Variation of Solar Flare Properties During Solar Cycles 24 and 25

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Abstract

Solar flares are eruptions that occur in the solar corona that produce X-ray and extreme ultraviolet radiation that can interfere with modern life by affecting power grids, GPS navigation, and telecommunication. Our research is focused on understanding the evolution of solar flare properties over the solar cycle. Using data from GOES's 16 and 18 Extreme Ultraviolet Irradiance Sensors (EXIS) instrument, we analyze the magnitude and duration of flares during the descending phase of solar cycle 24 and the ascending phase of solar cycle 25. Our results show that the duration of solar flares is not correlated with their magnitude. However, we find the frequency, magnitude, and duration of solar flares to be positively correlated with the sunspot number over the solar cycle. These results are in agreement with previous research that has shown a relationship between solar flare frequency and the solar cycle.

Background of Solar Flares

Solar Flares

Solar flares occur when the Sun's magnetic energy builds up, becomes unstable, and erupts, releasing electromagnetic radiation from the entire spectrum. Active regions are areas of magnetic fields. When conditions in active regions get unstable, magnetic reconnection occurs, resulting in the ejection of plasma particles into the solar system. There are five main classifications used when measuring the magnitude of a solar flare. These fall under the letters A, B, C, M, and X flares. These are all measured using the unit of peak flux in watts per square meter of X-ray wavelengths.

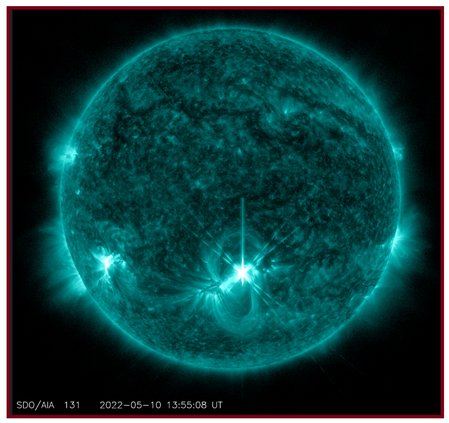

Fig 1. X1.5 class solar flare taken by NASA's SDO spacecraft in March of 2022

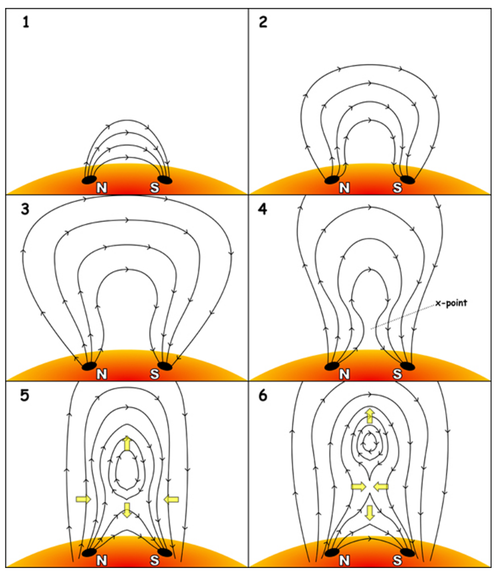

Fig 2. Diagram of magnetic reconnection in the context of a solar flare on the Sun.

Magnetic Reconnection

A simplified theory of magnetic reconnection is described as two oppositely pointing magnetic field lines reconnecting due to the gas pressure forces in the environment, overcoming the magnetic pressure in the magnetic field lines. In this process, magnetic energy is converted into kinetic and thermal energy.

Methods

By using flare data from GOES 16 and 18 Extreme Ultraviolet Irradiance Sensors (EXIS), we generate various scatterplots that depict solar flare magnitudes and durations during the descending phase of solar cycle 24 and ascending phase of solar cycle 25 (January 2017 - June 2023). Using NOAA flare logs based on GOES/EXIS data, we extracted flare properties including start time, end time, duration, and magnitude.

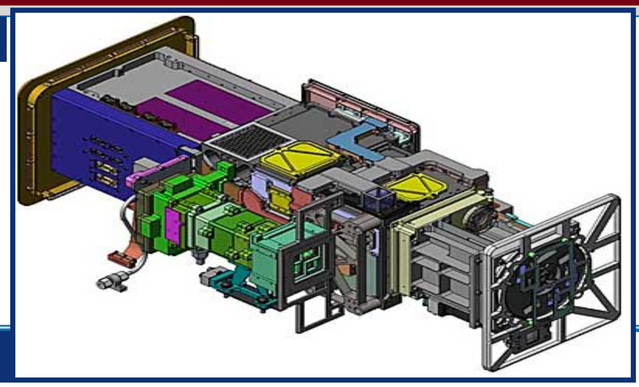

Fig 3. A blueprint of the Extreme Ultraviolet Irradiance Sensor used on the GOES R series satellites.

Results

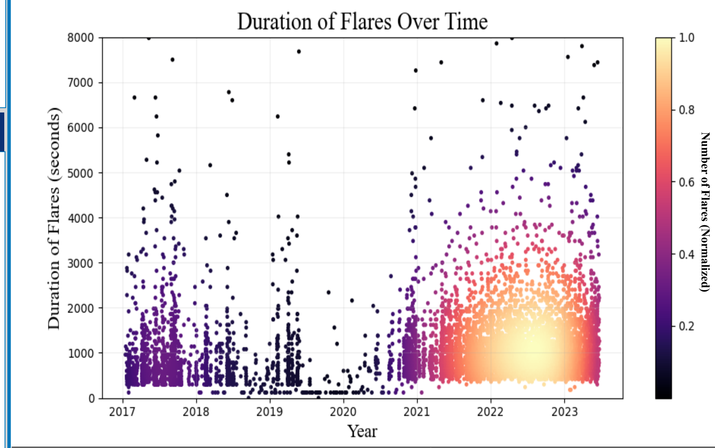

Fig 4. Scatterplot showing the duration of solar flares during the solar cycle.

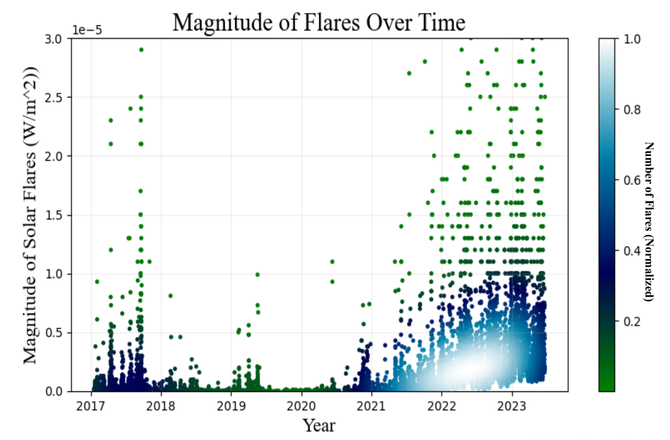

Fig 5. Scatterplot showing the magnitude of solar flares over the solar cycle.

Fig 6. Scatterplot showing the frequency of B class flares (peak flux range between 10^{-7} to 10^{-6}) over the solar cycle.

Fig 7. The frequency of C class flares (peak flux range between 10^{-6} to 10^{-5}) over the solar cycle.

Fig 8. Scatterplot showing the frequency of M class flares (peak flux range between 10^{-5} to 10^{-4}) over the solar cycle.

Fig 9. Scatterplot showing the frequency of X class flares (peak flux range 10^{-4}) over the solar cycle.

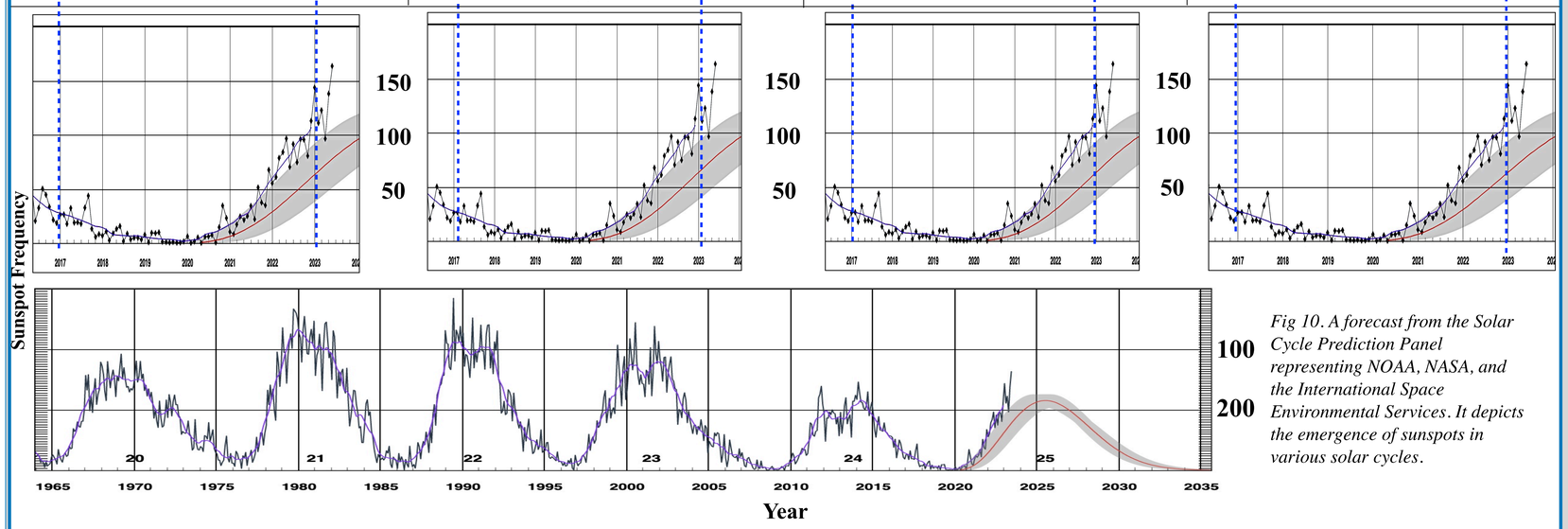

Fig 10. A forecast from the Solar Cycle Prediction Panel representing NOAA, NASA, and the International Space Environmental Services. It depicts the emergence of sunspots in various solar cycles.

Conclusion

Our results support previous research that indicates flare frequency has a positive correlation with the sunspot number along the solar cycle. We find the duration of solar flares to be independent of their magnitude. The frequency, duration, and magnitude of solar flares are positively correlated with sunspot frequency over the solar cycle. Figures 6-9 show that the higher the flare magnitudes are, the lower the frequency of flares occur during the solar minimum. In other words, the gap of few or no flares increases as the magnitude increases during solar minimum.

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