AY 204 – Astrophysical Flows

Overview:

This course covers gas dynamics and fluid mechanics, with a constant eye toward what working astronomers need to know and use. The beginning of the class is geared toward obtaining a deep understanding of what the fluid equations mean, with a focus on establishing the relation between continuum mechanics and kinetic theory, and on connecting these ideas to the dynamics of collisionless systems considered in AY212. The course stands on its own, however, and can be taken either before or after AY212 at equal profit. The second half of the class looks at a variety of astrophysical applications, and includes an integrated treatment of MHD (applications in this case include solar physics and space physics, with the aim of getting the students conversant on those topics).

Texts:

(1) Shu, F. H. 1992 *The Physics of Astrophysics: Part II Gas Dynamics* (Mill Valley: University Science Press)

(2) Landau L. D. & Lifshitz, E. M. 1987 *Fluid Mechanics* (2nd Edition) (Oxford: Pergammon Press)

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

Topics covered:

(approximately one topic per lecture.)

1. Barnard 68 as an exemplar of the basic principles of Astrophysical Fluid Dynamics. Order of magnitude estimates, rules of thumb, and a strategy for thinking about research problems.
2.Connecting the microscopic to the macroscopic. Heuristic basis for the equations of fluid dynamics.
3.More on the Boltzmann Equation.
4.The moment equations and the derivation of the equations of fluid dynamics.
5. Viscosity and the Navier-Stokes Equation.
6. Thermodynamics for astronomers.
7. Statistical physics, entropy and information.
8. Inviscid barotropic flow.
9. "Spheres" (a unifying review and overview of rocks – giant planets – main sequence stars -- white dwarfs – neutron stars)
10. "Disks" (viscous accretion disks and rings from the gas dynamics viewpoint)
11. Linear analysis and fluid instabilities.
12. Dispersion relations
13. Turbulence.

14. The method of characteristics.
15. Attacking partial differential equations.
16. Supersonic flow and shock waves.
17. Steepening of acoustic waves into shock waves.
18. Oblique and radiative shocks – with protostellar accretion used as an illustrative test case.
19. Similarity solutions – with the isothermal sphere as an illustrative case.
20. Blast waves. A primer on nuclear weapons.
20. Magnetohydrodynamics (derivation of the equations of ideal MHD).
21. The MHD wave families.
22. MHD instabilities.
23. Magnetic virial theorem.
24. Magnetic reconnection and dynamos.
25. Solar Physics
26. Space Physics