Hunting Plasma from the Sun

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Project title: Automatic Detection and Characterization of Coronal Mass Ejections
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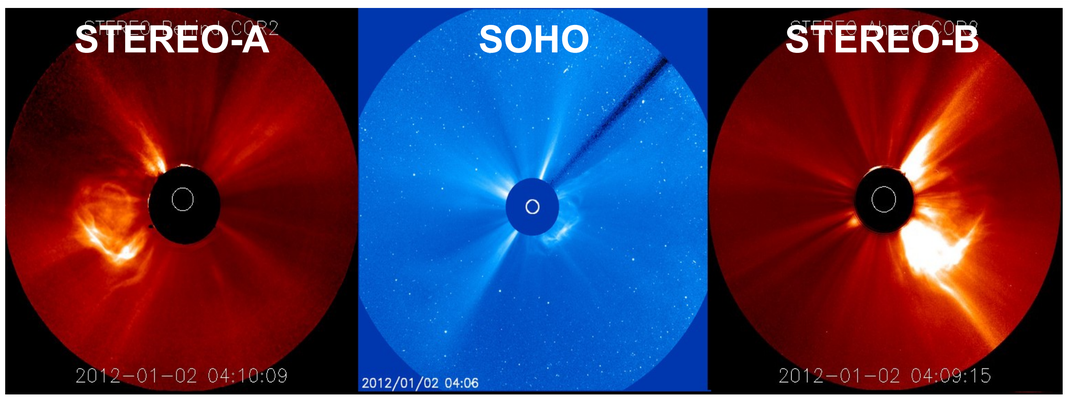
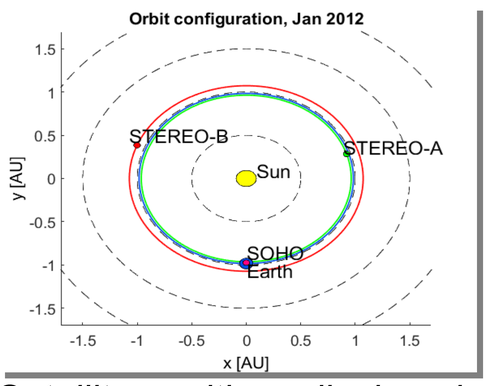
Introduction

The Sun influences the Earth in other ways than the climate. An example of such an influence are Geomagnetic storms caused by CMEs (Coronal Mass Ejections) which are expulled streams of plasma originating from the Sun, which can traverse the solar system and interact with the Earths magnetic field to create this effect. These storms can wreak havoc on electronic infrastructure, making the understanding and forecasting of such phenomena a great concern.
This project has built an automated pipeline to detect, characterize and model CMEs, by means of image processing performed on observations made from in-situ instruments.

Observations of Coronal Mass Ejections

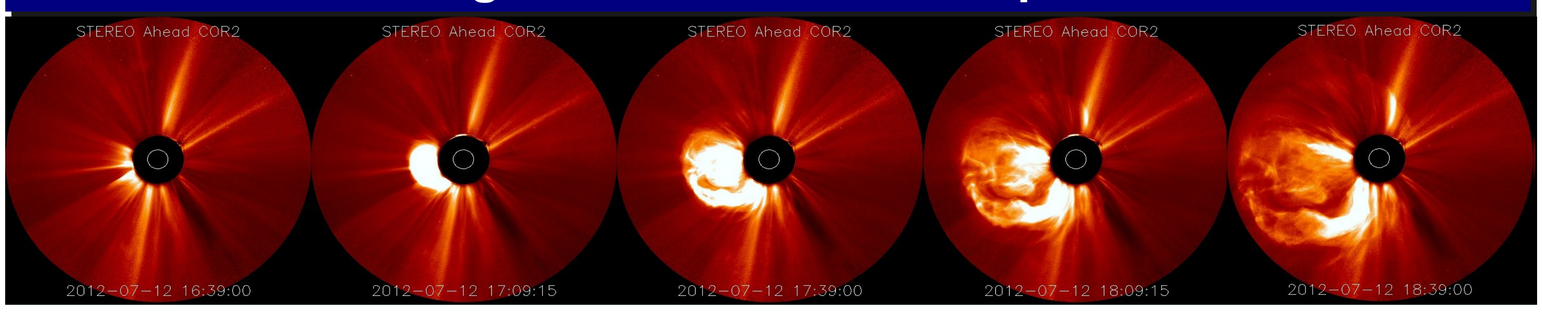


CME as seen from different perspectives by satellites STEREO-A & -B and SOHO. Pixel intensities are correlated with plasma-densities – black fields are blocked parts of the coronagraph, darker regions sparse plasma and white regions high density-plasma.



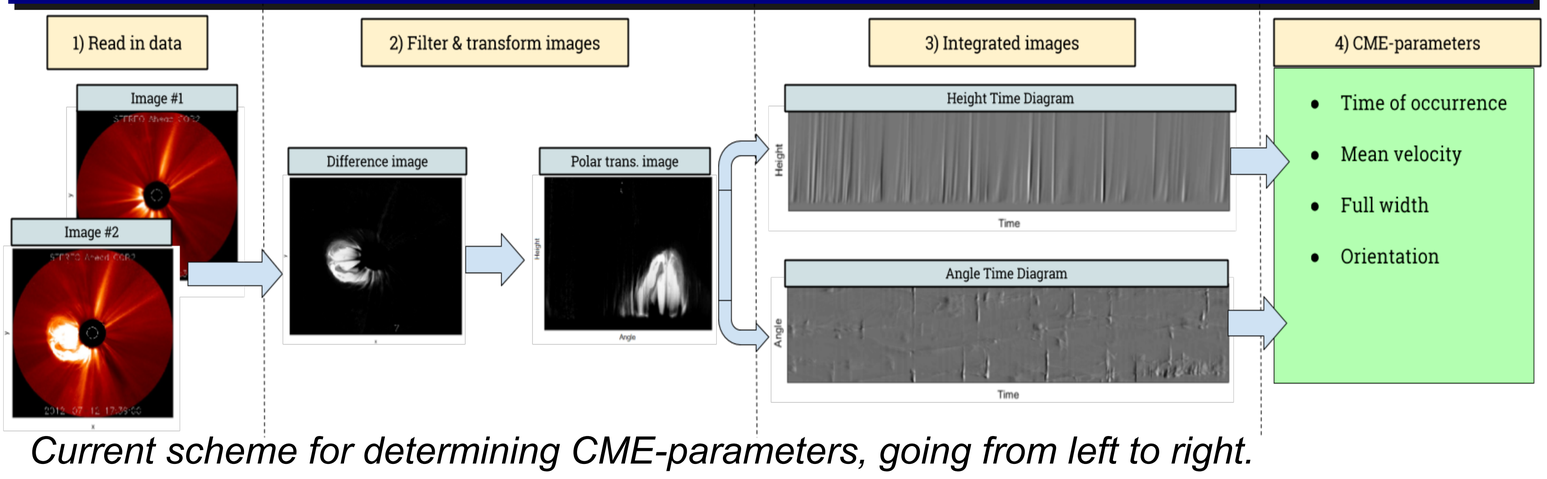
Satellite-positions displayed in the euclidean plane of the solar system, at the time of observations shown on the left.

Imageseries of CME-development



Observations from STEREO-A, starting from the left, taken at 30-min-intervals.

Flowchart of CME-TRAP



Current scheme for determining CME-parameters, going from left to right.

Methods

CMEs are the most significant features in the image-series of the differenced observations. This allows for simple, yet powerful segmentation of the phenomena.

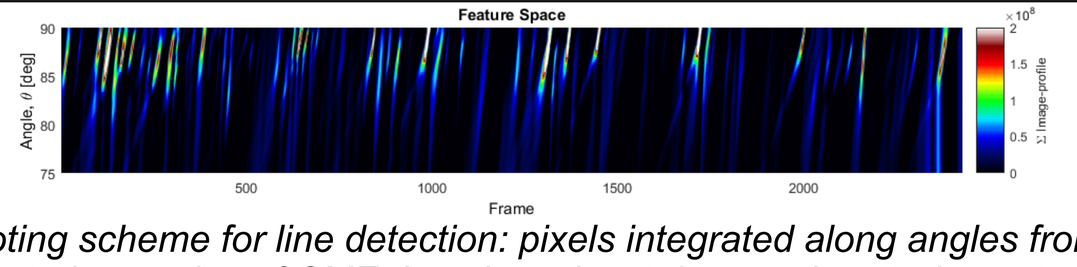
Transforming the differenced images to a feature space made up of the height above the Suns corona and angular orientation, it is possible to allow for simple descriptors to obtain information about the propagation of CMEs. The primary means include integration of pixel-intensties in two dimensions, creating height- & angle-time-diagrams. These images are then processed with blob- & line-detection-methodology to determine CME-parameters.

The algorithm developed for this study, abtly named CME-TRAP, has been implemented in MATLAB.

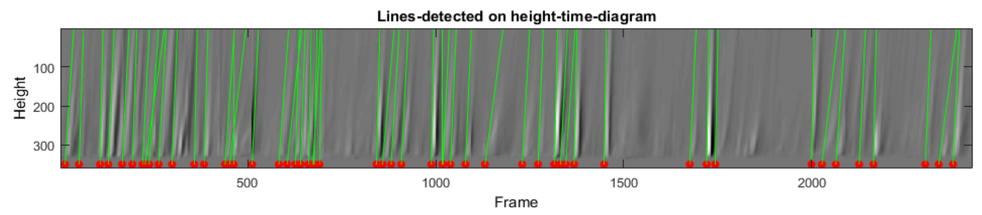
Preliminary Results

Reliable operation of the height-time-diagrams is well underway; the majority of determined velocities fall within the expectancy of 300-2000 km/s. All major events are detected according to the height-time-diagram. More faint and rapid events, such as halo-CMEs are more difficult to detect and may even require a different approach than outlined here.

Analysis from height-time-diagram

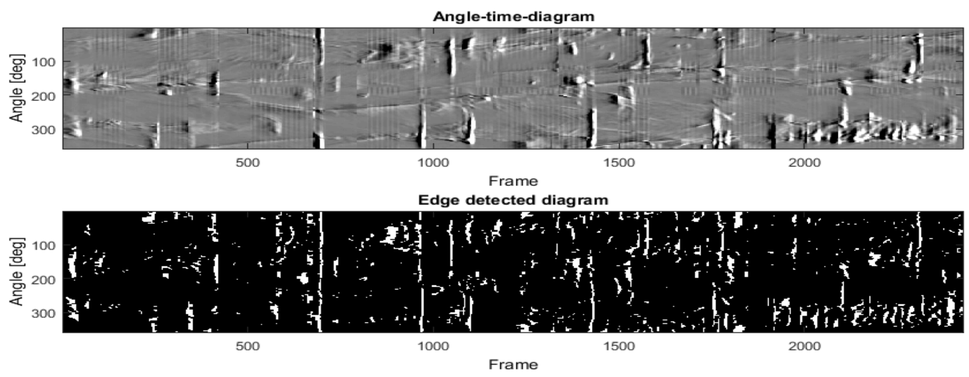


Voting scheme for line detection: pixels integrated along angles from First observation of CME. Local maxima taken as detected event.



Detected lines displayed on top of height-time diagram.

Status of angle-time-diagram analysis



***Top:** Angle-time-diagram in grayscale. **Bottom:** Current product of filtered edge-detection of angle-time-diagram.*

Analysis of the angle-time-diagrams, for extraction of CME-parameters is still to be carried out. The noisy smear of events tend to make the angular span inaccurate. Skeletonization does not resolve this issue. Literature in the field points to usage of apriori-knowledge to enhance these features, which will be the next step of this study.

Future work

Special phenomena of double CME-occurences are opportune studies, but more importantly halo-CMEs, which make up CMEs incident towards Earth should be addressed by the algorithm. Triangulation with multiple observations and inclusion of separate physical models to interface with CME-TRAP are up for consideration as expansion of the study.

Acknowledgements & further information

I would like to thank Susanne Vennerstrøm, Anders Bjorholm for counselling and the Image Group for discussion of the concepts utilized in this study.
If you would like to know more about the forecasting of space weather, visit **www.rumvejr.dk** or use QR.