Course title:	Introduction to General Relativity
Lecturer:	dr Surajit Kalita
Field, type and level of studies	Astrophysics, includes mathematics, all years of studies
Leading Institute	Astronomical Observatory, Faculty of Physics
Number of ECTS points:	3
Course character:	Lecture
Language	English
Criteria to complete the course	50% written examination, 50% reading project
Number of hours	30
Short description (Skrócony opis przedmiotu)	General relativity is the modern theory of gravity, describing how matter and energy influence the geometry of space and time. It governs planetary orbits, light deflection, cosmic expansion, and properties of compact objects. This theory is essential for understanding cosmology, gravitational waves, and extreme astrophysical phenomena. In this lecture, I will outline the basic principles of general relativity and show how they lead to remarkable predictions. The lecture will combine simple theoretical ideas with key observational tests and applications. ▪ Introduce and explain basic concepts of curved space-time. ▪ Present key equations and their physical meaning. ▪ Discuss classical tests of general relativity (light bending, time dilation, gravitational redshift). ▪ Show applications in black holes and gravitational waves.
Description (Pełny opis przedmiotu)	1. Review of tensor calculus and special relativity (2 classes): Index notation, metric tensor, raising/lowering indices, Minkowski spacetime, four-vectors, Lorentz transforma-

	tions, covariant derivatives, Christoffel symbols. 2. Principles of general relativity (3 classes): Riemann curvature tensor, equivalence principle, principle of general covariance, Einstein field equation, stress-energy tensor -- cases of perfect fluid and electromagnetic fields. 3. Vacuum solution: ▪ Non-rotating black holes (3 classes): Schwarzschild solution, singularities, motion of test particles, different orbits, perihelion precision, bending of light. ▪ Rotating black holes (2 classes): Basic idea of Kerr metric, ergosphere, and frame dragging. 4. Non-vacuum solution: ▪ Structure of white dwarfs and neutron stars (2 classes): Tolman–Oppenheimer–Volkoff (TOV) equation, maximum masses and role of equation of state. 5. Gravitational waves (3 classes): Linearized Einstein equation, solution of wave equations, transverse-traceless (TT) gauge, quadrupole formula, LIGO/Virgo and detection principles. o Software (recommended): Mathematica (https://www.wolfram.com/mathematica) o Basics knowledge of classical mechanics (required), special relativity (preferred), electromagnetism (preferred), differential equations (required), and tensor notation (preferred)
Bibliography (Literatura)	1. L. Ryder: *Introduction to General Relativity* (Cambridge University Press, Cambridge, 2009). 2. M. Maggiore: *Gravitational Waves: Volume 1* (Oxford University Press, Oxford, 2007). 3. B. F. Schutz: *A First Course in General Relativity* (Cambridge University Press, Cambridge, 1990). 4. S. Carroll: *Spacetime and Geometry* (Addison Wesley, New York, 2004). 5. S. L. Shapiro & S. A. Teukolsky: *Black Holes, White Dwarfs, and Neutron Stars* (Willey VCH 1983). 6. A. R. Choudhuri: *Astrophysics for Physicists* (Cambridge University Press, Cambridge, 2010). 7. M. P. Hobson, G. Efstathiou & A. N. Lasenby: *General Relativity: An Introduction for Physicists* (Cambridge University Press, Cambridge, 2006).
Learning outcomes (Efekty uczenia się)	Upon completing this course, students will learn the mathematical foundations of curved spacetime, including tensors and differential geometry, and solve Einstein's field equations for key scenar-

	ios like black holes and gravitational waves. They will apply these concepts to analytical problems, connect theoretical predictions to observable astrophysical phenomena, such as gravitational lensing and cosmological observations, and evaluate the physical implications of general relativity in modern astrophysics (WG_01, WG_02, WG_03). Knowledge P8S_WG, practical skills P8S_U, social skills: P8S_KK
Assessment methods and assessment criteria (Metody i kryteria oceniania)	1. 50% end-semester written examination 2. 50% reading project of papers on topics aligned to the course The lecturer is available every week during the planned time for the course. Contact with the lecturer: skalita@astrouw.edu.pl; s.kalita@uw.edu.pl.