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THE QUASIHYSTERESIS EFFECT IN T-T PLOTS OF RADIO SPURS BETWEEN 38, 408 AND 1420 MHz

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SUMMARY: The T-T plots of the North Polar Spur, the Spur in Aquarius, Pegasus and Taurus, using data at 38, 408 and 1420 MHz of the same resolution of $7^{\circ}.25\times8^{\circ}.25$, reduced to the case of scaled areas, are presented. The T-T graphs for all spurs have shown clear splitting of branches supporting the reality of quasihysteresis effect. An investigation on the influence of quoted errors on splitting was done. It was shown that the splitting may have astronomical causes. In an attempt to explain this effect the earlier introduced 4V (four vector) model was applied.

1. INTRODUCTION

Regions of increased sky brightness, having spur-like shape, starting almost vertically from the Galactic plane are unique radio objects. Spurs have not been found in any other part of electromagnetic spectrum. The largest of them - the North Polar Spur (NPS) has left its trace already on the very first measurements of radio sky. It was found that many spurs can be joined into loops: e.g. the North Polar Spur is part of Loop I, the Spur in Aquarius is a part of Loop II. Four major loops are generally recognized. In addition, several further radio loop structures were proposed (Milogradov-Turin, 1970, 1972). Their nature has not been well understood yet, partly because their spectra have not been well determined and interpreted.

The plots of brightness temperature at one frequency against brightness temperature at the other frequency (T-T plots) can provide information about the spectrum of a spur (Turtle et al., 1962). Early T-T graphs were plotted for constant declinations, but later it was done at constant galactic latitudes (e.g. Berkhuijsen, 1971) as a more useful way to investigate Galactic objects. It was already noticed by Berkhuijsen (1971) that the latitudinal T-T graphs of the NPS region at 240 and 820 MHz were divided into two branches: one outside the main ridge of the NPS and the other inside it. Such a fork - like structure is called also "quasihysteresis". She has found that the gap between them was real. According to the interpretation of Berkhuijsen (1971) the gap may be due to the presence of a smooth extra component, which has a low spectral index and is related to an extended HII region in these lines of sight. The splitting of T-T graphs for frequencies between 10 and 408 MHz for the NPS and several other loops was found by Milogradov-Turin (1982) and shown not to be caused by an HII region (Milogradov-Turin, 1982, 1987). She interpreted it as a presence of four components of radiation (Milogradov-Turin, 1982, 1985, 1987).

2. DATA

The data at 38 MHz were those from the 38 MHz survey of Milogradov-Turin and Smith (1973). The 408 MHz data were got from Haslam and Salter (1983), while the 1420 MHz data were received from Reich (1990), both convolved to the resolution of the 38 MHz survey of 7°.25 × 8°.25 by the authors. Observational errors were estimated for each survey by their authors. Namely, for the survey at 38 MHz Milogradov-Turin (1982) gave value of approximately 10 percent, the same as it is for the 408 MHz survey. At the 1420 MHz the radio-sky appears very smooth, so observational error was at least only 5 percent (Reich, 1994). Since the spur in Aquarius was laying in the region where comparatively high ionospheric absorption was present, correction for it was applied (Milogradov-Turin and Smith, 1973).

3. T-T PLOTS

In this work T-T graphs were plotted along constant latitudes, every 4°, in regions of four observed spurs: 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 is 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 $b \in (-22°, -34°)$, for all combinations of frequencies. Four radio spurs were analyzed. An example is given in Figure 1. where the T-T plots of the NPS for galactic latitude of 38° are given.

The splitting of a T-T graph means that for a given brightness temperature at a higher frequency inside the spur we get higher temperature at a lower frequency outside the main ridge of a spur. "Inside" for the main part of the NPS means a range of longitudes smaller than 30°, and "outside" is the region with greater longitudes.

In the majority of graphs the splitting was clearly found (Nikolić, 1994; Milogradov-Turin and Nikolić, 1995). In those cases when it was less clear, convincing explanation could be found (e.g. uncertain amount of ionospheric absorption, lower quality data etc.). For example, for the NPS splitting vanishes while going to the North Galactic Pole. But if we change range of galactic coordinates, especially galactic longitude toward values less than 0°, following the natural curvature of the NPS, a splitting in T-T graphs emerges again.

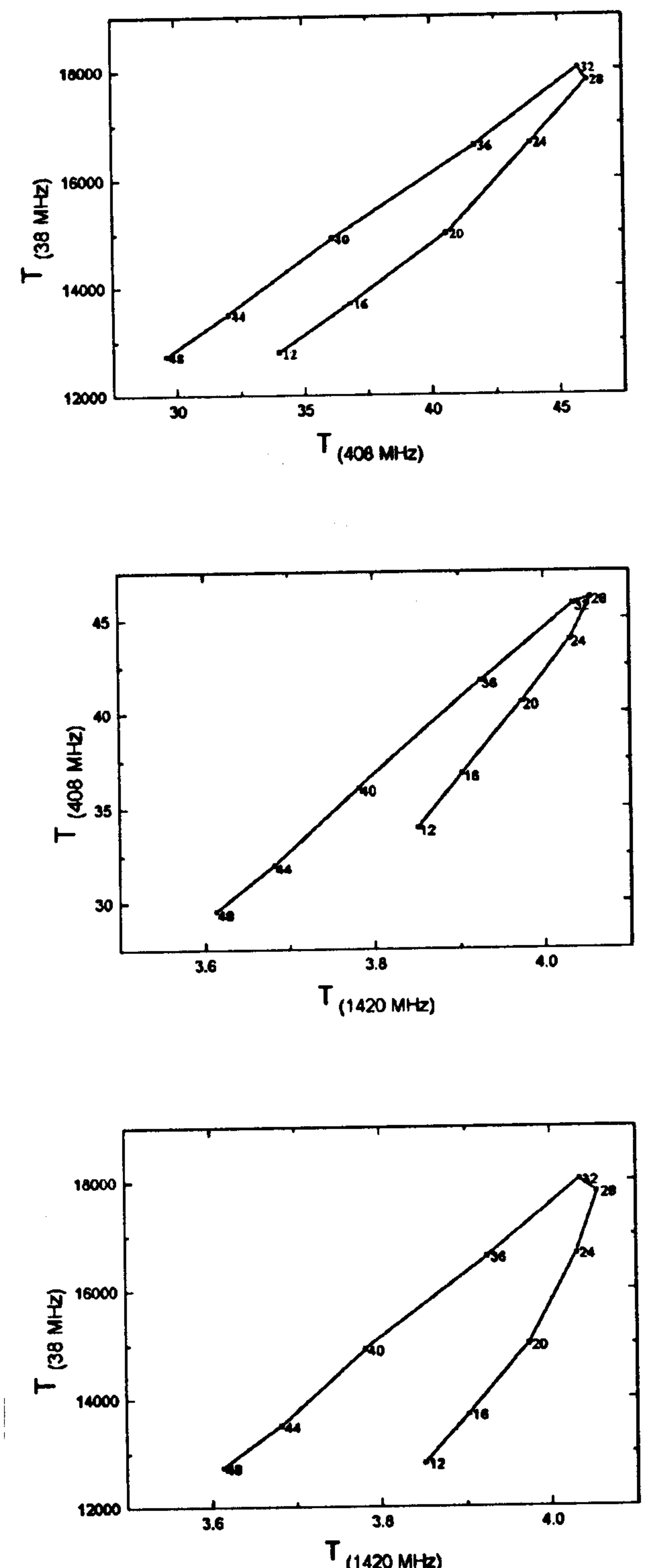

Fig. 1 - T-T plots for the NPS at $b = 38°$, for all three combinations of frequencies.

One possible explanation of quasyhisteresis as non-astronomical phenomenon, was an inaccuracy in position of the main ridge of a spur. As it was shown by Milogradov-Turin (1982) this effect could give a fork - like T-T graph. Nevertheless, no clear dependence of the position of the main ridge of the NPS on frequency in surveys at 38MHz (Williams *et al.* 1966) and 408 MHz (Haslam *et al.* 1974) exists. These surveys were of high resolution: HPBW on 38 MHz was $45' \times 45'$, while on 408 MHz HPBW was $37'$. The investigation was later extended to 1420 MHz. In the survey at 1420 MHz (Reich and Reich, 1986, 1988), with HPBW of $35'$, no difference in position was found either. In Table 1. are given the equatorial coordinates of the main ridge of NPS as read from the listed surveys (Milogradov-Turin, 1982; Nikolić, 1994). Another suspected non-astronomical reason for splitting of branches on T-T plots was the effect of side lobes. It has been, after detailed investigation, shown that it could not produce this feature (Nikolić, 1994).

Table 1. – The equatorial coordinates of the main ridge of the NPS

α	δ_r at 38 MHz	δ_r at 408 MHz	δ_r at 1420 MHz
13^h00^m		13.0	13.0
13^h20^m		16.6	16.5
13^h40^m	19.2	18.5	19.0
14^h00^m	18.0	17.7	17.4
14^h20^m	18.5	18.0	18.5
14^h40^m	19.0	18.4	18.5
15^h00^m	20.6	18.7	18.3
15^h20^m	20.8	18.9	19.0
15^h40^m	19.6	18.7	18.5
16^h00^m	19.8	18.8	19.0

This work has shown that the quasihysteresis is a real astronomical effect since it appears in all combinations of three used frequencies, in the data corresponding to scaled aerials measurements. Observational errors could not affect the clear quasihysteresis seen on almost all T-T plots. In Figure 2. on each plot in the middle is the T-T graph represented in Figure 1, and on the left and the right-hand side are the extreme values. Left-hand T-T plot is drawn for T_x+ΔT_x and T_y- ΔT_y, while the right-hand one is for T_x-ΔT_x and T_y+ΔT_y.

It is clear that even the worst combination of errors does not change two main characteristics of a T-T graph for a radio spur: the sides remain parallel and splitted. Only the slope changes.

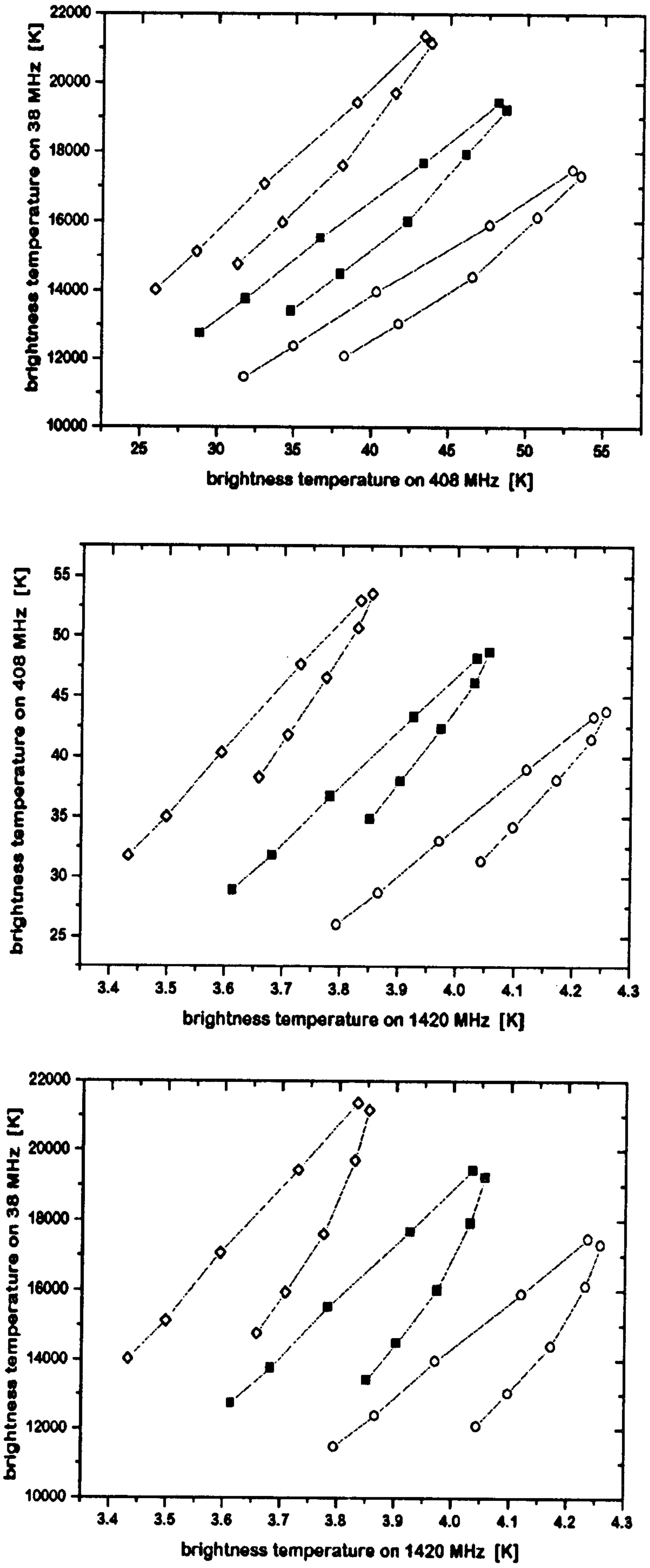

Fig. 2 – Extreme T-T plots for the NPS at $b = 38°$, for all three frequencies.

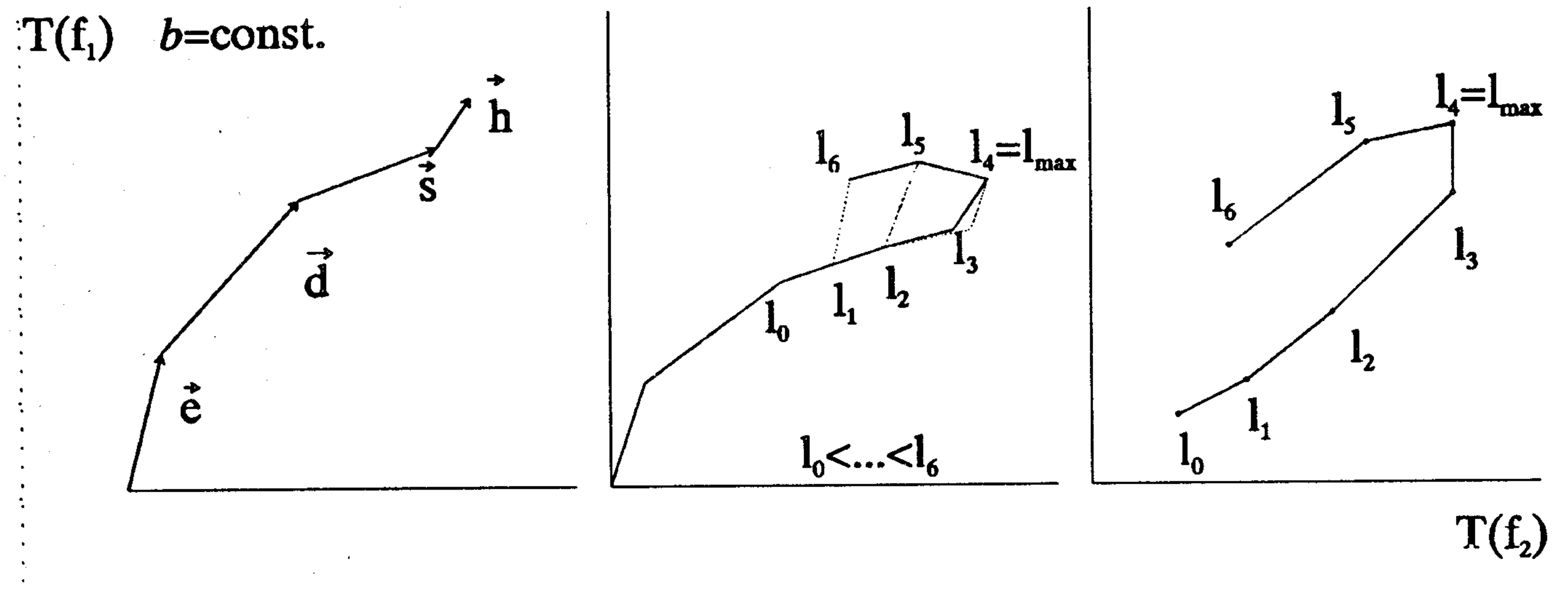

Fig. 3 – The construction of the T-T plots for a spur according to the 4V model.

4. DISCUSSION

A possible explanation of the quasihysteresis effect was proposed by Milogradov-Turin (1982, 1985, 1987) by the 4V model. Its basic idea is that the radiation from a spur can be represented by a sum of four vectors. The first component is extragalactic by origin. It has a high spectral index. This component consists of the relict radiation and of the integrated emission from external galaxies (labeled $\vec{e}$ in Figure 3). The second component, $\vec{d}$, is originating within the Galactic disk and therefore it is assumed to be constant for a given galactic latitude, within a region containing a spur. The spectral index of the disk radiation is less than the spectral index of the extragalactic component. The third component, $\vec{s}$, is related to the spur itself. It has a lower spectral index than the Galactic disc. The fourth component, $\vec{h}$, is originating in the region outside the main ridge of a spur and it has a high spectral index. It is almost isotropic in a layer next to a spur, decreasing sharply toward the main ridge. Such a behaviour could be expected from a component originating in a shell of the SNR. An example how the sum of four vectors reproduces a quasihysteresis effect is given in Figure 3.

The fact that the points on the convex side of all spurs lie in the upper part of a standard T-T diagram was named a "curvature rule" by Milogradov-Turin (1982, 1985, 1987).

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ЕФЕКАТ КВАЗИХИСТЕРЕЗИСА НА Т-Т ГРАФИЦИМА 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°.25×8°.25, сведена на случај сразмерних антена, Т-Т графици за Северни Поларни Лук, Лук у Водолији, Пегазу и Бику су нацртани. Т-Т графици за све лукове показују јасно раздвајање на две гране подупирући реалност квазихистерезисног ефекта. Истраживање утицаја наведених грешака је спроведено. Показано је да раздвајање на гране може имати астрономске узроке. Покушавајући да се објасни овај ефекат примењен је раније уведени 4V (четворовекторни) модел.