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A VLBI Search for a Pulsar Nebula in SN1993J in the Galaxy M81

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Abstract. Twenty consecutive VLBI images of supernova 1993J in M81 from the time of explosion to the present show the dynamic evolution of the expanding radio shell of an exploded star. No clear sign of a pulsar nebula, expected to have a spectral luminosity 10 to 1,000 times larger than that of the Crab, has yet been seen. The upper limit on the brightness at 8.4 GHz in the center of the shell in one of the latest images is 0.15 mJy per beam of 0.4 mas^2, corresponding to a spectral luminosity of that of the Crab. Any nebula that may have formed in the center is probably still obscured by the surrounding thermal matter with no substantial filamentation having yet occurred in the latter.

SN1993J in the galaxy M81 was the brightest optical supernova in the northern hemisphere since SN1954A and among the closest in modern history. Its progenitor star is believed to have been a massive supergiant, and a pulsar may have formed in the center of the explosion. After 10 years, a nebula generated by such a pulsar is estimated to have a spectral luminosity at 10 GHz of 10 to 1,000 times larger than that of the Crab nebula and should become visible if the opaque surrounding matter is filamented (Bandiera, Pacini, & Salvati 1984). However, if that matter is still uniform, then the nebula is not expected to become detectable for about 200 to 300 years (Reynolds & Chevalier (1984).

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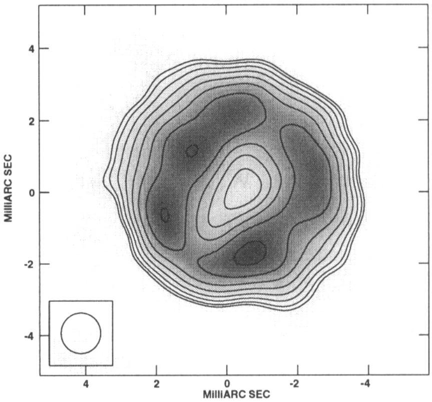

Figure 1. An 8.4 GHz image of SN 1993J on 15 November 1997. The contours are at 8.7, 11.3, 16, 22.6, 32, 45.3, 64, and 90.5 % of the peak of 1.06 mJy/beam. The beam is plotted in the lower left corner. North is up and east to the left.

Twenty images were obtained at 8.4 GHz with a global VLBI array between 1993 and 1997 (Bartel et al. 2000). They were phase-referenced to the radio nucleus of M81 (Bietenholz, Bartel, & Rupen 2000) and show a morphologically changing radio shell expanding isotropically from the explosion center. For the first year the outer angular radius of the shell develops with time as $\theta_o \propto t^{0.937\pm0.020}$ and after 2 years as $\theta_o \propto t^{0.772\pm0.013}$. These values rule out any acceleration like that found for the Crab nebula (Bietenholz et al. 1991) and are instead consistent with a shockfront decelerated by the circumstellar medium (see, e.g., Chevalier 1982). Figure 1 shows a typical supernova image at the latest epochs. The central region has a relatively low brightness, $\leq$ 0.15mJy per beam of 0.4 mas^2 in a high-resolution map version. This bound equals 6 $\times$ rms of the brightness outside the shell and 2 – 3 $\times$ standard error inside the shell when image fidelity considerations are taken into account. The limit corresponds to a spectral luminosity at 8.4 GHz of no more than that of the Crab nebula and 10 to 1,000 times smaller than estimated for a 10 year old nebula (Bandiera et al. 1984). If a pulsar nebula has formed, then the surrounding thermal matter cannot yet have become transparent by filamentation.

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