The X-Ray Afterglows of Short Gamma-Ray Bursts

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Background

- Gamma-ray bursts (GRBs): powerful bursts of radiation
  - First detected in gamma-ray band, afterglow in longer wavelengths
- Short GRBs: GRBs lasting < 2s from binary neutron star mergers
- X-ray afterglows detected by the *Neil Gehrels Swift Observatory* (*Swift*)
- Light curves of many afterglows follow a typical power law decay, but some are much more unusual
- We identified two types of unusual light curves:
  - Light curves with unusually steep decay
  - Light curves with a plateau
- Looked at their properties (duration [T_{90}], flux, fluence, hardness) to understand what makes these bursts different

Fitting the light curves

- 81 sGRB X-ray afterglow light curves from the *Swift*/XRT catalog (2005-2018)
- Fit light curves with single power-law (SPL) and double power-law (DPL) models using emcee in Python
- Sorted into three groups using χ^2 cutoff:
  - Bursts well fit by SPL
  - Bursts well fit by DPL
  - Bursts not well fit by either
- Of the 81 bursts:
  - 20 well fit by SPL
  - 30 well fit by DPL
  - 14 not well fit by either
  - 17 with too few points to be fit

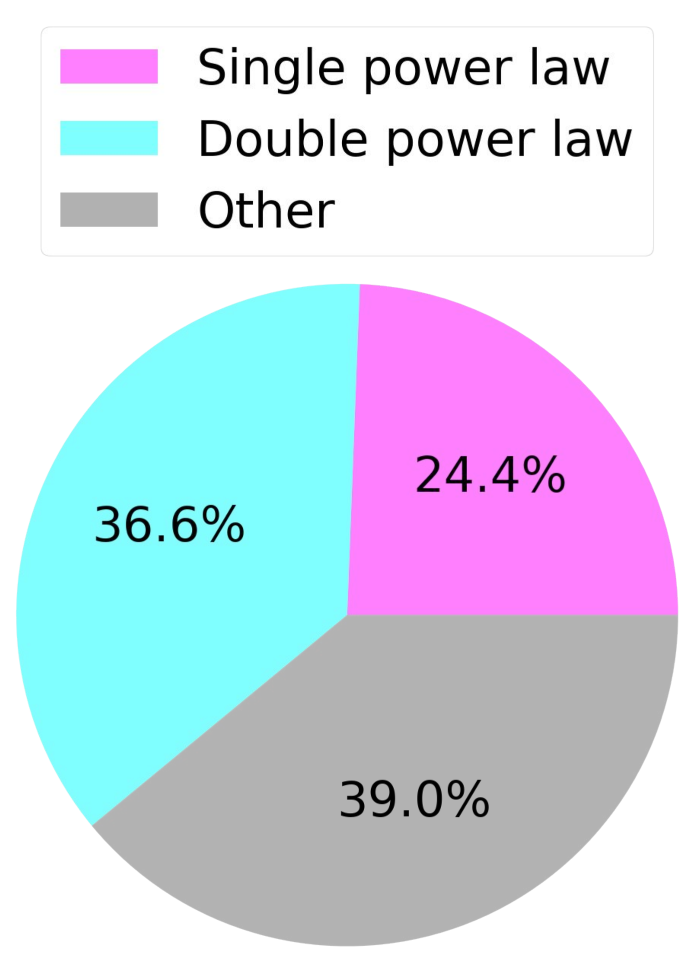


Figure 1: The distribution of bursts well fit by a SPL, bursts well fit by a DPL, and "other". Here, "other" includes both bursts not well fit by either a SPL or DPL as well as bursts with too few points to fit.

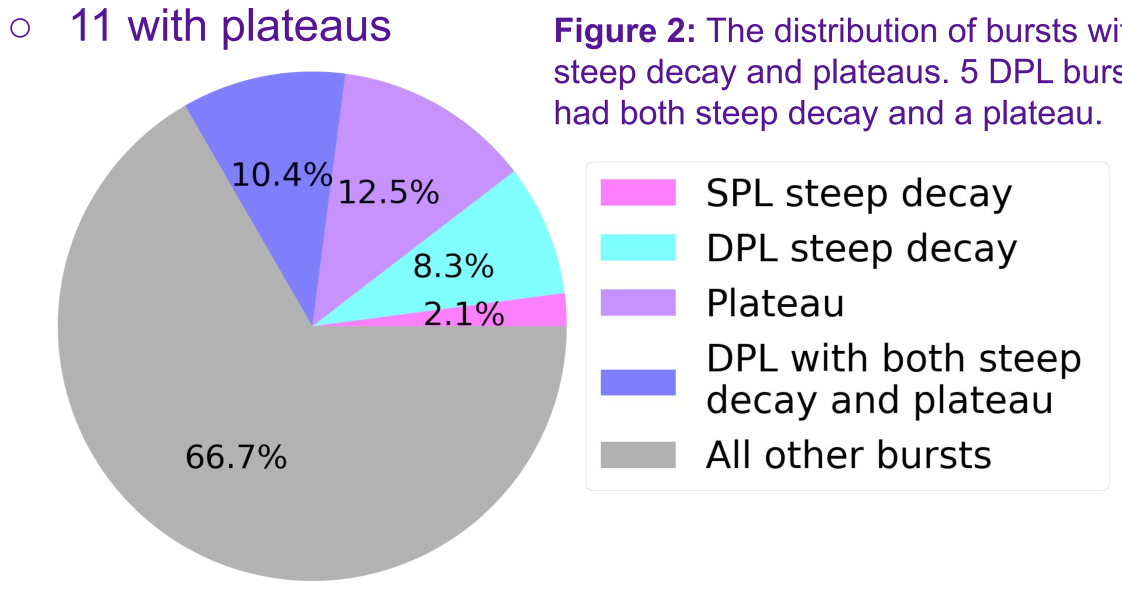
References

Berger, E. 2014, Annu. Rev. Astron. Astrophys., 52, 43-105
D'Avanzo, P. 2015, J. High Energy Phys., 7, 73-80
Evans, P. A. et al. 2007, Astron. Astrophys., 469, 379-385
Evans, P. A. et al. 2009, Mon. Notices Royal Astron. Soc., 397, 1177-1201

Identifying unusual bursts

- Based on the decay index (α), filters were applied to SPL and DPL to identify bursts with unusual light curves
  - Steep decay: α (SPL) or α_2 (DPL) < -2
  - Plateau: DPL with $-0.5 \leq \alpha_1$ or $\alpha_2 \leq 0.5$
- Of the 20 SPL bursts:
  - 1 with steep decay
- Of the 30 DPL bursts:
  - 9 with steep decay
  - 11 with plateaus

Figure 2: The distribution of bursts with steep decay and plateaus. 5 DPL bursts had both steep decay and a plateau.



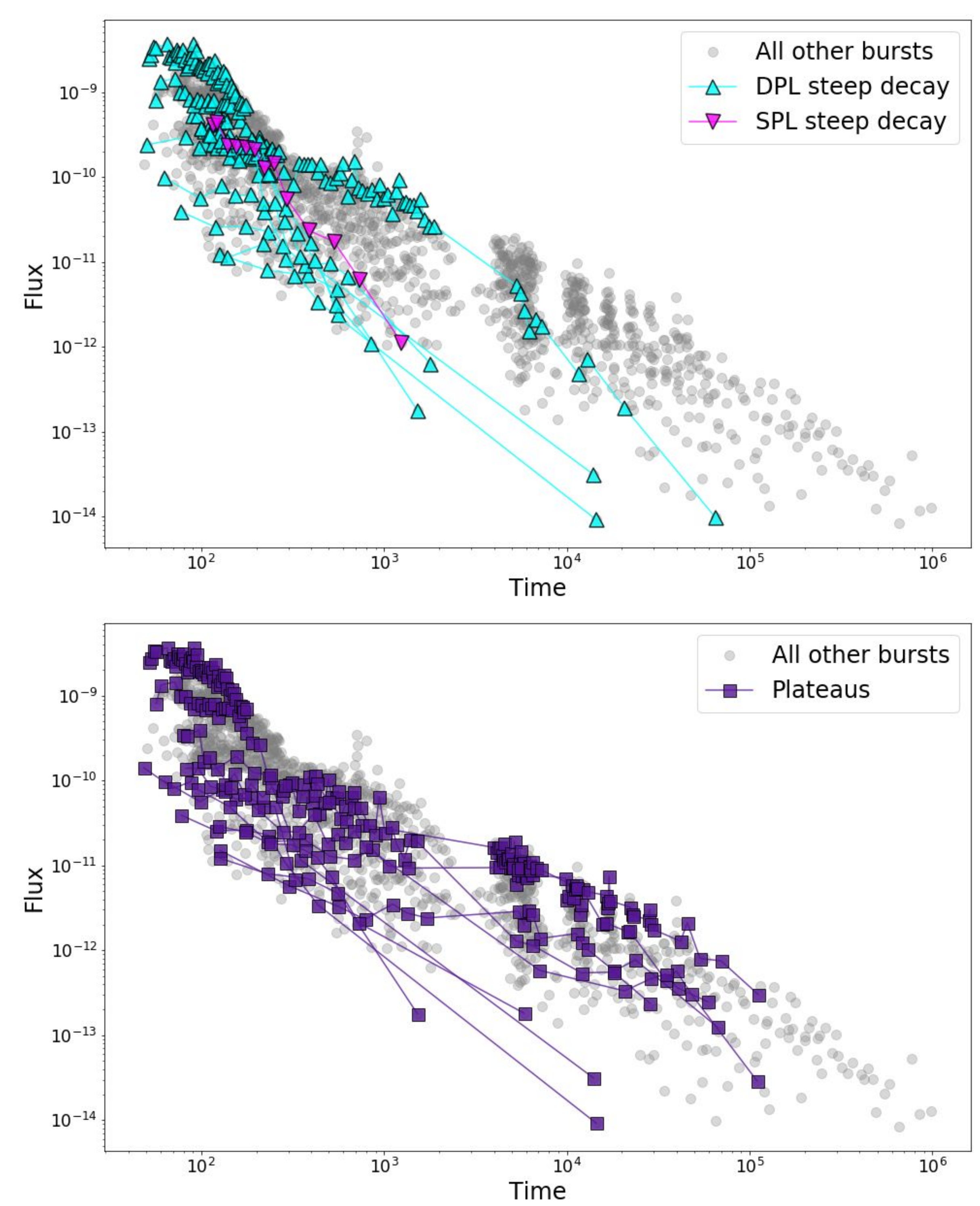


Figure 3: The light curves of bursts with steep decay (top) and plateaus (bottom), compared to the bursts with more typical light curves.

Investigating burst properties

- Looking at other properties of the bursts:
  - T_{90} (duration)
  - Flux (15-150 keV)
  - Fluence, S(15-150 keV)
  - Hardness, defined as S(50-100 keV)/S(25-50 keV)
- T_{90} > 2s indicates extended emission
  - We don't see extended emission in the plateaus
  - Could just be because of small numbers
- No other trends found to distinguish the unusual bursts

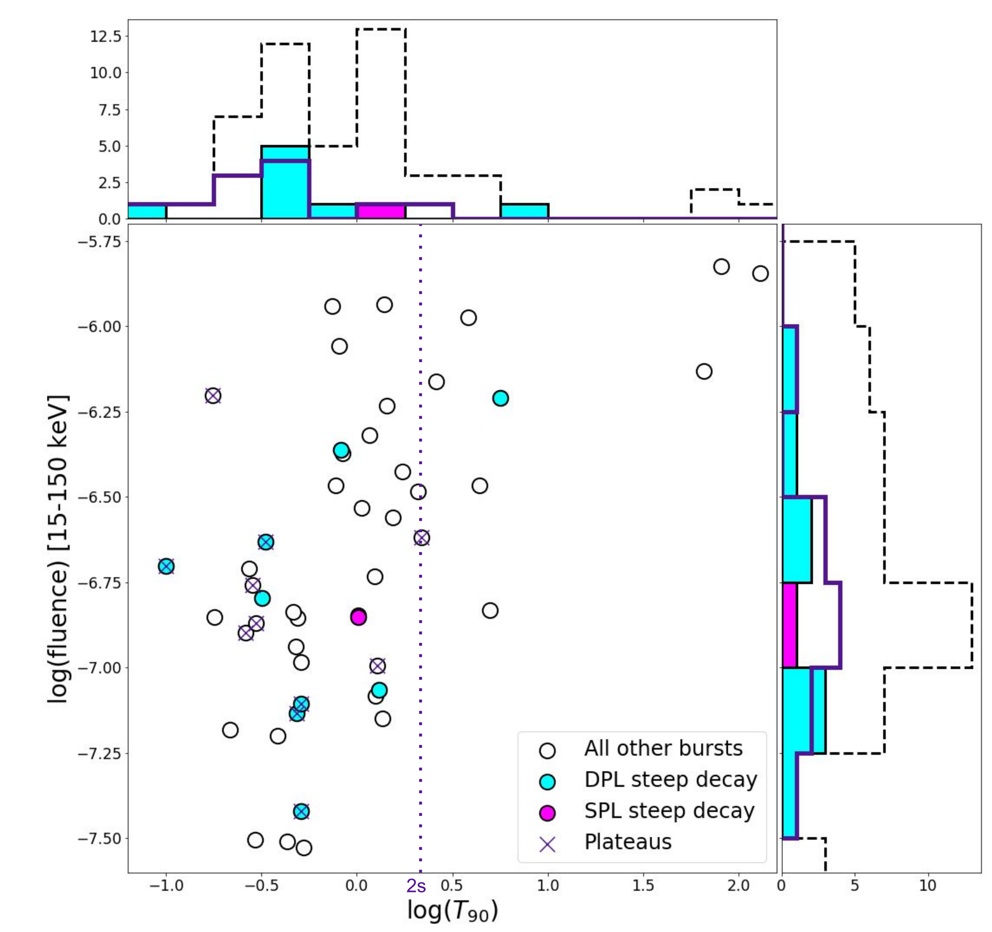


Figure 4: Fluence from 15-150 keV and T_{90} for bursts with steep decay and plateaus compared to the more typical bursts. The plateau bursts all have fairly low values of T_{90}, indicating that they do not have extended emission.

What's next?

- Statistical testing to determine SPL/DPL?
  - Based on a simple χ^2 cutoff almost every burst is sorted into DPL - in many cases, overfitting
  - Statistical tests would be more reliable
- More work needs to be done to investigate the bursts that were not well fit by SPL or DPL
  - Do they need to be fit with a triple power law? Something more complicated?
  - Some also have flares that need to be excluded
- Investigate properties of the host galaxies
  - Based on a cursory look, the plateaus with host information available seem to be in higher mass galaxies
  - Most of the bursts don't have host information right now, so this needs to be investigated more

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