Solar Flare Durations

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1. Introduction

Scientific investigation of solar flares is an ongoing pursuit by researchers around the world. Flares are described by their intensity, duration and frequency (spectral) characteristics. Flare durations are studied to understand the physics behind flares and to determine how they evolve over a solar cycle. These studies are helpful in developing space weather forecasts.

A given solar flare produces electromagnetic emissions over a very wide frequency range. Emissions at ultraviolet, extreme ultraviolet (UV and EUV) and x-ray frequencies reach Earth in slightly more than 8 minutes and can immediately affect Earth's ionosphere, leading to radio blackouts on terrestrial HF communications systems. There are many other potentially deleterious effects from solar flares such as damage to spacecraft electronics, disruption of navigation signals from global navigation satellite systems (GNSS), electrical grid disruptions and biological harm to astronauts and to the crews and passengers on polar airline flights.

This short article summarizes the statistics of solar flare durations at x-ray wavelengths. This data is from a quantitative study of solar flare durations over about a six year period during solar cycle 24, which were reported by *Solar Terrestrial Centre of Excellence* in the **STCE Newsletter** for 4 through 10 January 2016 {SCTE}.

2. X-Ray Flare Classifications

Solar flares are classified according to their peak x-ray flux (irradiance) in the wavelength range 0.1 to 0.8 nm. There are three main classes and two additional subsidiary flare classes. In ascending order of size the classes are: A, B, C, M and X. Each class is separated by a power of ten flux (table 1). Most scales list only C, M and X. The two lowest scales, A and B, represent a quiet Sun around the time of solar cycle minimum and maximum, respectively.

Table 1 – Solar flare classifications

Class	Peak flux (w/m^2)	Remarks
A	$I < 10^{-7}$	Near background level at solar cycle minimum
B	$10^{-7} \le I < 10^{-6}$	Near background level at solar cycle maximum
C	$10^{-6} \le I < 10^{-5}$	May produce CMEs if long duration
M	$10^{-5} \le I < 10^{-4}$	Often called "medium-large" flares
X	$10^{-4} \le I$	Relatively rare

The three highest classes have nine subdivisions ranging from 1 to 9, as in C1 to C9, M1 to M9, and X1 to X9. The subdivisions indicate a multiplier. For example, a flare classified as C7 has a peak flux of 7 x 10^{-6} w/m^2 and M2 has a peak flux of 2 x 10^{-5} w/m^2.

X-class flares are the most powerful and can trigger worldwide radio blackouts and long-lasting radiation storms. M-class flares are medium-sized and can cause brief radio blackouts that affect Earth's polar regions. Minor radiation storms sometimes follow an M-class flare. Compared to X- and M-class events, C-class flares are small with few noticeable effects on Earth but they are often detectable with sudden ionospheric disturbance (SID) monitors. The B-class flares have negligible effect on Earth and are the smallest that are reported by NOAA's Space Weather Prediction Center (SWPC).

3. Flare Durations at X-Ray Wavelengths

Flare durations generally are broadly classified as impulsive or long duration events (LDE) based on their durations at x-ray wavelengths. SWPC states the time threshold separating impulsive and LDE flares is not well defined but, generally, an event requiring 30 minutes or more to decay to one-half peak flux is regarded as an LDE. Other space weather research entities define an LDE as flare lasting more than 60 minutes. SWPC further states the likelihood of a coronal mass ejection (CME) increases with the duration of an x-ray flare and becomes practically certain for durations of 6 hours or more. Of course there are exceptions such as the long duration flares produced by NOAA active region 12192 in October 2014, for which no CME was detected. Type II (slow drift) solar radio bursts usually are associated with CMEs. Earth-directed CMEs can cause geomagnetic storms.

4. Study of X-Ray Flare Events

SCTE reported on the median duration of all flares that occurred between January 2009 and November 2015 in solar cycle 24 and compared them to a previous study published in 2002 for cycles 21 and 22 (table 1). The median value is the mid-point of all data samples such that there are an equal number of samples above and below the median. SCTE reported that medians and not averages were used for their investigations because of the frequency (rate of occurrence) distribution of solar flares. If the numbers of flares were categorized in 5 minute bins (for example, 5-9 minutes, 10-14 minutes, and so on) and are plotted, it is clearly seen that the distributions are skewed and do not follow a normal statistical distribution (figure 1).

Table 1 ~ Median flare duration for each x-ray class from January 2009 to November 2015 compared to a study by Veronig, at al from January 1976 to December 2000. Table from {SCTE}.

Jan 1976 - Dec 2000			Jan 2009 - Nov 2015		
Class	Number	Median	Class	Number	Median
B	8844	10	B	4041	10
C	16507	12	C	7015	14
M	1331	24	M	659	19
X	63	30	X	45	24
T	*26745*	*12*	*T*	*11760*	*13*

The results from both the SCTE and earlier study indicate that stronger flares generally last longer. The duration of M- and X-class flares in the SCTE study are slightly shorter than in the earlier study, which may be due to the smaller number of flares and only partial coverage of the relatively weak solar cycle 24 in the SCTE study.

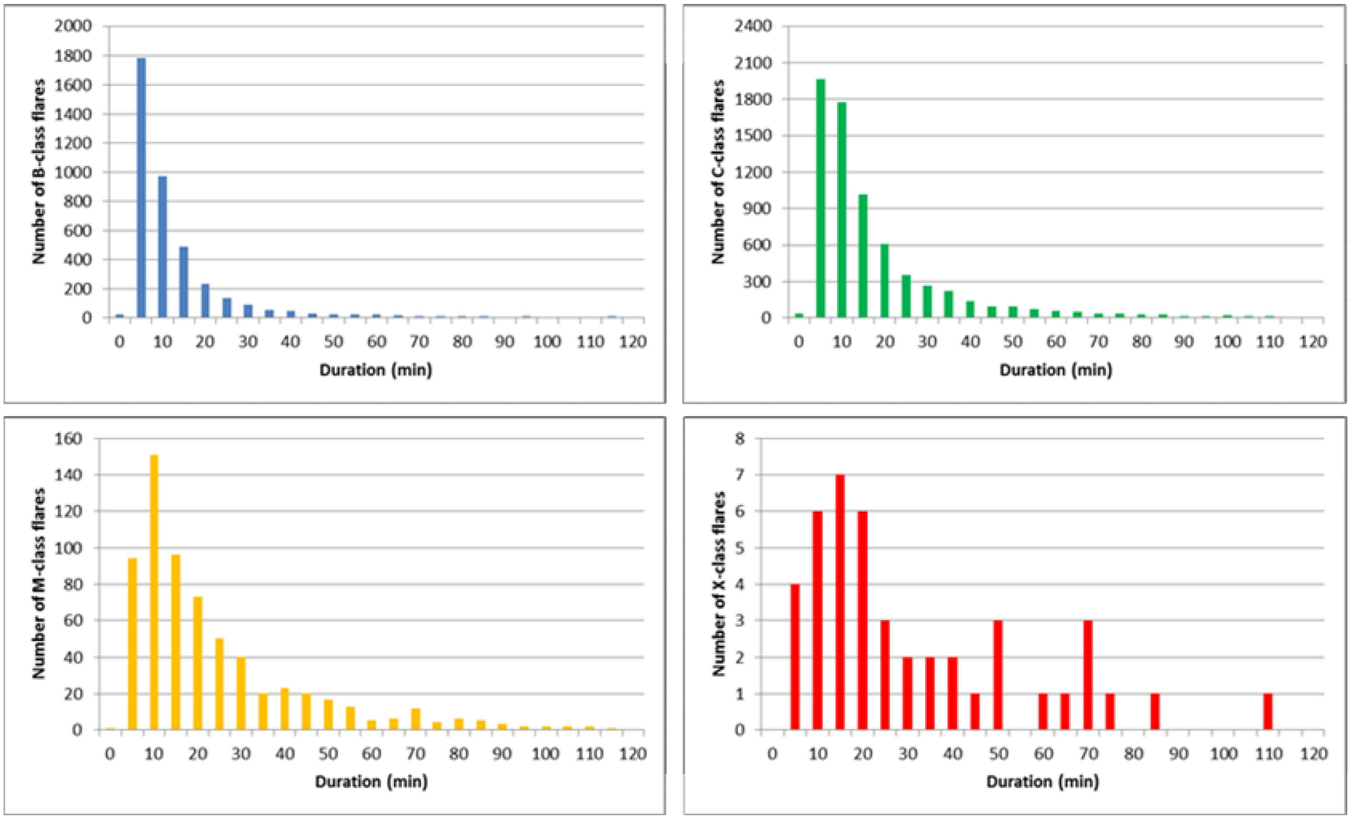

Figure 1 ~ flare duration distributions for the four x-ray classes (same color code as table above)

The histograms for the four x-ray flare classes show a wide range of durations but are concentrated toward shorter durations and have a long tail toward longer durations. Taking a simple average instead of the median duration would give a value that is too high for most flares within a given class. The histograms also show that the peak moves toward longer durations as the strength of the flare increases in terms of its x-ray class.

In the SCTE study the B- and C-class flares fall into the 10 minute duration bin 25-45% of the time. On the other hand, some M1 flares lasted only 5 or 6 minutes and others lasted several hours, such as the M1.7 flare on 17 July 2012 at NOAA activity region 11520 that lasted slightly more than 7 hours. Another example illustrating the difference between impulsive and long duration flaring events is seen in EUV imagery (figure 2).

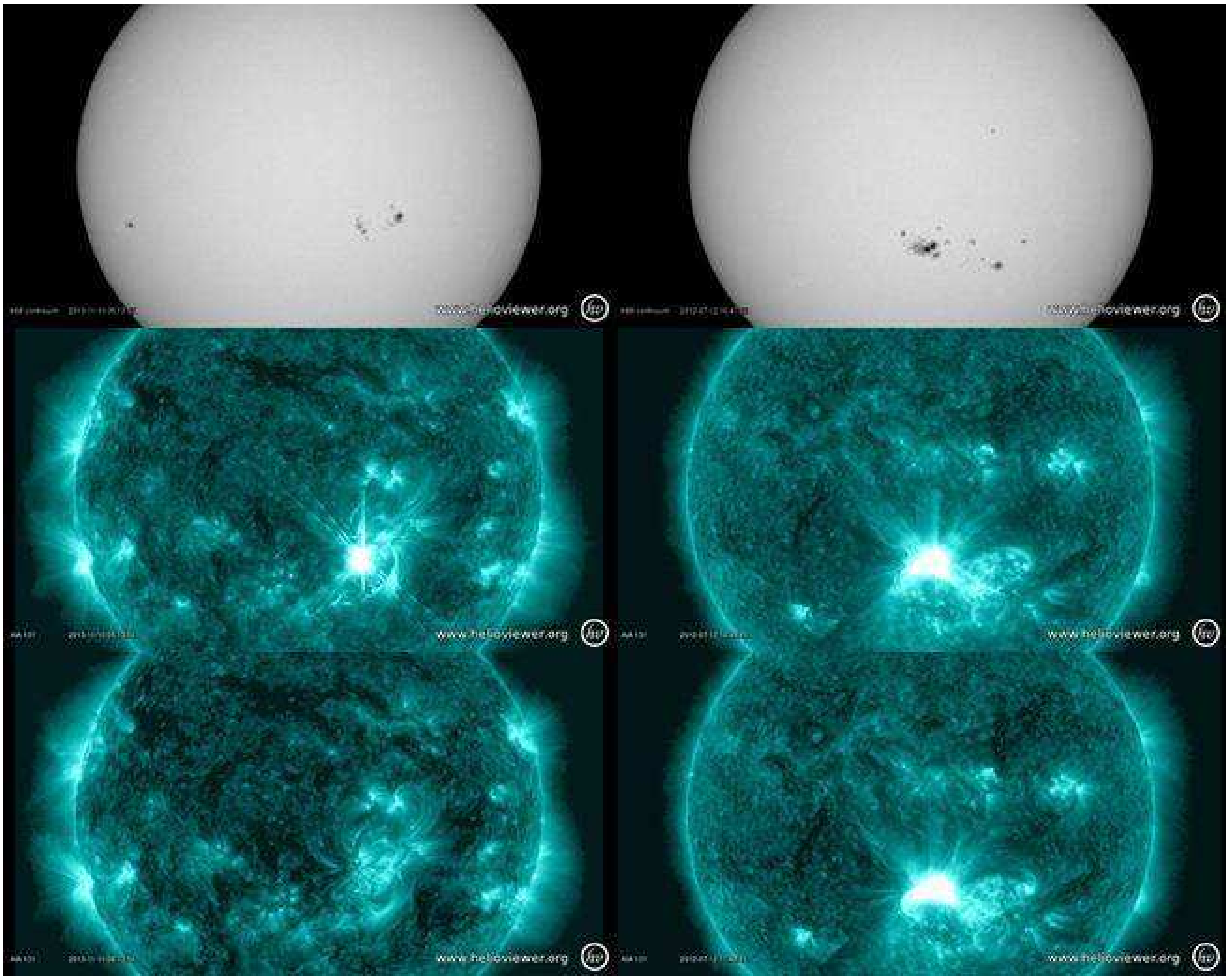

Figure 2 ~ Upper, left and right: White light image (SDO/HMI) of the active regions responsible for a short and a long duration X1 flaring event. These took place in NOAA active region 11890 on 10 November 2013 (left, duration: 10 minutes) and in NOAA AR 11520 on 12 July 2012 (right, duration: 113 minutes or nearly 2 hours). Middle- and lower-left and -right: The EUV images (SDO/AIA 131) show the remarkable difference in the flare at the x-ray peak (middle) and 1 hour later (lower). Image source: {SCTE}

5. Conclusions

Some of the statistics associated with solar flares durations in the last two solar cycles have been discussed. Studies of x-ray flare durations help us understand how the Sun works so we can more accurately forecast space weather with the aim of reducing space weather effects on us.

6. References

{SCTE} STCE Newsletter for 4 Jan 2016 - 10 Jan 2016: http://www.stce.be/newsletter/pdf/2016/STCEnews20160115.pdf

{Veronig} Veronig, A. et al, Frequency Distributions of solar Flares, 2002: http://adsabs.harvard.edu/full/2002HvaOB..26....7V

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