The neutron star born in the Antlia supernova remnant

N. Tetzlaff,1⋆ G. Torres,2 R. Neuhäuser1 and M. M. Hohle1
1Astrophysikalisches Institut und Universität-Sternwarte Jena, Schillergässchen 2-3, D-07745 Jena, Germany
2Harvard–Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138, USA

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ABSTRACT

Among all known young nearby neutron stars, we search for the neutron star that was born in the same supernova event that formed the Antlia supernova remnant (SNR). We also look for a runaway star that could have been the former companion to the neutron star (if it exists) and then got ejected due to the same supernova.

We find the pulsar PSR J0630–2834 to be the best candidate for a common origin with the Antlia SNR. In that scenario, the SNR is ≈1.2 Myr old and is presently located at a distance of ≈138 pc. We consider the runaway star HIP 47155 a former companion candidate to PSR J0630–2834. The encounter time and place is consistent with both stars being ejected from the Antlia SNR. We measured the radial velocity of HIP 47155 as 32.42 ± 0.70 km s−1.

Key words: pulsars: individual: PSR J0630–2834.

1 INTRODUCTION

The Antlia supernova remnant (SNR), located at (l, b) = (276:5, 19°), was first discovered by McCullough, Fields & Pavlidou (2002) in X-ray observations. It was later confirmed as an SNR in the ultraviolet (Shinn et al. 2007). Its observability in the UV range as well as its large projected diameter of ≈24° suggests small distance (up to a few hundred pc). McCullough et al. (2002) estimated the distance to the Antlia SNR as d_A ≲ 500 pc with a preference for smaller distances (≈100 pc). They assessed an SNR age of ≈2 Myr supported by their suggestion that the pulsar PSR J0953+0755 and the Antlia SNR share a common origin. Given the detection of 60Fe in the Earth’s crust of nearly ≈2 Myr old (Knie et al. 2004; Fitoussi et al. 2008), McCullough et al. (2002) also considered whether this could have been formed in that supernova. However, McCullough et al. (2002) only considered eight nearby pulsars listed by Hoogerwerf, de Bruijne & de Zeeuw (2001). Therefore, it is worthwhile to re-visit this issue.

Due to large uncertainties in the distances of neutron stars (NSs) and their (in most cases) unknown radial velocities, multiple possible birth places (young associations and clusters, isolated SNRs) can usually be associated (Tetzlaff et al. 2010, 2011). Therefore, further indicators are needed to decide on a particular birth place. A promising indicator is the identification of a possible former companion that is now a so-called runaway star (Blauw 1961). These are typically fast-moving young single stars that may show signs of former binary evolution such as high helium abundance and high rotational velocity due to mass and momentum transfer from the primary as it filled its Roche lobe as well as possibly enhanced α elements as supernova debris material.

By constructing the past flight paths of young NSs and young runaway stars, we aim on identifying the NS that was born in the Antlia SNR. For those NSs for which we consider an association with the Antlia SNR possible, we also investigate whether a different origin in a nearby young association or cluster is possible. To account for the errors on the observables as well as for the NSs unknown radial velocity, we perform Monte Carlo simulations.

With this work, we aim to extend the analysis done by McCullough et al. (2002), by investigating a larger sample of NSs and, as an additional indicator, search for a former companion candidate to the NS that was then ejected in the same supernova event that formed the Antlia SNR.

We describe our method in Section 2 before presenting the analysis and results in Section 3 and giving concluding remarks in Section 4.

2 METHOD

We use the same approach as already described in Tetzlaff et al. (2010, 2011) (see also Hoogerwerf et al. 2001). Therefore, only a brief description is given here.

To construct the trajectories of the Antlia SNR, young NSs and runaway stars (and young associations and clusters; Tetzlaff et al. 2010, 2012; Tetzlaff 2013), we apply Monte Carlo simulations by varying the observables (parallax, proper motion, radial velocity) within their error intervals. For the radial velocity of the NS, we assume a probability distribution such that the distribution of pulsar space velocities according to Hobbs et al. (2005) is satisfied. Runaway star data were taken from the Tetzlaff, Neuhäuser & Hohle (2011) catalogue for Hipparcos runaway stars (also Tetzlaff 2013). If the radial velocity of a runaway star is unknown, we vary it randomly within ±500 km s−1.
In a time range between 0 (today) and $5 \times 10^6$ yr (into the past, in steps of $10^3$ yr), the past separation between the centre of the Antlia SNR (adopting $(l, b) = (276.5, 19^\circ)$; McCullough et al. 2002) and the NS is evaluated. Later, also runaway stars are traced back simultaneously. The smallest separation $d_{\text{min}}$ for each pair of trajectories (Antlia SNR and NS or runaway star and NS) and the associated time $\tau$ in the past is stored. The distribution of separations $d_{\text{min}}$ is supposed to obey a distribution of absolute differences of two 3D Gaussians (see Hoogerwerf et al. 2001; Tetzlaff et al. 2010, 2011).

The distance to the Antlia SNR is uncertain. For the Monte Carlo simulations, we adopt values of $100_{-90}^{+100}$ pc to take into account the lower and upper limits by McCullough et al. (2002) and that they prefer a distance of $\approx 100$ pc.

The actual (observed) case is different from this simple model (no 3D Gaussian distributed positions, due to e.g. the Gaussian distributed parallax that goes into the position reciprocally, complicated radial velocity distribution, etc.). Therefore, we will adapt the theoretical formulae (equations 1 and 2 in Tetzlaff et al. 2012; here we use the symbols $\mu$ and $\sigma$ for the expectation value and standard deviation, respectively) only to the first part of the $d_{\text{min}}$ distribution (up to the peak plus a few more bins, see Tetzlaff et al. 2012). The derived parameter $\mu$ then gives the positional difference between the two objects. Typically, a few million trajectories are constructed throughout a Monte Carlo simulation.

This procedure was already successfully applied by Hoogerwerf et al. (2001), Bobylev (2008); Bobylev & Bajkova (2009) and us (Tetzlaff, Neuhaüser & Hohle 2009; Tetzlaff et al. 2010, 2011, 2012). An investigation of (artificial) test cases showed that it is well possible to recover place and time of the formation of an NS (Tetzlaff 2013).

3 RESULTS

3.1 Search for the related NS

Among all young (spin-down ages smaller than 50 Myr) nearby ($\lesssim 3$ kpc) NSs with known proper motion, 106 in total (ATNF pulsar data base;1 Manchester et al. 2005), the projected past paths of seven NSs the Antlia SNR during the past 5 Myr, Fig. 1. Four of them are too distant ($\approx 2$ kpc) and were not closer than a few hundred pc to the remnant for any reasonable radial velocity. Among the other three is RX J0720.4–3125 which was probably born in the Trumpler 10 association $\approx 1$ Myr ago (Motch, Zavlin & Haberl 2003; Kaplan, van Kerkwijk & Anderson 2007; Tetzlaff et al. 2010, 2011) but still should be considered as a candidate for an origin in the solar neighbourhood or the Antlia SNR (as it could be nearby; McCullough et al. 2002). The remaining two are PSR J0630–2834 and PSR J0953+0755. The properties of PSR J0630–2834, RX J0720.4–3125 and PSR J0953+0755 are given in Table 1.

To check whether nearby associations or clusters could host the birth places of PSR J0630–2834 and PSR J0953+0755,2 we investigated close encounters with young nearby associations and clusters (Tetzlaff et al. 2010, 2012; Tetzlaff 2013). The past trajectories of both stars point to several nearby young local associations (Fernández, Figueras & Torra 2008; Torres et al. 2008); however, no convincing birth association could be found. We consider an origin in the solar neighbourhood or the Antlia SNR most likely for these stars.

The past separation between the Antlia SNR and the three NSs PSR J0630–2834, PSR J0953+0755 and RX J0720.4–3125 were then evaluated, Fig. 2.3

For PSR J0953+0755, equation 2 in Tetzlaff et al. (2012) ($\mu = 0$) fits well the $d_{\text{min}}$ distribution. Note that the obtained encounter time of $\approx 0.5$ Myr is considerably smaller than the one claimed by McCullough et al. (2002) ($\tau \approx 2$–4 Myr). An encounter time of $\approx 2$ Myr is obtained if $v_r = 50 \pm 50$ km s$^{-1}$ is assumed for the pulsar (comparable to the range McCullough et al. 2002 adopted). However, then a theoretical curve with $\mu = 48.2$ pc and $\sigma = 25.8$ pc fits well the $d_{\text{min}}$ distribution rather than $\mu = 0$. It is still possible that PSR J0953+0755 was inside the Antlia SNR, though less likely. Moreover, the resulting space velocity of the pulsar would be very small, $\approx 80$ km s$^{-1}$, which is unlikely but not impossible. For the calculation using a reasonable space velocity distribution for PSR J0953+0755 (from Hobbs et al. 2005), the present NS position and proper motion of the encounter are given in Table 2. As already expected from Fig. 1, the predicted encounter position of PSR J0953+0755 is only marginally consistent with the observed position of the Antlia SNR.

Although the $d_{\text{min}}$ distribution in the cases PSR J0630–2834 and RX J0720.4–3125 are not well represented by equations 1 and 2 in Tetzlaff et al. 2012 (probably because the parallax error is large in both cases, 14 per cent for PSR J0630–2834, 44 per cent for RX J0720.4–3125, whereas for PSR J0953+0755 it is only 2 per cent), they suggest that both objects could have been at the same place (as the supernova) at the same time in the past. In the case of RX J0720.4–3125, the predicted encounter position is again only marginally consistent with the observed SNR centre (also seen

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1 http://www.atnf.csiro.au/research/pulsar/psrcat/
2 For RX J0720.4–3125, this analysis was already carried out by Tetzlaff et al. 2010, 2011. Thereafter, RX J0720.4–3125 was probably born in the Trumpler 10 association.
3 The Antlia remnant was assumed to be moving on a constant orbit around the Galactic Centre.
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Table 1. Parameters of PSR J0630—2834, RX J0720.4—3125 and PSR J0953+0755. α, δ: equatorial coordinates (J2000.0), τ: parallax (radio parallaxes for PSR J0630—2834 and PSR J0953+0755, optical parallax for RX J0720.4—3125), \( \mu_\alpha^* \) = \( \mu_\alpha \cos \delta \), \( \mu_\delta \): proper motion in right ascension and declination, respectively.

|                 | α (h:m:s) | δ (d:m:s) | τ (mas) | \( \mu_\alpha^* \) (mas yr\(^{-1}\)) | \( \mu_\delta \) (mas yr\(^{-1}\)) | Refs. |
|----------------|-----------|------------|---------|-------------------------------------|-----------------------------------|-------|
| PSR J0630—2834 | 06:30:49.4043 | −28:34:42.78 | 3.01 ± 0.41 | −46.30 ± 0.99 | 21.26 ± 0.52 | 1     |
| RX J0720.4—3125 | 07:20:24.9620 | −31:25:50.08 | 3.6 ± 1.6  | −92.8 ± 1.4   | 55.3 ± 1.7   | 2, 3  |
| PSR J0953+0755 | 09:53:09.3097 | +07:55:35.75 | 3.82 ± 0.07 | −2.09 ± 0.08 | 29.46 ± 0.07 | 4, 5  |

References: 1 – Deller et al. (2009), 2 – Kaplan et al. (2007), 3 – Eisenbeiss (2011), 4 – Hobbs et al. (2004), 5 – Brisken et al. (2002).

Table 2. Present-day parameters and encounter position and time for three NSs that might be associated with the Antlia SNR. Column 3: encounter time τ. Columns 4–8: predicted present NS parameters (heliocentric radial velocity \( v_r \), proper motion \( \mu_\alpha^* \) and \( \mu_\delta \), peculiar space velocity \( v_\text{sp} \), parallax \( \pi \)). Note that it is possible to derive the value for \( v_r \) if \( v_\text{sp} \) is larger than that of \( v_\text{sp} \) because \( v_r \) is heliocentric whereas \( v_\text{sp} \) is the peculiar velocity of the NS that reflects its kick velocity. Columns 9–12: predicted supernova position (supernova distance \( d_{\odot, \text{SN}} \), at the time of the supernova: present distance \( d_{\odot, \text{SN}} \), today and Galactic coordinates, \( l \) and \( b \), J2000.0 of the centre of the SNR). Error bars denote 68 per cent confidence (for the derivation of the parameters we refer to Tetzlaff et al. 2010). For PSR J0630—2834, the results using a radial velocity distribution derived from the pulsar spatial velocities (Hobbs et al. 2005) (*) as well as a Gaussian distribution with \( v_r = 200 \pm 100 \) km s\(^{-1}\) (\( \phi \)) are shown (see the text).

| NS             | (μ, σ)         | τ (Myr) | Predicted present-day NS parameters | Predicted supernova/SNR position |
|----------------|----------------|---------|-------------------------------------|---------------------------------|
|                | (pc)           | (km s\(^{-1}\)) | \( \mu_\alpha^* \) (mas yr\(^{-1}\)) | \( \mu_\delta \) (mas yr\(^{-1}\)) | \( v_\text{sp} \) (km s\(^{-1}\)) | \( \tau \) (mas) | \( d_{\odot, \text{SN}} \) (pc) | \( d_{\odot, \text{today}} \) (pc) | \( l \) (°) | \( b \) (°) |
| PSR J0630—2834 | (0, 23.9)      | 0.64 ± 0.36 | −46.3 ± 1.0 | 21.2 ± 0.5 | 375 ± 131 | 2.9 ± 0.5 | 62 ± 24 | 72 ± 21 | 268 ± 176 | 16.7 ± 14.2 | 12.7 ± 12.7 |
| PSR J0630—2834 | (0, 24.5)      | 1.08 ± 0.40 | −46.3 ± 1.0 | 21.3 ± 0.5 | 235 ± 87 | 3.1 ± 0.4 | 102 ± 35 | 105 ± 40 | 269 ± 94 | 18.6 ± 7.4 | 7.7 ± 7.7 |
| RX J0720.4—3125 | (0, 27.1)      | 0.47 ± 0.22 | −92.8 ± 1.5 | 55.3 ± 1.7 | 352 ± 172 | 4.1 ± 1.4 | 67 ± 22 | 75 ± 35 | 269 ± 104 | 10.9 ± 9.9 | 6.2 ± 6.2 |
| PSR J0953+0755 | (0, 36.9)      | 0.43 ± 0.15 | −2.1 ± 0.1 | 29.5 ± 0.1 | 435 ± 86 | 3.8 ± 0.1 | 50 ± 17 | 57 ± 28 | 250 ± 290 | −30 ± 20 | 92 ± 92 |

\( ^a \) For PSR J0953+0755, the distributions for \( f \) and \( b \) are very broad with no clear peak, thus an interval is given.

in Fig. 1). Together with the previous result that RX J0720.4—3125 was probably born in the Trumpler 10 association, we consider a common origin of this NS with the Antlia SNR less likely.

For PSR J0630—2834, the encounter position is the most consistent with the observed coordinates of the Antlia SNR centre, making it the best candidate for the pulsar that can be associated with the Antlia SNR. The inferred ages of the pulsar and the SNR if they originated from the same supernova event are ≈0.6 Myr.

The small supernova distance of ≈45—90 pc implies an absolute SNR radius of ≈10—20 pc. For an 0.4—1.0 Myr old SNR, SNR expansion theory (Snowplough expansion, e.g. Blinnnikov, Imshennik & Urtbron 1982) predicts a radius of ≈45—55 pc for an ISM density of \( n = 1 \) cm\(^{-3}\) and standard explosion energy of \( E = 10^{51} \) erg. Either the explosion energy was considerably smaller (≈10\(^{50}\) erg) or the supernova occurred at a somewhat larger distance (also implying a slightly larger age). Theoretical core-collapse supernova models do not predict explosion energies <4 × 10\(^{50}\) erg (Ugliano et al. 2012). For a larger supernova distance (≈100—200 pc) such that the predicted size of the SNR is consistent with the observed one at an age of ≈1—2 Myr), the radial velocity of PSR J0630—2834 is required to be smaller (≈100—300 km s\(^{-1}\)), inferring a spatial NS velocity of ≈100—300 km s\(^{-1}\) (kick velocity).

Assuming NS radial velocities of 200 ± 100 km s\(^{-1}\) yields a distribution \( d_{\text{min}} \) that is still consistent with equation 2 in Tetzlaff et al. 2012 (μ = 0, σ = 24.5 μyr). The time of the encounter is ≈0.7—1.4 Myr in the past. The predicted distance to the supernova is ≈70—150 pc (as seen from Earth today). The corresponding absolute SNR radius is ≈15—30 pc. This is in marginal agreement with the theoretically expected value of ≈30—60 pc.

Figure 2. Distributions of minimum separations \( d_{\text{min}} \) and corresponding flight times \( \tau \) for encounters between the Antlia SNR and three NSs, PSR J0630—2834 (top panel), RX J0720.4—3125 (bottom-left panel) and PSR J0953+0755 (bottom-right panel). For PSR J0630—2834, the distributions using a radial velocity distribution derived from pulsar spatial velocities (Hobbs et al. 2005) (top-left panel) as well as a Gaussian distribution with \( v_r = 200 ± 100 \) km s\(^{-1}\) (top right) are shown (see the text). The solid curves drawn in the \( d_{\text{min}} \) histograms (bottom panels) represent the theoretically expected distributions (equation 2 in Tetzlaff et al. 2012), adapted to the first part of each histogram: for PSR J0630—2834 \( \mu = 0, \sigma = 23.9 \) μyr (top left) and \( \sigma = 24.5 \) μyr (top right); for PSR J0720.4—3125 \( \mu = 0, \sigma = 27.1 \) μyr (bottom left); for PSR J0953+0755 \( \mu = 0, \sigma = 36.9 \) μyr (bottom right). The encounter times are \( \tau = 0.64^{+0.36}_{-0.21} \) Myr (top left) and \( \tau = 0.43^{+0.15}_{-0.15} \) Myr (top right) for PSR J0630—2834, \( \tau = 0.47^{+0.20}_{-0.12} \) Myr for RX J0720.4—3125 (bottom left) and \( \tau = 0.8^{+0.4}_{-0.4} \) Myr for PSR J0953+0755 (bottom right), respectively. One of these stars might be associated with the Antlia SNR.
3.2 The former companion candidate to PSR J0630−2834

The scenario in which the pulsar PSR J0630−2834 is the compact remnant of the Antlia SNR is supported by the identification of the former companion candidate HIP 47155 for which the encounter position with PSR J0630−2834 coincides with the Antlia SNR. The radial velocity of HIP 47155 (spectral type A5/7(IIw), Houk 1982; kA3hF2mA3V, Pauzen et al. 2001) was previously unknown. Its measurement is crucial to confirm or reject HIP 47155 as former companion candidate to PSR J0630−2834. HIP 47155 was considered a runaway star by Tetzlaff et al. (2011) due to its high transverse velocity of 31.3 ± 6 km s\(^{-1}\).

Spectroscopic observations of HIP 47155 were gathered using the Tillinghast Reflector Echelle Spectrograph (TRES) instrument (Fü尔ész 2008) on the 1.5 m Tillinghast reflector at the F. L. Whipple Observatory (Mount Hopkins, AZ, USA). Three exposures were obtained over a period of 25 d in 2013 April and May. Radial velocity standard stars were observed each night with the same setup to monitor the velocity zero-point of the instrument. The spectra cover the wavelength range \(\sim 3900−8900\) Å, and were taken at a typical resolving power of \(R \approx 44\,000\) with the medium fibre of the instrument. The signal-to-noise ratios for the individual 3- to 5-minute exposures range between 80 and 100 per resolution element of 6.8 km s\(^{-1}\), and refer to the region of the Mg \(\beta\) triplet (~5200 Å). All spectra were reduced and extracted using standard procedures as described by Buchhave (2010) and Buchhave et al. (2010). These templates cover a 300 Å window centred at 5200 Å, which generally contains the most information on the velocity of the star. Fig. 3 shows a portion of one of our observations.

Radial velocities were derived by cross-correlation against a synthetic template taken from a large library computed by John Laird, based on model atmospheres by R. L. Kurucz and a line list developed by Jon Morse (see Buchhave et al. 2012). The task of selecting the optimum template was somewhat complicated by the peculiar chemical composition of the star, which is considered to be a member of the \(\lambda\) Boo class with a spectral type of kA3hF2mA3V (Pauzen et al. 2001). To establish the best template we adopted the metallicity and surface gravity derived by Casagrande et al. (2011), which are [Fe/H] = −1.13 and \(g = 3.67\), and explored a range of temperatures (\(T_{\text{eff}}\)) and rotational broadenings (\(v\sin i\) when seen in projection), which are the two parameters that affect the velocities the most. The best match to the observed spectra was found for \(T_{\text{eff}} = 8250\) K and \(v\sin i = 45\) km s\(^{-1}\). The temperature is consistent with the above \(\lambda\) Boo classification for the metallic lines (A3). The weighted average of the three velocity measurements is \(+32.42 \pm 0.70\) km s\(^{-1}\), and the individual values (in the heliocentric frame) with corresponding uncertainties are listed in Table 3. The above average velocity is robust against changes in the template parameters. For example, changing the temperature within one step in our grid (250 K) leads to velocity changes that are well within the quoted uncertainties.

This radial velocity for the runaway star supports the notion that HIP 47155 is a former companion candidate to PSR J0630−2834 (Fig. 4). The predicted NS properties and time and place of the supernova event are given in Table 4. The position is close to the centre of the Antlia SNR. We therefore conclude that PSR J0630−2834 and HIP 47155 were ejected in the same supernova that formed the Antlia SNR \(\approx 1.2\) Myr ago at a distance to Earth of \(\approx 120\) pc.

4 CONCLUSIONS

We searched for the NS that was born in the same supernova event that formed the Antlia SNR. In order to account for the uncertainties in the observables as well as the known radial velocity of NSs, we performed Monte Carlo simulations and evaluated the outcome statistically.

The most promising candidate for an association with the Antlia SNR is the young pulsar PSR J0630−2834 (Fig. 5). The predicted kinematic age of the NS, i.e. age of the SNR is \(\approx 1.2\) Myr. This kinematic age is in reasonable agreement with the pulsar’s spin-down age of 2.77 Myr (Hobbs et al. 2004). Discrepancies between
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Predicted present-day parameters of PSR J0630–2834 and supernova position and time for those runs where PSR J0630–2834 and HIP 47155 were within the Antlia SNR. Predicted NS parameters: heliocentric radial velocity $v_r$, proper motion $\mu_\alpha$, peculiar space velocity $v_{sp}$; predicted supernova position: distance of the supernova to Earth at the time of the supernova ($d_{\odot,\text{SN}}$) and as seen today ($d_{\odot,\text{today}}$); Galactic coordinates (Galactic longitude $l$, Galactic latitude $b$, J2000.0) as seen from the Earth today; predicted time of the supernova in the past $\tau$. For the deduction of the parameters we refer to Tetzlaff et al. 2010.

| Parameter | Value |
|-----------|-------|
| $v_r$ (km s$^{-1}$) | 177.70 |
| $\pi$ (mas) | 2.90$^{+0.14}_{-0.03}$ |
| $v_{sp}$ (km s$^{-1}$) | 177.21 |

Predicted supernova/SNR position and time

| Parameter | Value |
|-----------|-------|
| $d_{\odot,\text{SN}}$ (pc) | 128$^{+17}_{-12}$ |
| $d_{\odot,\text{today}}$ (pc) | 138$^{+17}_{-12}$ |
| $l$ ($^\circ$) | 270.4$^{+1.9}_{-1.9}$ |
| $b$ ($^\circ$) | 19.2$^{+0.5}_{-0.5}$ |
| $\tau$ (Myr) | 1.20$^{+0.26}_{-0.18}$ |

Figure 5. Past trajectories for PSR J0630–2834 and HIP 47155 projected on a Galactic coordinate system (for a particular set of input parameters). Present positions are marked with a star for the NS and a circle for the runaway star. The large circle denotes the Antlia SNR with its present extension (but at the position at the time of the supernova).

Integrating the COMPTEL 1.8 MeV flux (Plüschke et al. 2001; Diehl et al. 2010) over a circle centred at ($l,b$) = (270.4$^{+1.9}_{-1.9}$, 19.2$^{+0.5}_{-0.5}$) with a radius of 12$^\circ$ and adopting a distance of 138$^{+17}_{-12}$ pc yields a mass of $^{26}$Al that was ejected during the supernova of $\approx5.2 \pm 1.6 \times 10^{-5}$ M$_\odot$. Compared to theoretical $^{26}$Al yields (from core-collapse supernovae) by Woosley & Weaver (1995) and Limongi & Chieffi (2005), this corresponds to a mass of the progenitor star of $\approx14–32$ M$_\odot$ (earlier than B1 on the main sequence, Schmidt-Kaler 1982; Hohle, Neuhausser & Schutz 2010).

The former host OB association or stellar cluster of the supernova progenitor probably lies in the Vela region. The massive progenitor possibly got ejected from its birth place prior its supernova due to dynamical interactions (see e.g. Leonard 1989). It is known that about 20–30 per cent of supernova progenitors are located outside stellar groups (e.g. Mason et al. 1998; Maíz-Apellániz et al. 2004).

At a supernova distance of $\approx110–150$ pc about 1.0–1.5 Myr ago, this supernova may not be the only candidate for the supernova that produced the $^{60}$Fe found on Earth (Knie et al. 2004; Fitoussi et al. 2008), as it might be too distant and/or too recent. However, this supernova may have produced some of the $^{60}$Fe found and contributed to reheating the Local Bubble.

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