Relation between Two-Ribbon Topology and Flare Eruptivity

[1]Saba, T; [1]Sadykov, V.; [1]Martens, P

[1]Georgia State University

Contact: tsaba1@gsu.edu

Introduction

Coronal mass ejections(CMEs) as shown in Figure 2 are massive eruptions of plasma coupled with a magnetic field from solar corona that can be initiated during a flare event. Flare ribbons that are energy release signatures in the solar chromosphere lie and develop at the base of the flares. Based on the Standard Flare Model as shown in Figure 1, it has long been argued that a “two-ribbon flare” would have a higher probability of being eruptive. In this study, we consider two catalogs consisting of data taken from SDO, AIA. So, how are two ribbon flares related to whether the flare event will be accompanied by a CME?

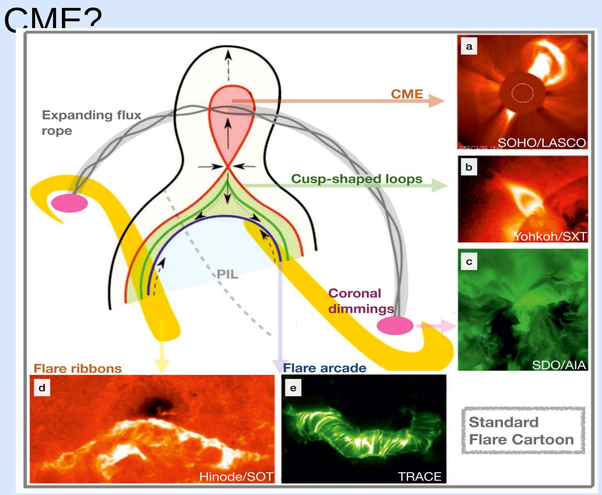

Figure 1: The Standard Flare Model
Diagram credit: Savcheva et al. 2016

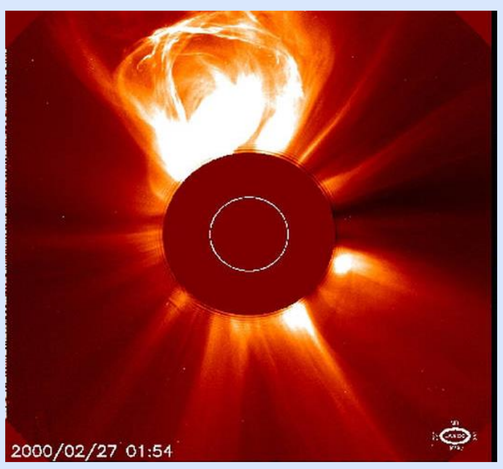

Figure 2: Coronal Mass Ejection; Image Credit: NASA

We try to investigate based on the model to find a relation, if any, between these underlying chromospheric features and flare eruptivity of an event.

Approach

Figure 3: Solar Dynamic Observatory
Image Credit: NASA

In this study, we consider two flare catalogs. Both catalogs consist of the flares observed by Atmospheric Imaging Assembly (AIA) instrument onboard Solar Dynamics Observatory (SDO) in the 1600A channel:

- Catalog 1: a catalog of 20 X-class and 30 M-class flares considered in Toriumi et al. (2017), Kazachenko et al. (2017)
- Catalog 2: a catalog of 40 C-class, 40 M-class, and 21 X-class flares down-selected from the larger catalog of 719 flares in Kazachenko et al. 2023

Methodology

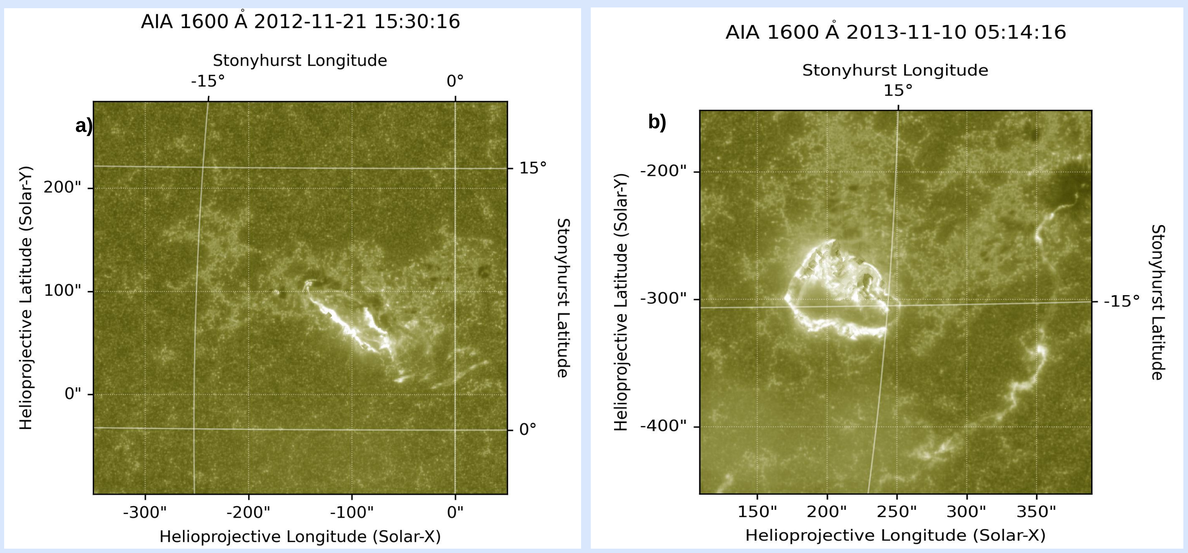

Figure 4: Two types of flare ribbons that appeared in two distinct events taken from this study **a) A two-ribbon flare b) A circular/compact ribbon flare**

1. Normalization and saturation correction using interpolation have been applied to the data first.
2. Pixels above saturation level 5000 counts/s were masked.
3. To understand the development of the ribbons, Graphics Interchange Format (GIF) images were made.
4. The GIFs were then distributed among three experts to vote on three categories: Two-ribbon, Not-two ribbon and Ambiguous to tag the flare events in order to recognize a two-ribbon topology in them.

Results

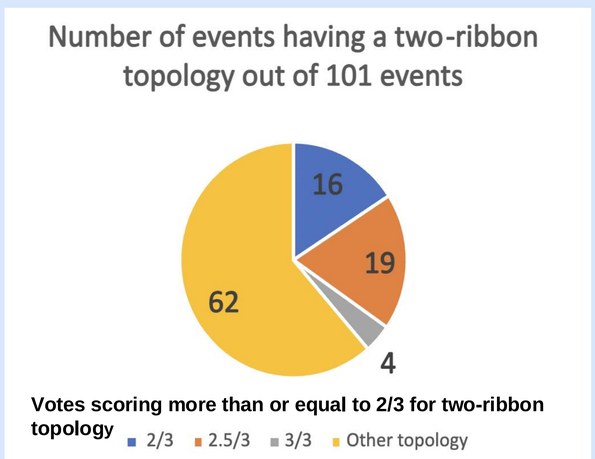

Figure 5: The sample of 101 C, M, X events have **39 two-ribbon** flares as per voted by experts

Figure 5 shows the results of the two-ribbon classification of events in Catalog 2. 39 events receive the combined two-ribbon score of 2/3 or more (i.e., at least two experts voted for that flare as for the two-ribbon flare), while 62 flares are determined to be not two-ribbon. Notice that partial scores are obtained when one expert votes for more than one category.

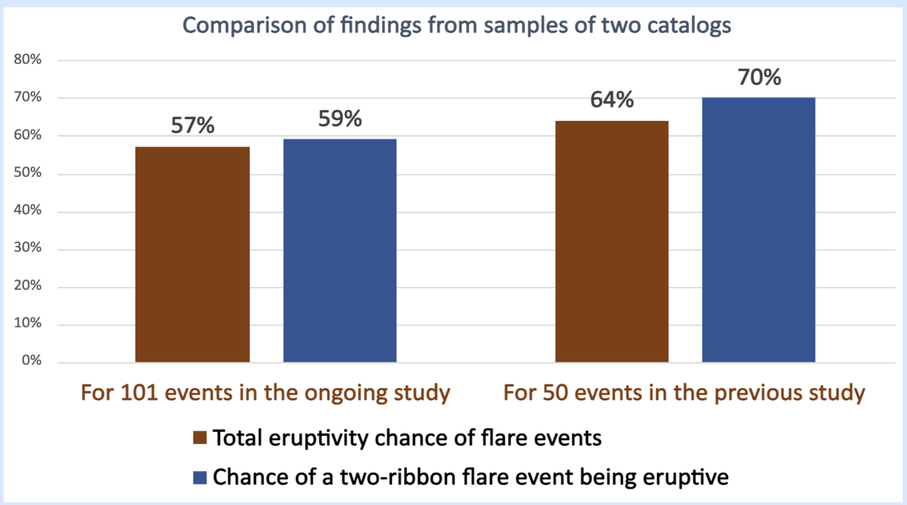

Figure 6: Comparison of the eruptivity in two studied flare samples (50 flares and 101 flares). The catalog of 50 flares has higher eruptivity, both overall and for the flares with two-ribbon topology.

In Catalog 2**, 57 out of 101** flares irrespective of class are eruptive. In Catalog 1, **32 out of 50** flares have been found eruptive. Most X-class two-ribbon flares have been found as eruptive (as might be expected) and it is common in both catalogs.

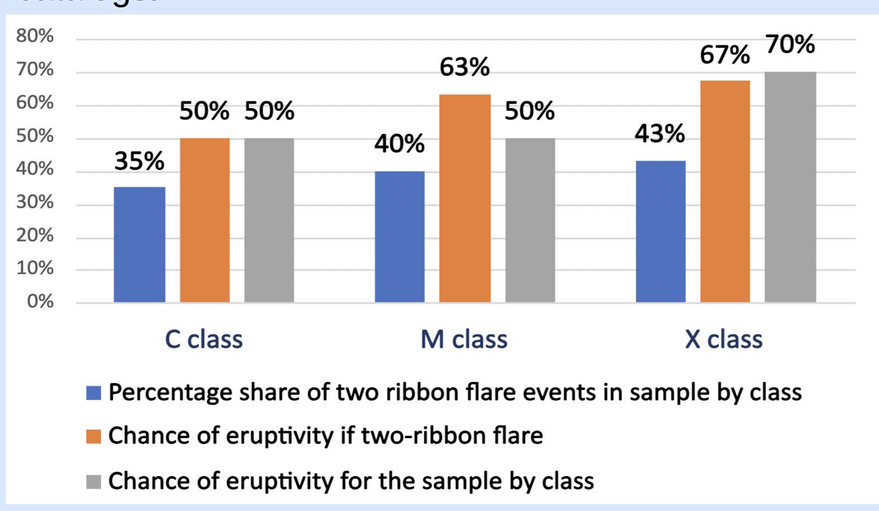

Figure 7: Catalog 2 results. **50%** of both C and M class flares taken in the sample are eruptive. Among these, **50%** and **63%** have a two-ribbon topology respectively. **70%** of X-class flares in the sample are eruptive and **67%** of these have a two-ribbon topology

Conclusion

- The percentage of flares with unambiguous two-ribbon topology is less than 50% for any flare class. The fraction seems to increase with class.
- Both the catalogs indicate high chances of the two-ribbon flare being eruptive (70% in Catalog 1 and 59% in Catalog 2). Catalog 2 shows that the fraction increases with the flare class.
- It can be concluded that the chance of eruptivity of any two-ribbon flare has been found comparable to the overall eruptivity in the considered catalogs: 70% against 64% for Catalog 1 and 59% against 57% for Catalog 2.
- To draw more statistically significant conclusions, we will analyze the entire catalog of 719 flare events in the near future.

References

1. Kazachenko, M. D., Lynch, B. J., Welsch, B. T., & Sun, X. 2017, The Astrophysical Journal, 845, 49
2. Kazachenko,M.D.2023,The Astrophysical Journal, 958, 104,
3. Savcheva, A., Pariat, E., McKillop, S., et al. 2016, The Astrophysical Journal, 817, 43, doi: 10.3847/0004-637X/817/1/43
4. Toriumi, S., Schrijver, C. J., Harra, L. K., Hudson, H., & Nagashima, K. 2017, The Astrophysical Journal, 834, 56,

Acknowledgement

I would like to acknowledge the contributions of Petrus Martens, Viacheslav Sadykov, and Griffin Goodwin in identifying the two-ribbon flare events. Thanks to Maria Kazachenko for sharing the catalog of 719 flares.