Astrophysical Fluid Dynamics (M24)

Professor G. I. Ogilvie

Fluid dynamics is involved in a very wide range of astrophysical phenomena, such as the formation and internal dynamics of stars and giant planets, the workings of accretion flows, winds and jets around stars and black holes, and the dynamics of the expanding Universe. Effects that can be important in astrophysical fluids include compressibility, self-gravitation and the dynamical influence of the magnetic field that is 'frozen in' to a highly conducting plasma.

The basic models introduced and applied in this course are Newtonian gas dynamics and magnetohydrodynamics (MHD) for an ideal compressible fluid. The mathematical structure of the governing equations and the associated conservation laws will be explored in some detail because of their importance for both analytical and numerical methods of solution, as well as for physical interpretation. Linear and nonlinear waves, including shocks and other discontinuities, will be analysed. Steady solutions with spherical or axial symmetry reveal the physics of winds and jets from stars and discs. The linearized equations determine the oscillation modes of astrophysical bodies, as well as their stability and their response to tidal forcing.

The course will aim to cover a selection of topics including:

- Overview of astrophysical fluid dynamics and its applications.
- Equations of ideal gas dynamics and MHD, including compressibility, thermodynamic relations and self-gravitation.
- Physical interpretation of ideal MHD. Magnetostatic equilibria and the Grad–Shafranov equation.
- Conservation laws, stress tensor and virial theorem.
- Linear waves in homogeneous media. Nonlinear waves, astrophysical shocks (supernova explosions) and other discontinuities.
- Spherically symmetric steady flows: stellar winds and accretion.
- Axisymmetric rotating magnetized flows: winds and jets from rotating stars and discs.
- Stellar oscillations. Introduction to asteroseismology and astrophysical tides.

Prerequisites

This course is suitable for both astrophysicists and fluid dynamicists. Knowledge of key elements of vector calculus, fluid dynamics, thermodynamics and electromagnetism will be assumed.

Literature

1. Choudhuri, A. R. (1998). *The Physics of Fluids and Plasmas.* Cambridge University Press.
2. Landau, L. D., & Lifshitz, E. M. (1987). *Fluid Mechanics*, 2nd ed. Butterworth–Heinemann.
3. Pringle, J. E., & King, A. R. (2007). *Astrophysical Flows.* Cambridge University Press.

4. Shu, F. H. (1992). *The Physics of Astrophysics*, vol. 2: *Gas Dynamics*. University Science Books.

5. Thompson, M. J. (2006). *An Introduction to Astrophysical Fluid Dynamics*. Imperial College Press.

6. Ogilvie, G. I. (2016). *Lecture Notes: Astrophysical Fluid Dynamics*. J. Plasma Phys. **82**, 205820301.

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will be a one-hour revision class in the Easter Term.