Sun’s retrograde motion and violation of even{odd cycle rule in sunspot activity

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ABSTRACT

The sum of sunspots numbers over an odd numbered 11 yr sunspot cycle exceeds that of its preceding even numbered cycle, and it is well known as Gnevyshev and Ohl rule (or G(O rule) after the names of the authors who discovered it in 1948. The G(O rule can be used to predict the sum of sunspot numbers of a forthcoming odd cycle from that of its preceding even cycle. But this is not always possible because occasionally the G(O rule is violated. So far no plausible reason is known either for the G(O rule or the violation of this rule. Here we showed the epochs of the violation of the G(O rule are close to the epochs of the Sun’s retrograde orbital motion about the centre of mass of the solar system (i.e., the epochs at which the orbital angular momentum of the Sun is weakly negative). Using this result it is easy to predict the epochs of violation of the G(O rule well in advance. We also showed that the solar equatorial rotation rate detemined from sunspot group data during the period 1879 (04 is correlated/anti-correlated to the Sun’s orbital torque during before/after 1945. We have found the existence of a statistically significant 17 yr periodicity in the solar equatorial rotation rate. The implications of these findings for understanding the mechanism behind the solar cycle and the solar-terrestrial relationship are discussed.

Key words: Sun: rotation { Sun: magnetic fields { Sun: sunspots { Solar system: general

1 INTRODUCTION

Solar activity vary on many time scales. It can impact climate and the near earth space environment (e.g., Hoyt & Schatten 1997; Hathaway, R.pson & Rehmk and 1999; Roeder 2000; Hamath & M and 2004; Georgieva et al. 2005). Therefore, prediction of the amplitudes of the variations in solar activity will greatly help the society. Sunspots are the earliest observed phenomenon of solar activity. The sunspot cycles are numerated from the cycle which was begun in the year 1755 (cycle 1). The current sunspot cycle, which began in the year 1996, is an odd numbered cycle (cycle 23). The well known Gnevyshev(Ohl rule Gnevyshev & Ohl 1948) states that the sum of sunspot numbers $R_{sun}$ over an odd numbered sunspot cycle exceeds that of its preceding even numbered sunspot cycle. By using the G(O rule, it is possible to predict the $R_{sun}$ of an odd numbered cycle from that of its preceding even numbered cycle with a reasonable accuracy (Ree 1988). However, some pairs of the even{odd cycles violated the G(O rule, i.e., in such a pair the $R_{sun}$ of the odd numbered cycle is less than that of its preceding even numbered cycle (e.g., cycles’ pairs 4,5 and 22,23). So far no plausible reason is known either for the G(O rule or its violation. In order to predict the amplitude of an odd cycle by using the G(O rule it is necessary and essential to know in advance whether the even{odd numbered cycles’ pair will satisfy the G(O rule or not. But there is no method available for predicting the violation of the G(O rule. Predictions on the basis of precursor technique, the G(O rule, and the statistical analysis of preceding cycles indicated a high $R_{sun}$ for the current cycle 23, similar to or exceeding that in cycle 22 (Joseph et al. 1997). The prediction of the violation of the G(O rule by the cycles’ pair 22,23 based on the long term trends...
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in sunspot activity [Schw 1955; Kom 1965 Javaraih 2002] seem s to be right. However, the epoch of the next violation of the G 0 rule is not yet predicted, and the available sunspot data may be inadequate to use this method.

There are two main approaches for explaining the mechanism of the solar cycle, viz., one is based on a turbulent dynamo operating in or immediately below the solar convection envelope and the other is a large scale oscillation superposed on a fossil magn etic eld in the radiative core. A coming to the turbulent dynamo theory the solar di reential rotation produces a toroidal eld (east-west com ponent) by continuously winding up a poloidal eld (north-south com ponent). Induction of cyclonic turbulence regenerates the poloidal eld, and the excess poloidal and toroidal elds are removed by the enhancement of di usion by convective turbulence. A su ciently detailed and realistic model of the dynamo process to account for all the di erent aspects of the solar magnetism is not yet available. The available turbulent dynamo models have several di culties. For example, in these models the role of the di reential rotation in the cyclic variation of the solar activity is not clear; the reason for the cycle-to-cycle modulations of solar activity is not yet found, and have no predictive power. The basic idea of the magnetic oscillator model is to consider the observed oscillations of toroidal solar magnetic eld as e ects of periodic ampli cation of the primordial elds due to oscillations in the di reential rotation rate of the solar interior. The main di culty in the oscillator models is regarding energetics. No oscillator models account for the means of maintaining the oscillations against dissipation of velocity and magnetic elds (see reviews by Rosner & Weiss 1999, Sonnert 2003). This regard may be worthwhile to investigate whether the solar system dynamo could in uence on the internal dynamics of the Sun Gokhale & Javaraih 1994).

The idea that the gravity of the planets might be the cause of the solar cycle dates back at least to Carrington Brown 1850. Subsequently, many scientists suggested a possibility of the tidal forces due to planets or the rate of change of the Sun’s orbital angular momentum about the centre of the solar system (barycentre) having a role in the mechanism of solar activity. Such an idea as a role of the solar system dynamo has been doubted because, (1) the energy of the tidal force due to the planets is small compare to the Sun’s surface gravity; and (2) the Sun’s centre of mass is free fall in the sum (total gravitational) eld of all of the planets. Nevertheless, the hypothesis of a relationship between the Sun’s motion and the solar activity is supported by a growing number of studies indicating something must be true in the planetary hypothesis: (1) the Sun’s orbital angular momentum about the centre of the solar system (barycentre) having a role in the mechanism of solar activity; and (2) the Sun’s centre of mass is free fall in the sum (total gravitational) eld of all of the planets. The Sun wobble about the centre of the solar system with the distance varying up to 2 times its radius. The Sun’s spin on ement contributes 1/2% to the total angular ement of the solar system, the Sun (Brown 1855) showed the existence of a relationship between a Hale cycle and the changes in the angular ement of the Sun’s motion about the barycentre. Recently Zagarashvili 1997 and Jukett 2000 found that the Sun’s motion about the barycentre is having a role even in the cause of the solar di reential rotation. The co positions and the directions of elms of the major planets are considerably di erent during the even and the odd numbered cycles. The di reential rotation of Javaraih & Gokhale 1995 and Javaraih 1996, 2003 revealed the frequencies which are compatible with the frequencies of the speci c align ements of two or more planets. The existence of an e relationship, which is similar to the G 0 rule in sunspot activity, is also found between the di erences in the di reential rotation during the odd and the even numbered cycles Javaraih, Bietil & Uher 2005). Therefore, one would reasonably expect that the violation of the G 0 rule and the variations in the di reential rotation are probably having a relationship with the Sun’s motion about the barycentre. In the present paper we have investigated this.

In the next section we describe the data and the analysis. In Section 3 we show the existence of a relationship between the violation of the G 0 rule in sunspot activity and the Sun’s retrograde motion about the centre of mass of the solar system. In Section 4 we show the existence of coupling in the Sun’s spin and or bital motion. In Section 5 we discuss about the implication of these results for understanding the long-term variations in the solar activity (including the M aunder minimum) and the solar-terrestrial relationship.

2 DATA AND ANALYSIS

Dr. Ferenc Varadi kindly provided us the values of the following: the distance (R) of the Sun’s centre from the solar system barycentre, the orbital velocity of the Sun (V), the orbital angular ement of the Sun (L), and the rate of change of the orbital angular ement (orbital torque c000), for each interval of length 10 days during the period 1600(2099). We determined these values using the recently Jet Propulsion Laboratory (JPL) DE405 ephemeris Section 3, Standish 1998 for the period 1600(2100).

The solar di reential rotation can be determined from the full disk velocity data using the standard polynomial expansion Howard & Harvey 1973,

\[ v(x,y) = A + B \sin^2(x) + C \sin^4(x) \]  

(1)
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Table 1. The values of \( \Delta L \), L, R, V and the ecliptic positions (in deg) of the giant planets (Jupiter (J), Saturn (S), Uranus (U), and Neptune (N)) (at the epochs for which the values of L are given and marked by the dotted and dashed vertical lines in Fig. 1) are from Table 1. The units of \( \Delta L \) are A.U.:A.U. day \(^{-1} \), day \(^{-1} \), respectively, where M is mass of the Sun and A.S.: is the Astronomical unit.

| Time  | \( \Delta L \) | 10 \(^{6} \) | Time  | L | 10 \(^{6} \) | R | 10 \(^{6} \) | V | 10 \(^{6} \) | J | S | U | N |
|-------|---------------|---------|-------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 1628.64 | -2.34         | 1632.28 | 0.039 | 0.747           | 5.773            | 37               | -120             | 178              | -138             |
| 1666.97 | -2.53         | 1671.79 | 0.153 | 0.303           | 5.094            | 157              | -8               | -13              | -53              |
| 1807.64 | -2.40         | 1812.05 | 0.033 | 1.334           | 5.535            | 96               | -87              | -127             | -106             |
| 1845.97 | -2.51         | 1850.85 | 0.227 | 0.462           | 4.941            | -171             | 20               | 30               | -22              |
| 1986.81 | -2.62         | 1990.97 | 0.021 | 1.364           | 5.285            | 126              | -63              | -80              | -75              |
| 2025.14 | -2.72         | 2029.99 | 0.310 | 0.638           | 4.940            | -138             | 53               | 76               | 10               |

While for sunspot data it is sufficient to use only the first two terms of the expansion (Newton & Nunn 1951): 

\[
\sin^2 = A + B \sin^2 \theta
\]

where \( \sin^2 \) is the solar sidereal angular velocity at latitude \( \theta \), the coefficients \( A \) represents the equatorial rotation rate and \( B \) and \( C \) measure the latitudinal gradient in the rotation rate with \( B \) representing mainly low latitudes and \( C \) largely higher latitudes (\( \theta \) is too small to be determined from sunspot data). (Note: The above equations have no theoretical foundation, but they very well to the corresponding data, said above.)

In this analysis the sunspot data and its reduction are same as in (Javvairah & Gokhale 1999) and (Javvairah 2003a, b). We have used the Greenwich data on sunspot groups during the period 1879-1976 and the spot group data from the Solar Optical Observing Network (SOON) during the period 1987-2004 (available at http://ftp.scds.nasa.gov/soi/pad/solar/greenwich.htm). The data consist of the observation time, heliographic latitude and longitude, central meridian distance (C.M.D.), etc. for each spot group on each day of its observation. The sidereal rotation velocities (\( \sin^2 \)) have been computed for each pair of consecutive days in the life of each spot group using its longitudinal and temporal distance between these days. We have not used the data corresponding to the C.M.D. \( > 75 \) deg on any day of the spot group life span and the displacements exceeding 3 deg in longitude or 2 deg in the latitude per day. We determined the annual variations in the coeclipsic A and B by fitting the each year spot group data to the equation (2).

3 VIOLATION OF THE G (O) RULE

Fig. 1 shows the variations in the R, V, L, and \( \Delta L \) determined from the planetary data available for every 10 days, during the period 1600-2009. In this guise we also show the variations in the yearly mean values of the sunspot numbers during the period 1600-2004 (bottom panel). The epochs 1632, 1811 and 1990 when the Sun’s motion about the barycentre was retrograde (i.e., when \( L \) was changed from positive to a weakly negative, Jose 1963) are indicated by the dotted vertical lines. The other two epochs of the big drops in \( L \) were at 1672 and 1851, and the expected next epoch of such a big drop in \( L \) will be at 2030. All these are indicated by the dashed vertical lines. For obvious reason near each of the big drops in \( L \) there is a big drop of \( \Delta L \). We have given in Table 1 the values of R, V, L, \( \Delta L \), and the values of the ecliptic longitudinal positions of the giant planets at these 6 epochs. The phase of \( \Delta L \) is leading the phase of \( L \) by about 4 years near the dotted lines and about 5 years near the dashed lines. This is expected because the Sun is the force and the latter is the motion and both have main period, 19.86 yr., the conjunction period of Jupiter and Saturn. At the epochs where the steep decreases in \( L \) are indicated by the dotted vertical lines the decrease in \( L \) is more steeper than the decrease in \( V \). It is opposite in case of at the epochs which are marked by the dotted vertical lines. The gap between the consecutive dotted vertical lines and also between the consecutive dashed lines is about 179 years, i.e., the period of the well known 179 yr cycle in the Sun’s motion related to the solar system barycentre. It is also the period of an interval between alignments of all the outer planets in a same e direction in space. It is approximately equal to the 9 conjunction periods of Jupiter and Saturn (Jose 1963). The gap between a dotted line and its neighbour dashed line is about 43 years, the conjunction period of Saturn and Uranus.

The G (O) rule was violated by the sunspot cycle 4.5 at the beginning of the Dalbon Minimum, and it is most likely to be violated by the cycles’ pair 22,23 (Javvairah 2003a). It seems that near the end of the cycle which was at just one cycle before the cycle at the beginning of the M aunder Minimum the G (O) rule was violated cycles’ pair -12, -11, say). Jose et al. (1962) have shown the existence of cyclic behaviour during the M aunder Minimum. Interestingly, each of these cycles’ pairs are close to an epoch at which the Sun’s orbit in motion is retrograde, which are indicated by the dotted vertical lines. The peak value of sunspot cycle 8 is higher than that of cycle 9. By virtue of this difference the cycle pair 8,9 violated the G (O) rule. The ten normal behaviours of L and \( \Delta L \) suggest such a situation might have occurred in the year 1672 and the next such a situation may occur near the year 2030. These findings indicate the existence of a relationship between
the violation of the G(O) rule and the Sun’s retrograde motion about the centre of mass of the solar system. In Table 1 it can be seen that the epochs at which \(L\) was steeply decreased Saturn was aligned approximately in opposition to Jupiter, and Uranus and Neptune were nearer to Saturn (i.e., Jupiter leads by about 180° w.r.t. the other three giant planets). Obviously such configurations of the major planets are responsible for the Sun’s retrograde motion about the barycentre, which is in turn seems to be responsible for the violation of the G(O) rule. Since the planetary configurations and the Sun’s retrograde motion can be computed well in advance, hence, it is possible to know the epochs of violations of the G(O) rule well in advance. Therefore, the G(O) rule is expected to be violated by the Hale cycle which will include (or end at) the year 2169, i.e., only after a gap of about eight Hale cycles after the current Hale cycle 11. However, the violation by virtue of the difference in the heights of the peaks of the cycles (like the cycles’ pair 8,9 near the year 1851) is expected to be happening near the year 2030, i.e., by the cycles’ pair 26,27.
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Figure 1. Values of $R, V, L, \frac{dL}{dt}$ in each 10 days interval during the period 1600-2099 and the annual mean of the number of sunspots during the period 1600-2004. The units of $R, V, L$ and $\frac{dL}{dt}$ are $\text{AU}^2\text{day}^{-1}, \text{AU}^3\text{day}^{-2}$ and $\text{AU}^2\text{day}^{-2}$, respectively, where $\text{AU}$ is the astronomical unit. Near the peak of each sunspot cycle the corresponding number of sunspots is marked. The epochs, 1632, 1811 and 1990, at which the Sun's orbital motion was retrograde are indicated by the dotted vertical lines. The other three epochs, 1672, 1851 and 2030, where also $L$ steeply decreased are marked by the dashed vertical lines. The horizontal lines represent the mean values.
4 SUN'S SPIN (ORBIT COUPLING)

Fig. 2 shows variations in the annual average values of $R, V, L, \frac{dL}{dt}$ and the values of the di-essential rotation parameters $A$ and $B$ determined from the yearly sunspot group data during the period 1879/2004. The error bars are 1 (standard deviation) values. Due to the reduced number of sunspot groups the values have large errors at the cycles' minima. We connected the time series of $A$ and $B$ by replacing the values which have errors larger than three times the median errors by the values simulated from the linear fits. A similar correction was applied in an earlier paper by Javaraiah & Kom (1999). In Fig. 2 the solid curves in the lower two panels connected the points of the corrected data and the dotted curves connected the uncorrected data. In this case the variations in the solar rotational equatorial rotation rate, $A$, looks to be largely similar to the variation of $\frac{dL}{dt}$. A figure 1945 the variations of both $A$ and $\frac{dL}{dt}$ have some extent. During this time the mean level of activity is also relatively large (see Fig. 1). The epoch 1990(1991) at which the Sun's orbital motion is retrograde the value of $A$ is low and the $\frac{dL}{dt}$ is almost zero. The correlation between $A$ and $\frac{dL}{dt}$ is positive before around 1945 and negative after that time. The correlation between $A$ and $\frac{dL}{dt}$ is 0.84 and 0.89 in intervals of about 50 years before and after 1945, respectively). These results indicate the existence of a relationship between $A$ and $\frac{dL}{dt}$. The orbital angular momentum of the Sun might have been transferred to the spin on entum for about 50 years before and after 1945 and the reverse might have been happened in the latter 50 years (Jukett, 2000).

The correlation between the latitudinal gradient of the rotation ($B$) and $\frac{dL}{dt}$ is weak. The signs of correlations ($r$ = -0.20 to +0.25) between the ($B$) and $\frac{dL}{dt}$ are found to be opposite during the aforementioned epochs of the positive and negative correlations between $A$ and $\frac{dL}{dt}$ (it should be noted here that there exists an anticorrelation between $A$ and $B$, e.g., Javaraiah et al., 2005a). Javaraiah & Gokha (1999) and Javaraiah & Kom (1999) found the 18.3-yr, 8-yr and few other short periodicities in $B$. Fig. 3 shows the FFT spectra of the annual variations of $\frac{dL}{dt}, A$ and $B$. From this graph it can be seen that both spectra of $A$ and $B$ have the dominant peaks at frequency $1/18 yr^{-1}$, which are significant on 3.5 and 5.5 levels, respectively. The corresponding periodicities in $A$ and $B$ match approximately with that of the main periodicity in $\frac{dL}{dt}$ (the peak at $1/21 yr^{-1}$, 6.6). We repeated the FFT analysis by extending the time series from the original 126 data points to 1024 data points by padding the time series with zeros. The values of the aforementioned main periodicities in $A$, $B$ and $\frac{dL}{dt}$ are found to be 17.1 yr, 18.29 yr, 19.69 yr, respectively.

Note there is about 1-yr difference between the aforementioned main periodicities of $A$ and $B$. This may be explained as follows: It is believed that the magnetic structures of the active regions originate near the base of the convection zone (about 200 000 km below the surface) and the magnetic buoyancy causes them to rise through the convection zone and emerge on the surface. The rotation rates of spot groups depend on their life spans and age. This can be interpreted as the rotation rates of the magnetic structures of spot groups vary as their anchoring depths vary during their life spans (Javaraiah & Kom, 1995, Gokha & Javaraiah, 2002, Hiremath, 2003, Sivarumkum et al., 2003). Fig. 4 shows the FFT spectra of $A$ and $B$ determined from the first two data sets (of young groups) of spot groups of life span 7-12 days. To have adequate data we have used the moving time intervals of sizes 5 years (same as in Javaraiah & Gokha, 1995, Javaraiah, 1999). In Fig. 4 we have also showed the FFT spectrum determined from the 5-yr smoothed time series of $\frac{dL}{dt}$. In this figure it can be seen that the dominant in peaks in the spectra of $A$ and $B$ are well coincided. We also repeated the FFT analysis for these smoothed time series by extending them as described above. The dominant peaks in the spectra of the extended time series of both $A$ and $B$ are found to be at $1/17 yr^{-1}$. This indicates that the 18.3-yr periodicity (found in $B$) derived from the combined data (dominated by small and short-lived groups) of spot groups of di-essential life spans and again may correspond to a slightly shallower layers. The 17.1 yr periodicity may correspond to a slightly deeper layers (also see Javaraiah, 1999).

The 17.1 yr periodicities of both $A$ and $B$ closely match with the 17.5 yr periodic found in the sum (or the low frequency components of $L$ and the instantaneous spin projection vector (Jukett, 2003). In addition, it seems that there exists a good agreement between the annual amplitudes of the variations in the Sun's spin and the orbital angular momentum, particularly at the minima of the steep decreases in both $L$ and $A$. At these epochs the amount of decrease in $L$ is approximately equal to the mean value of $L$. For example, at the epoch 1990.97 the amount of the steep decrease in $L$ is about $2 \times 10^{27}$ cm$^2$ s$^{-1}$. At this time the amount of the drop in $A$ is about 1% and the corresponding decrease in the spin on entum is found to be approximately $1 \times 10^{27}$ cm$^2$ s$^{-1}$. The mean yearly value of $A$ is 14.505, 0.008 deg day$^{-1}$. The uncertainty in the mean value suggests that the mean annual variation of the solar equatorial rotation rate during the period 1879/2004 is about 0.05%, only. Overall about 0.1% di-essential difference is found in the solar mean equatorial rotation rates during the even and the odd cycles (Jukett, 2003).

The results above provide a direct observational support to the models of the solar spin-orbit coupling of an oblate Sun (e.g., Jukett, 2003). The results also indicate that the perturbations required for maintaining the oscillations in the solar di-essential rotation and the solar magnetic eikai as the participants in the mechanism of solar cycle are coming from the solar system dynamics.
Figure 2. Variations in the yearly mean values of $R, V, L, \frac{dL}{dt}, A$ and $B$. The units of $R, V, L$ and $\frac{dL}{dt}$ are the same as in Fig. 1 and Table 1. In case of $A$ and $B$ the solid and dashed curves represent the corrected and the uncorrected data, respectively, and the error bars are 1σ values. The epoch 1990 at which the orbital motion of the Sun was retrograde is indicated by the dotted (vertical) line. The horizontal lines represent the mean values.
Figure 3. FFT power spectra of $\frac{dL}{dt}$ (dashed curve), A (dotted curve) and B (solid curve). The power values are normalized to unity. Near the tops of the dominant peaks, which are significant $> 3$ (particularly in A and B), the values of the corresponding periods are shown.
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Figure 4. Same as Fig. 3, but A and B are determined from only first two days (young groups) data of the spot groups of life span 7(12 days). To have adequate spot group data 5-yr moving time intervals are used. In case of \( \frac{1}{2} \), 5-yr smoothed time series is used.
DISCUSSION

Javaraih et al. (2005a) argued that between sunspot cycles 4 and 5 the data is sparse and unreliable, and interpreted the very long cycle 4 as consisting of two short cycles. If this interpretation is correct, then it seems that the G(O) rule was not violated by Hale cycle 2. Kristeva, Solanki & Beer (2002) by comparing the sunspot observations of the aforesaid period with those at other times, and also by analyzing other proxies of solar activity, showed that no cycle was misidentified at the end of the 18th century and that the observed sunspot cycle number and parameters are correct. Javaraih et al. (2003) argued the statistical analysis performed in the paper by Kristeva et al. (2002) as it is not validated by quantitative tests and even contains several errors. Hence, whether the G(O) rule was violated during the Hale cycle 2 or there was an additional weak cycle in 1790’s is yet to be commented. The result found in Section 3 essentially strongly suggests that the G(O) rule was indeed violated by the Hale cycle 2.

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proximity to the Sun their tidal forces on the Sun are larger than those of the outer planets (except Jupiter). Therefore, when they are closely aligned with the Jupiter the combination may cause “jolts” (rate of change of acceleration) in the orbit of the Sun. There are some spikes in the variations in A and B, particularly around some minor years when the values of B are almost zero or even positive (see Figs. 2). Any of these spikes may be resulted because of the sizes of the spot group data are smaller than three times the median error, M. Moreover, we found the similar abnormal behaviors in the values of B during the year 1962 from the Mt. Wilson Observatory and the Kodakanal Observatory sunspot data (available at http://www.astro.ucla.edu/obs/spotpdfnew.htm, Kamby & Nishikawa 1994) also derived a similar value of B during the year 1962 from the spot group data measured in the National Astronomical Observatory of Japan. Hence, the above abnormal behaviors of B seems to be a real property of the rotations of the sunspots during the aforesaid years. Interestingly, on February 5, 1962 the naked eye planets plus the Sun and M oon aligned within 15.8° and there was a solar eclipse at the same time (Kamby 1994).

In view of the existence of a statistical sign of 18.3 periodicity in B it is interesting to note that the major earthquakes in California seem to be occurred in the gaps of about 18 years (http://www.personal.psu.edu/users/m/a/mab573/sunam.htm). A similar periodicity may be exist in the Earth's rotation (Krivov, Georganos & Javaraiah 2004). The Precession period of the Moon is also 18.6 years. In addition, there were several droughts in 1886/1887, 1962/1963 and 1995/1996 (Fowler & Klippen 2000), when the values of the Sun slightly vary. So, in view of the results in Sections 3 and 4, it may be worthwhile to investigate whether the variations in the internal dynam ics of the Sun and the Earth, and the terrestrial phenomena all governed by the solar system dynamics. However, it should be noted here that so far no convincing evidence is found for the influence of the planetary dynamics on the terrestrial phenomena, climate, dynam ics of the Earth and/or earthquakes. Grubbin & Plagemann (1974) described the 1982 alignment of all the nine planets as a superposition with all the nine planets in line on the same side of the Sun. They had predicted that this alignment of planets cause a massive earthquake in 1982 and a major disaster in Los Angeles. Fortunately, that prediction was failed. In 1982 alignment the planets spread out over 98 degrees (Delcoun 1979).

It should be noted here that some of the relatively short-term predictions of the solar activity which were made based on the hypothesis of a role of solar system dynamics in the mechanism of solar activity have failed (Meier 1991, Li, Yun & Gi 2003). A reason for this may be the underlying physics is not clear. On the other hand, the inclinations of the orbital planes of the planets and the Sun’s equator to the ecliptic (or to the invariable plane) seem to be important (B.Ikeda 1983, Javaraiah 1998, 2002; Jucquet 2000), but they were not taken into account in most of the earlier investigations.

6 SUMMARY AND CONCLUSION

We have showed the epochs of the violations of the well known G (O) rule in pairing of sunspot cycles are close to the epochs of the Sun’s retrograde orbit. This is important to know well in advance the epochs of violations of the G (O) rule. The G (O) rule is expected to be violated by the H ale cycle which will include (or end at) the year 2169, i.e., only after a gap of about eight Hale cycles after the current Hale cycle 11. However, the violation of the G (O) rule by virtue of the di stance in the values of the peaks of the cycles’ pair (like the cycles’ pair 8,9 near the year 1851) is expected to be happening near the year 2030, i.e., by the cycles’ pair 26,27. We also showed that the solar equatorial rotation rate determined from the sunspot group data during the period 1879-2004 is consistent with the Sun’s orbital torque, positively before 1945 and negatively after that time. The equatorial rotation has a dominant periodicity at 17 yr. These results are well consistent with the results in the models of the spin-orbit coupling of an oblate Sun by Jucquet (2000), and may provide a direct observational support to the hypothesis that a role of solar dynamics on the internal dynamics of the Sun and in the variations of solar activity.

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