JAS1101 Final Project Proposal
Study of SMCNOD: Kinematics and Membership

Dingding WANG

[1]Department of Astronomy and Astrophysics, University of Toronto, 50 St George St, Toronto, ON M5S 3H4, Canada
esther.wang@mail.utoronto.ca

Abstract –

1 Background and Motivation

The Magellanic Clouds are the largest satellites of the Milky Way (MW), and the only irregular galaxies in its immediate surroundings. The Magellanic System is an important nearby cosmological laboratory. It consists of the Large and the Small Magellanic Cloud (LMC and SMC). Through interactions between both clouds as well as the Mily Way, the system also forms the Magellanic Bridge and Stream (D'Onghia & Fox 2016). In 2017, a stellar overdensity, 8° north of the center of SMC, was first discovered by Pieres et al. (2017). With Dark Energy Survey (DES, The Dark Energy Survey Collaboration 2005) and the MAGellanic SatelLITEs Survey (MagLiteS, Drlica-Wagner et al. 2016), they obtained data and follow-up imaging to study the overdensity. Pieres et al. (2017) called this feature the Small Magellanic Cloud Northern Over-Density (SMCNOD). The SMCNOD contains mainly intermediate-age stars ($\sim$ 6 Gyr with a metallicity of Z = 0.001) with a small fraction of young stars ($\sim$ 1 Gyr, Z = 0.01), and is indistinguishable in age, metallicity and distance from the nearby SMC stars. Recent works estimated velocities for the MCs to be higher than expected (Kallivayalil et al. 2013), and thus the gravitational interactions between the MCs may play a more significant role than the MW in triggering star formation. Identifying and analyzing the member stars in SMCNOD can not only learn the properties of itself, but also study the past star formation activity in the MCs as they encounter. In this project, we would identify member stars, discuss the spatial distribution of the selected member stars and their properties in comparison with the main body of the SMC.

2 Data

For the purpose of this paper, we would explore the yet-unreleased DR3 data from the Southern Stellar Stream Spectroscopy Survey (S5) spectroscopic data. S5 initially followed the dark energy survey (DES) spectroscopically with the eventual goal to survey stellar streams across the whole southern sky (Li et al. 2019). Additional photometry from the Gaia DR3 survey may also be used in latter analysis for cross-match.

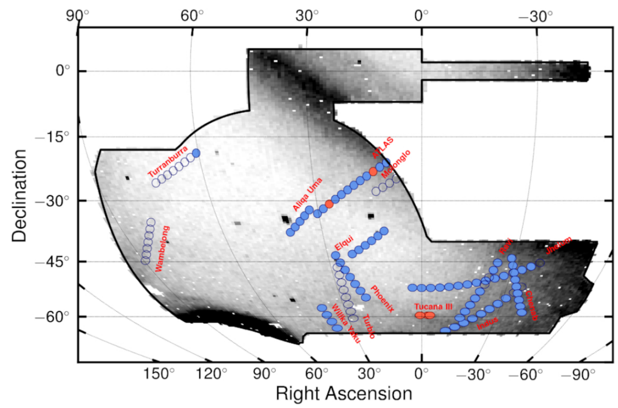

Figure 1: Figure 1. Pointing and status map of S5 within the footprint of DES(Li et al. 2019).

3 Methods and Approach

In this project, I would build mixture models for clustering, and sample parameters using different python packages for Markov Chain Monte Carlo for Probability.

3.1 Gaussian mixture models

A Gaussian mixture model is a simplified probabilistic model, which the assumption that data are all generated from a mixture of a finite number of Gaussian distributions with unknown parameters. We would first generalize k-means clustering to incorporate information about the covariance of the data, then proceed to estimate parameters of this distribution, like the mean and variance, using maximum likelihood estimation. In this project, we would fit the SMCNOD data with a three-component mixture model: one galaxy component and two background components

3.2 Markov Chain Monte Carlo

The Markov chain Monte Carlo(MCMC) method approximates the posterior distribution of the parameter of interest by random sampling in the probability space, proposed by Goodman

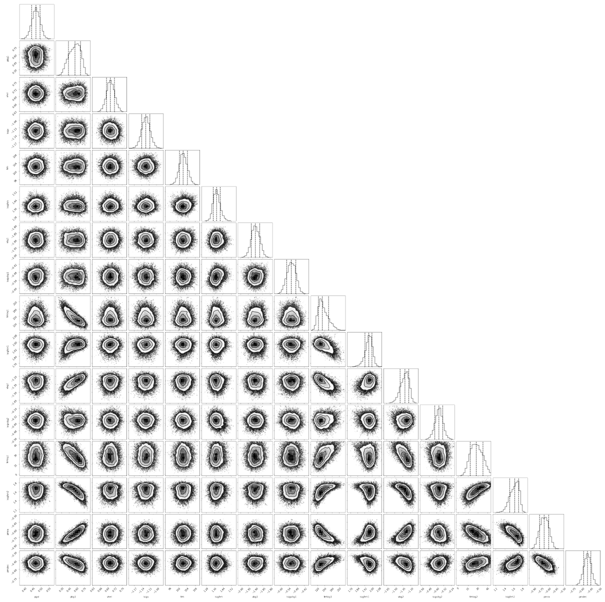

Figure 2: Cornerplot of 16 Optimized Parameters of SMCNOD from MCMC

& Weare (2010). MCMC sampling provides a class of algorithms for systematic random sampling from high-dimensional probability distributions. Unlike Monte Carlo sampling methods, which are able to extract independent samples from the distribution, Markov chain Monte Carlo methods extract samples whose next sample depends on existing samples, called Markov chains. This allows the algorithm to narrow down the number of approximations from the distribution, even with a large number of random variables. In this project, we would use different python packages including emcee(Mackey et.al 2021) and dynesty(Speagle 2020) for parameter comparisons.

4 Challenges and Limitations

MCMC produces a set of sample that is approximately distributed from the posterior distribution given a prior and likelihood function. However, it has significant drawbacks, such as inefficiency and too much rely on the priors. For instance, the average time for me to run through the chain is an hour thus it takes long to examine if the previous set up such as priors and likelihood has issues. In addition, since my prior knowledge of the SMCNOD data relies on previous literature and the properties of background parameters remains unknown, my initial guess may not be very close to the true value. It may be challenging for me to identify the foreground/background component. To resolve this problem, I would need to read more literature on relevant studies, as well as discuss the limitation of each technique in my final report.

5 Timeline

5.1 October - late October

The first weeks of project time were spent doing literature study of SMCNOD, building likelihood functions and fitting model to data using mcmc, as well as the general literature on S5 and Gaia. Since I have done the data visualization and exploration of S5 already, I would re-do this process on Gaia DR3 for comparison. I would finish building a full model on interested parameters of SMCNOD sample and select member stars for next step analysis.

5.2 early November - late November

In November I aim to analyze the spatial distribution of SMCNOD, and apply corrections for both the differential Solar reflex motion and the perspective motion to obtain accurate kinematics. With identified members of SNCNOD, we could further analyze the properties in comparison with the main body of the SMC, and discuss the origin of SMCNOD.

5.3 December

Write up findings and results. In this stage I should have finished all the coding and consulting questions I encountered with professors, and be ready to organize and conclude the results.

References

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