Rotational velocity of the solar corona versus solar activity

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ABSTRACT

This contribution describes the procedure by which we found relationship between the rotational velocity of the solar corona and the level of the solar activity (i.e. the phase of the solar cycle) in the period of 2011 - 2020. The deviation of the speed from the mean value is ± 0.0239°/day, which corresponds on the solar surface near the equator to ± 3.16 m/s, with a mean value of about 14.1°/day (1864.3 m/s). The level of activity was determined using the coronal index (CI) and we used the data on coronal rotational velocity from our recent work (Dorotovič and Rybanský, 2019). The correlation coefficient between the monthly averages of the CI and the rotational velocity during the given period (120 months) is 0.752. We did not find theoretical explanation for this phenomenon.

1. INTRODUCTION

The problem of temporal changes in the rotation of the solar corona (angular rotational velocity ω) and other layers of the solar atmosphere can still be considered open, unexplored. The reason is a large variance of the measured velocities, while the small contribution of changes in ω (if any exist) is overlaped with the scatter of the measured values of ω.

Main objective of the study:

• investigating eventual relationship between the rotational velocity of the solar corona and the level of the solar activity (i.e. the phase of the solar cycle) .

2. INPUT DATA

Monthly average values of ω for the period of 2011 – 2018 are published in Dorotovič and Rybanský (2019). We have added the data for 2019 and 2020 → we obtained a time series of 120 months.

3. METHOD OF DATA SELECTION

Daily values of coronal rotational speed were determined in Dorotovič and Rybanský (2019) using cross-correlation between two SDO/AIA 21,1 nm images with a time lag of 30 minutes → matrix (241 rows x 2761 columns, **±6°** around the meridian and **±70°** in heliographic latitudes); then monhtly averages of ω were calculated from daily values meeting certain defined criteria.

We used here only the data where the correlation coefficient was higher than **0.5** and with deviation from the average value less than **±3σ**;

- two groups of matrix rows: first where is a coronal bright point - CBP (time series ω_p) and second where only some other intensity structure exists (time series ω_n);
- to reduce scatter: only data with deviation from the average value less than **±σ** were used and then we computed average values of coronal rotational speed from the range of heliographic latitudes of **±35°** → the scatter of data was reduced to **0.05°/day;**

[we processed around 21 000 data in a month and approximately half of them meeted the above described criteria limits].

4. RESULTS

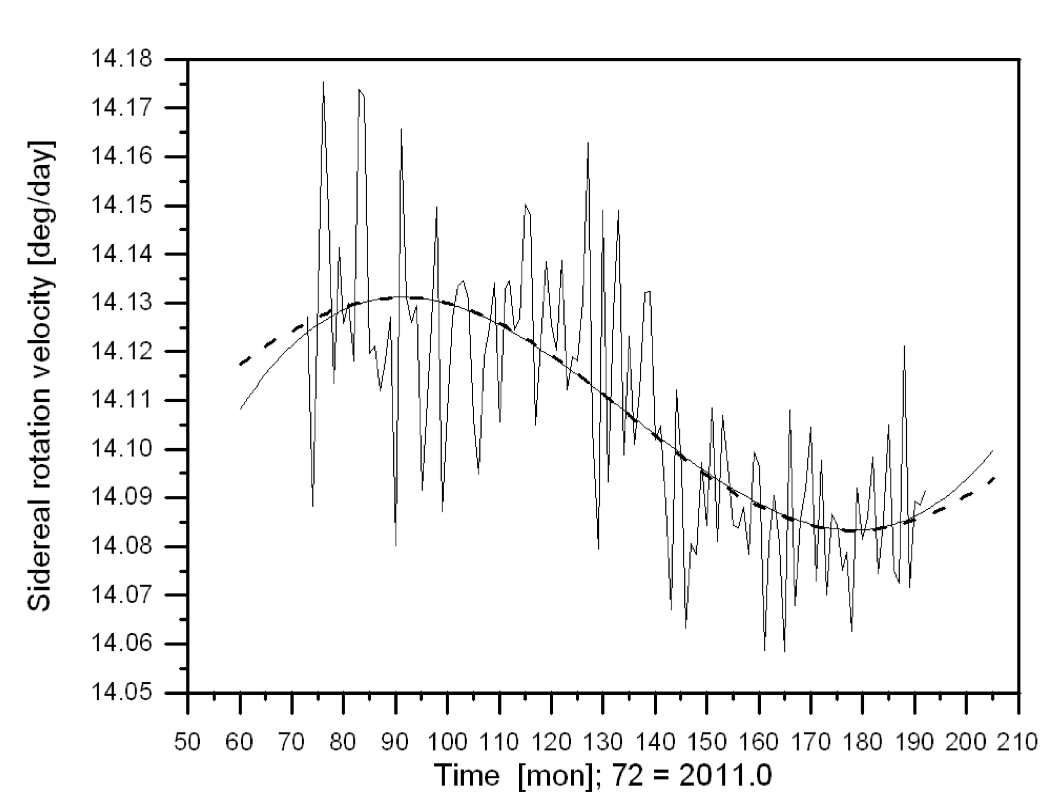

***Figure 1** - Time series graph of monthly averages of ω_n; cubic parabola approximation (thin solid line): $y = 14.123 + 8.93.10^{-4}\, t - 2.73.10^{-5}\, t^2 + 1.45.10^{-7}\, t^3$, where t is time in months; sinusoidal approximation (thick dashed line): $y = 14{,}1072 + 0{,}02388.\sin((t+24).2\pi/173{,}8)$.*

Model of an average solar cycle

The sinusoidal period is **173.8 months**, i.e. **14.48 years**. The length of the descending phase of the cycle is **7.24 years**. Ratio between the ascending and the descending phase of a cycle is 4:7, then the ascending phase lasts **4.14 years**, i.e. **49.68 months** → the whole cycle would have the length: 173.8/2 + 49.68 = **136.58 months**, i.e. **11.39 years**. Range of the sinusoid is **2 x 0.02388°/day** → rotational speed rate varies by **6.4 m/s** (in the equatorial regions of the Sun).

4. COMPARIS WITH SOLAR ACTIVITY

For comparison, we used monthly averages of the Wolf number (**W**), the level of solar radio flux at 2800 MHz (**IR**) and the coronal index (**CI**) and these values were correlated with ω_p and ω_n.

CI is derived from ground-based observations of the green corona emission line 530.3 nm above the solar limb (a network of coronal observatories: Rybanský (1975) and Rybanský et al.(2005). From these observations it is possible to determine the total radiated power in this line (in units of 10^{16} W/sr) at a distance of 1 au from the Sun. Those observations were later replaced by corona observations from satellites in the XUV region of the spectrum (Lukáč and Rybanský, 2010). For this purpose, we currently use observations of the SDO/AIA instrument at a wavelength of 21.1 nm.

We calculated the monthly averages from the indices W, IR and CI and then we correlated these with the monthly averages of ω_n and ω_p. The results are shown in Table 1.

Table 1: Correlation coefficients of the activity indices and the rotational speed ω_n and ω_p, respectively.

	ω_n	ω_p
W	0,678	0,188
IR	0,692	0,183
CI	**0,752**	0,215

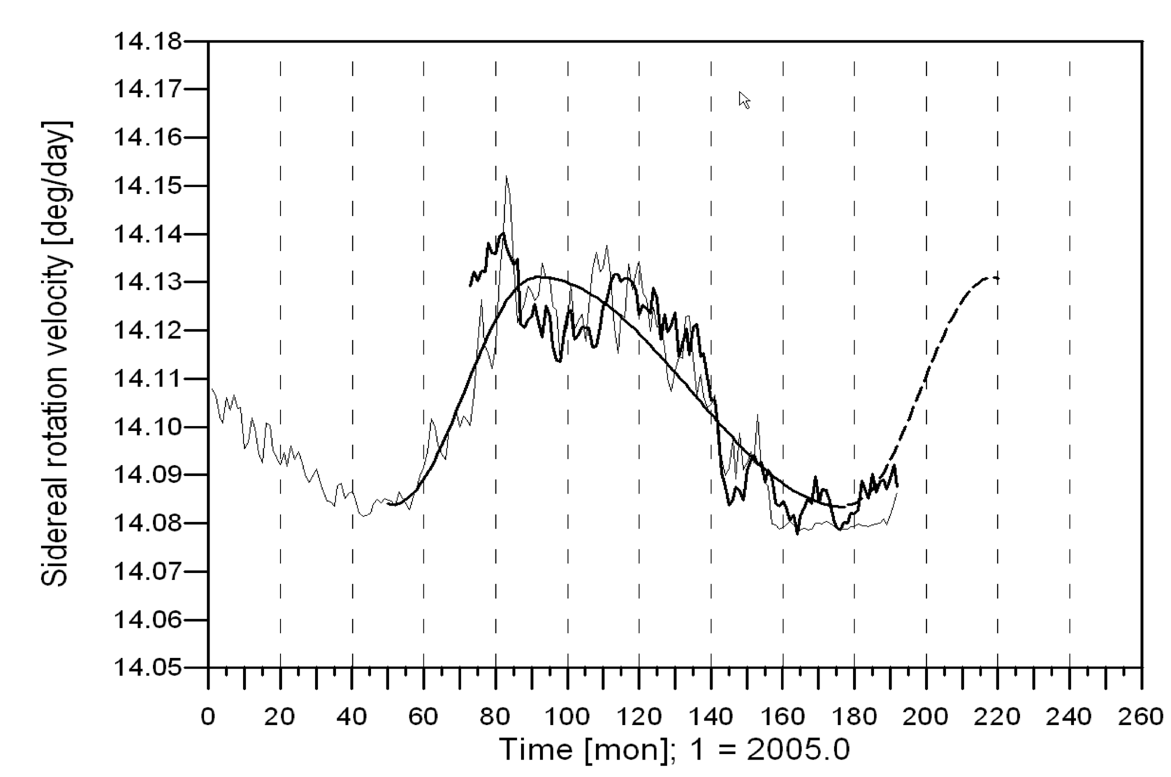

***Figure 2** - Graphs of monthly averages of CI (thin gray line), running mean of monthly averages of ω_n (thick black solid line) and model of solar activity cycle according to the sinusoidal approximation of evolution of the rotational speed of the solar corona (solid+dashed line).*

5. SUMMARY AND CONCLUSIONS

- the best correlation was found between the ω_n and the **CI** (**0.752**);

$$\omega = 14.08 + 0.0227\, CI$$

- according to constructed model of the solar cycle: minimum of the cycle 24 – **2009.2**, minimum of the cycle 25 – **2019.6**; maximum of the cycle 24 – **2012.4**, maximum of the cycle 25 – **2023.2**;
- we are aware that it is too early to definitively confirm the hypothesis. We would need a longer time series with the necessary resolution, i.e. at least about 0.05°/day.
- we do not know about any theoretical explanation for the relationship between the rate of corona rotation and the phase of the cycle of solar activity. If this hypothesis would be confirmed, its explanation will appear in the theory of the solar cycle;
- we cannot explain the difference between the behavior (correlation to level of solar activity) of the data files ωp and ωn.

Acknowledgments

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References

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