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Optical detection of the radio supernova SN 2000ft in the circumnuclear region of the luminous infrared galaxy NGC 7469*

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ABSTRACT

Context. (Ultra)Luminous Infrared Galaxies (ULIRGs) produce massive stars in large quantities in their central starburst regions. The expected rate of supernova explosions is, on average, about one per year. Detection of these supernovae in the expected numbers has proven elusive so far.

Aims. Illustrate the general benefits and limitations of supernova searches in (U)LIRGs in the optical using the previously detected luminous type II radio supernova SN 2000ft in NGC 7469 as a study case.

Methods. Multi-epoch Hubble Space Telescope (HST) optical imaging at different wavelengths and two dimensional PSF fitting algorithms are used to search, and characterize, the optical emission of SN 2000ft.

Results. SN 2000ft is detected in two independent Planetary Camera images (*F547W* and *F814W*) taken May 13, 2000, about two months before the predicted date of the explosion (July 19, 2000), based on the analysis of its radio light evolution by Alberdi and collaborators. The apparent optical magnitudes and red color of SN 2000ft indicate that it is observed through an extinction of at least $A_{\rm V} = 3.0$ mag. The extinction corrected lower limit to the absolute visual magnitude ($M_{\rm V} \leq -18.0$), identifies SN 2000ft as a luminous supernova in the optical, as other luminous radio supernovae before. SN 2000ft exploded in a region located at only $0\farcs1$ (i.e. 34 ± 3 pc) west of a faint cluster (C24). No parent cluster is identified within the detection limits of the HST short exposures.

Conclusions. The unambiguous detection of SN 2000ft in the visual shows that multi-epoch sub-arcsecond ($FWHM \sim 0\farcs1$) optical imaging is also a valid tool that should be explored further to detect supernovae in the dusty (circum)nuclear regions of (U)LIRGs.

Key words. galaxies: Seyfert – galaxies: starburst – supernovae: individual: SN 2000ft

1. Introduction

A large fraction of the star formation in the Universe has taken place in optically-obscured galaxies (Lagache et al. 2005). At low-z, luminous infrared galaxies (LIRGs) with luminosities $L_{\rm IR}(8{-}1000\,\mu{\rm m}) > 10^{11}\,L_{\odot}$, are more numerous than optically-selected starburst and Seyfert galaxies of comparable bolometric luminosity, and at the highest luminosities, $L_{\rm IR} > 10^{12}\,L_{\odot}$, they exceed the space density of quasi-stellar objects (QSOs) by a factor of 1.5–2 (Sanders & Mirabel 1996, and references therein). In a large fraction of low-z LIRGs the bulk of the star formation is concentrated in (circum)nuclear ring-like or mini-spiral structures (Alonso-Herrero et al. 2006, and references therein) characterized by the presence of numerous dusty, young ($\leq$100 Myr), massive ($\sim$$10^5$–$10^7\,M_{\odot}$) star clusters and HII regions (Scoville et al. 2000; Alonso-Herrero et al. 2002, 2006).

Searches for supernovae associated with recent star formation processes in LIRGs have proceeded with various rates of success. Multi-epoch Very Long Baseline Interferometry (VLBI) radio imaging (Lonsdale et al. 2006; Smith et al. 1998) has provided evidence for numerous radio supernovae in Arp 220. Candidates to radio supernovae have also been detected in LIRGs such as NGC 6240 (Gallimore & Beswick 2004) and Arp 299 (Neff et al. 2004) based on Very large Array (VLA) and VLBA imaging. Attempts to detect the expected high rate of supernovae in LIRGs have also been conducted in the near-infrared from the ground (Maiolino et al. 2002; Mannucci et al. 2003;

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Mattila et al. 2004; Mattila & Meikle 2001) and with NICMOS on the HST (Cresci et al. 2007). The observed near-IR supernova rate is a factor 3 to 10 smaller than estimated from the far-infrared luminosity (Mannucci et al. 2003). Thus the conclusion that dust extinction in these galaxies is so high that obscures most SN even in the near-IR seems unavoidable. However, the distribution of dust in the central regions of (U)LIRGs is clumpy on scales of 100 pc or less (Alonso-Herrero et al. 2006) and consequently star-forming regions with relatively low extinction ($A_V \leq 2-6$ mag) coexist with highly absorbed young star clusters (Scoville et al. 2000; Surace et al. 2000). Therefore, the possibility of detecting supernovae in the low-extinction regions is still open and should be explored further with high angular resolution imaging.

NGC 7469 is a LIRG with $L_{IR} = 5 \times 10^{11}\ L_{\odot}$, at a distance of 70 Mpc (Alberdi et al. 2006). NGC 7469 contains a luminous Seyfert 1 nucleus surrounded by a dusty circumnuclear starburst ring of about 1.6 kpc in diameter (Cutri et al. 1984; Wilson et al. 1986; Wilson et al. 1991; Miles et al. 1994; Genzel et al. 1995; Malkan et al. 1998; Scoville et al. 2000). SN 2000ft was detected at 8.4 GHz on October 27, 2000 (Colina et al. 2001a,b) during the course of a monitoring campaign designed to search for radio supernovae in NGC 7469. Detailed subsequent modelling of the radio multi-frequency light curve has allowed to establish that SN 2000ft displays the radio properties of a bright type II supernova that exploded on July 19, 2000 (Alberdi et al. 2006, 2007). Previous attempts at detecting SN 2000ft in the optical from the ground failed (Li et al. 2001). This letter presents the HST detection in the optical of supernova SN 2000ft in NGC 7469. Implications for the detection of supernovae in (U)LIRGs using multi-epoch sub-arcsec optical imaging are discussed.

2. Hubble Space Telescope imaging and photometry

Optical HST images of NGC 7469 were retrieved from the archive and calibrated using the *On the Fly Recalibration* (OTFR) system. Images were taken with the WFPC2 Planetary Camera (*F547M*, *F606W*, and *F814W*), and with the ACS High Resolution Camera (*F330W*). These images have a plate scale of 0.″0455 (WFPC2/PC) and 0.″026 (ACS/HRC), providing a PSF (TinyTim *FWHM*) of between 0.″051 (*F330W*) and 0.″085 (*F814W*). The full set of HST data also includes lower angular resolution ultraviolet (WFPC2/*F218W*) and near-infrared (NICMOS, Scoville et al. 2000) imaging, that have been used in the modelling of the properties of the circumnuclear star clusters (see Díaz-Santos et al. 2007, for details).

Accurate photometric measurements of point-like sources in complex local backgrounds as that present in the nuclear regions of NGC 7469 cannot rely on standard aperture photometry. The flux contribution of the background changes from source to source, and therefore has to be modelled and subtracted accordingly. The fluxes and magnitudes reported in this paper make use of a χ^2-minimizing Marquardt algorithm that models point-like sources on top of a diffuse background emission as the combination of a two-dimensional Gaussian and planes functions representing the point source and surrounding background, respectively (Díaz-Santos et al. 2007). Filter-dependant PSF corrections were done assuming realistic PSF TinyTim models (Krist et al. 1998).

3. Results and discussion

3.1. Optical detection of supernova SN 2000ft

Supernova SN 2000ft was first detected at 8.4 GHz on October 27, 2000 (Colina et al. 2001a,b). Subsequent monitoring at various radio frequencies allowed us to investigate in detail the radio light curve of SN 2000ft and to predict July 19th, 2000 (±40 days) as the date of the explosion (Alberdi et al. 2006, 2007). Optical HST images of NGC 7469 were taken for different programs at three different epochs (referred hereinafter as epoch 1, 2 and 3) from June 10, 1994 (*F606W*) to May 13, 2000 (*F547M* and *F814W*), and November 20, 2002 (*F330W*). In particular, epoch 2 images were taken about two months before the explosion date predicted from the radio light curve analysis. On the other hand, epoch 1 and 3 images were obtained about 6 years before and 2.5 years after the explosion, respectively.

Since the angular resolutions of the A configuration VLA and HST images are similar to within a factor of two, it is assumed that the bright radio and optical Seyfert 1 nucleus are spatially coincident. The comparison of the radio map and optical images shows the presence of an optical point source in the epoch 2 images (*F547M* and *F814W*) in a region of the circumnuclear star-forming ring coincident with the position of SN 2000ft, and close to cluster C24 (see Fig. 1; and Díaz-Santos et al. 2007, for the cluster naming convention). This point source is not detected in epochs 1 (*F606W*) and 3 (*F330W*) images indicating that the optical emission due to a transient source. Moreover, since the epoch 2 images were taken about two months before the predicted epoch of the explosion, the increase in flux must represent the transient optical emission of the radio supernova SN 2000ft.

To establish the reality of the optical transient, the increase in flux associated with SN 2000ft has been measured relative to that of non-variable bright star clusters like C2, C3 and C5 located in the ring (see Fig. 1). Since no pre-explosion images are available in the *F547M* and *F814W* filters, the fluxes of the different clusters and SN 2000ft are normalized to the epoch 1 *F606W* flux (see Table 1). The differences in the measured *F547M* and *F814W* to *F606W* fluxes of the clusters are due to differences in the bandpass of the filters (pivot wavelengths of 5483 Å, 8012 Å, and 5997 Å, respectively), and to intrinsic cluster to cluster changes in their spectral energy distribution due to variations in internal extinction and ages. All these effects combined result in *F547M* and *F814W* to *F606W* flux ratios that could be different from one. In fact, the average values (see Table 1) indicates that the *F547M* and *F606W* fluxes of the nearby star clusters are about the same (1.1 ± 0.2) while the *F814W* flux is about half (0.51 ± 0.04). However, the *F547M* and *F814W* flux associated with with the region where SN 2000ft exploded is about 5 and 8 times that of the *F606W* flux, respectively (see Table 1 for more accurate values). Therefore, relative to the non-variable bright star clusters, the optical flux associated with SN 2000ft increased the flux in the region where it exploded by factors of about 4 and 15 in the *F547M* and *F814W* light, respectively.

We should also note that image *F606W* taken in June 1994 shows the presence of a bright source at 0.″47 northeast of the Seyfert 1 nucleus (object SN? in the *F606W* image in Fig. 1). This source is not detected in the images *F547M* and *F814W* taken in May 2000, about six years later. It is unlikely that the source is an artifact. Ghosts of bright sources like the Seyfert 1 nucleus are known to exist. However, field flattener ghosts are

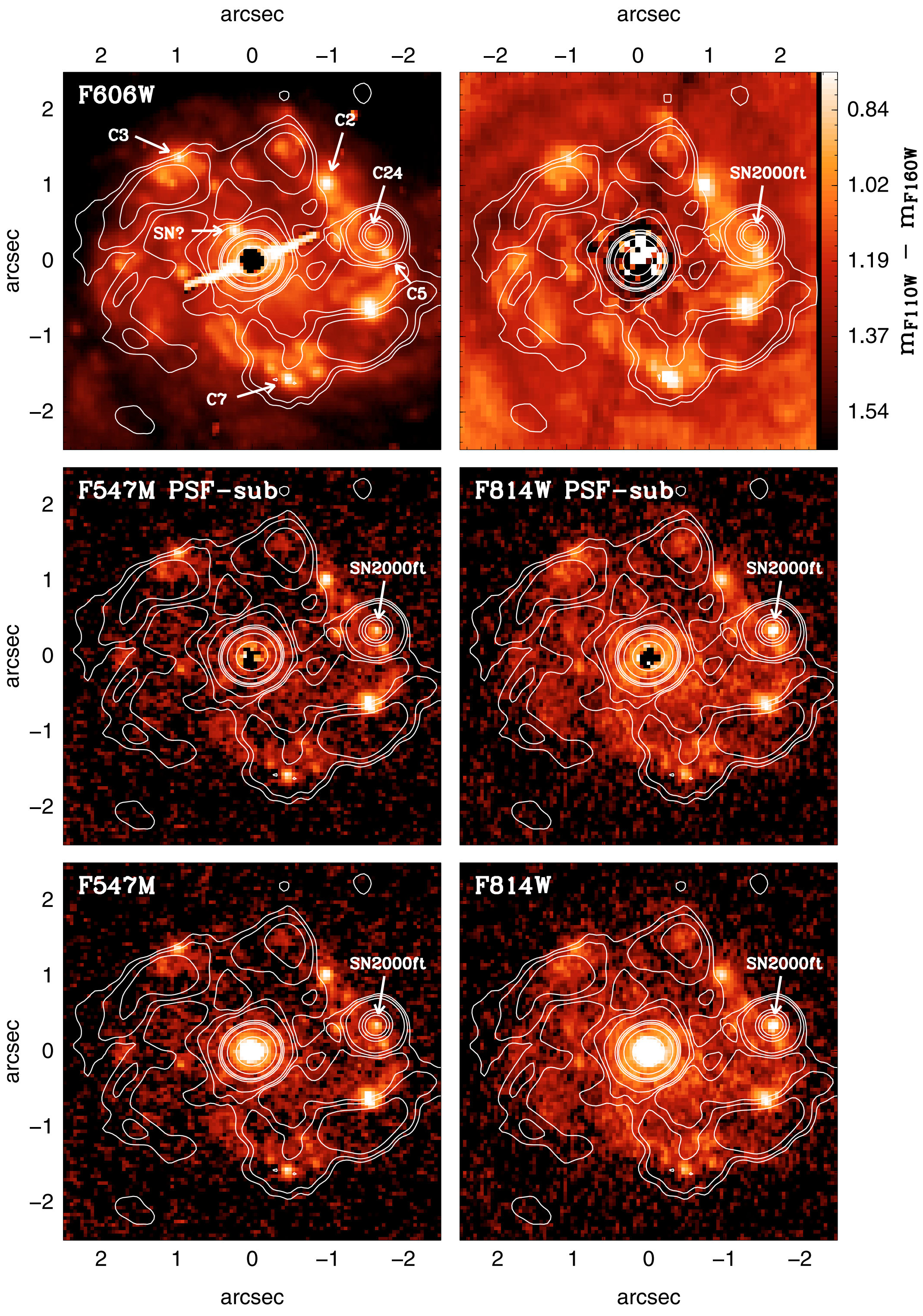

Fig. 1. HST WFPC2 Planetary Camera images of the nucleus and circumnuclear star-forming ring of NGC 7469 in the available optical filters. Contours represent the VLA 8.4 GHz image taken on October 27, 2000 when the supernova SN 2000ft was first detected (Colina et al. 2001). The HST images taken in May 2000 (*F547M* and *F814W*) clearly show an increase in flux in the region where SN 2000ft exploded with respect to that of clusters C2, C3 and C5 as observed through the *F606W* filter in 1994 (see text and Table 1). Image *F606W* shows a bright source (SN?) at 0.″47 from the nucleus that could be real and associated with another supernova (see Sect. 3.1 for details). The dust distribution is shown in the HST/NICMOS $J-H$ color image (*F110W* − *F160W*, upper right panel) taken in Nov. 1997. Assuming the diffuse stellar emission is associated with an old population, the range of colors corresponds to visual extinctions of $0 < A_V \leq 3$ mag (between 1 and 5 mag if a young stellar population is considered). The bright Seyfert 1 nucleus has been removed from the images in the top and central panels to better identify the surrounding star clusters and diffuse structure in the ring, in particular in the *F606W* and $J-H$ color images. The original *F547M* and *F814W* images with the bright nucleus are presented in the bottom panels for reference.

Table 1. HST photometry for SN2000ft and reference star clusters.

Region (1)[a]	*F330W* (2)[b]	*F547M* (3)	*F606W* (4)	*F814W* (5)	*F547M*/*F606W* (6)[c]	*F814W*/*F606W* (7)	*F330W*/*F606W* (8)
C2	1.69×10^{-16}	1.05×10^{-16}	8.85×10^{-17}	4.95×10^{-17}	1.2	0.6	1.9
C3	7.38×10^{-17}	6.74×10^{-17}	4.94×10^{-17}	2.36×10^{-17}	1.4	0.5	1.5
C5	6.42×10^{-17}	4.03×10^{-17}	4.67×10^{-17}	2.27×10^{-17}	0.9	0.5	1.4
Mean	…	…	…	…	1.1 ± 0.2	0.51 ± 0.04	1.6 ± 0.2
C24[d]	3.54×10^{-17}	…	1.60×10^{-17}	…	…	…	2.2
C24(fit)[e]	2.90×10^{-17}	1.97×10^{-17}	1.63×10^{-17}	1.01×10^{-17}	1.2	0.6	1.8
SN_Region[f]	1.48×10^{-17}	…	1.43×10^{-17}	…	…	…	1.0
SN 2000ft[g]	…	6.83×10^{-17}	…	1.08×10^{-16}	4.8	7.6	…

[a] Cluster label after Díaz-Santos et al. (2007). [b] Measured fluxes in Cols. (2) to (5) given in erg s^{-1} cm^{-2} Å^{-1}. [c] Flux ratios for the different regions as obtained from the measured fluxes given in previous columns. [d] Photometry of the closest cluster (C24) identified at a distance of 0.″1 from SN 2000ft. No measurement is given for filters *F547M* and *F814W* due to its close distance to SN 2000ft. [e] Flux values for the corresponding filters, obtained from the best-fitted spectral energy distribution to the cluster C24 photometry covering the ultraviolet to near-infrared range (Díaz-Santos et al. 2007). [f] *F330W* and *F606W* values represent the fluxes measured through an aperture of 0.″14 diameter centered at the position where SN 2000ft is detected in the *F547M* and *F814W* images. [g] Photometry of SN 2000ft in *F547M* and *F814W* images taken in May 13, 2000.

found along a line from the center of the Planetary Camera to the bright object (nucleus), and away from the center. This is not the case for this object. Filter ghosts can also be ruled out since they are usually fan-shaped and typically about 1% of the bright source (nucleus) countrate. The source is too bright and also point-like (0.″1 FWHM). The high counts (113 000 electrons) also rules out cosmic rays and hot pixels. Cosmic ray events produce a well defined distribution of the number counts per event with no single events producing more than 10 000 electrons (Heyer et al. 2004), i.e. a factor ten less than measured. Therefore if the object were real, it could have been a supernova that exploded at a distance of only 160 pc northeast of the Seyfert 1 nucleus with an apparent *F606W* magnitude of 19.1. No other image of NGC 7469 were taken close enough in time to confirm or disprove the reality of this detection.

3.2. SN 2000ft as a bright optical type II supernova

The increase in flux detected near cluster C24 (Fig. 1) in the epoch 2 images is interpreted as the optical emission from supernova SN 2000ft, with apparent magnitudes 19.29 ± 0.17 and 17.55 ± 0.14 in the *F547M* and *F814W* filters, respectively. Taking into account the *F547M* to *F555W* magnitude offset (0.006 mag) and the HST to ground-based V and I magnitude conversions for the Planetary Camera (Holtzman et al. 1995), the HST magnitudes translate to V and I magnitudes of $m_V = 19.20 \pm 0.17$ and $m_I = 17.45 \pm 0.14$.

The absolute optical magnitude of SN 2000ft can be derived after reddening corrections based on the comparison of the observed and expected intrinsic $V - I$ colors are applied. The detailed analysis of the SN 2000ft radio emission (Alberdi et al. 2006), allowed us to confirm that the shape of its radio light curve is not consistent with that of any known SNIb/c (Weiler et al. 2002) whereas it behaves like a typical type II supernova. Moreover, its peak radio luminosity identifies SN 2000ft as luminous radio supernova (Alberdi et al. 2006).

The epoch 2 optical images were taken on May 13, 2000, about two months before the predicted explosion date (July 19th, 2000 ± 40 days; Alberdi et al. 2006, 2007). Therefore within the uncertainties of the prediction, the optical detection of SN 2000ft appears to be close to the explosion date. Type II supernovae have intrinsic optical colors of $V - I \leq 0.5$ during the early 50 days after the explosion (Vinkó et al. 2006; Zhang et al. 2006; Ho et al. 2001; Fassia et al. 2000).Therefore, the intrinsic $V - I$ color of SN 2000ft is assumed to be 0.5, or less. Since the measured $V - I$ color for SN 2000ft is 1.75 ± 0.22, this color excess translates into extinctions of at least 3.0 ± 0.5 and 1.8 ± 0.3 mag in the V and I bands, respectively. The corresponding V and I extinction corrected absolute magnitudes are ≤−18.0 (±0.6) and ≤−18.5 (±0.3), respectively.

A relatively large fraction (7 out of 24) of type II supernovae classified as luminous have an average B magnitude of −18.8 (±0.6) at their maximum light, while more regular ones are about two magnitudes fainter with an average magnitude of −16.6 (±0.6). Considering that type II supernovae have an average $B - V$ color of 0.0 at maximum light (Patat et al. 1994), the visual (V) absolute magnitude of the luminous supernovae correspond to −18.8. Therefore since SN 2000ft is brighter than −18.0 in the visual, it can be identified as a luminous type II supernova in the optical. Moreover, prototypes of these bright optical type II supernovae include SN 1979C and SN 1988Z (Patat et al. 1994) which also belong, as SN 2000ft, to the class of luminous type II radio supernovae (Alberdi et al. 2006, and references). In conclusion, SN 2000ft is both a luminous optical and radio type II supernova.

3.3. SN 2000ft in a dust-obscured massive star cluster

To establish the exact location of SN 2000ft, the relative astrometry of the peak of the SN 2000ft optical emission with respect to that of several bright point- like clusters (clusters C2, C3, C5 and C7 in Fig. 1) has been independently measured in the *F547M* and *F814W* images. In addition, the same measurements have been performed for the cluster C24 using the *F606W* image. Positional measurements were done with different methods including TinyTim PSF fitting (Díaz-Santos et al. 2007), Gaussian and intensity weighted centroid algorithms. These methods give consistent results with positional uncertainties of a tenth of a Planetary Camera pixel (i.e. ≤0.″00455). This high precision relative astrometry allows us to pin down the position of SN 2000ft at a location of 0.″100 ± 0.″009 (34 ± 3 pc) west of the faint, unresolved ($FWHM \leq 0.''08$) cluster C24 (Fig. 1).

Thus, the high angular HST resolution allows us to conclude that the region where SN 2000ft exploded is not identified with any of the 1.1 μm-selected (or optical) clusters detected in the *F110W* HST image (Díaz-Santos et al. 2007). According to the

HST color map (Fig. 1), SN 2000ft appears to have exploded in a region near the edge of a strong lane of dust surrounding the ring. This region could trace the location of a dust-obscured star cluster. The vast majority of the 1.1 μm-selected clusters are low extincted ($A_{\rm V} \sim 1$ mag), intermediate age (~9−20 Myr) with stellar masses in the 0.1 to 1×10^{7} $M_{\odot}$ range, while a few are more extincted ($A_{\rm V} \sim 3$ mag) and younger (Díaz-Santos et al. 2007). The apparent optical flux of a cluster similar in mass to these, but obscured by a screen of dust with an extinction equivalent to about 4 visual magnitudes, would be below the detection limit of the present optical HST images. Only a very massive (i.e. mass above 10^{7} $M_{\odot}$) cluster would have been detected behind 4 mag of visual extinction. Therefore, the fact that no cluster is identified at the location of SN 2000ft is consistent with a dust-obscured parent star cluster having a mass of no more than 10^{7} $M_{\odot}$.

3.4. Optical detection of supernovae in (U)LIRGS

Although there is only one ULIRG, Arp 220, at a distance of less than 100 Mpc, the number of LIRGs (i.e. 10^{11} $L_{\odot}$ < $L_{\rm IR}$ < 10^{12} $L_{\odot}$) like NGC 7469 within this distance is large. Of the 629 galaxies in the IRAS Revised Bright Galaxy Sample (Sanders et al. 2003), approximately 200 are in the LIRG luminosity range, most of them at distances of about 100 Mpc, or less. The expected supernova rate in these LIRGs corresponds to 0.24−2.4 $\rm yr^{-1}$, if the infrared luminosity is entirely produced by starbursts (Mannucci et al. 2003).

Recent attempts to detect supernovae in (U)LIRGs with the HST/NICMOS near-IR camera have failed (Cresci et al. 2007). Based on the infrared luminosity and number (17) of galaxies in the sample, no less than 12 supernovae were expected of which no confirmed event was detected. According to the authors, the shortage of supernova detections could be explained by a combination of effects, the most important being the existence of strong extinction ($A_{\rm V} \geq 11$ mag.) everywhere within the starburst regions, and the size of the region where the supernovae are generated. If supernovae were exploding within the inner 500 pc, even NICMOS would not be able to detect them.

Although the non detection of supernovae using NICMOS is not very encouraging, there are several aspects of the detection strategy that can be improved, therefore increasing the chances of detecting a larger fraction of the expected supernovae. It is well known than massive starbursts in (U)LIRGs occur mostly in the inner regions of these galaxies, so the sample has to be selected such that the best linear resolution is achieved. While the sample of (U)LIRGs selected by Cresci and collaborators is at an average distance of 150 Mpc, monitoring of other galaxies such as the NICMOS volume-limited sample of nearby LIRGs (Alonso-Herrero et al. 2006), at an average distance of 60 Mpc, would be more desirable. The expected number of SNe per year in such a sample would be about 12 for a total of 30 LIRGs and an average luminosity ($L_{\rm IR}$) of 2×10^{11} $L_{\odot}$.

Regarding internal extinction, although (U)LIRGs are dusty galaxies, the dust distribution in the nuclear regions is very patchy presenting regions of high and moderate extinctions on scales of hundred parsecs (Alonso-Herrero et al. 2006). The nuclear regions of (U)LIRGs are on average very red with typical $I-H$ colors in the 1.5 to 2.5 range (Surace et al. 2000) due to a complex combination of stellar populations, and dust absorption and emission. Even though the extinction in the I-band is about a factor 2.5 times higher than in the H-band (e.g. Rieke & Lebofsky 1985), the advantage of going to the near-IR where the extinction is lower, is compensated in the optical by the fact type II supernovae have blue intrinsic $I-H$ colors of 0.5, or less, at or near maximum light (Pozzo et al. 2006; di Carlo et al. 2002), i.e. about one to two magnitudes bluer than the nuclear regions of (U)LIRGs. Therefore, even if as in NGC 7469, only 10% of the recent star formation in LIRGs were in regions of low to moderate visual extinctions (i.e. $A_{\rm V} \leq 5$ mag), one could expect to detect several supernova events a year by monitoring a representative sample of low redshift LIRGs with HST. In this respect, near-IR NIC2 imaging does not provide the best angular resolution. Selecting shorter (optical) wavelengths increases the angular resolution in diffraction-limited telescopes by a factor of at least two, if for example the I-band is used. Moreover, HST optical instruments such as the ACS High Resolution Camera (HRC) has pixels with an angular size three smaller than that of NIC2 ($0\farcs026$ versus $0\farcs0755$). The smaller pixelation coupled with the shorter wavelengths increases the overall angular resolution of I-band ACS/HRC images by a factor of more than two with respect to that of NIC2 H-band images.

The different size of the pixels implies that the extended galaxy surface brightness seen by ACS/HRC pixels is a factor 9 smaller than that seen by NIC2 pixels, and therefore the contrast between the expected supernova emission (i.e. high surface brightness point source) and the surrounding, lower surface brightness emission will increase accordingly. The apparent H-band surface brightness of the inner $1\farcs0$ radius region of ULIRGs is in the 16−18 mag $\rm arcsec^{-2}$ range (Colina et al. 2001c). The PSFs of ACS/HRC *F814W* and NIC2 *F160W* are such that 80% of the flux of a point source is within an aperture of $0\farcs15$ and $0\farcs3$ in radius, respectively. Thus, the apparent I- and H-band magnitudes of the galaxy in the corresponding apertures are in the 21−23.0 and 17.4−19.4 ranges, respectively, assuming typical $I-H$ colors of 2 for the nuclear regions of ULIRGs (Surace et al. 2000).

As shown in previous sections the combination of multi-epoch observations with high angular resolution has allowed us to detect supernova SN 2000ft in the optical through an extinction of at least three magnitudes in the visual. SN 2000ft is classified as a bright radio supernova similar in luminosity to other radio supernovae recently detected in the nucleus of Arp 220 (Lonsdale et al. 2006), and falling in the upper end of the range of observed radio peak luminosities for known type II supernovae (Alberdi et al. 2006). These intrinsically bright supernovae will have apparent red magnitudes of $m_I \leq 16.5$, for distances of less than 100 Mpc, if not affected by extinction. More regular type II supernovae are about two magnitudes fainter than their bright counterparts (Patat et al. 1994). Thus, both bright and regular type II supernovae would have I- and H-band apparent magnitudes $19.5 \leq m_I \leq 21.5$ and $17.5 \leq m_H \leq 19.5$, respectively, if located in regions of low to moderate extinction (i.e. $A_{\rm V} \leq 5$ mag). Therefore, supernovae in these regions could be detected close to maximum light with relatively short (i.e. snapshots) I-band ACS exposures, and more easily than in the near-IR H-band as the expected galaxy flux contribution is of the order of that of the supernova. Future HST instruments like the WFPC3 UVIS channel with pixels of $0\farcs040$ (i.e. 1.6 times ACS/HRC) and a throughput higher than that of ACS/HRC in the optical range are also adecuate for the detection of supernovae as explained above.

In summary, multi-epoch, high angular (~$0\farcs1$) resolution optical (red) imaging should be considered potentially as a valid technique to probe the presence of supernovae in moderately absorbed star-forming regions in (U)LIRGs. Recently, adaptive optics (AO) near-infrared imaging (angular resolution of $0\farcs08$ with pixels of $0\farcs027$) with the ESO Very Large Telescope AO system, has allowed to detect a supernova (SN 2004ip) in the nuclear region of the LIRG IRAS 18293−3413, at a distance of 500 pc from its nucleus (Mattila et al. 2007), i.e. about the same distance from the nucleus as SN 2000ft in NGC 7469 (Mattila et al. 2007). Detection and characterization of supernovae in the highly absorbed regions ($A_V \gg 5$ mag) will be accessible through mid-IR, or radio multi-epoch imaging as already demonstrated (Alberdi et al. 2006; Lonsdale et al. 2006; Beswick 2007, for a review).

4. Conclusions

Multi-epoch Hubble Space Telescope (HST) imaging has been used to search for the optical emission of the luminous radio supernova SN 2000ft, previously detected at radio frequencies in the circumnuclear star-forming ring of the luminous infrared, Seyfert 1 galaxy NGC 7469. The main conclusions of this study are:

1. SN 2000ft has been detected in the optical in two independent Planetary camera images taken on May 13, 2000, about two months (±40 days) before the predicted explosion date based on the analysis of its multi-year radio light evolution.
2. The extinction corrected absolute optical magnitudes place SN 2000ft in the range of luminous optical type II supernovae, as other luminous radio supernovae such as SN 1979C and SN 1988Z before.
3. SN 2000ft exploded in a region located at only $0\farcs1$ (i.e. 34 ± 3 pc) west of a faint cluster (C24). No parent cluster is identified in the HST images.
4. The unambiguous detection of SN 2000ft behind at least three magnitudes of extinction in the visual shows that multi-epoch sub-arcsecond ($FWHM \sim 0\farcs1$) optical imaging is also a valid tool to detect supernovae even in the dusty (circum)nuclear regions of (ultra)luminous infrared galaxies.

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