Gamma-Ray Bursts at High Redshift

Reporter: S. Basa

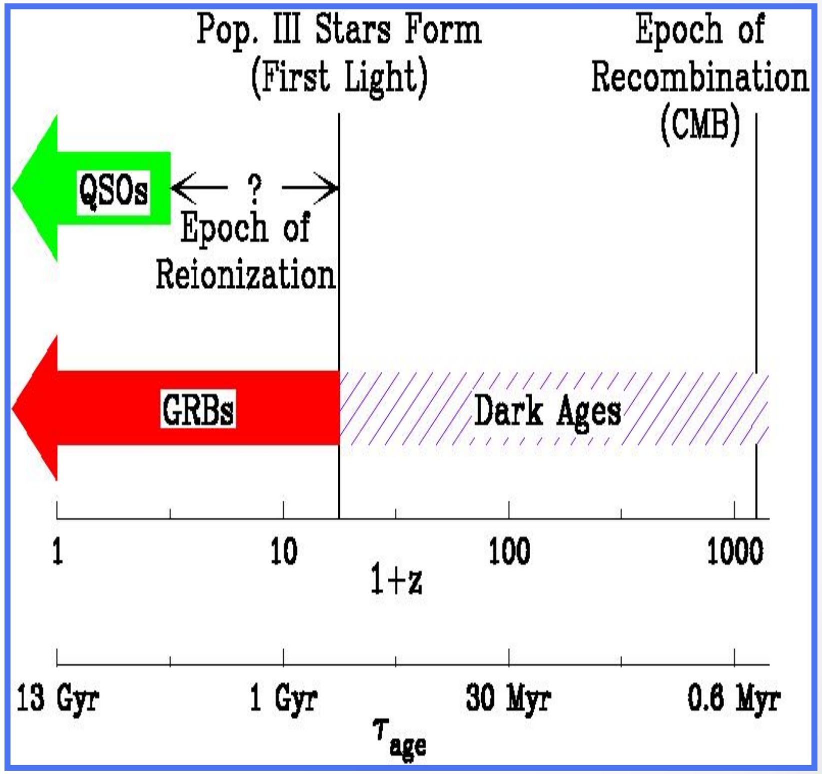
Collaborators (high-z): S. Basa, E.-W. Liang, J.-J. Wei and X.-F. Wu

Collaborators (cosmo): S. Basa, Z.-G. Dai and F. Wang

High-z GRBs as a tool

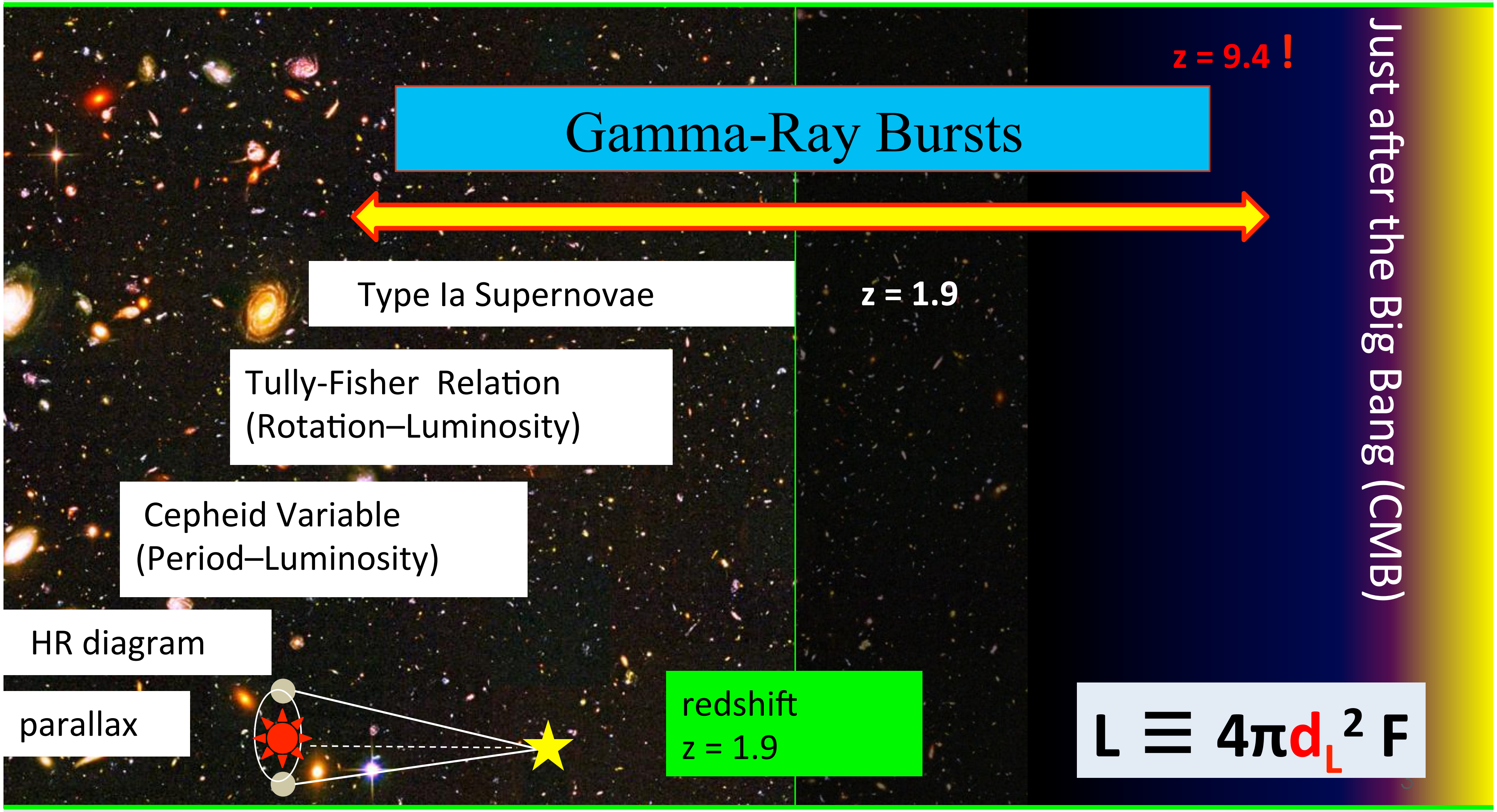
Why GRBs can be used to measure cosmology?

- The brightest event which can be observed.
- Wide redshift range, maybe up to z~15-20 (Lamb & Reichart 2000).
- Gamma ray suffer from no dust extinction.



High-z GRBs as a tool

Constraints on dark energy and cosmological parameters



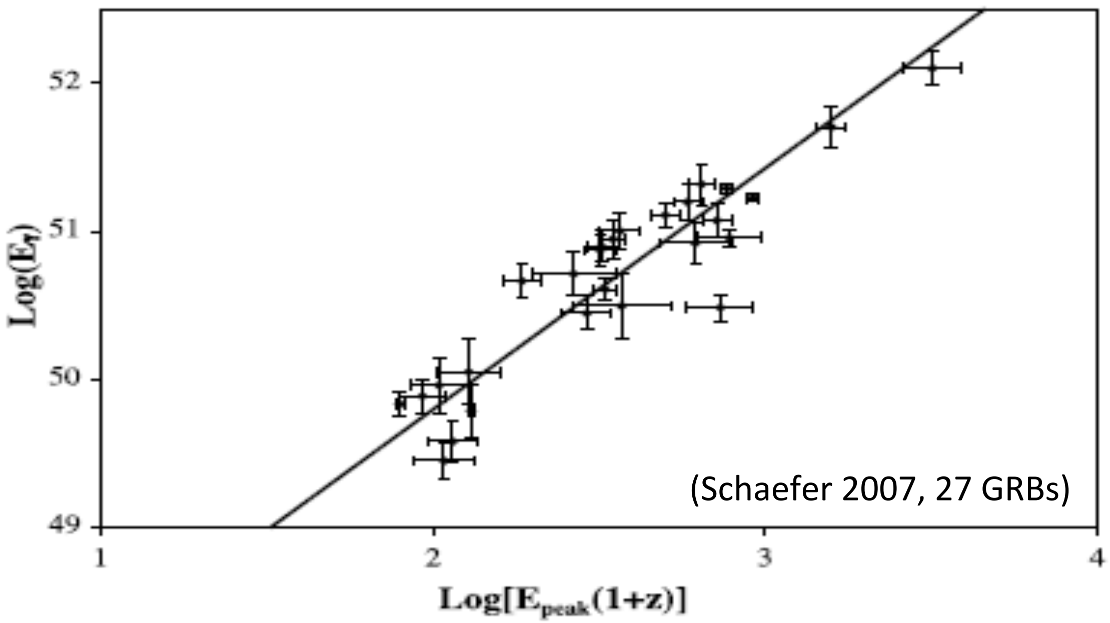
Constraints on the dark energy and the cosmological parameters

Similar to SNe Ia, GRBs luminosity correlations are minimized to measure cosmological parameters:

- ✓ *Liso – τ_{lag} correlation*: luminosity-time lag correlation (Norris et al. 2000).
- ✓ *Liso – V correlation*: time variability correlated with the luminosity of GRBs, which indicates that more luminous bursts have more variable light curves (Fenimore and Ramirez-Ruiz 2000).
- ✓ *Yonetoku correlation*: $L_{iso} \propto E^2_{peak}$ (Yonetoku et al. 2004).
- ✓ *Liang-Zhang correlation*: an empirical correlation among the isotropic energy of the prompt gamma-ray emission E_{iso}, the rest-frame peak energy E_{peak}, the rest-frame break time in the optical band t_{break}.
- ✓ *Amati correlation*: isotropic energy E_{iso} is correlated with the rest-frame peak energy of the prompt spectrum (i.e., $E_{peak} \propto E^{0.52}_{iso}$).
- ✓ *Ghirlanda correlation*: a tight correlation between spectral peak energy and collimated energy.
- ✓ Etc.

Example of correlation function

The so-called Guirlanda relation



$$E_\gamma - E_p: \qquad \log E_\gamma = a + \left[b(E_p(1+z)/300keV \right]$$

The Circularity problem

In order to measure the cosmological parameters, correlations must be calibrated in a cosmological model independent way:

- ✓ Otherwise a circularity problem appears...
- ✓ In principle, circularity problem can be avoided in two ways (Ghirlanda et al. 2006):
  1) A solid physical interpretation of these relations, which would fix their slope independently from cosmology.
  2) The calibration of these relations by several low redshift GRBs.

Not so easy in fact…

The Circularity problem

Many previous works treated the circularity problem with a statistical approach:

- ✓ Simultaneous fit (Schaefer 2003): parameters in the calibration curves and the cosmology are carried out at the same time.
- ✓ Bayesian method (Firmani et al. 2005).
- ✓ Markov Chain Monte Carlo global fitting (Li et al. 2008).

In any case, as a particular cosmology model is required in doing the joint fitting, the circularity problem is not solved completely by means of statistical approaches.

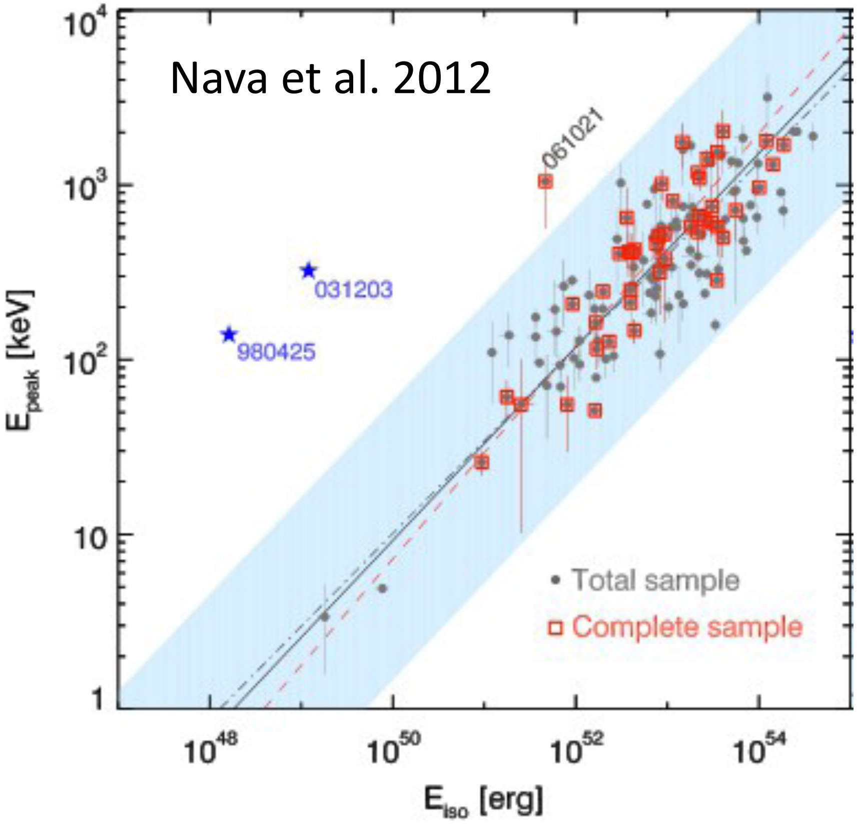
Evolution of the correlation?

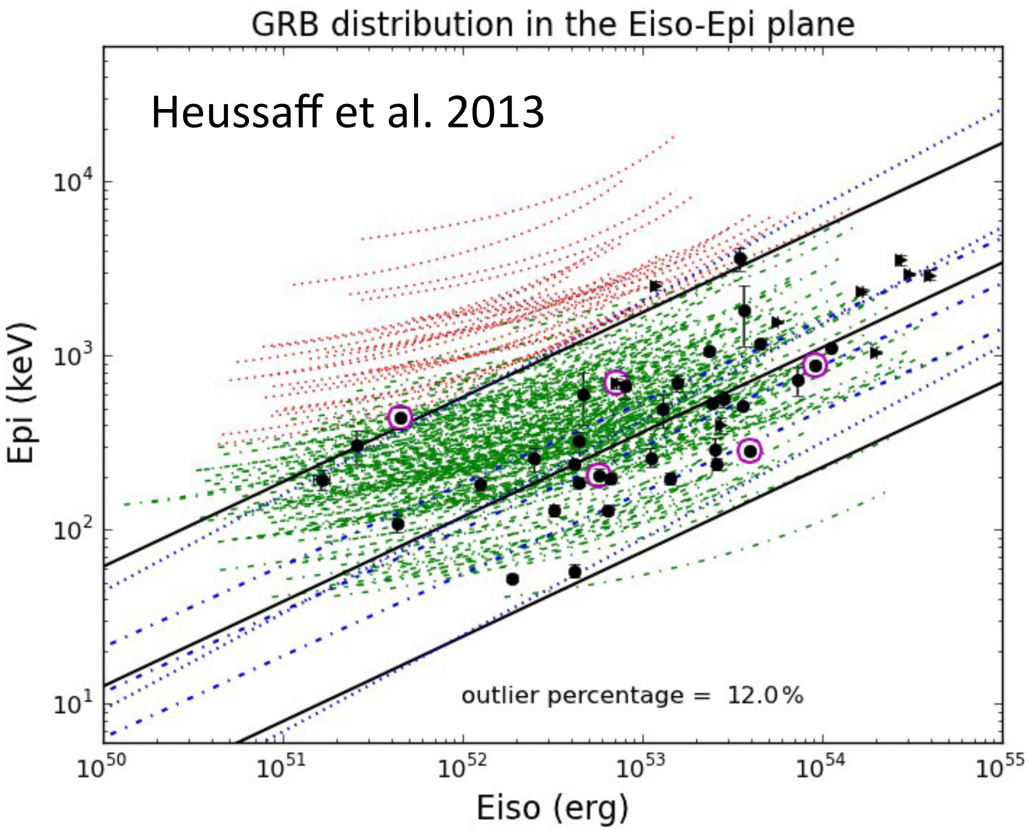
Due to the fact that GRBs cover large redshift range, whether the correlations evolve with the redshift must be studied:

- ✓ The slope of Amati correlation may vary with redshift significantly (Lin et al. 2007 & 2015).
- ✓ At the opposite, for other correlations, no statistically significant evidence for the evolution of the others luminosity correlations with redshift found (Basilakos & Perivolaropoulos 2008, Wang et al. 2001).
- ✓ Meanwhile, instrumental selection effects may affect the observed luminosity correlations (i.e., Nakar & Piran 2005).

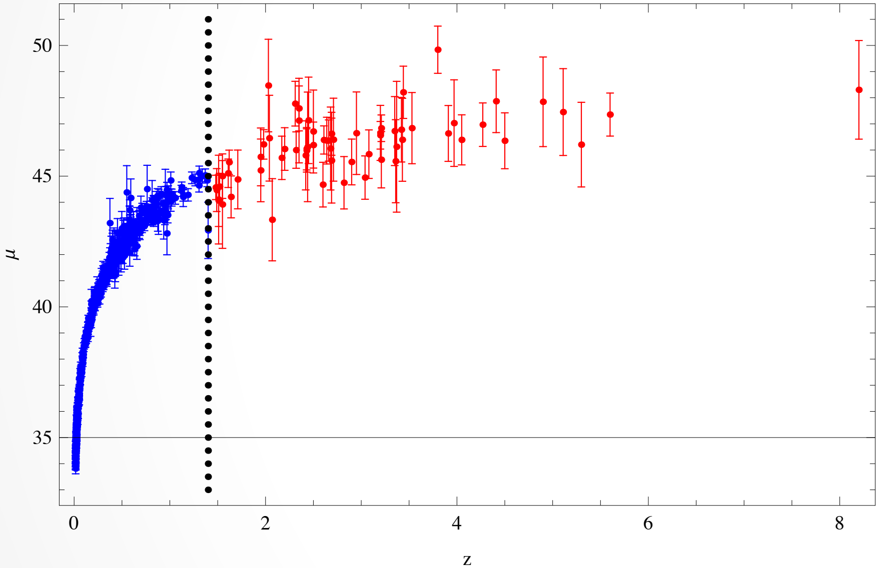
Selection effects!

- We need good spectral parameters **and** redshift, leading to strong selection effects on the GRB population used for these studies.

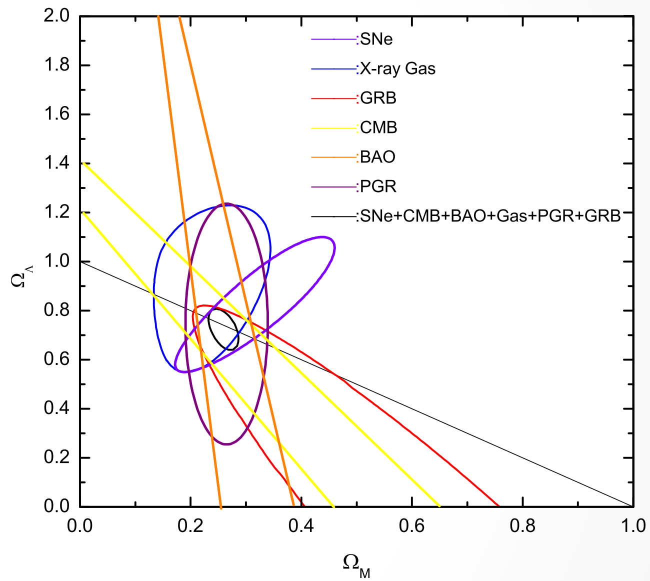




Present constraints on the dark energy and the cosmological parameters



Hubble diagram of 557 SNe Ia (blue) and 66 high-redshift GRBs (red) (adapted from Wang & Dai, 2011).

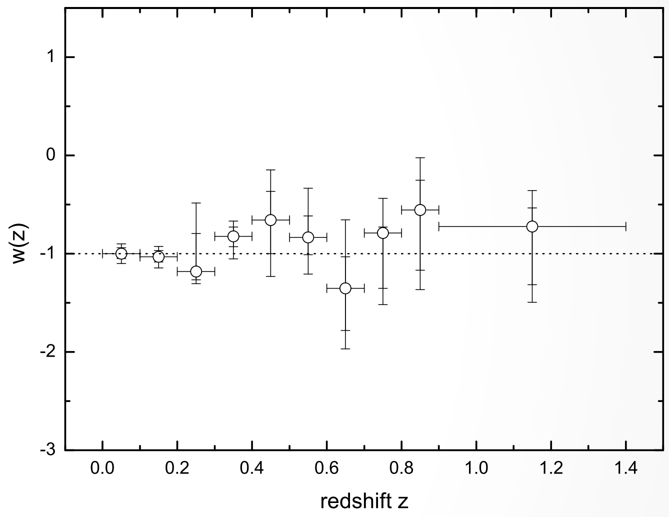


Joint confidence intervals of 1σ for (Ω_M,Ω_Λ) from the observational datasets (adapted from Wang et al. 2007).

Present constraints on the equation of state of the dark energy

The equation of state *w=p/ρ* is a key parameter to describe dark energy properties:

- ✓ Whether and how it evolves with time is crucial for revealing the physics of dark energy.
- ✓ GRBs can provide the high-redshift evolution property of dark energy.



Estimation of the uncorrelated the EOS parameter at different redshift bins from SNe Ia +BAO+WMAP9+H(z)+GRB data (adapted from Wang & Dai, 2014).

Until now, EOS consistent with the cosmological constant at 2σ confidence level, not preferring a dynamical dark energy model.

Prospect in the SVOM era

GRBs attracted a lot of attention as promising standardizable candles to construct the Hubble diagram at very high redshift:

- ✓ Complementarity to other cosmological probes, such as SNe Ia, CMB and BAO.
- ✓ However without reaching the level of details of these probes.

The most important thing is probably to search for a correlation similar to that used to standardize SNe Ia:

- ✓ In order to obtain these correlations, a better understanding of the physics inside GRBs is probably needed.