

WP2 Update: automatic CME identification

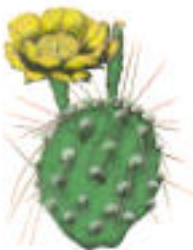


Luciano Rodriguez and the HELCATS team at the
Royal Observatory of Belgium

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.
- We have modified (**CACTus**) to work on HI data.
- A full CME catalogue has been created for the whole mission and both spacecraft.
- We are comparing manual and automatic catalogues.

Application of CACTus on STEREO/HI1



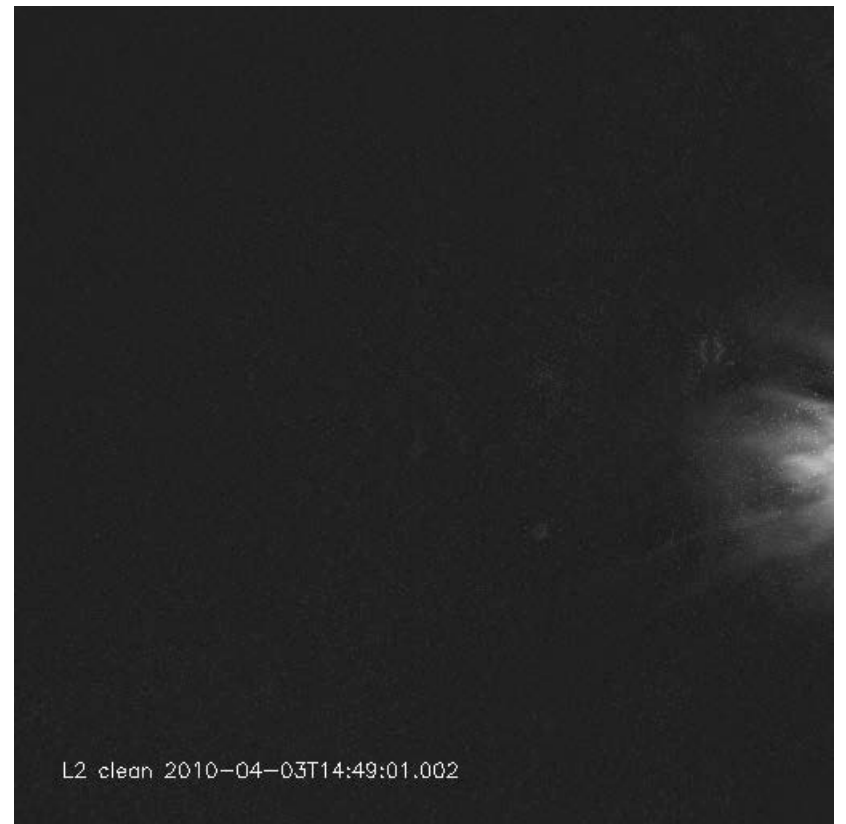
Preprocessing

L2 images

(1-day backgrounds removed)

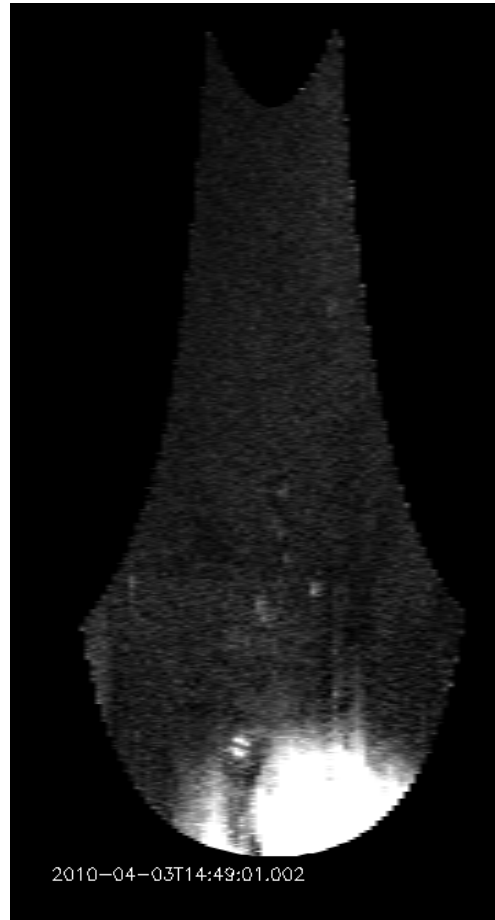


After some cleaning



Conversion to polar coordinates

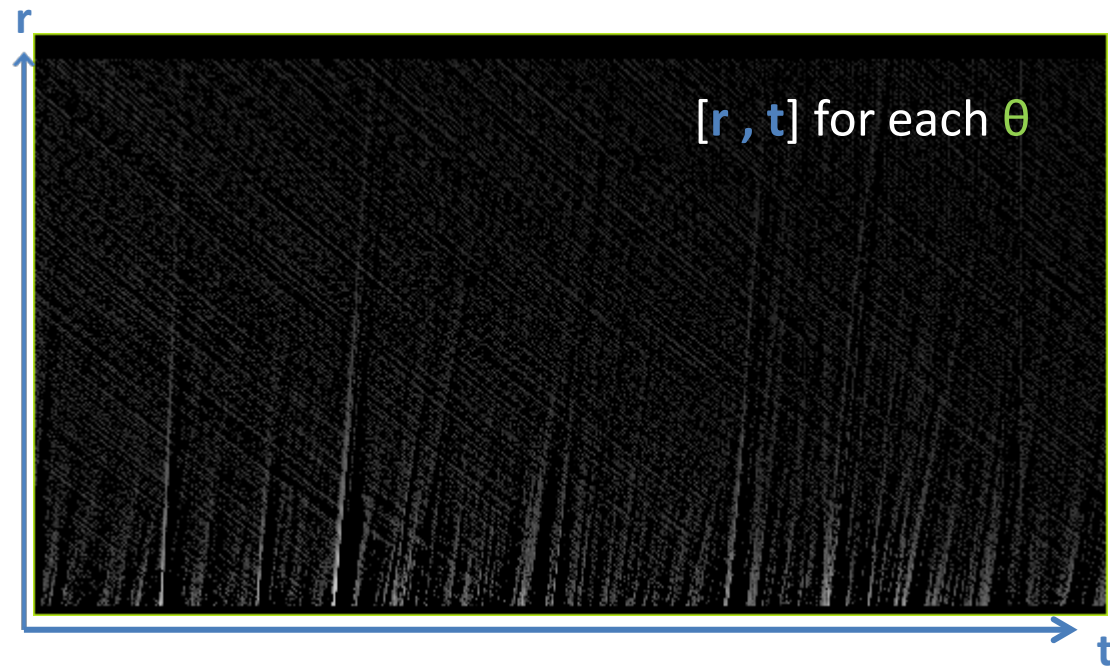
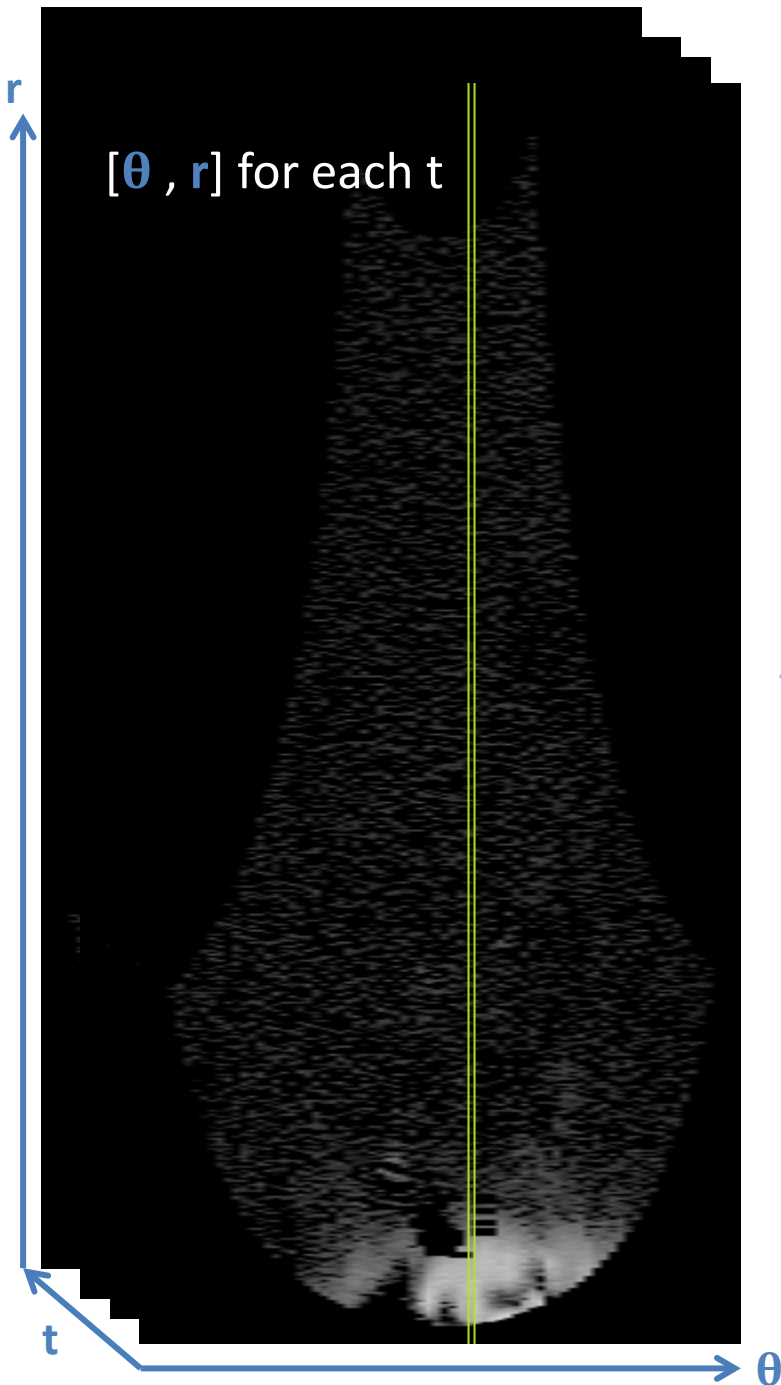
Projected distance from Sun (100,000 km/px)



Angle from solar north

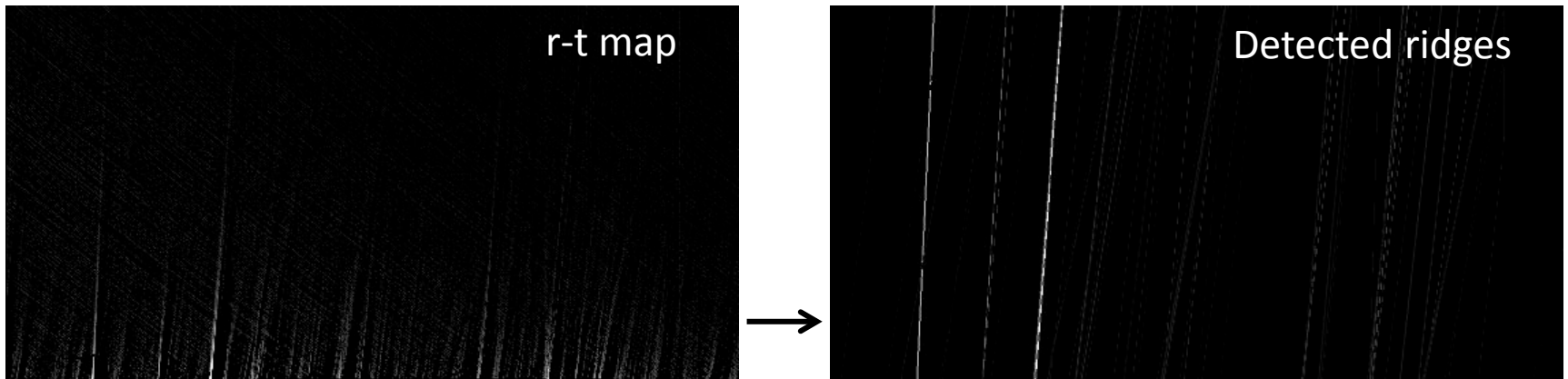
r-t slices

Extraction of r – t slices for each angle.



CME extraction

CMEs are seen in r-t slices as bright ridges by using the Hough transform.



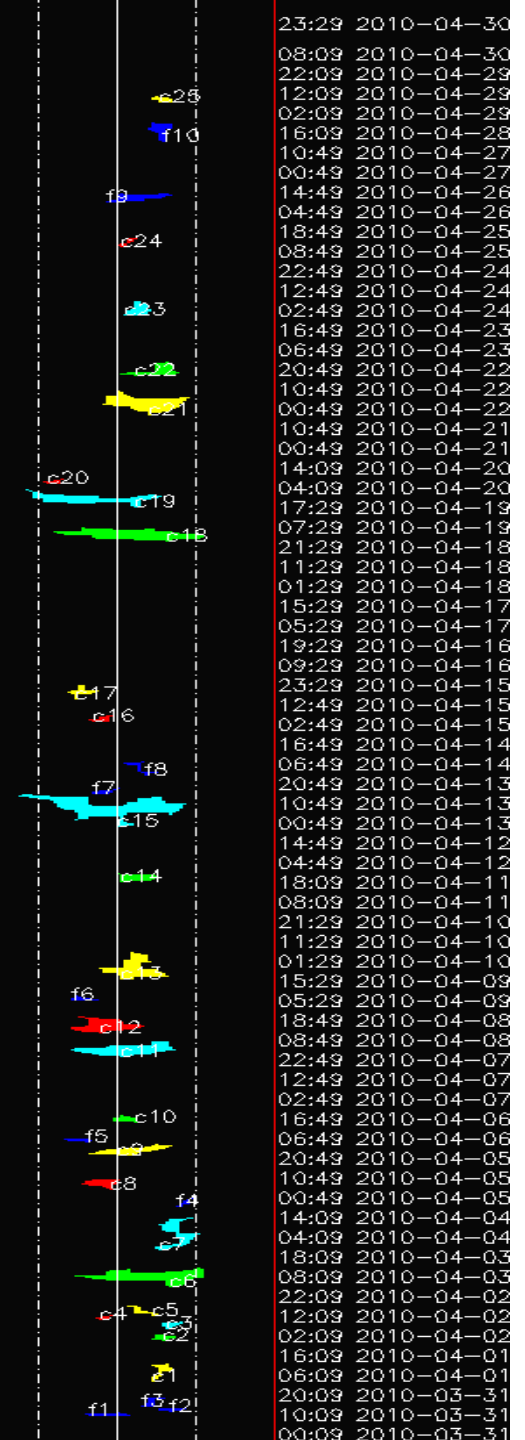
Hough transform
(considering speeds $\in [100,2100]$ km/s)

Original data

Filtered data

CACTus output: Visualisation

After some thresholding and clustering we obtain the final detection map in which each color indicates a different CME.



CACTus output: CME Parameters

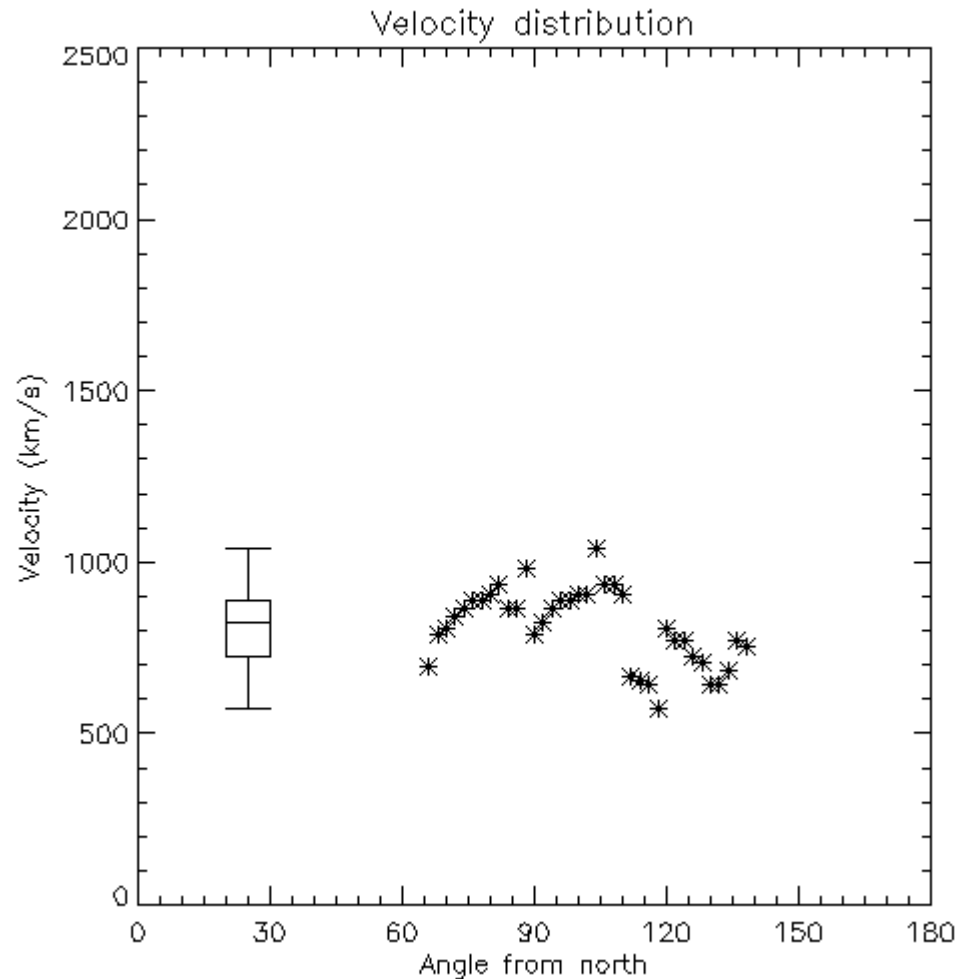
- Time of first apparition in HI1 images
- Propagation angle
- Angular width
- Velocity

#	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 CME, we associate a speed which corresponds to the median of the velocities placed in it.





CACTus for STEREO/Hi-1

A software package for 'Computer Aided CME Tracking' (adapted from CACTus)

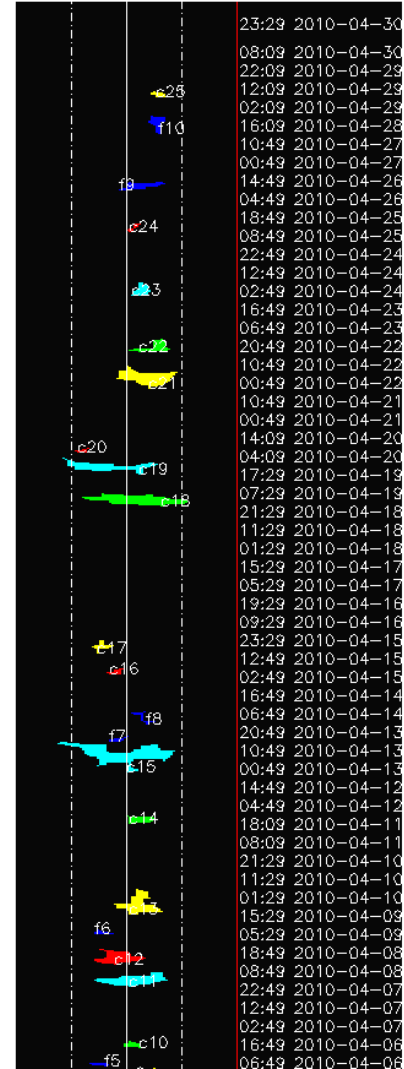
CMEs detected by CACTus - /A/2010/04/

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

```





CACTus for STEREO/Hi-1

A software package for 'Computer Aided CME Tracking' (adapted from CACTus)

The catalog

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

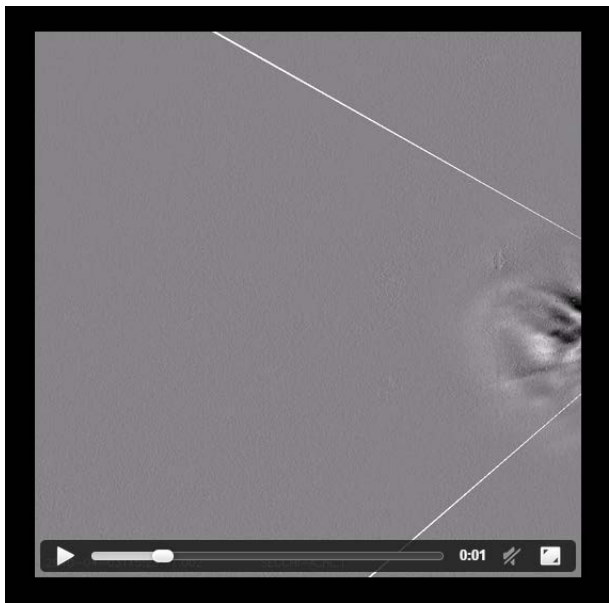
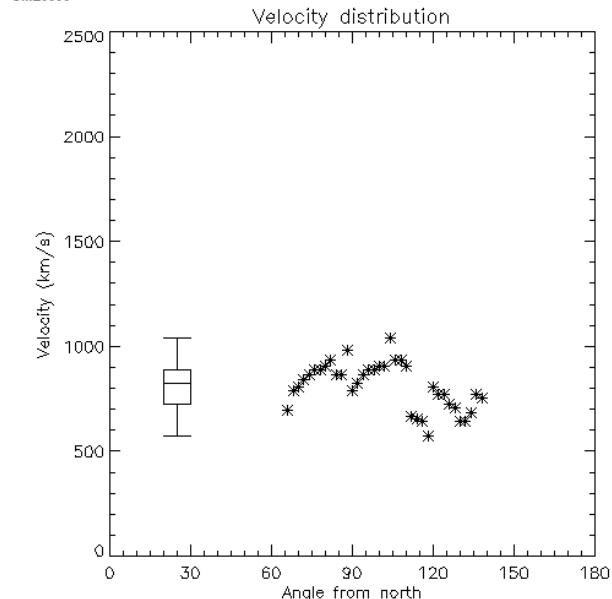
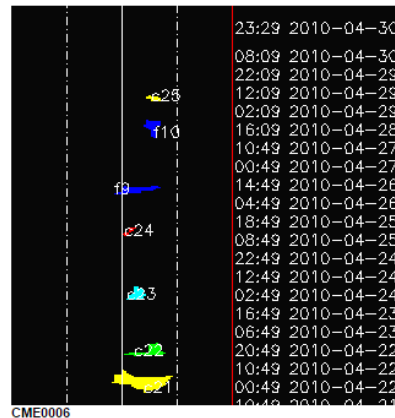
Show comparison with the Manual catalog and other level images

```

: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 cmap 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	



Manual vs. Automatic

	Manual A	Manual B	Automatic A	Automatic B
Date	17.04.2007 - 29.12.2013	15.04.2007 - 31.12.2013	13.01.2007 - 18.08.2014	20.01.2007 - 28.08.2014
Total events	856	817	1501	1794
Date	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013
Total events	856	817	1308	1556

Table 2. Events between 15.04.2007 and 31.12.2013. Common events (starttime differs by le 2 hours, overlap ge 60% of the minimum width).

	Manual A	Manual B	Automatic A	Automatic B
Total number	856	817	1308	1556
width >= 20 (width < 20)	855 (1)	813 (4)	884 (424)	1290 (266)
Poor events	144	179	-	-
Events out fov	361	317	-	-
Poor and out fov events	490	458	-	-
Common events	499	404	499	404
with speed estimations	425	328	(425)*	(328)*

*CACTus gives a speed estimation for all its detections but obviously for speed comparisons we only consider the events for which we have an estimation in the manual catalogue.

Position angle

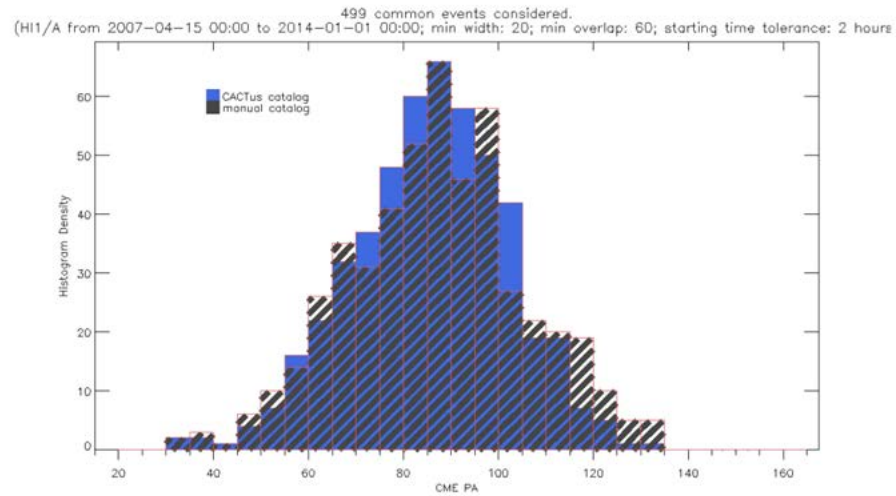


Fig1

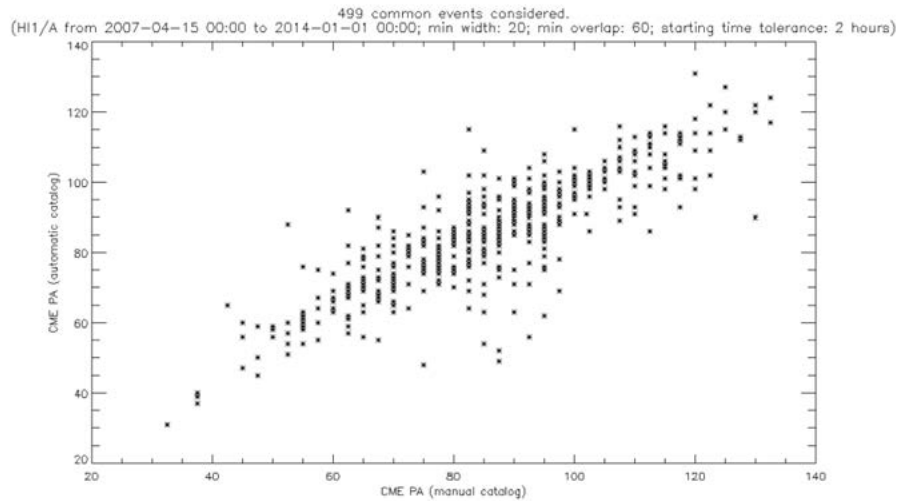


Fig2

Fig. 1 & 2 PA of the common CMEs (499) observed by HI1-A

Angular width

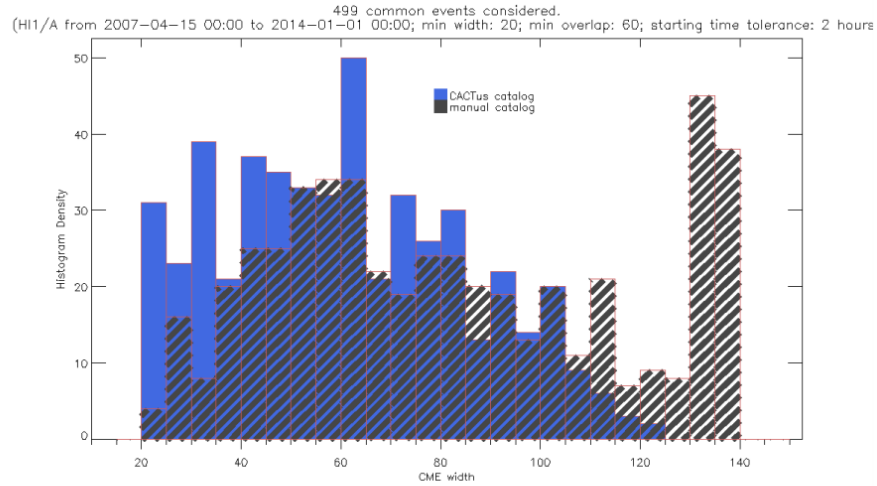


Fig3

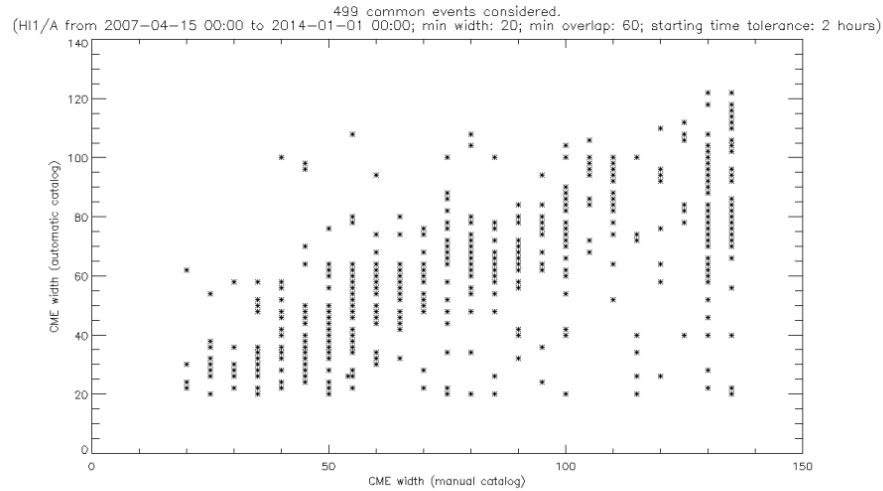


Fig4

Fig. 3&4 Width of the common CMEs (499) observed by HI1-A

Speeds

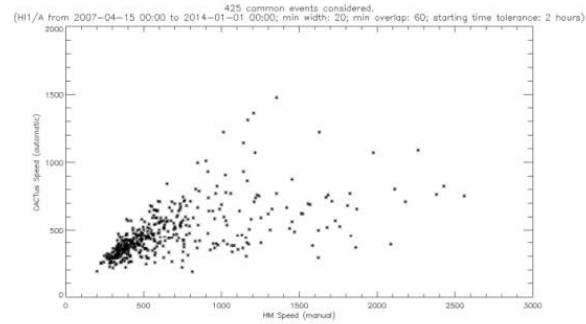
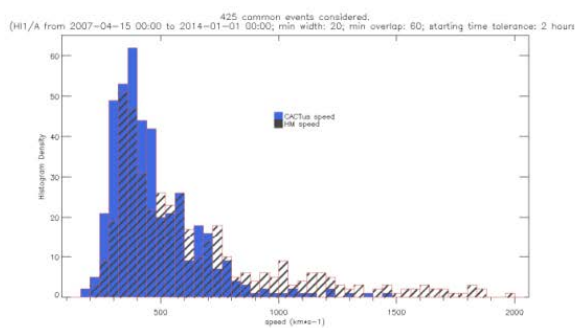


Fig 7&8 (HM) Speed estimation distribution of the common detections with a speed estimate (425)

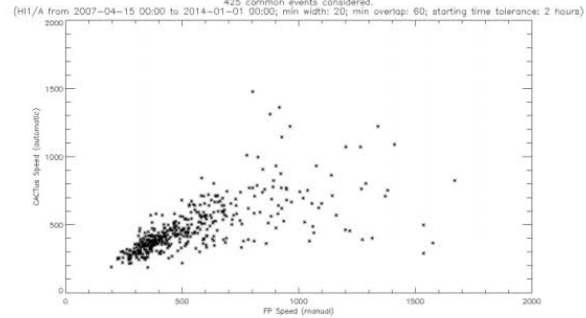
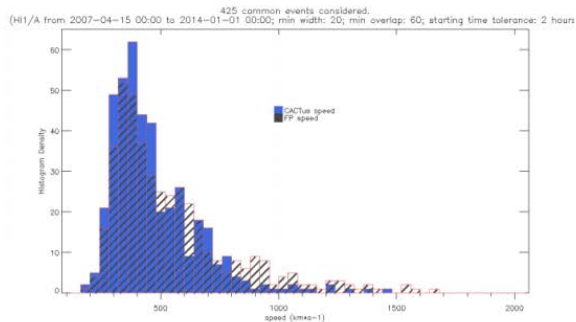


Fig 9&10 (FP) Speed estimation distribution of the common detections with a speed estimate (425)

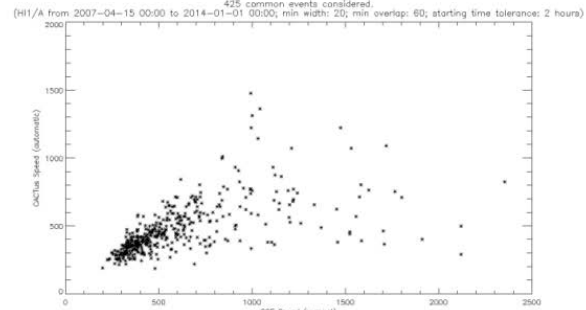
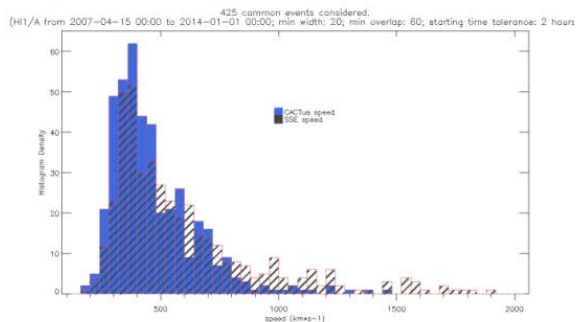


Fig 11&12 (SSE) Speed estimation distribution of the common detections with a speed estimate (425)

Work on progress and future

- Comparison of manual and automatic catalogues
- Initial statistical analysis
- Visual inspection of events
- Analysis of individual cases
- Fine-tuning of the algorithm
- Comparison with other catalogues
- ESWW

Extra material

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)