

STRUCTURE AND DYNAMICS OF GALAXIES

Lecture course at Beijing, China, September 2011

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LECTURES.: Each item below is a 45 to 50 minute lecture.

1. Distribution of stars in the Milky Way.

- Historical introduction.
 - Herschel and Kapteyn.
 - Shapley and Hubble.
- The luminosity distribution in the Galaxy.
 - Modern views of the Galaxy.
 - Pioneer 10 photometry.

2. Kinematics of the Milky Way.

- Differential rotation.
 - Relative motions.
 - Local approximations and Oort constants.
- Rotation curves and mass distributions.

3. Stellar Populations, classification of galaxies.

- Stellar Populations
 - Origin of the concept.
 - Vatican symposium.
 - The current situation.
- Classification
 - Definition by Hubble and later extensions.
 - Correlations along the Hubble sequence.

4. Galactic dynamics: Fundamental equations.

- The collisionless Boltzmann equation.
- Poisson's equation.
- Hydrodynamic equations.
 - Zeroth order moment of the Boltzmann equation.
 - First order moment of the Boltzmann equation.
 - Second order moment of the Boltzmann equation.
- Jeans equations.

5. Galactic dynamics: Virial equations and integrals of motion.

- Virial equations.
 - Moment of inertia tensor.
 - Kinetic energy tensor.
 - Potential energy tensor.
- Integrals of motion.
 - Isolating integrals; Jean's theorem.
 - Non-isolating integrals of motion.
 - Jean's theorem.

6. Galactic dynamics: Timescales.

- Timescales.
- Two-body relaxation time.
- Violent relaxation.
- Dynamical friction.

7. Galactic dynamics: Stellar orbits.

- Orbits in symmetric potentials.
 - Spherical potentials.
 - The harmonic oscillator.
 - The Keplerian potential.
 - Axisymmetric potentials.
- Third integral.
- Surface of section.
- Rotating non-axisymmetric potentials.

8. Galactic dynamics: Epicycle orbits, instabilities.

- Epicycle orbits.
 - Epicycle theory.
 - Vertical motion.
 - Resonances.
- Instabilities.
 - Jeans instability.
 - Toomre criterion for local stability.
 - Goldreich-Lynden-Bell criterion.
 - Global stability.
 - Tidal radius.

9. Galactic dynamics: The velocity ellipsoid.

- The Schwarzschild distribution.
- Properties of the velocity ellipsoid.
- The closure problem.

10. Galactic dynamics: The self-consistence problem and potential theory.

- The self-consistency problem.
- Isothermal solutions and related results.
 - Isothermal sphere and King models.
 - Isothermal sheet and other vertical distributions.
- Potential theory.
 - General axisymmetric theory.

11. Galactic dynamics: Various potentials.

- The exponential disk.
 - Forces and potential.
 - Rotation curves.
- Various potentials.
 - Plummer, Kuzmin and Toomre models.
 - Logarithmic potentials.
 - Oblate spheroids.
 - Infinitesimally thin disk.
- Stäckel potentials.
 - Coordinate system
 - The potential and density distribution.
 - Velocities, angular momentum and integrals of motion.

12. Luminosity distributions: Bulges and disks.

- Luminosity distributions.
 - Bulge luminosity laws.
 - Luminosity distributions in disks.
- Component separations.
 - Moderately inclined spirals.
 - Edge-on galaxies.

13. Luminosity distributions: Parameters

- Disk galaxies.
 - Distribution of parameters.
 - Selection effects.
 - Selection and Freeman's law.
- Elliptical galaxies.
 - Luminosity distributions.
 - Shells and ripples.
 - Color gradients.

14. Photometric evolution.

- Photometric evolution.
 - Fundamentals.
 - Analytical models.
 - Detailed studies.
 - Schmidt's law for star formation.
- Population synthesis.

15. Dynamics of spiral galaxies.

- Analysis of HI observations.
 - Moment analysis.
 - Tilted rings.
- Example of HI observations.
 - Example of an inclined galaxy: NGC 5055.
 - Example of an edge-on galaxy: NGC891
- HI velocity dispersion.
- CO and H₂.

16. Rotation curves and dark matter.

- Tully-Fisher relation.
- Rotation curves and mass distribution.
 - Exponential disk.
 - Dark matter halo.
 - Maximum disk hypothesis.
 - Independent checks of the maximum disk hypothesis.
 - Modified dynamics.

17. Warps and dust.

- Warps in HI.
 - Warps: observations
 - Warps: origin.
- Dust absorption.
 - Holmberg's analysis.
 - Analysis of Disney et al.
 - Background galaxies.

18. Stellar kinematics and spiral structure.

- Spiral structure.
 - Density wave theory.
 - Stochastic star formation model.
- Stellar kinematics.

19. Dynamics of spiral galaxies: stars.

- Stellar velocity dispersions.
 - Z-velocity dispersions.
 - R- and θ -velocity dispersions.
 - The Bottema relations.
 - Implications for maximum disk and stability.
- Global stability.

20. Elliptical galaxies: Global dynamics

- Fundamental Plane.
- Rotation and shapes
 - Flattening and oblate spheroids.
 - $V_m/\bar{\sigma}$ relation and triaxiality.
 - Detailed kinematics.

21. Elliptical galaxies: Dynamical structure.

- Central kinematics and black holes.
- Dynamical models and dark matter.
 - Stäckel potentials.
 - The perfect ellipsoid.
 - Types of orbits.
- Dark matter.

22. Chemical evolution.

- Abundance gradients.
- Theory of chemical evolution.
 - The Simple Model.
 - The Extended Simple Model.
 - The Inflow model.
 - The Simple Model with Bells and Whistles.
- Bi-modal star formation.
- Comparison with observations.

23. Formation of galaxies: The Milky Way Galaxy.

- Disk population.
- Eggen, Lynden-Bell and Sandage collapse model.
- The thick disk.
- Globular clusters.
- Sagittarius dwarf.

24. The formation of galaxies.

- Galaxies at high redshift.
 - Galaxy formation.
 - Background.
 - Bulge formation.
 - Disk formation.
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- This course is a combination of two existing courses I have given at Groningen University. One on *Structure of Galaxies* and one on *Dynamics of Galaxies*.
 - The full set of beamer presentations are available through my website. You can download them as pdf-files from www.astro.rug.nl/~vdkruit/jea3/homepage/Beijingn.pdf with *n* from 01 to 24.
 - For more background information you can also visit my homepage at:
[www.astro.rug.nl/~vdkruit/#Structure of galaxies](http://www.astro.rug.nl/~vdkruit/#Structure%20of%20galaxies)
[www.astro.rug.nl/~vdkruit/#Dynamics of galaxies](http://www.astro.rug.nl/~vdkruit/#Dynamics%20of%20galaxies)
 - A very recent extensive review, that may be helpful, is the Chapter ‘*Galaxy disks*’ by myself and K.C. Freeman in the 2011 volume of Annual Reviews of Astronomy & Astrophysics. This volume appears in September 2011, but has been pre-published in electronic form in August. For a formal reprint I have to provide the following text:
”I am pleased to provide you complimentary one-time access to my Annual Reviews article as a PDF file (<http://arjournals.annualreviews.org/eprint/dHqAPFISV9sYEJcGVaVq/full/10.1146/annurev-astro-083109-153241>), for your own personal use. Any further multiple distribution, publication, or commercial usage of this copyrighted material requires submission of a permission request addressed to the Annual Reviews Permissions Department, email permissions@AnnualReviews.org.”

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