Constraining Type Ia supernovae through their heights in edge-on galaxies

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ABSTRACT

In this Letter, using classified 197 supernovae (SNe) Ia, we perform an analyses of their height distributions from the disc in edge-on spirals and investigate their light-curve (LC) decline rates ($\Delta m_{15}$). We demonstrate, for the first time, that 91T- and 91bg-like subclasses of SNe Ia are distributed differently toward the plane of their host disc. The average height from the disc and its comparison with scales of thin/thick disc components gives a possibility to roughly estimate the SNe Ia progenitor ages: 91T-like events, being at the smallest heights, originate from relatively younger progenitors with ages of about several 100 Myr, 91bg-like SNe, having the highest distribution, arise from progenitors with significantly older ages $\sim 10$ Gyr, and normal SNe Ia, which distributed between those of the two others, are from progenitors of about one up to $\sim 10$ Gyr. We find a correlation between LC decline rates and SN Ia heights, which is explained by the vertical age gradient of stellar population in discs and a sub-Chandrasekhar mass white dwarf explosion models, where the $\Delta m_{15}$ parameter is a progenitor age indicator.

Key words: supernovae: individual: Type Ia – galaxies: disc – galaxies: stellar content – galaxies: structure.

1 INTRODUCTION

Type Ia supernovae (SNe Ia) are known to arise from carbon–oxygen (CO) white dwarfs (WDs) in interacting close binaries. About one-third of SNe Ia contain unusual properties and divided into following main subclasses: 91T-like SNe are $\sim 0.6$ mag overluminous than normal SNe Ia at the $B$-band maximum; 91bg-like events are $\sim 2$ mag subluminous than normal ones (e.g. Taubenberger 2017). SNe Ia luminosities at $B$-band maximum and their light curve (LC) decline rates ($\Delta m_{15}$ - difference between magnitudes at the maximum light and those of 15 days) are correlated (Phillips 1993): more luminous SNe Ia have slower declining LCs.

Many studies demonstrated that the progenitor population age of SN Ia subclasses is increasing in the sequence of 91T-, normal, and 91bg-like events (e.g. Howell 2001; Ashall et al. 2016). Theoretically, the progenitor age distribution at the current epoch should have a bimodal shape, with the first peak being below or close to 1 Gyr and corresponding to the young/prompt SNe Ia, and the second peak being at about several Gyr and including old/delayed events (e.g. Childress et al. 2014).

In Hakobyan et al. (2017, hereafter H17), taking into account that the height from the disc plane is an indicator of stellar population age (e.g. Seth et al. 2005; Yoachim & Dalcanton 2006; Ciucă et al. 2018), we showed that the majority of SNe Ia are localized in the discs of edge-on galaxies and they have about two times larger scale height than core-collapse (CC) SNe, whose progenitors’ ages are up to $\sim 100$ Myr. Also, we showed that the scale height of SNe Ia is compatible with that of the older thick disc population of the Milky Way (MW) galaxy. Nevertheless, we did not investigate different subclasses of SNe Ia separately. In this Letter, for the first time, we attempt to accomplish this by studying the distributions of heights of various SN Ia subclasses from the host discs.

Recently, in Hakobyan et al. (2020, hereafter H20), we verified an earlier finding on the correlation between LC decline rates of SNe Ia and the global ages of their host galaxies: SNe Ia from older and younger stellar populations, respectively, have larger and smaller $\Delta m_{15}$ values. This result can be interpreted within the frameworks of the sub-Chandrasekhar mass ($M_{\text{Ch}} \approx 1.4M_{\odot}$) WD explosion models. The explosion mechanism is realized in the double detonation of a sub-$M_{\text{Ch}}$ WD, in which accreted helium shell detonation initiates second detonation in the core of CO WD (e.g. Sim et al. 2010; Blondin et al. 2017; Shen et al. 2017). More luminous SNe Ia that have slower declining LCs (smaller $\Delta m_{15}$ values) are produced by the explosion of more massive sub-$M_{\text{Ch}}$ WD, because the luminosity of SN Ia is related to the mass of $^{56}\text{Ni}$ synthesized during the WD explosion (e.g. Stritzinger et al. 2006), which in turn is related to the mass of the WD (see e.g. Piro et al. 2014; Shen et al. 2018, for a variety of specific explosion models). On the other hand, more massive WD would come from more massive main-sequences stars, which have shorter lifetime than the progenitors of less massive WDs. In addition, due to the gravitational wave emission, massive WDs in the binary system would interact in a shorter timescale. Thus, it should follow that the LC decline rate $\Delta m_{15}$ of SN Ia is correlated with the age of the SN progenitor system (e.g. Shen et al. 2017, 2021). Given this, in our study we simply check the potential correlation between the SN Ia heights from host discs and their LC decline rates, which may provide an indication that both parameters are appropriate stellar population age indicators.

2 SAMPLE SELECTION AND REDUCTION

In this study, to ensure a sufficient number of SNe and to appropriately measure the SN heights from their host galactic discs, we...
selected the spectroscopically classified SN Ia subclasses (normal, 91T- and 91bg-like) with distances \( \leq 200 \text{ Mpc} \) from the Open Supernova Catalog (Guillochon et al. 2017). In order to have high confidence on the SN subclasses, the information is additionally verified utilizing data from the Weizmann Interactive Supernova data REPository (Yaron & Gal-Yam 2012), Astronomer’s Telegram, website of the Central Bureau for Astronomical Telegrams, etc.\(^1\)

Since we are interested in SNe Ia that exploded in highly inclined spiral galaxies, we need to roughly classify the morphology and estimate the inclination of hosts. To perform this we employed the Sloan Digital Sky Survey Data Release 16 (DR16; Ahumada et al. 2020), the SkyMapper DR2 (Oien et al. 2019), and the Pan-STARRS DR2 (Chambers et al. 2016), which together cover the whole sky and provide the \( g \) bands composed images for each host galaxy. Hosts with visible low inclinations (\( i \lesssim 60^\circ \)) and obviously elliptical, lenticular, or irregular morphology were excluded from the study.

Following H20, we further morphologically classified the hosts and created the 25 mag arcsec\(^{-2} \) elliptical apertures for each galaxy on the surveys’ \( g \)-band images enabling exact measurements of the SN hosts’ inclinations, semi-major (\( R_{25} \)) and semi-minor (\( Z_{25} \)) axes.

The next step was to use the estimated elongations (\( R_{25}/Z_{25} \)) and morphological types of galaxies to calculate inclinations, following the approach of Paturel et al. (1997). It is worth noting that the calculated inclinations for galaxies with prominent bulges are inaccurate, as the isophotes of bulges in highly inclined galaxies reduce the real galaxy disc inclinations. Such scenarios got special attention for exact inclination calculation, with only the isophotes of discs being taken into account (see H17). Finally, we limited the sample of host galaxies to those with an inclination of \( 80^\circ \) and/or host’s morphologies should be not significant in our sample.

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3 RESULTS AND DISCUSSION

3.1 Directional distributions of SNe Ia in edge-on spiral hosts

Following Hakobyan et al. (2021), for the SNe Ia in edge-on spirals of the current study, we perform the two-sample KS and AD tests comparing the \( |U|/R_{25} \) and \( |V|/R_{25} \) distributions between each other. Table 1 shows that the bulk of SNe Ia in all of the SN subclasses are localized in the host galaxies’ discs. For 91bg-like SNe only, the AD test shows barely significance, unlike the KS test, which is probably due to the statistics with the smallest sample size.

We then compare the projected and normalized radii \( |U|/R_{25} \) and the heights \( |V|/R_{25} \) between different SN Ia subclasses. In Table 2, the KS and AD tests show that the radial distributions of normal, 91T- and 91bg-like SNe are consistent with one another. In addition, the height distributions of normal and 91T-like SNe are consistent between each other. At the same time, the height distributions of 91T- and 91bg-like SNe are significantly different. The same is happens for the distributions of normal and 91bg-like SNe (with barely KS test significance). Fig. 1 shows a scatterplot of \( |V|/R_{25} \) versus \( |U|/R_{25} \), and the cumulative distributions of \( |V|/R_{25} \) values for different SN Ia subclasses. The 91T-like SNe have the smallest height distributions, closest to the disc plane, whereas the 91bg-like SNe...
Table 2. Comparison of the $|U|/R_{25}$ and $|V|/R_{25}$ distributions between different subclasses of SNe Ia.

| Subsample 1               | $N_{SN}$ versus | Subsample 2               | $N_{SN}$ | $P_{MC}^{KS}$ | $P_{MC}^{AD}$ |
|---------------------------|-----------------|---------------------------|---------|---------------|---------------|
| $|U|/R_{25}$ of Normal      | 144             | $|U|/R_{25}$ of 91bg       | 23      | 0.279         | 0.166         |
| $|U|/R_{25}$ of Normal      | 144             | $|U|/R_{25}$ of 91T        | 30      | 0.828         | 0.835         |
| $|U|/R_{25}$ of 91bg        | 23              | $|U|/R_{25}$ of 91T        | 30      | 0.756         | 0.611         |
| $|V|/R_{25}$ of Normal      | 144             | $|V|/R_{25}$ of 91bg       | 23      | 0.079         | **0.010**     |
| $|V|/R_{25}$ of Normal      | 144             | $|V|/R_{25}$ of 91T        | 30      | 0.685         | 0.588         |
| $|V|/R_{25}$ of 91bg        | 23              | $|V|/R_{25}$ of 91T        | 30      | **0.033**     | **0.022**     |

Notes. The explanations for the $P$-values are identical to those in Table 1.

Figure 1. Left panel: distributions of $|V|/R_{25}$ versus $|U|/R_{25}$ for normal, 91T- and 91bg-like SNe. The error bar on the right side of the panel shows the characteristic error in the height estimation due to possible inclination floating in $80^\circ - 90^\circ$. The lines show the mean $|V|/R_{25}$ values for each SN Ia subclass. Right panel: the heights’ cumulative distributions for different SNe Ia. The light coloured regions around each curve represent the appropriate spreads considering the uncertainties in height measurements.

Table 2 shows, statistically, that 91T- and 91bg-like SNe Ia are distributed differently toward the plane of their host disc. The mean heights are growing, starting with 91T-like events and progressing through normal and 91bg-like SNe (Table 1). On the other hand, it is well-known that spiral galaxies have a vertical stellar age gradient, with the age increasing as the vertical distance from the disc plane increases (e.g. Seth et al. 2005; Youchim & Dalcanton 2006; Ciucă et al. 2018). Therefore, from the perspective of the vertical distribution (an age tracer) it may be deduced that the progenitors of 91T-like and normal SNe Ia are relatively younger than those of 91bg-like events. At least the age differences should be significant for 91T- versus 91bg-like SNe (Table 2, Fig. 1). The results are unaffected when the $Z_{25}$ normalization is applied (Table A2). We emphasize that the current study is the first to demonstrate the observational differences in the heights of the SN Ia subclasses.

In fact, more luminous 91T-like SNe could be found more easily at the brighter host galaxy background than less luminous 91bg-like events. This would mean that 91T-like SNe could be observed closer to the disc than 91bg-like. If so, the observed effect would be a selection bias. However, it is crucial to note that 91T-like SNe are not as frequently detected at higher heights as 91bg-like (see Fig. 1). More luminous 91T-like SNe would undoubtedly be found if they had exploded at the higher heights from the disc. Hence, it is likely that the detection of 91T-like SNe at lower heights as opposed to 91bg-likes is a real effect rather than the product of the mentioned selection bias. This is further supported by the observation that 91T-like SNe are mostly associated with star-forming environments (e.g. Raskin et al. 2009; Ruiter et al. 2013; H20) than 91bg-like SNe, which are more frequently seen in older environments (e.g. Panther et al. 2019). On the other hand, the star-forming environment has the lowest height in the galactic disc (e.g. Jurić et al. 2008).

3.2 Constraining the age of SN Ia progenitors

It is noteworthy that along with the qualitative age constraints of SN Ia progenitors we can add also quantitative ones. Table A3 compares the scale heights of SN Ia subclasses in our sample with the exponential scale heights of the MW thin and thick discs, as well as with those of 141 edge-on S0/a–Sd galaxies from Comerón et al. (2018), sampled according to the different morphological groups. The scale height of CC SNe in late-type host galaxies is also shown from our previous paper H17. Here an exponential vertical distribution $\exp(-z/H)$ is used, where the scale height $H$ is normalized to the radius $R_{25}$. The scale height of SNe $H_{SN} = \langle |V|/R_{25} \rangle$ for an exponential vertical distribution (see H17, for more details). Because the scale height of a stellar population depends on the morphological type of galaxies, being larger in early-types (e.g. Yoachim & Dalcanton 2006; Bizyaev et al. 2014), we split the sample into early- and late-type hosts in Table A3 to accurately compare different scales. Note that in spiral galaxies the majority of 91T-like events are found in Sb–Sdm (late-type) morphological bin, while most of normal SNe Ia and 91bg-like events are distributed in S0/a–Sc (early-type) bin (Table A1, see also H20).

As shown in Table A3, in early-type spirals, the scale height of normal SNe Ia is found between those of the thick and thin discs, while the scale height of 91bg-like events is clearly consistent with the thick disc. In late-type spirals, the scale height of 91T-like SNe Ia is close to that of CC SNe, while being larger. The average height of normal SNe Ia again is between thin and thick discs. The scale height of 91bg-like events again is in agreement with those of thick...
stellar populations is not expected during the SN progenitor stellar age or the delay time of the systems. As mentioned above, 91T-like events (and the most of normal SNe Ia) are associated with star-forming environments (< 500 Myr; Raskin et al. 2009; Ruiter et al. 2013), therefore the effect of the gravitational inspiral’s timescale should play a role mostly for 91bg-like SNe.

3.3 Relating LC decline rates with SN heights from host disc

SNe Ia span a variety of properties from subluminous SNe with fast-declining LCs to overluminous and slowly evolving events (e.g. Taubenberger 2017). The majority of earlier theoretical studies have failed to fit the full range of observed SNe Ia properties with a single explosion/progenitor scenario (see reviews by Hillebrandt et al. 2013; Livio & Mazzali 2018). Fortunately, recent theoretical studies in the sub-\(M_{\odot}\) WD explosion models showed an excellent quantitative agreement with observed photometrical behaviours of SNe Ia in the entire range of the Phillips relation (e.g. Blondin et al. 2017; Shen et al. 2017, 2021). As mentioned in the Introduction, the explosion is realized in the double detonation of a sub-\(M_{\odot}\) WD, where the LC decline rate \(\Delta m_{15}\) of SNe Ia is positively correlated with the age of the SN progenitor system (e.g. Shen et al. 2017, 2021).

Numerous researches extensively studied the links between the SNe Ia LC decline rates and the global age (or age tracers) of host galaxies, as well as local age at SN explosion sites (e.g. Howell et al. 2009; Gupta et al. 2011; Pan et al. 2014; Ashall et al. 2016; Roman et al. 2018; H20). These studies demonstrated that, at different levels of significance, the LC decline rate is correlated with the global/local age: the \(B\)-band \(\Delta m_{15}\) values increase with stellar population age. However, the correlation between SNe Ia decline rate and the height from the host disc, which is a reliable age indicator of stellar population, has not yet been investigated. Here, we intend to fill this gap.

Fig. 2 and the Spearman’s rank correlation test in Table 3 show that the trend between \(|V|/R_{25}\) and \(\Delta m_{15}\) is positive, but not statistically significant. At low heights, in Fig. 2, we observe all the SN Ia subclasses (full range with slower and faster declining LCs), but with increasing height, the decline rate of objects increases on average. However, it should be taken into account that due to the dust extinction in galactic disc the discovery of SNe Ia in edge-on galaxies is complicated and biased against objects at lower heights from the host disc (e.g. Holwerda et al. 2015). The impact of this effect would be greatest on subluminous SNe (91bg-like events).

In late-type galaxies, the vertical distribution of dust has a scale height that is \(\sim 3\) times less than that of thick disc stars (e.g. Bianchi 2007). While the dust layer is \(\sim 1.5\) times thicker in early-type galaxies (e.g. Hacke et al. 1982; De Geyter et al. 2014), which is closer to our sample of SNe Ia host galaxies (see Table A1). Therefore, to avoid the possible impact of dust we truncate the heights of SNe with \(|V|/R_{25} \geq 0.04\), leaving 36 SNe Ia in our sample. For

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\textsuperscript{3} Time interval between the progenitor formation and the SN explosion.

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Table 3. The correlation test for the \(|V|/R_{25}\) versus \(\Delta m_{15}\) parameters.

| SN       | \(N_{SN}\) | \(|(V|/R_{25})\) versus \(|\Delta m_{15}\)| | \(r_s\) | \(P_{MC}^{s}\) |
|----------|------------|-----------------------------------------------|------|----------|
| All      | 69         | 0.08 ± 0.02 versus 1.21 ± 0.32 | 0.118 | 0.334    |
| All†     | 36         | 0.14 ± 0.06 versus 1.18 ± 0.29 | 0.471 | 0.004    |

\textit{Notes.} A coefficient of Spearman’s rank correlation \((r_s \in [-1; 1])\) is a metric for determining how closely two variables are related by a monotonic function. The variables are not independent when \(P \leq 0.05\) (highlighted in bold). The \(P_{MC}^{s}\) values are generated using permutations with \(s\) MC iterations. The subsample marked with † symbol corresponds to SNe with \(|V|/R_{25} \geq 0.04\).
this dust-truncated sample, the Spearman’s rank test reveals a significant positive correlation between the $|V|/R_{25}$ and $\Delta m_{15}$ parameters (Table 3, Fig. 2). The results are unaffected when the $Z_{25}$ normalization is applied (Table A4). Thus, despite the limited sample size, we demonstrate for the first time a significant correlation between LC decline rates and SNe Ia heights, which is consistent with a sub-$M_{\text{Ch}}$ WD explosion models (e.g. Sim et al. 2010; Blondin et al. 2017; Shen et al. 2017) and vertical age gradient of stellar population in discs (e.g. Yoachim & Dalcanton 2006; Ciucă et al. 2018).

It would be important to verify the results in Tables 2 and A2 while accounting for the selection effects brought by dust extinction. However, in these tables we compare the SN positions (importantly heights) between the subclasses, and after the dust-truncation the samples for 91T- and 91bg-like SNe become, unfortunately, insufficient to perform the statistical tests.

4 CONCLUSIONS

In this Letter, we analyse the height distributions of SN Ia subclasses (normal, 91T- and 91bg-like) from their host disc plane using spectroscopically classified 197 SNe in edge-on spiral galaxies with distances $\lesssim 200$ Mpc. In addition, this study is performed to examine potential links between photometric characteristics of SNe Ia, like LC decline rates ($\Delta m_{15}$), and SN heights from the disc.

For the first time, we demonstrate that 91T- and 91bg-like subclasses of SNe Ia are distributed differently toward the plane of their host edge-on disc. On average, the SN heights are rising, beginning with 91T-like events and progressing through normal and 91bg-like SNe Ia. Considering that the height from the disc is a stellar population age indicator and comparing the mean heights of the SN Ia subclasses with those of thin and thick discs with known ages, we roughly estimate that 91T-like events originate from relatively younger progenitors with ages of about 100 Myr, the ages of progenitors of normal SNe Ia are from about one up to $\sim 10$ Gyr, and 91bg-like SNe Ia arise from progenitors with significantly older ages $\sim 10$ Gyr. In addition, we show that the SN Ia LC decline rates correlate with their heights from the host disc, after excluding the selection effects brought by dust extinction. The observed correlation is consistent with the explosion models of a sub-$M_{\text{Ch}}$ mass WD (e.g. Blondin et al. 2017; Shen et al. 2017, 2021) and the vertical age gradient of stellar population in discs (e.g. Seth et al. 2005; Yoachim & Dalcanton 2006; Ciucă et al. 2018).

Fortunately, a far larger spectroscopic and photometric sample of nearby SNe Ia will be made available by the ongoing robotic telescope surveys at various locations throughout the globe (e.g. All-Sky Automated Survey for SuperNovae) and by the forthcoming Vera C. Rubin Observatory (the Large Synoptic Survey Telescope), which will allow for statistically more powerful and accurate analysis.

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DATA AVAILABILITY

The data underlying this study may be found in the article’s supplementary material online (see Table A5, for guidance).

REFERENCES

Ahumada R., et al., 2020, ApJS, 249, 3
Ashmall C., Mazzali P., Sasdelli M., Prentice S. J., 2016, MNRAS, 460, 3529
Bensby T., Zenn A. R., Oey M. S., Feltzing S., 2007, ApJ, 663, L13
Bianchi S., 2007, A&A, 471, 765
Bizyaev D. V., Kautsch S. J., Moskenov A. V., Reshetnikov V. P., Sotnikova N. Y., Yablokova N. V., Hillyer R. W., 2014, ApJ, 787, 24
Blondin S., Dessart L., Hillier D. J., Khokhlov A. M., 2017, MNRAS, 470, 157
Breda I., Papaderos P., 2018, A&A, 614, A48
Chambers K. C., et al., 2016, preprint, (arXiv:1612.05560)
Childress M. J., Wolf C., Zahid H. J., 2014, MNRAS, 445, 1898
Ciucă I., Kawata D., Lin J., Casagrande L., Seabroke G., Cropper M., 2018, MNRAS, 475, 1203
Comerón S., 2021, A&A, 645, L13
Comerón S., Salo H., Jahn J., Lurikainen E., Yoachim P., 2015, A&A, 584, A34
Comerón S., Salo H., Knappen J. H., 2018, A&A, 610, A5
De Geyter G., Baes M., Camps P., Fritz J., De Loose I., Hughes T. M., Viaene S., Gentile G., 2014, MNRAS, 441, 869
González Delgado R. M., et al., 2015, A&A, 581, A103
Graham A. W., Worley C. C., 2008, MNRAS, 388, 1708
Guillochon J., Parrent J., Kelley L. Z., Margutti R., 2017, ApJ, 835, 64
Gupta R. R., et al., 2011, ApJ, 740, 92
Hacker G., Schlieicer R., Schmidt K. H., 1982, Astron. Nachr., 303, 245
Hakobyan A. A., et al., 2016, MNRAS, 456, 2848
Hakobyan A. A., et al., 2017, MNRAS, 471, 1390 (H17)
Hakobyan A. A., Barkhudaryan L. V., Karapetyan A. G., Georgyov M. H., Mamon G. A., Kunth D., Adibekyan V., Turatto M., 2020, MNRAS, 499, 1424 (H20)
Hakobyan A. A., Karapetyan A. G., Barkhudaryan L. V., Georgyov M. H., Adibekyan V., 2021, MNRAS, 505, L52
Hillebrandt W., Kromer M., Röpke F. K., Ruiter A. J., 2013, Front. Phys., 8, 116
Holwerda B. W., Reynolds A., Smith M., Kraan-Korteweg R. C., 2015, MNRAS, 446, 3768
Howell D. A., 2001, ApJ, 554, L193
Howell D. A., et al., 2009, ApJ, 691, 661
Juric M., et al., 2008, ApJ, 673, 864
Kasparova A. V., Kavtov I. Y., Chilingarian I. V., Silchenko O. K., Moiseev A. V., Borisov S. B., 2016, MNRAS, 460, L89
Li W., et al., 2011, MNRAS, 412, 1441
Livio M., Mazzali P., 2018, Phys. Rep., 736, 1
Max D., Mannucci F., 2012, PASA, 29, 447
Onken C. A., et al., 2019, PASA, 36, e033
Pan Y. C., et al., 2014, MNRAS, 438, 1391
Panther F. H., Seitenzahl I. R., Ruiter A. J., Crocker R. M., Lidman C., Wang E. X., Tucker B. E., Groves B., 2019, PASA, 36, e031
Paturel G., et al., 1997, A&AS, 124
Phillips M. M., 1993, ApJ, 413, L105
Piro A. L., Thompson T. A., Kochanek C. S., 2014, MNRAS, 438, 3456
Raskin C., Scannapieco E., Rhoads J., Della Valle M., 2009, ApJ, 707, 74
Roman M., et al., 2018, A&A, 615, A68
Ruiter A. J., et al., 2013, MNRAS, 429, 1425
Seth A. C., Dalcanton J. J., de Jong R. S., 2005, AJ, 130, 1574
Shen K. J., Toonen S., Graur O., 2017, ApJ, 851, L50
Shen K. J., Kasen D., Miles B. J., Townsley D. M., 2018, ApJ, 854, 52
Shen K. J., Blondin S., Kasen D., Dessart L., Townsley D. M., Boos S., Hillier D. J., 2021, ApJ, 909, L18
Sim S. A., Röpke F. K., Hillebrandt W., Kromer M., Pakmor R., Fink M., Ruiter A. J., Seitenzahl I. R., 2010, ApJ, 714, L52
Stritzinger M., Leibundgut B., Walch S., Contardo G., 2006, A&A, 450, 241
Taubenberger S., 2017, in Alsabiti A. W., Murdin P., eds, The Extremes of Thermonuclear Supernovae, Handbook of Supernovae. Springer, p. 317
Yaron O., Gal-Yam A., 2012, PASP, 124, 668
Yoachim P., Dalcanton J. J., 2006, AJ, 131, 226
Yoachim P., Dalcanton J. J., 2008, ApJ, 683, 707
Table A1. Broadly binned morphological distribution of SN Ia subclasses in edge-on spiral host galaxies.

| SN        | S0/a–Sab | Sb–Sc | Scd–Sdm | All |
|-----------|----------|-------|---------|-----|
| Normal    | 46       | 81    | 17      | 144 |
| 91T       | 5        | 18    | 7       | 30  |
| 91bg      | 13       | 10    | 0       | 23  |
| All       | 67       | 108   | 22      | 197 |

Table A2. Comparison of the $|V|/Z_{25}$ distributions between different subclasses of SNe Ia.

| Subsample 1 | $N_{SN}$ | versus | Subsample 2 | $N_{SN}$ | $P_{\text{MC}}$ $^{KS}$ | $P_{\text{MC}}$ $^{AD}$ |
|-------------|----------|--------|-------------|----------|--------------------------|--------------------------|
| Normal      | 144      | versus | 91bg        | 23       | 0.112                     | **0.005**                |
| Normal      | 144      | versus | 91T         | 30       | 0.311                     | 0.307                    |
| 91bg        | 23       | versus | 91T         | 30       | **0.042**                 | **0.048**                |

Notes. The explanations for the $P$-values are identical to those in Table 1.

Table A3. Comparison of exponential scale heights of SN Ia subclasses with those of CC SNe, and thick and thin discs of edge-on galaxies.

| Disc                  | $N$     | $\tilde{H}$ | Reference                      |
|-----------------------|---------|--------------|--------------------------------|
| Early-type galaxies   |         |              |                                |
| S0/a–Sc thin disc     | 122     | 0.02$^{+0.01}_{-0.01}$ | Comerón et al. (2018)         |
| S0/a–Sab thin disc    | 38      | 0.04$^{+0.02}_{-0.01}$ | Comerón et al. (2018)         |
| Normal (S0/a–Sab)     | 46      | 0.07$^{+0.03}_{-0.02}$ | This study                    |
| S0/a–Sc thick disc    | 122     | 0.11$^{+0.02}_{-0.02}$ | Comerón et al. (2018)         |
| 91bg (S0/a–Sc)        | 23      | 0.14$^{+0.08}_{-0.04}$ | This study                    |
| 91bg (S0/a–Sab)       | 13      | 0.16$^{+0.15}_{-0.06}$ | This study                    |
| S0/a–Sab thick disc   | 38      | 0.17$^{+0.07}_{-0.04}$ | Comerón et al. (2018)         |
| Late-type galaxies    |         |              |                                |
| MW thin disc          |         | 0.02$^{+0.01}_{-0.01}$ | Jurić et al. (2008)           |
| Sb–Sc thin disc       | 84      | 0.02$^{+0.01}_{-0.01}$ | Comerón et al. (2018)         |
| CC SNe                | 27      | 0.03$^{+0.02}_{-0.01}$ | H17                           |
| 91T (Sb–Sdm)          | 25      | 0.04$^{+0.02}_{-0.01}$ | This study                    |
| Normal (Scd–Sdm)      | 17      | 0.05$^{+0.04}_{-0.02}$ | This study                    |
| MW thick disc         |         | 0.06$^{+0.01}_{-0.01}$ | Jurić et al. (2008)           |
| Normal (Sb–Sc)        | 81      | 0.07$^{+0.02}_{-0.01}$ | This study                    |
| Scd–Sd thick disc     | 19      | 0.08$^{+0.06}_{-0.01}$ | Comerón et al. (2018)         |
| Sb–Sc thick disc      | 84      | 0.08$^{+0.02}_{-0.02}$ | Comerón et al. (2018)         |
| 91bg (Sb–Sc)          | 10      | 0.12$^{+0.13}_{-0.05}$ | This study                    |

Notes. $\tilde{H}_{SN} = \langle |V|/R_{25} \rangle$. Morphological classification of galaxies from Comerón et al. (2018) is available via the HyperLeda and/or NED. The $\tilde{H}$ values are displayed in ascending order.

**APPENDIX A: ONLINE MATERIAL**

Table A1 shows broadly binned morphological distribution of SN Ia subclasses in edge-on spiral galaxies. Table A2 compares the $|V|/Z_{25}$ distributions between different subclasses of SNe Ia. Table A3 compares the exponential scale heights of SN Ia subclasses with those of CC SNe, and thick and thin discs of galaxies. Table A4 shows the correlation test for the $|V|/Z_{25}$ versus $\Delta m_{15}$ parameters.

A portion of the database underlying the study is shown in Table A5 for guidance regarding its content and format. The entire table is available in electronic format as an CSV file.
Table A5: The database of 197 SNe Ia and their 196 host galaxies. The first ten entries are displayed. The full table can be found in the article’s online version.

| SN   | Subclass | Source Bibcode | U     | V     | ∆m15 | Source Bibcode | Host Bibcode | Host            | Dist. Mpc | Morph. | R25 | Z25 |
|------|----------|----------------|-------|-------|------|----------------|--------------|----------------|-----------|--------|-----|-----|
| 1959C | norm     | 1993AJ....106.2383B | 8.340 | 0.066 | 0.74 ± 0.07 | 2017ApJ...835..64G | MCG+01-34-005 | 42.563         | Sc        | 44.826 | 11.715 |
| 1962J | norm     | 1993AJ....106.2383B | 40.100 | 13.776 | 1.01 ± 0.07 | 2017ApJ...835..64G | NGC6835      | 20.201         | Sab       | 89.277 | 29.850 |
| 1984A | norm     | 2009ApJ...699L.139W  | 25.132 | 13.913 | 1.21 ± 0.10 | 2005ApJ...623.1011B | NGC4419      | 16.095         | Sa        | 105.893 | 44.721 |
| 1990G | norm     | 2012MNRAS.425.1789S | 35.170 | 5.912 | -     | -              | IC2735        | 153.410        | Sab       | 40.386 | 14.789 |
| 1991bd| norm     | 2012MNRAS.425.1789S | 35.801 | 6.736 | -     | -              | UGC02936      | 51.771         | Sc        | 117.645 | 22.623 |
| 1991bf| norm     | 2012MNRAS.425.1789S | 25.416 | 1.118 | -     | -              | ESO471-030    | 120.768        | Sa        | 39.665 | 17.126 |
| 1991K | 91T      | 2012MNRAS.425.1789S | 18.898 | 7.251 | -     | -              | NGC2851       | 70.776         | S0/a      | 62.163 | 30.627 |
| 1992ag| norm     | 1992IAUC.5555....1M | 2.849  | 2.067 | 1.19 ± 0.10 | 1996AJ....112.2408H | ESO508-067    | 104.045        | Sb?       | 33.522 | 10.278 |
| 1993ah| norm     | 1993IAUC.5897....1B  | 7.661  | 0.914 | 1.30 ± 0.10 | 1996AJ....112.2408H | ESO471-027    | 120.357        | Sab       | 36.384 | 13.386 |
| 1993L | norm     | 1993IAUC.5782....1D  | 23.490 | 4.488 | 1.47 ± 0.07 | 2005ApJ...624..532R | IC5270        | 23.387         | Sbc       | 71.856 | 20.562 |

Notes. We more precisely identify the morphologies of edge-on galaxies by assessing the size of the bulge relative to the disc (see H17).