



Radiative signals from GRBs and multi-messenger searches

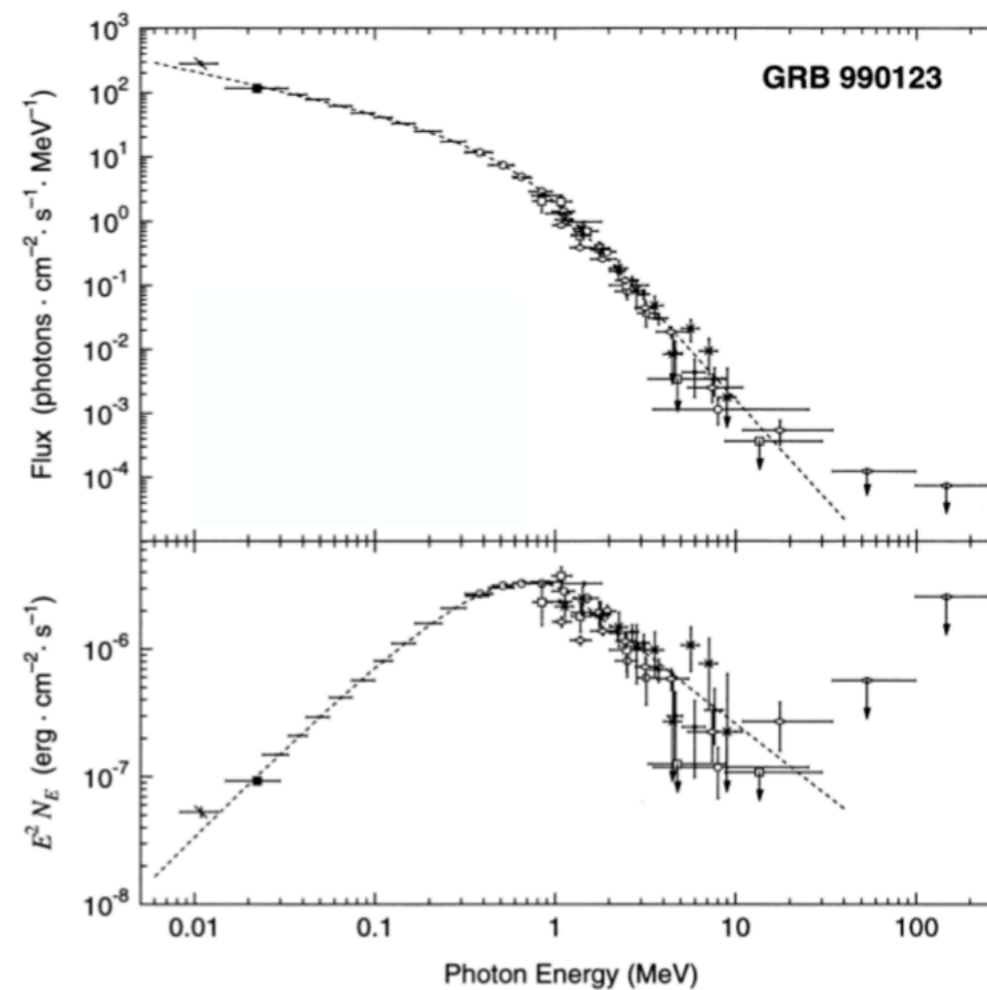
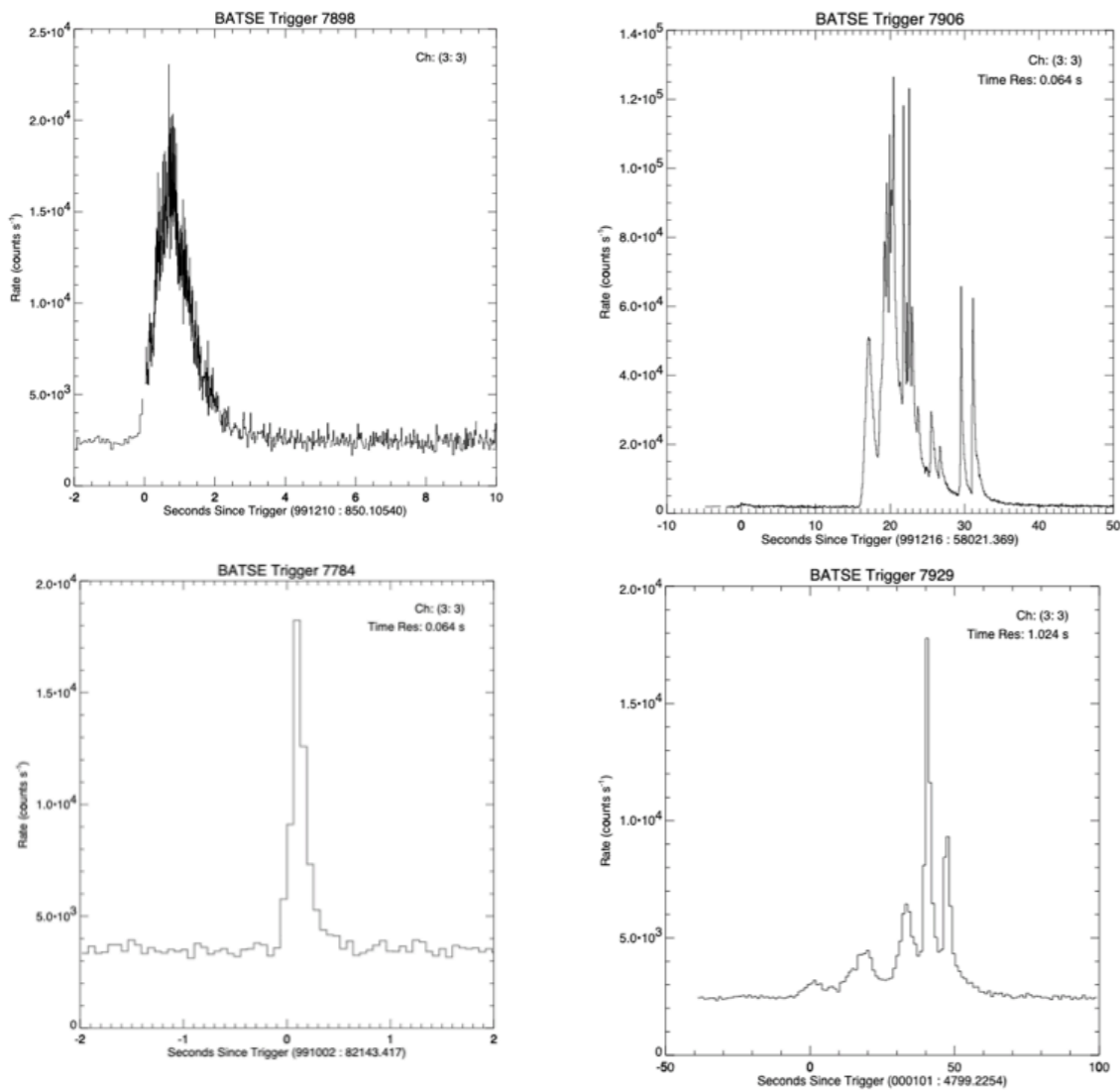
Gor Oganesyan

RICAP-24, Frascati, 27 September 2024

γ -ray bursts

The prompt emission

γ -ray bursts



Briggs et al. 1999

energy (iso) $\sim 10^{50} - 10^{54}$ erg

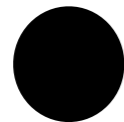
photons \sim MeV

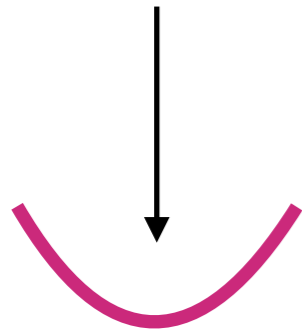
variability 0.01-1 s

duration 0.1 - 1000 s

$E_{peak} \sim 100 \text{ keV} - 1 \text{ MeV}$

Pair fireball

 **BH** $\sim 1 - 10M_{\odot}$



e^{\pm}, γ

$$L_{\gamma} \gg \gg 10^{10} L_{Edd}$$



$$T_{BB} \sim MeV$$

Cavallo & Rees 1978

Paczynski 1986

Goodman 1986

Baryon poisoning

Shemi & Piran 1990

Cavallo & Rees 1978

Paczynski 1990



$$R_{coll} \approx 2c \delta t \Gamma_s^2$$

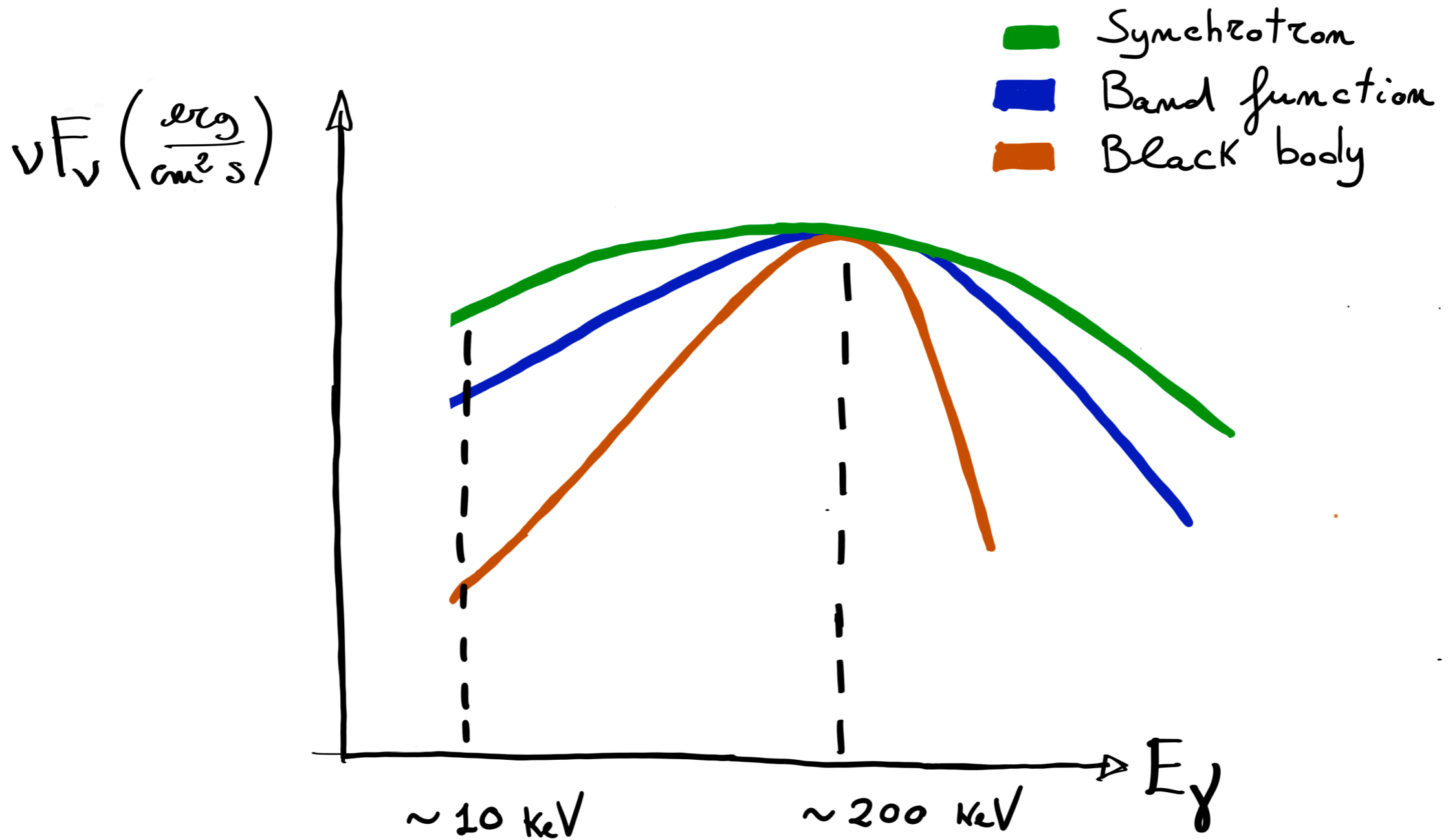
$$T_{BB} \rightarrow L_k \rightarrow L_{\gamma}$$

Rees & Mészáros 1994

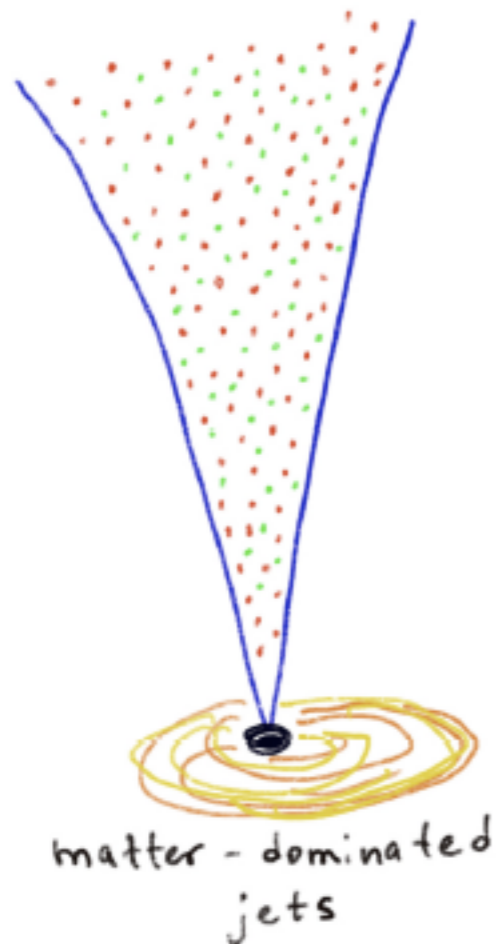
(Narayan et al. 1992, Paczynski & Xu 1994)

Daigne & Mochkovitch 1998

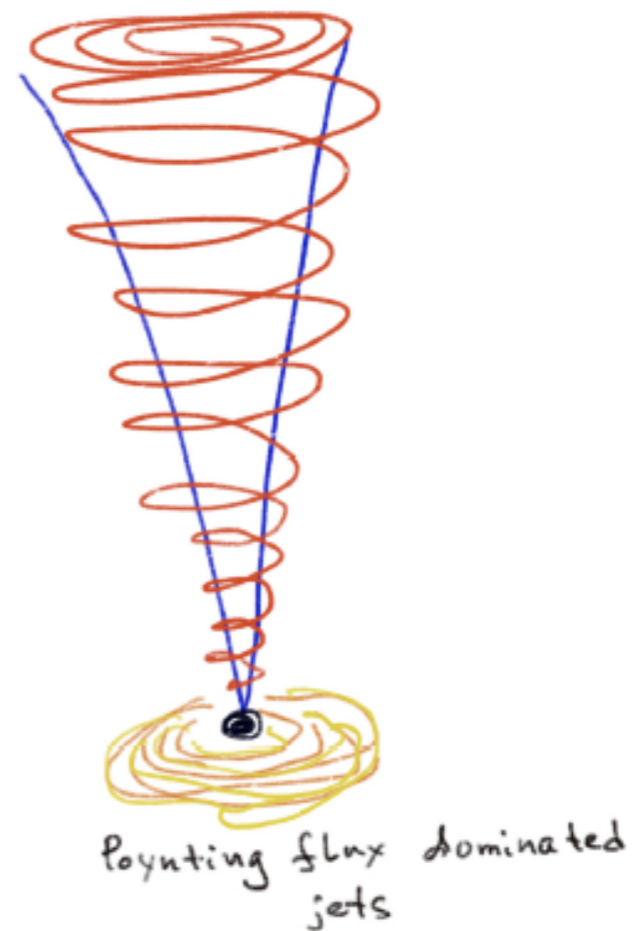
Synchrotron vs Thermal emission



GRB jet mystery

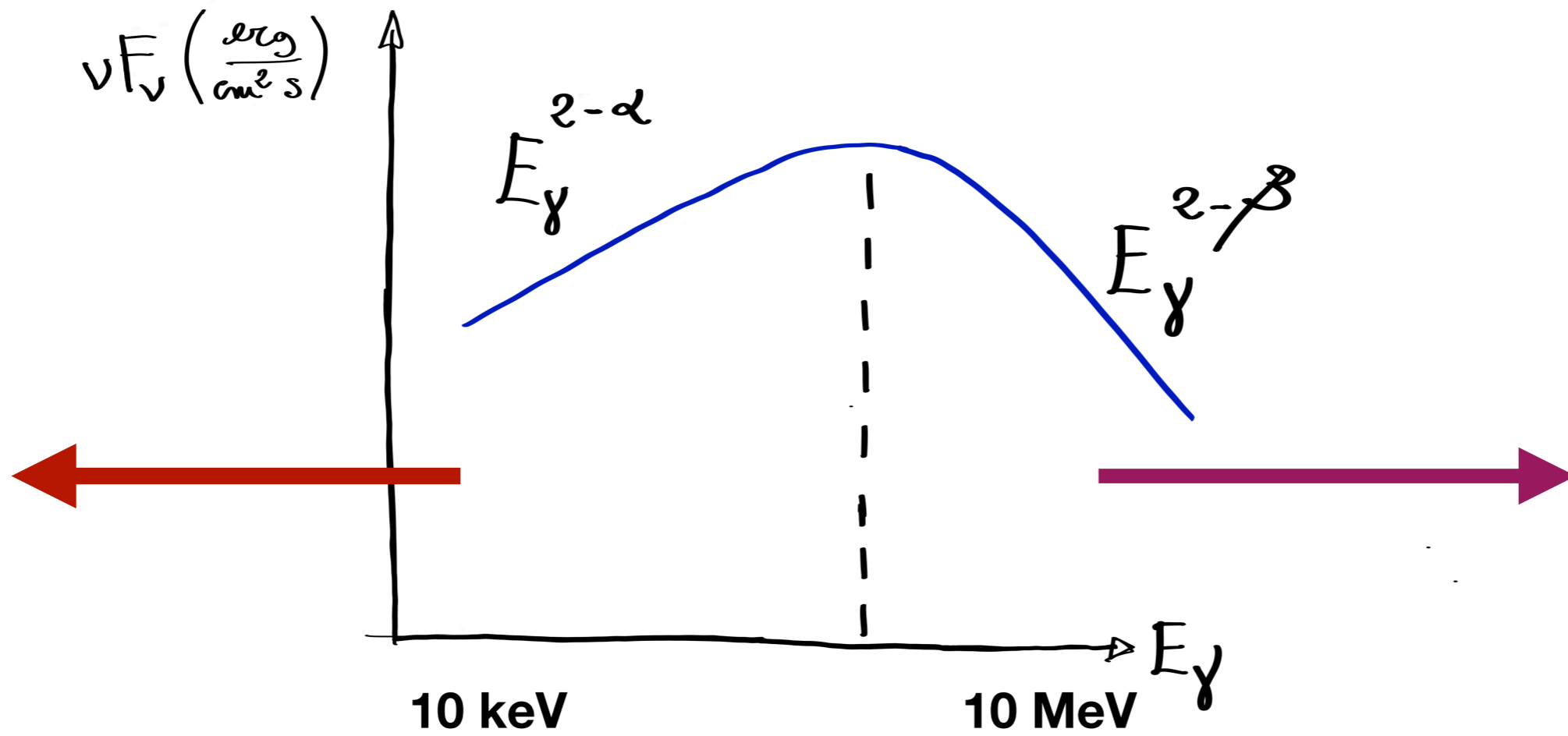


Cavallo & Rees 1978
Paczynski 1986
Goodman 1986
Shemi & Piran 1990



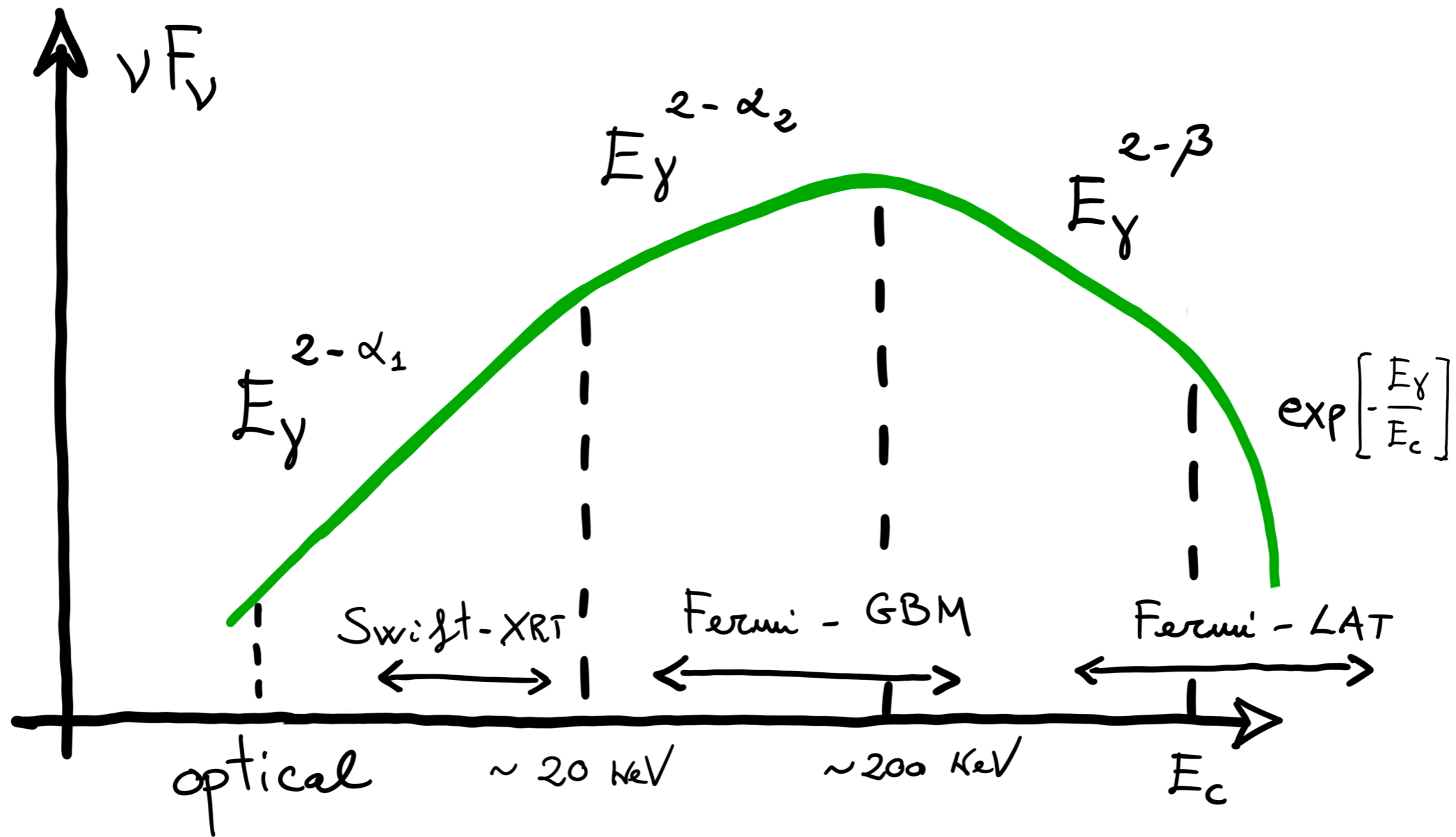
Usov 1992
Thompson 1994
Mészáros & Rees 1997
Lyutikov & Blandford 2003

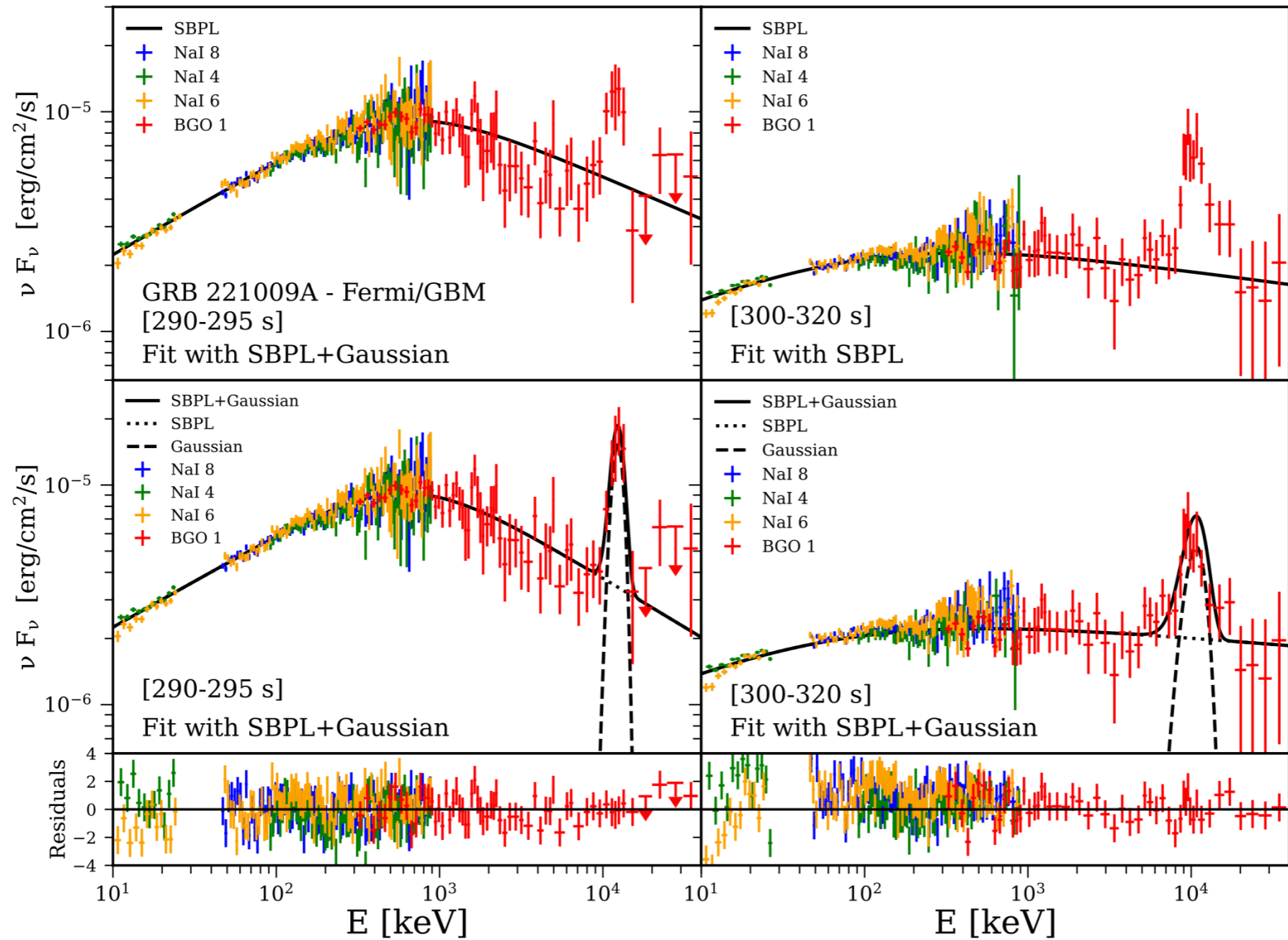
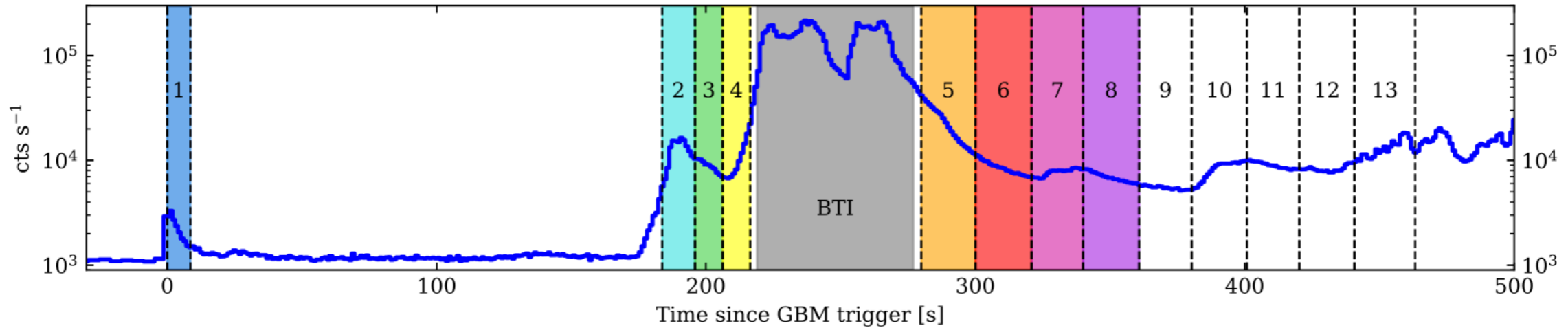
Multi-wavelength observations



γ -ray bursts

the prompt emission

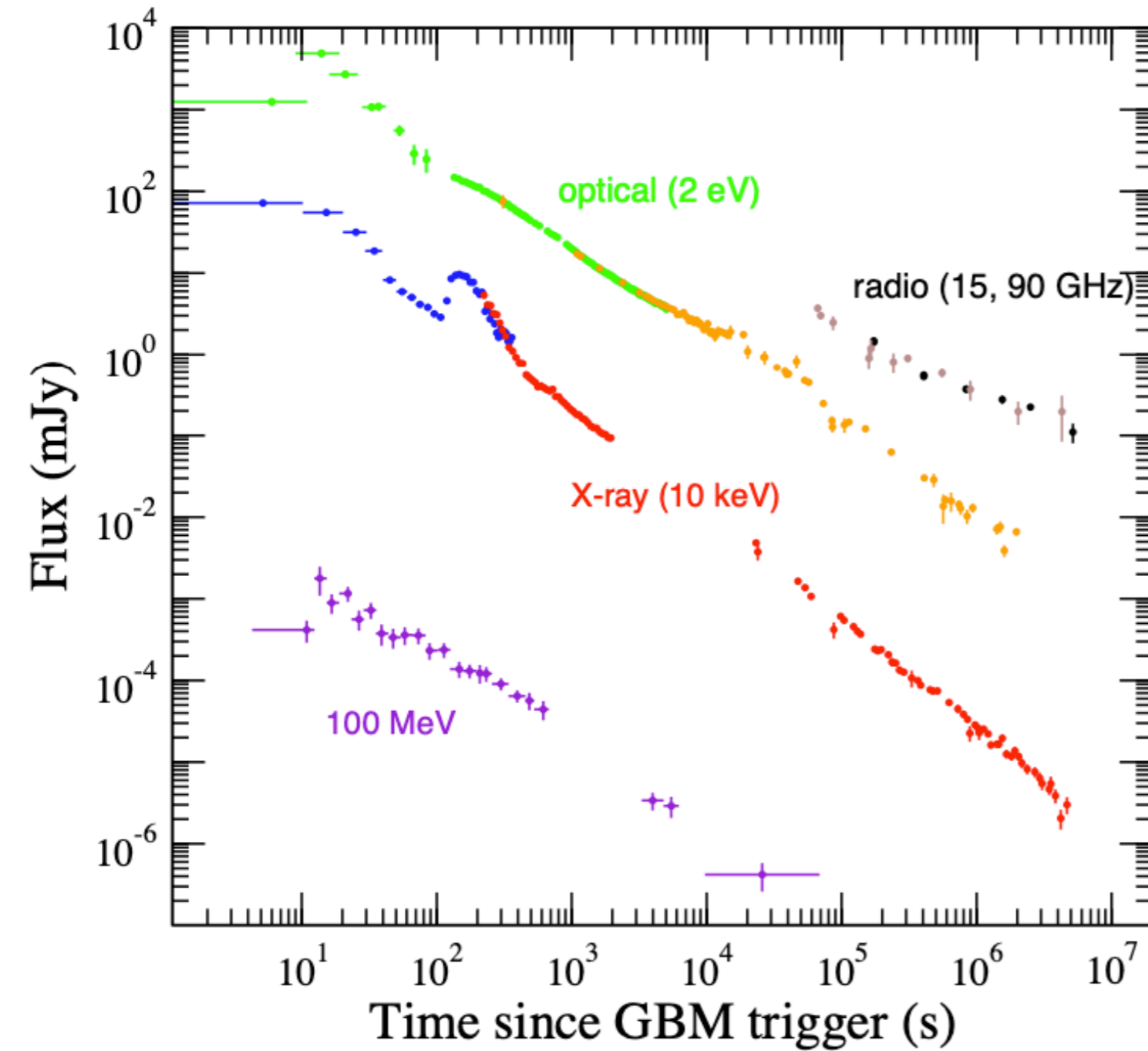




γ -ray bursts

the afterglow

Afterglow



example GRB 130427A Panaitescu et. al. 2013

discovered

Costa et al. 1997

predicted

Paczýnski & Rhoads 1993

Mészáros & Rees 1997

dynamics

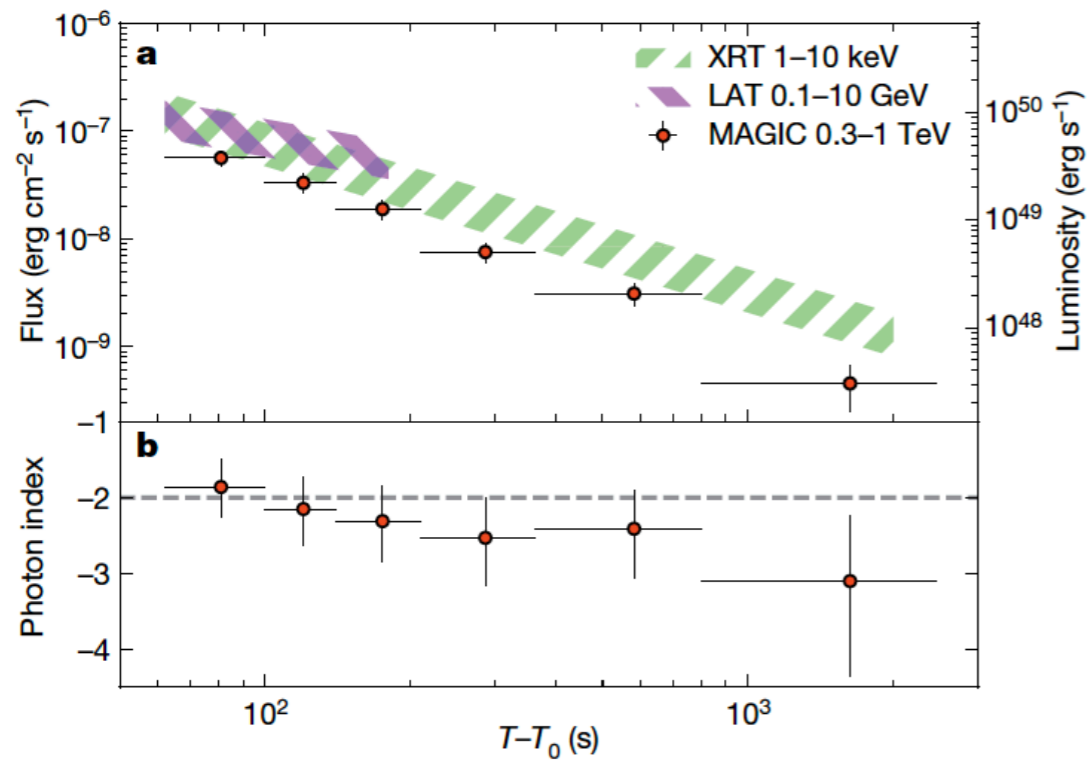
Blandford & McKee 1976

phenomenology

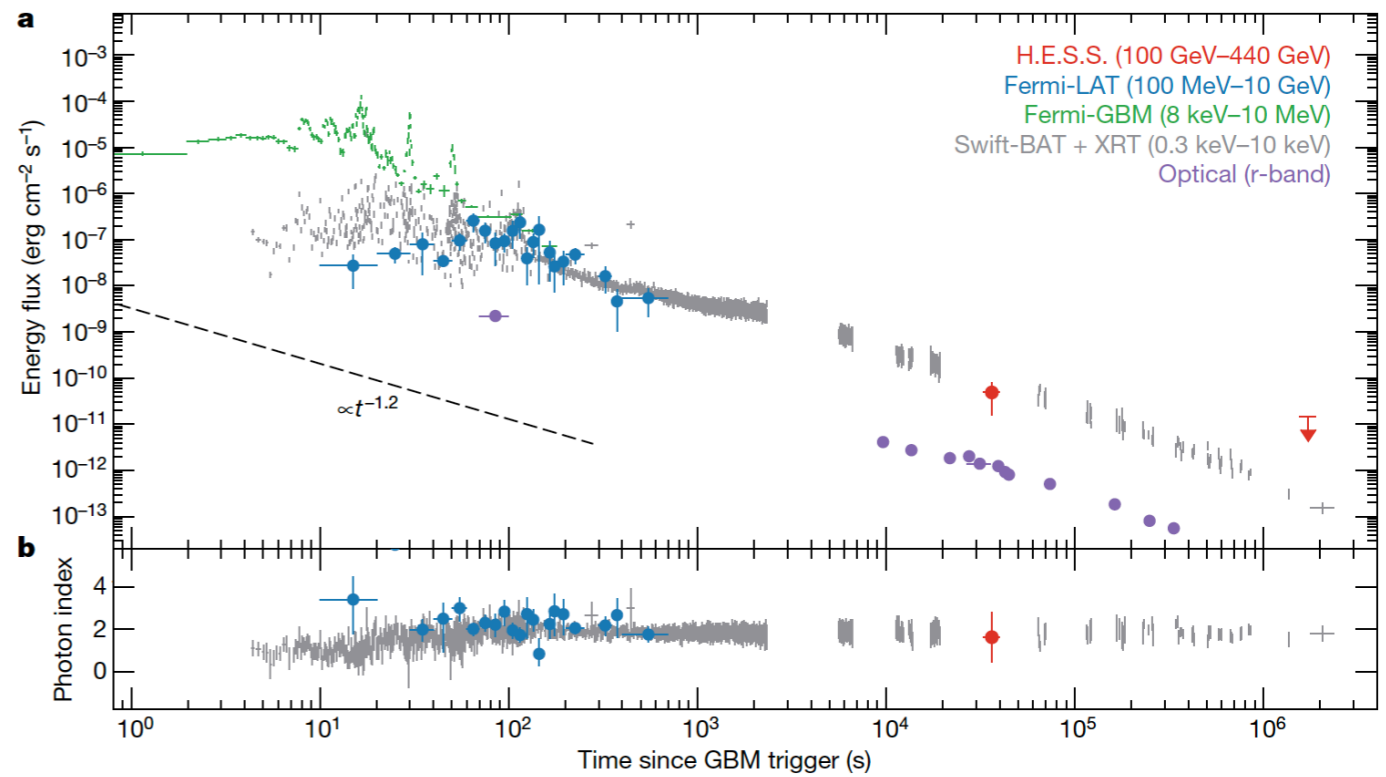
Sari et al. 1998

GRBs at Very High Energies - the discoveries of 2019

MAGIC and H.E.S.S. collaborations

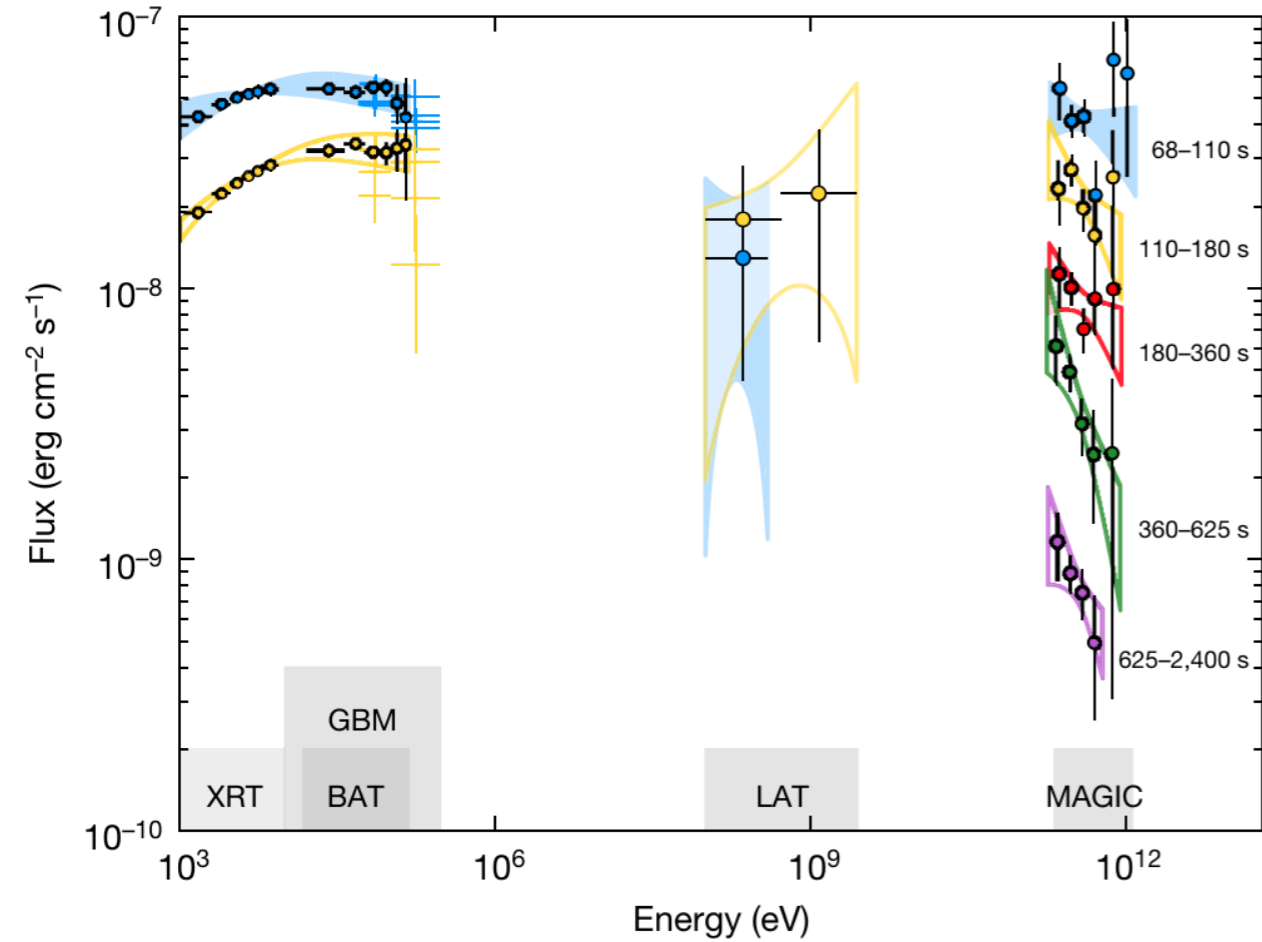


MAGIC collaboration
Nature 2019



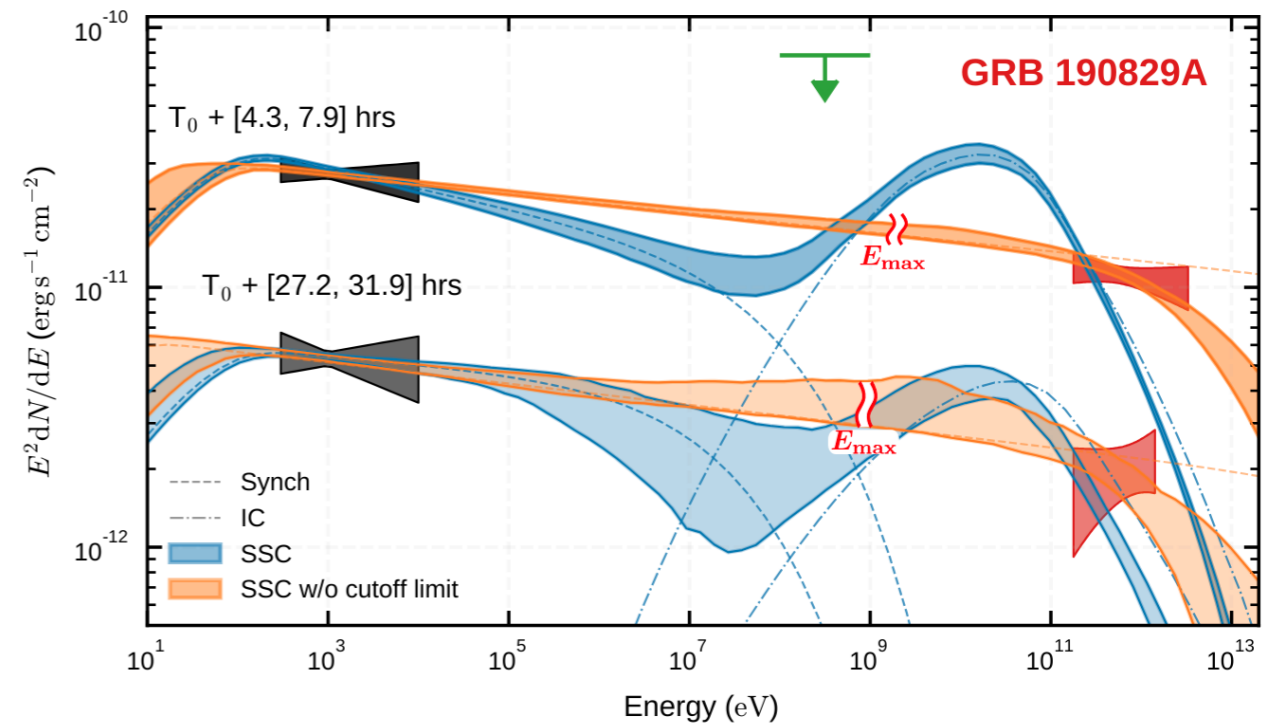
H.E.S.S. collaboration
Nature 2019

GRB 190114C





















MAGIC collaboration
Nature 2019

GRB 190829A



H.E.S.S. collaboration
Science 2021

GRBs	Time (t-T ₀)	0.3 keV	10 keV	100 keV	1 MeV	100 MeV	10 GeV	100 GeV	1 TeV
GRB 180720B	~10 hr	?	?		?		?		
GRB 190114C	68–110 s		 		?				
	110–180 s		 		?				
GRB 190829A	4.3–7.9 hr		?		?				
	27.2–31.9 hr		?		?				
GRB 201216A	60–1.2 ks		?		?				

XRT

BAT

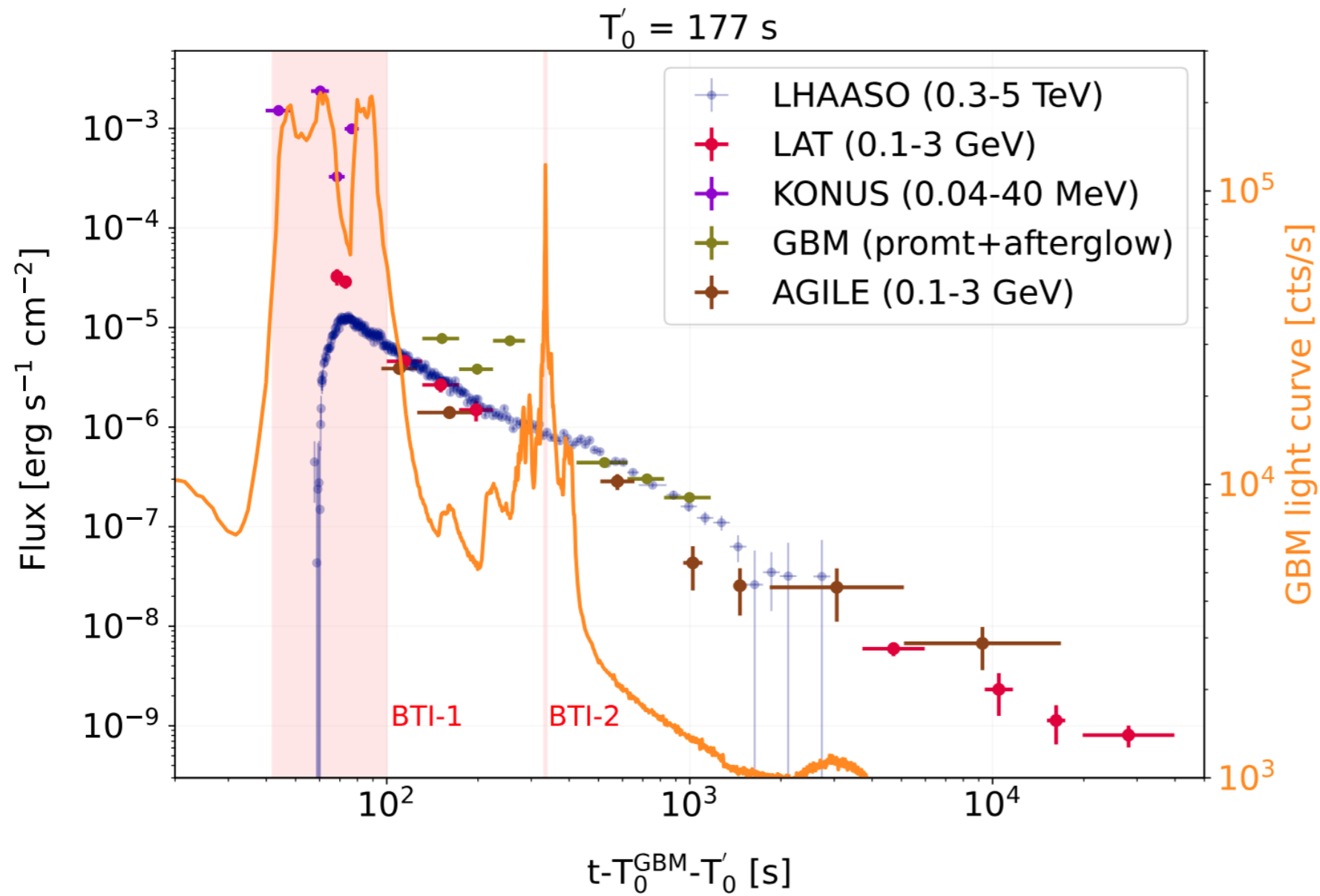
GBM

LAT

IACTs

MAGIC Collaboration:
 Nature v. 575, p. 455–458 (2019) and
 Nature v. 575, p. 459–463 (2019)
 H.E.S.S. collaboration, Nature, 2019
 H.E.S.S. collaboration, Science, 2021
 MAGIC Collaboration, MNRAS, 2024

GRB 221009A - BOAT



LHAASO Collaboration,
Science (2023)

Tavani et al 2023
ApJL 956 L23, 2023

Bissaldi et al 2023

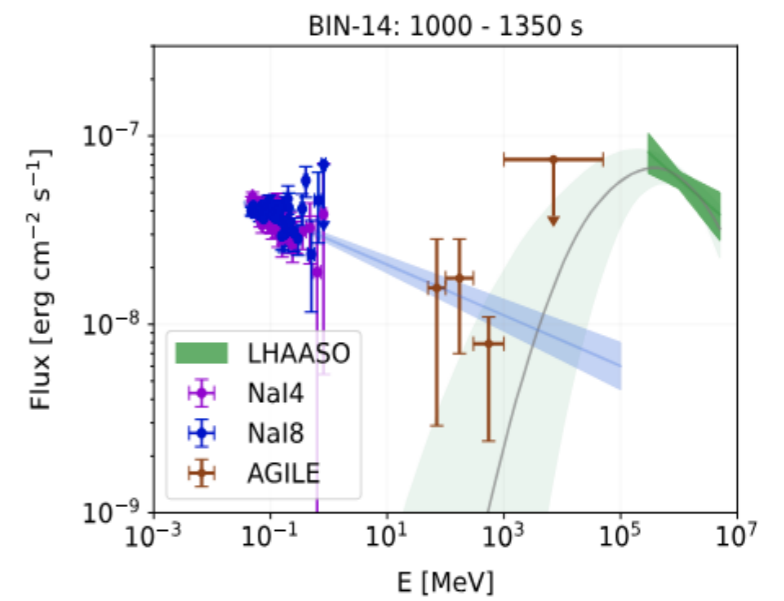
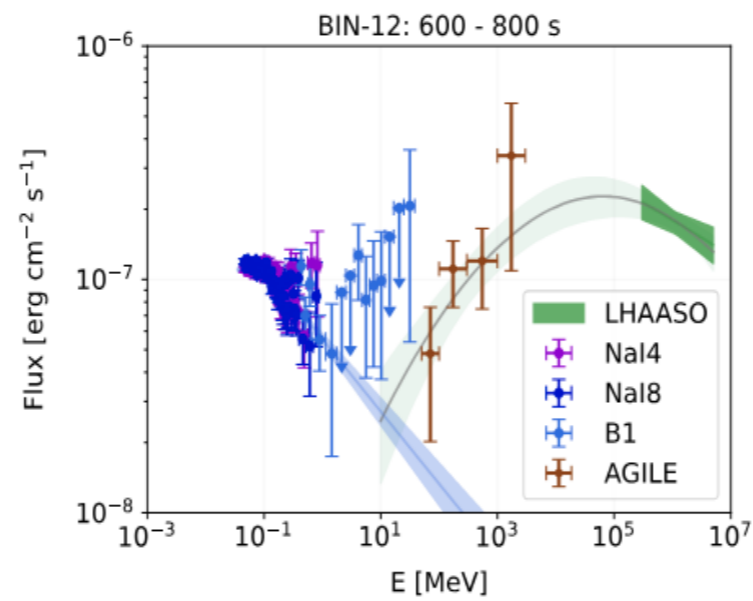
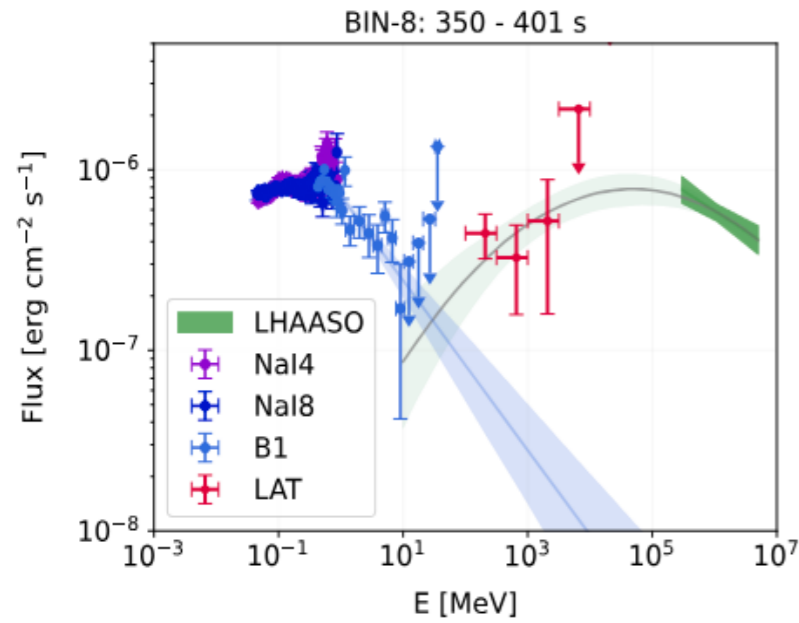
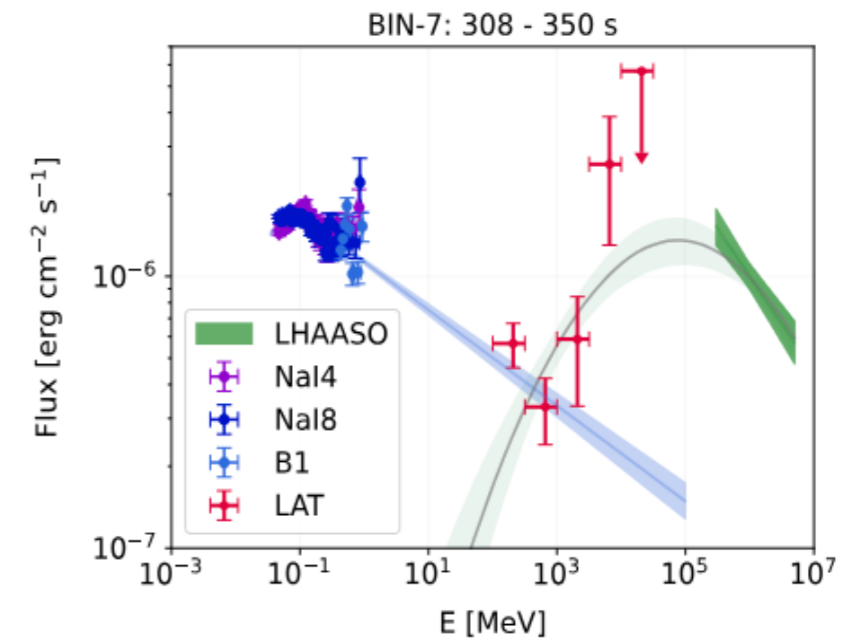
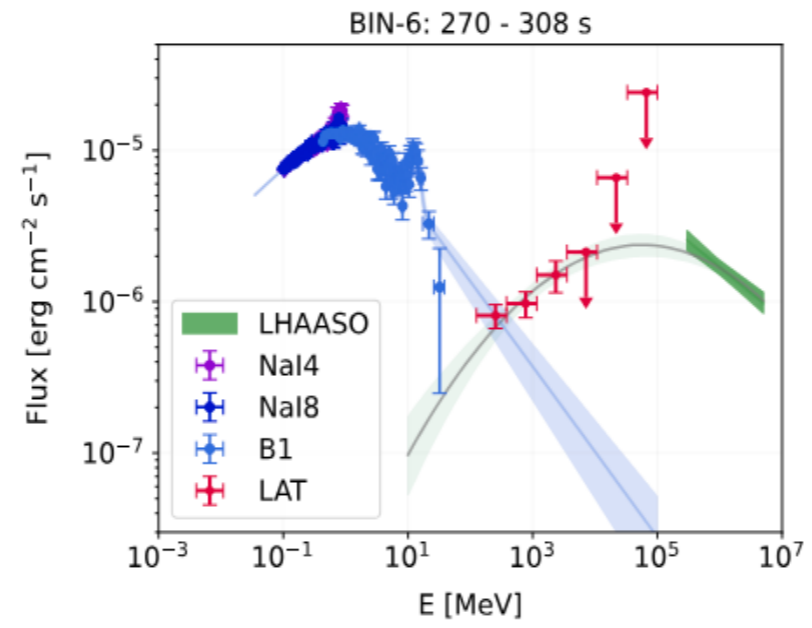
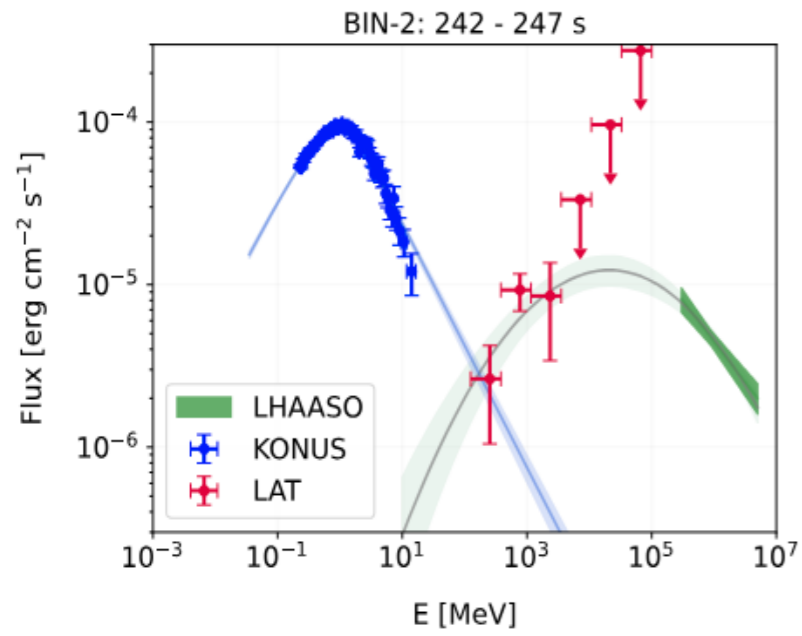
Frederiks et al 2023
ApJL, 949, L7 (2023)

Lesage et al 2023,
ApJL 952 L42

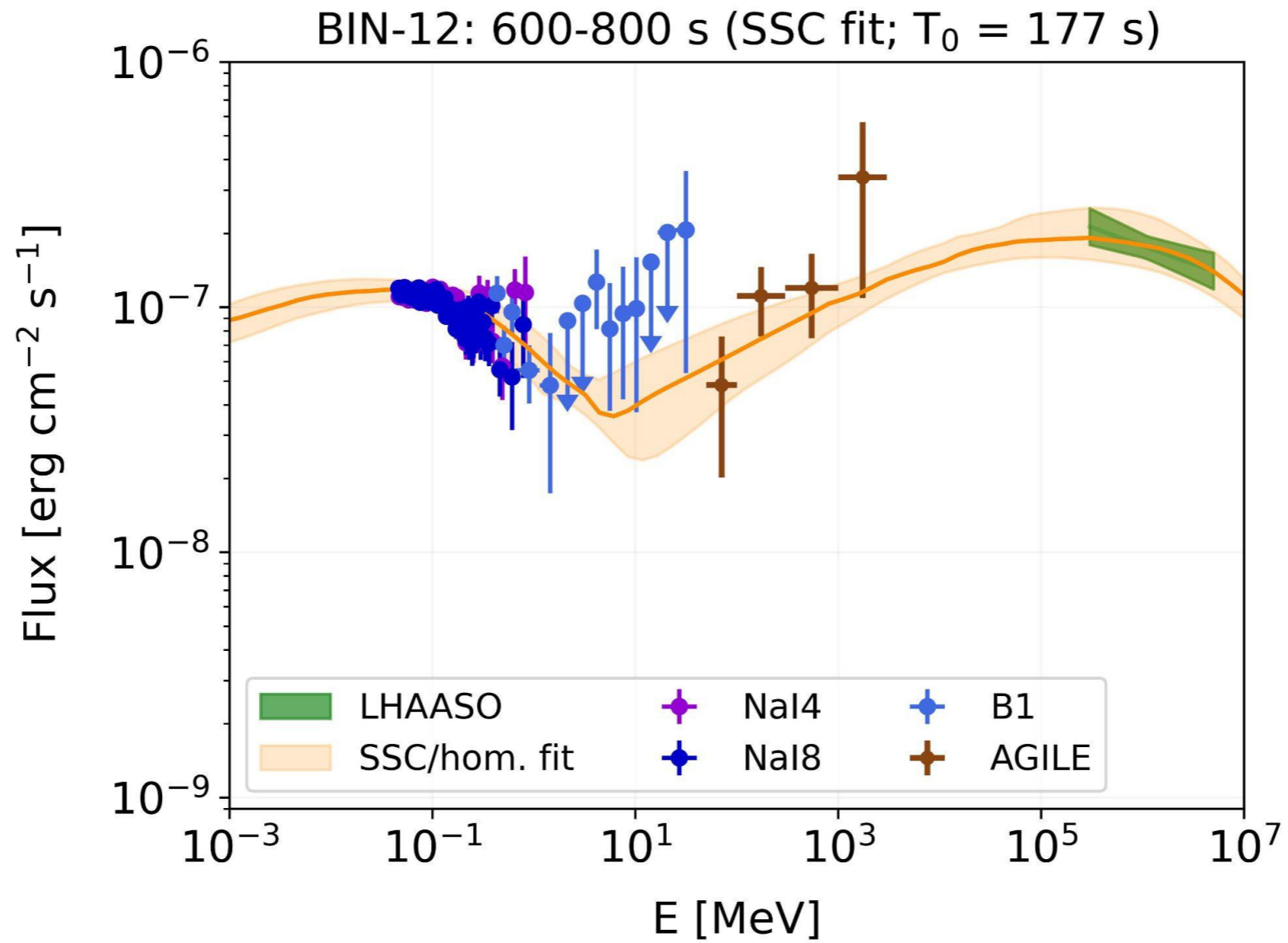
Burns et al 2023,
ApJL 946 L31

Banerjee et al. 2024

GRB 221009A - BOAT



GRB 221009A - BOAT



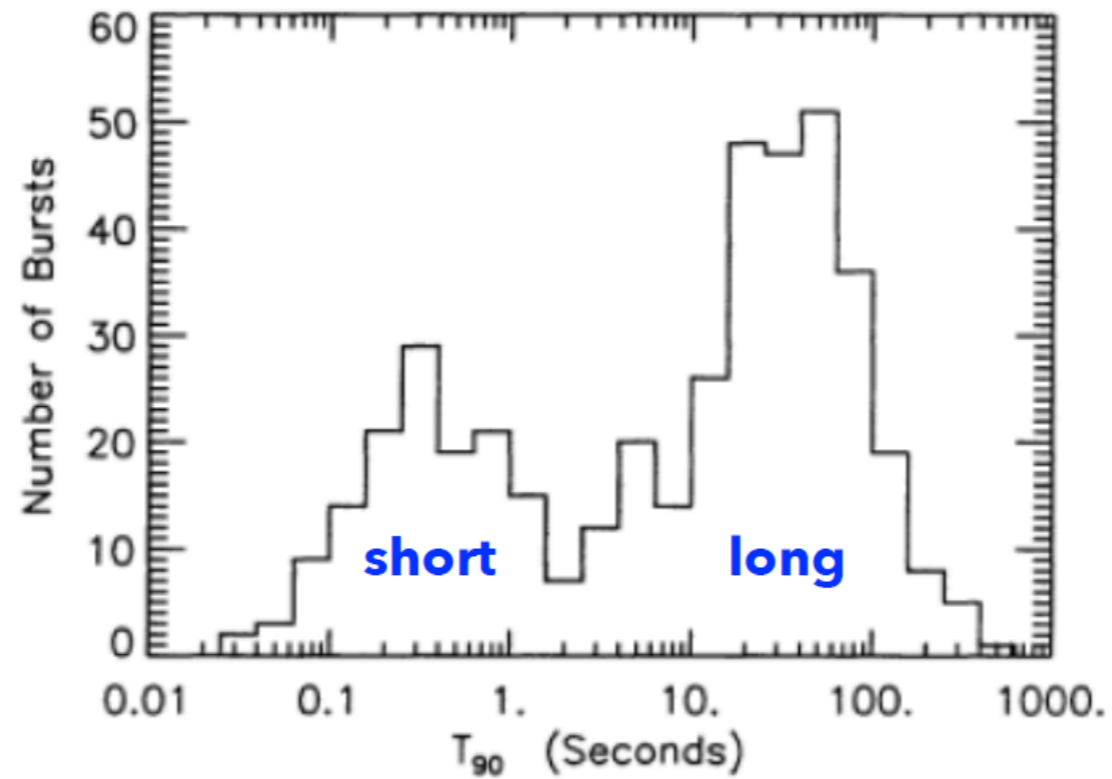
Banerjee et al. 2024

SSC: **LeHaMoC** [Stathopoulos et al 2023](#)

γ -ray bursts

Progenitors

Standard classification



short (<2 s) and long (>2 s)

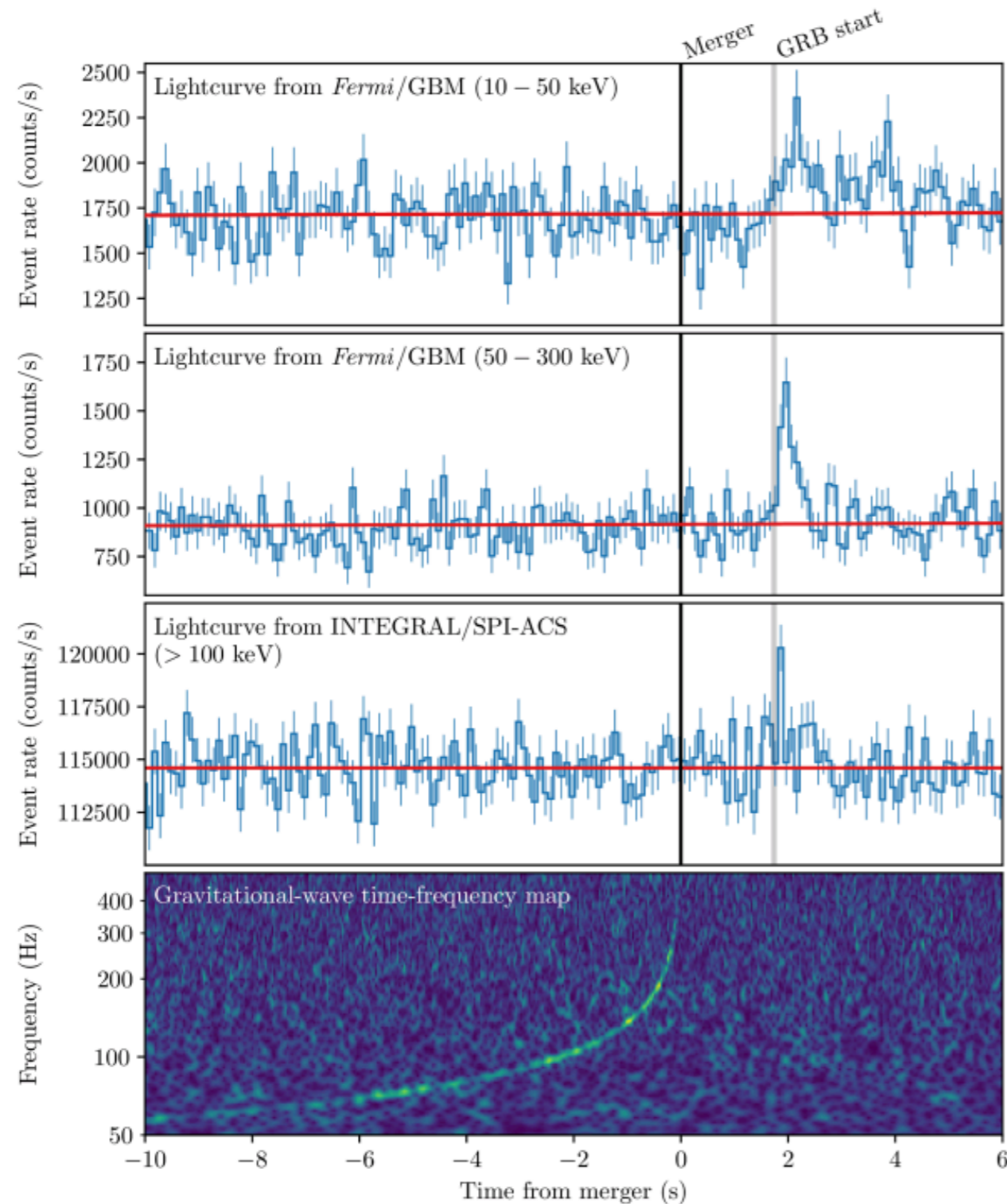
C. Kouveliotou et al. 1993, Meegan et al 1996,
Sakamoto et al. 2011, Paciesas et al 2012

short-hard vs long-soft GRBs

The only GW-GRB joint detection

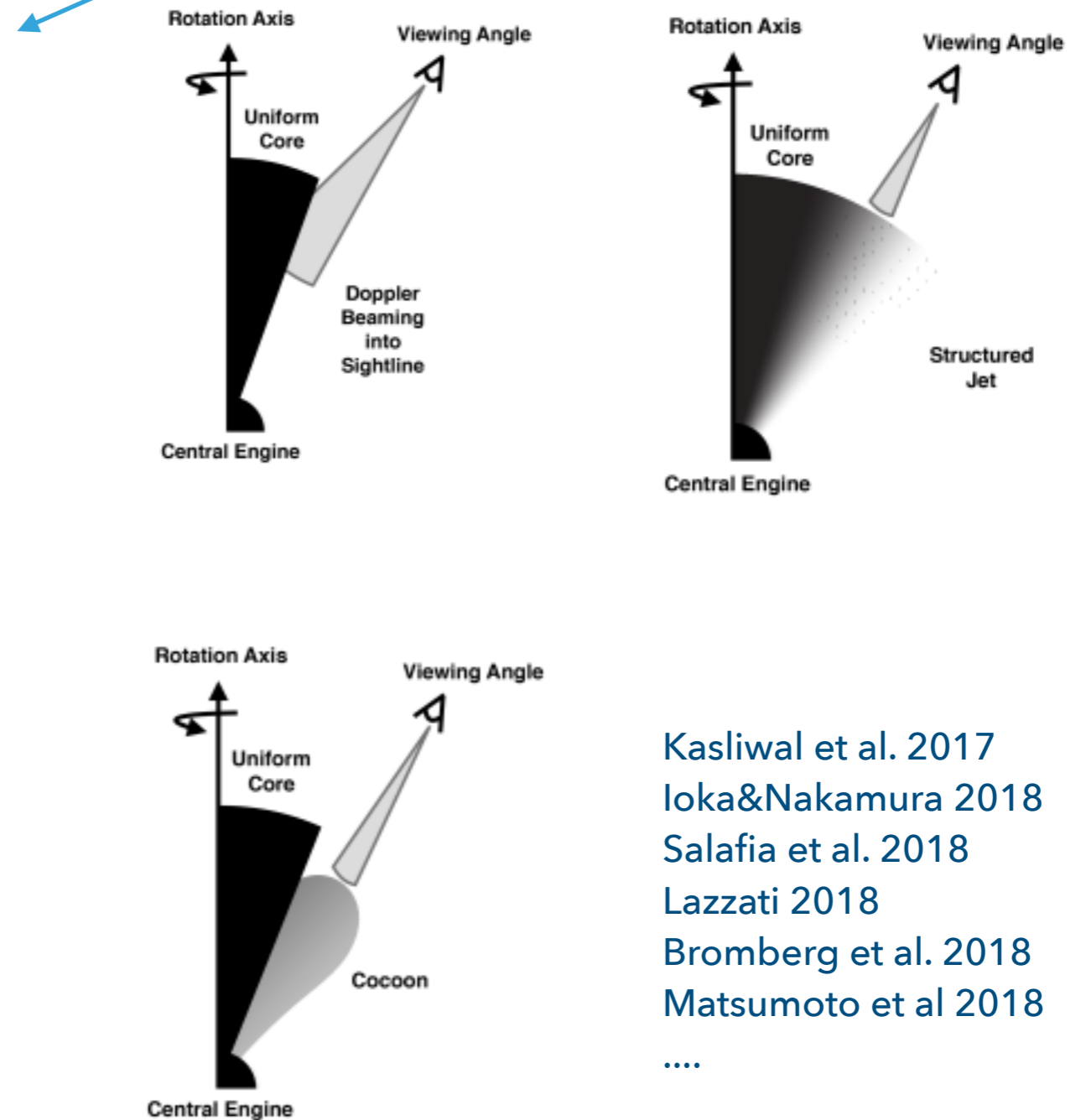
Jet structure: Lipunov et al. 2001; Dai & Gou 2001; Rossi et al. 2002; Zhang & Meszaros 2002

GRB 170817/GW 170817

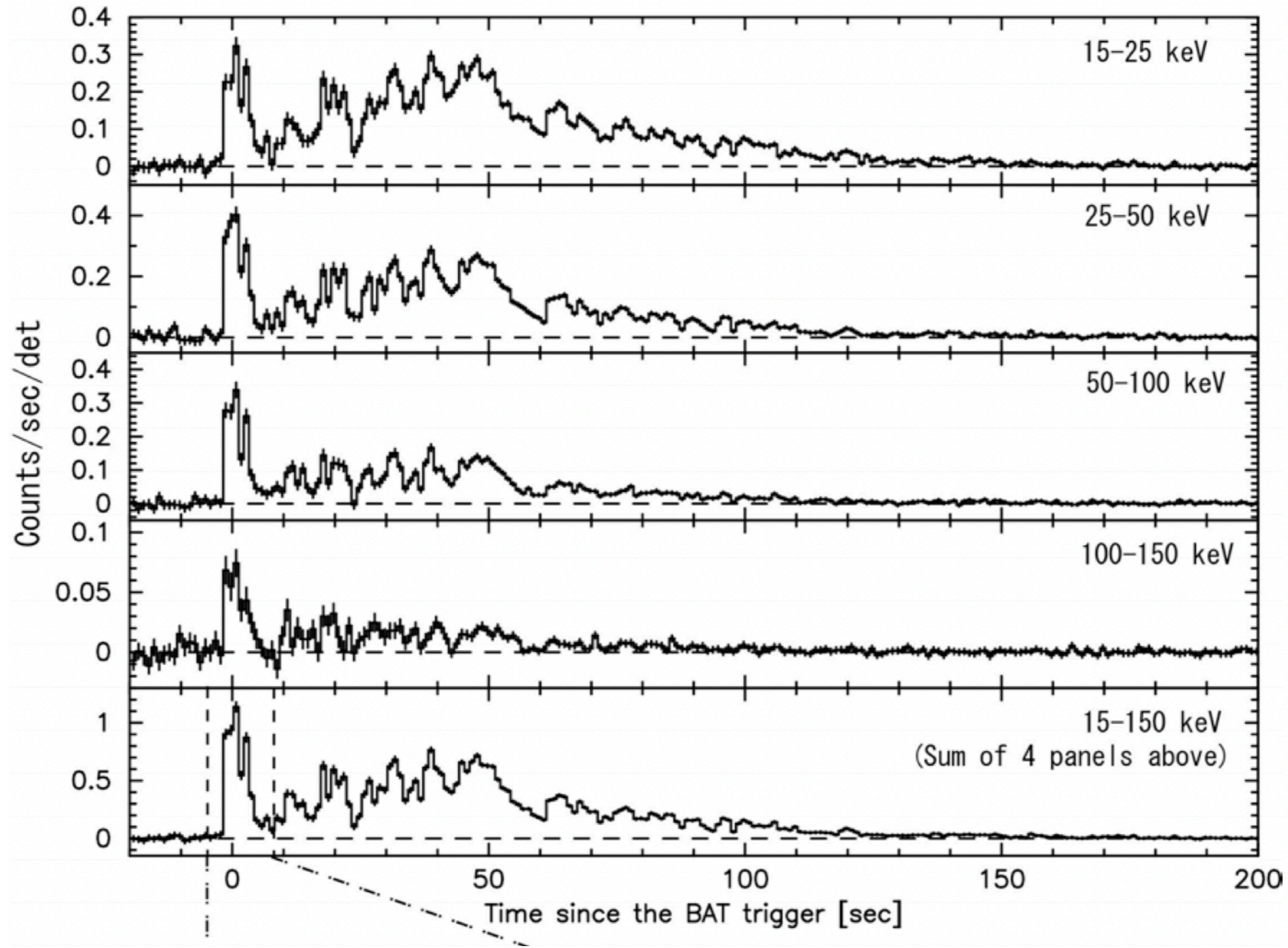


Abbott et al. 2017

What is it?

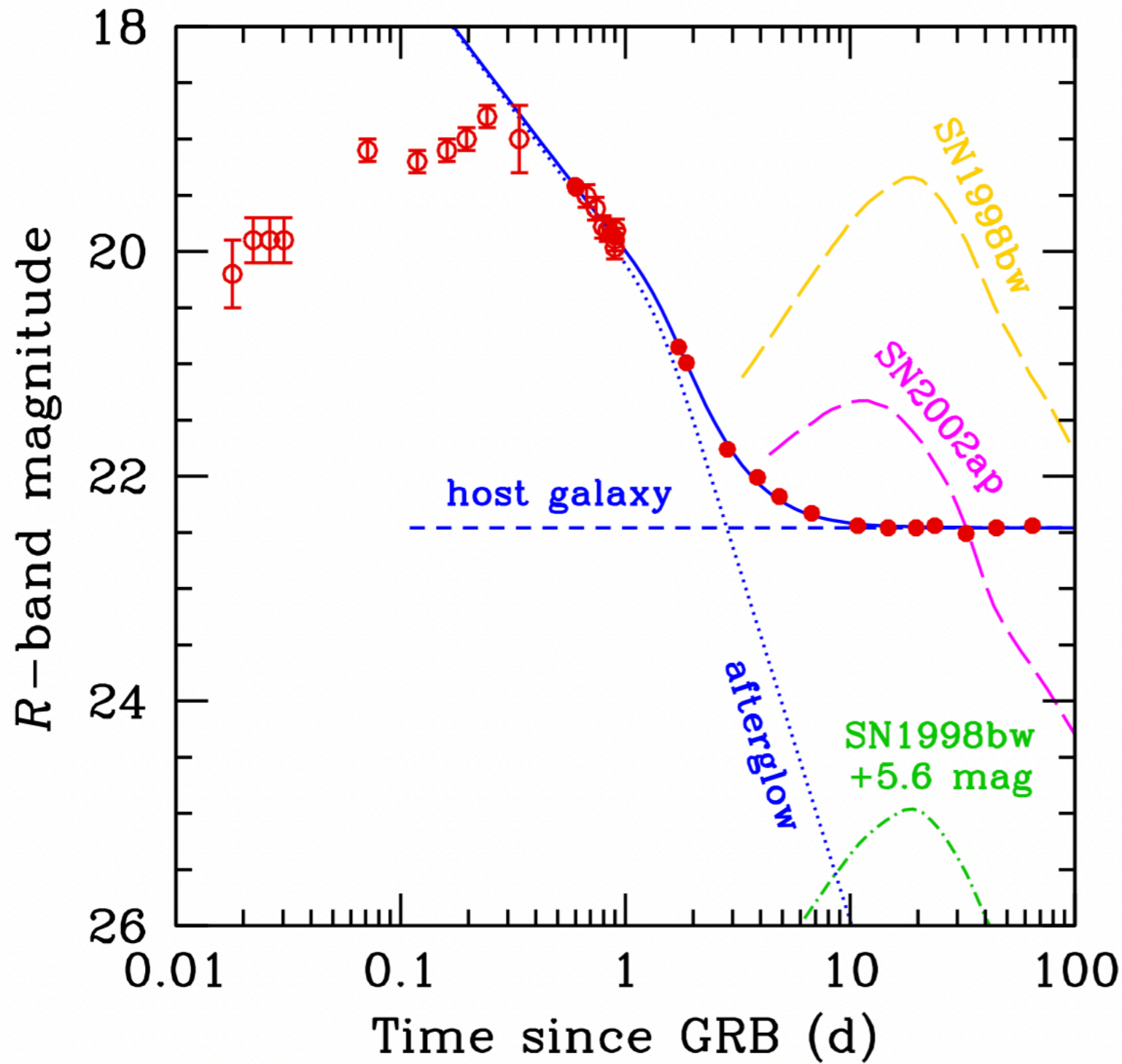


Kasliwal et al. 2017
 Ioka & Nakamura 2018
 Salafia et al. 2018
 Lazzati 2018
 Bromberg et al. 2018
 Matsumoto et al. 2018



Historical example #1

GRB 060614

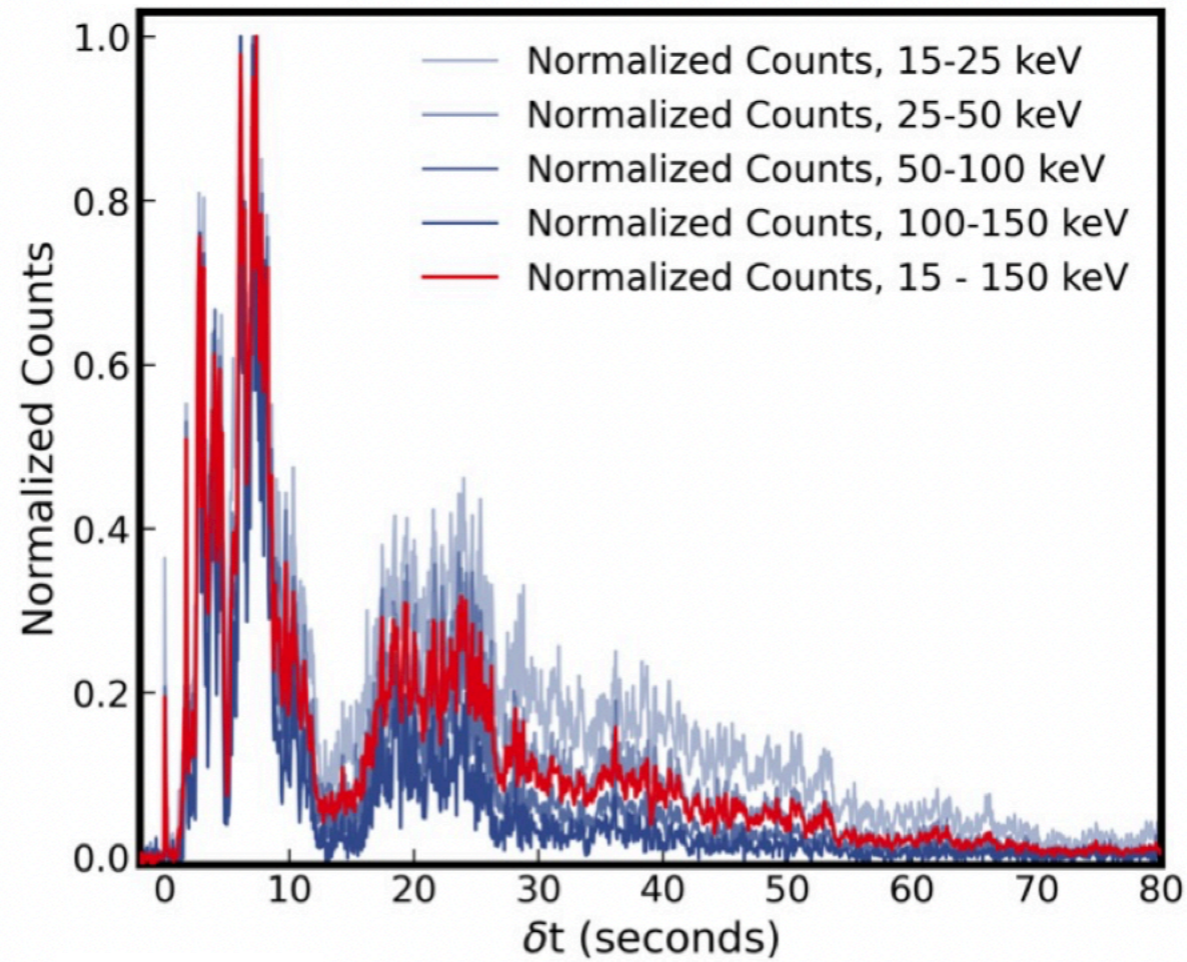


any SN should be x100 fainter

Della Valle et al. 2006, Nature

Gal-Yam et al. 2006, Nature 2006

GRB 211211A: *Swift*/BAT

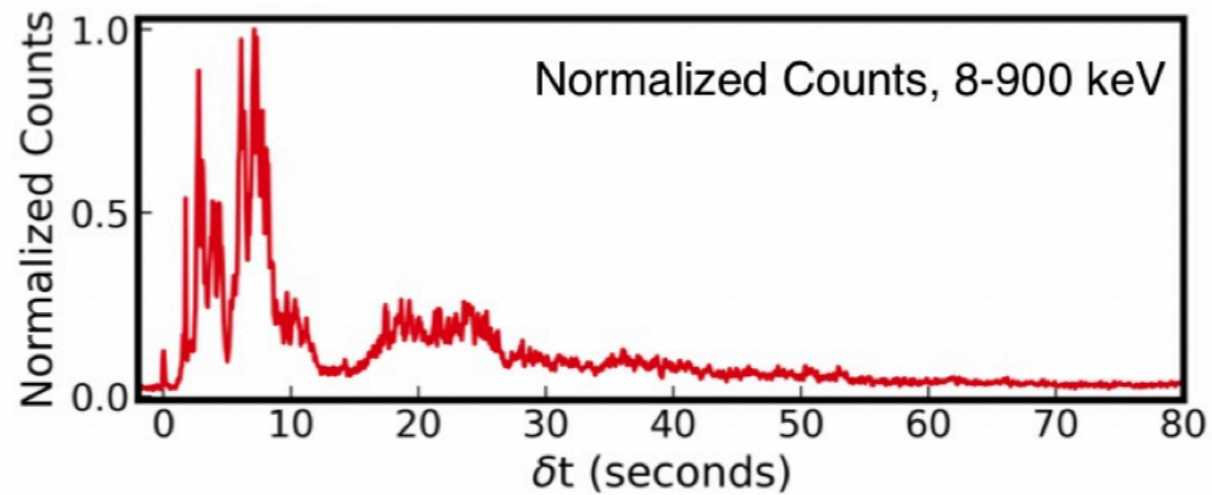


GRB 211211A

T90 ~ 34 s

350 Mpc

GRB 211211A: *Fermi*/GBM

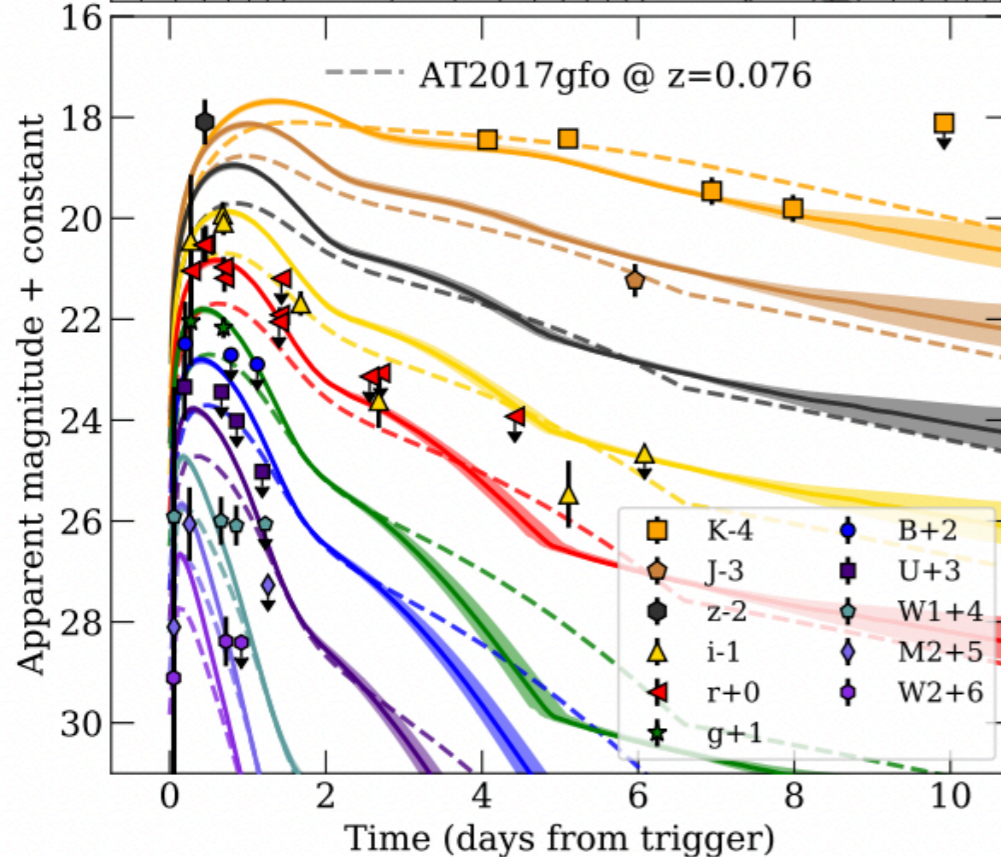
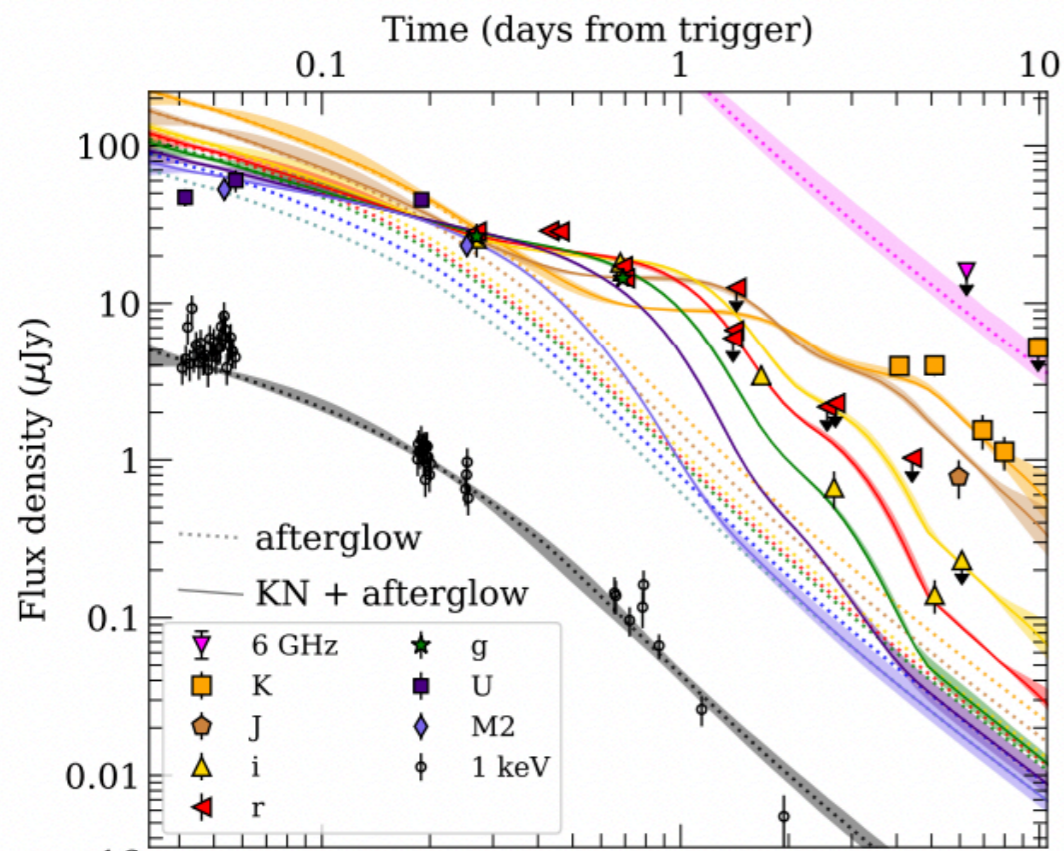


GRB 211211A

350 Mpc

Three-component kilonova fit

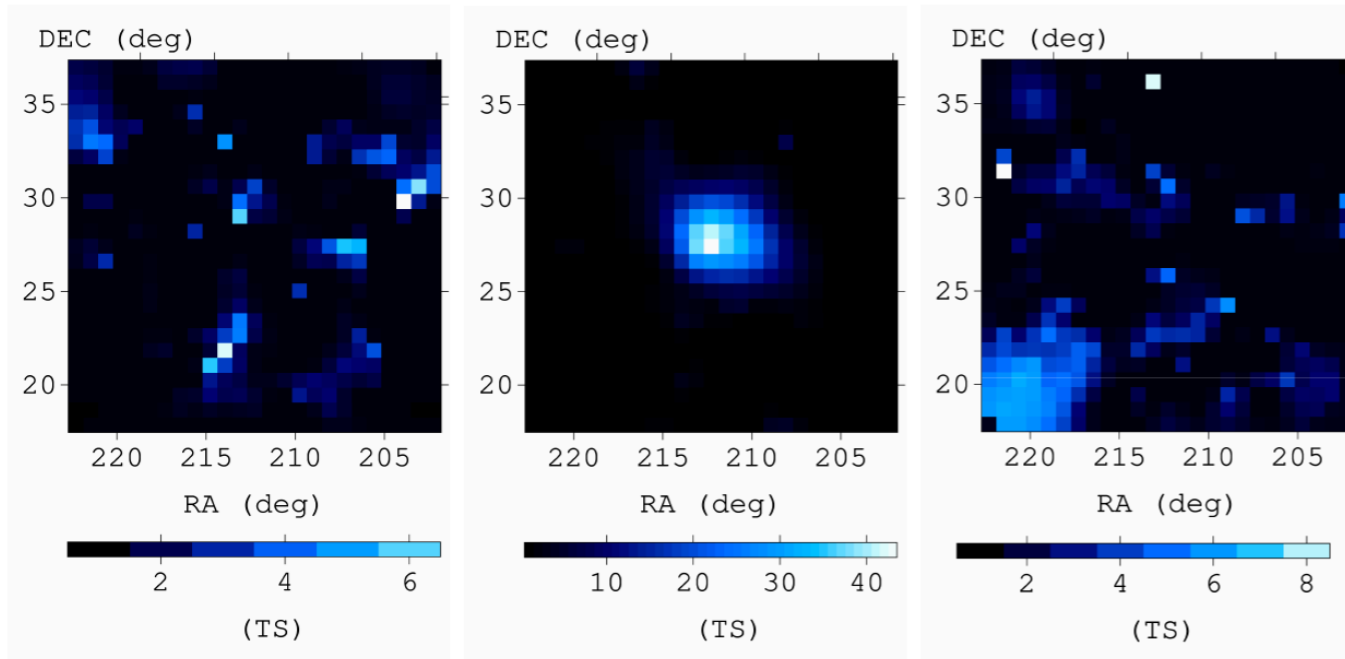
- $M_{ej} = 0.04 \pm 0.02 M_{\odot}$, almost all lanthanide-rich, in reasonable agreement with at2017gfo.
- $v_{ej} \simeq 0.25 - 0.3 c$
- Associated to compact object merger in a binary system, likely BNS



Rastinejad et al. 2022, Nature

GRB 211211A

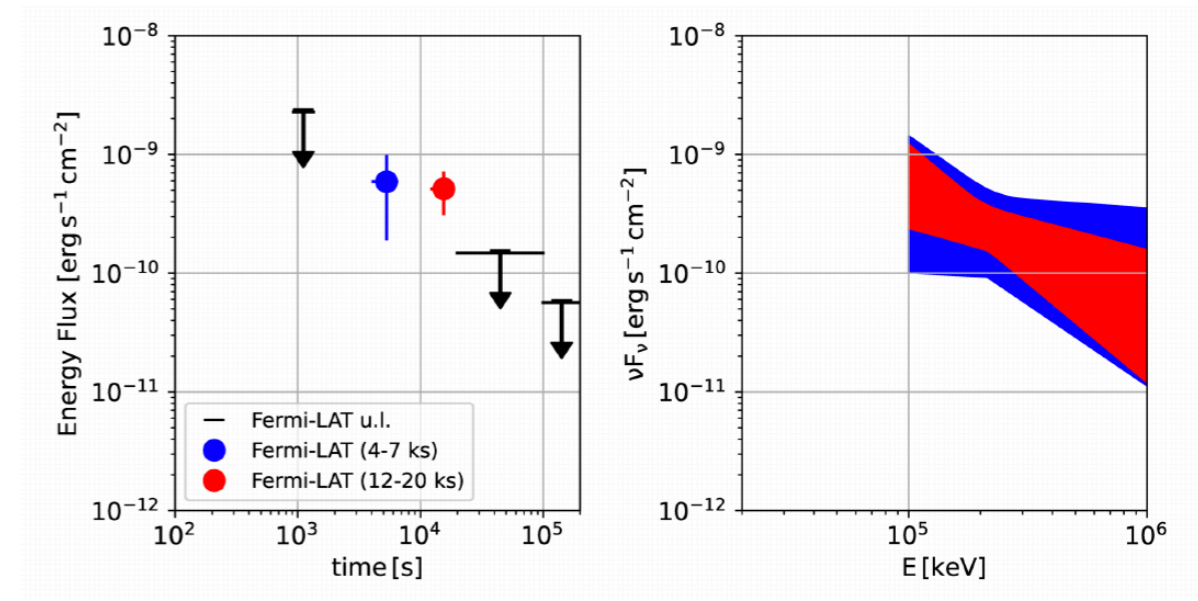
GeV emission



(a) $t_0 - 1$ d to t_0

(b) t_0 to $t_0 + 20$ ks

(c) $t_0 + 1$ d to $t_0 + 2$ d



(d) t_0 to $t_0 + 2$ d

Mei et al. 2022, Nature

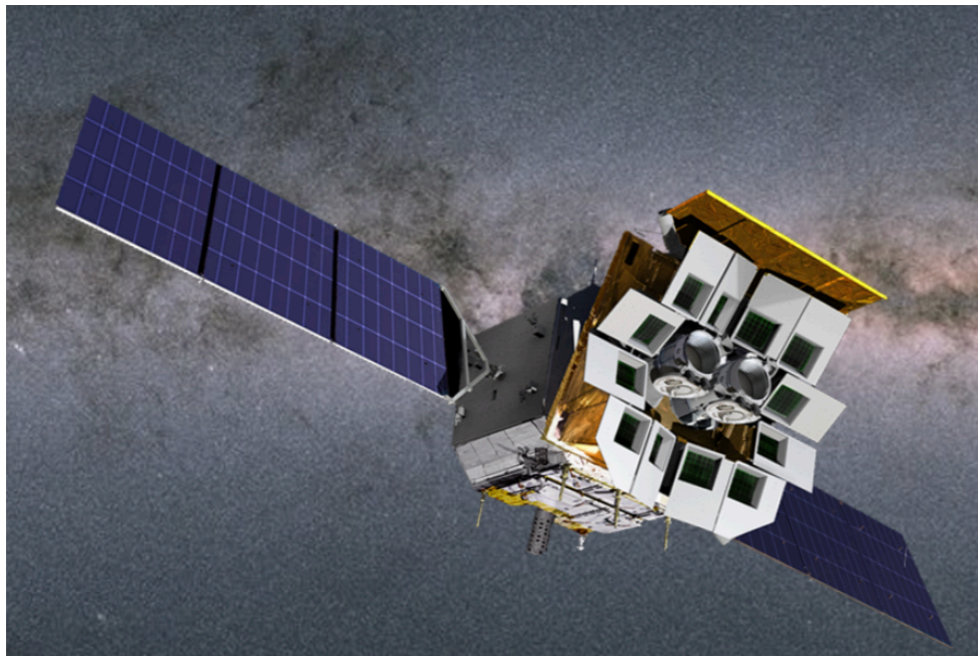
GRB	band	$T_{90}(s)$	$T_{50}(s)$	$D_L(Mpc)$	kilonova
060614	15-350 keV	106	43	590	hint (Yang et al. 2015)
060505	15-350 keV	4		409	hint? (Jin et al. 2021, arXiv)
111005A	15-350 keV	26	11	57	-
191019A	15-350 keV	64	30	1260	-
211211A	50-300 KeV	34	15	350	yes (Rastinejad et al. 2022)
230707A	50-300 KeV	30	13	294	yes (Levan et al. 2024)

γ -ray bursts

Future

Future/now

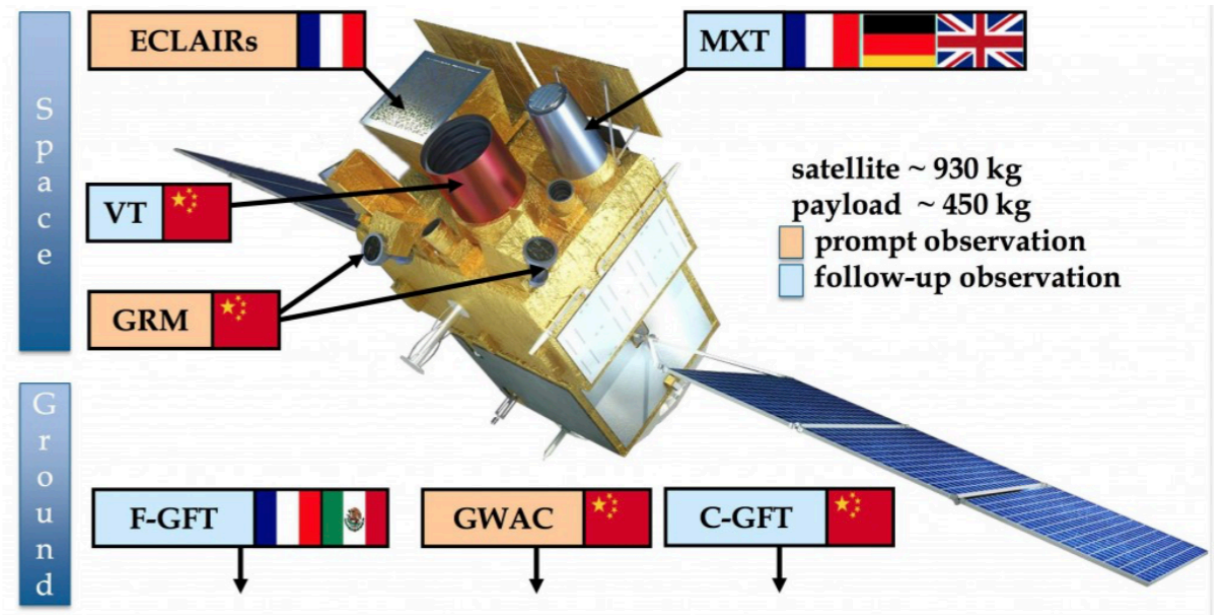
Einstein Probe



0.5-4 keV

Lobster-eye Angel 1979

SVOM

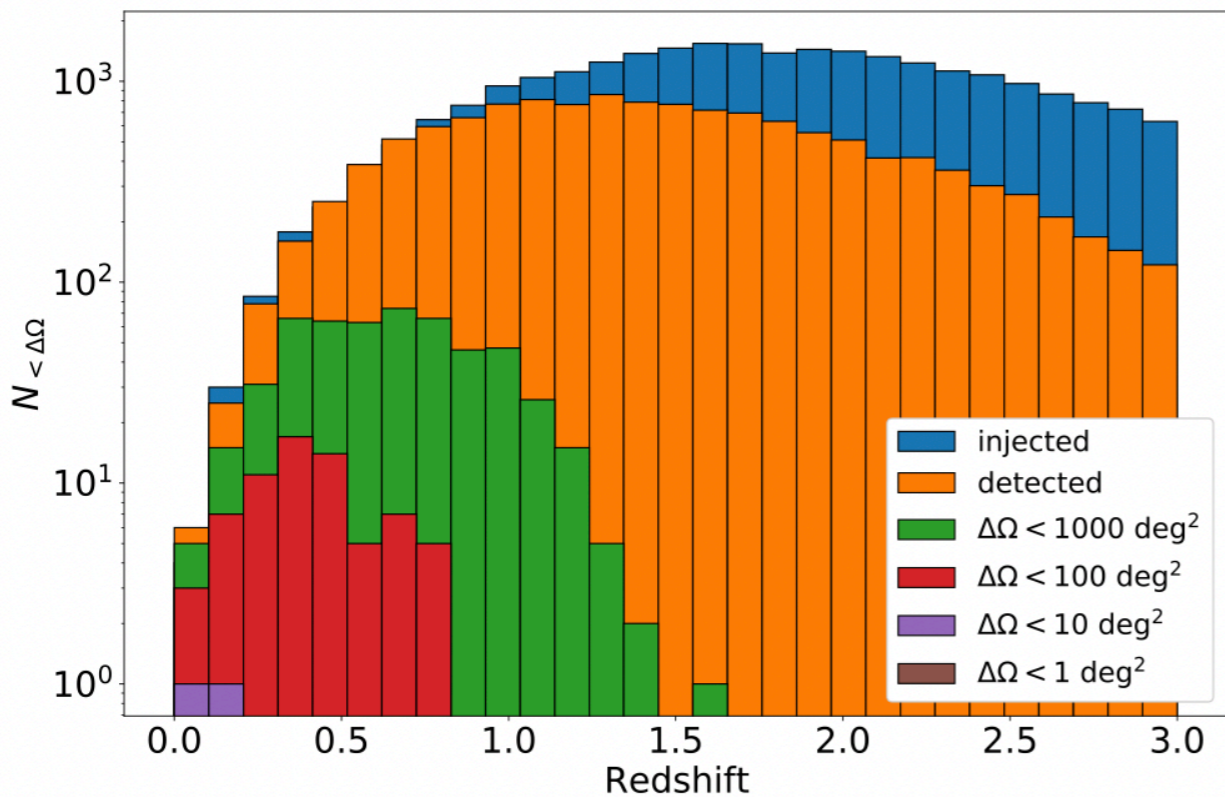


ECLAIRs > 4 keV

gravitational waves

high freq.

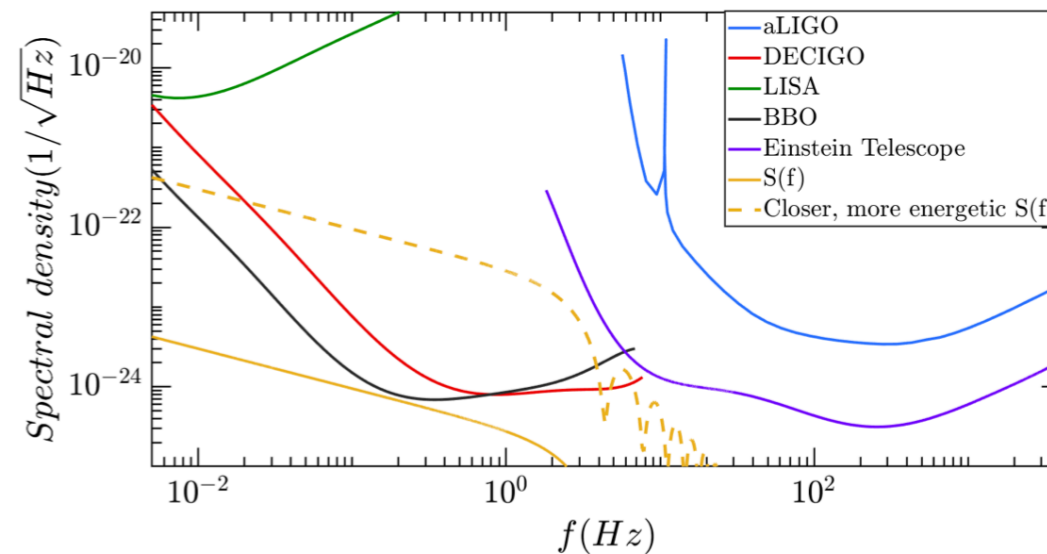
Einstein Telescope, v.a. < 15 deg



Ronchini et al. 2022

low freq.

Jet GWs



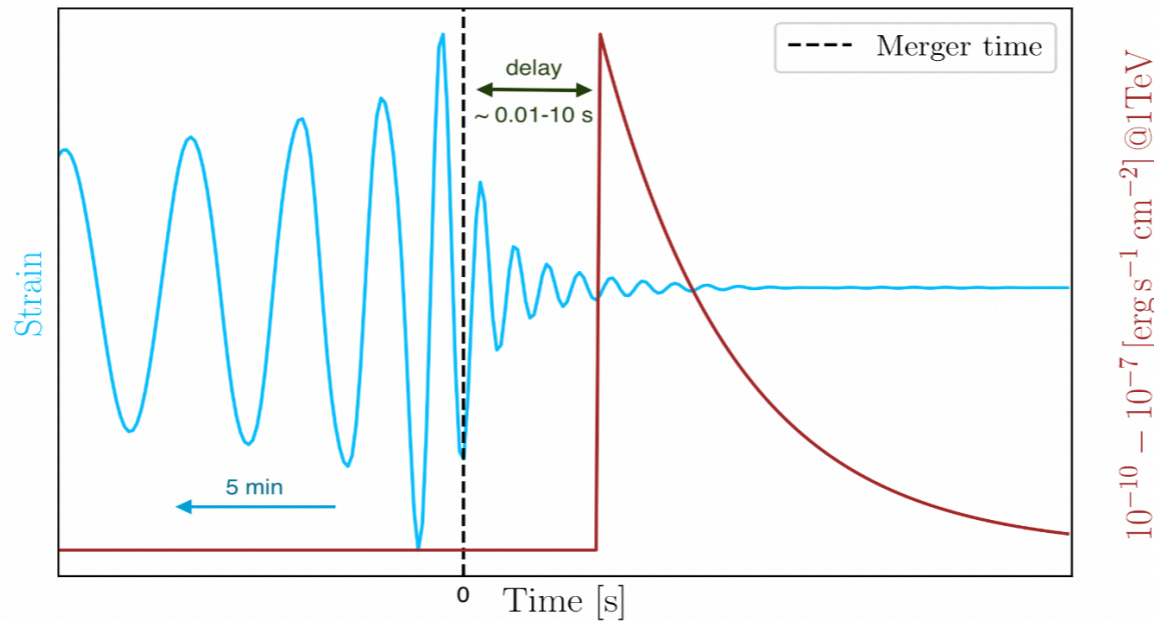
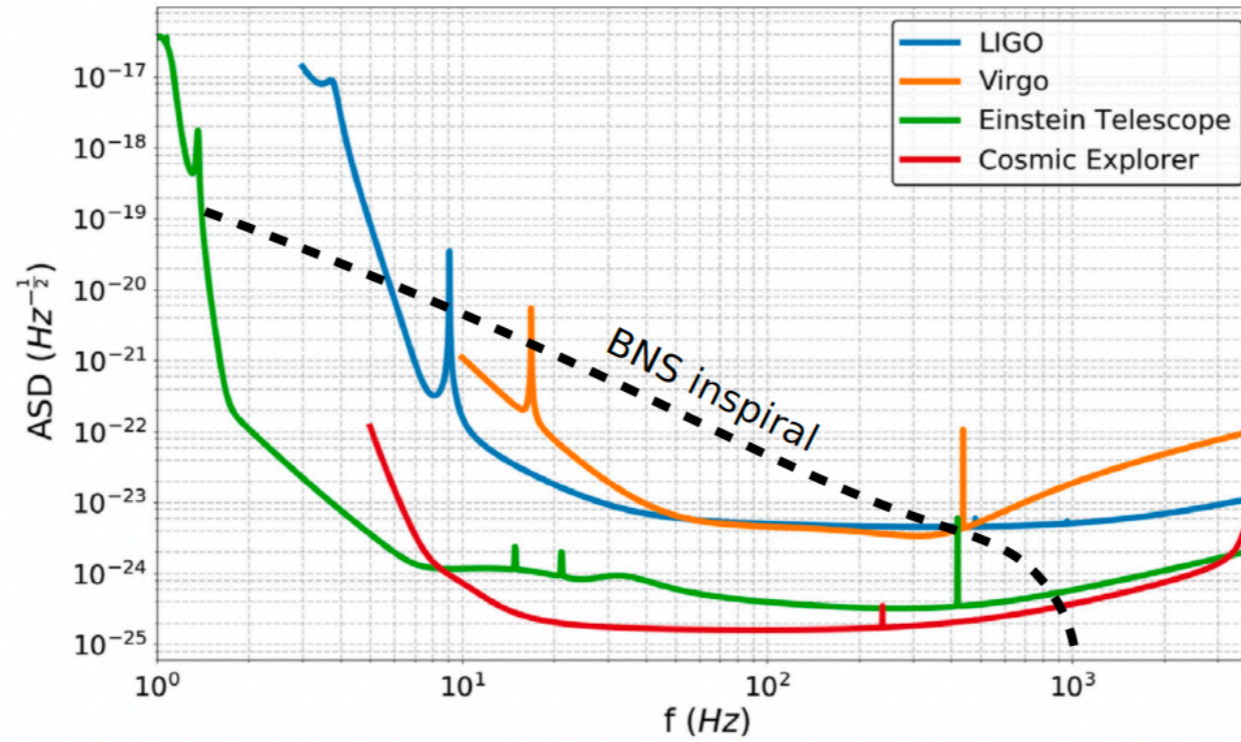
Leiderschneider & Piran 2022

Segalis & Ori 2001

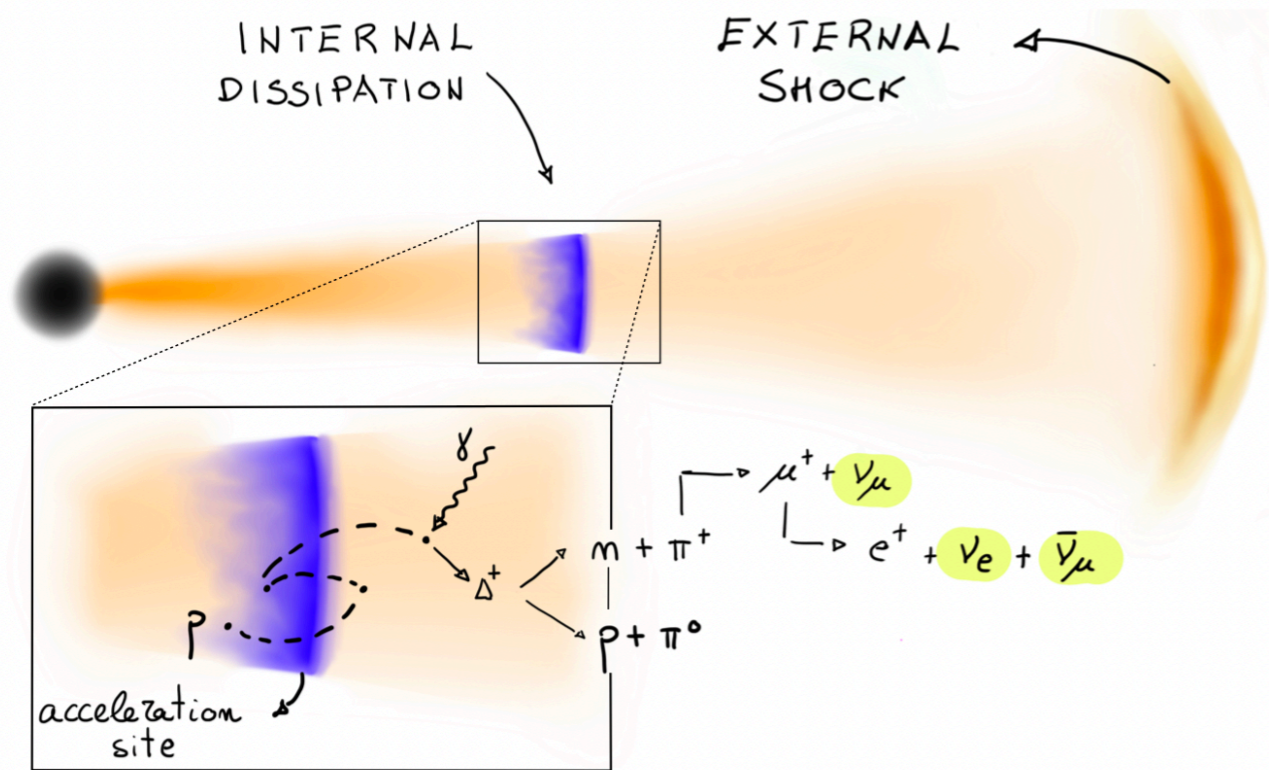
accretion-to-jet efficiency Salafia & Giacomazzo 2021

jet dissipation > jet core Ascenzi et al. 2020,
Duque et al. 2022

short GRBs & gravitational waves

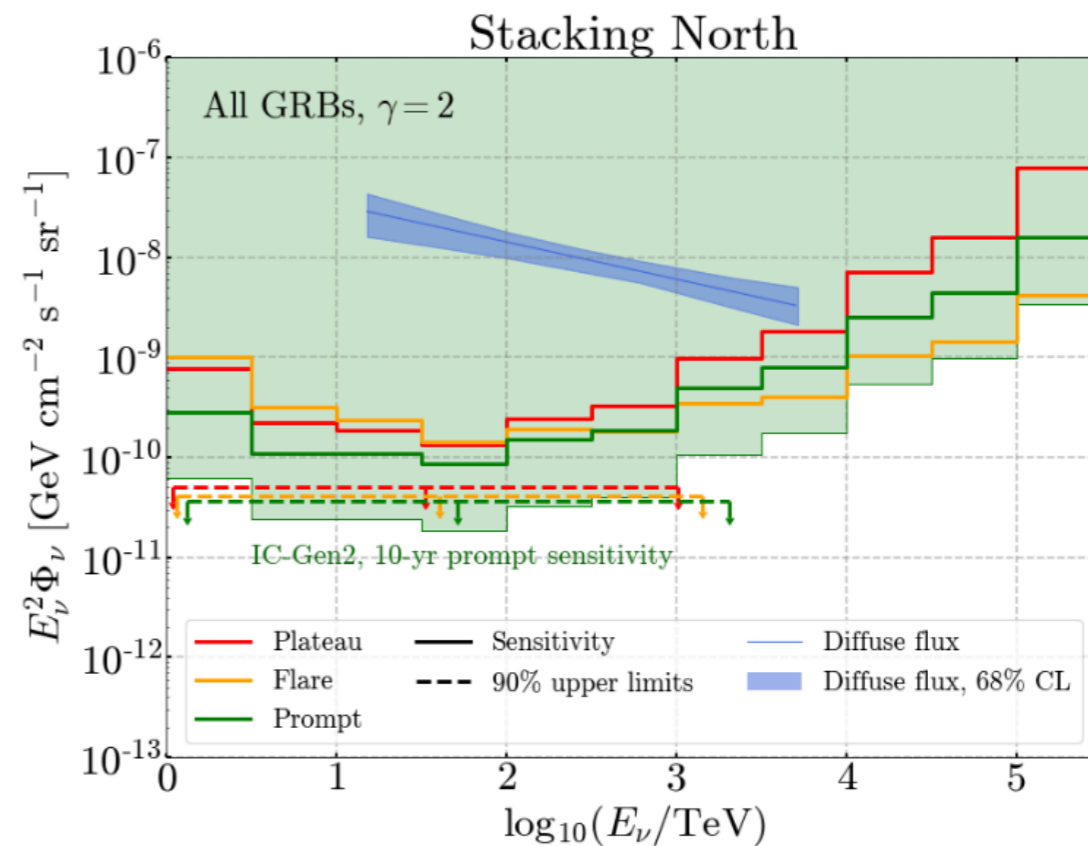


Banerjee et al. 2023



Paczynski & Xu 1994

Waxman & Bahcall 1997



Lucarelli et al. 2023

collisional heating

Beloborodov 2010, Vurm et al. 2011



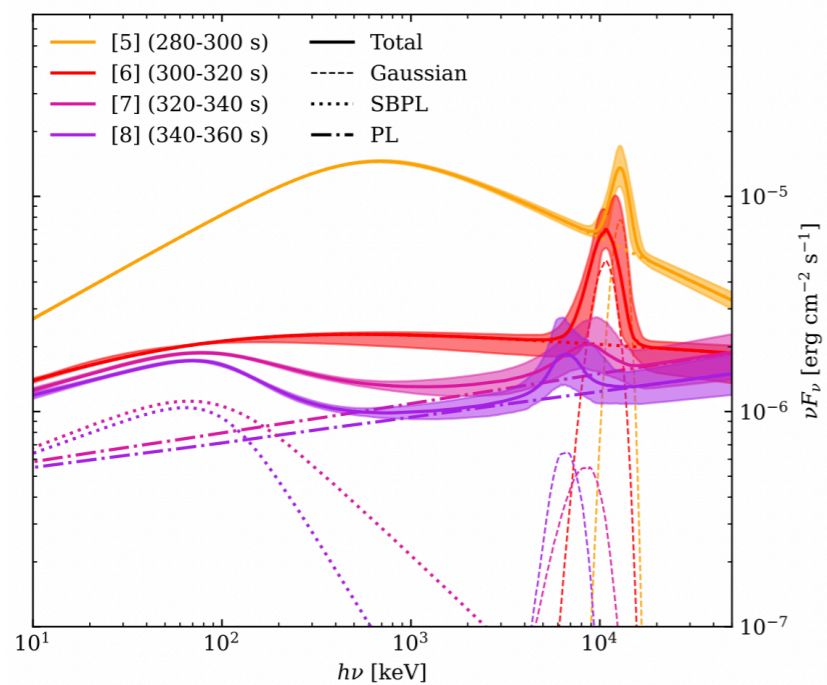
Zegarelli et al. 2022

γ -ray bursts

Summary

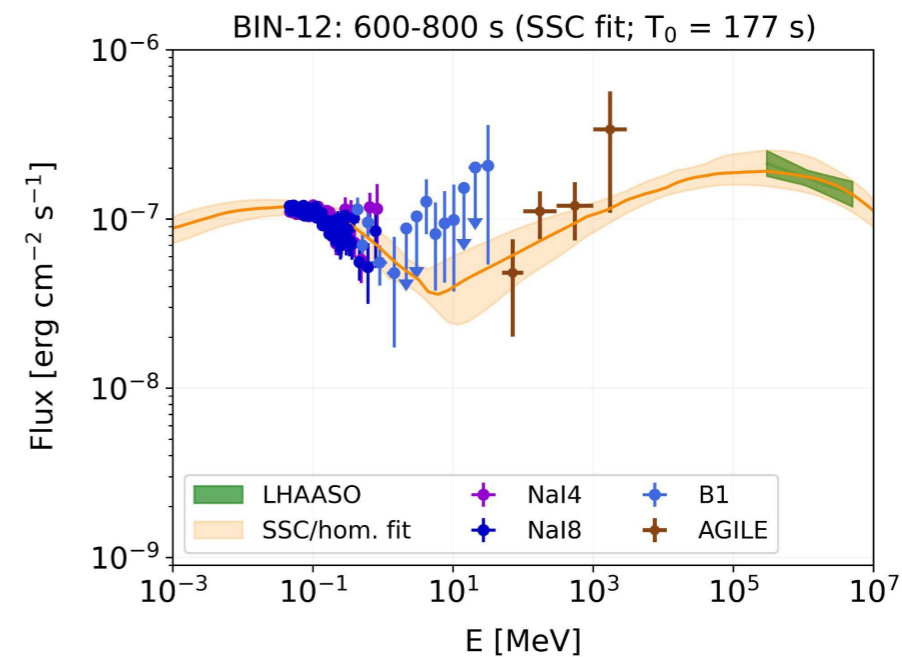
γ -ray burst

MeV line



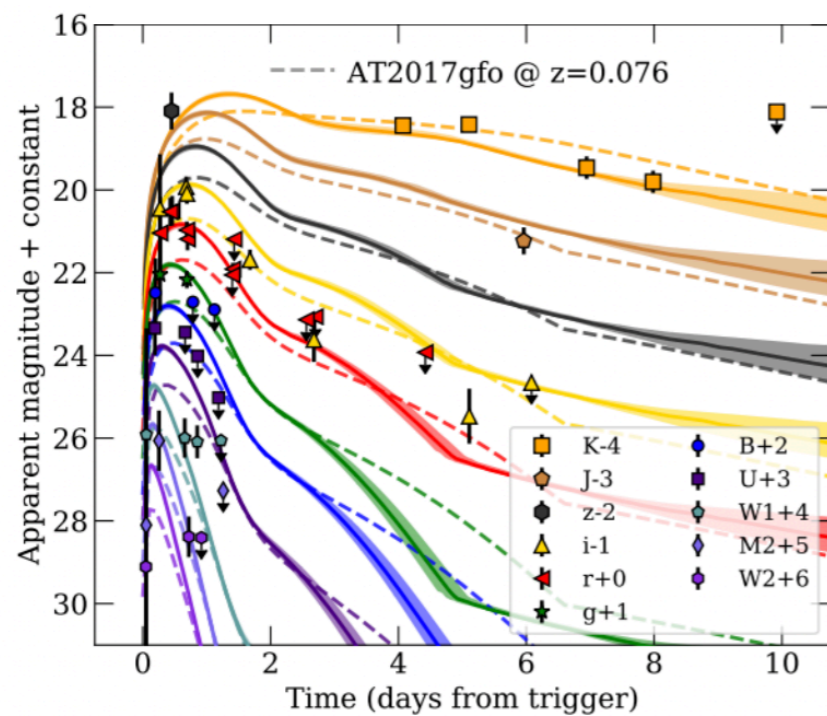
afterglow

laboratory for relativistic shocks



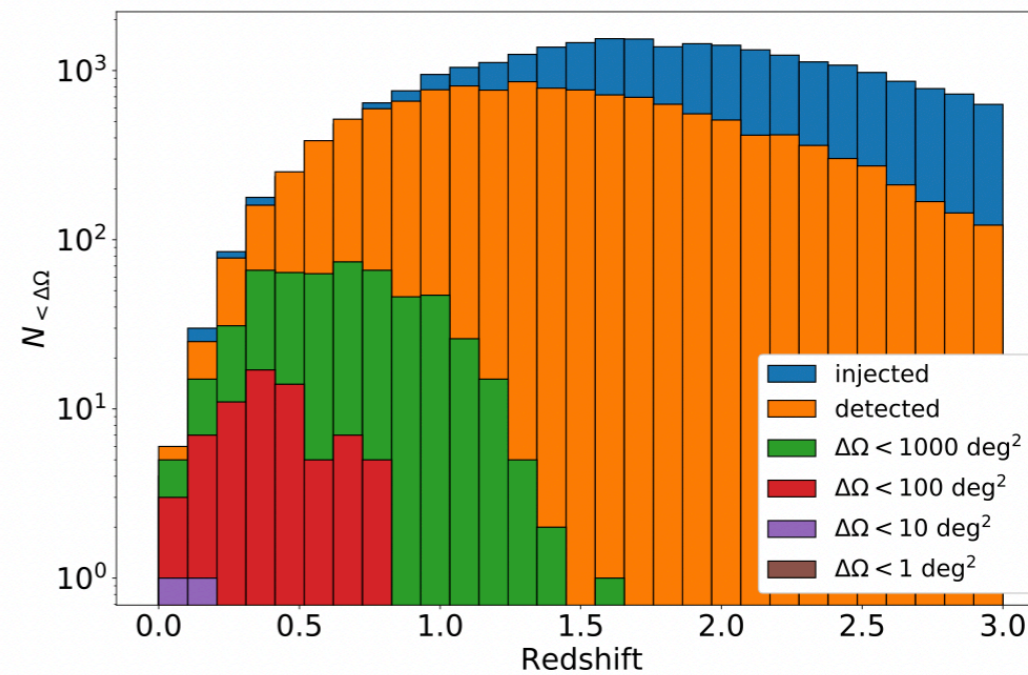
progenitors

odd GRBs



gravitational waves

future 3 gen. GW ET



Thank you!