

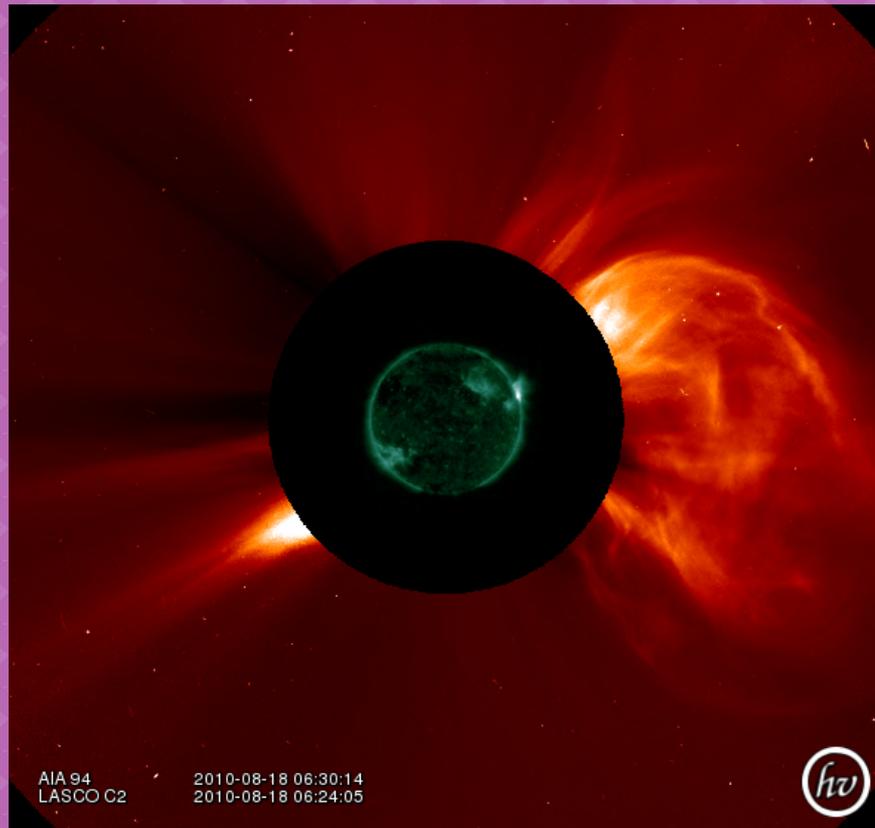
CAN CORONAL DIMMING BE USED TO FORECAST CMES?

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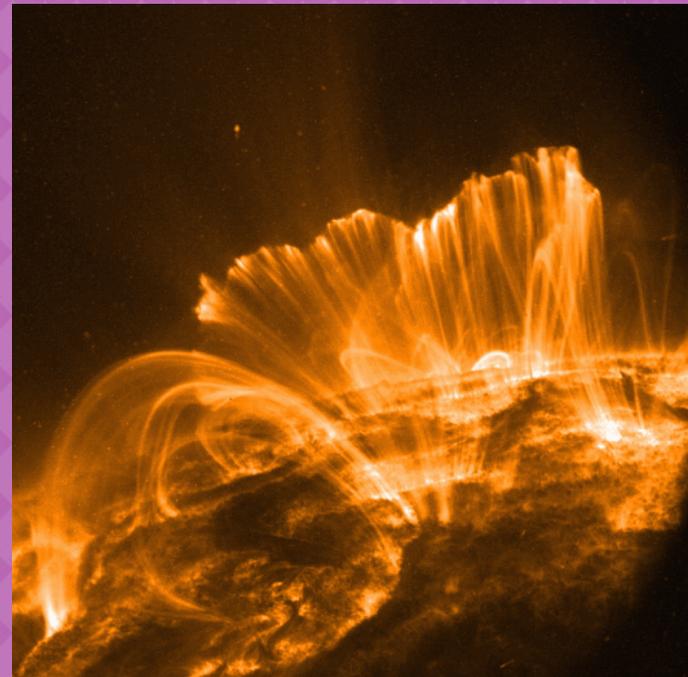
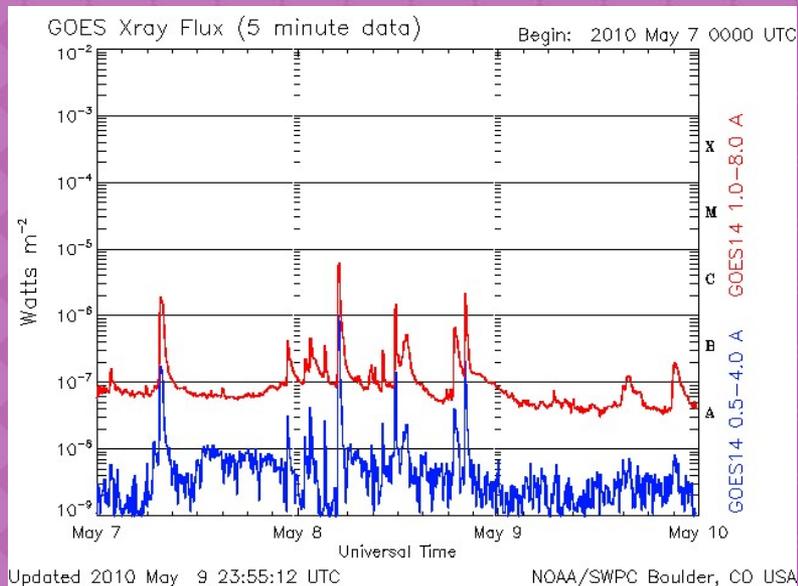
PROJECT GOAL

Study the parameters of flares that exhibit coronal dimming and coronal mass ejections (CMEs) to better understand the relationship between coronal dimming and CME properties.

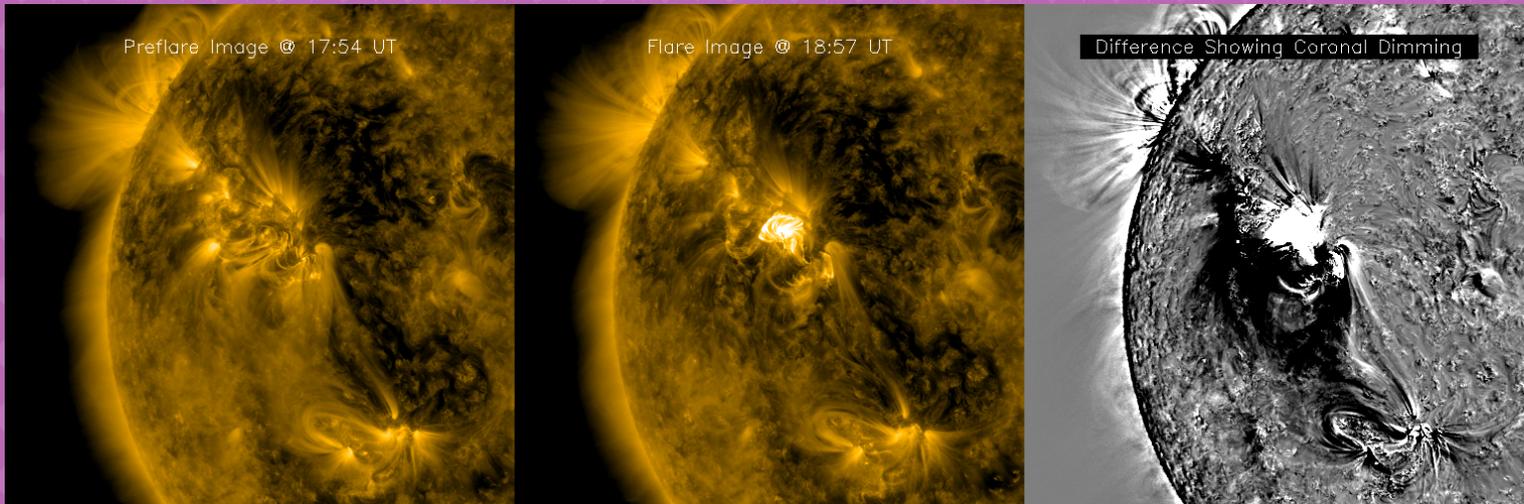


DEFINITIONS: FLARE

A solar **flare** is a sudden eruption of magnetic energy released on or near the surface of the Sun, which is usually associated with sunspots and accompanied by bursts of electromagnetic radiation and particles.

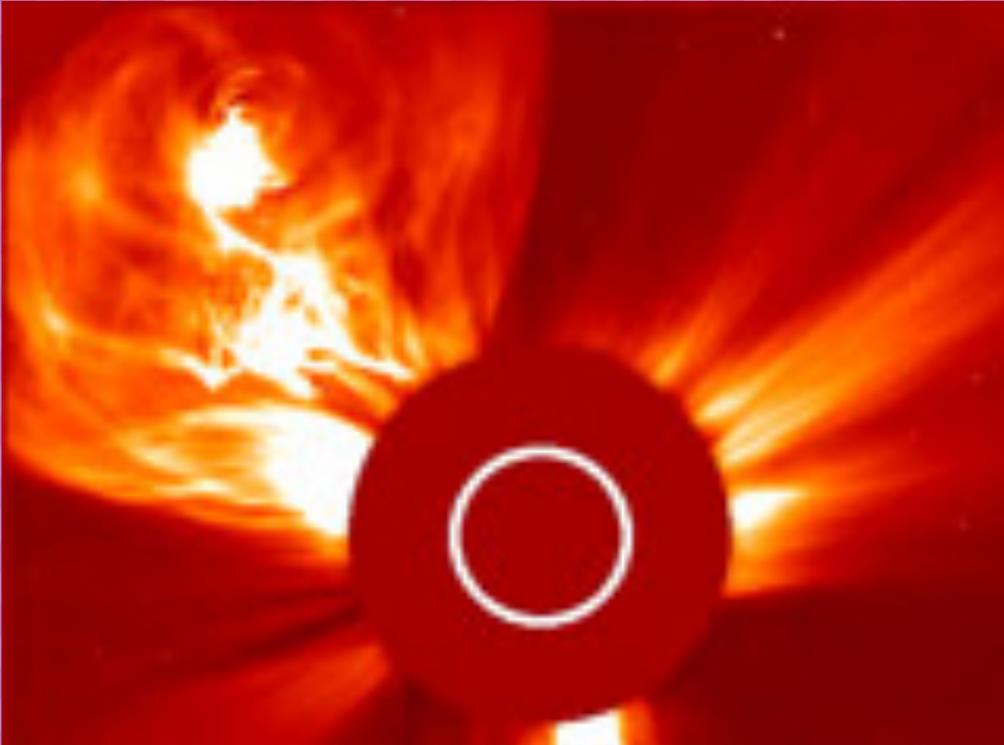


DEFINITIONS: CORONAL DIMMING



Coronal dimming is the darkening of a coronal feature. The dimming during a flare is often associated with the material lost during a CME.

DEFINITIONS: CORONAL MASS EJECTION (CME)



A **coronal mass ejection** is when the Sun's surface erupts and ejects material which leaves the corona at high speeds. CMEs can contain 10^{12} kg of material and can have speeds up to 3000 km s^{-1} .

WHY DO WE CARE?

- If a CME forecasting tool could be established from coronal dimming parameters, it would give people the warning they need to avoid serious technical disruptions from CME impact.
- A CME arrives at Earth days after the flare goes off. The warning time given by using EVE data, which is available minutes after a flare, is critical for the prediction of space weather.
- A forecasting tool would provide warning time so that people would be prepared in time so that limited electrical, satellite, communication, GPS, or airline problems could be mitigated.

WE CARE BECAUSE WE WANT TO
AVOID SITUATIONS LIKE THIS....

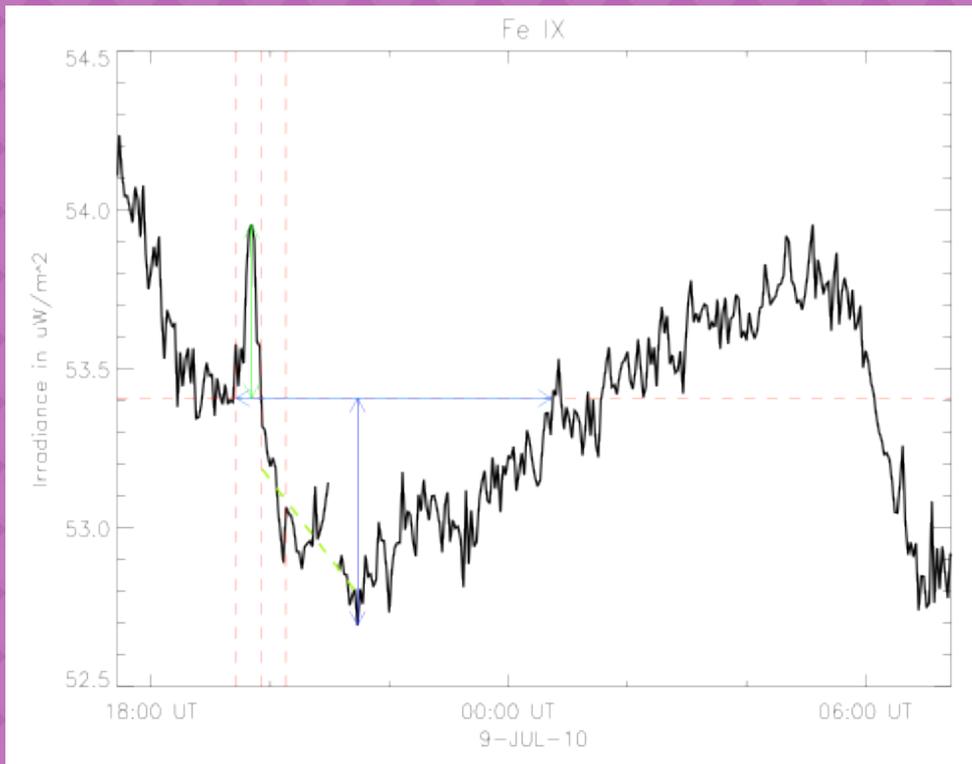
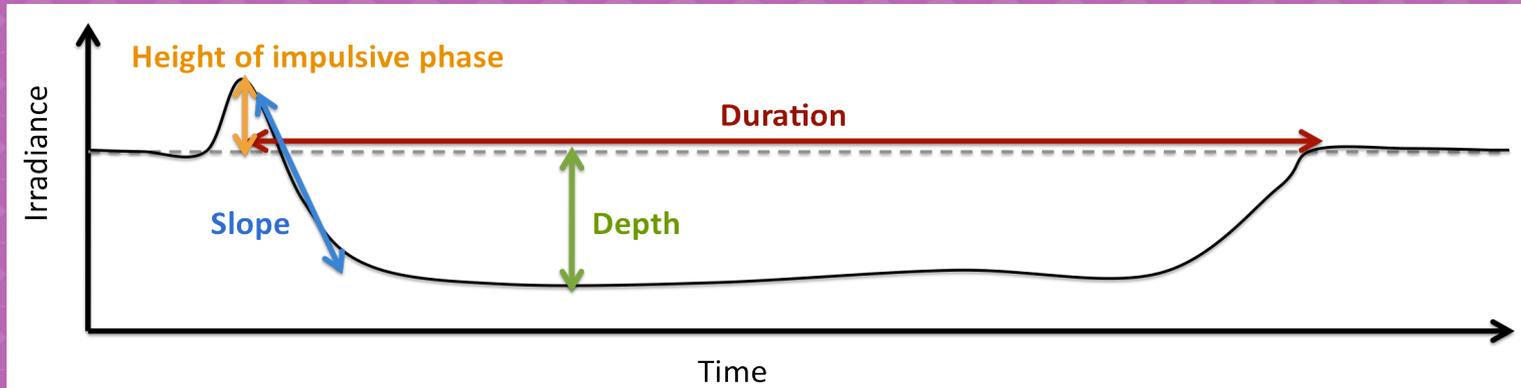


A transformer that was damaged by space weather.

WHAT I'VE DONE USING MY AUTOMATED IDL PROGRAM

- Analyzed 55 flare events that have coronal dimming mainly looking at 3 specific Iron light curves using EVE (EUV Variability Experiment) data.
 - Fe IX (17.107nm, 0.65 million K)
 - Fe XII (19.512nm, 1.35 million K)
 - Fe XIV (21.133nm, 1.86 million K)
- Matched the times and locations of these flares with CMEs observed by SOHO, and STEREO. Of the 55 flares, 34 had CMEs. Of those, 10 had complete CME catalog entries.
- Ran correlations between the flare parameters and the CME parameters to see which of the relationships could have the strongest relationships.

FLARE PARAMETERS



SDO-EVE data
can be found at
[http://
lasp.colorado.edu/
eve/](http://lasp.colorado.edu/eve/)

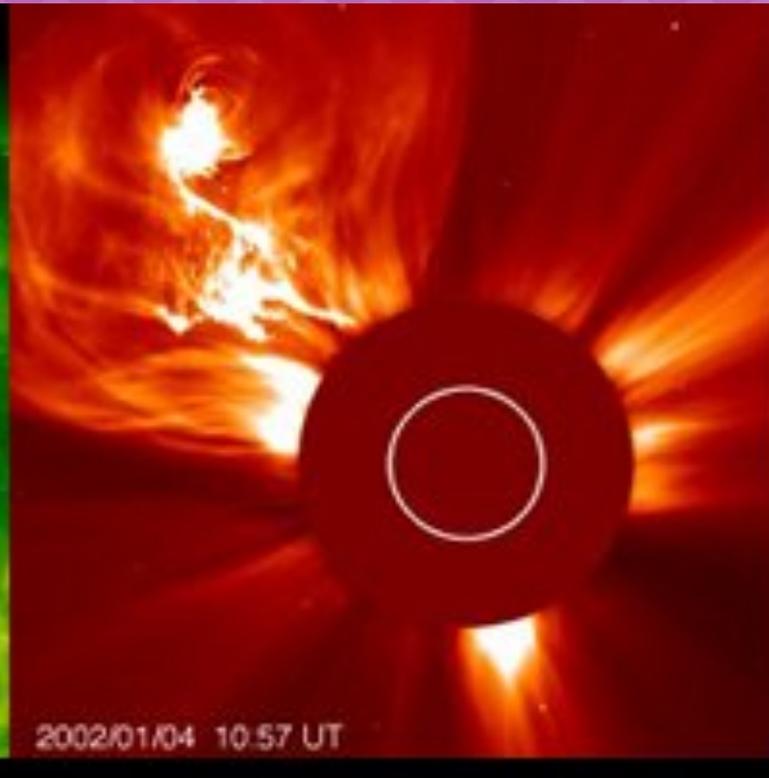
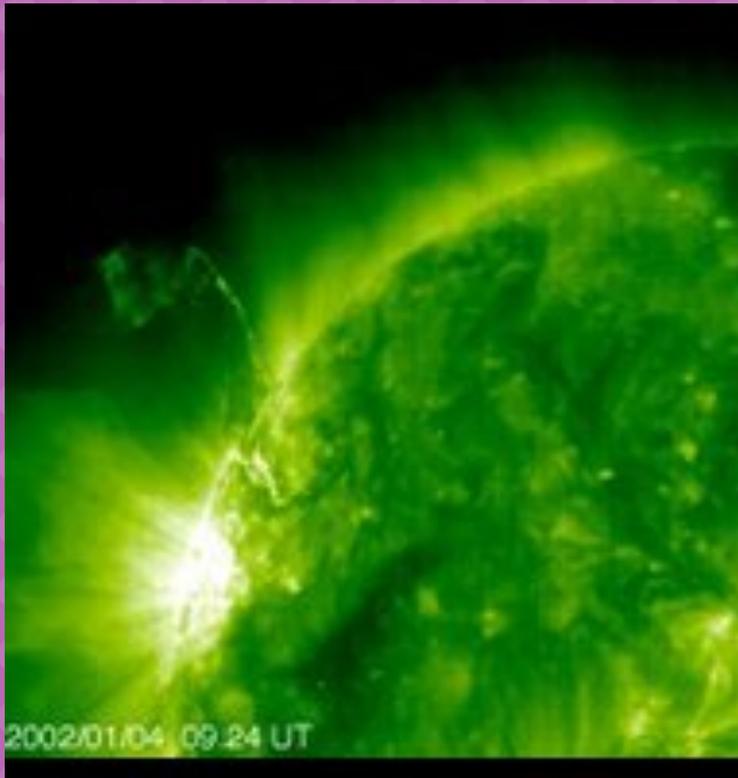
HOW DOES MY PROGRAM WORK?

- ◉ Given a flare id, it extracts the EVE data for Fe IX, Fe XII, and Fe XIV and plots the 3 light curves.
- ◉ The GOES X-ray data defines the start time and I manually select the end of the coronal dimming which determines duration. Depth, slope, and height are calculated automatically.
- ◉ The program re-plots everything, with the above parameters drawn in.
- ◉ Then it tests for CMEs during the time frame of the flare.
- ◉ All CME and flare parameters are saved in a IDL save set.

OK, SO... HOW ARE DEPTH, HEIGHT, AND SLOPE CALCULATED?

- ◉ The **depth** is calculated by finding the minimum within the flare duration, using the pre-flare level irradiance level as a baseline.
- ◉ **Height** is found by finding the maximum prior to the GOES x-ray peak so that the peak is during the flare's impulsive phase.
- ◉ **Slope** is the tricky one to program... but it is calculated by applying a linear fit to the data from the time of the GOES x-ray peak to one-half the depth of the coronal dimming.

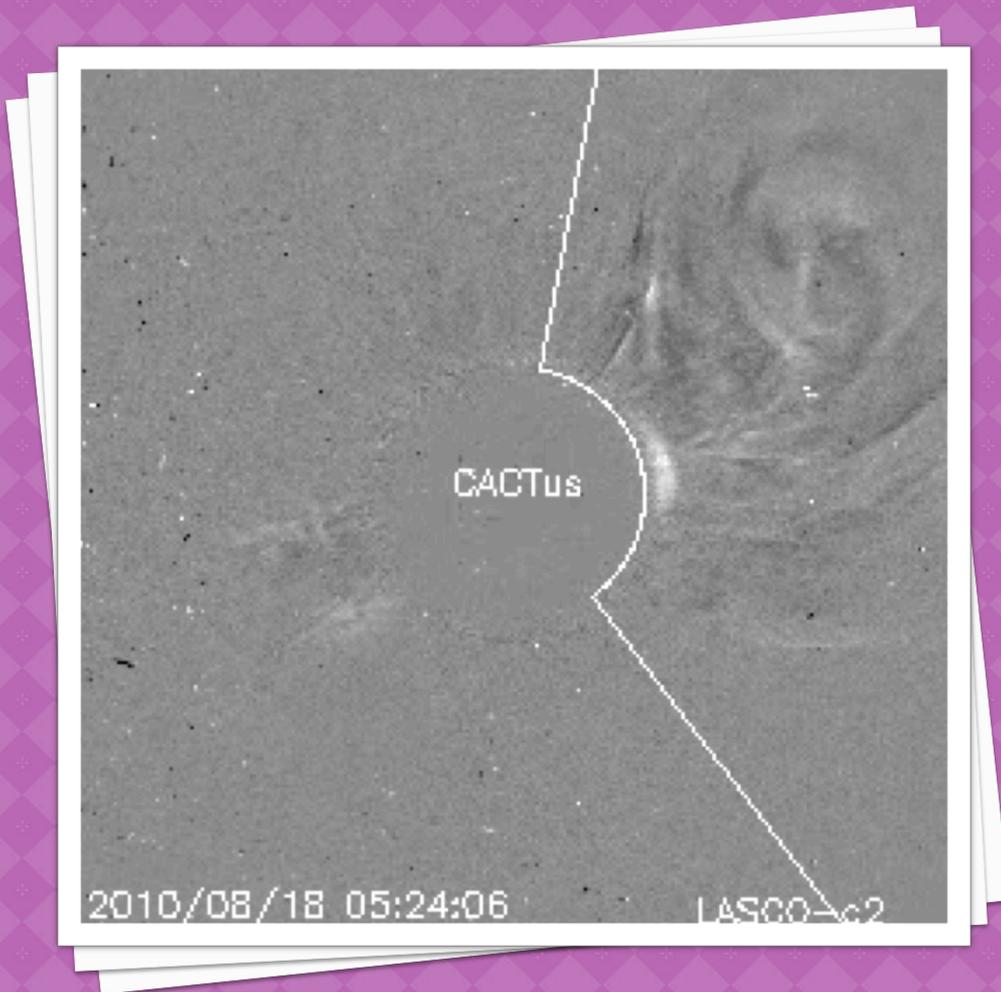
MATCHING FLARE/CME LOCATION



HOW DOES MY CODE FIND CME MATCHES?

- ⦿ Matched based on flare location and time of the flare.
- ⦿ First, take flare location and determine the expected CME location for SOHO, STEREO A and B.
- ⦿ Using the CME catalogs, find a CME within 45° within the expected location and a CME start time within 3 hours of the flare start time.
 - Use LASCO for limb flares
 - Use STEREO A & B for disk-center flares

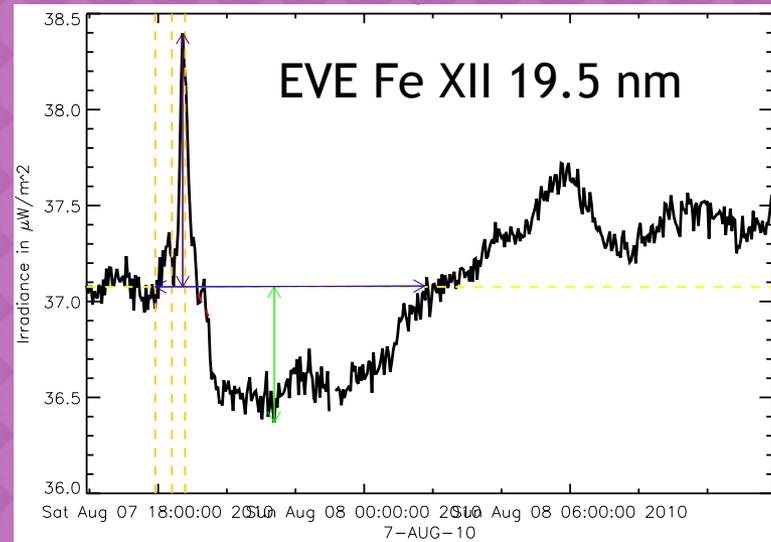
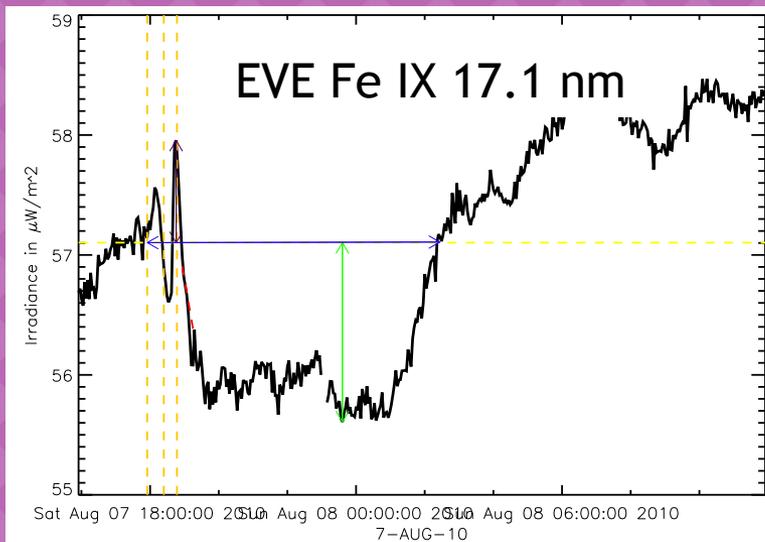
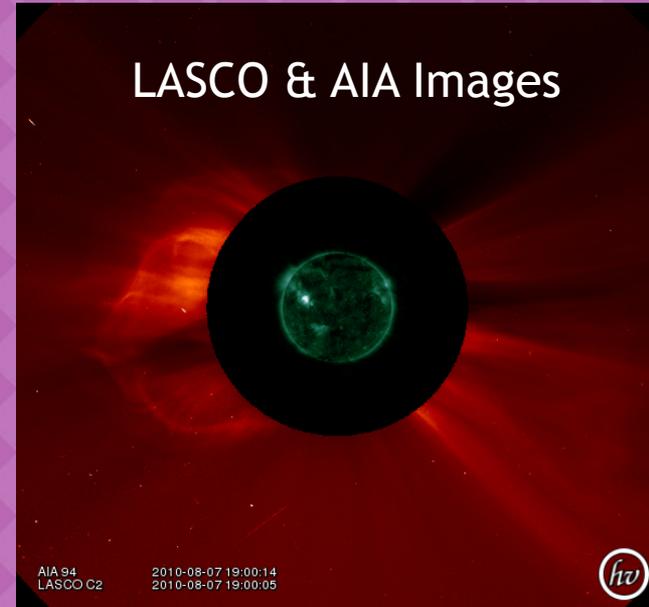
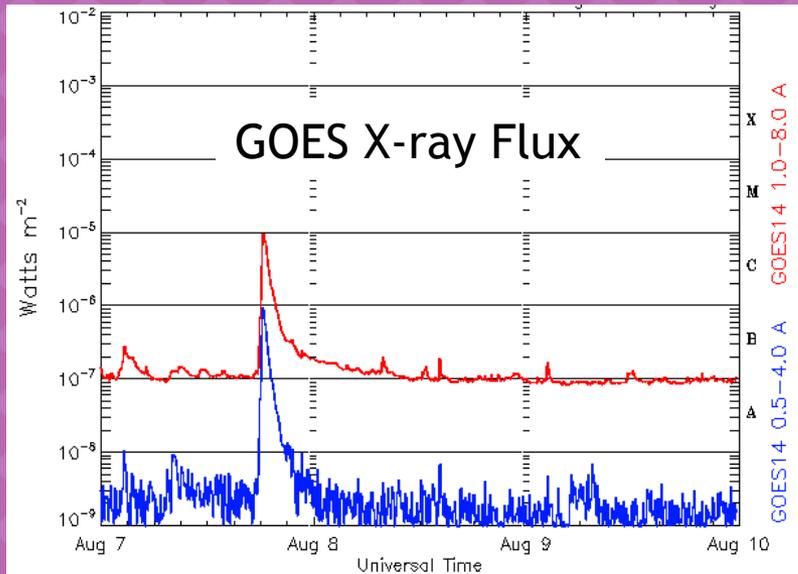
CME PARAMETERS



- ✧ Angular Width
- ✧ Average Velocity
- ✧ Second Order Initial Velocity
- ✧ Second Order Final Velocity
- ✧ Second Order 20R Velocity
- ✧ Mass (future task)

CME data can be found at the CACTUS catalog at <http://sidc.oma.be/cactus>
And CDAW catalog at http://cdaw.gsfc.nasa.gov/CME_list.

EXAMPLE: 07 AUG 2010



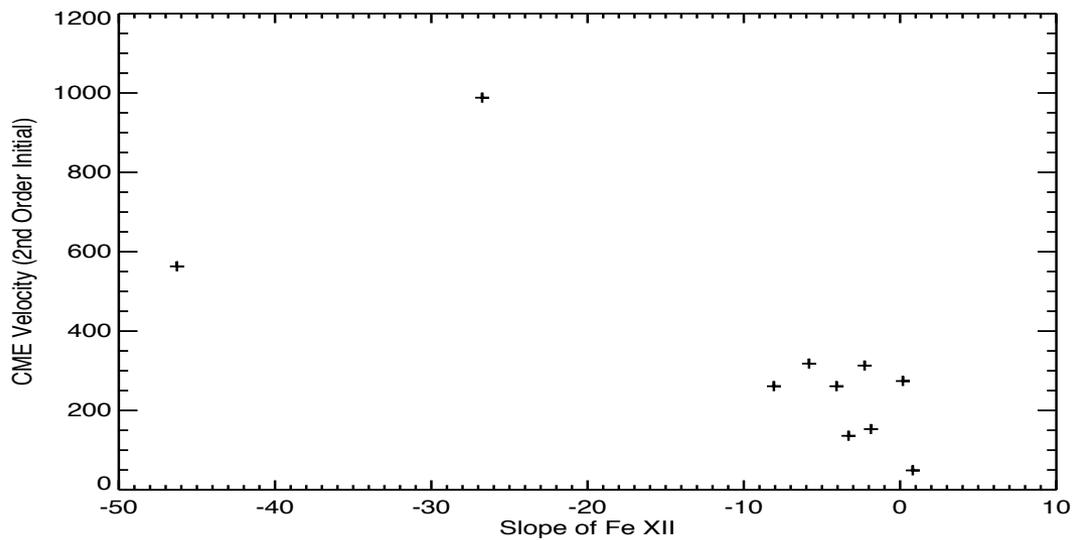
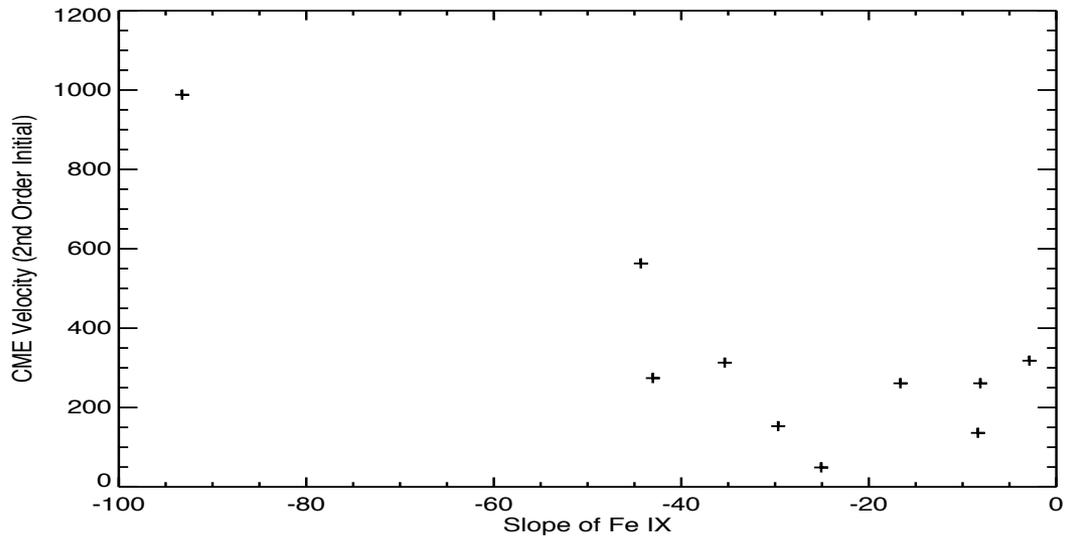
FINDING CORRELATIONS

- Ran correlations between the parameters of the two Iron lines against the parameters of the CMEs.
 - Fe XIV did not consistently show dimming so no correlations were calculated.
- Found the strongest correlations between
 - Fe IX Slope with CME Second Order Initial Velocity
 - Fe XII Slope with CME Second Order Initial Velocity
 - Fe XII Slope with CME Second Order Final Velocity

DATA TABLE

	Angular Width	Average Velocity	2nd Order Initial Velocity	2nd Order Final Velocity	2nd Order Velocity at 20R
Height Fe IX	-0.07	-0.27	-0.23	-0.21	-0.29
Depth Fe IX	0.4	0.19	0.4	0.59	0.08
Slope Fe IX	-0.02	-0.15	-0.82	-0.56	-0.57
Duration Fe IX	0.11	0.44	0.54	0.48	0
Height Fe XII	0.04	-0.27	-0.43	-0.47	0
Depth Fe XII	0.35	-0.08	0.01	0.44	-0.3
Slope Fe XII	-0.21	-0.17	-0.73	-0.71	-0.44
Duration Fe XII	0.19	-0.04	0.19	0.48	-0.36

CORRELATION PLOTS



CORRELATIONS JUSTIFIED?

- ◎ Yes.
- ◎ Slope is strongly correlated to initial velocity because the steeper the slope, the dimming is occurring faster, and the material is expected to be moving faster.
- ◎ Depth is expected to be related to CME mass, but this analysis is not complete. CME mass and velocity are correlated, so the result that depth is correlated with velocity is reasonable.

FUTURE PLANS

- ◎ There is high confidence in the EVE data for the Iron parameters, the focus will go into calculating parameters of CMEs. There are just not enough CME data at this time to have an accurate forecast of CMEs from coronal dimming measurements, but there is great promise to use coronal dimming as a CME forecast tool in the near future.
- ◎ For my senior project, I plan to focus in on the CME parameters of mass and the different velocities (average, second order initial, second order final, and second order 20R).

CREDITS

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- www.helioviewer.org
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- www.nasa.gov
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Questions?