Nuclear Physics of Multi-Messenger Mergers Summer School,

June 9-13, 2025

Indiana University, Swain Hall West, Bloomington, IN

	Monday	Tuesday	Wednesday	Thursday	Friday
9am	Capano	Capano	Capano	Sathyaprakash	Sathyaprakash
10:30	Coffee	Coffee	Coffee	Coffee	Coffee
11 am	Piekarewicz	Piekarewicz	TBA	Bardayan	Bardayan
12:30	Lunch	Lunch	Lunch	Lunch	Lunch
2pm	Dexheimer	Dexheimer	Sathyaprakash	TBA	TBA
3:30pm	Student Talks	PyCBC tutorial	Student talks	Problems / Discussion	Problems / Discussion

Lectures (Each morning will likely start in room 007, Swain Hall West):

1) Constraining Astrophysical Nucleosynthesis with Nuclear Measurements in the Physics Laboratory

D. W. Bardayan (Notre Dame)

The nucleosynthesis occurring in exotic astrophysical events provides critical insight into the conditions that must have been present. Model predictions rely upon accurate nuclear data that in many cases can only be obtained in the nuclear physics laboratory and cannot be predicted or calculated with the required precision. This series of lectures will focus upon the methods that are used to obtain the critical data, the incorporation of such data in astrophysical models, and emerging opportunities to significantly increase our understanding of astrophysical nucleosynthesis.

2) Gravitational Wave Astronomy and Bayesian Inference

Colin Capano (Syracuse),

I'll give a brief (~30 minute) overview of GW astronomy in the form of some slides, then dive into the Bayesian inference and the derivation of the likelihood (continuing into the second lecture). In the Tuesday Afternoon Problem / Discussion session I will go over one of the PyCBC Inference tutorials (most likely this one). [Note PyCBC is a software package used to explore astrophysical sources of GW.] Those can be run in Google Co-lab through a browser, so student wouldn't need to install anything on their computers ahead of time.

3) A modern description of dense matter,

Veronica Dexheimer (Kent State University)

In a series of lectures, I start by reviewing our current understanding of the interior of neutron stars and modern constraints relevant for dense matter. This includes theoretical first-principle results from lattice and perturbative QCD, as well as chiral effective field theory results. From the experimental side, it includes heavy-ion collision and low-energy nuclear physics results, as well as observations from neutron stars and their mergers. I also discuss different models for dense matter and present the brand new MUSES cyberinfrastructure, a large collaboration project that is developing a new online platform with downloadable open-source code and data that can be used to describe the entire multidimensional QCD phase diagram and be used in simulations of particle collisions and neutron star evolution and mergers.

4) Neutron-Rich Matter on Heaven and Earth

Jorge Piekarewicz (FSU)

The lectures will explain how to build an equation of state for neutron rich matter that is consistent with known properties of finite nuclei and neutron stars. Emphasis will be place on how physical observables that may be determined from terrestrial experiments constrain the properties of neutron stars. Conversely, I will explore how recent electromagnetic observations and gravitational-wave detections inform the equation of state in regions inaccessible to laboratory experiments.

5) Gravitational waves and data analysis

Bangalore Sathyaprakash (Penn. State).

The first session will give a general introduction to gravitational wave data analysis, focusing on Bayesian inference. Participants will download (either mock or real) data and learn how to do parameter estimation. The second session will focus on gravitational waves from neutron star binaries, determining the dense matter equation of state with model selection. Participants will work in groups of 3 or 4, prepare mock data and run a model selection algorithm. The third session will focus on measuring the Hubble parameter with Hierarchical Bayesian inference. Once again lecture plus group work.