CME Analysis with SWPC_CAT for Space Weather

1998/06/02 13:31
SOHO/LASCO C2

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Geometric Triangulation

Stereo CAT assumes you are measuring the same feature in two coronagraphs. It uses simple geometric relations to derive CME position and speed.

Unfortunately, the wider a CME is, the less likely it is that you're measuring the same feature. The leading edge from one viewpoint can be far away from the leading edge as seen from another viewpoint.
Narrow CME: "Leading Edge" locations from each viewpoint are clustered together. StereoCAT values are fairly accurate.
Wide CME: "Leading Edge" locations from different viewpoints can be far apart.

Geometric triangulation is not applicable – we need a new strategy!
Geometric Triangulation

• So, for wider CMEs your Stereo CAT measurement is unreliable.

• But faster CMEs also tend to be wider, so Stereo CAT becomes less applicable for fast CMEs as well.

• And there are issues with Halo CMEs. Let’s look at one issue, the “Half-angle – radial distance” conundrum.
When you see a Halo CME you see the sides, not the leading edge.

The CME on the left is faster and wider, the one on the right is slower and narrower. However, the observer (You) will measure the same change in distance $|x_2 - x_1|$ and derive the same plane of sky speed. To determine the 3D speed you need to know the CME width (which you might not know).
How do we fix this?

We can use a model of a 3D CME shape and project that model from the different viewing angles. The easiest version of this is SWPC_CAT.
The best of both worlds: SWPC_CAT

SWPC_CAT performs the triangulation measurements like StereoCAT does, but it uses 3D projection geometry, similar to the cone projection model.

Additionally:
- SWPC_CAT can be used to fit halo CMEs
- Allows multiple (2 or 3) viewpoints
- the image time stamps do not have to align, after the initial fit

Is not trivial: SWPC_CAT assumes the shape of the CME is symmetrical (“teardrop” shape), which is not always so.
The best of both worlds: SWPC_CAT
SWPC_CAT CME analysis Procedure

* Before starting the tool, look at coronagraph images in motion (e.g., on iSWA) and identify the CME and the start time (first appearance in a coronagraph).
* Look at EUV images in motion near the CME start time (on iSWA) and identify the source location and any lower coronal signatures of the CME (post eruption arcade, dimming, rising loops, filament eruption).
* On Where is STEREO tool identify where the satellites are on the date.
* Launch SWPC_CAT_Web
  https://ccmc.gsfc.nasa.gov/swpc_cat_web/
* Load the coronagraph images: select the date of the start of the CME in the upper right corner, and press "Load Images" button ➔ two (2) full days-worth of coronagraph difference images (starting with the selected date) is loaded into the top panel of the tool.
Space Weather Training 2020

SWPC_CAT

STEREO B COR2

SOHO LASCO

STEREO A COR2

2014-08-24T18:54:46Z

2014-08-24T18:54:05Z

2014-08-24T18:51:20Z

IMG-CONTROLS

CME-CONTROLS

Velocity Graph

Results

Latitude: -26.5
Longitude: -83.1
Angular Width: 81.4
Radial Distance: 10.4

Gamma: 0.98
Stretch Top: 0
Stretch Bottom: 255
Saturation: 0.23

Latitude: -26.49999999999996
Longitude: -83.10000000000001
Half-Width: 40.7
Radial Velocity: 310.26
Time at 21.5R: 08/24/2014 23:56:03

Calculate
SWPC_CAT CME analysis Procedure

* Adjust the images so you can see them well. Use "IMG-CONTROLS" panel (and select the satellite) to play with image saturation, etc. to get a clearer view of the CME.

* You can switch between the LASCO C3 and C2 images by clicking on the white bar below the SOHO image frame and selecting "SOHO LASCO C2 – Running Difference" (default is LASCO C3).

* Choose a time where you can see the CME well, but also be sure that the CME's width & location isn't varying too rapidly. You're trying to determine the values corresponding to 21.5 RSun (but keep in mind that the earlier images may correspond better with the EUV images).
SWPC_CAT CME analysis Procedure

* Use "CME-CONTROLS" panel to fit the yellow CME outline on the coronagraph images. Experiment with the parameters and do your best to fit all three (or two) viewpoints. Once you think you've got good parameters, go into an image pane and click "CME Matches Image."

* **Note:** Once you've chosen Latitude/Longitude/Angular Width, you can't change them! Choose wisely 😊

* After this, for each image time, adjust the “Radial Distance” slider until you think it matches closely. Note that the image times do not have to match! Adjust the distance for each image time and select "Match Image."

* Every time you click "CME Matches Image" you should see a small box appear on the "Velocity graph" plot (colors of boxes correspond to instruments). Clicking "Calculate" on the Results panel will draw a line fit to the data points and update the values in parameter boxes on Results panel.
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SWPC_CAT

STEREO B COR2

2014-08-24T18:54:46Z

STEREO B - Running difference

Match Image

Unmatch Image

SOHO LASCO

2014-08-24T18:54:05Z

Match Image

Unmatch Image

STEREO A COR2

2014-08-24T18:51:20Z

STEREO A - Running difference

Match Image

Unmatch Image

IMG-CONTROLS

STEREO B

Stretch Top: 0

0 63 127 191 255

Stretch Bottom: 255

0 63 127 191 255

Gamma: 0.98

0 0.25 0.5 0.75 1

Saturation: 0.23

CME-CONTROLS

Latitude: -26.6

-90 -45 0 45 90

Longitude: -83.1

-180 -90 0 90 180

Angular Width: 81.4

20 40 60 90 140 160

Radial Distance: 10.4

Velocity Graph

Results

Latitude: -26.499999999999996

Longitude: -83.0000000000001

Half-Width: 40.7

Radial Velocity: 310.26

Time at 21:55:

08/24/2014 23:56:03

Calculate
SWPC_CAT CME analysis Procedure

• Finally, examine the values of your CME parameters in the Results panel – if the speed looks roughly constant (small boxes on the Velocity graph fit the line well), you can use the derived values.

• If it looks like the CME decelerating or accelerating, you may want to "Unmatch" some of the earlier images to make sure the velocity fit is only using the later images (closer to 21.5 RSun).

• The final step is making a screenshot of the whole screen in case you need to reanalyze the CME again or if you are asked to share it with other forecasters (there is no “Save Session” option yet).