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Review

Cosmology with the Nearby Supernova Factory

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ABSTRACT

The Nearby Supernova Factory (SNfactory) is currently finishing its first survey of low redshift ($0.03 < z < 0.08$) type Ia supernovae. These data add to the understanding of the expansion history of the universe. Observations are performed using the Supernova Integral Field Spectrograph (SNIFS), an integral field spectrograph delivering full spectro-photometric information of the target. The corresponding dataset aims at the inference of the Hubble diagram zero point with unprecedented accuracy. Moreover, the data offers a variety of related physical studies such as the understanding of progenitor systems, explosion scenarios and host galaxy characteristics. The SNfactory is also working on novel methods accessible with spectro-photometric measurements, reducing systematic uncertainties and improving the statistical power of the SN data.

1. Introduction

Type Ia Supernovae (SN Ia) are used as standard candles in observational cosmology since their empirical standardizability makes them ideal probes for testing the expansion history of the universe. About a decade ago the observations of high redshift SN Ia led to the conclusion that the expansion of the universe is accelerating [1,2]. The magnitudes of high-z SN Ia are dimmer than predicted by a universe filled with matter only. One possible interpretation for those high-z SNe is that they must have receded further away due to recent acceleration in the cosmic expansion. The introduction of Dark Energy to the Einstein equations in the form of a cosmological constant Λ can explain the observational results since it leads to a

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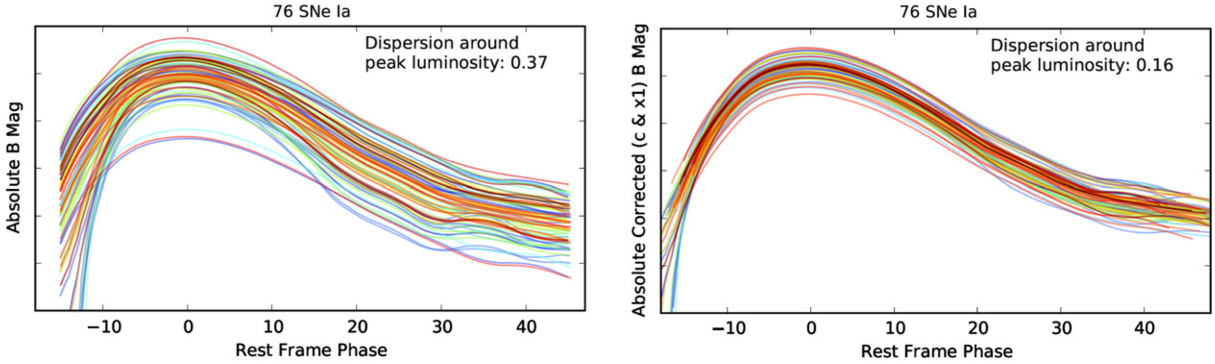

Fig. 1. Lightcurves of 76 SNe Ia from the Nearby Supernova Factory dataset. (left) Before and (right) after empirical standardization.

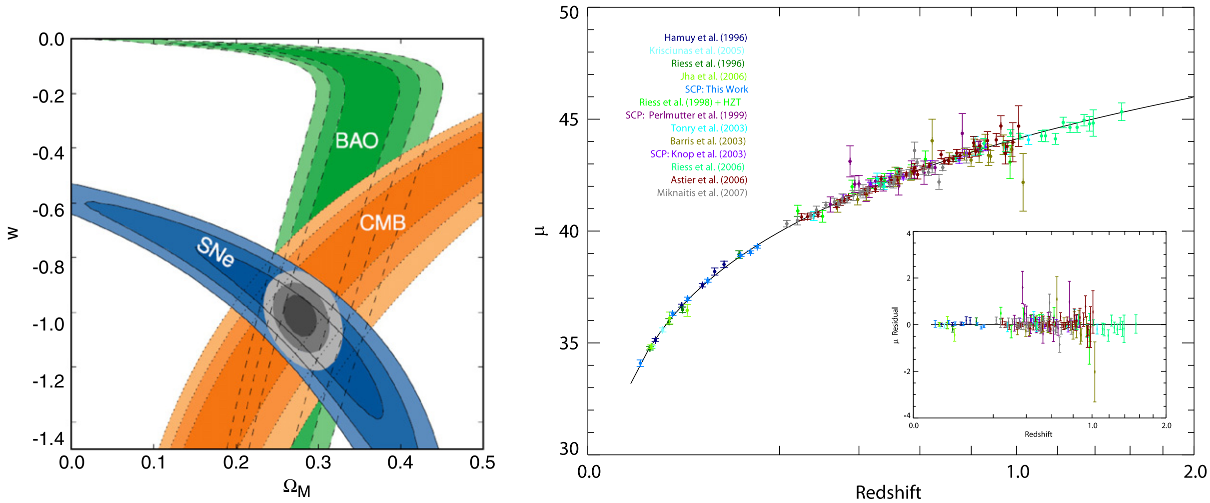

Fig. 2. (left) 1σ, 2σ and 3σ constraints in $\Omega_M - \omega$-space of SN Ia data combined with data from BAO and CMB (without systematics) [4]. (right) Hubble diagram of combined SNe Ia datasets [5].

negative pressure in the equation of state $p = \omega\rho$, counteracting the gravitational attractive force. The currently accepted *concordance model of cosmology*, the so-called ΛCDM model, thus features Dark Energy as an additional contributor to the overall energy density, Ω, in the universe. Apart from Dark Matter and the commonly known baryonic matter, Dark Energy is by far the biggest component in this model, making up $\sim 3/4$ of the energy content.

2. SN Ia cosmology

SN Ia are driven by the thermonuclear explosion of a white dwarf within a binary system comprising a massive donor star. In the scenario of such a single degenerate model the white dwarf accretes matter from its companion until approaching the Chandrasekhar mass limit M_{Ch} of ~ 1.4 solar masses. Once this limit is reached, gravitational attraction overcomes the electron degeneracy pressure. However, before such a scenario would lead to a collapse, the core of the white dwarf reaches temperatures triggering the ignition of carbon fusion terminating in a supernova explosion. Even if the physical parameters, such as the supernova progenitor mass, appear to be the same for most of the SN Ia they are not standard candles by themselves. Fig. 1(left) shows the intrinsic dispersion of ~ 0.37 mag observed in a set of SN Ia lightcurves. However, as pointed out in [3] SN Ia that have bluer colors or broader lightcurves appear to be intrinsically brighter. This empirical handle, the so-called *Phillips relation*, on the supernova intrinsic luminosity allows SN Ia to be standardizable. This reduces the luminosity dispersion in SNe Ia down to ~ 0.16 mag (see Fig. 1(right)). Thus standardized, SNe Ia are the established standard candles of cosmology adding to the understanding of the universe and complementing other sources such as data from the cosmic microwave background (CMB) and baryonic acoustic oscillations (BAO). The combination of these independent data yields accurate constraints on the ΛCDM cosmological parameters such as Dark Energy density Ω_Λ, dark matter density Ω_M and equation of state parameter ω. Fig. 2(left) illustrates the impact of SN Ia data on the parameter fits which are consistent with the existence of a cosmological constant, i.e. $\omega = -0.997^{+0.077}_{-0.082}$ [4]. The right plot in Fig. 2 shows the Hubble diagram (HD) of various SNe Ia data combined in the Union compilation [5]. While high-z SNe deliver information