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Editorial

Editorial to the Special Issue "Inflation, Black Holes and Gravitational Waves"

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This Special Issue concerns inflation, black holes and gravitational waves. The detections of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) Scientific Collaboration, Virgo Collaboration and Kamioka Gravitational Wave Detector (KAGRA) Collaboration (LVK) not only make it possible to probe gravitational theory in the strong and nonlinear regions, but also open a new window to understand the cosmic evolution, the formation of compact objects such as black holes and neutron stars, and the nature of gravity. Among the 90 detected gravitational-wave events so far, most are binary black-hole coalescences. The mass of the primary black hole in three binary black holes has a solar mass of more than 80, and the mass of the merged final black hole in 10 binary black holes has a solar mass greater than 80. There are also several events with the secondary black hole with masse less than 3 solar mass. Due to the pair instability, it a reasonable mass range for stellar-origin black holes is thought to be of around 3–70 solar mass, and there exists a gap in the mass spectrum of black holes between 80–120 solar mass. Therefore, black holes with a mass of larger than 80 solar mass or smaller than 3 solar mass observed from gravitational wave detections may provide evidence of a primordial black hole. During the radiation dominated era, if the density contrast of an overdense region in a small scale at the horizon reentry is greater than the threshold value, then primordial black holes are formed through gravitational collapse in the overdense region. The large density contrast may originate from large primordial scalar perturbations in small scales generated during inflation. This Special Issue aims to bridge inflation, black holes and gravitational waves, and therefore focuses on inflationary models, quantum gravity effects in inflationary observables, the production of primordial black-hole dark matter and secondary gravitational waves, black hole physics, gravitational waves in modified gravity and the constraints on modified gravity by gravitational waves, gravitational wave cosmology, and gravitational wave physics.

Since the observations of the cosmic microwave background radiation anisotropies constrain the amplitude of the primordial power spectrum to 10^{-9} at large scales, and the production of significant primordial black hole dark matter and secondary gravitational waves requires the amplitude of primordial power spectra to be around 0.01, some mechanisms are required to enhance the power spectrum at small scales. One such mechanism is ultra-slow-roll inflation, which is a special case of the constant-roll inflation. In [1], the authors discuss the apparent duality between large and small η_H in constant-roll inflation. They found that the evolutions of both the background and the scalar perturbations are different for large and small η_H, so the duality between large and small η_H in constant-roll inflation does not exist. They also found the constraints on both small and large η_H from observations.

Currently, there are a number of inflationary models that satisfy the observational constraints from the measurements of the cosmic microwave background radiation. Furthermore, some inflationary models have attractor behaviors for the observables n_s and r, this further imposes a challenge to distinguish different models. The observational constraints on n_s and r and the inflationary attractors suggest that there exist some universal relationships between the observables n_s and r and the number of e-folds N before the

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end of inflation. By parameterizing the slow-roll parameters or observables n_s and r with N, we can reconstruct inflationary potentials. In [2], discus the reconstruction procedure for inflation models with the non-minimal derivative coupling term is discussed, and the study reconstructed the non-minimal derivative coupling inflationary potential by parameterizing the tensor-to-scalar ratio r. Because the observational data only probes large scales, the reconstructed potentials approximate the inflationary potential in the slow-roll regime only at large scales.

Inflation is usually driven by a scalar field, which is described by the low-energy effective field theory. The effective field theory can be valuable if it can be successfully embedded in a theory of quantum gravity such as the superstring theory. The embedding requires the scalar field to satisfy two swampland conditions. The first swampland criterion requires the tensor-to-scalar ratio to be small while the second swampland criterion requires either large tensor-to-scalar ratio r or large scalar spectral index n_s. The single-field slow-roll inflation is generically in tension with the swampland criteria. In [3], Gauss-Bonnet inflation with the coupling function inversely proportional to the potential is proposed, so as to satisfy both the swampland conditions and the observational constraints imposed from the measurements of the cosmic microwave background radiation. The model overcomes the challenge imposed by the swampland criteria through the modification of the relationship between the tensor-to-scalar ratio and the slow-roll parameters.

Based on the area law of the black hole entropy, the holography principle is proposed to understand quantum gravity effect. The holographic principle was further evident by the Anti-de Sitter/Conformal field theory correspondence. The recent developments on the holographic entanglement entropy suggest that we could use quantum information theory to understand quantum gravity theory, but most discussions are limited in Anti-de Sitter spacetime. In [4], possible relations between de-Sitter universe and quantum information theory are discussed, and the study showed that the complexity of a tensor network can be regarded as a Fisher information measure of a de Sitter universe.

At high energy scales, the Lorentz invariance may be violated, i.e., the Lorentz invariance may be an emergent property of low energy physics rather than a fundamental symmetry. The Einstein aether theory is a gravitational theory that does not use Lorentz invariance. In [5], the spherically symmetric, static and time-dependent spacetimes in Einstein aether theory in the isotropic, Painlevè-Gullstrand, and Schwarzschild coordinates are discussed, and the study found several exact vacuum solutions in closed forms.

The above papers present state-of-the-art progress in the fields of inflation, black hole and gravitational waves. The Guest Editors of this Special Issue hope that it will make a useful contribution to the field and stimulate new and important research directions.

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