Searching for Tidal Tails in the Open Cluster M35

Anurathi Madasi[1], Aaron Geller[2], Anna Childs[2]

1. Loyola University Chicago
2. Center for Interdisciplinary Exploration and Research in Astrophysics(CIERA)

Abstract

Using an *N*-body model, we created a simulation of the open cluster M35. We used Gaia data to place the simulation stars on the sky at the location of M35. Since M35 is still very young, the tidal tails of the cluster are not as extended as an older cluster and thus it may be easier to look for. By creating models, we can see what current tidal tails do look like, and by running the simulation forward we make predictions about the future of the cluster.

Introduction

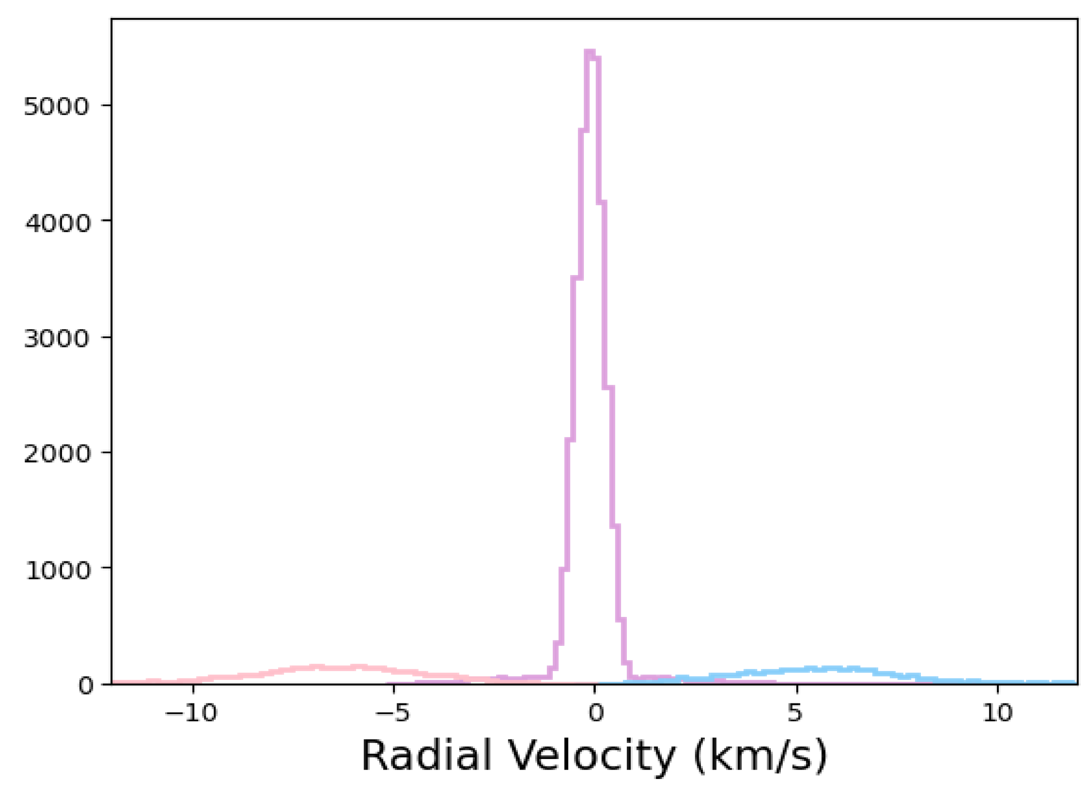
Messier 35(M35 or NGC 2168) is a young open cluster in the Milky Way. All the stars in the system are roughly the same age and have similar masses, velocities, and metallicities. M35 has an estimated age of 150-215 Myr and is centered at α = 6h09m07.5s and δ = +24◦20′28, with the mass of the cluster estimated to be 1600-3200 $M_{\odot}$ [2]. Tidal tails form when stars are pulled away from the cluster due to the gravitational pull of the center of the galaxy.

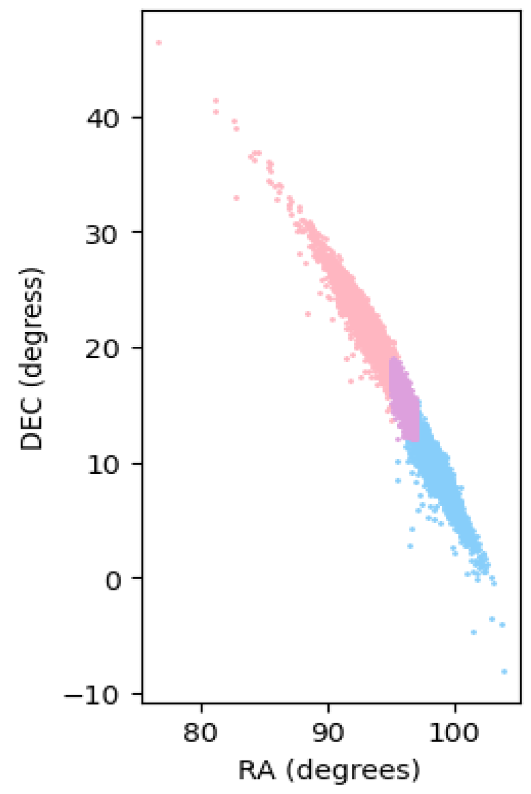
Methods

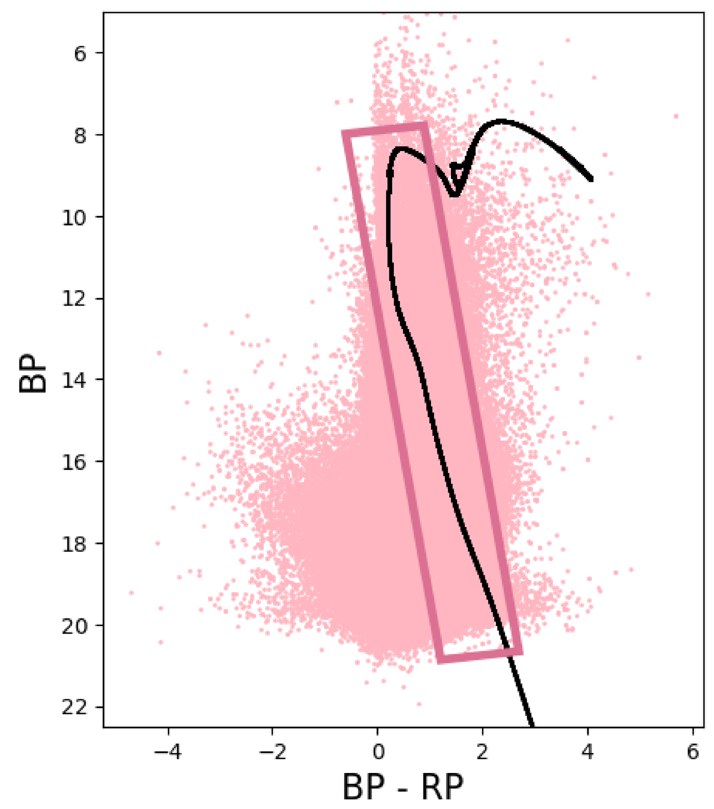
- Using the current location of M35, we integrate the cluster back to its birth, then run a simulation using galpy [1] and AMUSE [3] from birth to present day to create tidal tails.
- Projected simulation into RA and Dec to compare directly with the observations
- We downloaded Gaia datasets which correspond to the predicted location of the tidal tails.
- Using the Gaia photometry, we selected a region of the color magnitude diagram that could contain the members of M35's tidal tails
- We used the simulation data and plotted them with different parameters

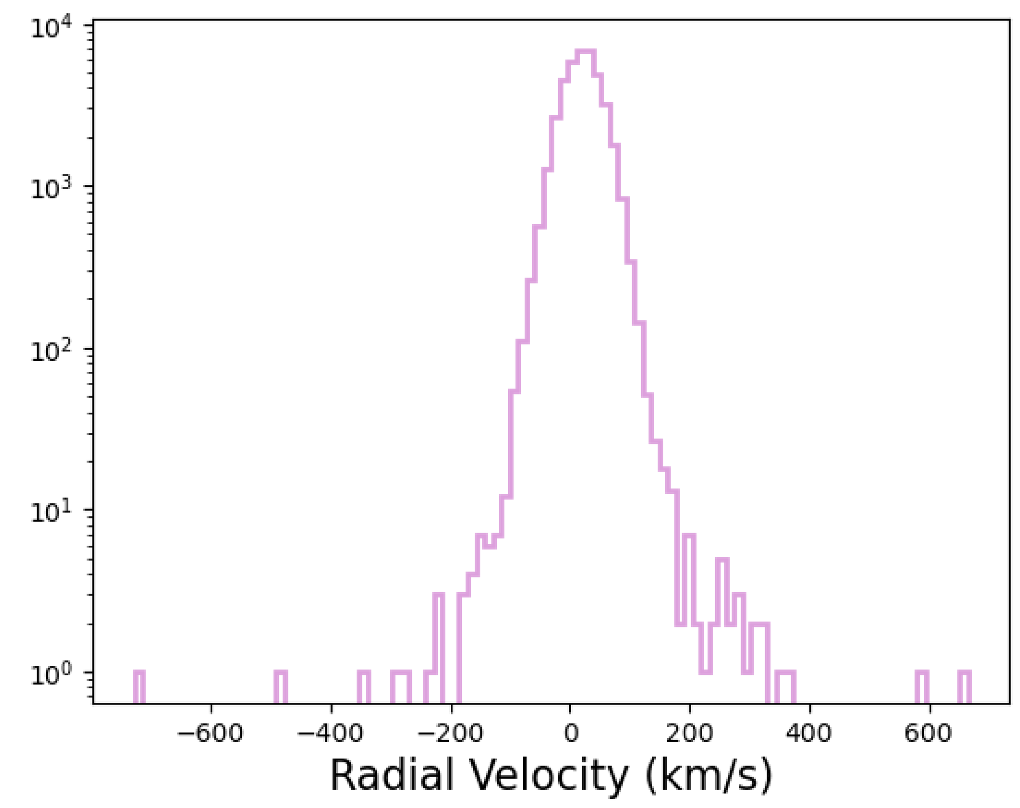
Results

- The Gaia data (within the box shown in the CMD) have wider velocity distributions than the M35 simulation, likely due to field stars
- We were able to further limit our observational sample using velocities and the convergent point point
- We obtain 2 CMDs, the top one was created using GAIA without cuts, and the bottom one was created with cuts

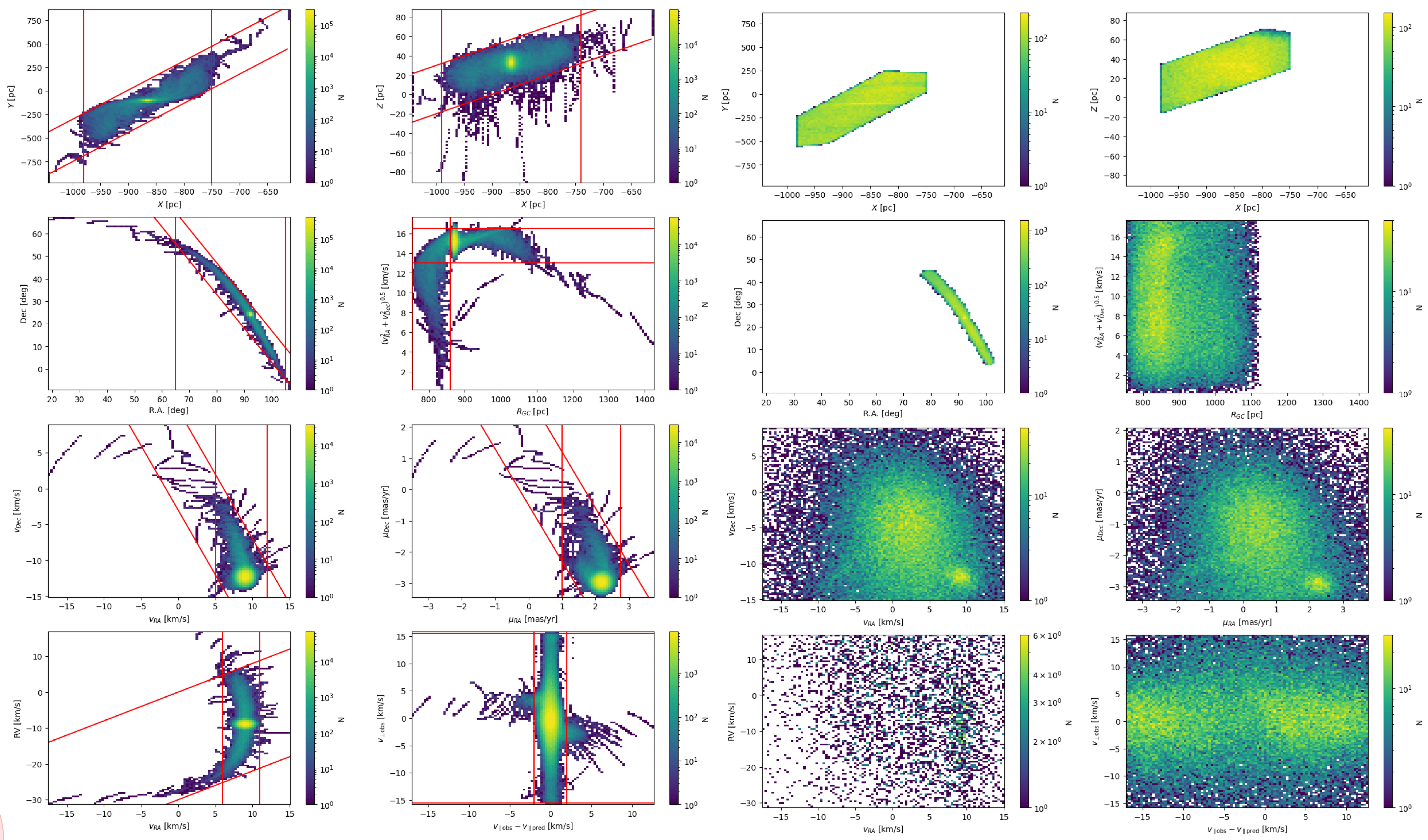




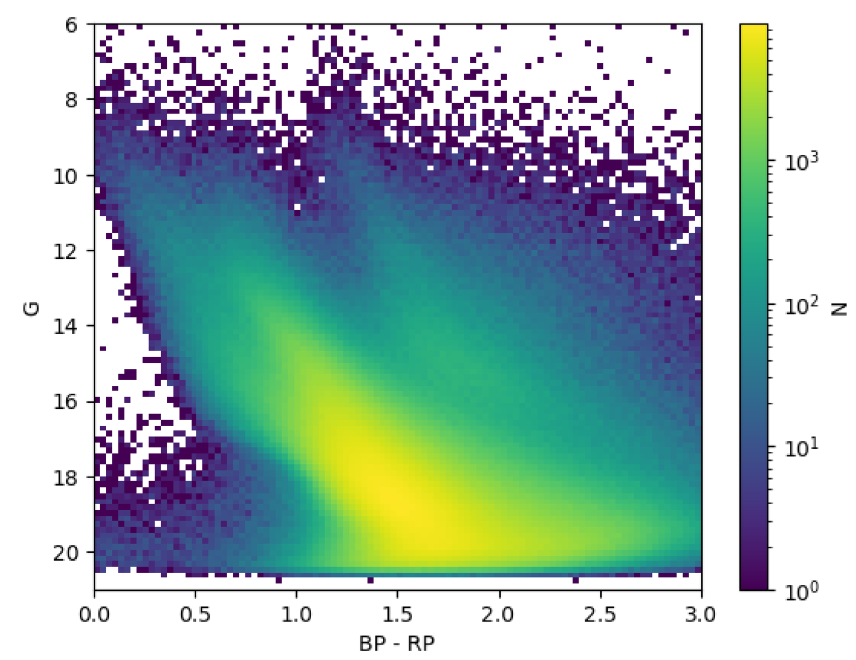




(Above) Older simulation data(on top) with GAIA data(bottom) The dark pink rectangle in the CMD is a "hand-drawn" region of potential members of M35. The black line is an isochrone for M35 provided by Anna Childs



(Figures) New simulation data(top left) plotted in different parameters. Cut(red) were made to the data and the same cuts were applied to GAIA data(top right). The convergent point method can be seen on the bottom right graphs in both the simulation and the GAIA data. Using the GAIA data with cuts, we obtain a new CMD(right). The GAIA data can still be refined, which will result in a cleaner CMD.



Conclusion

Using *N*-body simulations, we modeled the open cluster M35 and compare it against observational data. We also identified potential M35 cluster members along the tidal tails. We were able to refine the simulation by using the convergent point method [4]. We obtain a new CMD using the refined GAIA data. In the future, we want to utilize BASE-9 to verify that these stars are cluster members, using data from GAIA, Pan-Starrs and 2MASS.

Future

- Using the convergent point method[4] to identify members of the cluster
- Comparing the population of exotic stars and binaries in the center of the cluster vs the tails
- Studying the effects of dark matter on the formation of tidal tails
  - How dark matter affects the asymmetry of tidal tails[5]
  - Calculating the distribution of dark matter throughout the galaxy based on tidal tails

References

1. Bovy, J. (2015). Galpy: A Python Library for Galactic Dynamics. *The Astrophysical Journal Supplement Series*, *216*(2), 29. https://doi.org/10.1088/0067-0049/216/2/29
2. Geller, A. M., Mathieu, R. D., Braden, E. K., Meibom, S., Platais, I., & Dolan, C. J. (2010). Wiyn Open Cluster Study. XXXVIII. stellar radial velocities in the young open cluster M35 (NGC 2168). *The Astronomical Journal*, *139*(4), 1383–1393. https://doi.org/10.1088/0004-6256/139/4/1383
3. Portegies Zwart, S., & McMillan, S. (2018). *Astrophysical Recipes*. https://doi.org/10.1088/978-0-7503-1320-9
4. A refurbished convergent point method for finding moving groups in the ... (n.d.). https://arxiv.org/pdf/astro-ph/9903239.pdf
5. Reinoso, B., Fellhauer, M., & Véjar, R. (2017). Formation and evolution of substructures in tidal tails: Spherical Dark matter haloes. *Monthly Notices of the Royal Astronomical Society*, *476*(2), 1869–1876. https://doi.org/10.1093/mnras/stx2900

Acknowledgements

This material is based upon work supported by the National Science Foundation under grant No. AST 2149425, a Research Experience for Undergraduates (REU) grant awarded to CIERA at Northwestern University. Any opinions, findings, and conclusions or recommendations expressed in this material a re those of the author(s) and do not necessarily reflect the views of the National Science Foundation.