High Energy Astrophysics

Compact objects (neutron stars, black holes and white dwarfs) are the endpoints of stellar evolution. They are responsible for some of the most exotic phenomena in the universe: supernova explosion, radio pulsars, bright X-ray sources, magnetars, gamma-ray bursts, etc. Supermassive black holes also lie at the heart of the violent processes in active galactic nuclei and quasars.

Compact objects are also important from a fundamental physics point of view. Their high densities and strong magnetic fields allow one to probe physics under extreme conditions. Their strong gravitational fields provide an arena for exploring the consequences of general relativity.

Tentative Syllabus

Part I: Isolated (more or less) Compact Objects

- White dwarf: structure, formation and cooling.
- Neutron star: structure, EOS, mass limit, cooling, surface emission
- Pulsars: magnetosphere physics, B-field evolution, glitches, radio wave propagation
- Core-collapse Supernova: hydrodynamics, shock waves, neutrinos, explosion in ISM (Sedov solution)
- Black holes: introduction to GR, Schwarzschild and Kerr metric, motion of test mass, photon propagation, Penrose process

Part II: Accretion Power in Astrophysics

- Accretion in binary systems: Roche lobe overflow, disk formation, wind accretion, effect on binary evolution
- Spherical Accretion: Bondi and Bondi-Hoyle, feeding of supermassive BHs
- Accretion disks: The origin of viscosity (Balbus-Hawley), time-scales and stability
- Accretion disks: thin and thick disks, quasi-spherical accretion (ADAF), precession
- Accretion onto Neutron Stars: X-ray pulsars, bursts, QPOs; pulsar recycling
- White dwarf accretion: CVs, Nova and Type Ia SN, AIC vs explosion
- Supermassive BHs: introduction to AGN, radio sources, quasars, synchrotron radiation, minimum energy
- Jets: superluminal motions, launching mechanisms, Blandford-Znajek

Part III: Special Topics

- Photon interaction with matter: detection of high energy radiation
- GRBs: Simple fireball models and repercussion for optical/X-ray afterglows
- Magnetars
- Gravitational wave sources: NS/NS and NS/BH binaries, rotating collapse, LIGO and LISA sources
- Cosmic rays: EeV cosmic ray puzzles, particle acceleration, extremely high energy neutrinos

Recommended Part-texts:

There are no good textbooks available on the market which adequately cover all the topics for this course. However, the following three books combined cover most of the stuff:

- Shapiro and Teukolsky "Black Holes, White Dwarfs and Neutron Stars" (1983): covering equations of state, stucture, microphysics very well, but getting dated in places (especially observations); rather sparse on applications. This is most useful for Part I.
- J. Frank, A. King and D. Raine "Accretion Power in Astrophysics" (3nd Ed, 2002): Good coverage of the title subject, up to date. This is most useful for Part II.
- M. Longair "High Energy Astrophysics, Vol.1 and 2" (1994): broad coverage on general area of high energy astrophysics, but somewhat below the level of the course. (Vol 2 is supposed to be coming out soon).