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THE SHAPE OF RADIO SPECTRA OF SPURS BETWEEN 38, 408 AND 1420 MHz

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SUMMARY: The spectra of the North Polar Spur (NPS), the Spurs in Aquarius, Pegasus and Taurus were derived from the spectral indices between 38, 408 and 1420 MHz. The data were reduced to the case of scaled aerials with HPBW of 7.° 25×8.° 25. Using the second order polynomial approximation, mathematical spectra have been computed. They appeared similar for all three spurs. Clear maximum of relative flux for the NPS and for the Spur in Taurus is seen at about 14 MHz, for the Spur in Pegasus maximum is at about 17 MHz while for the Spur in Aquarius is near 19 MHz. The spectra are steeper at higher and flatter at lower frequencies. The general shape does not strongly depend on the claimed observational errors of the used surveys. The extreme cases were discussed. The curvature is greater if highest frequency data are increased and lower frequency data decreased for the quoted error. In the oposite case, if highest frequency data are decreased and lower frequency data increased for the quoted error, the curvature of a spectrum is very small, similar to one derived by Milogradov-Turin (1982). New observations at frequencies lower than 20 MHz are needed.

1. INTRODUCTION

The shape of spectra of large scale radio background features has not been studied extensively. The most investigated regions are those near the North and South Galactic Poles (e.g. Cane, 1979 and references therein) and the Regions I and II, as defined in early Cambridge papers (e.g. Bridle, 1967 and Sironi, 1974). The Region I lies between the so called North cold hole near the North Galactic Pole (NGP) and the anticentre while the Region II lies just outside the North Polar Spur and includes NGP. Low resolution of available antennas allowed them to be used only for parts where the sky is rather smooth.

Although radio spurs were noticeable in the very first background surveys, their spectra have been rather poorly studied. Even the spectrum of the NPS is not known in detail. One obtained by Milogradov-Turin (1982) is the only spectrum of the NPS covering the region from above 10 MHz up to almost 1000 MHz. It was derived from all spectral indices available at that time (Bridle, 1967; Berkhuijsen, 1971; Wilson, 1971; Milogradov-Turin, 1982) by the same method as described further in this paper. The spectrum of the NPS was found to be curved without the turnover in this frequency region. A tentative explanation for such a shape was suggested (Milogradov-Turin, 1982), while more detailed investigation was left to the time when better spectral indices would be obtained. Those mentioned above were taken from observations of different resolutions. Some authors (Salter, 1983) were expecting to see a turnover in the spectrum or a flattening at low frequencies.

Since then, better spectral indices of the radio background having resolution of about one degree were obtained (Reich and Reich, 1988) between 408 and 1420 MHz. They derived spectral indices not by a usual T-T method but by subtraction temperatures of known Galactic and extragalactic components according to assumed model.

In order to study the shape of the spectrum a larger span of frequences should be available. Therefore, it seemed desirable to attempt to obtain the spectra based on the data of the same resolution, as much as possible similar to scaled antennas in a wider frequency range 38 - 1420 MHz by the T-T method, as this method is more suited to the available data.

2. DATA

Three radio continuum surveys were used: the 38 MHz (Milogradov-Turin and Smith, 1973) with HPBW of 7.°25 × 8.°25, the 408 MHz (Haslam and Salter, 1983) and the 1420 MHz (Reich and Reich, 1988). The last two were convolved to the resolution of the 38 MHz survey by their authors. Therefore, the data were reduced to the case of scaled aerials. Since the spur in Aquarius was lying in the region with high ionospheric absorption, correction for it on 38 MHz was applied. Four radio spurs were analyzed: The North Polar Spur (NPS) covering the region of galactic longitudes between 0° and 48°, and galactic latitudes between 22° and 70°; the Spur in Aquarius lying in $l \in (32°, 60°)$ and $b \in (-34°, -54°)$, the Spur in Taurus ($l \in (168°, 196°)$ and $b \in (-18°, -30°)$) and the Spur in Pegasus ($l \in (64°, 92°)$ and $b \in (-22°, -34°)$.

3. METHOD

Flux density for majority of sources in parts of the radio region can be expressed as an exponential function of frequency

$$S \propto f^{-\alpha}, \qquad (1)$$

where α is called (flux density) spectral index.

Basic idea of the method used is the assumption that the function of radio flux can be written as a second order logarithmic polinomical of frequency (Milogradov-Turin, 1982):

$$\log S = a + b \cdot \log f + c \cdot \log^2 f. \qquad (2)$$

This is justified for the majority of simple curved spectra at least in a part of the radio frequency region. The coefficient a can not be determined if the values of flux are not absolute ones.

Spectral index α provides a means for determination of the coefficients b and c. Practicaly, measuring at two different frequencies one obtaines only a value α fairly close to a real α_r in this frequency range, but not α_r itself. Between two other frequencies the value of α is expected to be different. The simplest case is a linear dependence of spectral index α on $\log f$

$$\alpha = k \cdot \log f + d. \qquad (3)$$

Such a dependence was found in this work for the radio spurs (e.g. Figure 1). After differentiation of the equation (2) with respect to $\log f$ and combination with the equation (3) one gets

$$-\alpha = b + 2c \cdot \log f. \qquad (4)$$

Thus $c = -\frac{k}{2}$ and $b = -d$, i.e. the cut-off and the slope of the $(\alpha - \log f)$ straight line give us b and c. Knowing them a mathematical shape of spectrum can be calculated.

4. RESULTS

4.1 Spectral indices dependence on frequency

In this work three values of α (for three combination of frequencies) were calculated from corresponding T-T graphs for constant latitudes. (Nikolić, 1994; Milogradov-Turin and Nikolić, 1995a). The obtained values were plotted for corresponding geometrical means of frequency pairs. In Figure 1. dependence of the spectral index on frequency for the NPS is given (Nikolić, 1994). Dependence of spectral index on frequency for spurs in Aquarius, Pegasus and Taurus is similar, as shown. Preliminary results are already in press (Milogradov-Turin and Nikolić, 1995b). The so called "Upper value" of α is found from two spectral indices, at lowest frequency the quoted error is subtracted and at highest frequency the quoted error is added to already obtained spectral index (Nikolić, 1994; Milogradov-Turin and Nikolić, 1995a). Similarly, the so called "Lowest value" is found from two spectral indices, at lowest frequency the quoted error is added and at highest frequency the quoted error is subtracted from already obtained spectral index (Nikolić; 1994, Milogradov-Turin and Nikolić, 1995a). All fits were done by least square method.

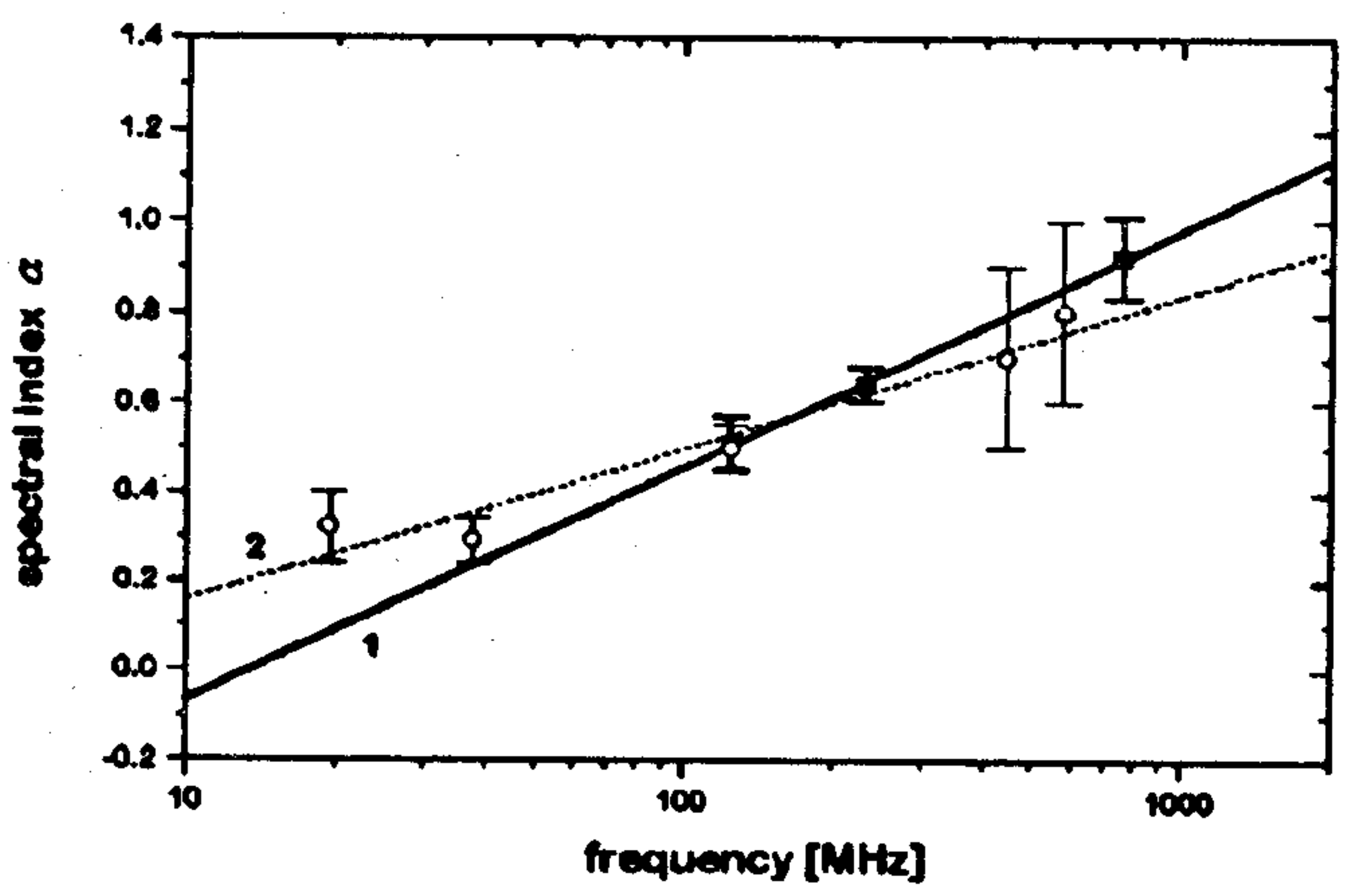

Fig.1 - Spectral index as a function of frequency for the NPS, [(1, solid squares from Nikolić, 1994); (2, open circles from Milogradov-Turin, 1982)].

The influence of errors in the case of weaker spurs is greater. In extreme case it can lead even to the change of sign of spectral index.

4.2 Spectra of radio spurs

The obtained mathematical spectra for all four spurs are shown in Figures 2. and 3. In Fig. 2. are given: the previously (Milogradov-Turin, 1982) derived spectra for the NPS (2), the new one (Nikolić, 1994) (1), spectra for "upper value" of the slope marked with "1a", and spectra for the "lower value" of the slope marked with "1b". The shapes of the previously derived spectra and spectra marked with "1b" are almost the same. The old one was derived from spectral indices for the frequencies between 20 and 600 MHz, while the new one was derived from spectral indices for the frequences between 100 and 800 MHz. This may indicate that new observation on frequencies lower than 20 MHz are needed. Geometrical means of pairs of frequencies are marked with dashed vertical lines, and frequencies of used surveys with dotted vertical lines.

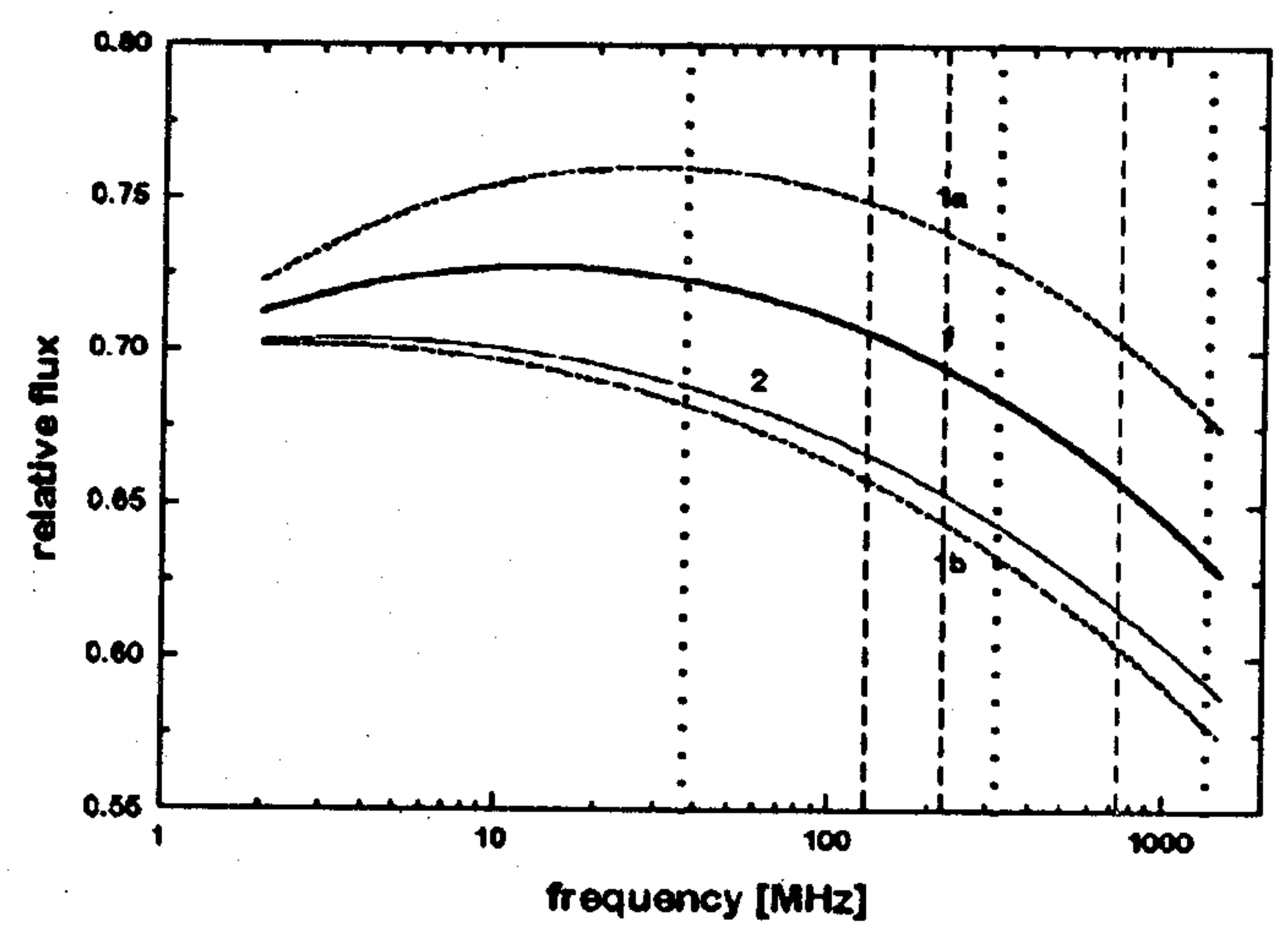

Fig. 2 - Spectra of the NPS.

In Figure 3. spectra for other three spurs are shown (Nikolić, 1994). Spectra marked with "a" and "b" have the same meaning as the one in Figure 2.

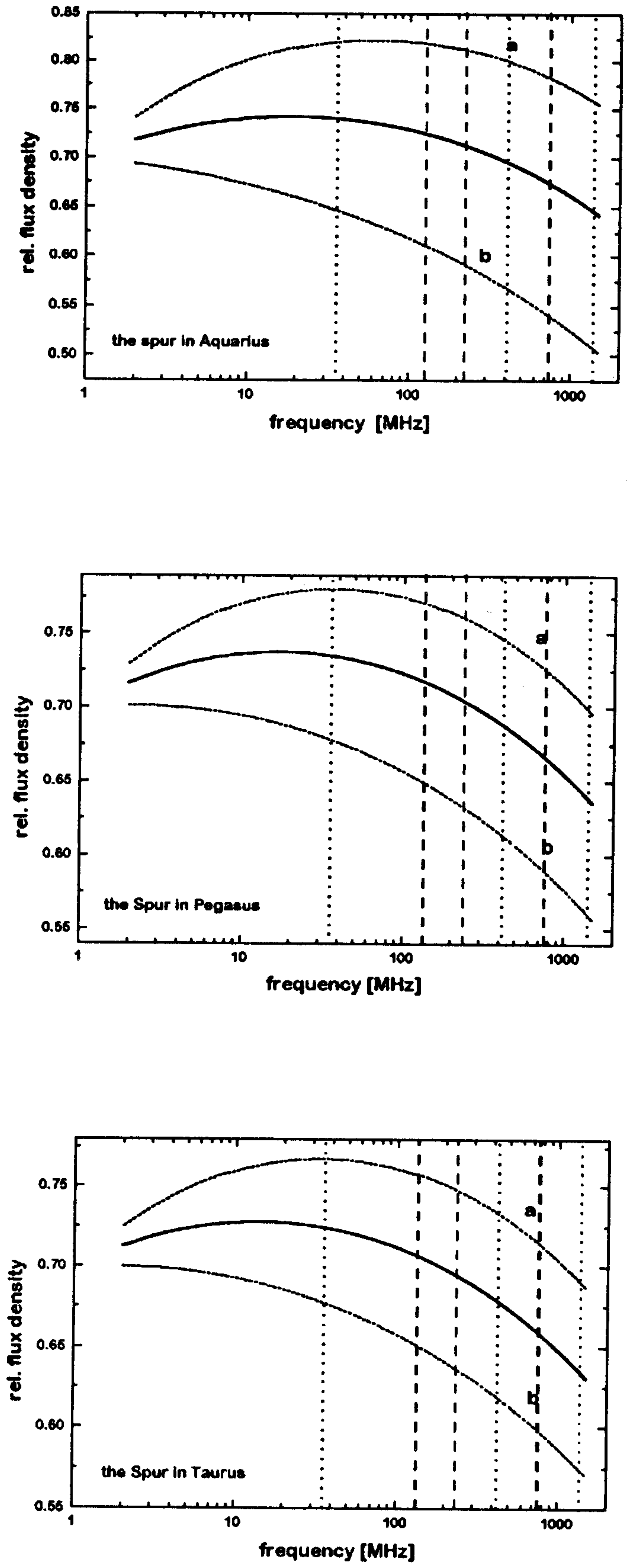

Fig. 3 - Spectra of the Spur in Aquarius, the Spur in Pegasus and the Spur in Taurus.

There is a clear maximum in the calculated spectra for all radio spurs: for the NPS and the Spur in Taurus near 14 MHz, for the Spur in Pegasus near 17 MHz and the Spur in Aquarius near 19 MHz. The shape of spectra remains almost the same when highest frequency data are increased and lower frequency data decreased for the quoted error: at lower frequencies it turns down having the negative spectral indices, and at the higher frequencies it is very steep. Spectra obtained from this "upper value" of the slope have clear maximum on higher frequencies: the North Polar Spur on about 29 MHz, the Spur in Aquarius at about 63 MHz, the Spur in Pegasus at about 37 MHz and the Spur in Taurus at about 34 MHz. On the other hand, all spectra obtained from the "lower value" of the slope have no extreme values at frequencies higher than a few megahertz, exactly as previously derived spectra for the NPS (Milogradov-Turin, 1982).

5. DISCUSSION

Essentialy, the shape of the calculated spectra is determined by the spectral indices at 38, 408 and 1420 MHz and the assumption introduced in the method. The turnover is lying in the regions of extrapolation. The new obtained shape might be due to the method applied. The old compiled data spectrum of the NPS (Milogradov-Turin, 1982) does not show a turnover up to 10 MHz, but this result should not be taken too seriosly since the data were obtained from very different surveys, not from scaled aerials. This position and a uniformity of data being scaled aerials type give a sense to this study. If the reality of turnover is confirmed by observations below 38 MHz, it would be an interesting result. The turnover is expected to be most likely caused by the shape of the synchrotron spectra itself and the history of a spur (injection of electrons, losses of energy etc.).

Comparison of the dependence of spectral indices on frequency for spurs with similar graphs for the region around the NGP (e.g. Yates and Wielebinski, 1967; Cane, 1979) and the Regions I and II (e.g. Bridle, 1967; Sironi, 1974) does not help to clearify the situation. Spectral index of the NGP follows a curved line, changing even the sign below 6 MHz. Therefore its spectrum has a maximum at 6 MHz. Regions I and II, down to 17.5 MHz do not show a turnover.

Only new, scaled aerial type observations below 38 MHz could show whether the implication of this work is real.

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ОБЛИК РАДИО-СПЕКТРА ЛУКОВА ИЗМЕЂУ 38, 408 И 1420 MHz

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Оригинални научни рад

Спектри Северног Поларног Лука, Лукова у Водолији, Пегазу и Бику израчунати су из спектралних индекса између 38, 408 и 1420 MHz. Посматрања су била сведена на случај сразмерних антена са раздвојном моћи 7.° 25×8.° 25. Користећи апроксимацију полиномом другог степена израчунат је математички спектар. Добијени спектри свих лукова су слични. За Северни Поларни Лук и Лук у Бику максимум релативног флукса се налази на око 14 MHz, док је за Лук у Пегазу на око 17 MHz, а Лук у Водолији на око 19 MHz. На вишим фреквенцијама спектар је стрм, док је на нижим блажи. Општи облик спектра не зависи много од посматрачких грешака прегледа. Екстремни случајеви су дискутовани. Закривљеност је већа ако се спектрални индекс на вишим фреквенцијама повећа, а спектрални индекс на нижим фреквенцијама смањи за наведену грешку. У супротном случају, ако се подаци на високим фреквенцијама смање, а подаци на нижим фреквенцијама повећају за наведену грешку, закривљеност спектра је веома мала, слично раније изведеном спектру за Северни Поларни Лук (Милоградов-Турин, 1982). Неопходна су нова посматрања на фреквенцијама нижим од 20 MHz.