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DIFFERENTIAL SPECTRAL INDICES OF RADIO SPURS BETWEEN 38, 408 AND 1420 MHz

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SUMMARY: The differential spectral indices of the North Polar Spur, the Spur in Aquarius, Pegasus and Taurus were derived using data at 38, 408 and 1420 MHz of the same resolution of 7°.25 × 8°.25, reduced to the case of scaled aerials. The method applied was the classical one, using slopes of the relevant T-T graphs. The T-T graphs plotted between these three frequencies have shown clear splitting of branches supporting the reality of this quasihysteresis effect. The values derived are in good agreement with those obtained at other frequencies by other authors and by other methods.

1. INTRODUCTION

The basic idea of a differential spectral index as spectral index of a feature (anisotropic component) projected on an isotropic background was introduced by radio astronomers in Cambridge who suggested a simple way of its derivation by plotting temperatures at one frequency versus temperatures at the other frequency (T-T graph) and determination of the slope of the line on such a graph (Turtle et al., 1962). This method was applied by many scientists interested in spectral characteristics of the radio spurs and loops (e.g. Bridle, 1967; Berkhuijsen, 1971; Webster, 1974). Recently an other way for determination of spectral indices of spurs was used by Reich and Reich (1988). They were directly subtracting from the total temperature at a given point all calculated contributions of isotropic components. Basically, both methods assume some characteristics of the underlining background. Therefore, it is justified to use the T-T graphs further, particularly for the low resolution surveys. The other reason for the use of the Cambridge method is that T-T graphs show some characteristics which were not sufficiently studied but could be significant indicators of the presence of several components in the radio emission arriving from radio spurs (Milogradov-Turin, 1982, 1987).

2. DATA

The main advantage of the work presented here is a big span of frequencies which makes differential spectral indices derived from them much less sensitive to errors. The lowest frequency used is 37 times smaller than the highest one, while the lowest frequency is about ten times smaller then the next one. An increase of the 1420 MHz data for 55% would give a decrease of differential spectral indices between 38 and 1420 MHz of 0.12, between 408 and 1420 MHz 0.35, while an increase od the 38 MHz data for 3% would give an increase of differential spectral indices between 38 and 1420 MHz of only 0.008 and between 38 and 408 MHZ of 0.01 (Nikolić, 1994). This example offers a good feeling for reliability of the derived values.

The data at 38 MHz were those from the 38 MHz survey of Milogradov-Turin and Smith (1973). Since the spur in Aquarius was lying in the region where comparatively high ionospheric absorption was present (Milogradov-Turin and Smith, 1973), correction for it was applied.

The 408 and 1420 MHz data were received from Haslam and Salter (1983) and Reich (1990) who convolved their surveys to the resolution of the 38 MHz survey.

They are of the same resolution of 7°.25 × 8°.25 and mimic the case of scaled aerials.

3. ANALYSIS

By definition, a differential temperature spectral index β_d is given by the slope a of the straight line on the T-T graph where temperatures at the higher frequency are plotted along the axis of abcissae. It is related to the temperature of the anisotropic component T_{an} as

$$T_{an} \propto \nu^{-\beta_d},$$

and to the slope

$$\beta_d(\nu_1, \nu_2) = \log \frac{\nu_2}{\nu_1} \cdot \log a.$$

All T-T graphs in this work were showing a clear splitting of branches plotted for the outer and the inner part of the spur. This is an interesting result by itself (Milogradov-Turin and Nikolić, 1995) and may be interpreted as a presence of a high spectral index component on the outer part of a spur (Milogradov-Turin, 1987).

In order to derive a differential spectral index we were taking the best fitted line through the middle of the T-T fork, almost parallel to the both branches. Such a line is represented as a full line in Figure 1.

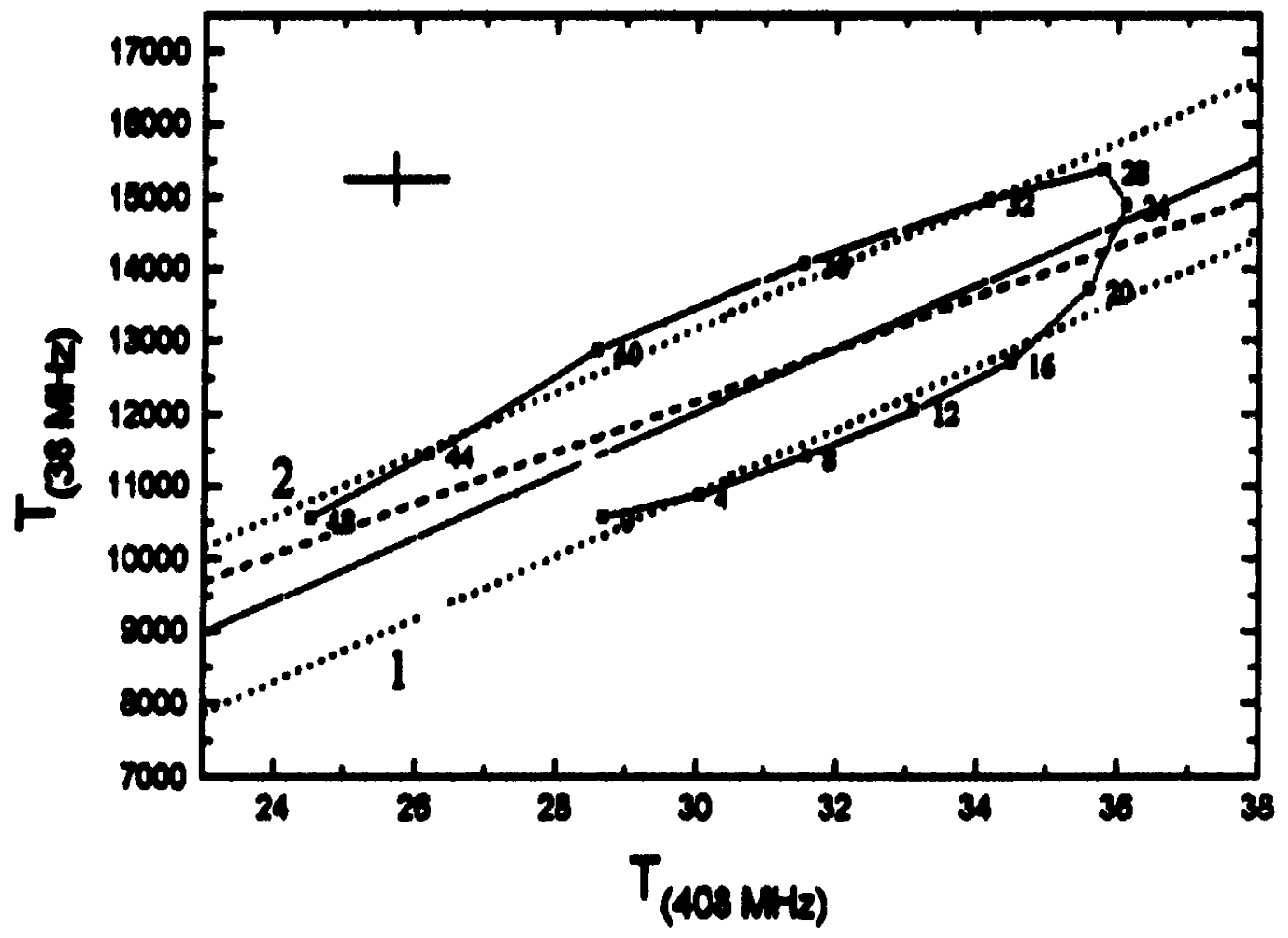

Fig. 1. T-T graph of the North Polar Spur for $b = 58°$.

The best fits to branches are given as dotted lines. The classical least square fit to all data is represented by a dashed line (Nikolić, 1994). It is obvious that it does not correspond to the effect expected from the T-T graph. Since we believe the splitting might have an astronomical reason, as mentioned above, we have decided to derive the differential spectral indices from the slope of the middle line, as it was already done by Milogradov-Turin (1982). The difference in indices obtained from the middle line and the least square fit line on the Figure 1. is 0.1. (Nikolić, 1994).

The errors quoted in Table 1. are internal ones. They represent deviations of points from the straight line while the errors of the averaged values contain internal and external errors.

4. RESULTS

Differential spectral indices for all radio-spurs on different latitudes are given in the Table 1, and the mean values of indices for all radio-spurs are given in Table 2.

Table 1. Differential spectral indices of radio-spurs on different latitudes

	408 – 38	1420 – 38	1420 – 408
North Polar Spur			
$b = 22°$	2.47 ± 0.04	2.55 ± 0.05	2.78 ± 0.02
26°	2.47 ± 0.04	2.60 ± 0.01	2.98 ± 0.03
30°	2.42 ± 0.01	2.64 ± 0.01	2.96 ± 0.02
34°	2.45 ± 0.01	2.63 ± 0.01	2.98 ± 0.01
38°	2.44 ± 0.01	2.66 ± 0.01	2.92 ± 0.01
42°	2.48 ± 0.02	2.61 ± 0.01	2.97 ± 0.01
46°	2.46 ± 0.04	2.59 ± 0.04	2.97 ± 0.02
50°	2.45 ± 0.05	2.72 ± 0.03	2.91 ± 0.02
54°	2.60 ± 0.02	2.67 ± 0.01	2.91 ± 0.02
58°	2.60 ± 0.04	2.67 ± 0.02	2.92 ± 0.01
62°	2.60 ± 0.02	2.65 ± 0.02	2.93 ± 0.01
66°	2.57 ± 0.01	2.66 ± 0.02	2.90 ± 0.01
70°	2.58 ± 0.01	2.67 ± 0.01	2.86 ± 0.01
Spur in Aquarius			
$b = -34°$	2.65 ± 0.04	2.74 ± 0.01	2.64 ± 0.04
−38°	2.63 ± 0.07	2.70 ± 0.01	2.67 ± 0.06
−42°	2.50 ± 0.06	2.69 ± 0.02	2.95 ± 0.05
−46°	2.49 ± 0.05	2.67 ± 0.06	3.06 ± 0.15
−50°	2.20 ± 0.20	2.70 ± 0.20	3.59 ± 0.08
−54°	2.30 ± 0.40	2.50 ± 0.30	3.32 ± 0.09
Spur in Pegasus			
$b = -22°$	2.64 ± 0.09	2.68 ± 0.05	2.77 ± 0.07
−26°	2.63 ± 0.02	2.68 ± 0.02	2.76 ± 0.04
−30°	2.57 ± 0.04	2.69 ± 0.02	2.98 ± 0.03
−34°	2.49 ± 0.09	2.67 ± 0.04	3.13 ± 0.05
−38°	2.64 ± 0.09	2.72 ± 0.04	3.24 ± 0.09
−42°	2.25 ± 0.09	2.57 ± 0.04	3.20 ± 0.10
Spur in Taurus			
$b = -18°$	2.46 ± 0.03	2.66 ± 0.08	3.00 ± 0.20
−22°	2.61 ± 0.01	2.77 ± 0.02	2.90 ± 0.08
−26°	2.44 ± 0.09	2.58 ± 0.08	2.88 ± 0.03
−30°	2.39 ± 0.07	2.53 ± 0.06	3.02 ± 0.03
−34°	2.53 ± 0.02	2.65 ± 0.01	2.87 ± 0.04

Table 2. Mean values of the differential spectral indices of radio-spurs

	408 – 38	1420 – 38	1420 – 408
North Polar Spur	2.51 ± 0.06	2.64 ± 0.04	2.92 ± 0.09
Spur in Aquarius	2.5 ± 0.2	2.7 ± 0.1	3.0 ± 0.1
Spur in Pegasus	2.53 ± 0.09	2.67 ± 0.04	3.0 ± 0.1
Spur in Taurus	2.49 ± 0.07	2.64 ± 0.06	2.9 ± 0.1

General conclusions are:

1. spectral indices of all the studied radio spurs are similar,
2. indices rise towards higher frequencies, meaning that the spectra of radio spurs are curved.

5. DISCUSSION

Although it is not easy to compare spectral indices between themselves since they are usually obtained for different sets of frequencies, different ranges of longitudes or declinations and for different resolutions, one can do it with a considerable caution. Most of the published results are related to the North Polar Spur; only Berkhuijsen (1971) gives indices for the spurs seen on her survey.

The only case where the comparison could be readily done was one with differential temperature spectral indices between 38 and 404 MHz (Milogradov-Turin, 1982). Since they were derived from almost the same type of telescopes (Milogradov-Turin and Smith, 1973 ; Pauliny-Toth and Shakeshaft, 1962) they represented real scaled aerials results. The agreement between $\beta_d(38, 404)$ and $\beta_d(38, 408)$ was within limits of errors for all observed radio-spurs.

The comparison with the spectral indices derived by Reich and Reich (1988) for the same pair of frequencies is less straightforward. Firstly, Reich and Reich (1988) have obtained spectral indices of the radio-spurs after subtraction of the components of radio emission they could calculate. Secondly, the resolution of their data used for this purpose was 2.°5. Thirdly, they published the map of indices only for the region of the North Polar Spur. Taking all this into account we find that the difference of about 0.2 in spectral indices is not too worrying. It lies just outside the quotted errors (Nikolić, 1994).

The analysis of the papers on differential spectral indices within the first decade since their introduction (Webster, 1974 and references therein) has shown that most of them must be corrected (Milogradov-Turin, 1982), for various reasons. One of the ways the comparison could be made more obvious is to plot spectral indices versus geometrical means of the pairs of frequencies used for their derivation (Milogradov-Turin, 1982). Comparison with such data does not show greater differences than could be expected.

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REFERENCES

Berkhuijsen, E. M.: 1971, ***Astron. Astrophys.*** **14**, 359.

Bridle, A. H.: 1967, ***Mon. Not. Roy. Astron. Soc.*** **136**, 219.

Haslam, C. G. T., Salter, C. J.: 1983, private communication.

Milogradov-Turin, J.: 1982, ***Ph. D. Thesis***, University of Beograd.

Milogradov-Turin, J.: 1987, ***Publ. Astron. Inst. Czek. Acc. Sci***, **659**, 225.

Milogradov-Turin, J., Nikolić, S.: 1995 (to be published).

Milogradov-Turin, J., Smith, F. G.: 1973, ***Mon. Not. Roy. Astron. Soc.*** **161**, 269.

Nikolić, S.: 1994, ***M.Sc. Thesis***, University of Beograd.

Pauliny-Toth, I. I. K, Shakeshaft, J. R.: 1962, ***Mon. Not. Roy. Astron. Soc.*** **124**, 61.

Reich, W.: 1990, private communication.

Reich, P., Reich, W.: 1988, ***Astron. Astrophys.*** **196**, 211.

Turtle, A. J., Pugh, J. F., Kenderdine, S., Pauliny-Toth, I. I. K.: 1962, ***Mon. Not. Roy. Astron. Soc.*** **124**, 297.

Webster, A. S.: 1974, ***Mon. Not. Roy. Astron. Soc.*** **166**, 355.

ДИФЕРЕНЦИЈАЛНИ СПЕКТРАЛНИ ИНДЕКСИ РАДИО-ЛУКОВА ИЗМЕЂУ 38, 408 И 1420 MHz

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Оригинални научни рад

Користећи посматрања на 38, 408 и 1420 MHz, исте раздвојне моћи од $7\overset{\circ}{.}25 \times 8\overset{\circ}{.}25$, израчунати су диференцијални спектрални индекси Северног поларног лука, Лука у Водолији, Лука у Пегазу и Лука у Бику. Индекси су израчунати из нагиба одговарајућих Т-Т графика. Потврђено је раније уочено расцепљење Т-Т графика на гране, што указује на реалност овог квазихистерезисног ефекта. Вредности израчунатих диференцијалних спектралних индекса у доброј су сагласности са индексима изведеним између других фреквенција и другим методама од стране других аутора.