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Variation of Quiet Sun Radiation during Solar Cycles 23 and 24

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Abstract. Radio observations play a very important role in understanding the structure of the solar atmosphere. In this paper the quiet sun component of the solar radio emission has been investigated using data obtained from the Solar Indices Bulletin, National Geophysical Data Centre. By statistical method, the quiet sun component is estimated for 84 successive basic periods containing three solar rotations each using data obtained at different frequencies. From the quiet sun component we estimate the brightness temperature in each observing frequency.

Keywords. Sun: Radio radiation - Sun: Quiet sun radiation - Sun: Chromosphere, etc.

1. Introduction

Since the discovery of solar radio waves by Hey (1946), Southworth (1945) and Reber (1944), radio emission from the Sun can be broadly classified into two categories: disturbed emission and undisturbed emission. The undisturbed emission is further divided into two classes, the quiet sun radiation and the slowly varying component. The slowly varying component is due to localized active regions on the solar disk such as sunspots, the sunspot associated magnetic field, coronal mass ejections, solar flares, filaments and prominences. If the emission due to these active regions in the solar atmosphere is subtracted or removed, we get quiet sun radiation. Study of the quiet sun radiation enables us to know the size of the corona, electron density and electron temperature in different layers of the solar atmosphere. Measurement of the quiet sun emission provides accurate information about the source region of the radio emission. It also provides detailed information about the brightness temperature, magnetic fields and physical nature of the various sources inside the solar structure (Kundu 1965). The various frequency bands ranging from 410 MHz to 15400 MHz originate from different layers of the solar atmosphere starting from upper chromosphere to lower chromosphere.

2. Data

Sunspot number (SSN) and solar radio flux (F) at different frequencies during solar cycles 23 and 24 (1995-2013) have been collected from the Solar Indices Bulletin, National Geophysical Data Centre, Boulder published from the Department of Commerce, U.S. The radio flux is given in Solar Flux Unit (SFU), a measure of energy received per unit time per unit frequency interval. One SFU is equals to $10^{-22} W/m^2 Hz$.

3. Procedure and Analysis

The present paper provides the variation of the quiet sun component during solar cycles 23 and 24 (1995-2013). The period under investigation has been divided into 84 periods each of 81 days consisting of three successive Carrington rotations. The quiet sun

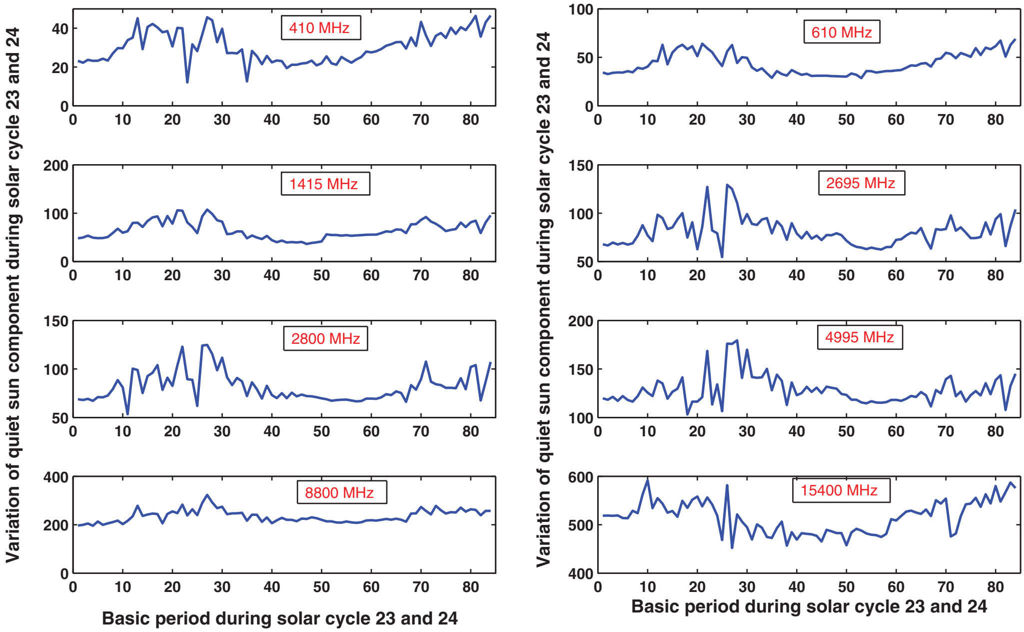

Figure 1. Variation of quiet sun radiation with basic periods at different frequencies(410, 610, 1415, 2695, 2800, 4995, 8800 and 15400 MHz) during solar cycle 23 and 24.

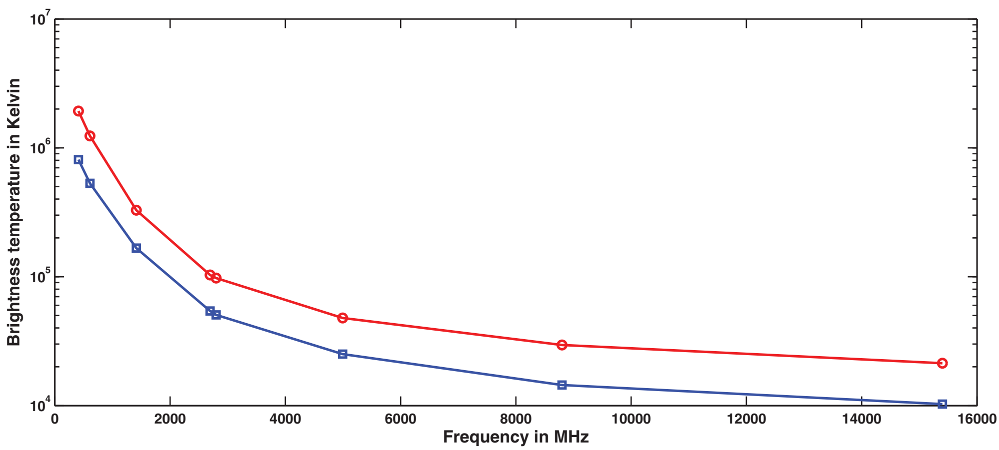

Figure 2. Variation of brightness temperature with frequency during solar cycle 23 (blue squares) and solar cycle 24 (red circles). To avoid data overlapping, cycle 24 data was shifted two times on y-axis.

component for each frequency under the present study is determined from the regression of scattered plot between radio flux and sunspot number. The generalised equation can be written as

$$F = A + B \times (SSN) \tag{3.1}$$

where A and B are arbitrary constants. The value of constant A contributes to the radio flux when the SSN is taken as zero; this simply gives the quiet sun component. The corresponding variations in brightness temperature has been determined by using the

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relation (Pawsey and Yabsley 1949)

$$T_b = \frac{Sc^2}{2k\nu^2\Omega}\,, \tag{3.2}$$

where k is the Boltzmann's constant (1.38×10^{-23} J / K), Ω is the solid angle subtended by the sun (where mean solid angle 6.8×10^{-5} Sr is taken from Pawsey and Yabsley 1949), ν is the frequency (MHz) and T_b is in degree Kelvin.

4. Results and Conclusion

Figure 1 shows the variation of quiet sun component at different frequencies averaged over 3 Carrington rotations, comprising 84 basic periods during the solar cycles 23 and 24 (1995-2013). The systematic fall and rise of quiet sun radiation connected with the 11-year solar cycle in Figure 1 shows some significant fluctuations in the course of passing from one basic period to another, similar to earlier studies (Zieba and Gula 1976). The quite sun component during solar minimum period is found to be stable at lower frequencies, consistent with the reports of Lokanadham & Subramanian (1986). Whereas at higher frequencies showing slight variation, while there is considerable variations during solar maximum period at all the frequencies. During the solar maximum period, the quiet sun component shows considerable differences at all the frequencies, and it remained more or less constant at lower frequencies with slight variations at higher frequencies during the solar minimum period. The number of disintegrating centres (break up of the solar activity centers) are so great that synchrotron radiation generated in their magnetic fields (during the maximum of the solar activity) could possibly have caused the differences. The decreasing density of electrons in the solar atmosphere causes a decline of thermal radiation especially on short waves (Kundu 1965). As outlined by Zieba & Gula (1976), the variation of the basic component with the phase of solar cycle depends on two basic processes namely variation of electron density in solar atmosphere and decay of vanishing magnetic fields. Mutual dependence of these two effects decides the actual shape of the quiet sun spectra. From Figure 2 the brightness temperature is decreasing with increasing frequency, this shows clearly the thermal nature of the quiet sun component at all frequencies.

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