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THE MONOCEROS RADIO LOOP: TEMPERATURE AND BRIGHTNESS

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Abstract. In this article we estimated the average brightness temperatures and surface brightnesses of Monoceros radio loop at 1420, 820 and 408 MHz. It is possible to make new estimation for distance to this loop using new derived brightnesses.

1. INTRODUCTION

It is well known that some radio spurs can be joined into small circles. The set of spurs which form the same small circle is called a loop. The Monoceros filamentary loop nebula, the shell source of radio emission, was suggested to be a supernova remnant (SNR) by Davies 1963 on the basis of 237 MHz observations. The Monoceros loop was suspected already by Davies 1963 to be a SNR, while Gebel & Shore 1972 developed this idea into a more detailed study. It was considered as an object similar to major loops when Spoelstra 1973 included it in his study of galactic loops as supernova remnants expanding in the local galactic magnetic field.

Graham et al. 1982 found that the constellation of Monoceros is remarkably rich in extended Galactic radio sources. Large parts of it have been mapped in the radio continuum over a wide range of frequencies. Monoceros Nebula can be found in a catalog of Galactic SNRs with number G205+0.5 (Green 2004, 2006).

The aim of this paper is to calculate the average brightness temperatures and surface brightnesses of the Monoceros radio loop at 1420, 820 and 408 MHz and to study how these results are getting along with previous result (Urošević & Milogradov-Turin 1998; Milogradov-Turin & Urošević 1996) and with current theories of supernova remnant evolution. These theories predict that SNRs are non-thermal sources which are spreading inside of the hot and low density bubbles made by former supernova explosions or by strong stellar winds (see Salter 1983, McKee & Ostriker 1977 and references therein).

2. ANALYSIS

2. 1. DATA

The radio continuum surveys at 1420 MHz (Reich & Reich 1986), 820 MHz (Berkhuijsen 1972) and 408 MHz (Haslam et al. 1982) are used as the basic source of data in this paper. The data were obtained from the 1420-MHz Stockert survey (Reich & Reich 1986), the 820-MHz Dwingeloo survey (Berkhuijsen 1972) and the 408-MHz all-sky survey (Haslam et al. 1982). The angular resolutions are $35'$, $1^\circ.2$ and $0^\circ.85$, respectively. The effective sensitivities are about 50 mK T_b (T_b is for an average brightness temperature) at 1420 MHz, 0.20 K at 820 MHz and about 1.0 K at 408 MHz. These data are available on MPIfR's Survey Sampler ("Max-Planck-Institut für Radioastronomie", Bonn). This is an online service (http://www.mpifr-bonn.mpg.de/survey.html), which allows users to pick a region of the sky and obtain images at a number of wavelengths.

2. 2. METHOD

The area of Monoceros loop is enclosed with brightness temperature contours (see Figure 1). These contour lines correspond to the minimum and maximum brightness temperatures which define its borders. A more complete description of method of calculation is given in Borka (2007) and Borka et al. (2008). The Galactic longitude and latitude intervals for spurs belonging to Monoceros loop are the following: l = [210°,200°], b = [-6°,5°].

3. RESULTS AND CONCLUSIONS

For deriving temperatures over the Monoceros loop, the areas used for the individual spurs were not defined with respect to their best-fit circles, but they were obtained from the radio continuum maps. The areas over which an average brightness temperature is determined at each of the three frequencies are taken to be as similar as possible within the limits of measurement accuracy. However, some differences between these areas still remain and we think that the major causes of differing borders between the three frequencies are small random and systematic errors in the calibrated data. The surface brightnesses of SNRs must be above the sensitivity limit of the observations and must be clearly distinguishable from the Galactic background emission (Green 1991). Therefore, the data from the fainter parts of the loops (which are very low - surface - brightness SNRs) are not taken into account because it is very difficult to resolve them from the background. On the other hand, this would significantly reduce brightnesses of entire loop and there is a general trend that fainter SNRs tend to be larger (Green 2005). For evaluation brightness temperatures over the spurs we had to take into account background radiation (Webster 1974). Borders enclosing the spurs are defined to restrict the spur and its background. For the method of calculation see Borka (2007).

The loops are SNRs which material is spreading inside of bubbles of low density, which are made by former SNR explosions or by strong stellar winds (Salter 1983; McKee & Ostriker 1977 and references therein). Shell type supernova remnants are believed to be particle accelerator to energy up to a few hundred TeV, and it is shown that Monoceros loop is a good candidate for acceleration of particles (Fiasson et al. 2007).

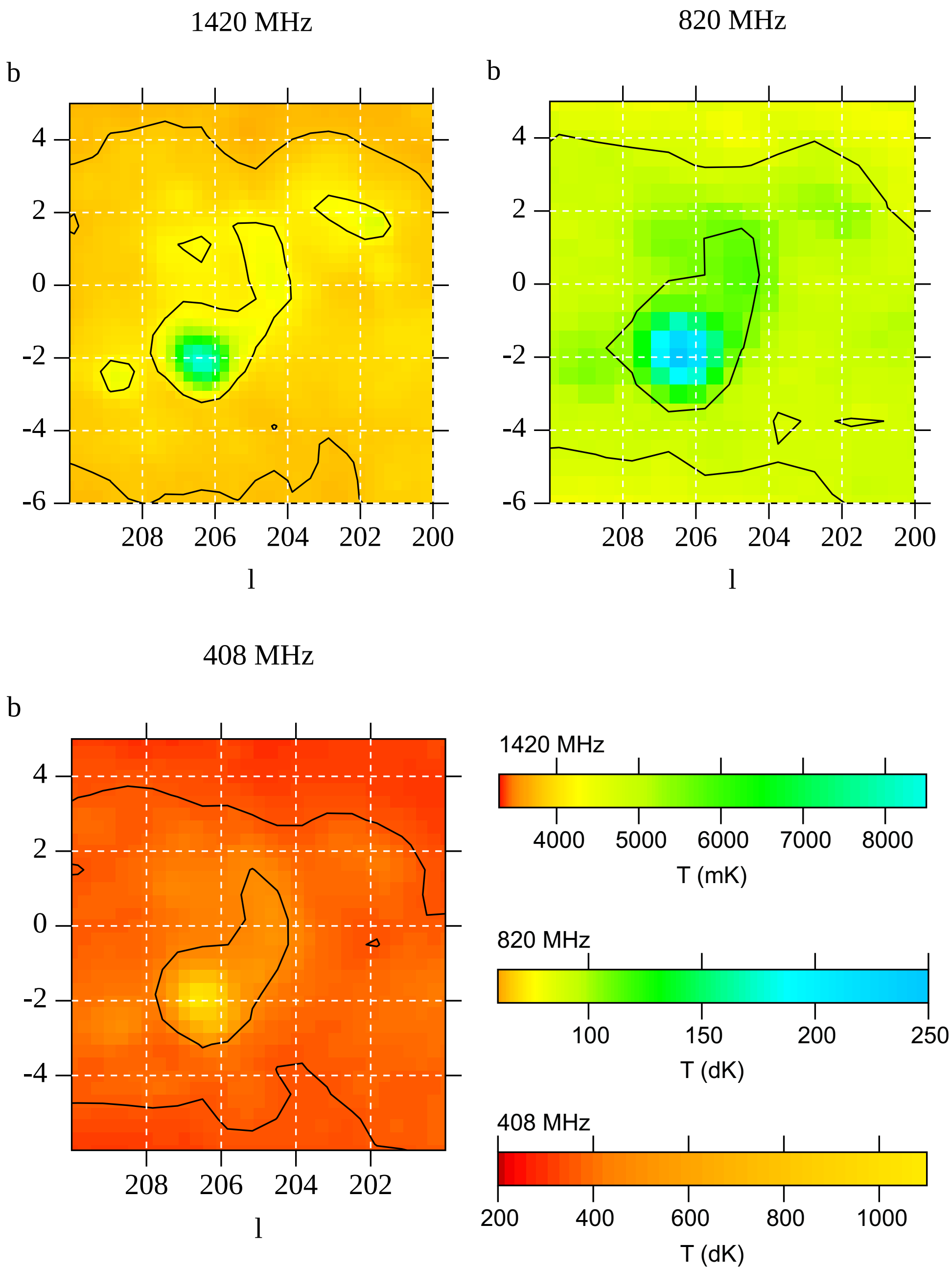

Figure 1: The area of Monoceros loop at 1420, 820 and 408 MHz, showing contours of brightness temperature. The two contours plotted represent the temperatures T_{min} and T_{max} in K, as given in Table 1. This radio loop has position: l = [210°,200°]; b = [-6°,5°].

Table 1: Temperatures and brightnesses of Monoceros radio loop at 1420, 820 and 408 MHz.

frequency (MHz)	temperature limits T_{min}, T_{max} (K)	temperature (K)	brightness (10^{-22} W/(m^2 Hz Sr))
1420	3.8, 4.2	0.18 ± 0.05	1.09 ± 0.30
820	8.8, 10.7	0.90 ± 0.20	1.85 ± 0.40
408	36, 47	5.15 ± 1.0	2.63 ± 0.50

In this paper we calculated the brightness temperatures and surface brightnesses of the Monoceros radio loop at 1420, 820 and 408 MHz. For 820 and 408 MHz frequencies it is the first time that the brightness temperature of Monoceros loop is calculated from the experimental data, and for frequency of 1420 MHz we sample it in much more points (more than 1 000 points) then in previous papers (95 points) (Urošević & Milogradov-Turin 1998, Milogradov-Turin & Urošević 1996) and they are derived using different method. The temperature of this radio loop at 1420 MHz is in good agreement with the result for temperature from papers (Urošević & Milogradov-Turin 1998). For the distance, mean optical velocity suggests 0.8 kpc, and low frequency radio absorption suggests 1.6 kpc (Graham et al. 1982, Green 2006). With new derived brightnesses, it is possible to calculate new diameters and distances to this loop at the three frequencies: 1420, 820 and 408 MHz and then do estimate some average distance. Our analysis indicates that Monoceros radio loop emission is in good agreement with current theories of supernova remnant evolution.

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