A NEW INTRINSIC 3 PARAMETER CORRELATIONS

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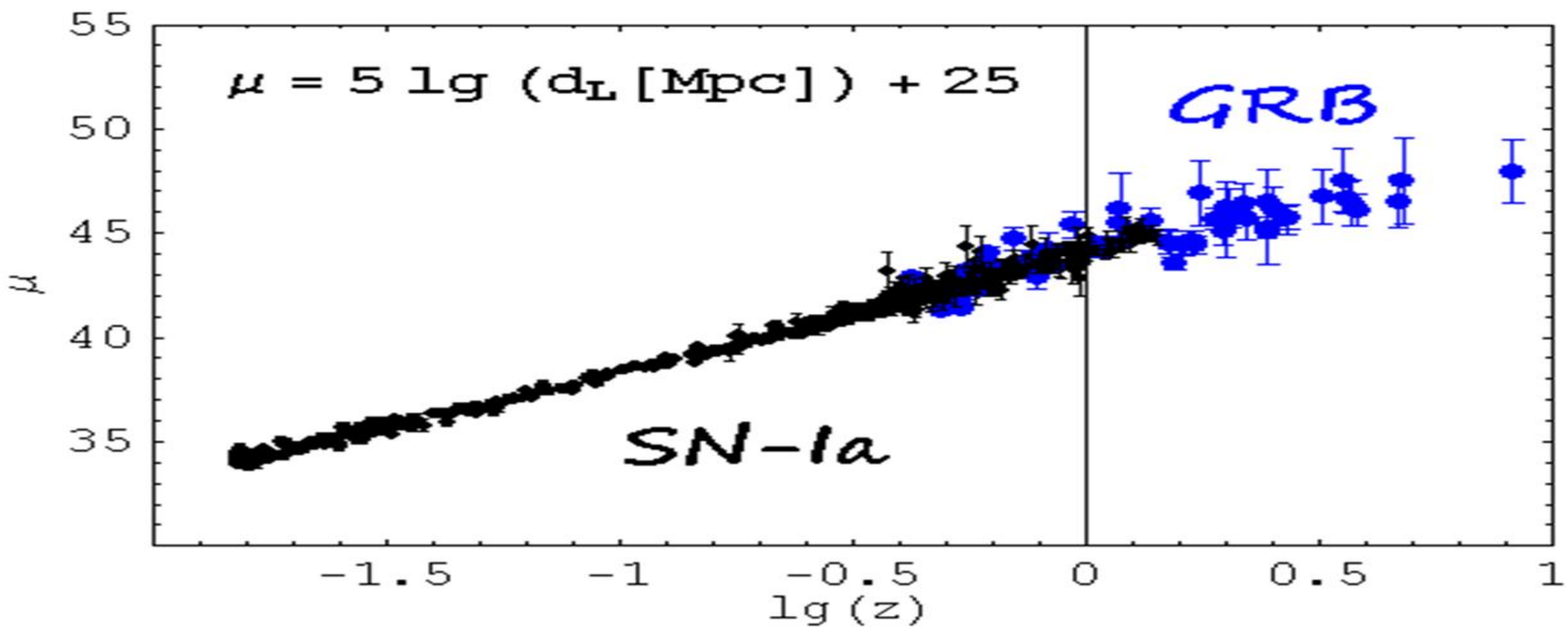
WHY GRBS AS POSSIBLE COSMOLOGICAL TOOLS?

They are the farthest astrophysical objects ever observed up to z=9.46 (Cucchiara et al. 2011)

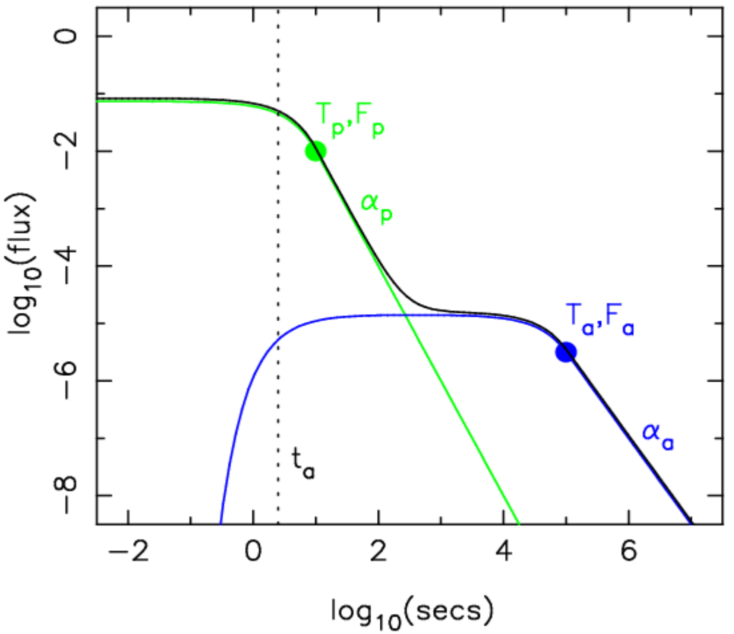
Much more distant than SN Ia (z=1.7) and quasars (z=6)



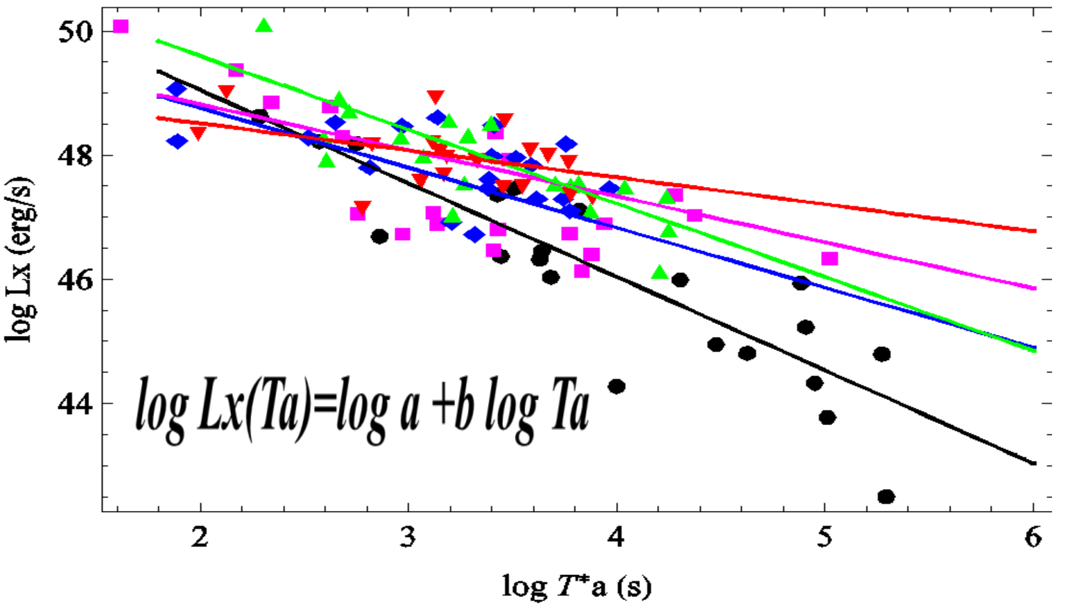
Free from dust extinction **BUT**

They don't seem to be standard candles with their luminosities spanning over 8 order of magnitudes

A possible reliable candidate is the $L_X - T^*_a$



Dainotti et al. 2013, ApJ, 774, 157D



black for $z < 0.89$, magenta for $0.89 \le z \le 1.68$, blue for $1.68 < z \le 2.45$, Green $2.45 < z \le 3.45$, red for $z \ge 3.45$.

Firstly discovered in 2008 by Dainotti, Cardone, & Capozziello MNRAS, 391, L 79D (2008) ,

Later updated by Dainotti, Willingale, Cardone, Capozziello & Ostrowski ApJL, 722, L 215 (2010)

Lx(T*a) vs T*a distribution for the sample of 101 afterglows

ALSO PROMPT – AFTERGLOW CORRELATIONS
CAN BE CANDIDATES

Dainotti et al., MNRAS, 418,2202, 2011

A search for possible physical relations between

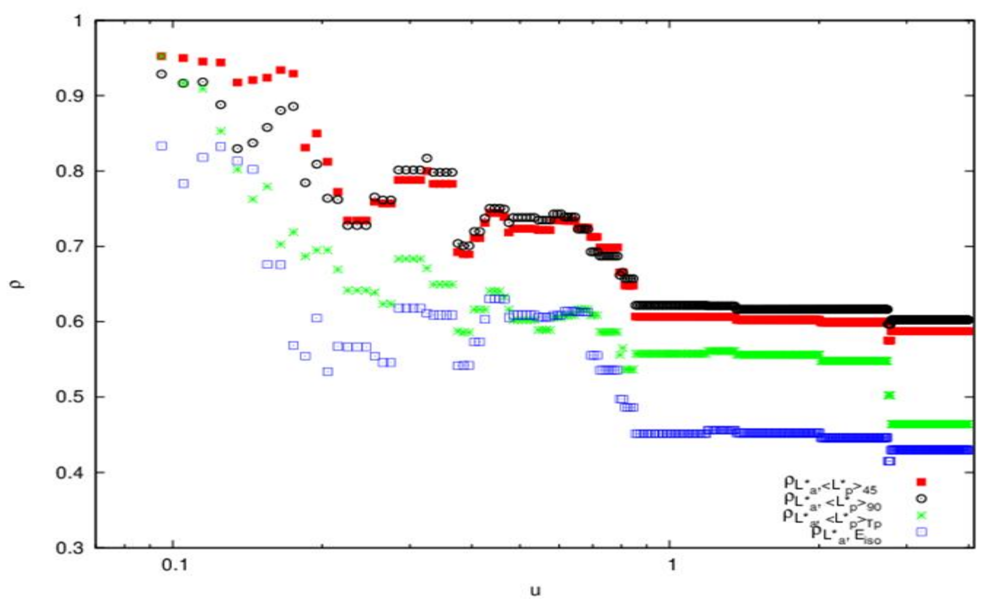
the afterglow characteristic luminosity L*a ≡Lx(Ta)

and

the prompt emission quantities:

1.) the mean luminosity derived
   as <L*p>45=Eiso/T*45
2.) <L*p>90=Eiso/T*90
3.) <L*p>Tp=Eiso/T*p
4.) the isotropic energy Eiso

$$\sigma(E) = (\sigma_{Lx}^2 + \sigma_{Ta}^2)^{1/2}$$



BUT, FOR A MORE MATHEMATICAL APPROACH WE APPLY:

The Efron & Petrosian method (EP) (ApJ, 399, 345,1992)

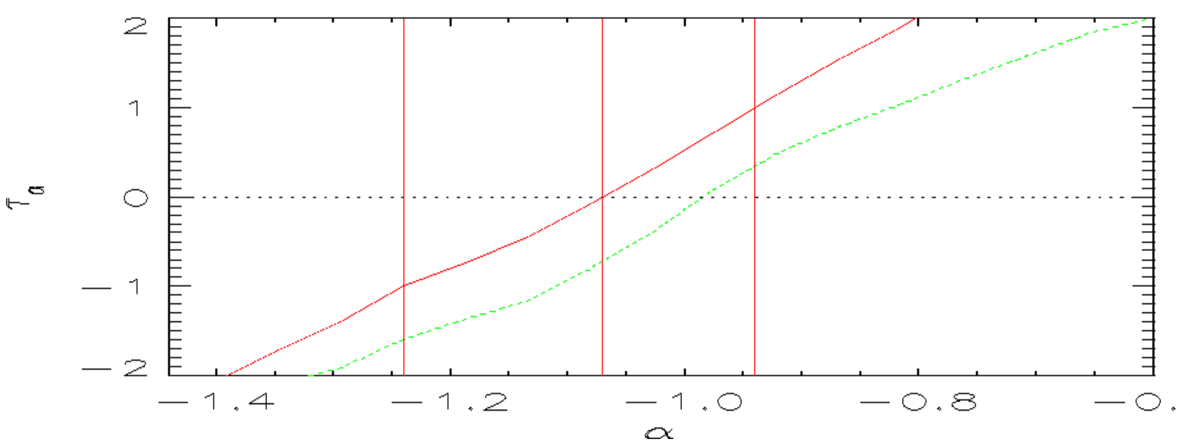
to obtain unbiased correlations corrected for instrumental threshold selection effect and redshift induced correlation (Lloyd,N., & Petrosian, V. ApJ, 1999)

If L^*_X and T^*_a are correlated with redshift

the luminosity vs. redshift evolution is **g(z)**

the plateau duration vs. redshift evolution is a **f(z)**

$$g(z) = (1+z)^k \quad \text{or} \quad g(z) = \frac{(1+z)^k}{1 + \left(\frac{1+z}{1+z_c}\right)^k}$$



The observed correlation slope ,
b=-1.27 ± 0.15
vs
the intrinsic one

-1.07 ± 0.14

Dainotti et al. 2013, ApJ, 774, 157D

CONCLUSIONS - PART I

The correlation La-Ta exists intrinsically!!!

It can be useful as model discriminator :

- **energy injetion model from a spinning-down magnetar** *Dall' Osso et al. (2010), Xu & Huang (2011), Rowlinson & Obrien (2011), Rowlinson et al. (2014). In this last paper the intrinsic correlation has been taken into account.*
- **Accretion model onto the central engine** *Cannizzo & Gerhels (2009), Cannizzo, Gerhels & Troja (2010)*
- **The Supercritical Pile Gamma-Ray Burst Model,** *Sultana, J., Kazanas, D., Mastichiadis, A. 2013 ApJ, 779, 16S*
- **Prior emission model for the X-ray plateau** *Yamazaki (2009)*

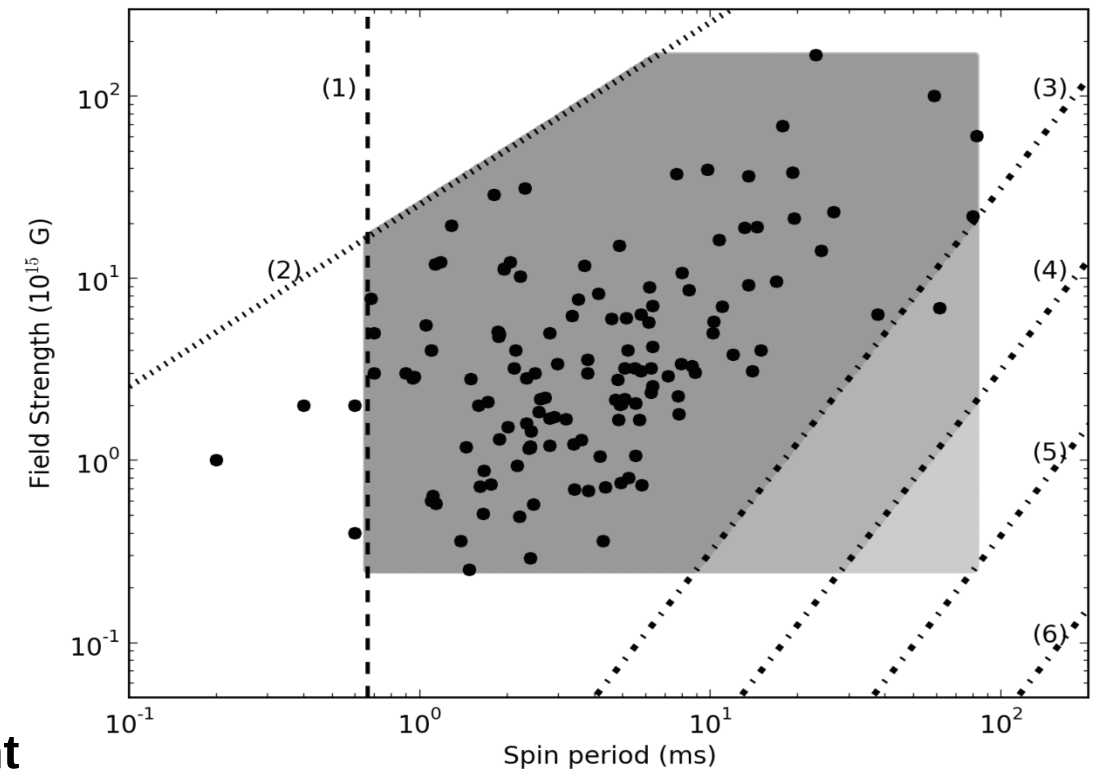
- The magnetar model analytically reproduces the LT intrinsic correlation
- Rowlinson, Gompertz, Dainotti, et al. 2014, MNRAS, 443,1779

$$L_{0,49} \sim (B_{p,15}^2 P_{0,-3}^{-4} R_6^6)$$

$$T_{em,3} = 2.05\,(I_{45} B_{p,15}^{-2} P_{0,-3}^2 R_6^{-6}),$$

Substituing Radius in the L0,49

$$\log(L_0) \sim \log(10^{52} I_{45}^{-1} P_{0,-3}^{-2}) - \log(T_{em})$$



GRB-magnetars vs Galactic magnetars: X-ray plateaus

Rea, N. et al. 2015, ApJ,813,92

GRB-magnetar model in its present form is safe if:

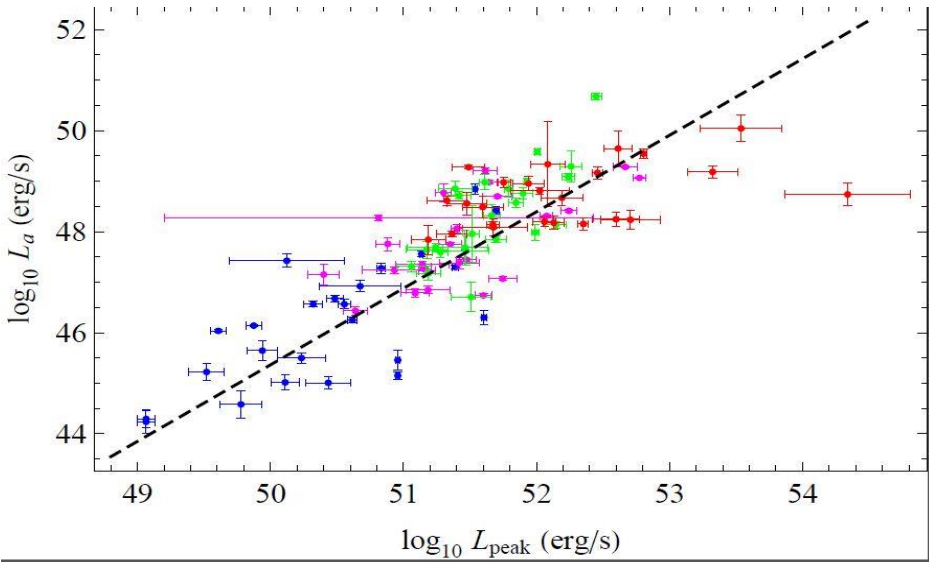
a) Two kinds of magnetar progenitors, GRB-ones being different from Gala ctic magnetar ones (i.e. Metallicity d ifferences?). GRB-magnetar should be considered supermagnetars with higher magnetic fields

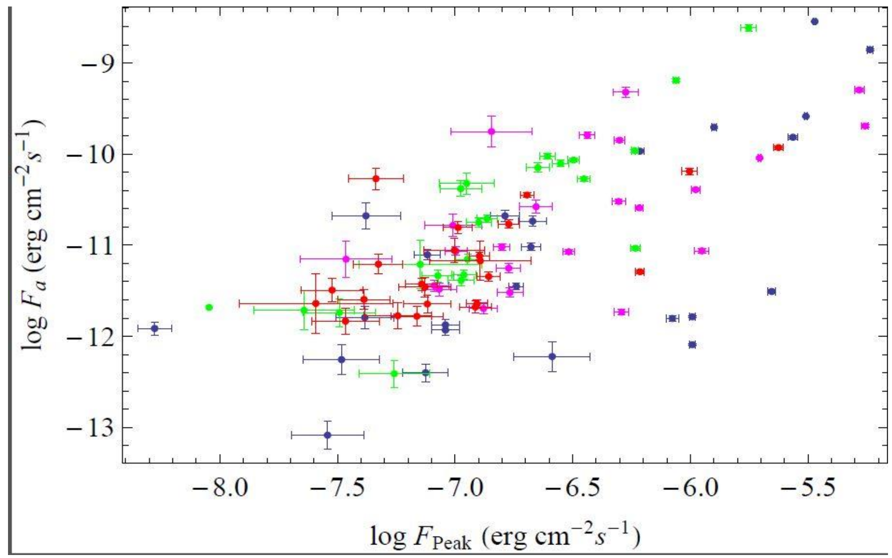
$B_{max} \sim 2 \times 10^{17}$ G and $B_{min} \sim 3 \times 10^{14}$ G

b) The No. of stable magnetars produced in t he Milky Way via a GRB in the past Myr is abo ut < 16

ALSO PROMPT-AFTERGLOW CORRELATIONS ARE INTRINSIC !!!

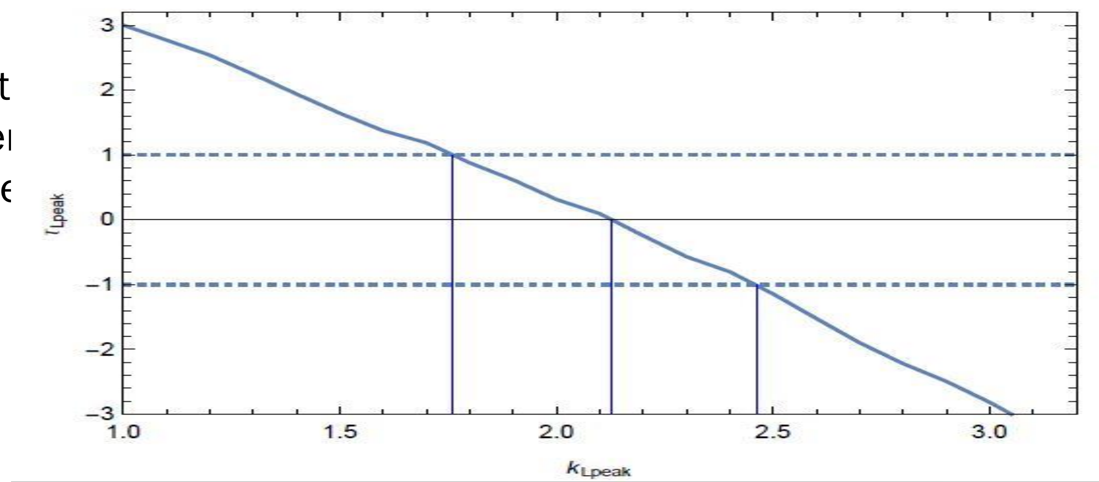
DAINOTTI ET AL. MNRAS 2015B, 31, 4



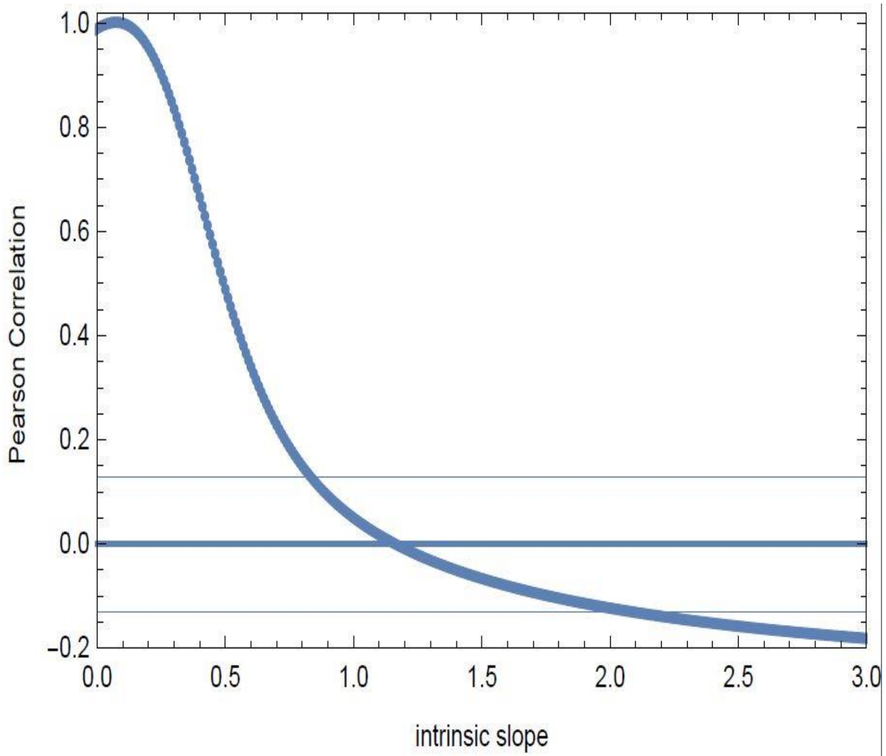


logLa=A+BlogLpeak A = −14.67 ± 3.46 and B=1.21+0.14−0.13

there is a strong evolution in the prompt 2.13+(0.33,−0.37) consistent with othe results, Petrosian et al. 2015,Yonetoku e al. 2005, found a steeper evolution 2.60+/0.15 but still compatible with 1 sigma with this one.



THE PARTIAL CORRELATION



$$r_{L'_{peak},L'_a,D_L} = \frac{r_{L'_{peak},L'_a} - r_{L'_{peak},D_L} * r_{L'_a,D_L}}{\left(1 - r^2_{L'_{peak},D_L}\right) * \left(1 - r^2_{L'_a,D_L}\right)}$$

Where r=Pearson correlation coefficient
And ‘ are the de-evolved quantities.
DL is the luminosity distance

Log L’’= log L’peak − α log L’afterglow

Where α is the intrinsic slope. The correlation becomes significant for $\alpha = 1.14+(0{,}83;−0{,}32)$, which is very close to the observed correlation 1.21(+0.14, −0,13). The error bars quoted are at the 2 σ significance level.

PHYSICAL INTERPRETATIONS

Hascoet et al. (2014) : 1) within the standard forward shock model with variation of the microphysics parameters ϵ_e the fraction of the internal energy that goes into electrons (or positrons to reduce the radiative efficiency at early times; the preferred model supposes a wind external medium and ϵ_e, and that can in principle be radiated away. $\epsilon_e = n^{\nu}$ (where n is the external density), with $\nu \approx 1$ to obtain a flat plateau.

2) the early afterglow results from a long-lived reverse shock in the forward shock scenario in which the typical Lorentz factor of the ejecta should increase with burst energy to satisfy the prompt–afterglow relations, more in particular the ejecta must contain a tail of low Lorentz factor with a peak of energy deposition at $\Gamma \geq 10$.

In both scenarios the plateaus following the prompt–afterglow correlations can be obtained under the condition that additional parameters are added.

Conclusions of Hascoet: acting on one single parameter can lead to the formation of a plateau that also satisfies the observed prompt–afterglow correlations presented in Dainotti et al. (2011b) and then the Lpeak-La correlation

Van Erten (2014a) shows that the observed L_{prompt}–$L_{afterglow}$ correlations rule out basic thin shell models but not basic thick ones.

In the thin shell model, the plateau phase ->the pre-deceleration emission from a slower component in a two-component or jet-type model.

For thick shells, the plateau -> energy injection either in the form of late central source activity or via additional kinetic energy transfer from slower ejecta which catches up with the blast wave.

It is shown that thin shell models it is inferred the existence of a correlation between the plateau end time and the ejecta energy that is not seen in the observational data.

However, it is difficult to distinguish between forward shock and reverse shock emission dominated models, or homogeneous and stellar wind-type environments.

How would be the parameters of Gamma and Radius considering the observed phenomenological Lpeak-La within the parameter of the Supercritical pile model, Sultana, Kazanas & Mastichiadis 2013?

UPDATING THE GRB HUBBLE DIAGRAM
WITH THE LUMINOSITY-TIME CORRELATION

Allows to increase both the GRBs sample (83 GRBs vs 69) in Schaefer et al. 2006 and reduce the uncertainty on the distance moduli μ*(z) of the 14%*

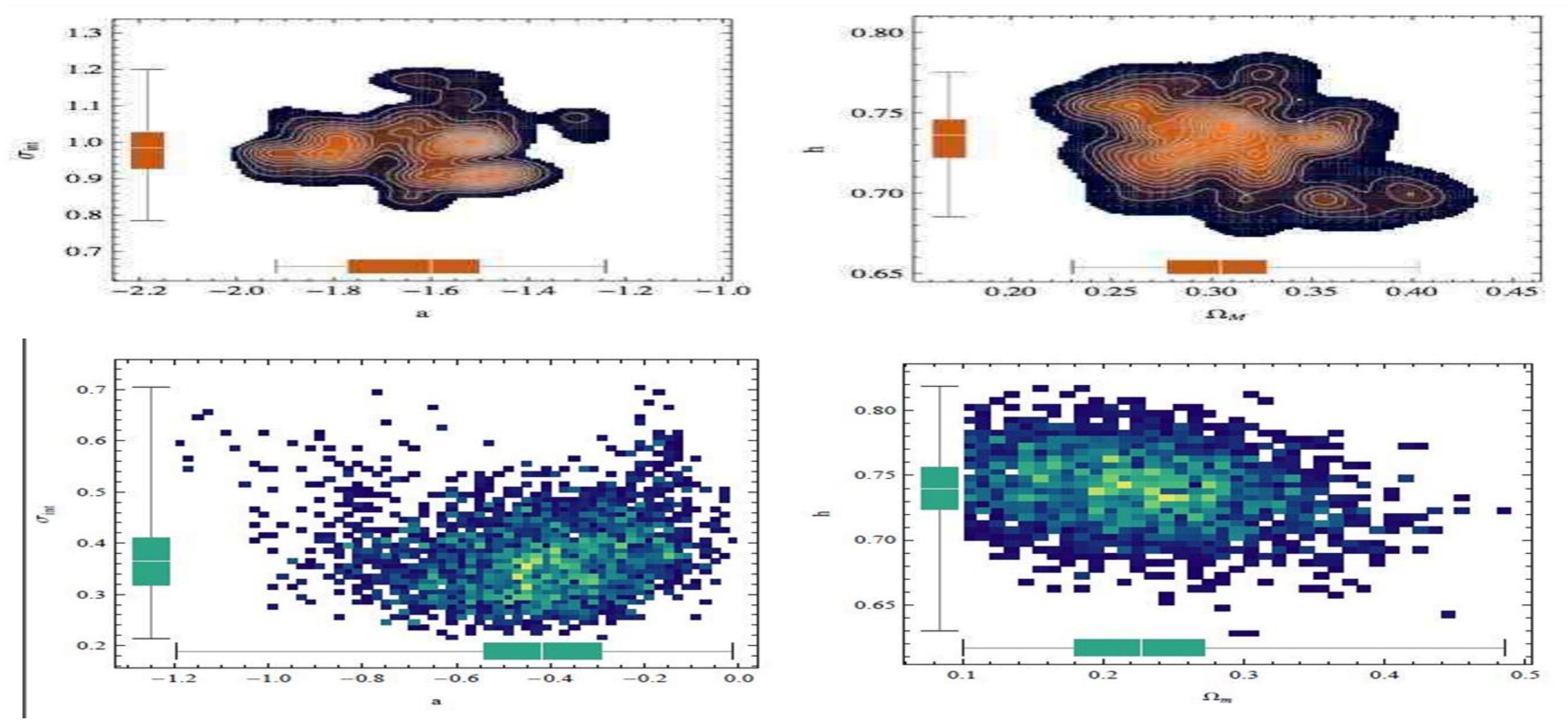
Cardone, V.F., Capozziello, S. and Dainotti, M.G 2009, MNRAS, 400, 775C

The use of the HD with the only Dainotti et al. correlation alone or in combination with other data shows results in agreement with previous ones in literature.

A larger sample of high-luminosity GRBs can provide valuable information in the search for the correct cosmological model (Cardone, V.F., Dainotti, M.G et al. 2010, MNRAS, 408, 1181)

Postnikov, Dainotti, Hernadez & Capozziello 2014,ApJ, 783, 126P inferring the dark energy equation of state with w=-1

HOW SELECTION EFFECTS CAN INFLUENCE CORRELATION AND THE CIRCULARITY PROBLEM?

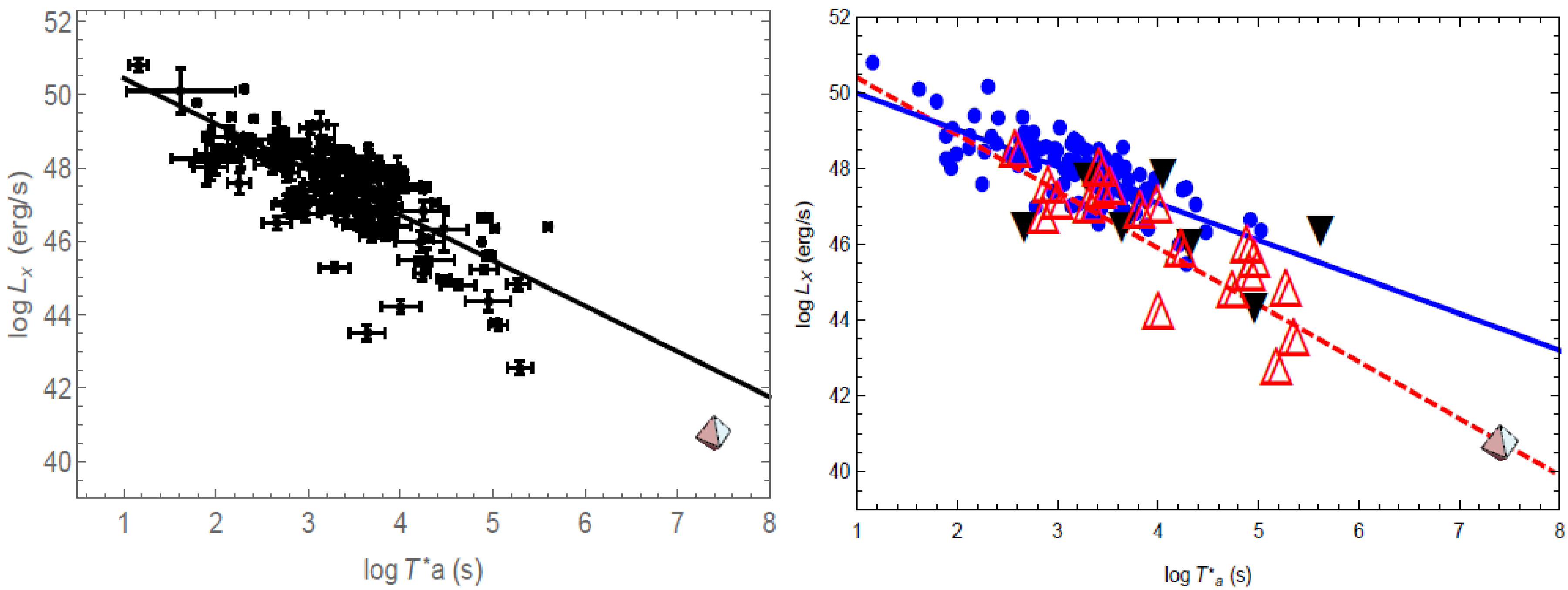


1)Parameters for non flat/flat models are not distinguishable:

Overestimated of the 13% in ΩM, compared to the Ia SNe (ΩM , σ_M) = (0.27, 0.034), while $H0$, best-fitting value is compatible in 1σ compared to other probes.

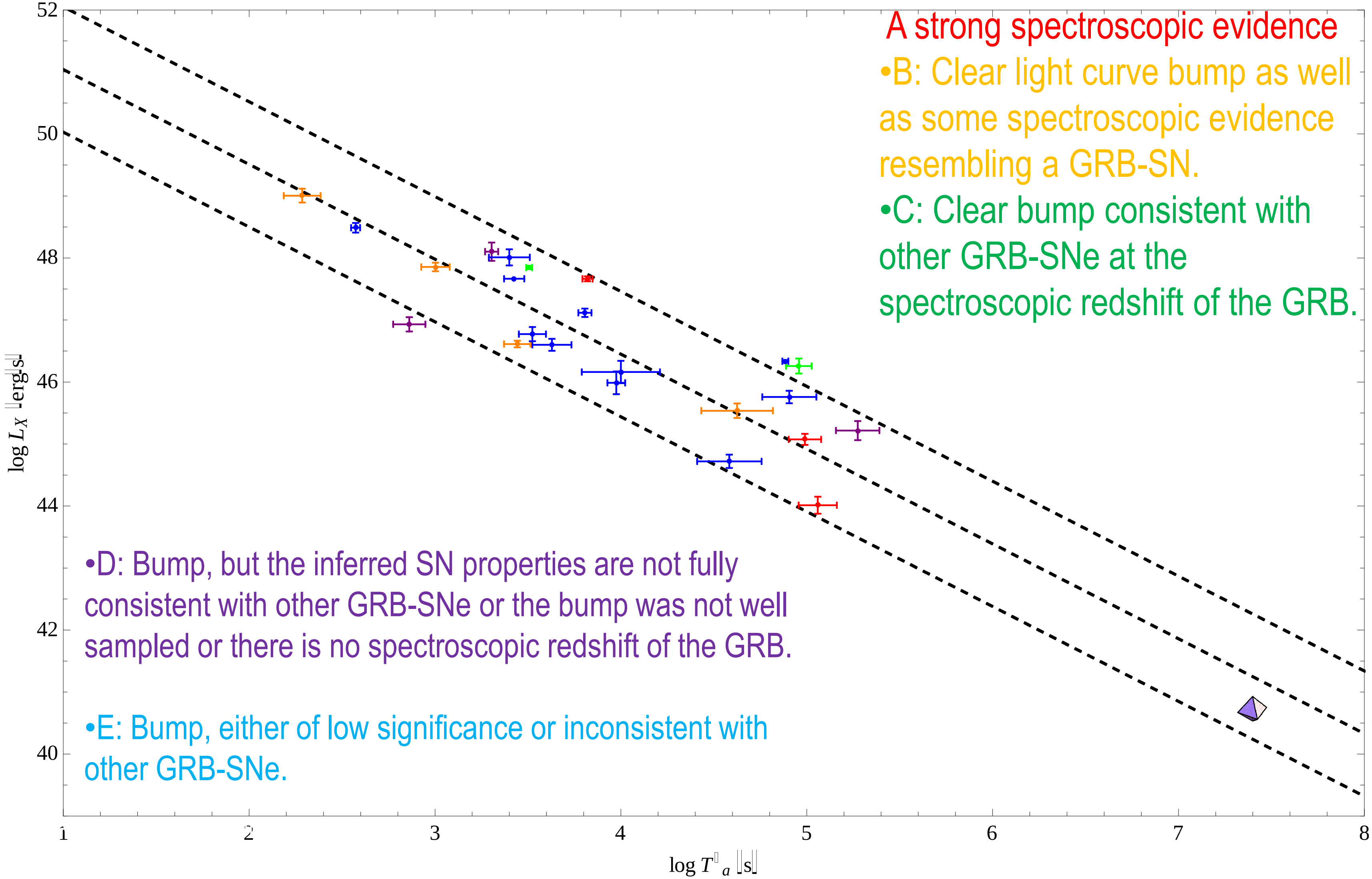
HighL sample differs of 5% in the value of H_0 computed in Peterson et al. 2010, while the scatter in Ω_M is underestimated by the 13%.

Looking for a more homogeneous sample for a "Standard GRB set for cosmology" (Dainotti et al. ApJ submitted)

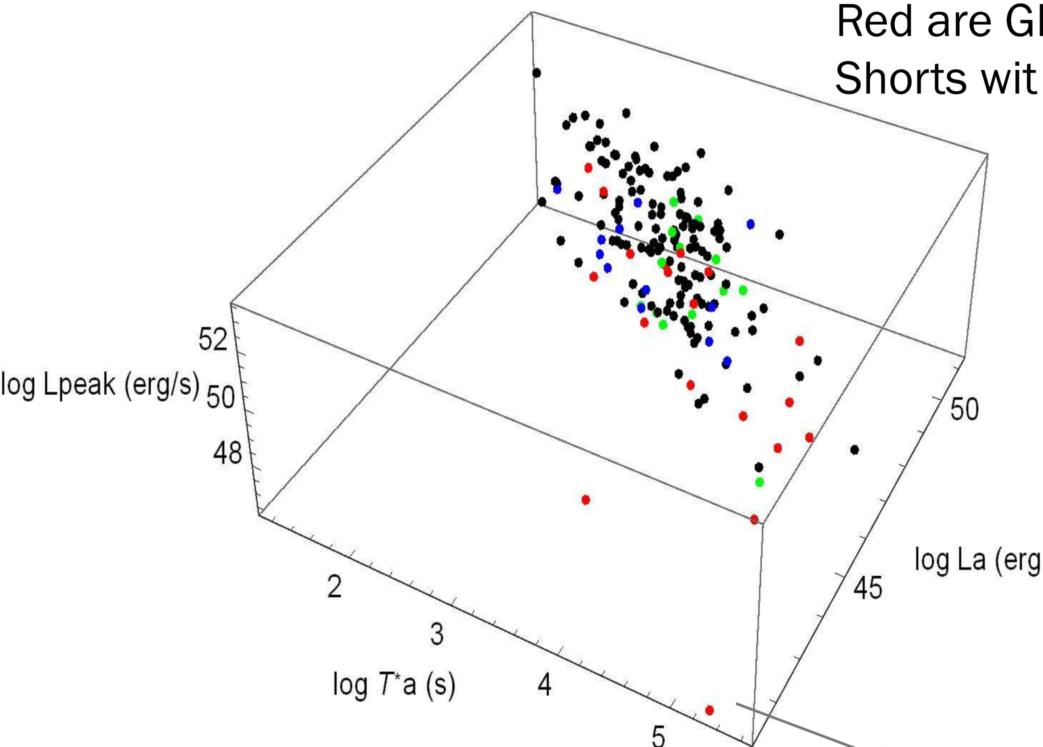


LONG SAMPLE (BLUE POINTS) FOR WHICH THE SNE IS NOT SEEN AND GRB-SNE ASSOCIATED (RED TRIANGLES)

The two dotted lines are the representation of 1 σ error around the best fitted slope. All the data points are within 1 σ. A+B category show ρ= -0.96 with P=1.4*10^-3

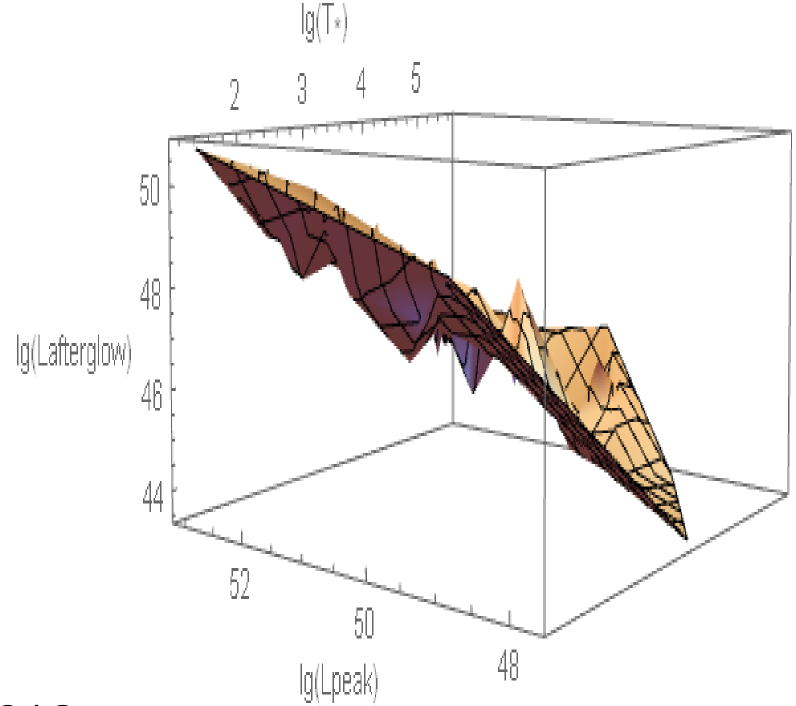


GIVEN THE INTRINSIC NATURE OF LX-TA AND LPEAK-LA WE DISCOVER ALSO THE LPEAK-LX-TA CORRELATION



GRB 060218

Red are GRB-Sne, Green are XRFs and Blue are Shorts wit



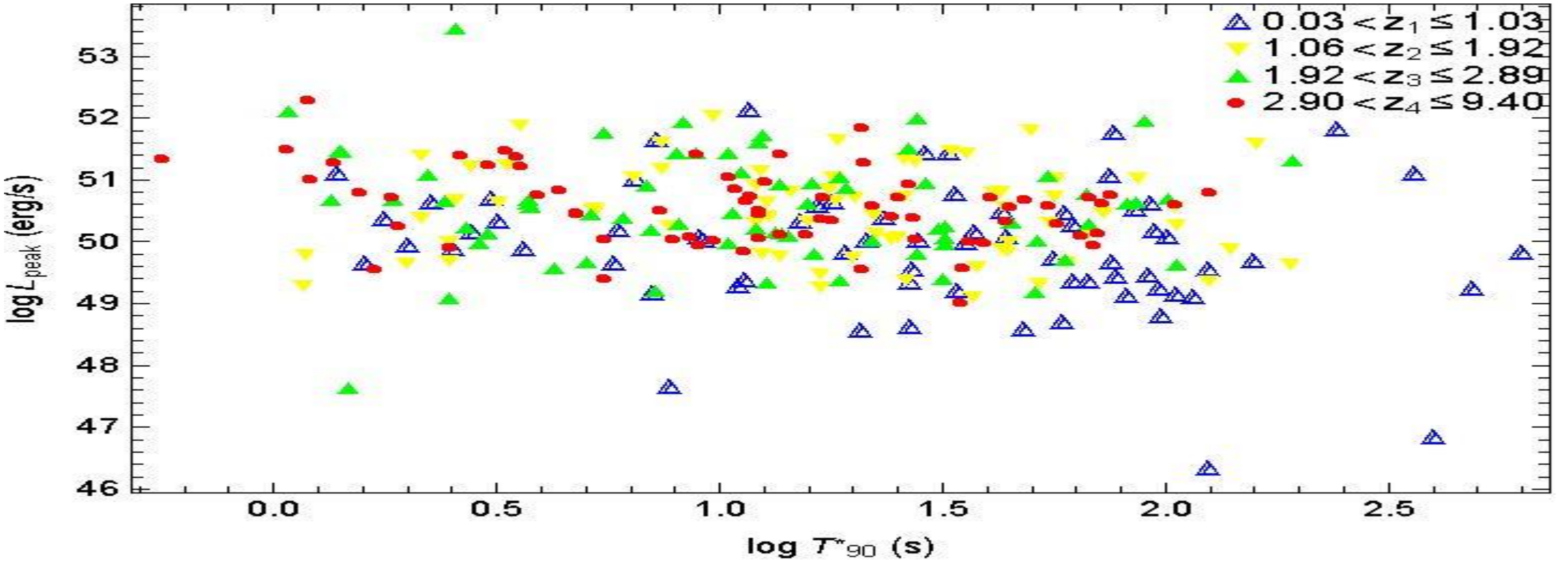
The correlation matrix (Ta,La,Lpeak)

$$\mathrm{Lpeak} = 30.66 + 0.10 * \mathrm{Ta} + 0.40 * \mathrm{La}$$

If I consider the L'peak,T'a and L'a the correlation is tighter, it reduced the 10% the scatter

{1., -0.76, -0.41},
{-0.76, 1., 0.58},
{-0.41, 0.58, 1.}

THE DEPENDENCE OF LPEAK-T90 VS Z



This distribution is more sparse compared to Lpeak-Ta, r=-0.22.

Therefore, the choice of Ta is more appropriate.
What is the physical interpretation of this fondamental plane?.

Energy of the plateau is related to the kinetic power of the peak of the prompt emission. Further investigation is needed.

CONCLUSIONS AND FUTURE PERSPECTIVES:

This new subsample of GRBs long with No-Sne for the new 3 parameter correlation could be as a test for cosmology together with type Ia Sne.

We extended study of DE EoS up to redshift 9 using tight observational correlation in subclass of GRBs (Postnikov, S., Dainotti et al. 2014).Resulting EoS band is consistent with cosmological constant (-1) and show small tendency for variations, although leaving it open for more data to come.

Current GRB events number and their luminosity distance estimation errors are consistent with what predicted by extrapolation from SNela and BAO. More (100 per $\Delta z=1$) and better quality (error/10) GRB data is needed to narrow DE EoS at higher redshifts (Dainotti et al. 2011 suggests it is within reach), but with this correlation with a 10% scatter less we expect more constraining results.

Future work is to repeat the method changing the a and b parameters of the correlation together with the cosmological setting and to change also the evolutions of both the variables luminosity and time.