The Dependence of Type Ia Supernova Luminosity on Star Formation Rate of Host Galaxies from a Sample without the Local-Global Environmental (LoG) Bias

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Diving into the Dark **July 19, 2016**

The Dependence of Type Ia Supernova Luminosity on Star Formation Rate of Host Galaxies from a Sample without the Local-Global Environmental (LoG) Bias

Diving into the Dark

July 19, 2016

Local Star Formation of Host Galaxies

Rigault, Perlmutter et al. 2013

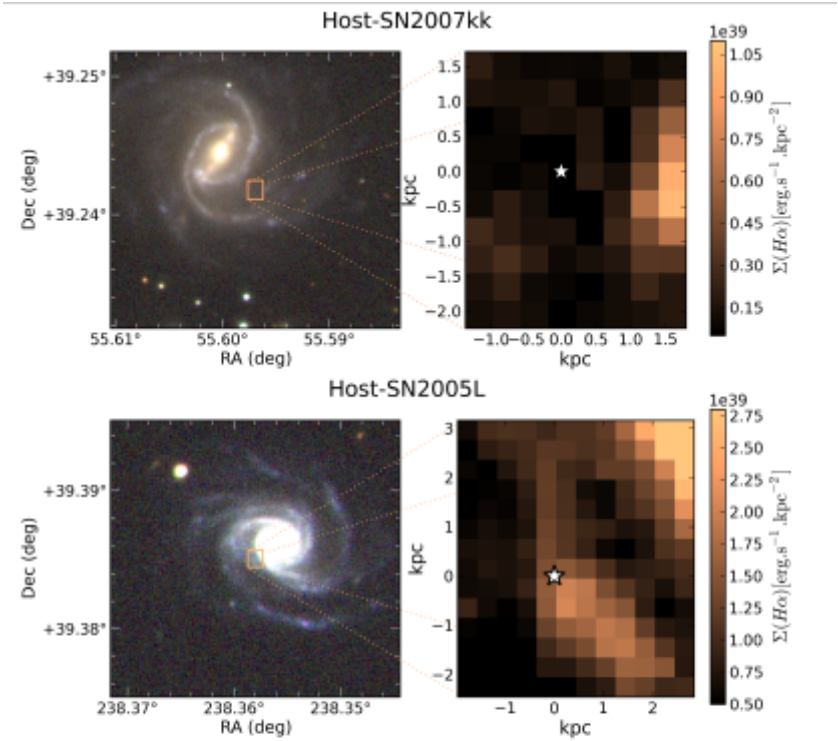


Fig. 1. *Top and bottom*: the hosts of SN 2007kk (UGC 2828) and SN 2005L (MCG+07-33-005), respectively, both classified as globally star-forming (Childress et al. 2013b). *Left*: color images made using observations from SNIFS and SDSS-III (Aihara et al. 2011). On both images, the field-of-view of SNIFS, centered on the SN position (white-star marker), is indicated by the orange central square. *Right*: Hα surface brightness maps of the SN vicinities (the generation of these maps is detailed in Sect. 2.3). SN 2007kk occurred in a passive environment more than 1.5 kpc from the closest star-forming region, while SN 2005L is located at the edge of such a region.

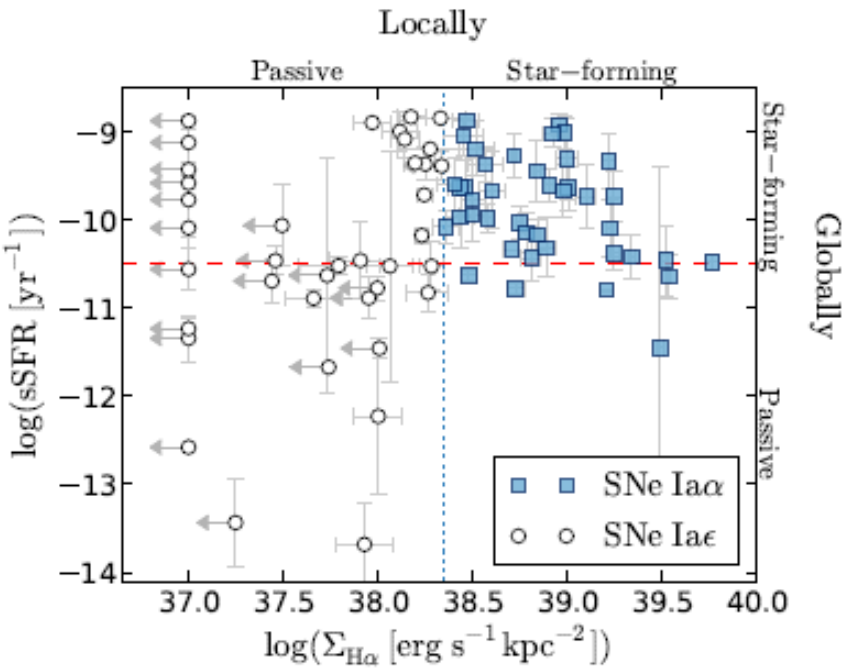
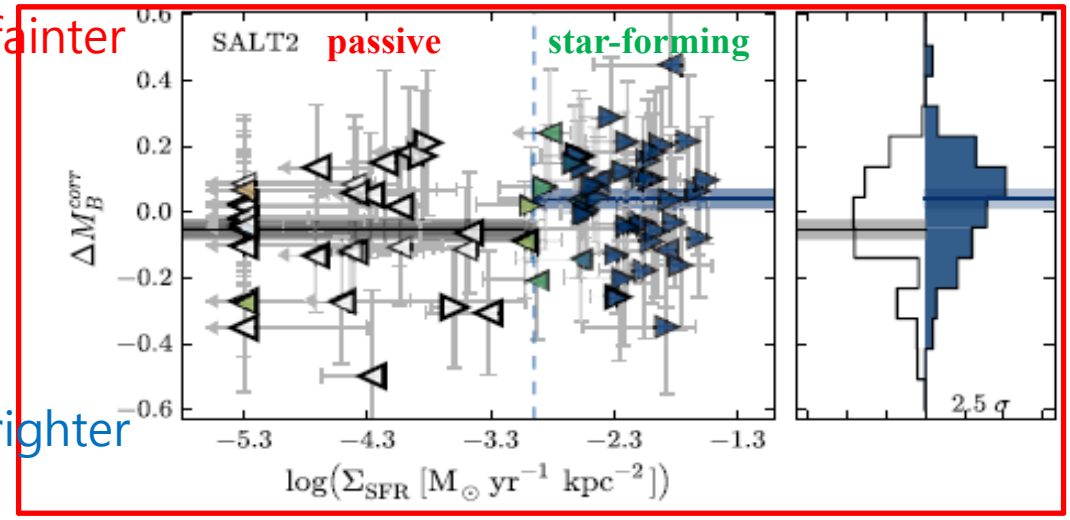


Fig. 5. Local vs. global star-forming environment. Blue squares and open-circles show the SNe Ia from locally star-forming and passive regions, respectively ($\log(\Sigma_{H\alpha}) \gtrless 38.35$, blue-dotted line). Gray arrows indicate points with $\Sigma_{H\alpha}$ signals compatible with zero (detection at less than 2σ). The red-dashed line indicates the limit that is commonly used to distinguish between star-forming and passive galaxies when using global host galaxy measurements ($\log(sSFR) \gtrless -10.5$). Three SNe Ia from our sample do not have sSFR measurements.

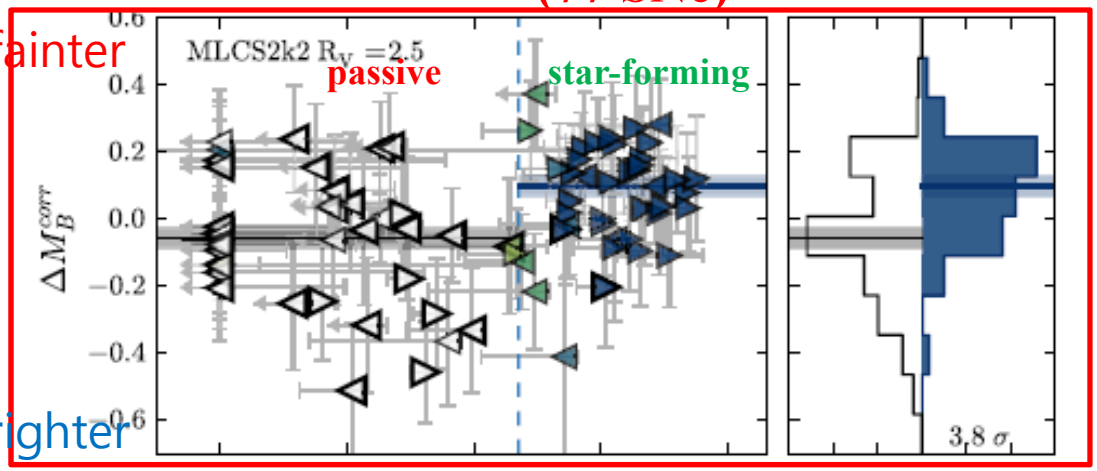
Local Star Formation of Host Galaxies

Rigault, Perlmutter et al. 2013 & 2015



0.094 ± 0.037 (2.5σ)

(77 SNe)



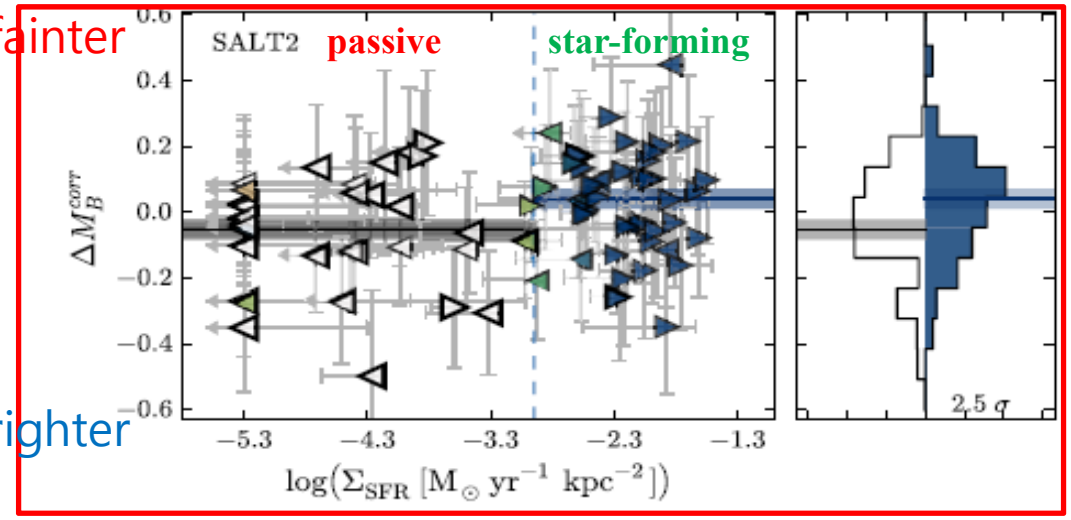
0.155 ± 0.041 (3.8σ)

(81 SNe)

Local Star Formation of Host Galaxies

Rigault, Perlmutter et al. 2013 & 2015

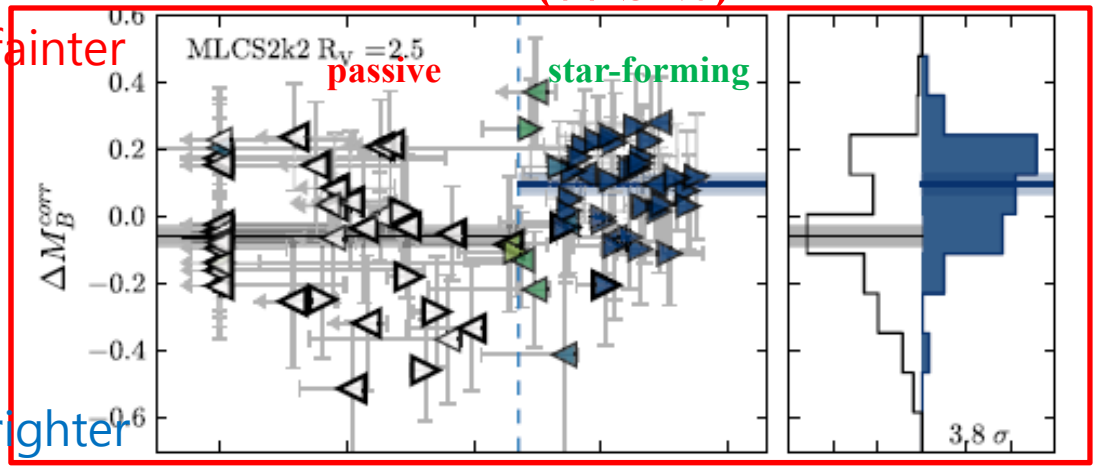
fainter



brighter

0.094 ± 0.037 (2.5σ)
(77 SNe)

fainter

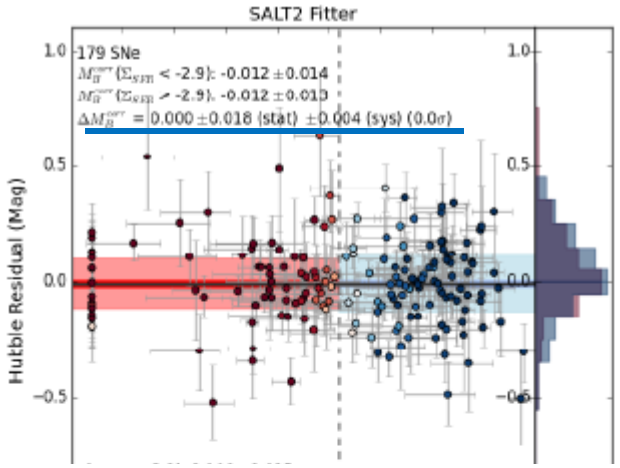


brighter

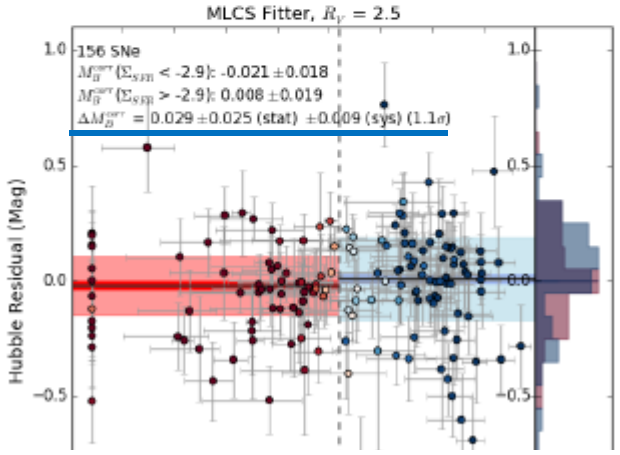
0.155 ± 0.041 (3.8σ)
(81 SNe)

VS.

Jones, Riess et al. 2015



0.000 ± 0.018 (0.0σ)
(179 SNe)

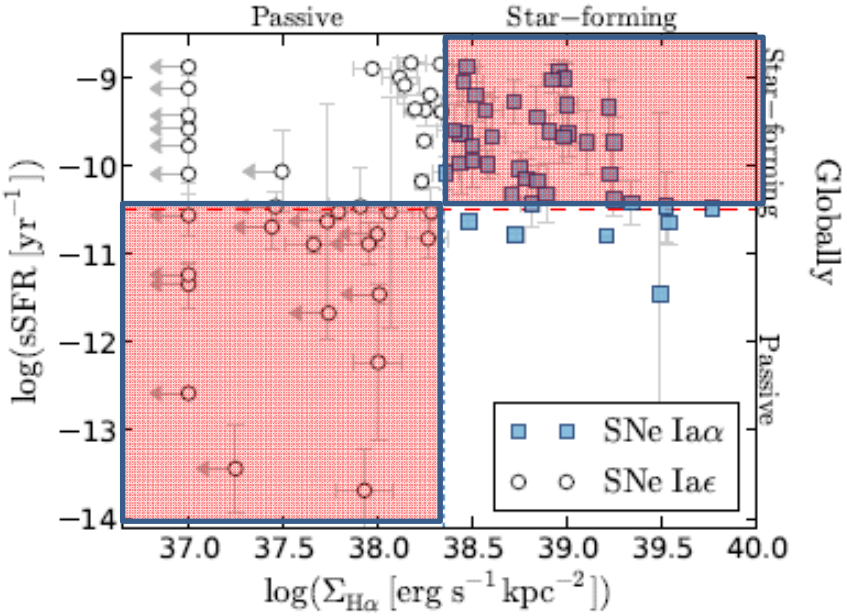


0.029 ± 0.025 (1.1σ)
(150 SNe)

Local Star Formation of Host Galaxies

Rigault, Perlmutter et al. 2013

from spectroscopic data



from photometric data

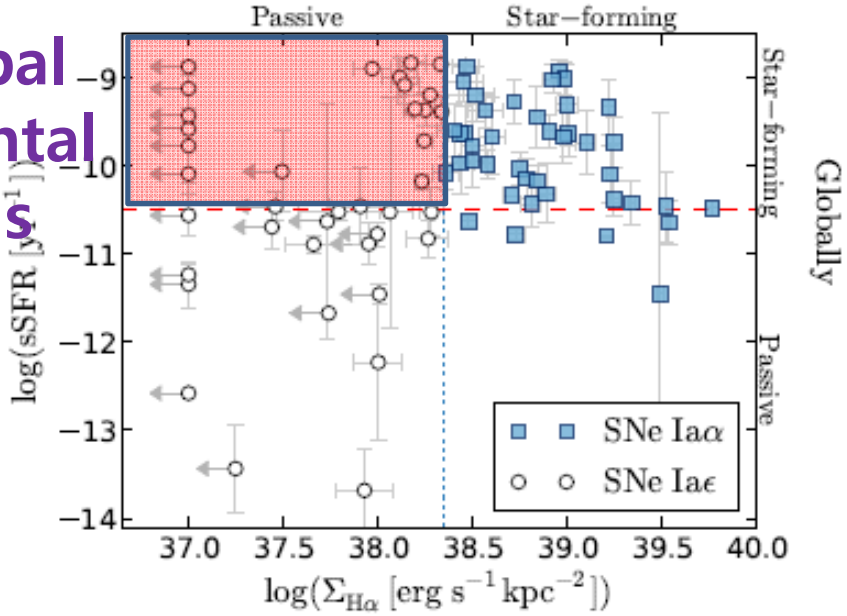
Fig. 5. Local vs. global star-forming environment. Blue squares and open-circles show the SNe Ia from locally star-forming and passive regions, respectively ($\log(\Sigma_{H\alpha}) \gtrless 38.35$, blue-dotted line). Gray arrows indicate points with $\Sigma_{H\alpha}$ signals compatible with zero (detection at less than 2σ). The red-dashed line indicates the limit that is commonly used to distinguish between star-forming and passive galaxies when using global host galaxy measurements ($\log(sSFR) \gtrless -10.5$). Three SNe Ia from our sample do not have sSFR measurements.

Local Star Formation of Host Galaxies

Rigault, Perlmutter et al. 2013

from spectroscopic data

Local-Global Environmental (LoG) Bias



from photometric data

Fig. 5. Local vs. global star-forming environment. Blue squares and open-circles show the SNe Ia from locally star-forming and passive regions, respectively ($\log(\Sigma_{H\alpha}) \gtrless 38.35$, blue-dotted line). Gray arrows indicate points with $\Sigma_{H\alpha}$ signals compatible with zero (detection at less than 2σ). The red-dashed line indicates the limit that is commonly used to distinguish between star-forming and passive galaxies when using global host galaxy measurements ($\log(sSFR) \gtrless -10.5$). Three SNe Ia from our sample do not have sSFR measurements.

YONSEI SN & Host Catalogue

YONSEI SN Catalogue: Kim et al., in preparation

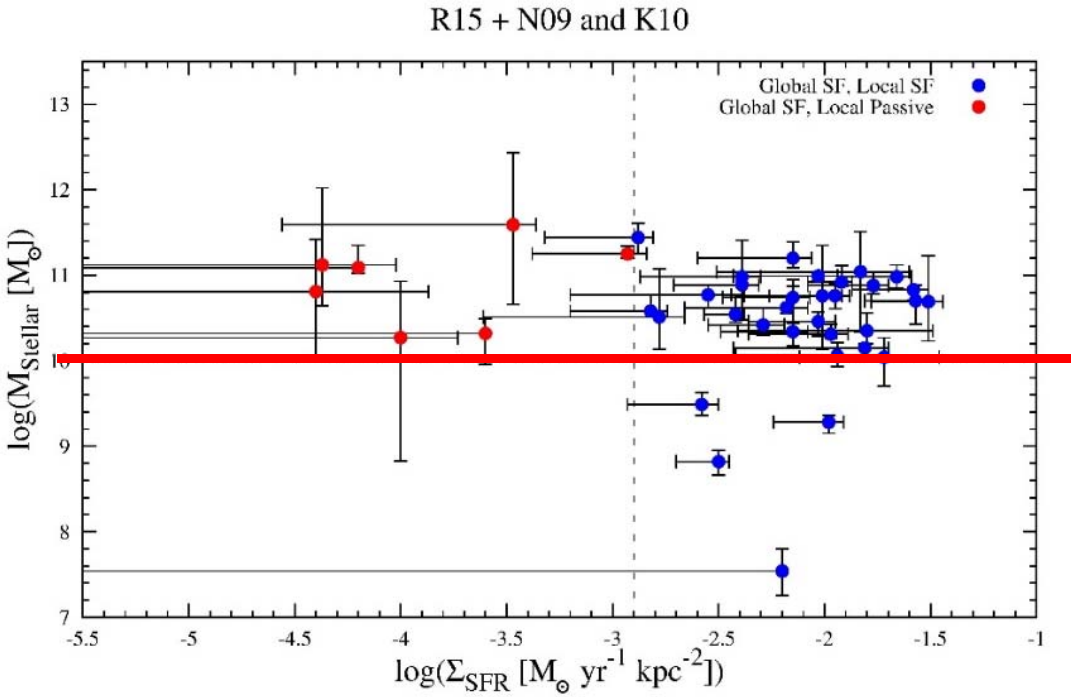
	MLCS2k2	SALT2
# of SNe	1128	1094
Assuming flat ΛCDM		
Ω_M	0.43	0.30

Combine host sSFR & Mass

	MLCS2k2	SALT2	Ref.s
LOWZ	109	105	Neill et al. 2009
SDSS3	378	394	Sako et al. 2014
SNLS3	227	228	Sullivan et al. 2010
Total	**714**	**727**	

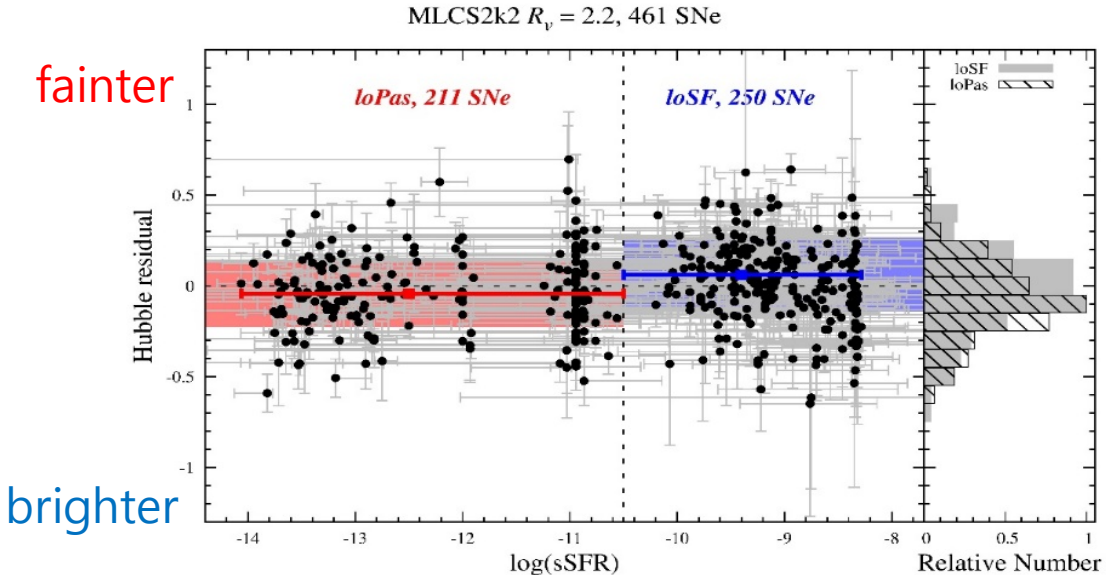
YONSEI Local-Global Environmental Bias (LoG Bias) Study

Criteria for Removing LoG Bias

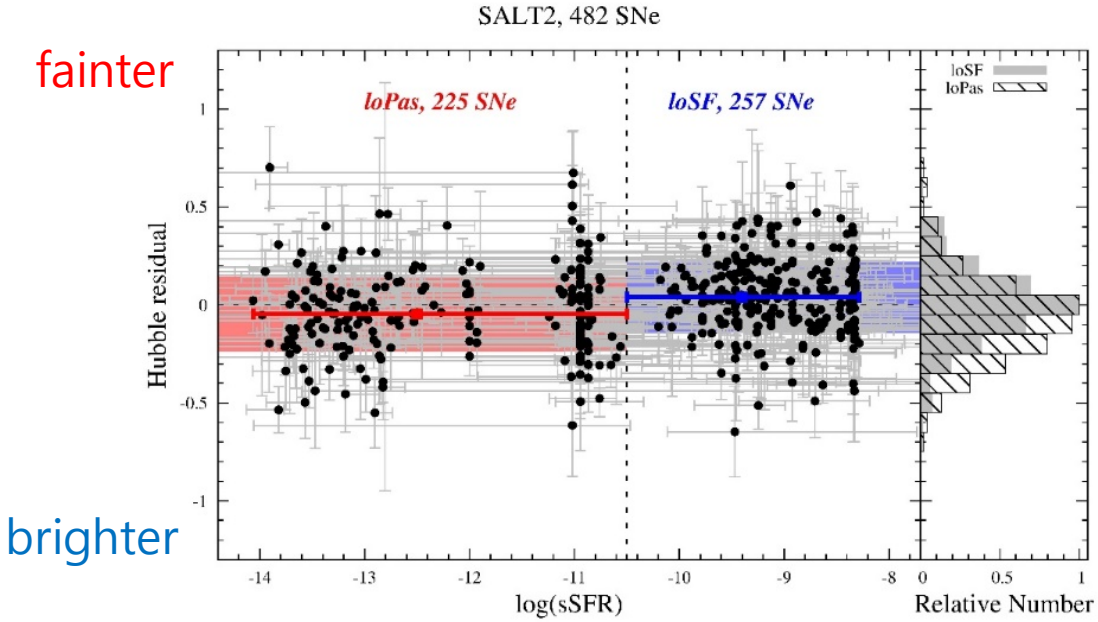


Number Ratio	Passive	Star-Forming
Before LoG Bias cut	31	69
After cut	47	53
cf. R13, R15, and J15	49	51

YONSEI Local-Global Environmental Bias (LoG Bias) Study



MLCS2k2:
ΔHR = 0.103 ± 0.010 mag (10.3σ)
(461 SNe)



SALT2:
ΔHR = 0.085 ± 0.012 mag (7.1σ)
(482 SNe)

YONSEI Local-Global Environmental Bias (LoG Bias) Study

	MLCS2k2 ΔHR (mag)	SALT2 ΔHR (mag)	
Rigault et al. 2013 & 2015	0.155 ± 0.041 (3.8σ) w/ 81 SNe	0.094 ± 0.037 (2.5σ) w/ 77 SNe	LOWZ
Jones et al. 2015	0.029 ± 0.034 (1.1σ) w/ 156 SNe	0.000 ± 0.018 (0.0σ) w/ 179 SNe	LOWZ
YONSEI w/o LoG Bias	**0.103 ± 0.010 (10.3σ) w/ 461 SNe**	**0.085 ± 0.012 (7.1σ) w/ 482 SNe**	**LOWZ+SDSS+SNLS (0.01 ~ 1.06)**
cf.			
YONSEI w/ LoG Bias	0.089 ± 0.008 (11.1σ) w/ 714 SNe	0.068 ± 0.014 (4.9σ) w/ 727 SNe	LOWZ+SDSS+SNLS (0.01 ~ 1.06)

YONSEI Local-Global Environmental Bias (LoG Bias) Study

-Considering the significant difference in the mean population age between these morphological types, this result would imply a possible look-back time evolution of SN Ia luminosity indirectly.

YONSEI

(YOnsei Nearby Supernova Evolution Investigation)

In order to investigate the evolution of SN Ia luminosity more directly and precisely and determine more reliable population age, we have initiated YONSEI project!

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EARLY-TYPE HOST GALAXIES OF TYPE Ia SUPERNOVAE. I. EVIDENCE FOR DOWNSIZING

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ABSTRACT

Type Ia supernova (SN Ia) cosmology provides the most direct evidence for the presence of dark energy. This result is based on the assumption that the lookback time evolution of SN Ia luminosity, after light curve corrections, would be negligible. Recent studies show, however, that the Hubble residual (HR) of SN Ia is correlated with the mass and morphology of host galaxies, implying the possible dependence of SN Ia luminosity on host galaxy properties. In order to investigate this more directly, we have initiated a spectroscopic survey for early-type host galaxies, for which population age and metallicity can be more reliably determined from the absorption lines. In this first paper of the series, we present here the results from high signal-to-noise ratio ($\gtrsim$100 per pixel) spectra for 27 nearby host galaxies in the southern hemisphere. For the first time in host galaxy studies, we find a significant ($\sim 3.9\sigma$) correlation between host galaxy mass (velocity dispersion) and population age, which is consistent with the "downsizing" trend among non-host early-type galaxies. This result is rather insensitive to the choice of population synthesis models. Since we find no correlation with metallicity, our result suggests that stellar population age is mainly responsible for the relation between host mass and HR. If confirmed, this would imply that the luminosity evolution plays a major role in the systematic uncertainties of SN Ia cosmology.

Key words: cosmology: observations – galaxies: elliptical and lenticular, cD – galaxies: fundamental parameters – supernovae: general

Origin of Well-Established Empirical Correlation between Host Mass and SN Ia Luminosity

Kang, Kim, Lee et al. 2016

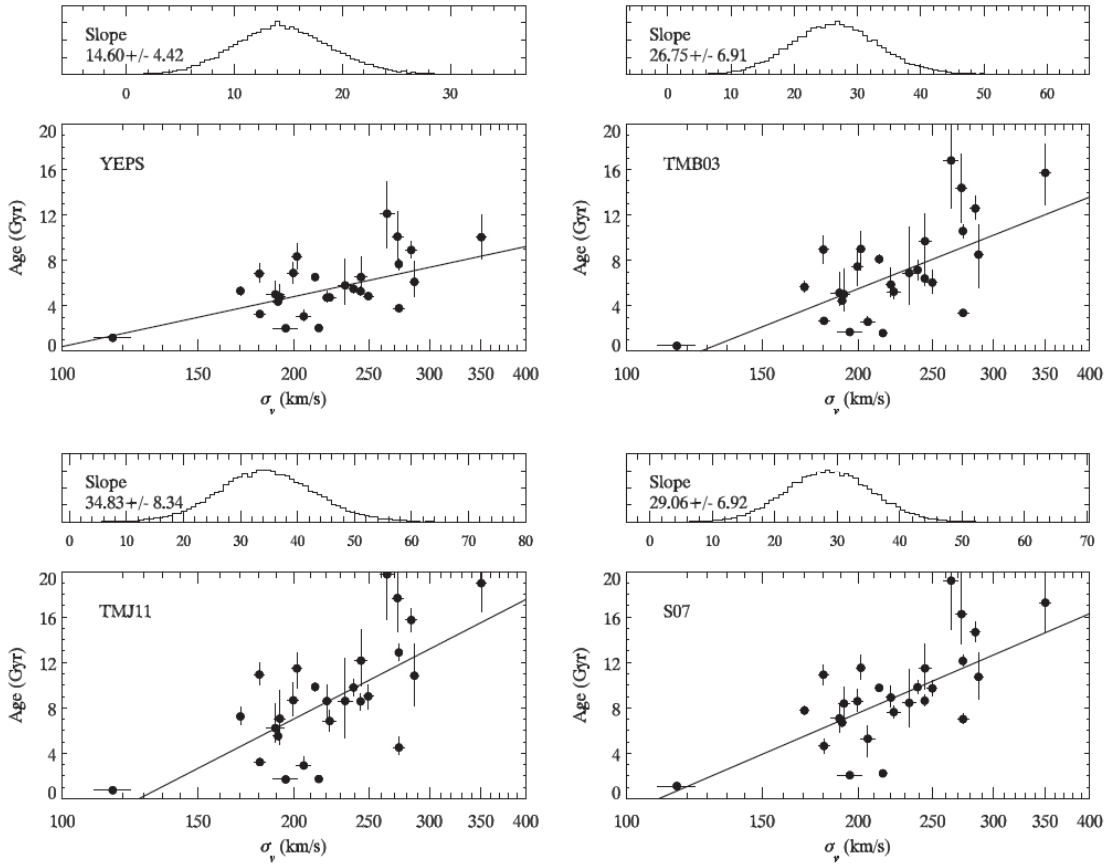
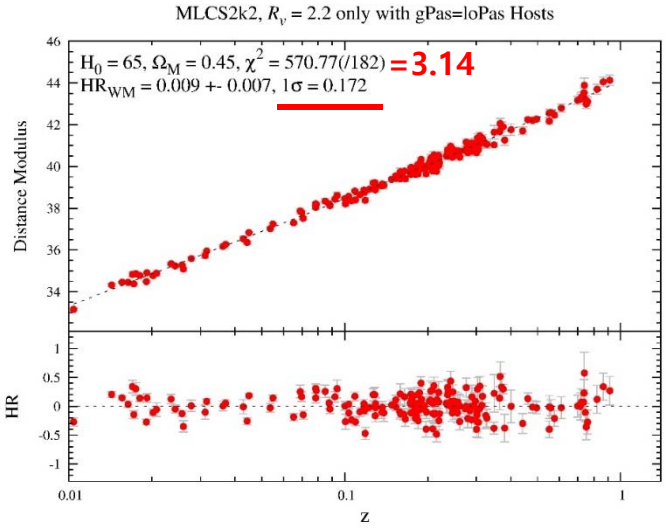


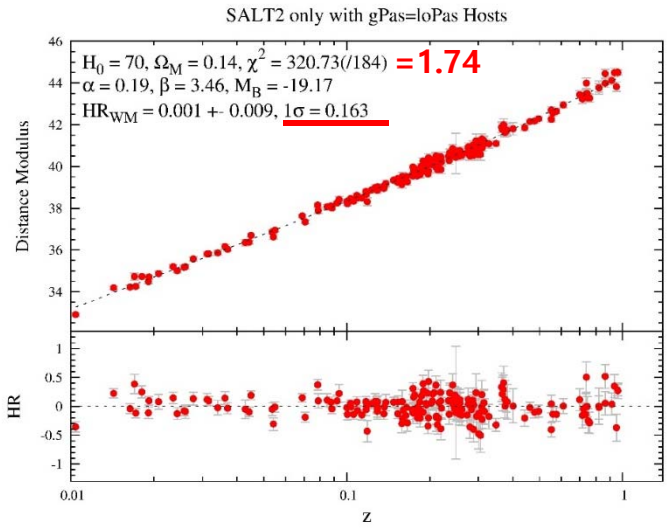
Figure 8. Correlation between velocity dispersion (σ_v) and population age for our sample of early-type host galaxies. Each panel shows, respectively, population ages determined from four different sets of EPS models, and the black solid lines indicate the regression line obtained from the posterior median estimate displayed in the upper panels (see the text).

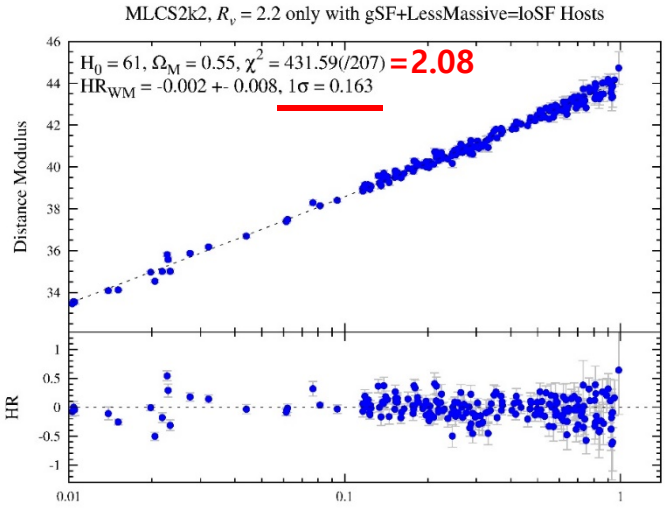
Population age is mainly responsible for the relation between host mass and HR.

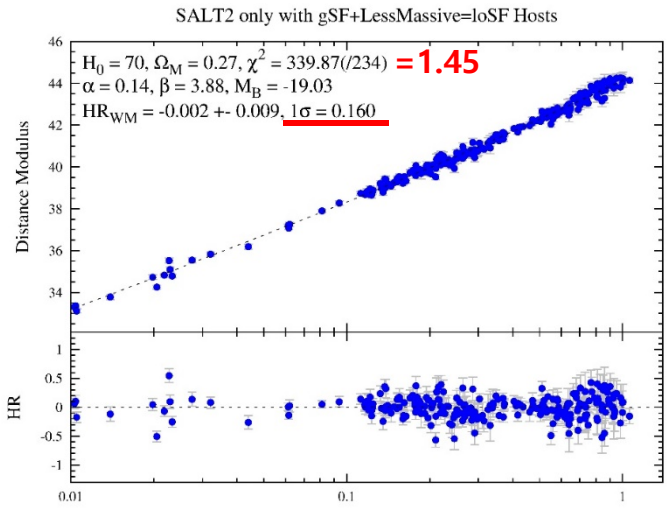
YONSEI Local-Global Environmental Bias (LoG Bias) Study

Hubble Diagram of SNe Ia with Their Host Environments









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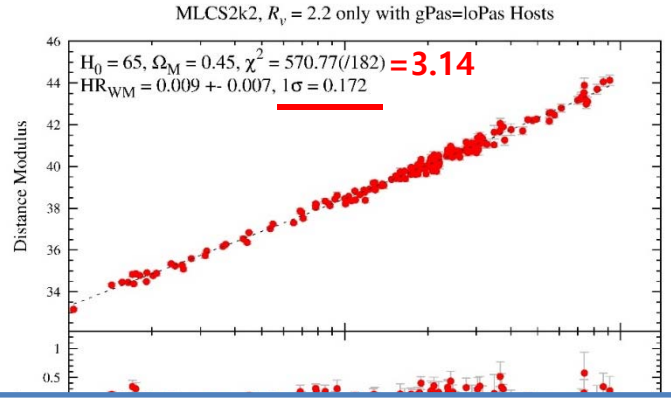
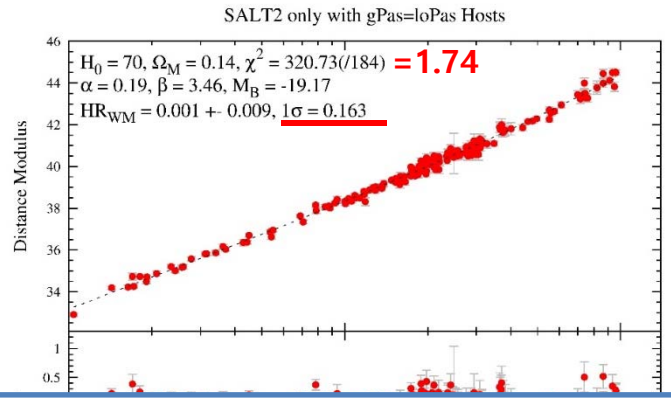
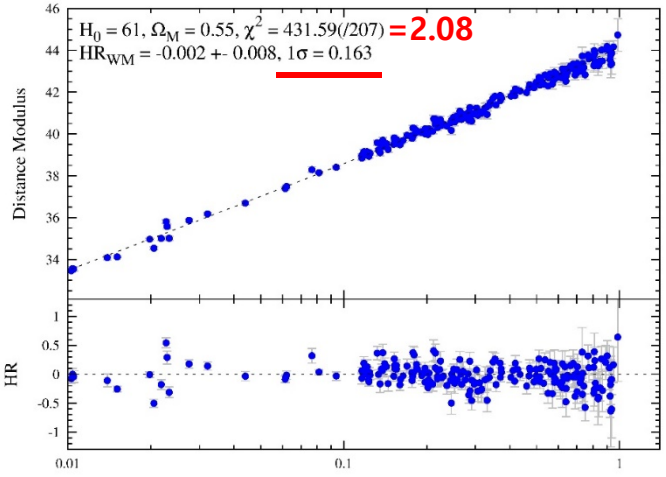
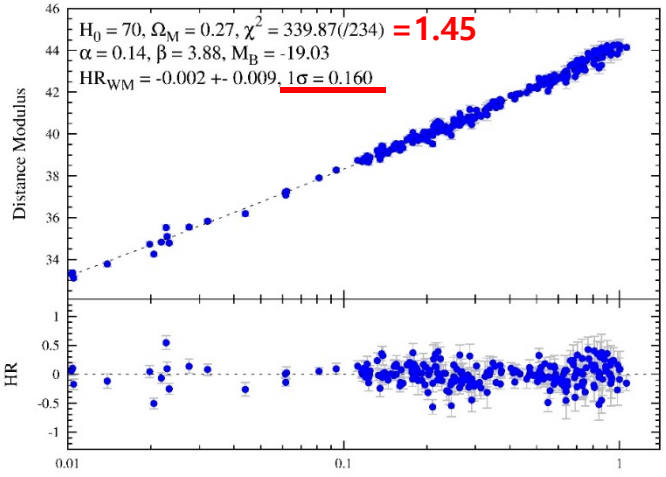




SNe Ia in star-forming environment show better fit-quality and less scatter in HR than those in passive region.





YONSEI Local-Global Environmental Bias (LoG Bias) Study

Summary

-**When we restrict a sample to the low mass hosts ($\leq 10^{10}$ M$\odot$)**, a sample without LoG bias is efficiently selected **only from photometric data.**
>Can be employed in the future high-z SN surveys.

-SNe Ia in star-forming environment are **0.103 ± 0.010 mag (10.3σ) and 0.085 ± 0.012 mag (7.1σ) fainter** than those in passive region, for MLCS2k2 and SALT2, respectively.
>***Imply a possible look-back time evolution of SN Ia luminosity***

-SNe Ia in star-forming environment show better fit-quality and less scatter in HR than those in passive region.

YONSEI

(YOnsei Nearby Supernovae Evolution Investigation)