AY 212 – Dynamical Astronomy

Overview:

Broadly, this class deals with the vast sweep of astrophysical situations in which the relevant physics are dictated by Newton's Law of Universal Gravitation. The motivating principle underlying the course is that solutions to Newton's equation describe intricate and diverse phenomena ranging from the orbit of the Moon around the Earth to the structure of the Kirkwood gaps in the asteroid belt to the evolution of globular clusters to the spiral structure of galaxies. Indeed, one can assemble a brilliant and fully modern career in astronomy by focusing exclusively on situations that are fully described by Newtonian gravity.

Texts:

(1) Murray, C. D. & Dermott, S. F. 1999 *Solar System Dynamics* (Cambridge: Cambridge University Press)

(2) Binney, J. & Tremaine, S. 1987 Galactic Dynamics (Princeton: Princeton University Press)

(3) Supplementary articles from the literature, usually one per class.

Topics covered:

(approximately one per lecture)

1. The 2-body problem in full generality, orbital elements, negative heat capacity as the key to understanding evolution of self-gravitating systems.
2. The orbit in space, Gauss f and g functions, computing orbits, the curious case of HD 80606b.
3. Numerical integration for impatient practitioners, N-body methods, and the use of computer algebra.
4. Orbital fitting (the classical case of binary stars, and the modern case of extrasolar planets).
5. The restricted 3-body problem, Lagrange points, the Jacobi Integral.
6. Lagrangian stability analysis, Trojan and Horseshoe orbits, Hill theory.
7. Rocket science: geodesy, spacecraft trajectiories, and mission design.
8. Secular theory and the disturbing function.
9. Laplace-Lagrange second order perturbation theory.
10. Mean-motion and secular resonances
11. Precession and transits.
12. Tidal gravity: equilibrium and dynamical theories.
13. Spin-orbit resonance and Cassini States
14. Long-term orbital evolution, nonlinear dynamics, and chaos.
15. Precise time, timekeeping, calendars and clocks.

16. Practical GR for astronomers.
17. Orbits in axisymmetric potentials.
18. Orbits in non-axisymmetric potentials.
19. Spiral structure and density wave theory #1
20. Spiral structure and density wave theory #2
21. Stellar orbits in the galaxy, the collisionless Boltzmann equation
22. Orbits and evolution of elliptical galaxies.
23. Dynamical friction
24. Fokker Planck techniques
25. Globular Cluster evolution
26. Dynamics of galaxies (collisions, mergers, etc.)
27. Dynamics on the largest scales.
28. Concordance cosmology from a dynamicist's viewpoint.
29. How to give an astronomical talk.