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Radio Light Curves of Supernova SN 2008iz in M82 Galaxy

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ABSTRACT
We report on multi-frequency Very Large Array (VLA) radio observations for an on-going monitoring campaign of supernova SN 2008iz in the nearby irregular galaxy M82. We fit two light curve models to the data, a simple power-law and a simplified weiler model, yielding a decline index, β = -1.23±0.01 and -1.41±0.02, respectively. The late time radio light curve evolution shows a flux density enhancement at 1500 days since the explosion at all frequencies. The flux density enhancement does not show signs of decline from results obtained so far. The enhancement is attributed to SN 2008iz expanding shock wave encounter with a clumpy dense circumstellar medium.

Keywords: *Supernova, SN 2008iz, Radio continuum, M82 galaxy*

1. INTRODUCTION

Radio supernove are supernovae that are visible at radio wavelengths. They are rare events with just a few dozens detected so far [15]. The lack of detections is attributed to either the supernovae being relatively distance or fairly weak, making them difficult to study in details. So far, SN 1993J in M81 is the best studied radio supernova, due to its proximity (3.6Mpc), unobscured environment and face-on galaxy orientation [2,7,10,11]. The more recent discovery of radio supernova SN 2008iz [3] offers the possibility to study another supernova at a similar distance in great details and make comparisons to SN 1993J.

The supernove SN 2008iz was discovered by Brunthaler and collaborators on April 2009 at radio wavelengths with VLA at 22GHz [3]. The discovery was confirmed with Multi-Element Radio Linked Interferometer Network (MERLIN) at 5GHz [1,13] and Urumqi single dish telescope at 5GHz [8]. The endeavours to make detections in other astronomical windows were not successful. For instance, there are no detections in visible light, Near-IR [6] and X-Ray [4]. The non-detection at other astronomical windows indicate that the supernova explosion happened behind a large gas or dust cloud, and make it hard to classify the supernova. However, since type Ia supernova are not known to show strong radio emission, SN 2008iz is most likely a core collapse supernova i.e. either Type Ib/c or Type II [4].

SN 2008iz is located in M82 galaxy at RA $09^h55^m51^s.551$ and DEC $69^\circ 40' 45''.792$ (J2000) [4]. This position is 2.5" (43pc assuming a distance of 3.6Mpc) SW of the dynamical center of M82 based on 2.2µm peak [18]. From their monitoring projects, it was found that the supernova explosion date is estimated to be 18 Feb 2008±6 days [8]. The VLBI study reveals the expansion velocity of SN 2008iz to be approximately $21000 kms^{-1}$ making it one of the fastest expanding radio supernova and also show a self-similar behaviour [5]. The self-similarity describes that the source shows similar structure on all scales when scaled to the same resolution. The derived spectral index in radio is α = -1.08±0.08 [5] and the deceleration index (*m*), which indicates that the deceleration of the supernova is 0.89 [5,8]. Both [5] and [8] find that synchrotron self-absorption (SSA) is not important when modelling SN 2008iz.

Multi-frequency measurements of the radio light-curves and their time dependent evolution help in understanding important information such as the density and structure of the circumstellear medium (CSM), evidence for possible binary companions, clumpiness or filamentation in the pre-supernova wind, and pre-supernova mass loss rates. We present a multi-frequency VLA evolution results of SN 2008iz for a period of 7yrs since its explosion. We also combine our observations with other archival data to get a comprehensive picture of its radio light curve evolution. In this paper, we describe the monitoring and data reduction process in section 2. In section 3 we present the multi-frequency light-curve results. In section 4 we discuss the results while in section 5, we present a summary of the work.

2. OBSERVATIONS AND DATA CALIBRATION

The radio monitoring campaign was conducted with the VLA, at L-(1.4GHz), C-(4.8GHz), X-(8.4GHz), K-(22.3GHz) and Q-bands (43.2GHz) to trace the evolution of the radio emission from supernova SN 2008iz since its discovery. The observation was done in the standard continuum observation mode with a total bandwidth

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of 128 MHz, each in dual circular polarization. Flux density measurements were derived using calibrator 3C48 and phase referenced against calibrator J1048+7143. The flux calibrator was observed for a total time of 2 minutes in each observation. The observation used a switching cycle of six minutes, spending on average 1 minute on the phase calibrator and 5 minutes on M82. The cycles were repeated 5 times over the observation, yielding an integration time of ∼25 minutes on M82 at each frequency.

The last epoch of VLA observations on 23 Jan 2014 is an observation done in search of a newly discovered supernova SN 2014j at C- and K-bands in configuration AB. The data was taken in the standard continuum observation mode with a total bandwidth of 128 MHz, each in dual circular polarization. The flux calibrator 3C48 was observed for a total time of 3 minutes. The observation used a switching cycle of 9 minutes, spending an average time of 30 seconds on the phase calibrator J1048+7143 and 8 minutes on M82. The cycle was repeated 4 times over the observation, yielding an integration time of approximately 32 minutes on M82 at both frequencies.

3. RESULTS

The standard data reduction steps and packages in AIPS are used in data reduction and calibration process. Inorder to reduce the contribution of galactic continuum flux emission to the SN 2008iz flux density, we restrict the interferometric (u,v) distance to >30kλ. The AIPS task 'JMFIT' is used to determine the flux density by fitting a 2D Gaussian fit to the visually identified compact SN 2008iz source. The flux density errors are derived by adding in quadrature the formal errors from the 2D Gaussian fit, a 5% uncertainty error due to continuum interference, and the difference between peak and integrated flux values. The 'GNUPLOT' package is used to fit the results using equations 1 and 2.

4. DISCUSSION

The light curve of the optically-thin regime of SN 2008iz is well fit by a power-law of the form shown by equation 1, especially at 22.3GHz which is our best sampled observation (see Fig. 1)

$$S = K_0(t - t_0)^{\beta} \quad (1)$$

where K_0 is a scaling factor, t is the number of days since the explosion, t_0 is the explosion day (18 Feb 2008), and the power-law decline index, β, describes the power-law decline at a later evolution date. The parameter β is normally affected by both the spectral index, α, and the opacity τ. We fit a single β value for the optically-thin regime excluding the last 3 epochs of our observations whose flux density values are beyond the expected values at this time. We also fit different K_0 for each frequency (Fig. 1) which results in a β = -1.23±0.01. The values of K_0 which appear to decrease with increasing frequency are $K_{0(1.4GHz)} = (1.06\pm0.1)\times10^5$, $K_{0(4.8GHz)} = (5.19\pm0.6)\times10^4$, $K_{0(8.4GHz)} = (3.80\pm0.4)\times10^4$, $K_{0(22.3GHz)} = (1.76\pm0.4)\times10^4$ and $K_{0(43.2GHz)} = (4.02\pm0.6)\times10^3$.

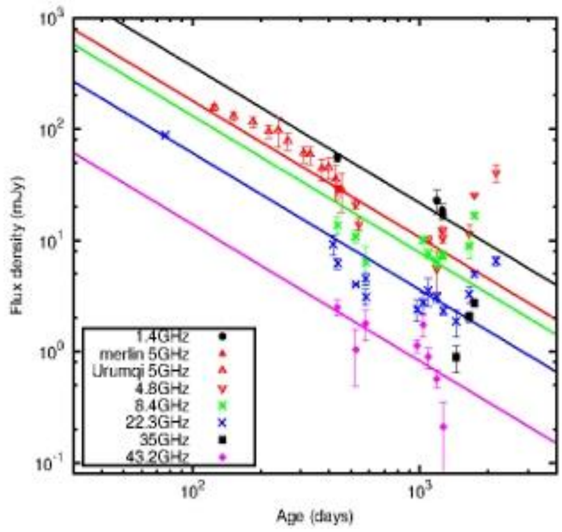

Figure 1: The multi-frequency light curve for the optical thin regime of SN 2008iz. The Merlin 5GHz data were obtained from [1], the Urumqi 5GHz data from [8], while the rest of the data is from our observations. The fits are done using the VLA observations.

To fit the complete supernova light curve model from out data was impossible since we only have one 22.3GHz observation in the optically-thick regime as confirmed by [8]. We therefore made use of the best fit results of the simplified weiler model (equation 2) as submitted by [8] at 5GHz. The model assumes the CSM distribution is homogeneous (i.e. there is no clumpy CSM) and do not consider SSA because it is insignificant. The fit parameters are $K_1 = (2.14\pm0.04)\times10^5$mJy, β = -1.43±0.05, t_0 = 18 Feb 2008, $K_2 = (11.0\pm0.7)\times10^5$, δ = -2.65 ±0.10 and from [5], we make use of the spectral index α = -1.08±0.08. The simplified weiler model fit to all frequencies at the same time is shown in Fig. 2, with β being a free parameter yield β = -1.41±0.02.

$$S_{(\nu)} = K_1 \left(\frac{\nu}{5GHz}\right)^{\alpha} \left(\frac{t-t_0}{1day}\right)^{\beta} e^{-\tau} \quad (2)$$

where K_1 is the flux density at 5 GHz one day after the explosion, while α is the spectral index of the emission in the optically-thin regime. The parameters β , t_0 and t are as indicated in equation 1 above, while τ is the opacity of the thermal electrons of the CSM to the radio emission which is modeled as

$$\tau = K_2 \left(\frac{\nu}{5GHz}\right)^{-2.1} \left(\frac{t-t_0}{1day}\right)^{\delta} \quad (3)$$

where K_2 is the uniform free-free absorption (FFA) value at 5 GHz one day after the explosion, while δ is the absorption decline index related to the CSM radial

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density profile derived as δ = α – β – 3. The exponent of -2.1 corresponds to the spectral dependence of FFA by thermally ionized gas in the radio regime.

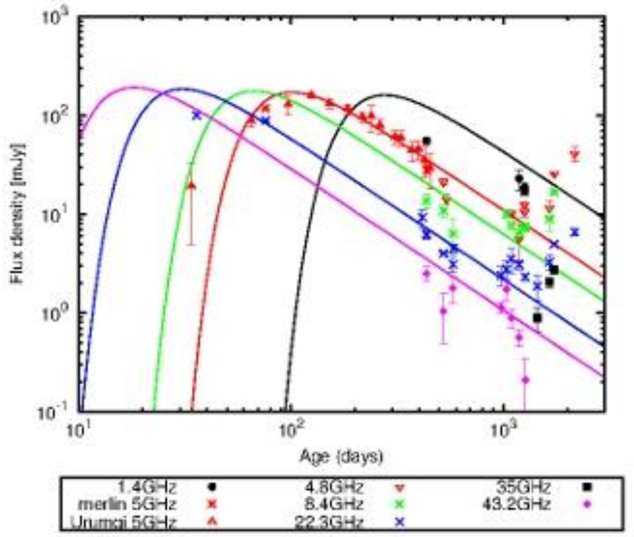

Figure 2: The multi-frequency light curve of SN 2008iz. The data sources areas indicated in Fig. 1 above. The fits are done using fit results from a well sampled 5GHz Urumqi single dish observations [8].

The light curve indicates a flux enhancement at 1500 days after the explosion. The enhancement is detected at all frequencies and does not show signs of decline from the observations done so far. This indicates that the supernova shock-wave is encountering dense CSM which must be remnants of winds of SN 2008iz's progenitor star.

The power-law decline index of the light curve of SN 2008iz is β = - 1.23±0.01 and -1.41±0.02 for the models fitted above. This value is lower than that derived for SN 1993J (β = -0.93) due to different processes in the supernovae [15]. Different processes are seen, for instance, SSA is important in SN 1993J, but not in SN 2008iz (e.g. [12,17]) also find a much higher value of β = -0.73 for SN 1980K, but include SSA in their model too. [14] report a power-law index of β = -1.18 for SN 1986J. Furthermore, they find SSA to not be important in this supernova, making it a better comparison for SN 2008iz.

5. SUMMARY

We report on multi-frequency VLA radio datasets for an on-going monitoring campaign of SN 2008iz. We fit two models to the data, a simple power-law and a simplified weiler model, yielding β = -1.23±0.01 and -1.41±0.02 respectively. The light curve also uncovers a flux density enhancements at 1500 days since the explosion at all frequencies. This is attributed to an increase in the number density of shocked CSM electrons as the expanding shock wave encounters a clumpy denser medium. The medium must be the remnant of winds of SN 2008iz's progenitor star. Further observations of SN 2008iz would offer more information on the nature of the dense medium and could thus give indications on the behaviour of its progenitor star.

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REFERENCES

[1]. Beswick, R. J., Muxlow, T. W. B., Pedlar, A., et al. 2009, The Astronomer's Telegram, 2060, 1

[2]. Bietenholz, M. F., Bartel, N., Rupen, M. P., et al. 2010, ApJ, 712,1057

[3]. Brunthaler, A., Menten, K. M., Reid, M. J., et al. 2009a, The Astronomer's Telegram, 2020, 1

[4]. Brunthaler, A., Menten, K. M., Reid, M. J., et al. 2009b, A&A, 499, L17

[5]. Brunthaler, A., Martí-Vidal, I., Menten, K. M., et al. 2010, A&A, 516, A27

[6]. Fraser, M., Smartt, S. J., Crockett, M., et al. 2009, The Astronomer's Telegram, 2131, 1

[7]. Marcaide, J. M., Alberdi, A., Ros, E., et al. 1997, ApJ, 486, 31

[8]. Marchili, N., Martí-Vidal, I., Brunthaler, A., et al. 2010, A&A, 509, A47

[9]. Martí-Vidal, I., Marcaide, J. M., Alberdi, A., et al. 2007, A&A, 470, 1071

[10]. Martí-Vidal, I., Marcaide, J. M., Alberdi, A., et al. 2011a, A&A, 526, A142

[11]. Martí-Vidal, I., Marcaide, J. M., Alberdi, A., et al. 2011b, A&A, 526, A143

[12].Montes, M. J., Van Dyk, S. D., Weiler, K. W., et al. 1998, ApJ, 506, 874

[13]. Muxlow, T. W. B., Beswick, R. J., Pedlar, A., et al. 2009, The Astronomer's Telegram, 2073, 1

[14]. Weiler, K. W., Panagia, N., & Sramek, R. A., 1990, ApJ, 364, 611

[15]. Weiler, K. W., Panagia, N., Montes, M. J., & Sramek, R. A. 2002, ARA&A, 40, 387

[16]. Weiler, K. W., Williams, C. L., Panagia, N., et al. 2007, ApJ, 671, 1959

[17]. Weiler, K. W., Panagia, N., Sramek, R. A., et al. 2010, Mem. S.A.lt, 81,374

[18]. Weiß, A., Neininger, N., Hüttemeister, S., & Klein, U. 2001, A&A, 365, 571