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Belgrade, Serbia,
September 5 - 9, 2022

CONTRIBUTED PAPERS

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ABSTRACTS of INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

Editors:
Dragana Ilić, Vladimir Srećković,
Bratislav Obradović and Jovan Cvetić

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The Workshop on X-ray and VUV Interaction with Biomolecules in Gas Phase (XiBiGP)

Publ. Astron. Obs. Belgrade No. 102 (2022), 265 - 268 *Contributed Paper*

WINGED DRAGN SOURCE FROM LEAHY'S ATLAS: 3C 315

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Abstract. The goal of this paper is to inspect the flux density as well as the spectral index distribution of 3C 315, an X-shaped radio source with a steep spectrum core. To this end we used publicly available data and images of the source at different frequencies (specifically 1646 MHz and 2695 MHz, as well as Leahy's atlas of double radio-sources). We found that synchrotron radiation is the dominant radiation mechanism over most of the area of 3C 315 with an average spectral index α of 0.956.

1. AN ATLAS OF DRAGNS AND WINGED SOURCE 3C 315

Double Radio Sources Associated with Galactic Nuclei (DRAGNs) are large radio structures which result from processes in Active Galactic Nuclei (AGN) and manifest as double radio sources.

The closest 85 of these DRAGNS from the 3CRR sample were compiled into an atlas (Leahy et al. 2013), along with highly detailed radio images of the sources and basic information concerning each one. The sources in this atlas have been subjects of many studies and plenty of observations at a multitude of frequencies have been made available, making them perfect candidates for the type of research conducted in this paper.

1. 1. 3C 315

The radio source 3C 315 was first listed in the Third Cambridge Catalogue of Radio Sources, where the number after 3C indicates its position in the dataset (cross-identifications: 3C 315; 4C +26.47; PKS 1511+26; B2 1511+26; LQAC 228+026 002). What distinguishes this source and makes it interesting are a few of its characteristics.

Firstly, it is an X-shaped (winged) radio source, meaning it has two sets of double lobes angled with respect to each other. This is a result of a rotation in the axis of the jets, which again might result from reorientations of the supermassive black hole in the center of the host galaxy in the aftermath of black hole merger.

DRAGN 3C 315 does not contain any true hotspots, apart from a weak hotspot in the far-side of the north-western lobe. However as an X-shaped radio galaxy it would still be classified as an FR-II radio galaxy.

The host galaxy of 3C 315 is highly elongated in the north west - south east direction (de Koff el al. 2000) and accompanied by an elliptical galaxy, both of which are located inside a cluster, which allows for the environment to play a role in the evolution of this object.

Lastly, 3C 315 is a steep spectrum core source, which means the core actually consists of a pair of lobes much like the outer kiloparsec sized lobes. These inner lobes have a flux density - frequency relation described by a power law (much like the outer lobes), from where the name is derived.

We used observations of 3C 315 at two different frequencies, 1646 MHz (21 cm) and 2695 MHz (11 cm) (see Alexander & Leahy 1987). In Figure 1 we present the flux density distribution at the two frequencies over the area of the source, where the lower boundaries of the source were determined to be contours $S_{\nu,min} = 0.002$ Jy at 1646 MHz and $S_{\nu,min} = 0.0022$ Jy at 2695 MHz. These lower limits are in agreement with contours drawn at 3.5 times the standard deviation of the background noise.

In Figure 2 the same data is shown, but on a 3D graph for additional clarity. The most distinguishing feature is the bright steep spectrum core in the center of the source and it is surrounded by the relaxed structure of the four lobes surrounding it. In the 2695 MHz image much of the north-east section of the structure is lost in the noise.

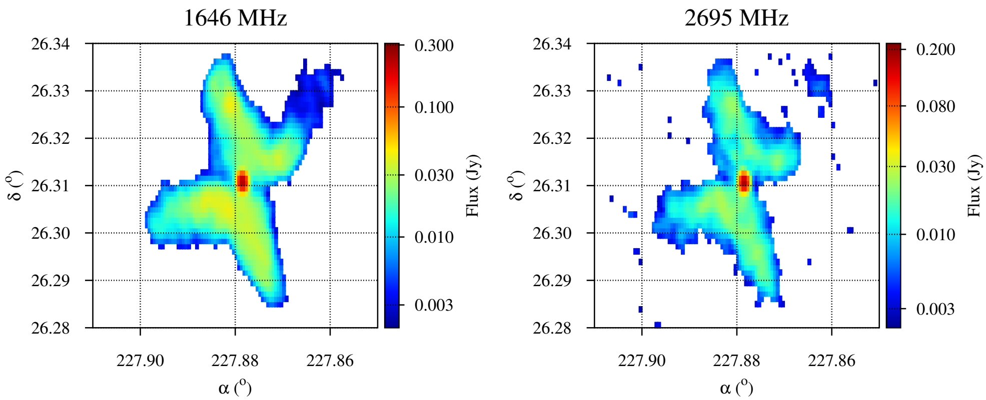

Figure 1: Flux density distribution of 3C 315 at 1646 MHz (left) and 2695 MHz (right). The areas with flux density levels below the lowest contour have been coloured in white.

2. DISTRIBUTION OF SPECTRAL INDICES BETWEEN 1646 AND 2695 MHz

In radio sources, the flux density S_ν dependence on frequency is characterized with the power-law relation $S_\nu \propto \nu^{-\alpha}$, where α is called the 'spectral index' and is easily obtainable by measuring the flux density at different frequencies and taking the negative slope of the above relation, resulting in:

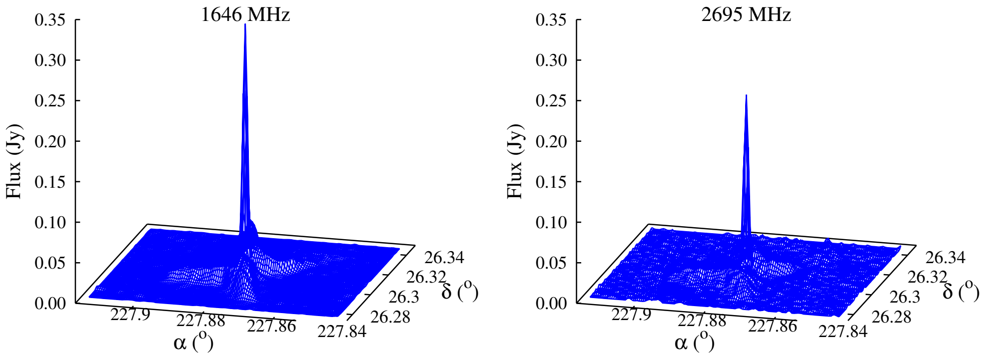

Figure 2: 3D plot of 3C 315 flux density distribution at 1646 MHz (left) and 2695 MHz (right).

$$\alpha = -\frac{\log\left(\frac{S_{\nu_1}}{S_{\nu_2}}\right)}{\log\left(\frac{\nu_1}{\nu_2}\right)}. \tag{1}$$

The spectral index can be used to classify radio sources and understand the origin of radio emission. More specifically, if $\alpha > 0.1$ the emission is non-thermal (synchrotron) in origin, meaning it does not depend on the temperature of the source, and for $\alpha < 0$ it is thermal (depends only on the temperature of the source) in origin.

In Figure 3 we present the spectral index map of 3C 315, derived from the flux density distributions at 1646 and 2695 MHz. The calculation methods we used and developed were first published in Borka (2007), and further elaborated in Borka Jovanović (2012) and Borka Jovanović et al. (2012).

It should be noted this is the first time such a spectral index map (i.e. its distribution over entire source) for this source has been shown. As can be seen, the spectral index is positive (with an average value of 0.956, which aligns with earlier studies such as Northover (1976)) over almost the entirety of the area of 3C 315, indicating that non-thermal emission is the dominant emission mechanism. The only region with a significantly negative spectral index is the far end of the north-east lobe with a mean spectral index of -0.35, which would imply thermal emission as the origin. It should also be mentioned that the spectral index is on average higher along the south west - north east axis, which would confirm these are more aged lobes from previous AGN activity.

3. CONCLUSION

We obtained the flux density of 3C 315 at 1646 MHz (21 cm) and at 2695 MHz (11 cm), and provided the spectral index distribution derived from these two frequencies for the first time. At both frequencies the core dominates the flux density distribution, while the rest of the structure is relaxed with no obvious hotspots. In the spectral index map the difference between the core and lobes is much less pronounced. Synchrotron

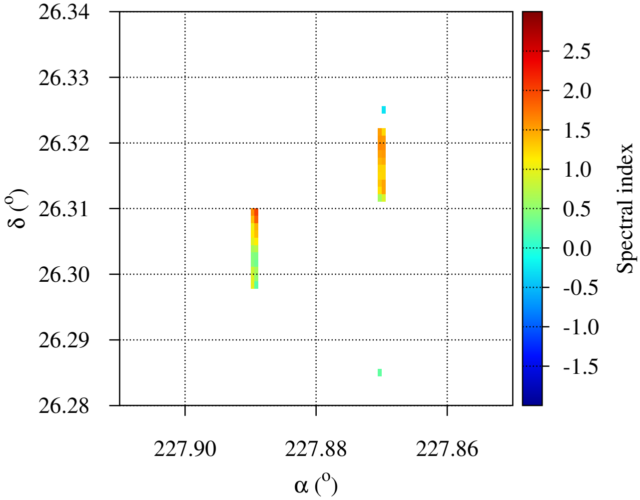

Figure 3: Spectral index map of 3C 315, obtained by combining 1646 MHz and 2695 MHz image data.

radiation is the dominant emission mechanism over the majority of the area of the source with an average spectral index of 0.956, with the exception of the north-eastern section where the spectral index is primarily negative with a mean value of -0.35.

The results of this study will be helpful for understanding the evolutionary process of the 3C 315 radio source.

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