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Epilogue

6.1 Concluding Remarks

In this thesis, we have presented (i) a consistent modelling platform for hard electron energy spectra and (ii) the low frequency campaign of GRB030329 afterglow and the interpretation of its evolution.

Hard electron energy spectra:

We have presented the modifications required in the standard theoretical model of GRB afterglows in order to accommodate hard electron energy spectra. We parametrised the upper cutoff lorentz factor γ_i of the $p < 2$ electron energy distribution to be a function of the bulk lorentz factor Γ of the shock ($\gamma_i = \xi\Gamma^q$). The flux decay depends on the evolution of this upper cutoff. In general, for an optically thin fireball, the decay is faster for a larger value of q . The expressions describing the decay recover the familiar form in the standard model when the value of q equals unity. The contribution from Synchrotron self-compton emission is rather small at energies below soft- γ -ray regime, for typical parameters. We model three candidate afterglows (GRB010222, GRB020813 and GRB041006) showing hard electron energy spectrum, which have well sampled multi-band lightcurves. The derived kinetic energy was an order of magnitude lower than the energy in radiation for all these afterglows. They also had rela-

tively low cooling frequency.

An alternative explanation for the shallow lightcurve is a jet viewed at an angle from the axis. Knowledge of the intrinsic afterglow spectral index, which is often impossible to estimate due to absorption and reddening by the host galaxy, is the only way to distinguish between the two. Future observations in the ultra-violet regime will be of help in this.

GRB030329:

Radio afterglows are seldom monitored in detail. We present the radio observations of the afterglow of GRB030329 upto two years since the explosion, carried out by the Giant Meter-wave Radio Telescope, Pune. The afterglow is followed up from ultra-relativistic to non-relativistic regime. We have seen the fireball becoming optically thin to 1280 MHz at around ~ 120 days. We modelled the multiband afterglow evolution following the double jet model . We also examined the possibility that instead of there being two jets, a refreshment of the initial outburst by a later injection of energy may explain the observed behaviour. We find that the two models can not be distinguished using the available data. (It has to be mentioned that since the double jet model faces difficulty in explaining the sharp rise seen at the deceleration epoch of the second jet, the refreshed jet model can be a better alternative)

6.2 Future Directions

We have assumed the fireball as a point source moving towards the observer, in all the modelling done in this thesis. The effects due to arrival of radiation from angles away from the jet axis is not included. This could make modifications in finer detail of the spectrum, especially at the turnovers. This refinement will help in inferring the location of the break frequencies more accurately, and hence in better estimation of the physical parameters.

Conclusive evidence of the presence of a hard electron energy spectrum can only be obtained by extensive modelling of afterglows which show shallow decay. At present, not many afterglows have well sampled data in all wavebands, however, the number of such instances are increasing. The cause of the shallow

x-ray decay index observed in some of the *Swift* afterglows could be an underlying hard electron energy spectrum, and they need to be investigated in detail. After collecting the physical parameters of a good sample of afterglows, a statistical study can be done to see whether the presence of hard electron energy spectrum correlates with any other feature (like early jet break, low cooling frequency or low kinetic energy content in the fireball)

Only in one of the modelled afterglows we find evidence for the presence of γ_i within the observed bands. The corresponding spectral break ν_i could in other cases, reside at energies higher than observed. The upcoming satellites like *GLAST* or *ASTROSAT* which are sensitive to hard x-rays and γ rays will hopefully be able to locate ν_i precisely. Such an observation will be exciting since it will provide a key to the process which terminates the acceleration mechanism in relativistic shocks.

The monitoring of the radio afterglow will certainly provide important insights into the late time dynamics of the fireball. The radio afterglows have in the past displayed deviations from standard fireball model predictions, which has not yet been properly explained. We hope the observations of GRB030329 afterglow will provide more information about the ‘radio flattening’ and the possible causes of it.

Both the models we used in explaining the spectral evolution of GRB030329 afterglow had difficulties in explaining the millimeter flux before one day, even before the re-energisation event. There are also slight discrepancies between the observed and predicted fluxes around that time. The emission from the reverse shock also in the calculation needs to be included to see whether the flux evolution can be reproduced better.

The ability of the refreshed jet model to explain the steep rise seen in the optical lightcurve of the afterglow around 1.5 days has to be investigated. This requires detailed modelling of the jet and the episode of refreshment considering the mixing of the hot gas and the fresh ejecta.

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