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Some results of cooperative investigations on solar radio emission with RATAN-600

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Results of cooperative work between the GAO/SAO and ZIAP obtained during eight years in the field of solar radio astronomy are reviewed. Main topics of investigation concern the S-component, coronal millimetre-wave sources, and different kinds of microwave bursts.

Es wird eine Übersicht über einige Ergebnisse der Zusammenarbeit zwischen dem ZIAP und GAO/SAO während der letzten acht Jahre auf dem Gebiet der solaren Radioastronomie gegeben. Der Hauptinhalt der Untersuchungen bezieht sich auf die S-Komponente, koronale Millimeterwellen-Quellen und verschiedene Typen von Mikrowellenstrahlungsausbrüchen.

Key words: Solar radio waves — S-component — microwave bursts — emission models.

AAA subject classification: 073; 077

1. Introduction

The microwave emission is an important indicator for physical processes in the solar atmosphere. Limits of the present knowledge of these processes are basically due to the tremendous technical difficulties of achieving sufficient resolution in time, frequency, and space, simultaneously. Overcoming these difficulties, within certain limits, the RATAN-600 is the unique telescope in the world which is capable to provide the above information about active regions achieved in an original manner. Advantages of RATAN-600 consist in a combination of spatial resolution (in the sub-arc minute range) with spectral coverage (from mm- to dm-waves) and providing information on the state of circular polarization. These advantages are purchased by considerable efforts in instrumental techniques and data reduction. Only some part of the totality of interesting observations available has been exploited for scientific studies yet, and a treasure of still unknown information may wait for its discovery. Moreover, further progress is anticipated with respect to (i) a broader computerization of data handling, (ii) efforts for achieving heliography, (iii) increasing time coverage and resolution, and (iv) introduction of spectrography in future (cf. BOGOD et al. 1988).

The present report deals with some results of mutual work organized between the Academies of Sciences of the USSR and GDR during recent time using observations of the Sun by RATAN-600. It can be remarked that the cooperative work of the solar groups of the GAO/SAO and HHI/ZIAP has some tradition which traces back to early papers in the sixties (BOROVIK et al. 1967, 1968; VYALSHIN et al. 1967). More recently, the mutual work has been intensified by studies combining model calculations, observations of photospheric magnetic fields, solar radio patrol observations, and results of RATAN-600 observations. During the past eight years about 16 cooperative papers have been achieved the main results of which are briefly reviewed in the following sections.

2. Diagnostics of the S-component

In the operational mode as a transit telescope the RATAN-600 is best suited to observe stationary and/or slowly varying-processes so that it can be well used for the study of the S-component of solar radio emission. Among the many questions related to this component, three topics have been picked up by the cooperative work mentioned here.

2.1. S-component models and diagnostics of mean magnetic scale heights in the corona

A sample of RATAN-600 observations of 36 compact S-component sources was compared with calculations of unified microwave emission models (KRÜGER et al. 1985, 1986a, 1983; AKHMEDOV et al. 1982, 1983; SEEHAFER et al. 1983). The diagnostic capacity of analyses of the spectral distributions in the radio flux, the degree of polarization, and the source sizes for the determination of magnetic scale heights and other source parameters were checked by different methods. The magnetic scale height

$$L_B(z) = B(z)\,(dB(z)/dz)^{-1} \tag{1}$$

at the height of the bottom of the corona above sunspots $z = 2 \times 10^3$ km above the photosphere resulted to

$$L_B = -(7.4 \pm 2.3) \times 10^3 \text{ km} \tag{2}$$

corresponding to dB/dz ranging approximately between 0.1 and 0.4 G/km.

2.2. Relation to flare activity

The average magnetic scale heights of active regions derived from the RATAN-600 observations above mentioned and the corresponding S-component flux density were found to be related to the flare production rate. This is illustrated by Fig. 1 where three groups of active regions A, B, C referring to different ranges of flare numbers per active region N (A: $N > 60$, B: $60 \leqq N \leqq 20$, C: $N < 20$) are compared with the mean magnetic scale heights of these regions estimated from RATAN-600 observations (KRÜGER et al. 1986a, AKHMEDOV et al. 1985).

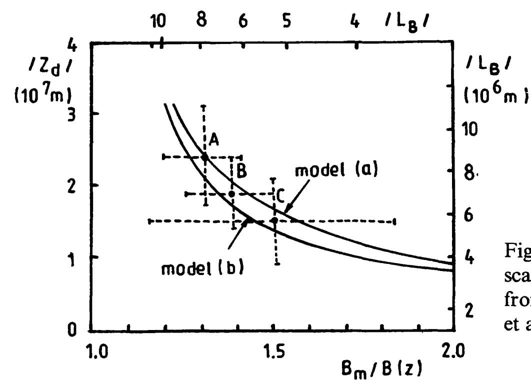

Fig. 1. Diagram demonstrating the connection between mean magnetic scale heights and groups of flare production rates (decreasing from A to C) from a sample of 36 RATAN-600 S-component observations (after KRÜGER et al. 1986a)

2.3. Classification of main subcomponents and peculiar emission features

The comparison of the RATAN-600 S-component observations with model calculations lead to the definition of the following subcomponents of S-component radiation: (1) Sunspot component (S), (2) playe component (P), (3) halo component (H), (4) loop component (L), and (5) peculiar or current-sheet component (C) which are schematically sketched in Fig. 2a, b.

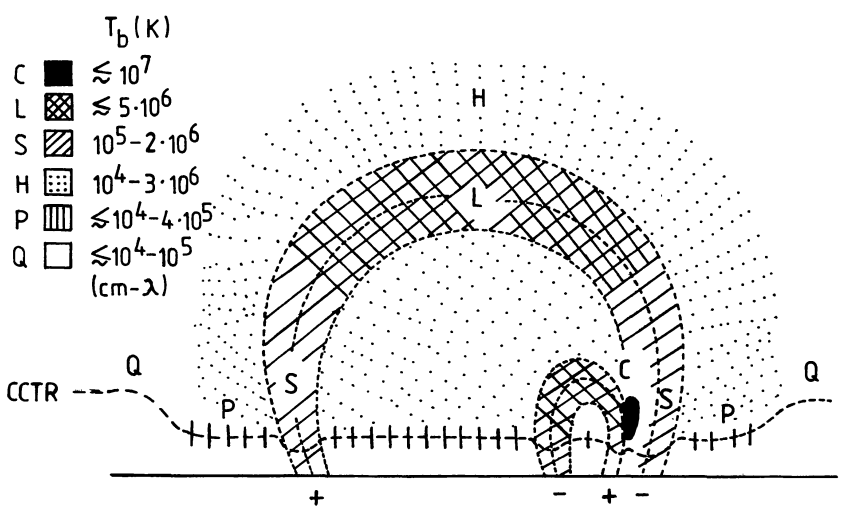

Fig. 2a. Classification of S-component subcomponents

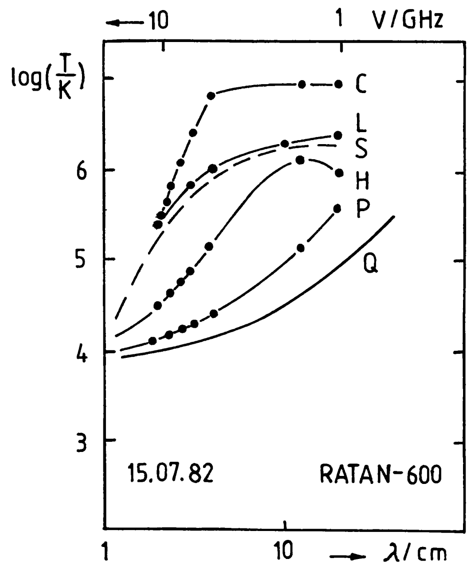

Fig. 2b. Examples of spectra related to Fig. 2a observed by RATAN-600 on July 15, 1982

The components outside sunspots sometimes exhibit remarkable features not explainable by usual models of component "S", in particular: (1) Excess of flux density at higher frequencies, (2) excess of brightness over a broad spectral range, including dm waves, (3) excess of brightness at short cm-wavelengths (AKHMEDOV et al. 1986; KRÜGER et al. 1987). The explanation of these features requires loop models with extraordinary parameter configurations.

3. Coronal mm-wave sources

Recently recognized coronal mm-wave sources (CMMSs) detectable at the solar limb have been interpreted as a special phenomenon of long-duration post- and inter-flare radiation at coronal altitudes of about 10^5 km above the photosphere. By means of RATAN-600 observations it was possible to present for the first time information about the spectra of brightness and polarization in the cm-range for one such event. The brightness temperatures observed favour the interpretation of the bulk of the emission by thermal optically thin Coulomb bremsstrahlung (cf. Fig. 3). The degree of polarization implies rather strong magnetic fields (≥ 300 G) and indicates a possible contribution of gyromagnetic radiation and/or optically thick bremsstrahlung at longer wavelengths (BOROVIK et al. 1989c; BOGOD et al. 1986).

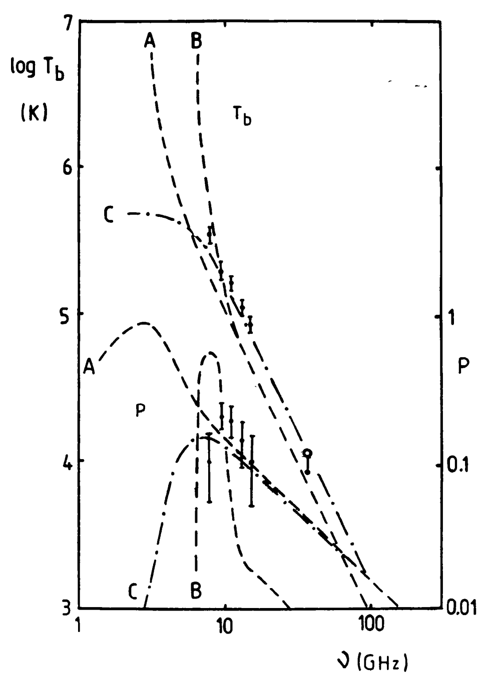

Fig. 3. Calculated and observed spectra of a CMMS on September 22, 1980 (after BOROVIK et al. 1989c)

4. Gradual burst emission

4.1. Gradual rise and fall (GRF)

The analysis of an up to now most complete data set of a GRF burst allows new conclusions about the extended spectral/spatial structure of the source region of this burst type. It was found that only less than 24% of the microwave flux of this events is emitted from an excessive small-scale (~ 20 arc sec) burst source while the bulk of the burst emission comes from a much broader region consisting of at least two major components coinciding with the source area of the S-component radiation (AKHMEDOV et al. 1989; BOGOD et al. 1990a).

4.2. Post-burst increase (PBI)

PBI microwave radiation has been recognized as an essential part of the burst emission embedded in a larger complex of post-flare phenomena (cf. also section 3). Present studies on this subject (KRÜGER et al. 1986b; BOROVIK et al. 1989a) are to be continued and theoretical models of the post-flare phase must still be completed.

5. Preburst and impulsive-burst emissions

A preliminary investigation (BOROVIK et al. 1989b) favours a site of pre-proton flare disturbances at magnetic fields of the order 100—300 G if the emission is interpreted by gyromagnetic radiation as usual. If, however, alternatively the "new" process of plasma bremsstrahlung is inferred, the origin of preflare radiation would be shifted into deeper levels where N_e is about 5×10^{11} cm^{-3}. Further investigations are needed to decide between the different possibilities of interpretation.

The investigation of particular strongly impulsive burst events leads to the conclusion that even "simple" microwave bursts are composed of a number of different spatially and temporally resolved components (BOGOD et al. 1990b).

6. Conclusions

Cooperative investigations of RATAN-600 observations have substantially completed our knowledge about various types of solar microwave emission features as documented by 16 papers which are briefly reviewed in the present article. Continuation of the work is required for achieving further progress in the field.

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