An intrinsic correlation between GRB optical/UV afterglow brightness and decay rate

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The Light curves:
up to June 2007

– Ordered by peak magnitude

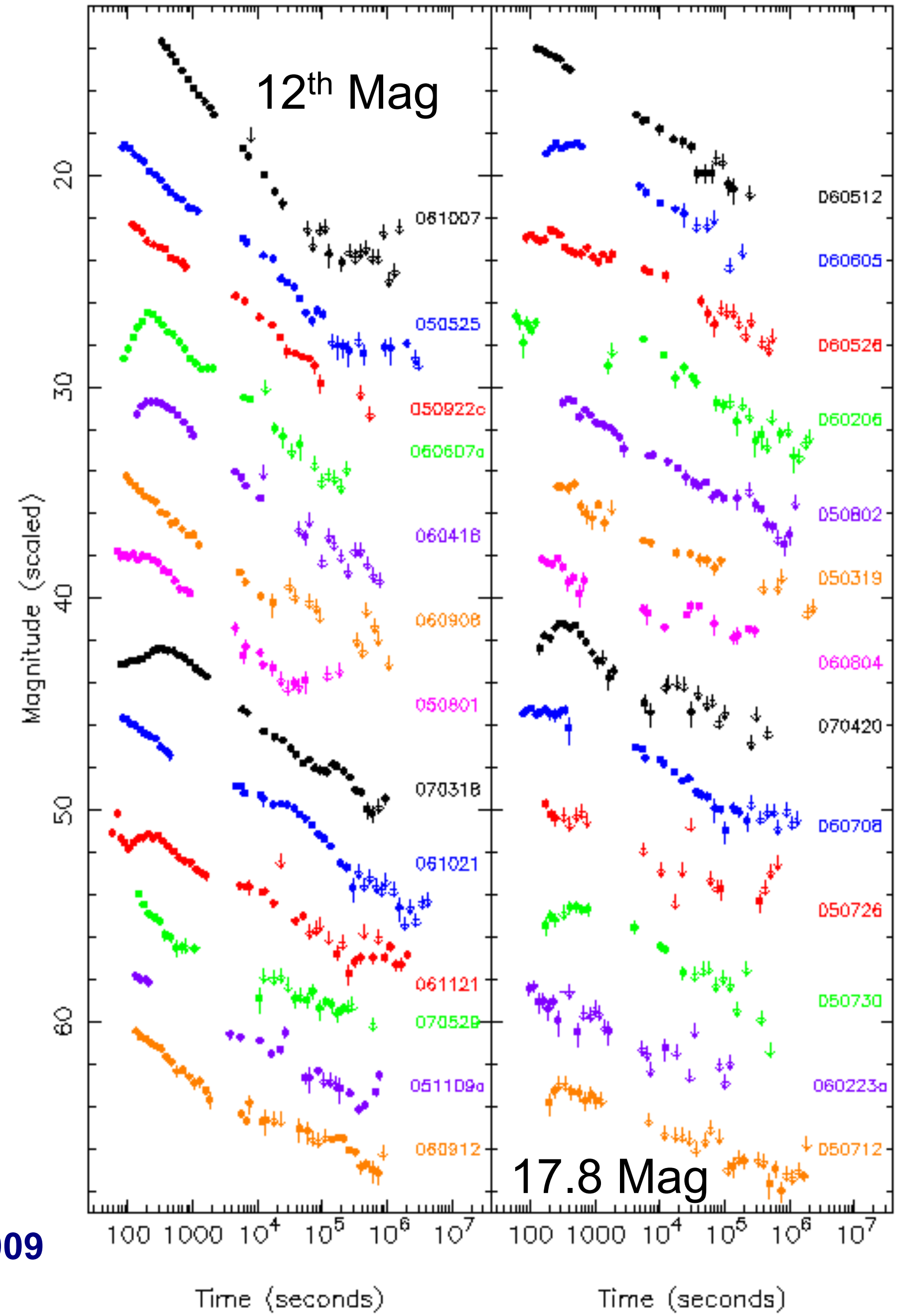
Selection Criteria:

- <17.89 mag in UVOT *v* band
- Observations from 400s to 10^5s after the trigger.

Construction:

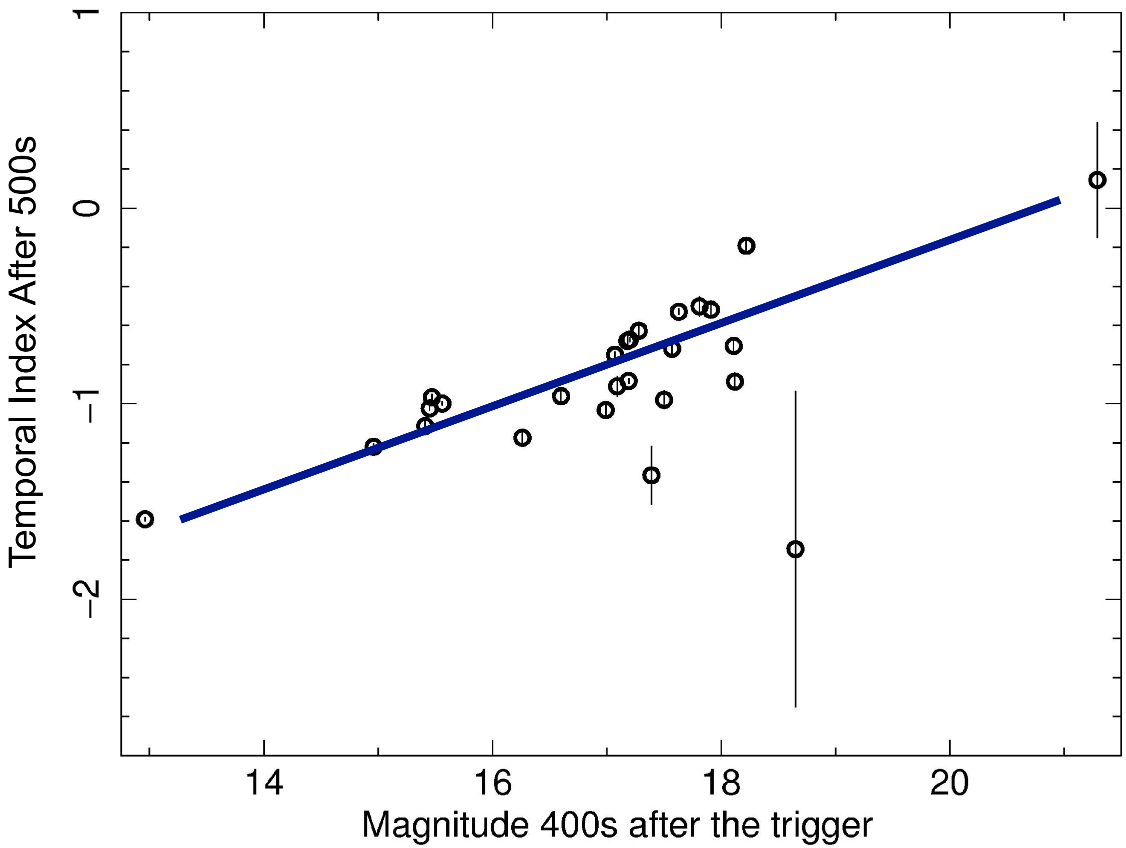
- 7 filters normalized and co-added to form single filter light curve, equivalent to UVOT *v* band

Brightest GRBs decay the quickest



Oates et al. 2009

Observed Brightness versus Decay Rate

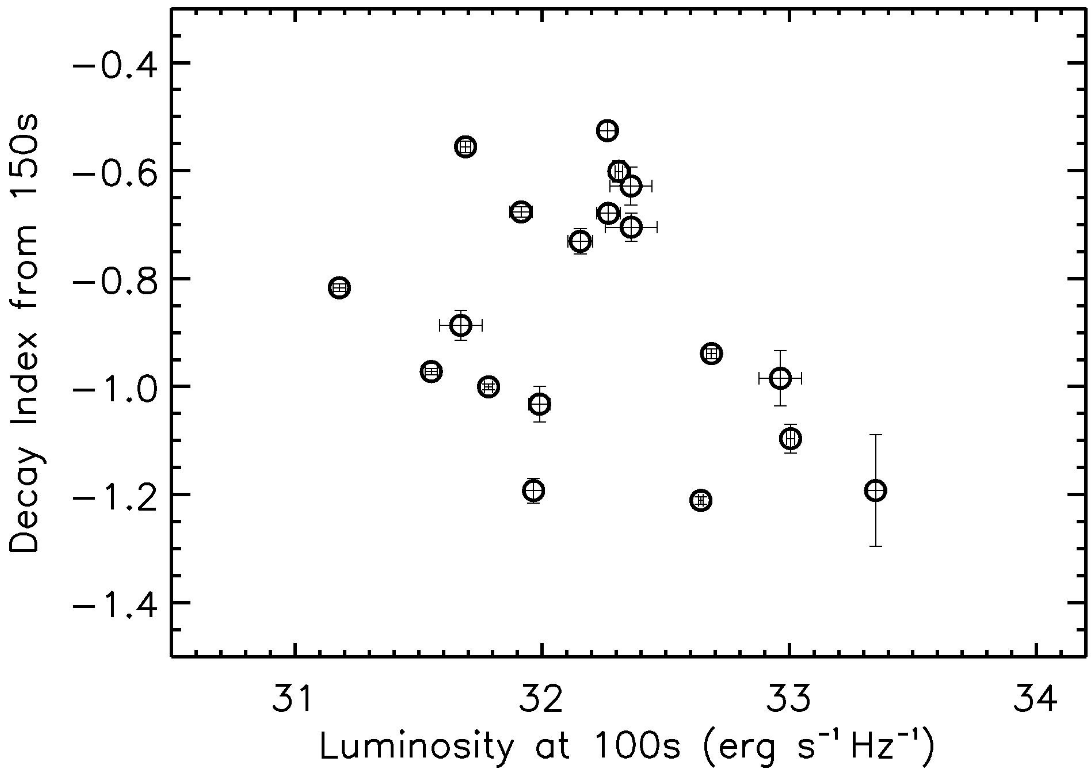


Significant correlation

Spearman rank correlation: 0.59 at 99.9%

Luminosity at 1600Å versus Decay Rate

-19 GRBs

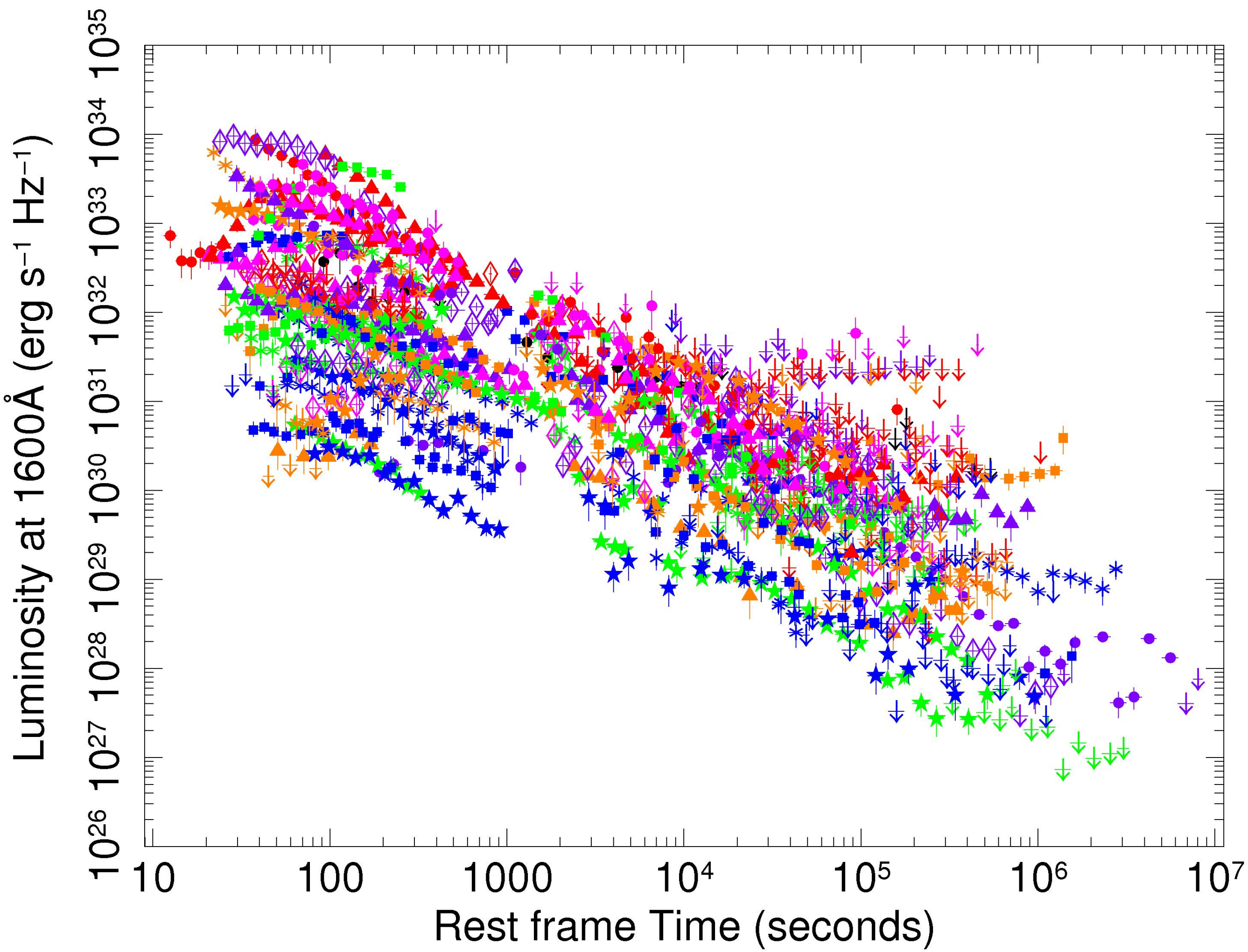


No Significant correlation

Spearman rank correlation: -0.25 at 70%

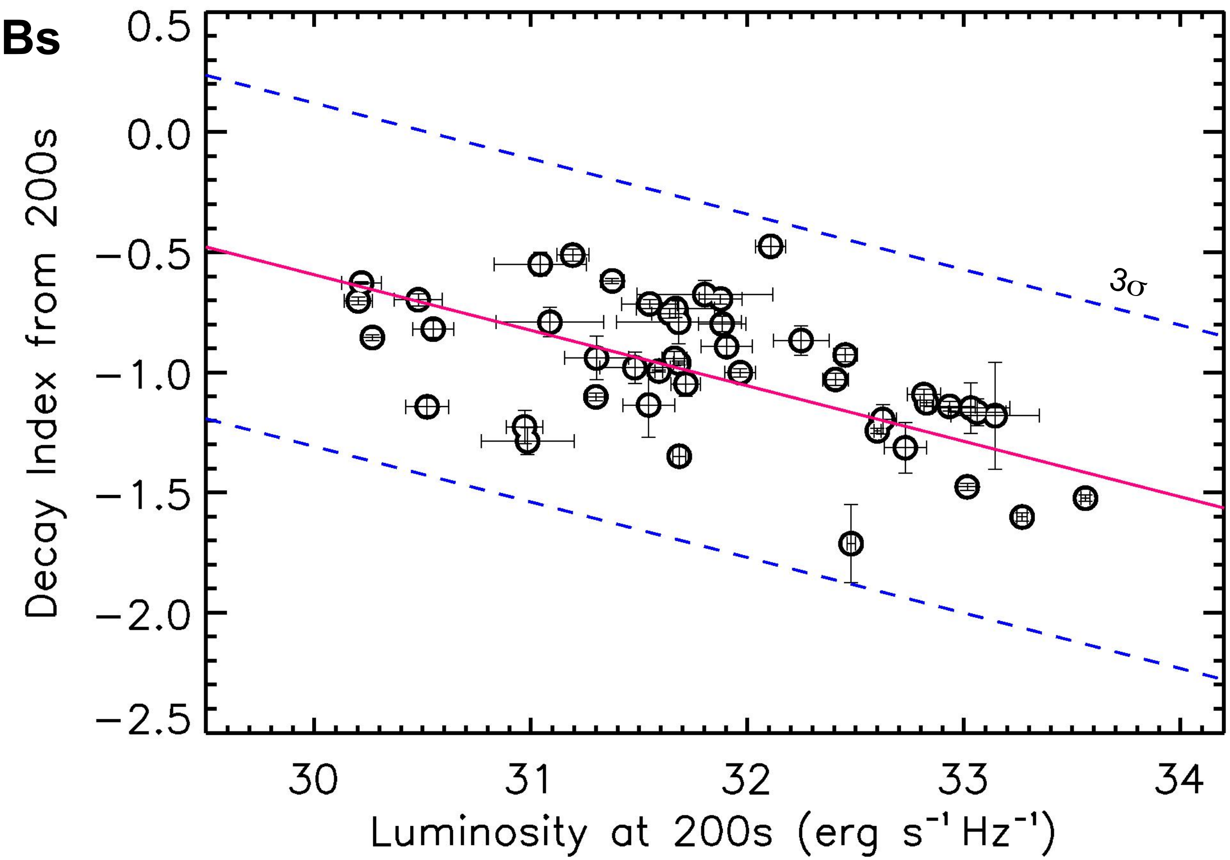
Luminosity Light curves at 1600 Angstrom

Sample: 56 GRB UVOT light curves (April 2005 - December 2010)



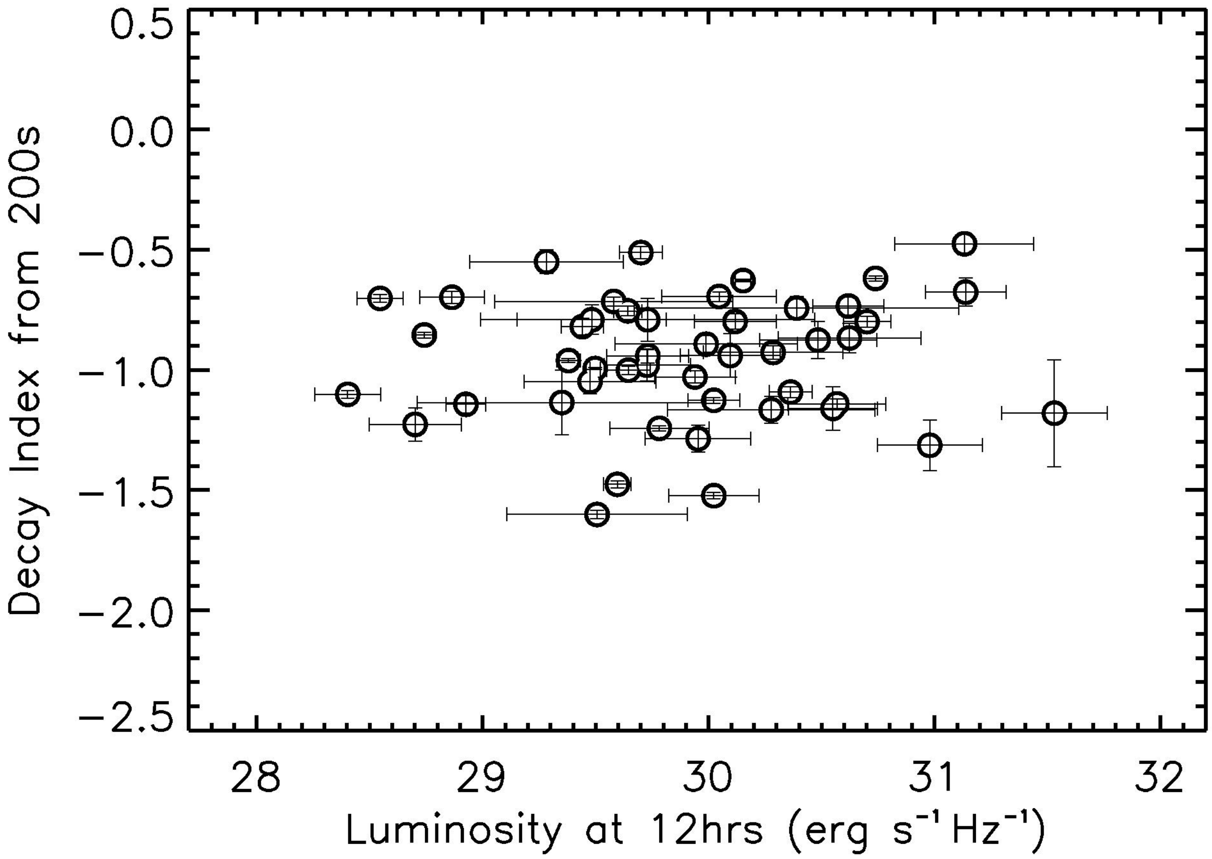
Luminosity at 200s versus Decay Index >200s

-47 GRBs



- Spearman Rank:
  - Coefficient of correlation: -0.54
  - Probability of Correlation: 99.99% (3.9σ)

Luminosity at 12hrs versus Decay Rate >200s

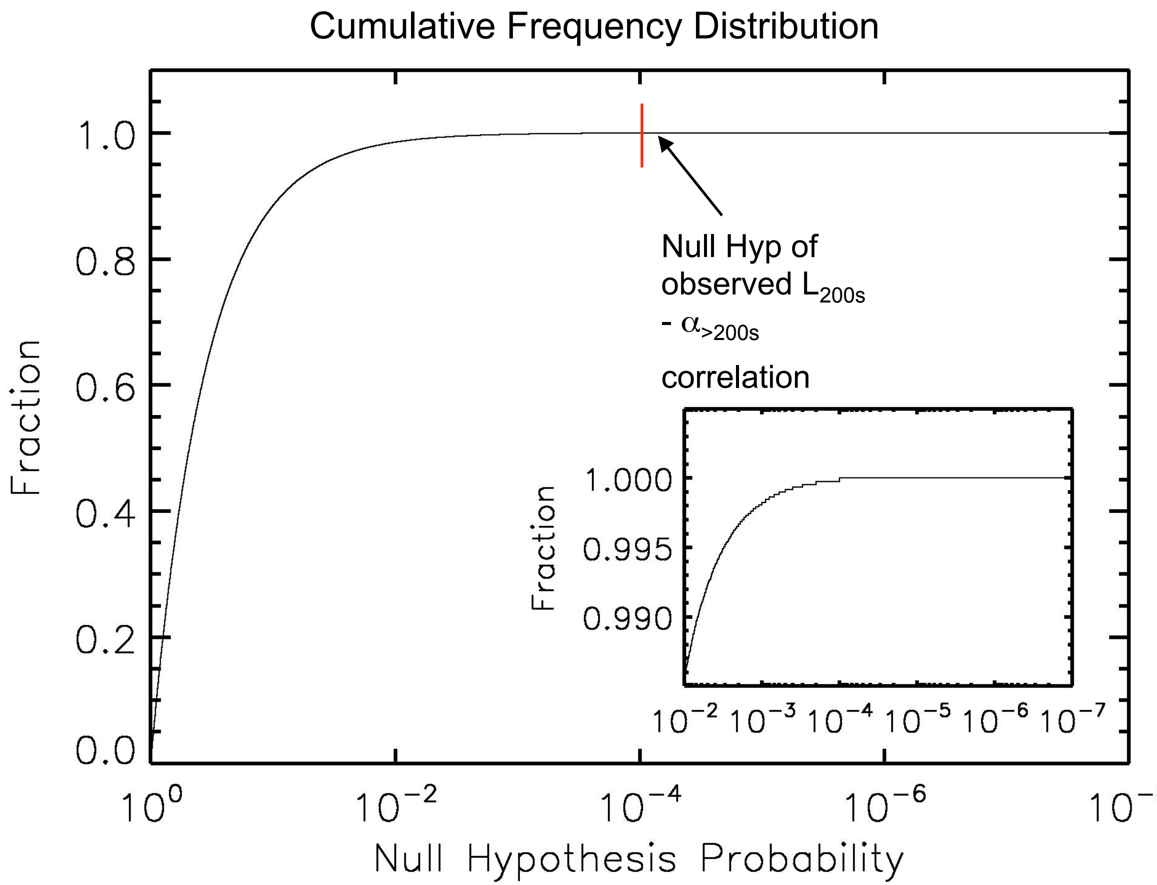


- Spearman Rank:
  - Coefficient of correlation: 0.07
  - Probability of Correlation: 36%

Is the correlation due to our selection criteria?

Monte Carlo Simulation 10^6 trials.

- Simulate 47 data points with random L_{200s} & $\alpha_{>200s}$
- Simulated observed frame light curve
- Is observed frame light curve consistent with selection criteria?
- If no exclude L_{200s} & $\alpha_{>200s}$ data point.
- Perform Spearman Rank test on remaining L_{200s} & $\alpha_{>200s}$



Probability that correlation is not due to chance: 99.97% (3.6σ)

What are the possible causes of this correlation?

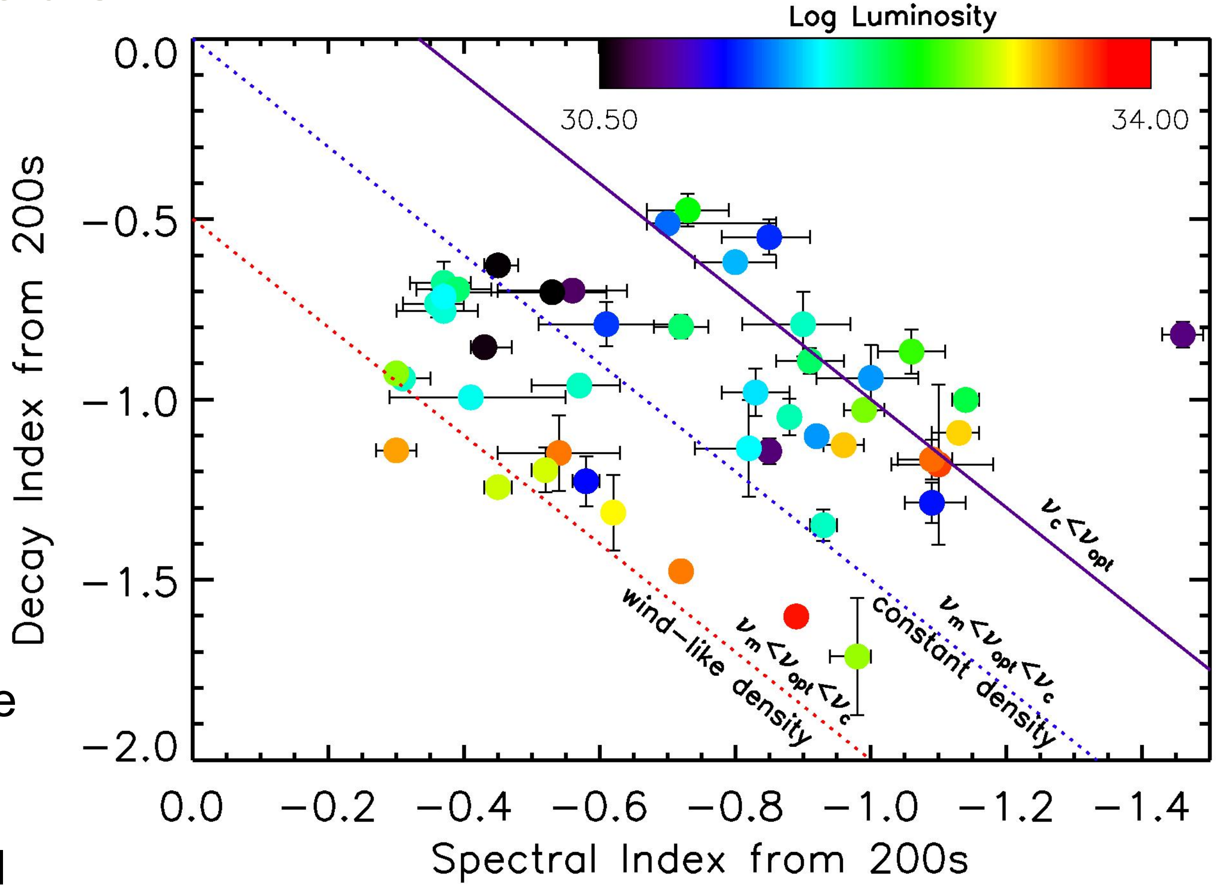
Intrinsic property of GRBs

- Geometric or physical/microphysical causes

Three Main Possibilities

Is the correlation a natural consequence of the standard model?

- $L \propto t^{\alpha}\nu^{\beta}$
  - Temporal index α
  - Spectral Index β
- Simplest case:
  - α and β related by closure relations
  - No energy injection
- Two options:
  - All optical afterglows produced by same relation, i.e lie on same spectral segment
  - Or, optical afterglows lie on different spectral segments i.e $\nu_c > \nu_{opt}$ or $\nu_c < \nu_{opt}$



Is the correlation determined by the GRB physical parameters?

- Including energy injection

- Physical and microphysical parameters that could be involved:
  - kinetic energy E_k, electron energy index p and the energy injection index q

- Optical afterglows have similar energies. Energy of the brighter optical afterglows released more quickly than the fainter optical afterglows.

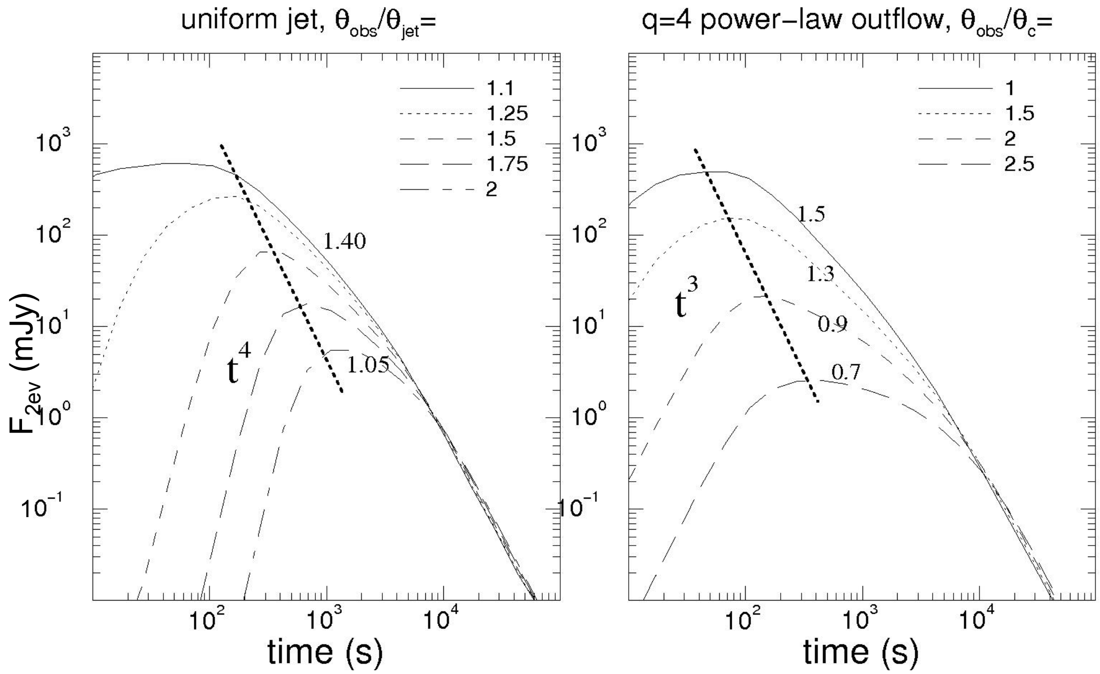
- The temporal indices of the shallow (faint) optical afterglows, possibly require energy injection.

- The outflow would somehow need to control how much energy is released initially and how much energy to continue to input into the afterglow.

Is it due to differences in our viewing angle?

- Optical afterglows viewed more on-axis are brighter and decay more quickly.

- Complicated by structure of the outflow



Panaitescu & Vestrand 2008

Evidence required to support this model:

- Peak time related to peak luminosity
- Late time behaviour tending towards narrow range of values

Conclusions

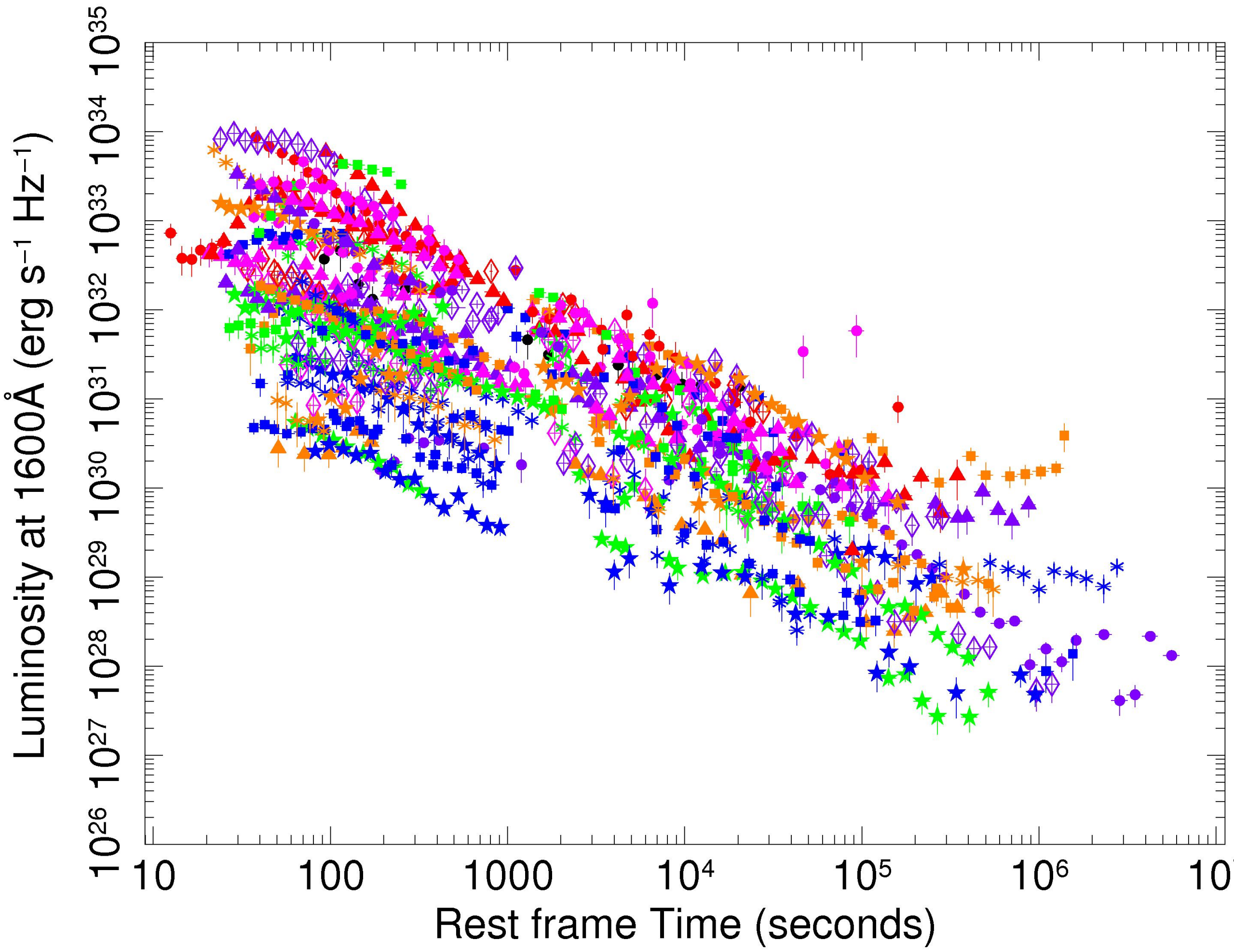
- Correlation observed between $L_{1600A@200s}$ & $\alpha_{>200s}$
  - Spearman Rank correlation coefficient of -0.53 at ~4σ

- Correlation is intrinsic to GRBs, not due to selection effects.
  - Unlikely this is a natural consequence of the standard model
  - Due either to:
    - Viewing angle effects, with jets viewed more on-axis having brighter and faster decaying afterglows than those viewed at larger angles.
    - Energy given to optical afterglow is similar for all GRBs, with energy being released more quickly in brighter events.

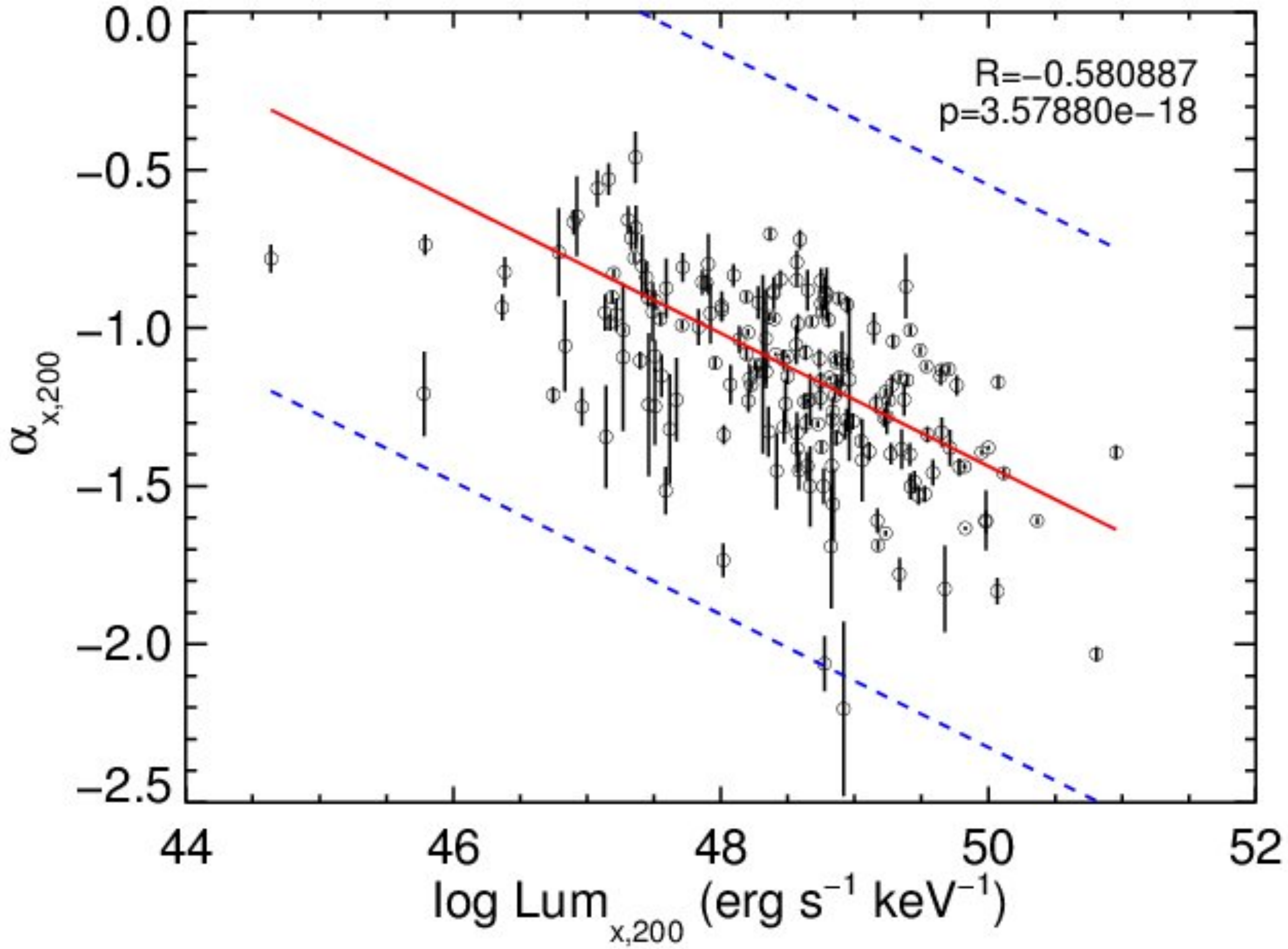
With further investigation it may be possible to determine the redshift of a GRB from the decay rate of the optical afterglow.

Luminosity Light Curves at 1600Å

-no upper limits

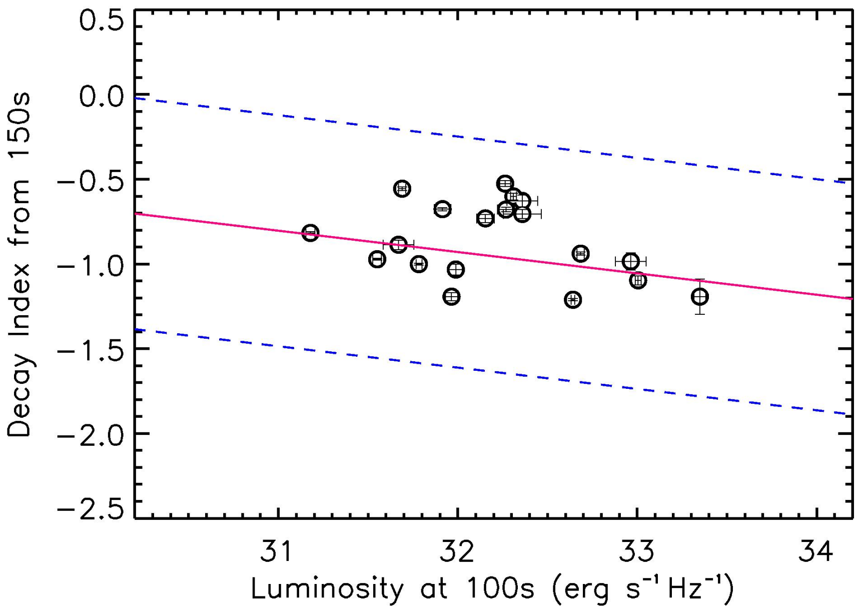


X-ray Luminosity at 200s versus Decay Rate >200s



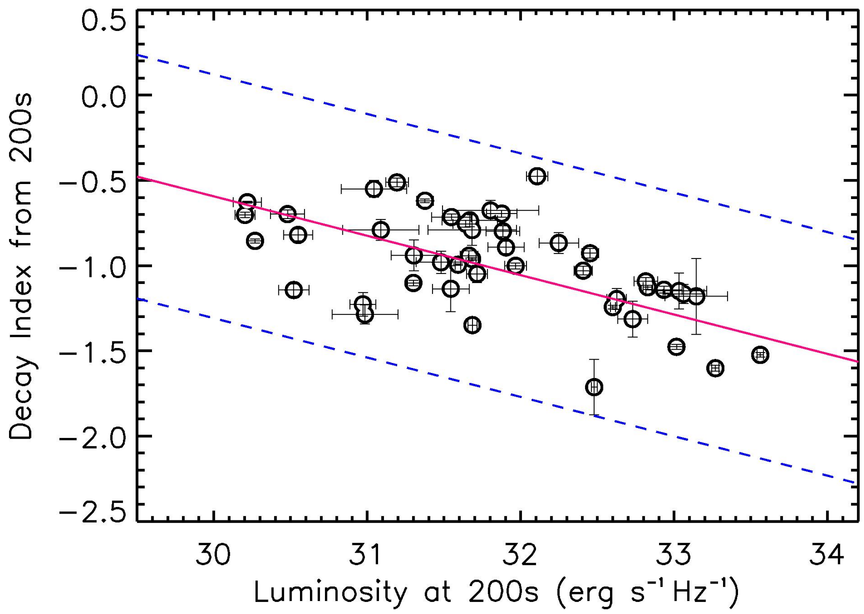
Luminosity at 200s vs Decay Rate > 200s

-comparison of samples



April 2007 - June 2007

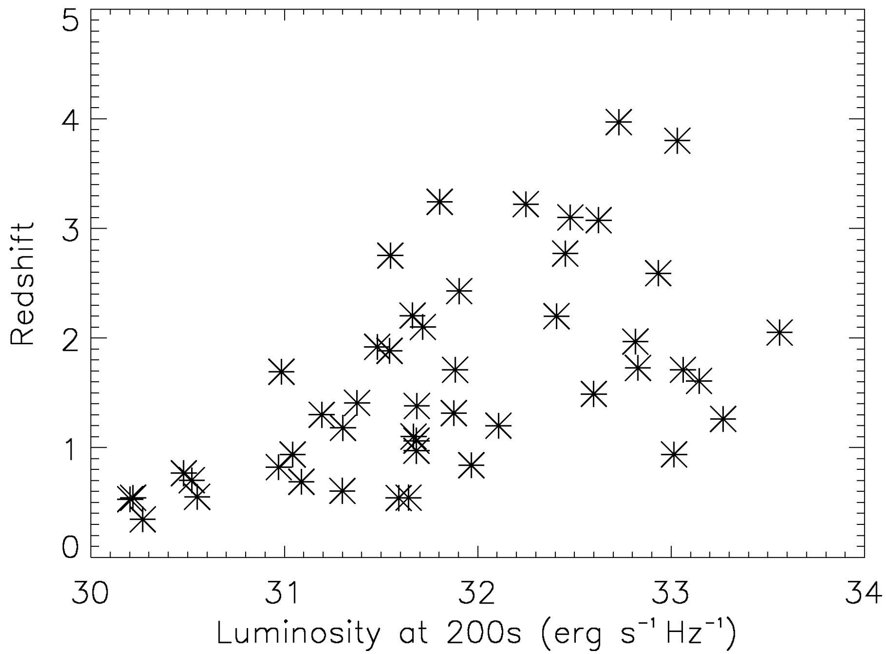
19 GRBs

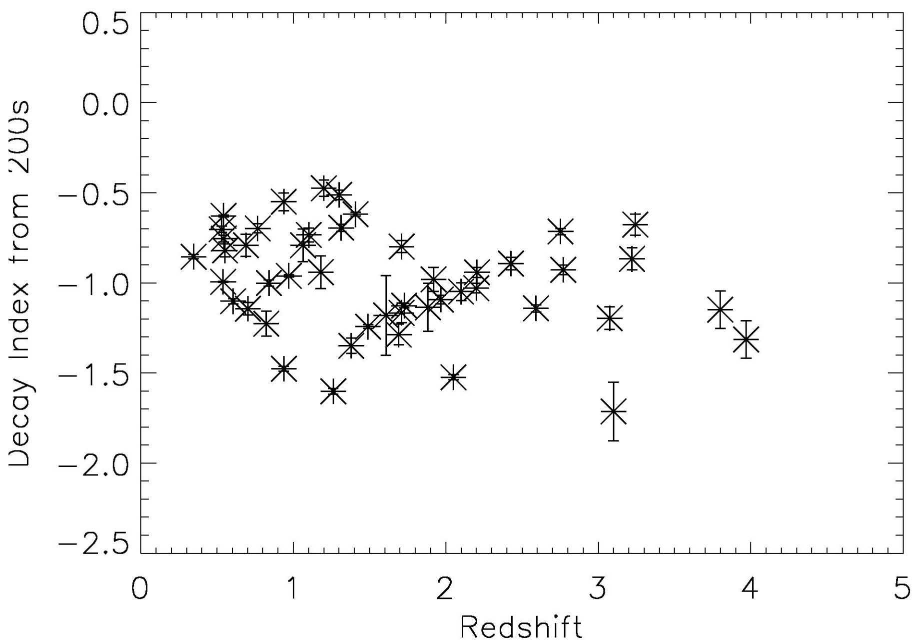


April 2007 - December 2010

47 GRBs

Is the correlation related to redshift?

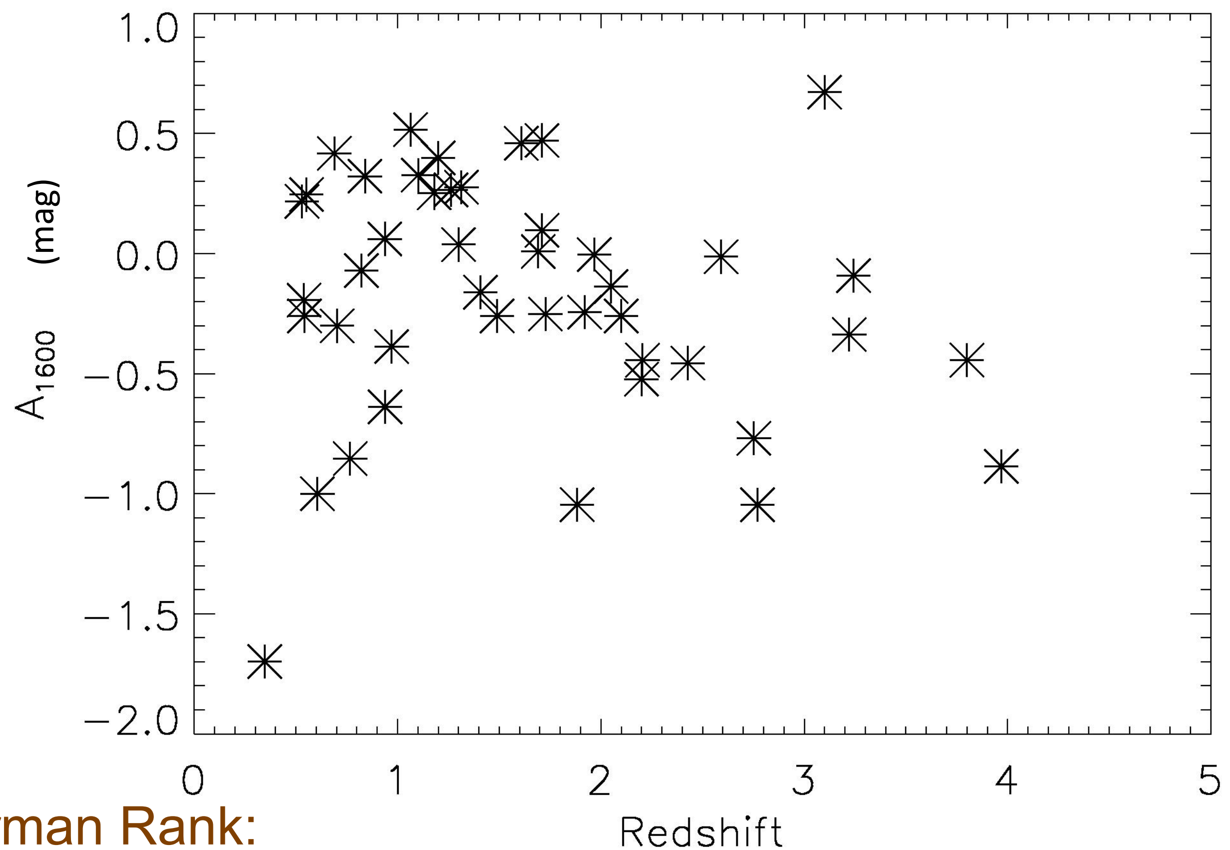




- Spearman Rank:
  - Coefficient of correlation: 0.62
  - Probability of Correlation: 99.997%
  - Selection effects

- Spearman Rank:
  - Coefficient of correlation: -0.35
  - Probability of Correlation: 96%

Redshift versus Host Extinction (1600Å)



- Spearman Rank:
  - Coefficient of correlation: -0.18
  - Probability of Correlation: 77%

Is the correlation a natural consequence of the standard model?

- $L \propto t^{\alpha}\nu^{\beta}$
- Simplest case:
  - α and β related by closure relations
  - No energy injection
- Two options:
  - All optical afterglows produced by same relation, i.e lie on same spectral segment
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