Observing GRB afterglows with SIMBOL-X

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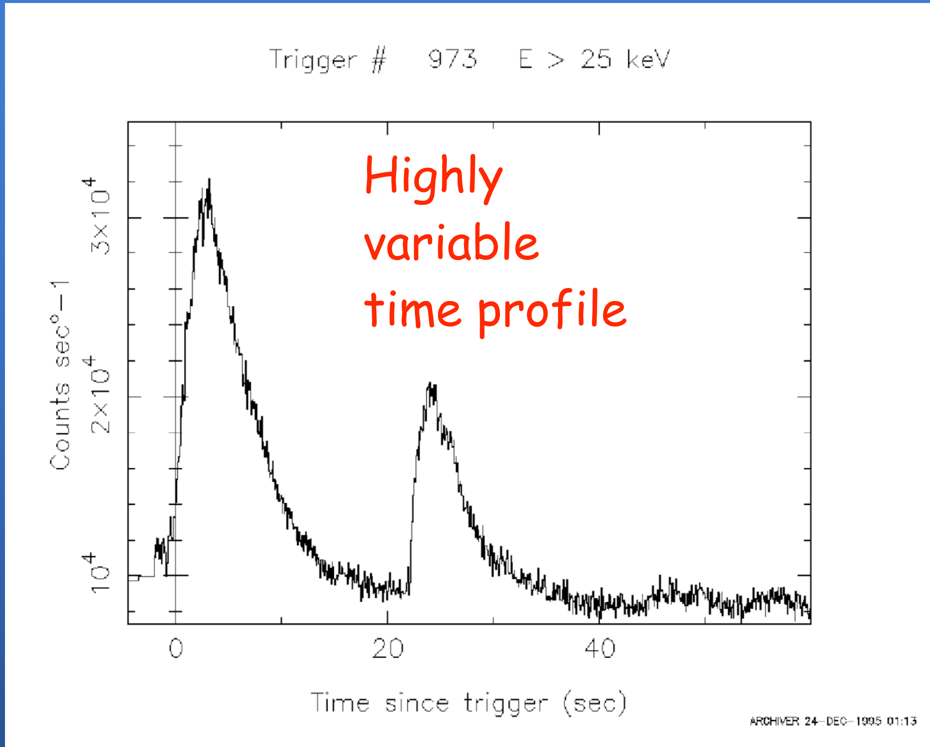
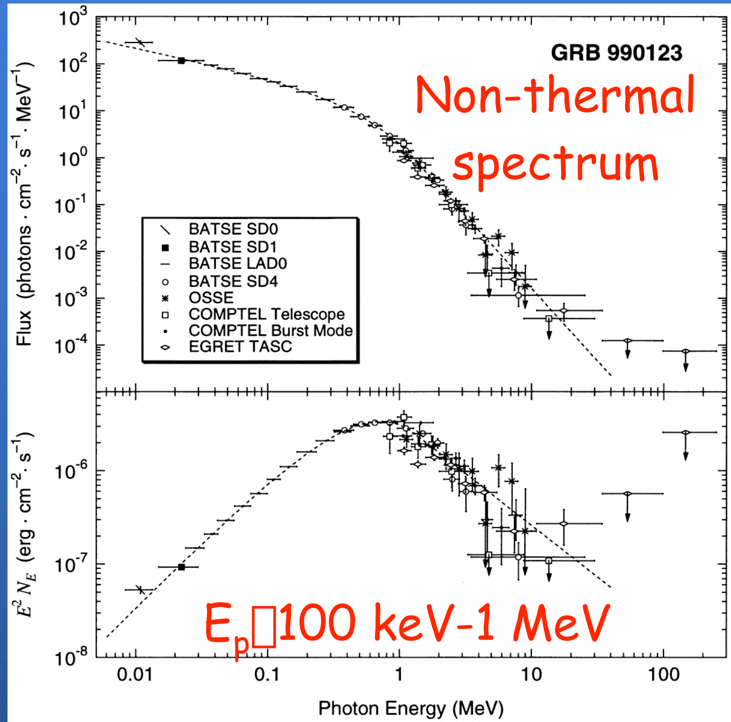
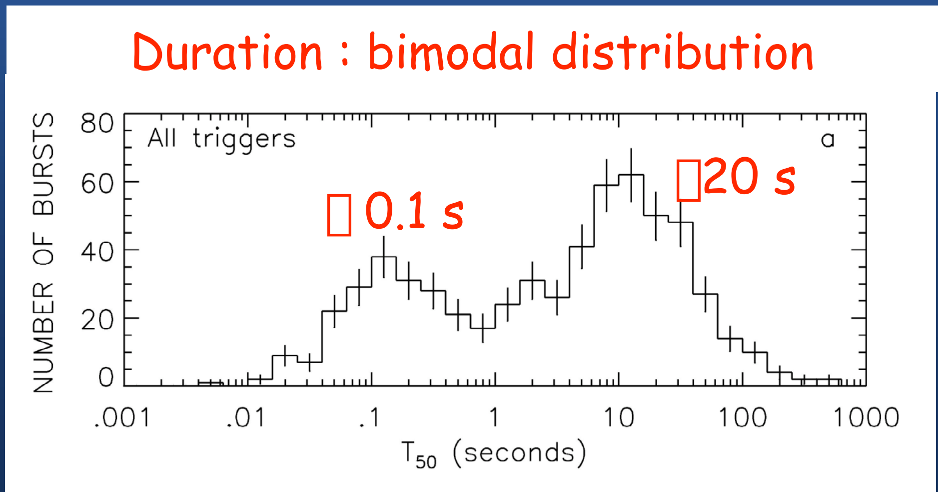
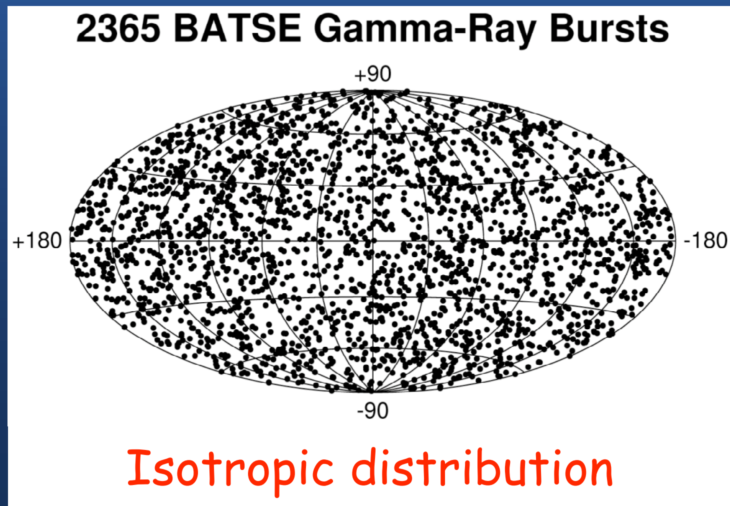
Gamma-ray bursts : prompt emission

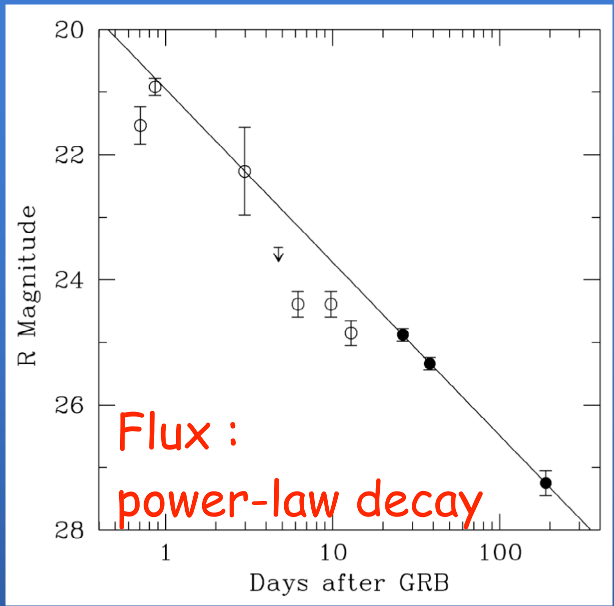


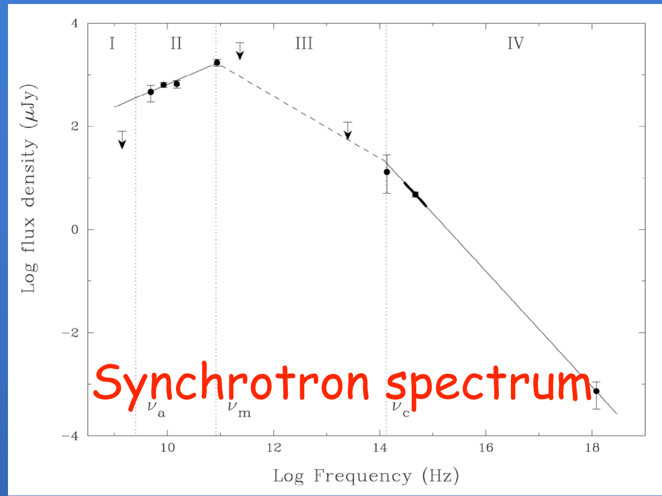


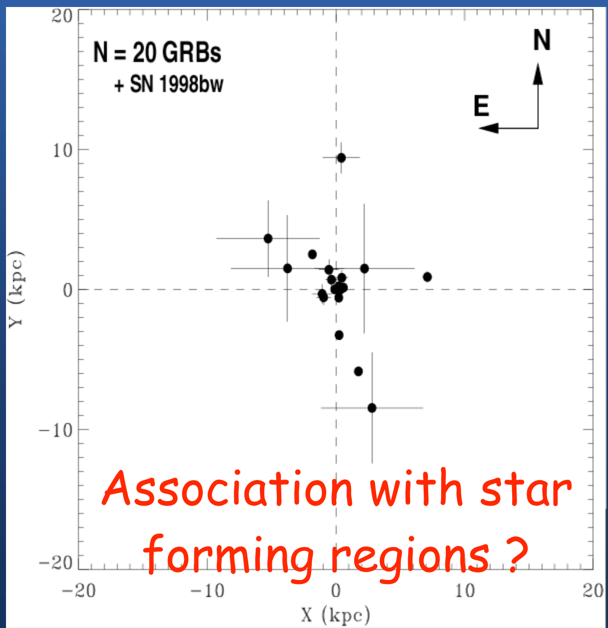




Afterglows (X, optical, radio)



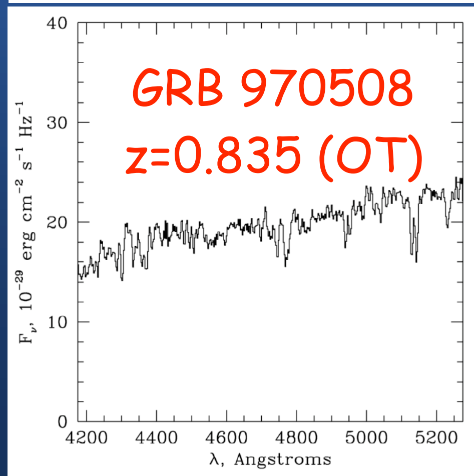


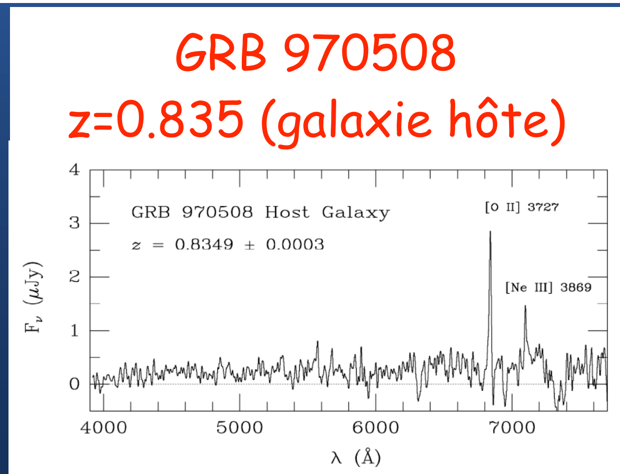


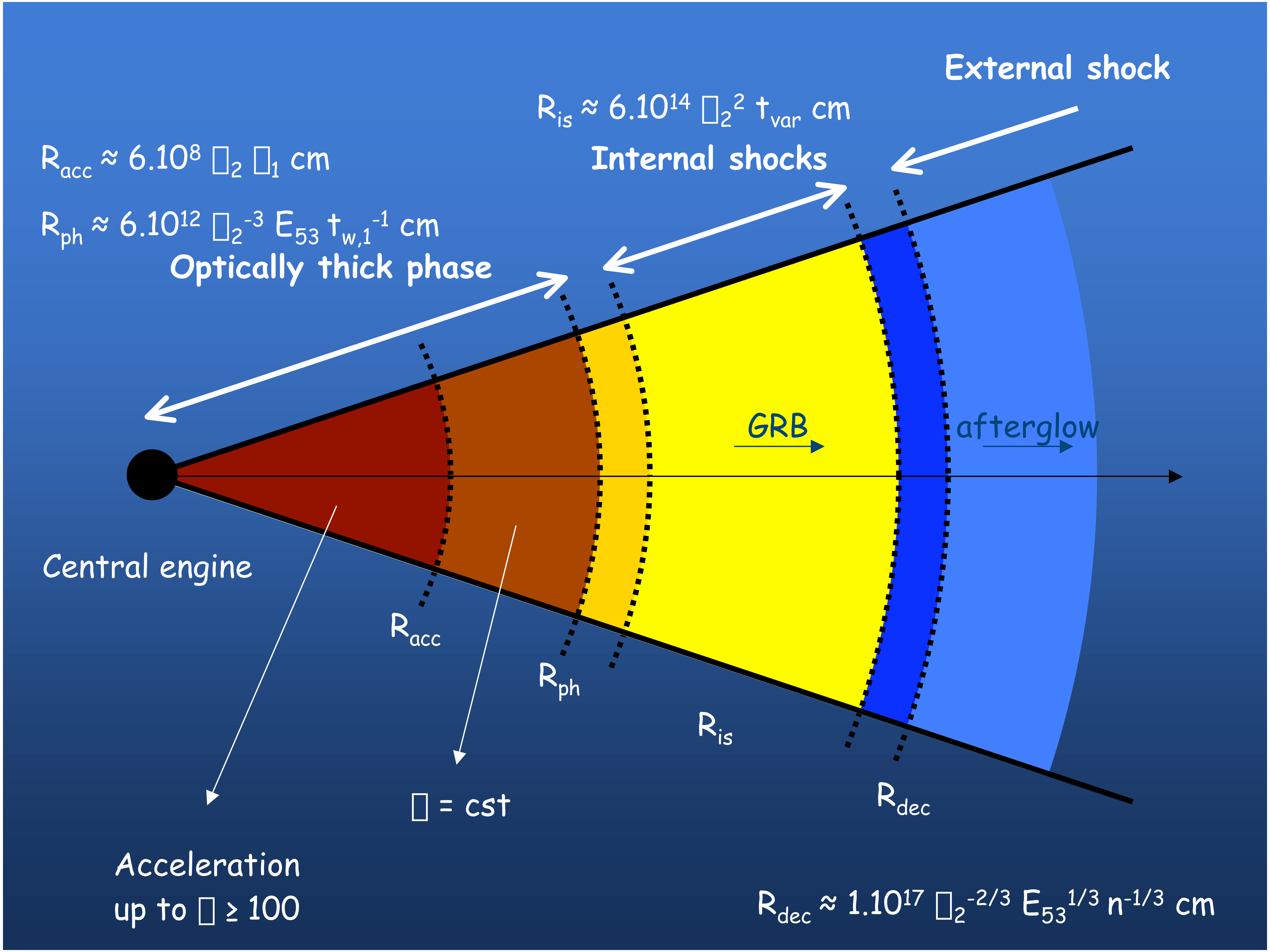
1997-2002 :

30 redshifts determinations : $z = 0.17 \rightarrow 4.5$

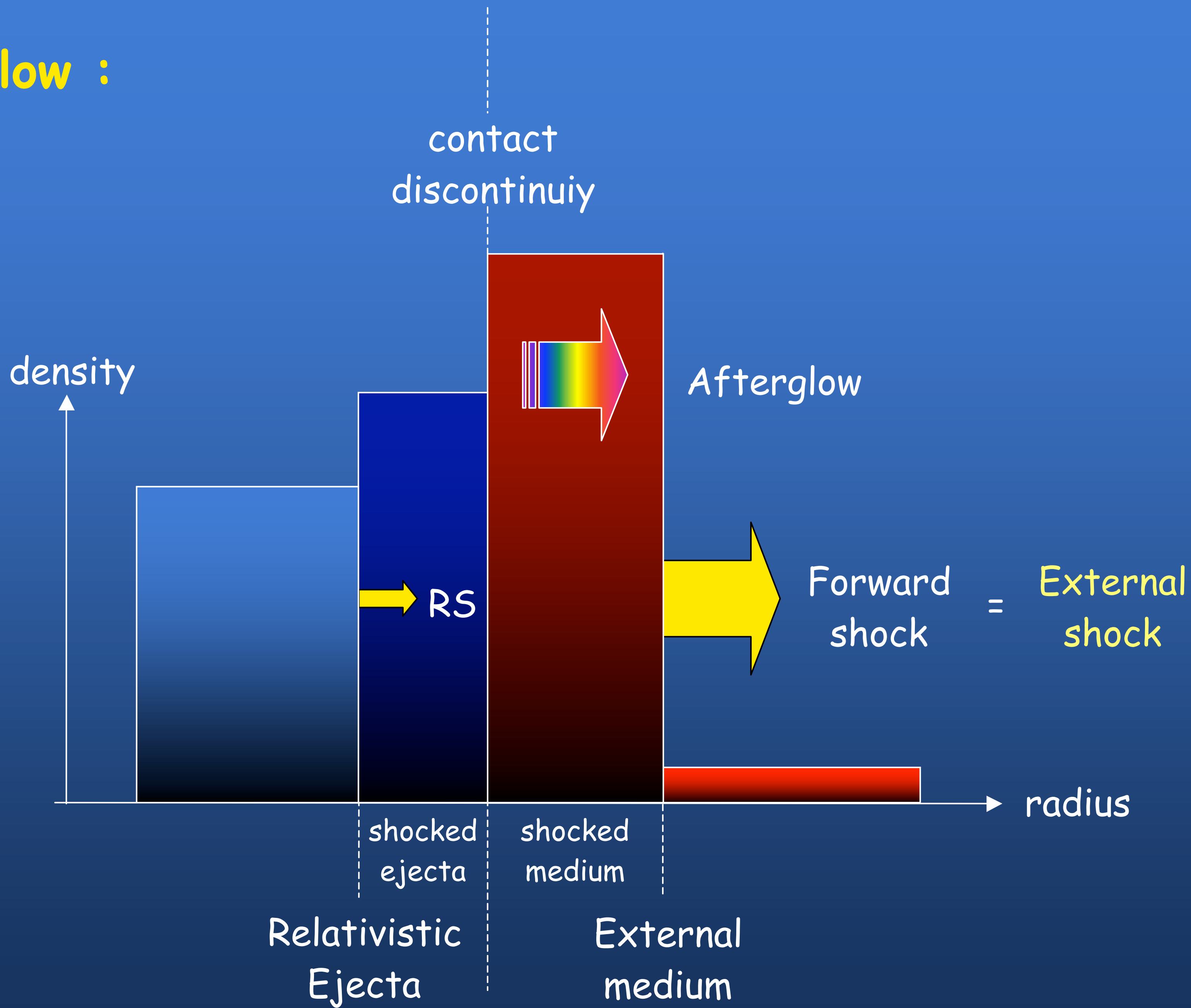
$E_{\gamma iso} \sim 10^{51} \rightarrow 10^{54}$ erg !



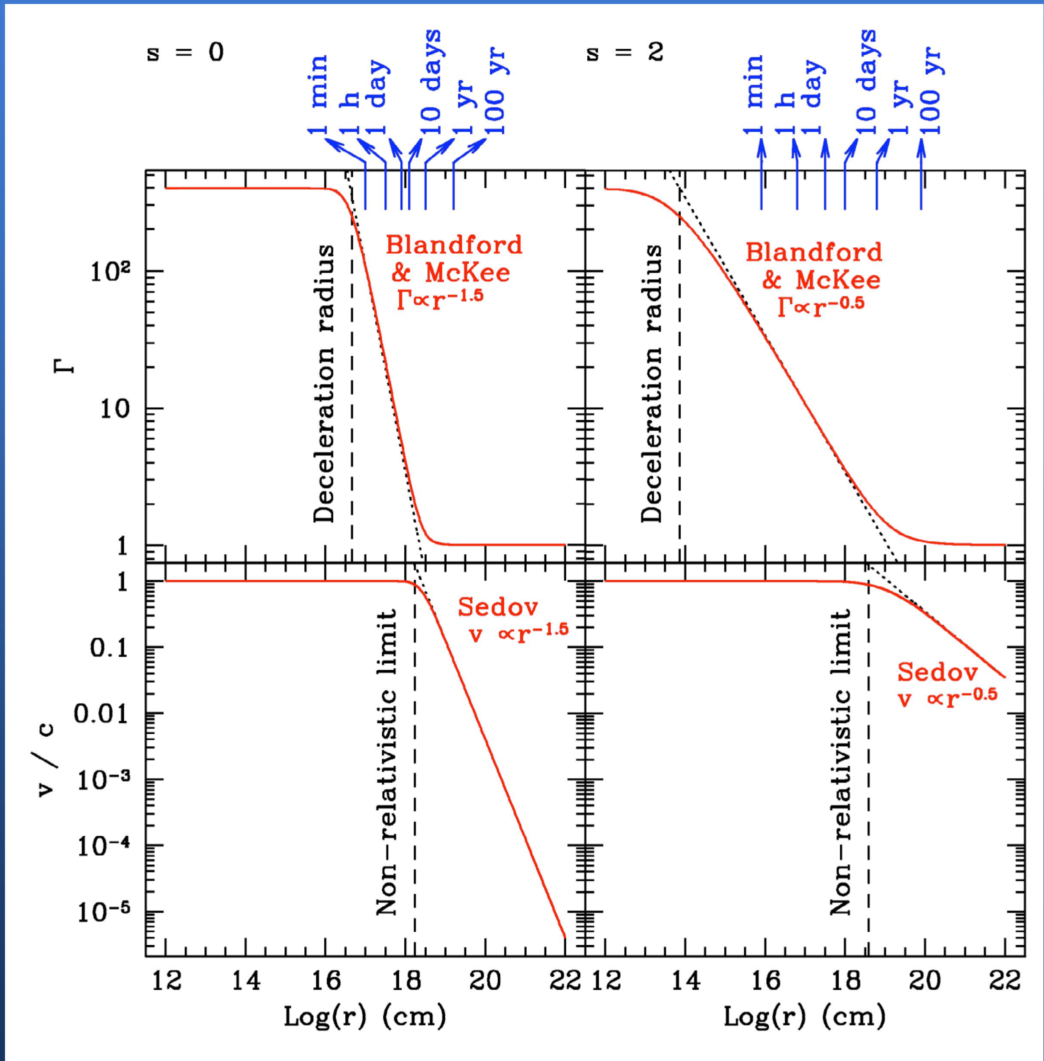



External shock
$R_{is} \approx 6.10^{14}$ □$_2{}^2$ t_{var} cm
Internal shocks
$R_{acc} \approx 6.10^8$ □$_2$ □$_1$ cm
$R_{ph} \approx 6.10^{12}$ □$_2{}^{-3}$ E_{53} $t_{w,1}{}^{-1}$ cm
Optically thick phase
GRB
afterglow
Central engine
R_{acc}
R_{ph}
R_{is}
R_{dec}
□ = cst
Acceleration
up to □ ≥ 100
$R_{dec} \approx 1.10^{17}$ □$_2{}^{-2/3}$ $E_{53}{}^{1/3}$ $n^{-1/3}$ cm

Afterglow :


contact
discontinuiy
density
Afterglow
RS
Forward
shock
=
External
shock
radius
shocked
ejecta
shocked
medium
Relativistic
Ejecta
External
medium

Density profile in the ambient medium _ deceleration law



Relativistic ejecta :

Γ_0 = 400

$E_0 = 10^{53}$ erg

$M_0 = E_0 / \Gamma_0 c^2 = 1.4\ 10^{-4}$ M

External medium :

s=0 case : $n = 1\ cm^{-3}$

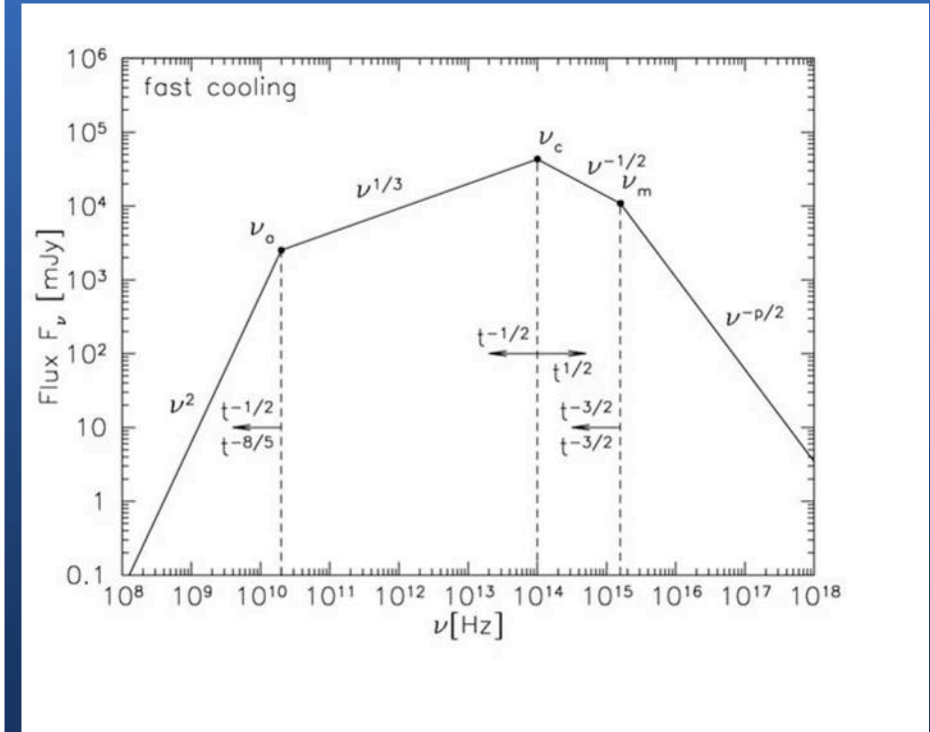
s=2 case : $A_* = 1$

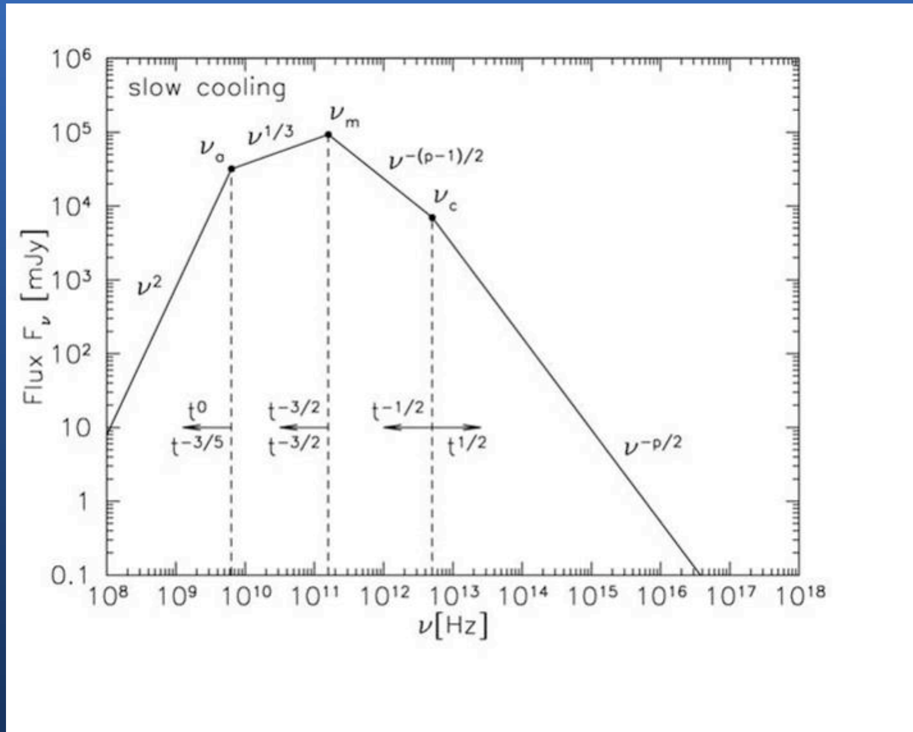
Radiative processes :

(1) Physical conditions in the shocked medium (given by hydro)

(2) Magnetic field – Relativistic electrons : "equipartition" assumptions

(3) Synchrotron spectrum : slow or fast cooling (Sari et al. 1998)





Theoretical prediction (X-ray range) : $F_{\nu} \propto \nu^{-p/2}\ t^{-(3p-2)/4}$

p : index of the electron power-law distribution

For p ~ 2.5 : spectrum slope ~ -1.3

temporal slope ~ -1.4

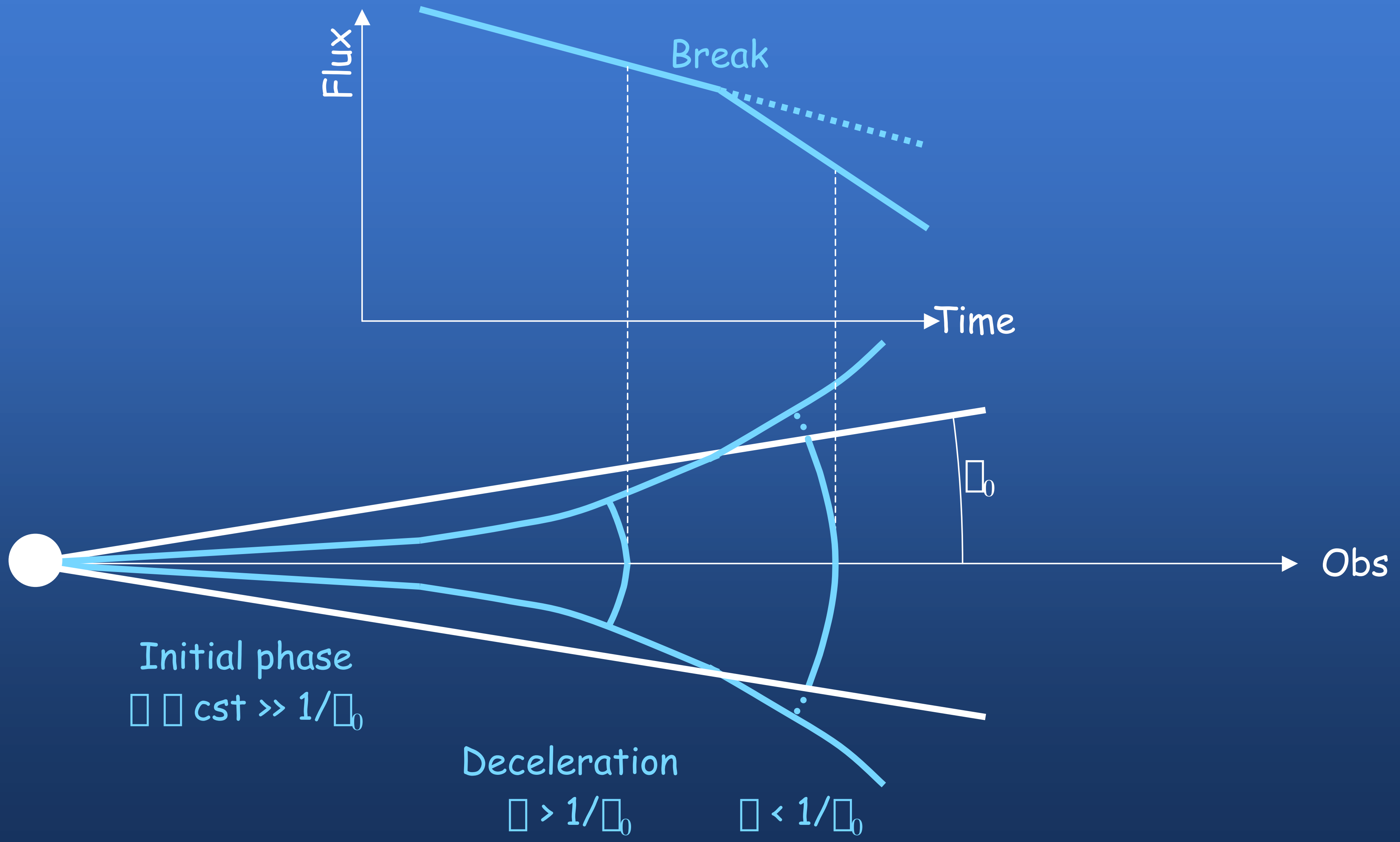
Typical flux :

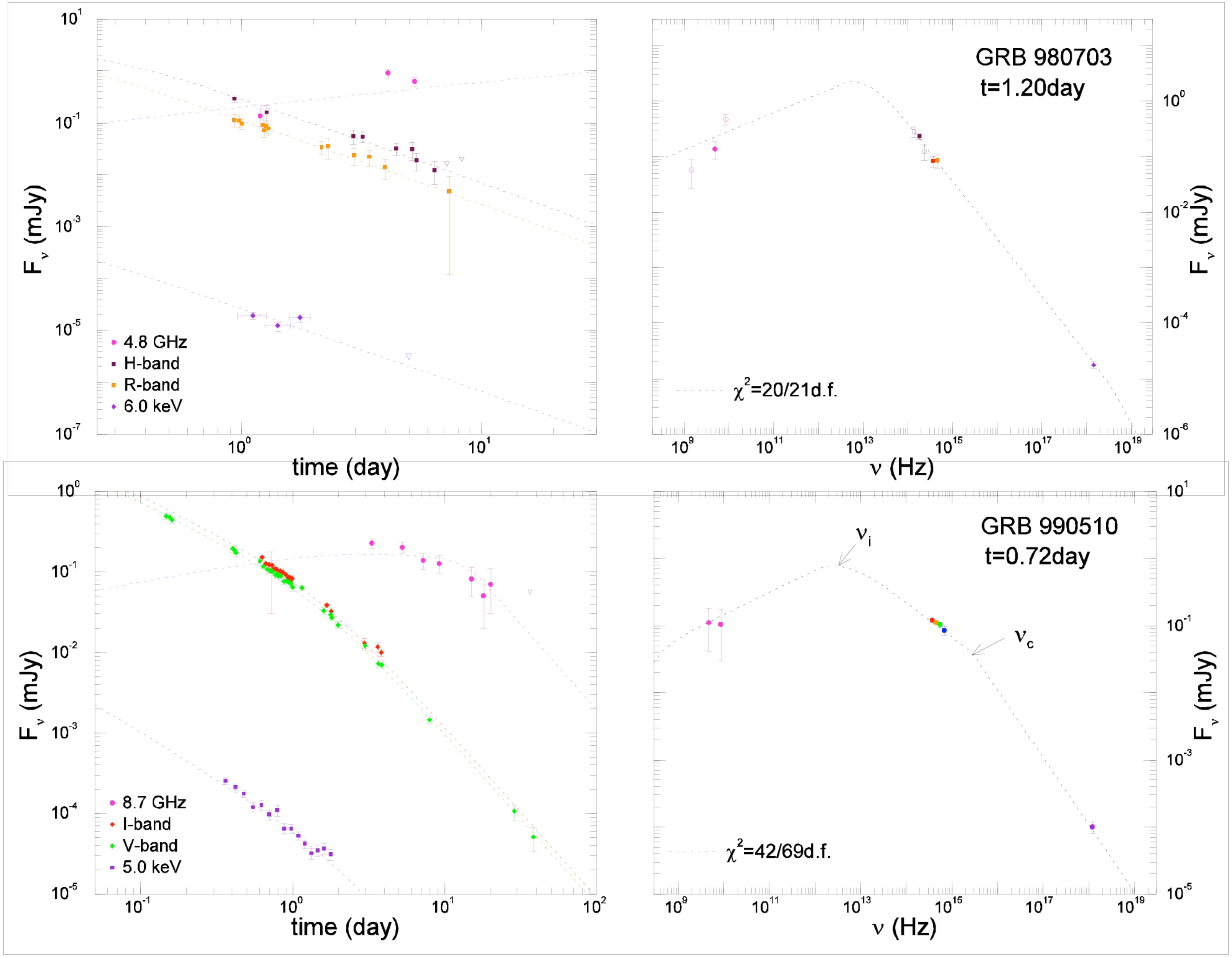
	@ 1 keV	@ 25 keV
@ 30 min	0.5 Jy	9 mJy
@ 1 h	0.2 Jy	4 mJy
@ 1 day	3 mJy	45 μJy

1 mJy = 1.5 keV/s/cm^2/keV

Effect of the angle : achromatic break in the lightcurve

t(break) scales as $\theta_0^{8/3}$: min _ days for θ_0 : 0.5° _ 10°





(Panaitescu & Kumar 2001)

Observing GRBs / afterglows in space :

90's : BATSE (CGRO) (25keV – 1 MeV) : prompt □

96 : Beppo-SAX (0.5 keV – 700 keV) : prompt X,□+ X-ray afterglow

Present : HETE-2 ; INTEGRAL + XMM-Newton / Chandra
(0.1 keV – 10 MeV) : prompt X,□+ X-ray afterglow

End 2004 : SWIFT (20 keV – 150 keV)
Prompt □+ optical, X-ray afterglow

2005 ? AGILE-GLAST (20 keV_GeV) : Prompt □, HE □

2008 ECLAIRs ? (optical + 4 keV – 700 keV)
Prompt optical, X, □+ early optical aterglow

2011 SIMBOL-X ? (0.5 keV – 70 keV)

X, □-ray afterglow

SIMBOL-X :

Prompt emission : no

(small field of view)

Afterglow : yes

(if there is another satellite providing GRB real-time alerts with an arcminute localization…)

Observing GRB afterglows with SIMBOL-X :

1. Long duration follow-up of the X-ray afterglow :

- After an alert, SIMBOL-X can rapidly point towards the afterglow (less than one hour ?)
- Orbit + good sensitivity, the follow up can last for a few days

better determination of the decay slope (gives the electron index p)

better time resolution : fluctuations, breaks (gives $\square_0$)

IC signature ?

Observing GRB afterglows with SIMBOL-X :

2. Observing the γ-ray afterglow ?

- **Predicted**

  (but F(50 keV) / F(1 keV) ~ 1/130)

- **Never observed ?**
  (may be in GRB tails GRANAT/BATSE/HETE-2)

- **The excellent sensitivity of SIMBOL-X above 10 keV is well adapted to this challenging observation**

better determination of the spectral slope (second constraint on p)

constrain the deceleration radius

Observing GRB afterglows with SIMBOL-X :

3. High-z GRBs ?

Observing the afterglow 30 min after the burst means

- at z = 1 : 15 min after the burst in the source frame
- at z = 9 : 3 min after the burst in the source frame

As the flux decreases as $t^{-1.1 \sim -1.4}$, the afterglow is intrinsically brighter (a factor of 25 from z=1 to z=9), which compensates partially the decrease of the flux with the luminosity distance.

Rees & Meszaros 2003 : X-ray flux		@ 17 min	@ 2.8 h
	z=3	19	1.5
X-ray flux : keV/s/keV	z=9	11	0.89
(effective area : 550 cm^2)	z=12	11	0.86
	z=18	11	0.89
	z=30	12	0.96

Measuring the redshift ? (iron lines…)

Observing GRB afterglows with SIMBOL-X :

4. Observing X-ray lines ?

*** A few possible detections :**

iron lines :

970508 (Beppo-SAX, Piro et al. 1999) : 6.7 keV / (1+z) = 3.7 keV @ 16 h
970828 (ASCA, Yoshida et al. 1999) : 9.28 keV / (1+z) = 4.7 keV
991216 (Chandra), etc…

metal lines :

011211 (XMM-Newton, Reeves et al. 2002) : 11h after the burst

*** All these observations are close to the limit of detection …**

- SIMBOL-X vs Beppo-SAX : better
- SIMBOL-X vs XMM/Chandra : not better except if the observation happens at earlier epoch.

_ constrains the source environment / the geometry of the system
_ constrains the temporal sequence (SN/GRB)
_ gives the redshift ?

Conclusions

The GRB field is evolving very rapidly : nobody knows what will be the state of our knowledge in 2010 …

However it seems that (assuming GRB real-time positions are provided) :

* SIMBOL-X can improve the knowledge of the X-ray/□-ray afterglow
  (slope, fluctuations, break, IC signature, …)

* SIMBOL-X can contribute to the detection of high-z GRB afterglows

* SIMBOL-X could confirm the presence of iron/metal lines

A big advantage : long observation times

A crucial parameter : the time needed to point towards the source after a GRB alert