GRBs with Low-luminosity Afterglows: separate population?

H. Dereli

Department of Physics, Royal Institute of Technology (KTH), AlbaNova, SE-106 91 Stockholm, Sweden
The Oskar Klein Centre for Cosmoparticle Physics, Stockholm, Sweden

In collaboration:
M. Boër, B. Gendre, L. Amati, S. Dichiara and N. B. Orange
husnedereli@gmail.com

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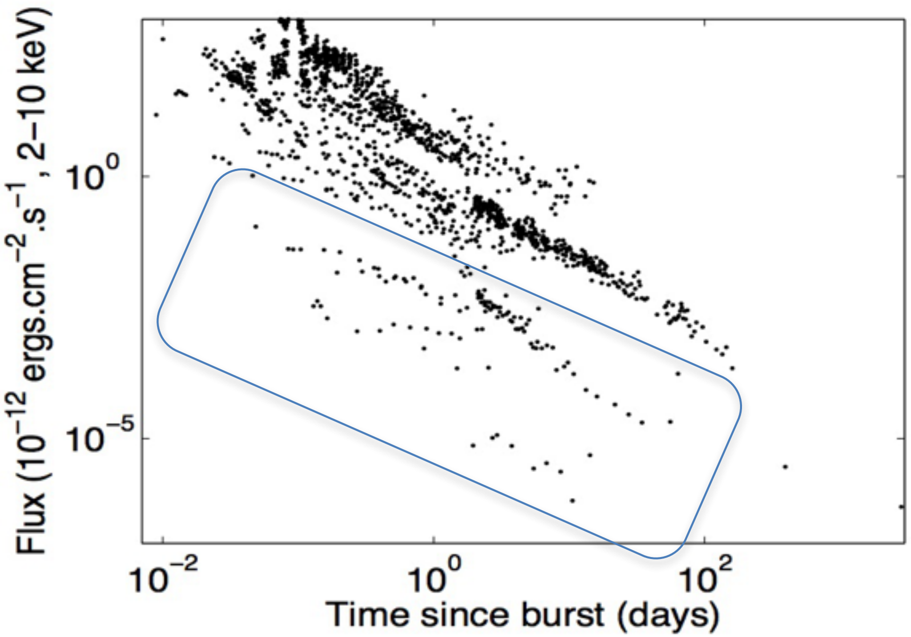
Introduction

- Gamma-ray bursts (GRBs), the most luminous events in the Universe: $E_{iso} = 10^{48} - 10^{54}$ erg (Mészáros 2006).

- A wide dispersion of the luminosity of their X-ray afterglows (Gendre et al. 2008).

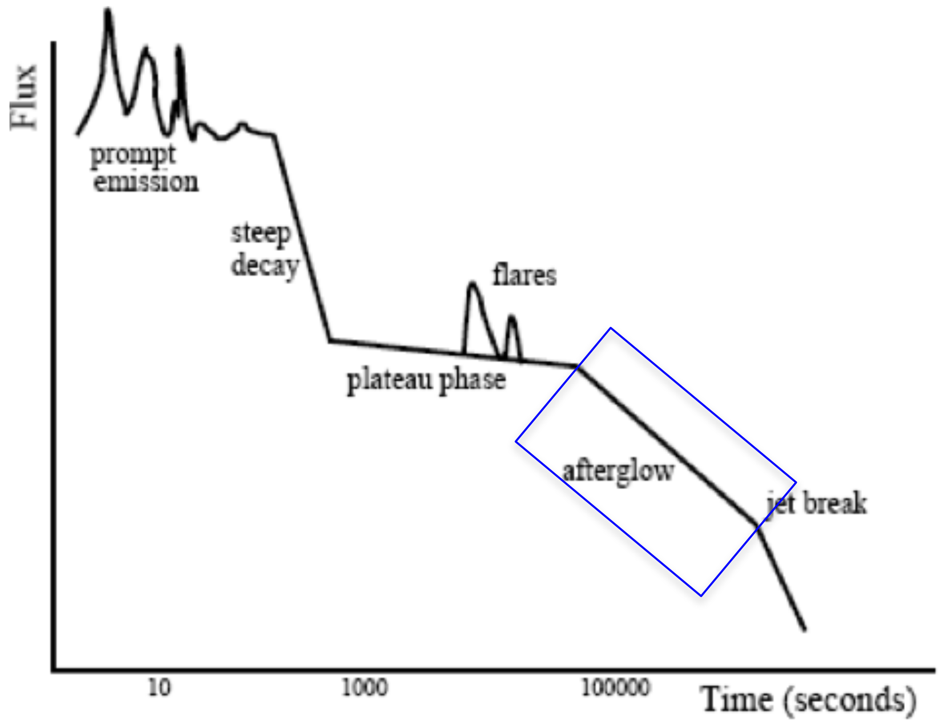
- Study of the faintest part of this distribution.

- Argued that they are a distinct population: published in H. Dereli et al. 2017)



Gendre et al. 2008

Introduction



Nousek J. A. et al. 2006;
Starling R.L.C 2008.

The outflow interact with the external medium : external shock

Constant ISM

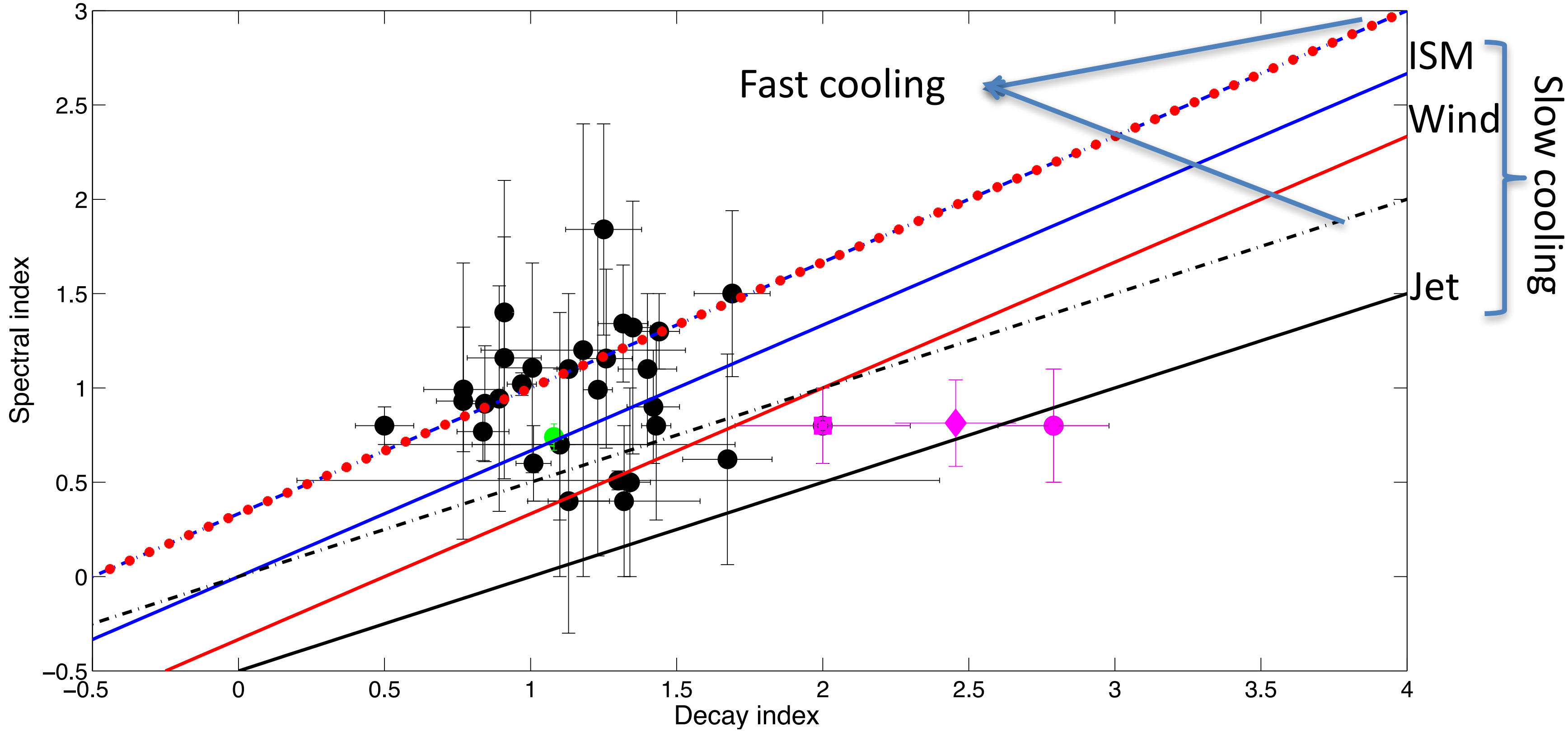
Wind: $n = \frac{n_0 r_0^2}{r^2}$

Sample Selection

- To define the sample:
  - ✓ all the bursts with a measured redshift, before 2017
  - ✓ only long GRBs: 326 bursts,
  - ✓ light curves rescaled at common $z = 1$,
  - ✓ a flux threshold of 10^{-13} ergs $s^{-1}cm^{-2}$ at one day, we discarded all the bursts above this limit,
  - ✓ 41 low luminosity afterglow events called group III GRBs.

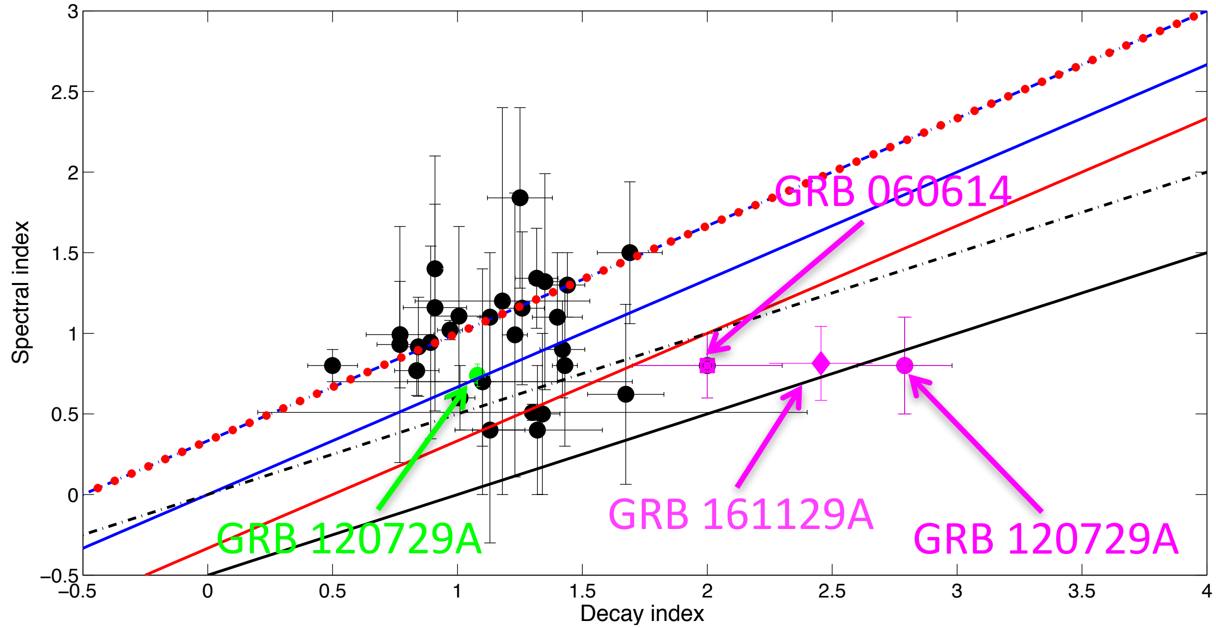
- No selection effects apply for gas absorption and dust extinction: the Milky-Way and the host galaxies.

Closure Relation I



- Combination of the spectral and decay indices into several closure relations (Mészáros et al. 1998; Sari et al. 1998, 1999; Chevalier & Li 2000; Zhang & Mészáros 2008).

Closure Relation II



- Group III GRBs follow the closure relation.
- Two GRBs can be explained by a jet:
  - $\nu_m < \nu_{XRT} < \nu_c$
  - achromatic jet break
  - opening angles: 2.7° (120729A), 6.3° (060614) compared to the mean: 4.7° (long GRBs)

It implies near on-axis observations for group III GRBs.

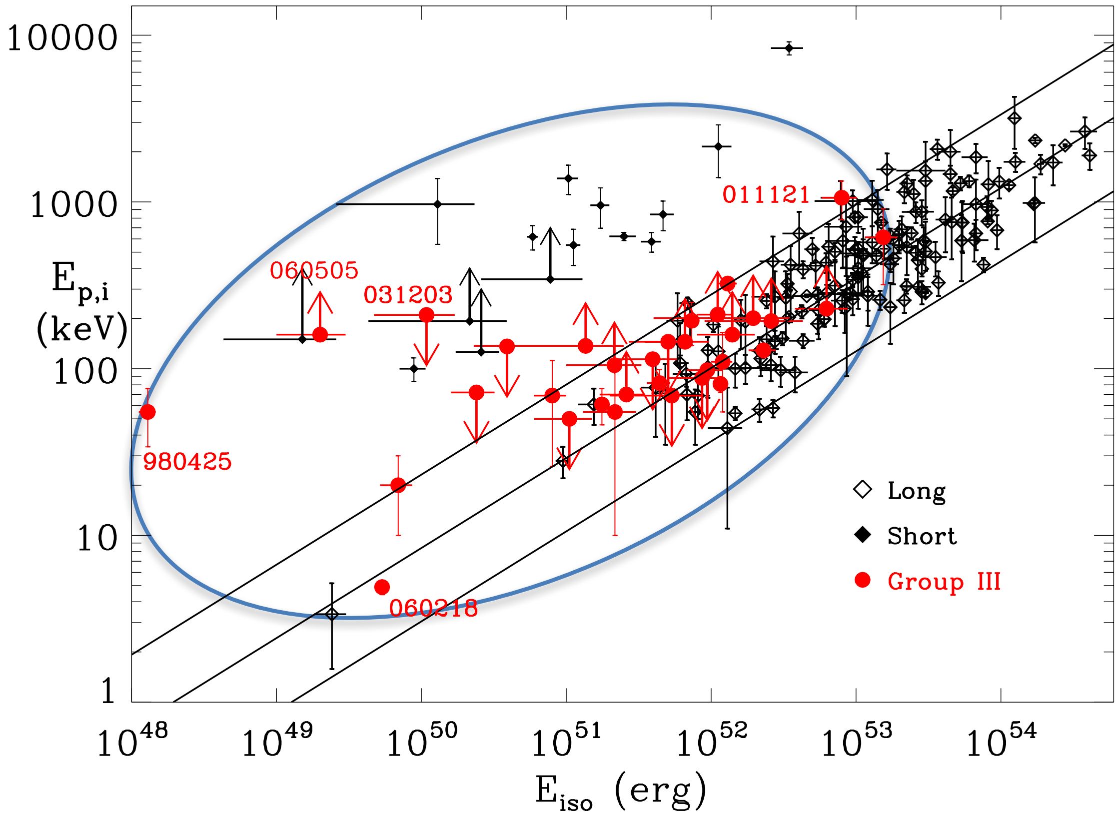
Microphysics of the fireball

- For most of the GRBs,
  - Gendre et al. 2006; De Pasquale 2006 show $\nu_c < \nu_{\mathrm{XRT}}$
- But in the group III GRB $\nu_c > \nu_{\mathrm{XRT}}$.

- The magnetic fraction of jet ($\varepsilon_{\mathrm{B},2}$) in homogenous ISM and in wind medium is not really constraining.

- Conclusion, under the hypothesis of the burst expanding in an ISM, the uncommon position of the cooling frequency is due to the small energy of the fireball.

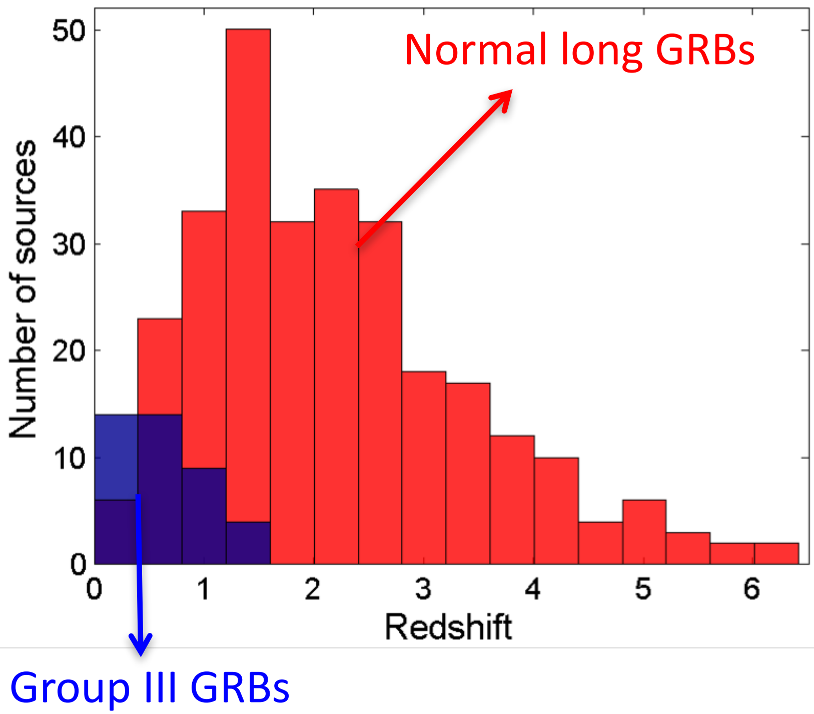
Amati Relation



- No large differences for the E_{peak} values, a bias due to Swift/BAT instruments.
- Smaller E_{iso} for group III sample: less energetic in their prompt phase compared to normal long GRBs.

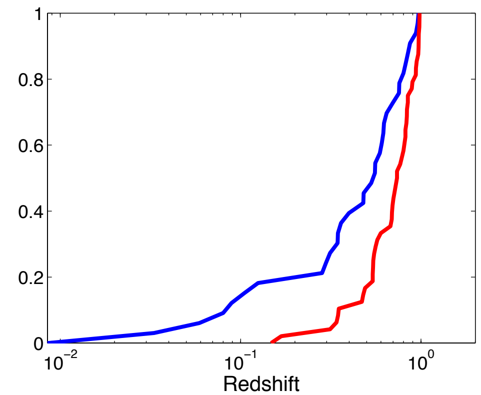
Redshift distribution

- One more significant difference when studying the redshift distribution.



Result of K-S test: 1.69×10^{-15}

- Considering the selection effects on the faint events at large distances,
  - ✓ compared the redshift distributions of the two types of GRBs truncating it at z=1



  - ✓ found that they are unlikely to be drawn from same sample.

Result of K-S test: 8.1×10^{-3}

Effect of the Luminosity Distribution Function

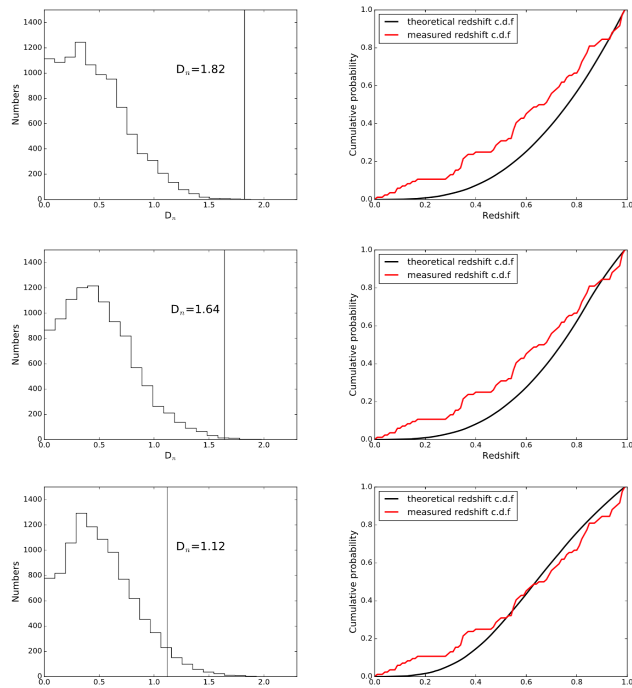
- First possible explanation for the difference in the redshift distributions
- Hypothesis: a low-luminosity tail of the luminosity function can introduce a population of sources seen only at low redshift.
- Ran a Monte Carlo (MC) simulation using existent luminosity and redshift distribution functions from the literature.

Results:

✓ Howell & Coward (2013) (power law with an exponential cutoff) corresponds to a probability of 99% to be rejected.

✓ Liang et al. (2007) (broken power-law) reflects a probability of 99.75% to be rejected.

✓ a customized version of the luminosity function from Liang et al. (2007), to which an exponential cutoff at 3×10^{48} erg s^{-1} was added, gives a probability of 91.57% to be rejected. This was done as it artificially increases the ratio between close and distant bursts.



- This leads us to conclude that group III GRBs seem to form a different population than classical lGRBs.

Discussion:

Link between Group III Events and Low-luminosity GRBs

- Several GRBs with a very faint prompt emission observed: GRB 980425, GRB 031203, GRB 060218 and GRB 100316D, they are associated to SN.
- On a single burst basis, they were found not to be part of the normal lGRB population.
- These low-luminosity GRBs are members of our group III events.
- The mean properties of GRBs with a low-luminosity afterglow presented here might apply to these GRBs.

New candidate: GRB 171205A/SN2017iuk

Conclusion

- Three groups found in X-ray observations of gamma ray burst afterglows. The low luminosity one
  - represent 12.5% of all the bursts.

- Group III GRBs are argued as a different population with
  - difference in the redshift distribution (in average closer than normal long GRBs)
  - not being effect by luminosity function (luminosity functions for lGRBs are unlikely to reproduce them)
  - position of the observed frequency (have cooling frequency larger than X-ray frequency)
  - prompt properties (intrinsically less energetic)
  - association with SN (several of them are associated to SN)

Reference:

H. Dereli, M. Boer, B. Gendre, L. Amati, S. Dichiara, and N. B. Orange. 2017 ApJ, 850:117