Introduction to General Relativity I: Fall/Spring 2019-2020

M- W-F 10:00 --10:50, 105 Allen Hall

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Office Hours: W-F, 4:15 pm to 5:00 pm in 208 Allen : if you cannot make these office hours call me or send me e-mail requesting an appt. (give me a few choices).

Program for first semester: Special Relativity, time dilation, length contraction and simultaneity. Lorentz transformations, intervals, world lines and geometry of SR, variational principle: Minkowski space-time, metric, space-time diagrams. Covariance of SR. Scalars, vectors and tensors. Applications of SR to astrophysics and particle physics: Doppler shifts (transverse and longitudinal), stellar aberration, beaming and gamma ray bursts, kinematical thresholds: an astrophysical puzzle: Ultrahigh energy cosmic rays and GZK. Energy in SR. Accelerated observers: an event horizon, comment: Unruh temperature and accelerated observers. General coordinate systems, geodesics and the variational method: Christoffel symbols.
Gravity at last: the equivalence of inertial and gravitational mass, the equivalence principle: gravitational redshift and light bending, tidal forces, gravity as geometry. GPS: SR + GR in action. Weak field limit. The geometry of space-time outside a non-rotating spherical star: the Schwarschild metric: consequences, Killing vectors and conservation laws, the gravitational redshift. Particle orbits: advance in the perihelion of Mercury, light bending, radar echo. PPN and solar system tests of GR. Gravitational lensing: thin lenses, microlensing and Machos, macrolensing and Dark Matter. Tidal forces and geodesic deviation, the geodetic effect, Lense-Thirring (frame dragging) and Gravity Probe B-experiment.
The march towards Einstein's field equations: geometry first, a taste of Riemannian geometry, absolute and covariant derivatives, curvature and the curvature tensor.

The second semester will include: energy momentum tensors, fluids: sound waves and eqn. of state. Einstein equations. A gravitating fluid and the Jeans instability: the origin of structure and galaxy formation. A *tour de force* on stellar evolution, relativistic stars and TOV: white dwarfs, neutron stars, supernovaes (I and II) and Black Holes as end points of stellar evolution. Schwarschild and Kerr black holes. Gravitational collapse, event horizons and ergospheres. Penrose processes, naked singularities. Some quantum aspects of BH: Hawking radiation, evaporation, BH thermodynamics and the information paradox. Gravitational Waves: Taylor Hulse pulsar, LIGO, perturbations: quasinormal modes and ring-down of Black Holes. Cosmology: homogeneous and isotropic Universe, FRW, standard Big Bang the CMB. The cosmological constant and Lambda CDM. Elements of Inflation, quantum fluctuations as seeds of CMB anisotropies and Galaxy formation. Basics of Gravitational collapse in expanding cosmology: structure formation.

Books: I recommend the following outstanding books: I) Modern General Relativity, Mike Guidry, II) General Relativity, an Introduction for Physicists by M. P. Hobson, G. Efstathiou, A. N. Lasenby, III) Gravity an introduction to Einstein's General Relativity by J. Hartle. Other excellent books are: An introduction to GR: spacetime and geometry by S. Carroll, although this book is more geometric-oriented. S. Weinberg's Cosmology and Gravitation is a classic and highly recommended. I will borrow material from many different books. Book I) is more up to date in cosmology and astrophysical applications, II,III) are more pedagogical and a true jewel, the ideal book is a combo of I+II+III +Weinberg, but it does not exist (yet!).

Format of the course: One homework problem set (4-5 problems) per week, one take home midterm and a take home final. The final grade is the average of HM+mid+final.