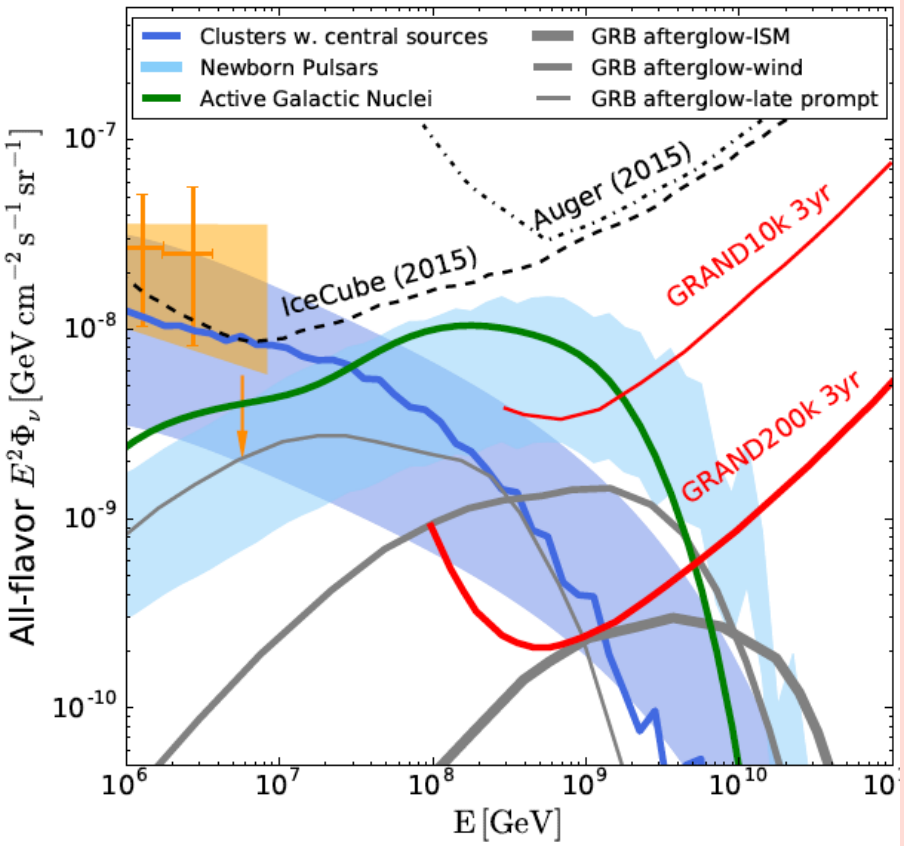
Summary



Cosmogenic?

Auger X_{max} -> ~10^{-10}-10^{-9} GeV/cm^2/s/sr proton fraction can be constrained

Diffuse ν sources?

pp scenarios can explain ν, γ & CR

-> ~3x10^{-9} GeV/cm^2/s/sr at 100 PeV

Point Sources?

blazars (FSRQs) as UHECR sources especially for flares

Transient Sources

Mergers, supernovae, GRBs, TDEs

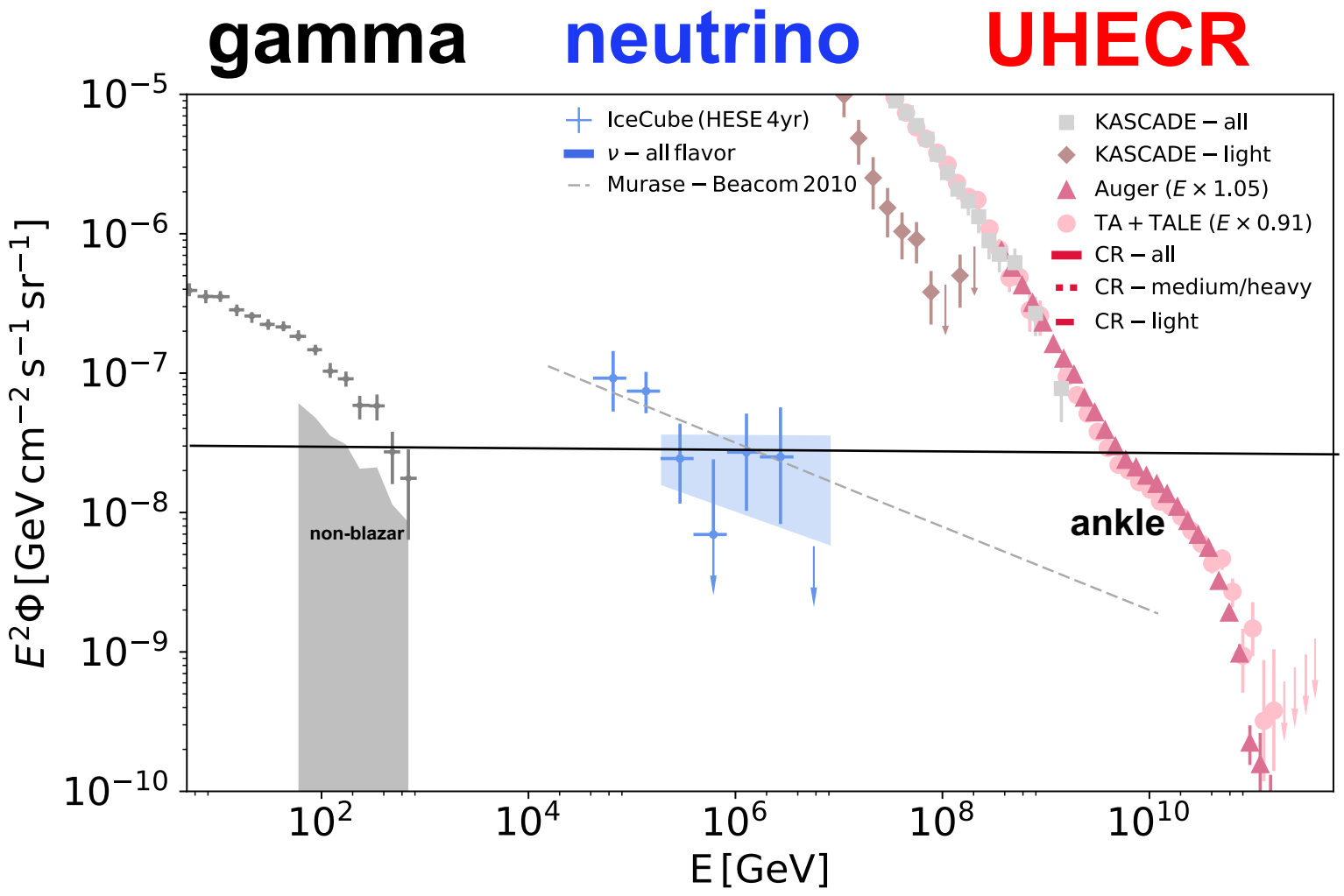
Transients could be detected by GRAND30k if lucky

Need 0.1-1 EeV ν obs. w. <1-3° res.

First UHE ν detection may be source ν

Encouraging real-time EHE ν alerts

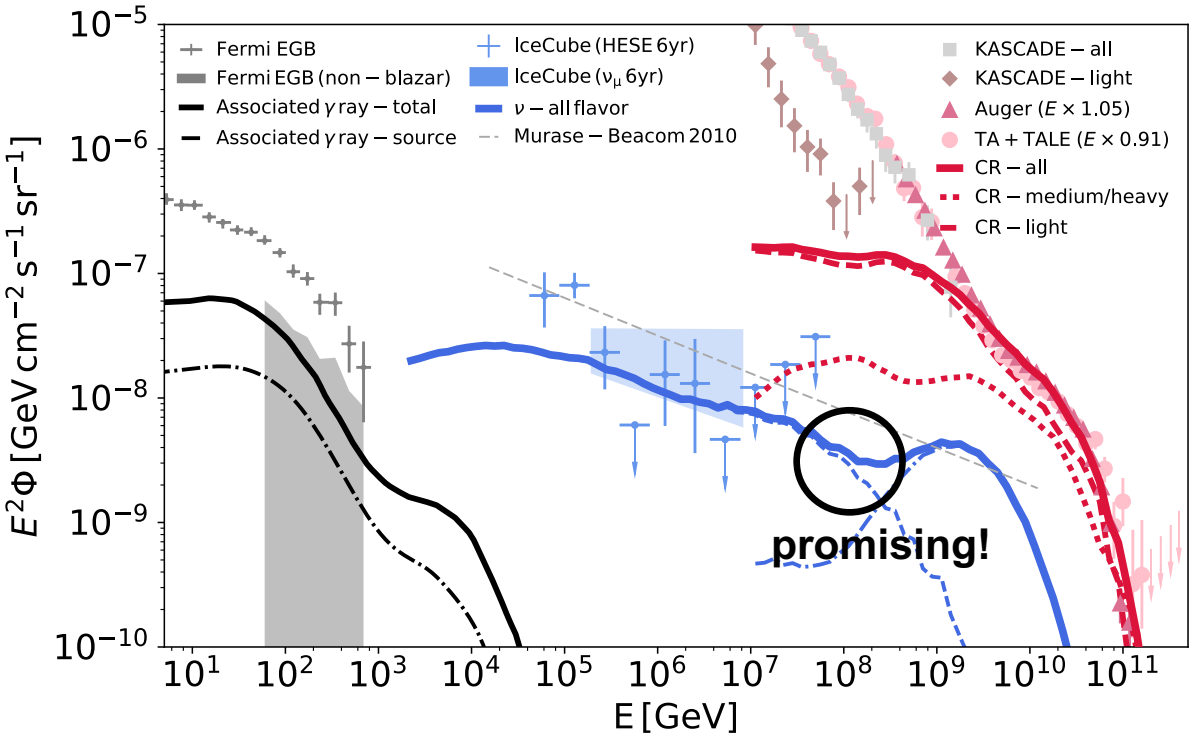
High-Energy Cosmic Particle Backgrounds



Diffuse fluxes are roughly comparable to a few x 10^{-8} GeV cm^{-2} s^{-1} sr^{-1}

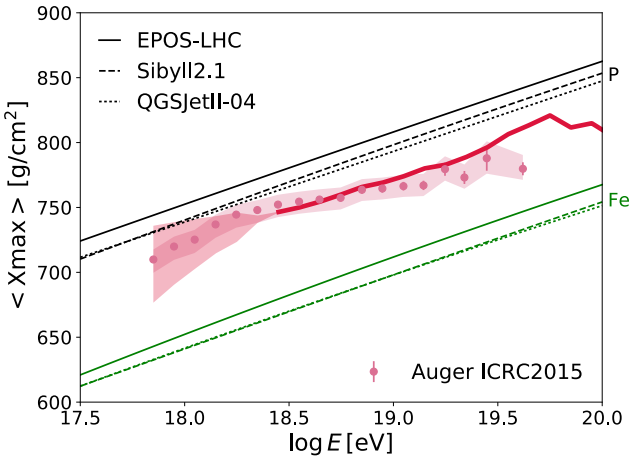
Testing the Grand-Unification Scenario for HE Cosmic-Ray Particles

- AGN as “UHECR” accelerators
- confinement in cocoons & clusters
- escaping CR nuclei: harder than CR protons
- smooth transition from source ν to cosmogenic ν



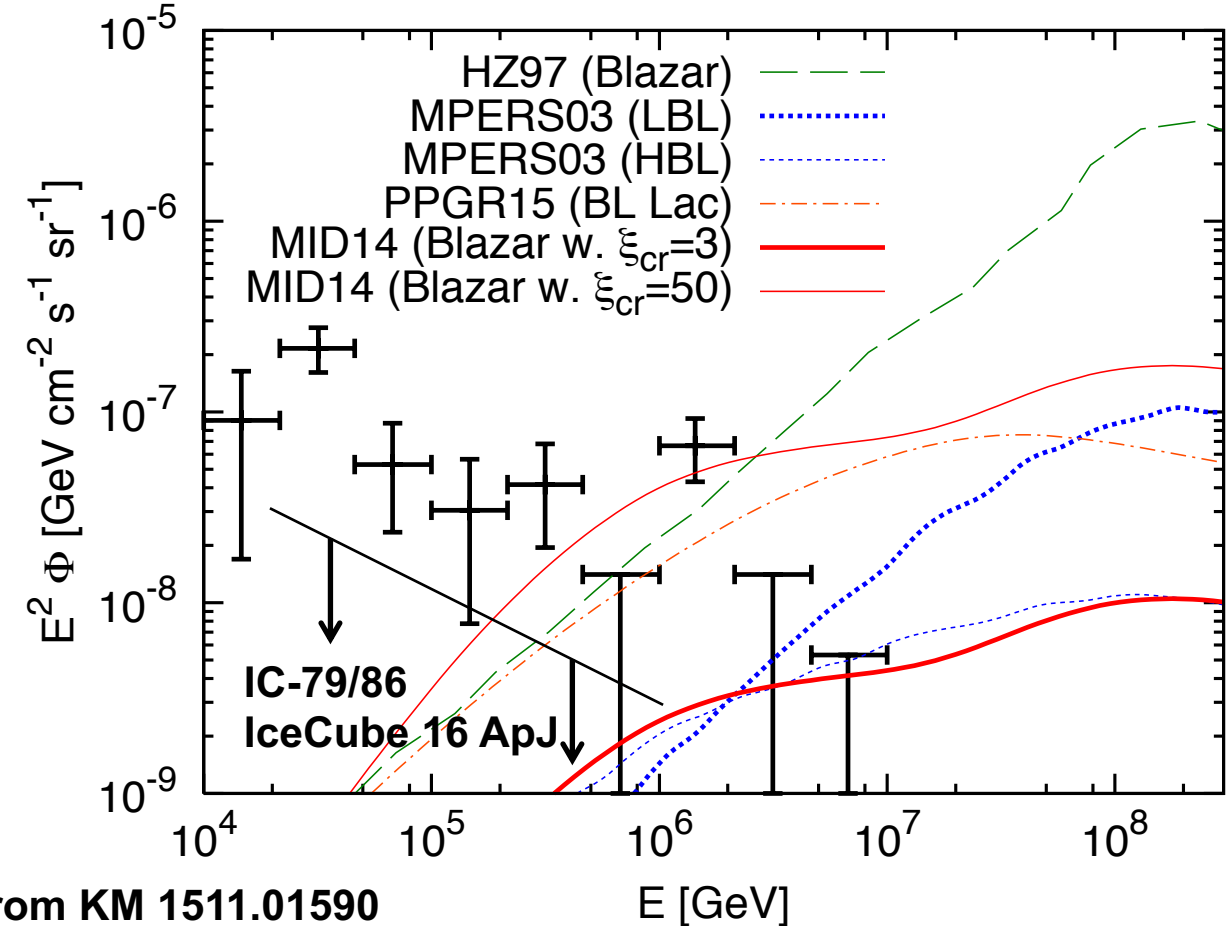
explaining >0.1 PeV neutrinos, sub-TeV gamma rays, and UHECRs (including proton ankle at 100 PeV & composition)

Fang & KM 18 Nature Physics



Testing AGN Jets as UHECR Accelerators

Standard simplest jet models as UHECR accelerators: many constraints…
- Blazars: power-law CR spectra & known SEDs→ hard spectral shape



from KM 1511.01590

leptonic w, neutrino norm, BL Lacs + FSRQs

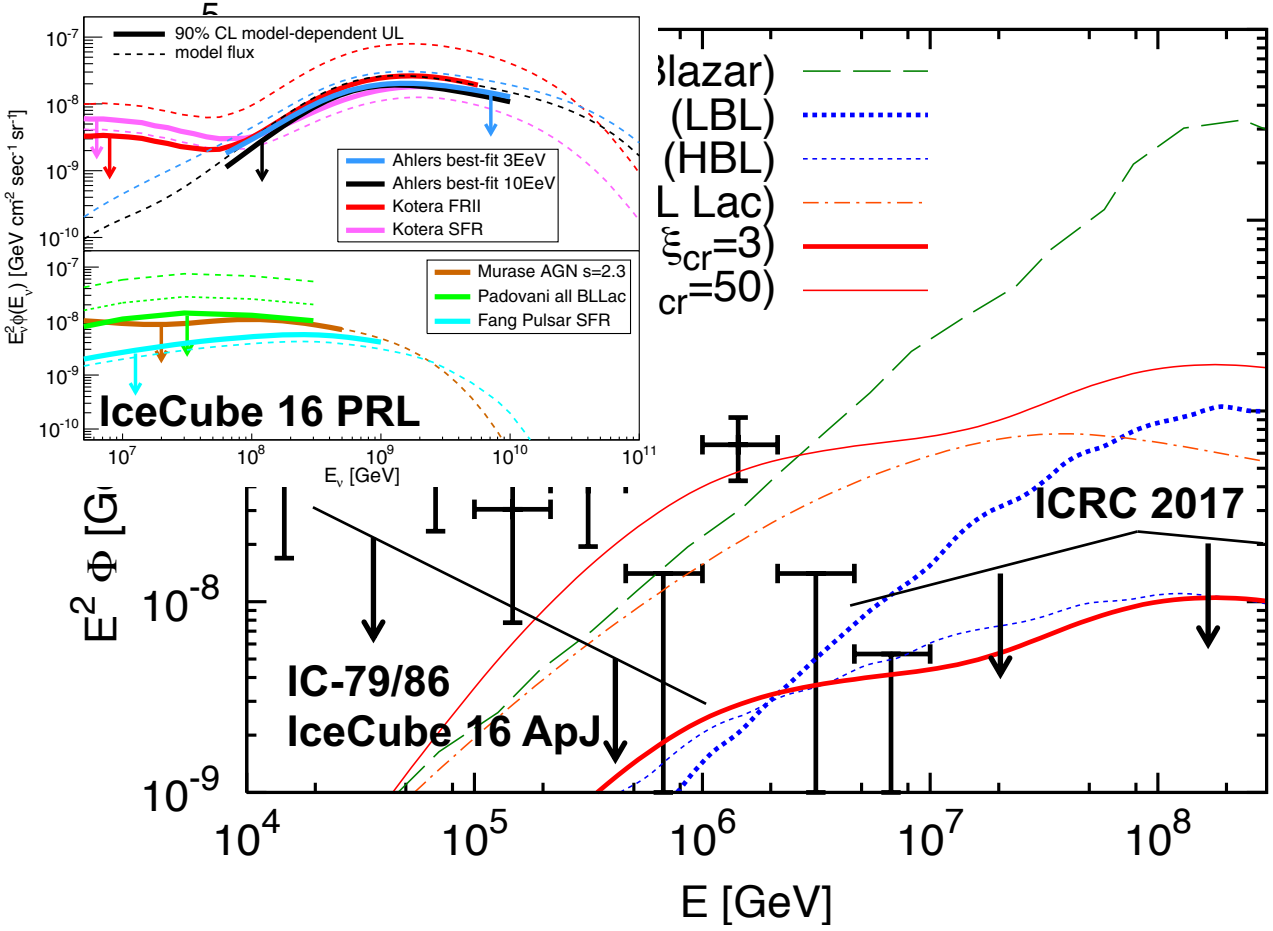
lepto-hadronic w. γ-ray norm. BL Lacs (w.o. external fields)

leptonic w. UHECR norm. BL Lacs + FSRQs

Testing AGN Jets as UHECR Accelerators

Standard simplest jet models as the cosmic ν origin: many constraints…

- Blazars: power-law CR spectra & known SEDs→ hard spectral shape
  IceCube 9-yr EHE analyses give a limit of $<10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1} at 10 PeV
  many existing models have been constrained!!

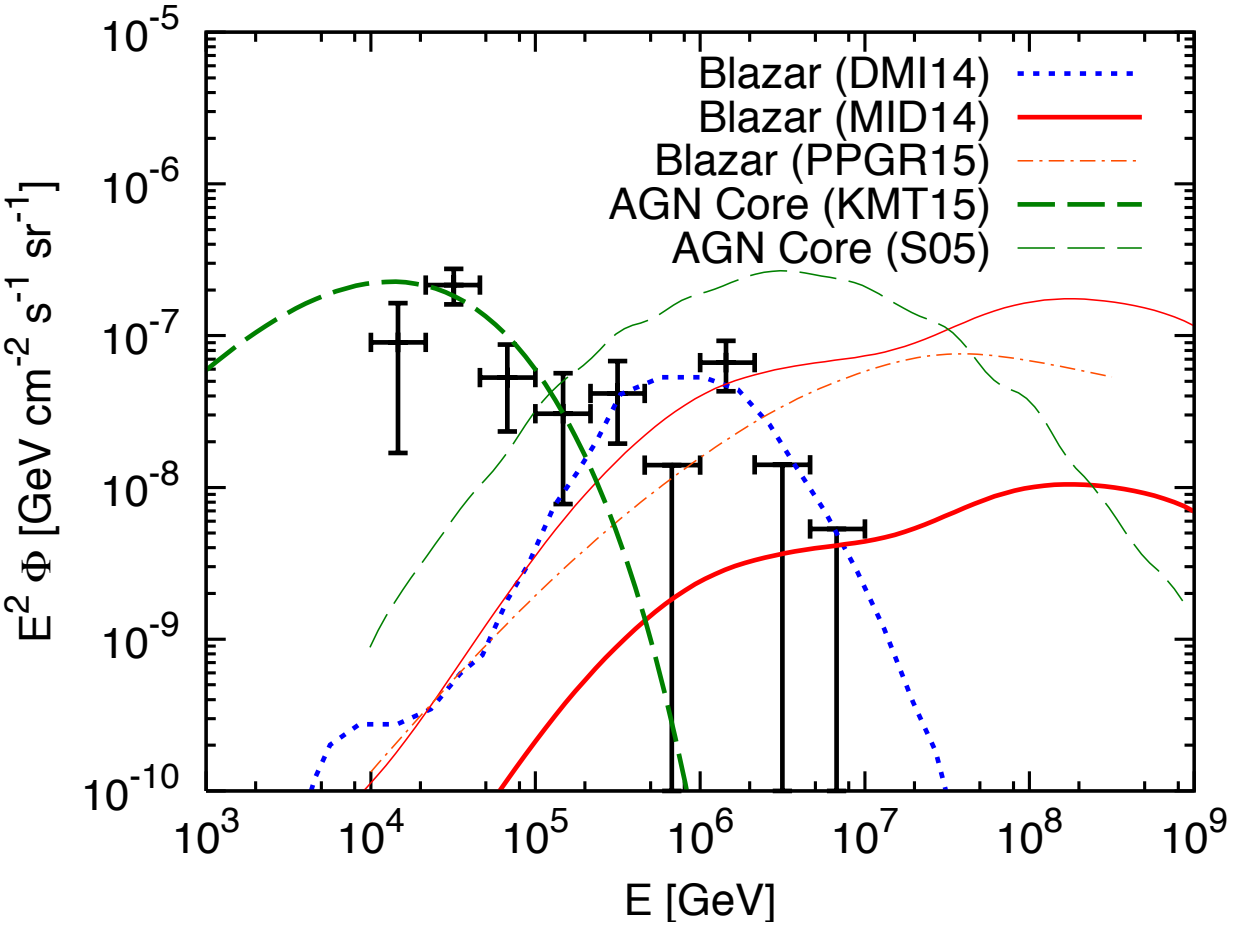


various diffuse ν predictions

leptonic
BL Lacs + FSRQ
(enhanced by BLR/IR photons)
lepto-hadronic norm.
BL Lacs (w.o. external fields)

leptonic w. UHECR norm.
BL Lacs + FSRQ

Can Blazars Explain the IceCube Data?



from KM 2015

Can blazars dominantly explain the IceCube data? – challenging

- Need a cutoff or steepening around a few PeV (ex. stochastic acceleration)

Can blazars dominantly explain the UHECR data? – maybe

- But the simultaneous explanation for the IceCube data is challenging

0.1-1 EeV Neutrino Transient Sources?

Remember: UHECR accelerators are cosmic monsters

$$L_B \equiv \epsilon_B L \gtrsim 2 \times 10^{45} \frac{\Gamma^2 {E_{20}}^2}{Z^2 \beta} \ \mathrm{erg\ s^{-1}}$$

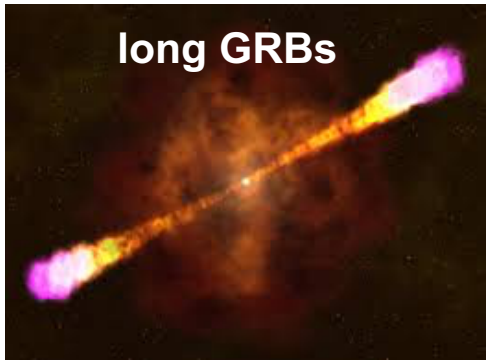
UHECR acceleration may be transients!

PeV-EeV ν

(ex. Atoyan & Dermer 01
Dermer, KM Inoue 14,
Petropoulou+ 15
Gao et al. 16)

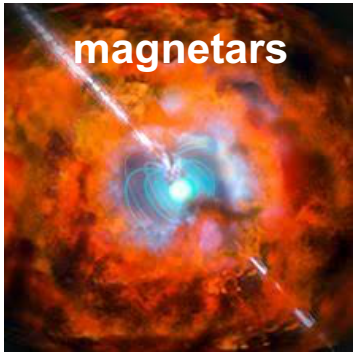
PeV-EeV ν

(ex. KM 08, Wang+ 11,
Wang et al. 16
Senno, KM &
Meszaros 17)



TeV-PeV ν (prompt)
EeV ν (afterglow)
GW source

(ex. Waxman & Bahcall 97, 01
KM & Nagataki 06)



EeV ν
GW source

(ex KM, Meszaros & Zhang 09
Kotera 11, Fang et al. 14
Fang & Metzger 17)

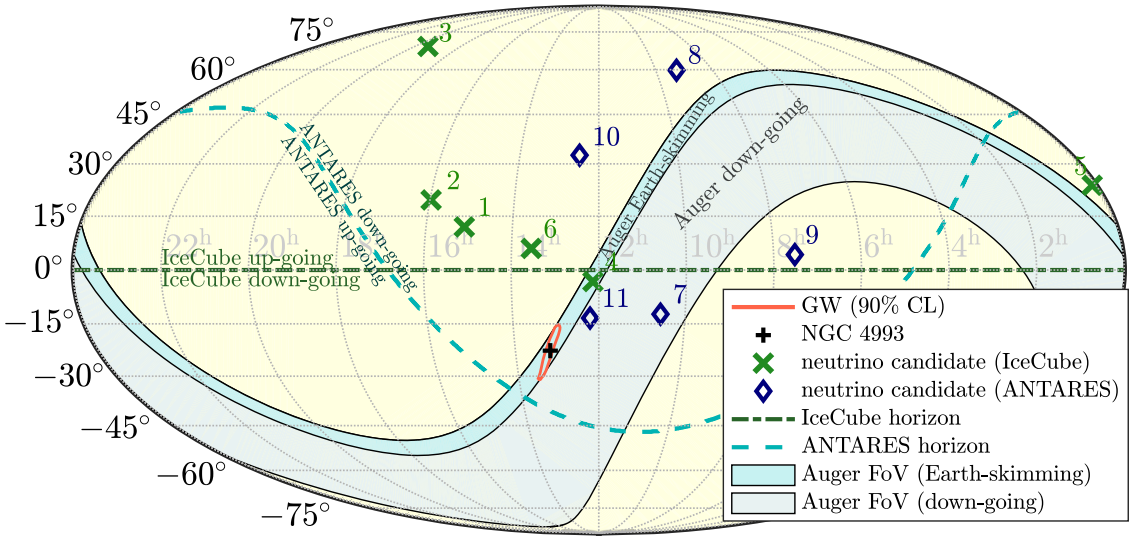
TeV-EeV ν
GW source

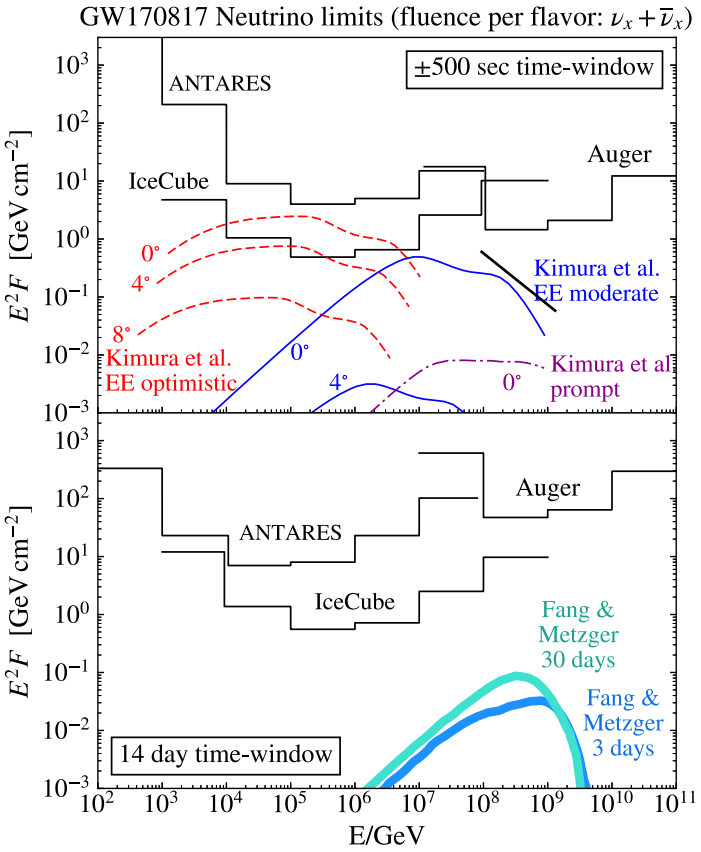
(ex Kimura, KM et al. 17
Kimura, KM et al. 18)

Neutrinos Coinciding w. Gravitational Waves?

GW170817: supporting the NS merger origin of short GRBs

ANTARES, IceCube, Auger, & LIGO-Virgo ApJL 17





theoretical models

short GRB jets (Kimura, KM, Meszaros & Kiuchi 17)

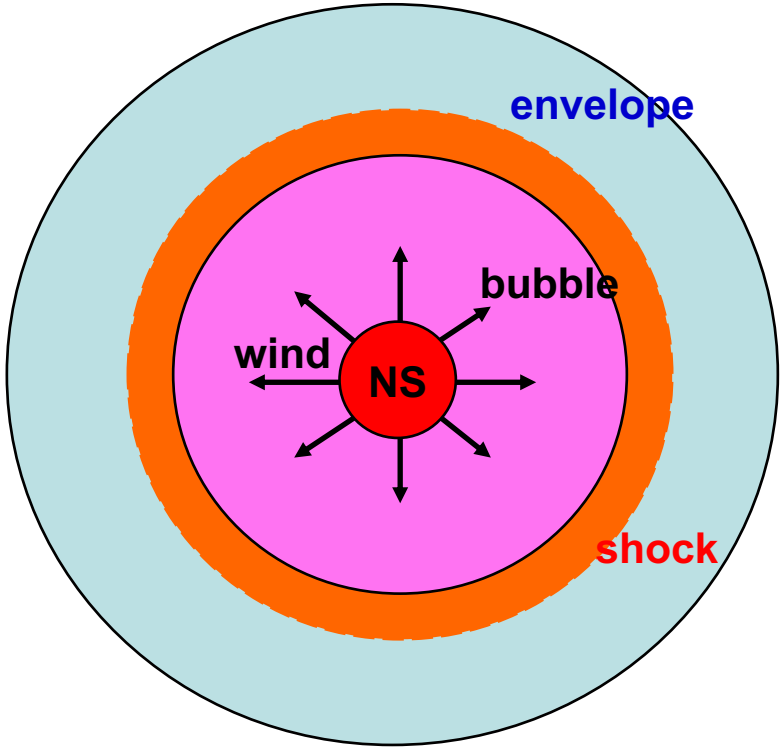
magnetar in the ejecta (Fang & Metzger 17)

(see also KM, Zhang & Meszaros 09)

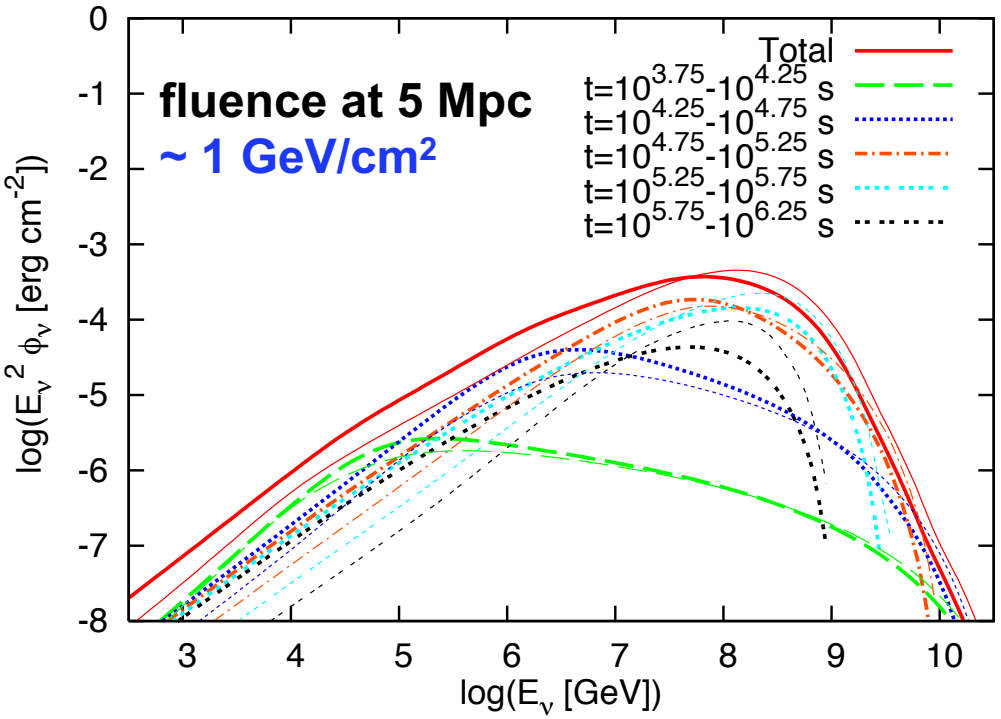
- GW170817: off-axis (~30 deg): the models are still consistent
- On-axis events coinciding w. GW signals could be seen

Neutrinos from Magnetars and Fast-Spinning Neutron Stars

- Ion acceleration (<~10%) has been speculated (ex. Blasi et al. 00, Arons 03)
- Efficient ν production must occur due to interactions w. ejecta/photons
- ν signals arrive earlier -> "ν alerts" will be followed by a supernova



KM, Meszaros & Zhang 09 PRD



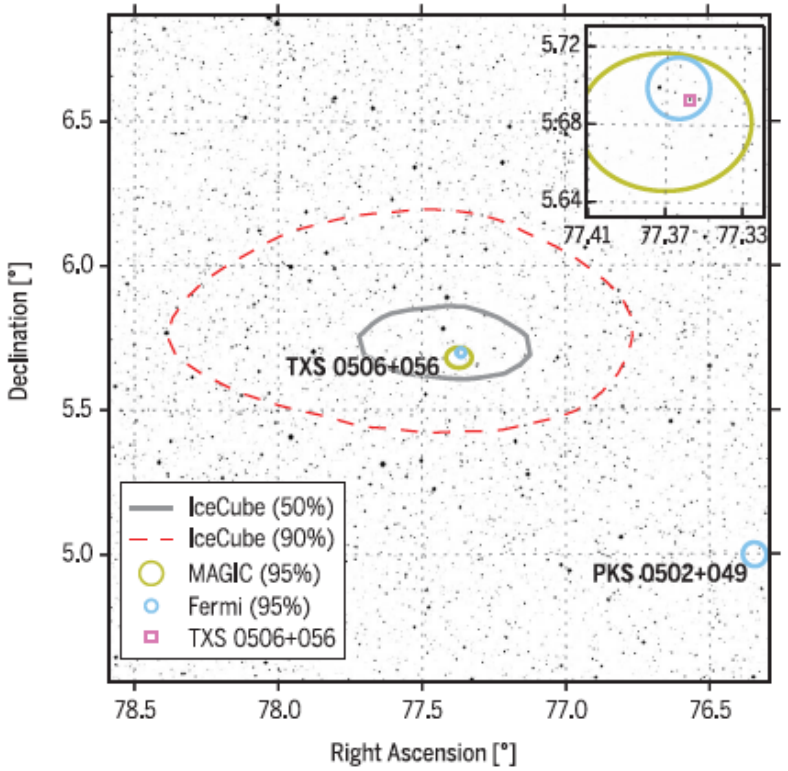
Recent developments:

- Possible to explain the UHECR data including X_{max} (Fang et al. 13)
- Similar spectrum for NS merger ejecta (but rarer) (Fang & Metzger 17)

IceCube 170922A & TXS 0506+056

```
////////////////////////////////////////////////////////////////////////
TITLE:            GCN/AMON NOTICE
NOTICE_DATE:      Fri 22 Sep 17 20:55:13 UT
NOTICE_TYPE:      AMON ICECUBE EHE
RUN_NUM:          130033
EVENT_NUM:        50579430
SRC_RA:            77.2853d {+05h 09m 08s} (J2000),
                   77.5221d {+05h 10m 05s} (current),
                   76.6176d {+05h 06m 28s} (1950)
SRC_DEC:           +5.7517d {+05d 45' 06"} (J2000),
                   +5.7732d {+05d 46' 24"} (current),
                   +5.6888d {+05d 41' 20"} (1950)
SRC_ERROR:        14.99 [arcmin radius, stat+sys, 50% containment]
DISCOVERY_DATE:   18018 TJD;   265 DOY;   17/09/22 (yy/mm/dd)
DISCOVERY_TIME:   75270 SOD {20:54:30.43} UT
REVISION:         0
N_EVENTS:         1 [number of neutrinos]
STREAM:           2
DELTA_T:          0.0000 [sec]
SIGMA_T:          0.0000e+00 [dn]
ENERGY :          1.1998e+02 [TeV]
SIGNALNESS:       5.6507e-01 [dn]
CHARGE:           5784.9552 [pe]
SUN_POSTN:        180.03d {+12h 00m 08s}   -0.01d {-00d 00' 53"}
SUN_DIST:         102.45 [deg]   Sun_angle= 6.8 [hr] (West of Sun)
MOON_POSTN:       211.24d {+14h 04m 58s}   -7.56d {-07d 33' 33"}
MOON_DIST:        134.02 [deg]
GAL_COORDS:       195.31,-19.67 [deg] galactic lon,lat of the event
ECL_COORDS:        76.75,-17.10 [deg] ecliptic lon,lat of the event
COMMENTS:         AMON_ICECUBE_EHE.
```

IceCube 2018 Science

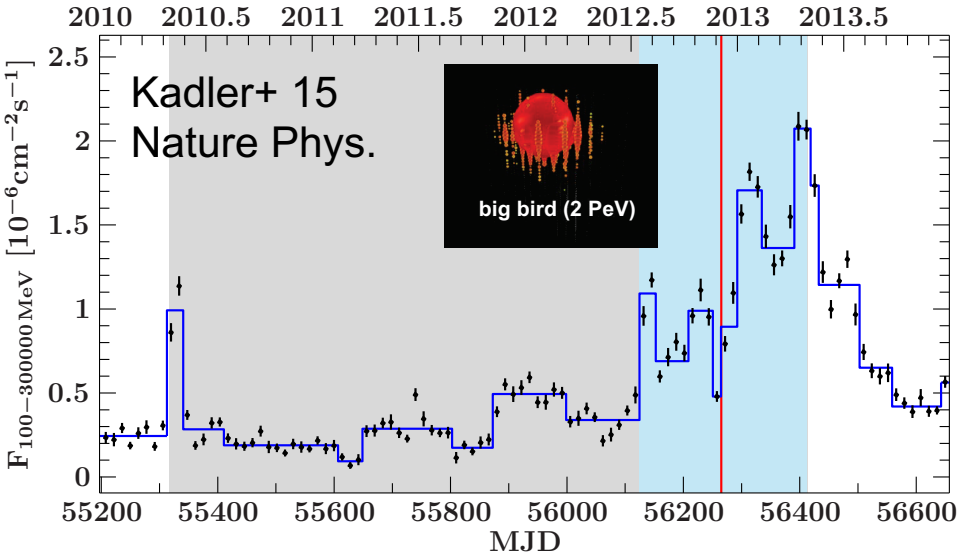


- EHE alert pipeline: from the Chiba group
- Automatic public alert: through AMON
  Track w. E_ν ~ 300 TeV
  (ang. res. < 1 deg)
- Kanata -> Fermi analysis (Tanaka et al.)
  ATel #10791 (Sep/28/17)

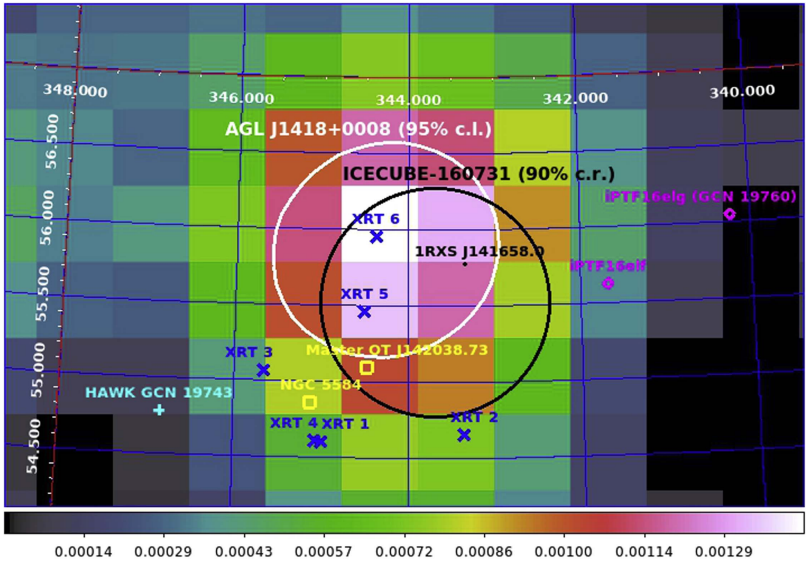
- X-ray observations were first reported by the AMON team from Penn State
- Swift observations (Keivani et al.)
  GCN #21930, ATel #10942 (Sep/26/17)
- NuSTAR observations (Fox et al.)
  ATel #10861 (Oct/12/17)

Blazar Flares?

Flares: NOT well-constrained: good chances to see them (ex. KM & Waxman 16)



Association w. three HESEs at PeV?
- Low significance (~2σ)
  for the 2 PeV event w. a FSRQ,
  PKS B-1424-418 (z=1.522)
- Association w. a HESE event can be
  explained if $L_\gamma \sim L_\nu$



- IceCube-160731
  public alert sent by AMON
- AGILE detection of γ-ray counterpart
  w. an excess significance of 4σ(?)
- 1RXS J141658.0−001449 (HSP)
  w. ~1-2 day delay
- $F_\gamma(>0.1\mathrm{GeV}) \sim 3\times10^{-7}$ GeV cm^{-2} s^{-1}

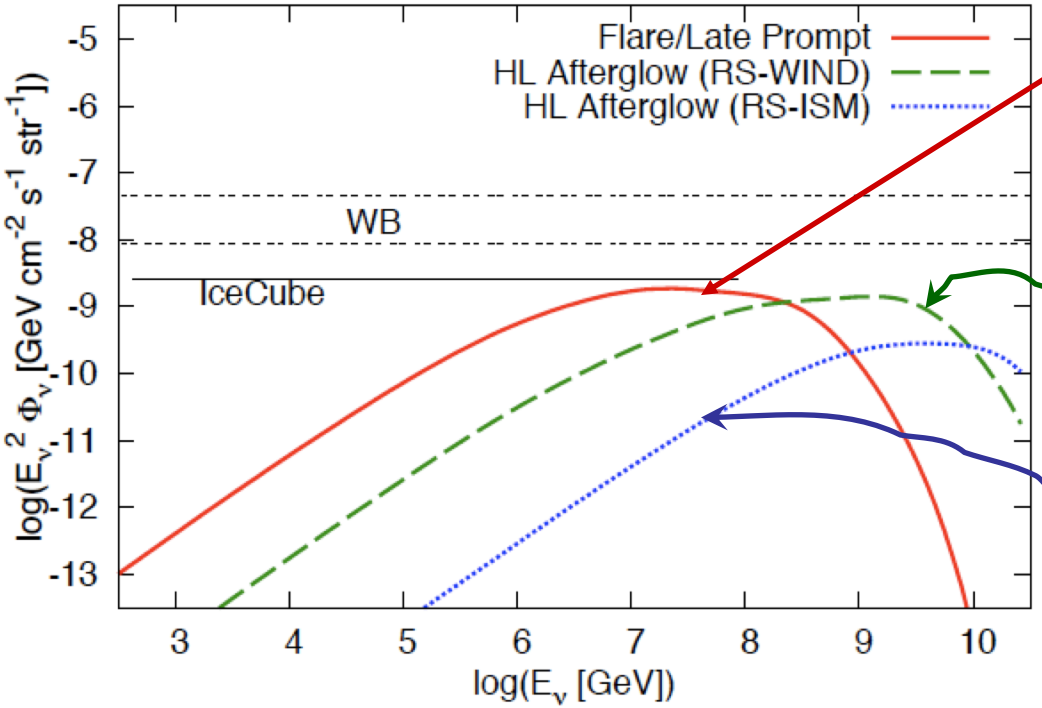
Lucarelli+ 17 ApJ

GRB Neutrino Afterglows

UHECRs may be accelerated during the afterglow phase

More important than prompt contribution at 0.1-1 EeV (less pion cooling)

KM & Nagataki 06 PRL, KM 07 PRD



Inner jet protons + flare x rays
(normalized by 10% of UHECR budget)

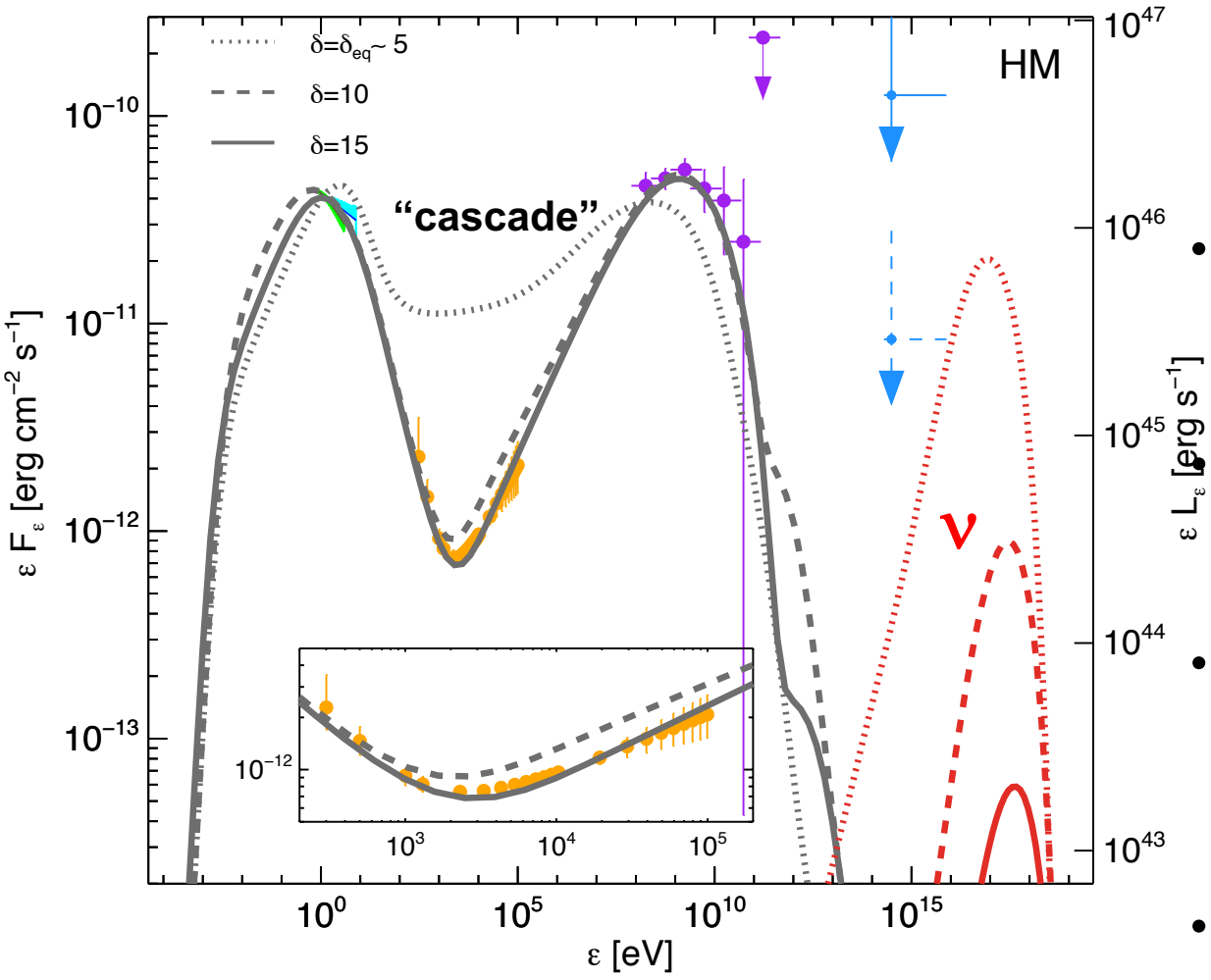
AG protons + AG opt-x rays
stellar wind medium
(normalized by UHECR budget)

AG protons + AG opt-x rays
interstellar medium
(normalized by UHECR budget)

- Not constrained by IceCube limits on prompt: UHE ν detectors are necessary
- Fluence at z=0.1: ~0.1-1 GeV/cm^2, GRB rate within z=0.1 is ~0.1-0.3/yr

TXS 0506+056 SED Modeling: Hadronic

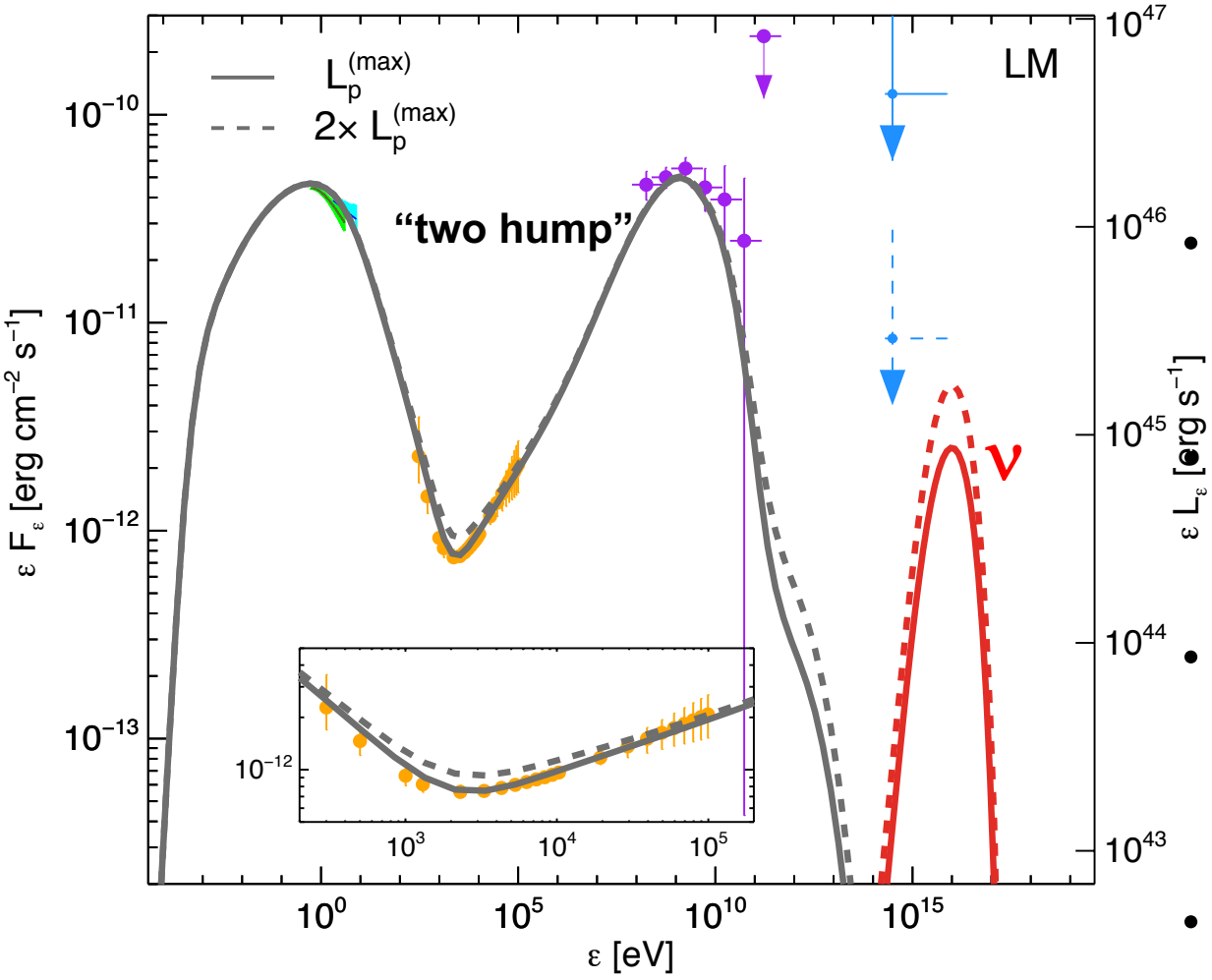
Keivani, KM, Petropoulou, Fox et al. 2018



- Swift-UVOT/X-SHOOTER, Swift-XRT/NuSTAR, and Fermi-LAT data
- UVOT/X-SHOOTER $\nu_{pk}<10^{14}$ Hz (ISP - LSP)
- γ = π-induced cascade
  $F_\nu \sim F_\gamma$: ruled out
- γ = p-syn. from UHECRs
  very low F_ν at 0.1-1 PeV
  $P_p < 10^{44}$ erg/s
- IC-170922A event CANNOT be explained

TXS 0506+056 SED Modeling: Leptonic

Keivani, KM, Petropoulou, Fox et al. 2018



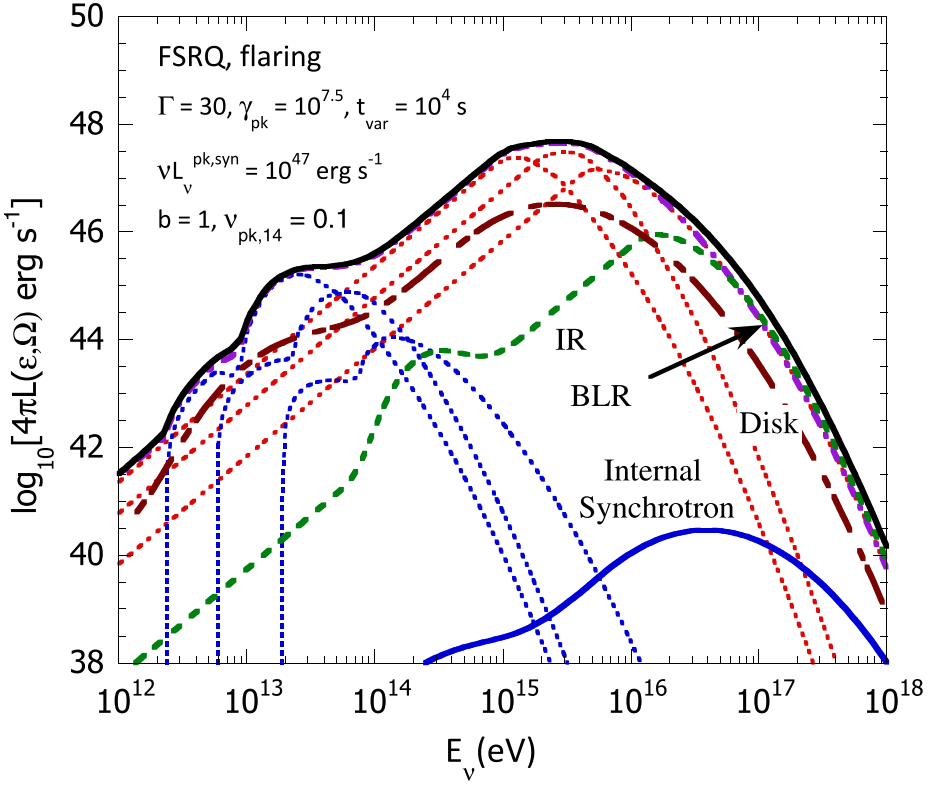
- Swift-UVOT/X-SHOOTER, Swift-XRT/NuSTAR, and Fermi-LAT data
- UVOT/X-SHOOTER $\nu_{pk}<10^{14}$ Hz (ISP - LSP)
- Leptonic scenario
  γ = external IC emission
- Upper limits on ν & CR
  $F_\nu < (1\text{-}2)\times10^{-12}$ erg/cm^2/s
  $P_p < 10^{45}$ erg/s
- $<N_\nu>\sim0.01\text{-}0.03$
  for a duration of T=10^7 s
  $\sim<$ 1-3 % to see 1 event

Blazar Flares?

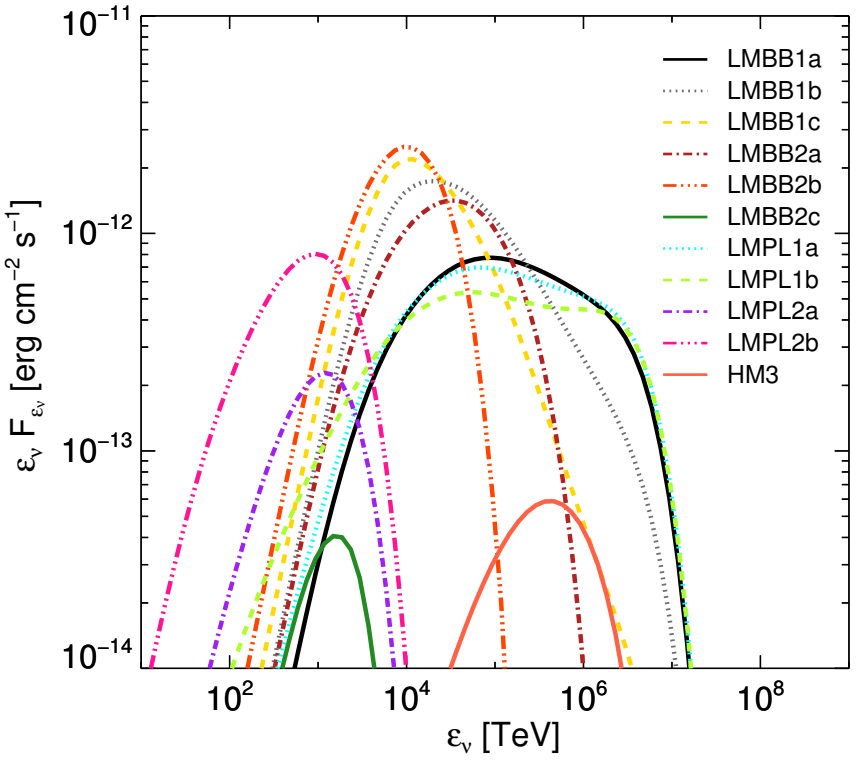
neutrino flares: brighter during the flare phase $f_{p\gamma} \propto L_\gamma$ $L_{cr} \propto L_\gamma$

$\Rightarrow$ $L_\nu \propto L_\gamma^2$

Dermer KM Inoue 14

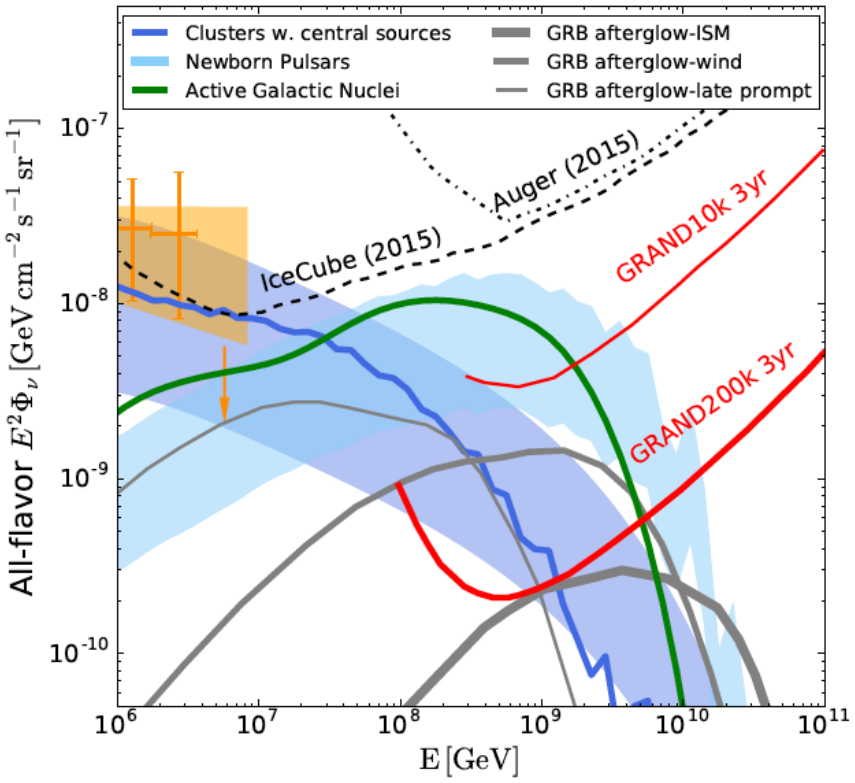


Keivani, KM et al. 18



GRAND can constrain cutoff energy and test the blazar-UHECR hypothesis

Summary



Class	$E_{\nu,\max}$ (GeV)	ϵ_γ (eV)	$\eta_p\,\Phi_{\gamma,\min}$ (ph cm^{-2} s^{-1})	$D_{\mathrm{L},\max}$ [$z_{\max}$]
Blazar flares	10^{10}	0.1	10^3	[1.2]
LL GRBs*	10^9	0.1	10^3	18 Mpc
TDEs	10^9	10^4	10^3	25 Mpc
SLSNe	10^9	10^{-3}	10^2	7.9 Mpc
SNe*	10^9	10^{-2}	10^4	79 kpc

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proton fraction can be constrained

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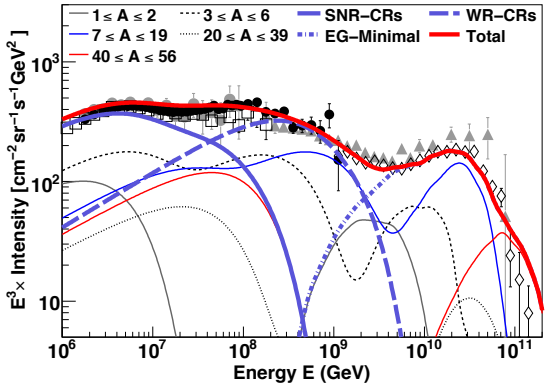
especially for flares

Transient Sources

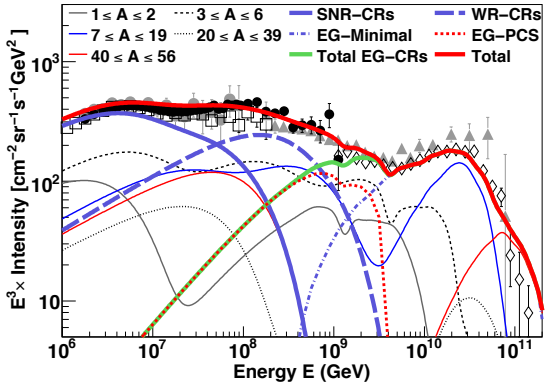
Mergers, supernovae, GRBs, TDEs

Need 0.1-1 EeV ν obs. w. <1-3° res.
First UHE ν detection may be source ν
Encouraging real-time EHE ν alerts

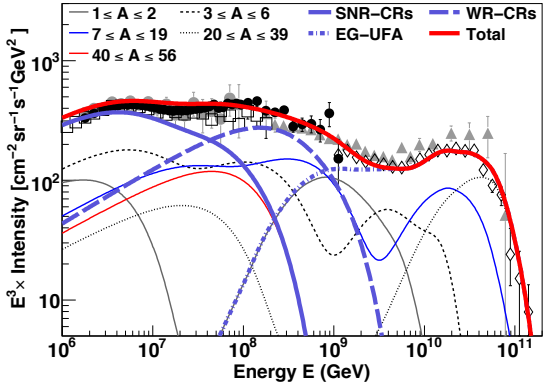
Galactic-Extragalactic Transition



minimal EG
(only above ankle)

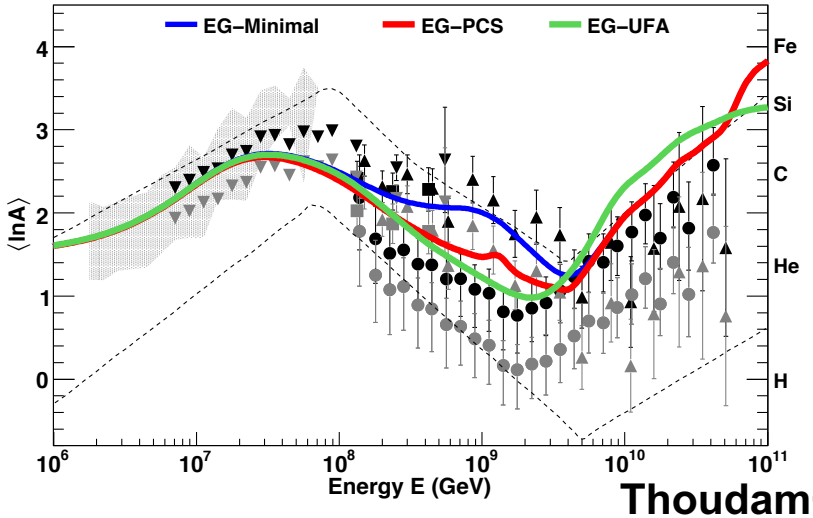


2 component
extragalactic

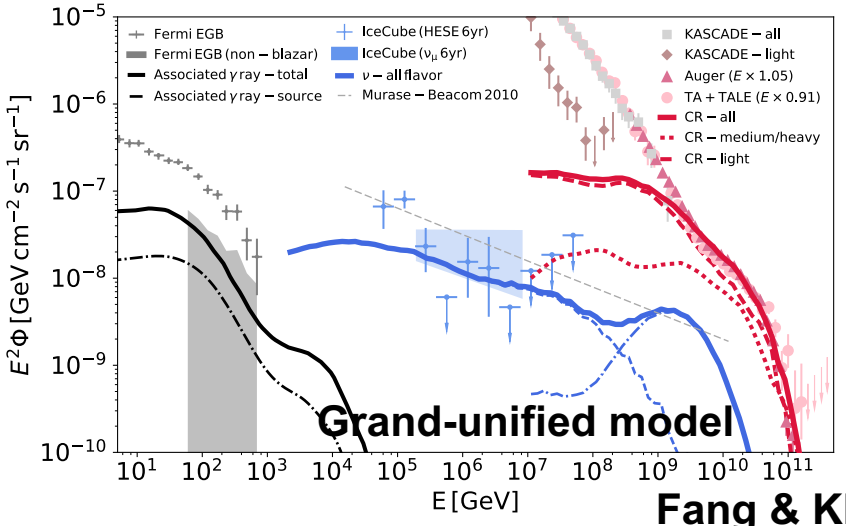


Aγ-induced
nucleon

What is the B-component?
Extragalactic CRs appear around 10^{17} eV?



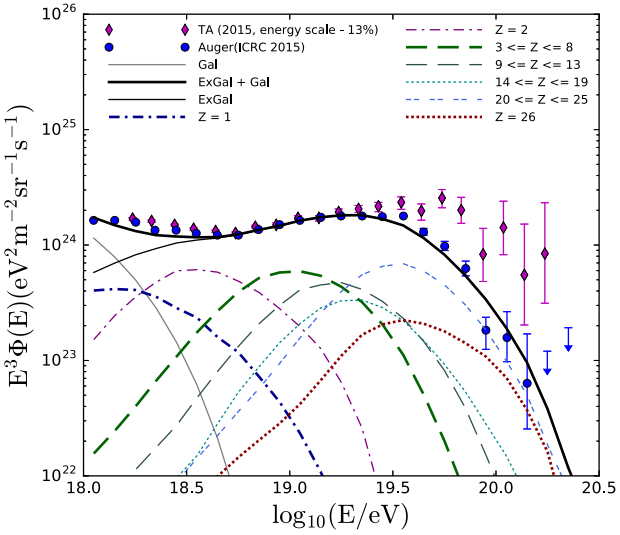
Thoudam+ 16

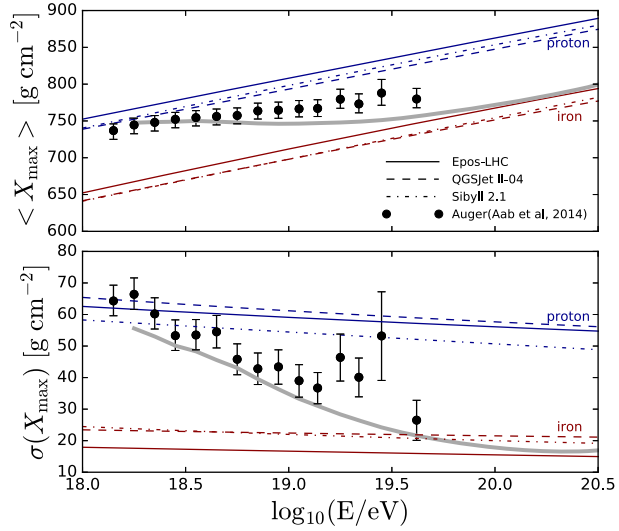


Fang & KM 18

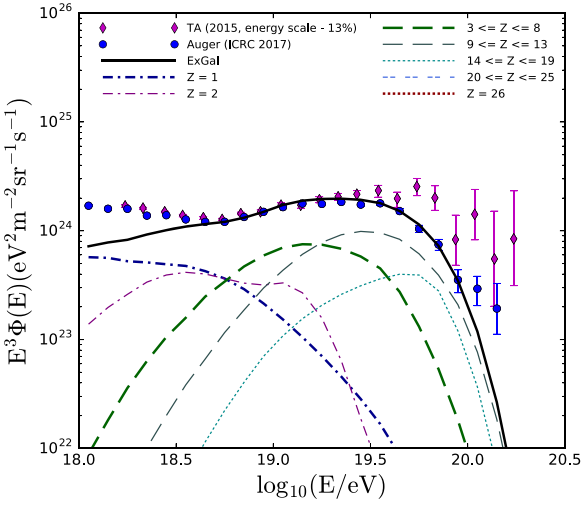
Composition-Deterministic Models

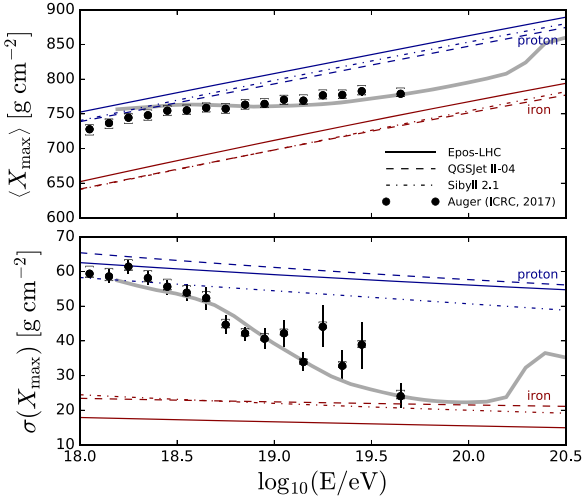
Shear acceleration (Kimura, KM & Zhang 18)



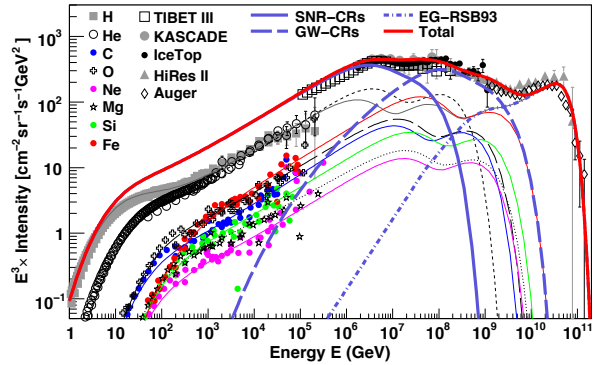


Low-luminosity GRB (Zhang, KM et al. 18)

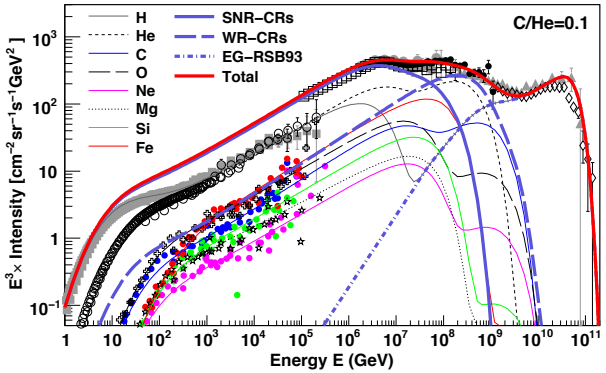




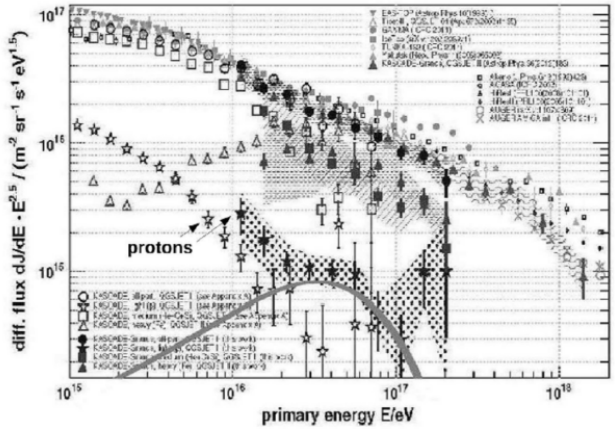
Galactic Models



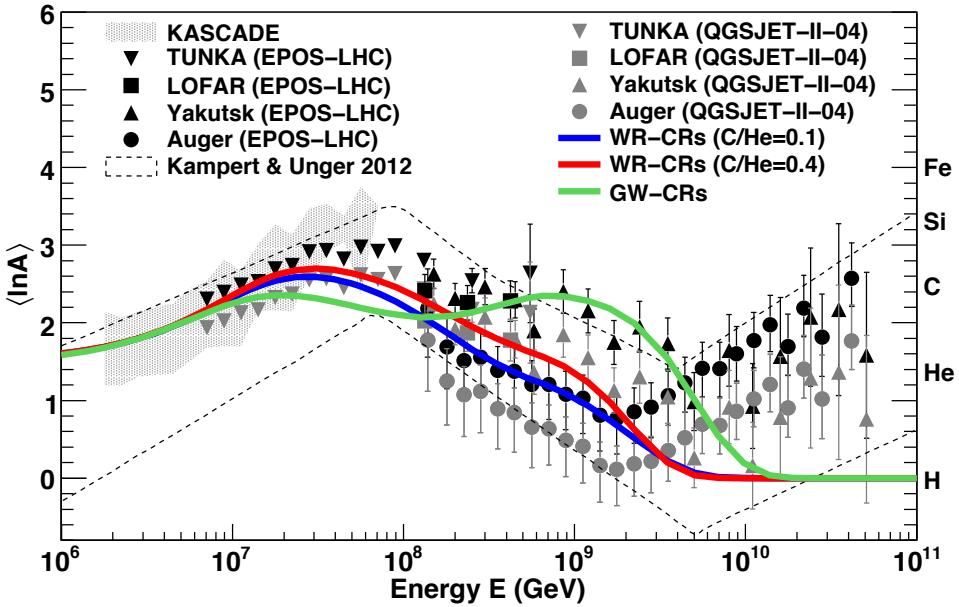
Galactic wind



SNe Ic



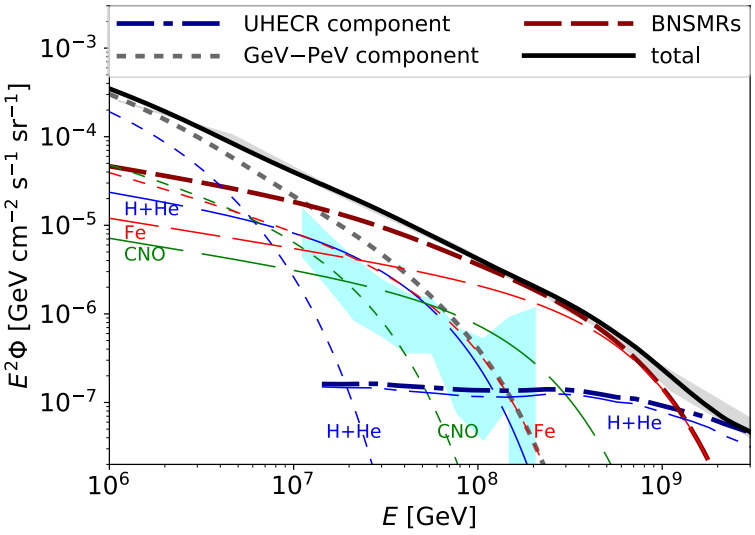
SNe IIn

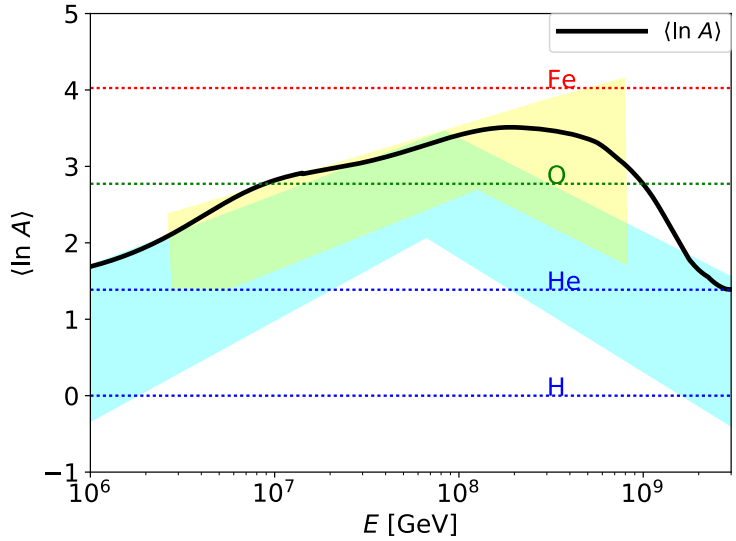


Thoudam et al. 16
Zirakashvilli & Ptuskin 17

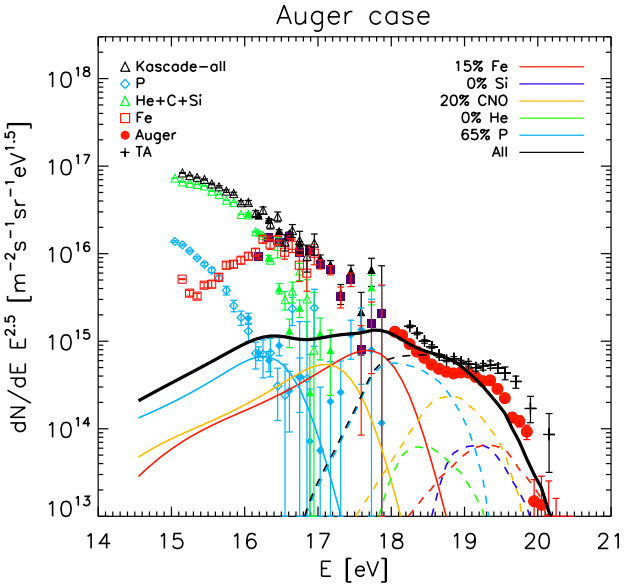
Galactic Models

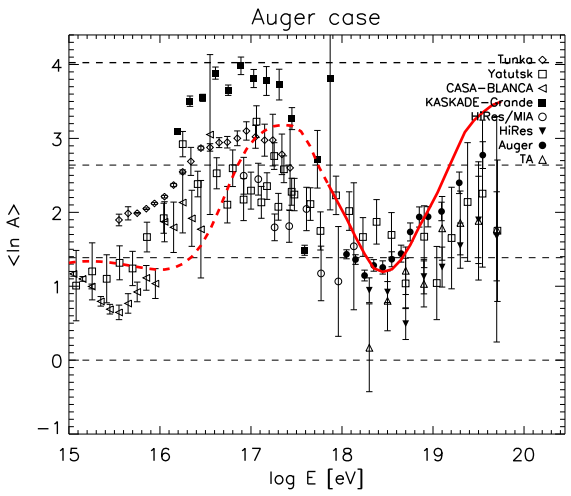
NS-NS/NS-BH merger remnants (Kumura, KM & Meszaros 18)





Fast-rotating pulsars (Fang, Kotera & Olinto 13)





Summary

- Hadronic interaction model uncertainties
- Astrophysical uncertainties
(only a few models with composition deterministic)

GRAND-300?
- Spectral features are already complicated
- Measuring X_{max} or ln A is great but it would not be precise enough to distinguish among models
- What is model dependence of the slope?
More studies are necessary (I do not know)