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DISTRIBUTION OF RADIO SPECTRAL INDEX OVER THE LUPUS LOOP

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Abstract. We use all-sky surveys at 408 and 1420 MHz with aim to investigate properties of the Galactic radio source Lupus Loop. We estimate the brightness temperature, surface brightness and radio spectral index of this supernova remnant using the method we have developed. The non-thermal nature of its radiation is confirmed, and also the distribution of spectral index over its area is given.

1. INTRODUCTION

The Lupus loop is a large arc of emission of low surface brightness discovered by Milne in the vicinity of the supernova of 1006 AD (Milne 1971, Milne & Dickel 1974), but it is not associated in any way with another supernova remnant (SNR). The radio shell of Lupus Loop is approximately $180'$ in diameter (Kaplan et al. 2006). This remnant is known as old SNR, and has been observed in radio and X-ray wavelength range. In "A Catalogue of Galactic Supernova Remnants" by Green (2014a,2014b) it is labeled as G330.0+15.0.

2. DETERMINING OF LOOP'S BORDERS

For our calculation, we used data from the digital surveys of the sky, available from Max-Planck-Institut for Radioastronomy, Bonn, Germany (at the internet address http://www3.mpifr-bonn.mpg.de/survey.html), which enables users to pick a region of the sky and to obtain data and images at a number of wavelengths. The sky surveys are obtained from continuum radio emission at: 1420 MHz (Reich, Testori & Reich 2001) and 408 MHz (Haslam et al. 1982). Both surveys are all-sky surveys.

Lupus Loop center has the cordinates: $(l, b) = (330°15', 15°3')$ in galactic system, or $(\alpha, \delta) = (15h\ 10min, -40°)$ in equatorial coordinate system. In Fig. 1 we show the location of Lupus Loop at 1420 MHz using galactic coordinates. Also, the contours for brightness temperatures are added, and below there is colorbar for T_b in mK. The

3D plots showing brightness temperatures of this loop and its surrounding, at the same frequency of 1420 MHz, we show in Figs. 2 and 3.

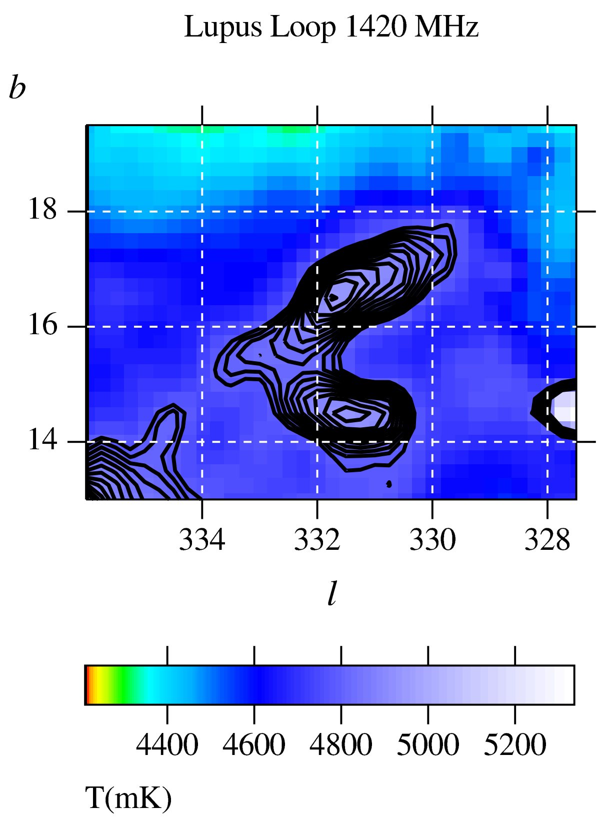

Figure 1: The area of Lupus Loop at 1420 MHz, with brightness temperature contours from 4.78 K to 4.96 K with step of 15 mK. Below, the colorbar is given for brightness temperatures in mK.

3. RADIO SPECTRAL INDEX DISTRIBUTION

Method of calculation is described, in detail, in Borka Jovanović (2012) and references therein. The method we have developed for large Galactic radio loops I-VI (Borka, Milogradov-Turin & Urošević (2006), Borka (2006), Borka (2007), Borka, Milogradov-Turin & Urošević (2008), Borka Jovanović & Urošević (2010) and Urošević & Borka Jovanović (2011)), we applied to angularly large SNRs: Mon, Cyg, HB 21 (Borka Jovanović & Urošević (2008), Borka Jovanović & Urošević (2009a,b), Borka Jovanović & Urošević (2010), Borka Jovanović & Urošević (2011), Borka Jovanović & Urošević (2011) and Borka, Borka Jovanović & Urošević (2012)), but also to the extragalactic radio sources: 3C 349, NGC 6251 (Borka Jovanović et al. (2012) and Borka Jovanović et al. (2013)).

Our motivation is to investigate the nature of emission for this SNR (thermal or non-thermal). If we express the flux density S_ν of some source as a function

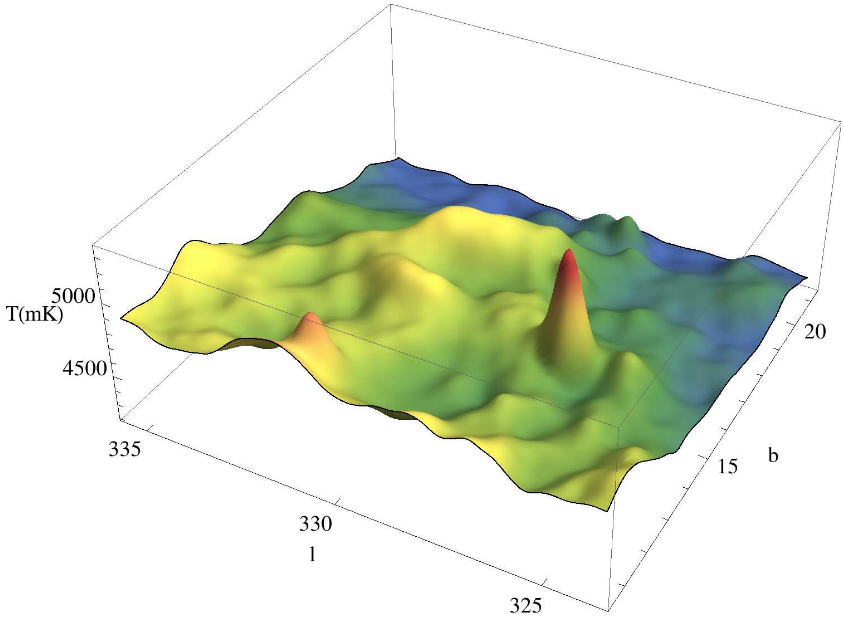

Figure 2: Lupus Loop and its surrounding at 1420 MHz. The brightness temperature is given in mK.

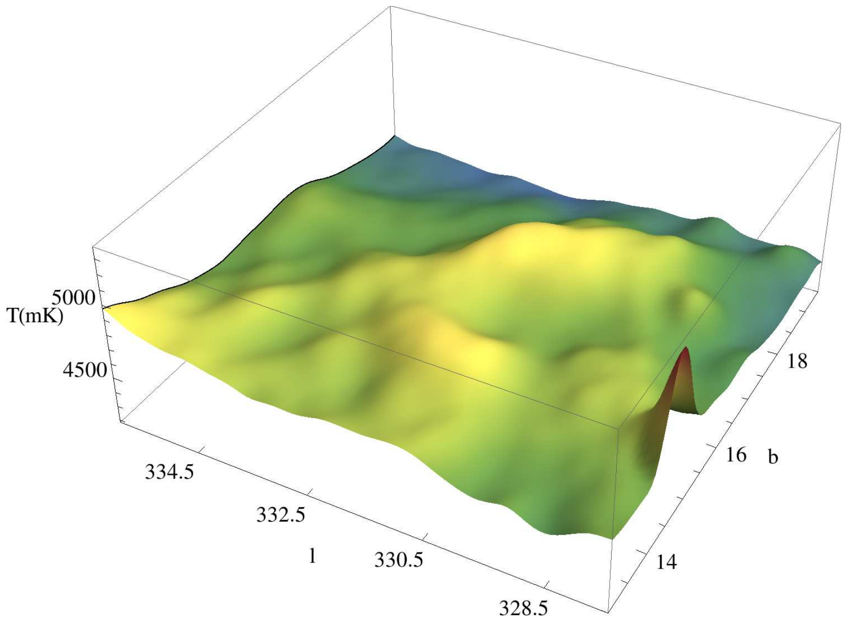

Figure 3: The same as Fig. 2, but for area closer to Lupus Loop.

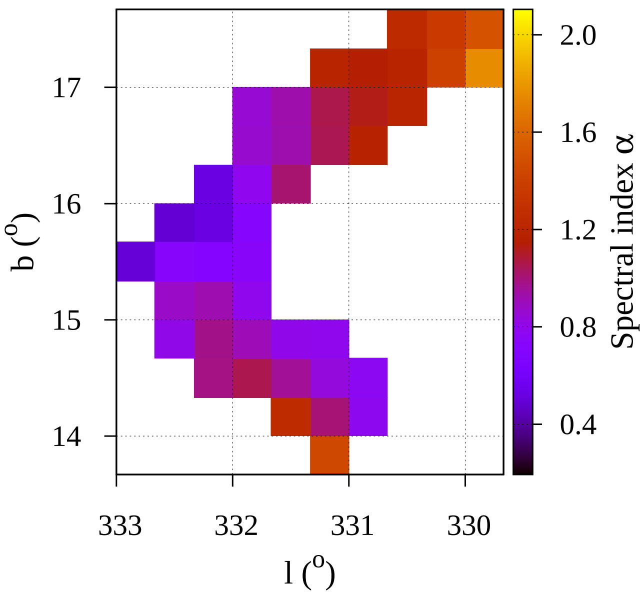

Figure 4: Radio spectral index distribution across the face of the Lupus Loop.

of frequency ν, we can define spectral index α in the following way: $S_\nu \sim \nu^{-\alpha}$. Its value could be then obtained as the slope in: $\log S_\nu = -\alpha \log \nu$, assuming that we have observations at two frequencies, at least. The obtained mean value of the radio spectral index between 408 and 1420 MHz is $\alpha \approx 0.95$, and it confirmed non-thermal emission of radiation for this source. The corresponding radio spectral index distribution is shown in Fig. 4, indicating that the greatest variations of α could be expected near the ridges of the loop.

When comparing our value for α with earlier results, these new observations yielded a greater value. Milne (1971) calculated spectral index between the following frequencies: 160, 408, 635, 1410, 1614, 2700 and 5000 MHz, and obtained mean value $\alpha = 0.38$, while Milne & Dickel (1974) used frequencies 1410, 1660 and 2700 MHz which resulted in $\alpha = 0.5$, although they mentioned that conclusions about Lupus Loop are uncertain and that more data were required. Our result is larger than the typical value for Galactic SNRs, but in Green's catalogue for spectral index about $\alpha \approx 0.5$ it is mentioned that it is not precisely determined, even a question mark is put as a notice that it should be recalculated. Probably previous authors took into account wider area for Lupus Loop (loop + part of the background) and in that way they lowered the brightness temperature of the loop and the value of mean spectral index. Also, we can notice tendency that more recent observations give higher value of α than previous. Because variation of spectral index over the loop is rather big, we think that distribution of spectral index over the loop is more adequate in description of the loop than mean spectral index. From our Fig. 4 it can be seen that most part of the loop's area has radio spectral index between 0.4 and 0.8. Greater values are connected with its ridges, and then as a whole it gives the mean value 0.95.

4. CONCLUSIONS

As we showed earlier (Borka Jovanović 2012 and references therein), the method for defining a loop border and for determining the values of temperature and brightness, which we developed for main Galactic Loops I-VI, could be applicable to all SNRs.

We used the spectral index to study the radiation mechanism of this radio source. The value of the radio spectral index $\alpha > 0.1$ confirmed non-thermal emission of radiation for this source. These new observations yielded value of α greater than Milne & Dickel (1974).

Besides the nature of the radiation, we also showed how spectral index varies across the face of the remnant.

Acknowledgments

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