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SEEDS (Solar Eruptive Event Detection System)

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http://solar.scs.gmu.edu/research/autocme

Objectives

- Develop an automatic system of solar transient events
  1. Detection (Current Work)
  2. Classification (Future Work)
  3. Association (Future Work) i.e. between EIT Dimming/CME/Flare

- An automatic system is needed
  - Explosive growth of data (STEREO and SDO)
    - Human detection becomes costly or impossible
  - Timely detection, for event catalog
  - Timely detection, for space weather forecasting
  - Objective detection, reducing human bias
  - Accurate measurement
  - Extracting more parameters
  - Classification using high dimensional input data

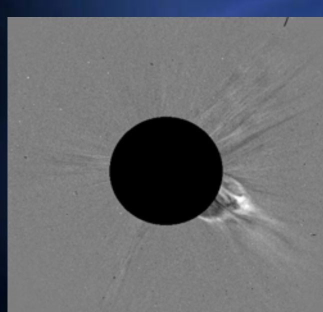
Methodology *(For CME Detection)*

- Pre-Processing
  - Apply filters
  - Polar Transformation
- Initial Detection
  - Apply x-axis projection to find outstanding angles
  - Parameter extraction (position angle, leading position, mean brightness, etc.)
- Tracking and Detection
  - Tracking CME's path
  - Calculation of Velocity and Acceleration
- Cataloguing

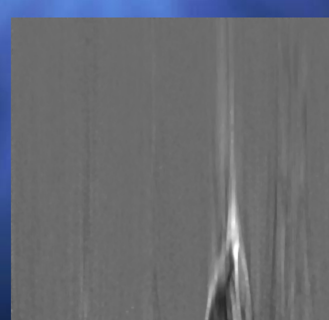
3

Pre-Processing

- Calibration
- Median and Smoothing filters to reduce noise
- Running Differencing to remove background
- Polar Transformation for easy array manipulation



Running Difference image

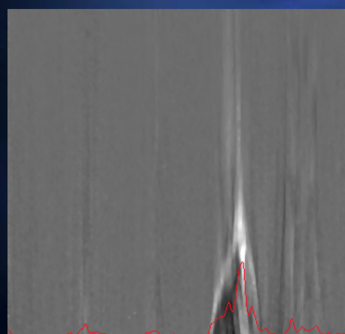


After polar Transformation

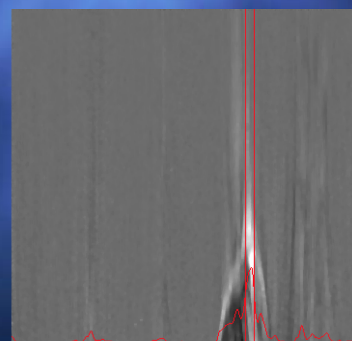
4

Initial Detection

- Detecting CME area or angles
  - 1-D Projection
  - Find CME core angles



1-D projection



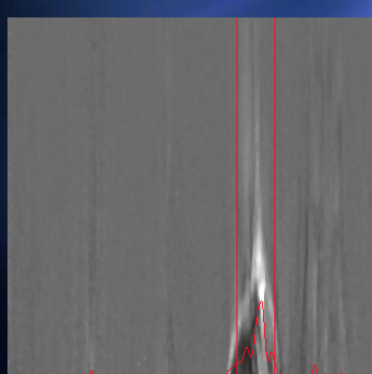
CME core angles found with thresholding

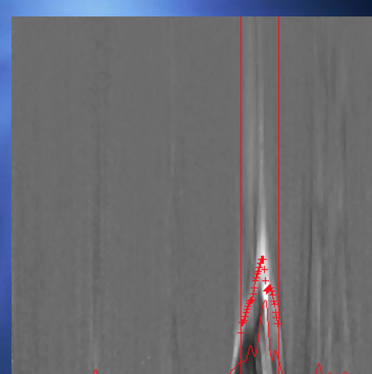
5

Initial Detection

Find CME full angles

- Region Growth
- Closing (Dilation + Erosion): join features with narrow gaps
- Opening (Erosion + Dilation): remove narrow features





Find CME Outline with threshold segmentation

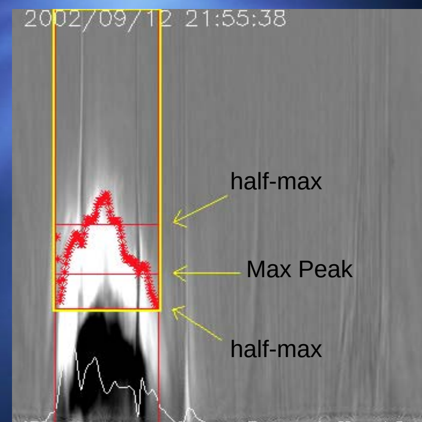
6

CME Tracking

***Setting tracking box** (yellow):*

- Project image within found angles onto the y-axis and find the max peak, when tracking, this height must be greater than previous height detection.

- Tracking box lower limit defined by finding the half-max bellow the max peak. Upper limit is the edge of the field of view.



7

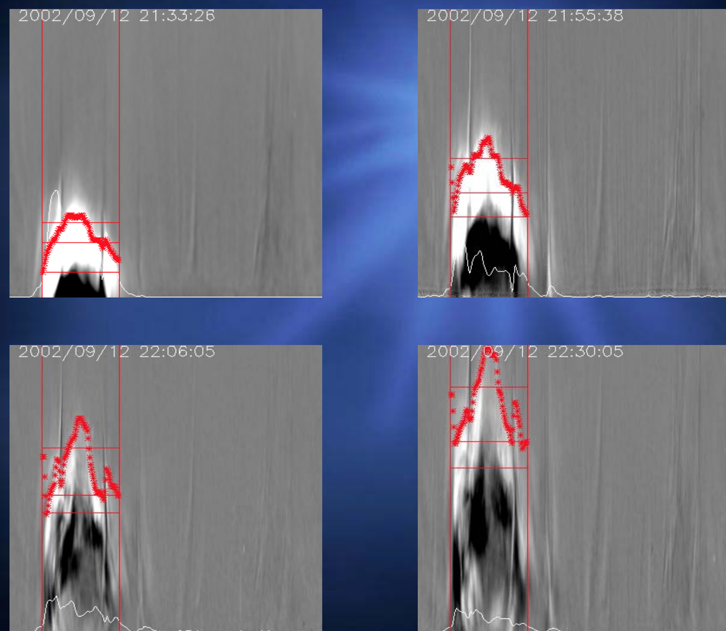
CME Trailing

***Setting trailing box** (yellow):*

- Some filament cores are brighter than the Leading Edge (LE)
- Remove the gusty outflow following a CME
- Some outflow blobs are brighter than the LE
- Initially re-setting all pixels in box to zero
- Gradually return,in time, pixel value to normal level
  - $F_m=F_0 *(1- \exp (-(T-T0)/T_m))$
    - Exponential modulation function is used
    - Suppressing blobs
    - But revealing a new CME

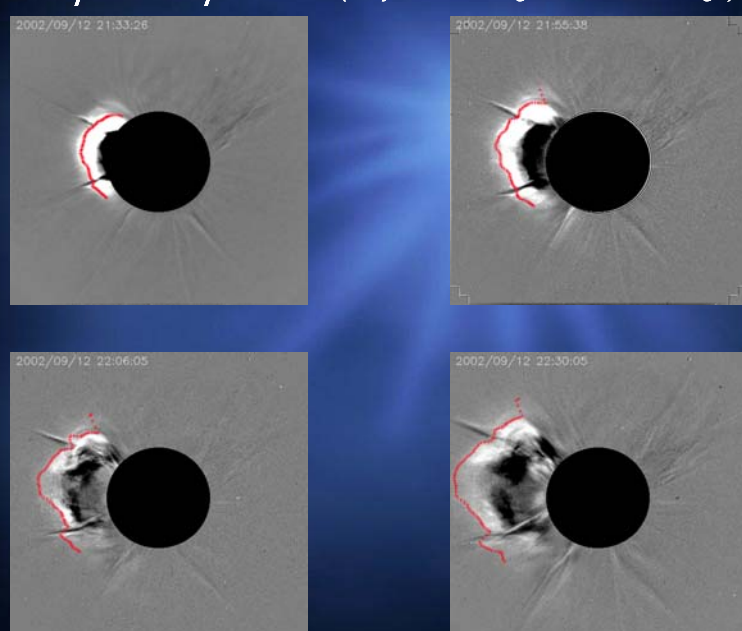
8

Example Tracking Sequence



9

Example Sequence *(Projection of edge onto Helio image)*



10

Statistics

- For one month data in 2002 September
  - SEEDS --- 253 events
  - CACTUS[1] --- 409 event
  - GSFC/NRL[2] --- 162 events
- Assuming GSFC/NRL catalog ground-truth
  - SEEDS detects 76.5% (True Positive rate) CMEs (124/162)
  - SEEDS misses 23.4% (False Negative rate) CMEs (38/162)
- SEEDS finds 79.6% more events than GSFC/NRL (129/162)
- GMU ground-truth (for the 253 events)
  - CME: 58.9% (149/253)
  - Blob/outflow: 23.7% (60/253)
  - Noise Feature: 17.4% (44/253)

[1] E. Robbrecht & D. Berghmans, “Automated recognition of coronal mass ejections (CMEs) in near-real-time data”, A&A 425, 1097 (2004)
http://sidc.oma.be/cactus/publi/

[2] CME catalog is generated and maintained at the CDAW Data Center by NASA and The Catholic University of America in cooperation with the Naval Research Laboratory. SOHO is a project of international cooperation between ESA and NASA.
http://cdaw.gsfc.nasa.gov/CME_list/

11

The Next Stage

- Formalize the C2 detection
- Extend to C3 detection
- Merging C2/C3 data
- Detecting dimming/flaring features in EIT
- Classification using data mining tools
- Association using data mining tools:
  - automatically identify solar surface source region of a CME
- A full online catalog

12

Discussion and the Future

- Apply the tools with twin SECCHI instruments plus SOHO LASCO/EIT
- Determine the true CME velocity and moving direction in the inner heliosphere in 3-D
- Fully develop the image processing, data mining, 3-D tracking tools for automatic detection/tracking of solar eruptive events
- Need real time tools for space weather forecasting

13