WP2 Update: automatic CME identification

Royal Observatory of Belgium

T2.2 - Automatic cataloguing of STEREO/HI CMEs [Months: 1-36]

- **Investigate the possibility** of the automatic detection of CMEs in the heliosphere from STEREO/HI-1 images.

- Never been tried before.

- ROB has experience (**CACTus**) in doing this with LASCO and COR.

- Parameters of the automatically-detected CMEs will be catalogued in an analogous manner to those detected manually.

- T2.3: comparison of both catalogues.

Application of CACTus on STEREO/HI1

Preprocessing

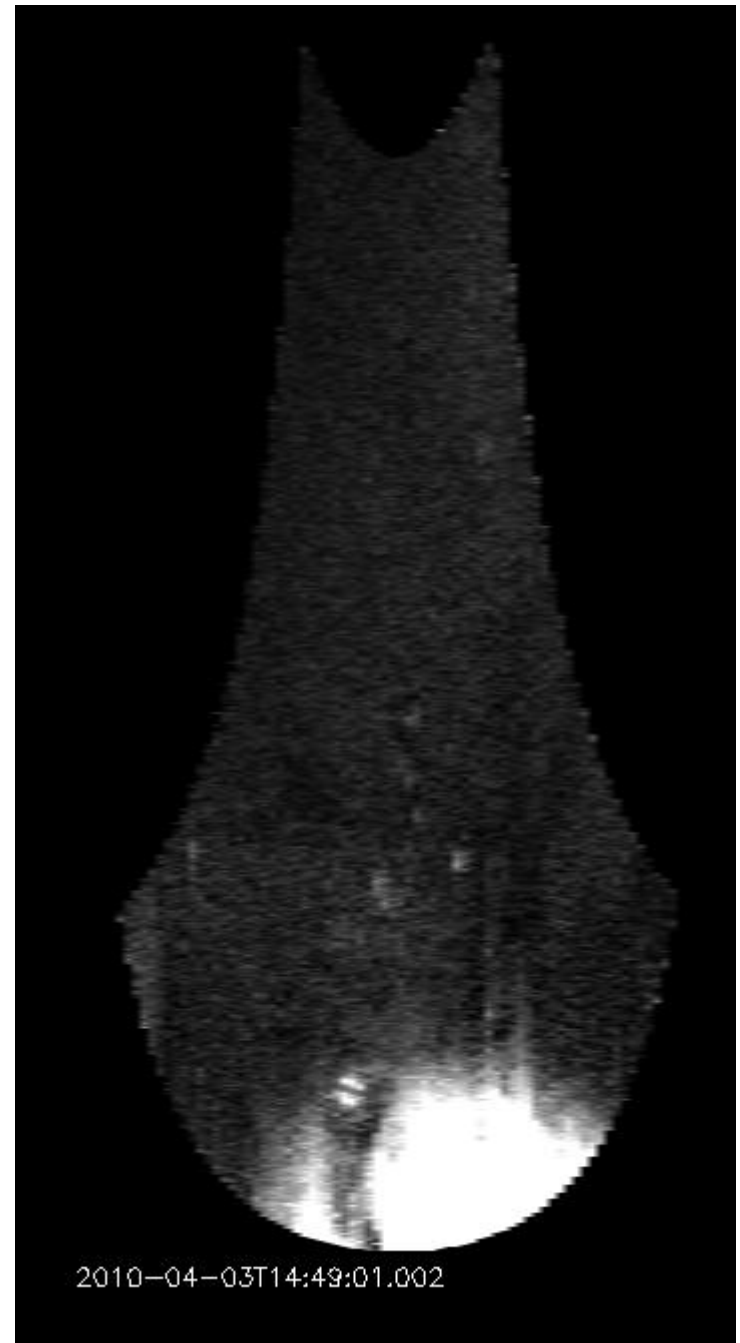## L2 images
(1-day backgrounds removed)

20100403_144901_24h1A_br01.fts

After some cleaning
(sigma_filter + filling black strips)

L2 clean 2010-04-03T14:49:01.002

Conversion to polar coordinates

1. Conversion of HPC longitudes and latitudes into HPR position angle and elongation with wcs_conv_hpc_hpr.

2. Conversion of the elongation into projected distance
   r = DSUN_OBS * tan(elong)

Projected distance from Sun (100,000 km/px)

2010-04-03T14:49:01.002

Angle from solar north

Difference images

Remove noise by median filtering in time in the datacube.
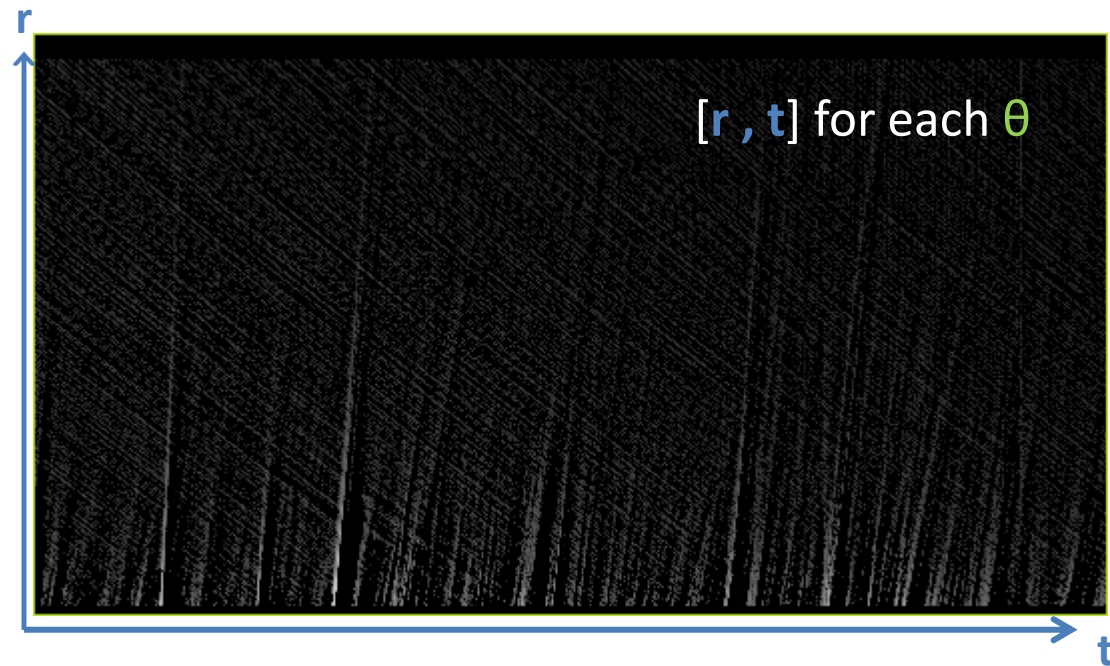
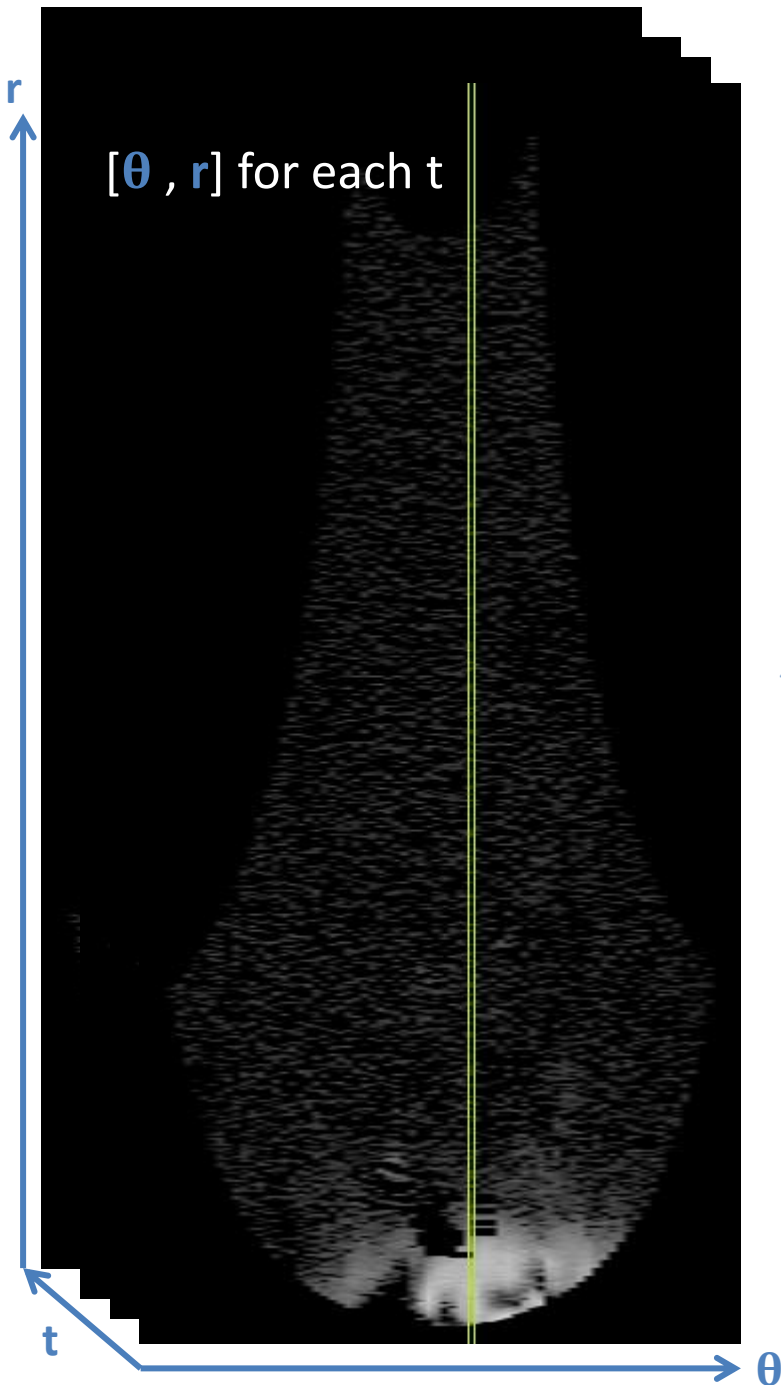Creation of the difference images (running difference).

Projected distance from Sun (100,000 km/px)

2010-04-03T14:09:01.003

Angle from solar north

r-t slices

Extraction of r − t slices for each angle (in reality, slices are 2 degrees wide).

[θ , r] for each t
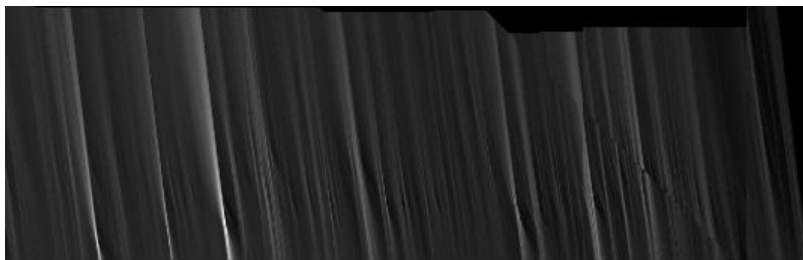
[r , t] for each θ

CME extraction (1)

CMEs are seen in r-t slices as bright ridges. From the Hough transform, we keep only the brightest points; this yields a t-v map for each angle.
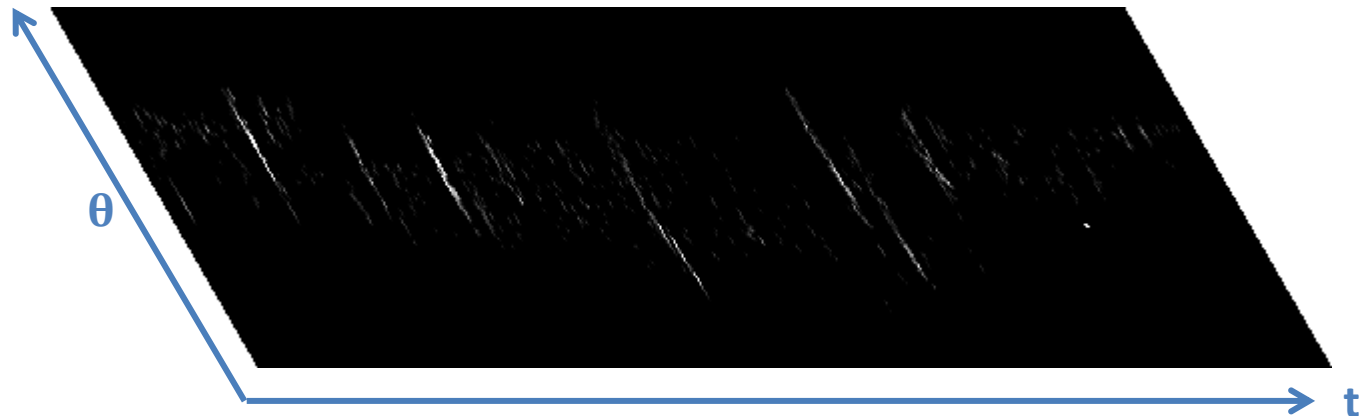

Original data

r-t map

Detected ridges
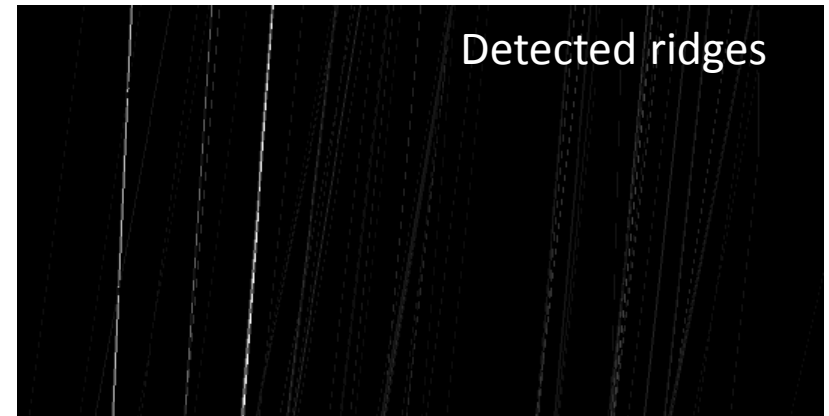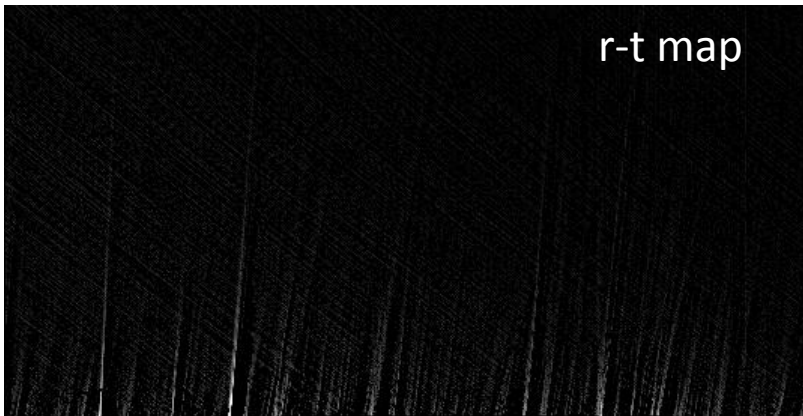
Filtered data

Hough transform
(considering speeds ∈ [100,2100] km/s)

t-v map

CME extraction (2)

The t-v maps for all angles are then summed along the v dimension to provide a time–angle map which contains all the information about detected CMEs.

CACTus output: Visualisation

After some thresholding and clustering in the previous time-angle map, we obtain the final detection map in which each color indicates a different CME.
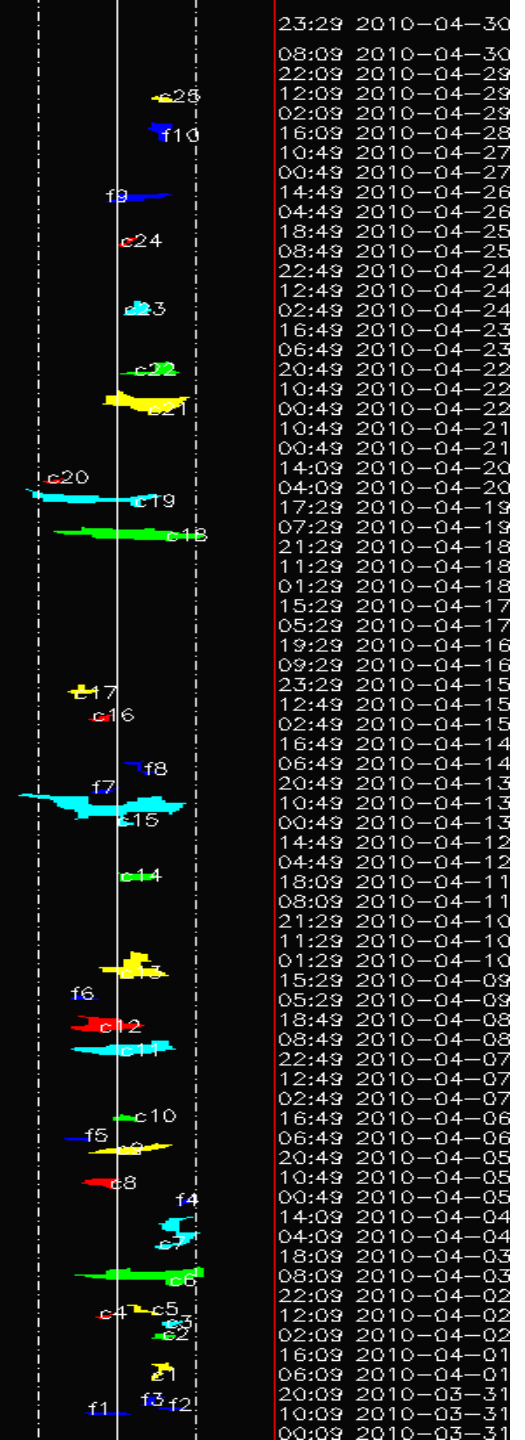
CACTus output: CME Parameters

- Time of first apparition in HI1 images
- Propagation angle – angular width
- Median velocity

```
# CME |        t0         | pa | da | NoPA| SuPA|  v  | dv | minv| maxv
  0025|2010/04/29 13:29| 0115| 010| 0110| 0120| 0283| 0017| 0266| 0313
  .......
  0008|2010/04/05 12:09| 0080| 020| 0070| 0090| 0268| 0009| 0256| 0285
  0007|2010/04/04 04:09| 0124| 024| 0112| 0136| 0397| 0084| 0357| 0562
  0006|2010/04/03 12:09| 0102| 072| 0066| 0138| 0823| 0110| 0571| 1041
  0005|2010/04/02 18:09| 0104| 016| 0096| 0112| 0276| 0075| 0195| 0397
  0004|2010/04/02 14:09| 0083| 010| 0078| 0088| 0407| 0033| 0361| 0454
  0003|2010/04/02 11:29| 0121| 010| 0116| 0126| 0409| 0101| 0327| 0621
  0002|2010/04/02 05:29| 0116| 012| 0110| 0122| 0459| 0073| 0316| 0505
  0001|2010/04/01 14:49| 0115| 010| 0110| 0120| 0427| 0058| 0372| 0544
```

CACTus output: Speed profile of a cme

```
# CME |       t0       | pa | da | NoPA| SuPA|  v  | dv | minv| maxv
  0006|2010/04/03 12:09| 0102| 072| 0066| 0138| 0823| 0110| 0571| 1041
```

In the detection map, for each pair (starting time, angle), we associate a speed which corresponds to the ridge with the more signal in the r-t slice; then we associate to each CME the median of the velocities placed in it.
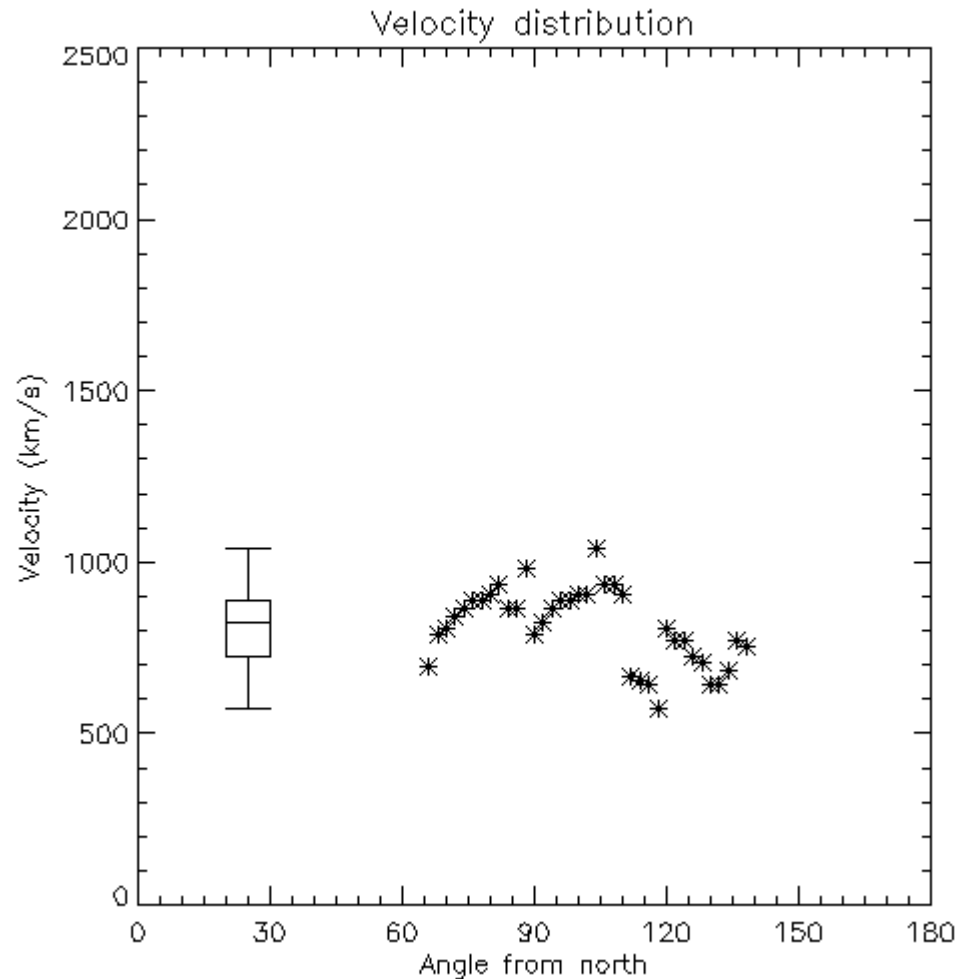
Velocity distribution

The catalog

The catalog

CMEs detected by CACTus - /A/2010/04/

Show comparison with the Manual catalog and other level images

```
:Issued: Fri Mar 20 00:19:07 2015
:Product: CACTus catalogue for HI
#-----------------------------------------------------------------
# Instrument: SECCHI-A | Detector: hi_1
# Minimal CME width: 0010
#
  first hi_1: 2010-03-31T00:09:01.008   20100331_000901_24h1A_br01.fts
  last  hi_1: 2010-04-30T23:29:01.005   20100430_232901_24h1A_br01.fts
#
#-----------------------------------------------------------------
# Output: Detected cmemap with the following characteristics:
#
#    CME: CME number
#   Flow: Flow number. Flows are suspicious detections,
#          their color in the detectionmap is dark blue
#     t0: first apparition in field of view
#     pa: principal angle, counterclockwise from North (degrees)
#     da: angular width (degrees),
#    NPA: Northernmost propagation angle (degrees),
#    SPA: Southernmost propagation angle (degrees),
#      v: median (projected) velocity (km/s)
#     dv: variation (1 sigma) of velocity over the width of the CME
#   minv: lowest velocity detected within the CME
#   maxv: highest velocity detected within the CME
#
# CME |      t0       | pa | da | NoPA| SuPA| v  | dv | minv| maxv
 0025|2010/04/29 13:29| 0115| 010| 0110| 0120| 0283| 0017| 0266| 0313
 0024|2010/04/25 16:49| 0095| 010| 0090| 0100| 0272| 0016| 0252| 0300
 0023|2010/04/24 05:29| 0101| 014| 0094| 0108| 0213| 0037| 0205| 0295
 0022|2010/04/22 23:29| 0108| 032| 0092| 0124| 0350| 0029| 0300| 0397
 0021|2010/04/22 05:29| 0106| 048| 0082| 0130| 0397| 0080| 0343| 0621
 0020|2010/04/20 09:29| 0053| 010| 0048| 0058| 0389| 0017| 0361| 0416
 0019|2010/04/20 02:09| 0076| 076| 0038| 0114| 0416| 0037| 0334| 0491
 0018|2010/04/19 06:49| 0096| 084| 0054| 0138| 0448| 0075| 0340| 0571
 0017|2010/04/15 22:49| 0070| 016| 0062| 0078| 0330| 0047| 0239| 0368
 0016|2010/04/15 08:49| 0080| 012| 0074| 0086| 0437| 0031| 0368| 0454
 0015|2010/04/13 10:49| 0081| 094| 0034| 0128| 0345| 0255| 0219| 0983
 0014|2010/04/12 00:09| 0101| 022| 0090| 0112| 0361| 0043| 0310| 0454
 0013|2010/04/10 00:49| 0099| 038| 0080| 0118| 0312| 0034| 0239| 0354
 0012|2010/04/08 18:09| 0084| 040| 0064| 0104| 0249| 0060| 0196| 0402
 0011|2010/04/08 06:49| 0093| 058| 0064| 0122| 0544| 0053| 0454| 0668
 0010|2010/04/06 20:49| 0094| 012| 0088| 0100| 0283| 0119| 0268| 0520
 0009|2010/04/06 04:09| 0097| 046| 0074| 0120| 0582| 0278| 0416| 1264
 0008|2010/04/05 12:09| 0080| 020| 0070| 0090| 0268| 0009| 0256| 0285
 0007|2010/04/04 04:09| 0124| 024| 0112| 0136| 0397| 0084| 0357| 0562
 0006|2010/04/03 12:09| 0102| 072| 0066| 0138| 0823| 0110| 0571| 1041
 0005|2010/04/02 18:09| 0104| 016| 0096| 0112| 0276| 0075| 0195| 0397
 0004|2010/04/02 14:09| 0083| 010| 0078| 0088| 0407| 0033| 0361| 0454
 0003|2010/04/02 11:29| 0121| 010| 0116| 0126| 0409| 0101| 0327| 0621
 0002|2010/04/02 05:29| 0116| 012| 0110| 0122| 0459| 0073| 0316| 0505
 0001|2010/04/01 14:49| 0115| 010| 0110| 0120| 0427| 0058| 0372| 0544
# Flow|      t0       | pa | da | NoPA| SuPA| v  | dv | minv| maxv
 0010|2010/04/28 22:09| 0114| 012| 0108| 0120| 0327| 0000| 0327| 0327
 0009|2010/04/26 12:49| 0102| 036| 0084| 0120| 0345| 0050| 0237| 0426
 0008|2010/04/14 04:09| 0103| 018| 0094| 0112| 0376| 0037| 0319| 0437
 0007|2010/04/13 18:49| 0083| 014| 0076| 0090| 0265| 0045| 0242| 0365
 0006|2010/04/09 08:49| 0071| 014| 0064| 0078| 0188| 0083| 0178| 0357
 0005|2010/04/06 08:09| 0067| 014| 0060| 0074| 0301| 0011| 0287| 0319
 0004|2010/04/04 23:29| 0129| 010| 0124| 0134| 0319| 0023| 0285| 0357
 0003|2010/03/31 17:29| 0110| 012| 0104| 0116| 0340| 0090| 0260| 0498
 0002|2010/03/31 14:49| 0121| 014| 0114| 0128| 0405| 0064| 0357| 0505
 0001|2010/03/31 12:49| 0084| 024| 0072| 0096| 1770| 0000| 1770| 1770
```
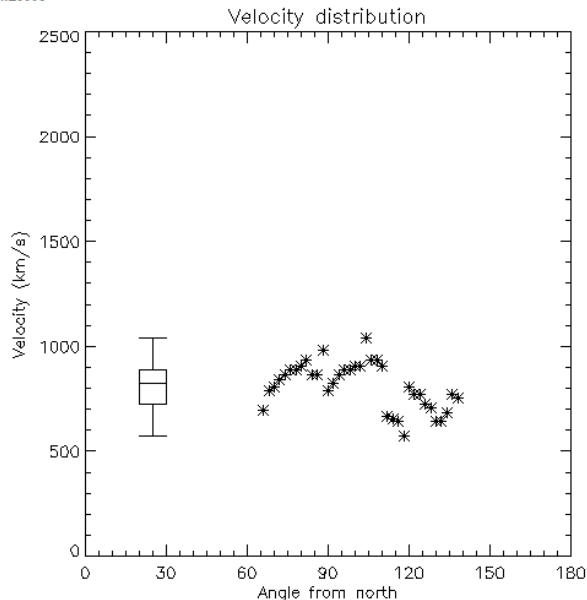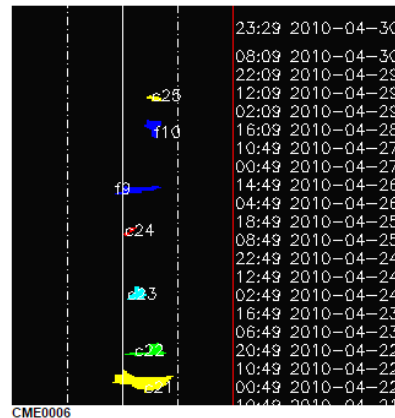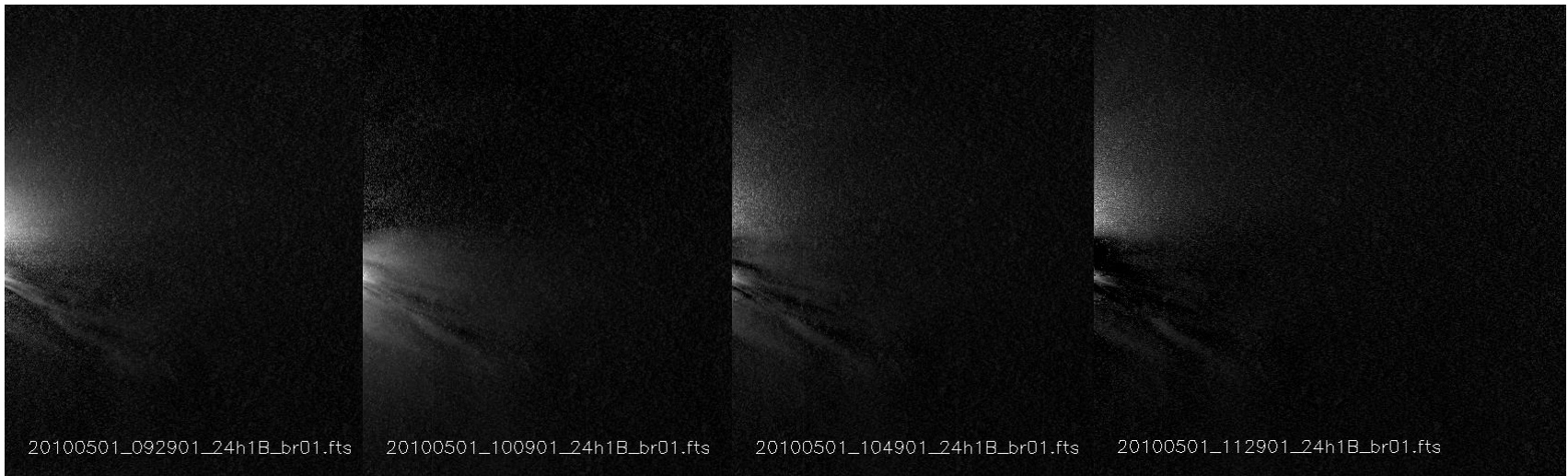
CME0006

Velocity distribution

How well does it work ?

A quick comparison of the results for 2010 STEREO-A/HI1 with the manual catalogue shows that we were able to find more than 80% of the CMEs listed in the manual catalogue.
However, we do have quite a lot of additional detections, which have not been investigated yet.

And for STEREO-B ?

Much more false detections. Seems to be due to bright & dark alternations in the images. We haven't found a way yet to either correct the images or discard those bad detections.

20100501_092901_24h1B_br01.fts   20100501_100901_24h1B_br01.fts   20100501_104901_24h1B_br01.fts   20100501_112901_24h1B_br01.fts

Other issues

- CME width is sometime underestimated, maybe because the CME becomes larger while propagating in the HI1 field of view.

- Merging / Splitting of CMEs

- To avoid too much false detections, we have to discard detections for which the computed width is below 10 degrees, we thus miss the narrow CMEs.

Deliverables

- D2.1: Catalogue of observational parameters of HI-1 manually identified CMEs (month 36, but 1st release month 9)

- D2.2: Report on the feasibility of automatic identification of CMEs in HI-1 data (month 12)

- D2.3: Report on the inter-comparison of the manual and automated CME catalogues (month 18)

- D2.4: Report in which the manual and automated HI CME catalogues are compared to pre-existing coronagraph CME catalogues (month 24)