第二届 GECAM 研讨会

VHE GRB, neutrino and jetted TDE

王祥玉

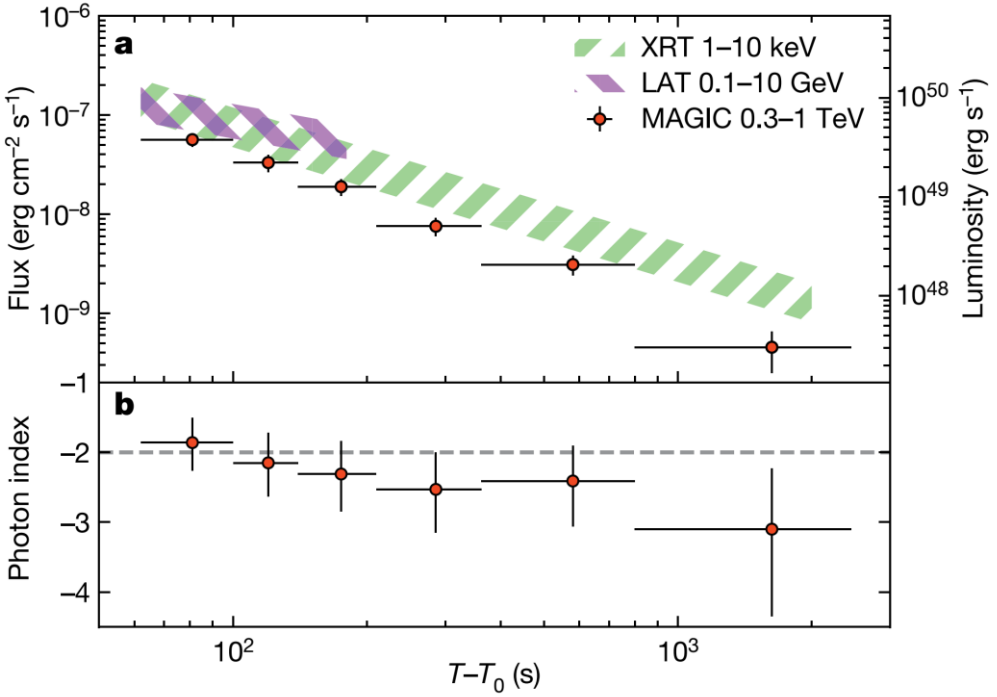
南京大学

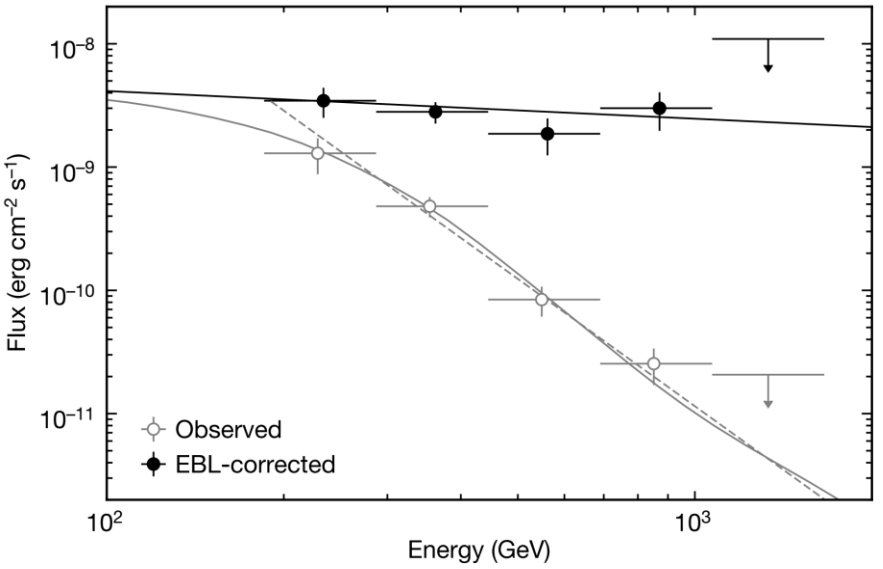
1. GRB高能光子辐射

观测现状

- EGRET/CGRO: 探测到少数几个GRB的GeV光子辐射
- Fermi: LAT已经探测到>180个GRB的高能 （>100 MeV）辐射
- 甚高能(VHE, >100GeV)：GRB190114C, GRB 180720B, GRB190829A

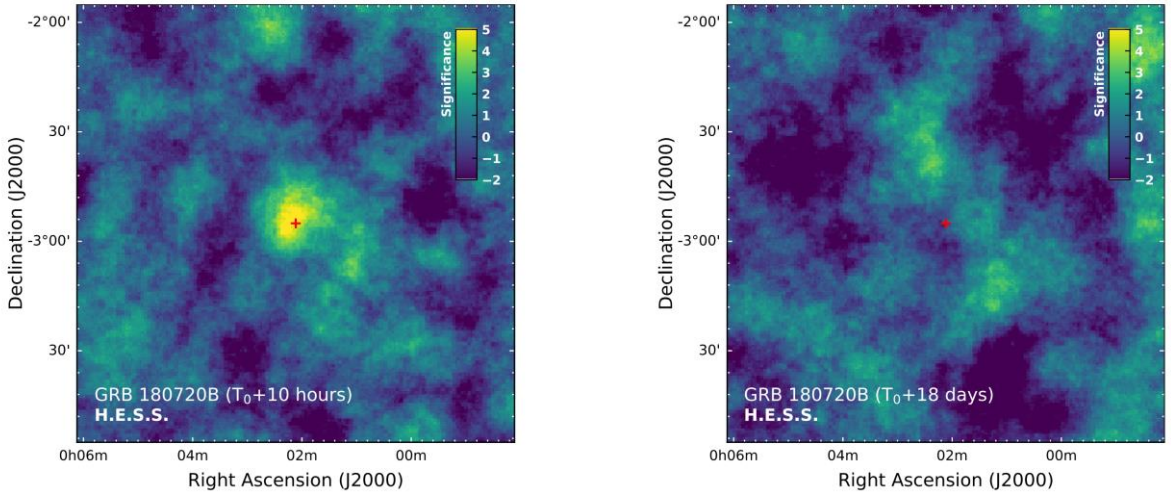
MAGIC detection of GRB 190114C



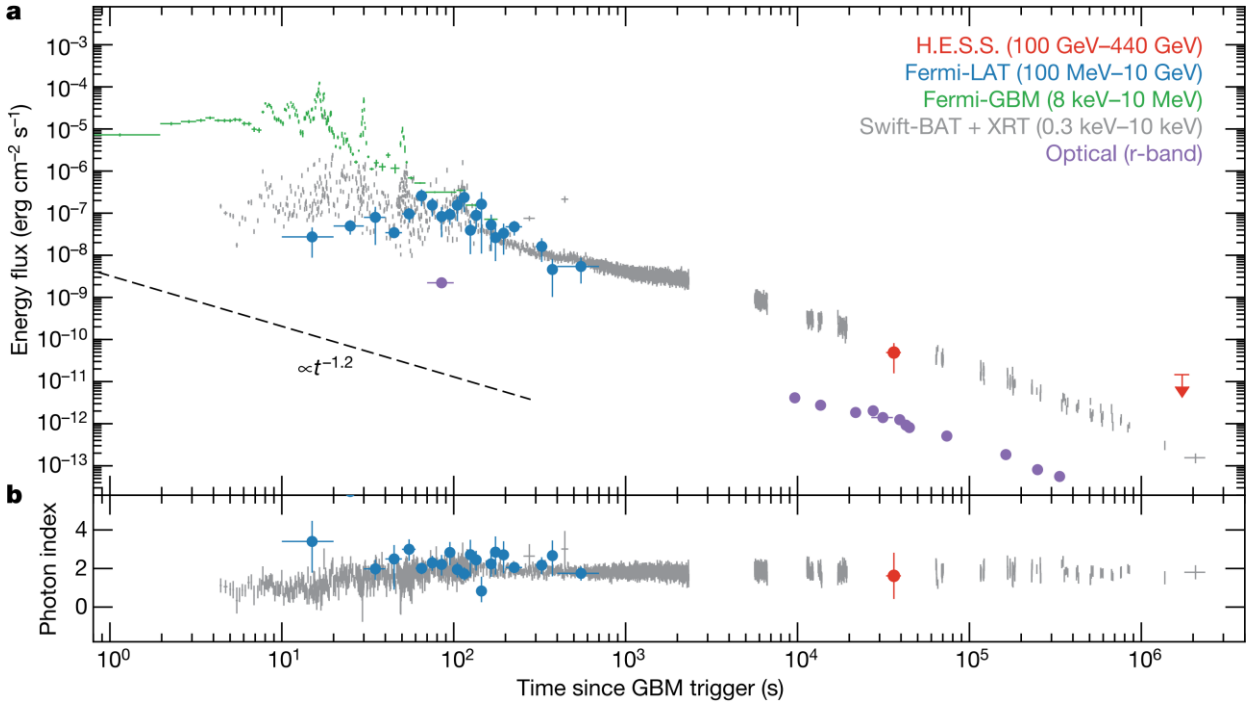


- TeV emission until 2ks
- Very bright X-ray afterglow
- Redshift z=0.42

HESS: GRB180720B



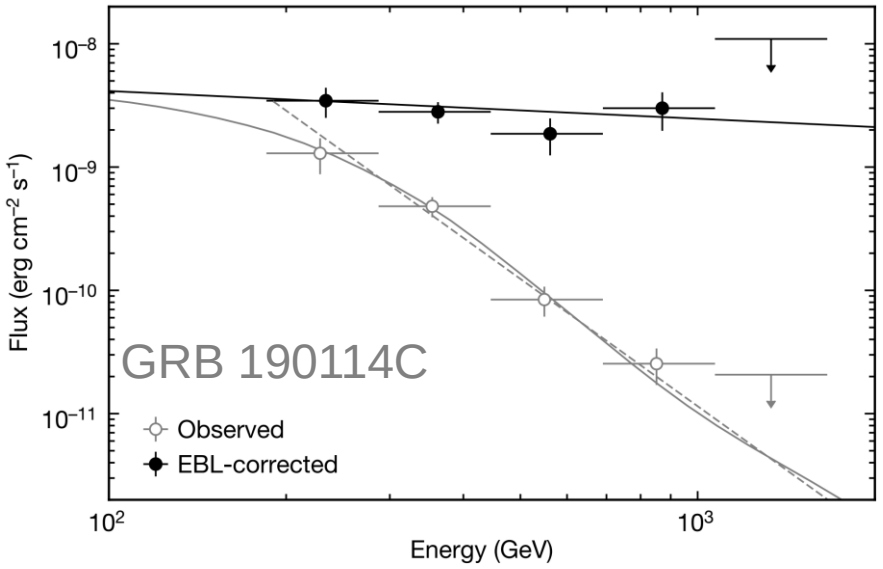
Observation started ~10 hours after the burst

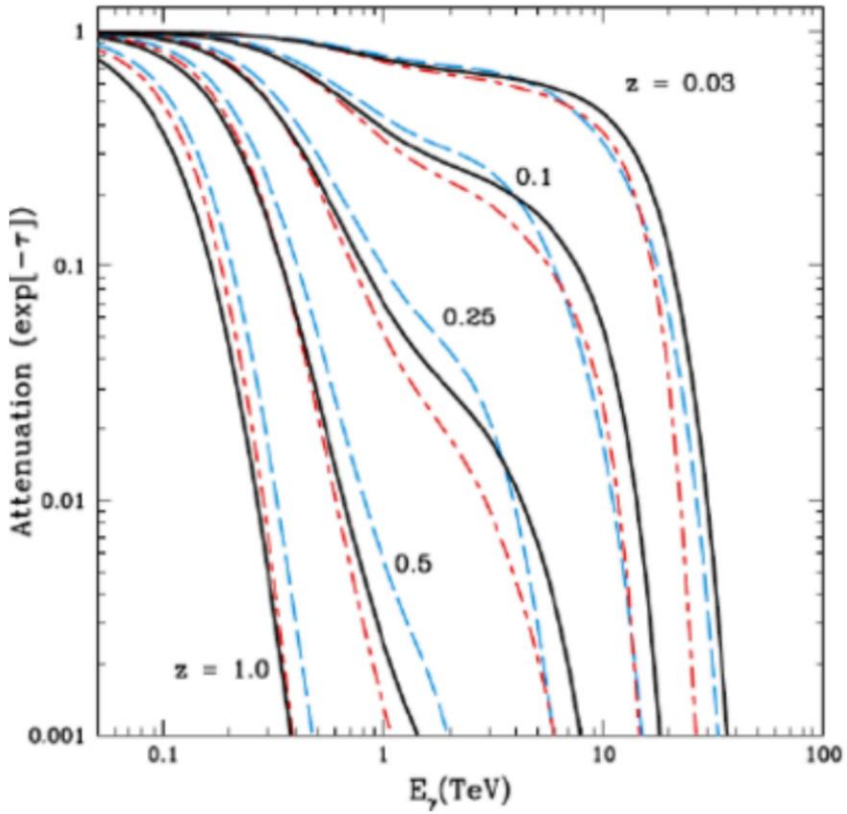


- 100-440 GeV detected at 10 hr
- Very bright X-ray afterglow
- Redshift z=0.65

Suppression effects at TeV

1) **EBL absorption (z=0.42, z=0.65)**
2) Internal γγ absorption in the source
3) Klein-Nishina effct for IC





AIP Conference Proceedings. Vol. 1381. No. 1. AIP, 2011.

Internal γγ absorption

$$\varepsilon_t = \Gamma^2 (m_e c^2)^2 / \varepsilon_\gamma \Rightarrow$$ X-ray photons

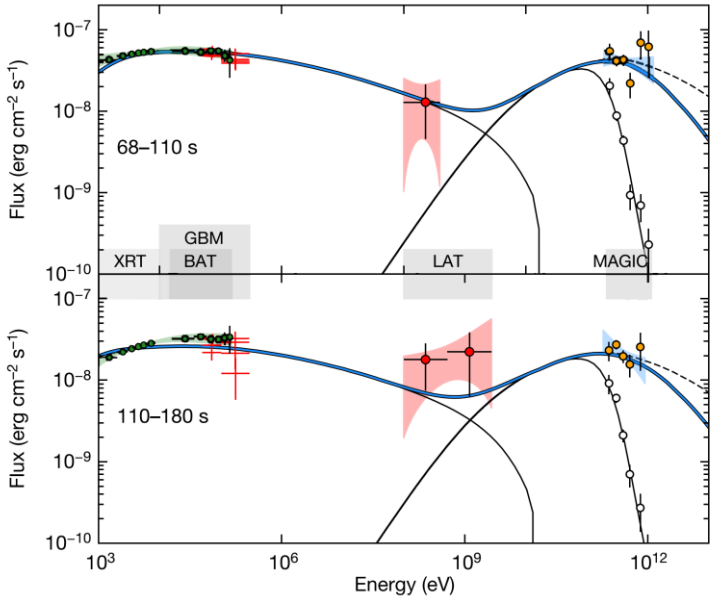
$$\tau_{\gamma\gamma} = \sigma_{\gamma\gamma} (R/\Gamma) n_t$$

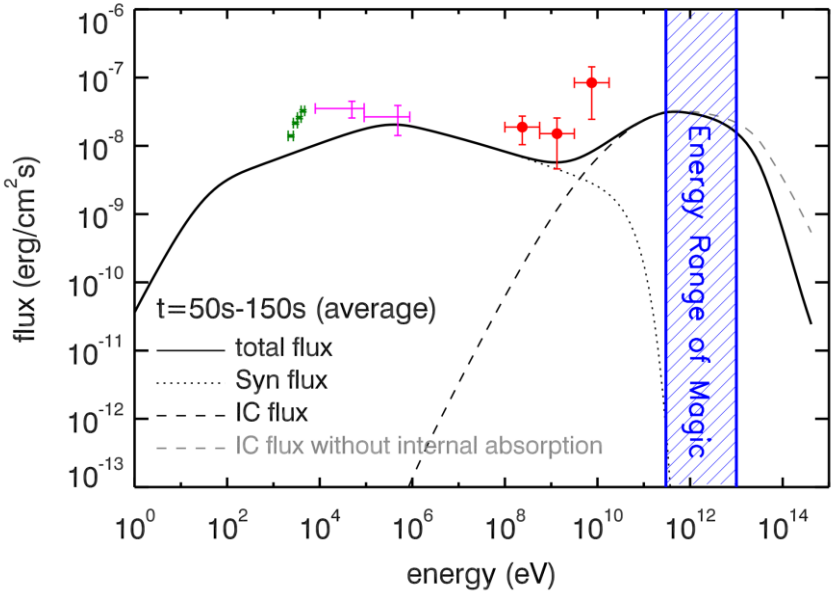
$$n_t = \frac{L_x}{4\pi R^2 \Gamma c \varepsilon_t} \qquad L_x \propto t^{-\alpha}$$

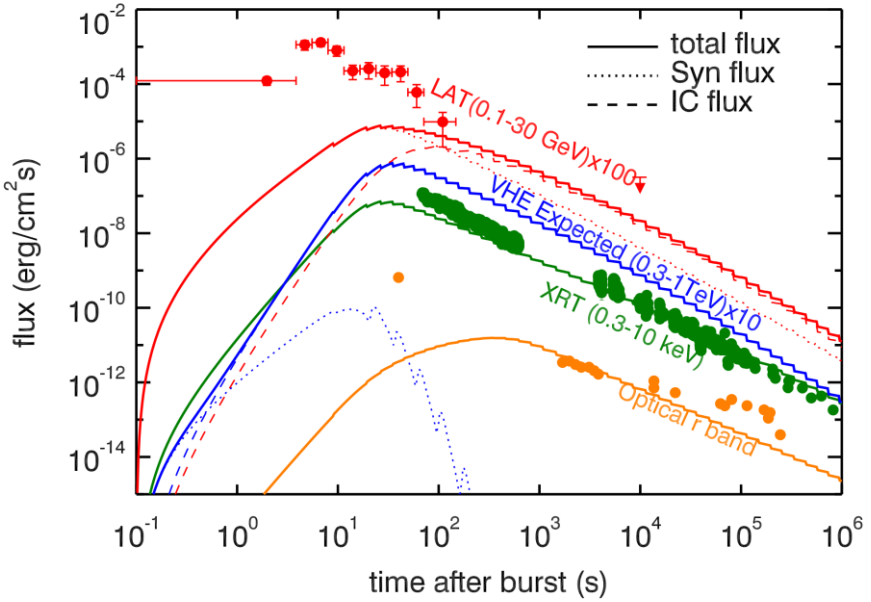
$$\tau_{\gamma\gamma} < 1 \Rightarrow \boxed{\Gamma > 160 \left(\frac{L_x}{5 \times 10^{49} \mathrm{ergs}^{-1}}\right)^{1/6} \left(\frac{\varepsilon_\gamma}{1\mathrm{TeV}}\right)^{1/6} t_2^{-1/6}}$$

$$n < 1 E_{54}^{-1} \left(\frac{\varepsilon_\gamma}{1\mathrm{TeV}}\right)^{-4/3} t_2^{(4\alpha-5)/3}$$

Broad-band modeling of GRB 190114C





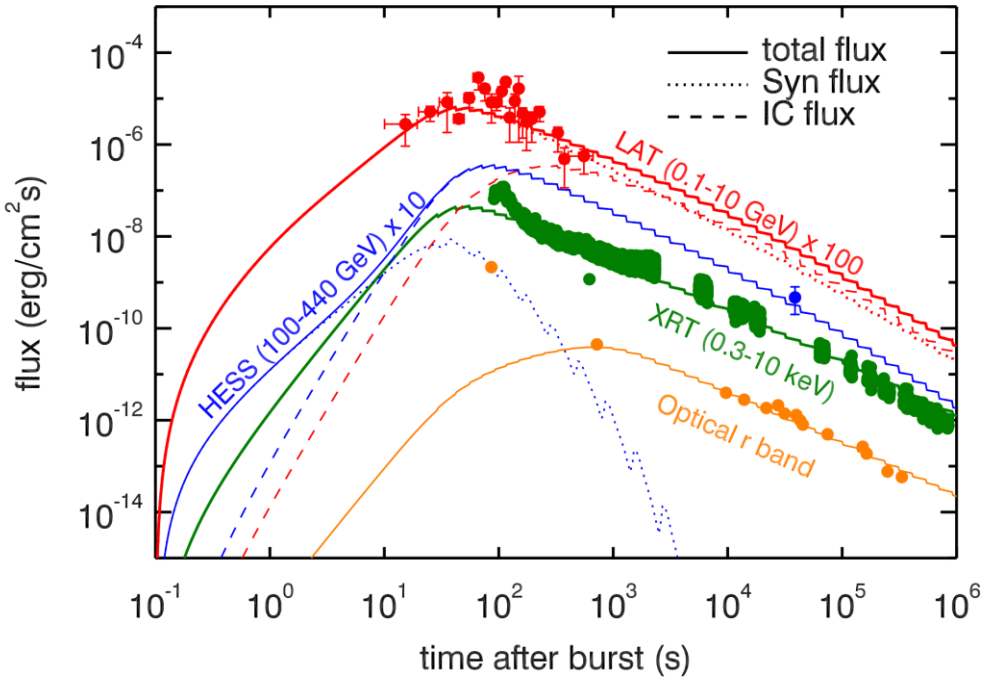


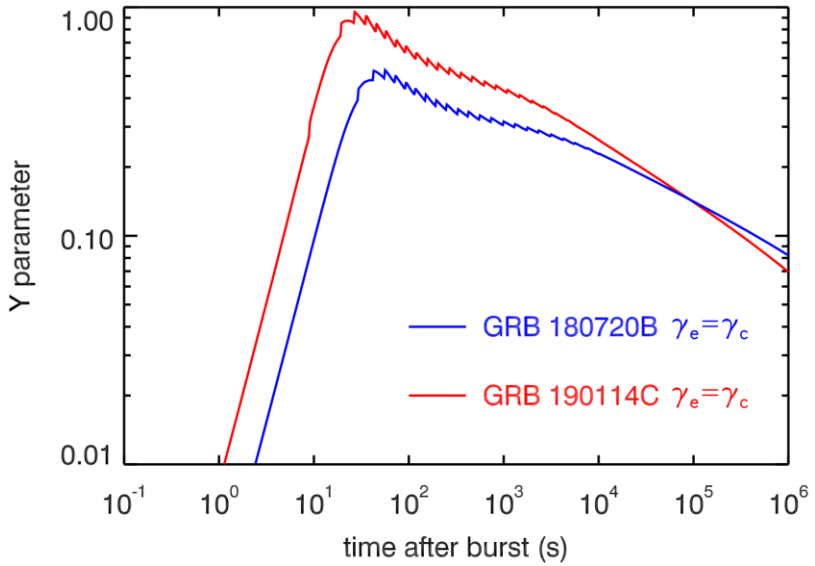
$E = 6 \times 10^{53}\mathrm{erg}, n = 0.3\mathrm{cm}^{-3}, \epsilon_e = 0.07, \epsilon_B = 4 \times 10^{-5}, \Gamma_0 = 300$ and $p = 2.5$

Need a low magnetic equipartition factor !

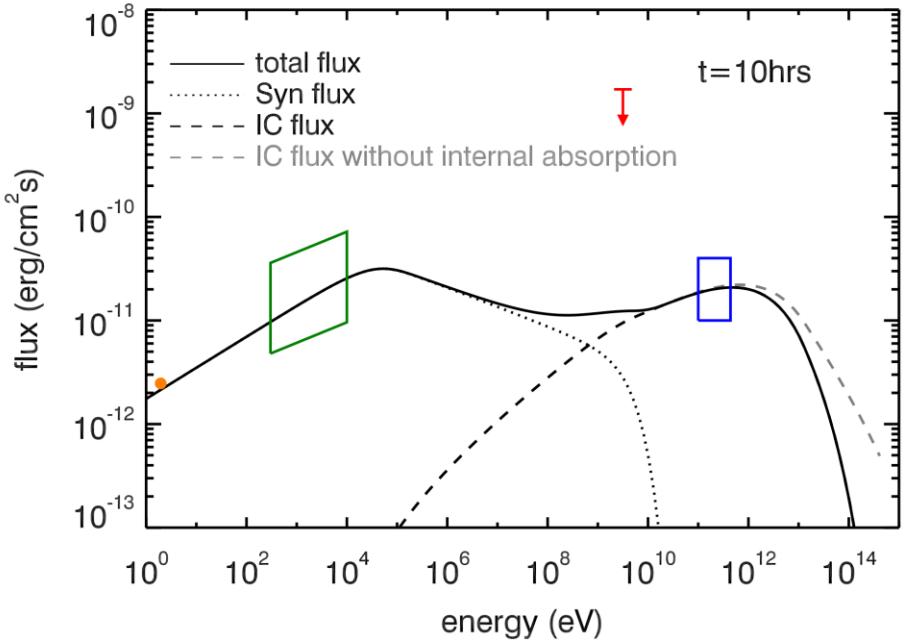
Wang, Liu, Zhang, Xi & Zhang, 2019

Broad-band modeling of GRB 180720B





Wang, Liu, Zhang, Xi & Zhang, 2019



Need a low magnetic equipartition factor !

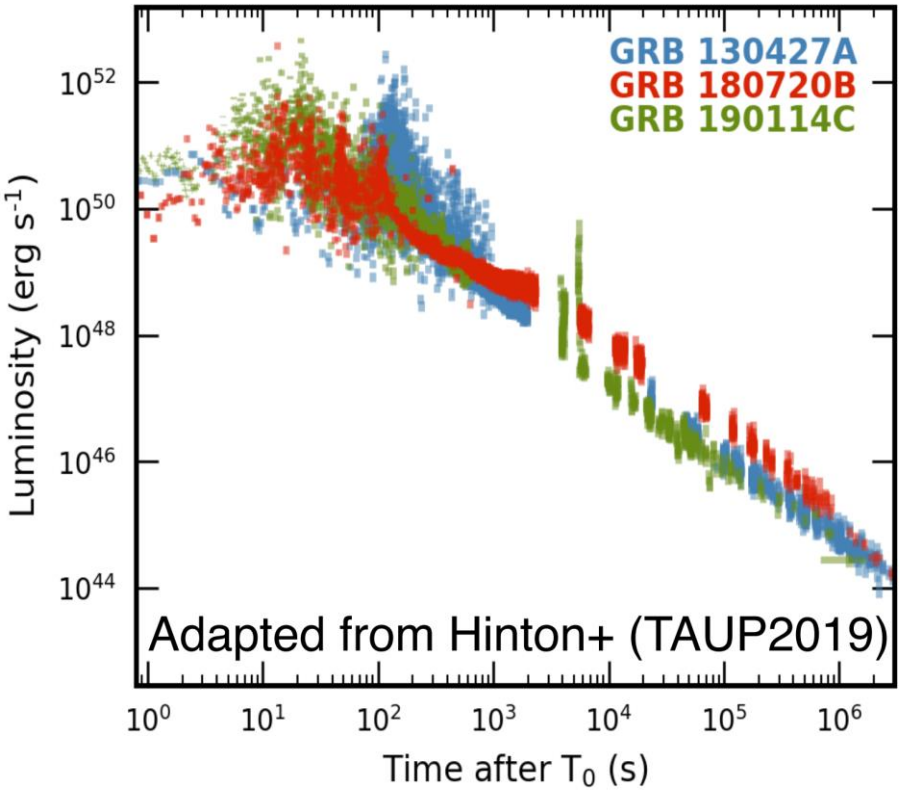
Why are these two GRBs detected ?

Common features:

1) The parameter values (such as the circum-burst density) are not unusual

2) both have low redshifts

3) both have high fluence and bright x-ray afterglow



GRB190829A: a very close GRB

GRB190829A: Detection of VHE gamma-ray emission with H.E.S.S.

ATel #13052; *M. de Naurois (H. E. S. S. Collaboration)*
*on **30 Aug 2019; 07:12 UT***
Credential Certification: Fabian SchÃ□Â¼ssler (fabian.schussler@cea.fr)

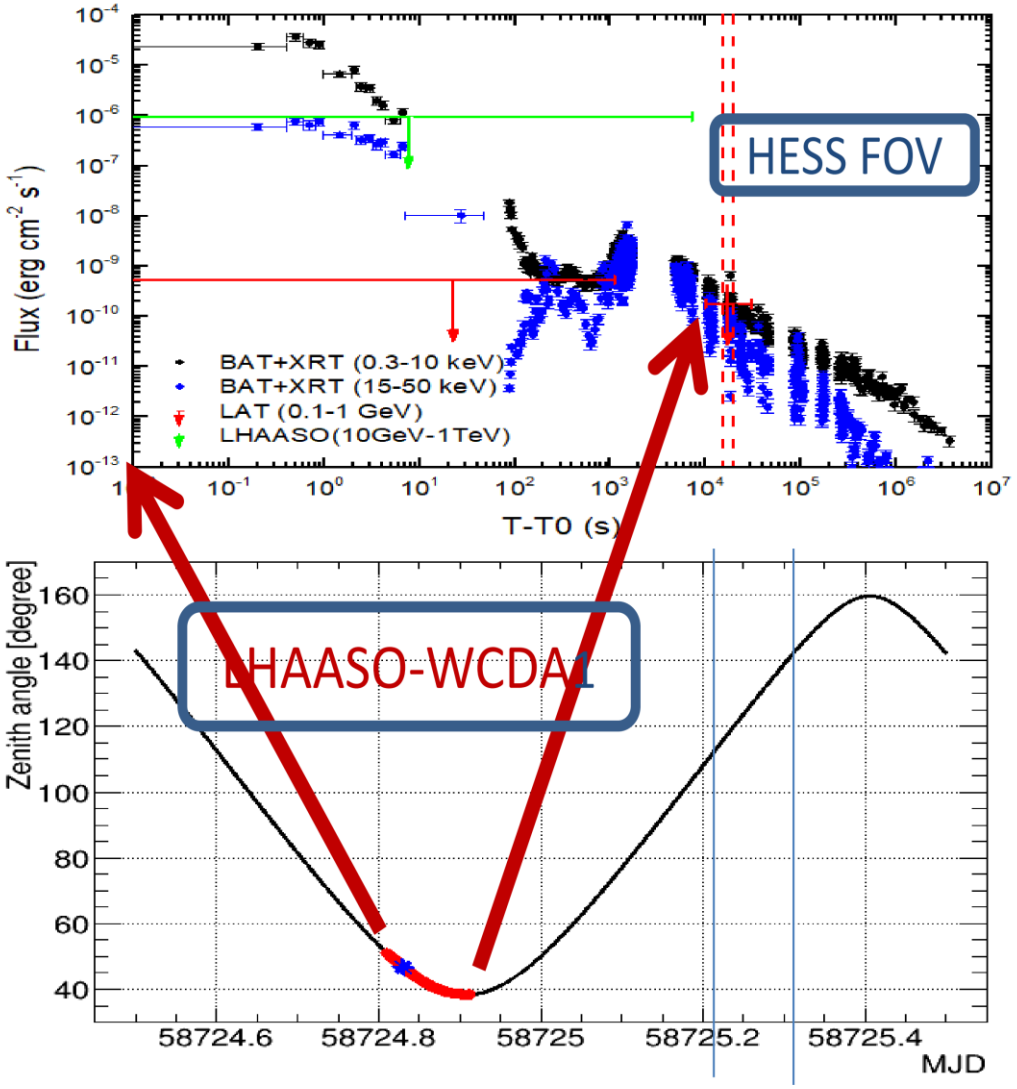
Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

Tweet

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out follow-up observations of the afterglow of GRB 190829A (Dichiara et al., GCN 25552). At a redshift of z = 0.0785 +/- 0.005 (A.F. Valeev et al., GCN 25565) this is one of the nearest GRBs detected to date. H.E.S.S. Observations started July 30 at 00:16 UTC (i.e. T0 + 4h20), lasted until 3h50 UTC and were taken under good conditions. A preliminary onsite analysis of the obtained data shows a >5sigma gamma-ray excess compatible with the direction of GRB190829A. Further analyses of the data are on-going and further H.E.S.S. observations are planned. We strongly encourage follow-up at all wavelengths. H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of very-high-energy gamma-ray sources and is located in the Khomas Highlands in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, France, Germany, Ireland, Japan, the Netherlands, Poland, South Africa, Sweden, UK, and the host country, Namibia. For more details see https://www.mpi-hd.mpg.de/hfm/HESS/

- E_iso=10^49 erg: 低光度伽玛暴
- Fluence:1.27 × 10^−5 erg cm^−2 in 10 - 1000 keV, 不算很大！
- Bright x-ray afterglow

LHAASO observation



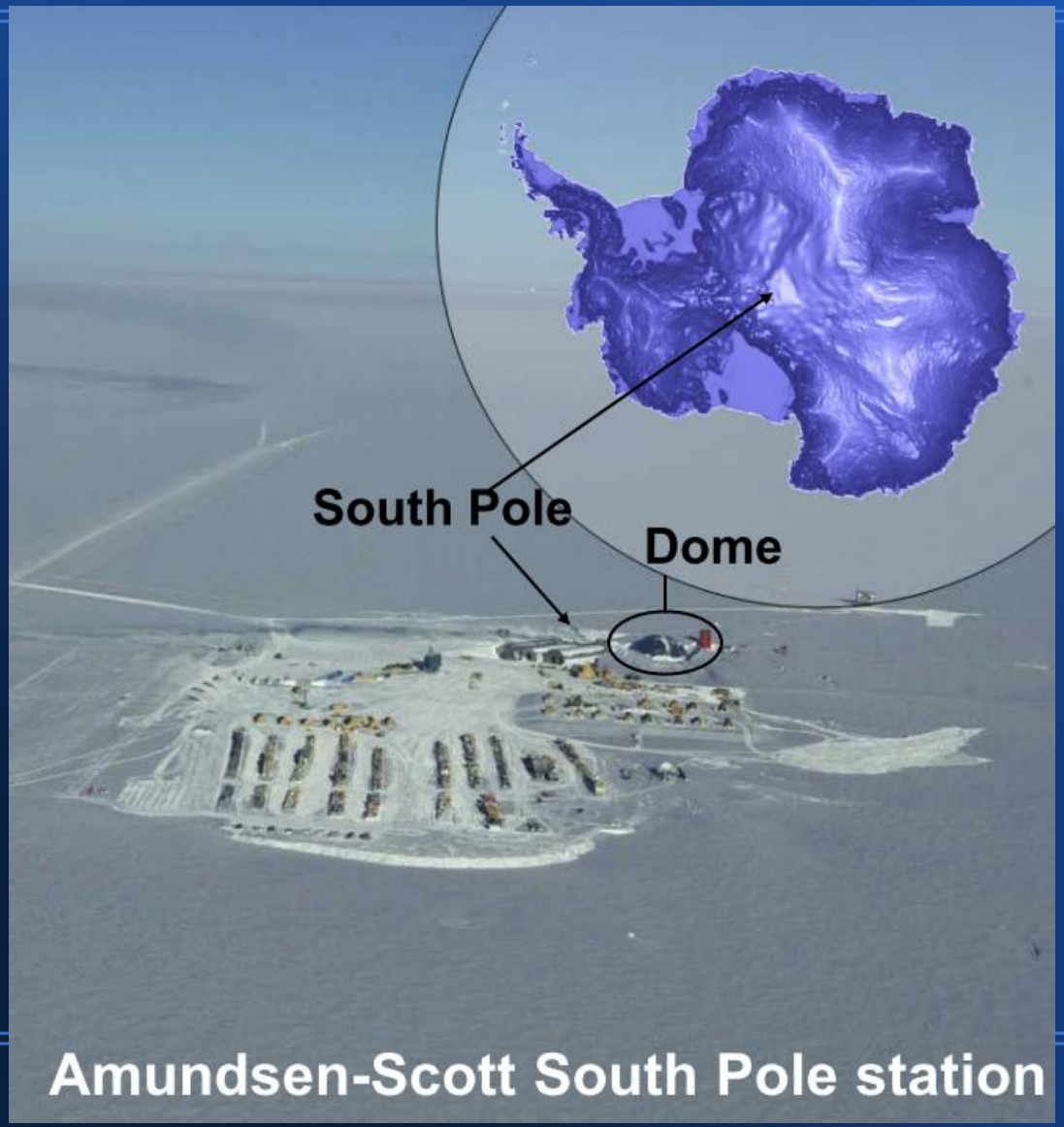
LHAASO observed the prompt phase

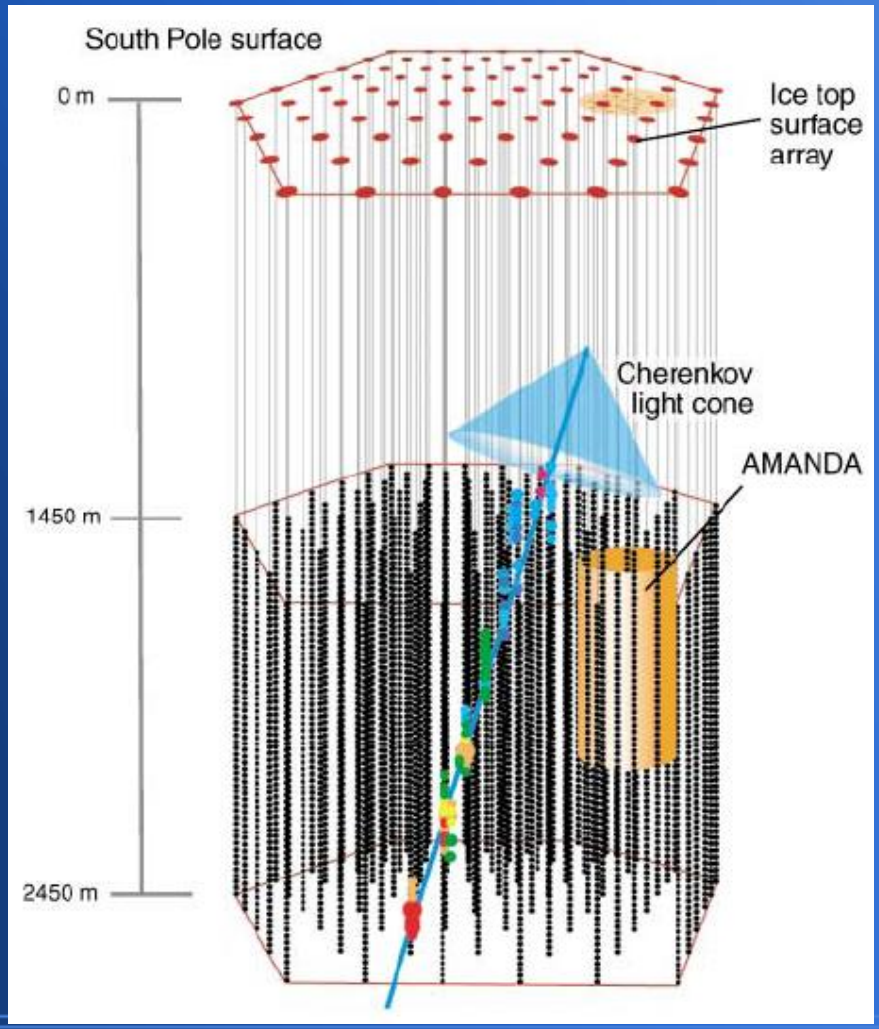
Upper limits have implications

Constrain Y parameter for the prompt phase

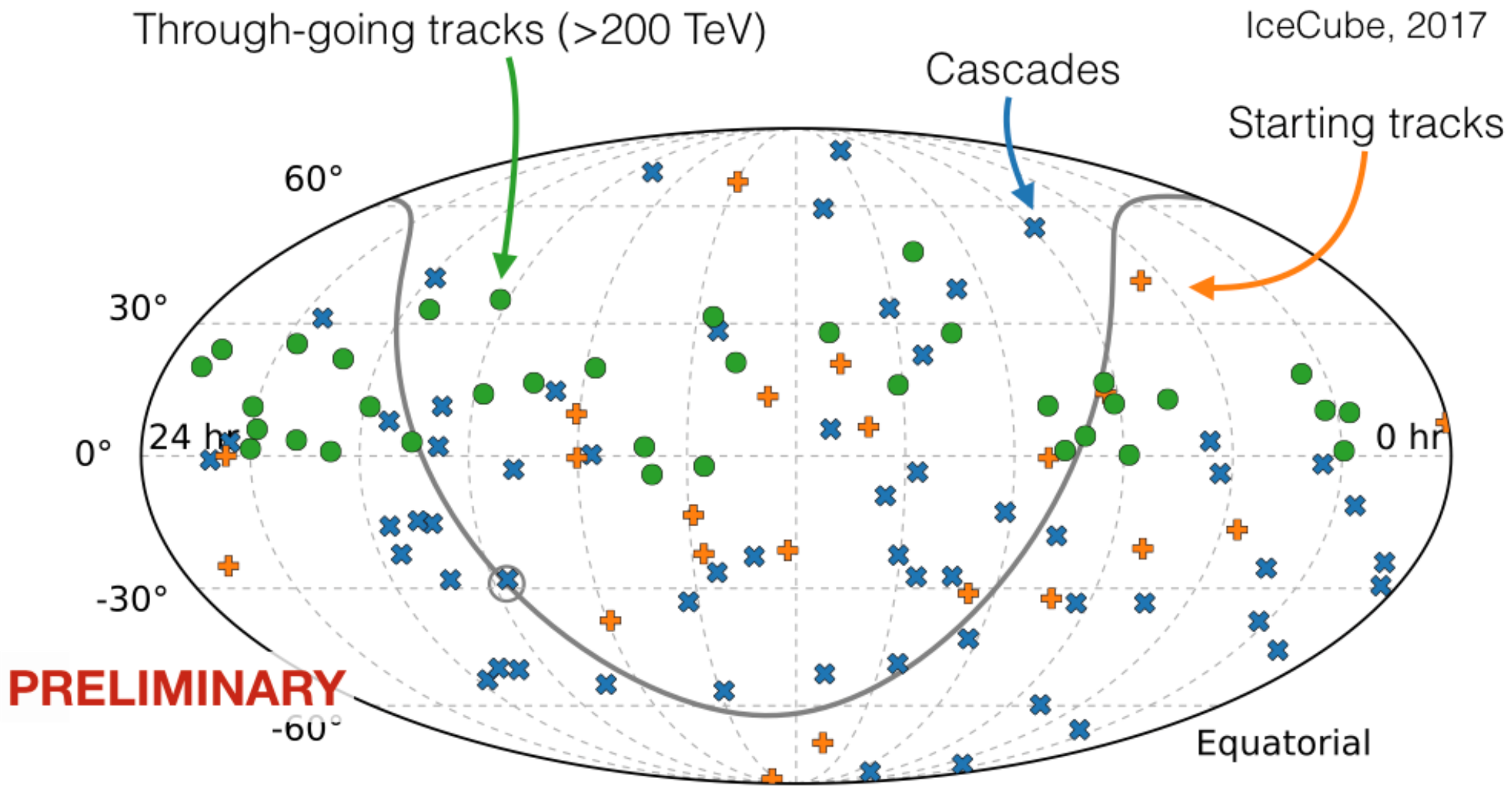
Credit: Yuhua Yao

2. 高能中微子


South Pole
Dome
Amundsen-Scott South Pole station


South Pole surface
0 m
1450 m
2450 m
Ice top surface array
Cherenkov light cone
AMANDA

High energy neutrinos in the sky



- isotropic distribution dominated
- Favor extragalactic origin

TeV/PeV neutrino models?

GRB (Waxman & Bahcall 97; Cholis & Hooper 13; Liu & Wang 13)

AGNs, radio galaxy: (Stecker et al. 91;Kalashev et al. 13)

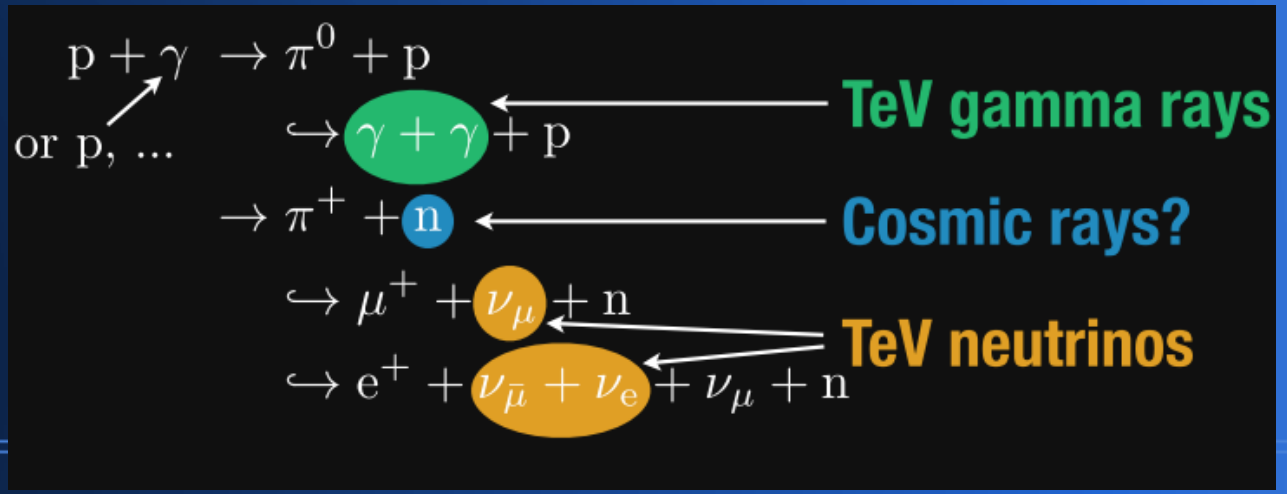
Starburst galaxy (Loeb & Waxman 2006)

Hypernova in star-forming galaxies (Liu, Wang XY, et al. 14)

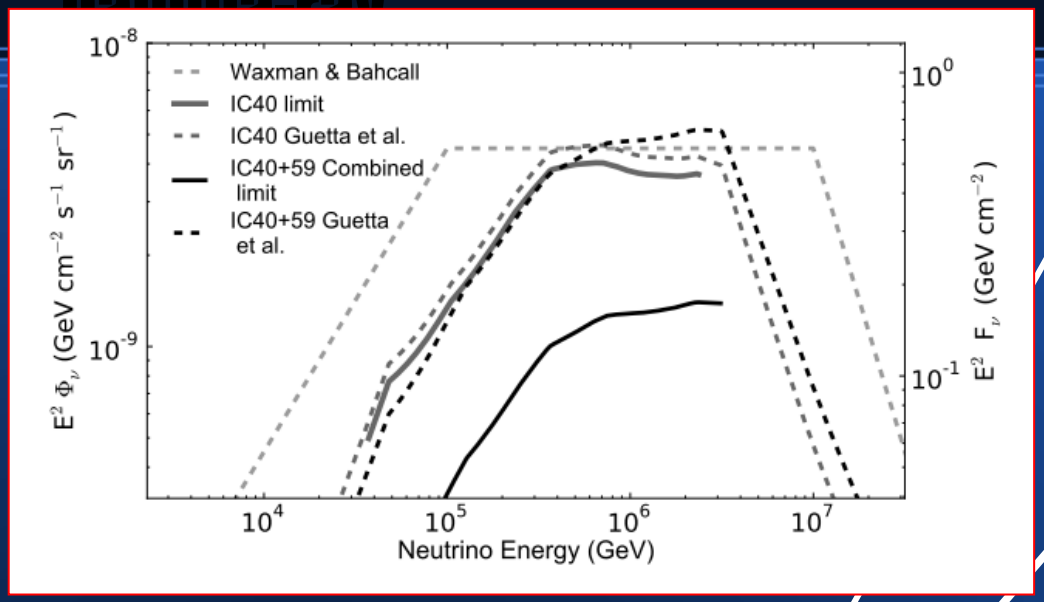
TDE

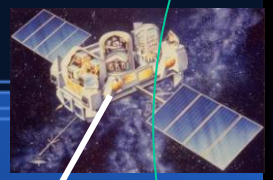
Galactic component

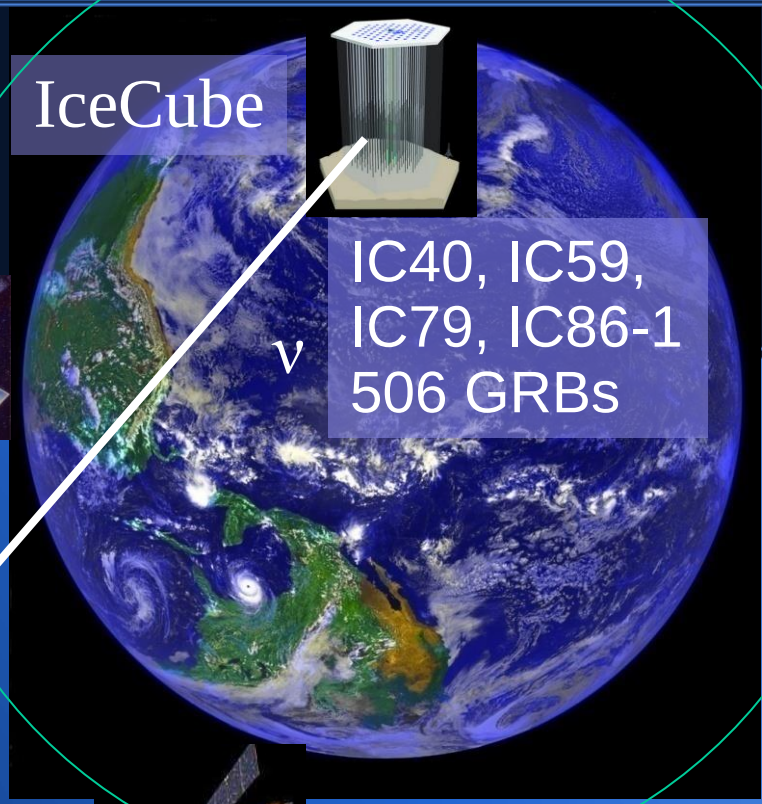
...

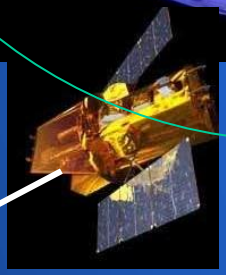


Neutrinos in coincidence with gamma-ray bursts?









Gamma-ray satellites

distant GRB

γ, ν

But few low-luminosity GRBs

Neutrinos from blazar TXS 0506+56

RESEARCH ARTICLE

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube Collaboration, *Fermi*-LAT, MAGIC, *AGILE*, ASAS-SN, HAWC, H.E.S.S., *INTEGRAL*, Kanat…

+ See all authors and affiliations

Science 13 Jul 2018:
Vol. 361, Issue 6398, eaat1378
DOI: 10.1126/science.aat1378

RESEARCH ARTICLE

Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert

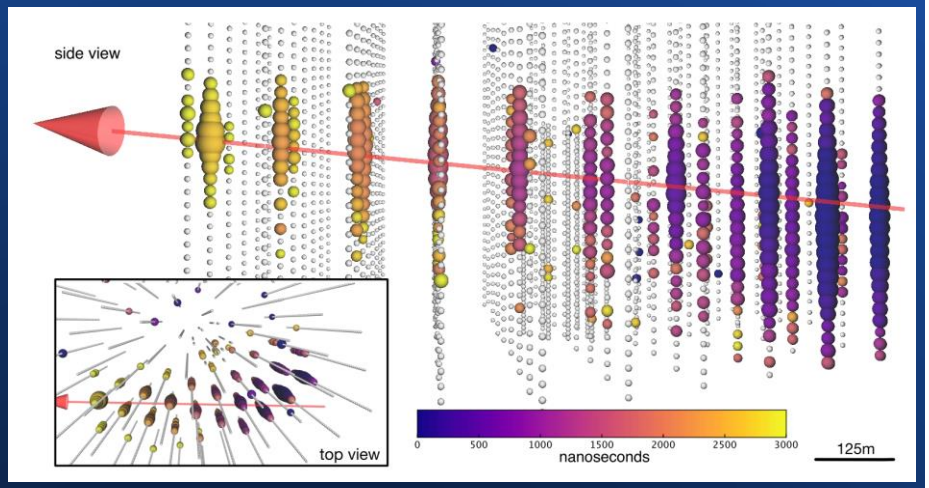
IceCube Collaboration[*,†]

+ See all authors and affiliations

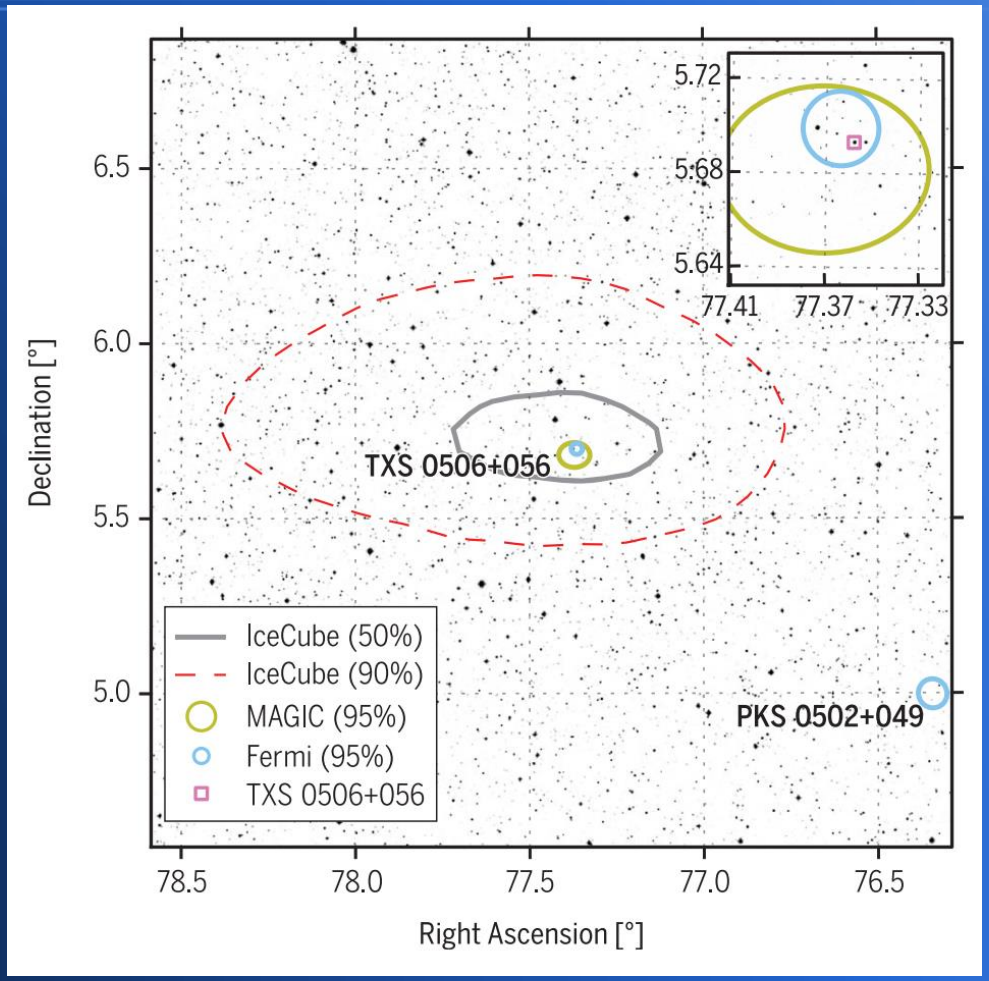
Science 13 Jul 2018:
Vol. 361, Issue 6398, pp. 147-151
DOI: 10.1126/science.aat2890

Science杂志：2018年十大年度进展之一

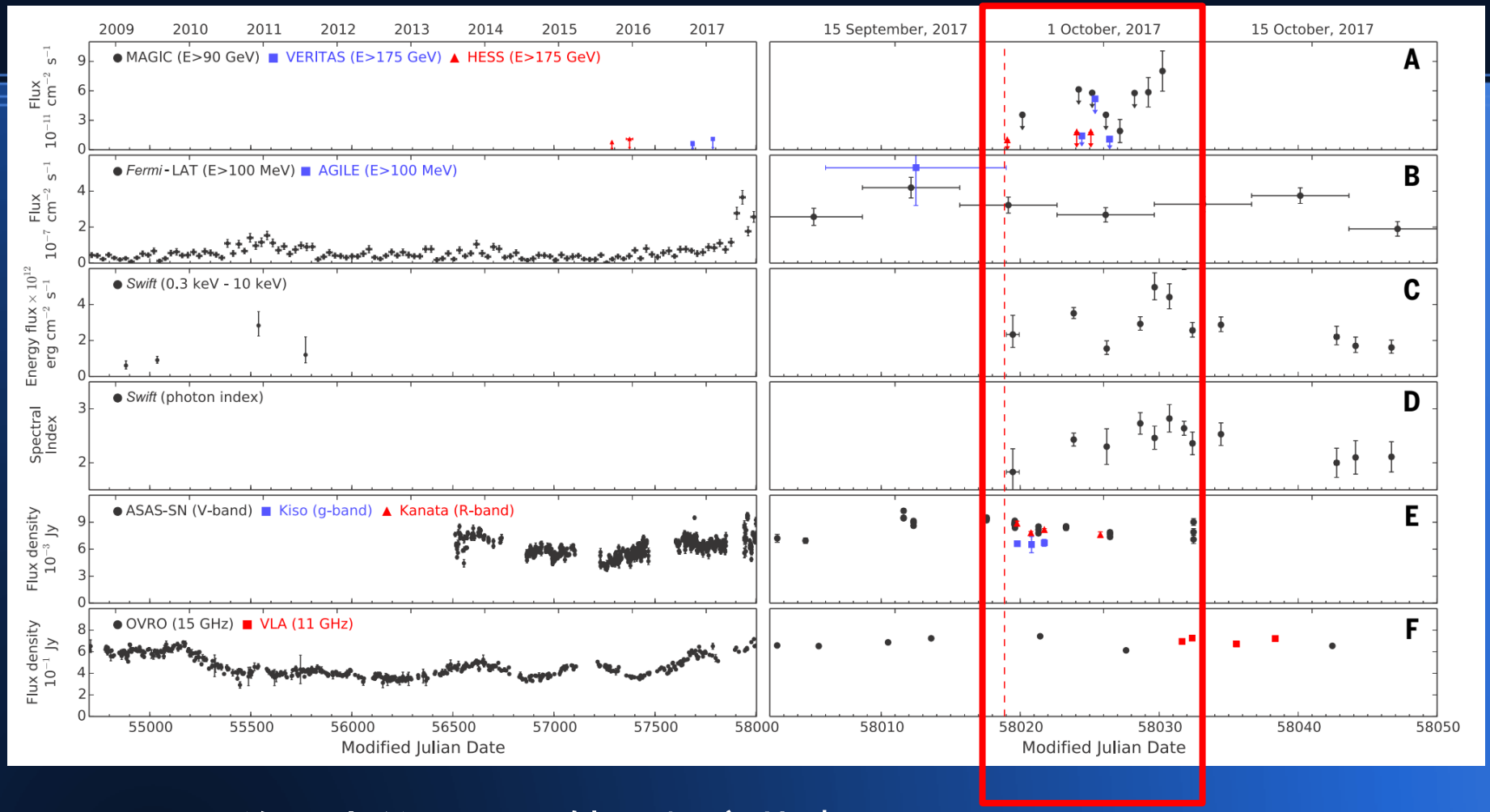
IC 170922A—muon track neutrino



最佳估算能量-290TeV (>183TeV)



多波段观测



前50亮的BL Lac, 处于耀变状态, Z=0.3365

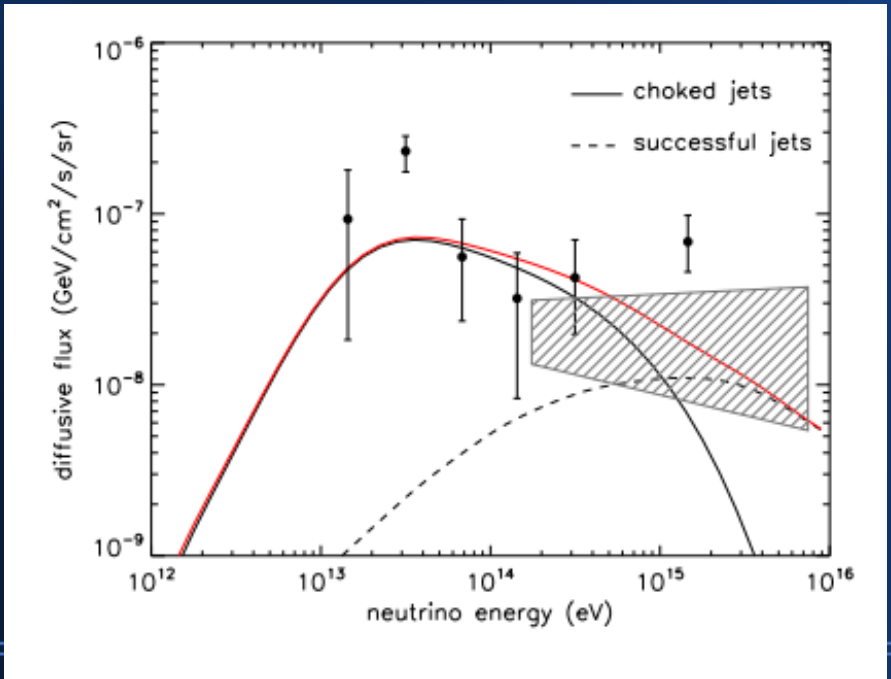
Chance coincidence is disfavored at the 3σ level

Tidal disruption event

- UHECR acceleration in TDE jets (Farrar & Piran 2014)

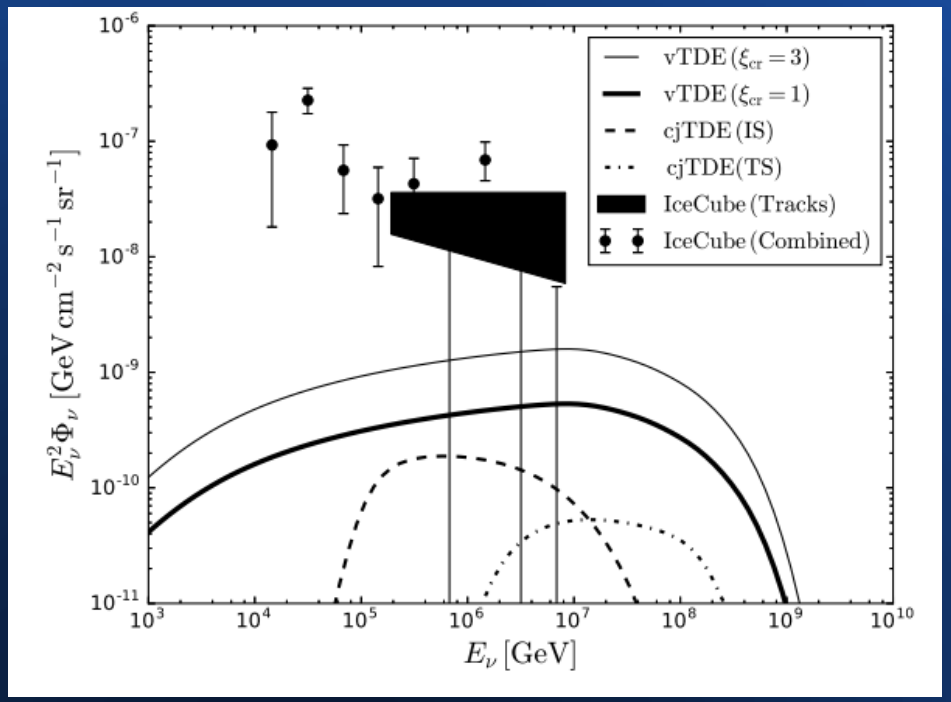
$$BR \gtrsim 3 \times 10^{17}\, \Gamma^{-1}\, Z^{-1}\, E_{20}\ \mathrm{Gauss\,cm}$$

$$L_{\rm bol} \approx \frac{1}{6} c \Gamma^4 (BR)^2 \gtrsim 10^{45}\, \Gamma^2\, (E_{20}/Z)^2\ \mathrm{erg/s}$$

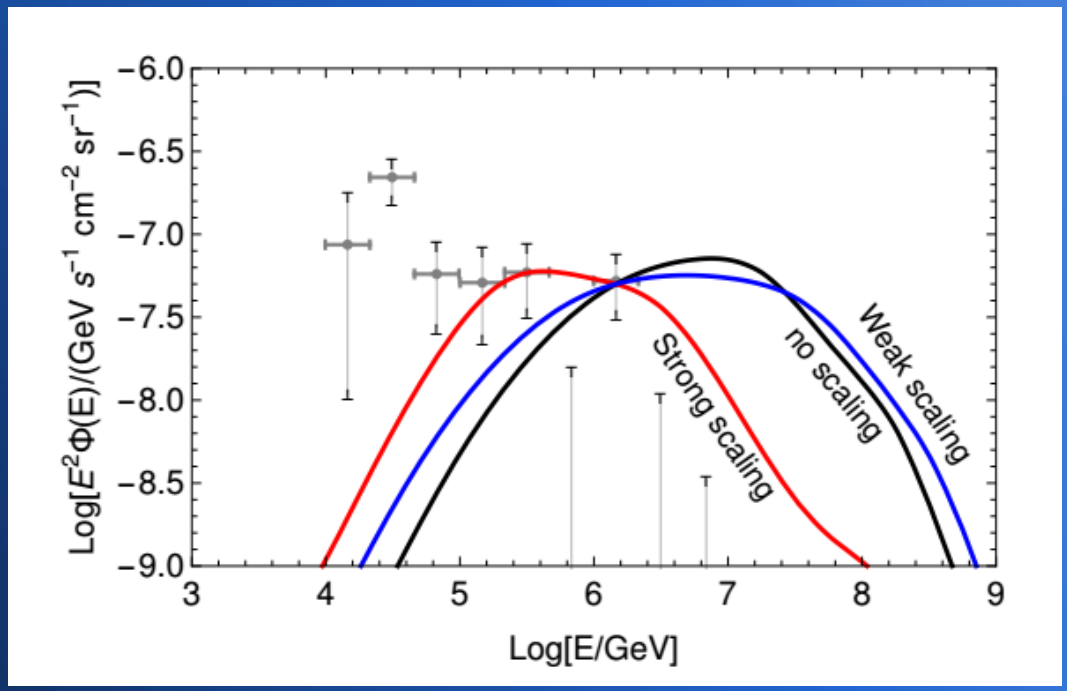


Wang & Liu 2016

Later results from other groups



Dai & Fang 2017



Lunardini & Winter 2017

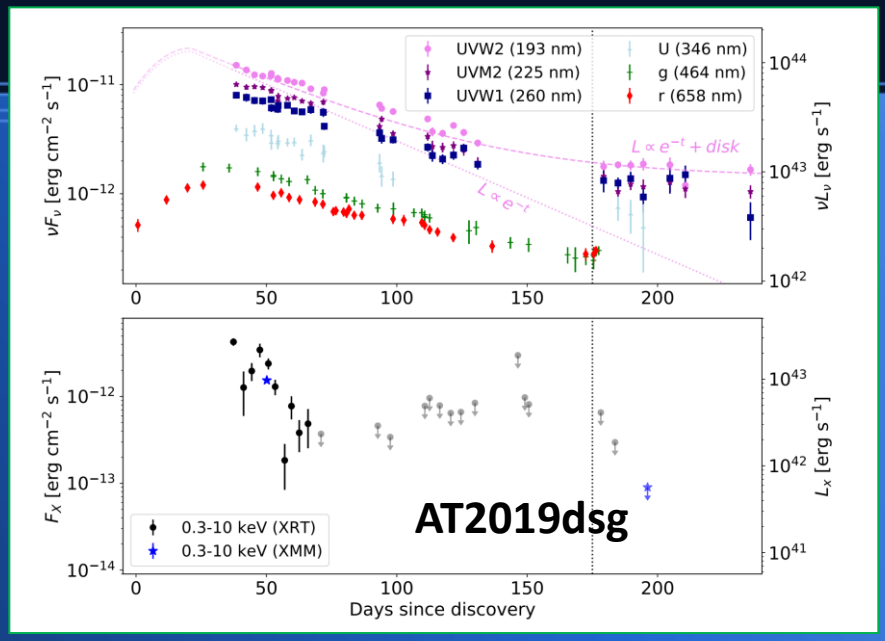
There are large uncertainties…

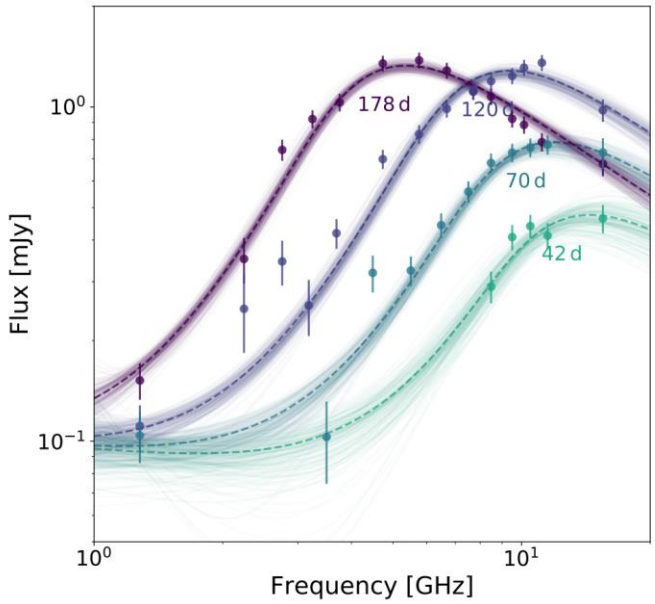
A neutrino possibly from TDE

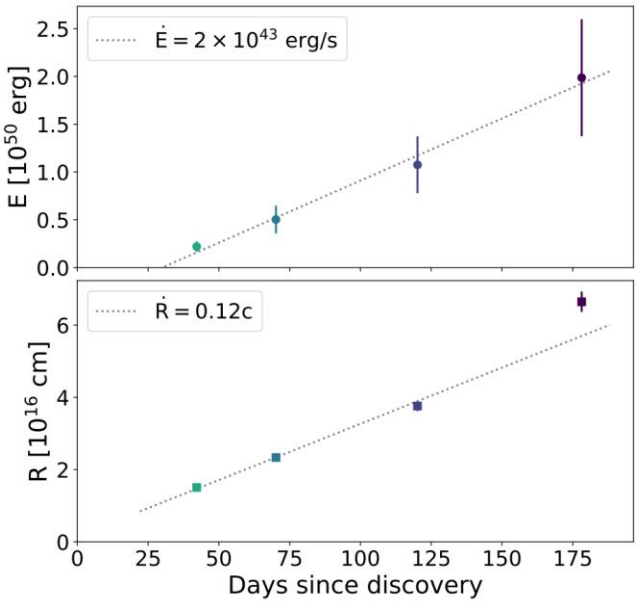
A high-energy neutrino coincident with a tidal disruption event

Robert Stein[*1,2], Sjoert van Velzen[*3,4], Marek Kowalski[*1,2,5], Anna Franckowiak[1,2], Suvi Gezari[4,6], James C. A. Miller-Jones[7], Sara Frederick[4], Itai Sfaradi[8], Michael F. Bietenholz[9,10], Assaf Horesh[8], Rob Fender[11,12], Simone Garrappa[1,2], Tomás Ahumada[4], Igor Andreoni[13], Justin Belicki[14], Eric C. Bellm[15], Markus Böttcher[16], Valery Brinnel[2], Rick Burruss[14], S. Bradley Cenko[6,17], Michael W. Coughlin[18], Virginia Cunningham[4], Andrew Drake[13], Glennys R. Farrar[3], Michael Feeney[14], Ryan J. Foley[19], Avishay Gal-Yam[20], V. Zach Golkhou[15,21], Ariel Goobar[22], Matthew J. Graham[13], Erica Hammerstein[4], George Helou[23], Tiara Hung[19], Mansi M. Kasliwal[13], Charles D. Kilpatrick[19], Albert K. H. Kong[24], Thomas Kupfer[25], Russ R. Laher[23], Ashish A. Mahabal[13,26], Frank J. Masci[23], Jannis Necker[1,2], Jakob Nordin[2], Daniel A. Perley[27], Mickael Rigault[28], Simeon Reusch[1,2], Hector Rodriguez[14], César Rojas-Bravo[19], Ben Rusholme[23], David L. Shupe[23], Leo P. Singer[17], Jesper Sollerman[29], Maayane T. Soumagnac[20,30], Daniel Stern[31], Kirsty Taggart[27], Jakob van Santen[1], Charlotte Ward[4], Patrick Woudt[12], Yuhan Yao[13]

h.HE] 11 May 2020



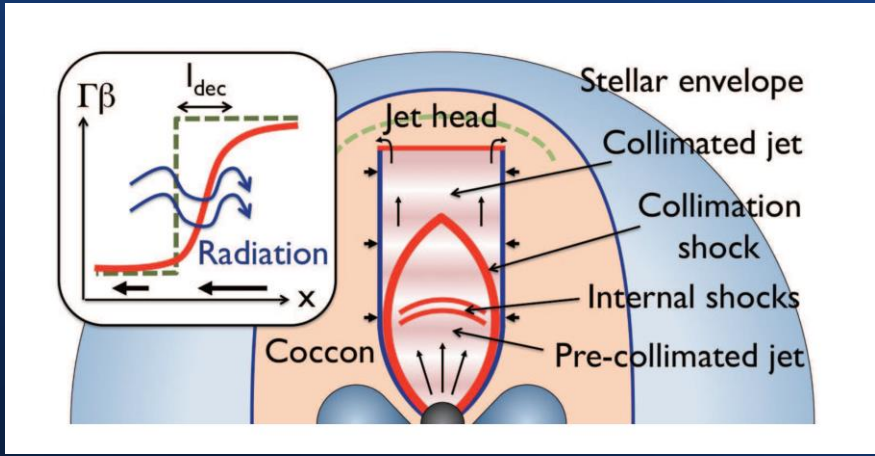




- **The probability of finding any radio-emitting tidal disruption event by chance is 0.5%**

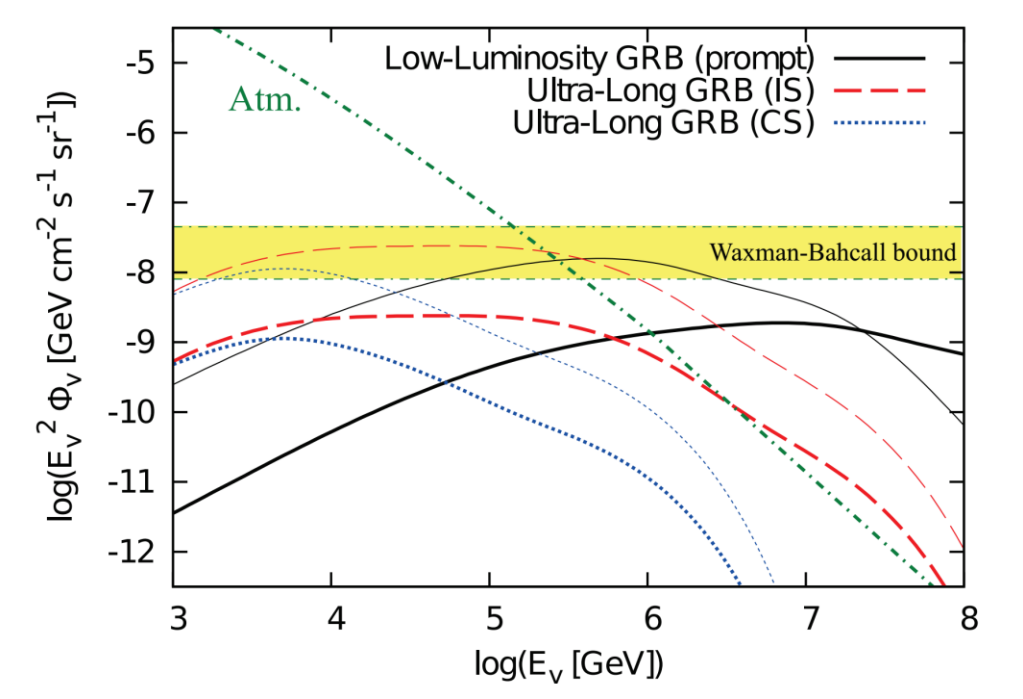
GECAM的观测相关(1)

Low-luminosity GRB model for neutrinos



Do not suffer the radiation shock constraint

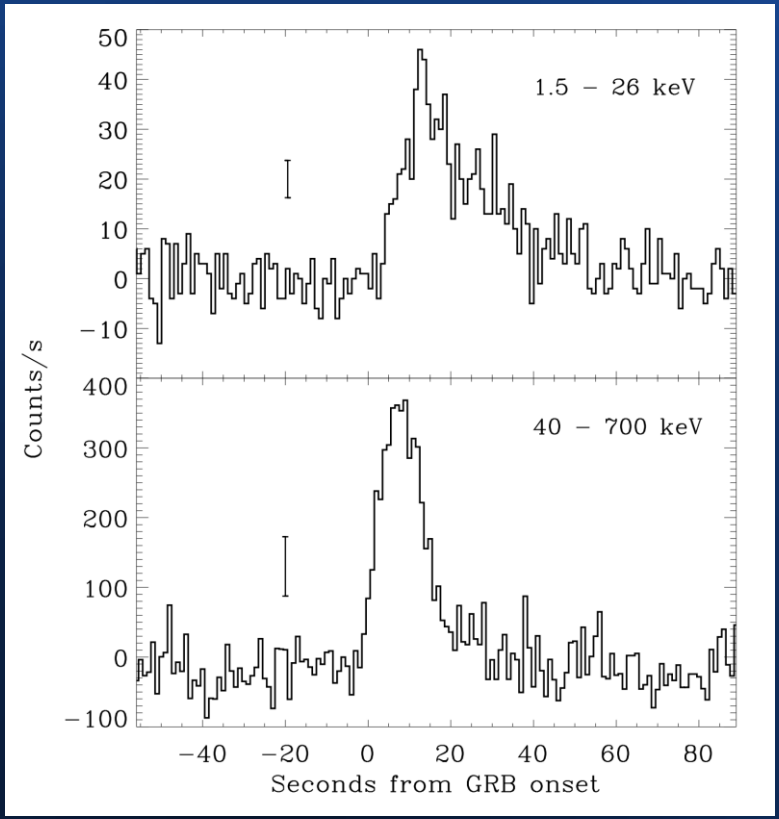
(Murase & Ioka 2013, PRL)

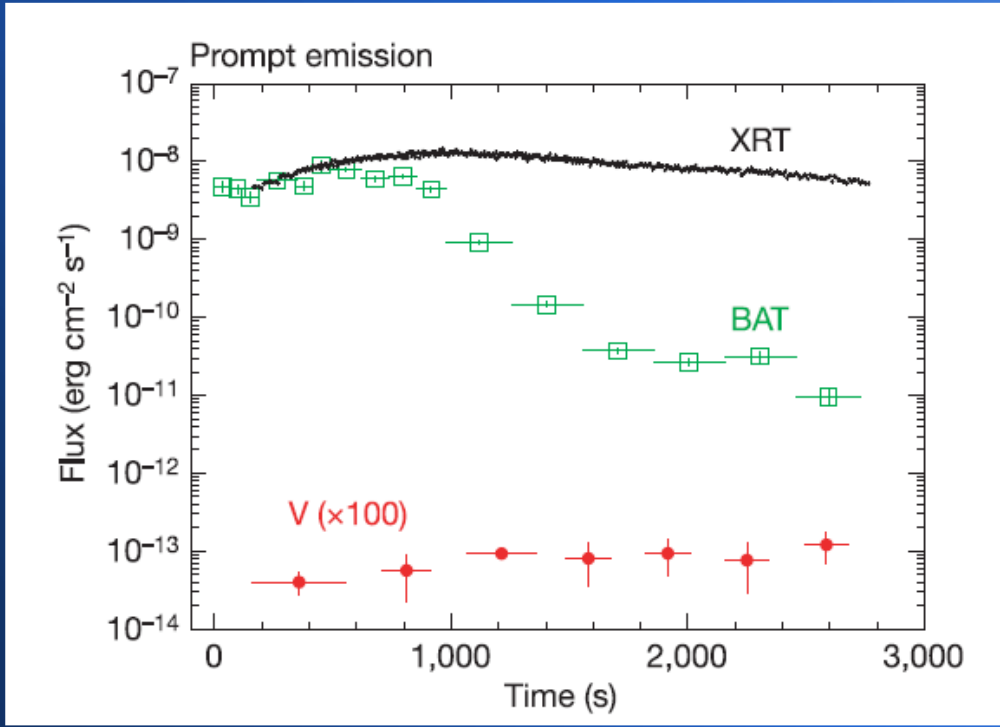


Also : Ultra-long GRBs

GECAM的观测相关(1)

1. Low-luminosity GRBs（GECAM: 增加样本）





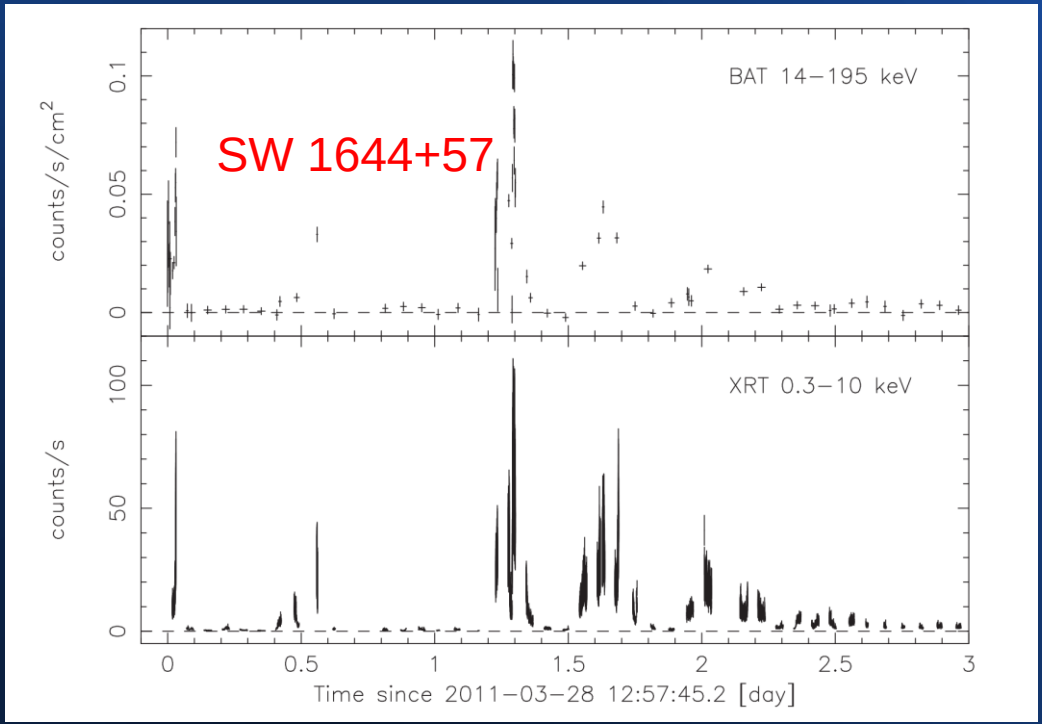
(3.0 ± 0.3) × 10^−7 erg cm−2 s−1 (24 –1820 keV)

GRB 980425

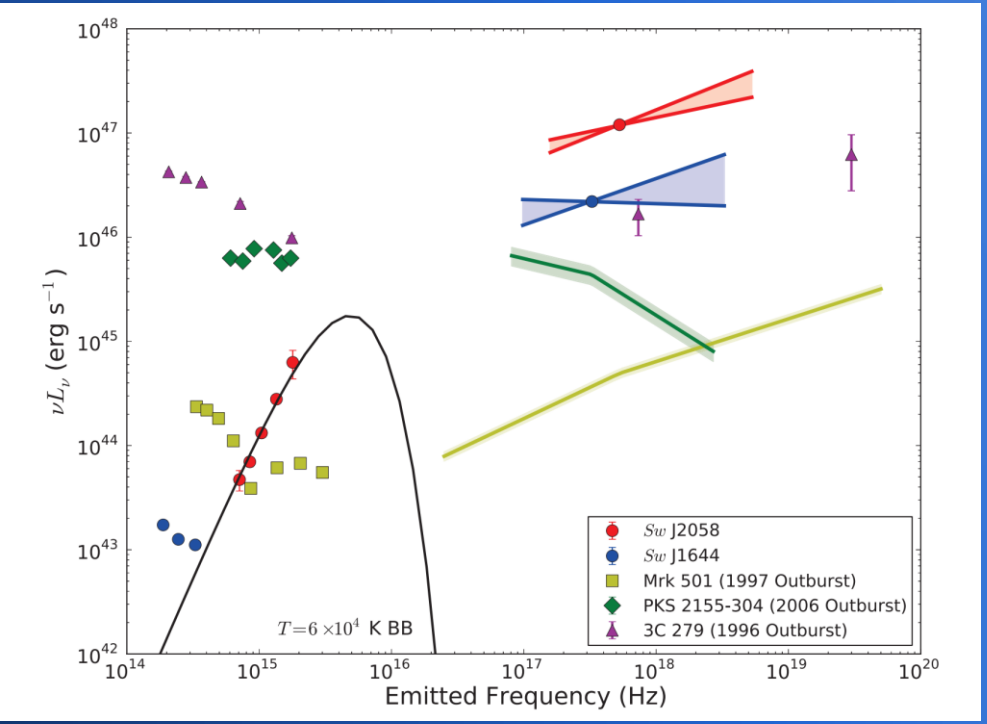
GRB 060218

GECAM的观测相关(2)

2. Jetted TDEs（增加样本）



Burrows et al. 2011



Cenko et al. 2012

讨论

1）甚高能伽玛暴：粒子加速和辐射机制

2）高能中微子起源未知：低光度伽玛暴，TDE

3) GECAM: 低光度伽玛暴, jetted TDE

Klein-Nishina effect

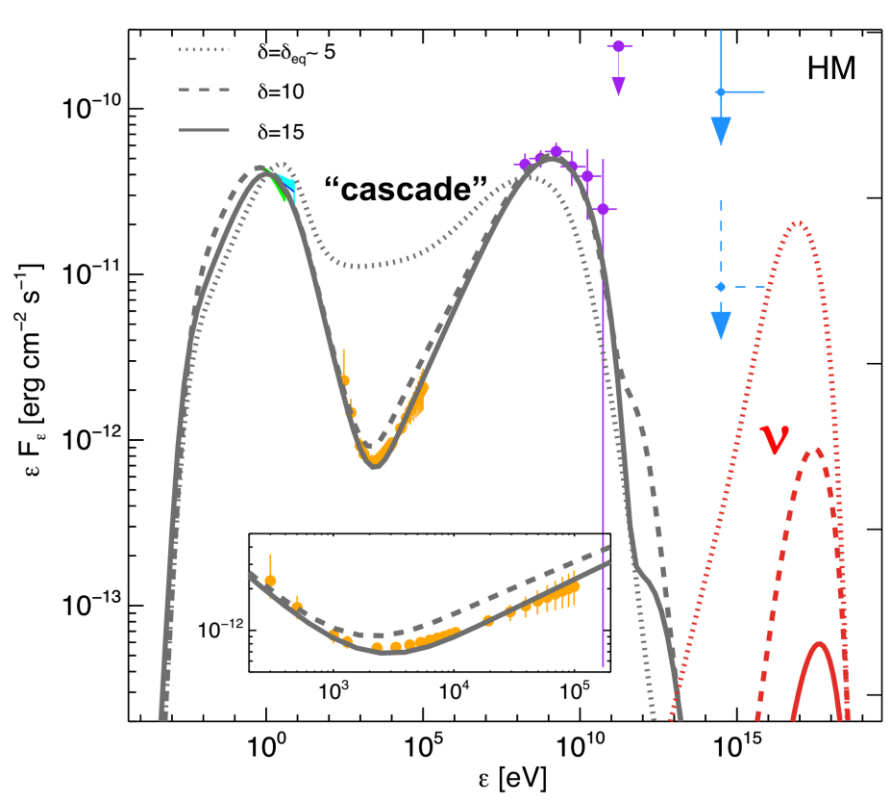
$$N(\gamma) \propto \begin{cases} \gamma^{-p}, & \text{if} \quad \gamma_m < \gamma < \gamma_c \,, \\ \gamma^{-p-1}, & \text{if} \quad \gamma_c < \gamma \,. \end{cases}$$

$$\gamma_M = \max(\gamma_m, \gamma_c) \qquad E_{\rm KN} = \Gamma \gamma_M m_e c^2$$

$$E_{\rm KN} = \Gamma \gamma_c m_e c^2 = 0.1{\rm TeV} \left(\frac{1}{1+Y_c}\right) \epsilon_{B,-2}^{-1} E_{54}^{-1/4} n_{-1}^{-3/4} t_{\rm 10hr}^{-1/4}$$

$$\epsilon_B < 2 \times 10^{-3} \left(\frac{1}{1+Y_c}\right) E_{54}^{-1/4} n_{-1}^{-3/4} t_{\rm 10hr}^{-1/4} \left(\frac{\varepsilon_\gamma}{0.44{\rm TeV}}\right)^{-1}$$

传统的单区Photomeson (pγ) 模型



Keivani et al. 2018

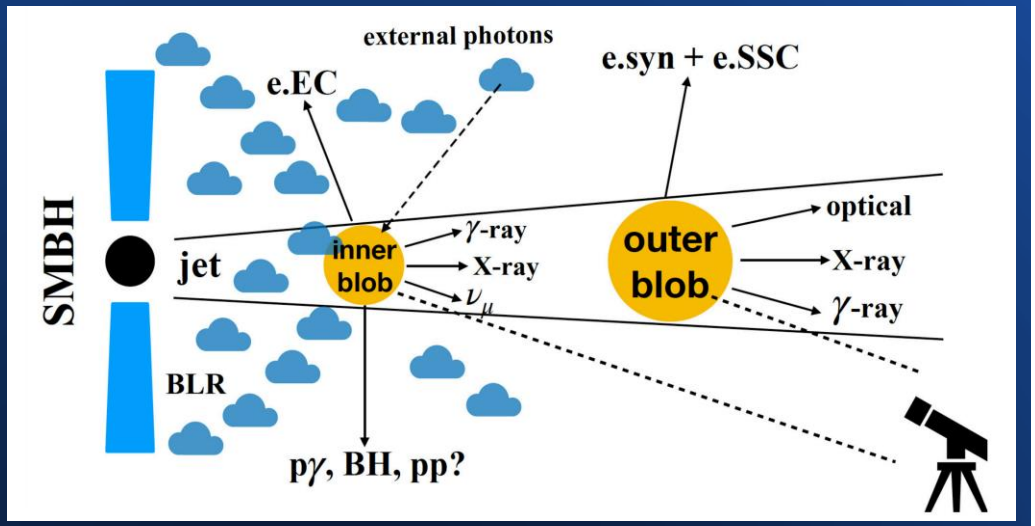
拟合存在问题：

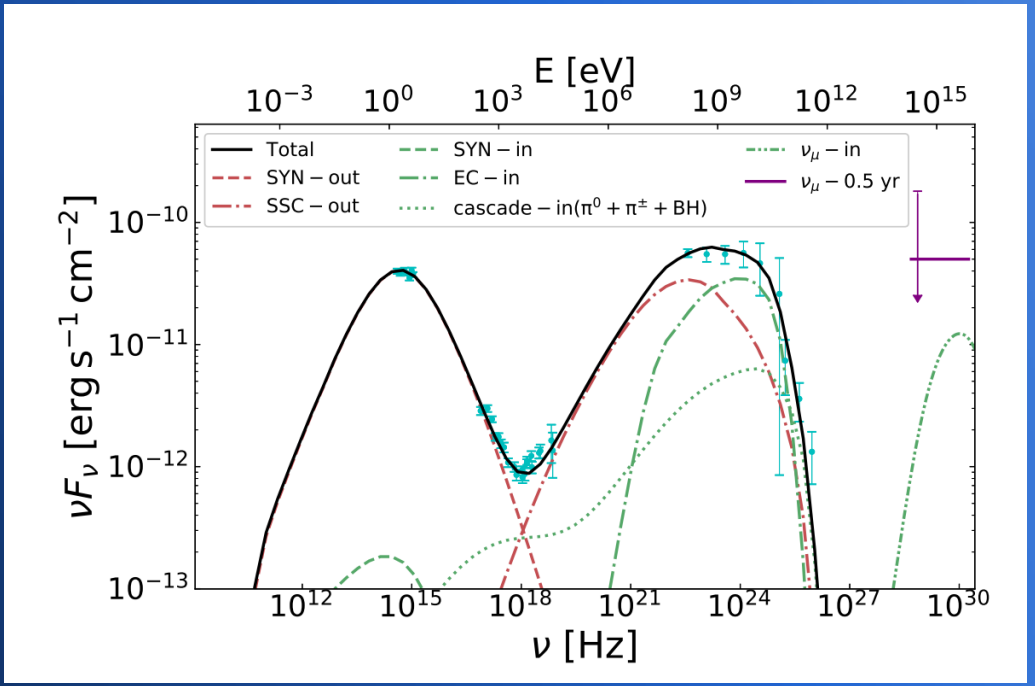
1）cascade 辐射不能超过X-ray观测, 导致中微子流量很低

2）inefficient: 要求jet光度超过中心黑洞的Eddington光度

a probability of <1%
Lucky Detection

双区pγ碰撞模型





Cascade 辐射由电子的EC主导

Xue, Liu, et al. 2019