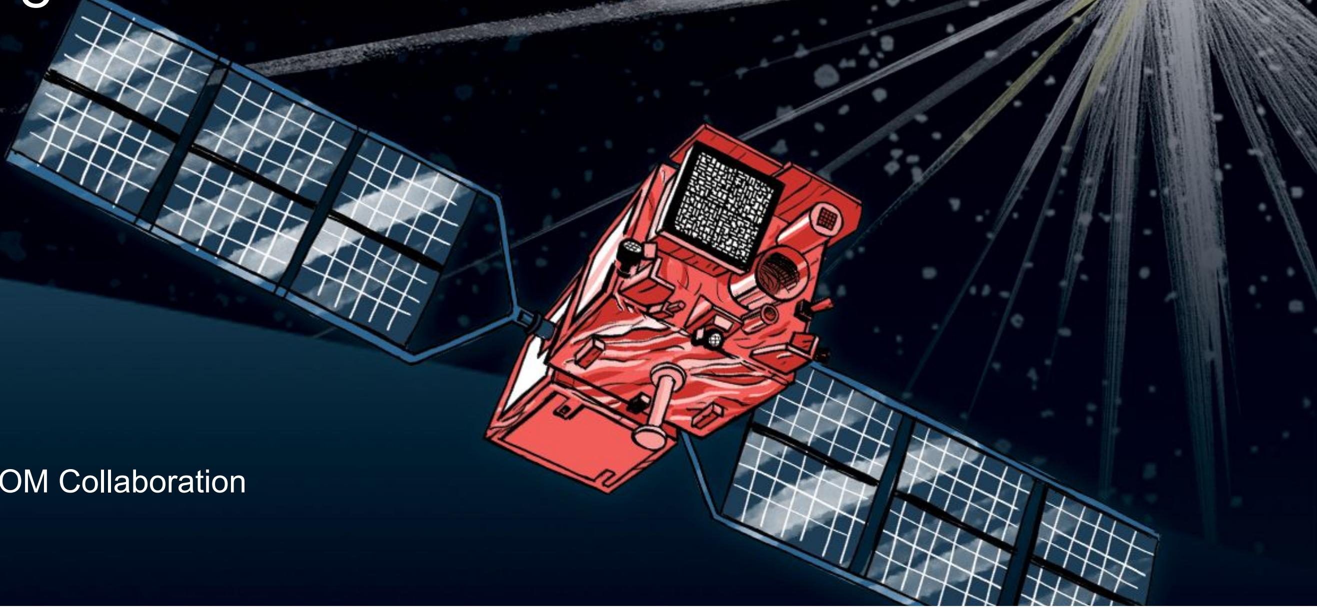
Gamma-ray burst and missions over the past 50 years

Why GRBs are still interesting today?

What KNC can bring into this research field ?



Damien Turpin on behalf of the SVOM Collaboration

damien.turpin@cea.fr

Kilonova-Catcher Webinar June 10, 2025

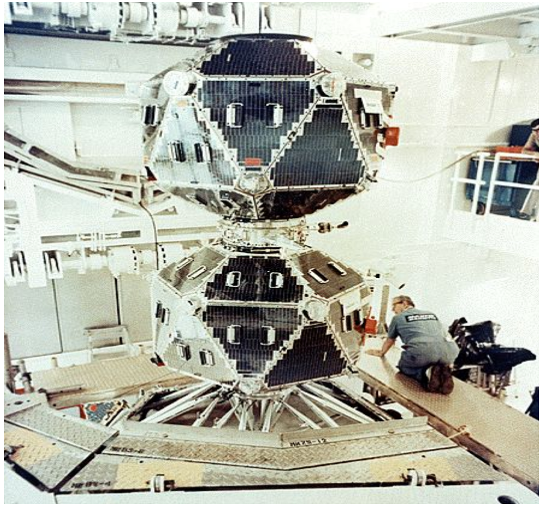
SVOM

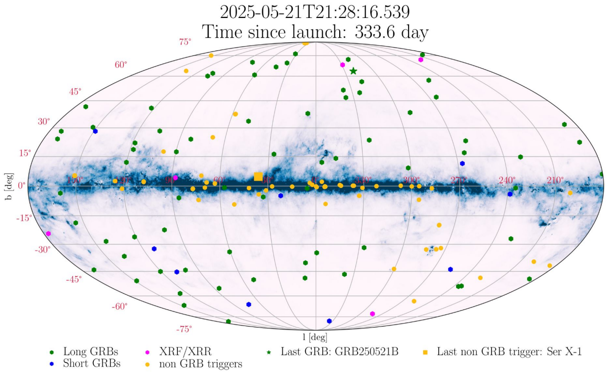
Outlines of the talk

Part I: The GRB mission from VELA to Fermi

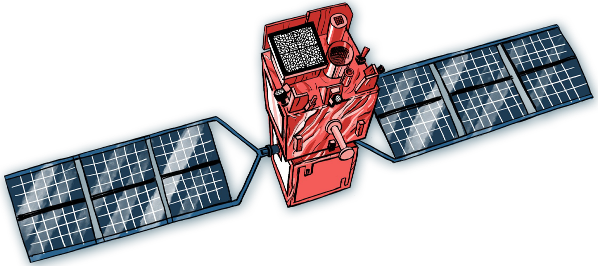
Part II: SVOM and Einstein Probe the new comers

Part III: What KNC can bring into this field of research?





KILONOVA CATCHER



Kilonova-Catcher Webinar June 10, 2025

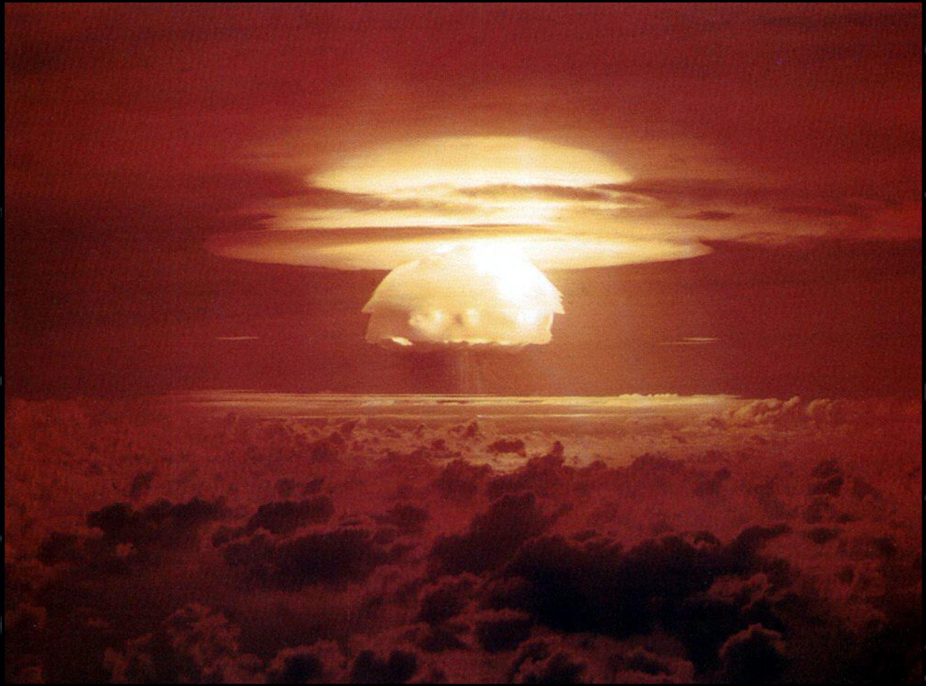
SVOM

Gamma-ray bursts

an exciting story...

...starting during the Cold War

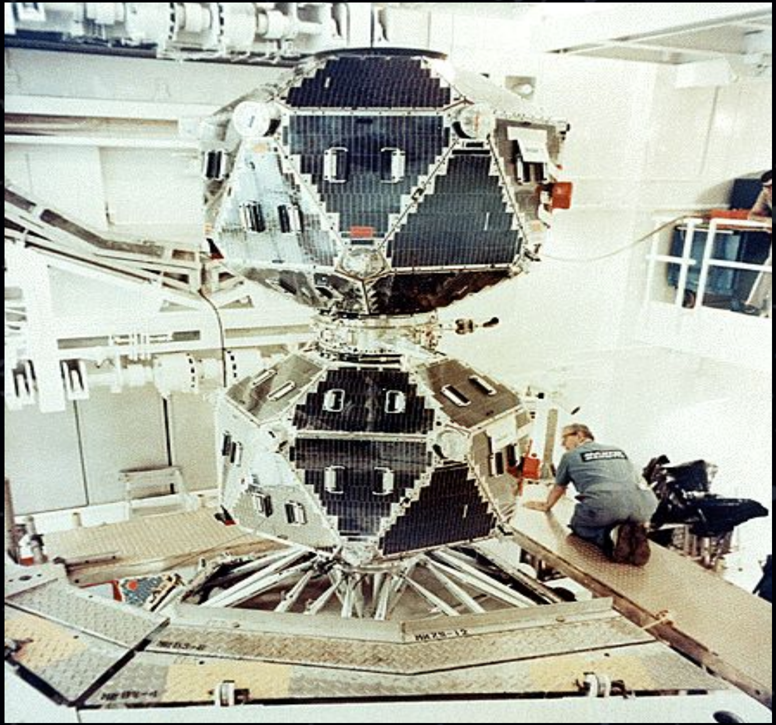
A little bit of history…



1963: USA, UK and USSR sign a treaty in Moscow to ban nuclear tests

Article 1: “In the atmosphere, beyond its limits, including outer space”

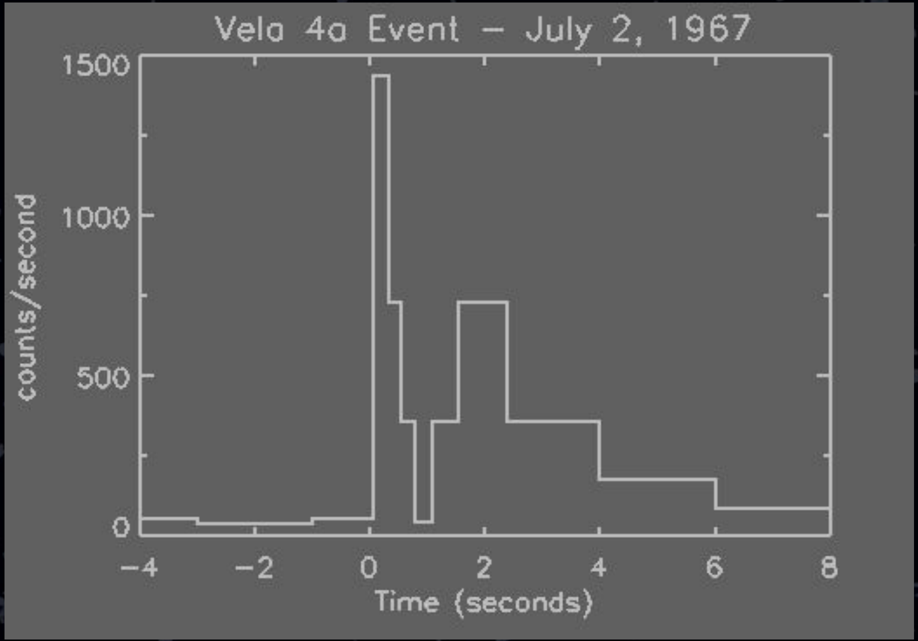
A little bit of history...



6 days later, the U.S. military launched two spy satellites, the Vela

Their instruments detect gamma-ray radiation!

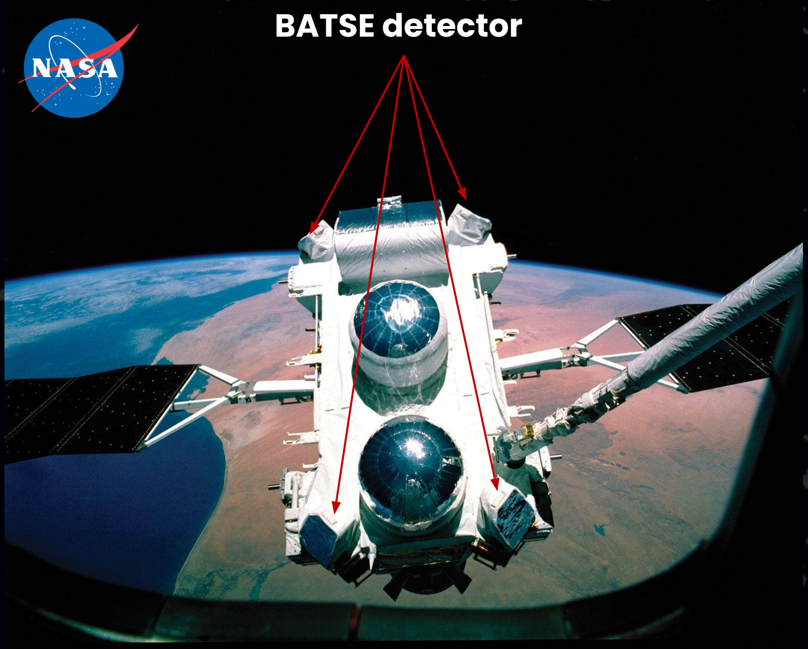
GRB 670702 : the first GRB detected by the VELA satellites

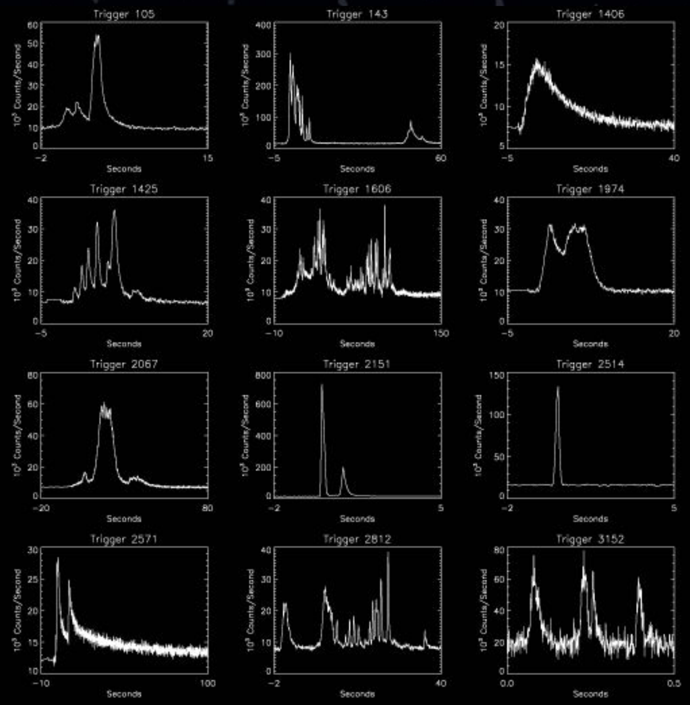


July 2, 1967, a gamma-ray burst is detected !

1973: the secret is out, and astrophysicists take up the case...

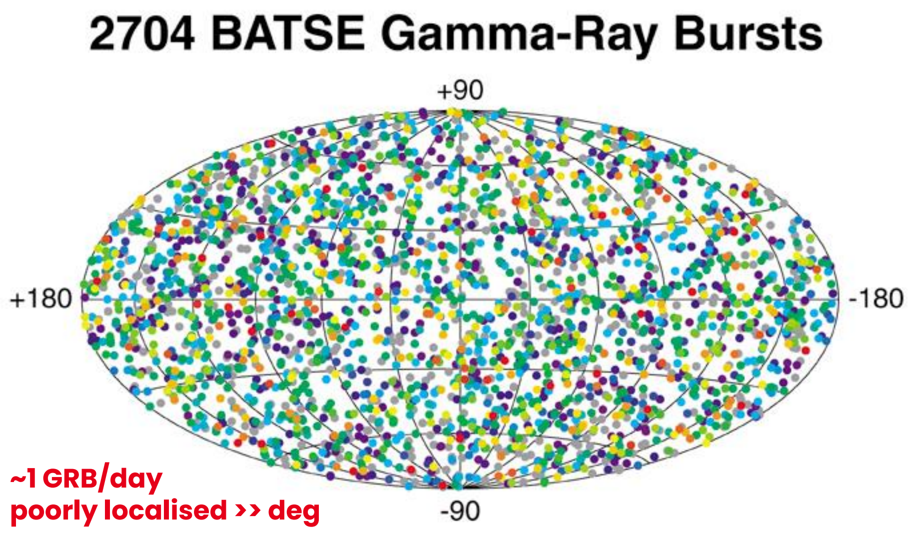
1991 – 2000 : CGRO/BATSE the 1st game changer mission in the GRB world

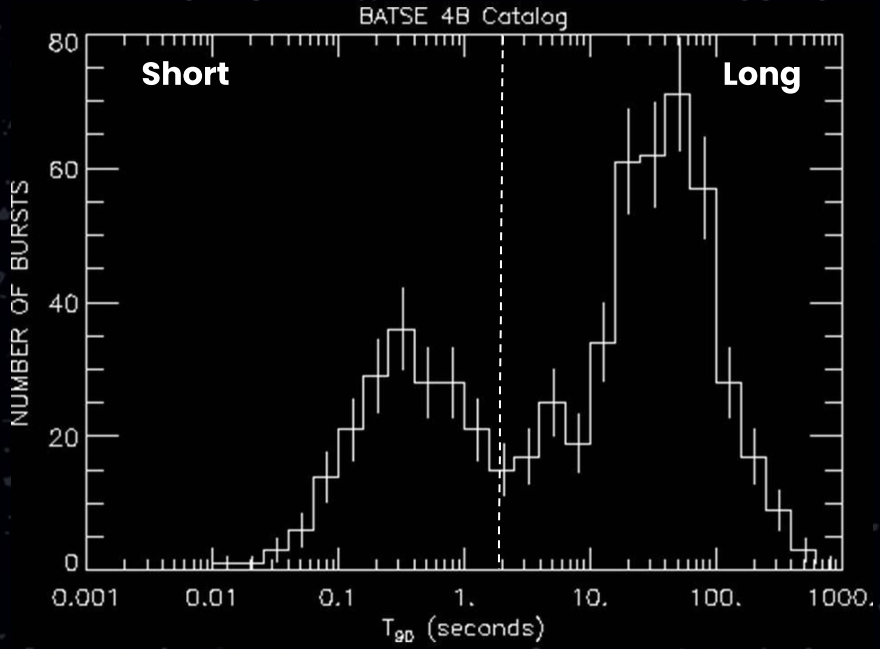




› 2000 GRBs recorded!

1991 – 2000 : CGRO/BATSE the 1st game changer mission in the GRB world



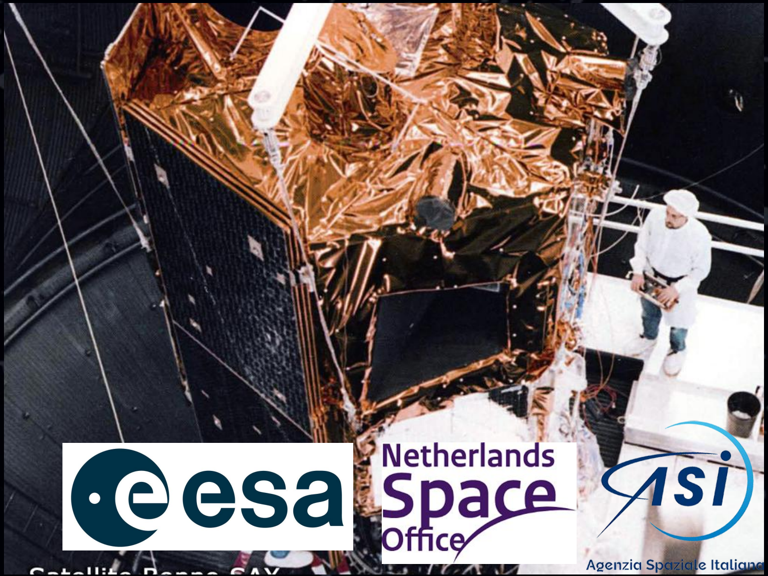


Where do those GRBs are coming? Milky Way sources or cosmologic origin?

1995: The Great Astronomy Debate
-> remember *Dr. Robert Nemiroff's webinar*

2 classes of GRBs = 2 different astrophysical scenario!
The "short" ones & the "long" ones

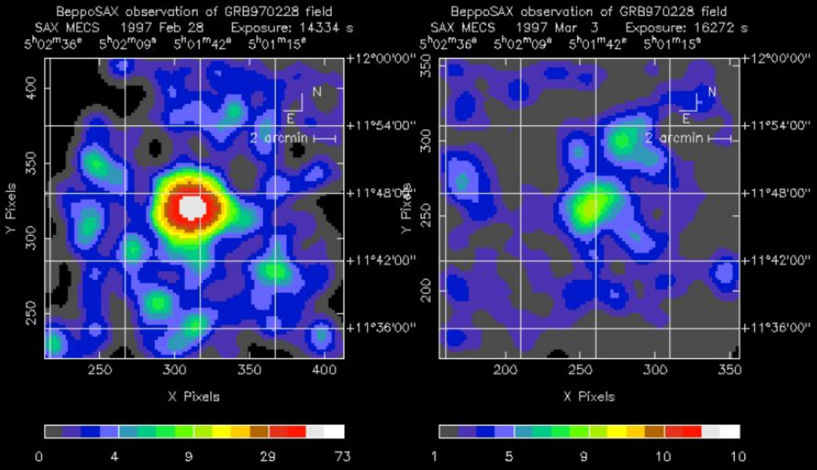
1996 – 2002 : BEPPO-SAX our 2nd game changer mission in the GRB world



- First arc-minutes position of GRBs.
- Position determination on rapid time scale
- First X-ray follow-up observations Broad band
- spectroscopy of different classes of X-ray sources

GRB 970228
first x-ray afterglow detection!

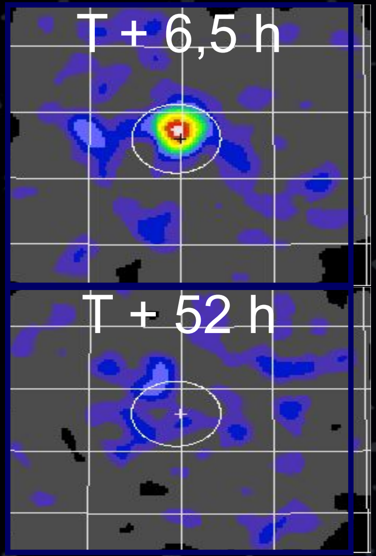
Arcminute localisation!



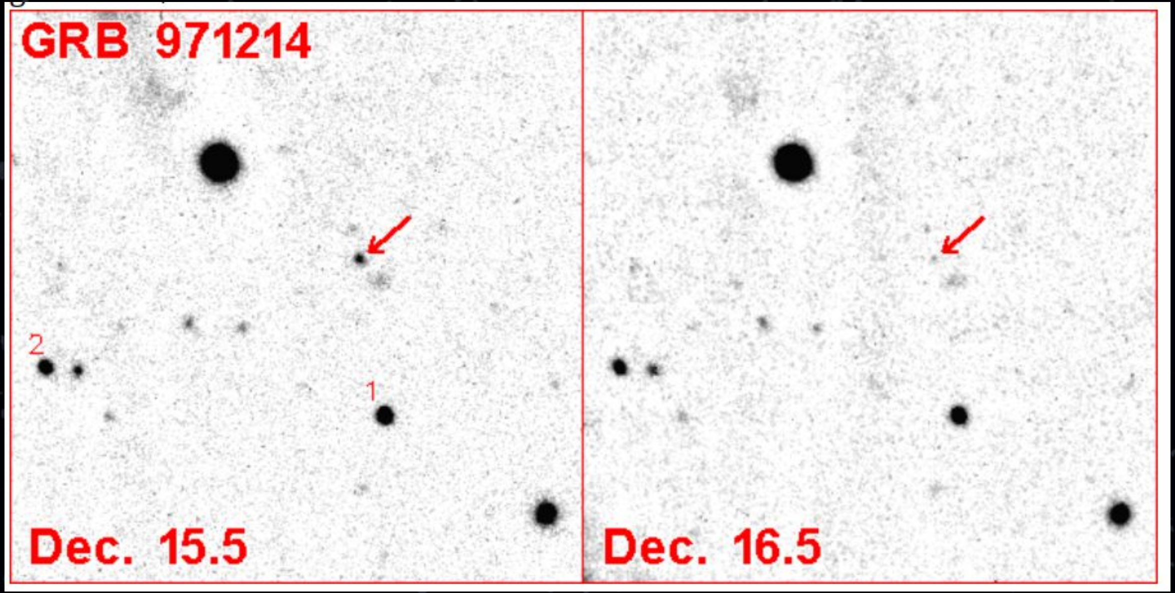
SVOM

1996 - 2002 : BEPPO-SAX our 2nd game changer mission in the GRB world

GRB 971214 x-ray afterglow



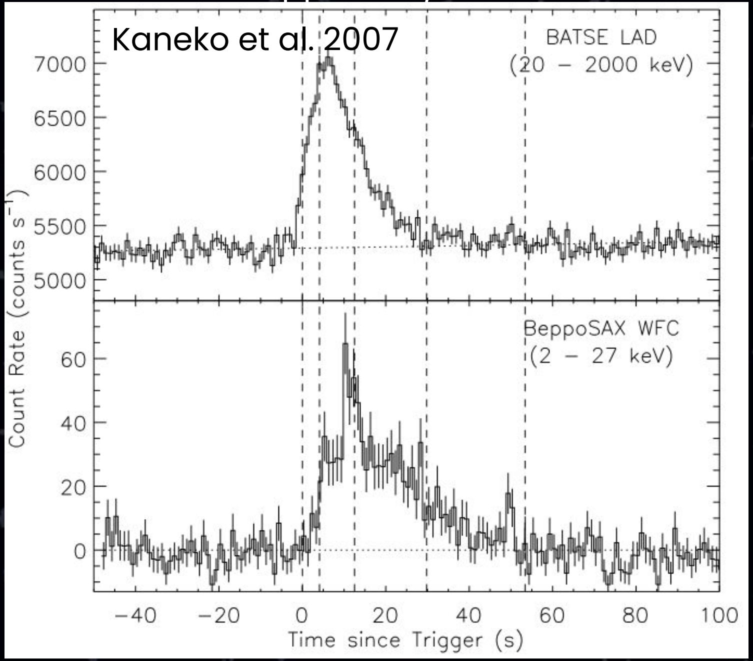
GRB 971214 optical afterglow! 3.5m ARC telescope

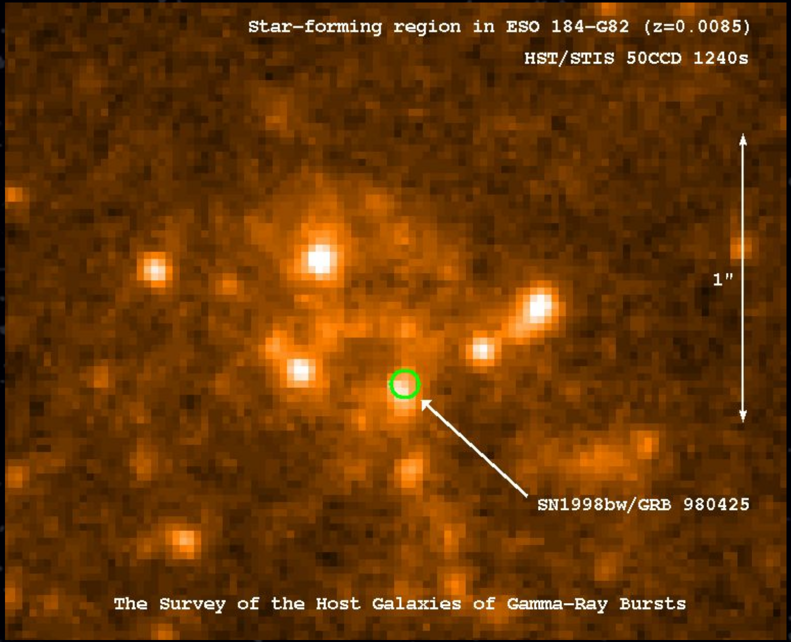


1996 – 2002 : BEPPO-SAX our 2nd game changer mission in the GRB world

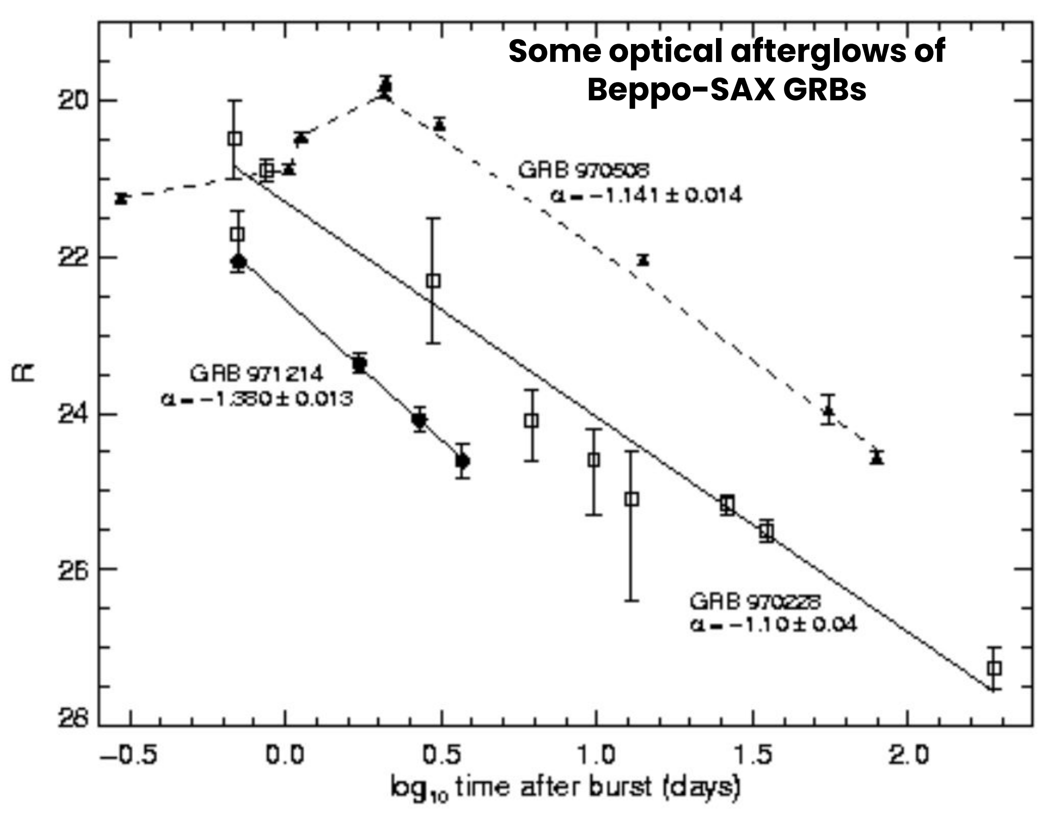
GRB 980425 and its associated Core-Collapse Supernova!

The GRB viewed by BATSE and Beppo-SAX/WFC





1996 – 2002 : BEPPO-SAX our 2nd game changer mission in the GRB world



By the end of 2002

- We know GRBs have all different light curves in gamma-rays but similar spectra
- They are followed by a "long" fading afterglow emission (x-rays, optical & radio)
- Long GRBs might be associated with CCSNe
- The GRB theory starts to be settled and tested

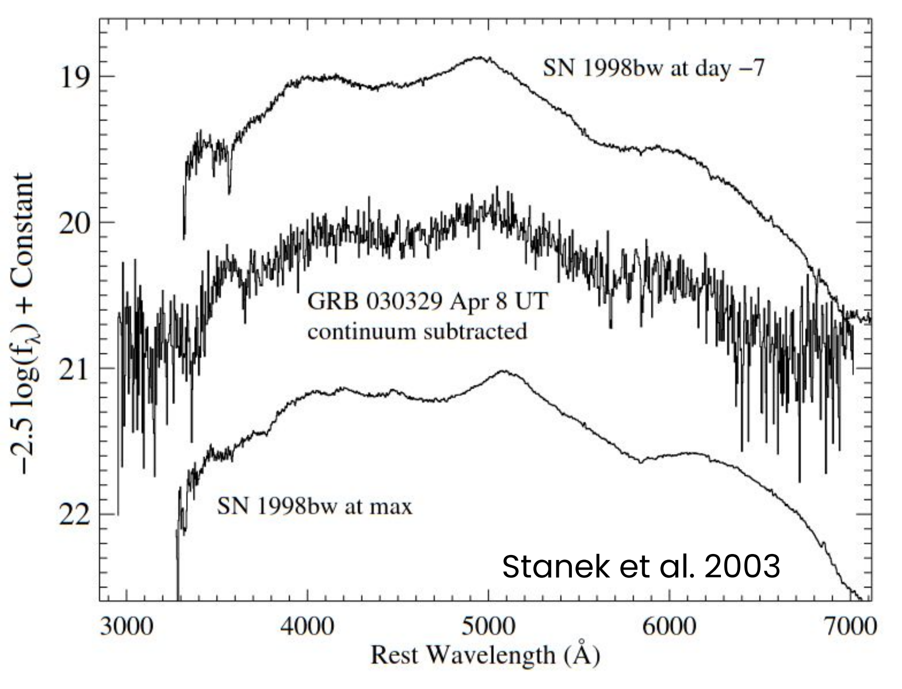
BUT

We have no idea about what happens between the the γ-ray flash and several hours after we finally detect the afterglow with sparse data

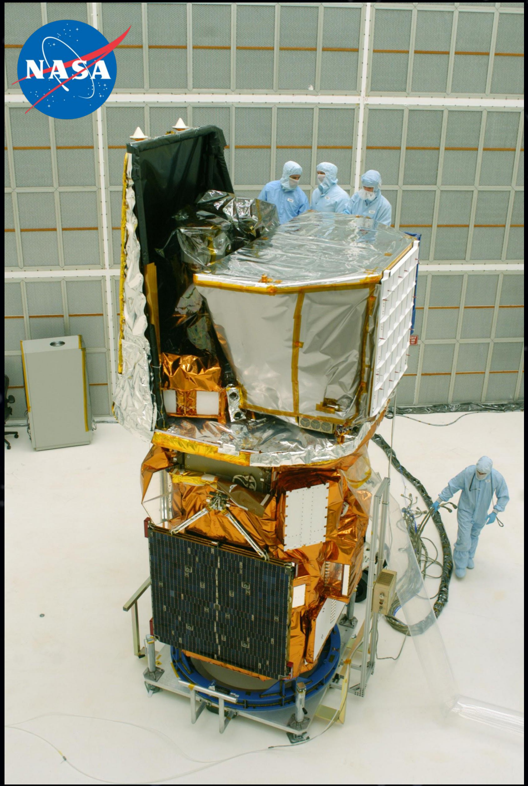
SVOM

2000 – 2008 : HETE-II confirms the origin of Long GRBs!

The association we've seen between GRB 980425 and SN1998bw is actually the astrophysical scenario for Long GRBs: the collapsar model (SNIc -> LGRBs) is viable!



2004 - Now : Swift our 3rd game changer mission in the GRB world



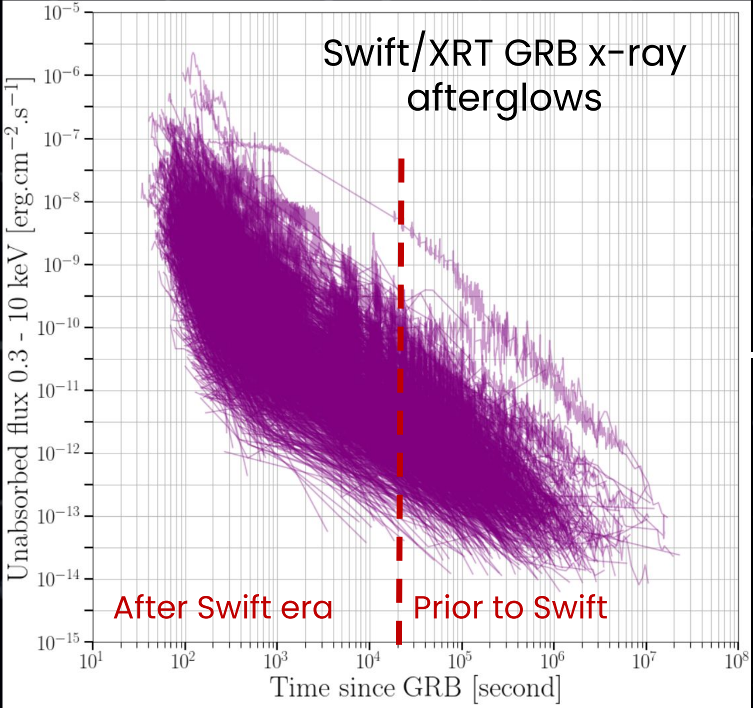
The legacy of Swift is unprecedented beyond the GRB science!

- Association of a coded-mask (BAT 15-150 keV, arcmin localization) with sensitive x-ray and UV-visible follow-up telescopes
- **Fast automatic slew on target (~1min)**
- **Fast alert communication (<30s the world knows the GRB arcminute/arcsecond position!!)**
- **Fast afterglow localization down arsecond accuracy (< few minutes)**
- Very versatile platform to perform fast Target-of-Opportunity observations (ToO): still today Swift performs more than 2000 ToO/year!!
- **Totally open source data**

For 20 years, Swift has significantly contributed to unify the GRB community (theorist + observers) and brought new opportunities in the field to the young generations!

2004 – Now : Swift our 3rd game changer mission in the GRB world

Fast automatic slew on target (~1min)



Thanks to Swift/XRT we have a great view of the early to late afterglow behavior and diversity

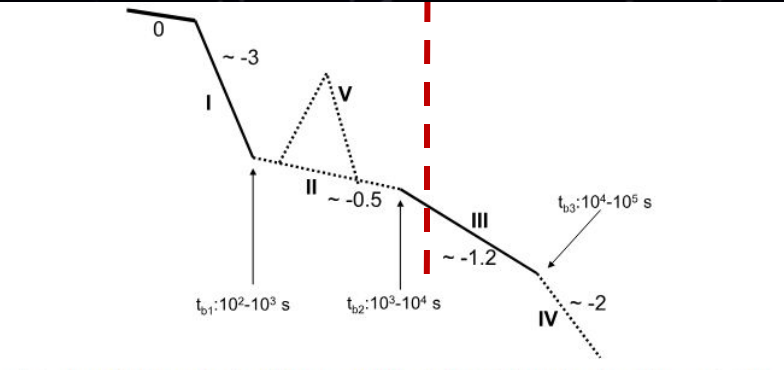
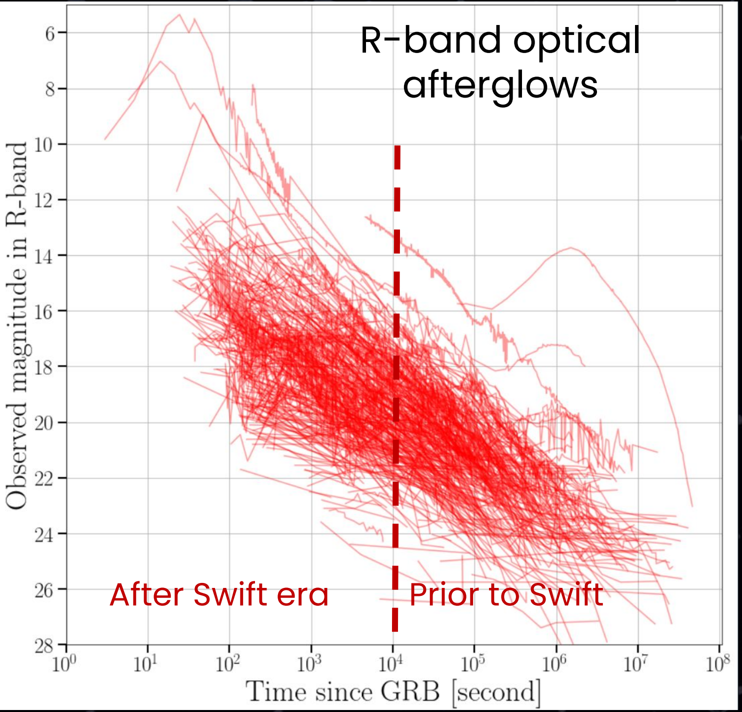


Fig. 1. A canonical X-ray afterglow lightcurve revealed by Swift XRT observations (from Zhang et al., 2006).

A great test lab for the GRB afterglow theory

2004 – Now : Swift our 3rd game changer mission in the GRB world

Fast alert communication
(<30s the world knows the GRB arcminute/arcsecond position!!)



Thanks to Swift/XRT we have a great view of the early to late optical afterglow behavior and diversity

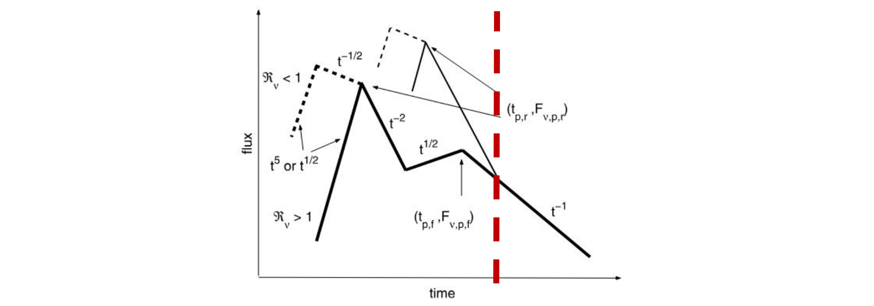


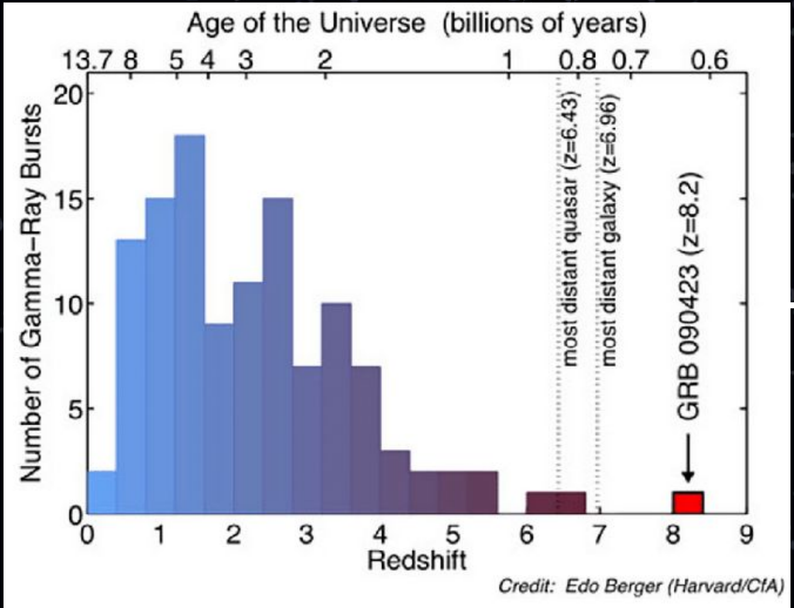
Fig. 2. Theoretically expected early optical afterglow lightcurves including emission from both reverse and forward shocks (from Zhang et al., 2003).

A great test lab for the GRB afterglow theory

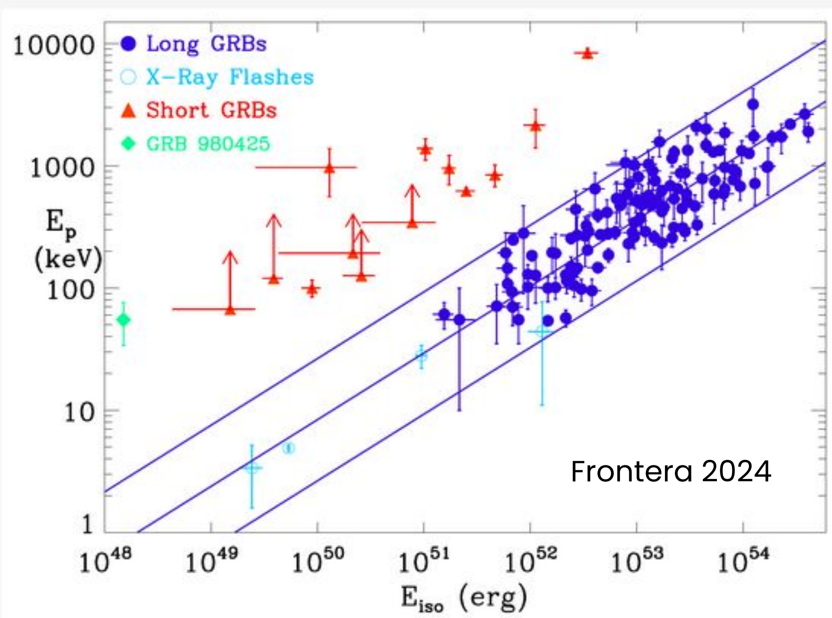
2004 – Now : Swift our 3 rd game changer mission in the GRB world

Fast afterglow localization down arsecond accuracy (< few minutes)

GRBs with redshift during 15 years of Swift operation

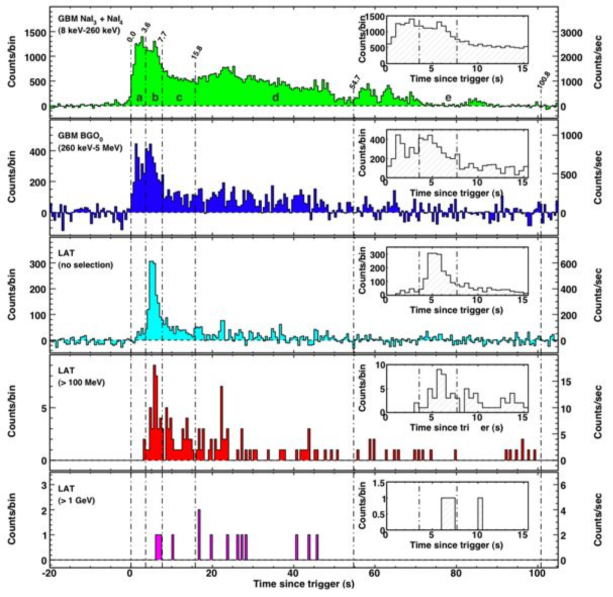


Better understanding of the GRB physics, environment, host galaxy properties, use GRB as cosmological probes

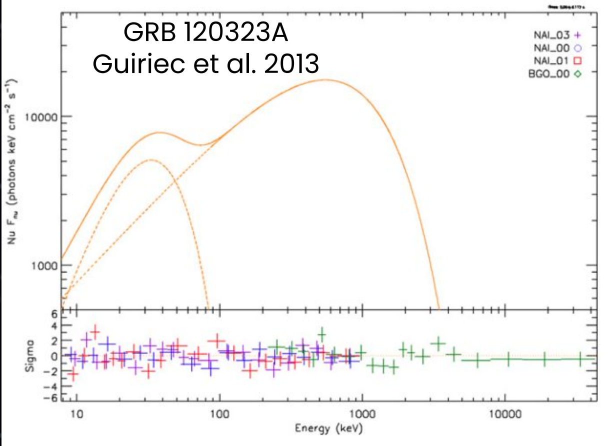


2008 – Now : Fermi reveals a more complex view of the GRB physics

GRB 080916C
seen by Fermi/GBM and LAT



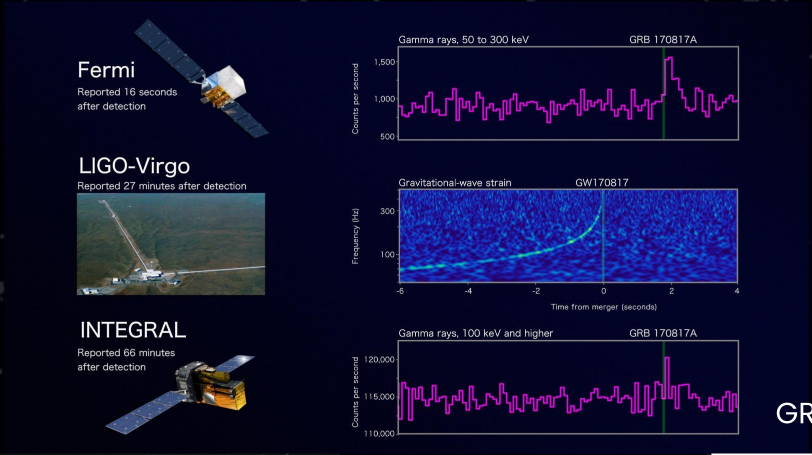
The GRB prompt emission spectrum can extend up to GeV gamma-rays



The GRB prompt emission spectrum can also show extra components at low energy towards the x-rays

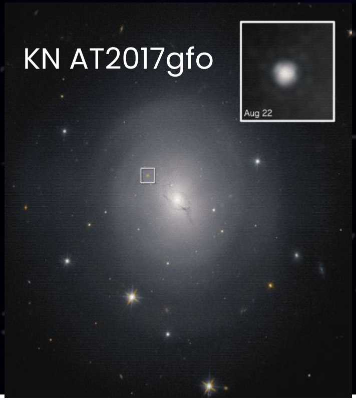
SVOM

2008 - Now : Fermi is one of the primary actor in the Multi-messenger physics

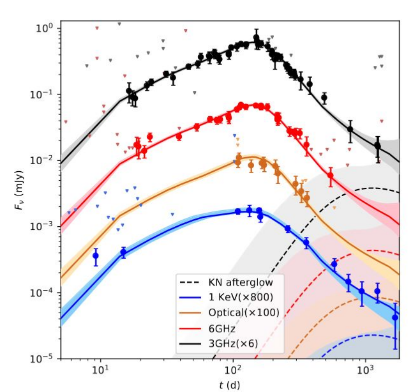


GW 170817 /GRB 170817A

GRB 170817A afterglow



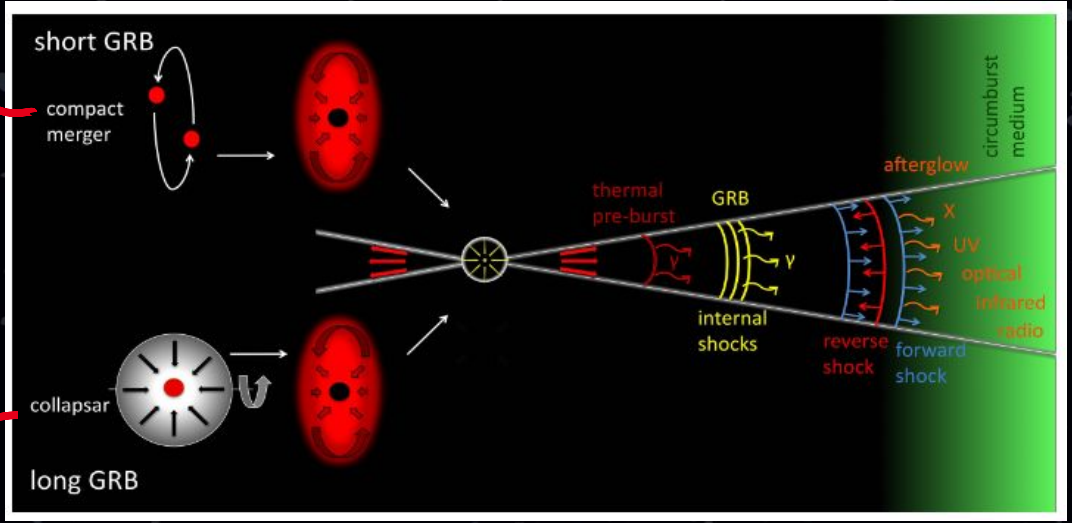
Wang et al. 2022



The GRB general (and very incomplete) picture

Indirect guess

- large offset from their host galaxy nucleus
- Less energetic (prompt and afterglow)



From Gomboc 2012

Direct evidences

- GRB longer $T_{90,\gamma}$>2sec regularly associated with SN Ic days after the T_{GRB}

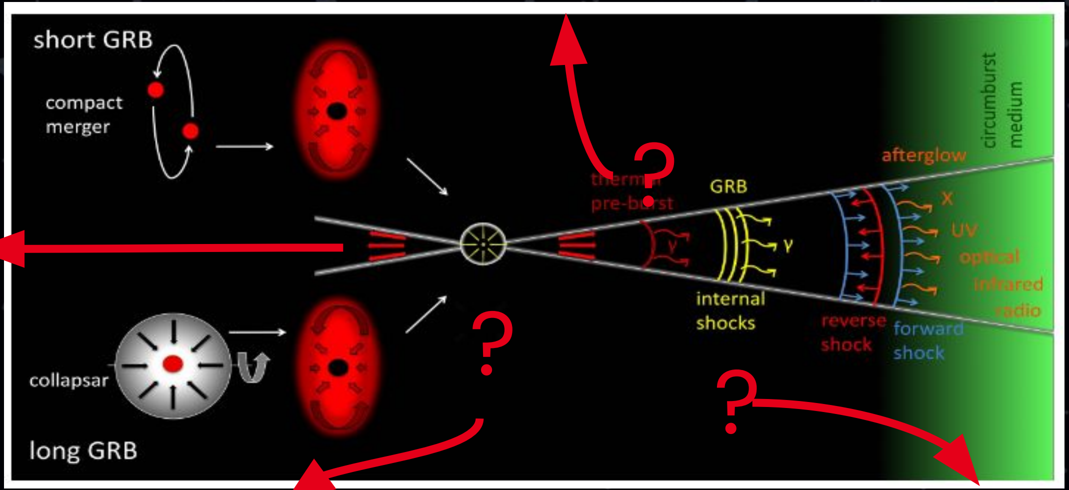
The GRB general (and very incomplete) picture

Prompt non-thermal spectra

- Synchrotron?
- Dissipative photosphere?
- Others?

jetted emission

- Prompt physics condition
- Direct obs. of the afterglow jet break signature

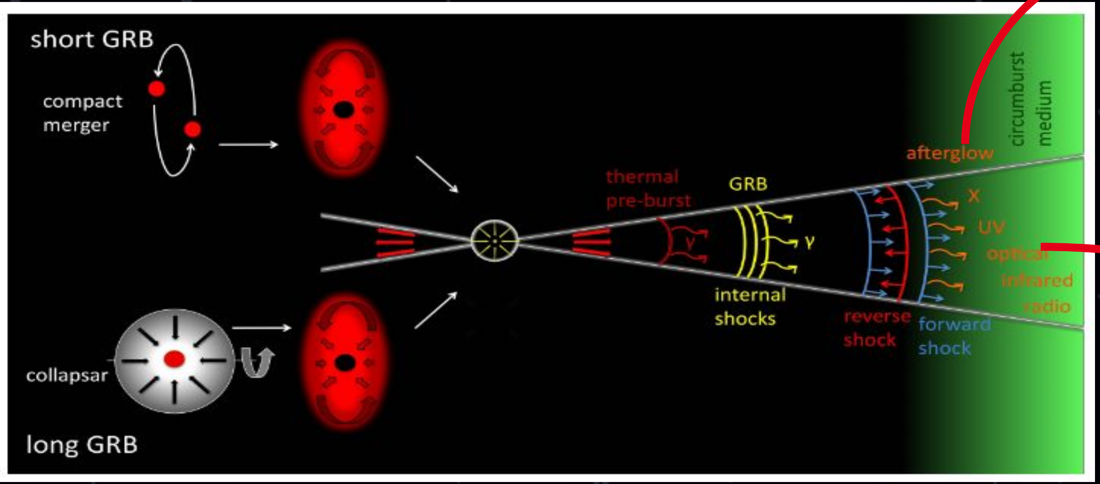


Central engine
Accreting BH or magnetar?

jet physics

- composition?
- energy profile?
- dissipative mechanisms

The GRB general (and very incomplete) picture



Afterglow light curve

- very diverse, why?
- Flares and late time activities?
- Plateau sometimes…
- Reverse shock sometimes…

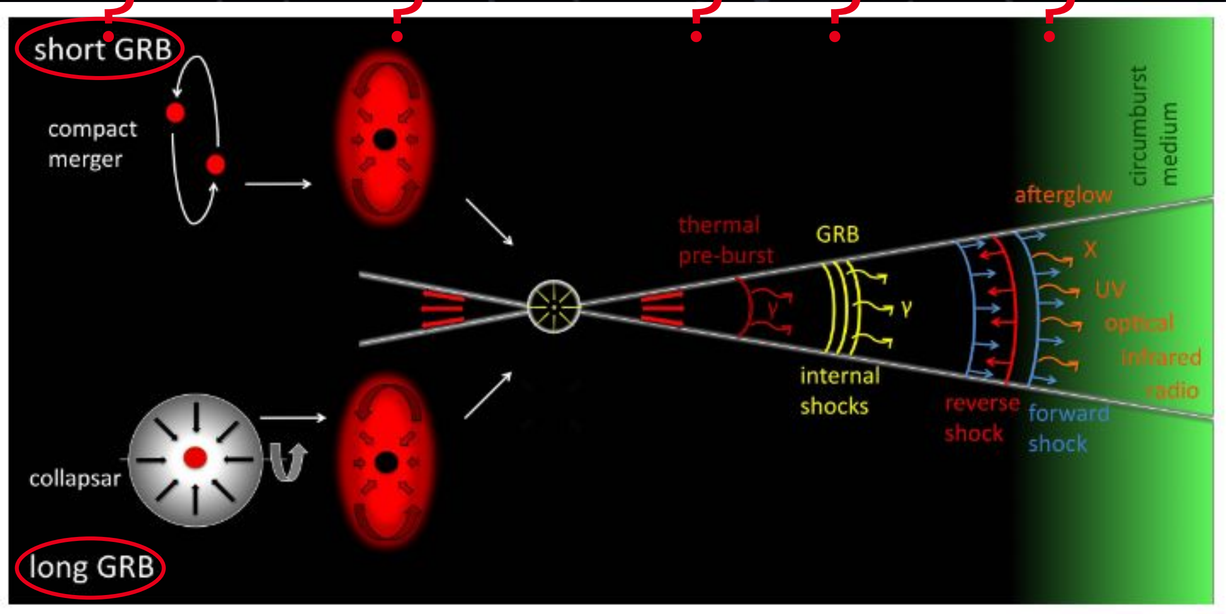
Afterglow Non-thermal spectra

- Synchrotron from a jet/ISM relativistic shock
- Additional components?
- Any Cosmic-ray acceleration?

We still have work to do...

Recent GRB detections have reveal that short GRBs may arise from collapsar and Long GRBs from mergers....

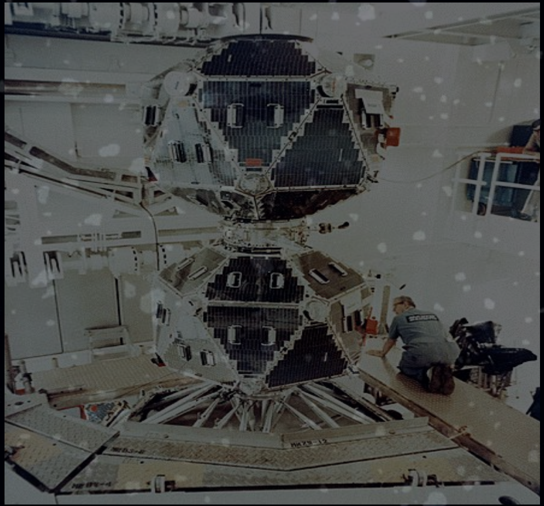
Type I GRBs



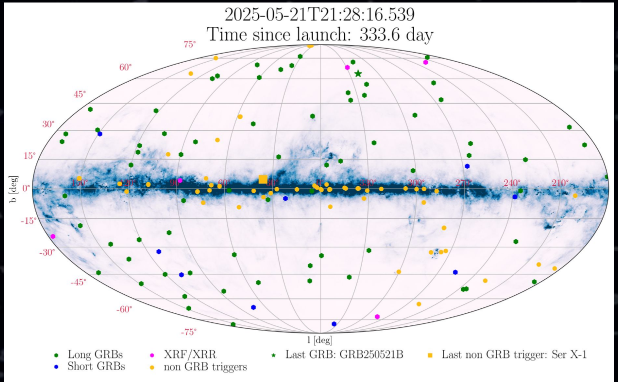
Type II GRBs

Outlines of the talk

Part I: The GRB mission from VELA to Fermi



Part II: SVOM and Einstein Probe the new comers



II- SVOM and Einstein Probe the 4th game changer in the GRB world ?

2024 - Now

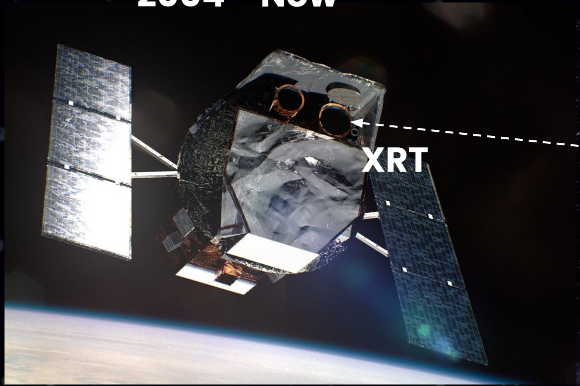
https://www.svom.eu/en/home/

2024 - Now

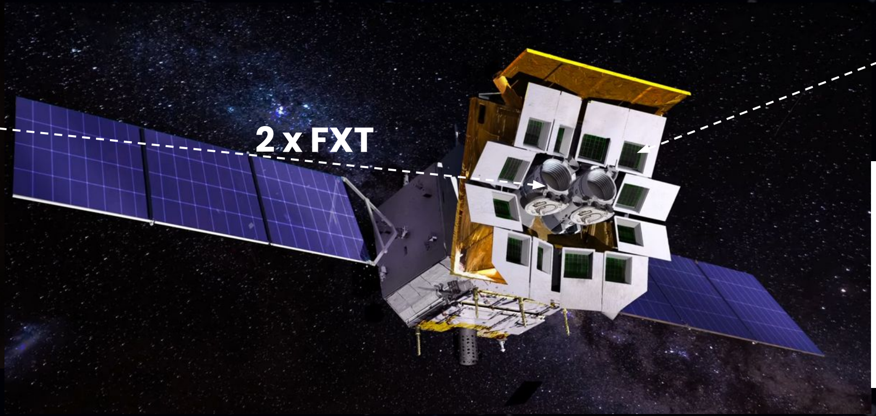
https://ep.bao.ac.cn/ep/

II- EP: a satellite to study the x-ray transient sky with unprecedented capabilities

2004 - Now



~1470 kg

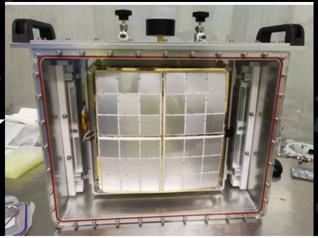


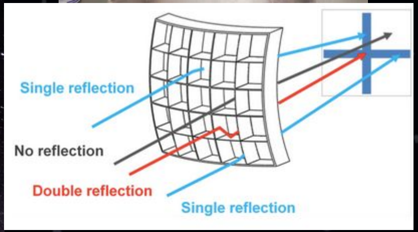
~1450 kg

Wide field x-ray telescope (WXT)

Micro pore optics new technology to focus x-rays

Much larger Field of view





12 modules (17kg each)

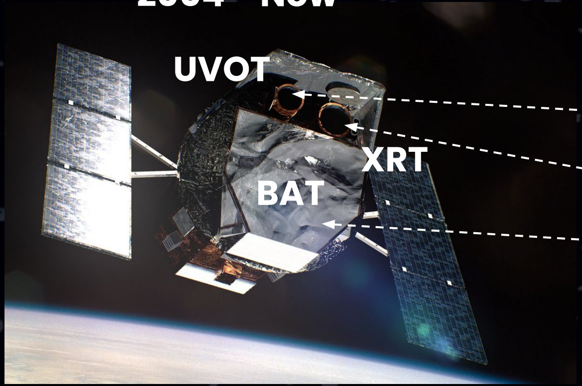
Total FoV = 3600 sq.deg
(1.1 sr ~ 1/12 of the entire sky)

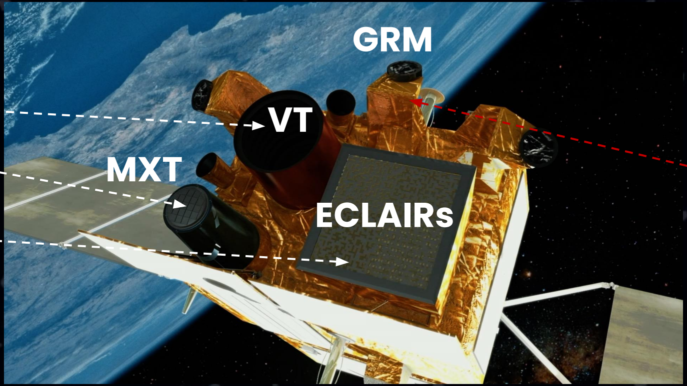
II- SVOM: a satellite inherited from the Swift and Fermi missions

2004 - Now

2024 - Now

2008 - Now





~1470 kg

930 kg

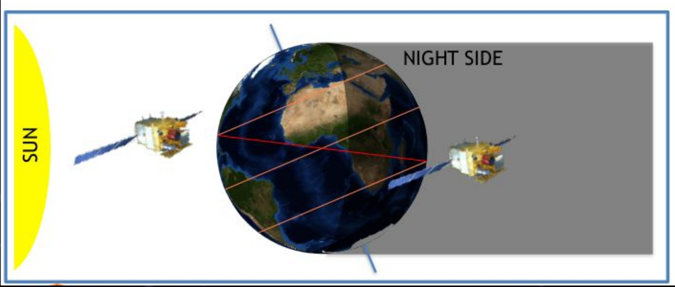
~4300 kg

II- 2024 June, 22nd when the SVOM story began

II- SVOM and EP are placed in a Low Earth Orbit (LEO)

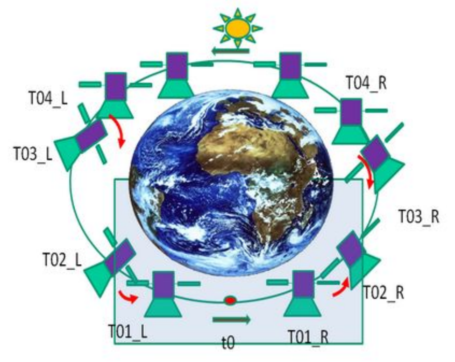
SVOM Anti-Solar pointing strategy

~625 km, ~29° inclination angle, 1 orbit ~ 96min



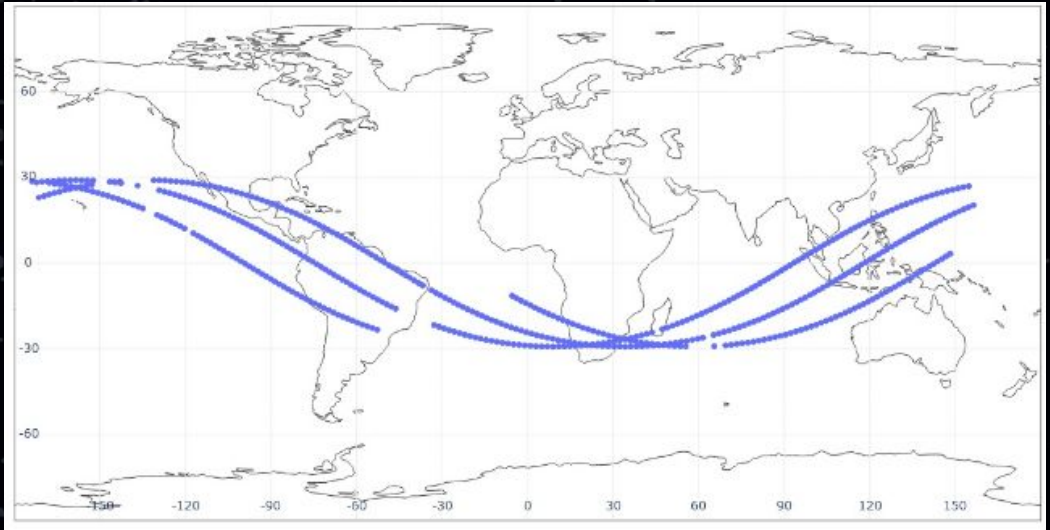
EP Anti-Solar pointing strategy

~600 km, ~29° inclination angle, 1 orbit ~ 90min

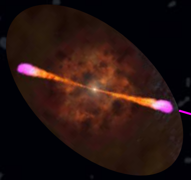


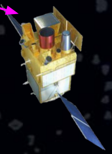
The satellite track on Earth (here for SVOM)

+/- 30° latitude



II- SVOM: an example of a powerful transient detection and alerting machine

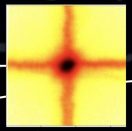




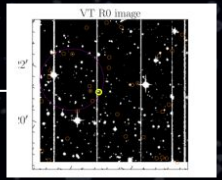
Alert GCN — **T0 + 15″**

slew+stabilization — **T0+2-3′**

First MXT position — **T0+5′**

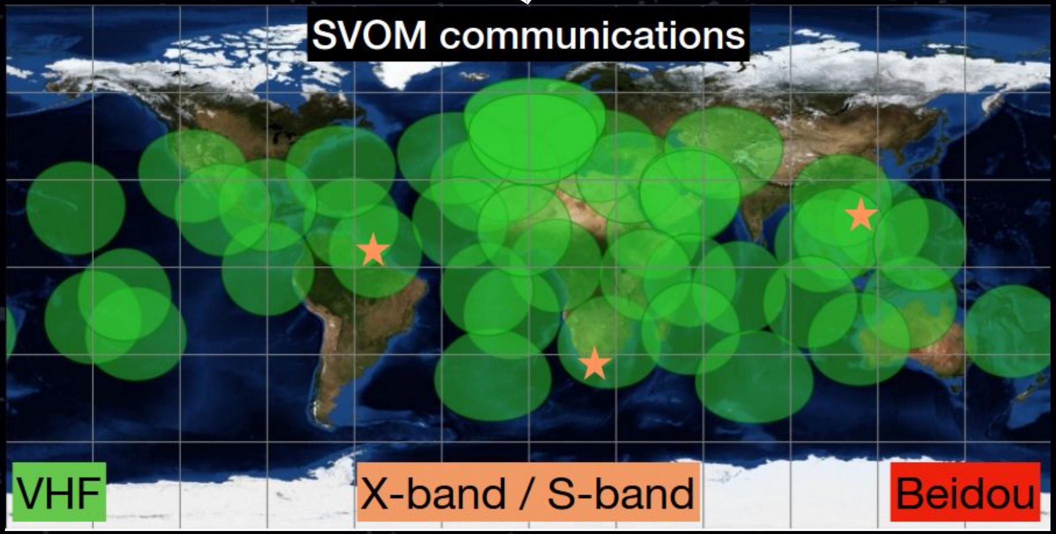


VT afterglow identification — **T0+30′-1h**



End of the auto onboard alert sequence — **T0+8h (5 orbits)**

T0



Downgoing links

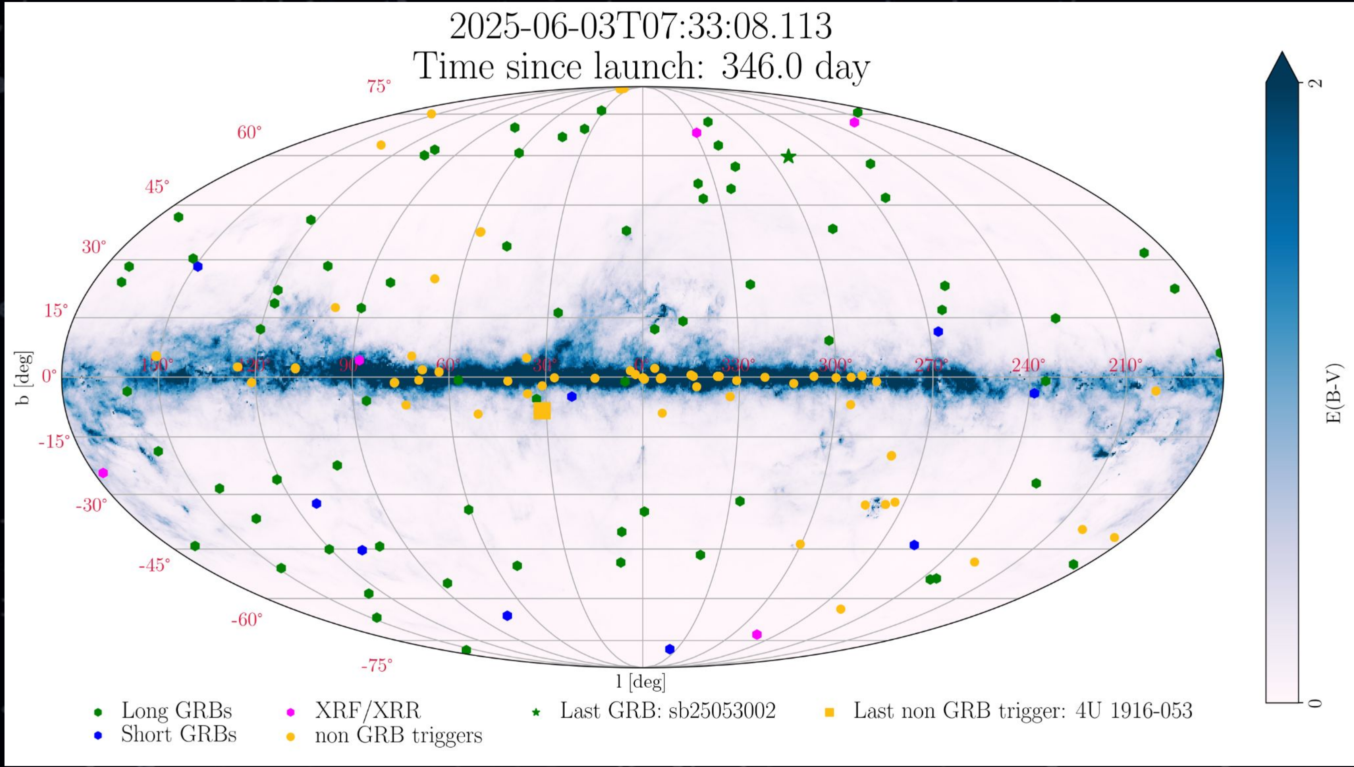
- **VHF** (fast but few data products)
- **X-band** (slow but complete data)

Upgoing links

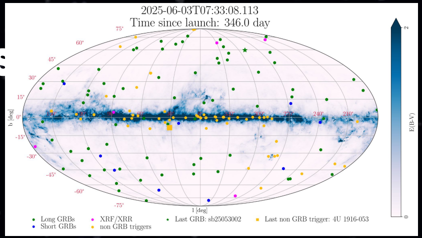
- **S-band** (slow, few hours)
- **Beidou** (fast, few minutes)

II- The SVOM x-ray/ γ-ray transient sky

II- The SVOM x-ray/ γ-ray transient sky in more details



II- The SVOM x-ray/ γ-ray transient sky in more details



Gamma-ray Burst general statistics

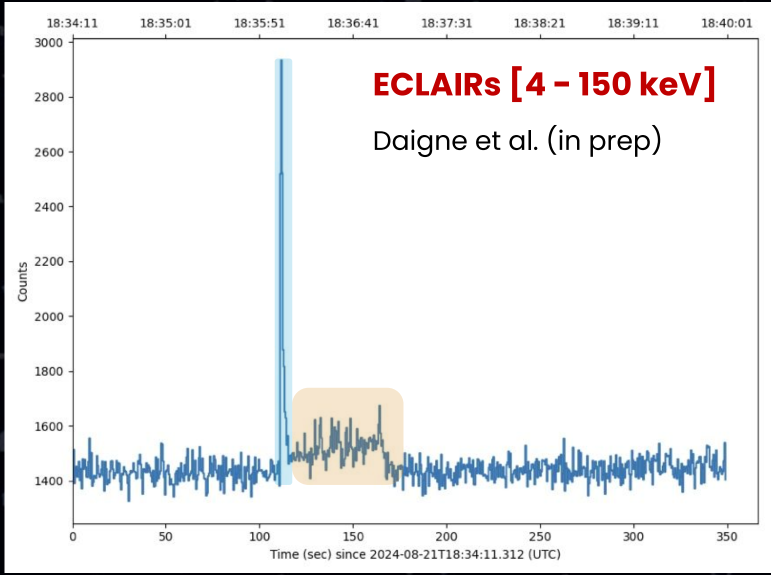
	GRM detection (Half time in commissioning)	ECL detection (Half time in commissioning)	Total ECL+GRM detection	Jointly detected by other missions	# z_{GRM}	# z_{ECL}
Observed	108	44	127	87 (68%)	10 (9%)	16 (36%)
Expected	130	30 - 60	–	–	–	> 50%

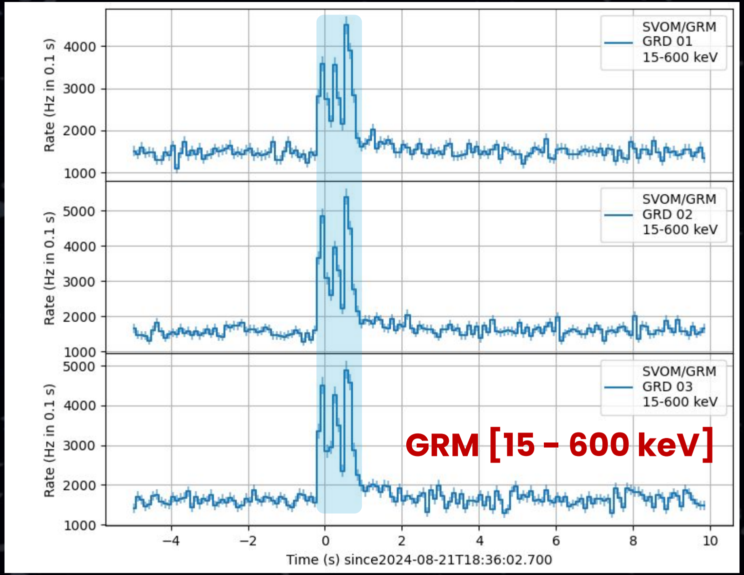
II- SVOM to explore the short GRB population and the merger origin

Our goal: Better understanding of the **short GRB-merger connection** and **the physics of ejection/emission in the post-merger phase**: SVOM can contribute to build a sample of fully characterized short GRBs, including the properties of the host galaxy.

GRB 240821A

the first ECLAIRs + GRM detection is a short merger burst with an Extended soft emission tail seen at z = 0.238



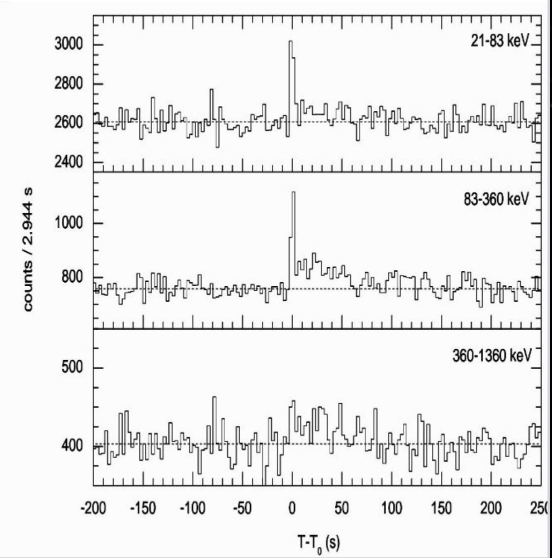


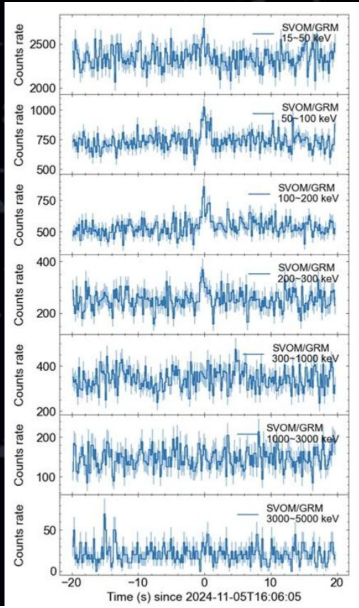
II- SVOM to explore the short GRB population and the merger origin

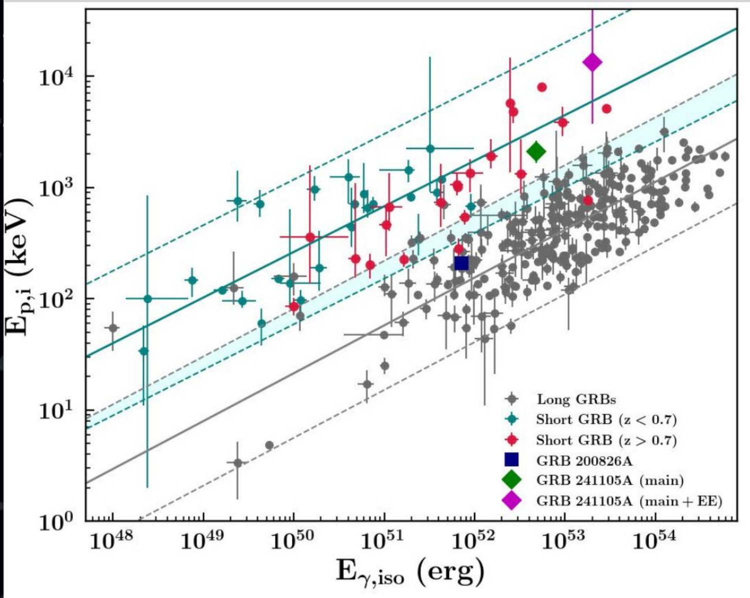
<u>Our goal:</u> Better understanding of the **short GRB-merger connection** and **the physics of ejection/emission in the post-merger phase**: SVOM can contribute to build a sample of fully characterized short GRBs, including the properties of the host galaxy.

GRB 241105A

An other SGRB+EE merger or a disguised collapsar GRB seen by Fermi/GBM Konus-WIND and SVOM GRM?





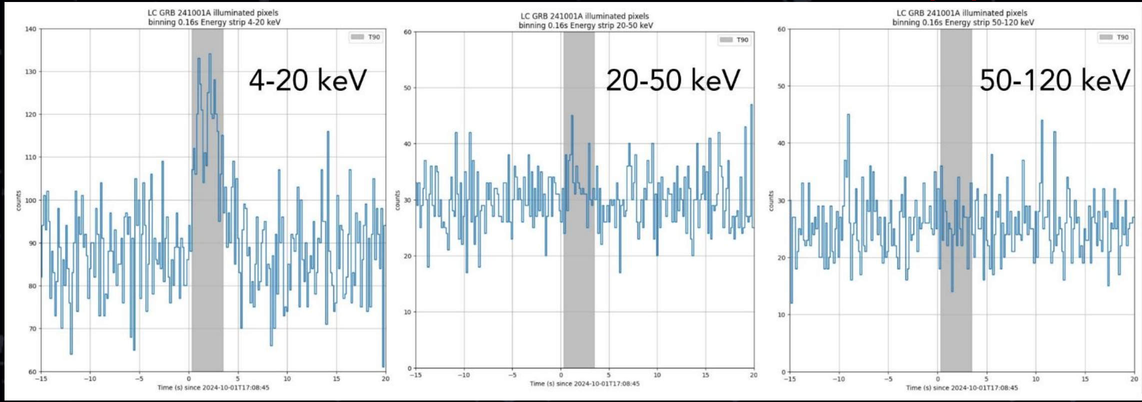


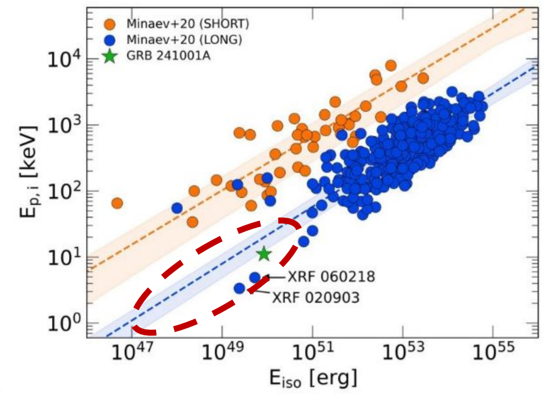
II- SVOM & EP to explore the poorly known XRR/XRF burst population

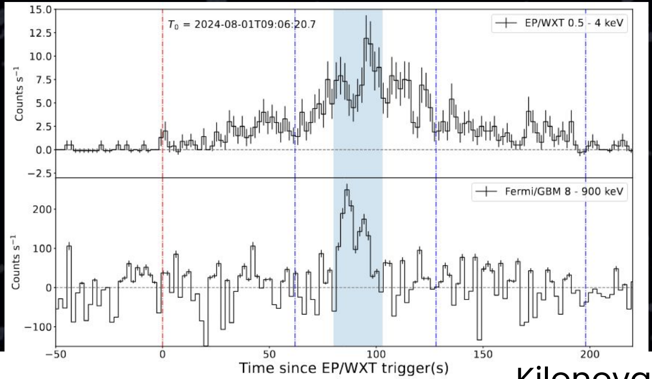
GRB 241001A (SVOM)

A very soft x-ray burst associated with a type Ic supernova (seen by JWST)

Schneider et al. (in prep)







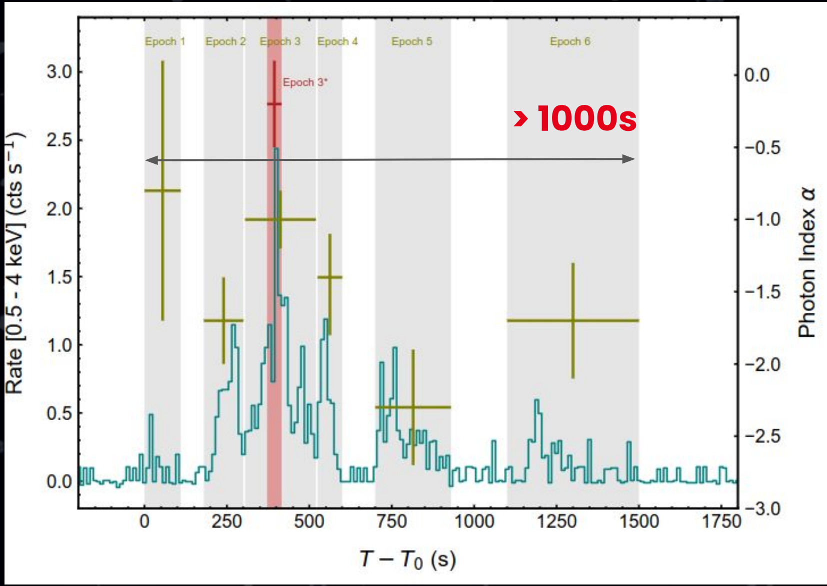
XRF 240801B

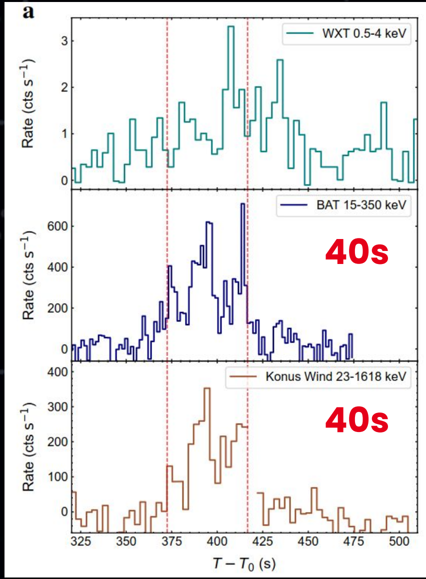
A very soft x-ray burst with a jetted emission

Jiang et al. (2025)

II- EP to explore the peculiar GRBs…

EP 240315a at z~5 a peculiar prompt emission in x-rays!
Liu et al. (2024)



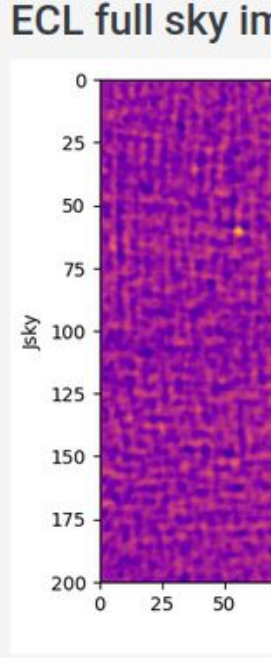


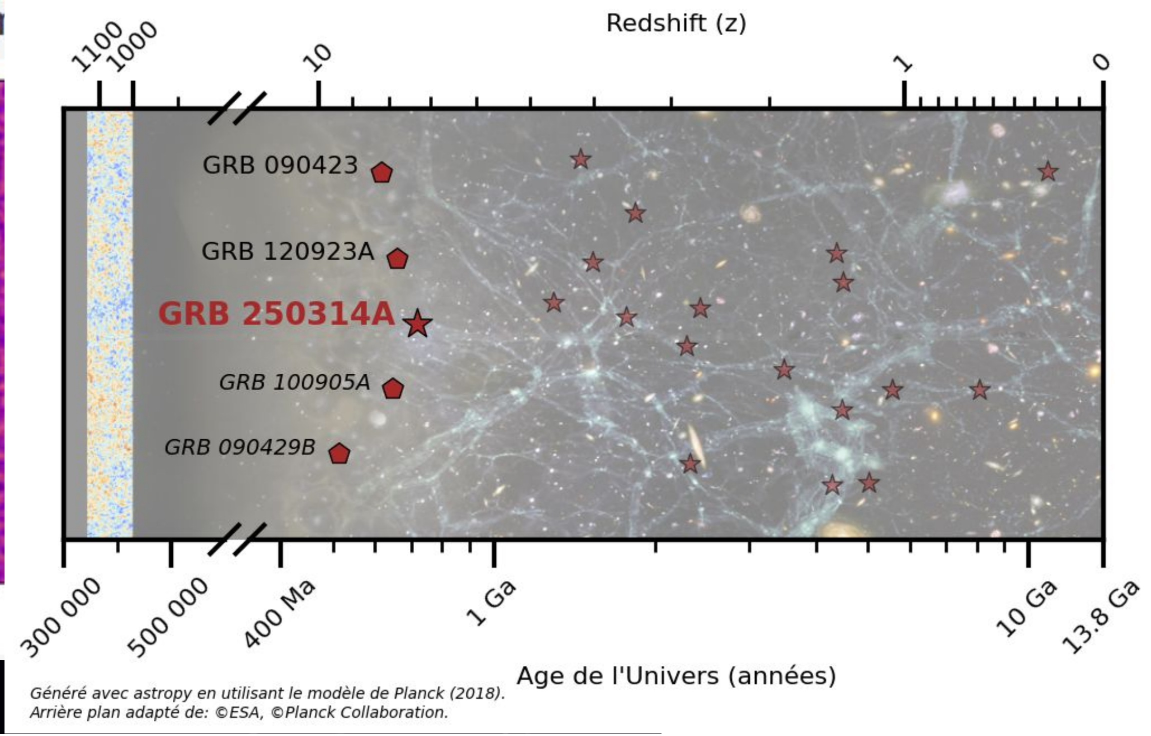
First Lessons from this event

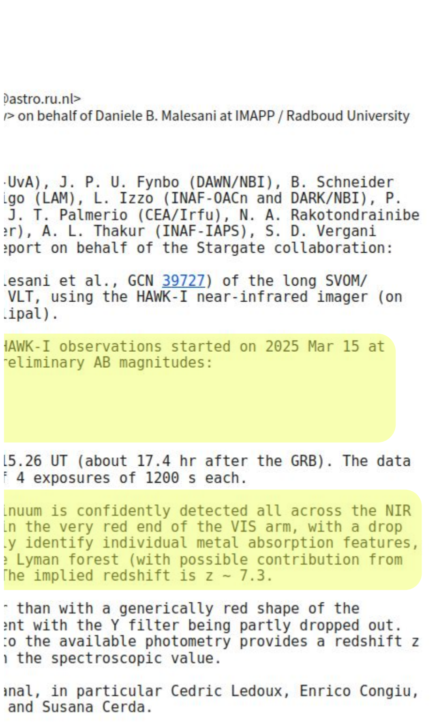
1. At sub-keV energies, the GRB duration may be much longer than the one regularly observed in the keV-MeV regime
2. New insights on the central engine activity with x-ray activity prior to the γ-rays

II- SVOM to explore the high-z GRB population

GRB 250314A at z~7.3!
5th most distant burst, we had to wait 12 years to get this new very high-z burst!






)astro.ru.nl>
/> on behalf of Daniele B. Malesani at IMAPP / Radboud University

-UvA), J. P. U. Fynbo (DAWN/NBI), B. Schneider
igo (LAM), L. Izzo (INAF-OACn and DARK/NBI), P.
J. T. Palmerio (CEA/Irfu), N. A. Rakotondrainibe
er), A. L. Thakur (INAF-IAPS), S. D. Vergani
eport on behalf of the Stargate collaboration:

.esani et al., GCN 39727) of the long SVOM/
VLT, using the HAWK-I near-infrared imager (on
.ipal).

HAWK-I observations started on 2025 Mar 15 at
reliminary AB magnitudes:

15.26 UT (about 17.4 hr after the GRB). The data
f 4 exposures of 1200 s each.

inuum is confidently detected all across the NIR
in the very red end of the VIS arm, with a drop
ly identify individual metal absorption features,
e Lyman forest (with possible contribution from
The implied redshift is z ~ 7.3.

- than with a generically red shape of the
ent with the Y filter being partly dropped out.
to the available photometry provides a redshift z
n the spectroscopic value.

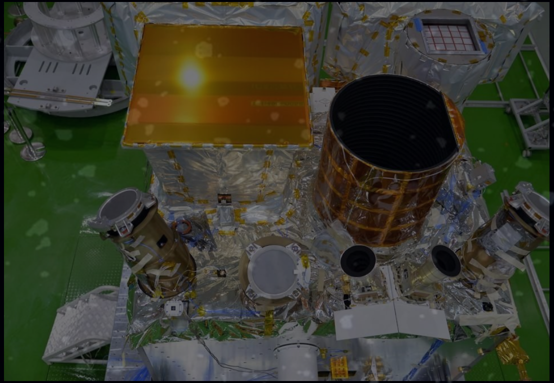
anal, in particular Cedric Ledoux, Enrico Congiu,
and Susana Cerda.

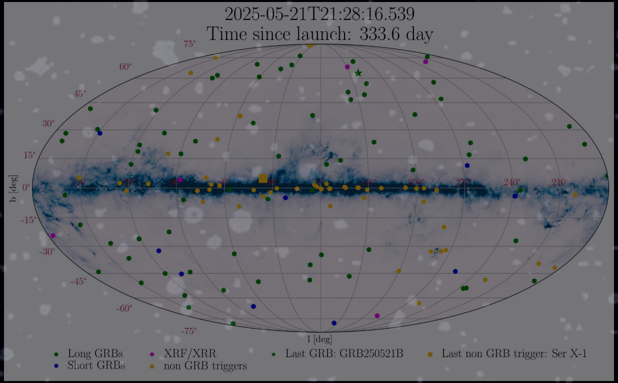
Outlines of the talk

Part I: The SVOM mission in a nutshell

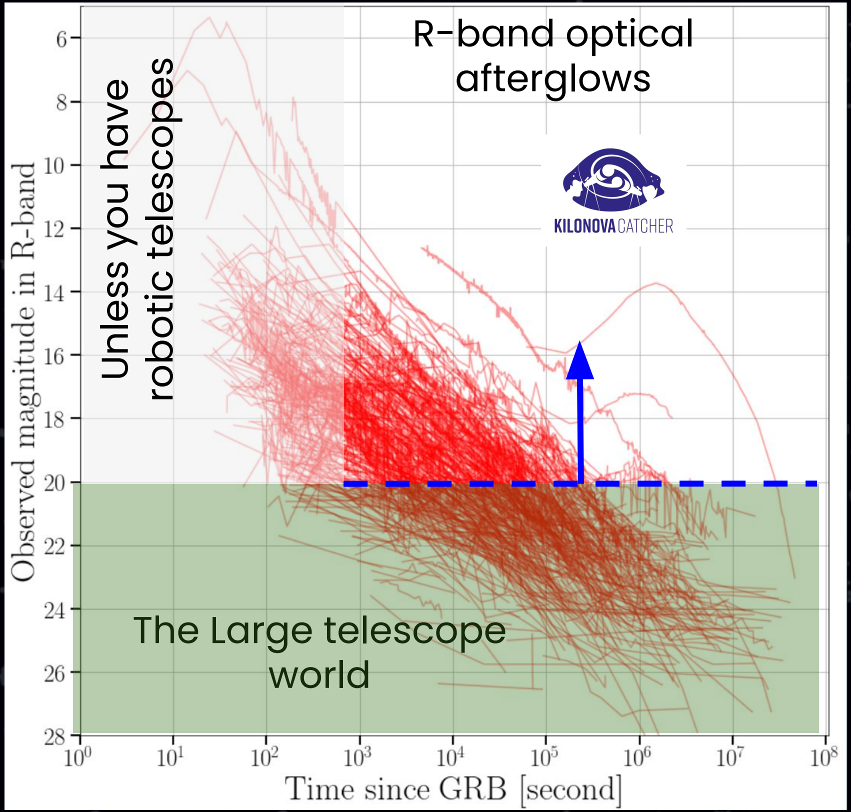
Part II: The SVOM first results

Part III: What KNC can bring into this field of research?





III- Help studying the GRB afterglow emission at optical wavelengths



Our discovery space is limited but not that small

1. GRB afterglow require fast (to not say immediate responses) to know where the GRB settle in the population (**probably not done by us**)

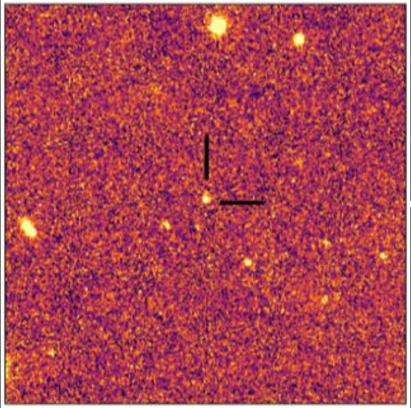
2. In second time, GRB afterglows must be monitored at least during the first 24h continuously (**this is where KNC can be one the best telescope network in this task**)

THE BIG PROBLEM OF GRBs at optical wavelengths (this is also why it is so exciting as observers)

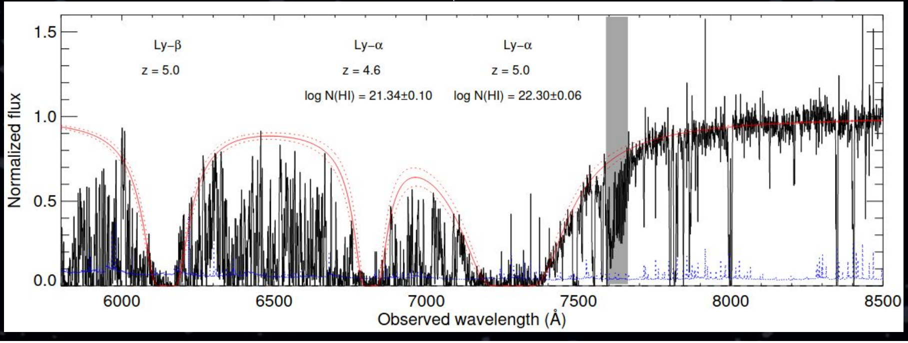
We never know in advance

if a GRB afterglow is peculiar, bright or faint, shows interesting features to capture before we just observe or people report observations....

III- Why even one detection point is important ?



GRB250314A seen by the 10.4m GTC



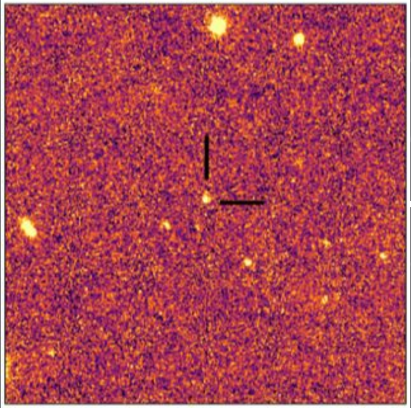
From photometry to spectroscopy !

1. Large telescopes such as the VLT need arcsecond localization to trigger spectroscopic observations
2. **Redshift = distance measurement => much much much more science can done!**
3. Quick GCN Circular publication is important (**we need to work on that point**)

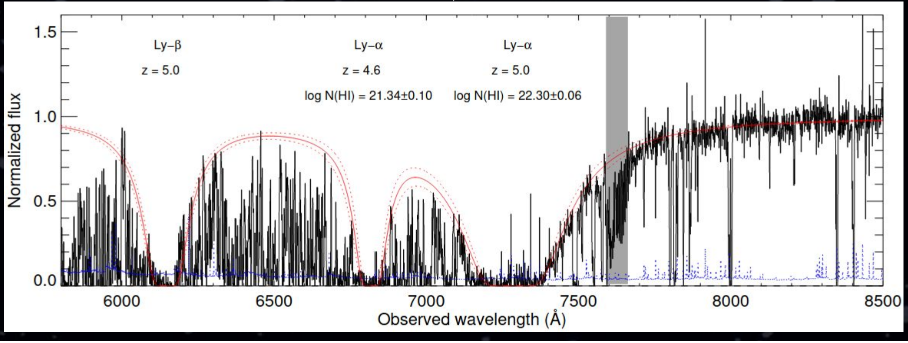
GRB111008 seen by the VLT z = 5!
Sparre et al. 2014

SVOM

III- Why deep upper limits in the first 12 hr are important ?



GRB250314A seen by the 10.4m GTC



Deep upper limits (r>21) can reveal

1. A discrepancy between the observed x-ray flux and the expected optical one -> **DARK burst population is largely unknown!**
2. **high-z GRB candidate -> so important for GRB physics and cosmological studies**
3. Achromatic behaviors beyond the GRB standard model picture!

GRB111008 seen by the VLT z = 5!
Sparre et al. 2014

SVOM

III- My take-home messages

1. *GRBs are still full of surprises in 2025! It is a vibrant research domain at the frontier with the Multi-Messenger astronomy. New missions such as SVOM and Einstein Probe has just come into the game! Worth a try ;)*

2. *GRB observations are challenging because these are one of the shortest transient we know*

3. *When a GRB occurs we never know its scientific level of interest, they all have to be investigated with the same care at the beginning*

4. *Every optical detection is important to asses the afterglow brightness with respect to the population, to provide arcsecond localization for large telescopes*

5. **As observers here are my suggestions (favored colored observation and favored red bands -> ri Rc, Ic):**
    a. If you are able to observe within 6h after the trigger time, go no matter what information you already got

    b. If you are able to observe between 6 - 12h after the trigger time, in 50% of the cases you should be able to catch the optical afterglow

    c. If you are able to observe only 12h after the trigger time, wait for information and decide to go or not depending on the already reported brightness or U.L.

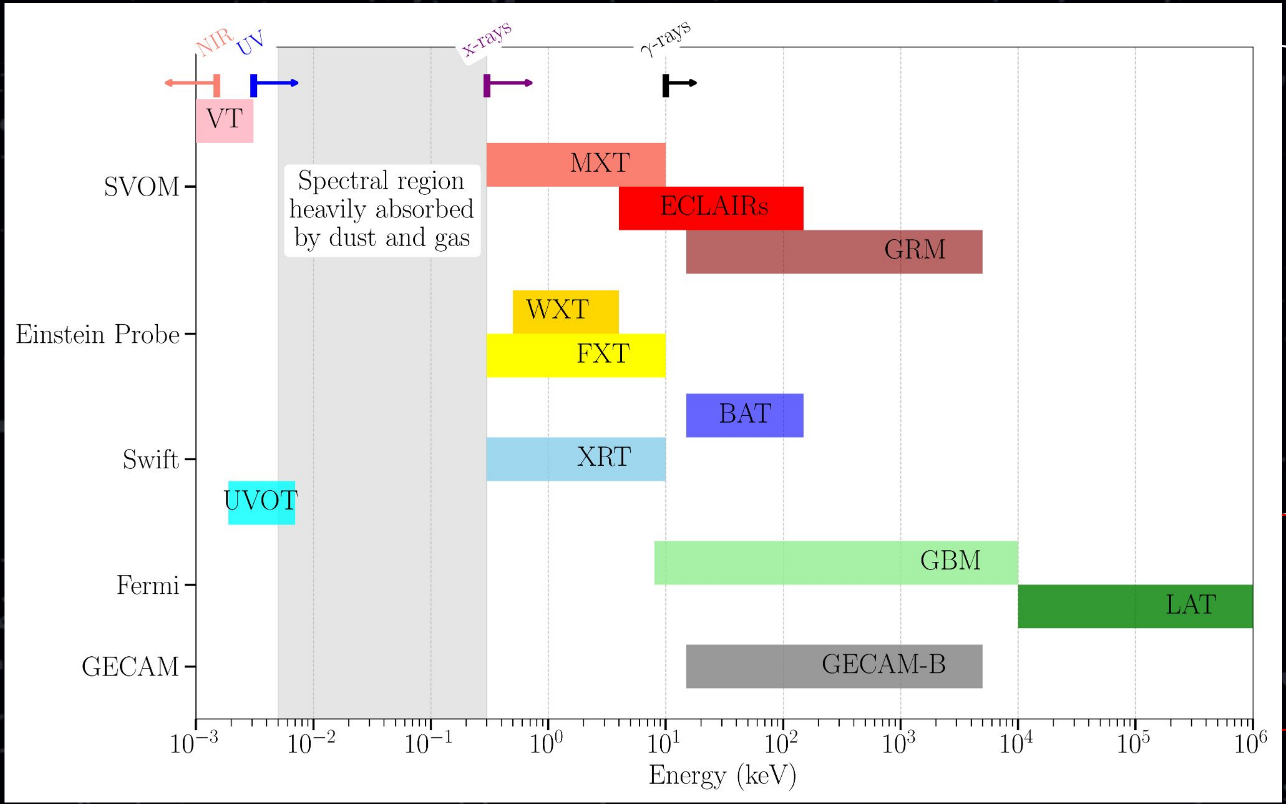
    d. After 24h, wait for more instructions from us and read the GCN Circulars. If the GRB is close enough, a Supernova may be seen a week or two after

Thanks for your attention!

Any questions?

SVOM

II- SVOM & EP: a unique spectral range to study the high-energy transients



They (except GRM) localize

(<10 arcmin)

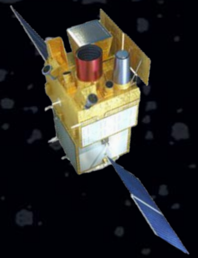
+

onboard auto follow-up of sources

They (don't) poorly localize

no follow-up

I- SVOM: Still the need for humans in the loop 24h/7d



Instrument Scientists and Trigger Advocates

Trigger validation

Burst Advocates

Trigger yes/no?

Main point of contact

Write the High-energy and retraction Circulars

Instrument Scientists

Write the follow-up Circulars