

User Manual

C.A.T.C.H.

Collection of Analysis Tools for Coronal Holes

Version 2.10 beta

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A special thanks goes to all the Testers.

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The CATCH tool code is currently licensed under a BSD 3-Clause License, which can be found in the file repository.

The CATCH tool has not yet been published, if you use it for a publication please contact the author for proper referencing.

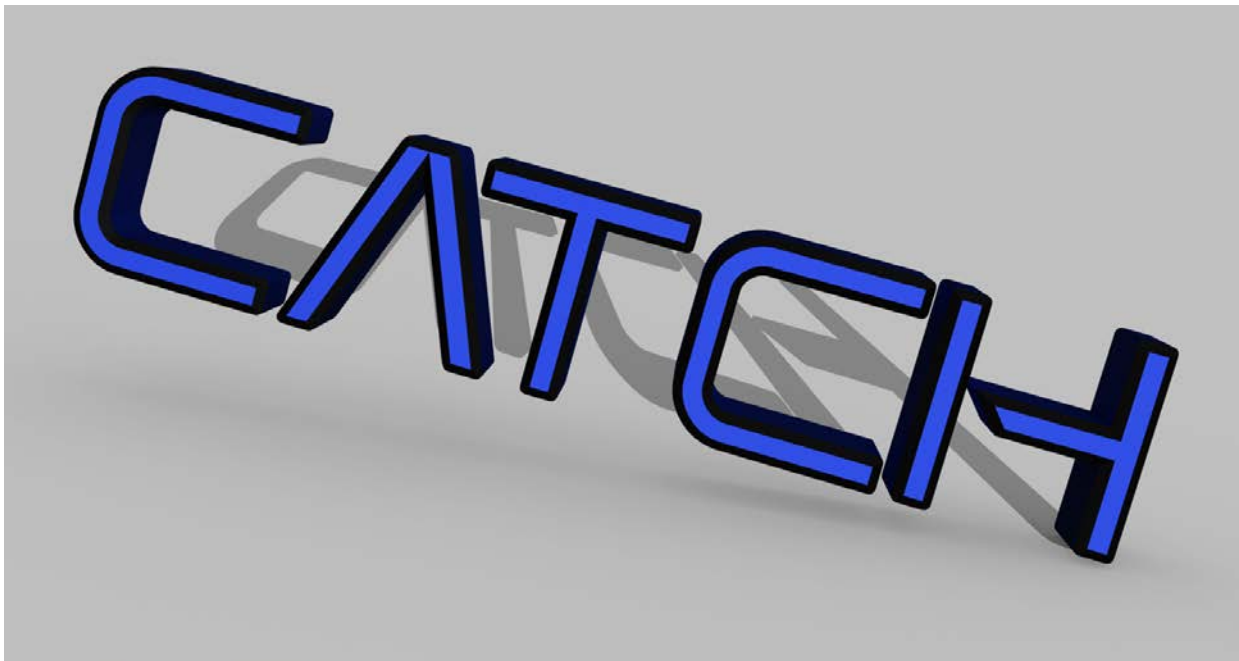


Figure 1: CATCH Logo

System Requirements

- SSW-IDL (tested under 8.6.)
- Coyote Library <http://www.idlcoyote.com/documents/programs.php>
- SSW Libraries:
 - AIA *ssw-path, /aia* (if needed add this line to your IDL startup file)
 - HMI *ssw-path, /hmi*
 - EIT *ssw-path, /eit*
 - MDI *ssw-path, /mdi*
 - STEREO *ssw-path, /stereo*

Setup

- Unzip *catch_XXX.tar.gz*
- Add the path to the unzipped folder to your IDL startup file:
 - *!path=!path + ':' + expand_path('+path_to_catch/', /all_dirs)*
- Add the routine to your IDL startup file:
 - *resolve_routine, 'catch_main', /COMPILE_FULL_FILE*

Run CATCH

- Call *catch_main* in the *sswidl*-command line to start the widget.

First Start

- The widget will alert the user that no configuration file was found, and if a new one should be created. To continue, proceed with *YES* and a default configuration file will be created.
- In the MAIN MENU (see Section: The Main Menu) got to the PROPERTIES window accessible through the button of the same name (right bottom corner). There the CATCH tool can be configured (see Section: The Properties Window). Then proceed with *SAVE*, and the CATCH tool is ready to use.
- Note: *This process may be repeated if the configuration file was deleted.*
- Note: *This process may give an error message concerning the default paths. This can be ignored as the paths should be set manually afterwards anyways.*

1. The Main Menu

The MAIN MENU is the primary navigation tool of CATCH. Through it the various tools may be accessed. The options are:

- DOWNLOAD DATA: See Section 3.
- CORONAL HOLE EXTRACTION: See Section 4.
- MAGNETIC FIELD ANALYSIS: See Section 5.
- PROPERTIES: See Section 2.
- EXIT: Exit the CATCH tool



Figure 2: CATCH MAIN MENU

2. Properties Widget

Through the PROPERTIES option, the CATCH tool can be modified. Options included are shown below:

- **PLOT OPTIONS:**
Default values for dmin, dmax, gridsize (in Degrees) and contour line thickness may be specified.
- **PATHS:**
Default paths for downloading, input and output may be specified here.
- **SAVES:**
The output of the SAVE option of the CORONAL HOLE EXTRACTION and MAGNETIC FIELD ANALYSIS can be configured here.
- **HANDLING:**
The default values for data input resolution as well as the limb brightening correction may be set here. The LOCK PROPERTIES option disables the option that the CATCH configuration may be updated during use.
- **RESET:**
Resets the configuration to the default.
- **ABORT:**
Exit the Properties Widget without saving.
- **SAVE:**
Save the changes and exit the Properties Widget .

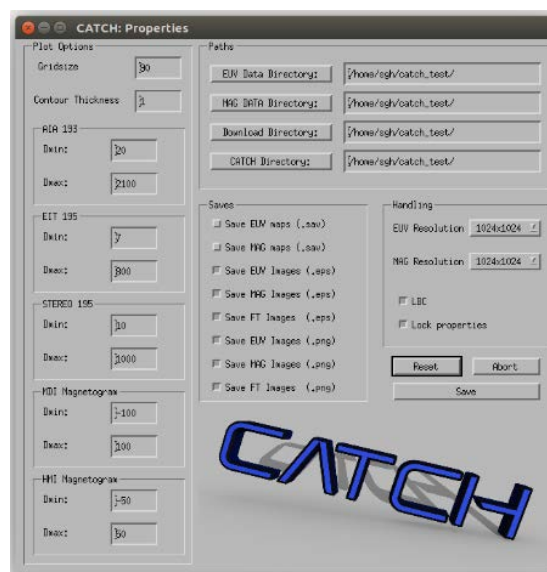


Figure 3: CATCH PROPERTIES

3. Download Data Widget

The DOWNLOAD DATA option is a way to download data for use in the CATCH tool using the SSIDL routines *vso_search* and *vso_get*.

Note: If problems with the download occur, the most probable causes are server problems at the server supplying the data. This seems to happen especially often for SDO data that is downloaded from JSOC. If problems persist, please download the data manually via <http://jsoc.stanford.edu/>.

The options of downloading data are limited to usable files for the CATCH tool:

- Filtergrams
 - AIA/SDO 193 Å
 - EIT/SOHO 195 Å
 - EUVI/STEREO 195Å
- Magnetograms
 - HMI/SDO 45s LoS
 - HMI/SDO 720s LoS
 - MDI/SOHO 96m LoS

The options are:

- DOWNLOAD DIRECTORY:
By clicking the button, you may navigate to the directory in which you want the data downloaded or you may type the path into the text field.
- SOURCE:
Specify source (SDO/SOHO/STEREO-A/STEREO-B).
- DATA PRODUCT:
Specify product (Filtergram or Magnetogram).
Note: For STEREO this option is not available as there is only one data product (EUVI 195Å)
- DATE/TIME:
Specify date and time of the data product desired.
- QUERY FILE:
Check for the data product closest to the set date, without downloading.
- DOWNLOAD:
Queries the closest data product to the set date and downloads it.
- DONE:
Exit the Download Widget.
- EXIT:
Exit the CATCH tool.

Figure 4: CATCH DATA DOWNLOAD

The screenshot shows a graphical user interface window titled "CATCH: Data Download". Inside the window, there is a section labeled "Data Download". It features a "Download Directory:" label followed by a text box containing the path "/home/sgh/catch_test/" and a small button to the right. Below this, there are two rows of controls. The first row has "Source:" followed by a dropdown menu and "Data Product:" followed by a dropdown menu showing the value "0". The second row has "Date:" followed by three separate input boxes for "Year:", "Month:", and "Day:". The third row has "Time:" followed by three separate input boxes for "Hour:", "Minute:", and "Second:". At the bottom of the window, there are four buttons arranged horizontally: "Download", "Query File", "Done", and "Exit".

4. Coronal Hole Extraction

The CORONAL HOLE EXTRACTION option is used to extract coronal holes from EUV (193/195 Å) and to calculate the associated parameters.

The options are:

- FILE MANAGEMENT:
 - OUTPUT/DATA DIRECTORY:
By clicking the button, you may navigate to the directory or you may type the path into the text field. In the output directory the results will be saved, the data directory specifies where the EUV data is stored.
 - REFRESH:
Refresh the files list.
 - FILES LIST:
Select an EUV file (can be a FITS file or a IDL-save file created by the CATCH tool).
 - LBC ON/OFF:
Apply a Limb Brightening Correction (LBC) based on Verbeeck et al. (2014) when loading the data.
 - RESOLUTION:
Select the pixel resolution for the input file. Files with lower resolution than selected can be scaled up using the SSIDL function *rebin_map*.
 - LOAD:
Loads and processes the selected file.
- EXTRACTION PARAMETERS:
 - THRESHOLD:
Select a threshold for the extraction. It is based on the median intensity of the solar disk (see Rotter et al. 2012; Reiss et al. 2014; Hofmeister et al. 2017 and Heinemann et al., 2018 for more details).
 - MORPH RADIUS:
Select the radius for the morphological operators (*morph_open* and *morph_close*) to smooth the coronal hole boundary. Set to 1 for no morphological operations.
 - HISTOGRAM:
Displays the intensity histogram of the solar disk with the currently selected threshold (red vertical line). This is used to find an optimal threshold using the method proposed by [Krista & Gallagher 2006?](#).
 - APPLY EXTRACTION:
Applies the coronal hole extraction based on the selected threshold and morph radius. All found structures are then over-plotted on the EUV image displayed to the right. To analyze a specific coronal hole left-click into a structure over-plotted in the image.

- CORONAL HOLE PROPERTIES:

- MEAN VALUES AND ERROR VALUES:

When selecting a coronal hole in the EUV IMAGE after initiating APPLY EXTRACTION five boundaries of the selected coronal hole are created. One with the selected threshold and four with a slightly bigger (+1, +2) and slightly smaller threshold (-1, -2). The properties of these five boundaries are calculated and the mean value (\bar{x}) is the value displayed (left value). The error value is the maximum deviation of the individual values from the mean value ($\sigma = \text{maximum}(\bar{x} - x_i)$). It represents a measure of the 'goodness' of the boundary as explained in Heinemann et al. 2019 (in preparation).

In principle: At the boundary there is a steep gradient in the intensity which should make the optimal boundary largely independent to small perturbations of the threshold. This can be interpreted as such that the smaller the error value the better the extraction.

- TRAFFIC LIGHT BUTTON:

The traffic light button (red, orange, green) is a visual display of the error value of the area. If the error value is below 5% it shows green (= good boundary). 5-10% would display orange (moderate) and >10% red (bad). However, it is not possible for ever coronal hole to get a green light nor even an orange one.

Note: It is a subjective suggestion of the author with values estimated empirically. But, in principle, it can be said that a green boundary is better than an orange or red one.

- EUV IMAGE:

The loaded data is displayed in the interactive window. A mouse-over shows X and Y position of the cursor (in arcsec) and the intensity of the pixel at the position.

If APPLY EXTRACTION was initiated, a structure can be selected which is then analyzed.

- PLOT OPTIONS:

Opens a tab to adjust the current dmin, dmax, gridsize and contour line thickness. These adjustments may be saved when exiting the widget (through EXIT or DONE) if the LOCK PROPERTIES option in the PROPERTIES is disabled.

- DRAWING TOOL:

See Section 4.1.

- IN-SITU DATA:

See Section 4.2.

- IN-SITU PREDICTION:

See Section 4.3.

- SAVE:

Save the currently analyzed coronal hole in from of a properties text file and a boundary FITS file. Additional options may be specified in the

PROPERTIES. These include saving the maps as a IDL-save file (which can be restored), and full-disk and cut-out images of the coronal hole in form of EPS or PNG files.

- DONE:

Exit the Coronal Hole Extraction Widget.

- EXIT:

Exit the CATCH tool.

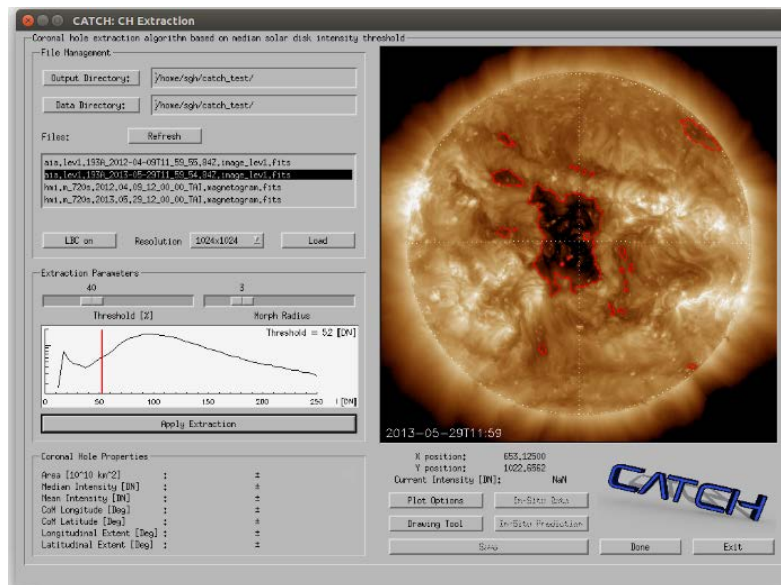


Figure 5: CATCH CORONAL HOLE EXTRACTION after initiating APPLY EXTRACTION

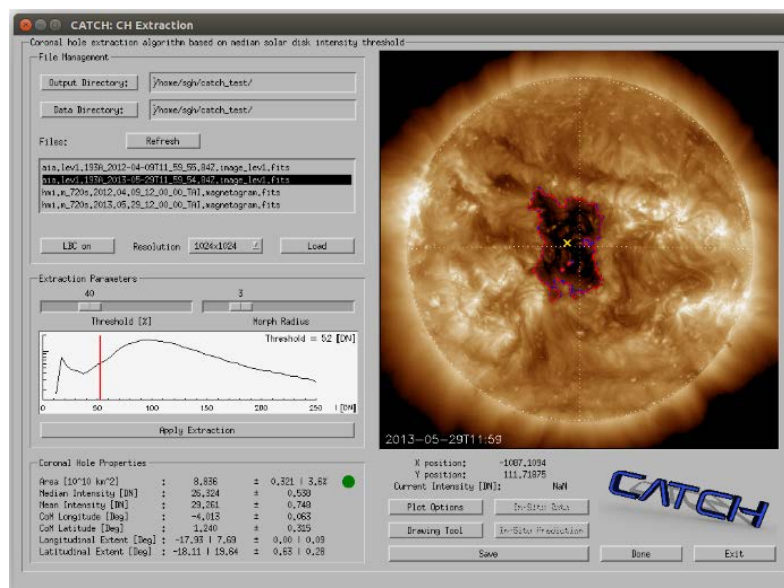


Figure 6: CATCH CORONAL HOLE EXTRACTION after selecting a coronal hole and calculating the associated parameters

4.1 Drawing Tool

The DRAWING TOOL option is used to manually extract coronal holes from EUV (193/195 Å) or to modify a coronal hole boundary extracted with a threshold. This is applied in a 'paint' like fashion. The coronal hole can simply be drawn on the EUV image.

Note: The wanted are must be filled. Therefore, everything covered by the red overlay will be counted as the area to analyse.

The options are:

- BRUSH:
 - DRAWING MODE/ERASER MODE:
Toggle between drawing (red) and erasing (blue).
 - BRUSH SIZE:
Brush size in pixels.
- SMOOTH:
 - SMOOTH EDGES:
Apply morphological operators (*morph_open* and *morph_close*) to smooth the coronal hole boundary.
 - MORPH SIZE
Select the radius for the morphological operators.
- NEW:
 - NEW MASK:
Remove the current coronal hole mask.
- PLOT OPTIONS:
 - PLOT:
Opens a tab to adjust the current dmin, dmax and gridsize. These adjustments may be saved when exiting the Coronal Hole Extraction widget (through EXIT or DONE) if the LOCK PROPERTIES option in the PROPERTIES is disabled.
- FINISH:
 - ABORT:
Close the drawing tool without saving the changes to the coronal hole mask.
 - APPLY:
Close the drawing tool and apply the changes to the coronal hole mask. Calculate the properties of the new coronal hole.

Note: When using a coronal hole mask created with the DRAWING TOOL no error values will be calculated as they are linked to the intensity threshold extraction method. The error values will only show NaN.

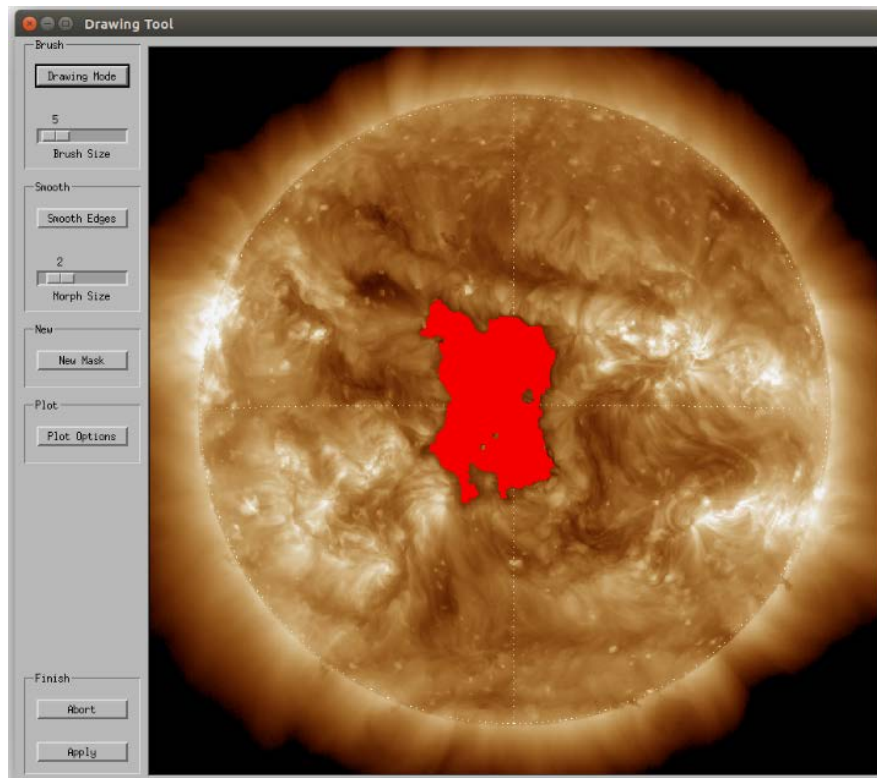


Figure 7: CATCH DRAWING TOOL

4.2 In-Situ Data

The IN-SITU DATA option is used to display the solar wind plasma and magnetic field parameters near the time of the loaded file.

Note: This option is currently disabled due to problems with the NASA servers for the in-situ data in combination with the SSW database. Will be reintroduced in a future update.

4.3 In-Situ Prediction

The IN-SITU PREDICTION option is used to calculate and predict the resulting high-speed stream from the extracted coronal hole parameters.

Note: This option is currently not available as the study for the part is still ongoing.

5. Magnetic Field Analysis

The MAGNETIC FIELD ANALYSIS option is used to extract and calculate the parameters of the photospheric magnetic field below the coronal hole extracted from EUV before using the CORONAL HOLE EXTRACTION option.

The options are:

- FILE MANAGEMENT:
 - OUTPUT/DATA/CATCH DIRECTORY:
By clicking the button, you may navigate to the directory or you may type the path into the text field. In the output directory the results will be saved, the data directory specifies where the magnetic field data is stored and the CATCH directory is where the results from the CORONAL HOLE EXTRACTION option were saved.
 - REFRESH:
Refresh the files list.
 - FILES LISTS:
Select a magnetic field file in the first file list and an extracted boundary in the second file list. The files must be temporally aligned.
 - RESOLUTION:
Select the pixel resolution for the input file. Files with lower resolution than selected can be scaled up using the SSIDL function *rebin_map*.
 - LOAD:
Loads and processes the selected magnetic field file and the selected coronal hole boundary. Also calculates the general magnetic properties of the photospheric magnetic field underlying the extracted mask.
General magnetic properties include the mean magnetic field strength (signed and unsigned), magnetic flux (signed and unsigned), flux balance (ratio of signed to unsigned magnetic flux) and the skewness of the magnetic field distribution. See Heinemann et al. 2018b for more details.
- FLUX TUBE ANALYSIS:
Analyse the magnetic field fine structure in form of flux tube. See Heinemann et al. 2018b for more details.

Note: This analysis is computational expensive, especially for the highest resolution. It usually takes several minutes to be completed but it may take up to 20 minutes for one image depending on size, resolution and computational power. There is a loading bar, to track the progress.
- CORONAL HOLE PROPERTIES:
 - MEAN VALUES AND ERROR VALUES:
For the magnetic field the same method of calculating the mean and error values is used as in calculating the coronal hole parameters in the CORONAL HOLE EXTRACTION option. For more details see Heinemann et al. 2019 (in preparation).

- PLOT OPTIONS:

Opens a tab to adjust the current dmin, dmax, gridsize and contour line thickness. These adjustments may be saved when exiting the widget (through EXIT or DONE) if the LOCK PROPERTIES option in the PROPERTIES is disabled.

- SAVE:

Save the currently analyzed coronal hole in form of a properties text file and a boundary FITS file. Additional options may be specified in the PROPERTIES. These include saving the maps as a IDL-save file (which can be restored), and full-disk and cut-out images of the coronal hole in form of EPS or PNG files.

- DONE:

Exit the Magnetic Field Analysis Widget.

- EXIT:

Exit the CATCH tool.

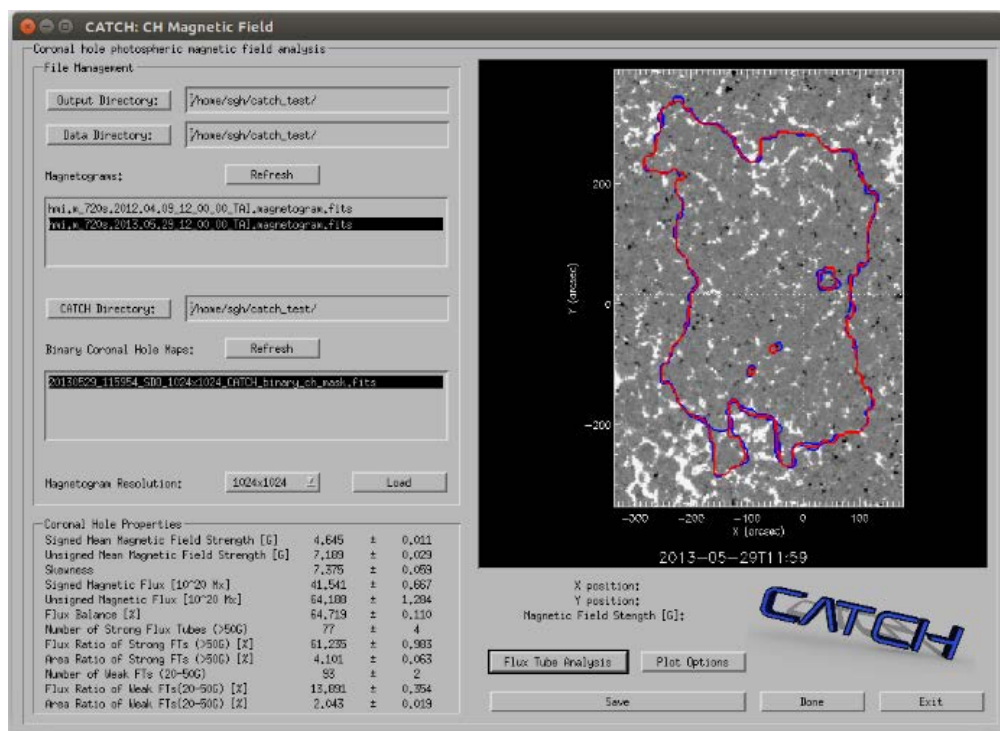


Figure 8: CATCH MAGNETIC FIELD ANALYSIS

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