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Solar coronal rotation and phase of solar activity cycle

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Abstract. Solar rotation continues to be observed by several techniques. We have tried to study coronal rotation using radio observations. Coronal rotation and its variation with height in solar atmosphere are studied. For this, we have used 11 different frequencies of radio emissions. We have also tried to look at dependence of rotation period on phase of solar cycle. The period of analysis is four solar cycles (cycle 19 to 22). The results of analysis do not show systematic relationship between coronal rotation period and phase of solar cycle.

Keywords : Sun: rotation – Sun: radio radiation – Sun: general

1. Introduction

Solar rotation is being studied since 18th century. Various methods have been applied to study differential rotation with respect latitudes. Different methods give different variation in rotation rate with latitudes; however, Adams and Tang (1977) showed that most of methods agree fairly at equator. Several attempts have been reported to measure variation in rotation period with respect to height in solar atmosphere E.g. Adams (1911), Solansky (1972), Parker et al. (1982). Most of them present insignificant results but some of them showed notable variation in rotation period with height (Parker et al. 1982). It seems that the rotation of Sun is not same among different layers. One can therefore expect some difference between rotational properties of photosphere and corona. An attempt is made to study variation in rotation period with respect to height in solar corona, by using radio observations at different frequencies. It is an open question whether solar rotation is cyclic or secular. Kambry and Nishikawa (1990) studied sunspot tracings and tried to look for variation in rotation rate from cycle to cycle and change within cycle also. They found that photospheric rotation period depends on phase of solar

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cycle and type of solar cycle i.e. high or low activity cycle. We have made an attempt to study such dependence through radio emissions at 2800 MHz. These radio emissions originate in solar corona and hence represent coronal rotation.

2. The data and analysis procedure

The data comprises of disc integrated flux measurements of radio waves at 2800 MHz, available through National Geophysical Data Centre, NOAA, USA. The daily measurements of radio emission can be represented in form of a time series. There are some techniques to analyze time series (e.g. fractal analysis, spectrum analysis, auto correlation method etc.). We first made fractal analysis (Watari 1995) of radio emissions at five different frequencies ranging between 410 MHz to 15.4 GHz. The value of fractal dimension varies between 1 (for perfectly periodic time series) and 2 (for completely random series). The value of fractal dimension close to 1 indicates better periodicity of series. Results of this analysis are discussed in next section. Autocorrelation method is a technique to estimate period from time series of daily solar flux observations. The autocorrelation analysis is performed in one year block and for whole solar cycle. The autocorrellograms are obtained by plotting autocorrelation coefficients against lag (in days) and rotation period is estimated. The autocorrelograms give rotation period of solar corona. The average coronal rotation period of solar cycle 22, obtained through autocorrelation of 2800 MHz emission is compared with average rotation period given by spectrum analysis.

3. Results and discussion

3.1 Fractal analysis at multiple frequencies

The fractal analysis made at five different frequencies 410, 1415, 2800, 8800 MHz and 15400 MHz revealed that fractal dimension is least near 2800 MHz and it increases systematically on both, higher and lower frequency side (Vats et al. 1998). We interpreted that 2800 MHz is the most appropriate frequency for study of solar coronal rotation. We have therefore used this frequency extensively to study long term variation in rotation period.

3.2 Single frequency autocorrelation

The autocorrelation analysis of 2800 MHz in one year block for 1970 - 95 shows that rotation period varies between 23.2 to 28.5 synodic days. The average synodic rotation period of cycle 22 is 26.49 days which is almost similar to that of spectrum analysis of 2800 MHz flux (26.52 days).

3.3 Multifrequency autocorrelation

This analysis was carried for 11 closely spaced frequencies between 275 MHz and 2800 MHz, over period of 26 months (June 1, 1997 to July 31, 1999). Solar radio emissions at various frequencies originate at different height in solar atmosphere. As per propagation characteristics of radio waves in plasma, the radio emissions at frequencies less than or equal to plasma frequency will be absorbed while those at second or higher harmonics will propagate. Therefore each value of electron density has a critical value of frequency below which radio emissions do not propagate. Using electron density model (Aschwanden and Benz 1995), frequency spectrum can be correlated with height in solar atmosphere. The lowest frequency 275 MHz seems to originate at 15×10^4 km above photosphere while highest frequency under present study - 2800 MHz originates near 6×10^4 km. The result shows that rotation period decreases from 24.1 days to 23.7 days (Vats et al. 2001).

3.4 Dependence of rotation on phase of solar cycle

We have analyzed 2800 MHz solar flux over a long period (for four solar cycles - cycle 19 to 22). Each cycle was divided into three phases - growth, peak and decay and rotation period is calculated in each phase. The results do not reveal any strong evidence for dependence of rotation period on solar cycle. However, except cycle 21, it is seen that rotation period is high during growth phase of solar cycle. Dependence of rotation on level of activity: Solar cycles are identified as low activity cycle and high activity cycle based on number of sunspot. Kambry and Nishikawa observed that mean rotation period varied from cycle to cycle in such a way that rotation period was less in low activity cycle and longer rotation period in high activity cycle. We calculated mean rotation period in each cycle and compared with photospheric rotation period. We do not find very significant variation in mean rotation period with level of activity but in solar cycle 20, which is low activity cycle, the rotation period is smallest. However such a small variation is not sufficient to prove or disprove any dependence of coronal rotation period on level of solar activity.

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