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Radio emission as a diagnostic for solar coronal rotation

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Abstract. The time series of solar radio emission at 2.8 GHz is analysed using correlation methods. The analysis showed that this type of time series can be used to infer the rotation period of the source (in this case solar corona). It is found that the correlograms have a very strong persistence of rotational modulation. These values are significantly lower than those reported earlier by other methods. The reasons for this difference are unknown.

1. Introduction

One of the first physical properties noted about the Sun was its rotation. Today it is known that Sun has a differential rotation. This differential rotation was explained as possibly due to the magnetic linkage to faster rotating subsurface layers (Howard 1984). D'Silva and Howard (1994) provided a different explanation; in that the effects of buoyancy and drag, coupled with the Coriolis force can lead to a faster rotation rate for emerged magnetic flux tubes. In general there are two methods for determining the rotation of the Sun; (1) by monitoring the motion of tracers, such as sunspots, faculae, plages, convection cells, oscillation wave patterns, low-level magnetic features, and (2) by Doppler shift of photospheric spectral lines. All these measure the rotation of the solar photosphere. The average sidereal rotation frequency ν is given as below :

$$\nu = 462 - 75Sin^2\phi - 50Sin^4\phi \; nHz, \quad (1)$$

where ϕ is the solar latitude. This formula implies sidereal rotation periods at equator and poles to be ~ 25 days and 28 days, respectively. At a precision better than a few percent, however, different techniques give different rotation rates. Here yet another method for solar rotation measurement is presented. This is based on the analysis of radio emission from solar corona. The method has been used by Vats et al. (1998a) for solar cycle 22.

Solar radio emission originates in the plasma of the outer solar regions, e.g. chromosphere and corona. The emission is believed to be either by thermal Bremstralhung from hot and dense coronal condensations in active regions or by gyro-resonance process. The propagation characteristic of the radio waves depend basically on the electron density in the regions. Each value of electron density is related to a certain critical frequency of the radio waves below which propagation is impossible. Therefore, and also because of the emission properties of the radio waves, the frequency spectrum can be roughly related to a height distribution in the solar atmosphere if the density distribution is known. Since the density decreases with increasing height in the solar atmosphere, the higher frequencies are emitted from levels closer to the photosphere. These are modelled in terms of the electron density distribution in the solar atmosphere and interplanetary space. The radio emissions that we examined here are at 2.8 GHz, which originate in the inner solar corona. This analysis seems to provide information regarding the rotation of solar corona.

2. Results and discussion

Solar radio measurements are available on regular basis at several frequencies in the range of a few hundred MHz to a few GHz and are available to the scientific community via Solar Geophysical Data Bulletins. The daily measurements at any frequency can be represented by a time series. The autocorrelation of such a continuous series can be obtained using standard formulation. Two examples of autocorrelation variation are shown in Fig. 1.

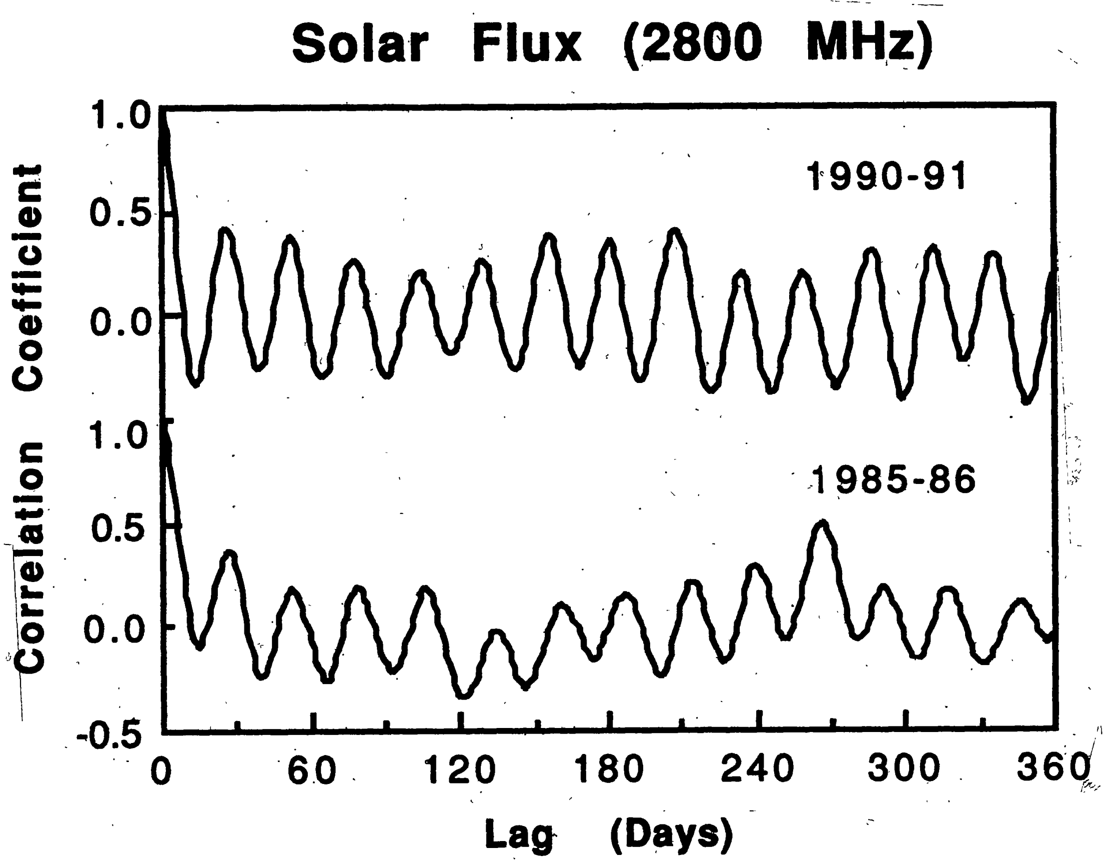

Figure 1. Variation of autocorrelation coefficient of radio flux at 2.8 GHz with lag in days for 1985-86 and 1990-91.

Both these clearly show a periodic variation which is due to rotational modulation. The two curves are for 1985-86 (minimum solar activity period) and for 1990-91 (maximum solar activity period). Since one can determine the time of more than ten cycles with an accuracy of one day, the rotation period derived here will have an accuracy better than 0.1 day. The synodic rotation periods thus derived are 26.6 and 25.8 days for 1985-86 and 1990-91, respectively. These correspond to sidereal rotation periods of 24.8 and 24.1 days, respectively.

Das and Chatterjee (1996) analysed the basal component of solar radio emission in the frequency range of 0.245-15.4 GHz and found two types of periodicities. A relationship between the radio flux and sunspot number was derived using a regression analysis. Here, it is demonstrated that autocorrelation analysis of long series of solar radio emission can provide information regarding the coronal rotation. Vats et al. (1998b) used fractal and correlation analysis for establishing that solar radio emissions are modulated by solar rotation. Vats et al. (1997a) used this information to divide the radio emission into two components, namely, the background emission and the localized emission. Fisher and Sime (1984) used the series of HAO K-coronameter data and derived synodic rotation period and found that the average value for the year 1965-1983 ranged from 27.22 to 28.20 days. Sime et al. (1989) reported an average synodic rotation period ~ 27.52 days over the duration 1973-1985 for latitudes between ±30° of solar equator. These measurements were from coronal FeXIV line at 5303 Å which supposedly come from a region ~ 1.15 $R_\odot$ in the solar atmosphere. The present results indicate a significantly lower (3 to 6% lower) rotation period and the reason for this difference is yet unknown. More work using this type of analysis and its comparison with other techniques is in progress and will be reported soon.

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