THERMAL EFFECTS DUE TO GAMMA-RAY HEATING OF CIRCUMSTELLAR ENVIRONMENT IN GRBs

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Physics of Neutron Stars – 2008, St. Petersburg, June 24-27, 2008

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1.Motivation.

Some GRBs show us features which can arise from the gamma-ray heating of circumburst structures:

- **X-ray lines (GRB 011211)** [1]
- **optical afterglow lightcurve bumps at 10^3-10^5 sec.**

GRB	L_{peak}, erg/s	T_{peak}, days	T_{90}, days	E_{bump}, erg
000301C	2.93×10^{44}	1.276	0.9	$(1.35\pm0.3)\times10^{49}$
020124	6.77×10^{43}	0.356	0.215	$(3.5\pm1.3)\times10^{50}$
021004	2.11×10^{46}	0.024	0.15	$(1.0\pm0.3)\times10^{50}$
030328	2.84×10^{44}	0.115	4.09 ?	$(7\pm3)\times10^{48}$
030429X	5.47×10^{43}	0.751	0.68	$(1.3\pm0.7)\times10^{49}$
060206	7.54×10^{43}	0.111	0.025	$(1.1\pm0.4)\times10^{49}$

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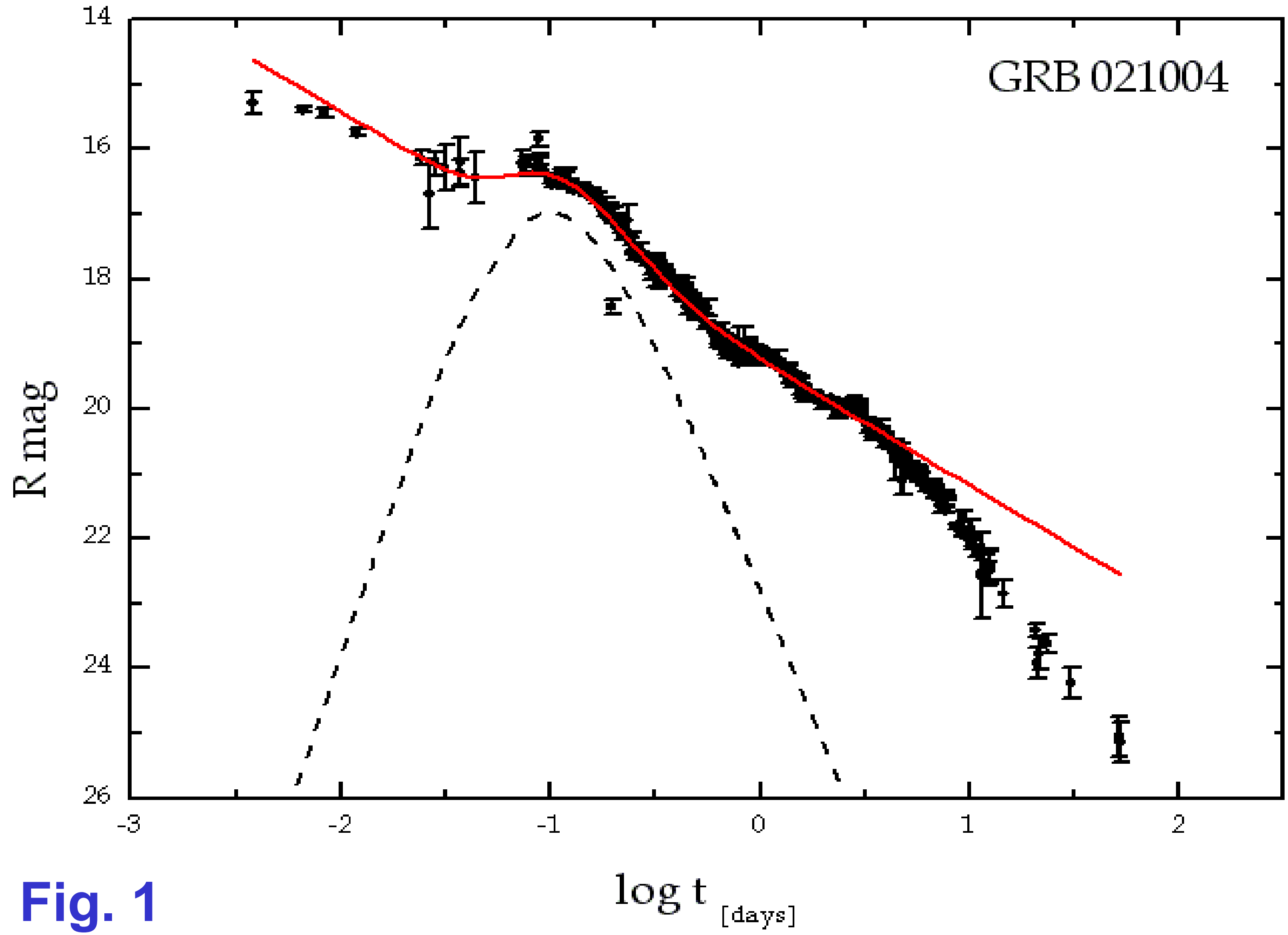

Fig. 1

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2. Our Model. **A relatively dense ($n \sim 10^{11}$ cm^{-3}) shell which was ejected by the GRB progenitor star is illuminated by GRB prompt emission, heated by Compton scattering and then radiates its thermal energy.**

Issues to take into account:

- **Non-stationary photoionization and temperature setting**
- **Geometry, hydrodinamics and spectral evolution**
- **Optical depth $\sim 10^{-1}$**

Accurate numerical calculations required, but some estimations can be made …

Assuming the ISM cooling function to be of order 10^{-21} erg·cm^3·s^{-1} we can estimate the radiating volume:

$$V \approx \pi\theta^2 R^2 h \approx 10^{44} \cdot n_{11}^{-2}\ cm^3$$

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3. Estimations. Using the characteristic rates per electron of plasma heating and cooling due to Compton scattering [2] one can obtain the temperature of heated electrons. For the typical rest frame GRB parameters (E_{iso}~10^{53}, L_{iso}~10^{53} [3], cut-off spectrum with E_{peak}=500 keV and power index α=-0.9) this will give T_e≈60keV which will relax to T≈30eV or $3 \cdot 10^5$K at the time scale of 10^2-10^3 sec due to collisions between electrons and atoms/ions.

We applied the STELLA [4] multi-group radiation hydro-code to calculate optical lightcurves of the heated shell emission. It is seen (Fig.2) that within about a day after heating stop the shell luminosity is sufficient to cause an optical rebrightening.

Now we modify the STELLA code to be able to represent correctly the rising stages of such flashes.

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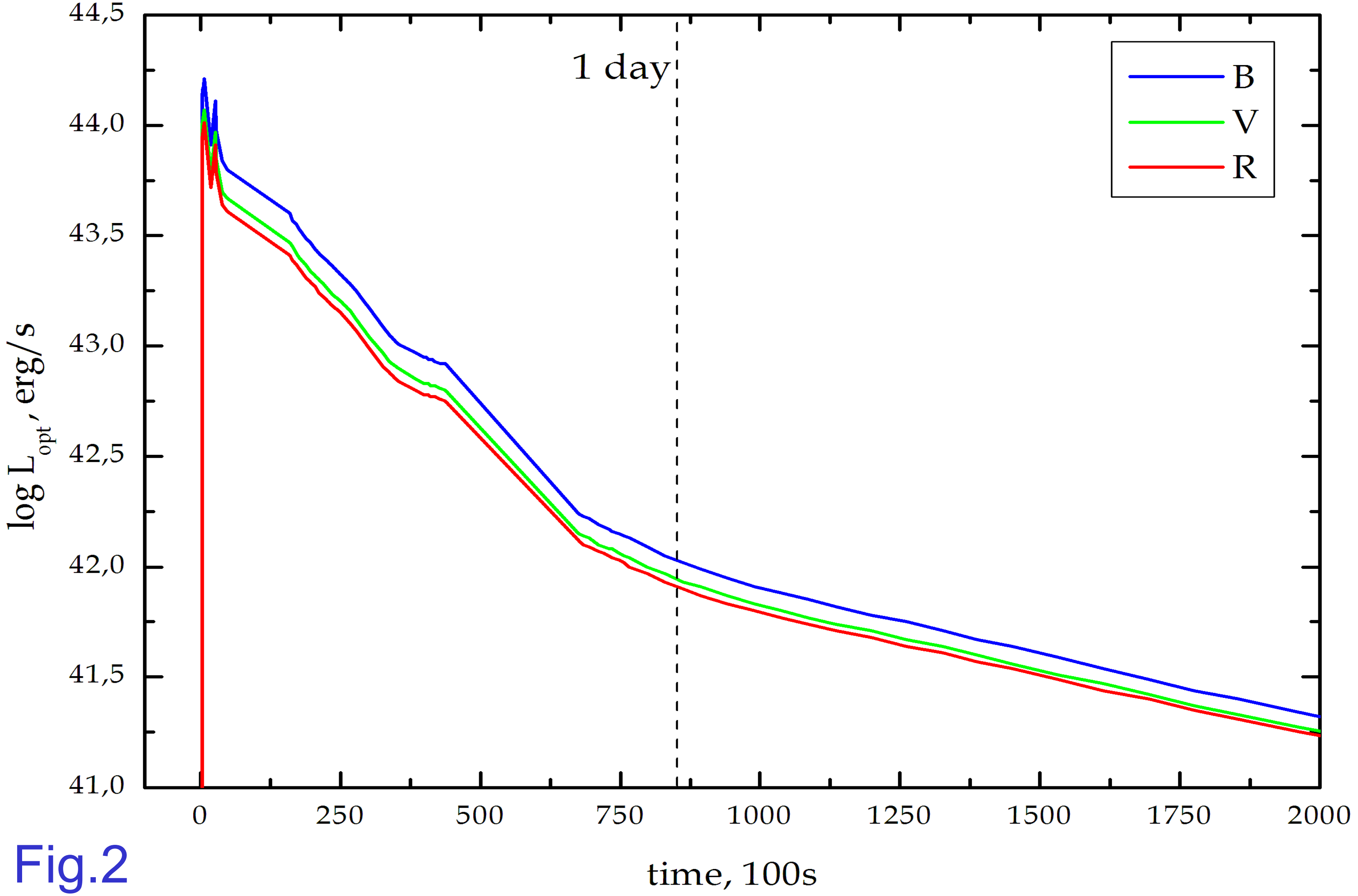

Fig.2

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4. Summary.

We show that thermal effects in some cases may be responsible for the irregularities appearing in GRB optical afterglow light curves.

The problem applies not only to GRBs but also to a wide range of phenomena where interaction between radiation and matter can not be easily computed in some simplifying approximation.

We try to solve this problem.

References:

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[3] D.A. Badjin, G.M. Beskin, G. Greco, 2008 in press

[4] S.I. Blinnikov et. al., *ApJ,* **496** (1998) 454