THE IMPACT OF THE ELEMENTAL ABUNDANCES OF THE GALAXIES HOSTING SN Ia OVER THE HUBBLE DIAGRAM

Manuel E. Moreno Raya[1], Mercedes Mollá[1], Ángel R. López-Sánchez[2,3], Aurelio Carnero[4],
Inmaculada Domínguez[5], José Manuel Vílchez[6]

[1]CIEMAT, Madrid, Spain [2]Australian Astronomical Observaroty, Sidney, Australia [3]Macquarie University, Australia
[4]Observatório Nacional, Río de Janeiro, Brasil [5]Universidad de Granada, Spain [6]Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain

The metallicity of the progenitor system producing a Supernova type Ia could play an important role in the estimate of the maximum luminosity of the explosion. This dependence should change the calibration between the light curve parameters of SN Ia and its absolute magnitude. To test this idea, we apply the metallicity dependent theoretical calibration by Bravo (2010) to a sample of 40 SNe-Ia in the range $z \leq 0.4$ selected from the existing data of Sloan Digital Sky Survey (SDSS) for which we have estimated the elemental abundances.

We analyze the impact over the absolute magnitude determined for the SNIa and over the Hubble diagram.

INTRODUCTION

The supernova cosmology is based on the well known Hubble diagram, which represents the distance of objects as a function of their redshift. The redshift z is determined with high accuracy from Sne Ia spectra, and distances are given by the distance modulus $\mu = m - M$ because SN Ia are supposed to be **STANDARD-CALIBRATED CANDLES** and hence magnitude *M* may be established.

Since the number of SN Ia will extraordinarily increase in the forthcomming surveys, statistical errors will decrease, and therefore the systematical errors will begin to dominate and will limit the precision of SN Ia as extragalactic distance indicators.

A correlation between the SN Ia light properties and the magnitude in its light curve maximum was empirically found by Hamuy (1996) and Phillips et al. (1999). Therefore, it is possible to estimate the distance to these objects only studying the light curve ot the supernova:
Width curve-luminosity relation (WLR)

$$M_{max,V} = g(\Delta m_{15}) = -19.267 + 0.672[\Delta m_{15}(B) - 1.1] + 0.633[\Delta m_{15}(B) - 1.1]^2 \text{ mag} \quad (1)$$

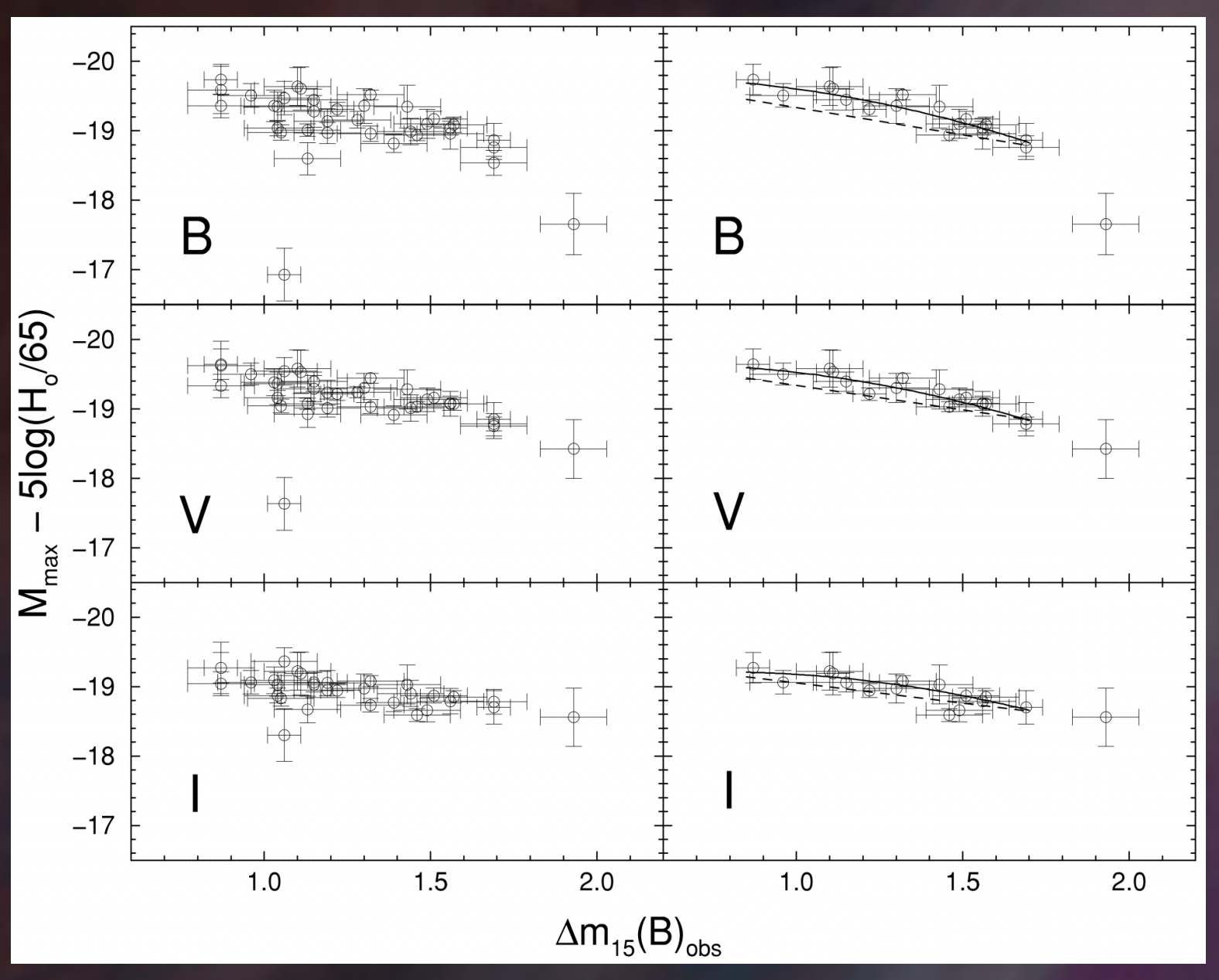

Figure 1. Calibration Absolute Magnitude–Δm_{15}. *Phillips et al. (1999)*

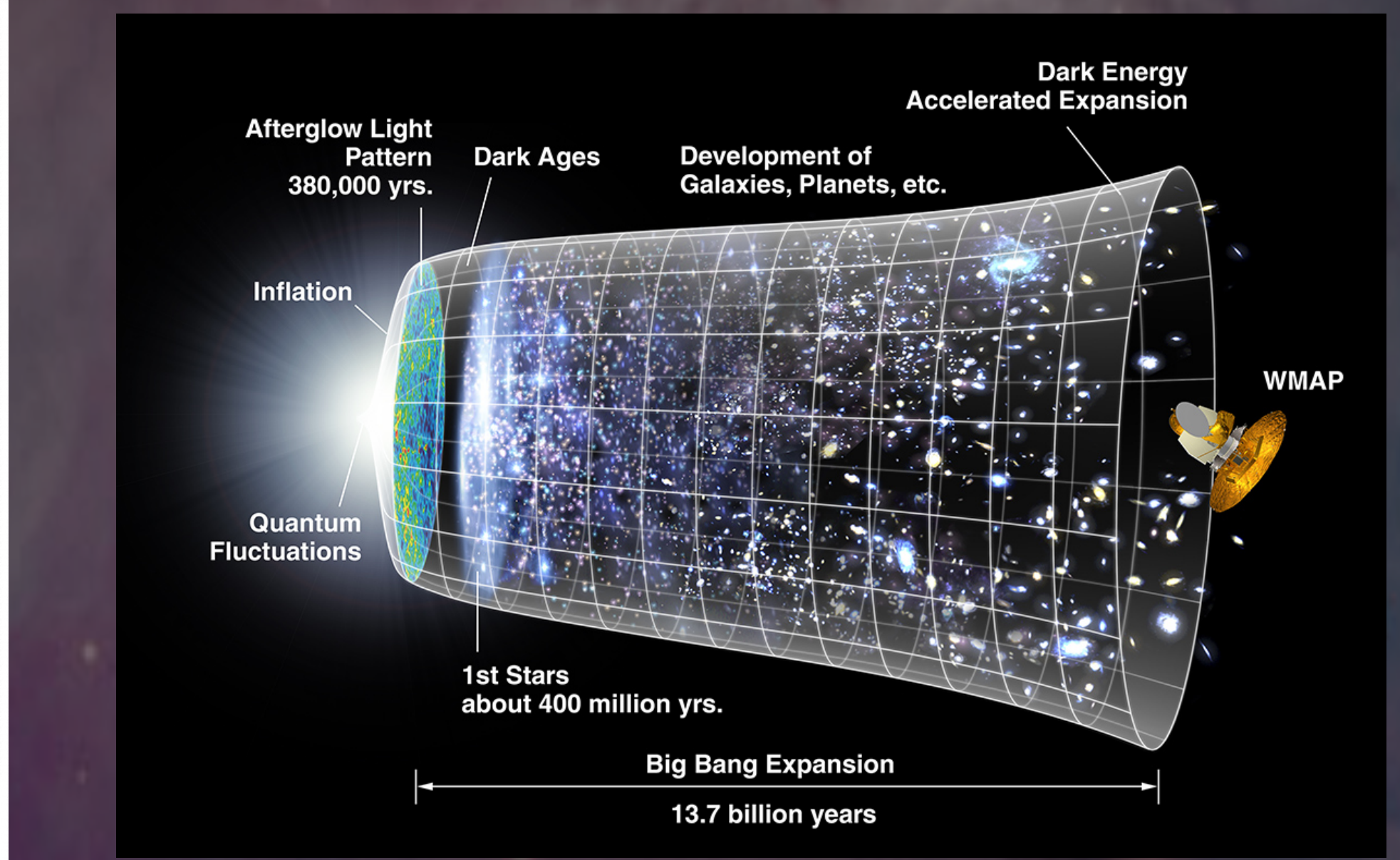

Figure 2. Universe time evolution

This calibration is based on local SN Ia, probably located in galaxies with solar or almost solar abundances.
Taking into account that elemental abundances may have changed with redshift due to the metal enrichment along the time evolution, the dependence of the SN Ia luminosity on the metallicity of the binary system may have been neglected.
The calibration light curve parameters–absolute magnitude may not be valid for high redshift objects.

METALLICITY DEPENDENCES

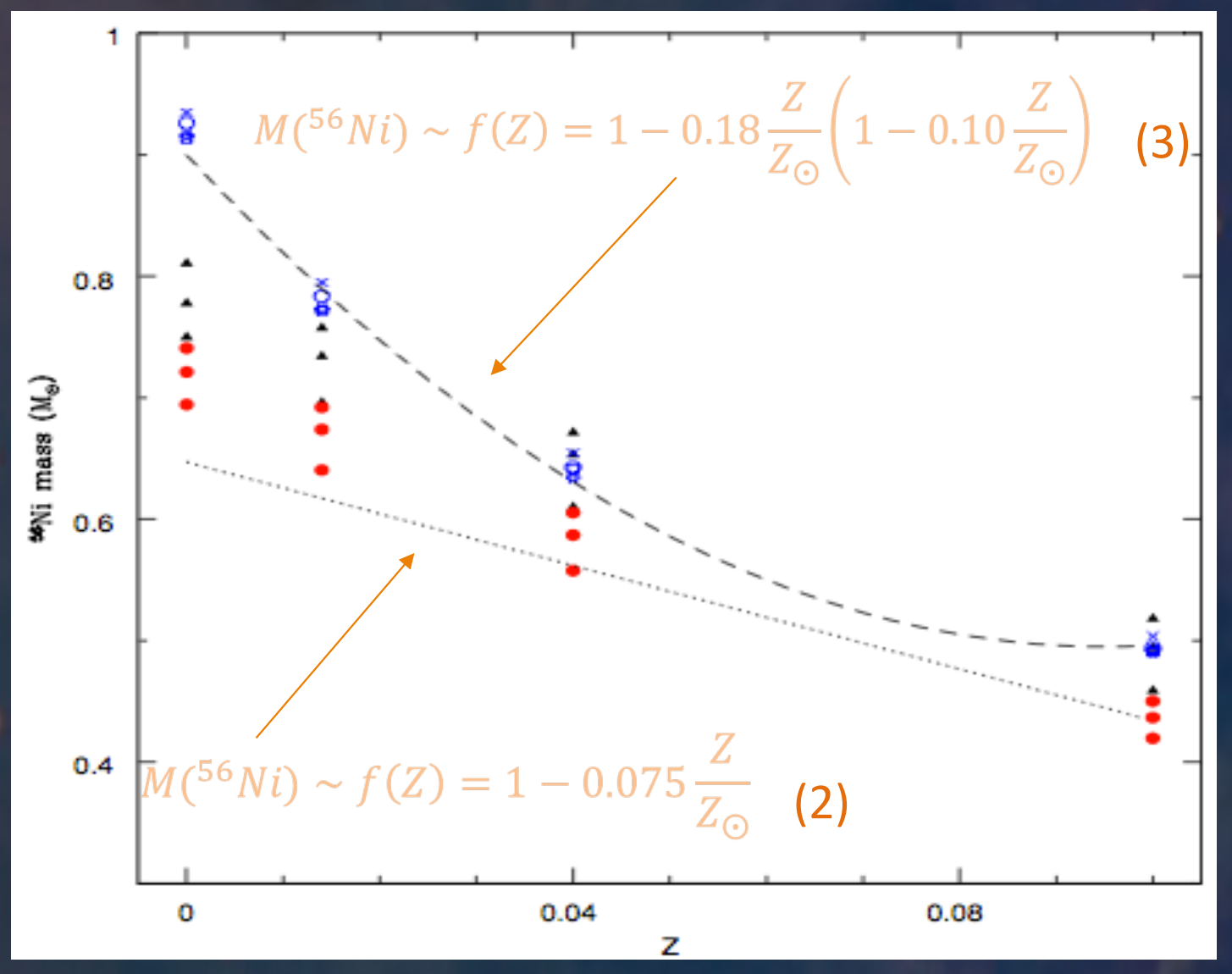

Figure 3. Relation *M(^{56}Ni)*–elemental abundance *Z. Bravo el al. (2010)*

A dependence of the maximum luminosity of the SN on the metallicity of the binary system is theoretically predicted: by assuming that the progenitor white dwarf (WD) mass is constant, the maximum magnitude depends on the total quantity of elements of the iron group, mainly ^{56}Ni: $L = 2 \cdot 10^{43}\, M(^{56}Ni)$ erg s^{-1}.

Timmes et al. (2003) found that the magnitude in the light curve maximum depends on the WD chemical abundance o elements C, N, O and Fe.
Recently, Bravo et al. (2010), computing a series of explosions of SN Ia, find two different relations (see Fig. 3) between the synthesized mass of ^{56}Ni and the abundance *Z* of the progenitor binary system (Eqs. 3 and 4)

The luminosity of the SN Ia depends crucially on the initial elemental abundance of the original stars, being brighter when *Z* is lower than for solar abundance

Bravo et al. (2010) suggest that the WLR also might change with the metallicity.
In that case we will obtain parallel curves for different metallicities.

$$M_V(Z, \Delta m_{15,B}) = M_V(\Delta m_{15,B}) + \Delta M_V(Z) \text{ mag} \quad (4)$$

$$\Delta m_{15,B} = \Delta m_{15,obs} + 0.1E(B-V) \quad (5)$$

$M_V(\Delta m_{15,B})$ is the standart calibration or WLR which would correspond to $Z_\odot$, given by Eq. 1, while the term $\Delta M_V(Z)$ would produce a shift in this standard curve.
By using Eqs. 2 and 3, we would obtain these two metallicity-dependent relationships respectively:

$$\Delta M_V(Z) = -2.5 \log\left(1 - 0.075\frac{Z}{Z_\odot}\right) - 0.0846 \text{ mag} \quad (6)$$

$$\Delta M_V(Z) = -2.5 \log\left[1 - 0.18\frac{Z}{Z_\odot}\left(1 - 0.10\frac{Z}{Z_\odot}\right)\right] - 0191 \text{ mag} \quad (7)$$

The terms 0.0846 and 0.191 dex have been introduced to have $\Delta M_V(Z) = 0$ for $Z_\odot$.
In turn there values represent the differences in magnitudes between objects with $Z = 0$ and $Z = Z_\odot$

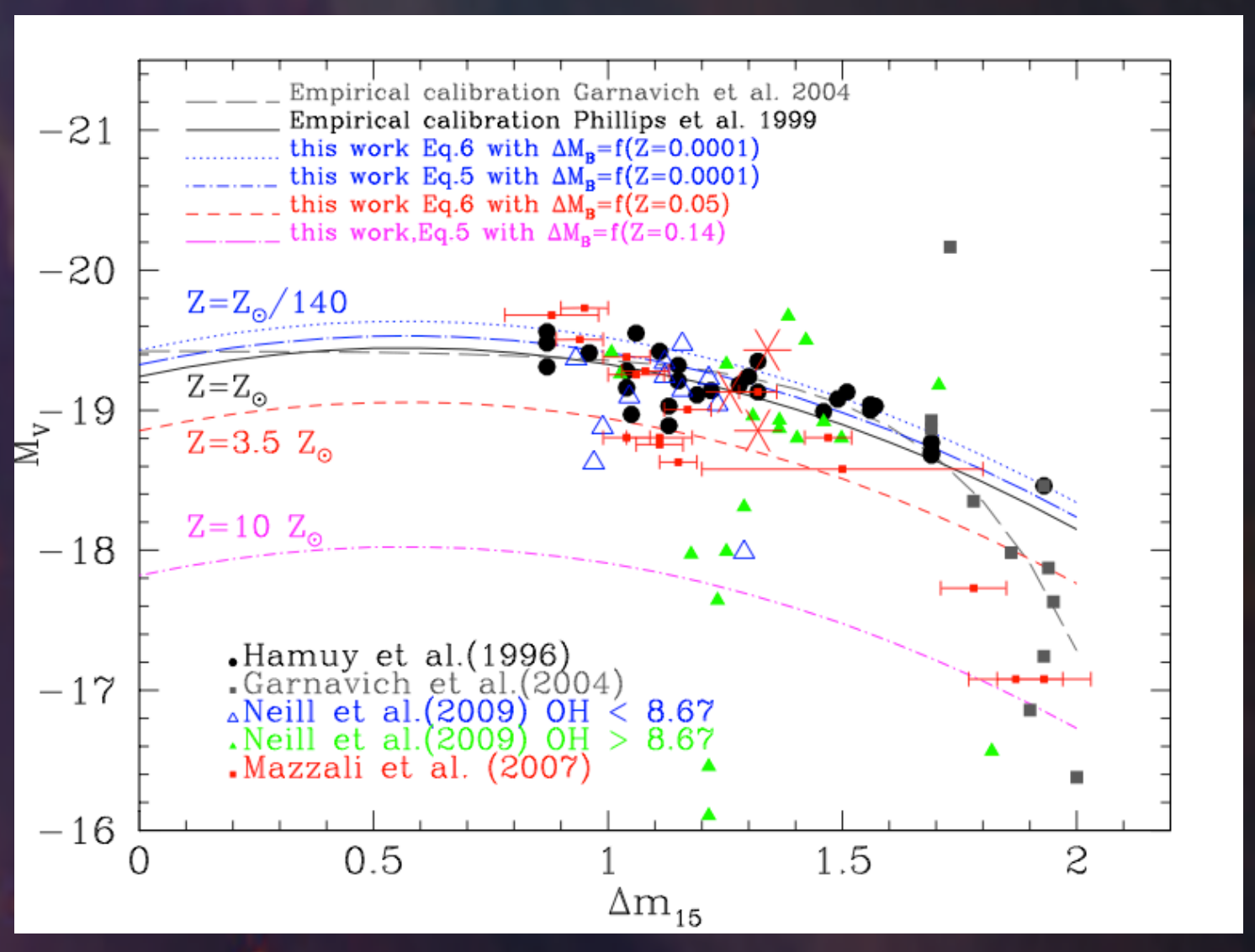

Figure4. Absolute magnitude $M_V - \Delta m_{15}$ calibration curves

DATA ANALYSIS

SN	IAU	RA	DEC	redshift	E(B-V)	12+log(O/H)	$\Delta m_{15,B}$	gMax	rMax
SN1580	2005fb	45.32495	-0.64510	0.18300	0.6489	8.83 ± 0.04	0.90	20.553	20.450
SN2561	2005fv	46.34430	0.85972	0.11819	0.5476	8.66 ± 0.09	1.10	19.939	19.874
SN2992	2005gp	55.49731	-0.78294	0.12656	0.9987	8.65 ± 0.24	1.10	20.107	20.043
SN3592	2005gb	19.05289	0.79061	0.08656	0.7105	8.79 ± 0.09	1.10	18.715	18.845
SN3901	2005ho	14.85049	0.00266	0.06283	0.2527	8.43 ± 0.07	0.90	17.901	18.060
SN5966	2005it	16.19056	0.51326	0.30955	0.9652	8.99 ± 0.06	0.60	21.853	21.604
SN6057	2005if	52.55368	-0.97448	0.06709	0.2225	8.62 ± 0.05	1.00	18.859	18.789
SN7876	2005ir	19.18279	0.79361	0.07636	0.2607	8.69 ± 0.09	1.10	18.283	18.461
SN8151	2005hk	6.95722	-1.19997	0.01306	0.2621	8.63 ± 0.07	1.60	14.678	14.752
SN10096	2005lj	29.42965	-0.17942	0.07775	0.1770	8.59 ± 0.10	0.90	20.340	19.949
SN10805	2005ku	44.92784	-0.01356	0.04546	0.5282	8.60 ± 0.04	1.20	17.631	17.671
SN12778	2006fs	17.49567	0.40859	0.09923	0.6770	8.75 ± 0.06	0.70	19.733	19.633
SN12856	2006fl	32.86538	0.75559	0.17173	0.1093	8.58 ± 0.31	0.80	20.070	20.186
SN12950	2006fy	51.66727	-0.84061	0.08268	0.2272	8.50 ± 0.10	1.00	18.942	18.978
SN13072	2006fi	4.96065	0.02368	0.23063	0.2782	8.50 ± 0.03	0.90	21.004	20.958
SN13254	2006gx	2.05870	-0.34681	0.18068	0.0905	8.59 ± 0.08	0.90	21.116	20.977
SN13610	2006hd	6.01425	0.72551	0.29828	0.4035	8.61 ± 0.07	0.70	21.449	21.288
SN15136	2006ju	1.16219	-0.71793	0.14869	0.3378	8.70 ± 0.05	1.10	20.340	20.325
SN15234	2006kd	6.95808	0.82859	0.13634	0.0621	8.66 ± 0.03	1.00	20.398	20.273
SN15421	2006kw	3.74128	0.60272	0.18500	0.0248	8.56 ± 0.22	1.00	20.510	20.543
SN15467	···	0.02009	-0.17735	0.21043	0.2842	8.66 ± 0.11	1.00	20.682	20.709
SN16069	2006nd	1.24505	-1.00639	0.12878	0.5966	8.66 ± 0.09	1.00	20.068	20.019
SN17117	2006qm	0.60192	-0.79517	0.14017	0.2990	8.55 ± 0.04	1.70	20.487	20.505
SN17134	2006rz	4.56786	-0.11012	0.08700	0.4431	8.74 ± 0.04	1.40	20.077	19.867
SN17176	2007ia	34.40283	0.61326	0.09345	0.0335	8.25 ± 0.07	0.80	19.355	19.328
SN17280	2007hz	55.79183	0.10401	0.13099	0.5698	8.75 ± 0.06	1.30	19.981	19.998
SN17366	2007jt	15.78499	-1.03117	0.13933	0.4008	8.68 ± 0.04	0.80	19.610	19.736
SN17497	2007jg	37.13650	-1.04286	0.14478	0.4598	8.68 ± 0.06	1.00	19.937	20.001
SN17784	2007jd	52.46180	0.05444	0.03710	0.0421	8.60 ± 0.12	1.20	17.544	17.469
SN17880	2007kq	44.97361	1.16003	0.07265	0.1133	8.68 ± 0.10	1.20	19.011	18.950
SN18030	2007lc	4.93321	-0.40009	0.15646	0.4129	8.35 ± 0.08	1.00	20.366	20.375
SN18612	2007ma	12.28801	0.59660	0.11504	0.6180	8.81 ± 0.03	1.10	19.465	19.518
SN18697	2007mh	11.22420	-0.99687	0.10725	0.5262	8.65 ± 0.02	0.90	19.053	19.173
SN18855	2007mn	48.63386	0.26887	0.12782	0.0598	8.72 ± 0.08	1.00	19.842	19.849
SN19155	2007nj	31.26481	0.17512	0.07689	0.3653	8.71 ± 0.07	0.80	18.275	18.453
SN19353	2007ok	43.11326	0.25174	0.15395	0.4156	8.70 ± 0.07	1.00	20.276	20.236
SN19616	2007ou	37.09966	0.18600	0.16554	0.7306	8.70 ± 0.03	1.00	20.152	20.234
SN19626	2007pt	35.92775	-0.82647	0.11321	0.7105	8.64 ± 0.10	0.80	20.480	20.232
SN19969	2007om	31.90982	-0.32403	0.17529	0.3834	8.63 ± 0.07	0.70	20.361	20.408
SN20528	2007qr	43.12132	-1.13946	0.13609	0.5302	8.74 ± 0.05	1.10	20.145	20.120

Table 1. Data sample. *Molla et al. (2012)*

We have taken the SDSS data sample and selected 40 galaxies hosting spectroscopically confirmed SN Ia.

For each galaxy we have a spectrum where we measure the emission lines fluxes with IRAF in order to estimate the oxygen abundance.

The lines are corrected by reddening using the extinction function by Cardelli et al. (1989) and the expression:

$$\frac{I(\lambda)}{I(H\beta)} = \frac{F(\lambda)}{F(H\beta)} \cdot 10^{C(H\beta)\cdot[f(\lambda) - f(H\beta)]} \quad (8)$$

We calculate the oxygen abundances taking the empirical calibrations by Pettini & Pagel (2004) by using the N2 and O3N2 parameters as described in López-Sánchez (2010):

$$12 + \log(O/H) = 8.9 + 0.57 \log\left(\frac{[NII]\,\lambda6584}{H\alpha}\right) \quad (9)$$

$$12 + \log(O/H) = 8.7 - 0.32 \log\left(\frac{[OIII]\lambda5007}{H\beta} \times \frac{H\alpha}{[NII]\,\lambda6584}\right) \quad (10)$$

Diagnostic diagrams are used to select only the *HII* galaxies, the ones valids for our purpose.

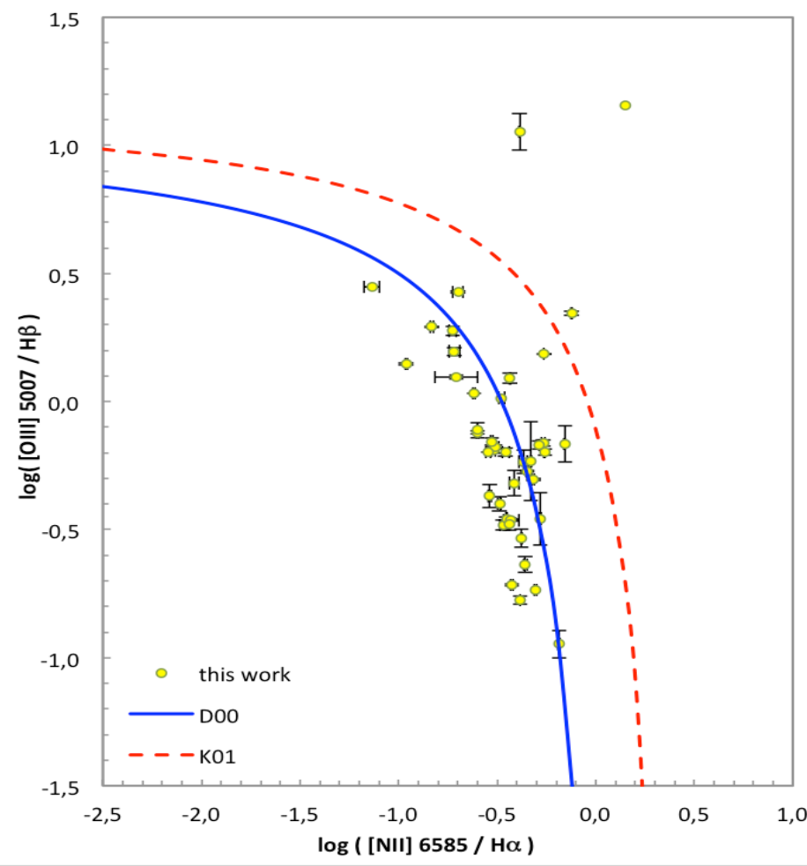

Figure 5. **BPT** diagnostic diagram

THE EFFECT OF METALLICITY

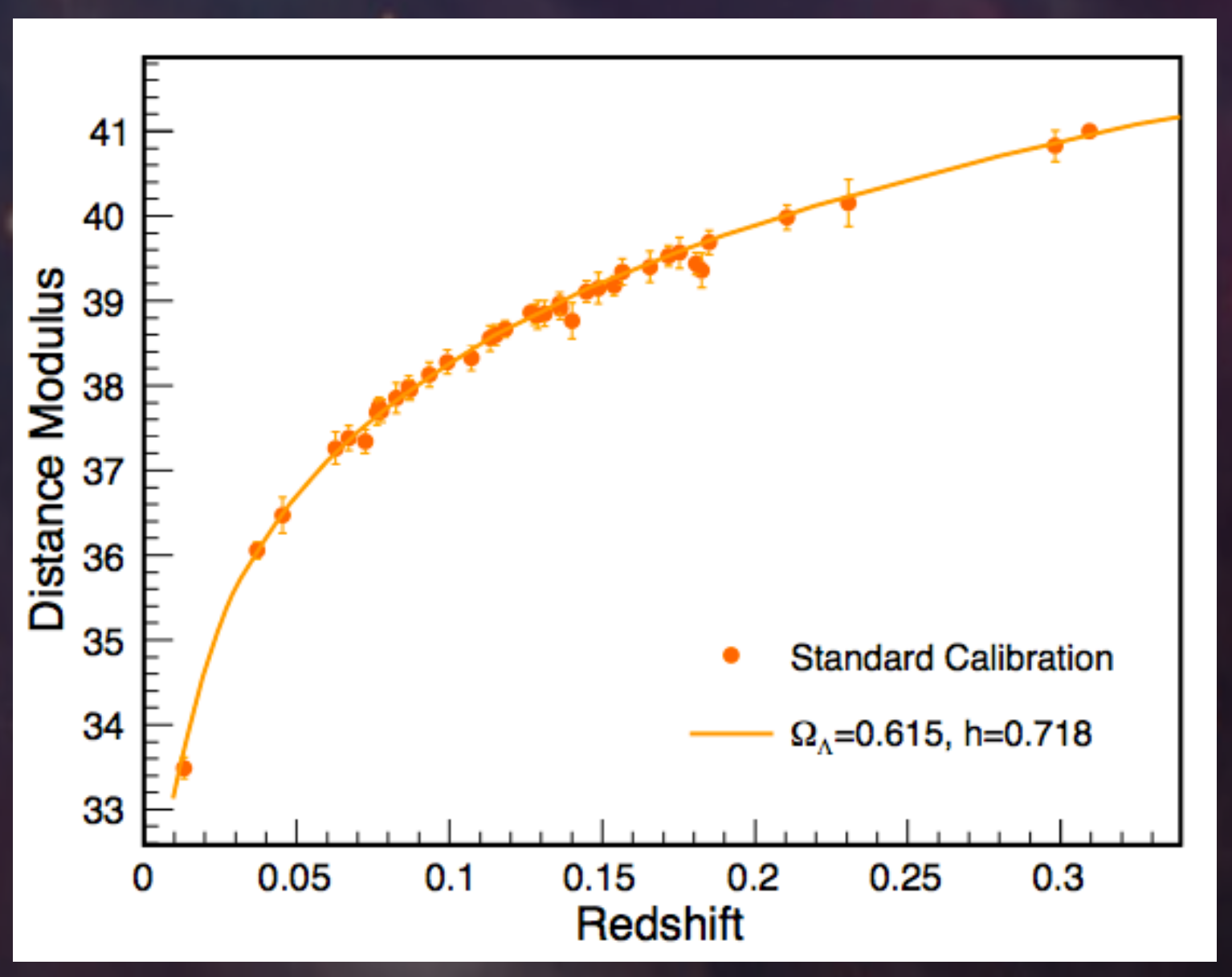

Figure 6. Hubble diagram without metallicity correction

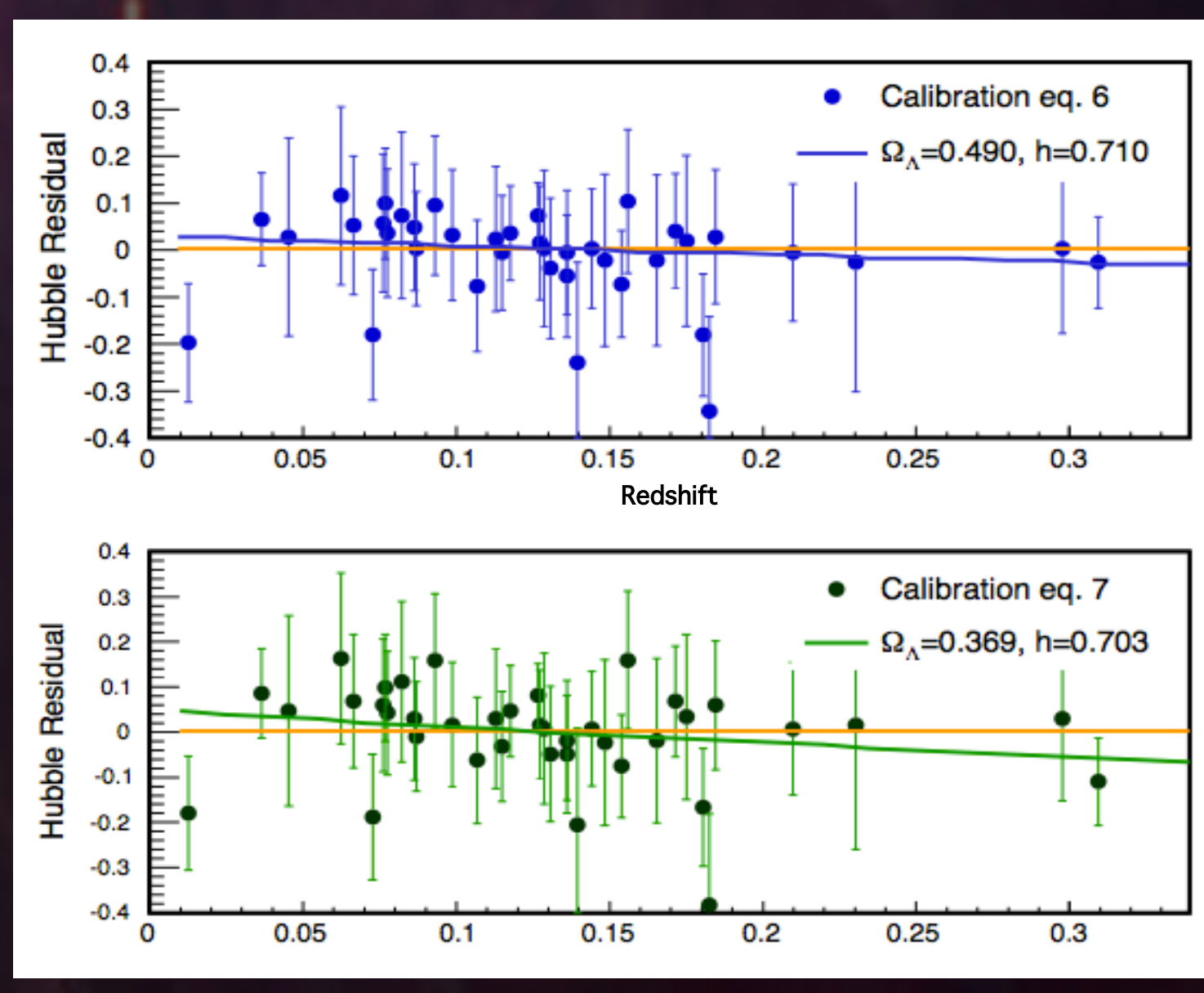

Figure 7. Residuals for the metallicity-dependence distance modulus calibrations

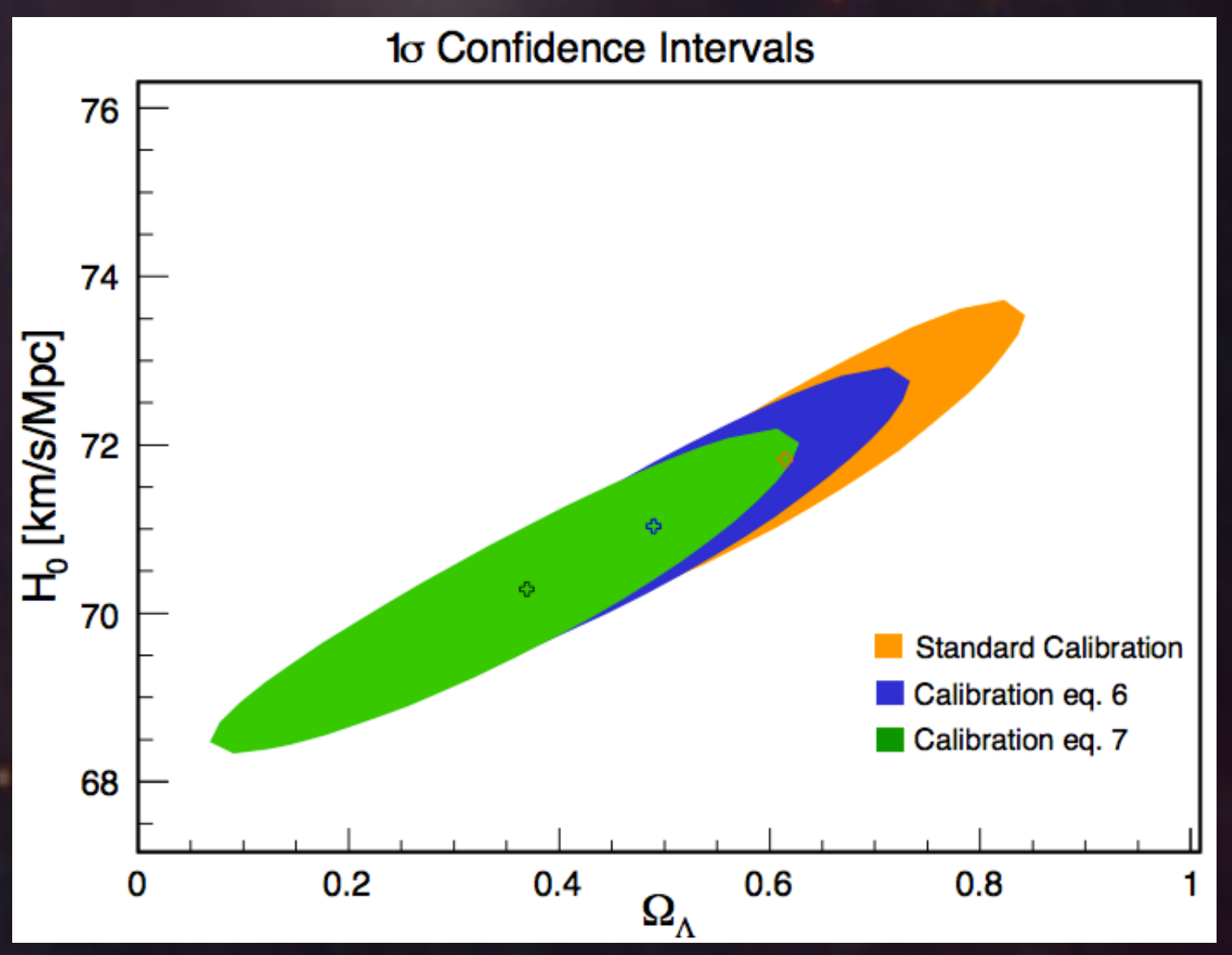

Figure 9. 1σ confidence intervals contours for the three calibrations

We show the Hubble diagram with $m_V - M_V$ without metallicity dependence in Figure 6, and the residuals for the metallicy calibrations in Figure 7.

It's clear that there is a trend in the sense of descreasing Ω_Λ when abundance dependence is taken into account.

A flat geometry ($\Omega_\Lambda + \Omega_M = 1$), following CMB data, is assumed.

The Hubble constant has been taken as $H_0 = 72$ km s^{-1} Mpc^{-1}

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CONCLUSIONS

Considering this possible dependence on metallicity, the cosmological models would have a lower value of Ω_Λ than tis one derived when the metallicity is neglected.

Our results come from the fact that the oxygen abundances estimated in the host galaxies at high redshift seem to be higher than now, which is interesting and not expected.

The effect of metallicity could be more important for z > 0.4, due to the chemical enrichment of the universe and to larger differences between cosmological models.

Is essential to take into account the dependence on metallicity in the SNe Ia absolute magnitude or distance determinations.