AST 221: Problem Set 6

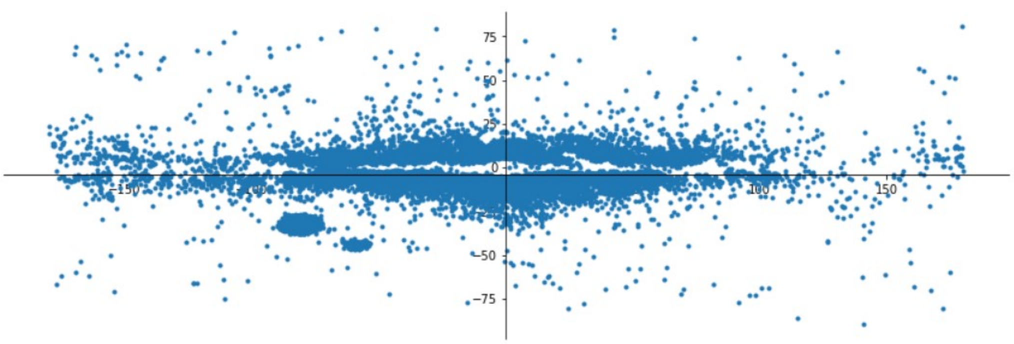
Gil Garcia

May 9, 2019

Due: Thursday, May 9 by midnight.

Problem 1. Conceive of a problem in galactic astronomy that you believe could be answered using data in the Gaia catologue. This could involve re-creating some known result (maybe from the book) with the much more numerous and accurate data available in Gaia. Or it could be some "wild and crazy" new idea that you came up with. Explain the origin and significance of your question and why you think the Gaia data would help answer it. Please write your answer to this question FIRST, then do not change it. You will be able to reflect on your own question 1 in answer to question number 3.

Answer 1. Originally, the result that I wanted to recreate in Gaia was to simply recreate an image of its sky map. Using a simple query I was able to create the following (inverted) map of Gaia:



Upon inspecting the plot, I realized that Gaia, in fact, has extensively observed the Large and Small Magellanic Clouds (seen at about (-80,-50) in the map). This is something I did not know Gaia had done and was quite surprised by it. Thus, my project shifted gears to explore how Gaia has brought insight (new and old) on the LMC and SMC. I wanted to explore the basic kinematics and structure of both clouds and see if I can generate results that have been shown in the literature before. In the process, I was also hoping to learn more about what exactly Gaia has to offer and what are all the data products it has provided astronomers with since up to now, we have mostly worked with its position and color products.

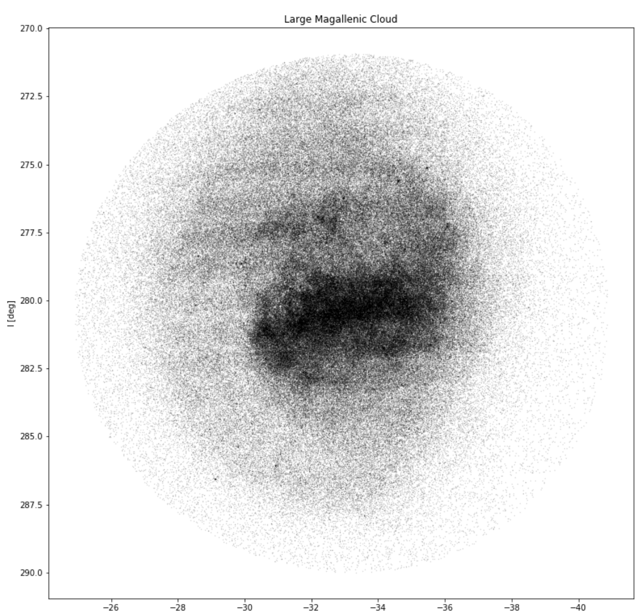
Problem 2. Use the Gaia data base to answer, or at least attempt to answer, the question that you asked yourself in number 1. Do the best you can. If it turns out you cannot answer your own question, at least get whatever insights into the general problem that you can.

To investigate the basic properties of the LMC and SMC, i first created SQL queries that got Gaia data around each of the clouds. I then had to go through a familiar data reduction process as prior Gaia projects where I cut by proper motions and by distances. This allowed me to get rid of a lot of foreground stars and stars that are not actually associated with the clouds but might be at a similar distance. Once we filter our results to get our final data set, we can begin finding scientific meaning in it. Thus, I created a couple of plots which used Gaia's positional accuracy to map out the structure of both clouds. I then used Gaia's temperature and radial velocity measurements to identify hidden structure in the clouds and to study the kinematics of them as well.

Answer 2.

Problem 3. Discuss your results. What did you learn about your initial problem, as expressed in question 1? Were you successful? If so, explain how the Gaia data have improved our understanding of the issue. If you were not successful for some reason, what is the reason or reasons? What did you learn about the subject in actually trying to use the Gaia data the way you thought you could use them. Note that most science questions end up being more complex and subtle than you imagined as you pursue them. If you were to repeat this assignment, how would you structure your answer to question 1 differently, if at all?

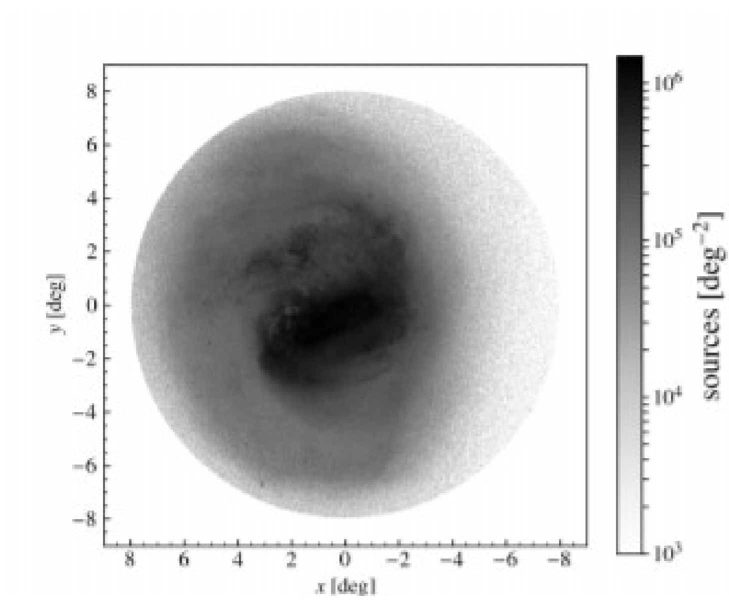
Answer 3. After filtering the data to get our final data set, I first wanted to look at the structure of the clouds. Therefore, I plotted the positions of all the stars to produce the following for the LMC,



The LMC's classification as an irregular dwarf galaxy is made immediately apparent. While we do see a bar-like center and a some spiral structure at the ends of the center, it is clear that LMC is much more chaotic than a regular galaxy. For comparison, we look at how the LMC looks in the optical:

Credit: Yuri Beletsky (ESO)

and also how it compares to a similar plot in a paper which uses Gaia DR2:

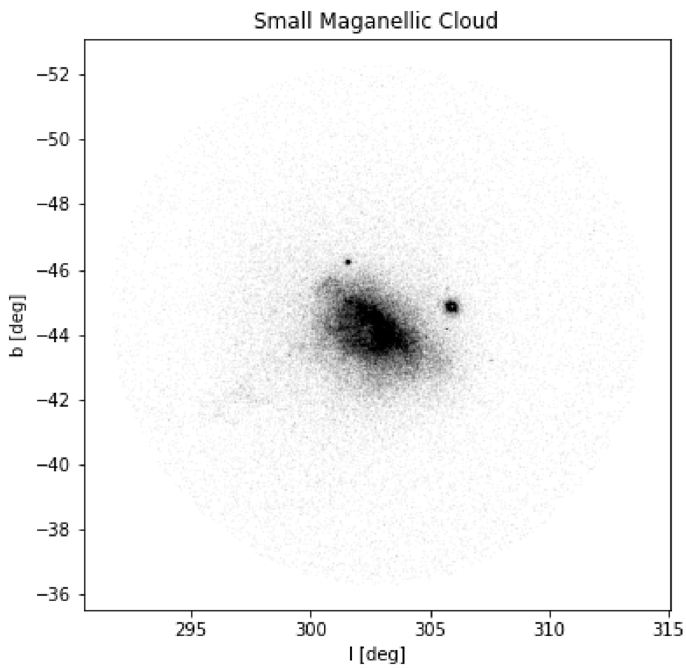


Credit: A. Helmi et al (Gaia Collaboration, 2018)[1]

While in our image, we use a much smaller sample (403,000 stars) than what was used in the paper release plot, we see a lot of similarities. To be able to include the same number of stars as in the Helmi et al paper, a larger query would be needed and more filtering techniques would have been needed. Nonetheless, we can conclude that we were able to generate a proper plot to examine the structure of the LMC.

Now, we take a look at the SMC. Plotting the position of all the stars, we produce:

[1] Gaia Data Release 2: Kinematics of globular clusters and dwarf galaxies around the Milky Way



Again, we can make out some of the large-scale features of the SMC. While also a pretty chaotic dwarf galaxy, we can see a bar-like center. We also got some serendipitous star clusters on top of the SMC. Later, I speculate that the top right cluster, 47 Tucane, is a globular cluster (which we know through literature).

To compare our plot, we look at an image in the infrared and a plot of the SMC in a paper[2] using Gaia DR1:

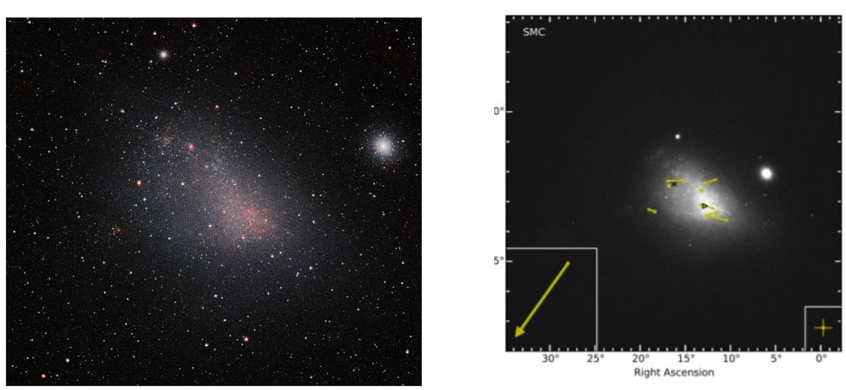


Figure 1: Images of SMC using infared (left, credit: ESO/VISTA VMC) and using Gaia DR1 (right, credit: van der Marel Sahlmann)

Again, the plot created in the image includes a much larger sample size that ours (10,000) but we are still able to create comparable results.

[2] FIRST GAIA LOCAL GROUP DYNAMICS: MAGELLANIC CLOUDS PROPER MOTION AND ROTATION

Following this, I wanted to use Gaia's stellar temperature product to look a temperature of the stars in the clouds. So creating a plot with an added temperature parameter, we produce:

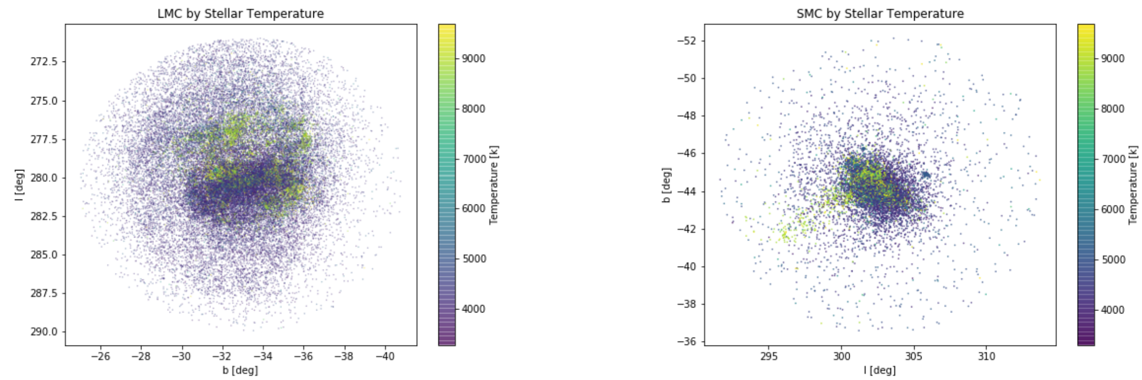
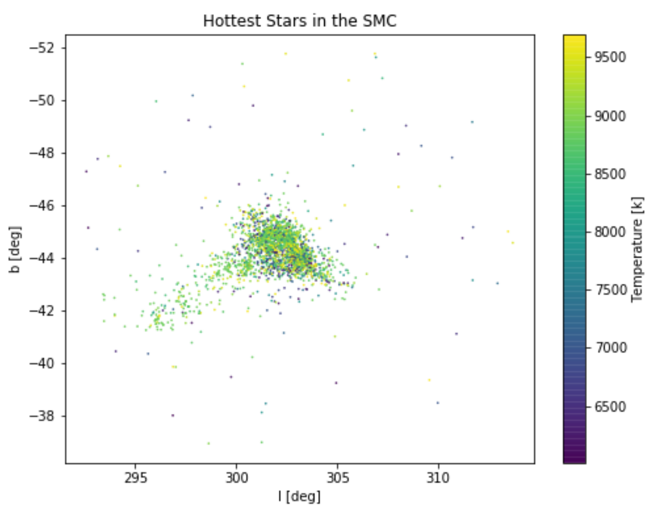


Figure 2: LMC and SMC by Stellar Temperature

Both clouds have a peculiar distribution of stars according to their temperature. However, with more consideration, the hotter stars (likely OB) in the LMC map out the spiral arm-like structure above its core. This is consistent with what we know about distribution of stars based off spectral type.

SMC's distribution of hot stars is perhaps a little more interesting since a new feature that we wasn't there before appears. That is, we see a stream-like structure stemming out from the core of the cloud. To more closely examine this, we produce a plot of only the hot stars in the SMC:



Filtering out the colder stars, a lot more hotter stars appear in the core, and we still have this stream of stars stemming out. Looking into the literature, I could not find much on this structure, so it is possible that upon further improvements in my cuts, I will eliminate these set of stars. One structure, however, that goes away is the the star cluster 47 Tuc and by the first plot, we see that the cluster has stars at about 4000K-5000K. So we can hypothesis that this cluster of stars is likely a globular cluster, which is indeed true.

Lastly, I wanted to see how Gaia's radial velocities measurements can help us learn about the LMC and SMC's kinematics. However, when there was very little stars in both of the queries that had a radial velocity measurement attached to them. Nonetheless, it was enough to get some basic information of of the clouds. Plotting now the stars with radial velocities over the LMC and SMC, we get:

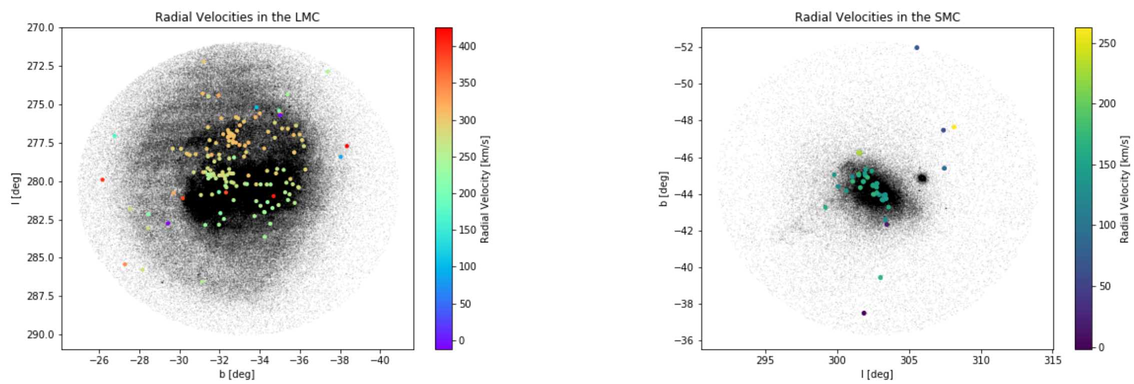


Figure 3: LMC and SMC by Radial Velocities

We see that a lot of the stars in each cloud share radial velocities, which is a nice consistency check. In the LMC, however, we see that the core and the structure on top have distinctly different radial velocities. This could imply a substructure of the LMC or a different one all together. If we filter stars to only get those in the core of each cloud, we get an average radial velocity for the LMC of 275.8 km/sec. For the SMC, we get 144.8 km/sec. Both of these results match closely with what is reported on Simbad since the report radial velocities of 262.2 km/sec and 145.6 km/sec for the LMC and SMC, respectively.