Oral Session

T1	Nami Uchikata	Niigata University
Analysis of echoes by a new template		
If the black hole event horizon is surrounded by a reflecting mirror, which is motivated by the quantum effect, the final part of the waveform of a binary black hole merger will be iteratively emitted, which can be observed as echoes. We analyze LIGO binary black hole merger event(s) using echo templates where the black hole linear perturbation effect is taken into account to the reflection rate of each echo, and evaluate the significance.		

T2	Takahiro Yamamoto	Kyoto University
Analysis of Ringdown Gravitational Wave by Neural Network		
Ringdown is the final part of the gravitational wave from binary black hole coalescence. It is occupied with the black hole quasi-normal mode (QNM).In General Relativity, QNM frequency and damping time are uniquely determined from the spin and mass of the remnant black hole. For this property, ringdown gravitational wave is expected to be useful for the test of the General Relativity or other gravity theories. The matched filtering is the standard method for the gravitational wave data analysis. But, for the ringdown, there are some ambiguity when ringdown is start and how rapid inspiral part fade out. Therefore, it is not clear whether the matched filtering is the optimal method for the analysis of the ringdown graviational wave. We participate in the mock data challenge project. Comparing the matched filtering, the neural network can estimate QNM frequency with the competitive error. If possible, we will discuss the improvement of the neural network method.		

T3	Hiroki Takeda	University of Tokyo
Polarization test of gravitational waves from compact binary coalescences		
Gravitational waves have only two tensorial polarization modes in general relativity. However, there are four possible nontensorial polarization modes in addition to two tensorial modes in a general metric theory of gravity. Thus, polarization tests of gravitational waves can be strong tools for probing into the nature of gravity and space-time structure. We study the separability of the polarization modes for the inspiral gravitational waves from the compact binary coalescences systematically. It is necessary to consider the binary parameters properly to separate the polarization modes unlike some other waveforms. We show the degeneracies and the correlations among the binary parameters in a realistic waveform of compact binary coalescences in the presence of nontensorial polarization modes.		

T4	Haruka Suzuki	Waseda university
The Effect of Kozai-Lidov Mechanism on the Period Shift of the Binary Neutron Stars by Gravitational Waves		
Orbital period of a binary neutron star decreases with the emission of the gravitational waves. The most famous example is the Hulse-Taylor binary, which is the first evidence of the existence of the gravitational waves. We investigated how such orbital period shift changes with the effect of the outer third body by numerical simulation. We especially focused on the effect of the Kozai-Lidov mechanism, which is the secular exchange of the orbital eccentricity and inclination in the inner orbit of hierarchical triple with inclined outer orbit. In our simulation, the effect of Kozai-Lidov mechanism is clearly seen in the cumulative shift of the periastron time.		

T5	Asuka Ito	Kobe University
A strategy for detecting the bispectrum of stochastic gravitational waves		
The bispectrum of primordial gravitational waves is one of the keys to probe the early universe and the beyond standard model. In this talk, I give a method for detecting bispectra of stochastic gravitational waves. Generally, bispectra form a momentum triangle because of homogeneity of the universe. I show that an optimal filter function enables us to extract a specific configuration of the momentum triangle from the correlation of the signals. Applying this method to the pulsar timing array gravitational wave detector, as an concrete example, I argue about the dependence of positions of three pulsars to the sensitivity, which is called the overlap reduction function in the case of power spectra.		

T6	Osamu Seto	Hokkaido University
Gravitational waves from seesaw phase tranistion		
The U(1)B-L gauge symmetry is a promising extension of the standard model of particle physics, which is supposed to be broken at some high energy scale. We show that the first order phase transition of the U(1)B-L gauge symmetry breaking can generate a large amplitude of stochastic gravitational waves (GWs) radiation for some parameter space of the model, which is detectable in future experiments.		

T7	Naonori Sugiyama	Kavli IPMU
Limits on primordial statistical anisotropy from large-scale structure		
We measure statistically anisotropic signatures imprinted in three-dimensional galaxy clustering. We then constrain a well-known quadrupolar anisotropy parameter g_* in the primordial power spectrum. Such an anisotropic signal is easily contaminated by artificial asymmetries due to specific survey geometry. We precisely estimate the contaminated signal and finally subtract it from the data. Using the galaxy samples obtained by the Baryon Oscillation Spectroscopic Survey Data Release 12, we find $-0.09 < g_* < 0.08$ with a 95% confidence level. This result is the best constraint on the quadrupolar parameter from galaxy survey data currently.		

T8	Hayato Fukunaga	Nagoya University

Flapping resonance instability of axions and prospects on gravitational wave forest

It was recently shown that string axions in wide mass range can be probed through multi wavelength observations of gravitational waves (GWs), dubbed gravitational wave forest. Inhomogeneous modes of axions can grow rapidly through resonance instabilities such as the flapping resonance and the conventional parametric resonance just after axions commence to oscillate. Among these instabilities, the flapping resonance leads to a rather efficient growth of the inhomogeneity and succeedingly to copious emissions of GWs. We discuss conditions that the flapping resonance instability persistently continues, considering various potentials and various initial conditions of axions. We show that for a certain class of potentials, the duration of flapping resonance is predominantly determined by the Hubble parameter at the begging of oscillation. We also discuss whether the flapping resonance can take place for the conventional cosine potential of axions.

T9	Toyokazu Sekiguchi	RESCEU, University of Tokyo

Long-term dynamics of axion strings

We present the results of our recent cosmological simulation of axion strings. The QCD axion is one of the promising candidates of dark matter (DM). Radiation from the axion strings is the primary production mechanism of the axion DM when the Peccei-Quinn symmetry breaking occurs after inflation. However, the dynamics of axion strings is not yet well-understood, and the theoretical prediction on the axion DM abundance from strings remains uncertain. Our simulation have found that the string parameter (i.e. the average number of strings per horizon) grows logarithmically in time, which confronts the scaling property of string networks, that has been assumed in the literature. We discuss possible causes of the logarithmic growth of the string parameter and implications for direct detection experiments of the axion.

T10	Emi Masaki	Kobe University

Axion-Photon Conversion in the Presence of Oscillating Axion Background

In the presence of background magnetic fields, it is well known that axion and photon can mix with each other. Moreover, it is also well known that propagating photon in the oscillating axion fields can be unstable. In this talk, I will discuss how will photon propagate in the situation where magnetic fields and oscillating axion fields coexist. Examples of such situation include galaxies and cluster of galaxies. There is a possibility that it can affect the observation of the electromagnetic waves.

T11	Ryo Kato	Kobe University

Searching for the axion dark matter with pulsar timing arrays

The axion dark matter is an ultralight scalar field with mass $m = 10^{-23} - 10^{-22}$ eV. The axion dark matter induces oscillations of gravitational potential, which is in the sensitive frequency range of pulsar timing arrays. Using the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) 11-year Data Set, we perform the analysis to search for the axion dark matter. We could not find any obvious evidence of axion dark matter signals in the data by calculating the Bayes factor. Then we set the upper limit for the energy density of the axion dark matter. The obtained upper limit is slightly better than the previous pulsar timing array upper limit. Furthermore, we confirm that the value of the Bayes factor highly depends the Solar System ephemeris error, as pointed out in a previous paper by the NANOGrav.

T12	Hiromasa Nakatsuka	ICRR,UTokyo

Primordial black holes in an axion-like curvaton model

We analyze the primordial black hole (PBH) formation mechanism in an axion-like curvaton model with a coupling to inflaton. Our model produces enough amount of PBHs to explain the black hole binaries observed in LIGO-Virgo collaboration or PBHs as dark matter. We numerically calculate the PBH mass spectrum, the curvature perturbation and the secondarily produced gravitational waves to compare them with the current constraints. In this talk, we also discuss the detailed analysis of the non-Gaussian effects on the PBH formation.

T13	Kensuke Akita	Tokyo Institute of Technology

Affleck-Dine baryogenesis in the SUSY DFSZ axion model without R-parity

We investigate the baryon asymmetry in the SUSY DFSZ axion model without R- parity. It turns out that the R-parity violating bilinear terms economically explain the atmospheric mass-squared difference of neutrino and the appropriate amount of baryon asymmetry through the Affleck-Dine mechanism. In this model, the axion is a promising candidate for the dark matter and the axion isocurvature perturbation is mildly suppressed due to the large field values of Peccei-Quinn fields. Remarkably, in some parameter region explaining the baryon asymmetry and the axion dark matter abundance, the proton decay will be explored in future experiments.

T14	Fabio Chibana	Tokyo Institute of Technology

Redshift space distortions in the presence of non-minimally coupled dark matter

The existence of dark matter and dark energy is indicated (and ever required) by several cosmological observations. Given our current lack of knowledge regarding the fundamental nature of these components, one can consider a non-minimal coupling between them, and it is important to test whether such a coupling is allowed or not. The coupling affects the formation of structure in our universe, hence it might be probed by experiments. In this talk, we will explore cosmological models in which dark matter and dark energy interact with each other, and will discuss how future galaxy surveys may provide us with information about the coupling.

T15	Katsuki Aoki	Waseda University

Ghost-free scalar-tensor theories in metric-affine formalism

We study scalar-tensor theories respecting the projective invariance in the metric-affine formalism and discuss a relation between the ghost-freeness of the theories and the symmetry. The metric-affine formalism is a formulation of gravitational theories such that the metric and the connection are independent variables in the first place. In this formalism, the Einstein-Hilbert action has an additional invariance, called the projective invariance, under a shift of the connection. We find that the general projective invariant Lagrangian, which is constructed by a single scalar field, the curvature tensor, and the metric up to quadratic in the connection, is equivalent to the quadratic U-degenerated theory and thus it is ghost-free. In particular, if the self-interactions of the scalar field are given by the (generalized) Galileon forms, the Lagrangian is reduced to the degenerated higher-order scalar-tensor theory.

T16	Keigo Shimada	Waseda University

Inflation in Metric-affine Gravity

Metric-affine formalism is a formalism when the considered independent variables of gravity are not only the metric but also the connection. In this talk, inflation with a 'minimally' coupled scalar, which is constructed through the metric-affine approach, will be introduced. After the review of the metric-affine formalism in General Relativity, a simple extension of a minimally coupled scalar to metric-affine gravity will be proposed. This theory will be formulated in three ways that are equivalent in GR; a projective invariant action, a torsionless connection, and a metric compatible connection. Certain parameters could satisfy observational constraints of the CMB and thus theories that are neglected in the metric formalism could be resurrected in the metric-affine formalism and becomes a viable candidate for inflation. One could conclude that the metric-affine approach is an important formalism to consider when extending theories of gravity.

T17	Zhi-Bang Yao	School of Physics and Astronomy, Sun Yat-Sen University

Spatially Covariant Gravity with Velocity of the Lapse Function

We investigate a large class of gravity theories that respect spatial covariance, and involve kinetic terms for both the spatial metric and the lapse function. Generally such kind of theories propagate four physical degrees of freedom, one of which is a ghost mode. Through a detailed Hamiltonian analysis, we derive two conditions that Lagrangian must satisfy in order to ensure that there are at most three physical degrees of freedom. We also give an explicit example to show how our formalism works.

T18	Aya Iyonaga	Rikkyo University

Extended Cuscuton: Formulation

Many scalar-tensor theories have more than 2 degrees of freedom because of additional scalar fields. However, there is a theory called "cuscuton" whose number of degrees of freedom is only 2 on a cosmological background. We construct more general theories with 2 degrees of freedom from the Horndeski and beyond Horndeski theories. We also study cosmological perturbations in this extended cuscuton theory(this part will be shown by Takahashi-san's presentation).

T19	Kazufumi Takahashi	Rikkyo University

Extended Cuscuton: Cosmology

Among single-field scalar-tensor theories, there is a special class called "cuscuton," which is represented as some limiting case of k-essence in general relativity. This theory has a remarkable feature that the number of propagating degrees of freedom is only two in the unitary gauge in contrast to ordinary scalar-tensor theories with three degrees of freedom. We specified a general class of theories with the same property as the cuscuton in the context of the beyond Horndeski theory, which we dub as the extended cuscuton (for its formulation, see the previous talk by Aya Iyonaga). In this talk, we study cosmology in the extended cuscuton models.

T20	Mai Yashiki	Yamaguchi Univ.

Cosmological viability of the unified models of inflation and dark energy in f(R) gravity

We research the unified model of inflation and dark energy in the model $f(R) = R + \alpha R^n - \beta R^m$. In this research, we investigate the cosmological evolution from the radiation dominated era to matter dominated era. As a result, we obtain the observational constraint of the parameter m by using time-varying equation of state w.

T21	Shin'ichi Hirano	Rikkyo University

Cosmological implication of DHOST theory

We focus on the viable models in the DHOST theory which can be applied to dark energy. We calculate the cosmological perturbations at a linear level and non-linear level. At the former level, the evolution equations of the density contrast has an additional friction term. The linear growth rate could be decrease compared to that of the LCDM model. At the later level, the integral kernel of the matter bispectrum has a new terms which induce the folded shape non-Gaussianity. We consider the analytic models of the DHOST theory which are satisfied with the tracker condition suggested in de Feclice and Tsujikawa (2011) only in the matter-dominated era. In this talk we discuss the observables in these models and the typical behavior of these.

T22	Shintaro Nakamura	Tokyo University of Science,

Observational constraints with integrated Sachs-Wolfe effect on generalized Proca theories

The integrated Sachs-Wolfe (ISW) effect contributes to the anisotropy of cosmic microwave background (CMB) on large scale. The detection of the ISW effect is difficult since the amplitude of the ISW effect is relatively small in the CMB power spectrum. However, by considering the cross-correlation between the CMB anisotropy and the galaxy number density fluctuations, we can isolate the part related to the ISW effect. This property become the probe of dark energy models. We discuss the key of the sign of ISW-galaxy cross-correlation, and we find that it is not only the effective gravitational coupling but also the quantity characterizing the weak lensing potential. In order to obtained the observational constraints for the dark energy models within the framework of generalized Proca theories, we run the Markov-Chain-Monte-Carlo code with the observational data of CMB, baryon acoustic oscillations, supernovae type Ia, local measurements of the Hubble expansion rate, redshift space distortion, and ISW-galaxy cross-correlation. As a results, even if we require the speed of gravitational wave is equivalent to 1, we find that the model is still favored over the Λ-Cold-Dark-Matter (ΛCDM) model. Existence of the additional parameter to those in the ΛCDM model allows to reduce tensions of the Hubble constant between the CMB and the low-redshift measurements.

T23	Hayato Motohashi	Yukawa Institute for Theoretical Physics, Kyoto University

Shape dependence of spontaneous scalarization

Spontaneous scalarization is an interesting mechanism for modification of gravity at high density region. We perform the stability analysis around background General Relativity solution for spherically symmetric profile as well as planar symmetric profile, and clarify that the spontaneous scalarization occurs much easily for the planar symmetric profile compared with the spherically symmetric profile.

T24	Masato Minamitsuji	Center for Astrophysics and Gravitation (CENTRA), University of Lisbon

Scalarized black holes in the presence of the Gauss-Bonnet coupling

It is well-known that the coupling of the scalar field to the matter inside a relativistic star triggers a tachyonic instability, and spontaneously scalarizes it. Recently, it was shown that in the presence of the coupling of the scalar-field to the Gauss-Bonnet gravity a similar tachyonic instability can also be triggered in the higher curvature regions around a vacuum black hole and scalarizes it. For the certain range of the parameters, new branches of hairy black hole solutions with the nontrivial profile of the scalar field appear, which are characterized by the number of nodes. It was recently pointed out, however, that scalarized black holes in the original model with the quadratic order Gauss-Bonnet coupling are unstable against the radial perturbations. Thus, there would be the two possibilities as the endpoint of the unstable scalarized black holes; The first is that such an instability is terminated by some higher order couplings of the scalar field or the curvature and ends up with a new stable black hole, and the second is that it ends up with a singularity for any kind of any higher order corrections. We will investigate the scalarized black holes in the presence of the quartic order the Gauss-Bonnet coupling as well as the quadratic one considered previously, and clarify whether and how the higher order coupling modifies the properties of each branch of hairy black holes and the stability.

T25	Yuya Nakamura	Hirosaki University

Slowly-rotating, Weakly-Gravitating Objects in dynamical Chern-Simons gravity and Constraints with Gravity Probe B

We study the gravitational field produced by an isolated, weakly self-gravitating ob ject with a uniform mass density and a constant angular velocity in the dynamical Chern-Simons gravity through the small-coupling and the post-Newtonian approximations. We find that the asymptotic peeling-off behavior of the exterior fields is consistent with that found for black holes and neutron stars, as well as for non- relativistic objects, with overall coefficients that are different and dependent on the structure of the weak-field source. We then use these fields to study the effect of dynamical Chern-Simons gravity on the spin precession of gyroscopes in orbit around Earth. Contrary to prior expectations from the analysis of the non-dynamical theory, we find that the dynamical Chern-Simons corrections to spin precession due to the spin of Earth on the gyroscope does not vanish and is in the same direction as the Lense-Thirring effect of General Relativity. We then use the results of the Gravity Probe B experiment, which verified the General Relativity prediction of the Lense- Thirring effect, to put a constraint on the dynamical Chern-Simons coupling strength that is comparable to current constraints.

T26	Masato Nozawa	Yukawa Institute for Theoretical Physics, Kyoto University

On the uniqueness theorems of static black holes

Equations of divergence type in static spacetimes play a significant role in the proof of uniqueness theorems of black holes. We generalize the divergence equation originally discovered by Robinson in four dimensional vacuum spacetimes into several directions. We propose a new tensor desribing a deviation from spherical symmetry, which is a useful clue for constructing a divergence equation.

T27	Antonino Flachi	KEIO University

Toying with Symmetry Breaking in Curved Space

Curvature is known to alter the patterns of symmetry breaking with positive curvature leading to an enhancement of disorder, and negative curvature showing the opposite tendency. In this talk I will show that this is not necessarily the case and present an amusing $(2+1)$-dimensional example where a positive curvature is accompanied by a tendency towards order.

T28	Sirachak Panpanich	Chulalongkorn University

Fitting rotation curves of galaxies by de Rham-Gabadadze-Tolley massive gravity

We investigate the effects of massive gravitons on the rotation curves of the Milky Way, spiral galaxies, and Low Surface Brightness (LSB) galaxies. Using a simple de Rham, Gabadadze, and Tolley (dRGT) massive gravity model, we find a static spherically symmetric metric and a modified Tolman-Oppenheimer-Volkoff (TOV) equation. The dRGT nonlinear graviton interactions generate density and pressures which behave like a dark energy that can mimic the gravitational effects of a dark matter halo. We find that rotation curves of most galaxies can be fitted well by a single constant-gravity parameter $\gamma \sim m_g^2 C \sim 10^{-28}$ m^{-1} corresponding to the graviton mass in the range $m_g \sim 10^{-21} - 10^{-30}$eV depending on the choice of the fiducial metric parameter $C \sim 1 - 10^{18}$ m. Fitting the rotation curve of the Milky Way puts a strong constraint on the Yukawa-type coupling of the massive graviton exchange as a result of the shell effects.

T29	Michele Oliosi	Yukawa Institute for Theoretical Physics, Kyoto University

Black holes and stars in the Minimal Theory of Massive Gravity

Black holes are notoriously hard to achieve in massive gravity, due among others to strong coupling issues. In this talk, I will show how the minimal theory of massive gravity (MTMG) allows to bypass this limitation. In particular, I will show how any solution of general relativity that can be rendered spatially flat by a coordinate change is also a solution of the self-accelerating branch of the MTMG, with or without matter. This allows, for the first time, to obtain black hole and stars solutions in a theory of massive gravity that agree with the corresponding solutions in general relativity and that are free from the aforementioned issues.

T30	Andrea Nerozzi	Instituto Superior Técnico

Tetrad formalisms and gauge fixing for binary black hole simulations

With the recent detection of gravitational waves and the expected improvements in accuracy of future experiments, it is of primary importance that numerical simulations achieve higher degrees of accuracy as well. For example, the process of extracting gravitational waveforms from a binary black hole numerical simulation can be still subject by possible systematic errors, mostly because of the gauge freedom that is encountered along the way. The most used approaches to study numerically Einstein's equations are based on 3+1 decompositions of the space-time. However, when extracting the physical outcome, tetrad approaches are employed to guarantee gauge independence. I will first present the state of the art techniques currently employed in numerical relativity. Next, I will describe the work in progress to promote tetrad approaches with appropriate gauge fixing as a stand-alone machinery to study Einstein's equations and binary black hole simulations analytically and/or numerically.

T31	Kazuma Takahashi	Osaka City University

Imaging of gravitational collapsing star by numerical simulation

In this study, we numerically obtained the image of a spherically symmetric dust which is gravitational collapsing with emitting light from its surface through the ray-tracing method. Our numerical calculations showed that even in the late stage of the gravitational collapse, the light rays through the rim of the image of the dust sphere does not suffer the redshift at all, although other light rays suffers large redshift. Hence, if the collapsing dust sphere emits photons with a continuous spectrum like blackbody one, the shape of the spectrum is preserved in time, although the luminosity decreases monotonically. The image of the collapsing dust sphere is monotonically darkened and eventually becomes the shadow image. In this presentation, we show the time evolution of the image of the star obtained by animation.

T32	Anton Khirnov	Institute of Theoretical Physics, Charles University

Numerical evolution of axisymmetric gravitational wave collapse

In numerical relativity, spacetimes involving compact strongly gravitating objects are constructed as numerical solutions of Einstein's equations. A major question in such simulations is the choice of a suitable time slicing, typically constructed dynamically during evolution. One specific class of problems where common slicing techniques run into problems is near-critical collapse of gravitational waves. We present the results of our research into choosing a viable slicing for such simulations.

T33	Muhammad Sharif	University of the Punjab

Tilted Anisotropic Polytropes

The purpose of this talk is to construct spherically symmetric models for anisotropic matter configuration by imposing conformally flat condition. This work is done for a relative moving observer with matter using two types of polytropic equation of state. We evaluate the corresponding conservation equation, mass equation as well as energy constraints for both choices of equation of state. The conformal flatness is employed to find a specific form of anisotropy which aids to study spherical polytropic configurations. It is found that the first model satisfies all the energy conditions while the second model does not meet the dominant energy bound. It is also found that both models remain stable throughout the evolution.

T34	Jiro Murata	Department of Physics, Rikkyo University

Laboratory Tests of Newtonian Gravity

Series of short-range gravity experiments have been performed at Rikkyo University, aiming to test gravitational inverse square law at below cm scale. In this talk, a review of worldwide experimental tests together with the status of our ongoing project at the micrometer scale will be introduced.

T35	Kei Yamada	Kyoto University

Near-horizon behavior of the second-order BH perturbations

The recent observations of gravitational waves has opened a new window to test general relativity. In the future, extreme-mass-ratio inspirals (EMRIs), in which a stellar-mass compact object of mass μ spirals into a supermassive black holes of mass M, are expected to be observed by LISA. Such systems can be expressed by using the BH perturbation approach, where we expand equations in the mass ratio μ/M. However, in order to extract physical parameters from GW observations, the second-order perturbations must be considered. In this talk, we will discuss the behavior of the second-order perturbations near the event horizon of the SMBH.

T36	Yasutaka Koga	Rikkyo University

Analysis of accretion flows in D dimensions: sonic points, critical points, and photon spheres

In an accretion of fluid, its velocity transits from subsonic to supersonic. The point at which such transition occurs is called sonic point and known to play an important role for the analysis. In this talk, we see there exists the correspondence between sonic points of accretion flows of radiation fluid and photon spheres of spacetime on which the fluid flows. The correspondence holds for spherical and rotational flows in any static and spherically symmetric spacetime of arbitrary dimension.

T37	Toshiaki Ono	Hirosaki University

Gravitomagnetic bending angle of light in stationary axisymmetric spacetimes

We discuss a possible extension of the method of calculating the bending angle of light to stationary, axisymmetric and asymptotically flat spacetimes [T. Ono et al, Phys. Rev. D 96, 104037 (2017)]. We introduce a spatial metric to define the bending angle of light in the finite-distance situation. We show that the proposed bending angle of light is coordinate-invariant by using the Gauss-Bonnet theorem. The non-vanishing geodesic curvature of the photon orbit with the spatial metric is caused in gravitomagnetism, even though the light ray in the four-dimensional spacetime follows the null geodesic.

T38	Tatsuya Ogawa	Osaka City University

Charge Screened Boson Stars

We investigate boson star solutions numerically for the system of bosonic fields coupled to the Einstein gravity. The bosonic fields consist of a massless complex scalar field coupled to a U(1) gauge field, and a complex Higgs scalar field with the Mexican hat potential which causes the spontaneous symmetry breaking. In the asymptotic far region, the U(1) symmetry is broken by the vacuum expectation value of the Higgs field, while in the central region, the massless scalar field yields charge distribution by its phase rotation. Immediately, the Higgs field and the gauge field yield counter charge which screen the source charge. The scalar fields and the gauge field are localized in a finite region of the space, and the asymptotic structure of the spacetime is described by the Schwarzschild metric. Upper bound of ADM mass that exists in this system is discussed.

T39	Takuma Tsukamoto	Nagoya univ.

superradiance in force-free electromagnetic region

At the center of a jet, we believe that there exist BH. And the force-free condition could be given around it, because electromagnetic fields may be dominant. For the peprturbation to its electromagnetic fields, we can obtaion two wave modes in the eikonal limit. One is the fast mode, and the other is the Alfvén mode. The Alfvén mode propagate along the magnetic field lines. There is no superradiance for the Alfvén mode in the eikonal limit, while the fast mode have superradiance. But, due to the shape of the magnetic field lines and the variation of the angular velocity of it with respect to the distance, the Alfvén mode can also have superradiance.

T40	Akira Matsumura	Nagoya University

Quantum discrimination for the Universe

We investigate a quantum state discrimination problem of the Bunch-Davies vacuum and the stationary random Gaussian distribution. Quantum state (minimum-error) discrimination gives the upper bound of the success probability when we identify two states. Using the formula of the upper bound for the Bunch-Davies vacuum and the random Gaussian distribution, we discuss the validity of the assumption of quantum-to-classical transition in the standard cosmology.

T41	Anupam Mazumdar	University of Groningen

Spin Entanglement Witness for Quantum Gravity

I will discuss that despite the weakness of gravity, the phase evolution induced by the gravitational interaction of two micron size test masses in adjacent matter-wave interferometers can detectably entangle them even when they are placed far apart enough to keep Casimir-Polder forces at bay. I will provide a prescription for witnessing this entanglement, which certifies gravity as a quantum coherent mediator, through simple correlation measurements between two spins: one embedded in each test mass. Fundamentally, the above entanglement is shown to certify the presence of non-zero off-diagonal terms in the coherent state basis of the gravitational field modes.

T42	Shinpei Kobayashi	Tokyo Gakugei University

Algebraic construction of solutions in noncommutative gravity and squeezed coherent state

We consider a Euclidean (1+1)-dimensional and a Lorentzian (2+1)-dimensional noncommutative gravity. Both are defined on spacetimes where the commutation relation between coordinates are imposed as $[x^\mu, x^\nu] = i\theta$. It is known that we can obtain the spacetime solutions in such gravitational theories by mapping this commutation relation to that of a quantum harmonic oscillation in the one-dimensional quantum mechanics. In this talk, we show how we can extend this construction of solutions to realize other solutions with various spacetime symmetry by using squeezed coherent states. We would also like to refer a time-dependent extension of it via Lewis-Riesenfeld approach.

T43	Yota Watanabe	Kavli IPMU, University of Tokyo

Anisotropy problem in Hořava-Lifshitz gravity

Hořava-Lifshitz gravity was proposed as a candidate of quantum gravity, and it is also studied as a candidate of an alternative to inflation. There is the anisotropy problem, which inflation solves and must be addressed by an alternative to inflation. I will address whether Hořava-Lifshitz gravity can solve the anisotropy problem or not.

T44	Tomotaka Kitamura	Waseda University

Matter Scattering and Unitarity in Hořava-Lifshitz Gravity

Unitarity of high energy scattering is one of the necessary conditions for the theory to be perturbatively UV complete. In Einstein gravity, which is known to be the non-renormalizable theory, matter scattering is shown not to satisfy tree-level unitarity in the high energy limit. This shows that UV correction to Einstein gravity is required. Among a few possible directions to cure unitarity (i.e. UV completion of Einstein gravity), such as string theory, we take Hořava-Lifshitz (HL) gravity coupled to matter. Projectable HL gravity has been shown to be renormalizable. Recently, renormalizability of HL gravity couple to the matter has been studied. It is interesting to find out that the matter scattering of HL gravity satisfies high energy unitarity and to compare the condition for renormalizability. In this talk, we show the result of the UV behaviors of the two-scalar elastic scattering with graviton exchanges in $z = 3$ $(1 + 3)$ dimensional projectable Hořava-Lifshitz gravity and discuss whether the HL gravity satisfies high energy unitarity.

T45	Satoshi Akagi	Nagoya University

Massive spin-two theory in arbitrary background

The linear theory of the massive spin-two field in the arbitrary curved background is investigated. In the flat spacetime, the Fierz-Pauli model is well known as the unique linear theory describing the massive spin-two field. On the other hand, in fixed curved background with arbitrary metric, the infinite series of the nonminimal coupling terms is necessary in order to keep the appropriate DoF. Buchbinder et. al. have derived the nonminimal coupling terms which has the appropriate DoF in the small curvature approximation. In the leading order, three free parameters of nonminimal coupling terms are allowed. On the other hand, recently, a class of the completion of the nonminimal coupling terms have been obtained by linearizing the dRGT massive gravity. However, the leading nonminimal coupling terms of the linealized dRGT model depend only on one free parameter. This fact means that the possibility of the existence of larger class than the dRGT class has not yet been removed. In this talk, we solve the condition proposed by Buchbinder et. al. in higher order and investigate whether lower order nonminimal coupling terms can be constrained by higher order condition or not. As a result, we obtain an additional constraint on the leading order nonminimal coupling terms from the fourth order condition.

T46	Shuntaro Mizuno	Yukawa Institute for Theoretical Physics

Blue-tilted Primordial Gravitational Waves from Massive Gravity

We study a theory of massive tensor gravitons which predicts blue-tilted and largely amplified primordial gravitational waves. After inflation, while their mass is significant until it diminishes to a small value, gravitons are diluted as non-relativistic matter and hence their amplitude can be substantially amplified compared to the massless gravitons which decay as radiation. We show that such gravitational waves can be detected by interferometer experiments, even if their signal is not observed on the CMB scales.

T47	Shi Pi	Kavli Institute for the Physics and Mathematics of the Universe

Gravitational Waves Induced by non-Gaussian Scalar Perturbations

We study the gravitational waves (GWs) induced by the non-Gaussian scalar perturbation. We calculate the energy density per logarithmic frequency $\Omega_{\rm GW}$, given that the power spectrum of the curvature perturbation $\mathcal{P}_\mathcal{R}(k)$ has a peak at some small scale k_*, with a scale-independent non-Gaussian parameter $f_{\rm NL}$, and constrain $f_{\rm NL}$ with the future LISA sensitivity curve as well as with constraints from the abundance of the primordial black holes. We find that $\Omega_{\rm GW}$ increases as k^3, peaks at $k/k_* = 2\sqrt{2/3}$, and has a sharp cutoff at $k = 4k_*$. The non-Gaussianity induced GWs will exceed the Gaussian part if $\mathcal{P}_\mathcal{R}^2 f_{\rm NL}^4 > O(1)$. If $\mathcal{P}_\mathcal{R}^2 f_{\rm NL}^4 = O(1)$, a characteristic double-peak structure will be conspicuous, which can be recognized as a smoking gun of the primordial non-Gaussianity if detected.

T48	Chao Kang	Sun Yat-sen University

Primordial gravitational waves and perturbations during an inhomogeneous inflation

We investigate the inhomogeneous inflation, in which the space exponentially expands with inhomogeneities, and its cosmological perturbations. The inhomogeneous inflation is realized by introducing scalar fields with spacelike gradients that break the spatial symmetry. We find that the space can expand uniformly in different direction with the same rate. By using the perturbative method, we calculate the corrections to the power spectra of gravitational waves and curvature perturbation up to the linear order in the background inhomogeneities. Since the background is inhomogeneous, perturbations modes with different wave numbers get correlated. We show that generally the power spectra of perturbations depend on the ratio and the angle of wave numbers of the two correlated modes. In particular, the two circular polarization modes of the gravitational waves gain different powers when the background inhomogeneity is of vector or tensor type.

T49	Yuki Niiyama	Hirosaki University

Energy density of tensor perturbations in Einstein-Weyl gravity and its application to primordial gravitational waves

We investigate the energy density of the cosmological tensor perturbation in Einstein-Weyl gravity after reheating. In this theory, there exist the massless and massive tensorial degrees of freedom. We find that the energy density for the massless and massive mode behave as a radiation and matter at the later universe, respectively.

T51	Hiroaki Tahara	RESCEU, Unviersity of Tokyo

Self-anisotropizing universe in Horndeski theory

Horndeski theory can have a cubic kinetic term. It leads anisotropic inflation without any anisotropic matter field such as a vector field, as opposed to Wald's cosmic no-hair theorem in general relativity. As a exanple, we show that Bianchi-I model with slow-roll condition has two terminal points. One is conventional isotropic inflationary attractor, and the other is anisotropic one. Which attractor the universe approaches is determined by the initial condition.

T52	Yoh Kobayashi	Maeda Laboratory, Department of Physics, Waseda University

Bouncing Bianchi-IX cosmologies in mimetic gravity

General relativity is plagued by singularities, such as cosmological initial singularity. In this study, we try to resolve the cosmological singularity by modifying general relativity by introducing mimetic matter. It was already shown that bouncing flat FLRW model and Kasner model are possible (Chamseddine and Mukhanov 2017). We extend their result to Closed FLRW model and Bianchi-IX model.

T53	Kazumasa Okabayashi	Department of Physics, Waseda University.

Maximal Efficiency of Collisional Penrose Process with Spinning Particles

We analyze collisional Penrose process of spinning test particles in an extreme Kerr black hole.We consider that two particles plunge into the black hole from infinity and collide near the black hole. For the collision of two massive particles, the maximal efficiency is about (extracted energy)/(input energy)=15.01, which is more than twice as large as the case of the collision of non-spinning particles. We also evaluate the collision of a massless particle without spin and a massive particle with spin (Compton scattering), in which we find the maximal efficiency is 26.85.

T54	Kota Ogasawara	Rikkyo University

Collision of two dust thin shells in the BTZ spacetime

We consider a collision of two dust thin shells with a high center-of-mass (CM) energy in a Banados-Teitelboim-Zanelli (BTZ) spacetime. The two shells divide the BTZ spacetime into three domains and the three domains are jointed by Darmois-Israel junction conditions. We treat only the collision of two shells which corotate with a background BTZ spacetime because of the junction conditions. The counterpart of the corotating shell collision is a collision of two particles with vanishing angular momenta. In this talk, we compare the dust thin shell collisions and the particle collisions in order to investigate effects of the self-gravity caused by the high-energy collision. The self-gravity of the shells affects the position of an event horizon. We conclude that the observable CM energy is bounded because the event horizon moves due to the gravitational backreaction and it covers the high-energy collision event.

T55	Hiromi Saida	Daido Univ.

Exploring GR Effect of Super-Massive BH at Galactic Center 1: current status of our project

The star, named S2, orbiting the super-massive BH candidate (Sgr A*) at the center of our galaxy has just passed the closest point to the central BH, at 20th May this year. The gravity that S2 experiences around the pericenter, 2018-2019, is two orders of magnitude stronger than the gravity ever observed electromagnetically such as the Hulse-Taylor pulsar. We have been carring out the monitoring observation of S2 with Subaru telescope from 2014, and estimating the GR effects detectable through S2 dynamics. Our observational quantity is the redshift of the photon coming from S2. We are now analyzing whether or not the time evolution of the redshift is fitted not by the Newtonian prediction but by the GR prediction. This talk reports the current status of our project.

T56	Takayuki Ohgami	Daido Univ.

Exploring GR Effects of Super-Massive BH at Galactic Center 2: on the detail of fitting theory with observational data

This talk is a continuation of Saida's talk. We have been carring out monitoring observation of the star, named S2, orbitting the super-massive BH candidate (Sgr A*) with Subaru telescope. S2 has just passed the pericenter at this year, 20th May 2018. At this time, this star has experienced gravity stronger than any other electromagnetic observations such as the Hulse-Taylor pulsar. We are now analysing to estimate the GR effects of Sgr A* from time evolution curve of redshit. In this talk, we report the detail of our method.

T57	Filip Ficek	Jagiellonian University

Planar domain walls in Kerr spacetime

Topological defects such as domain walls are present in many Beyond Standard Model theories and cosmological models. Behaviour of domain walls near black holes was so far studied with the emphasise on looking for static solutions or its dynamics in spacetimes with spherical symmetry. We wanted to investigate a transit of a thick, light domain wall through the Kerr black hole. Our simulations show how this process depends on the domain walls' parameters and the black hole's spin. They also reveal the presence of ringing modes. Finally, we compare transits through spinning and charged black holes to find further similarities between Kerr and Reissner-Nordstrom spacetimes.

T59	Masashi Kimura	Instituto Superior Tecnico, Universidade de Lisboa

Stability analysis of black holes by the S-deformation method for coupled systems

We propose a simple method to prove the linear mode stability of a black hole when the perturbed field equations take the form of a system of coupled Schrodinger equations. The linear mode stability of the spacetime is guaranteed by the existence of an appropriate S-deformation. Such an S-deformation is related to the Riccati transformation of a solution to the Schrodinger system with zero energy. We apply this formalism to some examples and numerically study their stability.

T60	Satsuki Matsuno	Department of Physics, Graduate School of Science, Osaka City University

Schwarzschild and Majumdar-Papapetrou spacetime in dielectric media

Recently, behaviors of photon in a 'meta-meterial', artificial dielectric media, are studied actively inspired by the nanotechnology that enables us to control refractive index of the media. Various electric devices are proposed by using correspondence between geometry and inhomogenious dielectric media to understand gravitational effect. We discuss photon trapping and circular orbits of massive particles in transformation media that mimic Schwarzschild and Majumdar-Papapetrou spacetimes.

T61	Yuichiro Tada	Nagoya U.

Stochastic formalism and curvature perturbations

After briefly reviewing our recent works about the stochastic formalism extended to general multi-field cases, we show several results of our new numerical code. Combining the stochastic and δN formalism, it can automatically calculate the statistics of e-folding numbers in the phase space for general inflationary models and then obtain the power spectrum of the curvature perturbations.

T62	Junsei Tokuda	Kyoto Univ.

On the contribution of infrared secular effects to primordial fluctuations via quantum interference

In the inflationary paradigm, correlation functions of primordial fluctuations are given by quantum correlation functions of adiabatic perturbation which inevitably contain loop contributions. However, it is known that the loop contributions of light scalar fields, which mimics isocurvature perturbations during inflation, become much larger than the tree level contributions due to the infrared (IR) secular effects. Then, in order to clarify whether IR secular effects contribute to observables, we investigate the possibility to interpret all the IR secular effects as increasing variances in a classical statistical ensemble. Our recent works revealed that all the IR secular effects could be reproduced by a classical stochastic process in a good approximation, which gave an extension of the Starobinsky's stochastic approach. However, in this talk, we shall show that the classical stochastic picture would be violated due to the remaining quantum interference during inflation. This suggests that the IR secular effects may affect primordial fluctuations via quantum interference. We shall also discuss how to estimate the order of magnitude of the contributions of IR secular effects to primordial fluctuations.

T63	Naoya Kitajima	Nagoya Universiry

Distribution of primordial black holes and 21cm signature

We show that the number of primordial black holes (PBHs) which is originated from primordial density perturbations with moderately-tilted power spectrum fluctuates following the log-normal distribution, while it follows the Poisson distribution if the spectrum is steeply blue. The log-normal, as well as the Poisson, fluctuation of the PBH number behaves as an isocurvature mode and affects the matter power spectrum and the halo mass function in a different way from those for the Poisson case. The future 21cm observation can potentially put a stronger constraint on the PBH fraction than the current one in a wide mass range, $10^{-5} - 10$ solar mass.

T64	Takafumi Kokubu	KEK, Rikkyo University

Effect of Inhomogeneity on Primordial Black Hole Formation in the Matter Dominated Era

We investigate the effect of inhomogeneity on primordial black hole formation in the matter dominated era. In the gravitational collapse of an inhomogeneous density distribution, a black hole forms if apparent horizon prevents information of the central region of the configuration from leaking. Since information cannot propagate faster than the speed of light, we identify the threshold of the black hole formation by considering the finite speed for propagation of information. We show that the production probability $\beta(\sigma)$ of primordial black holes, where σ is density fluctuation at horizon entry, is more enhanced than that derived in previous work in which the speed of propagation was effectively regarded as infinite. For $\sigma \ll 1$, we obtain $\beta \simeq 3.70\sigma^{3/2}$ which is larger by about an order of magnitude than the probability derived in earlier work by assuming instantaneous propagation of information.

T65	Kohei Fujikura	Tokyo Institute of Technology

Phase Transitions in Twin Higgs Models

We study twin Higgs models at non-zero temperature and discuss cosmological phase transitions. We analyze the phase transition associated with the global symmetry breaking, through which the Standard Model Higgs is identified with one of the pseudo-Nambu Goldstone bosons in terms of its linear realization, with and without supersymmetry. For this phase transition, we show that, only in the supersymmetric case, the phase transition is of the first order. We find that the stochastic gravitational wave background is generated through this first order phase transition, but it is impossible to be detected by DECIGO or BBO in the linear realization and the decoupling limit.

T66	Yi-Peng Wu	RESCEU, the University of Tokyo

Higgs as heavy-lifted physics during inflation

The mass-spectrum of Standard Model particles can be uplifted far above the electroweak scale during inflation as Higgs spontaneously acquires a non-zero vacuum expectation value. We investigate such a heavy-lifting mechanism due to couplings between Higgs and inflaton that constitute a non-trivial target field space, and show that the perturbative unitarity does not necessarily break down even in the strong-coupling regime. The heavy-lifted Higgs field can leave characteristic non-gaussianities of the equilateral type or the intermediate type, which are important background signals for searching new physics in the cosmological collider.

T67	Minxi He	RESCEU, UTokyo

Reheating in the Mixed Higgs-R^2 Model

We numerically analyse the reheating process after inflation in the Mixed Higgs-R^2 Model. This two field model involves both scalaron and Higgs field with a special potential shape so that it could be regarded as a non-trivial extension of the Higgs inflation case and Starobinsky model case. Due to the chaotic motion of both fields during inflation, there exist new decay channels for the Higgs field. Also, the production of the longitudinal modes of gauge fields should also be taken into account, which could have important effects on preheating and reheating.

T68	Keisuke Inomata	ICRR, The University of Tokyo

Power spectra of CMB circular polarizations induced by primordial perturbations

Circular polarizations of cosmic microwave background are considered to be zero at the last scattering surface. However, linear polarizations at the last scattering surface can be converted to circular polarizations through the birefringence while they are coming to us. The primordial perturbations can be a source of the birefringence. In this talk, we investigate the circular polarizations induced by general primordial perturbations such as scalar, vector, and tensor perturbations using the total angular momentum formalism. We derive the formulas of the induced circular polarizations and apply those to the standard cosmology. We finally get the angular power spectra and the mean value of the induced circular polarizations as $\langle V \rangle \sim 3 \times 10^{-14}$ for scalar perturbations with $P_R = 2.1 \times 10^{-9}$ and $\langle V \rangle \sim 1 \times 10^{-17}$ for tensor perturbations with $r = 0.1$.

T69	Ippei Obata	ICRR, The University of Tokyo

Footprint of Two-Form Field: Statistical Anisotropy in Primordial GWs

We study the observational signatures of two-form field in the inflationary cosmology. In our setup a two-form field is kinetically coupled to a spectator scalar field and generates sizable gravitational waves and smaller curvature perturbation. We find that the sourced gravitational waves have a distinct signature: they are always statistically anisotropic and their spherical moments are non-zero for hexadecapole and tetrahexacontapole, while the quadrupole moment vanishes. Since their amplitude can reach $\mathcal{O}(10^{-3})$ in the tensor-to-scalar ratio, we expect that this novel prediction will be tested in the next generation of the CMB experiments.

T70	Suro Kim	Kobe University

Spin Spectroscopy in the EFT of Inflation

Heavy fields which have the mass around Hubble scale can be present during cosmic inflation, and their imprint might be captured by late-time cosmological observation. However, signals by the fields heavier than Hubble scale are exponentially suppressed, thus it is difficult to detect. In this talk, we discuss that the signals suppressed by power of mass can be captured using effective field theory approach, and we can find the mass and spins of heavy field from the effective couplings.

T71	Hiroyuki Kitamoto	National Center for Theoretical Sciences

Schwinger Effect in Inflaton-Driven Electric Field

In a four dimensional inflation theory, a persistent electric field can be established by making the inflaton coupled to the gauge field like a dilaton. We investigate the pair production of scalar particles in the inflaton-driven electric field. In particular, we evaluate the induced current due to the pair production. The presence of the dilatonic coupling ensures the validity of the WKB approximation at the past and the future infinities, without tuning constant parameters. Thus, the semiclassical description is applicable in evaluating the induced current. Solving the field equations with the induced current, we evaluate the first-order backreaction to the electric field. It turns out that the electric field decreases with the cosmic expansion. The result indicates that the no-anisotropic hair theorem for inflation holds true regardless of whether the dilatonic coupling is present or not.

T72	Atsushi Nishizawa	KMI, Nagoya University

Test of the equivalence principle at cosmological distance with gravitational waves

Gravitational waves (GWs) have been detected directly and paved the way for testing general relativity in the cosmological and dynamical regime of gravity. From the coincident detection of GW170817 and GRB170817A, GW propagation speed has been measured so tightly that a class of gravity theories in which GWs propagate with the speed different from c has been ruled out. On the other hand, another conspicuous feature in modified gravity is the time variation of gravitational constant (G), which affects the amplitude damping of GWs and is a key observable to test gravity. From GW170817/GRB170817A, the constraint on the time variation of G has obtained, but is still too weak. In this presentation, I will forecast the future constraint on the time variation of G, or the equivalence principle at cosmological distance with the future observations of gravitational waves.

T73	Yuki Watanabe	NIT, Gunma College

Probing the Starobinsky R^2 inflation with CMB precision cosmology

In this talk I will show improved CMB predictions of the Starobinsky R^2 inflation model combined with a generic non-thermal stage after inflation. First I consider the gravity and matter sector in the higher curvature theory, and transform it to the equivalent standard supergravity coupled to additional matter superfields. I then discuss characteristic decay modes of the inflaton and the reheating temperature. Considering a simple model of supersymmetry breaking sector, I estimate gravitino abundance from inflaton decay, and obtain limits on the masses of gravitino and supersymmetry breaking field. Finally, I discuss the observable effect of TeV and multi-TeV supersymmetry breaking schemes assuming the neutralino and gravitino dark matter scenarios.

T74	Chulmoon Yoo	Nagoya University

PBH abundance from random Gaussian curvature perturbations and a local density threshold

The production rate of primordial black holes is often calculated by considering a nearly Gaussian distribution of cosmological perturbations, and assuming that black holes will form in regions where the amplitude of such perturbations exceeds a certain threshold. A threshold $\zeta_{\rm th}$ for the curvature perturbation is somewhat inappropriate for this purpose, because it depends significantly on environmental effects, not essential to the local dynamics. By contrast, a threshold $\delta_{\rm th}$ for the density perturbation at horizon crossing seems to provide a more robust criterion. On the other hand, the density perturbation is known to be bounded above by a maximum limit $\delta_{\rm max}$, and given that $\delta_{\rm th}$ is comparable to $\delta_{\rm max}$, the density perturbation will be far from Gaussian near or above the threshold. In this paper, we provide a new plausible estimate for the primordial black hole abundance based on peak theory. In our approach, we assume that the curvature perturbation is given as a random Gaussian field with the power spectrum characterized by a single scale, while an optimized criterion for PBH formation is imposed, based on the locally averaged density perturbation. Both variables are related by the full nonlinear expression derived in the long-wavelength approximation of general relativity. We do not introduce a window function, and the scale of the inhomogeneity is introduced as a random variable in the peak theory. We find that the mass spectrum is shifted to larger mass scales by one order of magnitude or so, compared to a conventional calculation. The abundance of PBHs becomes significantly larger than the conventional one, by many orders of magnitude, mainly due to the optimized criterion for PBH formation and the removal of the suppresion associated with a window function.

T75	Hector Hernandez	Universidad Autonoma de Chihuahua

Polymer representation for coherent states

In this talk we present the representation for coherent states in polymer quantum mechanics, which can be applied in studying properties of systems presenting loop-like quantum gravity effects, as in cosmology.

T77	Marcus Christian Werner	Yukawa Institute for Theoretical Physics, Kyoto University

New developments in optical geometry

Optical geometry is defined such that its geodesics correspond to spatial light rays. Thus, it provides the proper geometrical setting for gravitational lensing also beyond the standard approximation. In this talk, I will discuss recent developments in this field, some of which grew out of the AMS MRC collaborative workshop 'The Mathematics of Gravity and Light' held earlier this year. This includes a theorem on the isoperimetric problem in the Riemannian optical geomtry of static spacetimes, and the application of the so-called Gauss-Bonnet method to the Randers-Finsler optical geometry of stationary spacetimes.