21st International Conference on General Relativity and Gravitation: Plenary Talks

Columbia University in the City of New York

July 10th - 15th, 2016

Contents

Monday, July 11th, 2016

Precision Gravity Tests with Radio Pulsars

9:20 am

Norbert Wex

Max-Planck-Institut für Radioastronomie, Germany

For more than half a century, after its formulation, general relativity (GR) could only be tested in the slow-motion weak-field regime of the Solar system. The discovery of the first binary pulsar in 1974 opened up completely new possibilities for testing our understanding of gravity. For the first time, the gravitational interaction of two strongly self-gravitating objects could be studied. Furthermore, the back reaction of gravitational waves on their emitting source could be examined, by this providing the first evidence for the existence of gravitational waves.

To date there are a number of radio pulsars known, which can be utilized for precision test of GR and its alternatives. Depending on their orbital properties and their companion, these pulsars provide tests for various different aspects of relativistic gravity. In particular, the so-called 'Double Pulsar' has more than lived up to our early expectations.

Ongoing searches for pulsars in orbit around the black hole in the center of our Galaxy could soon provide a unique possibility to probe the spacetime of a supermassive black hole, in particular when combined with other experiments, like the Event Horizon Telescope.

Considerable effort also goes into the combined analysis of a set of the most stable pulsars in the sky. With such a 'pulsar timing array', pulsar astronomers hope to soon be able to observe gravitational waves in the nano-Hertz band.

The talk gives an introduction to gravity tests with radio pulsars, highlights some of the most important results, and gives a brief outlook into the future of this exciting field of experimental gravity.

10:40 am

Building Supermassive Black Hole Binaries

Kelly Holley-Bockelmann
Vanderbilt University, USA

Astronomers now know that supermassive black holes reside in nearly every galaxy. Though these black holes are an observational certainty, nearly every aspect of their evolution – from their birth, to their fuel source, to their basic dynamics – is a matter of lively debate. In principle, gas-rich major galaxy mergers are key to generate the central stockpile of fuel needed for a low mass central black hole 'seed' to grow quickly and efficiently into a supermassive one. When the black holes in each galaxy meet, they form a supermassive binary black hole, the loudest gravitational wave source in the Universe, and a powerful agent to transform the galactic center. This talk will touch on some current and ongoing work on refining our theories of how supermassive black hole binaries grow, evolve within, and alter, their galaxy host.

11:30 am

The Black Hole Stability Problem

Gustav Holzegel
Imperial College London, United Kingdom

I will review recent progress in the black hole stability problem. After discussing different notions of stability (non-linear, linear and mode-stability), the linear wave equation on sub-extremal and extremal Kerr spacetimes will be discussed. In addition, the recently established linear stability of the Schwarzschild solution to gravitational perturbations will be described. Finally, the results in the asymptotically flat case will be contrasted with results in the asymptotically AdS case where many interesting new phenomena occur.

Tuesday, July 12th, 2016

Searching for - and finding! gravitational waves

8:30 am

Gabriela Gonzalez

Louisiana State University, for the LIGO Scientific Collaboration and the Virgo Collaboration, USA

On September 14 2015, the two LIGO gravitational wave detectors in Hanford, Washington and Livingston, Louisiana registered a nearly simultaneous signal with time-frequency properties consistent with gravitational-wave emission by the merger of two massive compact objects. Further analysis of the signals by the LIGO Scientific Collaboration and the Virgo Collaboration revealed that the gravitational waves detected by LIGO came from the merger of a binary black hole (BBH) system. This observation marked the beginning of gravitational wave astronomy. I will describe some details of the observation, the status of LIGO and Virgo ground-based interferometric detectors, and prospects for future observations.

Multimessenger astronomy

9:20 am

Marica Branchesi

Università degli Studi di Urbino “Carlo Bo”, Italy

On September 14, 2015, the first observation of gravitational waves by the Advanced LIGO interferometers opened a new frontier of the observational astrophysics. After a long search, gravitational waves became part of the multi-messenger astronomy allowing us to probe the rich physics of energetic transient phenomena in the sky and to shed light on the formation, evolution and nature of compact objects. Starting from the multi-messenger campaign of GW150914, the talk will give an overview of the astrophysical sources expected to emit transient multi-messenger signals, the network of GW detectors observing together with space and ground-based electromagnetic and neutrino observatories, their observational strategies, and the multi-messenger data analysis. Perspectives and challenges of the multi-messenger astronomy will be presented highlighting the new gravitational-wave messenger detectable by ground-based and space GW detectors.

10:40 am

Clash of the Titans: New Astrophysics of Binary Black Holes from LIGO's First Observations

Samaya Nissanke

Radboud University Nijmegen, the Netherlands

From September 12, 2015 to January 19, 2016, the first observational run of the Advanced LIGO detectors saw the first detections of gravitational waves from binary black holes. In this talk, I will first discuss how to infer and characterise the fundamental properties of the black hole systems. I will then present the tests of general relativity and the implications for astrophysics that are made possible from these measurements. With these gravitational wave detections in hand, I conclude with the unprecedented opportunities and challenges that are opening up in strong-field gravity astrophysics during the next decade.

Wednesday, July 13th, 2016

Quasinormal modes of black holes

8:30 am

Claude Warnick

Imperial College London, United Kingdom

It is well known that an important part of the response of a black hole to an external perturbation is the quasinormal 'ringdown'. The complex frequencies describing the oscillation and decay of fields around the black hole carry information about the spacetime. In recent years much progress has been made to put quasinormal modes on a rigorous mathematical footing. In this talk I will give an overview of these results.

Scanning New Horizons: Information, Holography & Gravity

10:10 am

Rob Myers

Perimeter Institute, Canada

In science, new advances and insights often emerge from the confluence of different ideas coming from what appeared to be disconnected research areas. The theme of my talk will review an ongoing collision between the three topics listed in my title which has been generating interesting new insights about the nature of quantum gravity, as well as variety of other fields, eg, condensed matter physics and quantum field theory.

Asymptotic Safety

11:00 am

Martin Reuter

Massachusetts Institute of Technology, USA

The ultimate goal of the Asymptotic Safety program is the construction of a non-perturbatively renormalizable quantum field theory of gravity. After a general introduction into its basic ideas and the functional renormalization group methods it employs, we discuss various properties the quantum theory must possess beyond renormalizability, and a number of recent results and developments pointing towards the viability of this approach to quantum gravity.

Thursday, July 14th, 2016

Quantum Tests of Gravity

8:30 am

Markus Aspelmeyer
University of Vienna, Austria

It is well known that quantum systems can serve as extremely sensitive probes of gravity. For example, the early pioneering work by Colella, Overhauser and Werner on gravitationally induced quantum interference of neutrons was the first experiment that required the use of both Planck's constant and Newton's constant to describe the observed interference fringes. Over the following decades, modern quantum physics added new tools that significantly expanded the available quantum experiments for testing the effects of weak gravitational fields, including atomic fountains, lab-based atomic clocks or gravitationally bound states of ultracold neutrons. The last few years have seen a renewed interest accompanied by a dramatic increase of experiments and experimental proposals to explore the interface between quantum physics and gravity. On the one hand, quantum optics and cold atom experiments have been pushing the sensitivity of measurements of space and time to unprecedented regimes. For example, squeezed states of light have been shown to increase the sensitivity of interferometric gravitational wave detectors, atomic clocks have reached a precision to detect cm-scale displacements in earth's gravitational field, and atomic fountain experiments can measure Newton's constant with a precision comparable to the best known values to date. On the other hand, the fast progress in macroscopic quantum experiments may soon allow to study large quantum superposition states involving clocks or increasingly massive objects. The latter could open a completely new regime of experiments in which the source mass character of the quantum system starts to play a role. This is reminiscent of Feynman's proposal at the 1957 Chapel Hill Conference on the generation of entanglement through gravitational interaction. I will provide a review of some of the milestone experiments, as well as the current status and challenges for entering the next generation of these experiments.

9:20 am

Symmetries and Conservation Laws in GR *or* How to Grow Hair on a Black Hole

Andrew Strominger
Harvard University, USA

Friday, July 15th, 2016

Gravitational self-force in extreme-mass-ratio binaries

8:30 am

Leor Barack
University of Southampton, United Kingdom

The radiative dynamics in a gravitationally-bound two-body system with a small mass ratio can be described using a perturbative approach whereby corrections to the geodesic motion of the smaller object (due to radiation reaction, internal structure, etc.) are accounted for order by order in the mass ratio, invoking the notion of "gravitational self-force". The ongoing experimental effort to detect gravitational waves has in the past two decades motivated a program to obtain a rigorous formulation of the self-force and apply it numerically to describe the gravitational-wave signature of relevant inspiralling compact objects. I will review the theory of gravitational self-force in curved spacetime, describe how this theory is being implemented today in actual calculations, and discuss current frontiers. I will show results from recent calculations of gauge-invariant post-geodesic effects (like the finite-mass corrections to the rates of periastron advance and spin precession), and highlight the way in which such calculations allow us to make a fruitful contact with other approaches to the two-body problem.

Towards Fundamental Physics from the Cosmic Microwave Background

9:20 am

Hiranya Peiris
University College London, United Kingdom

Surveys of the cosmic microwave background (CMB) carry immense promise for measurements of new physics beyond the Standard Models of cosmology and particle physics. I will present an overview of current cosmological constraints from the CMB, and survey the capabilities of upcoming experiments, taking account of Galactic foregrounds and the effect of lensing by intervening large-scale structure. I will present some recent results that highlight the science enabled by combining CMB data with large galaxy surveys. I will comment on some of the experimental and methodological innovations that are needed to realise the promise of upcoming surveys.

10:40 am

Status of numerical relativity for astrophysical simulations

Masaru Shibata

Kyoto University, Japan

Numerical-relativity simulation for the mergers of binary compact systems composed of neutron stars and black holes and for stellar core collapse to a neutron star or a black hole is the unique approach for predicting gravitational-wave, electromagnetic, and neutrino signals. This field has been developed in the past two decades and now the numerical-relativity simulation has a robust predictability. Indeed, for the first direct detection of gravitational waves from the merger of binary black holes, numerical-relativity simulations play a crucial role. In this talk, I will summarize the current status of this field focusing in particular on the merger of compact neutron-star binaries and stellar core collapse.

11:30 am

Surprises in (nonlinear) strong gravity

Luis Lehner

Perimeter Institute, Canada

Recent years have seen a flurry of activities which have unraveled the behavior of gravity in non-linear regimes. In many instances, these efforts have uncovered surprising and intriguing behavior which have challenged our intuition and opened new research avenues across a number of fronts. This talk will describe a few results obtained through "stress-testing" GR and (some of) their possible consequences.
