# ASTR 511: Galaxies as Galaxies

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University of Washington, Winter Quarter 2021

**Location and Time:** Tuesday and Thursday 2:00-3:20pm, Virtual (see Slack for Zoom link)

**Office Hours:** Friday 4-5pm, by Zoom (same Zoom link as the lectures)

**Grading:** term project 40%, two homeworks 20% each, 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 and term project (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 term project
19. **Thu: Mar 9** Term paper presentations
20. **Thu: Mar 11** Term paper presentations
21. **Tue: Mar 16** Term project discussion and hackathon

**Homeworks and term project**

There will be two homeworks, designed as practical warm-up projects to prepare you for the term project towards the quarter's end. They 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) followed by simple operations with these vectors such as binning, low-order statistics and luminosity function estimation (ok, this one is not very simple but the code will be provided), and visualization of your results.

The homework problem description and links to data files will be posted at the class website about two weeks before the homework is due (due dates: January 26 for HW1 and February 18 for HW2).

The term project will be based on the recently released Gaia Early Data Release 3 and a few auxiliary datasets (e.g., ZTF and WISE). More details will be provided during January and discussed in class on Jan 26.

We will use modern software engineering tools, such as github for version control and Jupyter notebooks, for HW submission and work on the term project.

**Suggested Presentation Papers:**

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?