Part II Astrophysics: Astrophysical Fluid Dynamics

Prof. Chris Reynolds

(IoA, Room H15, csr12@cam.ac.uk)
The basics

• 24 lectures; 4 example sheets

• Resources:
• My lecture notes / slides
• Books:
  • Principles of Astrophysical Fluid Dynamics; Clarke & Carswell
  • Fluid Mechanics; Landau & Lifshitz
Lecture 1:

• Basic Principles
  • What is a fluid?
  • Where do we find fluids in astrophysics?
  • Concept of a fluid elements
  • Collisional vs collisionless fluids

• Formulation of the Fluid Equations (part I)
  • Eulerian vs Lagrangian framework
  • Kinematics
The Convection Zone
Energy continues to move toward the surface through convection currents of heated and cooled gas in the convection zone.

The Radiative Zone
Energy moves slowly outward—taking more than 170,000 years to radiate through the layer of the Sun known as the radiative zone.

Coronal Streamers
The outward-flowing plasma of the corona is shaped by magnetic field lines that extend millions of miles into space.

The Corona
The ionized elements within the corona glow in the x-ray and extreme ultraviolet wavelengths. NASA instruments can image the Sun’s corona at these higher energies since the photosphere is quite dim in these wavelengths.

Sun’s Core
Energy is generated by thermonuclear reactions creating extreme temperatures deep within the Sun’s core.

The Chromosphere
The relatively thin layer of the Sun called the chromosphere is outlined by magnetic field lines that restrain the electrically charged solar plasma. Occasionally, larger plasma features—called prominences—form and extend into the very tenuous and hot corona, sometimes ejecting material away from the Sun.
Interstellar medium
Supernova explosions and remnants
Intracluster medium
Stars in a galaxy (collisionless fluid)
Formulation of fluid equations

Lagrangian view

Eulerian view
**Computational fluid dynamics**

Smoothed Particle Hydrodynamics  
Lagrangian view

- fluid represented by a set of particles  
- gas density, velocity etc. estimated by averaging over a certain number of particles

Grid codes (+AMR)  
Eulerian view

- fluid represented by a set of cells  
- compute fluxes at cell faces
Streamlines past an airfoil