High-Energy Multimesssenger Emission from Supermassive Black Holes

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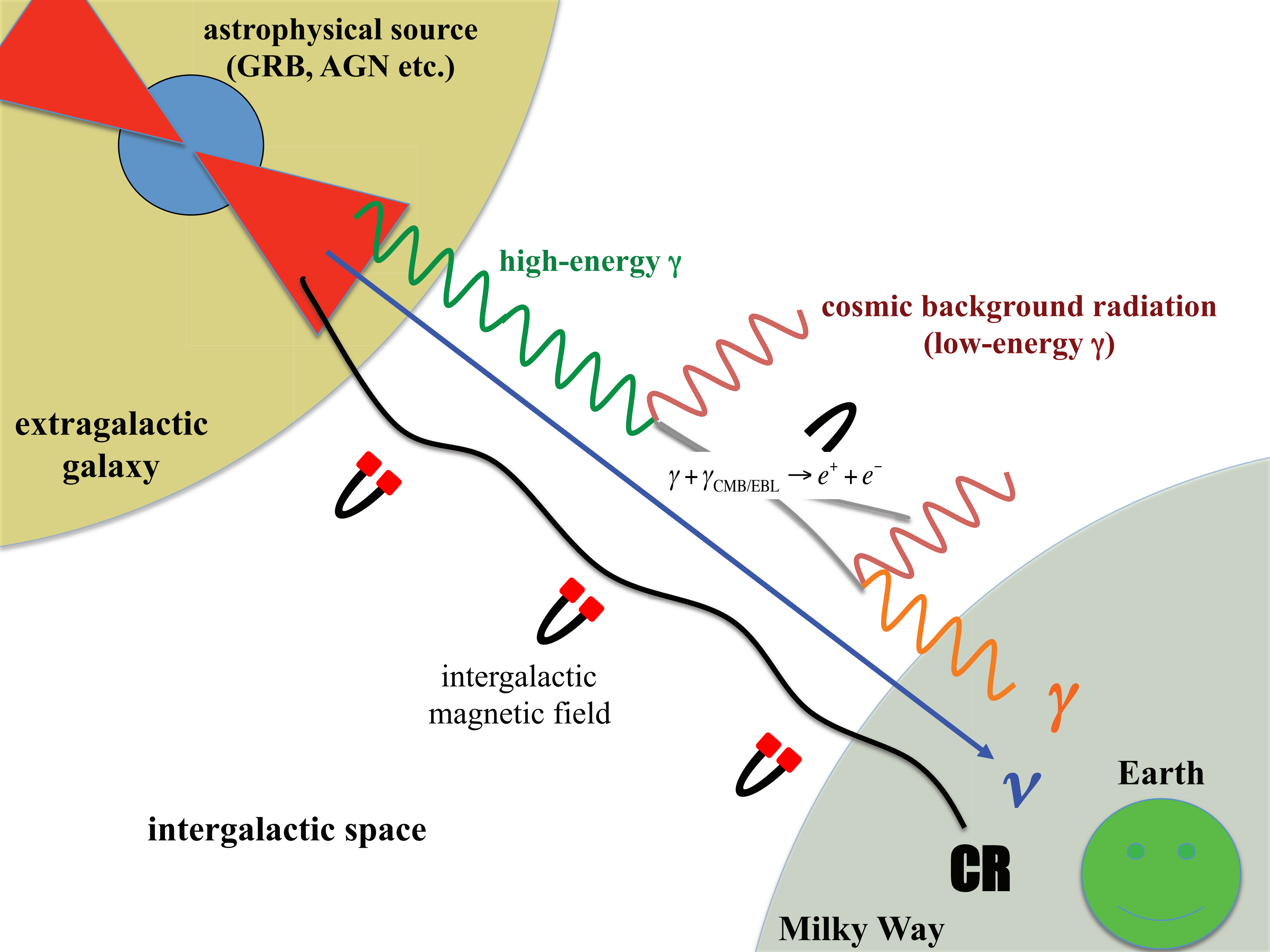
IIHE@Brussels

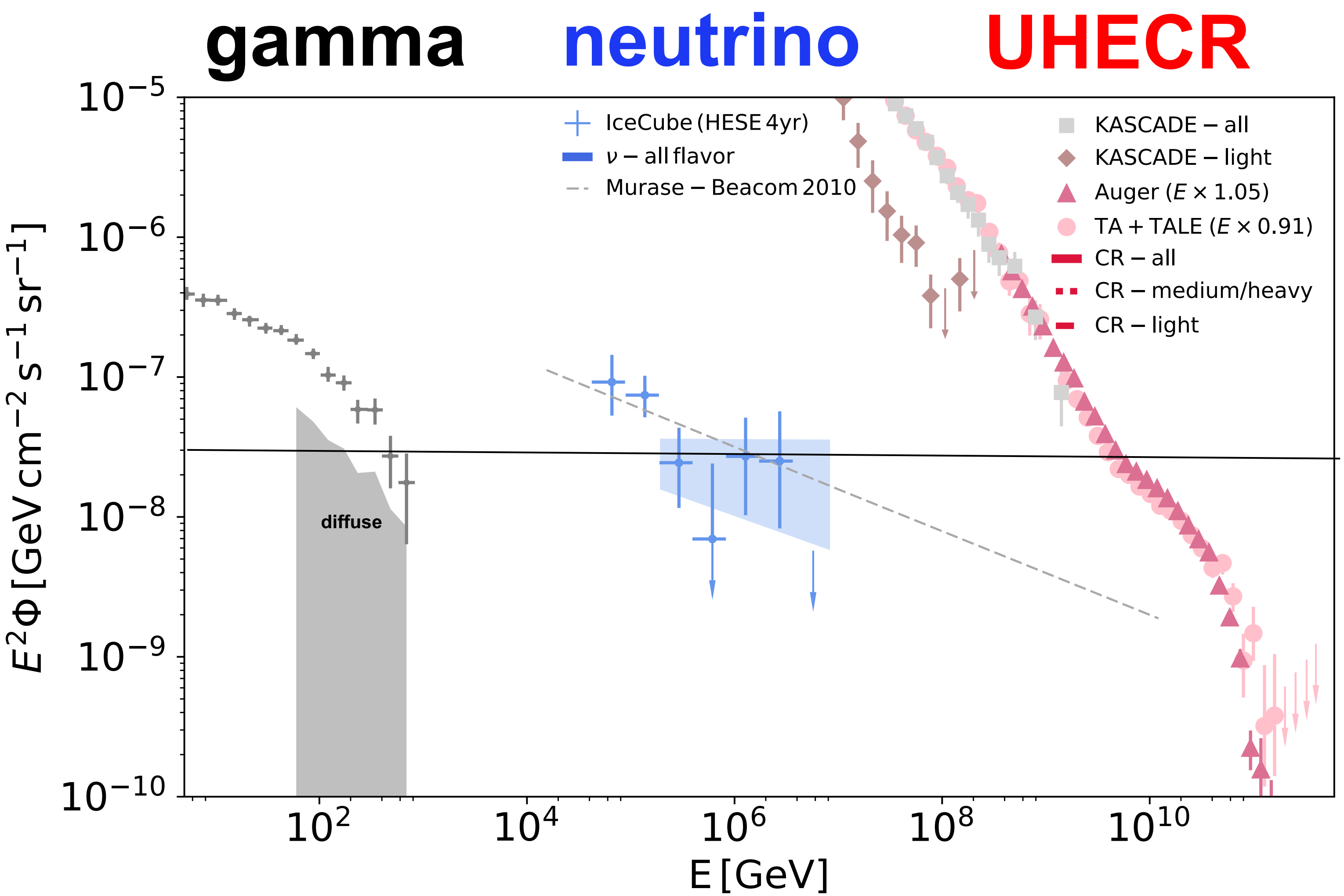
PENNSTATE 1855

IAS INSTITUTE FOR ADVANCED STUDY



astrophysical source
(GRB, AGN etc.)
high-energy γ
cosmic background radiation
(low-energy γ)
extragalactic
galaxy
$\gamma + \gamma_{\mathrm{CMB/EBL}} \rightarrow e^{+} + e^{-}$
γ
ν
Earth
intergalactic
magnetic field
intergalactic space
CR
Milky Way

Multi-Messenger Astro-Particle "Backgrounds"

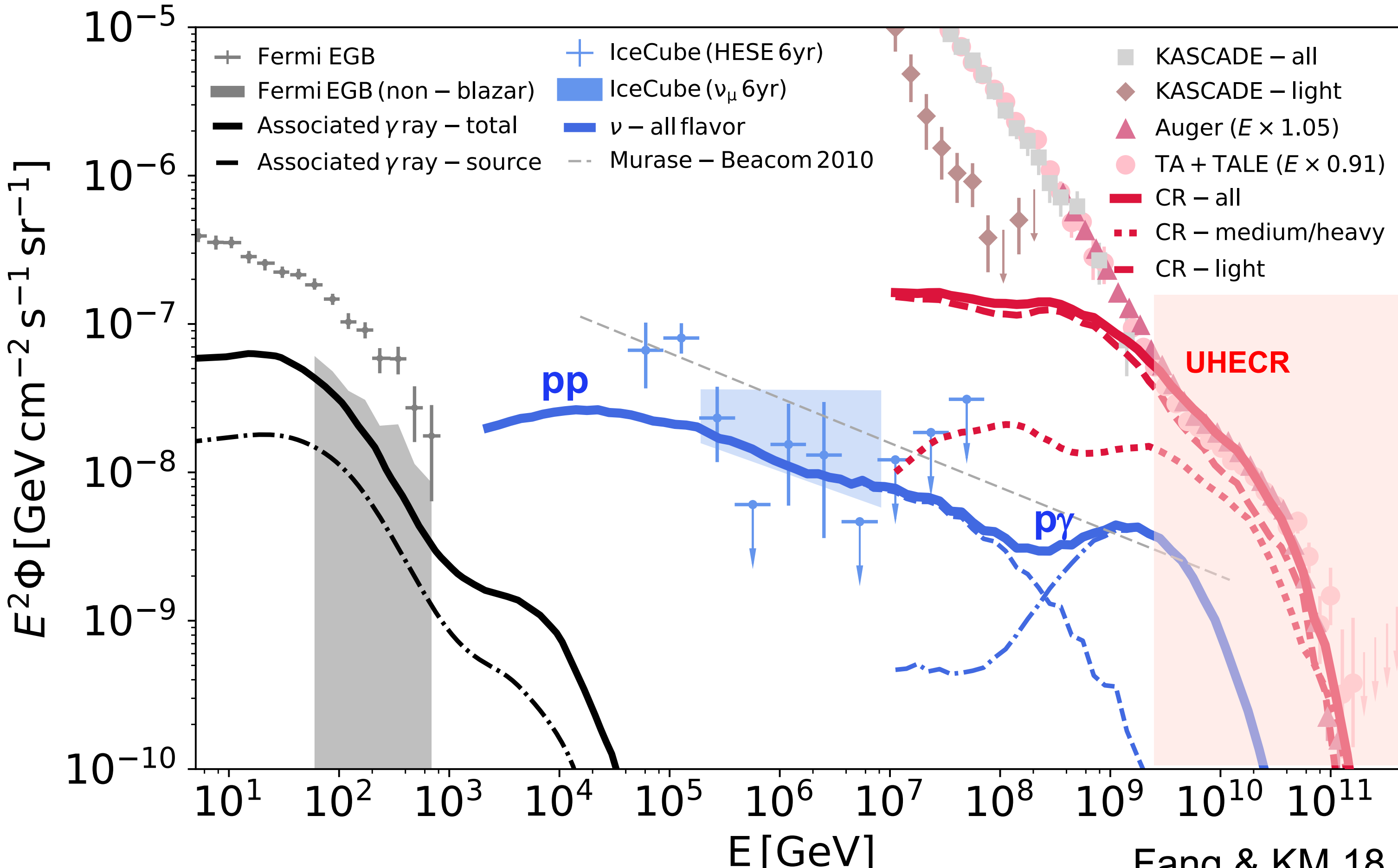


Energy generation rate densities of 3 messengers are all comparable

AGN are promising as the origins (e.g., KM & Fukugita 19 PRD)

Multi-Messenger Astro-Particle Grand-Unification?

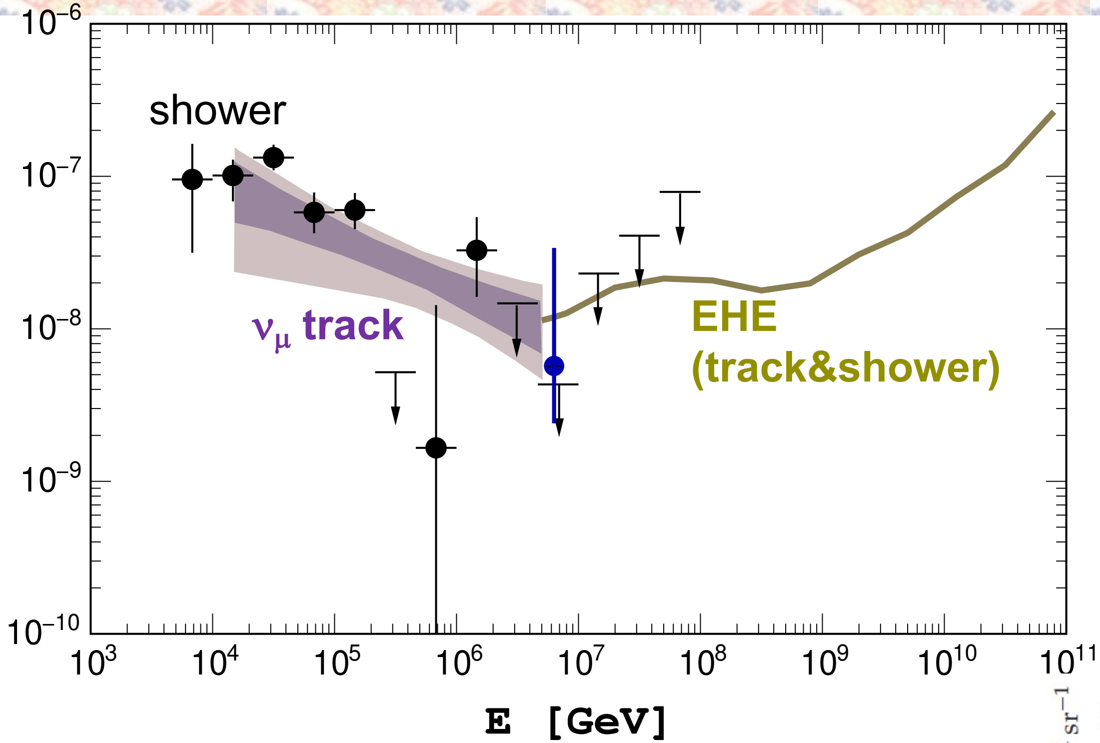
Concrete example of the "grand-unification" scenario with detailed simulations



Fang & KM 18 Nature Phys.
(see also Kachelriess+ 17)

- Jetted AGN as "UHECR" accelerators
- Neutrinos from confined CRs & UHECRs from escaping CRs

All-Sky Neutrino Flux & Spectrum



IceCube Collaboration 18 PRD
IceCube Collaboration 20 PRL
IceCube Collaboration 22 ApJ

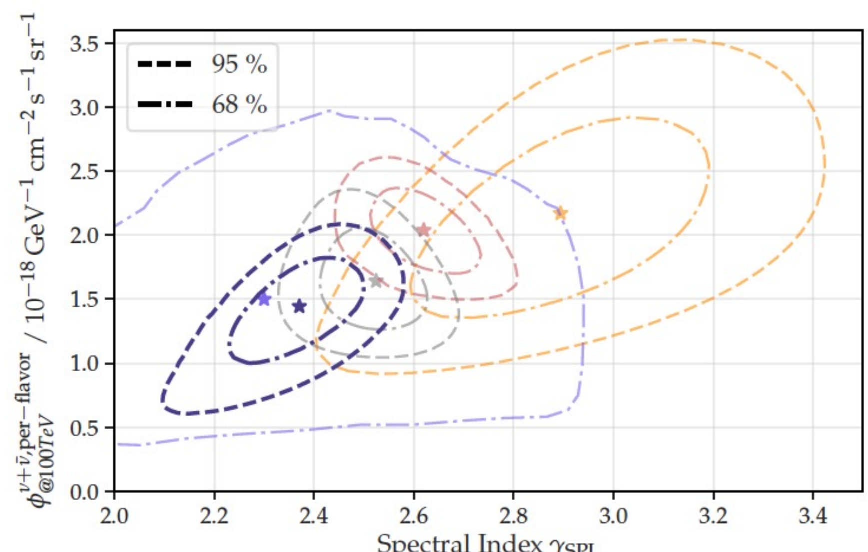
from KM & Yoshida 21

all-sky all-flavor ν flux at E_ν~200 TeV

$E_\nu^2\Phi_\nu \sim$ 3x10^{-8} GeV cm^{-2} s^{-1} sr^{-1}

all-sky all-flavor ν flux at E_ν~10 TeV

$E_\nu^2\Phi_\nu \sim$ 10^{-7} GeV cm^{-2} s^{-1} sr^{-1}



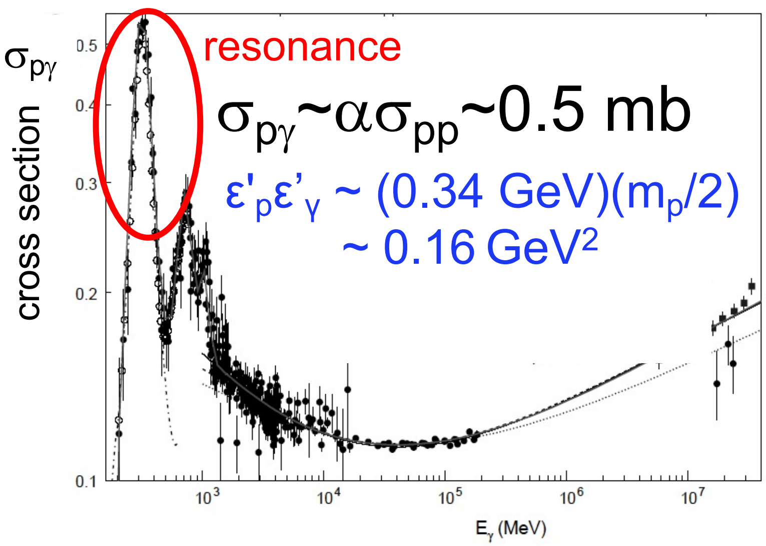
High-Energy Neutrino Production

Cosmic-ray Accelerators

Active galaxy

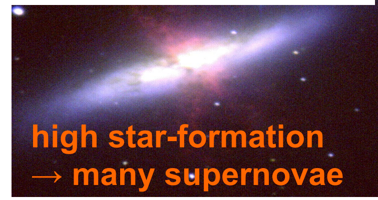
γ-ray burst

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



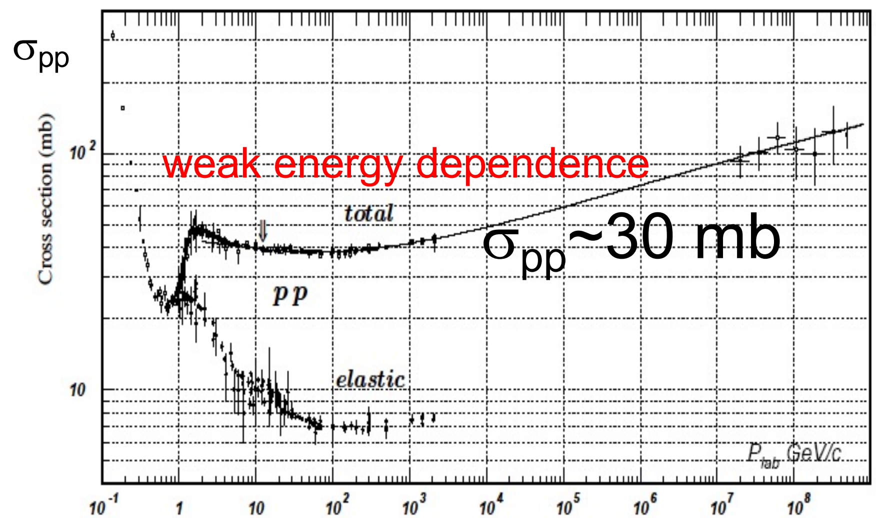
Cosmic-ray Reservoirs

Starburst galaxy



Galaxy cluster

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



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

Fate of High-Energy Gamma Rays

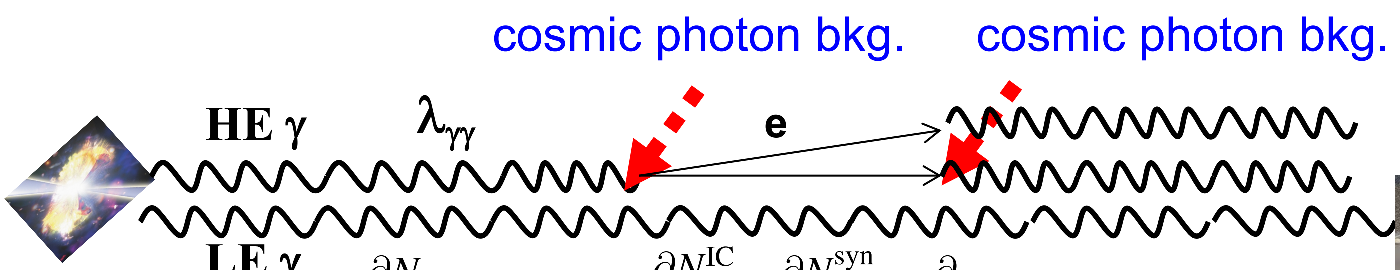
$$\boxed{\pi^0 \rightarrow \gamma + \gamma}$$

$p + \gamma \rightarrow N\pi + X$ $\quad \pi^0{:}\pi^{\pm} \sim 1{:}1 \rightarrow \mathbf{E_\gamma^2}\ \Phi_\gamma : \mathbf{E_\nu^2}\ \Phi_\nu \sim 4{:}3$

$p + p \rightarrow N\pi + X$ $\quad \pi^0{:}\pi^{\pm} \sim 1{:}2 \rightarrow \mathbf{E_\gamma^2}\ \Phi_\gamma : \mathbf{E_\nu^2}\ \Phi_\nu \sim 2{:}3$

comparable

Moreover, accelerated electrons make γ rays by synchrotron & Compton processes



Fermi satellite

airshower detectors

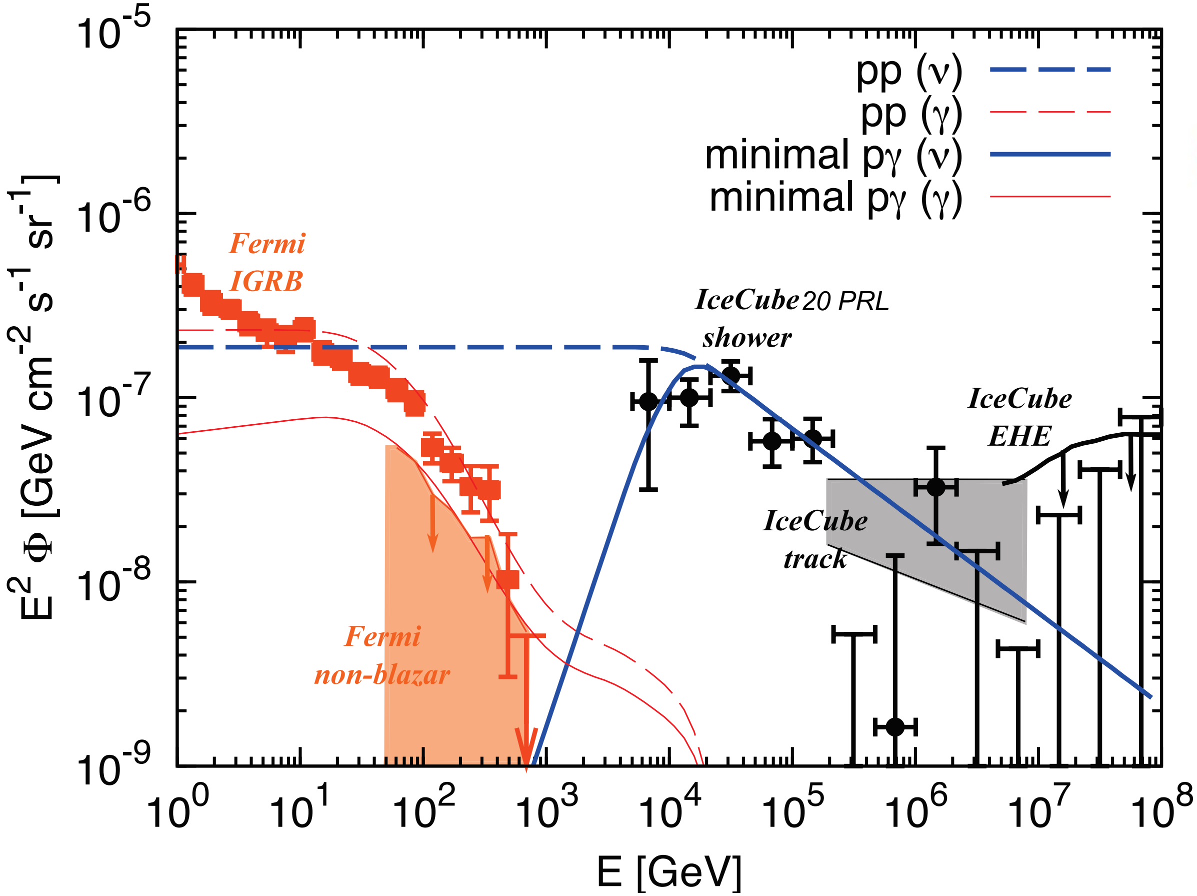
$$\frac{\partial N_\gamma}{\partial x} = -N_\gamma R_{\gamma\gamma} + \frac{\partial N_\gamma^{\rm IC}}{\partial x} + \frac{\partial N_\gamma^{\rm syn}}{\partial x} - \frac{\partial}{\partial E}[P_{\rm ad} N_\gamma] + Q_\gamma^{\rm inj},$$

$$\frac{\partial N_e}{\partial x} = \frac{\partial N_e^{\gamma\gamma}}{\partial x} - N_e R_{\rm IC} + \frac{\partial N_e^{\rm IC}}{\partial x} - \frac{\partial}{\partial E}[(P_{\rm syn} + P_{\rm ad}) N_e] + Q_e^{\rm inj},$$

>TeV-PeV γ rays are cascaded to GeV-TeV γ rays

Multi-Messenger Implications of 10 TeV ν All-Sky Flux

- 10-100 TeV shower data: large fluxes of ~10^{-7} GeV cm^{-2} s^{-1} sr^{-1}



$$\varepsilon_\gamma Q_{\varepsilon_\gamma} \approx \frac{4}{3K}(\varepsilon_\nu Q_{\varepsilon_\nu})|_{\varepsilon_\nu=\varepsilon_\gamma/2}$$

K=1 (pγ), K=2 (pp)

KM, Guetta & Ahlers 16 PRL
see also
KM, Ahlers & Lacki 13 PRDR
Capanema, Esmaili & KM 20 PRD
Capanema, Esmaili & Serpico 21 JCAP
Fang, Gallagher & Halzen 22 ApJL

Fermi diffuse γ-ray bkg. is violated (>3σ) if ν sources are γ-ray transparent

→ Requiring hidden (i.e., γ-ray opaque) cosmic-ray accelerators

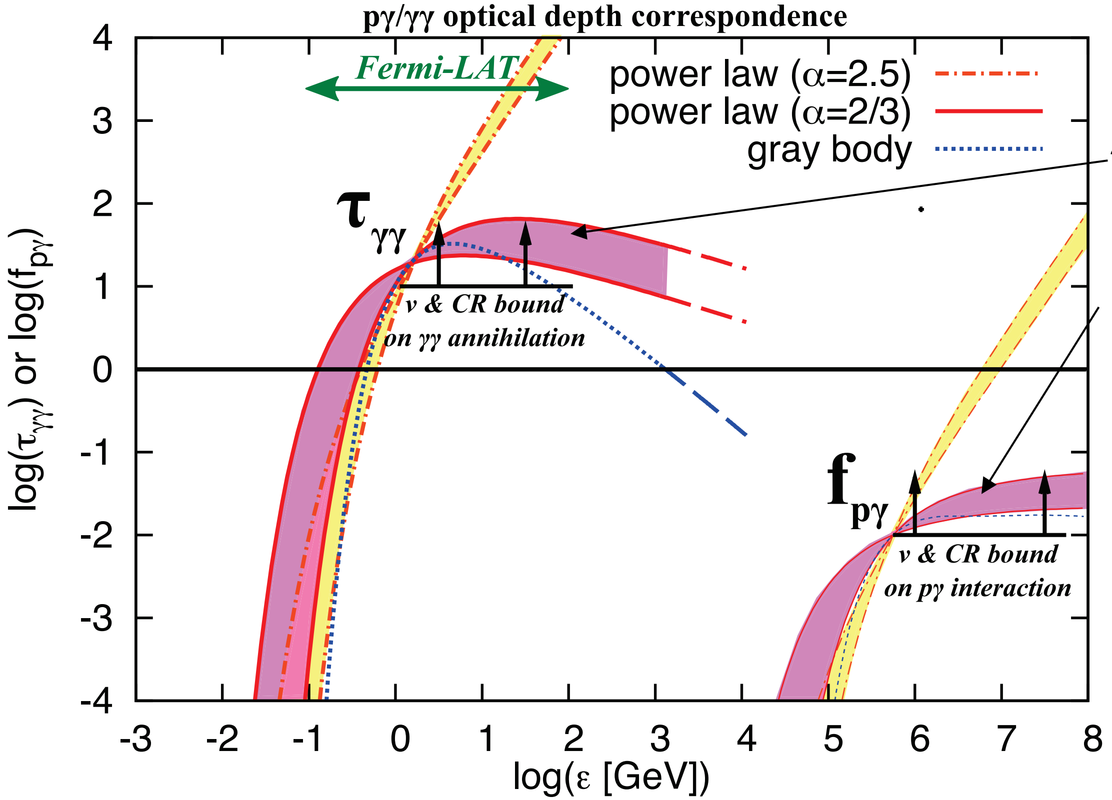
(Galactic components are not sufficient: see also Ahlers & KM 14 PRD, Fang & KM 21 ApJ)

Opacity Argument

Hidden (i.e., γ-ray opaque) ν sources are actually natural in $p\gamma$ scenarios

$\gamma\gamma \rightarrow e^+e^-$
optical depth $$\tau_{\gamma\gamma} \approx \frac{\sigma^{\rm eff}_{\gamma\gamma}}{\sigma^{\rm eff}_{p\gamma}} f_{p\gamma} \sim 1000 f_{p\gamma} \gtrsim 10$$

implying that >TeV-PeV γ rays are cascaded down to GeV or lower energies



$$\gamma + \gamma \rightarrow e^+ + e^-$$

$$\shortparallel$$

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

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

KM, Guetta & Ahlers 16 PRL

Solutions to "Excessive" All-Sky Neutrino Flux?

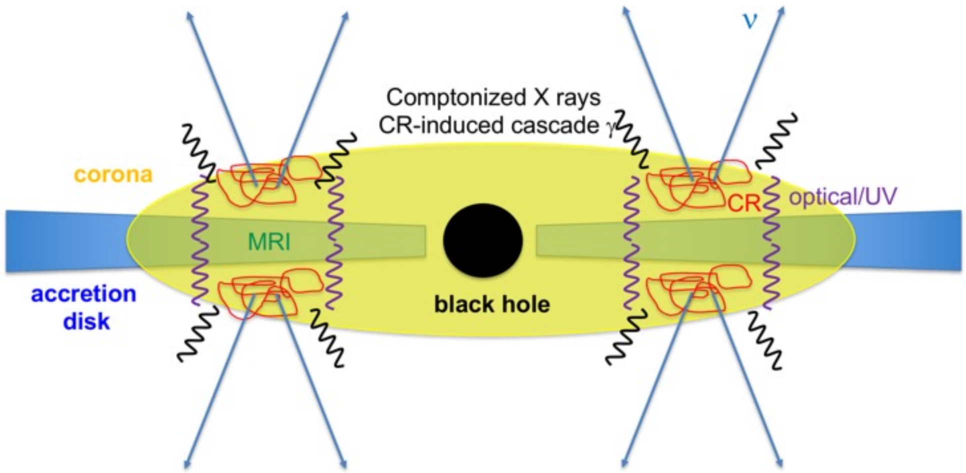
Hidden (i.e., γ-ray opaque) ν sources are actually natural in $p\gamma$ scenarios

(KM, Guetta & Ahlers 16 PRL)

$\gamma\gamma \to e^+e^-$ optical depth $\tau_{\gamma\gamma} \approx \frac{\sigma^{\rm eff}_{\gamma\gamma}}{\sigma^{\rm eff}_{p\gamma}} f_{p\gamma} \sim 1000 f_{p\gamma} \gtrsim 10$

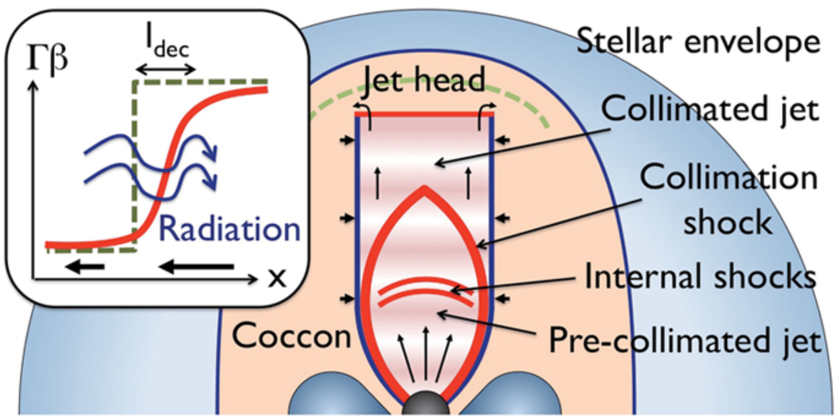
implying that >TeV-PeV γ rays are cascaded down to GeV or lower energies

vicinity of black holes



(from KM, Kimura & Meszaros 20 PRL)

choked jets in supernovae



(from KM & Ioka 13 PRL)

or exotic scenarios invoking new physics (ex. dark matter)…???

What Have We Learned from All-Sky Fluxes?

- ν budget ~ γ-ray budget ~ UHECR budget
- ν-γ-UHECR connection?: interesting open question
- Detailed studies on the ν-γ connection
  hidden neutrino sources, constraints on Galactic emission

Dominant sources?

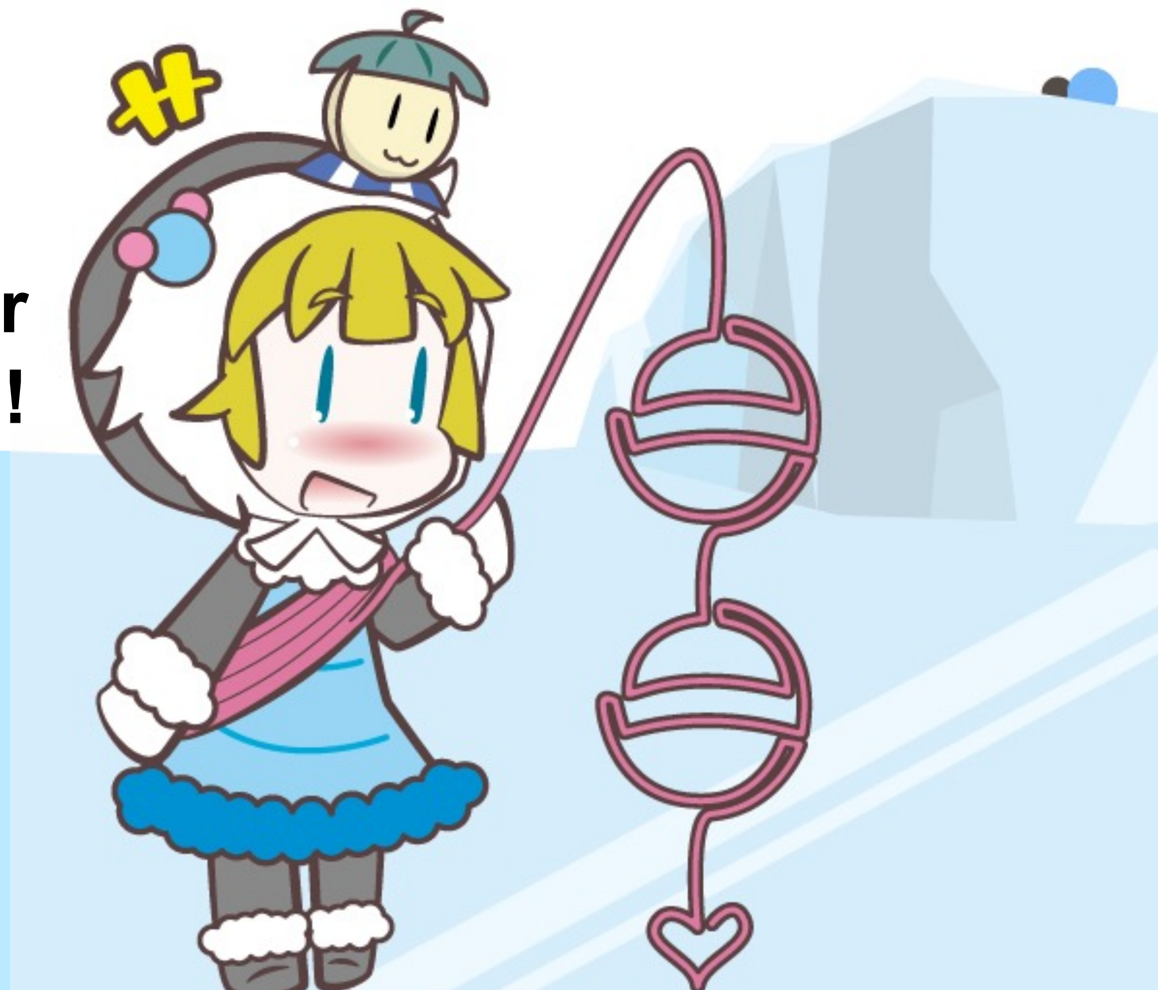
- CR accelerators (AGN jets, GRBs, SNe etc.)
  CR reservoirs (galaxy clusters/groups, starburst galaxies etc.)
- GRBs and blazars are likely to be subdominant
- AGNs are leading candidates in terms of energy budget

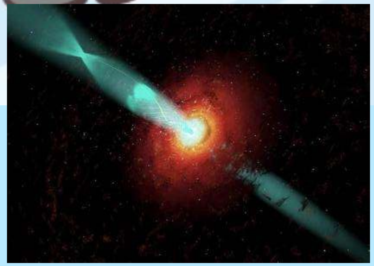
"Brightest" sources do not have to be "dominant" sources

Establishing the multimessenger picture for individual sources

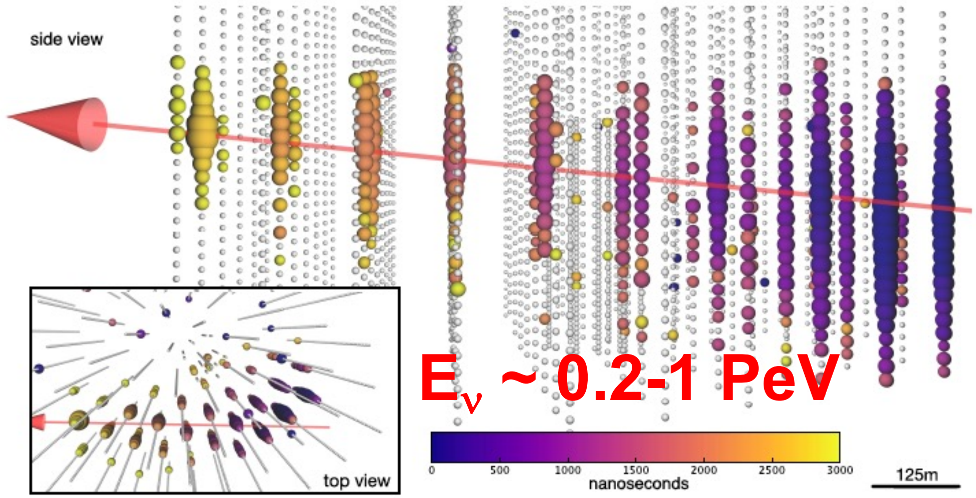
Brightest Neutrino Sources?

monster fishing!!



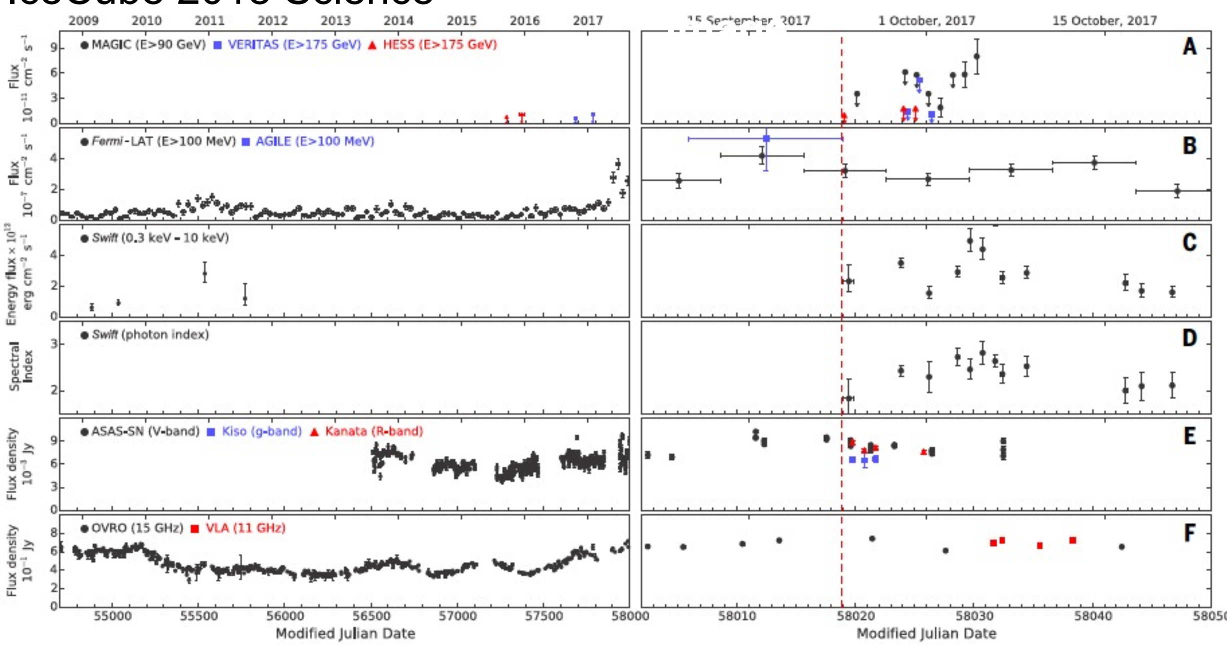


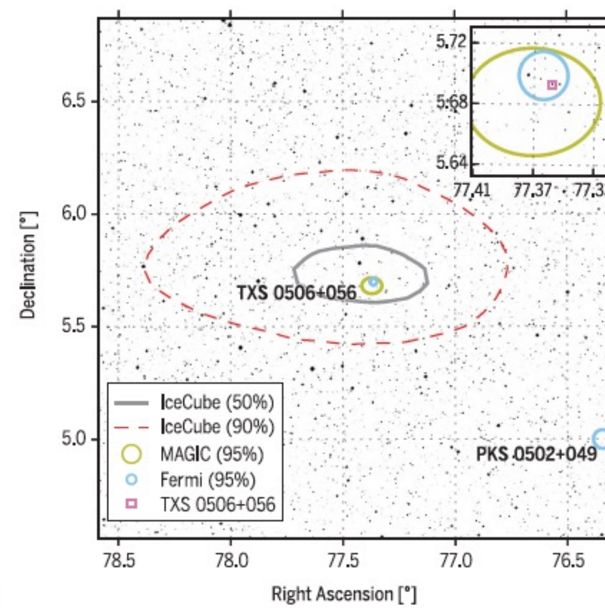
IceCube 170922A & TXS 0506+056



- IceCube EHE alert pipeline
- Automatic alert (via AMON/GCN)
- Kanata observations of blazars
  -> Fermi-LAT (Tanaka et al.)
  ATel #10791 (Sep/28/17)
- Swift (Keivani et al.)
  GCN #21930, ATel #10942
  NuSTAR (Fox et al.) ATel #10861
- **~3σ coincidence**

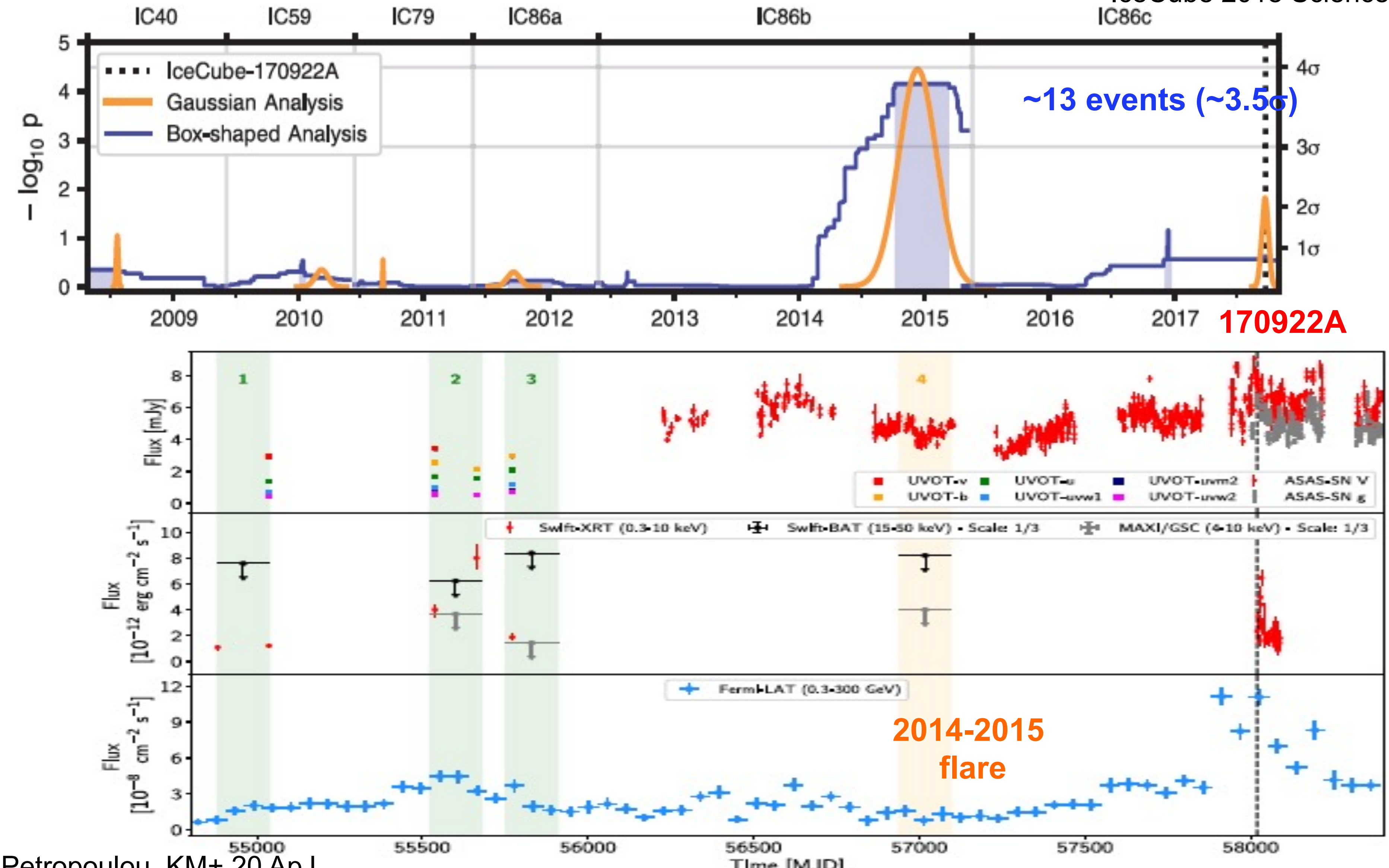
IceCube 2018 Science





2014-2015 Neutrino Flare

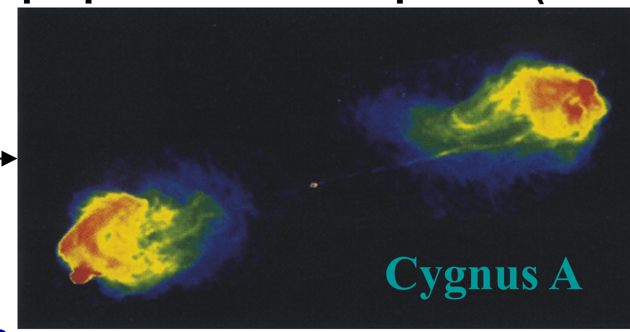
IceCube 2018 Science



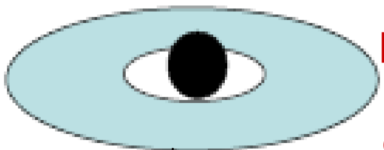
Petropoulou, KM+ 20 ApJ

Active Galactic Nuclei

FR-II radio galaxy
Flat spectrum radio quasar (FSRQ)
Steep spectrum radio quasar (SSRQ)



BH + accretion disk



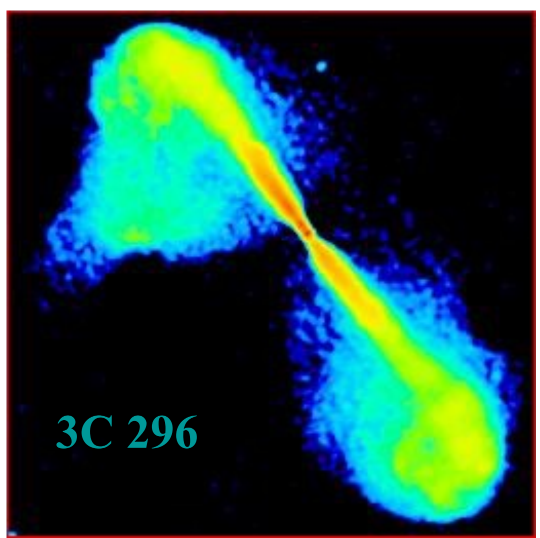
~ 10%
powerful jets
(Γ~1-10)
elliptical gal.

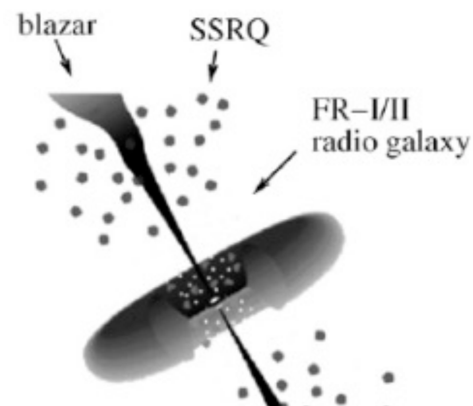
~ 1 %
$L_{radio} > 5 \times 10^{41}$ erg/s

~ 9%
$L_{radio} < 5 \times 10^{41}$ erg/s

~ 90%
jet-quiet
spiral gal.

FR-I radio galaxy
BL Lacertae object (BL Lac)





Seyfert galaxy
Radio quiet quasar
Low-luminosity AGN

"blazar" (FSRQ+BL Lac)
= on-axis jets
•Flares (e.g., T ~ day)

FR=Fanaroff-Riley

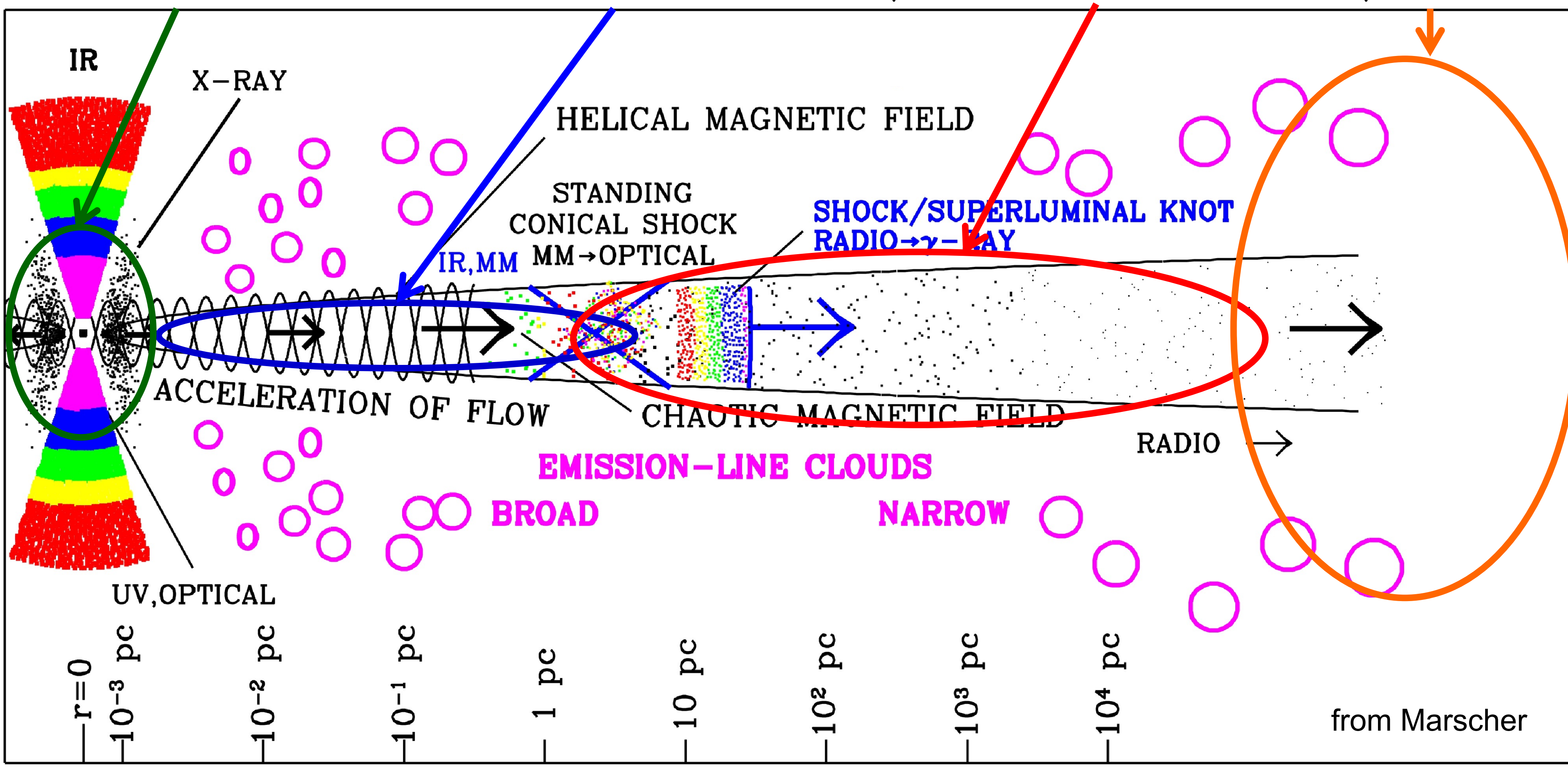
AGN Multi-Scale Particle Production

Black hole vicinity
r ~ 1-100 Rs,
B ~ 10-10^4 G, Γ ~ 1

Inner jet (blazar zone)
r ~ 10^{16}-10^{18} cm,
B ~ 0.1-100 G, Γ ~ 10

Large-scale jet/cocoon
r ~ 10^{20}-10^{21} cm,
B ~ 1μG -1 mG, Γ ~ 1

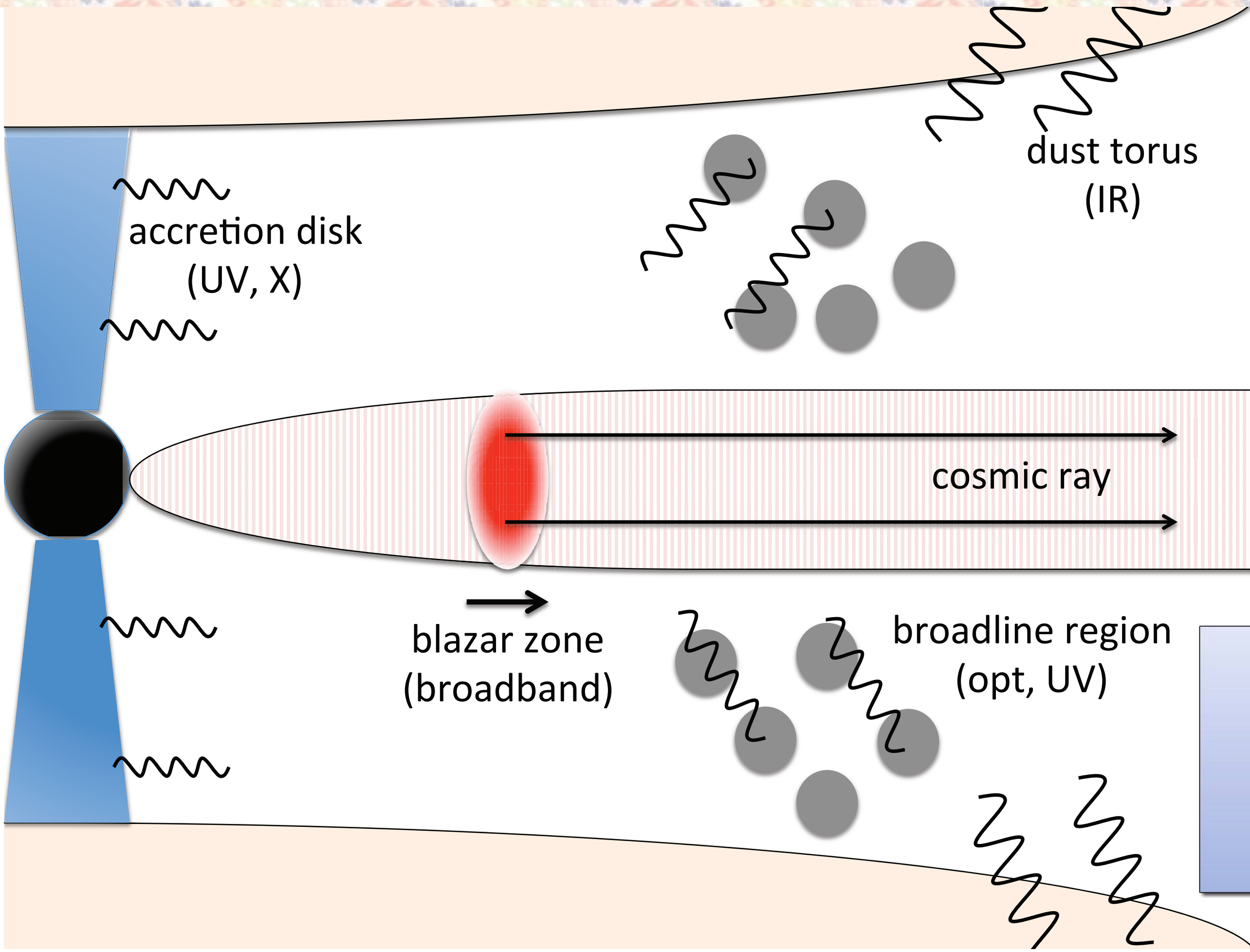
Intracluster medium
r ~ 10^{23}-10^{25} cm,
B ~ 0.1-1μG



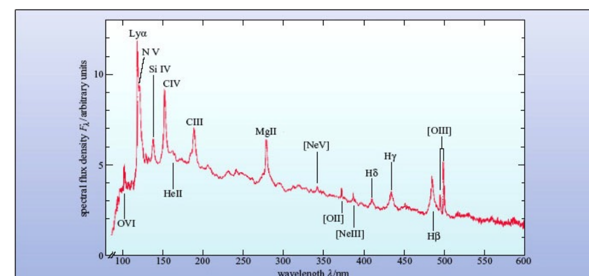
Hillas condition: E_{max} ~ZeBrΓ ~ 3x10^{19} eV Z (Γ/10) (B/0.1 G) (r/10^{17} cm)

High-Energy Neutrino Production in Blazars

KM, Inoue & Dermer 14



neutrinos beamed

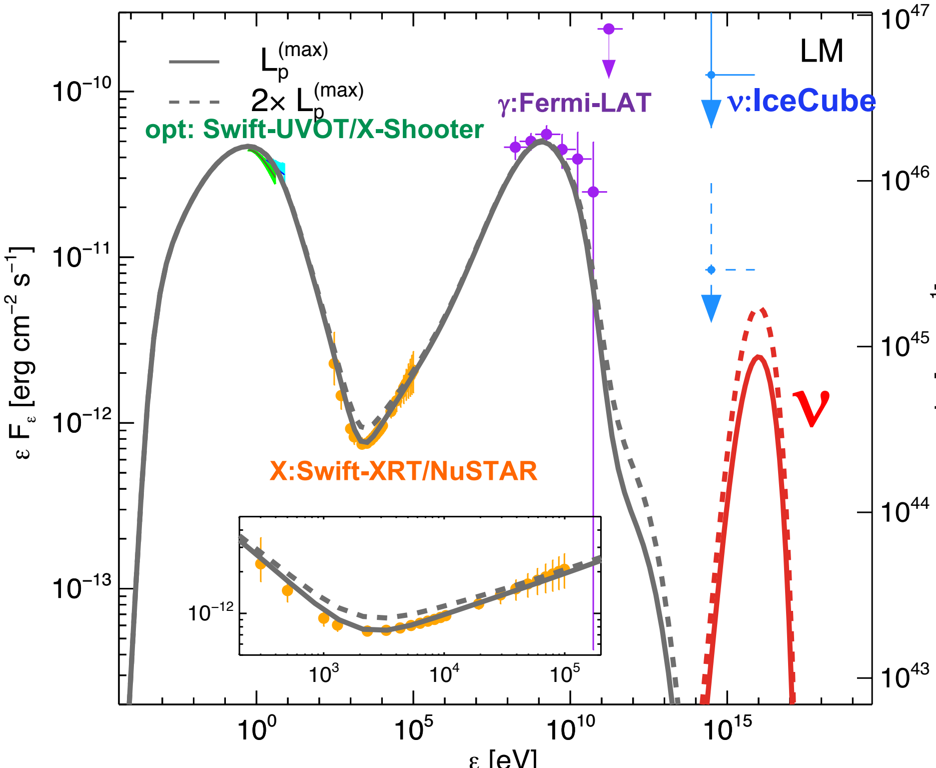


p+γ → Δ⁺ → π + N	$E'^{b}_{\nu} \approx 0.05 E'^{b}_{p} \simeq 80 \text{ PeV } \Gamma_1^2 (E'_s/10 \text{ eV})^{-1}$	**inner jet photons**
	$E'^{b}_{\nu} \approx 0.05 (0.5 m_p c^2 \bar{\varepsilon}_{\Delta}/E'_{\rm BL}) \simeq 0.78 \text{ PeV}$	**broadline photons**
	$E'^{b}_{\nu} \simeq 0.066 \text{ EeV} (T_{\rm IR}/500 \text{ K})^{-1}$	**dust torus photons**

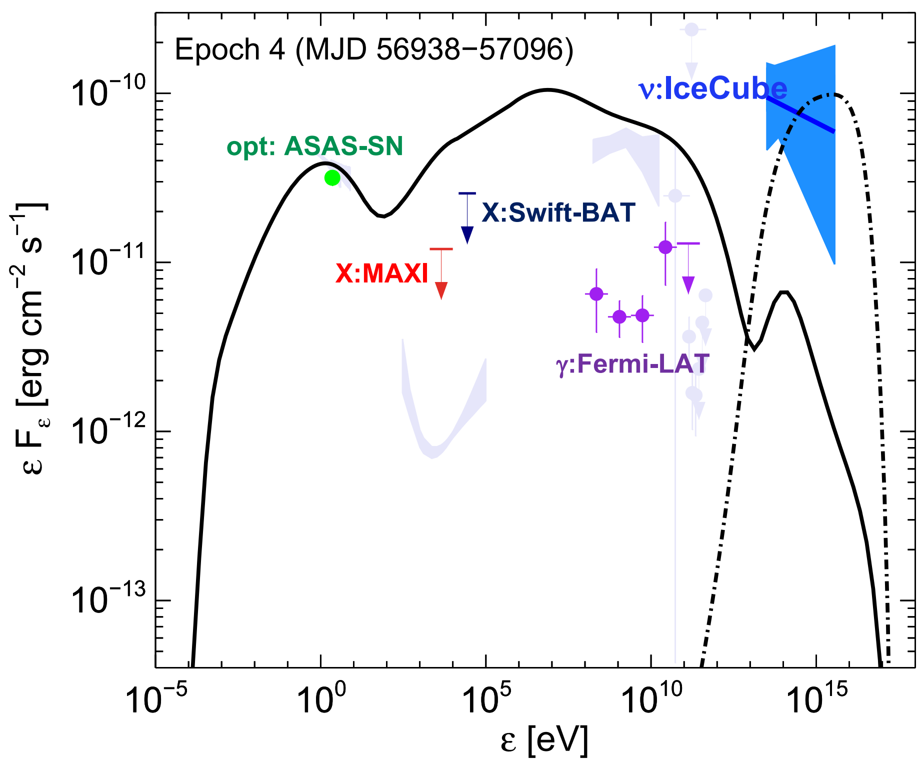
"Power" of Multi-Messenger Approaches

$p\gamma \rightarrow \nu, \gamma + e$ **electromagnetic energy must appear at keV-MeV**

2017 multi-messenger flare
Keivani, KM et al. 18 ApJ



2014-2015 neutrino flare
Petropoulou, KM et al. 20 ApJ



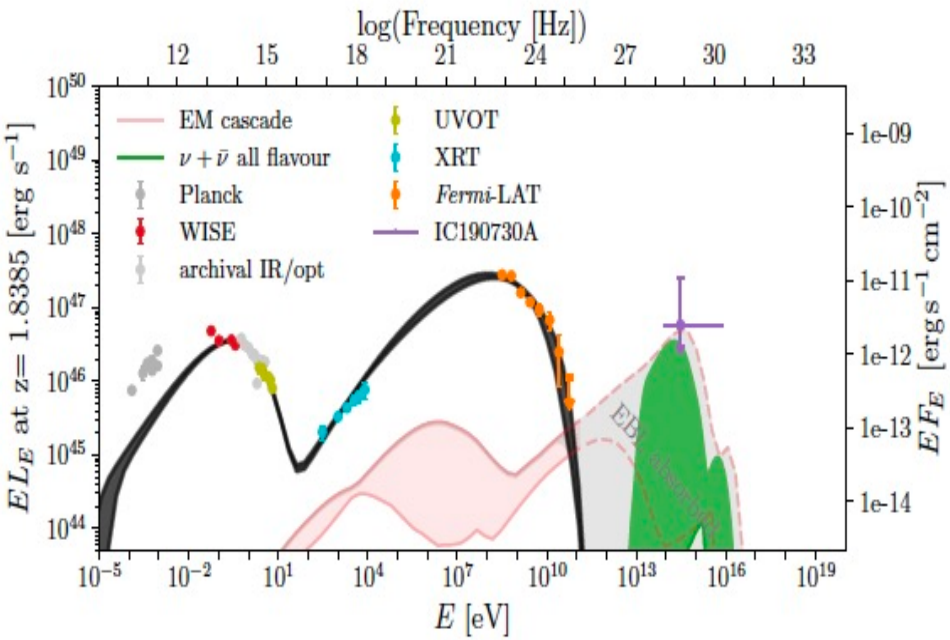
$F_\nu \sim F_{cas} < F_{obs}$

Puzzling: standard single-zone models do NOT give a concordance picture

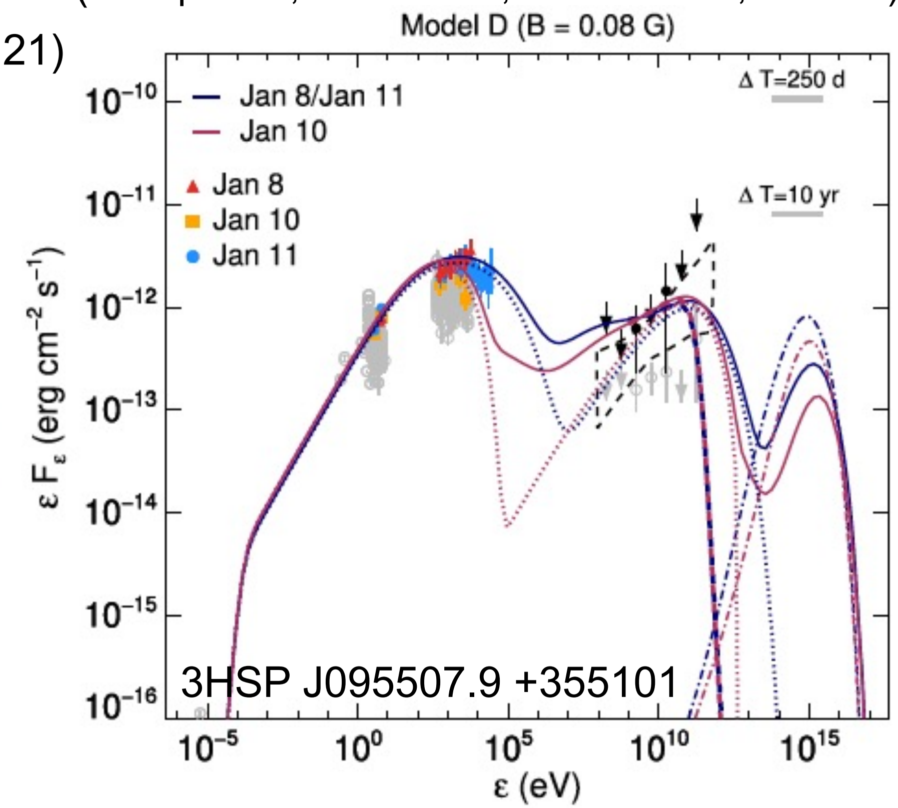
More Coincidences w. Blazars

More follow-up campaigns and/or larger statistics in ν data are necessary
But the situation is still puzzling…

IceCube-190730A (Oikonomou, Petropoulou, KM+ 21)



IceCube-200107A
(Petropoulou, Oikonomou, Mastichiadis , KM+ 20)

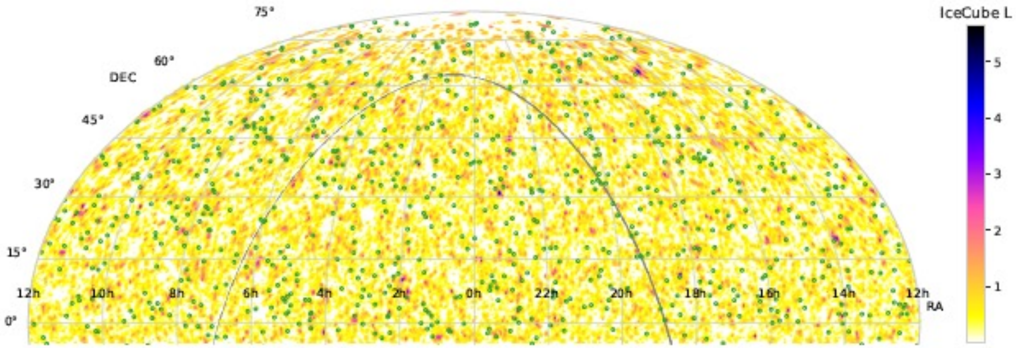


- PKS 1502+106: FSRQ
  promising but no coincidence w. γ-ray flaring, unseen in ν point-source search
- 3HSP J095507.9+355101: extreme BL Lac
  coincidence w. X-ray flaring but the alert rate is at most ~1-3% in 10 years
- PKS 0735+178: coincidence w. X-ray & γ-ray flaring TXS 0506+056-like (Sahakyan+ 22)

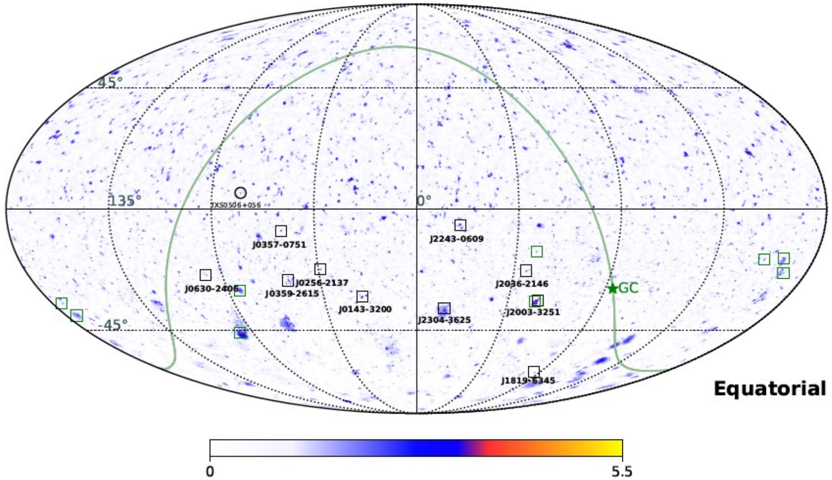
Correlation w. Radio/Optical-Selected Blazars

3411 sources from the flux density complete VLBI sample >150 mJy @ 8GHz

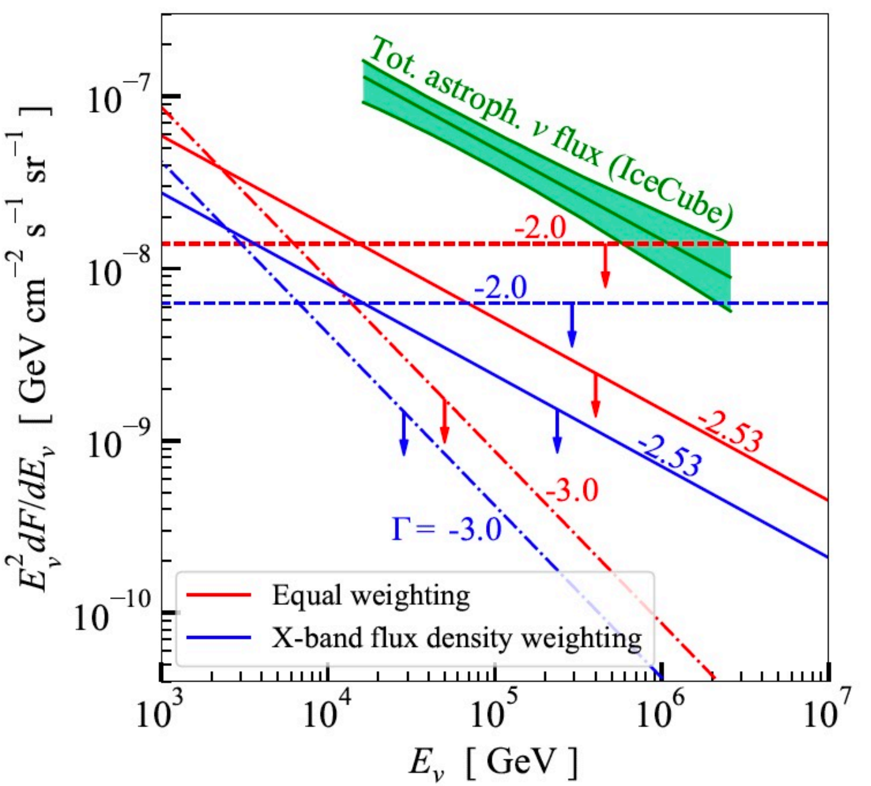
(Plavin+ 20, 21 ApJ)



All energies (2008-2015)
712830 (~2000 astrophysical) events
Combined significance: ~4σ



Focus on the southern sky data (2008-2015)
1177 samples from 5BZCat: ~4σ (Buson+ 22 ApJL)

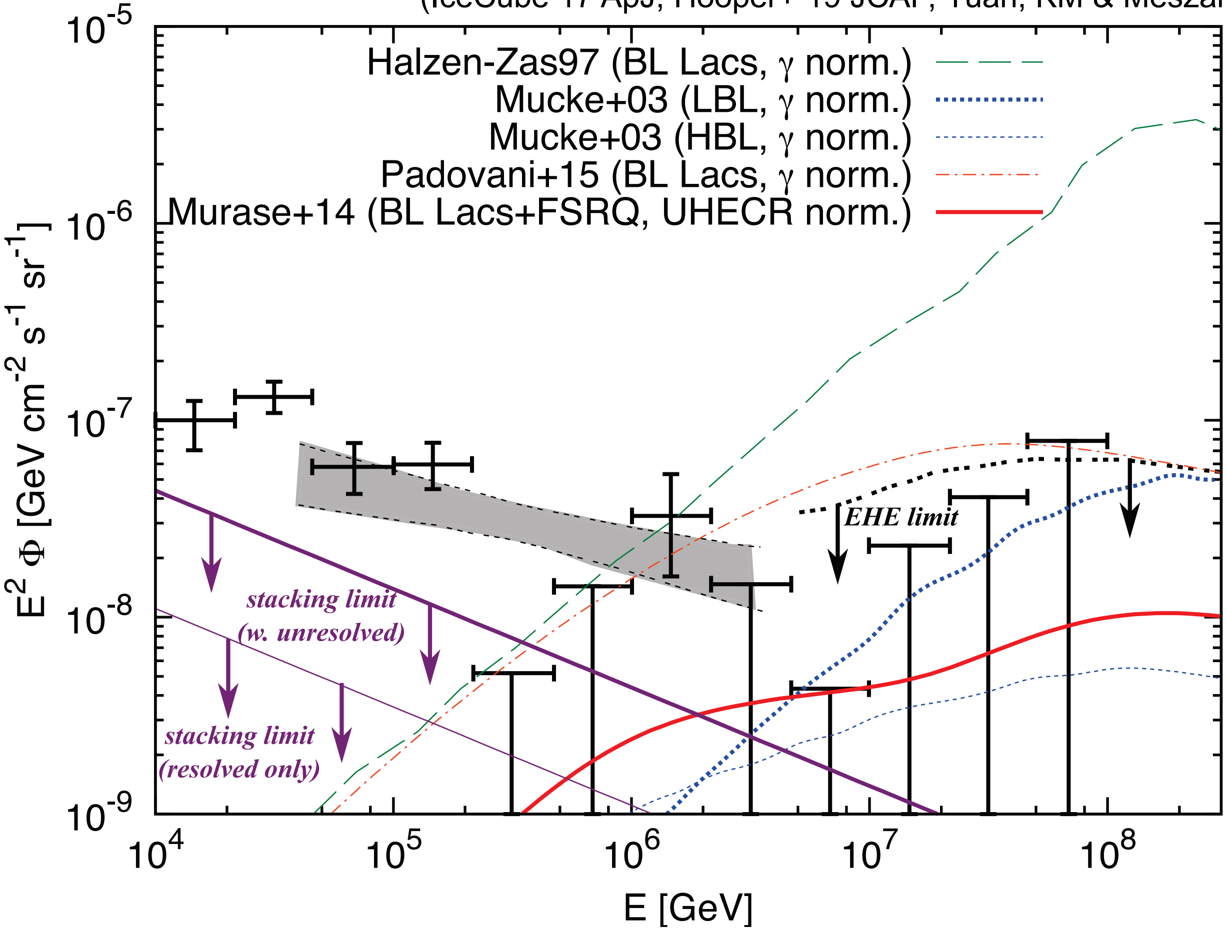


no significance w. 10 yr data
radio-bright AGN: at most <30%
(Zhou, Kamionkowski & Liang 21 PRD)

Can Blazars be the Origin of IceCube Neutrinos?

γ-ray bright blazars are largely resolved -> stacking analyses are powerful

(IceCube 17 ApJ, Hooper+ 19 JCAP, Yuan, KM & Meszaros 20 ApJ, Zou+ 21)



- Blazars are subdominant in all parameter space (most likely <~ 30%)
- Similar conclusion from neutrino anisotropy limits (ex. KM & Waxman 16 PRD)
- Correlation signal is explained even if subdominant (KM Inoue & Dermer 14 PRD)

Blazar Coincidences: Pros & Cons

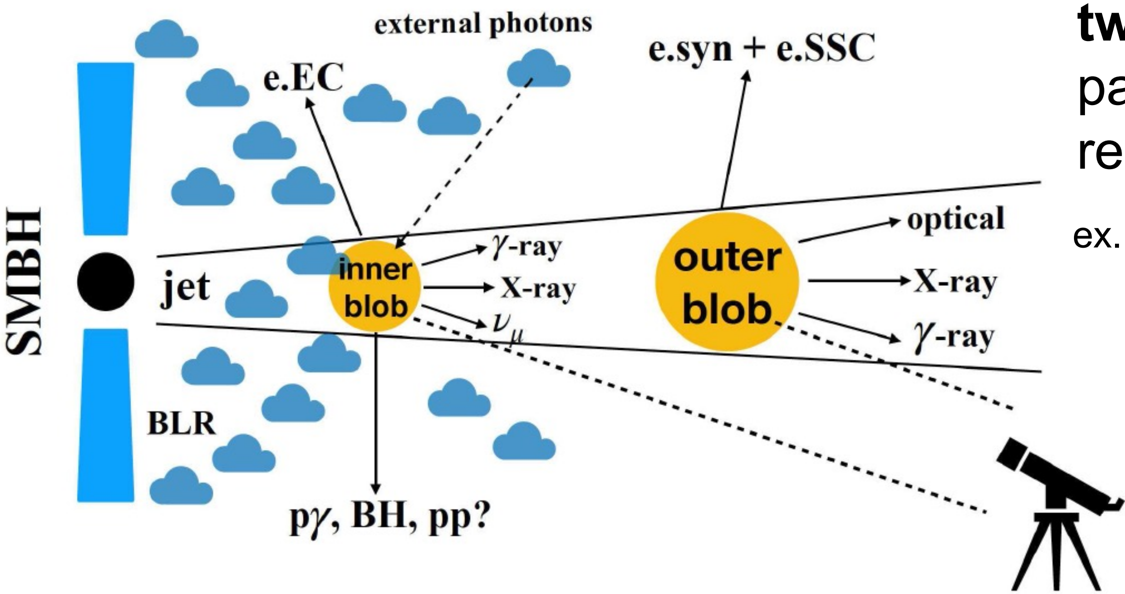
Pros:

- Several coincidences from ν alerts
  (TXS 0506+056, IC-190730A/PKS 1502 +106, IC-200107A/3HSP J095507.9 +355101, IC-211208A/PKS 0735+178)
- Stacking with radio-selected AGN and BZCat blazars
  (correlation level is consistent with theory even if subdominant)
- Possible dominance of flaring episodes

Cons: Lack of concordance for multi-messenger data

- Cascade constraints limit allowed ν fluxes
- Energetics issue
  $L_{CR} > L_{Edd}$ is often obtained
  $\varepsilon_p/\varepsilon_e > 300$ for the TXS 2017 multi-messenger flare
- Not clear why TXS is special

Beyond the Canonical Single-Zone Emission Model

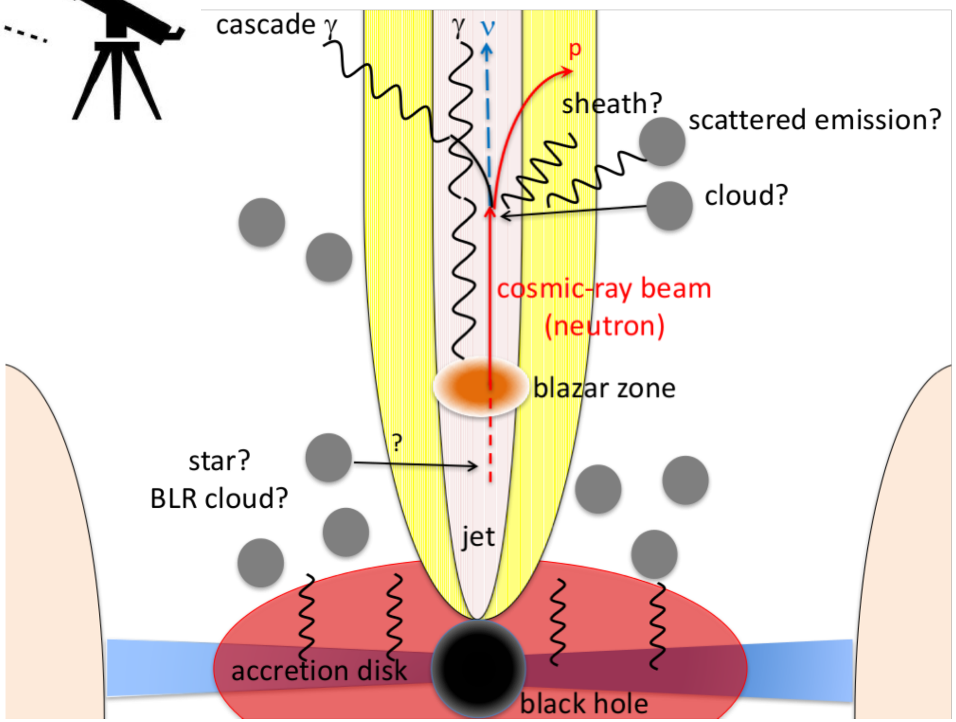


two-zone model:
parameters are doubled,
relaxing energetics requirement

ex. Gao+ 19 Nature Astron., Xue+ 19 ApJ

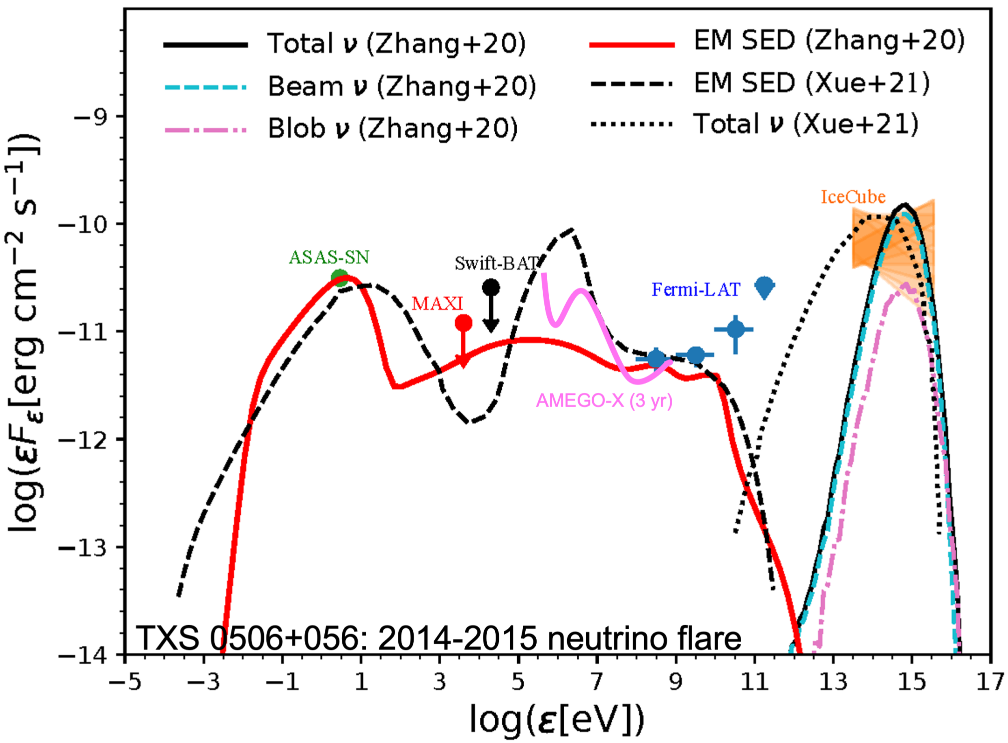
cosmic-ray beam model:
minimum extension,
relaxing cascade constraints
due to time delay & isotropization

KM, Oikinomou & Petropoulou 18 ApJ
Zhang, Petropoulou, KM & Oikonomou 20 ApJ

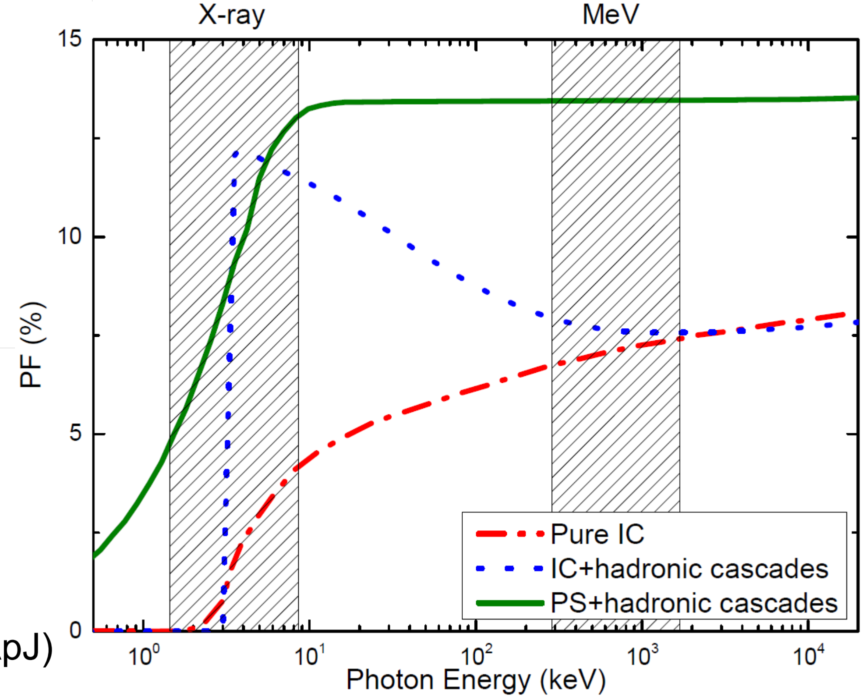


Possible Observational Signatures

MeV γ-ray signatures



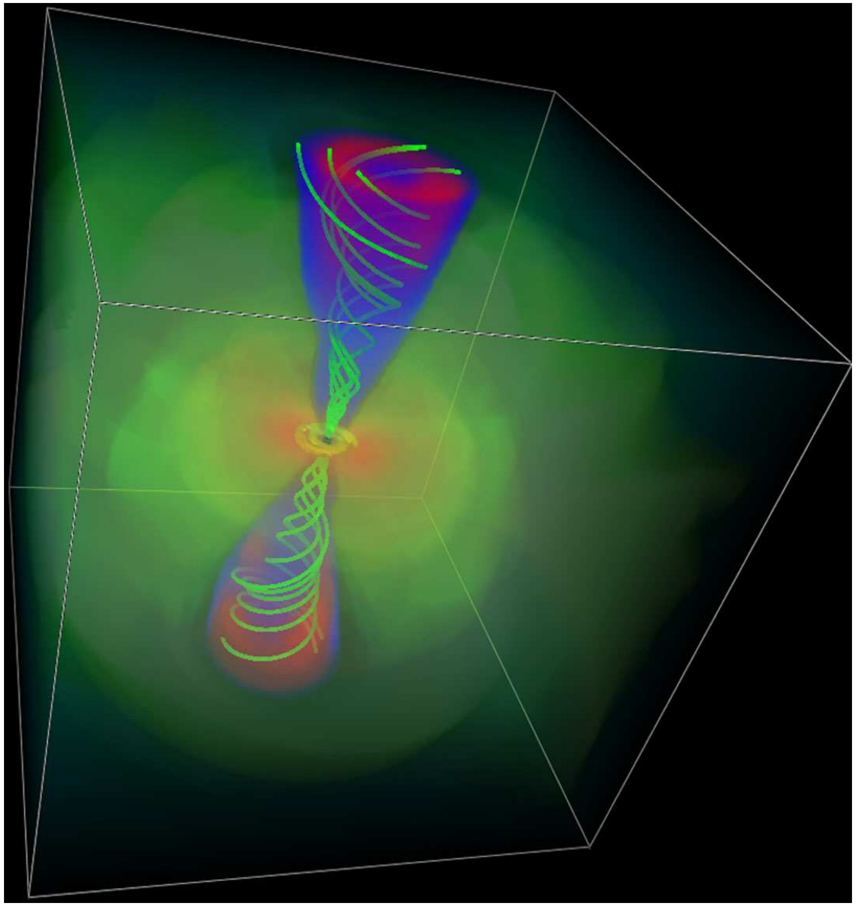
polarization



TXS 0506+056: 2017 multimessenger flare (Zhang+ 19 ApJ)

Particle Acceleration?

Blazar νs may require radical revisions of theoretical models



McKinney & Blandford 09

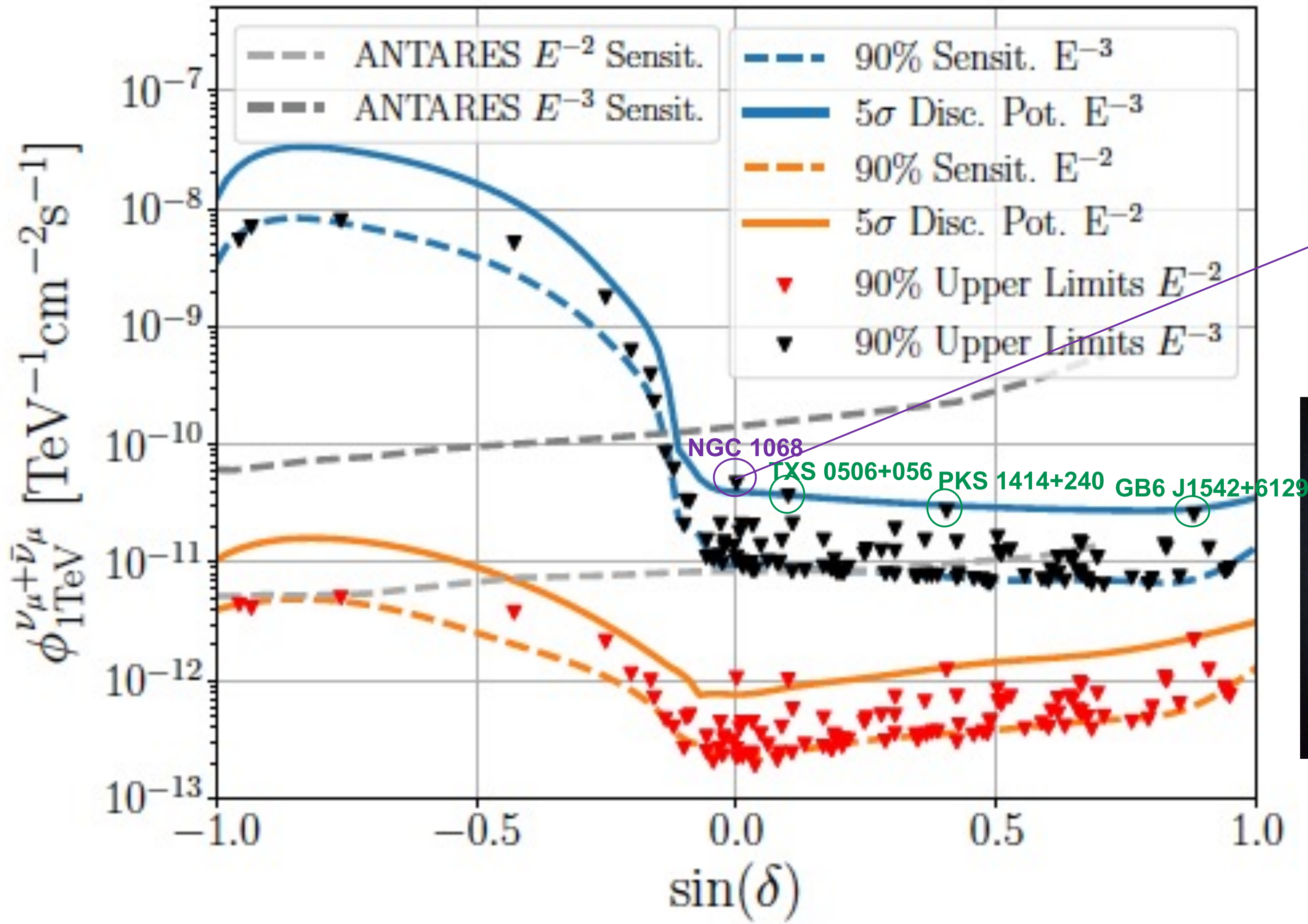
- Jet: launched as Poynting-dominated (e.g., Blandford-Znajek mechanism)
- Maybe copious pairs ($1<n_e/n_p<1000$)
- Emission region: particle-dominated but magnetized
- Toroidal-dominated at larger distances -> quasi-perpendicular shocks
- Relativistic magnetized shocks: acceleration is inefficient unless parallel (Sironi et al. 13, Bell et al. 18 etc.)

→ magnetic reconnection?

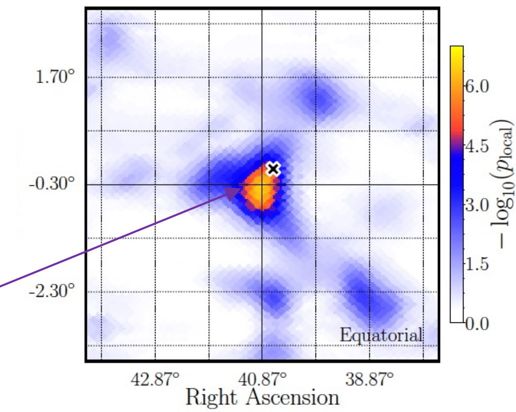
$\varepsilon_p/\varepsilon_e$ not typically large

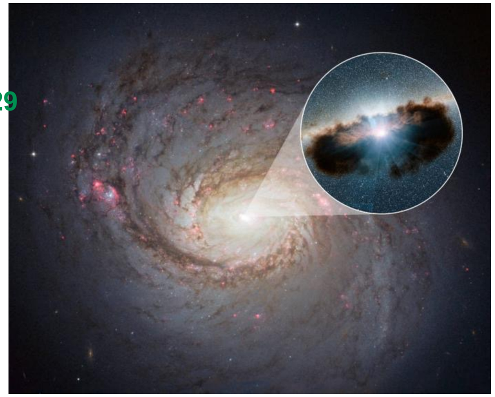
IceCube Point Source Searches

IceCube Collaboration 20 PRL



starburst galaxy/AGN

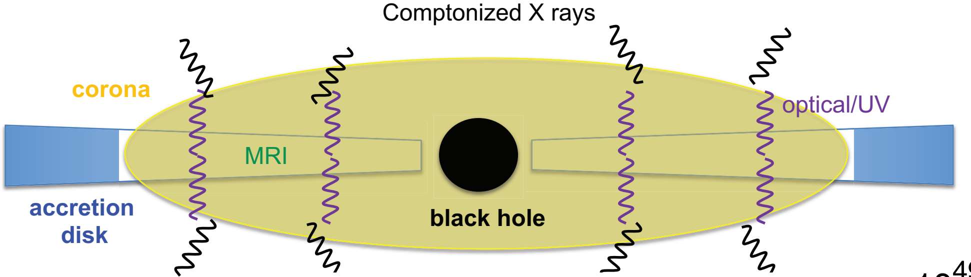




"Catches" (~3σ) exist but none have reached the discovery level

Vicinity of Supermassive Black Holes

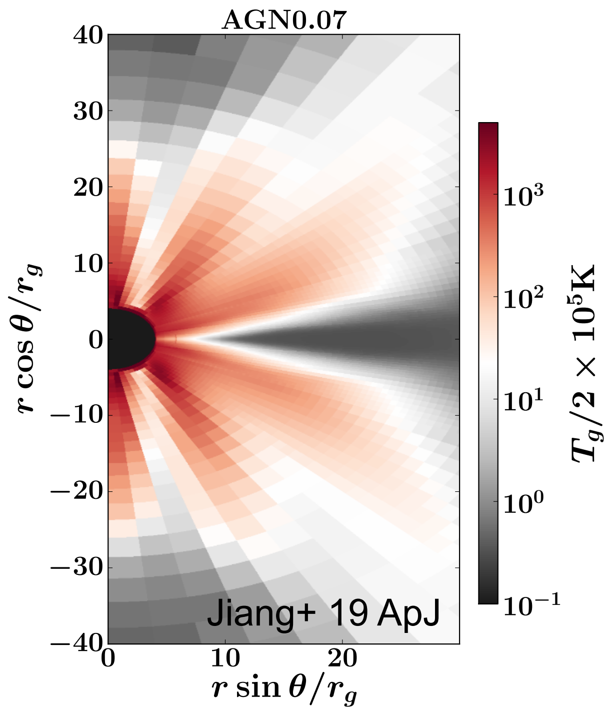
cores of active galactic nuclei (mainly jet-quiet AGNs)

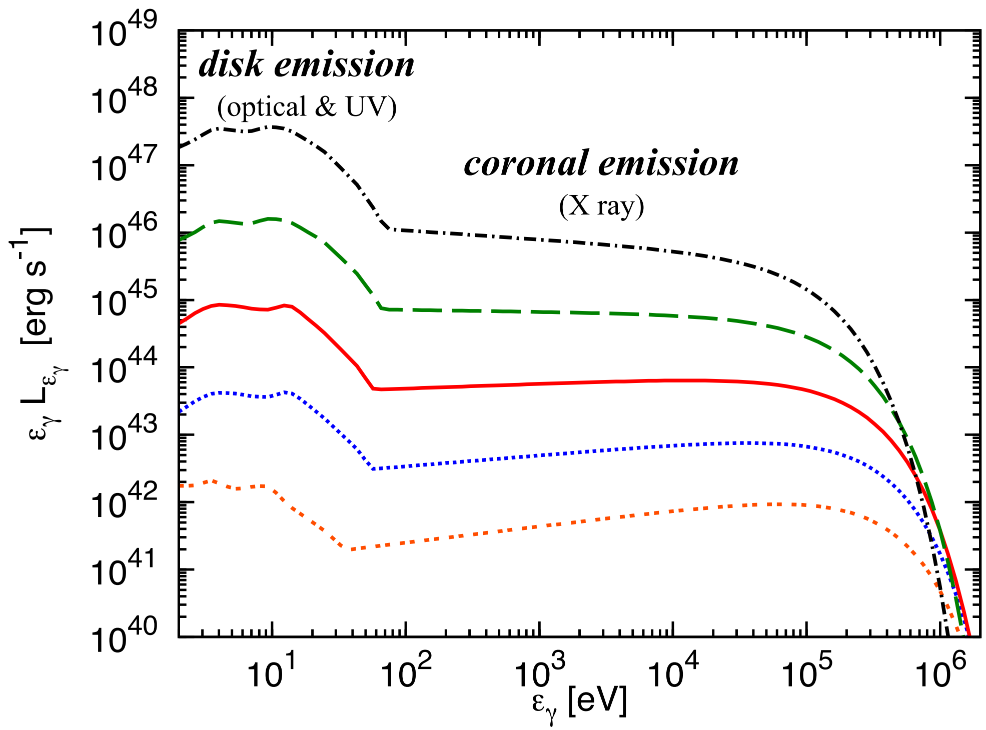


disk-corona model

opt/UV=multi-temp. blackbody

X-ray=Compton by thermal e

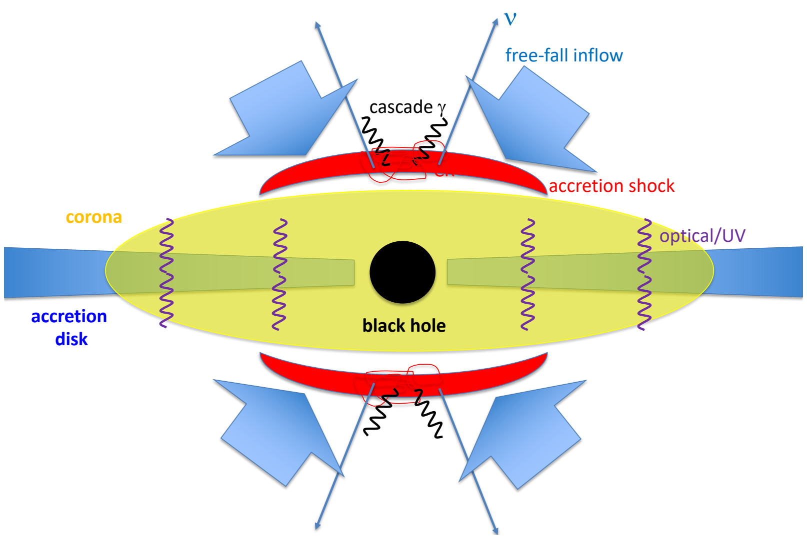




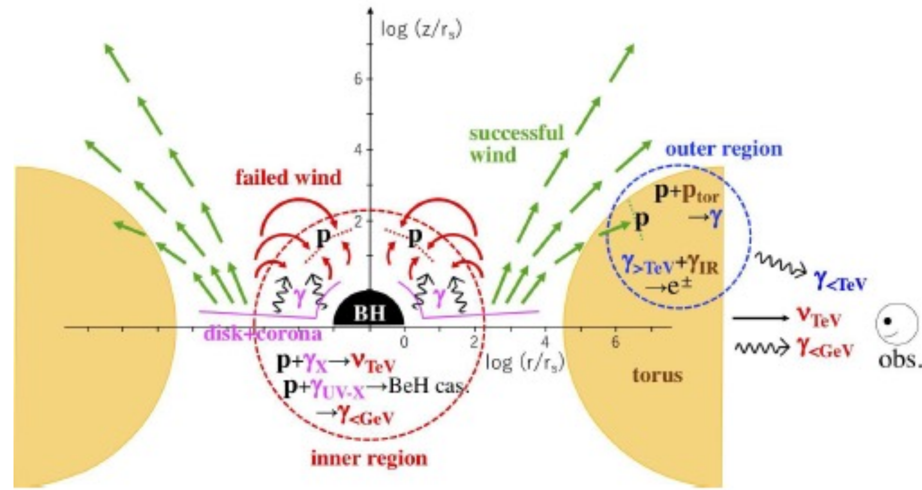
photomeson optical depths: both f_{pp} & $f_{p\gamma}$ > 1 ("calorimetric")

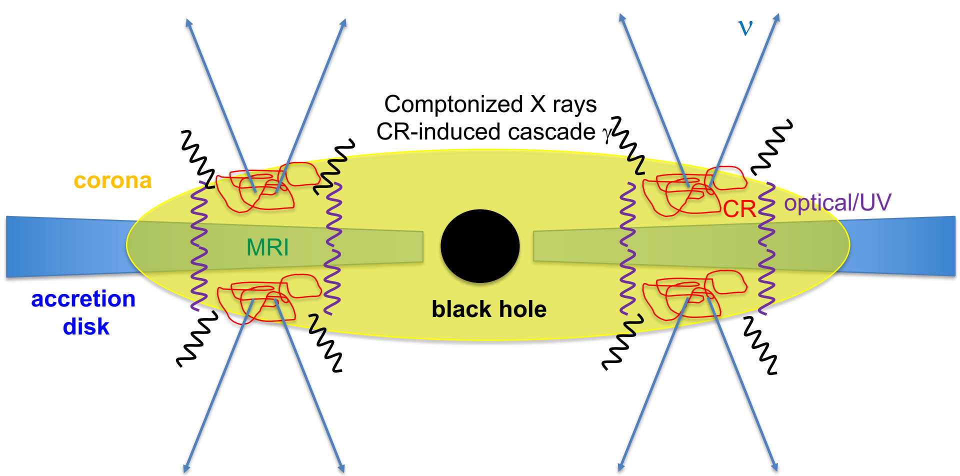
AGN Models

Accretion shock model
(ex. Stecker+ 91, Y. Inoue+ 20 ApJ)



Failed-wind model
(S. Inoue, Cerruti, KM+ 22)



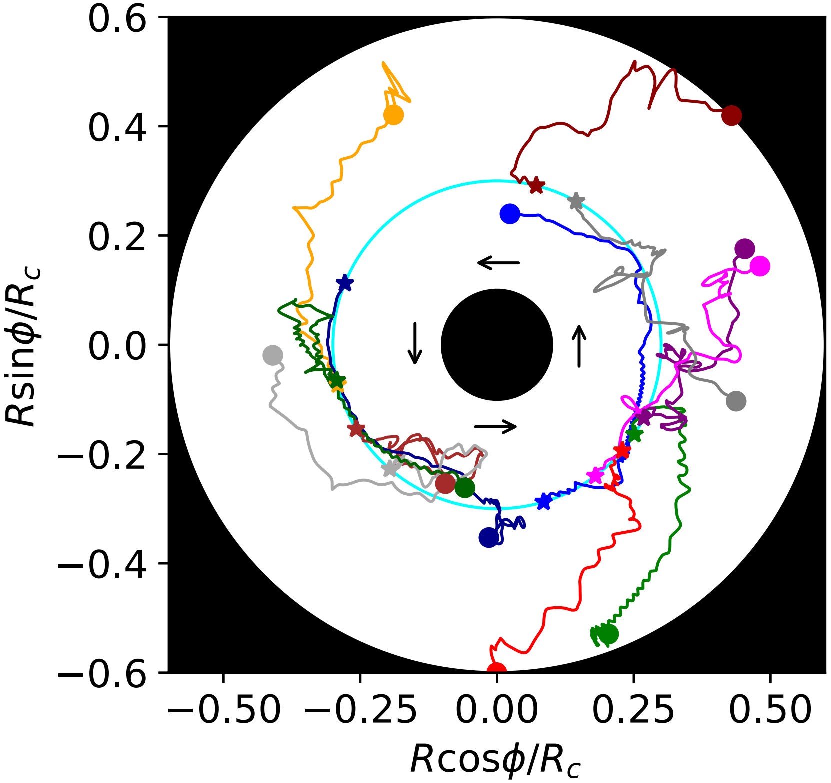


Magnetically-powered corona model
(KM+ 20 PRL, Eichmann+ 22)

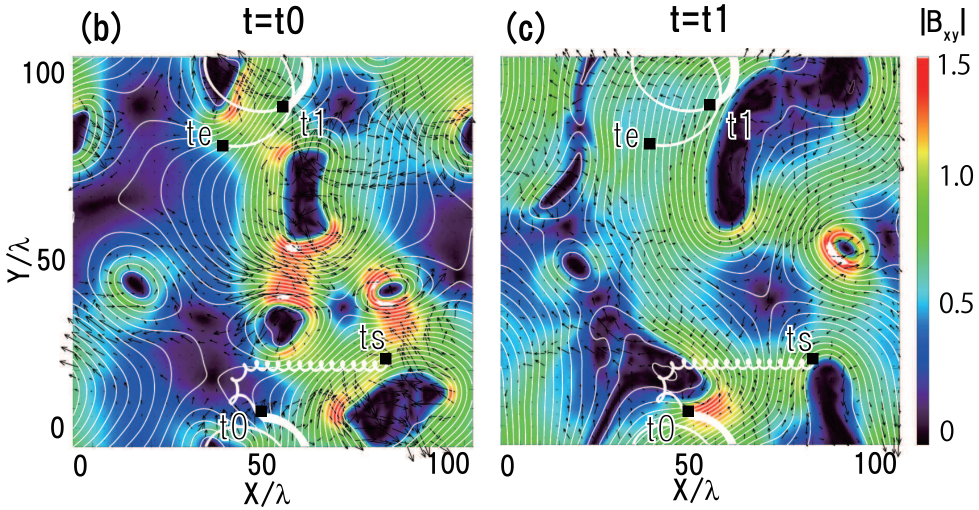
Particle Acceleration?

Magnetorotational Instability (MRI) -> turbulence & reconnection

stochastic acc. in global MHD simulations w. Athena++



reconnection/stochastic acc. in PIC simulations



Hoshino 12 PRL

magnetic reconnections
- acceleration by electric fields at X point
- subsequent stochastic acceleration via collisions w. islands or reconnection flows

Kimura, Tomida & KM 19 MNRAS
Sun & Bai 21 MNRAS

see also Hoshino 15 PRL, Sironi & Spitkovsky 14 ApJ, Ball, Sironi & Ozel 19 ApJ

NEUTRINO ASTROPHYSICS

Evidence for neutrino emission from the nearby active galaxy NGC 1068

IceCube Collaboration*†

A supermassive black hole, obscured by cosmic dust, powers the nearby active galaxy NGC 1068. Neutrinos, which rarely interact with matter, could provide information on the galaxy's active core. We searched for neutrino emission from astrophysical objects using data recorded with the IceCube neutrino detector between 2011 and 2020. The positions of 110 known gamma-ray sources were individually searched for neutrino detections above atmospheric and cosmic backgrounds. We found that NGC 1068 has an excess of 79^{+22}_{-20} neutrinos at tera–electron volt energies, with a global significance of 4.2σ, which we interpret as associated with the active galaxy. The flux of high-energy neutrinos that we measured from NGC 1068 is more than an order of magnitude higher than the upper limit on emissions of tera–electron volt gamma rays from this source.

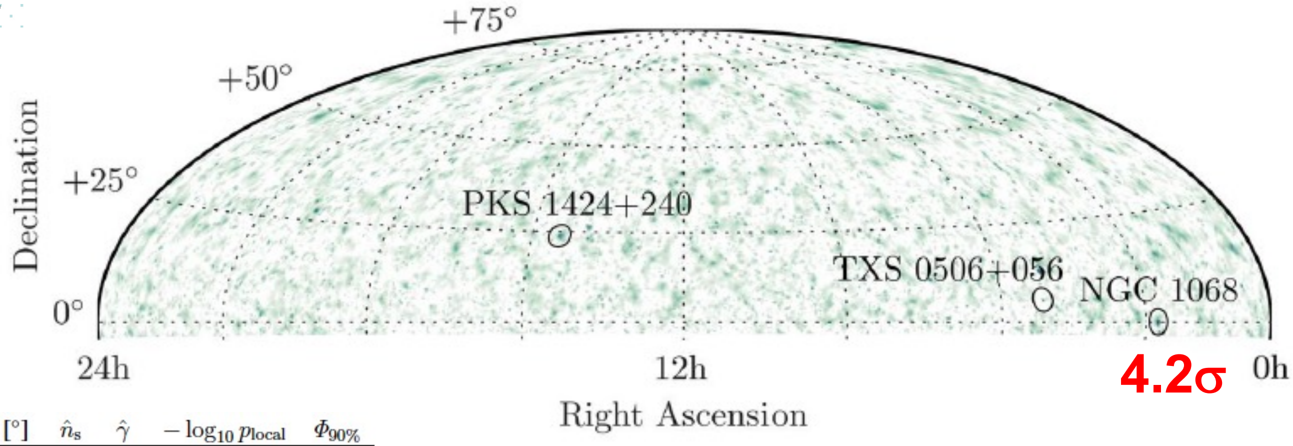
ASTRONOMY

Neutrinos unveil hidden galactic activities

An obscured supermassive black hole may be producing high-energy cosmic neutrinos

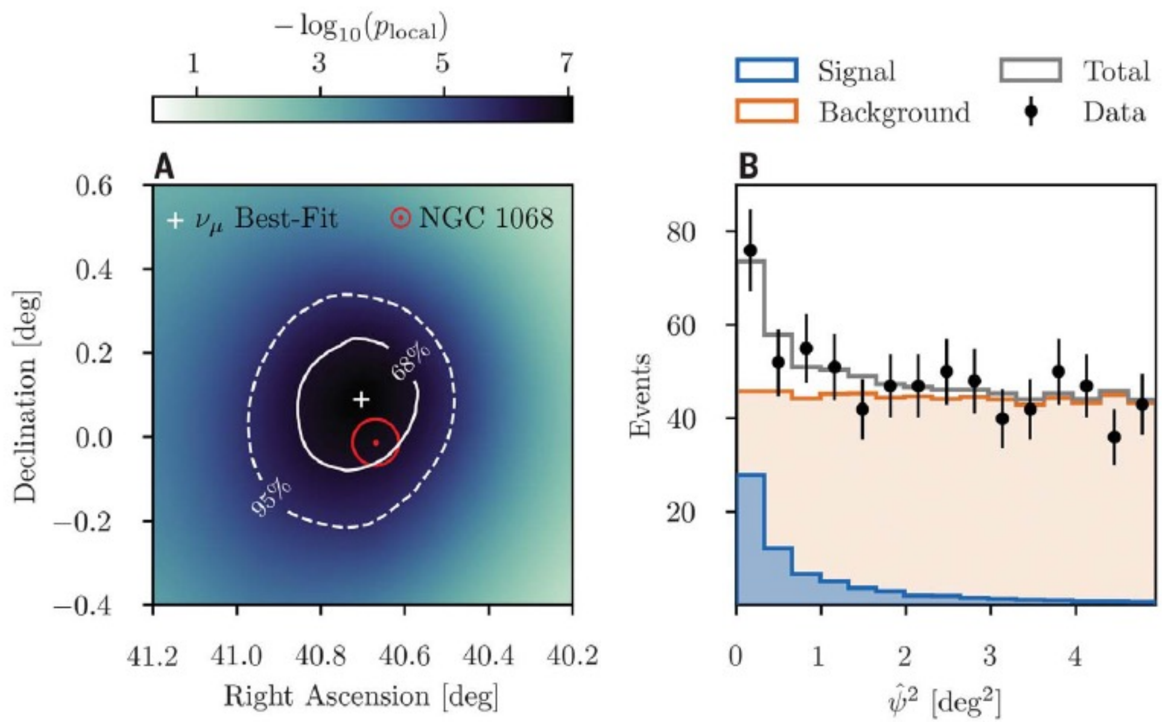
By **Kohta Murase**[1,2,3]

IceCube Collaboration+ 22

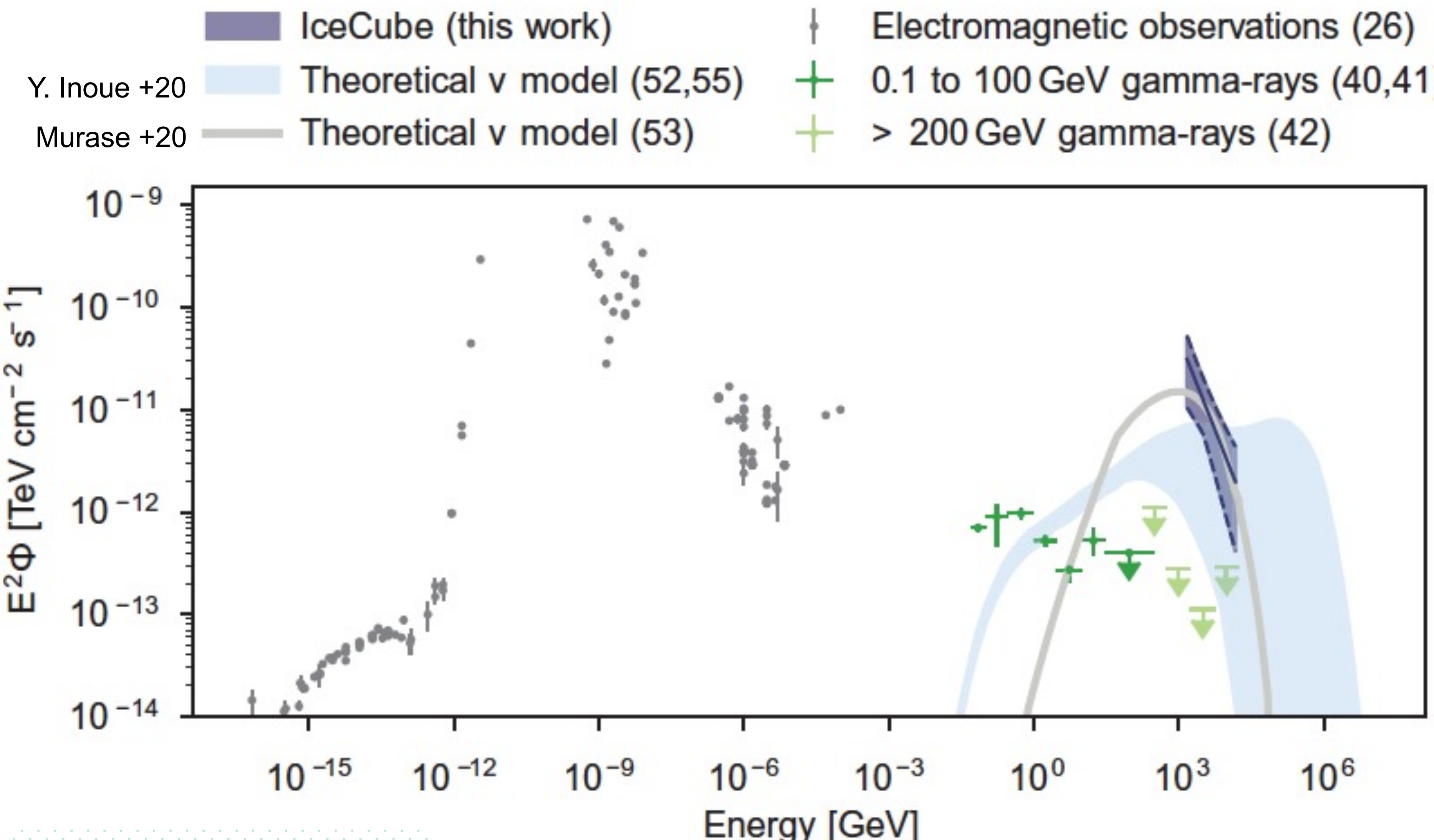


4.2σ

Source Name	Source Type	α [°]	δ [°]	$\hat{n}_s$	$\hat{\gamma}$	$-\log_{10} p_{\rm local}$	$\Phi_{90\%}$
NGC 1068	SBG/AGN	40.67	-0.01	79	3.2	7.0 (5.2 σ)	9.6
PKS 1424+240	BLL	216.76	23.80	77	3.5	4.0 (3.7 σ)	11.4
TXS 0506+056	BLL/FSRQ	77.36	5.70	5	2.0	3.6 (3.5 σ)	7.5

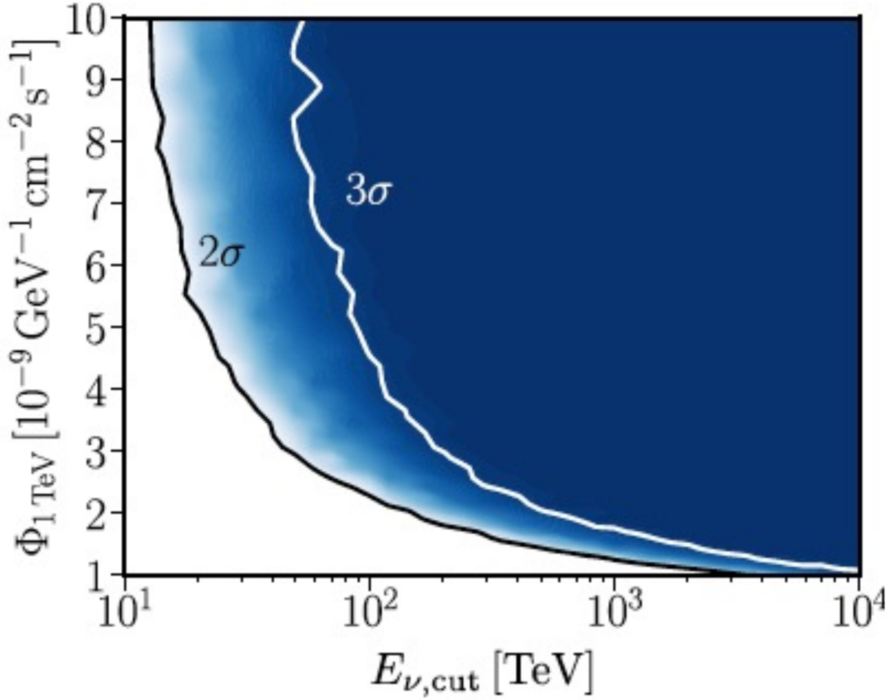


~79 excess events

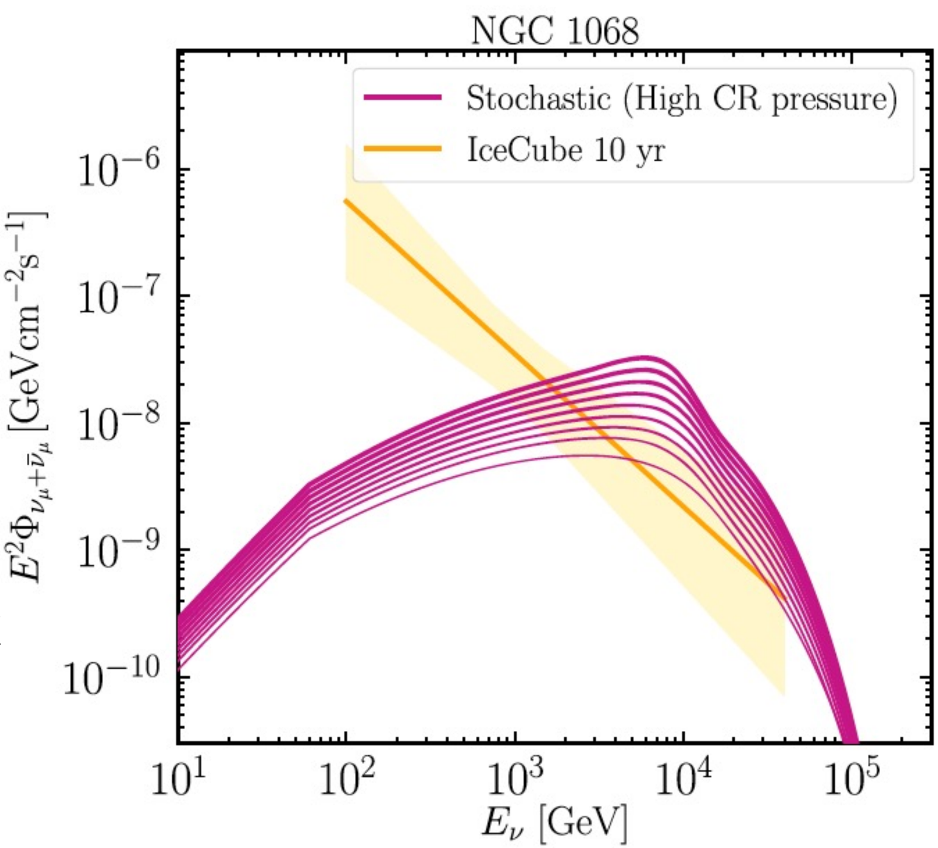


IceCube Collaboration+ 22

NGC 1068: Constraints & Uncertainty



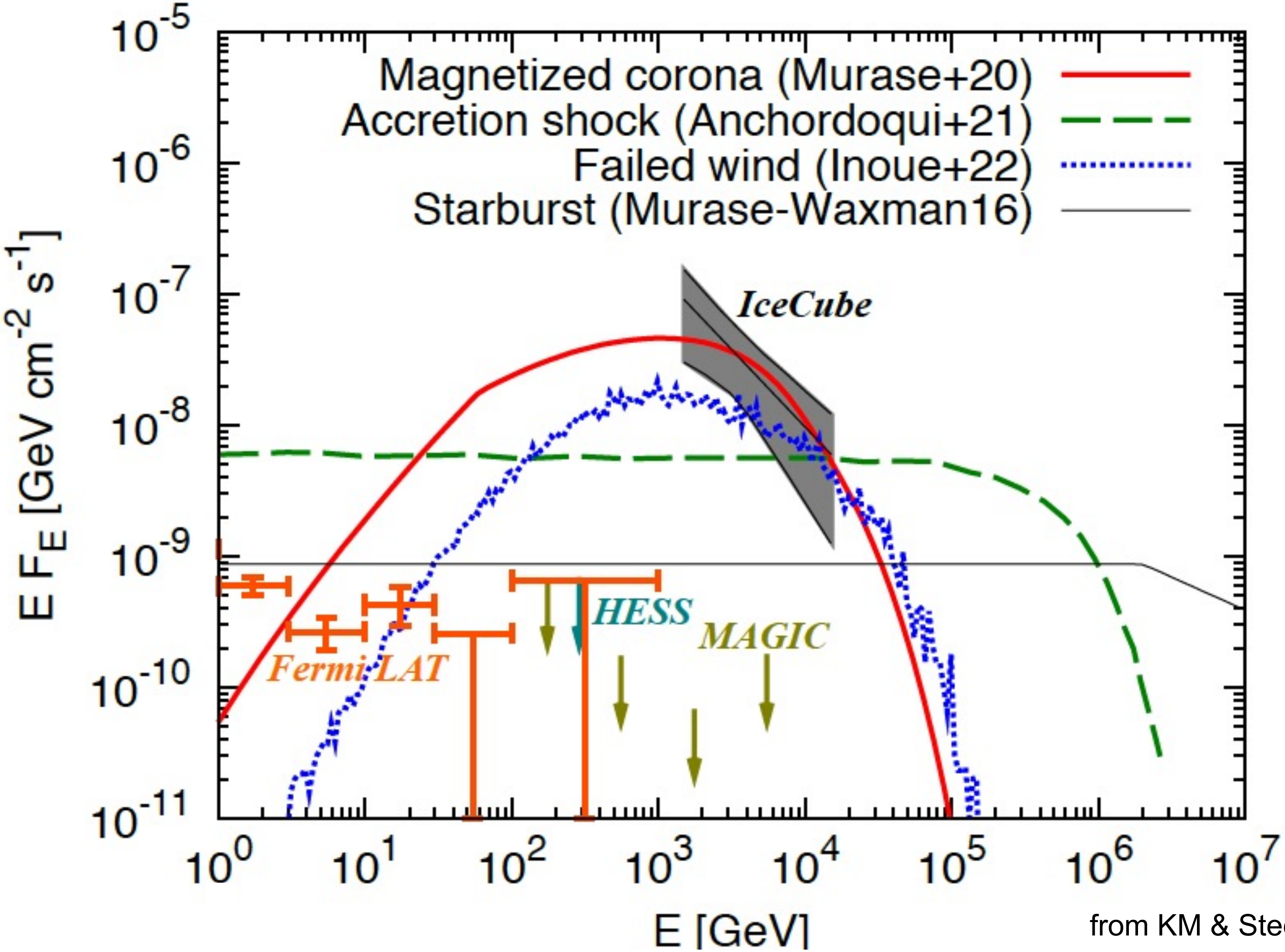
Constraints on E_{cut} for E^{-2} spectrum (Bohm diffusion is excluded for the accretion shock model)



Uncertainty from "intrinsic" X-ray flux

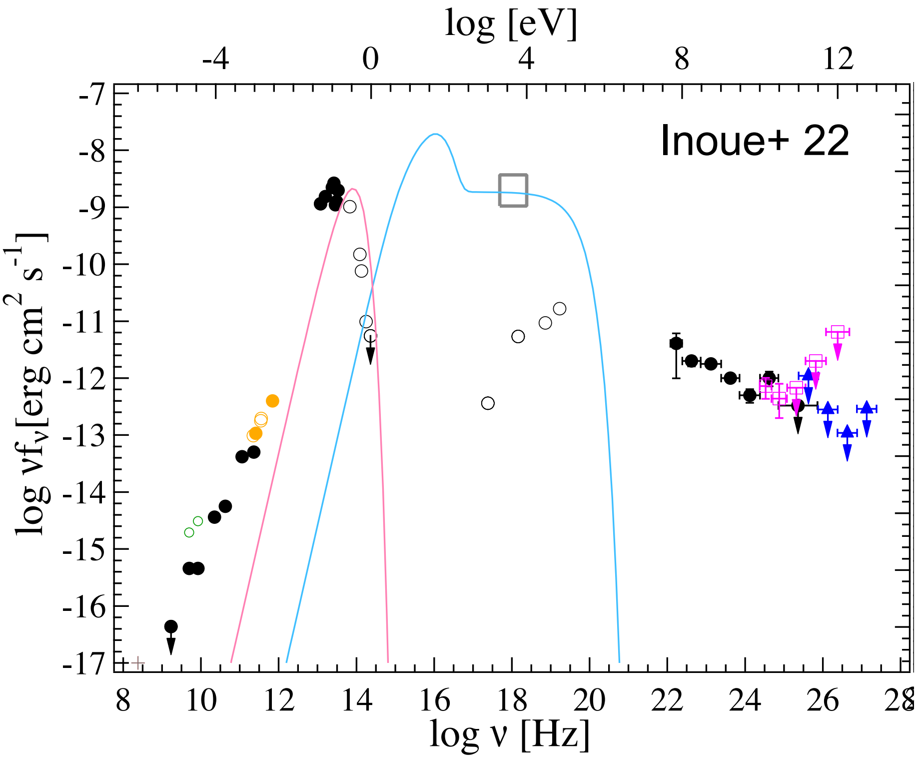
Kheirandish, KM & Kimura 21 ApJ

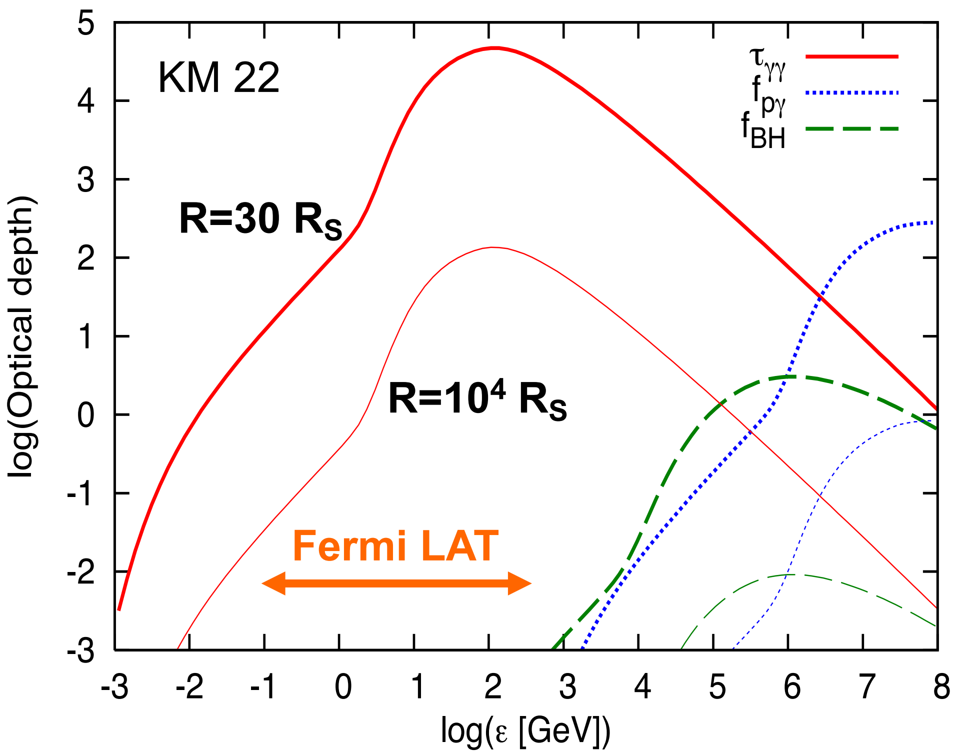
Evidence for a Hidden Source



from KM & Stecker 22

Gamma-Ray Optical Depth





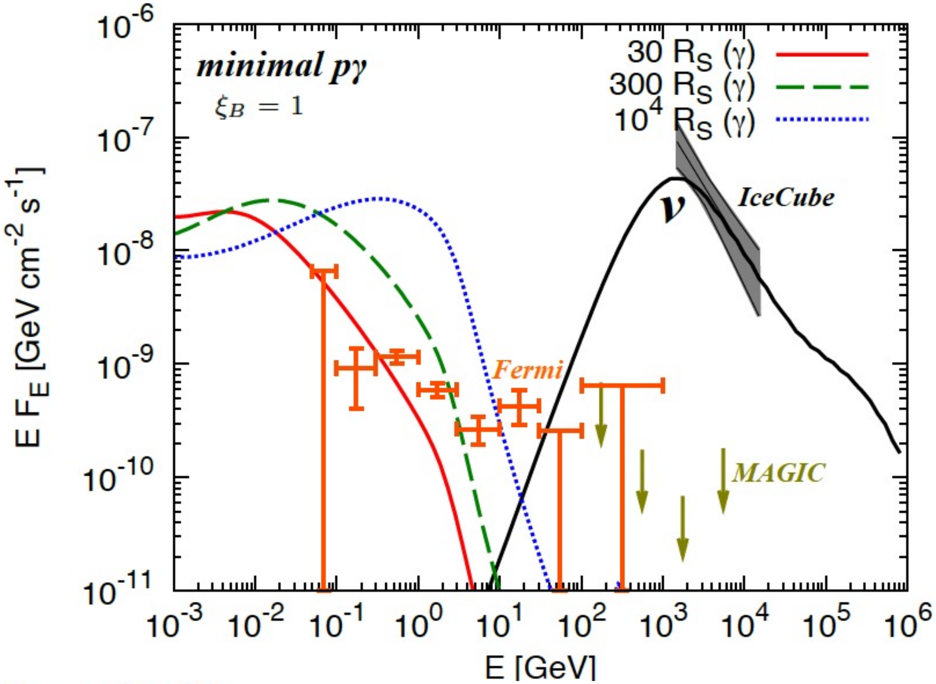
- NuSTAR: $N_H \sim 10^{25}$ cm^2 → $L_X = 7\times10^{43}$ erg/s (Marinucci+ 16 MNRAS)
- Bolometric luminosity: $\sim 10^{45}$ erg/s
- GeV gamma-rays can escape at $>10^4$ $R_S \sim R_{BLR}$

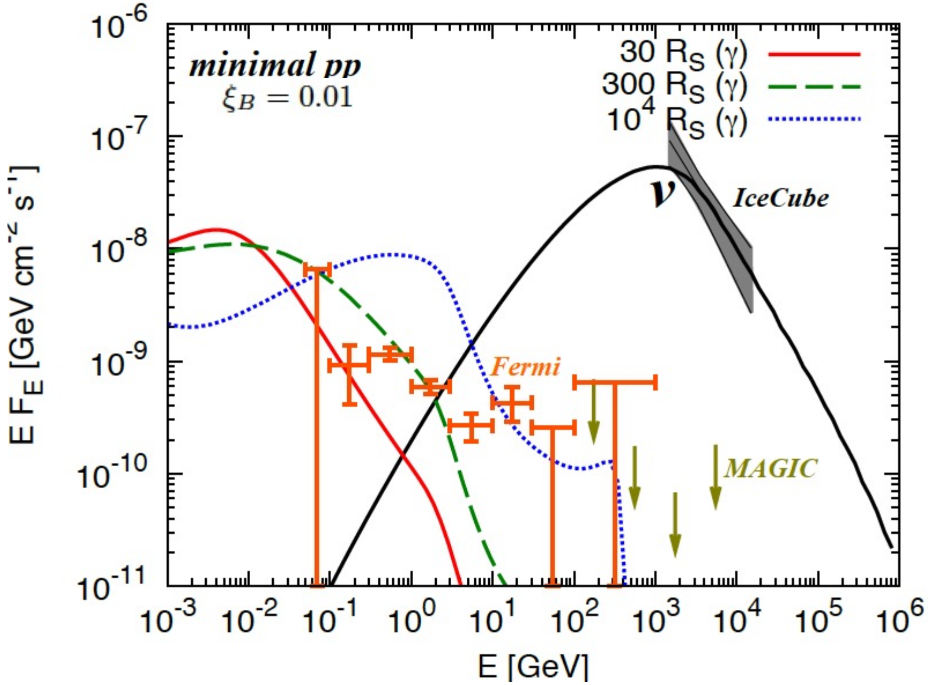
$\tau_{\gamma\gamma} \gtrsim 10$ for 0.1-300 GeV γ rays → **R < 100 R_S**

Where do Neutrinos Come from?

Q. neutrino emission radius?

KM 22



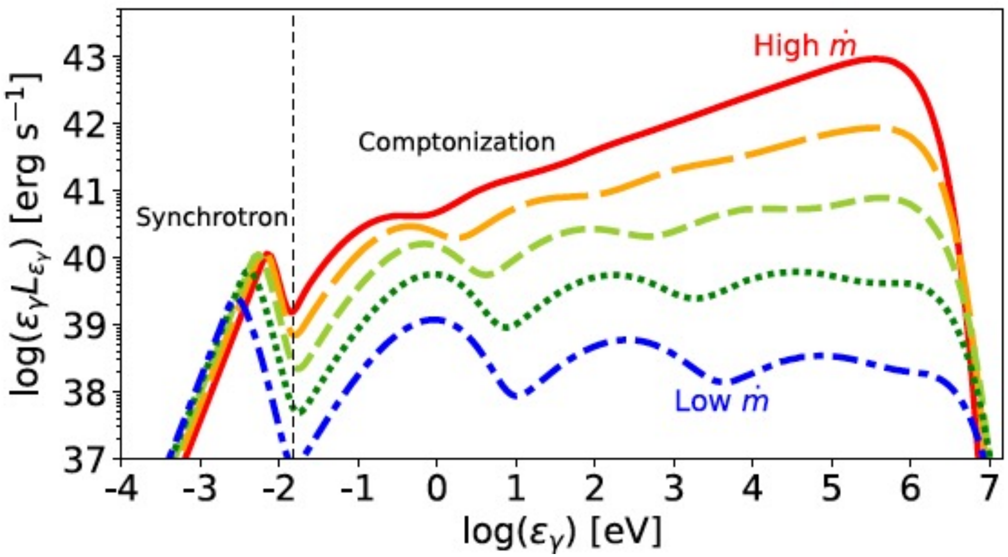


$\xi_B \equiv U_B/U_\gamma$

- Cascade constraints: **R < (30-100) R_S**
- Compatible w. pγ calorimetry ($f_{p\gamma}$>1) condition: R < 100 R_S

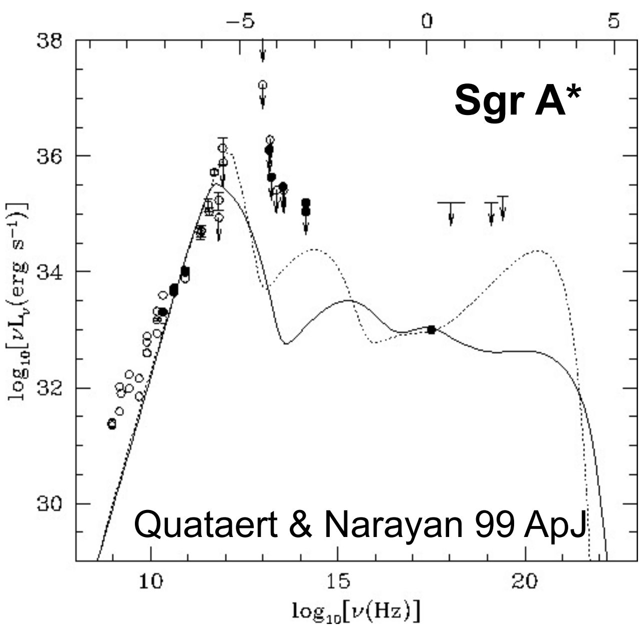
Neutrino emission most likely comes from the SMBH vicinity (ex. coronal regions, base of outflows)

Applications to Low-Luminosity AGNs

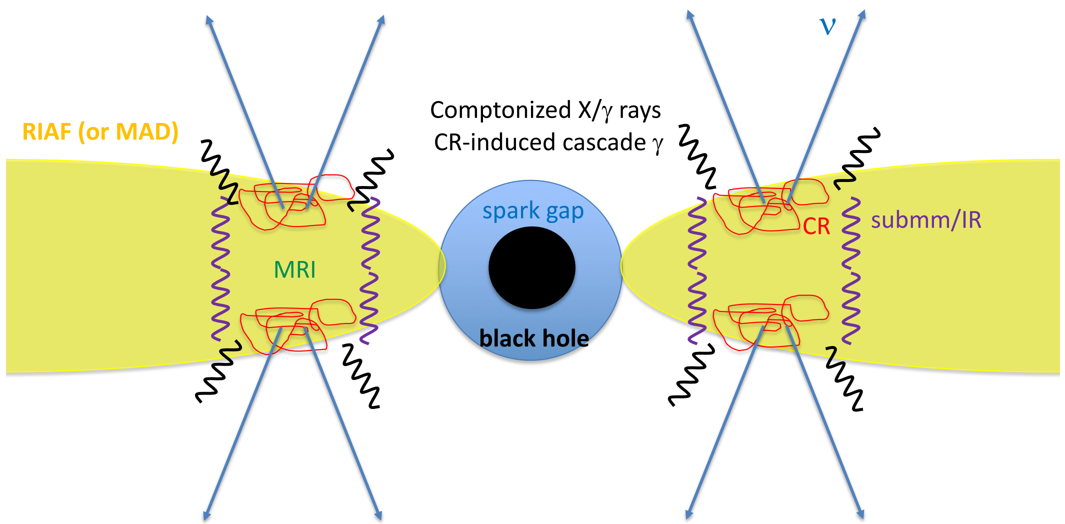


Kimura, KM & Toma 15 ApJ
Kimura, KM & Meszaros 21 Nature Comm.

- RIAF for mdot<0.03
- Electrons are mostly thermal (collisional for electrons but collisionless for protons)

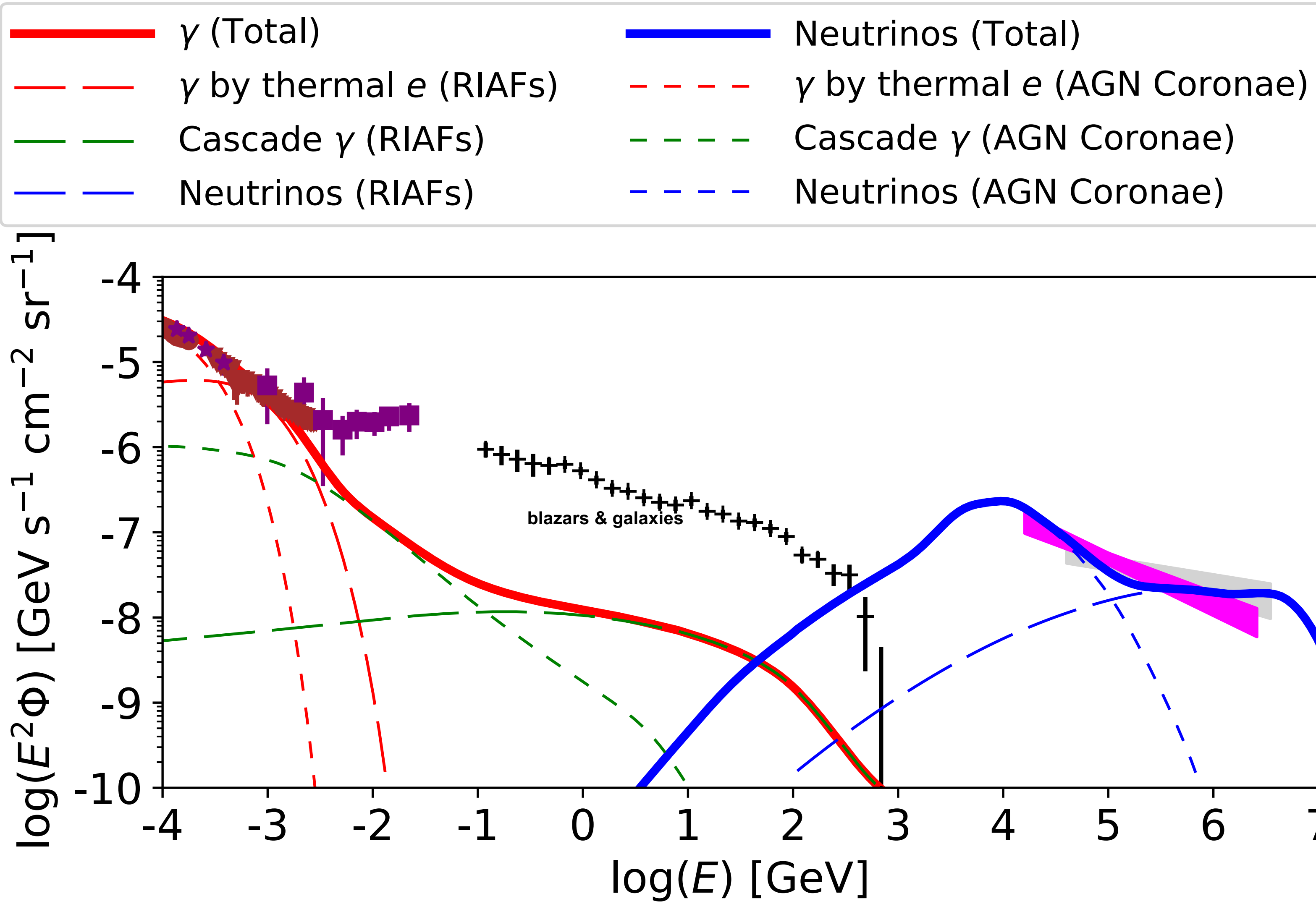


Quataert & Narayan 99 ApJ



AGN Manifesting in the Multi-Messenger Sky?

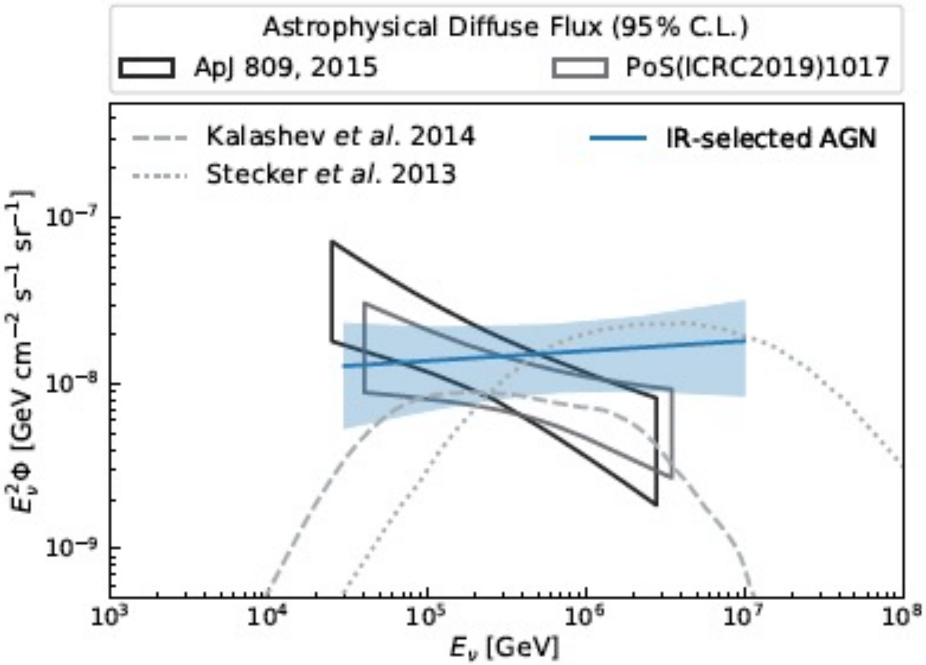
KM, Kimura & Meszaros 20 PRL
Kimura, KM & Meszaros 21 Nature Comm.

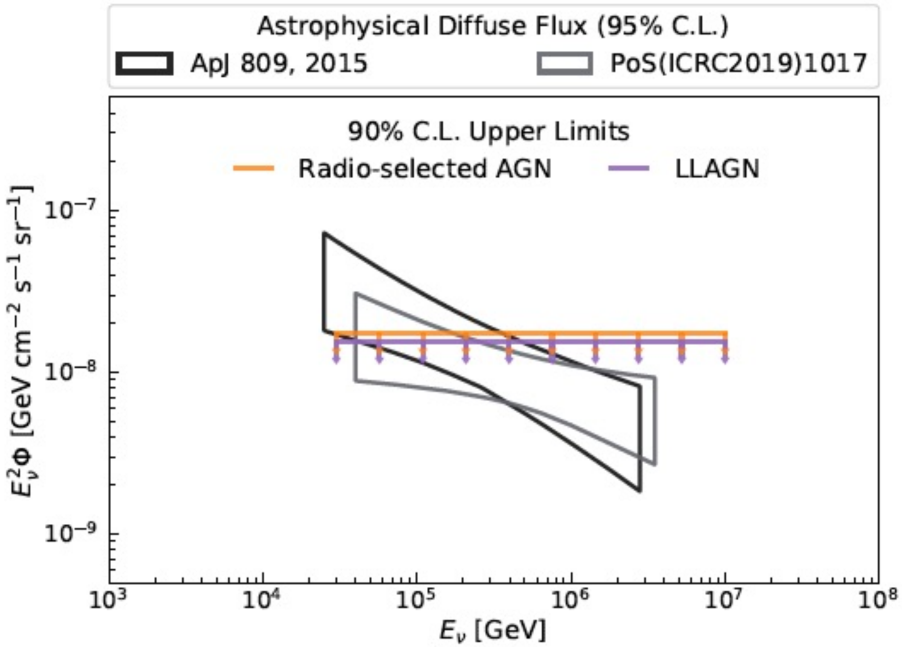


Correlation w. IR/Radio-Selected AGN & LL AGN?

IceCube Collaboration+ 22

	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}%





2.6σ (post-trial) with 8 yr upgoing ν_μ events and IR-selected AGN

apparent tension with the extremely high-energy limit

NGC 1068: Pros & Cons

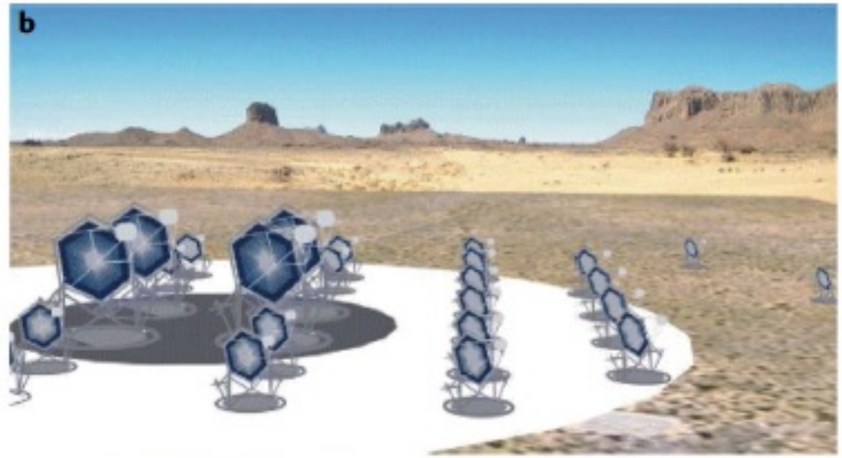
Pros:

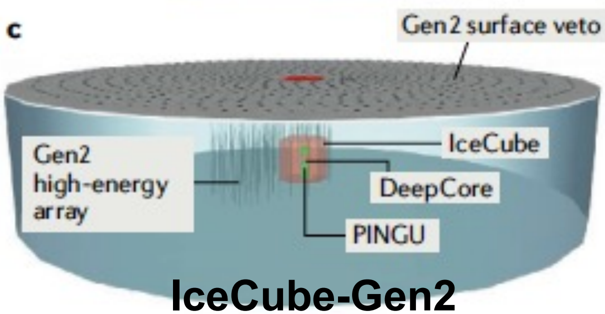
- L_ν~$3x10^{42}$ erg/s vs L_{bol}~10^{45} erg/s & L_X~10^{43-44} erg/s
  reasonable energetics: energy fraction of CRs: ~10%
- Obscured AGN & high-density (calorimetric) environments
- The brightest Seyfert in intrinsic X-rays in the IceCube sky
  (For PeV νs, the most promising starburst in the IceCube sky)
- Hidden sources motivated by both theory and diffuse ν-γ
- Hints from stacking with IR/radio-selected AGN (2.6σ)

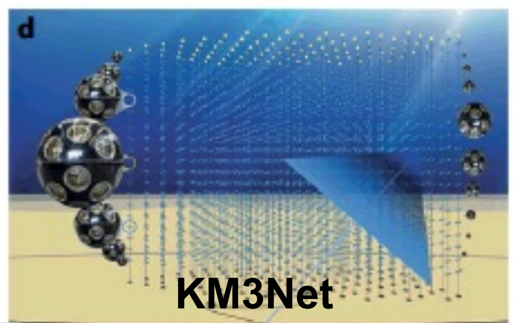
Cons:

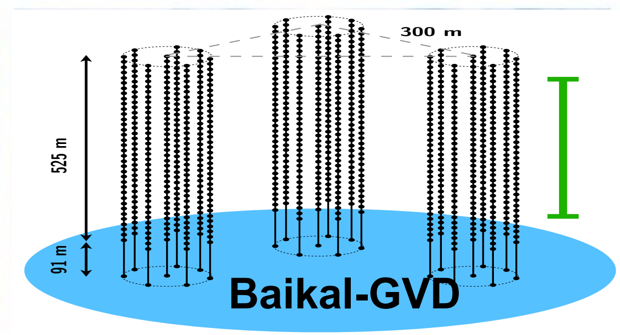
- More statistics are necessary (~4σ in the cataloged search)
- Particle acceleration mechanisms are unclear
  (but much progress has been made theoretically)

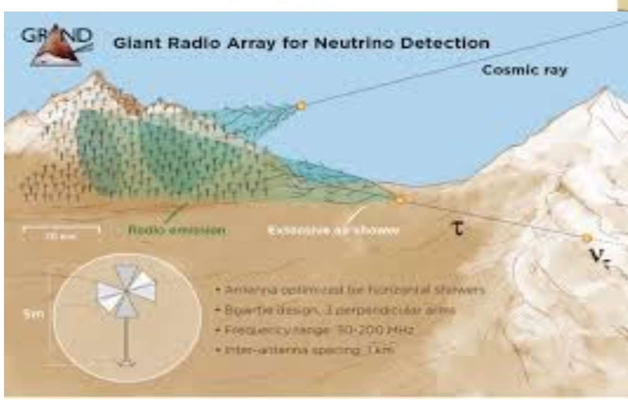
Testability











More multi-messenger data in the next decade will enable us to test the proposed models

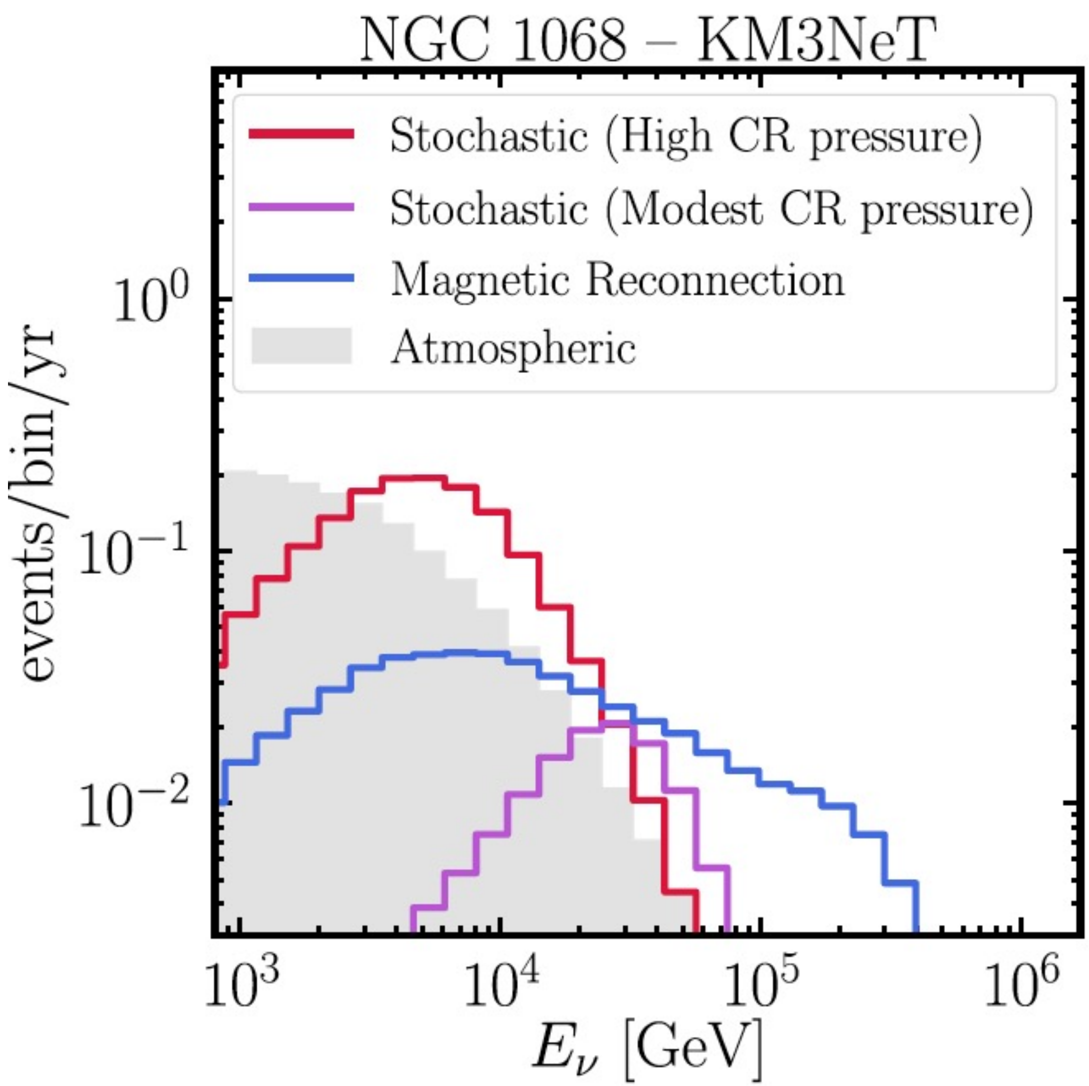
Importance of KM3Net Observations

Kheirandish, KM & Kimura 21 ApJ

Top 10 sources for KM3Net

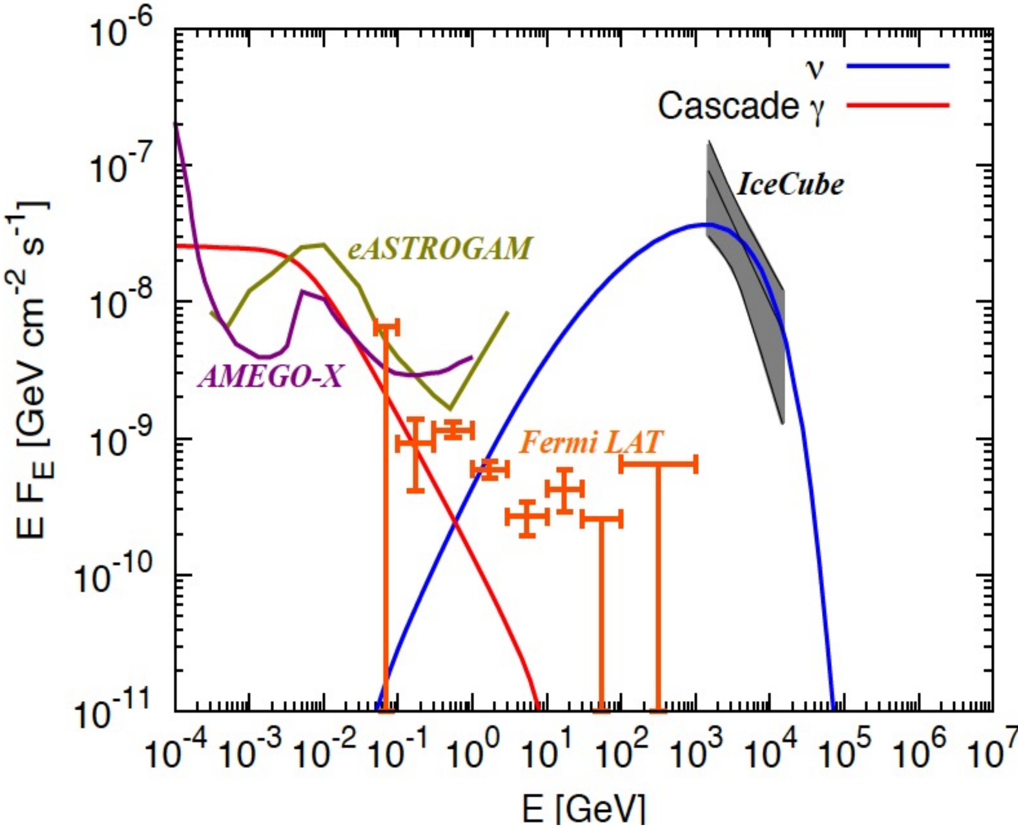
1. *Cen A
2. Circinus Galaxy
3. ESO 138-1
4. NGC 7582
5. NGC 1068
6. NGC 4945
7. NGC 424
8. UGC 11910
9. CGCG 164-019
10. *NGC 1275

*** may belong to different classes**

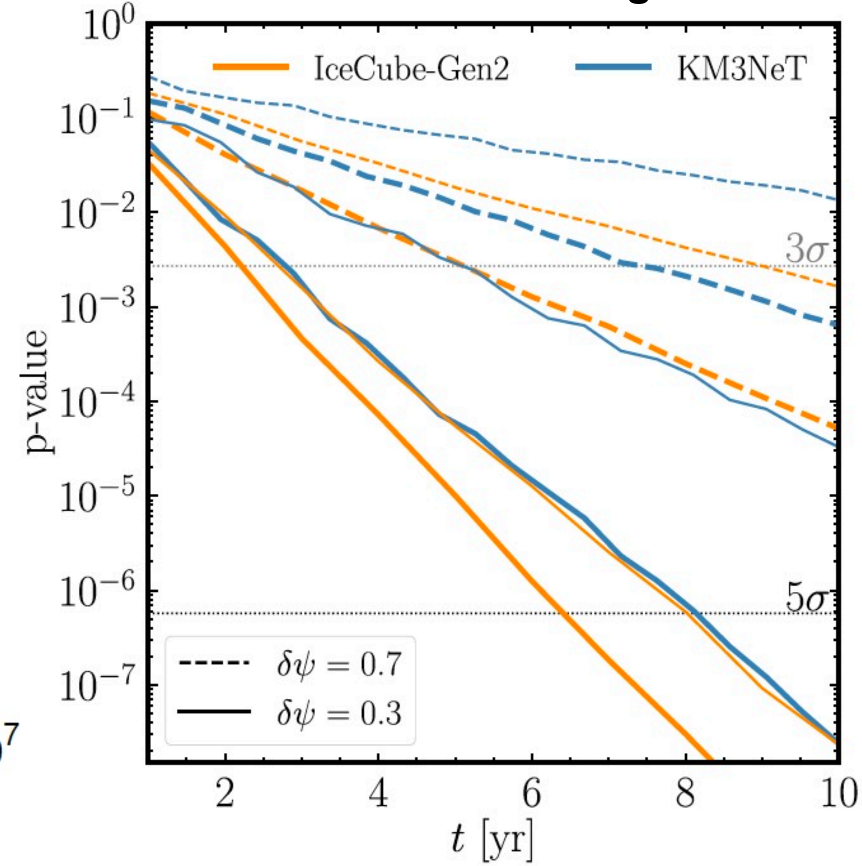


Detectability of Nearby Seyfert Galaxies

KM, Kimura & Meszaros 20 PRL, Kheirandish, KM & Kimura 21 ApJ



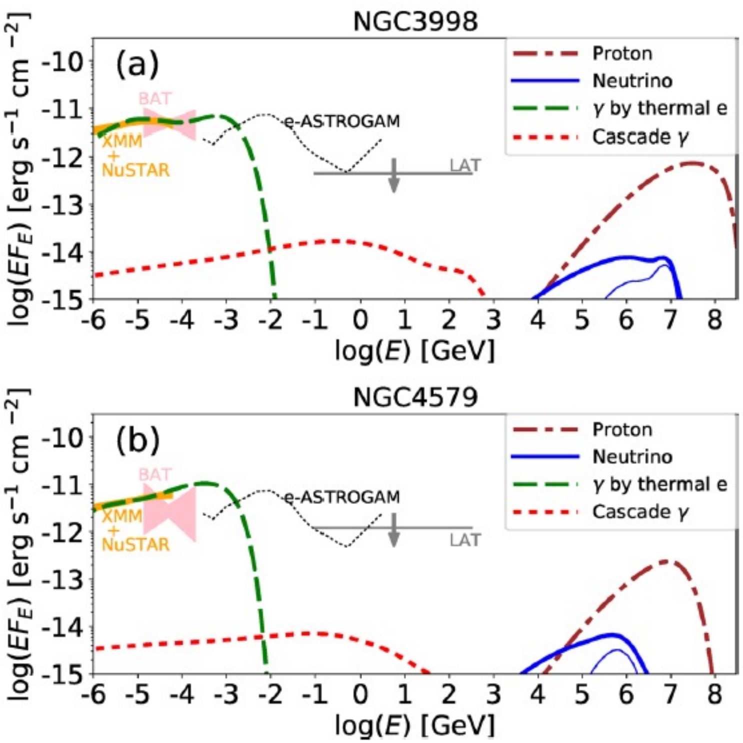
Predictions for stacking search



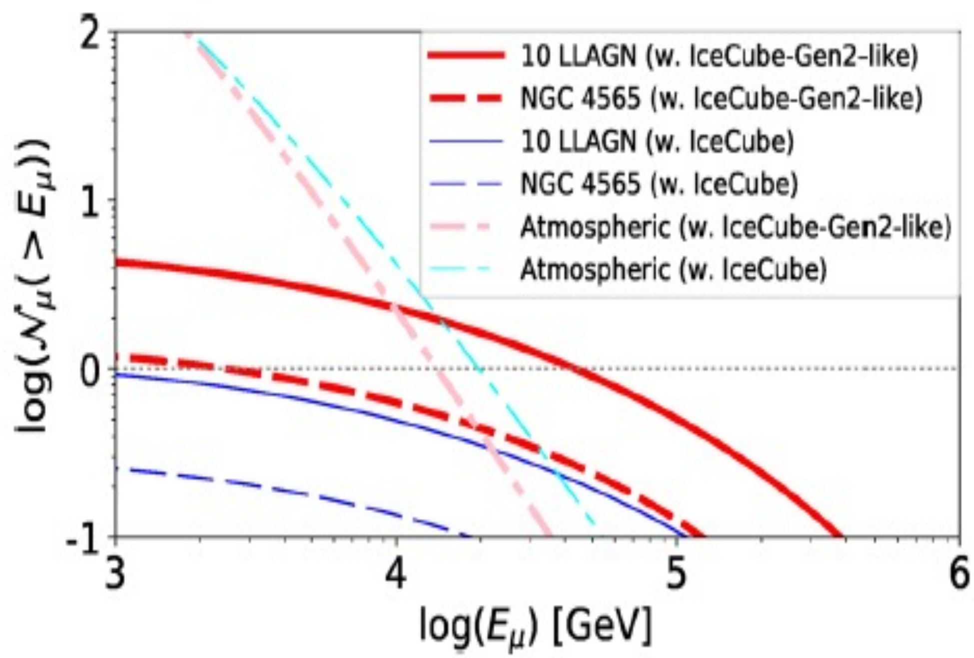
- CR-induced cascade γ rays are promising in the MeV range
- Testable w. near-future data or by next-generation neutrino detectors given that the angular resolution is <0.3 deg

Detectability of Nearby Low-Luminosity AGN

Kimura, KM & Meszaros 21 Nature Comm.

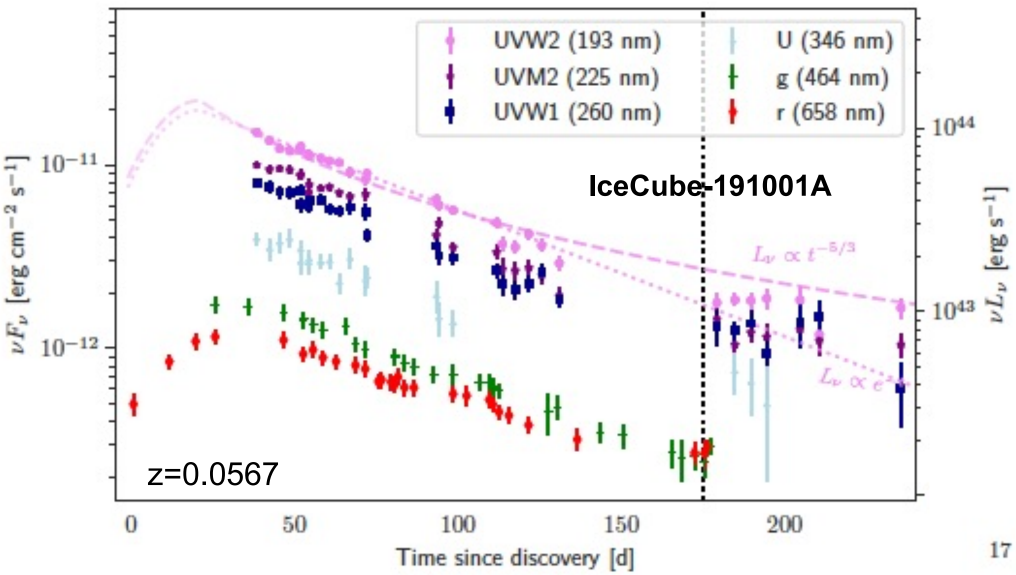


Predictions for stacking search



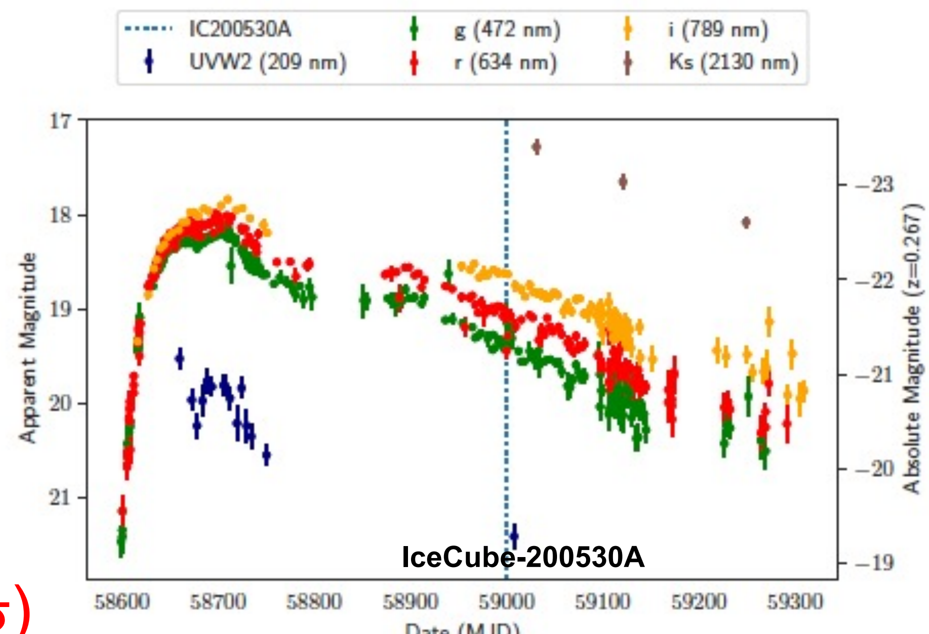
- Detection of MeV γ due to thermal electrons is promising (CR-induced cascade γ rays are difficult to observe)
- Nearby LL AGN can be seen by IceCube-Gen2/KM3Net

Coincidences w. Optical Transients



IceCube-191001A
& AT 2019dsg
(Stein+ 21 Nature Astron.)

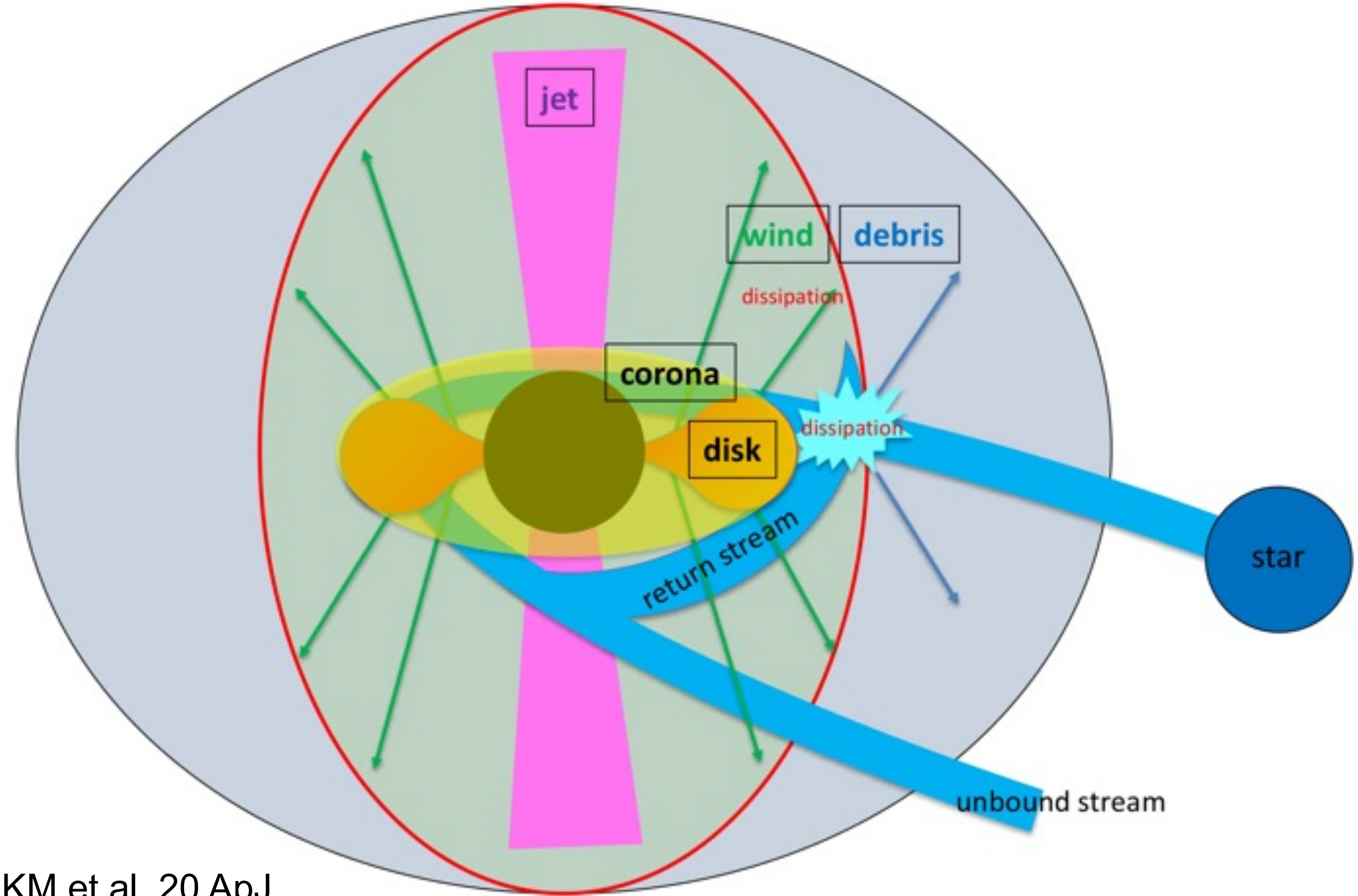
IceCube-200530A
& AT 2019fdr
(Reusch+ KM 21 PRL)



Both are rare optical transients
with strong radio emission (>3.4σ)

Neutrinos from Black Hole "Flares"?

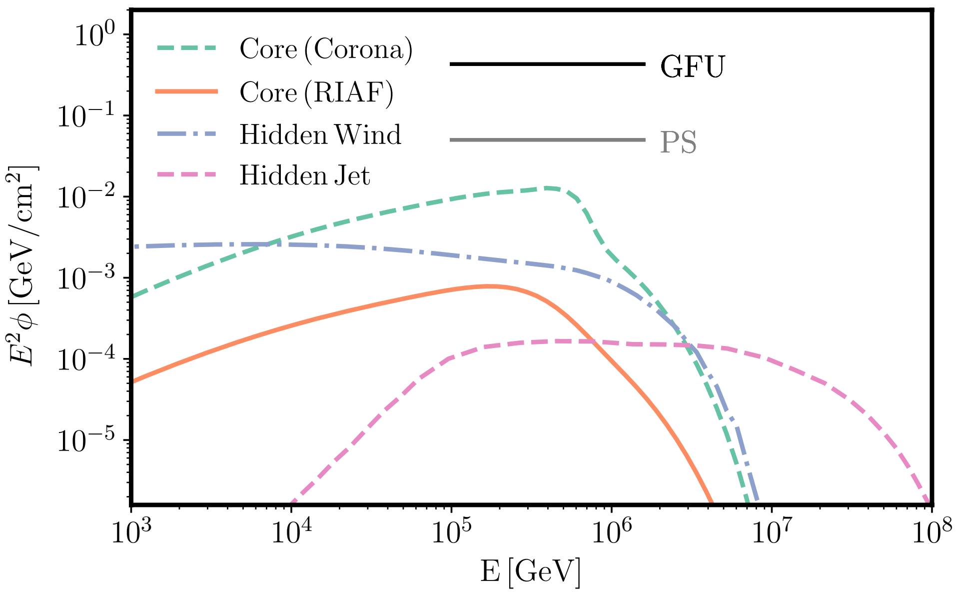
- AT 2019dsg, AT 2019fdr, AT 2019aalc: TDE candidates



KM et al. 20 ApJ

Implications for AT2019dsg & AT2019fdr

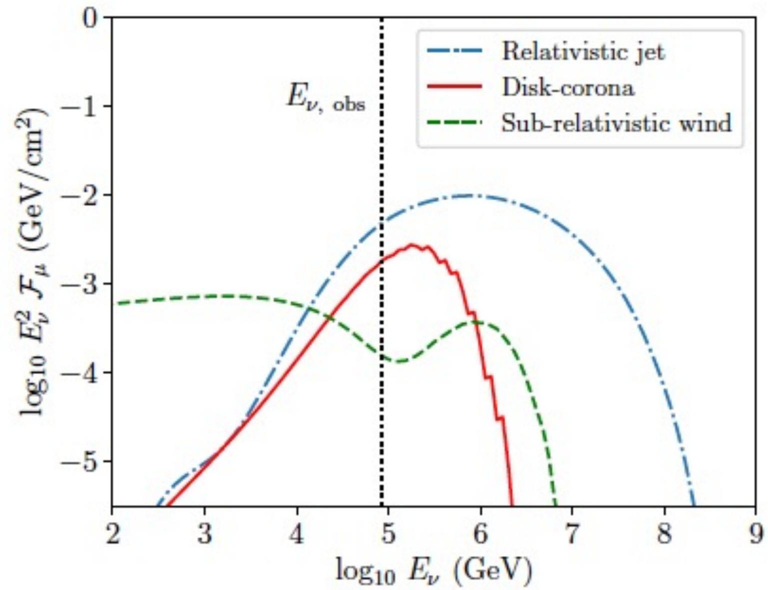
AT 2019dsg



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}

KM, Kimura, Zhang, Oikonomou & Petropoulou 20 ApJ

AT 2019fdr



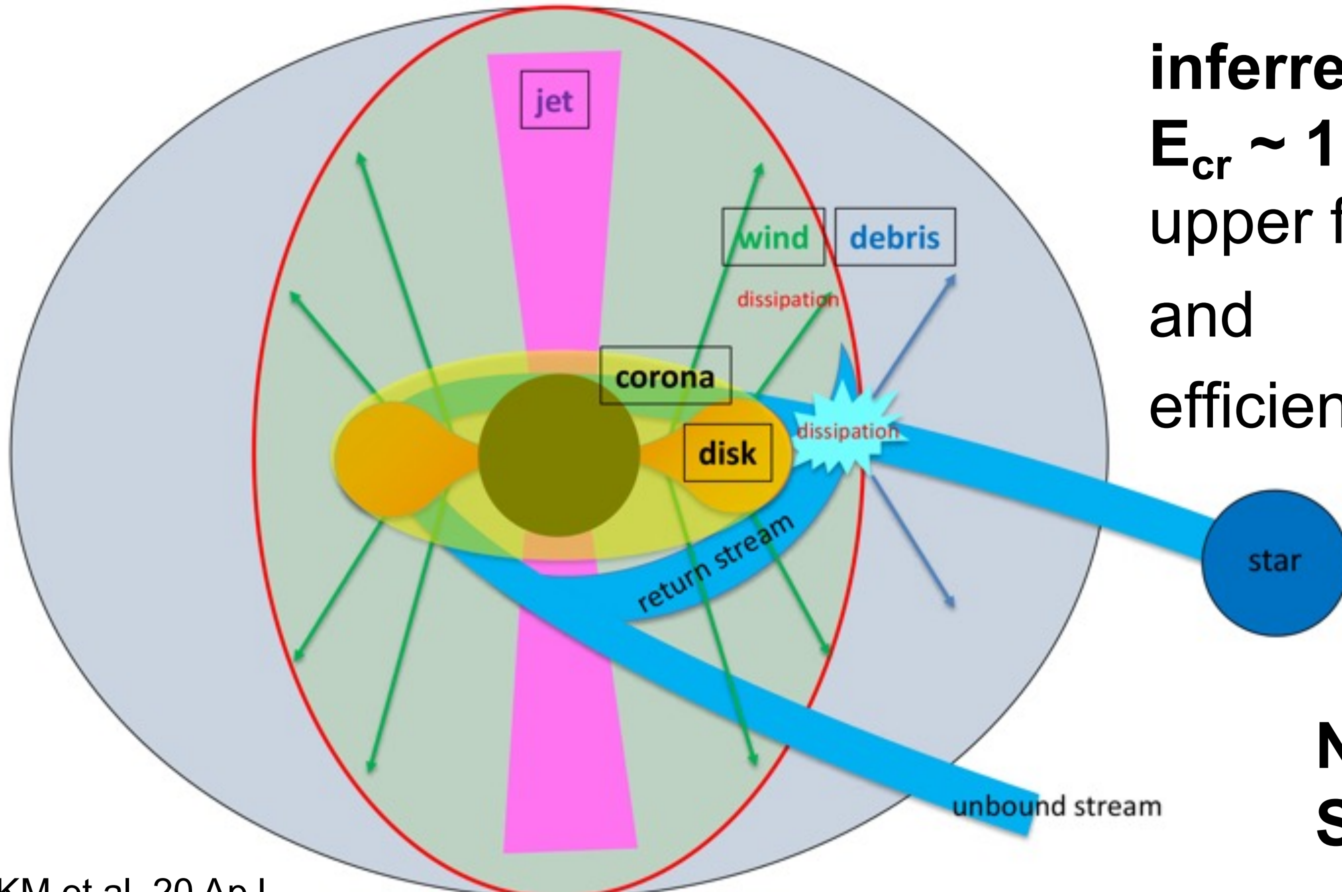
(Reusch+ KM 21)

N_ν ~ 0.01-0.1 events (alert)

No evidence of jets

Neutrinos from Black Hole "Flares"?

- AT 2019dsg, AT 2019fdr, AT 2019aalc: TDE candidates
- TDE and AGN νs could originate from common mechanisms (disk-corona? jet? wind colliding w. stellar debris?)



inferred CR energy
E_{cr} ~ $10^{53\text{-}54}$ erg > E_{EM}
upper fluctuation

and

efficient CR acceleration

Need more data
Stay tuned!!!

KM et al. 20 ApJ

Summary

- Multi-messenger analyses w. 10 TeV ν data suggest hidden CR accelerators
- >100 TeV ν data: many possibilities, astro-particle grand-unification?

Blazars/Jetted AGN

- TXS 0506+056 and other coincidences: no simple convincing picture
- Dominant in the extragalactic γ-ray sky but seems subdominant in the ν sky
- Correlations w. radio/optical blazars: contribution from the brightest blazars?
- Beyond handwavy models: MeV γ–ray tests, further theoretical studies

Jet-quiet AGN

- NGC 1068: evidence for a hidden neutrino source
- More in south (KM3Net/Baika-GVD), IceCube-Gen2, MeV γ–ray tests
- Nearby LL AGN: interesting targets for next-generation detectors
- All-sky νs (even at 10 TeV) can be explained as γ-ray hidden sources

Tidai disruption events

- TDE coincidences: theoretically possible but with upper fluctuations
- TDE and AGN ν emission could originate from common mechanisms

from Murase's talk
@ Neutrino 2014

WANTED

~~Diffuse or A~~ssociated

ν

- Source identification may not be easy
  (ex. starbursts: horizon of an average sourc TXS, TDEs)
- promising cases: "bright transients (GRBs, AGN flares)",
  "rare bright sources (powerful AGN)", "Galactic sources"
- Not guaranteed but rem NGC 1068 e success of γ-ray astrophysics