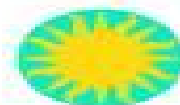




# Towards a More Standardized Candle Using GRB Energetics & Spectra



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## Abstract

The use of  $\gamma$ -ray bursts (GRBs) energetics for cosmography has long been advanced as a means to probe to redshifts beyond those possible with Type Ia SNe, to the epoch of deceleration. However, though relatively immune to systematic effects of dust extinction, the prompt energy release in GRBs, even when corrected for jetting geometry, is far from being a standard candle. Recently, two groups (Dai et al. and Ghislanda et al.) have claimed that by using the newly discovered relation between the apparent geometry-corrected energies ( $E_\gamma$ ) and the peak in the rest frame prompt burst spectrum ( $E_p$ ), GRBs now provide meaningful constraints on  $\Omega_b$ ,  $\Omega_\Lambda$  and the quintessence parameter  $w$ . In presenting the first self-consistent formalism for correcting GRB energies with a thorough accounting for observational uncertainties, we demonstrate that the **current sample of 18 GRBs is simply inadequate for cosmography** when compared to results from Type Ia supernovae, large-scale structure, and the microwave background. **The proper use of the relation clearly brings GRBs an impressive step closer toward a standardizable candle**, but until the physical origin of the  $E_p$ - $E_\gamma$  relation is understood, additional corrections are discovered, and a larger and homogeneous determination of prompt-burst and afterglow observables exists (e.g., from *Swift*), bold claims about the utility of GRBs for cosmography will have to wait.

## The $E_p$ - $E_\gamma$ relation

Although the  $E_p$ - $E_\gamma$  relation is a highly significant correlation (Spearman  $\rho = 0.88$ , null probability  $= 1.1 \times 10^{-10}$ ), **the relation itself is not well fit by a power law** [ $E_\gamma = \alpha(E_p/10^{51} \text{erg})^\beta$ ] across a range of cosmologies, with a reduced  $\chi^2_r = 3.22$  (16 dof) in the standard cosmology ( $\Omega_b, \Omega_\Lambda, h_0 = (0.3, 0.7, 1)$ ) and a minimum  $\chi^2_r = 3.20$ . The correlation, however, does provide a simple empirical correction to help standardize GRB energetics.



**The (weak) cosmological dependence of the  $E_p$ - $E_\gamma$  relation.** The best-fit power-law relation for a representative set of cosmologies are shown as a series of lines. Only the data for a standard cosmology of  $(\Omega_b, \Omega_\Lambda, h_0) = (0.3, 0.7, 1)$  is shown for clarity with upper/lower limits indicated with arrows. **Notable outliers** are indicated with a large square surrounding the data points. The best fit values of the slope ( $\eta$ ) and normalization ( $\kappa$ ) are shown inset. Note that the data for a standard cosmology (with best fit  $\eta = 0.70 \pm 0.07$ ) essentially brackets the fits across all cosmologies, excepting only the extreme cosmologies with  $\Omega_b = 0$  and  $\Omega_\Lambda = 1$ .

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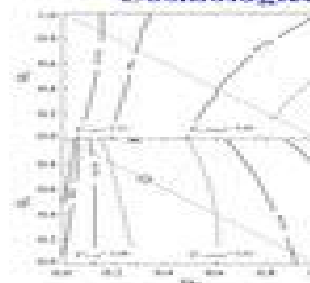
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## The GRB Hubble Diagram



**Are GRBs really useful for cosmology?** Shown is the improvement of GRB Hubble diagrams for  $(\Omega_b, \Omega_\Lambda, h_0) = (0.3, 0.7, 1)$ . From top to bottom there is a continual reduction in scatter after applying corrections to the energetics (i.e. different standard candle assumptions).  $E_{iso}$  is the isotropic equivalent prompt  $\gamma$ -ray energy release,  $E_\gamma = E_{iso}fb$  is the geometry-corrected energy where  $fb = 1 - \cos(\theta)$  is the beaming fraction, and  $E_{\gamma,cor} = E_\gamma(\alpha/E_p)^{1/\eta}$  is a further correction, making use the  $E_p$ - $E_\gamma$  relation. **Future empirical correlations, perhaps to be found in *Swift* data, will be necessary for GRB standard candles to be competitive with Type Ia SNe as cosmological distance indicators.**

## Cosmological Parameter Determination



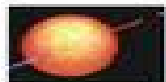
$\chi^2$  contours for the GRB Hubble diagram constructed using the corrected energy  $E_{\gamma,cor}$ . Top panel includes errors on correlation slope  $\eta$  and intercept  $\kappa$ . Bottom panel assumes fit parameters are known *a priori*. Although the fits are marginally acceptable (minimum  $\chi^2_r = 2.2$ , [top]), **the shape in the  $\chi^2$  surface and hence the best fit values and uncertainties for  $\Omega_b$  and  $\Omega_\Lambda$  are dominated by outliers in the  $E_p$ - $E_\gamma$  relation, and thus not yet meaningful.**

## Conclusion

Although cautious optimism is warranted with the addition of an order of magnitude more data, and possible new empirical corrections to GRB energetics in the *Swift* era, **GRBs are currently not useful for cosmography.**

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