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Important Property of GRB Pulse: Power-Law Indices of Time Properties on Energy

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Abstract. The dependence of pulse temporal properties (pulse width, pulse rise width and pulse decay width) on energy is power-law function. Some correlated relationships between the power-law indices of the pulse time properties on energy and the spectral lags, relative spectral lags, spectral parameters of band function, and photon flux using a well-separated long-duration γ-ray burst (GRB) pulse sample is demonstrated here. We argue that the curvature effect can explain the correlated properties.

Key words. γ-rays: bursts—method: statistical.

1. Introduction

GRB prompt emission generally consists of coherent pulsed radiation rather than stochastic processes. The pulse properties are the valuable constraints on the physics of Gamma-Ray Burst (GRB) prompt emission. In earlier statistical analysis, GRB pulse width on energy was found to be a power-law function (e.g., Fenimore *et al.* 1995, Norris *et al.* 1996, Peng *et al.* 2006). Zhang & Qin (2008) found that this power-law relationship can be extended to X-ray bands. In addition, Zhang *et al.* (2007) showed that the pulse peak time, rise timescale and decay timescale on energy are also power-law functions. It is found that the distributions of the power-law slopes of the pulse width and photon energy obtained by Peng *et al.* (2006) and Zhang *et al.* (2007) have large dispersions for different bursts, while GRB spectra also vary dramatically for two different bursts. Is the energy dependence of the pulse time properties connected to the observed spectrum or other pulse properties in someway or not? These issues lead to our investigation below.

2. Sample description and analysis results

We select a sample including 102 single pulses observed by CGRO/BATSE with durations longer than 2 s and there are 52 that are good enough to perform spectral analysis. We use GRB pulse model derived by Norris *et al.* (2005) and band function (Band *et al.* 1993) to model these pulses temporally and spectrally. The

Table 1. Correlations of the three power-law indices vs. analytic lags Δt_{31} as well as relative spectral lags $\Delta t_{31,\mathrm{rel},3}$.

Parameter	R_S	P_S	Parameter	R_S	P_S
δ_w–Δt_{31}	−0.41	2.55×10^{-5}	δ_w–$\Delta t_{31,\mathrm{rel},3}$	−0.60	2.17×10^{-11}
δ_r–Δt_{31}	−0.56	9.94×10^{-10}	δ_r–$\Delta t_{31,\mathrm{rel},3}$	−0.74	7.32×10^{-19}
δ_d–Δt_{31}	−0.29	3.07×10^{-3}	δ_d–$\Delta t_{31,\mathrm{rel},3}$	−0.45	2.23×10^{-6}

Table 2. Correlations of the three power-law indices vs. band spectral parameters as well as photon flux.

Parameter	R_S	P_S	Parameter	R_S	P_S
δ_w–α	−0.57	1.41×10^{-5}	δ_w–β	0.39	4.42×10^{-3}
δ_r–α	−0.24	8.99×10^{-2}	δ_r–β	0.34	1.37×10^{-2}
δ_d–α	−0.62	1.04×10^{-6}	δ_d–β	0.32	2.22×10^{-2}
δ_w–E_p	0.20	1.05×10^{-1}	δ_w– F	0.57	1.35×10^{-5}
δ_r–E_p	0.19	1.77×10^{-1}	δ_r– F	0.45	8.05×10^{-4}
δ_d–E_p	0.21	1.44×10^{-1}	δ_d– F	0.52	1.03×10^{-4}

pulse width, the pulse rise width, the pulse decay width per channel as a function of the geometric means of the lower and upper BATSE channel boundaries (Norris *et al.* 2005) are fitted and the power-law indices (let δ_w, δ_r, and δ_d denote the indices of the power-law relations between pulse width, pulse rise width, pulse decay width and energy, respectively) are also obtained. The correlated relationships between these indices and pulse spectral lag between BATSE channels 1 and 3 (Δt_{31}), relative spectral lag, $\Delta t_{31}/w_3$ (where w_3 is the pulse width of BATSE channel 3), band spectral parameters (α, β and E_p), and photon flux are thus investigated. The Spearman rank-order correlation coefficient, R_S, and significance, P_S, of these parameter pairs are listed in Tables 1 and 2.

We find from Tables 1 and 2 that the strong anticorrelated relations are identified between δ_d and α as well as δ_w and α. All the power-law indices are correlated with β. However, no apparent correlations are found between the three power-law indices and E_p. In addition, it is found that analytic lag and pulse photon flux are also correlated with the three power-law indices.

3. Conclusions

Based on the correlated relations between power-law indices of time properties on energy and the pulse spectral and temporal parameter, we tend to believe that these power law indices are important GRB pulse properties. In addition, we show that the curvature effect and the intrinsic band spectrum could naturally lead to the energy dependence of GRB pulse width and also $\delta_d - \alpha$ and $\delta_w - \alpha$ correlations. Our results would hold so long as the shell emitting γ-rays has a curve surface and the intrinsic spectrum is a band spectrum or broken power law (Peng *et al.* 2012).

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