Difficulties in Using GRBs as Standard Candles

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Problems

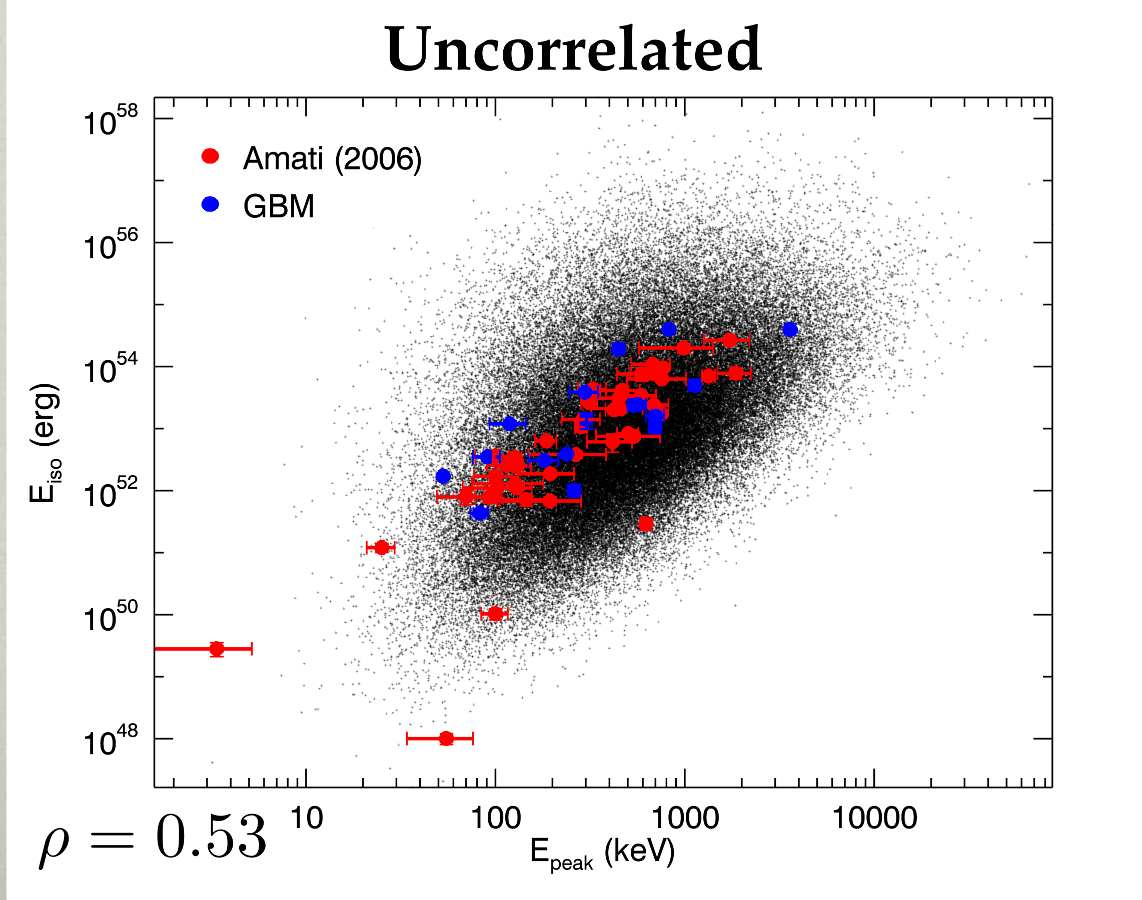
- Wide Range of Observed Properties
- Flux/Fluence intrinsically correlated with photon model parameters
- Luminosity (Energy) Indicators
- (Pseudo)redshift Predictions
- Emission Collimation
- Lorentz Factor

Simulations

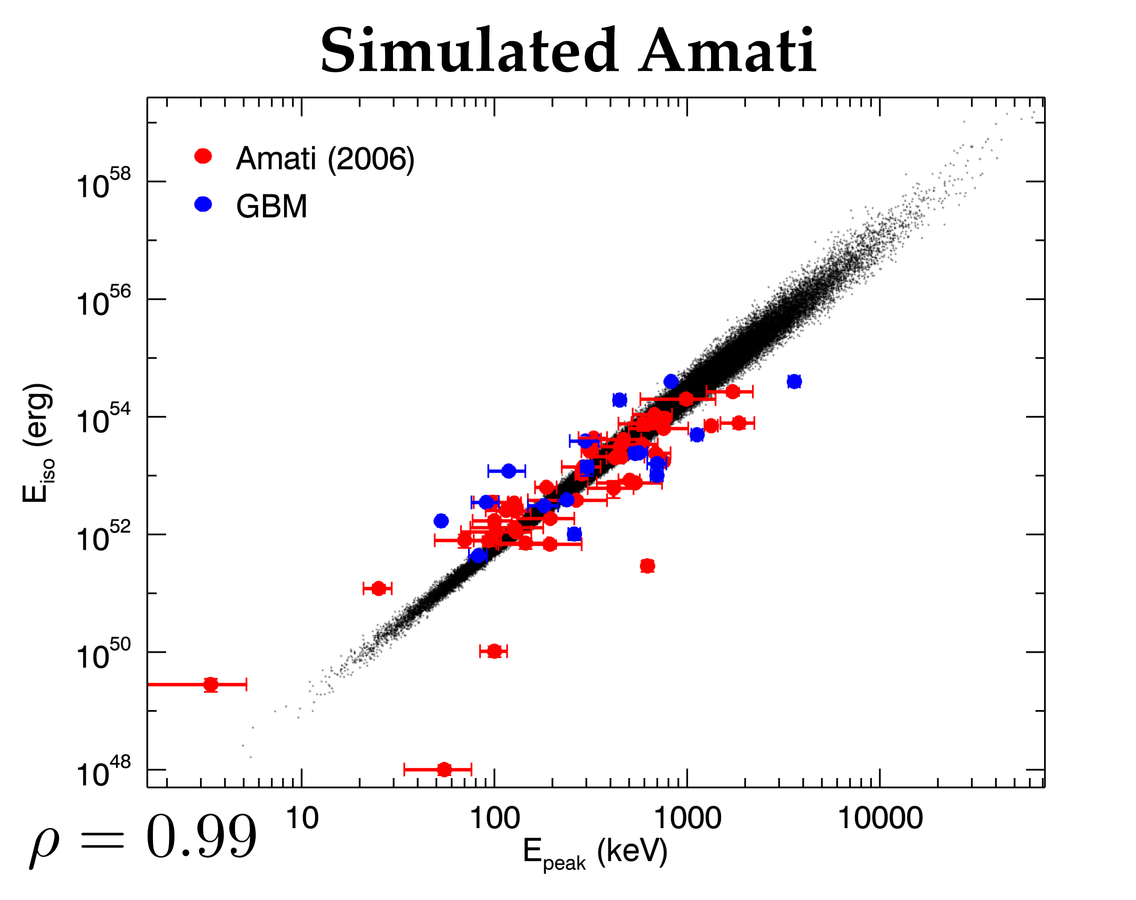
- **Have observed spectral parameter distributions (**Goldstein et al. 2012; Goldstein et al. in prep.**)**
- **Simulate GRB spectra based on observed Band model parameter distributions**
- **Simulate T_{90} duration from observed BATSE distribution and redshift from the distribution of currently known bursts with redshift (**Greiner, http://www.mpe.mpg.de/~jcg/grbgen.html**)**
- **Use the simulations to perform correlative analysis**

Amati Relation

- Simulate the relationship assuming no physical correlation
- Simulate the relationship assuming the Amati relation accounting for 3σ model dispersion

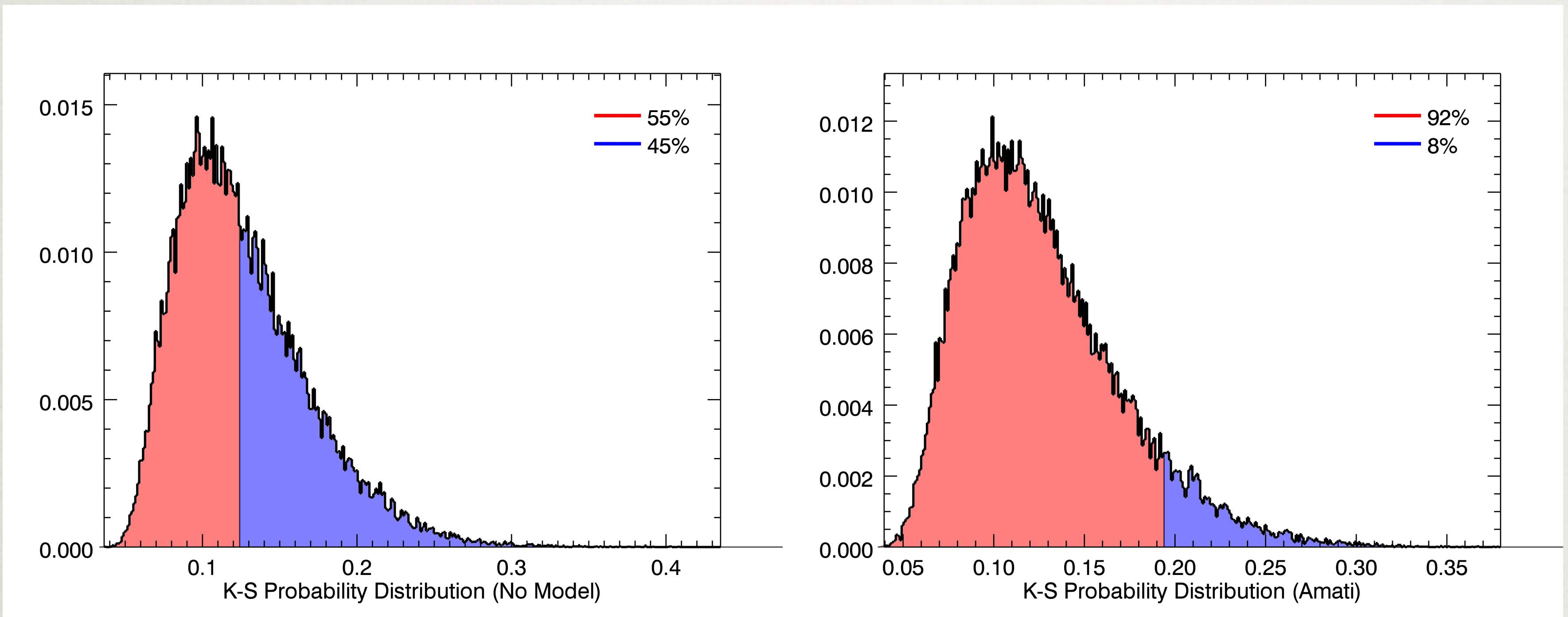


$\rho = 0.53$



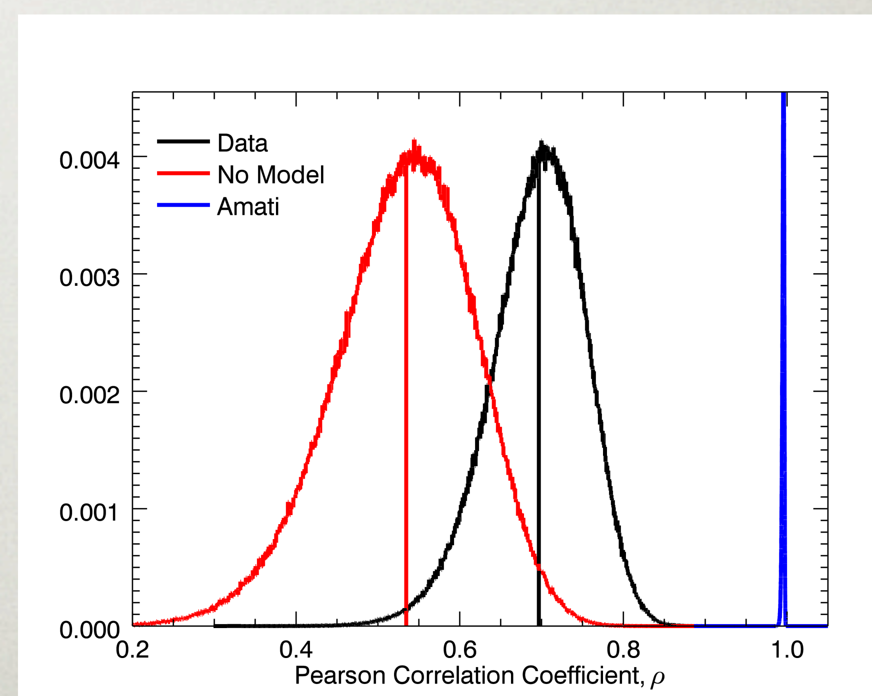
$\rho = 0.99$

Validity of the Amati Relation

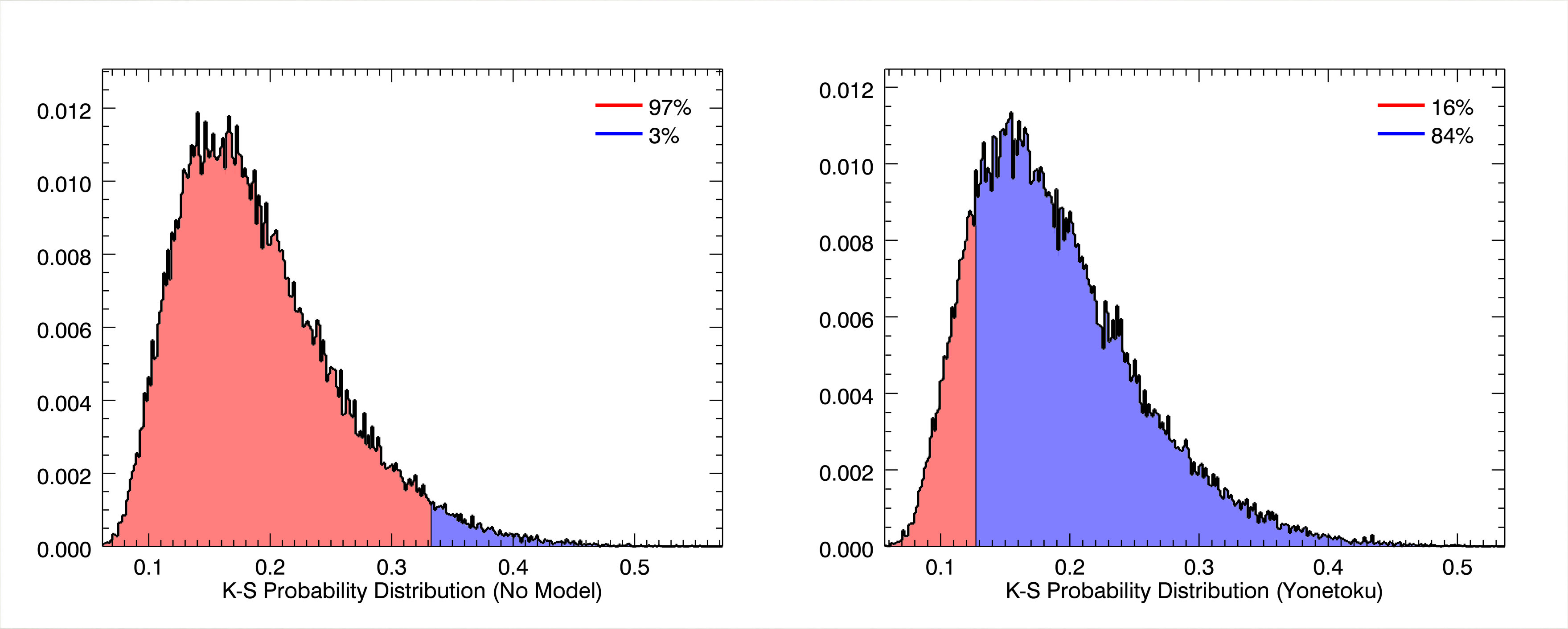


$$E_{iso} \propto E_{peak}^{\eta}$$

- K-S: Can reject Amati estimation of E_{iso} at 92% level
- Pearson: ~0% chance probability that the data E_{peak}-E_{iso} correlation is represented by Amati

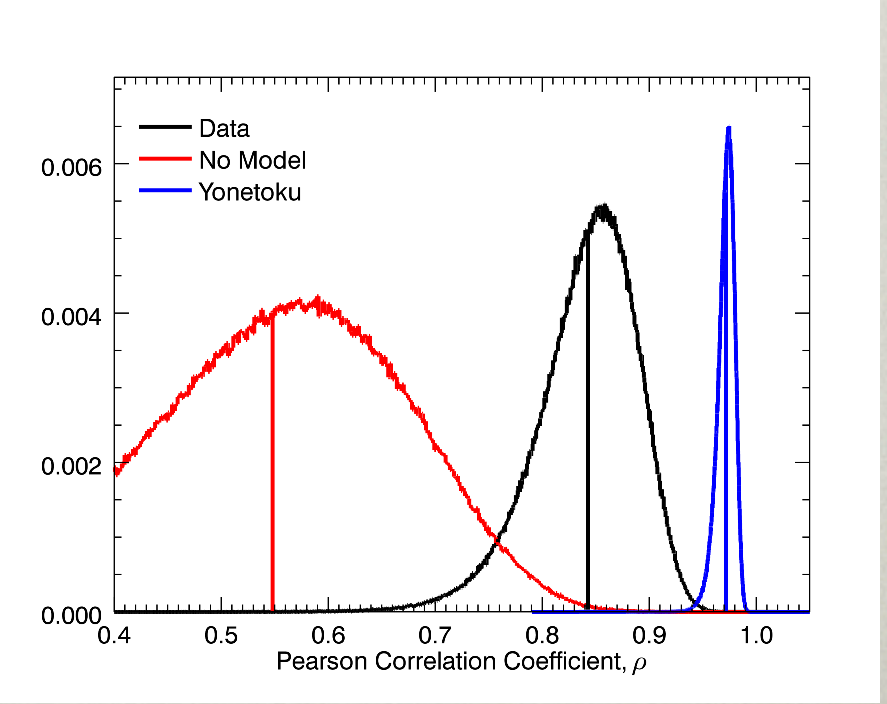


Validity of the Yonetoku Relation



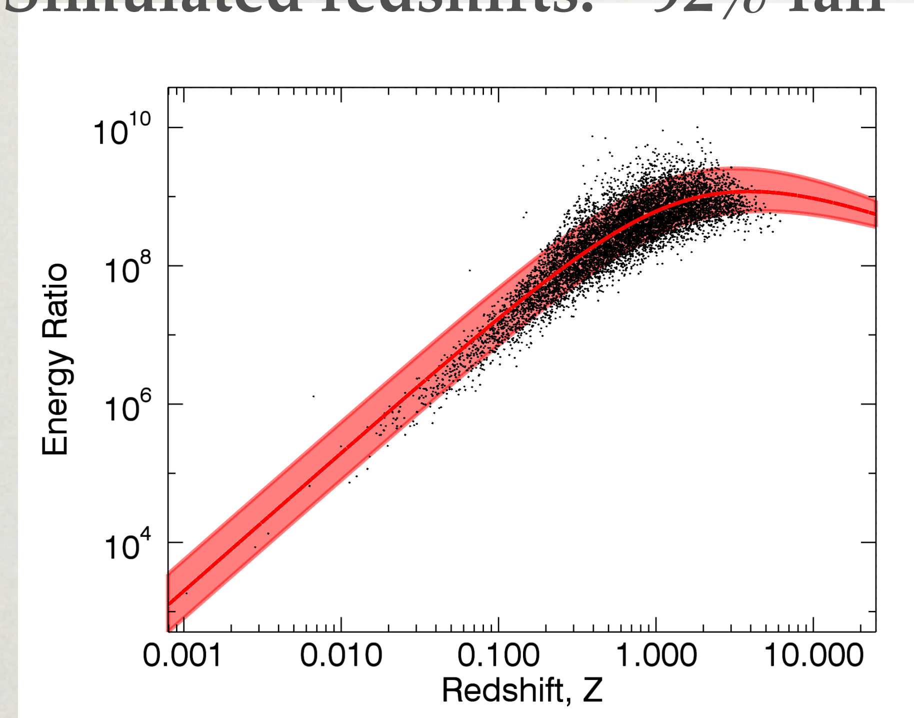
$$L_{iso} \propto E_{peak}^{\eta}$$

- K-S: Can reject the estimation of L_{iso} from model intrinsics at 97% level
- Pearson: ~0% chance probability that the data E_{peak}-L_{iso} correlation is represented by Yonetoku

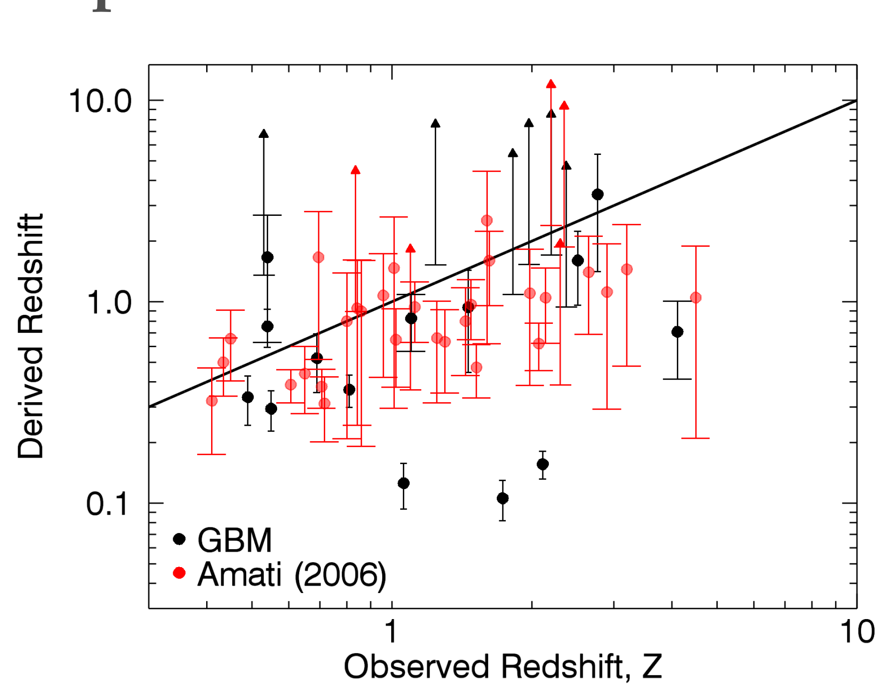


Amati Pseudo-Redshifts

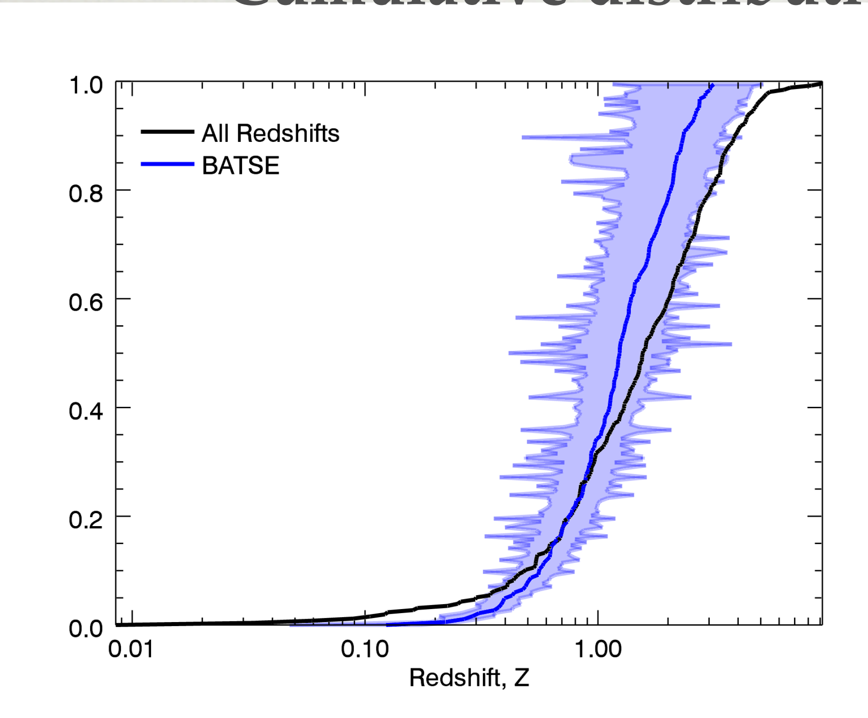
Simulated redshifts: ~92% fail

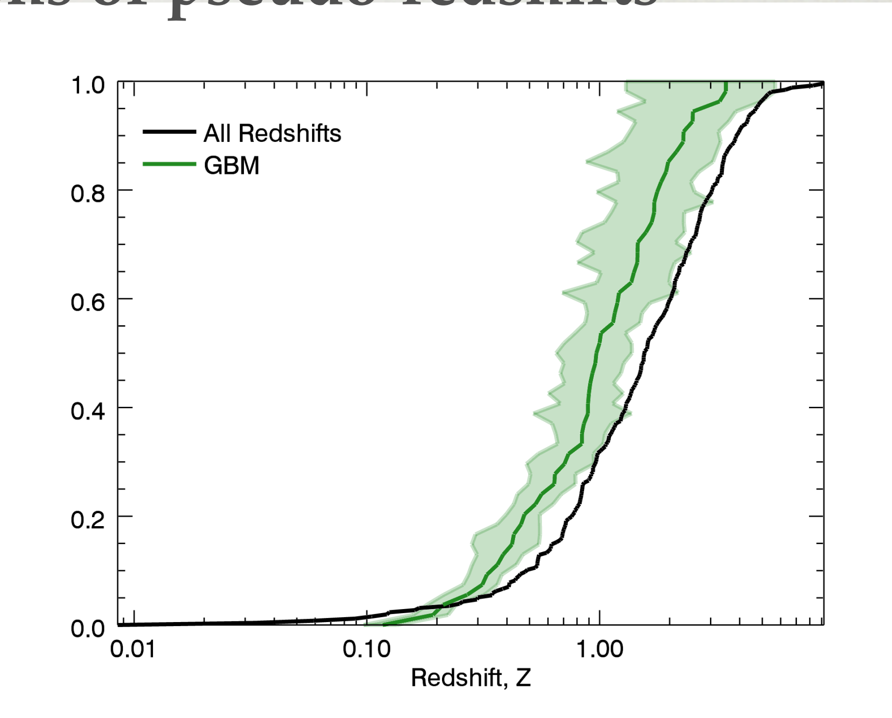


Comparison to observed redshifts



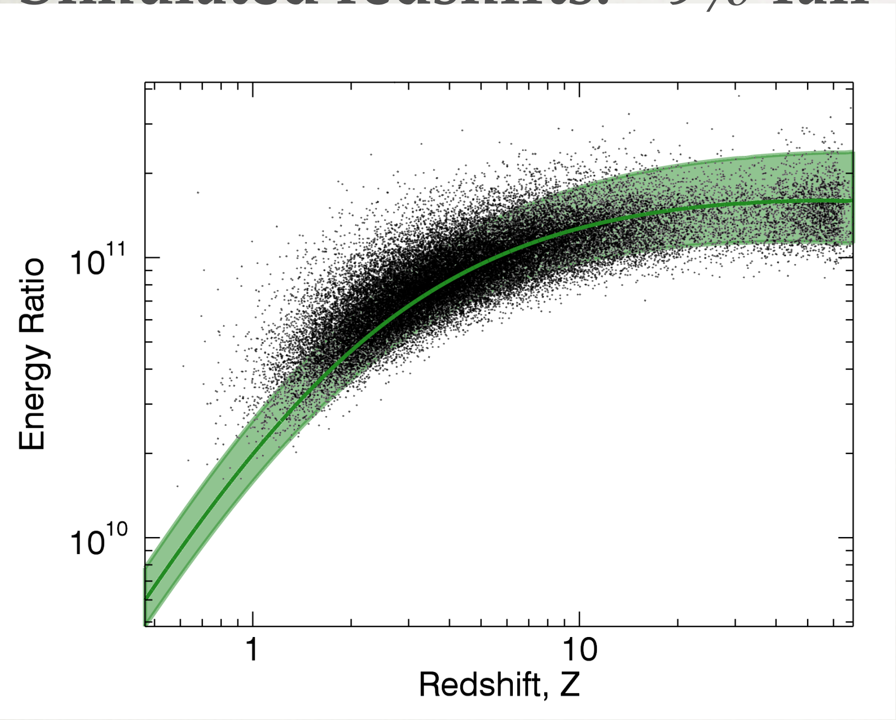
Cumulative distributions of pseudo-redshifts



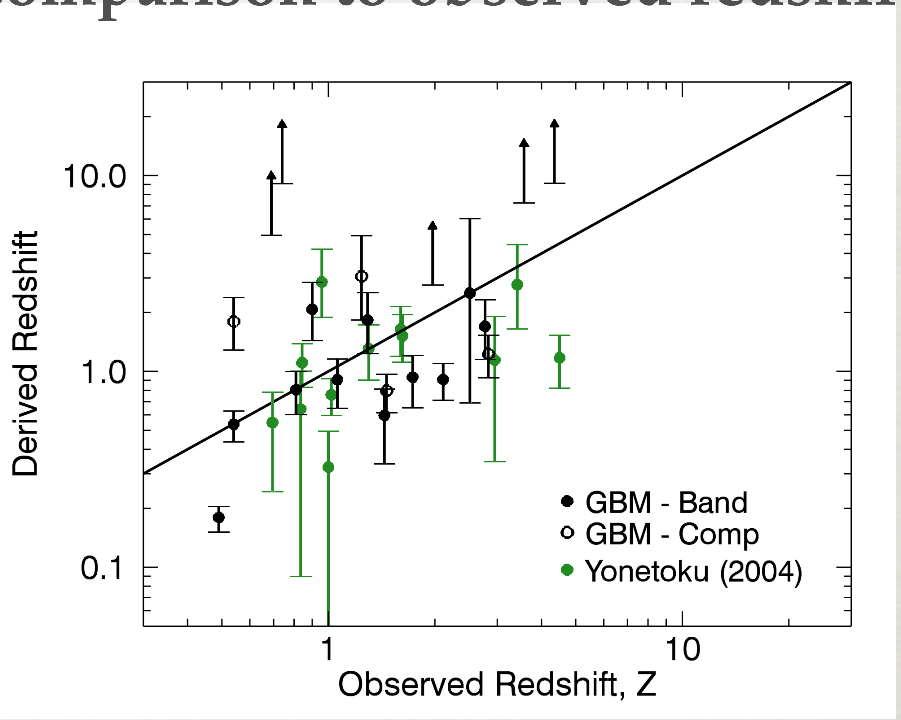


Yonetoku Pseudo-Redshifts

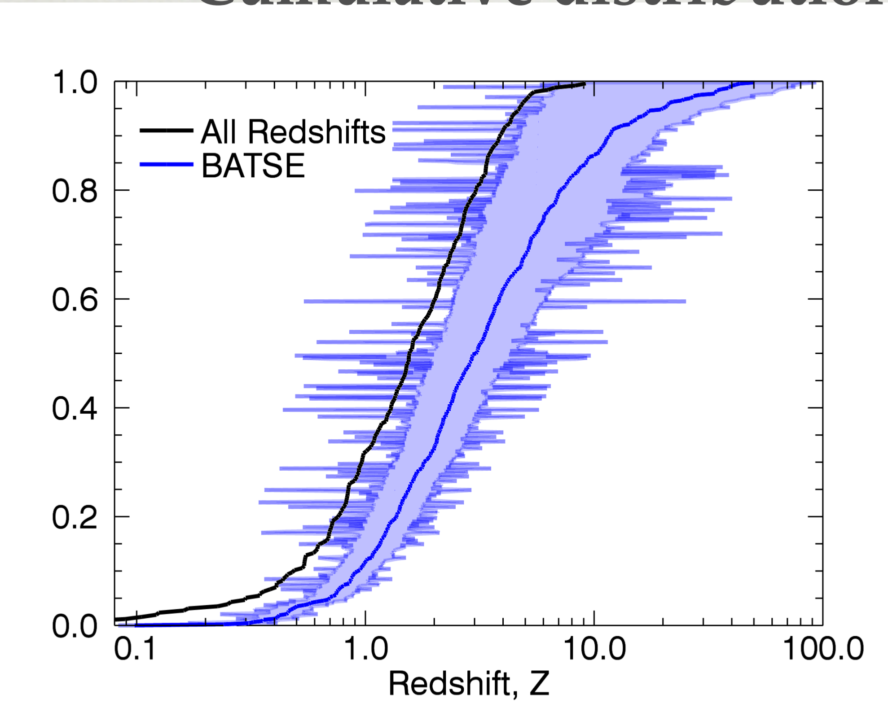
Simulated redshifts: ~9% fail

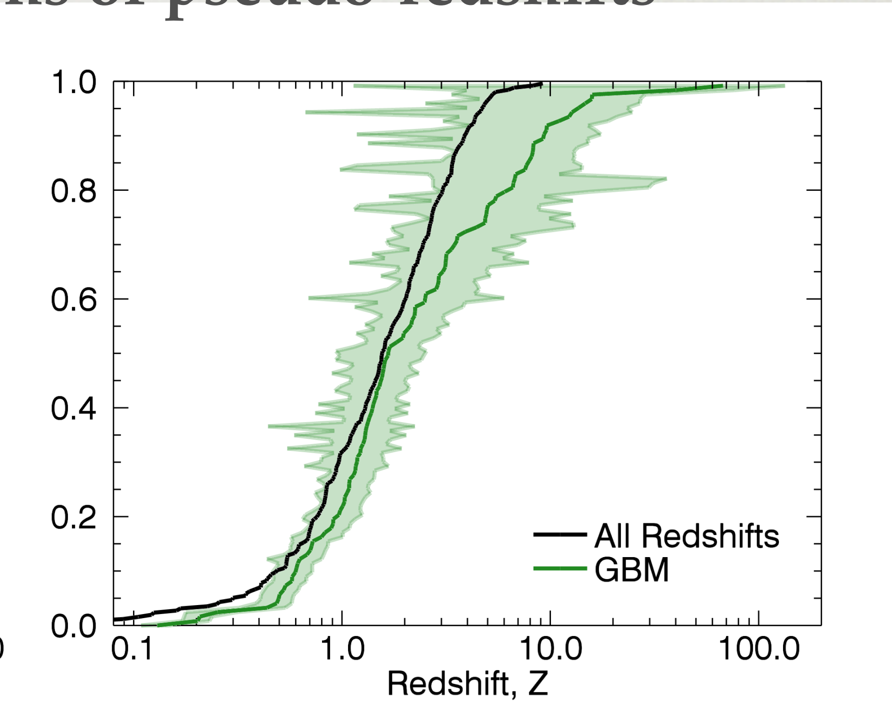


Comparison to observed redshifts

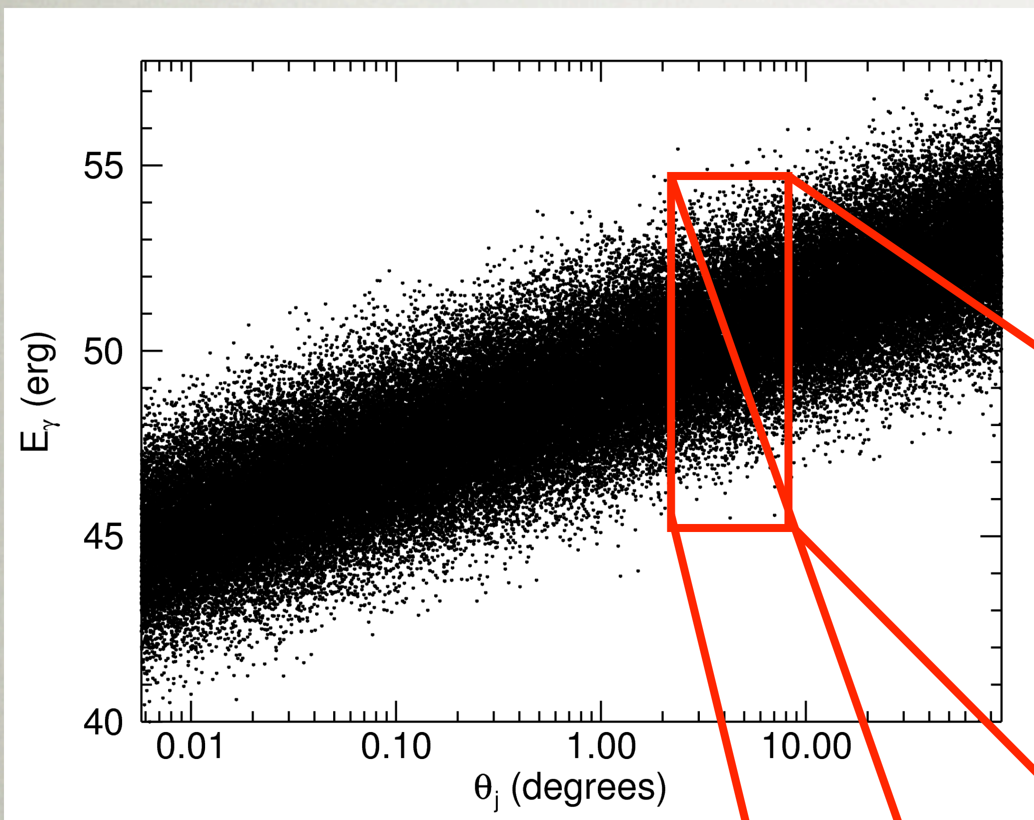


Cumulative distributions of pseudo-redshifts



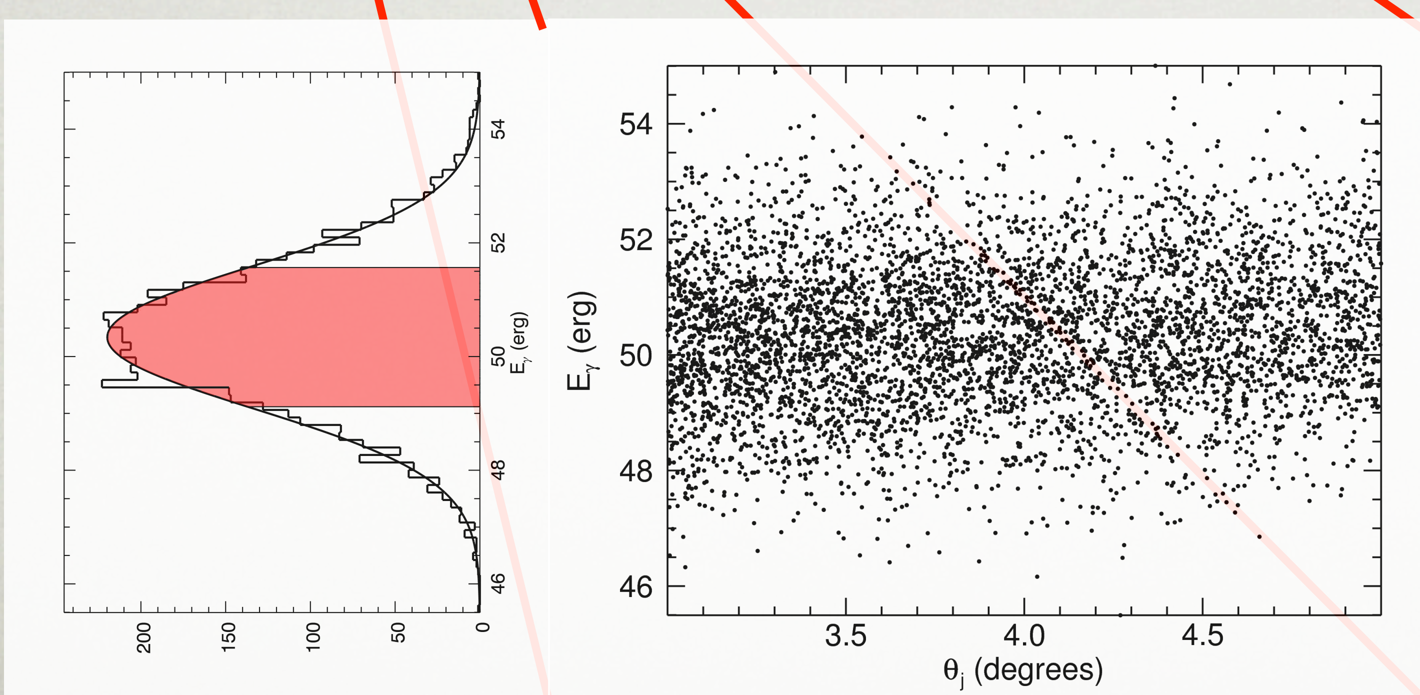


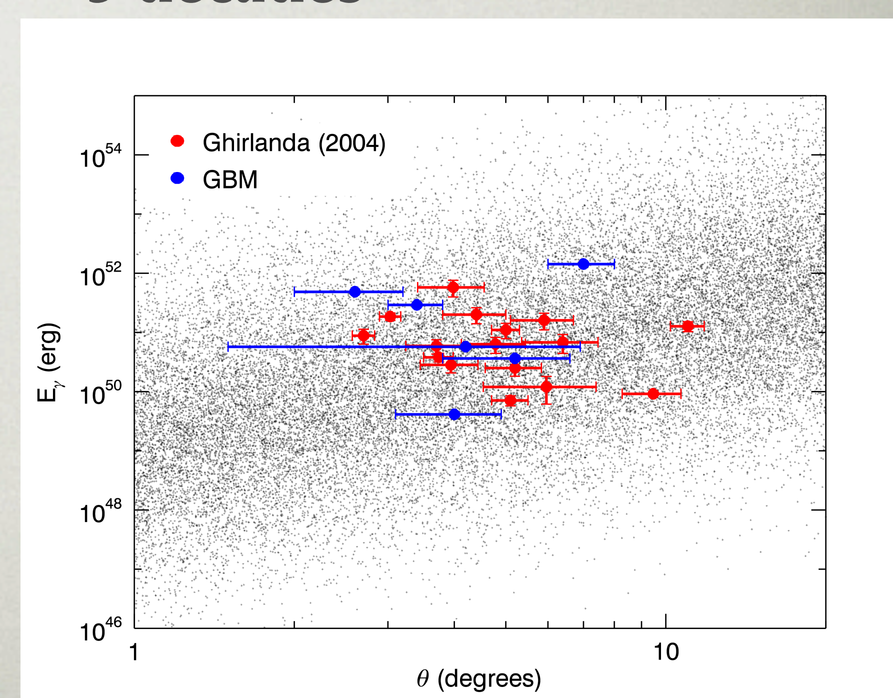
Jet Collimation



Example:
Inferred angle is 4.0±1.0 degrees. Based on the parameter distributions, the collimation-corrected energy can vary by > 2 decades (1σ).

Angles spanning < 1 decade result in energies spanning > 3 decades



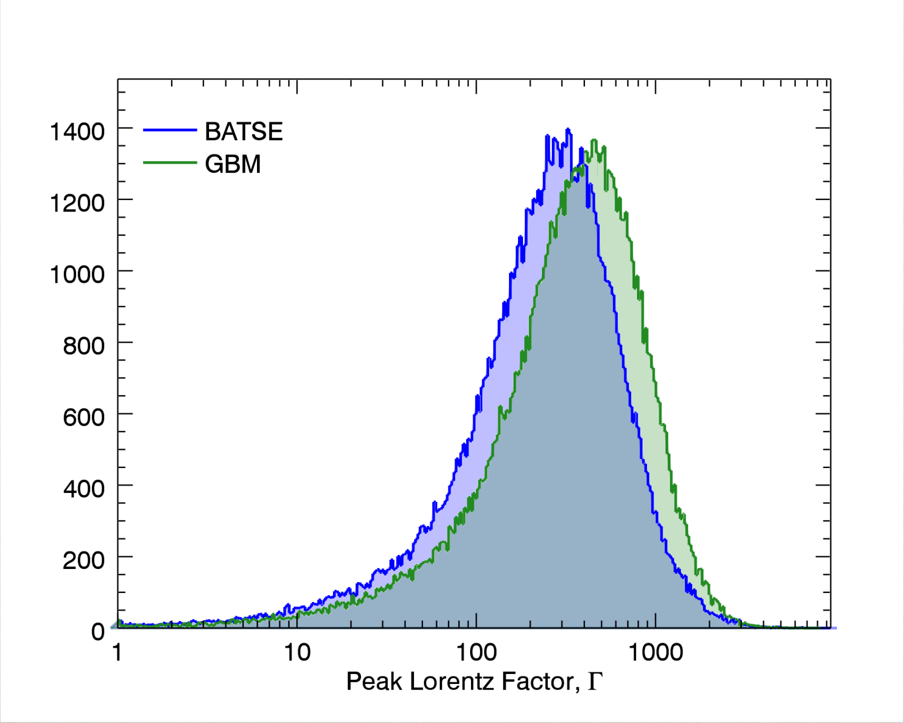


Lorentz Factors (Best Case Scenario)

$$F_{\gamma,\mathrm{obs}} \approx L_\gamma \delta^4, \quad \delta = \frac{1}{\Gamma(1-\beta\cos\theta_\mathrm{v})}$$

Assume Eddington mass limit:
$\sim 120\ M_\odot \implies$ Let $L_\gamma = L_{\mathrm{Edd}} \sim 2\times10^{40}$ erg

$$\Gamma\left(1-\sqrt{1-\frac{1}{\Gamma^2}}\right) \approx \left(\frac{L_{\mathrm{Edd}}}{4\pi d_L^2 F_{\gamma,\mathrm{obs}}}\right)^{1/4} \sec\theta_\mathrm{v}$$



Caveats:
- $F_{\gamma,\mathrm{obs}}$ is detector-dependent
- z distribution may be biased
- GRBs are assumed to be SCs
- Beam Profile
- LF evolution

Result:
These distributions are likely narrower than in reality.

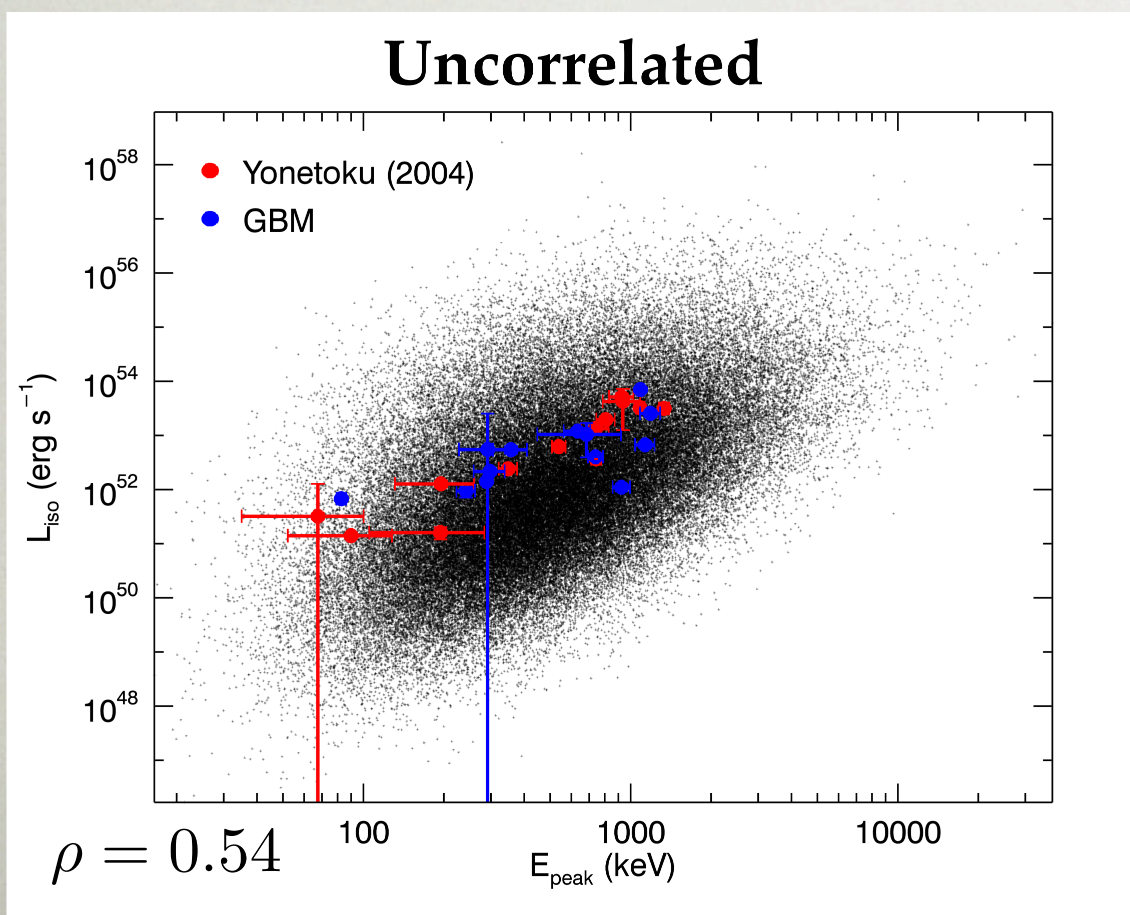
Recap

- Wide range of observed properties: Result of viewing angle, jet angle, Lorentz factor, distance, etc.?
- The Amati relation could simply be a selection effect & a result of model intrinsics, or even a mixture of artificial and physical effects. Not well suited for estimating redshifts.
- The Yonetoku relation appears to have *some* statistical support, but the error propagation shows that it is not well suited for estimating redshifts
- Even taking into account jet collimation, the rest-frame energy can vary by multiple decades based on the variance in the photon model.
- Bulk Lorentz Factors could possibly vary by at least two orders of magnitude from burst to burst

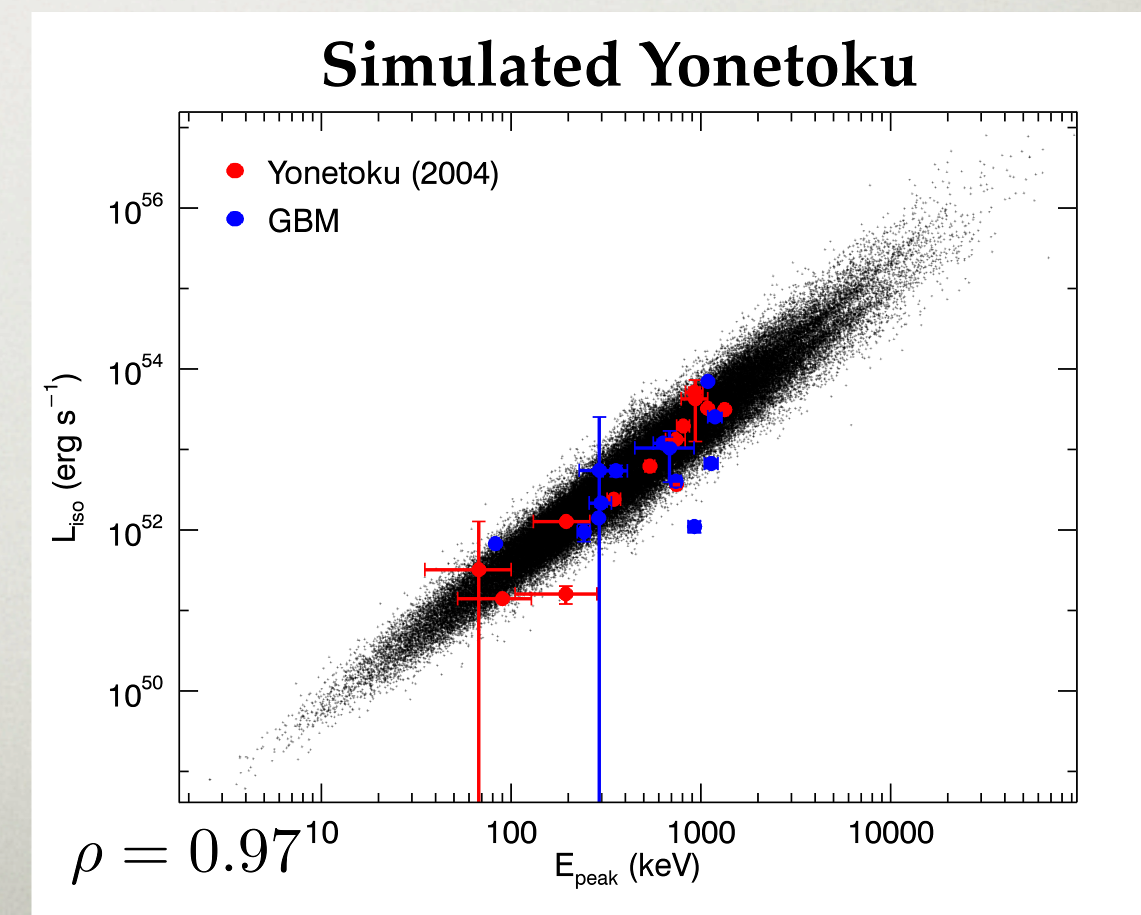
BACKUP

Yonetoku Relation

- Simulate the relationship assuming no physical correlation
- Simulate the relationship assuming the Yonetoku relation accounting for 3σ model



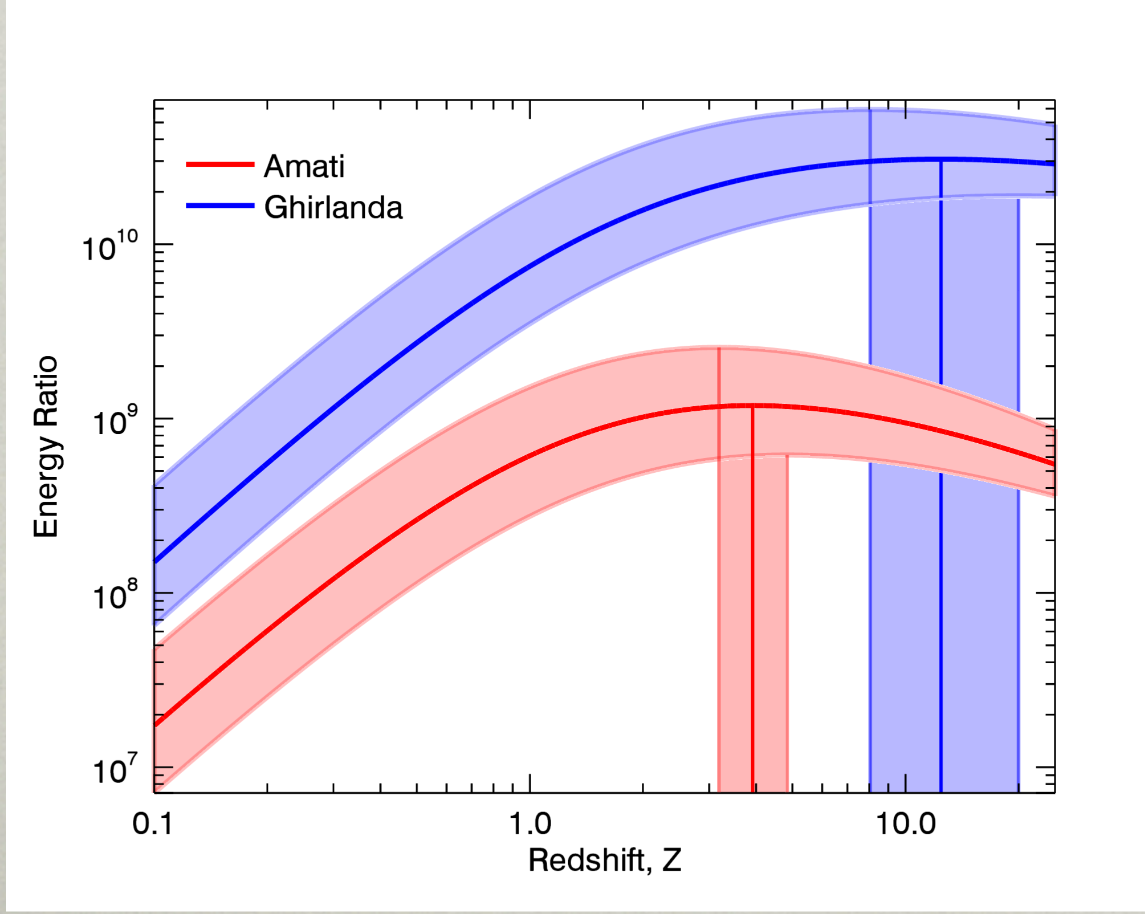
$\rho = 0.54$

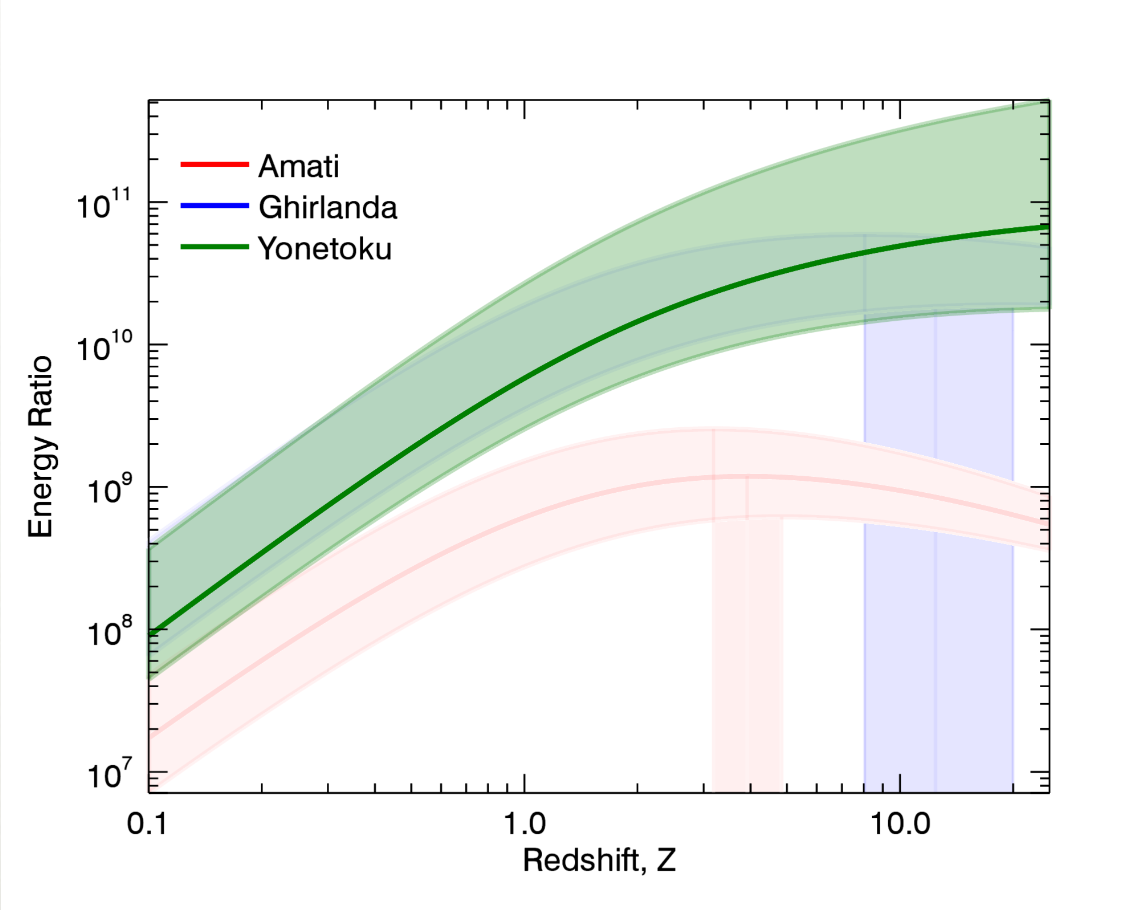


$\rho = 0.97$

Pseudo-Redshifts

- Relations as a function of Z
- Amati rolls over ~3-5
- Ghirlanda rolls over ~8-11
- Yonetoku does not roll over if Index < 2





Note: This is why error propagation is important