

# SWPC\_CAT

## README

Instructions on installing and using the SWPC CME Analysis Tool (CAT)

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**NOTE: SWPC\_CAT requires IDL version 8.0 or above**

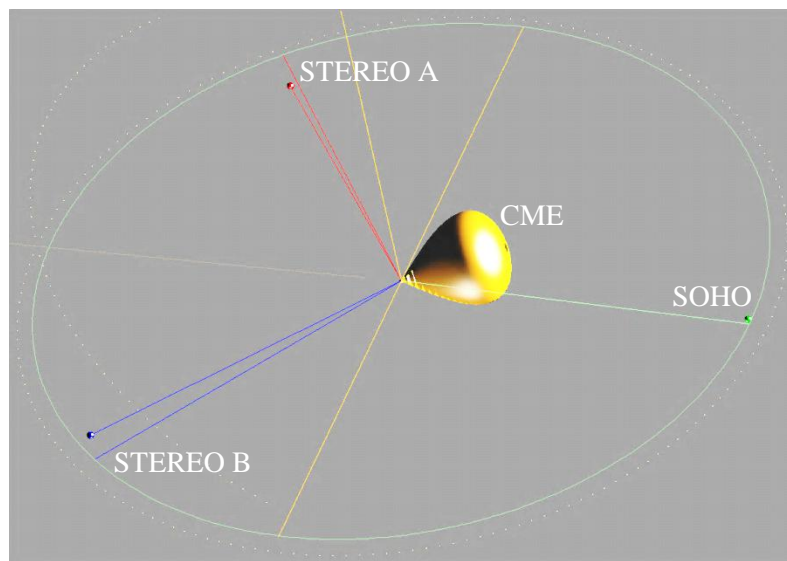
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## 1. Introduction

The CME Analysis Tool (CAT) is an IDL-based software system in routine operational use at the NOAA Space Weather Prediction Center (SWPC) as the primary means to determine key parameters of a CME as it emerges from the solar corona. It was developed by researchers at SWPC as part of transitioning the WSA-Enlil model to operations at the National Weather Service.

CAT works by modeling the geometric space of the inner Heliosphere using the 3D object graphics abilities in IDL. With the Sun occupying the center location, CAT calculates the relative positions of the 3 spacecraft, SOHO, STEREO A and STEREO B, at a given time of interest. A 3-dimensional geometric model of a CME, with its origin at the Sun, is placed in the modeled Heliosphere. The model CME can be adjusted with respect to the latitude and longitude of its axis, its angular width and its leading edge distance.

Three views are then constructed for ‘cameras’ located at the positions of each spacecraft. The views are made to be geometrically identical to the views seen by the STEREO A and B COR2 and LASCO C3 coronagraphs. [Note: C3 can also switch with C2, which occupies the same position, but has a different field of view.]



*Figure 1: The CAT geometric model, showing the positions of SOHO, the 2 STEREOs, and a model CME*

Actual coronagraph difference images from COR2 and LASCO are overlaid with the 3D modeled scenes. The model CME is not rendered as a solid object: rather the outline of the object, as seen from each of the 3 positions, is overlaid on the images.

The CME object can be adjusted in latitude, longitude, angular width and leading edge distance. The aim is to adjust these 4 parameters such that the overlaid model CME outline best matches the actual CME as seen from the 3 spacecraft in the coronagraph difference images. Matching to images at different times (by adjusting the leading edge distance parameter) allows for the calculation of CME radial velocity.

## 2. SWPC\_CAT License

```
-----  
;  
; NOAA/SWPC CME ANALYSIS TOOL (CAT)  
; Developed as part of the WSA-Enlil transition project  
; Released to the Solar Physics community via Solarsoft  
; February 2013  
;  
-----  
;  
; This software was developed at the NOAA Space Weather Prediction  
; Center by employees of the Federal Government in the course  
; of their official duties. Pursuant to title 17 Section 105 of the  
; United States Code this software is not subject to copyright  
; protection and is in the public domain. It is an experimental system.  
; NOAA assumes no responsibility whatsoever for its use by other parties,  
; and makes no guarantees, expressed or implied, about its quality,  
; reliability, or any other characteristic.  
;  
; We would appreciate acknowledgement if the software is used.  
; This software can be redistributed and/or modified freely provided  
; that any derivative works bear some notice that they are derived from it,  
; and any modified versions bear some notice that they have been modified.  
;  
; We would like to acknowledge use of several routines taken from the wider  
; Physics and idl programming communities - most notably software developed  
; by Craig Markwardt and David Fanning:  
;  
; http://cow.physics.wisc.edu/~craigm/idl/idl.html  
; http://www.idlcoyote.com/  
;  
; The development of CAT and it's use within the context of the WSA-Enlil  
; project has been published in Space Weather Journal:  
; http://onlinelibrary.wiley.com/doi/10.1002/swe.20024/abstract  
;  
; George Millward  
; Curt de Koning  
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;  
; NOAA Space Weather Prediction Center  
; 325 Broadway, Boulder, CO 80305  
;  
; george.millward@noaa.gov  
;  
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```

### 3. Installation

SWPC\_CAT consists of 3 files and 2 sub-folders:

- 1) SWPC\_CAT\_README.pdf      this file
- 2) swpc\_cat.pro                the idl code
- 3) swpc\_cat.in                .in configuration file
- 4) swpc\_library                folder containing various needed subroutines
- 5) swpc\_data                  folder containing a needed data file

FOR SWPC\_CAT to work, the SOHO LASCO and STEREO COR2 images have the following directory structure:

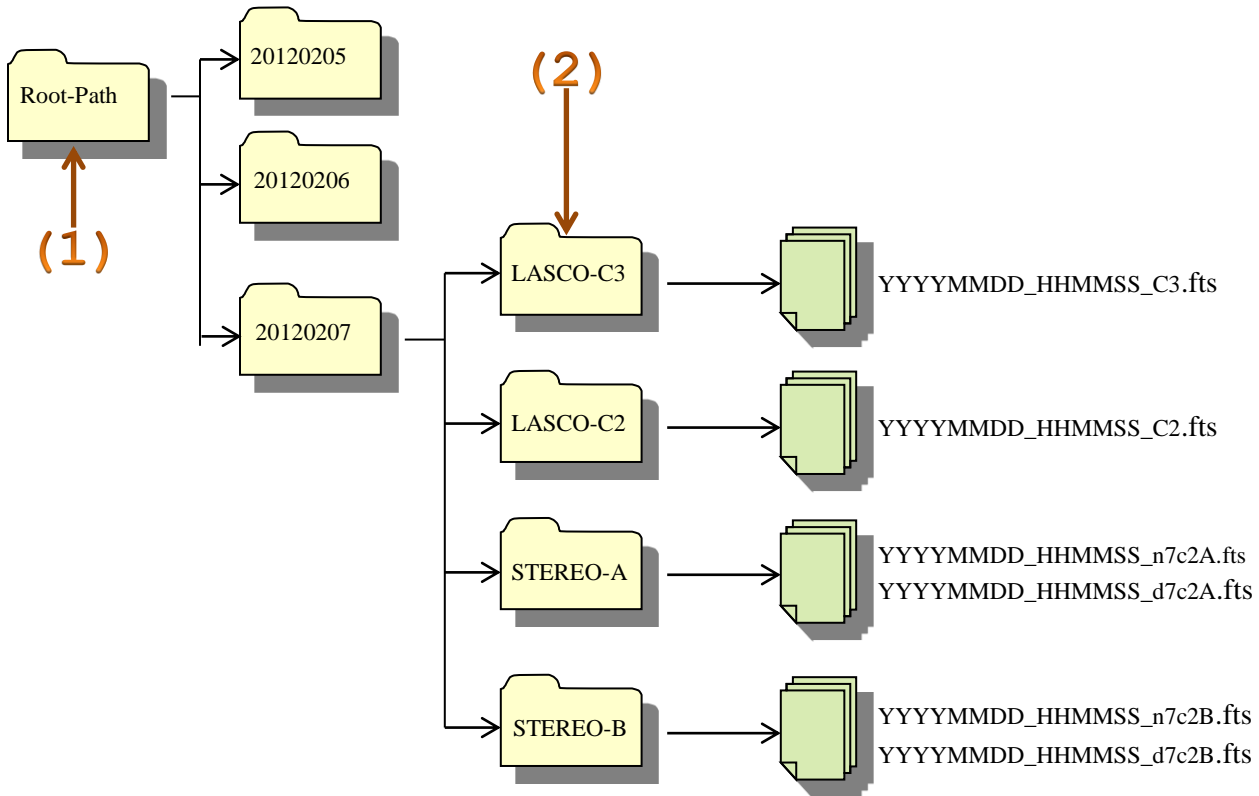


Figure 2: The required directory/file structure for the SOHO/STEREO images

The image files must have the naming formats as shown above in Figure 2.

Note:

- 1) LASCO images do not come with this naming format as standard – they must be renamed
- 2) SWPC\_CAT supports only STEREO COR2 beacon images. Not science data (which arrives too late to be of any use for a space weather application)

To get swpc\_cat to correctly identify the coronagraph images, edit the file swpc\_cat\_app.in as follows:

- (1) Set the 'image\_in\_root' to match your Root-Path
- (2) Set your 'image\_in\_folders' to be a list of your coronagraph folder names (separated by commas)

```
telescopes=LASCO C2,LASCO C3,STEREO A COR2,STEREO B COR2 (2)
image_in_folders=LASCO-C2,LASCO-C3,STEREO-A,STEREO-B ←
image_in_root=C:\Users\george.millward\Images ← (1)
export_location_root=C:\Users\george.millward\CAT_exports
preferences_folder=C:\Users\george.millward\CAT_preferences
max_interval_in_days=2
run_as_OPS_or_VnV=VnV
```

## 4. Where To Get The Image Files

LASCO C3 data:

[ftp://umbra.nascom.nasa.gov/pub/lasco/lastimage/level\\_05/YYMMDD/c3](ftp://umbra.nascom.nasa.gov/pub/lasco/lastimage/level_05/YYMMDD/c3)  
[ftp://zeus.nascom.nasa.gov/qkl/lasco/quicklook/level\\_05/YYMMDD/c3](ftp://zeus.nascom.nasa.gov/qkl/lasco/quicklook/level_05/YYMMDD/c3)

LASCO C2 data:

[ftp://umbra.nascom.nasa.gov/pub/lasco/lastimage/level\\_05/YYMMDD/c2](ftp://umbra.nascom.nasa.gov/pub/lasco/lastimage/level_05/YYMMDD/c2)  
[ftp://zeus.nascom.nasa.gov/qkl/lasco/quicklook/level\\_05/YYMMDD/c2](ftp://zeus.nascom.nasa.gov/qkl/lasco/quicklook/level_05/YYMMDD/c2)

STEREO A (beacon data)

<ftp://stereofp.nascom.nasa.gov/pub/beacon/ahead/secchi/img/cor2>

STEREO B (beacon data)

<ftp://stereofp.nascom.nasa.gov/pub/beacon/behind/secchi/img/cor2>

## 5. Using the SolarSoft swpc\_cat\_getdata routine

To use SWPC\_CAT you can create an image data tree yourself using a directory structure as described in section 3 and by pulling images from the ftp sites as in section 4. Alternatively, a SolarSoft routine 'swpc\_cat\_getdata' will do this for you. Many thanks to Sam Freeland for writing this.

The basic usage is just to type:

```
idl> swpc_cat_getdata
```

This defaults to download images from the previous 24 hours. The download can take a while to complete (~5 minutes)...everything is finished when IDL prints the following to the console:

```
***** All Done !!!! *****
```

swpc\_cat\_getdata will also accept a bunch of parameters and keywords, most notably to download data for different times by using the time0 and time1 parameters.

See the latest source code for the available options.

[http://www.lmsal.com/solarsoft/ssw/packages/swpc\\_cat/idl/ssw/swpc\\_cat\\_getdata.pro](http://www.lmsal.com/solarsoft/ssw/packages/swpc_cat/idl/ssw/swpc_cat_getdata.pro)

Note: The swpc\_cat\_getdata routine rebins the LASCO C2 and C3 files from their original 1024\*1024 size to 512\*512 for saving in the image data tree. The rebinned files are, of course, smaller and load more quickly into SWPC\_CAT. The rebinning process also defines a new keyword 'REBINVER' in each LASCO fits file. REBINVER is set to 2 for the files downloaded with swpc\_cat\_getdata.

The operational system at SWPC does a similar (but not identical) rebinning of LASCO files and sets the keyword REBINVER to 1.

Thus, SWPC\_CAT will work with original LASCO fits files (with no REBINVER), SWPC operational rebinned files (REBINVER=1) or SolarSoft/swpc\_cat\_getdata rebinned files (REBINVER=2).

## 6. Open CAT, Load Images

The CAT user interface is shown in Figure 3. Using the Start/End Time widget (Figure 3, panel 1), enter the time period of interest, being sure to include plenty of time prior to the event that you'll have good background images from which to choose. The CAT will load all the available imagery (Figure 3, panels 3 to 5) for the time period you selected.

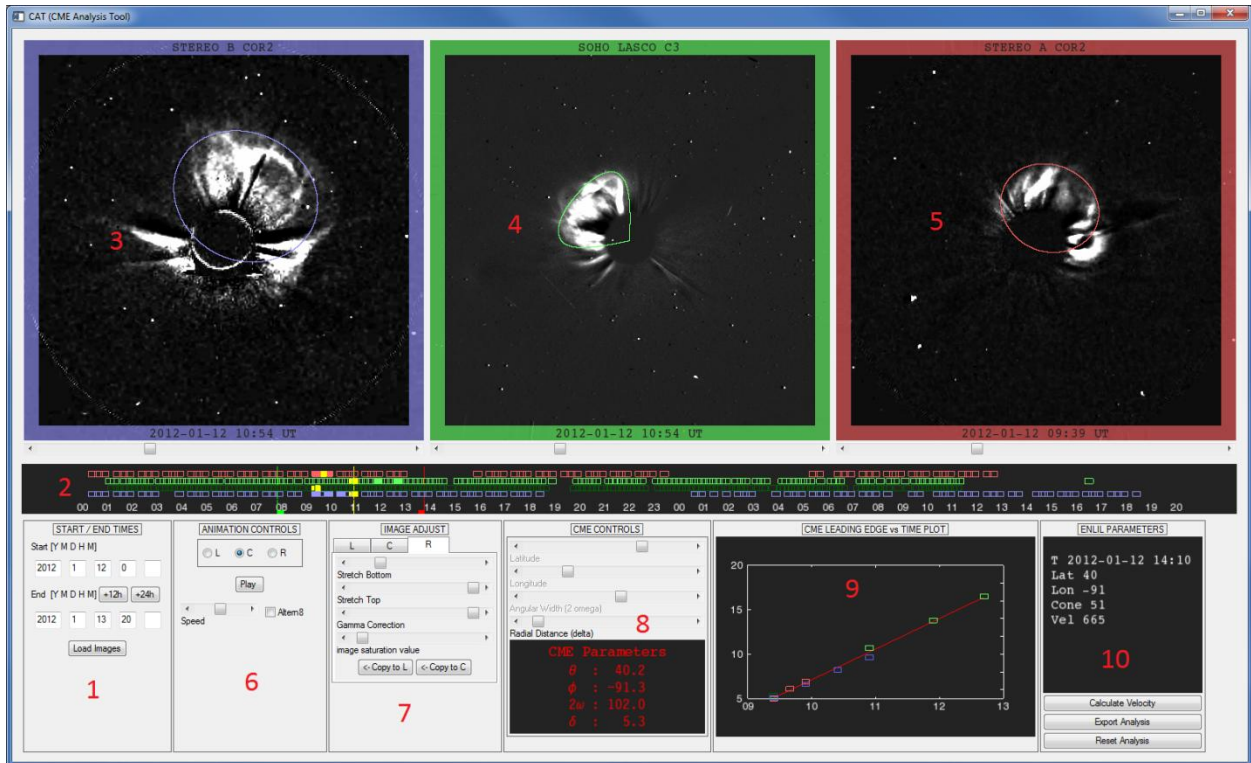


Figure 3: The CAT GUI consists of the (1) Start/End Time Widget; (2) Image Timeline; (3-5) STEREO-B, LASCO, STEREO-A displays; (6) Animation Controls; (7) Image Adjust Widget; (8) CME Controls; (9) CME Leading Edge vs. Time Plot; (10) Final CME Parameters and Export Widget

Look at the Image Timeline (Figure 4) to determine how many images you have to work with. It is color-coded: Red blocks } indicate STEREO-A; Blue blocks, STEREO-B; Light green blocks, LASCO C3; Dark green blocks, LASCO-C2. If an image is "matched" to the CME, then the box is filled in with the appropriate color. The currently displayed image for each spacecraft is indicated by an open (unmatched) or solid (matched) yellow block. You can quickly move to a particular image by left-clicking on the desired box in the Timeline. This is useful if you wish to un-match an image. The red and green lines displayed on the Timeline allow you to set the beginning and end of the animation; just left-click and drag. Similarly, sliding the yellow line allows you to move through the available images synchronously.

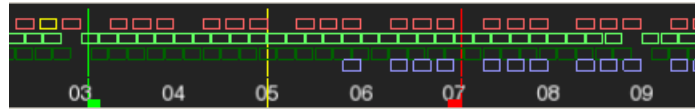


Figure 4: The image timeline provides image information and navigation functionality

## 7. Examine The Imagery

You can move forward and backwards in time using the slider at the bottom of each image window (Figure 3 (3 to 5)), or by clicking a box in the Timeline (Figure 4). By *right-clicking on the image*, you'll be able to Match/Unmatch the CME to the image; select an Image Differencing method (none, running difference, set current image as background); show LASCO C2/C3 in the center window, depending on what is currently displayed; set a representative image; or remove an image.

The Image Adjust widget (Figure 5) allows you to modify the image properties to better identify the CME boundaries. The tabs at the top allow you to select the Left, Center or Right window. The Copy button allows the same settings to be applied to the remaining windows.

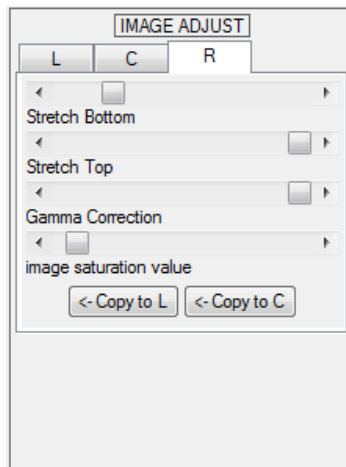


Figure 5: The image adjust widget allows you to modify the image properties to better identify the CME boundaries.

## 8. Lasso The CME Using The CME Controls

You'll spend most of your time using The CME Controls Widget shown in Figure 6. You will change location and shape of the yellow CME outline (the lasso) to match the imagery. The Latitude, Longitude, Angular Width and Radial Distance sliders allow you to match the CME in all three windows. A readout of the parameters resulting from your fit is shown below the sliders.



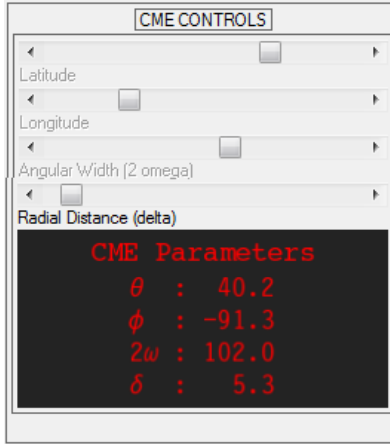


Figure 6: The CME Controls Widget is used to adjust the model CME to match to the images.

You'll quickly learn how the various CME Controls change the shape of the lasso. One subtlety to consider when fitting the CMEs is the effect of changing Longitude on the shape of the lasso. If you notice the sides of the lasso don't quite fit the CME, experiment with moving the Longitude slider. Figure 7 illustrates the effect as the longitude moves from  $0^\circ$  to  $75^\circ$  in a STEREO-B frame.

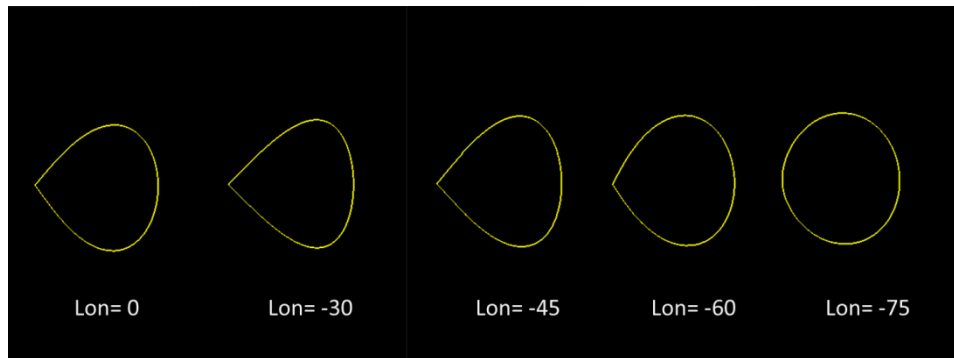


Figure 7: A subtlety to consider when fitting the CMEs is the effect of changing Longitude on the shape of the lasso.

## 9. CME Matches Image

Once you're satisfied with your CME fit, *right-click* on your preferred image and select "CME Matches Image". You'll notice the block on the timeline associated with the image becomes filled in, the CME lasso on the image turns green, blue or red, and the image border changes to the same color.

Having made your first 'Match' you'll also notice that the Latitude, Longitude, and Angular Width sliders on the CME Controls Widget are no longer available (greyed out). It is thus important to select the best, most representative image for the initial CME match, since all succeeding images will be fit with these "frozen" parameters.

Finally, you'll notice an open colored block corresponding to the matched image appears on the CME Leading Edge vs. Time plot (Figure 8).

Now, continue to lasso CMEs in other images at different times moving only the Radial Distance slider on the CME Controls (the only one available to you once you have made your initial match). If you notice you can't fit subsequent images using just the radial distance slider, there is probably a problem with your first match. You can quickly return to the matched image in the Timeline; just left-click on the filled block. Then *right-click* on the image and select “Unmatch”. Adjust your lasso and match again.

Every time you choose “CME Matches Image”, the Timeline and the CME Leading Edge vs. Time plot will change as described above. After you have two points, you'll be able to choose the “Calculate Velocity” button on the Export Widget (Figure~\ref{fig:export}) and a red line representing the best linear fit to the data will be added to the plot. With the addition of each new point, you can recalculate the velocity. If you notice one of your position blocks is an outlier, you can click the corresponding filled block on the Timeline and unmatch it as described above.

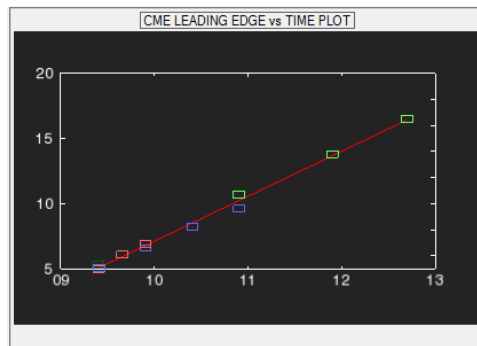


Figure 8: The Position/Time Display plots the time and distance for the images you match to the CME.

## 10. Export Your Analysis

Once you are satisfied with your analysis, it's time to export it. Before exporting, you must choose a representative image. Right-click on a good image and select “Set as Representative Image”. If you forget this step, the CAT will remind you.

Now, you can Export Analysis. You'll see lots of images flashing by. Once the process is finished, there will be several sub-directories in the export folder containing the imagery. There will also be a text file containing the CME parameters, and a copy of the CME Leading Edge vs. Time plot.

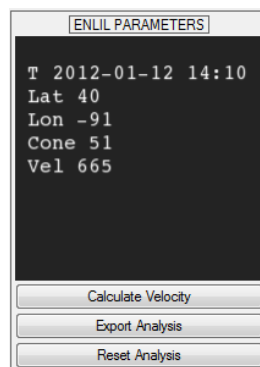


Figure 9: Use the Export Analysis Widget once you have matched the images, obtained a velocity, and selected a representative image.