MODERN GENERAL RELATIVITY

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PHY 620; Spring 2018, MWF 9.00-9.53 in P116

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We begin this class by showing how some physicists tried, and Einstein succeeded, in extending Special Relativity to include the kinematics of accelerations and rotations, and at the same time the dynamics of gravitation. By comparison with electromagnetism, this will lead (us) to the linearized field theory of spin 2 by Fierz and Pauli. Using the Noether method we derive full nonlinear General Relativity (GR) in two steps. From here we are led to the usual tensor calculus: manifolds, connections, curvatures, the Einstein field equations, and the Hilbert-Einstein action. We conclude this first part with the 4 classical tests: perihelion precession, gravitational redshift, light bending, and time delay.
Next we turn to gravitational radiation. We analyze the binary pulsar and the recent results on the detection of gravitational waves. Then come cosmological models: maximally symmetric spaces, Robertson-Walker metrics, de Sitter and anti-de Sitter spaces, Friedman universes, and the Hubble constant.
Then we turn more formal: the initial value problem for gravity as a gauge theory, resulting in constraints on the initial data. Using the Dirac formalism, we rewrite GR in Hamiltonian form.
We discuss relativistic compact objects: white dwarfs and neutron stars, the Chandrasekhar and Oppenheimer-Volkoff bounds and the TOV equation, and BLACK HOLES (Schwarzschild, Reissner-Nordström and Kerr). We discuss their BPS saturation and Penrose diagrams. If time permits we analyze Hawking radiation.
We do not discuss: quantum gravity and string theory, fermions and the Dirac equation in curved spacetime, and supergravity, because we discussed these topics last semester in PHY 680. But we do discuss the vielbein and Cartan-Maurer method for solving the Einstein equations, the Gauss-Codazzi equations for embedding hypersurfaces in curved space, the Gibbons-Hawking boundary term in GR, and the (in)stability of black hole solutions.

REQUIRED KNOWLEDGE, TEXTBOOKS, HOMEWORKS, EXAMS:
We assume prior knowledge of special relativity and Maxwell theory (electromagnetism) and some very basic field theory. We hand out notes, but recommend for beginners Lawden's Introduction to Tensor Calculus, Relativity and Cosmology, and for a readable graduate text Carroll's book Spacetime and Geometry, an Introduction to General Relativity. There are weekly home works, and we give both a final oral and a final written exam. Grading: 30 % home works, 30% oral and 40% written exam.