Gamma-ray burst afterglows from jet simulation to light curve
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CHAPTER 6

Epilogue

A large part of the research in this thesis has been devoted to the development and presentation of a new method to calculate synchrotron radiation from arbitrary relativistic flows. This, however, is only the start. Now that the code has matured into an approach capable of dealing with two-dimensional simulations and details of synchrotron radiation like self-absorption and cooling, we can use it to resolve theoretical issues surrounding the theory of GRB afterglows and apply it directly to broadband afterglow data (either through detailed case studies or indirectly by using it to fine-tune heuristic tools for fitting models to the data). A number of projects have been initiated in collaboration with various groups and we very briefly mention some of these.

The heuristic description provided in chapter 2 is currently being applied to X-ray data

![Figure 6.1](image)

**Figure 6.1**: The distribution of electron index $p$ (left) and environment density parameter $k$ (right) from 191 Swift afterglow X-ray hardness ratio fits. Figure from Evans et al. (2010).
Figure 6.2: A comoving density plot for a two-shell scenario, where a second shell is catching up with the forward blast wave that has a Blandford-McKee profile.

by the Leicester University X-ray group. They have applied the scaling laws to a set of 245 X-ray hard and soft-band light curves from the Swift-XRT light curve repository, finding 191 good fits (they are currently investigating the other 62 bursts to determine whether the poor fit is because the model cannot explain the data, or because the annealing did not start at a sufficiently high temperature to guarantee the global best-fit was found). An extension to the heuristic description was made to allow for prolonged energy injection from the central engine. Figure 6.1 shows the resulting distributions for $p$ and $k$.

In Amsterdam, we are working on a follow-up study to chapter 4 on trans-relativistic blast waves. Although simulations with different physical settings were discussed in that chapter, the results had not yet been quantitatively generalized to arbitrary values for the explosion energy, circumburst density profile and shock acceleration parameters. A comprehensive heuristic description analogous to that in chapter 2, now including the non-relativistic regime and the transition between relativistic and non-relativistic is being prepared by Kostantinos Leventis.

Chapter 3 explored and rejected a possible hypothesis on the origin of late time variability in afterglow light curves. What does cause late time variability is still an open question. To test a different scenario, where variability is explained through interaction of ejected pulses of cold matter from the central engine, Alkiviadis Vlasis of the Center for Plasma- Astrophysics of the K.U. Leuven is performing simulations combining AMRVAC again with the radiation
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code (see fig. 6.2).

Chapter 5 shows only the first results of our study of jet decollimation. We are investigating in more detail things like the differences between X-ray and optical, and with taking the meeting point of the pre- and post-break light curve asymptotes as the jet break time, we will quantify the consequences of the chromaticity of the jet break for model fits to data. Part of this work is being done in collaboration with Andrew MacFadyen and Weiqun Zhang from New York University, which allows for a cross-check and detailed comparison of the dynamics when calculated by two different hydrodynamics simulation codes (AMRVAC vs. RAM, see also Zhang & MacFadyen 2006). In numerical work it is very important to test one’s results by independent means, and this should be done not just for the dynamics but for the radiation code as well. Petar Mimica and collaborators at the university of Valencia have developed a radiation code that is similar to ours, but integrated with a dynamics code which does not allow for adaptive-mesh refinement but where the entire grid follows the blast wave instead. We have set up a number of test problems to directly compare the output from our codes.