IMAGING THE SUN AT 21 CM: BUDGETTING THE S-COMPONENT

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Abstract. On fourteen days in July and August 1992 and June 1993, we used the 7-element synthesis radio telescope at the Dominion Radio Astrophysical Observatory to make full-disc, arc-min resolution images of the Sun at 21 cm, with the objective of budgetting the contributions to the slowly-varying component of solar radio emission. This instrument has the advantage that the mapping field at this wavelength is about 2.5° wide. However, it has also the severe disadvantage that with only 12 hours to record each image, the brightness distribution is severely undersampled. This difficulty, along with solar rotation and declination motion during each observation, required development of special image correction procedures.

The two observing sessions spanned about 25% of the activity range over a solar cycle. Over this range, comparable contributions to the slowly-varying component came from active region sources and a weak emission, widely-distributed over the solar disk. Both these contributions are correlated with the total photospheric magnetic flux and with the 10.7 cm flux.

1. Introduction

Solar activity occurs over a wide range of spatial and temporal scales, from the appearance and decay of small magnetic features, to large-scale changes in the distribution of activity over the disc and in the structure of the corona. The activity is usually localized in complexes of activity (Gaizauskas et al., 1983), which cover large parts of the solar disc and persist for up to a dozen solar rotations. There is a net balance in the total amount of positive and negative magnetic flux in the complexes, suggesting that these entities are the basic 'units' of magnetic activity at and above the photosphere. There is usually a net imbalance in the positive and negative magnetic fluxes in active regions, with magnetic links to other structures in the same complex. These might be neighbouring active regions or other magnetic structures, such as network elements. All aspects of activity are strongly modulated by the 11 (or 22)-year solar cycle.

The definition of the S-component is somewhat empirical, and is a consequence of the poor angular resolution of the radio telescopes first used to observe the Sun. They could only measure the intensity and polarization of the integrated emission, together with their variability. Using the characteristic timescales of intensity variations as a criterion, the integrated emission was divided into three

components: a rapidly-varying or R-component, associated with flares; a slowly-varying or S-component, embracing all slower variations; and a quiet component, which is the extrapolated flux density corresponding to zero plage area. The S-component is therefore the total microwave emission with the flare and quiet component contributions subtracted. The components of solar radio emission are discussed extensively by Kundu (1965) and Krüger (1979).

The S-component was first described as a separate component of solar microwave emission at 10.7 cm wavelength by Covington (1947, 1948), and at 25 and 60 cm by Lehaney and Yabsley (1949). It is most easily observed in the microwave part of the radio spectrum, at wavelengths between 1 and 100 cm, with a broad spectral peak at about 10 cm.

The intensity of the S-component varies with the level of solar activity, reflecting the appearance and decay of active regions and complexes of activity (Denisse and Kundu, 1957; Kundu and Denisse, 1958). Measurements of the intensity of the S-component at 10.7 cm provide an internationally-recognized activity index, which correlates well with other activity indices such as sunspot number, integrated disc emission in the Ca II K and Mg II K spectral lines, full-disc UV and X-ray fluxes (Donnelly et al., 1983), and total magnetic flux (Tapping and Harvey, 1994). It is used as an index in its own right, and as a proxy for other quantities which are more difficult to measure.

There are two major contributions to the S-component: the integrated emissions from all the active regions present on the disc, and a weak but widely-distributed emission covering large areas outside the active regions. Measurements made at 10.7 cm (Tapping, 1987) and 2.8 cm (Tapping and Zwaan, 1995) suggest that the contributions to the S-component from active regions and widely-distributed emission are comparable.

The advent of large, single-antenna radio telescopes and then multi-antenna synthesis radio telescopes made it possible to map the distribution of the S-component over the disc and then within individual active regions, in some cases with arc-sec resolution. Inside active regions, sources were found in a variety of magnetic structures, such as sunspots (Alissandrakis, Kundu, and Lantos, 1980; Chiuderi Drago et al., 1982; Shibasaki et al., 1983; Alissandrakis and Kundu, 1984), with bright plage (Gaizauskas and Tapping, 1980; Felli, Lang, and Willson, 1981; Shevgaonkar and Kundu, 1985; Gaizauskas and Tapping, 1988), with filaments overlying magnetic polarity reversal lines (Kundu, Schmahl, and Rao, 1981; Erskine, Kundu, and Rao, 1983; Gaizauskas and Tapping, 1988), or with strong gradients of magnetic field strength (Alissandrakis and Kundu, 1984). However, each of these optical/magnetic structures often occur without accompanying microwave emission (Felli, Lang, and Willson, 1981; Webb et al., 1983, Gaizauskas and Tapping, 1988). The sources occur almost always within active regions, but sometimes at locations where there are no unique magnetic structures which might indicate the presence of a source. Sources can occur in regions having no sunspots (Pallavicini