ASTR 511: Galaxies as Galaxies

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University of Washington, Winter Quarter 2021

Location and Time: Tuesday and Thursday 2:00-3:20, Virtual

Office Hours: Any time my office door is open; after class is optimal.

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

Homework

There will be three homeworks, designed as term 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 modern software engineering tools, such as github for version control and Jupyter notebooks, for HW submission.

Some Possible Papers to Present:

Pick one below, or propose one that you find interesting, by **Jan 28** (e-mail me your choice).

1. Bahcall, J.N. & Tremaine, S. 1981 (ApJ 244, 805) *Methods for determining the masses of spherical systems. I - Test particles around a point mass*

2. Dehnen, W. & Binney, J.J. 1998 (MNRAS 298, 387) *Local stellar kinematics from HIPPARCOS data*

3. Helmi, A. & White, S.D.M. 2001 (MNRAS 323, 529) *Simple dynamical models of the Sagittarius dwarf galaxy*

4. Ibata, R., et al. 2001 (ApJ 551, 294) *Great Circle Tidal Streams: Evidence for a Nearly Spherical Massive Dark Halo around the Milky Way*

5. Jaffe, W. 1983 (MNRAS 202, 995) *A simple model for the distribution of light in spherical galaxies*

6. 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*

7. Kuijken, K. & Tremaine, S. 1994 (ApJ 421, 178) *On the ellipticity of the Galactic disk*

8. Navarro, J.F., Frenk, C.S. & White, S.D.M. 1996 (ApJ 462, 563) *The Structure of Cold Dark Matter Halos*

9. Spitzer, L. & Schwarzschild, M. 1953 (ApJ 118, 106) *The Possible Influence of Interstellar Clouds on Stellar Velocities. II*

10. 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*

11. Walsh, Willman & Jerjen 2009 (AJ, 137, 450) *The Invisibles: A Detection Algorithm to Trace the Faintest Milky Way Satellites*

12. Johnston et al. 2008 (ApJ, 689, 936) *Tracing Galaxy Formation with Stellar Halos*

13. Kauffmann et al. 2003 (MNRAS, 341, 33) *Stellar Masses and Star Formation Histories for 80,000 Galaxies from the Sloan Digital Sky Survey*

14. McGurk et al. 2010 (AJ, 139, 1261) *Principal Component Analysis of SDSS Stellar Spectra*

15. Sesar et al. 2010 (ApJ, 708, 717) *Light Curve Templates and Galactic Distribution of RR Lyrae Stars from Sloan Digital Sky Survey Stripe 82*

16. Schlaufman et al. 2009 (ApJ, 703, 2177) *Insight into the Formation of the Milky Way Through Cold Halo Substructure. I. The ECHOS of Milky Way Formation*

17. Law and Majewski 2010 (ApJ, 714, 229) *The Sagittarius Dwarf Galaxy: A Model for Evolution in a Triaxial Milky Way Halo*

18. Beers et al. 2012 (ApJ, 746, 34) *The Case for the Dual Halo of the Milky Way*

19. Berry et al. 2012 (ApJ, 757, 166) *The Milky Way Tomography with SDSS. IV. Dissecting Dust*

20. Evans & Williams 2014 (MNRAS, 443, 791) *A very simple cusped halo model*

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 10 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 a 5 min long question and answer session after the talk. The purpose of this exercise is to 1) learn some science, 2) practice extracting relevant information from papers 3) practice giving talks, 4) practice having over-active 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?