PAFT 2016 - Problemi Attuali di Fisica Teorica

Current Problems in Theoretical Physics

XXII Edition - March 18 - 23, 2016

Lloyd's Baia Hotel - Vietri sul Mare (Italy)

Gravitational Waves

Chairperson: V. Ferrari

Tuesday, 22nd March

15:00

GW150914. the first direct detection of gravitational waves

Fulvio Ricci

Sapienza, University of Rome

We report the first direct detection of gravitational waves done by the LIGO and Virgo col- laboration using the two LIGO detectors installed in USA. We summarize the characteristics of the signal and some of the investigations to determine whether GW150914 is consistent with a binary black-hole merger in general relativity.

15:30

How loud are neutron star mergers in the gravitational wave window?

Sebastiano Bernuzzi

University of Parma

Neutron stars in binary systems are among the strongest sources of gravitational waves and among the main targets for ground-based gravitational-wave interferometers Advanced LIGO and Virgo. The observation of these events in the gravitational-wave window can provide us with unique information on neutron stars' masses, radii, and spins, including the possibility to set the strongest constraints on the unknown equation-of-state of matter at supranuclear densities. However, a crucial and necessary step for gravitational-wave observations is the precise knowledge of the dynamics of the sources and of the emitted waveforms. I will talk about recent developments on the modeling of gravitational waves from neutron star mergers using numerical simulations in general relativity.

15:55

Tidal deformations of compact objects and their impact for gravitational-wave astronomy

Paolo Pani

Sapienza, University of Rome

The deformability of a compact object induced by a perturbing tidal field is encoded in the tidal Love numbers, which depend sensibly on the object's internal structure. So far these numbers have been computed only for static, spherically-symmetric objects. We present recent work on the theory of tidal deformability and the tidal Love numbers of a slowly spinning compact object within general relativity. Angular momentum introduces couplings between distortions of different parity and new classes of spin-induced, tidal Love numbers emerge. All tidal Love numbers of a Kerr black hole are exactly zero to first order in the spin and also to second order in the spin, at least in the axisymmetric case. For a binary sys- tem close to the merger, various components of the tidal field become relevant. Preliminary results suggest that spin-tidal couplings can introduce important corrections to the gravita- tional waveforms of coalescing neutron-star binaries, which are one of the main targets of advanced gravitational-wave detectors.

16:20 **Coffee break**

16:50

Relativistic tidal effects in non standard Kerr space-time

Andrea Maselli

University of Tubingen

Astrophysical phenomena involving massive black holes (BHs) in close binaries are expected to leave detectable signatures in the electromagnetic and gravitational-wave spectrum. Such imprints offer the chance to provide precious information to probe the spacetime around rotating BHs, and to reveal new insights on the nature of gravity in the strong-field regime. To support this observational window it is crucial to develop suitable tests to verify the predictions of General Relativity (GR). In this framework, the metric recently proposed by Johannes and Psaltis parametrises strong field deviations from a Kerr spacetime in a theory-independent way. In the following, we make use of this approach to describe the tidal field produced by spinning BHs. We compute the gravito-magnetic and gravito-electric tidal tensors for bodies moving on equatorial circular geodesics, comparing our results with those obtained in the standard GR scenario. Our calculations show significant differences even for distances far form the last stable orbit, which may affect the evolution of the binary and leave detectable signatures.

17:15

Testing gravity with gravitational wave observations

Leonardo Gualtieri

Sapienza, University of Rome

The detection of gravitational waves from the coalescence of a black hole binary system, opens the way to the study of gravity in the strong-field regime, using the most perfect and simple probes: black holes. Since general relativity is mostly untested in this regime, it is of utmost importance to devise tests of gravity, based on the study of gravitational waves emitted by black holes. I will discuss how the quasi-normal modes of black holes, which can be extracted (with some caution) from the ringing tail of the waveform emitted in a binary coalescence, would be affected by the presence of quadratic curvature corrections in the gravitational action.

17:40

Gravitational waves from supermassive black-hole binaries

Enrico Barausse

Institut Astrophysique de Paris/CNRS

I will review the current understanding of the cosmological co-evolution of supermassive black holes and their host galaxies. I will focus in particular on the evolution of the black- hole masses and spins, and on their merger rates. I will discuss the implications for existing gravitational-wave detectors (pulsar timing arrays) as well as for future space-based inter- ferometers such as eLISA.

18:05

Interfacing effective-one-body and numerical relativity results for coalescing binaries

Alessandro Nagar

Institut des Hautes Etudes Scientifiques,IHES France

I will report on recent results about the state-of-the-art effective-one-body (EOB) analytic model developed at IHES concerning two physical systems: (i) the coalescence of (spinning, nonprecessing) black hole binaries (BBHs), showing the performance of the NR-informed, EOBIHES model [PRD 93, 044046], that is able to generate analytical waveforms that are highly faithful with NR data (maximal EOB/NR faithfulness, integrated over the NR frequency range with total mass between 20 and 200 solar masses, ranging between 99.493% and 99.984%, with a median value of 99.944%) from the full transition from the quasi-circular inspiral, through plunge, merger and ringdown; (ii) the coalescence of neutron star (NS) binaries, with particular emphasis on the analytical modelization of tidal effects up to the merger. A class of EOB(NR) waveform templates for coalescing BBHs, similar (though different) to the EOB-IHES ones has been crucially used in the recent analysis of the gravitational wave event GW150914.

Wednesday, 23h March

9:30

Gravitational Wave Astronomy with second generation interferometric detectors

Paola Leaci

Sapienza, University of Rome

After a 5-year redesign and rebuild, the Advanced LIGO gravitational-wave interferometers have begun their first observations on September 12, 2015. In the next years, along with the Advanced Virgo detector, they are expected to make the first direct gravitational-wave detection, opening up breathtaking opportunities for observing the Universe. After shortly reviewing the status of the current ground-based gravitational-wave detectors, I will focus on the most stringent and constraining results obtained to date by the LIGO-Virgo collab- oration. I will describe methodologies used so far and new strategies to be employed in the current long-awaited advanced detector era.

9:55

Search for continuous gravitational waves from spinning neutron stars in the advanced detector era

Cristiano Palomba

Sapienza, University of Rome

Asymmetric spinning neutron stars are among the targets of interferometric detectors of gravitational waves. In this talk I will discuss the status of current searches and what would be the scientific pay-off of detections.

10:20

Massive, massless and ghost modes of gravitational waves from higher-order gravity

Salvatore Capozziello
University of Naples

Linearized field equations of higher order theories of gravity, containing curvature invariants other than the Ricci scalar, are considered. We find that, besides the massless spin-2 field (the standard graviton), theory contains also spin-0 and spin-2 massive modes. We investigate the possible detectability of such additional modes for a stochastic gravitational wave background by ground-based and space interferometer detectors. Finally, we extend the formalism of the cross-correlation analysis, including the additional polarization modes, and calculate the detectable energy density of the spectrum. We find that these massive modes are of interest for direct detection by the LISA experiment.

10:45 **Coffee break**

11:15

Pulsar dynamics in general black-hole spacetimes: spherically symmetric case

Mariafelicia De Laurentis
Inst. of Theor. Physics, Goethe-University, Frankfurt

Pulsar in a compact binary system could help us probe into strong gravitational field situations. One of the relativistic effects that could manifest itself in observations of such pulsars is the precession of the pulsars spin axis due to spinorbit coupling. We derive an analytical formula for the precessional frequency of the spin of a test particle around a nonrotating massive black hole in a general spherically symmetric background, that is not restricted to weak field regions only. Approximate analytical and numerical solutions of the spin precession have been investigated. Finally the observational implications of such a precession are discussed.

11:40

Electromagnetic emission from long-lived BNS merger remnants

Riccardo Ciolfi
University of Trento

Recent observations indicate that in a large fraction of binary neutron star (BNS) mergers a long-lived neutron star (NS) may be formed rather than a black hole. Unambiguous electro- magnetic (EM) signatures of such a scenario would strongly impact our knowledge on how short gamma-ray bursts (SGRBs) and their afterglow radiation are generated. Furthermore, such EM signals would have profound implications for multimessenger astronomy with joint EM and gravitational-wave (GW) observations of BNS mergers, which will soon become reality with the first science runs of the advanced LIGO/Virgo network of ground-based GW detectors already on the way. I will discuss recent numerical relativity simulations of BNS mergers leading to the formation of a long-lived NS and the scenarios that relate such mergers to SGRBs. Moreover, I will present a new model to follow the post-merger evolu- tion of the system and to predict its EM emission in a self-consistent way, bridging the gap between numerical simulations of the merger process and the relevant timescales for SGRB afterglows. I will present the computed lightcurves and spectra and discuss these results in the context of SGRBs, their X-ray afterglows, and multimessenger astronomy.

12:05

Modeling Equal and Unequal Mass Binary Neutron Star Mergers Using Public Codes

Francesco Maione

University of Parma

We present results for three-dimensional simulations of the dynamics of binary neutron star (BNS) mergers from the late inspiral stage and the post-merger up to 20 ms after the system has merged, either to form a hyper-massive neutron star (NS) or a rotating black hole (BH). We report here results for equal and un-equal-mass models and on the strength of the Gravitational Signal and its dependence on the EOS, the total ADM mass and the mass ratio of the two stars.

We use a semi-realistic descriptions of the equation of state (EOS) where the EOS is described by a seven-segment piece-wise polytropic with a thermal component given by th=1.8. One of the important characteristics of the present investigation is that it is entirely performed using only publicly available open source software, the Einstein Toolkit for the evolution and the LORENE code for the generation of the initial models.

12:30

From few to many: the effective interaction approach

Alessandro Lovato

Argonne National Laboratory

In recent years a great deal of effort has been put to use two- and few-body nuclear observables, such as the scattering data and the binding energies of light nuclei, to infer properties of astrophysical objects. In this context, we have developed a nuclear effective interaction and a consistent set of weak-transition operators, suitable to be used in standard many-body perturbation theory. Contrary to other effective interactions, ours reduce to the bare one in the limit of zero density; hence it is well grounded in the few-body systems. I will briefly discuss some applications of the effective interaction formalism to observables relevant for neutron stars and supernovae.

12:45

Gravitational waves from proto-neutron stars evolution

Giovanni Camelio

Sapienza, University of Rome

We determine the time variation of the rotation rate of a proto-neutron star (PNS) due to contraction and neutrino angular momentum loss in the first 10 seconds after the core bounce. We find that the mass shedding limit restricts the initial angular momentum, and- consequently the final rotation rate must be smaller than about 300Hz for a PNS of 1.6 solar masses. We also determine the gravitational wave signal that the PNS (assumed to be non- axisymmetric) emits as it contracts and speeds up, and discuss its detectability by advanced and future ground-based interferometric detectors. These results are obtained using a new code we have developed, which describes the PNS evolution. The code integrates the neutrino number and energy transport equations together with the relativistic stellar structure equations. The neutrino cross sections are determined consistently with the underlying EoS.

13:05

Multi-Messenger Astronomy with gravitational waves and electromagnetic transients

Giuseppe Greco
Urbino University

Advanced LIGO's first observing run (O1) was successfully concluded on January 2016 after about four months of operation. About sixty participating groups with access to ground- and space-based facilities were prepared to respond to a gravitational wave candidate alert.
The purpose of this large effort is to identify electromagnetic signals of gravitational wave candidates. The electromagnetic spectrum of detectable gravitational wave sources such as core-collapse supernova (SNe) and stellar-mass compact binary coalescences (CBCs) spans a wide range of wavelengths. This makes them among the most suitable candidates for searching for electromagnetic counterparts. Here, we will give an overview of the O1 follow-up activity.