"Measuring the cosmological parameters with Gamma-ray Bursts".

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Theseus Meeting – March 2021
Summary

Why we need GRBs for Cosmology?

- SN systematics: the need of an independent measurement for $\Omega_m$
- Tracing the history of Dark Energy: GRBs do it better
Conclusions from SNe

The two teams consistently found that SNIa at redshifts $z \sim 0.5$ appear dimmer than expected by $\sim 0.25$ magnitudes. $z \sim 0.5$ is the transition epoch between acceleration and deceleration (Perlmutter et al. 1998, Riess et al. 1998, Schmidt et al. 1998).

This suggests (after assuming a flat universe) that the expansion of the Universe is accelerating, propelled by “dark energy”, with $\Omega_\Lambda \sim 0.7$ and $\Omega_M \sim 0.3$. 
Marginal evidence for cosmic acceleration from Type Ia supernovae

J. T. Nielsen¹, A. Guffanti² & S. Sarzi³

The 'standard' model of cosmology is accelerating at present — as was inferred from the analysis of Type Ia supernovae. There exists now a much bigger data set than could be used previously to check whether these 'standardisable candle' supernovae are consistent with the empirical procedure by which cosmological parameters are derived from the varying shape of the light curve and its rise and decay. Here the data are still quite consistent with a constant cosmological constant and a 2% density of dark energy. However, the best fit model is one in which the cosmological constant varies, with more than a '1 in 1000' chance of a deviation in the value of the cosmological constant (but less than a '1 in 10' chance of a deviation in the value of the density of dark energy).

[Graph showing the relationship between distance modulus and redshift, with data points and best fit lines labeled as best fit Milne, best fit ΔCDM, SDSS, SNLS, lowz, and HST.]
Apparently, the Hubble diagram doesn’t take advantage of the increasing number of SN discoveries

Izzo et al. 2015
Source of (possible) Supernova systematics

The cosmological interpretation rely on the lack of evolutionary effects on progenitors of type Ia SNe.

1. two progenitor systems (z?)
2. more explosion mechanism (z?)
3. light curve shape correction methods for the luminosity normalisation may depend on z
4. anomalous reddening law ($R_V \ 1.5 \div 5$)
5. contaminations of the Hubble Diagram by no-standard SNe-Ia and/or bright SNe-Ibc (e.g. HNe)
Results from SNLS (231 SNe Ia at 0.15 < z < 1.1, Guy et al. 2010) compared to those of Astier et al. 2006 (44 low redshift SNe along with the 71 SNe from the SNLS first year sample)
If the zero point of SN-Ia calibration is “off” by 0.1 mag
The only way to demolish the SN systematics wall is to use a different experimental methodology and GRBs can do it!
Almost 3000 papers having Cosmology and GRBs in their abstracts
We found clear evidence that the observed scatter of the $E_{p,i}$-$E_{iso}$ correlation depends on the choice of cosmological parameters used to compute $E_{iso}$.

In other words the observed dispersion is sensitive at varying the values of the cosmological parameters.
<table>
<thead>
<tr>
<th>( \Omega_m ) (flat universe)</th>
<th>( \Omega_M )</th>
<th>68%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 GRBs (Amati+ 08)</td>
<td>0.26</td>
<td>0.10 – 0.62</td>
<td>0.07 – 0.87</td>
</tr>
<tr>
<td>140 GRBs (Amati+ 13)</td>
<td>0.28</td>
<td>0.13 – 0.57</td>
<td>0.09 – 0.81</td>
</tr>
<tr>
<td>211 GRBs (today)</td>
<td>0.24</td>
<td>0.12 – 0.44</td>
<td>0.07 – 0.64</td>
</tr>
<tr>
<td>600 GRBs</td>
<td>?</td>
<td>0.19 – 0.39</td>
<td>0.15 – 0.50</td>
</tr>
</tbody>
</table>
Present and Future

Swift + Konus-WIND + Fermi/GBM \rightarrow

**15 GRBs/yr** in the \( E_{p,i} - E_{iso} \) plane

SVOM (from 2022) \rightarrow

**20 GRBs/yr** in the \( E_{p,i} - E_{iso} \) plane

**Athena** (2028) & **Theseus** (selected by ESA on 2018 to enter an assessment phase study, \( \sim2032 \)).
GRBs can constraints the equation of state of DE (pressure to energy density ratio, $p=w \rho_{DE}$) better than SNe-Ia (i.e. they trace better the expansion history of the universe).
Equation of state: $w = \frac{p}{\rho}$

There are two proposed forms for dark energy:

i) the cosmological constant, i.e. a *constant* energy density per unit volume of vacuum filling space homogeneously

\[ w = -1 \]  

**Cosmological constant**

ii) a time depending form of energy density (proposed by Bronstein 1938) that can vary in time and space.

\[ w > -\frac{1}{3} \]
\[ -\frac{1}{3} > w > -1 \]
\[ w < -1 \]

**Quintessence**

**Phantom Energy**

Bronstein was executed on Stalin’s order in 1938 presumably for reasons not directly related to the decaying $\Delta$. 
Equation of state: \( w = p/\rho \)

\( w = -1.02 \pm 0.13 \) \text{ Riess et al. 2004}
The Combo relation (Izzo et al. 2015) has been applied to a sample of 180 GRBs to study the possible evolution of \( w(z) \) with redshift. The new sample shows that at \( z < 1.2 \) (8.5 Gyr in terms of look back time) \( w(z) \) matches, within 1\( \sigma \), the "standard" value -1. At larger redshifts the case \( w < -1 \) (phantom energy) cannot be excluded.