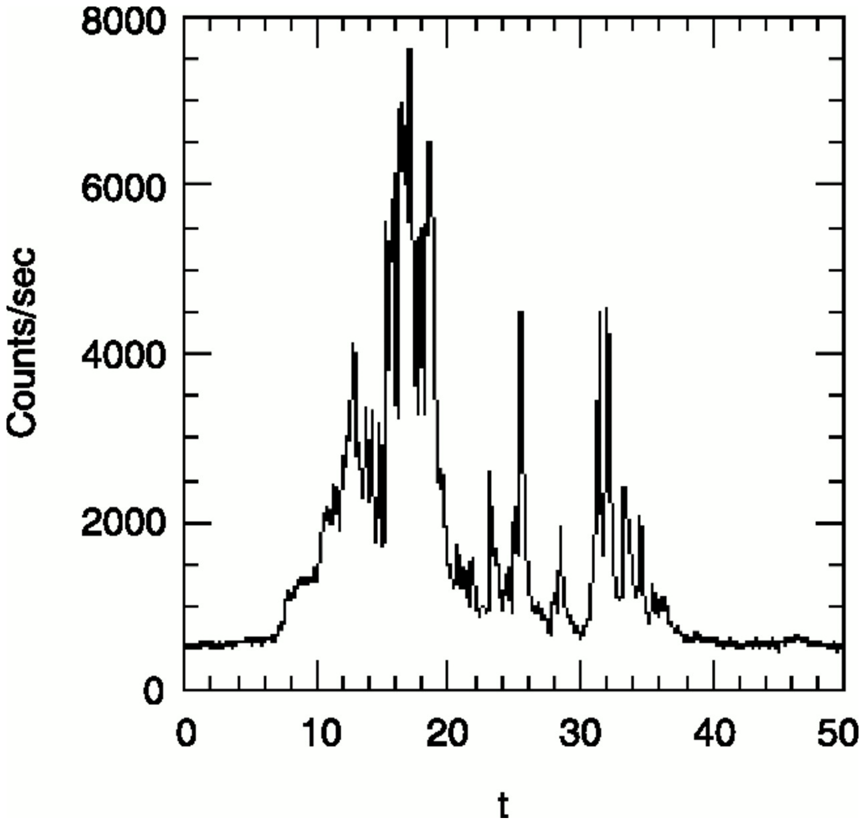
γ-ray bursts

PROMPT EMISSION



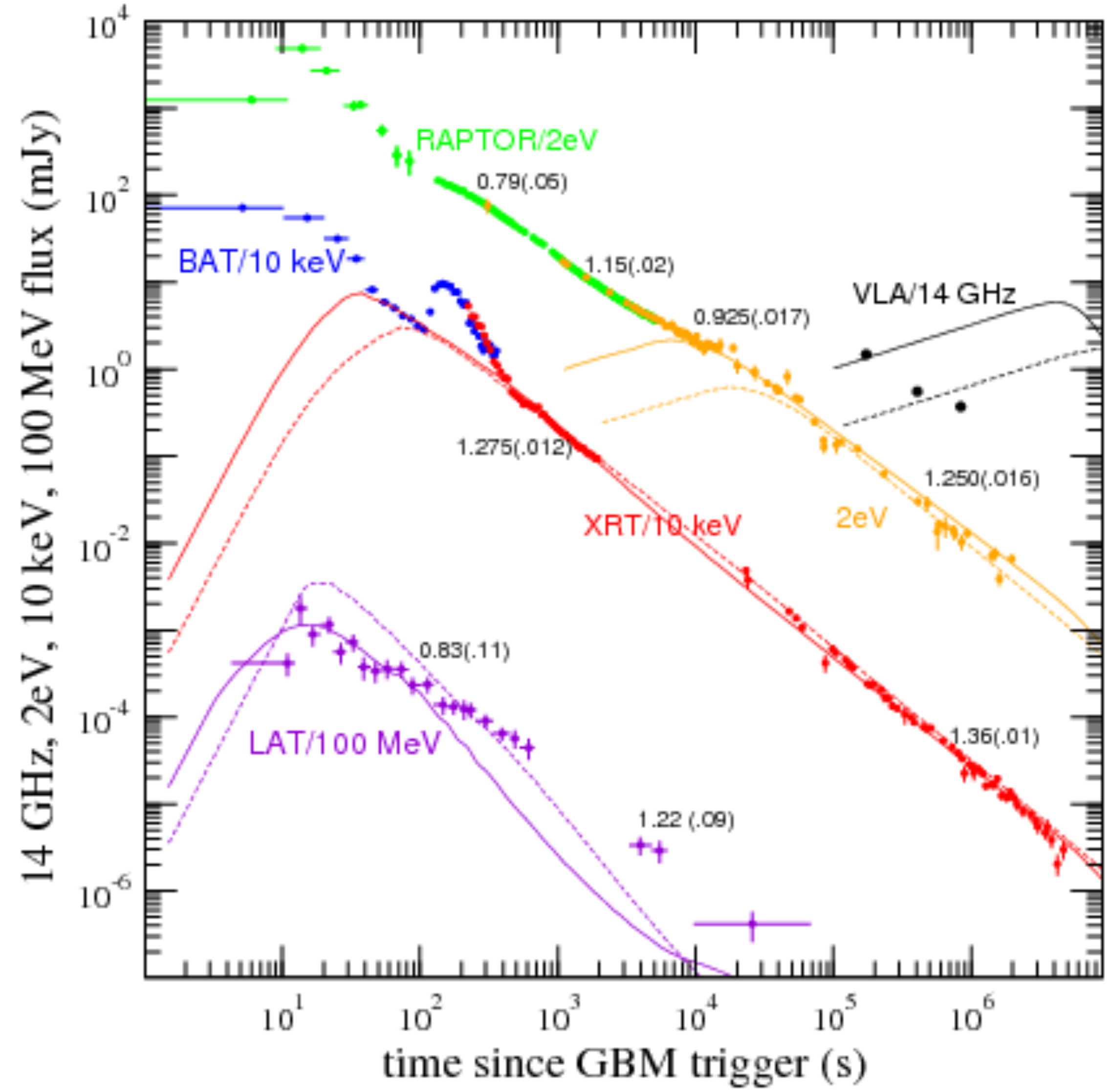
~ 10 keV - 10 MeV

~ 1 ms - 1000 s

few per week

well established: internal dissipation of jet's energy
(nothing more)

AFTERGLOW



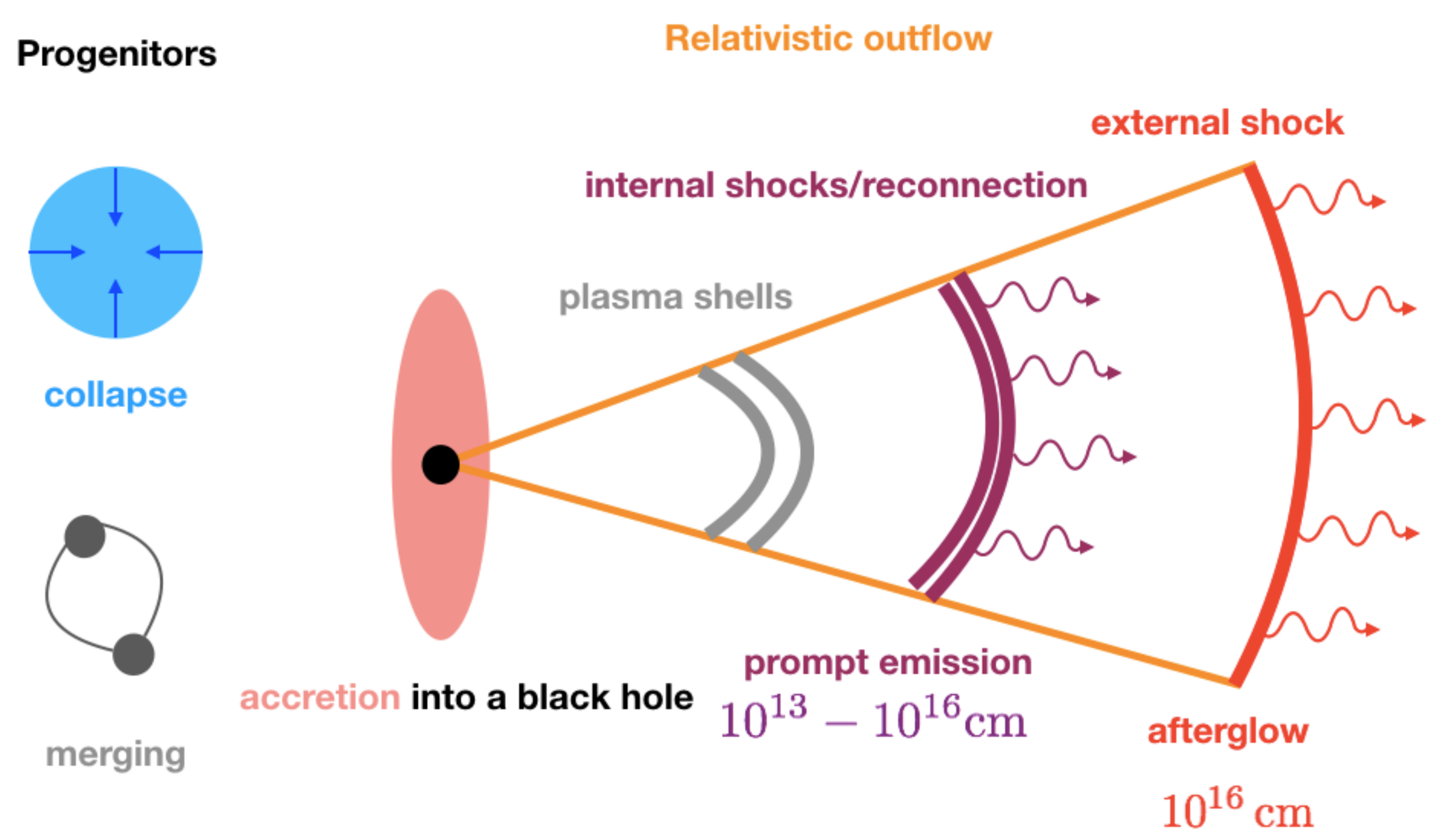
radio, optical, X-rays, VHE
(Last news: MAGIC and HESS detections)

lasting days after GRB

well established: external dissipation in ISM
(not the case in X-rays???)

Credits to: P. Mészáros 2001 and Panaitescu et al. 2013

γ-ray bursts: the model



Cavallo & Rees 1978; Paczýnski 1986; Goodman 1986
Shemi & Piran 1990; Rees & Meszaros 1994

Usov 1992; Thompson 1994; Meszaros & Rees 1997
Lyutikov & Blandford 2003

γ-ray bursts and more

What are the problems?

I - Prompt emission:
-what is the jet composition?
-where the emission is produced? (1E12-1E16 cm)
-what is the dissipation process?
-what is the topology of the magnetic field?

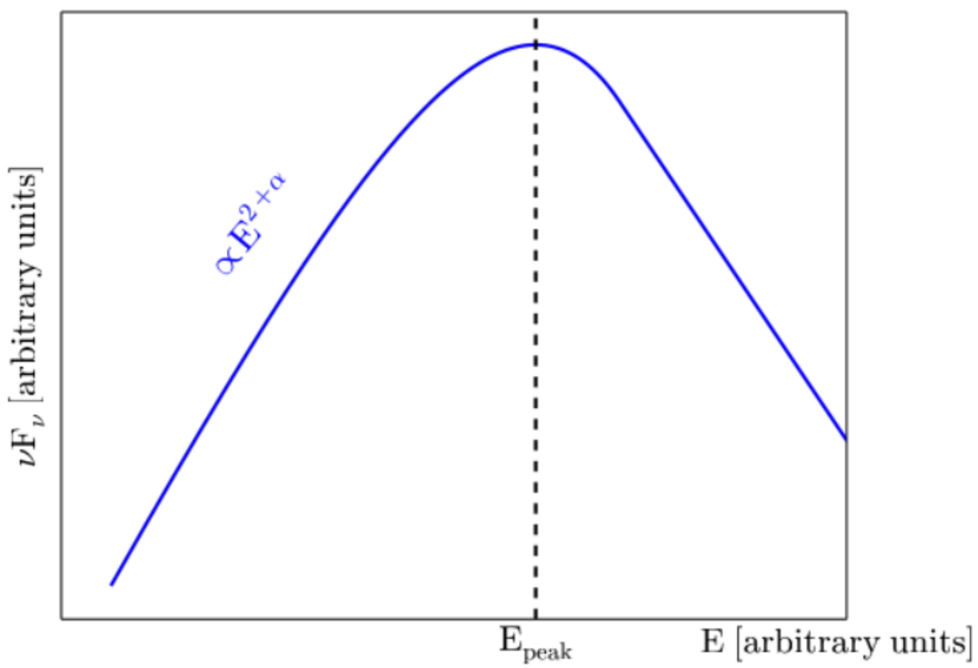
II - Soft X-ray afterglow:
- What is the origin of the plateau?
- What is the central engine of the GRB - BH or NS?

III - What we can learn with Wide FOV soft X-ray mission?
- Soft X-ray extension of the prompt emission spectra (now 10 keV - 10 MeV)
- Off-axis prompt emission tails (larger viewing angle - softer emission) - **GW counterparts**
- Off-axis afterglow emission - **GW counterparts**
- Shock break out - **GW counterparts** and Supernovae precursors

IV - From a polarisation?
- radiative process of prompt? (long tale emission)
- magnetic field structure of jet?
- structure of the jet?

Old mystery from GRB spectra

simple non-thermal like spectra



Preece et al. 1998; Frontera et al. 2000; Ghirlanda et al. 2002; Kaneko et al. 2006; Nava et al. 2011; Sakamoto et al. 2011; Goldstein et al. 2012; Gruber et al. 2014; Lien et al. 2016; Yu et al. 2016 + more

baryon load to the fireball ?

Shemi & Piran 1990
Rees & Meszaros 1994

dissipation of EM outflow?

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

synchrotron?

Katz 1994
Rees & Meszaros 1994
Tavani 1996
Sari et al. 1996, 1998

fast cooling?

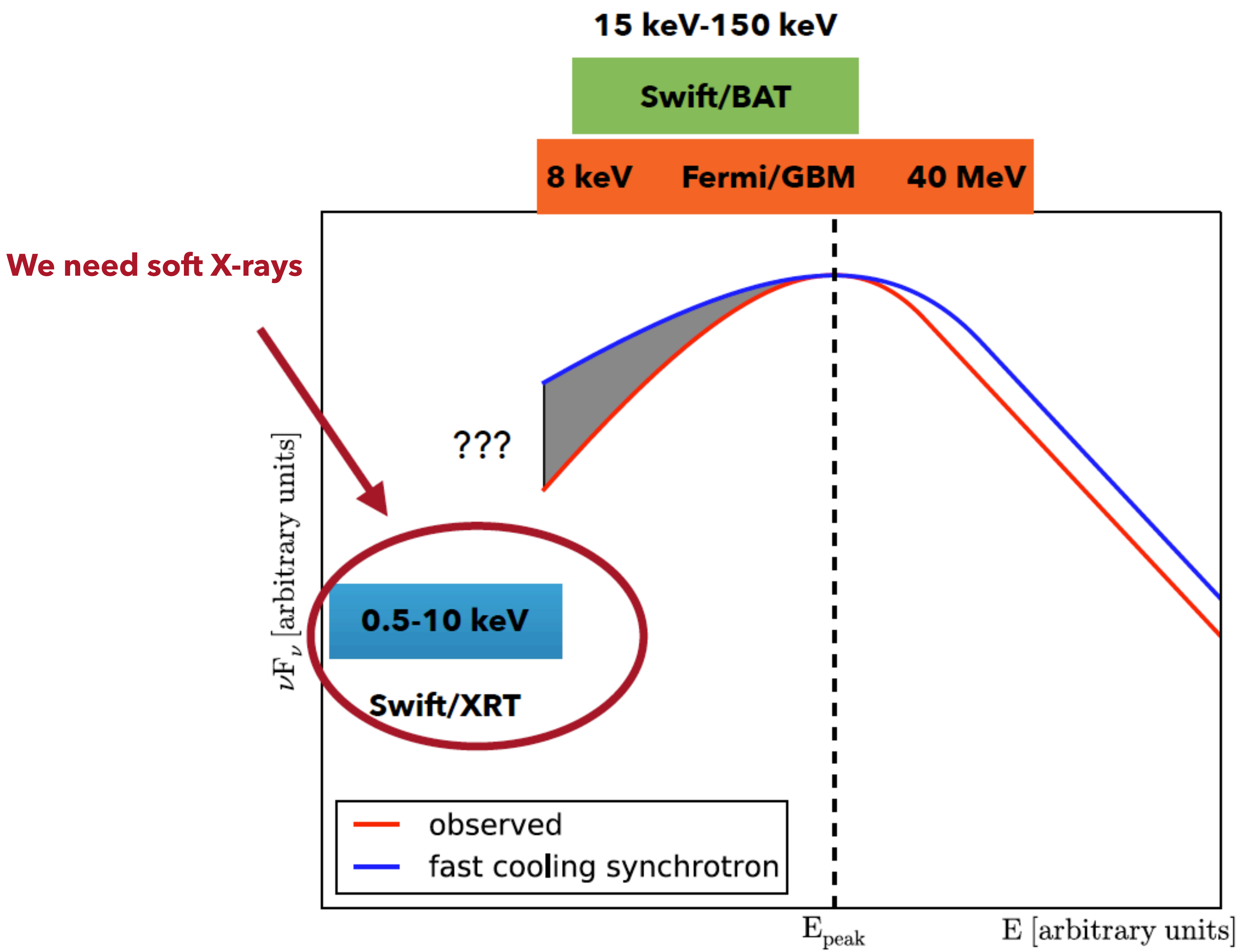
Ghisellini et al. 2000

$\alpha = -1.5$

$\alpha \sim -1$

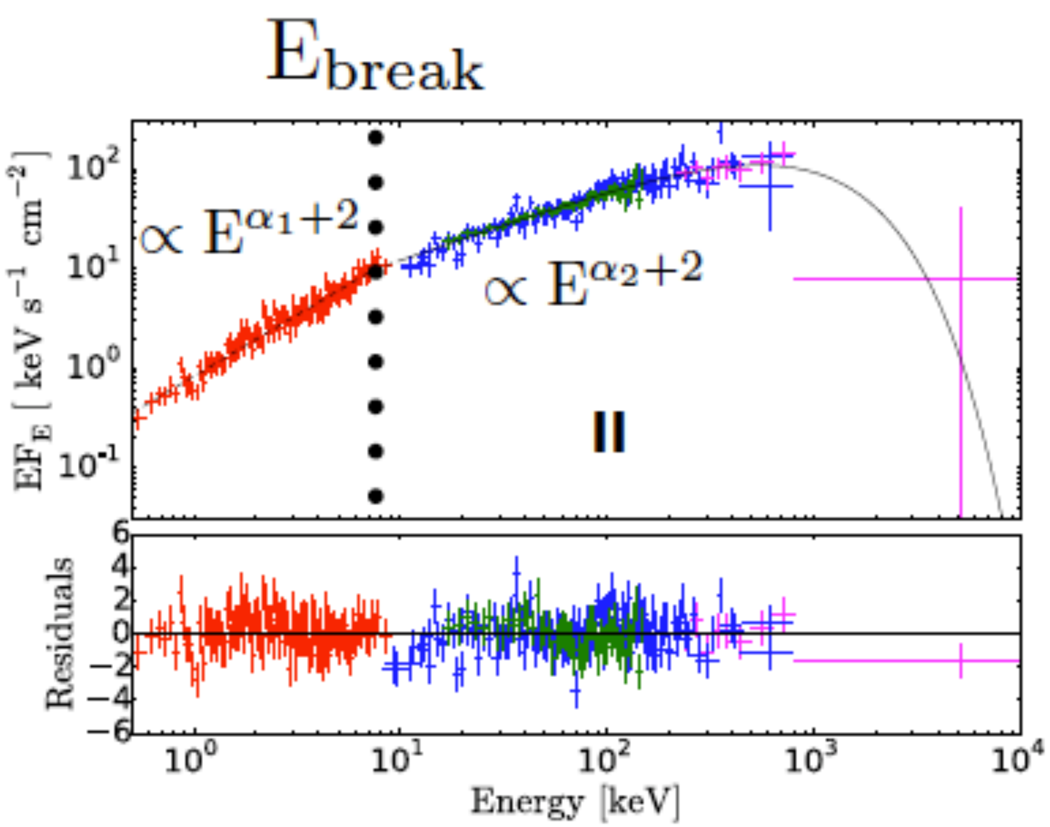
DOESN'T WORK

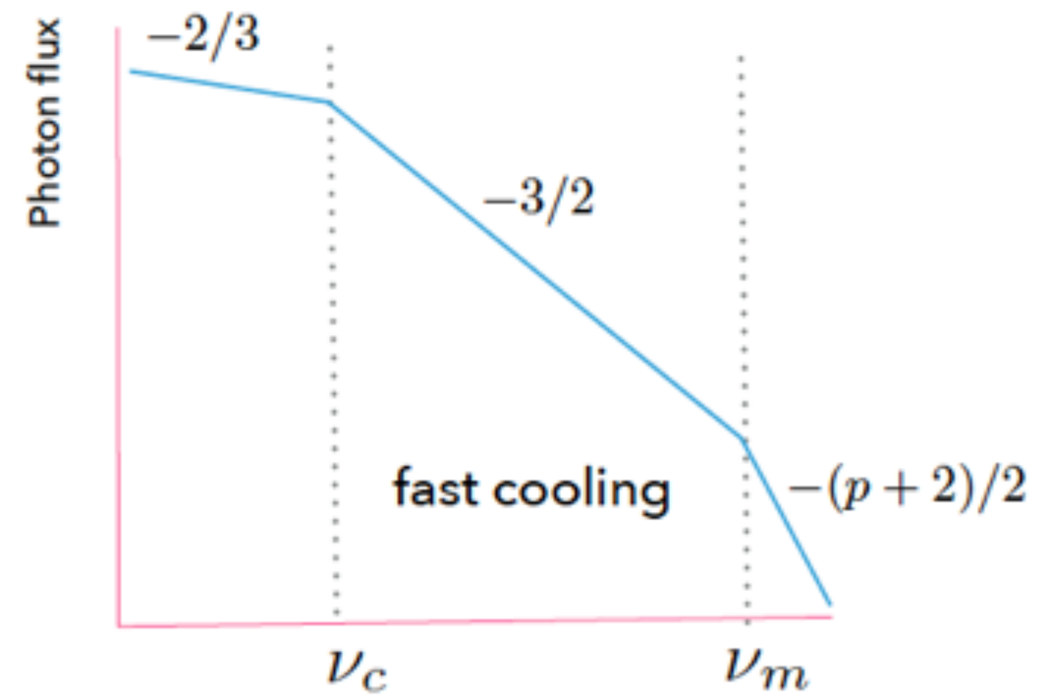
How to solve?

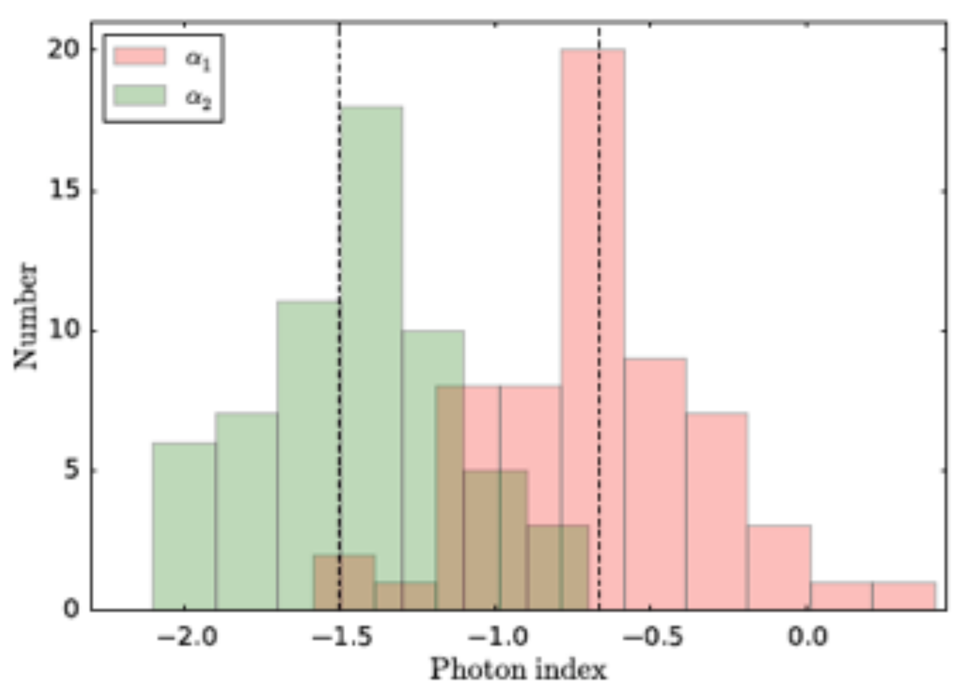


15 keV-150 keV
Swift/BAT
8 keV
Fermi/GBM
40 MeV
We need soft X-rays
???
0.5-10 keV
Swift/XRT
νF_ν [arbitrary units]
observed
fast cooling synchrotron
E_{peak}
E [arbitrary units]

Recent news and hopes for the future







synchrotron emission in marginally fast cooling regime

Thanks to Swift XRT (0.5-10 keV)

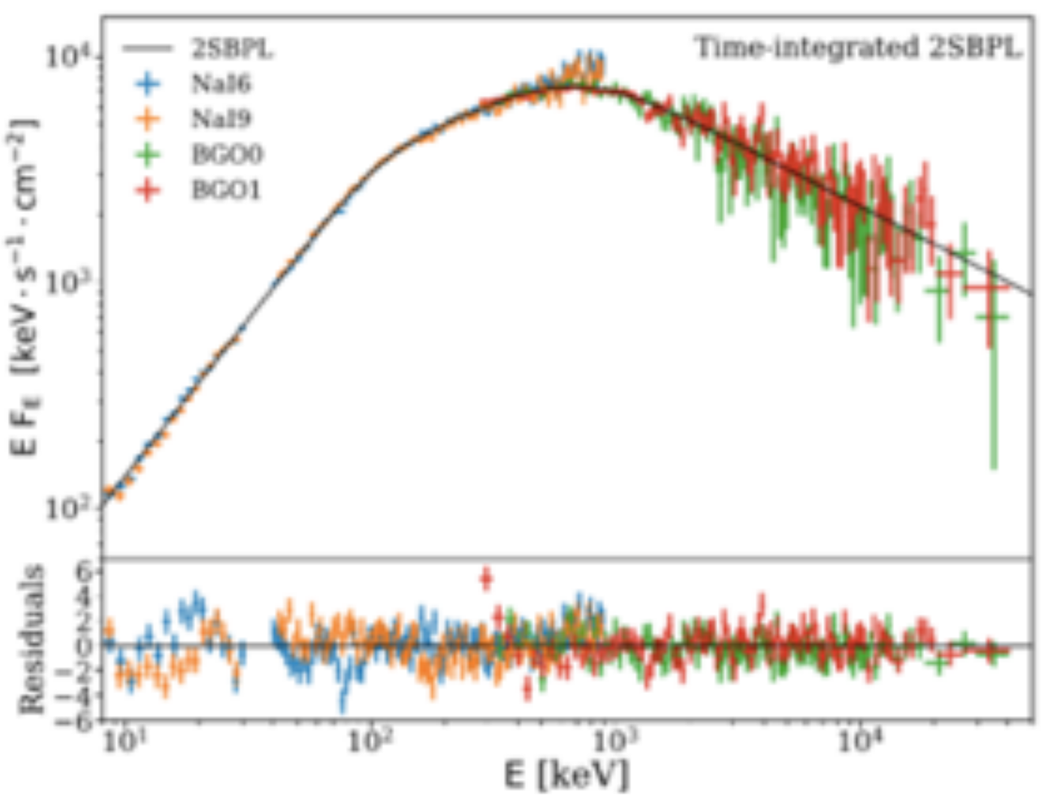
but only ~30 GRBs among 1400!

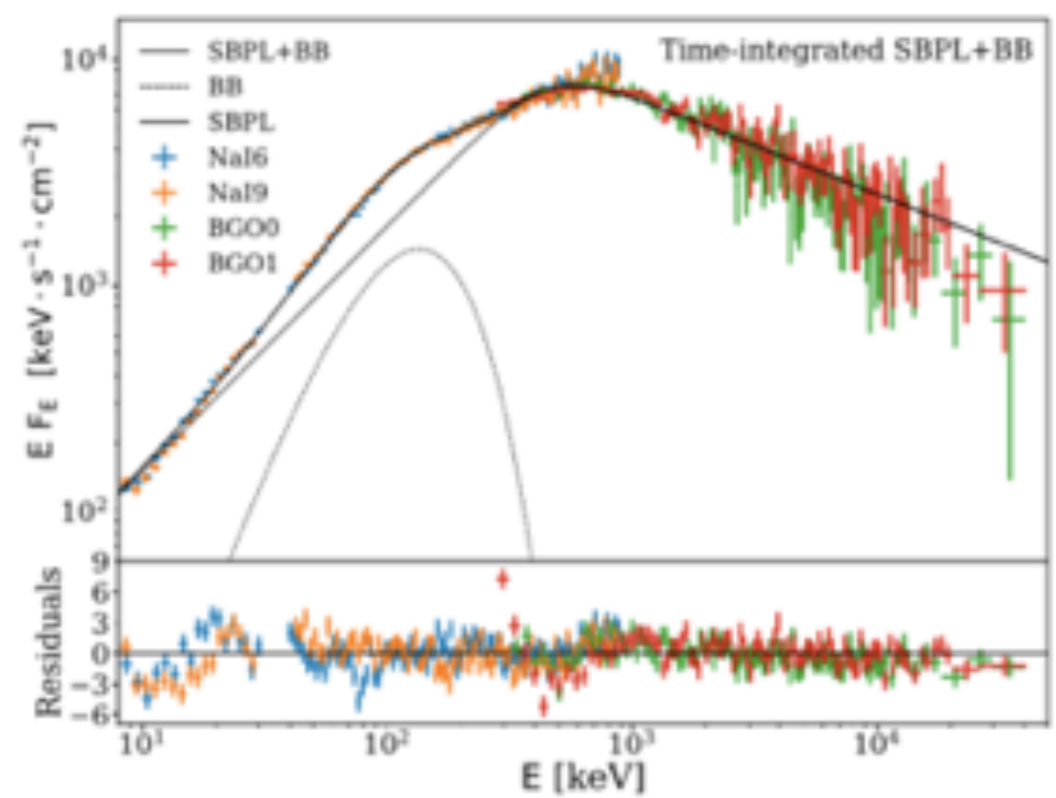
Oganesyan et al. 2017,2018

Recent news and hopes for the future

synchrotron emission in marginally fast cooling regime in Fermi/GBM GRBs (8 keV - 40 MeV)

Ravasio et al. 2018,2019

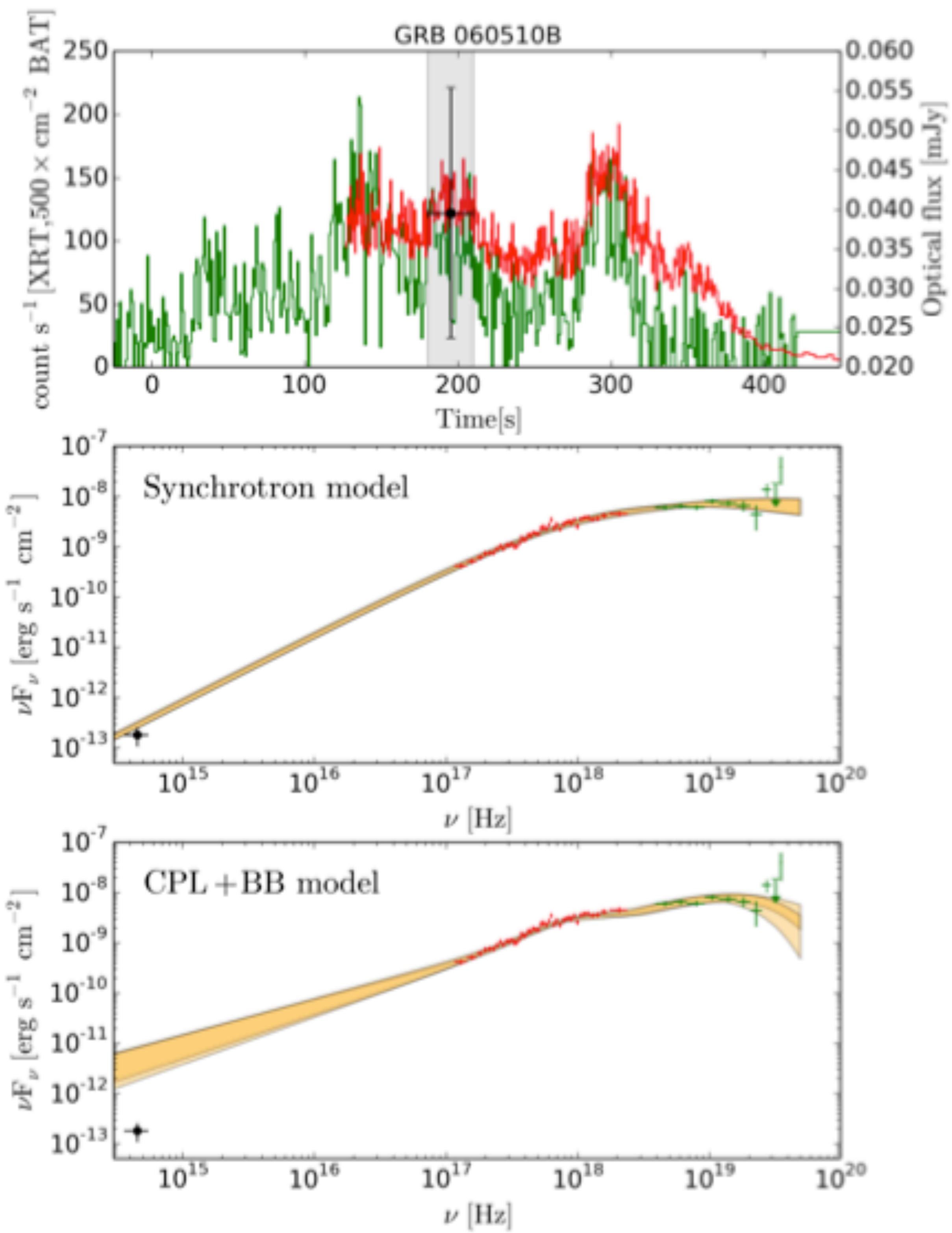




However, two-component (thermal + nonthermal) can also explain the very same feature

Ryde & Pe’er 2009; Guiriec et al. 2011,2013; Burgess et al. 2014 …..

Recent news and hopes for the future



Oganesyan et al. 2019

Low energy extension is the crucial point!

but only 21 GRBs

systematic DETECTION of GRBs in soft X-rays and optical range in the prompt phase is necessary!

eXTP WFM : 2-50 keV

Polarisation

POLARISATION during the prompt - NOT ONLY SPECTRAL SHAPES

Radiative process/es responsible for the prompt emission

synchrotron photospheric emission

Magnetic field structure

ordered vs random or even in-homogenous within gyro-radius

Viewing angle and Jet structure

!!!No well convincing measurements of polarisation during the prompt phase!!!

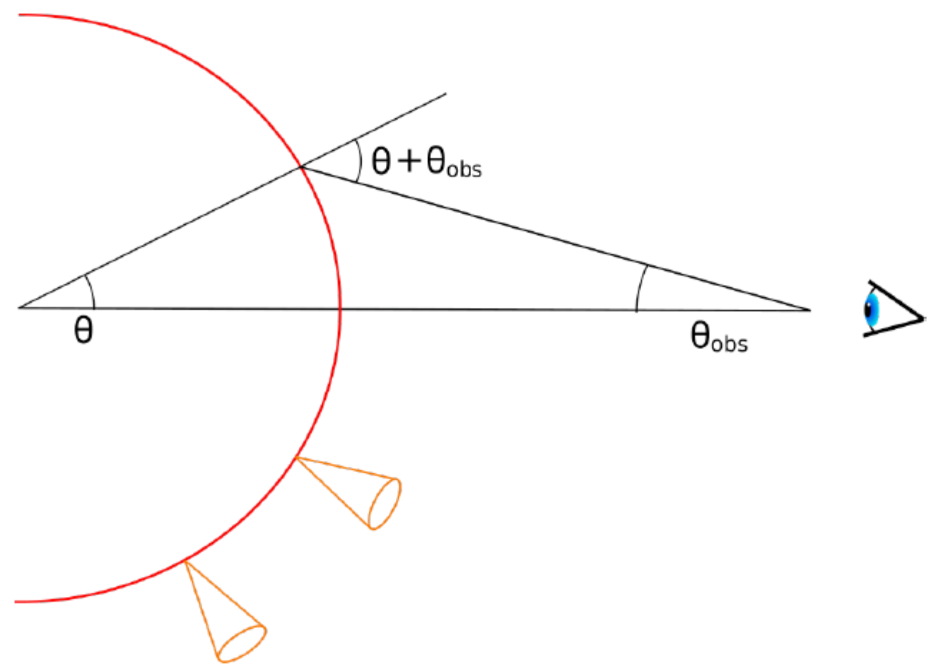
some reports by RHESSI, INTEGRAL-SPI, -IBIS, IKAROS-GAP, Astro-Sat, COSI, POLAR

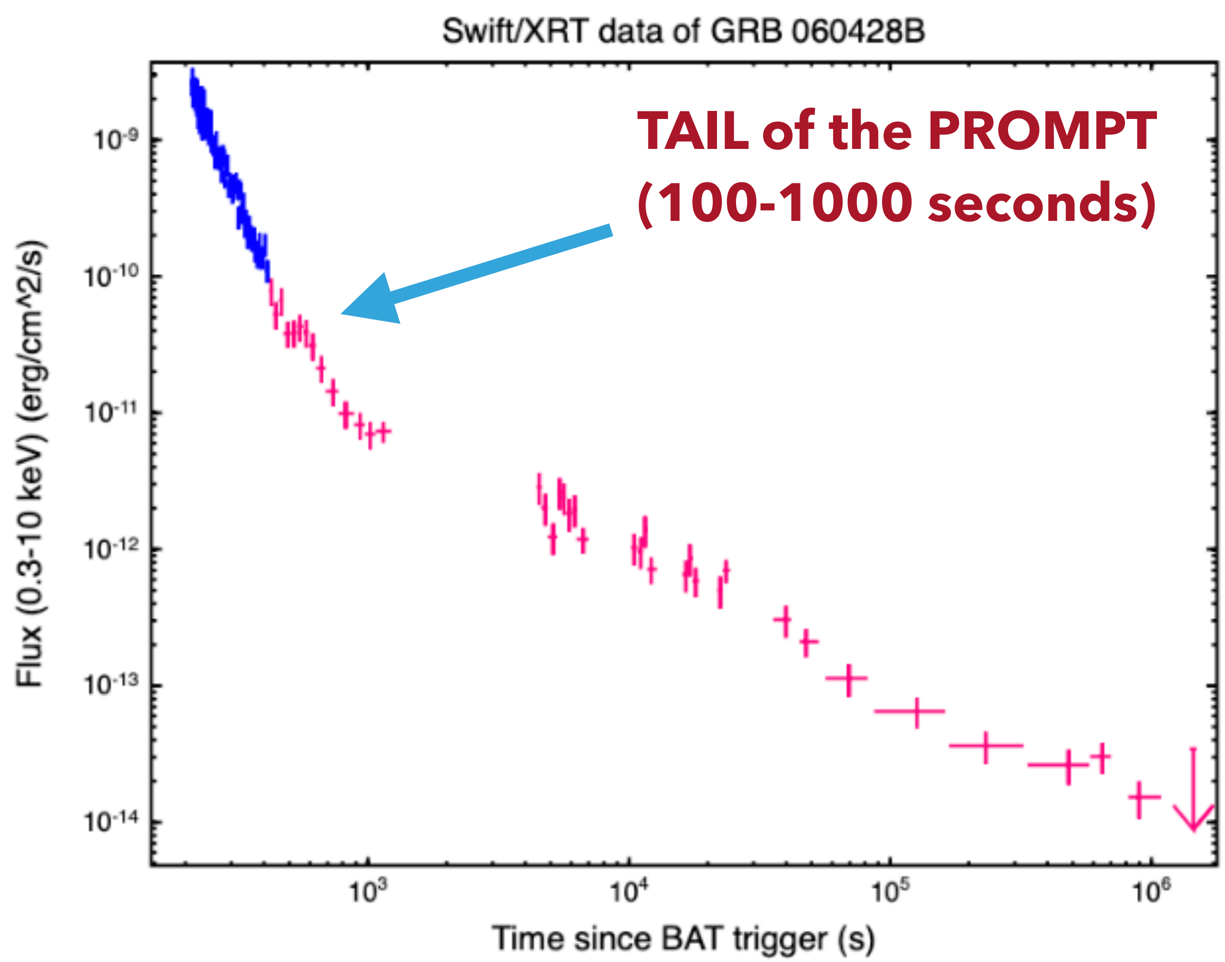
Gill, Granot, & Kumar (2019)

Polarisation: hard to resolve a single ~1s pulse

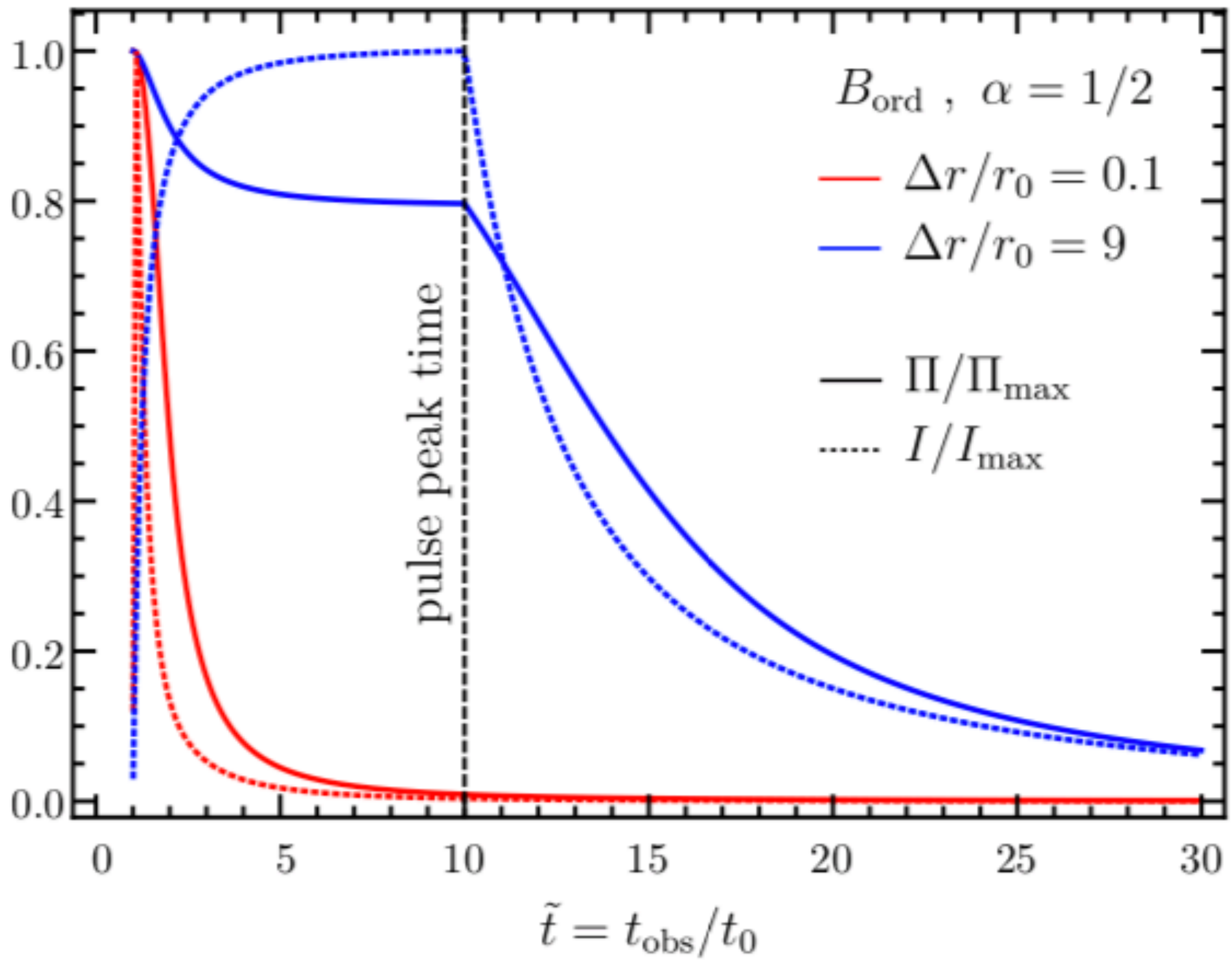
BUT

The tail emission of a GRB pulse is longer in X-rays! (well-delayed from GW for off-axis)





Polarisation of the tail emission



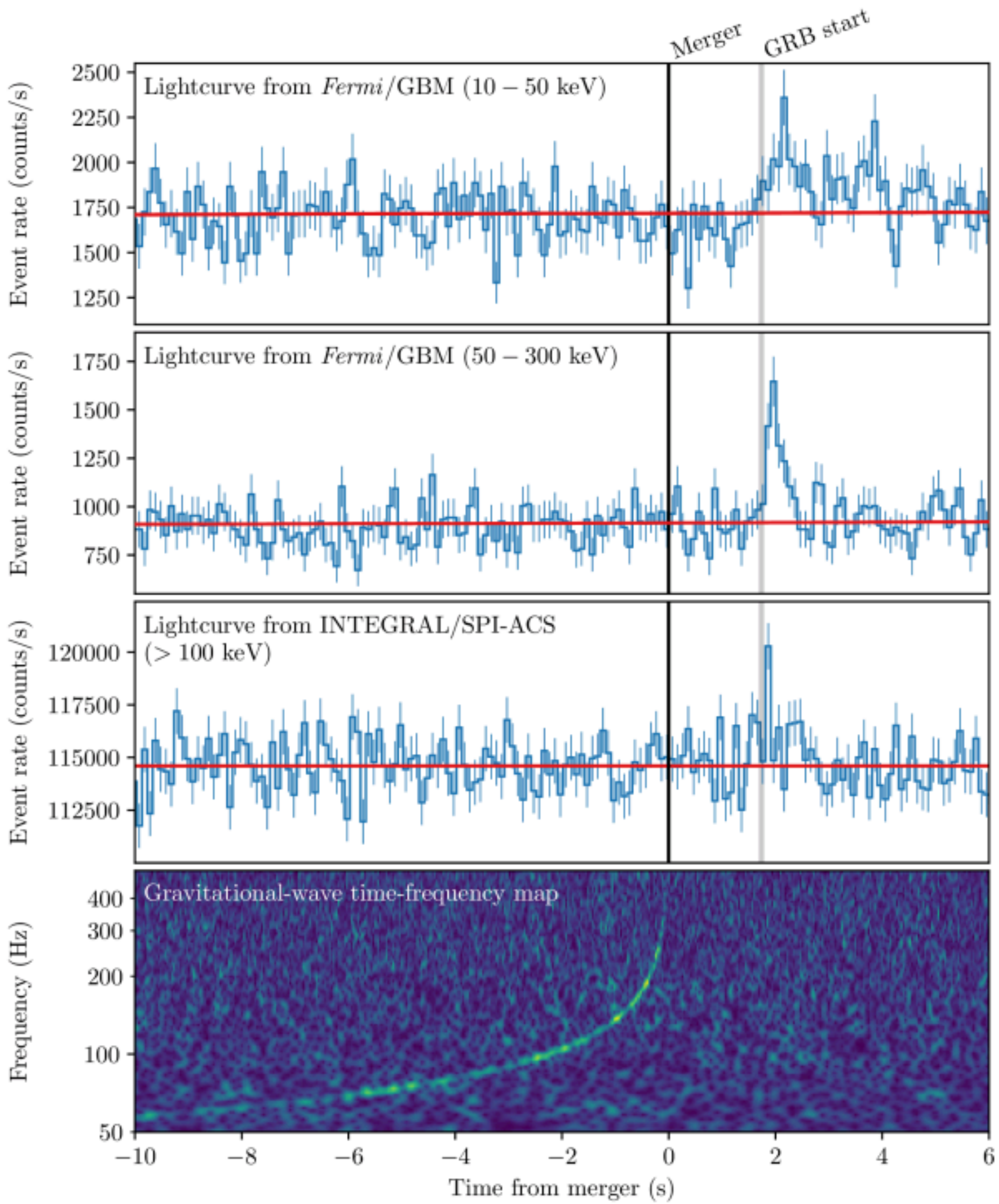
Gill, Granot, & Kumar (2019)

Structured jets-prompt emission

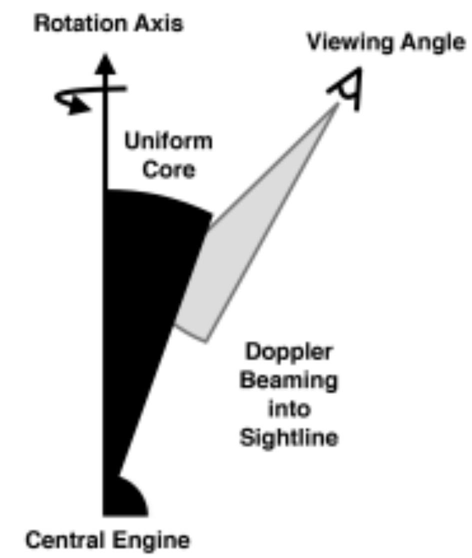
Lipunov et al. 2001; Dai & Gou 2001; Rossi et al. 2002; Zhang & Meszaros 2002

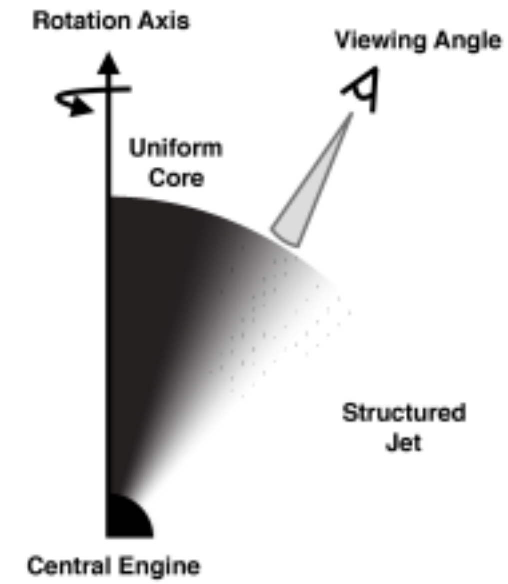
What is it?

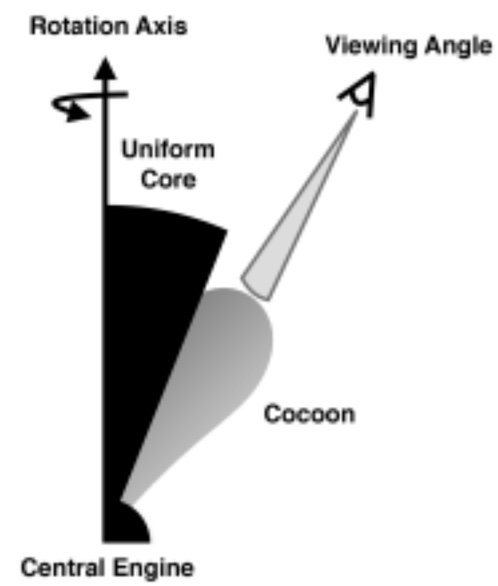
GRB 170817/GW 170817



Abbott et al. 2017





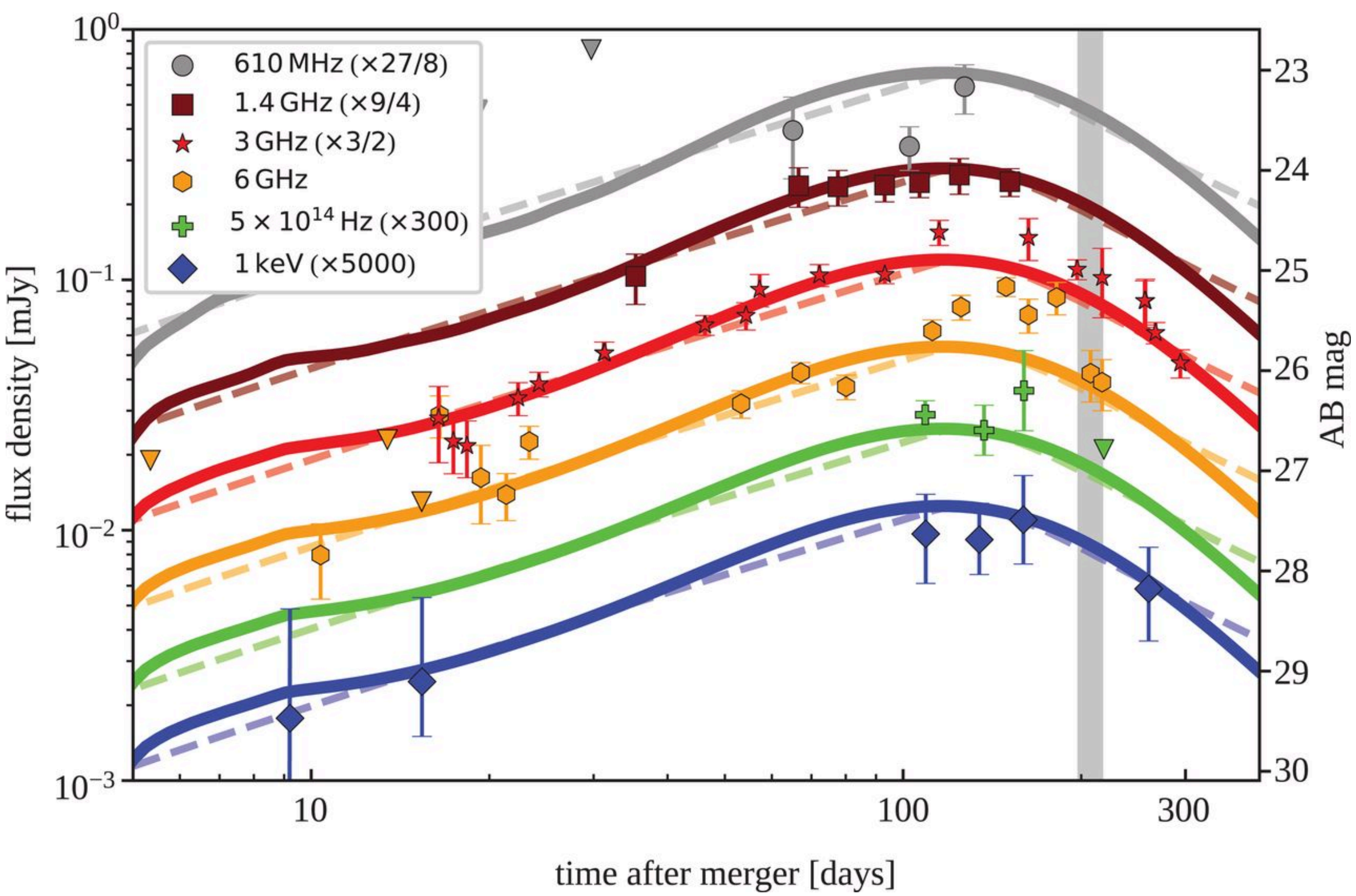


Kasliwal et al. 2017
Ioka&Nakamura 2018
Salafia et al. 2018
Lazzati 2018
Bromberg et al. 2018
Matsumoto et al 2018
....

Structured jets-afterglow-confirmed

GRB 170817/GW 170817

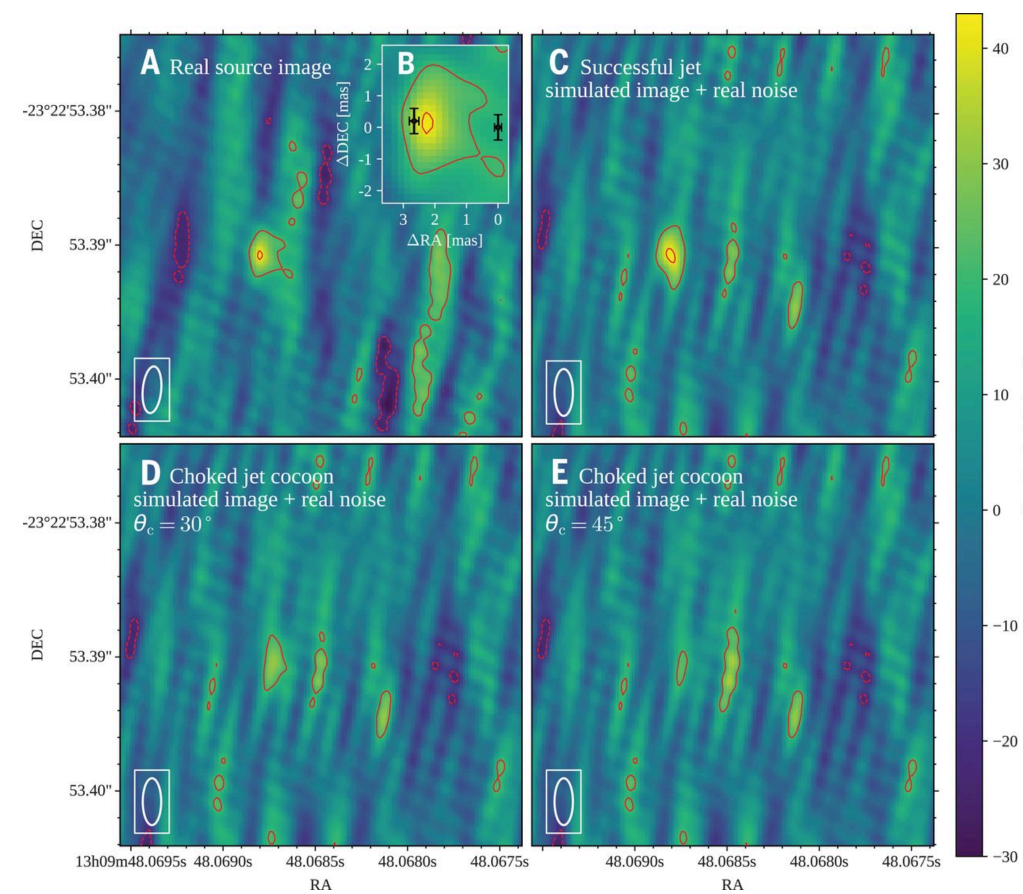
multi-wavelength LCs of the afterglow



D’Avanzo et al. 2018
Dobie et al. 2018
Alexander et al. 2018
Troja et al. 2018
…..

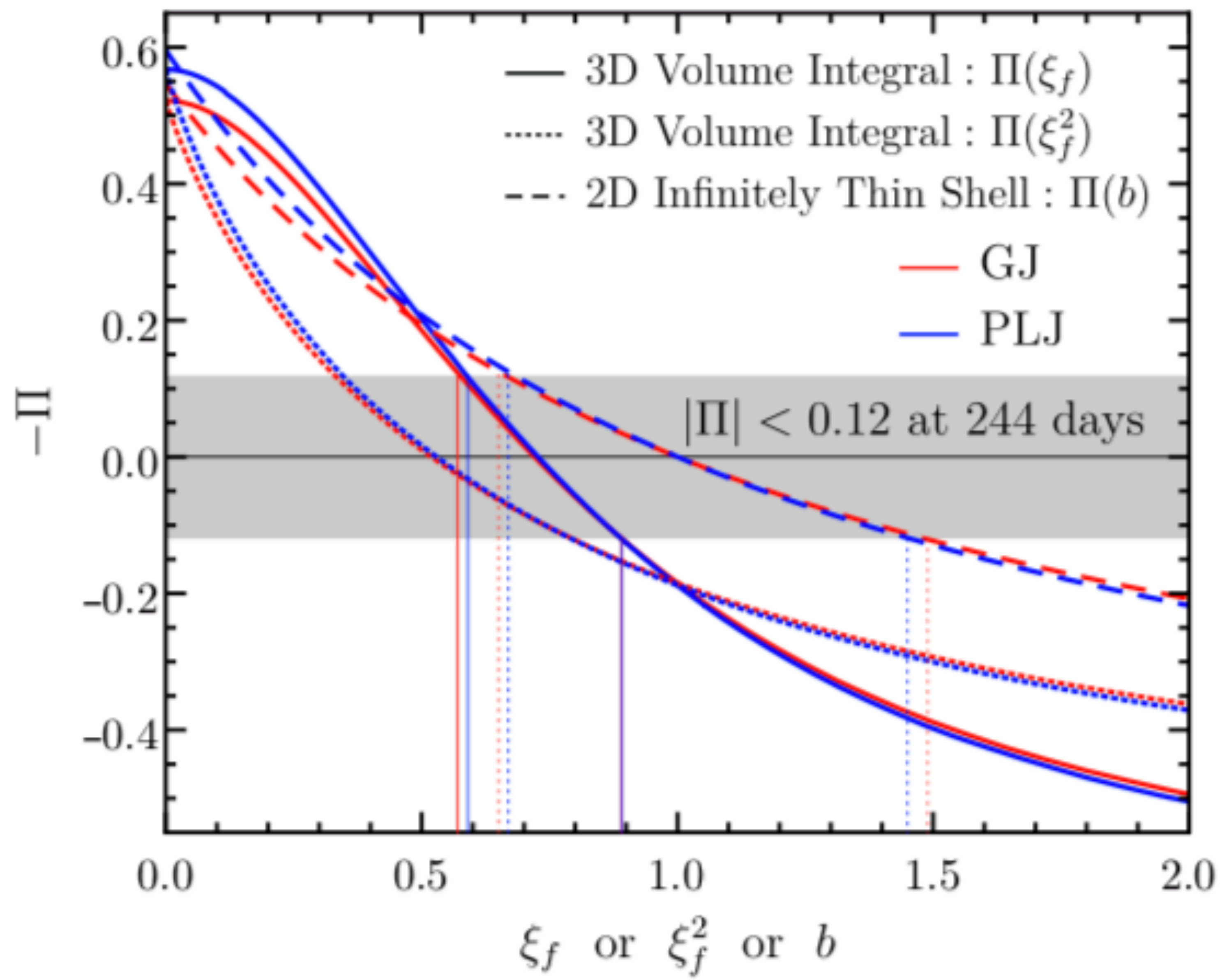
Ghirlanda et al. 2019

apparent size is 2.5 milli–arc seconds at > 200 days



see also **Mooley et al. 2018**

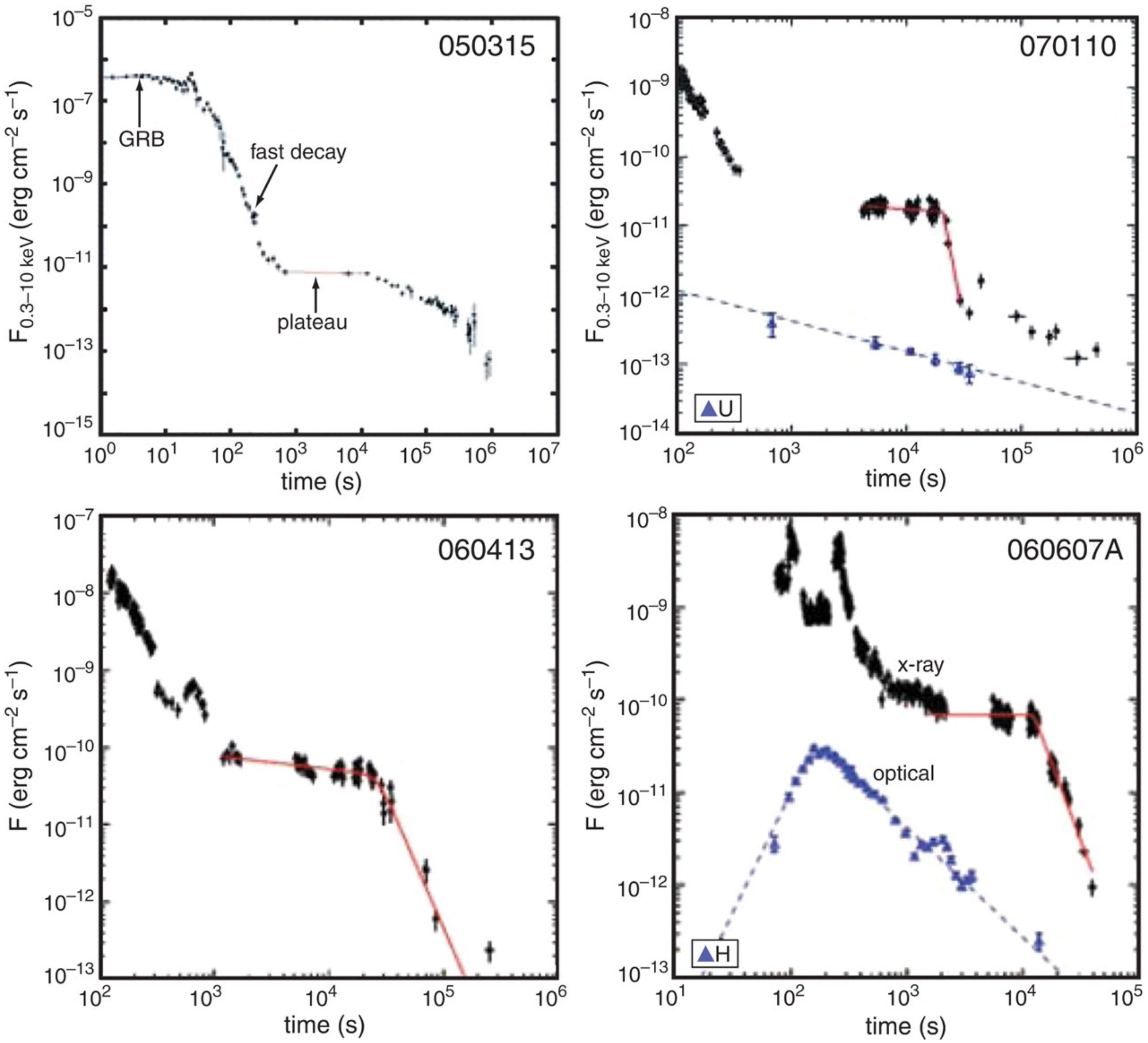
The polarisation limits in GRB170817/GW170817



A. Corsi et al. 2018

R. Gill & J. Granot 2019: **"the field just behind the shock must have a finite, albeit mildly sub-dominant, component parallel to the shock normal"**

X-ray afterglow emission: unknown nature

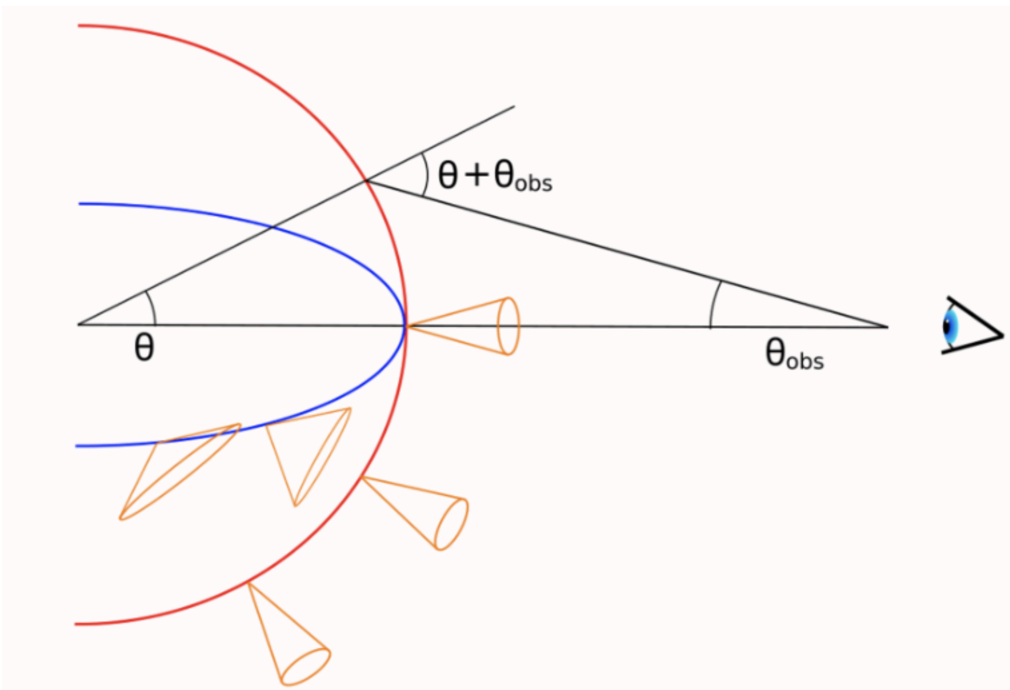


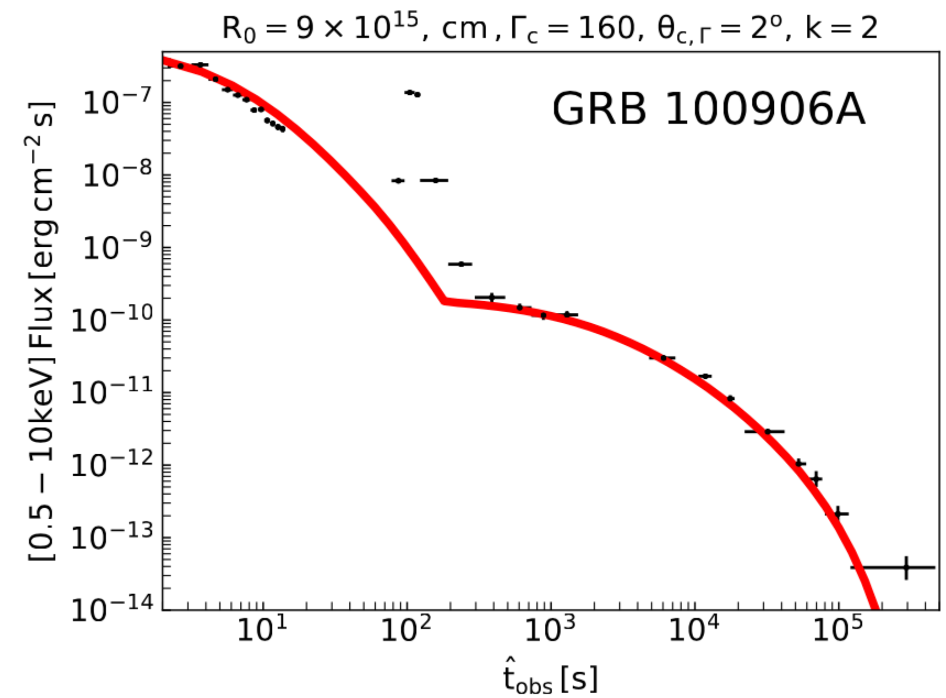
- plateau phase is observed at least in 1/3 of GRBs
- energy injection is the most discussed model
  (has chromaticity problem)
  Rees & Meszaros 1998
  Zhang et al. 2006
  Granot & Kumar 2006
  Nousek et al.2006
  would require a stable NS
  Dai & Lu 1998
  Zhang& Meszaros 2001
  Yu et al. 2010
  Metzger et al. 2011
  Dall'Osso et al. 2011
- recently geometric models are proposed
  Oganesyan et al. 2019; Beniamini et al. 2019

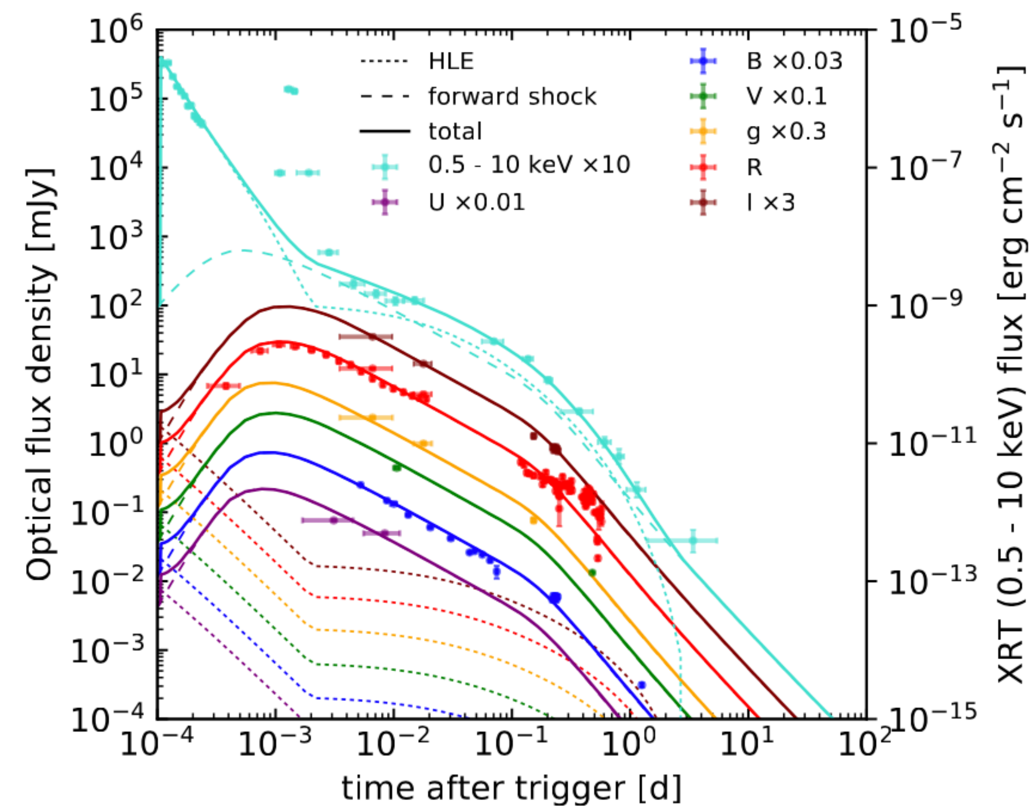
taken from Kumar et al. 2008

Geometric models for X-rays: from prompt

on-axis or inside of the core of the jet





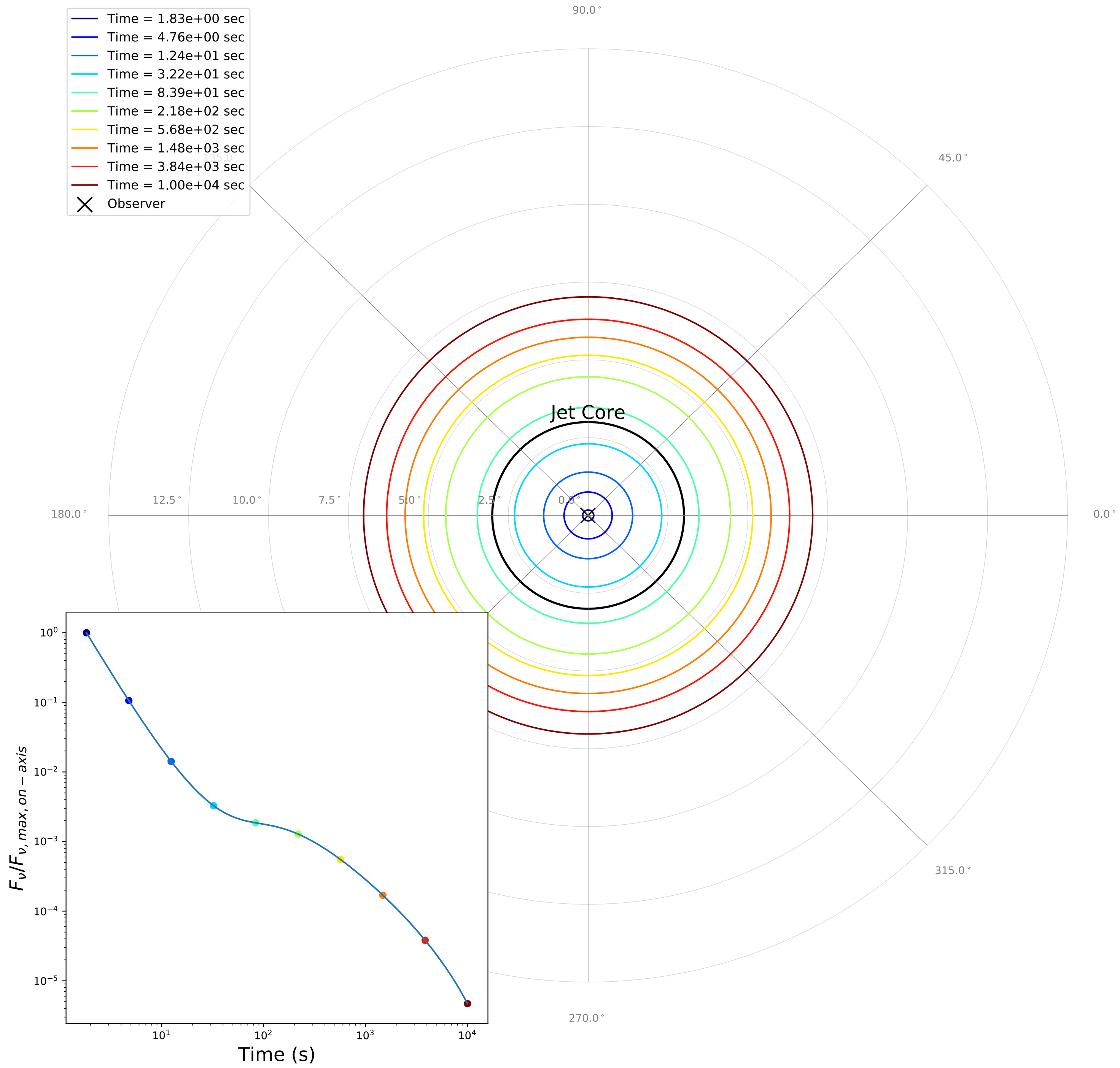


If long lasting (up to 1E6 s) **X-ray emission** is the tail of prompt, we again would benefit from **the polarisation measurements**

Oganesyan et al. 2019

Geometric models for X-rays: from prompt

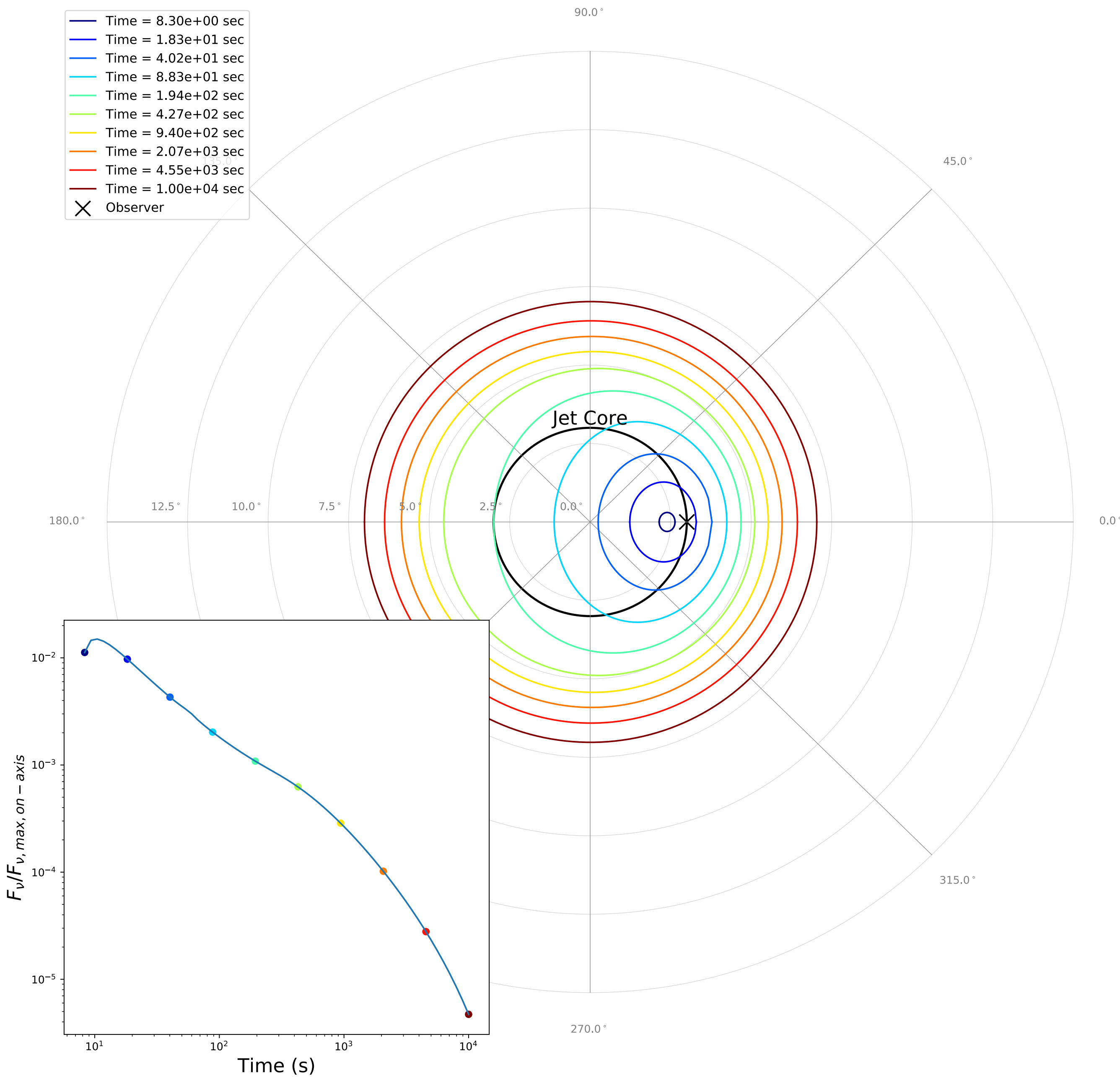
On-axis observer

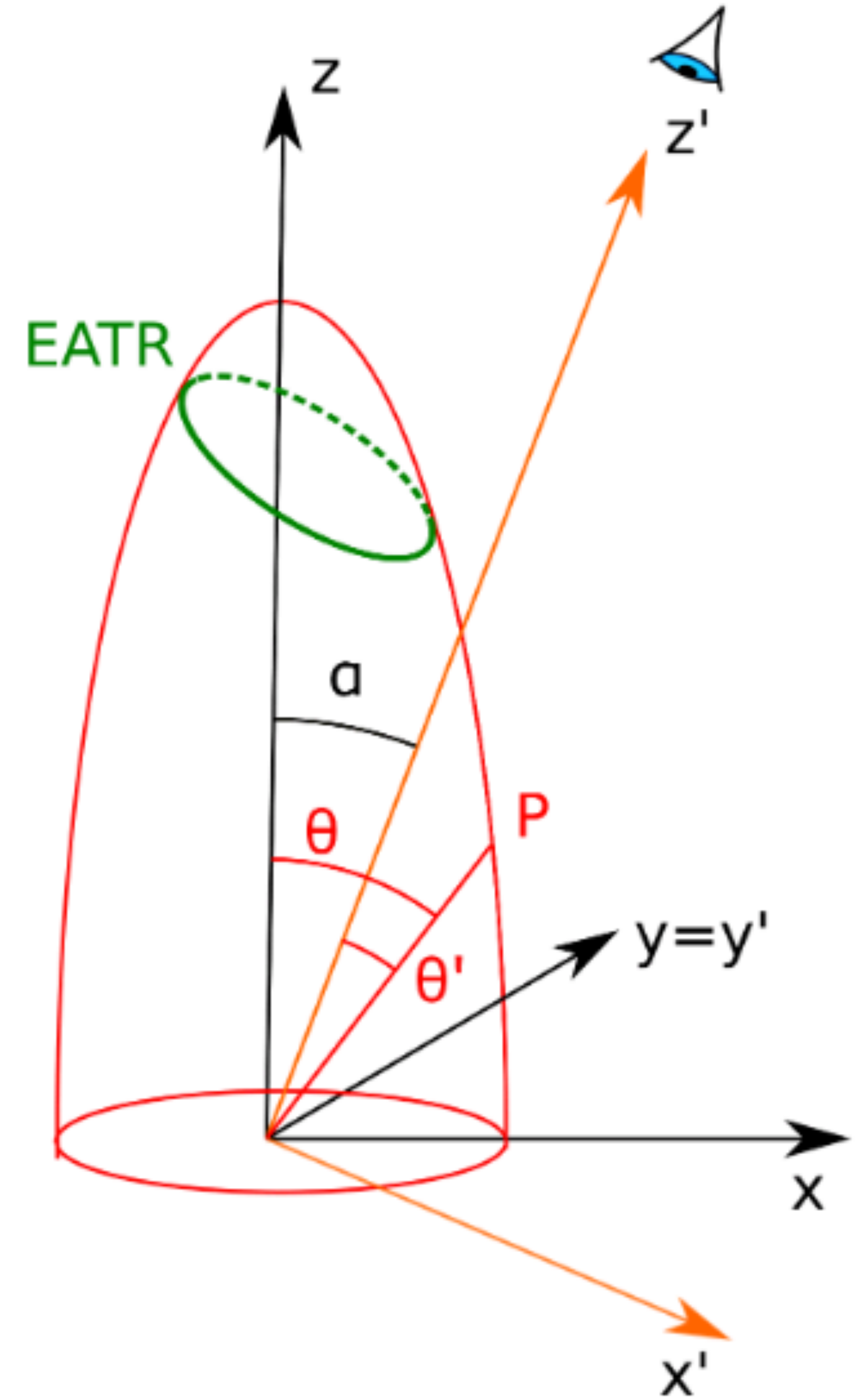


Ascenzi et al. 2019 (in prep)

Geometric models for X-rays: from prompt

At edge observer



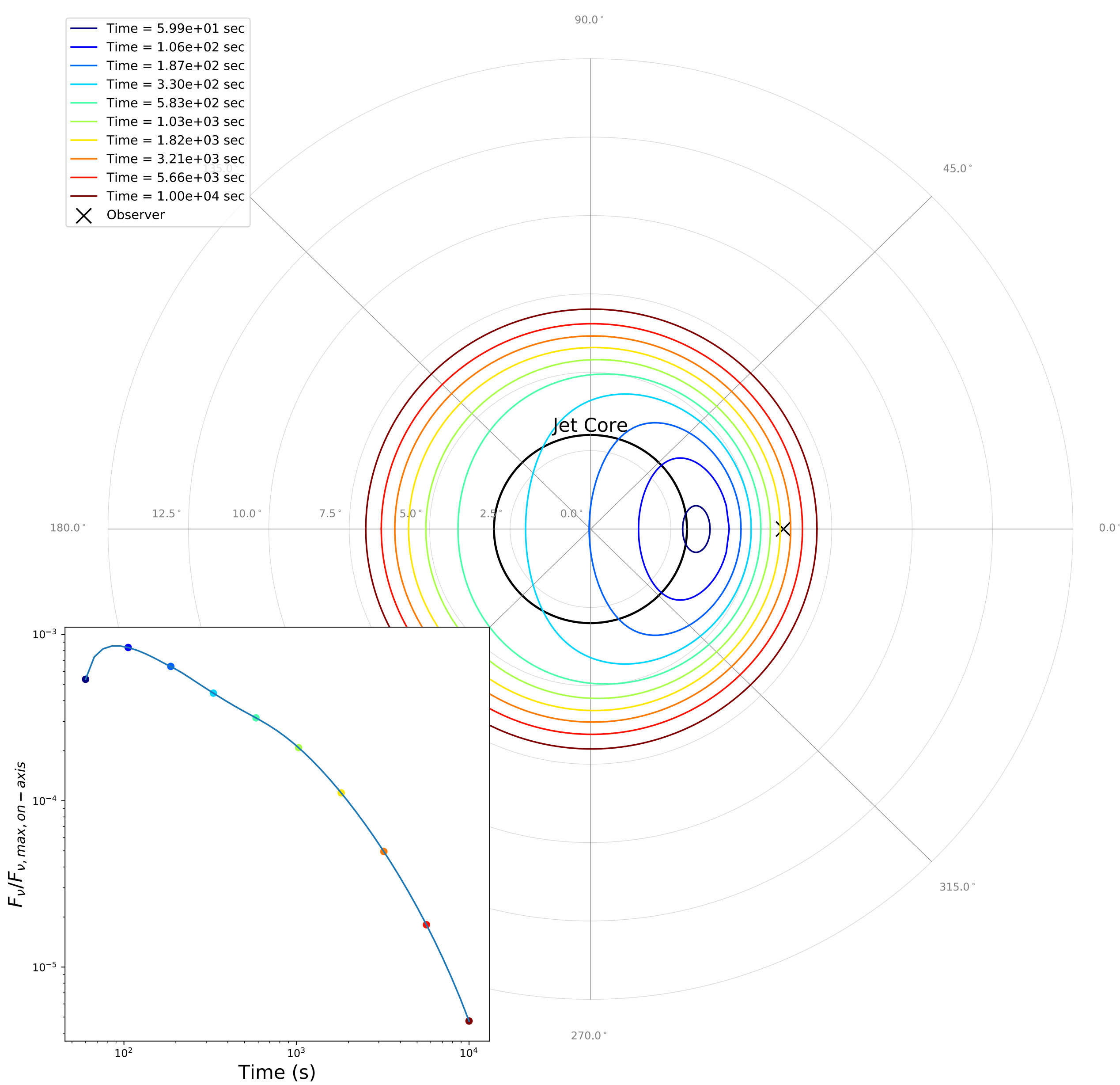


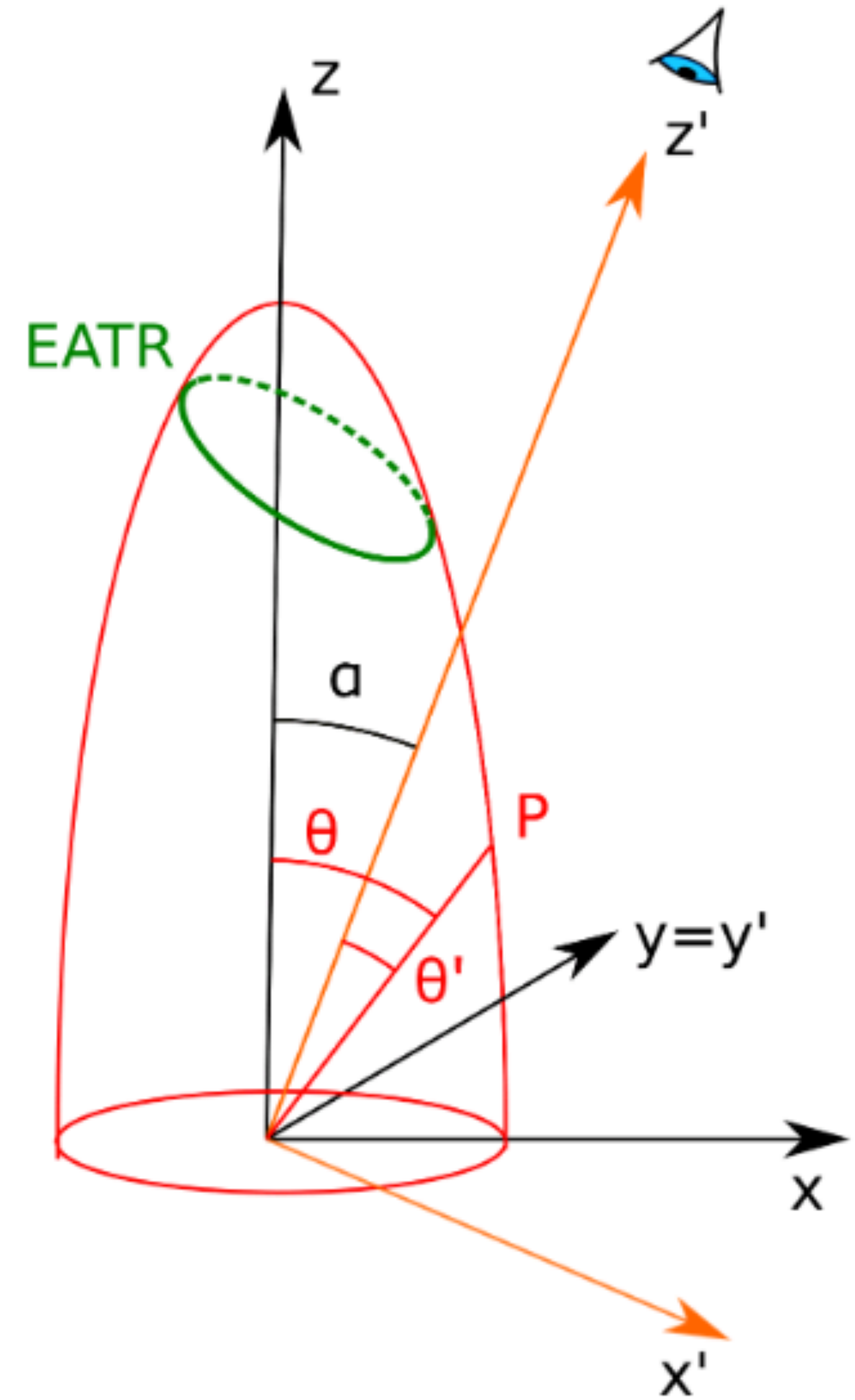
1 order fainter, **10 s delayed** with respect to **the merger/collapse**

Ascenzi et al. 2019 (in prep)

Geometric models for X-rays: from prompt

Off-axis observer

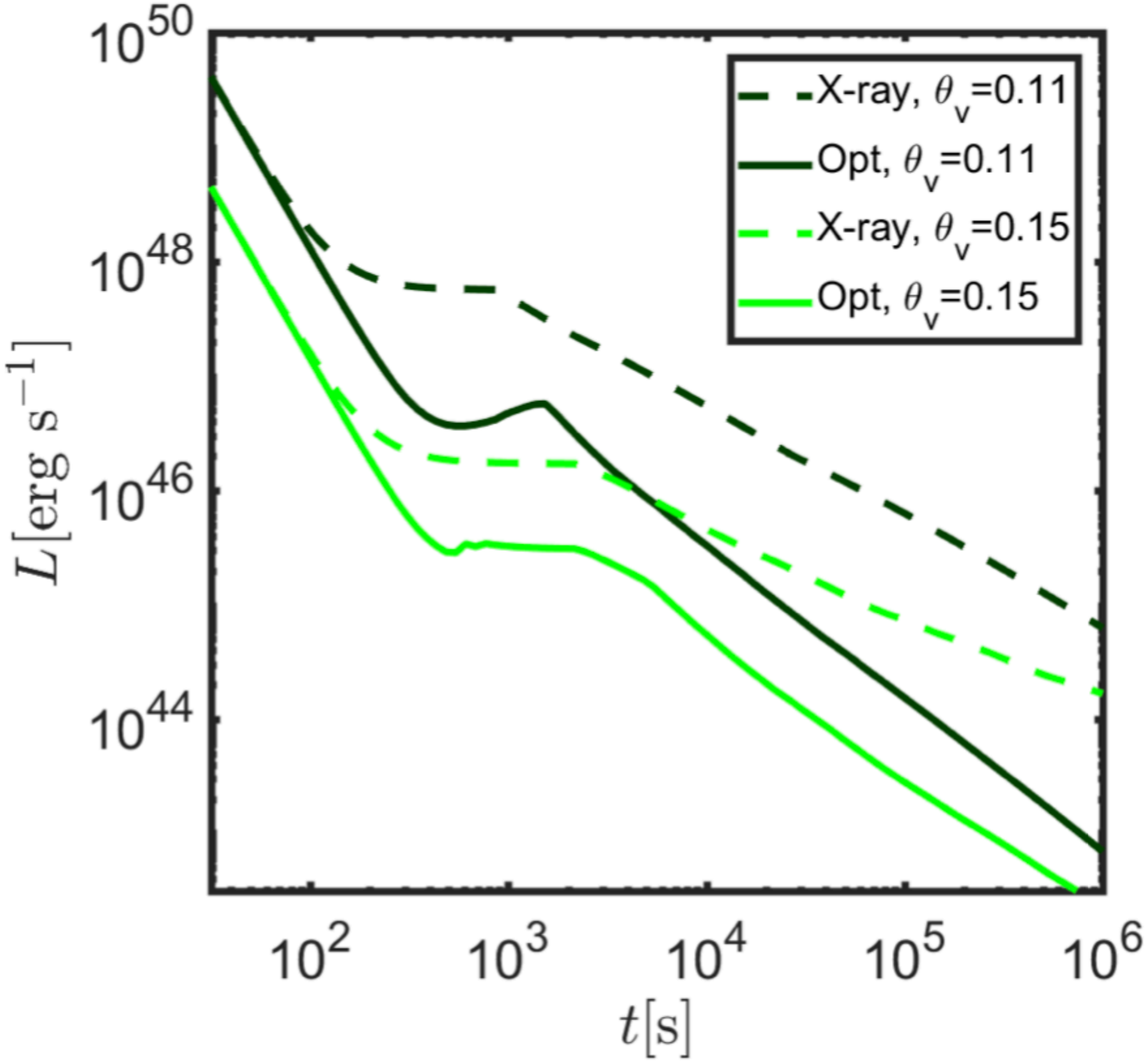




3 orders fainter, **100 s delayed** with respect to **the merger/collapse**

Ascenzi et al. 2019 (in prep)

Geometric models for X-rays: from the afterglow



Beniamini et al. 2019

- PLATEAU appears for a slightly off-axis observer only (in contrary to the prompt emission)
- PLATEAU is ~ achromatic
- very fast decays after plateau are not explained

We have a family of solutions from PROMPT and AFTERGLOW on and off axis highly predicative chromatic/achromatic LCs

We need Wide Field X-ray (and optical LSST?) detectors to identify the nature of the GRB afterglows

Key point of the multi-messenger detections

Skymap of GWs

FOV
gamma-ray instruments

BUT we need to look inside of the JET
(compactness problem, see e.g. Matsumoto et al. 2019)

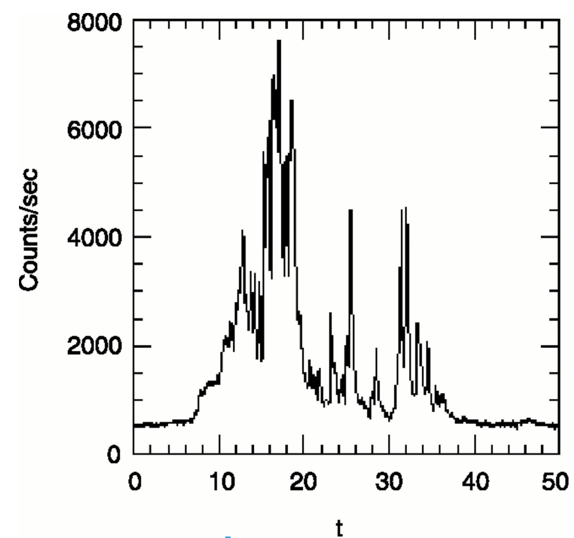
FOV
optical instruments

HOW TO IMPROVE?

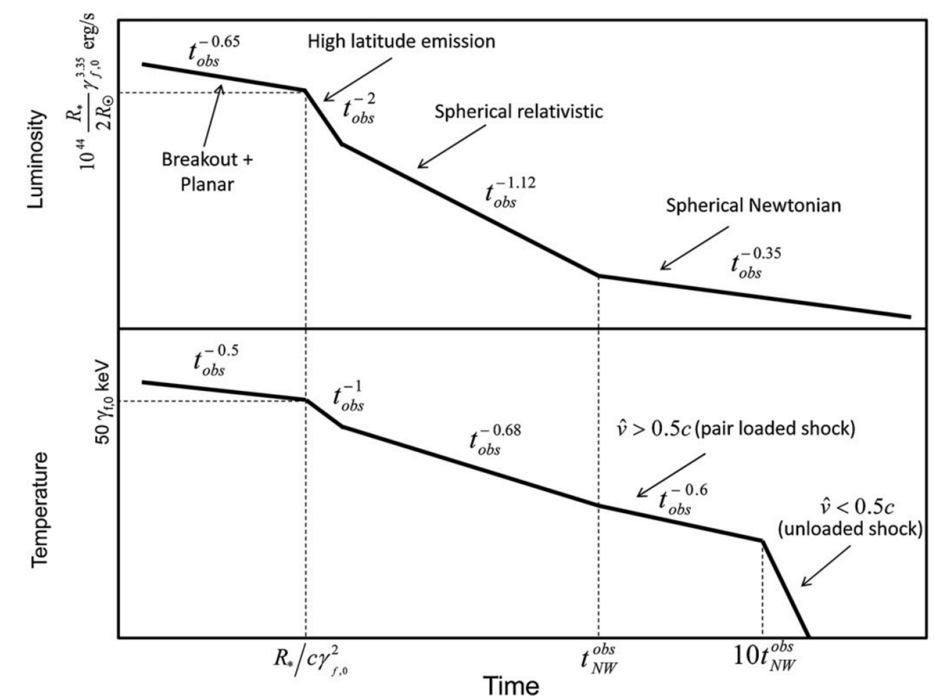
Key point of the multi-messenger detections

in soft X-rays

Gamma-rays (prompt emission)



in soft X-rays



Off-axis afterglow
(forward shock)

Off-axis prompt emission

The tail of the prompt emission

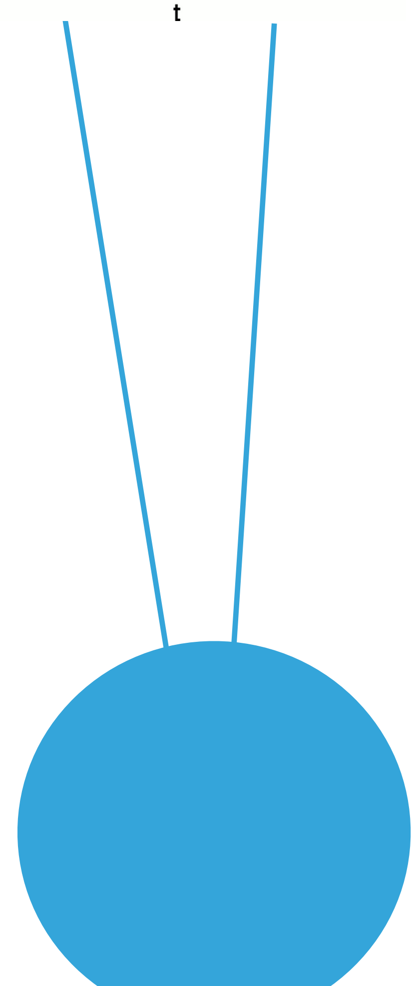
Polarisation is the key point
for the magnetic field structure

many papers by **J. Granot** and collaborators

Long lasting echo in X-rays
Nakar&Sari 2012

Shock break out (pulse of X-rays or gamma-rays)

many papers by **E. Nakar** and collaborators



Summary

I - Prompt emission:

- low energy extension of the spectra of GRBs down to 2 keV (WFM of eXTP)
(the key point to understand the rad. processes responsible for the GRB)

- off-axis prompt emission and its tails in soft X-rays
  as a **counterpart of GWs**

- polarisation of the prompt accessed by its long-lasting tail
  (key point for the magnetic field structure)

II - Afterglow

- Off-axis X-ray afterglow as a **counterpart of GWs**
  + probe of the jet structure

- Combining the merger remnant info from **GW observations and the X-ray plateau**
  better constraints on the nature of the merger remnant and EOS

- eXTP can increase the numbers of **joint GW/X-ray off-axis detections**

- Polarisation of X-ray afterglow as a key point for the acceleration physics

III - Shock break out: a short flash and its echo
important for making targeted search of **GWs from SN**
(GW signal from explosion or new born magnetar)