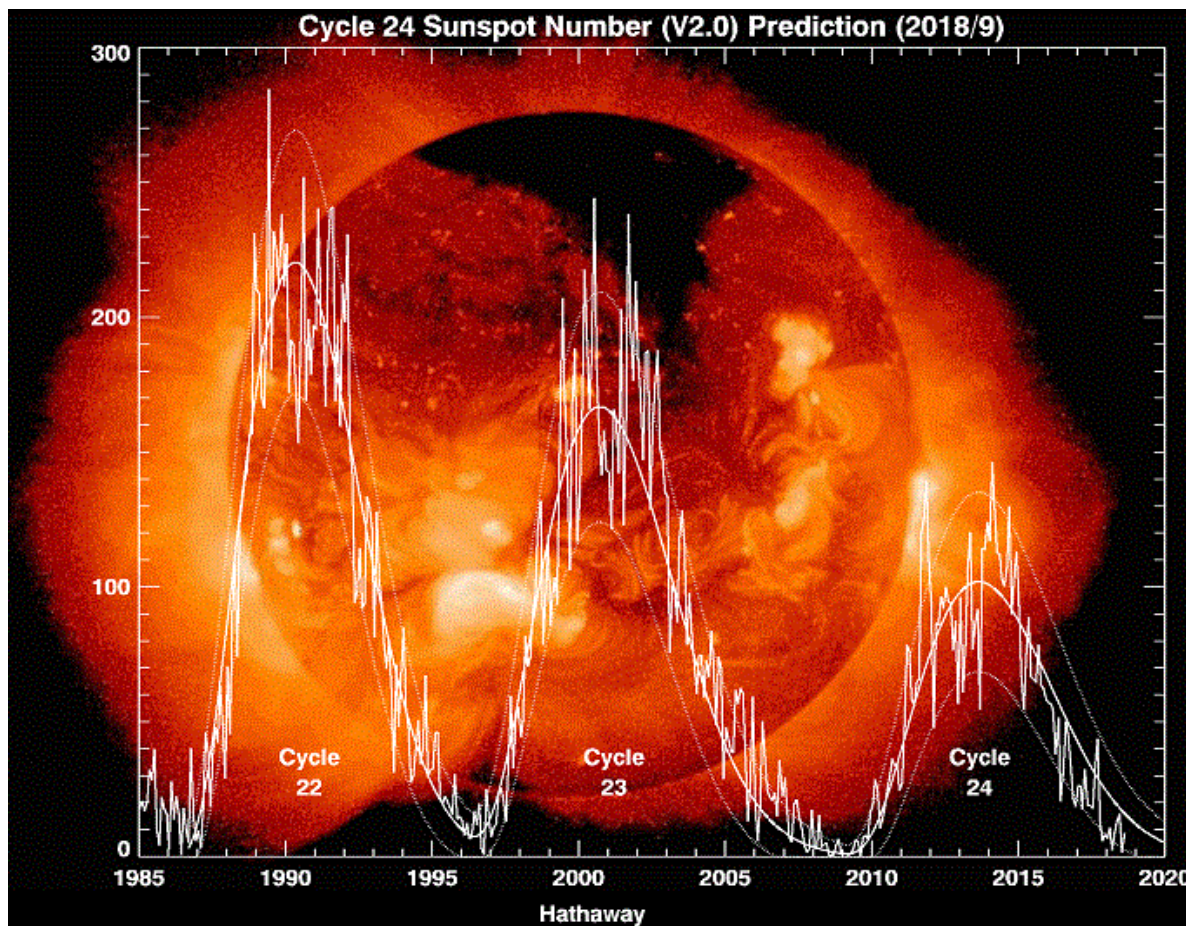


EVOLUTIONARY AND FLARE CHARACTERISTICS OF PROLONGED PHASES OF SOLAR MINIMUM



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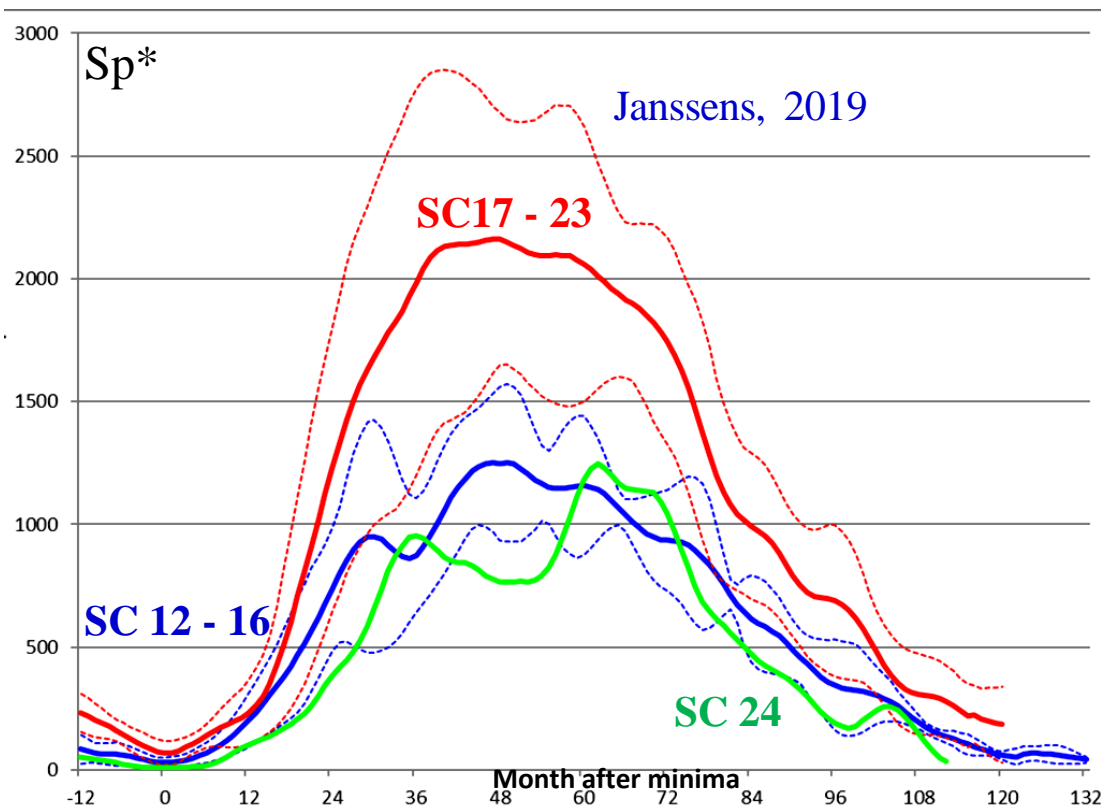
June 2019 – 10.4 years of SC 24 evolution



* The period of deep minimum of the current 24 SC ($W^* = 4.1$ in October 2018) – the first SC of the second epoch of the lowered SA.

* How long will the decay of the activity of the current solar cycle last and when will the moment of a minimum be felt?

1*. According to the scenario of cyclicity for reliable solar cycle, SC24, opened the second epoch of lowered SA, which will cover two-thirds of the XXI century. The main features of this period:



- a ban on high (strong) SCs and the indispensable implementation of basic observational rules, including the rules of Gnevyshev-Ol', according to which the next 25 SC should be of an average size.

The current 24th SA cycle, which began in January 2009, has given us a lot of new information about solar activity since the beginning of the space age.

After the 23rd SA cycle, the transitional period of the restructuring of the generation of magnetic fields in the solar convective zone passed and entered the stationary mode of alternating low and medium cycles similar to the 12–16 cycle time interval.

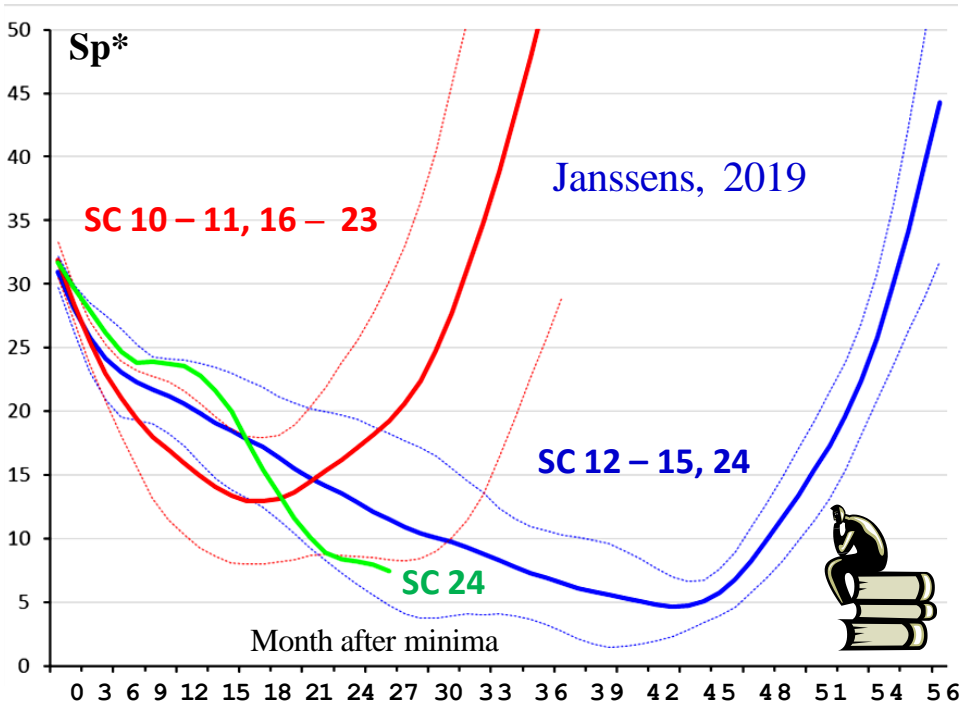
– By phase of the minimum here is understood the interval of the time, when the smoothed values of the relative numbers of sunspots remain within the limits $W^* \leq 30$.

– In this work we will distinguish the temporary sections of the phase of the minimum from the beginning of cycle to the point $W^*=30$ – **the phase of the minimum of the ascending SC branch**, and the subsequent phase of the minimum after the maximum of cycle – **the phase of the minimum of the descending SC branch**.

The table shows the main evolutionary characteristics of long-duration solar cycles. Solar cycles with extended minimum phases are highlighted in blue and red.

N	T_0	W^*_m	T_M	T_e	W^*_M	$T_Y \uparrow$	$T_Y \downarrow$	$T_{SC Y}$	$T1_m$	$T2_m$	Sp_{less}
10	1855XII	3.2	1860 II	1867 II	97.9	4.17	7.25	11.42	38 ^m	34 ^m	402
11	1867 III	5.2	1870 VIII	1878 XI	140.5	3.42	8.50	11.92	2.83	5.41	1025
12	1878XII	2.2	1883 XII	1890II	74.6	5.0	6.3	11.3	5.42	4.92	732
13	1890III	5.0	1894 I	1901III	87.9	4.5	8.2	12.1	4.92	6.42	937
14	1902 I	2.6	1906 II	1913VII	64.2	4.1	7.6	11.7	6.42	4.92	1045
20	1964 X	9.6	1968 XI	1976 VI	110.6	4.1	7.8	11.9	3.17	5.75	269
23	1996 VI	8.0	2000 IV	2008 XII	120.7	3.8	8.9	12.7	3.33	5.67	821
24	2009 I	1.7	2014 IV	2020V-IX	81.9	5.3	5.9	12,3	5.67	4.92	

So ^we will talk about a special class of longer SCs. The comparison of evolutionary changes of different SCs in the phases of the minimum made it possible to isolate two groups SCs on the rate of the decrease with the characteristic times (19+10/-3) also (45+0/-5) months.



The first group includes SCs whose duration exceeds ≥ 11.25 years ($\geq 135^m$). These are all the SCs of the XIX century and SCs 20 and 23, which were realized in the XX and XXI centuries. According to belonging to the CA epochs, they are distributed as follows:

- three of them constitute the initial SCs of the first epoch of lowered CA (SCs 12-14);
- two (out of three) - SCs of transition periods (SC11 and SC23), both carried out the restructuring of the total magnetic field to the epochs of lowered SA;
- and two SC of the average epoch of increased SA (SC 10 and 20).

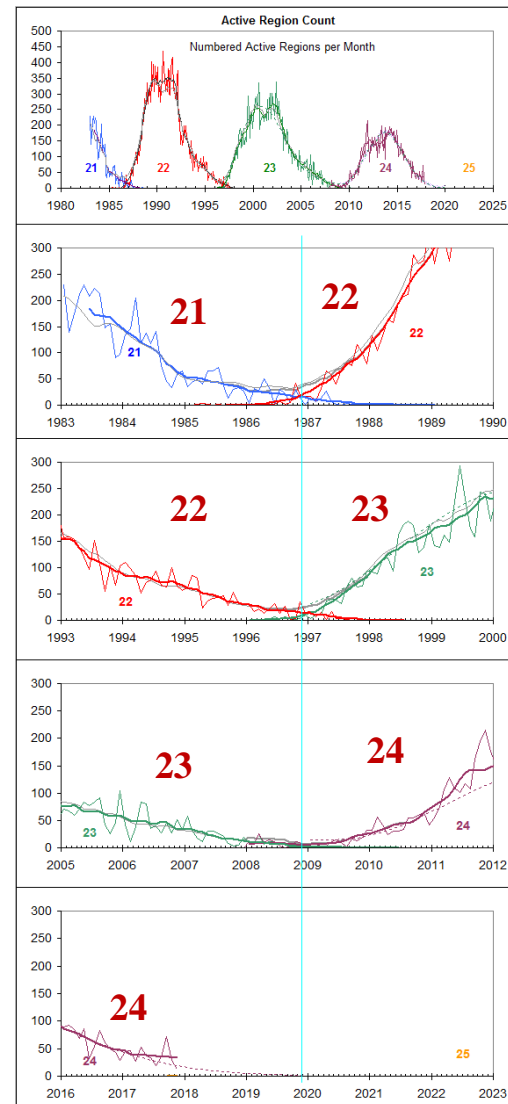
The second group includes SC lasting ≤ 10.5 years ($\leq 125^m$), which includes:

- all high (SC 18, 19, 21, 22) SC the epochs of increased SA;
- transitional SC 17 from the epoch of lowered to increased SA.

The main feature of SC20 and SC10 of the epochs of increased SA, falling into the first group, is the prolonged the descend phase to the beginning of the phase of minimum and the short minimum phase (19 and 20 months). The relatively short duration of interval of the phase of minimum (19–23^m) is a characteristic feature of all SCs the epochs of increased SA. That is, even for SCs of a long duration the epochs of increased SA, the rule of the short phase of the minimum for the fall branch is preserved. Therefore, in this talk, we will not affect the SCs of epochs of increased SA.

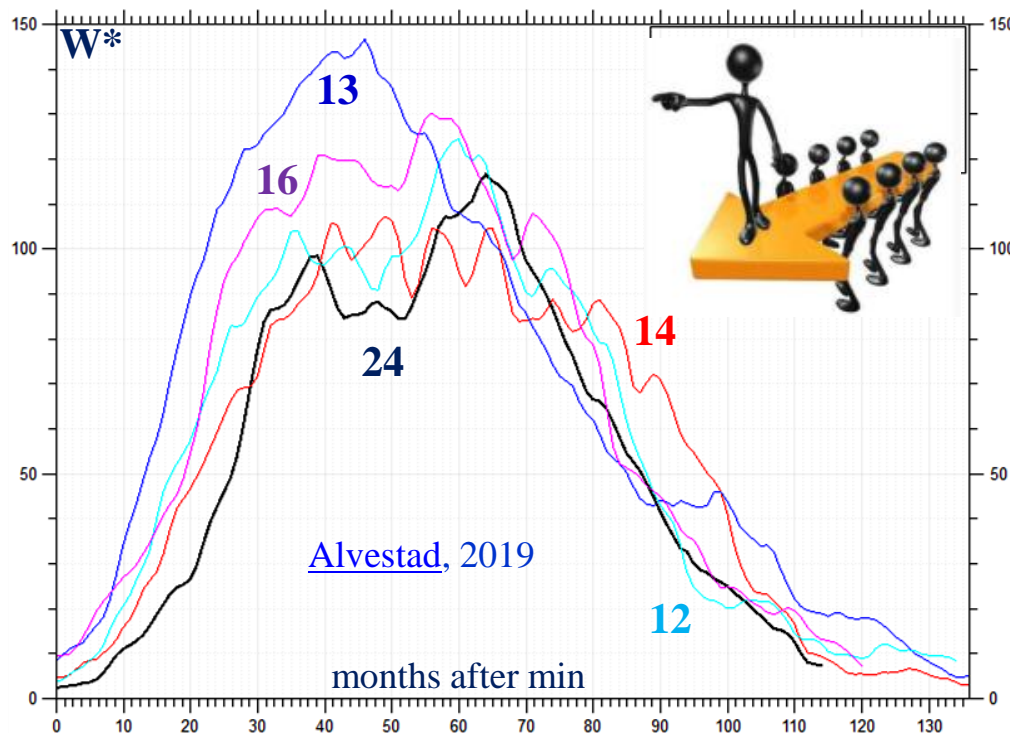
But for the transitional solar cycles to epochs of lowered SA, as well as SCs of epochs of lowered SA, which belong to SCs of long duration precisely due to the prolonged phase of the minimum for the descend branch. The average interval of the phase of minimum for such SCs is 41–47 months, however, SC 13th has become extremely prolonged – 57 months

Minima 21 – 24 CH



3*. After 10 the years of evolution SC24 it is important to reveal differences in its characteristics with SCs of the first epoch lowered SA. The motion of its development shows that since April 2016 the phase of the minimum realizes ($W^* \leq 30$). After the first peak in November 2011 after small, but prolonged (15 month) the decrease in the Wolf numbers, SC 24 became confidently grow and by April 2014 it reached its maximum ($W^* = 81.9$). **These special features:**

– **the first special feature** lies in the fact that not in one SC of the first epoch of lowered SA (and even for the entire totality of reliable SCs) the first peak was not manifested so clearly and with such difference in the peak values ($\Delta W^* \sim 15$), and taking into account the decrease of W^* after the first peak, the intermediate section of rise branch engage the interval $\Delta W^* \sim 30$;



– **the second feature** of the SC 24 became the record duration of the ascending branch, which is the largest and for the first epoch of low solar activity and for the entire reliable series – 5.32 year.

– **the third special feature** became the smallest quantity of high ($Sp \geq 1000$ mvh), very large ($Sp \geq 1500$ mvh) and gigantic ($Sp \geq 2000$ mvh) the sunspot groups not only among all SCs of the Space Age, but also all SCs of the first epoch lowered SA. By May 2019 on the Sun appeared only 16 the large sunspot groups, of them 5 very large and one gigantic – $Sp \geq 2000$ mvh (16/5/1), whereas into the SC 12 of such sunspot groups it was 32/11/0, in 13 SCs – 35/13/4, in 14 SC – 20/11/4, in 15 SC – 34/13/3 and, in 16 SC – 49/15/3;

– the smallest lifetime of the sunspot groups became **the fourth special feature**, moreover current SC became leader in a quantity of sunspot groups, that *live one day only*. The average number of sunspots in a groups, the average size of a single group, as well as the average number of recorded spots and groups are the smallest among all SCs of the Space Age [Otkidychev and Skorbezh, 2013];

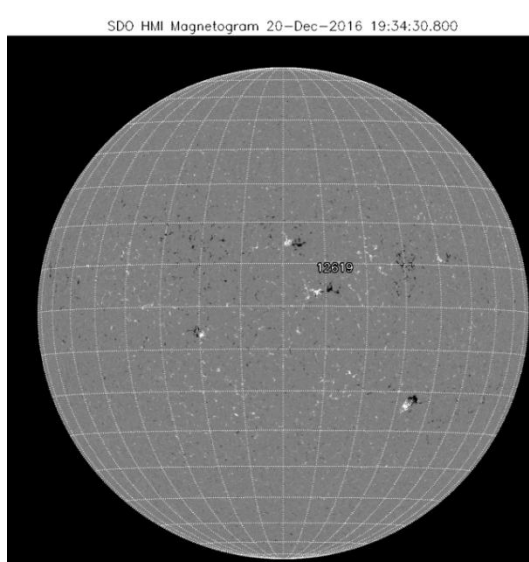
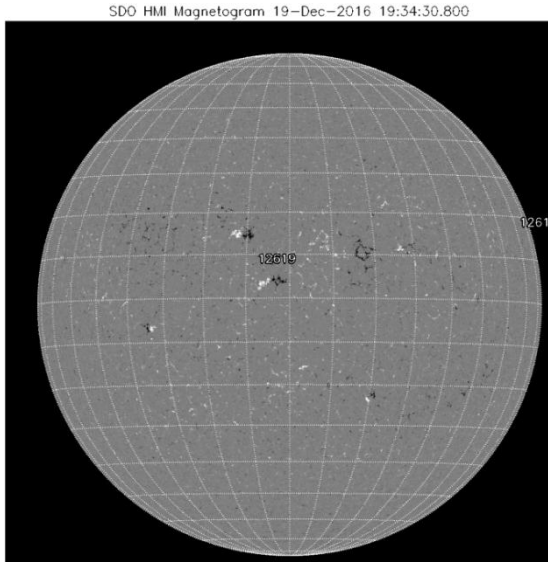
SC	B	S	G	Total
12	32	11		43
13	35	13	4	52
14	20	11	4	35
15	34	13	3	50
16	49	15	3	67

B – >1000 mvh; S – >1500 mvh; G – >2000 mvh

1*. SC25: first active regions

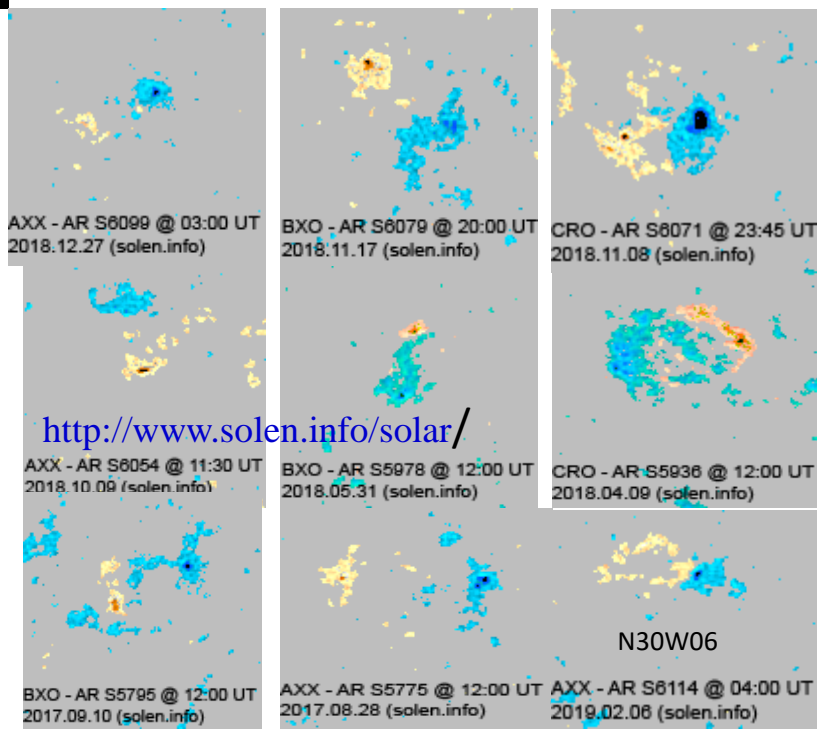
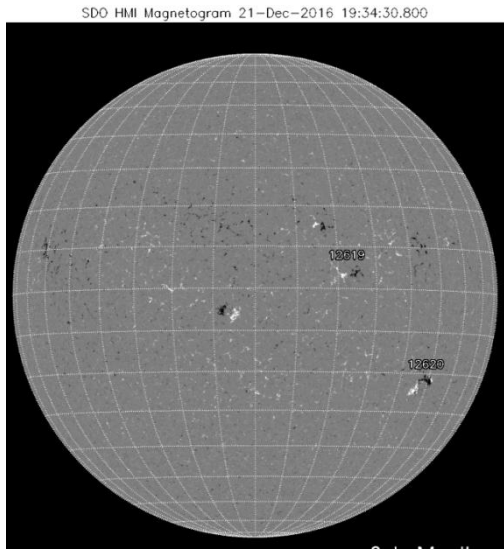
AR of SC25 according to SDO observations (**29** on June, 1, $\phi \leq 30^\circ$)

While smaller sunspots with the correct polarity of cycle 25 regions (with reversed polarity to SC24) have been observed at high latitude locations as early as 2016..



<https://www.solarmonitor.org/>

On December 19, 2016, the first bipolar structure of the SC25 appeared, which already grew 20.12 into the sunspot group AR12620 (S23W37 L305, Sp=50/5, $\Delta t=3^c$).



<http://www.solen.info/solar/>

SUMMARY

* Now the Sun has been spotless for 88 days so far this year – more than half the time. To find a similar situation, it have to go back to 2009 when the Sun was experiencing the deepest solar minimum in a century. Solar minimum has returned, bringing extra cosmic rays, long-lasting coronal holes in the Sun's atmosphere, and strange pink auroras.

*For solar cycles the epochs of increased solar activity, the duration of cycles is ensured due to the prolonged decline phase to the point beginning of the minimum phase;

* For solar cycles of epochs of lowered solar activity, the duration of cycles is ensured due to the prolonged half-phase minimum of the current cycle.

* The decline curve of the phase of minimum of the SC24 is carried out within the boundaries of the development of the SC characteristic of the epoch of lowered SA. This gives reason to believe that the point of minimum of the current cycle will take place no earlier than mid-2020 and no later than the beginning of 2021.

And here I put the point,
The trumpet blows release –
And the point grinned
And became a comma!

Yu. Kim

И вот поставил точку,
Труба трубит отбой –
А точка усмехнулась
И стала запятой!

Ю. Ким

THANKS FOR ATTENTION!

