Gravitational Waves - Theory and Analysis
- ***COURSE SYLLABUS***

1.	**Course title:** *Gravitational Waves - Theory and Analysis*	
2.	**Lecturer:** *Dr. Sreekanth Harikumar*	
3.	**Field, type and level of studies, year of study:** *Astrophysics, Doctoral Studies, all years of study*	
4.	**Course character:** *Monographic lecture*	
5.	**Teaching method:** *Traditional: Inperson classes with homework assignments.*	
6.	**Language:**	*English*
7.	**Course type and number of hours:** *Lecture - 16 hours ,* *Independent work- 10 hours*	
8.	**Estimated load of student's independent work:**	*8h*
9.	**Total workload and number of ECTS points:**	*24 h, 3 ECTS*
10.	**Short description and main focus of the course:** *This course provides a introduction to gravitational waves (GWs), from their theoretical prediction in General Relativity to modern detection techniques and astrophysical applications. Students will learn the mathematical foundations of gravitational radiation, data analysis methods, gravitational lensing and the scientific discoveries enabled by current GW observatories.* *The following topics will be covered during this course:* ***I.* Historical Introduction to GWs** - Einstein's prediction - Indirect evidence for GWs : Hulse Taylor Pulsar - Development of GW detectors - First direction detection (GW150914) - Multi-messenger astronomy ***II. Review of General Relativity and Gravitational waves*** *- Tensors* *- Spacetime, metric and geodesics* *- Einstein field equations* *- Linearized gravity*	

	- Metric perturbations and gauge freedom *- Transverse Traceless gauge and GW polarizations* *- Effect on test masses and geodesic deviation* *- Quadrupole formula* *- Propagation of GWs in curved spacetime* *- Energy of GWs* ***III . Astrophysical sources and applications*** *- Black Hole and Neutron Star mergers, pulsars , Core Collapse Supernovae* *- Data analysis tools and techniques: Matched filtering, Bayesian Analysis (Practical session)* *- GW lensing and cosmology with gravitational waves* *- Current and next generation ground based GW detectors, Space based detectors*
11.	**References:** 1. Michele Maggiore: Gravitational waves. Volume 1: theory and experiments. Oxford University Press, 2007 2. Schutz, B. (2022). A First Course in General Relativity (3rd ed.). Cambridge: Cambridge University Press. 3. P. Jaranowksi, A. Królak, Analysis of gravitational wave data, Camb.Monogr.Part.Phys.Nucl.Phys.Cosmol. 29 (2009) 4. Jolien. D.E. Creighton, Warren. G. Anderson, Gravitational Wave Physics and Astronomy - An introduction to Theory, Experiment and Data Analysis (2011), Wiley Series in Cosmology
12.	**Prerequisites:** *It is assumed: the knowledge of classical mechanics, knowledge of the basics of the General Relativity is not necessary, though it would be an advantage. A basic knowledge of Python will be helpful during the data analysis tutorials.*

13.	**Educational outcomes:**	**PQF level 8 codes:**
	Knowledge: *After completing the course, the student will have a solid understanding of the fundamental principles of gravitational wave physics and their significance in modern astrophysics. The student will understand how gravitational waves arise from the Einstein field equations, including the derivation of the gravitational wave equation and the physical effects of gravitational waves on test masses. In addition, the student will be familiar with the main experimental techniques used for gravitational wave detection and with the primary astrophysical sources that produce detectable signals. Finally, the student will understand the major scientific applications of gravitational wave observations and will have insight into the current challenges and future directions of gravitational wave astronomy.*	*PS8_WG*
	Practical Skills: *After completing the course, the student will be able to apply*	*P8S_UW*

	core concepts from physics and astrophysics to develop a solid understanding of gravitational waves. The student will be capable of reading, understanding, and critically assessing scientific papers on a broad range of topics in gravitational wave astronomy, and will be able to interpret research publications in this field. In addition, the student will acquire practical skills in performing basic gravitational wave data analysis and will understand the main computational methods and tools used in the analysis of gravitational wave signals.	
	Social Skills: *Students will understand the scientific importance of gravitational waves within a broad astrophysical and societal context. They will be able to communicate effectively about these topics with experts, peers, and non-specialist audiences. Students will also develop the ability to critically assess arguments and claims presented in both scientific literature and popular science media..*	*P8U_K*
14.	**Evaluation of the educational outcomes:** *Homework assignments and Oral exam*	
15.	**Criteria to complete the course:** *Completion of home works assigned during the theory and practical sessions, and passing the oral exam.*	
16.	**Contact with the lecturer:** *Email: sreekanth@camk.edu.pl*	