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Distance distribution of Sunlike stars in the milky way throughout the M31-M33-MW merging event

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1. ABSTRACT

We will analyse the fate of the stars at the sun's location in the milky way during the coming few Gyrs as the M31-M33-MW merger takes place. This is important so that we have a deeper understanding of galaxy stellar evolution, but it also works as a fun exercise of seeing what humanity's fate will be as the merging process begins. To do this, we will have the distance distribution of sunlike stars in the milky way and track their location as time goes on. Sunlike stars are defined as stars which are a maximum of .1 kpc away from the centre of mass of the milky as compared to the Sun. Finding sunlike stars is important because knowing the fate of the sun requires far more datapoints and concrete ideas on what a sunlike star is. We found 274 sunlike stars in the milky way, and the most concentrated region was ¡8kpc during the merging process, but we did have quite a few sunlike stars far beyond that point. This means that there aren't a huge number of sunlike stars, and there's a very high chance we stay inside the merger and reasonably close to the centre of mass.

2. INTRODUCTION

We will study the galaxy interaction of the M33-M31-MW group of galaxies by focusing on the fate of stars like our sun. To specify, According to Willman and Strader (2012), a galaxy is a gravitationally bound set of stars which has properties that cannot be explained by a combination of baryons (gas and stars) and Newton's laws of gravity. Galaxy interaction here means the interconnection between two or more galaxies that can lead to significant changes in their shapes, sizes, and dynamics. The sun is 8 kpc away from the centre of our milky way, and there are innumerable stars a similar distance away from the centres of other galaxies in the Universe. Gravitationally bound galaxies refers to a collection of objects that are held together by the gravitational force between them, in this context, M31,M33, and MW. Of all of these galaxies,we focus on M31 and M33, the fascinating spiral galaxies in our local group which are bound to merge in a few billion years, and analyse a part of this merger by seeing the trajectory of sun-like stars in the milky way galaxy when this process takes place.

Our subtopic, studying the fate of stars such as the sun in merging galaxies can help us understand the processes that lead to the formation rate and evolution of stellar populations, which is a critical aspect of galaxy evolution , as seen from Cox & Loeb (2008), Radial migration plays an important role in shaping the metallicity distribution and kinematics of stars in galaxies, and understanding this process is essential for interpreting observations and modeling galaxy evolution. Galaxy evolution is the change in the components of a galaxy (stars,dust, gas, and dark matter) as they evolve over time due to mergers, accretion of gas and change in star formation rate. Galaxy merging can lead to increase in star formation rate, formation of new structures and the removal of old, and new properties in the new galaxy.

According to van der Marel et al. (2012) , the Sun will most likely migrate outward during the merger process, compared to its current distance from the Galactic Center, with a small but significant probability that it will migrate out to very large radius. No candidate suns become entirely unbound from the MW-M31 merger remnant in the simulation.

Most open ended questions related to the topic arise due to not having the best observational capacities to perfectly predict things such as , according to van der Marel et al. (2012), the secular evolution of the MW galaxy due to which we cannot say how the phase space coordinates of the real Sun will change within the next 3 Gyr or its azimuth plane, which leads to the question, how can we best categorize sunlike particles in spite of these limitations? In this paper, we do it in an extremely simplified way by just considered particles less than.1 kpc away from the centre of mass of the milky way as compared to the Sun.

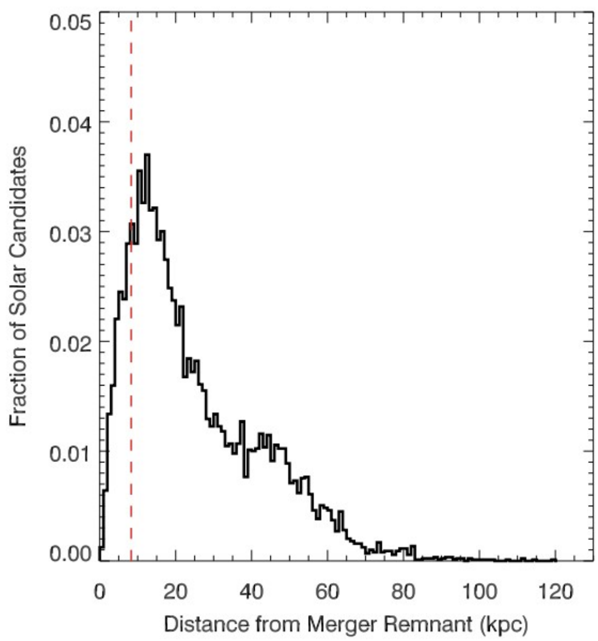

Figure 1. The given figure, from van der Marel et al. (2012), showcases that the radial distribution of candidate suns was analyzed with respect to the center of the MW-M31 remnant at the end of a 10 billion year N-body simulation. The majority of candidate suns migrated outward during the merger process (starting from the current distance of the Sun from the Galactic Center). Sun-like stars like to spread out during mergers.

When it comes to our topic in particular, Cox & Loeb (2008) consider 700 particles as candidate Suns, while van der Marel et al. (2012) uses 8786 particles that meet a certain criteria, so a question that does arise is how the difference in criteria influences the results in our data. It is also to be noted that Cox & Loeb (2008) had a lower number because of resolution issues at the time, but it might be more desirable to have a less computationally intensive project. Thus, using our given dataset, we will be seeing the distance distribution of sun-like stars in the milky way galaxy over time as the merger occurs.

3. THIS PROJECT

In this paper, we will study distance distribution of sunlike stars in the milky-way galaxy during the future collision and merging of it with the andromeda galaxy by analysing sunlike stars at different snapshots of given dataset.

In this project, we answer how many sunlike particles there are by fixing on the simple criteria of any particle within .1 kpc of the Sun, which is 8.29 kpc away from the centre of mass of the milky way galaxy (van der Marel et al. (2012)), we do not specify the edge on or face on case of the milky way discussed in lab 7 and instead go for the default position of the milky war for now. Alongside this, we will also see the trajectory of sunlike particles by plotting histograms at different snapshots, and see if it aligns with the results in van der Marel et al. (2012).

Answering how many sunlike particles lie in a particular galaxy and their trend during a merger will allow us to not only help us understand the radial migration of sun-like particles during mergers but also help us better understand what we can expect out of other galaxies like the milky way. This study will help by complimenting the conclusions drawn by van der Marel et al. (2012).

4. METHODOLOGY

In our given project, we utilize the simulation provided by van der Marel et al. (2012) , according to whom, the given simulation shows future orbital evolution and merging of the Milky Way (MW)- M31-M33 system through a combination of collisionless N-body simulations and semi-analytic orbit integrations. As the wording suggests, an

N-body simulation is the interaction of N particles over a given span of time, in our case, we have the simulation of particles during the M31-M33-MW merger. In our case, we use a small subset of these particles for our project where N would be the number of sunlike particles.

As seen in the figure, what we are trying to do is to classify sun-like stars in the milky way galaxy and observe how their distance from the centre of the milky way galaxy evolves with time. In our study, we have taken particles to be within 8.29 ± 0.1 kpc, and we do not set the galaxy to its edge on or face on state. Then, much like the paper by Cox & Loeb (2008), we chart out histograms for different times during the future using the snapshots provided in the simulation.

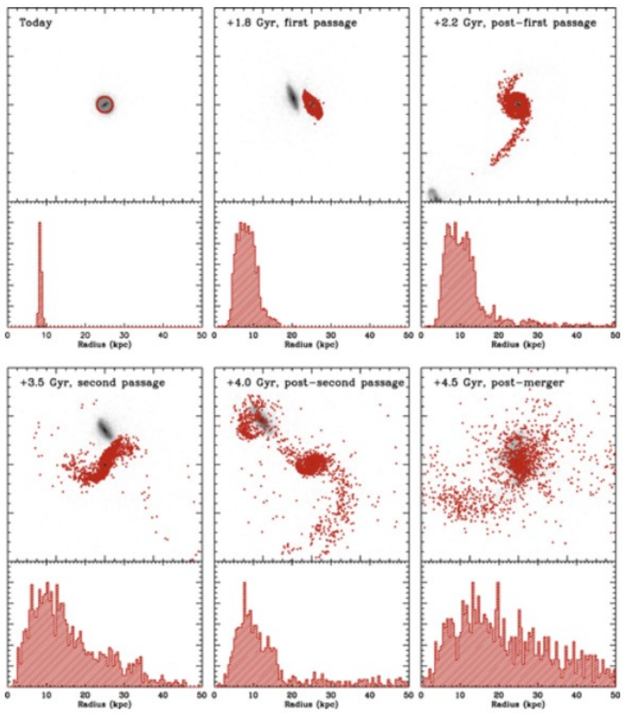

Figure 2. The given figure, from Cox & Loeb (2008), displays the potential position of the Sun during different phases of the merger between the Milky Way and M31. The top panel shows the future tracks of all stellar particles with a current radius of 8 ± 0.1 kpc, marked with a red cross. The bottom panel is a histogram showing the radial distance of these particles from the center of the Milky Way. We aim to do the same thing by utilizing snapshots.

Most of the calculations in our code have been done in previous works such as centre of mass which has the general formula of

$$COM = \frac{\sum_{i=1}^{n}(x_i * m_i)}{\sum_{i=1}^{n}(m_i)} \tag{1}$$

We subtract the centre of mass from our x,y, and z coordinates and add up the magnitude in all the directions as

$$(x^2 + y^2 + z^2)^{\cdot}5$$

and only select the ones which have a distance magnitude ¡.1 kpc different from that of Sun.

We will need to create a plot at snapshot 0 to verify the correctness of our code and have an idea of how many sunlike particles exist at initial time. After this, we will have multiple histograms for different snapshots showing the distribution of these same sunlike-stars with time.

Ideally, we should be able to see a rough distribution similar to that of the figure done by Cox & Loeb (2008), where a good amount of sun-like stars should be concentrated near the milky way at any point and have a minority of sunlike stars be very further out to support the results by van der Marel et al. (2012).

5. RESULTS

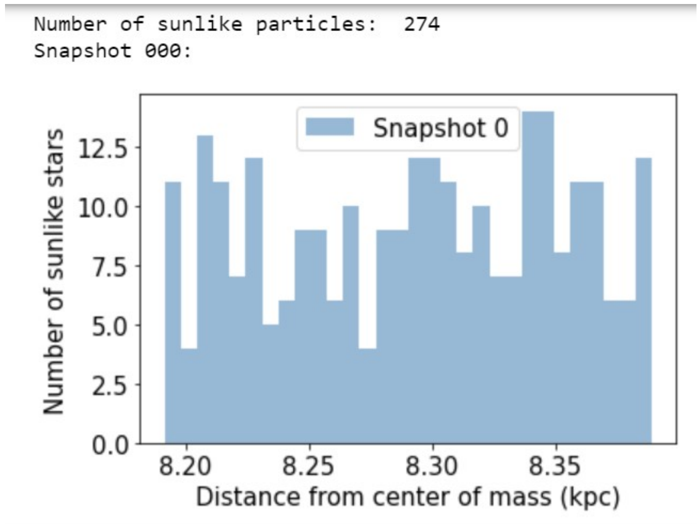

Figure 3. We have obtained 274 candidate suns at initial time 0

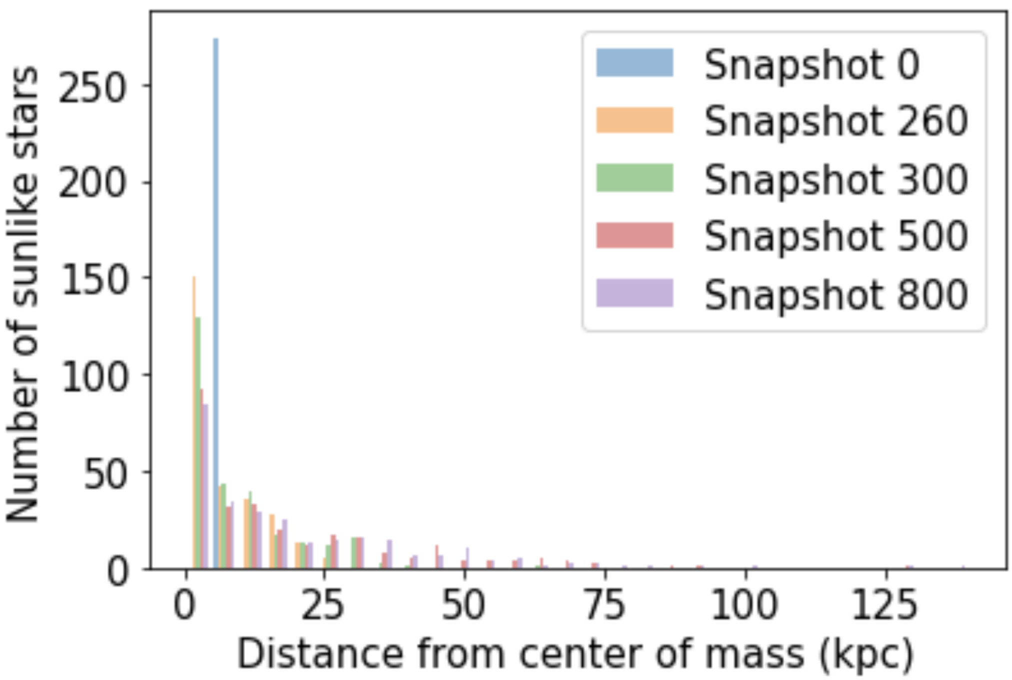

Figure 4. most stars seem to be close to the centre of mass of the milky way galaxy while a minority of them go far beyond 15 kpc.

In our first figure, we have the distribution of sunlike stars with our given criterion at initial time of 0. At snapshot zero, we have set a histogram of sunlike stars situated .1 kpc away from 8.29 kpc, these are 274 particles that we are going to track at future snapshots.

In the second figure, in addition to snapshot 000 at time t=0, we have the distribution of these same stars at the snapshots of 260 (3.7 Gyr), 300 (4.3 Gyr), 500 (7.1 Gyr) and 800 (11.5 Gyr) into the future to see how the distribution of sunlike stars changes as the merging process occurs. We notice that the region with the most stars is from 0 to

8kpc, and as time goes on, more and more stars seem to be further out, but the vast minority of stars are found after 20kpc. Thus, most stars seem to be close to the centre of mass of the milky way galaxy while a minority of them go far beyond 20 kpc.

6. DISCUSSION

The number of sunlike particles that were found are 274, we found the number of sunlike stars to be in the same ballpark as 700 candidate suns obtained by Cox & Loeb (2008), but three times less. The sunlike particles found by van der Marel et al. (2012) were a total of 8786, far more than our estimate. It is important to note that our estimate is only found through particles in the simulation, with crude methods of estimation such as grouping up all stars within a specific distance of the sun's magnitude from the centre of mass, .1kpc in our case.

Not accounting for the tilt of the milky way galaxy is one of the reasons why we didn't get a higher number, and it could also be the reason why the first figure of the histogram of sunlike stars taken at snapshot 000 of the simulation is a bit lopsided as more particles seem to be situated at a magnitude of ¿8.29 kpc, but since we have 274 datapoints, this nature of the distribution could also be due to relatively low sample size. This is assuming the sunlike star concentration is neglegibly different when assuming the sun's distance away from the centre of mass as 8.29 kpc or 8kpc.

In addition to this, when it comes to our distance distribution for different snapshots, we see that as time goes on, more and more sunlike stars do seem to migrate outwards as shown in van der Marel et al. (2012), with an outside but nonsignificant chance of it going far away. However, we still have a decent concentration of stars very close to the centre of mass. This trend is even more obvious when we compare our results to the figure from Cox & Loeb (2008), an abnormal amount of stars are closer to the centre of mass in our case throughout the merging process.

Again, this could be because of not taking the tilt into account. However, for crude estimates, this could show that not accounting for the tilt leads to a higher distribution of stars located near the centre of mass. In addition to this, we have too few datapoints, especially at more far out distances, to say with confidence that there is indeed a nonsignificant chance of sunlike stars going far away from the centre.

7. CONCLUSION

We set out to analyse the fate of the stars at the sun's location in the milky way as the M31-M33-MW merger takes place so that we have a clearer understanding of galaxy stellar evolution. To do this, we have made the distance distribution of sunlike stars in the milky way and tracked their location as time goes on. Finding these sunlike stars is essential as we need more datapoints to discover our own fate and get a better idea on evolution of particles like the sun during merging events in the universe.

A key finding we had was that more and more sunlike stars do seem to migrate outwards as shown in van der Marel et al. (2012), with an outside but nonsignificant chance it going far away, which seems to agree with our hypothesis and what is shown in other sources.

But, we also discovered that our sunlike stars are less spread out than the dataset in Cox & Loeb (2008) , and they don't always seem to be farther out from the centre of mass than they began, but a significant majority are, which supports van der Marel et al. (2012), albeit weakly. It is possible that not accounting for the tilt of the milky way leads to this effect which could be useful when considering far away galaxy mergers for which we barely have any information to start with.

I would start improving my code by accounting for the tilt of the milky way and cover the edge on and face on sides. In addition to this, assuming this gives me more datapoints, I could improve my definition of sunlike particles by bringing in factors like solar masses into consideration.

sectionAcknowledgements

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