GRB observations with eXTP

L. Amati

with G. Stratta and the LOFT/GRB team of the Observatory Science WG

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The LOFT contribution to GRB science

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Probing the emission physics and weak/soft population of Gamma-Ray Bursts with *LOFT*

White Paper in Support of the Mission Concept of the Large Observatory for X-ray Timing

Authors

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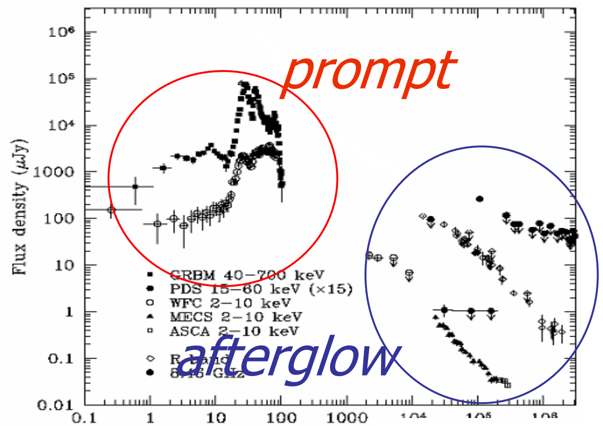
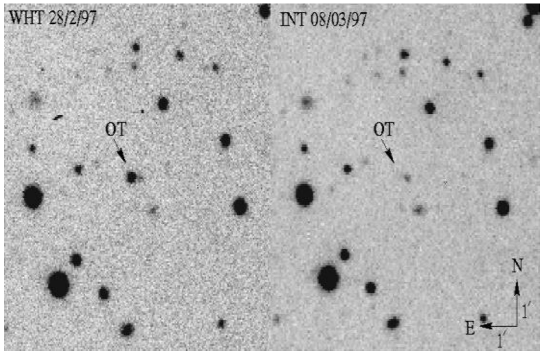
arXiv:1501.02772v1 [astro-ph.HE] 12 Jan 2015

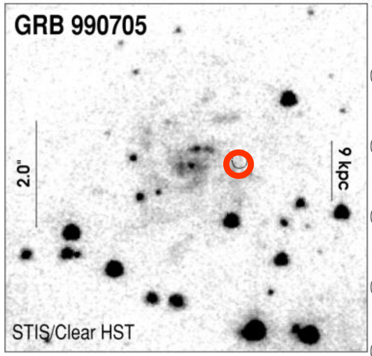
The GRB phenomenon: a puzzle still to be solved

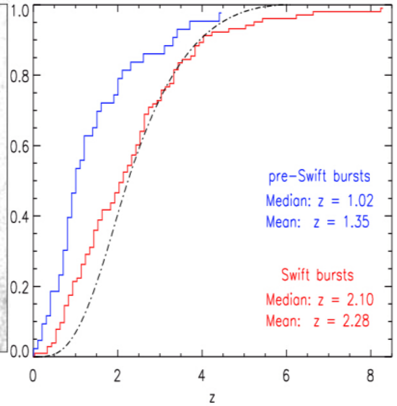
❑ Despite the huge advances occurred in the last years, the GRB phenomenon is still far to be fully understood

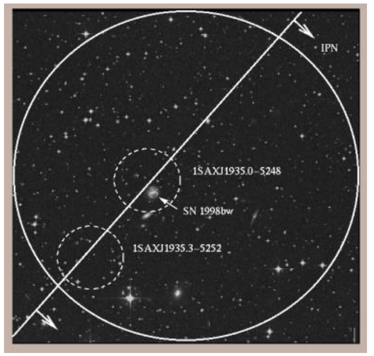
❑ **Open issues include**: physics and geometry of the prompt emission, unexpected early afterglow phenomenology (plateau, flares, …), identification and understanding of sub-classes of GRBs (short/long, XRFs, sub-energetic), GRB/SN connection, VHE emission, nature of the inner engine, cosmological use of GRBs, GWs, … and more !

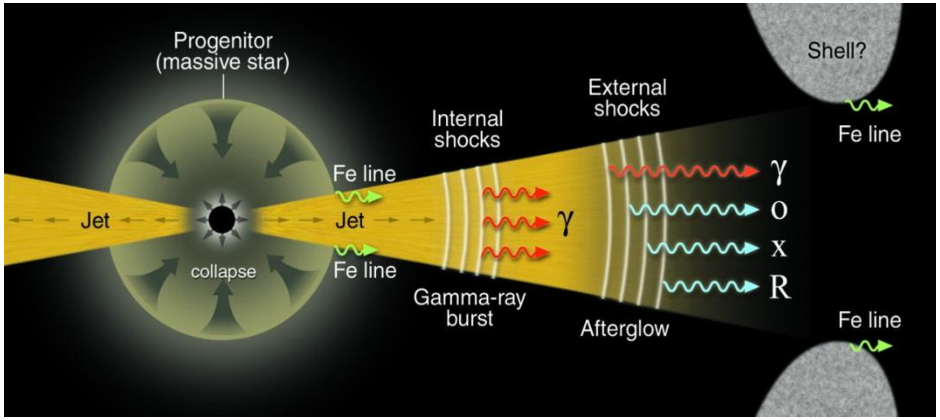










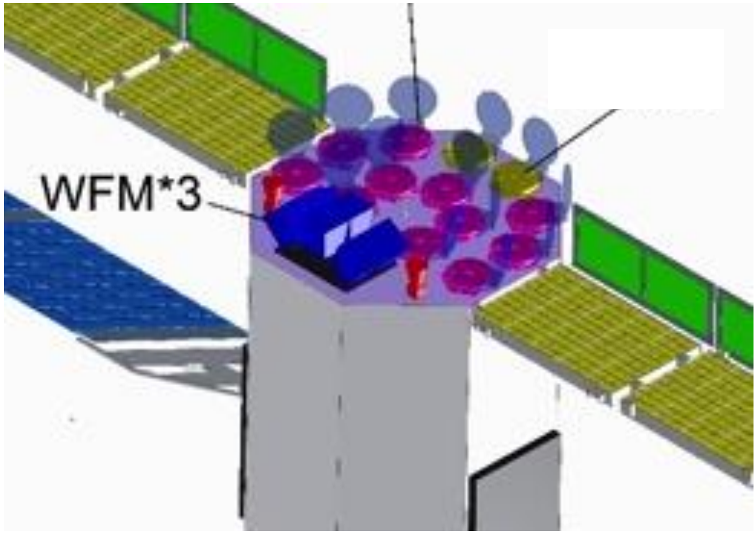


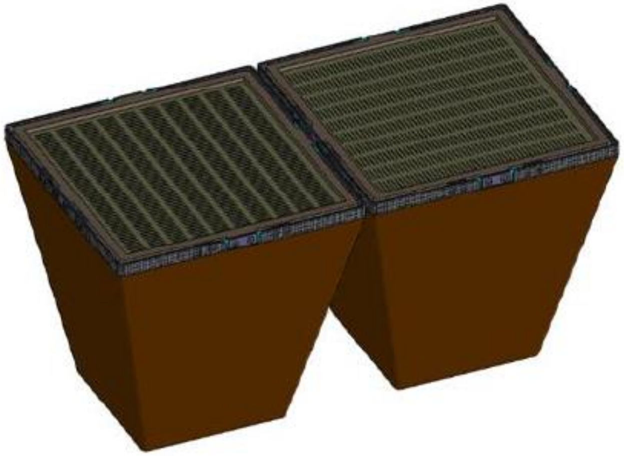
What can eXTP do for GRB science ?

❑ eXTP, possibly in combination with other GRB experiments flying at the same epoch, will give us useful clues to some of the still open issues through:

1) Detection, accurate location and characterization of GRB / XRFs prompt emission down to ~2 keV with the WFM (+ fast dissemination of ~arcmin position !) -> <u>THIS TALK</u>

2) Performing unprecedented spectroscopy and polarization measurements of the X-ray (early/late) afterglow emission with the **SFA, LAD and PFA -> <u>TALK by Wu</u>**





GRB X-ray prompt emission and weak/soft population with eXTP/WFM

- Main eXTP/WFM characteristics compared to previous, present and next future GRB monitors

	Energy Band	FOV	Energy resolution	Peak eff. area	Source location	Operation
CGRO/BATSE	20–2000 keV	4π sr	10 keV (100 keV)	~1700 cm^2	>1.7 deg	ended
BeppoSAX/WFC	2–28 keV	0.25 sr	1.2 keV (6 keV)	140cm^2	1 arcmin	ended
HETE-2/WXM	2–25 keV	0.8 sr	1.7 keV (6 keV)	350cm^2	1–3 arcmin	ended
Swift/BAT	15–150 keV	1.4 sr	7 keV (60 keV)	~2000 cm^2	1–4 arcmin	active
Fermi/GBM	8 keV – 40 MeV	4πsr	10 keV (100 keV)	126 cm^2	>3 deg	active
Konus–WIND	20 keV – 15 MeV	4π sr	10 keV at 100 keV	120 cm^2	–	active
Lomonosov/UFFO–p	5–100 keV	1.5 sr	2 keV (60 keV)	191 cm^2	5–10 arcmin	active
CALET/GBM	7 keV – 20 MeV	3 sr	5 keV (60 keV)	68 cm^2	–	active
SVOM	4 keV – 5 MeV	1.5 sr	2 keV (60 keV)	400 cm^2	2–10 arcmin	>2021–2022
eXTP/WFM	**2–50 keV**	**3.7 sr**	**300 eV (6 keV)**	**120 cm^2**	**0.5–1 arcmin**	**>2024–2025**

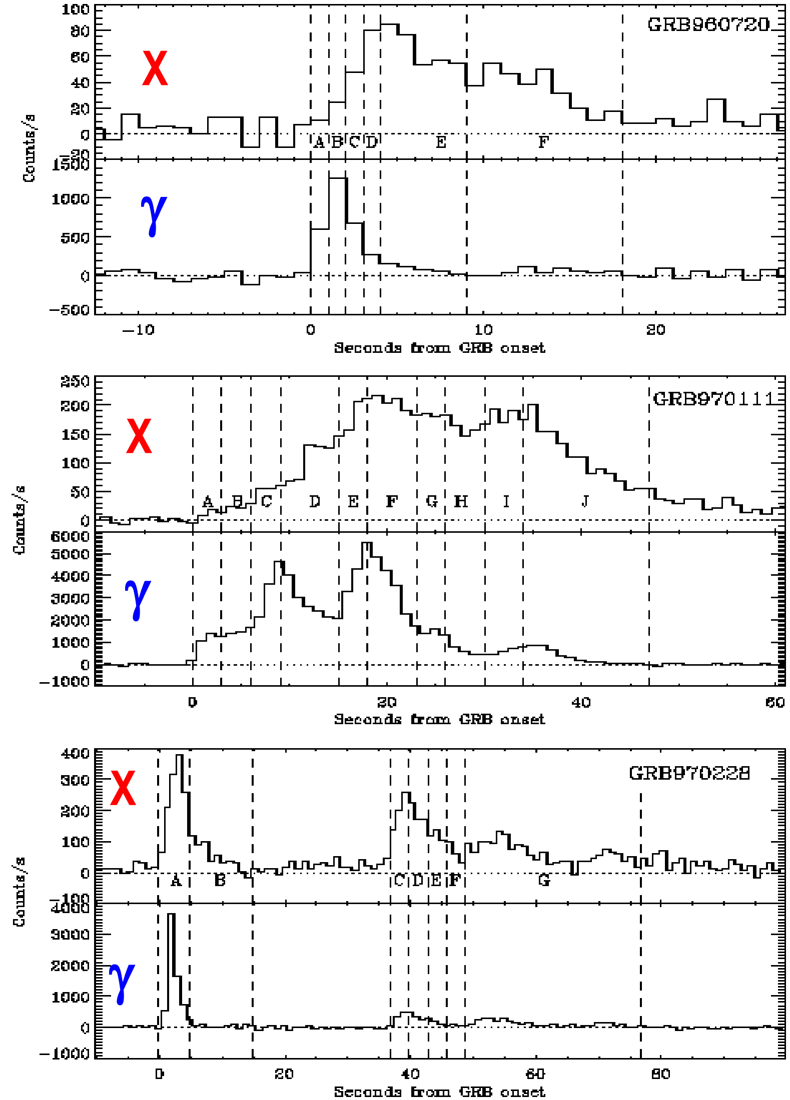
- **eXTP/WFM: unque combination of soft energy band, broad FOV, few hundreds eV energy resolution, <1 arcmin source location accuracy**

- It is recognized that the GRB phenomenon can be understood only going back to the study of the Prompt Emission

- **An energy band extending down to soft X-rays is needed.**

- Measurements down to a few keV were provided in the past by BeppoSAX and HETE-2, but better sensitivity and energy resolution are required to make a step forward

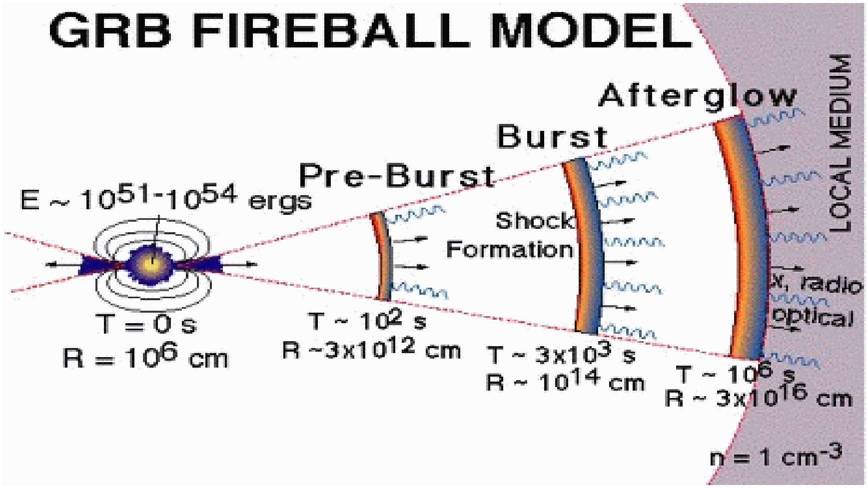
- Present GRB experiments are limited to prompt emission > ~10 keV; near future (SVOM, UFFO, CALET/GBM) > ~ 5 keV; proposed / under study (JANUS, LOBSTER, HiZ-GUNDAM, THESEUS) aim at going down to 1 keV or below

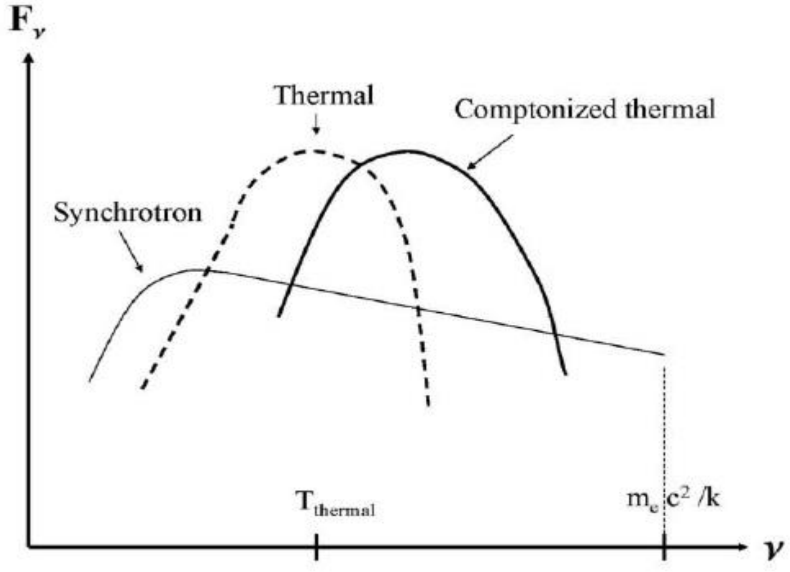


BeppoSAX (top: 2-28 keV, bottom: 40-700 keV)

❑ Testing prompt emission mechanisms with X-ray spectra

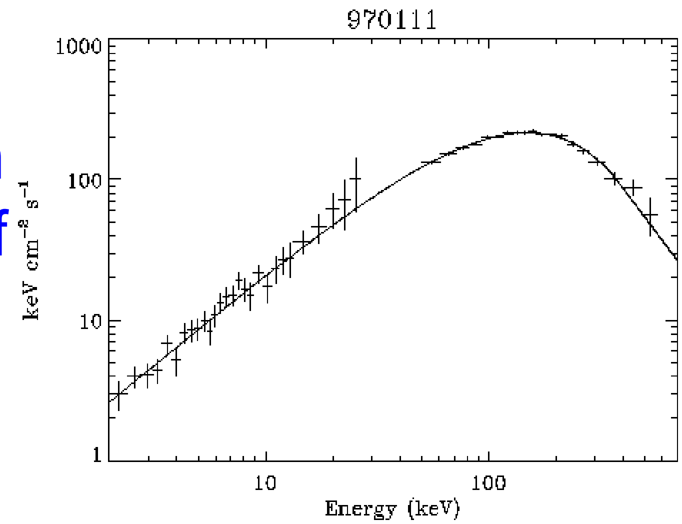
❑ physics of prompt emission still not settled, various scenarios: SSM internal shocks, IC-dominated internal shocks, external shocks, photospheric emission dominated models, kinetic energy dominated fireball , Poynting flux dominated fireball

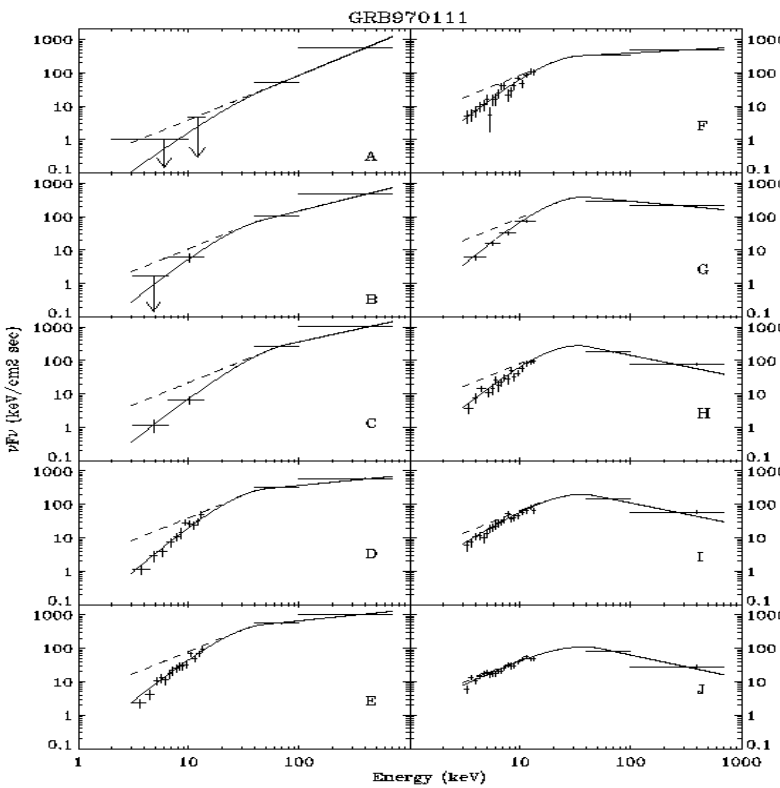


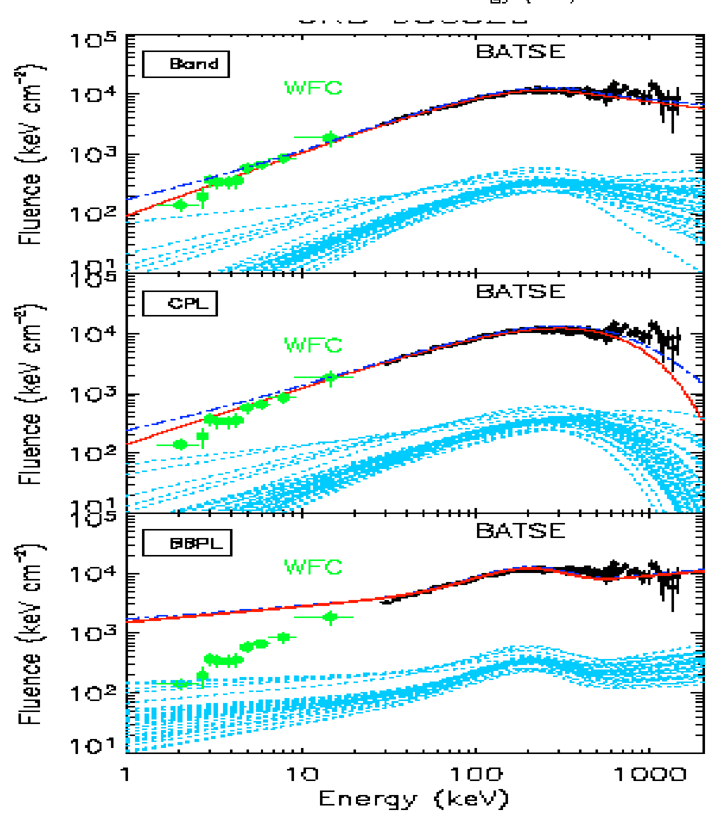


α $N(E)$	$\alpha+1$ $F(E)$	$\alpha+2$ EF_E	model/spectrum
-3/2	-1/2	1/2	Synchrotron emission with cooling
-1	0	1	Quasi–saturated Comptonization
-2/3	1/3	4/3	Instantaneous synchrotron
0	1	2	Small pitch angle/jitter
			inverse Compton by single e^-
1	2	3	Black Body
2	3	4	Wien

- most time averaged spectra of GRBs are well fit by synchrotron shock models
- at early times, some spectra inconsistent with optically thin synchrotron: possible contribution of IC component and/or thermal emission from the fireball photosphere
- thermal models challenged by X-ray spectra



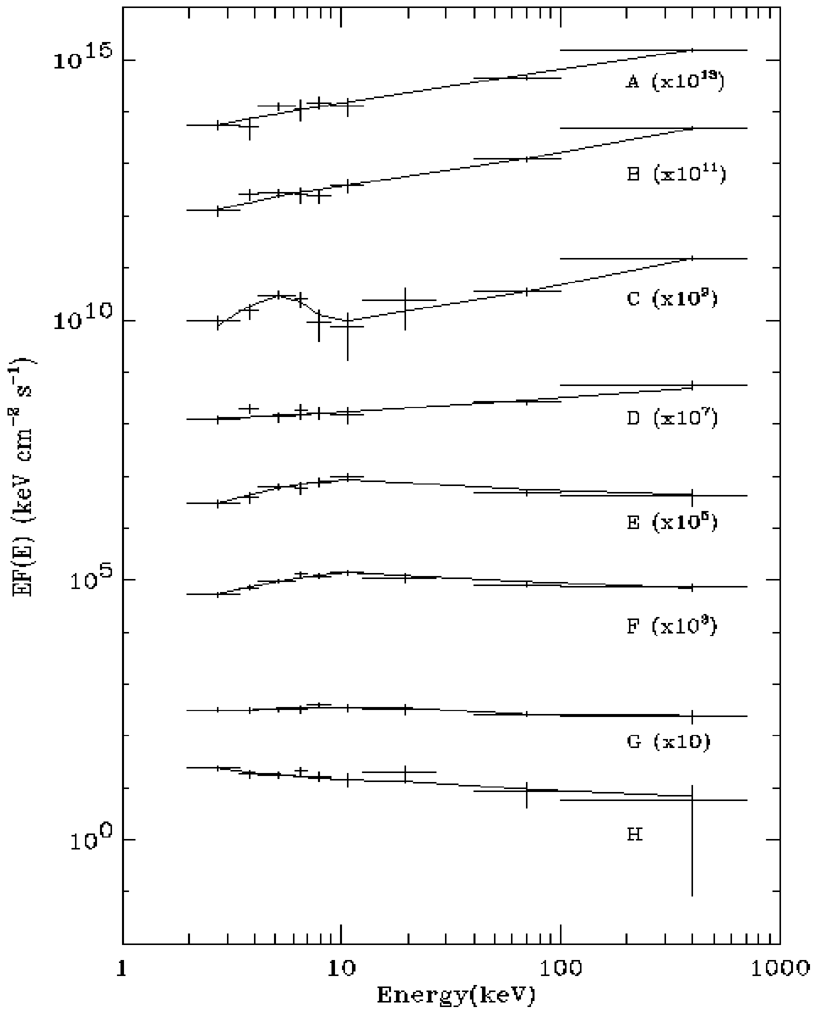




Amati et al. 2001, Frontera et al. 2000, Ghirlanda et al. 2007

❑ Transient bump, consistent with a 2 keV blackbody, observed in the low energy band with BeppoSAX WFC

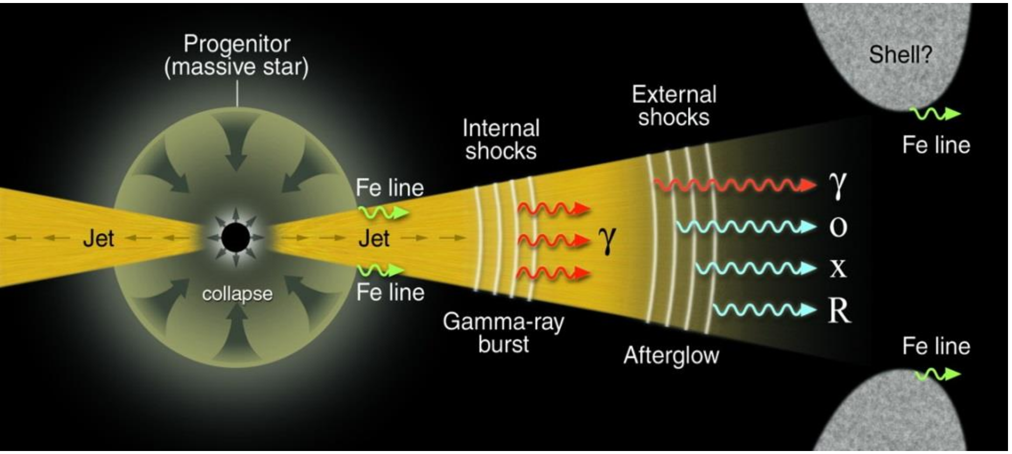
GRB 990712



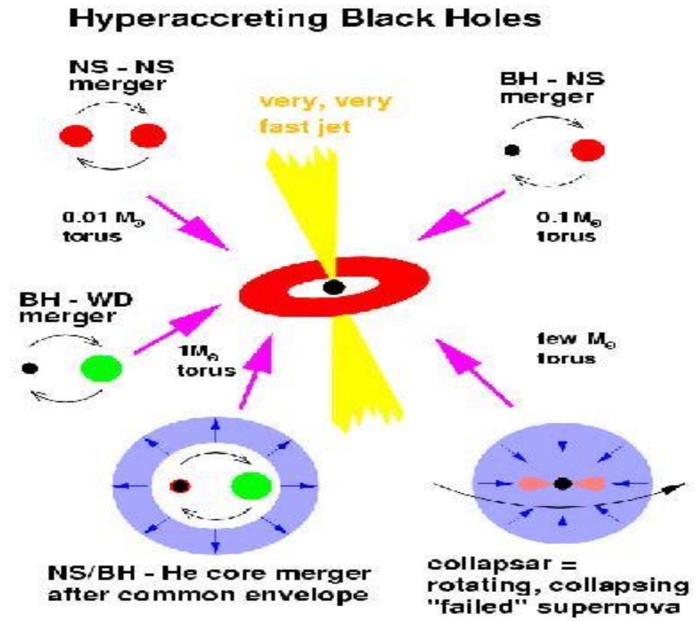
Frontera et al. 2001

❑ Probing the circum-burst environment with X-ray spectra

LONG



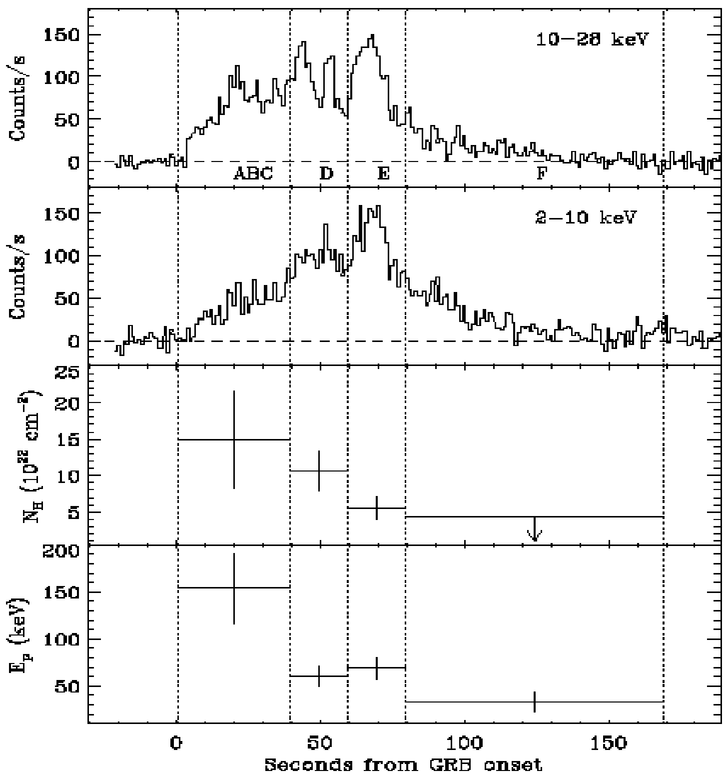
SHORT

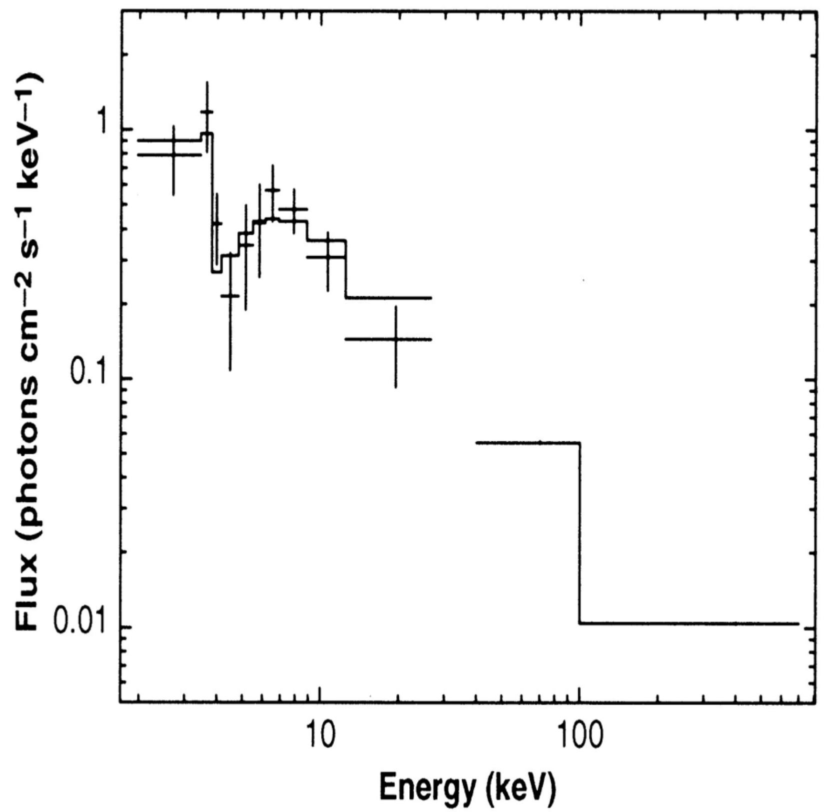


- ➢ energy budget up to >10^{54} erg
- ➢ long duration GRBs
- ➢ metal rich (Fe, Ni, Co) circum-burst environment
- ➢ GRBs occur in star forming regions
- ➢ GRBs are associated with SNe
- ➢ likely collimated emission

- ➢ energy budget up to 10^{51} - 10^{52} erg
- ➢ short duration (< 5 s)
- ➢ clean circum-burst environment
- ➢ old stellar population

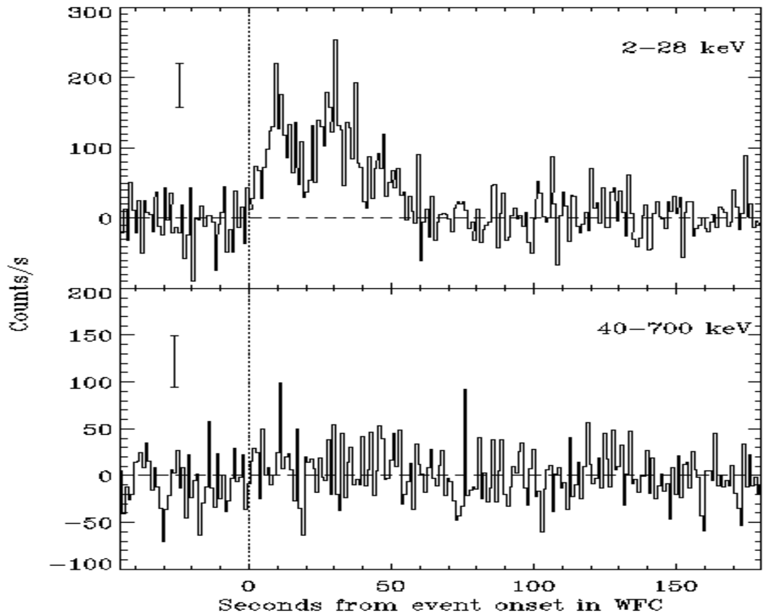
❑ X-ray features: properties (density profile, composition) of circum-burst environment (progenitors, X-ray redshift)

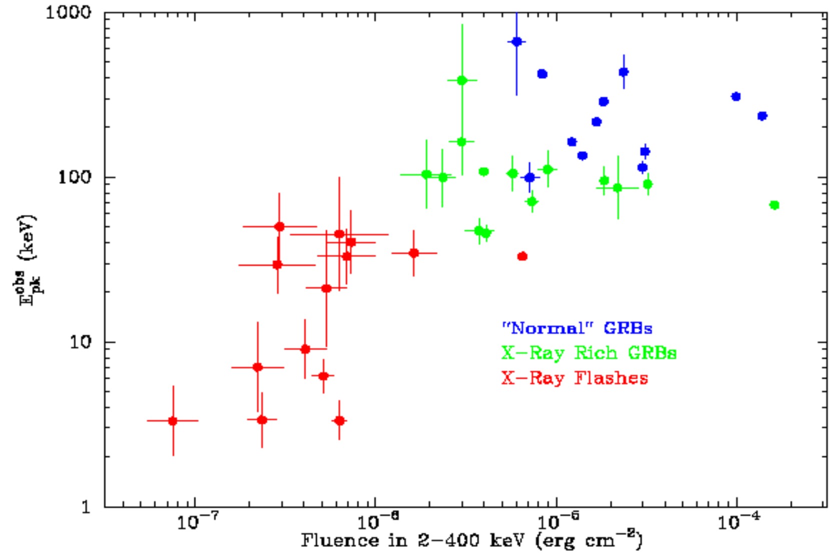


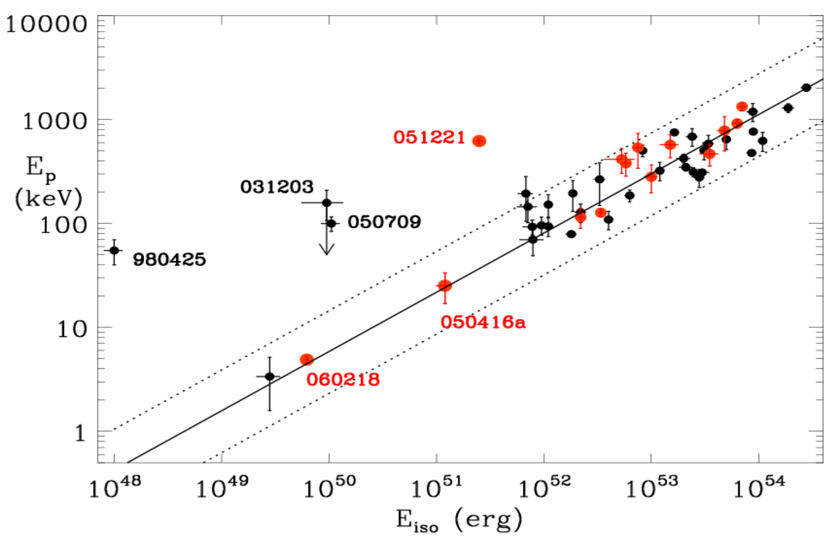


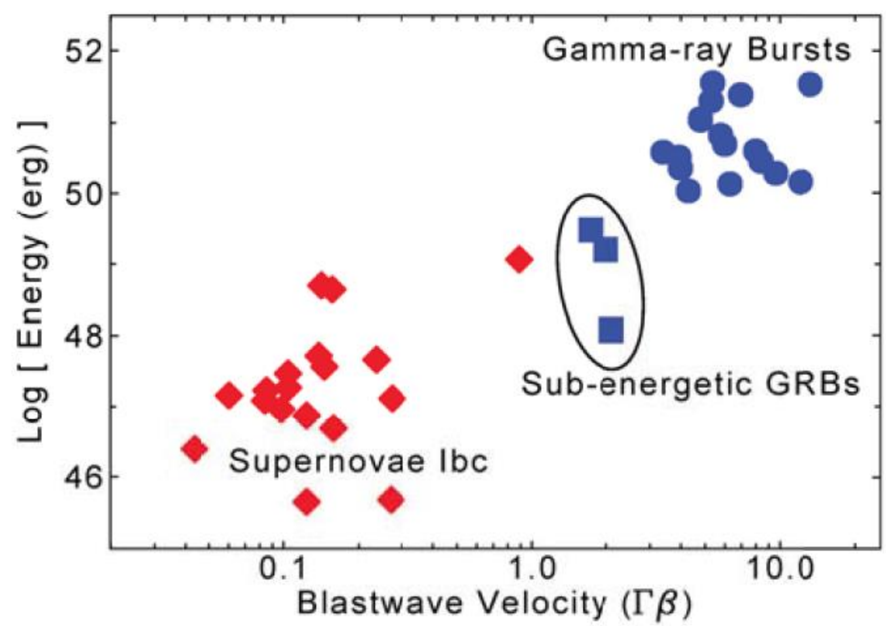
Frontera et al., ApJ, 2004, Amati et al, Science, 2000

❑ X-Ray Flashes: origin, population size, link with GRB

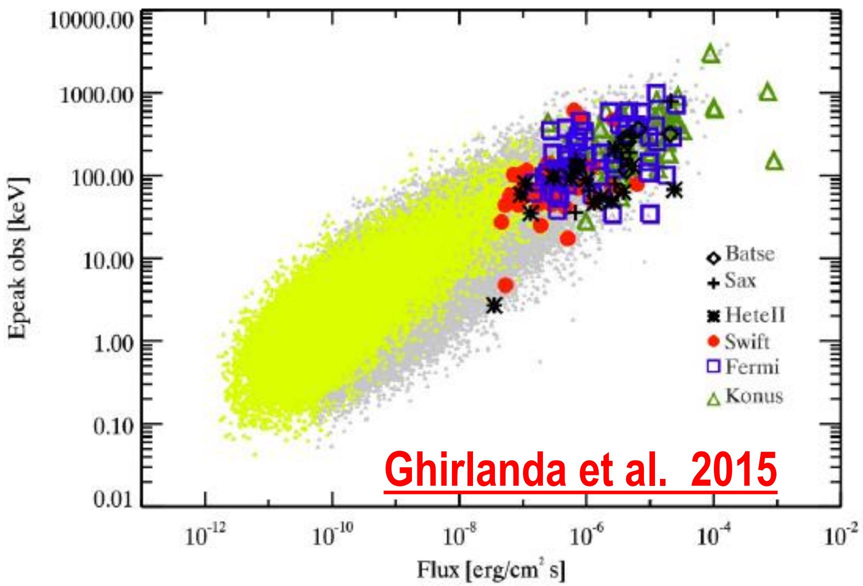


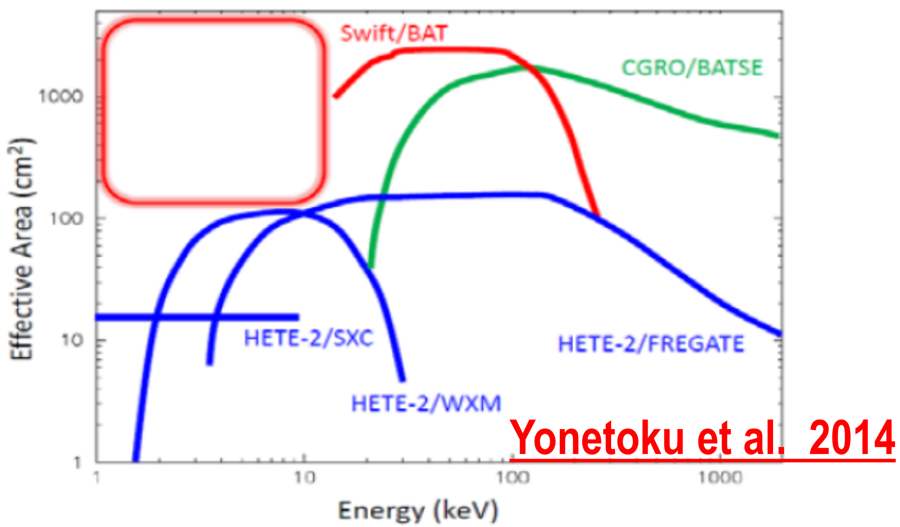


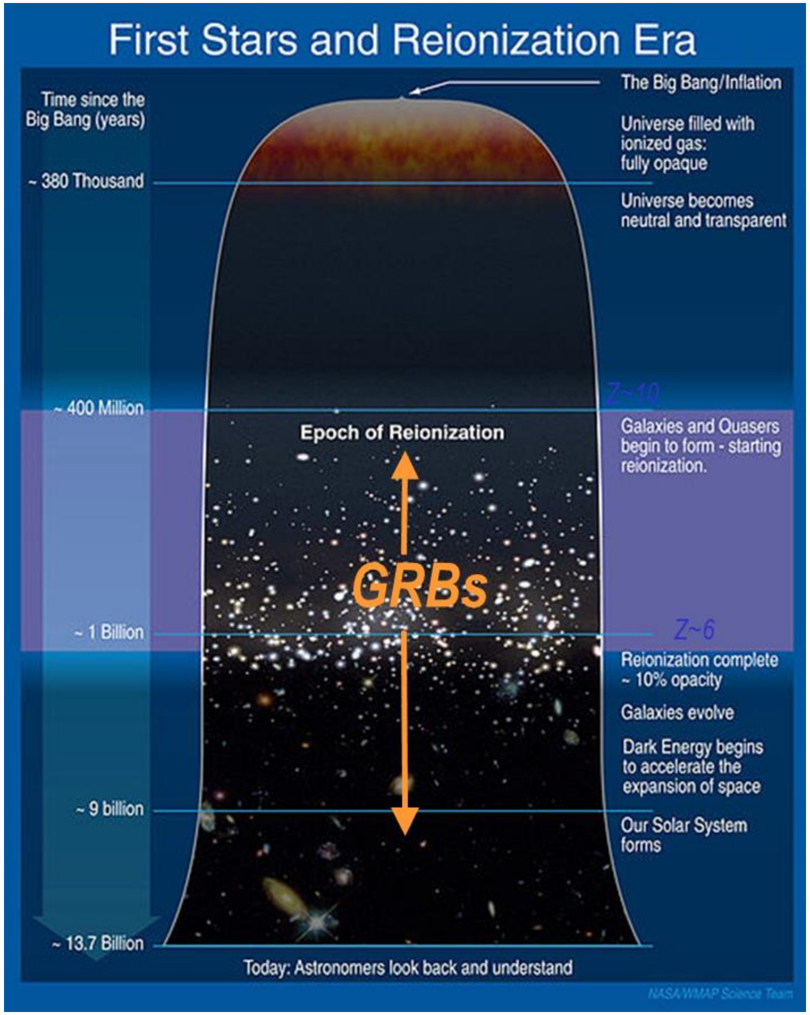




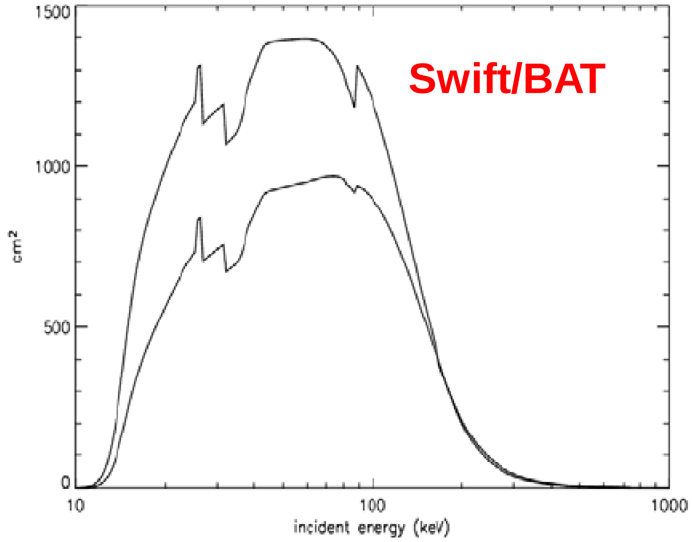
❑ Increasing the detection rate of high-z GRB with low energy threshold: SFR up to dark ages, pop III stars, re-ionization

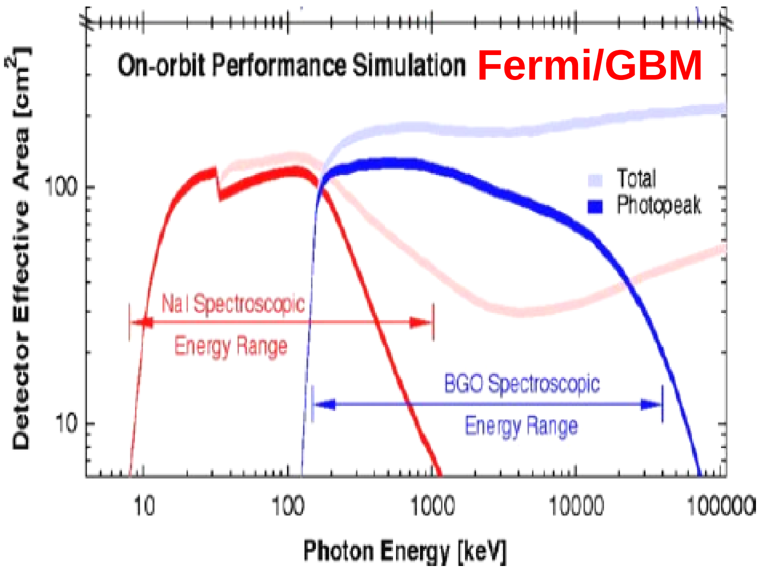


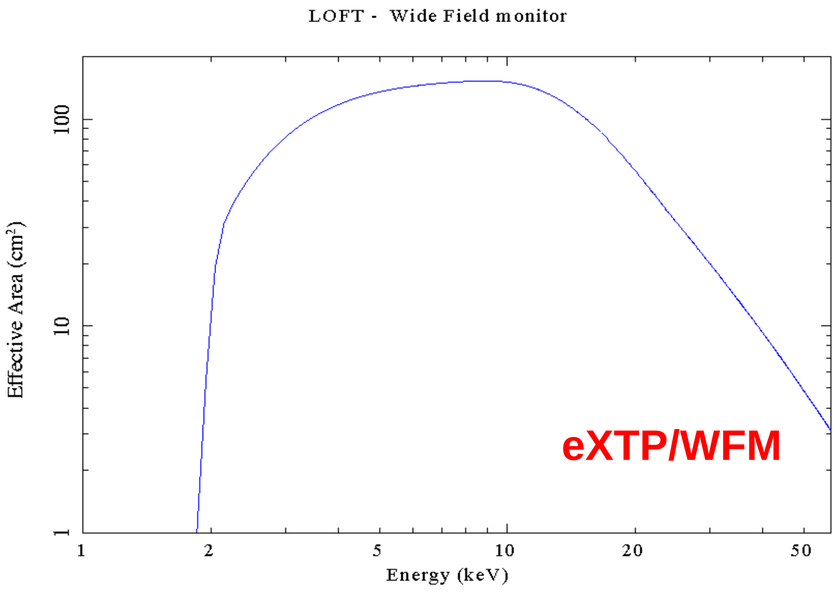


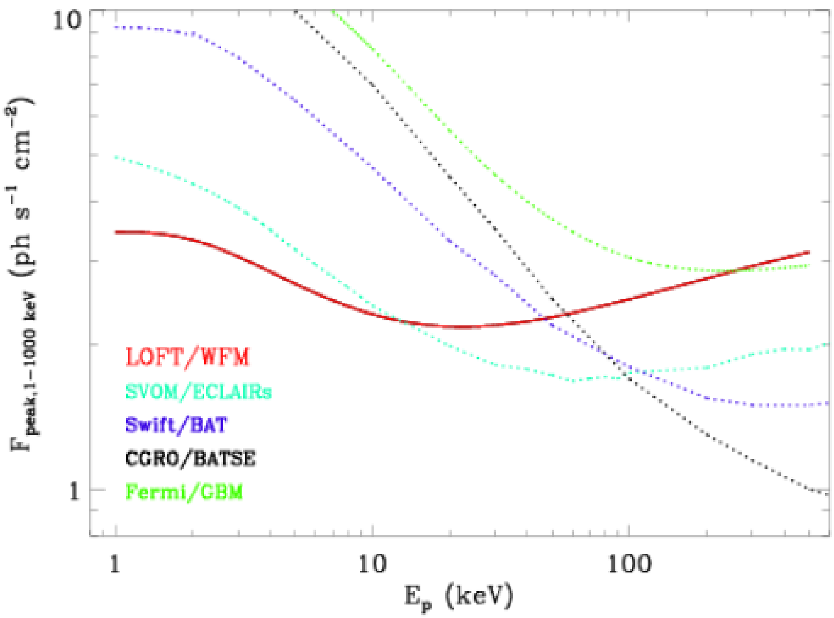


❑ Eff. Area and GRB sensitivity of the eXTP/WFM w/r to present GRB detectors









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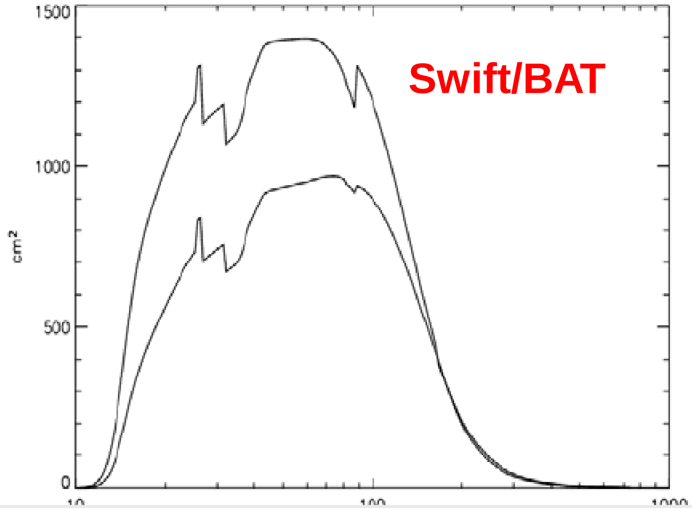
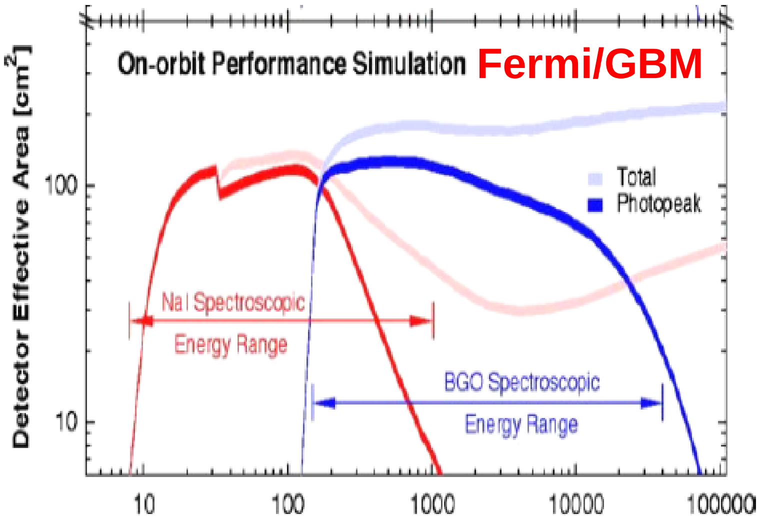
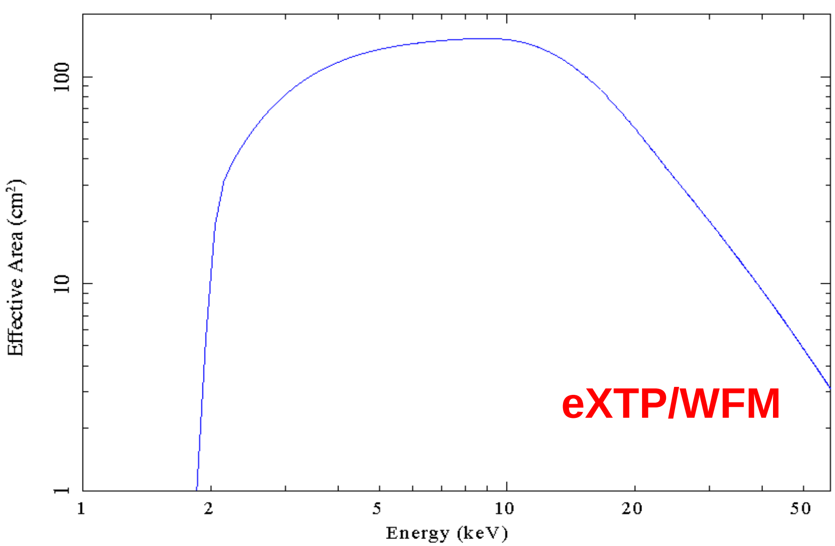
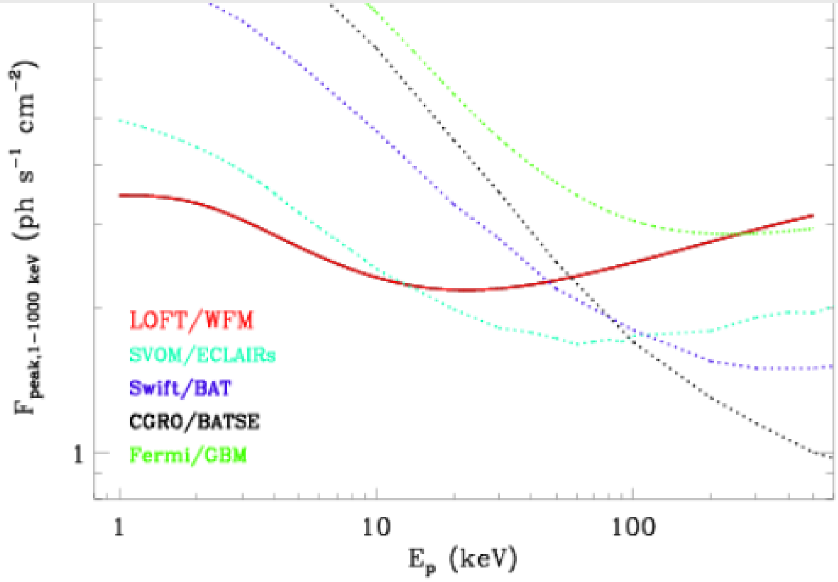


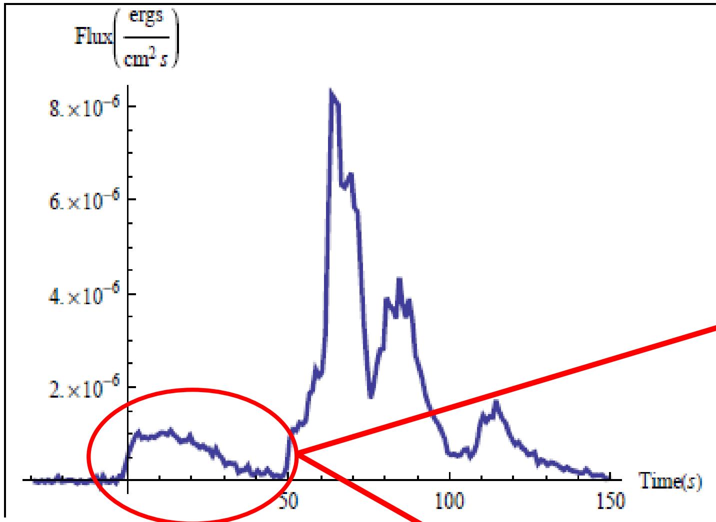


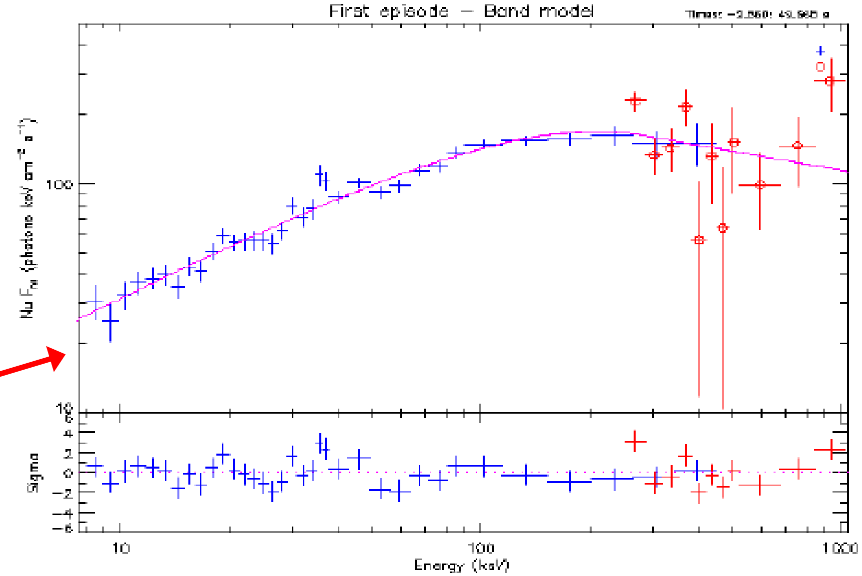
eXTP/WFM: 30-40 XRFs/year ; ~2 GRB/year @ z > 6

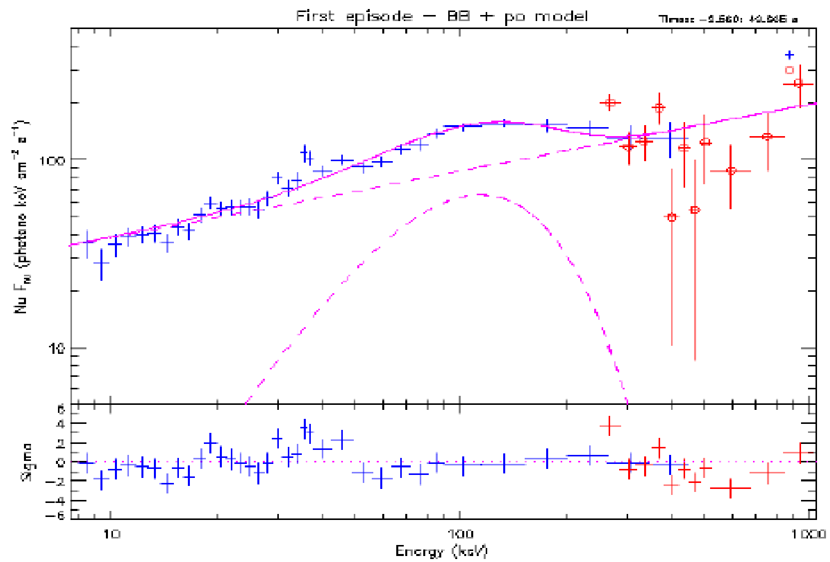




❑ Discriminating among different models: the case of GRB 090618





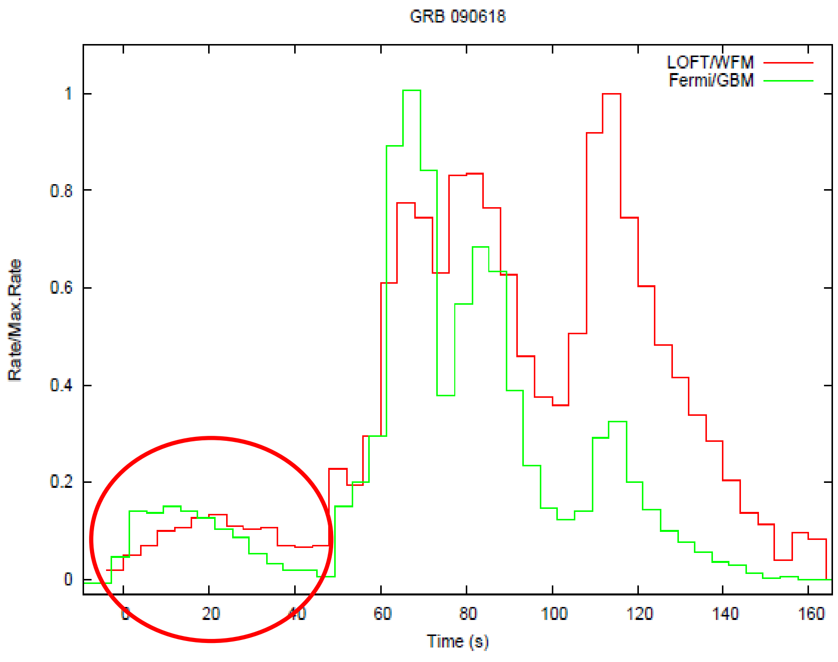


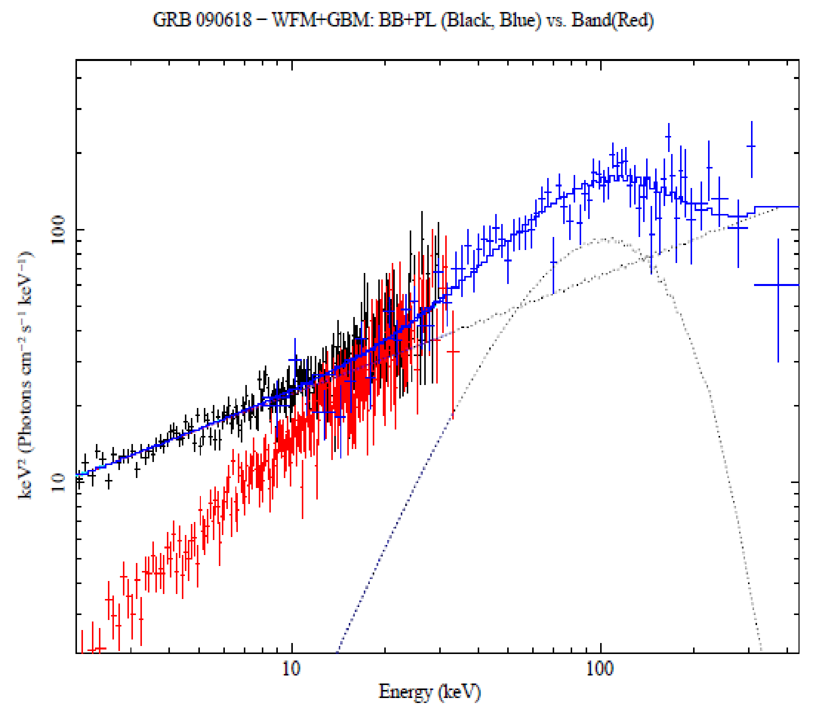
Fermi GBM (10 – 1000 keV) cannot distinguish among BB + PL and standard GRB Band function (Izzo et al. 2012)

Time Interval (s)	α	β	$E_0(keV)$	$\tilde{\chi}^2_{BAND}$	$kT(keV)$	γ	$\tilde{\chi}^2_{BB+po}$
0 - 50	-0.74 ± 0.10	-2.32 ± 0.16	118.99 ± 21.71	1.12	32.07 ± 1.85	1.75 ± 0.04	1.21

❑ Discriminating among different models - The case of GRB 090618:

eXTP/WFM will be capable of discriminating among Band and BB+PL thanks to its energy band extending below 10 keV

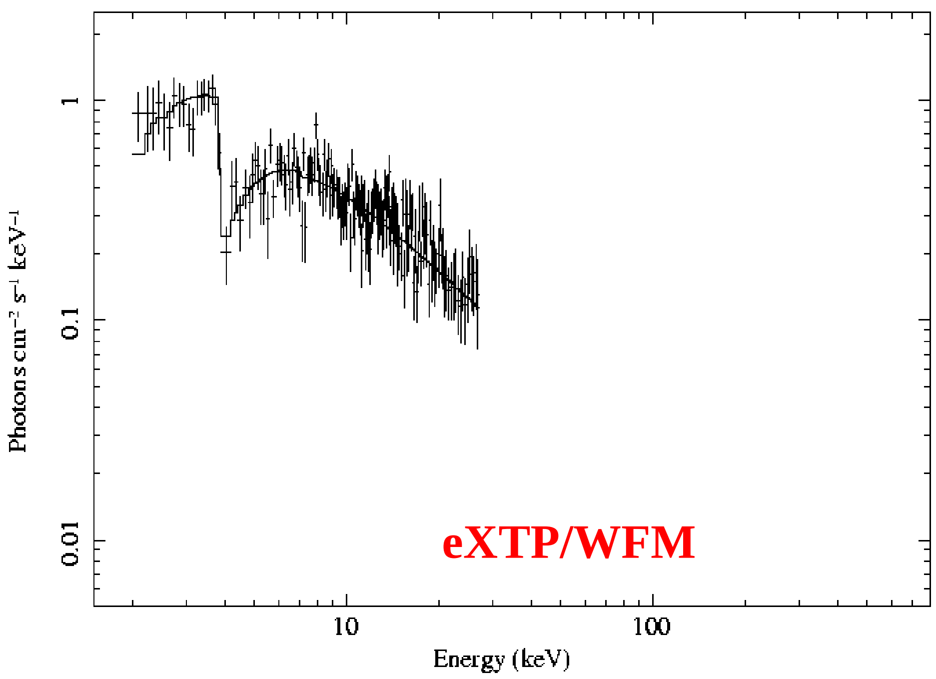


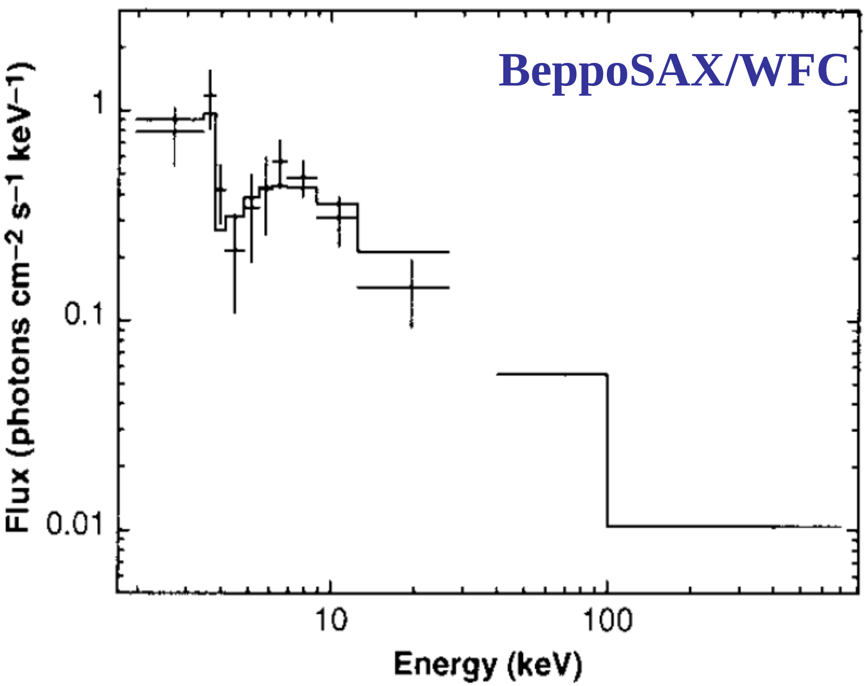


Fermi/GBM **eXTP/WFM (BB+PL)**

eXTP/WFM(Band)

❑ Expected spectrum with eXTP/WFM assuming the K-edge observed from GRB990705 with BeppoSAX/WFC: higher significance (thanks to better en. res) and higher detection rate (thanks to much broader FOV)





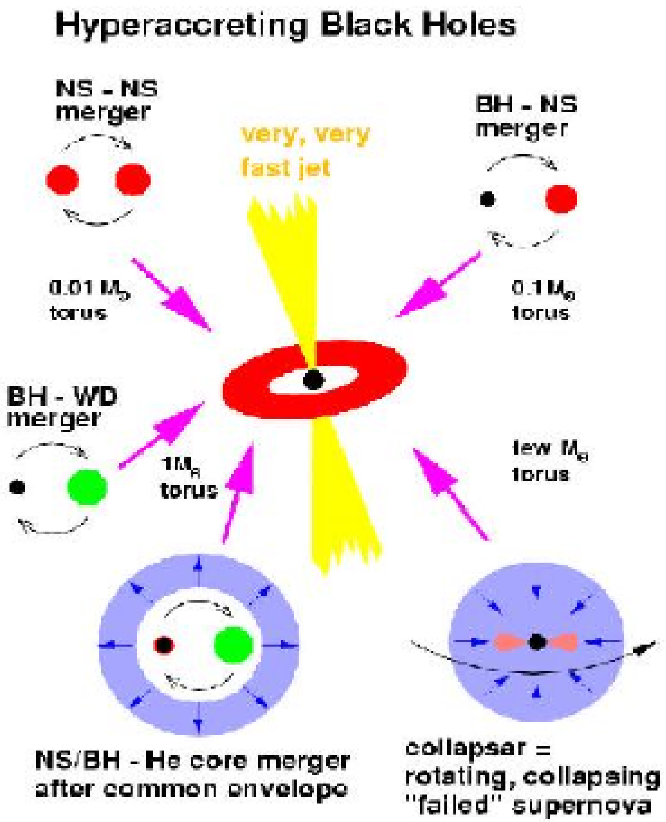
eXTP/WFM

BeppoSAX WFC+ GRBM

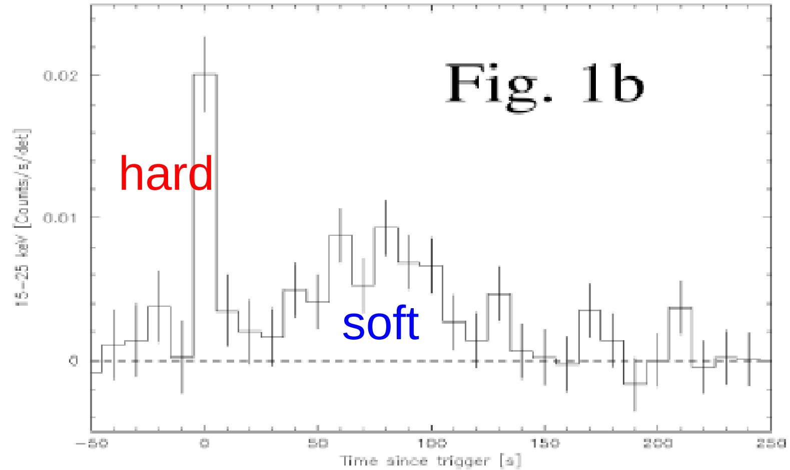
- **Providing short GRB trigger and location (fundamental for next generation gravitational waves detectors)**

SGRB progenitors

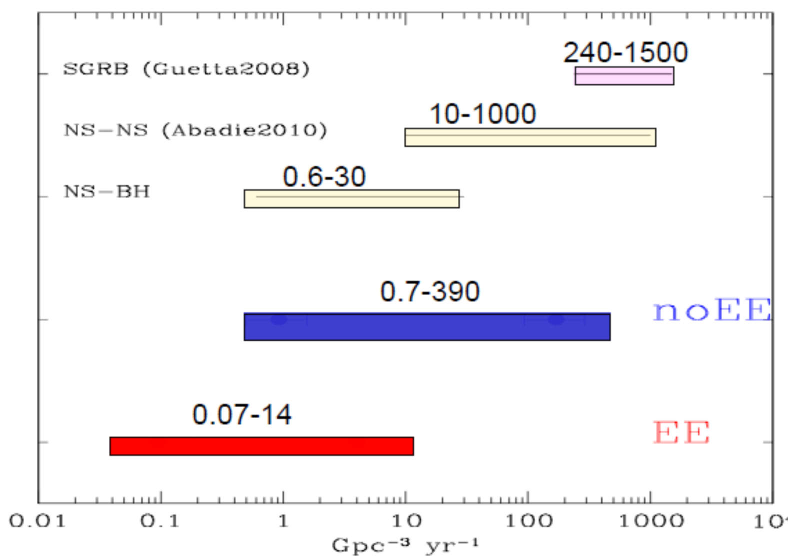
- Binary NS star mergers are favoured as the progenitors for SGRBs (although other scenarios as NH-BH cannot be excluded)
- If so, we expect:
  - Association with old stellar population
  - Association with GW



➢ eXTP/WFM suitable for detecting short GRBs through the soft Extended Emission



Swift/BAT (15 – 150 keV)



➢ due to its softer energy band w/r to Swift/BAT, Fermi/GBM, BATSE, eXTP/WFM should detect an higher rate of EE from short GRBs/GW events

Conclusions

❑ **GRB science is of high interest to the broad astrophysical (cosm.) community**

❑ **eXTP/WFM can do important GRB science** thanks to its unique combination of broad FOV, low energy threshod, excellent energy resolution and good effective area:

✓ investigating the physics of prompt emission, absorption features by circum-burst material, the weak/soft population of GRB (XRF), detecting extended X-ray emission from short GRBs (-> GW counterparts)

✓ complementing simultaneous observations by GRB experiments flying on other satellites (as is presently done, e.g., with Swift + Fermi, Swift + KW)

✓ **onboard computation and prompt dissemination of GRB (~arcmin) position would be a fundamental service to the GRB (and not only) community in the > 2024 time frame (e.g., GW detectors, E-ELT, CTA, SKA, ATHENA, etc.)**

❑ **eXTP SFA, PFA and LAD:** unprecedented spectroscopy and polarization measurements of X-ray afterglow emission (depending also on TOO policy and capabilities) (talk by Wu)