This paper presents a statistical analysis of Soft X-ray (SXR) flares during the period January 1976 to December 2007 covering solar cycles (SCs) 21, 22, and 23. We have analysed north-south (N-S) and east-west (E-W) asymmetry of SXR at low (≤40°), high (≥50°) and total latitudes and center meridian distances (CMDs) respectively. We have also presented the N-S and E-W asymmetry of different intensity classes (B, C, M, and X) during the period of investigation. A slight southern and eastern excess is found after analysis during SC 21, 22, and 23. We found that the annual N-S and E-W hemispheric asymmetry at low latitudes and CMDs is the same as total latitudes and CMDs respectively. E-W asymmetry is different at low and high CMDs. Our statistical result shows that N-S asymmetry is statistically more significant than E-W asymmetry. Total SXR flare activity during SC 23 is high compared to SC 21 and 22. The B class flare activity is higher for SC 23 whereas as C, M and X class activities are higher for SC 21. We have also analysed the flare evolution parameters, i.e. duration, rise time, decay time and event asymmetry for total SXR as well as for different classes for last three SCs. The duration, rise time and decay time increase with increasing intensity class. On analysing event asymmetry indices, we found more positive values during SC 21 (∼64.86%) and SC 22 (∼54.31%), but for SC 23 we have more negative values (∼48.08%). Our study shows that during SC 23 we have more SXR flare events having shorter decay time as compared to SC 21 and SC 22.

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**Keywords:** Sun: activity; Sun: Soft X-ray flares

1. **INTRODUCTION**

Solar activity phenomena are not uniformly distributed between solar hemispheres. The north-south (N-S) and east-west (E-W) distribution and asymmetries of several manifestations of solar activities have been studied earlier by various authors (Bell, 1962; Garcia, 1990; Howard, 1974; Hensen and Hensen, 1975; Joshi and Pant, 2005; Li et al., 1998; Li et al., 2003; Oliver and Ballester, 1994; Reid, 1968; Roy, 1977; Swinson et al., 1986; Temmer et al., 2001; Temmer et al., 2006; Verma, 1987; Verma, 2000). Bell (1962) found a long-term asymmetry in the sunspot area data for cycles 8 through 18. Garcia (1990) studied the N-S asymmetry of soft X-ray (SXR) flares (class ≥ M1) during the solar cycle (SC) 20 and 21 and found the preponderance of flares occur in the north in the early part of the cycle and move south as the cycle progresses. Li et al. (1998) studied the N-S asymmetry of SXR flare (M ≥ 1) during the maximum period of SC 22 and investigated that during this cycle asymmetry was found to be in favor of the southern
hemisphere. Li et al. (2003) studied the N-S asymmetry of the solar active prominence (SAP) at low ($\leq 40^\circ$) and high ($\geq 50^\circ$) latitudes from 1957-1998 and found a little connection between asymmetry at low and high latitudes. Study of long term behavior of different flare activities as well as N-S asymmetry and distribution gives important clue to the dynamics of SC and the underlying dynamo process. However, there are relatively few studies addressing the longitudinal (E-W) distribution of solar activity (Heras et al., 1990; Letfus, 1960; Letfus and Růžičková-Topolová, 1980). Letfus and Růžičková-Topolová (1980) have analysed the E-W asymmetries of Hα flares from 1959 to 1976 and their conclusion was that they were statistically significant, for certain periods of time. Verma (2000) examined latitudinal as well as longitudinal distribution and asymmetry of SAP for the period 1975-1988 and found that the SAP events are most prolific in the 11-20° and 81-90° latitude and center meridian distance (CMD) respectively. Joshi and Pant (2005) also analysed the data of solar Hα flares during solar cycle 23 and investigated their N-S and E-W distribution and asymmetry. Statistical investigations on temporal aspects of Hα and SXR solar flares have been investigated in various studies in past (Barlas and Altas, 1992; Culhane and Phillips, 1970; Drake, 1971; Pearce and Harrison, 1988; Reid, 1968; Temmer et al., 2001; Veronig et al., 2002). Temmer et al. (2001) statistically analysed the temporal behavior of Hα flares as well as the spatial distribution on the solar disk during the period January 1975 to December 1999. Veronig et al. (2002) presented a statistical analysis of SXR flare (temporal properties i.e., duration, rise and decay time) during the period 1976-2000.

In this paper, we have investigated the N-S and E-W distribution and asymmetry of SXR flare events separately at low and high latitudes as well as that of different SXR classes (B, C, M and X) for the last three solar cycles i.e., 21, 22 and 23. We have also investigated the temporal aspects and event asymmetry for the same period. In Section 2 data set is described. Statistical analysis is presented in Section 3 and Section 4 contains a brief description of distribution and N-S asymmetry (Section 4.1), E-W asymmetry (section 4.2), temporal aspects and event asymmetry (Section 4.3) of SXR flares. In Section 5 discussion and conclusions have been presented.

2. DATA

For the present analysis data for the time span of 01 January 1976 to 31 December 2007 have been downloaded from national geophysical data center’s (NGDC’s) anonymous ftp server: 
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/XRAY_FLARES. During this period the occurrence of 63594 SXR flares are reported. To perform the study, we have split the data in three parts corresponding to the period of SC 21 (January 1976 to December 1985) with 3652 days data, cycle 22 (January 1986 to December 1995) with 3652 days data and cycle 23 (January 1996 to December 2007) with 4383 days data. In NGDC’s data set there are a number of events for which heliographic latitude and CMD are not given. Also in the data set there are events which lie on zero latitude and CMD. After rejecting these events we get a total of 34502 events for N-S and 34272 for E-W distribution and asymmetry analyses. In our data base we have 99.35% of total SXR flare events at low latitudes whereas only 0.14% SXR events at high latitudes. We have 51.80%, 36.09% of total SXR events at low and high CMD respectively. The original data set are listed in Table 1 for SC 21, 22, and 23. The present analysis also deals with temporal aspects of SXR flare events. Events for which the listed times are marked as inaccurate have been rejected. After rejecting these we get a total of 55431 events for temporal parameter analysis and event asymmetry analysis.
Table 1 lists the total number of SXR flares reported for the period under investigation, subdivided into the different SXR flares classes (B, C, M, and X). Since A class events are few in number, we have combined this class events into B class. It can be seen from this table that the bulk of flares belongs to class C for all the three SCs whereas class X event are less in numbers. The percentage of C, M, and X class events during SC 21 is large as compared to SC 22, and 23. During SC 23 the number of M and X class event are small as compared to SC 21 and 22. SC 23 produced maximum number of B class (36.56%) and total SXR events. For the three SCs we list the average monthly rate of SXR flares for total as well as different class data in Table 2. On the one hand, SC 21 reveals a conspicuously higher rate of C, M and X class events whereas SC 23 shows higher rate of B class events. The flare activity in terms of B and C class events during SC 23 is high compared to SC 22 but C class activity is low compared to SC 21 whereas in terms of M and X class events it is low in comparison to SC 21 and 22. In terms of total SXR flare events SC 23 depicts higher flare activity than SC 21 and SC 22. Fig. 1 represents the plot for total number as well as for different importance classes of flares. It can be clearly seen that the variation of class B is different as compared to other classes and the total SXR.

3. STATISTICAL METHODS

We have calculated the north-south ($A_{NS}$) and east-west ($A_{EW}$) asymmetry indices by using the formula

$$A_{NS} = \frac{N - S}{N + S} \text{ and } A_{EW} = \frac{E - W}{E + W} \text{ respectively.}$$

(1)

Here $N$ and $S$ are the numbers of SXR flare events observed in the northern and southern halves of the solar disk. If $A_{NS} > 0$, the activity in the northern hemisphere dominates or else it will dominates the southern hemisphere. The E-W asymmetry index is defined analogously. To study the statistical significance of the N-S and E-W asymmetry indices we have used binomial probability distribution. Let us consider $n$ objects in 2 classes. The binomial formula to compute the actual probability $p(k)$ of obtaining $k$ objects in class 1 and $(n-k)$ objects in class 2, is given by (Li and Gu, 2000; Vizoso and Ballester, 1990).

$$P(k) = \frac{n!}{(n-k)!k!} \left(\frac{1}{2}\right)^n.$$  

(2)

The probability of obtaining more than $d$ objects in class 1 is

$$P(\geq d) = \sum_{k=d}^{n} p(k)$$

(3)

In general, when $P(\geq d) > 10\%$ implies a statistically insignificant result (flare activity should be regarded as being equivalent for the two hemispheres); when $5\% < P(\geq d) < 10\%$ it is marginally significant; when $P(\geq d) < 5\%$ and $P(\geq d) < 1\%$ we have statistically significant and highly significant results respectively (flare occurrence in not due to random fluctuations) (Li et al., 2001; Li et al., 2003; Oliver and Ballester, 1994).

For the study of temporal behavior of SXR flares we have used some statistical parameter. Since the distributions of rise, decay, and duration are asymmetric they are better represented by the median, $\bar{x}$, than the arithmetic mean. To know the measure of dispersion we have applied the median absolute deviation, which can be calculated as
\[ D = \text{Median}\left\{ x_i - \bar{x} \right\}, \]  

where \( x_i \) denote the data values and \( \bar{x} \) is the median of the \( x_i \). As a measure of statistical significance we make use of the 95% confidence interval, \( \bar{x} \pm c_{95} \), with

\[ c_{95} = \frac{1.58 (Q_3 - Q_1)}{\sqrt{n}}, \]  

where \( Q_1 \) and \( Q_3 \) denote the first and the third quartile, respectively, \( n \) being the total number of data values (Veronig et al., 2002). We have also calculated 90th percentile (\( P_{90} \)), which states that only 10% of the events have a value larger than \( P_{90} \). To study a characterization of the degree of asymmetry of a distribution around its mean we have also calculated the skewness of the distribution. We computed the event asymmetry index \( (A_{ew}) \) in order to characterize the proportion of the rise and the decay time of a flare event defined as

\[ A_{ew} = \frac{t_{\text{decay}} - t_{\text{rise}}}{t_{\text{decay}} + t_{\text{rise}}}, \]  

where \( t_{\text{rise}} \) is the rise time, and \( t_{\text{decay}} \), the decay time of events. The event asymmetry index is a dimension-less quantity. A value close to zero states that the rise and the decay times are roughly equal. And if \( A_{ew} > 0 \) the decay phase is longer then the rising phase otherwise the rising phase will be longer than the decay phase (Temmer et al., 2001).

4. ANALYSIS AND RESULTS

4.1 N-S ASYMMETRY OF SXR FLARES AT LOW, HIGH AND TOTAL LATITUDES DURING SC 21, 22, 23

To investigate the existence of a spatial distribution of flares with respect to heliographic latitude, we have evaluated the total number of flares in the interval of 10° latitude for northern and southern hemispheres for SC 21, 22 and 23 in Table 3. Figure 2 represents the yearly number of SXR flares at low and high latitudes. Figure 2 shows that both the SXR flare events at high and low latitudes are not uniformly distributed in the northern and southern hemispheres. In Figure 3 we have plotted the heliographic latitudes verses number of total SXR flares as well as for different classes for SC 21, 22 and 23. All curves show a pronounced peak at 11-20° latitude band on both side of solar equator. Here 0° represent the equator of the Sun. The N-S asymmetry indices for total SXR flares and different intensity classes (B, C, M, and X) based on annual counts from 1976 to 2007 have been plotted in Figure 4. 21 out of 32 N-S asymmetry indices come out to be highly significant, 4 come out to be significant and 2 and 5 values come out to be marginally significant and insignificant respectively. It is clear from this figure that the variation of N-S asymmetry for total as well as B, C, M, and X flare events is more or less similar. In Figure 5 we have fitted a straight line to the yearly values of the asymmetry for total SXR data as well as for different classes for SC 21, SC 22 and SC 23. The plots clearly show that the slopes of the X class events are quite different from the other classes and total SXR flare events for SC 22
and 23. In Figure 6 we have plotted the N-S asymmetry versus years separately at low and high latitudes. At low latitude 21 out of 32 N-S asymmetry values come out to be highly significant 4 come out to be significant and 2 and 5 come out to be marginally significant and insignificant respectively. At high latitude 2 out of 32 N-S asymmetry values come out to be significant and rest of the values are insignificant. Highly significant, marginally significant, significant and insignificant values of asymmetry indices are marked with different symbols in Fig. 4 and Fig. 6. In Figure 7 we have fitted a straight line to the yearly values of the asymmetry of the SXR flare events at total, low and high latitudes for SC 21, 22 and 23 respectively.

4.2 E-W ASYMMETRY OF SXR FLARES AT LOW, HIGH AND TOTAL CMDs
DURING SC 21, 22, 23

Table 4 presents the total number of flares at longitudinal intervals of 10° from the CMD towards the east and west limbs for SC 21, 22 and 23. Figure 8 represents the yearly number of SXR flares at high and low CMDs. Figure 8 show that the SXR flare events at high and low CMDs are not uniformly distributed in the eastern and western hemispheres. In Figure 9 we have plotted the heliographic CMDs verses number of SXR flares and different classes for SC 21, 22 and 23. There is no pronounced peak obtained. The E-W asymmetry indices for total SXR flares based on annual counts from 1976 to 2007 have been plotted in Figure 10. Also plotted in the figure is the E-W asymmetry of different intensity classes (B, C, M, and X) for the same period. 14 out of 32 E-W asymmetry indices turn out to be highly significant, 5 come out to be significant and 1 and 12 values come out to be marginally significant and insignificant respectively. In Figure 11 we have fitted a straight line to the yearly values of E-W asymmetry for total SXR data as well as for different classes for SC 21, SC 22 and SC 23. From this figure we can find out that for SC 21 the slope of the fit for total SXR as well as for different intensity classes are different whereas for SC 22 and 23 the slop are the same for all classes and total SXR events. In Figure 12 we have plotted the E-W asymmetry versus years separately at low and high CMDs. At low latitude 7 out of 32 E-W asymmetry values turn out to be highly significant 6 turn out to be significant and 4 and 15 turn out to be marginally significant and insignificant respectively. At high latitude 12 out of 32 E-W asymmetry values turn out to be highly significant, 6 turn out to be significant and 2 and 12 turn out to be marginally significant and insignificant respectively. At high CMDs E-W asymmetry is statistically more significant than low CMDs. Highly significant, marginally significant, significant and insignificant values of asymmetry indices are marked with different symbols in Fig. 10 and Fig. 12. In Figure 13 we have fitted a straight line to the yearly values of the E-W asymmetry of the SXR events at total, low and high CMDs for SC 21, 22 and 23 respectively and show that for SC 21 and 22 the slopes at high and low CMDs are different whereas for SC 23 it is the same.

4.3 TEMPORAL ASPECTS AND EVENT ASYMMETRY

In Table 5 we give a list of various statistical measures characterizing the duration, rise and decay times of the SXR data set, namely the mean, the median, the mode, and the 90th percentile (P_{90}) for SC 21, 22, and 23. In Table 6 we list the median values (plus 95% confidence intervals) and the 90th percentile values of the temporal parameters calculated for different classes of SXR flares as well as for total SXR flares for SC 21, 22 and 23. It is clear form this table that all the
temporal parameter i.e., duration, rise and decay times increases with the flare class. The differences from one class to the other are larger than the 95% confidence limit, indicating the statistical significance of the effect. From this table we have found that for SC 21 and 22 the increase is more pronounced for duration and decay times but for SC 23 the increase is more pronounced for duration only. In Table 7 we list the median values of the event asymmetries for different intensity classes as well as the 95% confidence intervals, the absolute median deviations and the 10th percentile. It can be seen that the asymmetries increase with increasing intensity class for SC 21 and 22 but for SC 23 it is decreasing with increasing intensity classes. Since the difference of event asymmetries between the various classes are larger than the 95% confidence intervals, the effect can be considered as statistically significant. Figure 14 shows the distributions of the event asymmetries calculated versus number of flare for SC 21, 22 and 23. For SC 21 distribution reveals a negative skewness, i.e. an accumulation at positive values, showing that the majority of the events the decay phase is longer than the rising phase, but for SC 22 and 23 distributions reveal a positive skewness. For SC 21 and 22 median values of event asymmetries are ≈ 0.3 and ≈ 0.1 respectively, which imply that for about 50% of events the decay phase is more than 1.85 and 1.22 times as long as the rising phase respectively. Whereas for SC 23 median value of asymmetry is ≈ 0.0, which means that for about 50% of events the decay phase is equal to the rising phase. For SC 21, 22 and 23 the value of $P_{10}$ is ≈ -0.33 which means that for about 90% of the events, the decay time is even more than 0.50 times the rise time.

5. DISCUSSION AND CONCLUSIONS

The SXR flare data in the period 1976 to 2007 are used to study the N-S and E-W asymmetry of SXR flares at low (≤ 40°), high (50° ≥) and total latitudes as well as for different intensity classes, temporal aspects and event asymmetry during SC 21, 22 and 23. The results obtained are the following:

1. N-S distribution study of total SXR flare events and different importance class events shows similar distribution whereas E-W distribution study shows same variation only for total SXR and C class flare events for SC 21, 22 and 23. For N-S distribution the flares are most prolific between 11° to 20° latitudes whereas for E-W distribution no pronounced peak obtained.

2. The annual variation of N-S and E-W asymmetry at low latitudes and CMDs is similar to that of total latitudes and CMDs respectively. E-W asymmetry is different at low and high CMDs for SC 21 and 22 but similar for 23.

3. From Table 2 and 3 it can be seen that during SC 21, 22 and 23 the activity was southern and eastern hemisphere dominated. Our Statistical study shows that N-S asymmetry is more statistically significant than E-W asymmetry.

4. The duration, rise and the decay times increase with increasing intensity class. For SC 21 and 22 this increase is more pronounced for the duration and decay times, but for SC 23 it is more pronounced for duration.

5. From event asymmetry analysis we found more positive values during SC 21 (≈ 64.86%) and SC 22 (≈54.31%) compared to SC 23 where we found more negative values (≈48.08%).
From Fig. 1 it can be found out that during the minimum activity of SCs the B class events dominate whereas for the maximum activity other classes dominate. This is because, during the period of maximum activity the X-ray background is too high to detect A and B class flares form full-disk measurements. The increased X-ray background during maximum solar activity may be due to emission from many flare events as well as due to a steady coronal heating mechanism (e.g., Feldman et al., 1997). Garcia (1990) gave the distribution of $M \geq 1$ flares from 1969 to 1984 with respect to the heliographic latitude and found that the majority of the flare events occurred within $\pm 30^\circ$ latitudes. Li et al. (1998) examined the latitudinal distribution of flares during the maximum period of SC 22 and found that the majority of flares occurred in the latitudes between $8^\circ - 35^\circ$ in both the hemispheres. In our study most of the SXR events (99.35%) occurred at low latitudes ($\leq 40^\circ$), which is the same as the above conclusion. Joshi and Pant (2005) and Verma (2000) presented the distribution of H$\alpha$ flares and SAP and found that in both the hemispheres (N, and S) the flares are more prolific between $11^\circ$ to $20^\circ$ latitudes. In our study we have also found the same result for SXR flares as well as its different intensity classes (Fig. 3). E-W distribution is not found prolific in any CMD bands (Fig. 9). Li et al. (2003) presented the asymmetry of SAP at low and high latitudes from 1957 through 1998 and found that the annual hemispheric asymmetry indeed exists at low latitudes, but strangely, a similar asymmetry does not seem to occur for SAPs at high latitudes. In our study we have found that N-S asymmetry at low latitudes is of similar nature to that of total latitudes for all three SCs (Fig. 6 and 7) whereas E-W asymmetry for SCs 21 and 22 (Fig 12 and 13) is different at low and high CMDs. At low CMDs it is shifting from west to east whereas at high CMDs it is shifting from east to west but for SC 23 this remains the same at low, high and total CMDs surface (Fig. 13). Temmer et al. (2001), Joshi and Joshi (2004), and Verma (2000) studied N-S asymmetry during SC 21, 22 and 23 by taking H$\alpha$ solar flare, SXR flare index and solar active prominence respectively and found a significant N-S asymmetry with a prolonged southern excess. Similar result is reported in our study also. Joshi and Joshi (2004) fitted straight line to asymmetry time series for cycles 21 and 23 and found out that the activity in the northern hemisphere is more important during the ascending branch of cycle whereas during the descending branch the activity becomes dominates the southern hemisphere. Similar variation is observed in the present investigation (see Fig. 7). According to Verma (1993) the reason for the N-S asymmetry period is not known, but perhaps it may be due to the asymmetry in the internal magnetic structure of the Sun. From the above discussion we have concluded that there exists a real N-S asymmetry which is not due to random fluctuations. Temmer et al. (2001) studied E-W asymmetry and found a slight but significant E-W asymmetry. Li et al. (1998) also studied E-W asymmetry and reported a not significant but a non–uniform flare distribution in CMDs. Heras et al. (1990) analysed the E-W solar flare distribution from 1976-1985 and found a pronounced and prolonged E-W asymmetry in flares and subflares. They also concluded that simple random distribution of flares over the solar disk cannot account for the asymmetries found, but they can be explained in terms of the transit of active regions in front of the observer’s position. Joshi and Pant (2005) found that the H$\alpha$ flare activity in SC 23 is low compared to previous SC whereas in our study we have found that total SXR flare activity during SC 23 is higher in comparison to previous SCs i.e., SC 21 and 22.

The shape of N-S and E-W asymmetry curve (Fig. 4 and Fig. 10) shows that the asymmetry has peaked at or around the minimum of solar activity. This result is complementary to the study of N-S asymmetry made by many authors (Ataç and Özgüç, 1996; Visoso and Ballester, 1990). We
have also found out that N-S as well as E-W asymmetry for SXR and different intensity classes has no relation with a solar maximum year or solar minimum year during SCs (see Fig. 4 and Fig. 10). These results are in agreement with the work done by Verma (2000), who analyzed the variation N-S and E-W asymmetry of SAP from 1957 to 1998. Temmer et al. (2001) and Veronig et al. (2002) statistically analysed Hα and SXR flares and found that the temporal parameter increases with increasing importance and intensity classes respectively. Similar result is reported in our analysis for SC 21, 22 and 23 (see Table 6). Temmer et al. (2001) also studied the event asymmetry from 1975 to 1999 and investigated that there are predominantly positive values of event asymmetry. These results are confirmed in our analysis for SC 21 and 22 but for SC 23 we found more negative values.

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Table 1. The number of flares and their percentage for different classes and for last three solar cycles.

| Class | SC 21 | SC 22 | SC 23 |
|-------|-------|-------|-------|
| B     | 2311  | 6486  | 8476  |
|       | (12.03%) | (30.58%) | (36.56%) |
| C     | 14556 | 12532 | 13146 |
|       | (75.82%) | (59.09%) | (56.70%) |
| M     | 2165  | 2038  | 1438  |
|       | (11.28%) | (9.61%) | (6.20%) |
| X     | 166   | 154   | 126   |
|       | (0.86%) | (0.73%) | (0.54%) |
| T     | 19198 | 21210 | 23186 |
|       | (100.00%) | (100.00%) | (100.00%) |

Table 2. Comparison of the average monthly flare rate for SC 21, 22 and 23.

| Class | SC 21 | SC 22 | SC 23 |
|-------|-------|-------|-------|
| B     | 19.3  | 54.1  | 71.6  |
| C     | 121.3 | 104.4 | 109.8 |
| M     | 18.0  | 17.0  | 12.0  |
| X     | 1.4   | 1.3   | 1.1   |
| T     | 160.0 | 176.8 | 194.4 |

Table 3. Total number of SXR flares at different latitude bands in the northern (N) and southern (S) hemispheres and tabulated for last three SCs. The dominant hemisphere (DH) and asymmetry index (A-Index) are given for each SCs. SXR flares that occurred exactly at the equator have been excluded.

| Cycle | Total number of SXR flares | Total | A-Index | DH |
|-------|----------------------------|-------|---------|----|
|       | 1-10° | 11-20° | 21-30° | 31-40° | 41-50° | 51-60° | 61-70° | 71-80° | 81-90° |       |
| 21    | N     | 1489   | 2871   | 644    | 116    | 4     | 1     | 0     | 0     | 0     | 5125 |
|       | S     | 1565   | 2963   | 891    | 99     | 20    | 1     | 0     | 1     | 0     | 5540 |
|       |       |        |        |        |        |       |       |       |       |       | -0.03891 |
| 22    | N     | 1305   | 2259   | 1248   | 357    | 5     | 0     | 0     | 0     | 0     | 5174 |
|       | S     | 1349   | 3114   | 1631   | 351    | 10    | 0     | 0     | 0     | 0     | 6455 |
|       |       |        |        |        |        |       |       |       |       |       | -0.11016 |
| 23    | N     | 1252   | 2879   | 954    | 84     | 24    | 10    | 6     | 6     | 1     | 5216 |
|       | S     | 2481   | 3342   | 1051   | 84     | 14    | 8     | 2     | 8     | 2     | 6992 |
|       |       |        |        |        |        |       |       |       |       |       | -0.14548 |

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Table 4. Number of SXR flares at different CMD bands in the eastern (E) and western (W) hemispheres and tabulated for last three SCs. The dominant hemisphere (DH) and asymmetry index (A-Index) are given for each SCs. SXR flares that occurred exactly at the equator have been excluded.

| Cycle | Total number of SXR flares | Total | A-Index | DH   |
|-------|---------------------------|-------|---------|------|
|       | 1-10°| 11-20°| 21-30°| 31-40°| 41-50°| 51-60°| 61-70°| 71-80°| 81-90°|       |
| 21    | E    | 703   | 717   | 748   | 698   | 750   | 685   | 555   | 408   | 208   | 5472  |
|       | W    | 750   | 742   | 691   | 678   | 622   | 567   | 514   | 366   | 210   | 5140  | 0.031285 E |
| 22    | E    | 755   | 775   | 789   | 761   | 775   | 712   | 645   | 466   | 263   | 5941  |
|       | W    | 797   | 780   | 746   | 727   | 715   | 657   | 564   | 415   | 258   | 5659  | 0.024310 E |
| 23    | E    | 793   | 801   | 759   | 737   | 765   | 664   | 650   | 555   | 389   | 6113  |
|       | W    | 741   | 747   | 653   | 665   | 700   | 653   | 585   | 496   | 707   | 5947  | 0.013765 E |

Table 5. Mean, median, mode and 90th percentile values of duration, rise, and decay times of the total number of SXR flares.

| Cycle | Stat. measure | Duration (min) | Rise time (min) | Decay time (min) |
|-------|---------------|---------------|-----------------|------------------|
| 21    | Mean          | 24.81         | 8.45            | 16.38            |
|       | Median        | 16.00         | 4.00            | 9.00             |
|       | Mode          | 5.00          | 3.00            | 2.00             |
|       | P90           | 52.00         | 18.00           | 37.00            |
| 22    | Mean          | 21.52         | 8.44            | 13.08            |
|       | Median        | 13.00         | 5.00            | 7.00             |
|       | Mode          | 7.00          | 4.00            | 3.00             |
|       | P90           | 44.00         | 17.00           | 29.00            |
| 23    | Mean          | 18.65         | 9.53            | 9.12             |
|       | Median        | 12.00         | 6.00            | 6.00             |
|       | Mode          | 7.00          | 4.00            | 3.00             |
|       | P90           | 35.00         | 19.00           | 18.00            |
Table 6. Median values with 95% confidence interval (\( \bar{x} \pm c_{95} \)), absolute median deviation (\( \bar{D} \)) and 90\(^{th}\) percentile (\( P_{90} \)) of the duration, rise and decay times for the different intensity classes (B, C, M and X) and the total number of flares (T). All values are given in minutes.

| Cycle | Class | Duration | Rise time | Decay time |
|-------|-------|----------|-----------|------------|
|       | \( \bar{x} \pm c_{95} \) | \( \bar{D} \) | \( P_{90} \) | \( \bar{x} \pm c_{95} \) | \( \bar{D} \) | \( P_{90} \) | \( \bar{x} \pm c_{95} \) | \( \bar{D} \) | \( P_{90} \) |
| B     | 11.00\( \pm 0.40 \) | 8.0 | 31.0 | 4.00\( \pm 0.13 \) | 2.0 | 13.0 | 6.00\( \pm 0.23 \) | 5.0 | 20.0 |
| 21    | C     | 15.00\( \pm 0.24 \) | 8.0 | 46.0 | 4.00\( \pm 0.08 \) | 2.0 | 17.0 | 9.00\( \pm 0.18 \) | 5.0 | 33.0 |
| M     | 33.00\( \pm 1.41 \) | 17.0 | 98.6 | 7.00\( \pm 0.40 \) | 4.0 | 32.0 | 23.00\( \pm 1.12 \) | 14.0 | 72.0 |
| X     | 65.00\( \pm 8.77 \) | 49.0 | 193.0 | 12.00\( \pm 2.58 \) | 8.0 | 41.2 | 53.00\( \pm 8.09 \) | 44.0 | 144.8 |
| T     | 16.00\( \pm 0.24 \) | 8.0 | 52.9 | 4.00\( \pm 0.07 \) | 2.0 | 18.0 | 9.00\( \pm 0.18 \) | 6.0 | 37.0 |
| B     | 10.00\( \pm 0.20 \) | 4.0 | 29.0 | 4.00\( \pm 0.08 \) | 2.0 | 12.0 | 6.00\( \pm 0.14 \) | 3.0 | 18.0 |
| 22    | C     | 15.00\( \pm 0.33 \) | 7.0 | 47.0 | 5.00\( \pm 0.13 \) | 2.0 | 20.0 | 8.00\( \pm 0.22 \) | 5.0 | 31.0 |
| M     | 37.00\( \pm 2.60 \) | 20.0 | 111.0 | 9.00\( \pm 0.64 \) | 5.0 | 31.0 | 26.00\( \pm 2.16 \) | 16.0 | 80.0 |
| X     | 71.00\( \pm 26.73 \) | 41.5 | 228.1 | 12.00\( \pm 4.68 \) | 8.0 | 55.0 | 60.50\( \pm 23.86 \) | 39.5 | 154.0 |
| T     | 13.00\( \pm 0.21 \) | 6.0 | 44.0 | 5.00\( \pm 0.08 \) | 2.0 | 17.0 | 7.00\( \pm 0.14 \) | 4.0 | 29.0 |
| B     | 10.00\( \pm 0.14 \) | 4.0 | 25.0 | 5.00\( \pm 0.05 \) | 2.0 | 12.0 | 5.00\( \pm 0.09 \) | 2.0 | 13.0 |
| 23    | C     | 13.00\( \pm 0.19 \) | 5.5 | 38.0 | 6.00\( \pm 0.10 \) | 2.0 | 20.0 | 6.00\( \pm 0.10 \) | 3.0 | 19.0 |
| M     | 21.00\( \pm 0.10 \) | 10.0 | 62.0 | 11.00\( \pm 0.50 \) | 5.0 | 33.0 | 9.00\( \pm 0.46 \) | 5.0 | 29.0 |
| X     | 26.50\( \pm 3.62 \) | 11.5 | 76.0 | 15.50\( \pm 1.69 \) | 6.5 | 42.5 | 11.00\( \pm 1.65 \) | 5.0 | 29.0 |
| T     | 12.00\( \pm 0.13 \) | 5.0 | 35.0 | 6.00\( \pm 0.06 \) | 2.0 | 19.0 | 6.00\( \pm 0.06 \) | 3.0 | 18.0 |

Table 7. Median values of event asymmetries for the different SXR classes with 95% confidence intervals (\( \bar{x} \pm c_{95} \)). Also listed are, the absolute median deviations (\( \bar{D} \)) and the 10\(^{th}\) percentiles (\( P_{10} \)).

| Cycle | Class | Event asymmetries |
|-------|-------|-------------------|
|       | \( \bar{x} \pm c_{95} \) | \( P_{10} \) | \( \bar{D} \) |
| B     | 0.077\( \pm 0.018 \) | -0.333 | 0.332 |
| 21    | C     | 0.290\( \pm 0.010 \) | -0.333 | 0.384 |
| M     | 0.472\( \pm 0.023 \) | -0.211 | 0.381 |
| X     | 0.636\( \pm 0.063 \) | -0.130 | 0.431 |
| T     | 0.272\( \pm 0.009 \) | -0.333 | 0.384 |
| B     | 0.043\( \pm 0.012 \) | -0.333 | 0.243 |
| 22    | C     | 0.111\( \pm 0.012 \) | -0.333 | 0.289 |
| M     | 0.467\( \pm 0.034 \) | -0.178 | 0.288 |
| X     | 0.642\( \pm 0.130 \) | -0.148 | 0.210 |
| T     | 0.103\( \pm 0.008 \) | -0.333 | 0.297 |
| B     | 0.000\( \pm 0.006 \) | -0.333 | 0.200 |
| 23    | C     | 0.000\( \pm 0.005 \) | -0.371 | 0.182 |
| M     | -0.111\( \pm 0.014 \) | -0.444 | 0.173 |
| X     | -0.182\( \pm 0.042 \) | -0.484 | 0.151 |
| T     | 0.000\( \pm 0.004 \) | -0.339 | 0.185 |
Fig. 1. Monthly plot for flares of all classes, class X, M, C, and B form 1976 to 2007 (from top to bottom panel).
Fig. 2. Top panel: the yearly number of the SXR flare events at low latitudes in the northern hemisphere (the solid line) and that in the southern hemisphere (the dotted line); Lower panel: the yearly number of the SXR flares events at high latitudes in the northern hemisphere (the solid line) and that in the southern hemisphere (the dotted line).
Fig. 3. Plot of number of SXR flares versus heliographic latitudes for total SXR flares as well as different classes (B, C, M and X) for SC 21 (plus symbol), 22 (cross symbol), 23 (star symbol) (from top to bottom panel).
Fig. 4. Plot of N-S asymmetry indices for SXR flares (solid line), class B, C, M and X (doted line) events versus years (1976-2007). Downward arrows indicate solar activity minima.

Fig. 5. The fit of regression line to the yearly values of the N-S asymmetry of the SXR events for all classes, class X, M, C, and B for SC 21, 22, and 23 (from top to bottom panel).
Fig. 6. The N-S asymmetry of the yearly numbers of the SXR flares at low (the solid line) and that at high latitudes (the dotted line).

Fig. 7. The fit of a regression line to the yearly values of the N-S asymmetry of the SXR flare events respectively at total latitudes, high latitudes and low latitudes for solar cycle 21, 22, and 23 (from top to lower panel).
Fig. 8. Top panel: the yearly number of the SXR flare events at low CMDs in the eastern hemisphere (the solid line) and that in the western hemisphere (the dotted line); Lower panel: the yearly number of the SXR flares events at high CMDs in the eastern hemisphere (the solid line) and that in the western hemisphere (the dotted line).
Fig. 9. Plot of number of SXR flares versus heliographic CMDs for total SXR flares as well as different classes (B, C, M and X) for SC 21 (plus symbol), 22 (cross symbol), 23 (star symbol) (from top to bottom panel).
Fig. 10. Plot of E-W asymmetry indices for total SXR flares (solid line), class B, C, M and X (dotted line) events versus years (1976-2007). Downward arrows indicate solar activity minima.

Fig. 11. The fit of regression line to the yearly values of the E-W asymmetry of the SXR events for all classes, class X, M, C, and B for SC 21, 22, and 23 (from top to bottom panel).
Fig. 12. The E-W asymmetry of the yearly numbers of the SXR flares at low (the solid line) and that at high CMDs (the dotted line).

Fig. 13. The fit of a regression line to the yearly values of the E-W asymmetry of the SXR flare events respectively at total CMDs, high latitudes and low latitudes for solar cycle 21, 22, and 23 (from top to lower panel).
Fig 14. Histograms of the event asymmetry, separately for SC 21, 22, and 23 (from top to bottom panel). The solid line indicates the median of the distribution, the dashed line the 10th percentile.