Galaxy formation and evolution

PAP318, Galaxy formation and evolution, 5 op, Autumn, 2020
Time and place: Fridays at 12.15-14.00 on Zoom, beginning 04.09.2020
Lecturer: Peter Johansson
Course assistant: Stuart McAlpine
Homepage:
https://wiki.helsinki.fi/display/astjourn/Galaxy+formation+and+evolution

- The course will provide a thorough overview of galaxy formation theory and the essential observations required for understanding the galaxy population.
- Course material: Provided lecture notes and the textbooks “Galaxy formation” (Longair) and “Galaxy formation and evolution” (Mo, van den Bosch, White).
- Lecture course. Problem sets and Final exam.

Information about the course:

PAP318 Galaxy formation and evolution (Galaksien synty ja kehitys)
Lecturer: Prof. Peter Johansson (Room D311)
Course assistant: Dr. Stuart McAlpine (Room D326)

Lectures: Fridays 12.15-14.00. Due to the Corona virus situation this course will be organised as an online course, with all lectures given over Zoom. The problem sets will appear on the course homepage and in Moodle, where the problem set answers should also be returned.

Problem sessions: Fridays 14.00-16.00 in Zoom/Moodle, every two weeks on the following dates: 18.9, 2.10, 16.10, 6.11, 20.11, 4.12
First lecture on 6.9.

- In total 14 lectures (the last lecture is on 5.12.)
- Problem sets will be handed out every two weeks on the course homepage and Moodle. Each problem set will contain 5 questions totaling 6x5=30 questions.
- The minimum requirement for the problem sets is 1/3 of the points, surplus points will result in bonus points for the exam.
- Problem sets are handed out on Thursdays and they should be returned by the next week Thursday in Moodle.
- The problems consist of both regular exercises and problems based on journal articles.

Course material:

- The primary course material will consist of the lecture notes provided by the lecturer.
- In addition parts of the two following books will be extensively used:

Final exam:

- The final exam will be held on Friday 18.12.2020 at 10-14. The exact details on how the exam will be arranged will be discussed later during the course.

Course dates and syllabus:

Lecture 1: 04.09.2020: “Introduction to galaxy formation and overview”
• Basic elements of galaxy formation
• Galaxy formation timescales
• Historical review of galaxy formation theory

Lecture 2: 11.09.2020: “Observations of galaxies”
• The classification of galaxies
• Statistical properties of the galaxy population
• Galaxies at high redshifts

Lecture 3: 18.09.2020: “Cosmology and the evolution of small perturbations” – Problem session 1
• Robertson-Walker metric and the Friedmann equations
• The age of the Universe and cosmological distances
• The evolution of small perturbations

• The Jeans’ instability in a static and expanding Medium
• Instabilities in the relativistic case
• Cosmological horizons and perturbations on superhorizon scales

Lecture 5: 02.10.2020: “Baryonic and dark matter models of galaxy formation” – Problem session 2
• The sound speed and baryonic models of galaxy formation
• Adiabatic and isothermal perturbations
• Hot and cold dark matter in galaxy formation models

Lecture 6: 09.10.2020: “Correlation functions and the spectrum of the initial fluctuations”
• The two-point correlation function for galaxies
• The initial power spectrum
• Transfer functions

• The non-linear collapse of density perturbations
• Top-hat collapse and the Zeldovich approximation
• The Press-Schechter mass function and dark matter density profiles

Lecture 8: 30.10.2020: “Formation and evolution of gaseous haloes”
• The cooling and heating of gas in dark matter haloes
• Radiative cooling and photoionization heating
• The cooling function and galaxy formation

Lecture 9: 06.11.2020: “Star formation and supernova feedback in galaxies” – Problem session 4
• Molecular clouds and self-regulated star formation
• Empirical star formation laws
• Supernova feedback: The ejection and heating of gas

Lecture 10: 13.11.2020: “Formation of disk galaxies”
• Observations: Mass components, angular momentum and rotation curves
• Formation of disk galaxies
• The origin of disk scaling relations

Lecture 11: 20.11.2020: “Galaxy interactions and transformations” – Problem session 5
• Galaxy interactions and encounters
• Tidal stripping and dynamical friction
• Orbital decay and galaxy merging

Lecture 12: 27.11.2020: “Formation of elliptical galaxies”
• Structure and dynamics of elliptical galaxies
• Formation of elliptical galaxies
• Observational constraints on formation scenarios

• The physics of AGNs
• Formation and evolution of AGNs
• AGNs and galaxy formation

Summary of the main results.
Putting it all together.
How do galaxies form and evolve?

Lectures:

- Lecture 1: galform_lecture1.pdf
- Lecture 2: galform_lecture2.pdf
- Lecture 3:
- Lecture 4:
- Lecture 5:
- Lecture 6:
- Lecture 7:
- Lecture 8:
- Lecture 9:
- Lecture 10:
- Lecture 11:
- Lecture 12:
- Lecture 13:
- Lecture 14:

Videos showing the formation of disk galaxies also by the FIRE collaboration: http://www.tapir.caltech.edu/~phopkins/Site/animations/Movies_cosmo.html

Problem sets:

- Problem set 1: galform_prob_1.pdf
- Link to article used in problem set 1: Straatman, C.M.S. et al., 2014, ApJL, 783, 14: "A Substantial Population of Massive Quiescent Galaxies at z ~ 4 from ZFOURGE"
- Problem set 2:
- Problem set 3:
- Problem set 4:
- Link to article used in problem set 4: Daddi, E. et al., 2010, ApJL, 714, 118: "Different Star Formation Laws for Disks Versus Starbursts at Low and High Redshifts"
- Problem set 5:
- Problem set 6:
- Link to article used in problem set 6: Mortlock, D.J. et al., 2011, Nature, 474, 616: "A luminous quasar at a redshift of z = 7.085"

Final results and course grading:

- Results from the problems sets:
- Final grades:

Set of equations that will be distributed in the exam:

- equations_galform.pdf