

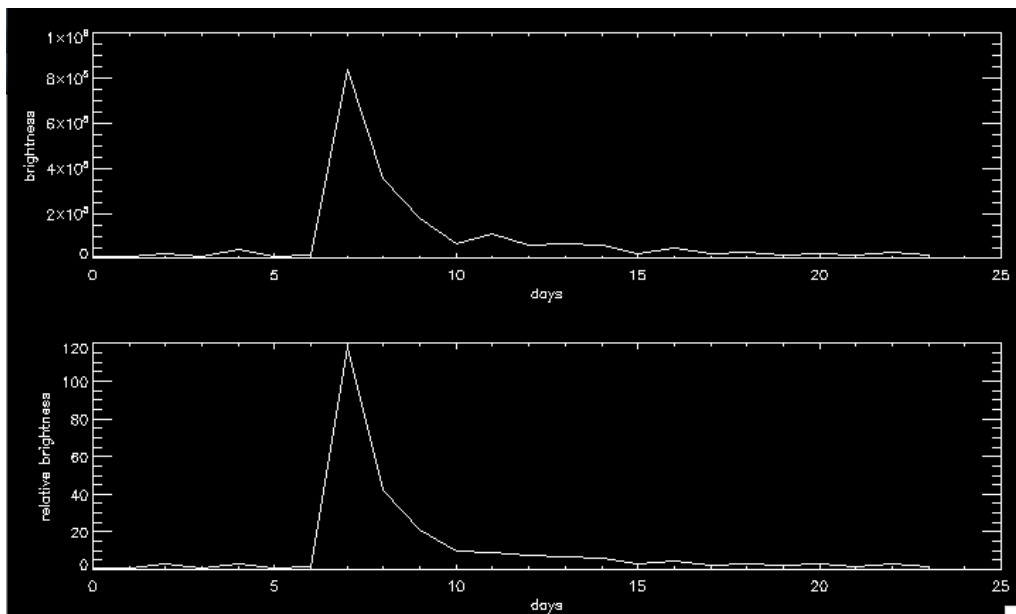
# 2013 REU Summary

David Stauffer

August 7, 2013

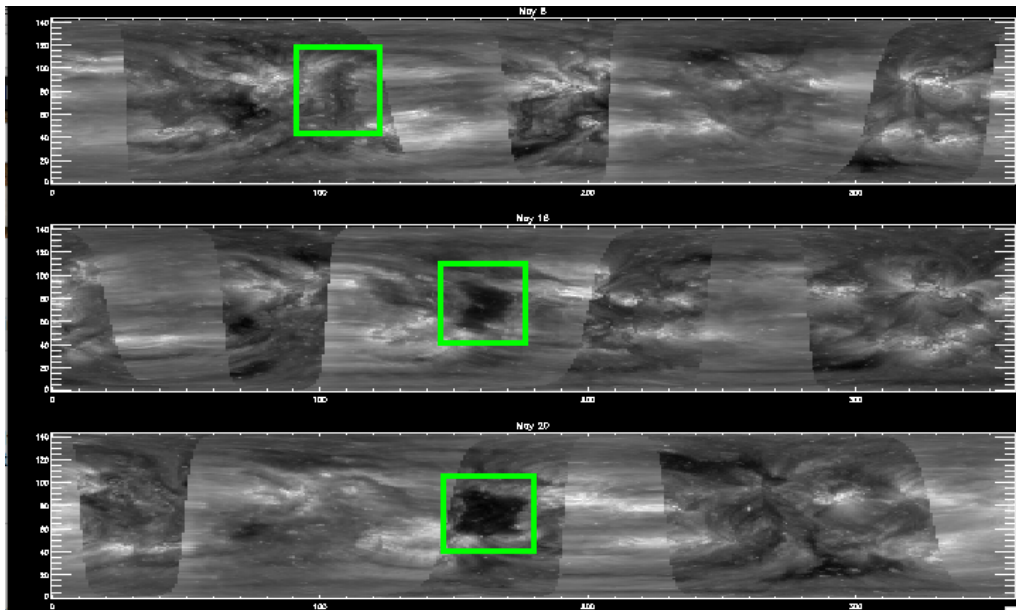
## Week One

Attended introductory meetings and learned how to use the computer system. 5 IDL tutorial sessions and two lectures: Sun as a Star and Sun's Interior and Dynamo. As part IDL tutorial, downloaded images of sun during solar flare and compared brightness of flare to quiet sun value:



The top plot shows the brightness of a section fo the sun containing the flare, clearly peaking when the flare goes off. The bottom graph shows the relative brightness of this flare as compared to the quiet sun brightness value.

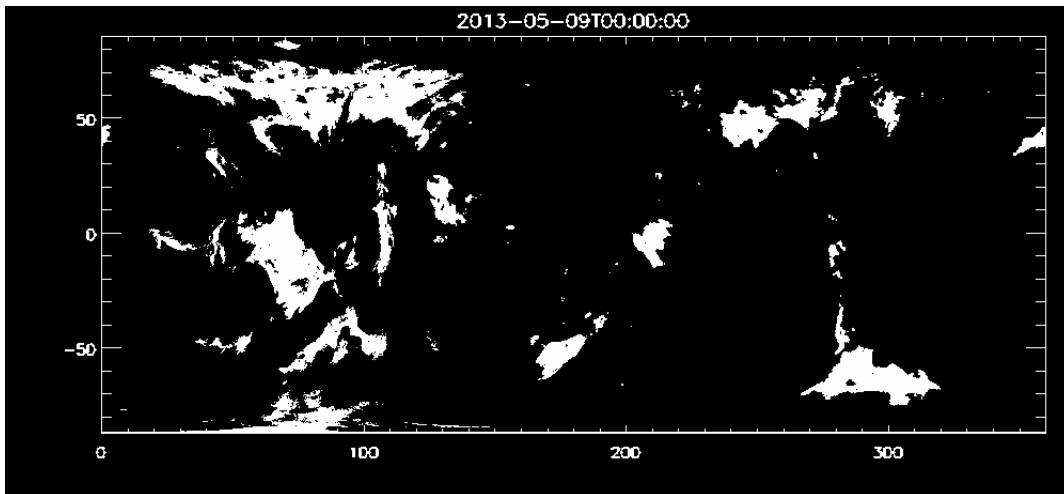
The main project this week was writing code to track a large coronal hole across the surface of the sun. Images from the Solar Dynamics Observatory orbiting earth and the STEREO (A and B) satellites orbiting around the sun. Most of the actual code was pre-existing so we wrote a program that called subprograms to download satellite data from online databases. The program then called another subprogram that projected the images into flat maps and combined the flat images into one picture of the whole sun. The overlaps in the images are not processed very well because the sun appears brighter in places (near the limbs). Then, we animated these full sun images into a video showing the progress of a large coronal hole moving across the sun from May 8-24, 2013. Here are three of the frames from this movie:

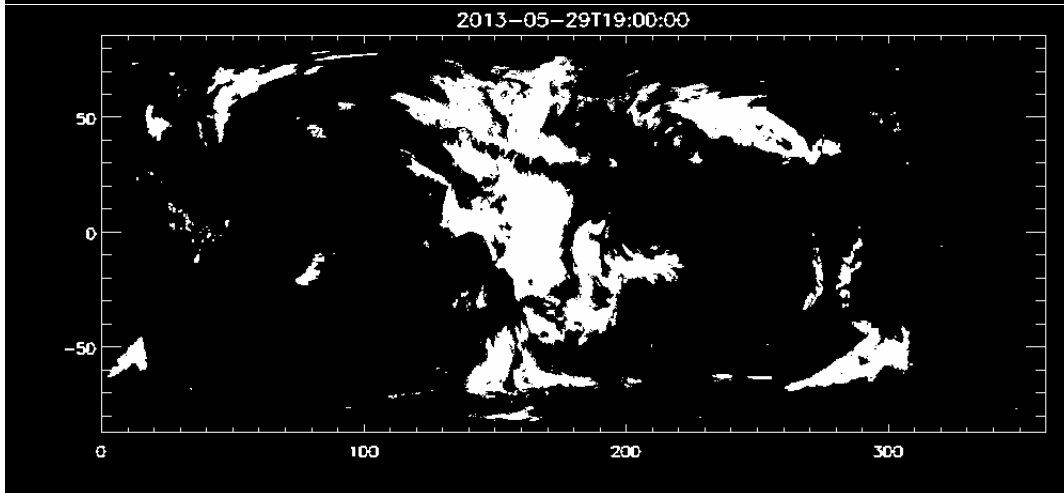
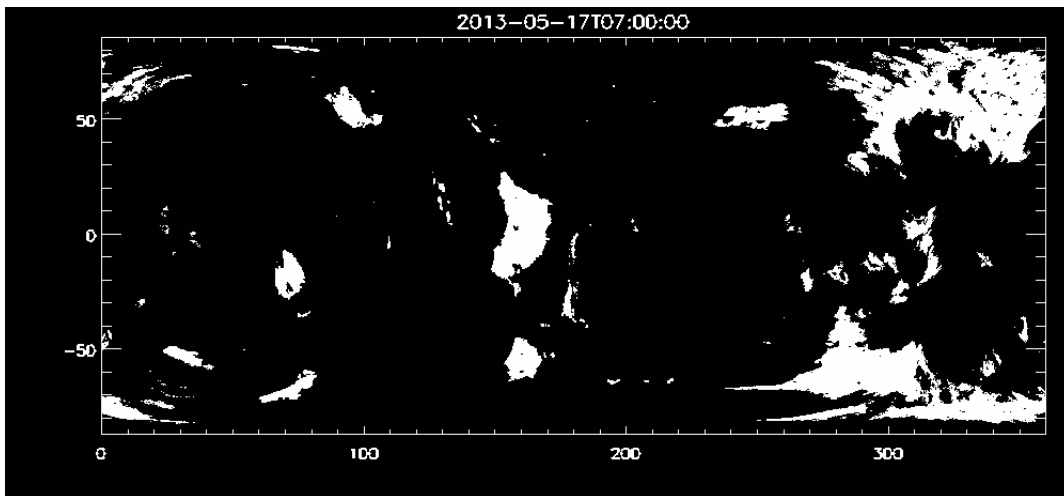


## Week Two

Monday I read the main program (`ch_track_surf.pro`) myself and then went over it with Chris. I read two papers on a NP model of the sun that included electric currents in the corona and calibration of the HMI/HDI tools on satellites. I downloaded Python for future use with plotting results. I also read notes from Dana Longcope on Magnetohydrodynamics written at an appropriate mathematical level for me.

The main project this week was downloading aia, sta and stb data at a 3 hour cadence and writing a program to turn it into a movie. The corona holes appear in white with the rest of the sun black and the large corona hole we made a video of last week is very visible in this form. The data is downloaded by `ch_data_grab` and combined into a single image by `ch_track_surf` and then I wrote code (`ch_animate`) that takes these images and puts them into a datacube with the help of `ch_map_restore`. Finally, `dat2mov` converts the datacube of frames into an mp4 file. Selected frames below:





### **Week Three**

Over the weekend I downloaded aia, sta and stb data at a one hour cadence for 2013/05/09 - 2013/06/10 and then ran `ch_track_surf` on it. We made it into another movie and with the high frame rate it looks smoother than previous videos. I wrote a program `ch_baddates` that may be able to replace bad frames from aia with new from from nearby times. `Ch_baddates` takes the `baddates` file created by `ch_track_surf`, increments the timestamp of the bad frames by a minute and uses `ch_data_grab` to get a new frame in the slightly offset time.

Thursday, Friday and this weekend I've worked on writing two pieces of code. One, `ch_track`, tracks a specified coronal hole across different frames of aia sun images. It uses a recursive structure and was fun to write. The second program, `ch_sync`, takes "monthly" synoptic hmi charts, daily synoptic hmi charts and aia/sta/stb images and syncs them up because they have different cadences in data recording. Both are now written but will most likely need exactly a LOT of time to debug. My IDL abilities are improving a lot with matrix manipulation.

## **Week Four**

I started this week by testing my code `ch_sync` which worked after the addition of a parenthesis, pretty remarkable that was the only mistake. `Ch_track` is now running after some minor fixes but takes quite a while because I traverse through every region detected by `ch_track_surf` on each frame so I might have to switch to using overlap to detect holes. I also wrote code to take my mask from `ch_track` and the hmi data from `ch_sync` to calculate flux.

The tracking code ended up taking a long time to debug after I sped it up by creating a smaller box around the hole to track the hole in. But, now the code takes about 1 percent of the time it used to. The new masks that track the hole of interest intermittently lose some other holes towards the edges of the picture, seems like some sort of rounding error but I have yet to figure out what's really going on there. There's also a problem with connecting and disconnecting with new regions but I can probably fix that with some new code in the coming weeks. So now I have some results to look at. The flux plots are somewhat hard to decipher but they'll appear on the summary for week 5, after I pretty them up. The code seems to track the hole very well, I'm so glad it's finally working.

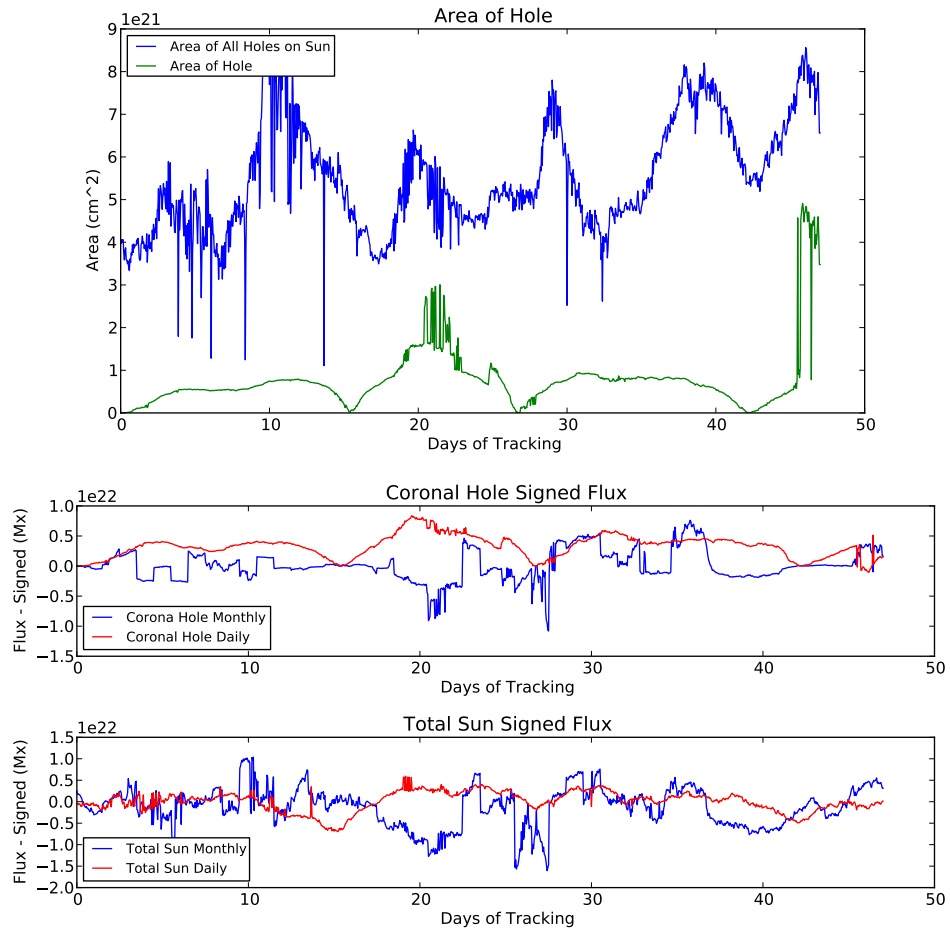
## Week Five

I started this week by testing my code `ch_sync` which worked after the addition of a parenthesis, pretty remarkable that was the only mistake. `Ch_track` is now running after some minor fixes but takes quite a while because I traverse through every region detected by `ch_track_surf` on each frame so I might have to switch to using overlap to detect holes. I also wrote code to take my mask from `ch_track` and the hmi data from `ch_sync` to calculate flux.

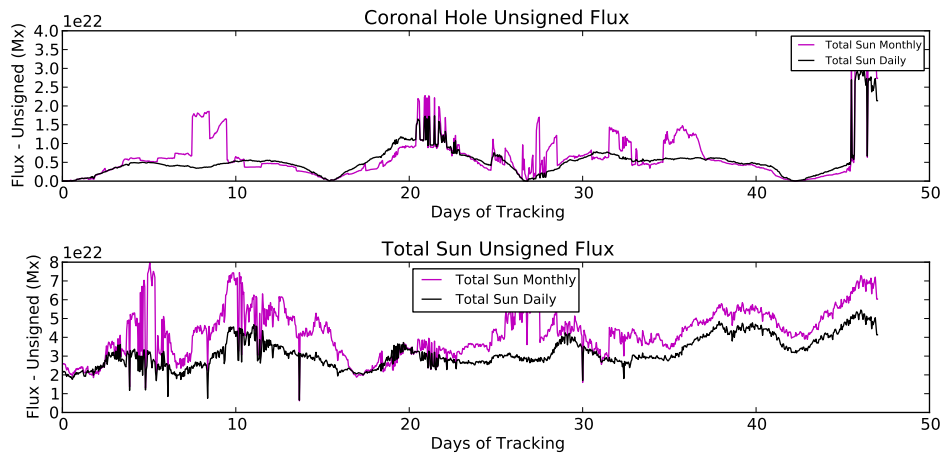
The tracking code ended up taking a long time to debug after I sped it up by creating a smaller box around the hole to track the hole in. But, now the code takes about 1 percent of the time it used to. The new masks that track the hole of interest intermittently lose some other holes towards the edges of the picture, seems like some sort of rounding error but I have yet to figure out what's really going on there. There's also a problem with connecting and disconnecting with new regions but I can probably fix that with some new code in the coming weeks. So now I have some results to look at. The flux plots are somewhat hard to decipher but they'll appear on the summary for week 5, after I pretty them up. The code seems to track the hole very well, I'm so glad it's finally working.

## Week Six

This was the week of the SPD conference. I went to a few hours of lectures most days and understood a little of what was said. I expanded the time range of the coronal hole we're looking at through June 25. After finding all the bad frames, I ran the tracking program on the extended data and it worked quite well. I fixed the tracking program so the user can click on a picture to choose the hole to track. Hopefully, this will make the program easier to use in the future. Here are the extended plots of are, signed flux and unsigned flux:



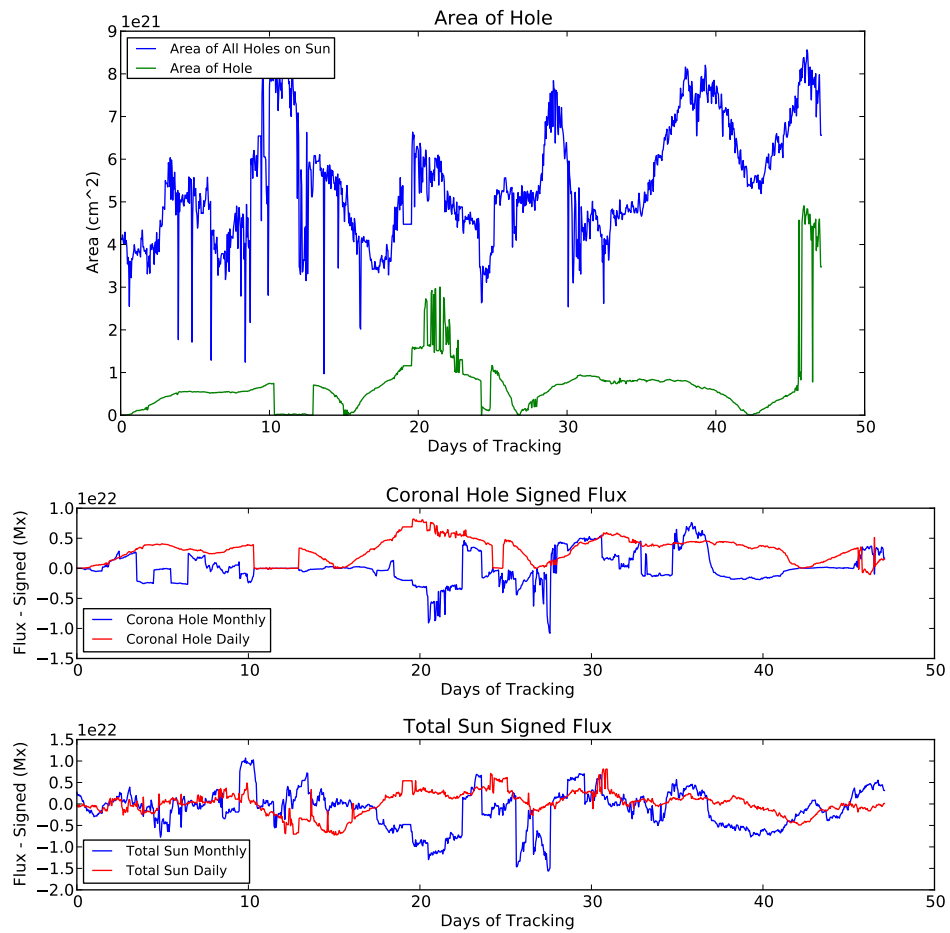


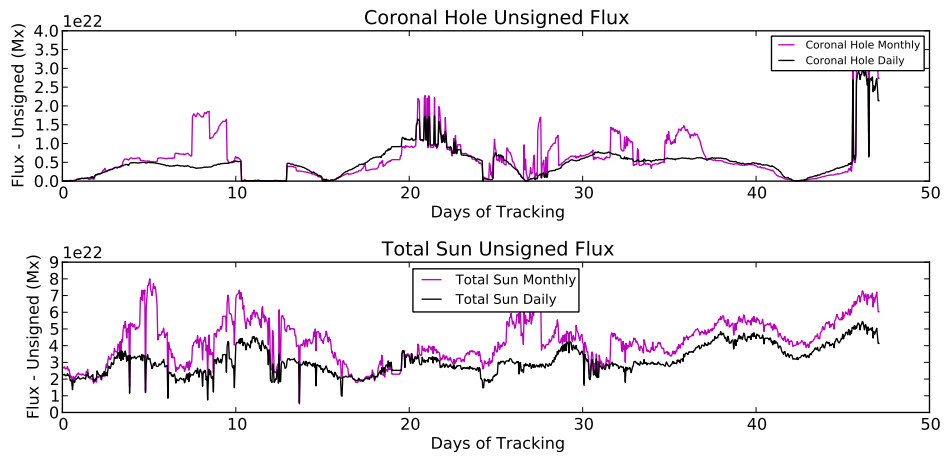


There's really good correspondence near the end of the unsigned flux plot, just off by some small factor. I'm not sure why they correspond so well there. For the next few weeks while my advisor Chris is gone I'll try to run our automate the routine more fully and run it on more coronal holes in the last couple years.

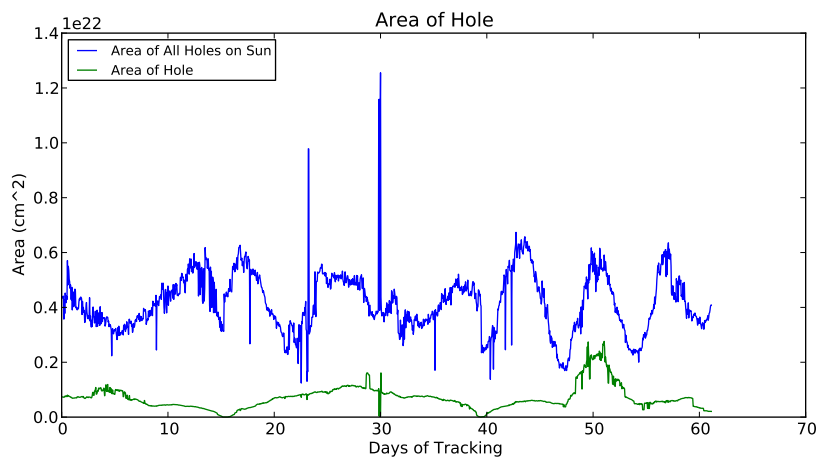
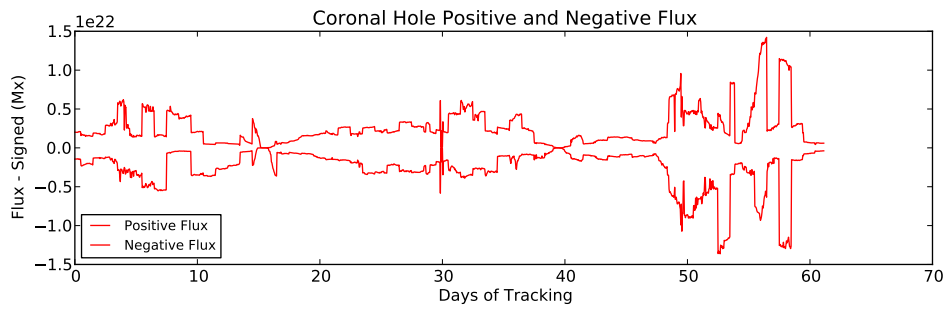
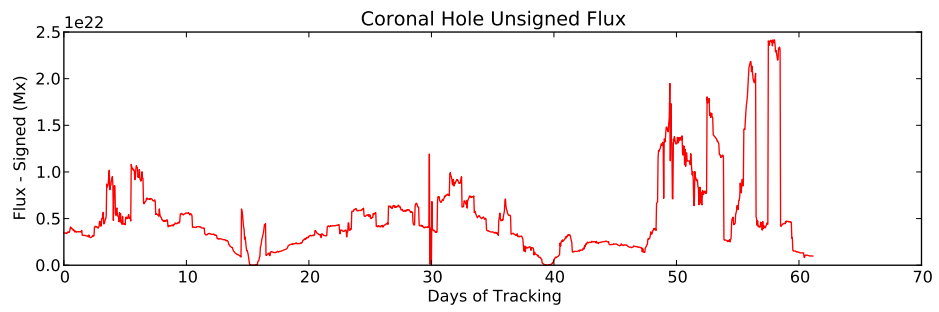
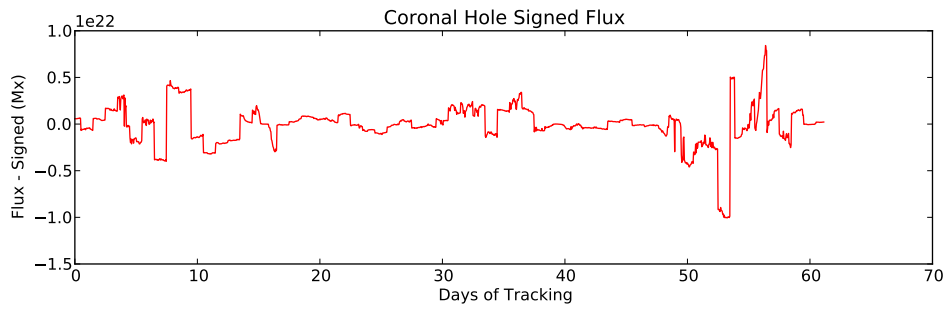
## Week Seven

I rewrote the coronal hole detecting program, `ch_track_surf`, to use daily synoptic charts instead of the monthly charts. I reran the coronal hole tracking routine in the hope that using daily charts would help track the holes better but they still appear to blink in and out quite frequently on the tracking video. I also reran the flux measuring routines and got these results (fairly similar to the old ones, the coronal hole we're tracking disappears for a bit with the daily HMI charts):





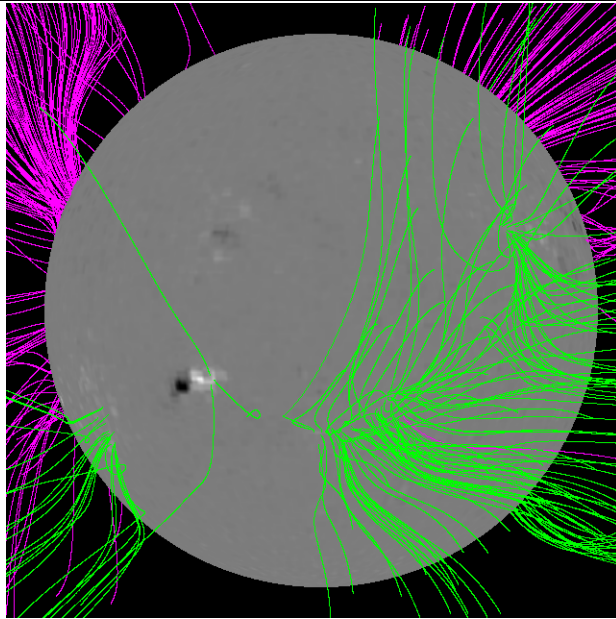
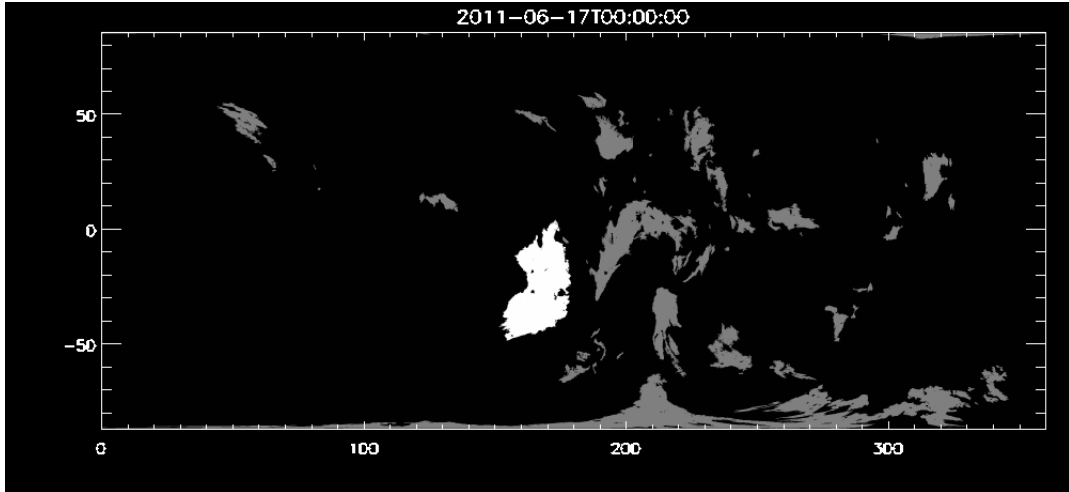
Next, I downloaded data for a new hole to examine over the dates 2011/6/17 - 2011/8/23. The data download program has some serious problems running over such a long time; it slows by a factor of at least 10 and eventually ends up freezing. So downloading such a lengthy data series took quite a while. I added some more filtering to the hmi magnetic data (cutting off very small and very large measurements) and added the ability to track positive and negative flux in the hole individually. The resulting flux measurements for our new hole look like this:

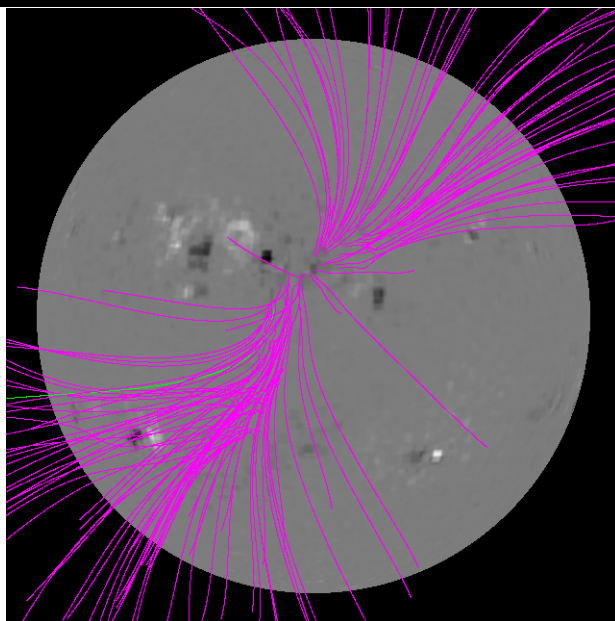
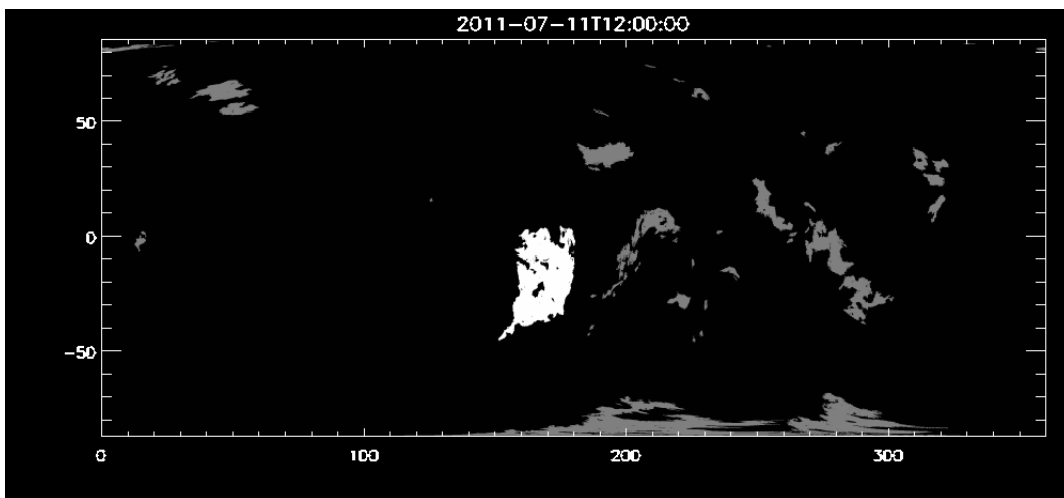


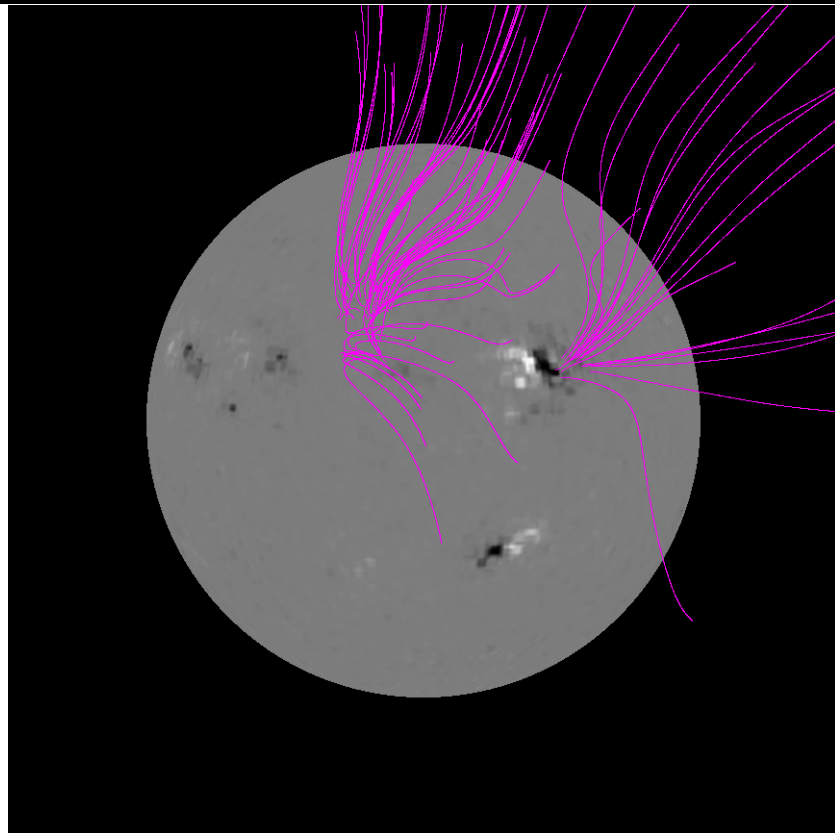
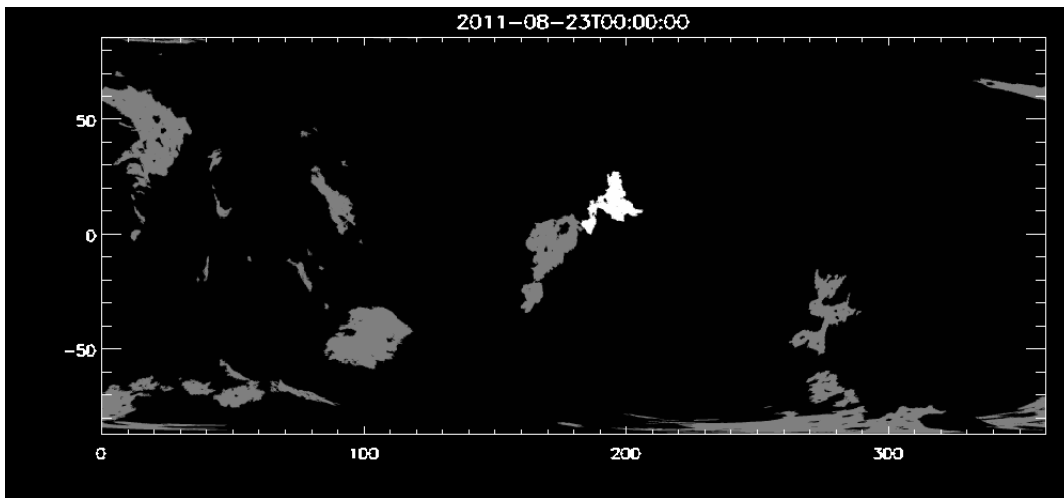
### **Week Eight**

This week's summary will be in the form of an analysis on the second hole I've analyzed over the time 2011.6.17-2011.8.23. There are also videos of corrected daily synoptic hmi frames and the hole being tracked on the website.

In an attempt to verify coronal hole boundaries detected by our program, I've used pfss viewer to trace open field lines. The results are inconclusive at best. Below are frames from the detection program followed by the corresponding pfss\_viewer image:

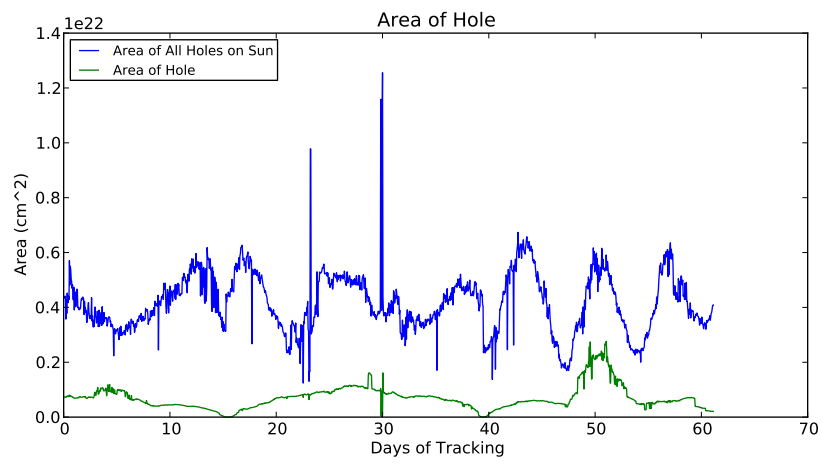
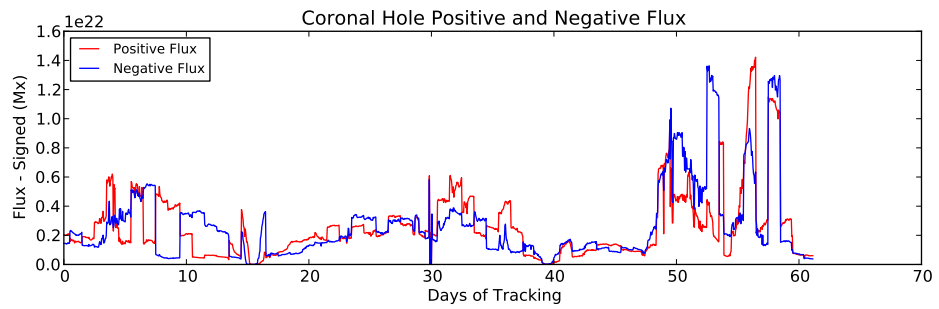
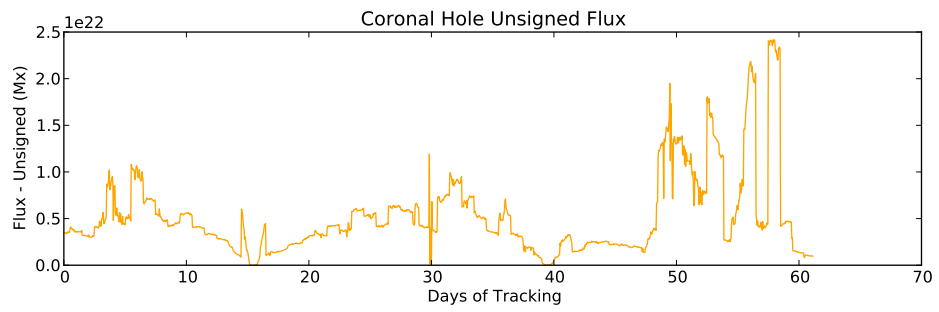
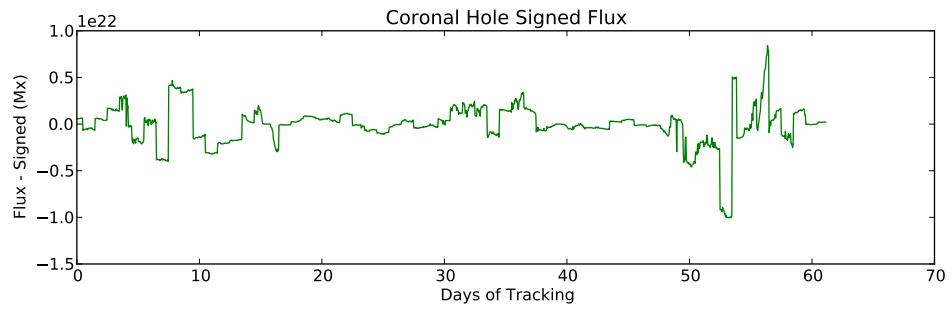






The resulting flux plots appear as follows:

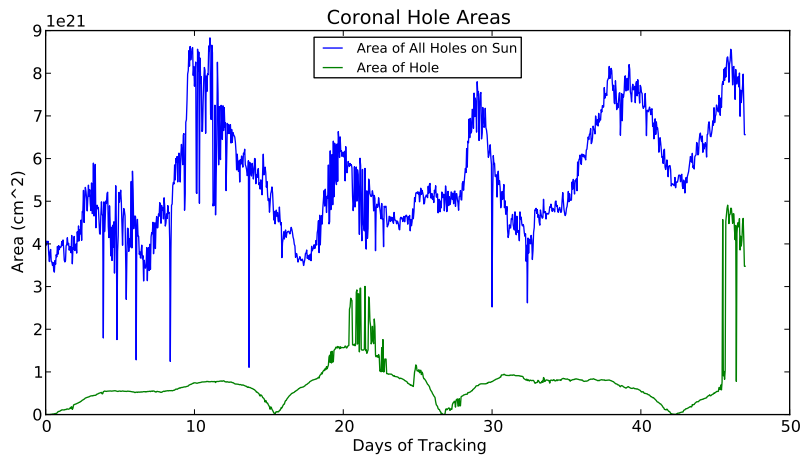


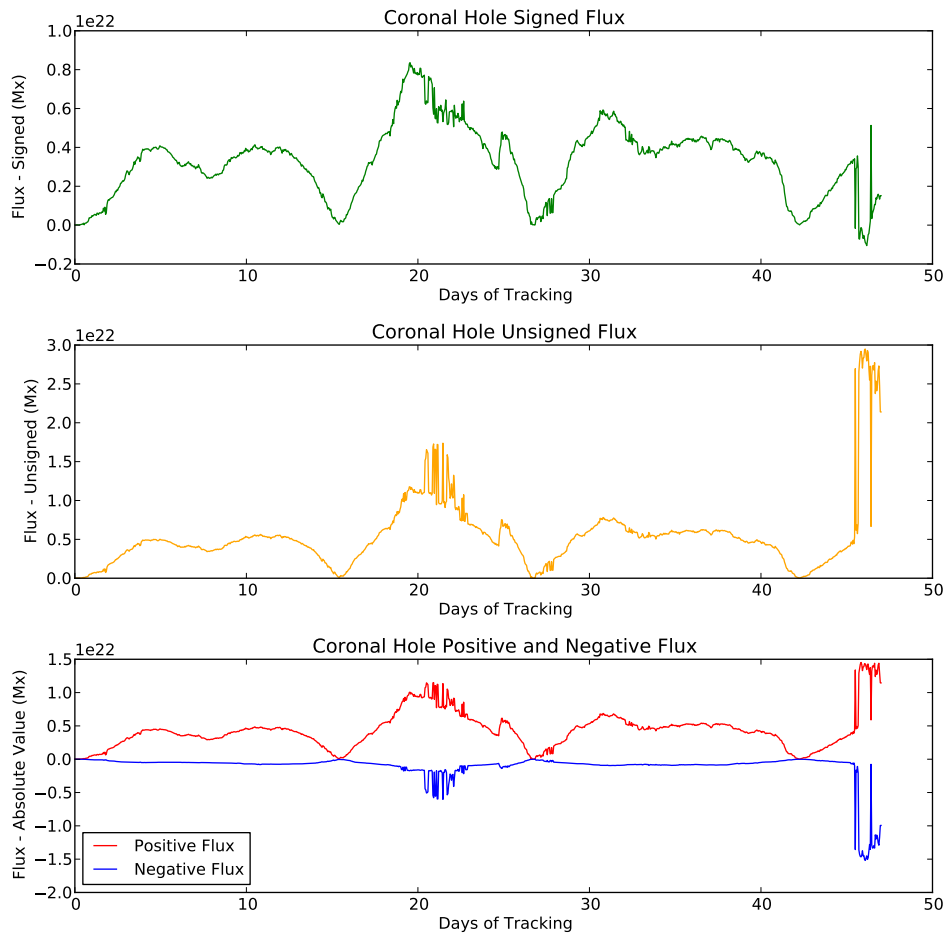


## Weeks Nine and Ten: Final Results

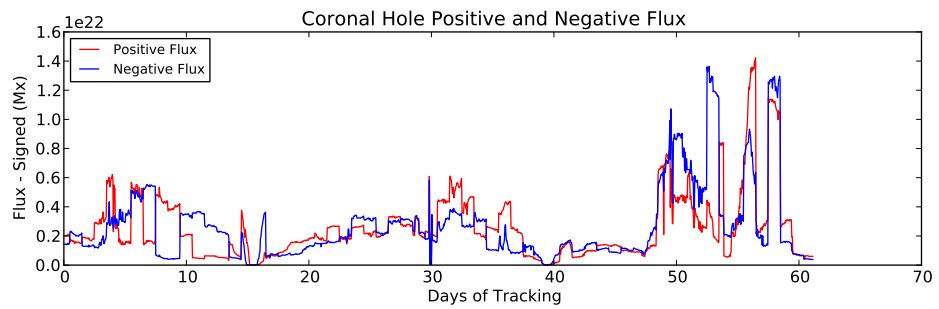
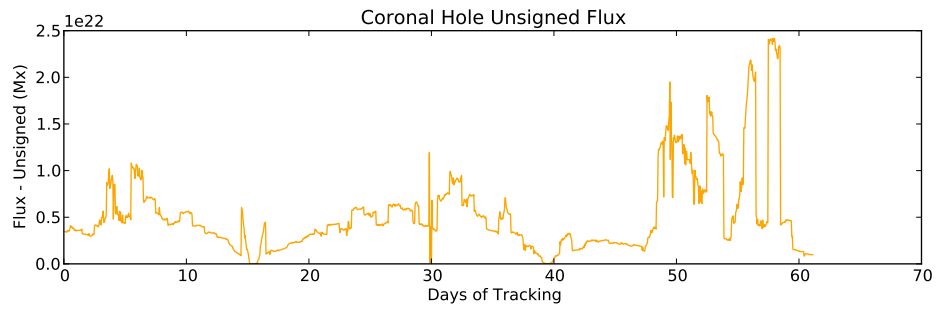
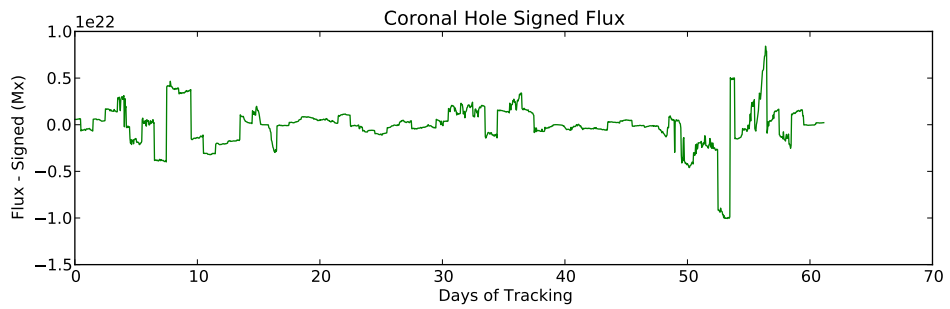
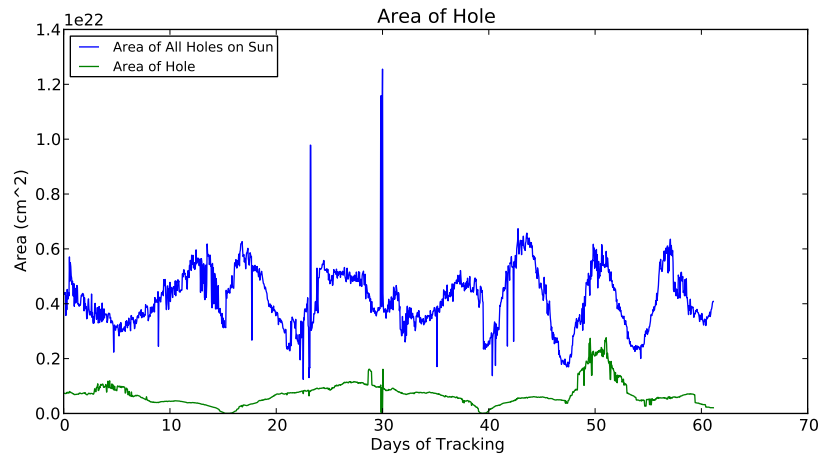
Here are plots of the flux of four holes that were tracked as well as areas:

2013/5/9-2013/6/25

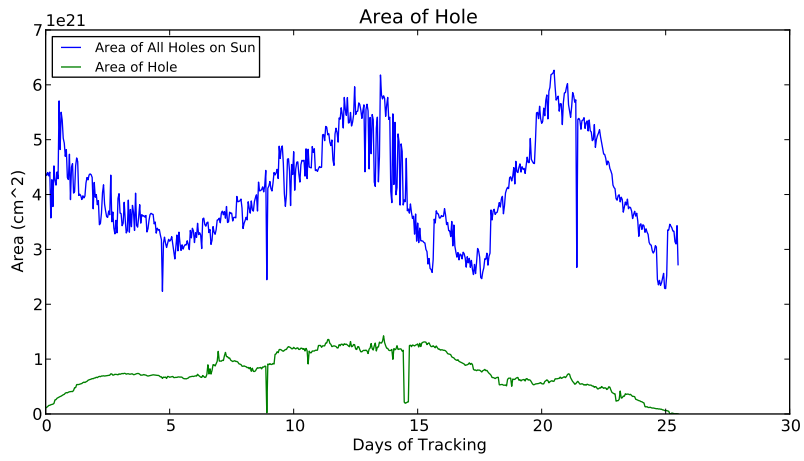


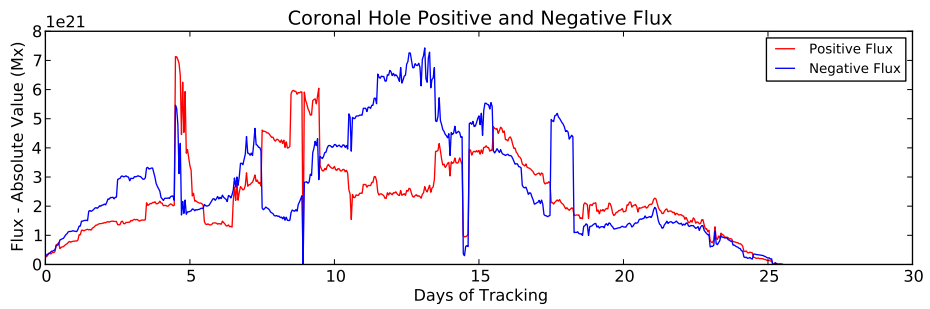
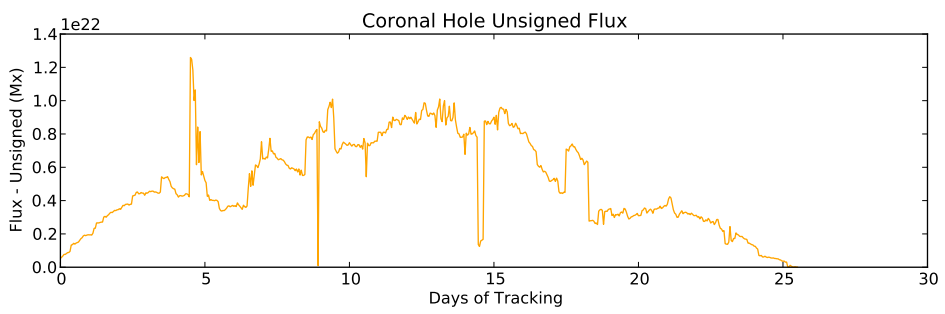
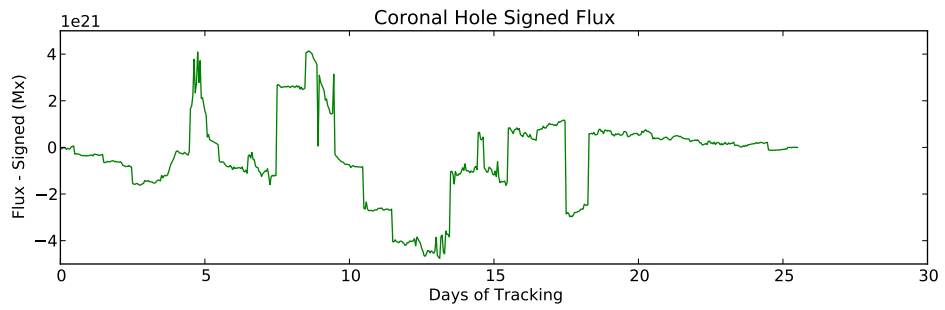


2011/6/17-2011/8/23

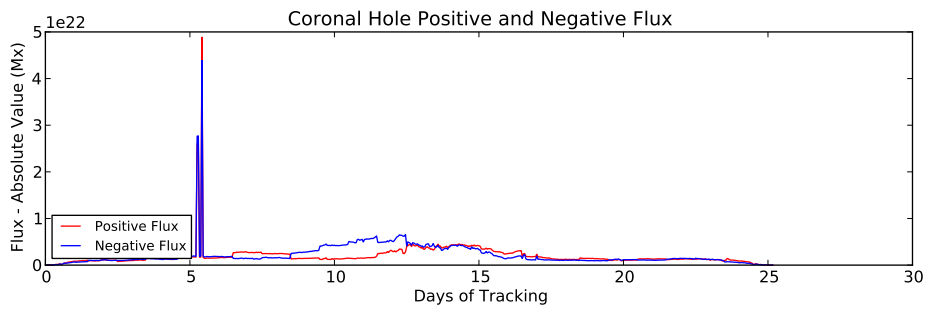
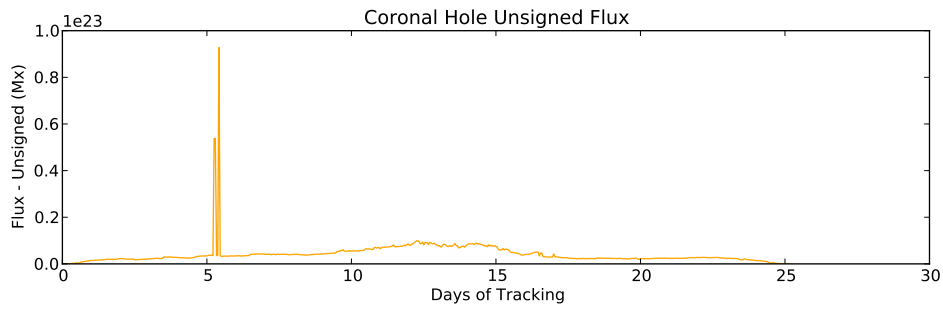
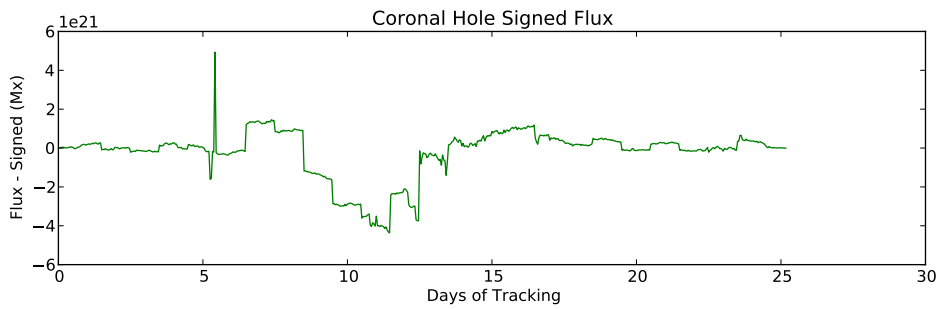
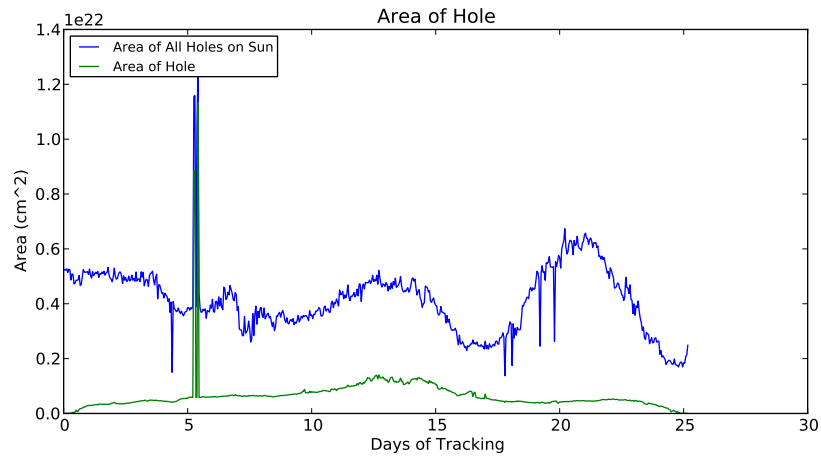


2011/6/17-2011/7/12





2011/7/15-2011/8/9



2011/8/6-2011/6/23

