Gamma-ray bursts and multi-wavelength correlations in afterglows

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Instituto de Astronomía – UNAM,Mexico

First Workshop of the Mexican-French LIA ERIDANUS
June 03 – 06, 2019, Toulouse

Outline

Gamma-ray bursts (Some generalities)

Multi-wavelength correlations

- Typical observations
- Atypical observations
- A weird observation

Forward-shock model

+ On-axis outflow
- Synchrotron
- Inverse Compton scattering

+ Off-axis outflow
- Synchrotron
- Inverse Compton scattering

+ Structure jets
(Universal, Gaussian …)
- Synchrotron
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+ Isotropic materials
(cocoon, breakout, dynamical …)
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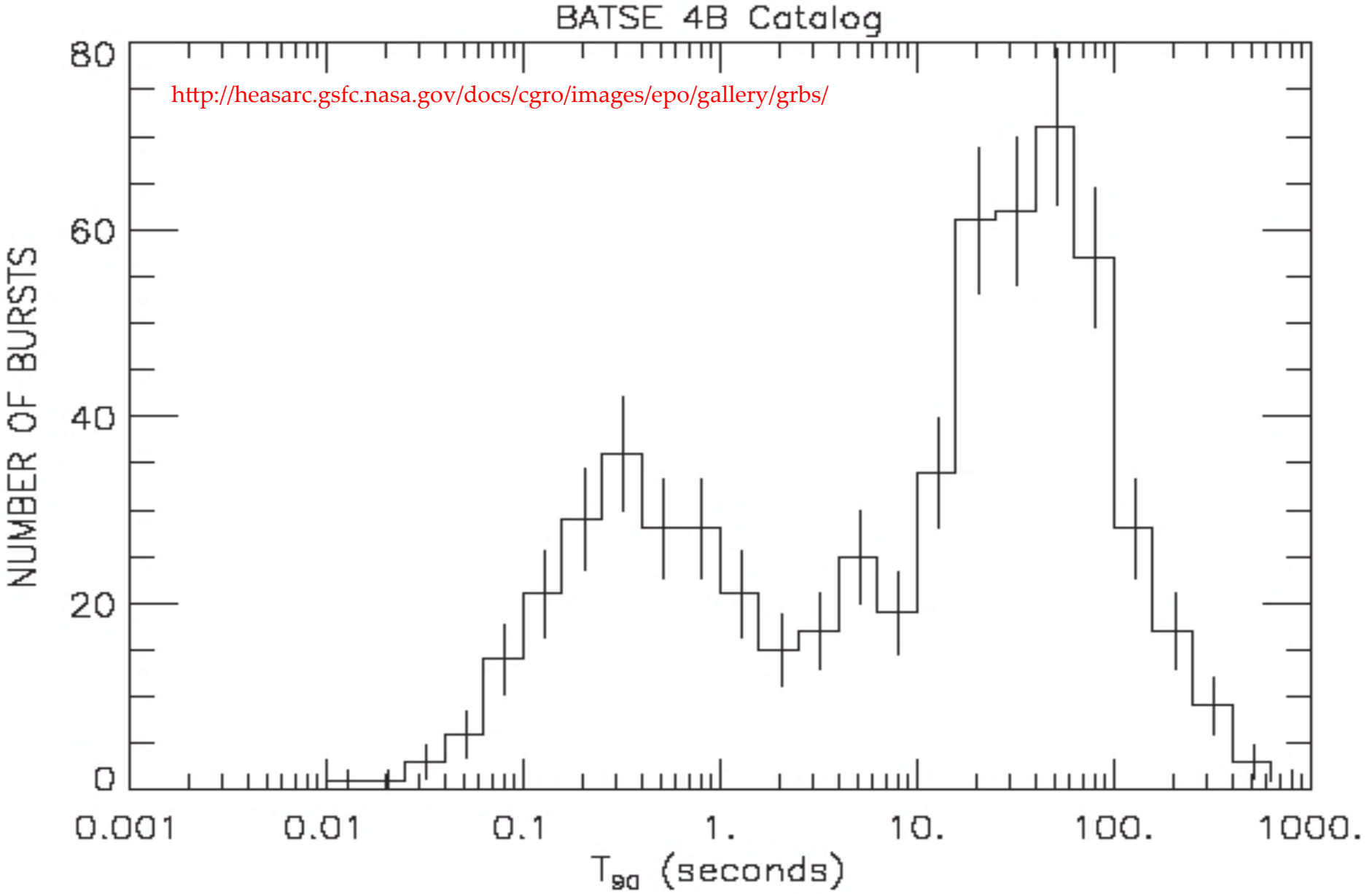
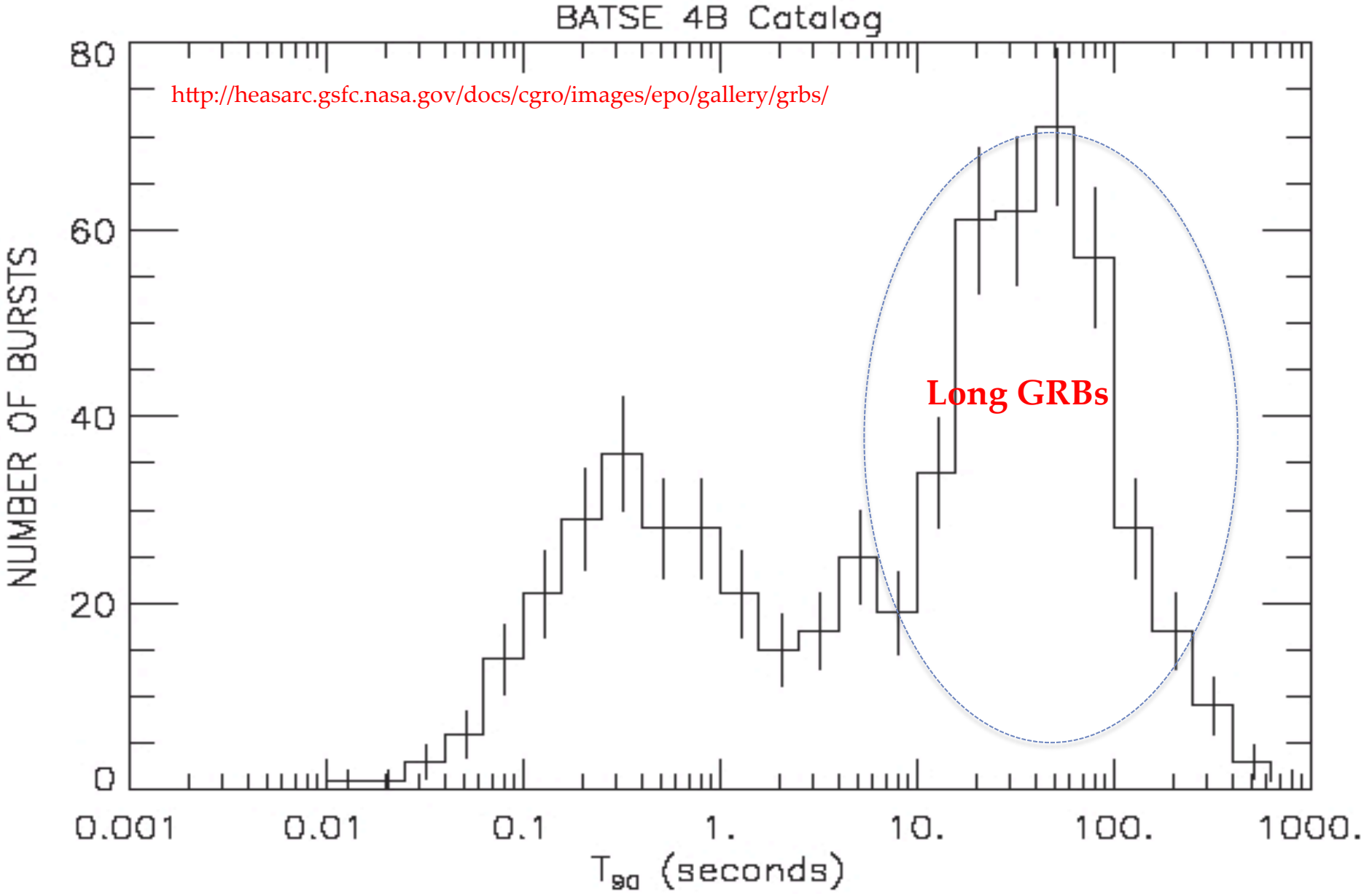
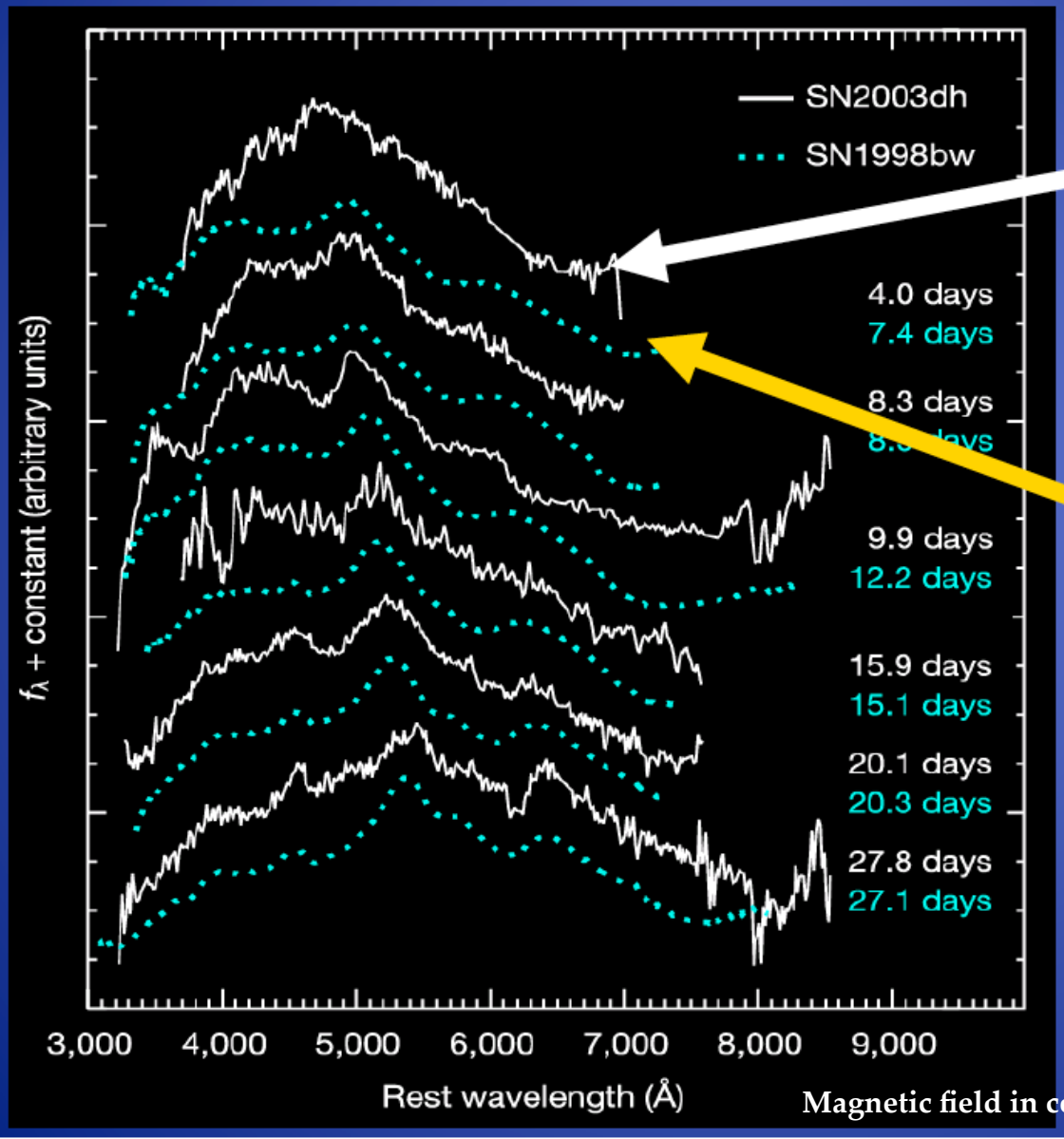
GRB duration



GRB duration



Long-GRB – collapse of a massive star (Woosley and Paczynski)

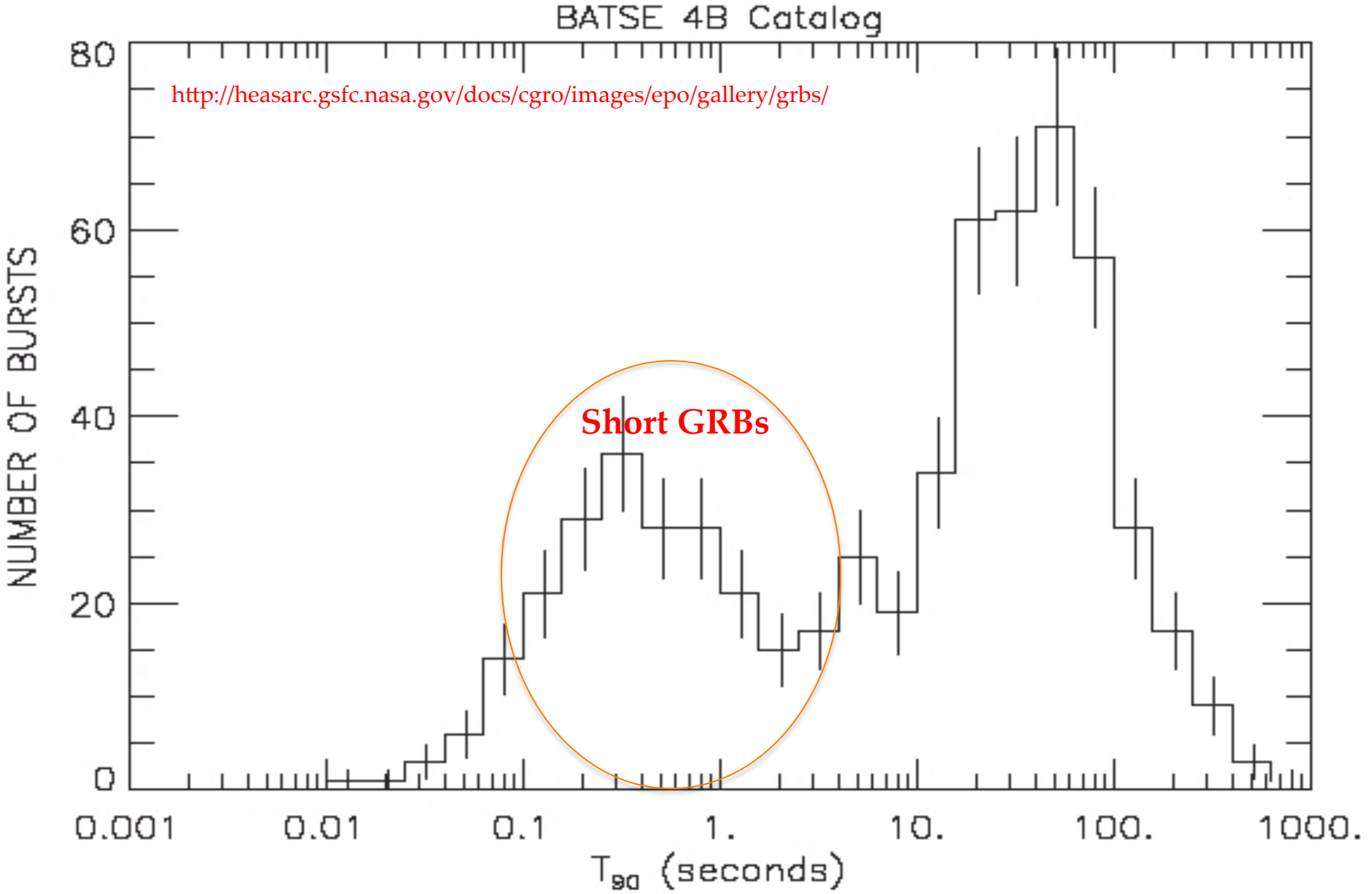


GRB 030329: z=0.17
(afterglow-subtracted)

SN 1998bw:
local, energetic, core-collapsed Type Ic

Stanek et al.,
Chornock et al.
Eracleous et al.,
Hjorth et al.,
Kawabata et al.

GRB duration



Neutron star merger

Berger (12)

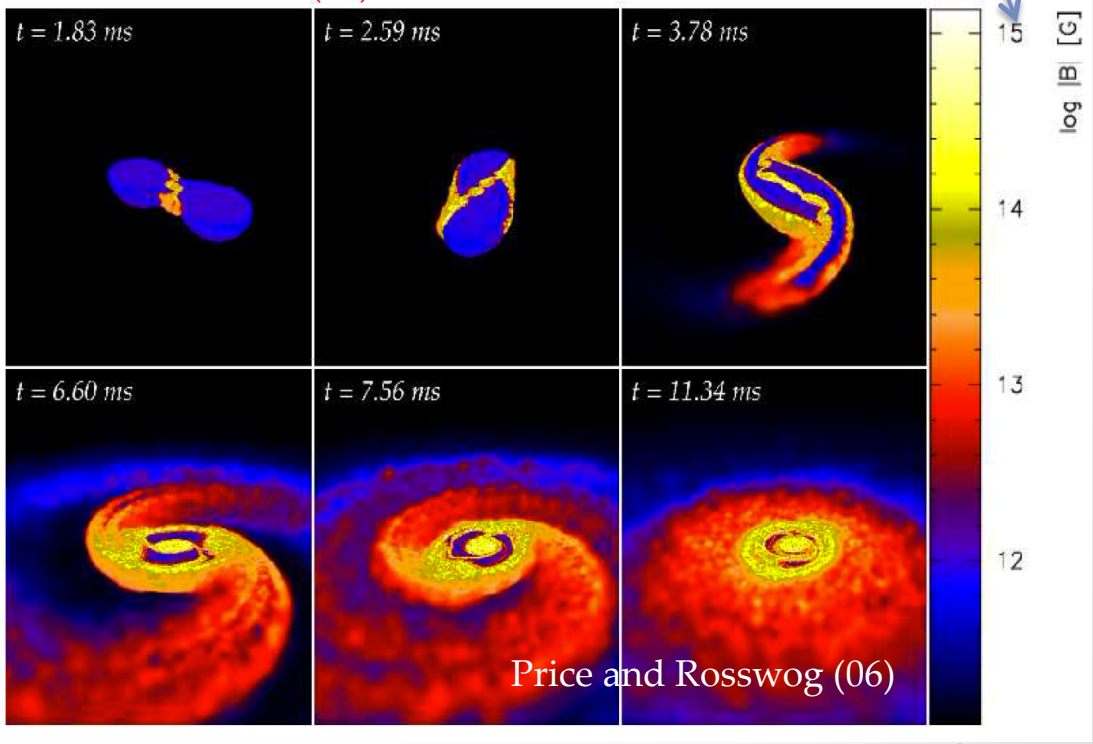
- The most popular progenitor associated with sGRBs is the merger of compact object binaries

  NS-NS or NS – BH

- Magnetic field amplification during the merger NS - NS
- The growth related to KH instabilities and turbulent amplification

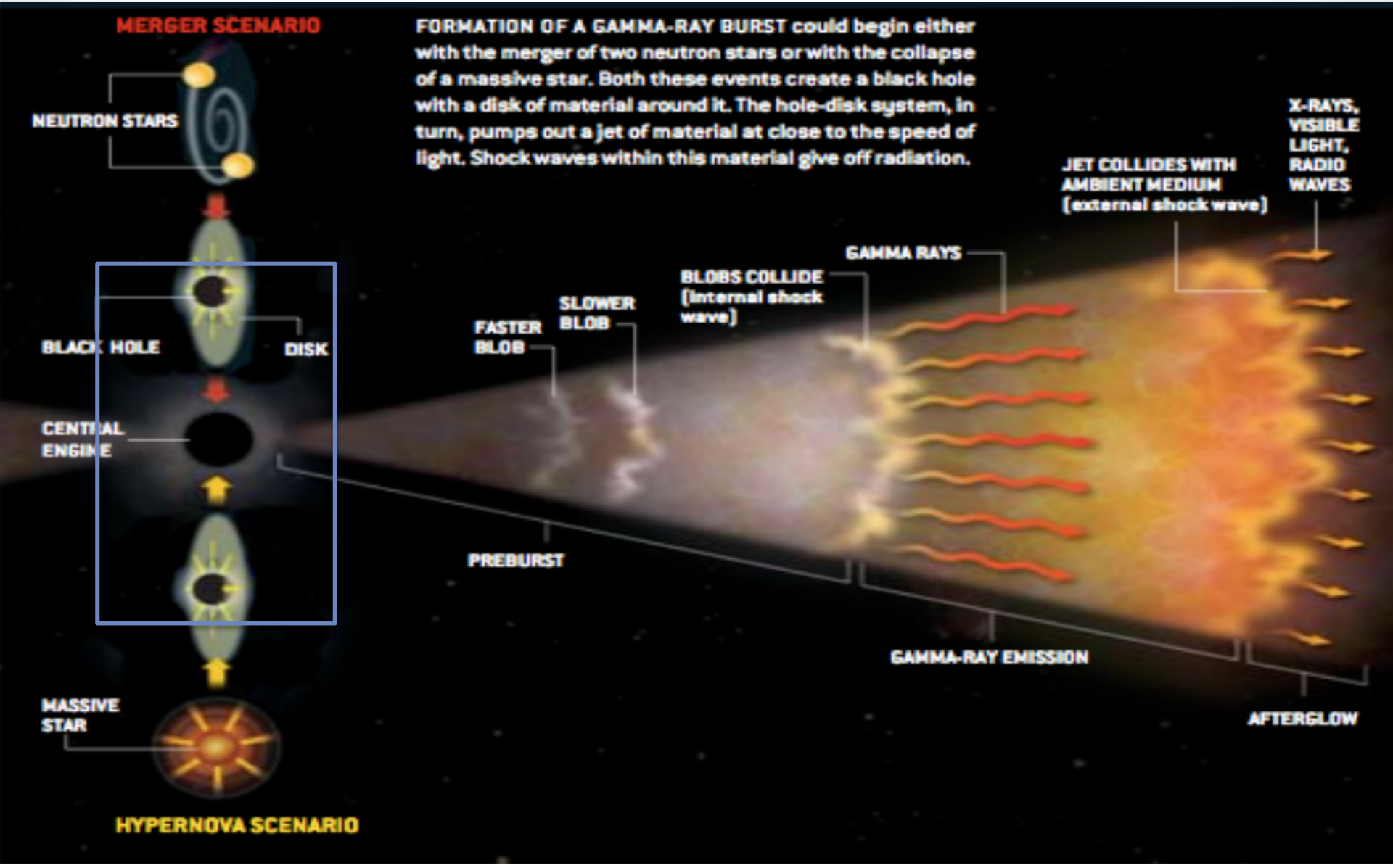
Zrake and MacFadyen (13)
Giacomazzo et al (09)

Magnetic field can increase up to 10^{15} G or more

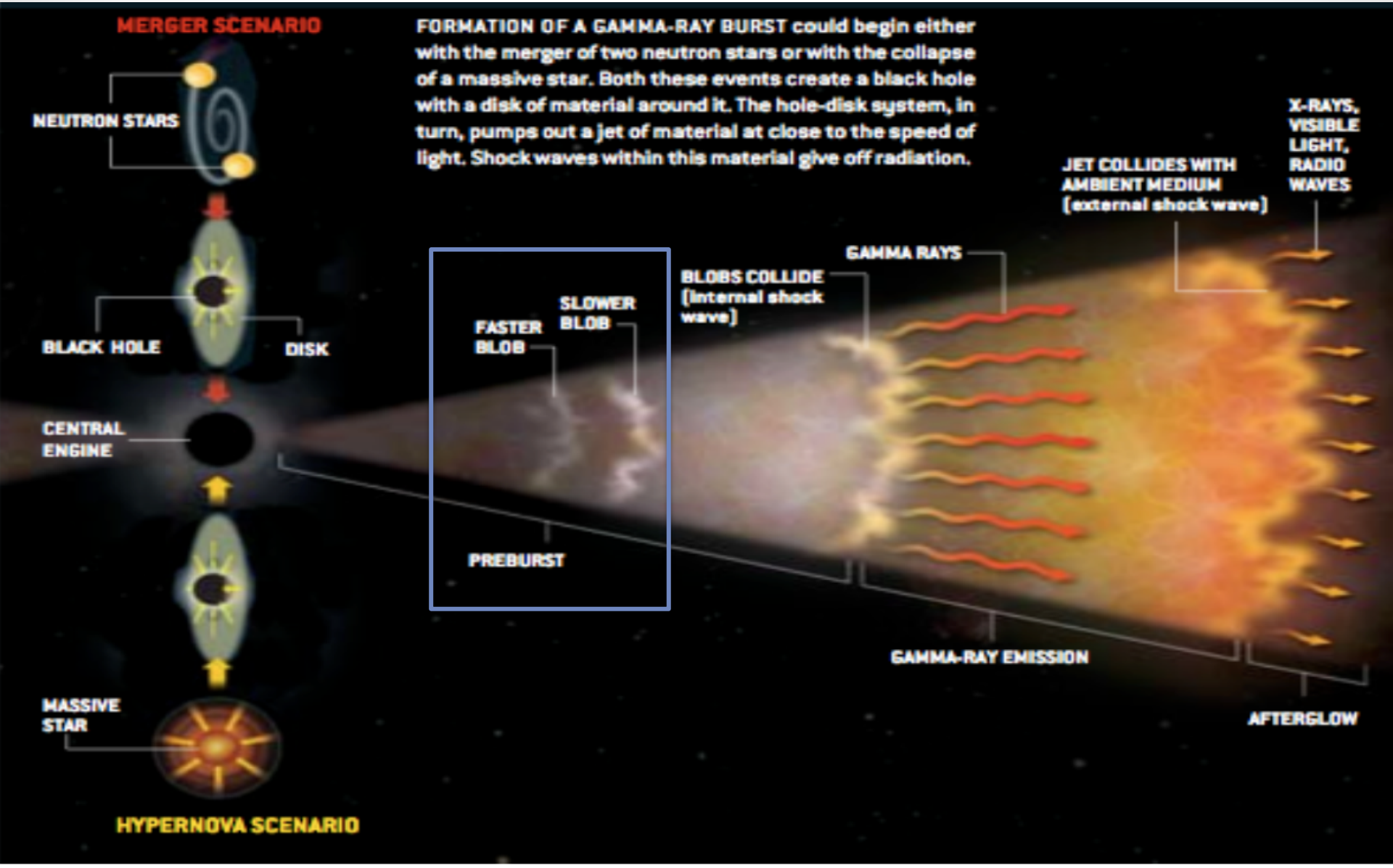


Price and Rosswog (06)

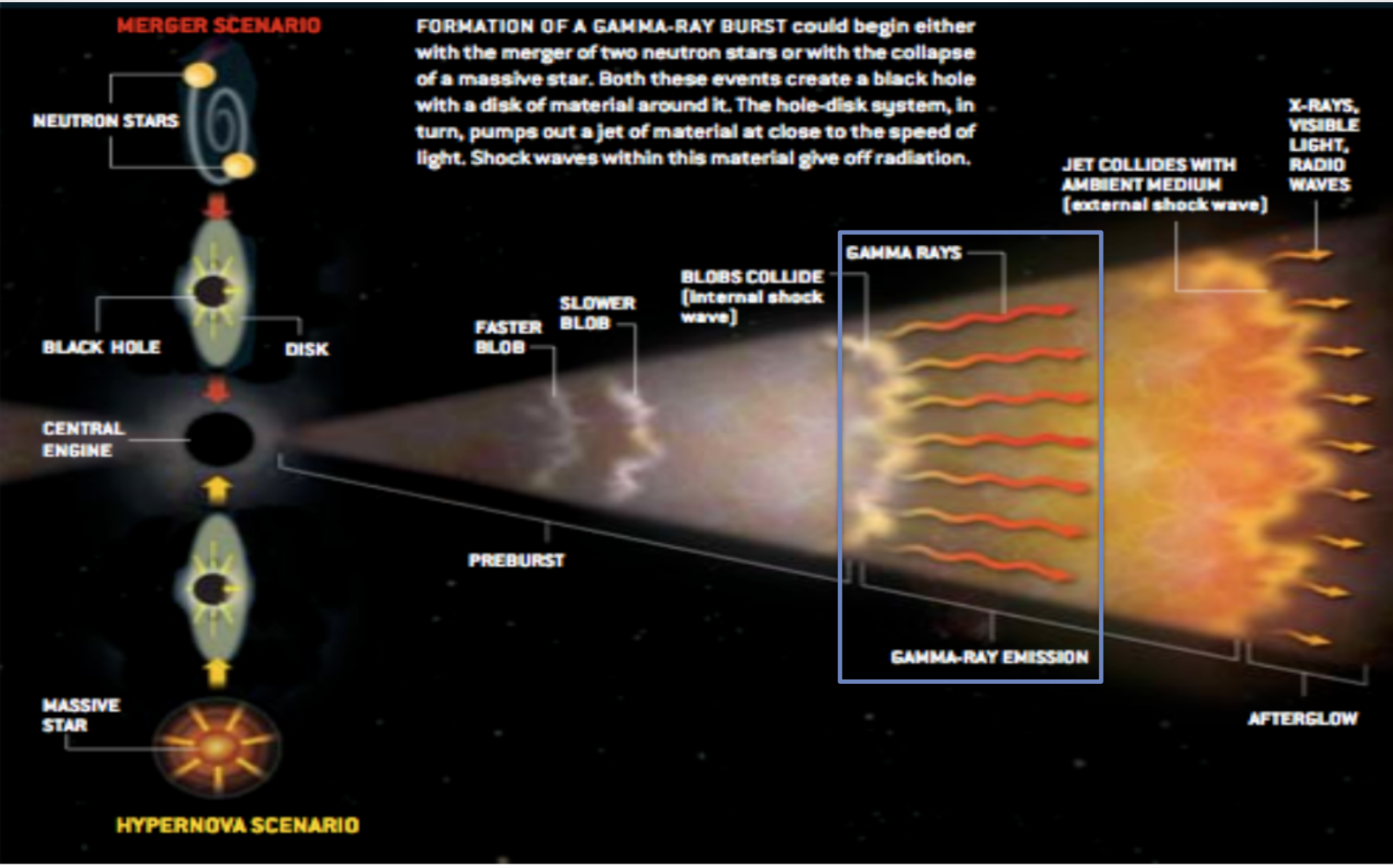
Fireball model



Fireball model



Fireball model



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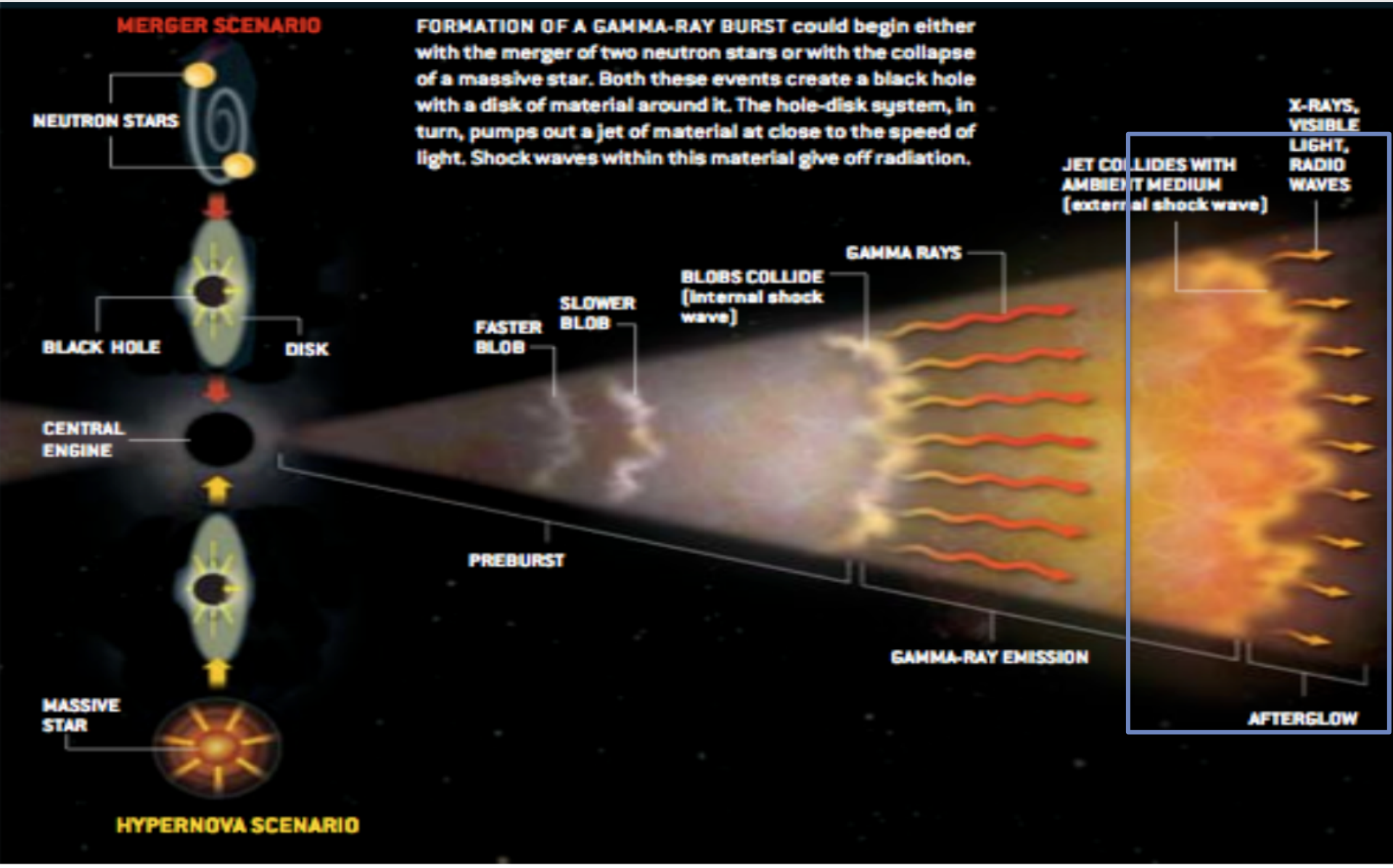

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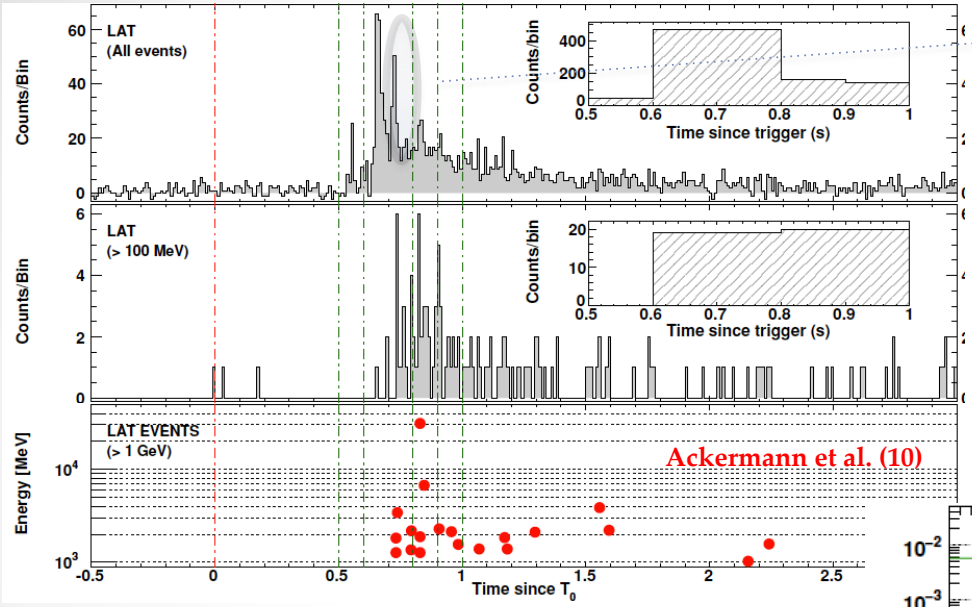
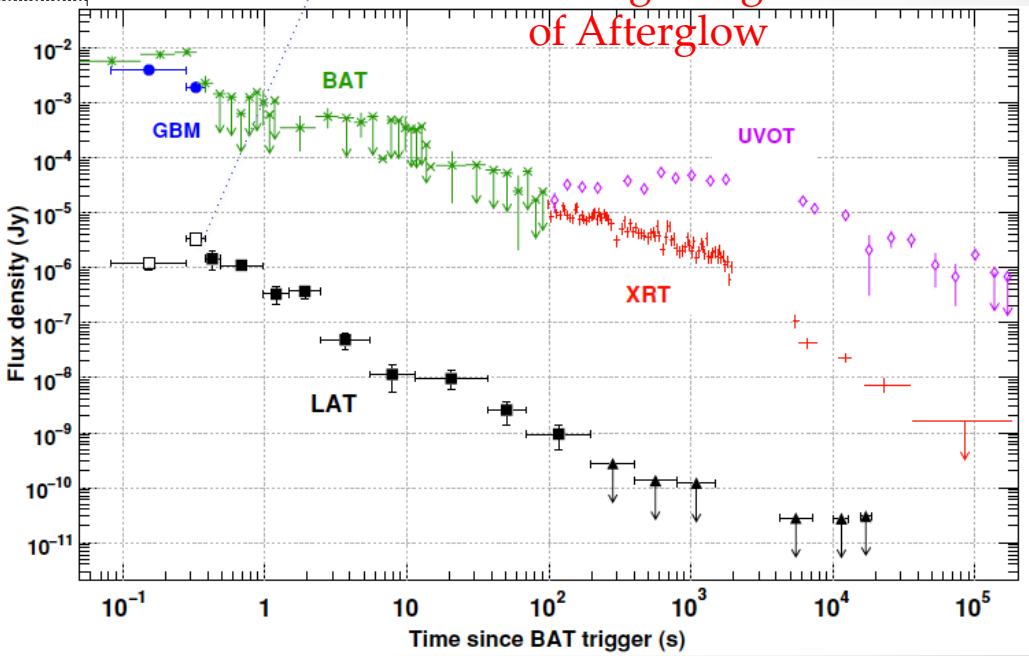
GRB090510



Ackermann et al. (10)

The brightest peak before 1s

Multiwavelength Light Curve of Afterglow



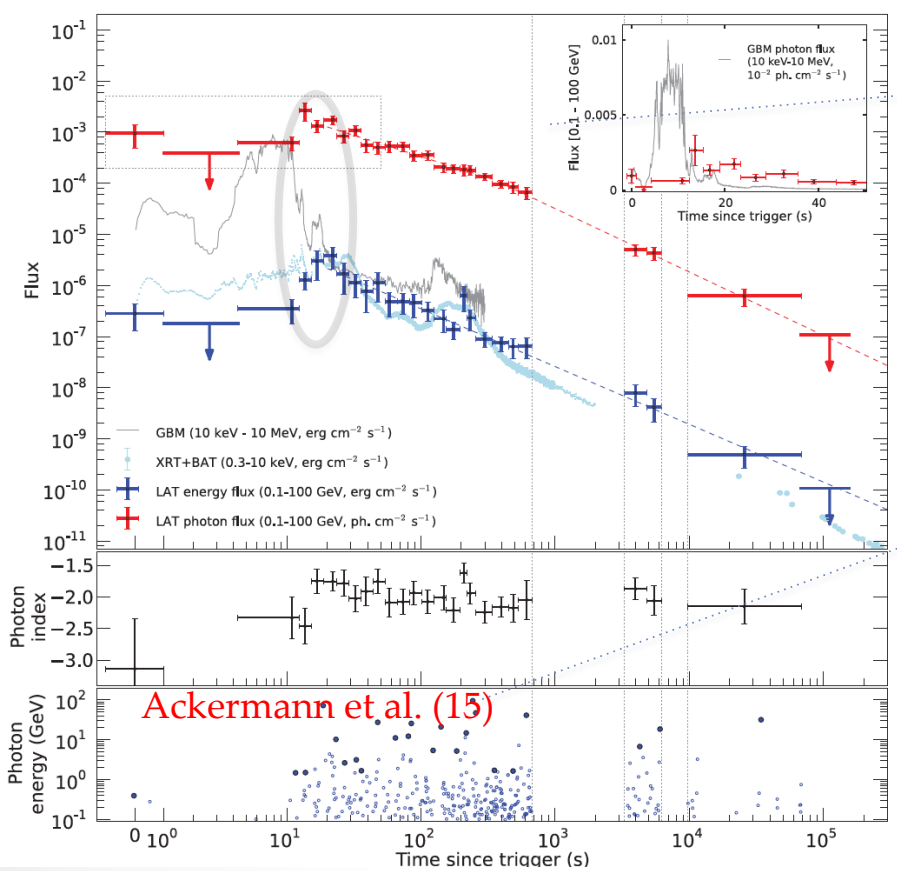
Three important features:

1. The LAT emission is delayed with respect to the GBM light curves.

2. An outstanding peak with high count rate was presented before 1s in the LAT data.

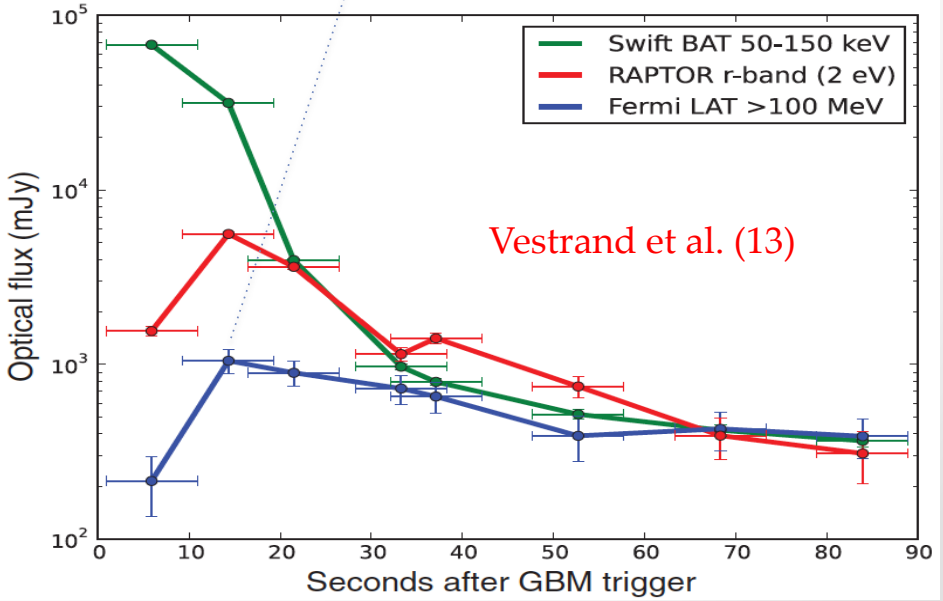
3. A temporally extended emission lasting hundreds of seconds.

GRB130427A



The brightest peak at 15s

LAT observed the highest-energy photon ever recorded of 95 GeV



Three important features:

1. The LAT emission is delayed with respect to the GBM light curves.

2. An outstanding peak was presented at 15s in the LAT and optical data.

3. A temporally extended emission lasting more than thousand of seconds.

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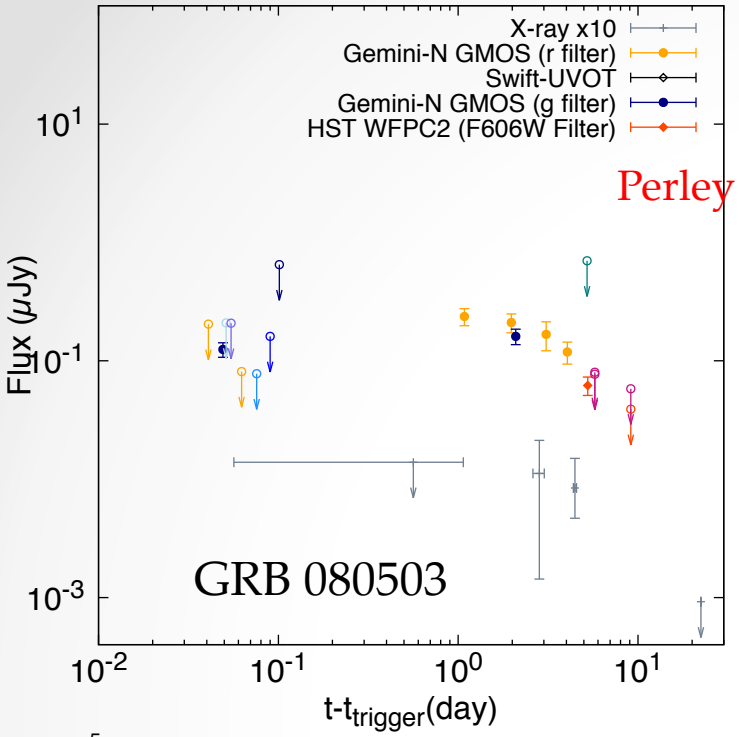
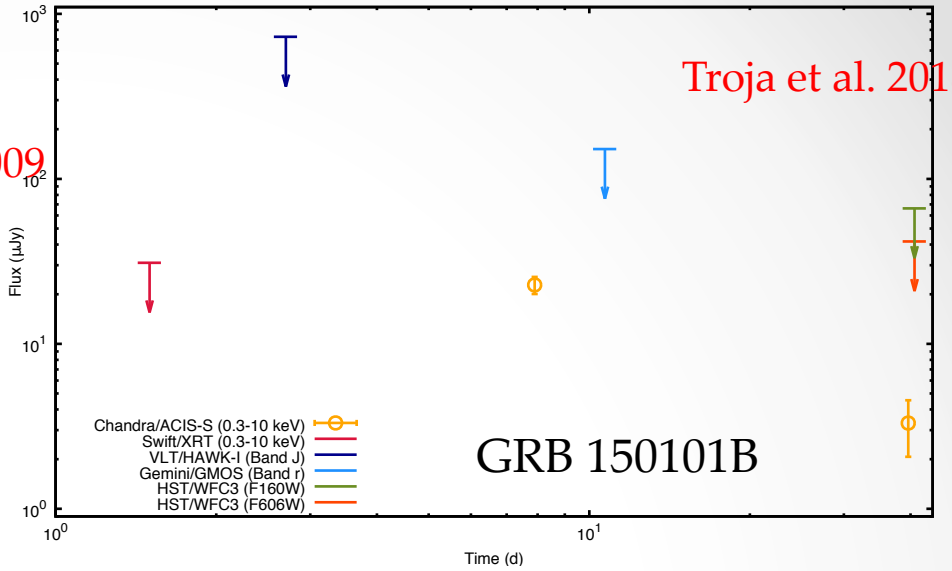
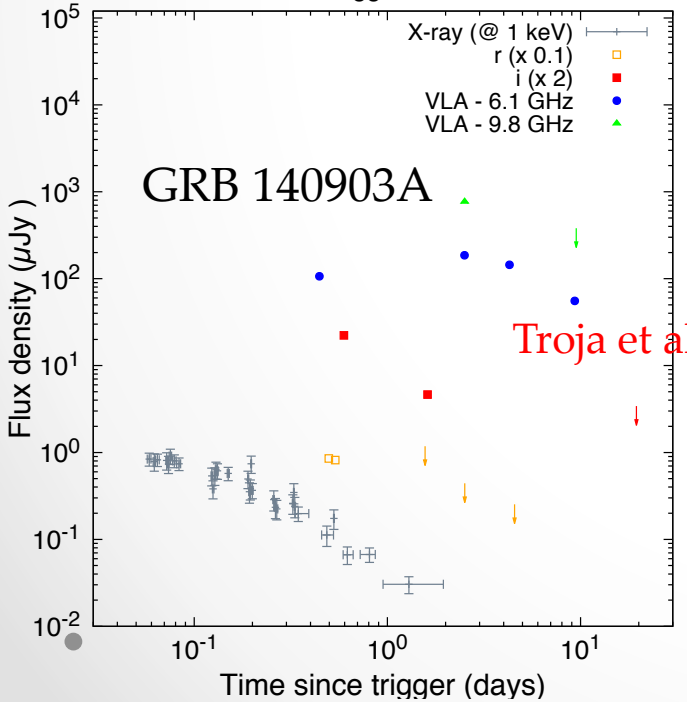


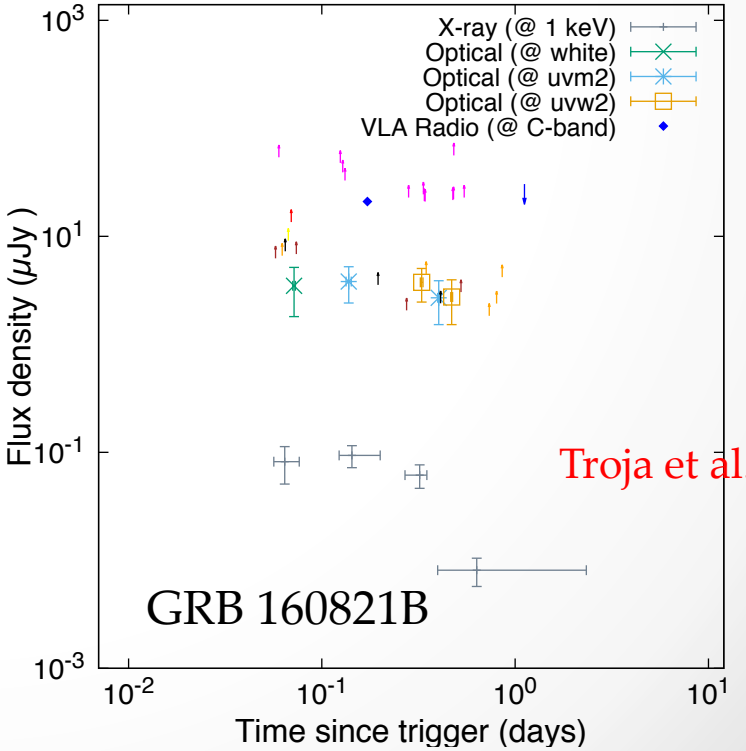
Perley et al. 2009



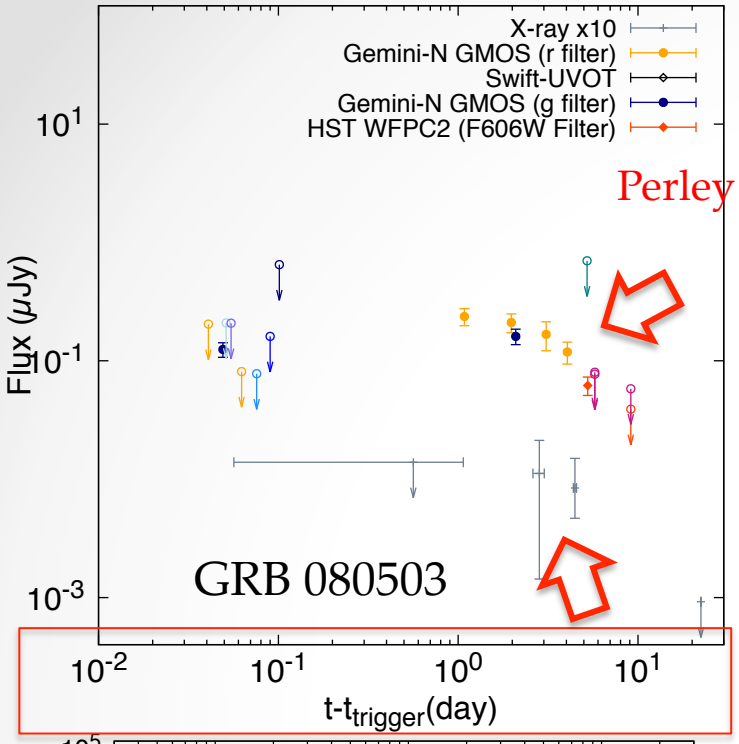
Troja et al. 2018



Troja et al. 2016



Troja et al. 2019



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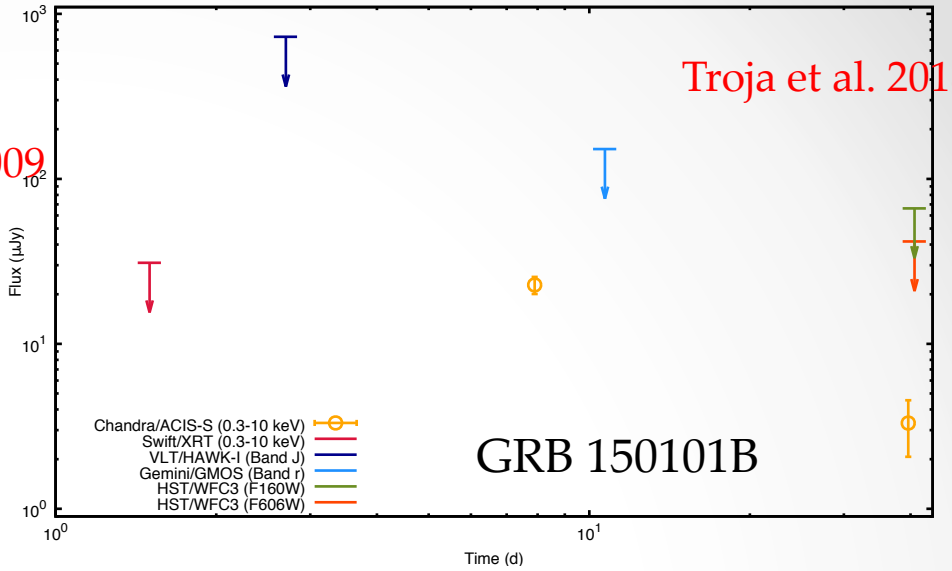

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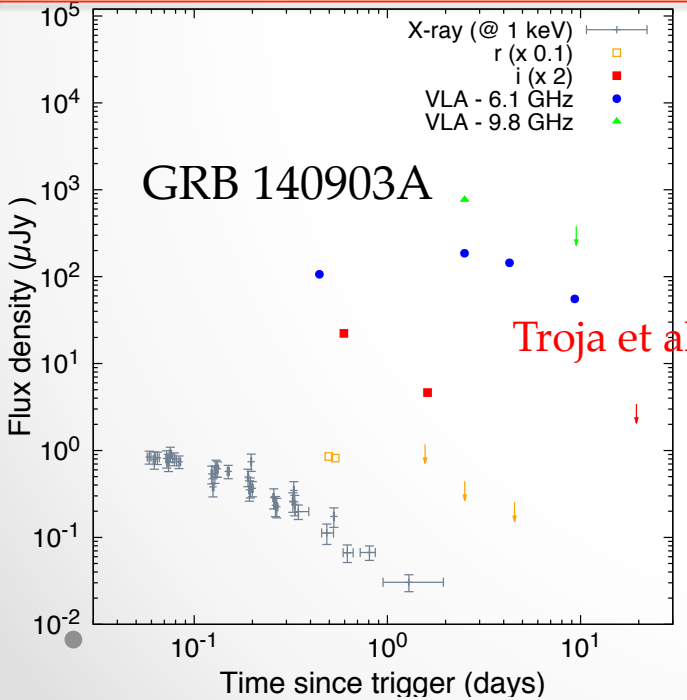
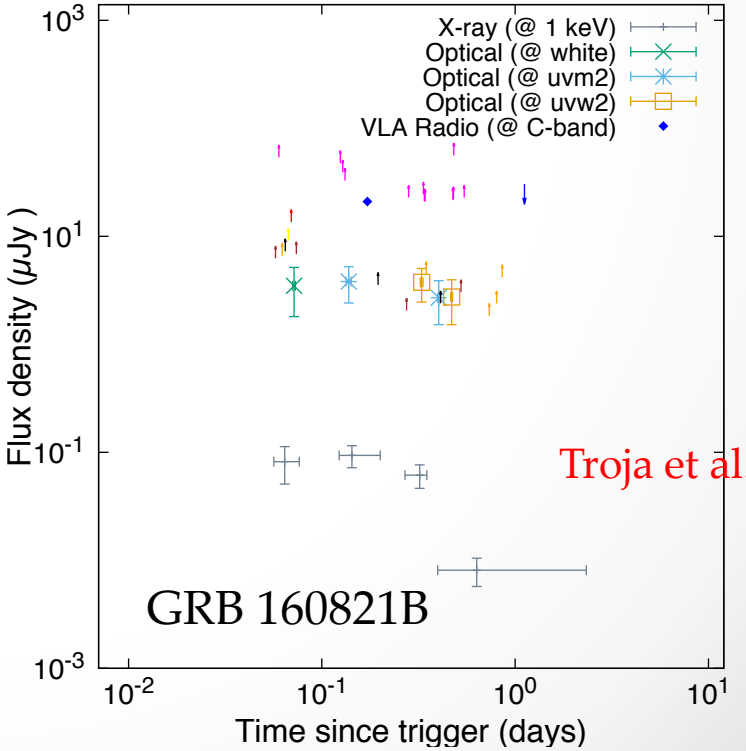
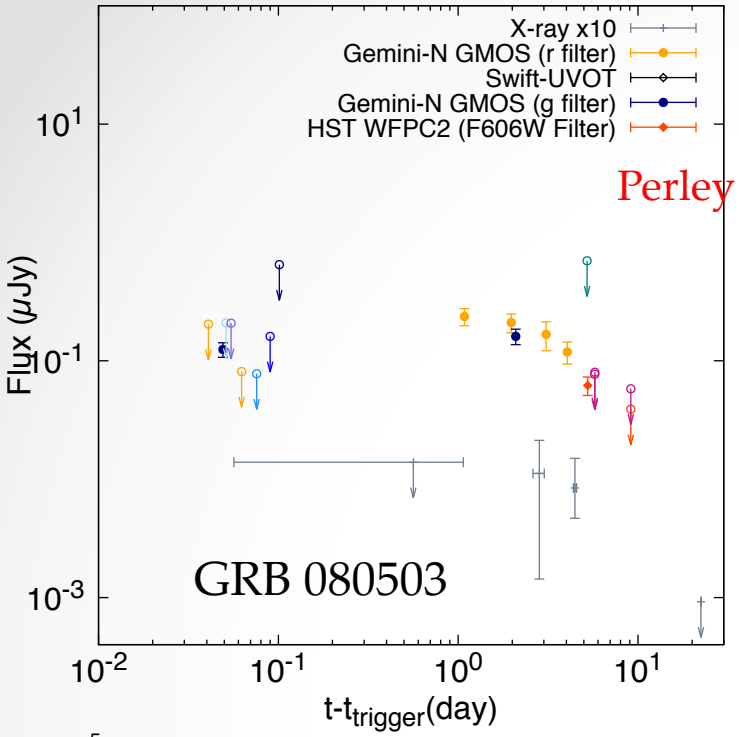


Troja et al. 2016



Troja et al. 2019



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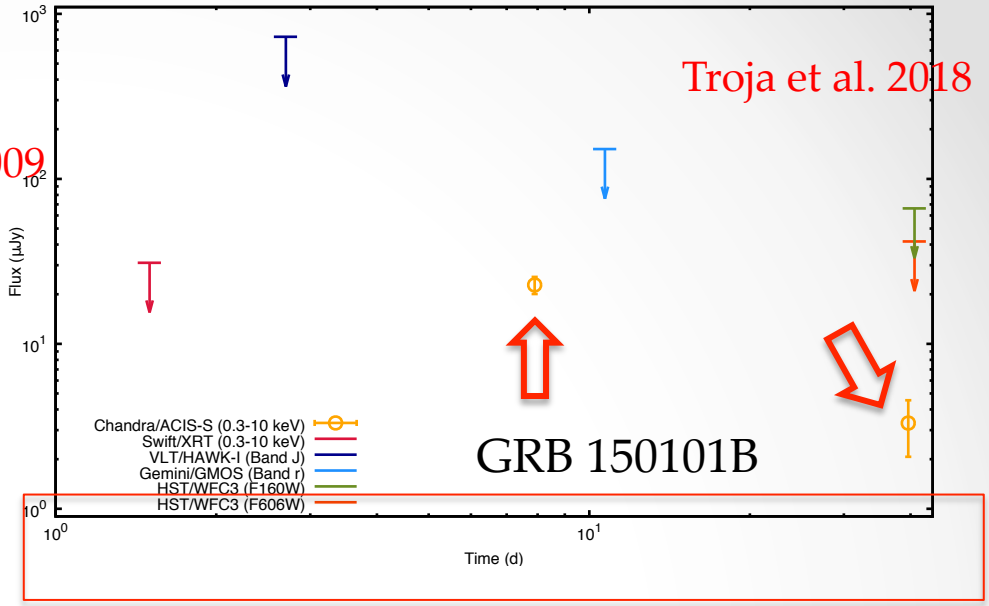

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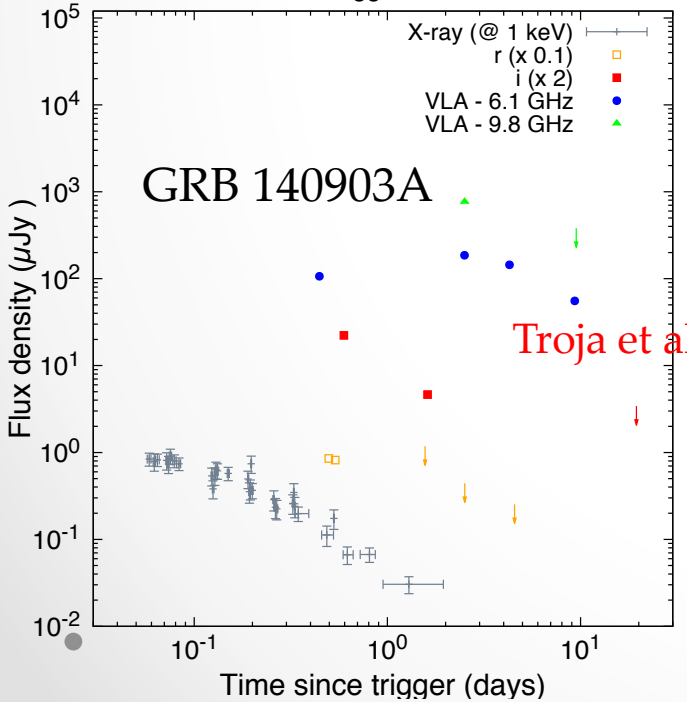

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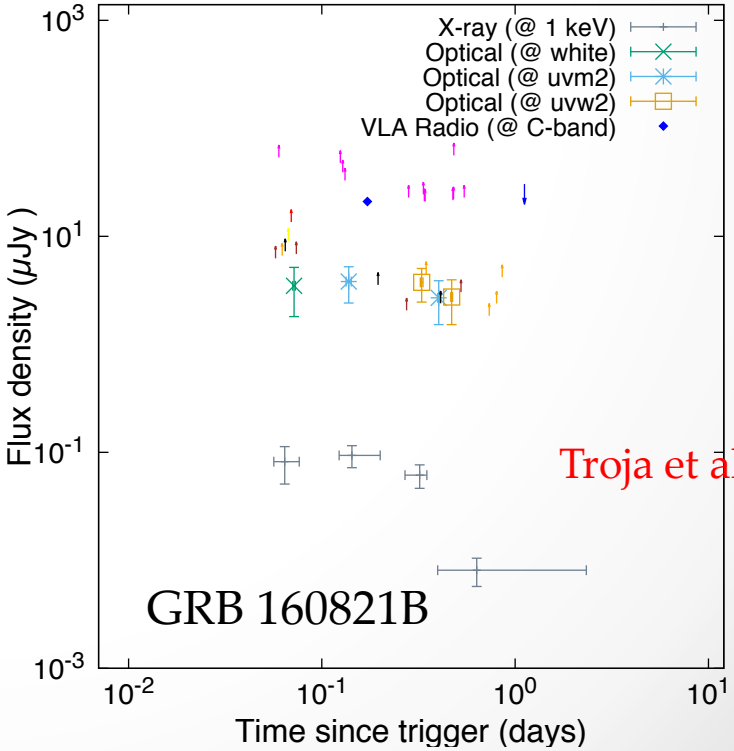

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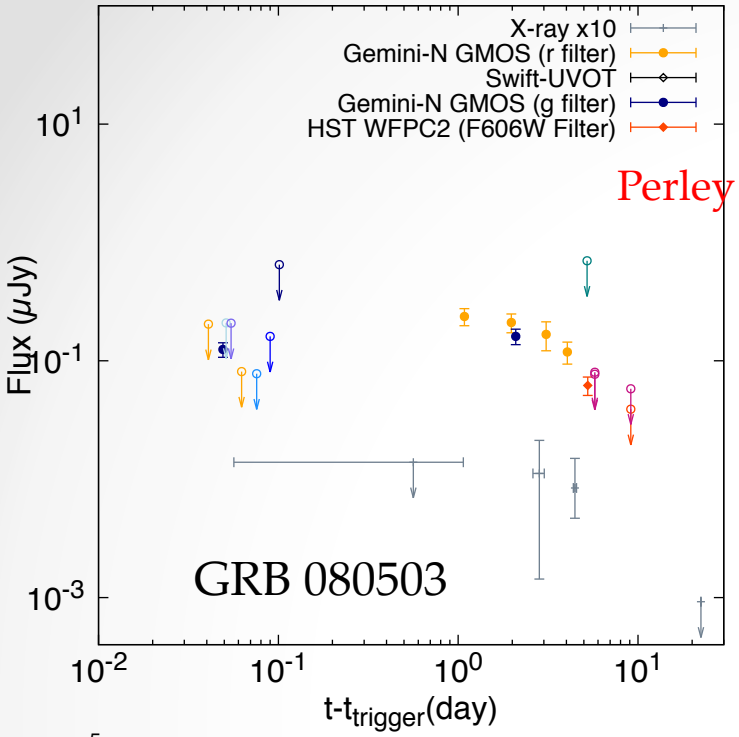

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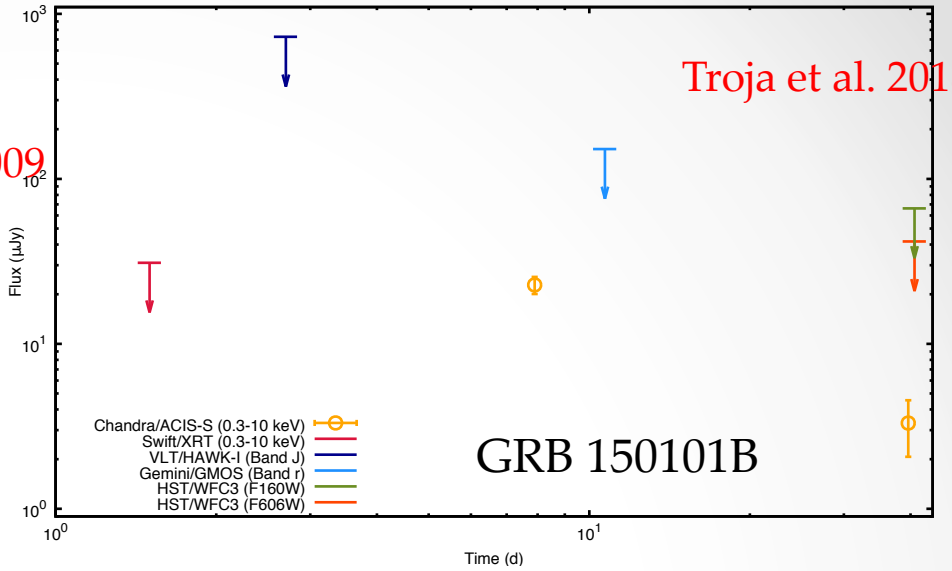

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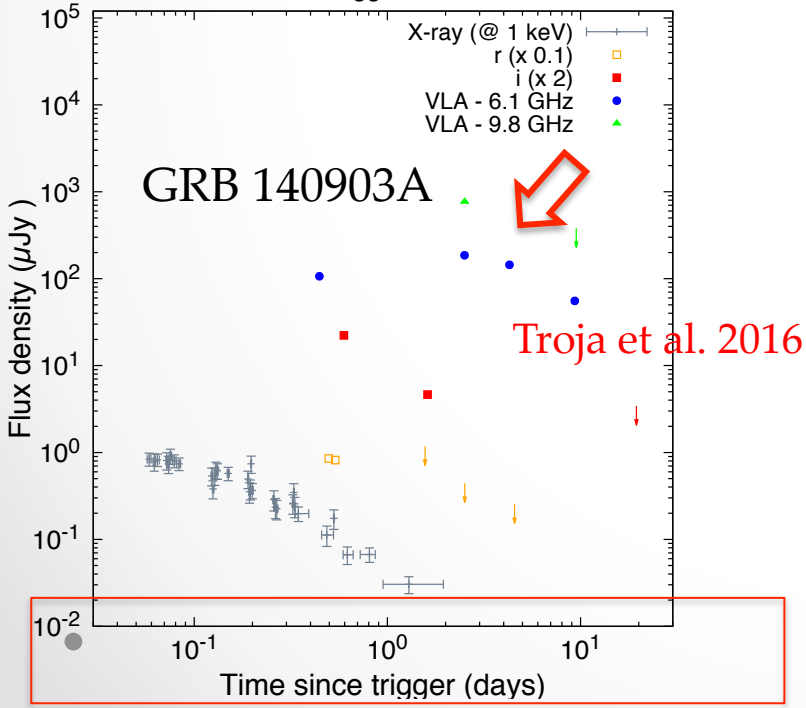

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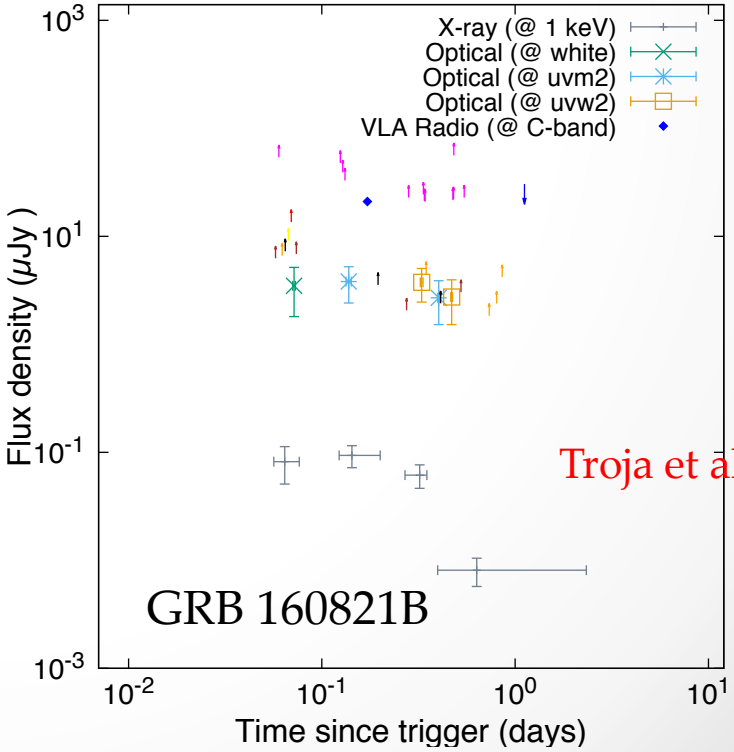
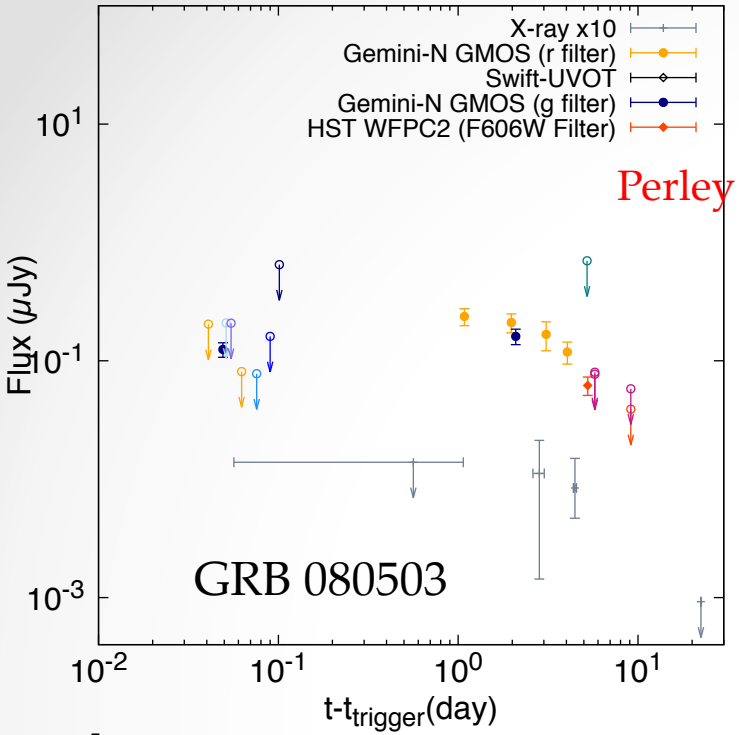


Troja et al. 2019



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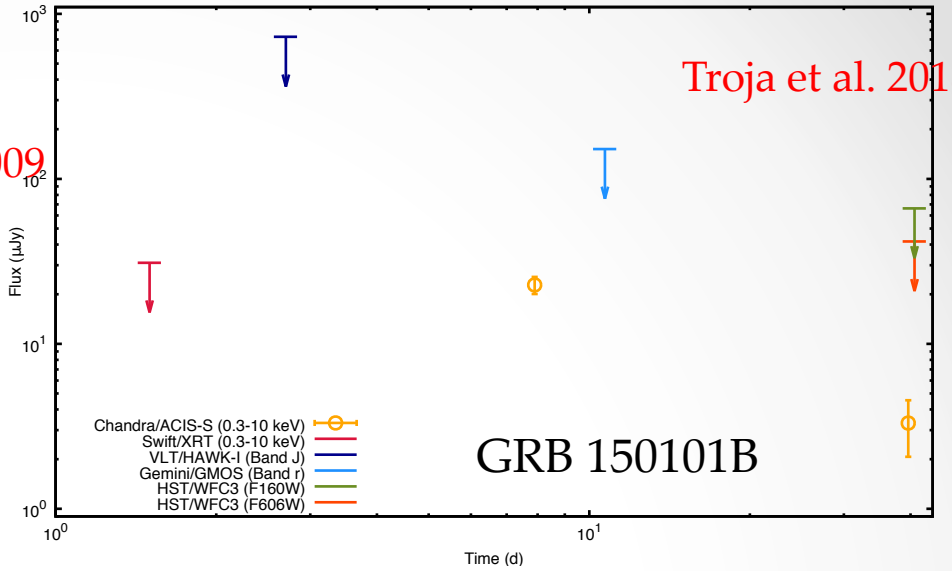

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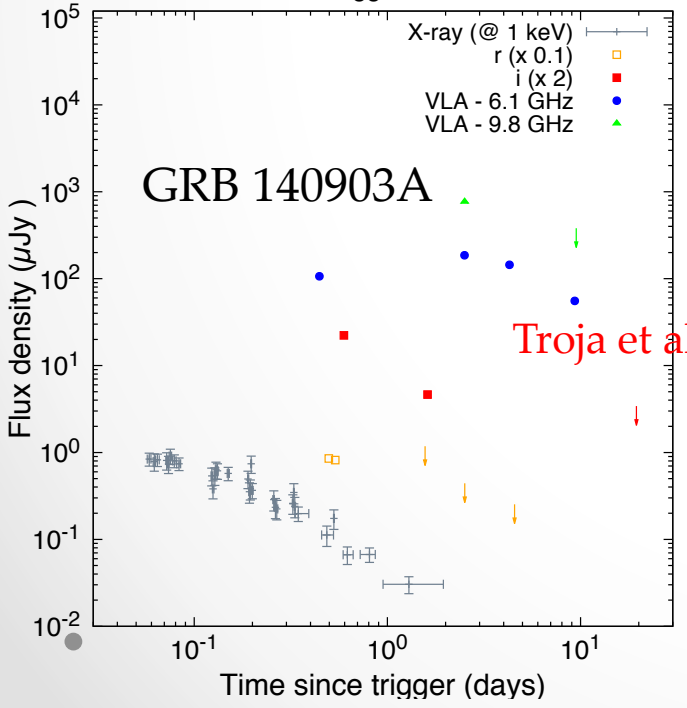

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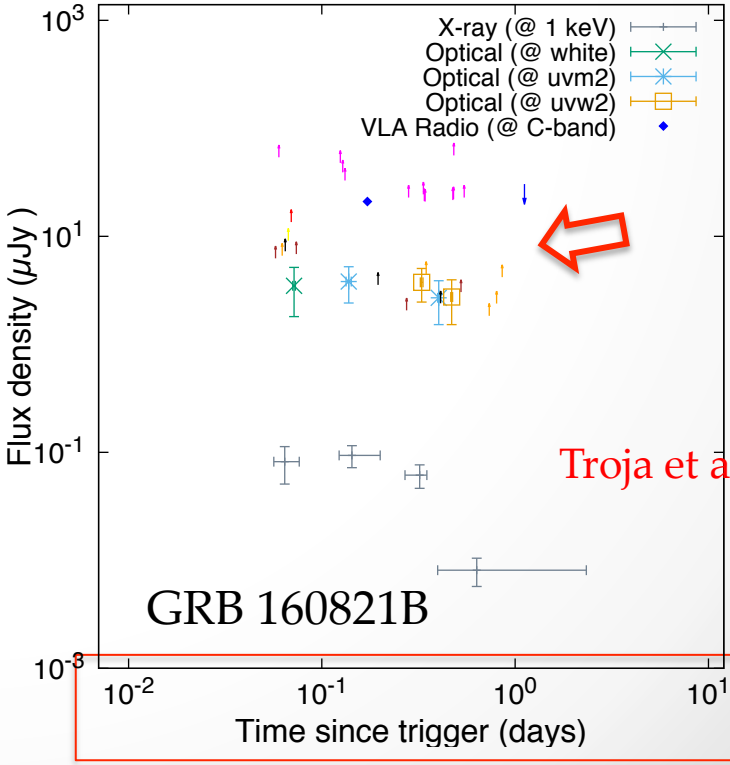
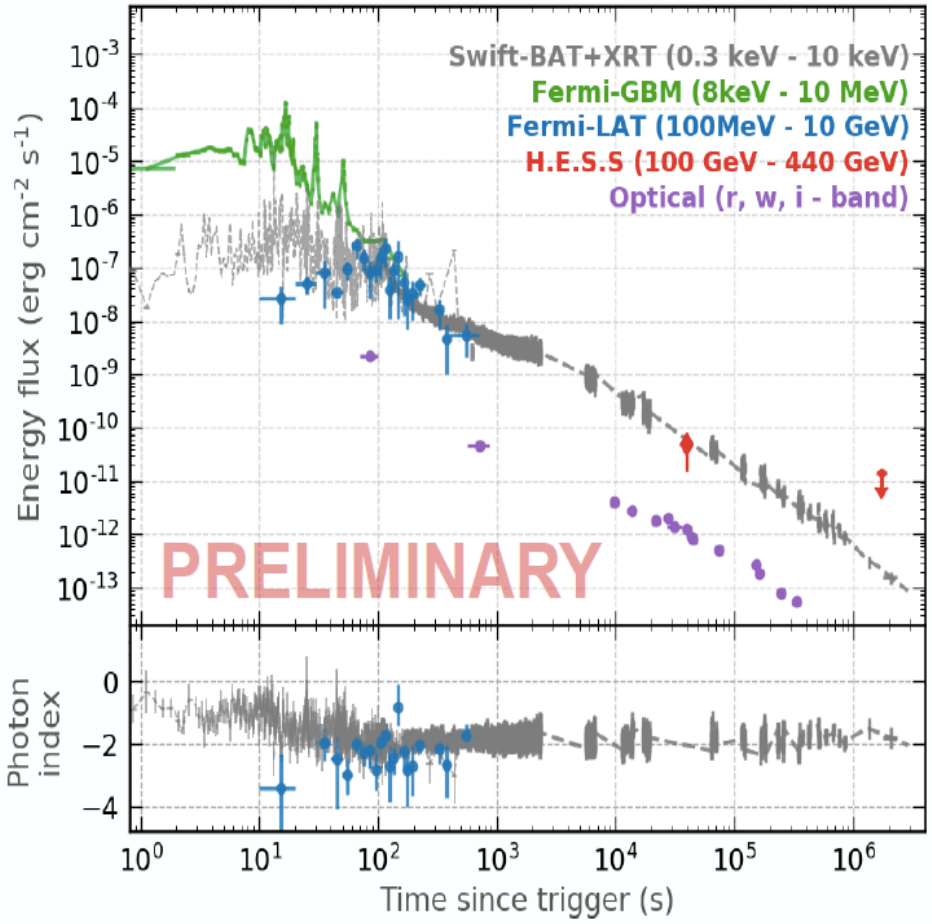
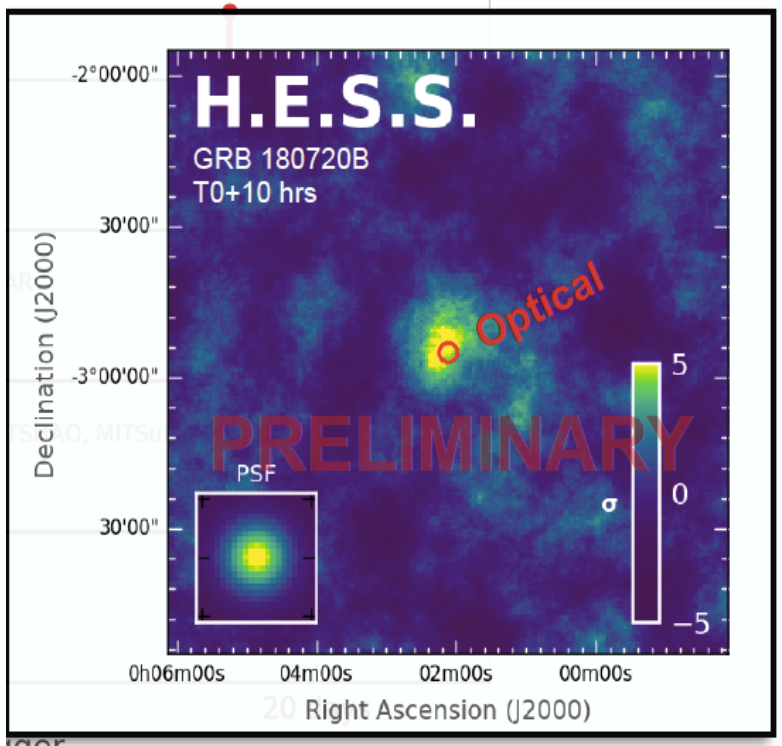


Troja et al. 2019

GRB 180720B





CTA symposium 2019

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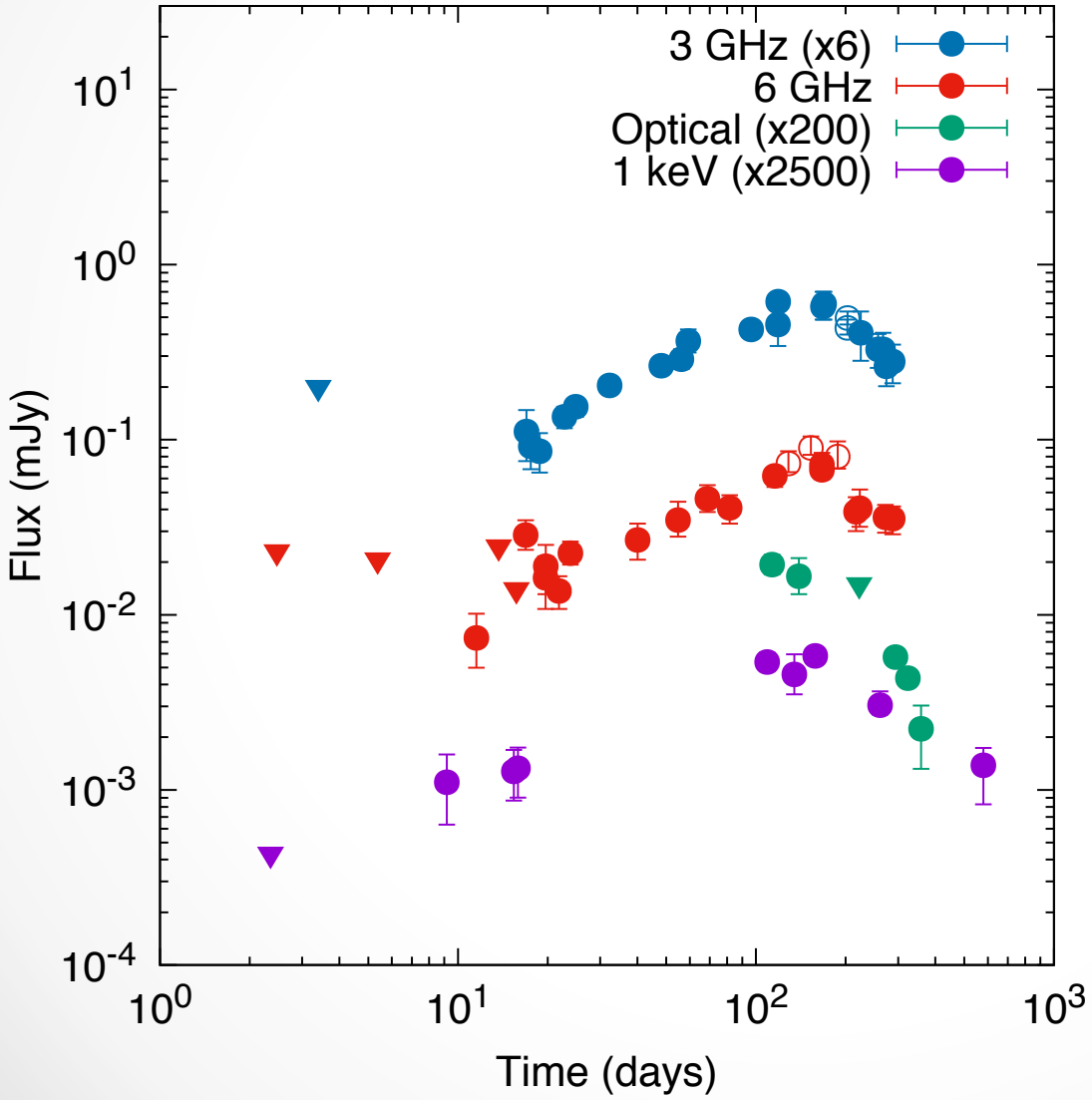
GRB 170817A



+ GRB ☑

+ GW event (NS- NS) ☑

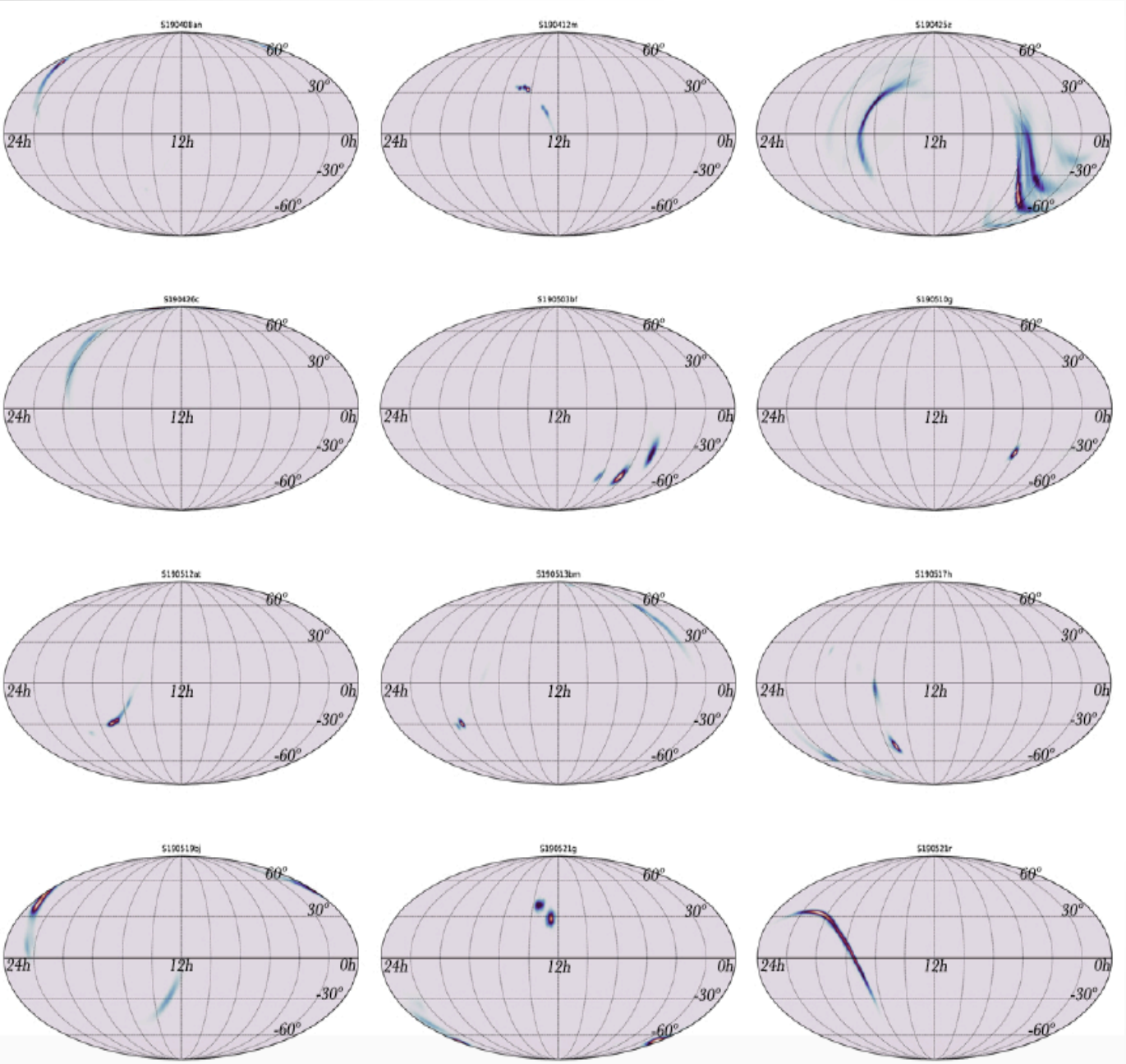
+ Kilonova ☑

+ Neutrinos ☒

+ Cosmic rays ☒

Diego's talk
Frederic's talk

More GW events but ……



+ GRB ☒

+ GW event ☑
binary NS and BH

+ Kilonova ☒

+ Neutinos ☒

+ Cosmic rays ☒

Different LIGO + Virgo GCNs …

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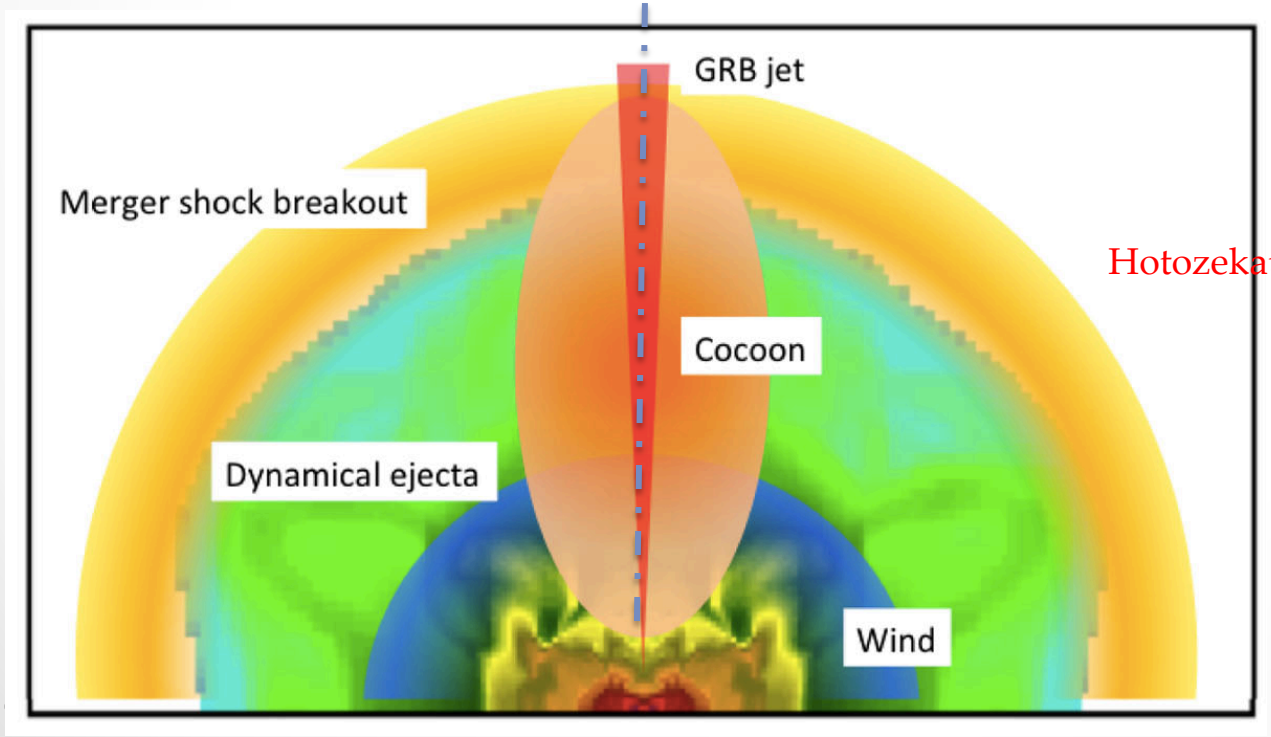
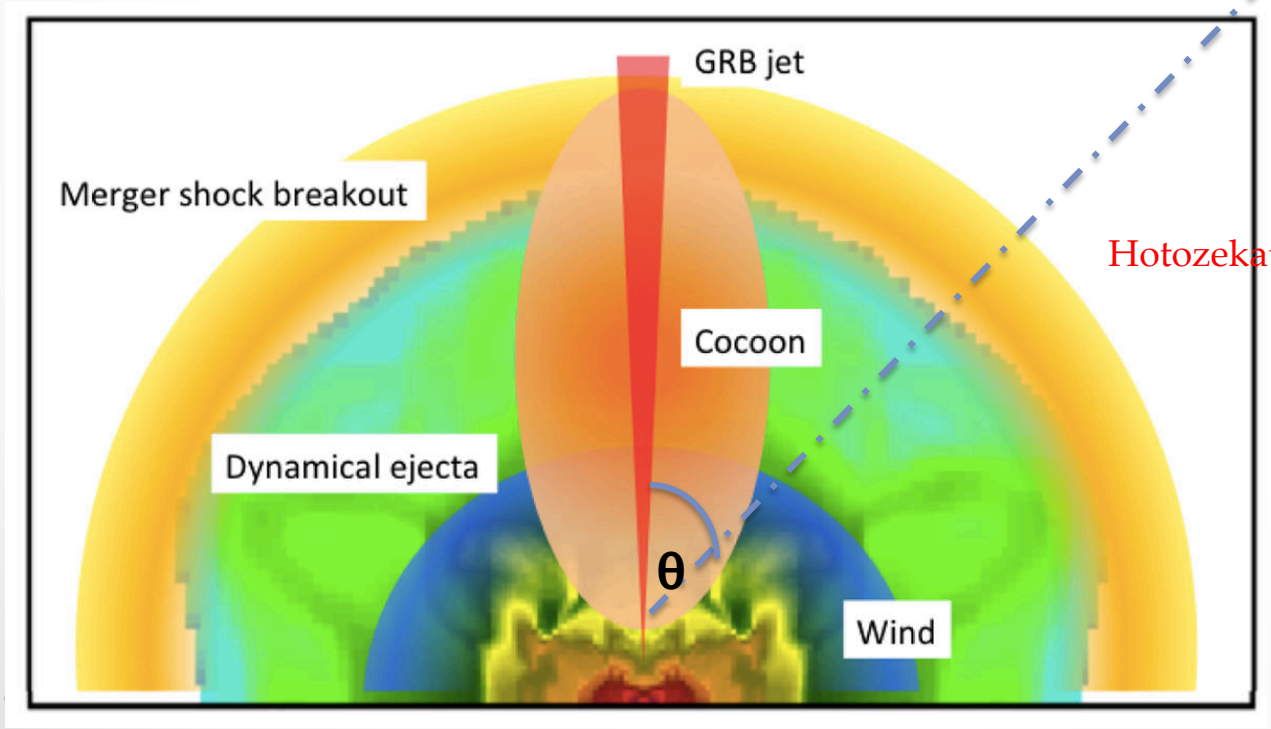
Schematic representation



Hotozekata & Piran et al 2015

Schematic representation



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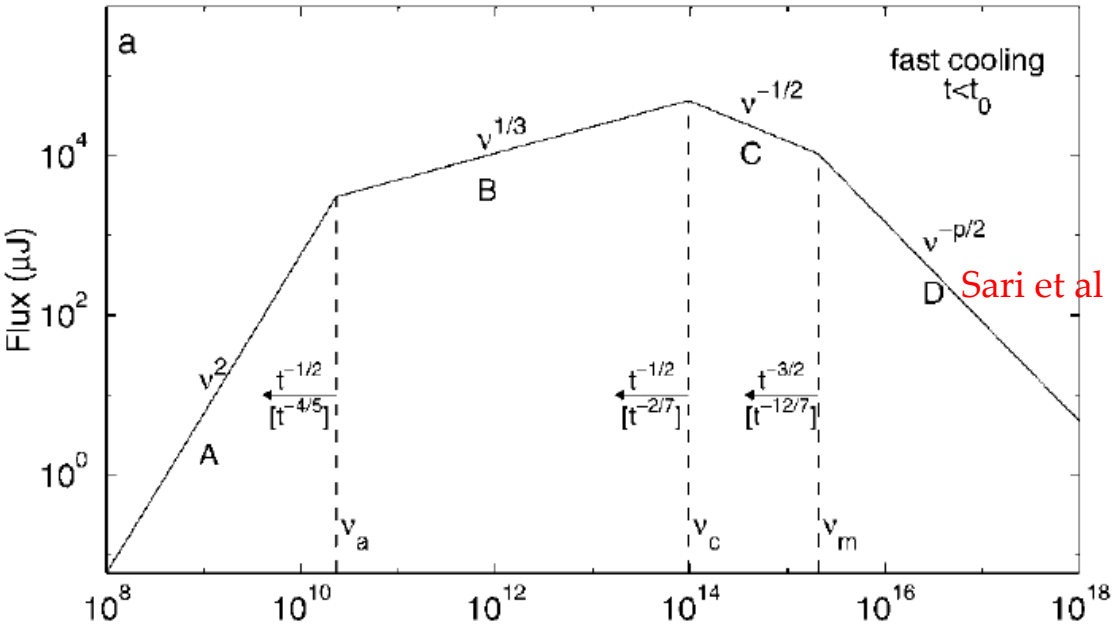
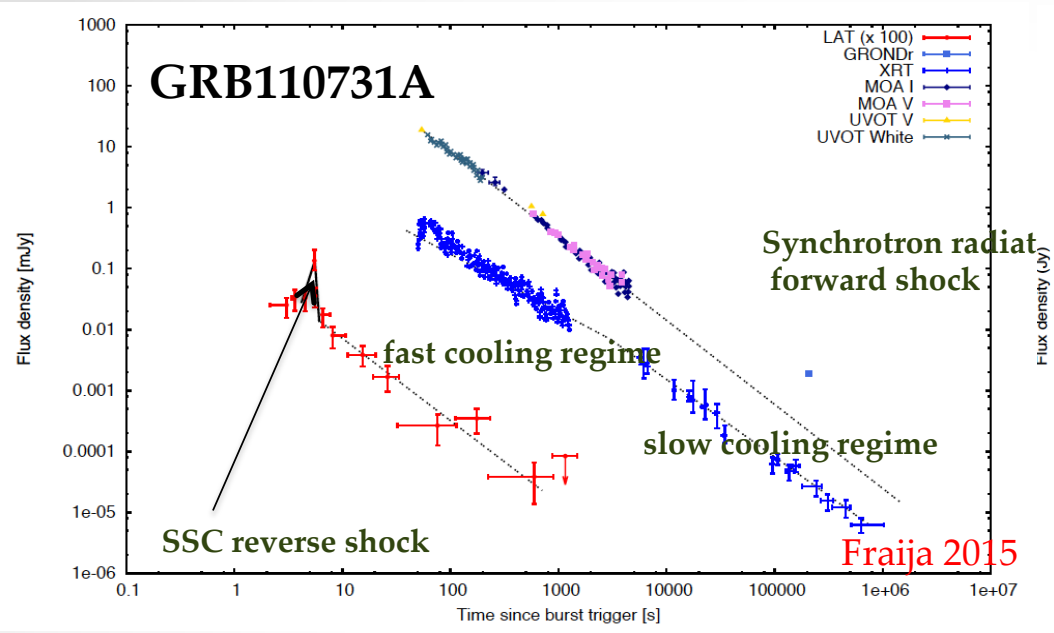
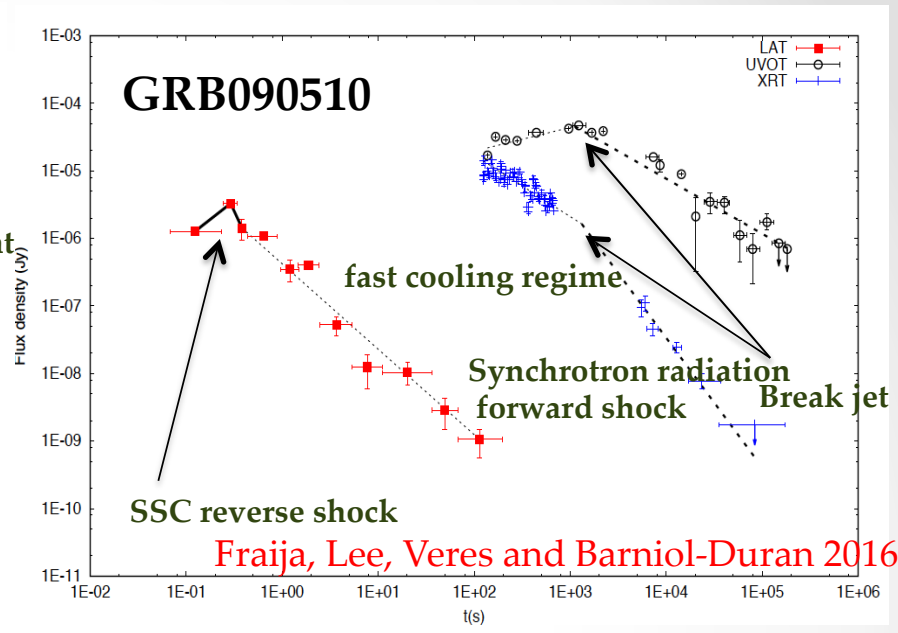
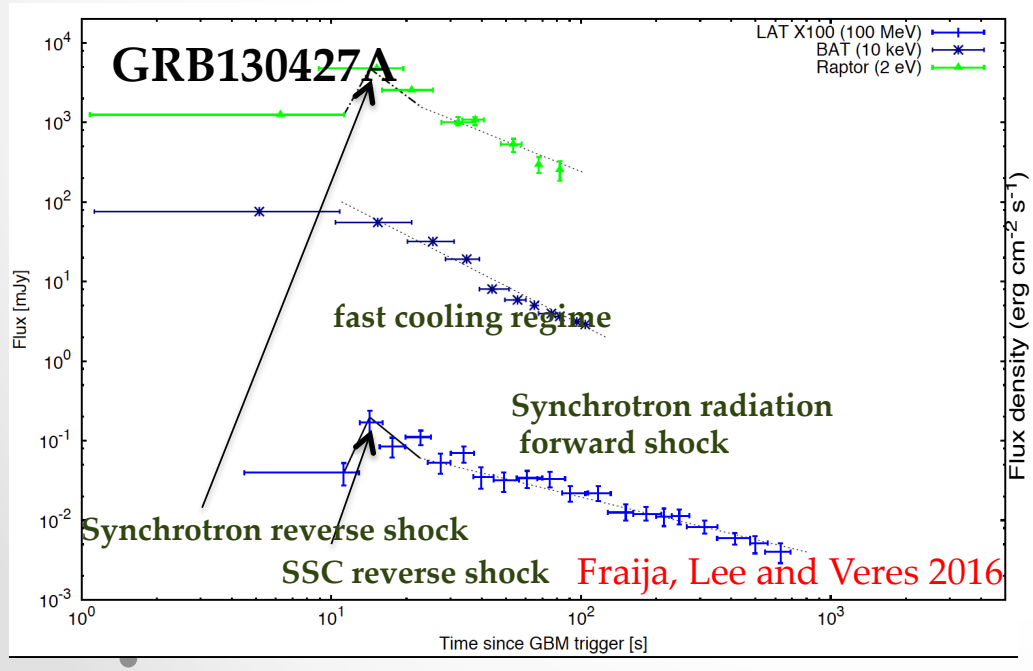
Typical Light curve
On-axis jet

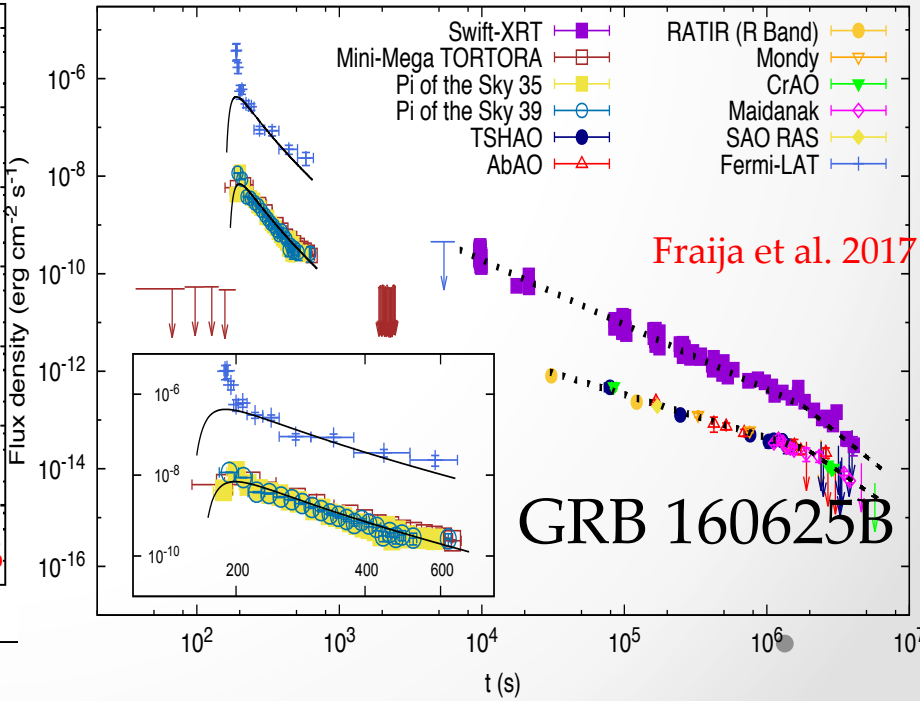


Sari et al 1998

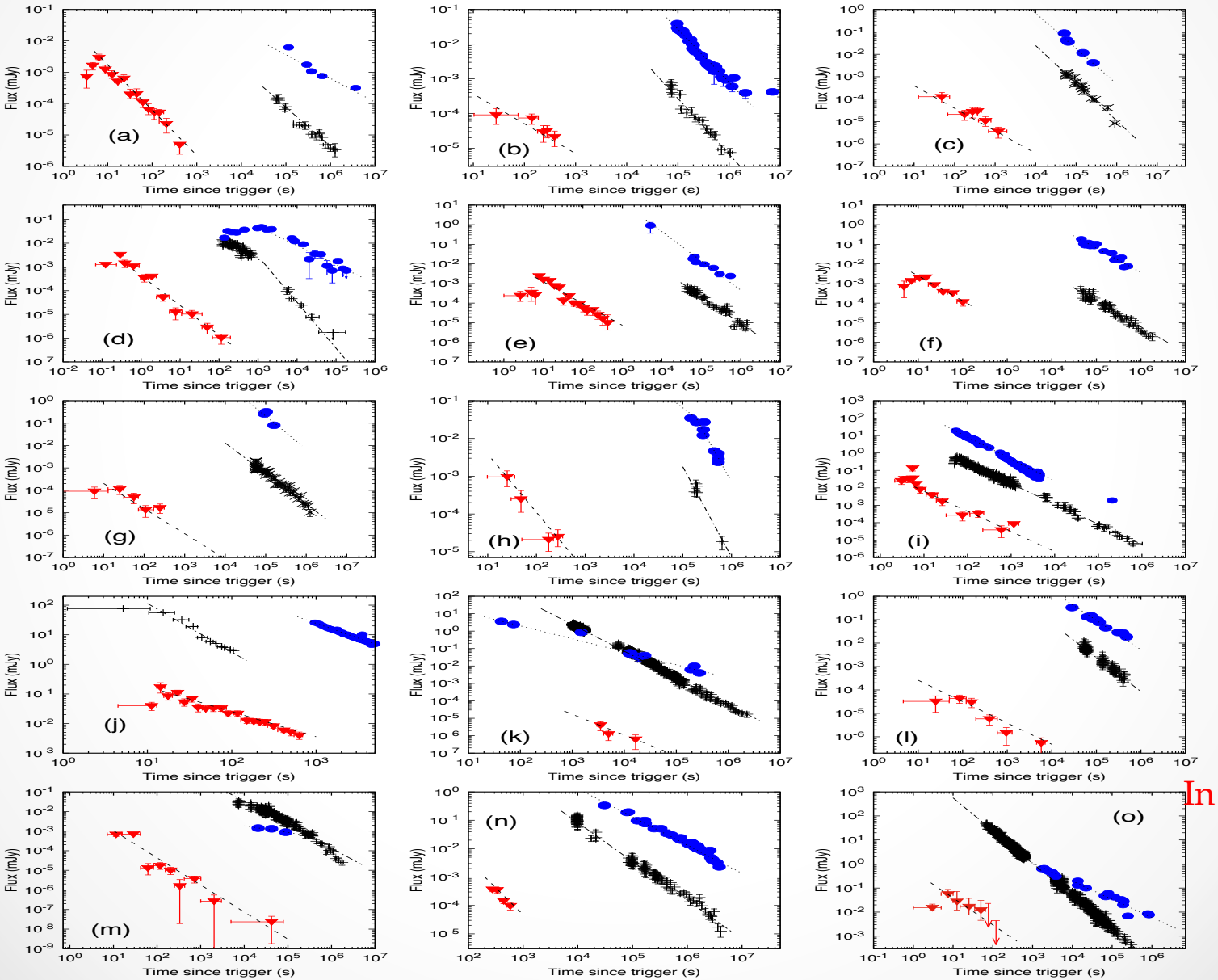

GRB110731A
LAT (x 100)
GRONDr
XRT
MOA I
MOA V
UVOT V
UVOT White
Synchrotron radiat
forward shock
fast cooling regime
slow cooling regime
SSC reverse shock
Fraija 2015
Flux density [mJy]
Time since burst trigger [s]


GRB090510
LAT
UVOT
XRT
fast cooling regime
Synchrotron radiation
forward shock
Break jet
SSC reverse shock
Fraija, Lee, Veres and Barniol-Duran 2016
Flux density (Jy)
t(s)


GRB130427A
LAT X100 (100 MeV)
BAT (10 keV)
Raptor (2 eV)
fast cooling regime
Synchrotron radiation
forward shock
Synchrotron reverse shock
SSC reverse shock
Fraija, Lee and Veres 2016
Flux [mJy]
Time since GBM trigger [s]

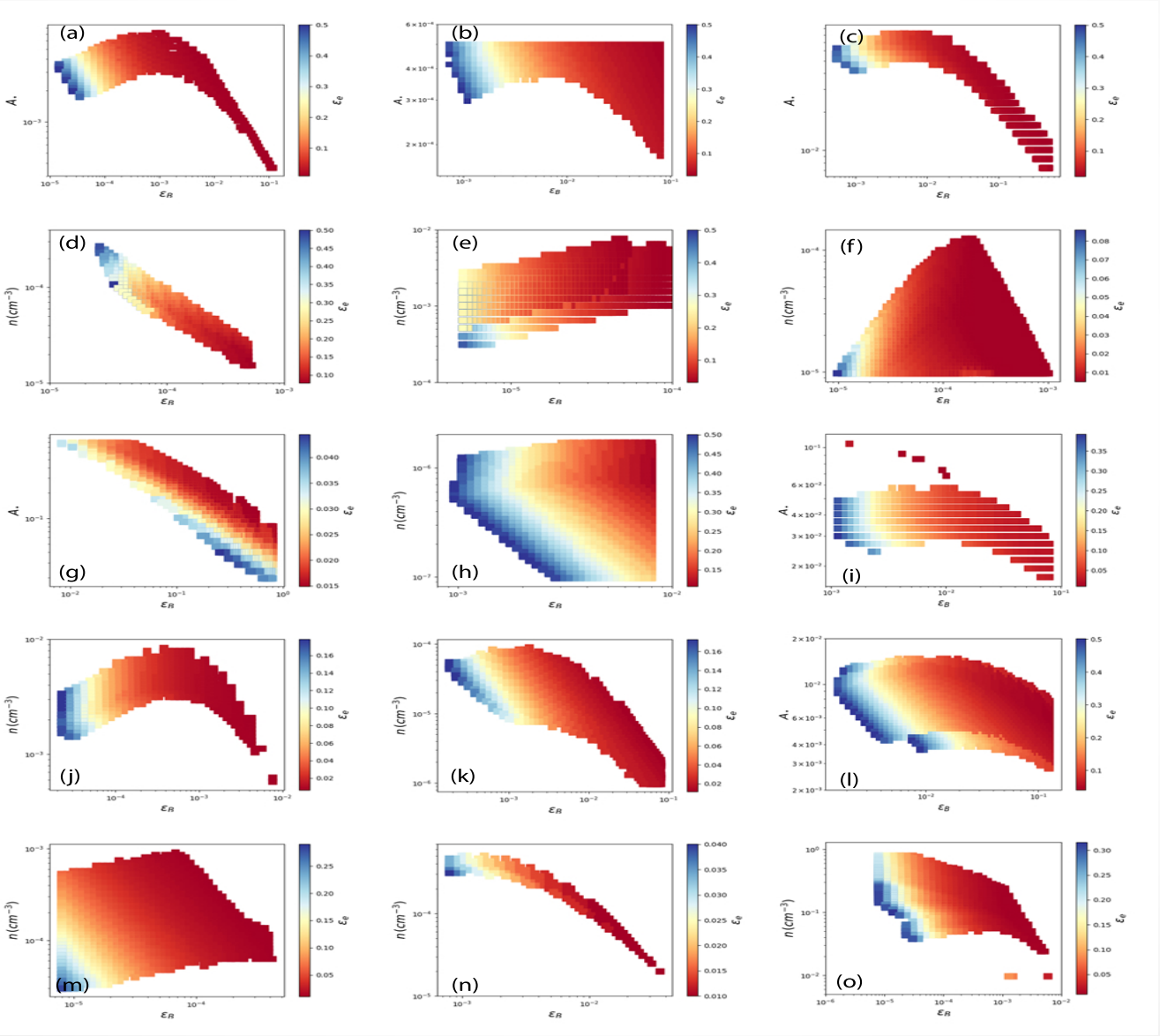

Swift-XRT
Mini-Mega TORTORA
Pi of the Sky 35
Pi of the Sky 39
TSHAO
AbAO
RATIR (R Band)
Mondy
CrAO
Maidanak
SAO RAS
Fermi-LAT
Fraija et al. 2017
GRB 160625B
Flux density (erg cm-2 s-1)
t (s)

Several GRBs
Fermi-LAT, Swift and optical



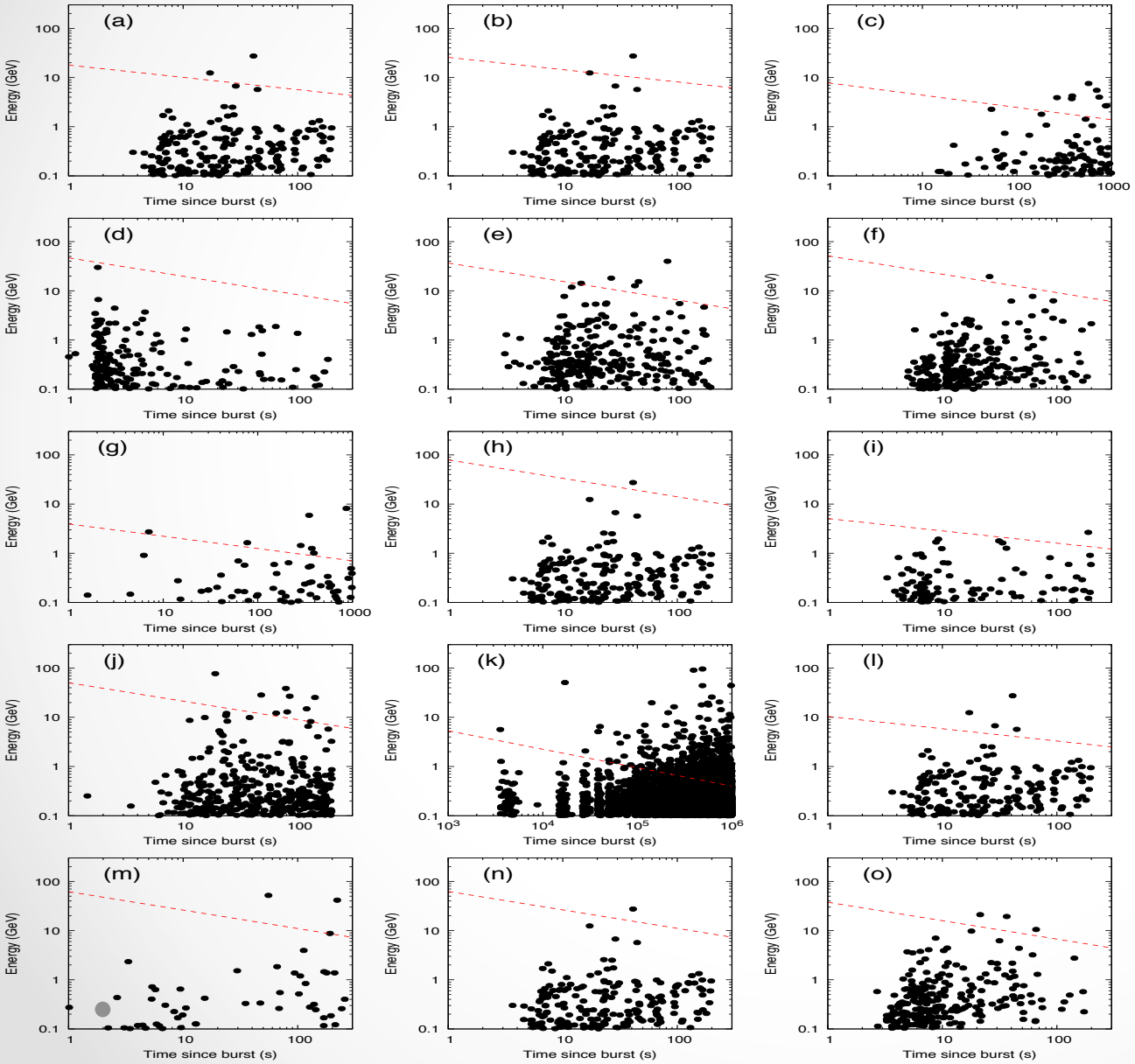
In progress

Parameter space



In progress

Very-high-energy LAT photons



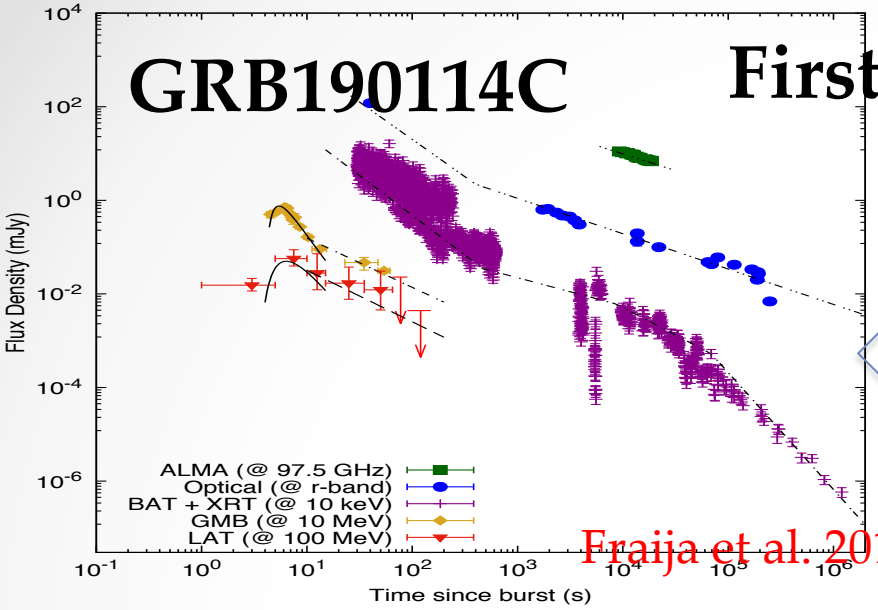
Synchrotron limits

below synchrotron

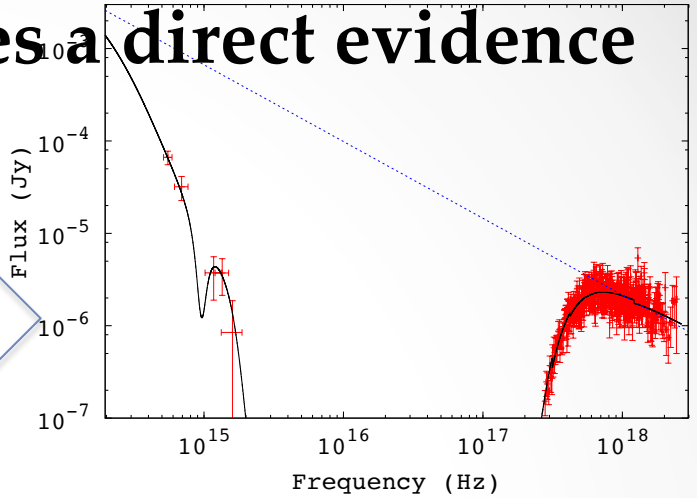
above
- Leptonic models
- Hadronic models

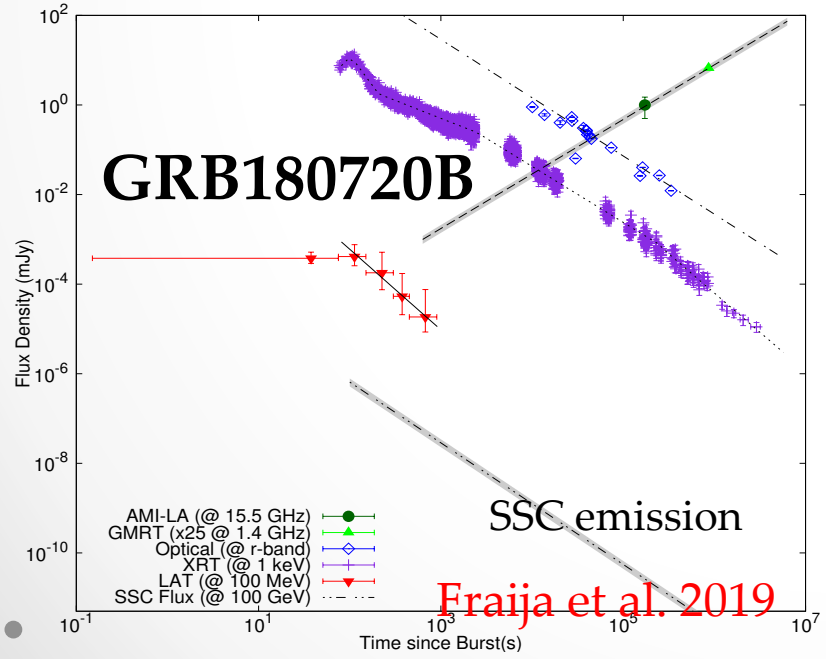
In progress

First times a direct evidence

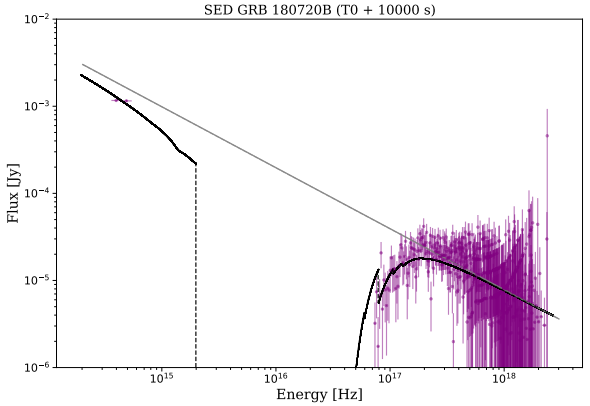


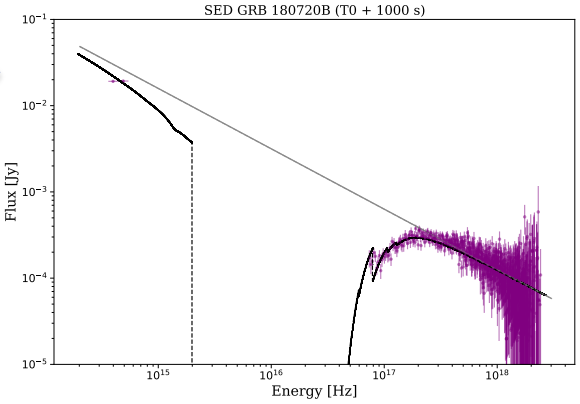
Fraija et al. 2019





Fraija et al. 2019





Outline

Gamma-ray bursts (Some generalities)

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- Atypical observations
- A weird observation

Forward-shock model

+ On-axis outflow
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(Universal, Gaussian …)
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+ Isotropic materials
(cocoon, breakout, dynamical …)
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Summary

Different Profiles

+ Double-jet

$$E_k = \begin{cases} E_1\,, & 0 < \theta \leq \theta_{\rm j}, \\ E_2\,, & \theta_{\rm j} < \theta \leq \theta_{\rm k}, \end{cases}$$

+ Gaussian jet

$$E_k = E_0\, e^{-\frac{\theta^2}{2\theta_j^2}}$$

Fabio's talk (simulations)

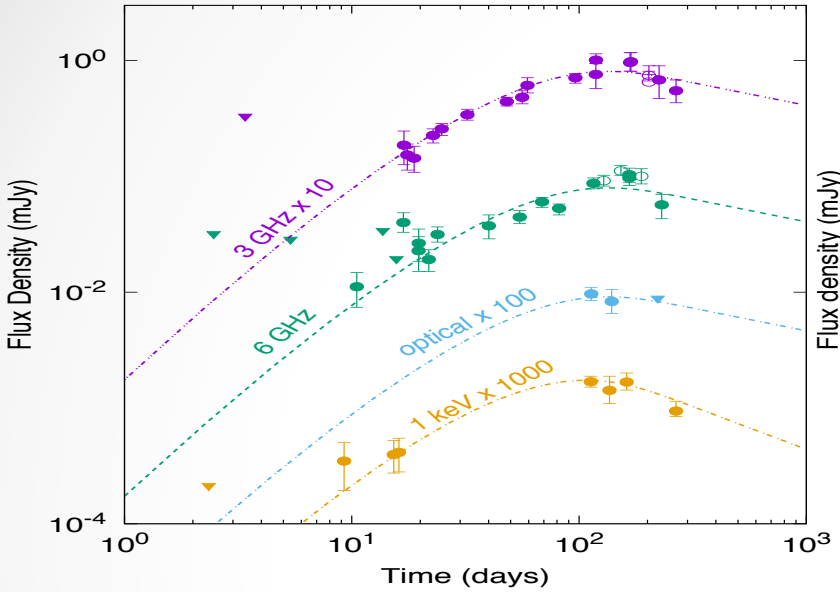
+ Universal jet

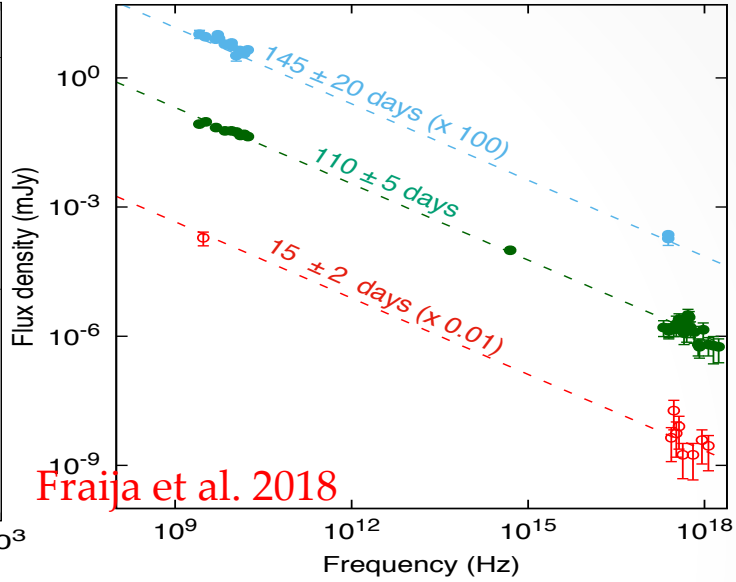
$$E_k = E_0 \left(1 + \frac{\theta^2}{\theta_j^2}\right)^{-\frac{a}{2}}$$

+ Veloc. and angular distribution

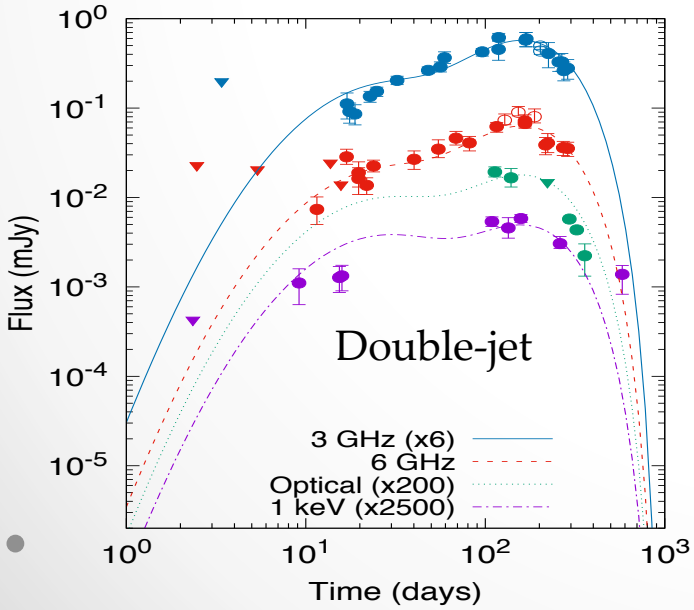
$$E_{\rm k} = \tilde{E}\,\Gamma^{-\alpha_s}(1 + \Delta\theta^2\Gamma^2)^{-3}$$

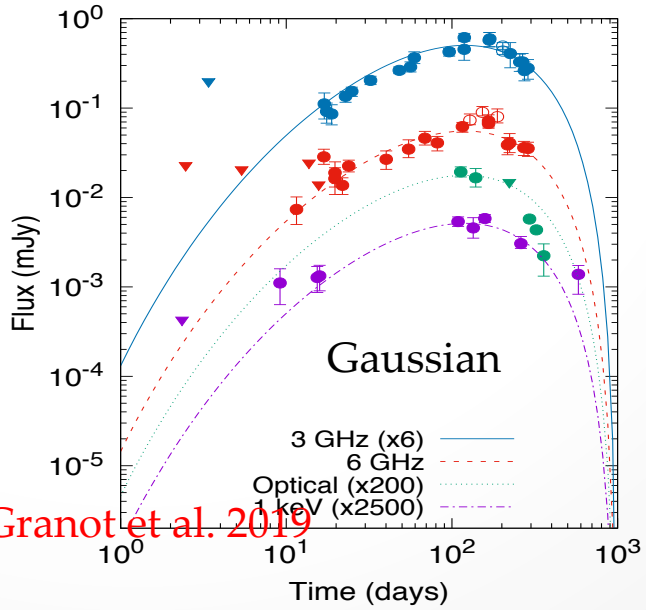
GRB 170817A



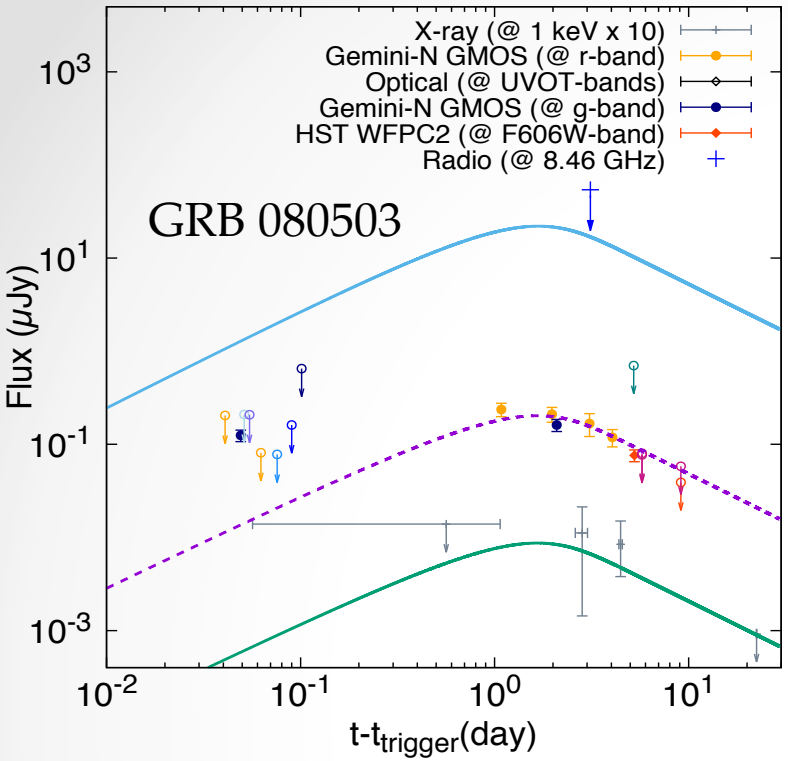


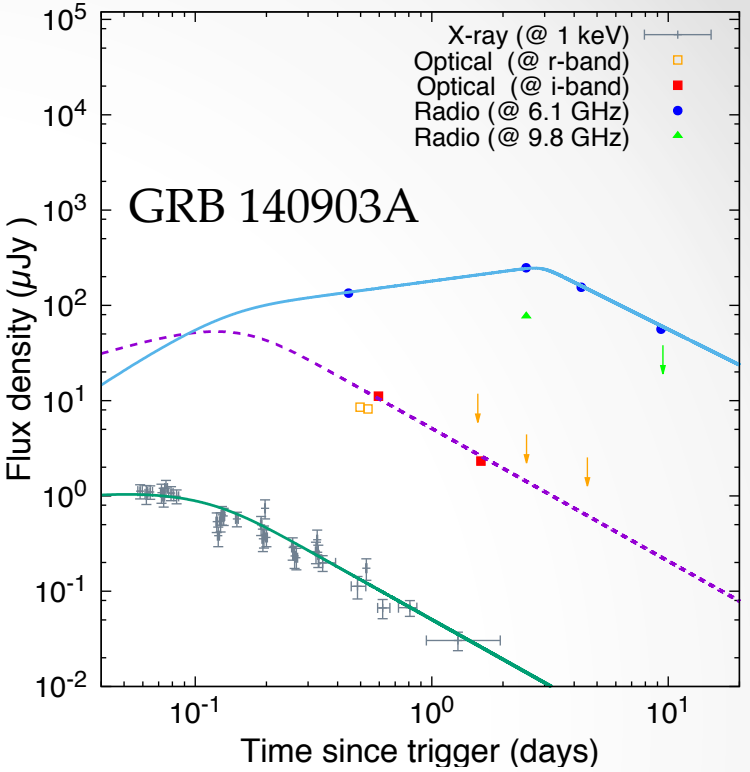
Fraija et al. 2018

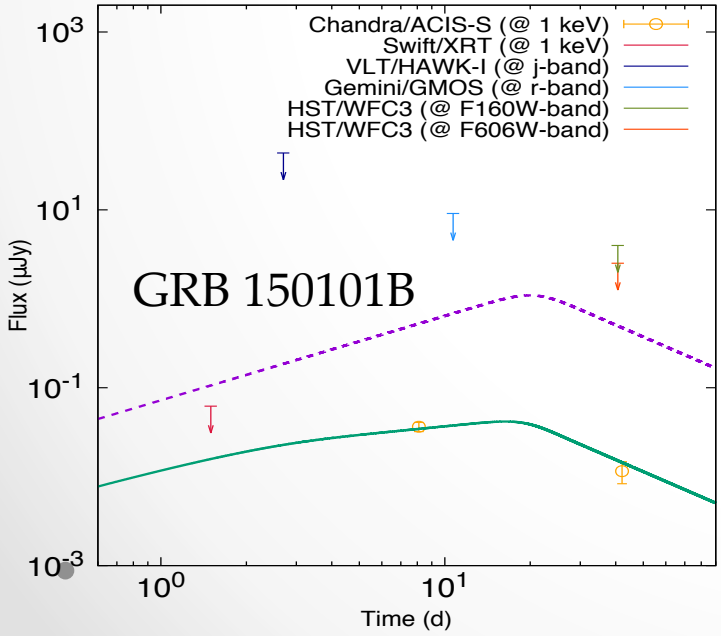




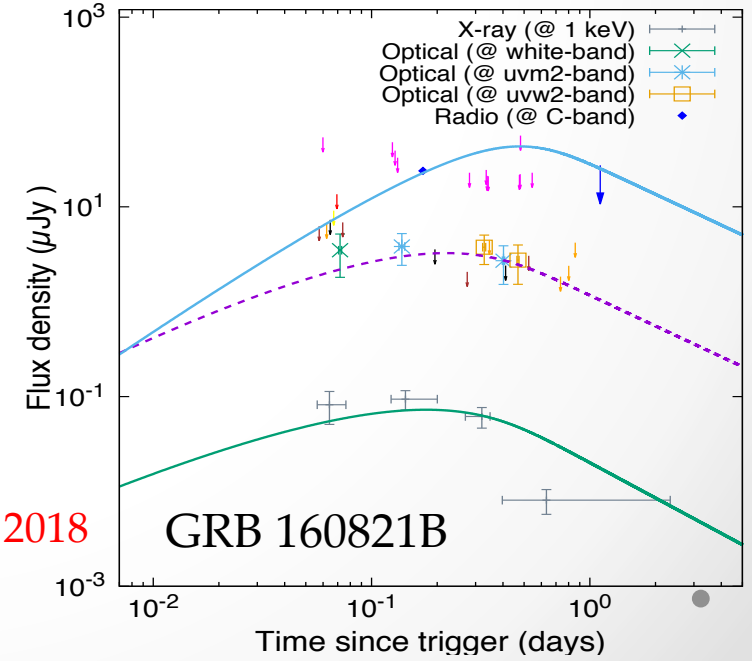
Granot et al. 2019







Fraija et al. 2018



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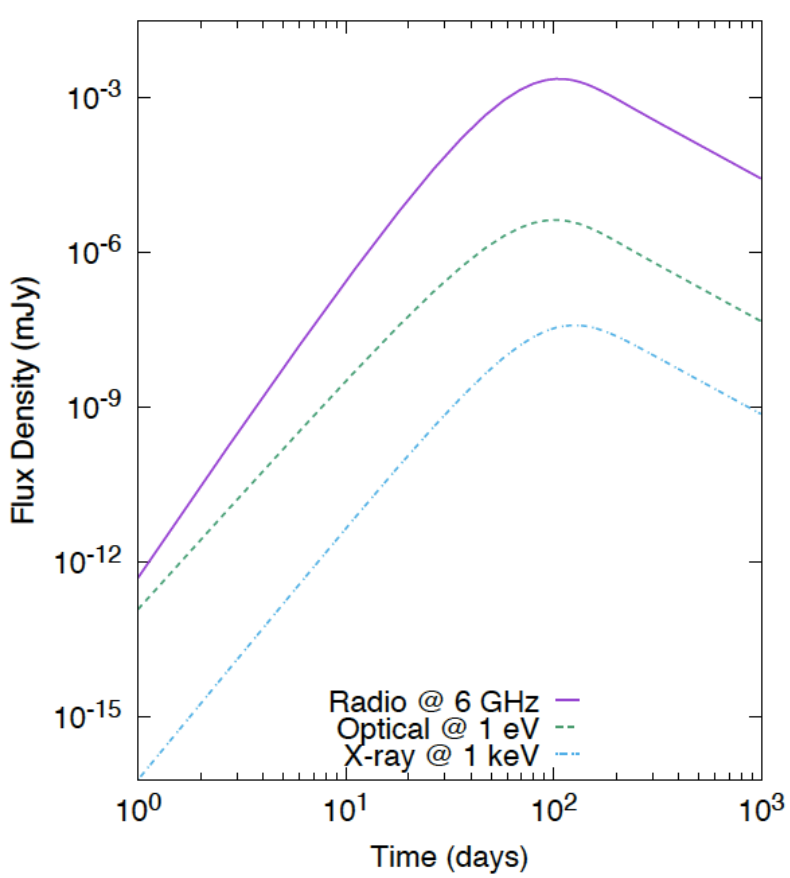
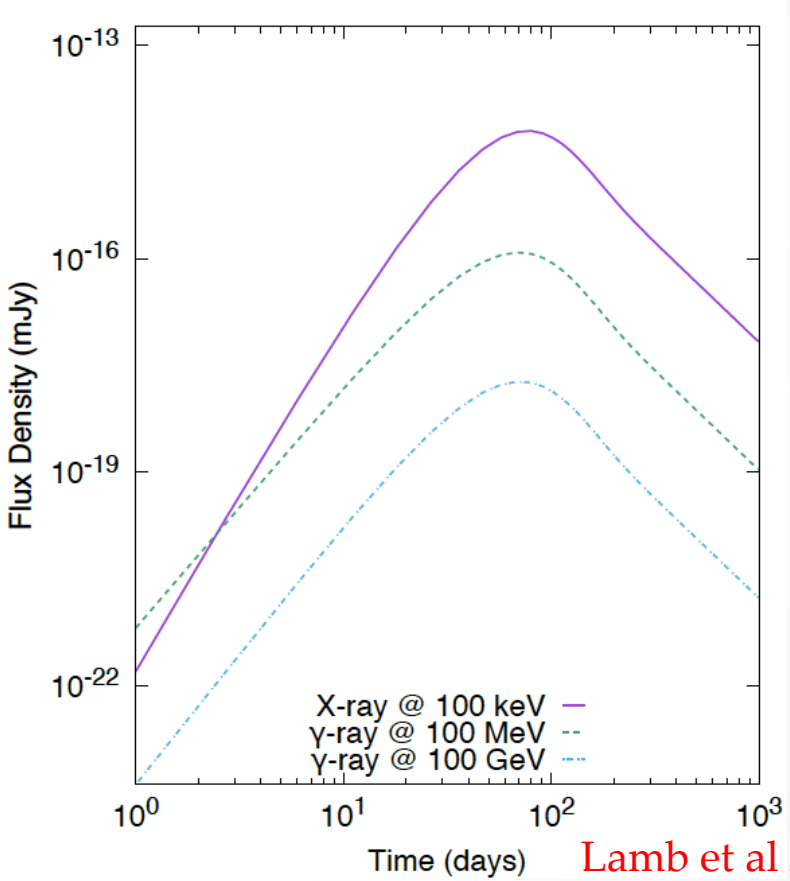
Summary

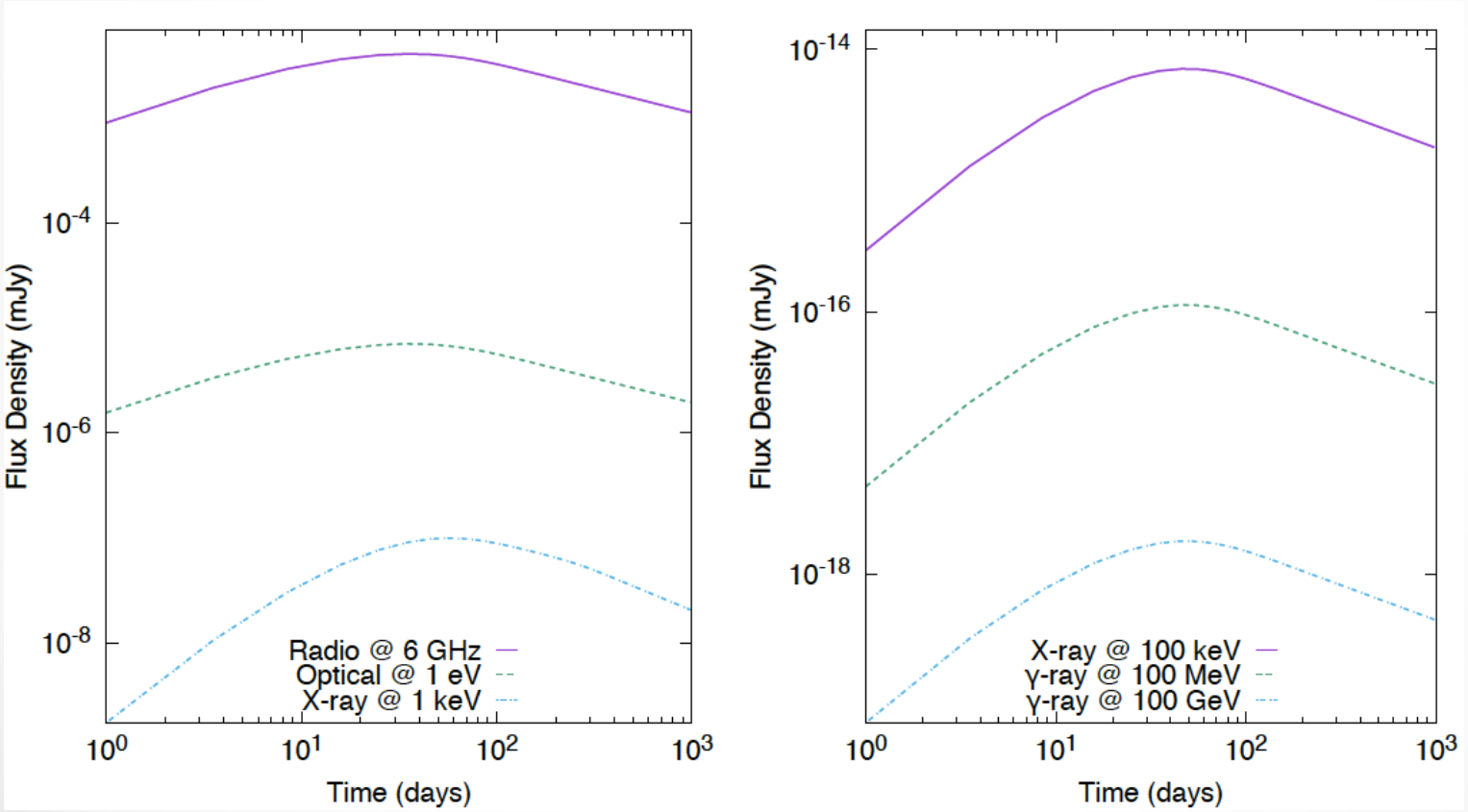
Typical Light curve
Off-axis jet





Lamb et al 2018
Fraija et al. 2018

Typical Light curve
Isotropic material



Narayan & Piran al. 2018
Fraija et al. 2018

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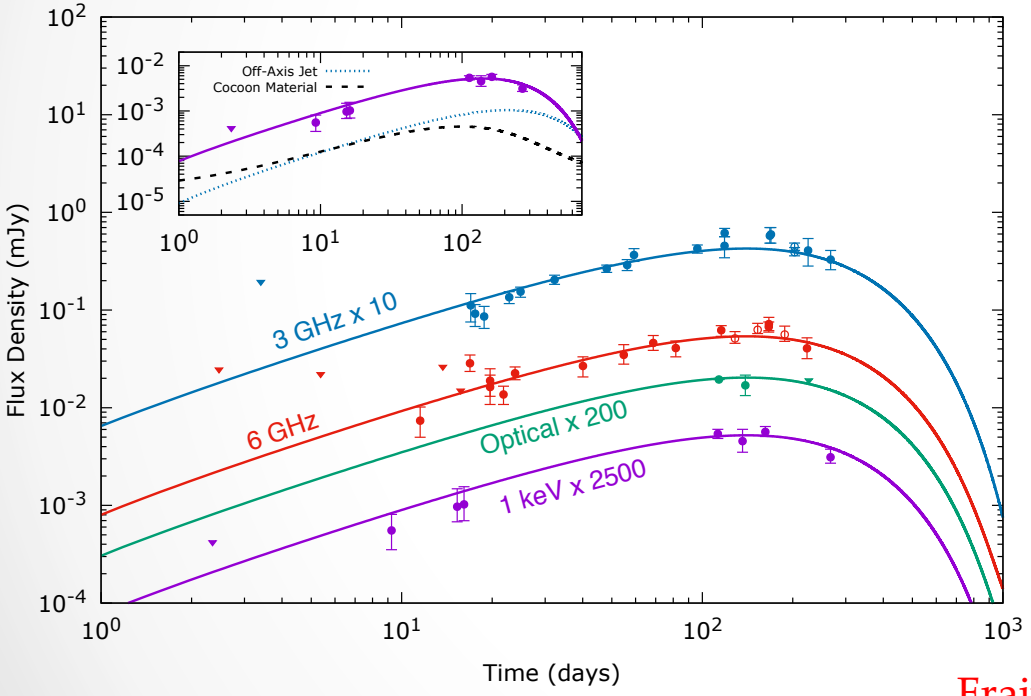

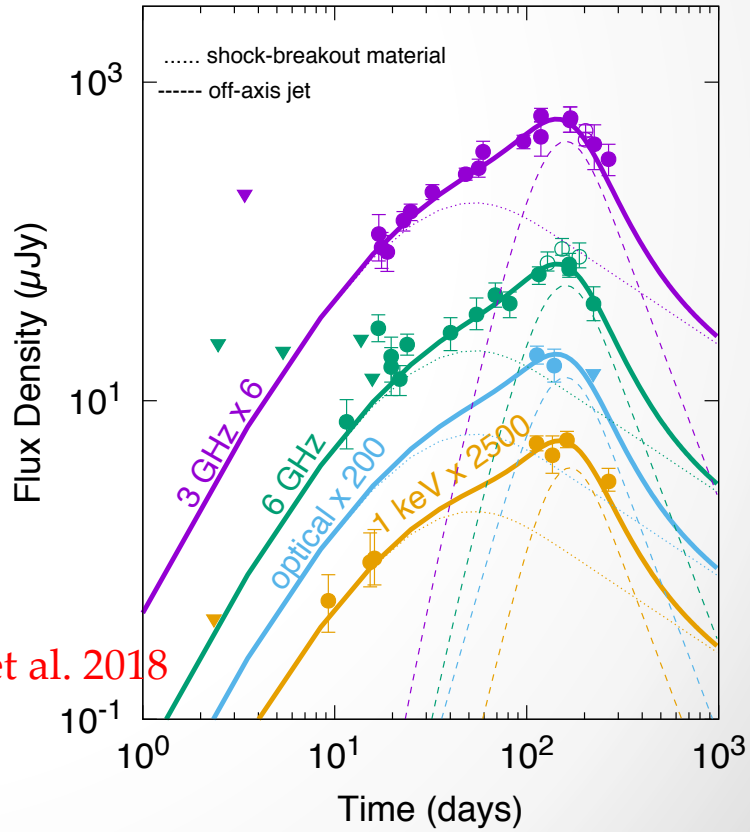

Fraija et al. 2018

Diego's talk
Frederic's talk

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Summary

+ Multi-wavelength observations play an important role in determining the physical processes, the nature of the central engine and constrain the density of the circumburst medium and microphysical parameters.

+ More and early observations (***Colibri < 20 s***) become potentially more interesting and informative, allowing afterglow models to be tested more rigorously.

+ We expect more electromagnetic counterparts from GW events (NS-BH and BH-BH ?, possible exotic objects and mechanisms)

+ Multi-messenger (neutrinos, cosmic rays) detections help us to understand better GRBs.