Automated tracking Coronal Mass Ejections using CACTus

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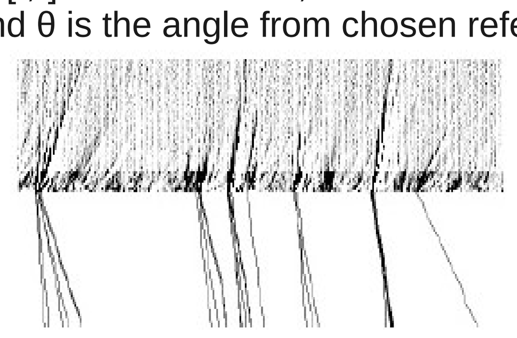
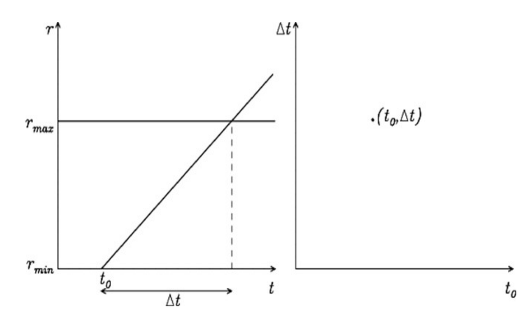
Abstract

Coronal Mass Ejections (CMEs) are responsible for most extreme space weather effect. Detection by human operator is subjective and labor intensive task. To make detections more objective a software package called Computer Aided CME Tracking (CACTus) is developed at Royal Observatory of Belgium which detects CMEs in Coronagraphic images and is compatible with LASCO (C2 and C3) and SECCHI (COR-2). It works on the principle of Hough transform, a technique of detecting straight lines in noisy data. The output of software is the list of events similar to classic catalogs. The CME detection using CACTus is fast which is especially important for space weather prediction. We tried to expand the current limitation of CACTus to make it compatible with masked disk images of AIA and SWAP to track eruptions closer to limb and Heliospheric Imager (HI) to track eruptions in heliosphere. Detection algorithm and possiblity of using CACTus with masked disk images of AIA, SWAP and HI with some preliminary results are presented.

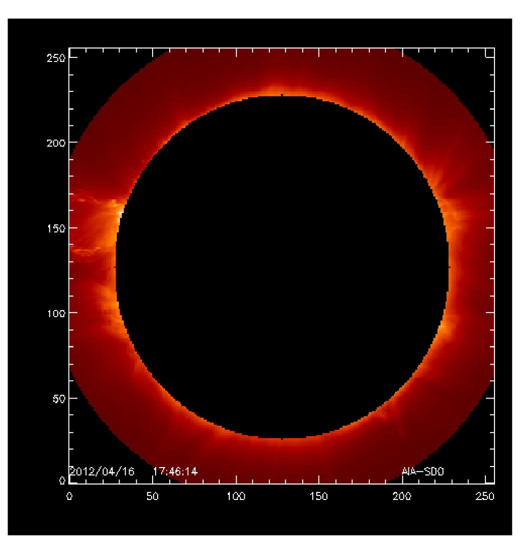
Method of Detection

- Hough transform is used to detect ridges in noisy data
- In [t,r] slice of each θ, CME looks like a bright inclined ridge, where t is time, r is the radial direction and θ is the angle from chosen reference frame

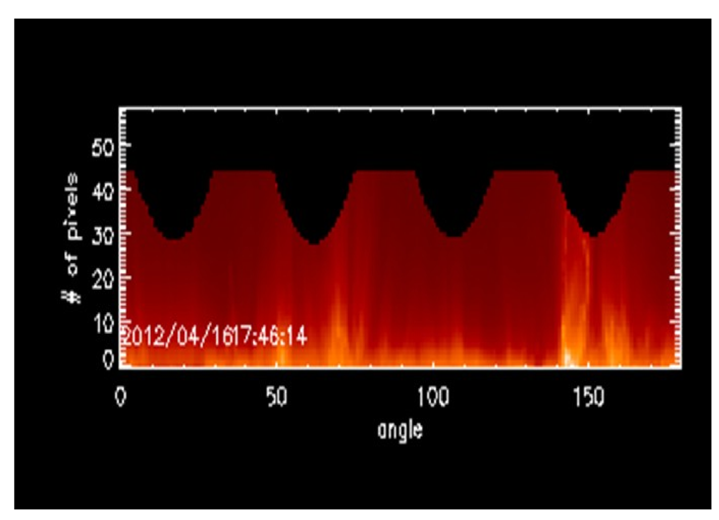




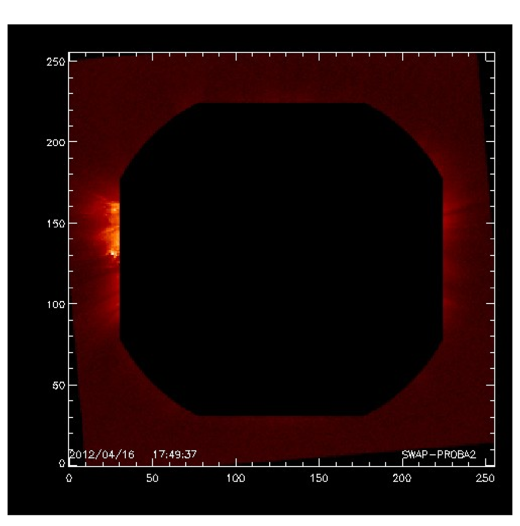
CME detection in SDO-SWAP Field of view



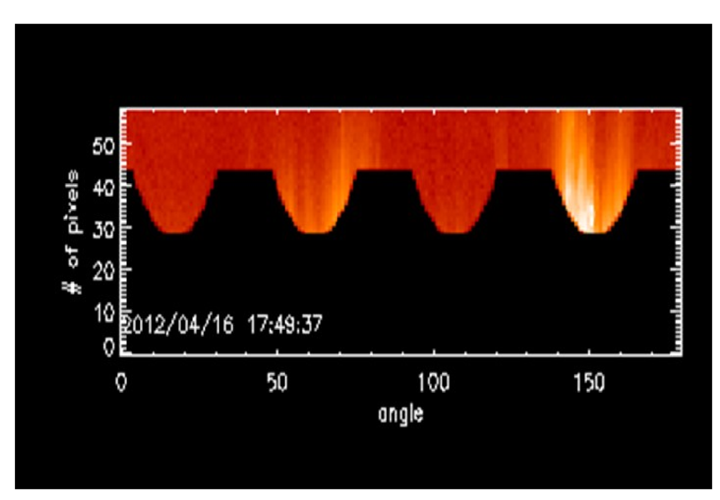
AIA 171 Å masked disk image



Polar image

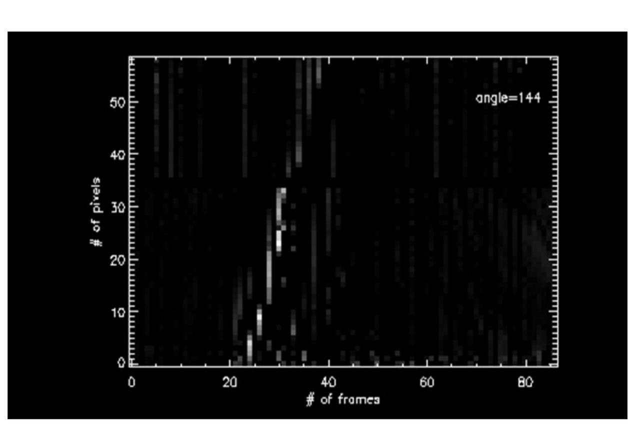


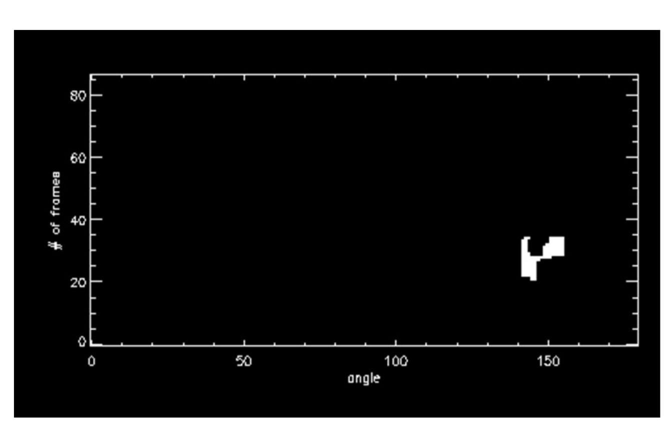
SWAP 174 Å masked disk image



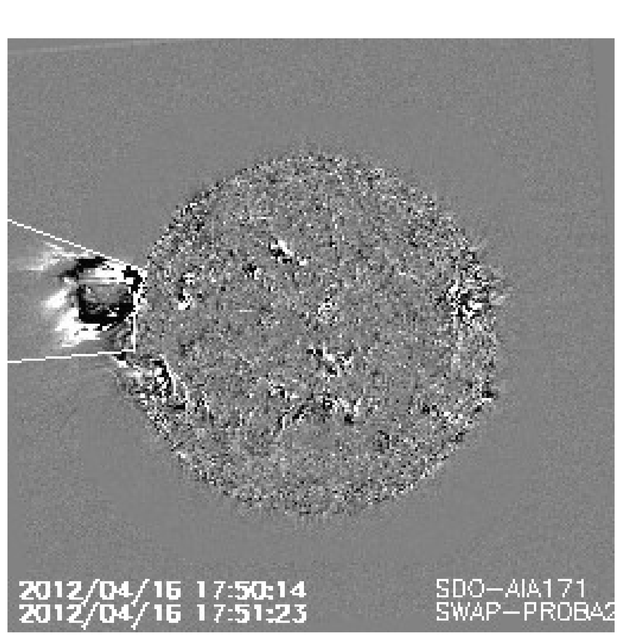
Polar Image

- Polar Images of AIA and SWAP are merged together

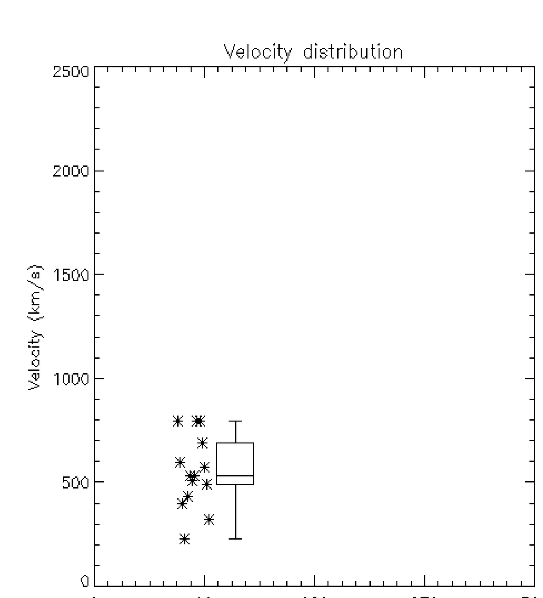




- CME looks like a ridge in [t,r] slice. Hough transform is applied to detect the ridge.
- CME is identified as dense cluster of points in [θ,t_0] space, where t_0 is the intercept obtained by applying Hough transform. Output of algorithm is shown below



Difference image of SDO-SWAP white lines show the angular width

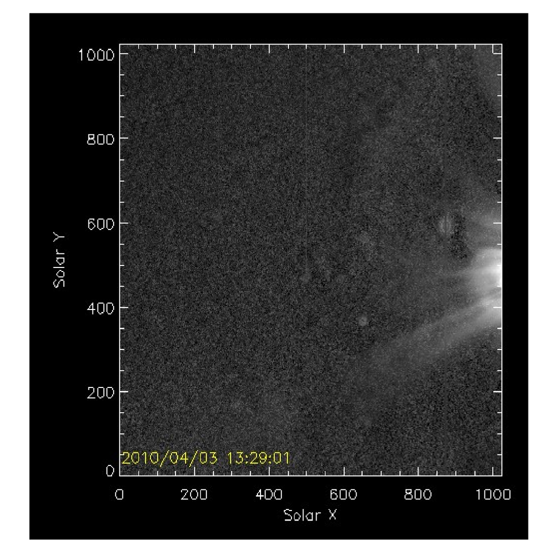


Velocity distribution of CME

t0	dt0	pa	da	v	dv	minv	maxv
2012/04/16 17:26	19	082	026	0529	0169	0229	0794

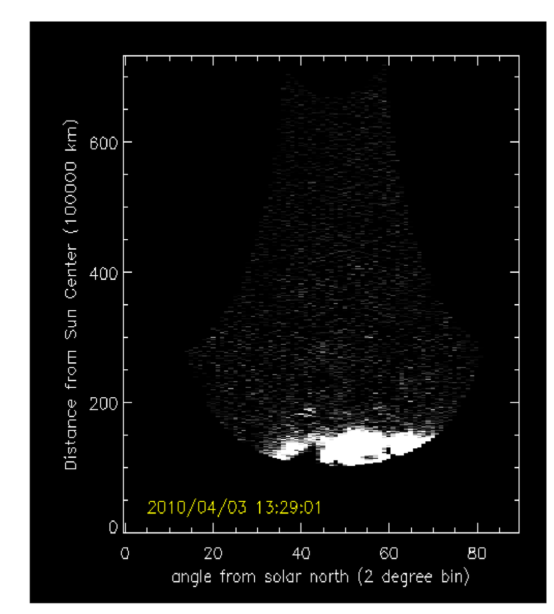
CME Detection in Heliospheric Imager

- Level 1 HI Images are created using *secchi_prep.pro* and minimum background is subtracted
- Bright points like planets and stars are removed using sigma filter
- Bright streaks are filled to remove the false impression of CME in difference image

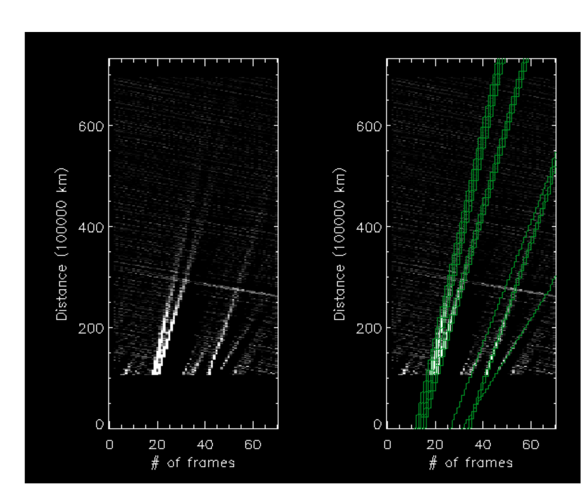


HI 1 SECCHI-A image after processing

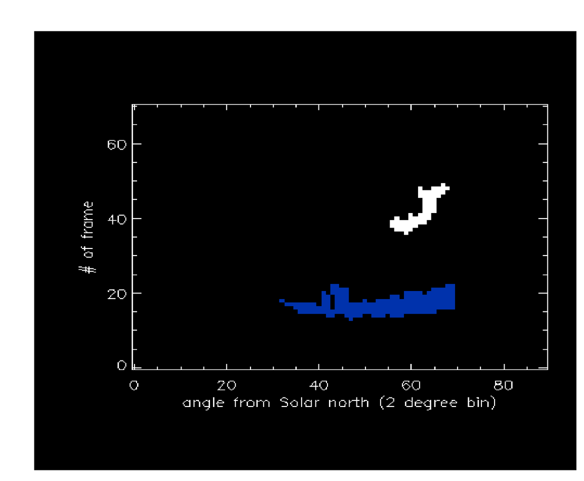
- Polar transformation is done using World Coordinate System transformation (see Thompson 2006)
- Y-axis is projected distance from Sun's center and X-axis is angle from Solar north counterclockwise (2 degrees are binned)



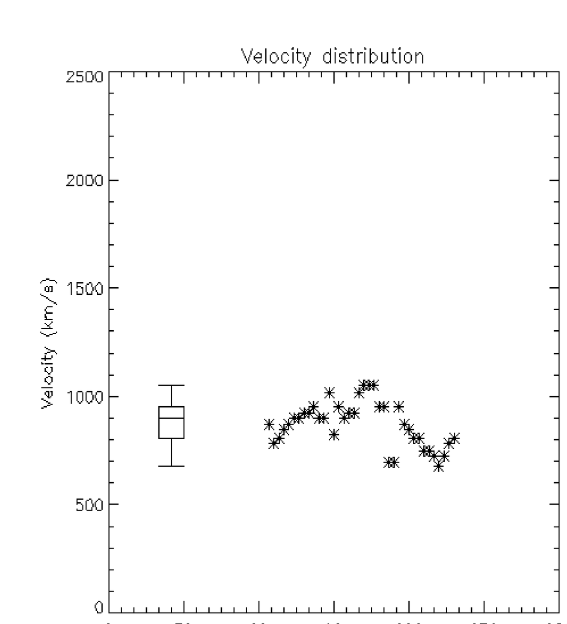
- CME looks like an inclined ridge in [t,r] slice. Hough transform is applied to isolate the significant ridges.



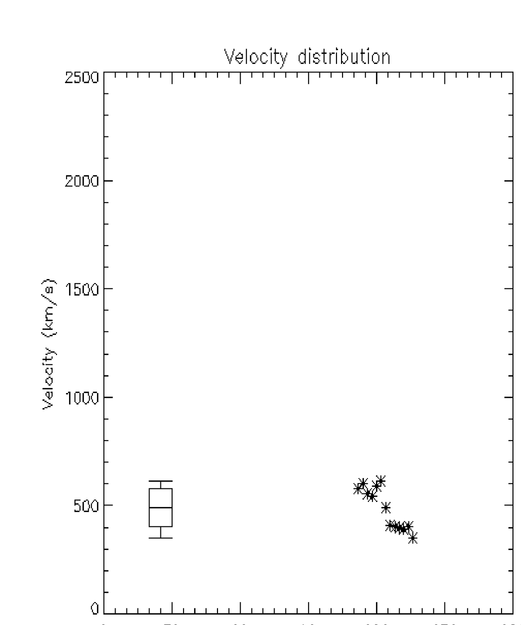
[t,r] slice at θ=112° from solar north. Green ridges represent Hough transform detection



θ-t_0 map showing detection of two CMEs



Velocity distribution of CME shown in blue in θ-t_0 map



Velocity distribution of CME shown in white in θ-t_0 map

t0	pa	da	v	dv	minv	maxv
2010/04/03 12:09	101	074	0885	0104	0678	1053
2010/04/03 23:29	124	024	0492	0092	0351	0610

Summary

- It is possible to detect CMEs automatically not only in coronagraphic images but also in EUV and heliospheric Images
- Advantage of CACTus is that a precise definition can be used, therefore making detections more objective
- It can be used for automatic detection of CMEs in future coronagraphic missions (ADITYA-1)