Upper limits on bolometric luminosities of 10 Type Ia supernova progenitors from Chandra observations

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ABSTRACT

We present an analysis of Chandra observations of the position of 10 nearby (<25 Mpc) Type Ia supernovae, taken before the explosions. No sources corresponding to progenitors were found in any of the observations. We calculated upper limits on the bolometric luminosities of the progenitors assuming blackbody X-ray spectra with temperatures of 30–150 eV. This is inspired by the fact that luminous super-soft X-ray sources have been suggested as the direct progenitors of Type Ia supernovae. The upper limits of two supernovae in our sample are comparable to the luminosities of the brightest observed super-soft sources, ruling out such sources as the progenitors of these supernovae. In contrast to Liu et al., we find that for SN2011fe we can rule out Eddington luminosity systems for blackbody temperatures as low as 40 eV. Our findings are consistent with statistical studies comparing the observed Type Ia supernova rate to the number of super-soft sources or the integrated X-ray luminosity in external galaxies. This suggests that either the progenitors of Type Ia supernovae are not accreting, nuclear burning white dwarfs or that they do not look like the classical super-soft sources, e.g. because they are obscured.

Key words: binaries: close – binaries: symbiotic – circumstellar matter – supernovae: general – white dwarfs – X-rays: binaries.

1 INTRODUCTION

Type Ia supernovae (SNe Ia) are important astrophysical phenomena, both in relation to cosmology (Riess et al. 1998; Perlmutter et al. 1999) and galactic chemical and dynamical evolution. Despite some 40 years of research on the subject, the exact nature of the progenitor systems of SNe Ia remains undetermined. Two scenarios are usually considered by the community (e.g. Hillebrandt & Niemeyer 2000): the single degenerate (SD) and double degenerate (DD) scenarios. In the former, a single carbon–oxygen white dwarf (WD) star accretes matter from a non-degenerate companion star (Whelan & Iben 1973; Nomoto 1982), thereby growing in mass until it reaches a critical mass (∼1.37 M⊙), at which point the temperature and density in its interior are high enough for carbon and oxygen to fuse explosively into radioactive iron-group elements. In the DD scenario, two WDs with individual masses less than the Chandrasekhar mass merge to form a single carbon–oxygen WD at or above the critical mass needed for thermonuclear runaway (Tutukov & Yungelson 1981; Iben & Tutukov 1984; Webbink 1984). In both cases, the resulting SN explosion completely unbinds the WD, and the subsequent decay of radioactive nickel powers a light curve that can be used as standardizable cosmology candles (Philips 1993).

It has been suggested that the steady accretion and nuclear burning of material on the surface of the WD in the SD scenario will emit super-soft X-rays (van den Heuvel et al. 1992; Kahabka & van den Heuvel 1997). The spectrum of this type of emission is expected to resemble a blackbody with $kT_{BB} = 30–100$ eV and luminosities between $10^{37}$ and $10^{38}$ erg s$^{-1}$. For SNe closer than ∼25 Mpc, such emissions should theoretically be observable with the Chandra X-ray Observatory. For this reason, a search for archival Chandra images taken before the SN explosions was conducted by Voss & Nelemans (2008), and the results were one possible detection (SN2007on; however, see also Roelofs et al. 2008) and four upper limits (SN2002cv, SN2004W, SN2006mr and SN2007sr; see Nelemans et al. 2008). Upper limits for the progenitor of SN2011fe based on archival Chandra images were reported by Butler, Ofek & Bloom (2011) and later by Li et al. (2011), both studies using a blackbody temperature of $kT_{BB} = 67$ eV. Upper limits for SN2011fe were also reported by Liu et al. (2012); however, below we show that we do not find the same upper limits to the bolometric luminosities as reported in that study.

The search for progenitors in archival X-ray images was inspired by the analogous search for the progenitors of core-collapse SNe in Hubble Space Telescope (HST) archive (see review by Smartt 2009). A similar search for SN Ia progenitors in HST archival...
images was performed by Mannucci & Maoz (2008) for SN2006dd and SN2006mr in NGC 1316, but no optical counterparts of these SNe were observed. Additionally, HST archival images were used to put upper limits on the optical luminosity of the progenitor of SN2007on (Voss & Nelemans 2008) and SN2007sr (Nelemans et al. 2008). Limits on the optical magnitude and bolometric luminosity of the progenitor of SN2011fe were reported by Li et al. (2011).

In this paper, we present a homogenous analysis of 10 recent, nearby (≤ 25 Mpc) SNe Ia for which pre-explosion Chandra images are available: SN2002cv [Larionov et al. (2002a,b), classified by Meikle & Martilla (2002)], SN2003cg [Itagaki et al. (2003), classified by Kotak & Meikle (2003)], SN2004W [Moore & Li (2004), classified by Filippenko et al. (2004)], SN2006X [Suzuki & Migliardi (2006), classified by Quimby et al. (2006)], SN2006dd [Monard (2006a), classified by Salvo et al. (2006)], SN2006mr [Monard (2006b), classified by Phillips et al. (2006)], SN2007gi [Itagaki et al. (2007), classified by Harutyunyan et al. (2007)], SN2007sr [Drake et al. (2007), classified by Naito et al. (2007)], SN2008fp [Pignata et al. (2008), classified by Wang et al. (2008a)] and SN2011fe [discovered and classified by Nugent et al. (2011)]. We derive upper limits on the bolometric luminosities of the progenitors assuming blackbody spectra with effective temperatures between 30 and 150 eV. The luminosities found in this study are compared to those of known super-soft X-ray sources (SSSs) in nearby galaxies.

Together with SN2007on, the 10 SNe examined in this study comprise the complete set of currently known SNe Ia that have pre-explosion images in the Chandra archive. We note that it is currently unclear if the progenitor of SN2007on has been directly observed or not (see Roelofs et al. 2008; Voss & Nelemans 2008). Due to this ambiguity, we refrain from dealing with SN2007on in this study.

In Section 2, we describe the Chandra observations used in this study. Section 3 relates the methods employed in the data analysis of these observations. Section 4 discusses our results, and Section 5 concludes.

2 OBSERVATIONS

By searching the Chandra Data Archive, we found pre-explosion images taken with the Advanced CCD Imaging Spectrometer (ACIS-S) at the positions of 10 nearby (< 25 Mpc) SNe Ia. The SNe in question are SN2002cv, SN2003cg, SN2004W, SN2006X, SN2006dd, SN2006mr, SN2007gi, SN2007sr, SN2008fp and SN2011fe. No obvious sources were found on the pre-explosion images for any of these SNe.

For SN2002cv, SN2003cg, SN2004W, SN2006X, SN2006dd, SN2006mr, SN2007gi and SN2008fp, only a single pre-explosion Chandra image exists for each of the SNe, and SN2006dd and SN2006mr are on the same image. Several of these images have long (> 30 ks) exposure times. For SN2007sr and SN2011fe, multiple pre-explosion Chandra images exist, and these can be combined to give very long (several 100 ks) exposure times.

The observations analysed in this study are summarized in Table 2.

3 DATA REDUCTION

We analysed the Chandra observations using the CIAO 4.3 software suite. Initially, we examined the images in the entire photon energy range of Chandra, i.e. ~300 eV to ~10 keV, to determine whether a source was present. Thereafter, we limited our analysis to photon energies between 300 eV and 1 keV. For an SSS, any counts above 1 keV will be background anyway, so this approach allows more stringent upper limits to be placed on an assumed super-soft progenitor. No sources were found at or near the positions of any of the SNe analysed in this study in the two energy ranges used (i.e. 300 eV–10 keV and 300 eV–1 keV).

For our data model, we assumed an absorbed blackbody, using the spectral models xphabs and xrtbody, which correspond to XSPEC’s phabs and bbody, respectively. We generated spectral-weights files for the appropriate interstellar absorption columns (see below) and four different effective temperatures: $kT_{\text{eff}} = 30, 50, 100$ and 150 eV. The spectral-weights files were used to generate exposure maps for each of the images for each of the four effective temperatures. For SN2007sr and SN2011fe, multiple pre-explosion images exist, and for these SN position we combined the binned images and the exposure maps to obtain deeper observations.

The distances to the progenitors of SN2002cv, SN2003cg, SN2004W, SN2006X, SN2007gi and SN2008fp were assumed identical to the galactocentric distances to their host galaxies as listed in the NED online data base. The distance to the progenitor of SN2006dd and SN2006mr is taken from Stritzinger et al. (2010). The distance to the progenitor of SN2007sr is the one given in Schweizer et al. (2008). For SN2011fe, we used the recent distance value given in Shappee & Stanek (2011).

The hydrogen columns were found either directly in the literature or by using the formula (Güver & Özel 2009) $N_\text{H} \equiv 2.21 \times 10^{21} A_V$, where $N_\text{H}$ is the neutral hydrogen column in cm$^{-2}$ and $A_V$ is the total V-band extinction given in magnitudes. The total V-band extinction is found from the reddening law $R_V \equiv A_V/E(B-V)$, where $R_V$ is the reddening and $E(B-V)$ is the selective optical extinction or colour excess $E(B-V) \equiv A_B - A_V$.

For two SNe (SN2004W and SN2008fp), no explicit values for the hydrogen column, reddening or extinction could be found in the literature. For the two SNe in NGC 1316, the column in the host galaxy was assumed to be negligible, following Stritzinger et al. (2010). For these four cases, we used the value for the Galactic column found in Dickey & Lockman (1990), as referenced with CIAO’s COLDEN tool. For SN2011fe, Chomiuk et al. (2012) estimated a column value about twice that of the Galactic one, while Stritzinger et al. (2010) assumed the column in the host galaxy to be negligible. Since SN2011fe is the closest SN Ia in several decades, and the closest to have pre-explosion archival Chandra data, we consider both column values in our analysis. The host galaxies, distances and columns for the SNe analysed in this study are summarized in Table 1.

For each observation, we found a good estimate of the average number of background photons from a suitably chosen region free of point sources close to the source. We then used a circular aperture of radius 4.5 pixel (covering more than 90 per cent of the point spread function of all observations) around the position of the SN and extract the number of photons. This aperture contains a Poissonian realization of the expected average number of counts from a SN.
source plus the background.\textsuperscript{3} For this photon count \(N_{\text{obs}}\), we found the maximum average number of counts \(\mu\), for which the probability \(P\) of observing \(N_{\text{obs}}\) photons is within \(3\sigma\), assuming Poissonian statistics [see e.g. Gehrels 1986; \(P(\mu, N \leq N_{\text{obs}}) \leq 0.0013\)]. This \(\mu\) represents the \(3\sigma\) upper limit of any progenitor including background. We find the upper limit to the luminosity of the source according to the formula

\[
L_{\text{X,UL}} = 4\pi (\mu - b) (E_\gamma) d^2 / \zeta,
\]

where \(b\) is the expected background for a circular aperture of radius 4.5 pixel, \((E_\gamma)\) is the average energy of the photons found from the absorbed XSPEC model for the assumed spectrum, \(d\) is the distance to the SN and \(\zeta\) is the value of the exposure map for the given spectrum at the position of the SN on the detector.

The luminosities were then corrected for interstellar absorption to yield the unabsorbed luminosities.

Since our data model is limited to photons from 300 eV to 1 keV, the luminosities found are scaled to provide bolometric luminosities:

\[
L_{\text{bol,UL}} = L_{\text{X,UL}} / C.
\]

For the values of \(kT_{\text{BB}}\) used in our analysis, the scaling factors are

\[
\begin{align*}
30\text{eV} & : C = 9.58 \times 10^{-3}, \\
50\text{eV} & : C = 1.40 \times 10^{-1}, \\
100\text{eV} & : C = 6.01 \times 10^{-1}, \\
150\text{eV} & : C = 7.22 \times 10^{-1}.
\end{align*}
\]

The observations analysed in this study, along with the photon counts and exposure map values used to calculate the upper limit luminosities, are listed in Tables 2 and 3. The bolometric luminosities are shown in Figs 2–11. These images show all events from 0.3 to 1 keV.

Our results are summarized in Table 3.

\section{4 DISCUSSION}

Disregarding the ambiguous case of SN2007on, we now have 10 pre-explosion \textit{Chandra} X-ray images of the positions of SNe Ia, and none of them shows evidence of a progenitor.

Fig. 1 shows a comparison between our results and the bolometric luminosities of known persistent close-binary and symbiotic SSSs in the Galaxy, Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) from Greiner (2000). Clearly, the bolometric luminosity upper limits of SN2011fe and SN2007sr are probing the luminosity space of ‘canonical’ SSSs (i.e. \(kT_{\text{BB}} = 30–100\text{eV}\), \(L_{\text{bol}} = 10^{37–39}\text{erg s}^{-1}\)). For both these SNe, we can rule out a naked, bright SSS progenitor. However, an SSS progenitor in the lower part of the expected effective temperature space is still permitted by the observations.

Upper limits based on archival \textit{Chandra} observations were reported previously for SN2002cv, SN2004W and SN2006mr by Voss & Nelemans (2008) and later corrected in Nelemans et al. (2008). However, the method used in those earlier studies was rather different from the one used in the present study: the \textit{Chandra} counts were binned into soft, medium and hard photons, and for each energy bin the total luminosity was calculated from an assumption that the spectrum was flat. The upper limits given for SN2002cv, SN2004W and SN2006mr in Voss & Nelemans (2008) were \(\lesssim 7.9 \times 10^{37}, \lesssim 3.5 \times 10^{37} \text{ and } \lesssim 1.3 \times 10^{38}\text{erg s}^{-1}\), respectively. However, due to the simplified spectral assumption used in that study, and the fact that only Galactic hydrogen was taken into account in Voss & Nelemans (2008), the upper limits found in the present study should be considered more accurate. Bolometric upper limits for SN2007sr for \(kT_{\text{BB}} = 50, 100\) and 150 eV were reported in Nelemans et al. (2008) and are consistent with the results of the present study. For SN2011fe, X-ray upper limits of \(<10^{36}\text{erg s}^{-1}\) were reported by Butler et al. (2011) for photons with energies between 300 and 700 eV and a 67 eV blackbody spectral model. Subsequently, Li et al. (2011) reported upper limits of \(2.7 \times 10^{37}\text{erg s}^{-1}\) on the bolometric luminosity of the progenitor of SN2011fe, similarly based on a blackbody model with \(kT_{\text{BB}} = 67\text{eV}\). The results of both of the aforementioned studies are in agreement with the results of this paper. We note that the slightly larger upper limits found by Li

\begin{table}[h]
\centering
\begin{tabular}{llll}
\hline
Supernova & Host galaxy & Distance (Mpc) & Absorbing column \((N_\text{H} \text{cm}^{-2})\) & Reference \\
\hline
2002cv & NGC 3190 & 16.4 & \(1.93 \times 10^{22}\) & Elias-Rosa et al. (2008) \\
2003cg & NGC 3169 & 15.1 & \(2.99 \times 10^{21}\) & Elias-Rosa et al. (2006) \\
2004W & NGC 4649 & 14.6 & \(2.12 \times 10^{21}\) & Dickey & Lockman (1990) \\
2006X & NGC 4321 & 20.9 & \(2.30 \times 10^{21}\) & Wang et al. (2008b) \\
2006dd & NGC 1316 & 17.8 & \(2.13 \times 10^{20}\) & Dickey & Lockman (1990) \\
2006mr & NGC 1316 & 17.8 & \(2.13 \times 10^{20}\) & Dickey & Lockman (1990) \\
2007gi & NGC 4036 & 21.2 & \(6.85 \times 10^{20}\) & Zhang et al. (2010) \\
2007sr & NGC 4038/39 & 22.3 & \(4.00 \times 10^{20}\) & Nelemans et al. (2008) \\
2008fp & ESO 428-G14 & 20.4 & \(2.21 \times 10^{21}\) & Dickey & Lockman (1990) \\
2011fe & M101 & 6.4 & \(3.02 \times 10^{20}/1.14 \times 10^{20}\) & Chomiuk et al. (2012)/Dickey & Lockman (1990) \\
\hline
\end{tabular}
\caption{Host galaxies, distances and total hydrogen columns for each of the SNe analysed in this study.}
\end{table}

\textsuperscript{3} This was unproblematic for all observations except one; for SN2006mr, choosing a suitable background region was more difficult, due to the proximity of a large, unresolved and uneven background. To be conservative, for SN2006mr we chose a background region that was less bright than the immediate background of the assumed progenitor position and made our calculations using the resulting background photon count. Since this background is clearly smaller than the actual background, our upper limits for the progenitor of SN2006mr should be considered even more solid than the rest of our results. However, it also means that formally our analysis indicates the presence of a source at the position of the progenitor of SN2006mr, even though it is not actually possible to infer the presence of one.
et al. (2011) can be explained by the shorter exposure time of their combined image used in their study.

We note that upper limits for SN2011fe were also reported in Liu et al. (2012), who found a value of $L_X < 6.2 \times 10^{55} \text{ erg s}^{-1}$ for $kT_{BB} = 100 \text{ eV}$ in the same energy band as the one used in our study (0.3–1 keV). However, for reasons that are unclear to us, Liu et al. (2012) subsequently find different corresponding bolometric luminosities, which could indicate an incorrect conversion factor from X-ray to bolometric luminosity. Additionally, that paper makes an incorrect statement concerning the blackbody temperatures and response matrices used to find the upper limits found in our study (last paragraph of section 3 in that paper). As should be clear from our Section 3, we have consistently used the blackbody temperature to calculate our X-ray to bolometric luminosity conversion factors. Also, the fact that the ACIS-S detector is unreliable below 300 eV has no impact on our results, because we only use observed photons with energies above this threshold.

As mentioned in Section 1, Di Stefano (2010) showed that the number of observed SSSs in nearby galaxies is one to two orders of magnitude too small compared with the estimated number of expected SSSs if these were the progenitors of SNe Ia. A similar result was found by Gilfanov & Bogdán (2010), who showed that the integrated super-soft X-ray luminosity of elliptical galaxies is roughly two orders of magnitude too low to account for the SN Ia rate. Although our constraints are not as strong as those found in the two above-mentioned studies, our results are consistent with them.

The search for archival Chandra images was initially undertaken in an attempt to solve the SD versus DD question, since at least in the na"ive picture the SD progenitors were expected to be X-ray bright, while the DD progenitors were not. However, as a number of recent studies show, the question of X-ray brightness of SN Ia progenitors has turned out to be somewhat more complicated than this.

(i) Chandra and other current X-ray satellites are only sensitive to photon energies considerably above the $kT_{BB}$ of SSS, above $\sim$300 eV or so. The corrections applied in equation (2) illustrate that a small change in $kT_{BB}$ has a drastic effect on the correctional constant $C$ for lower $kT_{BB}$ sources. The effective temperature of
an SD progenitor depends crucially on the extent of the emitting region, and the radius of an actual SD accretor therefore does not have to diverge much from that of the theoretical model to make the system unobservable to Chandra. For such lower \( kT_{BB} \) sources, ultraviolet (UV) observations should be more useful than X-rays. However, UV observations of these sources are problematic for other reasons, such as interstellar extinction.

(ii) As discussed by Hachisu, Kato & Nomoto (2010), a significant fraction of the progenitors of SD SNe Ia may spend the final phase of their accretion towards going SN in the nova regime where their accretion and associated X-ray emission will be periodic instead of continuous. For recent observations of super-soft X-ray emissions from novae, see Henze et al. (2010, 2011), Schaefer & Collazzi (2010) and Voss et al. (2008).

(iii) Even a steadily accreting massive WD consistent with a naked, canonical SSS may be obscured by local matter lost from the system (see Nielsen et al. 2012). Several recent studies have found indications of the presence of circumstellar matter (e.g. Gerardy...
Figure 1. Comparison between the bolometric luminosity upper limits found in this paper with bolometric luminosities of known SSSs in nearby galaxies. The black lines are the upper limits reported in this paper (for SN2011fe, the two curves correspond to the two different column values used; see Section 3). The green, blue and red points are known persistent SSS in the Milky Way, SMC and LMC, respectively, taken from the online SSS catalogue by Greiner (2000, see also references therein). The plot only includes sources that are characterized as close-binary super-soft (CBSS) or symbiotic (Sy) systems. We note that many of the fits are based on single observations, and suffer from relatively large systematic uncertainties.

Figure 2. Cut-out of Chandra image for observation 2760. The circle corresponds to an aperture of 4.5 pixel at the position of SN2002cv.

Figure 3. Cut-out of Chandra image for observation 1614. The circle corresponds to an aperture of 4.5 pixel at the position of SN2003cg.

Figure 4. Cut-out of Chandra image for observation 785. The circle corresponds to an aperture of 4.5 pixel at the position of SN2004W.

Figure 5. Cut-out of Chandra image for observation 400. The circle corresponds to an aperture of 4.5 pixel at the position of SN2006X.

et al. 2004; Borkowski, Hendrick & Reynolds 2006; Immler et al. 2006; Patat et al. 2007; Chiotellis, Schure & Vink 2011; Sternberg et al. 2011).

(iv) If the progenitor is a rapidly rotating WD of the type suggested in Di Stefano, Voss & Claeys (2011), the X-ray emission of the progenitor would have ceased long before the explosion itself.

(v) The detailed spectral shape of the SSS is uncertain (Orio 2006), and the assumption of a blackbody spectrum used in this study may therefore be inaccurate. Due to the higher sensitivity of Chandra above 1 keV, the upper limits are more constraining for harder spectra. This is at most an order of magnitude different compared to our 150 eV data points, for the unrealistic assumption of a power law with photon index $\Gamma' = 2$, typical of X-ray binaries.
Figure 6. Cut-out of Chandra image for observation 2022. The circle corresponds to an aperture of 4.5 pixel at the position of SN2006dd.

Figure 7. Cut-out of Chandra image for observation 2022. The circle corresponds to an aperture of 4.5 pixel at the position of SN2006mr.

Figure 8. Cut-out of Chandra image for observation 6783. The circle corresponds to an aperture of 4.5 pixel at the position of SN2007gi.

Figure 9. Cut-out of combined image consisting of Chandra observations 315, 3040, 3041, 3042, 3043, 3044 and 3718. The circle corresponds to an aperture of 4.5 pixel at the position of SN2007sr.

Figure 10. Cut-out of Chandra image for observation 4866. The circle corresponds to an aperture of 4.5 pixel at the position of SN2008fp.

Figure 11. Cut-out of combined image consisting of Chandra observations 4731, 5296, 5297, 5300, 4732, 5309, 4733, 5322, 5323, 4737, 5338, 5339, 5340, 4735, 6114, 6115, 6118, 4736, 6152, 4737, 6169, 6170 and 6175. The circle corresponds to an aperture of 4.5 pixel at the position of SN2011fe.
[cf. the limits for power law and blackbody in Li et al. (2011) for 2011fe].

(vi) To make things more difficult, a DD progenitor may also emit soft X-rays for a significant period of time (see Yoon, Podsadiłowski & Rosswog 2007). However, the luminosities expected in this scenario are approximately an order of magnitude lower than for the steadily accreting SD progenitor. In any case, the detailed workings of the DD merger are still not fully understood (cf. Lorén-Aguilar et al. 2009; Pakmor et al. 2010; van Kerkwijk, Chang & Justham 2010). It is currently unclear if the lighter WD forms a disc around the more massive companion, or if both WDs are disrupted in the course of the merging event, and this would have an important effect on the possible X-ray emissions from such systems.

For the above-mentioned reasons, the question of an SD versus DD progenitor cannot be decided based solely on the X-ray brightness (or lack hereof) of an SN Ia progenitor. However, a direct detection of X-ray emissions from a progenitor would still be interesting, and would provide much needed observational evidence for the progenitors of SNe Ia with which to compare theoretical work, something that is sorely lacking at the moment.

5 CONCLUSIONS

We have examined archival Chandra pre-explosion images corresponding to the position of 10 SNe Ia to determine upper limits to the bolometric luminosities of the progenitors. Disregarding the ambiguous case of SN2007on, our study comprises a complete list of nearby SNe that have pre-explosion images in Chandra. We compared this sample with known SSSs in the Milky Way and Magellanic Clouds. While most of the luminosities of our sample SNe are too loosely constrained, two SNe (SN2007sr and SN2011fe) probe the luminosity space of known SSSs. The results indicate that the progenitors of these SNe were not bright SSSs shortly before they exploded as SNe Ia. However, our upper limits are not constraining enough to rule out less bright super-soft X-ray progenitors.

The theoretical picture concerning the super-soft X-ray characteristics of SN Ia progenitors is less than clear. A non-detection does not rule out an SD progenitor, but neither does a positive detection necessarily implicate an SD progenitor or rule out a DD progenitor. Regardless, the archival search method of the Chandra archive is highly useful in putting much needed observational constraints on the progenitors, and is a powerful complement to statistical studies of the characteristics of progenitor populations. The method will be increasingly useful as the sky coverage grows. As SN2011fe shows, if an SN Ia explodes in a nearby galaxy, the chances that several pre-explosion Chandra images of the position exist are good, hence affording stringent upper limits to be calculated or, in the case of an X-ray-bright progenitor, a direct detection to be made.

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