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 and thus indirectly influence galactic structure and the intracluster medium. Although astrophysical discs can vary by ten orders of magnitude in size and differ hugely in composition, all 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). In fact, an astrophysical disc is a rotating shear flow that can sustain various instabilities, waves, and turbulence, which allow the necessary accretion. On the other hand, the resonant gravitational interaction of a planet within the disc generates waves that leads to orbital evolution of the planet and is one of the processes shaping the observed distribution of extrasolar planets.

Provisional synopsis:

- Occurrence of discs in various astronomical systems, basic physical and observational properties.
- Orbital dynamics, characteristic frequencies, precession, elementary mechanics of accretion.
- Viscous evolution of an accretion disc.
- Vertical disc structure: thin-disc approximations, thermal instability in cataclysmic variables.
- The shearing sheet, symmetries, shearing waves.
- Incompressible dynamics: hydrodynamic stability, vortices and dust in protoplanetary discs.
- Compressible dynamics: density waves, gravitational instability and 'gravitoturbulence' in planetary rings and protoplanetary discs.
- Satellite-disc interaction, impulse approximation, gap opening by embedded planets.
- Magnetorotational instability, 'dead zones' and outbursts in protoplanetary discs, magnetised outflows and jets

Pre-requisites

Newtonian mechanics and basic fluid dynamics. Some knowledge of magnetohydrodynamics is helpful for the topic of magnetorotational instability.

Literature

Astrophysical background can be found in reference [1] below, while the classical theory is summarised in the two review articles [2,3].

1. Frank, J., King, A. & Raine, D. (2002), Accretion Power in Astrophysics, 3rd edn, CUP.
2. Pringle, J. E. (1981), Annu. Rev. Astron. Astrophys. 19, 137.
3. Papaloizou, J. C. B. & Lin, D. N. C. (1995), Annu. Rev. Astron. Astrophys. 33, 505.

Additional support

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