2018 Spring — PHYS 315 [8255]

Book: Peter Schneider Extragalactic astronomy and cosmology
ISBN-13: 978-3642540820
ISBN-10: 3642540821

3 credits

Pre-requisites: PHYS122 or PHYS 122H with grade C or higher. A good grade in either PHYS 105 or PHYS 304 will be of some advantage, but not required.

Material: scientific calculator

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Overview: The formation, constituents, structure and dynamics of galaxies. Galaxy types. Hierarchy of structure. AGN. Dark matter. Distance estimation.

Course objectives: Main objectives are for students to become familiar with the characteristics and components of the various galaxy types in the known universe.

Detailed Objectives: By the end of the course students will be able to
-describe the various types of galaxies found in the universe
-describe some of the observing techniques used in the study of galaxies
-understand the components of our Galaxy, the Milky Way
-understand the importance of supermassive black holes in galaxy nuclei
-understand the importance of galaxy studies to cosmology

Grading:
Final Exam 20%
2 Mid term Exams 20% each
Telescope attendance 10%
Class attendance 10%
Homework 20%

The course will include (provisional topics, may be revised in the details):

- The Milky Way as a galaxy
  - Galactic coordinates
    - Determination of distances within our Galaxy
      - + Trigonometric parallax
      - + Proper motions
      - + Moving cluster parallax
      - + Photometric distance; extinction and reddening
      - + Spectroscopic distance
      - + Distances of visual binary stars

- + Distances of pulsating stars
- o The structure of the Galaxy
  - + The Galactic disk: Distribution of stars
  - + The Galactic disk: chemical composition and age
  - + The Galactic disk: dust and gas
  - + Cosmic rays
  - + The Galactic bulge
  - + The visible halo
  - + The distance to the Galactic center
- o Kinematics of the Galaxy
  - + Determination of the velocity of the Sun
  - + The rotation curve of the Galaxy
- o The Galactic microlensing effect: The quest for compact dark matter
  - + The gravitational lensing effect I
  - + Galactic microlensing effect
  - + Surveys and results
  - + Variations and extensions
- o The Galactic center
  - + Where is the Galactic center?
  - + The central star cluster
  - + A black hole in the center of the Milky Way
  - + Flares from the Galactic center
  - + The proper motion of Sgr A*
  - + Hypervelocity stars in the Galaxy

The world of galaxies

- o Classification
  - + Morphological classification: The Hubble sequence
  - + Other types of galaxies
- o Elliptical galaxies
  - + Classification
  - + Brightness profile
  - + Composition of elliptical galaxies
  - + Dynamics of elliptical galaxies
  - + Indicators of a complex evolution
- o Spiral galaxies
  - + Trends in the sequence of spirals
    - + Brightness profile
  - + Rotation curves and dark matter
  - + Stellar populations and gas fraction
  - + Spiral structure
  - + Corona in spirals?
- o Scaling relations
  - + The Tully-Fisher relation
  - + The Faber-Jackson relation
  - + The fundamental plane
  - + The Dn-sigma relation
- o Black holes in the centers of galaxies
  - + The search for supermassive black holes
  - + Examples for SMBHs in galaxies
  - + Correlation between SMBH mass and galaxy properties
- o Extragalactic distance determination
  - + Distance of the LMC
  - + The Cepheid distance

+ Secondary distance indicators
- o Luminosity function of galaxies
  + The Schechter luminosity function
  + The bimodal color distribution of galaxies
- o Galaxies as gravitational lenses
  + The gravitational lens effect - Part II
  + Simple models
  + Examples for gravitational lenses
  + Applications of the lens effect
- o Population synthesis
  + Model assumptions
  + Evolutionary tracks in the HRD; integrated spectrum
  + Star formation history and galaxy colors
  + Metallicity, dust, and HII regions
  + Summary
  + The spectra of galaxies
- o Chemical evolution of galaxies

Active galactic nuclei

- o Introduction
  + Brief history of AGNs
  + Fundamental properties of quasars
  + Quasars as radio sources: synchrotron radiation
  + Broad emission lines
- o AGN zoology
  + QSOs
  + Seyfert galaxies
  + Radio galaxies
  + OVVs
  + BL Lac objects
- o The central engine: a black hole
  + Why a black hole?
  + Accretion
  + Superluminal motion
  + Further arguments for SMBHs
  + A first mass estimate for the SMBH: the Eddington luminosity
- o Components of an AGN
  + The IR, optical, and UV-continuum
  + The broad emission lines
  + Narrow emission lines
  + X-ray emission
  + The host galaxy
  + The black hole mass in AGNs
- o Family relations of AGNs
  + Unified models
  + Beaming
  + Beaming on large scales
  + Jets at higher frequencies

Clusters and groups of galaxies

* The Local Group
  - o Phenomenology

    - Mass estimate
    - Other components of the Local Group
  * Galaxies in clusters and groups
    - The Abell catalog
    - Luminosity function of cluster galaxies
    - Morphological classification of clusters
    - Spatial distribution of galaxies
    - Dynamical mass of clusters
    - Additional remarks on cluster dynamics
    - Intergalactic stars in clusters of galaxies
    - Galaxy groups
    - The morphology-density relation
  * X-ray radiation from clusters of galaxies
    - General properties of the X-ray radiation
    - Models of the X-ray emission
    - Cooling flows
    - The Sunyaev-Zeldovich effect
    - X-ray catalogs of clusters
  * Scaling relations for clusters of galaxies
    - Mass-temperature relation
    - Mass-velocity dispersion relation
    - Mass-luminosity relation
    - Near-infrared luminosity as mass indicator

Clusters of galaxies as gravitational lenses

  * Luminous arcs
  * The weak gravitational lens effect