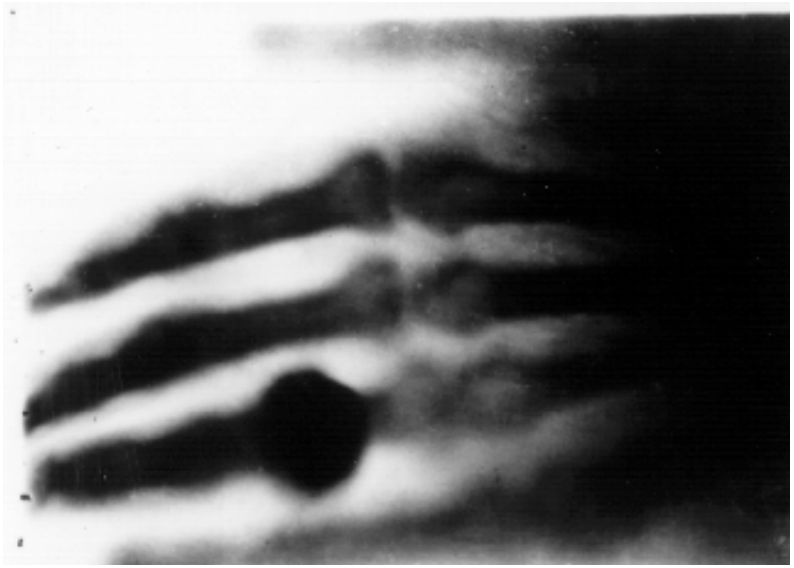
Journée prospective rayons X
Transitoires & nouveaux messagers

Frédéric Daigne (Institut d'Astrophysique de Paris)



Journée Prospective Rayons X – CNES, 24 septembre 2013

Plan de l'exposé :

Quelques phénomènes transitoires,
observés en rayons X,
et d'intérêt pour la communauté PNHE…
…sans aucun souci d'exhaustivité !

Et quelques évidences en guise de conclusion, quant aux nécessités instrumentales dans le domaine des rayons X pour l'étude des phénomènes transitoires.

1. Tidal disruption events

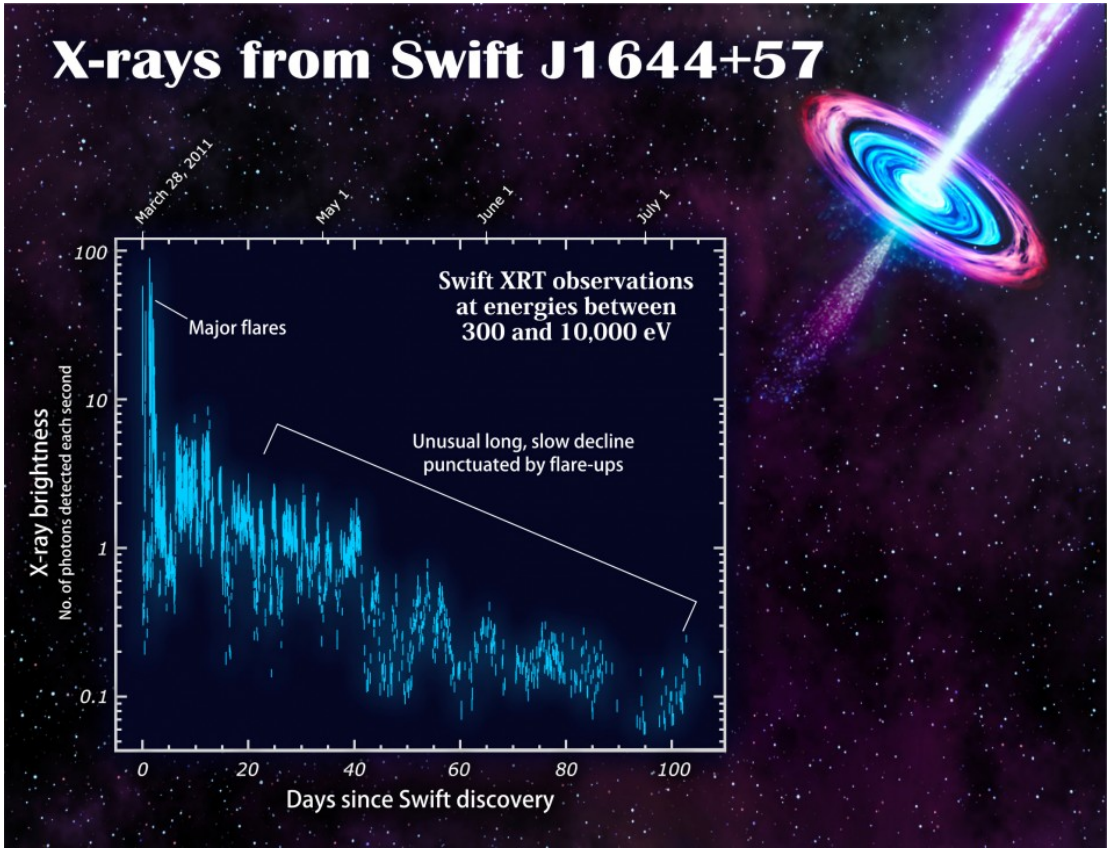
Tidal Disruption Events : gigantic flares from galactic nuclei
= tidal disruption of a star by a supermassive BH

Tidal Disruption Events : gigantic flares from galactic nuclei = tidal disruption of a star by a supermassive BH

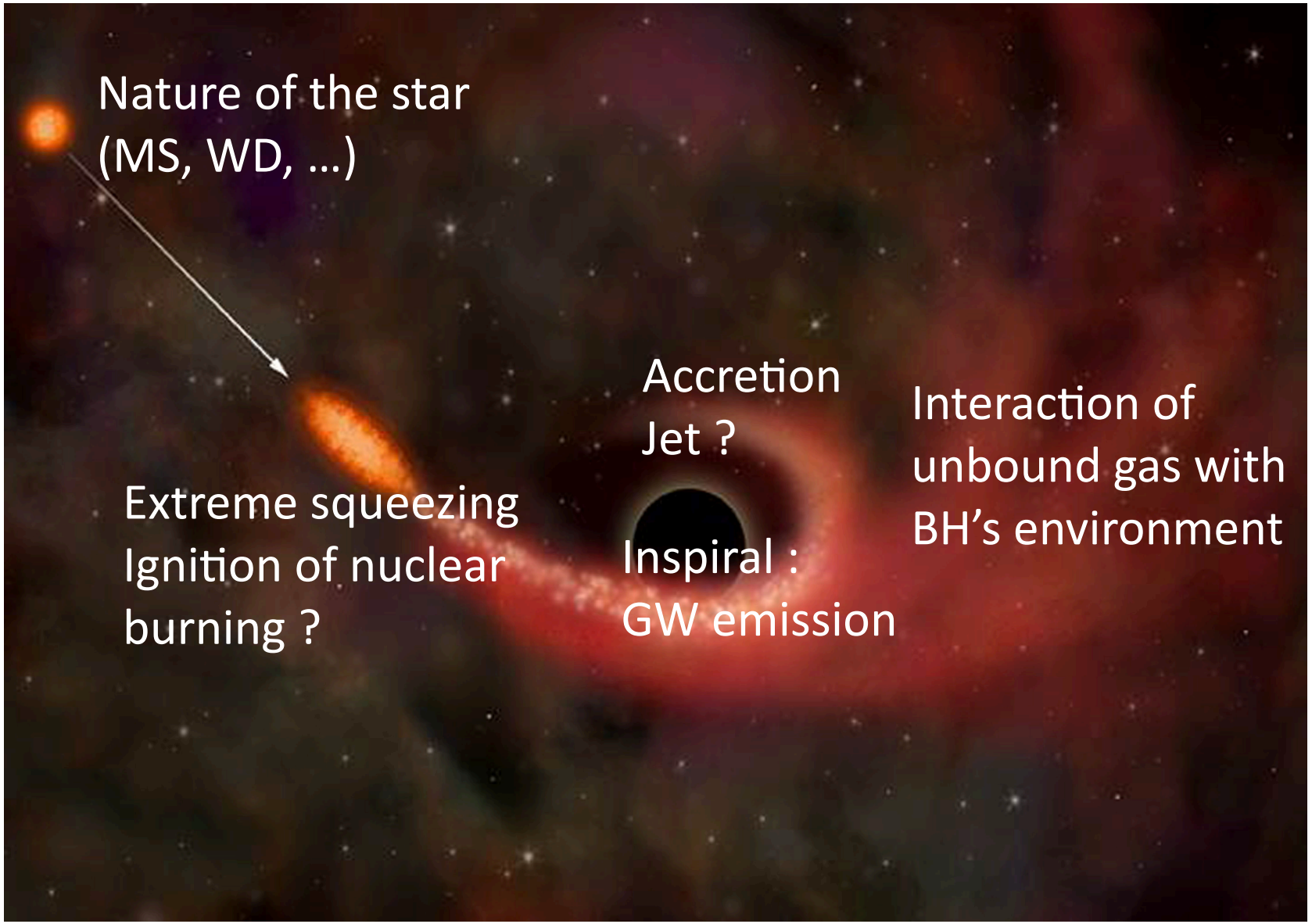
- X-ray, UV and optical flares

  X-rays: ROSAT (discovery) – Chandra, XMM – Swift

- Quiescent BH or AGN
- Swift J1644+57 : clearest candidate - relativistic jet ?



Tidal Disruption Events : a rich physics



D'après S. Komossa (MPIfR, Bonn)

Tidal Disruption Events : a rich physics

- What is the immediate environment of SMBHs ?
- Physics of accretion/ejection
- How do SMBHs grow ?

- Statistics of TDEs,
  fraction of extreme mass ratio inspirals,
  GW emission

Tidal Disruption Events :

requirements for future X-ray missions

- Improve the statistics of events

- Large survey
- Broad spectral band
- Rapid response for follow-up at other wavelengths

- Response to TDE detections at other wavelengths

(e.g. LSST : a few 10^2 TDEs/year ?)

2. Magnetars

Magnetars :

anomalous X-ray pulsars / soft gamma-ray repeaters

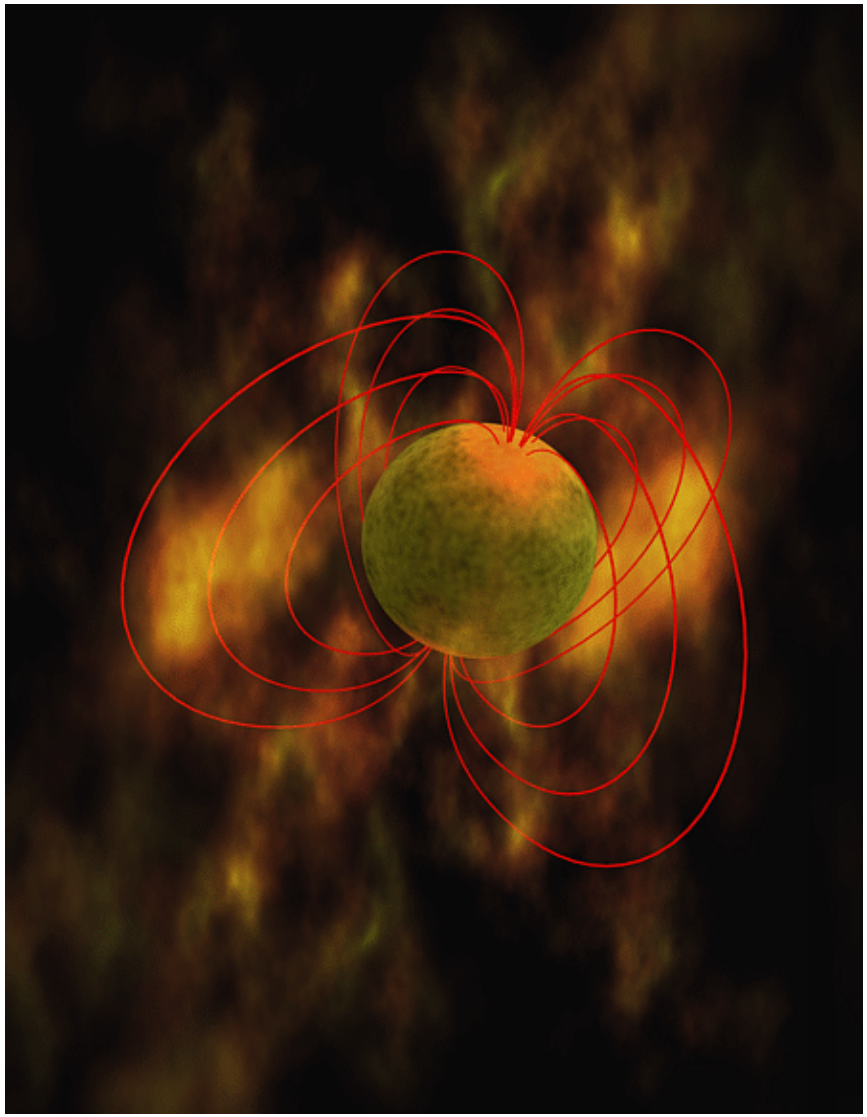
＝a magnetically powered neutron star

≠ normal NS :

rotation,

accretion,

or residual heat



Magnetars :

anomalous X-ray pulsars / soft gamma-ray repeaters

＝a magnetically powered neutron star

• AXP ＝ bright pulsar in soft X-rays (<10 keV) with several features different from “normal” accreting NS

• SGR ＝ bright and short bursts of hard X-rays, repetition

＝magnetars : $B \sim 10^{13}$-10^{15} G

Magnetars : flares & bursts

- Giant flares of SGRs

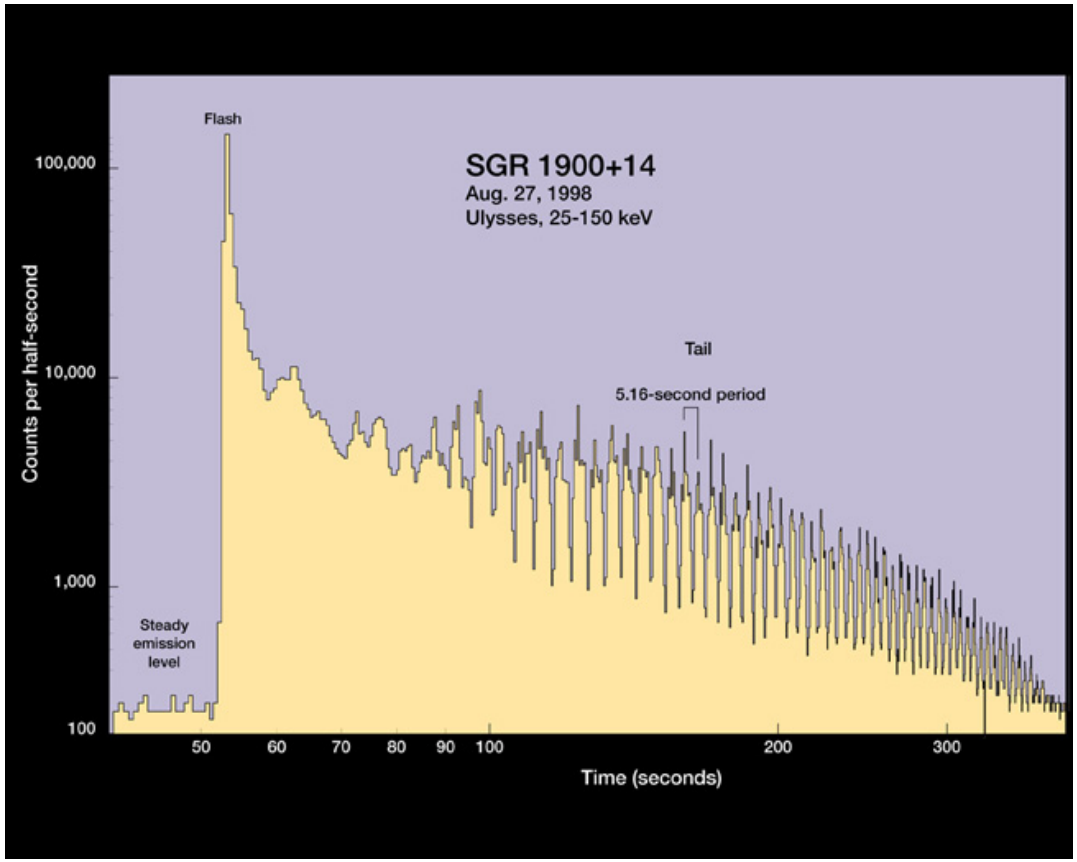
(three cases, more classified as short GRBs ?)

= a spike (< 1 s ; MeV photons)

+ a softer tail

(a few min ;

pulsed with NS period)



Magnetars : flares & bursts

- Giant flares of SGRs
- Short bursts of AXPs/SGRs (more frequent)

  0.01 to 1 s ; hard X-rays ; thermal spectrum
- Intermediate flares :

  strong burst in SGR 1627-41 ; 1ES1547.0-5408

Continuum of events with a common physics ?

Magnetars : physics

- Understanding the most extreme case of magnetized stars – how is the magnetic energy extracted ?

- An example of a debated question :

are magnetar properties defined by the internal or the external field intensity ?

2009 : SGR 0418+5729, two short burst in X-rays

Pdot : $B_{ext} < 6\ 10^{12}$ G

Magnetars : requirements for future X-ray mission

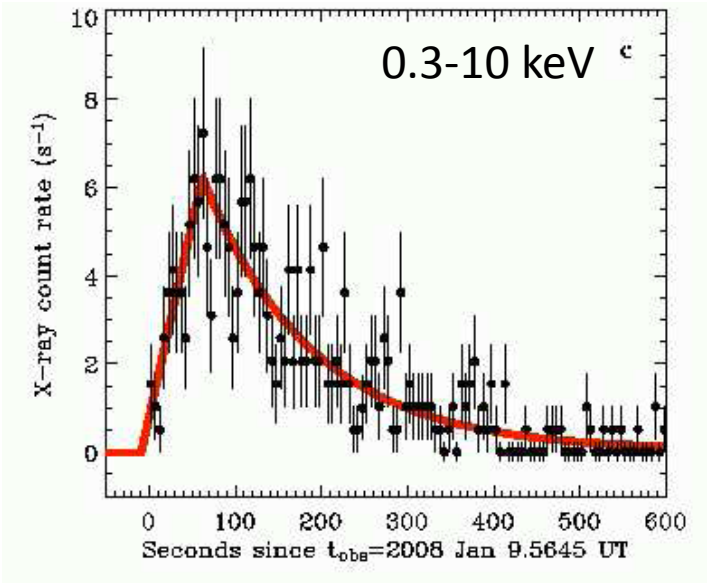
- Magnetar flares are rare events =
  large field of view + good sensitivity
  + monitoring of known sources

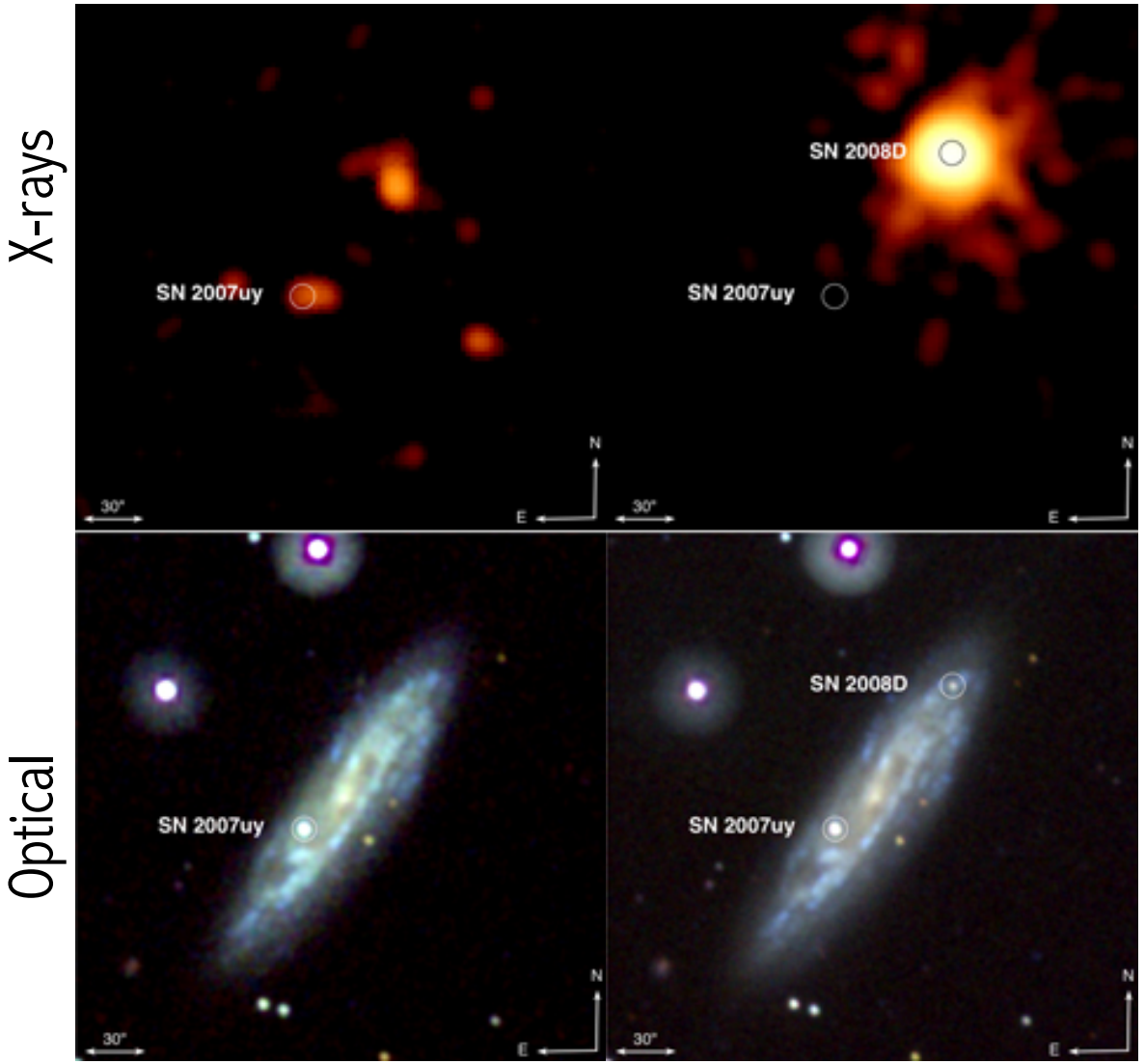
- Broad spectral range
- Good temporal resolution

3. Supernova shock breakout

Supernova Shock breakout :

for any core-collapse supernova = flash of thermal UV/ soft X-ray photons when the SN shock reaches the stellar surface.





SN2008D

Soderberg et al. 2008

Supernova Shock breakout :

for any core-collapse supernova = flash of thermal UV/ soft X-ray photons when the SN shock reaches the stellar surface.

- Very rare observations : UV (Gallex) ; X-rays (Swift)
  more to come in optical (LSST, PTF, …)
  in X-rays ?

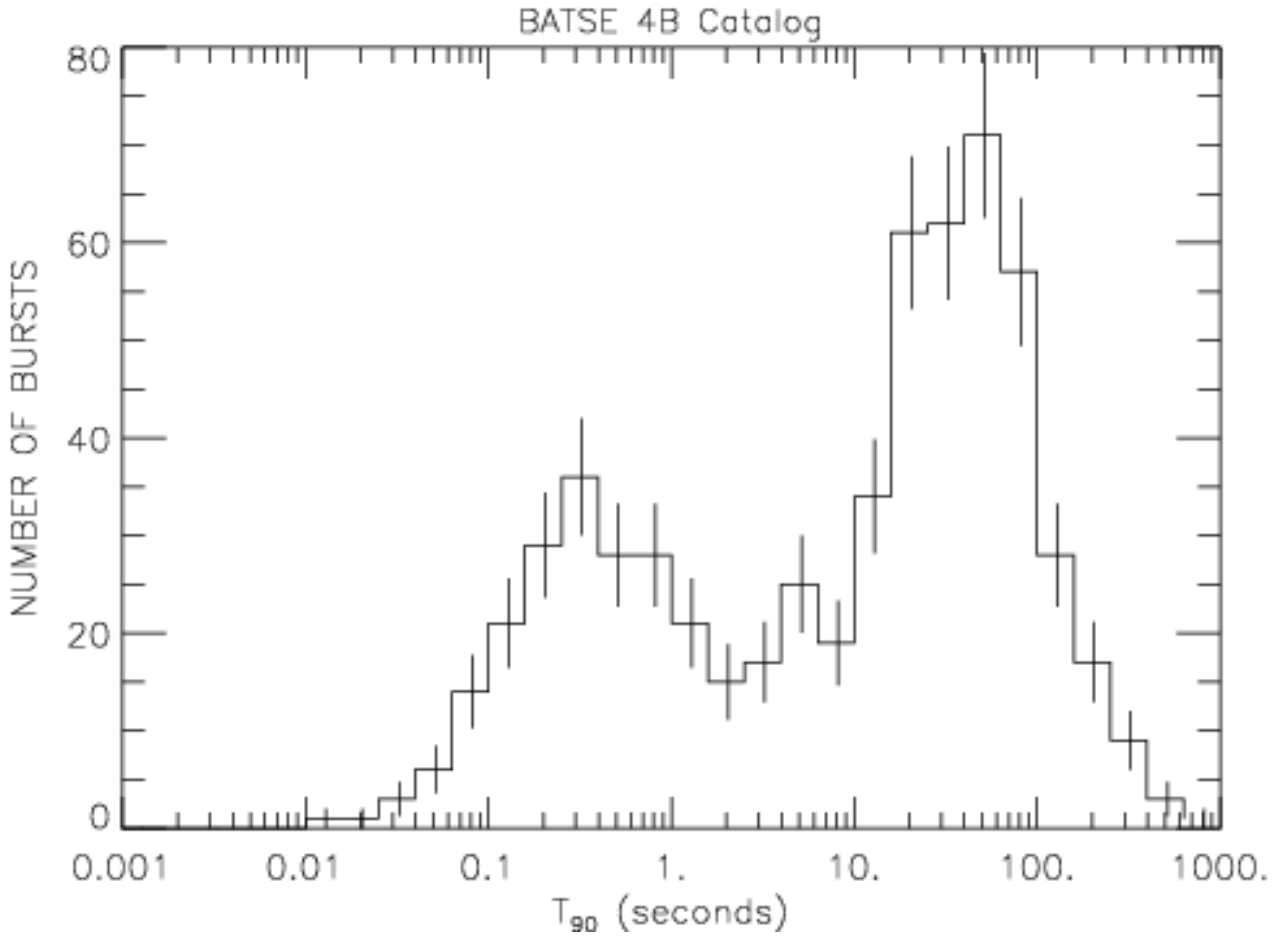
- X-ray shock breakout observation can provide important constraints on the nature of the SN progenitor

- Requirements :
  large field of view (rare events) ; soft X-rays

4. Gamma-ray bursts & NS-NS/BH-NS mergers

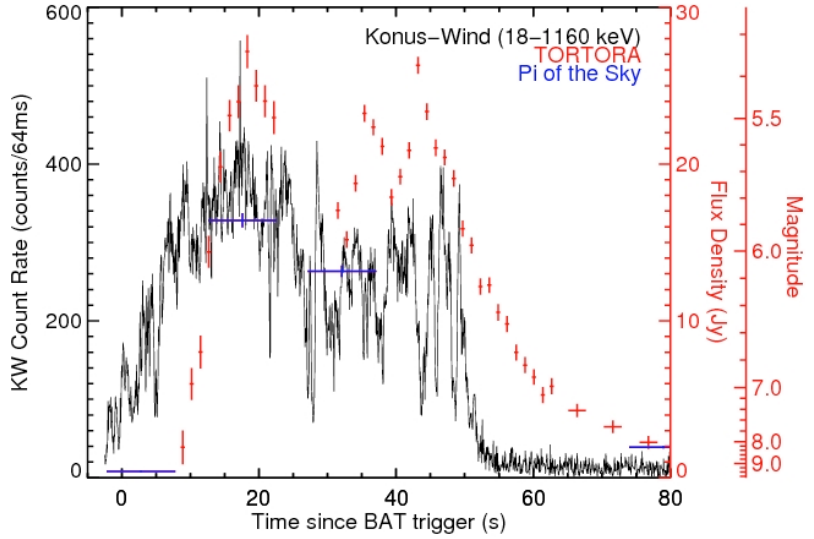
Gamma-ray bursts :

- Cosmological distance
- Short duration: a few ms to a few min
- Two groups

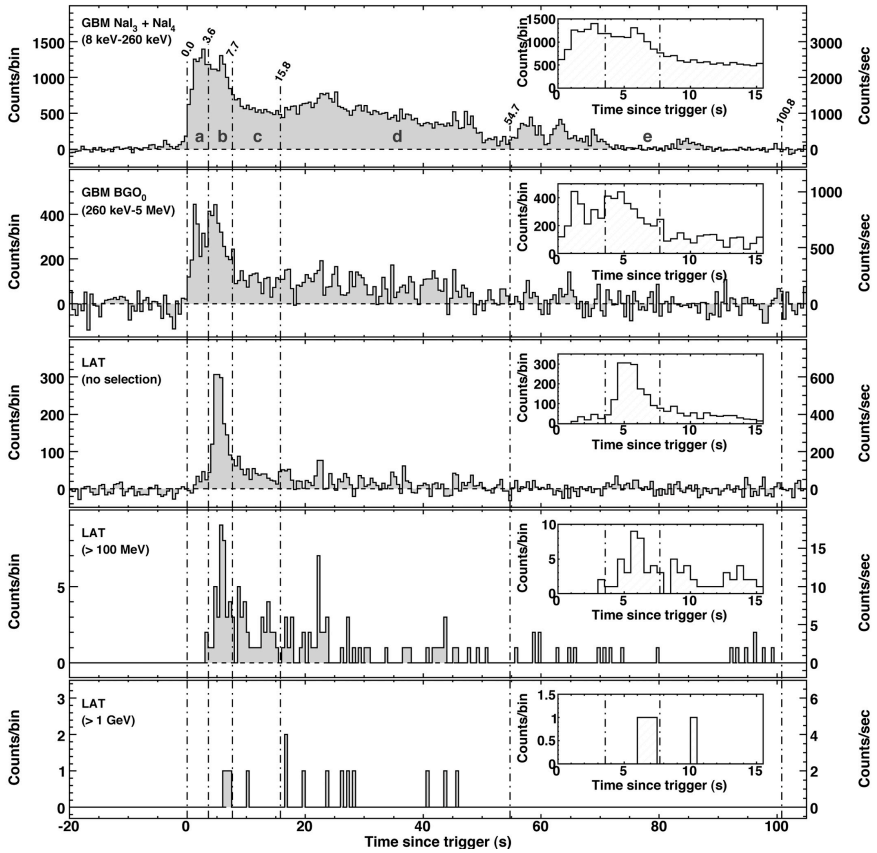


Gamma-ray bursts :

- Short duration a few ms to a few min
- Huge isotropic energy
- Broad band spectrum : opt.→GeV

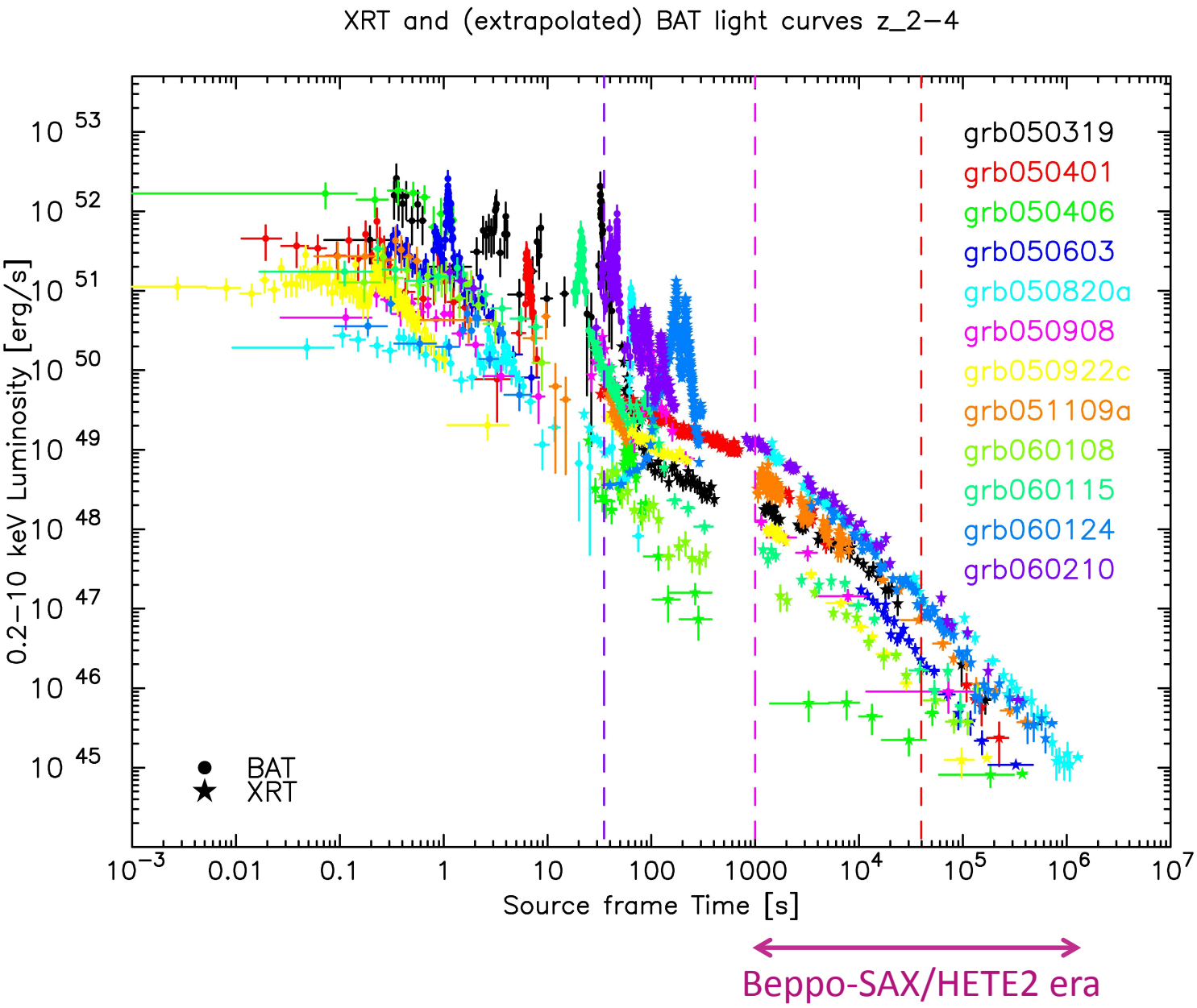


Racusin et al. 2008

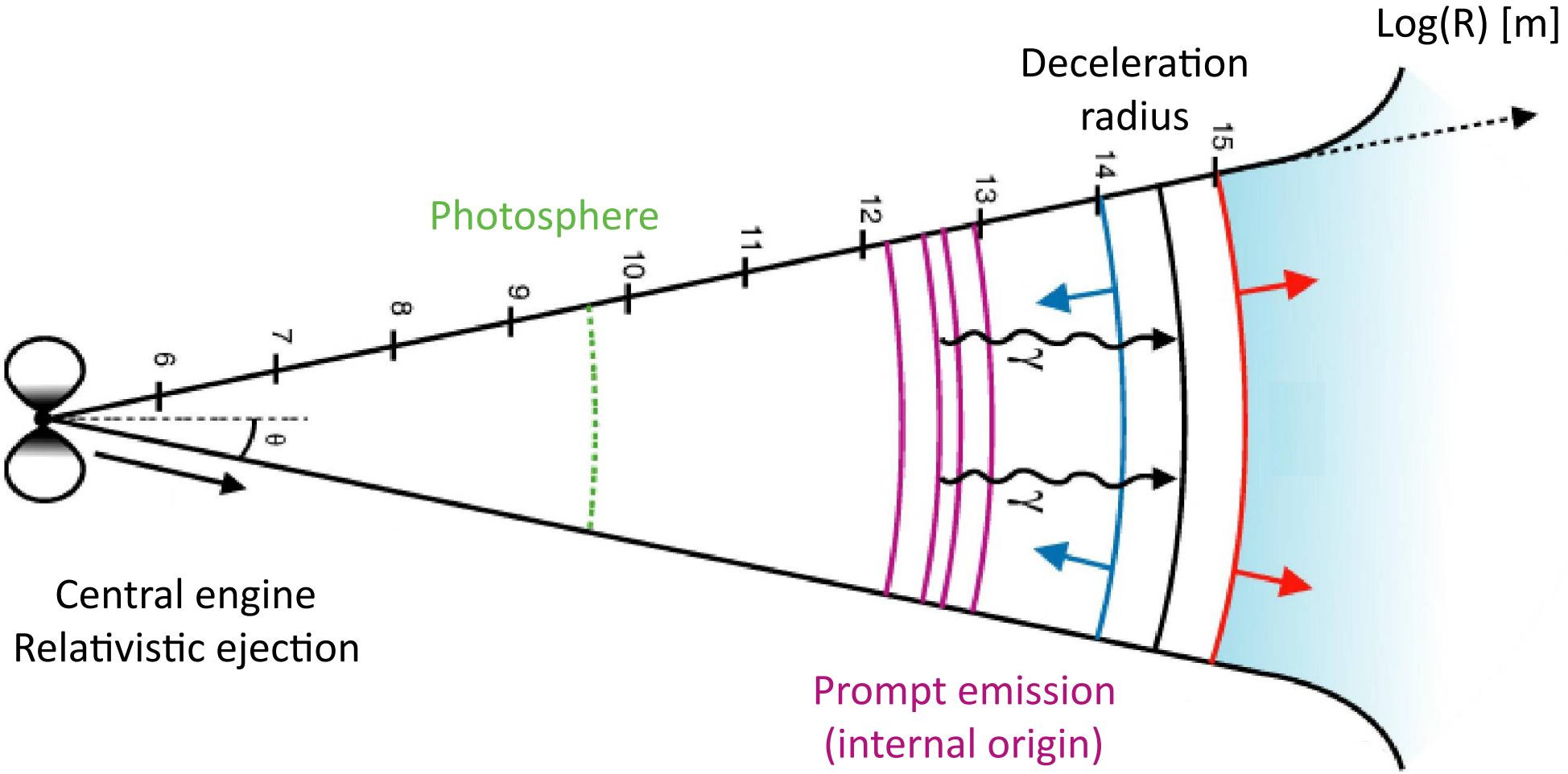


Abdo et al. 2009

Gamma-ray bursts : afterglow (X, opt, radio)



Gamma-ray bursts : model(s ?)



Gamma-ray bursts : questions

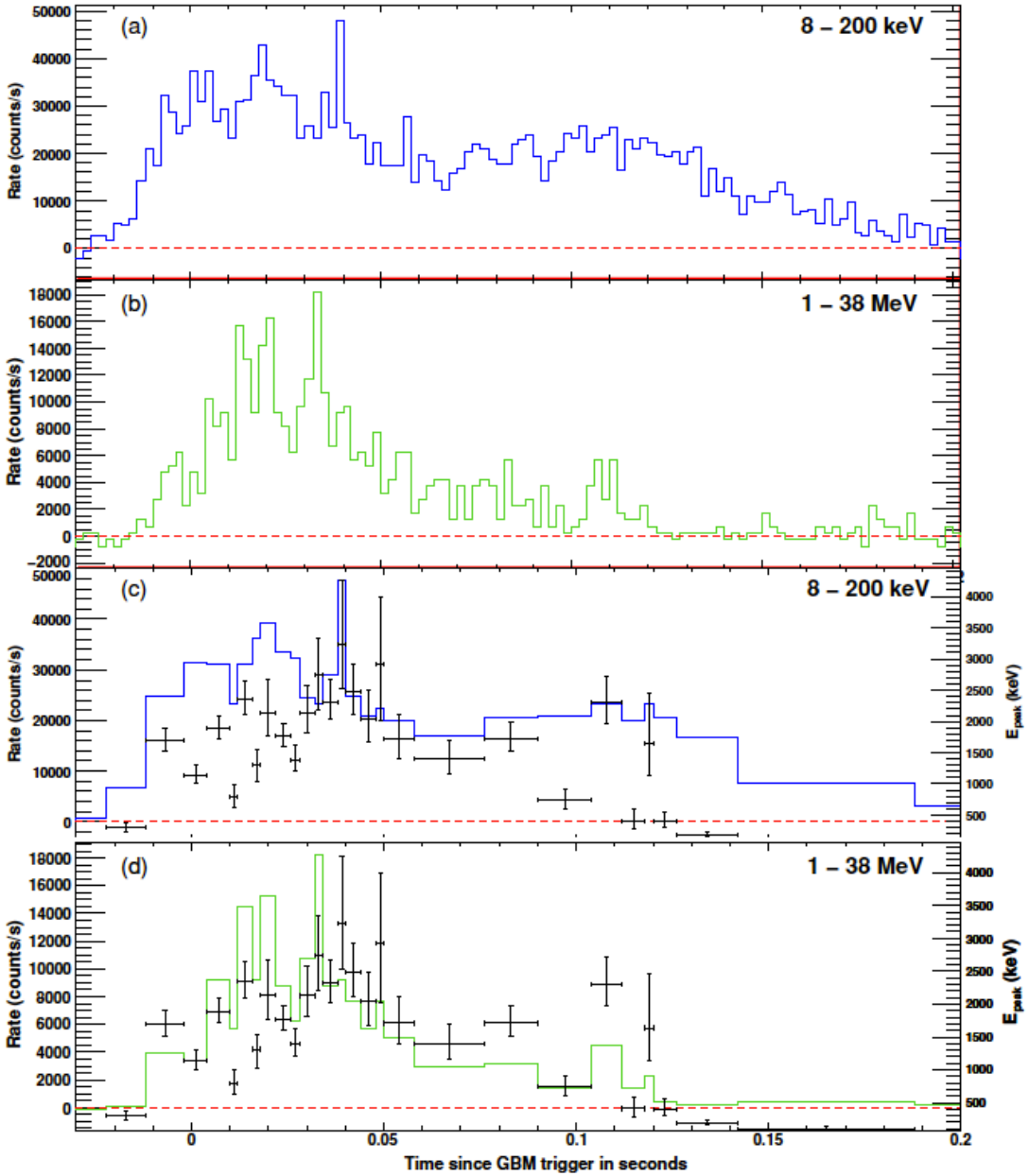
- Nature of progenitors, populations of GRBs
- Continuum of events from “standard core-collapse supernovae” to “standard GRBs” ?

Requirements :

- Long bursts, XRFs : soft+hard X-rays
- Short bursts : increase towards the MeV range
- Localization, follow-up, host galaxy : soft X-rays + rapid localization + real-time dissemination + synergy with other wavelengths

A short GRB seen by Fermi/GBM :

Short GRBs emit
at higher energies
→ MeV domain



GRB 090227B
(*Fermi*/GBM)
duration ~ 0.15 s

← 3 MeV

← 1 MeV

Guiriec et al. 2010

Figure 1. Light curves of GRB 090227B in two energy bands (panel (a): 8 keV to 200 keV, NaI detectors) and (panel (b): 1 MeV to 38 MeV, BGO detectors) with 2 ms time resolution. The count rates are background subtracted. Two bottom panels: the same light curves with variable time bins (histograms), optimized for time-resolved spectroscopy. The Band function peak energy, E_{peak}, is plotted over the light curve for each time interval.

Gamma-ray bursts : questions

- Nature of the central engine ?
- Nature of the relativistic outflow ? Of the dissipative process responsible for the prompt emission ?
- What determines the time scales ? the energetics ?

Requirements :

- Broad band spectra : gamma-ray domain
  + multi-lambda of the prompt (opt, X, GeV)

(hard X-rays only alla Swift/BAT : not enough !)

- Polarization in hard X-rays

Gamma-ray bursts : questions

- Physics of the afterglow : emission sites (FS, RS) ?
- Geometry of the jet, long term evolution, GRB remnant ?

Requirements :

- Real-time localization / alerts / follow-up at other wavelengths

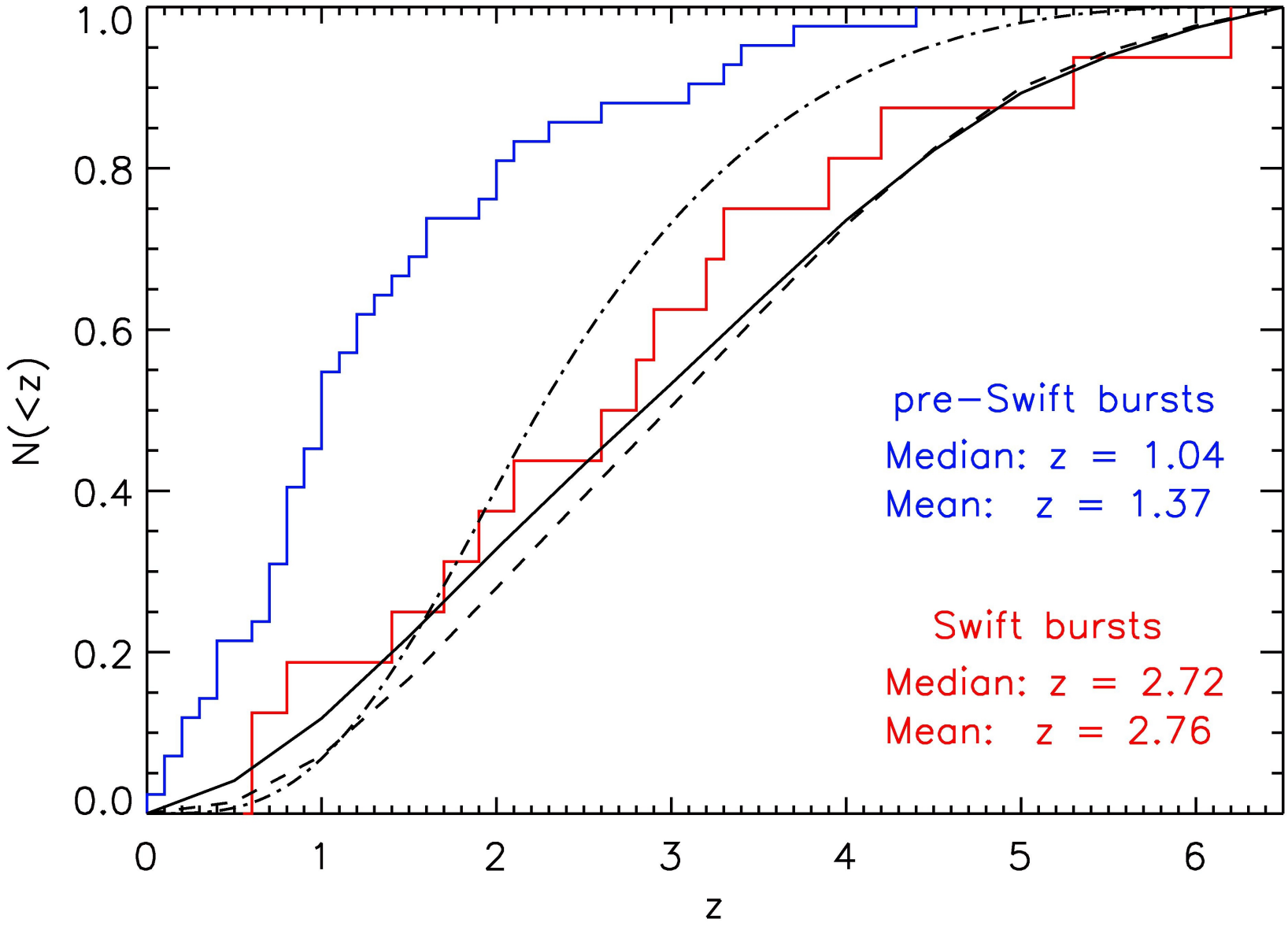
Gamma-ray bursts : questions

- GRB rate, GRB redshift distribution (per class)
- GRBs as a tool for cosmology
  [take advantage of new facilities]

Requirements :

- Importance of X-rays (redshifted long GRBs are softer)
- Importance of the large f.o.v. and of the sensitivity (GRBs at large redshift are fainter)
- Importance of the rapid follow-up in IR
- Importance of a rapid spectroscopic follow-up with large telescopes

Present z_{max} = 8 ~ 10



Jakobsson et al. 2006

Gamma-ray bursts : questions

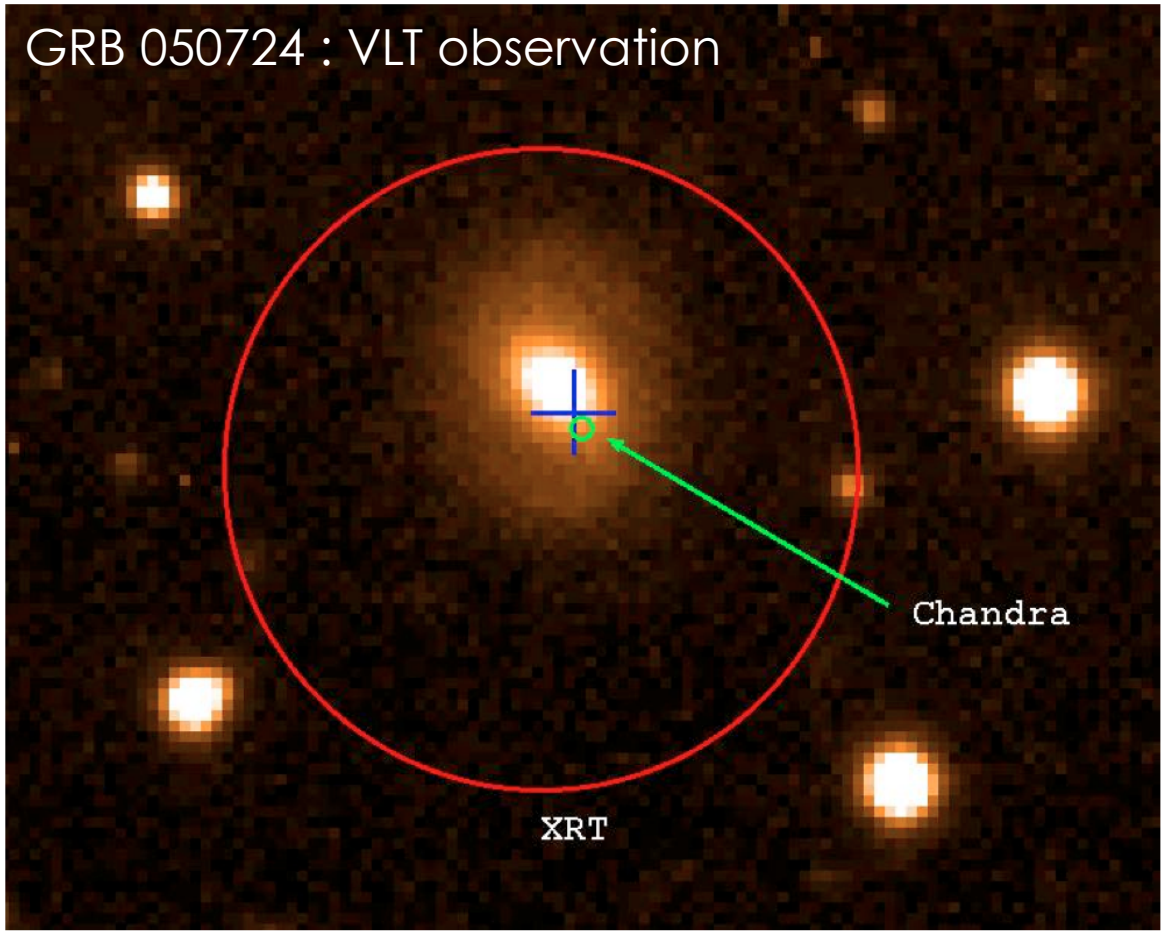
- GRBs as a source of HE neutrinos ?
- GRBs as a source of gravitational waves ?
  [take advantage of the next generation of detectors]
- GRBs as a source of (U)HECRs ?

Requirements :

- For GW : capacity to detect and localize short GRBs (mergers) and then trigger a rapid follow-up
- For all messengers :

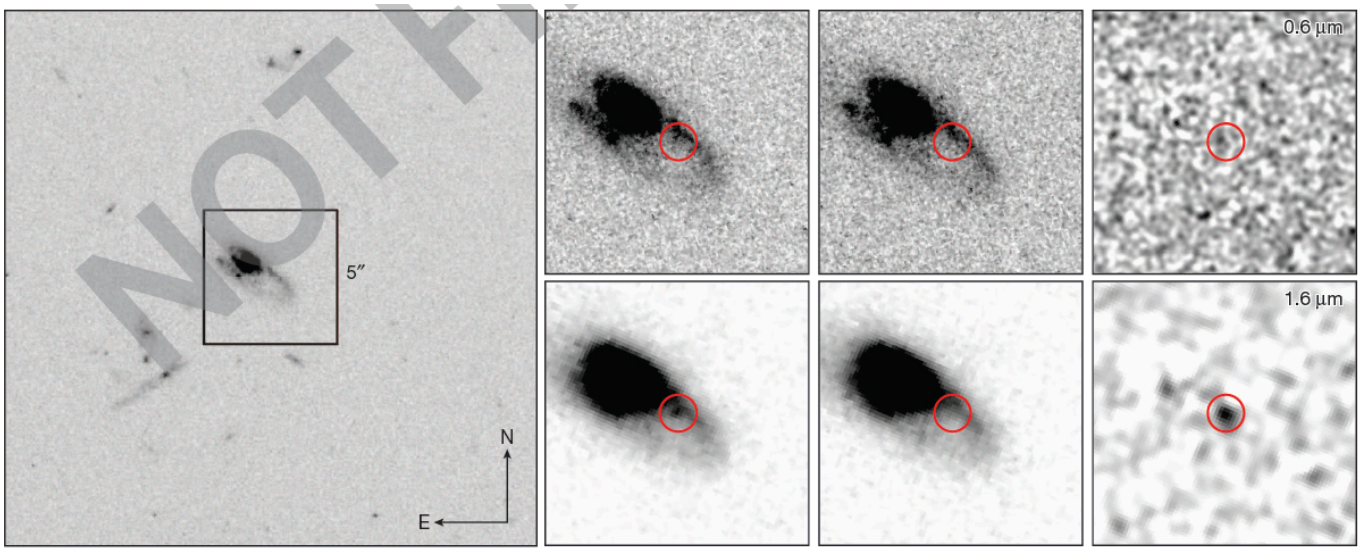
better contrain the GRB rate and redshift distribution

A future association short GRB / GW / kilonova ?



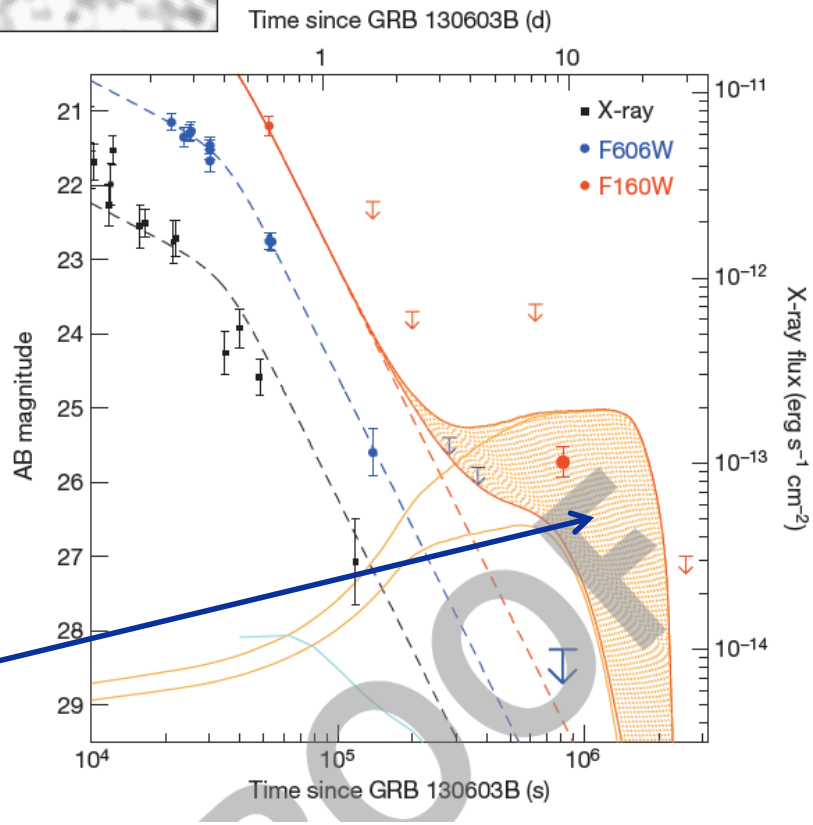
Barthelmy et al. 2005

A future association short GRB / GW / kilonova ?



Tanvir et al. 2013

Short GRB 130603B



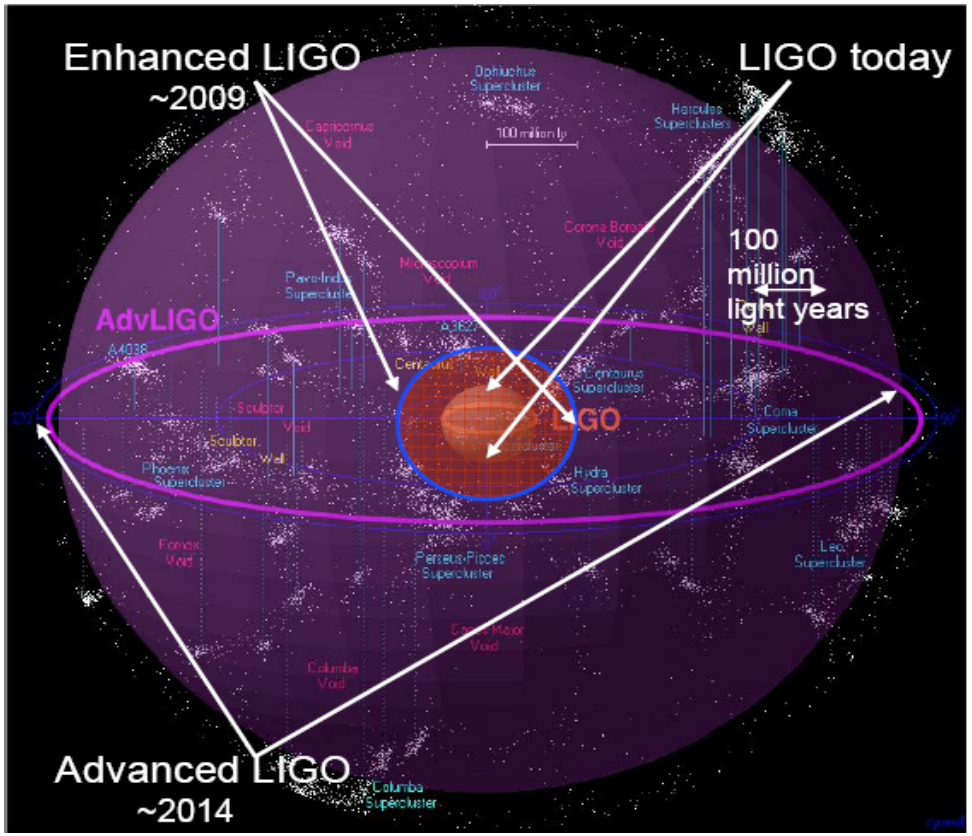
Kilonova ?

A future association short GRB / GW / kilonova ?

- GW : inspiral, merger, ringdown
- GRB + afterglow : relativistic jet
- kilonova : r process in ejecta

	NS/NS	NS/BH
LIGO I/ Virgo	15 Mpc	30 Mpc
Ad LIGO/ Ad Virgo	200 Mpc	420 Mpc

	NS/NS	NS/BH
LIGO I/ Virgo	0.02 yr^{-1} (2e-4 – 0.2)	0.004 yr^{-1} (7e-5 – 0.1)
Ad LIGO/ Ad Virgo	40 yr^{-1} (0.4 – 400)	10 yr^{-1} (0.2 – 300)



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Association short GRB / GW ?

Optimistic = 10% of GW detections (geometry, detection efficiency, …)

Future of GRB observations in space

- Something really new: polarization

  [GRB physics]

Future of GRB observations in space

- Minimum requirement:

  maintaining the capability of detecting GRBs
  (with near real-time localizations)

→ To take advantage of new instruments for the follow-up

→ To have GRB triggers for the new generation of non-photonic detectors

[GRB physics; Cosmology with GRBs; New messengers]

- Possible improvements compared to the *Swift/Fermi* era:

  improve sensitivity/extend spectral coverage/
  improve the localization of short GRBs/
  (extend the spectral resolution)

Conclusions

Phénomènes transitoires & astronomie X : conclusions

- Plusieurs de ces sujets sont à l'interface entre plusieurs communautés : PNHE/PNCG ; PNHE/PNPS
[e.g. TDEs ; SN shock breakout ; GRBs]

- Sur chacun de ces sujets, la communauté française est souvent petite si on ne considère que les personnes dont c'est le cœur d'activité.

[e.g. GRBs]

Phénomènes transitoires & astronomie X : conclusions

• Il y a parfois une tension entre les différentes contraintes instrumentales au sein d'un même sujet.

[exemple : les sursauts gamma
- Aller vers les X mous pour les sursauts à grand z
- Aller vers les X très durs/γ pour les sursauts courts]

Phénomènes transitoires & astronomie X : conclusions

• Il y a très souvent un rôle central de l'observation multi-longueurs d'onde, avec une difficulté supplémentaire de mise en œuvre due à l'aspect transitoire.

• La réactivité d'un éventuel instrument X est primordiale, avec des échelles de temps éventuellement très courtes.
[e.g. seconde-min pour sursauts gamma]

- Capacité de localisation / alerte en temps réel
- Capacité de pointage rapide sur alerte

Phénomènes transitoires & astronomie X : conclusions

- Les rayons X ne sont pas systématiquement le domaine spectral de la détection initiale : réactivité !
- Cette fonction va encore s'accentuer dans le futur :
  - Grands relevés dans l'optique/le domaine radio : moisson de phénomènes transitoires dont on veut rechercher la contrepartie en X

    [Palomar transient factory ; LSST ; EUCLID ; SKA ; …]
  - Futures alertes « nouveaux messagers »

    [GW: advanced Virgo/LIGO 2015 ? ; HE neutrinos : ?]

Phénomènes transitoires & astronomie X : conclusions

- Il y a une tension générale entre ce domaine et les autres sujets d'intérêt pour l'astronomie X
  - Tout le ciel contre petit champ
  - Surveillance du ciel contre mode pointé
  - Nécessité d'une bonne résolution temporelle
  - Grande couverture spectrale (soft+hard X-rays) privilégiée
  - Surcoût de la réactivité, de la localisation/alerte temps réel
- Tension plus facile à résoudre avec une grosse mission qu'une petite…