Subphotospheric heating in GRBs: analysis and modeling of Fermi bursts

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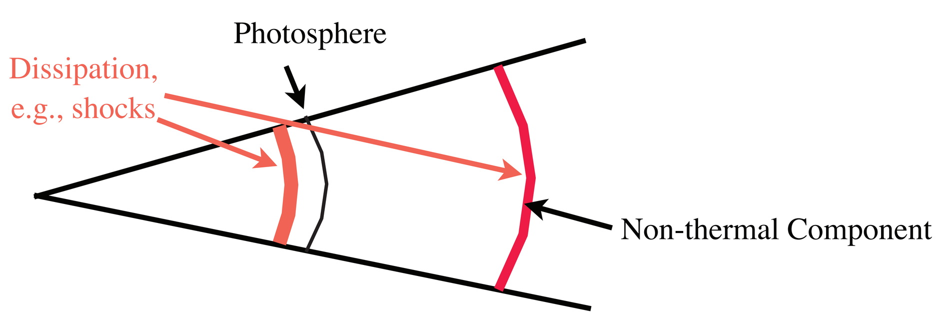
Summary: We analyze strong Fermi bursts and show that subphotospheric dissipation plays an important role in the spectrum formation. We further discuss numerical models of the dissipation and relate these to the observed spectra.

The emission from a GRB photosphere can give rise to a variety of spectral shapes. The spectrum can have the shape of a Planck function or be broadened, resembling a typical Band function. The shape mainly depends on the strength and location of the dissipation in the jet, the ratio of the energy densities of thermal photons and of the electrons at the dissipation site, as well as on the strength of the magnetic field. We analyze strong Fermi bursts showing that subphotospheric dissipation can explain the spectra and spectral evolution. We further discuss numerical models of the dissipation and relate these to the observed spectra.

Subphotospheric dissipation

In the fireball model of gamma-ray bursts a strong photospheric component should be present [1] [2] [3].



- Shocks are expected to occur in the outflow, leading to dissipation of the kinetic energy
- Shocks occurring above the photosphere give rise to a non-thermal component in the spectrum
- Shocks occurring below the photosphere give rise to a thermal component

Numerical modeling

- Initially the thermal emission takes the form of a Planck function
- When the kinetic energy is dissipated the interaction between the photons and the electrons modifies the spectrum
- Due to the non-linearity of the problem detailed numerical calculations are needed
- We solve the kinetic equations self-consistently, taking into account synchrotron emission, SSA, Compton and inverse Compton scattering, pair production/annihilation and electromagnetic cascades. [4]
- A fraction ε_d of the kinetic energy is assumed to be dissipated - part goes to acceleration of the electrons, part to magnetic field generation

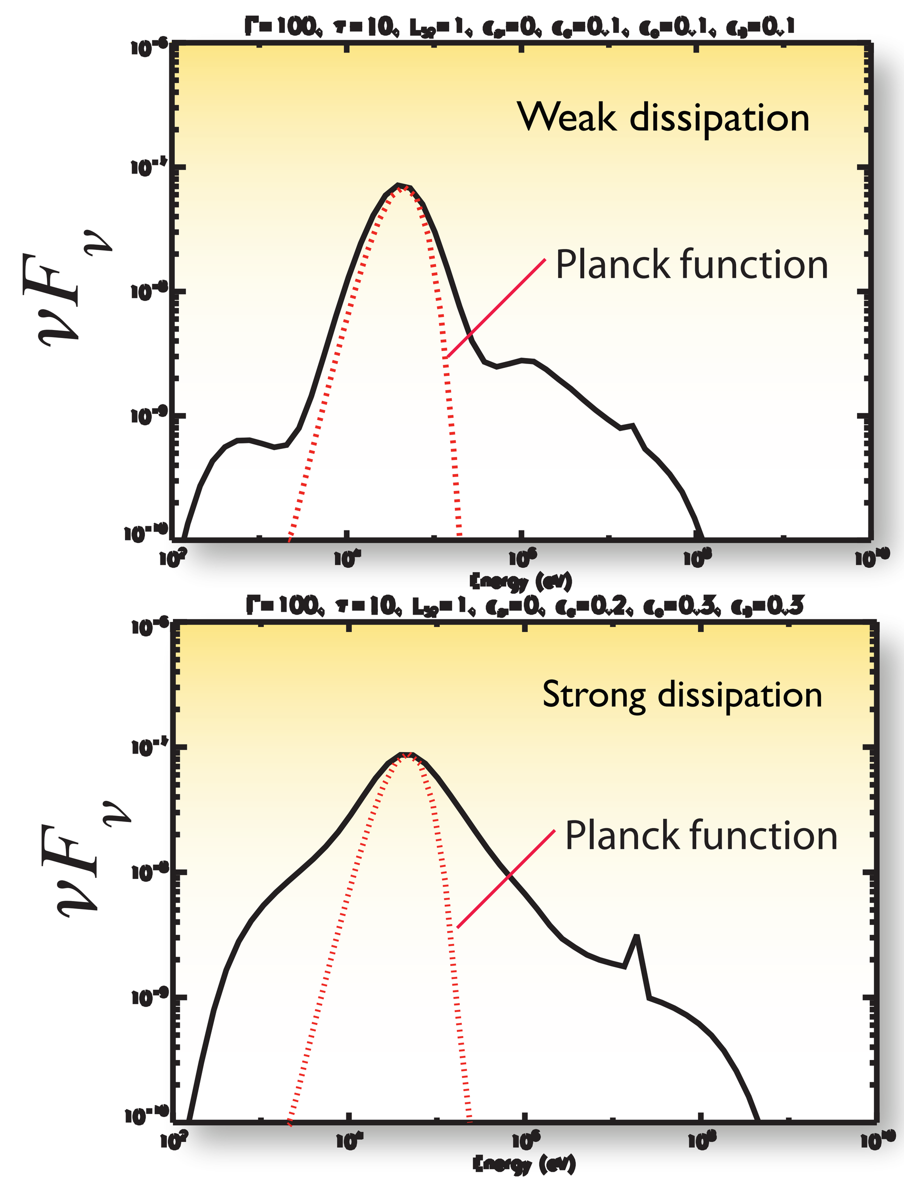


Figure 1 : Weak (top) and strong (bottom) dissipation gives Planck-like and Band-like spectrum.

GRB 090902b

- GRB090902b is one of the strongest bursts detected by Fermi
- Emission above 8 keV was detected for 25 s
- The spectral characteristics change after 12.5 s [5].
- A narrow photospheric component is present during epoch 1 [6].
- Later this broadens and is well fit by a typical Band function [5].
- This can be explained by subphotospheric dissipation, with a change in the location or characteristics of the dissipation leading to a broadening of the spectrum.

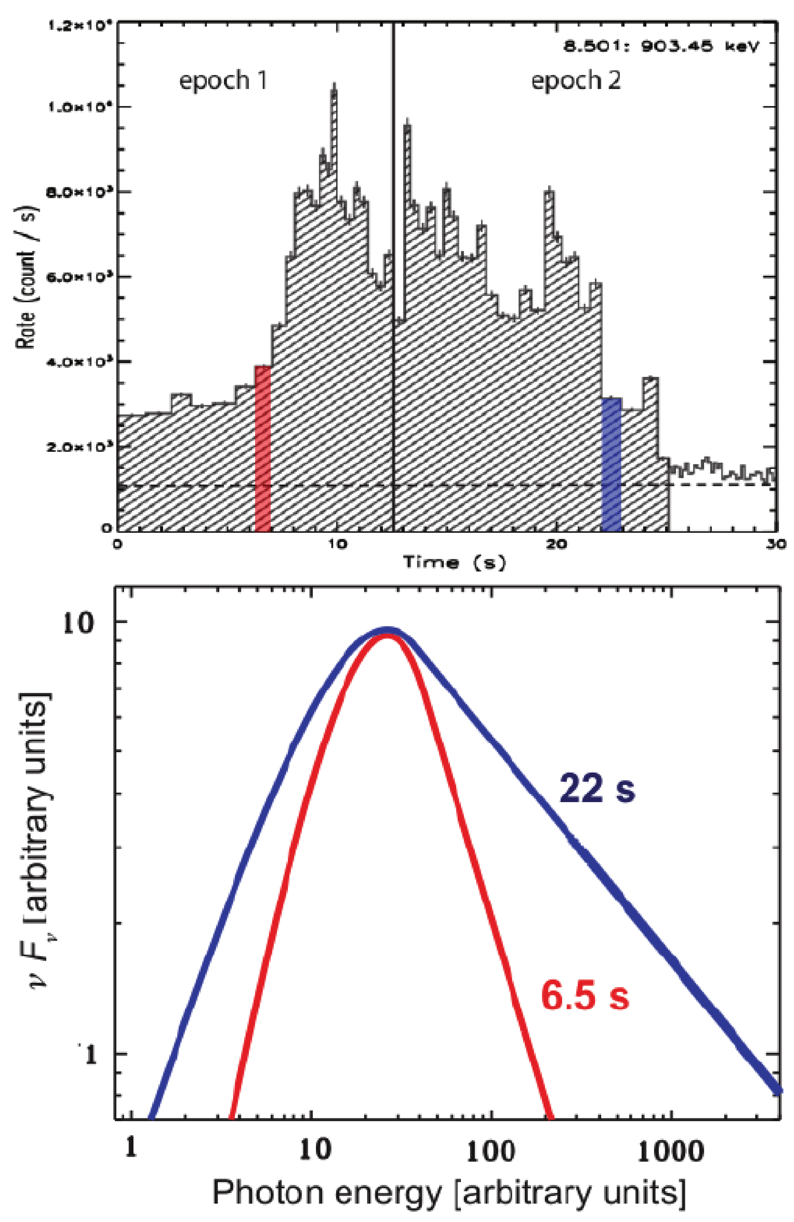


Figure 2 : Lightcurve (top) and peak aligned Band functions illustrating the broadest and narrowest spectra (bottom).

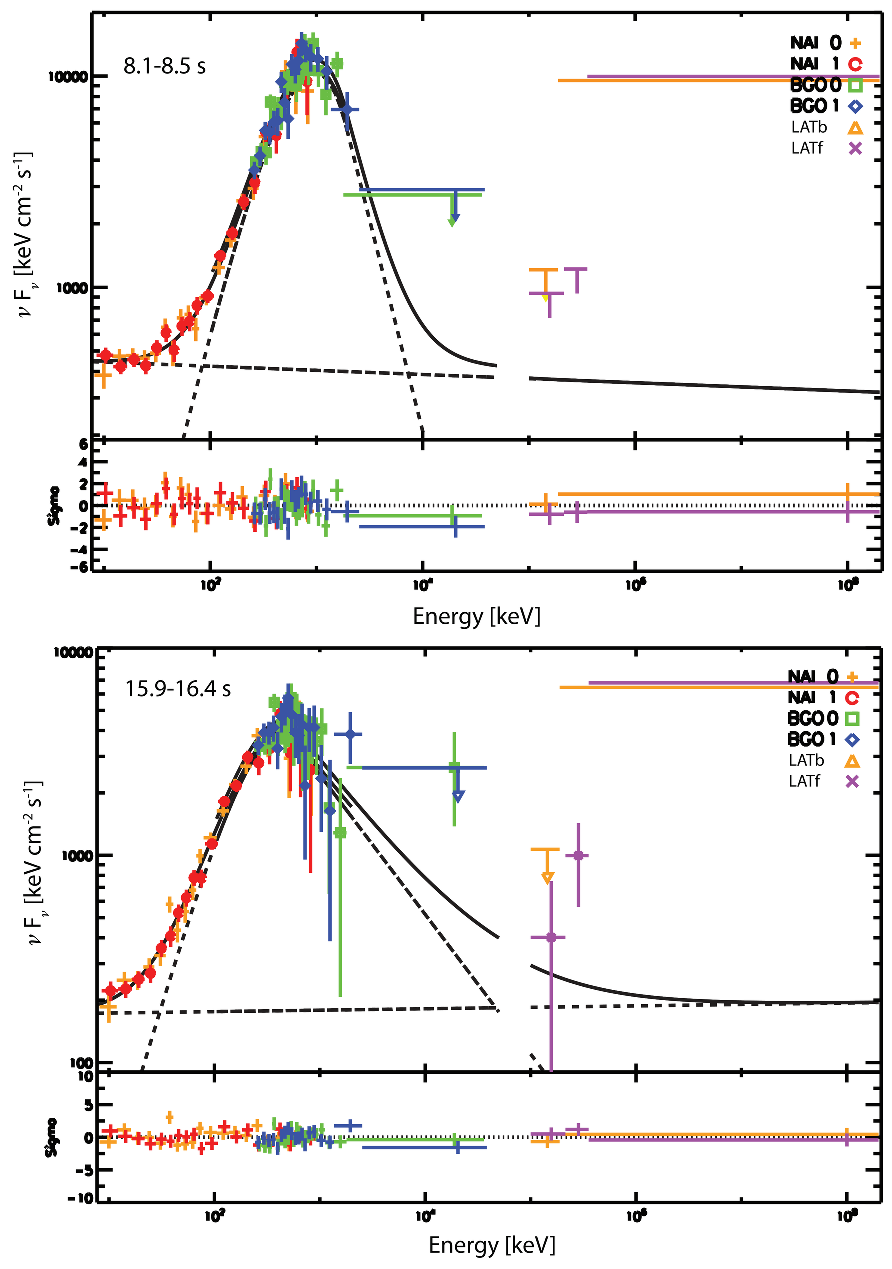


Figure 3: Time resolved spectra from epoch 1 and epoch 2.

Conclusions

- The observed spectrum from a GRB photosphere can take on a variety of shapes. A thermal component does therefore not need to be a Planck function, but can in fact mimic a Band function $\leq$ 100 MeV
- Photospheric emission is thus probably common in GRBs.

References

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