THE RADIUS OF THE SUN AT CENTIMETER WAVES AND THE
BRIGHTNESS DISTRIBUTION ACROSS THE DISK

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Abstract. We report observations of the solar radio radius at wavelengths between 1.2 and 11 cm performed with the Bonn 100 m-telescope. In combination with former measurements of the centre-to-limb variation of the solar brightness these observations are discussed in terms of atmospheric models. We consider the solar disk to be covered by arches at low latitudes, while at the poles coronal holes are located. The temperature dependence on height is taken from EUV-line intensities, hydrostatic equilibrium is adopted, spicules are assumed to be responsible for the relatively low brightening. The interpretation of our measurements demands certain values of the brightness temperature of spicules as a function of wavelength within a modest interval.

1. Introduction

The brightness distribution at radio wavelengths across the solar disk and beyond the limb is determined by the structure of the solar chromosphere and corona. In general, the brightness temperature $T_B$ is normalized to the temperature $T_C^C$ of quiet regions close to the centre of the disk. At wavelengths $\lambda$ of about 3 cm the distribution of $T_B$ is nearly circular and uniform (Fürst et al., 1973). At longer wavelengths it is of elliptical shape connected to an increase of $T_B$ towards the limb close to the equatorial plane (Christiansen and Warburton, 1955). At wavelengths shorter than 1 cm the distribution is still a matter of controversy. While at 3.5 mm, Lantos and Kundu (1972) reported a slight limb darkening, Hagen et al. (1971) at 3.2 mm and Labrum et al. (1978) at 3 mm found a well defined complex brightening of $T_B$ with heliocentric angle.

The distribution of $T_B$ also determines the radius of the Sun at radio waves by identifying the isophote of $T_B = T_C^C/2$ as the outer boundary of the radio Sun.

Recent X-ray maps of the Sun have shown that the equatorial zone is occupied in general by long ranging arches, whereas at the poles most often coronal holes are observed. The reference temperature $T_C^C$, therefore, usually includes a contribution from the arches, being proportional to their optical depth $\tau$, i.e. proportional to $\lambda^2$. Towards the poles this contribution vanishes. This leads to an elliptical shape of the Sun at long wavelengths, where the contribution is relatively large. In Section 2 we
report on observations of the corresponding variation of the radio radius of the Sun along the limb at wavelengths between 1.2 and 11 cm.

The chromospheric and coronal layers, mainly responsible for the measured radio flux, are also observed in other spectral domains, in particular in the EUV-range. The latter observations are incorporated in the discussion of Section 3, where a model is developed which fits the radio data and the EUV data as well.

2. Observations of the Radio Radius

Measurements of the radio radius of the Sun have been undertaken by various observers during the last twenty years, very often taking advantage of a solar eclipse, in order to achieve high angular resolution. These observations are limited to the equatorial belt of the Sun and only poor information is obtained on the north–south radius. Only a few observers used interferometers or big single dishes.

The early measurements have been summarized by Swanson (1973) resulting in a best fit which is plotted in our Figure 5 as curve c.

In order to improve these observations in particular for the north–south direction, new measurements have been performed with the Bonn 100 m-telescope at centi-metre wavelengths. This telescope can be used for solar observations only sporadically, therefore the number of maps is limited. The period of observations was between 1973 and 1976. Wavelengths, half power beam widths and the number of maps treated in this paper are listed in Table I. The technical details of the Bonn 100 m-dish can be found in Hachenberg (1970). The method of observation described in an earlier paper (Furst et al., 1973) yields maps of the Sun with a spacing of data points of about half the beam width.

The radius of the Sun as defined in the introduction was deduced from the individual maps given in Table I. The estimation of the central brightness temperature $T_B^C$ is affected by small scale structures in the solar atmosphere seen as temperature variations of $\approx 3\%$ of $T_B^C$ between 1 cm and 6 cm wavelengths (Furst et al., 1974; Chiuderi-Drago et al., 1975). At 11 cm, where the angular resolution is low, confusion with active regions may be present affecting the level of $T_B^C$. According to Bird et al. (1977) the error in $T_B^C$ is of the order of $\pm 5\%$. This error is

<table>
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<th>Wavelength (cm)</th>
<th>Half power beam width (arc min)</th>
<th>Number of maps</th>
<th>Confusion error (arc sec)</th>
<th>Positional error (arc sec)</th>
<th>Statistical error (arc sec)</th>
<th>Sum of errors (arc sec)</th>
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