WP2 Update: automatic CME identification

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HELCATS 4th Bi-annual Steering Committee Meeting, Albena, 7th June 2016

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.
- **CACTus** has been applied to HI data.
- A full CME catalogue has been created for the whole mission and both spacecraft.
- We are comparing manual and automatic catalogues.

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) (publication submitted)

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

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

CACTUS

A software package for 'Computer Aided CME Tracking'

http://sidc.be/cactus/

CACTUS autonomously detects coronal mass ejections (CMEs) in image sequences from LASCO. The output of our software is a list of events, similar to the classic catalogs, with principle angle, angular width and velocity estimation for each CME. In contrast to catalogs assembled by human operators, these CME detections by software can be faster, which is especially important in the context of space weather, and possibly also more objective, as the detection criterion is written explicitly in a program.

The CME list is automatically generated by CACTus. There is no human intervention or supervision at this stage. Therefor we ask to use caution when using the data for statistical purposes.

When any of this data is used, please cite one of the following publications:

- Astronomy and Astrophysics 425 (2004)
- Astrophysical Journal 691 (2009)

(Near) real time output:

- Latest CME detections (updated every six hours)
- Difference movie of latest c2 images
- Halo CME detection email-alert

CACTus COR2 CME list:

- The CACTus COR2 CME list is updated daily and posted here.
- Beacon COR2 CME speed calculator here

CACTus LASCO CME catalog:

- Online Catalog (version 2: CACTus version 2.5.0): from April 1997 until now (updated every 5 days)
  - Catalog as IDL save file: contains list of all CMEs detected in lz and qkl, flows detected in lz and qkl and a list of flows and cmes detected in lz and qkl
  - A list of CMEs detected in lz data
  - A list of flows detected in lz data
  - A list of CMEs and flows detected in lz data
  - A list of CMEs detected in qkl data
  - A list of flows detected in qkl data
  - A list of CMEs and flows detected in qkl data
- Online Catalog (version 1): from April 1997 until March 2007
- Composition of the catalog
- Acknowledgement

CACTUS

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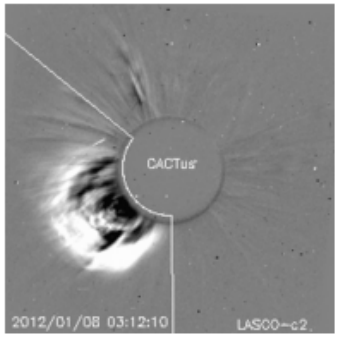
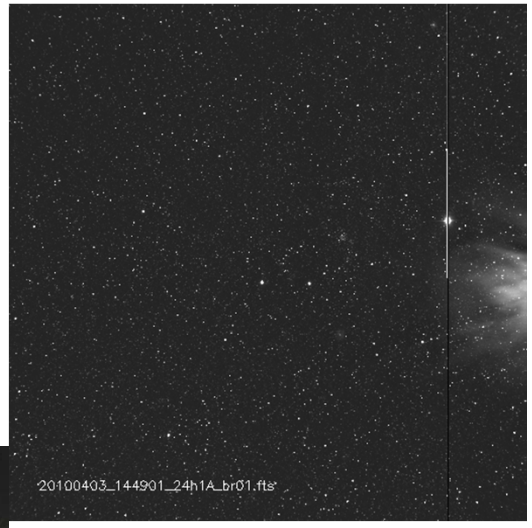
Details and graphs for CME0029

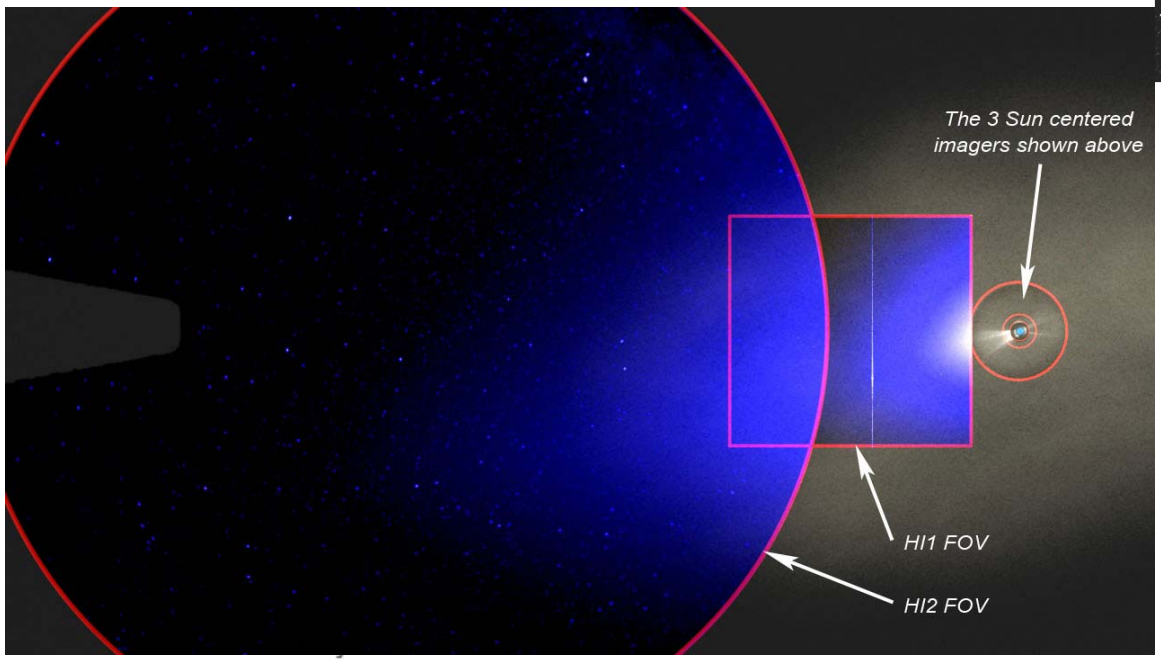
#	CME	t0	dt0	pa	da	v	dv	minv	maxv	halo?
	0029	2012/01/08 02:12	02	116	130	0523	0084	0307	0637	II

CME Movie :: Download ::

Sample Image







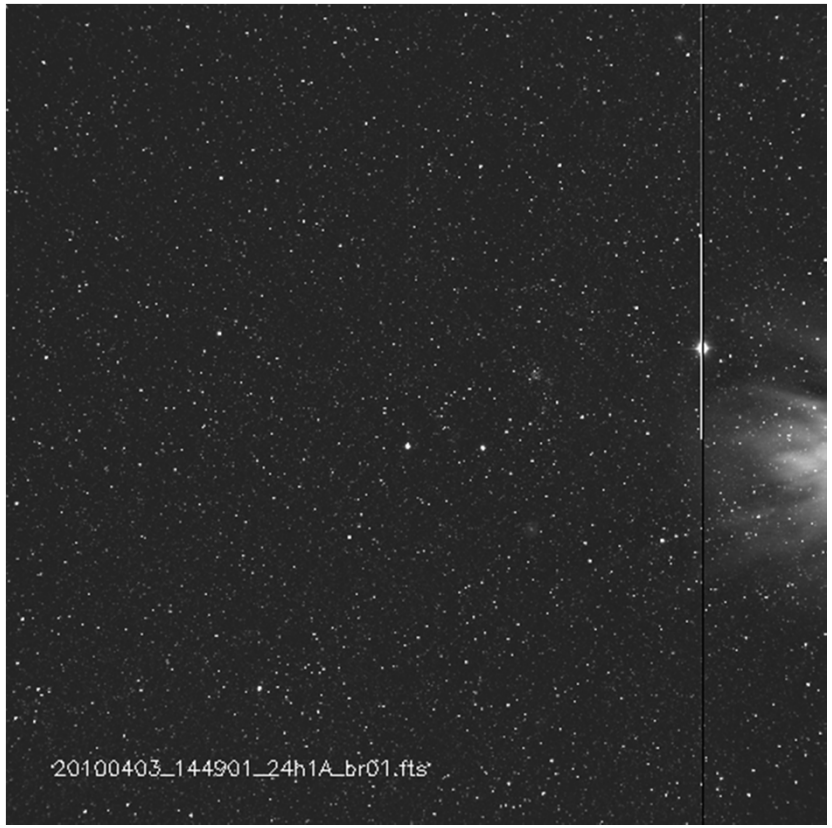
- Different geometry
- CMEs are fainter
- Include planets and stars
- Lower cadence

Application of CACTus on STEREO/HI1

Preprocessing

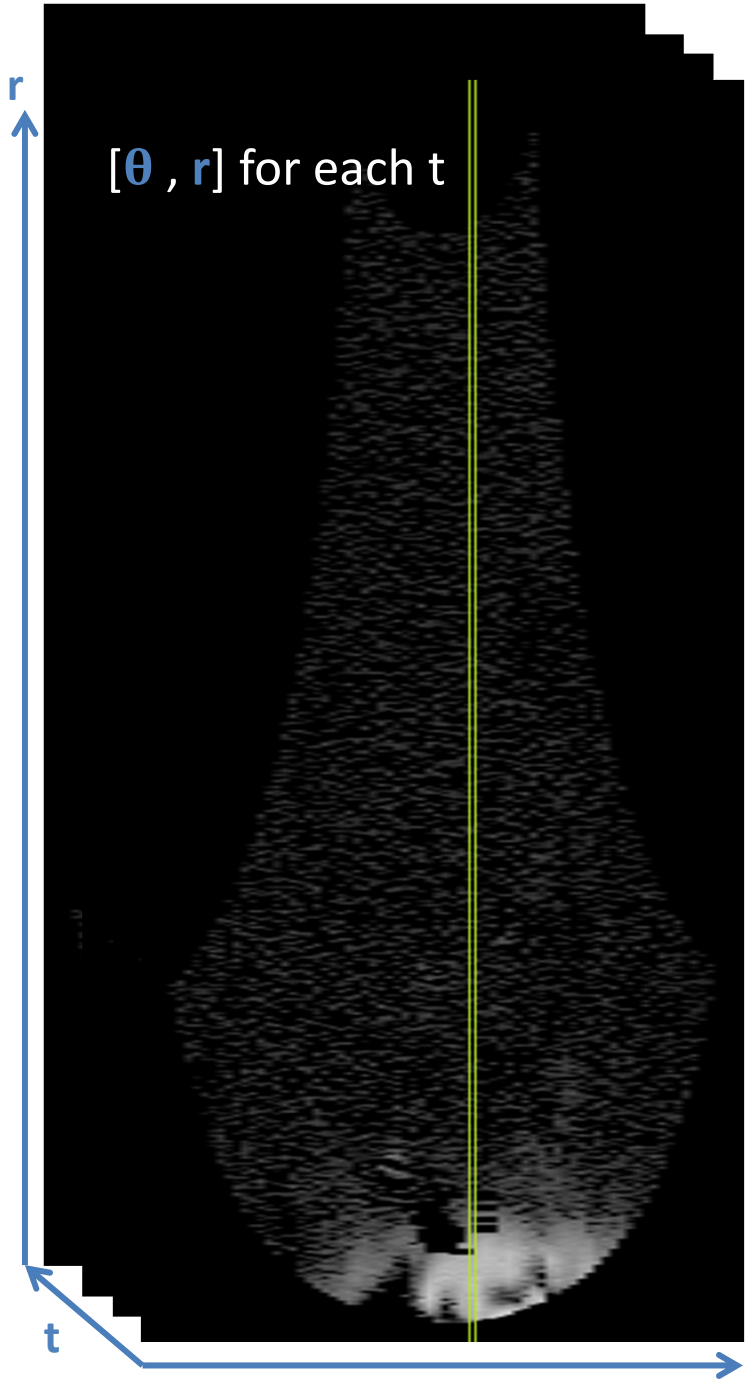
L2 images

(1-day backgrounds removed)



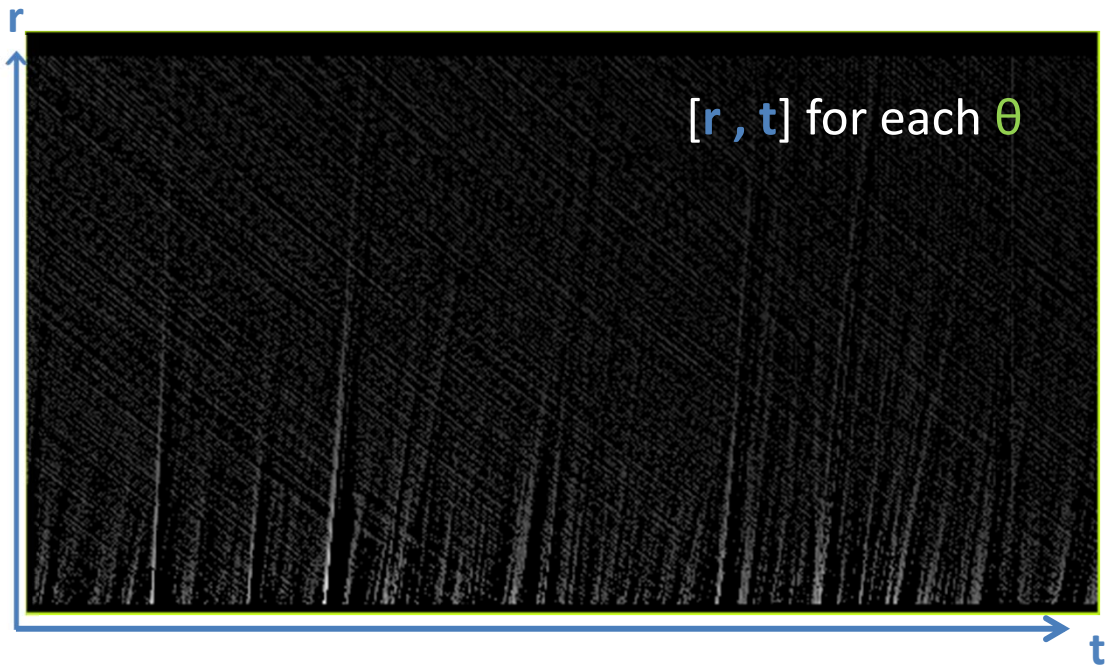
After some cleaning

Conversion to polar coordinates



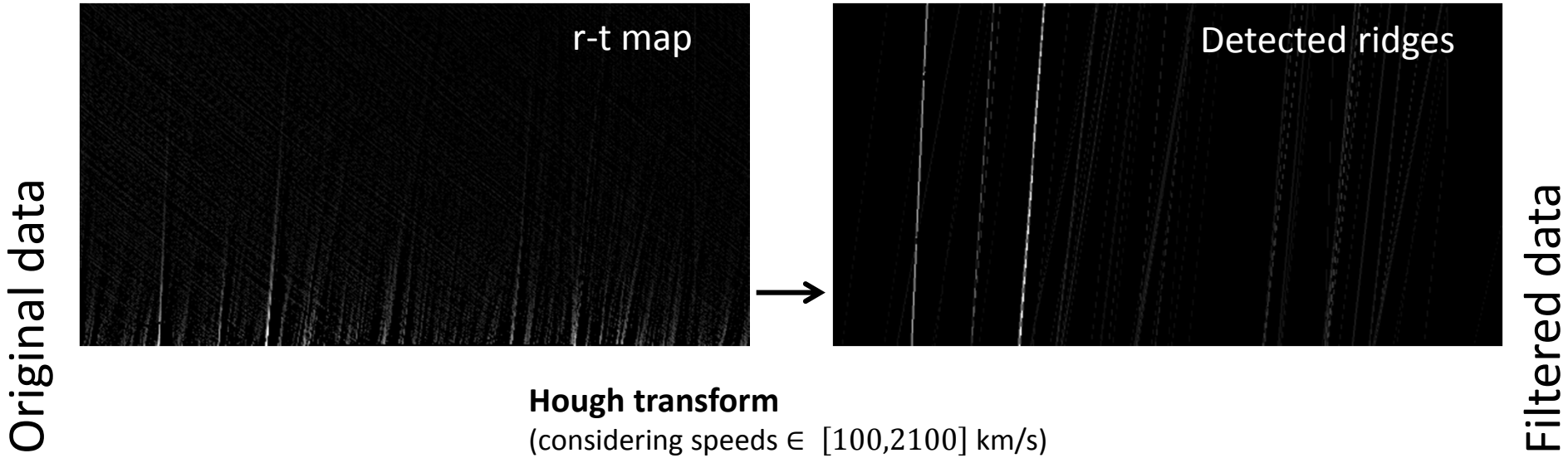
r-t slices

Extraction of r – t slices for each angle.



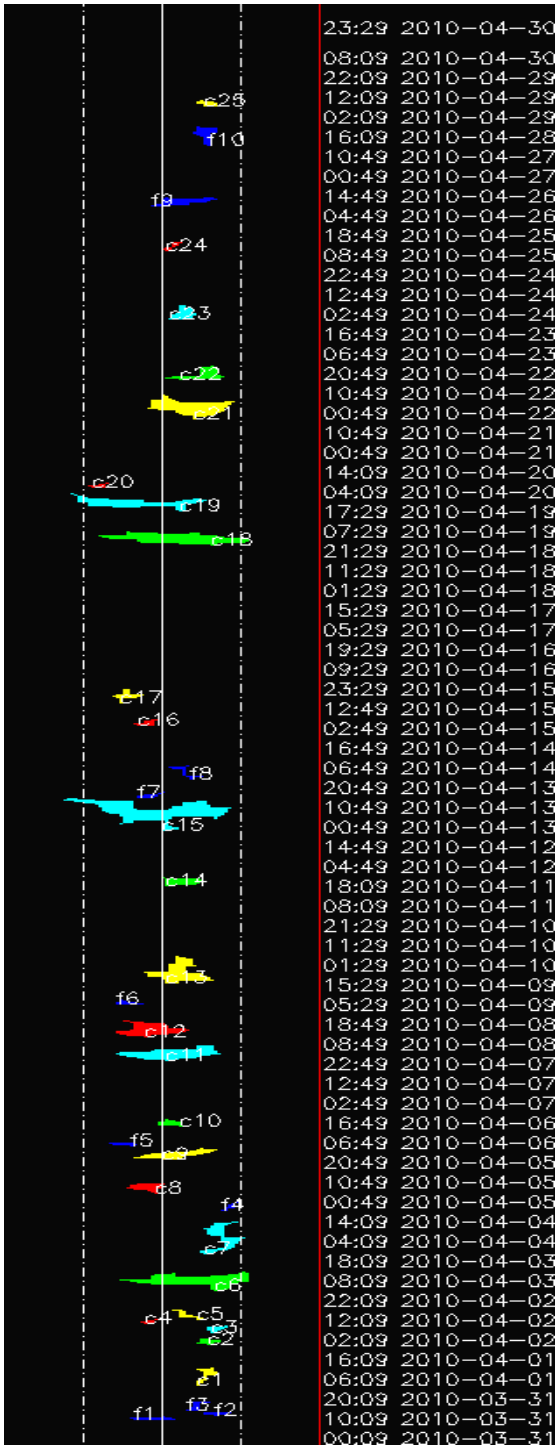
CME extraction

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



CACTus output: Visualisation

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



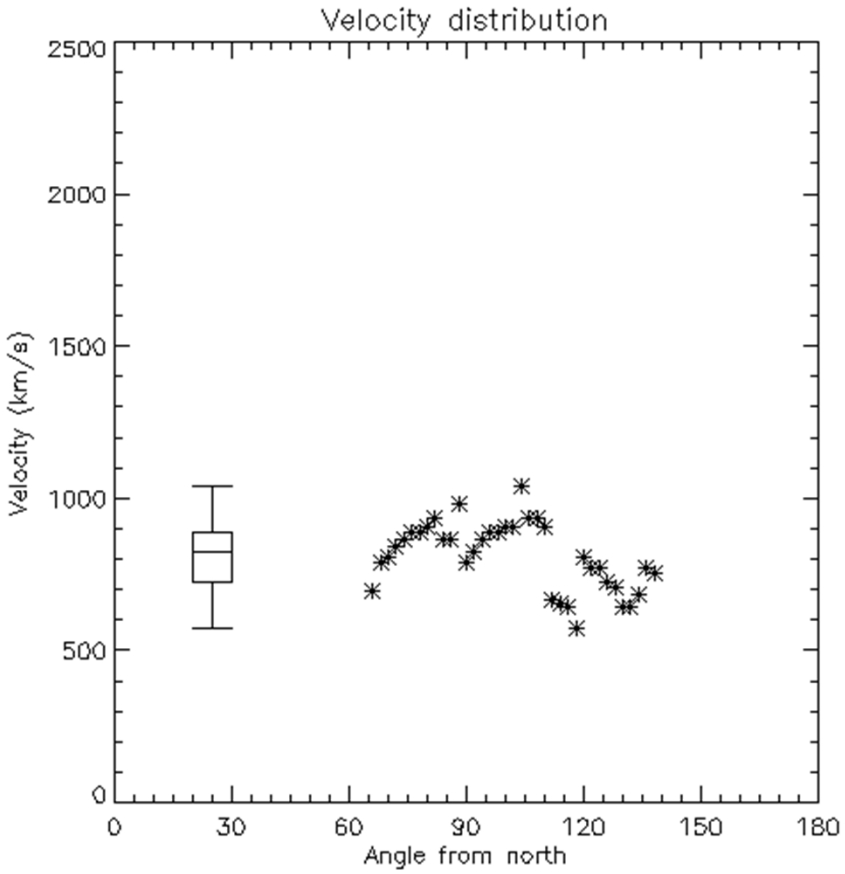
CACTus output

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

Starting time

Position and width

Speed



CACTus for STEREO/HI-1

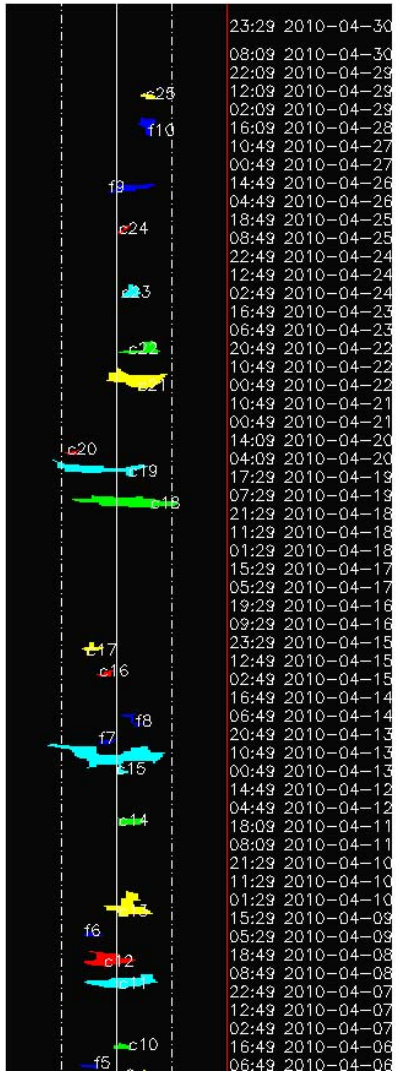
A software package for 'Computer Aided CME Tracking' (adapted from CACTus)

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

Show comparison with the Manual catalog and other level images

http://sidc.be/cactus/hi/

```
: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
```



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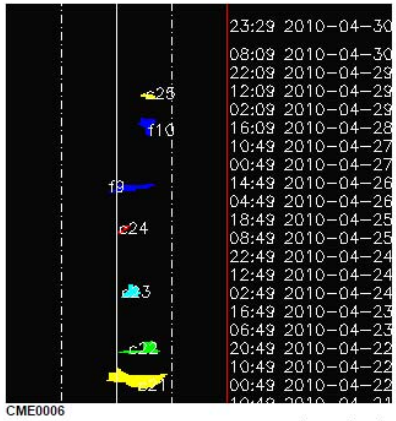
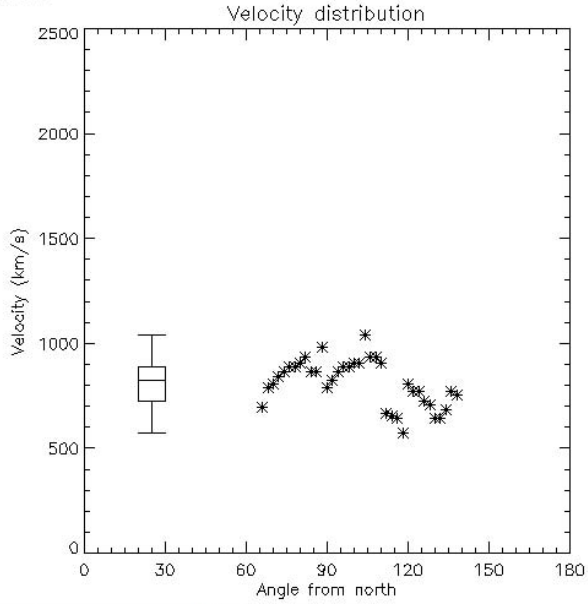
#    SPA: Southernmost propagation angle (degrees),
#      v: median (projected) velocity (km/s)
#     dv: variation (1 sigma) of velocity over the width of the CME
#   minv: lowest velocity detected within the CME
#   maxv: highest velocity detected within the CME
#
```

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



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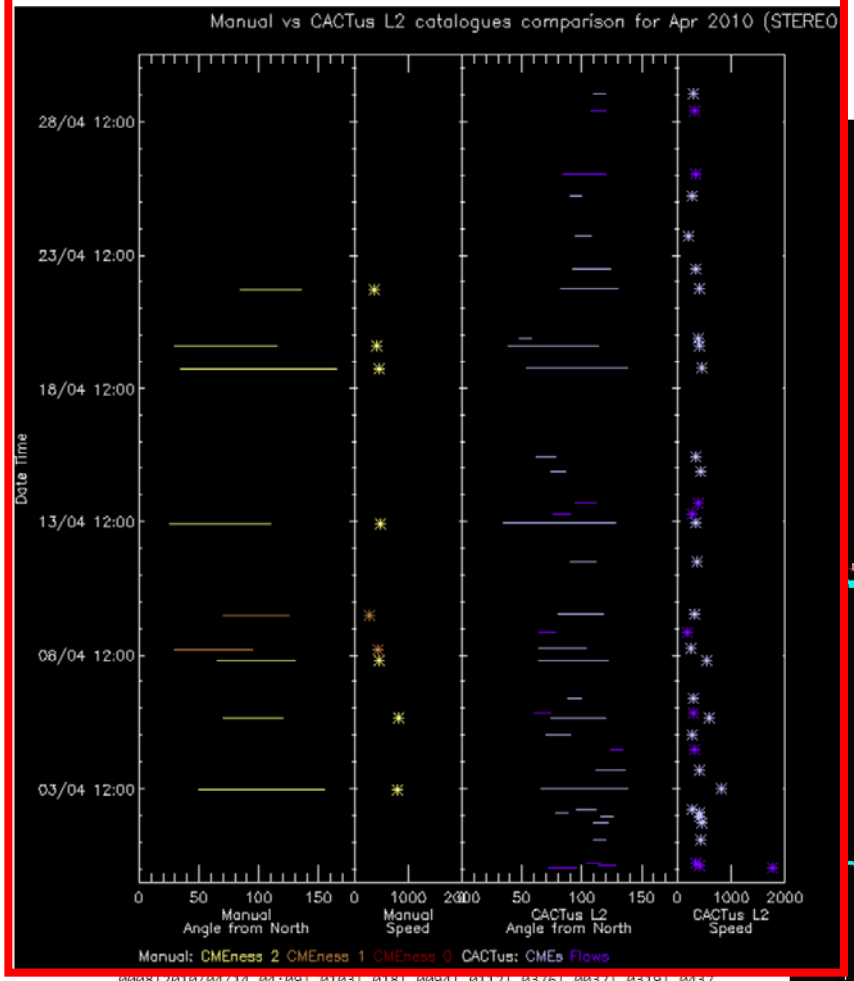
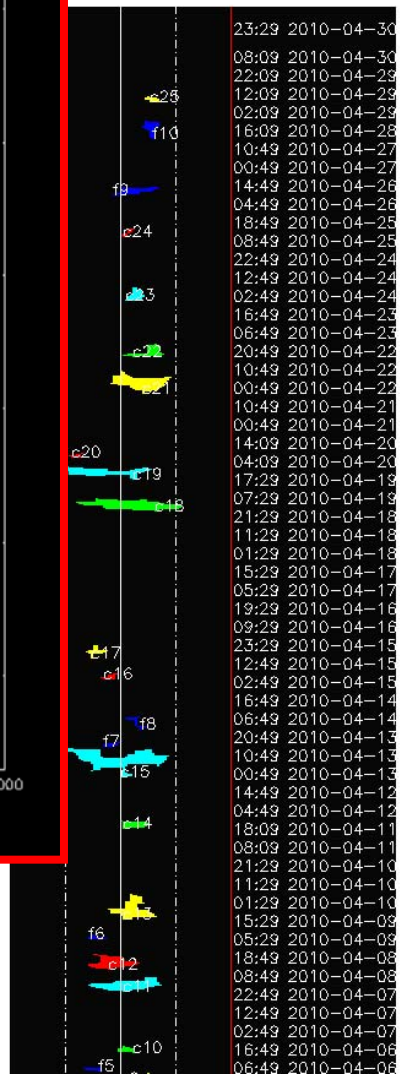
CMEs detected by CACTus - /A/2010/04/

Show comparison with the Manual catalog and other level images

http://sidc.be/cactus/hi/

Hide comparison with the Manual catalog and other level images





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

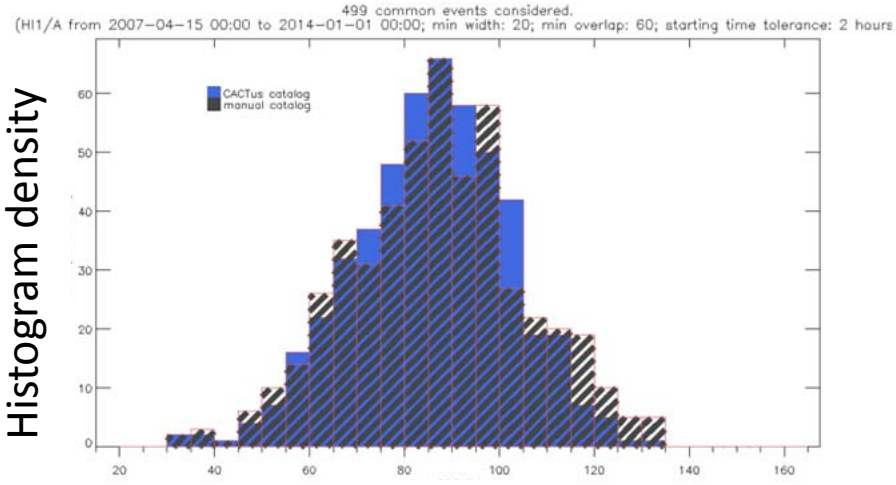
	Manual A	Manual B	Automatic A	Automatic B
Date	17.04.2007 - 29.12.2013	15.04.2007 - 31.12.2013	13.01.2007 - 18.08.2014	20.01.2007 - 28.08.2014
Total events	**856**	**817**	**1501**	**1794**
Date	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013	15.04.2007 - 31.12.2013
Total events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

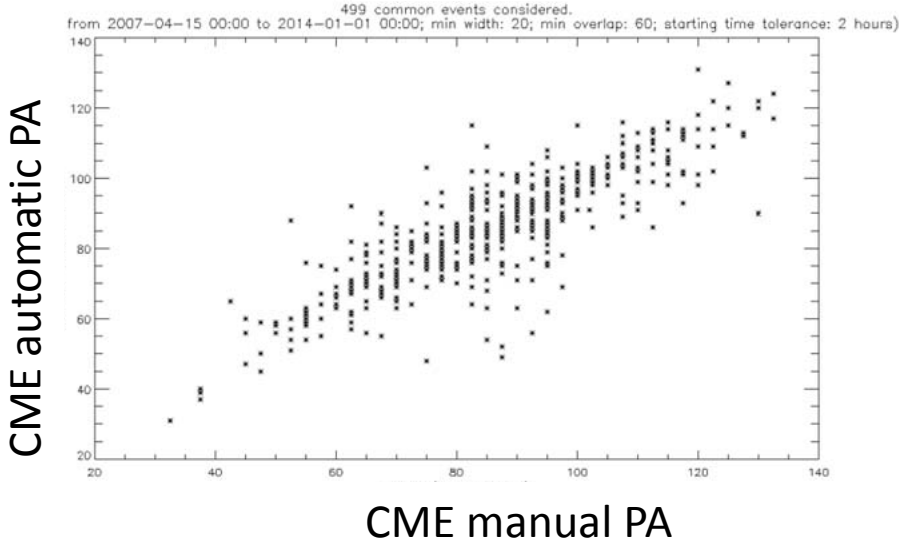
Table 2. Events between 15.04.2007 and 31.12.2013. Common events (starttime differs by le 2 hours, overlap ge 60% of the minimum width).

	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)*

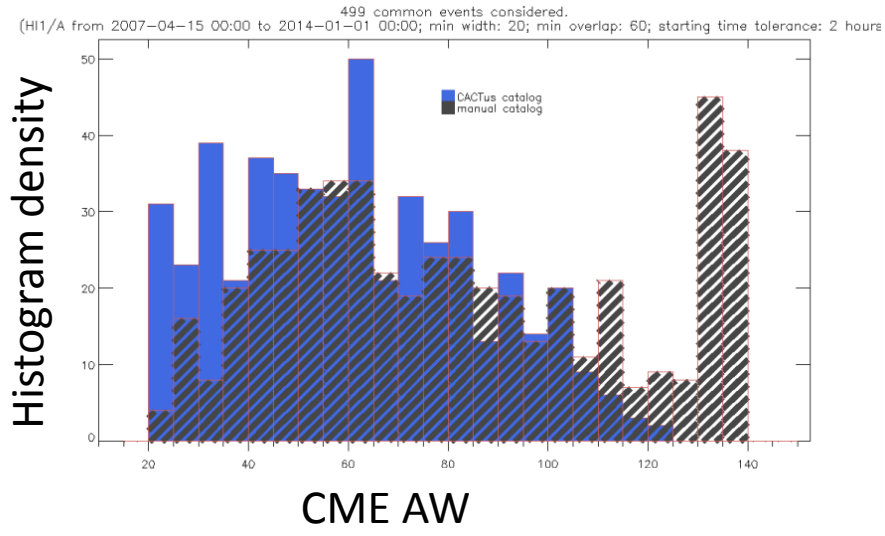
*CACTus gives a speed estimation for all its detections but obviously for speed comparisons we only consider the events for which we have an estimation in the manual catalogue.

Position angle





Angular width



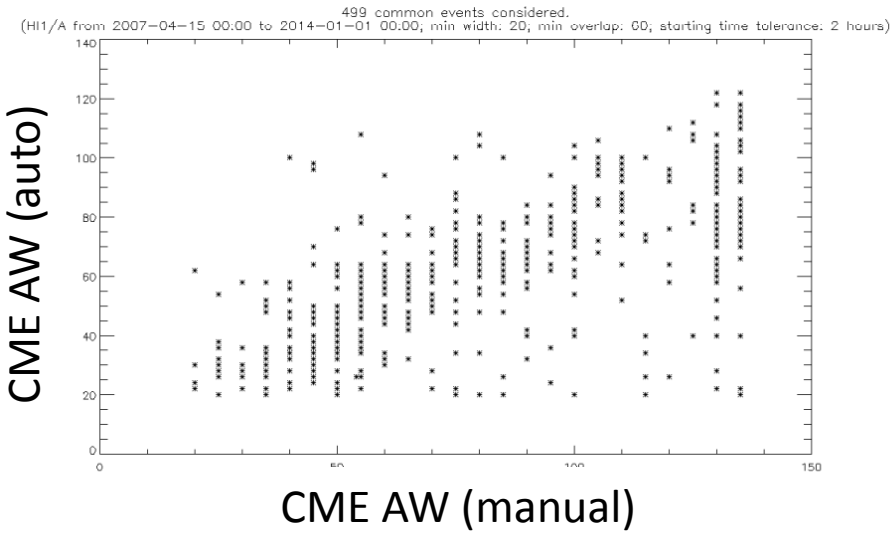
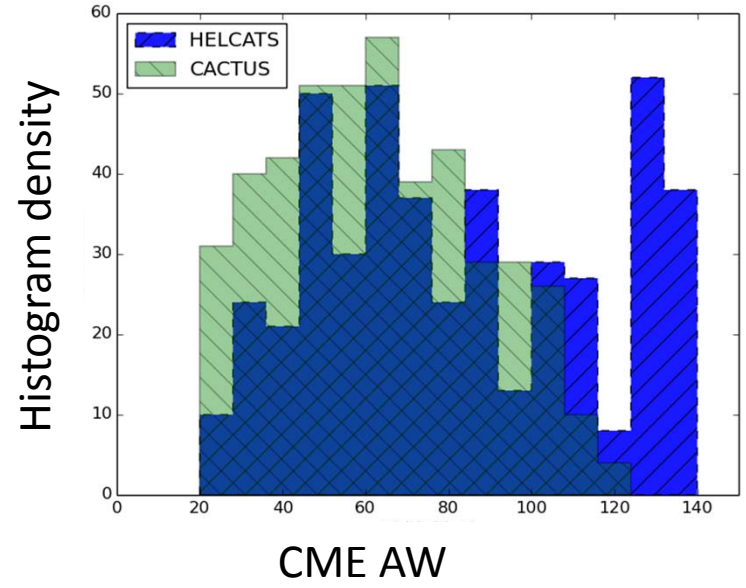
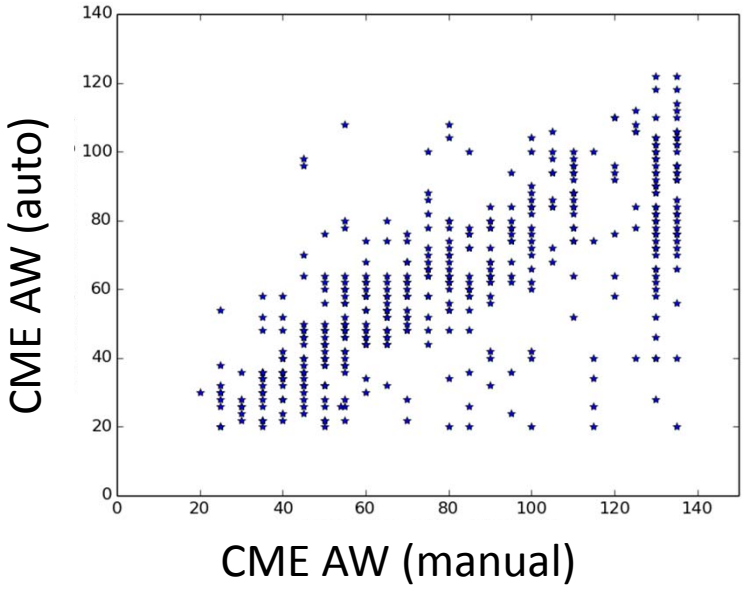
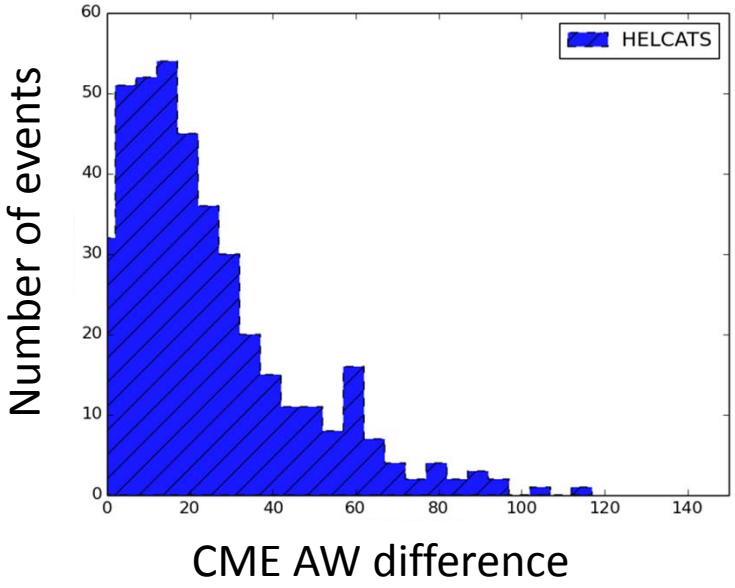


Fig. 3&4 Width of the common CMEs (499) observed by HI1-A

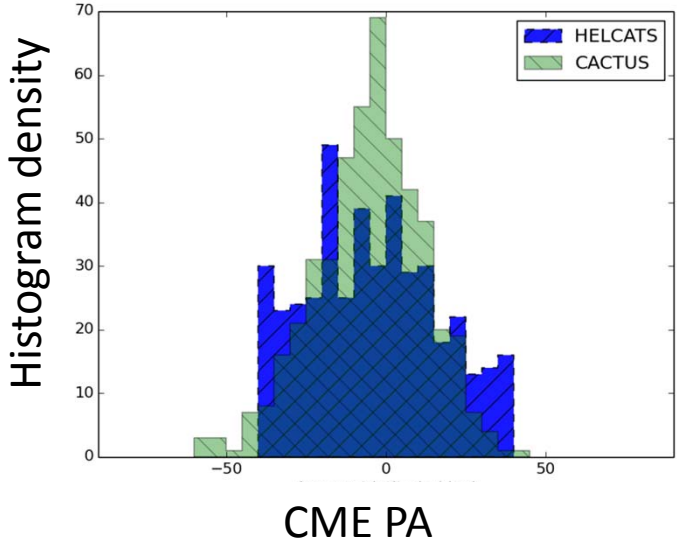
Angular width (human)

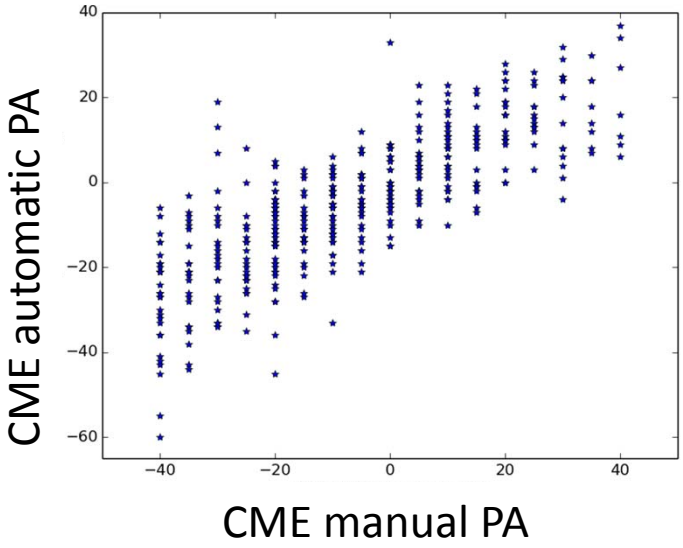


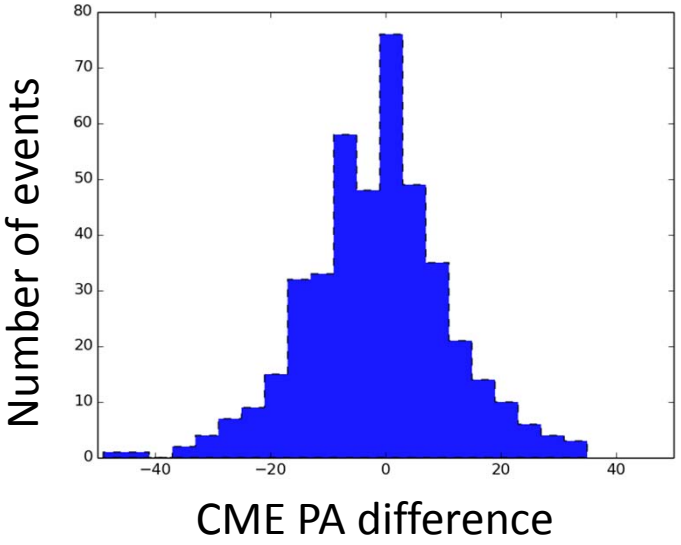




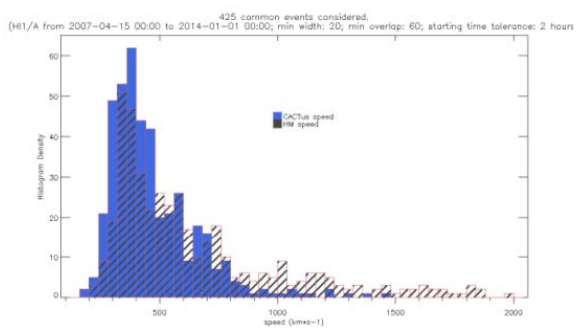
Position angle (human)

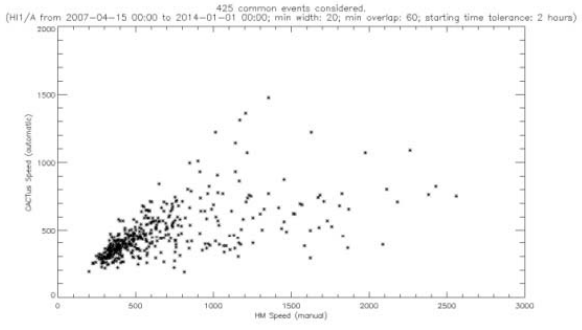


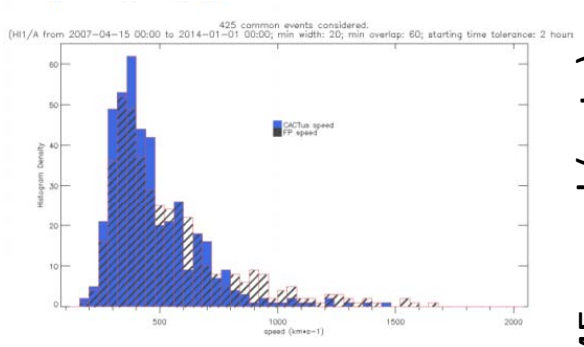


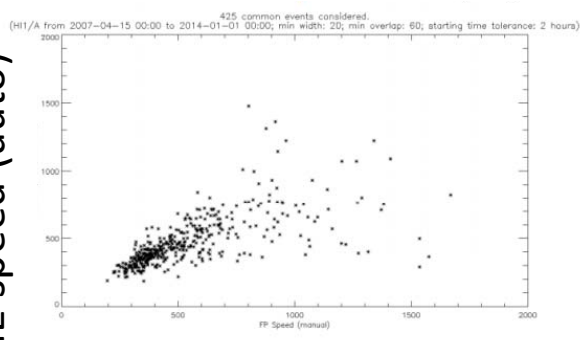


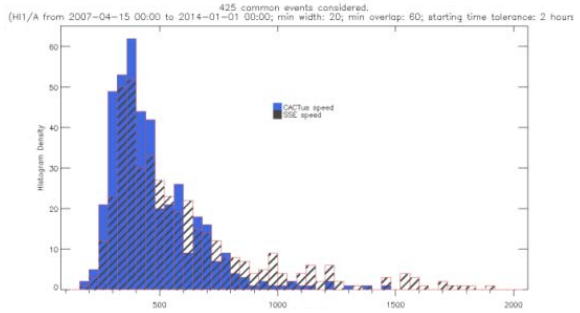
Speeds

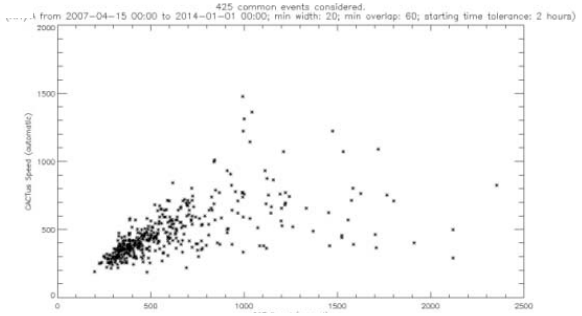












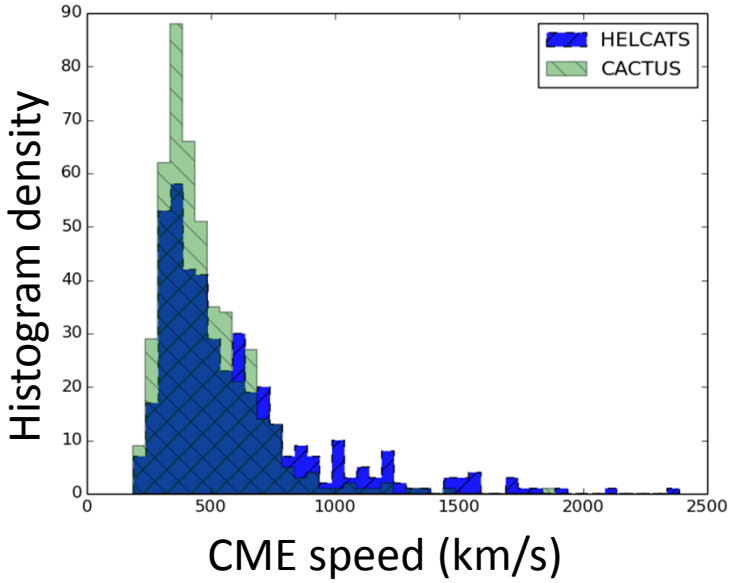
Histogram density

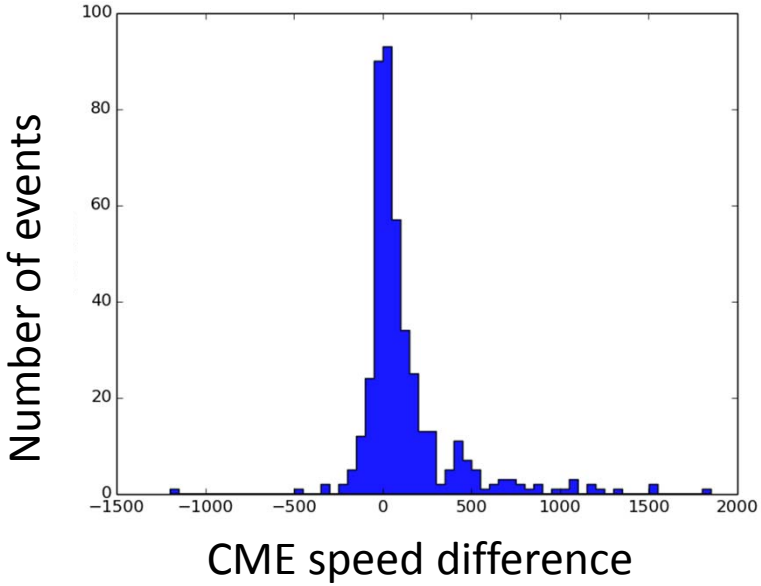
CME speed (auto)

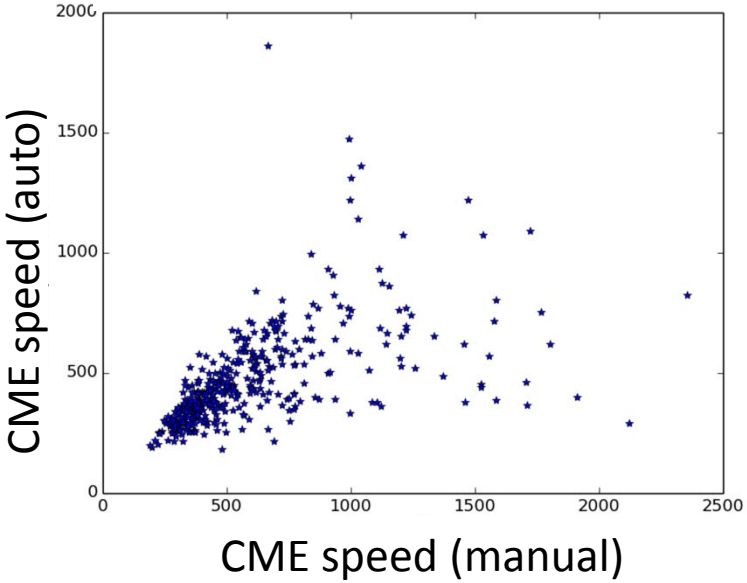
CME speed (km/s)

CME speed (manual)

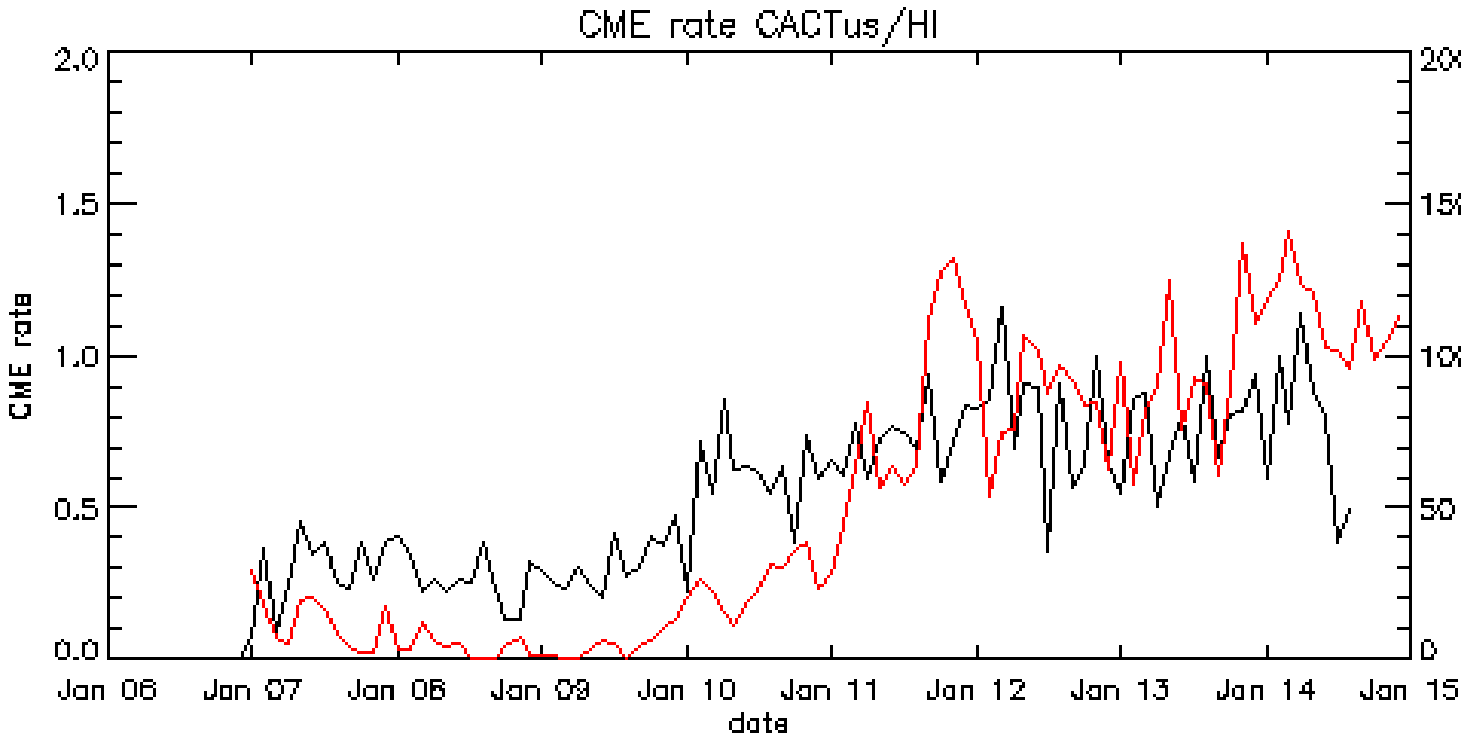
Speeds (human)







Automatic CME rate vs. sunspot number



Work on progress and future

- Comparison of manual and automatic catalogues
- Statistical analysys
- Visual inspection of events
- Comparison with other catalogues
- Real time catalogue of CACTus for HI
- Associated radio catalogue

Radio signatures

- list of CMEs observed in the HI field of view → Events from 'manual' & 'CACTUS catalog'
- radio observations by STEREO WAVES, WIND WAVES (http://secchirh.obspm.fr/) & ground based observations (European day time)

5 categories of events:

0 = no associated radio event

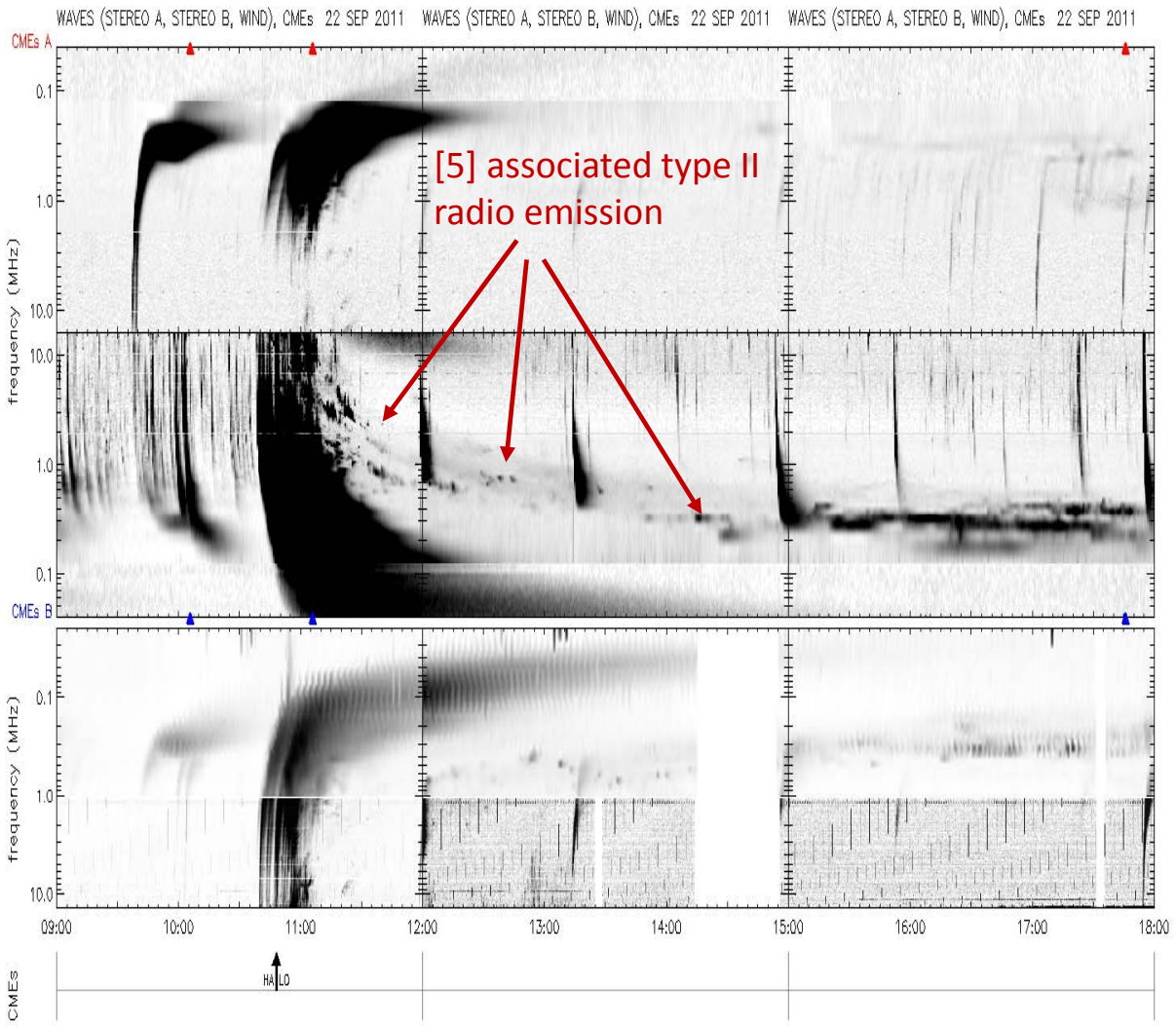
1 = weak radio emission observed, association is questionable

2 = radio emission observed, association is unclear

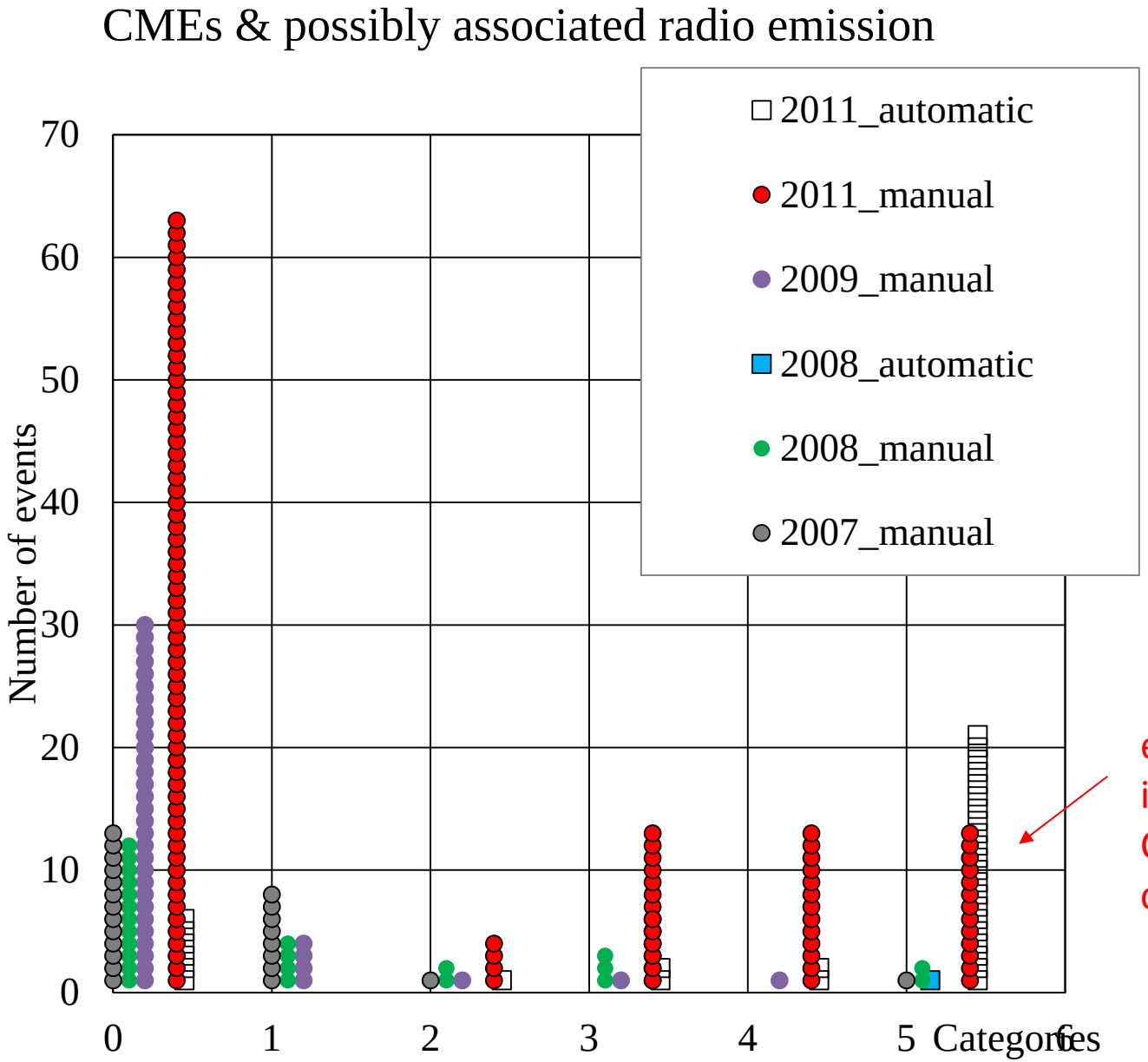
3 = drifting radio emission, possibly associated

4 = short segment, probably type II radio burst

5 = associated type II radio burst



Some statistics



5 categories of events:

0 = no associated radio even

1 = weak radio emission, association questionable

2 = radio emission observed, association is unclear

3 = drifting radio emission, possibly associated

4 = short segment, probably type II radio burst

5 = associated type II radio burst

events 'lost' in the CACTUS catalog