High-Energy Astrophysics **Astr 702**

Instructor: Charles R. Evans Spring 2012

MW 10:30-12:00

Office: Phillips 284

Email: evans@physics.unc.edu

This course is a selective survey of high-energy and relativistic phenomena in astrophysics. Astrophysical phenomena of interest include white dwarfs, neutron stars, pulsars, black holes, relativistic winds, accretion disks, X-ray sources, active galaxies, extragalactic radio sources, jets, and cosmic rays. In the process of discussing many of these phenomena we will cover or review as needed the following physics: thermodynamics and nuclear physics (of compact stellar interiors), hydrodynamics, special relativity, general relativity, electrodynamics, synchrotron emission, inverse Compton scattering, black holes, accretion flows, jets, shocks, and particle acceleration.

My lectures do not follow any single text but are probably most closely related to the primary text, *Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects* by Stu Shapiro and Saul Teukolsky. I also recommend that you obtain access to a copy of *Radiative Processes in Astrophysics* by George Rybicki and Alan Lightman.

Homework will be assigned at intervals and there will be a midterm exam and a final exam. Some homework problems may involve numerical modeling.

Class schedule:

- Class will be held each Monday and Wednesday from 10:30 to 11:45 (or 12:00), except January 16, March 5, and March 7. Last day of classes is April 25.

General Outline of Course Topics

White Dwarfs

Thermodynamics, equations of state
Newtonian stellar equilibrium, gravity, hydrodynamics
Polytropes
Special relativity
Degenerate electron gas
White dwarfs: internal structure
Nuclear equilibrium, beta decay, photo-disintegration
Chandrasekhar mass and stellar collapse, neutrino trapping

Neutron Stars

General relativity
Tolman-Oppenheimer-Volkoff equation
Neutron star structure
Nuclear statistic equilibrium, n/p ratio
Observed masses of neutron stars

Pulsars

Pulsar phenomenology
Special relativistic covariance and electromagnetism
Magnetic dipole radiation, pulsar braking, glitches
Crab pulsar nebula energetics
Synchrotron radiation, Inverse Compton scattering
P–P dot diagram
Pulsar winds: hydrodynamics, winds and magnetized outflows, electron-positron pair winds
Pulse emission mechanism, Death line
Recycled pulsars, millisecond pulsars

Accretion Powered Sources: X-ray Binaries and Active Galactic Nuclei

Accreting neutron stars: phenomenology of HMXB, LMXB, and X-ray bursts
Active galactic nuclei: quasars, blazars, BAL systems, Seyfert galaxies
Physics of Schwarzschild and Kerr black holes
Relativistic orbits and energy conversion efficiency
Physics of accretion disks: hydrodynamics, viscous transport, radiation losses, vertical structure, relativistic effects

Jets, Cosmic Rays

Relativistic outflows: jet sources and supernova remnants
Relativistic beaming and superluminal motion, one-sided jets and
Shock waves
Particle acceleration at shocks: Fermi process and cosmic rays
Comptonization by hot electrons, photon-pair plasmas