Gamma Ray Bursts in the Swift era

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WIEN - January 17 2011

The discovery

OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

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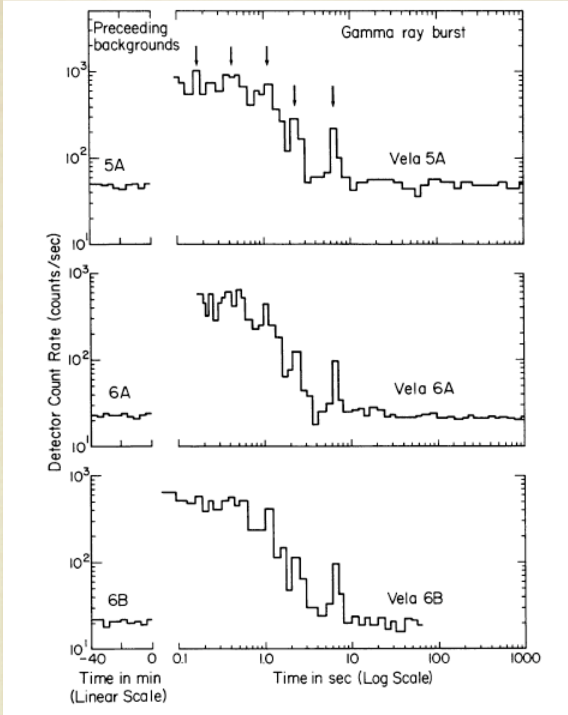
University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
Received 1973 March 16; revised 1973 April 2

ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs cm^{-2} to $\sim 2 \times 10^{-4}$ ergs cm^{-2} in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.



The lack of correlation between gamma-ray bursts and reported supernovae does not conclusively argue against such an association, since it is possible that there are supernovae, not necessarily bright in the optical region ("theoreticians' supernovae"), whose rate of occurrence may exceed those which are optically visible (see, e.g., Thorne 1969). A source at a distance of 1 Mpc would need to emit $\sim 10^{46}$ ergs in the form of electromagnetic radiation between 0.2 and 1.5 MeV in order to produce the level of response observed here. Since this represents only a small fraction ($<10^{-3}$) of the energy usually associated with supernovae, the energy observed is not inconsistent with a supernova as a source.

Distances to the sources of observed gamma-ray bursts

STRONG & KLEBESADEL 1974

WE suggest that the brief, intense outbursts of hard X rays, or soft γ rays of cosmic origin which have been termed γ-ray bursts[1] are mainly, though not necessarily entirely, of Galactic origin. More specifically, the γ-ray bursts reported so far[2] seem to originate in the local (Orion) spiral arm of our Galaxy, at distances of, typically, several hundred parsec. If we assume that the sources radiate into 4π sr, the absolute luminosities are $\sim 10^{39}$ erg per event. (It may be significant that this is of the order of the predicted Eddington limit radiation from accretion disks around collapsed stars.)

ANDY FABIAN 1975

I conclude that the arguments for a galactic origin for γ-ray bursts are by no means sound, and that the distance estimates are extremely uncertain. Num-

SNe

GALACTIC

MAY BE

ZELDOVICH - REIZER
THE ATOMIC BOMB

&

Can soft γ-ray bursts be emitted by accreting black holes?

TSVI PIRAN
JACOB SHAHAM

Racah Institute of Physics,
The Hebrew University, Jerusalem, Israel

1975

A qualitative study of cosmic fireballs and γ-ray bursts

1978

G. Cavallo* and M. J. Rees *Institute of Astronomy, Madingley Road, Cambridge*

Received 1977 September 30

Summary. If a large amount of energy is suddenly converted into a concentrated burst of (MeV) γ rays, the prolific creation of electron–positron pairs will inhibit the escape of photons until they have been degraded below the pair-production threshold. This sets general constraints on the possible luminosities of rapidly varying γ-ray sources and suggests why the observed γ-ray bursts have an approximately standardized and 'soft' spectrum.

High-entropy fireballs and jets in gamma-ray burst sources

P. Mészáros[1] and M. J. Rees[2]
[1] *Astronomy and Astrophysics Department, Pennsylvania State University, University Park, PA 16802, USA*
[2] *Institute of Astronomy, Madingley Road, Cambridge CB3 0HA*

Accepted 1992 May 4. Received 1992 April 28

1992

SUMMARY
We propose two mechanisms whereby compact coalescing binaries can produce relatively 'clean' fireballs via neutrino–antineutrino annihilation. Pre-ejected mass due to tidal heating will collimate the fireball into jets. The resulting anisotropic gamma-ray emission can be efficient and intense enough to provide an acceptable model for gamma-ray bursts, if these originate at cosmological distances.

GAMMA-RAY BURSTS - A PUZZLE BEING RESOLVED

1999

Tsvi Piran[1]

Racah Institute for Physics, The Hebrew University, Jerusalem, 91904, Israel[2]
Physics Department, New York University, New York, NY 10003, USA
and
Physics Department, Columbia University, New York, NY 10027, USA

SEE REFERENCES THEREIN

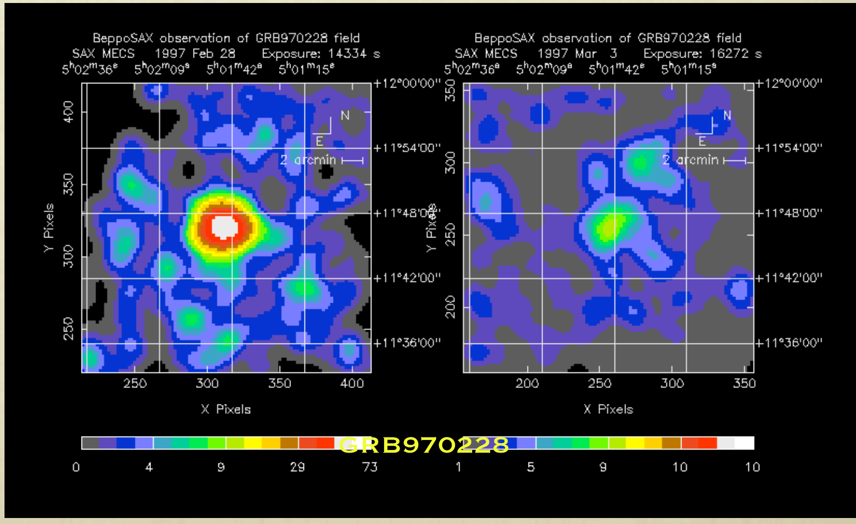
The Physics of Gamma-Ray Bursts

2004

Tsvi Piran*

Racah Institute for Physics, The Hebrew University, Jerusalem, 91904, Israel

BATSE & BEPPO_SAX

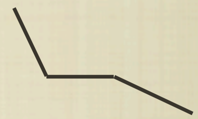


When a large amount of energy is released within a small volume, an explosion will result and a strong shock wave will expand supersonically into the surrounding medium.

When the energy release E is so large that $E \gg (M+\rho V) c^2$, *where M is the of the explosion products,* ρ *is the ambient density, and V is the volume swept by the shock, then the motion of the shock front will be relativistic.*

see Blanford and McKee (1976) for the theory

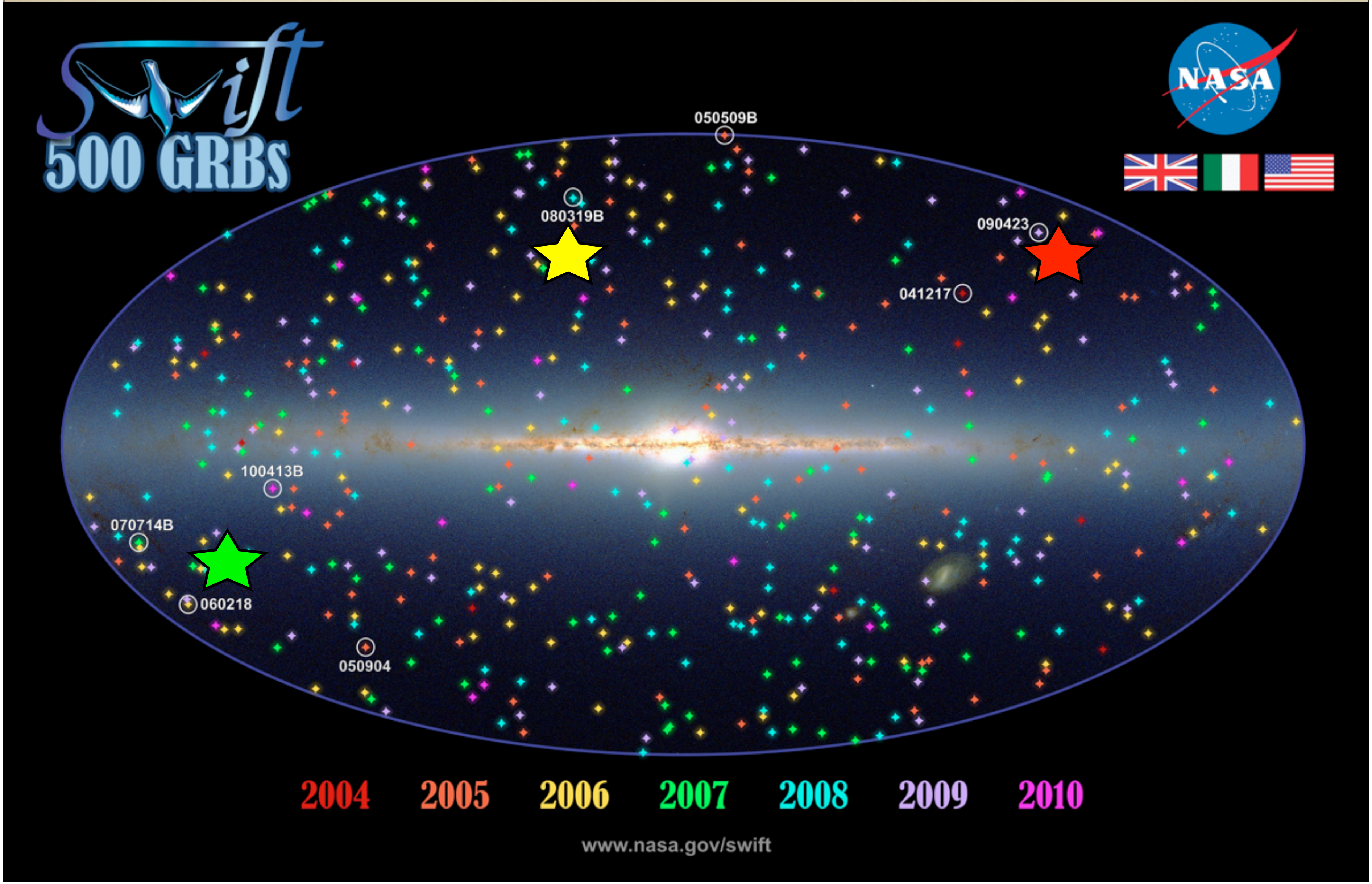
GRB: Observable
and
model ingredients

- The essential we observe of a Gamma Ray Burst
    - Energy 10^{49} - 10^{53} erg
    - Evolution of the light curve & spectra 
- The ingredients of the model [and we have problem in each one of them]:
    - A central engine - generates jets & energy
    - A mechanism of emission
    - a medium (CSM & ISM)
    - A progenitor

Highlights

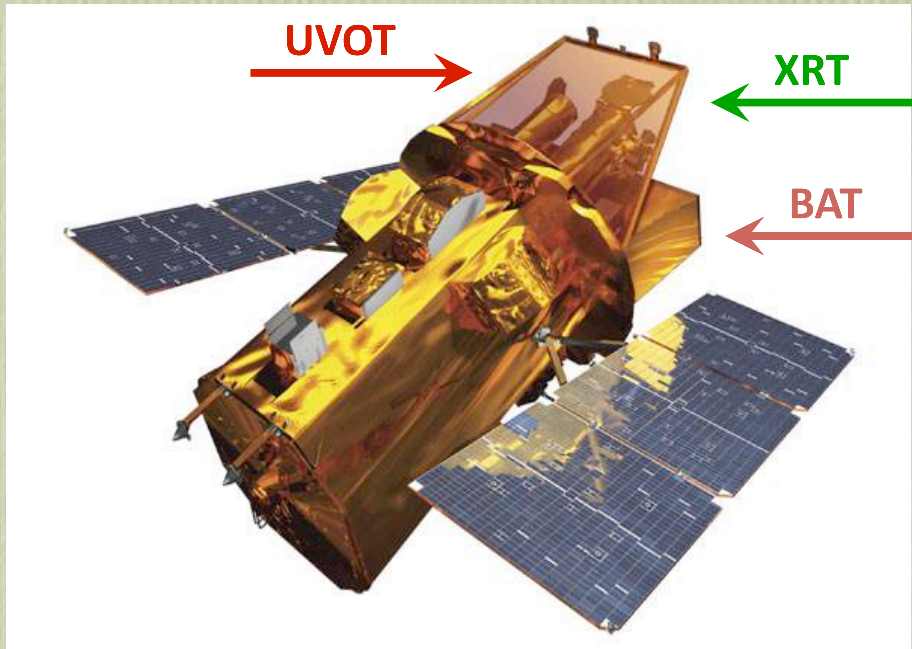
Swift: A U. S. A. - Italy - UK collaboration

Physics Astrophysics Cosmology



The Observations

The *Swift* satellite



BURST ALERT TELESCOPE

- Imaging: **15-150 keV**
- Precision: **2-3 arcmin**
- Field of view: **1/6 of sky**

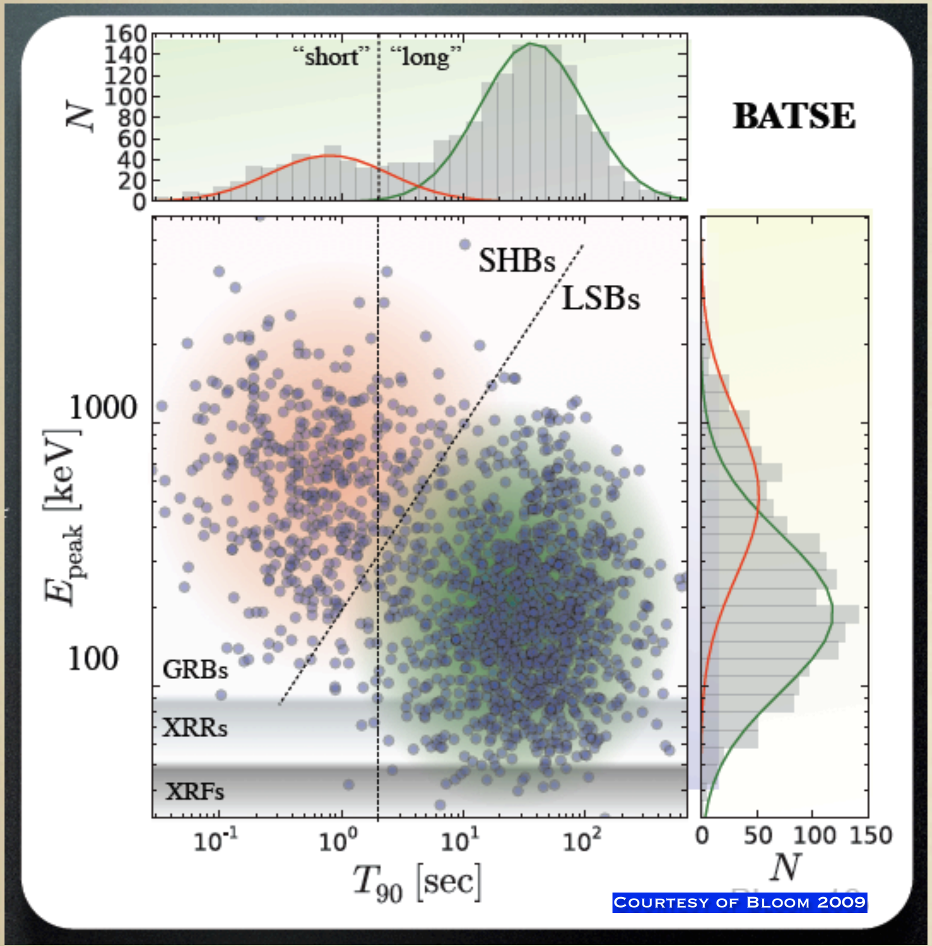
X-RAY TELESCOPE

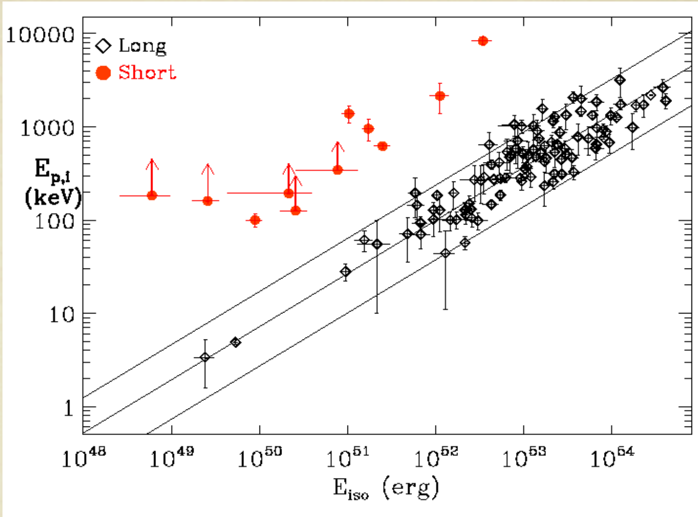
- Imaging in **0.2–10 keV**
- Precision: **3 arcsec**
- Sensitivity: **2 [illegible] 10^{-14} cgs**

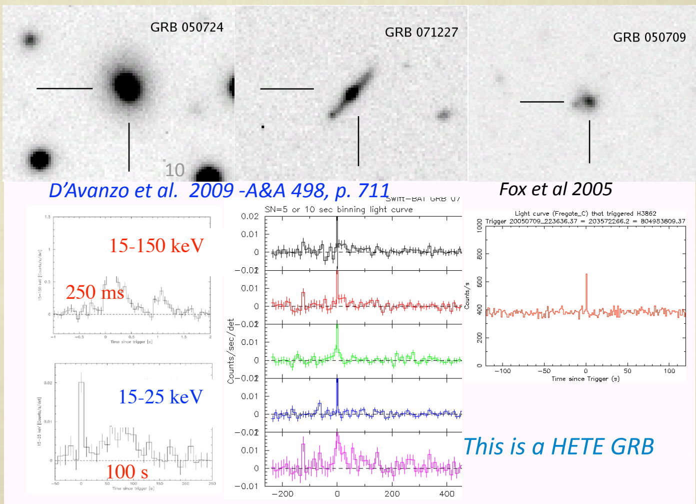
UV/OPTICAL TELESCOPE

- Imaging: **1700 – 6500 Å**
- Precision: **0.5 arcsec**
- Sensitivity: *V* [illegible] 20

GRB Visiting CARD



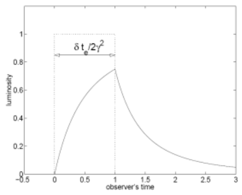


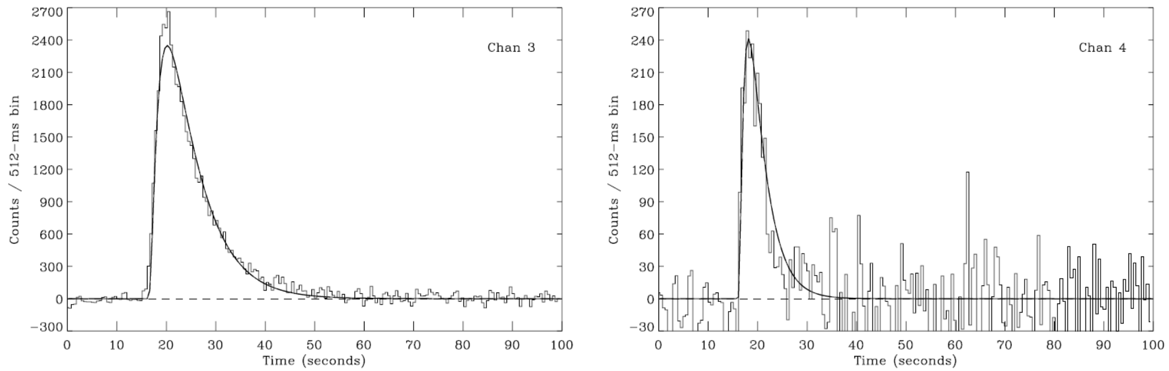


Non-thermal, peaking at ~ 10 keV - MeV in our frame, 0.1-1 ~ keV in rest frame.

Long GRBs & Flares

(Kobyashi) Et al. 1997





(Norris 1996)

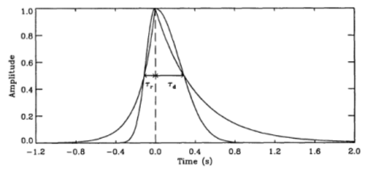
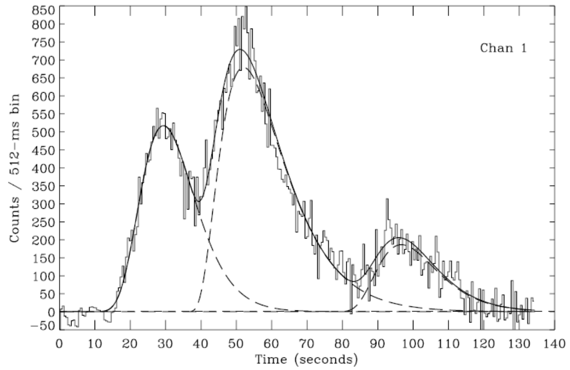
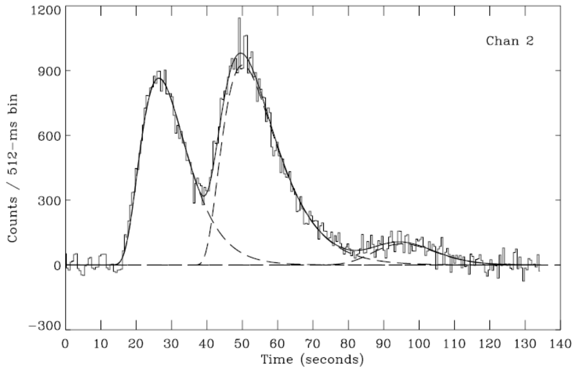


FIG. 25.—Plots of GRB 990102a, a single-pulse burst in which emission near the peak is spikier than that accommodated by the pulse model in channels 1, 2, and
e pulse decreases in width across channels 1–4 as 26, 18, 11 and 6 s, with associated asymmetry parameter values of 0.65, 0.56, 0.51, and 0.50.





Kocevski, Ryde,Liang 2003

Norris 2005

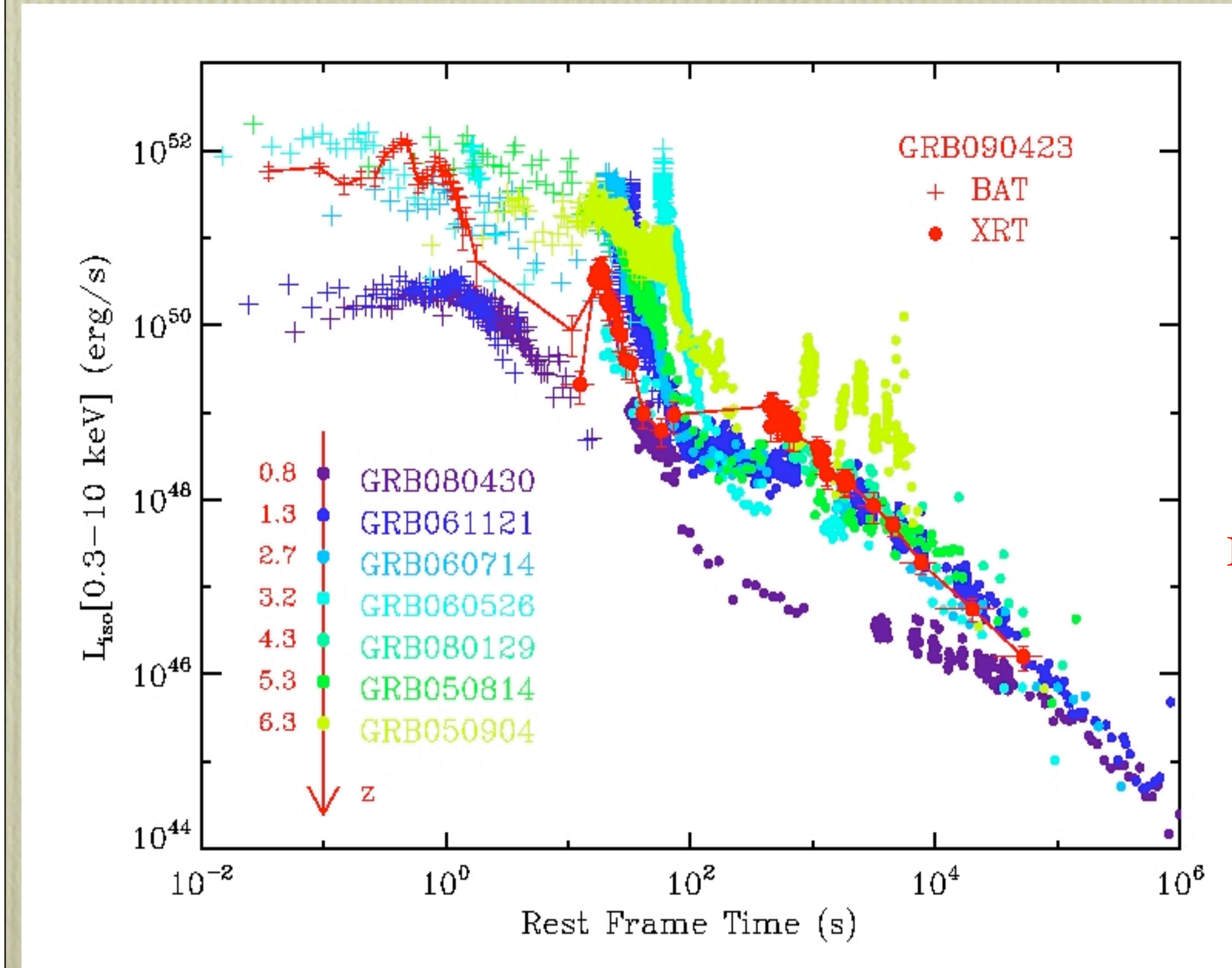
$$F(t) = \left(\frac{t}{t_m}\right)^r \left[\frac{d}{d+r} + \frac{r}{d+r}\left(\frac{t}{t_m}\right)^{r+1}\right]^{-\frac{r+d}{r+1}}$$

$$F(t) = \frac{A_0\left(1 - e^{-\frac{t}{t_r}}\right)}{\left[1 + \left(t + t_r e^{-\frac{t}{t_r}}\right) t_d^{-1}\right]^{d-1}}$$

$$I(t) = A\,\lambda\,\exp\left(-\frac{\tau_1}{t} - \frac{t}{\tau_2}\right) \quad for\ t \succ 0$$

$$Width = \tau_2\left(1 + 4\sqrt{\frac{\tau_1}{\tau_2}}\right)^{1/2}$$

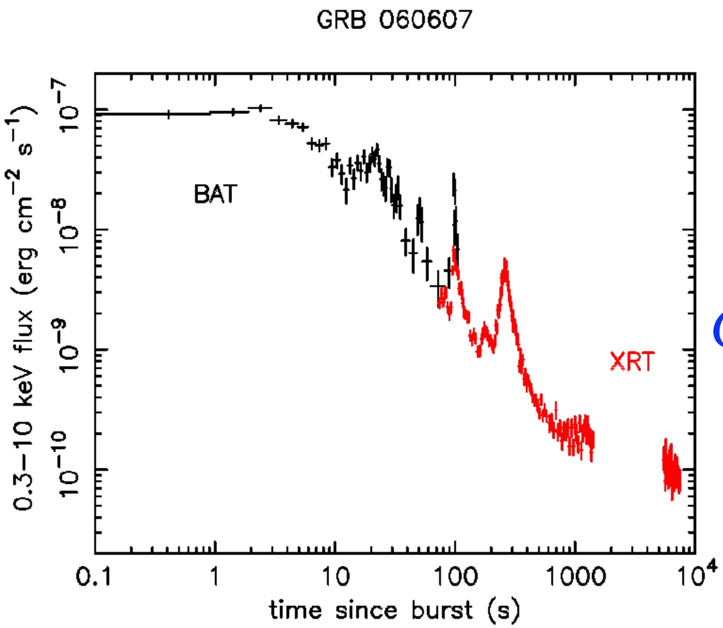
GRB 090423: X-ray afterglow



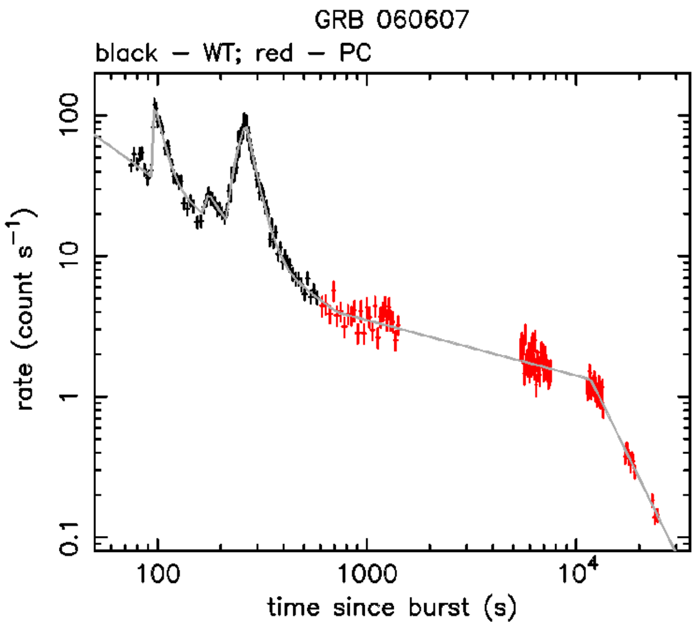
canonical light curve

analysis of the XRT spectrum shows intrinsic absorption N_H=7x10^{22} cm^{-2}

Lower limit on the metallicity of the circum-burst medium Z> 0.04 Zsun

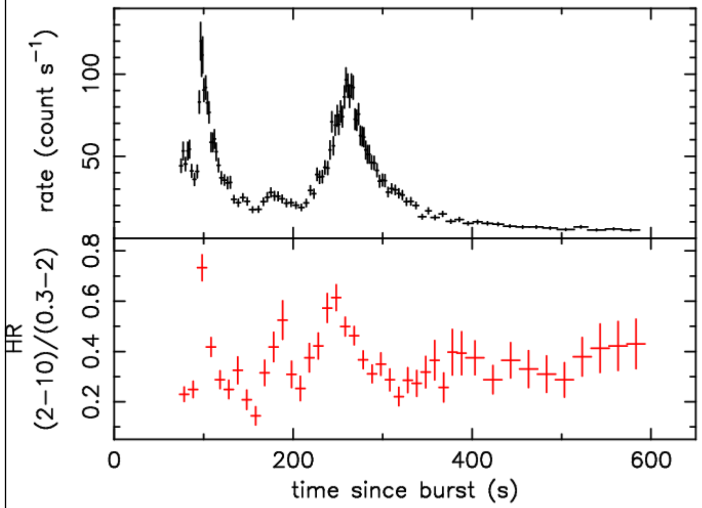


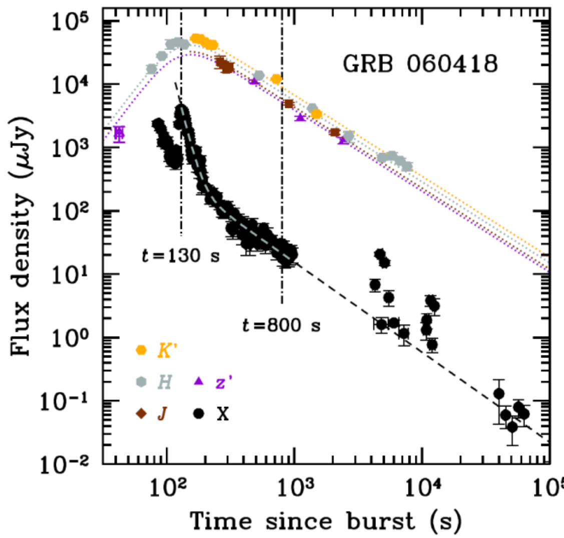
GRB 060607

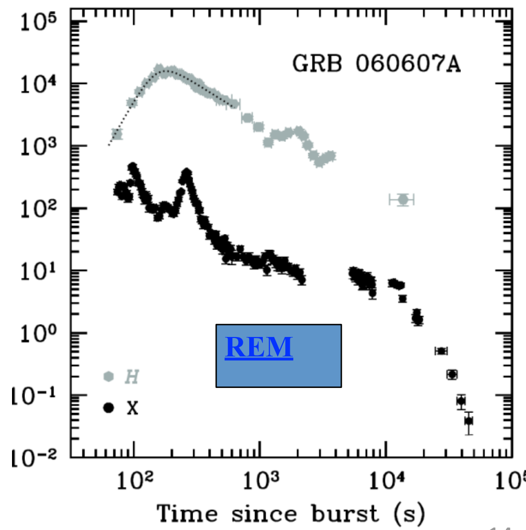


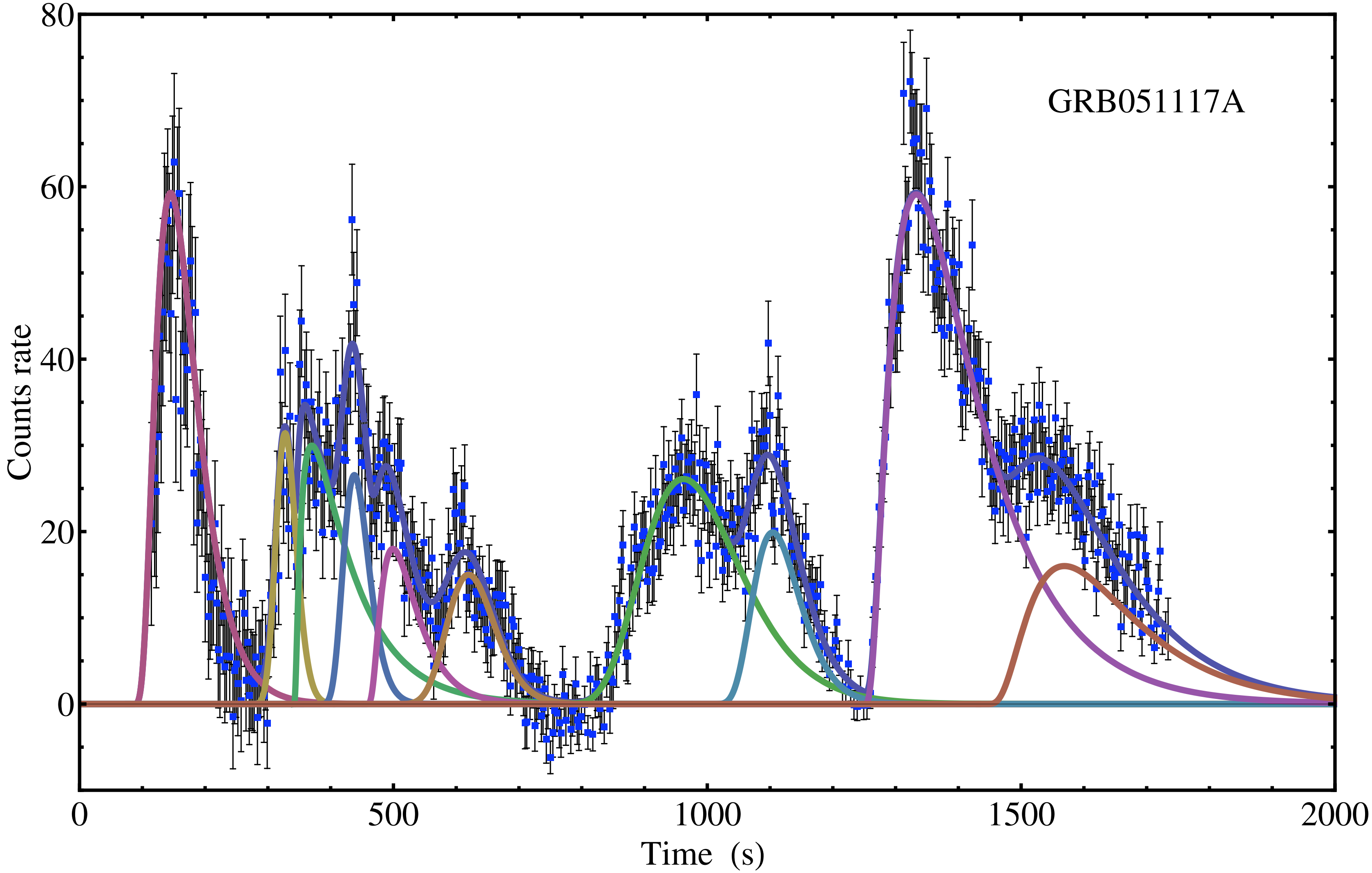
Opt-In between the X_Ray Flares Observed by REM & UVOT

$$\Gamma(t_{\rm peak}) = \left(\frac{3E_\gamma}{32\pi n m_{\rm p} c^5 \eta_\gamma t'^3_{\rm peak}}\right)^{1/8} \sim 160 \left(\frac{E_{\gamma,53}}{\eta_{\gamma,20} n_1 t'^3_{\rm peak,2}}\right)^{1/8}$$

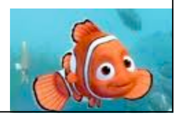


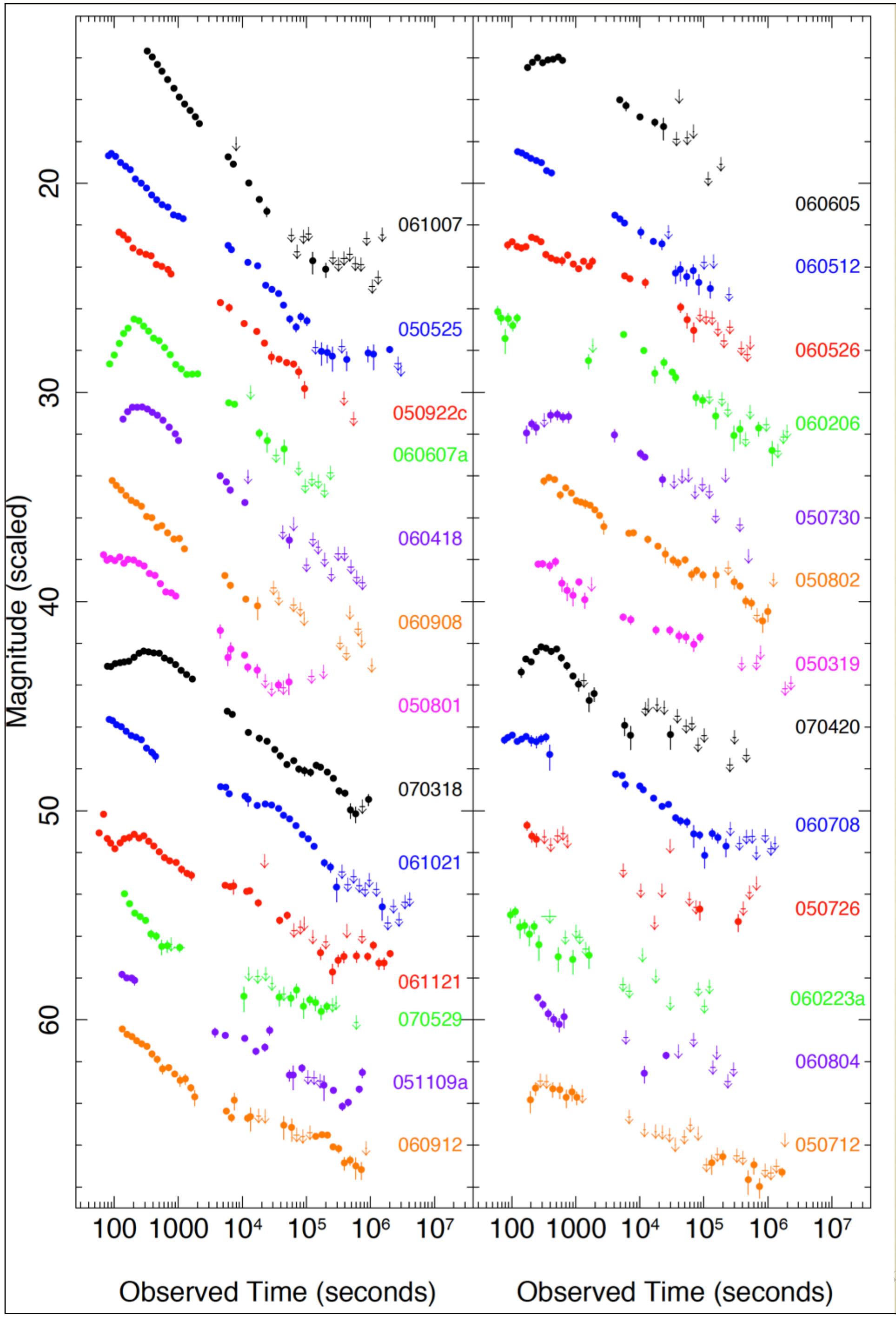






Chincarini et al., 2010, Margutti et al., 2010, Bernardini et al., 2010





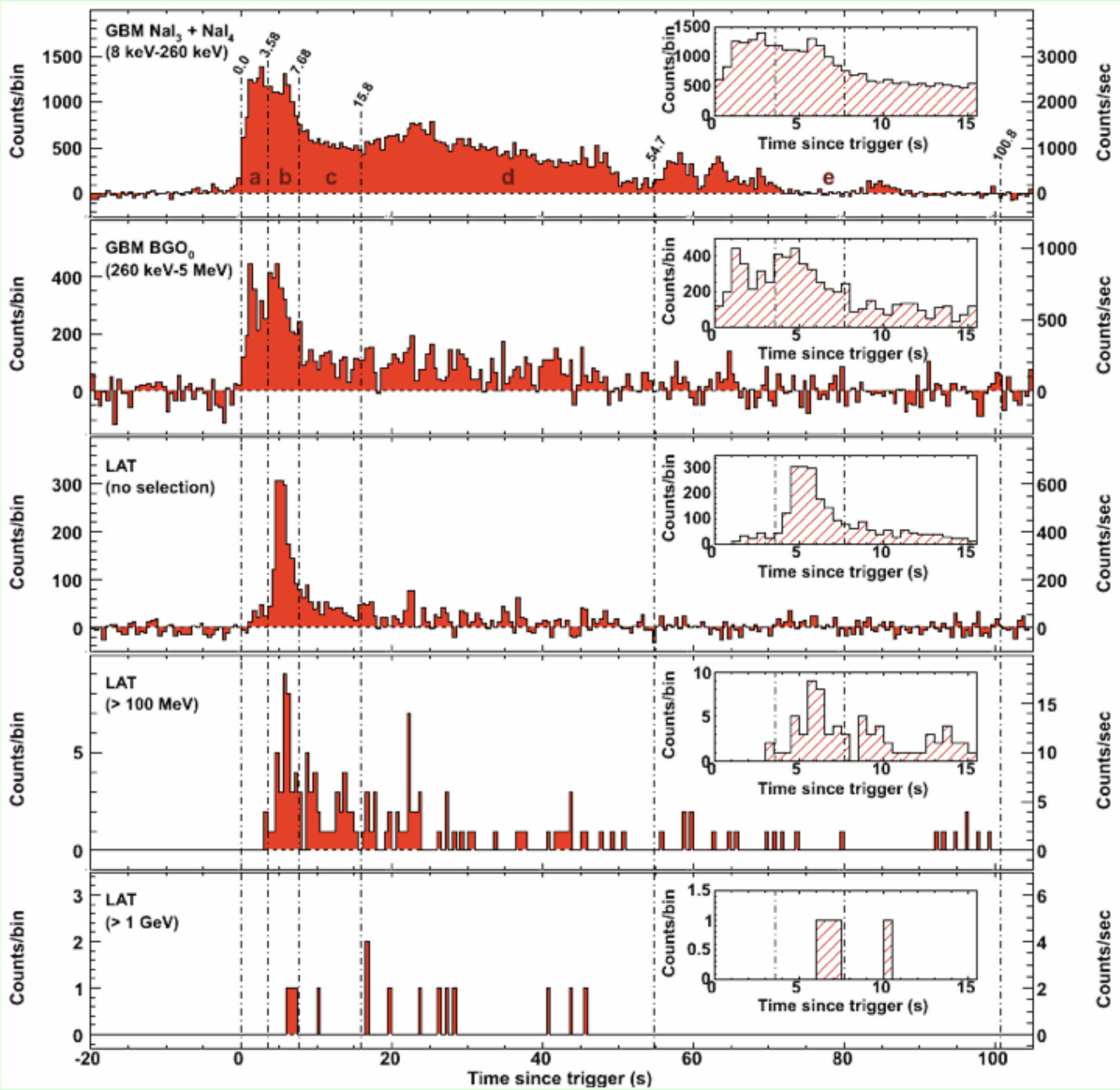
Oates et al 2009 Astro - ph 0901.35971
Sample of 27 GRBs 21 redshifts

Apparently the brightness is correlated with the slope, brighter decay faster. See however rest frame. The maximum is not always detected in the early phase, may be not early enough.

Flare activity is visible, and however the characteristics are somewhat different, not so prominent, from those observed in the X_ray. A correlation OPTICAL - X is under way.

Various GRBs shows a peak of the light curve during the first 1000 seconds. See also Molinari et al. 2006 and Kruehler et al. 2009 XRF 071031.

See also Rykoff et al., ROTSE -III - Astro_ph 0904.0261

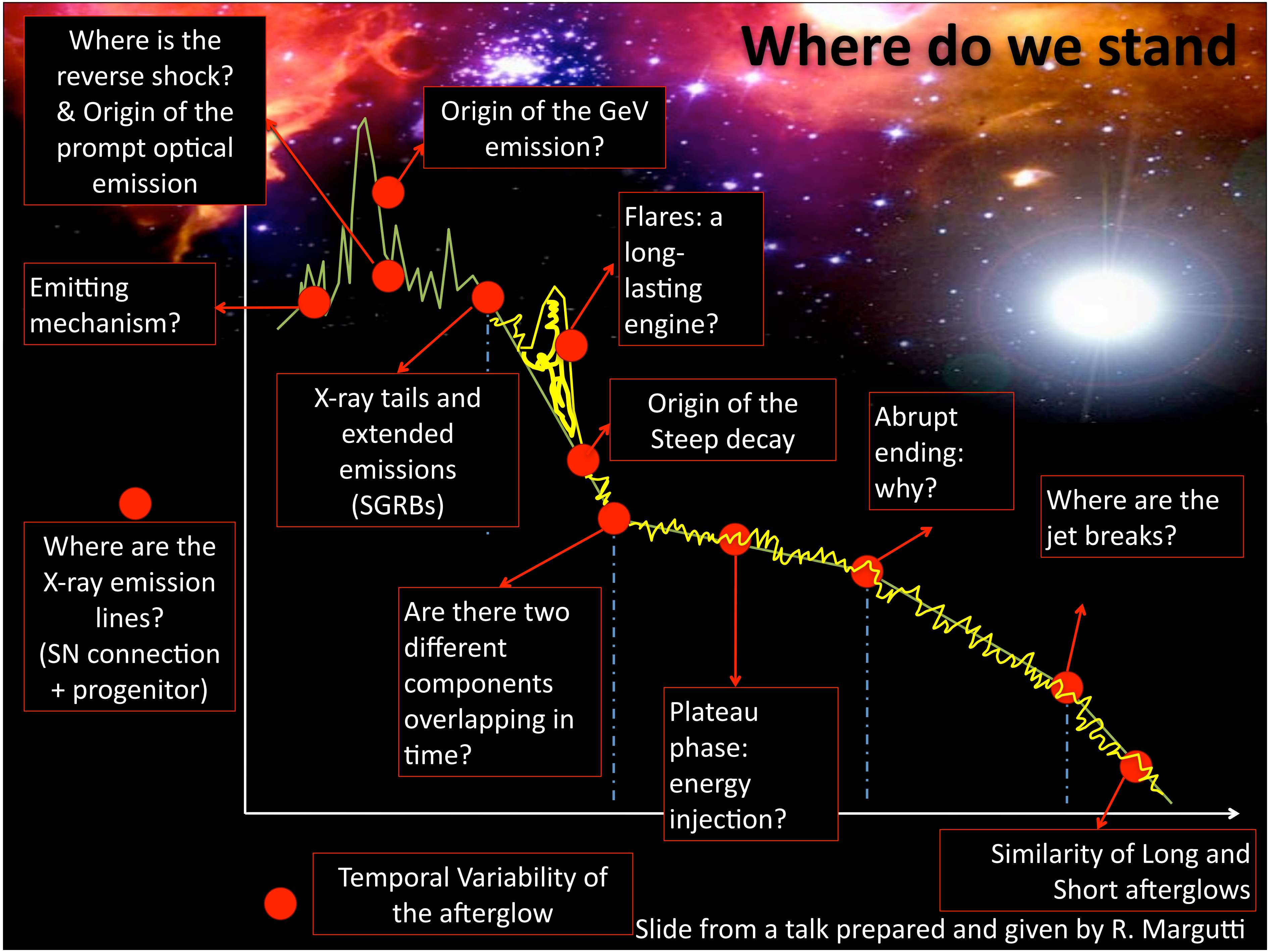


HIGH ENERGY PHYSICS

Fermi GRB080916C
Highest En Photon
30 GeV

EGRET
GRB940217
18 Gev

Acceleration Mechanism ??

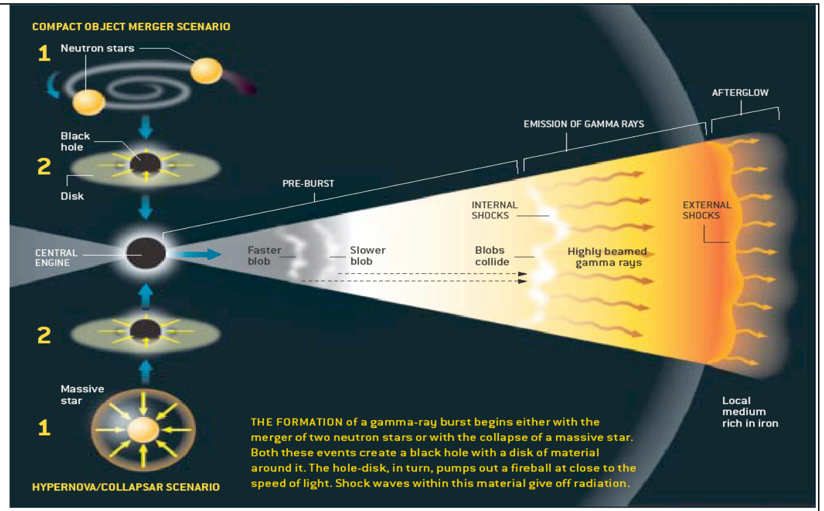

Where do we stand
Where is the reverse shock? & Origin of the prompt optical emission
Origin of the GeV emission?
Emitting mechanism?
Flares: a long-lasting engine?
X-ray tails and extended emissions (SGRBs)
Origin of the Steep decay
Abrupt ending: why?
Where are the jet breaks?
Where are the X-ray emission lines? (SN connection + progenitor)
Are there two different components overlapping in time?
Plateau phase: energy injection?
Similarity of Long and Short afterglows
Temporal Variability of the afterglow
Slide from a talk prepared and given by R. Margutti

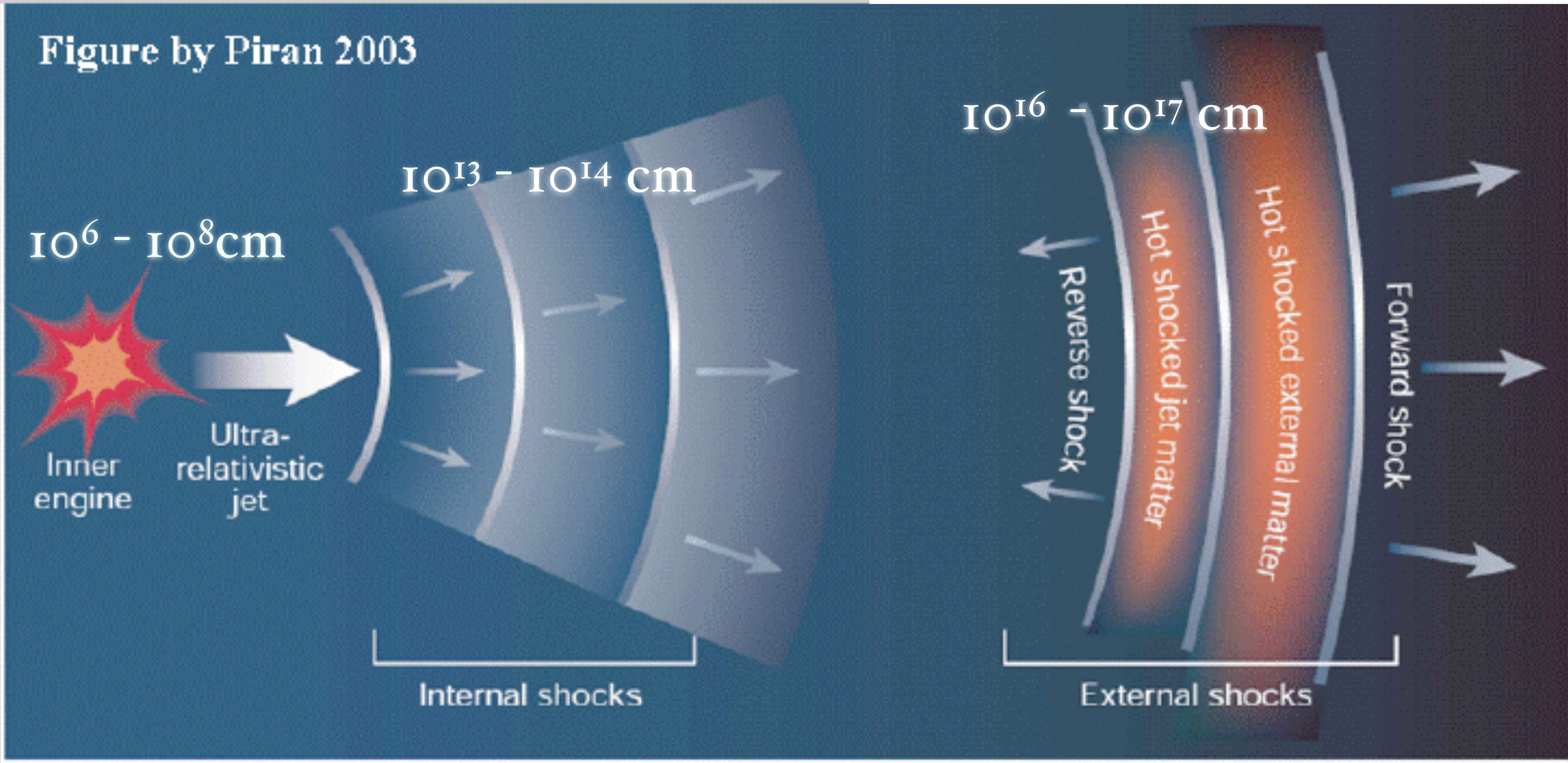
What is it?

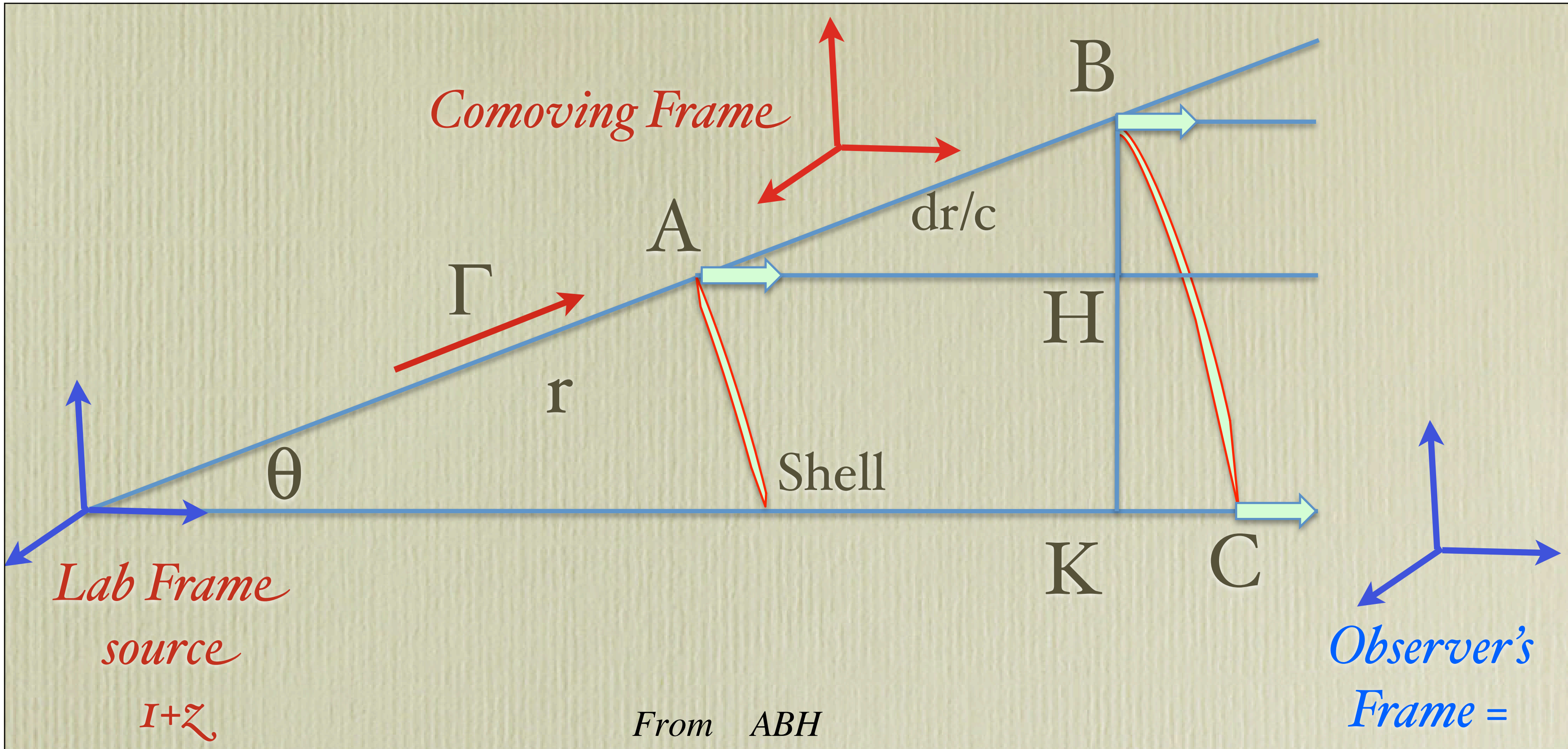
According to the standard fireball shock model we distinguish between prompt emission and afterglow. The prompt emission if due to internal shocks, that is shocks generated by clashing shells that have been ejected at various speeds. Gamma ray burst afterglows are the result between the decelerating relativistic jet and the surrounding medium. Synchrotron radiation is produced by shock - accelerated electrons interacting with a shock - generated magnetic field.

The radiation will peak at progressively longer wavelengths and the observed light curve will change shape whenever the observed frequency crosses into different spectral regimes, when the flow becomes non relativistic and when the lateral spreading of the initially strongly collimated outflow becomes significant.
Furthermore:
Off axis jets to the never observed orphan afterglows

The standard model





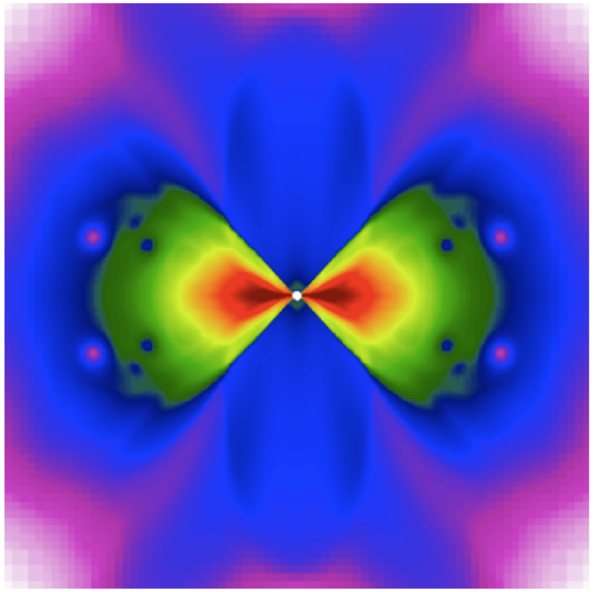


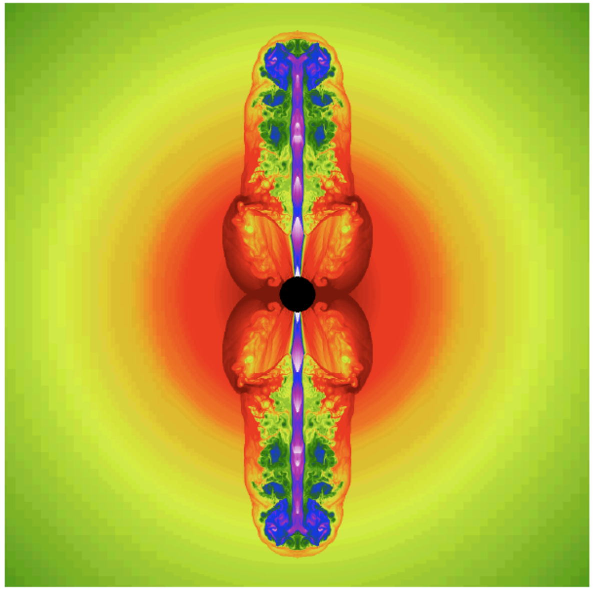
From ABH

$$dt_{Observer} = dt_{Lab}\left(1-\beta\cos\theta\right) = \frac{dt_{Lab}}{2\,\Gamma^2} = \frac{dr}{2\,\Gamma^2 c}$$

From BKC

$$\Delta t = \frac{r}{2\,\Gamma^2 c}$$





Zhang, W., Woolsey, MacFadyen - 2006

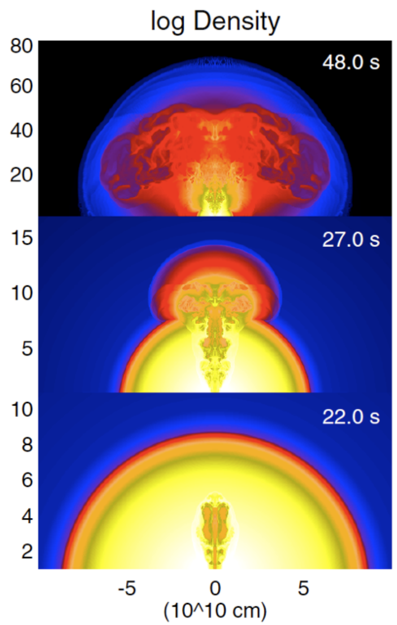
Left: Collapse and explosion in a 14 solar mass Wolf-Rayet star.
Disk T ~ several MeV, Density ~ 10^9 g cm^{-3}. BH ~ 4 solar masses.
Right: GRB_SN - Introduction of a two component jet: 1) 10^{51} erg s^{-1}, Gamma=50, jet 10 degrees 2) ~ 40 degrees jet, 5 10^{50} erg s^{-1}, speed 14000 km s^{-1}.

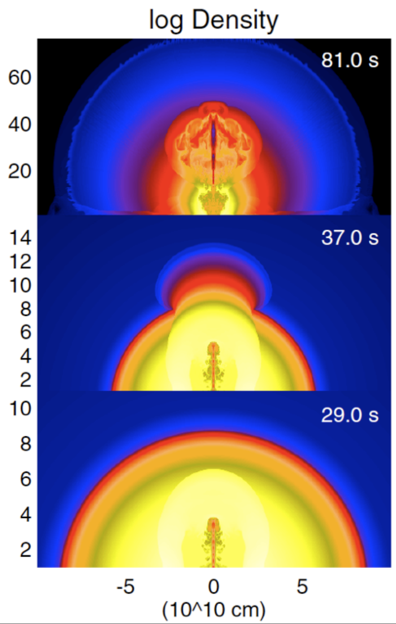
SNe 3 10^{53} in neutrinos in seconds; < 0.01% light in a few months
GRBs Most light in Gamma Rays - less than 1% as frequent as ordinary SNe

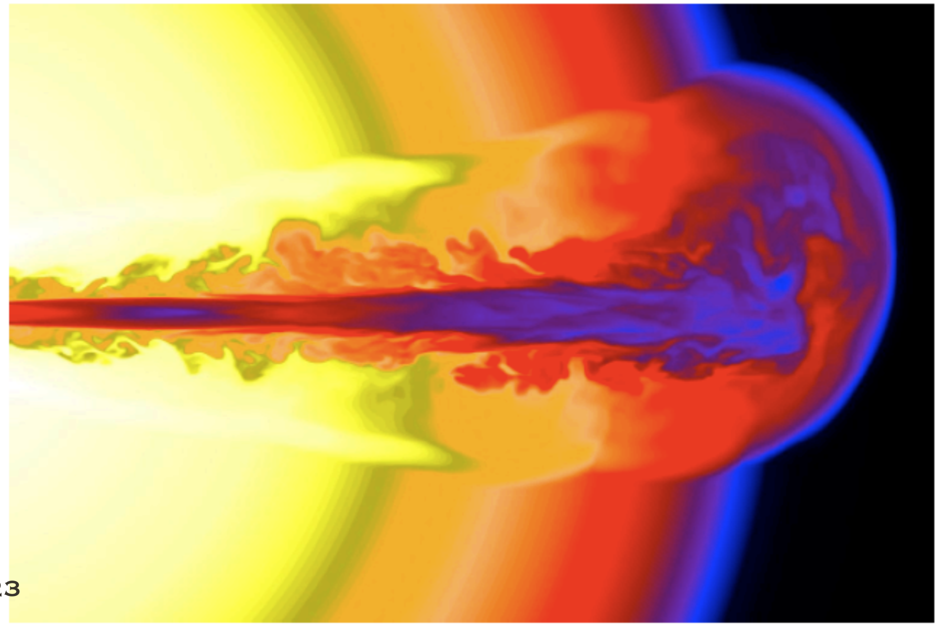
3 10^{49} erg s^{-1}
no yper-relativistic
jet core

1 10^{48} erg s^{-1}
rather slow
may be bright transient

5 degrees opening and Gamma 200 - 3 10^{50} erg s^{-1}.

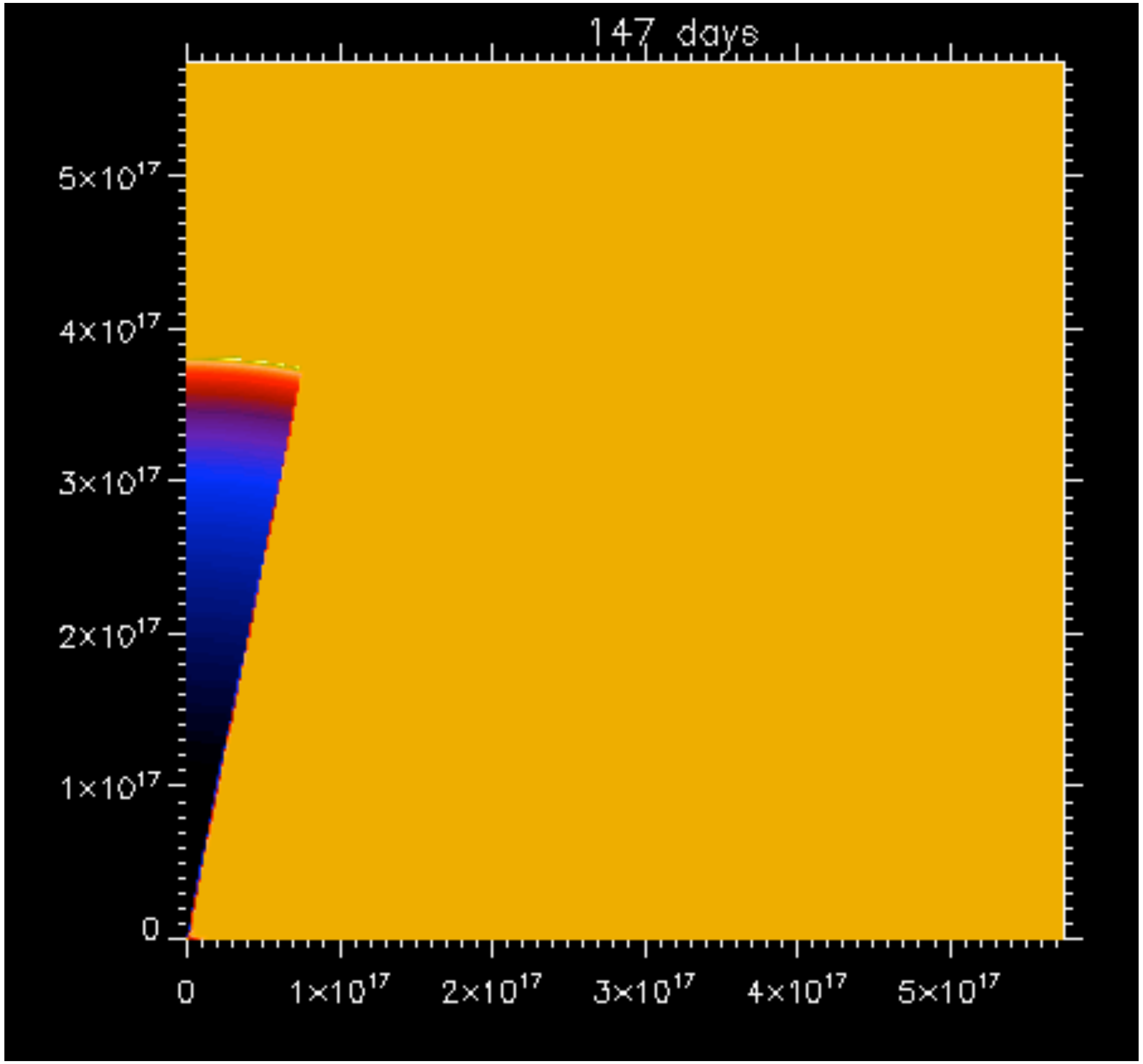






2D GRB Blastwave

Weiquin Zhang, Andrew McFadyen, 2009, ApJ 698, 1261



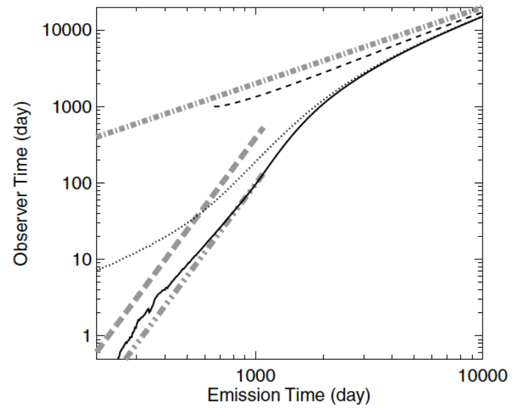
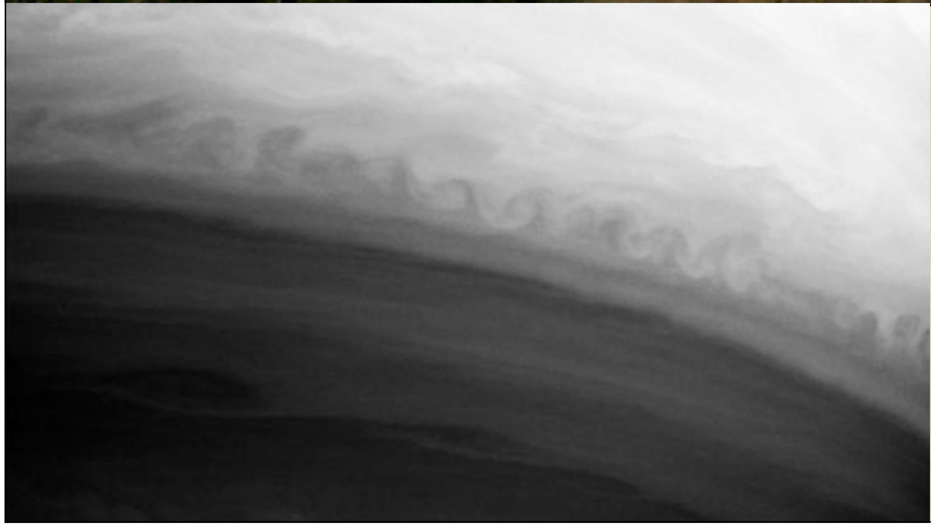


Figure 6. Observer time vs. emission time. The results for fluid elements just behind the shock at various angles are shown: $\theta = 0$ (solid line), 0.19 (dotted line), and $\pi/4$ (dashed line). The relations $t_{\oplus} = (1+z)t/4\gamma^2$ (long dashed gray line) and $t_{\oplus} = (1+z)t/16\gamma^2$ (dash–dot–dot gray line) are plotted for comparison. Here, γ is assumed to obey the Blandford–McKee solution, and the cosmological redshift is set to $z = 1$. Also plotted is $t_{\oplus} = (1+z)t$ (dash-dotted gray line).

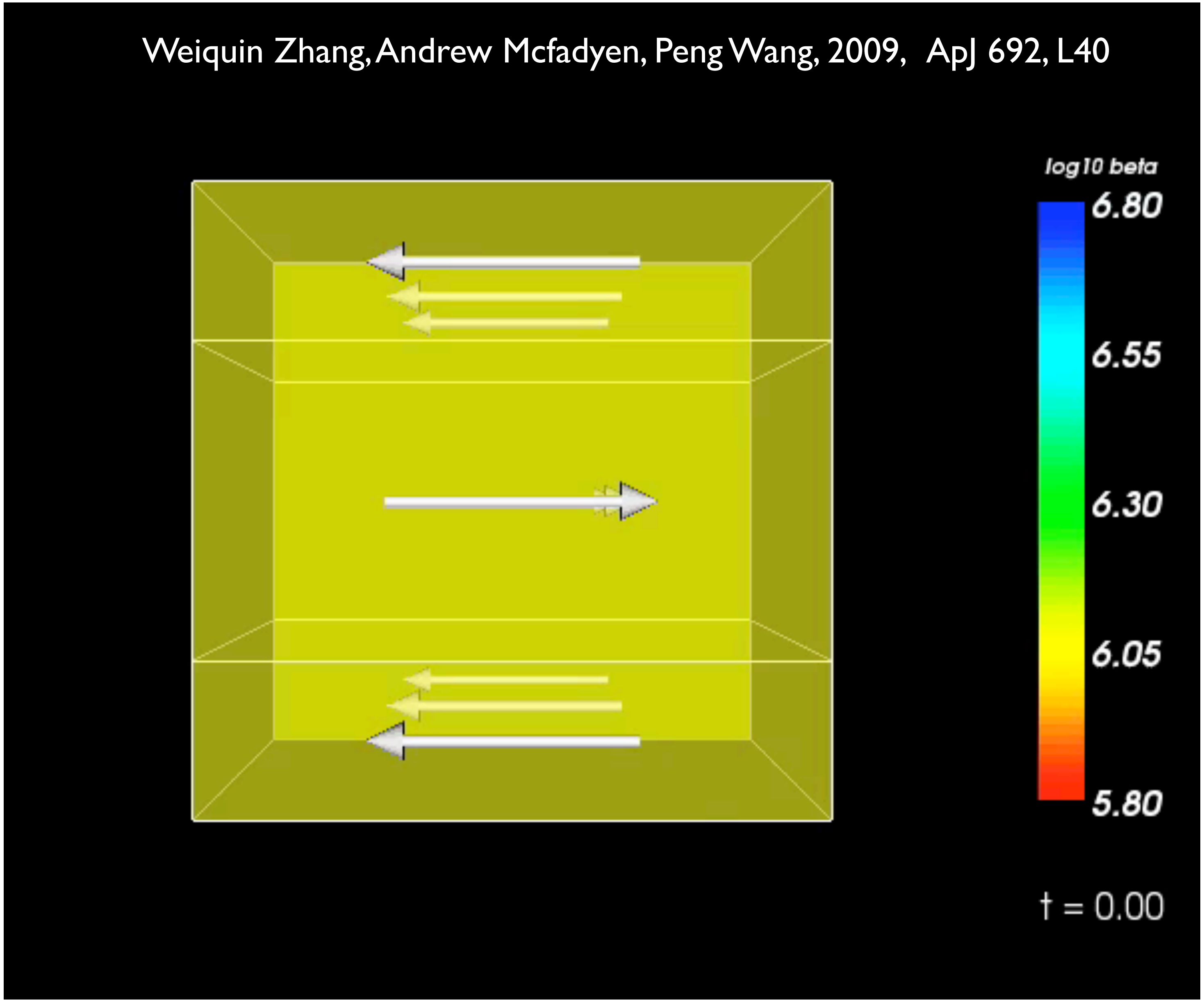
Wave clouds forming over Mount Duval, NSW.



A Kelvin-Helmholtz instability on Saturn, caused by the interaction between two bands of the planet’s atmosphere. Image from the Cassini probe. Caption from NASA’s press release: This turbulent boundary between two latitudinal bands in Saturn’s atmosphere curls repeatedly along its edge in this Cassini image. This pattern is an example of a Kelvin-Helmholtz instability, which occurs when two fluids of different density flow past each other at different speeds. This type of phenomenon should be fairly common on the gas giant planets given their alternating jets and the different temperatures in their belts and zones.

Saturn from NASA

KH: 1024^3 Rel. MHD



New Inputs

- The simulations predict a ratio of the magnetic energy to total energy to be:
  $\varepsilon_B = 5\ 10^{-3}$
- Clumpy structure of the magnetic energy. Therefore likely a site for the Fermi acceleration of charged particles, may be a source of high energy cosmic rays.
- May give information on the origin of cosmic magnetic fields.

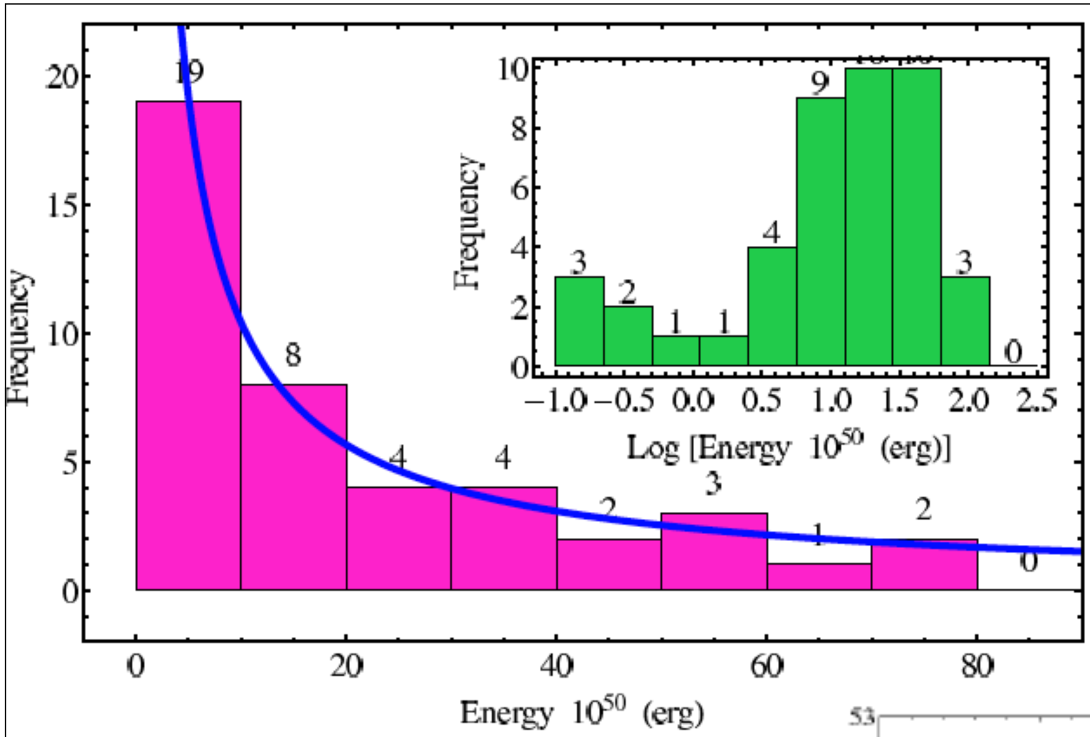
Weiquin Zhang, Andrew Mc Fadyen & Peng Wang
2009, ApJ 692, L40

The most recent flare sample
Chincarini et al. 2010

Period April 2005 – March 2008.
321 GRBs – 87 with redshift
273 by Swift, 82 with z.
27 by INTEGRAL 1 with z
10 by IPN – 1 with z
9 by HETE (3 w z), 3 by AGILE
Afterglow observations for 234.
Data set of 56 GRBs with flares.
Peak count rate > 1 count/s.
36 present a single flare.
15 two flares.
More that 5 cases with more than two flares
Analysis in 5 channels
0.3-10, 0.3-1, 1-2, 2 – 3, and 3 – 10 keV.
Fit Norris 2005 function

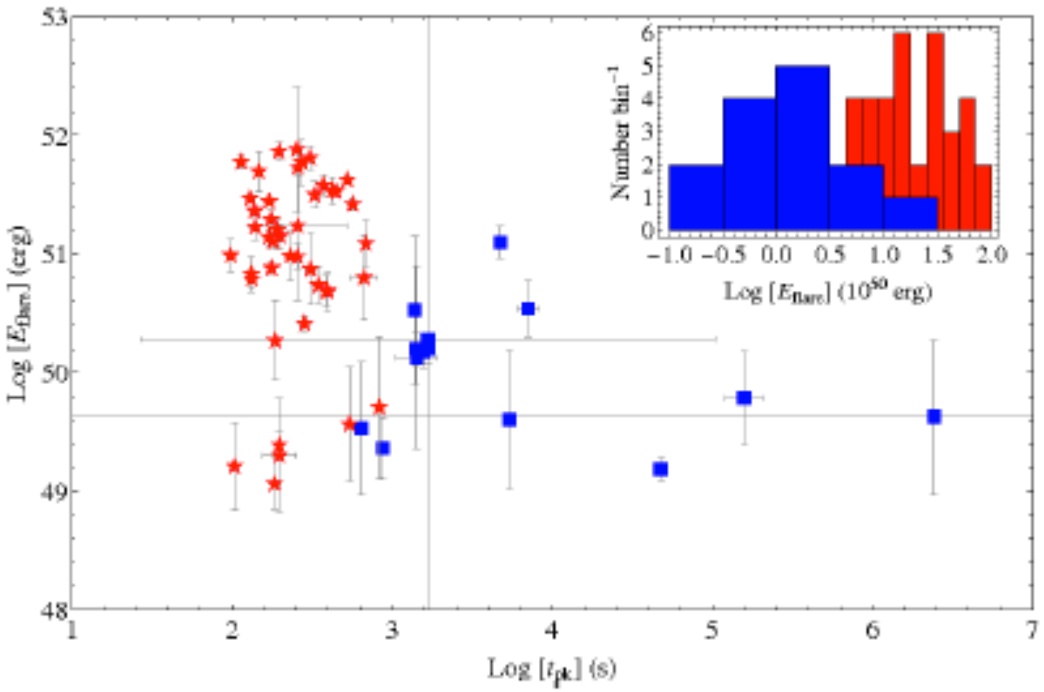
NEXT: *TO THE END OF 2010 ~ 600 GRBs. 2011 => Light curves et al. IN PREPARATION*

CONTINUE



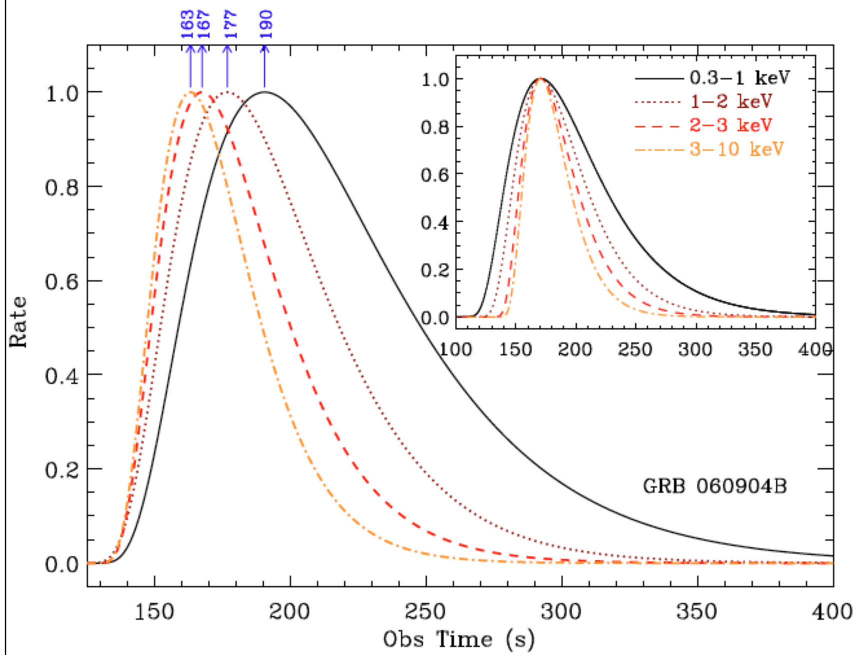
DISTRIBUTION OF THE ENERGY EMITTED IN SINGLE X - RAY FLARES OF THE PRESENT SAMPLE. IN THE INSET THE DISTRIBUTION OF THE LOGARITHM OF THE ENERGY TO BETTER EVIDENCE THE FAINT TAIL OF THE DISTRIBUTION.

LATE FLARES ARE LESS ENERGETIC. MORE OR LESS 10% OF THE ENERGY WE OBSERVE IN EARLY FLARES.



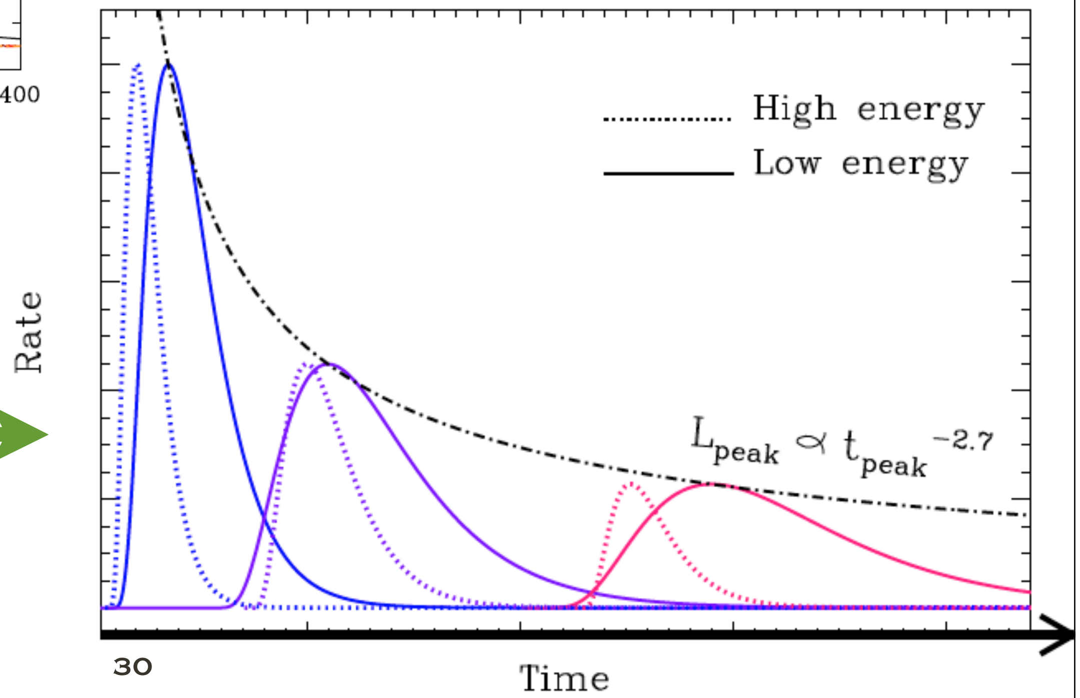
Conclusions

Accretion or magnetic reconnection or???



Phase lag as detected in GRB060904B. The high energy peak precedes the lower energy peak. Note that after normalization (inset) higher energy profiles are broader than low energy profiles.

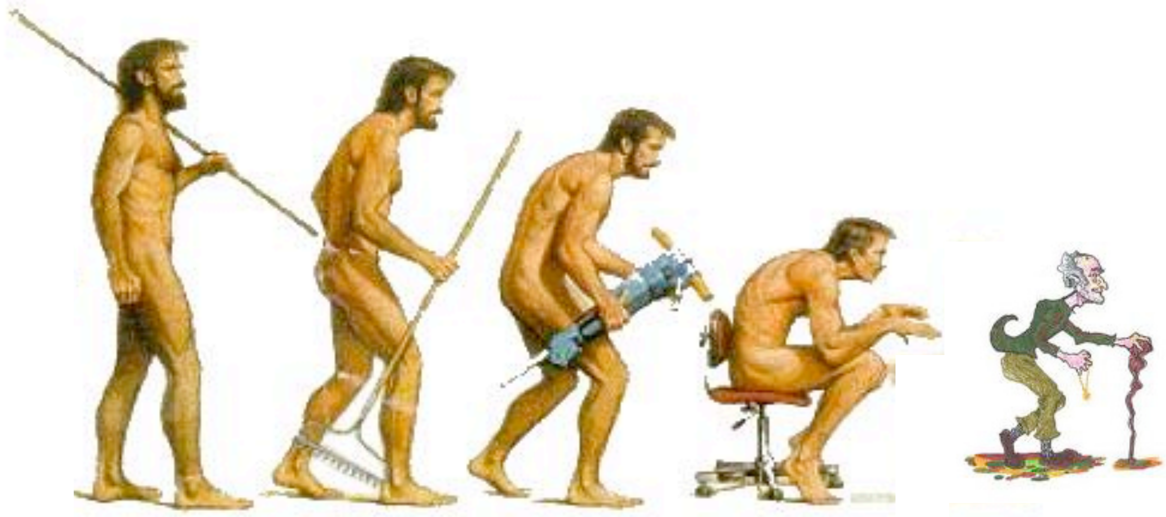
The whole story in a plot. Flares know that if they occur late they must be fainter and broader. There is memory.

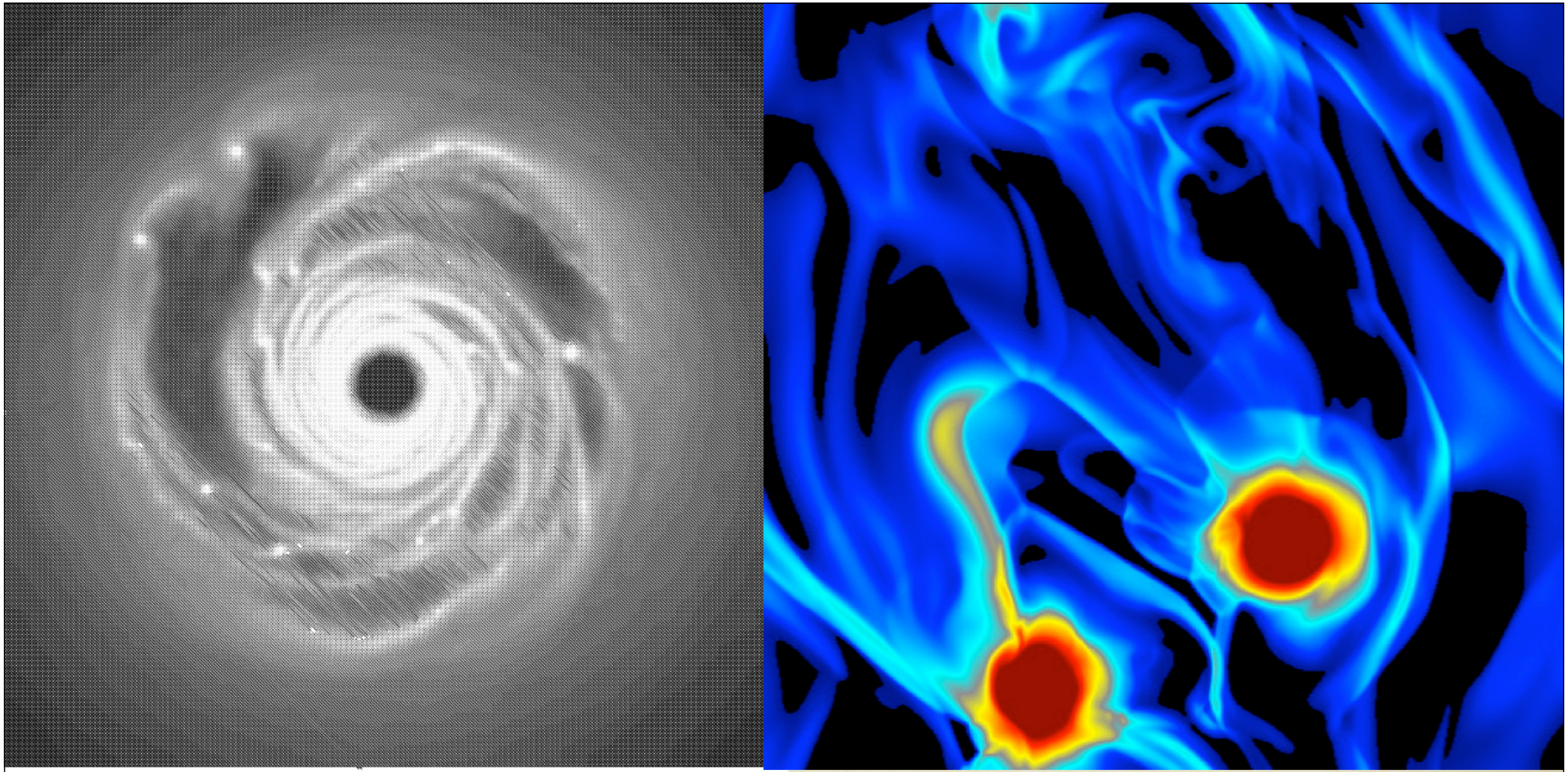


Margutti et al. 2010 MNRAS, 406, 2149

FLARES AS A FUNCTION OF TIME

?





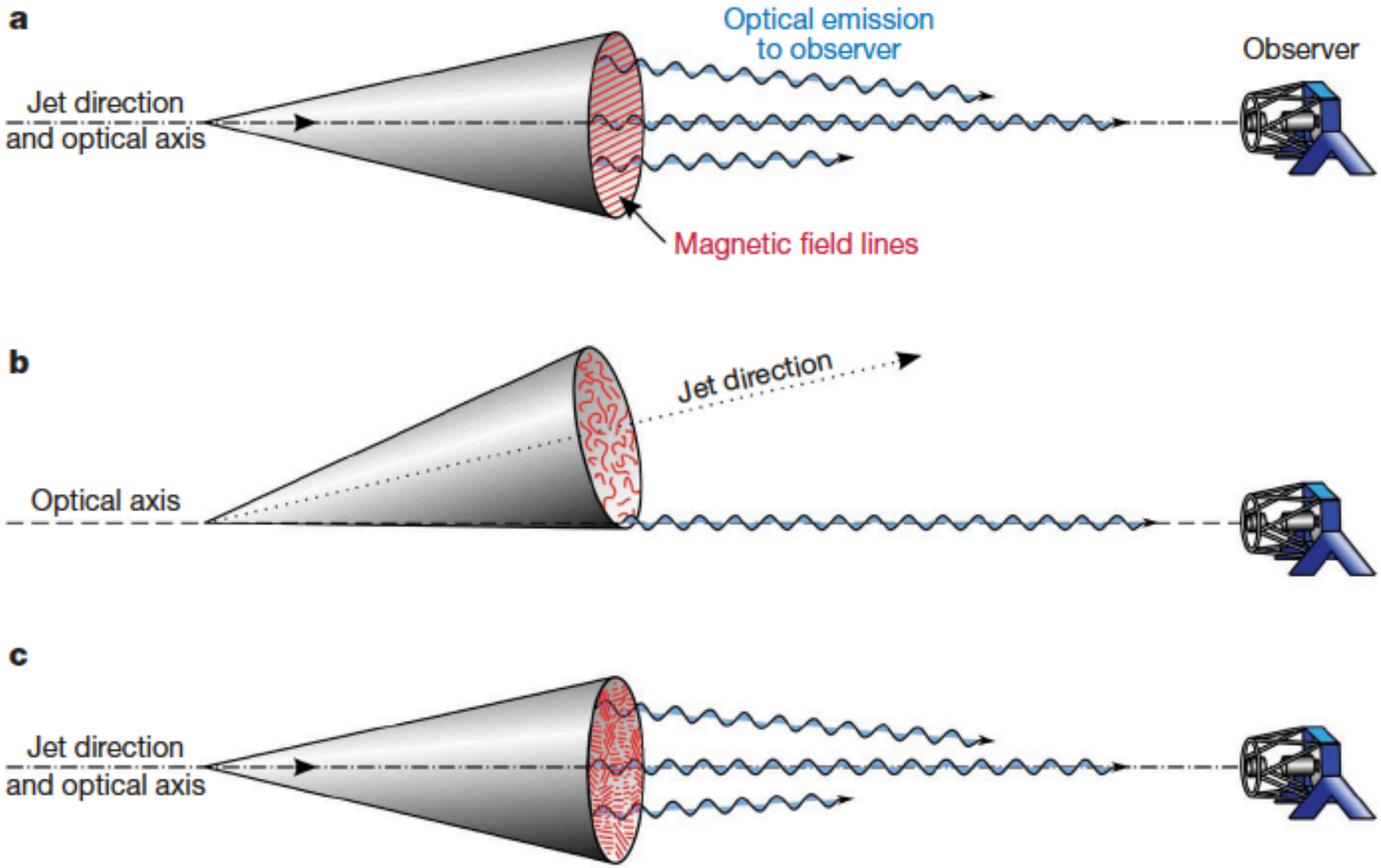
The instability setting up in the rotating disk (gammie 2001, Rice 2003, Lodato et al. 2005) when the cooling time is low. Blobs will form with a mass that is about 10% of the mass of the central object. If the cooling time is large (larger than about 3 Ω) then the blobs form but rotates about the central object with rather stable orbits.

The cooling time $\tau_c \sim (\alpha\Omega)^{-1}$ and $\tau_c < 3\ \Omega^{-1}$ therefore $1/\alpha < 3$ [α -> Shakura Sunyaev]

FLARES

Flares have the same characteristics of the spikes we observe in the prompt emission. They get softer and weaker with time

Chincarini et al., 2007
Chincarini et al., 2010


a
Optical emission
to observer
Observer
Jet direction
and optical axis
Magnetic field lines
b
Jet direction
Optical axis
c
Jet direction
and optical axis

In the magnetar model the main ingredients are: { Lyutikov etc

The Luminosity due to spin down energy losses

$$\int_{t_i}^{t_0} -\frac{dE}{dt} \quad \text{where} \quad -\frac{dE}{dt} = -\frac{d}{dt}\left(\frac{1}{2} I \Omega^2\right) =$$

$$= I \Omega \dot{\Omega} = \frac{B^2 R^6 \Omega^4}{6 c^3}$$ { Landau Page 190, Pacini 1968

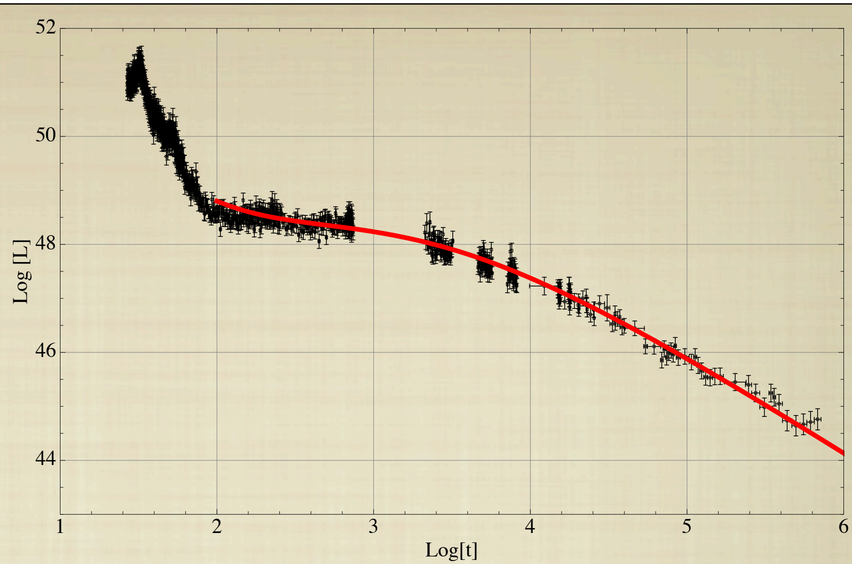
and Following Cohen - Piran (1999)

$$\frac{dE}{dt} = L_{in}(t) - k\, E/t$$

with the detailed by dall'Osso (2010)

The solution of the equation is straight forward

- But as usual the fit is not enough, and free parameters many fits Rather well the X ray light curves from the plateau on ward with Reasonable values of the parameters. (easy to adjust). The main assumption is that the X ray decay is identical to the bolometric decay. What happens before 100 s ?



THE FIT OF GRB061121 IS QUITE REASONABLE AS SHOWN PREVIOUSLY

BY DALL'OSSO ET AL. WE HAVE 5

FREE PARAMETERS AND TWO (RADIUS AND INERTIA OF THE NEUTRON STAR FIXED AT IN = 1.45 10^{45} AND R = 10^6 CM. THE RESULT IS GOOD AND HOWEVER IT IS NOT A ROBUST PROVE OF THE PRESENCE OF THE NEUTRON STAR. THE MAGNETIC FIELD WE DERIVE IS B = 1.8 10^{15} GAUSS IN AGREEMENT AS EXPECTED WITH THAT DERIVED BY DALL'OSSO ET AL.
(THE FIT WAS DONE BY MARIA GRAZIA BERNARDINI).

CONCLUSIONS

GENERALITIES:

Steep decay - Curvature effect does not fully explain spectroscopic variations. See also evolution of E_peak in Margutti et al. 2009

Plateau: Injection of energy, external shock or what.The light curve after flaring returns to its no flare value level.

....

FLARES

All main characteristics are similar to wide spikes observed during the prompt emission.

External shock cannot be the origin of the flares. A possibility is Internal shock.

The engine reactivate and may be was never completely off. Pressure holding accretion?

May have to take a better look at the accretion from the disk and related instabilities. Lazzati & Perna, Margutti et al. in preparation.

OPEN QUESTIONS

Remembering that statistically in time everything gets weaker and softer

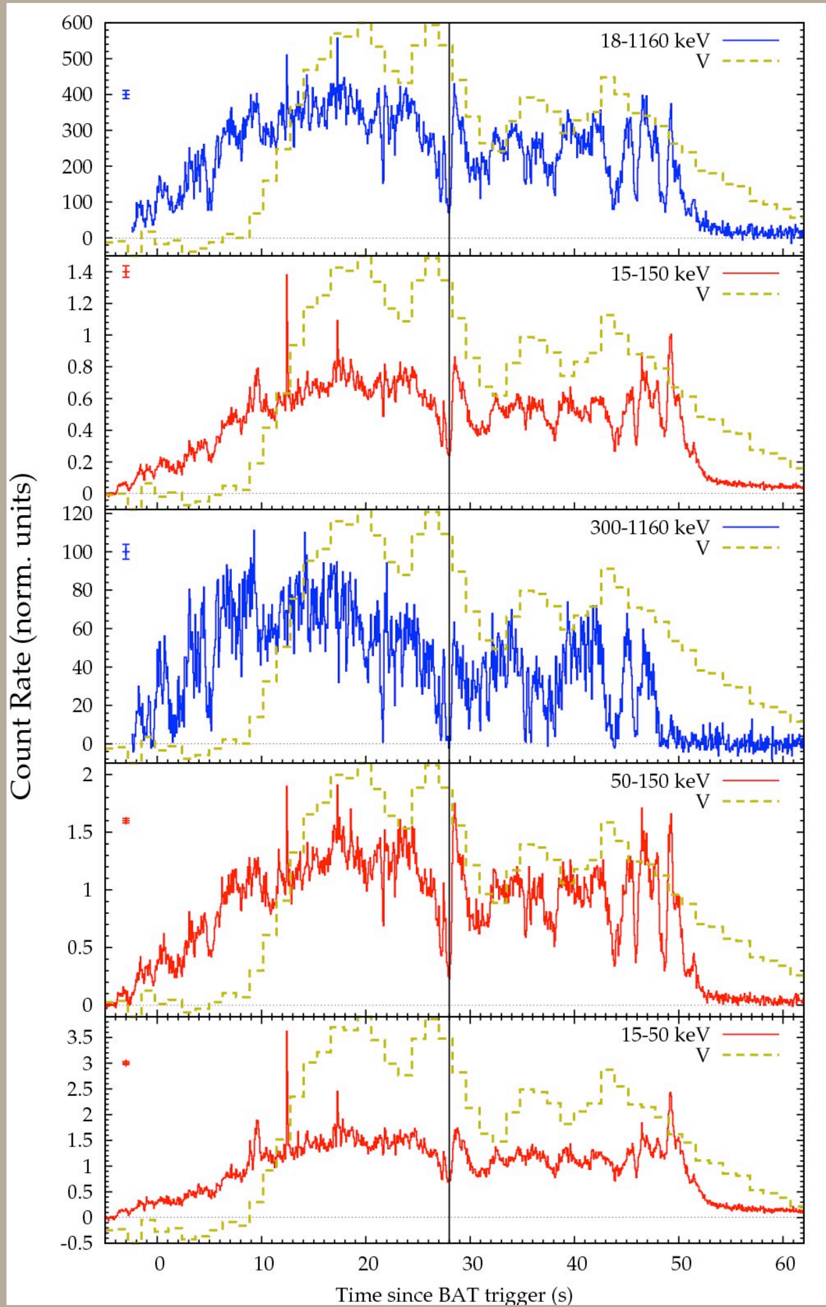
- ***Standard Fireball model may not survive - Flares remain unexplained.***
- ***Ordered magnetic fields and polarization.***
- ***Magnetar - Pulsar Model - Poynting flux.***
- ***Simulations & New targeted observations.***
- ***The real conclusion is that while we are progressing very well in sharply characterizing the properties of flares and their relation to the prompt emission spikes and prompt emission energy, at the moment there is no yet satisfactory model explaining the overall picture and the origin, evolution and energetic of flares.***


Non tutti quelli che vagano si sono persi
[J.R.R. Tolkien]


THE END
ODILIA LIUZZI

BAT Swift

- 4 ms
  - 15 – 25 keV
  - 25 – 50 keV
  - 50 – 100 keV
  - 100 – 150 keV



- Konus-WIND
  - 64 ms
  - **18-70 keV**
  - **70-300 keV**
  - **300-1160 keV**

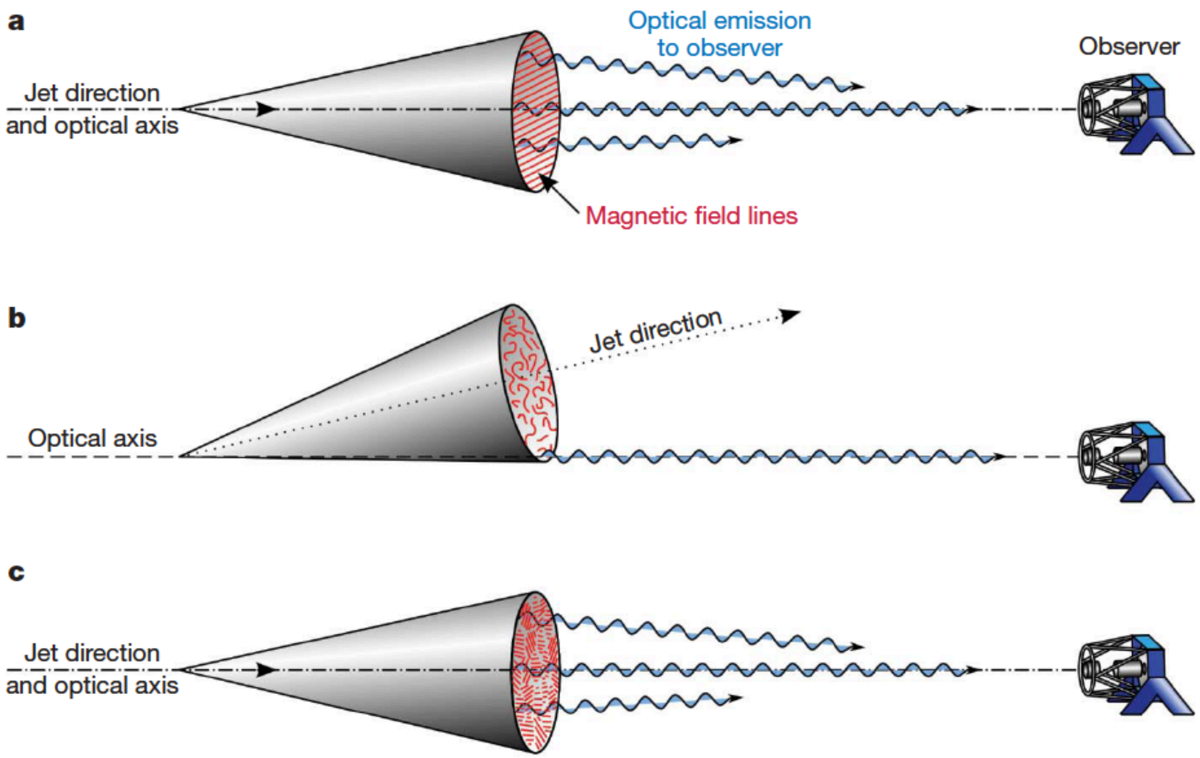


Figure 4 | Competing models of GRB magnetic field structure. The schematic shows three representations of a GRB outflow in the context of the standard fireball model for a variety of magnetic field structures and different orientations to the observer's line of sight (optical axis). A large degree of polarization is predicted when the ejected material is threaded with a large-scale ordered magnetic field as shown in **a** and is the favoured model to explain the measured polarization in GRB 090102. Alternatively, if no ordered magnetic field is present and instead a tangled magnetic field is produced in the shock front, the detected light will be polarized only if the observer's line of sight is close to the jet edge (**b**). In this case, however, the predicted steepening of the light curve that is expected when observing an off-axis jet is inconsistent with the flattening exhibited in the light curve of GRB 090102. A compromise is shown in **c** in which the shock front contains a number of independent patches of locally ordered magnetic fields; a measured polarization of 10% is at the very uppermost bound for such a model.

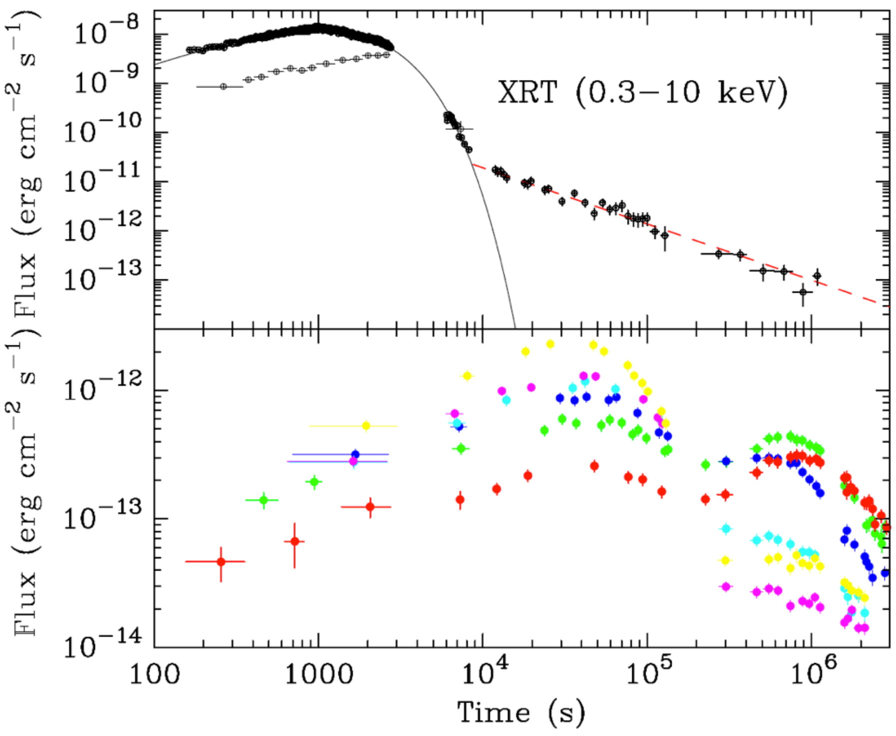


Fig. 2.— **Long-term Swift light curve of GRB060218.** *Upper panel*: the XRT light curve (0.3–10 keV) is shown with open black circles. Count rate-to-flux conversion factors were derived from time-dependent spectral analysis. We also plot with open black squares the contribution to the 0.3–10 keV flux by the blackbody component. Its percentage contribution is increasing with time, becoming dominant at the end of the exponential decay. The X–ray light curve has a long, slow power-law rise followed by an exponential (or steep power-law) decay. At about 10,000 s the light curve breaks to a shallower power-law decay with index -1.2 ± 0.1 characteristic of typical GRB afterglows. This classical afterglow can be naturally accounted for by a shock driven into the wind by a shell with kinetic energy $E_{\rm shell} \sim 10^{49}$ erg. The t^{-1} flux decline is valid at the stage where the shell is being decelerated by the wind with the deceleration phase beginning at $t_{\rm dec} \lesssim 10^4$ s for $\dot{M} \gtrsim 10^{-4}(v_{\rm wind}/10^8\,{\rm cm\,s^{-1}})\,M_\odot\,{\rm yr}^{-1}$, consistent with the mass-loss rate inferred from the thermal X–ray component.
Lower panel: the UVOT light curve. Filled circles of different colors represent different UVOT filters: red – V (centered at 544 nm); green – B (439 nm), blue – U (345 nm), light blue – UVW1 (251 nm); magenta – UVM1 (217 nm) and yellow – UVW2 (188 nm). Specific fluxes have been multiplied by their FWHM widths (75, 98, 88, 70, 51 and 76 nm, respectively). Data have been rebinned to increase the signal to noise ratio. The UV band light curve peaks at about 30 ks due to the shock break-out from the outer stellar surface and the surrounding dense stellar wind, while the optical band peaks at about 800 ks due to radioactive heating in the SN ejecta.

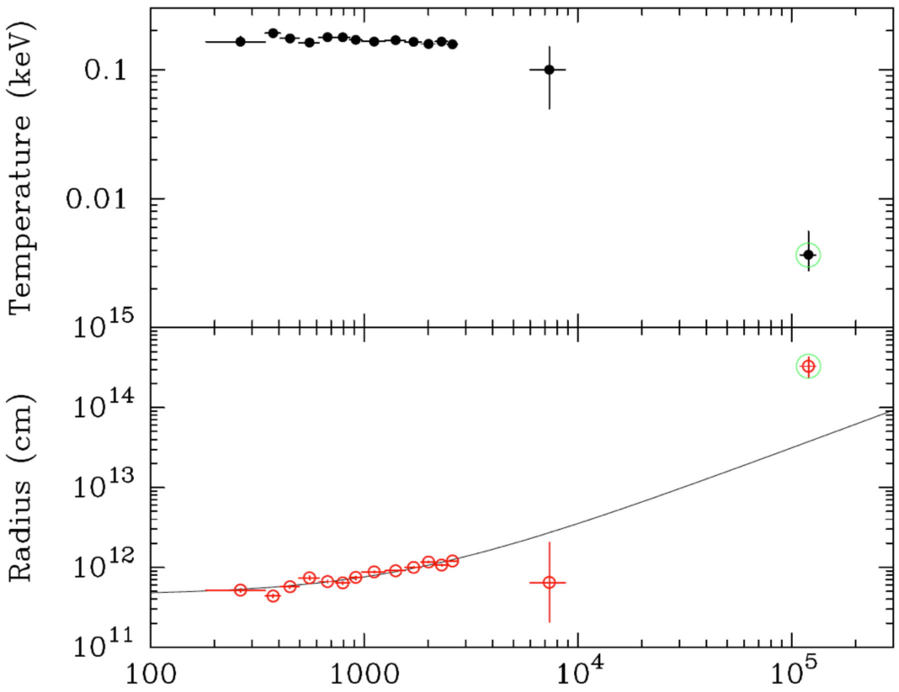
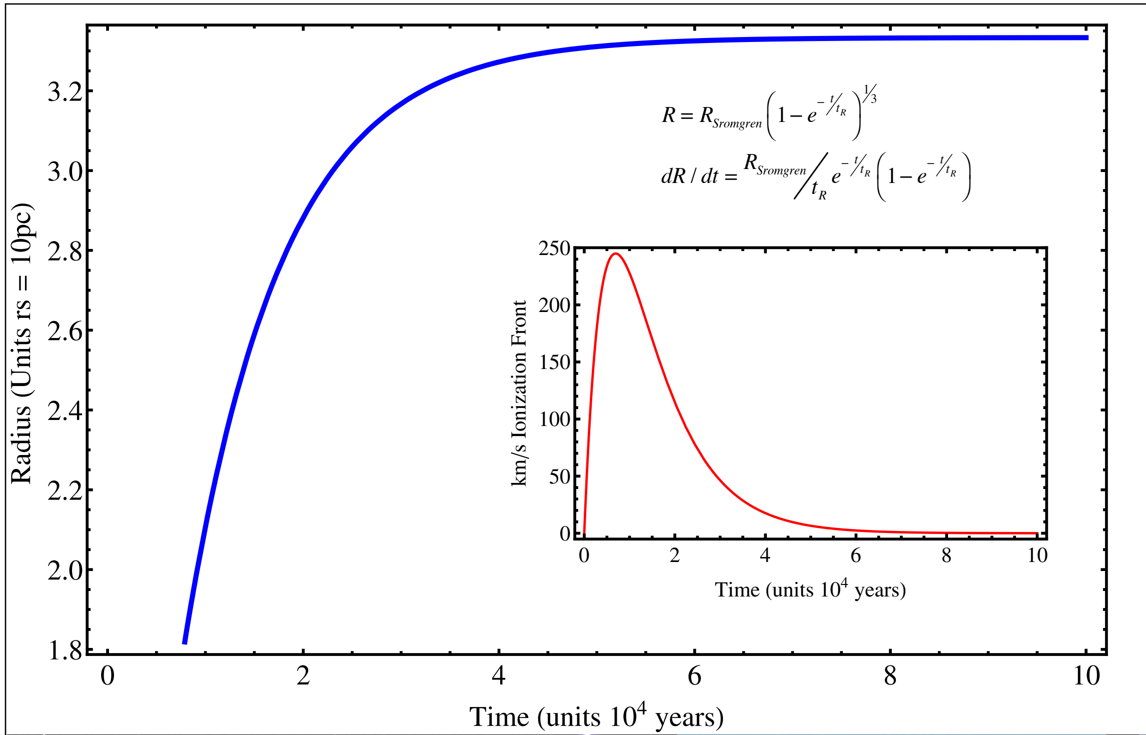
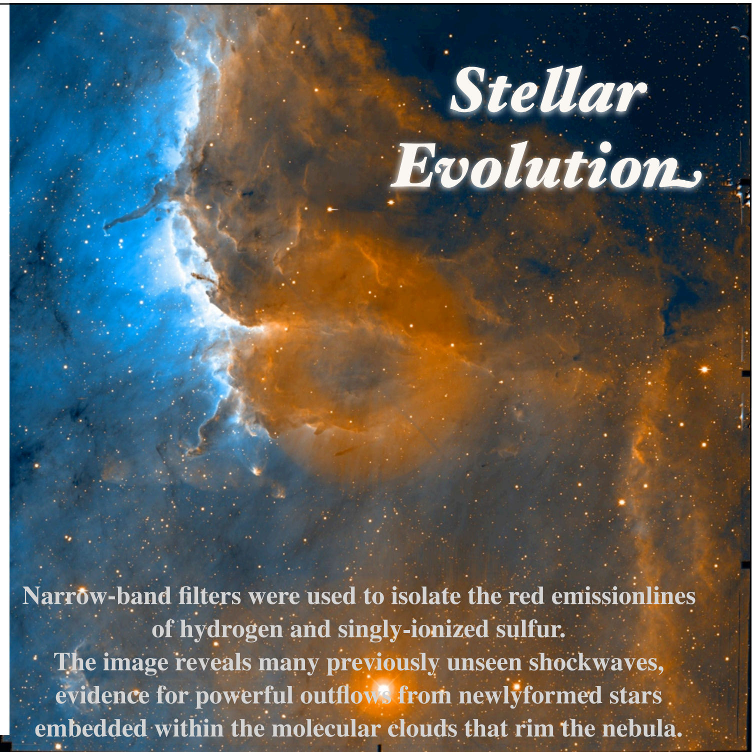


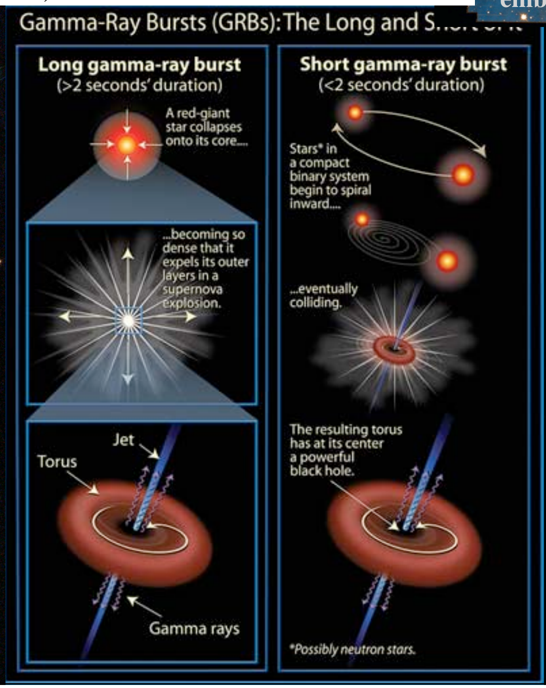
Fig. 3.— **Evolution of the soft thermal component temperature and radius.** *Upper panel*: evolution of the temperature of the soft thermal component. The joint BAT and XRT spectrum has been fit with a blackbody component plus a (cut-off) power-law in the first $\sim 3,000$ s (see also the caption of Fig. 1). The last point (circled in green) comes from a fit to the six UVOT filters, assuming a blackbody model with Galactic reddening $[E(B-V) = 0.14]$ and host galaxy reddening. This reddening has been determined by fitting the Rayleigh-Jeans tail of the blackbody emission at 32 ks (9 hours). The data require an intrinsic $E(B-V) = 0.20 \pm 0.03$ (assuming a Small Magellanic Cloud reddening law[18]). *Lower panel*: evolution of the radius of the soft thermal component. The last point (circled in green) comes from the fitting of UVOT data. The continuous line represents a linear fit to the data.



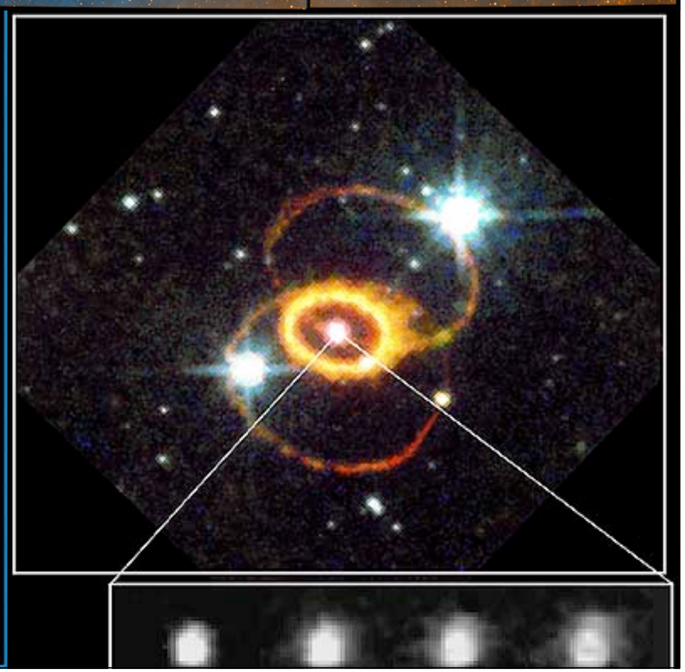
$R = R_{Sromgren}\left(1-e^{-t/t_R}\right)^{1/3}$
$dR/dt = \frac{R_{Sromgren}}{t_R} e^{-t/t_R}\left(1-e^{-t/t_R}\right)$
km/s Ionization Front
Time (units 10^4 years)
Radius (Units rs = 10pc)
Time (units 10^4 years)



Stellar Evolution
Narrow-band filters were used to isolate the red emissionlines of hydrogen and singly-ionized sulfur.
The image reveals many previously unseen shockwaves, evidence for powerful outflows from newlyformed stars embedded within the molecular clouds that rim the nebula.



Gamma-Ray Bursts (GRBs): The Long and S...
Long gamma-ray burst
(>2 seconds' duration)
A red-giant star collapses onto its core....
...becoming so dense that it expels its outer layers in a supernova explosion.
Jet
Torus
Gamma rays
Short gamma-ray burst
(<2 seconds' duration)
Stars* in a compact binary system begin to spiral inward....
...eventually colliding.
The resulting torus has at its center a powerful black hole.
*Possibly neutron stars.



BAT Swift

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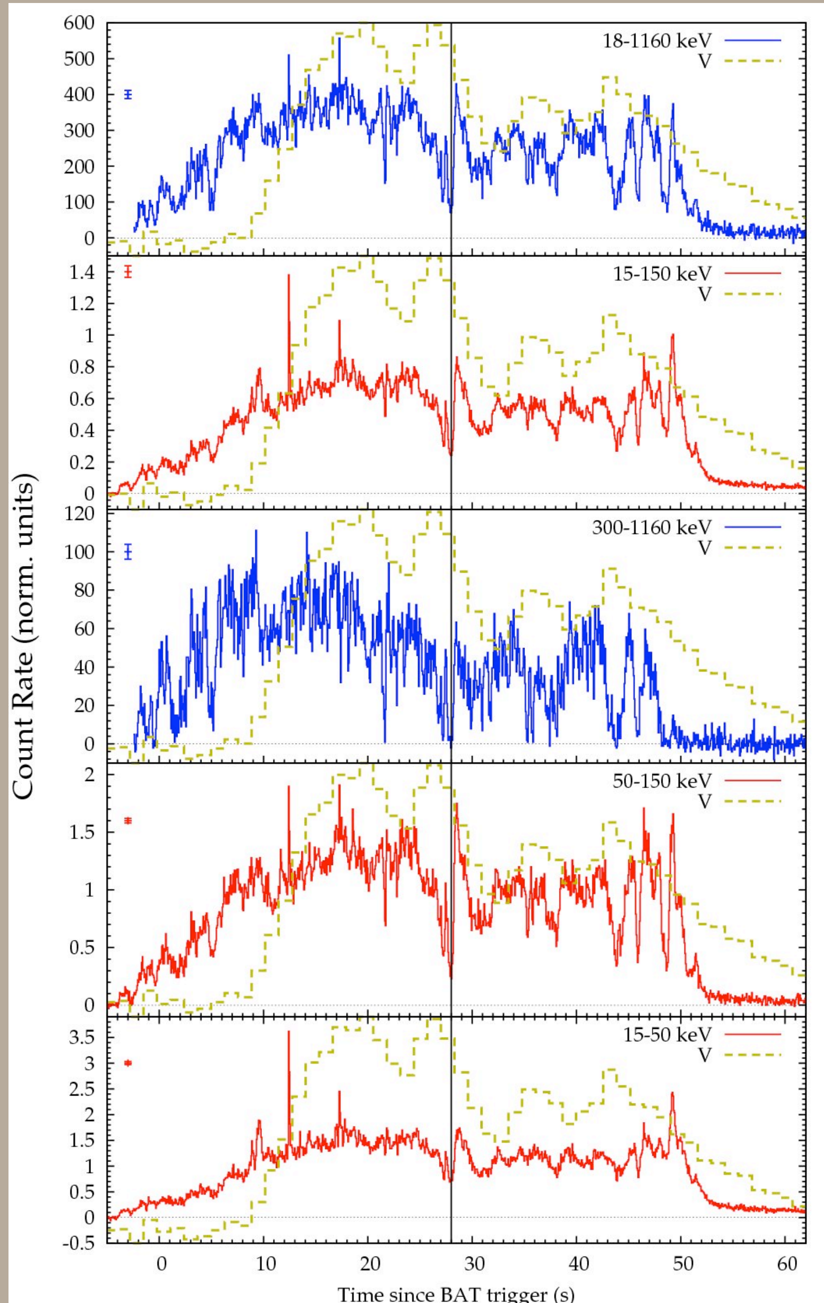
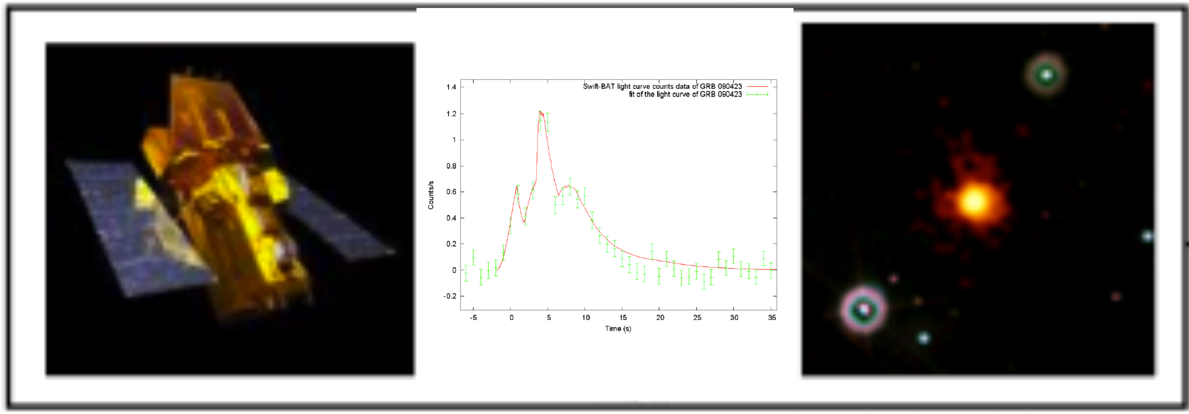
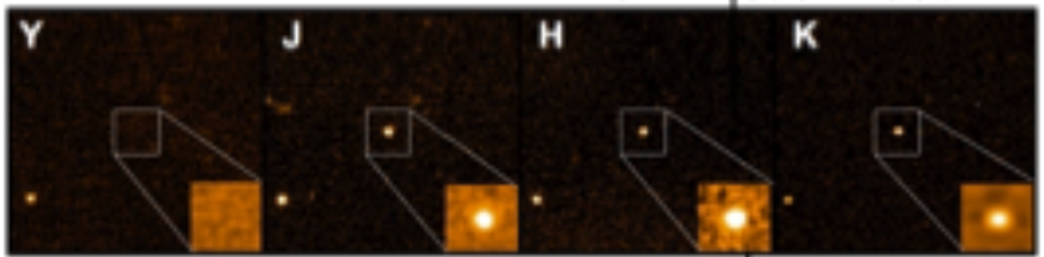
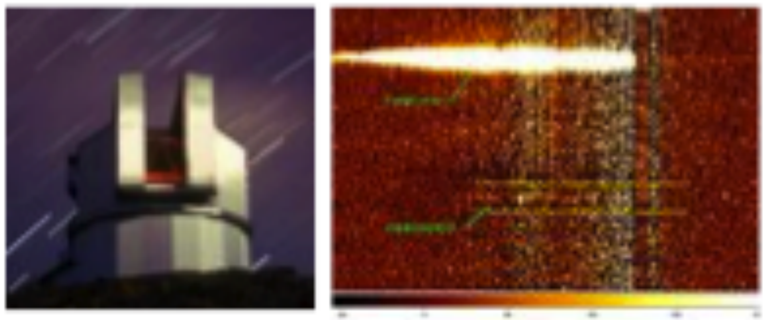


GRB 090423



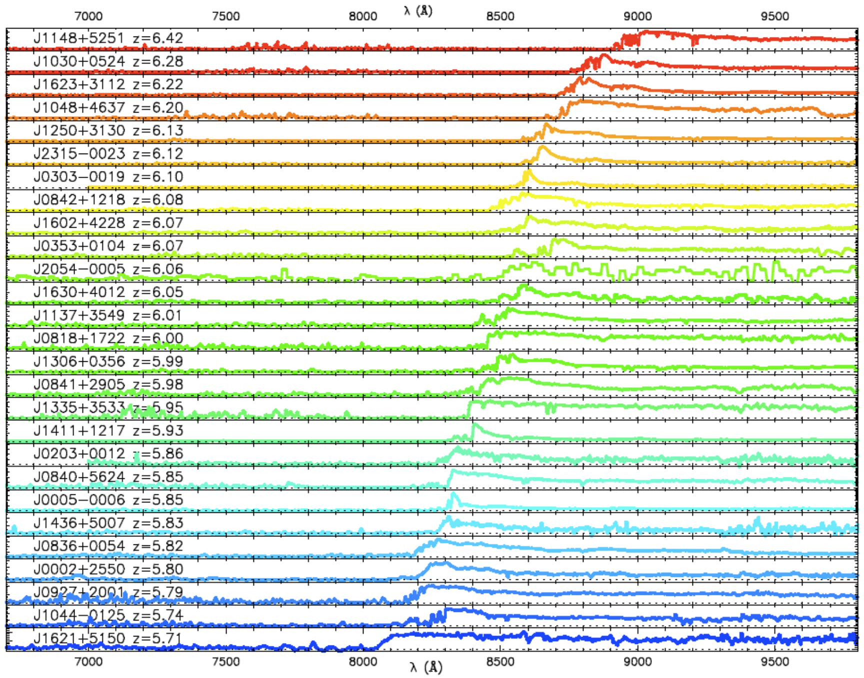
Tanvir et al. 2009



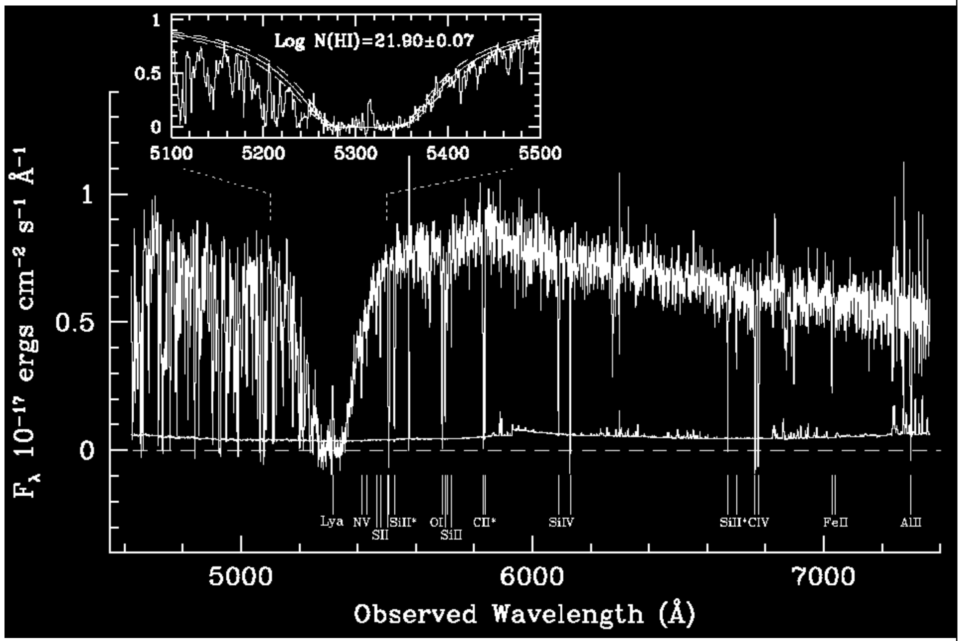


Telescopio
Nazionale
Galileo
~14hrs after trigger

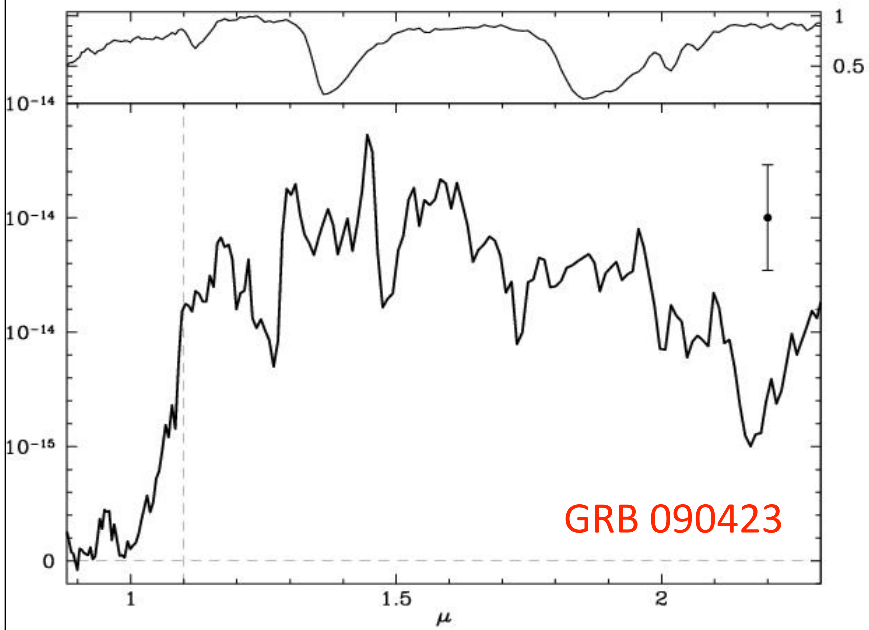
Salvaterra et al., 2009



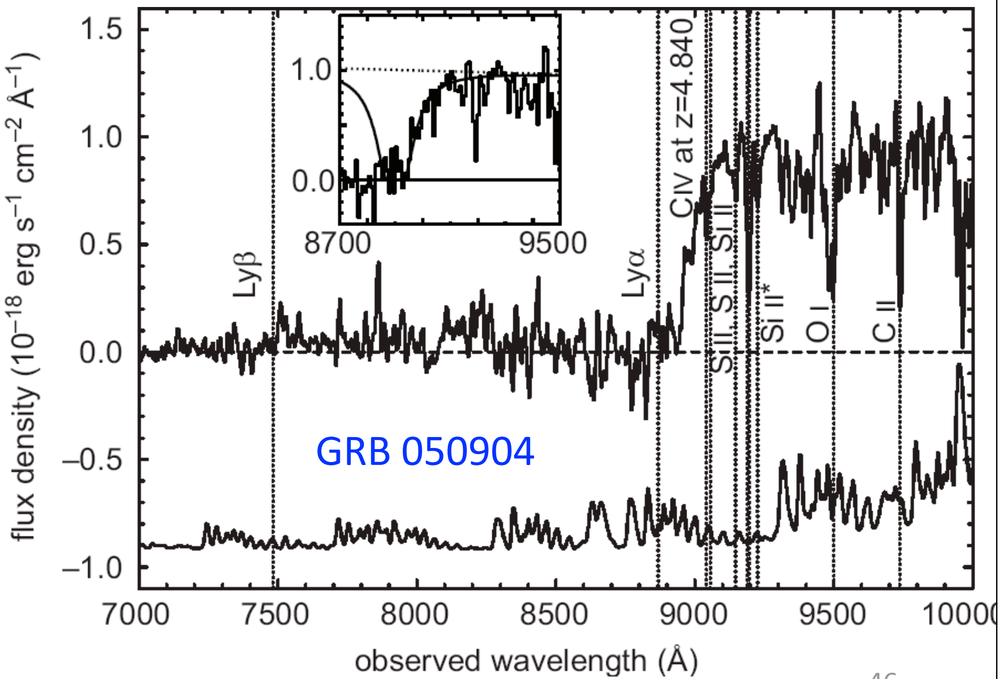
λ (Å)
7000
7500
8000
8500
9000
9500
J1148+5251 z=6.42
J1030+0524 z=6.28
J1623+3112 z=6.22
J1048+4637 z=6.20
J1250+3130 z=6.13
J2315−0023 z=6.12
J0303−0019 z=6.10
J0842+1218 z=6.08
J1602+4228 z=6.07
J0353+0104 z=6.07
J2054−0005 z=6.06
J1630+4012 z=6.05
J1137+3549 z=6.01
J0818+1722 z=6.00
J1306+0356 z=5.99
J0841+2905 z=5.98
J1335+3533 z=5.95
J1411+1217 z=5.93
J0203+0012 z=5.86
J0840+5624 z=5.85
J0005−0006 z=5.85
J1436+5007 z=5.83
J0836+0054 z=5.82
J0002+2550 z=5.80
J0927+2001 z=5.79
J1044−0125 z=5.74
J1621+5150 z=5.71



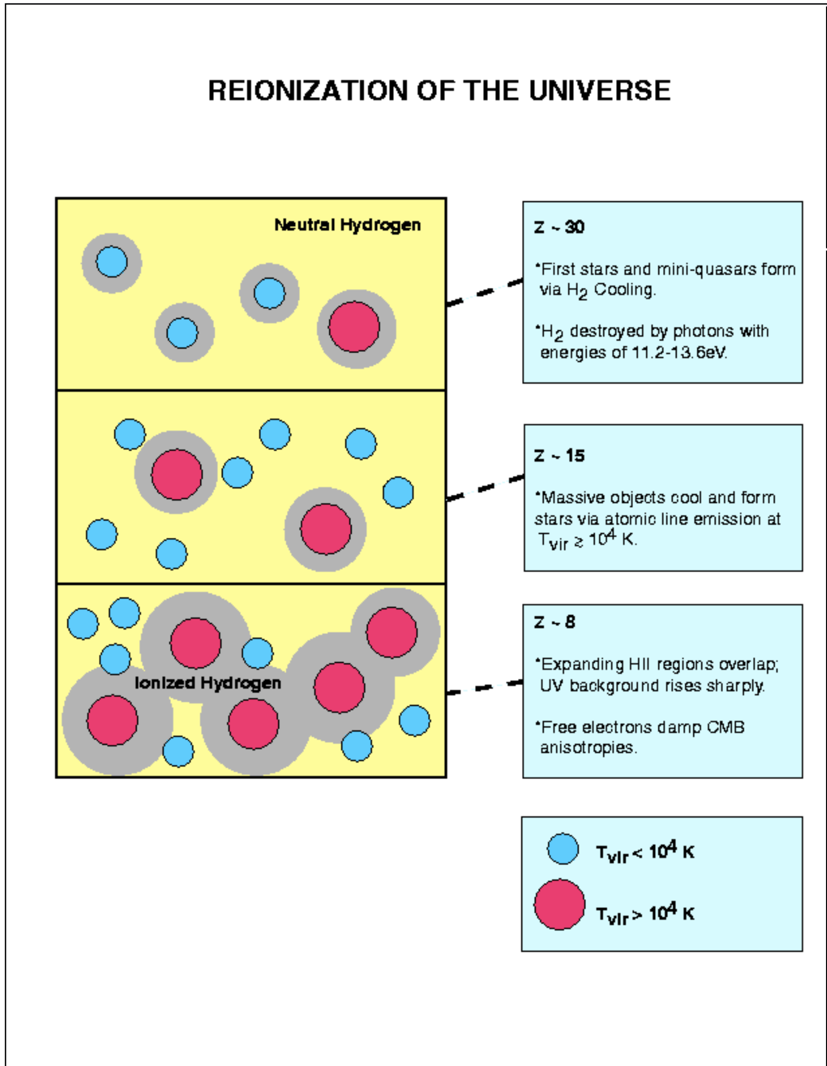
Log N(HI)=21.90±0.07
5100
5200
5300
5400
5500
F_λ 10^{-17} ergs cm^{-2} s^{-1} Å^{-1}
Lyα NV SII SiII* OI SiII CII* SiIV SiII*CIV FeII AlII
5000
6000
7000
Observed Wavelength (Å)

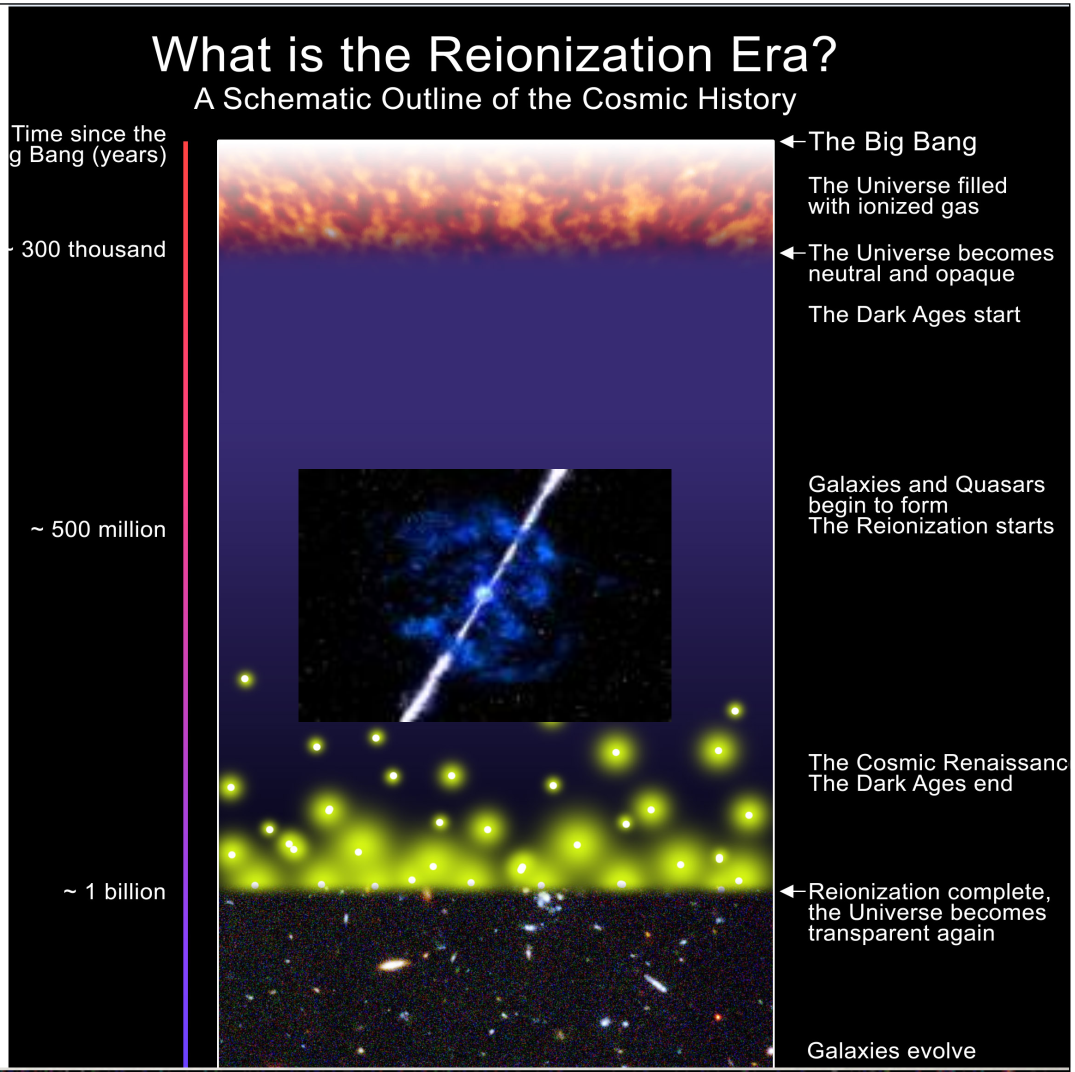


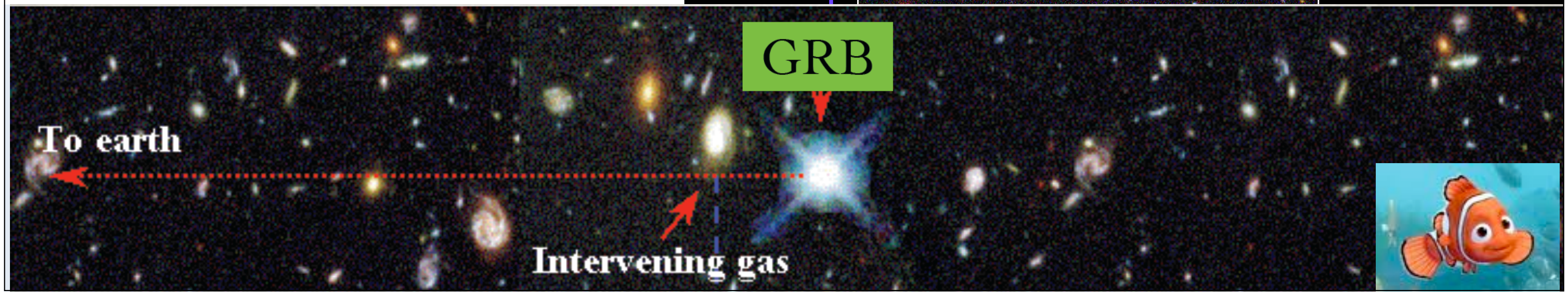
10^{-14}
10^{-15}
0
0.5
1
1.5
2
μ
GRB 090423



flux density (10^{-18} erg s^{-1} cm^{-2} Å^{-1})
Lyβ
Lyα
CIV at z=4.840
Si II
S II
Si II
Si II*
O I
C II
8700
9500
GRB 050904
7000
7500
8000
8500
9000
9500
10000
observed wavelength (Å)


REIONIZATION OF THE UNIVERSE
Neutral Hydrogen
Ionized Hydrogen
Z ~ 30
*First stars and mini-quasars form via H_2 Cooling.
*H_2 destroyed by photons with energies of 11.2-13.6eV.
Z ~ 15
*Massive objects cool and form stars via atomic line emission at $T_{vir} \gtrsim 10^4$ K.
Z ~ 8
*Expanding HII regions overlap; UV background rises sharply.
*Free electrons damp CMB anisotropies.
$T_{vir} < 10^4$ K
$T_{vir} > 10^4$ K


What is the Reionization Era?
A Schematic Outline of the Cosmic History
Time since the
g Bang (years)
300 thousand
~ 500 million
~ 1 billion
The Big Bang
The Universe filled
with ionized gas
The Universe becomes
neutral and opaque
The Dark Ages start
Galaxies and Quasars
begin to form
The Reionization starts
The Cosmic Renaissanc
The Dark Ages end
Reionization complete,
the Universe becomes
transparent again
Galaxies evolve

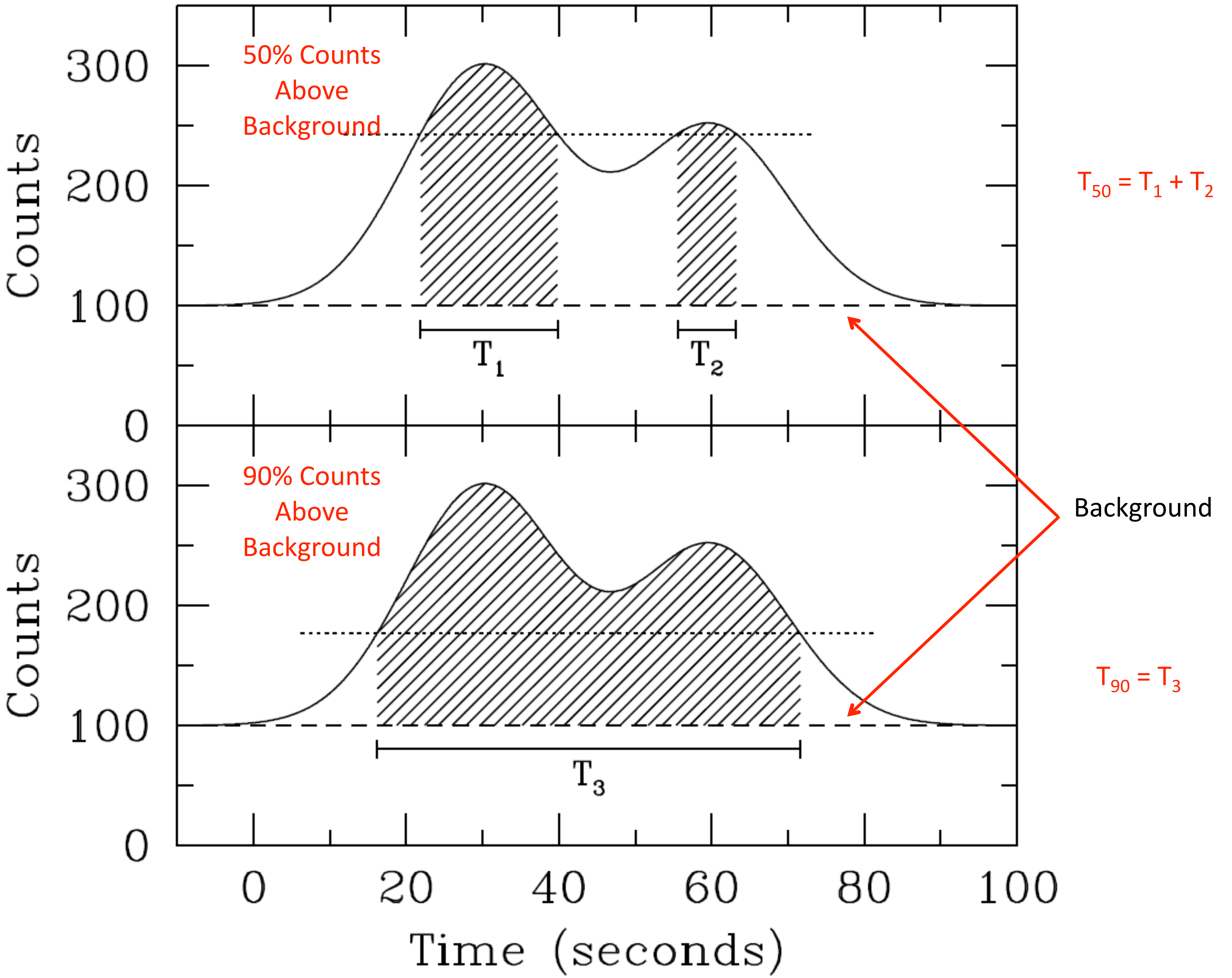

GRB
To earth
Intervening gas

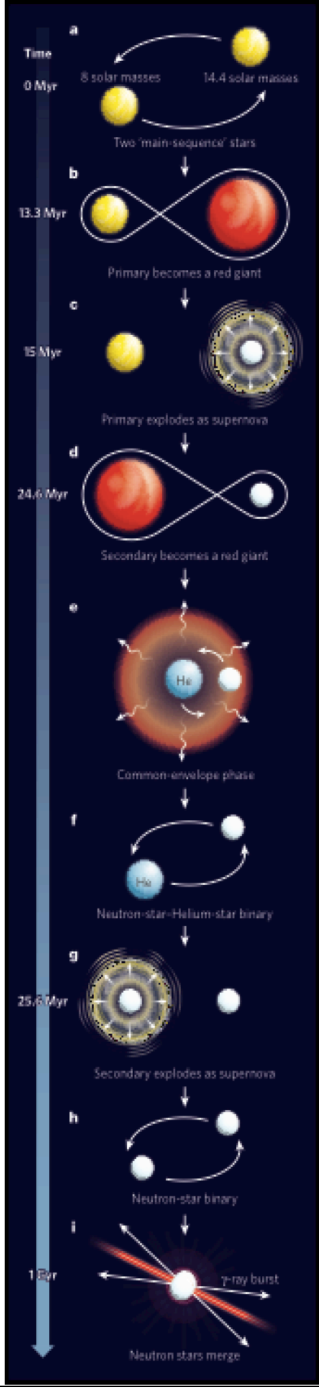
The simulations are from the presentation given by A. McFadyen in the Venice 2009 meeting

This talk benefited form discusion I had with

Raffaella Margutti

OTHERS


50% Counts
Above
Background
90% Counts
Above
Background
Counts
300
200
100
0
0
20
40
60
80
100
Time (seconds)
T_1
T_2
T_3
$T_{50} = T_1 + T_2$
Background
$T_{90} = T_3$



Possible evolutionary path to a short-lasting gamma-ray burst. a, b, In a binary-star system consisting of two high-mass, 'main-sequence' stars, the more massive member (primary) exhausts its hydrogen nuclear-fuel supply, becomes a bloated red giant and transfers large amounts of mass to its lighter companion (secondary). **c,** The primary explodes as a supernova, leaving behind a neutron star. **d,** The secondary becomes a giant. **e,** Its expansion leads to a common-envelope phase in which the neutron star ploughs through the giant's outer layers, ejecting them from the system and leaving it in a tight orbit. **f,** The likely outcome is a neutron-star–helium-star binary. **g,** The helium star undergoes a supernova explosion. **h,** The resulting neutron-star pair is left in a short-period (about a day) orbit. **i,** With time, the system loses orbital energy and the stars merge, producing a gamma-ray burst; the time delay between the formation of the neutron-star binary and the burst occurrence is extremely sensitive to the separation of the stars after the common-envelope phase. The discovery[1] of GRB 070714B suggests that smaller separations than previously anticipated are needed. (Diagrams and temporal axis not to scale.)

[OII], z= 0.923 - Graham et al. 2009

Enrico Ramirez Ruiz 2009

Syn. cooling & curvature

Sari et al.

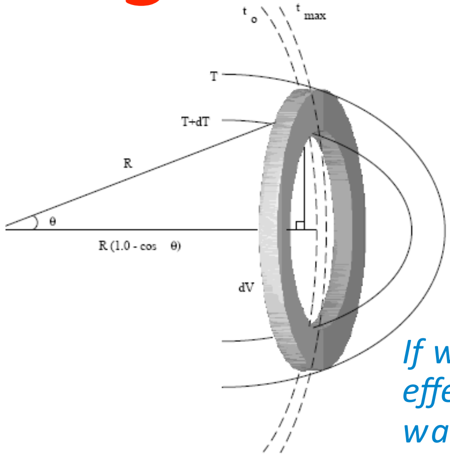
$$\tau_{\rm syn} = (1.4 \times 10^{-2}\ {\rm s})\epsilon_B^{-3/4}\left(\frac{h\nu_{\rm obs}}{100\ {\rm keV}}\right)^{-1/2} \times \left(\frac{t_{\rm dur}}{10\ {\rm s}}\right)^{3/4} l_{18}^{-3/4} n_1^{-3/4}\ .$$

This equation is quite robust.
It is valid for both the forward and reverse shock and it is independent of whether the reverse shock is relativistic or Newtonian.

$$t_{\rm dur} = \left(\frac{l}{c}\right)\gamma^{-8/3}\xi^{-2} = (150\ {\rm s})\left(\frac{\gamma}{100}\right)^{-8/3}\xi^{-2} l_{18}$$

$$\xi \equiv \left(\frac{l}{\Delta}\right)^{1/2}\gamma^{-4/3}$$

Fennimore et al. ACF Width = k E$^{-0.42}$



Kumar&Panaitescu
Dermer

$$\alpha = 2 + \beta$$

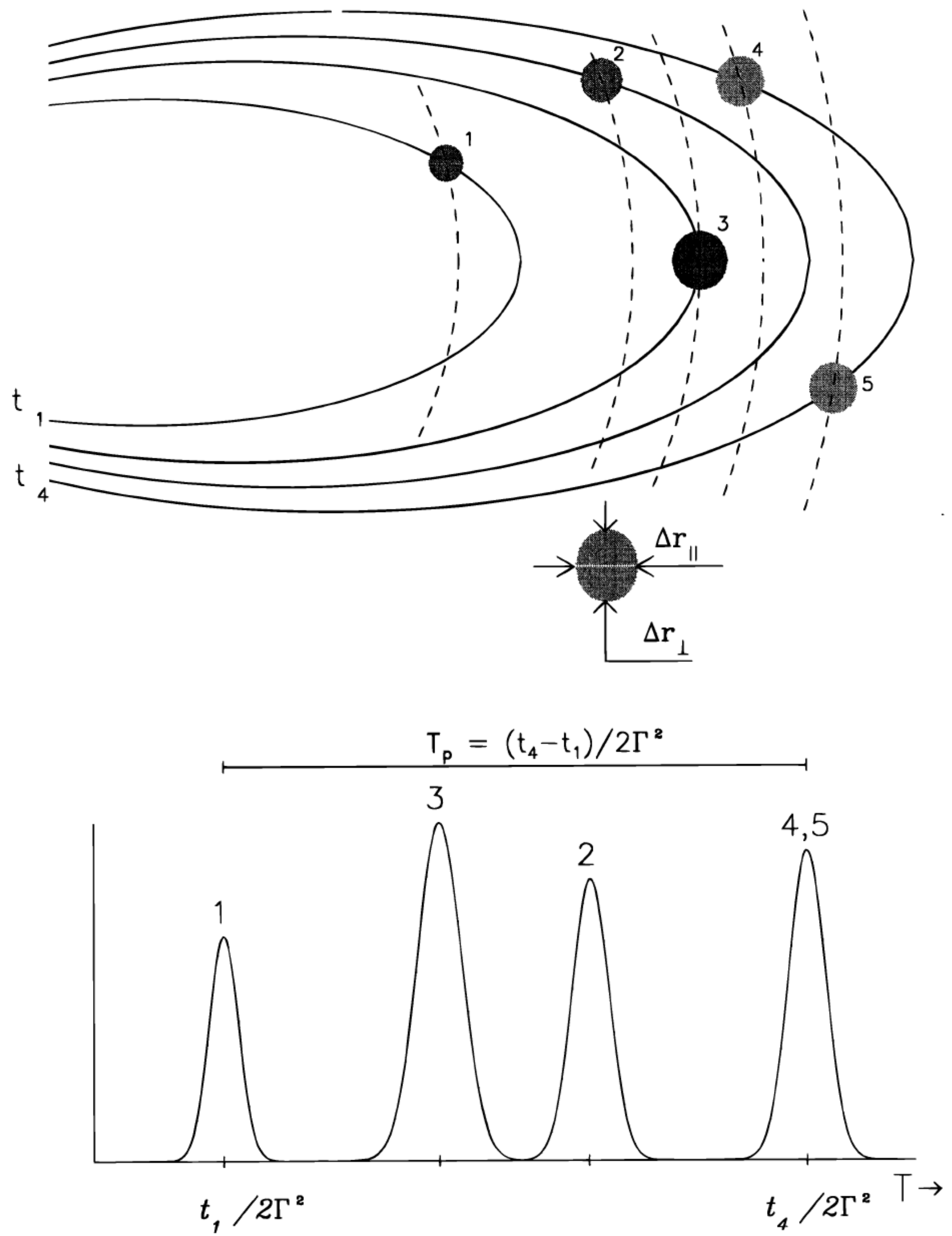
If we assume the main factor is the curvature effect we have the following [The Observer way, however see later more formal derivation by Lazzati & Perna:

$$f_\nu \propto t^{-\alpha}\ \ with\ \alpha = 2 + \beta$$

$$t \propto f^{-\frac{1}{\alpha}}\ ;\ \frac{t_{\frac{f_{peak}}{2}}}{t_{f_{peak}}} = \frac{\left(\frac{f}{2}\right)^{-\frac{1}{\alpha}}}{f^{-\frac{1}{\alpha}}} = \left(\frac{1}{2}\right)^{-\frac{1}{\alpha}}$$

$$HPFW = t_{\frac{f_{peak}}{2}} - t_{f_{peak}} = \left(2^{\frac{1}{2+\beta}} - 1\right) t_{f_{peak}}$$

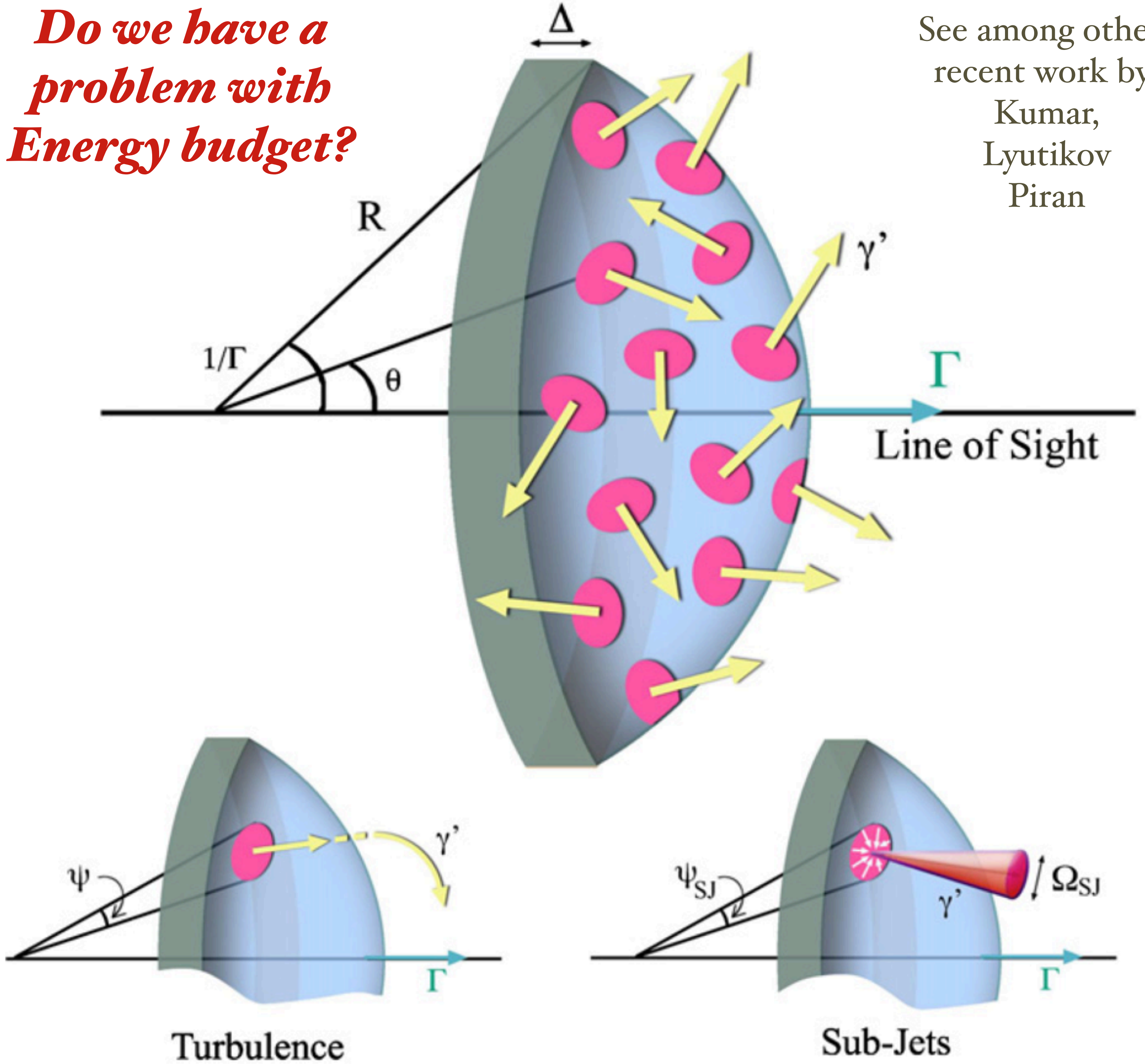
$$\frac{HPFW}{t_{f_{peak}}} = 0.29$$



A way to form short variability and related geometry

Do we have a problem with Energy budget?

See among others recent work by:
Kumar,
Lyutikov
Piran



2D Uni.Blastwave (energy - erg cm^{-3})

surrounding medium internal energy density ~ 2.25 10^{-13} erg cm^{-3}

Zhang et al., 2009 see also Venice 2009 presentation by A. McFadyen