Variations in the rotational speed of the solar corona (2011–2022)

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Lorenc et al. (2012) – On rotation of the solar corona

Shahamatnia et al. (2016) – An evolutionary computation based algorithm for calculating solar differential rotation by automatic tracking of coronal bright points

Dorotovič et al (2018) – Automatic detection and tracking of coronal bright points in SDO/AIA images

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- **INPUT DATA for the current research:**

- monthly average values of $\boldsymbol{\omega}$ for the period of 2011 - 2018 published in Dorotovič and Rybanský (2019).

On Rotation of Some Solar Coronal Bright Features

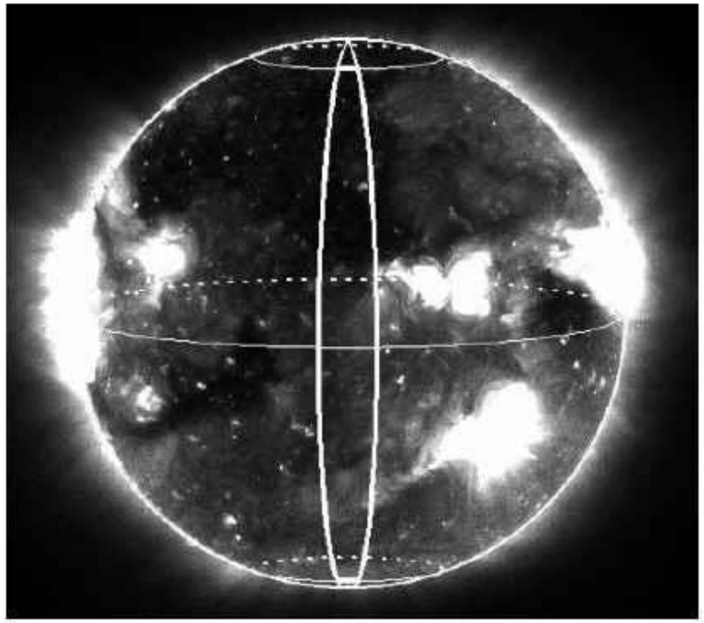


Figure 1. Solar corona on 30 August 2016 at 12:00:12.8 UT. The region of interest that we use for our investigation is marked by a *bold line*.

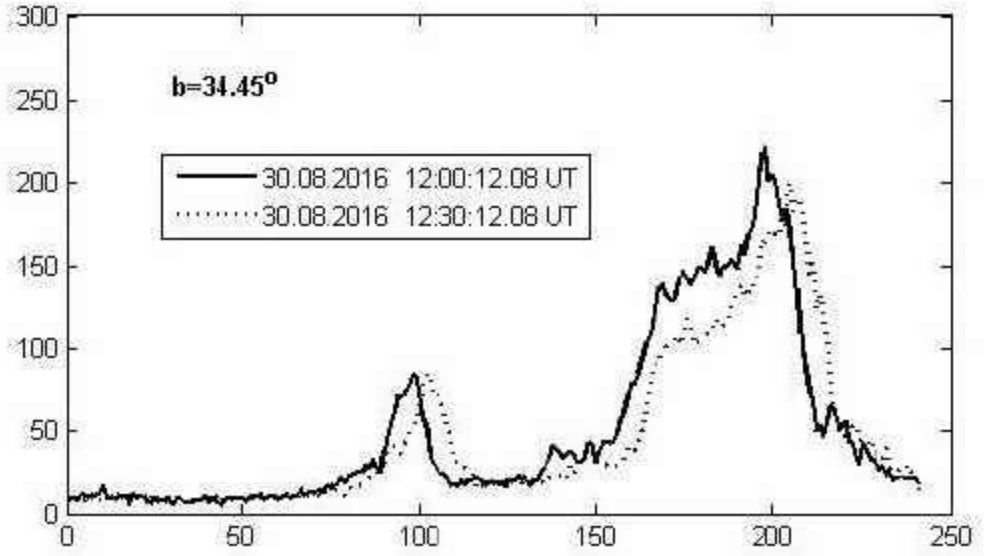


Figure 3. Evolution of intensities in two neighboring images from 30 August 2016 at the latitude of 34.45°.

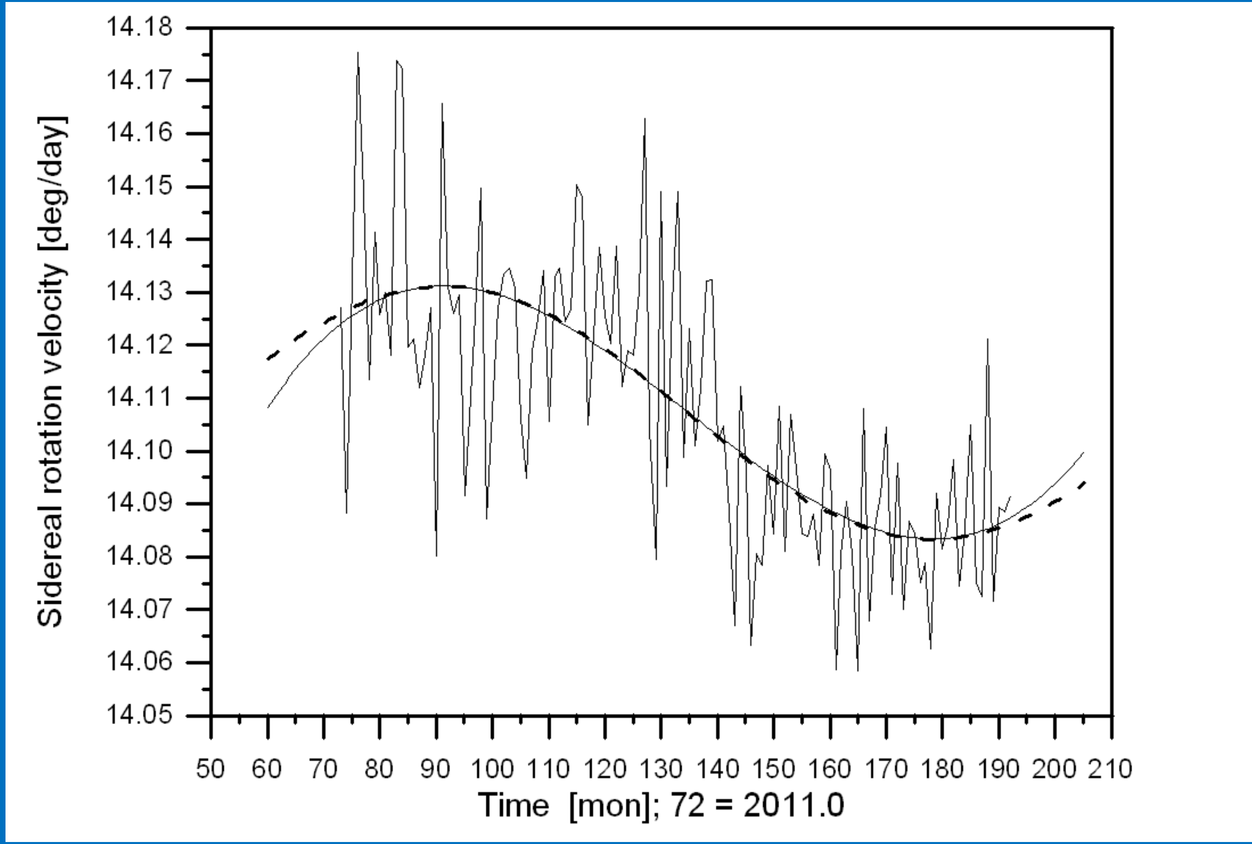
- We have added the data (**SDO/AIA 21.1 nm images**) for 2019 - 2022 → time series of **144 months**.

Method of data selection:

- 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 **±65°** in heliographic latitudes) of monthly averages of coronal rotational speed
- Dorotovič and Rybanský (2019);
- we used 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 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 where inside the above criteria limits].



- **RESULTS:**

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):

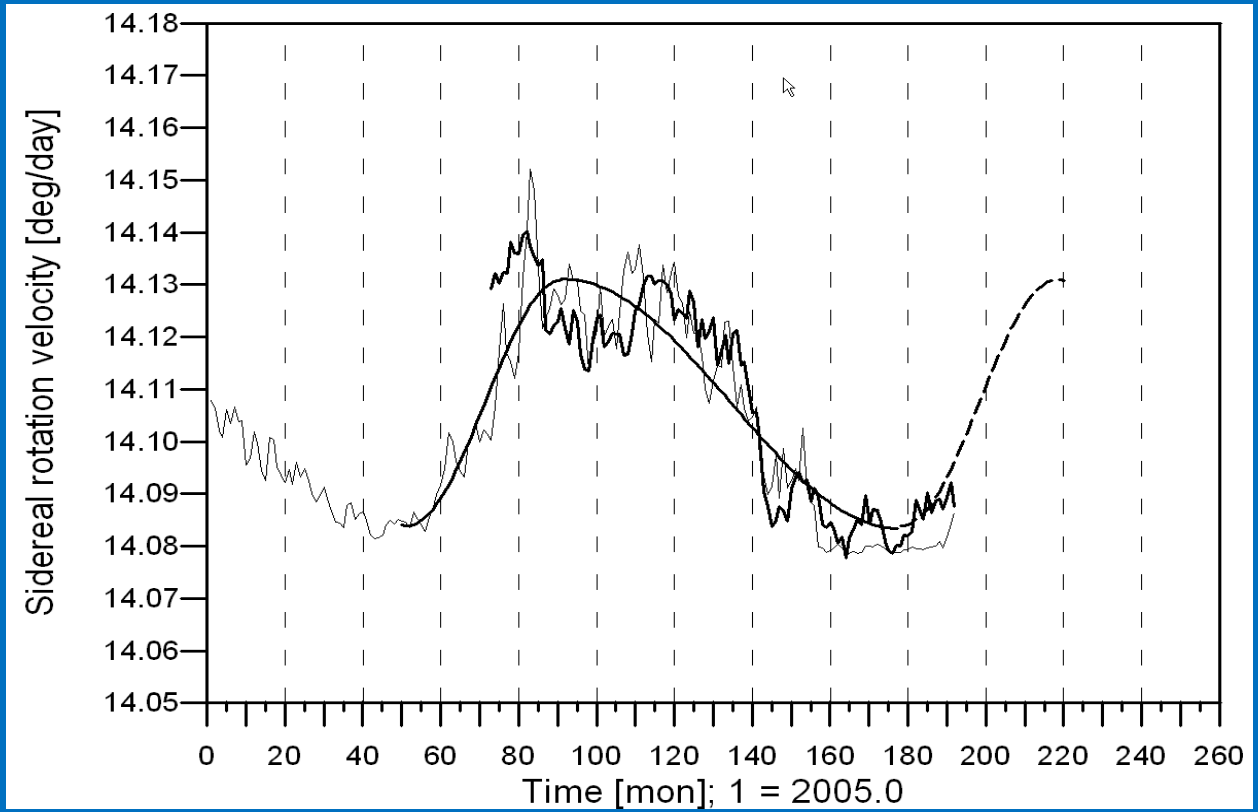
$$y = 14{,}1072 + 0{,}02388.\sin((t + 24).2\pi/173{,}8).$$

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 of: 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).

- **COMPARISON 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.



Graphs of monthly averages of ***CI*** *(thin gray line), running mean of monthly averages of* $\boldsymbol{\omega_n}$ *(thick black solid line) and model of solar activity cycle according to the rotational speed of the solar corona (solid+dashed line).*

- **SUMMARY AND CONCLUSIONS:**

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

$$\omega_n = 14.08 + 0.0227\ CI$$

- 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 did not investigated:
  - 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;
  - the reason of difference between the behavior (correlation to level of solar activity) of the data files ω_p and ω_n.

Acknowledgement:

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References:

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Lukáč, B. and Rybanský, M.: 2010, **263**, 43.
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Rybanský, M., Rušin, V., Minarovjech, M., Klocok, L., Cliver, E.W.: 2005, *J. Geophys. Res.,* **110,** A08106.