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Gamma-ray Bursts'

Physical Properties from Statistical Analyses

Theses

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1 Background and research goals

In this thesis I present my work carried out in the field of gamma-ray bursts (GRBs). GRBs are the most luminous events known in the Universe. A typical GRB emits the bulk of its energy in gamma-rays lasting between 10^{-2} and 10^{3} seconds. This prompt phase is followed by quickly fading emission at longer wavelengths. GRBs involve jetted emission from collision of relativistic (speeds close to the speed of light) shells. The shells are emitted from the collapse of supermassive stars or the merger of compact binaries. From the variations occurring in the lightcurve we can infer the characteristic size of the emitting object to be of the order of thousand kilometers. The non-thermal nature of the spectrum points to synchrotron and inverse Compton as the main emission processes.

The astrophysics of gamma-ray bursts has a number of open questions such as the behaviour of the X-ray afterglow, the number of physically different species of GRBs or the prospect of applying GRBs for cosmological studies. Throughout my thesis I have addressed these questions and carried out research in these directions.

2 Applied methods

Earth's atmosphere is opaque to gamma-radiation, thus the observation of GRBs is carried out by spaceborne observatories. Besides their spectral and temporal behaviour, GRBs are characterized by their position and redshift. Because they are at cosmological distances, one line of research consists of relating observed properties to intrinsic ones, making GRBs possible probes of cosmology. I

have carried out the k-correction together with an error calculating procedure which accounts for asymmetric errors in the spectral parameters. I have intensively used the Kolmogorov-Smirnov test to compare distributions: first the X-ray luminosity, the isotropic-equivalent energy and X-ray hydrogen column density distribution for different classes of bursts, then the peak flux distributions of classes. I used parametric and model based classification methods to infer the group structure of Swift GRBs. Finally, I carried out Monte Carlo simulations of the celestial distribution of GRBs, testing the significance of the anisotropy for three classes of bursts.

3 Theses

1. I have analyzed the X-ray afterglows of gamma-ray bursts. I used the Bayes-blocks algorithm to delimit the lightcurve of the prompt phase into physically meaningful parts [4]. To account for the spectral evolution of the prompt phase of the burst, I have fitted spectra for each interval. I transformed X-ray counts into flux also by fitting spectra and accounting for spectral evolution. I concluded that the X-ray afterglow and the prompt gamma-ray phase fit together [5].

2. GRB 080913 is one of the farthest gamma-ray bursts at redshift $z = 6.7$. Based on its measured duration, GRB 080913 belongs to the long class. According to its duration, transformed to the frame comoving with the burst, this is a short GRB. I developed a method to account for the asymmetric errors in the spectral parameters for the cosmological k-correction. I have performed the k-correction on this burst and this gave the basis for the restrictions of the physical pa-

rameters of the central engine [3]. In addition I have calculated the physical properties of a high redshift ($z = 4.7$) quasar after it produced a large flare [8].

3. I created an extended database of the Swift BAT GRBs which has in its current form measurements of 408 GRBs [2].

4. Besides the duration and hardness of the bursts, I also investigated observational properties which discriminate the third population from the short and the long classes. I have analyzed the distribution of the X-ray afterglow luminosities at early and late times. I found that intermediate and long duration bursts differ significantly [1].

5. I found that the isotropic energy distribution of the intermediate group differs significantly from the same distribution of the long group. At the same time the hydrogen column density distribution for the intermediate does not show a significant difference when compared to the distribution of the long population [1].

6. I have investigated the group structure of GRBs with three different grouping methods. On the duration-hardness plane I have confirmed previous results of three distinct GRB groups with a model based and two model independent classification methods [7].

7. Based on the classification method presented here, I found that the peak flux distribution of the third group differs significantly from the peak flux distribution of the short and long classes [7].

8. I have shown that the distribution of long GRBs with measured redshift has a significantly different peak flux distribution compared to long GRBs without measured redshifts [7].

9. I found there is a strong overlap between the third group of GRBs and the previously known class of GRBs, the X-ray flashes. Assuming they are the same events, I have given a new definition for this class of events [7].

10. There is a weak anisotropy in the sky distribution of the third group. I have developed a method to generate random catalogs of GRBs which follow the observing program of the Swift BAT instrument. Using this method, I have tested the anisotropy of the different GRB groups on the sky with coordinate-system independent tests. I found the short and long population is distributed isotropically and the third population shows a weak anisotropy, which is not significant [6].

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