

Cosmology with GRBs

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In coll. with

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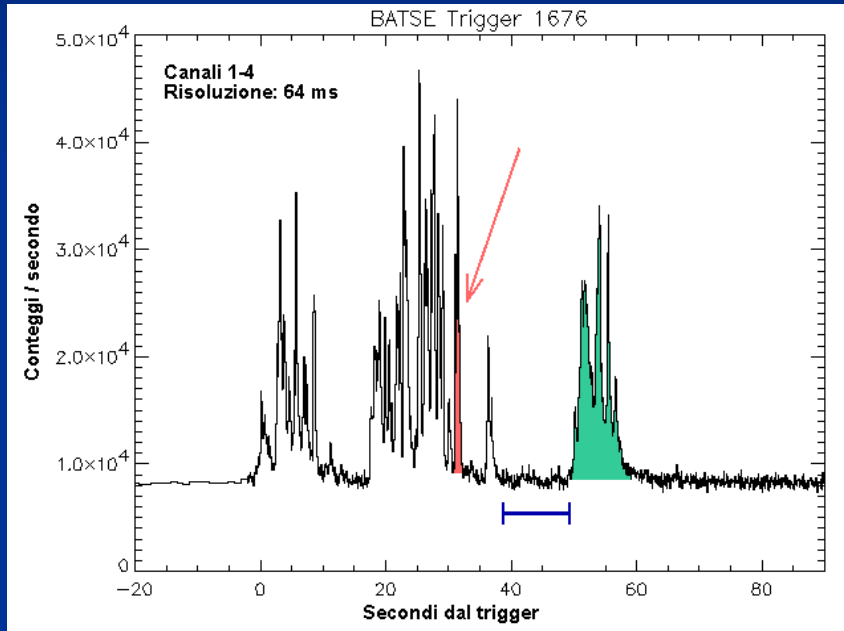
Davide Lazzati

Claudio Firmani

Vladimir Avila-Reese

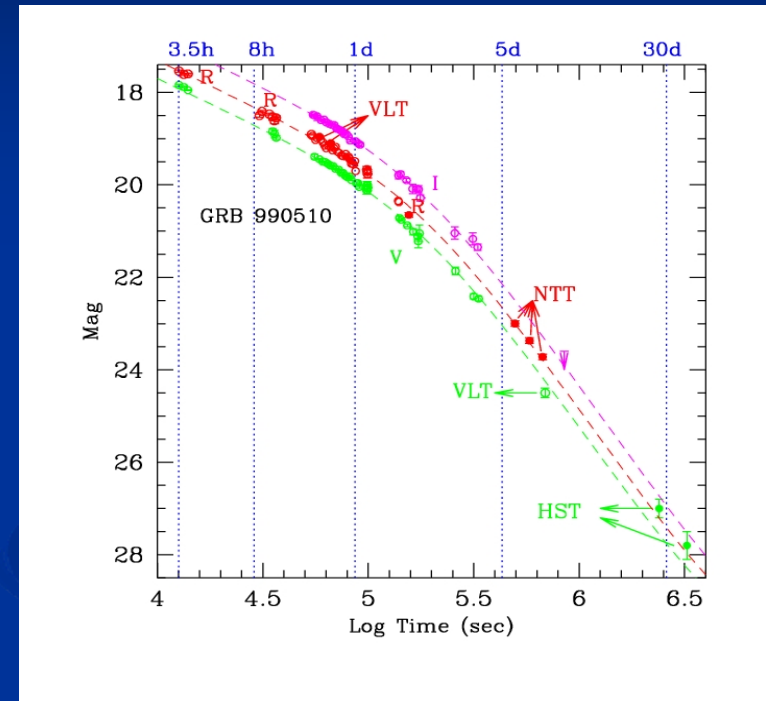
GRBs are fast transient high energy sources @ cosmological distances

Prompt emission



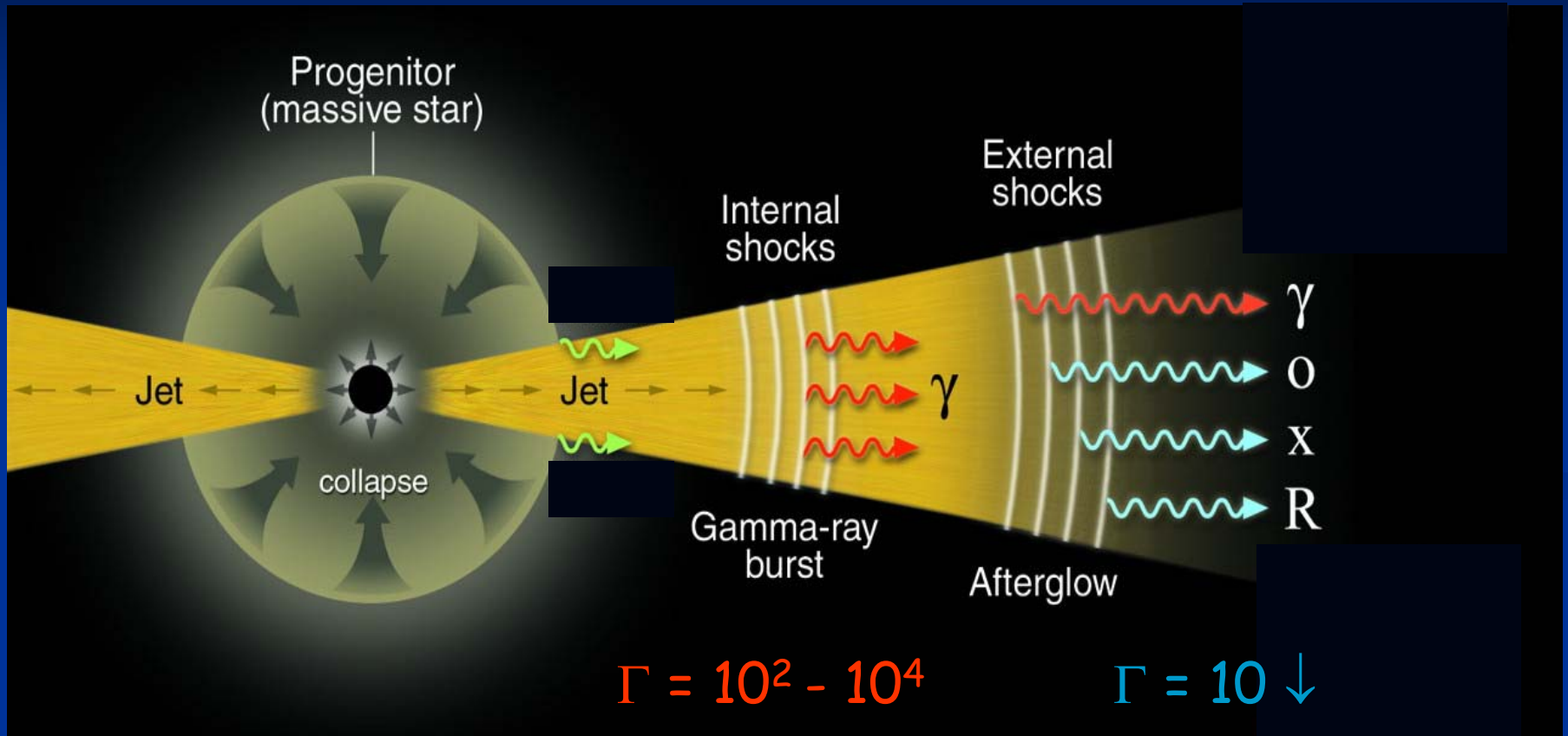
- energies > 10 keV
- 1 ms to 1 ks
- high variability

Afterglow emission



- energies X, Opt, IR, Radio
- days to months
- smooth powerlaw(s)

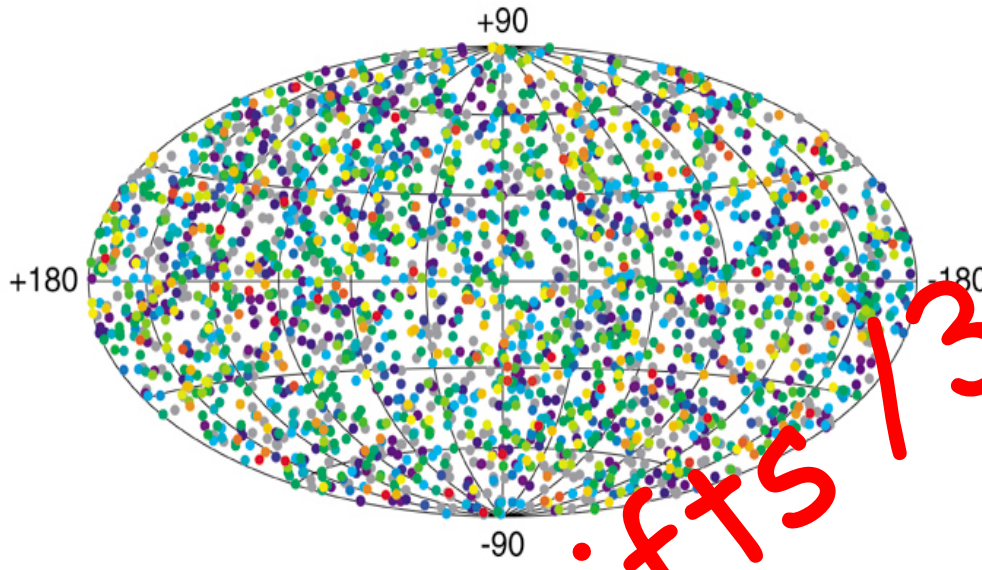
The standard picture



GRBs are cosmological

GRB 970228

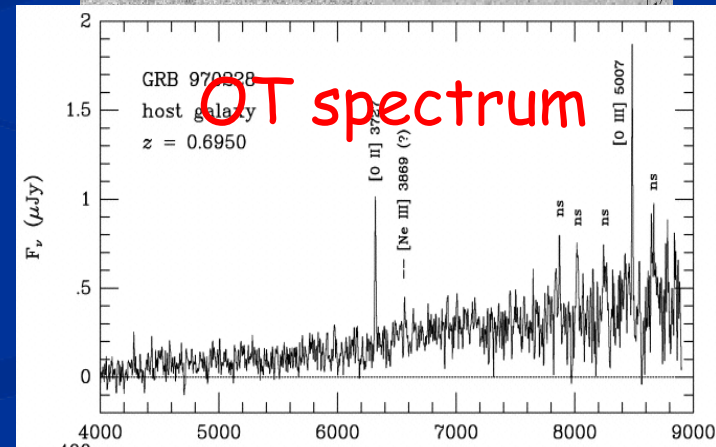
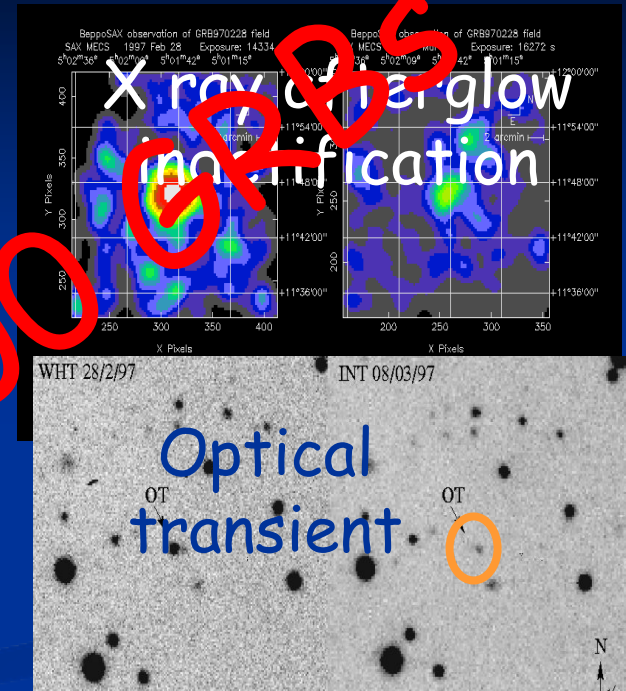
2704 BATSE Gamma-Ray Bursts



Gamma ray position accuracy 2 deg!!

Need arcmin accuracy to

1. Identify the counterpart
2. Follow the afterglow and measure the redshift

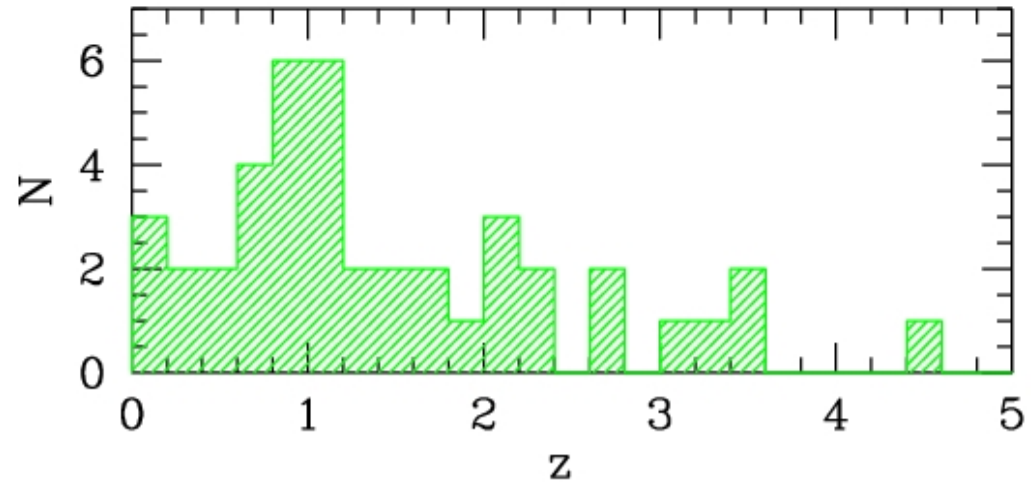
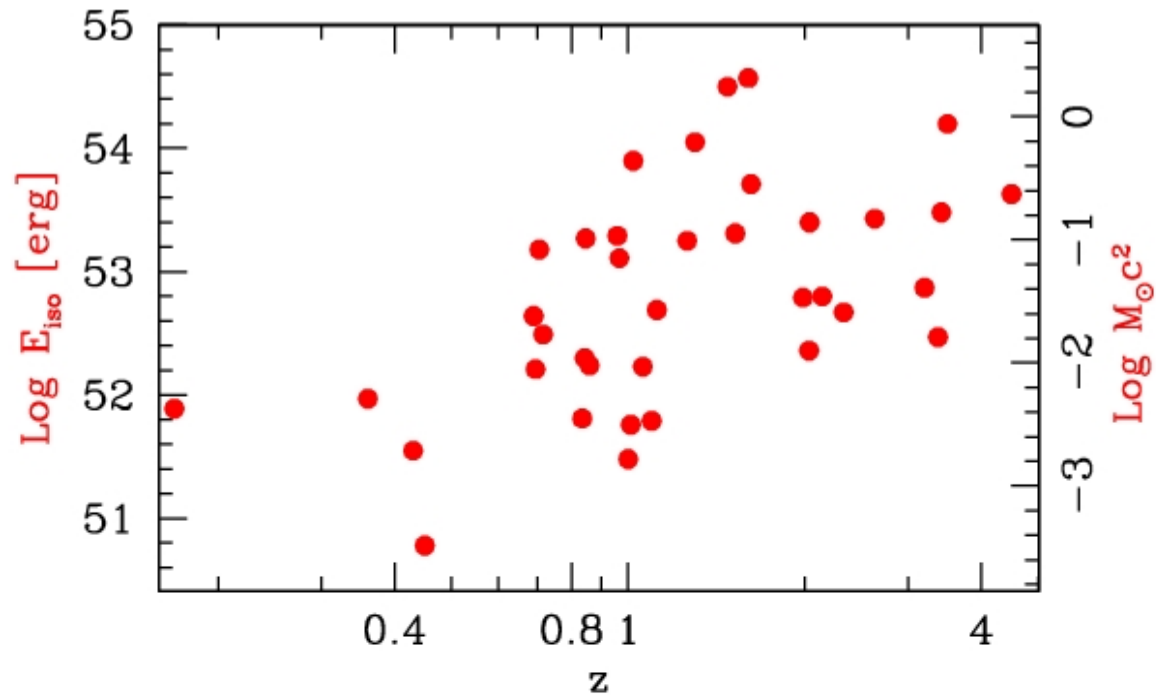


GRB typical Fluence
(i.e. time int. flux) is
 $10^{-8} - 10^{-4} \text{ erg/cm}^2$

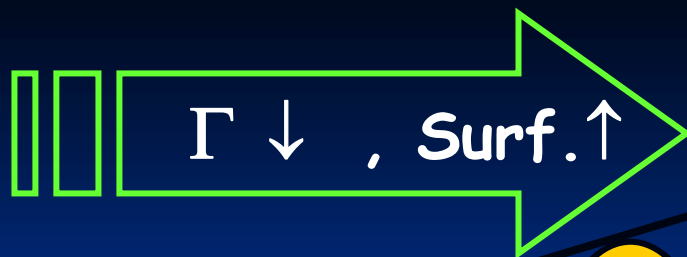
42 GRBs with redshift

Assuming isotropy

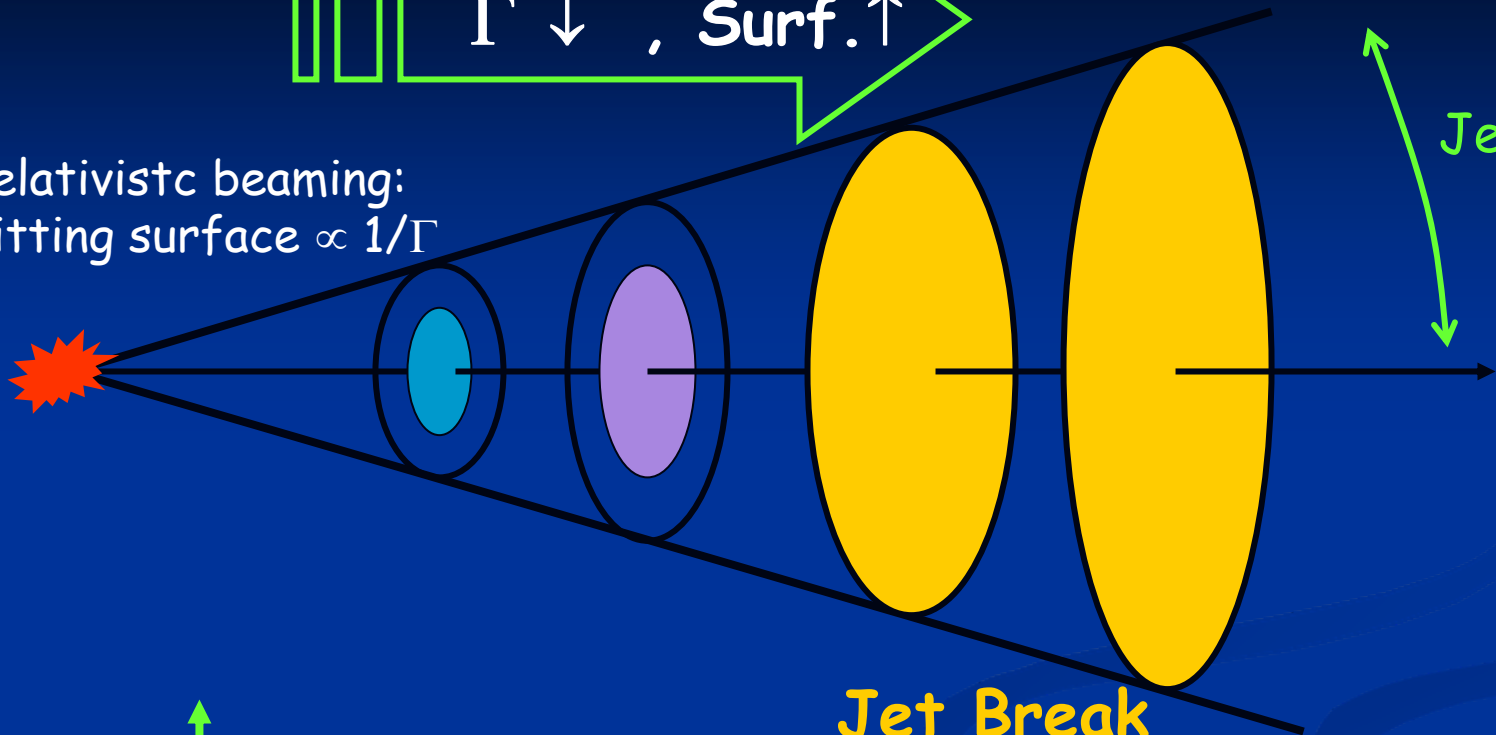
Huge isotropic
equivalent energy!!



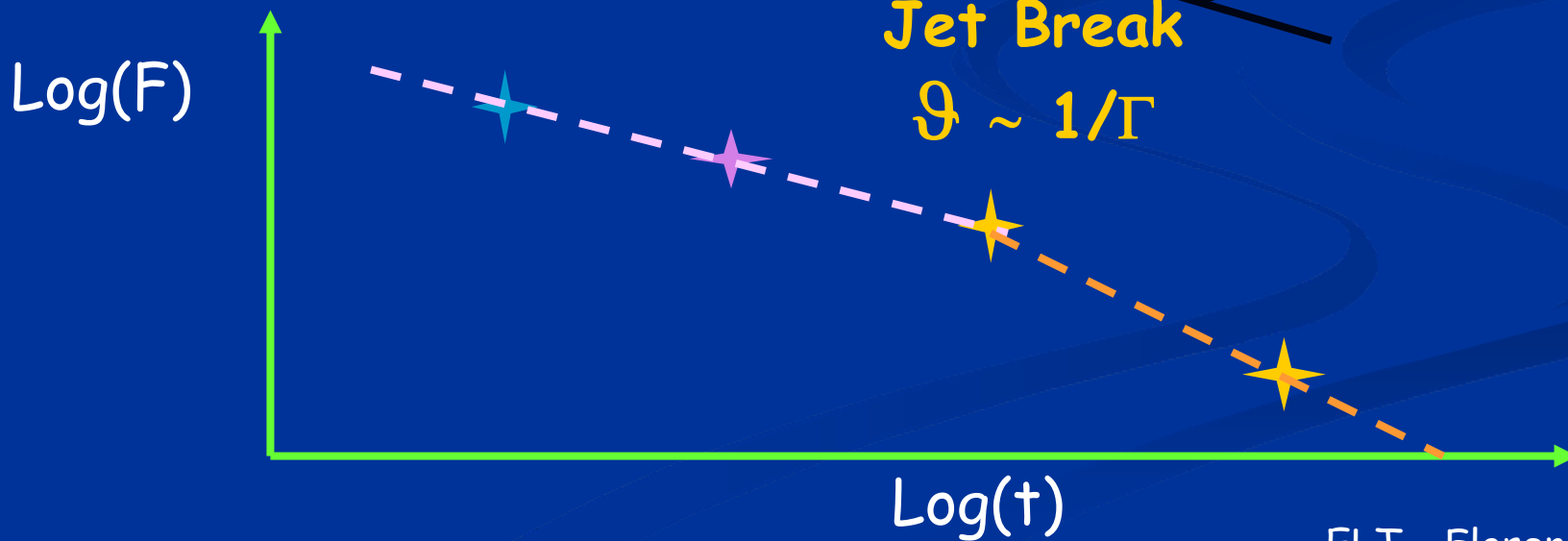
Jet effect



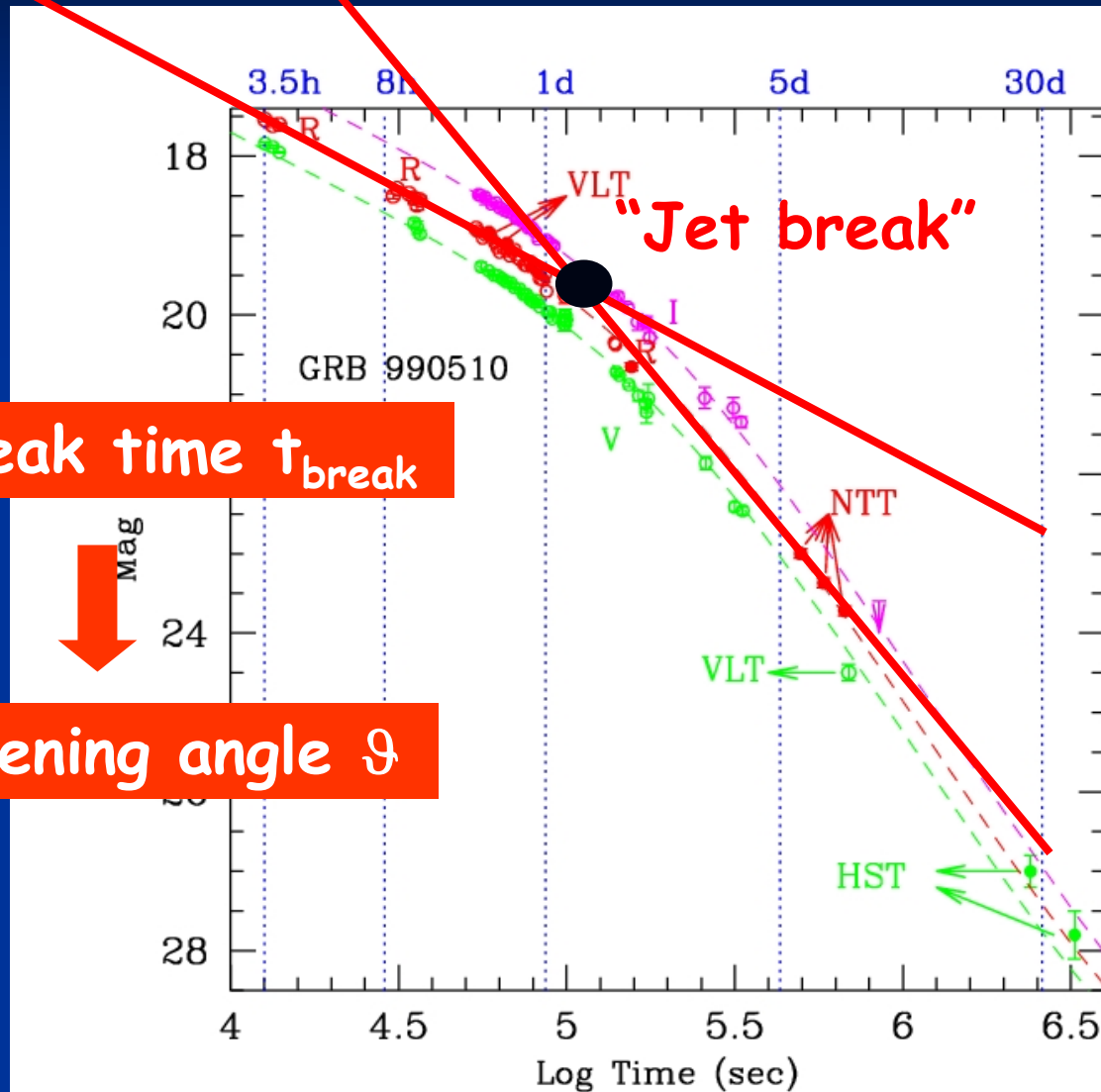
Relativistic beaming:
emitting surface $\propto 1/\Gamma$



Jet Break
 $\vartheta \sim 1/\Gamma$



GRB Jet measure

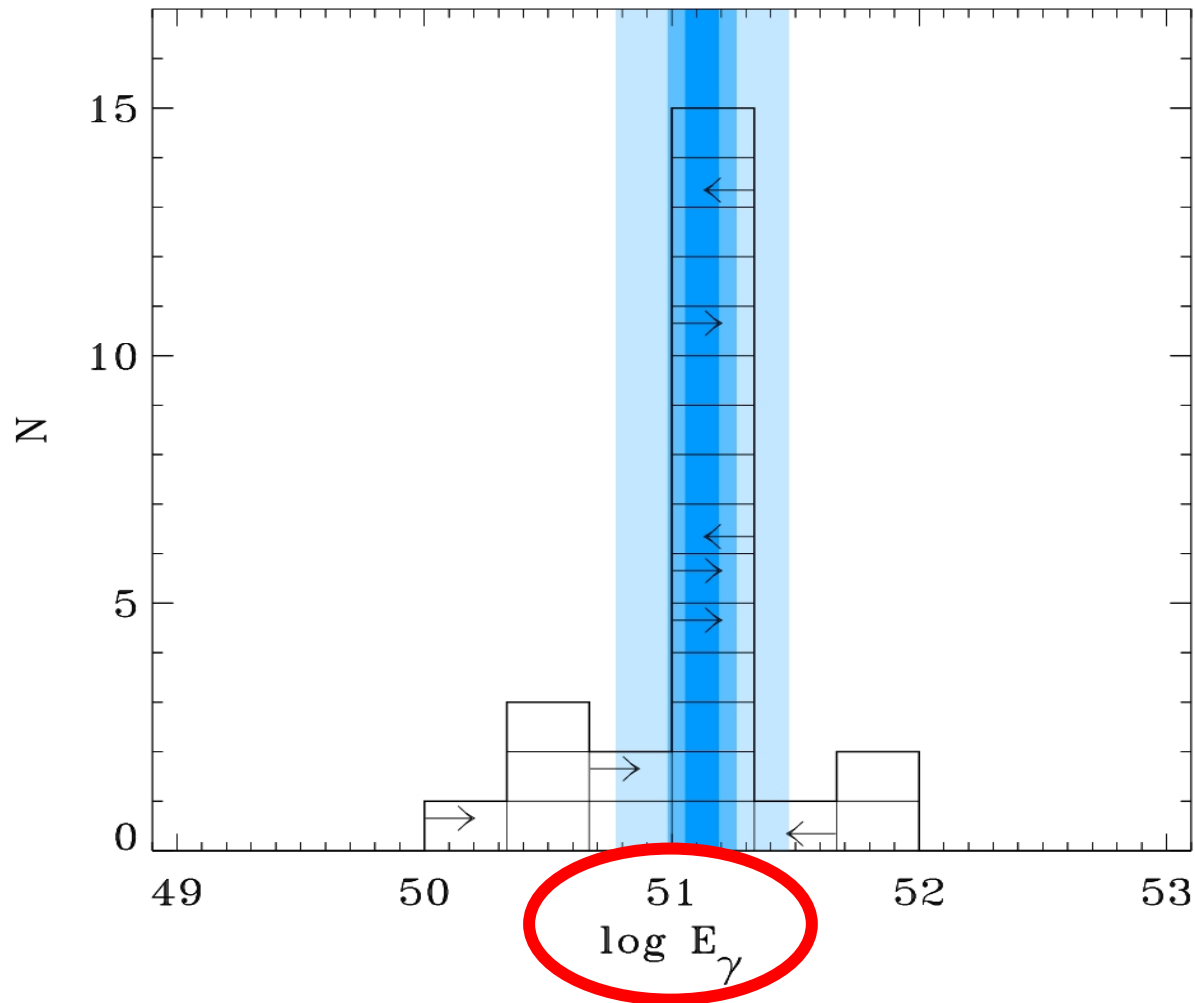


Jet break time t_{break}

Jet opening angle θ

"True" energetics

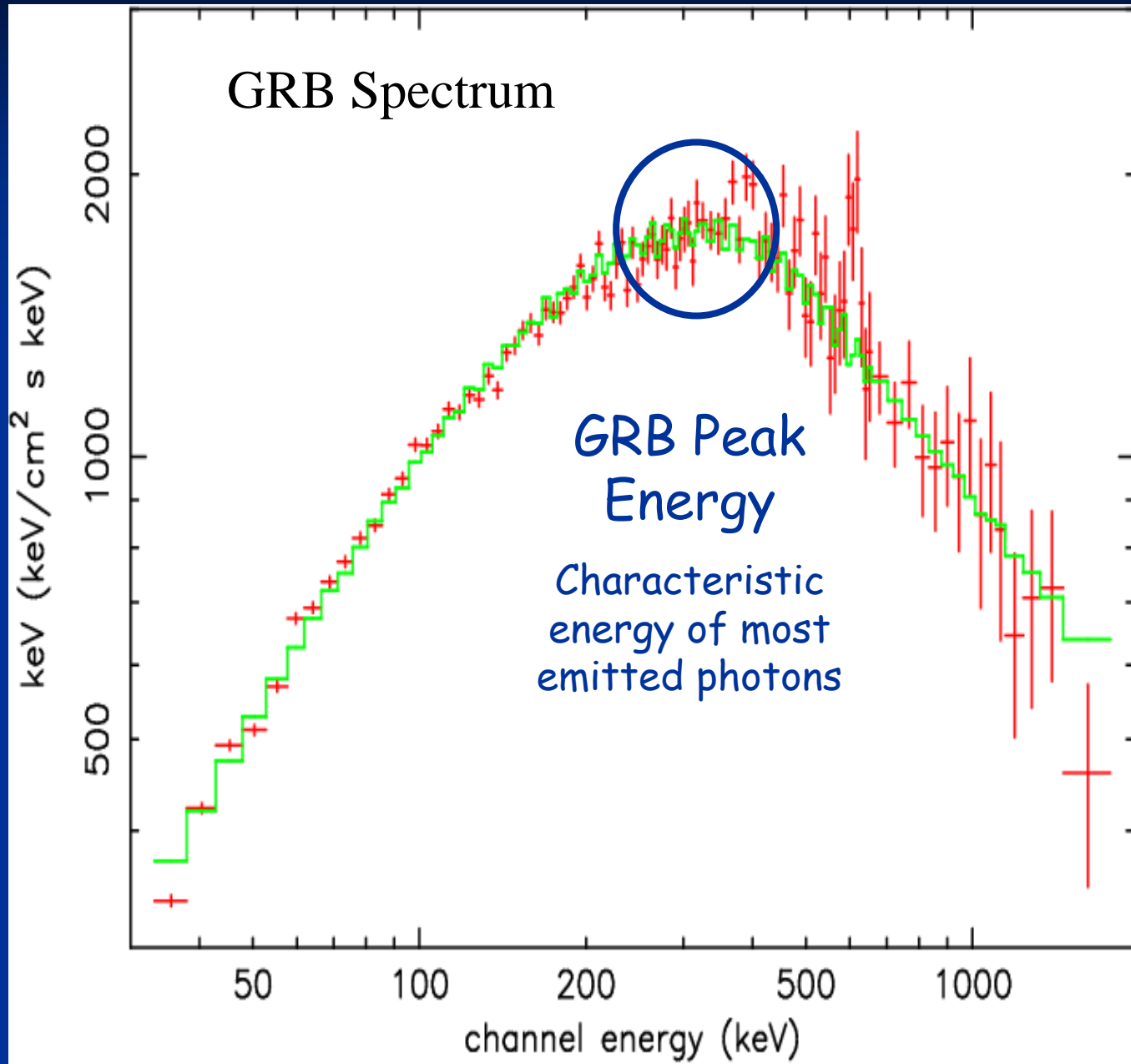
Frail et al. 2001



9)

Bloom et al. 2003

Prompt emission spectrum



28 GRB +2 XRF

$$\theta = 0.16 \frac{t_{\text{jet,d}}^{3/8} (\eta_{\gamma} n)^{1/8}}{(1+z)^{3/8} E_{\gamma,\text{iso},52}^{1/8}}$$

uniform n , $1 < n < 10$ if unknown

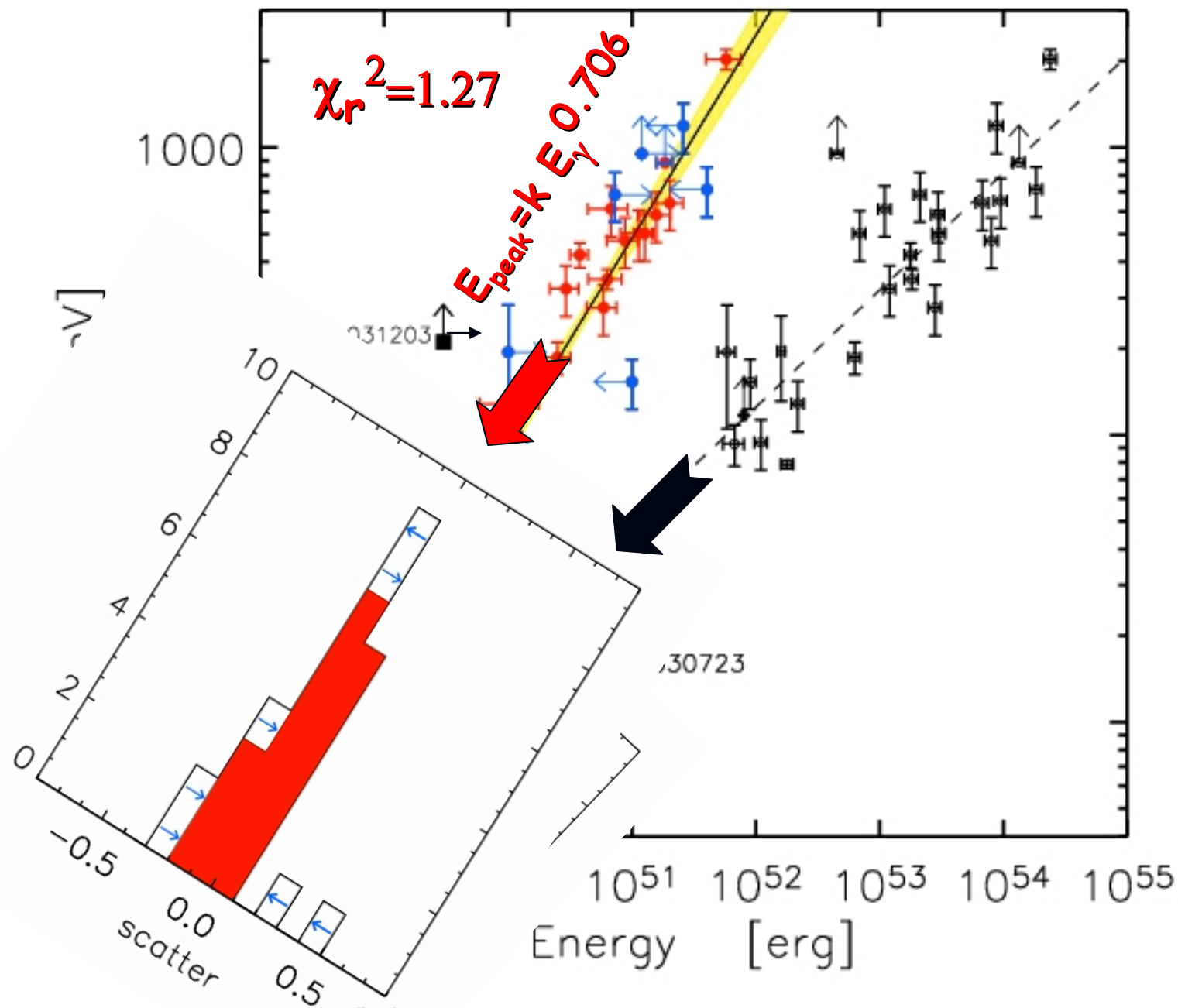
1 keV - 10 MeV

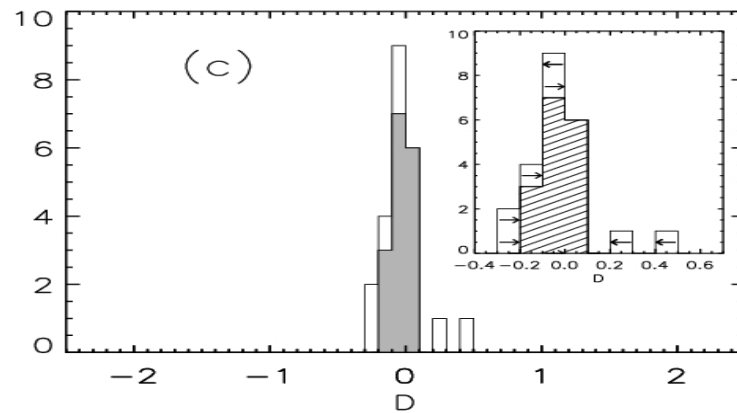
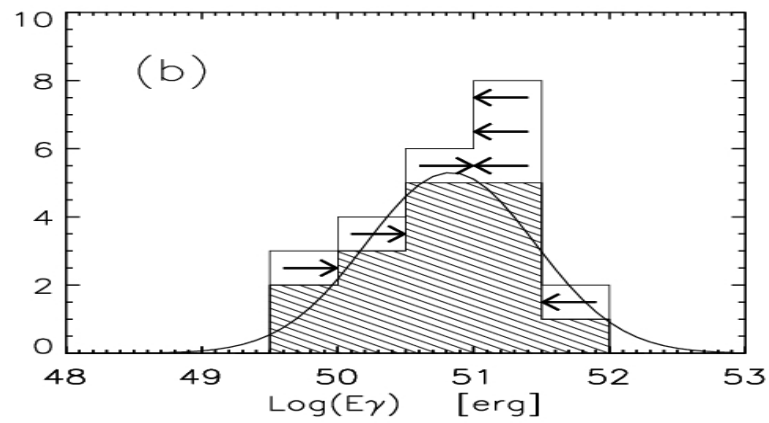
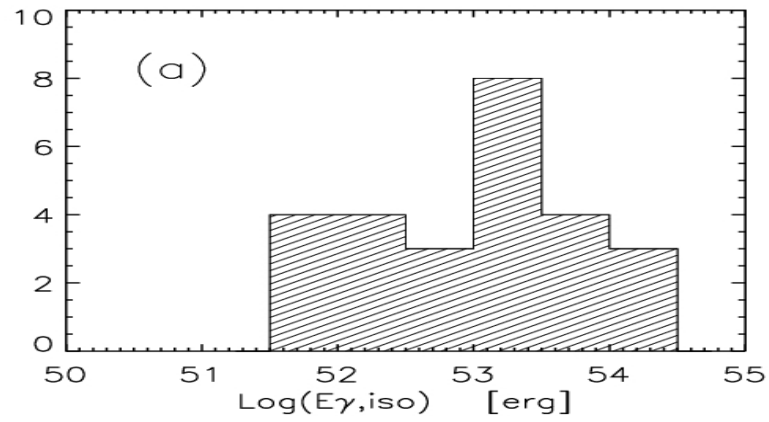
$\eta_{\gamma} = 0.2$

Energy [erg]

55

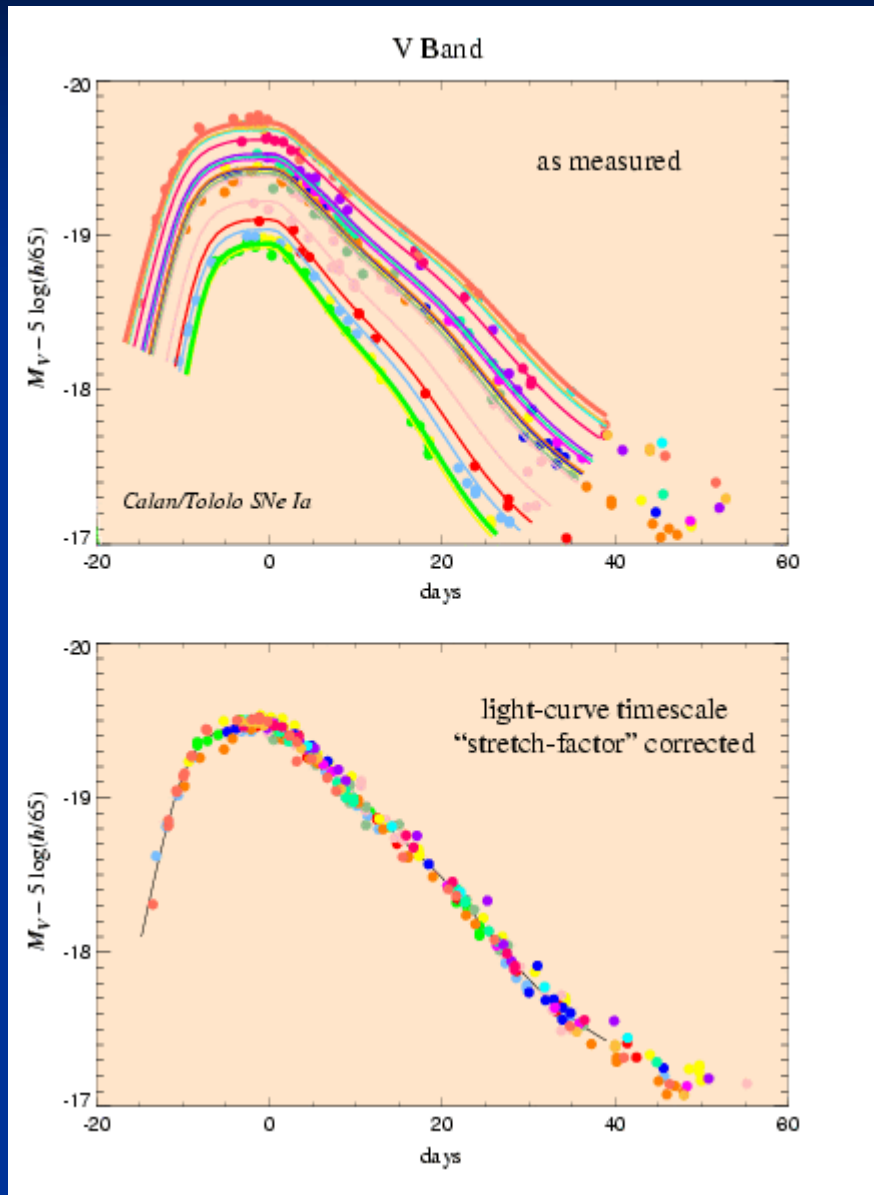
$E_{\text{peak}} - E_{\text{true}}$ correlation





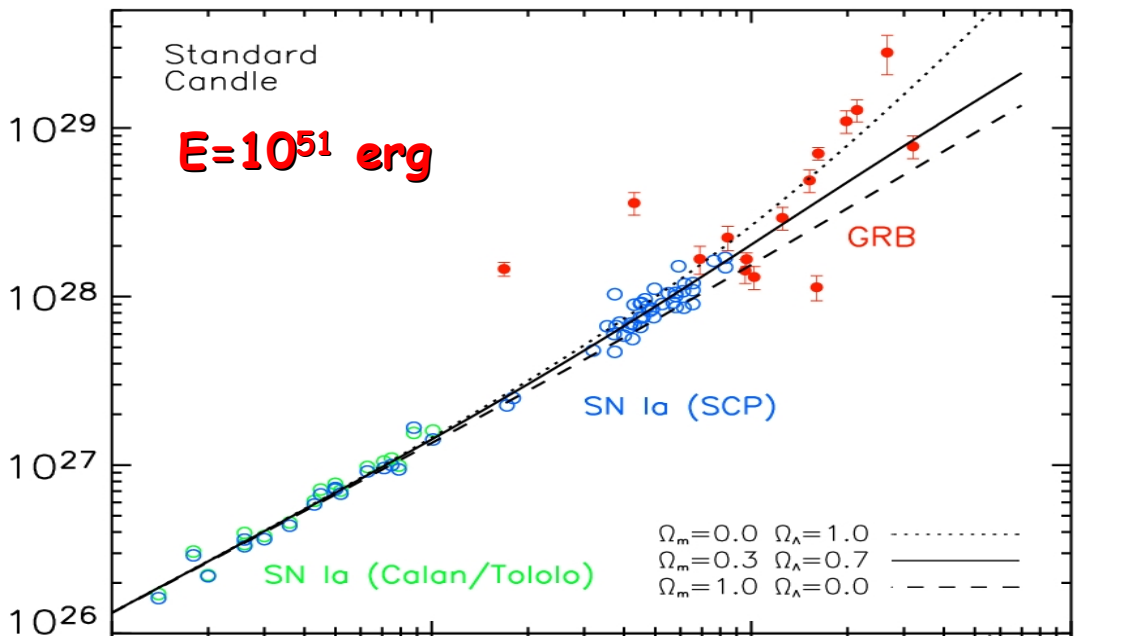
Ghirlanda, Ghisellini & Lazzati 2004

Similar to Supernovae Ia

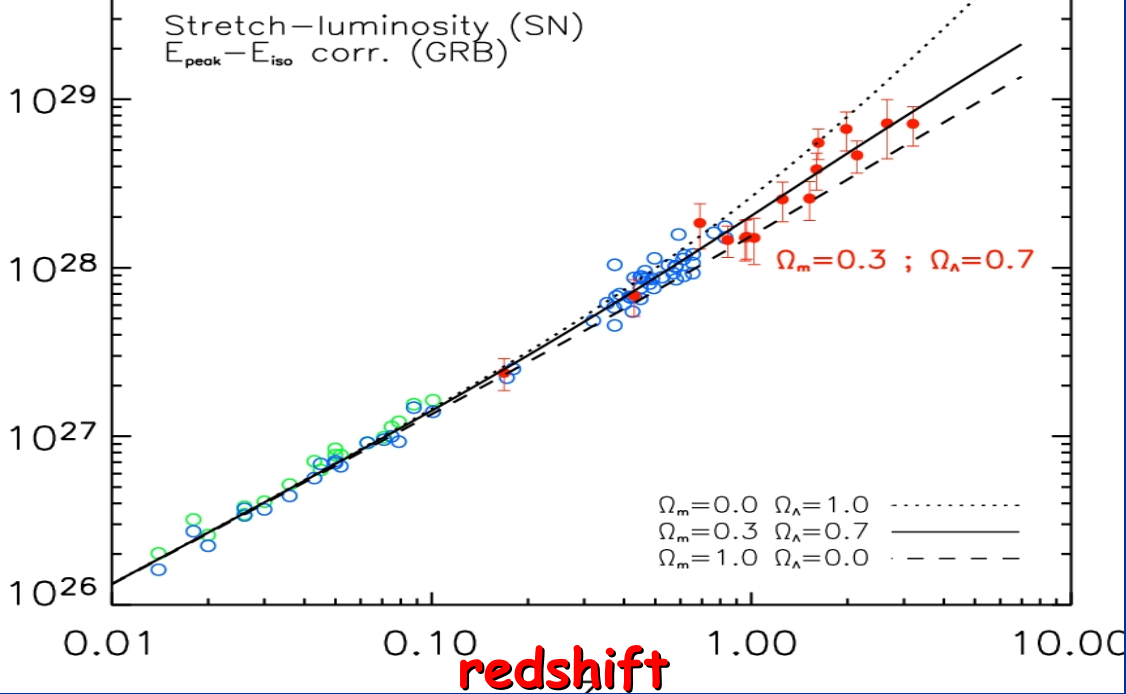


**"Stretching":
the slower
the brighter**

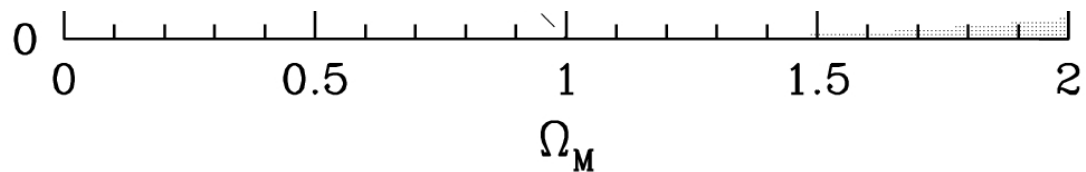
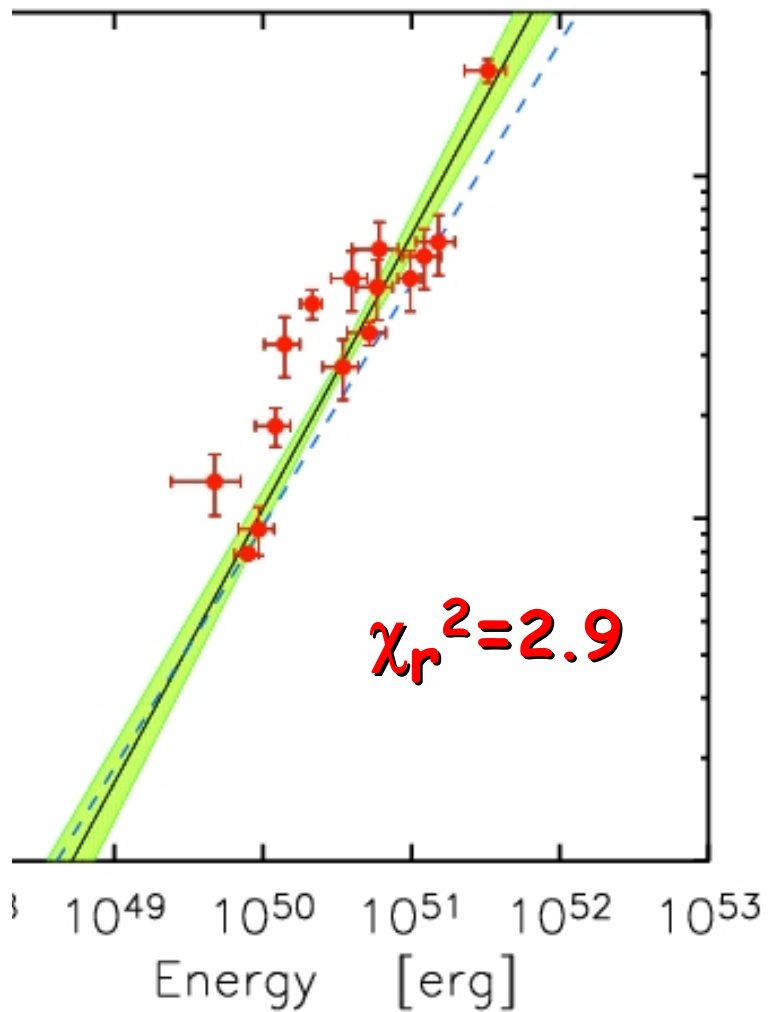
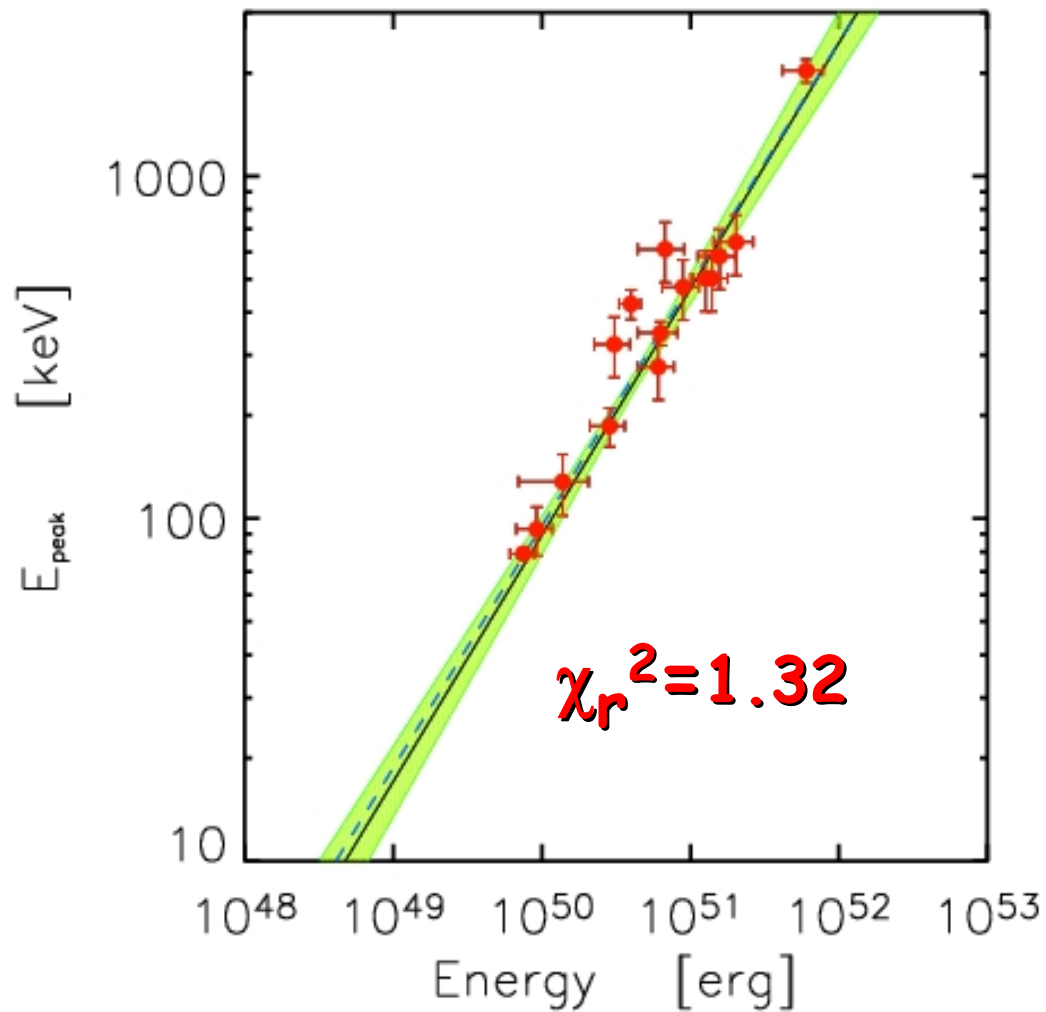
Luminosity distance

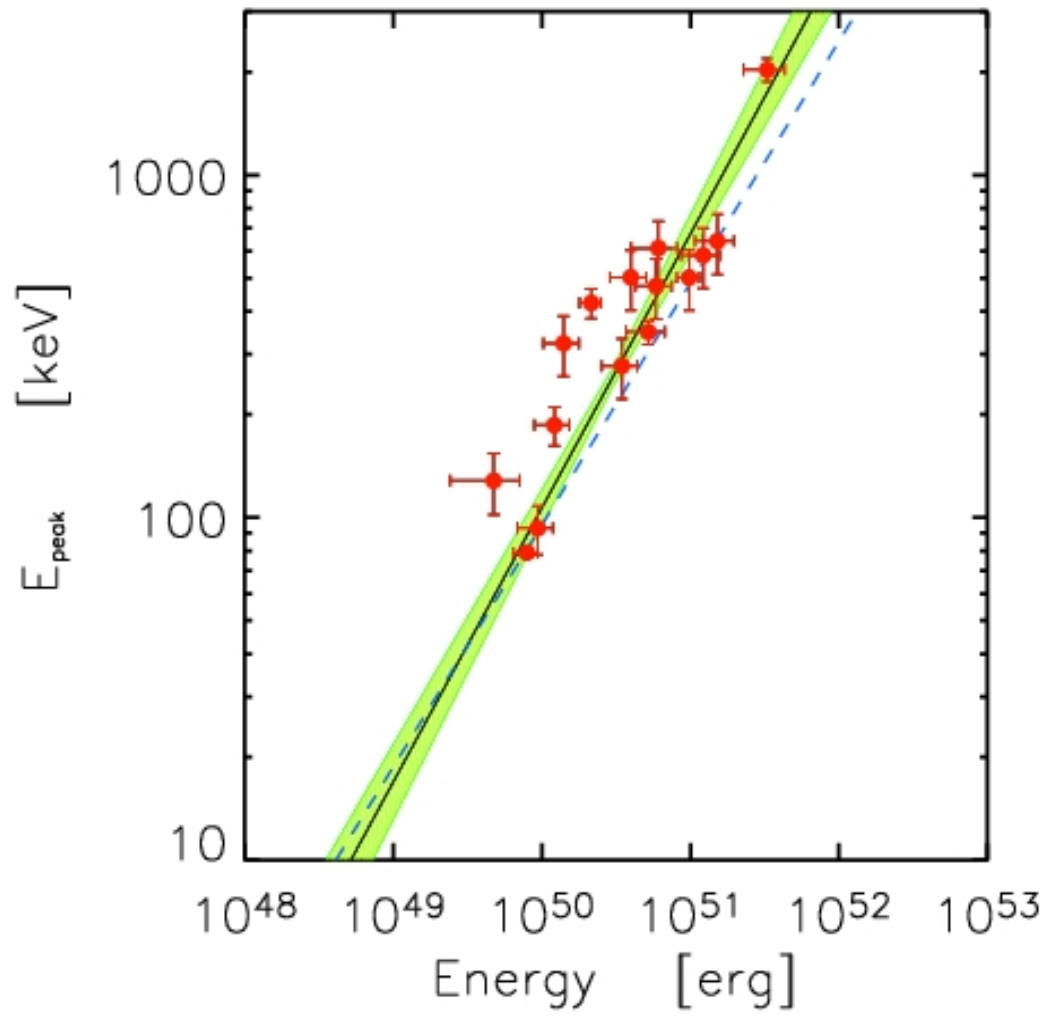


Luminosity distance

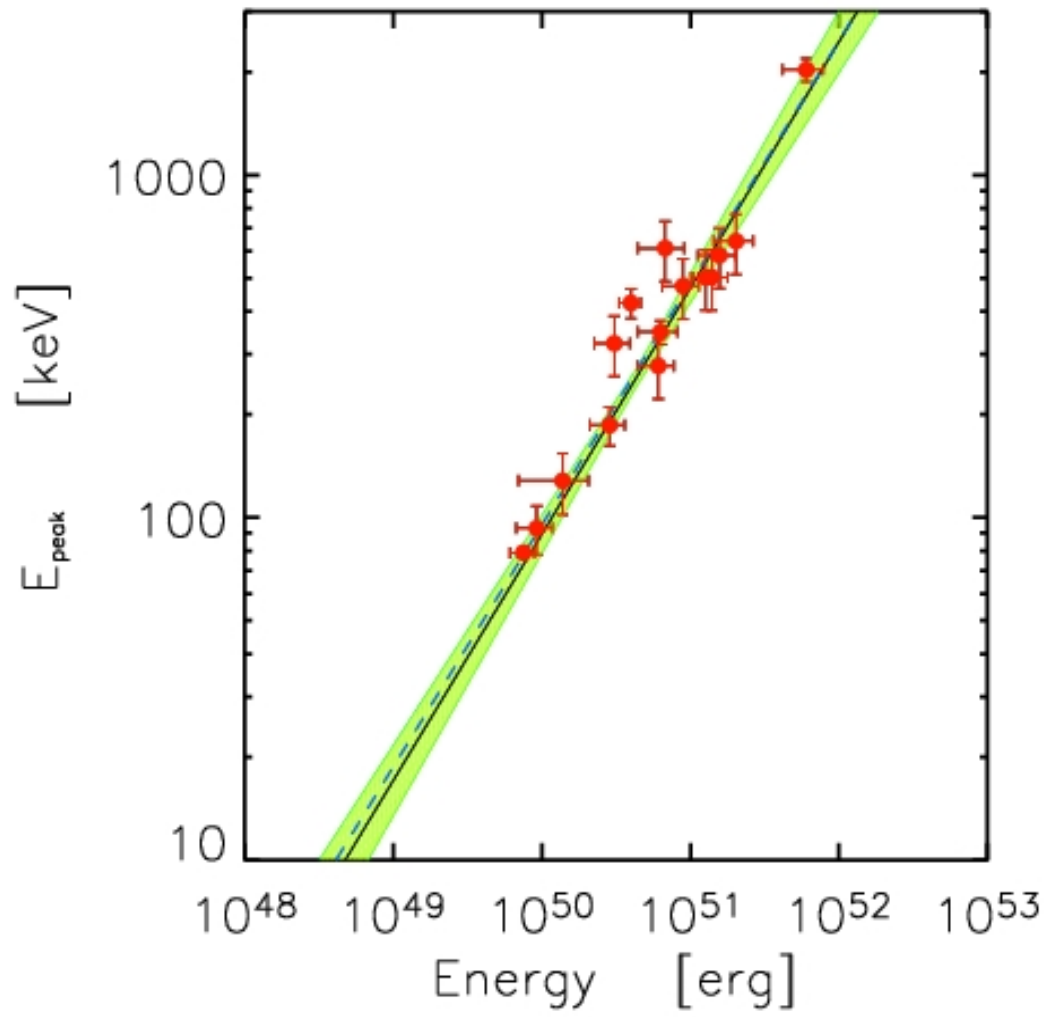


Ghirlanda, Ghisellini, Lazzati & Firmani 2004

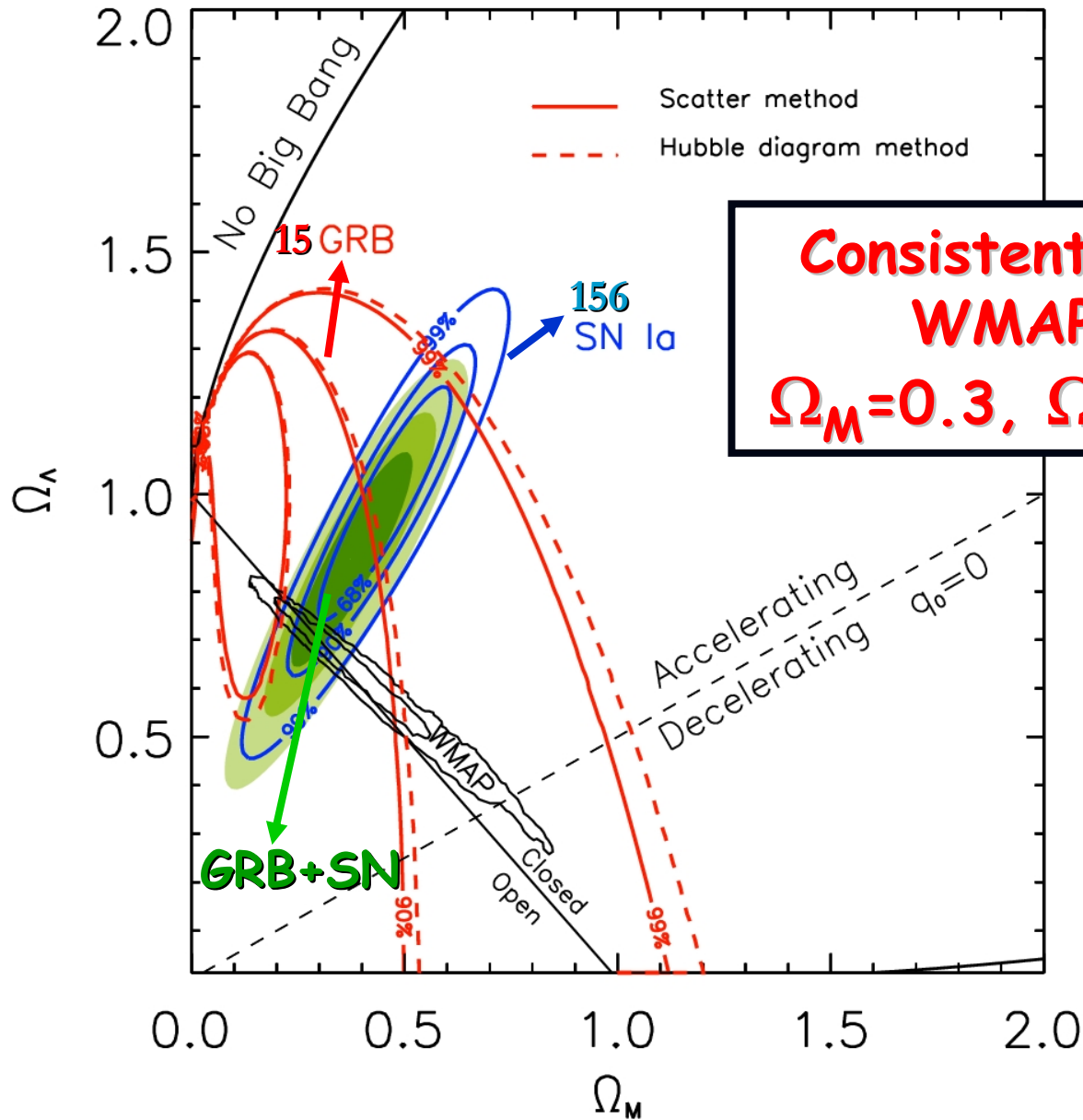




1.5 -1.5



0.2 - 0.1

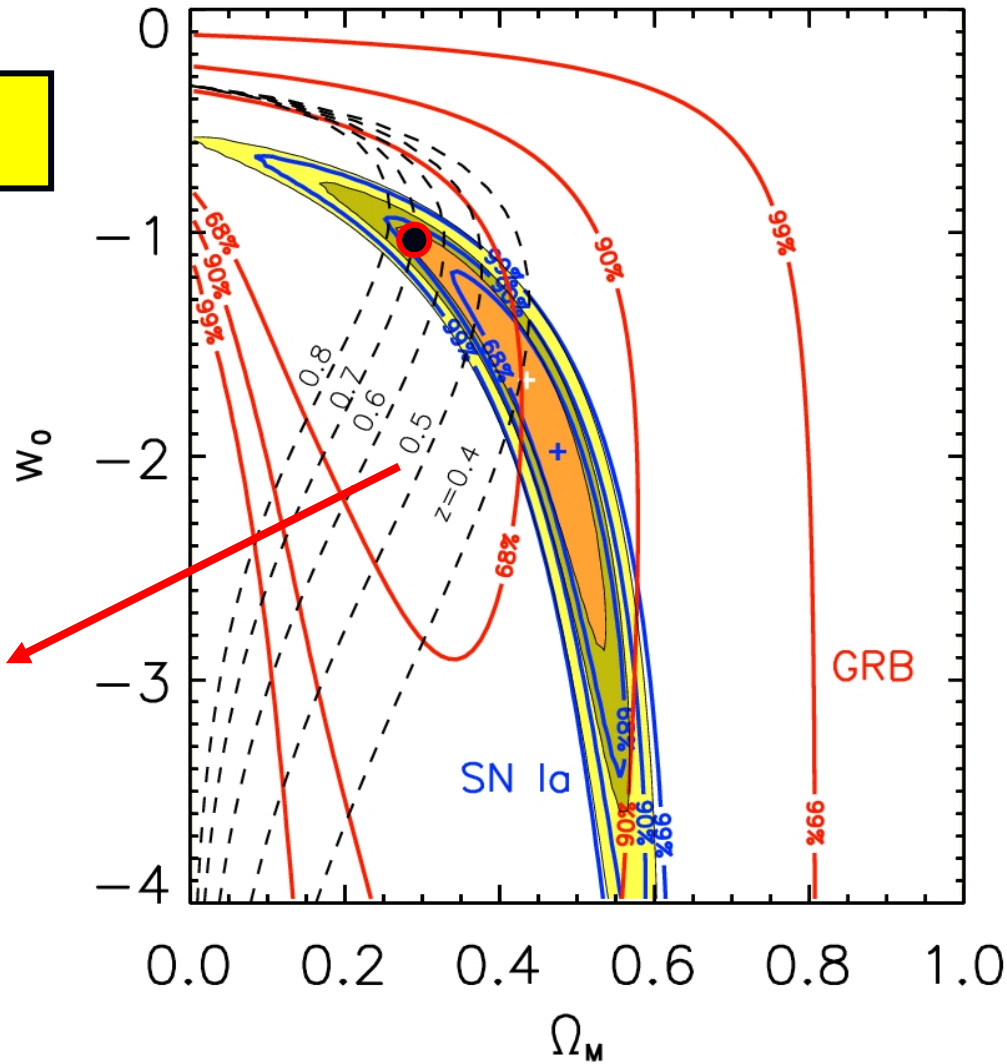


Consistent with WMAP:
 $\Omega_M = 0.3, \Omega_\Lambda = 0.7$

Flat Universe: $\Omega_{\text{tot}}=1$

$P = w_0 \rho c^2$

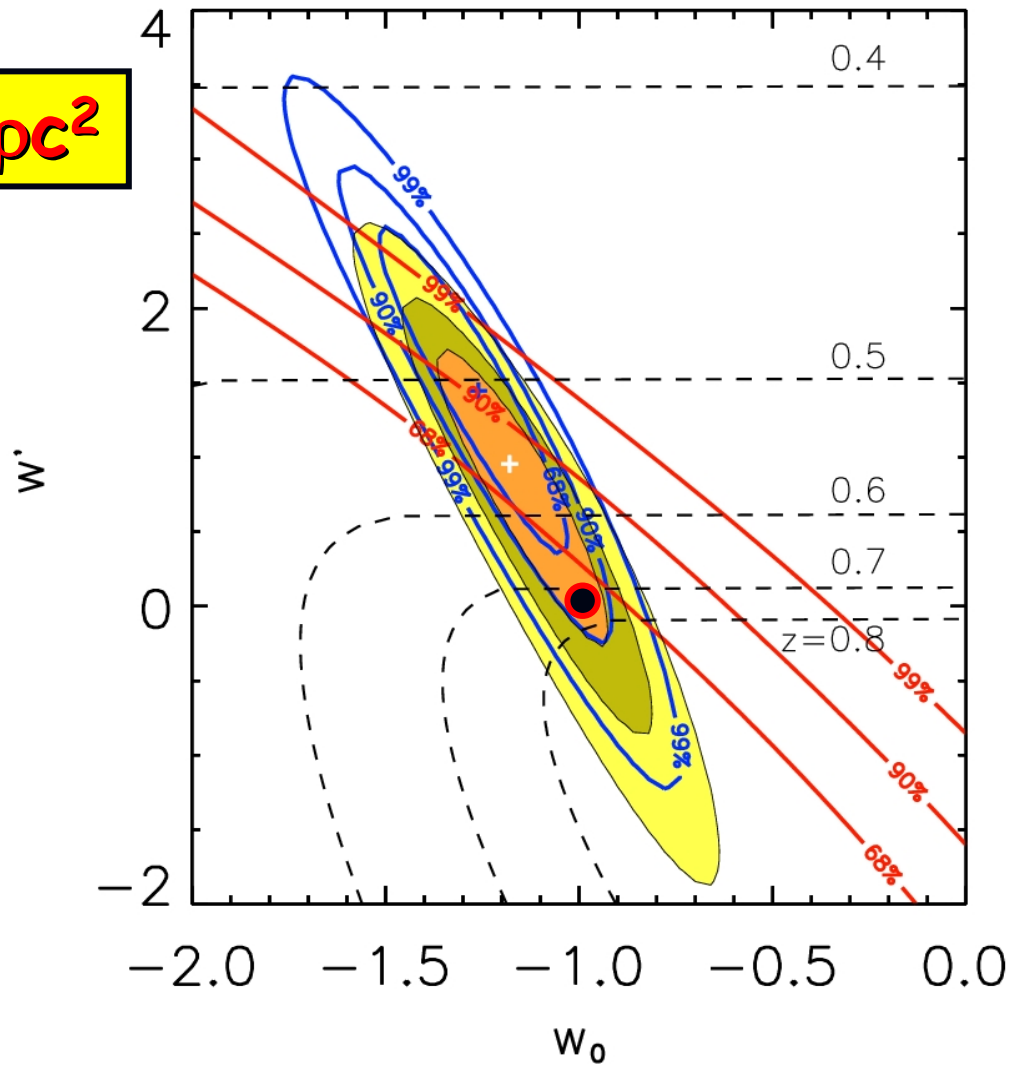
transition z :
 $\ddot{a} = 0$



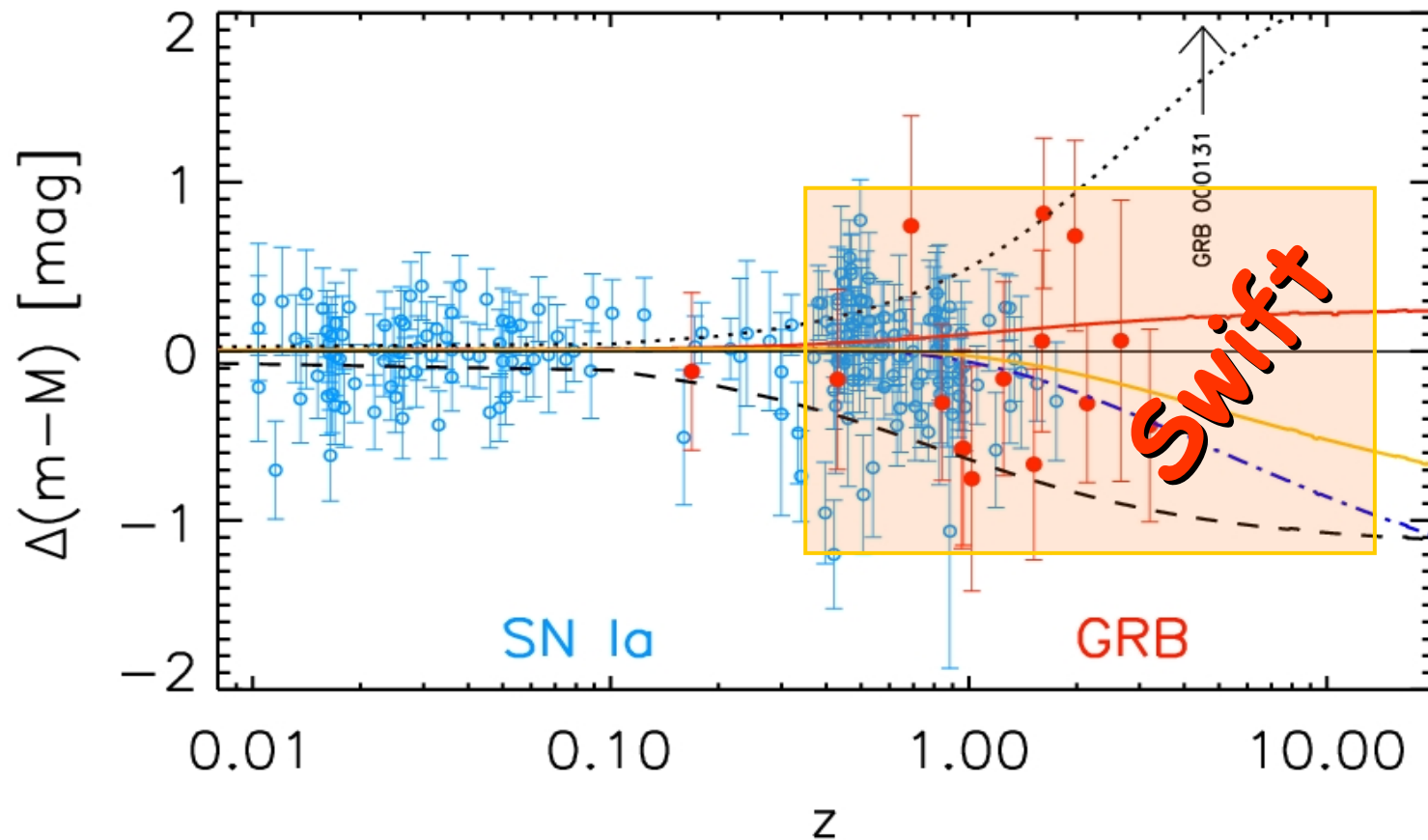
Firmani, Ghisellini, Ghirlanda & Avila-Reese, 2004

Flat Universe: $\Omega_{\text{tot}}=1$, $\Omega_M=0.27$

$$P=(w_0+w'z)\rho c^2$$



Firmani, Ghisellini, Ghirlanda & Avila-Reese, 2004

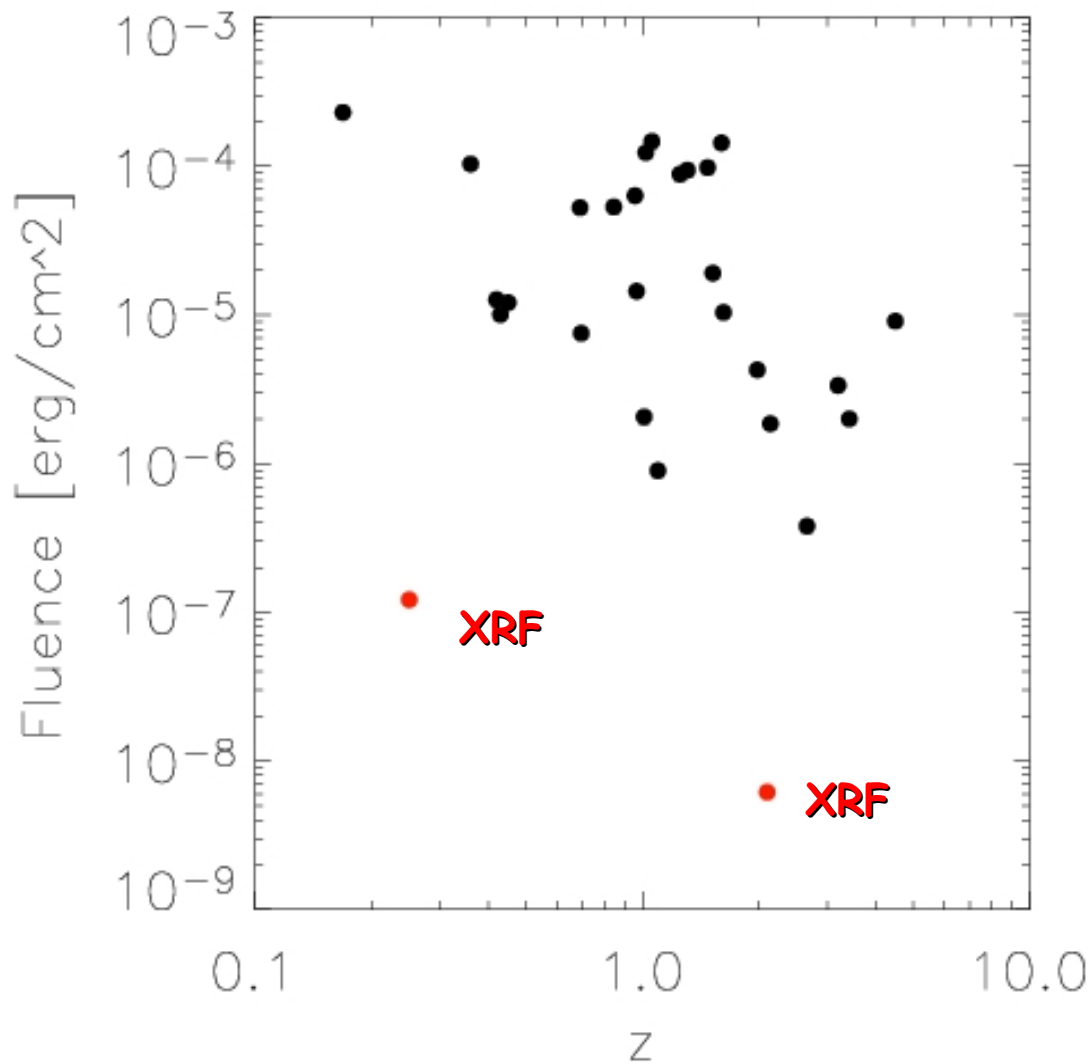


Firmani, Ghisellini, Ghirlanda, & Avila-Reese, 2004

● Fluence

● Early

Hope

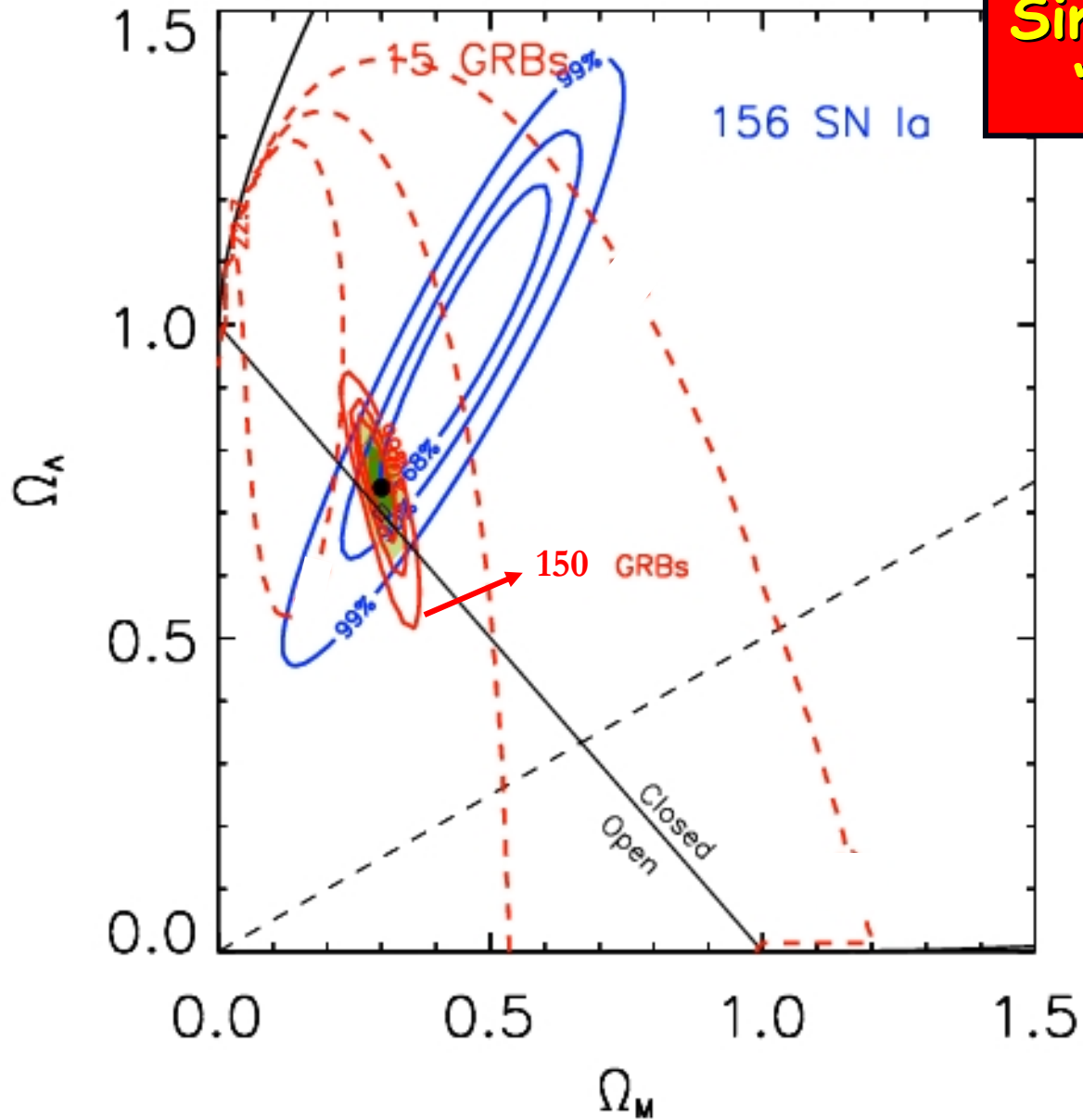


n z

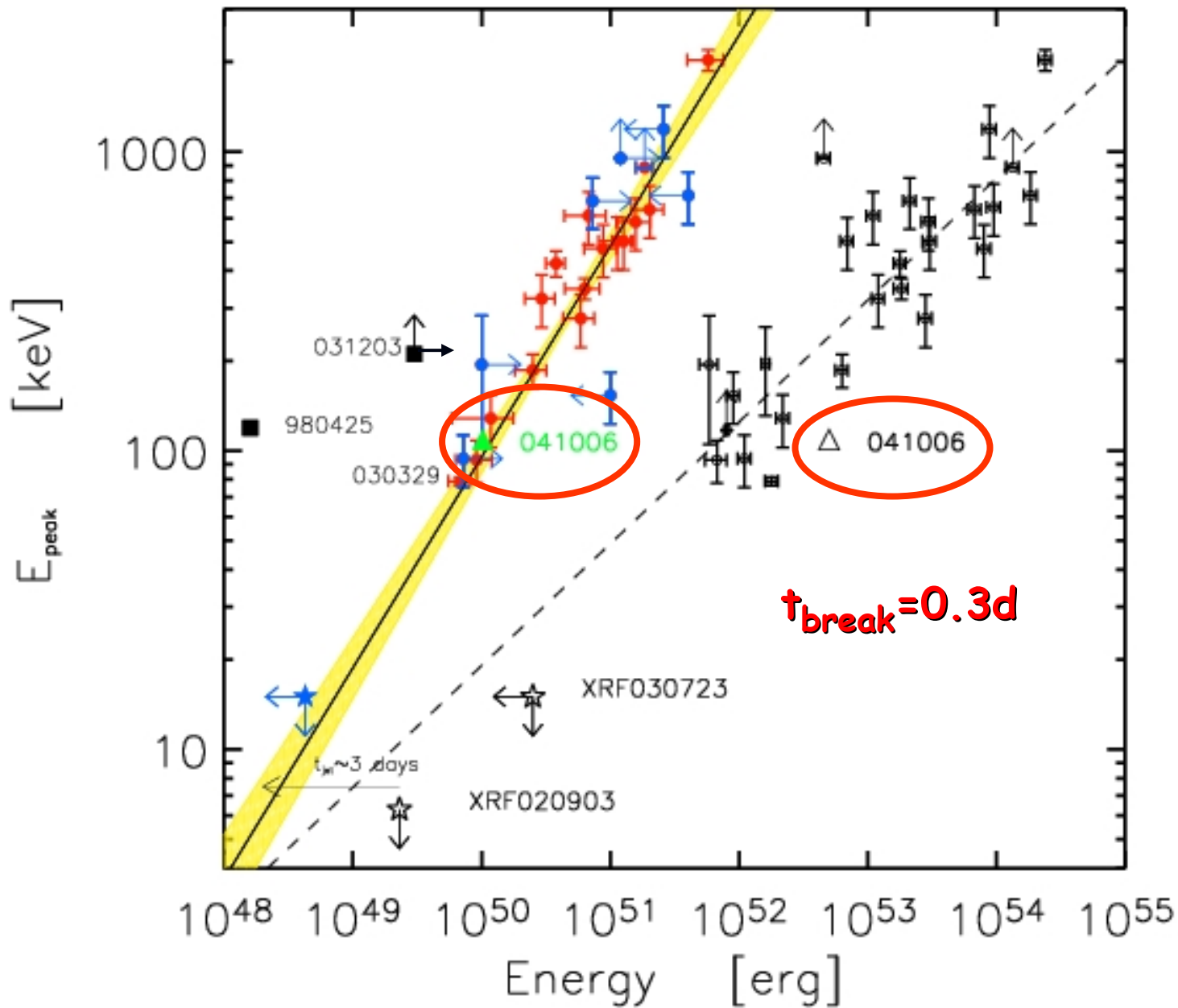
d

n-z

**Simulation for 150
"Swift bursts"**



... the latest GRB ...





Updated Correlation

Updated cosmological constraints

www.merate.mi.astro.it/~ghirla/deep/blink.html

High redshift GRBs and t_{break}

Typical Afterglow

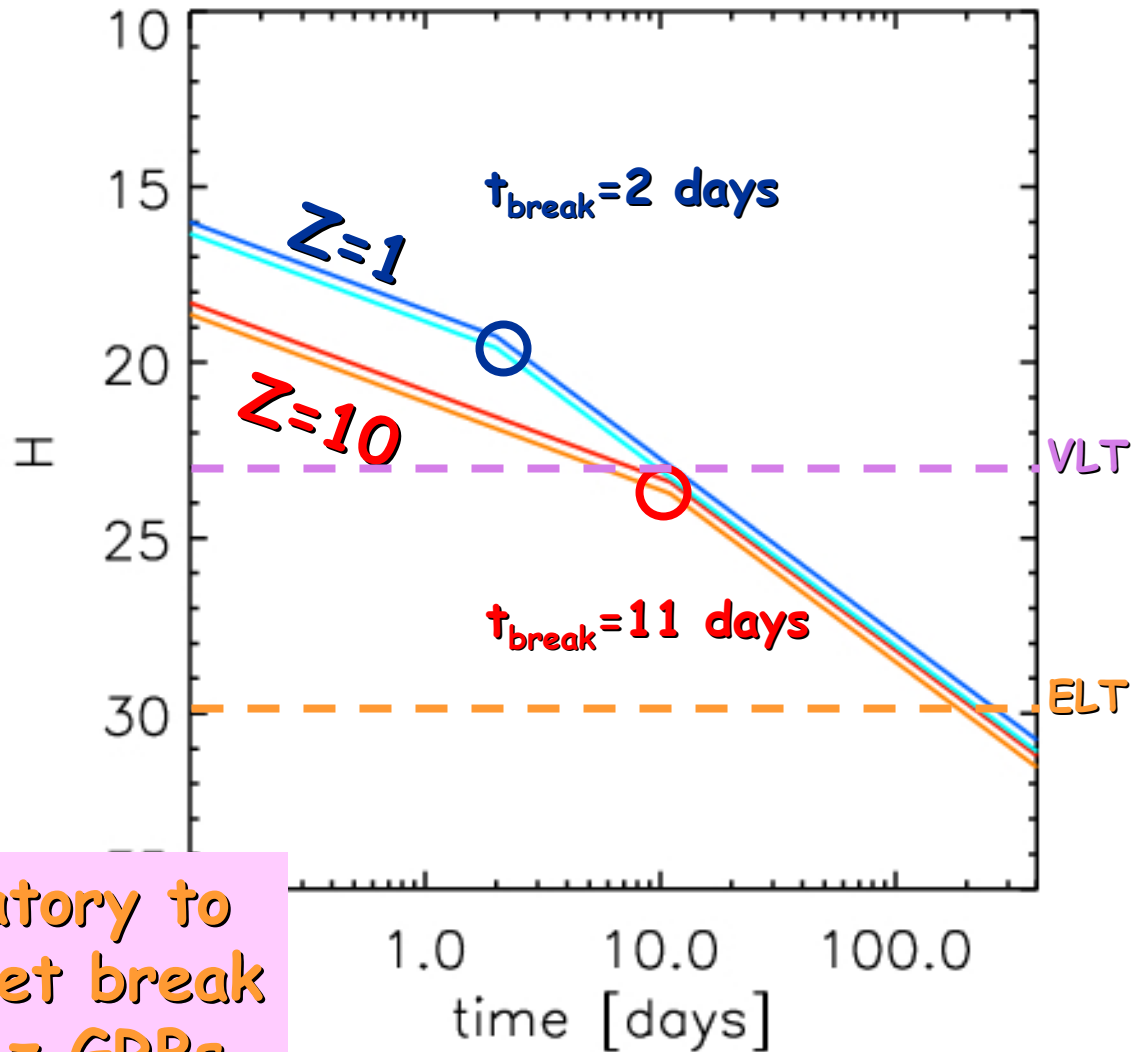
$F \propto t^{-1}$ for $t < t_{\text{break}}$

$F \propto t^{-2}$ for $t > t_{\text{break}}$

@ $z=1$

$t_{\text{break}} = 2$ days

$H \approx 19$ @ 1 day



ELT is mandatory to measure the jet break time of high z GRBs

Cosmology with high z GRBs

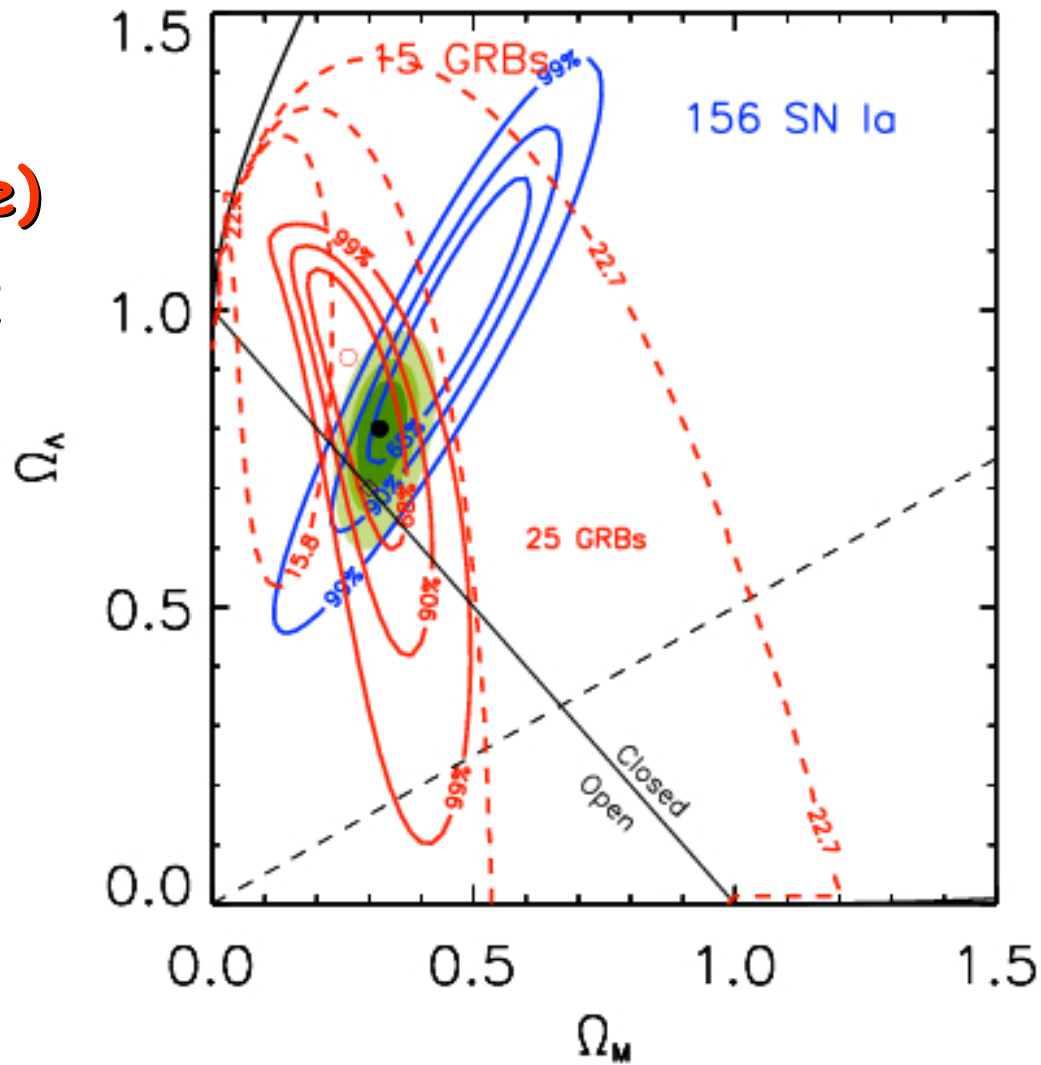
15 GRBs
(present sample)

$0.1 < z < 3.2$

+

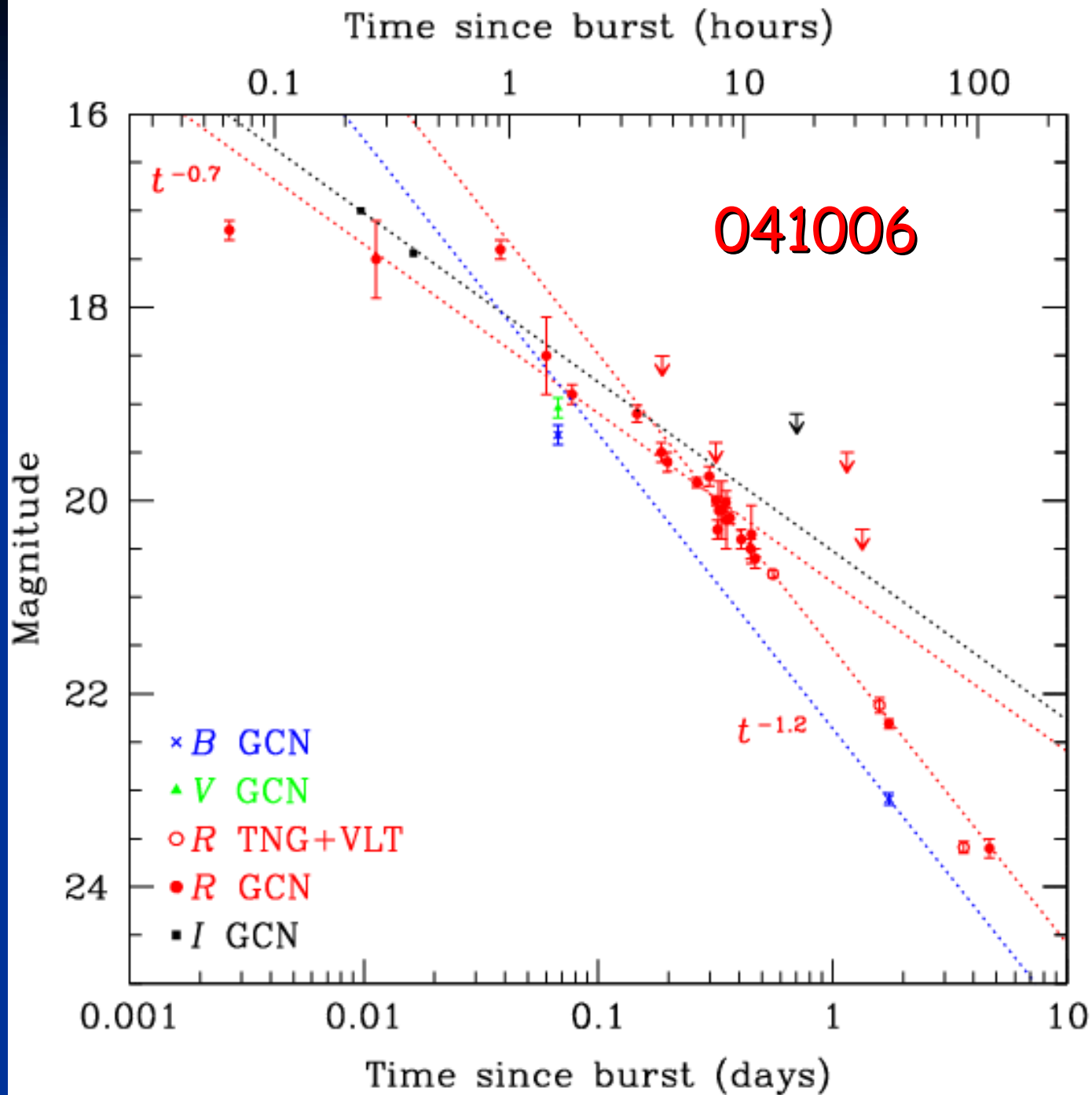
10 GRBs

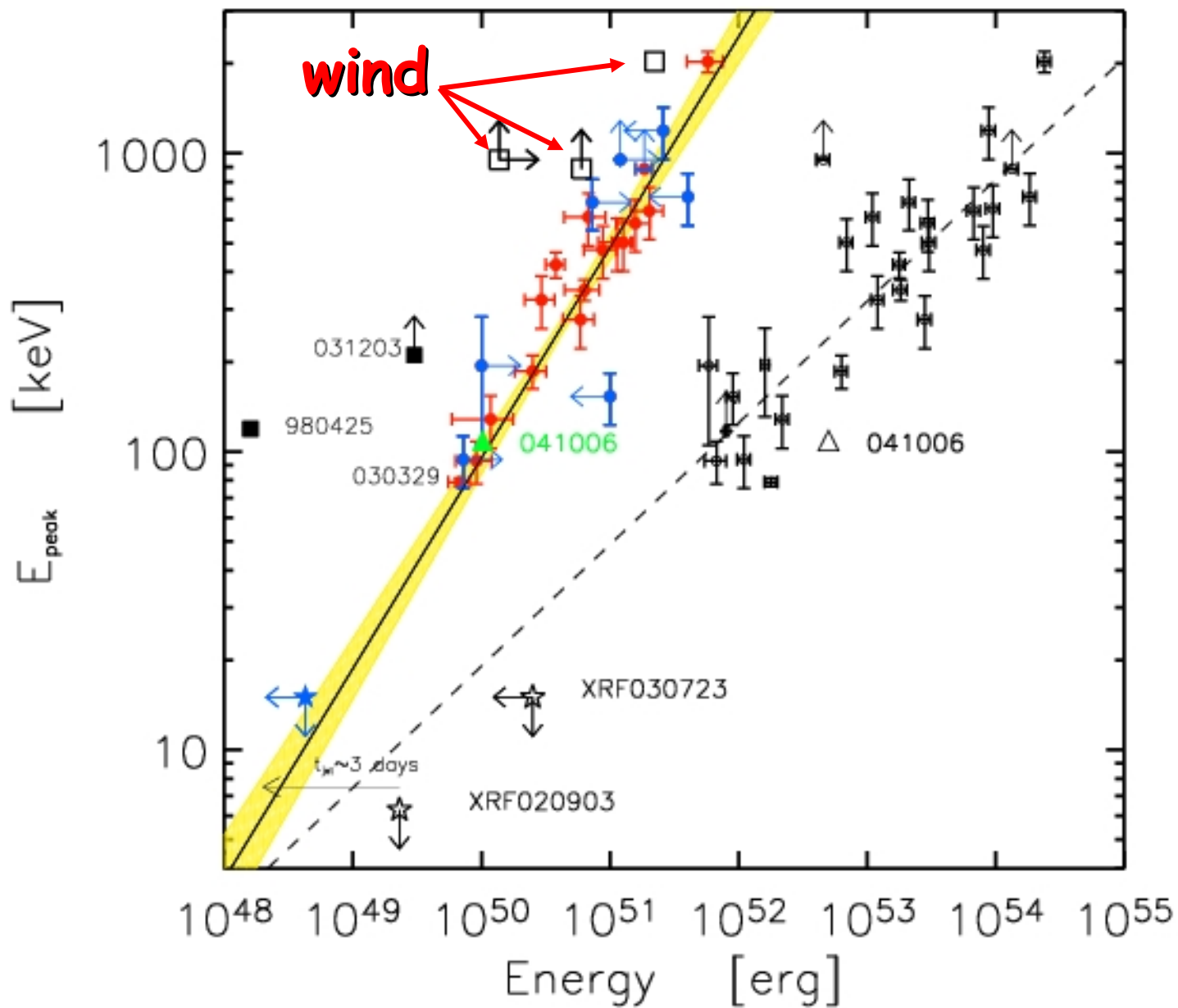
$9 < z < 10$

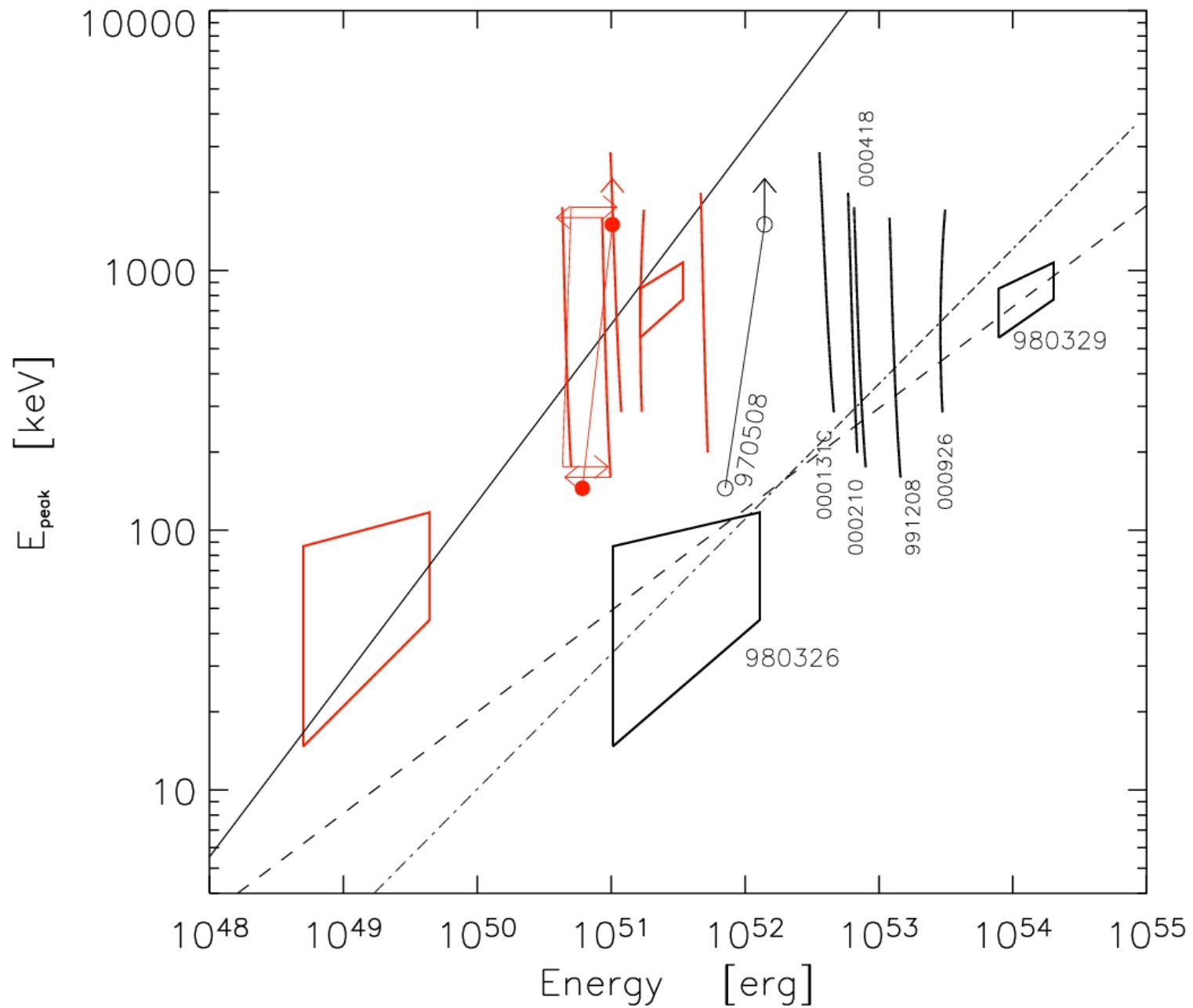


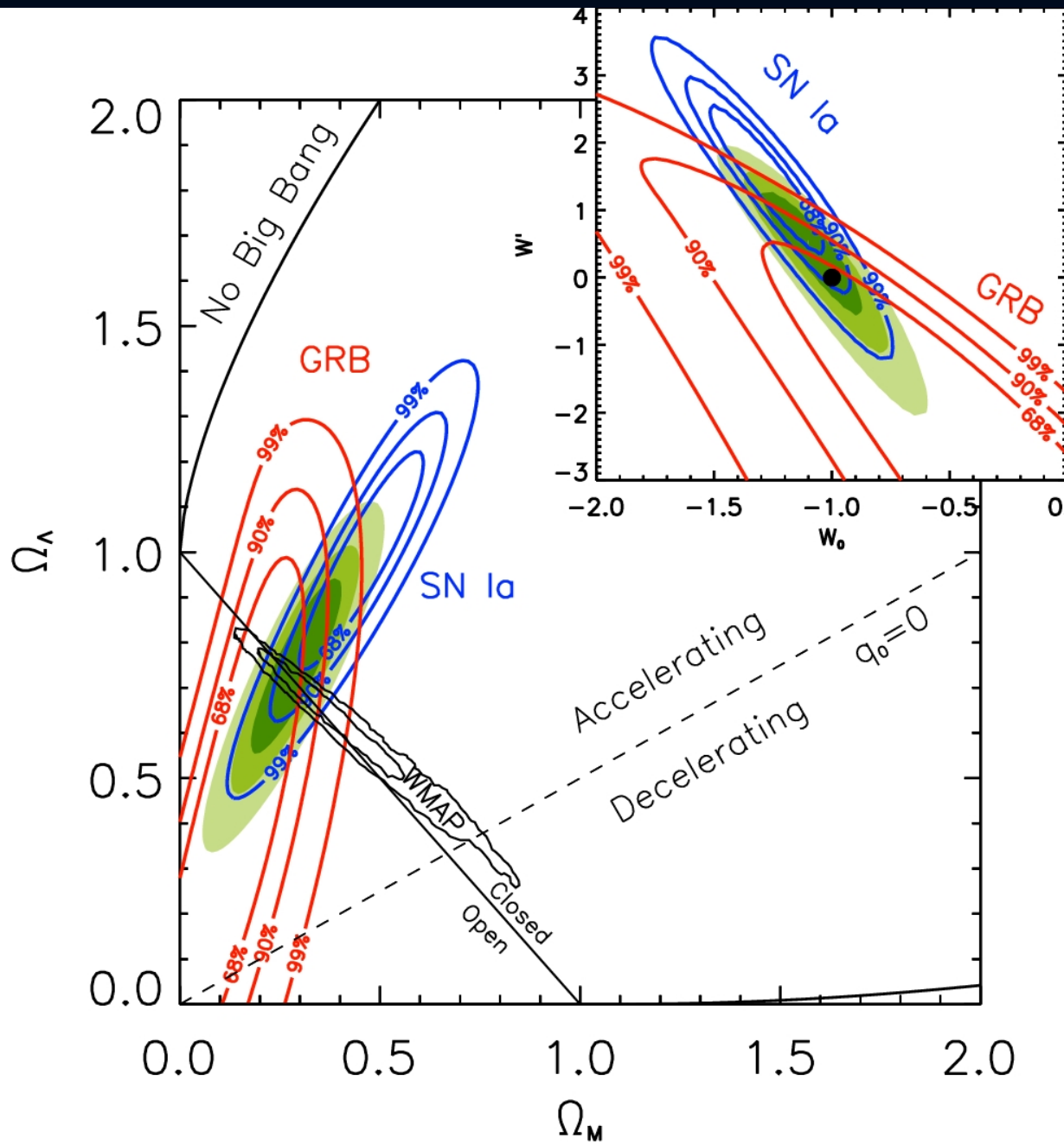
Conclusions

- **GRBs** are among the most powerful sources of the universe and through the *GGL04* correlation can be used as **cosmological rulers**.
- GRBs (detectable out to $z=17$) represent the link between SN Ia and CMB primary anisotropies, and allows to **study the Universe geometry and dynamics**.
- Requirements: **accurate measure of t_{break}** + inclusion of **very high redshift GRBs**. At $z > 6-7$ need for Extremely Large Telescopes.
- **ELT** high res. Imaging can also contribute in understanding the GRB **progenitor** nature, **emission process** nature, GRB **dynamics**
- **ELT** high res. Spectroscopy can contribute in understanding the GRB **environs**, **galaxy** population.



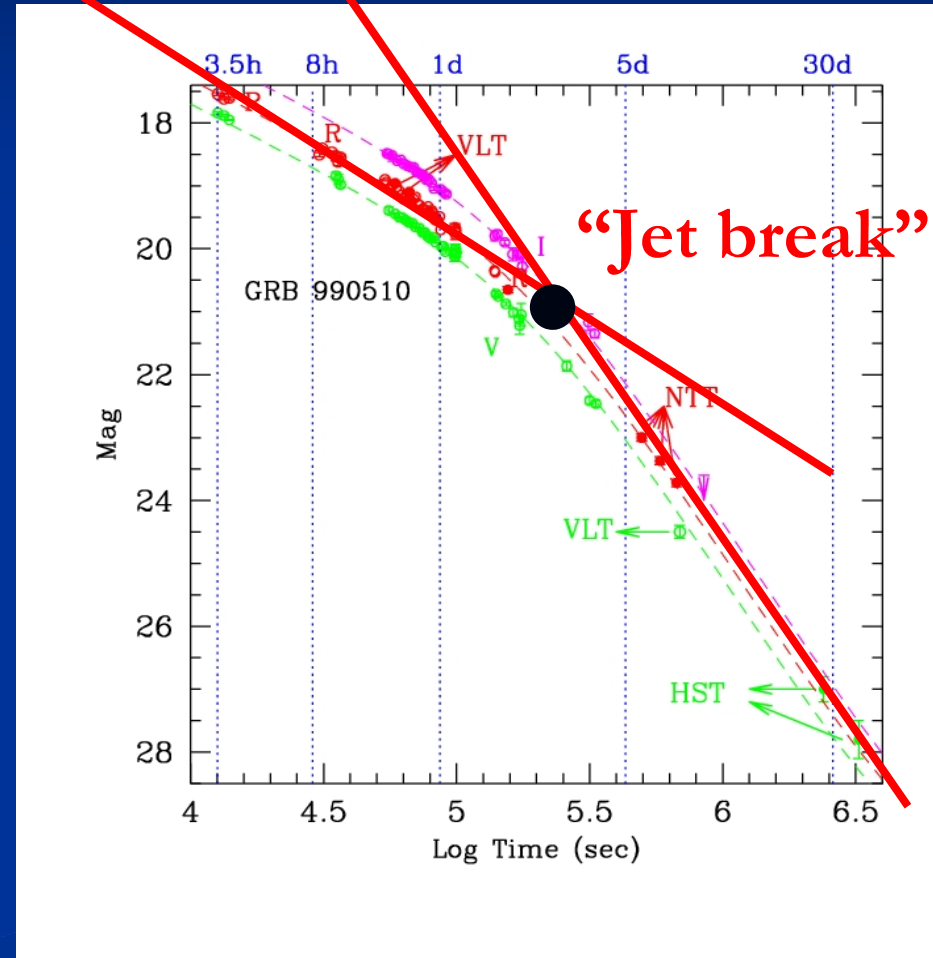
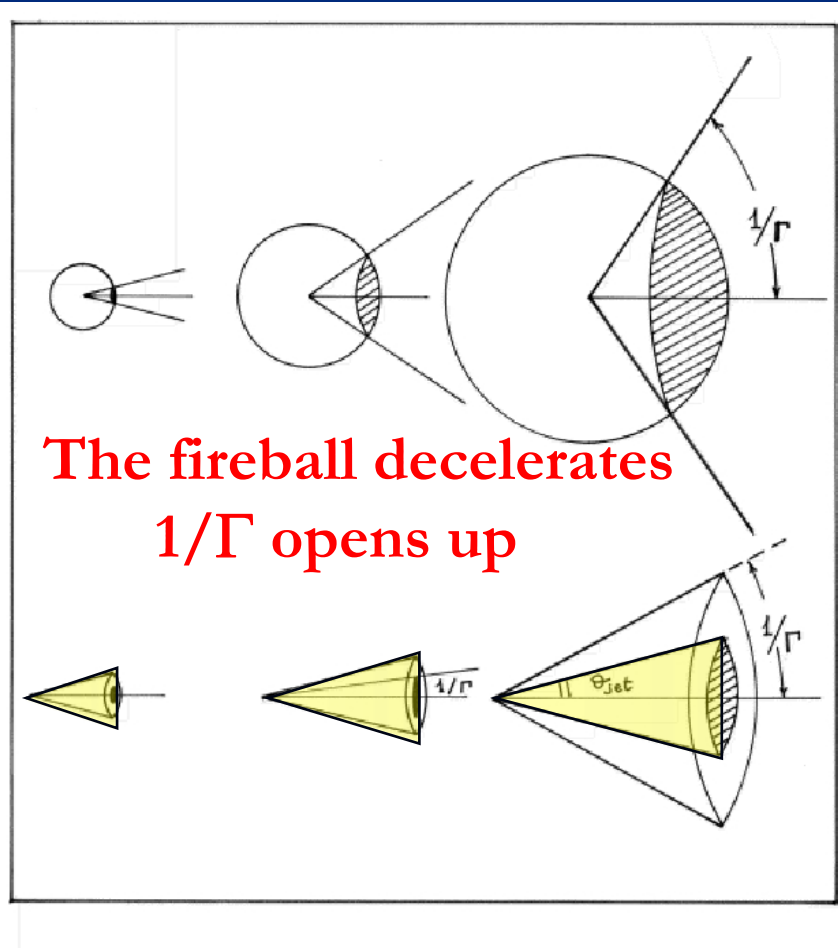






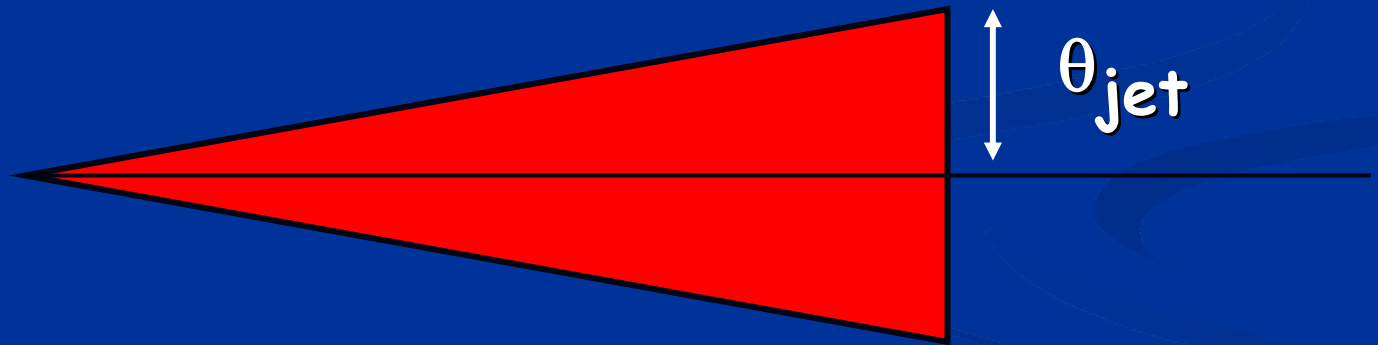
Ghirlanda, Ghisellini, Lazzati & Firmani 2004

Spheres or jets?



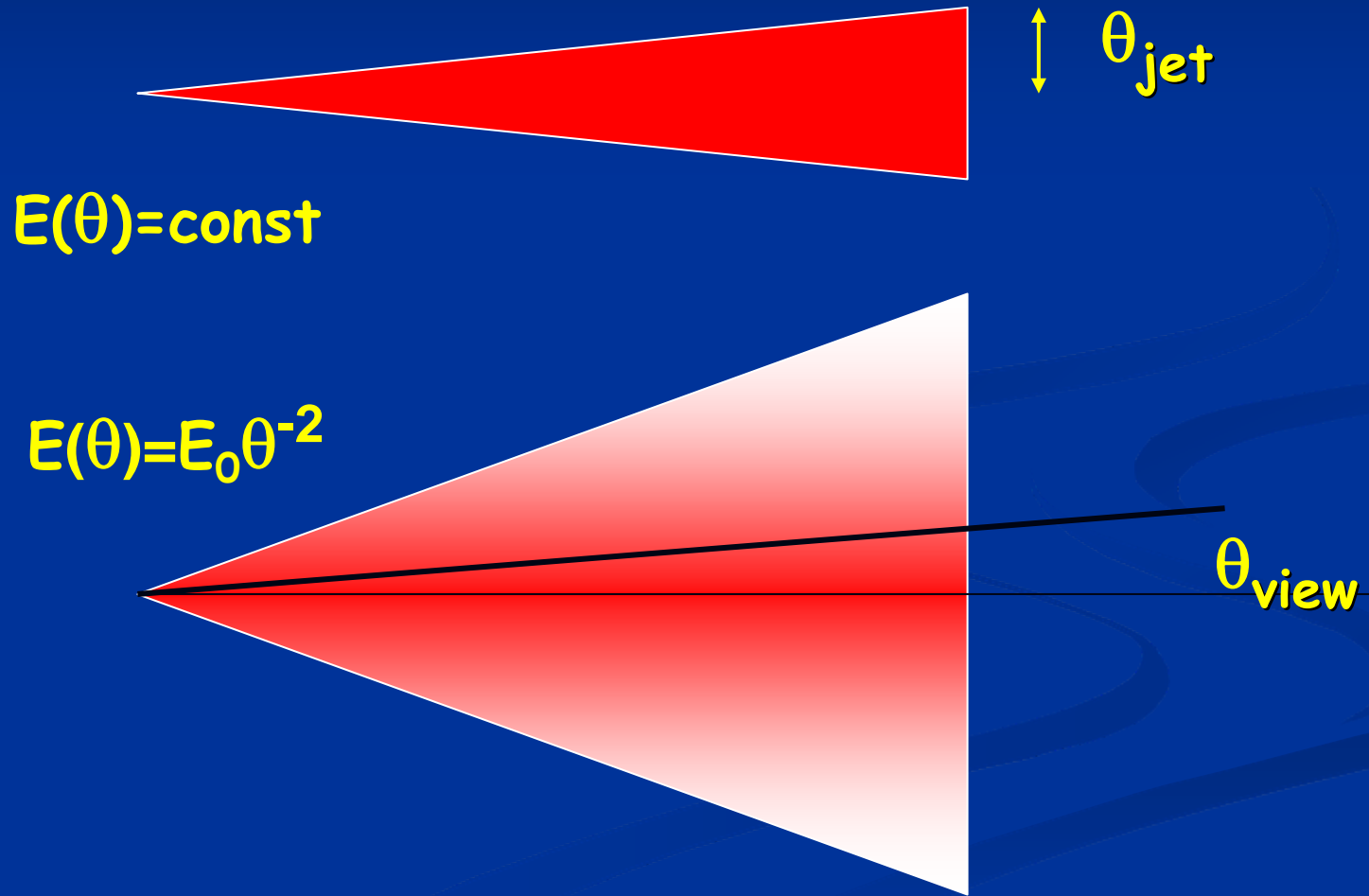
$$E_{\text{iso}} - E_{\text{"true"}}$$

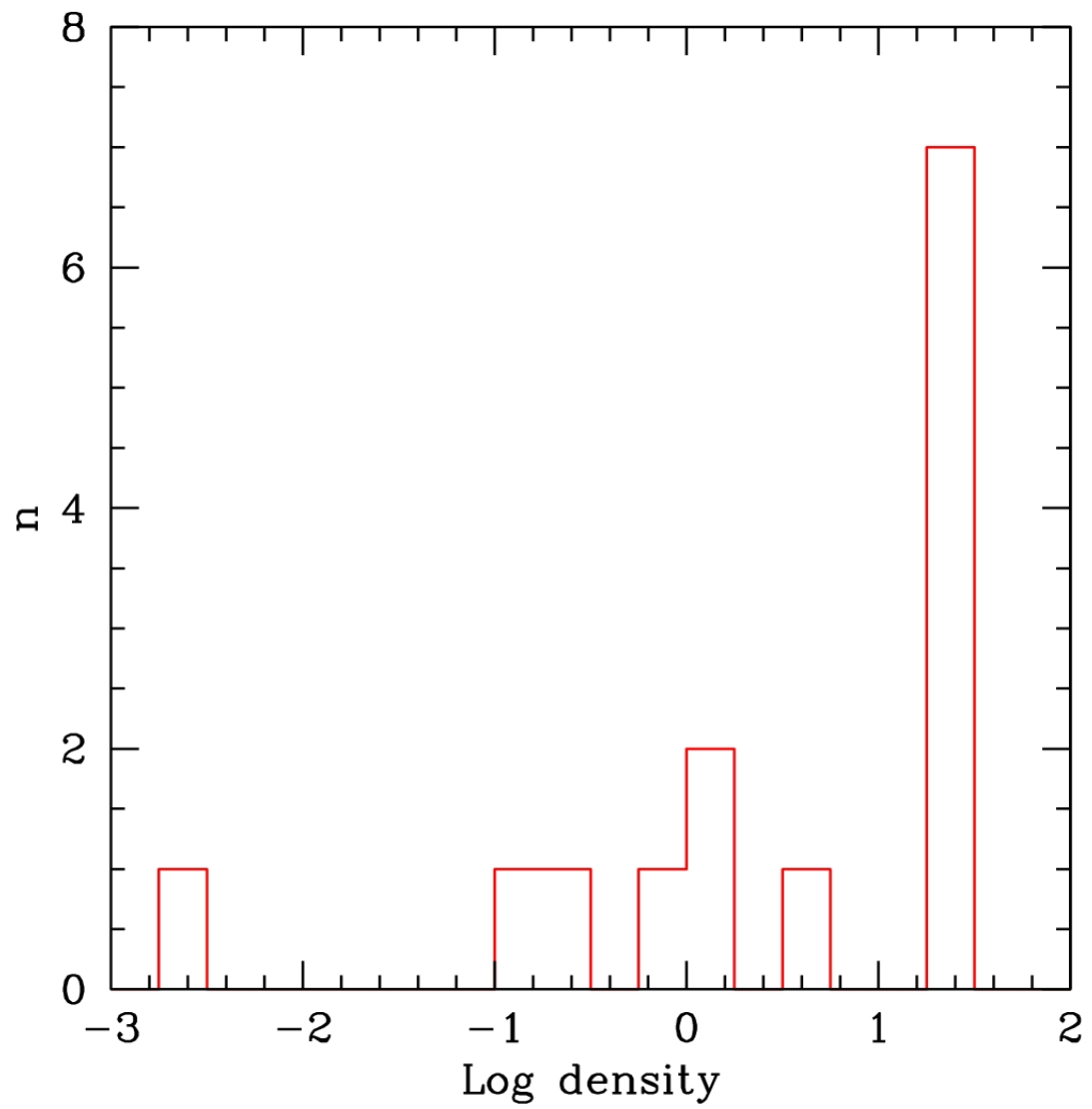
t_{break} measures θ_{jet}

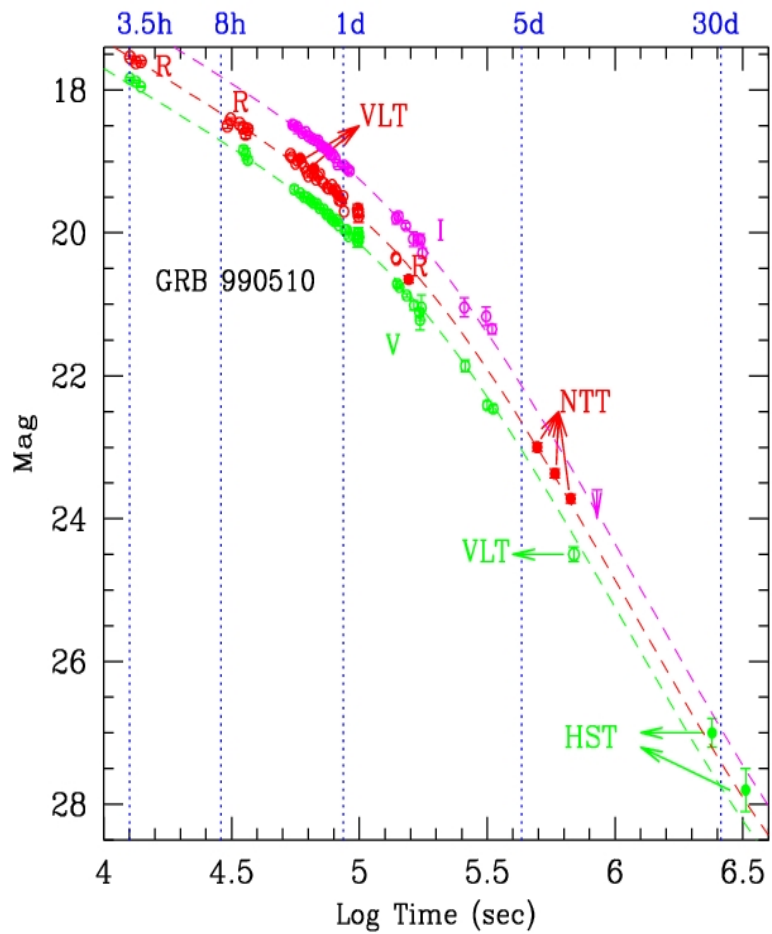


$$E_{\text{"true"}} = E_{\text{iso}} (1 - \cos\theta_{\text{jet}})$$

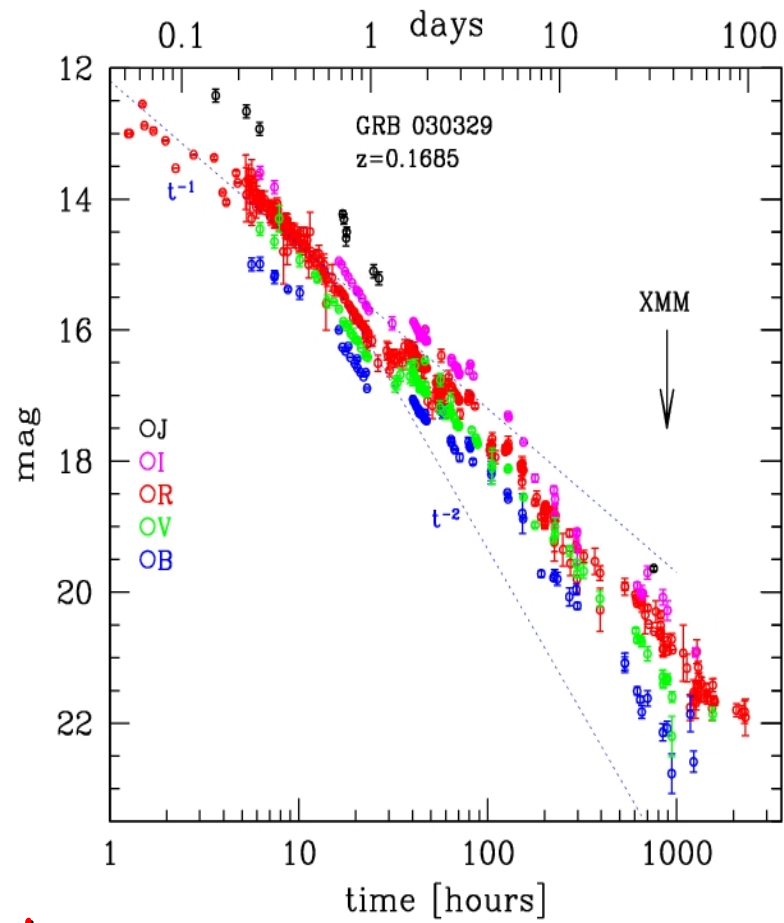
Structured jets?





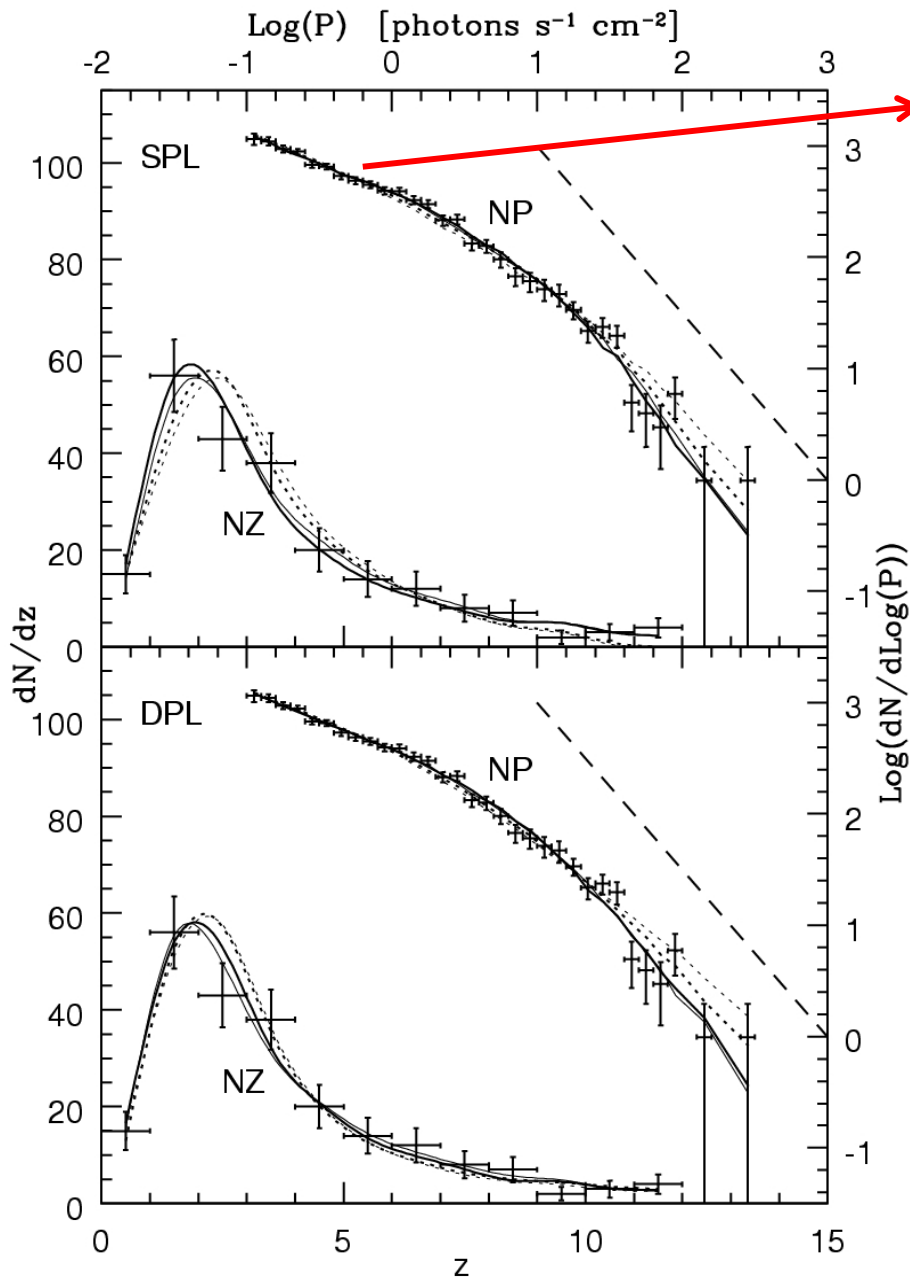


smooth



bumpy

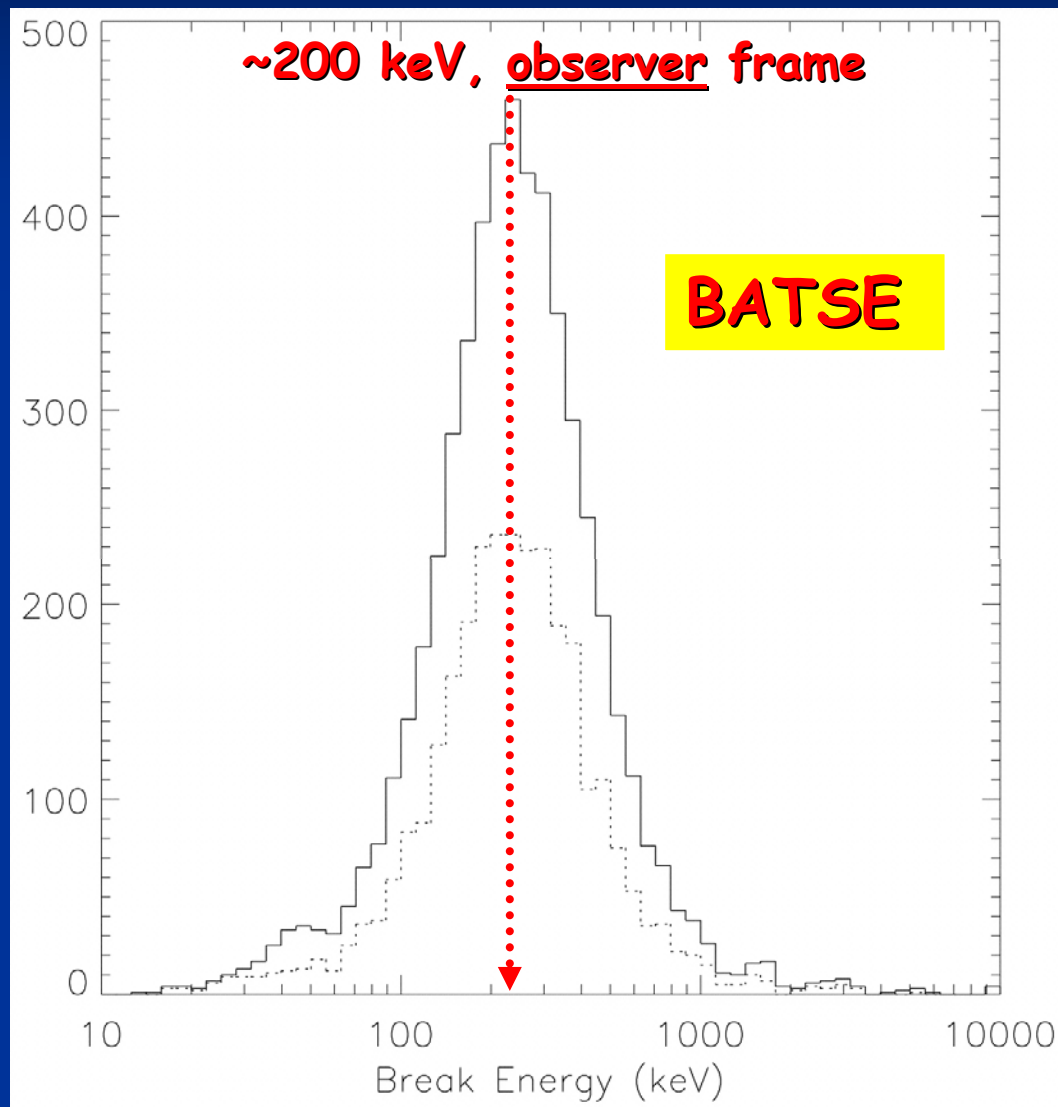
Firmani et al. 2004

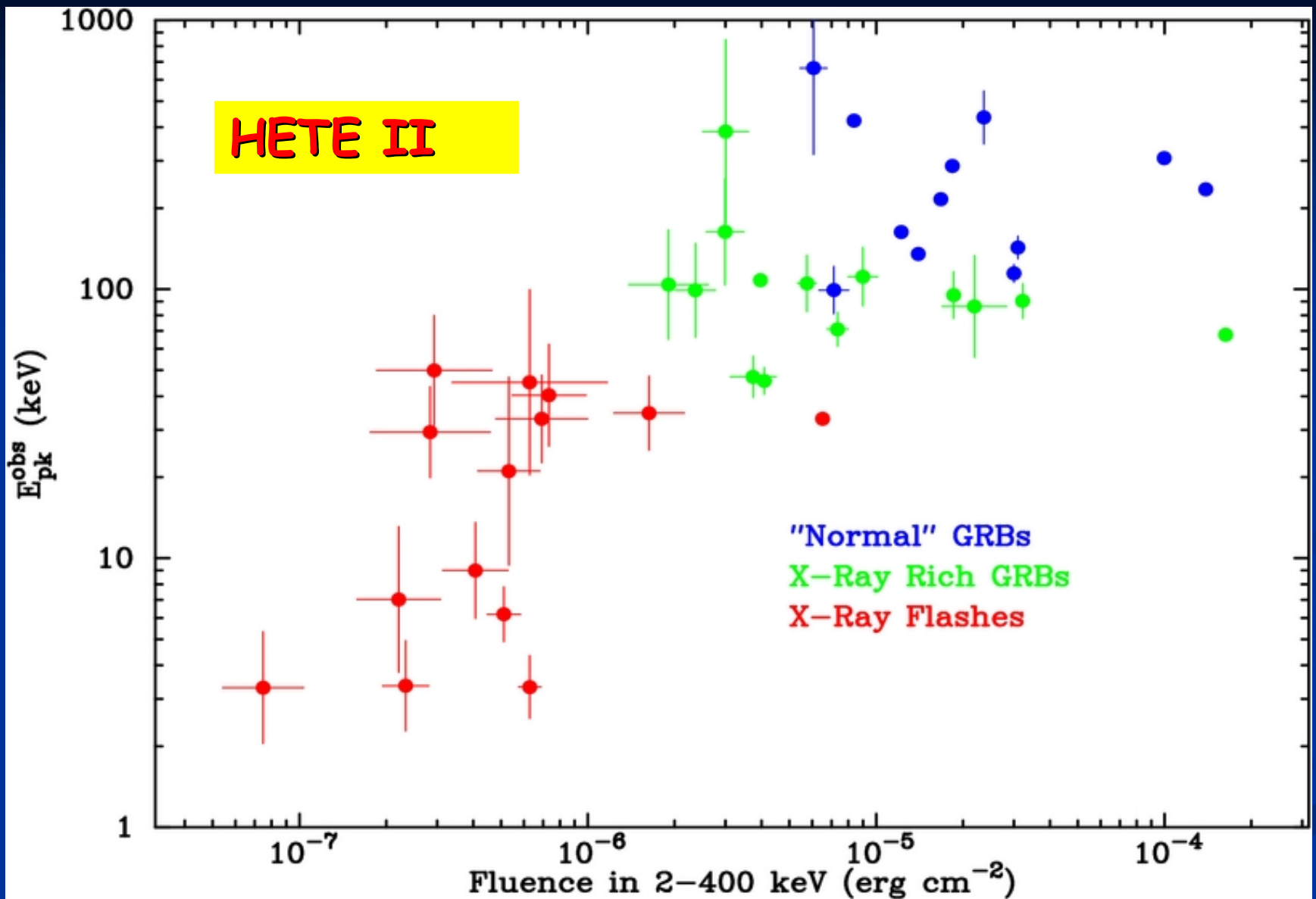


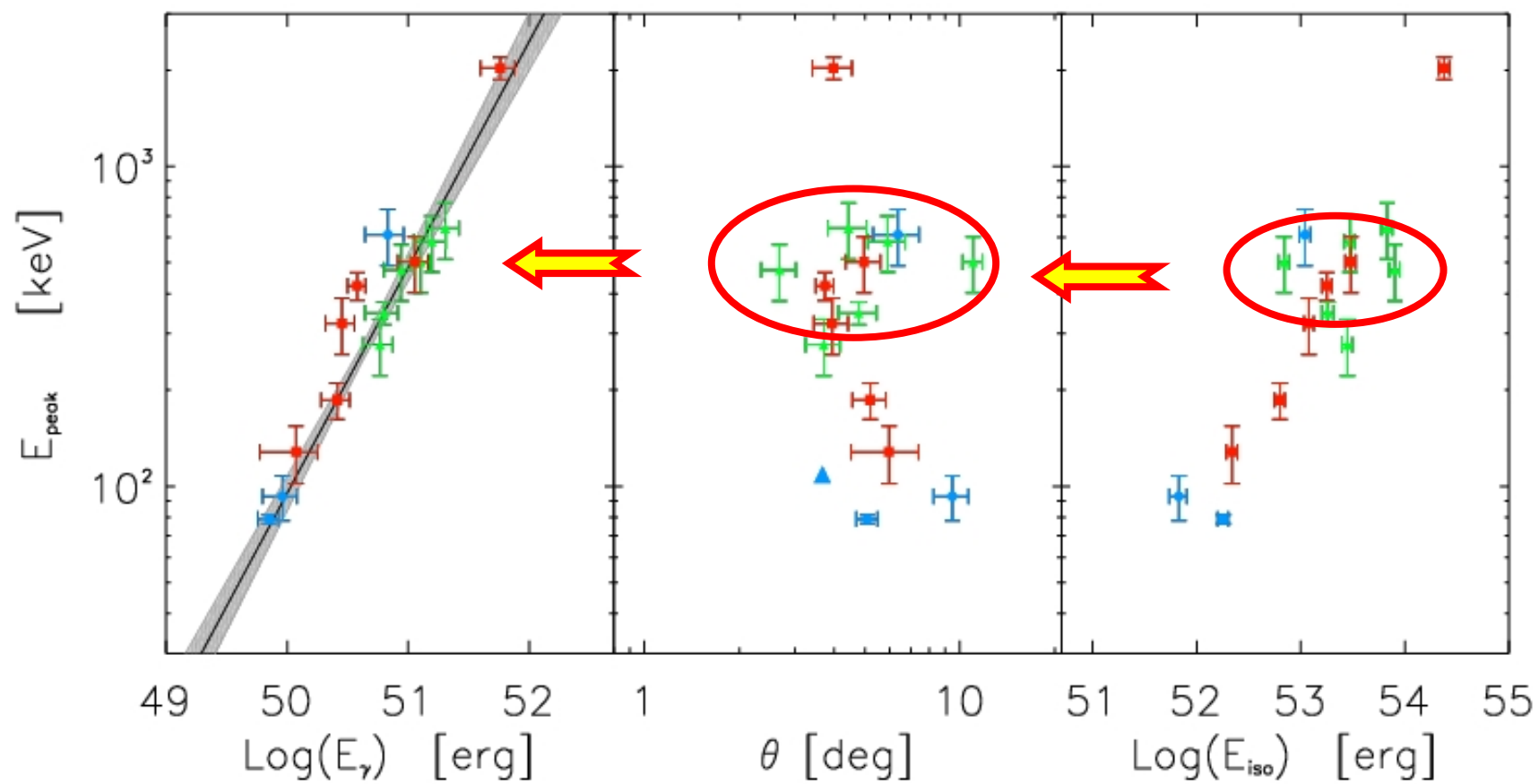
-1.5 ± 0.05

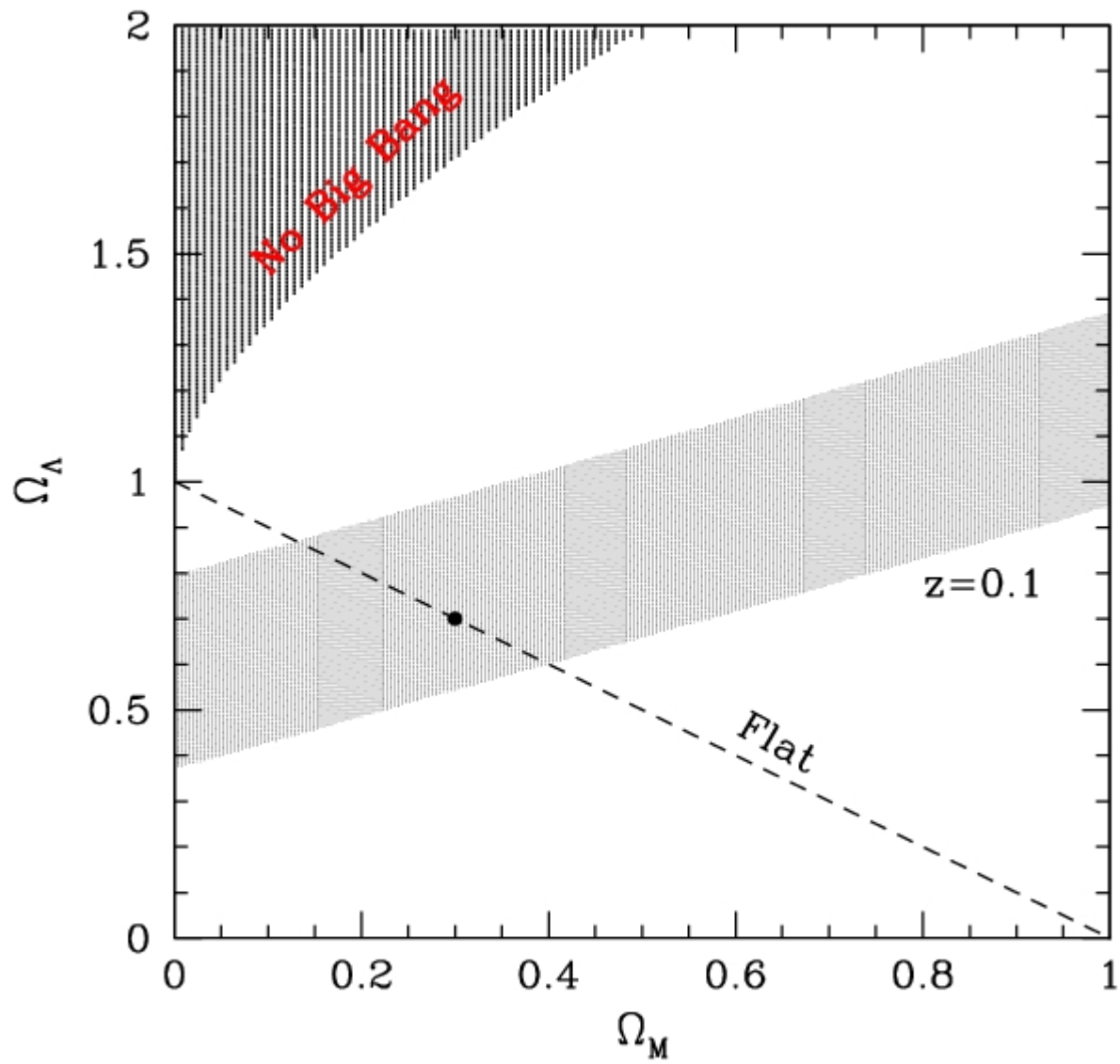
Universal E_{peak} ?

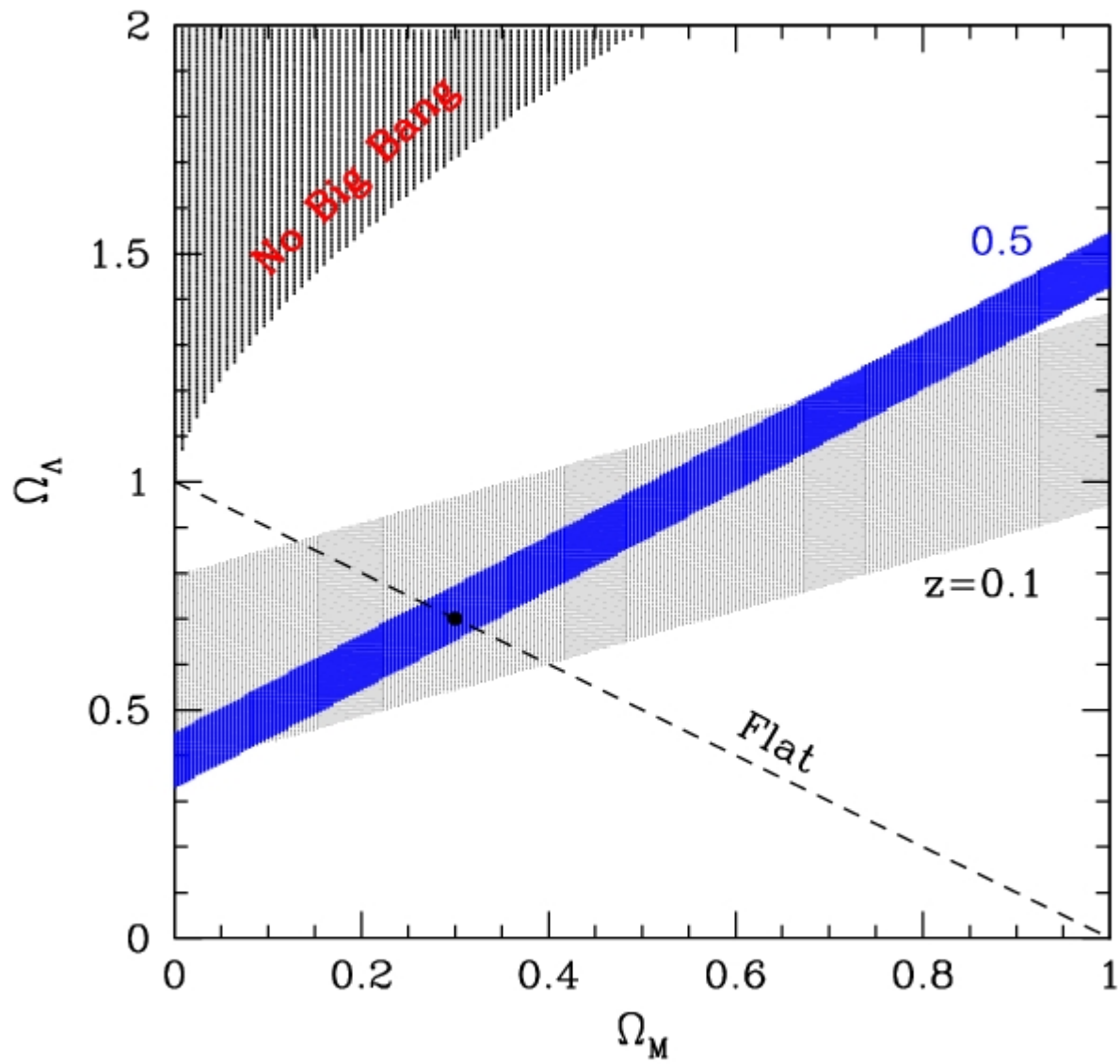
Preece et al.

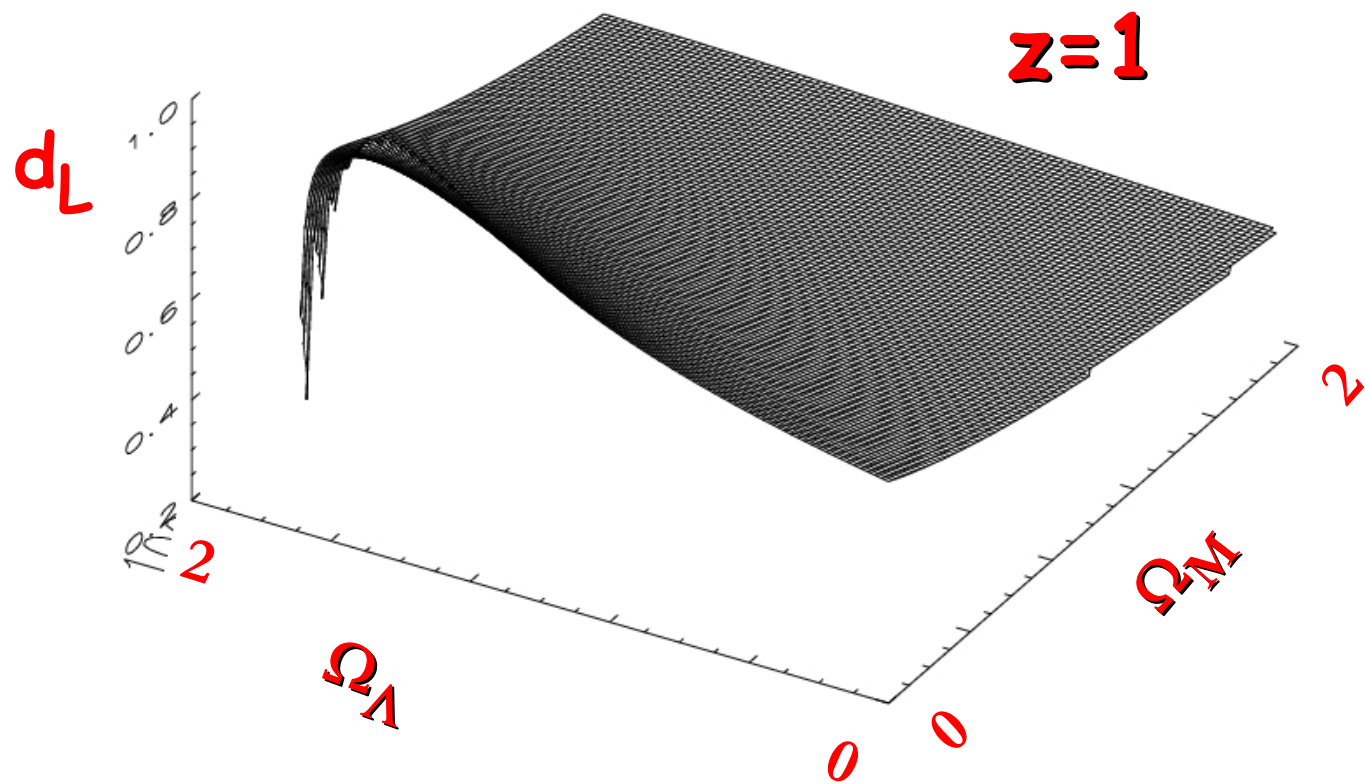


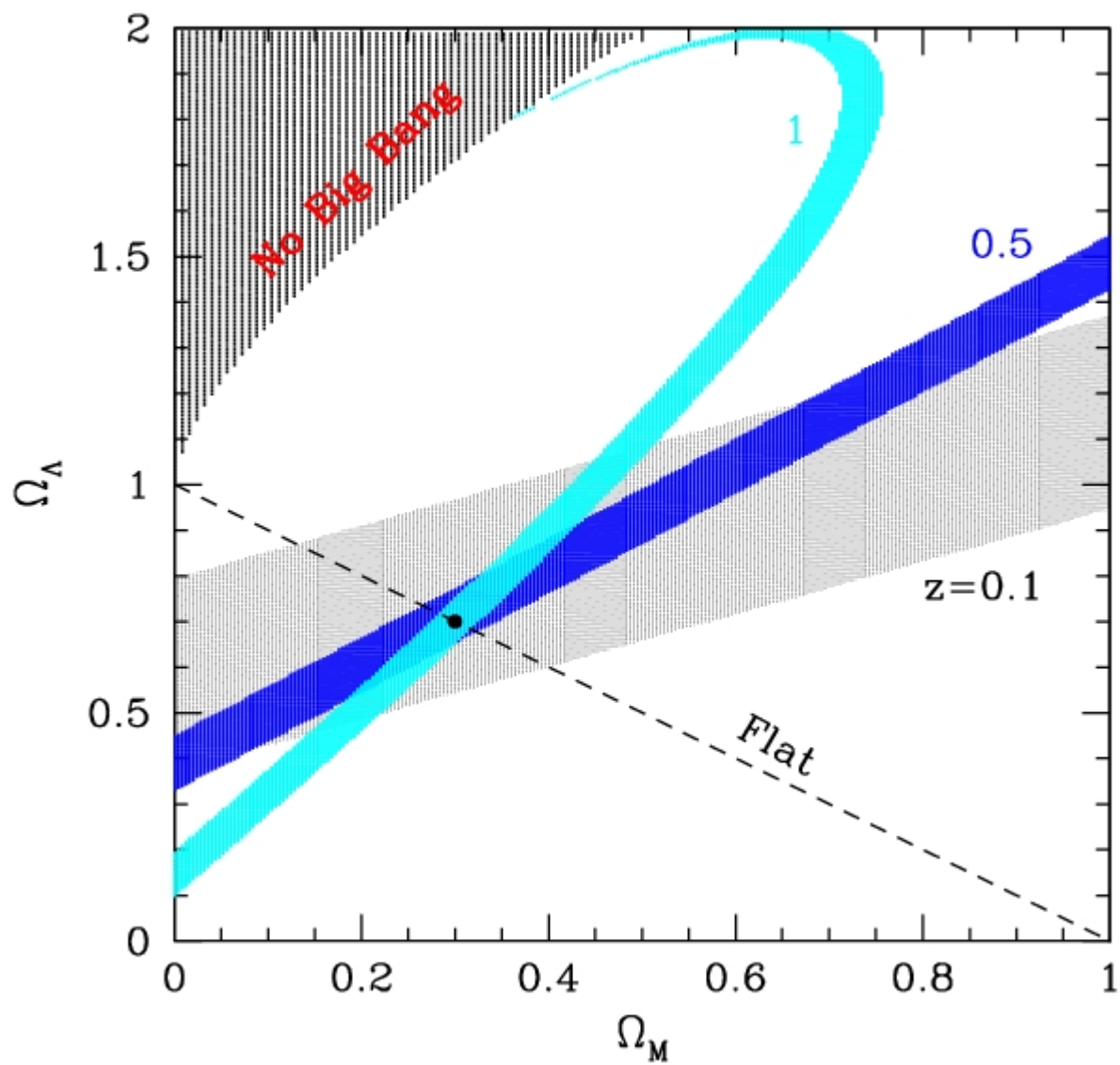


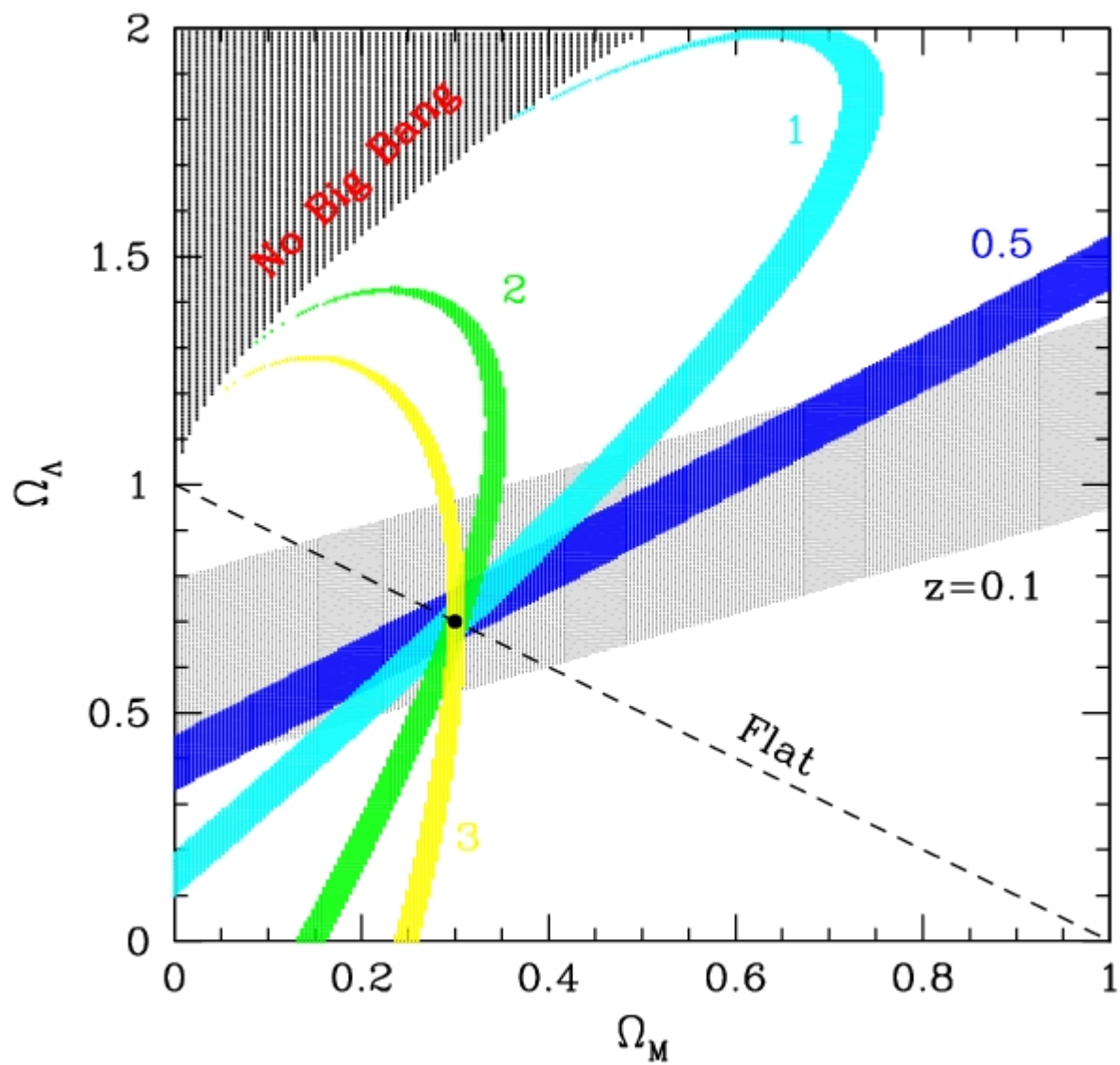












The cosmic whirl

