Introduction

Solar flares are rapid and sudden explosion of energy depicted by increased in brightness on the solar disk. They are normally observed close to active regions on the solar surface. One explosion could last only for a few minutes but is can powerful enough to energize our country for at least a year.

Solar flares are classified according to their peak flux (W/m^2) of x-rays in the 1-to-8-Å bands measure by the GOES satellite. The classification is summarized in Table I. The weakest ones are the A- and B-classes, which is close to background levels. This is followed by B, C, M, and X, where X is the strongest. The classes are in logarithmic scale. That is, an X-class solar flare is 100 times a C-class flare. Furthermore, each class is sub-divided into a finer scale of 1-9. Typically, C-class flare have barely noticeable effect on Earth. M-class flares, on the other hand, can cause brief radio blackouts at the poles and minor radiation store that might affect astronauts in space. X-class flares are the strongest and can go higher than X9. They are so strong that their effects, such as radio blackouts and radiation storms, can be felt much longer and much wider than M-class flares.

Table I. Classification of solar flares based on Peak flux

Class	Peak flux (W/m^2) range at 1–8 Å (10^{-10} m)
A	$< 10^{-7}$
B	$10^{-7} – 10^{-6}$
C	$10^{-6} – 10^{-5}$
M	$10^{-5} – 10^{-4}$
X	$> 10^{-4}$

X-ray flux data obtained from GOES X-ray Sensors (XRS) are used specifically to classify solar flares. For example, figure 1 shows the 1-minute x-ray flux data in W/m^2 obtained from GOES13 and GOES15 XRS at wavelength bands 0.5-4.0 Å and 1.0-8.0 Å from September 4 to 6, 2017 where a series of M-class and X-class solar flares were observed. Here, there were a total 15 M-class, and 2 X-class solar flares recorded during this period. The strongest of these is the X9.3 solar flare that started at 11:53 UT, peaked at 12:02 UT, and ended at 12:10 UT. In fact, this is the strongest solar flare recorded in Solar Cycle 24.

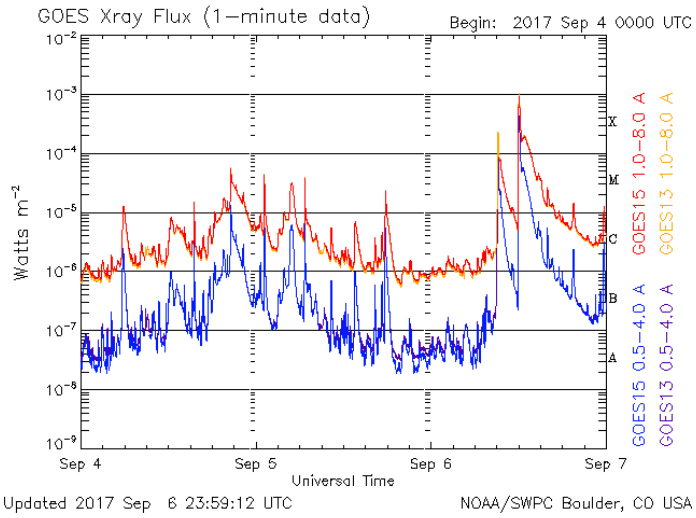

Figure 1. 1-minute X-ray flux from September 4 to 6, 2017 obtained from GOES13/15 XRS.

Figure 2 shows the intensitygram and x-ray imagery at 131 Å of the solar disk at this X9.3 obtained from the Solar Dynamics Observatory (SDO) Helioseismic and Magnetic Imager (HMI) and Atmospheric Imaging Assembly (AIA), respectively. Here, the solar flare seen as a bright light originated from Active Region (AR) 2673.

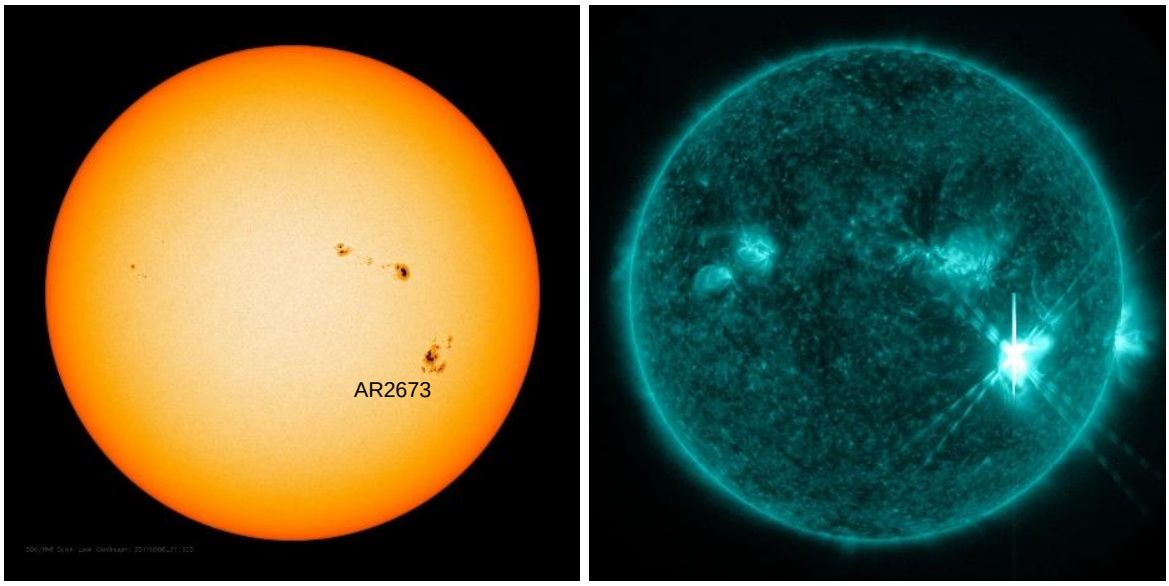

Figure 2. The (a) intensitygram using SDO/HMI, and (b) x-ray imagery at 131 Å using SDO/AIA of the solar disk on September 6, 2017 at approximately 12:00UT.

Figure 3 shows the time series of the solar flare at 131 Å and 193 Å from roughly 11:10 UT to 12:30 UT. It demonstrates the brightening of the solar flare at around 12 UT. In fact, the solar flare is so strong that it affected the 131-Å sensor of SDO/AIA at 12:13 UT, which introduced some instrumental noise to the image.

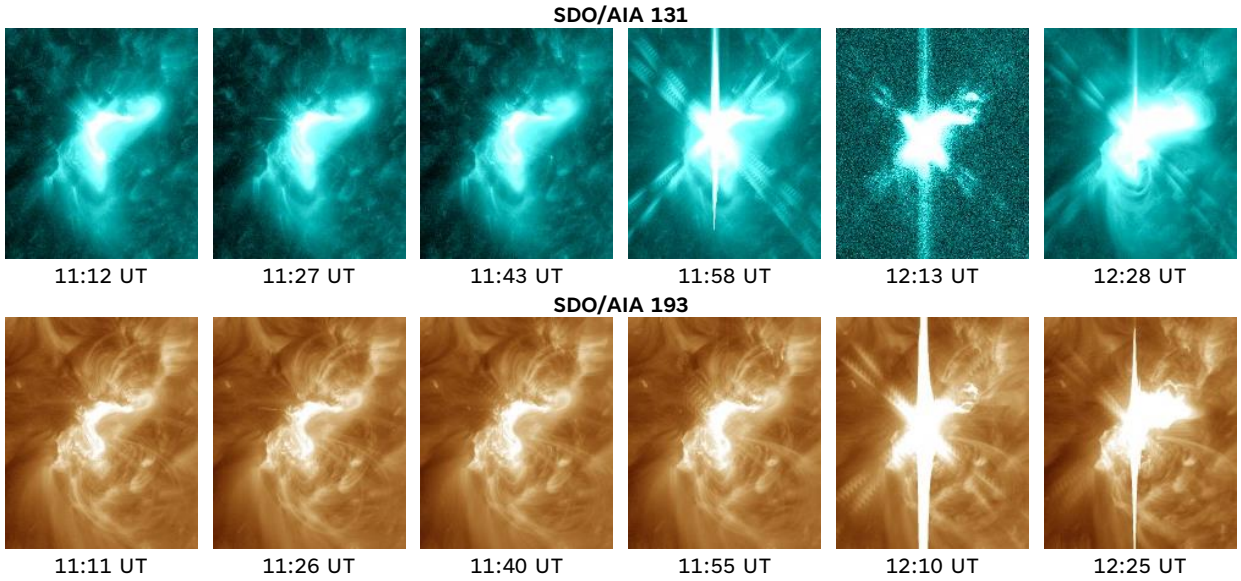

Figure 3. Sequence of event during the September 6, 2017 X9.3 solar flare from (upper row) 11:12 UT to 12:28 UT at 131 Å and (lower row) 11:11 UT to 12:25 UT at 171 Å.

In this activity, you will determine how many X-class flare have occurred in a solar maximum year and visualize brightening of the region using ultraviolet imagery which active regions they originated.

Materials:

- Computer
- Internet
- Photo Editing software
- Word Processor Software

Instructions:

1. Go to the GOES x-ray flux data archive at: ftp://ftp.swpc.noaa.gov/pub/warehouse/
    a. Go throughout the year 2013 and record all X-class flares that occurred.
    Tip: You do not need to look at individual files since each file already covers 3 days. The number of X-class flares in 2013 will not exceed 20.
    (Link for 2013: ftp://ftp.swpc.noaa.gov/pub/warehouse/2013/2013_plots/xray/)
    b. Download x-ray flux data only the days that contains the X-class flare.
    c. Classify each flare as X1, X2, ..., X9. No need to be precise.
    d. Identify the 5 strongest solar flares. (Note: Strongest happened in November 5, 2020)
    e. Make a histogram of the distribution of these X-class flares.
    Use two (2) groups: X1-X5 & X6-X9.
2. Go to SDO Data Browser: https://sdo.gsfc.nasa.gov/assets/img/browse/
    a. Navigate through the directory by choosing the desired year, month and day of the identified solar flares.
    b. Download 6 SDO/AIA frames at 131 Å and 193 Å the around the time that a solar flare. Do this for the top 5 solar flares.
    c. Document your results in a word processor software (e.g., *Microsoft Word*, *Google Doc*, *Libre Office Writer*, *Apple Pages*, etc.)
    d. Label and arrange them according to figure 3. You may or may not crop them. Notice if the solar flare disrupts the sensors just like in figure 3.

CHALLENGE 1:

1. Extend your data by considering the whole solar cycle 24 (2009-2019).
2. Make a histogram of X-class flares by year.
3. Observe how the occurrence of X-class flares vary with solar activity.
4. Download the daily video of the top 10 solar flare using the SDO Data Brower for AIA/HMI.

CHALLENGE 2:

1. Extend your data by considering M-class flares in 2013.
2. Make a histogram of the distribution of these X-class flares.
Use four (4) groups: M1-M5, M6-9, X1-X5 & X6-X9.
3. Make a stacked bar graph showing the number of M- and X-class flares per month.

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