Program of the 8th Korea-Japan Workshop on Dark Energy

Chair: Shinji Tsujikawa

Monday 18th October, Session 1 (15:00-16:30 JST&KST/8:00-9:30 CEST)

Tsutomu Kobayashi (Rikkyo University)

"Distinguishing modified gravity with just two tensorial degrees of freedom from general relativity"

We consider spatially covariant modified gravity in which the would-be scalar degree of freedom is made non-dynamical and hence there are just two tensorial degrees of freedom, i.e., the same number of dynamical degrees of freedom as in general relativity. Focusing on a class of such modified gravity theories characterized by three functions of time, we discuss how modified gravity with two tensorial degrees of freedom can be distinguished observationally or phenomenologically from general relativity. It is checked that the theory gives the same predictions as general relativity for weak gravitational fields and the propagation speed of gravitational waves. We also find that there is no modification to asymptotically flat black hole solutions. Due to a large degree of freedom to choose the time-dependent functions in the theory, the homogeneous and isotropic cosmological dynamics can be made close to or even identical to that of the ΛCDM model. We investigate the behavior of cosmological perturbations in the long and short wavelength limits and show that in both limits the effects of modified gravity appear only through the modification of the background evolution.

Mohammad Ali Gorji (YITP, Kyoto University)

"Dark Matter via Entropy Perturbations"

The accumulated energy density of excited entropy modes in the multiple field inflationary scenarios can play the role of dark matter. In the usual case of flat field space without any turning trajectory, only superhorizon entropy modes can be excited through the gravitational instability. In the case of curved field space, we show that subhorizon entropy modes can be excited as well through the tachyonic instability induced by a negative curvature of field space. The latter allows for production of entropy modes with masses of order of the Hubble parameter during inflation, leading to a new dark matter scenario.

Masato Minamitsuji (University of Lisbon)

"Frame invariance in higher-order gravitational theories"

In the first part, we investigate whether the cosmological perturbations are invariant under general disformal transformation with the second-order covariant derivatives of the scalar field. We show that on superhorizon scales the difference in the comoving curvature perturbations between frames is given by the combination of the time derivative of the comoving curvature perturbation itself and the intrinsic entropy perturbation of the scalar field. In the case that the intrinsic adiabaticity of the scalar field is satisfied, the comoving curvature perturbation becomes invariant under generalized disformal transformation on superhorizon scales.

In the second part, we investigate how physical quantities associated with relativistic stars are related by the generalized disformal transformations constructed by the scalar and vector fields within the slow-rotation approximation. By imposing the asymptotic flatness in both frames, the

ADM mass becomes frame invariant. We then discuss the disformal transformations of the frame-dragging function, angular velocity, angular momentum, and moment of inertia of the star. While the angular velocity of the star is frame invariant in all the cases, the invariance of the angular momentum and moment of inertia depends on whether the transfromation is generated by the scalar or vector field.

Monday 18th October, break time (16:30-17:00 JST&KST/9:30-10:00 CEST)

Monday 18th October, Session 2 (17:00-18:30 JST&KST/10:00-11:30 CEST)

Lefteris Papantonopoulos (National Technical University of Athens)

"Stability of black holes with non-minimally coupled scalar hair"

We consider static and spherically-symmetric solutions of a Horndeski subclass which includes a massless scalar field non-minimally coupled to the Einstein tensor. We study the stability of such solution under scalar and axial perturbations and find that it is gravitationally stable at the linear level.

Joan Solà Peracaula (Departament FQA and ICCUB, Universitat de Barcelona)

"Cosmological Constant and Running Vacuum in the Universe"

The cosmological constant is usually associated with the notion of vacuum energy density in quantum field theory (QFT). In an expanding universe one may expect that $¥Lambda$, and the corresponding vacuum energy density, $¥rho_{¥rm vac}$, evolve slowly with the cosmological expansion. In this talk I will consider the class of running vacuum models (RVMs), which can describe inflation followed by essentially the concordance model evolution. For these models, the vacuum energy density is dynamical and takes the form of a constant plus a series of (even) powers of the Hubble rate. There are theoretical reasons backing up this structure in the context of QFT in curved spacetime. The RVM's, in addition, prove very competitive against the standard $¥Lambda$CDM model and give a handle for solving the $¥sigma_8$ and H_0 tensions.

Savvas Nesseris (IFT UAM-CSIC)

"The Genetic Algorithms and their cosmological applications"

In the last decade or so, machine learning (ML) has become a very useful tool in cosmology. In this talk I will describe a particular ML approach called the Genetic Algorithms (GA) that can be used to determine the nature of dark energy and probe for deviations from the cosmological constant model (LCDM). In particular, I will provide several interesting applications of the GA using late time distance and large scale structure data, along with a plethora of new consistency tests of LCDM, such as the Om statistic etc.

Chair: Antonio De Felice

Tuesday 19th October, Session 1 (15:00-16:30 JST&KST/8:00-9:30 CEST)

Teruaki Suyama (Tokyo Institute of Technology School of Science)

"Universal Relation of Lensed Gravitational Waves"

Gravitational waves are gravitationally lensed during their propagation through the intervening matter inhomogeneities before arriving at detectors. In my talk, I present my recent result that the variance of the amplitude fluctuation and that of the phase fluctuation of the lensed waveform obey a simple relation irrespective of the shape of the matter power spectrum. I will also discuss some potential applications of the relation.

Tomohiro Fujita (Waseda University)

"Cosmic Birefringence and Axion Dark Energy"

Recently, a re-analysis of Planck data indicated a measurement of the isotropic cosmic birefringence (i.e. the rotation of CMB polarization angle) with the statistical significance of 2.4σ. This observational result can be explained in a minimal manner, if axionlike particle is responsible for dark energy and coupled to photon via Chern-Simons term. Moreover, axionlike particle working as early dark energy, which alleviates the Hubble tension problem, can also account for the measured comic birefringence. These models will be tested by future CMB experiments like LiteBIRD, CMB S-4, etc.

Satadru Bag (KASI)

"Identifying Lensed Quasars and Their Time-Delays in Unresolved Systems"

Identifying strong lensed (multiply imaged) quasars is challenging due to their low density in the sky and the limited angular resolution of wide-field surveys. We show that lensed quasars can be identified using unresolved light curves, without assuming a light curve template or any prior information. After describing our method, we show using simulations that it can attain high precision and recall when we consider high-quality data with marginal noise well below the variability of the light curves. As the noise level increases to that of ZTF telescope, we find that precision can remain close to 100% while recall drops to roughly 60%. We also consider some examples from the Time Delay Challenge 1 (TDC1) and demonstrate that the time delays can be recovered from the joint light curve data in realistic observational scenarios accurately. We further demonstrate our method by applying it to publicly available COSMOGRAIL data of the observed lensed quasar J1226. We identify the system as a lensed quasar based on the unresolved light curve and estimate a time delay in good agreement with the one measured by COSMOGRAIL using the individual image light curves. The technique shows great potential to identify lensed quasars in wide field imaging surveys, especially the soon to be commissioned Vera Rubin Observatory.

Tuesday 19th October, break time (16:30-17:00 JST&KST/9:30-10:00 CEST)

Tuesday 19th October, Session 2 (17:00-18:30 JST&KST/10:00-11:30 CEST)

Jose Beltran Jimenez (Universidad de Salamanca)

"Charging dark matter up"

We consider cosmological models where dark matter is charged under a dark Abelian gauge field. This new interaction is repulsive and competes with gravity on large scales and in the dynamics of galaxies and clusters. We focus on non-linear models of dark electrodynamics where the effects of the new force are screened within a K-mouflage radius that helps avoiding traditional constraints on charged dark matter models. We discuss the background cosmology of these models in a Newtonian approach and show the equivalence with relativistic Lemaitre models where an inhomogeneous pressure due to the electrostatic interaction is present. In particular, we find that dark matter shells of different radii evolve differently as they exit their K-mouflage radii at different times, resulting in a breaking of the initial comoving evolution. In the large time regime, the background cosmology is described by comoving but inhomogeneous model with a reduced gravitational Newton constant and a negative curvature originating from the electrostatic pressure. Baryons do not directly feel the electrostatic interaction, but are influenced by the inhomogeneous matter distribution induced by the electric force. We find that shells of smaller radii evolve faster than the outer shells which feel the repulsive interaction earlier. This mimics the discrepancy between the large scale Hubble rate and the local one. Similarly, as galaxies and clusters are not screened by the new interaction, large scale global flows would result from the existence of the new dark electromagnetic interaction.

Gianluca Calcagni (IEM-CSIC)

"Dark energy in multifractional spacetimes - reloaded"

We discuss the possibility to get late-time acceleration in a universe with a multiscale geometry. Out of four classes of theories with multi-fractional measure, at least two can realize a dark-energy-like era without using dynamical fields, where acceleration is purely driven by geometry and symmetry effects.

Reginald Christian Bernardo (University of the Philippines)

"Towards well-tempered dark energy models"

Well-tempering is a promising way for dark energy to screen an arbitrarily large, possibly Planck scale, vacuum energy to deliver a late-time, low energy state. In this talk, we briefly review well-tempered cosmology and discuss recent progress on its teleparallel gravity extensions. We focus on features that dark energy models may hold in order to be well-tempered. Provided time, we also report on the first observational constraints on well-tempered cosmology. *Based on 2107.08762 and 2108.02500.

Atsushi NARUKO (CGP, YITP, Kyoto University)

"Axion Cloud Decay due to the Axion-photon Conversion with Background Magnetic Fields"

We consider an axion cloud around a black hole with background magnetic fields. We calculate the decay rate of the axion cloud due to the axion-photon conversion associated with the axion-photon coupling. For simplicity, we consider the situation where the axion configuration is dominated by a solution for the eigenvalue equation equivalent to that for the Hydrogen atom, and the coupling term can be evaluated by a successive perturbation method. For the monopole background, we find the decay rate of the axion cloud is given by ~ $q^2 ¥kappa^2 (GM)^5 ¥mu^8$, where $¥mu$, M, G, $¥kappa$ and q are the axion mass, black hole mass, gravitational constant, coupling constant of the axion-photon coupling and monopole charge, respectively. For the uni- form background magnetic field, we obtain the decay rate of the axion cloud ~ $B_0^2 ¥kappa^2 (GM)^7 ¥mu^6$, where B_0 is the magnetic field strength. Applying our formula to the central black hole in our galaxy, we find that the value of the decay rate for the case of the uniform magnetic field is comparable to the growth rate of the superradiant instability with $¥kappa$ ~ $10^{-12} GeV^{−1}$, B_0 ~ $10^3 G$ and $¥mu$ ~ $10^{−18} eV$. The ratio is 10^5 times larger for the monopole magnetic field with the same values of the parameters.

Nikolaos Chatzarakis (School of Mathematics, Trinity College, Dublin)

"f (R) gravity phase space in the presence of thermal effects"

In this paper, we shall consider f(R) gravity and its cosmological implications, when an extra matter term generated by thermal effects is added by hand in the Lagrangian. We formulate the equations of motion of the theory as a dynamical system, that can be treated as an autonomous one only for specific solutions for the Hubble rate, which are of cosmological interest. Particularly, we focus our analysis on subspaces of the total phase space, corresponding to (quasi-)de Sitter accelerating expansion, matter-dominated and radiation-dominated solutions. In all the aforementioned cases, the dynamical system is an autonomous dynamical system. With regard to the thermal term effects, these are expected to significantly affect the evolution near a Big Rip singularity, and we also consider this case in terms of the corresponding dynamical system, in which case the system is non-autonomous, and we attempt to extract analytical and numerical solutions that can assess the specific cases. This course is taken twice: the first for the vacuum theory and the second when two perfect fluids (dust and radiation) are included as matter sources in the field equations. In both cases, we reach similar conclusions. The results of this theory do not differ significantly from the results of the pure f(R) in the de Sitter and quasi-de Sitter phases, as the same fixed points are attained, so for sure the late-time era de Sitter is not affected. However, in the matter-dominated and radiation-dominated phases, the fixed points attained are affected by the presence of the thermal term, so surely the thermal effects would destroy the matter and radiation domination eras. However, with regard to the Big Rip case, several instabilities are found in the dynamical system, since the initial conditions dramatically affect the behavior of the dynamical system near the starting point of the -foldings number evolution.

Chair: Arman Shafieloo

Wednesday 20th October, Session 1 (15:00-16:30 JST&KST/8:00-9:30 CEST)

Benedict Bahr-Kalus (KASI)

"Challenges at the Largest Scales"

Large Scale Structure surveys will probe larger and larger volumes, opening up a window to test the physics of the Universe at previously untested scales. However, entering this unchartered territory, we have to revisit some of the assumptions entering well-tested analysis pipelines at smaller scales, as well as think of new systematic effects that we have not encountered so far. In my talk, I shall give a brief overview of the challenges we are facing at these ultra-large scales.

Seokcheon Lee (Sungkyunkwan University)

"Cosmology of the minimally extended varying speed of light (meVSL)"

Even though there have been the various varying speed of light (VSL) cosmology models, they remain out of the mainstream because of their possible violation of physics laws built into fundamental physics. In order to be the VSL as a viable theory, it should inherit the success of special relativity including Maxwell equations and thermodynamics at least. Thus, we adopt that the speed of light, $\tilde{c}$ varies for the cosmic time not for the local time, i.e., $\tilde{c}$ [z] where z is the cosmological redshift. When one describes the background FLRW universe, one can define the constant-time hypersurface by using physical quantities such as temperature, density, and $\tilde{c}$. It is because they evolve in time, and the homogeneity of the Universe demands that they must equal at the equal cosmic time. The variation of $\tilde{c}$ accompanies the joint variations of all related physical constants in order to satisfy the Lorentz invariance, thermodynamics, and Bianchi identity. We call this VSL model as a "minimally extended VSL (meVSL)". We derive cosmological observables of meVSL and obtain the constraints on the variation of $\tilde{c}$ by using the current observations. Interestingly, z and all geometrical distances except the luminosity distance of meVSL are the same as those of general relativity. However, the Hubble parameter of meVSL is rescaled as $H=(1+z)^{-b/4}H^{(GR)}$ which might be used as a solution for the tension of the Hubble parameter measurements. In this manuscript, we provide the main effects of meVSL on various cosmological observations including BBN, CMB, SZE, BAO, SNe, GWs, H, SL, and $\Delta\alpha$.

Vesselin Gueorguiev (Institute for Advanced Physical Studies)

"The Scale Invariant Vacuum Paradigm - main results and current progress"

We will review the Scale Invariant Vacuum idea as related to Weyl Integrable Geometry. Main results related to SIV and inflation [1], the growth of the density fluctuations [2], and application of the SIV to scale-invariant dynamics of Galaxies, MOND, Dark Matter, and the Dwarf Spheroidals [3] will be summarized. If time permits, a potential connection of the weak field SIV results to the un-proper time parametrization within the reparametrization paradigm, will be discussed as well [4].

[1] Maeder, A., Gueorguiev, V. G., Scale invariance, horizons, and inflation. MNRAS 504, 4005 (2021). arXiv: 2104.09314 [gr-qc].
[2] Maeder, A., Gueorguiev, V., G., The growth of the density fluctuations in the scale-invariant vacuum theory, Phys. Dark Univ. 25, 100315 (2019). arXiv: 1811.03495 [astro-ph.CO]
[3] Maeder, A.; Gueorguiev, V.G. Scale-invariant dynamics of galaxies, MOND, dark matter, and the dwarf spheroidals, MNRAS 492, 2698 (2019). arXiv: 2001.04978 [gr-qc]
[4] Gueorguiev, V. G., Maeder, A., Geometric Justification of the Fundamental Interaction Fields for the Classical Long-Range Forces. Symmetry 13, 379 (2021). arXiv: 1907.05248 [math-ph].

Hareesh Thuruthipilly (National Center for Nuclear Research, Poland)

"*On the emergence of cosmic space and the first law of thermodynamics in a non-flat universe"*

Based on connections between gravity and thermodynamics, interpreting the dynamics of the universe as a quest for achieving holographic equipartition is a novel concept proposed by Padmanabhan. However, the generalization of Padmanabhan's conjecture to the non-flat universe had resulted in uncertainty about the choice of volume. We have shown that the exact mathematical formulation of the conjecture is impossible with the proper invariant volume (Volume term derived from the FRW metric) for a non-flat universe. The deep connection between the first law of thermodynamics and the law of emergence motivated us to also explore the status of the first law in a non-flat universe when one uses proper invariant volume. We have shown that the first law of thermodynamics, $dE=TdS+WdV$, cannot be formulated properly for a non-flat universe using proper invariant volume. We can also show that the energy change within the horizon is not equivalent to the outward energy flux in the non-flat universe if one used the proper invariant volume. We further point out that the consistency between the above two forms of the first law will hold only with the use of areal volume, which hints us why our universe appears to be spatially flat.

Pawan Joshi (IISER BHOPAL, INDIA)

“Hamiltonian Formalism for Nonlocal Gravity Models”

Nonlocal gravity models are constructed to explain the current acceleration of the universe. These models are inspired by the infrared correction appearing in Einstein Hilbert action. We develop the Hamiltonian formalism of a nonlocal model by considering only terms to quadratic order in Riemann tensor, Ricci tensor and Ricci scalar. We show how to count degrees of freedom using Hamiltonian formalism including Ricci tensor and Ricci scalar terms. In this model we have also worked out with a choice of a nonlocal action which has only two degrees of freedom equivalent to GR. Finally we find the existence of additional constraints in Hamiltonian required to remove the ghosts in our full action. We also compare our results with that of obtained using Lagrangian formalism.

Wednesday 20th October, break time (16:30-17:00 JST&KST/9:30-10:00 CEST)

Wednesday 20th October, Session 2 (17:00-18:30 JST&KST/10:00-11:30 CEST)

Jiajun Zhang (Shanghai Astronomical Observatory, China)

“21cm Intensity Mapping with BINGO”

BINGO is a 40m radio telescope under construction in Brazil. It is intended to perform 21cm intensity mapping in the frequency range of 980 MHz to 1260 MHz. It will cover ~5000 square degree and detect BAO signal at z=0.13-0.45. I will briefly introduce the idea of 21cm intensity mapping, the progress of BINGO and its scientific implications.

Katsuki Aoki (YITP, Kyoto University)

“Positivity vs. Lorentz-violation”

Underlying assumptions on ultraviolet completion can impose constraints on its low-energy effective field theories (EFTs). One of the most well-established constraints is called positivity bounds, provided that general assumptions such as Poincare invariance and unitarity are satisfied at all scales. On the other hand, the spacetime symmetry is spontaneously broken in cosmology and the standard argument cannot be applied to such a situation. In this talk, I will offer a top-down perspective on cosmological EFTs by studying a particular class of UV completion. In particular, I will show how a class of multi-field scalar-field theories in a Lorentz-breaking background imposes consistency conditions on its effective theory of a single field and provides an example of an order-unity violation of a naively applied positivity bound.

Shin'ichi Hirano (Nagoya university)

“UV-divergent one-loop matter power spectrum in DHOST theory and its rescue with EFT of LSS”

Scalar-tensor theories can be the origin of the late-time acceleration and the scalar field does not propagate around matter thanks to non-linear self-interactions. These non-linear interactions affect the non-linear evolution of density fluctuations. We show that in Degenerate Higher-Order Scalar-Tensor (DHOST) theory the one-loop correction for the matter power spectrum have UV divergent terms. Then, we discuss its rescue by using an effective field theoretic approach of Large Scale Structure.

Kazufumi Takahashi (YITP, Kyoto University)

"Stealth solutions in scalar-tensor theories"

We discuss stealth solutions in scalar-tensor theories. We derive a set of conditions under which the scalar-tensor theories accommodate stealth solutions in the presence of a general matter component minimally coupled to gravity. I also mention some recent results on the linear stability of stealth black hole solutions in degenerate higher-order scalar-tensor theories.

Lotte ter Haar (SISSA)

"Kinetic Screening in the Strong-Field Regime"

Gravitational theories differing from General Relativity may explain the accelerated expansion of the Universe without a cosmological constant. However, their viability crucially depends on a "screening mechanism" needed to suppress, on small scales, the fifth force driving the cosmological acceleration. I will discuss a scalar-tensor theory with first-order derivative self-interactions exhibiting such a mechanism, and present screened solutions in this theory for both non-relativistic and relativistic stars. I will also show how the screening mechanism enables this theory to pass Solar System tests up to 1PN order.

Chair: Shinji Mukohyama

Thursday 21th October, Session 1 (15:00-16:30 JST&KST/8:00-9:30 CEST)

Sunghoon Jung (Seoul National University)

"Hubble selection of the weak scale"

We show that the weak scale vh could be a result of self-organized criticality driven by an inflationary quantum phenomenon -- Hubble selection. If vh is determined by the relaxion scalar field value, it can be evolved by inflationary quantum fluctuations toward some quantum critical points, commonly in most Hubble patches. Interestingly, the QCD sector may have relevant critical points, realizing the weak scale close to the observed value while explaining its closeness to ΛQCD. We introduce a model and mechanism for the weak scale.

Rampei Kimura (Waseda University)

"Vainshtein screening in Lorentz-invariant massive gravity"

In this talk, I will focus on new massive gravity theories with 5 dynamical degrees of freedom. By adopting the generalized massive gravity framework, where a global translation invariance is broken, two novel classes of Lorentz-invariant theories have found. In both theories, cosmological solutions, that accelerates the late-time universe, is stable, i.e., free of ghost and gradient instabilities. I will briefly summarize these results. In addition, I will explain the Vainshtein screening for the extension theory of dRGT massive gravity.

Shuichiro Yokoyama (Nagoya University)

"What does the Planck ns-r tell us about inflation?"

Recent precise CMB measurements such as Planck and BICEP/Keck have given us a deeper understanding of cosmic inflation. In fact, conventional simple models (e.g., proposed in the early '80s) are in tension. In this talk, with an introduction to my own related works, I'd like to give a brief review of how these models can be consistent with the observations by introducing simple(?)

modifications. In particular, I will focus on the non-minimal coupling to gravity and also multi-scalar extension.

Thursday 21th October, break time (16:30-17:00 JST&KST/9:30-10:00 CEST)

Thursday 21th October, Session 2 (17:00-18:30 JST&KST/10:00-11:30 CEST)

Cedric Deffayet (CNRS IAP/IHES)

“Degeneracy, matter coupling and disformal transformations”

Alexander Vikman (CEICO, Czech)

“Inverse phase transition, beyond freeze-in Dark Matter and gravitational waves”

I will discuss a recently proposed class of models where Dark Matter (DM) is produced via an inverse phase transition. The inverse phase transition can be caused by coupling to some cosmological field. For instance, this field can be the Ricci scalar, as in e-Print: 2004.03410; primordial magnetic field, as in e-Print: 2010.03383; or thermal fluctuations of other fields, as in e-Print: 2104.13722. In this most recent work we proposed a novel scenario of DM production tidy connected with generation of gravitational waves. DM is modelled as a real scalar, which interacts with the hot primordial plasma through a portal coupling to another scalar field. For a particular sign of the coupling, this system exhibits an inverse phase transition. The latter leads to an abundant DM production, even if the portal interaction is so weak that the freeze-in mechanism is inefficient. The model predicts domain wall formation in the early Universe, long before the inverse phase transition. These domain walls have a tension decreasing with time, and completely disappear at the inverse phase transition, so that the problem of overclosing the Universe is avoided. The domain wall network emits gravitational waves with characteristics defined by those of DM. In particular, the peak frequency of gravitational waves is determined by the portal coupling constant, and falls in the observable range for currently planned gravitational wave detectors.

Yusuke Manita (Kyoto University)

“Evolution of the large-scale-structure based on projected massive gravity”

Is it possible to explain the accelerating expansion of the universe using the theory of gravitons with non-zero mass, i.e., massive gravity? If gravitons have a mass as small as the Hubble constant, gravity weakens at long distances of the Hubble length, and the universe is expected to expand at an accelerating rate without introducing a cosmological constant or dark energy. In fact, the simplest ghost-free massive gravity called de Rham-Gabadadze-Tolly theory (dRGT theory) has an accelerating expan- sion solution without introducing the unkown dark energy or cosmological constant. However, this solution cannot explain the current accelerating expansion because the solution has ghost in the nonlinear perturbation which causes the fatal instability. The dRGT theory assumes Poincar´e symmetry of the field space, but this assump- tion can be removed for general massive gravity. The previous study was the first to success in generalizing the dRGT theory by breaking the translational symmetry of the field space, while keeping the Lorentz symmetry. The new theory differs from the dRGT theory in that it has a non-minimal coupling and a new mass term. Further- more, the new theory has two classes of mass terms. One is called generalized dRGT theory, which is a straightforward generalization of the mass term of dRGT theory. The other is called projected massive gravity, which has a completely different mass term from the dRGT theory: the field space metric of dRGT theory is the Minkowski metric, whereas the field space metric of projected massive gravity is the projected tensor of the Stuckelberg field. Furthermore, these new theories have homogenous isotropic cosmological solutions it can avoid the ghosts in the nonlinear perturbation. In this study, we investigate the linear evolution of matter density in the homoge- nous isotropic cosmology based on the projected massive gravity by using numerical calculations. It is found that there exists a parameter region where instability does not exist, and that the mass term behaves like a time-varying dark energy in the background. In the case of minimal coupling, the effective Newton constant in the perturbation equation is consistent with that of general relativity, indicating that the evolution of matter density behaves similarly to the ΛCDM model. This talk is based on the work with Rampei Kimura (WIAS).

Sreekanth Harikumar (National Centre for Nuclear Research, Poland)

"Estimation of weak field parameters in Scalar-Tensor-Vector-Gravity for X-COP cluster sample"

Scalar-Tensor-Vector-Gravity(STVG) also know as MOdified Gravity(MOG) is a metric theory of gravity with dynamical scalar fields and a massive vector field introduced in addition to the metric tensor. In the weak field approximation MOG modifies the Newtonian acceleration with a Yukawa like repulsive term due to Maxwell-Proca type Lagrangian. This associates matter with a fifth force and a modified equation of motion. MOG has been successful in explaining galaxy rotation curves, gravitational lensing, cosmological observations and all other solar system observation without the need of dark matter. In this talk I will discuss existing observational bounds on MOG parameters.In particular I will present our original results obtained from X-COP sample of galaxy clusters.

Ricardo Landim (Technical University of Munich)

"Fractional Dark Energy"

The fractional dark energy (FDE) model describes the accelerated expansion of the Universe through a non-relativistic gas of particles with a non-canonical kinetic term. This term is proportional to the absolute value of the three-momentum to the power of 3w, where w is simply the dark energy equation of state parameter, and the corresponding energy leads to an energy density that mimics the cosmological constant. This inverse momentum operator appears in fractional quantum mechanics and it is the inverse of the Riesz fractional derivative. The observed vacuum energy can be obtained through the integral of the Fermi-Dirac (or Bose-Einstein) distribution and the lowest allowed energy of the particles. Furthermore, a system of FDE particles may present negative absolute temperatures (NAT). NAT are possible in quantum systems and in cosmology, if there exists an upper bound on the energy. This maximum energy is one ingredient of the FDE model and indicates a connection between FDE and NAT, if FDE is composed of fermions. In this scenario, the equation of state parameter is equal to minus one and the transition from positive to negative temperatures could happen in the early Universe.

Chair: Sachiko Kuroyanagi

Friday 22th October, Session 1 (15:00-16:30 JST&KST/8:00-9:30 CEST)

Junsup Shim (KIAS)

"The clustering of critical points in the evolving cosmic web"

Focusing on both small separations and baryonic acoustic oscillation scales, the cosmic evolution of the clustering properties of peak, void, wall, and filament-type critical points is measured using two-point correlation functions inCDM dark matter simulations as a function of their relative rarity. A qualitative comparison to the corresponding theory for Gaussian random fields allows us to understand the following observed features: (i) the appearance of an exclusion zone at small separation, whose size depends both on rarity and signature (i.e. the number of negative eigenvalues) of the critical points involved; (ii) the amplification of the baryonic acoustic oscillation bump with rarity and its reversal for cross-correlations involving negatively biased critical points; (iii) the orientation-dependent small-separation divergence of the cross-correlations of peaks and filaments (respectively voids and walls) that reflects the relative loci of such points in the filament's (respectively wall's) eigen-frame. The (cross-) correlations involving the most non-linear critical points (peaks, voids) display significant variation with redshift, while those involving less nonlinear critical points seem mostly insensitive to redshift evolution, which should prove advantageous to model. The ratios of distances to the maxima of the peak-to-wall and peak-to-void over that of the peak-to-filament cross-correlation are ∼sqrt(2) and ∼sqrt(3), respectively, which could be interpreted as the cosmic crystal being on average close to a cubic lattice. The insensitivity to redshift evolution suggests that the absolute and relative clustering of critical points could become a topologically robust alternative to standard clustering techniques when analyzing upcoming surveys such as Euclid or Large Synoptic Survey Telescope (LSST).

Mijin Yoon (Yonsei University/German Centre for Cosmological Lensing)

"The constraints on baryonic feedback effect and cosmology from weak lensing"

The baryonic feedback effect is an important element that should be understood better to reach precision cosmology with future surveys. For cosmological study, people have cut out a significant fraction of signals to avoid the bias from the baryonic effect or have marginalized over the range of baryonic feedback amplitudes chosen based on simulations. However, different cosmological simulations adopted different baryonic feedback amplitudes, which eventually requires observational inputs to validate their relevance. My previous study using the Deep Lens Survey with galaxy-galaxy lensing and galaxy clustering is the first study which constrained the baryonic feedback effect with cosmological parameters simultaneously. The constrained baryonic feedback prefers a stronger amplitude than the level of the most simulations, which could have been contaminated from the nonlinear galaxy bias. My recent study with the KiDS-VIKING 450 data used only the cosmic shear which is free from nonlinear galaxy bias. I will present the results of the DLS and KV450 analyses with the focus on the simultaneous constraints of the baryonic feedback and cosmology.

Emil Mottola (University of New Mexico)

"An Effective Theory of Vacuum Energy"

An Effective Theory of Dynamical Vacuum Energy based on First Principles of QFT and the Conformal Anomaly is proposed.

Michael Zantedeschi (Max Planck Institute for Physics, Munich)

"Primordial Black Holes from Confinement"

A mechanism for the formation of primordial black holes is proposed. Here, heavy quarks of a confining gauge theory produced by de Sitter fluctuations are pushed apart by inflation and get confined after horizon re-entry. The large amount of energy stored in the colour flux tubes connecting the quark pair leads to black-hole formation. These are much lighter and can be of higher spin than those produced by standard collapse of horizon-size inflationary overdensities. Other difficulties exhibited by such mechanisms are also avoided. Phenomenological features of the new mechanism are discussed as well as accounting for both the entirety of the dark matter and the supermassive black holes in the galactic centres. Under proper conditions, the mechanism can be realised in a generic confinement theory, including ordinary QCD. Moreover, for certain values of the confinement scale, the produced gravity waves are within the range of recent NANOGrav events. Simple generalisations of the mechanism allow for the existence of a significant scalar component of gravity waves with distinct observational signatures.

Friday 22th October, break time (16:30-17:00 JST&KST/9:30-10:00 CEST)

Friday 22th October, Session 2 (17:00-18:30 JST&KST/10:00-11:30 CEST)

Cristiano Sabiu (University of Seoul)

"Probing Ultra-light Axion Dark Matter from 21cm Tomography"

We present forecasts on the detectability of Ultra-light axion-like particles (ULAP) from future 21cm radio observations around the epoch of reionization (EoR). We show that the axion as the dominant dark matter component has a significant impact on the reionization history due to the suppression of small scale density perturbations in the early universe. This behavior depends strongly on the mass of the axion particle. Using numerical simulations of the brightness temperature field of neutral hydrogen over a large redshift range, we construct a suite of training data. This data is used to train a convolutional neural network that can build a connection between the spatial structures of the brightness temperature field and the input axion mass directly. We construct mock observations of the future Square Kilometer Array survey, SKA1-Low, and find that even in the presence of realistic noise and resolution constraints, the network is still able to predict the input axion mass.

Christoph Saulder (KASI)

"Using cross-correlations to recover the BAO peak in sparse spectroscopic surveys"

As it takes a long time for large spectroscopic surveys, like DESI, to complete their observations of all their targets, we present a robust way to extract viable cosmological information from incomplete datasets. To this end, we calculate the cross-correlations between the photometrically selected targets and the spectroscopically observed targets. Using a toy model inspired by the footprint of the DA0.2 DESI data for LRGs, we find that even in the case of such a highly incomplete and patchy spectroscopic data, we are able to clearly recover the features like the BAO peak with this cross-correlation.

Shun Arai (CGP, YITP, Kyoto University)

"Gradient expansion approach for generic scalar-tensor theories"

We apply the spatial gradient expansion method to generic scalar-tensor theories in order to investigate the non-linear nature of cosmological perturbations. Extending previous studies, we consider a rather wide class of scalar-tensor theories up through the so-called quadratic DHOST theories, which could describe the ancient as well as current cosmic accelerations. In addition we take into account spatial anisotropies at the leading order in gradient expansion, namely the effect of conserved gravitational waves on large scales for the first time. In the analysis, we employ the action approach and derive the reduced action for the scalar and tensor degrees of freedom after solving constraints, which makes manifest the presence of closed equations for those degrees of freedom.

Masroor C. Pookkillath (YITP, Kyoto University)

"Minimal theory of massive gravity and constraints on the graviton mass"

The Minimal theory of Massive Gravity (MTMG) is endowed non-linearly with only two tensor modes in the gravity sector which acquire a non-zero mass. On a homogeneous and isotropic background the theory is known to possess two branches: the self-accelerating branch with a phenomenology in cosmology which, except for the mass of the tensor modes, exactly matches the one of $¥Lambda$CDM; and the normal branch which instead shows deviation from General Relativity in terms of both background and linear perturbations dynamics. For the latter branch we study using several early and late times data sets the constraints on today's value of the graviton mass $¥mu_{0}$, finding that $(¥mu_{0}/H_{0})^{2}=0.119_{- 0.098}^{+0.12}$ at 68¥% CL, which in turn gives an upper bound at 95¥% CL as $¥mu_{0}<8.4¥times1 0^{-34}$ eV. This corresponds to the strongest bound on the mass of the graviton for the normal branch of MTMG.

Artur Alho (CAMGSD- IST Univ. Lisbon)

"Dynamical systems analysis of quintessence"

We consider quintessence models with a scalar field and matter in a spatially flat and isotropic spacetime. The field equations are recast into complementary dynamical systems, which enables situating quintessence evolution in a global solution space context. Moreover, we use the dynamical systems to obtain straightforward derivations of new and known simple and accurate approximations for quintessence evolution which includes thawing and tracker solutions.

Lu Yin (Sogang University)

"Reducing the H0 Tension with Exponential Acoustic Dark Energy"

We explored a new dark fluid model in the early universe to relieve the Hubble tension significantly, that tension is the different result of the Hubble constant derived from CMB inference and local measurements within the LCDM. We discussed an exponential form of the equation of state in the acoustic dark energy for the first time, in which gravitational effects from its acoustic oscillations can impact the CMB phenomena at the epoch of matter radiation equivalent, called the exponential acoustic dark energy (eADE). And the constraints were given by the current cosmological data and the comparison of the phenomena with the stander model was shown through CMB and matter power spectra. The result shows our model has the H0 = 71.65+1.62-4.4 in 68% C.L. with a smaller best fitted Chi^2 value than that in LCDM.

Hanwool Koo (KASI/UST)

"Bayesian vs Frequentist: Comparing Bayesian model selection with a frequentist approach using the iterative smoothing method"

We have developed a frequentist approach for model selection which determines the consistency between any cosmological model and the data using the distribution of likelihoods from the iterative smoothing method. Using this approach, we have shown how confidently we can conclude whether the data support any given model without comparison to a different one. In this current work, we compare our approach with the conventional Bayesian approach based on the estimation of the Bayesian evidence using nested sampling. We use simulated future Roman (formerly WFIRST)-like type Ia supernovae data in our analysis. We discuss the limits of the Bayesian approach for model selection and show how our proposed frequentist approach can perform better in the falsification of individual models. Namely, if the true model is among the candidates being tested in the Bayesian approach, that approach can select the correct model. If all of the options are false, then the Bayesian approach will select merely the least incorrect one. Our approach is designed for such a case and we can conclude that all of the models are false.

William Davison (KASI)

"STag: Supernova Tagging and Classification"

Supernovae classes have been defined phenomenologically, based on spectral features and time series data, since the specific details of the physics of the different explosions remain unrevealed. However, the number of these classes is increasing as objects with new features are observed, and the next generation of large-surveys will only bring more variety to our attention. We apply the machine learning technique of multi-label classification to the spectra of supernovae. By measuring the probabilities of specific features or 'tags' in the supernova spectra, we can compress the information from a specific object down to that suitable for a human or database scan, without the need to directly assign to a reductive 'class'. We use logistic regression to assign tag probabilities, and then a feed-forward neural network to filter the objects into the standard set of classes, based solely on the tag probabilities. We present STag, a software package that can compute these tag probabilities and make spectral classifications.