Galactic Astronomy

University of Zagreb, Spring 2014
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Duration: As arranged via email.

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1. **Aims**

   - Main concepts of dynamics of stellar systems
   - Hubble sequence of galaxies
   - Scaling relations for galaxies

2. **Material**

   - *Textbooks:* The main material can be found in Spark & Gallagher: Galaxies in the Universe, An Introduction (Cambridge University press, 2000). There are two editions, one from 2000 and the other from 2007. You can use either one (I have the one from 2000). I recommend you read the full book but we will focus on Chapters: 3 (The Orbits of Stars), 5 (Spiral and S0 Galaxies), and 6 (Elliptical galaxies). I recommend also using Binney & Tremaine: Galactic dynamics (Princeton University Press, 2008), and Binney and Merrifield: Galactic Astronomy (Princeton University Press, 1998). These books cover some topics in greater depth. Specifically, have a look at Chapter 2 of BT and Chapter 4 of BM.
   - *Problems:* There will be two problems set. The second one will be posted on the web site after the first one is completed.
   - *Recommended Papers:* At the bottom of this document there is a list of recommended papers. This is just a selection of papers, classical and more recent, which cover some of the material presented in the text books, but also supplement it by extending the covered subjects. In particular, papers address the scaling relations of galaxies and cover some theoretical considerations of galaxy formation and evolution. You will have to choose two of them (and inform me about your choice), one to present to the class and one to discuss during the final exam. The papers should be different.

3. **Requirements**

   - Grading: Final exam 25%; Paper presentation 25%; Problem sets 50%.

- Problem sets: You need to complete problem sets posted on the web, and send them to me with all required material by the arranged date. Some problems will require writing code for fitting and plotting (use any one you like, e.g. IDL, Mathematica....). Perhaps the easiest it to write derivations by hand, then scan them and send them to me together with the plots generated in your favourite plotting software.
- Paper presentation: you will have to prepare a presentation from the list of recommended papers (or a relevant paper of your choice). The main goal for you is to train presenting scientific results. You have to present it as if this would be your result and you are presenting it at an international conference. Don't forget to give a relevant overview of the background. Presentations should be maximum 20 min long. The presentation will be followed by questions and a discussion.
- The oral exam is based on a discussion of a paper (from the list of the recommended papers), and further discussion of the course material (Chapters 3, 5 and 6 of SG). You can choose the paper for the exam, but it has to be different from that presented by you (also in the topic) or other classmates.

Recommended papers for presentations and exam:

1. Statler, T., 1991, AJ, 102, 882, *On the velocity fields of elliptical galaxies*
2. Bender, R., Burstein, D., & Faber, S. M., 1992, ApJ, 399, 462, *Dynamically hot galaxies. I - Structural properties*
3. Mo, H.J., Mao, S. & White, S., 1998, MNRAS, 295, 319, *The formation of galactic discs*
4. Courteau, S., & Rix, H-W. 1999, ApJ, 513, 561, *Maximal Disks and the Tully-Fisher Relation*
5. van der Marel, R.P., 1999, AJ, 117, 744, *The Black Hole Mass Distribution in Early-Type Galaxies: Cusps in Hubble Space Telescope Photometry Interpreted through Adiabatic Black Hole Growth*
6. Khochfar, S. & Burket, A. 2003, ApJ, 597, 117, *The Importance of Spheroidal and Mixed Mergers for Early-Type Galaxy Formation*
7. Shen, S. et al. 2003, MNRAS, 343, 978, *The size distribution of galaxies in the Sloan Digital Sky Survey*
8. Bernardi, M. et al. 2003, AJ, 125, 1866, *Early-Type Galaxies in the Sloan Digital Sky Survey. III. The Fundamental Plane*
9. Baldry, I. K., et al. 2004, ApJ, 600, 681, *Quantifying the Bimodal Color-Magnitude Distribution of Galaxies*
10. Springel, V. et al. 2005, Natur, 435, 776, *Simulations of the formation, evolution and clustering of galaxies and quasars*
11. Di Matteo, T., Springel, V., & Hernquist, L 2005, Natur, 433, 604, *Energy input from quasars regulates the growth and activity of black holes and their host galaxies*

12. Naab, T., Khochfar, S. & Burket, A. 2006, ApJ, 636, 81, *Properties of Early-Type, Dry Galaxy Mergers and the Origin of Massive Elliptical Galaxies*

13. Dekel, A., & Birnboim, Y. 2006, MNRAS, 368, 2, *Galaxy bimodality due to cold flows and shock heating*

14. Cox, T. J., et al. 2006, ApJ, 650, 791, *The Kinematic Structure of Merger Remnants*

15. Ferrarese, L. et al. 2006, ApJS, 164, 334 , *The ACS Virgo Cluster Survey. VI. Isophotal Analysis and the Structure of Early-Type Galaxies*

16. Gallazzi, A., et al. 2006, MNRAS, 370, 1106, *Ages and metallicities of early-type galaxies in the Sloan Digital Sky Survey: new insight into the physical origin of the colour-magnitude and the $Mg_2 - \sigma_V$ relations*

17. Faber, S. M., et al. 2007, ApJ, 665, 265, *Galaxy Luminosity Functions to $z\sim$ 1 from DEEP2 and COMBO-17: Implications for Red Galaxy Formation*

18. Bournaud, F., Jog, C.J., & Combes, F. 2007, A&A, 476, 1179, *Multiple minor mergers: formation of elliptical galaxies and constraints for the growth of spiral disks*

19. Cappellari, M., et al. 2007, MNRAS, 379, 418, *The SAURON project - X. The orbital anisotropy of elliptical and lenticular galaxies: revisiting the $(V/\sigma, \epsilon)$ diagram with integral-field stellar kinematics*

20. van den Bosch, R. C. E, et al. 2008, MNRAS, 385, 647, *Triaxial orbit based galaxy models with an application to the (apparent) decoupled core galaxy NGC 4365*

21. De Lucia, G. & Blaizot, J., 2007, MNRAS, 375, 2, *The hierarchical formation of the brightest cluster galaxies*

22. Franx, M et al. ApJ, 688, 770, *Structure and Star Formation in Galaxies out to z = 3: Evidence for Surface Density Dependent Evolution and Upsizing*

23. Hopkins, P. F., et al. 2009, ApJ, 691, 1424, *Dissipation and Extra Light in Galactic Nuclei. IV. Evolution in the Scaling Relations of Spheroids*

24. Khochfar, S., & Silk, J. 2009, MNRAS, 397, 506, *Dry mergers: a crucial test for galaxy formation*

25. Jesseit, R., et al. 2009, MNRAS, 397, 1202, *Specific angular momentum of disc merger remnants and the λ_R–parameter*

26. Gultekin, K. et al. 2009, ApJ, 698, 198, *The M-σ and M-L Relations in Galactic Bulges, and Determinations of Their Intrinsic Scatter*

27. Martig, M., et al. 2009, ApJ, 707, 250, *Morphological Quenching of Star Formation: Making Early-Type Galaxies Red*

28. Bezanson, R., et al. 2009, ApJ, 697, 1290, *The Relation Between Compact, Quiescent High-redshift Galaxies and Massive Nearby Elliptical Galaxies: Evidence for Hierarchical, Inside-Out Growth*

29. Williams, M.J., Bureau, M. & Cappellari M. 2010, 409, 1330, *The Tully-Fisher relations of early-type spirals and S0 galaxies*

30. Oser, L., et al. 2010, ApJ, 725, 2312, *The Two Phases of Galaxy Formation*

31. Kormendy, J., et al. 2010, ApJ, 723, 54, *Bulgeless Giant Galaxies Challenge Our Picture of Galaxy Formation by Hierarchical Clustering*

32. Peng, Y.-j., et al. 2010, ApJ, 721, 193 *Mass and Environment as Drivers of Galaxy Evolution in SDSS and zCOSMOS and the Origin of the Schechter Function*

33. Emsellem, E., et al. 2011, MNRAS, 414, 888, *The ATLAS3D project - III. A census of the stellar angular momentum within the effective radius of early-type galaxies: unveiling the distribution of Fast and Slow Rotators*

34. van de Sande et al. 2011, ApJ, 736, 9, *The Stellar Velocity Dispersion of a Compact Massive Galaxy at z = 1.80 Using X-Shooter: Confirmation of the Evolution in the Mass-Size and Mass-Dispersion Relations*

35. Cappellari M.,et al. 2013, MNRAS, 432, 1709, *The ATLAS3D project - XV. Benchmark for early-type galaxies scaling relations from 260 dynamical models: mass-to-light ratio, dark matter, Fundamental Plane and Mass Plane*

36. Hilz M., et al. 2013, MNRAS, 429, 2924, *How do minor mergers promote inside-out growth of ellipticals, transforming the size, density profile and dark matter fraction?*