Gamma Ray Bursts
[overview and recent facts]

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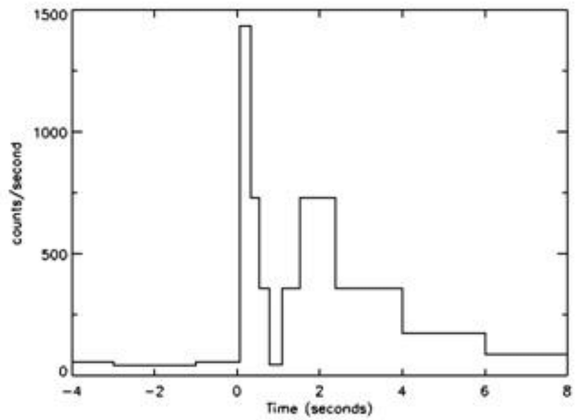
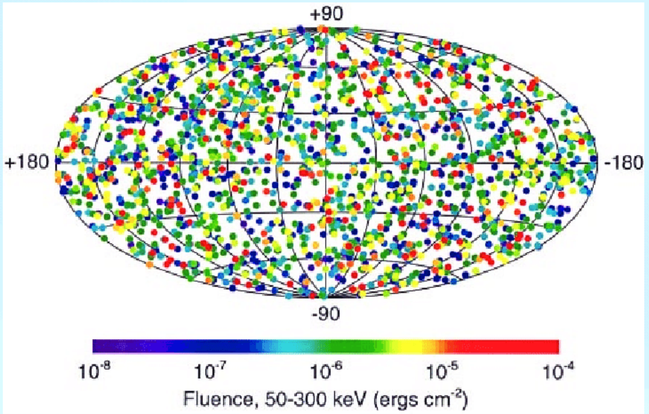
Gamma Ray Bursts: an amazing half century

Vela Satellites



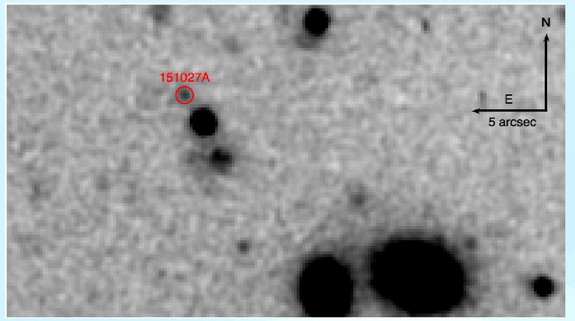
1973

CGRO



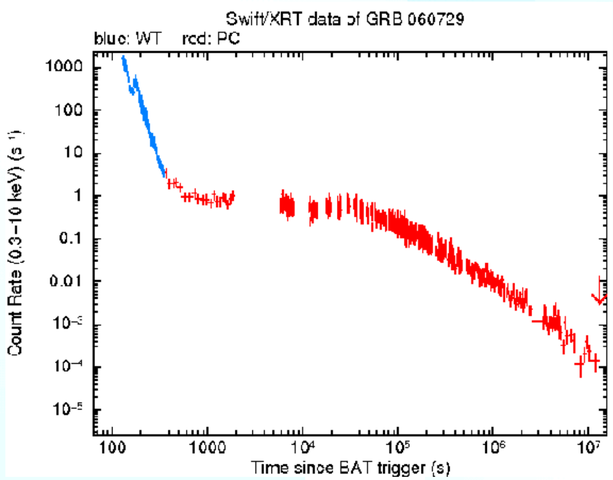
1992

BeppoSAX+Ground



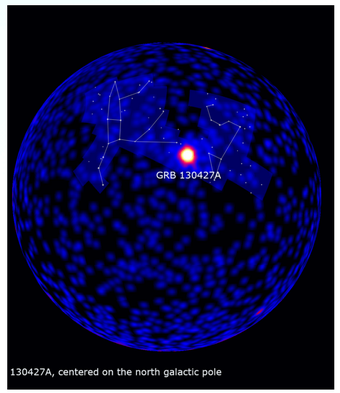
1997 1998

Swift



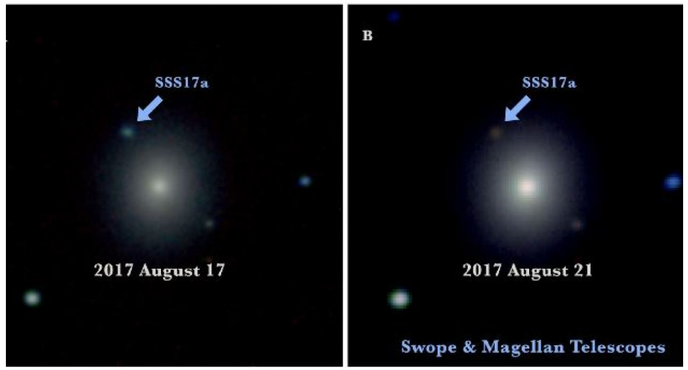
2005

Fermi



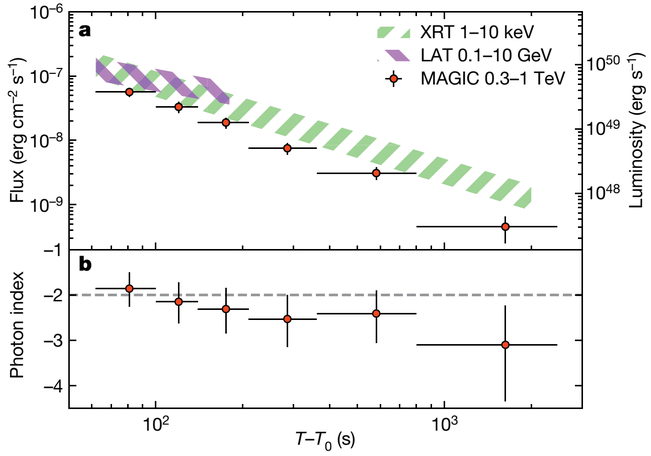
2008

LVC+Space+Ground



2017

Magic/HESS



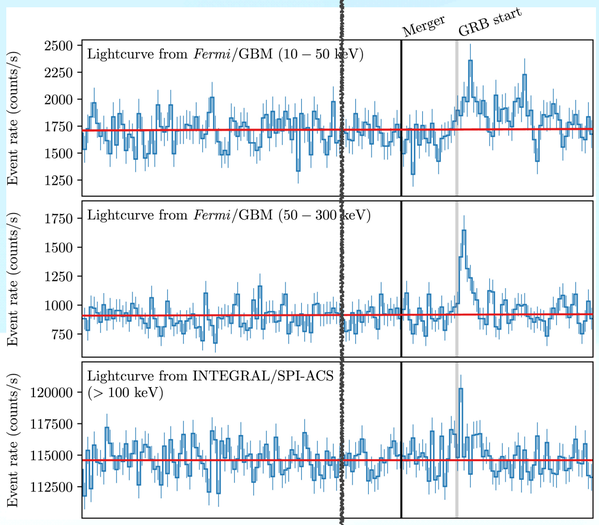
2019

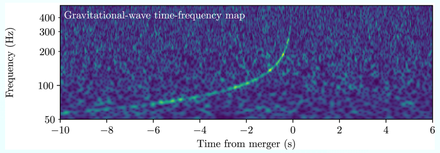
ToC: the last half decade

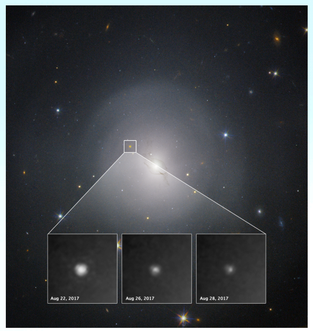
1. Multi Messenger
2. Multi Wavelength (up to HE, VHE). A. Berti, G. D'Amico, O. Salafia, M. Giroletti, D. Horan, C. Pittori, M. Zha, M. De Nouris, M. Errando … +CTA
3. Dying or merging?
4. Radiation process
5. Exceptional events

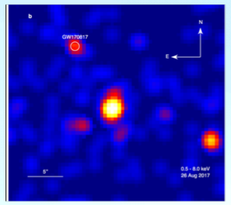
2017 2023

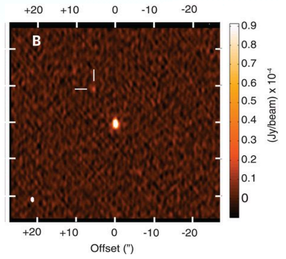
MultiMessenger: GW/GRB/KN 170817, a Rosetta Stone

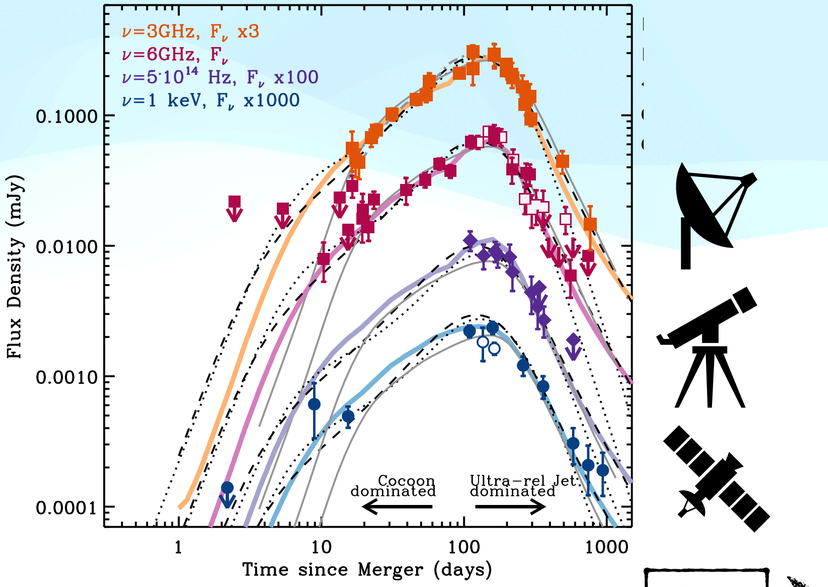








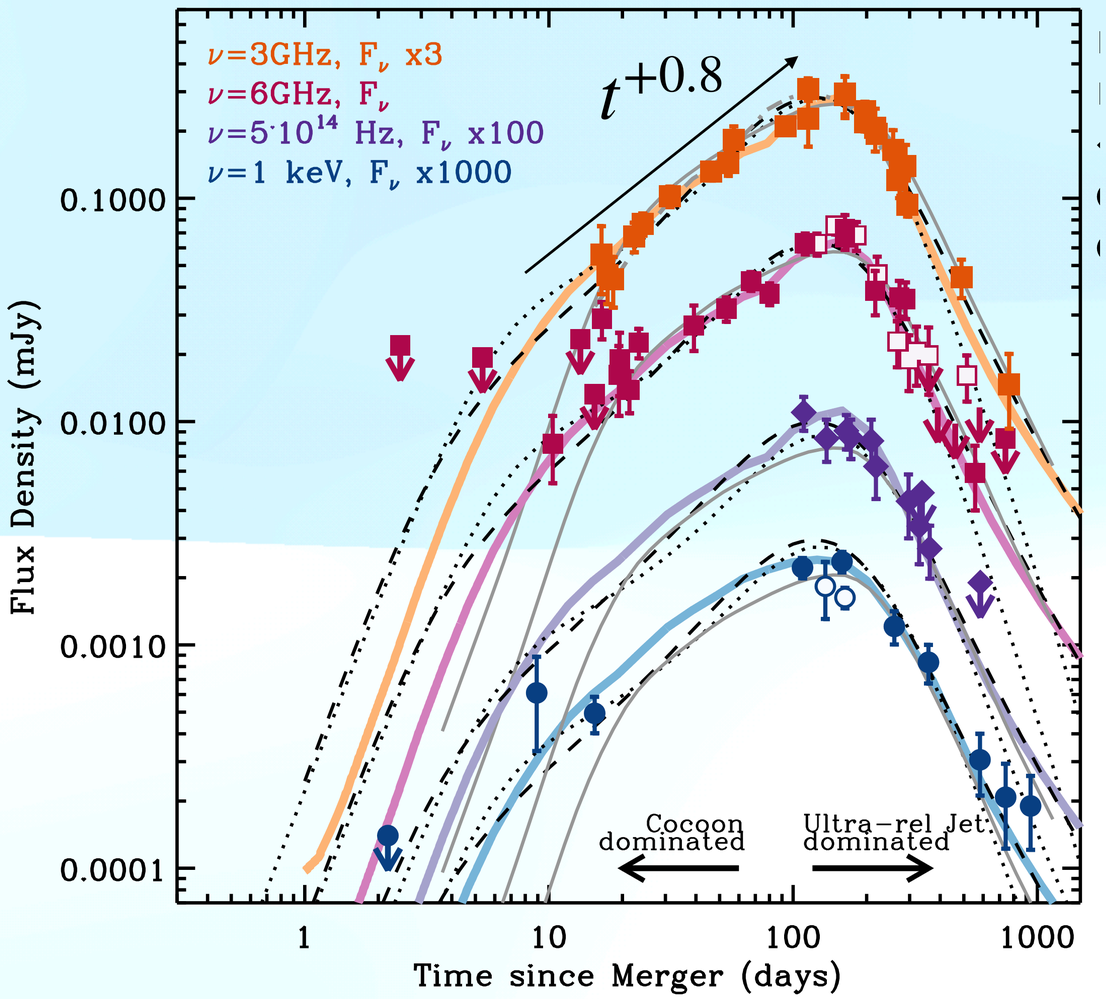




1.7 sec → 10.5 hours → 9 days → 16 days → 2.7 years

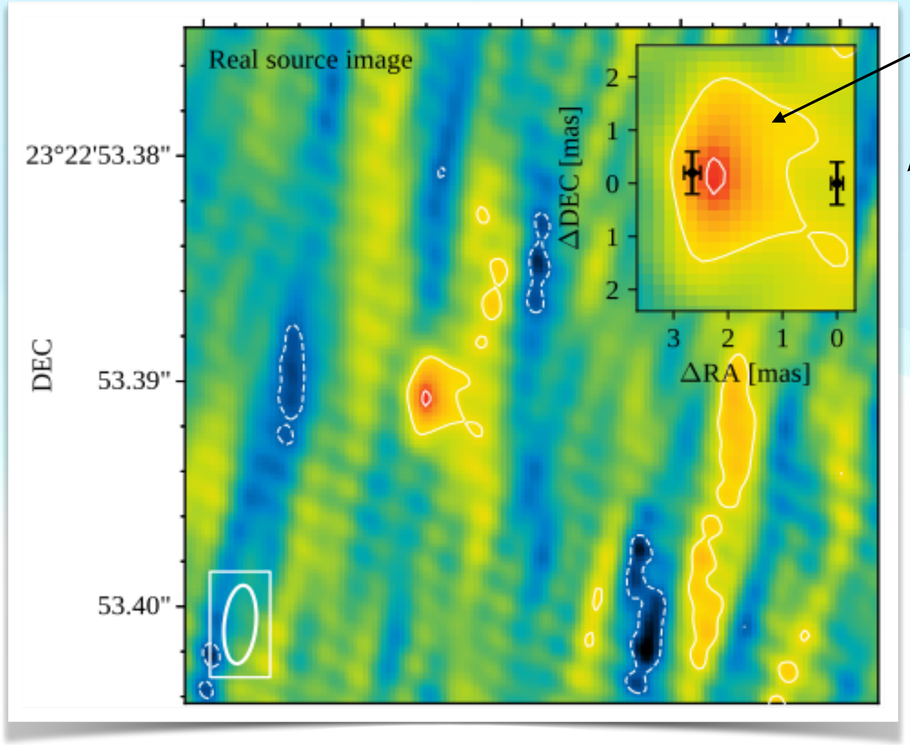
Jet properties

Margutti & Chornock 2021



Ghirlanda, Salafia et al. 2019

Mooley et al. 2018



- A jet emerged
- Obs from ~20 deg
- Angular structure
- Can be quasi-universal (O.Salafia talk)

[see Salafia & Ghirlanda 2022 for a review]

Afterglow physics

$\Gamma(t)$

θ

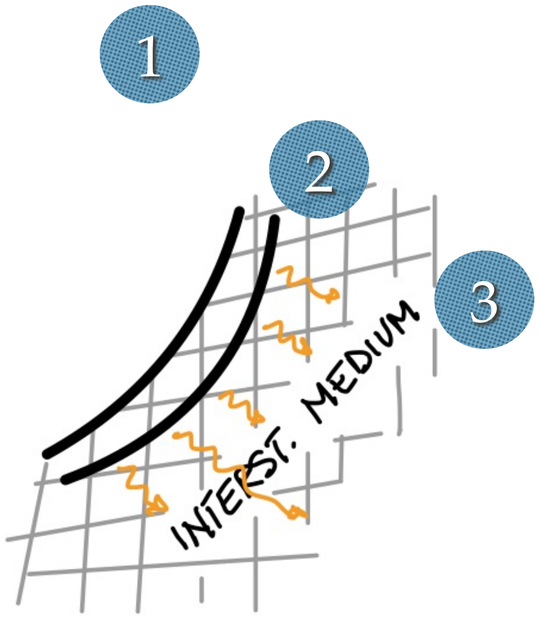
1) Jet energy $E_{\rm k} \approx E_{\rm prompt}/\eta$

2) Dissipation mechanism

3) Ambient medium n

ϵ_e ϵ_B p $\gamma_{\rm min}$ $\gamma_{\rm max}$ ξ_e

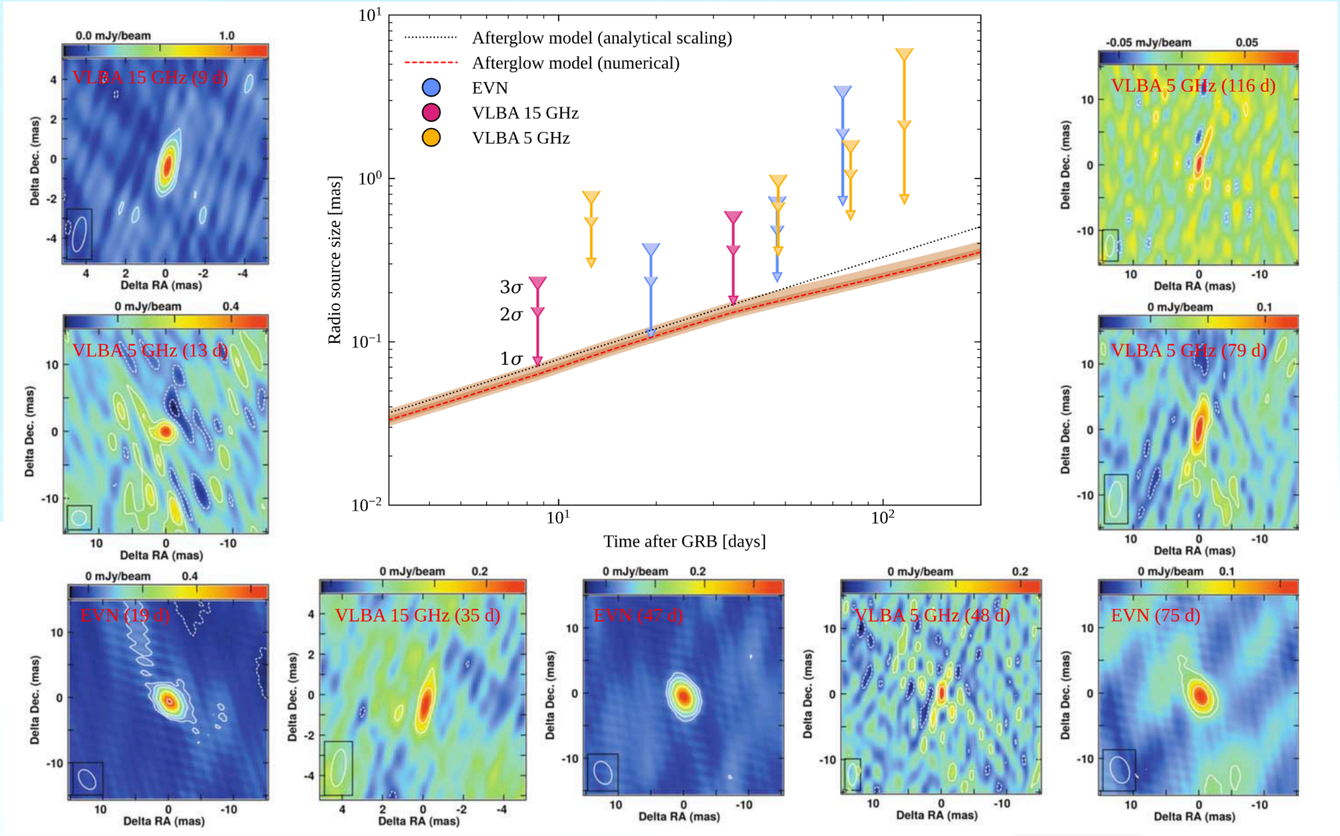
Intrinsic + extrinsic

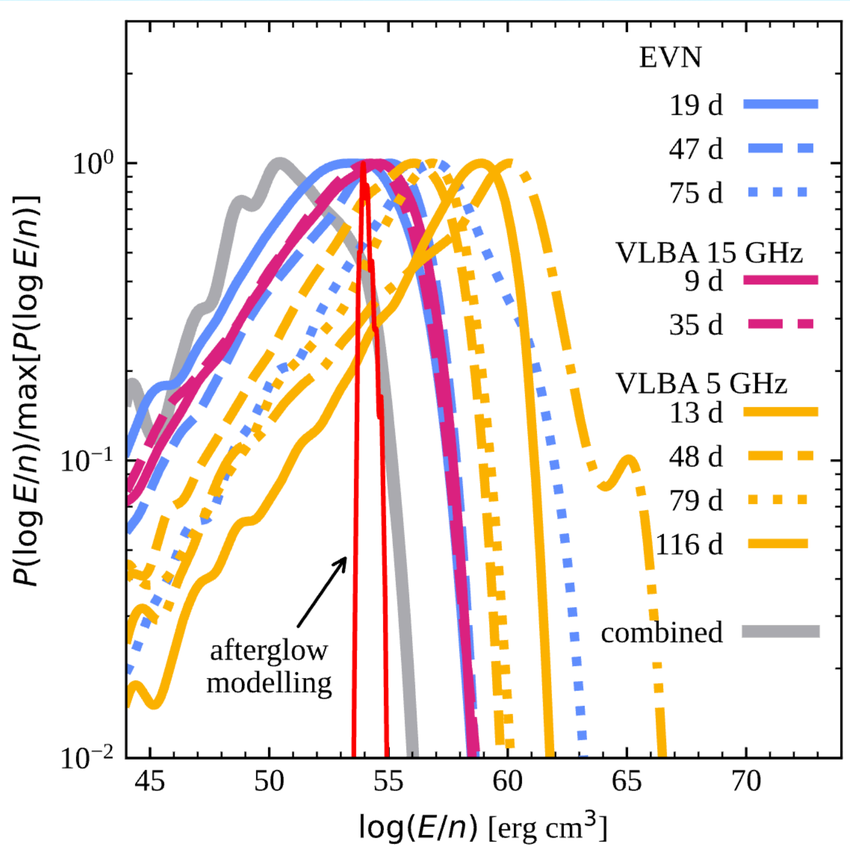


Parameter degeneracies

Multiwavelength: e.g. 190829A

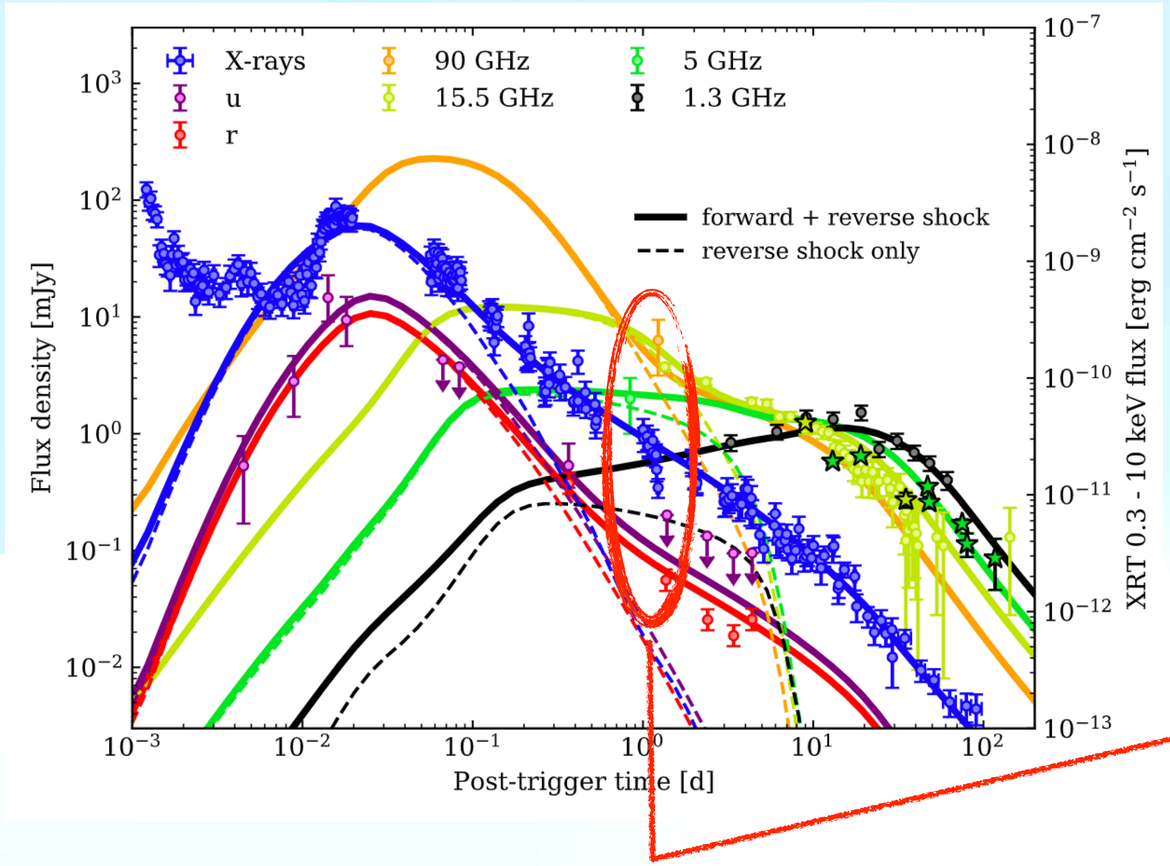
O. S. Salafia, et al, 2022





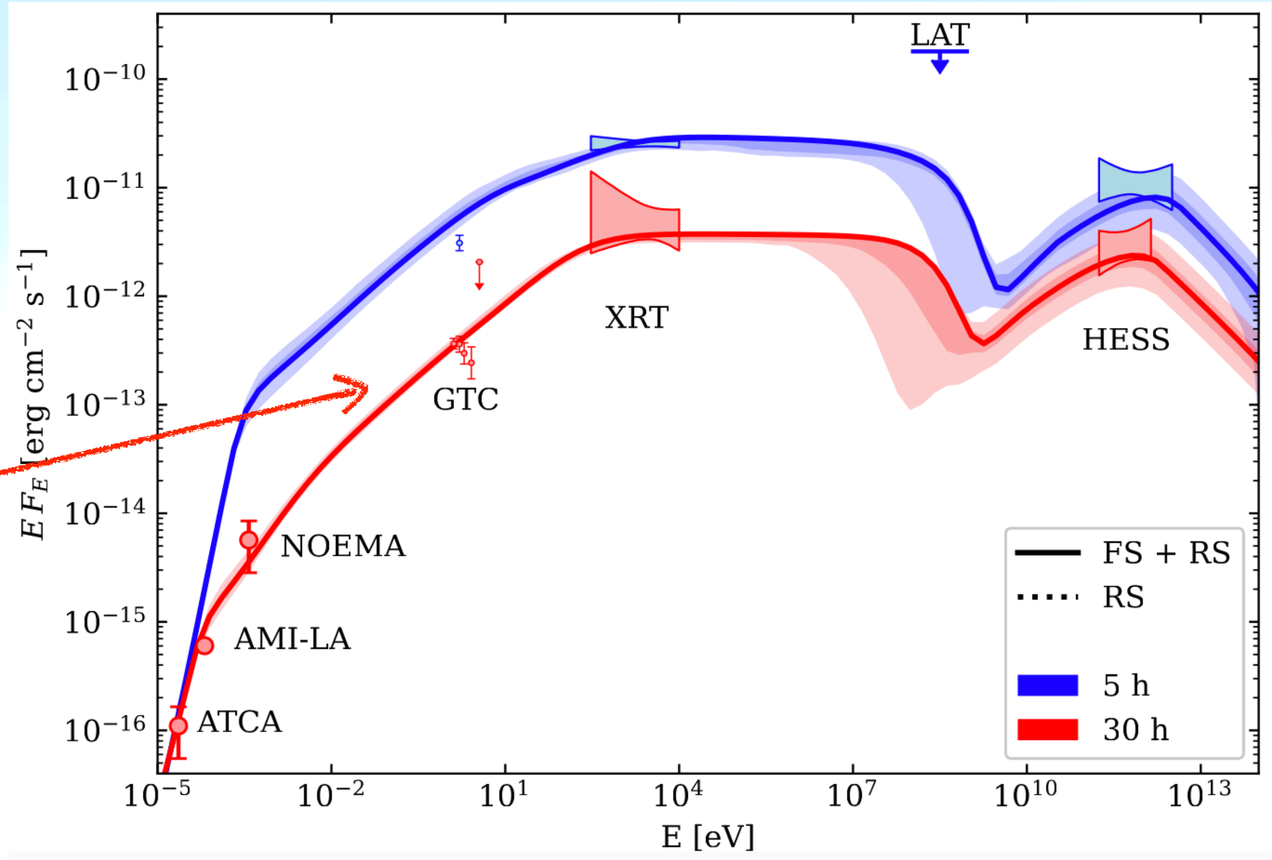
n~0.21 cm^-3

GRB 190829A



$L_{SSC}/L_{syn} \sim U_r/U_B$

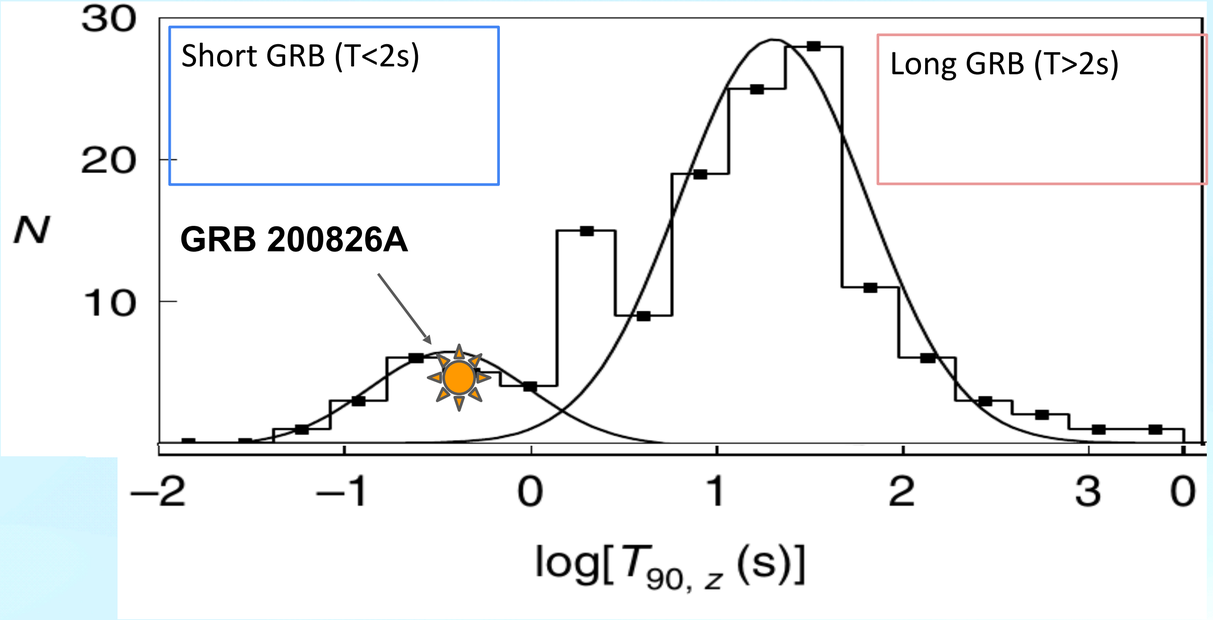
$\gamma_e \sim \sqrt{\nu_{SSC}/2\nu_{syn}}$



Notable:

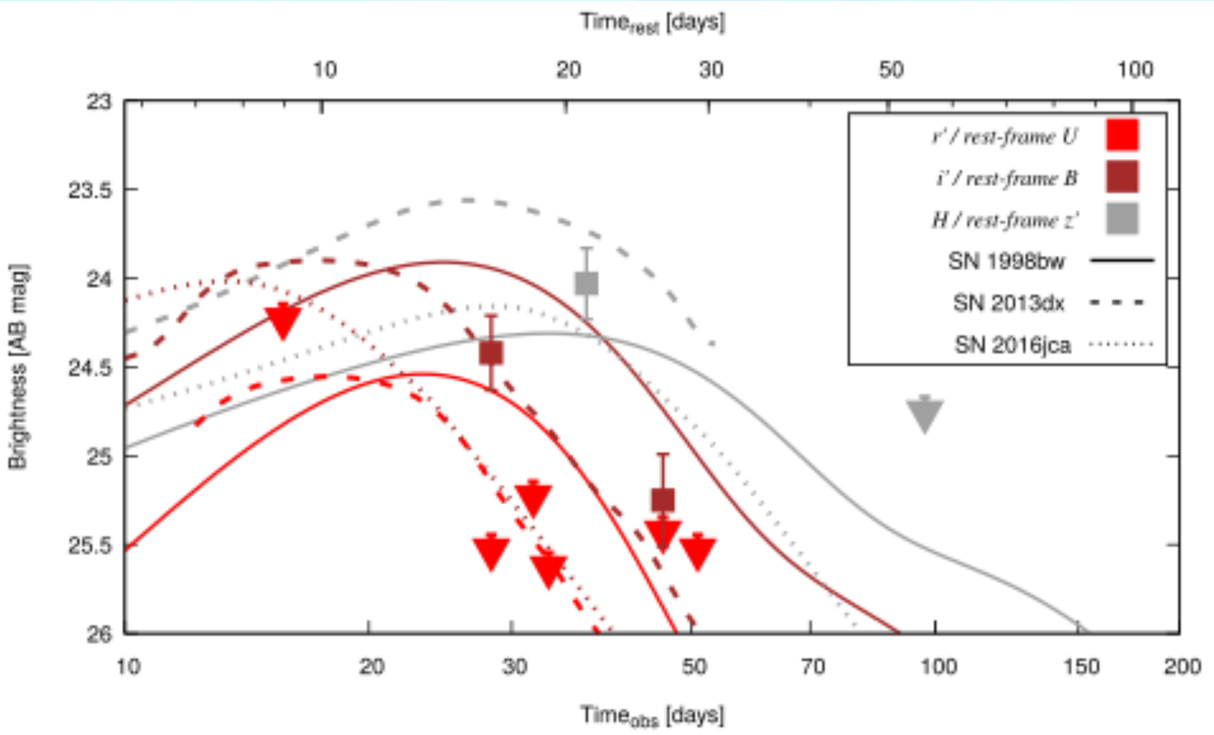
- Low prompt efficiency
- 7% acc. Electrons
- Jet orientation <2 deg off
- $\epsilon_B \sim 10^{-5}$

Merging rather than dying: GRB200806A

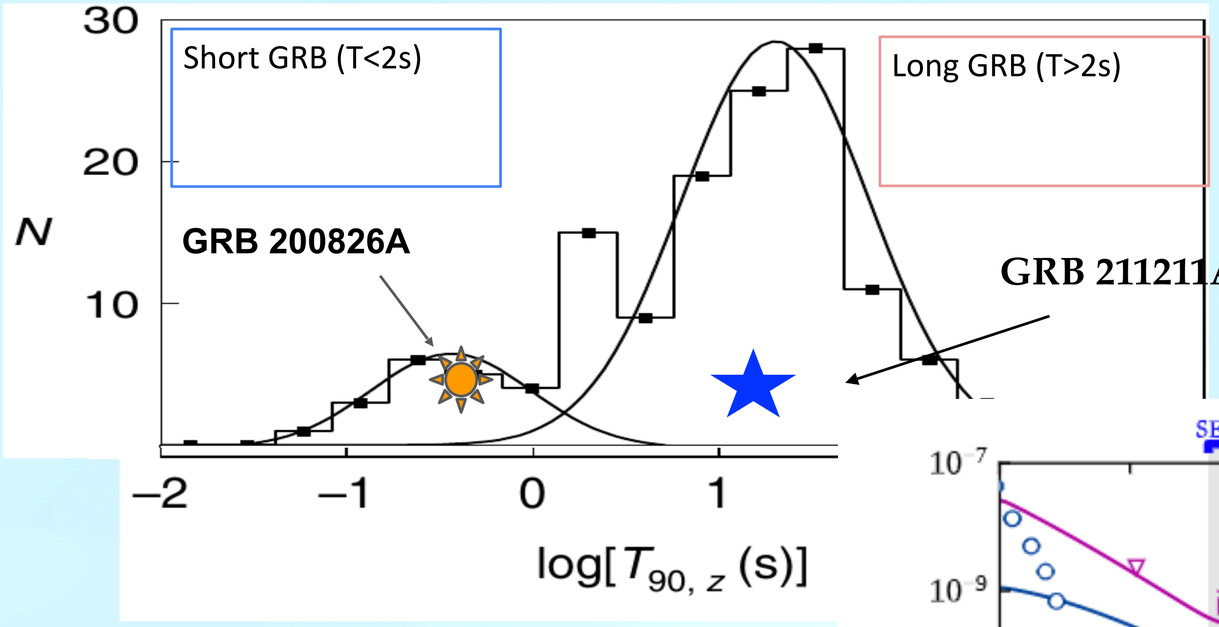


- Rest frame duration ~0.5 sec
- Soft spectrum (L)
- SN signature (L)
- Ep-Eiso correlation (L)
- Host (L)

Rossi et al. 2022

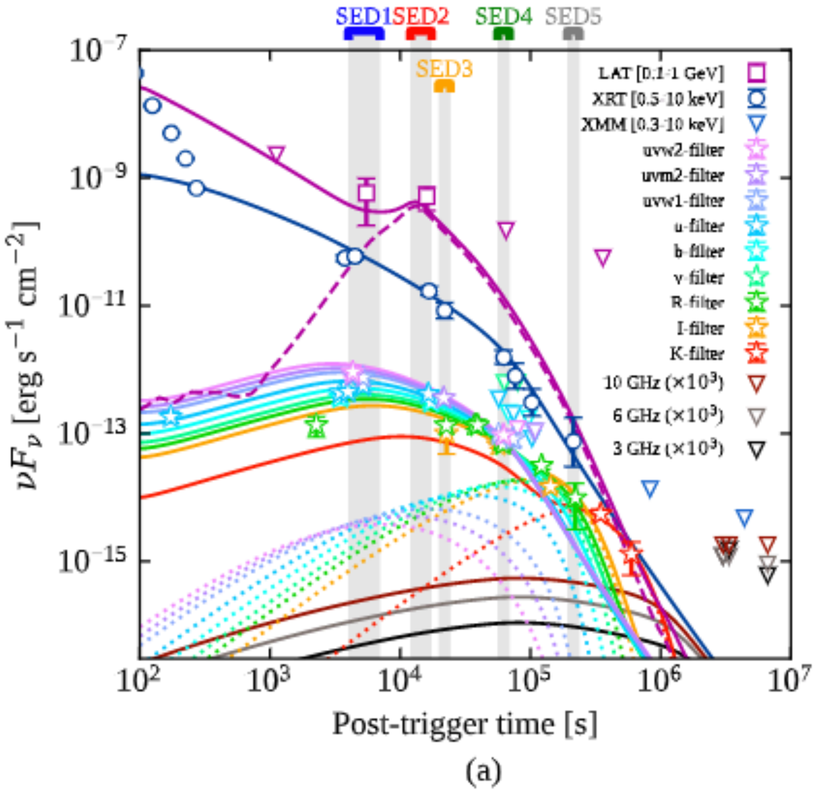


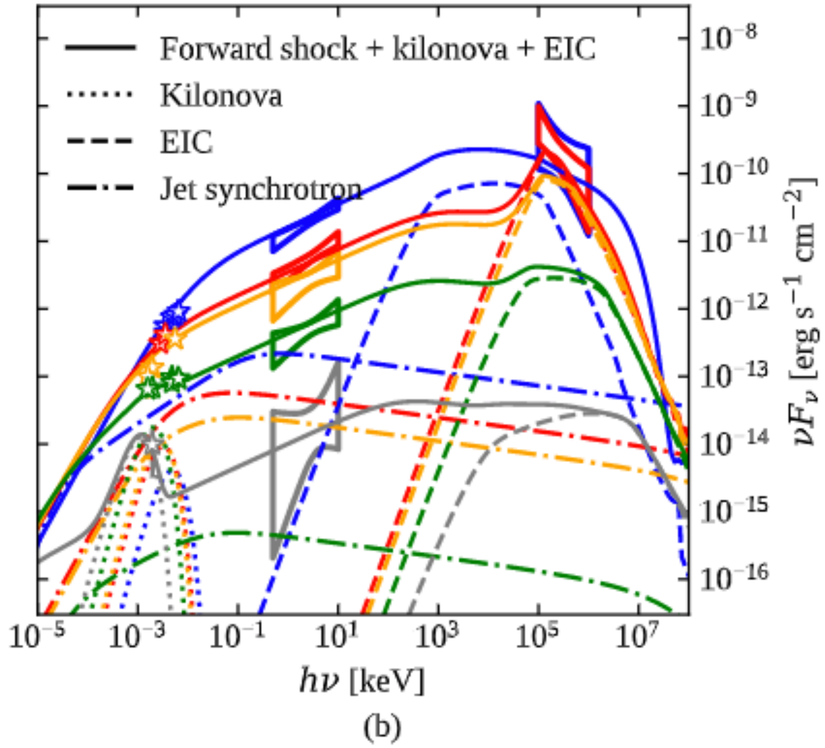
Dying rather than merging: GRB211211A



Mei et al. 2022

- Rest frame duration ~60 sec
- KN signature [Rastinejad+2022] (S)
- Host offset (S)
- Hour-timescale GeV emission





Radiation process

1) $t_{var} \sim 10 - 100$ ms $\longrightarrow$ $R_{diss} \sim 10^{13}$ cm

2) $L \sim 10^{52}$ erg/s $\xrightarrow{\text{(BZ)}}$ $B \sim 10^{4-6}$ G

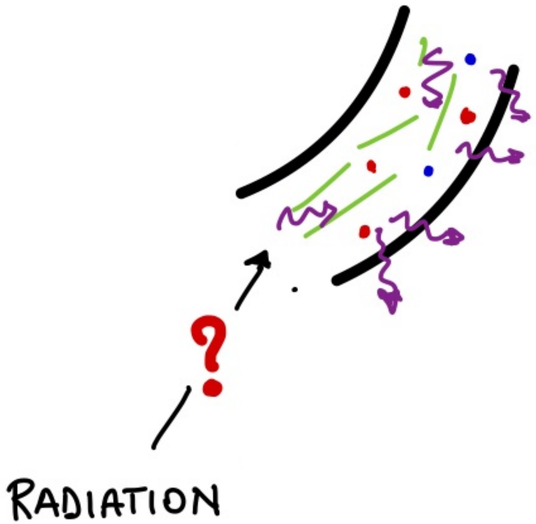
3) Non-thermal spectrum

Synchrotron + SSC

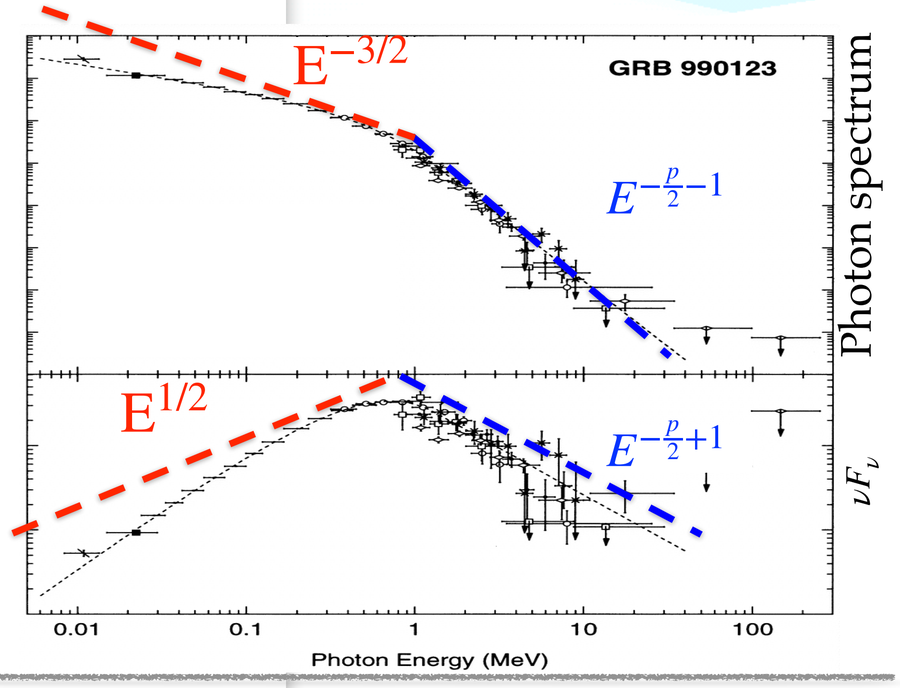
$t_{cool,e} \ll t_{dyn}$

BUT

Ghisellini & Celotti 2000



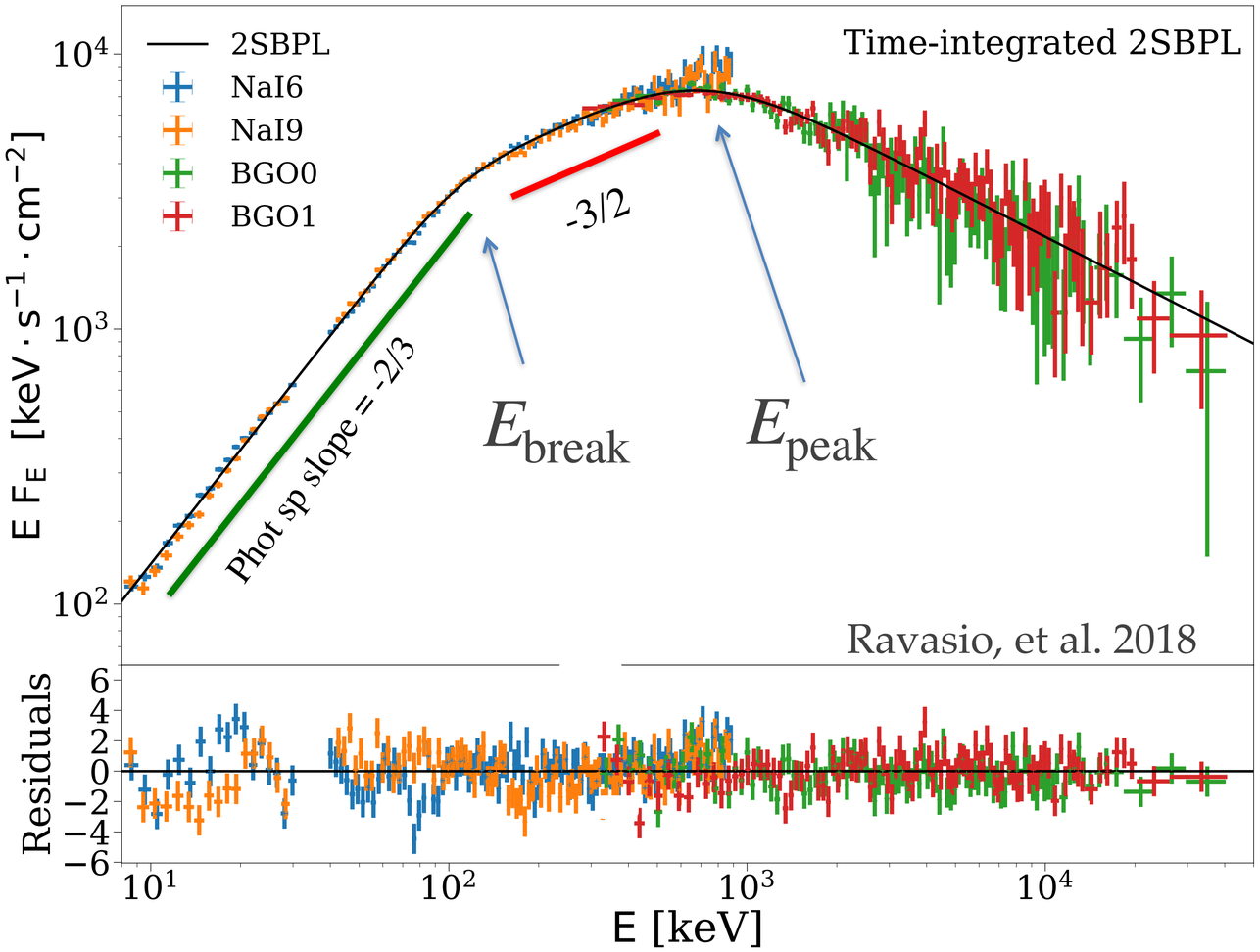
"prompt emission should be synchrotron but it doesn't look like"

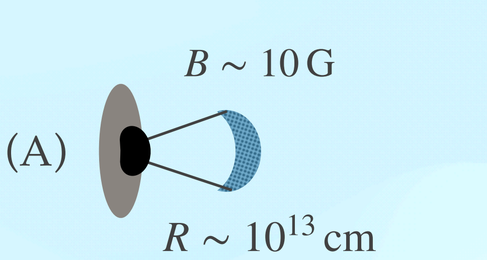


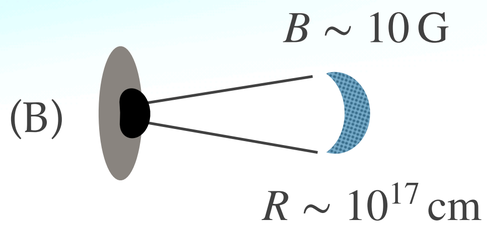
Inefficient cooling

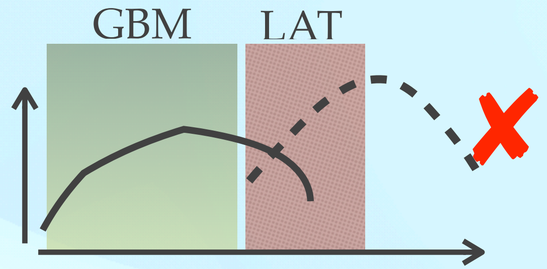
"Back to the data" (Oganesyan+2017,2018; Ravasio, et al. 2018, 2019; Ronchi, et al. 2020, Toffano, et al. 2021)

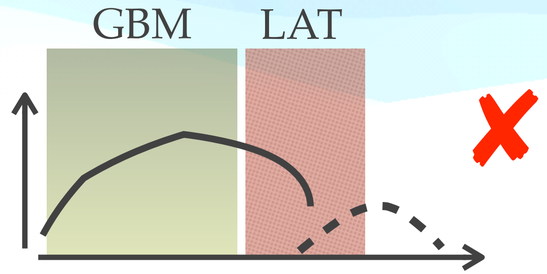
Eureka! The prompt looks very much like synchrotron











(C)
- B↓ downstream
- Acceleration clumps (reconn)

(D) Protons cool at a lower peace owing to their larger mass (Ghisellini+2019) but see Petropoulou+2020

Exceptional Events

GRB 221009A

[55 Refereed articled + 180 non ref @ 21/09/2023]

Fluence = 0.2 erg/cm2 z=0.151 —> Eiso~1e55 erg ; Liso~1e54 erg/s

Saturated several instruments
(talk by Horan & Pittori)

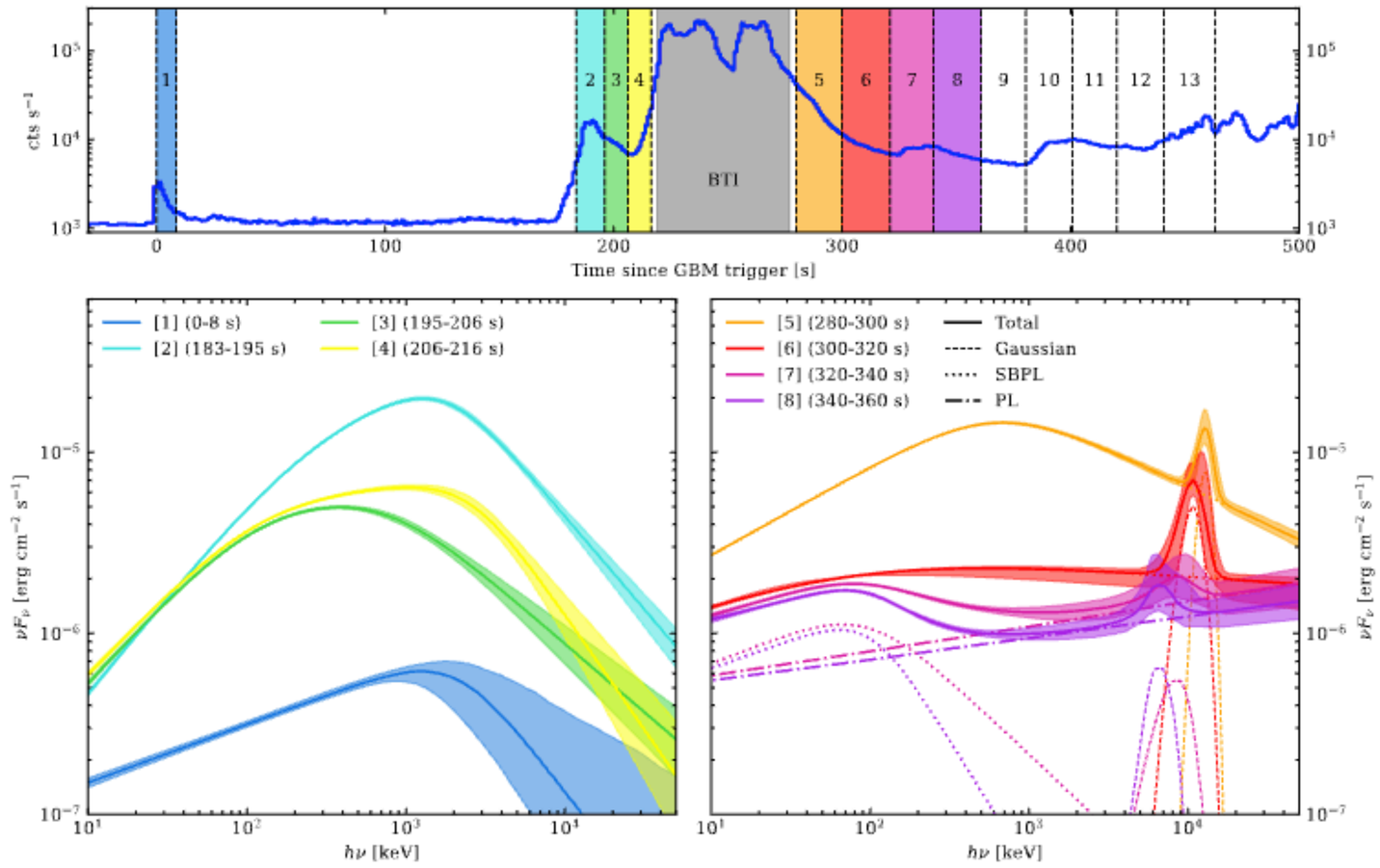
~ 18 TeV photons LHAASO talks by M. Zha, M. Errando

~Once per -thousand years (Malesani et al. 2022; Burns 2023)

~first JWST spec (Levan 2023)

Afterglow model challenges

First ever significant emission line in a GRB at MeV energies (Ravasio, Salafia et al. 2023)



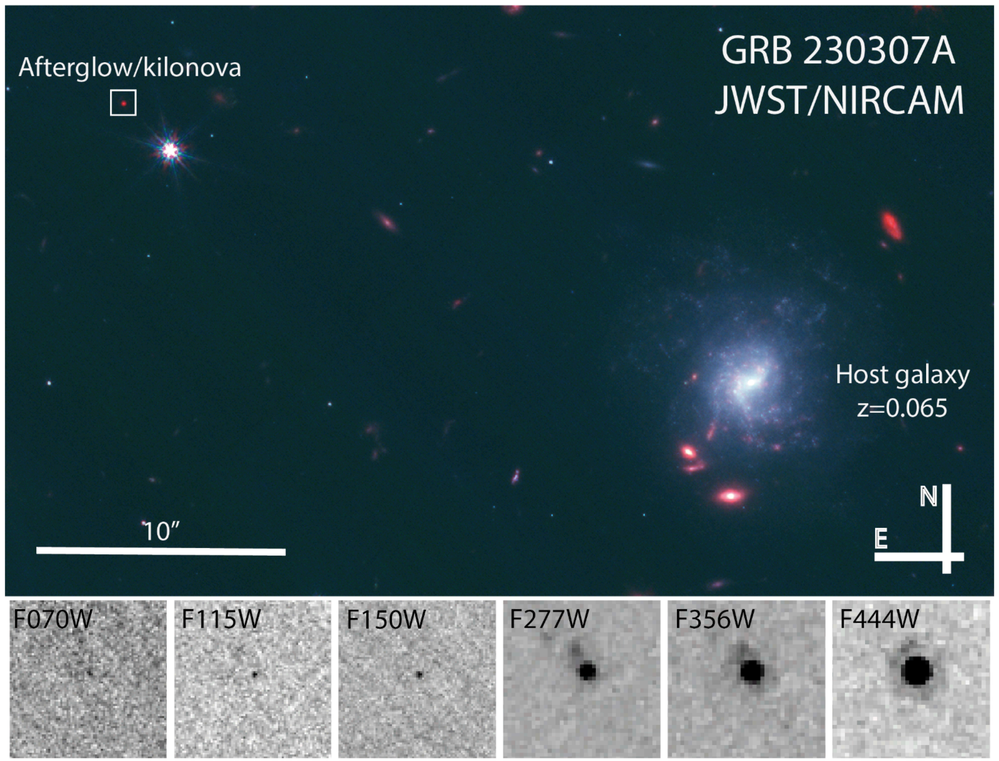
Exceptional Events

GRB 230307A

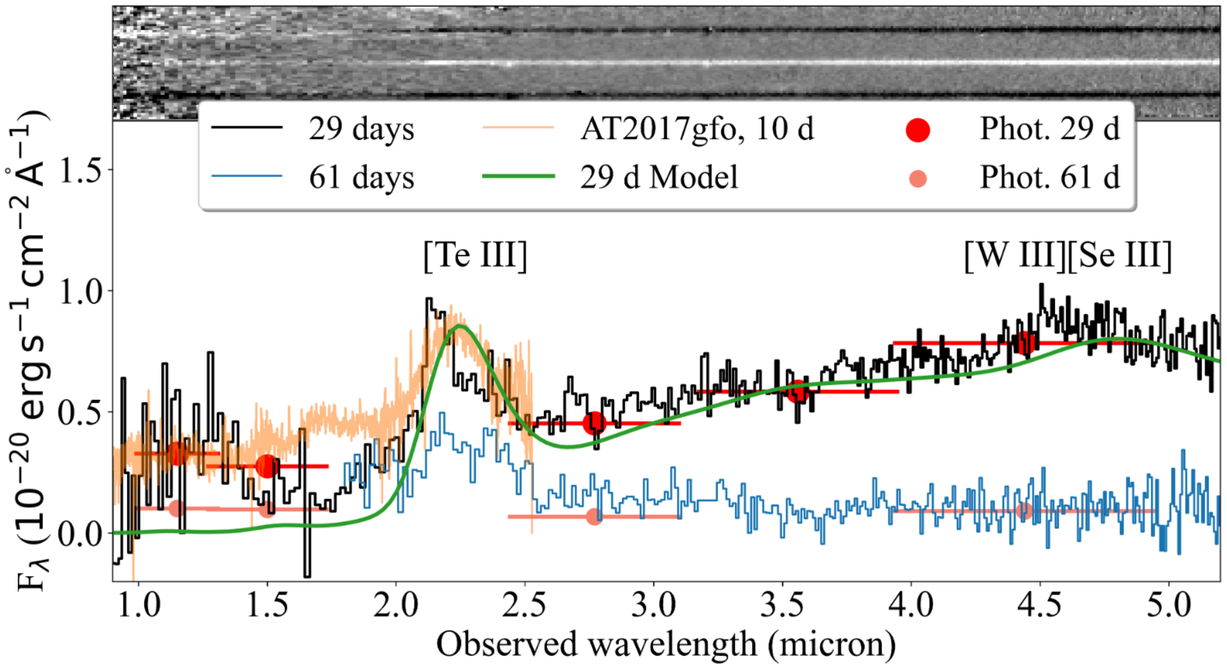
Fluence = 3e-3 erg/cm2

35 sec

Levan, Gompertz et al. 2023



28 days



Conclusions

- Start of MM era: 170817 direct proof of the origin of short GRBs from binary mergers.
- 170817 a structure jet can emerge from the dense ejecta produced by the merger
- Afterglow modeling needs MW (+imaging when possible)
- Impostors show the possible variety of physical scenarios
- Prompt emission nature still a puzzle to be solved
- Exceptional events: test cases for model but often complicated by instrumental effects