Syllabus

Astrophysical compact objects

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October 20, 2025

Format. 8 Lectures (2 hours each)

Course Description. This lecture series provides an introduction to the physics of astrophysical transients — such as core-collapse supernovae, (proto-)neutron stars, and binary neutron star mergers — compact objects comprising matter at the highest densities that can stably exist in the Universe. The course will explore the astrophysical origins of these systems, their internal structure and modeling, and their observational signatures. Special emphasis is placed on possible insights on matter under theses extreme conditions from future multi-messenger observations.

Target Audience. Graduate students and early-career researchers in astrophysics, nuclear physics, and particle physics.

Learning Objectives.

- Understand the astrophysical origin and evolution of supernovae and neutron stars.
- Learn how to model compact object structure and evolution using realistic EOSs.
- Grasp the role of neutrino emission in the cooling and dynamics of compact stars.
- Gain some idea of open-source tools for neutron star modelling.

Lecture Plan

Lecture 1. Astrophysical basics

- Historical overview
- Neutron stars
- Neutron star formation in a core-collapse supernova: from stellar evolution to collapse
- Binary coalescences

Suggested reading:H.-T. Janka et al., 2007; Shapiro and Teukolsky, 1983; Dmitry G. Yakovlev et al., 2013; Burns, 2020.

Lecture 2. Modelization

- Microphysics: equilibrium (equation of state) and out-of-equilibrium aspects (neutrino interactions etc)
- Global modelling

Suggested reading: H. .-. Janka, 2025; Haensel, Potekhin, and D. G. Yakovlev, 2007; Oertel et al., 2017; Bernuzzi, 2020; Schmitt and Shternin, 2018; D. G. Yakovlev et al., 2001.

Lecture 3. Observational signatures

- Electromagnetic probes
- Gravitational waves
- Neutrinos

Suggested reading: Lattimer and Prakash, 2007; G. G. Raffelt, H.-T. Janka, and Fiorillo, 2025.

Lecture 4. Outlook: compact objects as probe of fundamental physics

- Strongly interacting matter
- Theory of gravity
- Dark matter and BSM searches

Suggested reading: M. Kramer et al., 2021; Wex and Michael Kramer, 2020; Lattimer and Prakash, 2007; Caputo and G. Raffelt, 2024; Garani, Genolini, and Hambye, 2019.

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