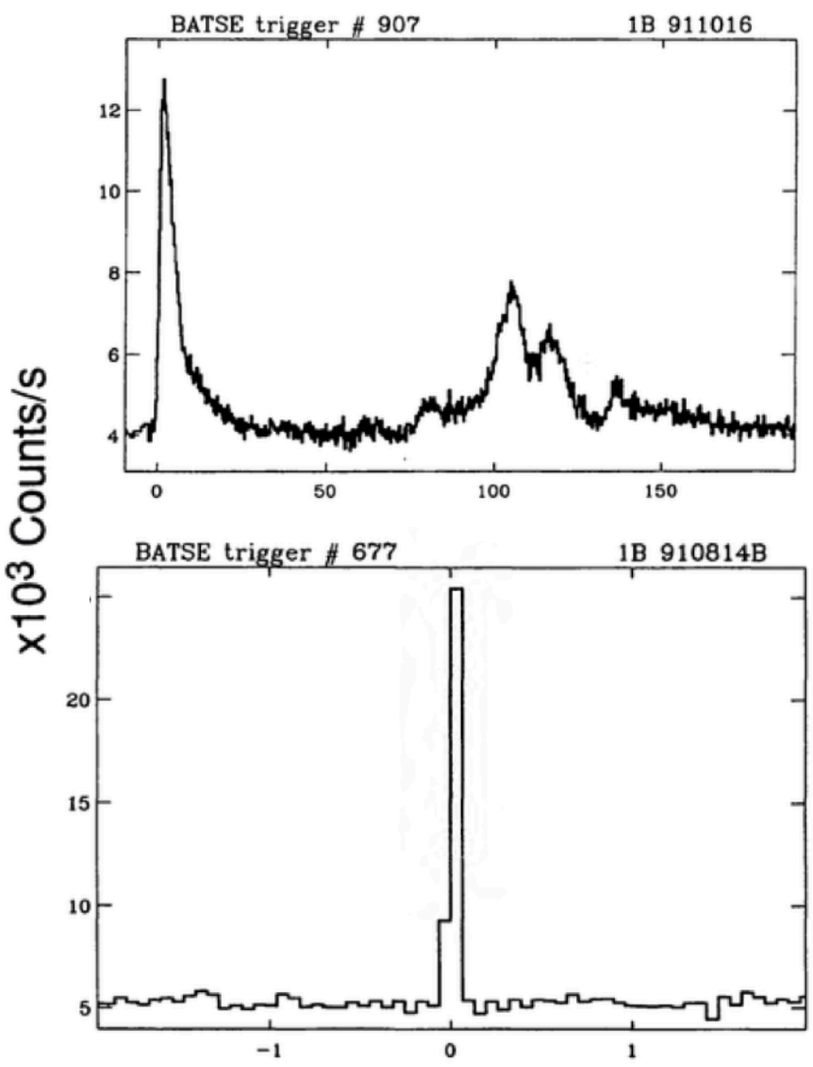
Catch me if you can

brief optical flashes from γ-ray bursts and gravitational wave sources

Gor Oganesyan

Expanding Horizons in Italy, 15 May 2025

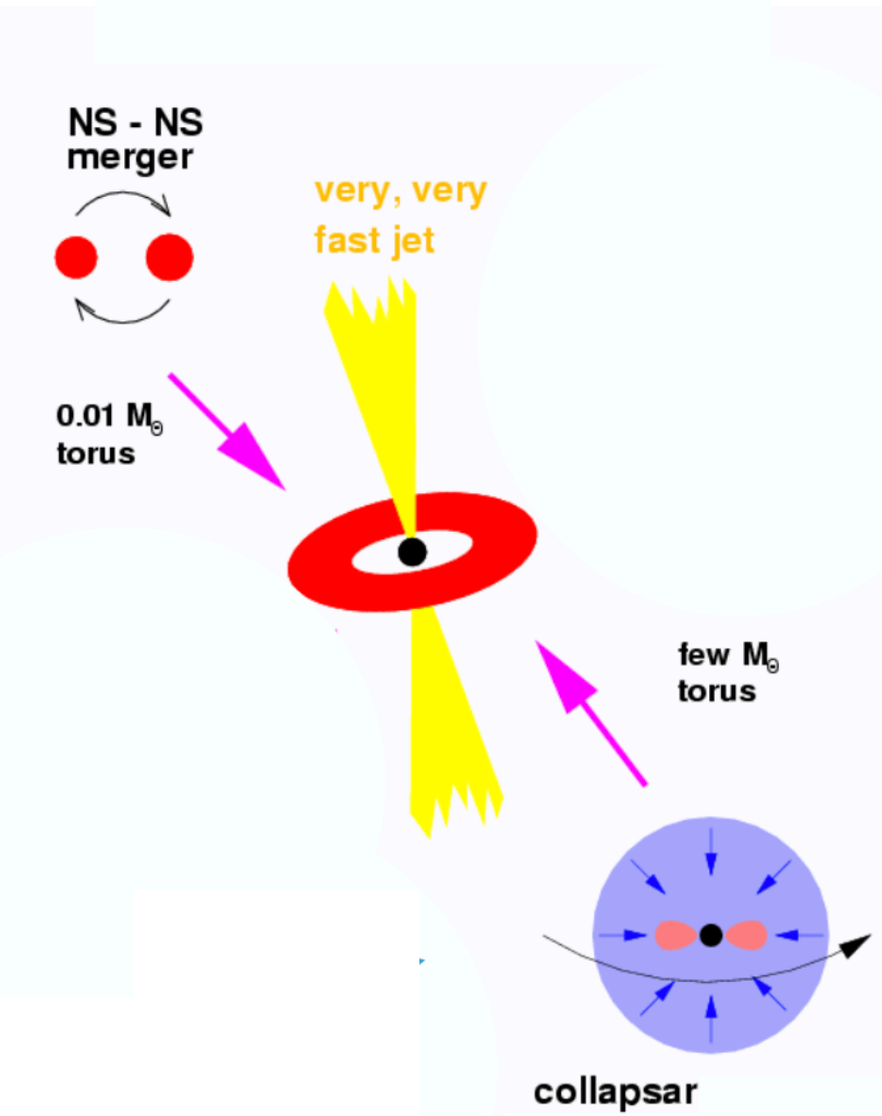


$$\epsilon_\gamma \sim (0.1 - 1)\,\mathrm{MeV}$$

$$E \sim (0.1 - 1)\,M_\odot c^2$$

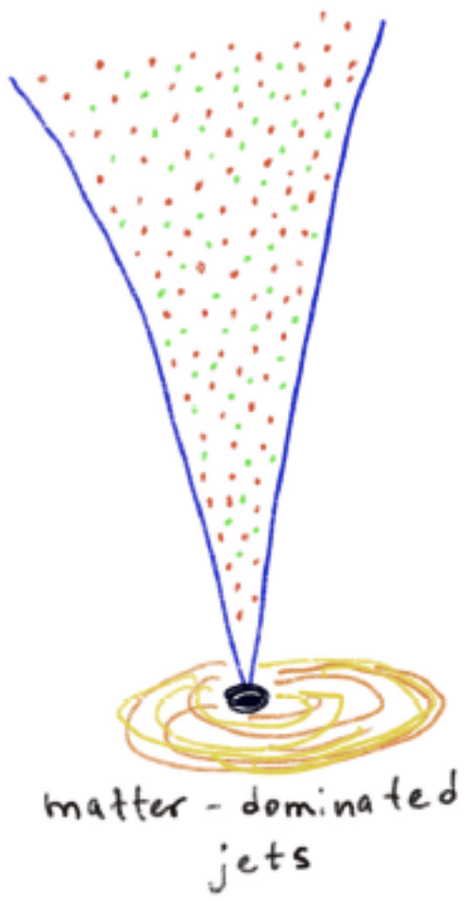
$$T \sim 1 - 100\,s$$

$$\delta T \sim 10\,ms - 1\,s$$

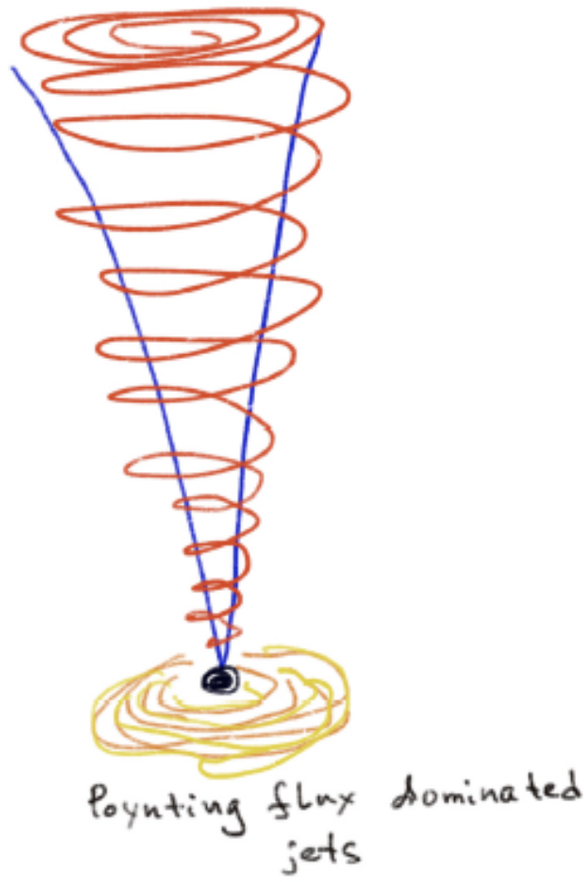


BATSE, Fishman et al. 1994

GRB conundrum

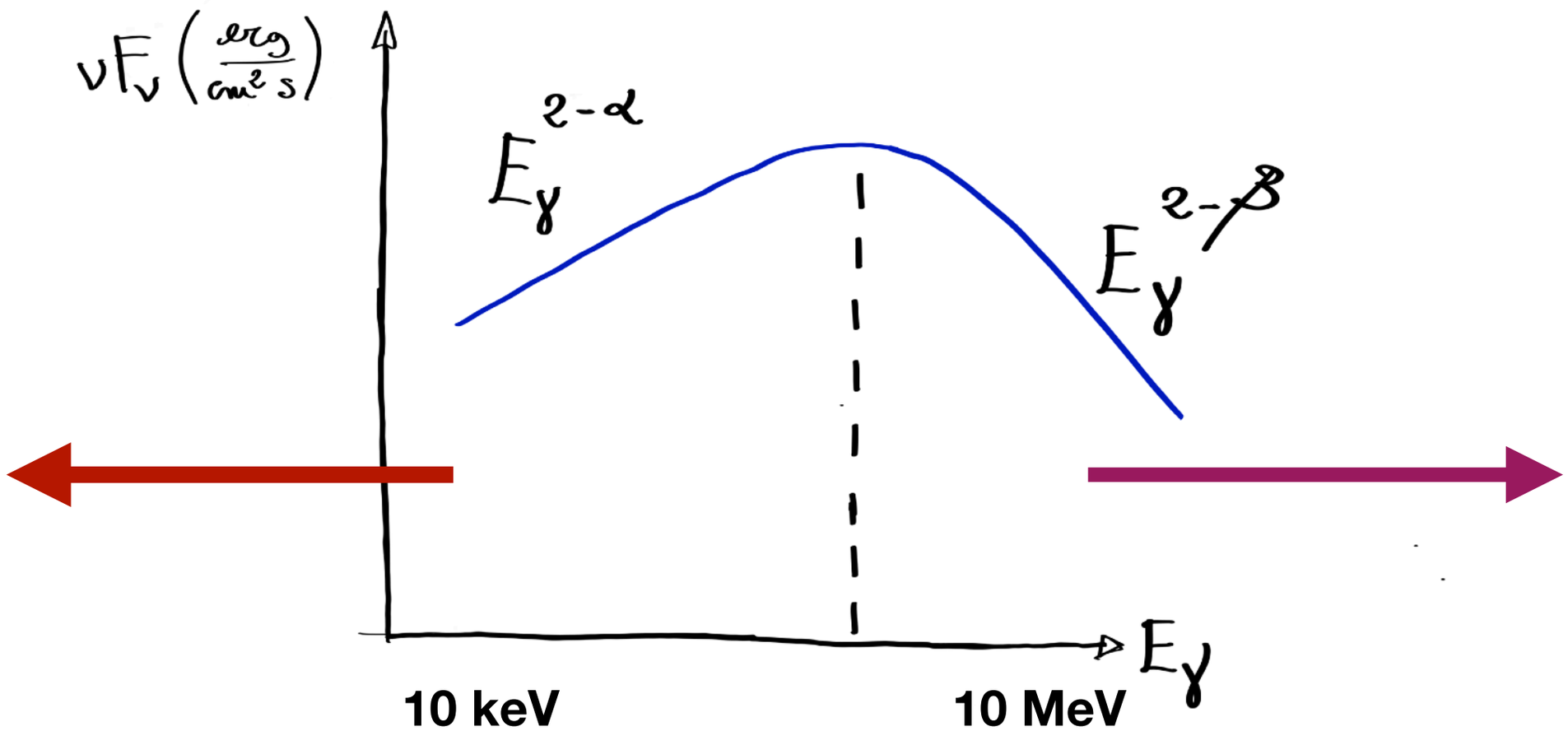


Cavallo & Rees 1978
Paczýnski 1986
Goodman 1986
Shemi & Piran 1990



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

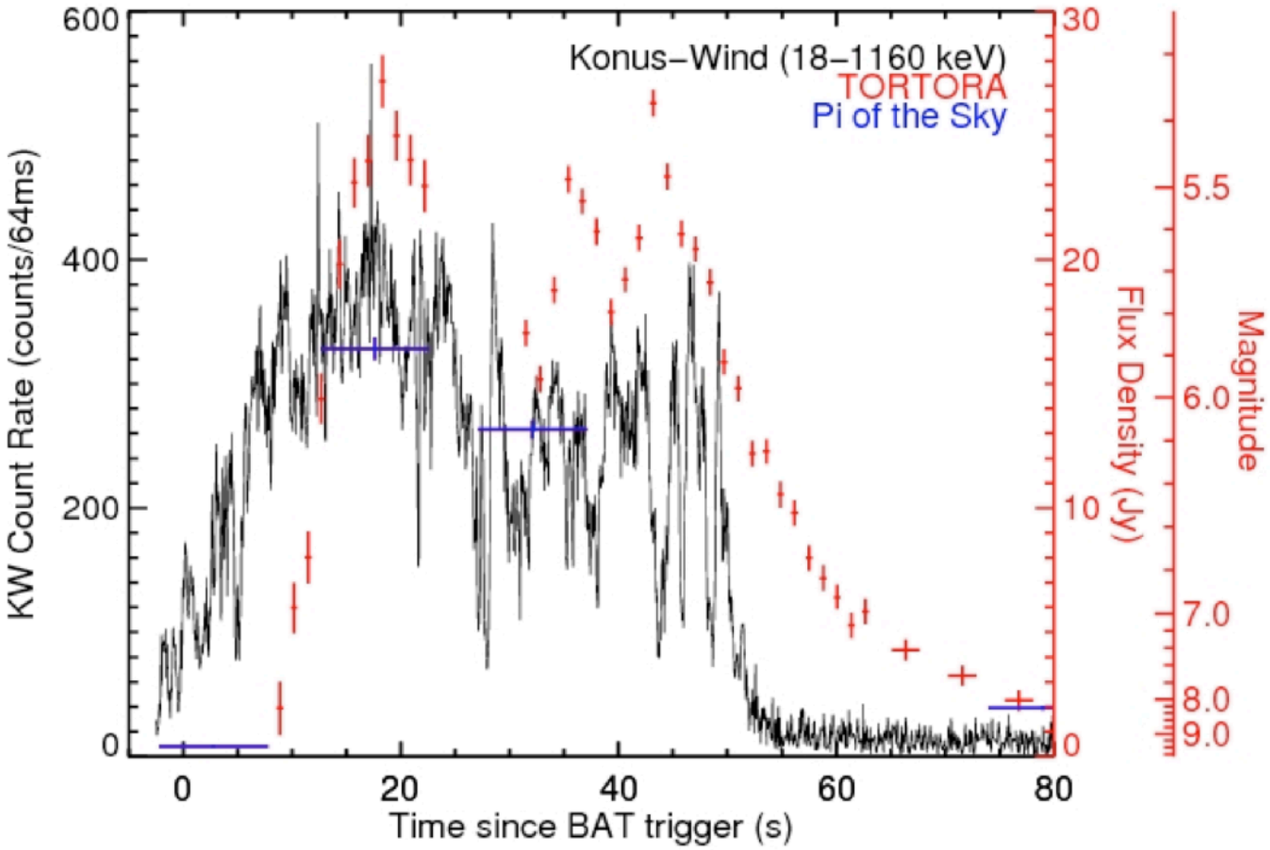
Beyond MeV


$\nu F_\nu \left(\frac{erg}{cm^2\,s}\right)$
$E_\gamma^{2-\alpha}$
$E_\gamma^{2-\beta}$
E_γ
10 keV
10 MeV

	visible light (robotic telescopes)	X-rays Einstein Probe *Swift*/XRT	GeV Fermi/LAT	TeV MAGIC, LHAASO, CTA
wide field *(almost) all sky* *or* *fast reaction*	**x** **~ min**	**yes** **~ min**	**yes**	LHAASO - yes **~ 20 s**
high temporal resolution	**x** (Cherenkov?)	**yes**	**yes**	**yes**

Exceptional observations

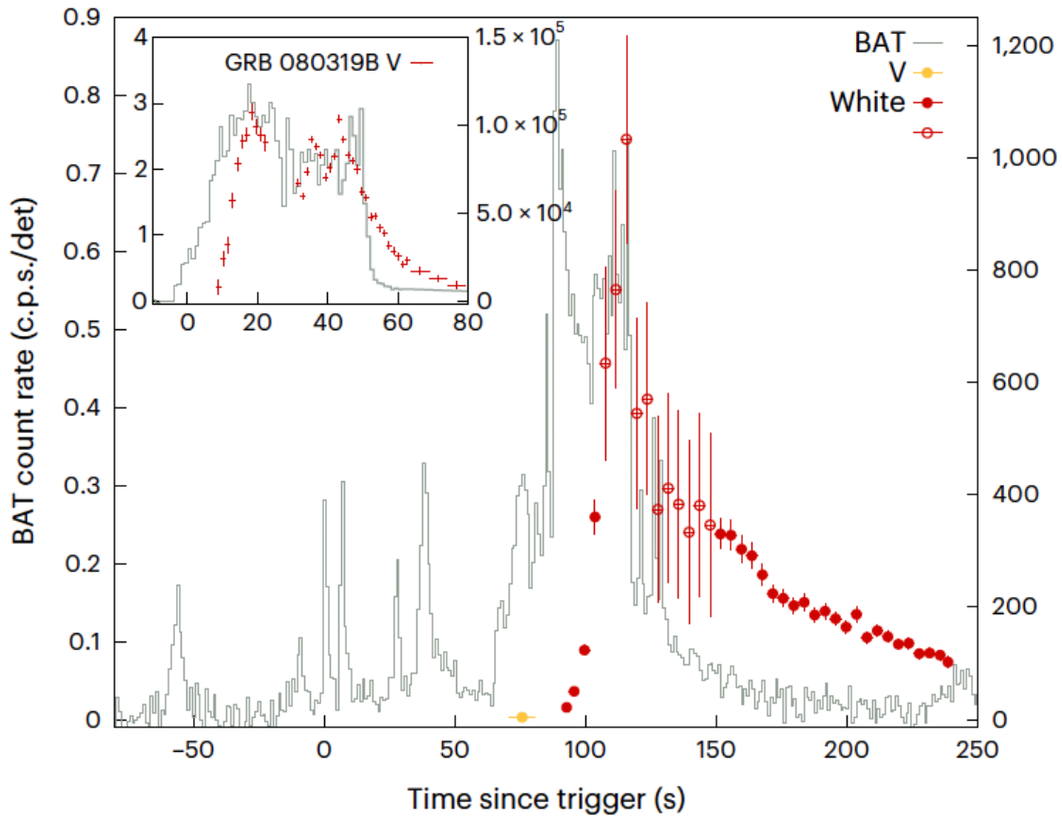
Naked eye GRB 080319B, z=0.937



0.13 s

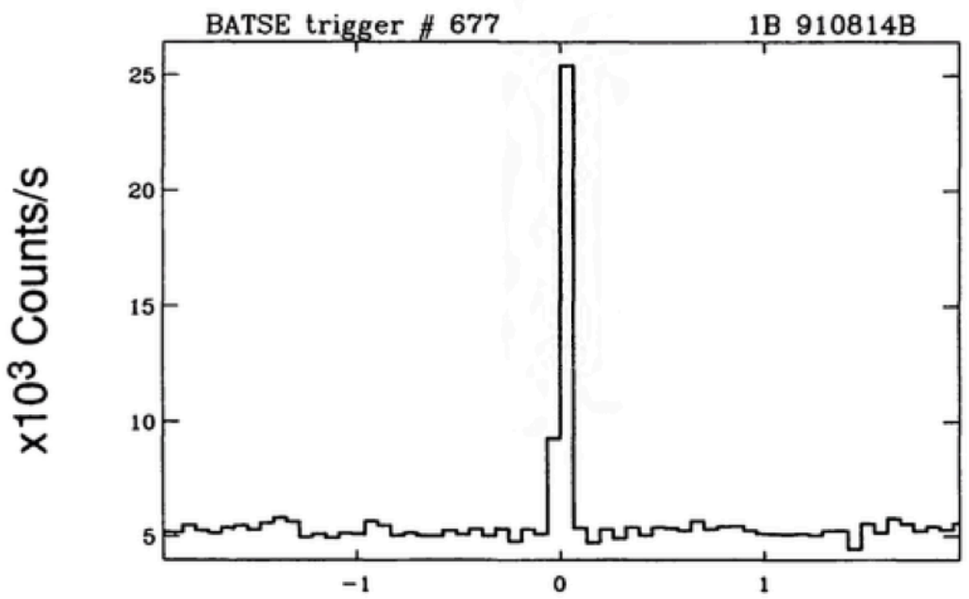
Racusin et al. 2008, Nature

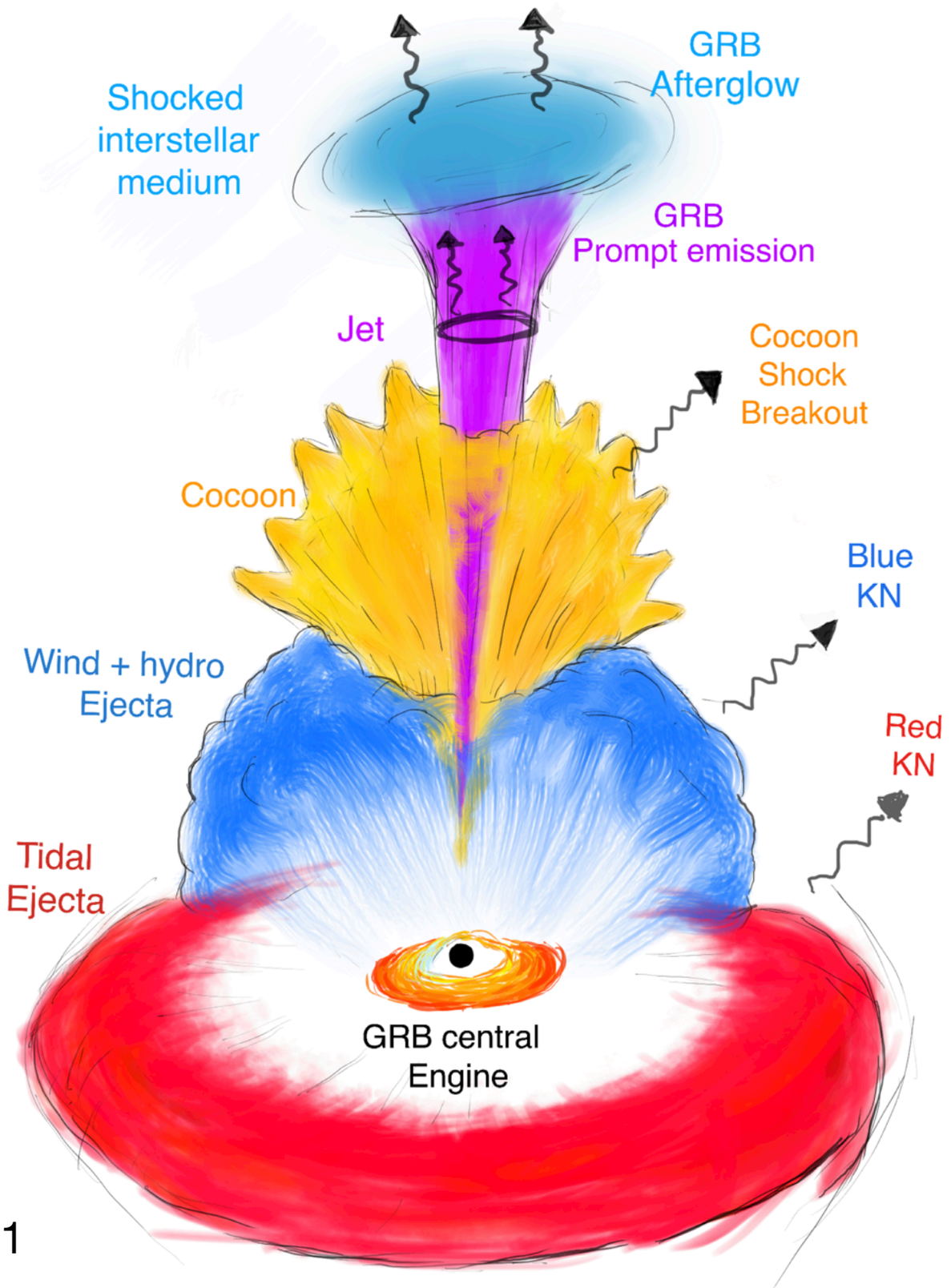
GRB 220101A, z=4.6



Jin et al. 2023, Nature Astronomy

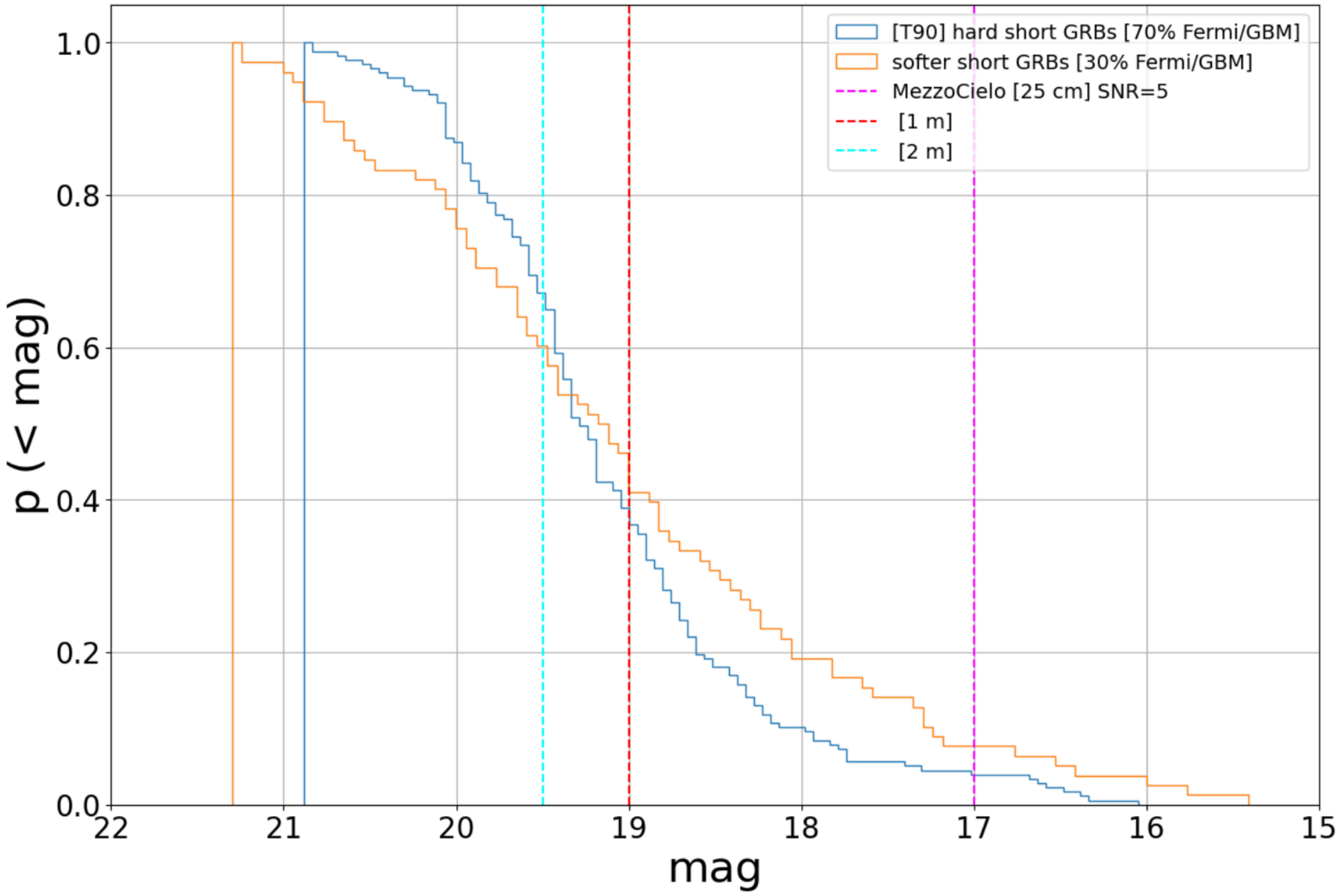
Compact Binaries Coalescence
(NS+NS and NS+BH)





Ascenzi et al. 2021

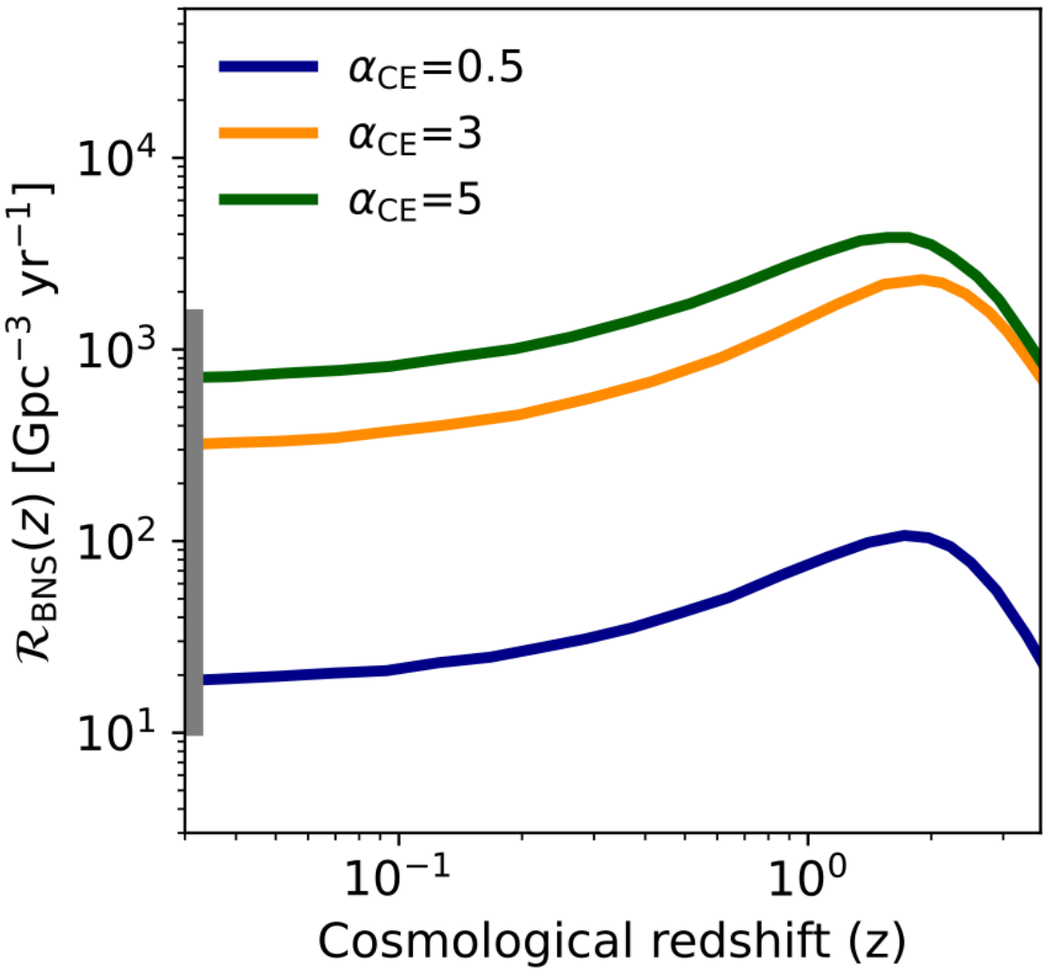
short (merger-driven GRBs)



preliminary sensitivity of **MezzoCielo** (D. Magrin, C. Arcidiacono et al. private communication)

almost all sky

Banerjee et al. 2023 **mergers**

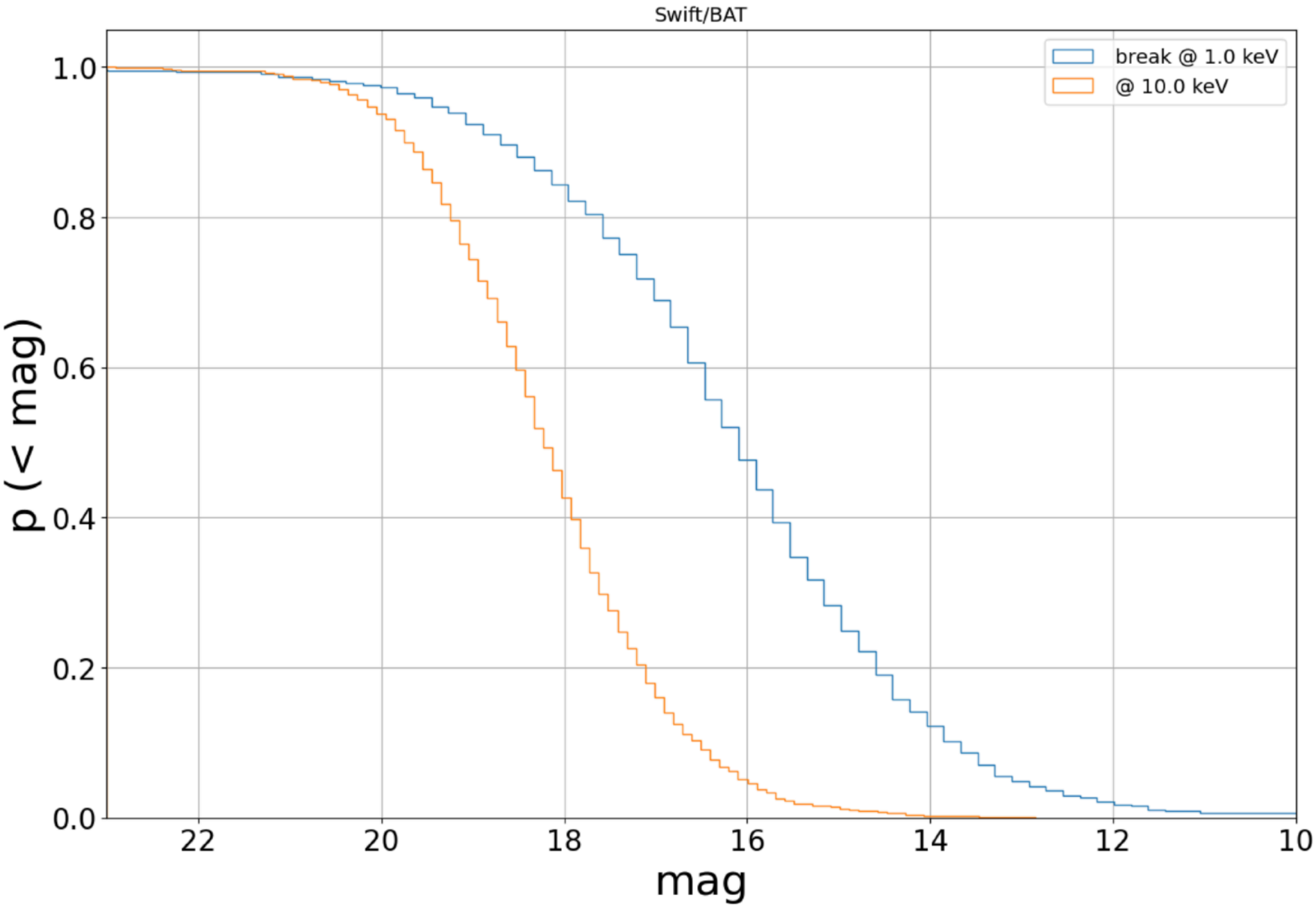


+ 19 mag + 1/4 sky

$$N_{GW+EM} = N_{BNS} \times f_{jet} \times \frac{\theta_{jet}^2}{2} \times f_{opt} \times f_{sky} \times f_{D.C.}$$

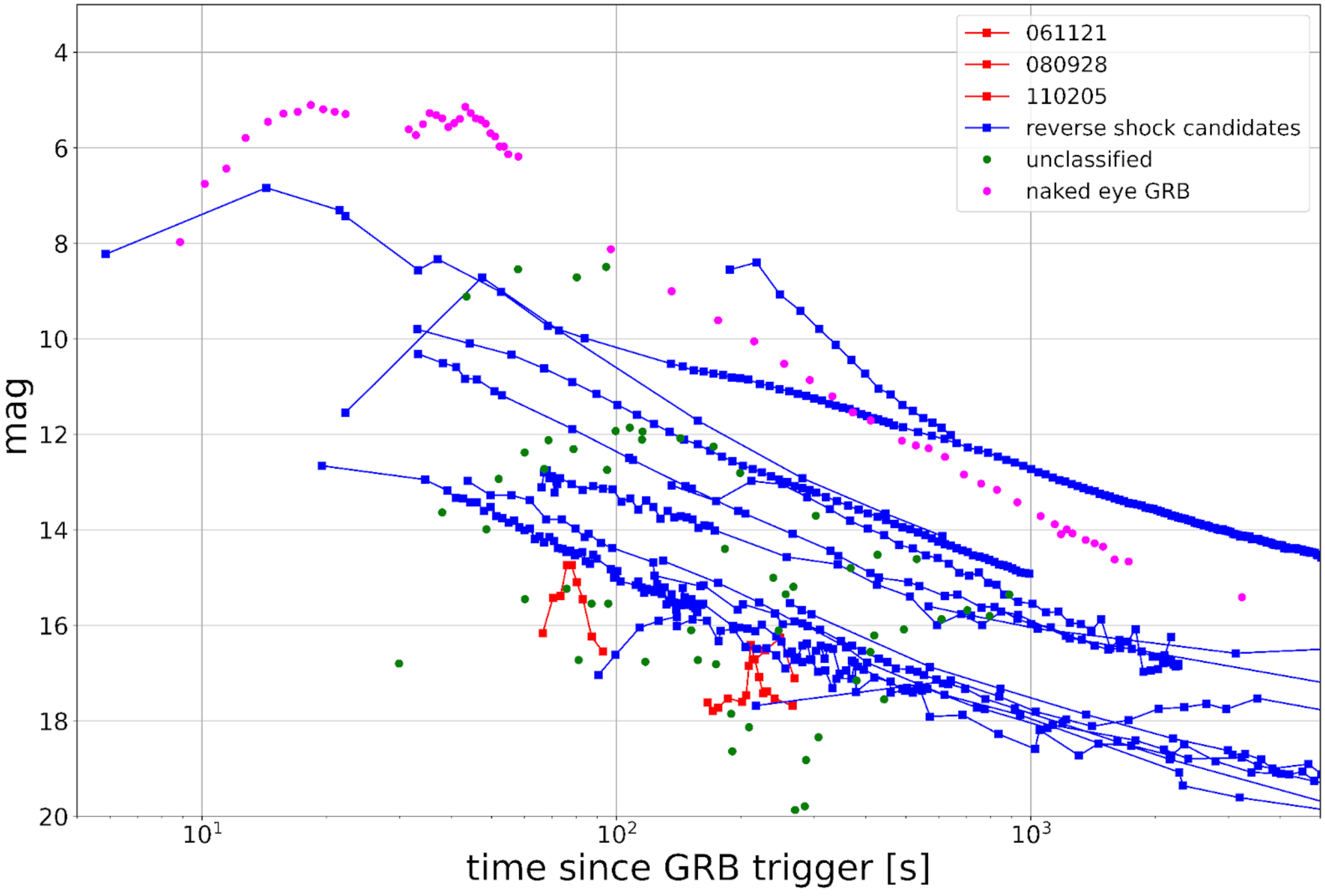
$4^{+36}_{-3.6} f_{jet}/year$ $2^{+3}_{-1}/year$

long (collapsar GRBs)

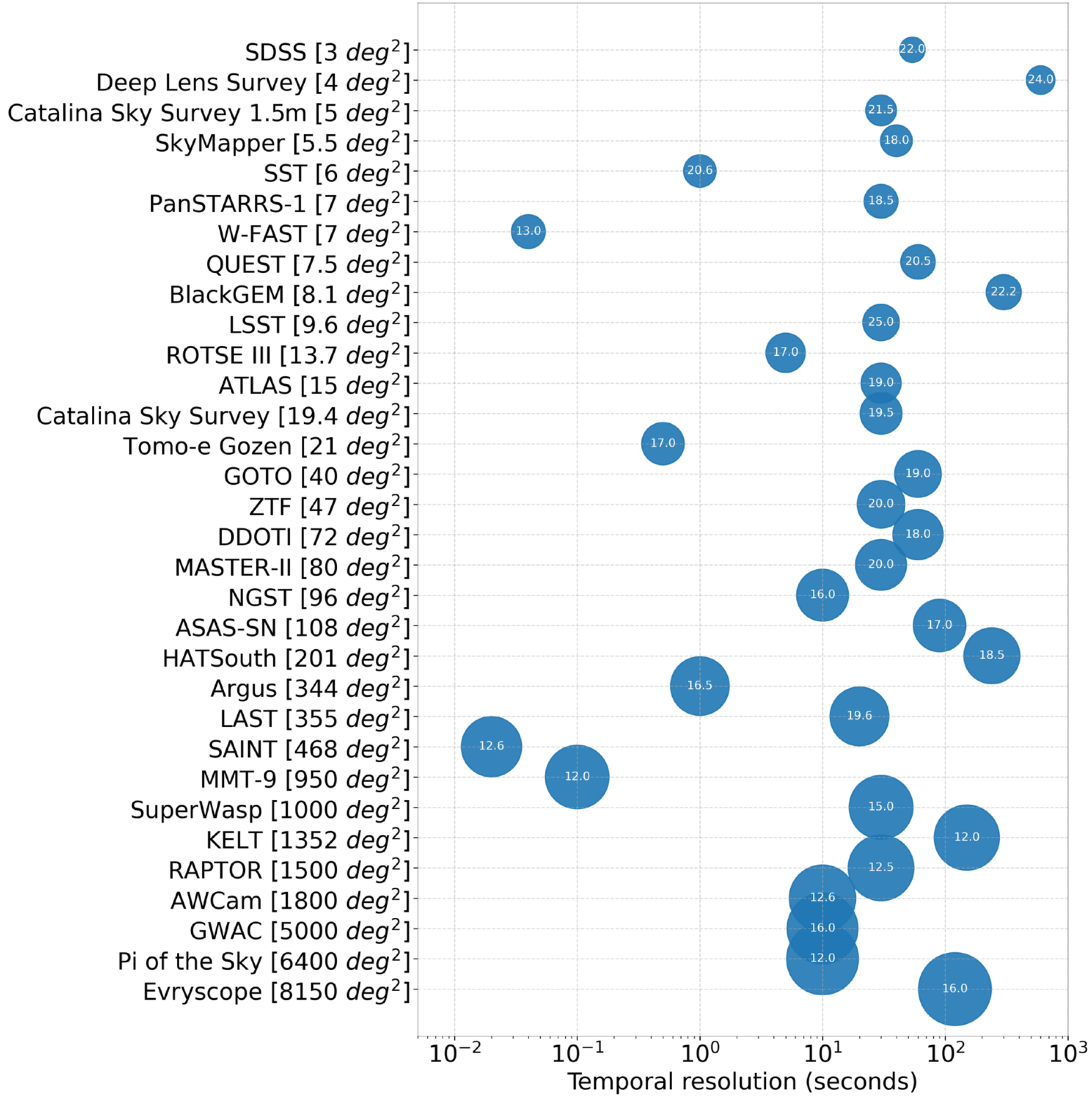


$$f_{lGRB} > 5 \times f_{GW+EM}$$

$\delta T = 0.13\,\mathrm{s}$

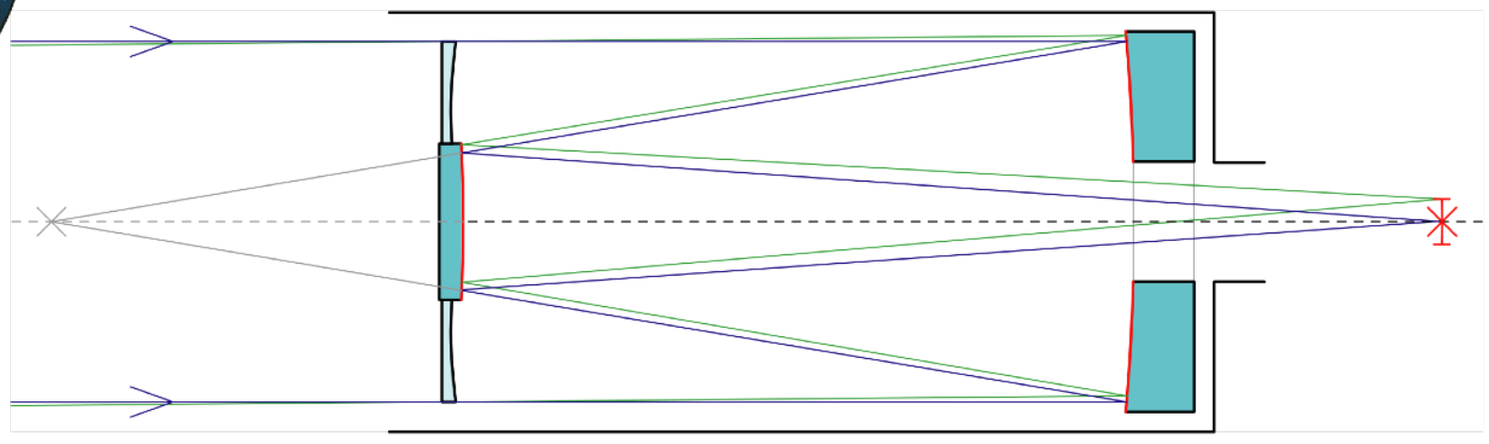


collection from GO+ 2023

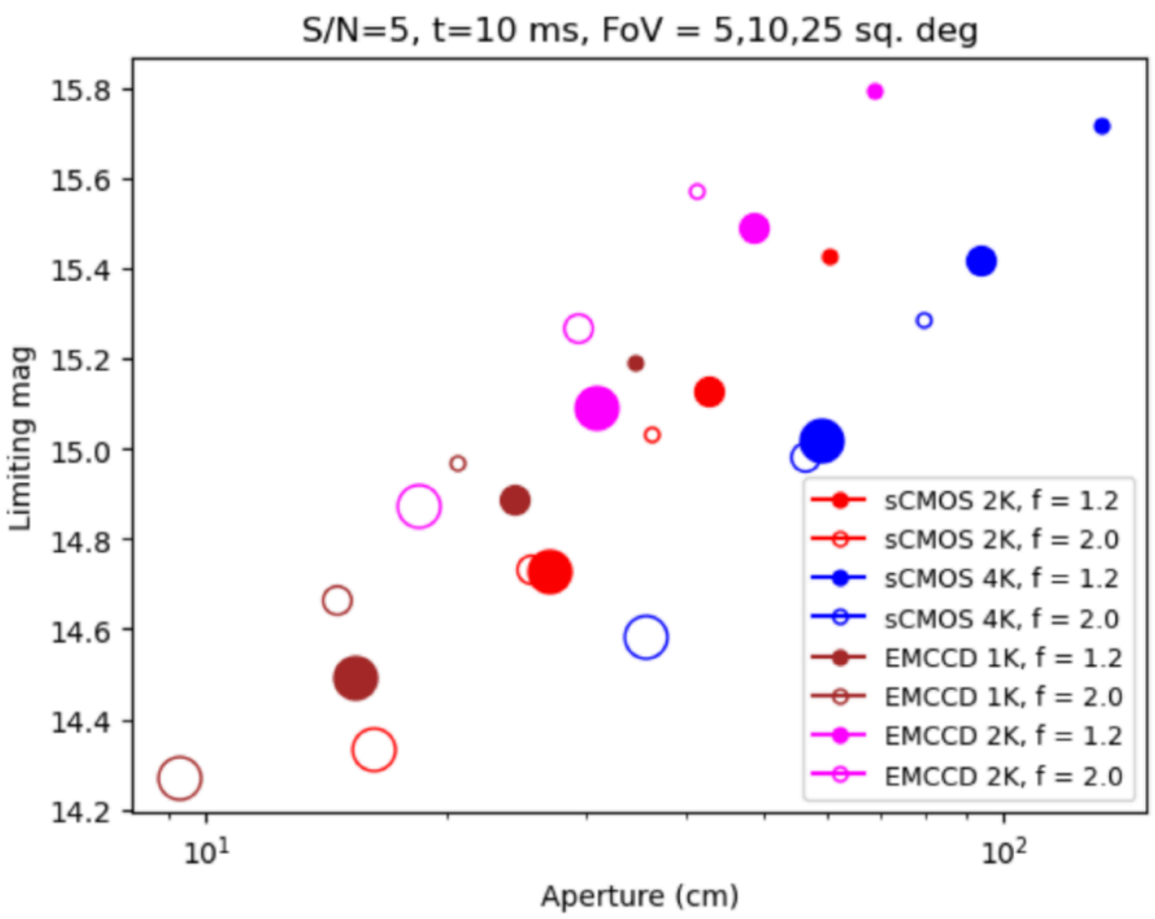

SDSS [3 deg^2]
Deep Lens Survey [4 deg^2]
Catalina Sky Survey 1.5m [5 deg^2]
SkyMapper [5.5 deg^2]
SST [6 deg^2]
PanSTARRS-1 [7 deg^2]
W-FAST [7 deg^2]
QUEST [7.5 deg^2]
BlackGEM [8.1 deg^2]
LSST [9.6 deg^2]
ROTSE III [13.7 deg^2]
ATLAS [15 deg^2]
Catalina Sky Survey [19.4 deg^2]
Tomo-e Gozen [21 deg^2]
GOTO [40 deg^2]
ZTF [47 deg^2]
DDOTI [72 deg^2]
MASTER-II [80 deg^2]
NGST [96 deg^2]
ASAS-SN [108 deg^2]
HATSouth [201 deg^2]
Argus [344 deg^2]
LAST [355 deg^2]
SAINT [468 deg^2]
MMT-9 [950 deg^2]
SuperWasp [1000 deg^2]
KELT [1352 deg^2]
RAPTOR [1500 deg^2]
AWCam [1800 deg^2]
GWAC [5000 deg^2]
Pi of the Sky [6400 deg^2]
Evryscope [8150 deg^2]
22.0
24.0
21.5
18.0
20.6
18.5
13.0
20.5
22.2
25.0
17.0
19.0
19.5
17.0
19.0
20.0
18.0
20.0
16.0
17.0
18.5
16.5
19.6
12.6
12.0
15.0
12.0
12.5
12.6
16.0
12.0
16.0
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Temporal resolution (seconds)

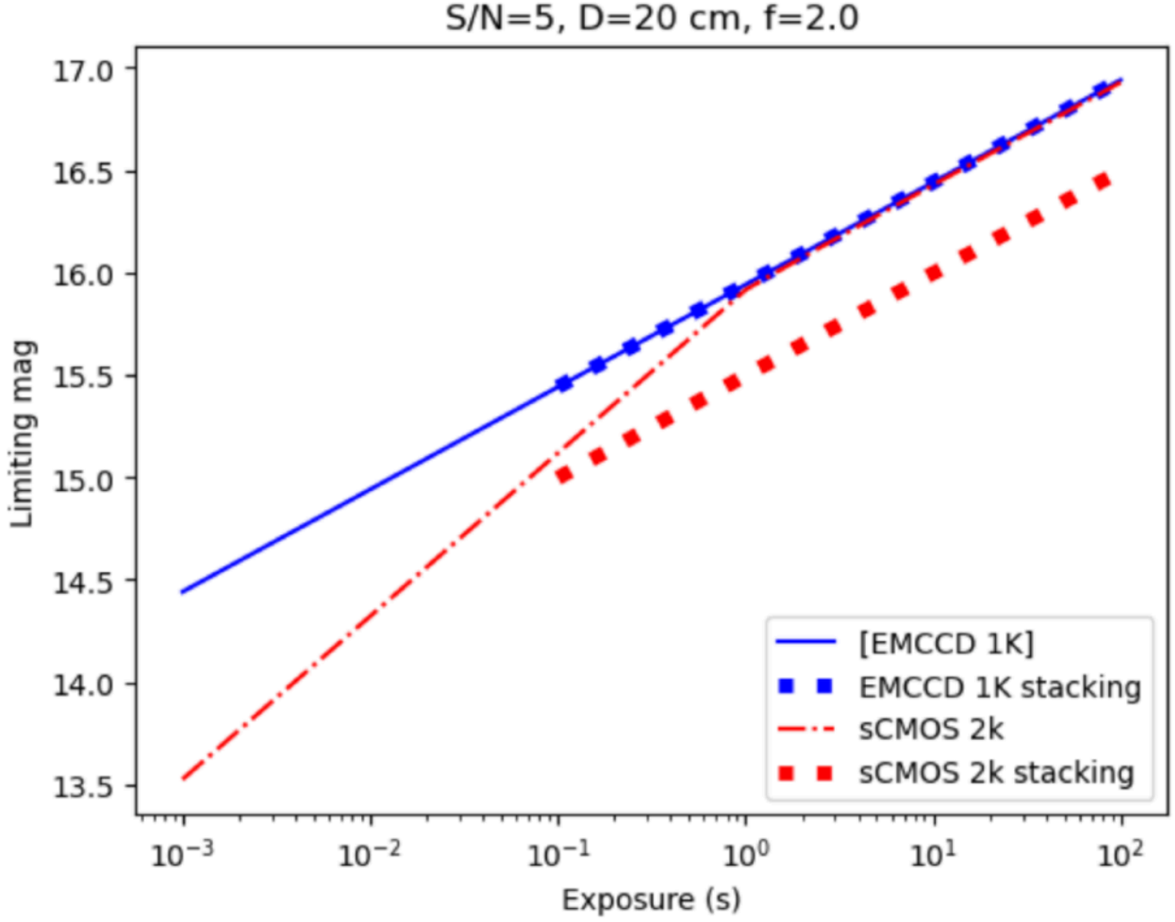
Prompt and **I**nstantaneous **C**amera to **C**atch **H**ighly **I**rregular **O**bjects

PICCHIO



EMCCD
cameras

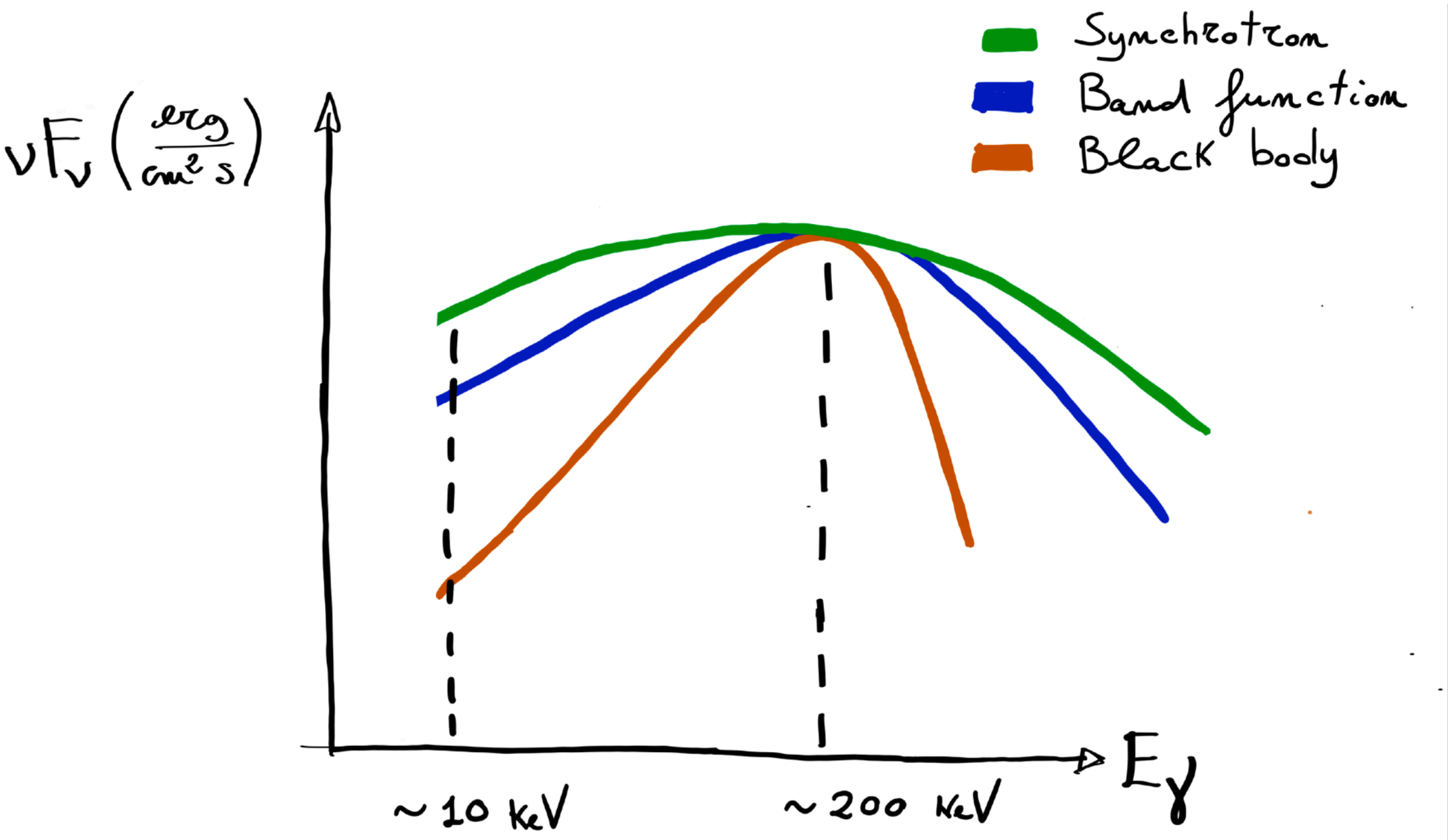




Thank you!

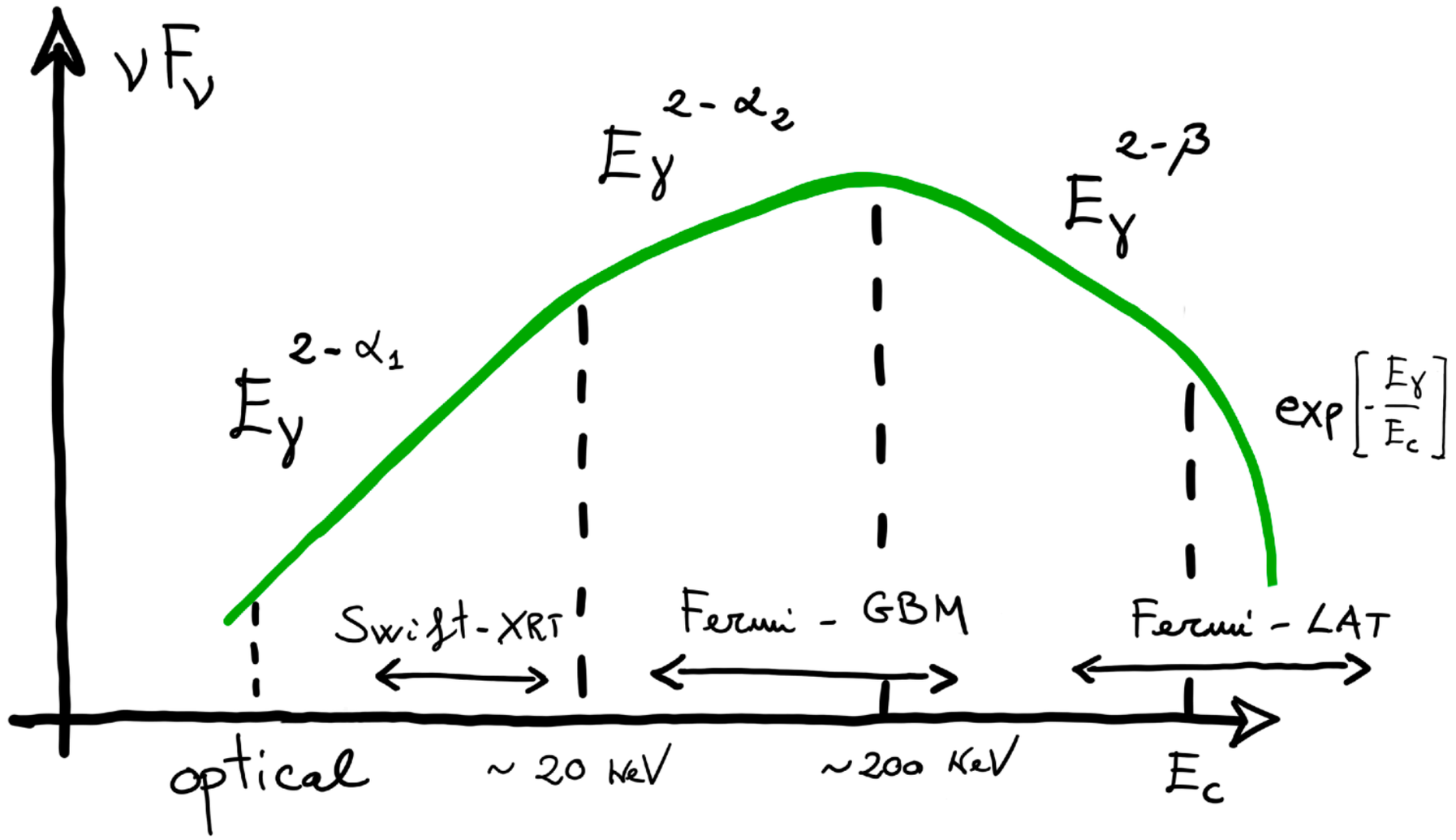
back up slides

Observed vs Expected



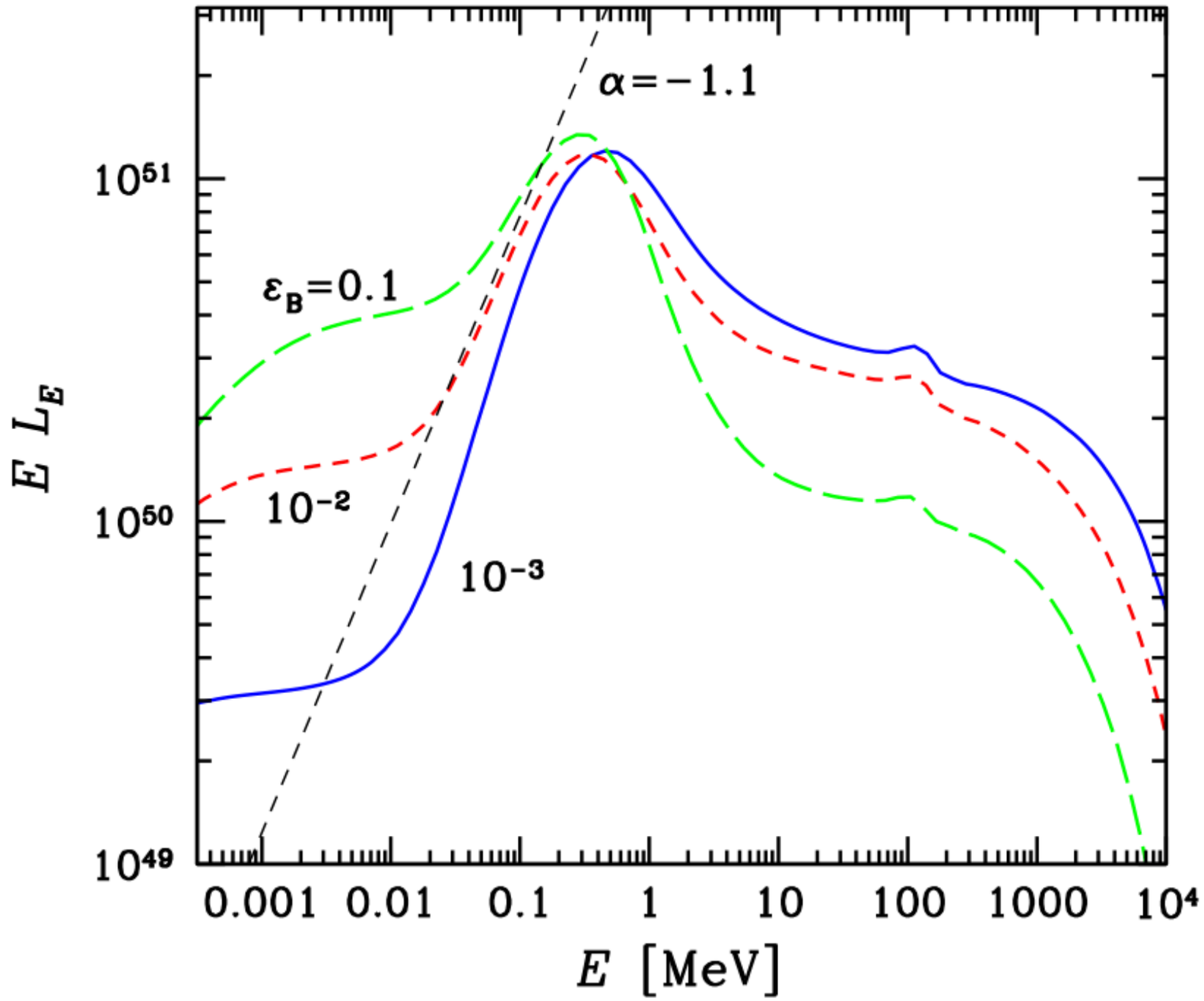
Ghisellini et al. 2000

Optically thin models



GO+ 2017, 2019; Ravasio et al. 2018, 2019

Photospheric models



Vurm & Beloborodov 2016

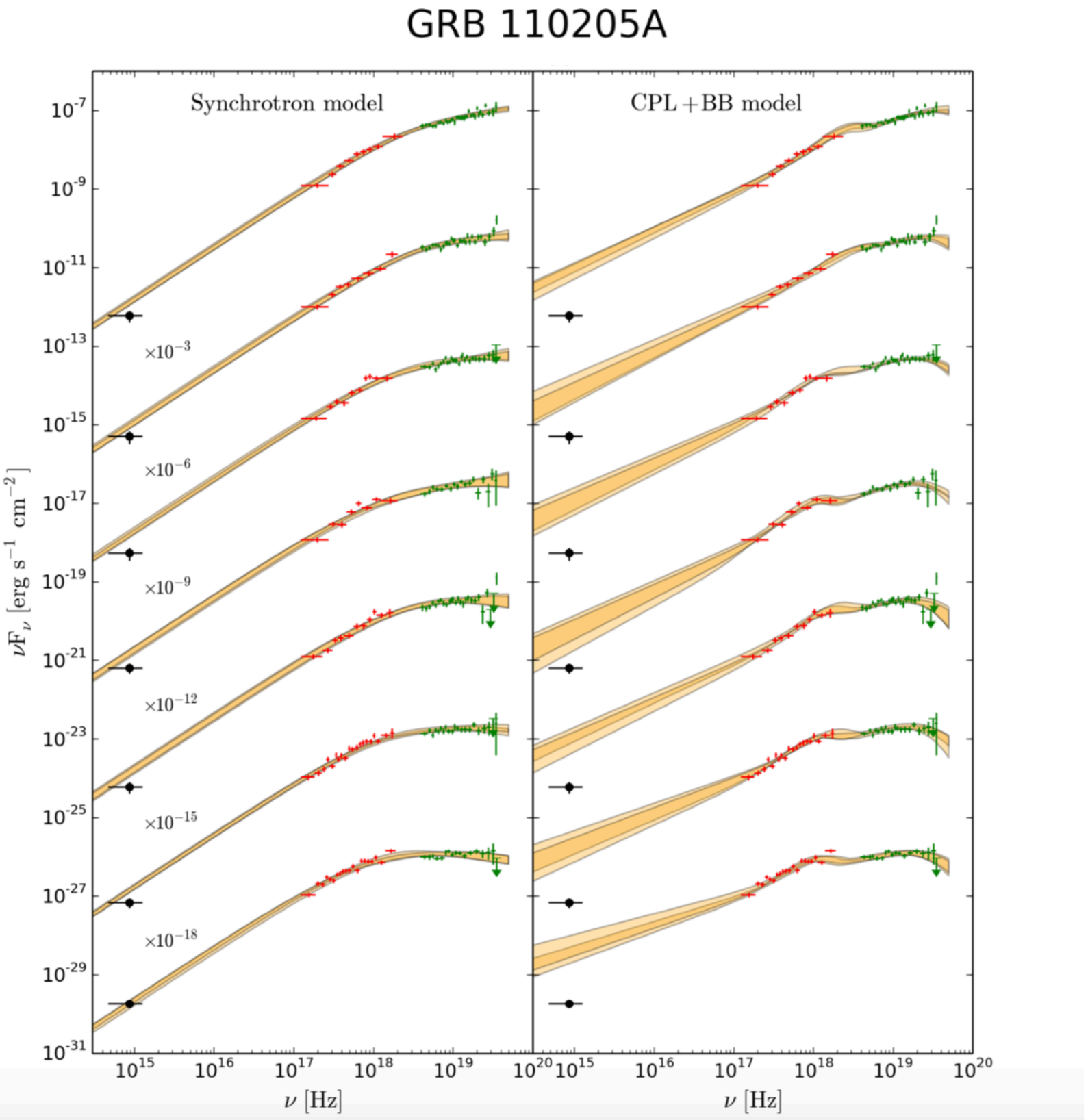
single synchrotron vs 2 component model

~ 90% of spectra are inconsistent with CPL+BB model!

synchrotron model is preferred

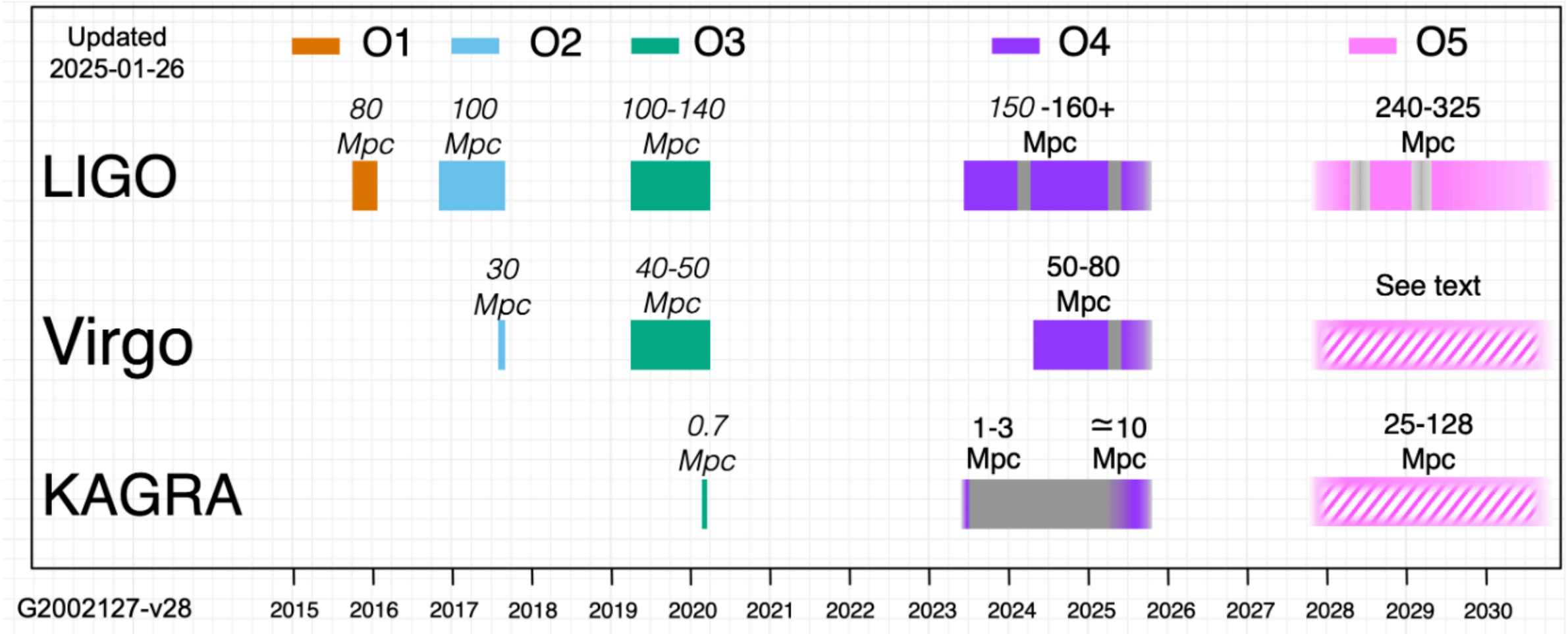
[21 GRBs, 52 spectra]

GO+ 2019



LIGO Virgo KAGRA schedule

All sky sensitivity to BNS mergers

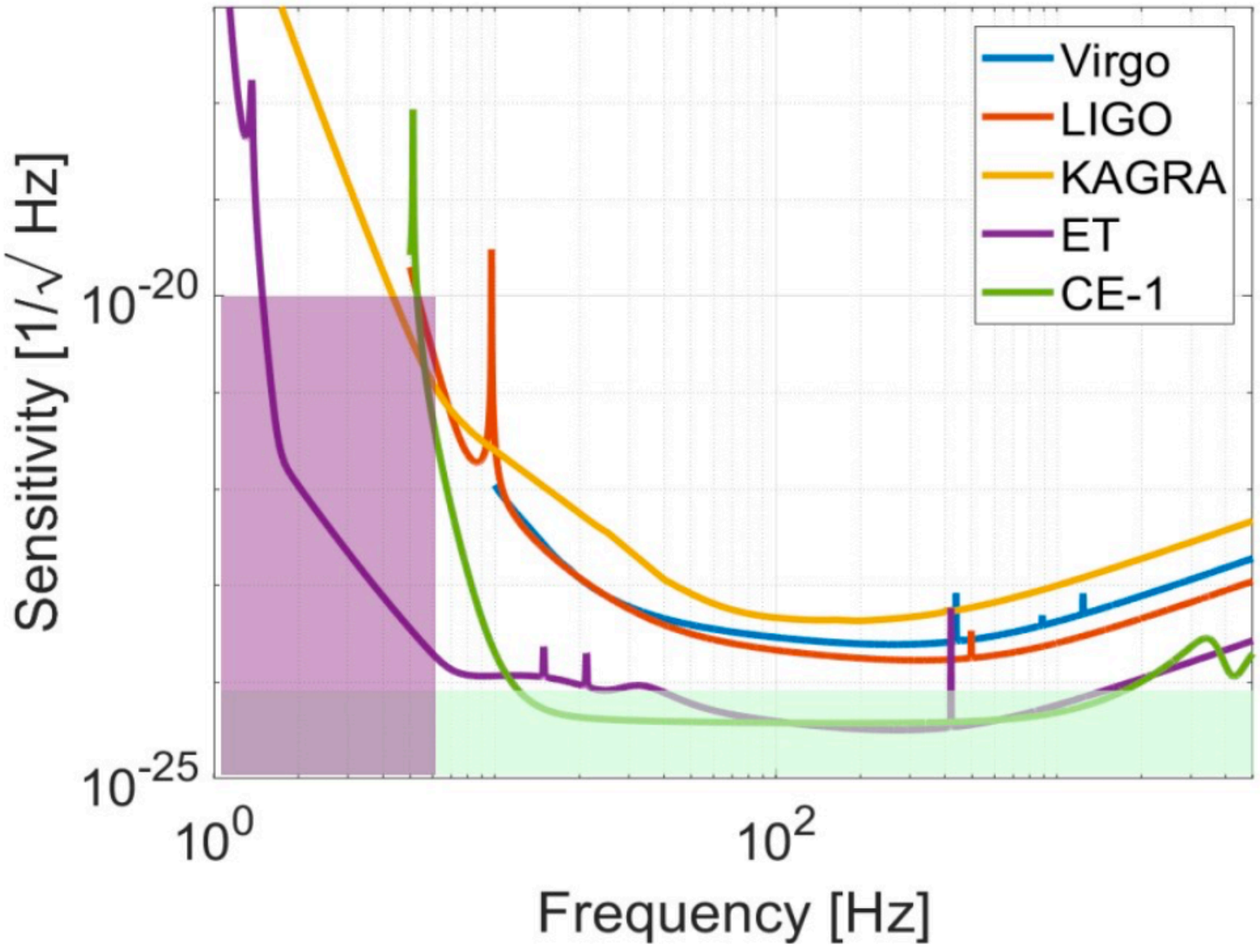


Offline GW search from GRBs

O2 Abbott et al. 2019, ApJ

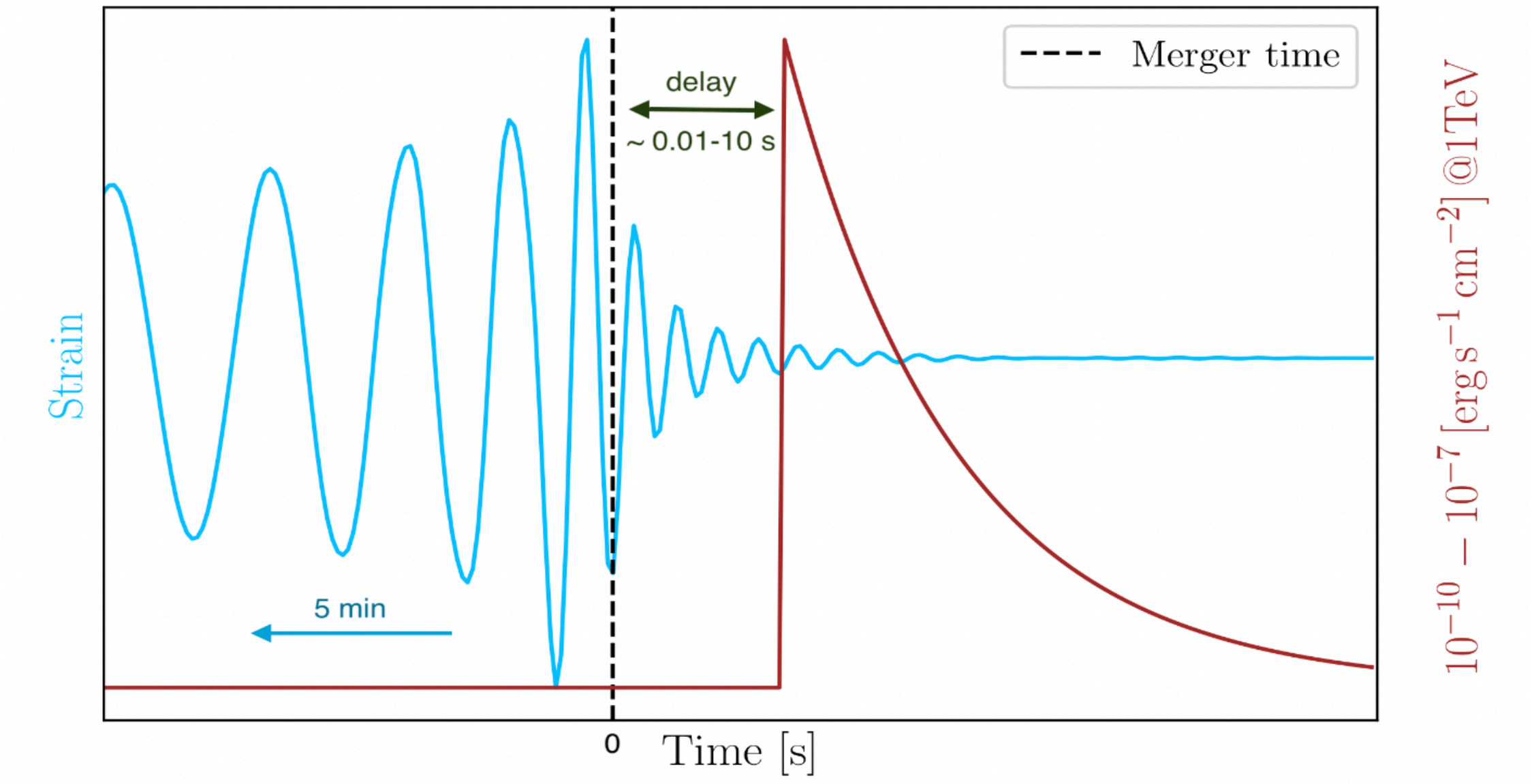
O3a Abbott et al. 2021, ApJ

O3b Abbott et al. 2022, ApJ



Banerjee et al. 2023, A&A

GW pre-alerts



Banerjee et al. 2023, A&A

GRB conundrum