



# The influence of host galaxy morphology on the properties of Type Ia supernovae from the JLA compilation



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## HIGHLIGHTS

- We study the influence of host galaxy morphology on LC parameters of the JLA data.
- The  $\alpha$  parameter decreases from elliptical/lenticular to late-type spiral galaxies.
- In an old stellar population SNe Ia are fainter after stretch and colour corrections.
- The host galaxy morphology affects the residual dispersion on the Hubble diagram.
- SNe Ia in late-type spiral galaxies are more homogeneous in comparison with others.

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## ABSTRACT

The observational cosmology with distant Type Ia supernovae (SNe) as standard candles claims that the Universe is in accelerated expansion, caused by a large fraction of dark energy. In this paper we investigate the SN Ia environment, studying the impact of the nature of their host galaxies on the Hubble diagram fitting. The supernovae (192 SNe) used in the analysis were extracted from Joint-Light-curves-Analysis (JLA) compilation of high-redshift and nearby supernovae which is the best one to date. The analysis is based on the empirical fact that SN Ia luminosities depend on their light curve shapes and colors. We confirm that the stretch parameter of Type Ia supernovae is correlated with the host galaxy type. The supernovae with lower stretch are hosted mainly in elliptical and lenticular galaxies. No significant correlation between SN Ia colour and host morphology was found.

We also examine how the luminosities of SNe Ia change depending on host galaxy morphology after stretch and colour corrections. Our results show that in old stellar populations and low dust environments, the supernovae are slightly fainter. SNe Ia in elliptical and lenticular galaxies have a higher  $\alpha$  (slope in luminosity-stretch) and  $\beta$  (slope in luminosity-colour) parameter than in spirals. However, the observed shift is at the  $1-\sigma$  uncertainty level and, therefore, can not be considered as significant.

We confirm that the supernova properties depend on their environment and that the incorporation of a host galaxy term into the Hubble diagram fit is expected to be crucial for future cosmological analyses.

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## 1. Introduction

Type Ia supernovae (SNe) are well known as cosmological distance indicators. Among the other types of supernovae they have less dispersion at maximum light and show higher optical luminosities. Through observations of distant SNe Ia the accelerating expansion of the Universe was discovered (Riess et al., 1998; Perlmutter et al., 1999). The most recent analysis of SNe Ia indicates that considering a flat  $\Lambda$ CDM cosmology, our Universe is accelerating due to dark energy contamination ( $\Omega_{\Lambda} = 0.705 \pm 0.034$  (Betoule et al., 2014)).

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However, the use of SNe Ia as “standard candles” would never be possible without the empirical relation between their peak luminosity and light curve shape. This relation was independently discovered by the American statistician and astronomer B. W. Rust and Soviet astronomer Yu. P. Pskovskii in the 1970th. Using a limited sample of Type I supernovae they were able to show that the brighter the supernova, the slower its luminosity declines after achieving maximum brightness (Pskovskii, 1977; 1984; Rust, 1974). Later, the dependence of colour was also reported by Hamuy et al. (1996); Tripp (1998).

By now several realizations of the “standardization” idea were developed: the  $\Delta m_{15}$ -method (Phillips, 1993; Phillips et al., 1999), the stretch-factor (Perlmutter et al., 1997; 1999), the Multicolor Light Curve Shape (MLCS) (Riess et al., 1996; Jha et al., 2007), PRES (Prieto et al., 2006), the Spectral Adaptive Light curve Template for Type Ia supernova (SALT) (Guy et al., 2005; 2007), the Color-Magnitude Intercept Calibration (CMAGIC) (Wang et al., 2003). Nevertheless, the SN Ia “standardization” procedure is one of the main sources of systematic uncertainties in the cosmological results.

The problem is that the physical properties of SN Ia explosions, which lead to the relation between SN luminosity and its light-curve shape and colour, are still not fully understood. It is generally believed that the SN Ia phenomenon is an explosion of a CO white dwarf (WD) which exceeds the Chandrasekhar limit. However, the progenitor system is unclear. The accumulation of mass by a WD could be a result of either the matter accretion from a companion star (single degenerate mechanism, SD (Whelan and Iben, 1973)) or merger with another WD (double degenerate mechanism, DD (Iben and Tutukov, 1984; Webbink, 1984)). Moreover, during the last decade the discovery of superluminous supernovae and Type Iax SNe challenges our views on possible explosion mechanisms. Without detailed spectral classification these SNe could mimic SNe Ia.

Another important factor which could violate the “standard candle” hypothesis is dust. Dust around the supernovae, as well as in the host galaxy, surely affects light curve behaviour. The distribution and properties of dust in host galaxies of supernovae could be different from that in the Milky Way. Furthermore, one noteworthy ambiguity is connected to the so-called grey dust: its absorption is wavelength independent and essentially cannot be taken into account. Grey dust can be large dust particles with typical sizes greater than  $0.01 \mu\text{m}$  (Aguirre, 1999). This could lead to the dimming of distant supernovae and mimic the accelerated expansion (Bogomazov and Tutukov, 2011). Indeed, the amount of such dust inside host galaxies of SNe is proportional to the star formation rate, which increases into the past, and could produce an apparent fall in the luminosity of distant supernovae. However, in Pruzhinskaya et al. (2011) it was shown that SNe which are free from grey dust absorption, i.e. “pure” SNe, also indicate the accelerating expansion.

At last, the metallicity of the progenitor defines the Chandrasekhar limit. A lower metallicity involves an increase of the Chandrasekhar limit and could affect the explosion process.

The above-listed factors could be considered as environmental effects. In the epoch of large transient surveys, development of observational techniques, and further processing of the data, a study of environment is of high priority.

In this paper we consider the properties of SNe and their impact on Hubble diagram in different environments. We separate Type Ia supernovae according to the type of host galaxy into three subsamples: supernovae that exploded in elliptical/lenticular (E-S0), early-type spiral (Sa-Sc), and late-type spiral (Sd-Ir) galaxies. The idea of our approach is close to the idea described in Sullivan et al. (2003); Pruzhinskaya et al. (2011). The reasoning behind this idea is as follows. First, the oldest, i.e. metal-poor, stars with an

age comparable to that of the Universe lie in elliptical/lenticular galaxies. This automatically leads to a more homogeneous chemical composition of the progenitor stars. Second, the dust (including grey dust) is almost absent in these regions. And thirdly, SNe in elliptical galaxies probably have a common explosion mechanism – DD. Indeed, while in elliptical galaxies it is anyway the white dwarf merger mechanism which provides up to 99% of SN Ia explosions (see Lipunov et al., 2011), this is not the case for spiral galaxies. In the latter galaxies some fraction of SNe Ia can explode via the SD mechanism which suggests the accumulation of mass by a white dwarf from an intermediate-mass star in a binary system. The considered types of the galaxies differ in star formation rate, which is low for elliptical/lenticular galaxies and high for spirals. However, while in early-type spirals star formation regions are located in spiral arms, in late-type they are not associated with any particular structures.

Our analysis is based on the Joint Light-curve Analysis (JLA) sample of supernovae which includes 740 spectroscopically confirmed Type Ia supernovae (Betoule et al., 2014). The JLA sample is the best SNe sample to date. The main advantages of JLA compared to previous compilations are: an intercalibration between different surveys and a thorough investigation of systematic uncertainties. The presented analysis is the first study of JLA supernovae depending on host galaxy morphology.

The paper is organized as follows. In Section 2 we describe how we make a sample of SNe Ia for our analysis and how we divide them considering the morphology of the host galaxy. Section 3 contains the description of the Hubble-diagram fitting procedure. In Section 4 we perform the analysis of impact of the host morphology on SN Ia properties and compare our results with those of earlier studies. The conclusions are presented in Section 5.

## 2. Type Ia supernovae and host galaxy data

### 2.1. JLA compilation

The JLA compilation (Betoule et al., 2014) regroups 740 nearby and distant supernovae up to redshift 1.3, that has been acquired between 1990 and 2008. In this sample, 374 objects come from the Sloan Digital Sky Survey (SDSS), 239 from the Supernovae Legacy Survey (SNLS), and 9 from the Hubble Space Telescope (HST). The remaining 118 are low-redshift supernovae measured by different nearby experiments. The JLA supernovae were standardized using the SALT2 model, an empirical model of spectro-photometric time evolution of SN Ia (Guy et al., 2007).

The following data for each supernova were extracted from JLA to perform the analysis:

- $z_{\text{cmb}}$ : the redshift in the CMB frame with its uncertainty;
- $z_{\text{hel}}$ : the redshift in the heliocentric frame;
- $m_B^*$ : the value of the  $B$ -band peak magnitude with its uncertainty;
- $X_1$ : SALT2 shape parameter (stretch) with its uncertainty;
- $C$ : SALT2 colour parameter with its uncertainty;
- $ra$ : right ascension in degrees (J2000);
- $dec$ : declination in degrees (J2000).

### 2.2. Host galaxy morphology

The morphological classification of galaxies proposed by Hubble (Hubble, 1926; 1936) and after developed by de Vaucouleurs (1959) and Sandage (1961) is strongly correlated with physical properties of the galaxies such as colour, mean surface brightness, neutral hydrogen content etc (see Buta, 2013 for a review).

For our analysis it is important that the stellar population, amount of dust, star formation rate also evolve along the morphological sequence. Elliptical galaxies are dominated by old-stars and

**Table 1**  
Morphological classification of galaxies implemented in the paper.

Elliptical/Lenticular (E/L)				Early type spiral (ES)				Late type spiral (LS)								
cE	E	E <sup>+</sup>	S0 <sup>-</sup>	S0 <sup>0</sup>	S0 <sup>+</sup>	S0/a	Sa	Sab	Sb	Sbc	Sc	Scd	Sd	Sdm	Sm	Im

they are relatively dust-free. Spiral galaxies are characterized by the appearance of the spiral arms with star formation regions and diversity of stellar population. Irregular galaxies like spirals have old and young stellar populations but the star formation occurs in the absence of spiral arms (Hunter, 1997).

We divided the host galaxies of supernovae into three groups: elliptical/lenticular (E/L), early-type spiral (ES), and late-type spiral (LS) galaxies (see Table 1):

- E/L: in this category elliptical and lenticular galaxies were included. Elliptical galaxies have a shape of ellipse or sphere, without apparent substructure. The surface brightness is uniform in the core and declines suddenly outwards. Lenticular galaxies have a spheroidal bulge and a disk, without spiral arms.
- ES: galaxies with type from S0/a to Sc belong to the early-type spirals. This type is characterized by a prominent bulge, well formed arms and dust lanes.
- LS: the late-type spirals (Scd-Im) have loosely wound and weak arms, and a weak bulge. Both, arms and bulge completely disappear in irregular galaxies (Im) Baillard et al. (2011); Buta (2013).

Our choice was limited by statistics and difficulties connected with morphological classification. While confident detailed classification is possible only for nearby galaxies, to classify the distant galaxies usually the comparison between the observed spectra and standard spectra templates for each morphological type is applied. However, even for nearby galaxies sometimes there is a contradiction between different catalogs. For instance, the host galaxy of nearby SN 19930 in our sample is classified as S0 and Sb by different authors (Reindl et al., 2005; Neill et al., 2009).

To classify host galaxies of the SDSS supernovae we used the data provided by Zheng et al. (2008). Zheng et al. have developed automatic classification programs to define SN and host-galaxy types as well as precise redshifts, exploring template cross-correlation and principal component analysis. The morphological types for host galaxies, independently provided by both techniques, are given in Tables 3 and 4 of Zheng et al. (2008). We made a cross-correlation between JLA SNe and Zheng et al. data; 77 coincidences were found. For 18 galaxies (Zheng et al., 2008) provides several morphological types. In such case we adopted the type obtained by cross-correlation method. If cross-correlation gives several possible types we chose the one corresponding to the highest best-fit criterion.

The host morphology for nearby supernovae was extracted from different sources (Reindl et al., 2005; Neill et al., 2009; Baillard et al., 2011; Tully et al., 2013). If different catalogs provided the different morphological types for the same galaxy, the final decision was rendered by visual examination of images.

We did not find in the literature the detailed morphology of hosts of SNLS SNe in the JLA sample.

The classification of JLA HST supernovae can be found in Chary et al. (2005); Meyers et al. (2012). However, this classification divides hosts on early-type (E/S0) and late-type (S) galaxies that is not enough for our analysis.

Therefore, the detailed host classification was found for 192 SN Ia from JLA sample (see Table 2). The full list of 192 SNe is presented in Appendix (Table 6).

**Table 2**  
Final sample of SN Ia relative to host galaxy type. The redshift range is  $0.01 < z < 0.4$  for the whole sample.

Host type	Number of SNe
E/L	39
ES	88
LS	65
Total:	192

**Table 3**  
Best-fit parameters for the full JLA dataset and the sample extracted from JLA and used in the current analysis.  $\Delta_M = 0$  in both cases.

	Full JLA sample	Our sample
Number of SNe	704	192
$Z_{\max}$	1.3	0.4
$\chi^2/\text{dof}$	0.99	0.79
$\Omega_\Lambda$	$0.720 \pm 0.033$	$0.740 \pm 0.088$
$\alpha$	$0.132 \pm 0.006$	$0.137 \pm 0.011$
$\beta$	$3.12 \pm 0.08$	$2.75 \pm 0.15$
$M_B$	$-19.08 \pm 0.02$	$-19.11 \pm 0.03$

**Table 4**  
The mean values and RMS for stretch  $X_1$  and colour  $C$  for our full sample and the three subsamples.

	$\langle X_1 \rangle$	$X_1$ RMS	$\langle C \rangle$	$C$ RMS
Our sample	$-0.19 \pm 0.08$	$1.07 \pm 0.06$	$-0.009 \pm 0.006$	$0.081 \pm 0.004$
E/L	$-0.93 \pm 0.17$	$1.06 \pm 0.12$	$-0.023 \pm 0.010$	$0.060 \pm 0.007$
ES	$-0.18 \pm 0.11$	$1.04 \pm 0.08$	$-0.008 \pm 0.009$	$0.088 \pm 0.007$
LS	$0.25 \pm 0.11$	$0.86 \pm 0.08$	$-0.003 \pm 0.010$	$0.081 \pm 0.007$

### 3. Hubble diagram fitting

The cosmological analysis is based on empirical relations between the light curve parameters and absolute magnitude of supernovae (Tripp, 1998). We use SALT2 parameters  $X_1$  describing the time stretching of the light-curve and the colour offset with respect to the average at the date of maximum luminosity in the  $B$ -band,  $C = (B - V)_{\max} - \langle B - V \rangle$ .

In this analysis we adopt the classical standardization of the distance modulus:

$$\mu = m_B^* - (M_B - \alpha X_1 + \beta C), \quad (1)$$

where  $M_B$  is a standardized absolute magnitude of the SN Ia in the  $B$ -band for  $X_1 = C = 0$ ,  $\alpha$  and  $\beta$  describe, consequently, the stretch and colour law for the whole sample. The standardized absolute magnitude of a SN can be defined as  $M = M_B - \alpha X_1 + \beta C$ . The value of the  $B$ -band apparent magnitude  $m_B^*$  at maximum light, stretch factor  $X_1$  and colour  $C$  are taken directly from the JLA dataset (Betoule et al., 2014), while the three nuisance parameters  $M_B$ ,  $\alpha$  and  $\beta$  are free parameters of the Hubble diagram fit, as well as the cosmological parameter  $\Omega_\Lambda$ . All free parameters are determined by minimizing the following chi-square:

$$\chi^2 = [\mu(M_B, \alpha, \beta) - \mu_{\text{theory}}(\Omega_\Lambda)]^\dagger V^{-1} \times [\mu(M_B, \alpha, \beta) - \mu_{\text{theory}}(\Omega_\Lambda)], \quad (2)$$

where  $\mu$  is given by Eq. 1,  $\mu_{\text{theory}} = 5 \lg d_L - 5$ , where  $d_L$  is the luminosity distance in parsecs.  $V$  is a full covariance matrix of the vector of the distance modulus estimates that includes

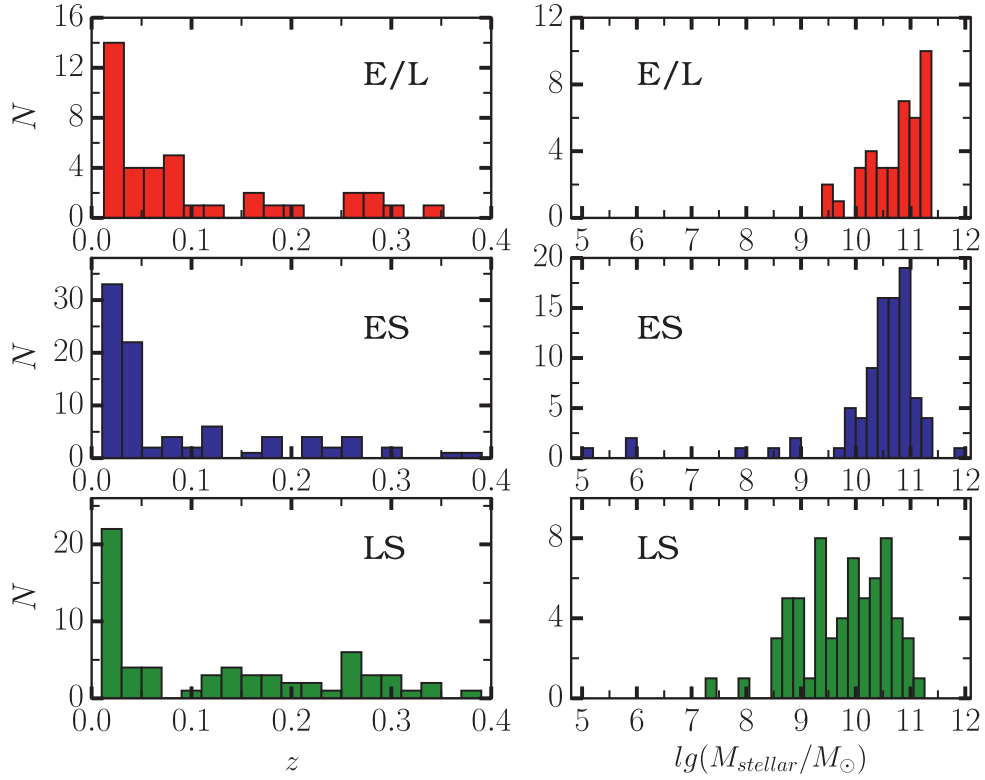


Fig. 1. Redshift (left) and stellar mass (right) distributions for different host galaxy morphologies.

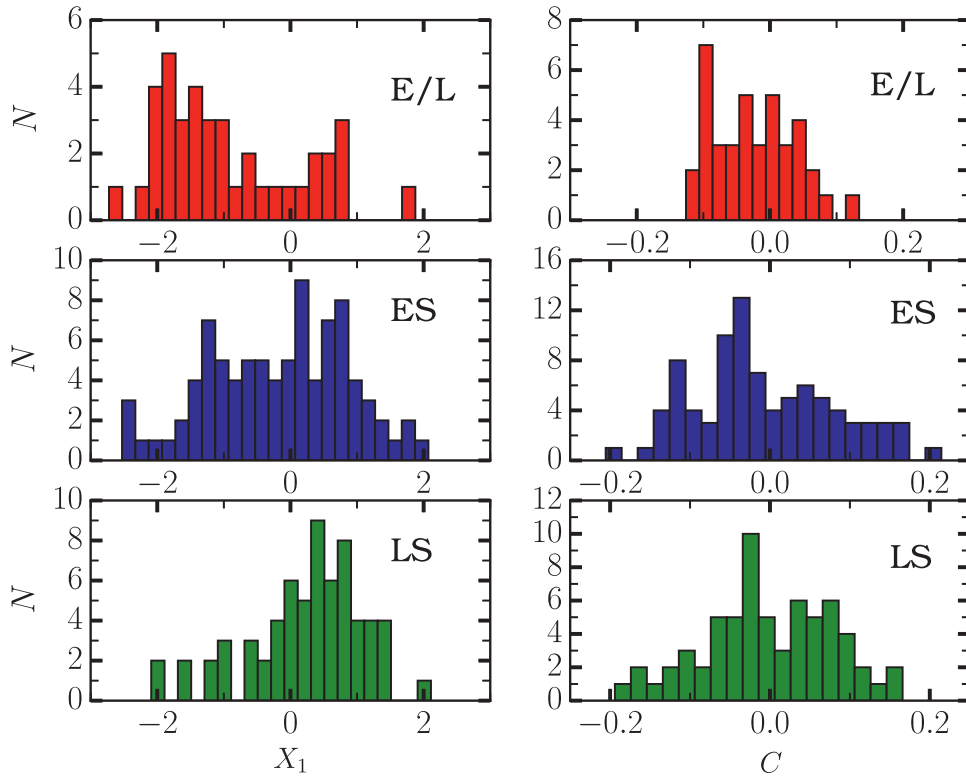
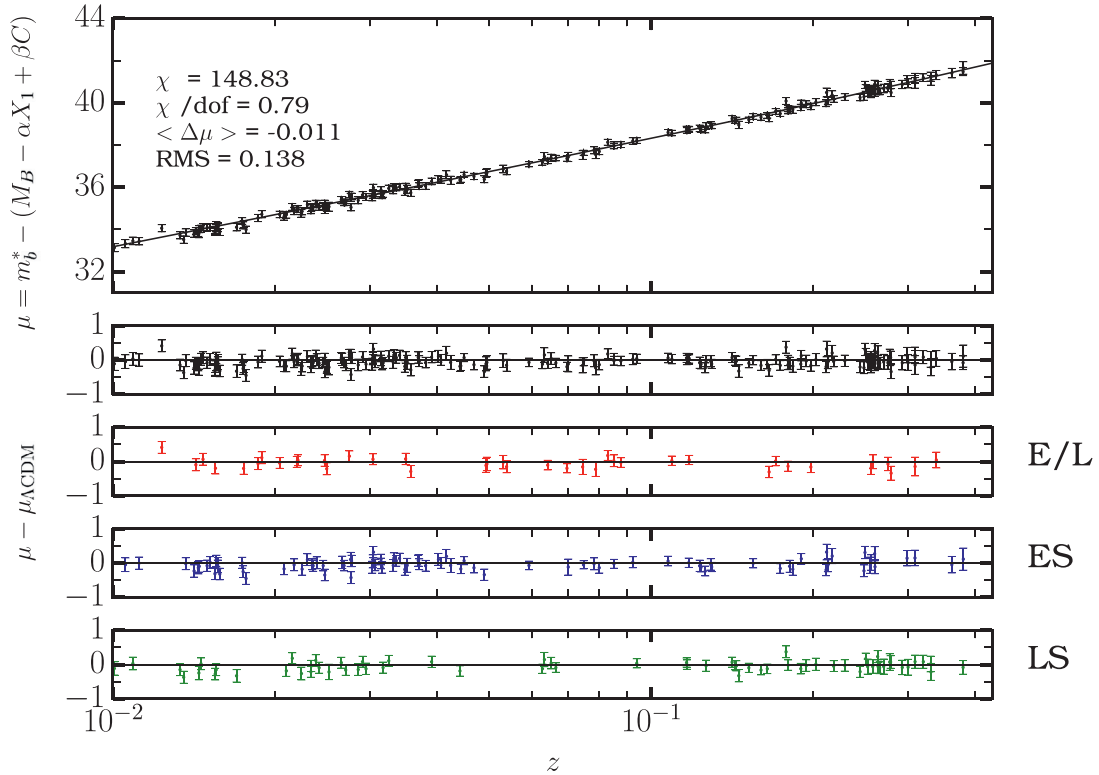


Fig. 2. The distribution of the SALT2 parameters, stretch  $X_1$  (left) and colour  $C$  (right) for different host galaxy morphologies.



**Fig. 3.** The Hubble diagram for the full selected sample of SN Ia (192 SNe) with identified host galaxy morphology. The residuals for the three morphological subsamples of SN Ia from one global fit in which the  $\alpha$ ,  $\beta$ , and  $M_B$  parameters are common for the entire sample are presented. The cosmology is fixed at  $\Omega_\Lambda = 0.705$ .

uncertainties in cosmological redshift due to peculiar velocities, the magnitude variations due to gravitational lensing, the uncounted intrinsic variation in SN magnitude, and different systematic errors such as calibration and bias uncertainties (for the full description of the covariance matrix see (Betoule et al., 2014)). The Hubble constant is fixed,  $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ , and the fit assumes a flat Universe dominated by its matter content  $\Omega_m$  and the dark energy  $\Omega_\Lambda$ , i.e. such that  $\Omega_m + \Omega_\Lambda = 1$ .

The fit we applied is absolutely the same as described in Betoule et al. (2014). However, in the JLA fit one more additional parameter was introduced. It was assumed that  $M_B$  is related to the host stellar mass by a simple step function:

$$M_B = \begin{cases} M_B & \text{if } M_{\text{stellar}} < 10^{10} M_\odot \\ M_B + \Delta_M & \text{otherwise.} \end{cases} \quad (3)$$

To study the environmental effects of SNe Ia we removed this correction as well as the corresponding component of the full covariance matrix from our fitting procedure.

The  $\chi^2$  has been minimized with the minimizer “iminuit” of python 2.7.

Due to the fact that we use only a part of the JLA sample (192 SNe), first, we checked that our sample is unbiased by comparing the Hubble diagram fit of the selected sample to the full JLA dataset, as shown in Table 3. The results are compatible within one standard deviation, except for the  $\beta$  parameter which varies up to about  $2\text{-}\sigma$ . This difference can express the fact that the selected sample of SNe Ia is not fully representative of the full JLA dataset in term of colour. It could be also connected to the colour evolution with redshift (Marriner et al., 2011). One important point is that the selected sample gives a cosmological result in agreement with the full JLA dataset. To examine the systematic effects due to redshift we made the plot of the redshift distribution of the three types of galaxies (see Fig. 1, left plot). For all three subsamples the redshift is distributed in the same way.

## 4. The study of environmental effects

### 4.1. Stretch and colour

Before studying the impact of the host galaxy morphology on the Hubble diagram fitting we analyze the stretch and colour distributions for each SN subsample.

The correlation between the stretch-factor and host galaxy properties was found in previous studies (Hamuy et al., 1995; 1996; Riess et al., 1999; Hamuy et al., 2000; Sullivan et al., 2003). It was established that the SNe Ia with the slowest decline rate, therefore, the most luminous ones, appear in galaxies with a younger stellar population (spiral and irregular galaxies).

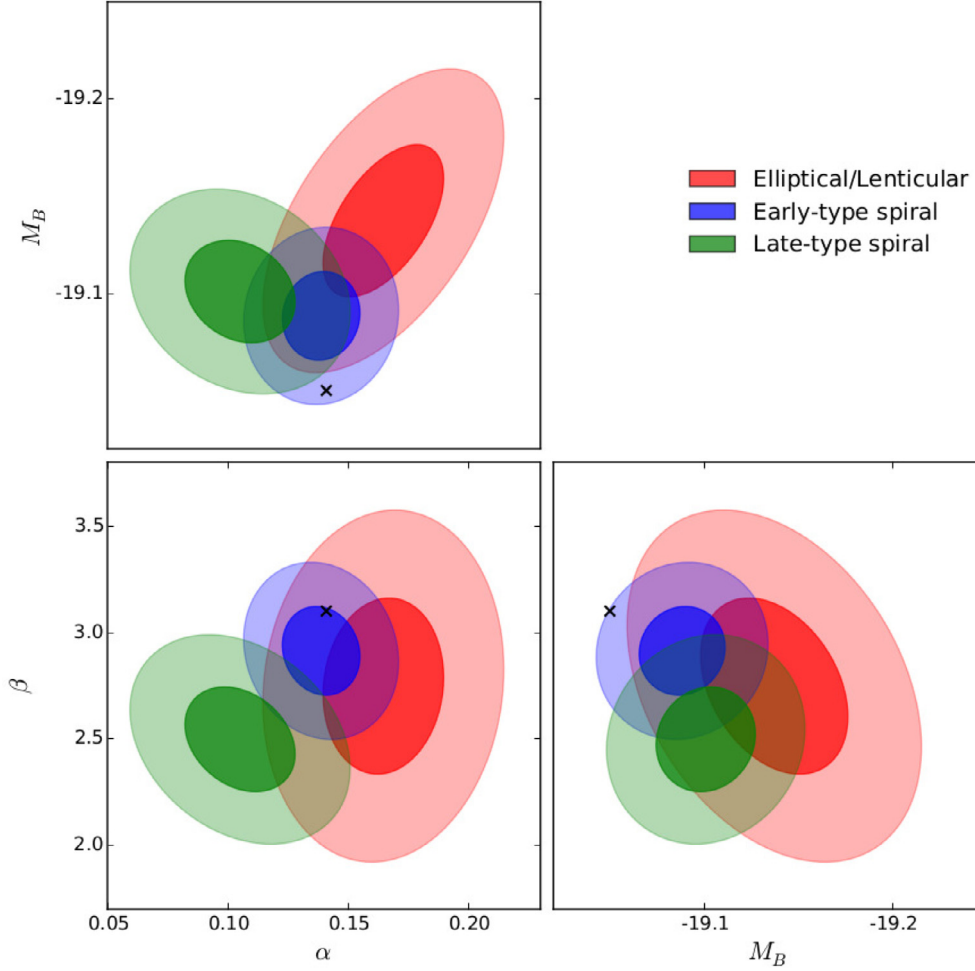
The results of this analysis are represented in Table 4 and visualized in Fig. 2. The trend in stretch behaviour is found. Low-stretch supernovae appear in E/L galaxies, the intermediate-stretch supernovae are related to ES galaxies, and the highest average stretch belongs to supernovae in LS hosts. If we assume that star formation rate connects with host galaxy morphology, so that low-star formation rate is common for elliptical galaxies, and that high-star forming regions are usually located in arms of spiral galaxies, our results are consistent with (Sullivan et al., 2006; Neill et al., 2009; Sullivan et al., 2010; Smith et al., 2012; Johansson et al., 2013). They found that low-stretch supernovae are preferentially hosted by galaxies with little or no ongoing star formation. Moreover, Sullivan et al. (2010); Johansson et al. (2013) showed that fast decline rates (low-stretch) SNe Ia are almost absent in low- $M_{\text{stellar}}$  galaxies and usually happen in more massive galaxies. This result is consistent with ours, as illustrated by Fig. 1 showing that E/L hosts have the highest stellar mass, on average.

In addition, a small trend between SN colour and host galaxy type is identified. SNe Ia in E/L galaxies have slightly bluer colour than others (see Table 4). This could be explained by the fact that

**Table 5**

The results of Hubble diagram fitting for the full selected sample and two approaches we used, with fixed and free  $\alpha$ ,  $\beta$  and  $M_B$  parameters.  $\langle\Delta\mu\rangle$  is the average of the residuals. The cosmology is fixed at  $\Omega_\Lambda = 0.705$ .

	$\langle\Delta\mu\rangle$	$\Delta\mu$ RMS	$\chi^2/\text{dof}$	$\alpha$	$\beta$	$M_B$
Our sample	$-0.011 \pm 0.010$	$0.138 \pm 0.007$	0.79	$0.136 \pm 0.011$	$2.74 \pm 0.14$	$-19.09 \pm 0.02$
E/L	$-0.022 \pm 0.023$	$0.144 \pm 0.016$	0.92	0.136	2.74	-19.09
ES	$-0.004 \pm 0.016$	$0.146 \pm 0.011$	0.87	0.136	2.74	-19.09
LS	$-0.014 \pm 0.016$	$0.125 \pm 0.011$	0.69	0.136	2.74	-19.09
E/L	$-0.001 \pm 0.023$	$0.143 \pm 0.016$	0.86	$0.165 \pm 0.025$	$2.75 \pm 0.39$	$-19.14 \pm 0.04$
ES	$-0.005 \pm 0.016$	$0.147 \pm 0.011$	0.86	$0.139 \pm 0.016$	$2.91 \pm 0.21$	$-19.09 \pm 0.02$
LS	$-0.011 \pm 0.014$	$0.115 \pm 0.010$	0.64	$0.105 \pm 0.023$	$2.50 \pm 0.24$	$-19.10 \pm 0.03$



**Fig. 4.** Joint confidence contours (1- and 2- $\sigma$ ) in two-parameter plots of  $\alpha$ ,  $\beta$  and  $M_B$  for fits where the SNe are split according to the host galaxy morphology. The black crosses represent the best fitting values ( $\alpha = 0.141$ ,  $\beta = 3.101$ ,  $M_B = -19.05$ ) from (Betoule et al., 2014). The cosmology is fixed at  $\Omega_\Lambda = 0.705$ .

early-type and late-type spirals contain more dust which make the SN colour redder. However, the errors are too large to allow a conclusion.

#### 4.2. Hubble residuals and RMS

We apply two different approaches. First, we examine the residuals for each subsample of SNe Ia from one global fit in which the  $\alpha$ ,  $\beta$ , and  $M_B$  parameters are common for the entire sample. The second approach examines the residuals and the variation of the three nuisance parameters,  $M_B$ ,  $\alpha$ , and  $\beta$ , by performing a separate fit for each subsample (e.g., Sullivan et al., 2010). We aim to investigate if SNe Ia could be physically different in the separate samples due to environmental effects. Therefore, we assume constant cosmological parameters in both approaches ( $\Omega_\Lambda = 0.705$  (Betoule et al., 2014)).

The Hubble diagram for the full selected sample of 192 SNe Ia is presented in Fig. 3. The different subsamples are indicated by different colours. The average residuals  $\langle\Delta\mu\rangle$  for all three types of host are compatible with zero (see Table 5). However, the RMS in E/L hosts is a bit higher than the one in LS galaxies. This result suggests that SN Ia could be different in the considered types of galaxies.

To better understand the reason of the RMS variations we perform the Hubble diagram fitting for each subsample of supernovae separately. The fitting parameters are collected in Table 5. Fig. 4 shows the joint confidence contours in the three combinations of  $\alpha$ ,  $\beta$  and  $M_B$  parameters for each SN subsamples.  $M_B$  parameter is almost left unchanged under the uncertainties. The shift in the  $\beta$  parameter is also included in the uncertainties. On the other hand, there is a systematic shift of the value of the  $\alpha$  parameter. Using the current values of the nuisance parameters and the

average values of  $X_1$  and  $C$  for each subsample, we calculate the average absolute magnitudes in  $B$ -band:  $\langle M_{E/L} \rangle = -19.05 \pm 0.11$ ,  $\langle M_{ES} \rangle = -19.09 \pm 0.05$ ,  $\langle M_{LS} \rangle = -19.13 \pm 0.05$ . The obtained result does not agree with results from previous studies where after light-curve and colour corrections SN Ia are brighter in E/S0 galaxies or in low star-formation hosts than those in late-type spirals or high star-formation hosts (Hicken et al., 2009; Sullivan et al., 2010). The  $\alpha$ ,  $\beta$ , and  $M_B$  parameters parametrize the luminosity variations within the SN Ia samples and are likely related to the physics of the SN Ia explosion and/or the SN Ia environment. Therefore, the found difference even in one parameter ( $\alpha$ ) emphasizes the importance of the environment in SN Ia studies.

SNe Ia from LS galaxies (star-forming) appear to be more homogeneous than the others. The Hubble residual dispersion is smaller for them ( $0.115 \pm 0.010$ ) in comparison with the full sample residual dispersion ( $0.138 \pm 0.007$ ). This result suggests that a division of SNe Ia by types according to the morphology of their host galaxies would improve the future cosmological analysis. Previous studies supported the idea that SNe Ia in locally star-forming regions are more appropriate for cosmology due to their low brightness dispersion (Rigault et al., 2013).

## 5. Conclusions

We derived the host galaxy morphology for 192 SNe Ia from the nearby and SDSS JLA sample. The supernovae were divided into three subsamples depending on host morphology: elliptical/lenticular (E/L), early-type spiral (ES), and late-type spiral galaxies (LS).

Our main conclusions are:

- (1) As was previously shown by other studies, the SN Ia stretch parameter is closely correlated with host morphology. The low stretch (fast decline) SNe usually exploded in E/L galaxies, i.e. in old stellar population environment.
- (2) We did not find a statistically significant trend for the colour parameter.
- (3) We found a trend in the stretch nuisance parameter  $\alpha$ . Its value decreases from E/L to LS galaxies.
- (4) We saw that, in an old stellar population and with low dust environment, supernovae are intrinsically fainter after stretch and colour corrections. This conclusion contradicts the results obtained by Hicken et al. (2009) (see also Sullivan et al., 2010 and references in it). However, our results are consistent within  $1-\sigma$  for all subsamples. This can be improved by adding SNLS JLA supernovae in the analysis.
- (5) The host galaxy morphology affects the residual dispersion in the Hubble diagram. We noticed that SNe Ia in LS are more homogeneous with  $RMS = 0.115 \pm 0.010$ .

The variation of the light curve parameters, especially the luminosity, with morphological type of host galaxy influences the cosmological analysis (e.g., Hicken et al., 2009; Rigault et al., 2013). We conclude that for further cosmological studies the environmental effects should be taken into account.

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## Supplementary material

Supplementary material associated with this article can be found, in the online version, at [10.1016/j.newast.2016.08.009](https://doi.org/10.1016/j.newast.2016.08.009).

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