GRB events and spectra of the afterglow

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Emission and absorption features

- Thanks to their exceptional brightness, and although fading very rapidly, Gamma-Ray Burst (GRB) afterglows can be used as powerful extragalactic background sources. Since GRBs can be detected up to very high red-shifts their afterglow spectra can be used to study the properties and evolution of galaxies and the IGM, similarly to what is traditionally done using QSO spectra. Even if the number of available GRB lines of sight (los) is much smaller than those of QSOs, it is interesting to compare the two types of lines of sight.
- A high energy radiation is generated during the event. Whatever the density of the GRB environment, photoionization of the circumburst material by the prompt X-ray emission and by the X-ray and UV afterglow emission will be inevitable. Within the recombination of such ionized gas and dust the emission lines are generated.
- Also, intergalactic gas and dust directly influence the radiation from GRB source and create absorption lines. In many of the GRB spectra acquired to date, the researchers have reported the presence of a Mg II absorber with rest equivalent width $W_r > 1$ A . In particular, Prochter et al. (2006) found that the number density of strong intervening MgII absorbers is more than 4 times larger along GRB los than what is expected for QSOs over the same path length.

Shock wave evolution

- In the fireball model of GRBs, the energy released probably from the collapse of a massive star is converted into kinetic energy of thin baryonic shells which expand at ultra-relativistic speeds. After producing the prompt γ-ray emission by internal shocks between different shells, the residual impacts on the surrounding gas and drives an ultra-relativistic shock into the ambient medium. The shock accelerates relativistic electrons leading to the observed X-ray to radio afterglow radiation through synchrotron emission. The emission of the X-ray afterglow, integrated over the first 7–10 days, typically contains the same energy as the primary γ-ray burst itself.
- System of given phenomenological equations, evolve basic variables of the shock wave:

$$\frac{dR}{dt} = c\sqrt{\Gamma^2 - 1}[\Gamma + \sqrt{\Gamma^2 - 1}]$$

$$\frac{d\Gamma}{dm} = -\frac{\Gamma^2 - 1}{M_{ej} + 2(1-\xi)\Gamma m + \xi m}$$

$$\frac{dm}{dt} = 2\pi n m_p (1 - \cos\theta)\frac{R^2}{\Gamma^3}\left[3\Gamma\frac{dR}{dt} - 2R\frac{d\Gamma}{dt}\right]$$

$$n = n_0(4\Gamma + 3)\left(\frac{R_0}{R}\right)^s$$

$$\Delta R = \frac{R}{\Gamma^2}$$

Shock wave evolution

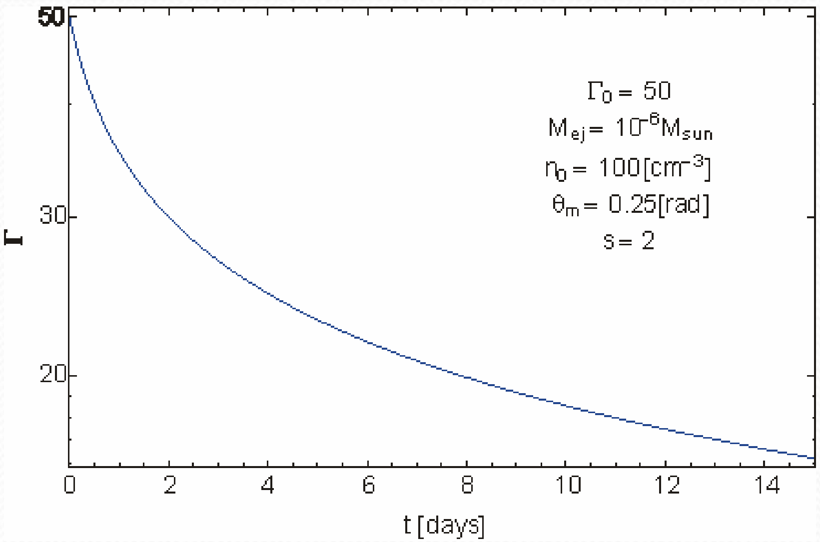
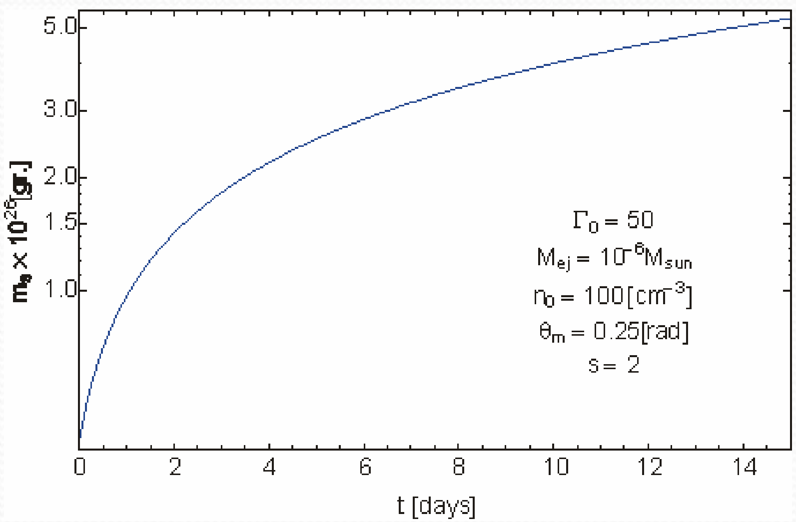


Fig. 1: Evolution of Lorentz factor for the time of afterglow.

Fig. 2: Same as in Fig. 1, but for shock wave mass.



Emission in afterglow phase

Typical spectra in fast cooling regime $\gamma_c < \gamma_m$ (Sari & Piran, 1998):

$$F_\nu = \begin{cases} (\nu/\nu_c)^{1/3} F_{\nu,\max}, & \nu_c > \nu \\ (\nu/\nu_c)^{-1/2} F_{\nu,\max}, & \nu_m > \nu > \nu_c \\ (\nu_m/\nu_c)^{-1/2} (\nu/\nu_m)^{-p/2} F_{\nu,\max}, & \nu > \nu_m \end{cases}$$

Typical spectra in slow cooling regime $\gamma_c > \gamma_m$ (Sari & Piran, 1998):

$$F_\nu = \begin{cases} (\nu/\nu_m)^{1/3} F_{\nu,\max}, & \nu_m > \nu, \\ (\nu/\nu_m)^{-(p-1)/2} F_{\nu,\max}, & \nu_c > \nu > \nu_m, \\ (\nu_c/\nu_m)^{-(p-1)/2} (\nu/\nu_c)^{-p/2} F_{\nu,\max}, & \nu > \nu_m \end{cases}$$

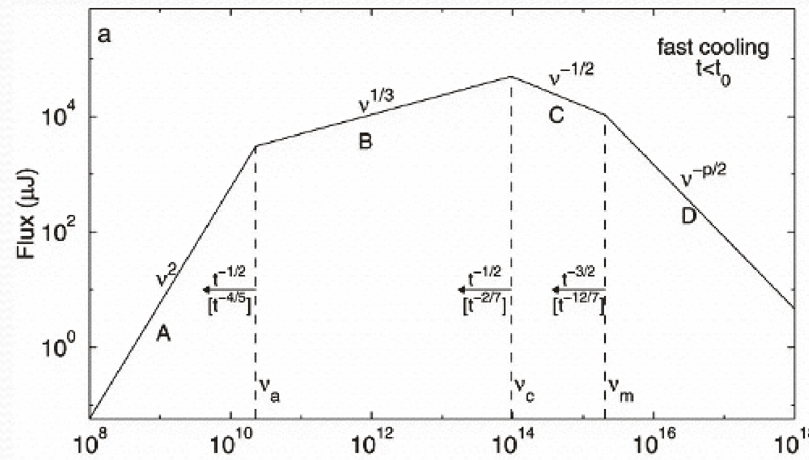
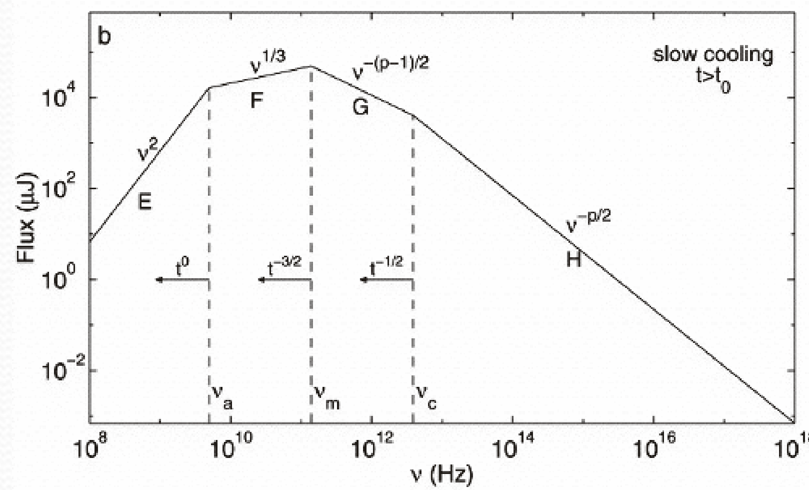


Fig 3. Spectra in case of fast (above) and slow (belove) cooling.



Observation of spectral lines in the afterglow phase

Table 1: Some of the observed GRBs from the sample of Tejos et al., (2009).

GRB	z_{GRB}	z_{start}	z_{end}	z_{abs}	W_r (2796) W_r (2803)
021004	2.33	0.447	2.27	0.56	0.140 ± 0.013 0.129 ± 0.014
050730	3.97	1.578	3.88	1.77	0.923 ± 0.019 0.792 ± 0.020
050820	2.61	0.569	2.55	0.69	2.988 ± 0.022 2.335 ± 0.025
051111	1.54	0.106	1.50	0.82	0.369 ± 0.010 0.297 ± 0.012
060418	1.49	0.081	1.44	0.60	1.299 ± 0.015 1.233 ± 0.015

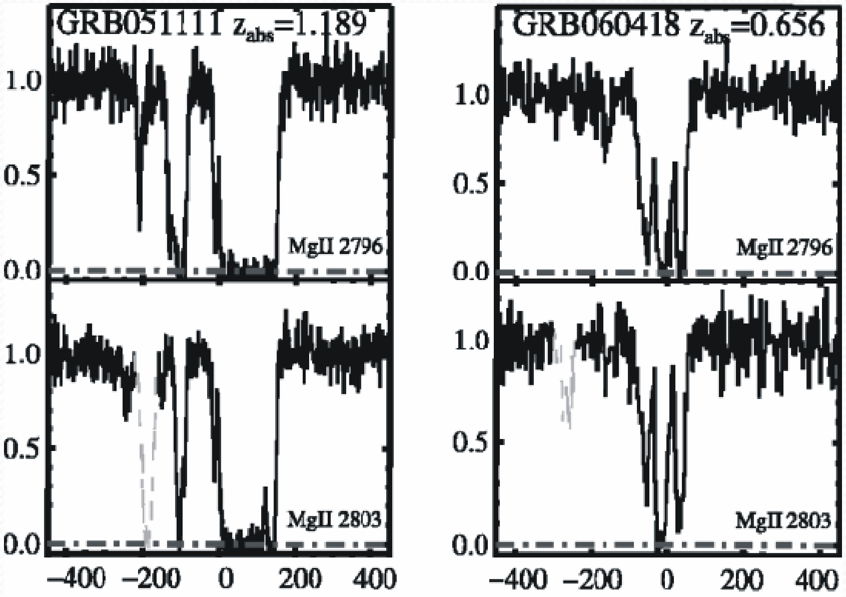


Fig. 4: Velocity profiles of the MgII absorbers identified along the sight lines for GRB051111 and GRB060418 (Sudilovsky, et al., 2007).

The advent of Gamma-ray burst (GRB) exploration in the last 10 years has changed our view of the universe. These highly energetic events have been found over a very large interval of redshifts, from the local to z = 6.3 (Kawai et al. 2006). They are so bright that when one of these events occurs, the most remote structures can be temporarily “illuminated” and studied in unprecedented detail.

Thanks for your attention!