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CONSTRAINING THE AGES OF SUPERNOVA PROGENITORS. I. SUPERNOVAE AND SPIRAL ARMS

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ABSTRACT

We present the first results of a three-part study of supernova (SN) ages using positional age indicators in spiral galaxies. We have measured the positions of 90 spectroscopically identified Type Ia and Type II SNs (SNs Ia and SNs II) relative to spiral arms in their host galaxies, making a special effort to reduce inhomogeneity in the process of arm tracing for different galaxies. We find that SNs II are more tightly concentrated to the arms than SNs Ia, but both kinds of SNs occur closer to arms than a random disk population. However, when compared with the distribution of V and I light relative to the arms, the SNs Ia are no more tightly concentrated than the general stellar population. This indicates that SNs Ia occur in a population old enough to have diffused away from their formation regions.

Subject headings: galaxies: spiral — galaxies: structure — supernovae: general

1. INTRODUCTION

Type Ia supernovae (SNs Ia), unlike SNs II, sometimes occur in elliptical galaxies, and so are assumed to originate in an older population. However, SN Ia rates are higher in late-type and irregular galaxies than in ellipticals (van den Bergh 1994), and some studies have indicated that those ellipticals that produce SNs Ia are more likely to be active or unusual in some regard (e.g., Oemler & Tinsley 1979). This suggests that the bulk of SNs Ia may occur in a population that is not very old, perhaps less than 10^9 yr. Other indicators point to a greater age; studies of chemical evolution in our Galaxy (Yoshii, Tsujimoto, & Nomoto 1996) have found that iron enrichment from SNs Ia may not have begun until 1.5 Gyr after the Galaxy's formation.

Various theories of SN Ia formation also give conflicting predictions for their progenitor ages. Simulations of binary white dwarf coalescence show that such events should begin $\sim 10^8$ yr after star formation (Ruiz-Lapuente, Burkert, & Canal 1995); however, these computations are quite sensitive to the assumed value of the common envelope ejection parameter α, which is poorly understood. Efforts to identify existing white dwarf binaries that will eventually coalesce have had limited success; the only identified candidates have combined masses below the Chandrasekhar limit (Marsh, Dhillon, & Duck 1995) or will take several Hubble times to spiral together (Bragaglia et al. 1990). Alternative progenitors such as symbiotic white dwarf systems may also produce SNs Ia at ages of a few times 10^9 yr (Yungelson et al. 1995).

An observational determination of the ages of SN progenitors can be obtained from their location in spiral galaxies. Because spirals include localized star formation and stellar populations of different ages, they offer a number of positional age indicators. Several excellent studies (Van Dyk 1992; Bartunov, Tsvetkov, & Filimonova 1994) have examined the positions of different types of SNs relative to H II regions. Others have focused on the radial distribution of SNs in the disk or correlation of SNs with spiral arms.

Maza & van den Bergh (1976) measured the positions of 84 SNs relative to spiral arms and found that SNs II were largely confined to the arms, while SNs I were more uniformly distributed. However, their sample included only 17 spectroscopically classified SNs I, some of which must have fallen into the Type Ib and Ic subclasses, which were not recognized at that time. Moreover, Maza & van den Bergh measured the SN positions relative to a subjectively determined "width" of the arms, rather than physical distance from the arm spine. More recently, Bartunov et al. (1994; hereafter BTF) compared a much larger sample of SNs II, SNs Ia, and SNs Ib/c against spiral arms and found that all three types were more closely correlated with arms than expected of a random sample. They used several different parameters, including physical distance, to characterize the SN position relative to the nearest arm and found the same results with all methods. They concluded that SNs Ia in spirals arise from an intermediate-age population rather than a very old one.

The BTF sample was well-defined and large enough to be statistically reliable, but the images that they used to trace the spiral arms of their sample galaxies were not entirely homogeneous. The visibility of spiral arms varies not only with the host galaxy's intrinsic characteristics but also with the distance to the galaxy, the length of the exposure, the filter through which the observation was made, and the seeing at the time of the observation. While most of the photographic images used by BTF were from the Palomar Observatory Sky Survey, which is consistent in filter and telescope setup, additional images came from a variety of other sources, creating the possibility of a bias in their data. A similar study that uses a homogeneous set of CCD images and manipulates the digital data to compensate for the effects of varying distances can eliminate many of these systematic effects and allow for a more accurate determination of the ages of SNs Ia.

This is the first part of a three-pronged study of the progenitor ages of SNs Ia and SNs II using their position relative to spiral arms, their membership in bulge or disk populations, and their scale height in the galactic disk. The primary purpose of this study is to constrain the ages of SN

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Ia progenitors, using SNs II as a control sample of known age.

2. SAMPLE DEFINITION AND OBSERVATIONS

The key to any statistical study is careful sample selection. Our initial sample, chosen to be as large as possible, included every well-identified SN Ia and SN II discovered in the past century. We excluded only those SNs described as peculiar in the IAU Circulars or with uncertain spectroscopic identification in the Asiago or van den Bergh catalogs (Barbon, Cappellaro, & Turatto 1989; van den Bergh 1994). In particular, we required that the SNs Ia have a spectroscopic type determination (Leibundgut et al. 1991). Thus, we avoided the historical confusion between SNs Ia and SNs Ib/c; SNs of the latter type were excluded from this study because they do not form a sufficiently large sample and because our focus is on SNs Ia. All of the SN host galaxies in the initial sample were targeted for observing, except those listed as elliptical in the Third Reference Catalog of Bright Galaxies (RC3) (de Vaucouleurs et al. 1991). Later divisions of the sample were made from examination of the images obtained specifically for this study.

Since homogeneity of the data was a central goal of our effort, all of the northern hemisphere galaxies were imaged with the same telescope and CCD setup. Three runs at the *f*/7.5 focus of the KPNO 0.9 m telescope—1994 February and November, and 1995 March—provided the bulk of our data. These images were taken with a Tektronix 2048 × 2048 CCD (T2KA), which afforded a field of view of 23′ on a side with a scale of 0″.68 pixel^{-1}. Southern hemisphere observations were carried out with the CTIO 0.9 m telescope and a TI quad-readout CCD, providing 13′.5 × 13′.5 images at 0″.40 pixel^{-1}.

All exposures were 15 minutes long to allow for good signal-to-noise ratios down to the sky level without saturating the nuclei of the brighter galaxies. Each galaxy was observed in both V and I; the V images were used for identification of the blue spiral arms, while the I images provided color information and allowed us to perform surface photometry with less interference from dust.

Altogether, we obtained images of 248 galaxies containing 289 SN positions. Only 57 galaxies from the target sample were not observed; of these, 40 were anonymous galaxies less than 1′ in diameter, which were not likely to be of use for this study. Upon examination of the images, we chose the host galaxies of 115 SNs for the spiral arm portion of our study; these were mostly galaxies of later types (Sb, Sbc, and Sc). This Hubble-type distribution was similar for both samples of SNs.

3. REDUCTION

One shortcoming of previous studies of SN distances from spiral arms (Maza & van den Bergh 1976; BTF) is that they used an inhomogeneous set of images, with different types of photographic plates exposed for different times through various filters. By using similar telescopes and instruments, constant exposure times, and identical reduction methods, we have reduced this source of inhomogeneity. However, an equally important source of variation arises from the different distances of the host galaxies. SNs Ia are significantly brighter than SNs II and can be observed at greater distances. As a result, samples of SN Ia host galaxies have larger mean distances than their SN II counterparts and are typically observed with coarser spatial resolution. Since some of the fainter arm structure of a spiral galaxy becomes undetectable when viewed at low-spatial resolution, this selection effect causes SNs at greater distances to appear farther from the spiral arms than nearby SNs.

To overcome this problem, we smoothed and rebinned our images so that each galaxy would appear at a common spatial resolution, i.e., as if it were being observed at a standard distance with standard seeing. We used two different distances in order to balance the advantages of good resolution against sample size. First, we smoothed our images to the spatial resolution we would expect for a galaxy observed at 50 Mpc (assuming $H_0 = 75$ km s^{-1} Mpc^{-1}) with our typical 1″.8 seeing; we defined this as our medium resolution. Similarly, we created a set of coarse resolution images corresponding to observations of a galaxy at 100 Mpc with 1″.8 seeing. The comparison of these two samples enabled us to determine the effect of distance on spiral-arm visibility.

Determination of the SN position in each galaxy was hampered by the lack of accurate astrometry for many objects. In general, the offsets between SNs and galaxy nuclei published in the IAU Circulars, and listed in SN catalogs (Barbon et al. 1989; van den Bergh 1994), are only accurate to 2″–3″; in some cases (especially with older SNs), the offsets are good to no better than 10″. Absolute positions for some SNs were published in the IAU Circulars, while others are available in the Sternberg catalog (Tsvetkov & Bartunov 1993) and from remeasurements of many of Zwicky's photographic plates (Porter 1993). Wherever a position was quoted to subarcsecond precision, that position was considered to be accurate and was used instead of the nuclear offset. A few of the most recent SNs were unambiguously visible on the images we obtained; for these, we used a centroid of the SNs point-spread function (PSF).

The actual identification of the nearest arm to an SN position was made by eye using a consistent set of rules. For the purposes of this study, an "arm" was defined to be a local maximum in the surface brightness of the galaxy that was extended with an axis ratio of 6 or more. In the case of very flocculent galaxies, an arm could also be defined by three or more collinear "clumps," all of which must be larger than a typical stellar PSF. When an SN occurred near an isolated clump, a note was made of this fact, but the distance was measured to the nearest arm fitting our definition. From the accuracy of the positions and the effects of the rebinning process, we estimate that most of our arm distances should be accurate to approximately 0.2 kpc; this will be slightly better for SNs that occurred in nearby galaxies or that have more accurate measured positions, but it also depends upon the more subtle effects of the arm identification process.

For galaxies with inclinations greater than 30° (taken in most cases from RC3, otherwise from Barbon et al. 1989), we corrected the measured arm distance for projection effects using

$$d^2 = \left[\frac{r \sin(\Delta\theta)}{\cos i}\right]^2 + [r \cos(\Delta\theta)]^2 , \tag{1}$$

where r is the measured distance to the nearest arm, i is the inclination of the galaxy, and $\Delta\theta$ is the difference between the position angle of the galaxy's major axis and the direction from the SN to the arm.

Tables 1 and 2 list 89 SNs for which arm distances (in kiloparsecs) were measured at the medium or coarse equivalent resolution. Negative distances indicate SNs that occurred inside the nearest arm. No distances are listed at the coarse resolution for galaxies the arms of which were too badly blurred by the smoothing process; similarly, no distances are given at the medium resolution for galaxies more distant than 50 Mpc, or at the coarse resolution for galaxies more than 100 Mpc away, unless the galaxy was observed under very good seeing. The distance to each galaxy is also listed in megaparsecs; in most cases, these were taken from Tully (1988). For the fainter galaxies where no distances were available, we used velocities from the Asiago or van den Bergh SN catalogs (Barbon et al. 1989; van den Bergh 1994) or galaxy velocities from RC3. In some cases, galaxies intrinsically more distant than 50 or 100 Mpc have listings at those resolutions because the observation was made in conditions of better than average seeing.

TABLE 1

Arm Distances for SN II

Galaxy	Type	SN	D (Mpc)[a]	d_{medium} (kpc)	d_{coarse} (kpc)
NGC 6946	Scd	1917A	5.5	0.00	0.00
NGC 5236	Sc	1923A	4.7	0.25	0.50
NGC 4303	Sbc	1926A	15.2	0.60	3.01
NGC 4273	SBc	1936A	35.1	1.30	1.42
NGC 4725	Sab p	1940B	12.4	1.27	1.32
NGC 4559	Scd	1941A	9.7	0.31	...
NGC 4136	Sc	1941C	9.7	1.41	1.28
NGC 6946	Scd	1948B	5.5	0.22	0.29
NGC 7331	Sb	1959D	14.3	0.78	...
NGC 4303	Sbc	1961I	15.2	1.00	−1.20
NGC 3938	Sc	1961U	17.0	0.22	0.22
NGC 536	SBb	1963N	71.2	...	−0.90
NGC 3631	Sc	1964A	21.6	0.28	0.71
NGC 4303	Sbc	1964F	15.2	−1.50	−1.60
NGC 3631	Sc	1965L	21.6	0.14	0.07
NGC 3074	Sc	1965N	68.6	...	0.23
NGC 6946	Scd	1968D	5.5	−0.15	−0.87
NGC 5457	Scd	1970G	7.5	3.96	3.96
NGC 4254	Sc	1972Q	16.8	0.11	0.11
IC 43	Sc	1973U	64.8	...	−2.35
MCG +10-16-117	Scd	1978B	39.0	−0.39	−0.13
NGC 4321	Sbc	1979C	16.8	1.16	1.16
NGC 1255	Sbc	1980O	19.9	−0.34	−0.31
NGC 6946	Scd	1980K	5.5	2.03	−2.32
NGC 5597	Scd	1981E	38.6	−0.57	−0.42
NGC 4490	SBd	1982F	7.8	0.48	0.57
NGC 3359	SBc	1985H	19.2	3.95	3.75
NGC 5033	Sc	1985L	18.7	0.51	0.75
NGC 1433	SBab	1985P	11.6	0.18	0.18
IC 1809	SBab	1985R	78.3	...	−0.70
NGC 4254	Sc	1986I	16.8	0.06	0.11
NGC 1559	SBcd	1986L	14.3	0.88	0.91
MRK 90	S p	1987C	56.9	1.31	1.31
NGC 5878	Sb	1988H	31.6	0.83	...
NGC 4496	Sc	1988M	60.6	...	0.60
NGC 3646	Sbc	1989N	56.8	...	0.89
UGC 5295	Sb	1989U	64.1	...	−0.29
NGC 3294	Sc	1990H	26.7	0.38	−2.00
NGC 150	SBc	1990K	19.2	0.66	0.69
UGC 12565	S?	1990X	113.8	...	3.51
NGC 4088	Sbc	1991G	17.0	0.42	0.56
NGC 3367	SBc	1992C	43.6	...	0.28
NGC 5377	SBa	1992H	31.0	−3.61	−3.61
NGC 4411B	Scd	1992ad	16.7	−0.11	0.00
NGC 7637	Sc	1992ao	49.1	7.35	7.35
NGC 818	Sc	1992az	59.4	...	−0.23
NGC 2082	SBb	1992ba	12.1	0.14	0.09
NGC 2223	Sb	1993K	33.7	0.48	0.37
NGC 2276	Sbc	1993X	36.8	−0.49	−0.49
IC 1501	Sb p	1993ad	68.9	...	1.90
NGC 2848	Sc	1994L	27.7	0.21	0.21
UGC 6983	SBcd	1994P	17.0	1.12	1.12
IC 2627	Sbc	1994R	29.5	1.64	1.70
NGC 5371	Sbc	1994Y	37.8	−1.19	−1.19

[a] Assuming $H_0 = 75$ km s^{-1} Mpc^{-1}.

TABLE 2

Arm Distances for SN Ia

Galaxy	Type	SN	D[a] (Mpc)	d_{medium} (kpc)	d_{coarse} (kpc)
NGC 4496	SBc	1960F	13.1	−0.28	−0.28
NGC 4096	Sc	1960H	8.8	4.33	...
MCG +6-6-62	Sd	1961P	48.9	4.29	4.29
NGC 3389	Sc	1967C	22.5	5.85	...
NGC 2713	SBab	1968E	49.2	−0.37	−0.37
NGC 3811	SBcd	1969C	41.6	−0.36	−1.74
NGC 7495	Sc	1973N	65.2	...	0.21
NGC 7343	SBbc	1974J	19.1	−0.13	...
NGC 2207	Sbc	1975A	33.3	4.95	5.90
NGC 7723	SBb	1975N	23.7	−0.45	...
NGC 5427	Sc p	1976D	38.1	0.14	0.20
NGC 3913	Sd	1979B	17.0	−0.45	−0.35
NGC 4536	Sbc	1981B	13.3	−0.77	5.52
IC 1731	Sc	1983R	46.1	−0.22	0.97
NGC 3227	Sa	1983U	20.6	−0.38	...
NGC 3625	SBb	1983W	26.2	−0.79	...
NGC 3367	SBc	1986A	43.6	...	1.01
NGC 1667	Sc	1986N	61.3	...	1.72
NGC 2227	SBcd	1986O	27.5	−0.80	−0.94
NGC 2336	SBbc	1987L	33.9	2.00	2.20
MCG +2-20-9	S?	1987O	62.4	...	3.84
NGC 7606	Sb	1987N	28.9	0.48	0.48
MCG +7-16-8	Sbc	1988C	78.4	...	0.72
MCG +9-23-9	S?	1988R	96.0	...	−0.95
NGC 3687	Sbc	1989A	37.2	1.23	1.23
NGC 2963	SBab	1989D	87.2	...	−0.52
UGC 11699	SBd	1990R	55.8	...	0.74
NGC 5426	Sc	1991B	35.9	0.16	0.16
IC 1151	SBc	1991M	27.8	3.17	3.05
NGC 4902	SBb	1991X	39.2	−0.90	−0.90
IC 344	S?	1991bj	72.7	...	1.48
NGC 3294	Sc	1992G	26.7	0.22	0.61
IC 3690	S?	1992P	101.6	...	2.11
NGC 1164	Sa	1993ab	57.1	...	0.00
NGC 1808	Sa	1993af	10.8	5.73	5.73

[a] Assuming $H_0 = 75$ km s^{-1} Mpc^{-1}.

4. ANALYSIS

In order to interpret our SN positional data in terms of progenitor ages, we generated a random sample of SNs with the properties of a smooth, exponential disk. We chose NGC 5457 (M101) as a template because of its face-on inclination, well-defined arms, smooth surface brightness profile, and well-determined distance of 7.5 Mpc (Kelson et al. 1996; Feldmeier, Ciardullo, & Jacoby 1996). The V image of NGC 5457 taken as part of this study was smoothed to simulate distances of 50 and 100 Mpc, and at each resolution the arms were traced according to the strict definition above.

Using our own surface photometry measurements, we determined that an exponential disk with a scale length of 6.0 kpc was a good fit to the disk light of the galaxy. One

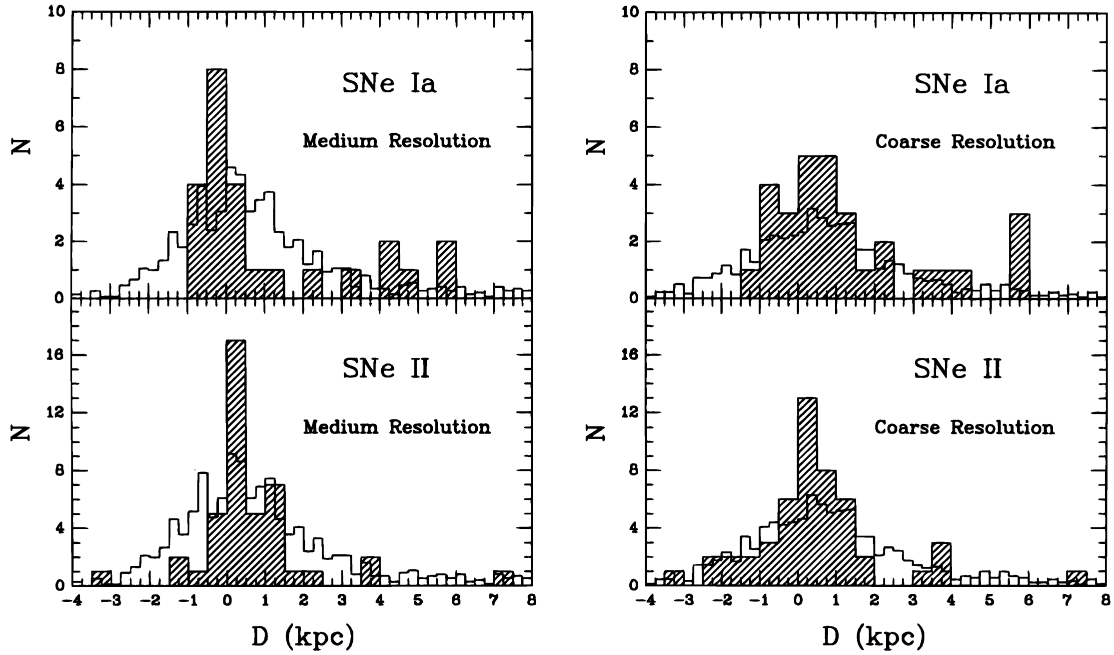

FIG. 1.—Distribution of SN offsets from spiral arms for medium and coarse resolutions. A sample of randomly generated disk objects is overplotted for comparison. Both types of SN are more tightly concentrated to the arms than a random disk population.

thousand SNs were generated randomly following this exponential falloff, and for each one the distance to the nearest pretraced arm was measured. Although our disk-scale length is roughly consistent with the findings of Elmegreen & Elmegreen (1984), Knapen & van der Kruit (1991) note that the disk-scale length measurements of different authors typically scatter by 23%. Fortunately, this uncertainty has very little effect on our final results.

Figure 1 shows a histogram of the arm distances for SNs Ia and II at the medium and coarse resolutions. A histogram of the distribution for the randomly generated SNs is overplotted for comparison. Both SN types show a distinct positive tail caused by the appearance of SNs outside of the main body of the galaxy. It is at once apparent to the eye that both types of SNs are more tightly concentrated to the arms than a pure disk population. It is more difficult to distinguish between the SNs II and SNs Ia by appearance, but it is worth noting that the peak of the Type II distribution occurs outside of the arms, while the Type Ia distribution peaks somewhat to the inside.

Another useful comparison is to the stellar population itself. Even the redder stars in a galaxy show an increase in

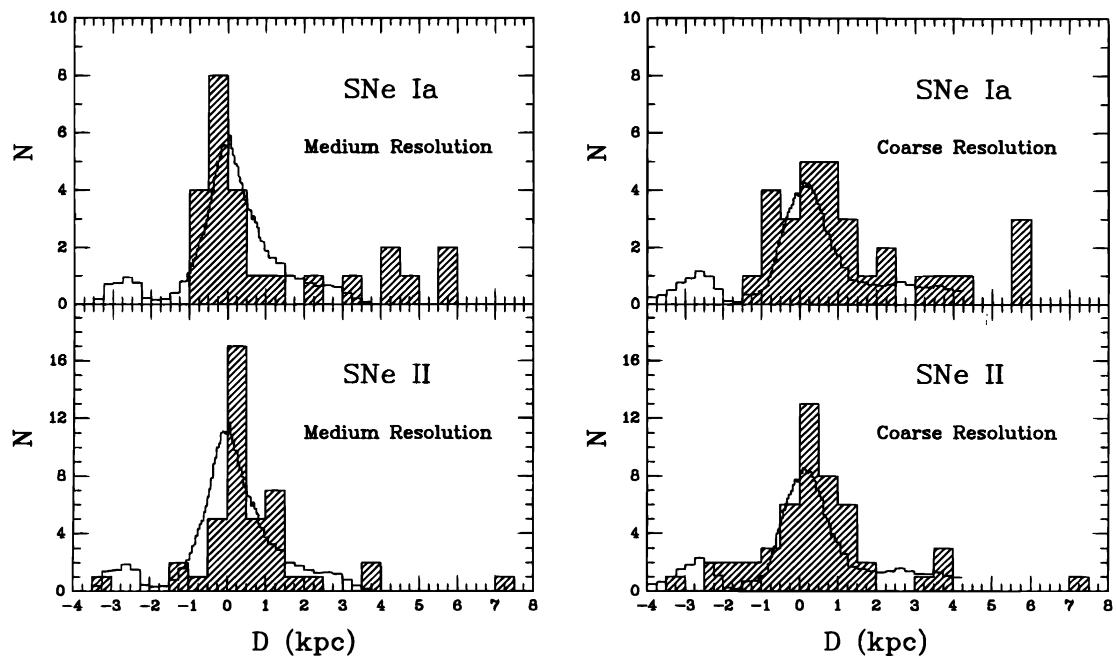

FIG. 2.—Distribution of SN offsets from spiral arms for medium and coarse resolutions. Spiral arm enhancement in *I* is overplotted for comparison. SNs Ia are indistinguishable from the spiral light enhancement, while the SNs II are more tightly concentrated, especially at the medium resolution.

population density near the spiral arms (Elmegreen 1990). To model this, we once again used NGC 5457 and subtracted a smooth, elliptically averaged profile from the image of the galaxy itself, thereby removing most of the radial variation in surface brightness. When the strongest remaining source of contrast was the spiral structure, we computed the median pixel value as a function of distance from the arm spine and used this as a tracer of the stellar density in the arms. This procedure was performed at both resolutions in the V and I images to allow a comparison with both the red and blue populations of the galaxy.

Figure 2 shows the SN distributions again, this time with the spiral enhancement in the I light overplotted. The distribution of the V light is qualitatively very similar to that of the I light and is not shown. The small bump at -3 kpc probably indicates additional spiral structure that was not traced because of the smoothing; since the same procedure was applied to NGC 5457 as to the rest of the sample, this should not introduce a bias. Clearly, the light distribution is more concentrated to the arms than a smooth disk. This holds true even in I, where a more evolved population should dominate.

5. DISCUSSION

A quantitative determination of the peak of the distribution requires a measurement of the mode that is insensitive to binning. We achieved this by fitting a Gaussian to the distribution of arm distances using the maximum likelihood method. Both the model Gaussian and the data were truncated at 3 kpc from the arm spine in order to remove the effects of the asymmetrical tail of the distribution. This fit returned a most likely value of 0.35 kpc for the SNs II and -0.05 for the SNs Ia. Given our estimated errors, the SN Ia peak is consistent with 0; i.e., the SNs Ia are just as likely to occur on the inside of a spiral arm as on the outside. The offset of the SN II distribution is probably real and indicates that most SNs II occur shortly *after* the stellar density wave has passed by (Elmegreen 1994).

Table 3 shows the probability that various samples are different according to the Kolmogorov-Smirnov method. Direct comparison between the two types of SNs indicates that they are most likely distributed differently at medium resolution, although we cannot be so definite at the coarse resolution. SNs II are clearly more tightly concentrated than the random disk distribution, while SNs Ia are less so.

TABLE 3

KS Probability That Samples Are Different

Sample 1	N_1	Sample 2	N_2	P_{diff}
SN Ia......	24	SN II	43	0.93
	29		51	0.65
SN Ia......	24	Random	1000	0.83
	29		1000	0.41
SN II	43	Random	1000	0.987
	51		1000	0.997
SN Ia......	21	I light	...	0.63
	26		...	0.991
SN II	41	I light	...	0.998
	47		...	0.965
SN Ia......	21	V light	...	0.64
	26		...	0.988
SN II	41	V light	...	0.997
	47		...	0.95

Note.—The first line in each pair is medium resolution; the second line is coarse resolution.

For comparison with the spiral light enhancement, we restricted the range of the samples to the region between -2 kpc and 4.4 kpc to avoid the slight bump at the inner edge of the arms. SNs II are different from the spiral light in both I and V, particularly at medium resolution; SNs Ia are not appreciably more concentrated than the light at the more accurate resolution. These results are substantially similar if the distance (or size) of NGC 5457 is allowed to change by up to 20%. The results are most limited by the sample size, which is listed in Table 3. In particular, 10 additional objects in the SN Ia sample could greatly strengthen the results. However, it is still possible to draw conclusions about the implications for the progenitor ages of SNs Ia.

Our findings show that, although SNs II are more tightly correlated with spiral arms than SNs Ia, both kinds of SN occur closer to arms than a perfectly randomized disk population. However, SNs Ia are not statistically distinguishable from the distribution of stellar light around arms, which should be a tracer of stellar density. The random disk SN sample and the spiral light distribution were both constructed using NGC 5457, meaning that the conclusions above may be somewhat biased if NGC 5457 is not representative of the set of spiral SN host galaxies as a whole. However, there is still evidence that the SNs Ia are distributed more loosely than the SNs II, and the fact that the peak of the SN II distribution is offset slightly to the outside of the arm, while the SN Ia distribution is not. This suggests that the progenitors of SNs Ia have had enough time to diffuse away from their places of formation and mix with the general stellar population.

Since disk stars typically rotate about the galaxy at constant speeds, while the spiral pattern is expected to have a solid-body rotation, the amount of time required for an individual star to drift out of a spiral arm varies with its radial position in the galaxy (Sempere et al. 1995). Thus, it is difficult to make a quantitative estimate of age from spiral arm offsets. Nevertheless, we can say that it would require at least 1 or 2 galactic years for a population to diffuse fully away from the arm spine. In contrast, SNs II are most likely to go off shortly after the passage of the stellar density wave, or considerably less than 1 galactic year after formation. The length of a galactic year also depends upon an object's radial position and the characteristics of the individual galaxy, but considering that most of our objects occur in the middle range of their spiral disks, we estimate that the SN II offset indicates an age of less than a few times 10^7 yr; this is consistent with theories of SN II formation from massive star evolution and with findings that SNs II tend to occur near star formation regions (Van Dyk 1992; Van Dyk, Hamvy, & Filipenko 1996; Barth, Van Dyk, & Filipenko 1996). Thus, the evidence indicates that SNs Ia are significantly older than SNs II, occurring several galactic years, or $\gtrsim 5 \times 10^8$ yr, after star formation.

6. CONCLUSIONS

We have made a careful study of any possible correlation between spiral arms and the positions of SNs Ia and SNs II, with special attention paid to making the data sets as homogeneous as possible for comparison. In particular, we smoothed the images so that all the host galaxies would match a standard spatial resolution. The SN samples were also compared against the distribution of stellar light and the appearance of a random disk population. Our conclusion is that SNs II are most likely to occur near and slightly outside of the spines of spiral arms, indicating that their progenitors are indeed young, massive stars. SNs Ia are no more restricted to spiral arms than the rest of the stellar population, and therefore their age is $\gtrsim 5 \times 10^8$ yr. Further constraints on the age of SN Ia progenitors will require indicators that are more sensitive to older populations, such as bulge/disk membership and scale height in edge-on galaxies.

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