Study of Gamma-Ray Burst correlations via a hierarchical Bayesian model

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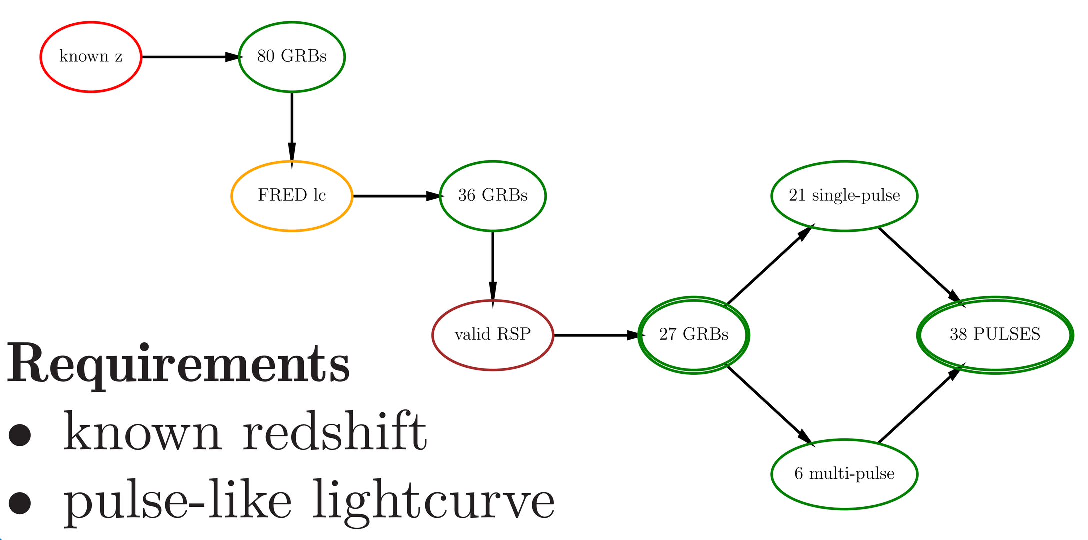
What are GRBs?

Gamma-**R**ay **B**ursts are short, intense flashes of γ rays. They are the brightest EM events known to occur in the universe. Bursts arrive from cosmological distances from random directions in the sky. Emitted radiation spans over decades in energy range (keV-GeV), with peak energy at several hundred keVs. Bursts last from a fraction of a second to several hundred seconds, with light curves being extremely diverse and complex. Progenitors of GRBs are believed to be core-collapse supernovae (for long GRBs) and compact-binary-system mergers (for short GRBs). Theoretical understanding of emission mechanism has emerged in the form of the fireball internal-external shocks model, but the means by which gamma-ray bursts convert energy into radiation is still under debate.

Sample selection

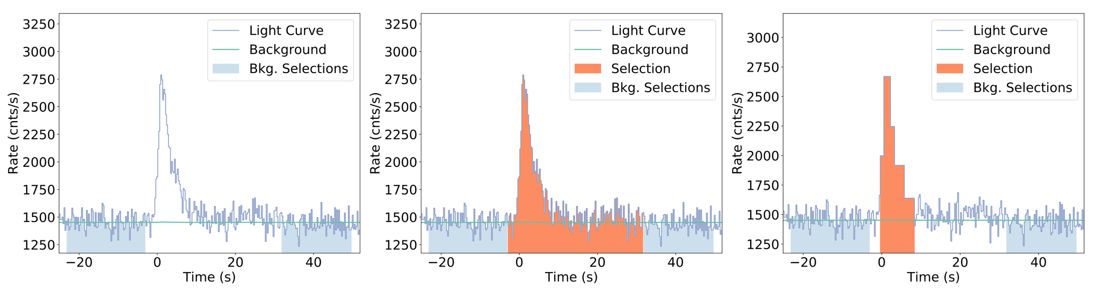


Requirements

- known redshift
- pulse-like lightcurve

Data reduction

- download: Fermi data; TTE & RSP files
- background fitting: best polynomial via unbinned likelihood ratio tests
- binning: Bayesian blocks method
- final selection: bins with $>5\sigma$ significance

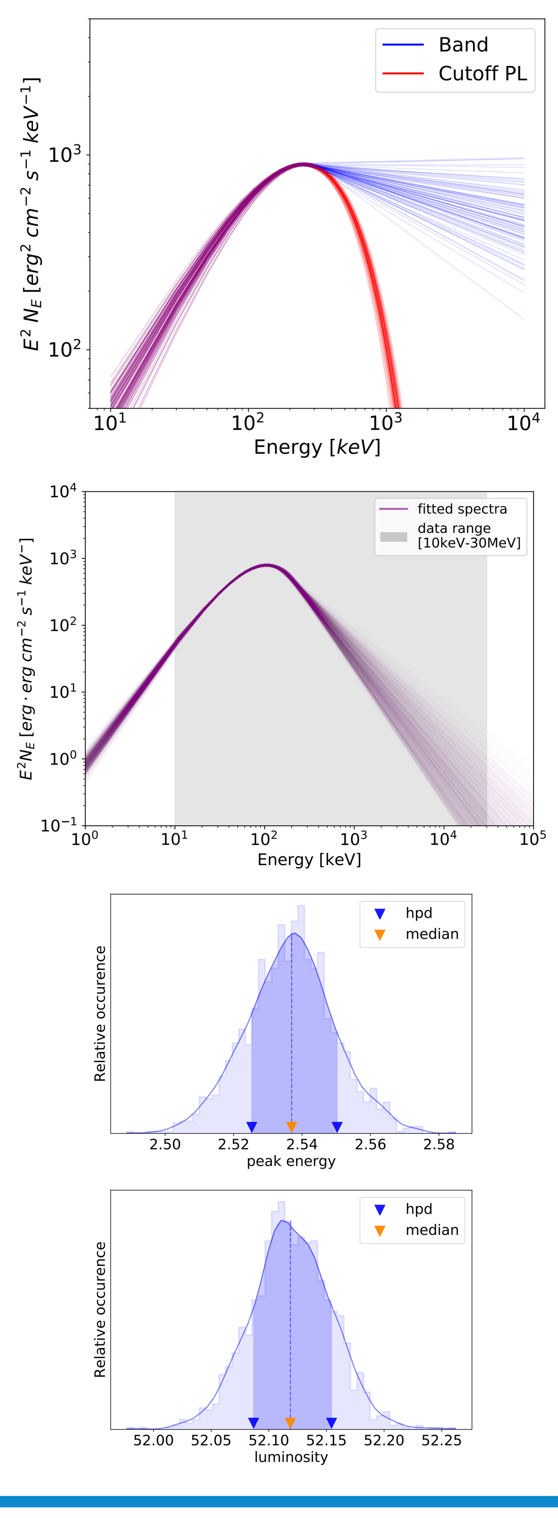


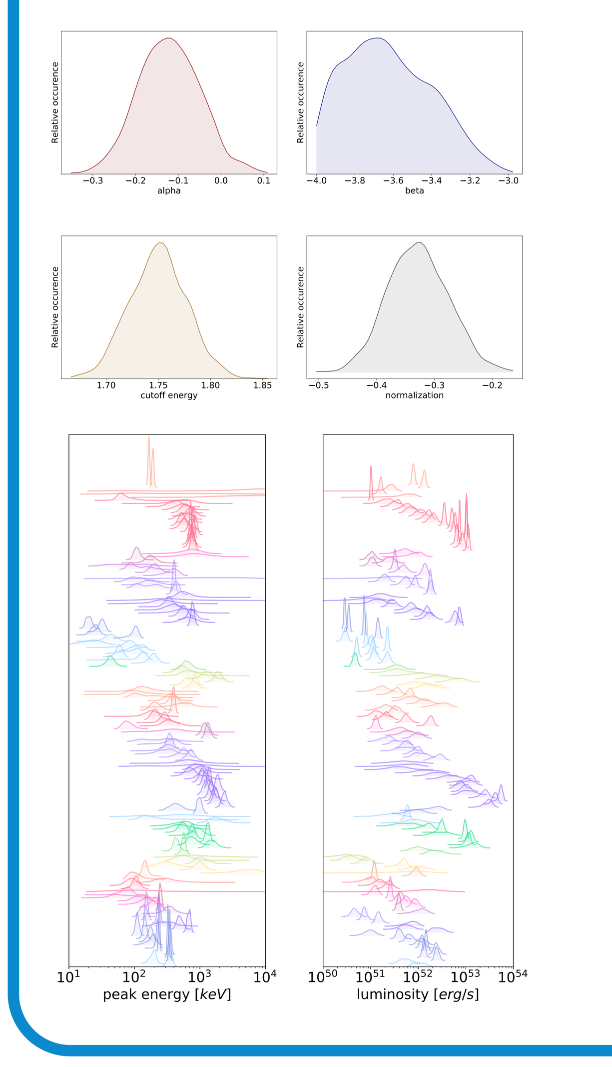
Spectral analysis

- band model
- cutoff power law

Model selection:

$$DIC = \bar{D} + p_D$$





Empirical approach & correlations

- light curves and spectra do not resemble any familiar physical process → fitting empirical models → attempts to infer physical origin of spectra → discovery of empirical correlations among physical parameters

Golenetskii correlation: $L_{iso} \propto \left(E^{rest}_{peak}\right)^{\gamma}$

transfer to log-space → linear form:

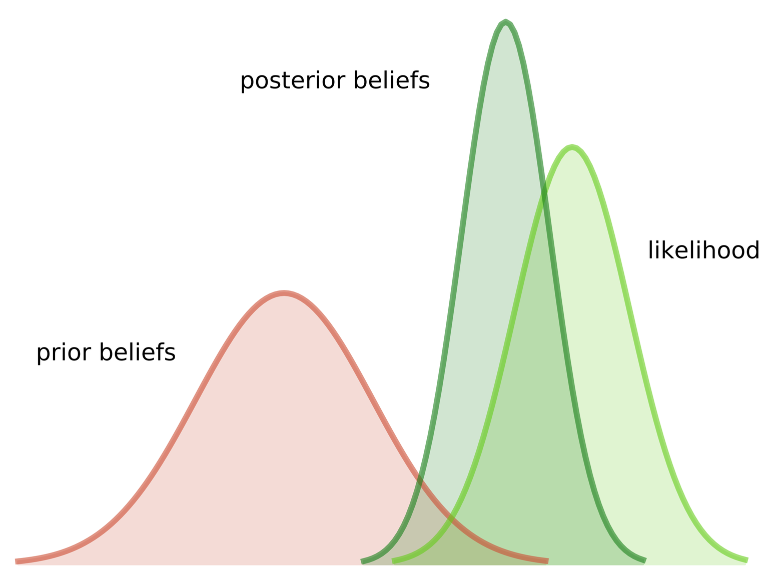
$$\log(L) = \gamma \cdot \log\left(\frac{E^{rest}_{peak}}{100keV}\right) + \log(N_{rest})$$

Why study GC correlation?

1. possible **model discriminators**
2. possible **cosmological tools**

Bayesian method

- Bayesian LR: $Y \sim \mathcal{N}(\alpha + X\beta, \sigma^2)$

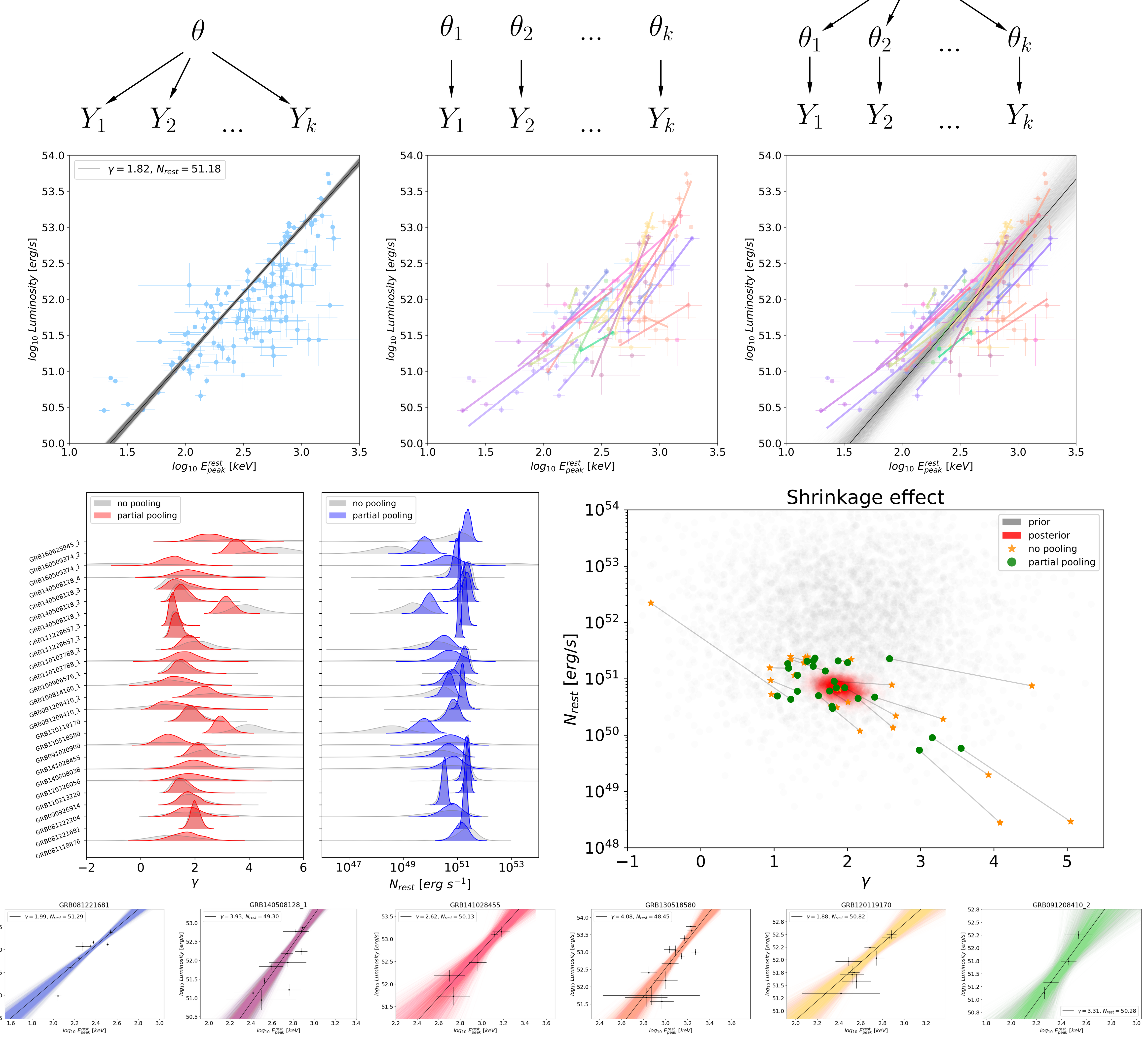


$$p(\boldsymbol{\theta}|\boldsymbol{Y},\boldsymbol{I}) = \frac{p(\boldsymbol{Y}|\boldsymbol{\theta},\boldsymbol{I})p(\boldsymbol{\theta}|\boldsymbol{Y})}{p(\boldsymbol{Y}|\boldsymbol{I})}$$

Bayesian hierarchical modeling

NON-HIERARCHICAL CASES: **Partial pooling**

Complete pooling **No pooling**



Conclusions

Results show that Golenetskii correlation does not possess a common rest N_{rest} which precludes them from being used as redshift estimators and hence cosmological tools. Furthermore, the spread in normalizations points towards variable physical settings of the emission (magnetic field strength, number of emitting electrons, viewing angle, etc.). Values of correlation parameter γ also show clustering near a common value of $\gamma = 2$, (which points towards synchrotron emission), but also show broad spread, leaving possible emission mechanism model inconclusive.

References

[1] Michael Burgess. The rest-frame golenetskii correlation via a hierarchical bayesian analysis. *MNRAS*, 2017.

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[3] Stan Development Team. Stan modeling language users guide and reference manual, version 2.17.0. `http://mc-stan.org`, 2017. Accessed: 30.7.2018.