Dynamics of Astrophysical Discs (L16)

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Discs are ubiquitous in astrophysics and participate in some of its most important processes. Most, but not all, feed a central mass: by facilitating the transfer of angular momentum, they permit the accretion of material that would otherwise remain in orbit. As a consequence, discs are essential to star, planet and satellite formation. They also regulate the growth of supermassive black holes at the centres of galaxies. Although astrophysical discs can vary by some ten orders of magnitude in size and vary hugely in composition and their thermodynamic state, many of them share the same basic dynamics and many physical phenomena.

The theoretical study of astrophysical discs combines aspects of orbital dynamics and continuum mechanics (fluid dynamics or magnetohydrodynamics). The evolution of an accretion disc is governed by the conservation of mass and angular momentum and is regulated by the efficiency of angular-momentum transport. An astrophysical disc is a rotating shear flow whose local behaviour can be analysed in a convenient model known as the shearing sheet. Various instabilities can occur and give rise to sustained activity and angular-momentum transport. The resonant gravitational interaction of a planet or other satellite with the disc within which it orbits generates waves that carry angular momentum and energy. This process leads to orbital evolution of the satellite and is one of the factors shaping the observed distribution of exoplanets.

Provisional synopsis:

- Occurrence of discs in various astronomical systems; basic physical and observational properties.
- Orbital dynamics, characteristic frequencies, precession, elementary mechanics of accretion.
- Global and local views of an astrophysical disc.
- Evolution of an accretion disc.
- Vertical disc structure, scaling relations and timescales, thin-disc approximations, thermal and viscous stability and outbursts.
- Shearing sheet, symmetries, shearing waves.
- Hydrodynamic waves and instabilities; gravitational instability and turbulence.
- Vortices, zonal flows and dust dynamics.
- Satellite–disc interaction: tidal potential, resonant torques, migration and gap-opening.
- Magnetic fields and magnetorotational instability.

Prerequisites

Newtonian mechanics and basic fluid dynamics. Some previous knowledge of basic magnetohydrodynamics is helpful for the magnetorotational instability, but self-contained notes on this topic will be available.

Literature

Much information on the astrophysical background is contained in [1]. Some of the basic theory of accretion discs is described in review articles [2,3]. A number of useful results on discs is in [4].

1. J. Frank, A. King and D. Raine, *Accretion Power in Astrophysics*, 3rd edition. Cambridge, 2002.

2. J. E. Pringle, Annu. Rev. Astron. Astrophys. **19**, 137 (1981).

3. J. C. B. Papaloizou and D. N. C. Lin, Annu. Rev. Astron. Astrophys. **33**, 505 (1995).

4. J. Binney and S. Tremaine, *Galactic Dynamics*, 2nd edition, Princeton University Press, 2008

Additional support

Three example sheets will be provided and three associated example classes will be given. There will be a revision class in the Easter Term.