# Insight on GRB physics from a novel data driven method for systematic analysis of X-ray light-curves.


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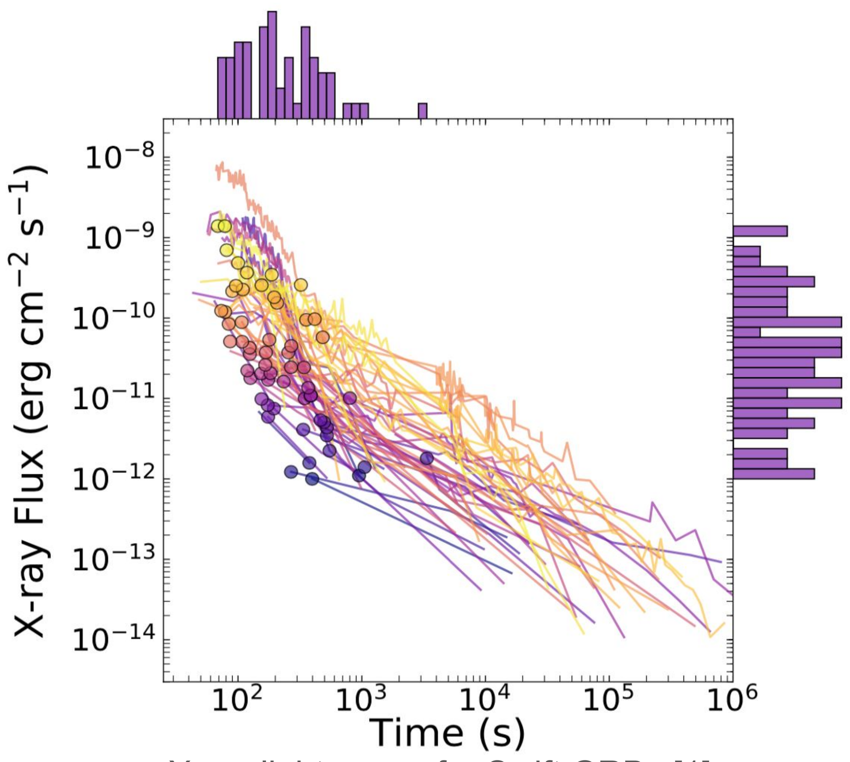
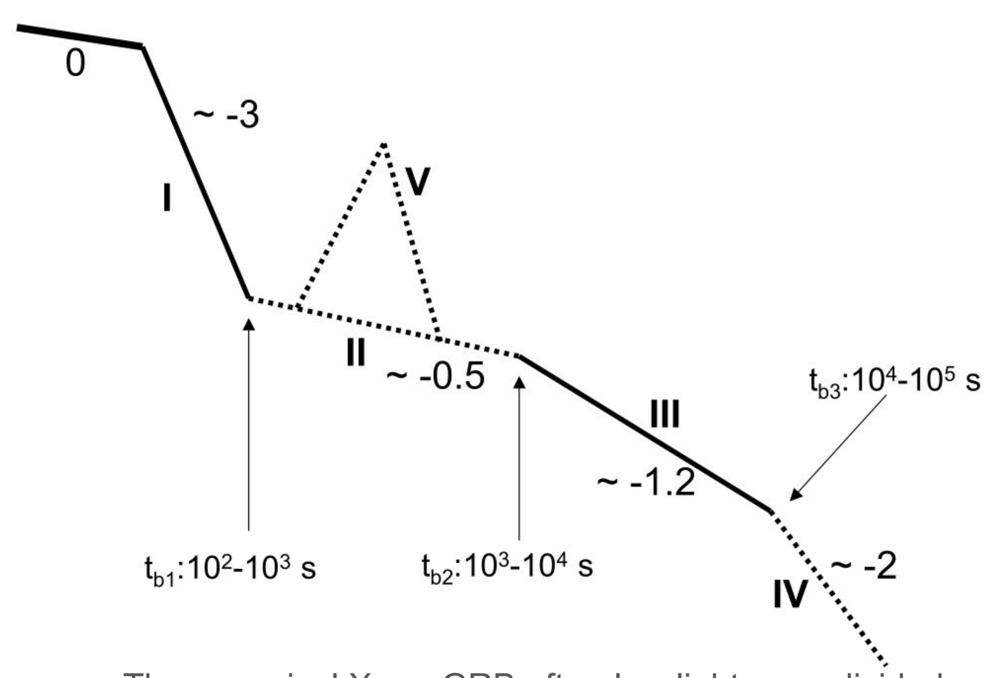
Gamma-ray bursts (GRBs) display a rich variety of X-ray lightcurve behaviors, including flares and plateau phases, whose physical origins remain debated. Traditional analyses rely on small GRB samples and diverse modeling approaches, leading to results that may be difficult to generalize.

To address this, we present a **data-driven**, **model-independent method** for systematically analyzing Swift XRT data. This approach enables **consistent feature extraction across a significantly large dataset**, allowing for more robust trend identification in GRB afterglows.




X-ray lightcurves for Swift GRBs [1]

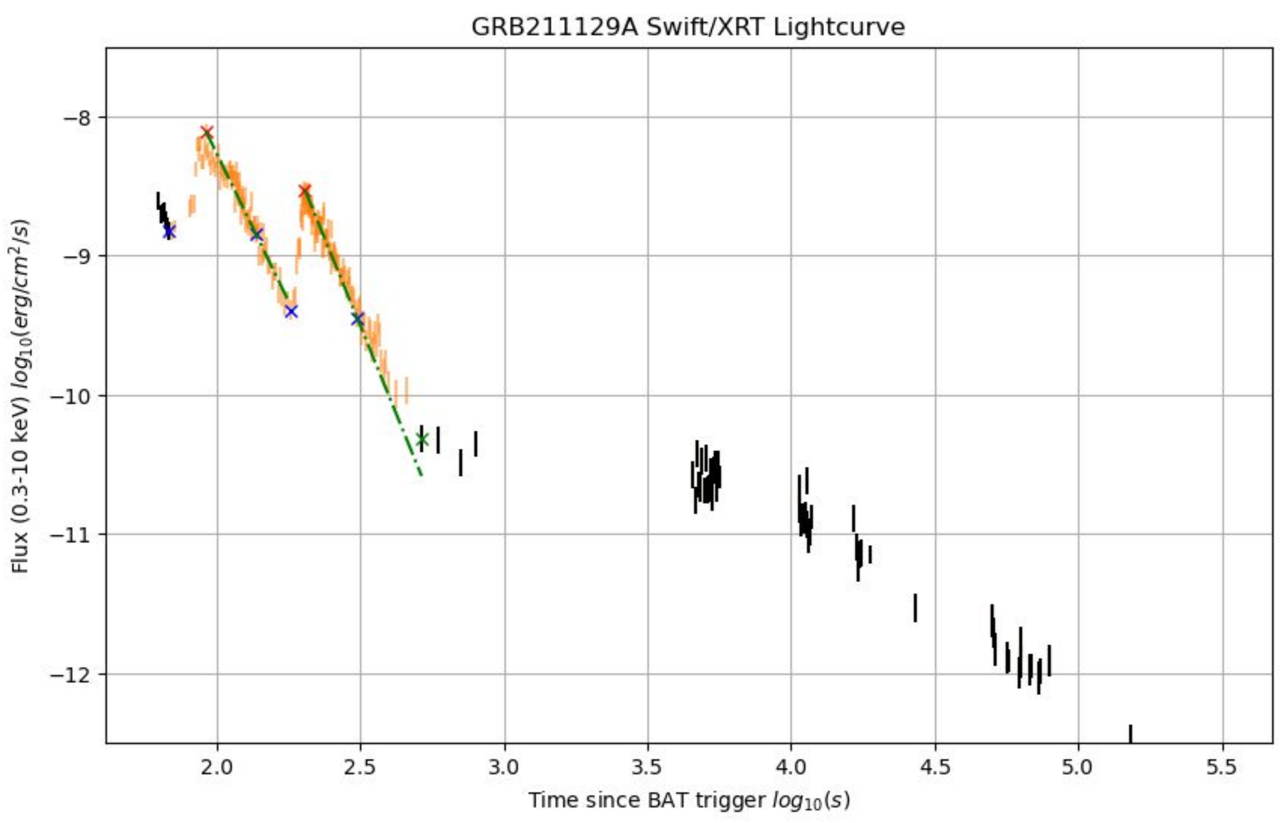



The canonical X-ray GRB afterglow lightcurve divided in 5 phases [2]

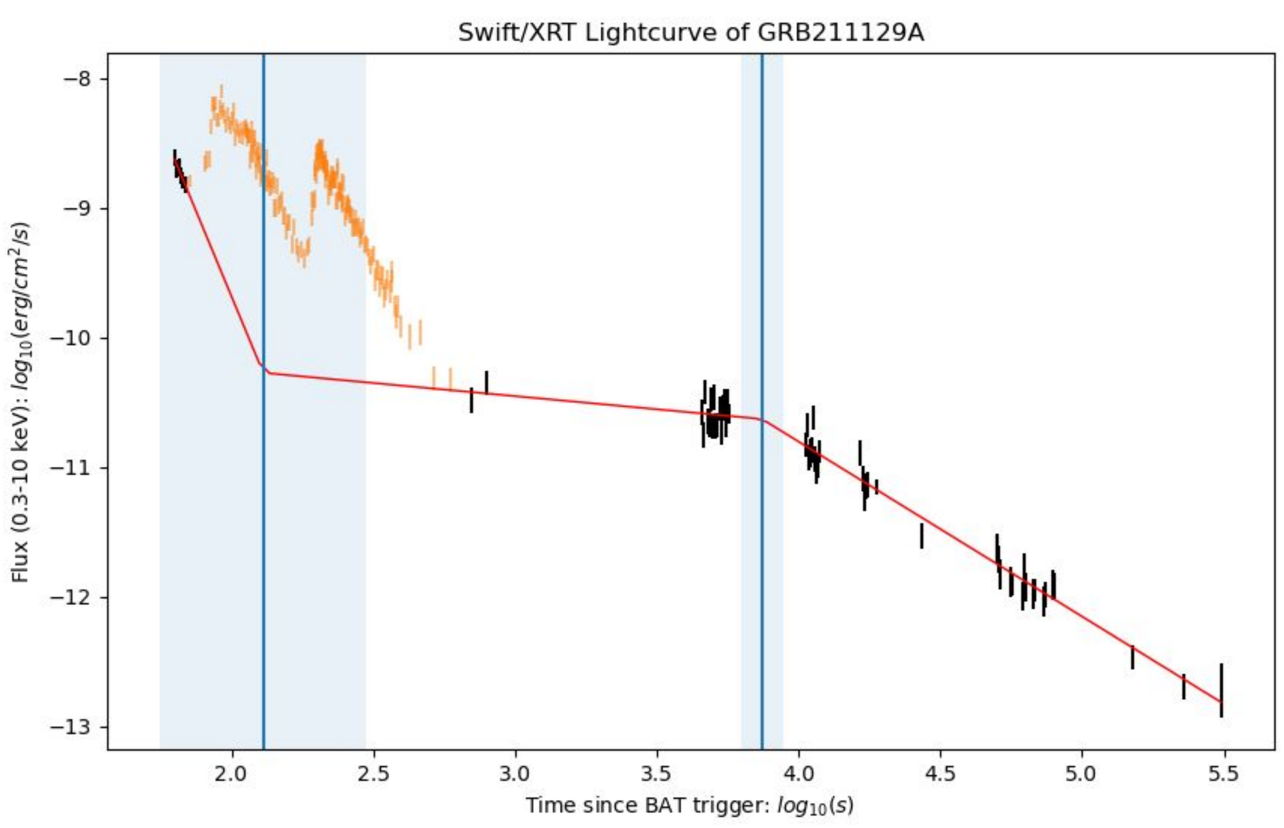
## Automated Analysis Pipeline

We developed an **automated**, **model-independent pipeline** to analyze Swift XRT data, enabling consistent feature extraction from GRB X-ray lightcurves. This approach ensures uniform characterization across a significantly large dataset, improving trend identification and physical interpretation.

1. **Lightcurve Selection:** The pipeline first checks the number of data points. If below a threshold (set by the maximum number of breakpoints for fitting), the lightcurve is rejected.
2. **Log-Log Transformation:** The data is converted to log-log space, allowing the use of linear interpolation techniques instead of direct power-law fitting.
3. **Flare Removal:**
   a. Peaks are identified based on prominence, width, and statistical significance (>3σ in the rising part, with a minimum data fraction).
   b. The tail end of each flare is determined by comparing post-flare points to a reference slope between the peak and an initial parallel point. The flare is considered ended when deviations exceed 5σ.

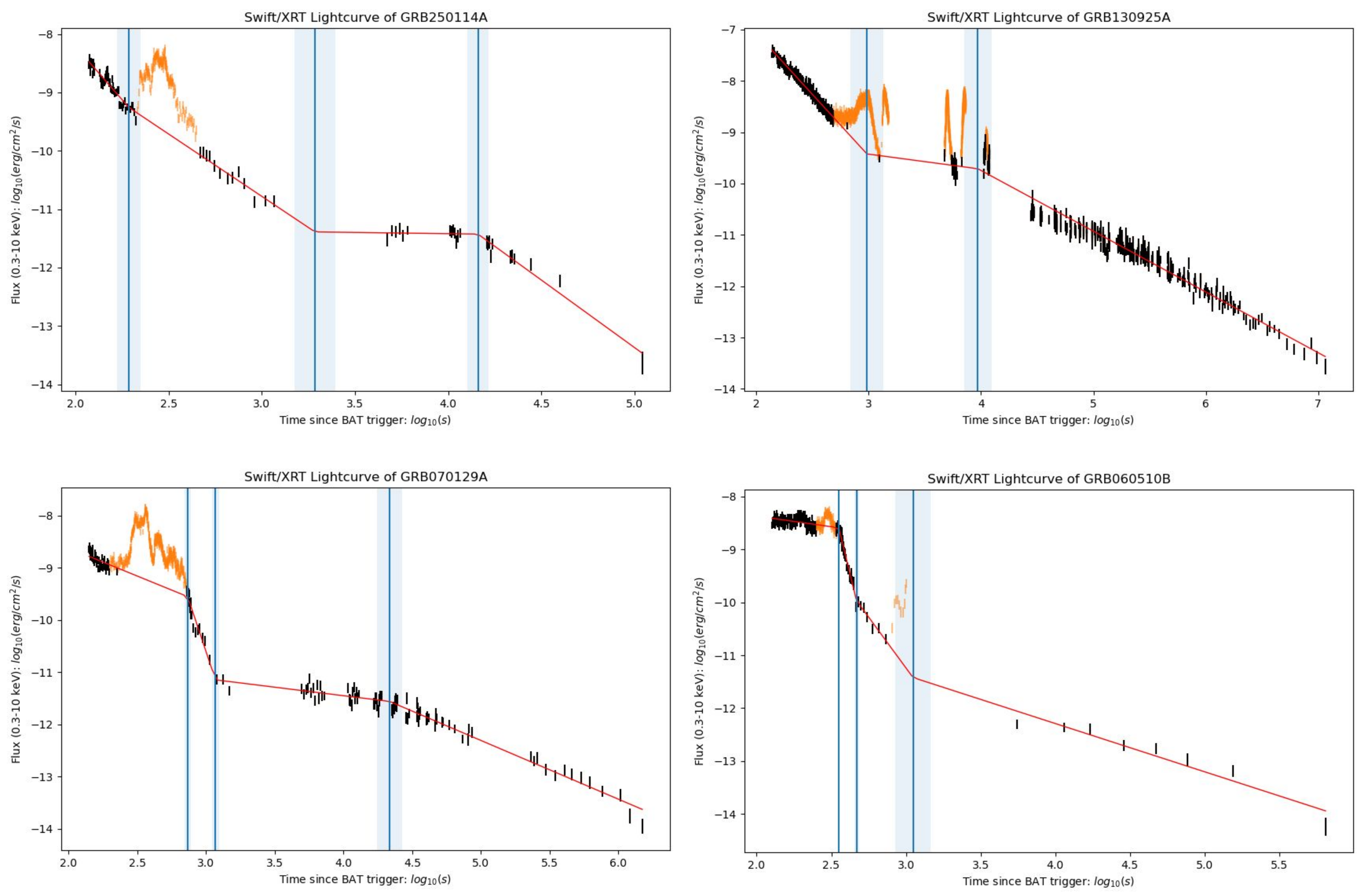



4. **Segmented Regression:** Muggeo's method [3,4] is applied in log-log space to fit the lightcurve with up to five breakpoints [5].
5. **Model Selection:** The Bayesian Information Criterion (BIC) is computed for each fit [4], and the model with the minimum BIC is selected.



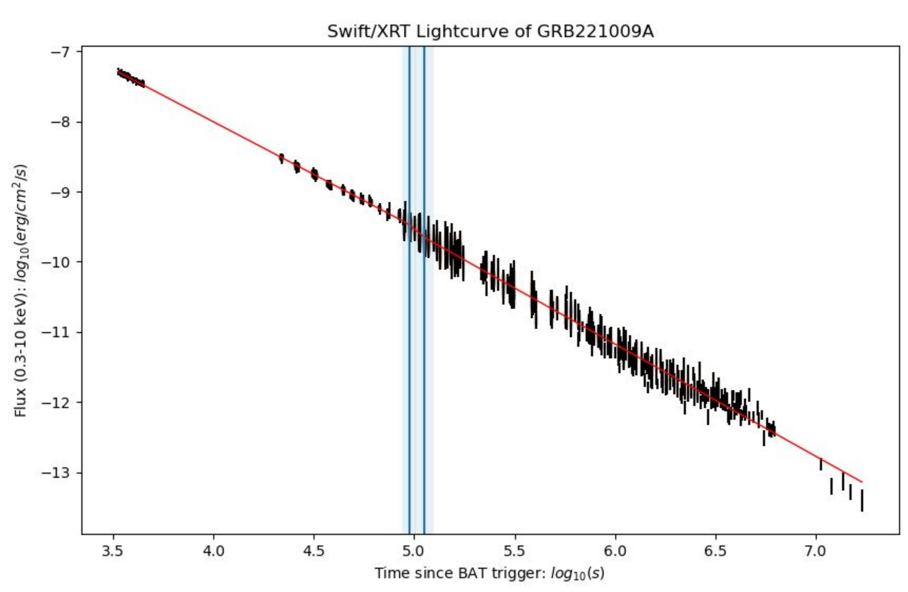

## Results

Below are some examples of flaring GRBs with complicated lightcurves analyses and fitted with this new automatic method.

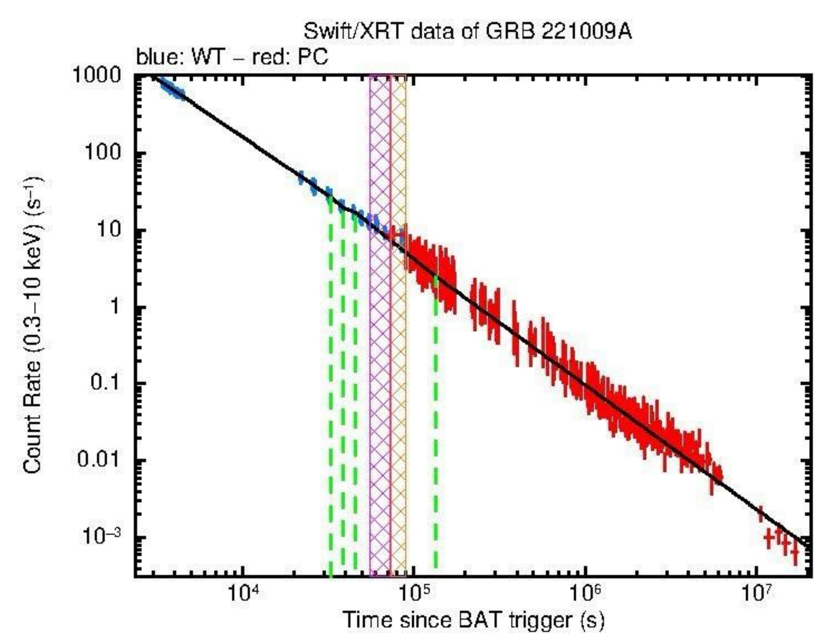



Examples of application of this new method for automatic analysis to some complicated flaring GRB lightcurves.

The following examples showcase the similarities and differences between this system and the Swift automated analysis [5].
The example comparison of GRB 221009A highlights how both methods identify key features such as flares and breakpoints.

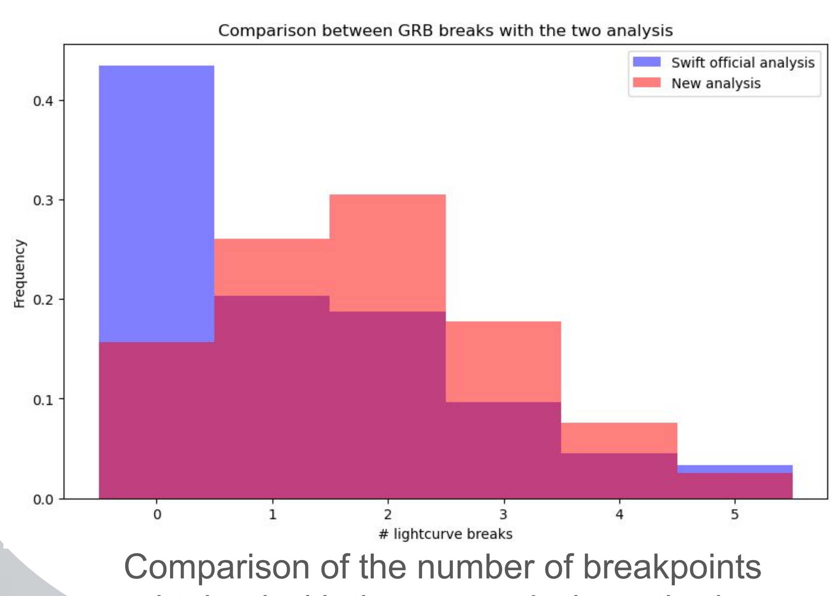



GRB221009A analysis with the new method: no flare and 2 breakpoints identified.

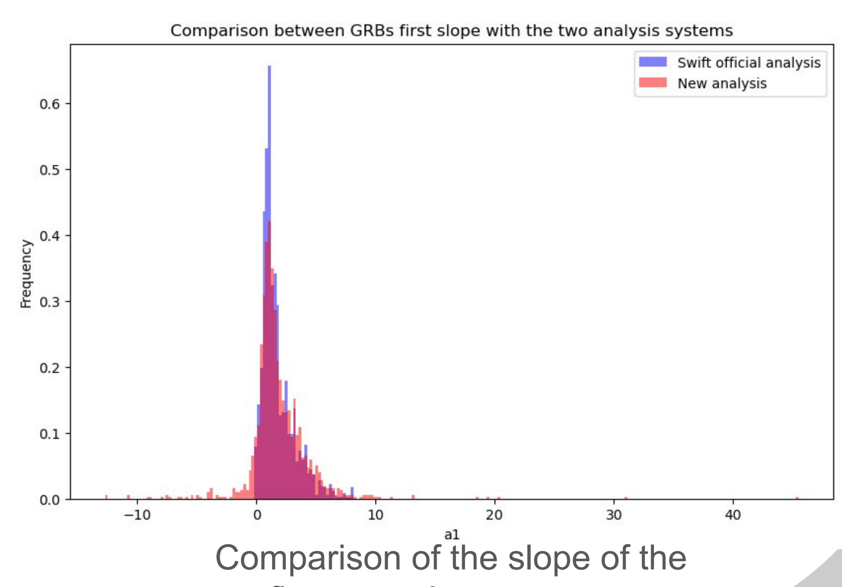



GRB221009A analysis with the Swift method: 2 flares and 4 breakpoints identified.

The analysis is then extended to the full Swift XRT catalog, comparing the distributions of the number of breakpoints and the first slope obtained with each system. These distributions showcase both the differences and similarities in lightcurve characterization between the two approaches.




Comparison of the number of breakpoints obtained with the two analysis methods.




Comparison of the slope of the first powerlaw segment.

### References: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2. Zhang et al., ApJ 2006, DOI: 10.1086/500723
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