ASTRONOMY 506 Spring 2005 Instructor: Anatoly Klypin

Part I : STELLAR DYNAMICS
Part II: HYDRODYNAMICS

Midterm: 17 March. It is a written exam: two questions and two problems to solve
Final : 5 May. It will be an a written exam: short questions and two problems to solve

Project: Study dynamical evolution of a gravitational system of few thousand particles using provided N-body code. Chose one of the following projects:

(1) Dynamical friction: Motion of a massive "satellite" in a halo. Study changes of the orbit (radius, angular momentum, eccentricity) of a massive particle moving in the halo made of 30,000 small particles. Compare results with theoretical predictions. What happens to the halo when the satellites sinks to the center of the system? Where the angular momentum of the satellite is deposited? How energy of halo particles changes? The halo ("galaxy") is a spherically symmetric non-rotating object in equilibrium. Run two models with different initial eccentricities.

(2) Violent relaxation in a simple system ("Formation of a galaxy cluster"). Set initial out-of-equilibrium system and study its subsequent evolution. Analyze the evolution of the distribution of angular momenta of particles. Estimate the time-scale of the violent relaxation and compare it with the dynamical time-scale of the initial system. How many particles become unbound? What is the density profile of the final equilibrium system? Use two initial configurations with 30,000 equal-mass particles.

(3) Collision and merging of two "elliptical galaxies". Prepare two equilibrium systems of 10,000 particles each. Put them in an orbit. Study the merging process. What is the density profile of the final system? How much does it change as compared with the initial profile? What happens with the angular momentum of the system? What fraction of particles and angular momentum escapes? What is the distribution of the angular momentum of the final configuration? Run two models with different orbit parameters.

(4) Study effects of the two-body scattering in a system of 5,000 particles which is initially in equilibrium ("globular cluster"). How does the density profile evolves with time? Compare the time-scale of the two-body scattering with theoretical predictions. In a system with different masses of particles estimate the time for development of the mass segregation. How does the average radius and the rms velocity of particles with different mass evolve with time?

(5) Use your n-body code to study evolution of a simplified model of the Solar system: 10,000 objects orbiting a massive central object. How orbital parameters of particles change? What are the effects of placing relatively massive objects ("Jupiters") in the system? How orbit of "Jupiter" evolves when placed in relatively massive disk?

You should use Fortran.

The project should be written as an article:

- Abstract
- Introduction
- Method and tests
- Analytical estimates
- Results
- Conclusions

You should use TEX or LATEX to format the text. Use supermongo or IDL to make plots.

Project is due 15 April

Homeworks will be given regularly.

Books: Handouts, lecture notes, and

Binney & Tremain "Galactic Dynamics"
Zeldovich & Raizer "Elements of Gasdynamics and the Classical Theory of Shock Waves"
Landau & Lifshitz "Hydrodynamics"

Grading: for AST506

25% for Homework	25% for Midterm	5% for class activity
25% for Project	25% for Final	

Grading: for AST406

33% for Homework	33% for Midterm	5% for class activity
33% for Final	20% extra credit for a simplified project.	

Part I: STELLAR DYNAMICS

(1) N-body problem: numerical methods.
(2) Gravitational potential. General results.
(3) Potentials of spherically symmetric systems.
(4) Potentials of non-spherically systems : general trends and general results.
(5) Motion of particles in a central force: basic equations and properties.
(6) Orbits of stars. Epicycle approximation.
(7) Virial theorem: derivation and limits of application
(8) Two-body relaxation: mechanism, different effects, time-scales.
(9) Two-body relaxation: more formal approach.
(10) Dynamical Friction: basic results and assumptions.
(11) Violent relaxation: basic ideas. Discussion
(12) Boltzman equation: distribution function, phase-space, mean velocity and "pressure".
(13) Boltzman equation: derivation and basic properties.
(14) Jeans equations.
(15) Jeans Instability. Toomre instability.

(16) Midterm

Part II: HYDRODYNAMICS

(1) Elements of Thermodynamics, gas cooling rates.
(2) Hydrodynamics: introduction. Continuity and Euler eqs.
(3) Energy equation. Lagrangian approach I.
(4) Lagrangian approach II
(5) Bernoulli equation. Kelvin theorem.
(6) Propagation of waves: Jeans instability, sound.
(7) Shock waves I.
(8) Shock waves II.
(9) Instabilities I.
(10) Instabilities II.
(11) Bondi flow
(12) Accretion disks
(13) Discussion