The impact of density waves on the distribution of supernovae in galaxies

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We present an analysis of the impact of density waves on the radial distributions of the different types of supernovae (SNe) in the stellar discs of host galaxies with various morphologies based on the Sloan Digital Sky Survey (SDSS).

THE SAMPLE

- Sa-Sc host galaxies of Type Ia and core-collapse (CC) SNe from SDSS (Hakobyan et al. 2012)
- Morphologically non-disturbed host galaxies (Hakobyan et al. 2014)
- Inclination $\leq 60^{\circ}$ and distance ≤ 150 Mpc
- Grand-design (GD; arm classes 9 and 12) and non-GD (arm classes 1-8) hosts (Elmegreen & Elmegreen 1987; Aramyan et al. 2016)

RESULTS

Kolmogorov–Smirnov (KS) and Anderson–Darling (AD) tests indicate that there are no statistically significant differences between the restricted radial distributions ($0.2 \leq \tilde{r} \leq 1$) of Type Ia and CC SNe in GD and NGD subsamples (Table 1). However, when we select massive host galaxies ($M_g \leq$ -20 mag), the distributions of CC SNe in unbarred GD and NGD galaxies are inconsistent, while in barred counterparts the distributions are not different.

Table 1.
COMPARISON OF THE NORMALIZED, DEPROJECED RADIAL ($\tilde{r} = R_{SN}/R_{25}$) DISTRIBUTIONS OF SNe IN DIFFERENT SUBSAMPLES OF Sa-Sc GALAXIES ($0.2 \leq \tilde{r} \leq 1$).

Subsample 1				Subsample 2				
Host	SN	N_{SN}		Host	SN	N_{SN}	P_{KS}	P_{AD}
All								
GD	Ia	62	versus	NGD	Ia	107	0.898	0.903
GD	CC	135	versus	NGD	CC	148	0.052	0.114
GD	Ia	62	versus	GD	CC	135	0.734	0.544
NGD	Ia	107	versus	NGD	CC	148	0.519	0.519
Barred								
GD	Ia	34	versus	NGD	Ia	49	0.810	0.709
GD	CC	68	versus	NGD	CC	42	0.992	0.990
GD	Ia	34	versus	GD	CC	68	0.904	0.765
NGD	Ia	49	versus	NGD	CC	42	0.936	0.958
Unbarred								
GD	Ia	28	versus	NGD	Ia	58	0.791	0.844
GD	CC	67	versus	NGD	CC	106	0.069	0.071
GD	Ia	28	versus	GD	CC	67	0.434	0.545
NGD	Ia	58	versus	NGD	CC	106	0.440	0.413
All ($M_g \leq -20$)								
GD	Ia	58	versus	NGD	Ia	95	0.884	0.910
GD	CC	130	versus	NGD	CC	134	**0.012**	**0.037**
GD	Ia	58	versus	GD	CC	130	0.676	0.517
NGD	Ia	95	versus	NGD	CC	134	0.397	0.315
Barred ($M_g \leq -20$)								
GD	Ia	33	versus	NGD	Ia	45	0.810	0.709
GD	CC	65	versus	NGD	CC	40	0.866	0.964
GD	Ia	33	versus	GD	CC	65	0.692	0.701
NGD	Ia	45	versus	NGD	CC	40	0.767	0.869
Unbarred ($M_g \leq -20$)								
GD	Ia	25	versus	NGD	Ia	50	0.995	0.951
GD	CC	65	versus	NGD	CC	94	**0.042**	**0.030**
GD	Ia	25	versus	GD	CC	65	0.704	0.660
NGD	Ia	50	versus	NGD	CC	94	0.400	0.304

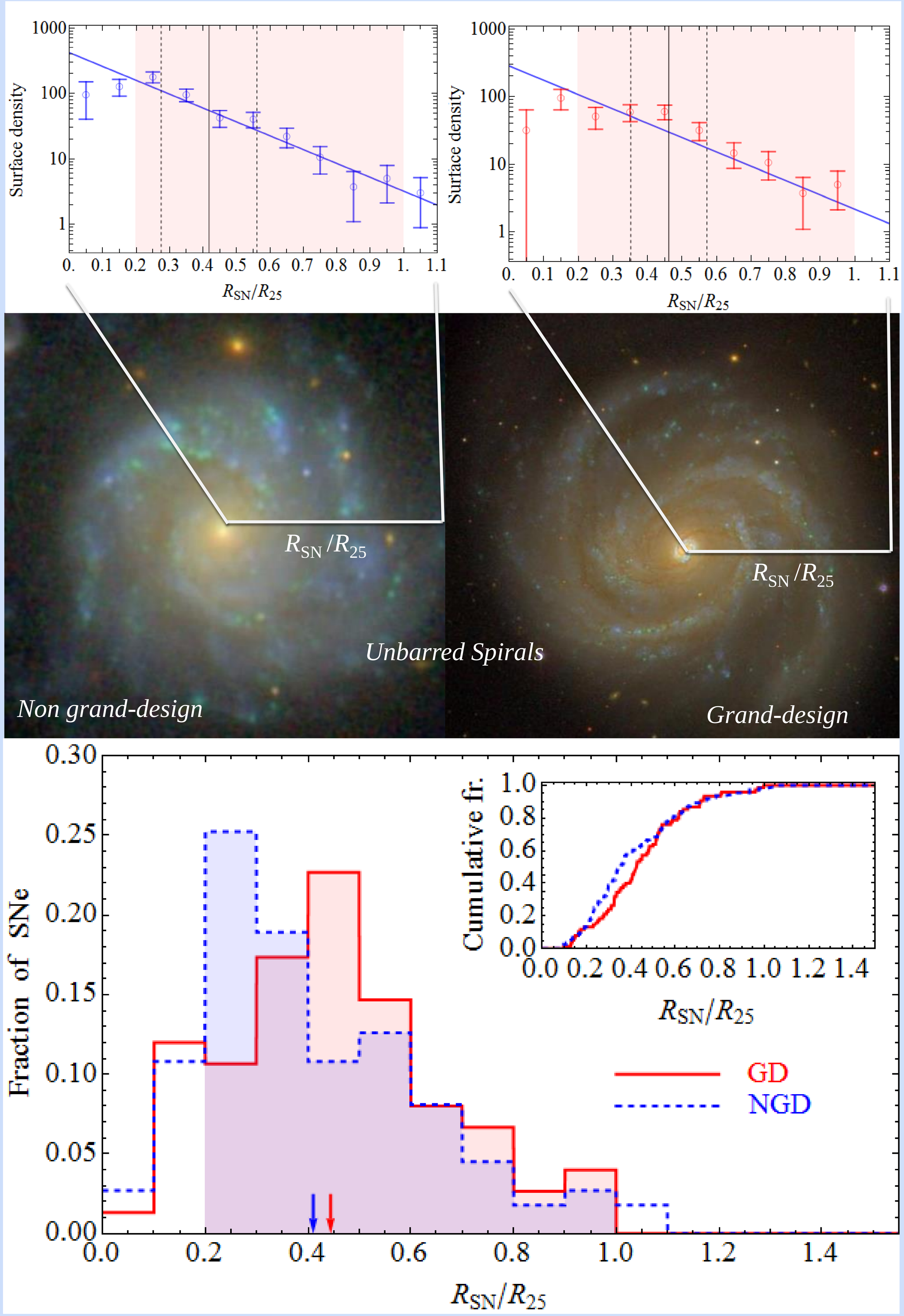

Figure 1. Upper panel: surface density distributions of SNe in unbarred NGD and GD Sa-Sc hosts. The blue lines show the best-fit exponential surface density profile estimated for the restricted NGD discs. The mean corotation radius (black solid line) with the one-sigma interval (black dashed lines) are mentioned. Middle panel: examples of the spirals. Bottom panel: histograms of the distributions. The insets present the cumulative distributions. The mean values of the distributions are shown by arrows.

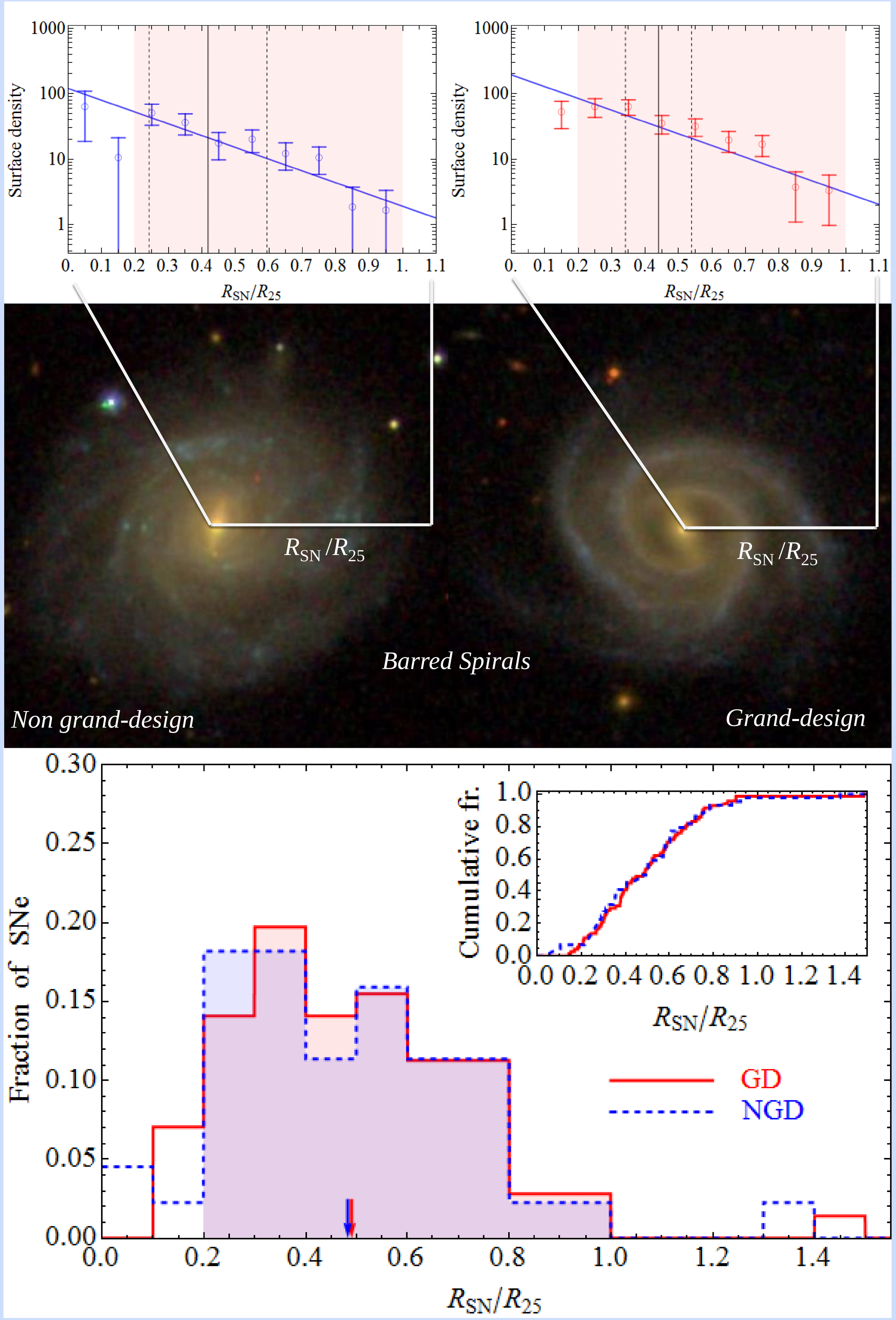

Figure 2 is the same as Figure 1, but for barred host galaxies.

Table 2.
CONSISTENCY OF CC AND TYPE Ia SN DISTRIBUTIONS WITH AN EXPONENTIONAL SURFACE DENSITY MODEL IN Sa-Sc GALAXIES WITH $0.2 \leq \tilde{r} \leq 1$ AND $M_g \leq$ -20.

Host (1)	SN (2)	N_{SN} (3)	P_{KS} (4)	P_{AD} (5)	$\tilde{h}_{SN}$ (6)
All					
GD	Ia	58	0.744	0.958	0.22 ± 0.03
NGD	Ia	95	0.468	0.573	0.22 ± 0.02
GD	CC	130	0.387	0.188	0.25 ± 0.03
NGD	CC	134	0.841	0.917	0.20 ± 0.02
Barred					
GD	Ia	33	0.901	0.942	0.22 ± 0.04
NGD	Ia	45	0.707	0.701	0.23 ± 0.04
GD	CC	65	0.713	0.715	0.25 ± 0.03
NGD	CC	40	0.876	0.885	0.24 ± 0.04
Unbarred					
GD	Ia	25	0.910	0.909	0.22 ± 0.08
NGD	Ia	50	0.549	0.876	0.22 ± 0.03
GD	CC	65	0.352	0.168	0.24 ± 0.03
NGD	CC	94	0.865	0.976	0.18 ± 0.02

The radial distribution of CC SNe, in contrast to Type Ia SNe, has the weakest consistency with the exponential surface density profile in massive unbarred GD hosts (Table 2). While the distributions of both the types of SNe are well consistent with the exponential profile in massive barred GD hosts, as well as in barred and unbarred NGD galaxies.

CONCLUSIONS

The results can be explained by the additional massive star formation, which occurs directly at the inner and outer sides from the corotation radius (Figure 1), most effectively in massive galaxies, and appears to be caused by the density waves in unbarred GD galaxies. In barred GD galaxies this effect is unseen (Figure 2) because of the suppression of massive star formation within bar radius (see James et al. 2009; Hakobyan et al. 2016). In NGD galaxies, the density waves are weak and does not affect the distribution of SNe.

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