# NewCompStar School 2016 - “Neutron stars: gravitational physics theory and observations”

# Report of Contributions

https://indico.global/e/8915

Contribution ID: **9** Type: **not specified**

# Introduction to General Relativity

*Monday 5 September 2016 09:05 (1h 30m)*

**Presenter:** Dr CARDOSO, V (IST - University of Lisbon)

Contribution ID: **10** Type: **not specified**

# Introduction to Numerical Relativity

*Monday 5 September 2016 11:00 (1h 30m)*

**Presenter:** Dr SPERHAKE, U. (University of Cambridge)

Contribution ID: **11** Type: **not specified**

# Microscopic description of the Dense Matter EoS

*Thursday 8 September 2016 14:30 (1h 30m)*

## Summary

**Presenter:** Dr BURGIO, F. (INFN - Catania)

Contribution ID: **12** Type: **not specified**

# Tests of general relativity and neutron star mass measurements from timing of radio pulsars

*Monday 5 September 2016 16:30 (1h 30m)*

In this lecture, I will introduce some basic concepts related to neutron stars, radio pulsars and their evolution. I then describe in detail timing of radio pulsars in binary systems, using the results from the first binary pulsar, PSR B1913+16, as an important example. First, I describe how pulsar timing of this system was used to determine the masses of the components, and then I describe how it was used to test general relativity and to achieve, in the 1980's, the first detection of gravitational wave emission.
This fundamental discovery opened up a wide field of research, by encouraging the construction of ground-based gravitational wave detectors, but also by further stimulating pulsar surveys (which I describe in some detail), which lead to the discovery of many more binary pulsars.
I then describe many of the results from these new pulsars. I concentrate first on neutron star mass measurements, in particular the special difficulties that arise from measuring masses of millisecond pulsars, and the great rewards from this effort, with a special emphasis on the consequences for our knowledge of the behaviour of super-dense matter in the cores of neutron stars. I finally describe in detail the current status of tests of general relativity, both with double neutron star systems (in particular the "double pulsar" system, J0737-3039), millisecond pulsar - white dwarf systems and the triple system, J0337+1715.

**Presenter:** Dr FREIRE, P (Max Planck Institute - Bonn)

Contribution ID: **15** Type: **not specified**

# Analytical Relativity Modelling of Coalescing Compact Binaries

*Wednesday 7 September 2016 11:00 (1h 30m)*

In this lecture, I will give an introduction to the analytical approximation methods that are used to model the orbital dynamics and gravitational-wave emission of binary systems of compact objects (neutrons stars and black holes), namely the post-Newtonian approximation, black hole perturbation theory and the gravitational self-force formalism, and the effective one-body model. The key ideas underlying each approximation method will be illustrated in the simplest cases, while state of the art results and sub-leading physical effects (spins, tidal deformations) will be briefly reviewed.

## Summary

**Presenter:** Dr LE TIEC, A. (Observatoire de Paris)

Contribution ID: **16** Type: **not specified**

# General relativity computations with SageManifolds

*Tuesday 6 September 2016 16:30 (2 hours)*

SageManifolds [1] is an extension of the Python-based modern computer algebra system SageMath [2] towards differential geometry and tensor calculus. We shall use it to perform computations and draw figures regarding neutron star and black hole spacetimes. The School participants are encouraged to install the free software SageMath on their computer prior to the school or to open a free account on the SageMathCloud [3] in order to run SageMath remotely.

[1] http://sagemanifolds.obspm.fr/
[2] http://www.sagemath.org/
[3] http://cloud.sagemath.com/

## Summary

**Presenter:** GOURGOULHON, E. (Observatoire de Paris)

Contribution ID: **17** Type: **not specified**

# Gravitational wave source modeling

*Wednesday 7 September 2016 09:00 (1h 30m)*

Gravitational Wave source Modelling 1: Basic formalism

In this lecture I will present the so-called quadrupole formalism for describing the gravitational wave emission from a neutron star. Within this formalism, General Relativity is treated as a correction to Newtonian physics. I will sketch out the key formulae, and show how they lead to some well known results for the gravitational wave amplitude and luminosity of a source. Insights and formulae from this formalism provide a great deal of our intuition as to how compact objects emit gravitational waves, and are made use of in other lectures in this school.

## Summary

**Presenter:** Dr JONES, I. (University of Southampton)

Contribution ID: **18** Type: **not specified**

# Effect of the Magnetic Field on the Dense Matter EoS

*Wednesday 7 September 2016 14:30 (1h 30m)*

I will present a lecture about the modifications introduced in the EOS of dense by the presence of strong magnetic fields. We know that magnetic fields of up to 10ˆ15 G have been measured on the surface of neutron stars and a field of 10ˆ16 have been measured somewhere inside a neutron star. We speculate further that magnetic fields of more than 10ˆ18 Gauss can exist in the center of massive stars. In this case, the equation of state becomes anisotropic, presenting a larger component of the pressure in the direction parallel to the magnetic field. Eventually, such anisotropy is overturned by the pure field contribution to the pressure, which is larger in the direction perpendicular to the magnetic field and turns the star oblate. Nevertheless, strong magnetic field corrections to the EOS can change the macroscopic properties of stars. First, I will introduce the magnetic field formalism in a relativistic Fermi gas, followed by anomalous magnetic moment corrections, finite temperature, numerical procedures and, finally, results for a more realistic model within the context of general relativity.

## Summary

**Presenter:** Dr DEXHEIMER, V. (Kent State University)

Contribution ID: **19** Type: **not specified**

# General Relativistic Hydrodynamics & Magnetohydrodynamics

*Monday 5 September 2016 14:30 (1h 30m)*

## Summary

**Presenter:** Dr REZZOLLA, L. (Institute for Theoretical Physics, Frankfurt am Main)

Contribution ID: **21** Type: **not specified**

# Gravitational wave source modeling

*Thursday 8 September 2016 11:00 (1h 30m)*

Gravitational Wave source Modelling 2: Applications

In this lecture I will apply the basic formalism described in my previous lecture to the gravitational wave emission from neutron stars in various contexts. In particular I will discuss rotating non-axisymmetric neutron stars, making the connection between neutron star microphysics and possible gravitational wave amplitudes explicit.

**Presenter:** Dr JONES, I. (University of Southampton)

Contribution ID: **23** Type: **not specified**

# Bulk & Shear Viscosities in Nuclear Matter

*Thursday 8 September 2016 16:30 (1h 30m)*

In this lecture I will review the main features of bulk and shear viscosities in application to neutron stars. Starting with the discussion of the main processes contributing to both viscosities in super-dense matter I will proceed to the effects of superfluidity. I will show how the baryon superfluidity affects the functional dependences and values of the coefficients and,
moreover, how it increases the number of bulk viscosity coefficients in hydrodynamic equations. The role of the viscosity in neutron star evolution will also be discussed.

## Summary

**Presenter:** Dr KANTOR, E. (Ioffe Physical-Technical Institute of the Russian Academy of Sciences, St.-Petersburg)

Contribution ID: **24** Type: **not specified**

# Introduction to NS Oscillations & Instabilities

*Friday 9 September 2016 09:00 (1h 30m)*

This lecture provides a detailed discussion of gravitational wave-driven instabilities in neutron stars
and highlights their implications for the photon and gravitational wave astronomy of these objects.

The emphasis is given on the analysis of the (most promising) r-mode and f-mode instabilities: we discuss the, occasionaly exotic, physics that determines their instability "windows", the role they may play in the astrophysics of systems like accreting and newly formed neutron
stars (or strange stars), and the prospects for detection by present and future gravitational wave observatories.

The lecture concludes with a list of key theory assignments/open issues in this research topic.

**Presenter:** Dr GLAMPEDAKIS, K. (University of Tuebingen)

Contribution ID: **25** Type: **not specified**

# NS-NS and BH-NS coalescing binaries

*Friday 9 September 2016 14:30 (1h 30m)*

**Presenter:** Dr FONT, T. (University of Valencia)

Contribution ID: **26** Type: **not specified**

# Bulk & Shear Viscosities in Dense Quark Matter

*Friday 9 September 2016 16:30 (1h 30m)*

I will review and explain calculations of bulk and shear viscosity in various phases of dense quark matter, in unpaired quark matter as well as in color-superconducting phases such as the color-flavor locked phase. I will discuss and interpret the results, which are relevant for instance for the r-mode instability in rotating stars and thus are measurable, at least indirectly, through astrophysical observations.

**Presenter:** Dr SCHMITT, A. (University of Southampton)

Contribution ID: **28** Type: **not specified**

# Introduction to General Relativity

*Tuesday 6 September 2016 09:00 (1h 30m)*

**Presenter:** Dr CARDOSO, V (IST - University of Lisbon)

Contribution ID: **29** Type: **not specified**

# Introduction to Numerical Relativity

*Tuesday 6 September 2016 14:30 (1h 30m)*

**Presenter:** Dr SPERHAKE, U. (University of Cambridge)

Contribution ID: **30** Type: **not specified**

# Gravitational waves: Detection & Anaysis

*Thursday 8 September 2016 09:00 (1h 30m)*

## Summary

**Presenter:** Dr PAPA, M. A. (Max Planck Institute for Gravitational Physics - Hannover)

Contribution ID: **31** Type: **not specified**

# General Relativistic Hydrodynamics & Magnetohydrodynamics

*Tuesday 6 September 2016 11:00 (1h 30m)*

## Summary

**Presenter:** Dr REZZOLLA, L. (Institute for Theoretical Physics, Frankfurt am Main)

Contribution ID: **32** Type: **not specified**

# Wellcome

Contribution ID: **33** Type: **not specified**

# Selected Poster:The liquid-gas phase transition within the temperature-dependent DD-NLD mode

*Friday 9 September 2016 11:00 (30 minutes)*

The equation of state (EOS) of dense matter is essential for modeling compact astrophysical objects and sets the conditions for the creation of chemical elements in the universe. To provide it, we use the generalized DD-NLD relativistic mean-field model (RMF) with density-dependent nucleon-meson couplings and higher-order derivative couplings between nucleons and mesons. The model is extended to describe the properties of homogeneous nuclear and stellar matter at finite temperatures, covering the full range of isospin asymmetries from neutron matter to symmetric and proton matter. The properties of the liquid-gas phase transition for sub-saturation densities and not too high temperatures are studied in comparison to the standard RMF descriptions. Furthermore critical lines and points in the phase diagram can be extracted, and the general features of the phase transitions can be explored.

## Summary

**Presenter:** ANTIC, Sofija (GSI)

Contribution ID: **35** Type: **not specified**

# Selected Poster: Thermodynamic Geodesics of a Supermassive Reissner-Nordström Black Hole

*Friday 9 September 2016 11:30 (30 minutes)*

Abstract: Starting from a Geometrothermodynamics metric for the space of thermodynamic equilibrium states in the mass representation, numerical techniques are used to analyse the thermodynamic geodesics of a supermassive Reissner-Nordström black hole in isolation. Appropriate constraints are obtained by taking into account the processes of Hawking radiation and Schwinger pair-production. It turns out that the relation which the geodesics establish between the electric charge and entropy of the black hole extremises changes in the black hole's mass.

## Summary

**Presenter:** FARRUGIA, Christine

Contribution ID: **36** Type: **not specified**

# Selected Poster

*Friday 9 September 2016 12:00 (30 minutes)*

## Summary

**Presenter:** DOMMES, Vasiliy (Ioffe Institute)