HELCATS: Cataloging CMEs in the STEREO HIs

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1 Computer set up:

On stereo-ops is a shared folder for the HELCATS team that Matthew Wild created and emailed everyone about following discussions on having a centralised set of codes, which can be accessed by the team for (version controlled) editing or updating, and indeed for being able to reproduce any output results.

stereo-ops: /soft/ukssdc/share/Solar/HELCATS/

In my .cshrc file I have set environment variable

setenv IDL_STARTUP ~/idl_startup.pro

where my idl_startup.pro contains

.run /soft/ukssdc/share/Solar/HELCATS/codes/init_routines.pro

addpath, '/soft/ukssdc/share/Solar/HELCATS/codes/', /expand

2 IDL Procedures:

Relevant IDL procedure codes are stored in:

stereo-ops: /soft/ukssdc/share/Solar/HELCATS/codes/

- **secchi_display.pro**

  Based upon James Tappin's codes. Produces a widget GUI with the option of choosing the date interval of HI images to be read-in and undergo processing (e.g. differencing of a specified window) to generate a movie interface with the ability to overlay a coordinate system.

  I have edited this, and relevant sub-procedures, to provide the smoothed difference images from plot_diff_images.pro and overlay the grids of the chosen coordinate system in reference to the ecliptic.

  The sub-procedures are (in alphabetical order):

  - add_cor_occ.pro
  - add_secchi_grid.pro
  - diff_secchi_data.pro
  - display_secchi_frame.pro
  - do_prep.pro
  - eh_tilt.pro
  - frame_find.pro
  - get_secchi_coords.pro
  - handle_draw_event.pro
  - make_secchi_gif.pro
  - make_secchi_section.pro
  - match_secchi_name.pro
  - median_secchi_data.pro
  - mk_secchi_path.pro
  - plot_diff_images.pro (below)
  - read_secchi_data.pro
  - read_secchi_points.pro
  - scc_get_missing.pro
  - secchi_contours.pro
  - secchi_geometry.pro
  - secchi_select.pro
  - secchi_show.pro
  - set_secchi_range.pro

- **plot_diff_images.pro**

  Based upon Jackie Davies' codes. Produces the processed SECCHI/HI images for CME inspection, by aligning the images for running-difference, calculating the resistant mean and smoothing the signal.

  I have edited this code to accept any specific start date and end date, to work on a single image or subset of a day or multiple days, with the option of saving the difference images as fits files (as well as the PDF outputs).

3 Demo.:

On stereo-ops call secchi_display to open the widget in Fig. 1. The default 'Data Directory' is /data/ukssdc/STEREO/ares.nrl.navy.mil/lz/ with the options to 'Pick...' the directory manually or specify 'Files...' via a separate widget shown in Fig. 2.

In this demonstration the date of 2008/02/01 was specified for spacecraft A, instrument HI-1, level 2, in units DN. The background length defaults to 1 for HI-1, or 3 for HI-2. 'Update list' shows the results with three fits files manually selected here (or there is the option to 'Select all') then click 'Apply' to return to the Secchi Display widget (Fig. 1).

With the relevant fits files selected, the option to 'Use smoothed running different images' calls plot_diff_images.pro which is optimal for inspecting CMEs in the images. The 'Difference stride' is set to 1. The choices of 'Grid type', 'Data range', 'Kill range', 'Frame delay' and 'Colour table...' may be prescribed now and/or changed during the image movie by holding right-click to reveal a drop-down menu, as shown in Fig. 3. For the plot_diff_images.pro output, a data range of min. 0 and max. 255 with kill range set to 0 often looks best.

Figure 3 shows the first differenced frame of the HI-1 data on 2008/02/01 at 00:09:01 UT. Right-click is held to reveal the drop-down menu with the option to 'Pause/Resume' and change speed and direction of playback; set the 'Data range'; change the 'Colour table' (here set to 'Red Temperature'); or overlay a 'Grid' of either (if I understand the coordinates' descriptions correctly):

1. 'Lat_Lon': Heliocentric inertial (HCI) latitude and longitude coordinates.
2. 'Elong_H-PA': Heliocentric inertial (HCI) elongations / position angles.
3. 'Elong_E-PA': Heliocentric earth-ecliptic (HEE) elongations / position angles.

On any paused single frame there is the option to 'Mark Points' whereby the user can point-&-click along a structure in the image, e.g., to trace a CME front. Clicking 'Mark Points' brings up a cursor icon to click within the image, and a right-click ends the process and saves the clicked points. These points are written to a text file named after the image header filename with "_pts.txt" appended to it (e.g., 20080201_000901_24h1A_br01_pts.txt), containing the following column-format information:

Date, Time, X, Y, Hlon, Hlat, Elong, H-PA, E-PA, Value.

An example text file of a point-&-click along the structure in the HI image of Fig. 3 is shown in Fig. 4.

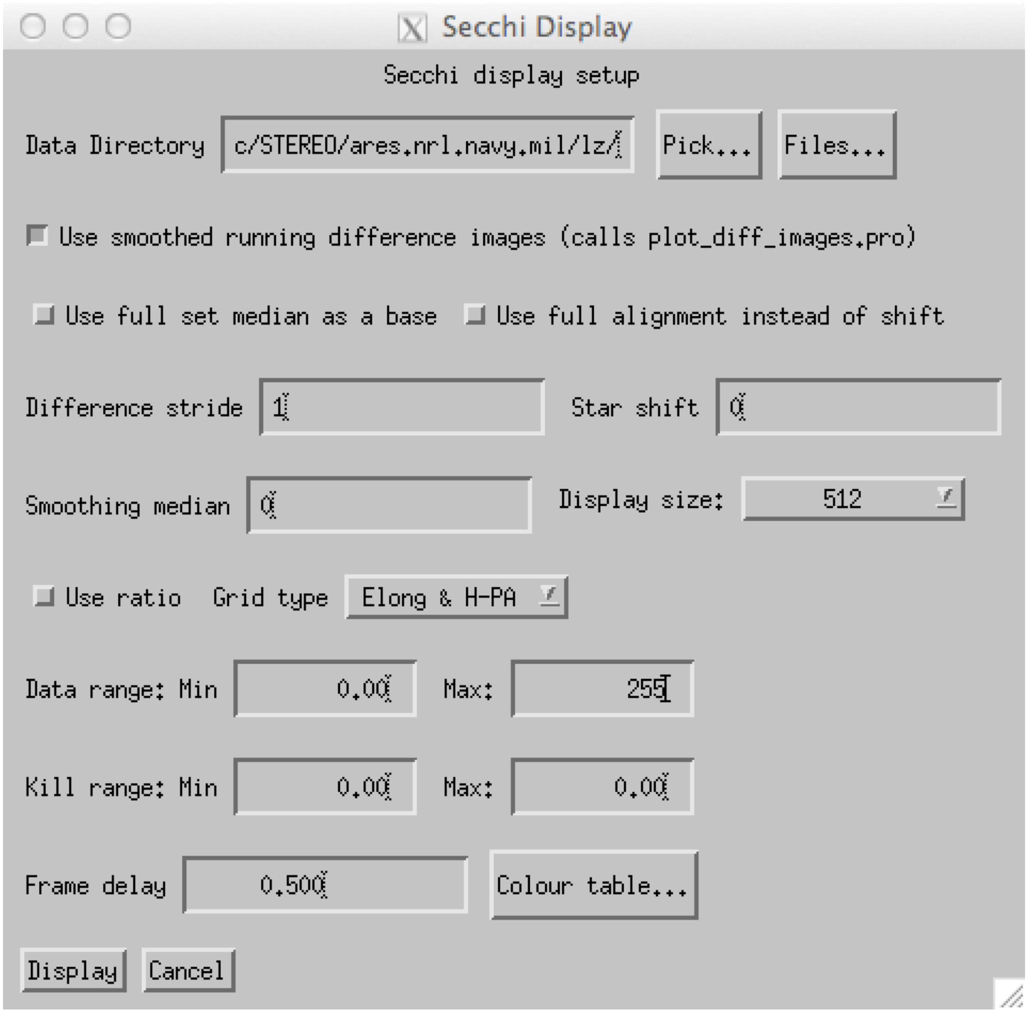

Figure 1: Screenshot of the widget GUI called by secchi_display.pro. In this demo the 'smoothed running difference images' are determined by calling plot_diff_images.pro with a 'Difference stride' of 1. The 'Display size', 'Grid type', 'Data range', 'Kill range', 'Frame delay', and 'Colour table...' are chosen to suit the user (with optimum values for this demo as displayed).

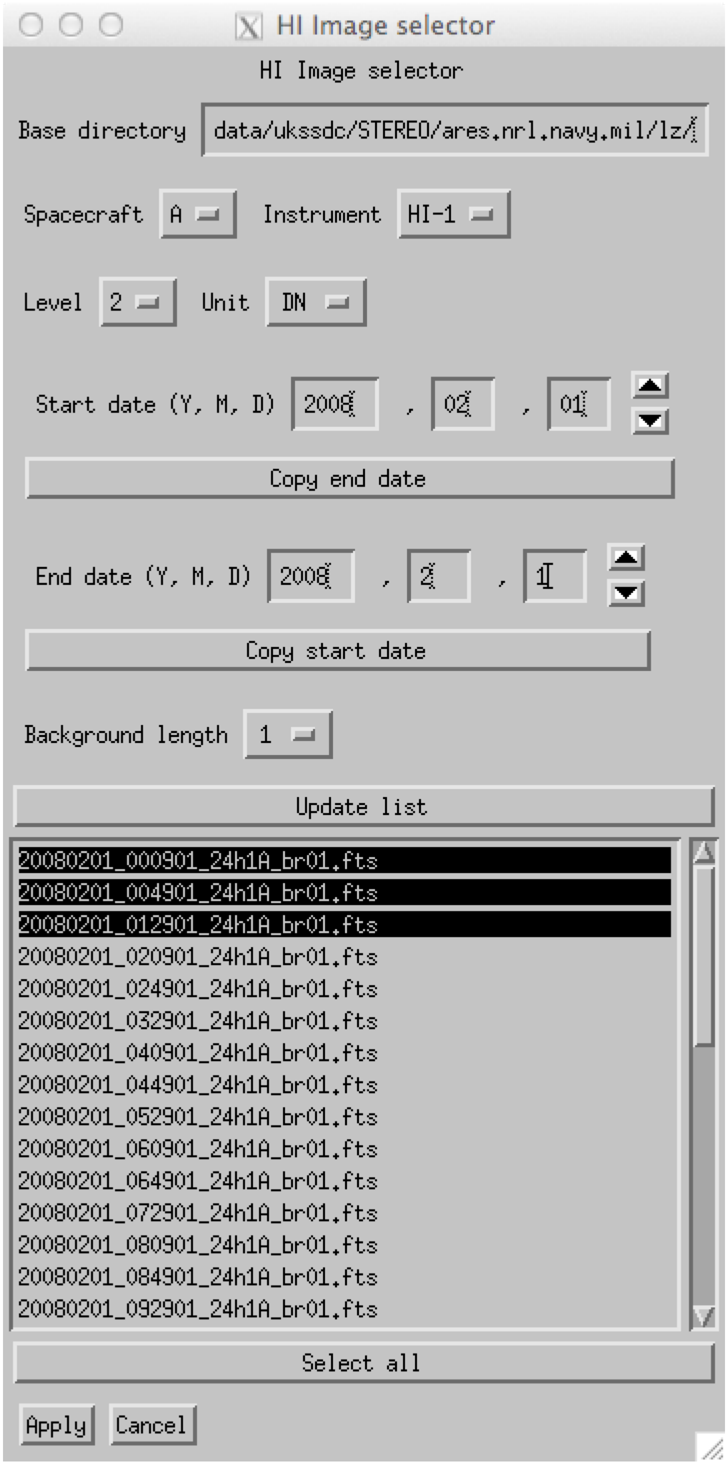

Figure 2: The HI image selector allows the specification of spacecraft, instrument, data level and units, for a given date interval. In this demo the HI-1 Ahead level-2 data for 2008/02/01 is chosen with the default background length of 1. The required fits files are highlights, or the user can click 'Select all', then click 'Apply'.

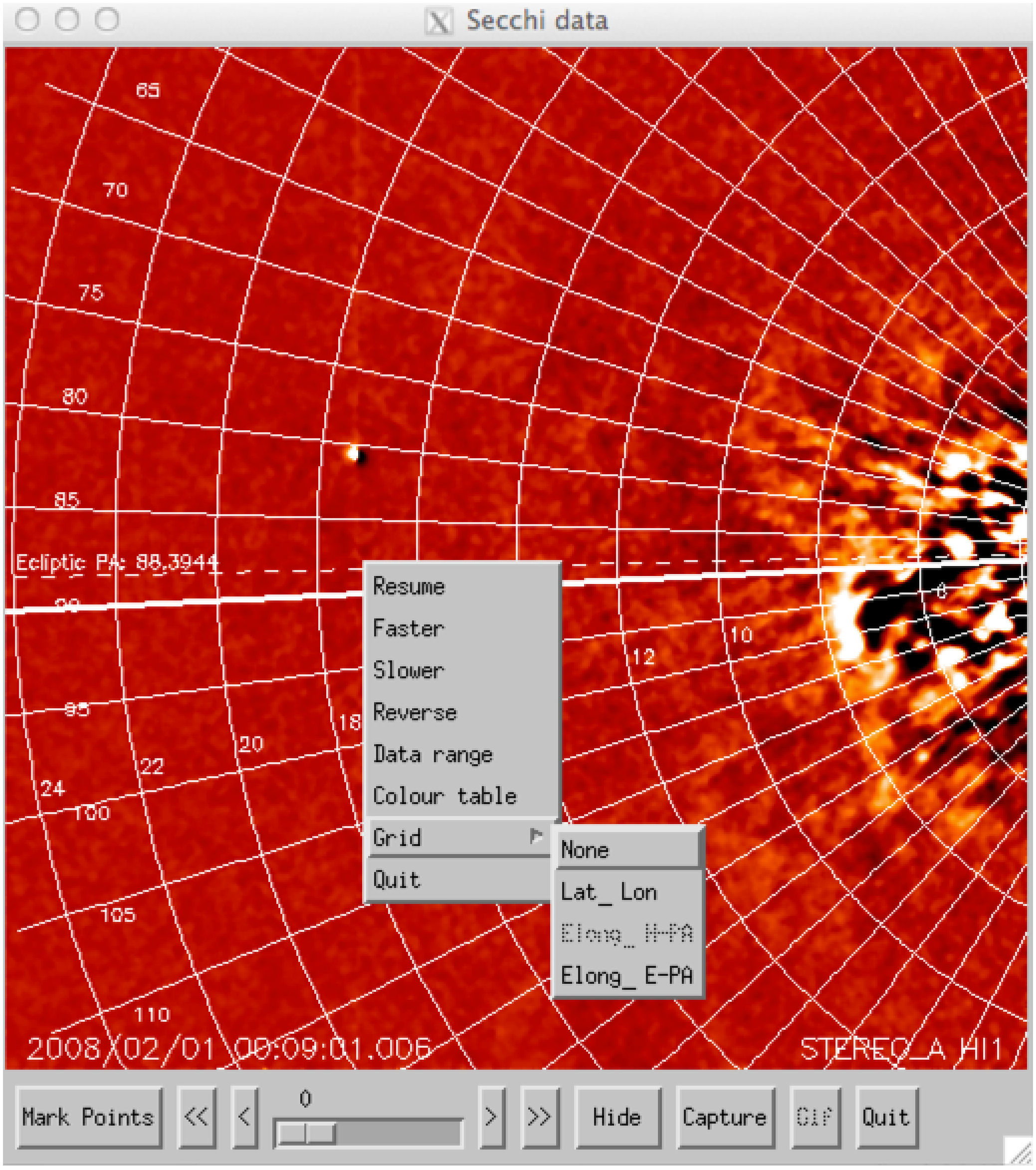

Figure 3: The resulting smoothed difference images are displayed in a playback format as shown. Holding right-click reveals a drop-down menu with options on playback and image presentation. This image shows a resulting HI image with the Elong_H-PA grid overlaid, wherein the thicker line is the central position-angle (90°) and the dashed line indicates the ecliptic plane ($\sim 88.4°$).

DATE	TIME	X	Y	Hlon	Hlat	Elong	H-PA	E-PA	Value
2008/02/01	00:09:01.006	1010	222	-4.417	-5.627	7.149	141.985	143.590	133.
2008/02/01	00:09:01.006	940	222	-5.784	-5.577	8.028	134.093	135.699	148.
2008/02/01	00:09:01.006	874	252	-7.052	-4.937	8.601	125.134	126.739	142.
2008/02/01	00:09:01.006	842	318	-7.617	-3.609	8.424	115.448	117.054	128.
2008/02/01	00:09:01.006	822	386	-7.944	-2.246	8.254	105.841	107.447	136.
2008/02/01	00:09:01.006	820	452	-7.918	-0.935	7.972	96.757	98.362	213.
2008/02/01	00:09:01.006	822	522	-7.808	0.452	7.821	86.674	88.279	132.
2008/02/01	00:09:01.006	850	574	-7.203	1.455	7.347	78.547	80.153	119.
2008/02/01	00:09:01.006	882	624	-6.522	2.411	6.951	69.661	71.266	64.8
2008/02/01	00:09:01.006	942	642	-5.326	2.700	5.970	63.065	64.671	86.5
2008/02/01	00:09:01.006	1008	660	-4.020	2.980	5.002	53.405	55.011	17.5

Figure 4: Column-format text file of information on the manual point-&-click of the HI image in Fig. 3. The columns contains the date and time of the image, the x and y coordinates of each click, and its corresponding value in the associated coordinate systems of the 'Grid' options above: HCI longitude & latitude; Elongation angle from the spacecraft; HCI position angle; HEE position angle; and the image value at that point.

4 Inspecting J-maps:

I edited Jackie's jmap_widget_pa_final.pro to accept a specific date range in its generation of the J-maps of HI data, as in Fig. 5. I also included an fmedian smoothing operation via the keyword smooth_fac. The main addition I've worked on is employing a multiscale filter by simple keyword call (/canny_atrous) that can plot the resulting image in place of the original in the widget display of Fig. 5. Examples of output images from the multiscale filtering are shown in Fig. 6. It may be possible to somewhat automate the edge charaterisation of J-map tracks with the pixel-chaining demonstrated in Fig. 7 but this is only speculative since it is probably not robust enough against the overlapping of features on top of the background noise.
The example call to produce Fig. 5 is:

jmap_widget_pa, 'A', 'file.out', date_start='20080201', date_end='20080228'

Note: this calls the saved data from:
/data/ukssdc/STEREO/stereo_work/jaq/KEOGRAM_DATA/
keogram_HI1A_widget_data_2008_pa.sav

5 Ongoing efforts:

It is planned to combine these aspects of work such that it be possible to cross-correlate / inspect the structures that would be characterised in both the images and the J-maps, to ensure that the most appropriate CME structures be tracked and catalogued.

With these codes in place, a subset of the data may be inspected to produce an initial deliverable in the form of the intended final exhaustive CME list and their catalogued properties.

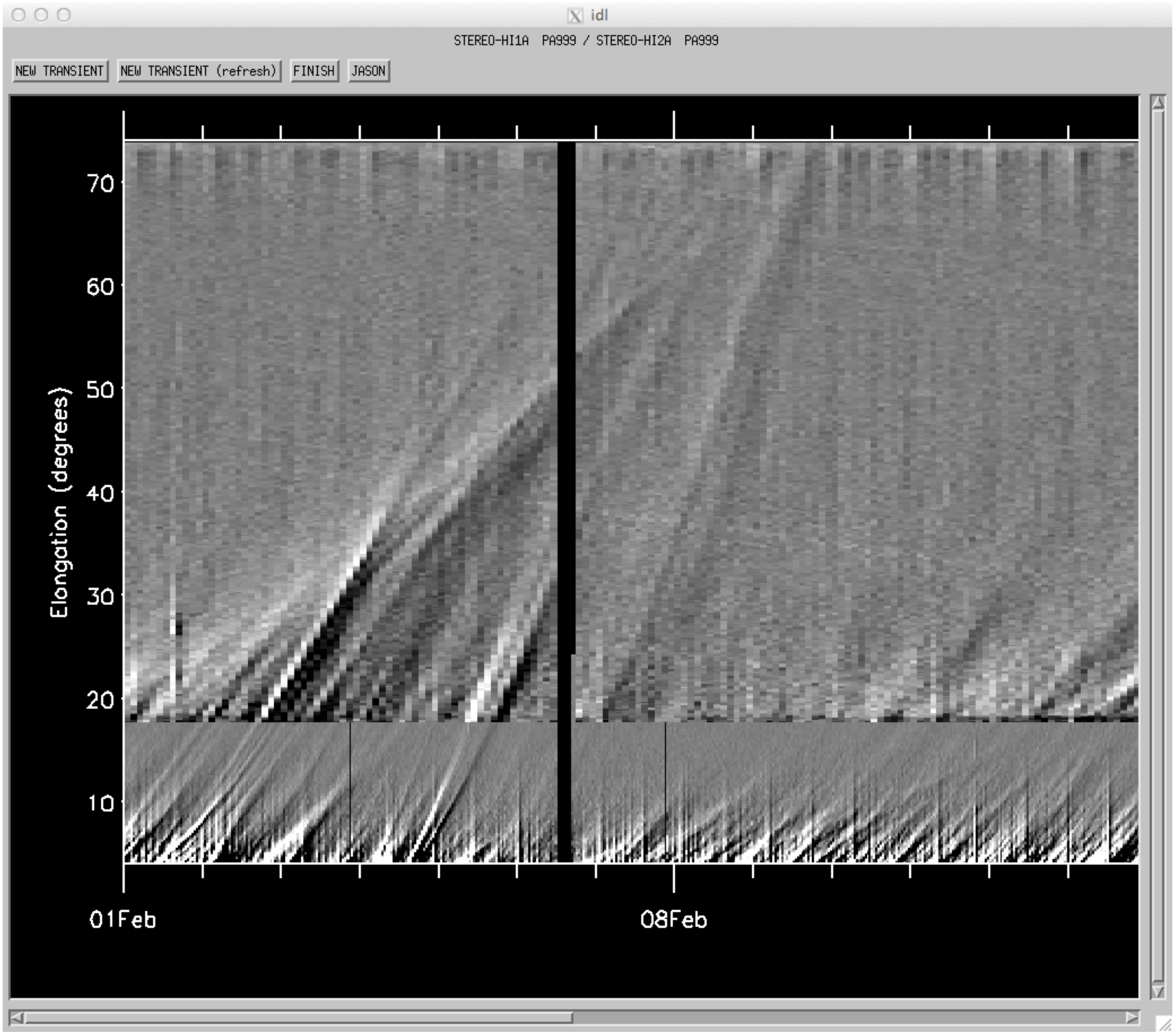

Figure 5: The output J-map from the jmap_widget_pa code, plotting elongation angle in the HIs against time. The 'New Transient' button allows a point-&-click along structures of interest, saving out the points to the specified output file.

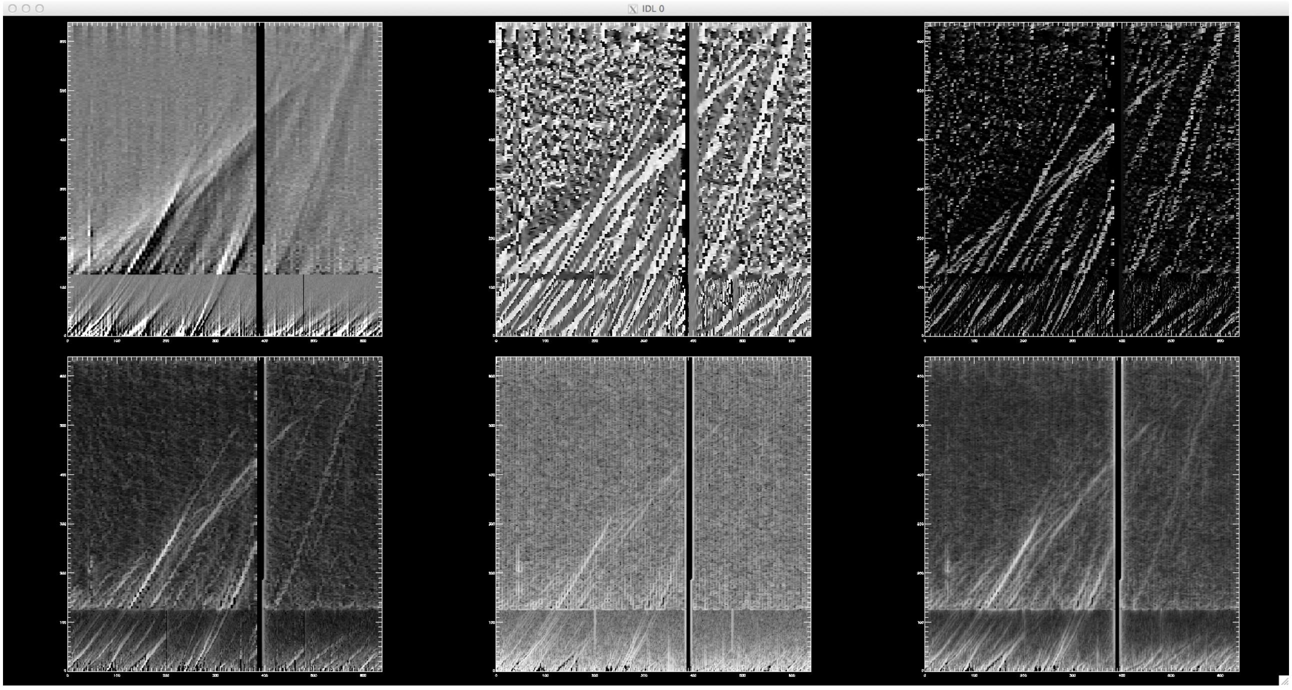

Figure 6: The application of a multiscale filter (namely the Canny-Atrous of Young et al. 2008) to the original HIs J-map shown in the top left image. The subsequent images combine the magnitude and angular information from the filtering process in different ways to highlight and contrast the structures.

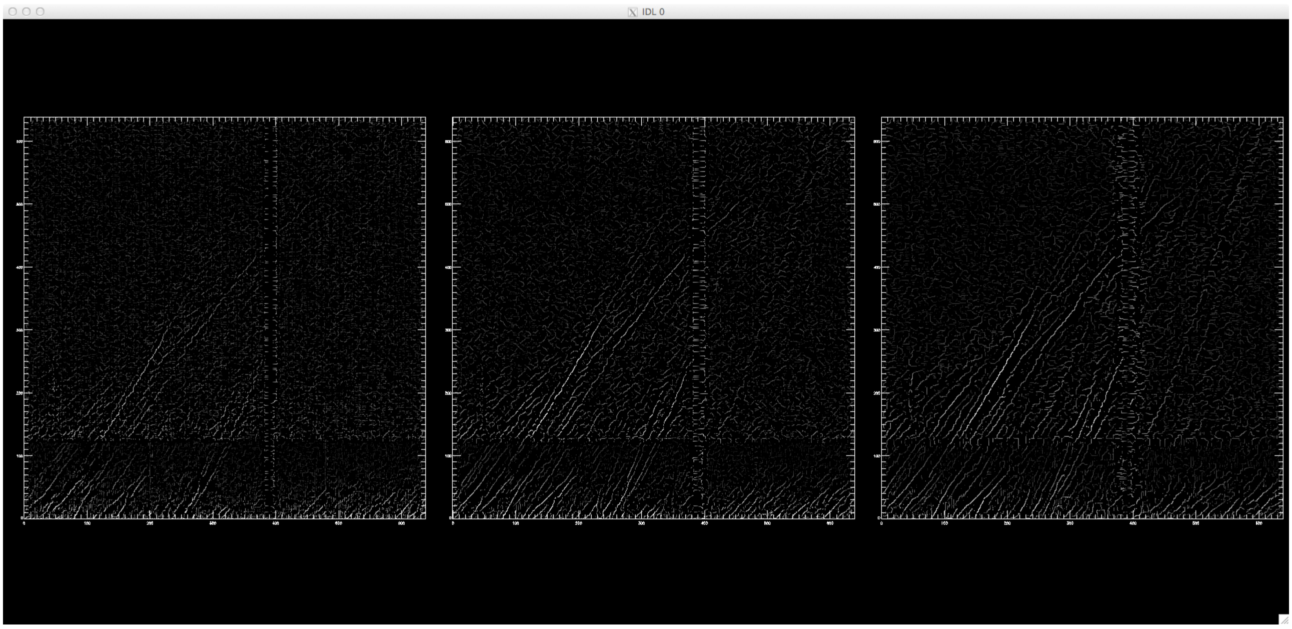

Figure 7: A pixel-chaining algorithm may be applied to trace the edges revealed by the multi-scale filtering, at various levels of thresholds.

WP2 Observational Catalogue

The WP2 observational catalogue[1] is generated via the following steps (on the stereo-ops machine):

1. Open HI1 image file to be inspected: e.g. for the date 2008/02/01
   gv /data/ukssdc/STEREO/stereo_work/jaq/CME_LIST_PLOTS/
   2008_A_DIFF/HI1A_20080201_diff.pdf

2. Into the respective year file in the HELCATS directory is entered the CME date and time (of first appearance), the north and south position angles, a central position angle (deemed best for performing a J-map tracking of the event) and quality index (0, 1 or 2): e.g. for the date 2008/02/01 in file
   /soft/ukssdc/share/Solar/HELCATS/catalog/STA2008.txt
   there is an entry for a CME with parameters
   date 01 | month 02 | hour 10 | min 49 | pa_N 55 | pa_mid 80 | pa_S 95 | quality 1

3. The yearly text files are then collated into a single text file in the appropriate format for the observational catalogue, using the code convert.pro in directory
   /soft/ukssdc/share/Solar/HELCATS/codes/convert.pro
   So this generates, e.g.,
   STEREO-A_CME_LIST_WP2_ddmmyy.txt
   where the most recent date ddmmyy indicates the most updated version.
   And similarly for the Behind spacecraft, e.g.,
   STEREO-B_CME_LIST_WP2_ddmmyy.txt

4. Use the process_wp2_cat.sh script in the /soft/ukssdc/share/Solar/HELCATS/catalog directory to merge the STEREO-A and -B lists into a single time ordered catalogue, remove the 'Halo' field and output in ASCII, JSON and VOTable formats. The resulting files are named according to the scheme HCME_WP_Vnn.[txt|json|vot].

WP3 CME Tracking in J-maps

The WP3 tracking catalogue is then generated by inspection and characterisation of the J-maps for the CMEs in the WP2 catalogue, by the following steps (on the stereo-ops machine):

1. The code list.pro is run to generate a list of all fair and good events, to remove the poor events for the tracking. This code is in directory
   /soft/ukssdc/share/Solar/HELCATS/codes/list.pro

2. From the list of fair and good events, a J-map for each event is called in the code
   /soft/ukssdc/share/Solar/HELCATS/codes/jmap_widget_pa_final.pro
   In IDL the code is compiled as .r jmap_widget_pa_final and then called as, e.g.,

[1] http://www.helcats-fp7.eu/catalogues/wp2_cat.html

jmap_widget_pa, ‘A’, 2008, 02, 01, ‘01’, /dofit, posa=80
where the ‘01’ entry corresponds to the first CME to be tracked on that day (so a small number of events are ‘02’ if they are the second CME to be tracked on that day), the ‘dofit’ keyword performs the model fitting to the J-map clicked tracks, and the ‘posa’ is the position angle suggested as pa_mid in the WP2 observational catalogue.

3. In WP3 each CME track is characterised 5 times by a point-&-click along the bright front/ridge corresponding to the front of the CME (along the position angle chosen to generate the J-map). Two output files are produced for each track, e.g.:
/soft/ukssdc/share/Solar/HELCATS/tracks/HCME_A__20080201_01_PA080.dat
which contains the 5 point-&-clicks date-time, distance (in Helioprojective-radial coordinates), J-map position angle (PA), and spacecraft (A/B); and
/soft/ukssdc/share/Solar/HELCATS/tracks/HCME_A__20080201_01_PA080.dat_fit
which contains the 5 resulting fittings of each of the three methods: Fixed Phi, Self-Similar Expansion, and Harmonic Mean.