MULTIFREQUENCY OBSERVATIONS OF ONE OF THE LARGEST SUPERNOVA REMNANTS IN THE LOCAL GROUP OF GALAXIES, LMC – SNR J0450–709

K. O. Ćajko1, E. J. Crawford 2, M. D. Filipović2

1Faculty of Sciences, University of Novi Sad
Try Dositeja Obradovića 4, 21000 Novi Sad, Serbia
E–mail: tinacaj@gmail.com

2School of Computing and Mathematics, University of Western Sydney
Locked Bag 1797, Penrith South DC, NSW 1797, Australia
E–mail: e.crawford@uws.edu.au, m.filipovic@uws.edu.au

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SUMMARY: We present the results of new Australia Telescope Compact Array (ATCA) observations of one of the largest supernova remnants, SNR J0450–709, in the Local Group of galaxies. We found that this Large Magellanic Cloud (LMC) object exhibits a typical morphology of an old supernova remnant (SNR) with diameter D=102 ± 75 pc and radio spectral index α=– 0.43±0.06. Regions of high polarisation were detected with peak value of ∼40 %.

Key words. ISM: supernova remnants – Magellanic Clouds – Radio Continuum: ISM – Polarisation – ISM: individual objects : SNR J0450–709

1. INTRODUCTION

The Magellanic Clouds (MCs) are one of the most favorable places for investigations of objects such as supernova remnants (SNRs). Beside their position, close to the South Pole, they are found in one of the coldest parts of the radio sky allowing us to investigate and detect radio emission without interrup-
tions from Galactic foreground radiation (Haynes et al. 1991). The MCs are located out of the Galactic plane and thus the influence of dust, gas and stars is small, making detailed investigations of SNRs pos-
sible. The Large Magellanic Cloud (LMC) at a distance of 50 kpc (Hilditch et al. 2005), allows for analysis of the energetics of each remnant.

SNRs are usually characterised by their strong and predominately non-thermal emission that they emit at radio wavelengths. They have typical spectral index of α ∼ –0.5 defined by $S \propto \nu^\alpha$. SNRs have very important influence on the interstellar material (ISM). Appearances of shell-like filaments are very often perturbed by interaction with and non-

homogeneous structure of the ISM. SNRs dictate be-

havior, structure, morphology and evolution of the ISM. But on the other hand, the evolution of SNRs is dependent on the environment which surrounds them.

Here we report on new moderate-resolution radio-continuum observations of SNR J0450–709, one of the largest SNRs in the Local Group of Galaxies. It was initially classified as SNR by Mathewson et al. (1985), based on optical obser-
3. RESULTS AND DISCUSSION

The remnant has a shell-like morphology centered at RA(J2000)=4°50′33.4′′, DEC(J2000)=-70°50′43.5′′ with a diameter of 420′×310′×5′ (7′×5.16 or 101.8×75.2±1 pc), which is in agreement with optical diameter of 6.5′×4.7′ reported by Williams et al. (2004). We note that it is elongated in north-south direction and “clump” along its western side (see Fig. 1 and Fig. 2).

Flux density measurements were made at 4800 MHz resulting in a value of 0.448 Jy. New measurements were also made at 843 MHz (from the LMC MOST image), 1400 MHz and 8640 MHz (both from the mosaics presented by Filipović et al. 2009 and Hughes et al. 2007). Using values of flux densities obtained from the observed frequencies in Table 1, a spectral index was plotted (Fig. 4) and estimated to be $\alpha = -0.43 \pm 0.06$, confirming the non-thermal nature of this object as the still dominant emission mechanism. However, our value is slightly “flatter” in comparison with typical and estimated value of ~0.5 for SNRs (Mathewson et al. 1985).

Urošević and Pannuti (2005) showed models for two cases when SNRs could produce significant amount of thermal emission. Further on, they discuss the contribution of that thermal emission to the radio-continuum spectral index make-up of SNR. Urošević and Pannuti (2005) derived flatter empirical $\Sigma - D$ relation which is in a good agreement with previous modified theoretical relations. Discrepancies between theoretically derived and empirically measured $\Sigma - D$ relations may be partially explained by taking into account thermal emission at radio frequencies from SNRs at particular evolutionary stages and located in particular environments. In the case of SNR J0450–709, this may indicate an older age for the remnant where contribution of thermal component could be significant, similar to the example given in Urošević et al. (2007) and elaborated on in Onić and Urošević (2008). Also, SNR J0450–709 is most likely expanding in a denser and warmer medium of $n \sim 1 - 10$ cm$^{-3}$.

We note that the point at 408 MHz (Table 1; Fig. 4) lies slightly off the line of best fit. This is most likely due to an older data (1970-ties) processing. Particularly in this case it may overestimate flux density due to a clean bias effect. We estimate that the combined flux density errors from all radio images used in this study, are less than 10% at each given frequency.

Linear polarisation image for SNR J0450–709 at 4800 MHz is shown on Fig. 3. Regions of fractional polarisation are quite strong. They are designated with polarisation vectors located at north-west side of the shell. Linear polarisation images for each frequency were created using $Q$ and $U$ parameters. While we do not have any measurements at 8640 MHz, the 4800 MHz image reveals some strong linear polarisation. Without reliable polarisation measurements at another wavelength, we could...
not determine the Faraday rotation. The mean fractional polarisation at 4800 MHz was calculated using flux density and polarisation:

$$P = \frac{\sqrt{S_Q^2 + S_U^2}}{S_I} \cdot 100\% \quad (1)$$

where $S_Q, S_U$ and $S_I$ are integrated intensities for $Q$, $U$ and $I$ Stokes parameters. Our estimated peak value is $P \approx 40\%$. Along the shell there is a pocket of uniform polarisation possibly indicating varied dynamics along the shell. This unordered polarisation is consistent with the appearance of an older SNR.

### Table 1. Integrated Flux Density of SNR J0450–709.

| SNR J0450–709 | $S_I$ (0.408 GHz) | $S_I$ (0.843 GHz) | $S_I$ (1.4 GHz) | $S_I$ (4.8 GHz) | $S_I$ (8.64 GHz) |
|---------------|------------------|------------------|----------------|----------------|-----------------|
| SNR J0450–709 | 1470 mJy         | 837.3 mJy        | 643.7 mJy      | 448 mJy        | 360 mJy         |
| Reference     | Clarke et al. 1976 | Mills et al. 1984 | This Work     | This Work      | This Work       |

**Fig. 1.** ATCA observations of SNR J0450–709 at 4800 MHz (6 cm). The side bar quantifies the pixel map and its units are mJy/beam.
Fig. 2. *MCELS* composite optical image (RGB = $H_\alpha$, [Sii], [Oiii]) of SNR J0450–709.

Fig. 3. *ATCA* observations of SNR J0450–709 at 4800 MHz (6 cm). The blue circle in the lower left corner represents the synthesised beam-width of 21" × 19", and the blue line below the circle is a polarisation vector of 100%. The sidebar quantifies the pixel map and its units are Jy/beam.
4. CONCLUSION

We analysed one of the largest SNRs in the Local Group of Galaxies – SNR J0450–709. Here, the new radio-continuum observations of this SNR together with the multi-frequency analysis are presented. From these new observations, we found SNR diameter of $101.8 \times 75.2 \pm 1$ pc, spectral index of $\alpha = -0.43 \pm 0.06$ and relatively strong level of linear polarisation with peak value of $\sim 40\%$. We concluded that these are all indicators of an older SNR.

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MULTIFREKVENCIONA POSMATRANJA JEDNOG OD NAJVEĆIH OSTATAKA SUPERNOVIH U LOKALNOJ GRUPI GALAKSIJA – LMC SNR J0450–709

K. O. Čajko¹, E. J. Crawford² M. D. Filipović²

¹Faculty of Sciences, University of Novi Sad
Try Dositeja Obradovia 4, 21000 Novi Sad, Serbia
E-mail: tinacaj@gmail.com

²School of Computing and Mathematics, University of Western Sydney
Locked Bag 1797, Penrith South DC, NSW 1797, Australia
E-mail: e.crawford@uws.edu.au, m.filipovic@uws.edu.au

У овој студији представљамо нове АТСА резултате радио-посматрања у континууму остатка супернове у Великом Магелановом Облаку – SNR J0450–709. Нашли смо да овај остатак супернове има љускату морфологију која је типична за старије остатке супернових. Измерена вредност радио спектралног индекса износи $\alpha = -0.43 \pm 0.06$, а дијаметра $D = 101.8 \times 75.2 \pm 1$ парсека. Детектовали смо релативно висок степен поляризације где максимална вредnost износи око 40%.