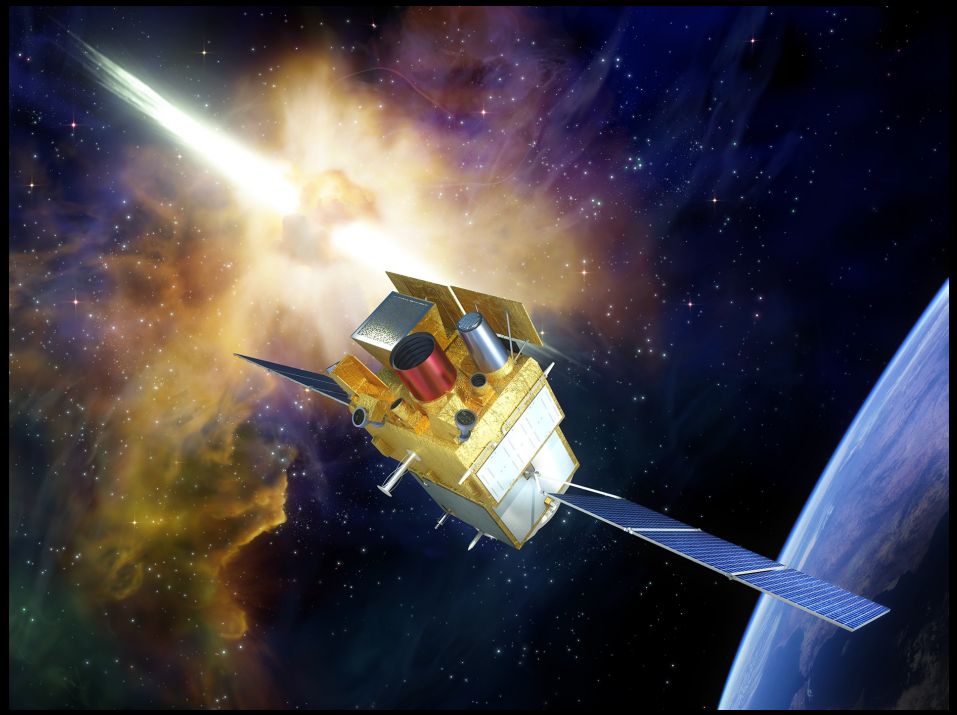
Institut d'Astrophysique de Paris

GRB MODELLISATION & PERSPECTIVES WITH THE SVOM MISSION

Frédéric Daigne
(Institut d'Astrophysique de Paris, Sorbonne Université)



ASTROVIBE – Astrophysical Studies of Time delays frOm Violation of Lorentz Invariance and Blazar Emission – LPNHE, Paris – 17 July, 2024

Institut d'Astrophysique de Paris

GRB MODELLISATION & PERSPECTIVES WITH THE SVOM MISSION

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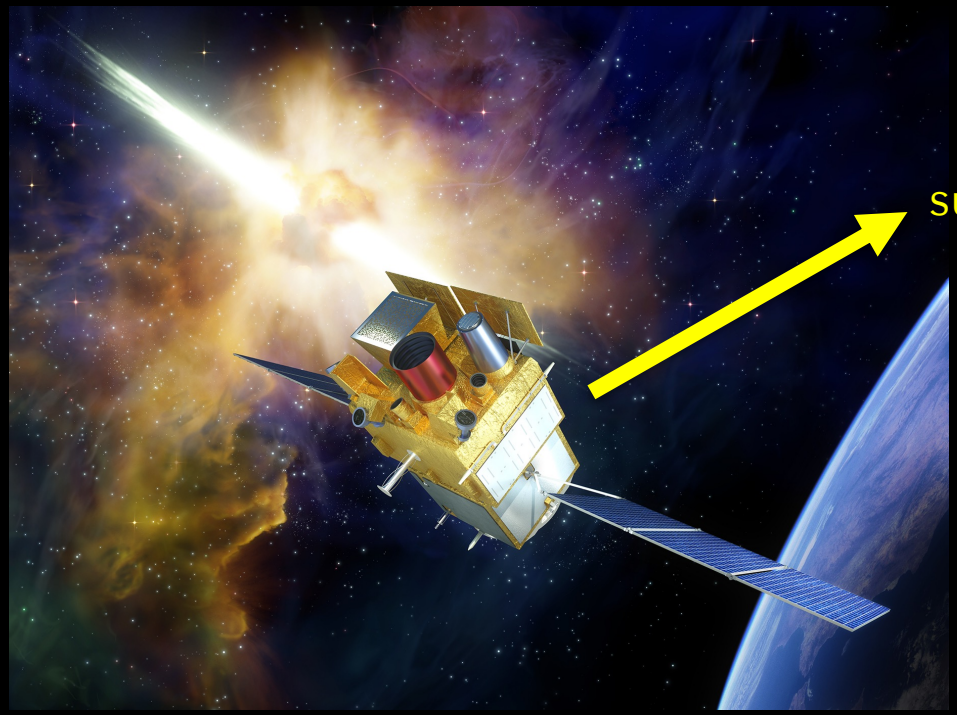


SVOM was successfully launched on June 22!

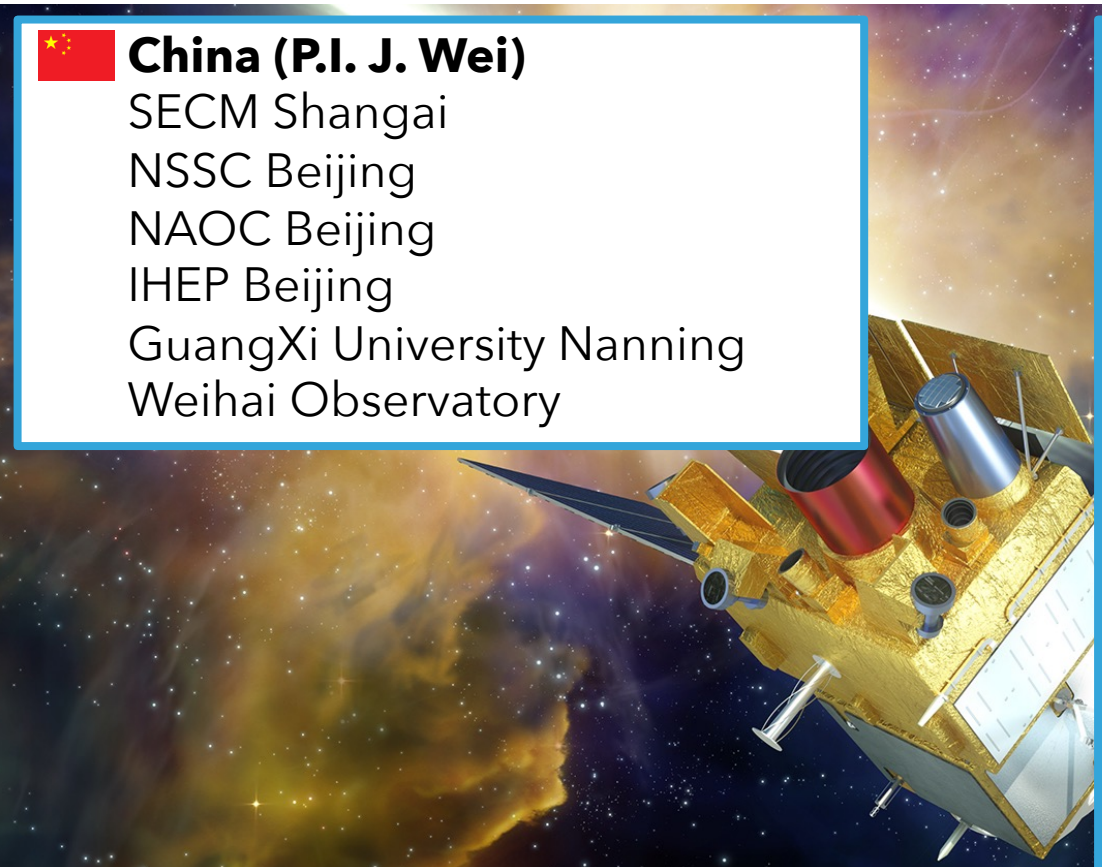
Institut d'Astrophysique de Paris

GRB MODELLISATION & PERSPECTIVES WITH THE SVOM MISSION

Frédéric Daigne

1. SVOM: what to expect within a few months
2. GRB Prompt emission: recent results, open issues and perspectives with SVOM and other instruments

THE SVOM COLLABORATION



China (P.I. J. Wei)
SECM Shangai
NSSC Beijing
NAOC Beijing
IHEP Beijing
GuangXi University Nanning
Weihai Observatory

France (PI B. Cordier)
CNES Toulouse
APC Paris
CEA Saclay
CPPM Marseille
GEPI Meudon
IAP Paris
IJCLab Orsay
IRAP Toulouse
LAM Marseille
LUPM Montpellier
ObAS Strasbourg
OCA Nice

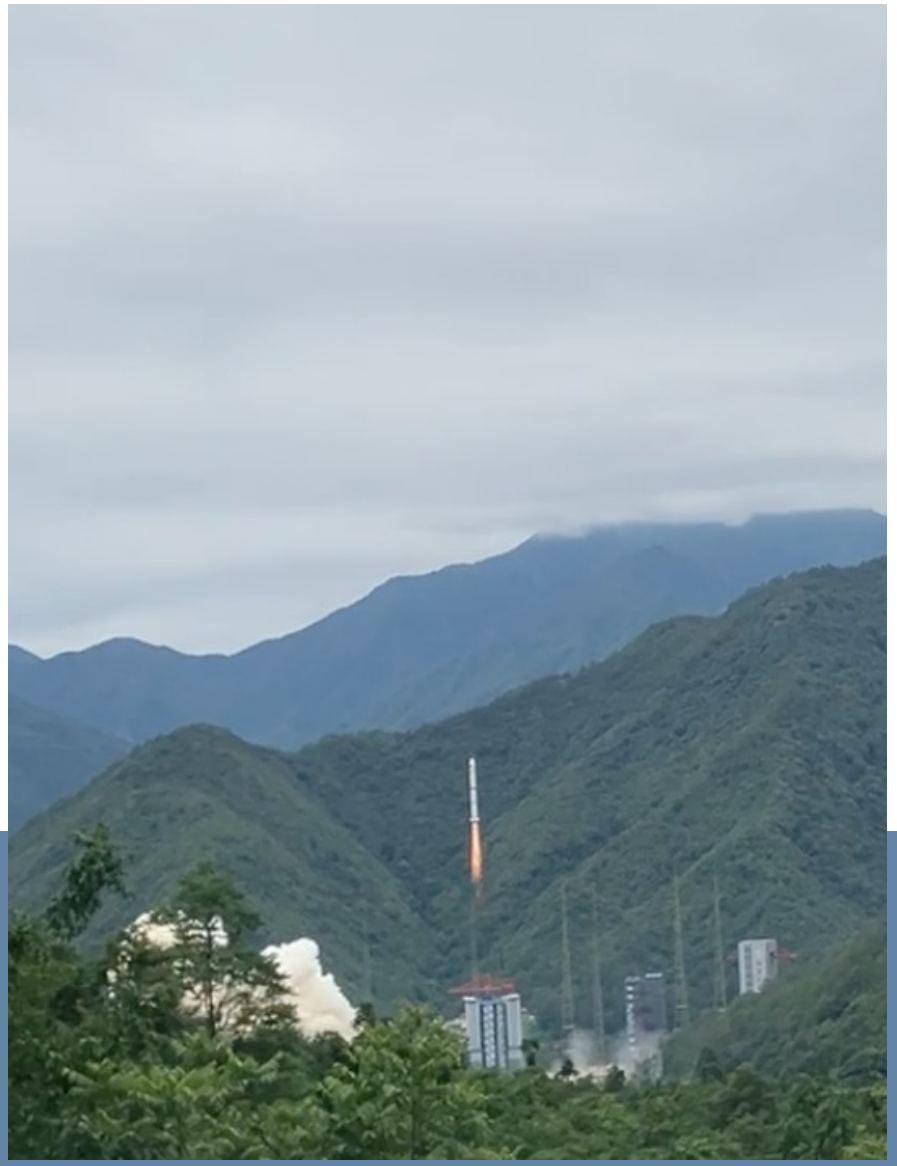
Mexico, UNAM (Colibri)

UK, University of Leceister (MXT)

Germany, MPE Garching & IAAT Tübingen (MXT)

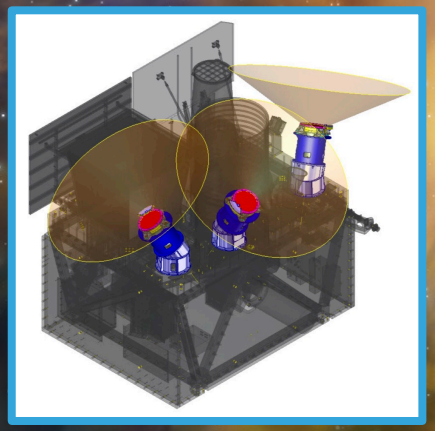
SVOM AT A GLANCE

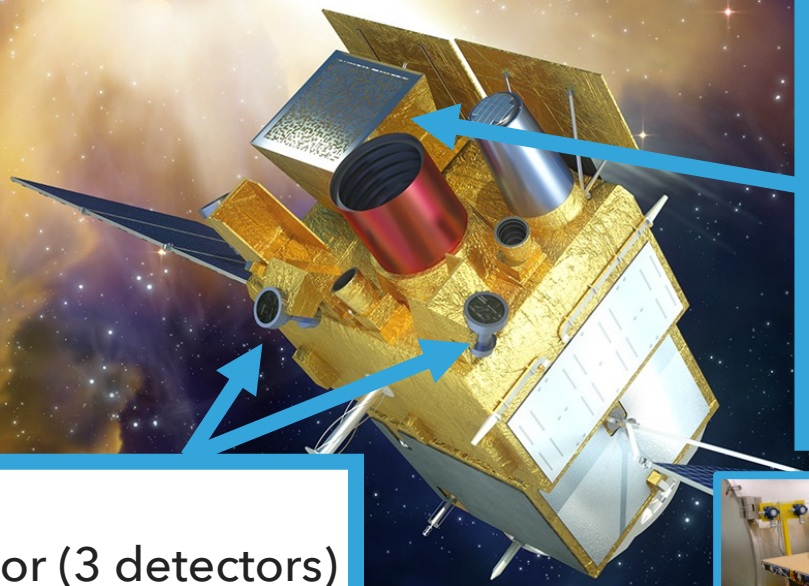
- **SVOM: “Space-based multi-band astronomical Variable Objects Monitor”,**
  a Chinese-French mission dedicated to Gamma-Ray Bursts, and HE/MM astronomy.
- **Sucessfully launched on June 22, 2024! From Xichang, Sichuan**
- **Commissionning phase until at least mid September**
- **Then: 3+2 years (+possible extensions)**



SVOM AT A GLANCE

- **A spacecraft with four instruments + rapid slewing capabilities**
- **Two wide-field instruments (X/γ): ECLAIRs & GRM**





ECLAIRs

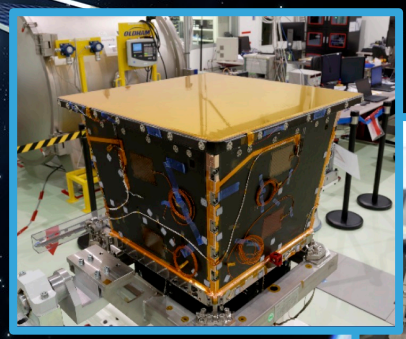
Coded telescope
4-150 keV
Loc. accuracy < 12 arcmin

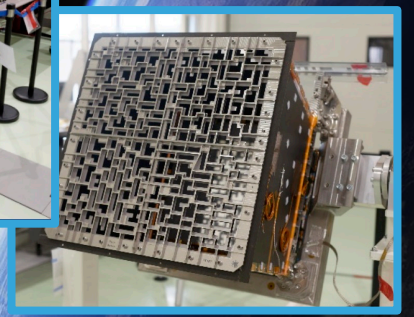
- 40% open fraction
- Detection area: 1000 cm^2
- 6400 CdTe pixels (4x4x1 mm^3)
- FoV 2 sr

GRM

Gamma-Ray Monitor (3 detectors)
15 keV-5 MeV
Loc. accuracy ~ 5-10 deg

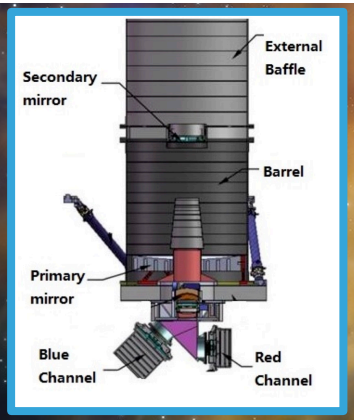
- NaI (16 cm Ø, 1.5 cm thick)
- Effective area 190 cm^2 at peak
- FoV 2.6 sr per detector

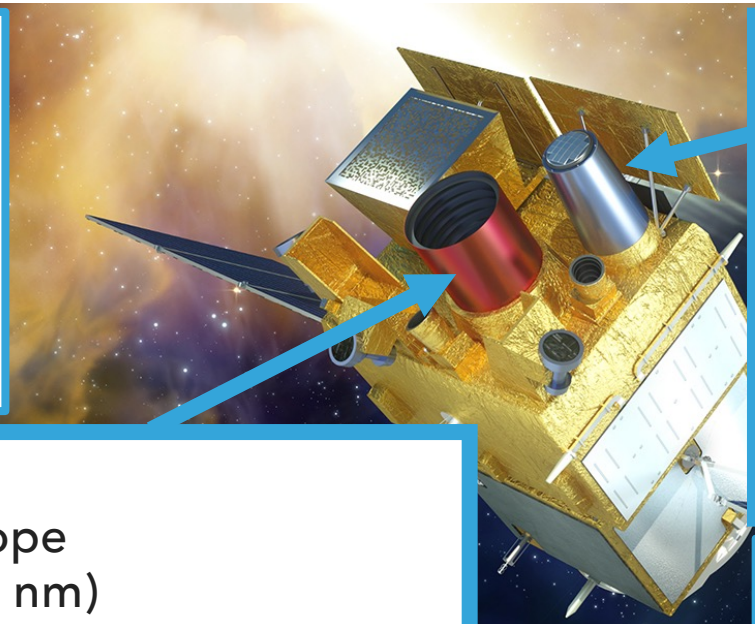




SVOM AT A GLANCE

- **A spacecraft with four instruments + rapid slewing capabilities**
- **Two wide-field instruments (X/γ): ECLAIRs & GRM**
- **Two narrow-field instruments (X/V): MXT & VT**





MXT

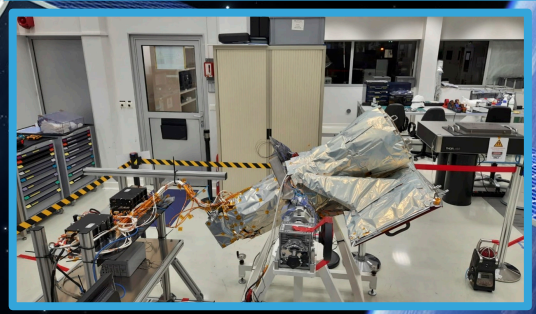
Micro-channel X-ray Telescope
0.2-10 keV
Loc. accuracy < 1 arcmin

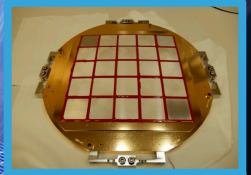
- Micro-pore optics (Photonis) with square 40 µm pores in a « Lobster Eye » config.
- pnCCD camera
- Effective area 27 cm^2 @ 1 keV
- FoV 57x57 $arcmin^2$

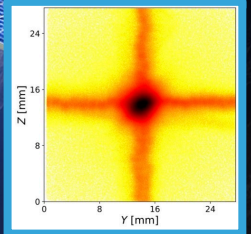
VT

Visible Telescope
Blue (400-650 nm)
& Red (650-1000 nm) channels
Loc. accuracy <1″

- Ritchey-Chretien telescope (40 cm ∅, f=9)
- m_V = 22.5 in 300 s
- FoV 26x26 $arcmin^2$

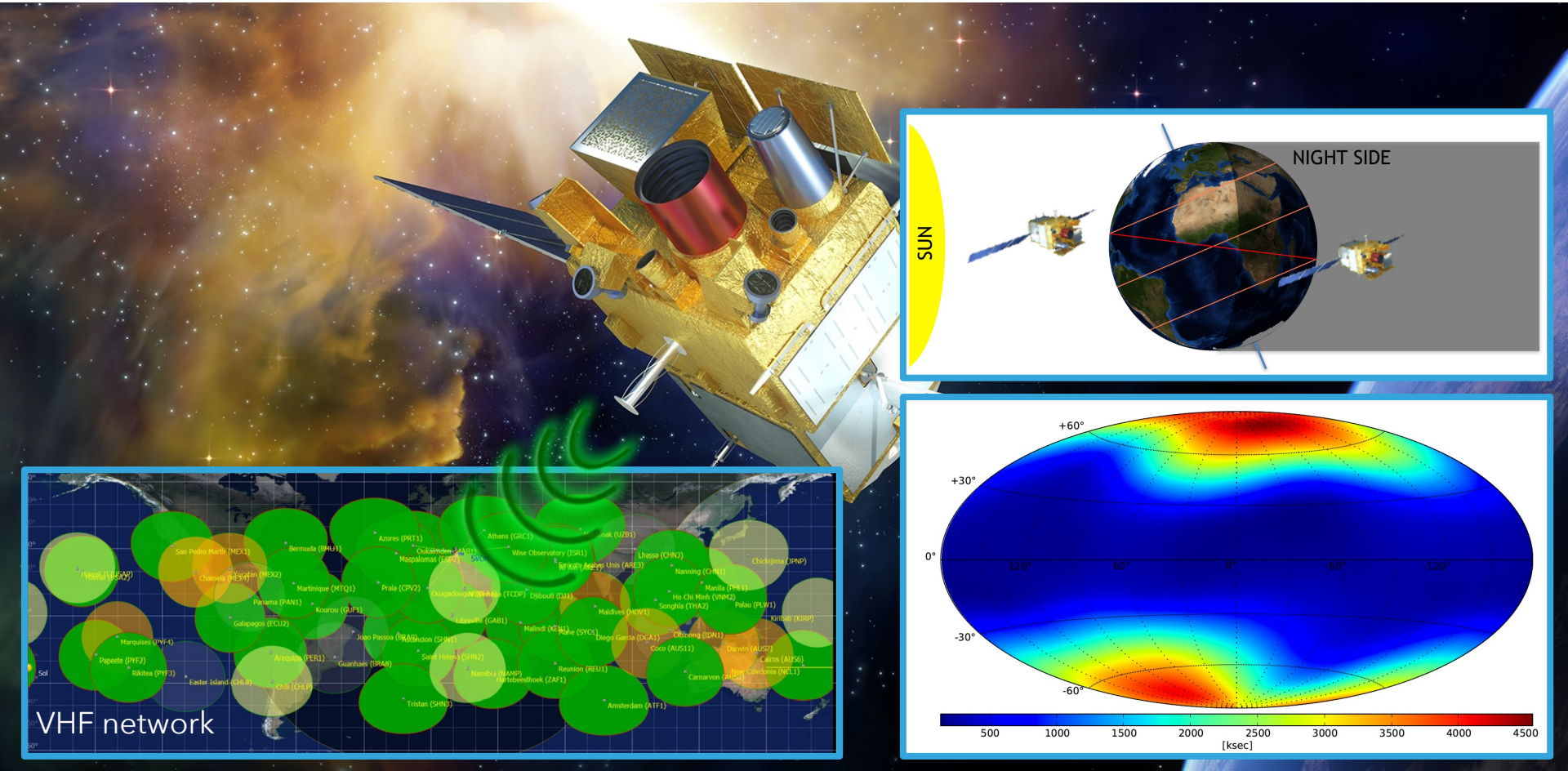






SVOM AT A GLANCE

- **A VHF network for near real-time alerts (GCN: notices & circulars)**
- **A nearly anti-solar pointing for optimizing the follow-up of GRBs and other transients**



SVOM AT A GLANCE

- **A ground segment for a rapid follow-up: GWAC, C-GFT, F-GFT**

GWAC

Ground-based Wide Angle Camera
Visible

- ~6000 deg^2
- V = 16 (10 s)

GFTs

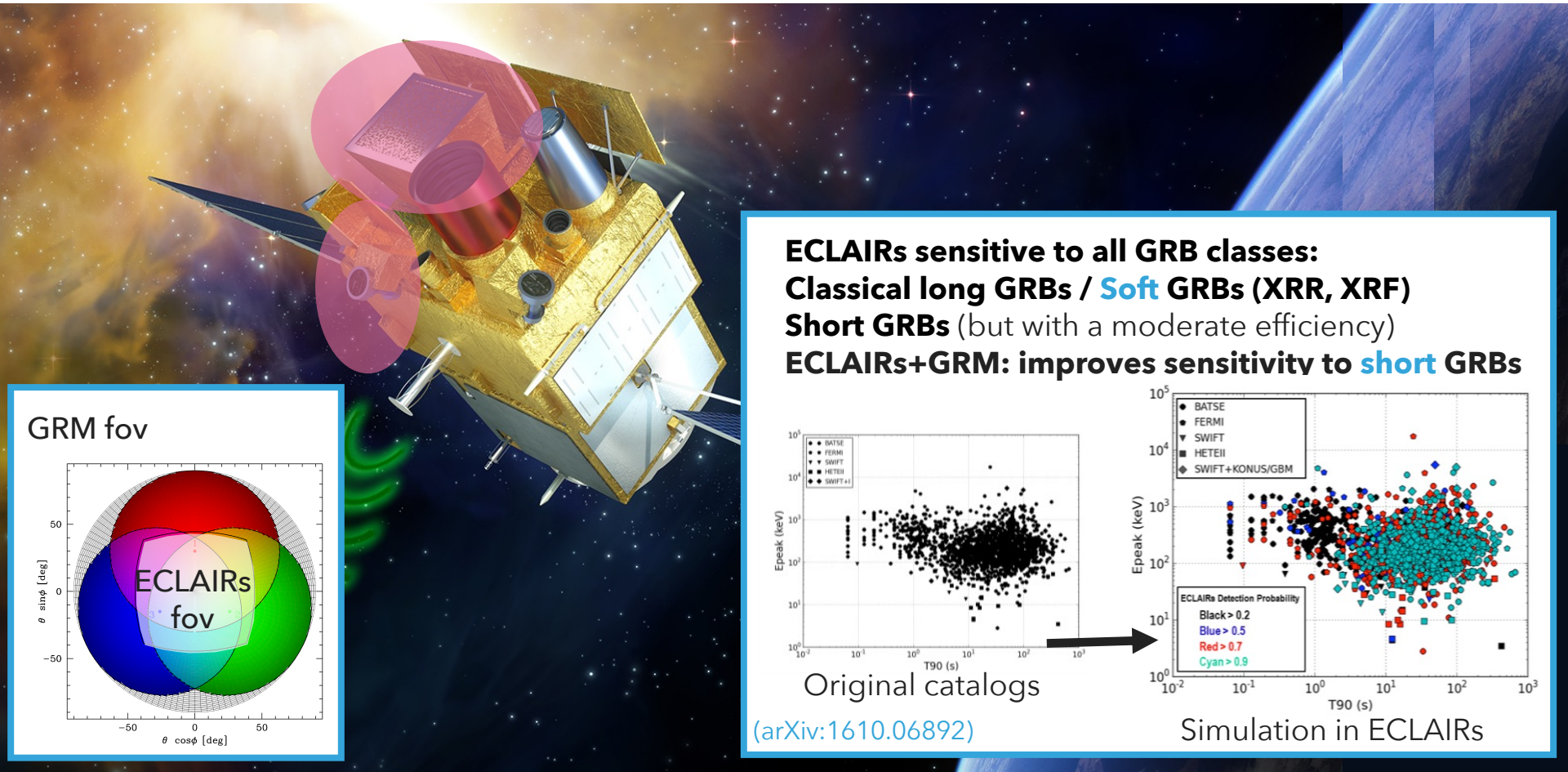
Ground Follow-up Telescopes
Visible (+NIR for F-GFT)

- C-GFT @ Weihai Obs.
  (120 cm, 90x90 arcmin^2, 400-900 nm)
- F-GFT @ OAN San Pedro Mártir
  (130 cm, 26x26 arcmin^2, 400-1700 nm)

SVOM GRB SEQUENCE: TRIGGER

- **Trigger: ECLAIRs** (4 -150 keV ; ~ 2 sr ; Loc. < 12′)
- **Expected rate: 42-80 GRB/yr**
- **GRM** (15 keV-5 MeV ; ~ 5.6 sr ; Loc.: 5-10° if 3 detectors)**: ~90 GRB/yr**

(but poor localization: no slew for GRM-only triggers)



GRM fov

ECLAIRs sensitive to all GRB classes:
Classical long GRBs / Soft GRBs (XRR, XRF)
Short GRBs (but with a moderate efficiency)
ECLAIRs+GRM: improves sensitivity to short GRBs

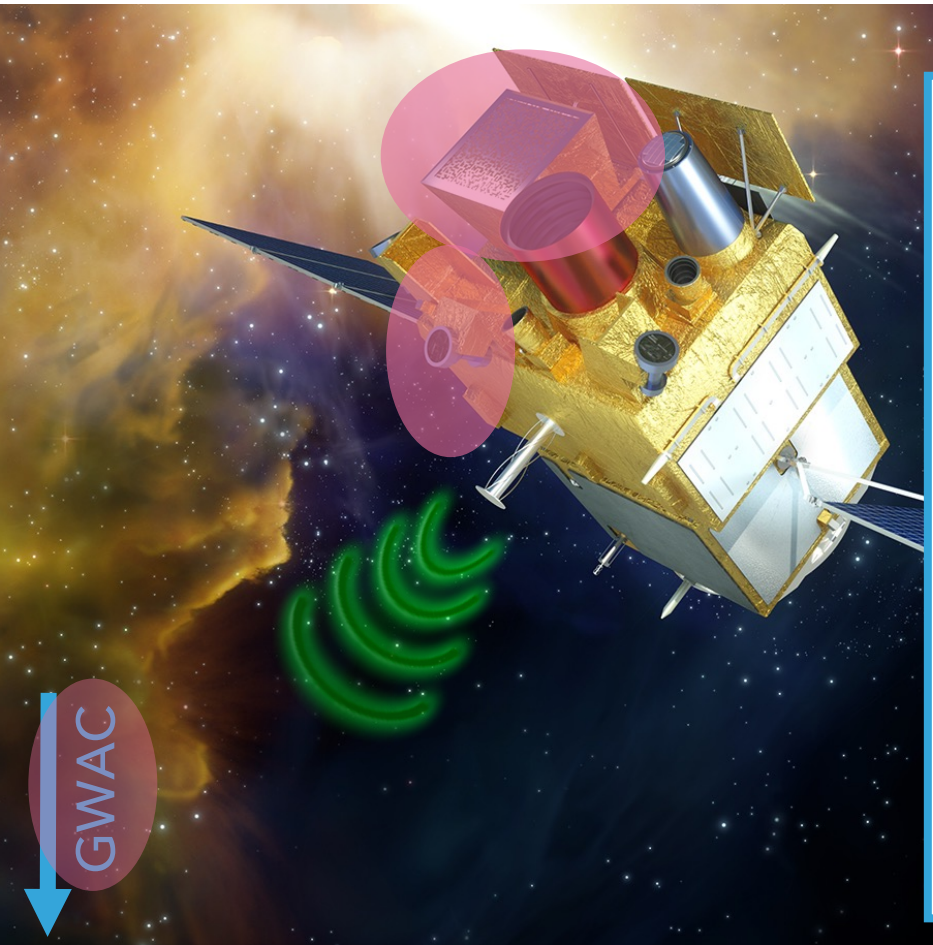
Original catalogs

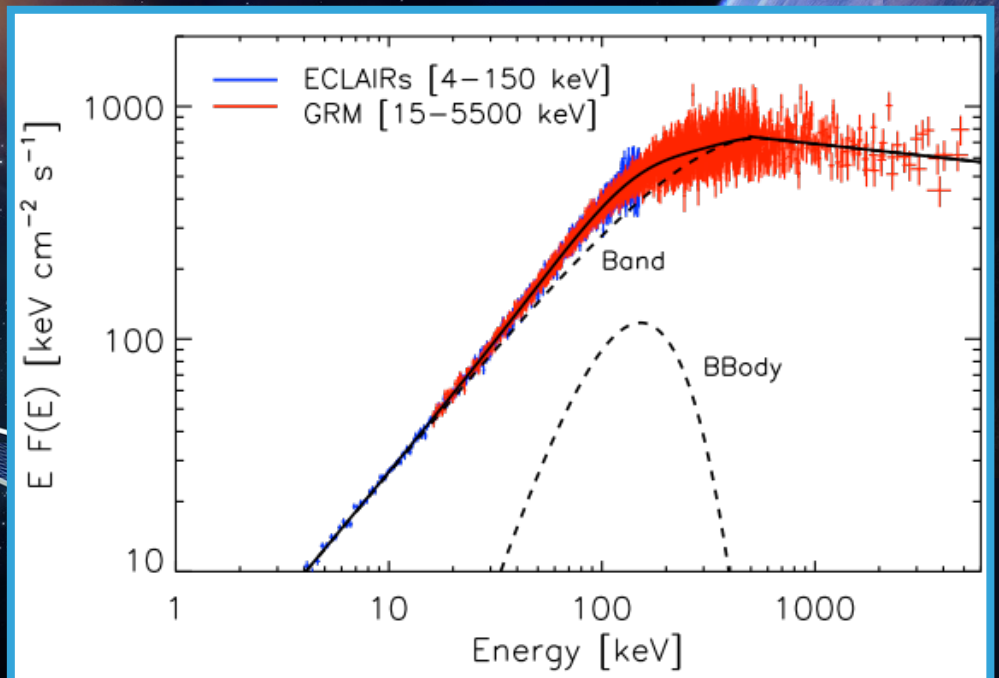
Simulation in ECLAIRs

(arXiv:1610.06892)

SVOM GRB SEQUENCE: PROMPT GRB EMISSION

- **Prompt emission from 4 keV to 5 MeV with ECLAIRs and GRM**
- **Visible detection/upper limit in ~10-15% of cases with GWAC**

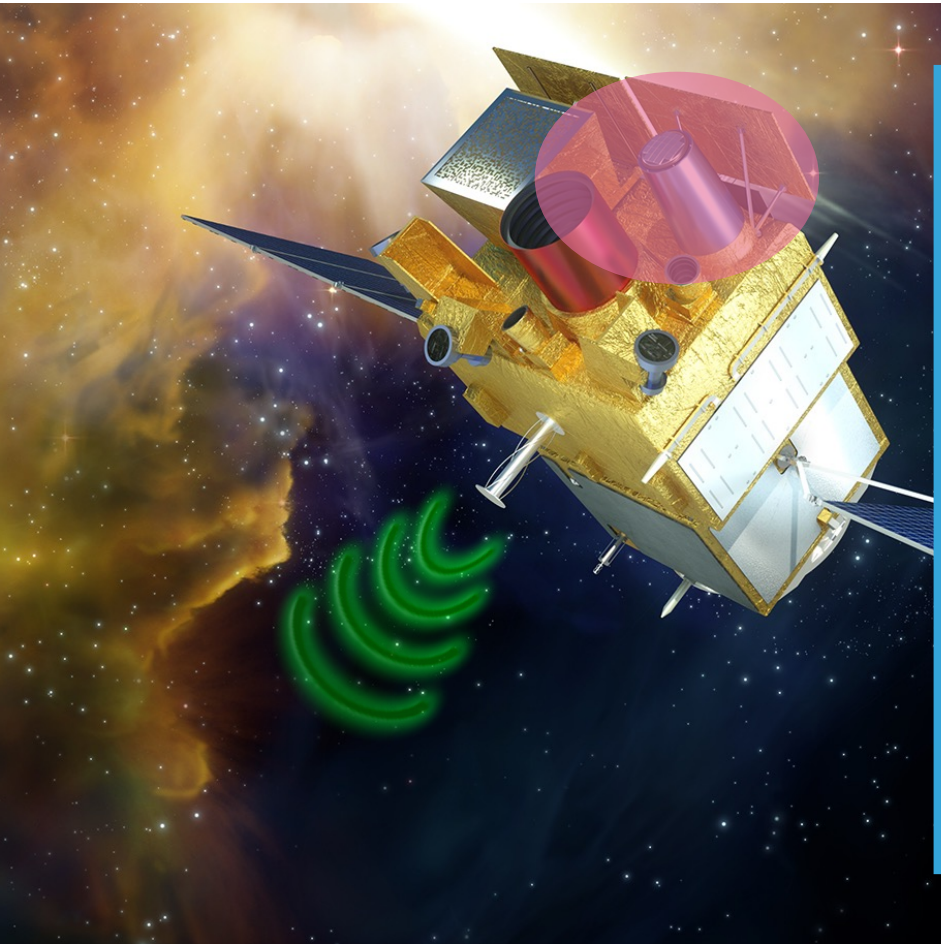


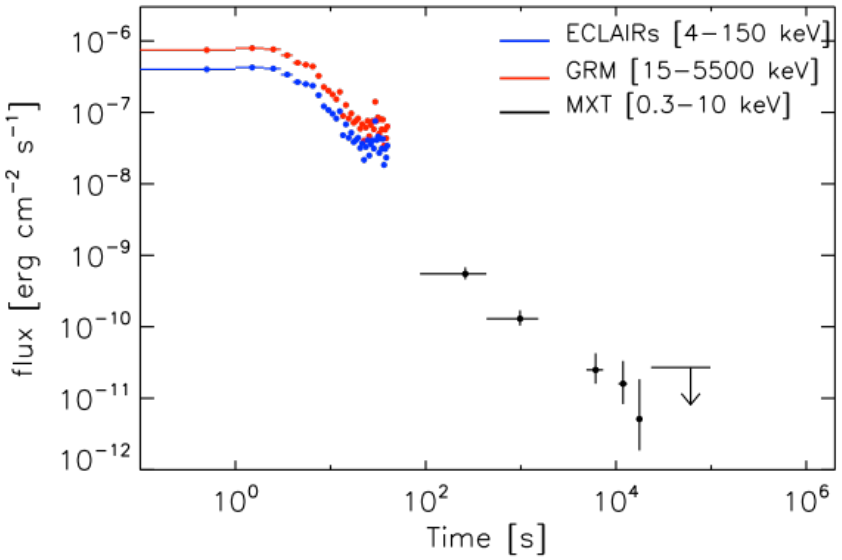


Multi-component spectrum of the Fermi burst GRB 100724B simulated in ECLAIRs+GRM. (Bernardini et al. 2017)

SVOM GRB SEQUENCE: EARLY AFTERGLOW (1) X-RAYS

- **Slew: ~36-72 GRB/yr**
- **Follow-up: detection and localization by MXT in >90% of cases (0.2-10 keV)**

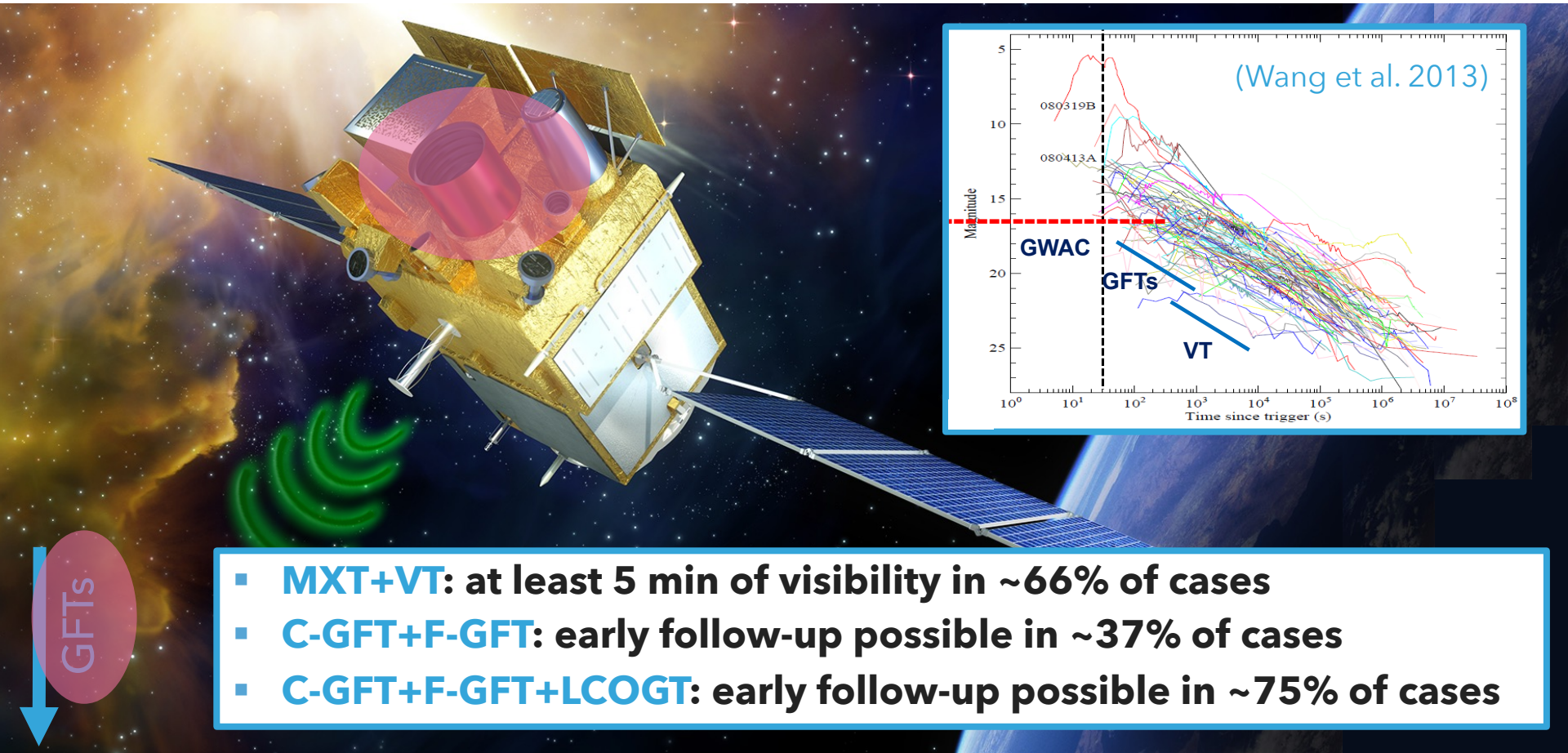




The X-ray afterglow of the Swift burst GRB 091020 simulated in MXT. (arXiv:1610.06892)

SVOM GRB SEQUENCE: EARLY AFTERGLOW (2) V/NIR

- **Visible/NIR early follow-up : VT/GWAC/C-GFT/F-GFT (lightcurve/photo-z)**
- **Pointing strategy favors a rapid follow-up by ground-based instruments (long-term afterglow, spectro-z, SN/KN association, host galaxy, …)**
- **Objective: redshift in ~2/3 of cases**



- **MXT+VT: at least 5 min of visibility in ~66% of cases**
- **C-GFT+F-GFT: early follow-up possible in ~37% of cases**
- **C-GFT+F-GFT+LCOGT: early follow-up possible in ~75% of cases**

A GRB SAMPLE WITH A COMPLETE DESCRIPTION

An expected sample of ~30-40 GRB/yr with

- **prompt GRB over 3 decades (4-5000 keV) + V flux/limit in ~10-15 % of cases**
- **X/V/NIR early afterglow**
- **redshift**

Physical mechanisms at work in GRBs

Nature of GRB progenitors and central engines
Acceleration, composition, dissipation & radiation process of the relativistic ejecta

Diversity of GRBs: event continuum following the collapse of a massive star

Low-luminosity GRBs / X-ray rich GRBs / X-ray Flashes and their afterglow
GRB/SN connection

Short GRBs and the merger model

GW association / Short GRBs with extended soft emission

GRBs as a tool to study the distant Universe

Host galaxies
Rate of very high-z GRBs similar to Swift,
better fraction of redshift measurements expected

SVOM STATUS

- **Commissioning phase until at least mid-September**
- **The community will be informed when SVOM will start to send alerts (end of commissioning phase? earlier?)**
- **A first GCN with the three first bursts detected by SVOM/GRM!**

GCN Circular 36805
Subject The first three GRBs detected by SVOM: GRB 240627B, GRB 240629A and GRB 240702A
Date 2024-07-03T03:46:41Z (6 days ago)
From Shaolin Xiong at IHEP <xiongsl@ihep.ac.cn>
Via Web form

SVOM/GRM team: Yong-Wei Dong, Jiang-Tao Liu, Shi-Jie Zheng, Wen-Jun Tan, Jian-Chao Sun, Chen-Wei Wang, Jiang He, Min Gao, Hao-Xuan Guo, Yue Huang, Lu Li, Yong-Ye Li, Hong-Wei Liu, Xin Liu, Hao-Li Shi, Li-Ming Song, You-Li Tuo, Hao-Xi Wang, Jin Wang, Jin-Zhou Wang, Ping Wang, Rui-Jie Wang, Yu-Xi Wang, Bo-Bing Wu, Shao-Lin Xiong, Jian-Ying Ye, Yi-Tao Yin, Wen-Hui Yu, Fan Zhang, Li Zhang, Peng Zhang, Shuang-Nan Zhang, Wen-Long Zhang, Yan-Ting Zhang, Shu-Min Zhao, Xiao-Yun Zhao, Chao Zheng (IHEP), Maria-Grazia Bernardini (LUPM/INAF-OAB), Laurent Bouchet (IRAP), David Corre (CEA), Patrick Maeght (LUPM), Frédéric Piron (LUPM), Jingwei Wang (IAP)

SVOM JSWG: Jian-Yan Wei (NAOC), Bertrand Cordier (CEA), Shuang-Nan Zhang (IHEP), Stéphane Basa (LAM), JeanLuc Attéia (IRAP), Arnaud Claret (CEA), Zi-Gao Dai (USTC), Frédéric Daigne (IAP), Jin-Song Deng (NAOC), Andrea Goldwurm (APC), Diego Götz (CEA), Xu-Hui Han (NAOC), Cyril Lachaud (APC), En-Wei Liang (GXU), Yu-Lei Qiu (NAOC), Susanna Vergani (Obs.Paris), Jing Wang (NAOC), Chao Wu (NAOC), Li-Ping Xin (NAOC), Bing Zhang (UNLV)

report on behalf of the SVOM team:
During the commissioning phase of SVOM which was launched on June 22, 2024 from the Xichang Satellite Launching Center, China, the Gamma-Ray burst Monitor (GRM), as one of the four multi-wavelength telescopes on-board SVOM, detected three long gamma-ray bursts (GRBs), GRB 240627B at 2024-06-27T20:08:11.750 UTC (T0), GRB 240629A at 2024-06-29T16:53:53.000 UTC (T0) and GRB 240702A at 2024-07-02T21:14:50.700 UTC (T0), with on-ground blind search using event-by-event data downloaded through the X-band ground station. The light curves of GRB 240627B were also successfully downloaded through the VHF system with low latency owing to an in-flight trigger just about 50 s after this burst. Although the calibration is ongoing, the preliminary GRM light curves are well consistent with the Fermi/GBM and GECAM-C observations. The automatic in-flight trigger strategy of GRM is under commissioning.
The GRB 240627B light curves can be found here: http://www.bursthub.cn//admin/static/svgrb240627B.png
The GRB 240629A light curves can be found here: http://www.bursthub.cn//admin/static/svgrb240629A.png
The GRB 240702A light curves can be found here: http://www.bursthub.cn//admin/static/svgrb240702A.png
We note that these are the first three GRBs detected by SVOM. More GRBs are expected to be detected by SVOM as other instruments are gradually turned on according to the operation plans.

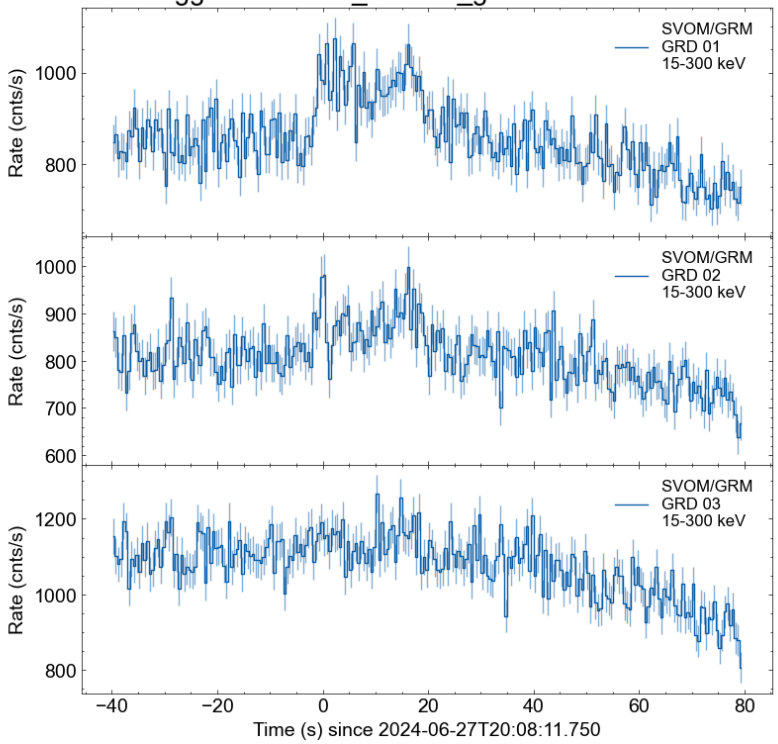
The Space Variable Objects Monitor (SVOM) is a China-France joint mission led by the Chinese National Space Administration (CNSA, China), National Center for Space Studies (CNES, France) and the Chinese Academy of Sciences (CAS, China), which is dedicated to observing gamma-ray bursts and other transient phenomena in the energetic universe. GRM is developed by the Institute of High Energy Physics (IHEP) of CAS.
The SVOM point of contact for these bursts is: Shao-Lin Xiong (IHEP)(xiongsl@ihep.ac.cn)

SVOM STATUS

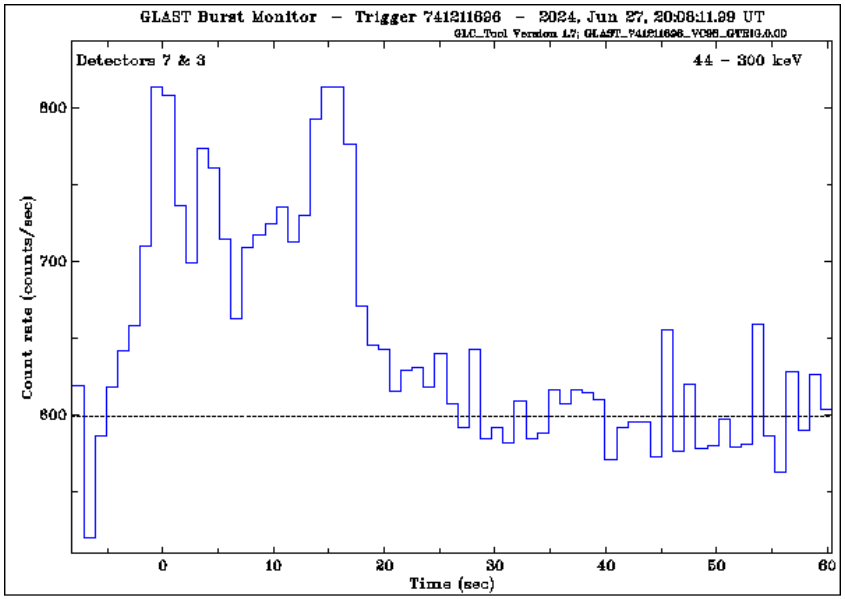
- Commissioning phase until at least mid-September
- The community will be informed when SVOM will start to send alerts (end of commissioning phase? earlier?)
- A first GCN with the three first bursts detected by SVOM/GRM!

GRB 240627B

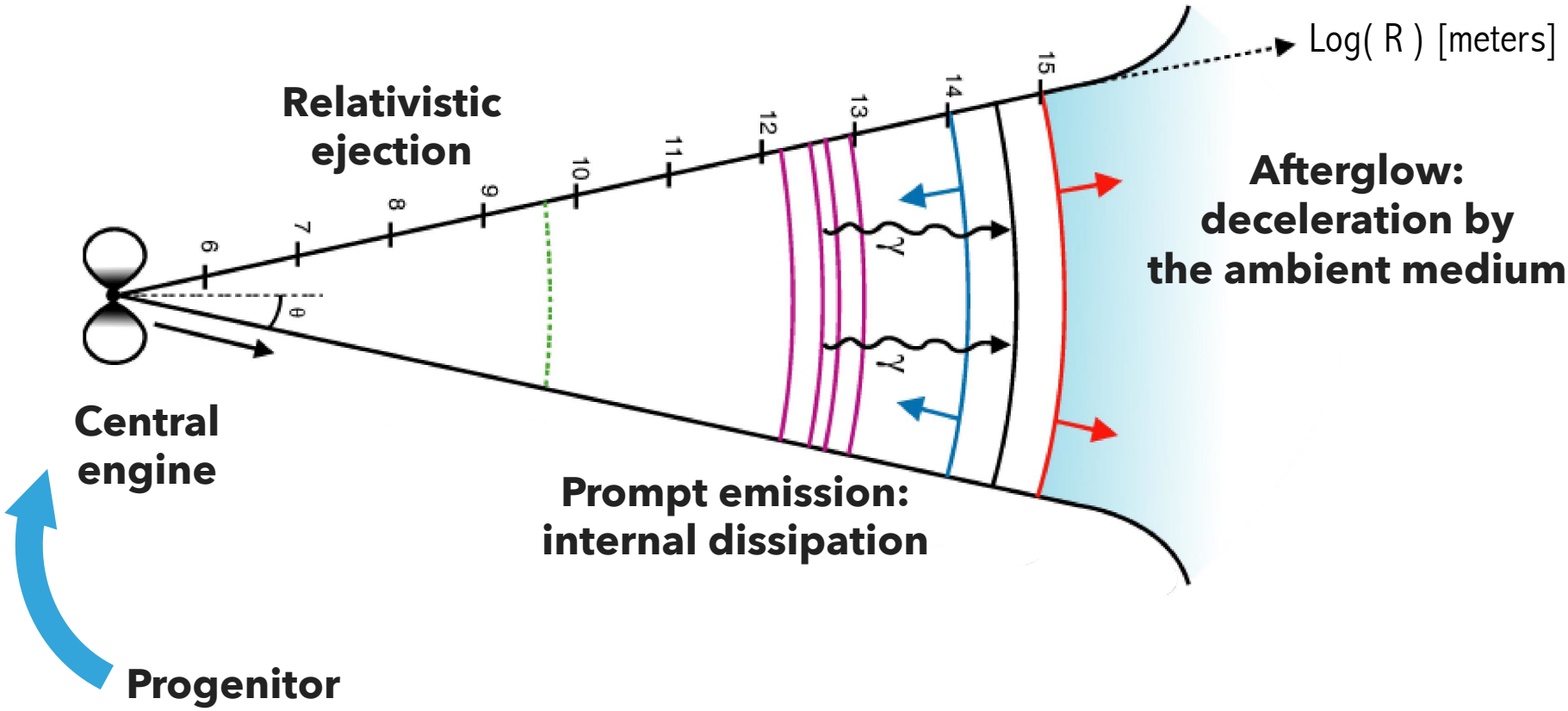
SVOM/GRM



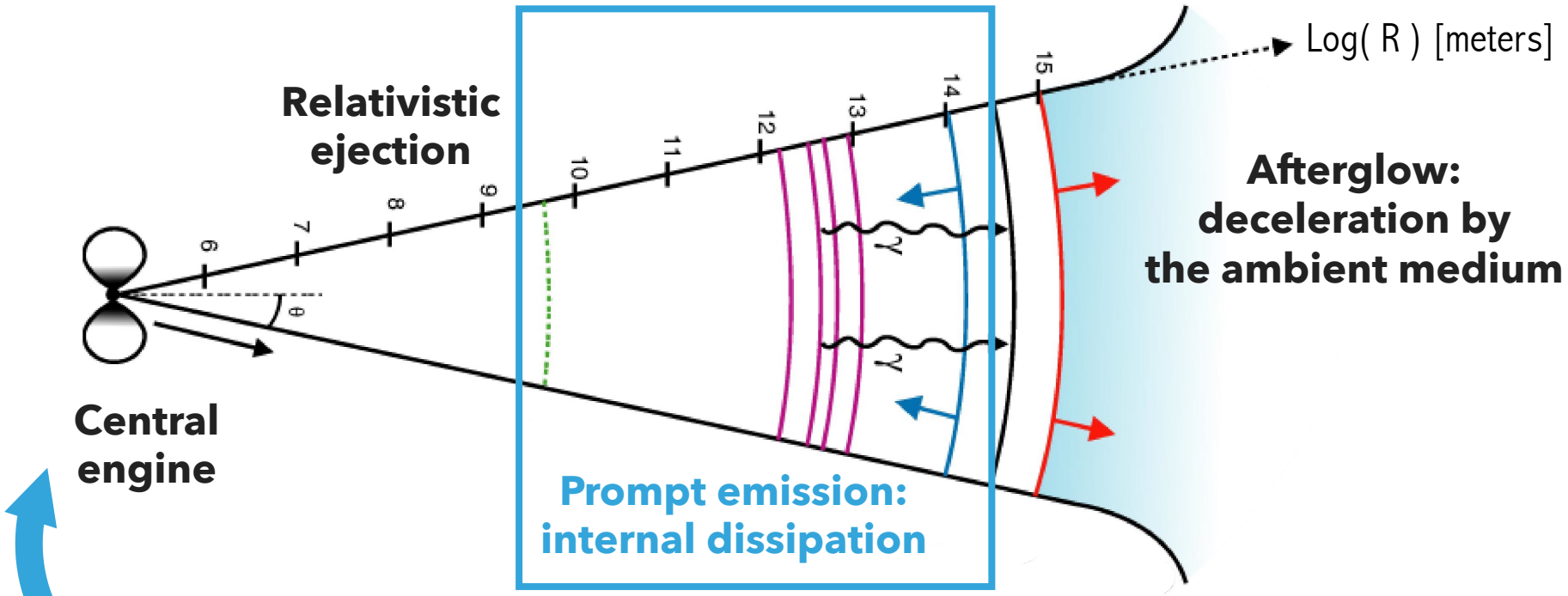
Fermi/GBM



GRB PHYSICS


Log(R) [meters]
Relativistic ejection
Afterglow: deceleration by the ambient medium
Central engine
Prompt emission: internal dissipation
Progenitor
6
7
8
9
10
11
12
13
14
15
θ
γ
γ

GRB PHYSICS



Optically thick: (dissipative?) photosphere?

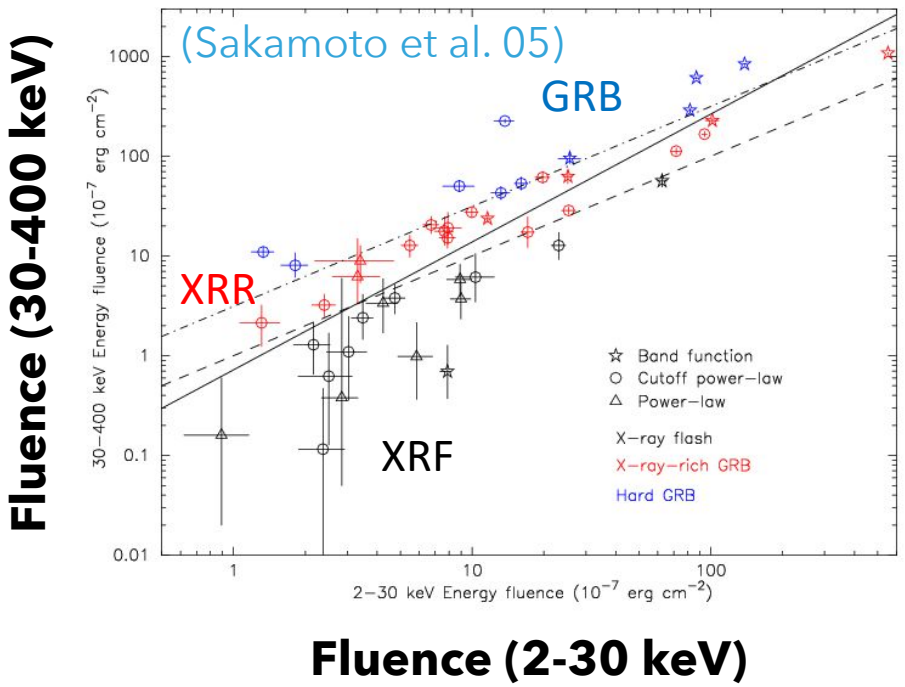
Progenitor

Optically thin:
-internal shocks?
-magnetic reconnection?

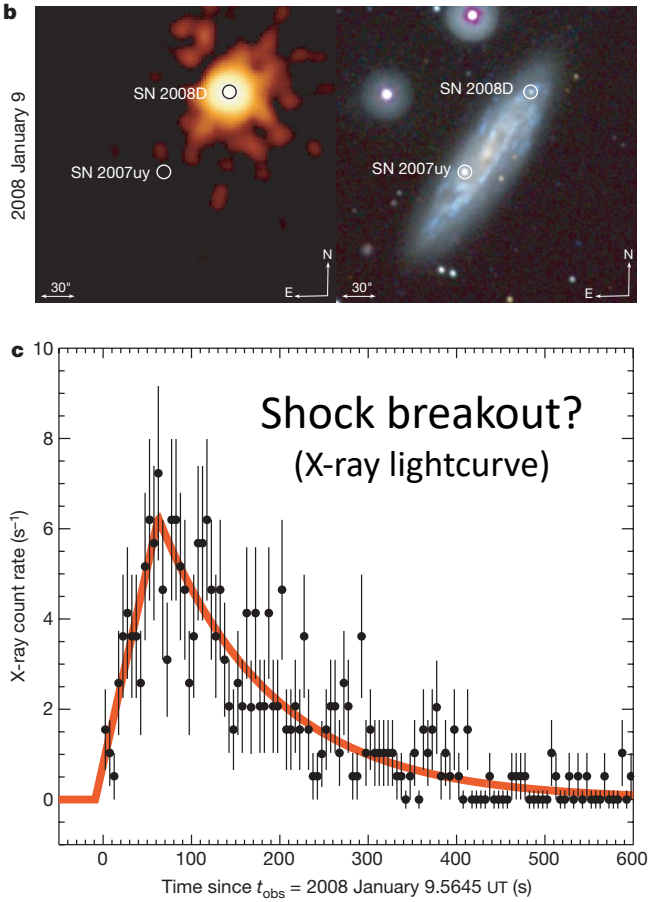
GRB PROMPT EMISSION PHYSICS: SOFT EVENTS?

Diversity of fast transients in the X-ray/soft gamma-ray range:
Fast X-ray Transients, X-Ray Rich GRBs, X-Ray Flashes/Low-L GRBs, etc.

HETE2 sample



The soft tail of the GRB population?



(Soderberg et al. 08)

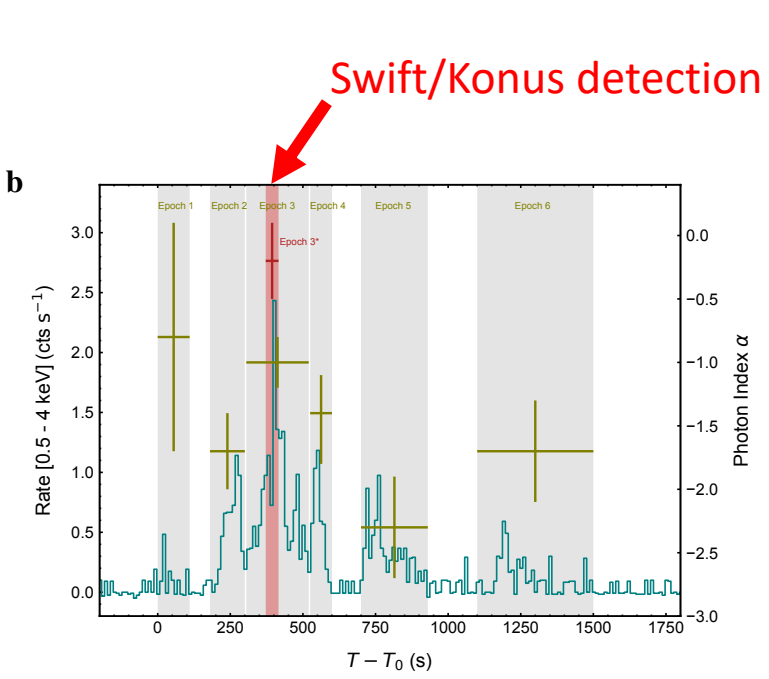
Other classes of events?

GRB PROMPT EMISSION PHYSICS: SOFT EVENTS?

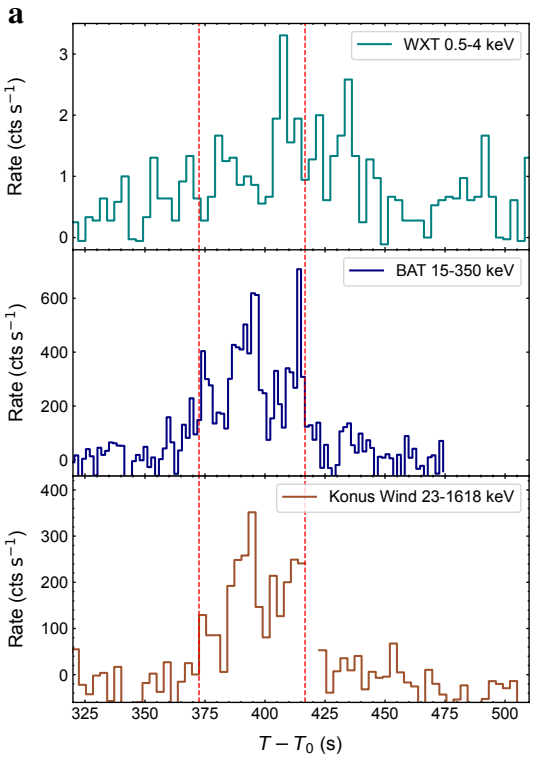
Diversity of fast transients in the X-ray/soft gamma-ray range:
Fast X-ray Transients, X-Ray Rich GRBs, X-Ray Flashes/Low-L GRBs, etc.

EP240315a/GRB230315C

(Liu et al. 24)



EP 0.5-4 keV Lightcurve

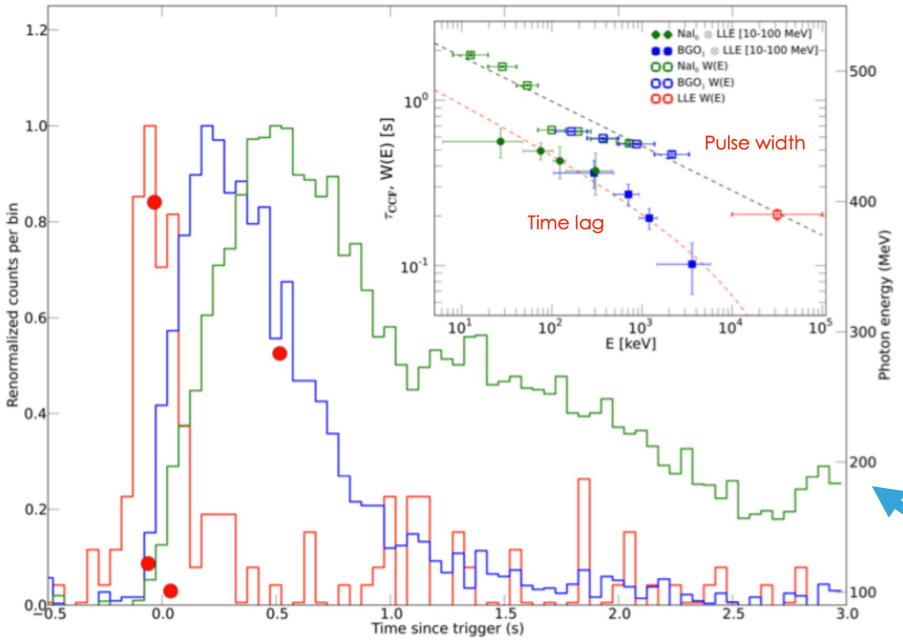


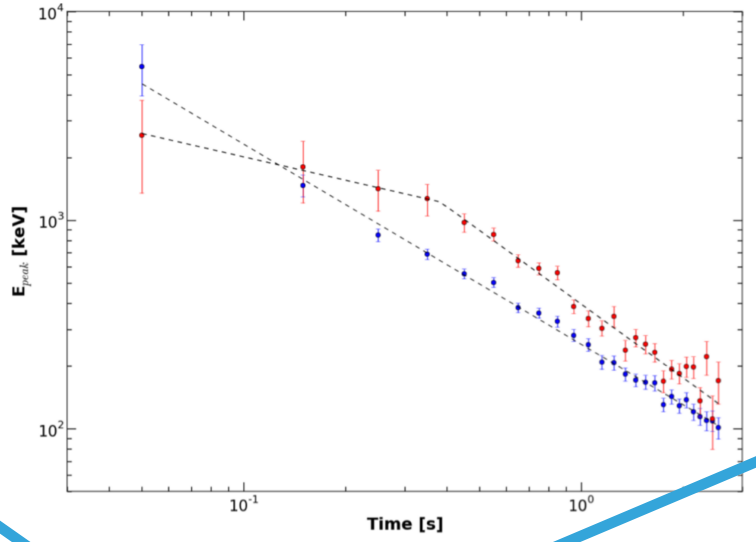
z=4.9
« normal » afterglow
(Levan et al. 24 , Liu et al. 24)

The prompt X-ray emission of classical long GRBs?

GRB PROMPT EMISSION PHYSICS: SOFT EVENTS?

Prompt X-ray emission of classical long GRBs?





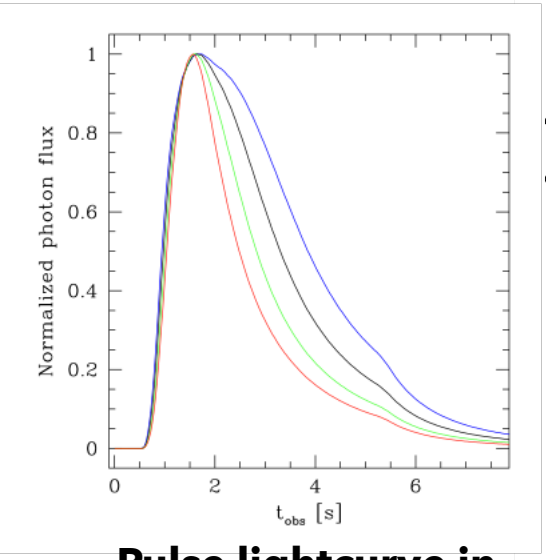
First pulse of the « Fermi monster » GRB 130427A (Preece et al. 14)

Prompt X-ray emission?

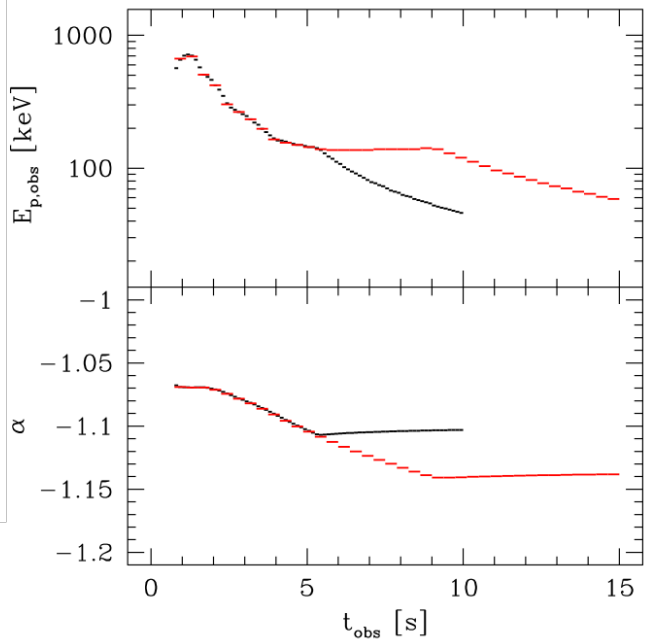
PROMPT X-RAY EMISSION OF CLASSICAL LONG GRBS?

Pulse hard-to-soft evolution in internal shocks: properties of a synthetic pulse

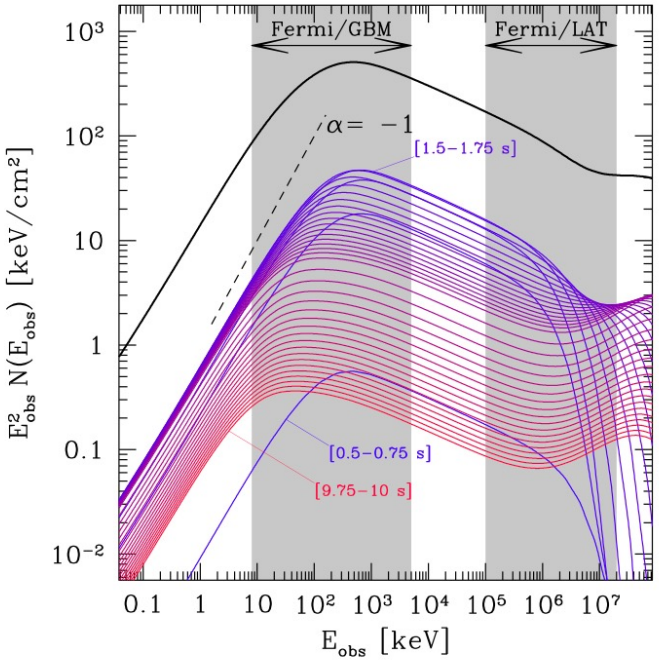
(Bosnjak & Daigne 14)

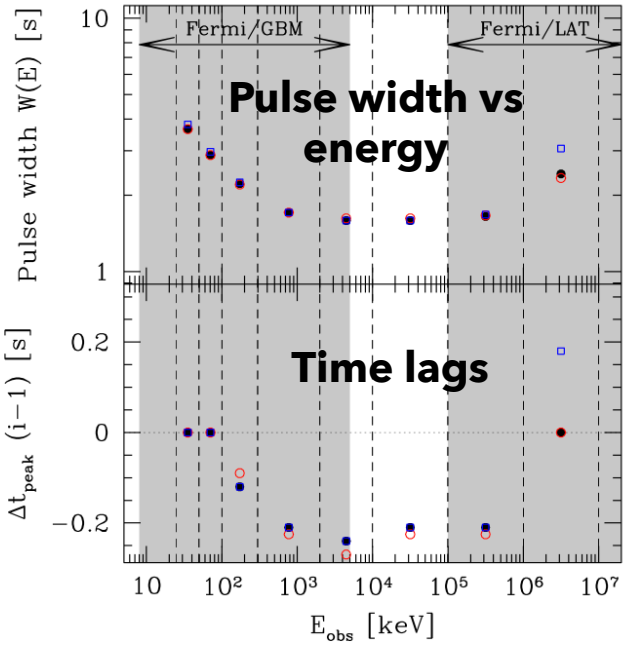


Pulse lightcurve in four energy bands



Spectral evolution

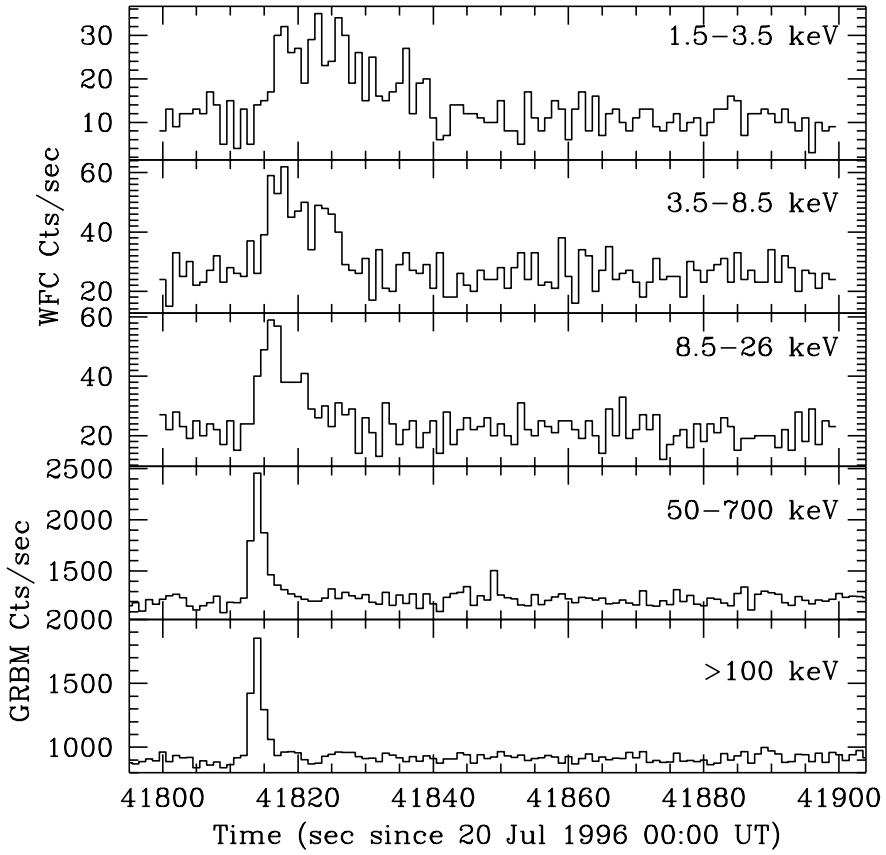




PROMPT X-RAY EMISSION OF CLASSICAL LONG GRBS?

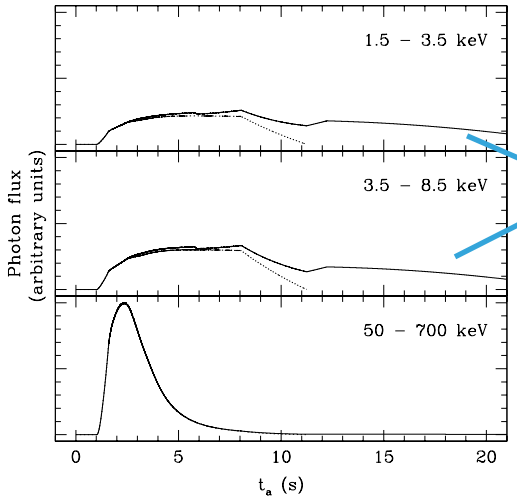
Additional contribution of the Reverse Shock?

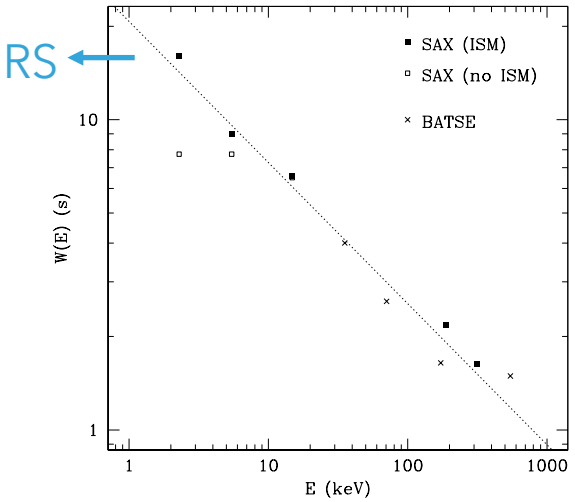
(possible if microphysics parameters similar as in internal shocks)



BeppoSAX observation of GRB960720

(Piro et al. 97)





(Daigne & Mochkovitch 02)

See also Swift/BAT+XRT observations

GRB PROMPT EMISSION PHYSICS: SOFT EVENTS?

Observations needed:

Characterization (afterglow, host, …) & classification

- SVOM can explore the diversity of these transients and their afterglows (low-energy threshold of ECLAIRs: 4 keV)

- Strong synergy with Einstein Probe

Physics:

- Progenitors: understanding the diversity of transients expected following the collapse of a massive star – role of the viewing angle

- Prompt emission: among these transients, some will appear as the soft tail of the classical GRB population: constraints on the prompt emission mechanism.

Soft events: which conditions to produce them in photospheric/shock/reconnection scenarios? (not always intuitive: e.g. in internal shocks → high Lorentz factor, see Barraud et al. (FD) 2005)

Origin of the X-ray prompt emission in classical long GRBs?

GRB PROMPT EMISSION PHYSICS: GRBS ASSOCIATED TO MERGERS

Diversity to explore

Nature (and diversity ?) of the “soft extended emission”?

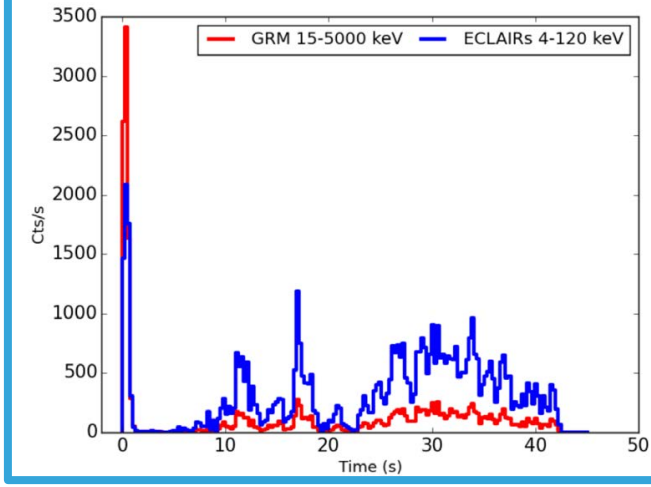
Transition to the early afterglow?

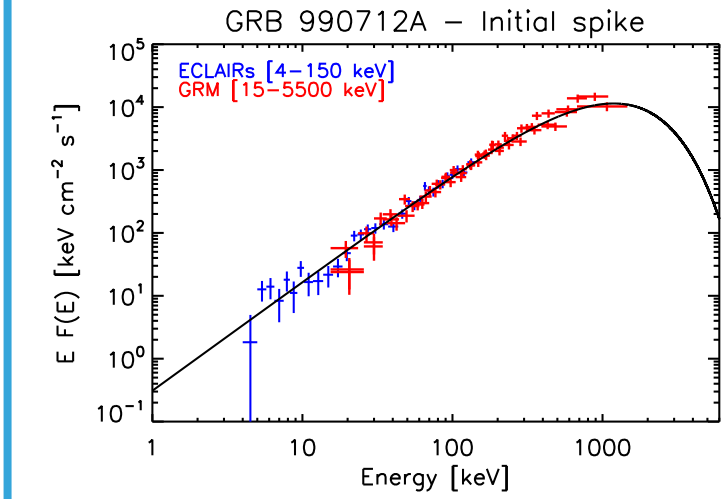
GRB PROMPT EMISSION PHYSICS: GRBS ASSOCIATED TO MERGERS

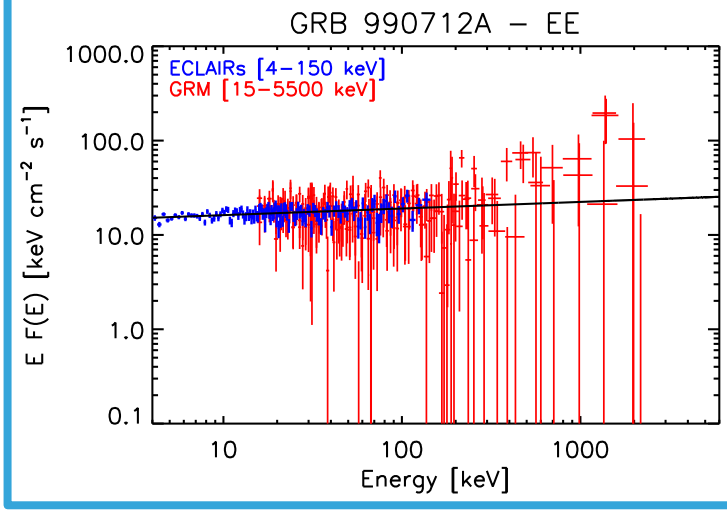
Diversity to explore
Nature (and diversity ?) of the "soft extended emission"?
Transition to the early afterglow?

SVOM can bring new observations:
- ECLAIRs+GRM: spectral coverage adapted to a short hard spike + soft ext. Emission
- transition to X-ray afterglow?
(ECLAIRs: 4-150 keV ; MXT: 0.2-10 keV)
- fast localization + anti-solar pointing: improves the probability to catch the early optical afterglow (VT/GWAC/GFTs)

Simulation of a short GRB with a soft tail in ECLAIRs+GRM: GRB 990712A. (arXiv: 1610.06892)







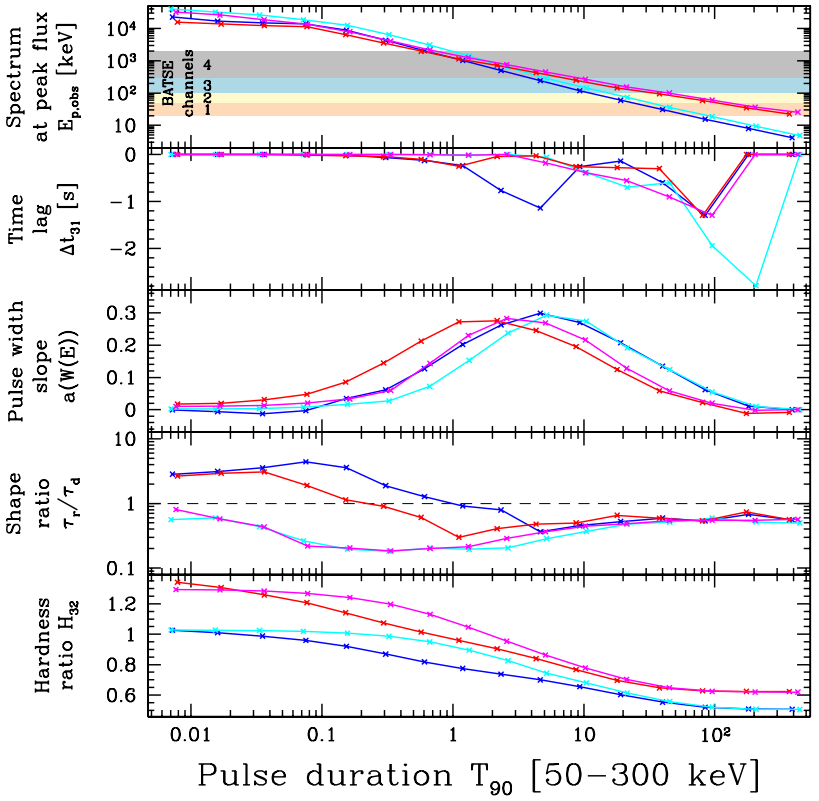
GRB PROMPT EMISSION PHYSICS: GRBS ASSOCIATED TO MERGERS

Diversity to explore
Nature (and diversity ?) of the "soft extended emission"?
Transition to the early afterglow?

GRB Prompt Emission Physics:

- short hard spike: same mechanism as in long GRBs?
If yes, which conditions explain the hardness in photospheric/shock/reconnection scenarios?

- origin of the soft extended emission?
(emission site, mechanism, constraints on the central engine, etc.)



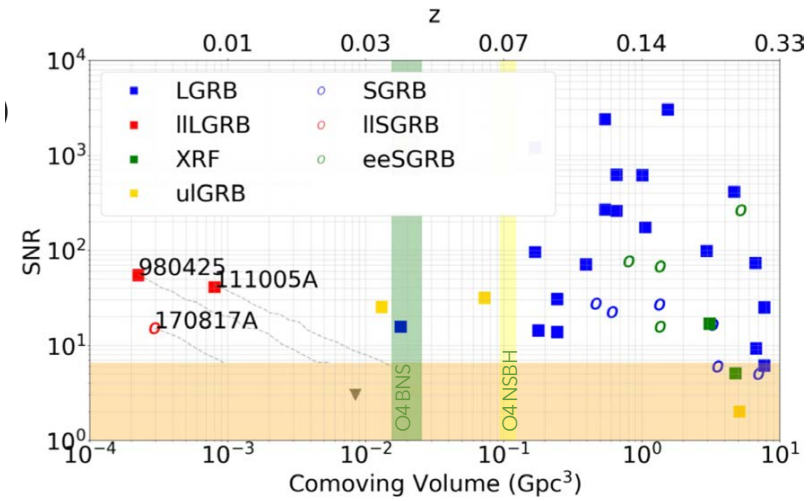
Origin of the hardness-duration relation in internal shocks (Bosnjak & Daigne 14)

GRB DIVERSITY: « LOCAL » GRBS

SVOM GRBs in the local Universe are excellent targets for a complete characterization:
- SVOM instruments+early follow-up strategy: explore the diversity

Simulation of 34 nearby GRBs (z<0.3): detection by ECLAIRs.

- **22/24 long GRBs**, including
  3 ultra-long
  2 low-luminosity
  2 X-Ray Flashes
- **8/10 short GRBs**
  (including the simulated 170817)



(Arcier et al. 2020)

GRB DIVERSITY: « LOCAL » GRBS

SVOM GRBs in the local Universe are excellent targets for a complete characterization:

- SVOM instruments+early follow-up strategy: explore the diversity
- **best targets for the search of associated SN/KN**
- **best targets for VHE counterparts**

Associated SN/KN can be searched with VT/GFTs for these local events.

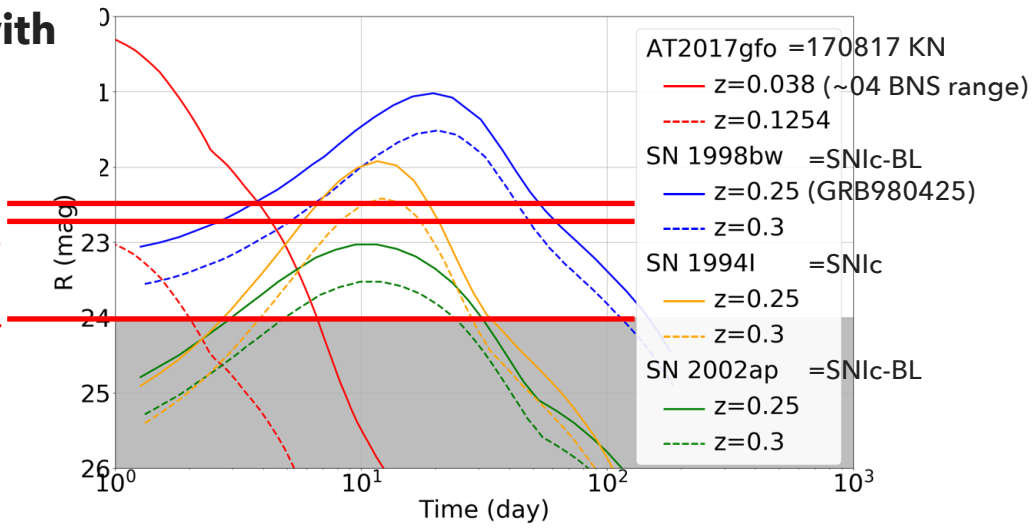
(Arcier et al. 2020)

SVOM limit R-mag

VT (300 s) 22.5

GFT (300 s) 22.8

VT (4800 s) 24



HIGH-REDSHIFT GRBS WITH SVOM?

Detection:
Low-energy threshold of ECLAIRs: favors the detection of high-z GRBs at z>6.

Identification:
Pointing strategy: favors a rapid follow-up (GRB is in the night hemisphere).
-VT/GFTs: rapid identification of high z candidates?
-A challenge: rapid spectroscopic follow-up with very large telescopes

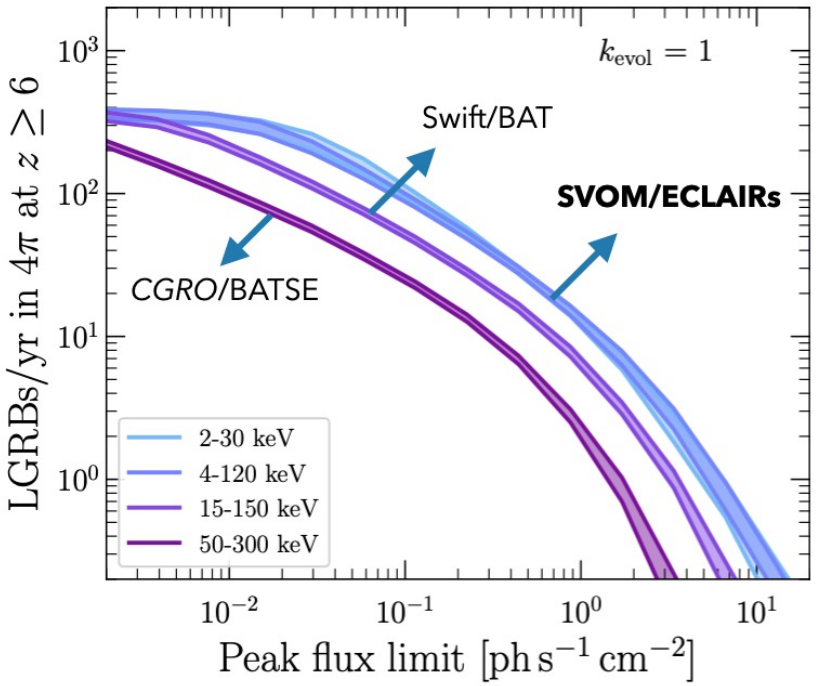
Pop. model: all-sky rate above z=6 as a function of the peak flux limit

(Palmerio & Daigne 2021)

Effect of the energy channel on the detected rate:

Color: energy band

From 50-300 keV (violet) to 2-30 keV (blue)

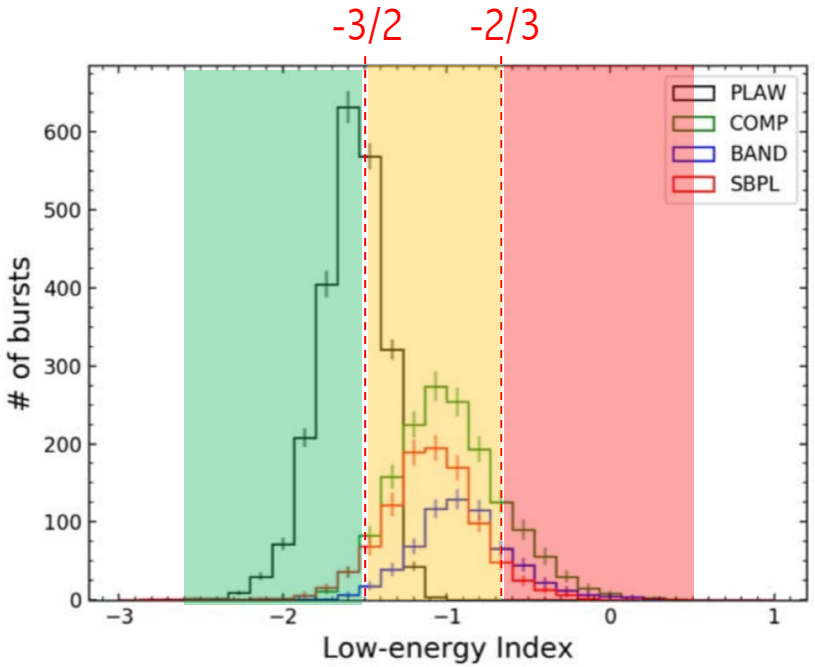


See also Ghirlanda & Salvaterra 22

GRB PROMPT EMISSION PHYSICS: SPECTRUM

The spectrum of the prompt emission, especially the low-energy photon index in the soft gamma-ray range, is at the heart of the (still) on-going debates on the various possible physical scenarios for the GRB prompt emission.

Both a data analysis and a theoretical challenge.



Low-energy photon index?

(Poolakkil et al. 2021: Fermi GBM spectral catalog: 10 years)

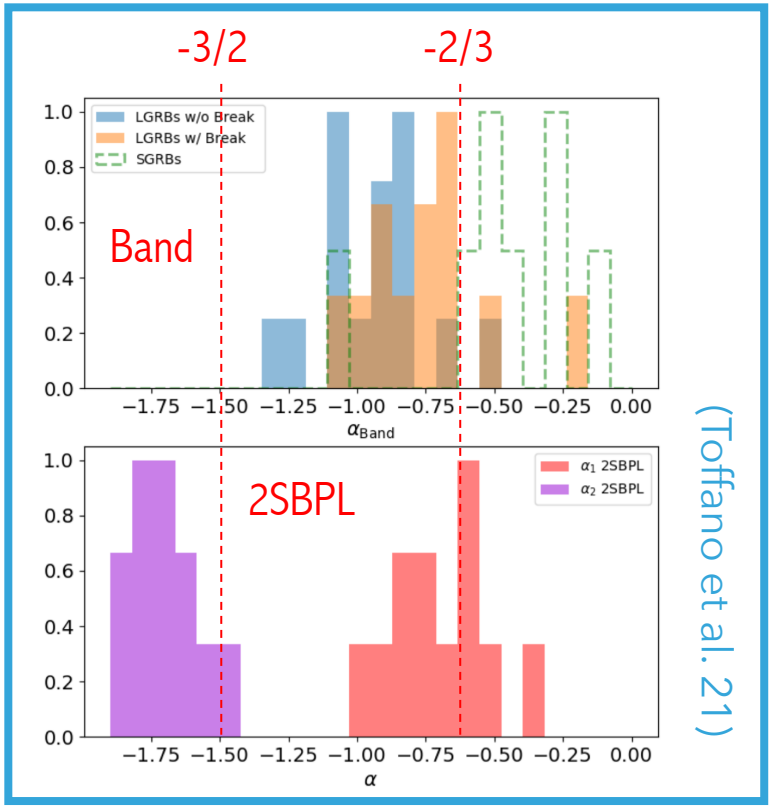
Impact of the assumed spectral shape? Burgess et al. 2011, 2014

GRB PROMPT EMISSION PHYSICS: SPECTRUM

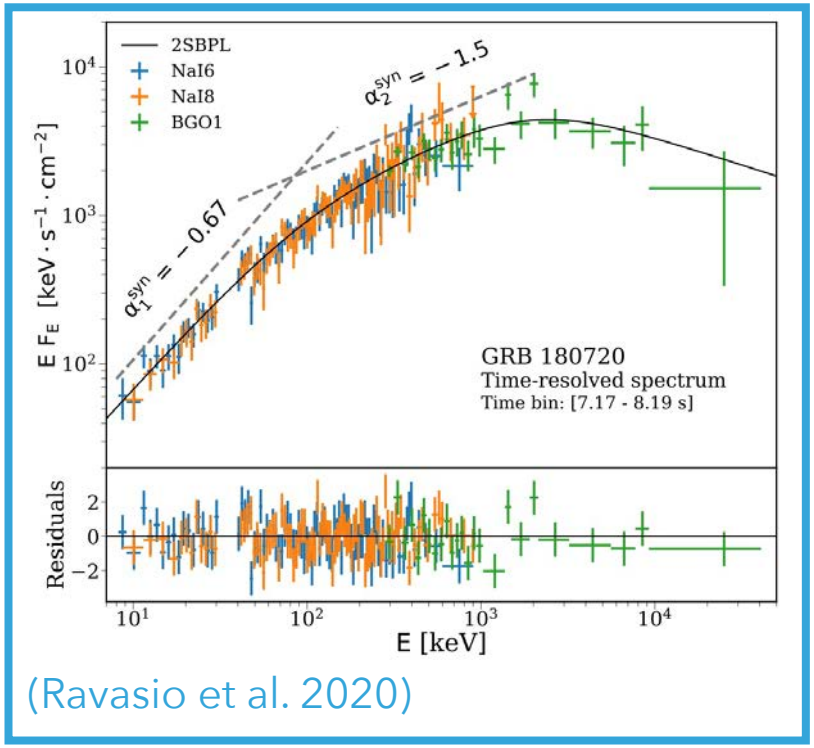
Which spectral shape to fit data?

Doubly broken power-laws?
(Oganesyan et al. 17, 18 ;
Ravasio et al. 18, 19 ; Toffano et al. 21)

Synchrotron marginally fast-cooling?
(Daigne et al. 11, Beniamini & Piran 13)



(Toffano et al. 21)

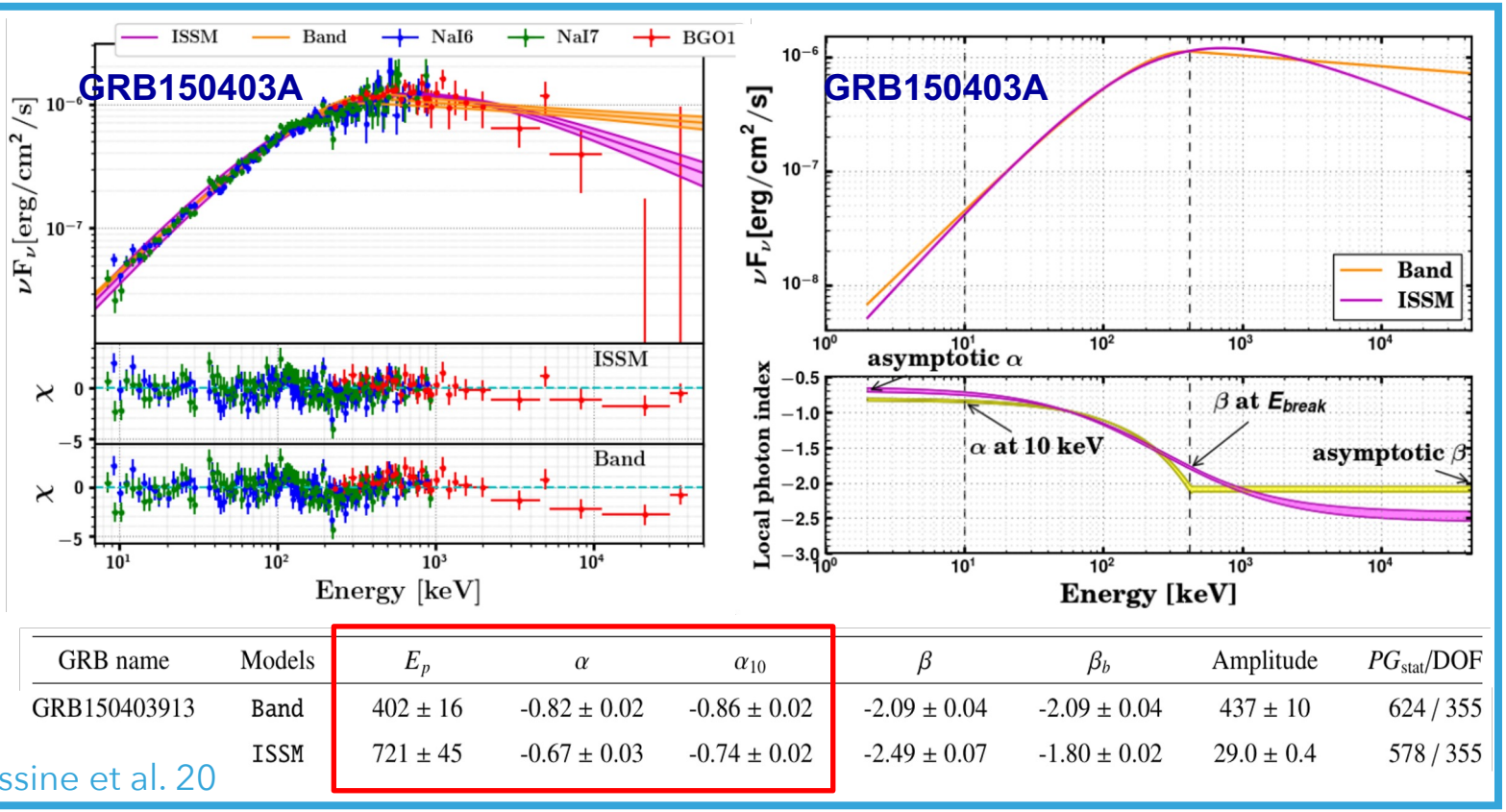


(Ravasio et al. 2020)

GRB PROMPT EMISSION PHYSICS: SPECTRUM

Which spectral shape to fit data?

ISSM: a new 4-parameters function with a smoothly evolving slope
(Yassine et al. (FD) 20, Scotton et al. (FD) in preparation)



GRB name	Models	E_p	α	α_{10}	β	β_b	Amplitude	PG_{stat}/DOF
GRB150403913	Band	402 ± 16	-0.82 ± 0.02	-0.86 ± 0.02	-2.09 ± 0.04	-2.09 ± 0.04	437 ± 10	624 / 355
	ISSM	721 ± 45	-0.67 ± 0.03	-0.74 ± 0.02	-2.49 ± 0.07	-1.80 ± 0.02	29.0 ± 0.4	578 / 355

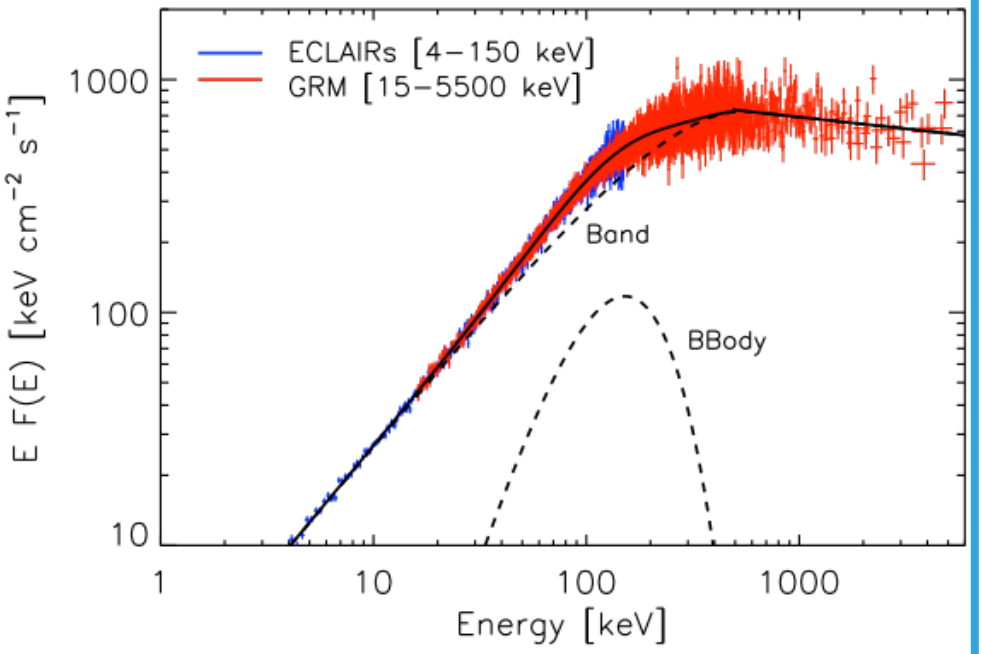
Yassine et al. 20

GRB PROMPT EMISSION PHYSICS: SPECTRUM

The spectrum of the prompt emission, especially the low-energy photon index in the soft gamma-ray range, is at the heart of the (still) on-going debates on the various possible physical scenarios for the GRB prompt emission.

A data analysis challenge.

SVOM will improve the spectral coverage of the prompt emission at low-energy.
(ECLAIRs low-energy threshold: 4 keV)



Multi-component spectrum of the Fermi burst GRB 100724B simulated in ECLAIRs+GRM. (Bernardini et al. 2017)

GRB PROMPT EMISSION PHYSICS: SPECTRUM

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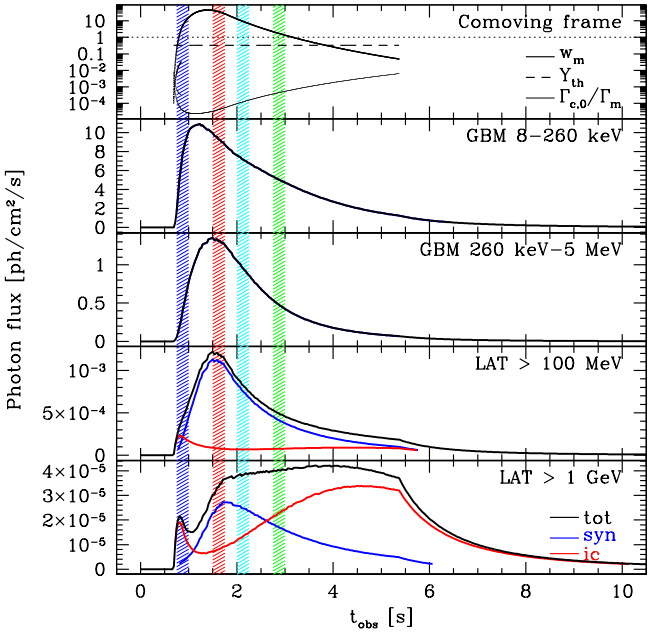
A theoretical challenge

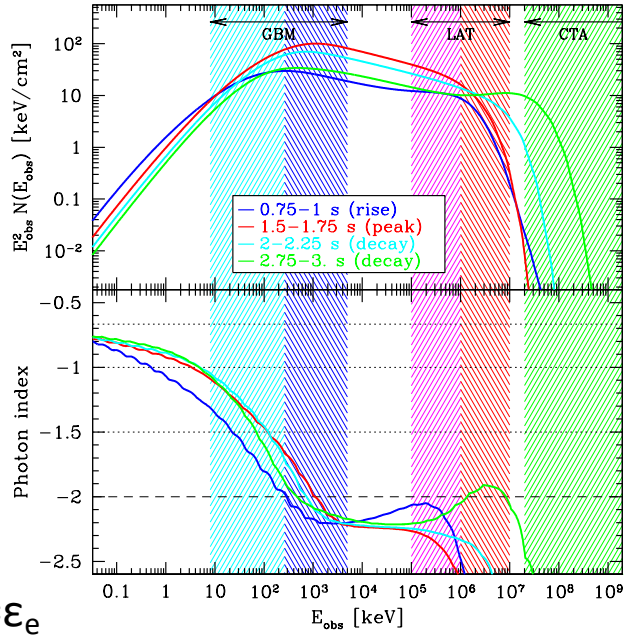
Interesting tests to come:
spectral index in X-rays/soft gamma-rays? Optical? HE emission?

A synthetic pulse from internal shocks

keV-GeV range
marginally fast cooling
synchrotron+SSC
(**rapid B decay**)

Daigne & Bosnjak submitted





$\varepsilon_B=\varepsilon_e$

↔EP

SVOM: GWAC

SVOM: ECLAIRs+GRM

GRB PROMPT EMISSION PHYSICS: SPECTRUM

The spectrum of the prompt emission, especially the low-energy photon index in the soft gamma-ray range, is at the heart of the (still) on-going debates on the various possible physical scenarios for the GRB prompt emission.

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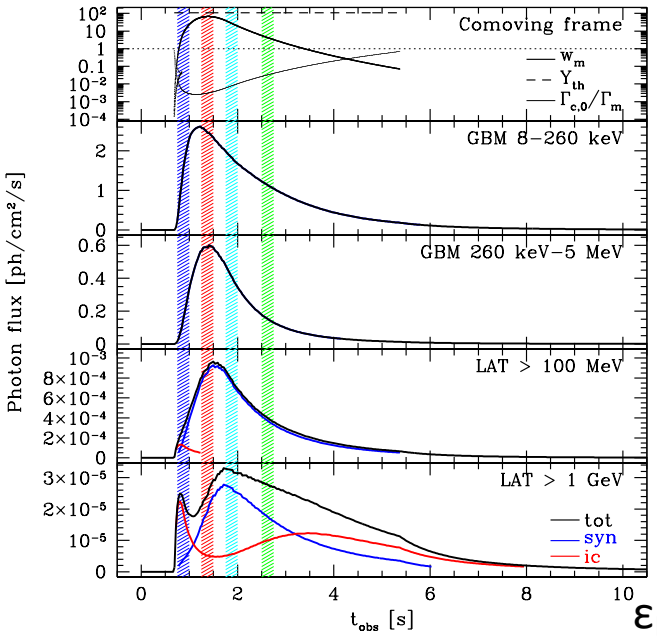
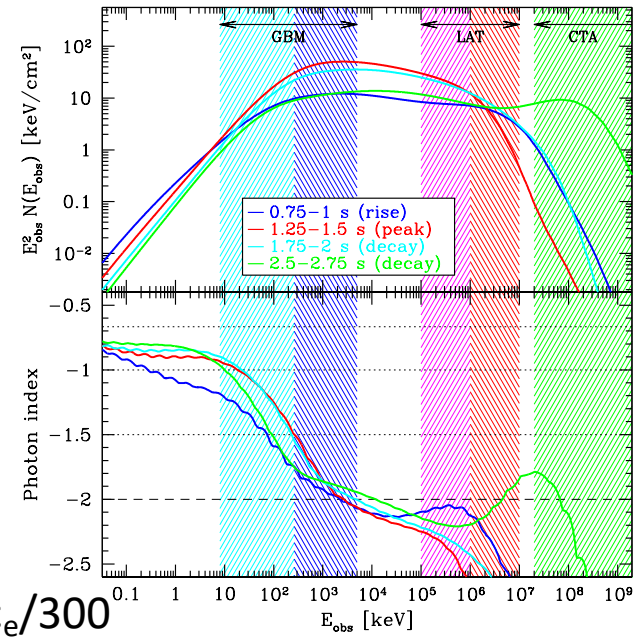




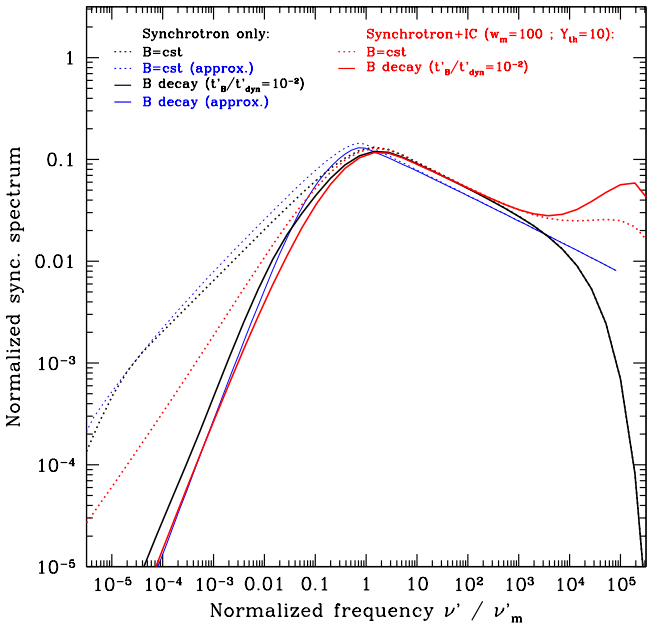
$\varepsilon_B=\varepsilon_e/300$

↔ EP

SVOM: GWAC ↑

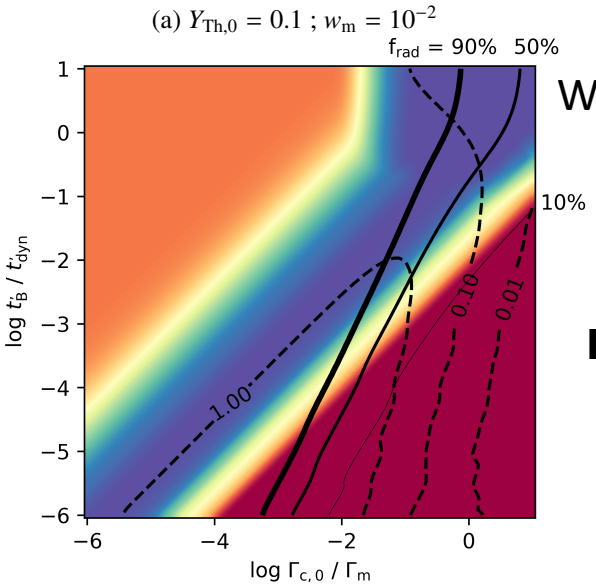
SVOM: ECLAIRs+GRM ↔

EFFECT OF B DECAY ON THE SYNCHROTRON SPECTRUM



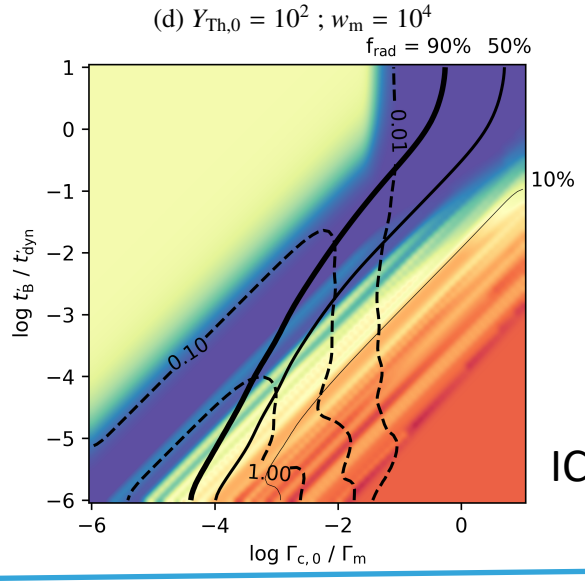
Daigne & Bosnjak submitted

B decay timescale



Weak IC case

Low-energy photon index α



IC case in KN regime

Initial Γ_c/Γ_m

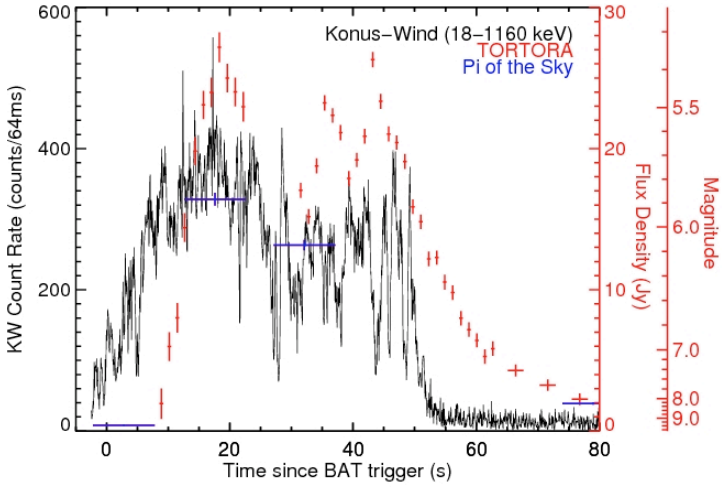
GRB PROMPT OPTICAL EMISSION ?

Observations are rare

Flux can be very different from the extrapolation of the soft gamma-ray spectrum (great diversity)

Effect of synchrotron self-absorption? Constraint on radius.

Reverse shock? Internal origin? (variability ?)

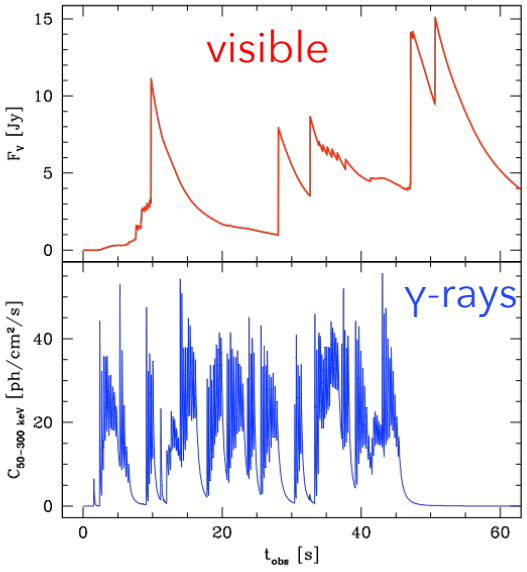


Naked eye burst GRB080319B

Racusin et al. 08

Variable prompt optical emission from internal shocks

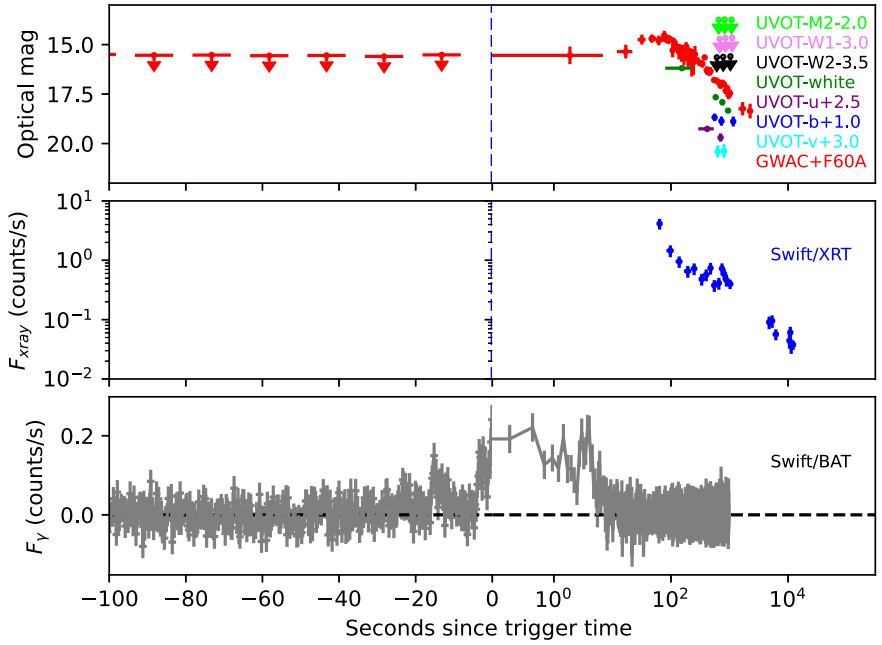
(Hascoet, Daigne et al. 08)

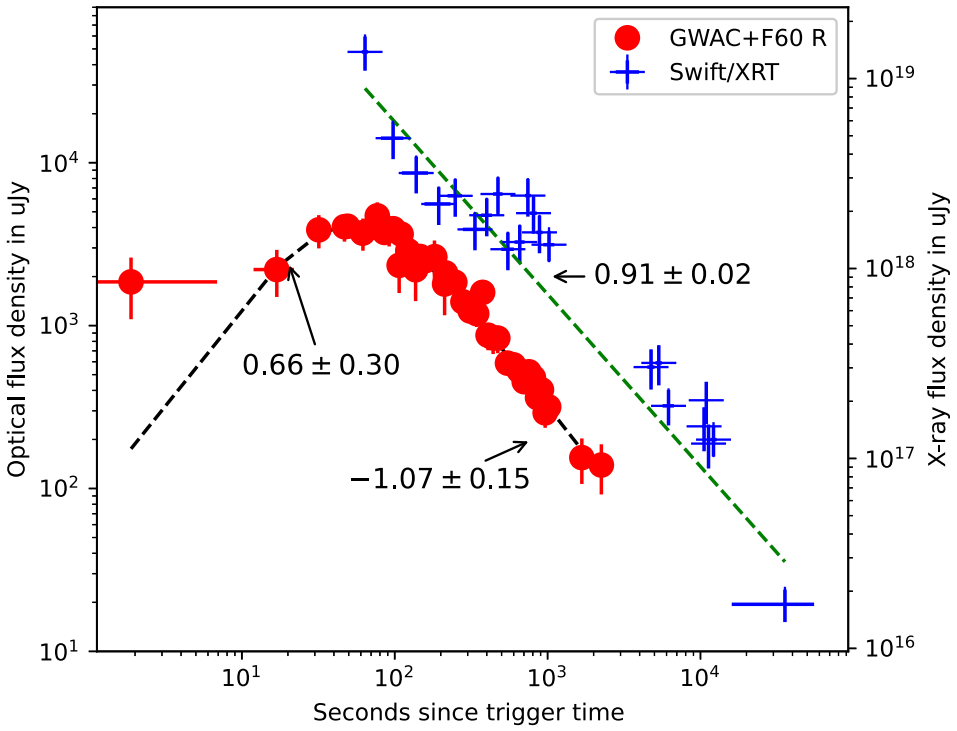


GRB PROMPT OPTICAL EMISSION ?

SVOM/GWAC should provide a constraint (flux/upper limit) in ~15% of cases

GWAC observation of GRB 201223A (Xin et al. 23)





Onset of the afterglow?

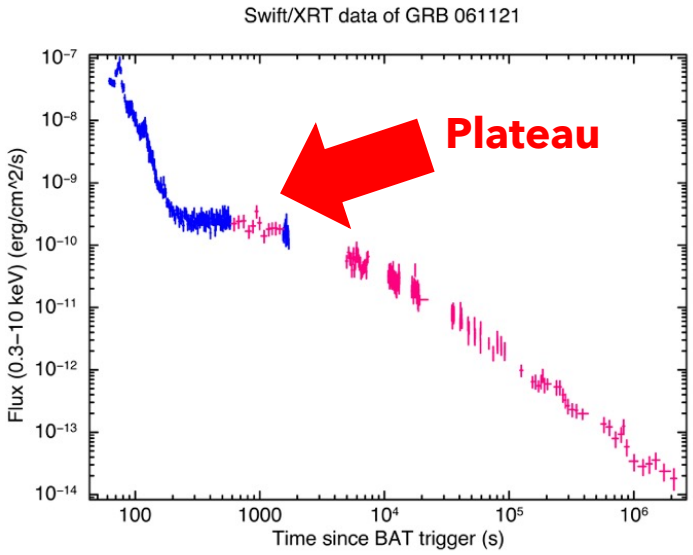
(Xin et al. 23)

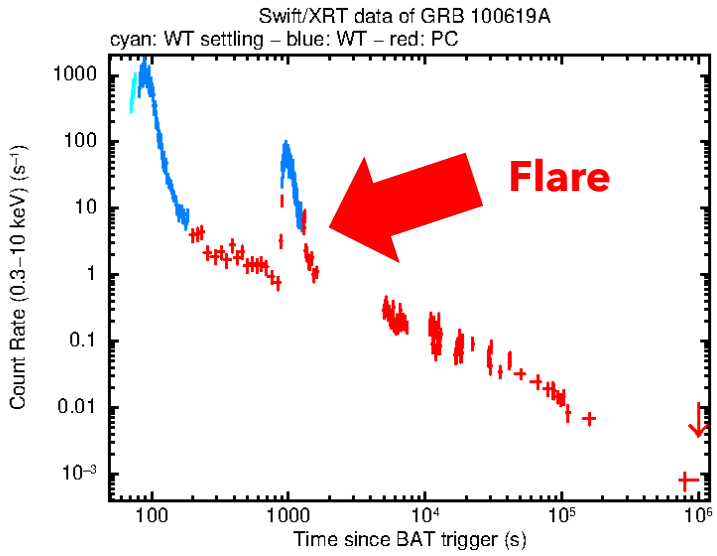
GRB PROMPT EMISSION PHYSICS: PROMPT-TO-AG TRANSITION

The prompt-to-transition phase shows many puzzling features (early steep decay, plateaus, flares, bumps, etc.).

Internal vs external origin?
Many proposed models, some putting some strong constraints on the central engine lifetime and/or energetics, on the efficiency of the prompt phase, etc.

Swift/XRT afterglows:





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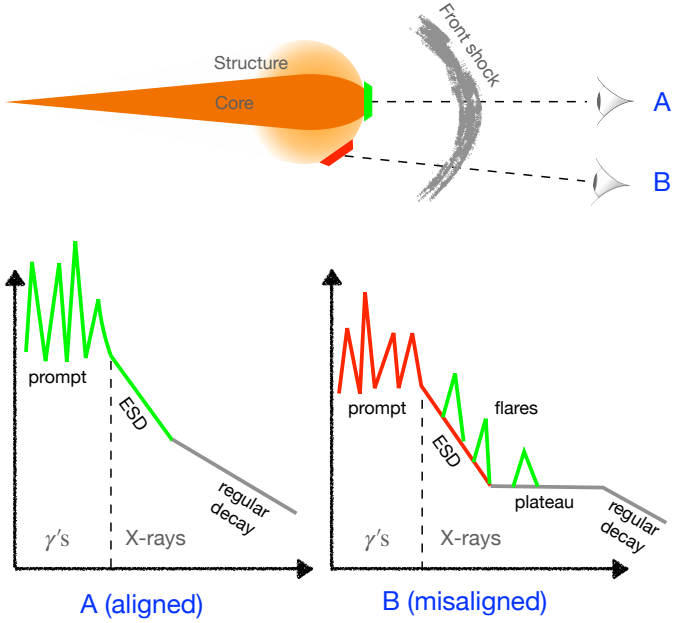
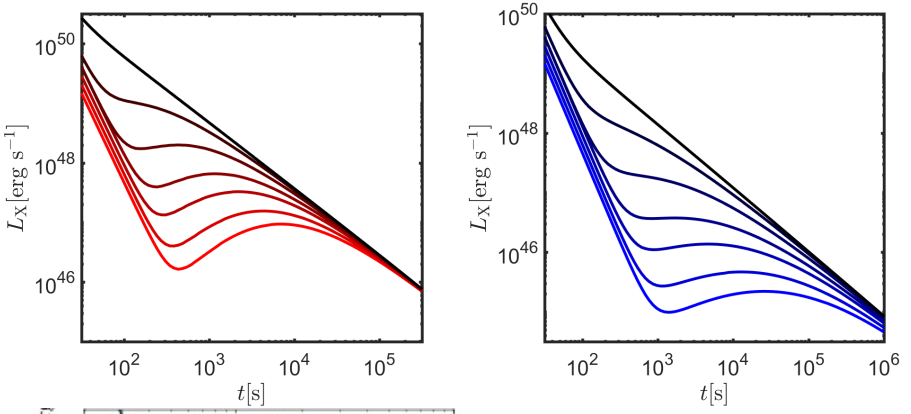
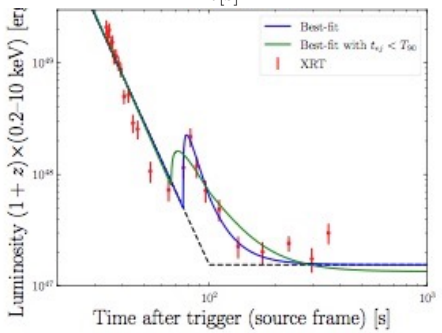
Internal vs external origin?
Many proposed models, some putting some strong constraints on the central engine lifetime and/or energetics, on the efficiency of the prompt phase, etc.

An example of a physical model with implications for the jet structure rather than the central engine activity: slightly off-axis structured jets





Beniamini et al. 20



Beniamini, Duque, Daigne, Mochkovitch

Duque et al. 22

GRB PROMPT EMISSION PHYSICS: PROMPT–TO–AG TRANSITION

The prompt-to-transition phase shows many puzzling features (early steep decay, plateaus, flares, bumps, etc.).

SVOM will explore this transition:
X-rays: ECLAIRs+MXT (+synergy with EP)
VT/GWAC/GFT+anti-solar pointing: increase the rate of early optical detection?

GRB PROMPT EMISSION PHYSICS: CONSTRAINTS FROM THE AFTERGLOW

One aim of SVOM is to build a sample of GRBs where both the prompt and afterglow emission are well characterized.

Afterglow observations can bring important constraints on the prompt emission physics, especially if they include the early afterglow:

- energetics/prompt efficiency
- Lorentz factor at the end of the prompt phase (AG onset)
- Magnetization at the end of the prompt phase (reverse shock)

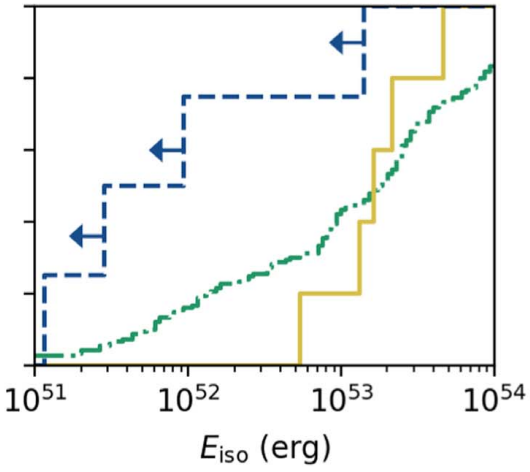
GRB PROMPT EMISSION PHYSICS: CONSTRAINTS FROM THE AFTERGLOW

One aim of SVOM is to build a sample of GRBs where both the prompt and afterglow emission are well characterized.

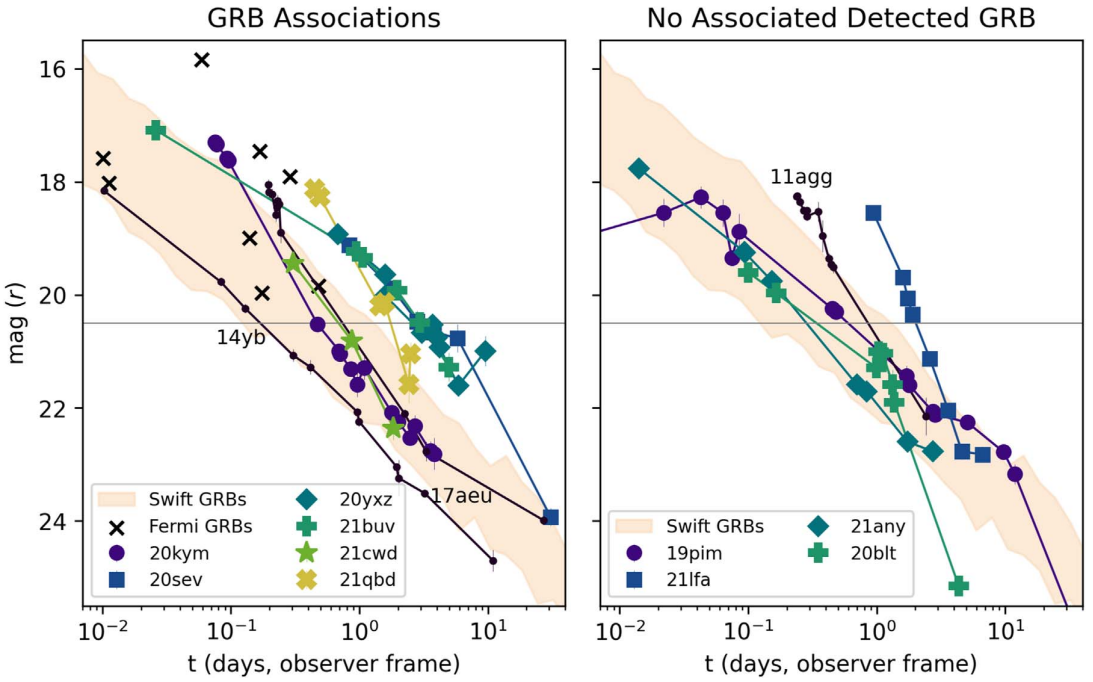
Afterglow observations can bring important constraints on the prompt emission physics, especially if they include the early afterglow:

- energetics/prompt efficiency

Prompt efficiency: an interesting constraint provided by recent detections of on-axis orphan afterglows by PTF/ZTF (Ho, Perley et al. 22,24)

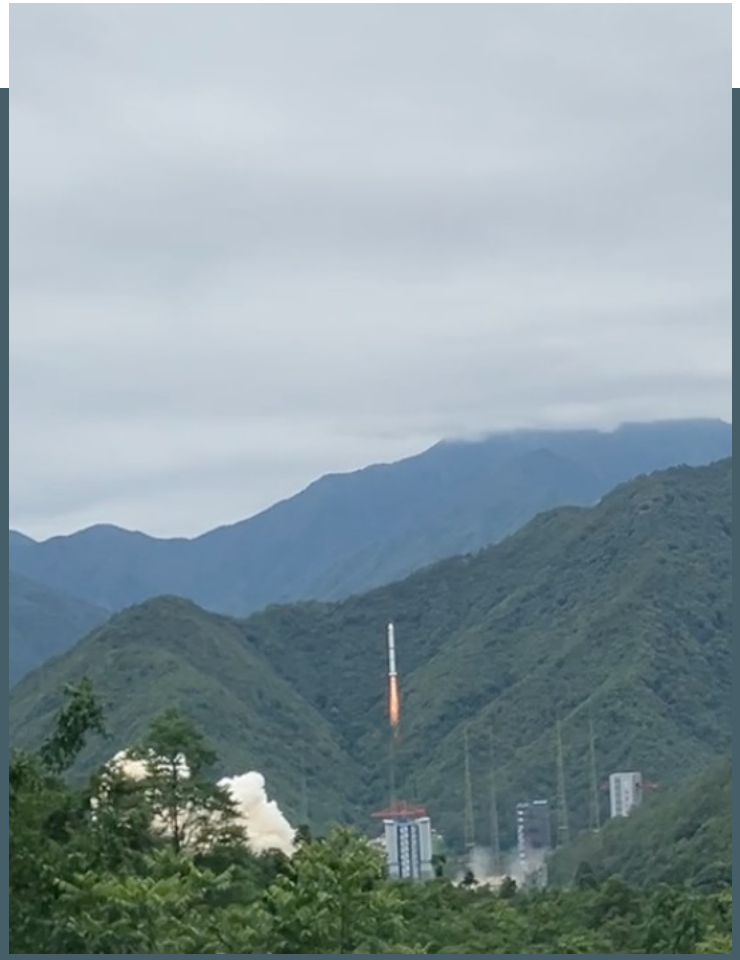


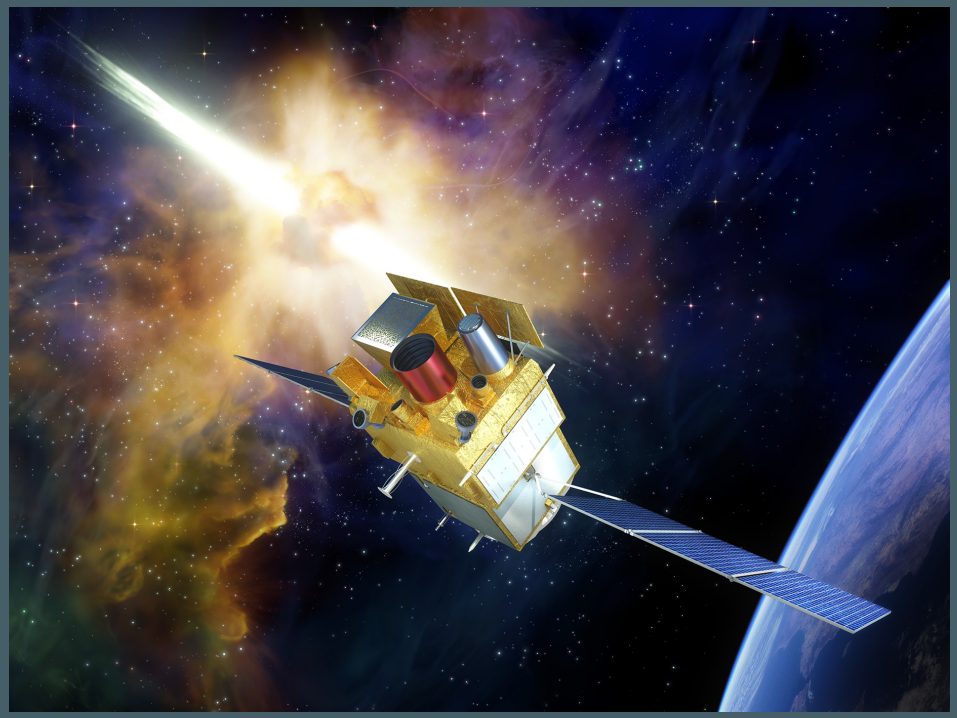
Ho et al. 22



Prompt GRB emission physics: many remaining open issues

SVOM will bring soon new observations: let's wait for the first detections with all SVOM instruments!

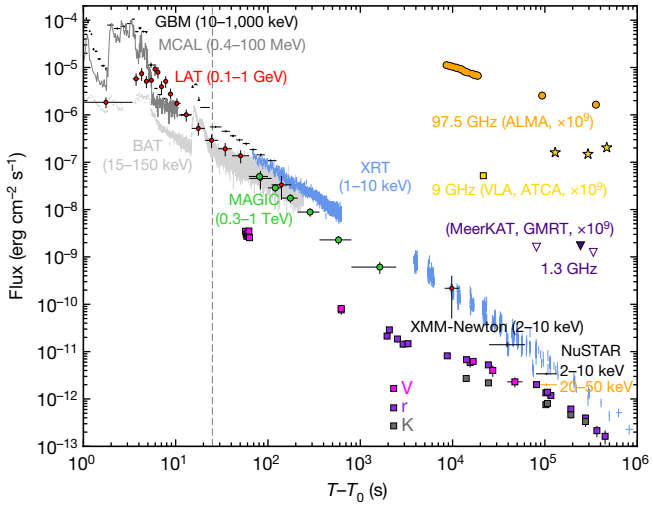


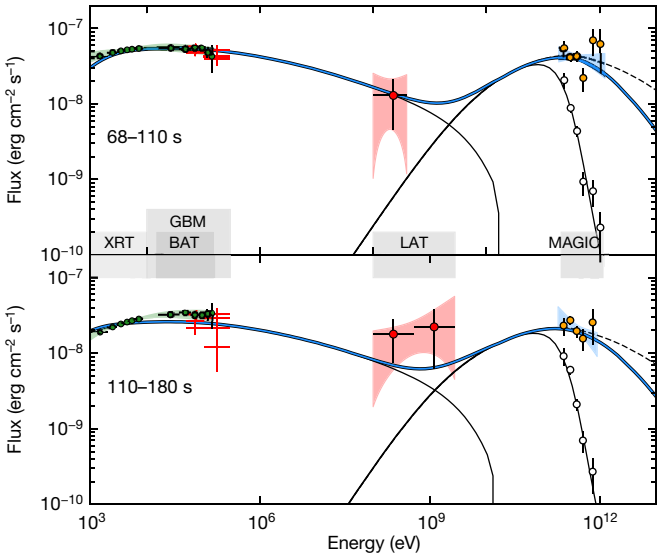


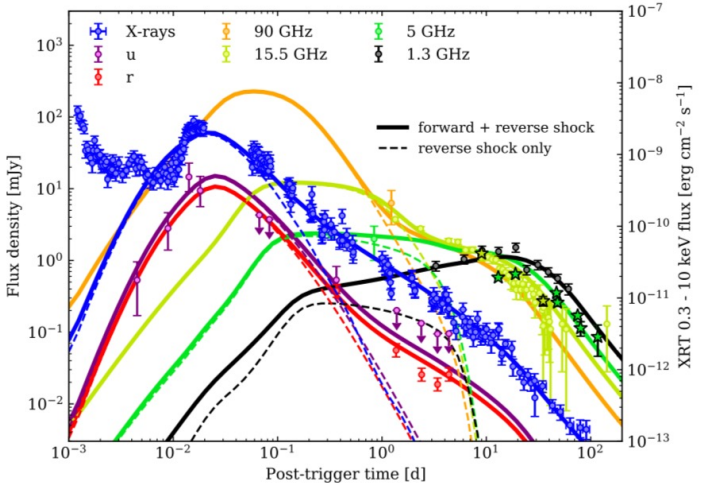
GRB afterglows at VHE

- First detections at very high-energy (MAGIC, HESS, LHAASO)

MAGIC collab. 2019a,b GRB 190114C (MAGIC) @ z=0.14



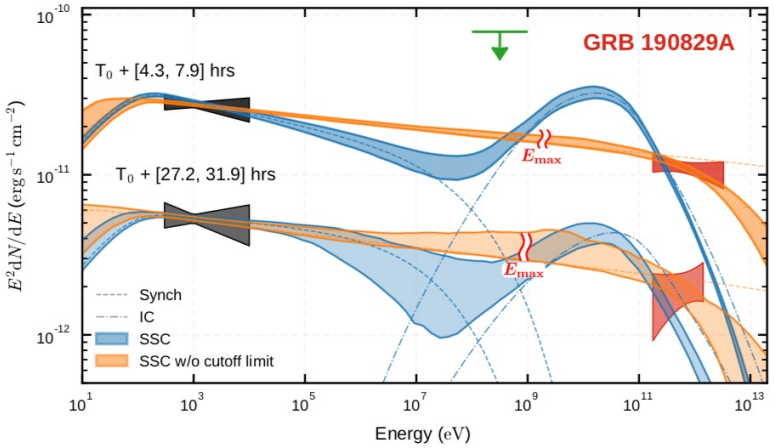




Salafia et al. 2021

GRB 190829A (HESS) @ z = 0.0785

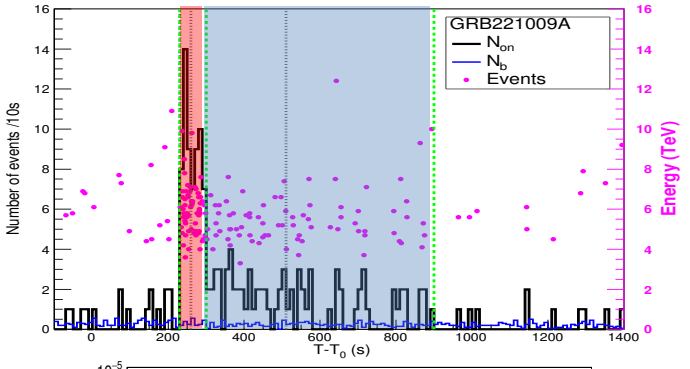
A low-luminosity burst



HESS collab. 2021

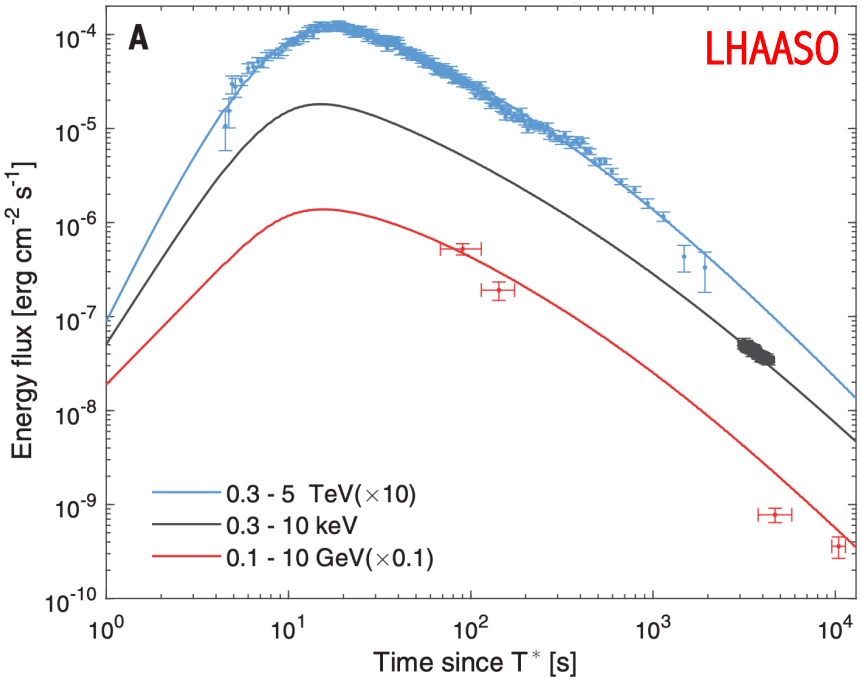
GRB afterglows at VHE

- First detections at very high-energy
- **The BOAT** ($E_{\gamma,iso} \sim 10^{55}$ erg!)
  (140 photons > 3 TeV ; E_{max} = 13 TeV !)

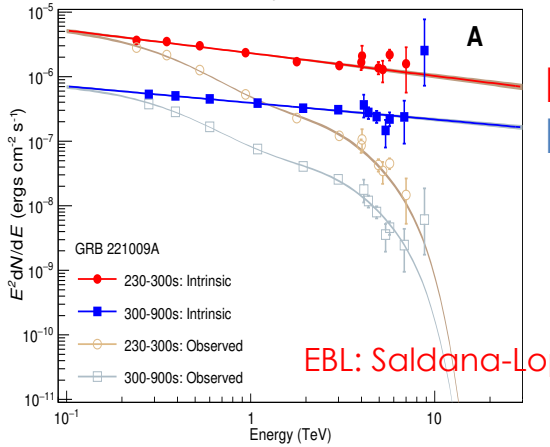


Lightcurve > a few TeV (KM2A)
= two peaks

GRB 221009A @ z=0.15

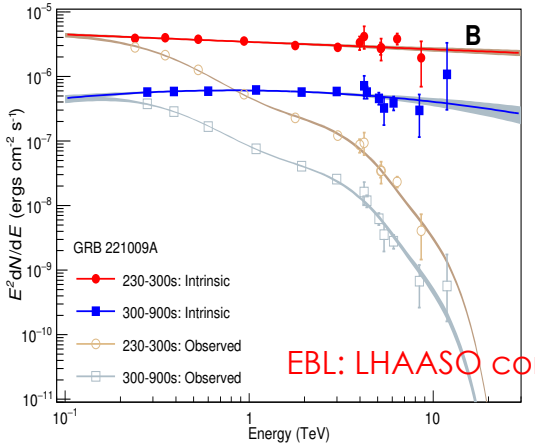


LHAASO Collab 2023a



PL -2.35
PL -2.26

EBL: Saldana-Lopez 21



PL
Log-parab.

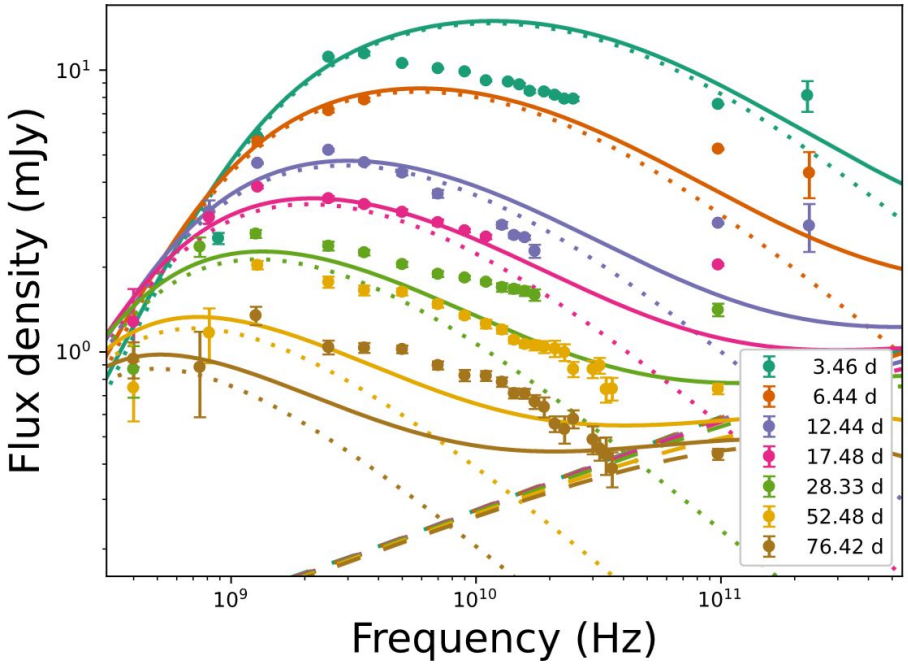
EBL: LHAASO constrained

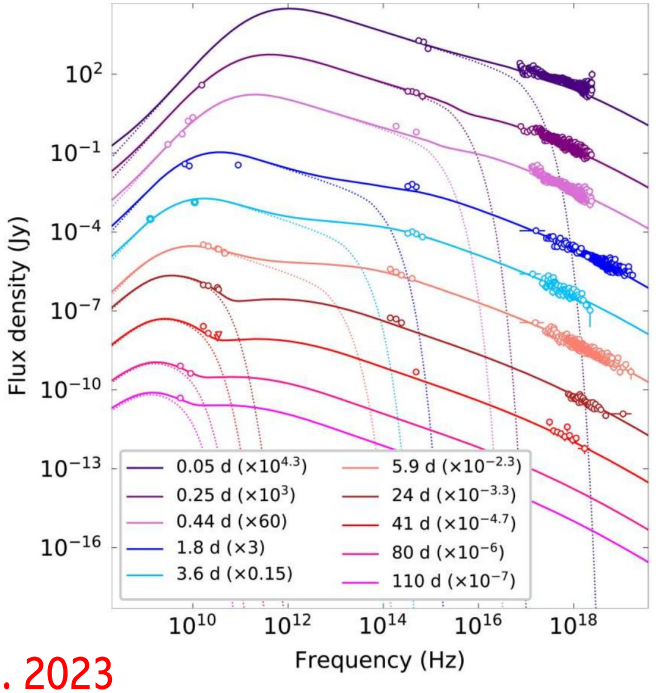
LHAASO Collab 2023b

GRB afterglows at VHE

- First detections at very high-energy
- **The BOAT** ($E_{\gamma,iso} \sim 10^{55}$ erg!) — **Excellent followup: multi-wavelength afterglow**

GRB 221009A @ z=0.15: difficult modelling





Laskar et al. 2023
Need to include the contribution of the RS

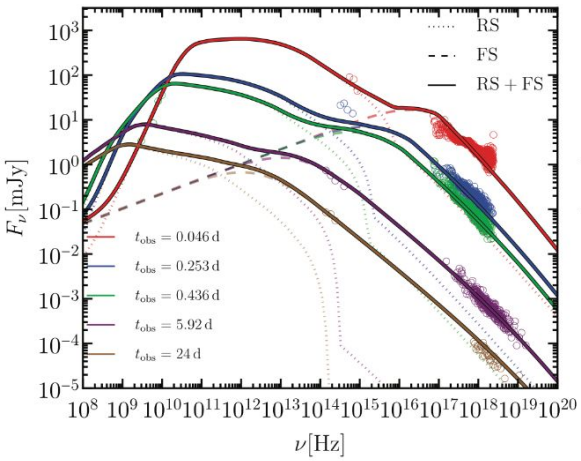
O' Connor et al. 2023
Need to include the lateral structure of the relativistic jet.

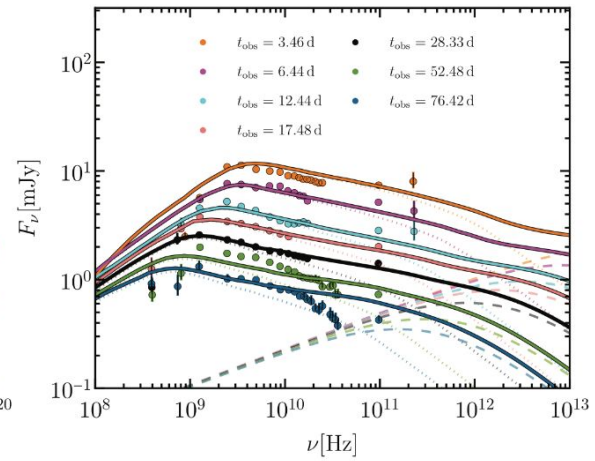
TeV emission (e.g. : Zheng et al. 23, Derishev & Piran 23)
Need to have a vary narrow core jet? Contribution from the reverse shock?

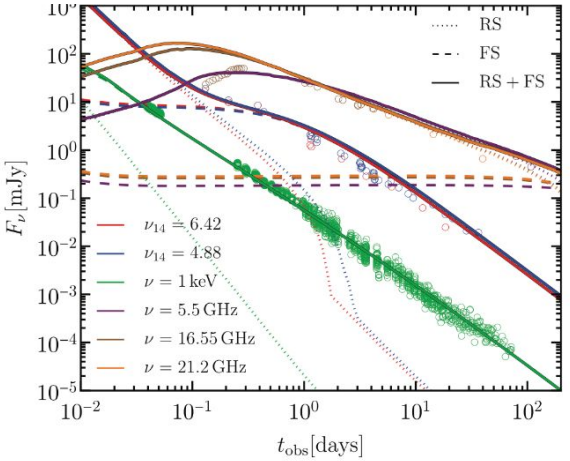
GRB afterglows at VHE

- First detections at very high-energy
- **The BOAT** ($E_{\gamma,iso} \sim 10^{55}$ erg!)

GRB 221009A @ z=0.15: difficult modelling







θ_{obs}	$E_{k,iso,c}$	Γ_c	$n_0(R_0)$	k	A_*	p_{FS}	$\epsilon^{FS}_{e,-2}$	$\epsilon^{FS}_{B,-4}$	$\xi_{e,FS}$	p_{RS}	$\epsilon^{RS}_{e,-2}$	$\epsilon^{RS}_{B,-4}$	$\xi_{e,RS}$	g	t_{GRB}
0.02 rad	2×10^{55} erg	300	0.1 cm^{-3}	2	0.33	2.4	1.0	1.0	0.01	2.03	8	10	0.01	1.3	500 s

Microphysics: FS & RS

Gill & Granot 2023

-Satisfactory fit from radio to X-rays (FS+RS ; structured jet)

-Consistent with the TeV emission? Still to be checked

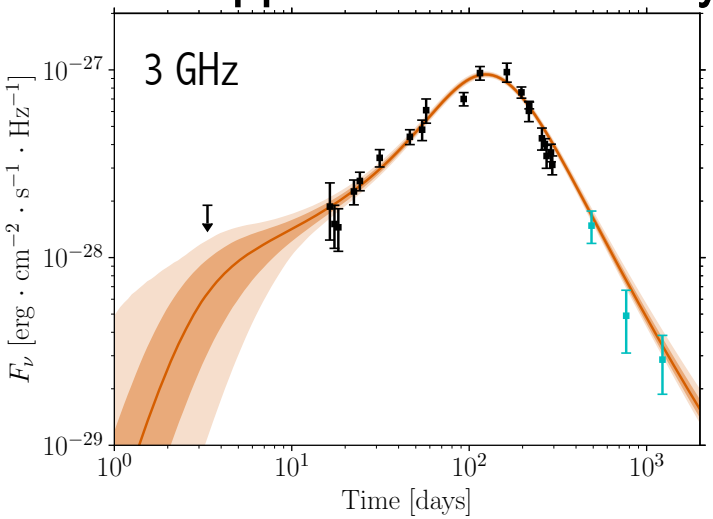
GRB afterglows at VHE

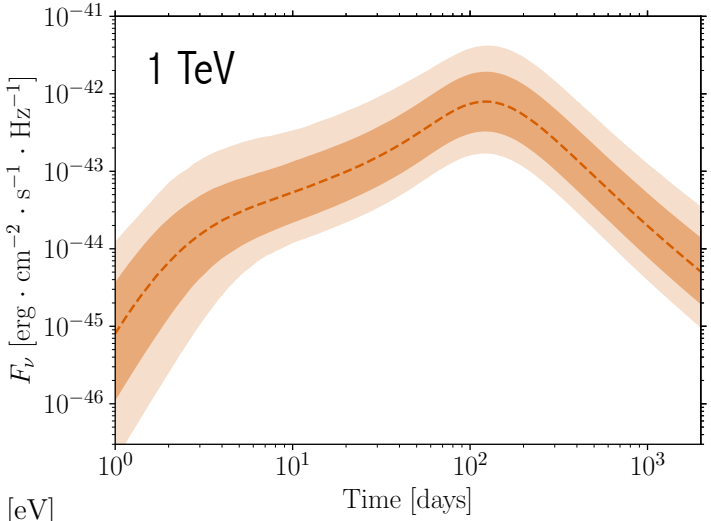
- First detections at very high-energy
- **The BOAT** ($E_{\gamma,iso} \sim 10^{55}$ erg!)

- **These VHE detections bring new constraints on GRB models:**
  - Obviously the **particle acceleration** & **radiation mechanisms** (e.g. SSC)
  - But also the **structure** and **dynamics** of the jet
    (e.g. potential RS contribution)
  - Potentially the **efficiency of the prompt emission**
    (e.g. low-L GRB 190829A detected by HESS, or no clear evidence
    for a prompt TeV emission in GRB221009A)
  - And potentially the density of the **external medium**, as SSC is favored by a higher density.
    = this is of interest of short GRBs associated to mergers

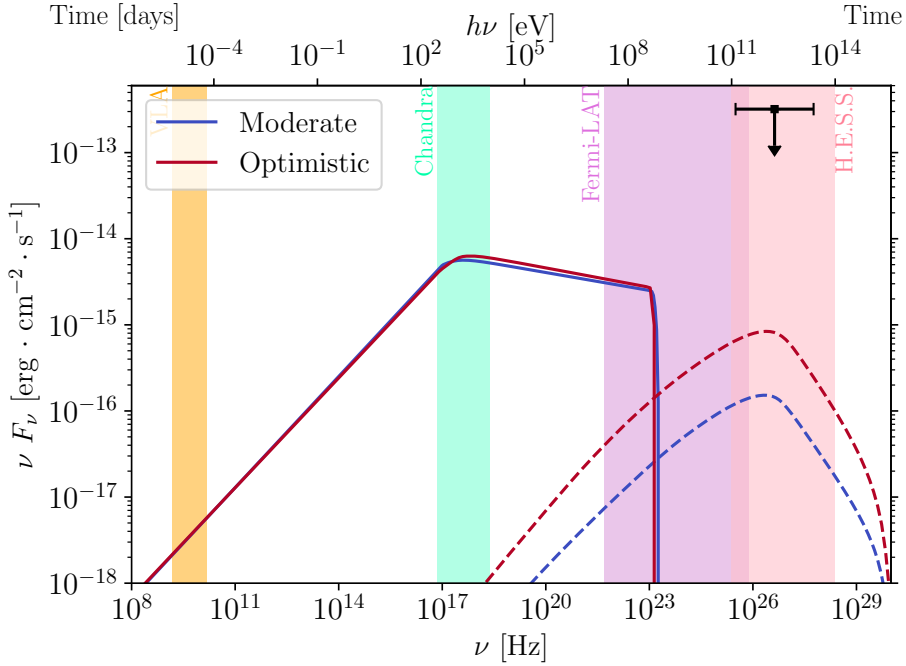
What could have been the VHE afterglow of 170817?

- The VHE afterglow of 170817 (D=40 Mpc, very offaxis) is predicted to peak well below the upper limit obtained by H.E.S.S.





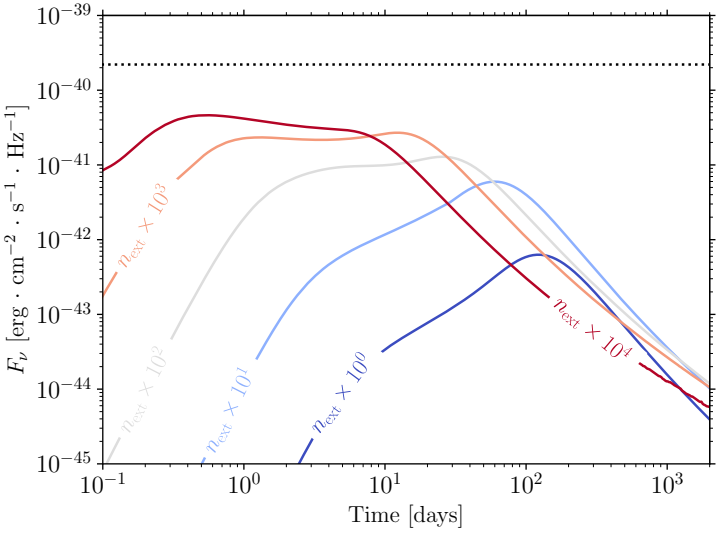
Spectrum at the peak

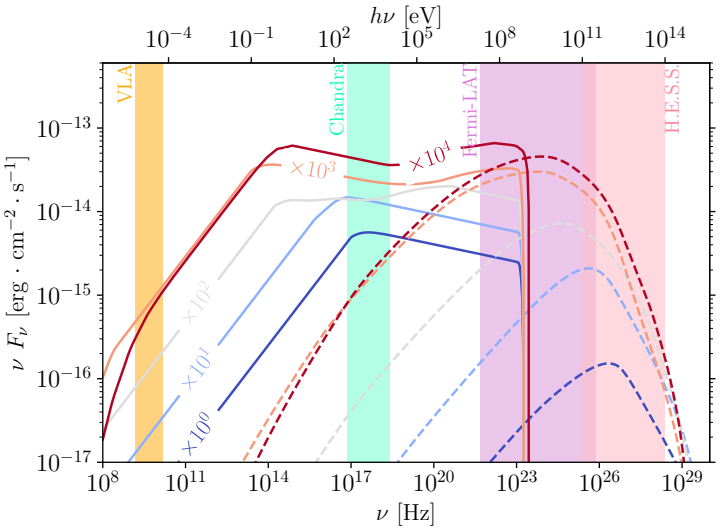


Pellouin & Daigne 2024

How to detect the VHE afterglow of 170817-like event?

- The VHE afterglow of 170817 (D=40 Mpc, very offaxis) is predicted to peak well below the upper limit obtained by H.E.S.S.
- **The VHE flux can be increased by**
  - **External conditions: lower viewing angle** (but on-axis observation is very unlikely for GW-triggered events)
  - **Intrinsic conditions: higher external density** (high external density are expected for fast mergers, if they exist: potential constraint on the physics of compact binaries)





Moderate (resp. Optimistic) case with a slightly less offaxis observation and a denser environment

$n_{ext} = 1$ cm^{-3} (instead of 10^{-3}-10^{-2} cm^{-3})
and $\theta_v/\theta_c = 6$ (instead of 12-18)

would be detectable with CTA up to 90 Mpc (resp 400 Mpc)

Pellouin & Daigne 2024