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# Radio studies of young core collapse supernovae

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**Abstract.** Multi-frequency observations of two radio bright SNe (SN1993J, SN1979C) carried out over a year with GMRT are presented. Their radio light curves trace the evolution of the mass loss in the stellar wind before the pre-supernova star exploded. Their spectra at low frequencies distinguish between the synchrotron self-absorption and free-free absorption based models. Two very similar type IIp SN1999gi and SN1999em were also observed and we comment on their progenitor mass. These observations of different subclasses of core-collapse supernovae will aid in defining their progenitors.

*Keywords* : Core collapse supernovae – SN1993J, SN1979C – progenitors

## 1. GMRT observations of supernovae

The ejecta from a core collapse SN interacts with the circumstellar medium (CSM), soon after the explosion. The SN shock (with speed $\sim$ 1000 times the speed of the progenitor wind) quickly probes the region of the wind which was lost many thousand years before. It thus probes the past history of the star. Relativistic electrons and the magnetic fields in the interaction region give rise to the radio-emission. The shock heated SN ejecta and the CSM also emit X-rays.

### 1.1 SN1993J and SN1979C

In the next page, we show the GMRT maps of SN1993J in four separate frequency bands. The table 1 gives the summary of GMRT observations of SN1993J and SN1979C. We also display the low frequency spectrum of SN1993J around day 3100.

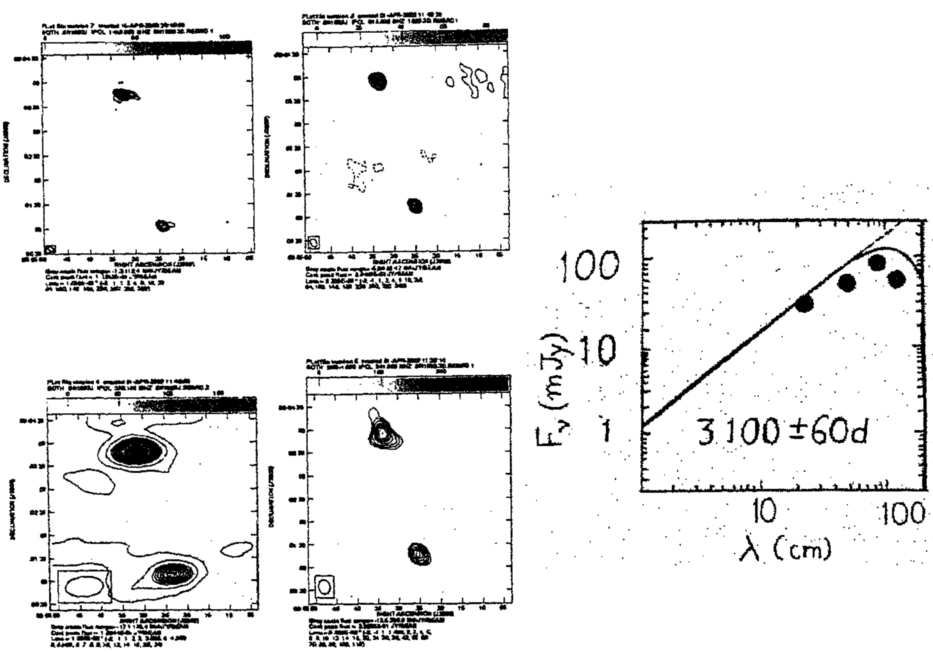


Figure 1: ***Left panel:*** GMRT maps of SN1993J at 1420, 610, 243 and 325 MHz(clockwise). The SN is the bottom right source in each panel, while the top left source is the host galaxy NGC3031 centre. ***Right panel:*** SN1993J spectrum as observed in the above four bands. The separation in time for the three lowest frequency observations is ~ 120 days. The solid line is the predicted model (extended from Perez-Torres et al (2001)) where synchrotron self-absorption dominates while the dashed line is that for free-free absorption.

Table 1: Results of GMRT observations of SN1993J and SN1979C

| SNe | Date of Observation | Band MHz | Beam Size (" x ") | Good Antennae | Good Time Interval | Flux± rms mJy |
|---|---|---|---|---|---|---|
| 1993J | 08 Nov,2000 | 1420 | 13 x 9 | 15 | 68% | 35.07± 1.0 |
| 1993J | 16 Dec,2000 | 1420 | 4 x 3 | 19 | 92% | 36.19± 0.4 |
| 1993J | 24 Mar,2001 | 610 | 16 x 13 | 18 | 72% | 40.79± 1.2 |
| 1993J | 02 Jun,2001 | 1420 | 5 x 3 | 28 | 95% | 32.18± 0.3 |
| 1993J | 04 Jul,2001 | 325 | 47 x 26 | 23 | 77% | 75.03± 7.7 |
| 1993J | 24 Aug,2001 | 610 | 15 x 8 | 23 | 82% | 56.03± 1.0 |
| 1993J | 30 Dec,2001 | 235 | 30 x 30 | 24 | 20% | 57.21± 4.8 |
| 1993J | 31 Dec,2001 | 610 | 10 x 9 | 24 | 80% | 43.77± 2.0 |
| 1979C | 08 Nov,2000 | 1420 | 26 x 19 | 13 | 54% | 07.41± 0.5 |
| 1979C | 24 Mar,2001 | 610 | 20 x 9 | 16 | 63% | 13.02± 1.4 |
| 1979C | 04 Jul,2001 | 325 | 13 x 12 | 25 | 85% | 16.44± 1.8 |
| 1979C | 23 Aug,2001 | 610 | 8 x 6 | 24 | 83% | 10.08± 0.9 |
| 1979C | 14 Oct,2001 | 1420 | 12 x 5 | 19 | 64% | 03.31± 0.6 |

Table 2. Results of GMRT observations of SN1999gi and SN1999em

| SNe | Date of Observation | Wave Band MHz | Flux mJy | Progenitor mass (Smartt et al.) |
|---|---|---|---|---|
| 1999gi | ~750 | 610 | ≤0.7 | 9± 3 $M_\odot$ |
| 1999em | ~800 | 610 | ≤1.0 | 12± 1 $M_\odot$ |

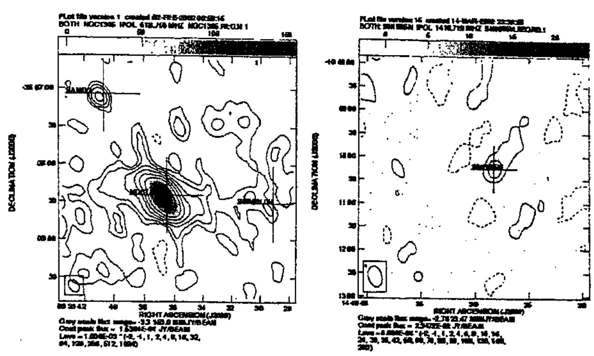

Figure 2. *Left panel*:GMRT map of SN2001du at 610 MHz band. SN is in the right center region near 2 mJy contour. *Right panel*: GMRT map of SN1995N at 1420 MHz band. Supernova (4.5 mJy) is at the position of the cross.

Table 3. Supernovae undetected by GMRT and their 2 $\sigma$ upper limits

| SNe | Gal.Center Offset | Wave Band MHz | Beam Size (" x ") | Good Antennae | Good Time Interval | Flux limit mJy |
|---|---|---|---|---|---|---|
| 1997ef | 10E 20S | 1420 | 19 x 10 | 18 | 56% | 0.3 |
| 2001du | 90W 10S | 1420 | 60 x 33 | 9 | 21% | 3.0 |
| 1983V | 57W 30S | 1420 | 60 x 33 | 9 | 21% | 3.0 |
| 1957C | 54W 75N | 1420 | 60 x 33 | 9 | 21% | 3.0 |
| 2000E | 06W 27S | 1420 | 13 x 7 | 20 | 63% | 0.5 |
| 1999el | 22E 08S | 1420 | 13 x 7 | 20 | 63% | 0.5 |
| 2000W | 02W 21S | 1420 | 11 x 3 | 19 | 57% | 0.5 |
| 2000cx | 23W 109S | 1420 | 48 x 27 | 8 | 20% | 0.9 |
| 1999gi | 04W 61N | 610 | 10 x 10 | 23 | 69% | 0.7 |
| 1999em | 15W 17S | 610 | 8 x 6 | 24 | 73% | 1.0 |
| 2001ig | 139E 10N | 610 | 10 x 9 | 22 | 69% | 2.0 |
| 2001du | 04W 61N | 610 | 11 x 10 | 23 | 70% | 2.0 |

### 1.2 Other recent supernovae

Although radio and X-ray observations of SNe provide complementary information, both depend upon interaction of superova shocks with CSM. X-ray luminosities reported by Chandra from SN1999gi and SN1999em (both type IIP SNe) are relatively faint (Pooley et al 2001 and Smartt et al 2001). This indicates that they have low CSM density. Schlegel (2001) suggested that the low CSM density implied in the IIP SNe may support a supernova mass-loss "order", first described by Chugai(1997) , in which circumstellar appearance of a SN is dictated by its progenitor's zero-age main sequence (ZAMS) mass. Chugai argues that mass-loss rate rises to a peak near 10 $M_\odot$ and falls with mass above that value, which introduces an ordering in circumstellar matter density. Since the SN1999gi mass, as determined from its presupernova star field's image (see Table 2 last column) is close to the boundary of a critical stellar mass (See Fig. 3 of Chugai,1997), where it is expected to have undergone more mass loss in the wind compared to SN1999em, it should have been more radio luminous than SN1999em. This appears not to be the case in our GMRT data (see Table 2), implying that their CSM densities are similar.
In the last figure we show the GMRT maps of SN2001du and SN1995N. SN1995N is detected by GMRT with a flux of $\sim$ 4.5 mJy at 1420 MHz. Table 3 gives the list of undetected supernovae by GMRT.

## 2. Conclusions

Synchrotron self absorption of radio emission from SN1993J may be the dominant absorption mechanism which is determining the spectrum and light curve at current epochs at long wavelengths.
SN1995N is clearly detected with GMRT at 1420 MHz band. This Type IIn supernova is still a radio emitter and a good target for study of spectrum and light curves along with SN1993J and SN1979C.
The optically determined position of SN2001du is consistent (within astrometric errors and size of the synthesized beam) with a region of enhanced radio emission at 2 mJy level at 610 MHz.

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