Correlations on the derivation of Cosmological parameters from Supernovae Ia with the host galaxy mass.

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1 Introduction

Since the late $20's$ the expansion Universe was observed by Edwin Hubble, this observations proobe to Lemaitres theroy that states that the Universe is expanding, this was the foundations of the Big Bang Theory. Hubble measures relate the velocity at which galaxies are reciding due to the expansion of the Universe with their distances, this is know as the Hubble diagram. The slope of this relation known as the Hubble constant is a direct measure of the expansion rate of the Universe, this rate depends on the compositions of mass-energy in the Universe Eq.1. Where H_0 is the value of the Hubble constant at the present time, z the redshift, Ω_m is the amount of matter in the Universe which is mostly dark matter, in principle Ω_m decelerates the expansion of the Universe but this could be modified by the energy content of the Universe Ω_Λ, this form of energy is believed to be the energy of the vacuum (Einstein Cosmological constant) which acts as a negative pressure that do work making the expansion of the Universe being accelerate. Measures of objects at higher redshifts will allow to constrain more the evolution of the cosmological parameters and then to distinguish between feasible cosmological models.

$$H^2(z) = H_0^2[\Omega_m(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\Lambda] \tag{1}$$

Type Ia supernovae are of particular interest in this endeavour since they are the most brightest of all the supernovas types reaching an absolute magnitude of -19.3, therefore at higher redshifts must of the observed supernovas are Type Ia. Furthermore, their peak luminosity present less dispersion than other types of supernovas. In addition to that correlations of their photometric properties such as the width of their light curves and the color with the peak absolute magnitude reduces the dipsersion in the distance modulus (μ) to ~ 0.14 mag. All these properties make Type Ia SN an excellent cosmological distance indicators. With high-z Type Ia SN observations two research teams The high-z Supernova search team lead by Adam Riess and Brian P. Schmidt and the Supernova Cosmology project lead by Saul Perlmutter led to the discover that the expansion of the Universe is accelerating Riess98, Perlmutter99.

The derivation of the cosmological parameters rely on fitting the light curve of each SN Ia from the apparent magnitude measurements, once the light curve is reconstructed the absolute magnitude and consequently the distance modulus of each SNe can be derived. However, recent works of Kelly2010 have revealed that there might be a correlation in the absolute magnitude derived from the procedure explain above with the host galaxy mass. In particular the mass of the host galaxy is related with the dust extinction, stellar population age and progenitor metallicity. Further investigation in this correlations will lead to decrease the scatter in the distance modulus and therefore a decrease in the error of the cosmological parameters derived.

Quantifying this correlations is the main purpose of this project, we explore the correlations between host of a SNe Ia galaxy mass with the derivation if the cosmological parameters. To this aim we derive the cosmological parameters from SNe measurements in different host galaxy masses. In §2 we review the methodology to derive the cosmological parameters from the SNe distance modulus measurements computed by Campbell2013. In §3 we explain the assumptions made in our derivations and in the distance modulus computation made by Campbell. In §4 we explain the main characteristics of the data used in this project which was obtained from Cambell2013. The main results are presented in §5 and the discussions and conclusions are presented in §6.

2 Methods

From observations of the apparent magnitude at different times the light curve of the SNe Ia can be reconstructed and therefore the absolute magnitude at the peak can be derived see §3 for details. Therefore the distance modulus μ_0 to each SN can be computed. On the other hand from the Friedmann-Lemaitre-Robertson-Walker cosmology the distance modulus μ_p can be derived as a function of the luminosity distance see Eq.2.

$$\mu_p = 5Log[D_L(z : \Omega_m, \Omega_\Lambda)] + 25 \tag{2}$$

Where the luminosity distance is defined as:

$$D_L = cH_0^{-1}(1+z)|\Omega_k|^{-1/2} sinn \left[|\Omega_k|^{-1/2} \int_0^{\infty} dz[(1+z)^2(1+\Omega_M z) - z(2+z)\Omega_\Lambda]^{-1/2} \right] \tag{3}$$

Where $\Omega_k = 1 - \Omega_M - \Omega_\Lambda$ and $sinn$ is $sinh$ when $\Omega_K \geq 0$ and sin when $\Omega_K \leq 0$. The data described in §4 already computes μ_0 from XXX method. With this data the corresponding likelihood is computed:

$$\chi^2(H_0, \Omega_M, \Omega_\Lambda) = \sum_i \frac{[\mu_p - \mu_{0,i}]^2}{\sigma_{\mu_{0,i}} + \sigma_v^2} \tag{4}$$

Where σ_v is the associated uncertainty of the peculiar velocity of the galaxy and $\sigma_{mu_{0,i}}$ the uncertainty of the observed distance modulus.

We compute the χ^2 as a function of the three free parameters $H_0, \Omega_m, \Omega_\Lambda$ and then marginalize over H_0 to find contours in the $\Omega_m - \Omega_\Lambda$ plane.

3 Assumptions

In this section we explain the methods us

3.1 Light Curve Model

3.2 K-correction

3.3 Host Galaxy Mass

4 Data

The data used in this project can be downloaded online in `http://www.mnras.oxfordjournals.org/lookup/suppl/d` this data was observed with the SDSS 2.5m telescope (?). The photometry was taken by the SDSS-II-SN Survey (????), the survey scan the sky in 300 deg2 during three years 2005-2007, the survey took multicolor images (u, g, r, i, z) during three months per year. Approximately 500 SNe Ia were found and have spectroscopic confirmation. On the other hand, XXX candidates where observed but doesn't have spectroscopic confirmation. However, (?) show that with an efficient photometric calibration these objects might be used to constrain the cosmological parameters. In order to perform such a calibration the redshift of the SNe-Ia host galaxy has to be known, data from the BOSS survey where used to this aim this allowing to a sample of 752 SNe Ia candidates between redshift $[0.05 - 0.55]$.

The procedure to identify these candidates is based on a Bayesian light curve classifier method (PSNID) (?). Bellow we briefly resumed the main aspects of this method:

The likelihood χ is computed for the observed photometry and templates of SN Ia and core-collapse SN and identify the more likely SN type. The algorithm also compute the probability that a SN candidate could be either Ia, Ib/c or type II. The Bayesian evidence is computed by marginilizing PDF over the parameter space:

$$E_{Ia} = \int P_{pr}(z, A_v, T_{max}, \Delta m_{12,B}, \mu) e^{-\chi^2/2} dz dA_v dT_{max} d\Delta m_{15,B} d\mu \quad (5)$$

Where z is the redshift, A_v the host galaxy extinction, T_{max} the time of maximum light, $\Delta m_{15,B}$ the amount of magnitude decline in the B-band during the first 15 days after the maximum light, and μ is the distance modulus. The method use flat prior in $A_v, T_{max}, \Delta_m 12, B\&\mu$, while in redshift it assumes Gaussian priors. The evidece of non SNe Ia is given by:

$$E_{Ibc,II} \sum \int P(z) e^{\chi^2/2} dz dA_v dT_{max} d\mu \quad (6)$$

Then the probability that the light curve it's of a one type of SN is given by:

$$P_{type} = \frac{E_{type}}{E_{Ia} + E_{Ibc} + E_{II}} \quad (7)$$

After selecting the SNe Ia the distance modulus is derived by fitting the light curve as a function of the stretch (x_1) the colour c and the apparent magnitude m_B. With these parameters the distance modulus can be derived using:

$$\mu = m_B - M + \alpha x_1 + \beta c - \mu_{corr} \quad (8)$$

Where α, β and M (absolute magnitude in the B band) are constants, that are going to be marginalized with flat priors. The μ_{corr} term corresponds to the correction due to the Malmquist bias correction defined as:

$$\mu_{corr} = a e^{(bz)} + c \quad (9)$$

With $a = -0.004 \pm 0.001, b = 7.26 \pm 0.31$ and $c = 0.004 \pm 0.006$.

Finally the host galaxy properties are also taken from the BOSS survey, From the sample of 752 SNe Ia candidates AGN host galaxies have to be removed from the sample because the line emission might dominate over the line flux from star formation which is one of the properties that (?) studied. The stellar mass of the remaining 581 host galaxies was derived by studying the broad band photometry and comparing it with the best SED fit template. The chosen template used a (?) population synthesis model and a Kroupa IMF.

5 Results

6 Conclusions