1. Gyrokinetics

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Gyrokinetics is a branch of plasma kinetic theory that provides a rigourous analytical description of low-frequency phenomena in plasmas in a strong magnetic field. When characteristic time scales of the interesting dynamics are much longer than the period of the ion Larmor motion, one can average over the Larmor orbits and, instead of the kinetics of particles (electrons and ions), consider the kinetics of Larmor rings. The resulting theory is analytically beautiful and has many practical uses. In astrophysics, gyrokinetics is the natural theoretical framework for the description of MHD turbulence in solar wind, interstellar medium, galaxy clusters, some accretion discs etc. (the conventional fluid theory has limited applicability because these plasmas are only weakly collisional and the fluid approach manifestly fails to answer many of the key questions). In thermonuclear fusion research, gyrokinetics has emerged as the primary tool in the investigations of small-scale plasma instabilities, turbulence, turbulent transport and magnetic reconnection in tokamaks — these are all key effects that affect plasma confinement. Understanding them is a prerequisite for the successfull development of a future fusion power plant. This is an area of very active current research and many interesting problems. Gyrokinetics will prove an essential subject for any student interested in pursuing postgraduate work in plasma physics or astrophysics. An essay on gyrokinetics will also be an excellent opportunity for an anlytically minded student to learn a great deal about the principles of kinetic theory, asymptotic methods and theory of turbulence.

The essay might follow roughly the following outline:
1. Charged particle motion in a magnetic field (e.g., Sturrock 1994, Hazeltine & Waelbroeck 2004)
2. Derivation of gyrokinetics from the general plasma kinetic theory (Howes et al. 2006, Brizard & Hahm 2006).
3. Gyrokinetic theory of Coulomb collisions (Helander & Sigmar 2002, Catto & Tsang 1977).
4. Linear theory of gyrokinetic waves and collisionless damping (Howes et al. 2006).
5. Connection to MHD turbulence theory: MHD cascade in gyrokinetic theory and relevant asymptitic limits (Schekochihin et al. 2006).

Anyone considering this essay is welcome to discuss it with Alex Schekochihin (F1.04, DAMTP/CMS). The description given above is flexible and can be adjusted to best meet the student's inclinations.

Relevant Courses

Magnetohydrodynamics and Turbulence (M16)

References

1. Brizard A J & Hahm T S 2006, "Foundations of nonlinear gyrokinetic theory," PPPL Report 4153 (see `http://www.pppl.gov/pub_report/`)
2. Catto P J & Tsang K T 1977, *Physics of Plasmas* **20**, 396
3. Hazeltine R D & Waelbroeck F L 2004, *The Framework of Plasma Physics* (Wesview Press, Cambridge MA)
4. Helander P & Sigmar D J 2002, *Collisional Transport in Magnetized Plasmas* (CUP)
5. Howes G G, Cowley S C, Dorland W, Hammett G W, Quataert E, & Schekochihin A A 2006, "Astrophysical gyrokinetics: basic equations and linear theory," *Astrophysical Journal* **651**, 590
6. Schekochihin A A, Cowley S C, & Dorland W 2006, "Interplanetary and interstellar plasma turbulence," e-print astro-ph/0610810 (see `www.arxiv.org`)
7. Sturrock P A 1994, *Plasma Physics* (CUP)