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GEOMETRY OF LARGE RADIO LOOPS AT 1420 MHz

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SUMMARY: The small circles of the well known major Radio Loops I, II, III and IV (Berkhuijsen, 1971; Salter, 1970, 1983 and references therein), and the tentative loops V, VI and their combination V+VI (Milogradov-Turin, 1970, 1972, 1982) were computed using the high resolution 1420 MHz survey (Reich and Reich, 1986). The results agree well with the parameters computed at other frequencies confirming independence of the position of loops of frequency. Rather good fit of circles to the loops in Leo, Cancer, Taurus, Pisces and Pegasus on 1420 MHz supports possibility of existence of another major loop – Loop V or its variety V+VI. The tentative Loop VI fits less. Comparison of the position of small circles with neutral hydrogen and polarisation data does not provide a crucial confirmation for the reality of the Loop V and V+VI.

1. INTRODUCTION

It is known already for more than three decades that some radio spurs can be joint into small circles. The set of spurs belonging to the same small circle is named a loop. Four major loops were recognized by early seventies. They were discovered and studied in this order: Loop I (Large et al., 1962; Haslam et al., 1964; Large et al., 1966; Salter, 1970), Loop II (Large et al., 1962; Quigley and Haslam, 1965; Salter, 1970), Loop III (Quigley and Haslam, 1965; Salter, 1970) and Loop IV (Large et al., 1966; Salter, 1970). The most precise determination of parameters of these circles was performed by Salter (1970) and published in Berkhuijsen et al. (1971). Salter used the best data available then, at 408 MHz, 404 MHz, 240 MHz and 178 MHz. A detailed review of the subject was published by Salter (1983).

It was noticed by Milogradov-Turin (1970, 1972, 1982) that some other spurs could be connected into loops. She proposed the Loop V to be formed by negative latitudes spurs in Taurus, Pisces and Pegasus and the Loop VI to correspond to the weak positive latitudes spurs in Leo and Cancer. The Loop V has well defined "end" spurs and weak "bridge" between them, while the Loop VI is practically equivalent to the higher antenna temperature region between cold holes near the North Galactic Pole. She computed parameters of the proposed loops using the survey at 38 MHz by Milogradov-Turin and Smith (1973). It turned out that small circle of the Loop V was passing close to the spurs defining the Loop VI, indicating that all the quoted spurs could correspond to a single feature – the Loop V+VI. A variety of this small circle without the ridge in Pisces was tested (labeled V′ etc.) also. It is interesting to point out that these new circles from V to V+VI lie rather close to the small circle of the Loop III. Basically it did not differ much from the circle derived including the Pisces ridge. No further development of these idea has been made.

The survey at 1420 MHz (Reich and Reich, 1986) provided a new base for recomputation of small circles for major loops and investigation of the proposed Loop V, VI and V+VI. Although non thermal sources, such as spurs, are weaker at higher frequencies, the novelty of data was a sufficient stimulus to investigate the geometry of loops at 1420 MHz.

2. ANALYSIS

Since the 1420 MHz survey has a resolution of 35′, brightness temperatures along the main ridges were read at every 18′.75 in equatorial regions and 18′ within the polar cap.

The coordinates and the radius of the best fit circle were computed by searching coordinates for which the sum of the squares of differences between the radius and the distances of spur points from the estimated center is the least. The radius was obtained as a mean value of distances of spur points from the estimated center. The original programme was written by C. J. Salter and adapted to PC by one of the authors (Urošević, 1996) who introduced some changes: a subprogramme for calculation of standard deviations and errors by the χ^2 method and reorganized it so that it could be used for small size circles. The criterium applied for the computation of errors was 2σ for the North Polar Spur, 1.5σ for the Loop II, III and IV and 3σ for the Loops V and VI. The criteria applied for filtration of sampled points were the same as the criteria applied for computation of errors.

3. RESULTS

The results are presented on Figures 1 and 2 and in the Tables 1 and 2, as computed by Urošević (1996). The parameters in the Table 2 were got by filtration of the sampled points, while for the other loops filtration was not needed.

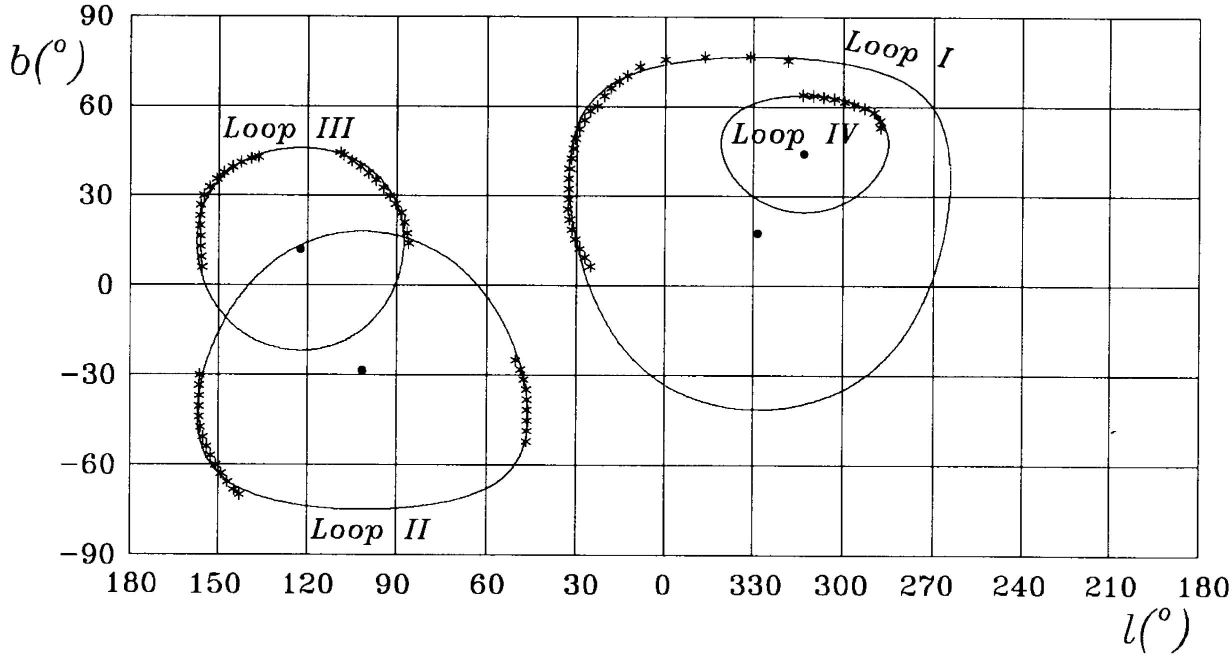

Fig. 1. The small circles of the major radio loops at 1420 MHz. The sampled points are indicated by asterisks, while the centers are dots. Every tenth sampled point is indicated.

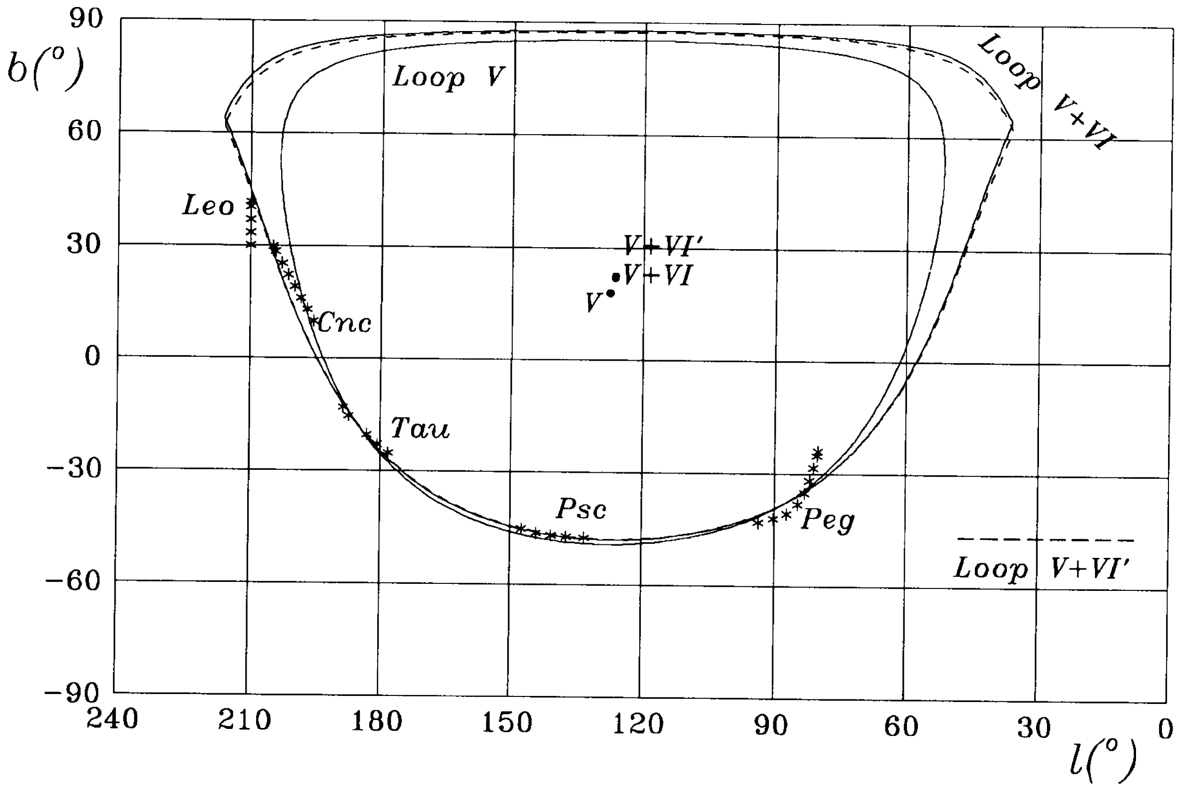

Fig. 2. The small circles of the radio loops defined by spurs in Leo, Cancer, Taurus, Pisces and Pegasus at 1420 MHz. The sampled points are indicated by asterisks, while the centers are dots. Every tenth sampled point is indicated.

Table 1. The parameters of the small circles of large radio loops.

Loop	l_{center} (°)	b_{center} (°)	Radius (°)
Loop I	328.3 ± 1.6	$+17.6 \pm 1.8$	59.0 ± 2.6
Loop II	101.4 ± 1.3	-28.4 ± 1.3	46.4 ± 2.1
Loop III	122.4 ± 1.4	$+12.0 \pm 1.1$	33.9 ± 2.0
Loop IV	312.9 ± 0.3	$+44.3 \pm 0.9$	19.6 ± 1.1
Loop V	127.5 ± 1.5	$+18.0 \pm 2.5$	67.2 ± 3.4
Loop V′	130.2 ± 2.5	$+3.3 \pm 2.0$	58.1 ± 3.6
Loop VI	120.5 ± 3.2	$+30.8 \pm 1.3$	72.4 ± 4.0
Loop V+VI	126.4 ± 1.9	$+22.2 \pm 1.8$	70.1 ± 3.2
Loop V+VI′	126.2 ± 2.0	$+22.5 \pm 1.4$	70.2 ± 3.1

Table 2. The parameters of the small circles V and V+VI (after filtration of points).

Loop	l_{center} (°)	b_{center} (°)	Radius (°)
Loop V	125.5 ± 1.7	$+22.4 \pm 3.0$	71.2 ± 3.9
Loop V+VI	124.5 ± 2.2	$+22.9 \pm 2.1$	71.5 ± 3.6
Loop V+VI′	124.4 ± 2.4	$+22.9 \pm 1.6$	71.6 ± 3.6

4. DISCUSSION

Agreement with the best previously calculated parameters for the major loops (Salter, 1970; Berkhuijsen et al., 1971) is very good. This is an extra argument for the statement that the position of loops does not depend on frequency. Some cases when ridges were found to be placed differently at different frequencies must be explained otherwise; in the case of the North Polar Spur on the low resolution 38 MHz survey (Milogradov-Turin and Smith, 1973) it could be perhaps explained by ionospheric refraction (Milogradov-Turin, 1986).

A good fit of spurs to small circles is an argument in favour of their origin as SNR.

Agreement with previously found small circles for the Loop V and the Loop V+VI (Milogradov-Turin, 1982) is good. These loops are less reliable because the spurs which define them do not lie so well on the circle. Nevertheless, it is very interesting to see that the calculated circles lie so close to each other that one could conclude that all the quoted spurs define a unique circle. Its size suggests that it could be a rather nearby feature. Although, it must be stressed that a pure geometrical fit does not necessarily mean that the shell corresponding to such a best fit circle is real.

The major spurs observations were already discussed elsewhere (e.g. Salter 1970, 1983). In this paper we have to discuss the tentative Loop V, VI and V+VI. The comparison of such large features must be performed mostly with rather old data because large scale features were rarely investigated by modern techniques. Comparison with HI surveys (Fejes and Wesselius, 1973; Heiles, 1975) shows that there is an increased amount of neutral hydrogen along the "Pisces ridge", "Pegasus ridge" and "Taurus ridge". Nevertheless, considerable offset in positions of the continuum and hydrogen ridges exists. It should be not surprising since an offset was noticed already in the case of the North Polar Spur (Berkhuijsen et al., 1970, 1971). The connection between the neutral hydrogen and the continuum ridge in Taurus was noticed already by Berkhuijsen et al. (1971). Heiles and Jenkins (1976) found kinematic arguments against the connection of the Taurus and Pisces HI complex. Similar situation is with the Pegasus complex. Nevertheless, it should not be necessarily crucial for continuum ridges connection. There is such a quantity of hydrogen in Pegasus and particularly in Taurus, that it could happen that the component connected with continuum spurs is masked. An optimist could claim correlation of HI and spurs in Leo and Cancer but the features are too weak to be sure. There are some infrared cirus clouds (Gautier, 1986), which corresponds to HI discussed by Heiles and Jankins (1976). Comparison with the radio and optical polarisation maps does not provide a crucial argument. Some alignement between the E vectors of starlight polarization (Mathewson and Ford, 1970; Axon and Ellis, 1976) and the radio spurs could be claimed. Nevertheless, the reality of the Loop V, i.e. Loop V+VI and its connection with the Loop III is still under question.

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ГЕОМЕТРИЈА ВЕЛИКИХ РАДИО ПЕТЉИ НА 1420 MHz

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Мали кругови добро познатих Радио петљи I, II, III и IV (Berkhuijsen 1971, Salter 1970, 1983 и референце у њима) и могућих Петљи V, VI и њихове комбинације V+VI (Милоградов-Турин, 1970, 1972, 1982) су израчунате користећи преглед радио неба високе раздвојне моћи на 1420 MHz (Reich and Reich 1986). Добијени резултати се добро слажу са параметрима израчунатим са података на другим учестаностима потврђујући да су положаји радио лукова независни од учестаности. Добра подешеност круга V односно његове варијанте V+VI на лукове у Лаву, Раку, Бику, Рибама и Пегазу на 1420 MHz поткрепљује претпоставку о његовој реалности. Лукови петље VI лошије леже на одговарајућем малом кругу. Поређење са расподелом неутралног водоника и поларизације није дало пресудан аргумент у корист реалности Петље V односно V+VI.