Periodicities in the coronal rotation and sunspot numbers

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Accepted 8888 XXX 88 Received 8888 XXX 88; in original form 8888 XXX 88

ABSTRACT
The present study is an attempt to investigate the long term variations in coronal rotation by analyzing the time series of the solar radio emission data at 2.8 GHz frequency for the period 1947 - 2009. Here, daily adjusted radio flux (known as \textit{Penticton flux}) data are used. The autocorrelation analysis shows that the rotation period varies between 19.0 to 29.5 sidereal days (mean sidereal rotation period is 24.3 days). This variation in the coronal rotation period shows evidence of two components in the variation; (1) 22-years component which may be related to the solar magnetic field reversal cycle or Hale’s cycle, and (3) a component which is irregular in nature, but dominates over the other components. The crosscorrelation analysis between the annual average sunspots number and the coronal rotation period also shows evidence of its correlation with the 22-years Hale’s cycle. The 22-years component is found to be almost in phase with the corresponding periodicities in the variation of the sunspots number.

Key words: Sun: corona – Sun: radio radiation – Sun: rotation

1 INTRODUCTION
Coronal rotation can be observed through various solar tracers at different frequencies, like coronal green line (Fe XIV emission line at 530.3 nm), white light, He I line (at 1083 nm), soft X-rays, UV rays, radio waves. The coronal green line has been used to measure the rotation rate of the solar corona at higher latitudes by Waldemier (1950, 1955); Trellis (1957); Cooper et al. (1962); Šyška (1971); Sime et al. (1989); Rybáč (1994); Badalyan et al. (2006a, b) and others. The results of Waldemier (1950) and Cooper et al. (1962) indicate a faster rate of rotation as compared to the rate of rotation of the sunspots, suggesting a much lower differential rotation rate in the corona. In his work on green corona Šyška (1971) found that the Sun shows little or no differential rotation for six latitudinal zones \(\pm 7.5, \pm 27.5\) and \(\pm 47.5\). For low latitudes the rotation period was near to that found by Trellis (1957). The green (Fe XIV at 530.3 nm) emission line for the period 1973 - 2000 and red (Fe X at 637.4 nm) emission line for the period 1984 - 2000 were analyzed by Altrock (1997, 2003). It was reported that the corona, at green and red emission lines, shows more rigid rotation than does the photosphere. Sime et al. (1989) also concluded, after analyzing the Sacramento Peak Observatory (SPO) data observed between 1973 and 1985, that the Fe XIV corona rotates more rigidly than do features in the photosphere or chromosphere. The synodic period obtained by Rybáč (1994) for the period 1964 - 89 again confirmed the differential rotation of the green corona. Badalyan et al. (2006a, b) carried out a comprehensive analysis using a long database (1939 - 2001) on the brightness of the coronal green line. The results support previous conclusions that the differential rotation in the corona is less pronounced than in photospheric tracers.

Hansen et al. (1994) used the K-coronometer for coronal rotation measurement at different latitudes, for heights ranging from 1.125 to 2 \(R_\odot\). The rotation found at the equator is in good agreement with the sunspot’s rotation results and shows less variation with latitude at higher latitudes in comparison to the rotation of the chromosphere. A detailed study of the white light corona, from 1.1 \(R_\odot\) to 30 \(R_\odot\), was done with the LASCO coronagraphs on board the \textit{SoHO} spacecraft. It was concluded that the rotation of the corona displayed a radially rigid rotation of 27.5 days synodic period from 2.5 \(R_\odot\) to > 15 \(R_\odot\) (Lewis et al. 1999).

The He I 1083 nm maps, from the National Solar Observatory (NSO), have been used to determine the rotation. It is found, both from observations and from magnetic extrapolation methods, that the corona becomes more rigid with height. By considering coronal holes as tracers (from an atlas of coronal holes mapped in He I 1083 nm data) of the differential rotation Insley et al. (1993) demonstrated that the mid-latitude corona rotates more rigidly than the photosphere, but still exhibits significant differential rotation, with an equatorial rate of 13.30 \(\pm 0.04\) deg/day, and at 45° latitude a rate of 12.57 \(\pm 0.13\) deg/day. An analysis of the rotation of coronal holes spanning 18 years (from