Stealth Coronal Mass Ejection Detection

Extended Abstract

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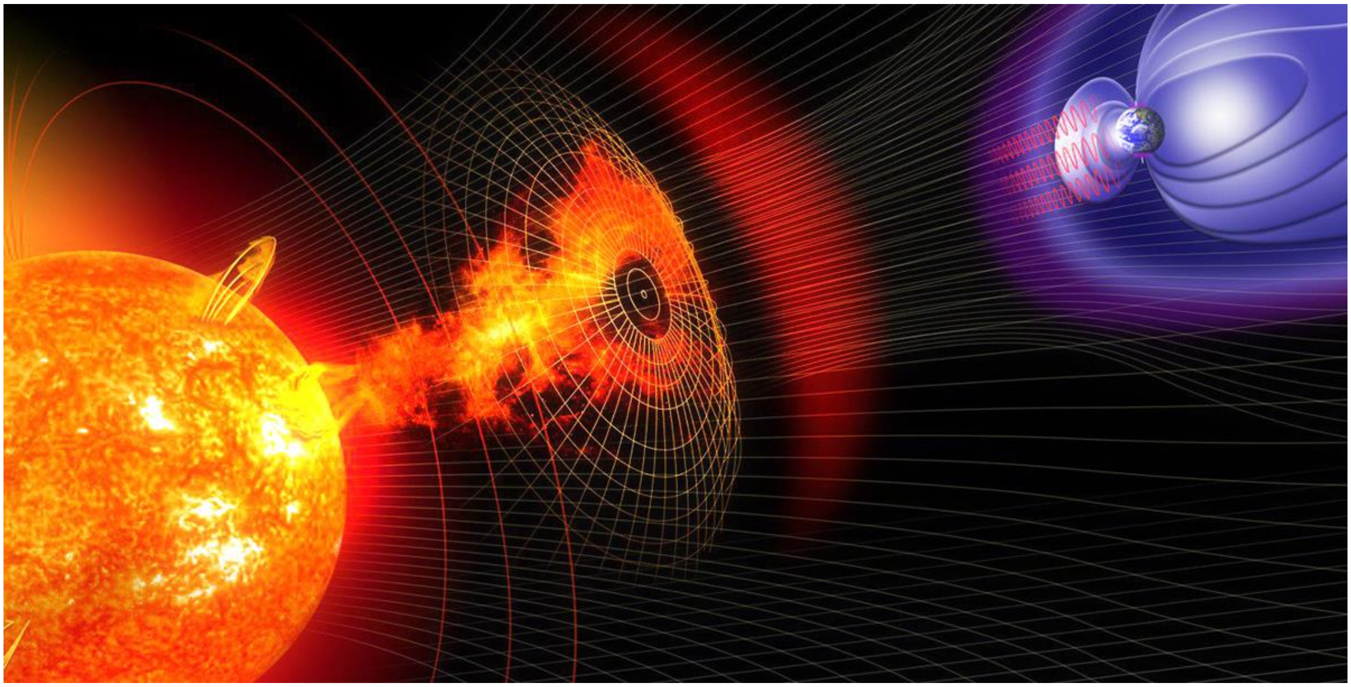

Figure 1: An artistic representation of a coronal mass ejection

ABSTRACT

This project intends to help with the detection and characterization of stealth coronal mass ejections (CMEs) by classifying coronal dimming events in SDO EVE telemetry. Stealth CMEs are solar events not preceded by obvious solar activity wherein portions of the Sun's corona erupt into space. These are distinct from classic CMEs mainly in their lack of obvious preceding solar activity. SDO EVE is an instrument in space equipped with spectrographs and other measuring devices, and is maintained by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder [2].

KEYWORDS

Stealth, CME, Coronal Mass Ejection, detection, coronal dimming, LASP, SDO EVE, spectrograph, data mining

ACM Reference format:

S. Polson, T. Albee. 2018. Stealth Coronal Mass Ejection Detection. In *CSCI-4502, Boulder, Colorado USA, March 2018 (CSCI-4502)*, 3 pages https://github.com/tyleralbee/Stealth-CME-Detection.

1 PROBLEM STATEMENT/MOTIVATION

Stealth CMEs are a hot topic in space science; the mechanisms behind these mysterious solar eruptions were just uncovered last year (2017) [3]. This is largely why LASP is actively involved in stealth CME research. The authors of this project became involved with this work by reaching out to scientists at LASP to see what areas of research their data mining knowledge could potentially assist. This led the authors to their subject matter experts (SMEs): James Mason and Don Woodraska. More information about them can be found in the "Acknowledgements" section.

In short, this project aims to create the first ever catalog of stealth CMEs by cataloging coronal dimming events—that are unrelated to classic CMEs—in the SDO EVE data. Coronal dimming events are the mark of CMEs because CMEs leave behind temporary voids when they depart from the solar corona. Information about a CME, such as its mass and velocity, can be learned by analyzing these dimming events. As such, this project also aims to characterize the dimming events in terms of slope and depth. This would extend prior work done in this field. In particular, this project will expand upon the work done by James Mason in his PhD dissertation [1], where he pioneered methods of characterizing classic CMEs by observing coronal dimming events.

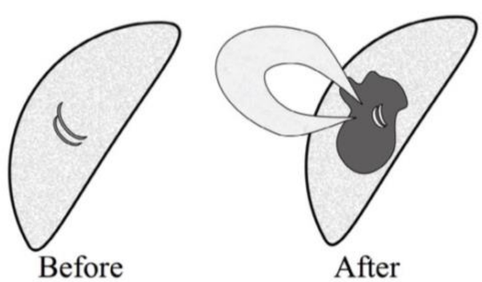

Figure 2: An illustration of a void left in the Sun's corona after a solar eruptive event

Stealth CMEs differ from classic CMEs in that they lack any obvious preceding solar activity. They also tend to be lower in magnitude compared to classic CMEs and because of this, novel detection methods will have to be invented during this project. It will also be trickier to detect stealth CMEs because solar flare events (or similarly known solar activity) cannot be used to "trigger" searches for them. This project is essentially trying to find a smaller needle in a larger haystack.

2 LITERATURE SURVEY

As previously mentioned, stealth CMEs are a relatively new area of research, and this project is the first of its kind. However, it will expand upon work done by James Mason in his PhD dissertation entitled "Solar Eruptive Events: Coronal Dimming and a New CubeSat Mission." In his dissertation, Mason pioneered methods of characterizing classic CMEs by observing coronal dimming events. This project will mine for data in essentially the same dataset used by Mason (SDO EVE telemetry), so his methods can serve as the lead inspiration for methods that will ultimately detect stealth CMEs.

3 PROPOSED WORK

This project has two main goals: to detect coronal dimming events in SDO EVE emission line time series data without the use of solar flare event times to trigger the search, and to characterize the detected dimming events in terms of slope and depth. To accomplish this, the authors will take two main approaches. The first approach will be to look for slope drops in derived values from the SDO EVE data set. Admittedly, the authors do not yet know which values will be derived or how they will be derived (because that requires astrophysical knowledge that they do not yet have). The second approach will be to look for new emission lines temporarily appearing in the spectrum view of the SDO EVE data, but again, which lines to look for, or how, has yet to be determined.

The authors will work closely with their SMEs to develop detection methods. Data cleaning will involve assigning missing values to null values; the current proposed method is to assign the value "-1" to all null values. Another consideration is the fact that a power anomaly in the *MEGS-A* spectrograph (described in the "Data Set" section) rendered the instrument unable to measure wavelengths from 6nm to 33nm beyond May 26, 2014. Aside from that, no other cleaning is expected to be needed, as the SDO EVE data has already normalized the measured solar irradiance values to what they would be at a distance of 1 AU. No data integration is planned because the SDO EVE data has all needed information, although it may be useful to compare our results with catalogs of known CMEs (to distinguish stealth CMEs from class ones). The methods used in this project will differ from those identified in the "Literature Survey" section in that they will detect stealth CMEs instead of classic CMEs.

4 DATA SET

The data set for this project comes from SDO EVE telemetry. SDO EVE stands for "Solar Dynamics Observatory Extreme ultraviolet Variability Experiment," and it is an instrument that has been in orbit in space since 2010 [2]. Before describing the data, it is pertinent to better describe what the instrument is.

Onboard the EVE instrument are two spectrographs, known as *MEGS-A* and *MEGS-B*. Together, they measure the irradiance of the Sun's spectrum from 6nm to 106nm. *MEGS-A* failed due to a power anomaly on May 26, 2014, so after that date, only wavelengths from 33nm to 106nm are measured. Two forms of data are regularly produced by this instrument: "lines" data and "spectrum" data. The "lines" data represents the solar irradiance measurements in terms of irradiance (in W/m^2) at selected emissions lines (elements such as Fe XVIII or He II). The "spectrum" data represents solar irradiance across the whole spectrum of wavelengths. Measurements are taken with a ten second cadence for three hours of every day. Before the *MEGS-A* power anomaly, measurements were taken every ten seconds all hours of the day. The instrument is still in operation and has been in operation since February 11, 2010.

The data is provided and maintained by LASP, which is where Shawn Polson is employed.

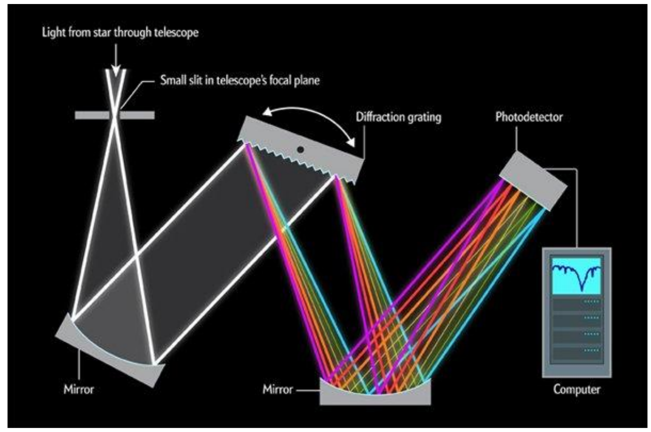

Figure 3: A rough depiction of how a spectrograph splits light into its component wavelengths

5 EVALUATION METHODS

5.1 Metrics

- **Accuracy** (**Accurate Detection Rate**) – The ADR of our detection of a stealth CME event. What percentage of the time does the software trigger a false positive? a false negative? In order to achieve the highest possible accuracy, the events could first be checked against a known database of CMEs that aren't "stealthy".
- **Applicability** – The team's success depends on the applicability of the gained knowledge. Finding and cataloging stealth CMEs from past data would be beneficial to the scientific community, and this project will partially be evaluated in terms of how helpful its results are. The applicability of the project can be quantified into a number on a scale of 1-10 (for example).
- **SME Approval Rating** – The project is under supervision by two subject matter experts, Don Woodraska and James Mason. The feedback given to us by Don and James on our work can be quantified into a number on a scale of 1-10 (for example).

5.2 Existing Solutions

James Mason has devised an existing solution for the detection and categorization of classic (non-stealth)

CMEs using Python. These CMEs detected by Mason's code have been cross checked with pictures to prove that the dimming events in the spectrograph data are indeed coronal mass ejections. Recall that a *stealth* CME has no obvious preceding solar activity in the corona, but still results in a CME-like dip in the spectrograph data. The logic in Mason's software to detect CMEs in the data can thus be used as a starting point for the logic of detecting stealth CMEs.

6 TOOLS

- **LaTiS** – LaTiS is a data modeling framework developed and maintained at LASP (partially by Shawn Polson). It employs a "functional data model" which captures the functional relationships between attributes, and will serve as an alternative to Python or IDL. LaTiS will also serve as a more powerful file conversion tool; when working with FITS files, it is often advantageous to convert to CSV files.
- **Python** – Python will be the language used to compile data into graphs and perform analysis. The version used throughout the project will be Python 3.6.
- **IDL** – IDL will be the last resort in cleaning, preprocessing, and analysis. The FITS files and the saveset given to us is native to IDL. If the authors have problems with LaTiS or Python, they will use IDL.
- **Pandas** – The pandas library will be used for the creation and manipulation of dataframes within Python.
- **Matplotlib** – The generation of graphs and charts for interpretation will be done using the matplotlib library in Python.
- **Numpy** – numpy will be used for the high-level manipulation of numbers within the dataframe
- **savReaderWriter_**– savReaderWriter is used to take the saveset originally created in IDL and format it to be read into a Pandas dataframe in Python.
- **Jupyter** – Jupyter Notebook will allow for code, writing, and pictures to be cleanly interwoven. The technical presentation of findings will be most efficiently shown in Jupyter Notebook.

7 MILESTONES

7.1 Shawn - Programming Milestones

0. Optimize LaTiS to be accepting of FITS format files

1. Get data imported and readable in LaTiS

2. Clean data of NULL values in LaTiS

3. Experiment with the usefulness of LaTiS for data analysis

4. Compile the data into another saveset for future work

5. Use LaTiS to quickly and efficiently convert between FITS and CSV files

7.2 Tyler - Programming Milestones

0. Take the IDL saveset into Python and read it

1. Experiment with the plotting and visualization of the data in Python

2. Become acquainted with James' functions and methodology in Python

3. Make changes to James' functions and methodology in Python based upon theory developed during this project

4. Finalize and comment changes to James' functions and methodology in Python

5. Get extensive peer review on new code

6. Present new code/results to James Mason and Don Woodraska for professional evaluation

8 SUMMARY OF PEER REVIEW SESSION

On Wednesday, February 28th, 2018 at 2:12 PM Shawn and Tyler gave their presentation on stealth CMEs. The specialized feedback that was given to them by Professor Elizabeth Boese was to "Make sure [everyone] is involved!". When it comes to teams, project creation and execution, it is imperative that everyone is involved. They will also heed the advice of their professor by working closely with their SMEs—they have a wealth of knowledge to share and this project will leverage that whenever possible.

In addition, the peer review session assisted in the understanding of a data mining project as a whole. While the team does not need a specific question, the team needs to uncover meaningful information and make suggestions on the implementation of that knowledge. For example, one team specifically looks to answer a question – do baseball teams that travel to away games perform worse when travelling further? Another team, though, seeks to find the general strategy behind PUBG, a game that has incredible amounts of data to mine. Both teams seek to find meaningful information and implement it. However, one team has specifically nailed down the question they need to answer. This project leans towards the more general knowledge collection, since the topic is so new and complex.

ACKNOWLEDGMENTS

First on the list to thank is James Mason, who wrote his dissertation on CMEs and coronal dimming. James Mason is currently a post-doc at NASA's Goddard Space Flight Center. He provided the knowledge and inspiration for this project. Don Woodraska, another SME who works at LASP, deserves a massive thank you for the coordination and knowledge he has provided us. Work done in LaTiS was made possible by the LASP Web Team, with special consideration to Doug Lindholm the man who envisioned and created LaTiS back in the 1990s. The authors of this project are incredibly honored to be working among these extremely talented individuals.

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