Consequences of selection effects on Epi-Liso and Epi-Eiso relations

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GRBs as standard candles ?

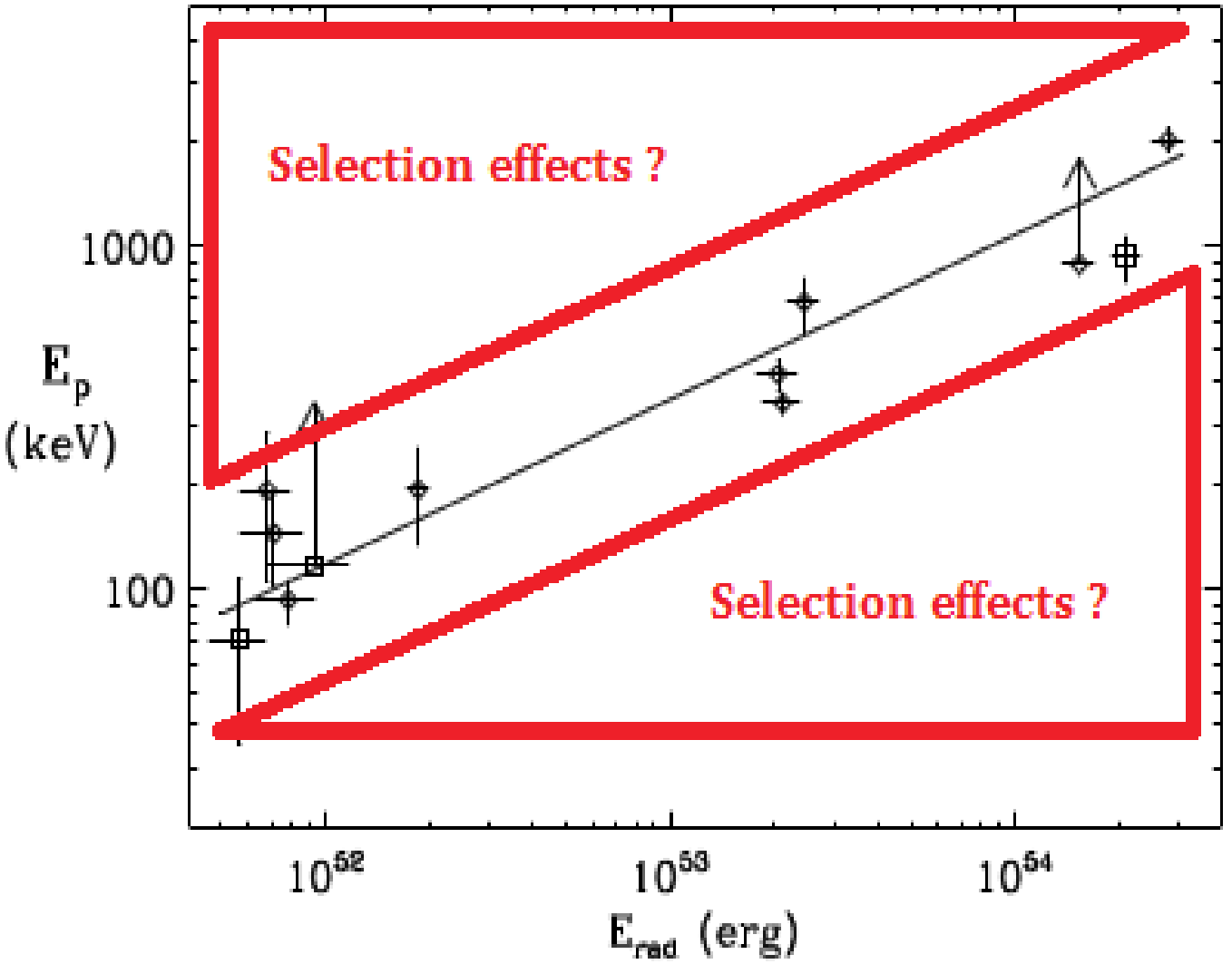
GRBs = **large redshift domain** : access to **early Universe phases**

Not directly standard candles → standardize them

Two ways to do this :

- **Spectral relations** : work presented here (Heussaff et al 2013)
- **Temporal relations** : work in progress

A long debate



Nakar et Piran 2005,
Band et Preece 2005,
Schaefer et Collazzi 2007,
Butler et al 2009,
Goldstein et al 2010,
Shahmoradi et al 2011,
Collazzi et al 2012,
Kocevski et al 2012

Amati et al 2006,
Krimm et al 2009
Ghirlanda et al 2010,
Amati et al 2010,
Nava et al 2012

The sample

We need : homogenous sample and reliable spectral parameters
→ same instrument + Epo measurement → **Fermi GBM catalogue**
→ selection criteria on alpha, beta and Epo

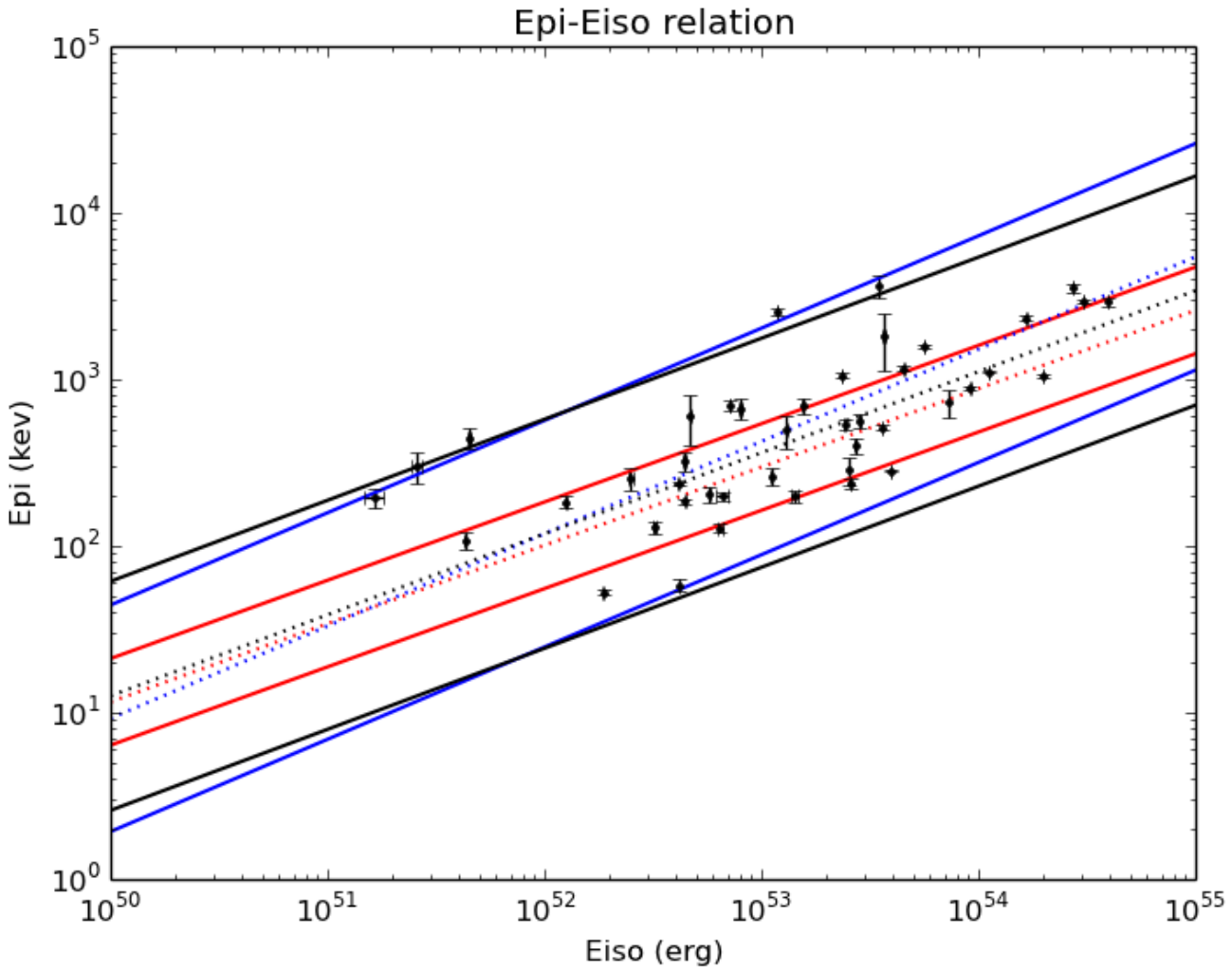
Criteria :

- **2s<T90<1000s** : exclude short and very long GRBs
- **Error on alpha <0.4**
- **Error on Epo smaller than a factor 3**
- Alpha < -2.0, alpha < beta
- Beta > -2.0 → not the real Epo → GCN circulars

Sample :

Fermi GBM Catalogue GRB080714086 to GRB100709602 = **482** GRBs
267 pass the cuts, **24** with z + **19** Fermi GRBs (GCN circulars)
→ **243** without redshift, **43** with one

The relation

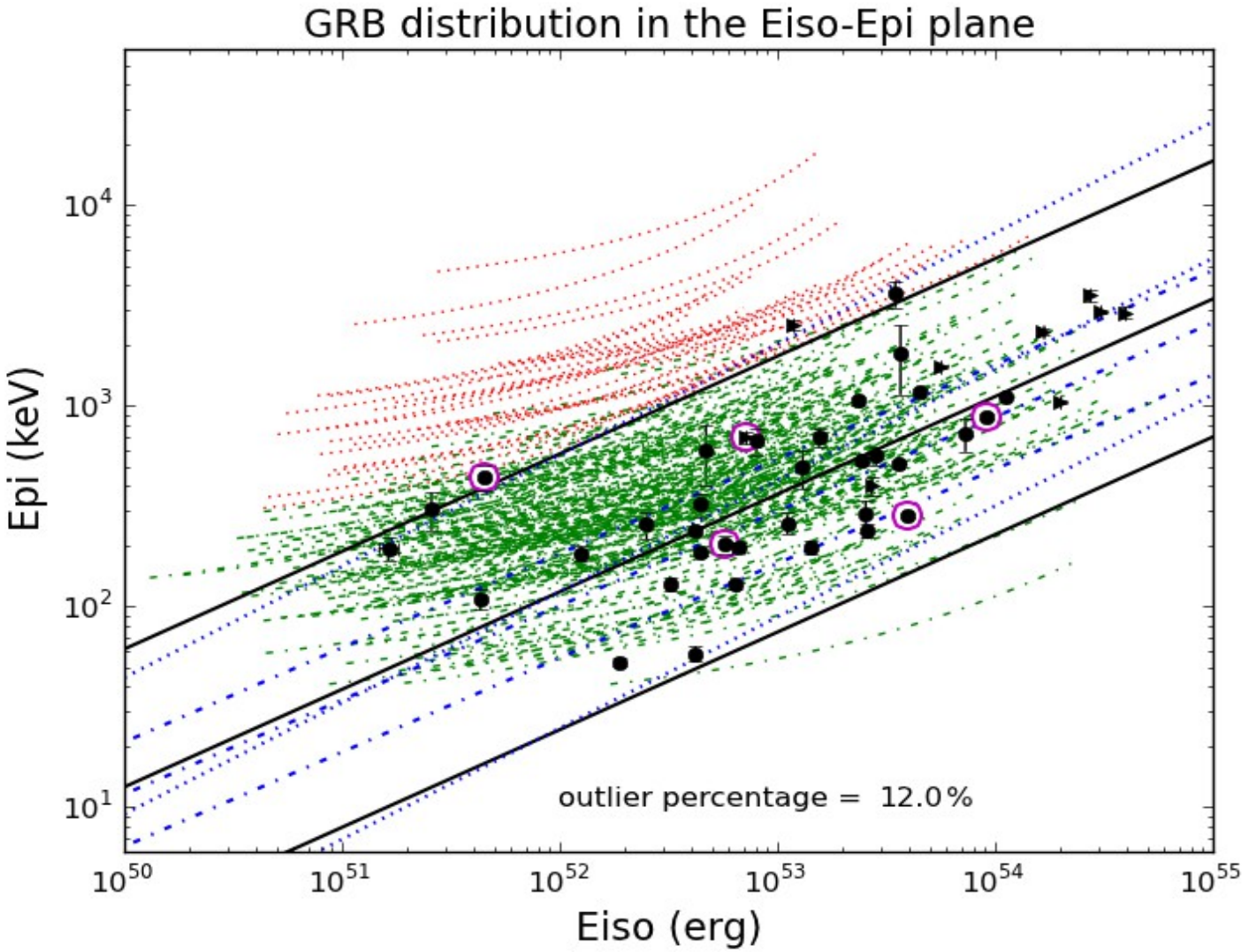


Epi = 118 (E52)^{0,486}
Vertical standard deviation = **0.34**
Standard deviation perpendicular to the best fit line = **0.21**

Gruber et al. (2012) :
Epi = 120 (E52)^{0,55}
Nava et al. (2012) :
Epi = 119 (E52)^{0,554}

Amati et al. (2006) :
Epi = 101 (E52)^{0,47}

Existence of outliers



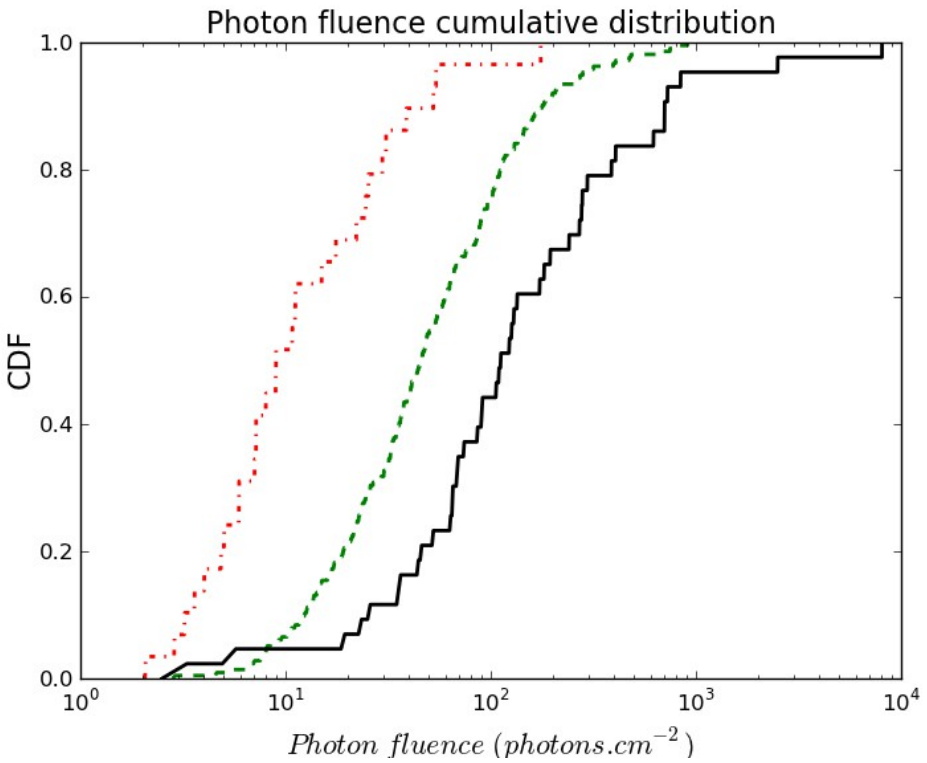
GRBs without redshift = Lines in the Epi-Eiso plane

Redshift range of the lines = **0.34-4.35**

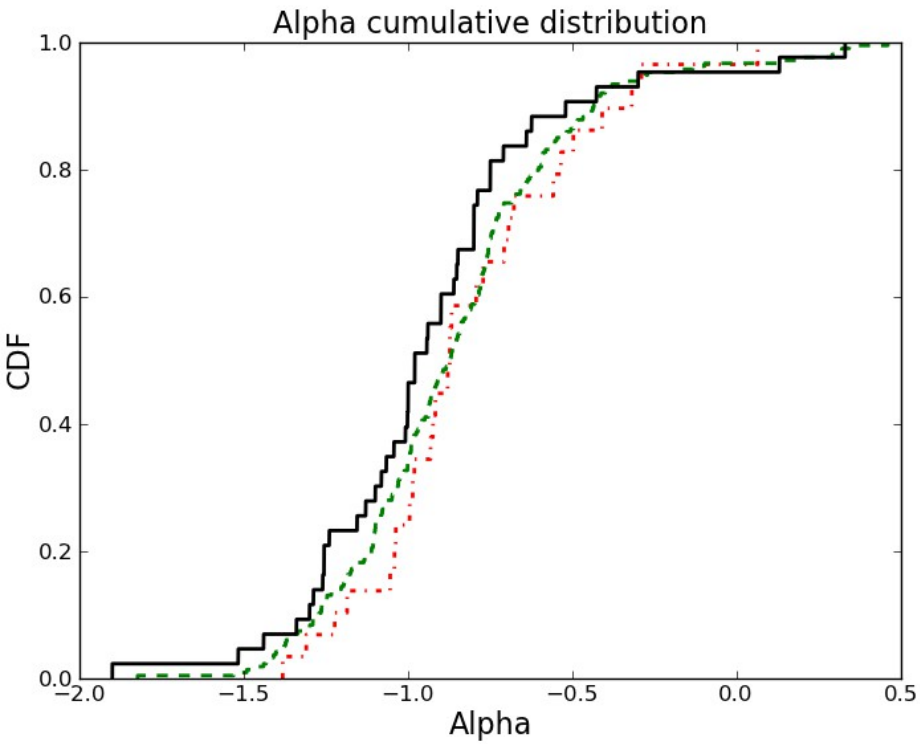
Outlier percentage = 12 %

Outliers properties

CDF of Fluence

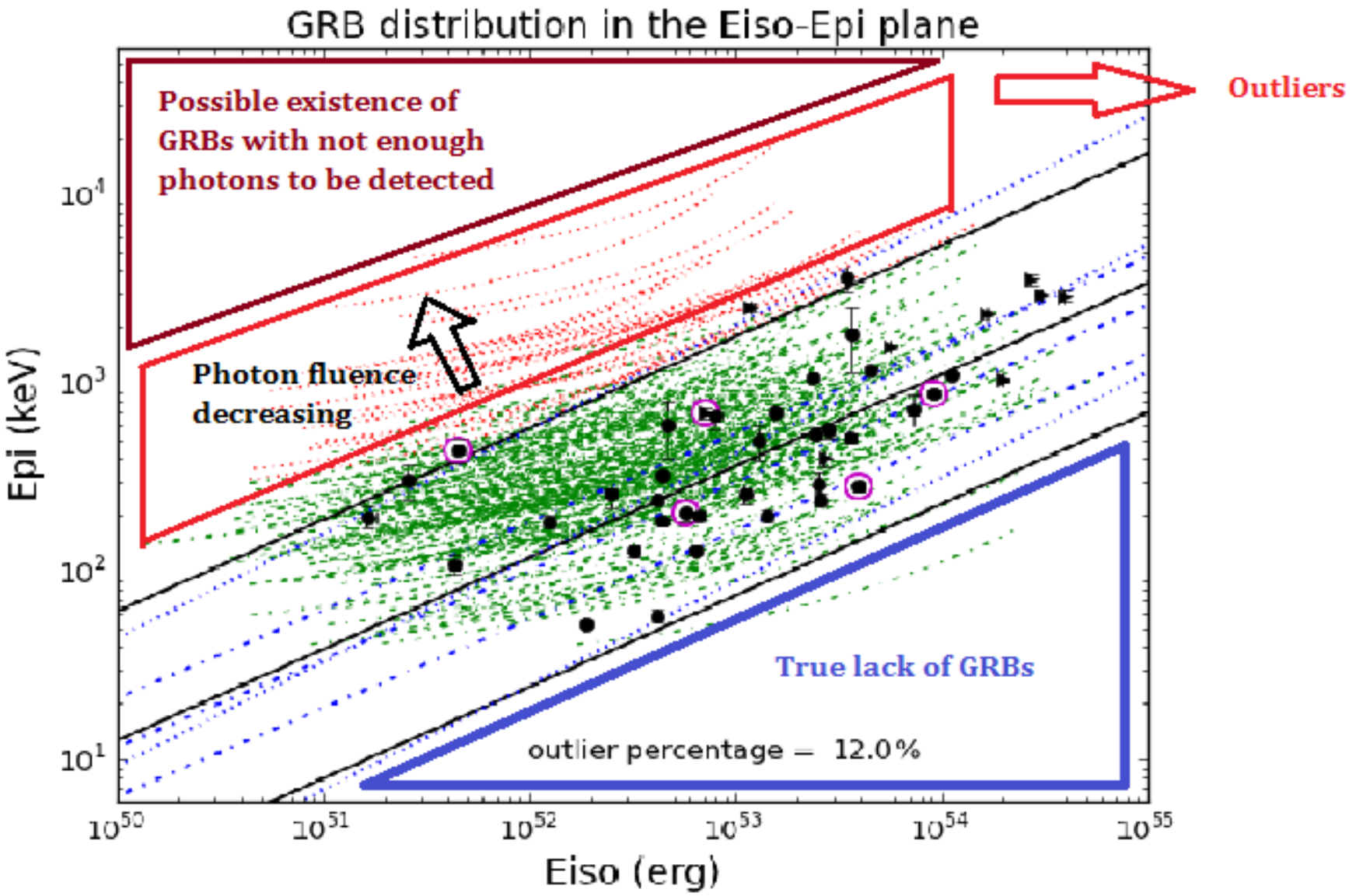


CDF of alpha



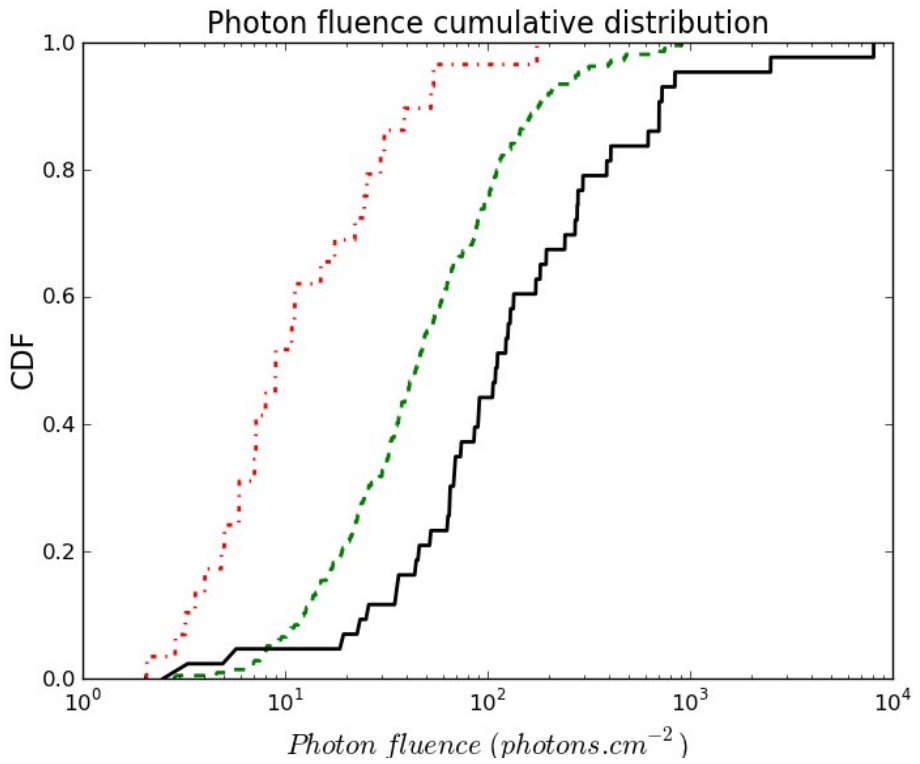
Outliers are fainter = lower fluence

First selection effect

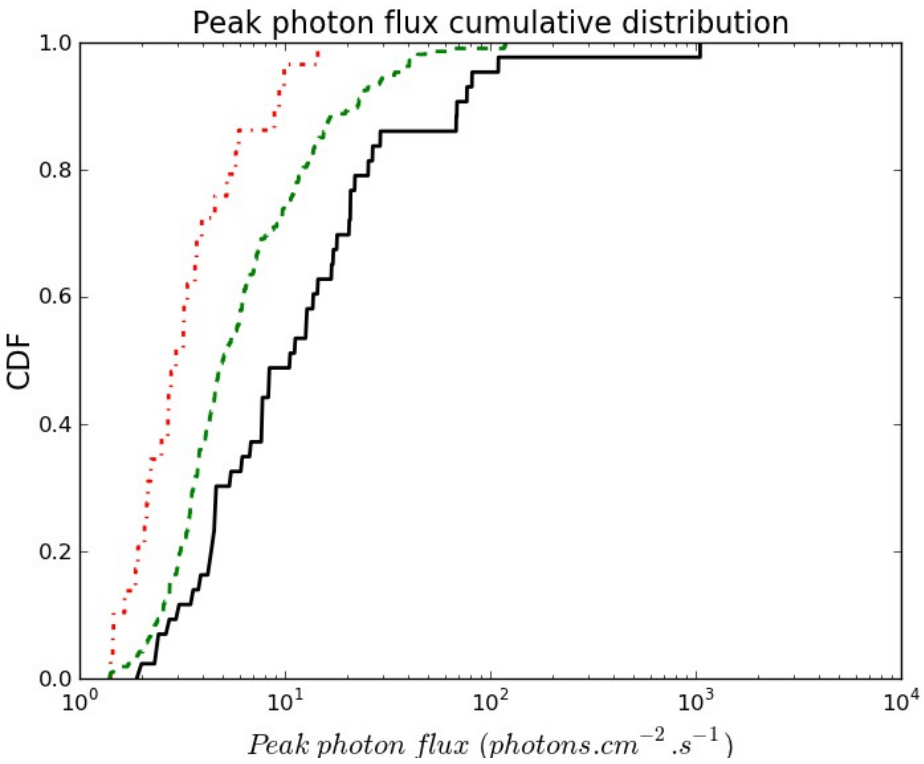


GRBs with z properties

CDF of Fluence



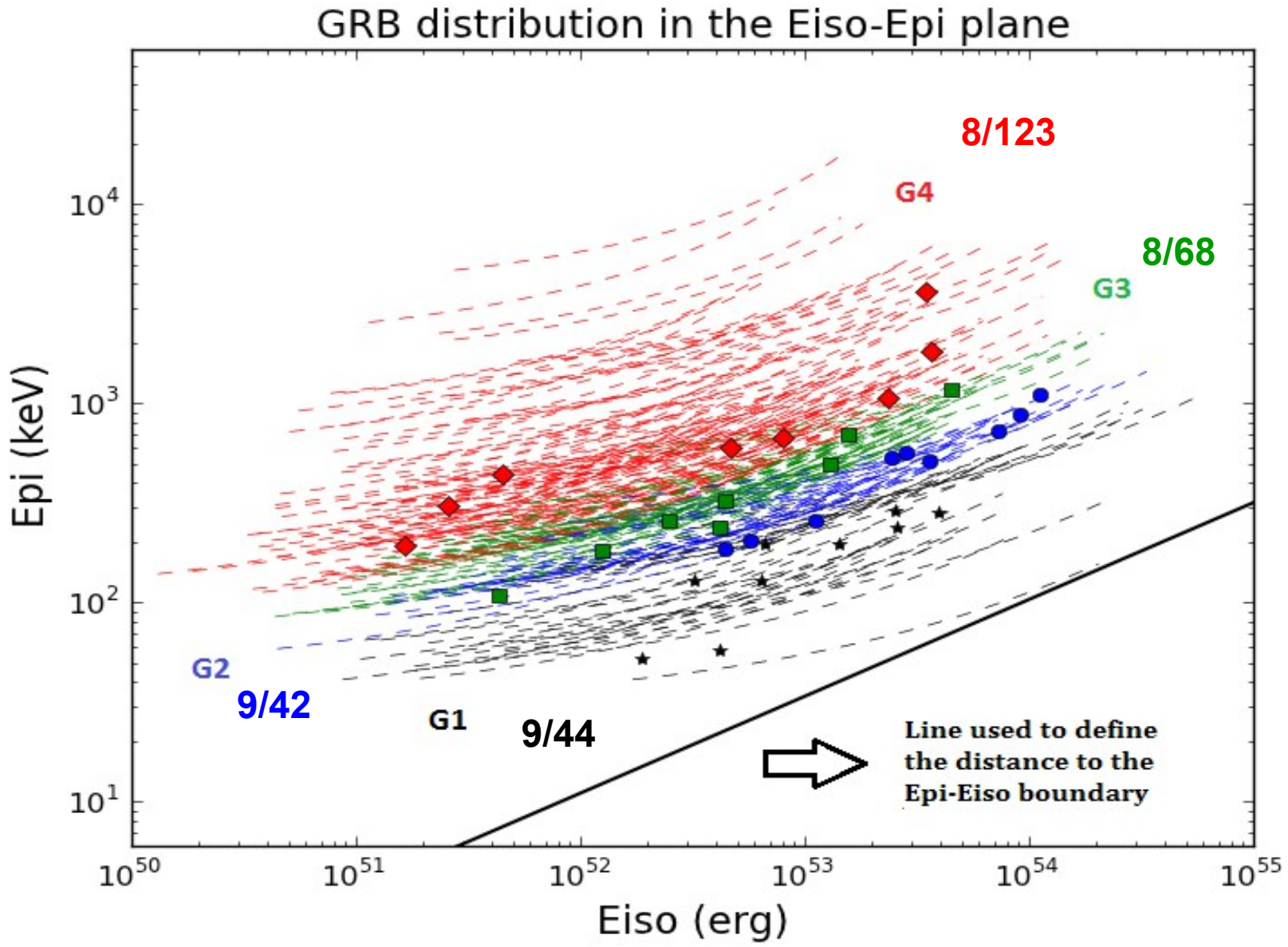
CDF of Peak flux



GRBs with redshift are brighter = higher fluence and peak flux

Is there a selection effect on redshift measurement?

GRBs with redshift study



GRBs with redshift study

V/Vmax values :

- G1 : 0.28
- G2 : 0.35
- G3 : 0.51
- G4 : 0.75

→ **Increasing with the distance** to the Epi-Eiso boundary

→ **GRBs with z** more easily detected **close to the Epi-Eiso boundary**

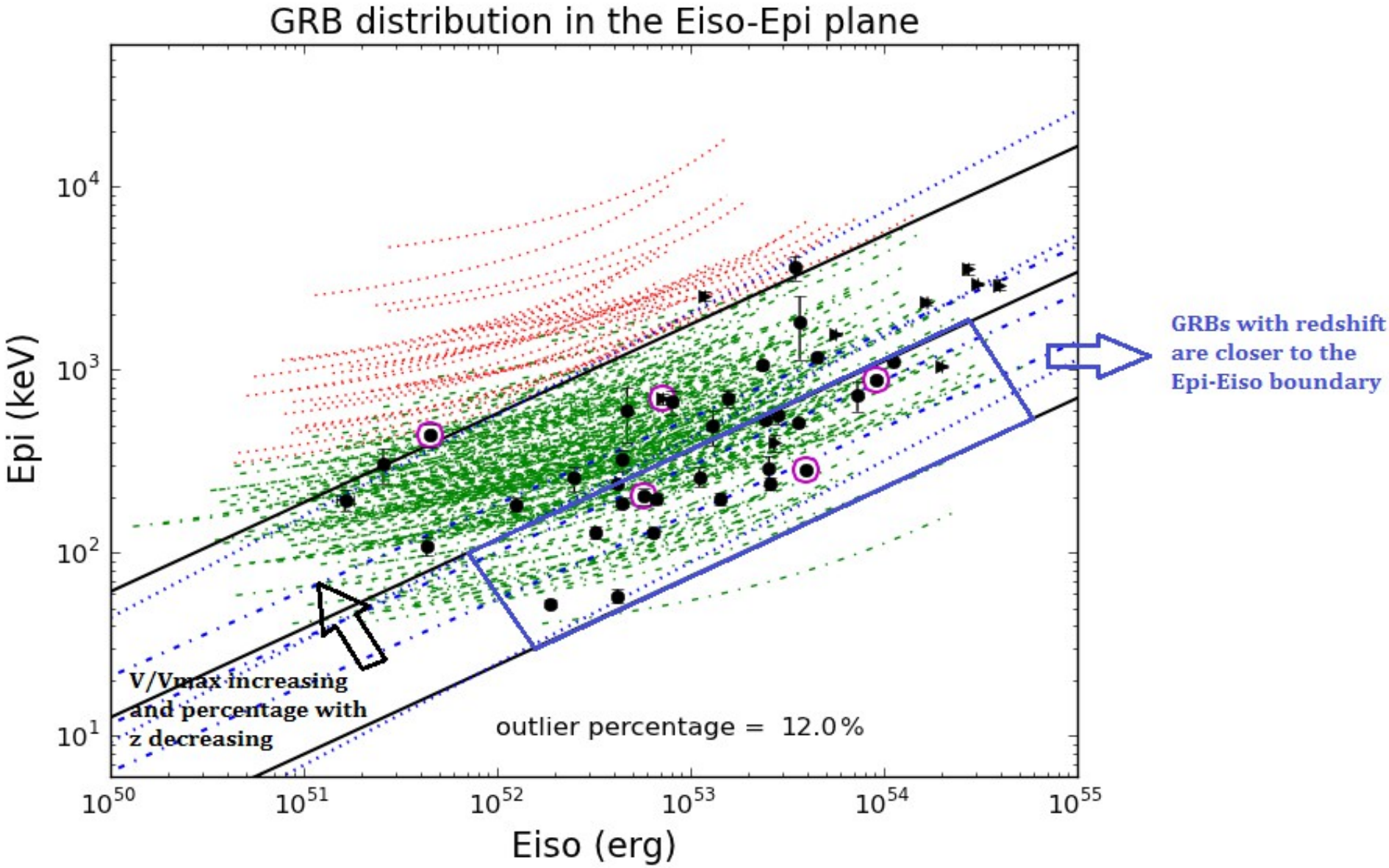
GRBs with z percentage :

- G1 : 9/44 → 0.20
- G2 : 9/42 → 0.21
- G3 : 8/68 → 0.12
- G4 : 8/123 → 0.065

→ **Decreasing with the distance** to the best fit line

→ It is **easier to measure z** for GRBs **close to the Epi-Eiso boundary**

Second selection effect



Conclusions Epi-Eiso

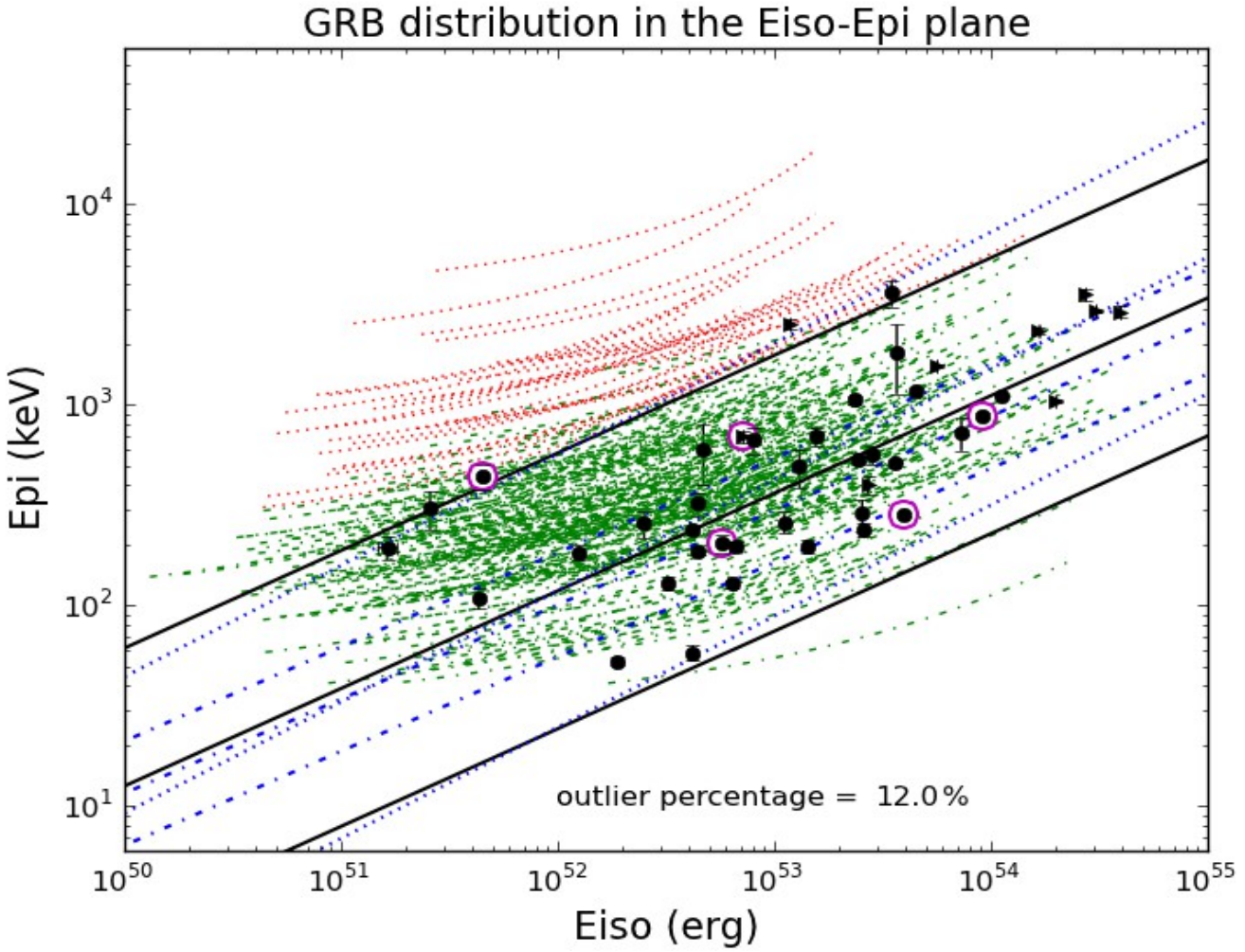
We have **2 selection effects** :

• **Detection limit** : **faint GRBs with high Epi are not seen** by gamma ray instruments due to a lack of photons

• **Redshift limit measurement** : **GRBs with redshift** are **brighter** and **follow the Epi-Eiso relation better**.
We are investigating whether it could be due to a **correlation** between the **prompt gamma** emission and the **optical afterglow** luminosity

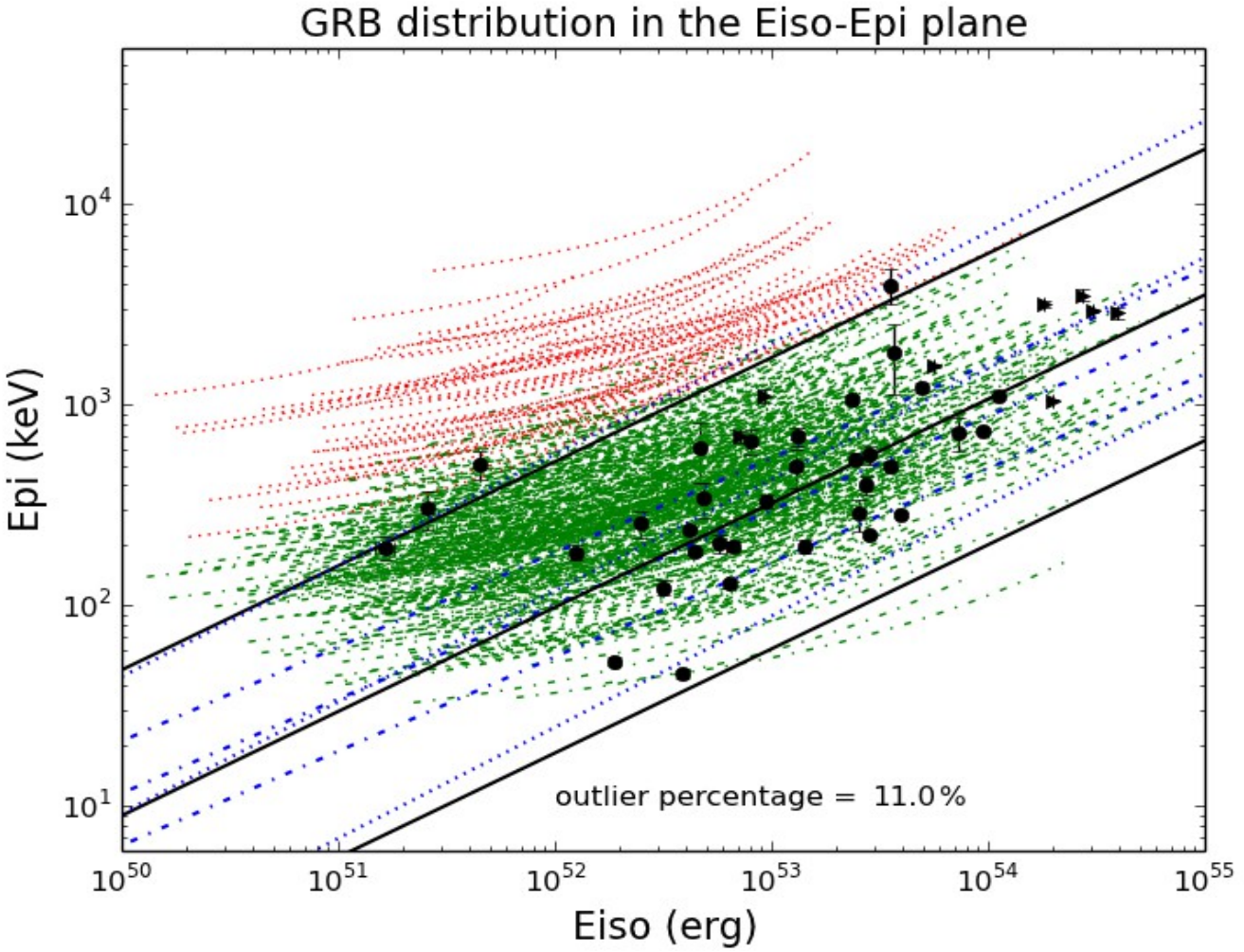
→ **As GRBs with redshift follow the Epi-Eiso relation better than GRBs without one, we can explain the apparent contradiction between studies involving only GRBs with redshift and those which deal with large samples of GRBs without redshift**

With the 4-year Fermi GRB catalog ?



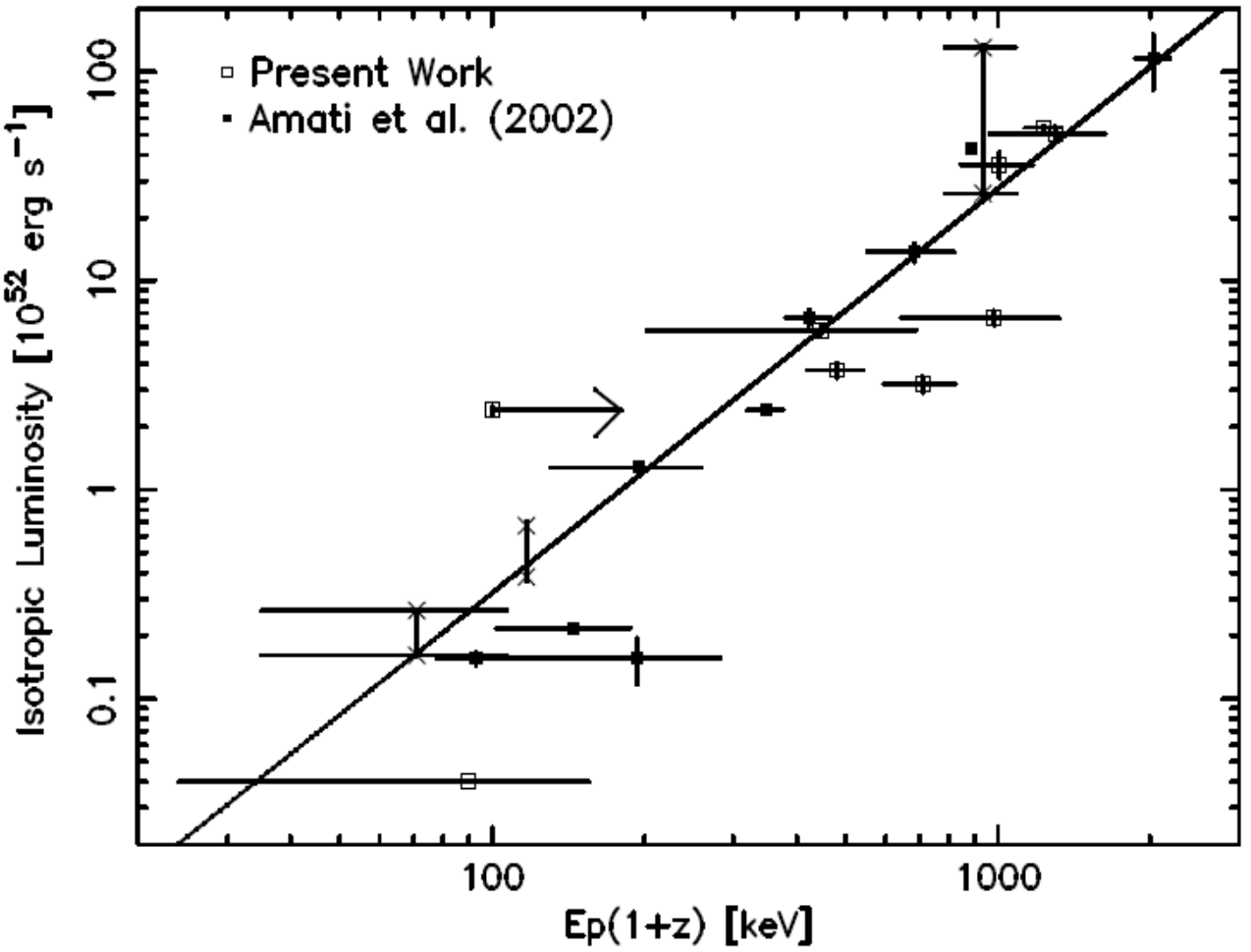
Sample size : 243

With the 4-year Fermi GRB catalog ?



Sample size : 462

Epi-Liso relation

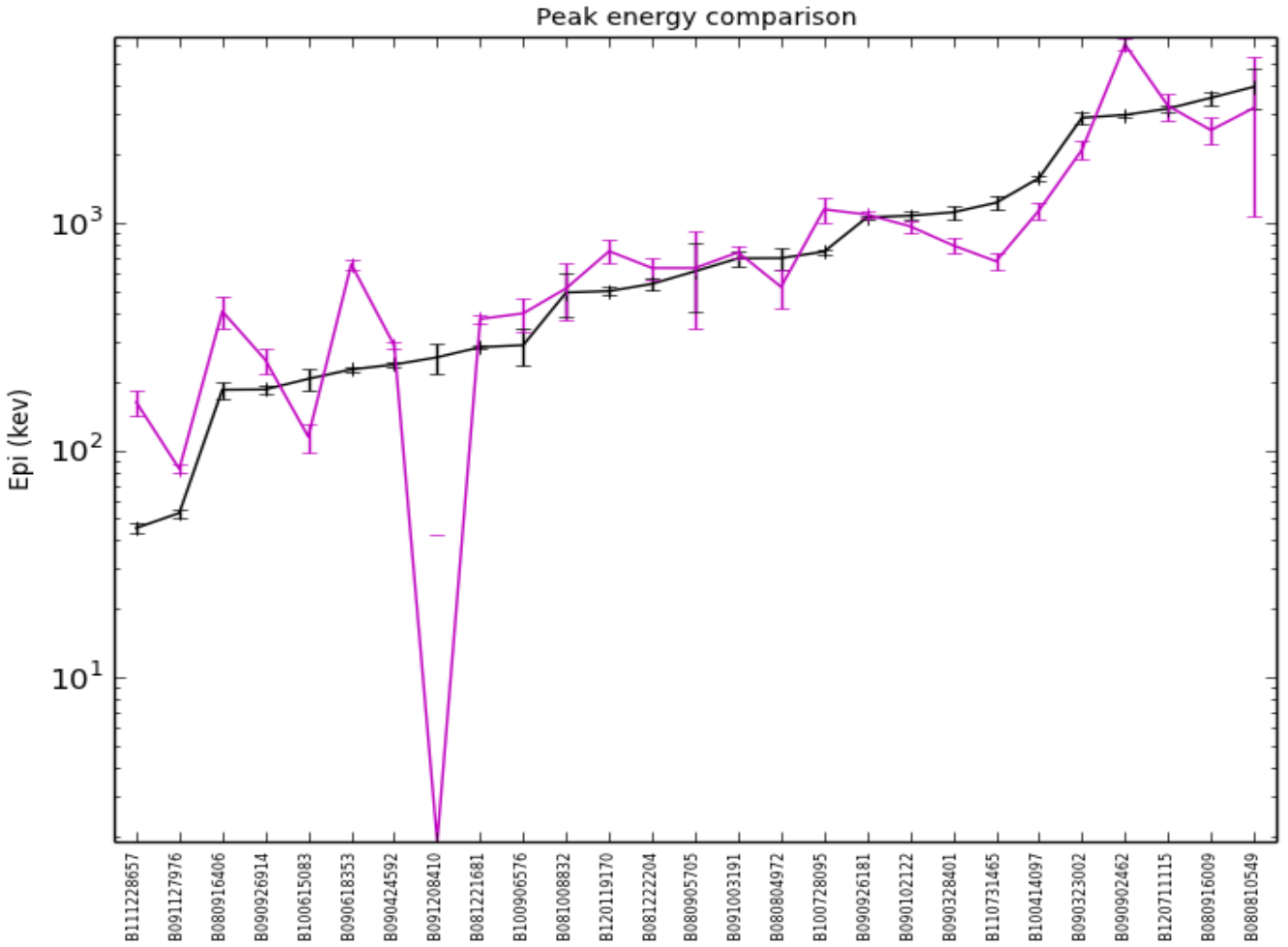


Yonetoku et al 2004 : **correlation** between L**iso and Epi**

same origin
→
same problems ?

Parameters definition : source frame Liso, Epi at the peak ?

Epi vs Epi(peak)



Standard Epi

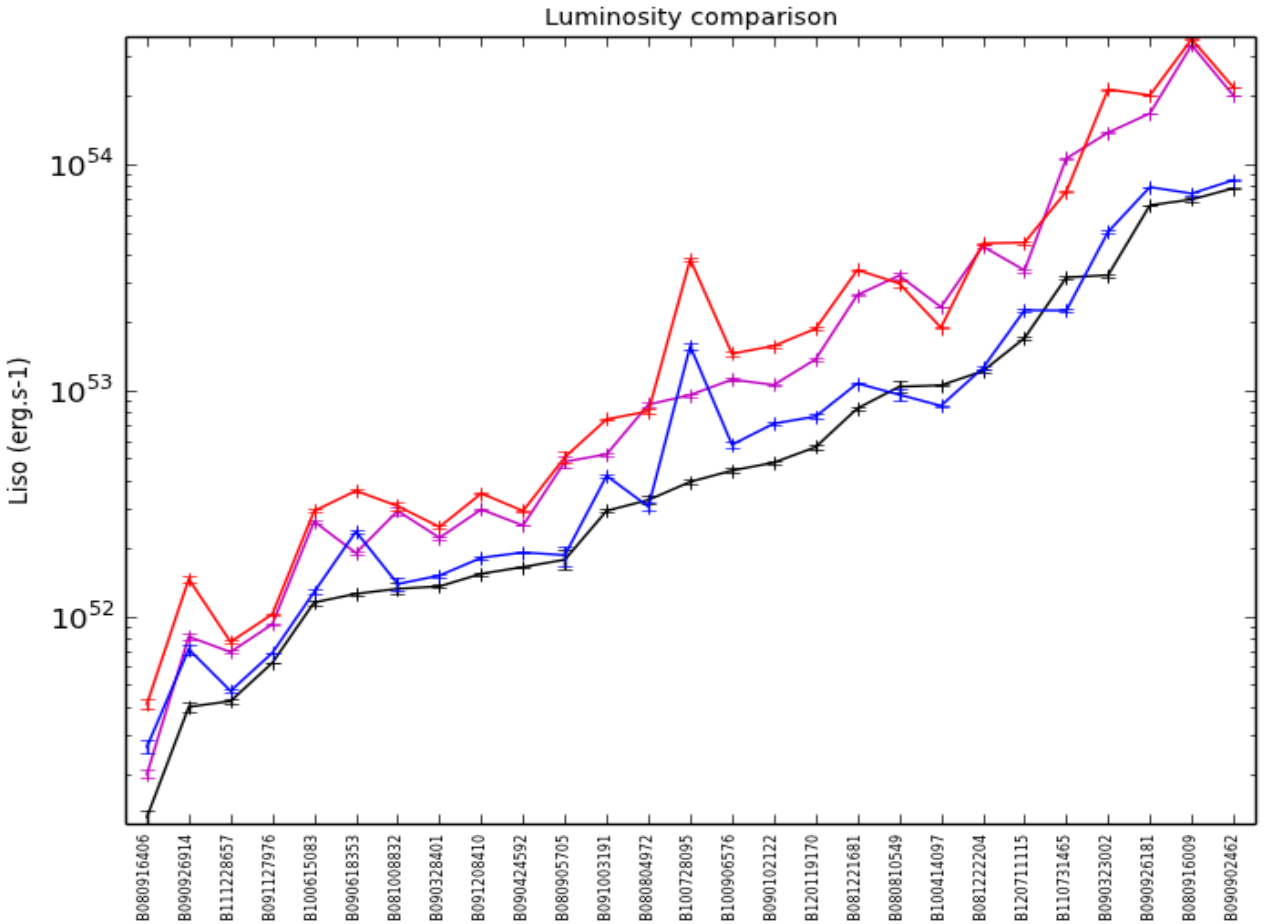
Epi at peak = Epi(peak)

Same general behaviour

No peculiar trend

Epi(peak) can be larger or smaller than Epi

Liso definition



Liso 1s source frame with peak spectral parameters

Liso 1s source frame

Liso with peak spectral parameters

Liso standard definition

Same general behaviour, no peculiar trend

The four relations : standard deviation and outliers

Liso1s-Epi(peak) :
Vertical standard deviation = **0.32**
Percentage of outliers = **1,2 %**

Liso1s-Epi :
Vertical standard deviation = **0.27**
Percentage of outliers = **4,4 %**

Liso-Epi(peak) :
Vertical standard deviation = **0.26**
Percentage of outliers = **6,1 %**

Liso-Epi :
Vertical standard deviation = **0.32**
Percentage of outliers = **1,5 %**

Liso → Liso1s = no change

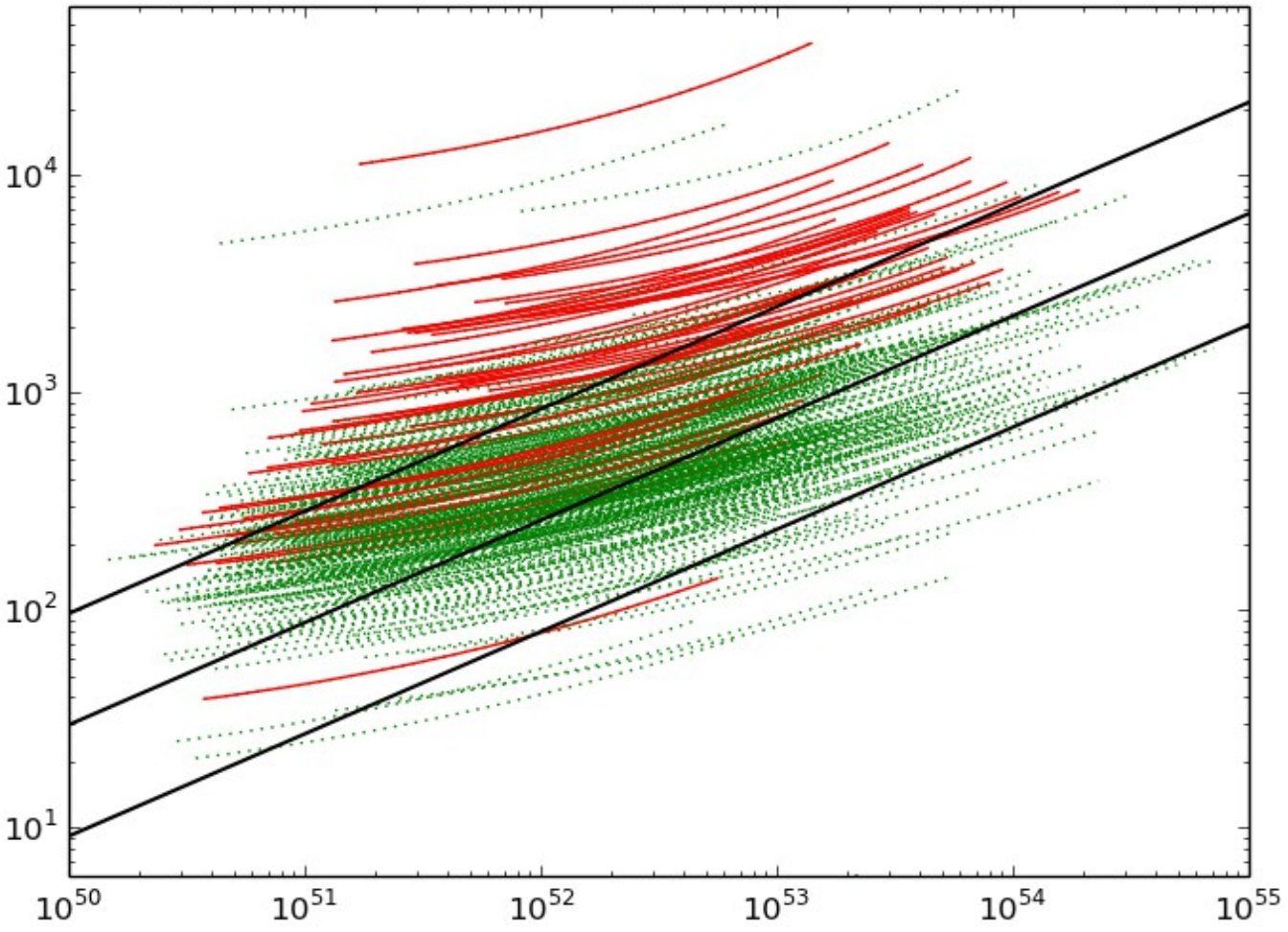
Epi → Epi(peak) = improvement of the correlation, relation narrower

Percentage of outliers always negligible

Redshift measurement selection effect = no

Detection selection effect = ?

Eiso outliers in Epi(peak)-Liso plane



The most part of Eiso outliers are above the relation
→ same selection effect ?

Representating selection effects in the Epi(peak)-Liso plane

How to construct this limit ?

We need : a **redshift**, a **peak photon flux** value, **alpha** and **beta** values

Redshift → narrowest interval with enough GRBs with z : 1.6-2.8

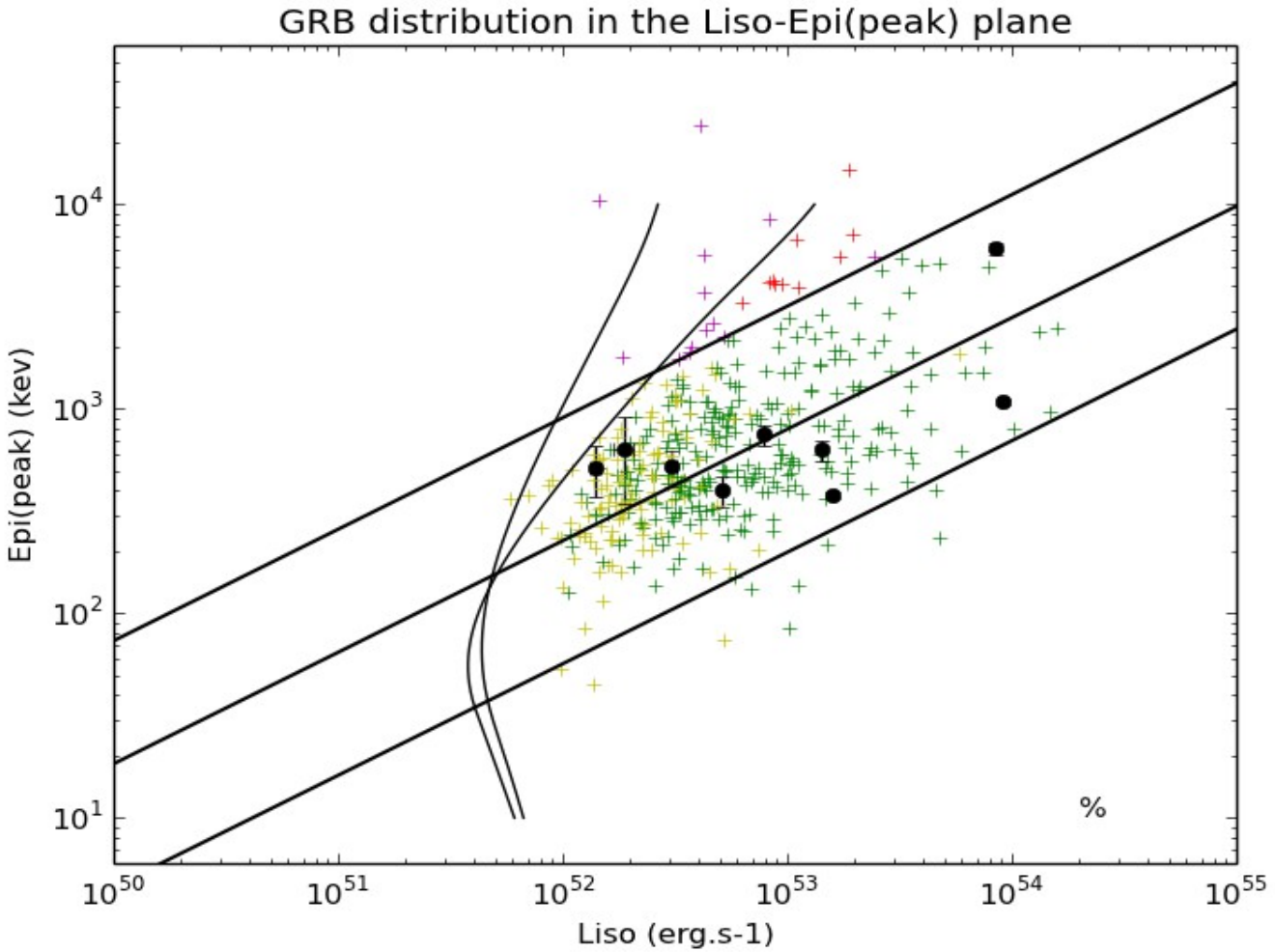
→ **redshift of the limit = 2.2**

Detection limit = Minimum peak photon flux of the sample

spectrals parameters = minimum and maximum of alpha and beta

→ **less and more restrictive case**

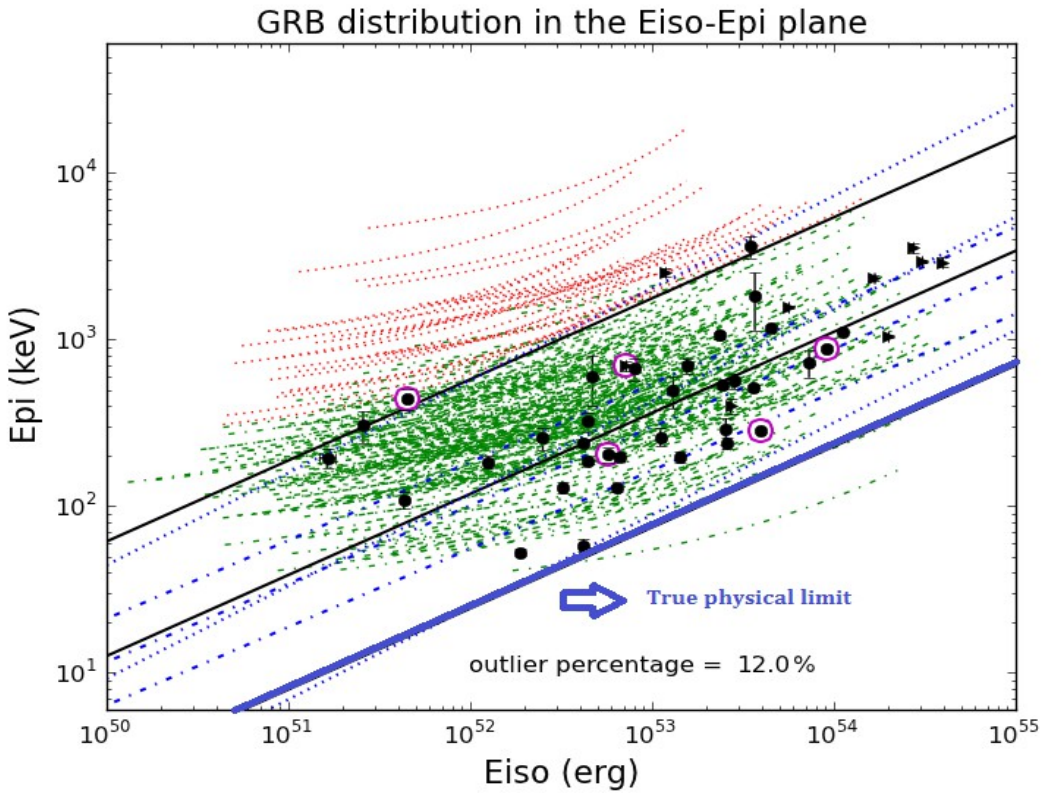
Representating selection effects in the Epi(peak)-Liso plane



Detection selection effect shape epi(peak)-Liso relation

Conclusions : cosmological use ?

The **selection effects** we have evidence prevent **using spectral relations** for **cosmological purpose**



A true physical limit
→ Do GRBs close to the boundary have special properties ?

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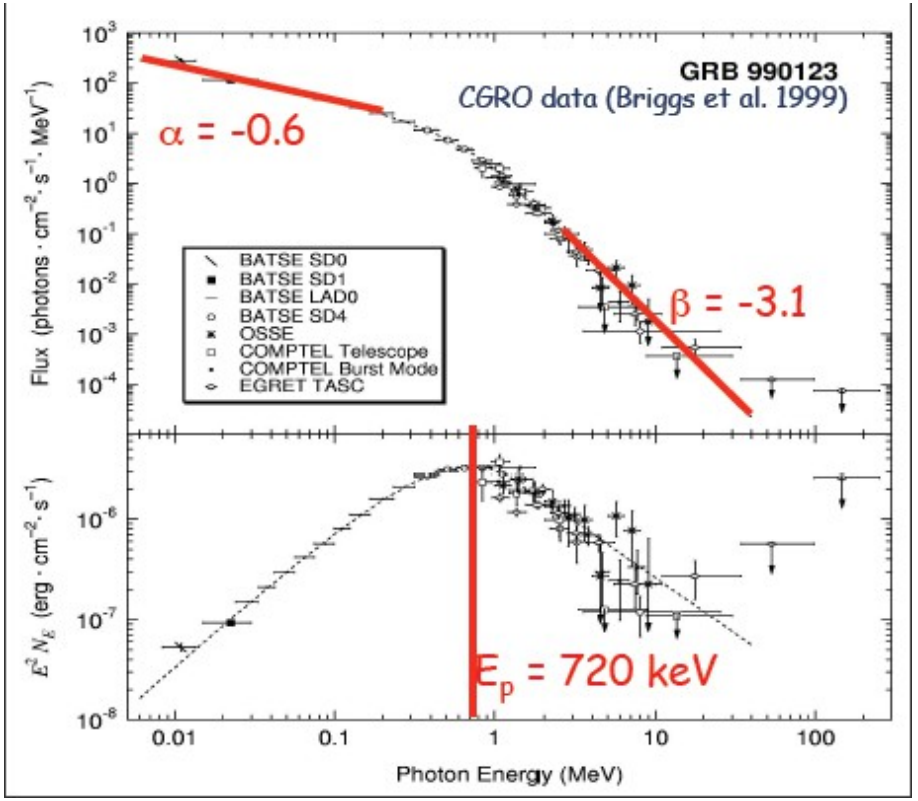
Band Model



GRB spectrum of 990123 Briggs et al 1999

$$\Phi(E) = \begin{cases} AE^{\alpha} e^{-(2+\alpha)E/E_{\text{peak}}}, & E \leq \left(\dfrac{\alpha-\beta}{2+\alpha}\right) E_{\text{peak}}, \\ BE^{\beta}, & \text{otherwise.} \end{cases}$$

Alpha = low energy spectral index
Beta = high energy spectral index
Epo = peak energy in the observer frame