GR 7: Cosmo I, Relastro II, GW II

Time: Wednesday 13:30–15:50 Location: ZHG008

GR 7.1 Wed 13:30 ZHG008

Backreaction and Cosmic Butterflies: what simulations can tell us about inflation — •Angelo Caravano — Institut d'Astrophysique de Paris, France

In this talk, I will describe how lattice simulations can improve our understanding of the inflationary epoch of the Universe. I will focus on two examples: first, a model of axion inflation where the inflaton couples to a gauge field via a Chern-Simons interaction; and second, a single-field inflation model with a localized deviation from slow-roll. I will demonstrate how nonlinear effects significantly impact the inflationary dynamics and their predictions, even in cases conventionally believed to be under perturbative control. This makes lattice simulations essential for interpreting both large-scale observables (like large-scale structure and the CMB) and small-scale observables (such as primordial black holes and gravitational wave backgrounds).

GR 7.2 Wed 13:50 ZHG008

Non-linear structure formation in Horndeski gravity — •Ashim Sen Gupta — Bielefeld University, Bielefeld, Germany

Precision cosmology is poised to enter a new era with the advent of Stage IV surveys, such as the Legacy Survey of Space and Time (LSST) and the Euclid satellite. With it will come the ability to probe scales of the universe where non-linear gravitational physics plays a strong role in the formation of large-scale structures (LSS). This provides an opportunity to constrain the elusive set of Modified Gravity (MG) theories with screening mechanisms, theories which can evade classical tests of General Relativity (GR). In this talk, I shall discuss my development of the hybrid particle-mesh code, Hi-COLA. It can rapidly simulate matter clustering for the Horndeski class of scalar-tensor theories. I will also discuss the phenomenology uncovered through the use of Hi-COLA, and present an analysis of the effects that give rise to the enhancements of the Horndeski matter power spectrum relative to GR. I shall additionally touch on my work to extend the scope of Hi-COLA to include the rarely-simulated K-mouflage gravity. Finally, I will conclude with an evaluation of the cutting edge in numerically predicting matter clustering for modified gravity, through which we will see the promise in the prospects of bridging theory and observation that will enable the application of Stage IV constraints.

GR 7.3 Wed 14:10 ZHG008

Resolving σ_8 tension with time-varying gravitational constant — •Tilek Zhumabek[1], Azamat Mukhamediya[2], Hrishikesh Chakrabarty[1], and Daniele Malafarina[1] — [1]Department of Physics, School of Sciences and Humanities, Nazarbayev University, Astana 010000, Kazakhstan — [2]Department of Electrical and Computer Engineering, School of Engineering and Digital Sciences, Nazarbayev University, Astana 010000, Kazakhstan

We consider a modified gravity model, dubbed GCDM, with running gravitational constant $G(a)$, to test its imprints on the growth of structure. Using Redshift Space Distortion (RSD) measurement results, we show a tension at the 3σ level between the best fit ΛCDM and the corresponding Planck18/ΛCDM parameters ($w_0 = -1$, $\Omega_m = 0.31$, $\sigma_8 = 0.81$). Unlike many modified gravity based solutions that overlook the scale dependence and model specific background evolution, we study this problem in the broadest possible context by incorporating both factors into our investigation. We obtain the model specific background quantities and perform a full perturbation analysis of the model to demonstrate a scale dependence in the growth equation. Fixing the scale to $k = 0.1h$ Mpc^{-1} and introducing a specific functional form for $G(a)$ with one free parameter, we conducted likelihood analysis of RSD selected data. This analysis reveal that GCDM can bring the tension level within 1σ while maintaining the deviation from Newton's gravitational constant at the fifth order.

GR 7.4 Wed 14:30 ZHG008

Tidal resonances of stars in precessing orbits around a spinning black hole — •Matteo Stockinger[1] and Masaru Shibata[1,2] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Am Mühlenberg 1, D-14476 Potsdam-Golm, Germany — [2]Center for Gravitational Physics and Quantum Information, Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, 606-8502, Japan

Tidal disruptions of stars on the equatorial plane orbiting Kerr black holes have been widely studied. However thus far, there have been fewer studies of stars in inclined precessing orbits around a Kerr black hole.

We use the tensor virial equations to analyze perturbatively the influence of the precession on the star.

We show the presence of possible resonances in these systems for typical physical parameters of black hole-neutron star binaries in close orbits or of a white dwarf/an ordinary star orbiting a supermassive black hole.

This suggests the presence of a new instability before the tidal disruption limit is encountered in such systems.

GR 7.5 Wed 14:50 ZHG008

Simulating Relativistic Binary-Single and Binary-Binary Encounters — •Felix Heinze and Bernd Brügmann — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

The motion of N bodies under their mutual gravitational interaction has been a central problem in astrophysics and celestial mechanics for centuries, dating back to 1687, when Isaac Newton published his Principia. Despite centuries of progress, gravitational N-body systems remain a rich and active field of research, with binary-single and binary-binary encounters forming an important subset of interest in astrophysics. For N>2, even Newtonian systems generally defy analytical solutions, exhibiting complex dynamics and chaotic behavior. For the problem of N black holes moving in close proximity and at high speeds, relativistic effects must be taken into account, introducing additional complexity to the solutions.

In this talk, we will present the first results of a series of fully relativistic simulations of black hole binary-single and binary-binary encounters using the numerical relativity code BAM. These simulations reveal intricate dynamics and characteristic waveforms that are absent in (Post-)Newtonian N-body simulations or fully relativistic simulations limited to two black holes. The results highlight the importance of relativistic effects in shaping the outcomes of close black hole interactions and provide new insights into their gravitational wave phenomenology.

GR 7.6 Wed 15:10 ZHG008

Stochastic gravitational wave background from Cosmic B-L Symmetry breaking — •Alexander Schneider, Gudrid Moortgart-Pick, and Tom Krokotsch — University of Hamburg, Hamburg, Germany

The stochastic gravitational wave background could be a window in the early universe, possibly even before the decoupling of the cosmic microwave background. Studying in detail such a stochastic gravitational background is therefore also a possible way to find physics beyond the standard model.

A proposed background rises due to the spontaneous B-L symmetry breaking, occurring around the grand unification scale in certain cosmogical models.

In the talk, we concentrate in particular on the question, whether the gravitational waves produced in such an event could be detected with future high frequency detectors.

GR 7.7 Wed 15:30 ZHG008

Scattering and dynamical capture of two black holes — •Simone Albanesi — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — INFN sezione di Torino, Torino, 10125, Italy

All gravitational wave (GW) events detected by the LIGO-Virgo-KAGRA collaboration have been generated by the coalescence of compact binaries, mostly binary black holes. The dynamics of these systems typically circularize by the time they enter the detector's sensitivity band, resulting in signals with monotonically increasing frequency. However, dense astrophysical environments, such as globular clusters, may host populations of black holes undergoing scatterings and dynamical captures, resulting in significantly richer phenomenologies that strongly deviate from the quasi-circular scenario. Full Bayesian analysis suggest that the event GW190521 may have originated from such a system, highlighting the need for accurate descriptions to fully exploit the scientific potential of current and future gravitational wave detectors. We study scatterings and dynamical captures for comparable mass spin-aligned systems, using the semi-analytical effective-one-body model TEOBResumS-Dalí and numerical relativity simulations performed with the code GR-Athena++. We focus, in particular, on the transition from unbound to bound orbits in the low energy regime. Challenges and future steps, both on the numerical and analytical fronts, are also discussed.