γ-ray bursts

news and hopes for the future

Gor Oganesyan

in collaboration with

Alessio Mei, Biswajit Banerjee, Francesco Lucarelli, Francesco Brighenti, Marica Branchesi, Teresa Montaruli, Samuele Ronchini, Om Sharan Salafia, Giancarlo Ghirlanda,Gabriele Ghisellini, Sergey Karpov, Gregory Beskin

Dissipation of kinetic energy
(internal shocks)

↓

particles acceleration

↓

radiative processes

↓

prompt emission

external shock

↓

afterglow

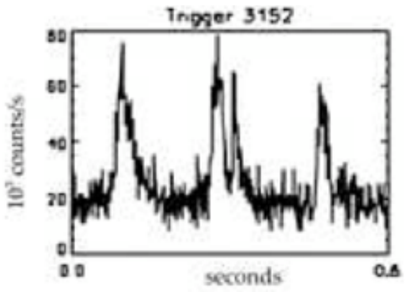
plasma shells

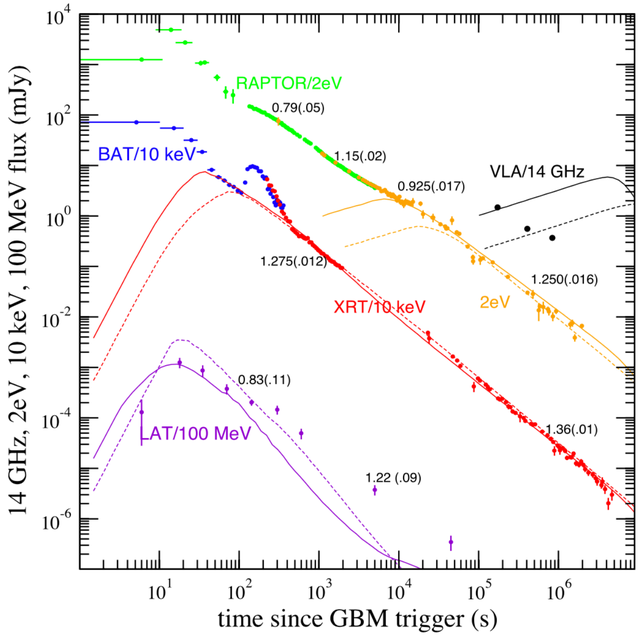
fireball

$e^{\pm}, \gamma, p$

$10^{12} - 10^{15}$ cm

$10^{16} - 10^{17}$ cm





Dissipation of electromagnetic energy

(magnetic reconnection)

particles acceleration

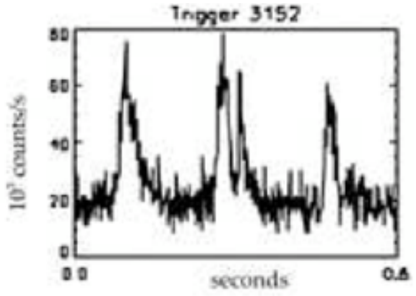
radiative processes

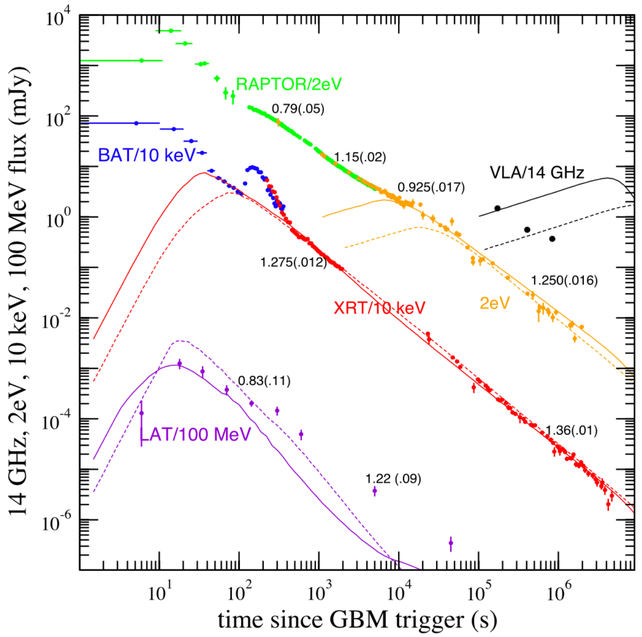
prompt emission

external shock

afterglow

electromagnetic outflow



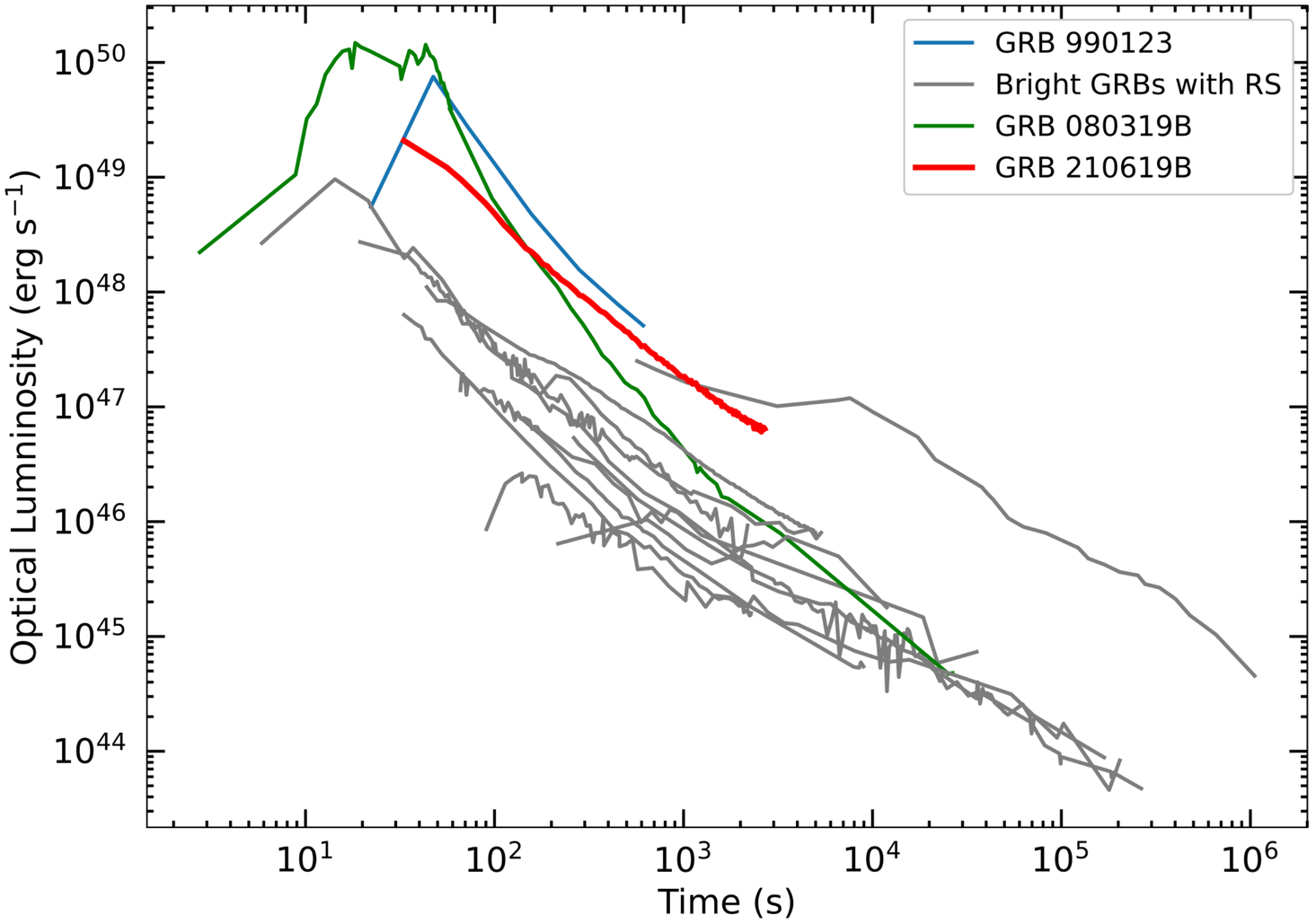


Optical domain

Catch every single pulse of a GRB

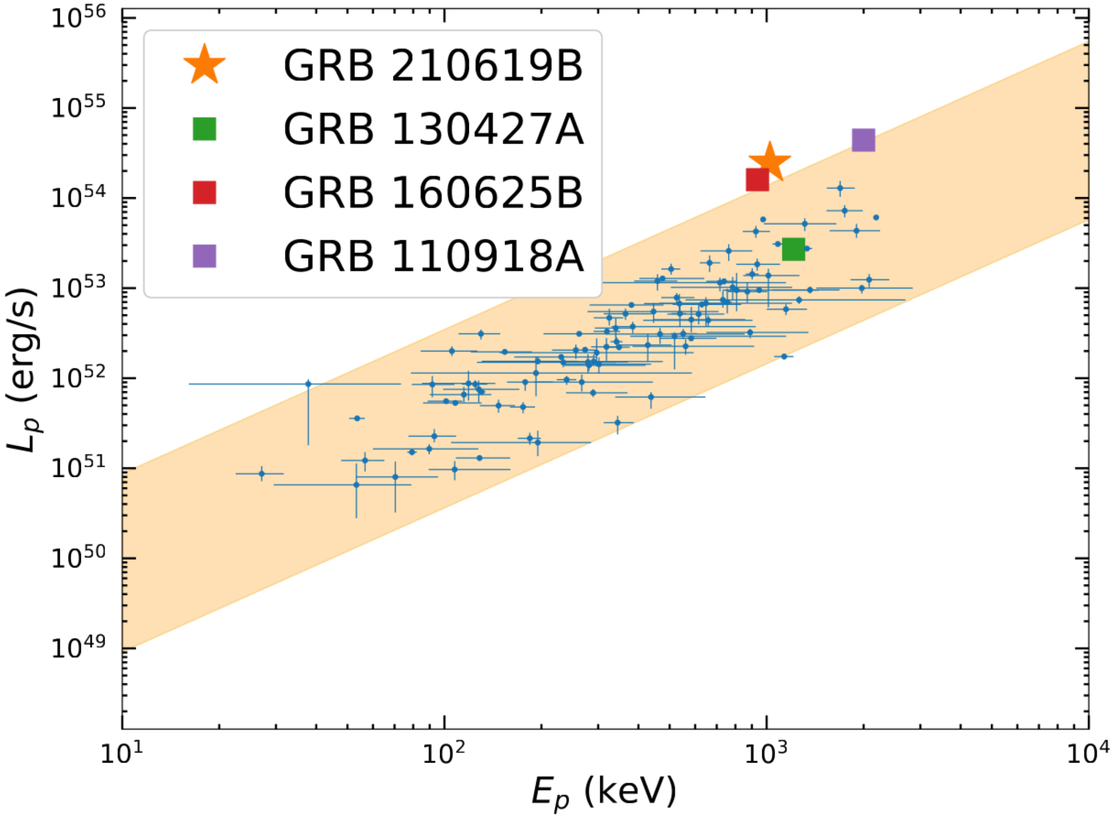
Immediate follow up + high temporal resolution + polarisation

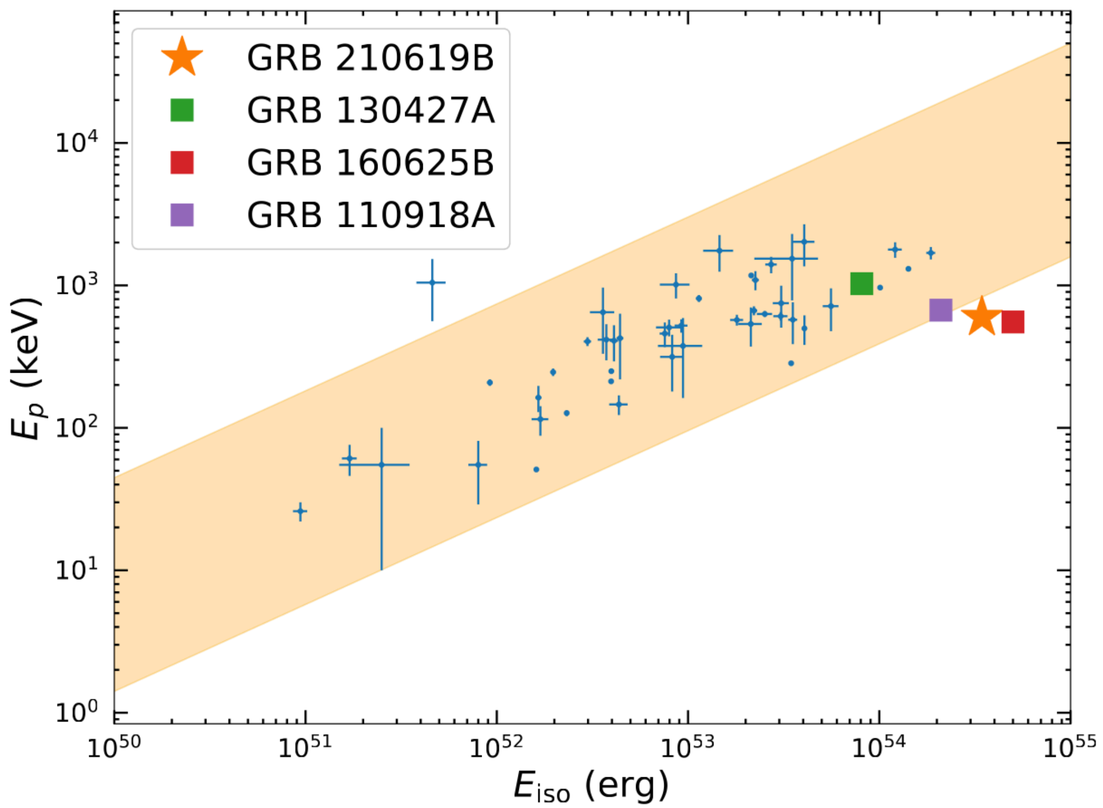
Extremely fast optical follow-up



Oganesyan & Karpov et al., arXiv: 2109.00010, under review in NA

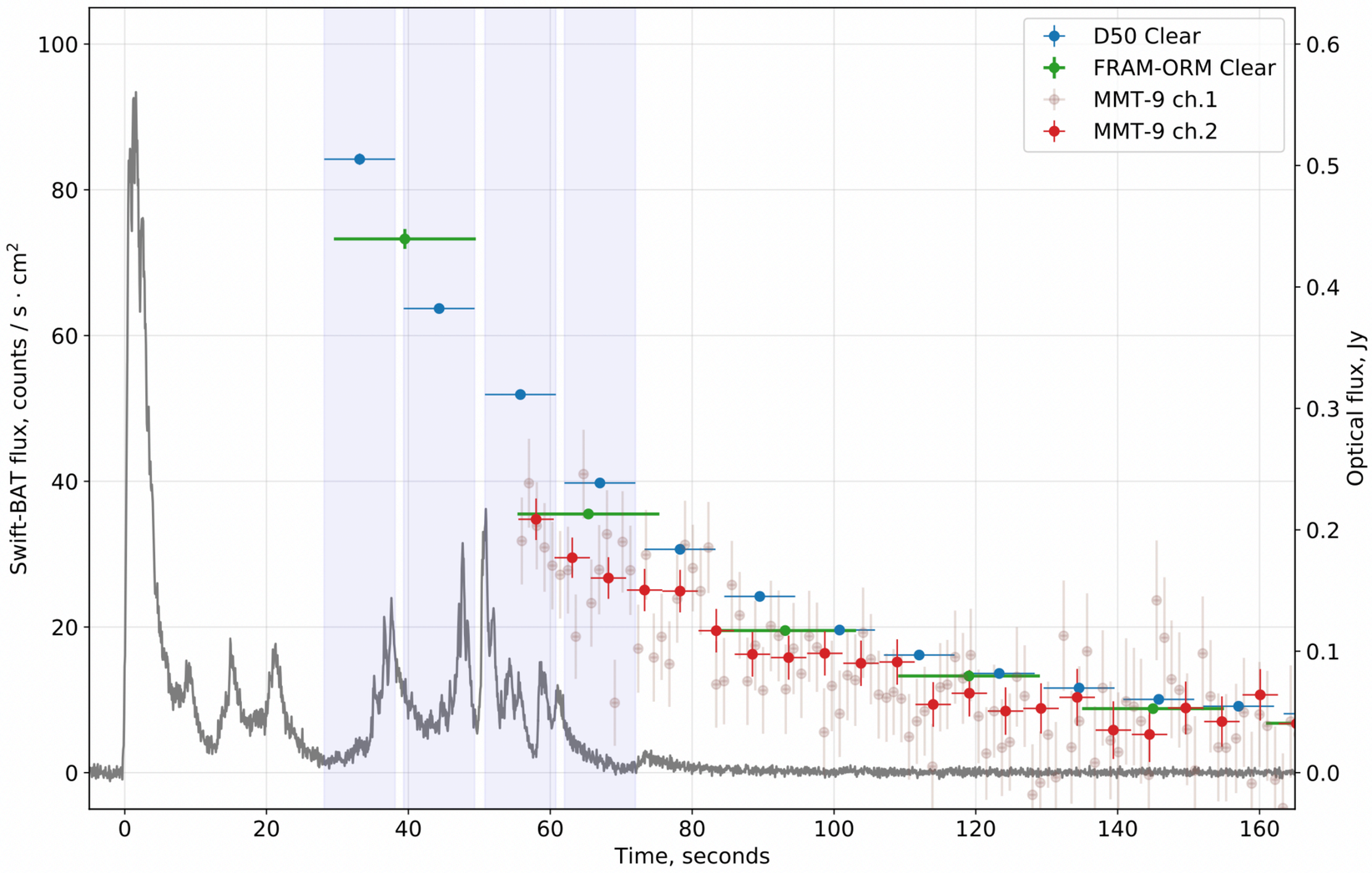
GRB 210619B at z=1.937





Extremely fast optical follow-up

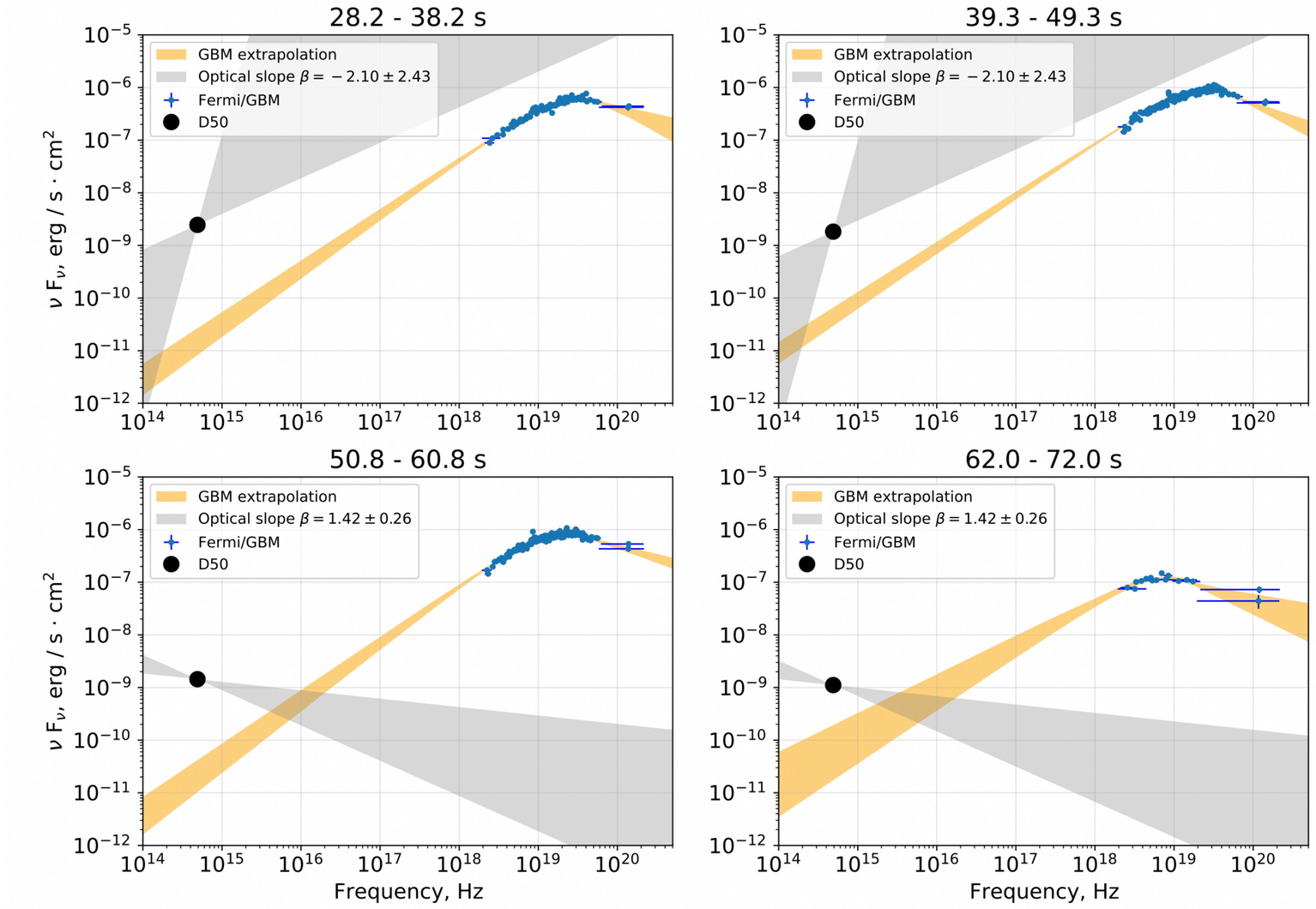
GRB 210619B at z=1.937



Oganesyan & Karpov et al., arXiv: 2109.00010, under review in NA

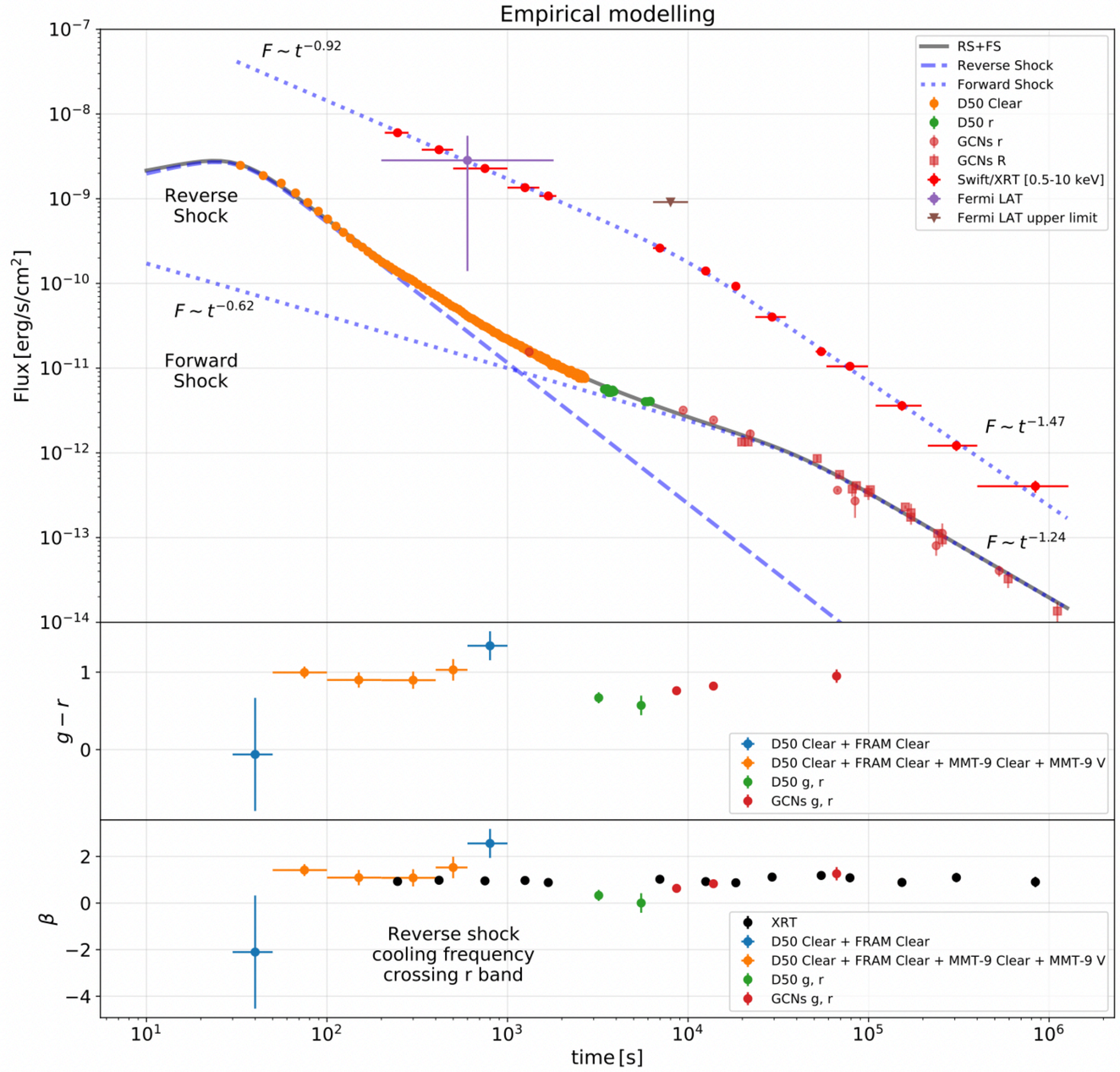
Extremely fast optical follow-up

GRB 210619B at z=1.937



Extremely fast optical follow-up

GRB 210619B at z=1.937



$$\Gamma \approx 1400 \qquad \epsilon_{\mathrm{B,RS}} \approx 0.1$$

Piran 2003

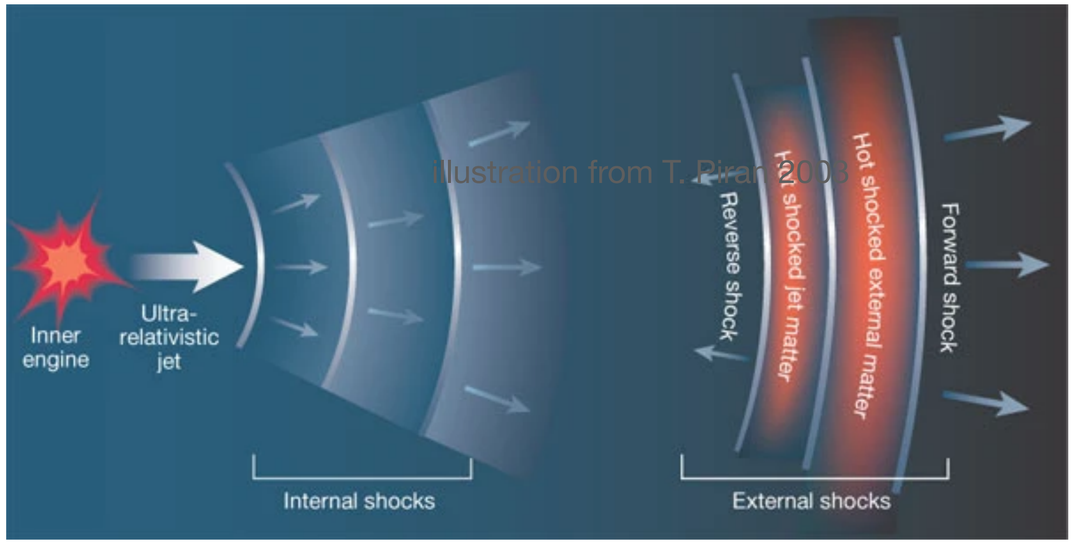
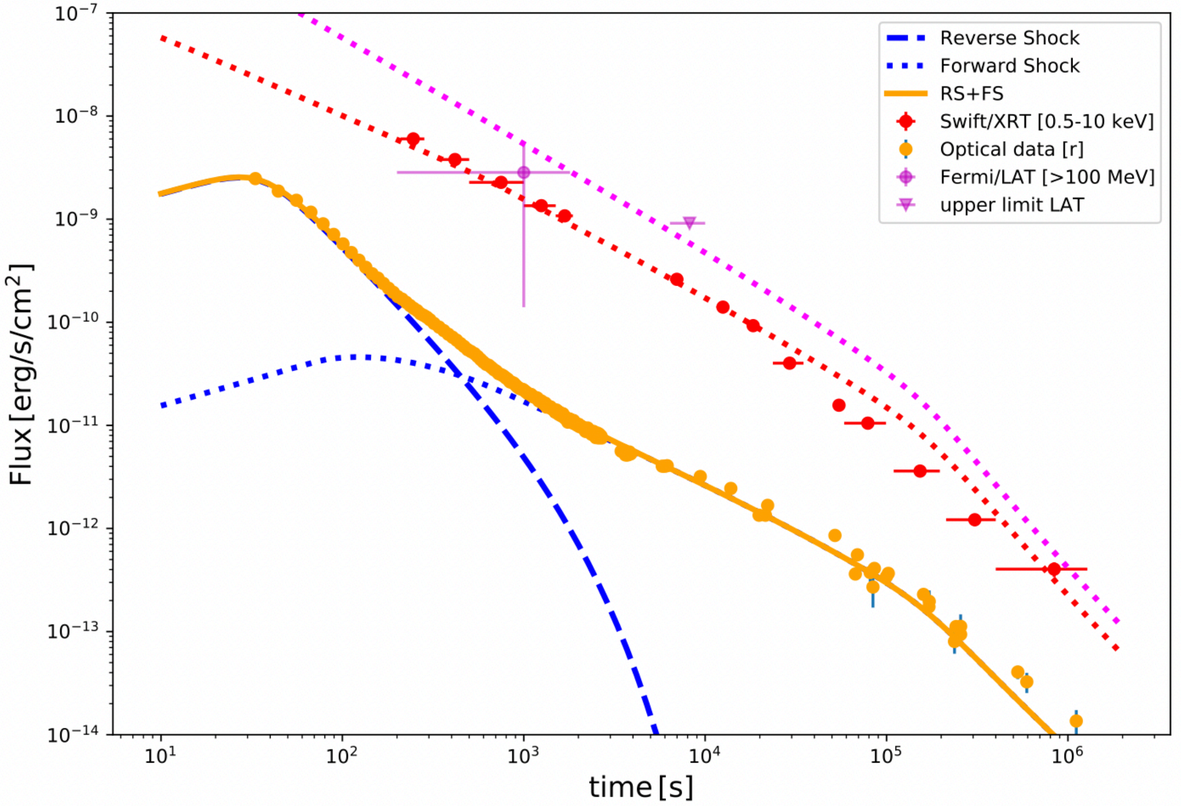


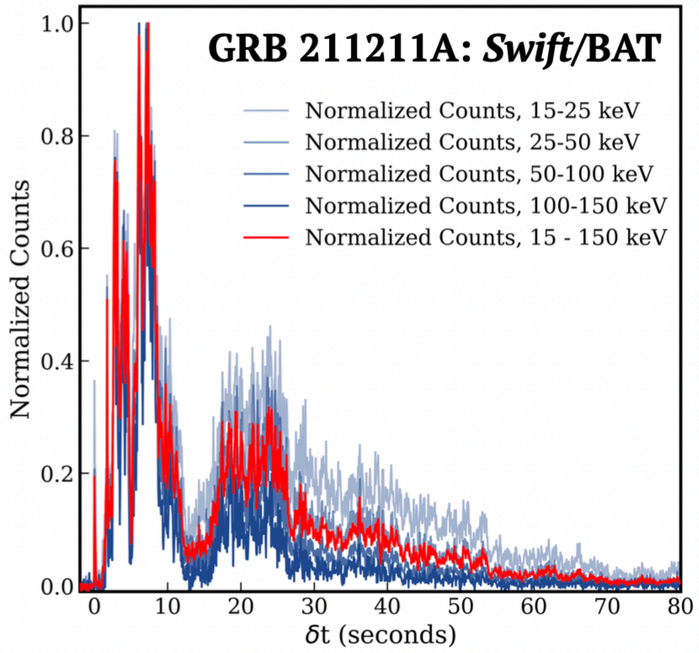
illustration from T. Piran 2003

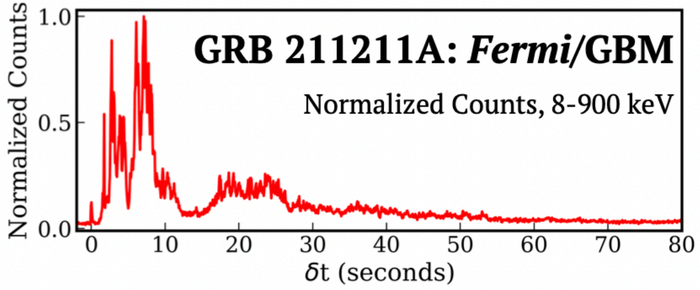


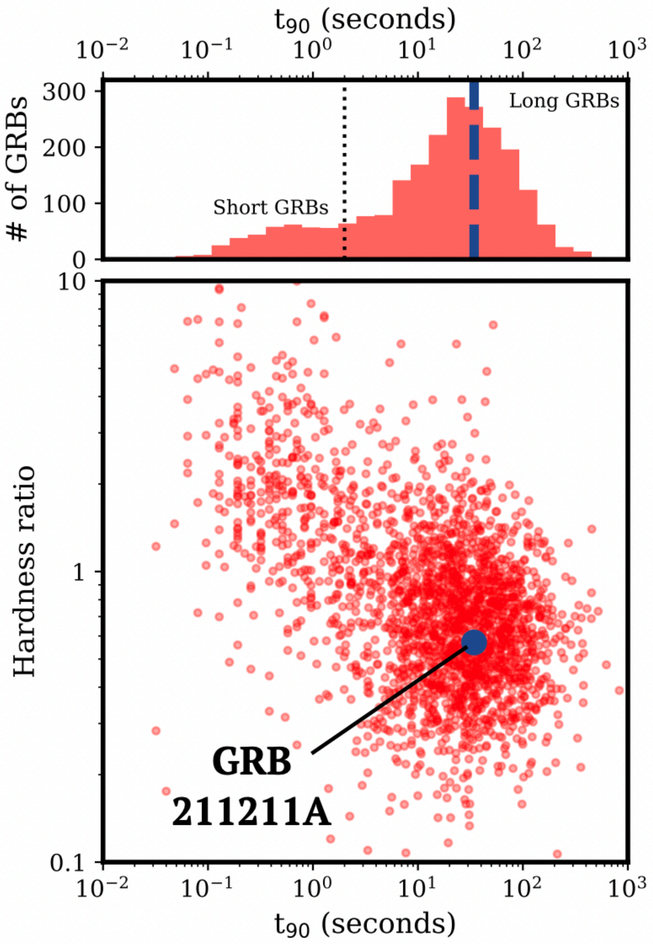
Optical/NIR domain

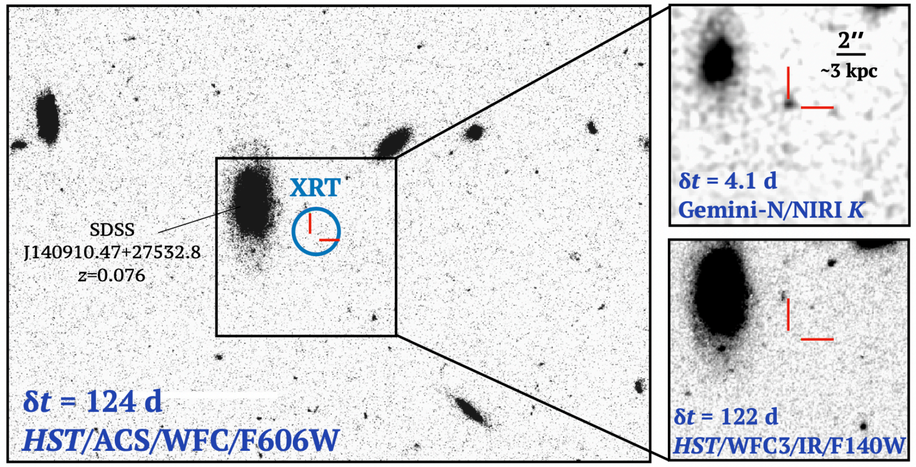
faint late-time counterparts

Usual long GRB in offset from the host



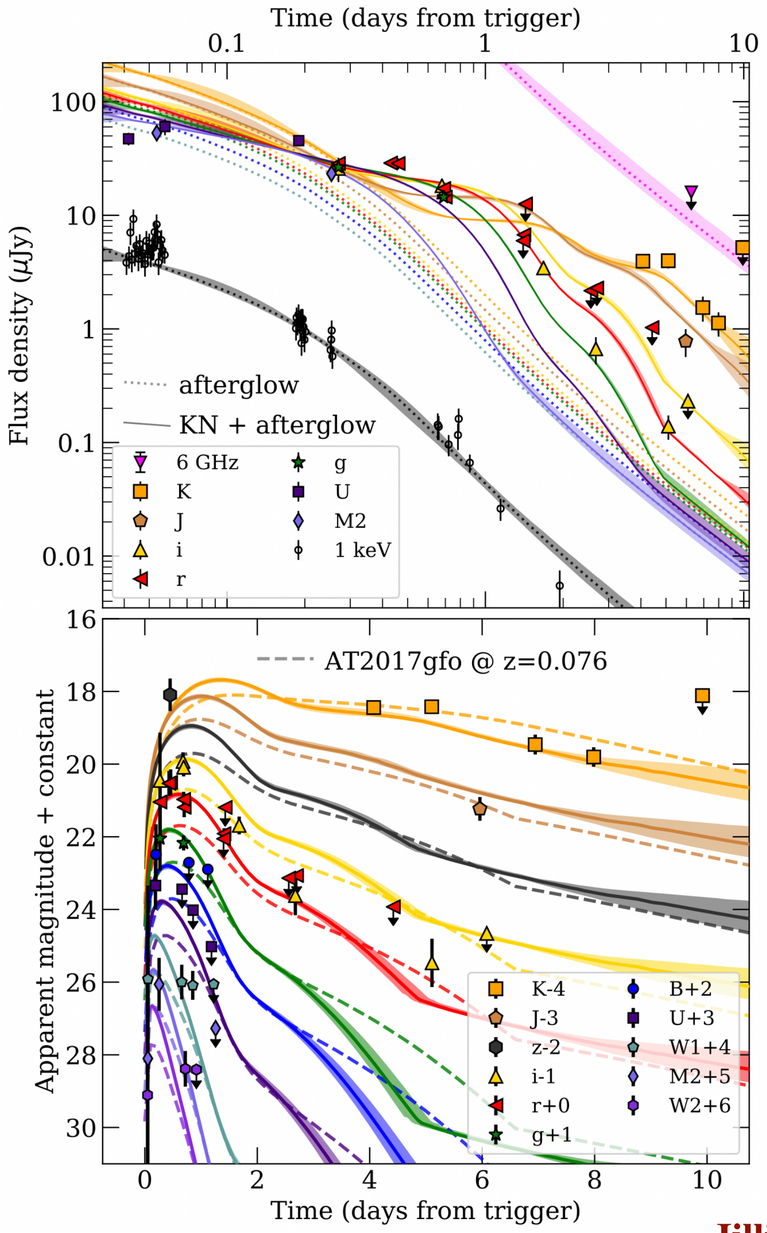






Jillian Rastinejad et al. 2022, arXiv 2204.10864, see also Jun Yang et al. 2022, arXiv 2204.12771

~~Usual~~ long GRB in offset from the host and kilonova!



distance ~ 350 Mpc

no SN

KN with $\approx 0.04\mathrm{M}_{\odot}$

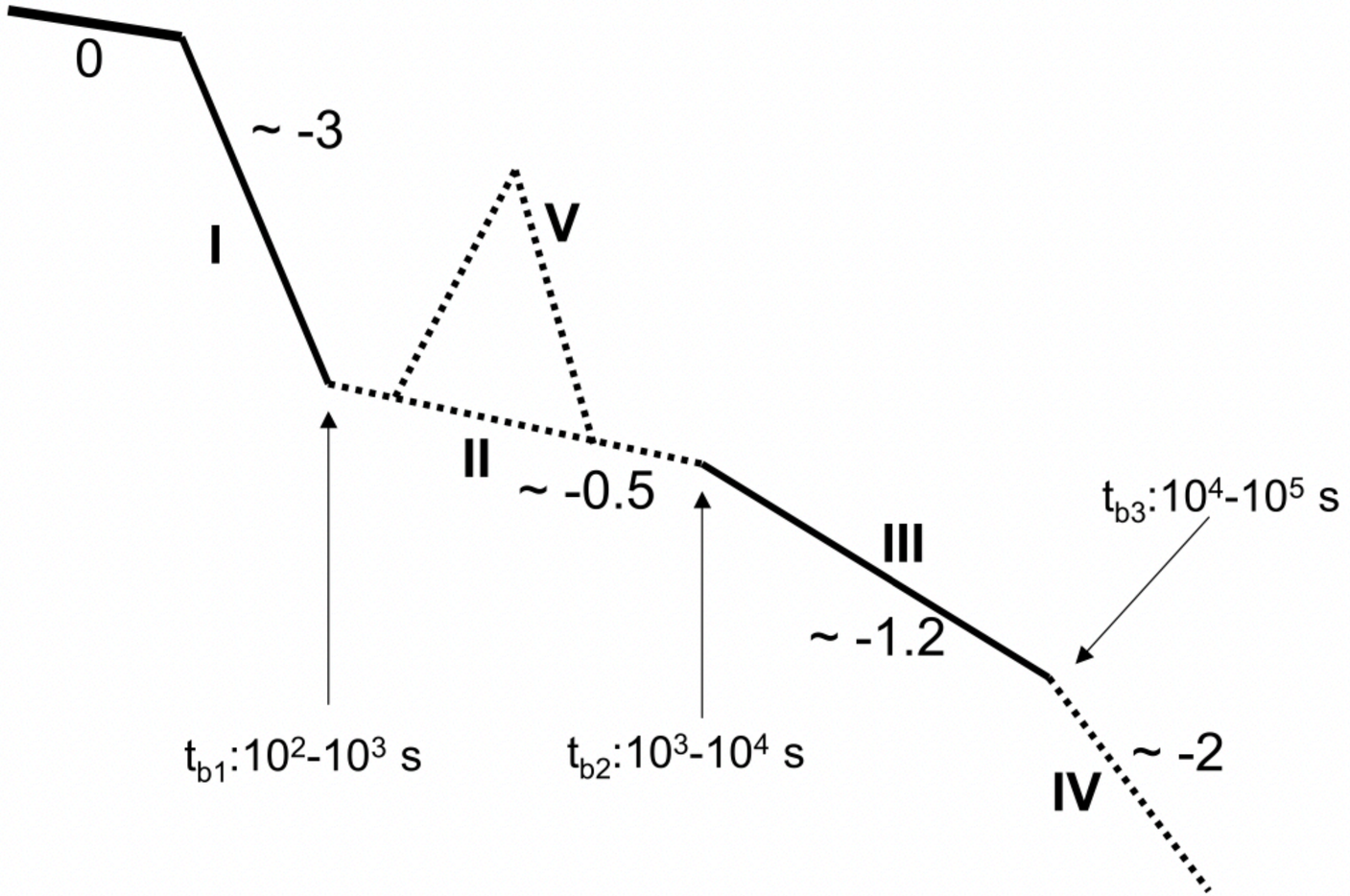
NS-NS or NS-BH merger

detectable in O4 and O5 runs of LIGO/Virgo

We do not understand the population of BNS

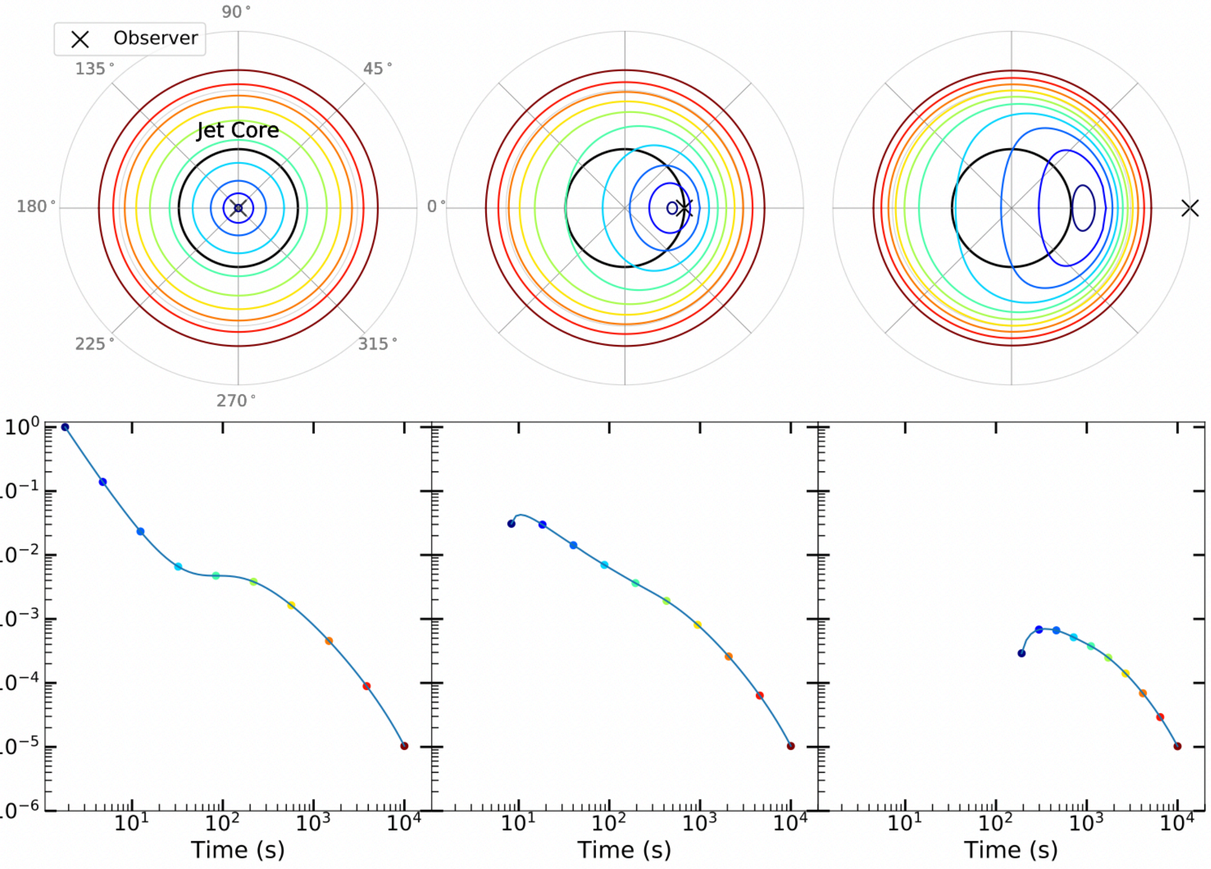
Jillian Rastinejad et al. 2022, arXiv 2204.10864, see also Jun Yang et al. 2022, arXiv 2204.12771

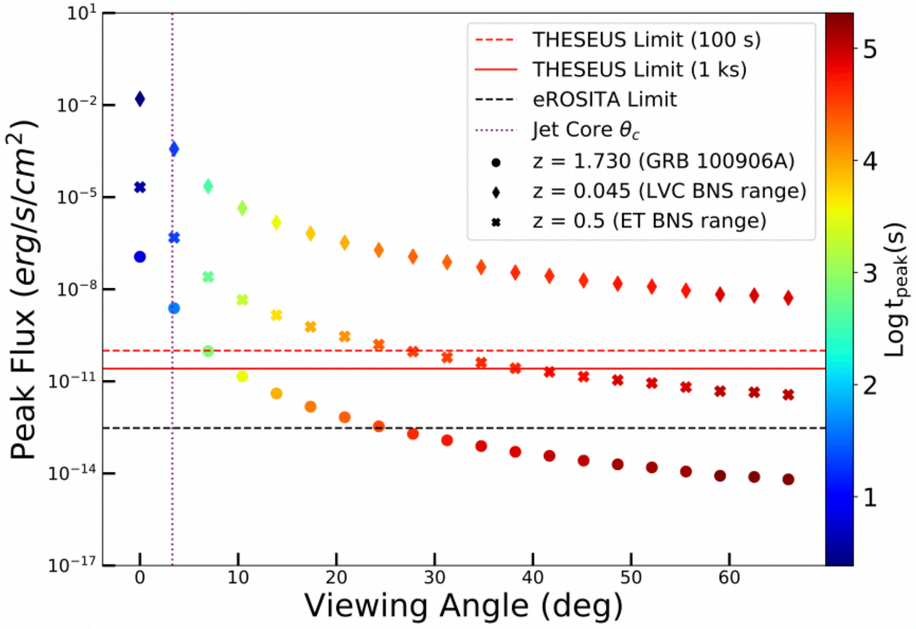
X-ray domain



Zhang et al. 2006

Large Angle Emission



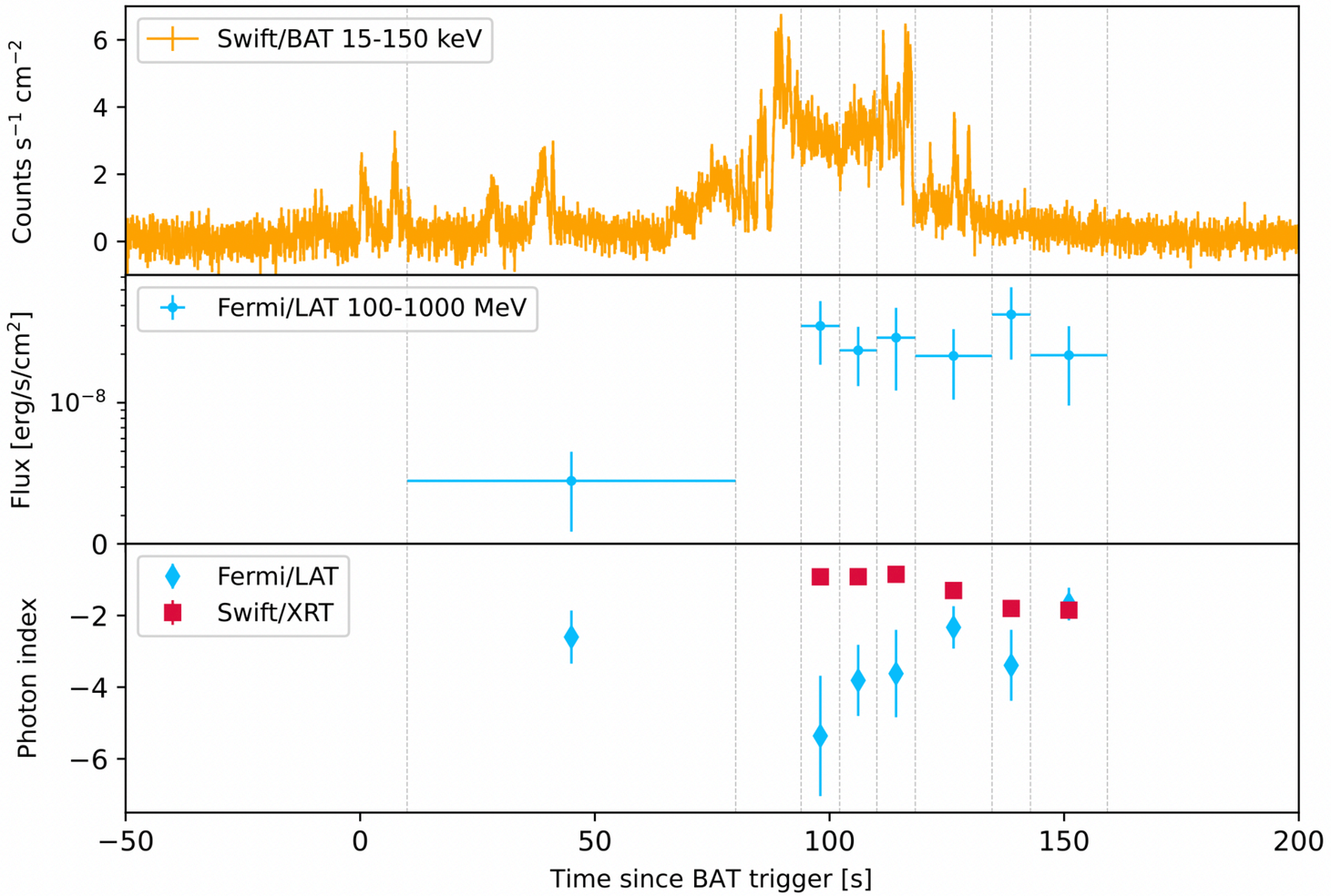


Oganesyan et al. 2020, Panaitescu 2020, Ascenzi et al. 2021

High energies

GRB 220101A

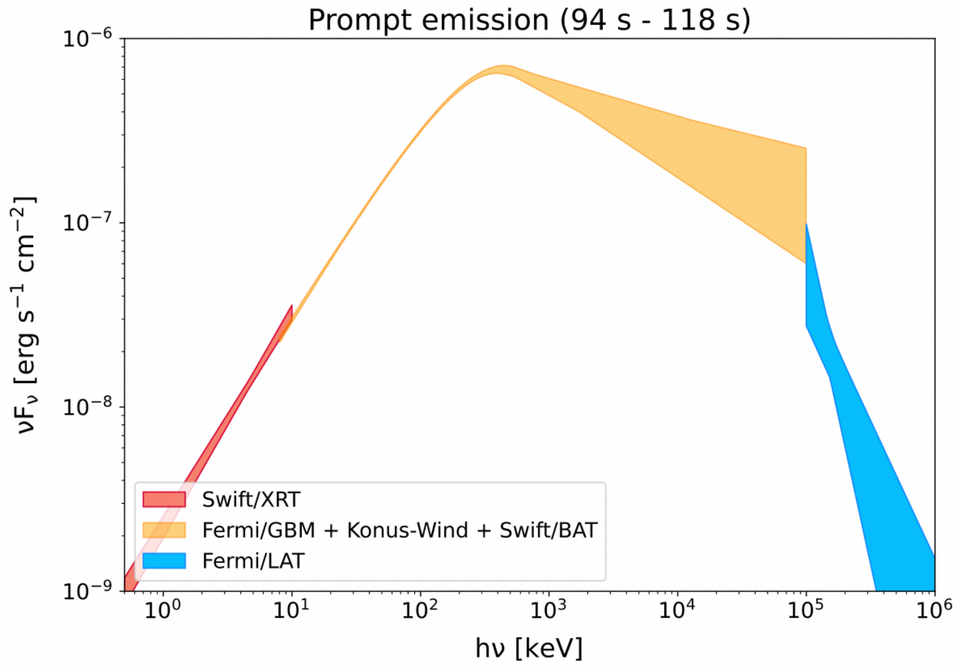
$$E_{iso} \approx 3 \times 10^{54} erg \qquad z = 4.618$$

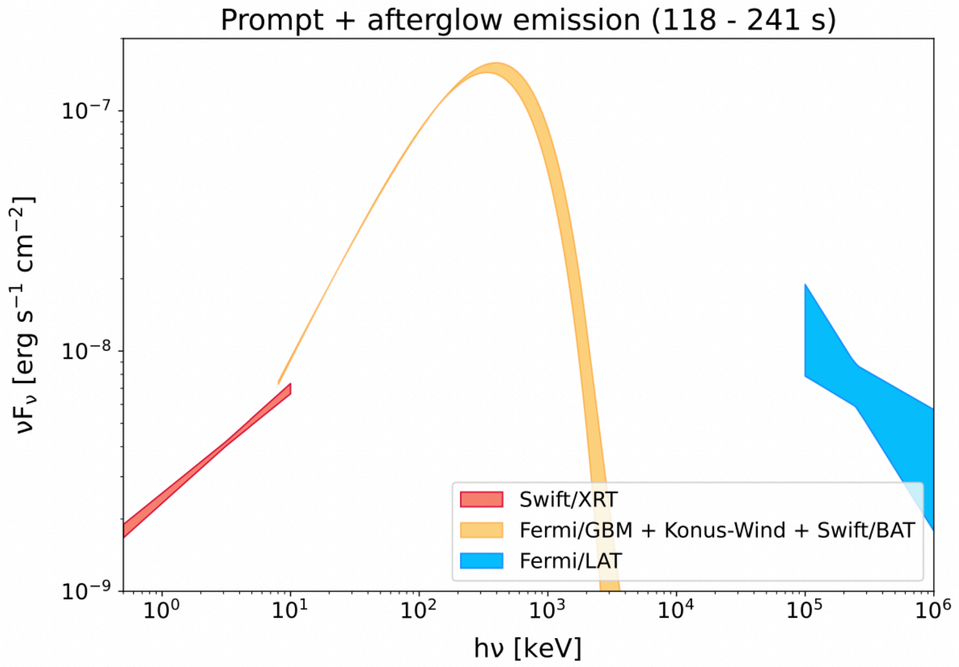


A. Mei et al. 2022, arXiv:2203.04971

GRB 220101A

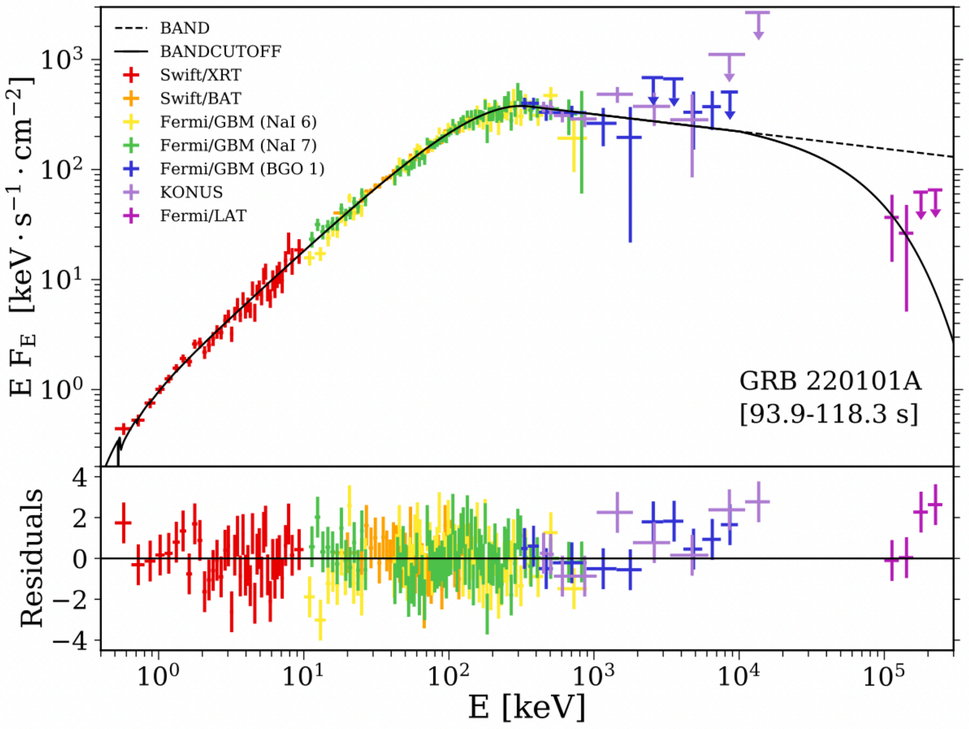
optical emission + Swift/XRT + Swift/BAT + Fermi/GBM + Konus-WIND + Fermi/LAT

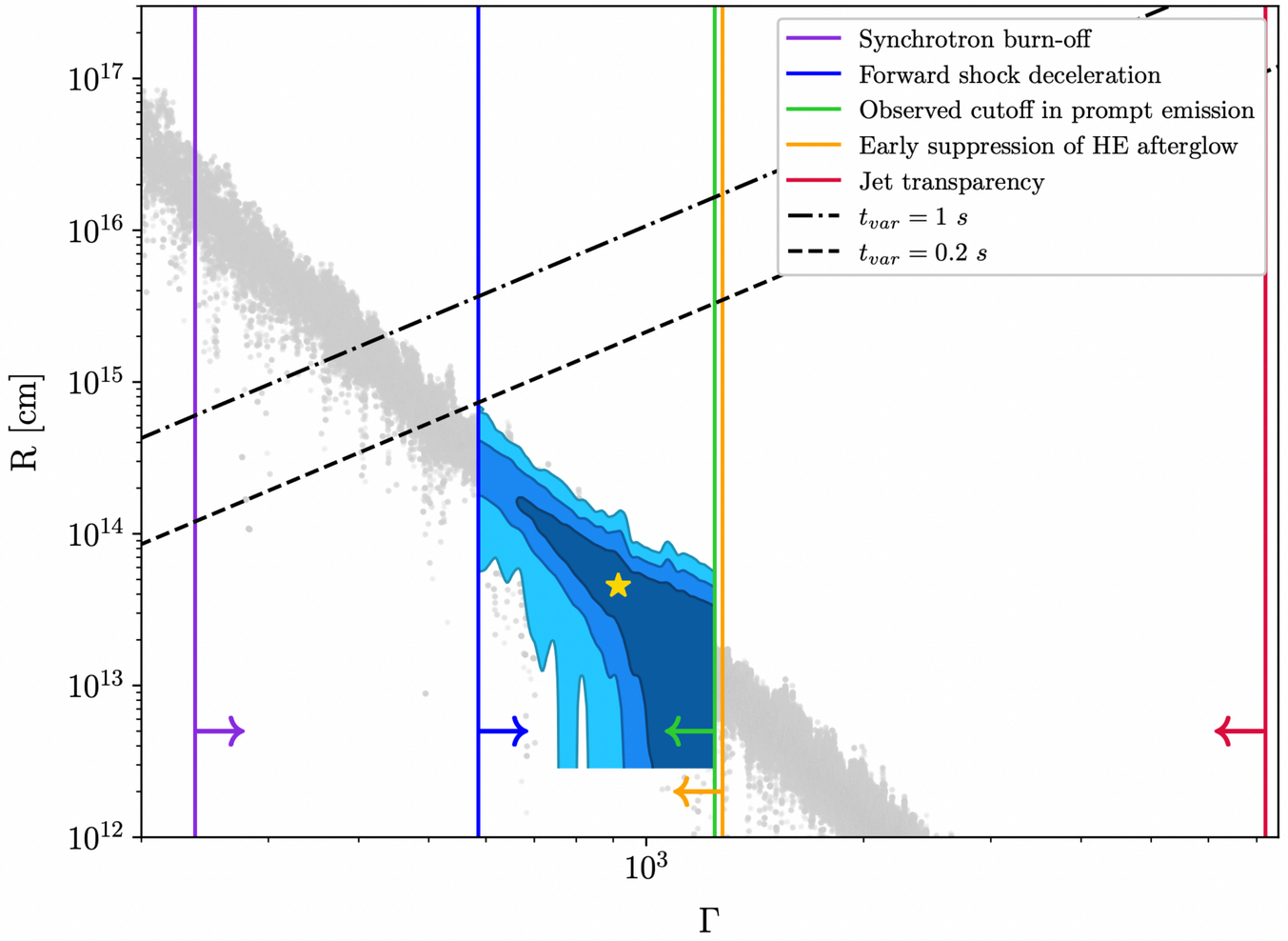




A. Mei et al. 2022, arXiv:2203.04971

GRB 220101A

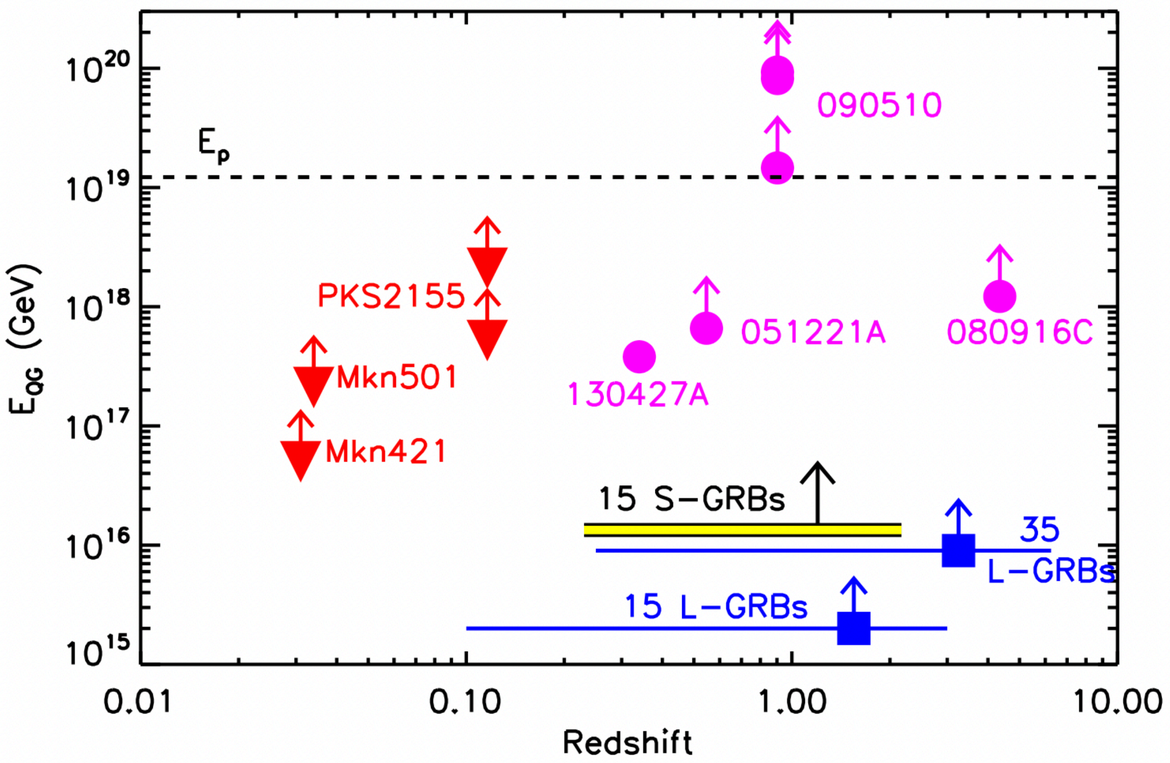




A. Mei et al. 2022, arXiv:2203.04971

Very High Energies

Almost the only way to access the fundamental physics beyond GR



M.G. Bernardini et al. 2017

$$\Delta t = \frac{\Delta E}{M_{\mathrm{QG}} c^2} \int_0^z \frac{1+z}{H_0 \sqrt{\Omega_m (1+z)^3 + \Omega_\Lambda}} \, \mathrm{d}z$$

Amelino-Camelia et al. 1998, Jacob & Piran 2008

Requirements:

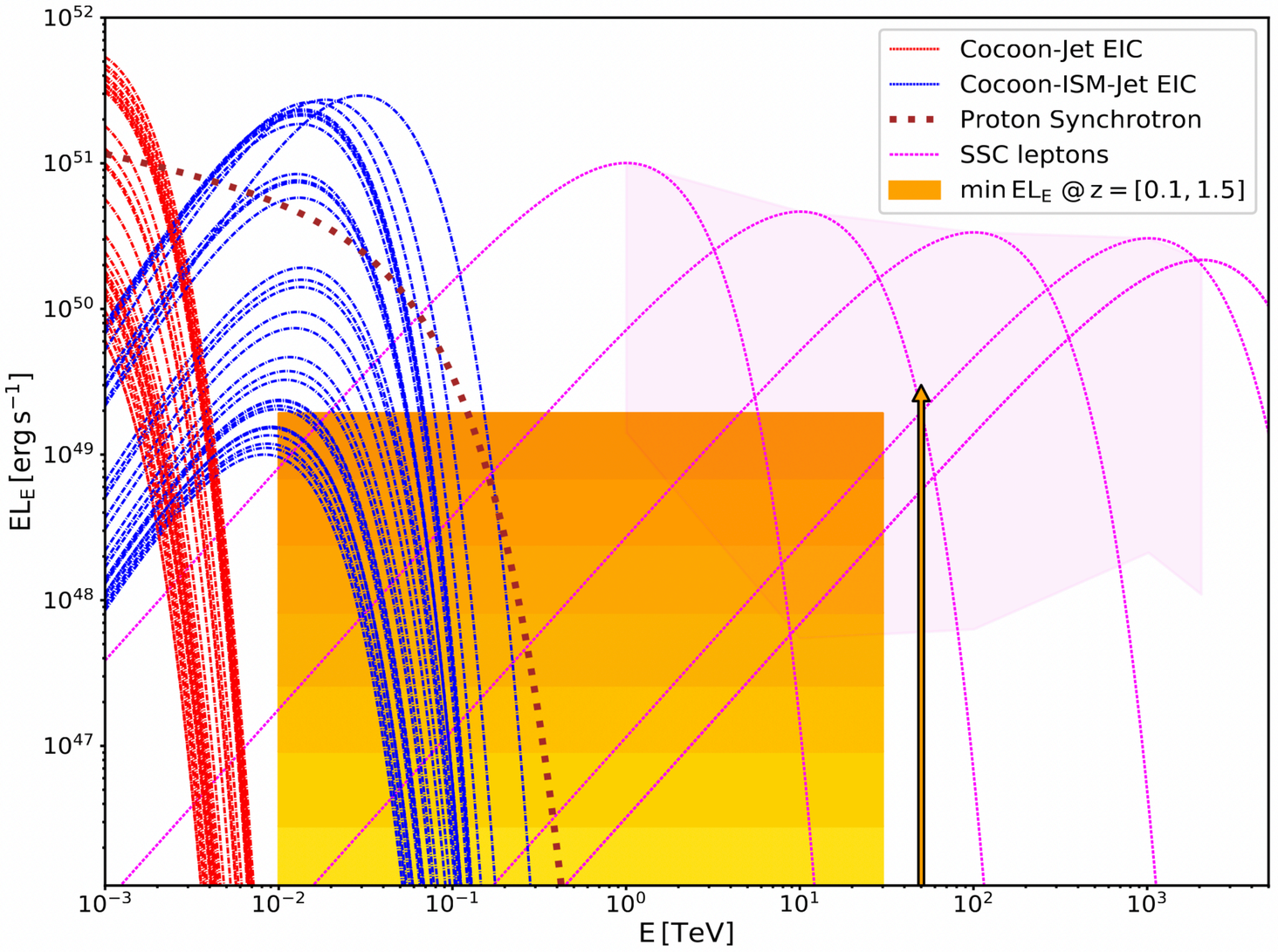
1) **Highly variable transient**

2) **Large distances**

3) **Emission at VHE**

4) **No intrinsic degeneracy with LIV**

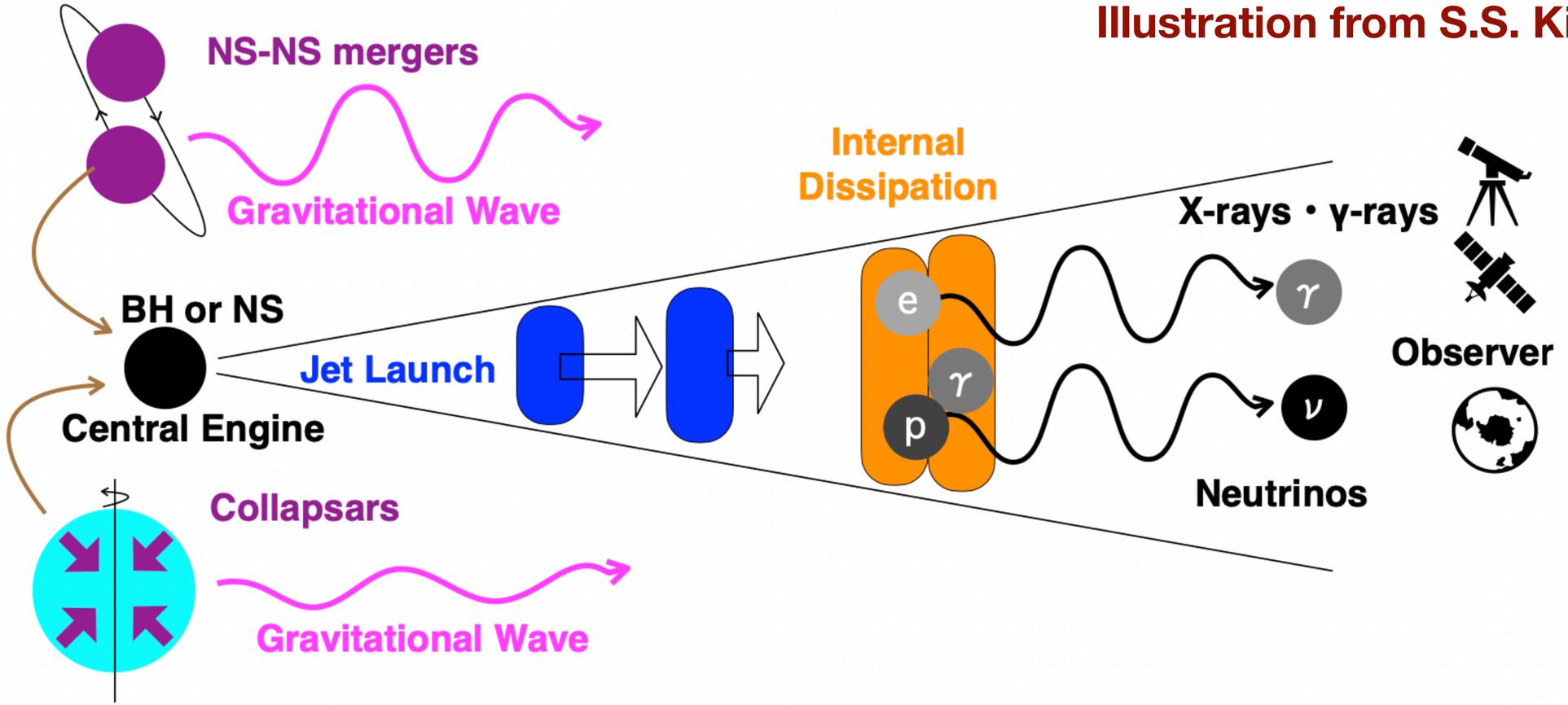
GRB prompt emission at VHE



B. Banerjee et al. 2022, in preparation

High energy neutrinos

Illustration from S.S. Kimura 2022

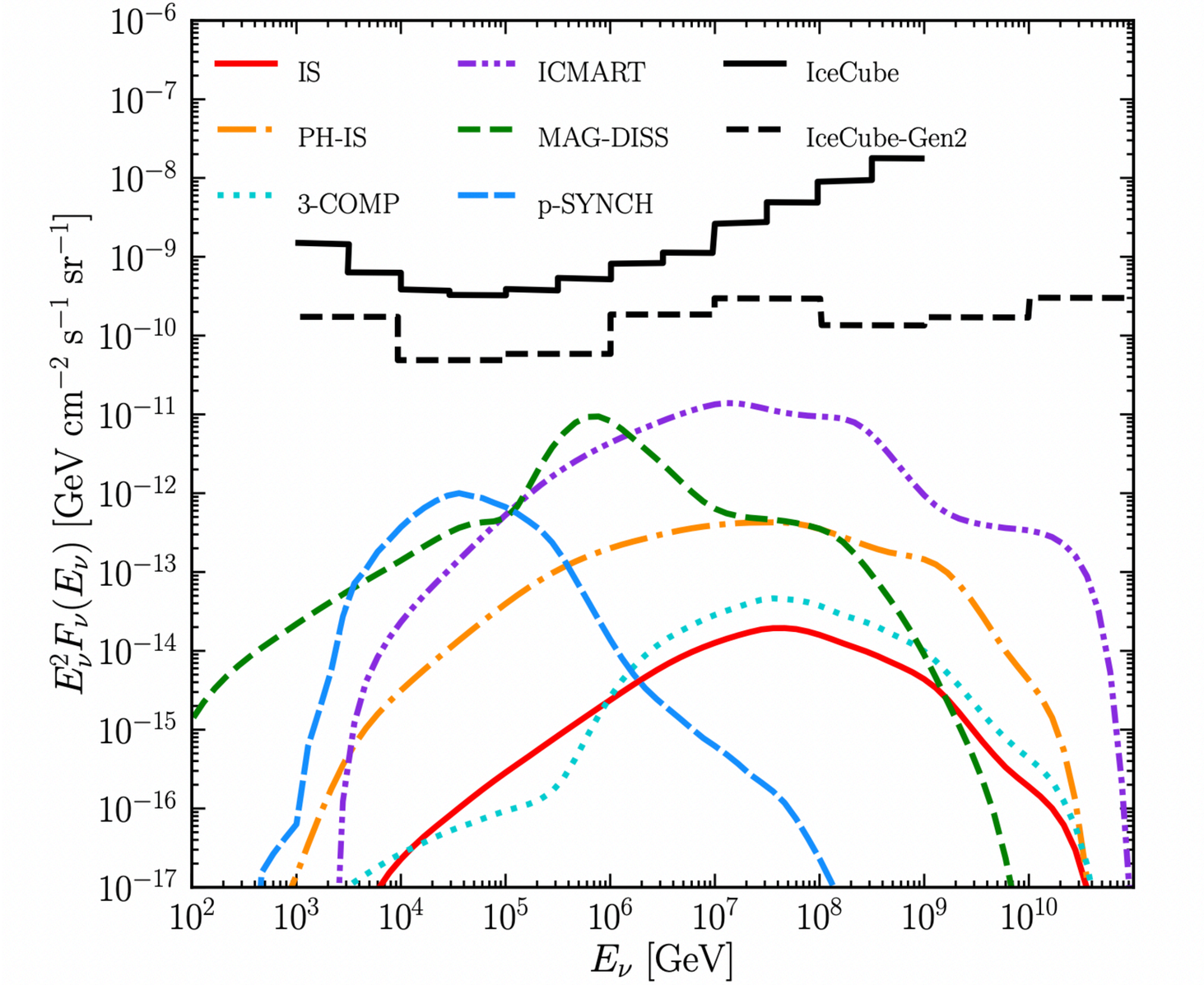


$$p + \gamma \rightarrow \Delta(1232) \rightarrow \pi^+ + n$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

Idea for GRBs: E. Waxman & J.N. Bahcall 1997



Tetyana Pitik, Irene Tamborra & Maria Petropoulou, 2021

$$E_{\nu_\mu}^2 \phi_{\nu_\mu} = \frac{1}{8} \xi_p f_p f_{p\gamma} f_\pi^{syn} f_\mu^{syn} S_{iso}$$

$$f_{p\gamma} \approx 0.5 \frac{L_{iso,52}}{\Gamma_2^2 R_{14}} E_{\gamma,peak,200}^{-1}$$

↓

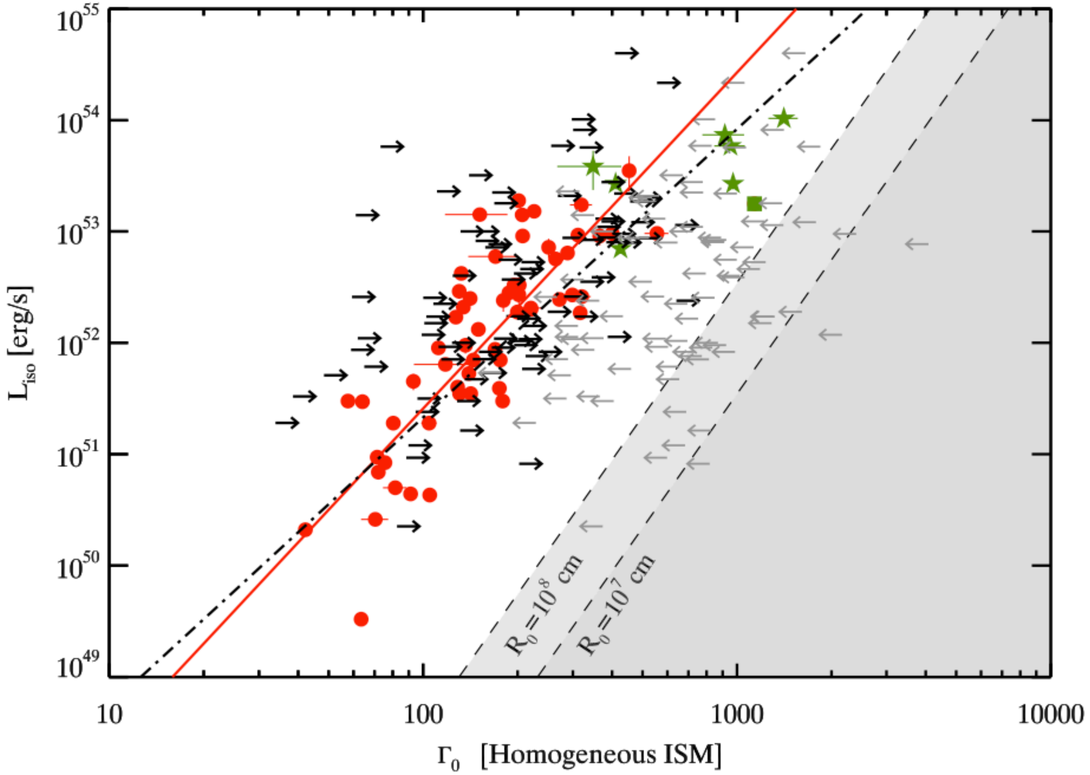
(1st simplification - **slightly model dependent**)

↓

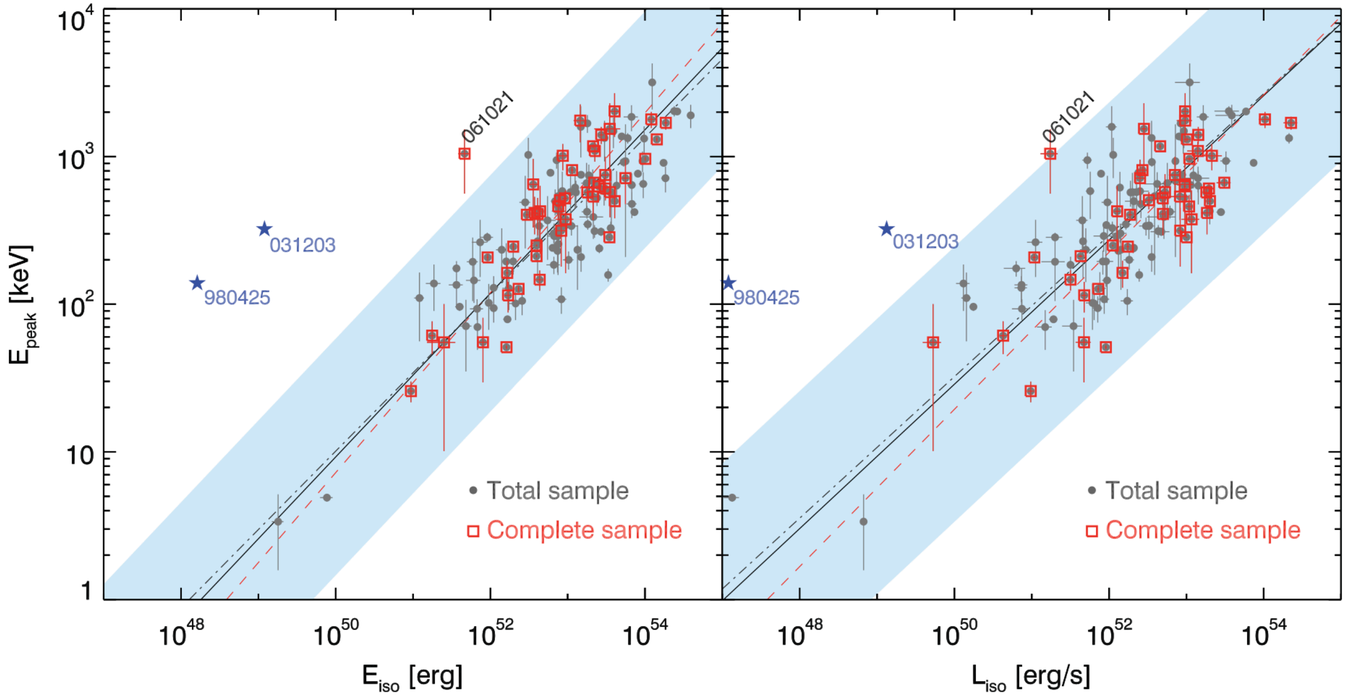
$$R = 2c\Gamma^2 \delta t_v$$

(All the models except mini-jets)

$$f_{p\gamma} \propto \frac{L_{iso}}{\Gamma^4} E_{\gamma,peak}^{-1} \delta t_v^{-1}$$



Ghirlanda et al. 2017



Nava et al. 2012

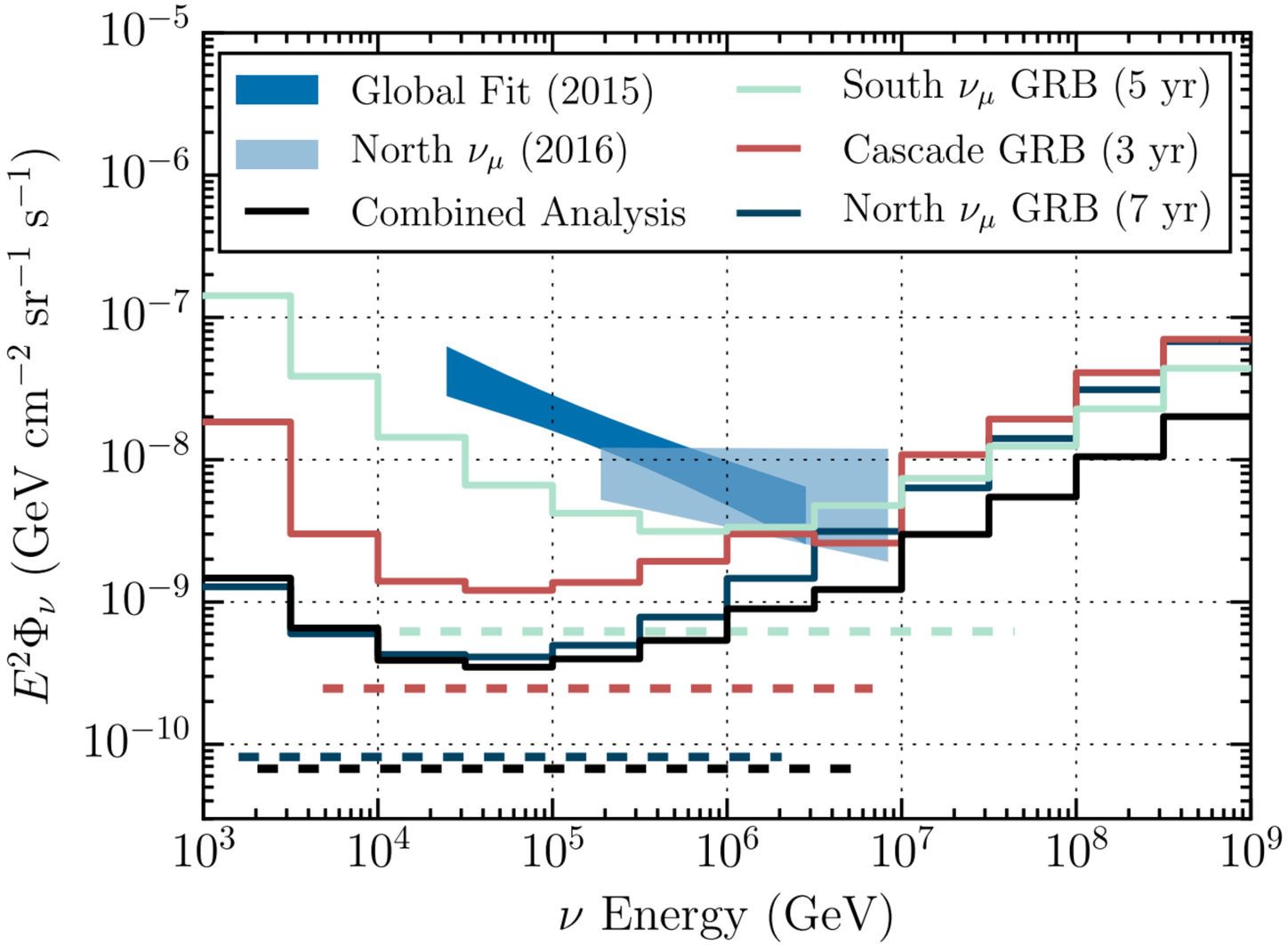
The Method

$$E^2_{\nu_\mu}\phi_{\nu_\mu} \propto [S_{iso} \times E^{-5/3}_{\gamma,peak} \times \delta t_v^{-1} \times (1+z)^{-2/3}] \times [\xi_p / ln(E_{p,max}/E_{p,min})]$$

WE OBSERVE **WE CONSTRAIN**

F. Lucarelli et al., in preparation

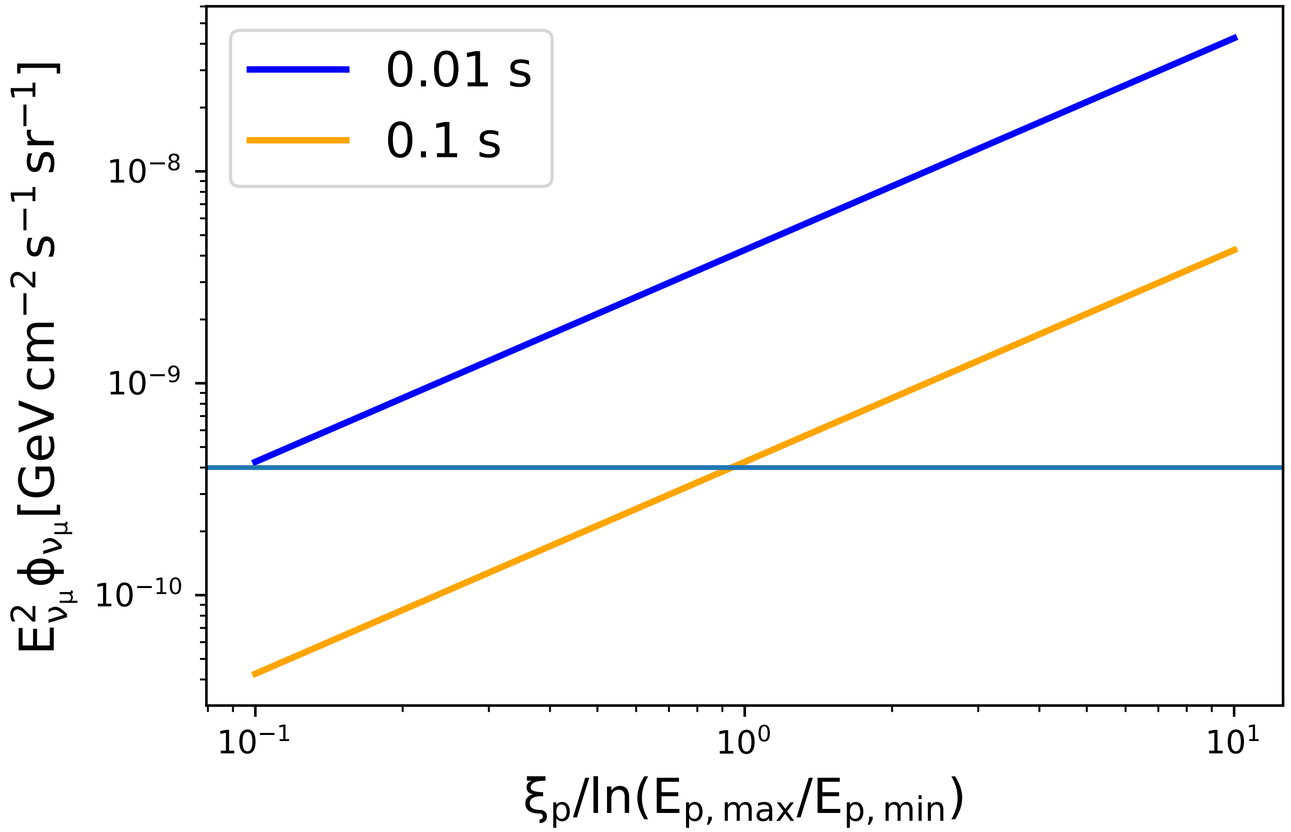
(I) Prompt emission



Aarsten et al. 2017

(I) Prompt emission

1784 GRBs in the free Ice-Cube data epoch with measured peak energy and the fluence



F. Lucarelli et al., in preparation

(II) X-ray flares

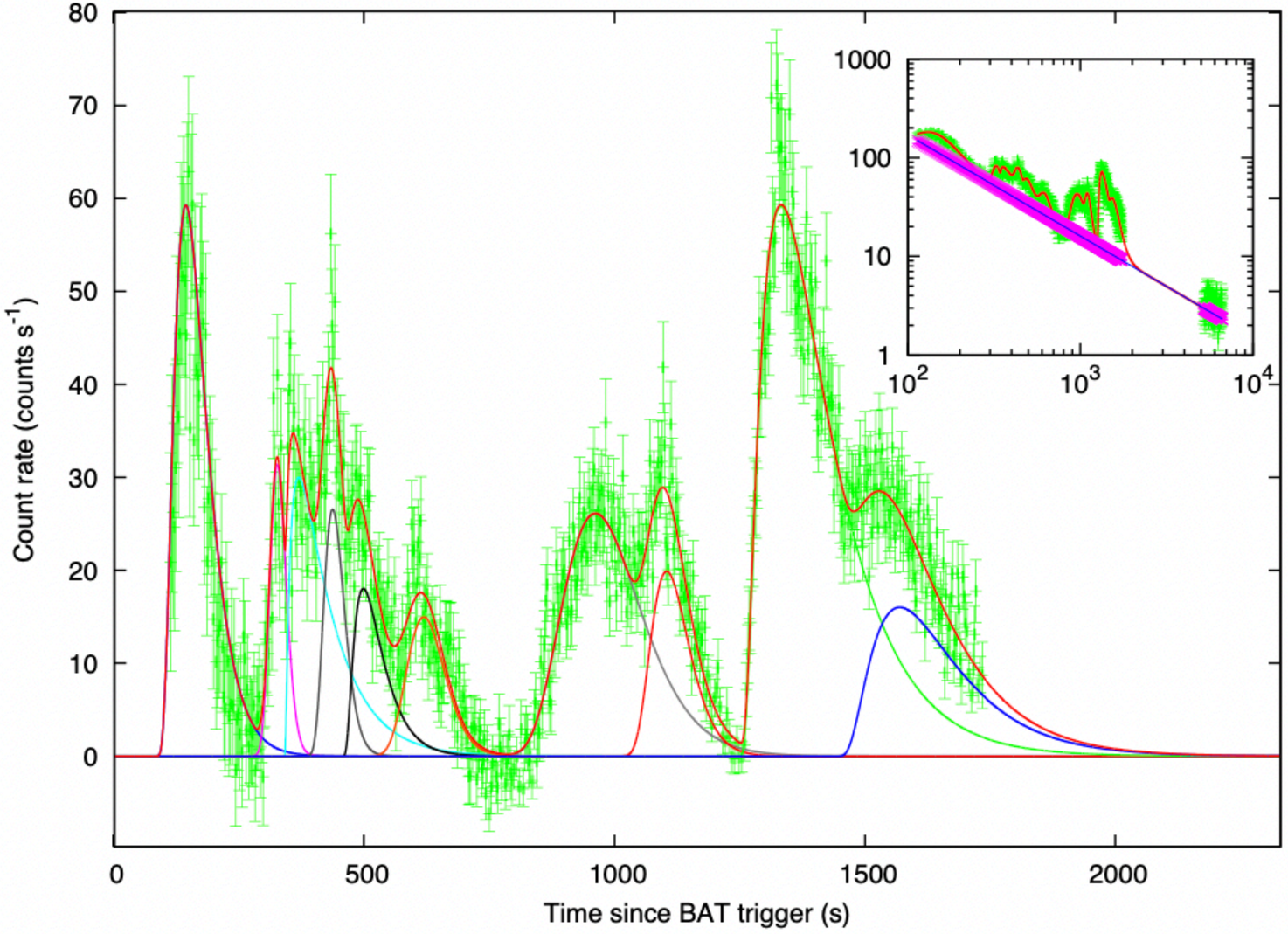
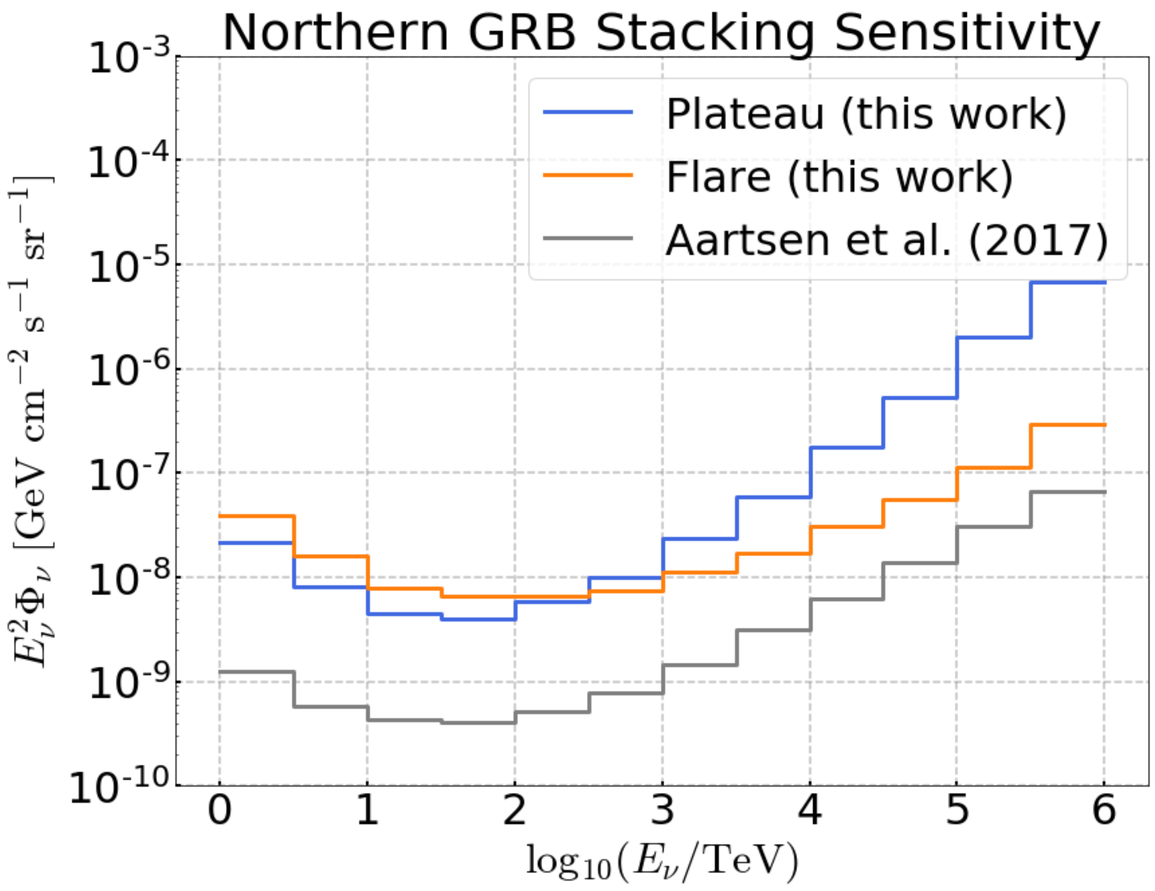
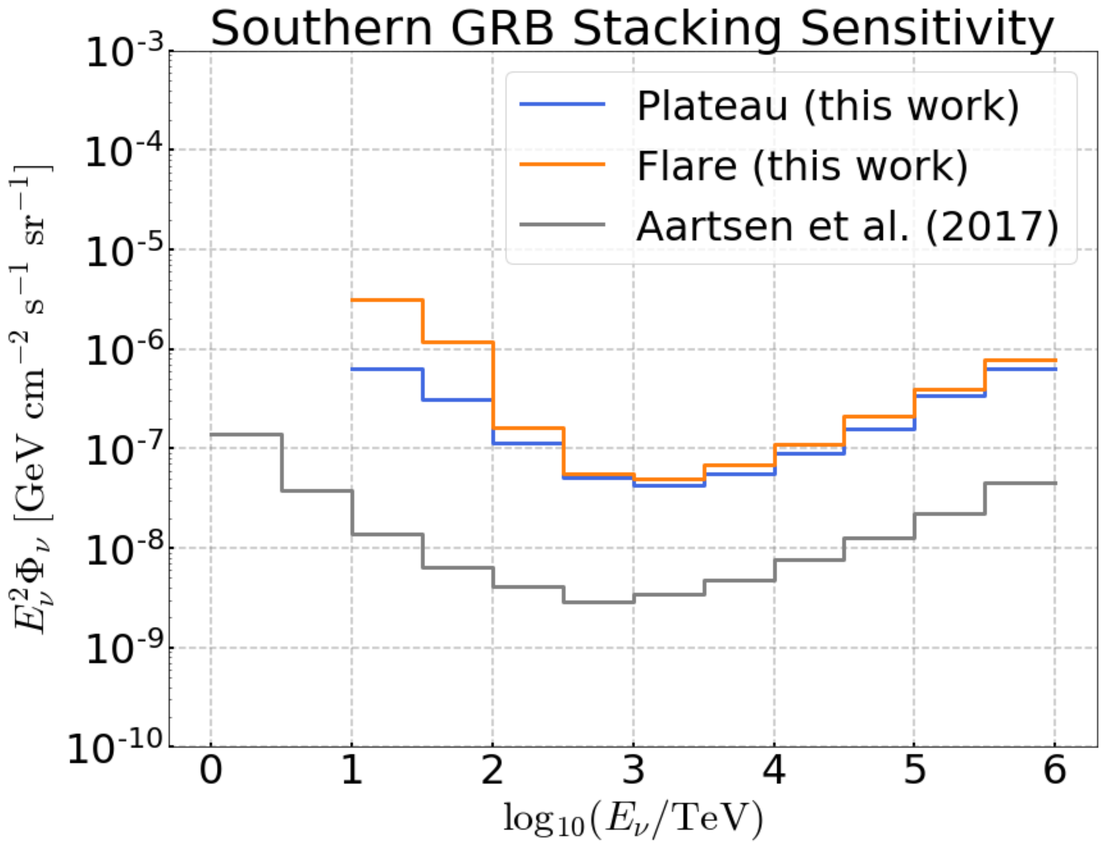


Figure from Chincarini et al. 2010

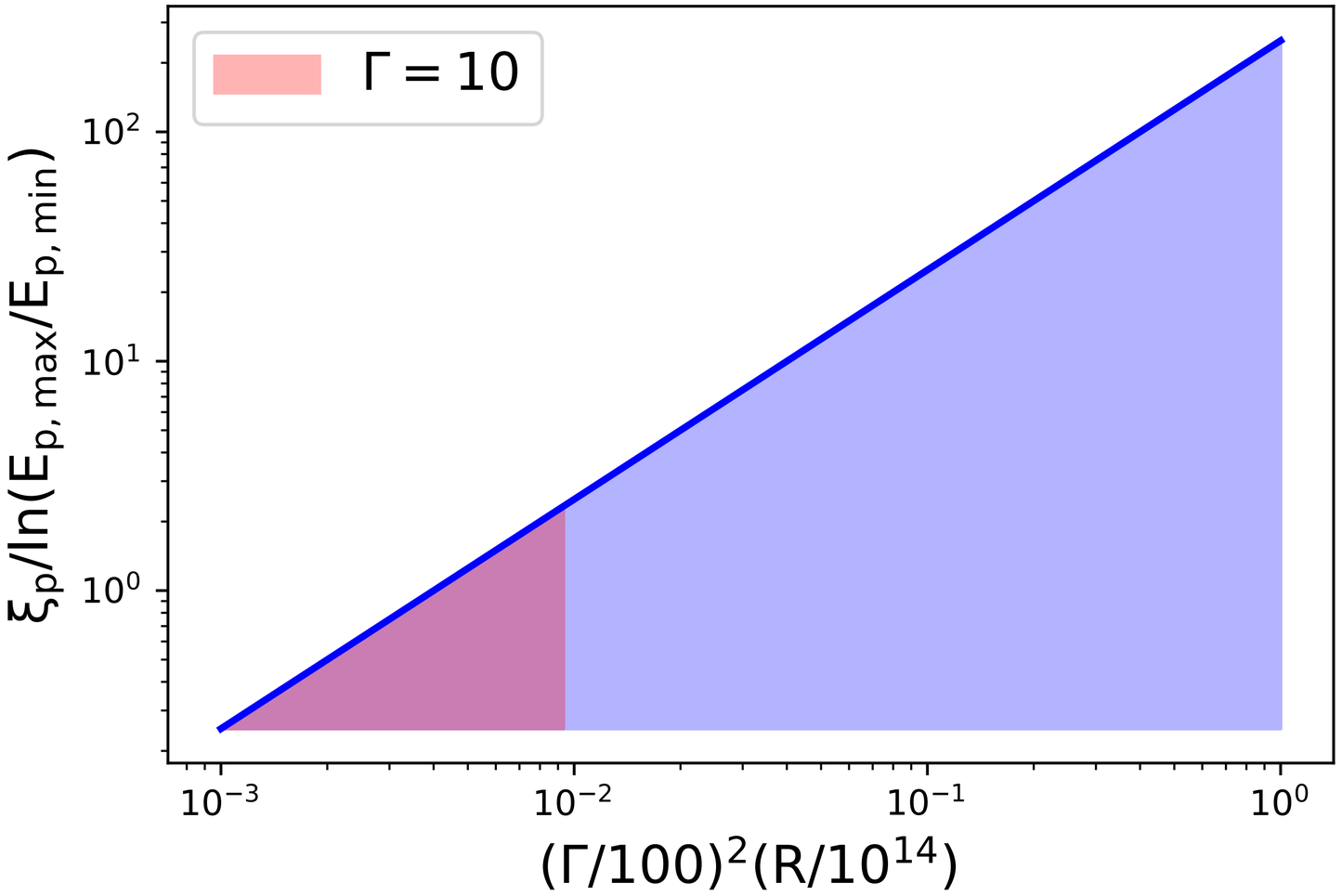
(II) X-ray flares





F. Lucarelli et al., in preparation

(II) X-ray flares



F. Lucarelli et al., in preparation

Optical domain

fast - high temporal resolution - polarisation

nature of the jet and prompt emission

soft X-rays

wide FoV - space ground communication

multi-messenger astronomy GW-EM

high energies

gap between MeV and VHE

VHE

game-changer for the GRB physics

the only way to access quantum gravity?

high energy neutrinos

game-changer for the GRB physics

nature of UHECRs