Week 1

This has been an excellent first week of the program! I started the week by going to the Boulder Solar Alliance REU bootcamp sessions. Laura Peticolas told the other mentee and me that the MACH SUR program was partnered with BSA, so the two of us promised to work with the BSA REU program as needed. We got a solid introduction to space physics and IDL, which I admit was a bit frustrating to get used to. Apart from the BSA REU, I had my first zoom meeting with the mentors (Laura Peticolas, Aimee Merkel and Dave Brain) and the other mentee, Aislyn Bell, to discuss the objectives, expectations and prospects of the program. I also got to meet my mentor Aimee Merkel's Mercury exosphere team in a zoom call where we all discussed the research experience, and I must say I am really excited for the rest of the summer. As for my project, I got in touch with my mentors who promptly sent me some articles to read and prepare for next week when the program and research officially start. It looks like I will be looking into Mercury's exosphere and learning more about the atmosphere loss processes that fuel said exosphere. After bootcamp and the initial meetings with the team, I'm left with some articles and papers to read in order to catch up on the research project.

Week 2

This week was the first official week of research after the REU bootcamp sessions. Before this point I was really interested in space physics/astronomy, but had never taken any astronomy classes. While the BSA REU ran us through some quick lectures on heliophysics and the physics behind magnetospheres, there were still some gaps in my knowledge. This is why we decided to hold an additional zoom meeting with Laura and Aislyn to go over some plasma physics on Wednesday. On Friday, we decided to change our weekly meetings with Laura to Wednesdays, which worked out great because that meant that Aislyn and I could still attend the BSA REU professional development sessions that same day. There wasn't a Mercury exosphere team meeting since Carl Schmidt, a planetary scientist who is currently a professor of astronomy and research assistant at Boston University, went to a Mercury conference this week. I did, however, get to meet Dave Brain's team on Thursday which was fun. These team meetings are mostly science presentations given by the various team members, and this week was on a CubeSat project. Apart from the plasma and IDL tutorials, I also worked on reading the articles that were sent to me, and worked on loading the nexoclom program on my computer. Since the best observations we have of Mercury's exosphere came from the MESSENGER mission, it seems like we need models of the exosphere to help explain what we see, which is exactly what this NEXOCLOM program does. I reached out to the creator, Matthew Burger to help me install it, since the program was created with Linux and I'm on a Windows machine. By the end of next week, I expect to have this program downloaded and to discuss more about Mercury's exosphere as it pertains to calcium, magnesium, and sodium.

Week 3

I spent this week working on getting the NEXOCLOM program to finally run on my computer with Matthew, and after it did I used the integrated functions to make some plots of the model sodium and calcium exospheres. What's interesting about the program is that it's a monte

carlo simulation that keeps track of the trajectories of the atoms to make the model exosphere. The program is in python, so Aime and I discussed the advantages of python and the potential to translate between the language she's used to (IDL) and python. We also discussed more about the MESSENGER observations, how the radiance data for the main three species (Ca, Na, and Mg) was obtained and calibrated using solar spectra, and how that was plotted (with an error bound) against the radiance data that the NEXOCLOM model creates. My project could then be to see how previous research that my mentor conducted was done, and to see if I can get the same results using an updated NEXOCLOM. Said research focused on finding out why there was an observed enhancement of calcium over the north polar cusp region of the planet, and modeling different atmospheric escape processes to see which might explain it. The articles that I have been reading all mention that the spatial distribution of calcium is not symmetrical, with most of it being around the dawn hemisphere. I also attended the BSA REU imposter syndrome session and talked to peers about this common occurrence.

Week 4

I spent this week working with NEXOCLOM and MESSENGERuvvs packages trying to get my own plots of the model calcium exosphere of Mercury compared to the UVVS data. For the model to work, I needed to first familiarize myself with the input file, and then the actual data collection/plotting routine. Here I used the integrated plotting functions to make three bokeh pictures of the model exosphere. One was of the radiance of the model and the UVVS data (in kR) over time (UTC), the second was of the radiance of the model and data depending on the local time and latitude, and the last was a picture of the model exosphere in two dimensions (x and y). This week, I mainly worked with a sample sodium and magnesium run, but I started collecting the right inputs for a calcium run. To answer the question of why we were seeing this enhancement, my mentor suggested we look at the dawn source (as they had for the previous study) and, if time permits, solar wind ion sputtering. Next week I will work on creating my own code for making plots and getting a calcium exosphere running.

Week 5

This was an interesting and busy week, as I not only got to present my progress on the project thus far but also got Tim's code from Aimee. I finally got plots of my model exospheres compared to the UVVS data over orbits 3735 and 2012, but they did not seem to match the old research study that I was trying to replicate. The calcium input file for the model exosphere isolates the dawn source source process at 60,000 degrees K with a maxwellian speed distribution. The reason why it was important for me to get Tim's code was because it was the routine that was used to run the old study, so I spent the beginning and end of the week repurposing the code to work with the newer NEXOCLOM and MESSENGERuvvs packages. Apart from my work on the project, I also gave a five minute presentation of my work so far to the BSA REU students and mentors. I will admit that I was pretty nervous about the talk since I didn't have solid results/plots to share yet, so my presentation had a larger focus on the importance of the study and background behind it. For next week, I will continue to work on my own plotting code (and not use the integrated plotting functions of Matthew's program) to get solid results going.

Week 6

This week was not as eventful as last week, but I did have some pretty bad headaches that made focusing a bit difficult. In any case, I still worked on the first and second versions of my calcium model plotting code, which combined Tim's old code with my plotting routine. The old code took a list of orbits to make plots out of, but since I was only interested in a few, I got rid of the loop and only specified the plot I wanted to look at. Previously, I was making plots of the entire orbit, which explained why the plots were looking very distinct. With my mentor, we figured out what masks the data set should have, with the biggest one being obstype_num being 19. This isolated the radiance data that was collected over the north polar cusp region that we were interested in. Next week I will continue work with this dawn source model and see if this source process (atmospheric escape process) can't really account for the enhancement over the cusp.

Week 7

For this week, I encountered an interesting discrepancy between my plots and the old study plots. The x axis, which referred to the x-tan values of the observations (or the x axis value when MESSENGER's line of sight was tangent to the planet), was incorrect on my plots. After talking to Aimee about it, it seemed like the issue stemmed from the way the MESSENGERuvvs package retrieves the observation data. For the following week, we agreed on finding a way past this discrepancy issue in addition to finally looking at creating a sputtering input file for calcium.

Week 8

As we get closer to the end of the summer project, I must admit that I become more anxious about the final presentations. That being said, this week was a massive step forward as I finally got the alpha and beta values from Tim's code to run some sputtering models of the calcium exosphere. The sputtering models didn't quite resemble what my mentor and I thought it would look like, so we will focus some time on figuring out why the sputtering model doesn't come close to following the shape/intensity of the MESSENGER observations. As of now, we think that there may be an issue with the way the nexoclom routine gathers the data and if it fits it to the MESSENGER observations or if it just yields the raw model radiance data.

Week 9

In the beginning of the week, I finally fixed the x-axis discrepancies by loading the x-tan values directly from the pickle file instead of relying on the built in functions of the nexoclom package. Apart from that, this is the first week that the BSA is in person since the final presentations for the REU are next week. I decided last minute to present the progress I've made on the project so far, but I must admit that it was very nerve-racking to come up with what to show and say for my presentation (which I started but haven't quite finished yet). Next week, I will finish the presentation and present my work on Thursday.

Week 10

This week marks the end of the BSA REU, and as such the final presentations and poster session was held at the end of the week. I was extremely nervous to present my findings to my BSA REU peers, as we have not finished conducting research yet. Interestingly enough, I

was the only person really covering Mercury, so I had to make sure that my background information and motivation slides were comprehensive and detailed. The presentation itself went pretty well, though I'm sure I misspoke a number of times and may have had awkward body language from time to time. Though there were things I wish I would have done better, I was overall happy with my presentation (and the way I answered the audience's questions). Since the research is still not done at this point, I had to present my current plots with smoothed and scaled dawn source calcium exosphere data. I also threw in a sputtering case just to show that we were considering sputtering, but I mainly hand waved its inclusion. Next week, I will work on fine tuning the plots with the extra 70,000 degrees K calcium runs and sputtering as well. I will also work on finalizing an AGU abstract with Aimee as they are due next week.

Week 11

Well, this is the week after the program should have officially ended but since Dave could not make our presentations for last week, we still got this and next week to go. I spent most of the week working on my plots for the solar wind sputtering and dawn source processes, and noticed that when I updated the nexoclom and MESSENGERuvvs packages, the data for all orbits were different. My mentor and I also had some difficulties figuring out the correct geometry to use for the sputtering model, but I imagine we will have something to show by next week. Speaking of, for next week, I will work on having a picture of the whole orbit (not just the north cusp region) and a sputtering model for one of the orbits that I will show next week. I will also decide on whether I want to show the 70,000 K dawn source model or the 60,000 K model in addition to figuring out whether I should use radial angular distribution or isotropic.

Week 12

This is it, the final week of the SUR program with MACH. I have to say, I am incredibly sad that this is the last week of work, but I'm glad that I got the opportunity to work with Laura, Aimee, Dave and everyone else at MACH/Aimee's Mercury team. This has been an absolutely eye opening experience as my first official research project. I ended up going with the 60,000 K radial dawn source model and a sputtering model for orbit 3231 for the final presentation since they both seemed to be reasonable plots to show. The final presentation went phenomenally, and though I struggled with a few of the questions afterwards, I am really proud of myself for how far I've come this summer. I think that one of the most important take-aways I have from participating in the MACH SUR program is how valuable curiosity and speaking up for yourself are. If at some point I got stuck, there was no textbook or course lectures that I could reliably consult, as the research was (and I guess still is) contemporary. There were no textbooks or course lectures because there were no concrete answers to the questions! This is why it was really important for me to speak up for myself and ask my mentors for help when dealing with the code or trying to understand the science behind the research. Ron Vervack, one of the members of Aimee's Mercury team, told me in the beginning of summer that the best scientists aren't afraid to ask questions as they have them, and that's something that will stick with me for the rest of my career.