ASTR 400B Research Assignment 6

Due: April 29 2025, midnight

In this assignment you will begin writing up your results and discussion sections for your Final Report.

The primary goal of this assignment is designed to keep you on track to finish the course.

This assignment builds on Assignment 4 in terms of writing. The difference is that here you need to write up your findings based on the plots you created for Assignment 5. Upload the resulting pdf to your github repository under a folder called ResearchAssignment6.

1 General Expectations for the Final Report

- The final report is 30% of your final grade.
- The report must be written in LaTeX using ApJ or MNRAS formatting (double column). You can find templates on overleaf.
- The final report is not to exceed 5 pages in ApJ or MNRAS format (not including figures) but must be at least 3 pages (not including figures). For this assignment, you should aim for 2 pages (with figures, excluding results).
- Note, Plagiarism will result in a grade of 0. Your work must be unique.
- You must be able to justify the language/terms that you utilize. This means that, while you can use Chat GPT, if you cannot explain terms/meaning of sentences in your paper when asked, you will get a grade of 0. Please recall these instructions from the course syllabus: Any use of AI tools or content must be acknowledged or cited (see https://style.mla.org/citing-generative-ai/). If you do not acknowledge or cite your use of an AI tool, what you submit will be considered a form of cheating or plagiarism.
- Proofread the text! Grammar is part of the grade for the final report.
- All papers must be properly cited using BibTeX. Citations must appear as a bibliography at the end of the document. There must be at minimum 3 refereed papers cited.

- Follow the below outline (section headings and content guidelines). This is how I will grade your paper. Each heading refers to a heading or component that is expected in your report.

2 The Report Outline

The below is the same as in Assignment 4. However, you are now required to complete two more sections: Results and Discussion (towards the end). That's the main goal for this assignment.

2.1 Title

Include a descriptive title that relates to the question you are trying to answer. Below the title, you must include your name and the submission date.

When you first use a keyword in the main text, you must *define* it and bold face the word. A definition can be an equation.

Proper Motion •Local Group •Stellar Disk •Stellar Bulge •Stellar Bar •Stellar Halo •Spiral Arm •Pitch Angle •Major Merger •Minor Merger •Dry Merger •Dynamical Friction •Jacobi Radius •Tidal Stripping/Sharing •Quenching •Spiral Galaxy •Elliptical Galaxy •Flocculent Spiral •Tidal Tails •Tidal Bridge •Hierarchical Growth •Cold Dark Matter Theory •Hernquist Profile •NFW Profile •Satellite Galaxy •Dark Matter Halo •Halo Spin •Halo Shape •Oblate/Prolate/Triaxial •Ellipticity •Red Sequence •Blue Cloud •Green Valley •Rotation Curve •Velocity Dispersion •Virial Equilibrium •Virial Radius •M200 •Critical Density •Gravitationally Bound •Star Formation Main Sequence •Star Burst •AGN •Disky/Boxy Isodensity Contours •Rapid/Slow Rotator •Baryon Fraction •Sersic Profiles •Stellar Mass-Halo Mass Relation •Wolf Mass Estimator •Core/Cusp Debate •Escape Speed.

You may propose additional terms, provided they have been discussed/defined in lecture. You must run these additional terms past Prof. Besla in advance of submission.

2.2 Section: Introduction

Your Introduction must be written in the style of an introduction to a paper. The introduction is expected to be at minimum 1 page, double column in ApJ/MNRAS format. You must follow the below outline. Include the relevant key words from the above list.

1. **Paragraph 1:** Introduce your topic (as defined under "assigned topics" in the instructions for Assignment 2). This does not mean write "My project is to ..". Instead, if your topic were e.g. the evolution of SMBHs, you would write "Super Massive Black Holes (SMBHs) are believed to reside in the center of massive galaxies" . I.e. **define** the topic and associated broad concepts in galaxy evolution (e.g. dark matter halos, tidal tails, Local Group - see keywords).

2. **Paragraph 2:** Explain why your topic matters to our understanding of galaxy evolution. You must define the terms "galaxy" (Lecture 1, Willman & Strader 2012 AJ) and "galaxy evolution". Bold-face these words when they are first defined.

3. **Paragraph 3:** Explain what we currently know about your chosen topic. Papers must be cited in this paragraph. A figure must be referenced within the text to help explain something learned about the topic (what the topic is or why it matters).

4. **Figure 1:** The figure should be a paper from a refereed journal paper that illustrates something we have learned about the topic. The figure must have a caption that includes the paper citation and describes everything that is plotted. This **cannot be verbatim** from the original paper. The caption must finish with the punchline for the figure - what should the reader take away from the figure?

5. **Paragraph 4:** What are the open questions in your chosen topic area (as defined in Paragraph 1)? One of these open questions must relate to your specific project. How are people trying to solve these questions? You must include citations.

2.3 Section: This Project

1. **Paragraph 1:** Introduce your **specific** project. (e.g. "In this paper, we will study the change in position of the SMBHs of the Milky Way and M31's throughout the future collision and eventual merger of these two galaxies"). This isn't supposed to be general. Be as specific as you can be.

2. **Paragraph 2:** Which of the open questions (paragraph 4 of the intro) does this project address?

3. **Paragraph 3:**Why is this open question an important problem to solve for our understanding of Galaxy Evolution? How will your study help us to address the open question?

2.4 Section: Methodology

1. **Paragraph 1:** Start with an introduction to the simulations you are using. You must reference the paper associated with the simulations and describe what is meant by an "N-body" simulation. Describe how each galaxy is initially modeled (Dark matter halo with what profile, disk, etc).

2. **Paragraph 2:** Overview your approach. What particle types are you using, what resolution of the simulation data (VLowRes, LowRes, HighRes).

3. **Figure 2:** Include a figure to explain what you are trying to do. This figure can be from a published paper or can be a detailed diagram you created to describe your logic. The figure must have a caption, follow guidelines for the caption as listed for Figure 1. If you are using a figure from a published paper you cannot copy the caption from that paper.

4. **Paragraph 3:** Describe the calculations your code will compute. You must include all relevant equations and citations, and describe the meaning behind every parameter in the equation (e.g. The circular speed is defined as $V_c^2 = GM/r$, where M is the

Mass of the host galaxy ($M_\odot$) and r is the Galactocentric radius (kpc)). Note that the reference for the Hernquist profile is Hernquist 1990 ApJ 356.

5. **Paragraph 4:**: Describe the plots you will need to create and explain why those plots will answer your question. Note that later your results section must feature at least two figures that you created. One Figure can be generated entirely by code from Homeworks or In Class Labs (e.g. phase diagrams, density plots). The other figure must be generated by code that includes one new function or method that YOU created BY YOURSELF.

6. Note: You do not need to describe in detail what your code is doing - this must be done in the code itself (see Code Requirements). However, you can include a figure to describe a flow chart for your code logic if that helps to explain your methodology.

7. **Paragraph 5:** Describe your hypothesis for what you think you will find. Explain your motivation for this hypothesis.

2.4.1 Code Requirements

1. For this assignment, code does not need to be complete.

2. Code must be documented, with each step outlined and all parameters defined.

3. Equations must have references to papers if applicable.

4. Code can be largely based on Homework Assignments and In Class Labs, but there **must be at least one function or method that YOU created.**. Indicate this new code in the code documentation. You can get help from others, but must acknowledge their support in the code description and they cannot use the same code in their submission.

5. Your code cannot be one long stream on consciousness or even one code with multiple functions. You must import some code from separate classes or functions. E.g. importing functions/methods from past homeworks or labs. You can also create your own standalone functions that you then import.

6. Your code(s) must generate 2 figures (one created using your new function or method)

7. Code must be uploaded to Github

8. **You are expected to use arrays instead of lists in your code. You should never have to "append" to a list in your code. The usage of "append" will result in a 5 point penalty.**

2.5 Section: Results

For Assignment 6 you must complete this section. Here is where you will report on what your code produced.

There must be two Figures in this section that were generated by your code.

1. **Paragraphs 1 and 2:** Describe each of the two figures (Figures 3, 4) that you have created from your code. One paragraph per figure. **End each paragraph with the main take away result.**

2. **Figure 3:** This figure can be generated entirely by code from Homeworks or In Class Labs (e.g. phase diagrams, density plots).

3. **Figure 4:** This figure must be generated by code that includes one new function or routine that YOU created BY YOURSELF.

4. Each figure must have a detailed caption where everything plotted is explained, including axis labels and line types/colors. Include in the caption a punchline for each figure that explains what the reader should take away.

2.6 Section: Discussion

For Assignment 6 you must complete this section.

1. **Paragraph 1:** Summarize one result from the previous section. Does this result agree or disagree with your hypothesis?

2. **Paragraph 2:**

   - How does the result from Paragraph 1 relate to existing work in the literature? E.g. the papers you cited in the introduction.
   - What is the importance/meaning of this result for our understanding of galaxy evolution?

3. **Paragraph 3:** What are the uncertainties in your analysis?

4. **Subsequent Paragraphs:** Repeat the above 3 paragraphs if you have a 2nd result (etc.)