International Max Planck Research School
on Physical Processes in the Solar System and Beyond
at the Universities of Braunschweig and Göttingen

HYDRODYNAMICS

Antonio Ferriz Mas, University of Vigo

21 – 25 July 2008

1. **Kinematics of the continuum. Spatial and material descriptions.**
   - 1.1. Spatial (eulerian) and material (lagrangian) descriptions of the motion. Material derivative. Velocity and acceleration. Trajectories and streamlines.
   - 1.2. Deformation and vorticity tensors. Physical interpretation.
   - 1.3. Reynolds' transport theorem.
2. **Fundamental equations in Continuum Mechanics.**
   - 2.1. Conservation of mass: continuity equation.
   - 2.2. Long-range (volume) forces and contact (surface) forces. Stress tensor.
   - 2.3. Momentum balance: equation of motion. Mechanical energy balance.
   - 2.4. Angular momentum balance: symmetry of the stress tensor.
   - 2.5. Conservation of energy and first principle of Thermodynamics.
   - 2.6. Constitutive relations.
3. **Viscous fluids. Navier-Stokes equation.**
   - 3.1. Hydrostatic pressure. Ideal fluid model. Euler's equation.
   - 3.2. Stress tensor for a linearly viscous fluid. Newtonian fluid model. Coefficients of viscosity. Derivation of Navier-Stokes' equation.
   - 3.3. Boundary conditions.
   - 3.4. Scale analysis and dimensionless numbers.
4. **Energy equation for a Newtonian fluid.**
   - 4.1. Second principle of Thermodynamics. Energy equation in the entropic representation. Concepts of adiabatic, isentropic and homoentropic motions.
   - 4.2. Heat conduction. Entropy sources.
   - 4.3. Alternative forms of expressing the energy equation.
5. **The hydrodynamic equations in conservation form.**
   - 5.1. Momentum equation in conservation form. The momentum density flux tensor.
   - 5.2. Energy equation in conservation form. The energy density flux vector.
   - 5.3. Derivation of the jump relations across a discontinuity. Tangential discontinuities and shock fronts. Rankine-Hugoniot relations.
6. **Circulation and vorticity.**
   - 6.1. Circulation and vorticity. Vortex tubes. Some kinematic results.
   - 6.2. Theorems of Kelvin and Helmholtz for ideal fluids.
   - 6.3. Navier-Stokes' equation in terms of the vorticity. 2-D results.
   - 6.4. Crocco's equation and Bernoulli's theorems.