UNIVERSITY OF
TABRIZ

دانشگاه تبریز

FRONTIERS in GENERAL RELATIVITY, MODIFIED THEORIES, and COSMOLOGY

3rd online international conference

March 11th, 2025

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About the Conference

This conference brings together researchers to discuss the latest advancements in General Relativity, Modified Gravity Theories, and Cosmology. It serves as a platform for exchanging ideas and fostering collaboration on topics such as modified gravity models, dark energy, inflation, and black hole physics.

Understanding gravity and cosmology is crucial for addressing fundamental questions in physics. While General Relativity has been highly successful, modifications to Einstein's theory are actively explored to explain dark energy, cosmic inflation, and quantum gravity effects. This conference aims to push the boundaries of our knowledge, linking theoretical developments with observational data and promoting scientific collaboration.

Scientific Committee:

Dr. Amin Rezaei Akbarieh (Tabriz)
Dr. Hossein Motavvali (Tabriz)
Dr. Yaghoub Heydarzade (Bilkent)

Organized by:

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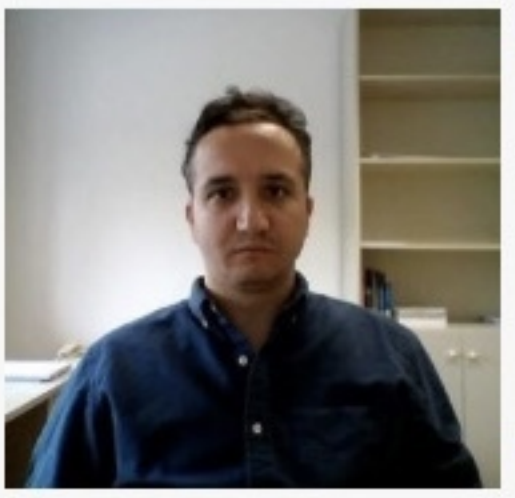
CONFERENCE SPEAKERS

Dr. Yaghoub Heydarzade

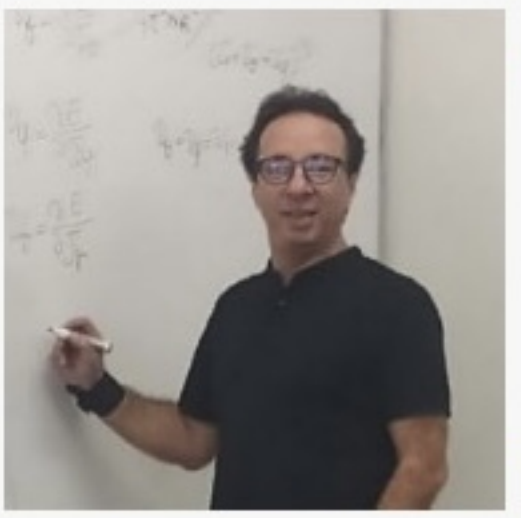
Dr. Kamal Hajian

Dr. Rahim Moradi



Dr. Çetin Şentürk

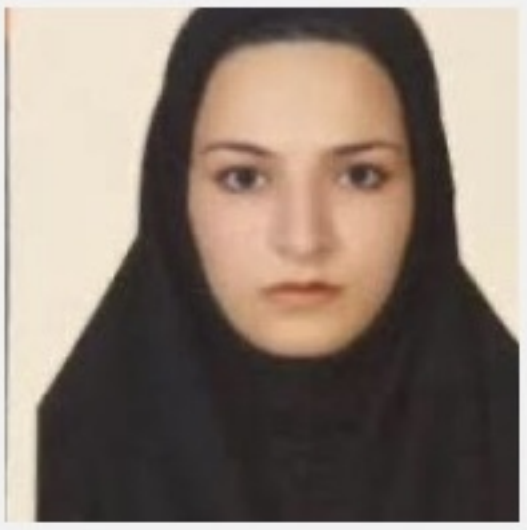
Dr. Pouya Bakhti



Dr. Shahram Jalalzadeh

CONFERENCE SPEAKERS

Dr. Hamed Hadi



Dr. Samira Golsanamlou

Dr. Goksel Daylan Esmer

Dr. Minou Khoshrangbaf

Saliha Türkmen

Aytül Filiz

🎤 **Speaker: Dr. Yaghoub Heydarzade**

🏛️ **Affiliation: Bilkent University**

FLRW-Cosmology in Generic Gravity Theories

I will present a brief outline of the proof for the following theorem and its corollary.

Theorem: For the D-dimensional FLRW spacetimes, any second rank symmetric tensor obtained from the metric tensor, Riemann tensor, Ricci tensor, and their covariant derivatives at any order becomes a combination of the metric tensor $g_{\mu\nu}$ and $u_\mu u_\nu$; that is $E_{\mu\nu} = A g_{\mu\nu} + B u_\mu u_\nu$ where A and B are functions of the scale factor a(t) and its time derivatives at any order and they depend on the underlying gravity theory.

Corollary: In FLRW cosmology, the field equations of any generic gravity theory in arbitrary dimensions are of the perfect fluid type.

🎤 ***Speaker: Dr. Rahim Moradi***

🏛️ ***Affiliation: Institute of High Energy Physics Chinese Academy of Sciences***

Gamma-Ray Bursts: Bridging Observations and Theory

This talk provides an overview of the observational history of gamma-ray bursts (GRBs) and the key space missions that have significantly contributed to understanding their astrophysical properties. The discussion will explore recent advancements in GRB research, focusing on the role of black holes in driving the prompt emission phase and the contribution of pulsar-like sources to the afterglow phase. These two distinct theoretical frameworks offer insights into the possible interplay between black holes and pulsar-like behaviors in GRBs. Additionally, new observational features of the brightest GRB ever recorded, GRB 221009A, will be presented, highlighting its supernova association as observed by satellites of the Chinese Academy of Sciences. This unprecedented dataset offers new perspectives on GRB physics and their connection to supernovae, challenging and refining current theoretical models.

🎤 ***Speaker: Dr. Shahram Jalalzadeh***

🏛️ ***Affiliation: Federal University of Pernambuco***

Fractal horizons in fractional quantum gravity

This presentation will summarize the studies regarding the influence of the Riesz fractional derivative in quantum black hole physics and the de Sitter universe. I will illustrate how the fractional Wheeler-DeWitt equation enhances our comprehension of physics in both quantum and classical gravity.

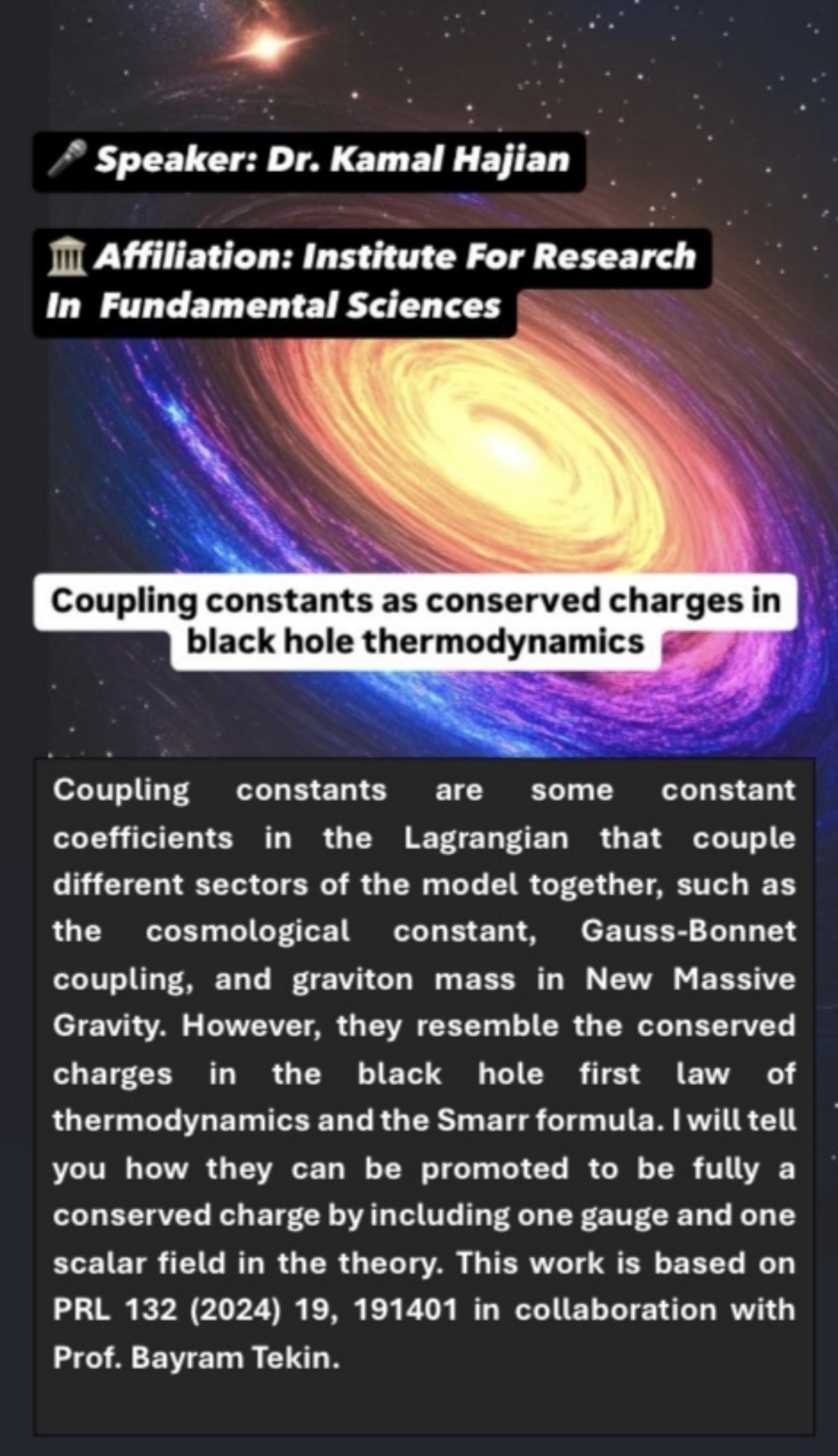
I will demonstrate that the event horizon of a fractional Schwarzschild black hole does not possess the properties of a smooth surface but instead resembles a fractal structure. This statement is also relevant to the fractional de Sitter spacetime. Moreover, the fractional de Sitter space investigation advances us toward the notion of power law inflation. This finding is universal and remains devoid of any parameters of the inflaton field.

🎤 **Speaker: Dr. Minou Khoshrangbaf**

🏛️ **Affiliation: University of Tabriz**

Accretion disk around regular black holes

Regular black holes are crucially important as approaches to solving the singularity problem, and in this work, the accretion disk of Bardeen and Hayward models has been studied. For this purpose, we calculated the physical properties of black holes, including radiant energy, luminosity derivative, temperature, and conversion efficiency of accretion mass into radiation. The obtained results show that the nonzero-free parameters of regular black holes cause the radius of the innermost stable circular orbit of the disk to shift to smaller values. As a result of this displacement, we saw an increase in the profiles of radiant energy, luminosity derivative, and temperature. We also find that Bardeen and Hayward's black holes are more efficient in converting mass to radiation than Schwarzschild. Finally, we compared the free parameter of these two black holes with the spin of the rotating black hole and found that the Bardeen and Hayward black holes can mimic the slowly rotating Kerr black hole.



🎤 Speaker: Dr. Kamal Hajian

🏛️ Affiliation: Institute For Research In Fundamental Sciences

Coupling constants as conserved charges in black hole thermodynamics

Coupling constants are some constant coefficients in the Lagrangian that couple different sectors of the model together, such as the cosmological constant, Gauss-Bonnet coupling, and graviton mass in New Massive Gravity. However, they resemble the conserved charges in the black hole first law of thermodynamics and the Smarr formula. I will tell you how they can be promoted to be fully a conserved charge by including one gauge and one scalar field in the theory. This work is based on PRL 132 (2024) 19, 191401 in collaboration with Prof. Bayram Tekin.

🎤 ***Speaker: Dr. Samira Golsanamlou***

🏛️ ***Affiliation: Azarbaijan Shahid Madani University***

Investigating Gravitational Baryonogenesis in Generalized Metric-Palatini Gravity

This research aims to analyze the impact of hybrid metric-Palatini gravity on the baryogenesis process. The hybrid metric-Palatini model combines two gravitational theories that allow for a more detailed examination of the behavior of spacetime and its interaction with matter. This combination is critical in the early radiation-dominant universe, where unusual gravitational effects may play a key role in generating baryonic asymmetry and the production of baryons and antibaryons.

🎤 **Speaker: Dr. Hamed Hadi**

🏛️ **Affiliation: University of Tabriz**

Dynamical non-locality in the near-horizon region of a black hole with quantum time

The formalization of the modular energy operator within the curved spacetime is achieved through the timeless approach proposed by Page and Wootters. The investigation is motivated by the peculiar behavior of the near horizon region of a black hole and its quantum effects, leading to a restriction of the study to the immediate vicinity.

The focus lies on the perspective of a static observer positioned close to the horizon. This paper highlights the alteration of the modular energy's behavior in this region compared to flat spacetime.

Furthermore, it is observed that the geometry of the spacetime influences the non-local properties of the modular energy. Moreover, within the event horizon of the black hole, the modular energy exhibits a completely distinct behavior, rendering its modular behavior imperceptible in this specific region.

🎤 **Speaker: Saliha Türkmen**

🏛️ **Affiliation: Istanbul University**

The Physical and Mathematical Properties of Kerr-Newman Black Holes in f(R) Gravity

In recent years, advancements in gravitational wave detection and black hole imaging have reignited interest in alternative theories of gravity. This study investigates the physical and mathematical properties of Kerr-Newman black holes within the framework of f(R) gravity, a prominent extension of General Relativity. The study begins with an exploration of the general features of black holes, including their formation mechanisms, observational evidence, and classification. The focus then shifts to the Hamilton-Jacobi method, utilized to analyze the geodesic motion of test particles around Kerr-Newman black holes in f(R) gravity. Hidden symmetries, crucial for understanding the spacetime structure, are explored through Killing and Killing- Yano tensors. These tensors reveal the underlying geometric properties and contribute to the separability of the Hamilton-Jacobi equations. Moreover, the study delves into the gyromagnetic ratio, demonstrating that the g factor for Kerr-Newman black holes in f(R) gravity remains consistent with the Dirac value of g = 2, aligning with Einstein-Maxwell theory predictions. The findings underscore the importance of exploring black holes within alternative gravity frameworks, not only to deepen our understanding of astrophysical phenomena but also to assess the viability of f(R) gravity as a candidate for explaining discrepancies between general relativity and quantum mechanics.

🎤 ***Speaker: Dr. Çetin Şentürk***

🏛️ ***Affiliation: University of Turkish AeronauticaAssociation***

Reduced and Minimal Versions of Einstein-Aether Theory

We show that there is a phenomenologically and theoretically consistent limit of the generic Einstein-Aether theory in which the Einstein-Aether field equations reduce to Einstein field equations with a perfect fluid distribution sourced by the aether field. This limit is obtained by taking the of the coupling constants of the theory to be zero but keeping the expansion coupling constant to be nonzero.

We then consider the further reduction of this limited version of Einstein-Aether theory by taking the expansion of the aether field to be constant (possibly zero), and thereby we introduce the Minimal Einstein-Aether theory that supports the Einstein metrics as solutions with a reduced cosmological constant.

The square of the expansion of the unit-time like aether field shifts the bare cosmological constant and thus provides, via local Lorentz symmetry breaking inherent in the Einstein-Aether theories, a novel mechanism for reconciling the observed, small cosmological constant (or dark energy) with the large theoretical prediction coming from quantum field theories. The crucial point here is that minimal Einstein-Aether theory does not modify the well-tested aspects of General Relativity such as solar system tests and black hole physics including gravitational waves.

🎤 ***Speaker: Dr. Göksel Daylan Esmer***

🏛️ ***Affiliation: Istanbul University***

Dark Energy Effects in Rotating Black Hole Dynamics

Recent cosmological observations have confirmed that the universe is accelerating, a phenomenon commonly attributed to dark energy's negative pressure. In this work, we explore the influence of dark energy on the dynamics of particles moving in the vicinity of rotating black holes, specifically within the framework of Kerr–de Sitter spacetime. By employing both analytical and numerical techniques, we investigate the quasi-periodic oscillations that arise near the event horizon—focusing on radial and vertical epicyclic frequencies as well as periastron and Lense–Thirring precession effects. Our study examines a range of cosmological constant values, from the idealized case of $\Lambda = 0$ to the extremely small observational value ($\Lambda \approx 10^{-52}$ m^{-2}), thereby providing insights into how dark energy modifies the relativistic motion in strong gravitational fields. The results not only enhance our understanding of particle dynamics in such extreme environments but also shed light on the broader role of dark energy in shaping the structure of spacetime around rotating black holes. This investigation has significant implications for interpreting high-energy astrophysical phenomena and contributes to the ongoing dialogue between cosmology and gravitational physics.

🎤 **Speaker: Aytül Filiz**

🏛️ **Affiliation: Istanbul University**

Chern-Simons Formulation of Higher Spin Gravity Theories

Higher Spin Gravity (HS) theories extend the framework of general relativity by incorporating an infinite hierarchy of higher-spin fields, offering a potential pathway toward a more profound understanding of quantum gravity. Among the various formalisms developed for HSG, the Chern-Simons (CS) formulation has emerged as a particularly elegant and powerful approach, especially in lower-dimensional settings. The Chern-Simons formulation is especially effective in three-dimensional gravity, where standard Einstein gravity with a cosmological constant can be reformulated as a Chern-Simons gauge theory based on the AdS or ds group. This framework extends naturally to higher-spin theories by promoting the underlying gauge algebra to a higher-spin algebra, such as hs(2), which encompasses an infinite set of generators corresponding to higher-spin fields.

One of the principal advantages of the CS formulation is its manifest background independence and gauge invariance, which provide a more structured and concise description of higher-spin dynamics. Unlike metric-based approaches, where the inclusion of higher-spin fields introduces considerable complexity, the CS formulation describes these degrees of freedom in terms of gauge connections. The field equations are given by flatness conditions on these connections, significantly simplifying the analysis of classical solutions and their associated asymptotic symmetries. In the context of the AdS/CFT correspondence, three-dimensional higher-spin gravity formulated via CS theory has been extensively investigated due to its duality with two-dimensional conformal field theories (CFTs) featuring extended symmetries, such as the W_N algebras. This correspondence provides valuable insights into holography beyond Einstein gravity and offers new perspectives on the quantum structure of spacetime. Despite these successes, several challenges persist, particularly in extending the CS formulation to four and higher dimensions, where additional constraints and complications arise. Nonetheless, the Chern-Simons approach remains a promising avenue for exploring the fundamental aspects of higher-spin theories.

🎤 *Speaker: Dr. Pouya Bakhti*

🏛️ *Affiliation: Jeonbuk National University*

Future Solar Neutrino Observatories

In this talk, I will discuss future solar neutrino observatories and their role in measuring solar neutrino oscillation parameters. These observatories will discontribute to determining the structure of the Sun and the Earth through the study of * day-night asymmetry. Solar neutrinos, produced via the pp-chain and CNO cycle, travel directly from the solar core to the • Earth. Detecting these neutrinos provides • crucial insights into the thermonuclear reactions occurring in the solar core, enhancing our understanding of both the Sun and the standard stellar model.

Conference program

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Time	Speaker	Topic
08:45-09:00	Host	Welcome speech, introduction, and webinar objectives
09:00-09:15	Vice President for Research (Dr. Kheradmand)	
09:15-09:35	Pouya Bakhti	Future Solar Neutrino Observatories
09:35-10:05	Rahim Moradi	Gamma-Ray Bursts: Bridging Observations and Theory
10:05-10:25	Minou Khoshrangbaf	Accretion disk around regular black holes
10:25-10:45	Ğoksel Daylan Esmer	The Influence of Dark Energy on the Dynamics of Rotating Black Holes
10:45-11:00	❖ **Break**	
11:00-11:30	Çetin Şentürk	Reduced and Minimal Versions of Einstein-Aether Theory
11:30-11:50	Hamed Hadi	Dynamical non-locality in the near-horizon region of a black hole with quantum time
11:50-12:20	Yaghoub Heydarzade	FLRW-Cosmology in Generic Gravity Theories
12:20-15:00	❖ **Break**	
15:00-15:20	Samira Golsanamlou	Investigating Gravitational Baryonogenesis in Generalized Metric-Palatini Gravity
15:20-15:50	Shahram Jalalzadeh	Fractal horizons in fractional quantum gravity
15:50-16:20	Kamal Hajian	Coupling constants as conserved charges in black hole thermodynamics
16:20-16:40	Saliha Türkmen	The Physical and Mathematical Properties of Kerr-Newman Black Holes in f(R) Gravity
16:40-17:00	Aytül Filiz	Chern-Simons Formulation of Higher Spin Gravity Theories