ASTR 511: Galaxies as Galaxies

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University of Washington, Winter Quarter 2021

Location and Time: Tuesday 1:30-2:50pm and Thursday 2:00-3:20pm, Virtual

Office Hours: Friday 4-5pm, by Zoom: ls.st/mjz

Grading: closed-book final exam 20%, 3 homeworks 60%, term paper presentation 20%;
key: >90%=A, >80%=B, >70%=C, >50%=D.

Class web site: http://research.majuric.org/public/teaching/astr511/

Required reading: Ivezić, Beers & Jurić 2012, ARA&A, 50, 251.

Reference Books:
Binney & Merrifield: *Galactic Astronomy*
Binney & Tremaine: *Galactic Dynamics*
Reid & Hawley: *New Light on Dark Stars*
Sparke & Gallagher: *Galaxies in the Universe*

The main Goals for this Class are:

1. Introducing the motivation for studying galaxies in general, and the Milky Way in particular. Overview of the most relevant literature. Overview of galaxy formation theories, galaxy dynamics, and connection to dark matter.
2. Informing students about the current research in galactic astronomy, including discussion of the expected observational and theoretical progress for the next decade.
3. Exposing students to practical problems through hands-on seminars, with emphasis on numerical methods and data mining, and using modern software engineering tools.
4. Training students to give professional talks.

Expected Class Schedule

1. **Tue: Jan 5** Introduction to the course (MJ & ZI)
2. **Thu: Jan 7** L1: Review of stellar astrophysics (ZI)
3. **Tue: Jan 12** L2: Basic properties of the Milky Way and the Local Group (ZI)
4. **Thu: Jan 14** L3: Basic properties of galaxies (ZI)

5. **Tue: Jan 19** L4: Luminosity and mass functions of galaxies: I (ZI)
6. **Thu: Jan 21** L5: Luminosity and mass functions of galaxies: II (ZI)
7. **Tue: Jan 26** Discussion of homework and term papers (ZI) **(HW 1 due)**
8. **Thu: Jan 28** L6: Stellar kinematics in galaxies (MJ)
9. **Tue: Feb 2** L7: Galactic Dynamics I: Potentials and Orbits (MJ)
10. **Thu: Feb 4** L8: Galactic Dynamics II: Galaxy models (MJ)
11. **Tue: Feb 9** L9: Galactic Dynamics III: Advanced Dynamics (MJ)
12. **Thu: Feb 11** L10: Galactic Dynamics IV: Instabilities and Resonances (MJ)
13. **Tue: Feb 16** L11: Evidence for dark matter in galaxies (MJ)
14. **Thu: Feb 18** Discussion of homework (MJ & ZI) **(HW 2 due)**
15. **Tue: Feb 23** L12: Stellar count distribution in the Milky Way (MJ)
16. **Thu: Feb 25** L13: Stellar metallicity and kinematics in the Milky Way (ZI)
17. **Tue: Mar 2** L14: Open questions in galactic astronomy and modern sky surveys (ZI)
18. **Tue: Mar 4** Term paper presentations, discussion of homework **(HW 3 due)**
19. **Thu: Mar 9** Term paper presentations
20. **Thu: Mar 11** Term paper presentations, final exam discussion
21. **Tue: Mar 16** FINAL EXAM

Homework

There will be three homeworks, designed as practical projects. All three will be similar from the technical point of view: they will involve reading a number of vectors with several million elements from provided files (using Python and Jupyter notebooks), simple operations with these vectors such as binning and low-order statistics, and visualization of your results.

The problems and links to data files will be posted at the class website about two weeks before the homework is due. They will address these three general themes:

1. Stellar number density distribution in MW
2. Determination of luminosity function
3. Stellar metallicity distribution in MW

We will use SDSS and Gaia data, and modern software engineering tools, such as github for version control and Jupyter notebooks, for HW submission.

Some Possible Papers to Present:

Pick one below by **Jan 25** (e-mail your choice to both of us).

1. Bailer-Jones et al. 2020 (https://arxiv.org/abs/2012.05220): *Estimating distances from parallaxes. V: Geometric and photogeometric distances to 1.47 billion stars in Gaia Early Data Release 3*

2. Belokurov et al. 2018 (MNRAS, 478, 611) *Co-formation of the disc and the stellar halo*
3. Gaia Collaboration 2018 (A&A 616, A11) *Mapping the Milky Way disc kinematics*
4. Gaia Collaboration 2018 (A&A 616, A10) *Observational Hertzsprung-Russell diagrams*
5. Gaia Collaboration 2018 (A&A 616, A12) *Kinematics of globular clusters and dwarf galaxies around the Milky Way*
6. Gaia Collaboration 2019 (A&A 623, A110) *Variable stars in the colour-absolute magnitude diagram*
7. Gaia Collaboration: X. Luri et al. 2020 (accepted to A&A)) *Gaia Early Data Release 3: Structure and properties of the Magellanic Clouds*
8. Gaia Collaboration: T. Antoja et al. 2020 (accepted to A&A)) *Gaia Early Data Release 3: The Galactic anticentre*
9. Helmi, A. & White, S.D.M. 2001 (MNRAS 323, 529) *Simple dynamical models of the Sagittarius dwarf galaxy*
10. Johnston et al. 2008 (ApJ, 689, 936) *Tracing Galaxy Formation with Stellar Halos*
11. Kauffmann et al. 2003 (MNRAS, 341, 33) *Stellar Masses and Star Formation Histories for 80,000 Galaxies from the Sloan Digital Sky Survey*
12. Kuijken, K. & Gilmore, G. 1991 (ApJ 367, L9) *The galactic disk surface mass density and the Galactic force K(z) at Z = 1.1 kpc*
13. Kuijken, K. & Tremaine, S. 1994 (ApJ 421, 178)
14. Navarro, J.F., Frenk, C.S. & White, S.D.M. 1996 (ApJ 462, 563) *The Structure of Cold Dark Matter Halos*
15. Spitzer, L. & Schwarzschild, M. 1953 (ApJ 118, 106) *The Possible Influence of Interstellar Clouds on Stellar Velocities. II*
16. van den Bosch, F.C. & Dalcanton, J.J. 2000 (ApJ 534, 146) *Semianalytical Models for the Formation of Disk Galaxies. II. Dark Matter versus Modified Newtonian Dynamics*

These papers are very relevant for our class and cover subjects that are not going to be discussed in detail. Choose a paper and prepare a 20 min long Powerpoint (or equivalent) presentation (presumably including the most important figures from the paper). Pretend you did the work yourself and are giving an invited talk at a meeting. There will be about 10-15 min long question and answer session after the talk, with everyone participating. The purpose of this exercise is to 1) learn some science, 2) practice extracting relevant information from papers 3) practice giving talks, 4) practice answering questions from your audience.

Do not forget the following good practices: 1) empty your pockets (no loose change, keys, phone, and such), 2) talk slowly and sufficently loud, 3) don't look at the floor, control your audience with direct eye contact, don't turn your back to the audience, don't be agressive with the pointer, etc. 4) don't rush (don't overload your 10 min long presentation), concentrate on the most important points, 5) emphasize what are truly new, and, possibly, unexpected results. 6) comment on the limitations and pitfalls of the presented analysis; how do we know it's right, could it be wrong?