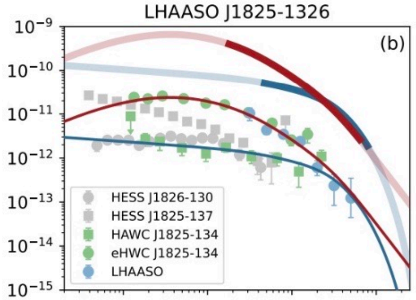
A.Neronov talk

Isolated Galactic sources

LHAASO Collab. Nature 594, 33, 2021





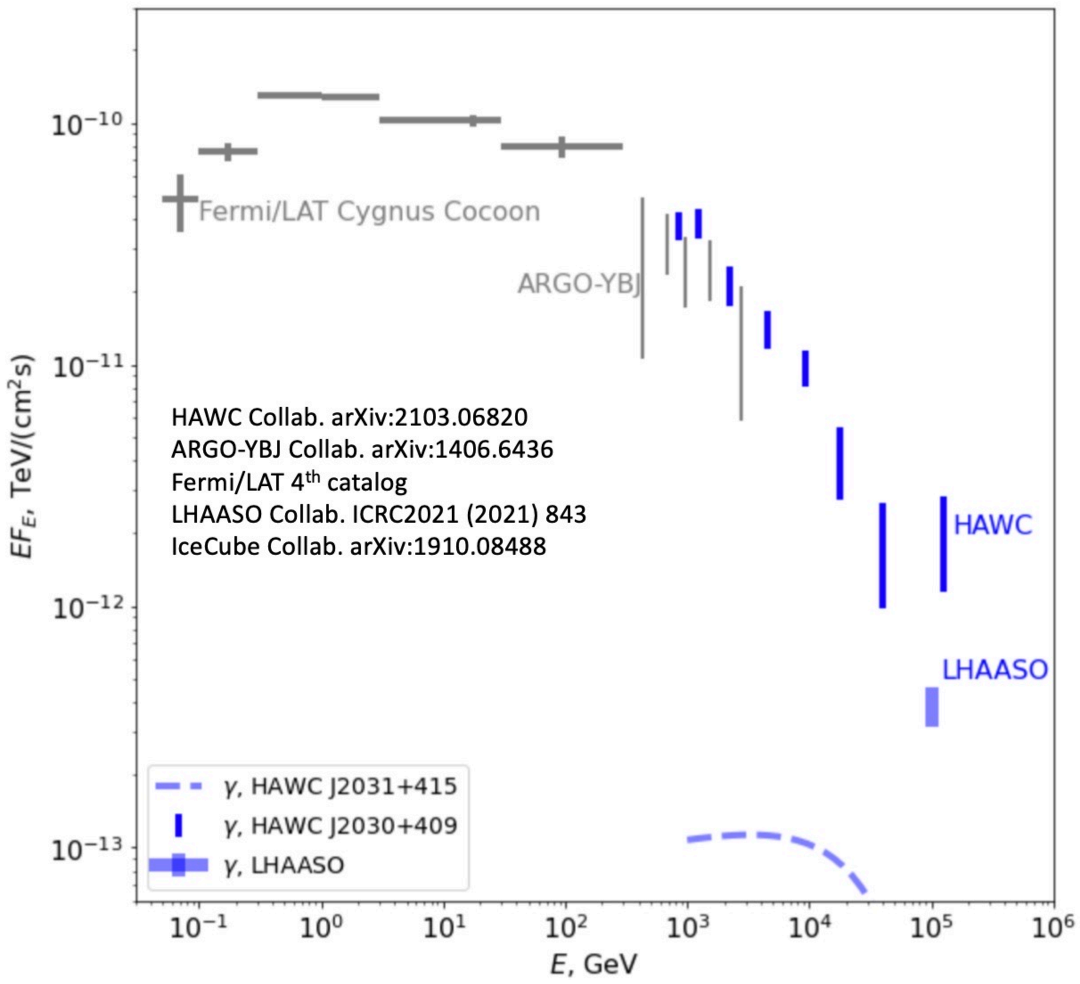


Huang, Li, arXiv:2112.14062

A.Neronov talk

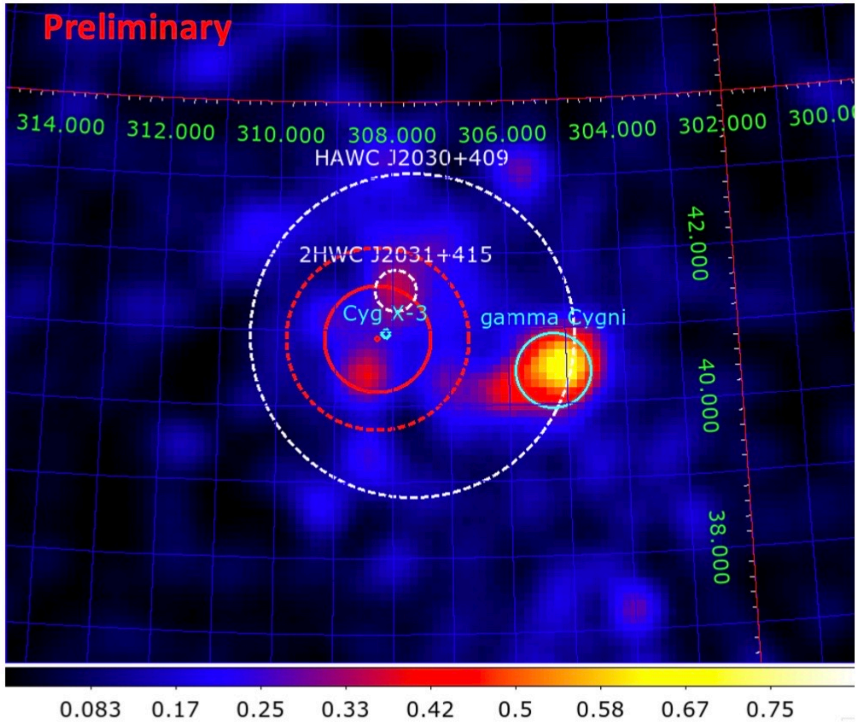
Decade-long exposure of IceCube in the track channel is not sufficient for detection of even the brightest HAWC / LHAASO Galactic gamma-ray source(s).

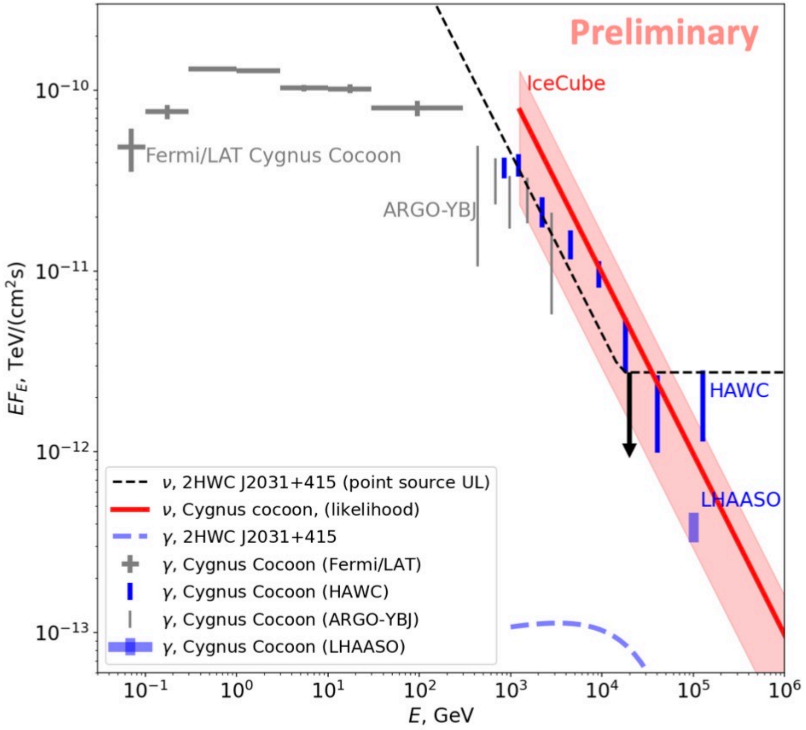
A closer look at Cygnus region



- The γ-ray flux is dominated by emission from extended Cocoon.
- Radio-to-X-ray synchrotron measurements show that TeV emission is of hadronic origin.
- In this case neutrino flux is expected to be comparable to γ-ray flux.

.Neronov talk





Source position is consistent with either HAWC or LHAASO extended source position.

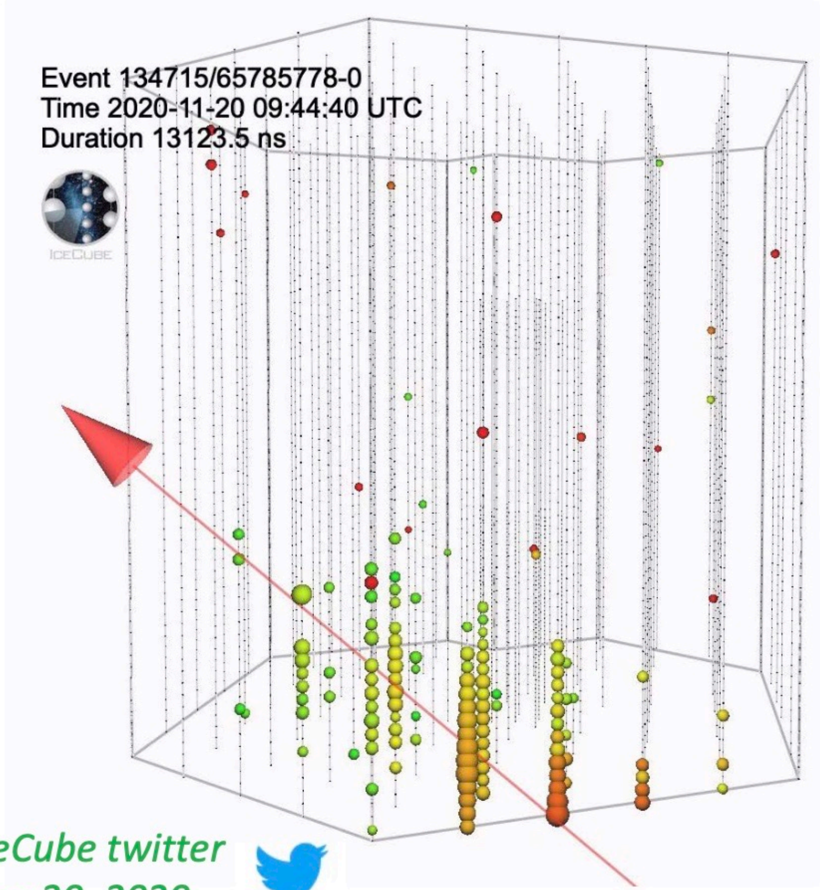
Neutrino flux level is consistent with the γ-ray flux of the extended Cocoon source.

A.Neronov talk

AN, Semikoz, Savchenko, (submitted)

Binaries

IceCube neutrino from Cygnus Cocoon



IceCube twitter
Nov 20, 2020

//

TITLE: GCN CIRCULAR
NUMBER: 28927
SUBJECT: IceCube-201120A: IceCube observation of a high-energy neutrino candidate event
DATE: 20/11/20 13:57:56 GMT
FROM: Cristina Lagunas Gualda at DESY <cristina.lagunas@desy.de>

The IceCube Collaboration (http://icecube.wisc.edu/) reports:

On 20/11/20 at 09:44:40.56 UT IceCube detected a track-like event with a moderate probability of being of astrophysical origin. The event was selected by the ICECUBE_Astrotrack_Bronze alert stream. The average astrophysical neutrino purity for Bronze alerts is 30%. This alert has an estimated false alarm rate of 0.295 events per year due to atmospheric backgrounds. The IceCube detector was in a normal operating state at the time of detection.

After the initial automated alert (https://gcn.gsfc.nasa.gov/notices_amon_g_b/134715_65785778.amon), more sophisticated reconstruction algorithms have been applied offline, with the direction refined to:

Date: 20/11/20
Time: 09:44:40.56 UT
RA: 307.53 (+ 5.34 - 5.59 deg 90% PSF containment) J2000
Dec: 40.77 (+ 4.97 - 2.80 deg 90% PSF containment) J2000

Due to the topology of this event, with a short distance traversed through the detector, the updated angular uncertainty is significantly larger than average error contours.

We encourage follow-up by ground and space-based instruments to help identify a possible astrophysical source for the candidate neutrino.

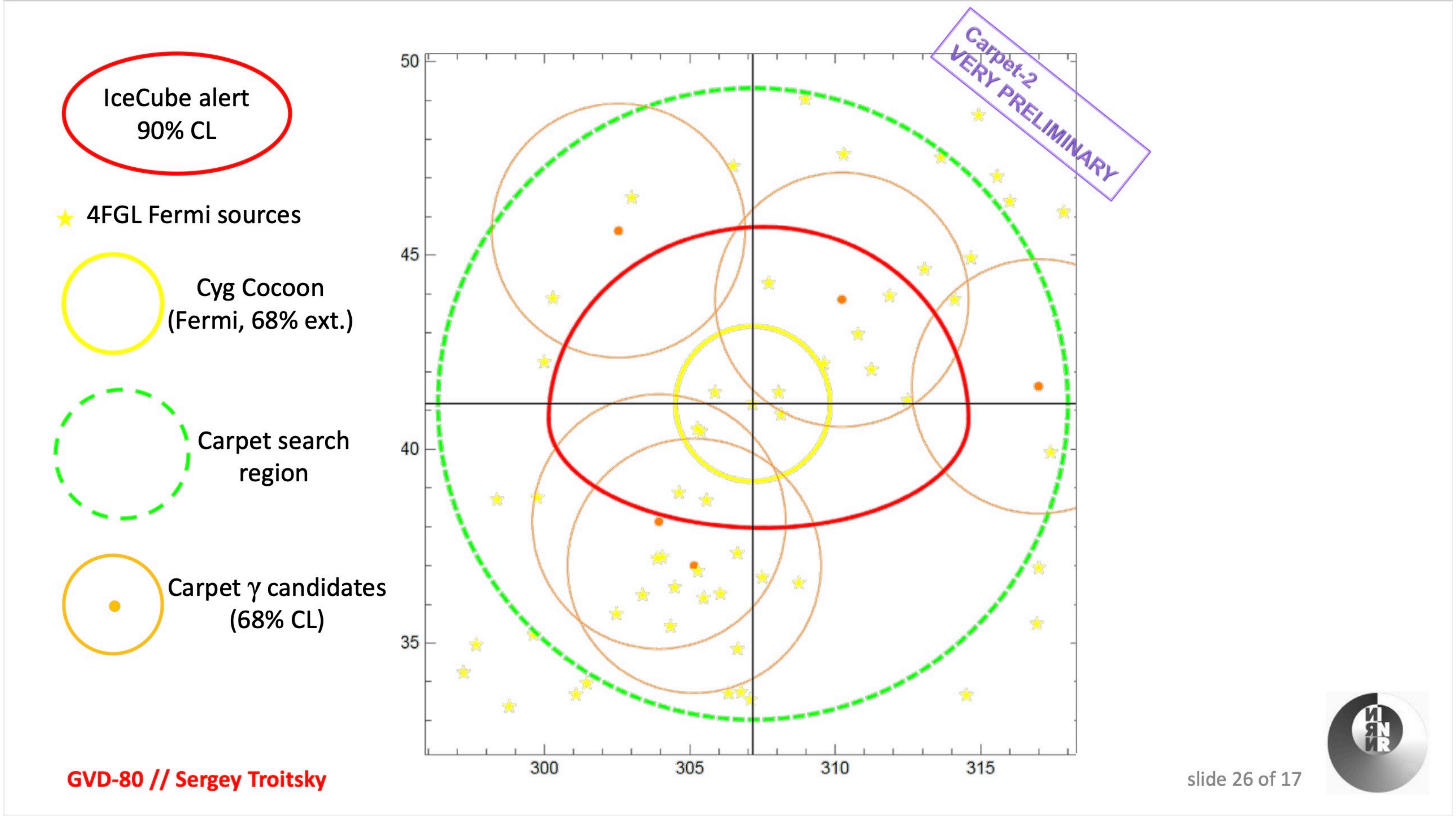
There are several Fermi-LAT 4FGL sources inside the 90% localization region. The closest source is 4FGL J2028.6+4110e (Cygnus Cocoon) located at RA 307.17 deg and Dec 41.17 deg (J2000), at a distance of 0.484 degrees from the best-fit location.

The IceCube Neutrino Observatory is a cubic-kilometer neutrino detector operating at the geographic South Pole, Antarctica. The IceCube realtime alert point of contact can be reached at roc@icecube.wisc.edu

GCN #28927

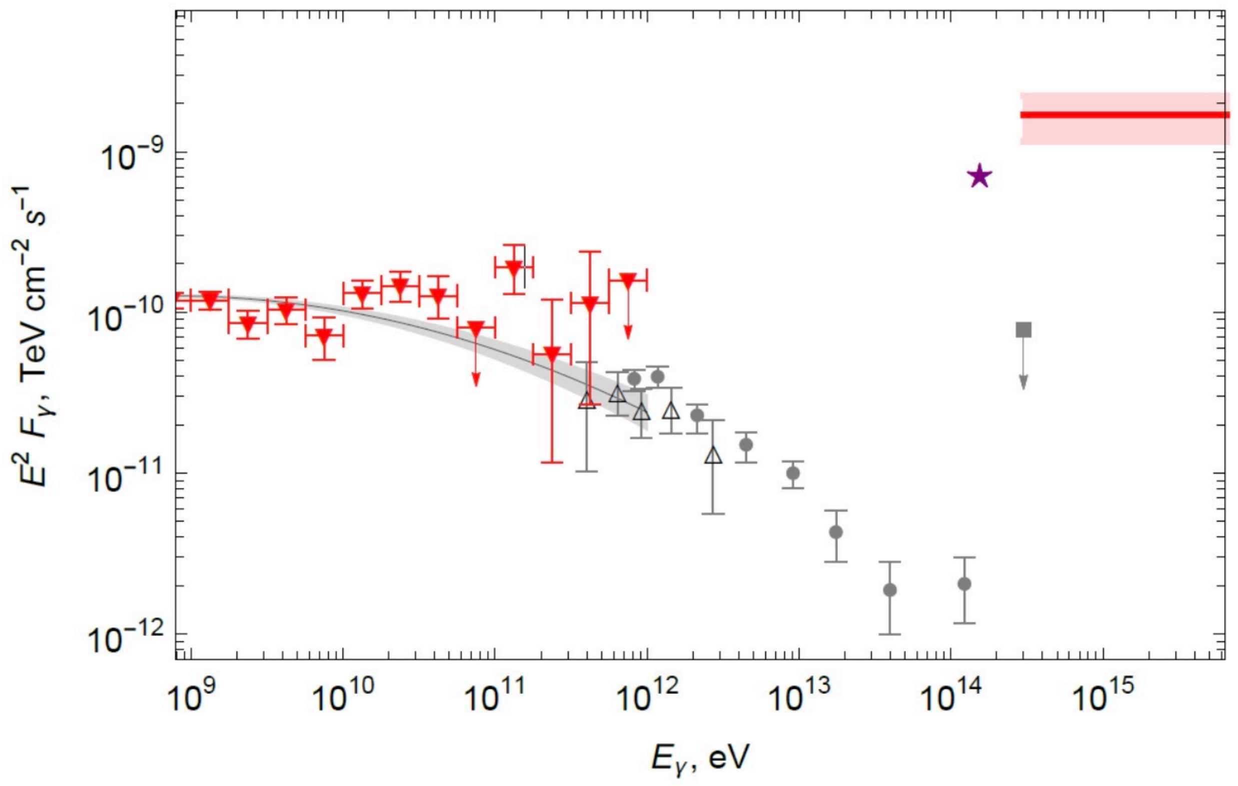
despite poor localization, this event is exceptional:
the first neutrino alert associated with a plausible Galactic source

A.Bykov talk


IceCube alert
90% CL
4FGL Fermi sources
Cyg Cocoon
(Fermi, 68% ext.)
Carpet search
region
Carpet γ candidates
(68% CL)
Carpet-2
VERY PRELIMINARY
50
45
40
35
300
305
310
315
GVD-80 // Sergey Troitsky
slide 26 of 17

A.Bykov talk

Spectral energy distribution of Cygnus Cocoon above 1 GeV.



Time-averaged

4FGL flux model (Abdollahi et al. 2020)

ARGO (Bartoli et al. 2014)

HAWC (Abeysekara et al. 2021)

Carpet-2, this work

Flare

Fermi LAT

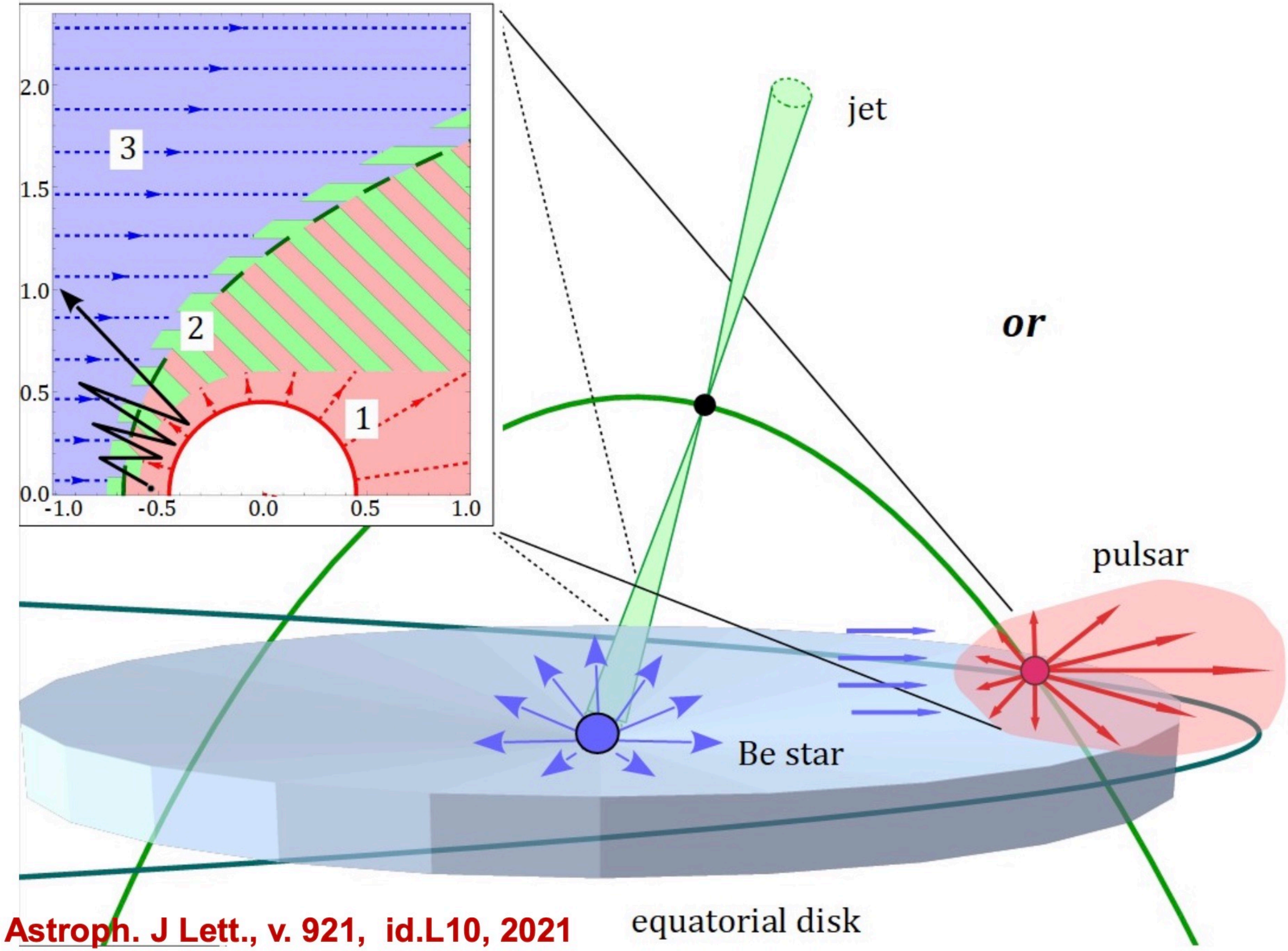
Carpet-2, this work

Estimate of the IceCube neutrino fluence

Spectral energy distribution averaged over the same d = 82-day period around the neutrino arrival using publicly available data of the Fermi Large Area Telescope (Fermi-LAT)

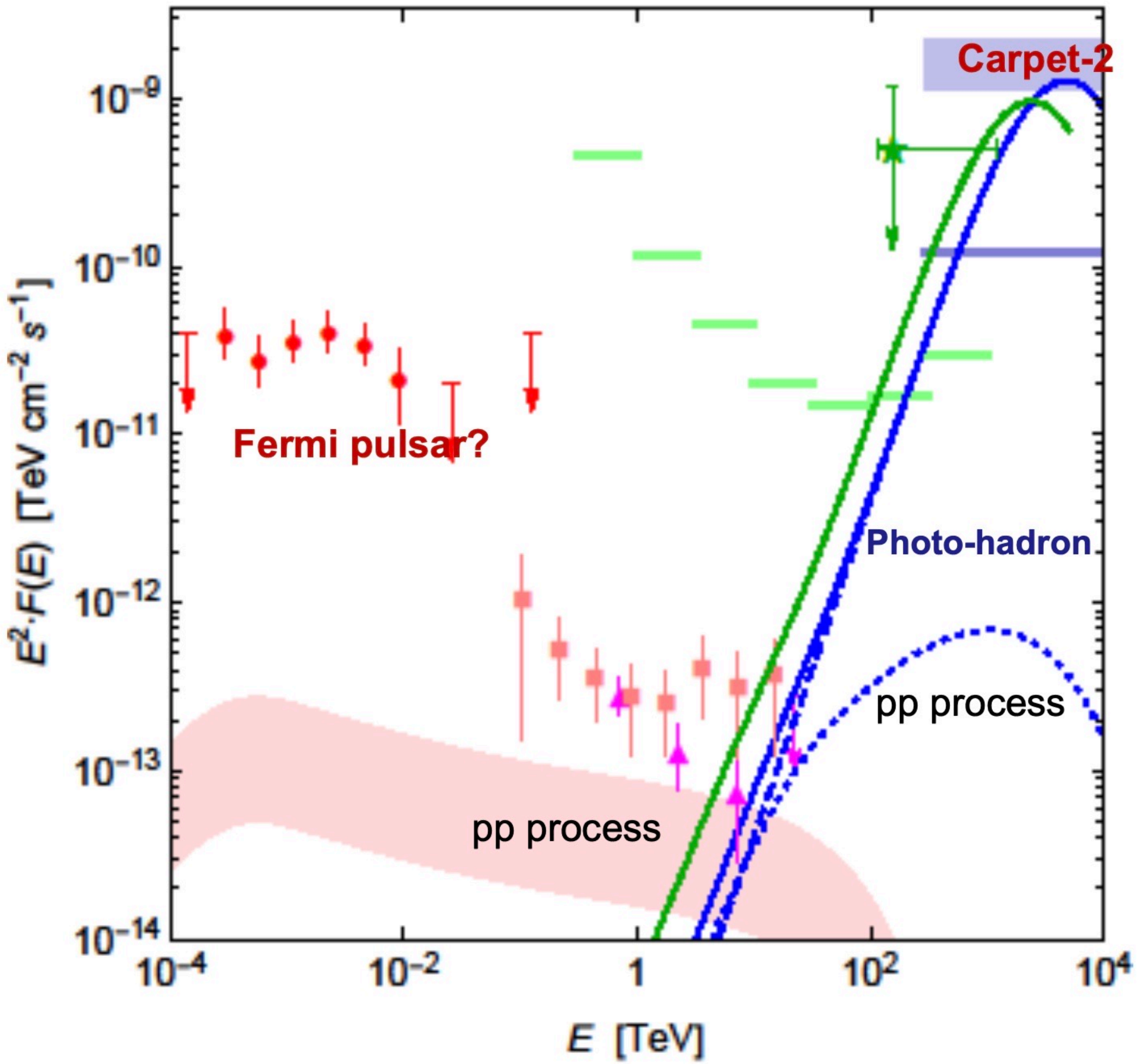
V.Romanenko,
for the Carpet-3 Collaboration

A.Bykov talk



Bykov + Astroph. J Lett., v. 921, id.L10, 2021

A.Bykov talk



Bykov+ Astroph. J Lett., v. 921, id.L10, 2021

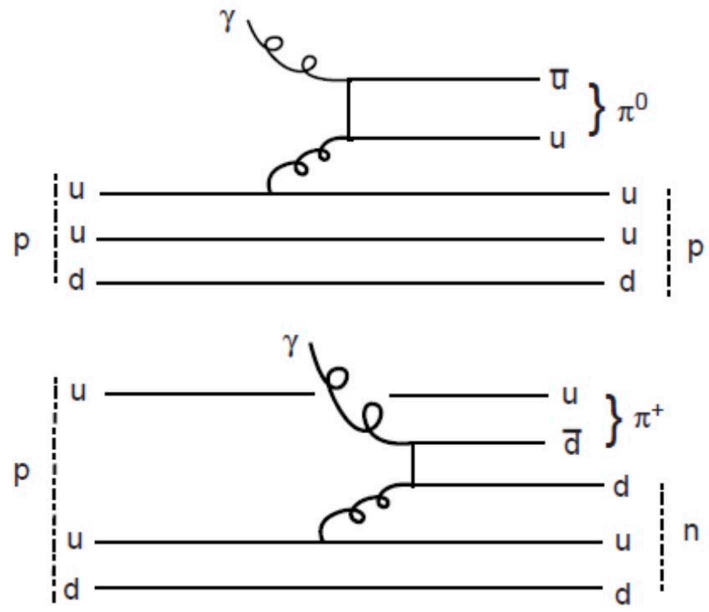


Photo-hadron cross-sections are from Kelner Aharonian PhRvD, 78, 034013

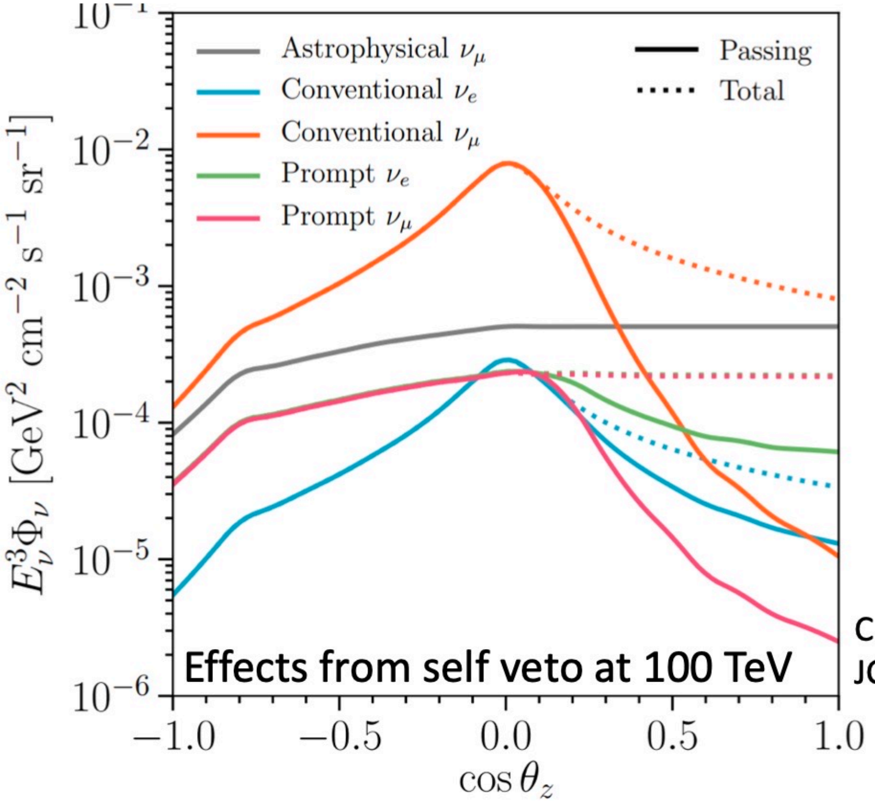
A.Bykov talk

Beyond Standard Model

Constraints from ν

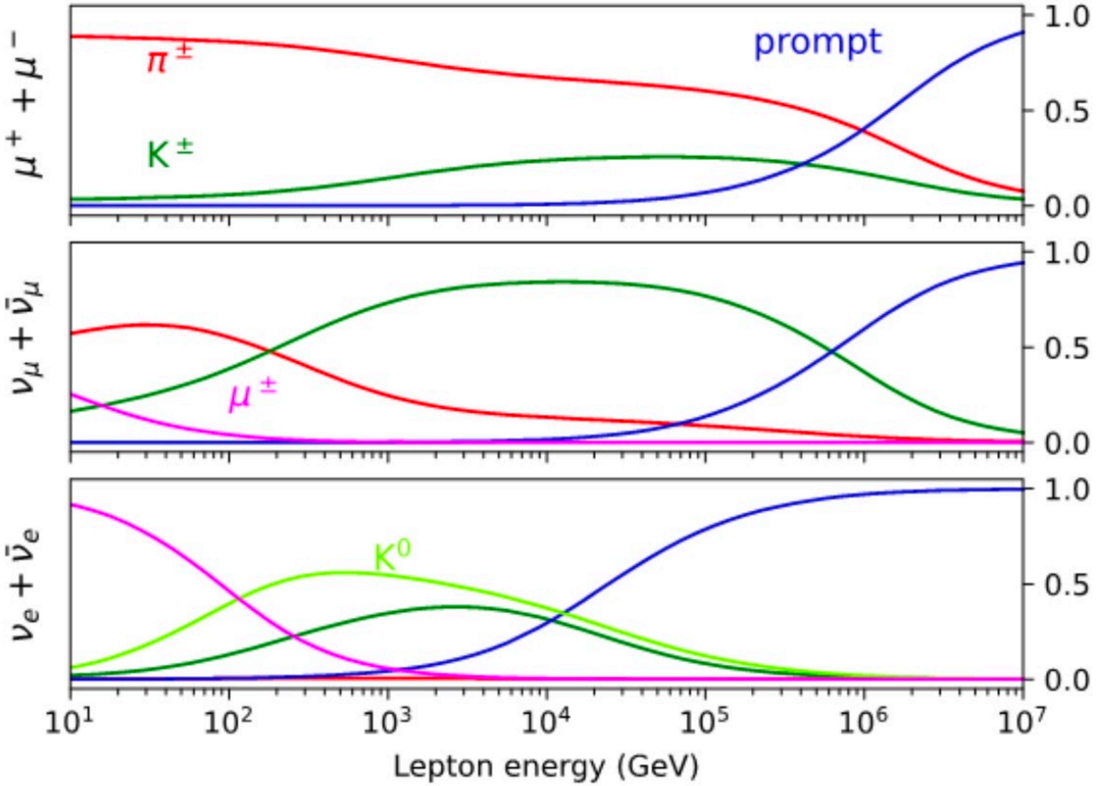
J.Yanez talk

- The ν_e channel is dominant at 10's TeV
- The ν_μ channel is degenerate with $\Phi_{\nu\, astro}$
- Self-veto rejects prompt, breaks degeneracy



C. Arguelles et al
JCAP 07 (2018) 047

Fraction of flux coming from each meson

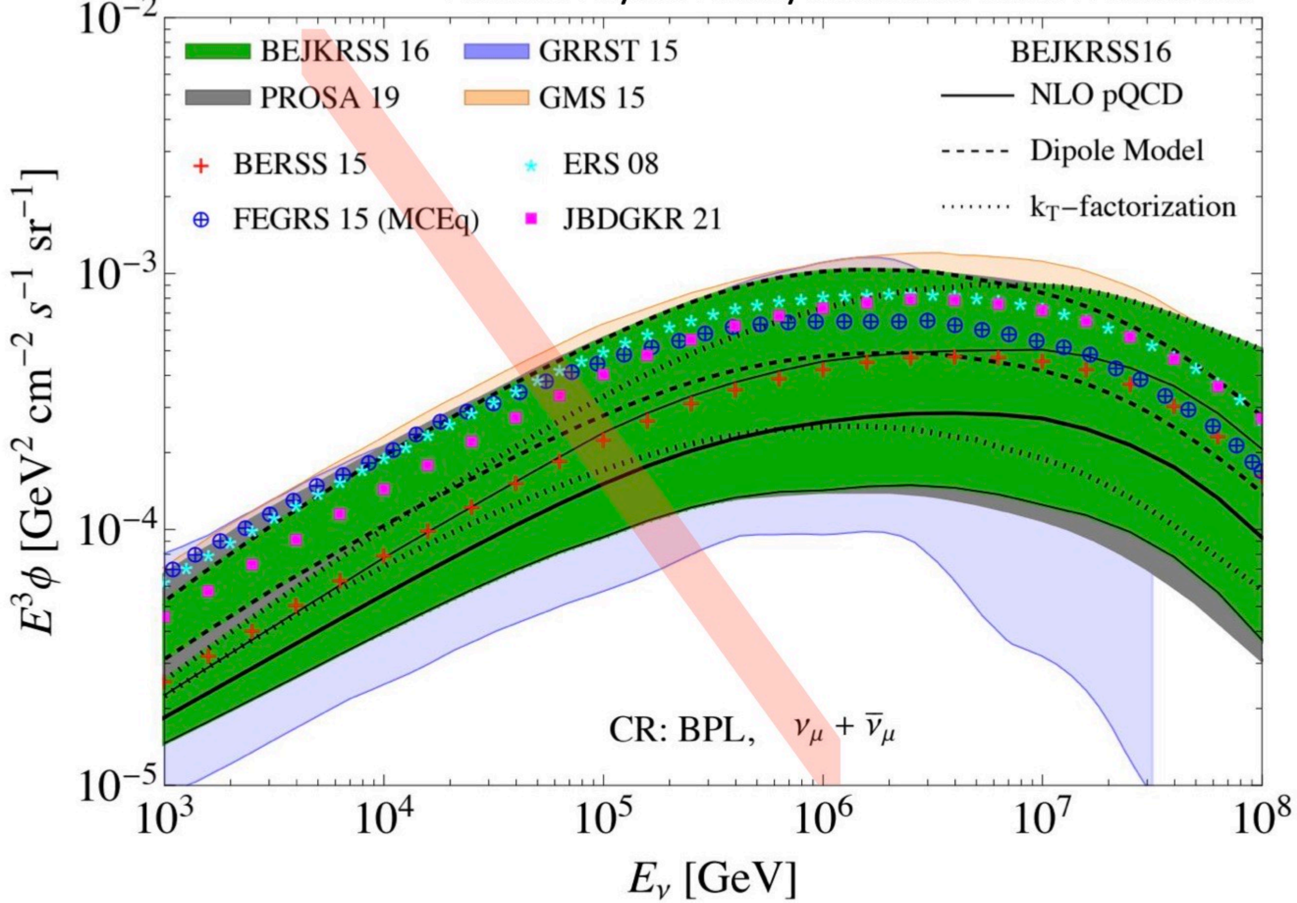


A. Fedynitch, F. Riehn, R. Engel, T.K. Gaisser, T. Stanev
PRD 100 2019

J.Yanez talk

The problem of prompt

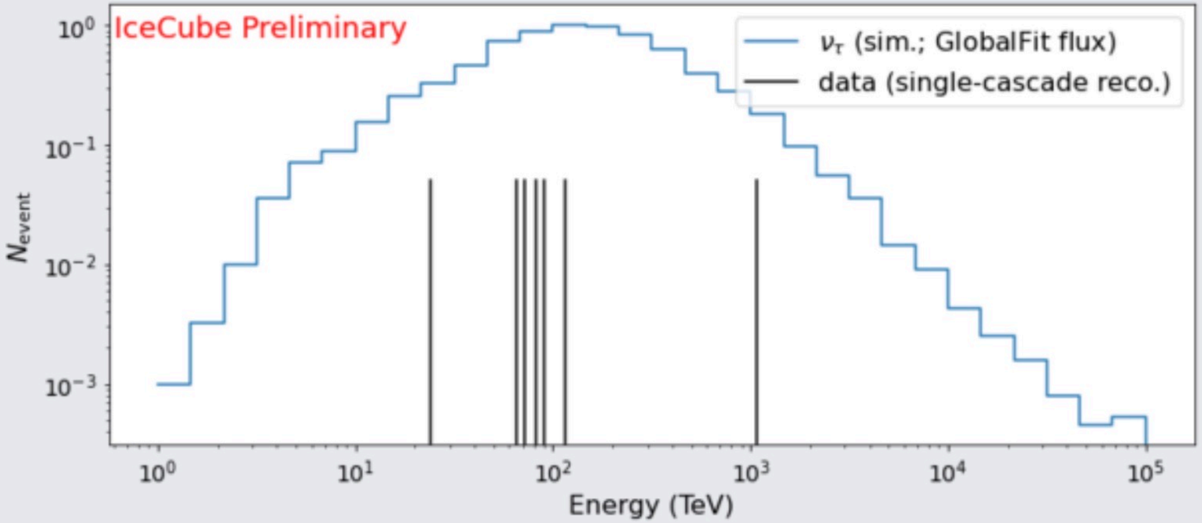
Forward Physics Facility Snowmass arXiv: 2203.05090

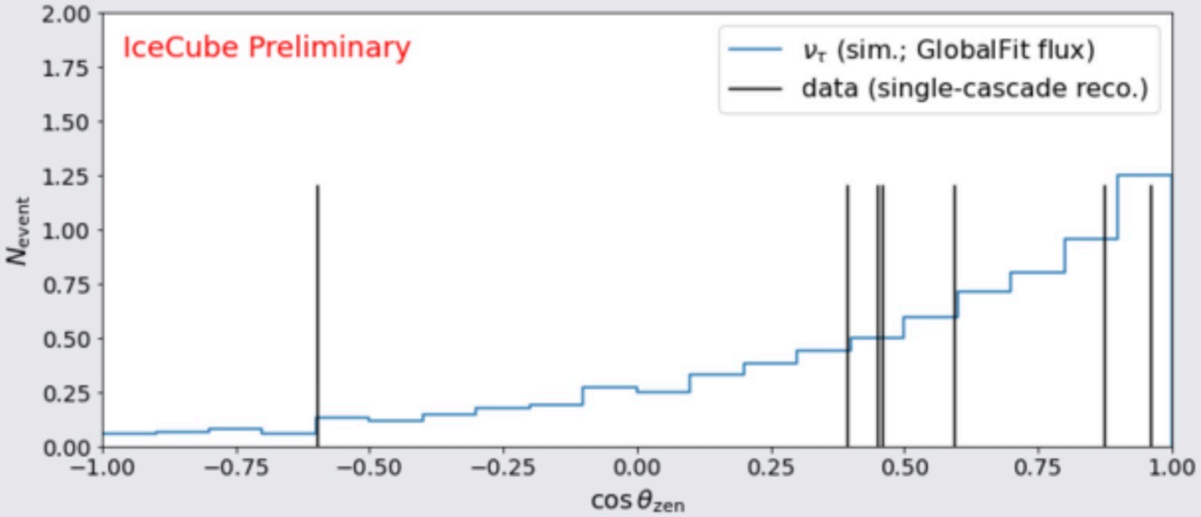


- Expected to dominate atm. ν flux above 100 TeV – 1 PeV but **<u>not yet observed</u>**
- Predictions have issues
  - Large uncertainties from pQCD
  - pQCD might be incomplete (intrinsic charm)
  - The fragmentation (c → D) function is a choice
- No hadronic data available to directly constrain the models

ν_τ^{astro}: Post-Unblinding Checks

- Apply single-pulse reco. to
  - simulated ν_τ
  - candidate ν_τ
- Reasonably good agreement…
  - …but take actual numbers with a *big* grain of salt

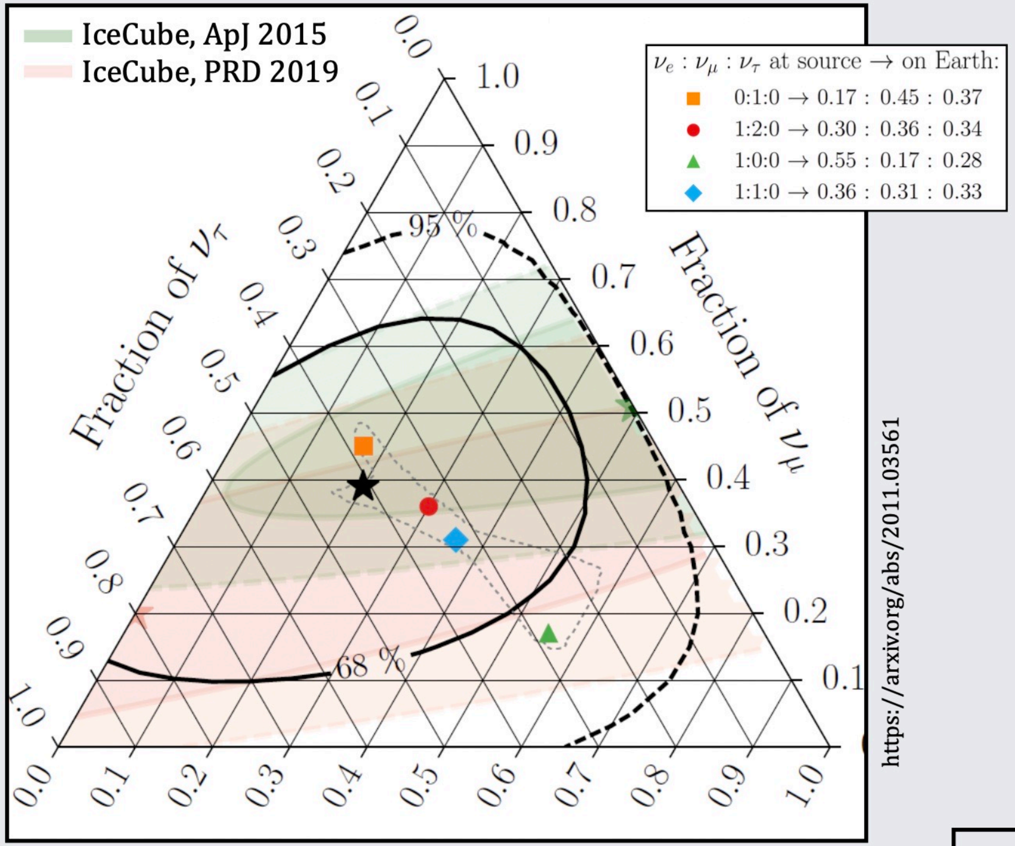




Doug Cowen talk

Importance of Flavor ID for ν^{astro}

Status quo:



Measured flavor composition of IceCube HESE events. ★ is best fit point, consistent with presence of all 3 flavors, but ν_τ flux only weakly constrained.

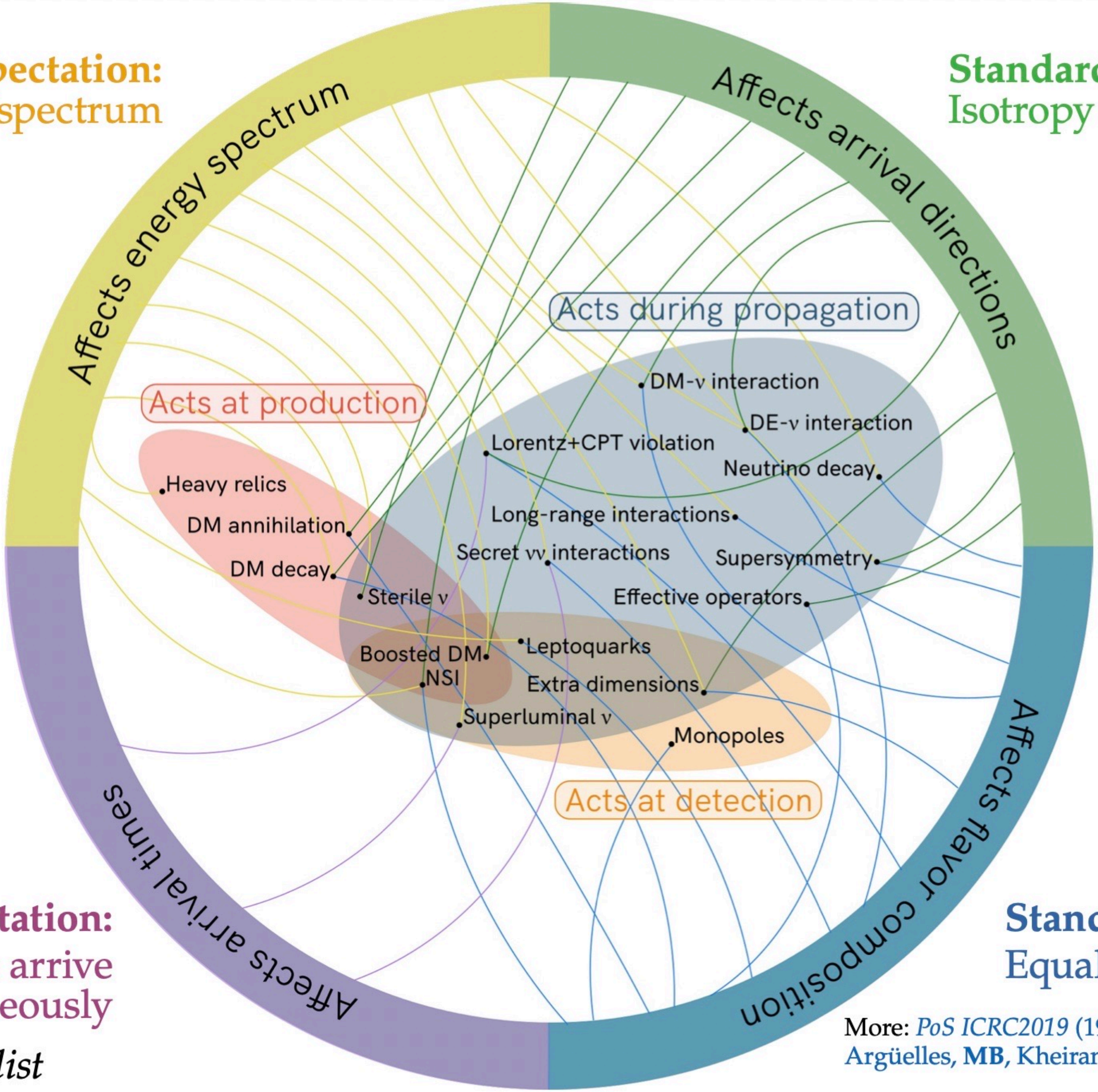
To shrink the contour, need better P.I.D., certainly more than just “track” vs. “cascade.”

Doug Cowen talk

Standard expectation:
Power-law energy spectrum

Standard expectation:
Isotropy (for diffuse flux)

M.Bustamante talk



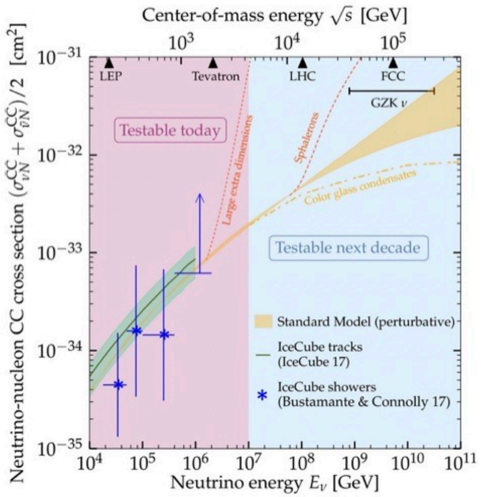
Standard expectation:
ν and γ from transients arrive simultaneously

Standard expectation:
Equal number of ν_e, ν_μ, ν_τ

Note: Not an exhaustive list

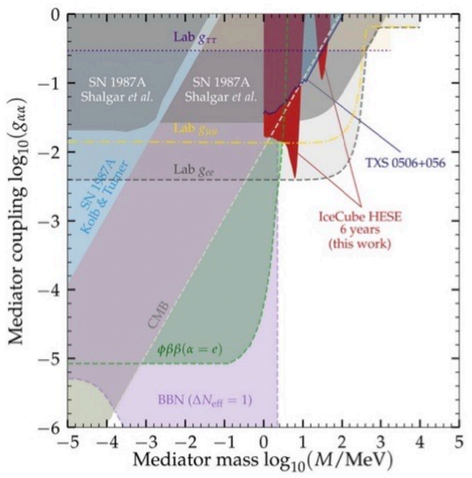
More: *PoS ICRC2019* (1907.08690)
Argüelles, **MB**, Kheirandish, Palomares-Ruiz, Salvadó, Vincent

TeV–EeV ν cross sections



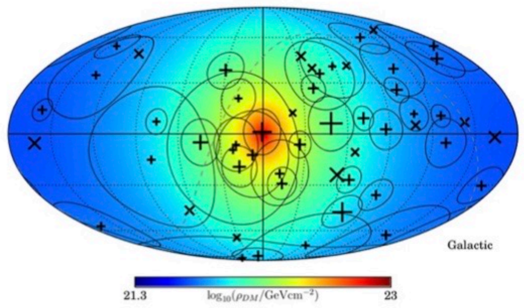
MB & Connolly, *PRL* 2019

ν self-interactions



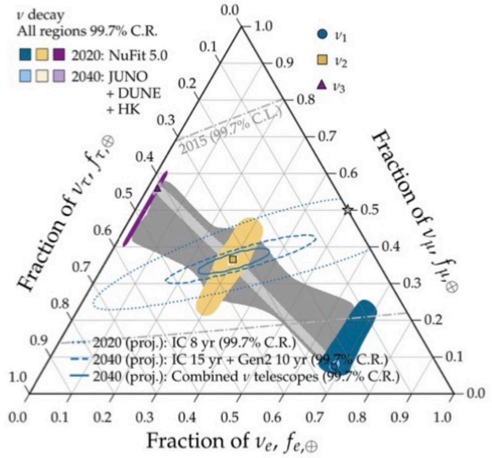
MB, Rosenstrøm, Shalgar, Tamborra, *PRD* 2020

ν scattering on Galactic DM



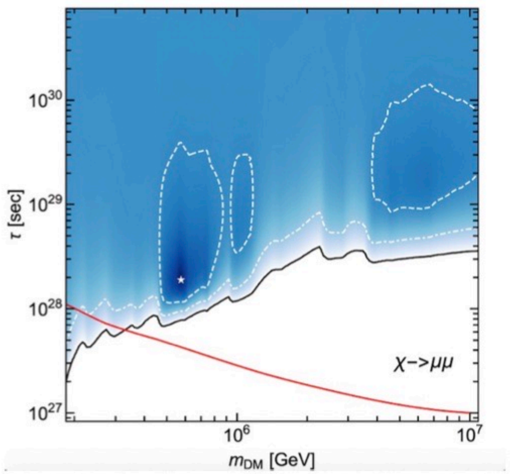
Argüelles, Kheirandish, Vincent, *PRL* 2017

ν decay



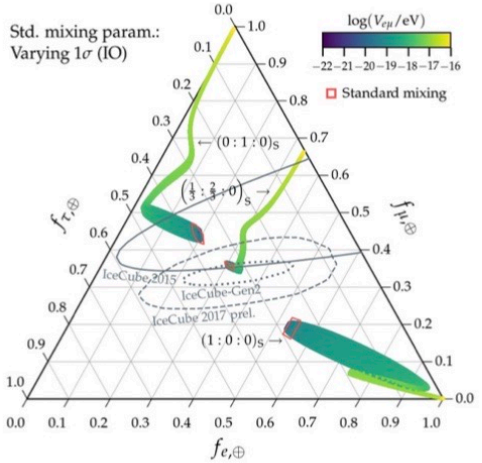
Song, Li, Argüelles, **MB**, Vincent, *JCAP* 2021

Dark matter decay



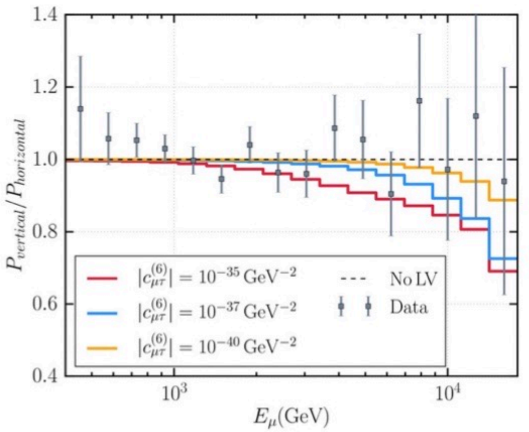
Chianese, Fiorillo, Miele, Morisi, Pisanti, *JCAP* 2019

ν-electron interaction



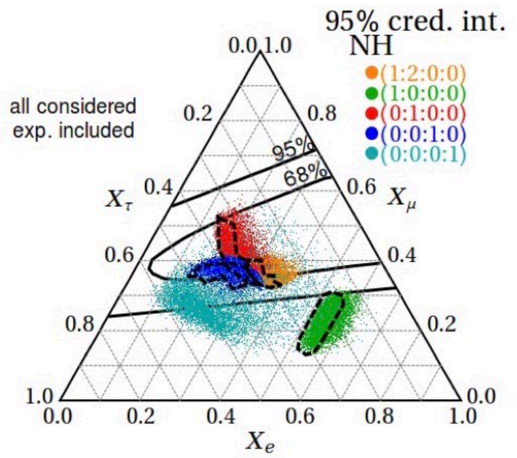
MB & Agarwalla, *PRL* 2019

Lorentz-invariance violation



IceCube, *Nature Phys.* 2018

Sterile neutrinos



Brdar, Kopp, Wang, *JCAP* 2017

M.Bustamante talk

Conclusions

- There is no single source population, which dominated diffuse neutrino flux. Main contributors are radio-loud blasars, TDE events, AGN cores and unknown sources
- Every new neutrino source TXS 0506, NGC 1068 challenge existing hadronic models of sources
- Contribution of GRB constraint by neutrino observations
- There are first indications of Galactic flux from ridge and Cygnus region at TeV energies. Unidentified flux at $|b|<20$ degrees can be due to cosmic ray interactions in local molecular clouds
- Already existing neutrino data constraint parameters of theories beyond standard model