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Solar flare excess in 2024

E.S. Isaeva[1,*], S.A. Yazev[1,2]

[1]*Irkutsk State University, 1 Karl Marx Str., Irkutsk, 664003 Russia*
[2]*Institite of Solar-Terrestrial Physics, Siberian Division, Russian Academy of Sciences, 126A Lermontov Str., Irkutsk, 664033 Russia*

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An analysis of the active areas that produced multiple flares in May 2024 has been performed. A comparison has been made with similar flares that occurred in November 2003.

Keywords: Sun, flare, solar activity, sunspot

1 Introduction

In May 2024, there was a surge in solar flare productivity, accompanied by a number of CME emissions. One of the consequences was the strongest magnetic storm in the last two decades on May 10–12, which reached a G5 score (Yasyukevich et al. 2025). Four active regions (AR) produced 25 X-flashes within 39 days. The total flare index for AR 13663 and 13664 amounted to 12% of the integral index in cycle 25, starting from January 2020 to June 2024. The paper is devoted to a preliminary analysis of this unusual flare-up, which nevertheless managed to find an analogue.

2 The beginning of the 25th cycle and its development

It is generally assumed that cycle 25 began in January 2020, but the first spots of the new cycle began to appear in mid-2019, that is, during the recession phase of the 24th cycle. In general, the cycle started out in a fairly standard way, with the number of flares increasing consistently from year to year. During the entire first year of the cycle (2020), 88 flare events occurred, of which only two flares were classified as X-ray class M (the rest were C; Class A and B flares were not taken into account). No Class X flares have been reported. In 2021, flare activity began to increase, the total number of flares increased fivefold, and two X-ray class X flares (X1.0 and X1.5) were observed.

*Email: ele3471@yandex.ru

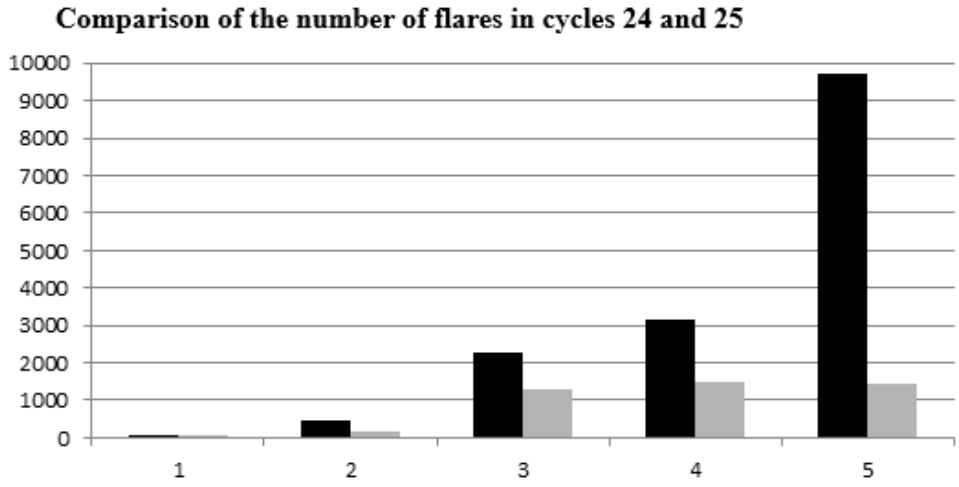


Figure 1 The number of flares of all points in the 24th (gray) and 25th (black) cycles of solar activity. 1, 2009/2020; 2, 2010/2021; 3, 2011/2022; 4, 2012/2023; 5, 2013/2024.

In 2022, there were already 2,297 flares of all classes, including 7 Class X flares (https://xras.ru). In 2023, flare activity continued to increase, with the total number of flares reaching 3,170. The number of strong flares has also increased (Fig. 1). Flashes of X-ray classes M5.0–M8.0 are noted (flares of a class exceeding M5.0 are considered strong). The power of the strongest flares has also increased.

From the beginning of 2020 to the end of 2023, 6,010 solar flares occurred, including 566 Class M and 22 Class X flares. This significantly exceeded the figures of the previous 24 cycles for the same time interval from the start of the cycle in January 2009 (a total of 1,473, 188 class M and 29 class X). Figure 1 shows these data, to which the data for the fifth year of the cycle is added. It can be seen that the difference in the flash productivity of cycles in 2024 and in 2013 has worsened. Let us take a closer look at the flares in 2024. Taking into account the powerful surge in spot activity in June–July 2023, it can be assumed that the cycle has reached the maximum stage by this time. Accordingly, the intensity of flares generation has increased. The total number of flares of different classes from January 1 to December 31, 2024 was 9728 events. At the same time, the three active regions (hereinafter AR) observed in May 2024 demonstrated extremely high flare productivity, with more than 100 flares per group of spots. These are AR 13576 (123 flares), AR 13615 (157 flares) and AR 13664 (101 flares). At the same time, AR 13576 (the maximum area of the spot group is 660 millionths of a hemisphere, hereinafter MDP) produced two very strong flares – M9.0 and X2.5, respectively, on February 11 and 16, 2024. On October 3, 2024, one of the most powerful flares occurred, starting on September 6, 2017, a flare of class X9.0.

3 Flare activity in May 2024

In May 2024, quite unexpected events were observed on the Sun – there were numerous flares of the highest X-ray class, which occurred in two active regions – 13663 and 13664. Table 1 shows data on strong flares.

Table 1 Strong flares in May 2024.

X-flare number	Flare class	Flare date	Number of flare AR	Max area AR	Hemisphere and longitude	Carrington turnover number
	M9.53	01.05.2024	3654	550	S 134	2283
29	X1.6	03.05.2024	3663	600	N 36	2283
	M9.1	04.05.2024	3663	600	N 36	2283
	M9.0	05.05.2024	3663	600	N 36	2283
	M8.4	05.05.2024	3663	600	N 36	2283
30	X1.32	05.05.2024	3663	600	N 36	2283
	M7.4	05.05.2024	3663	600	N 36	2283
31	X1.2	05.05.2024	3663	600	N 36	2283
32	X4.52	06.05.2024	3663	600	N 37	2283
	M5.1	07.05.2024	3663	600	N 37	2283
	M8.2	07.05.2024	3663	600	N 37	2283
33	X1.0	08.05.2024	3663	600	N 37	2283
34	X1.0	08.05.2024	3664	2400	S 354	2284
35	X1.0	08.05.2024	3664	2400	S 354	2284
36	X1.0	08.05.2024	3664	2400	S 354	2284
37	X2.2	09.05.2024	3664	2400	S 354	2284
38	X1.1	09.05.2024	3664	2400	S 354	2284
39	X3.98	10.05.2024	3664	2400	S 354	2284
	M5.9	10.05.2024	3664	2400	S 354	2284
40	X5.89	11.05.2024	3664	2400	S 354	2284
41	X1.54	11.05.2024	3664	2400	S 354	2284
	M8.8	11.05.2024	3664	2400	S 354	2284
42	X1.02	12.05.2024	3664	2400	S 354	2284
	M6.6	13.05.2024	3664	2400	S 354	2284
43	X1.72	14.05.2024	3664	2400	S 354	2284
44	X1.2	14.05.2024	3664	2400	S 354	2284
45	X8.79	14.05.2024	3664	2400	S 354	2284
46	X3.48	15.05.2024	3664	2400	S 354	2284
47	X2.99	15.05.2024	3685	420	S 153	2284
	M7.2	17.05.2024	3685	420	S 153	2284
48	X2.9	27.05.2024	3697	420	SE limb	2285
49	X1.45	29.05.2024	3697	420	S 353	2285
50	X1.1	31.05.2024	3697	420	S 353	2285
51	X1.43	01.06.2024	3697	420	S 353	2285
52	X1.03	01.06.2024	3697	420	S 348	2285
	M9.75	08.06.2024	3697	420	S 348	2285
53	X1.55	10.06.2024	3697	420	SW limb	2285
	M9.5	10.06.2024	3697	420	SW limb	2285

Note: V_r and distance refs: 1, Smith et al. (2010); 2, Zhong et al. (2014); 3, Boubert et al. (2018); 4, Brown et al. (2014); 5, Alam et al. (2015); 6, Brown et al. (2009).

It can be noted that during the period under review, the number of Class M flares (13 events from May 1 to June 10) turned out to be less than the number of X-flares (24 events). Such an inversion of the flare power distribution is an atypical situation. Let us consider the most flare-active areas of this period. AR 13663 was observed in the northern hemisphere of the Sun from May 1 to May 11 until sunset beyond the western limb. The group of spots reached its maximum region (600 MPH) on May 7. In this AR, 80 flares of all classes occurred during their stay in the visible hemisphere of the Sun, including, as can be seen from Table 1, 11 strong flares, including 5 Class X flares. It should be noted that the flare activity of AR 13663 continued after its sunset over the western limb of the Sun on May 12.

It is possible that strong flares have also occurred here beyond the limb, which have not been observed from Earth. AR 13664 was located in the southern hemisphere of the Sun in the period from May 2 to May 14, 2024, in fact, the entire growth process of the group of spots took place before the eyes of terrestrial observers. The group of spots reached its maximum region (2,400 MPH) on May 11, already near the western limb. Note that the peak area of this group of spots is one of the largest in the current cycle. There were 101 flares in this group of spots in the visible hemisphere, including 16 strong ones, including 13 Class X flares.

It is important to note that at the same Carrington coordinates, during the next passage through the disk at 2285 Carrington rotation, there was a large group of spots 13697, whose flare activity in June also attracted attention. This area produced the first X-class outbreak while still in eastern limbo.

A total of 119 flares were registered here, including 5 X-ray class X. Since AR 13697 was located at the site of AR 13664 and can be considered as a manifestation of the same magnetic complex, it seems that summing up their flash activity during two passes through the disk can be considered justified.

At that time, the total number of flares in this complex of activity was 220, including 18 X-class ones. This is one third of the total number of X-flares observed during the first 4.5 years of the current 25th solar activity cycle. There is no doubt (among the authors) that the flares did not stop even during the presence of the 13664–13897 complex on the far side of the Sun, which means that the number of X-flares generated by this complex is actually even greater.

4 Comparison of flash excesses in 2003 and 2024

AR 10486, which was observed from October 23 to November 11, 2003, (with a maximum area of 2610 mis) and generated 17 strong flares, including 8 Class X, can be called an analog of AR 13664 (Table 2) (https://www.spaceweatherlive.com/).

Table 2 Comparison of the number of flares in groups 10486 and 13664.

	C	M	X
10486	10	23	9
13664	36	52	13

However, it should be noted that, although AR 13664 surpasses AR 10486 in the number of X-flares, it is inferior in their power: AR 10486 has the strongest

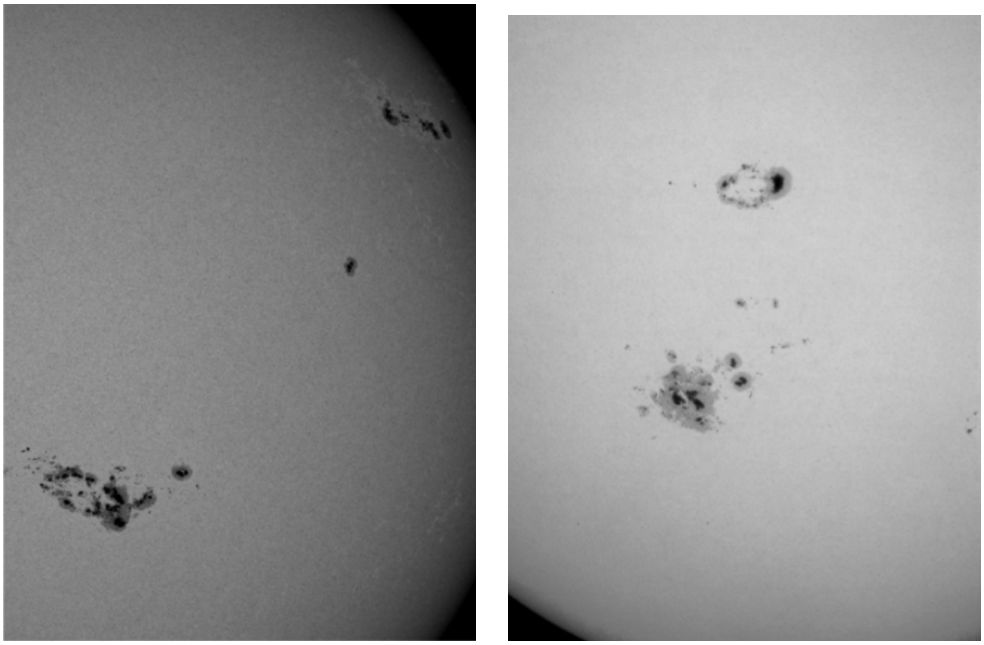


Figure 2 Left, AR 13664 (down) and 13663; right, AR 10486 (down) and 10488.

flares of classes X40+, X24+, X14 and X12 in the entire history of observations, while estimates of the most powerful of them are conditional, since they are indirect (observed sensor overload).

Note the phenomenological similarity of the events of May 2024 and October–November 2003 (Fig. 2). In both cases, at least two large groups of spots with a large maximum area (one of the two exceeding 2,400 MIS) were simultaneously observed, while there were a small number of other (small) groups of spots on the disk. In both cases, flare-active groups (in 2024, 13663 and 13664; in 2003, 10486 and 10488) were located in different (northern and southern) hemispheres) in both cases, the northern group of spots was west of the southern one, in both cases flare activity prevailed in the southern, larger group of spots, in both cases a small group of spots was located between the flare AR near the equator.

It can be pointed out that in both cases, a similar global magnetic configuration was realized on the Sun in at least one hemisphere, which (probably) led to similar manifestations of flare activity. In both cases, flare-active AR belonged to activity complexes (Yazev, 2015); here, for three consecutive revolutions, spot activity was observed at the same Carrington coordinates.

In addition to the analogies, there are differences. The flash excess of 2003 occurred during the recession phase, after the peak of the 23rd cycle. In contrast to this situation, after the flare in May 2024, a powerful surge in spot activity was observed in August 2024, which largely determined the epoch of the 25th cycle maximum. As a result, it can be stated that, unlike the excess of 2003, the excess of 2024 occurred not in the recession phase, but in the maximum phase of the cycle.

Conclusions

Two large groups of spots 13663 and 13664, observed simultaneously in May 2024, demonstrated extremely high levels of flare activity, generating X-ray class X flares one after the other. By the number of X-flares (13 events) AR 13664 has been in second place since 1976 for the entire period of continuous observations in the X-ray range (AR 5395, observed in March 1989, is in the first place). If we add here 5 X-events in AR 13697, which developed in the next revolution at the same coordinates as AR 13664, plus an unknown number of flares that may have occurred on the far side of the Sun, the features of this AR become even more impressive. Attention should also be paid to the fact that the average flare power here was also abnormal – the number of class M flares in AR 13644 exceeded the number of class C flares (Table 2), which, as a rule, is not observed. This means that extremely high reserves of free magnetic energy were concentrated in the active region with a complex field topology (AR – beta-gamma-delta type), which contributed to the frequent generation of powerful events. The authors suggest that for almost a month there was a kind of "channel" in the thickness of the convective zone, through which new portions of the magnetic flux consistently surfaced, providing prolonged flare activity. Probably, something similar was observed in October–November 2003. Such channels may be characteristic of so-called activity complexes (Yazev et al., 2021). Nevertheless, there are many solar activity complexes (76 have been identified in cycle 25 until the end of 2024), and the appearance of giant active areas with high flare productivity (such as AR 13664) is infrequent. The study of such phenomena will continue.

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