# The 6th Conference of the Polish Society on Relativity

Monday 23 September 2019 - Thursday 26 September 2019

Other Institutes


# Book of Abstracts

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**Parallel Sessions** / **20**

## 1+1+2 covariant formulation of light propagation in cosmological models

**Author:** Krzysztof Głód[1]

[1] *Astronomical Observatory of the Jagiellonian University*

**Corresponding Author:** krzysztof.glod@uj.edu.pl

We present a covariant approach to the problem of light beam propagation in cosmological models. We develop our considerations within the framework of classical geometric optics in general relativity. Using the concept of screen surface orthogonal to the observer velocity and to the bundle of geodesics, we introduce covariant four-dimensional definitions for Sachs and Jacobi fields and for the area distance. Then we derive relationships between them and their propagation equations and initial conditions for these equations. Ultimately, for practical use, we transform the resulting formulas into a redshift dependent form.

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## Anti-evaporation of Schwarzschild–de Sitter lack hole revisited

**Author:** Maciej Kolanowski[1]

[1] *University of Warsaw, Faculty of Physics*

**Corresponding Author:** mp.kolanowski@student.uw.edu.pl

It is widely believed that in the presence of positive cosmological constant, heavy black holes can exhibit behaviour different than the standard Hawking radiation, namely there is a possibility of anti-evaporation of such objects. We point out that all those results (obtained in different frameworks) rely heavily upon the identification of the Naiari spacetime with the Schwarzschild–de Sitter (Kottler) spacetime. We argue that it is incorrect assumption and, as a result, also heavy black holes radiate thermally. We also discuss possible meaning of this results for the primordial black holes' lifetime.

**Student's Talks** / **75**

## Anti-evaporation of Schwarzschild-deSitter black hole revisited

**Corresponding Author:** mp.kolanowski@student.uw.edu.pl

**Student's Talks** / **42**

## Antisymmetric Tensors in Friedmann Cosmology

**Author:** Nils A. Nilsson[1]

[1] *National Centre for Nuclear Research*

**Corresponding Author:** albin.nilsson@ncbj.gov.pl

Antisymmetric tensor fields arise naturally in superstring theory as well as in some theories with broken Lorentz invariance. However, models containing antisymmetric tensor fields often include anisotropic pressure. I will present a general prescription for constructing ansätze for antisymmetric tensor fields for use in cosmology. With a series of coordinate-dependent constraints I will show that these models can fit Friedmann-type geometry.

**Parallel Sessions** / **45**

## Black-hole mimickers and echos from compact objects

**Author:** Roman Konoplya[1]

[1] *Silesian University in Opvava*

**Corresponding Author:** roman.konoplya@gmail.com

Here we will discuss two questions related to black-hole mimickers: a) whether echoes from a compact object, if observed, should necessarily mean a qualitatively non-Einsteinian behavior near its surface or may also indicate presence of astrophysical environment? b) whether a perfect, stable black-hole mimicker is possible in the form of a Schwarzschild star.

**Parallel Sessions** / **85**

## Breaking the Vainshtein Screening in Clusters of Galaxies

**Author:** Vincenzo Salzano[1]

[1] *University of Szczecin*

**Corresponding Author:** vincenzo.salzano@usz.edu.pl

After a (necessarily) short introduction about why and how General Relativity, assumed as the established consensus gravity theory, should be modified/extended, we will discuss the constraints we obtained for a particular class of Extended Theory of Gravity (technically defined as “Beyond Horndeski” and “Vainshtein-breaking” theory), using data from clusters of galaxies, both from X-ray observations and from gravitational lensing events.

**Parallel Sessions** / **70**

## Breaking the Vainshtein Screening in Clusters of Galaxies

**Corresponding Author:** vincenzo.salzano@usz.edu.pl

**Selected Talks** / **21**

## Canonical Quantization of Massive Symmetric Rank-Two Tensor in String Theory

**Author:** Taejin Lee[1]

[1] *Department of Physics, Kangwon National University*

**Corresponding Author:** taejin9457@gmail.com

Canonical quantization of massive symmetric rank-two tensor in string theory has been studied. The Lagrangian describing symmetric rank-two tensor, containing two Stueckelberg fields, was obtained by Siegel and Zwiebach from string field theory. Performing canonical analysis, we found that the Lagrangian possesses first class constraints only, which generate a local gauge transformation. By an explicit calculation, we show that the constraints form a closed algebra only in the critical dimension of string, $d = 26$. It reminds us that the origin of local symmetry is nilpotency of BRST operator, which is valid only in the critical dimension.
In a particular gauge, imposed on the Stueckelberg fields, the gauge invariant Lagrangian of Siegel and Zwiebach reduces to the Fierz-Pauli Lagrangian proposed for a massive spin-two particle. Thus, the Fierz-Pauli Lagrangian is a gauged fixed version of the gauge invariant Lagrangian for massive symmetric rank-two tensor. In comparison to the Fierz-Pauli Lagrangian, which contains second class constraints, it is much simpler to quantize the gauge invariant Lagrangian. We also constructed a covariant propogator which may be useful to develop a perturbation theory for massive spin-two particle.

**Parallel Sessions** / **17**

## Conformally recurrent heavenly spaces

**Author:** Chudecki Adam[1]

[1] *Lodz University of Technology, Center of Mathematics and Physics*

**Corresponding Author:** adam.chudecki@p.lodz.pl

Two-sided conformally recurrent complex and real 4-dimensional spaces are considered. It is proved, that such spaces are equipped with nonexpanding congruence of totally null and geodesic 2-dimensional surfaces, null strings. Two-sided conformally recurrent heavenly spaces of the Petrov-Penrose type [D] are considered. Also, some real slices of type [D] heavenly metric are discussed.

**Parallel Sessions** / **52**

## Conserved quantities related to (3+1) decomposition of CYK tensors

**Author:** Tomasz Smołka[1]

**Co-author:** Jacek Jezierski [1]

[1] *University of Warsaw*

Conformal Yano-Killing (CYK) tensor is a generalization of Killing vector to anti-symmetric two-form which describes so called hidden symmetries. (3+1) decomposition of CYK tensor enables one to construct charges from initial data in a new, simple and geometric way. I will present the construction and compare it with traditional ADM approach. Joint work with Jacek Jezierski.

**Parallel Sessions** / **14**

## Construction of the cosmological model with periodically distributed dust inhomogeneities with growing amplitude.

**Authors:** Szymon Sikora[1] ; Krzysztof Głód[2]

[1] *Jagiellonian University*

[2] *Astronomical Observatory of the Jagiellonian University*

**Corresponding Authors:** krzysztof.glod@uj.edu.pl, szymon.sikora@uj.edu.pl

Analytical models which generalize the Friedmann-Lemaitre-Robertson-Walker space-time are important tools in the analysis of a possible impact of the large-scale structure inhomogeneities on the cosmological observables (angular diameter distance-redshift relation, local measurements of the Hubble constant, etc.)
In this talk I will present some progress in the construction of the dust-like cosmological model with a periodically distributed inhomogeneities. The most important idea in this framework is to simplify the Einstein equations by imposing specific symmetry conditions on the matter distribution in space.

**Plenary Session** / **7**

## Cosmography as a tool to discriminate between modified gravity and dark energy

**Author:** Salvatore Capozziello[1]

[1] *INFN - National Institute for Nuclear Physics*

**Corresponding Author:** salvatore.capozziello@na.infn.it

Cosmography can be considered as a sort of a
model-independent approach to tackle the dark energy/modified gravity
problem. In this talk, the success and the shortcomings of the
$\Lambda$CDM model, based on General Relativity and standard model of
particles, are discussed in view of the most recent observational
constraints. The motivations for considering extensions and modifications
of General Relativity are taken into account, with particular attention to
$f(R)$ and $f(T)$ theories of gravity where dynamics is represented by
curvature or torsion field respectively. The features of $f(R)$ models
are explored in metric and Palatini formalisms.
Cosmological dynamics of $f(R)$ models is investigated through the
corresponding viability criteria. Afterwards, the equivalent formulation
of General Relativity (Teleparallel Equivalent General Relativity) in
terms of torsion and its extension to $f(T)$ gravity is considered.
Finally, the cosmographic method is adopted to break the degeneracy among
dark energy models. A novel approach, built upon rational Pad\'e and
Chebyshev polynomials, is proposed to overcome limits of standard
cosmography based on Taylor expansion. The approach provides accurate
model-independent approximations of the Hubble flow. Numerical analyses
are presented to bound coefficients of the cosmographic series. These
techniques are thus applied to reconstruct $f(R)$ and $f(T)$ functions
and to frame the late-time expansion history of the universe with no
\emph{a priori} assumptions on its equation of state. A comparison
between the $\Lambda$CDM cosmological model with $f(R)$ and $f(T)$ models
is reported.

**Parallel Sessions** / **35**

## Curvature perturbations in quantum cosmological spacetimes

**Author:** Przemysław Małkiewicz[1]

[1] *National Centre for Nuclear Research*

**Corresponding Author:** pmalkiew@gmail.com

I will present some preliminary results on the evolution of perturbations in quantum cosmological spacetimes. The classical framework is derived with the Dirac procedure from the second order ADM formalism. Then the framework is quantised covariantly, i.e., respecting the symmetries of the phase space. Next, a semi-classical framework is established and the evolution of perturbations in semi-classical spacetimes is investigated for a range of cosmological fluids. A discussion on the final amplitude spectra will follow. I will conclude with an outlook for the future investigations in anisotropic cosmological spacetimes.

**Student's Talks / 30**

## Decaying Massive Scalar in the Early Universe

**Author:** Juho Lankinen[1]

[1] *University of Turku*

**Corresponding Author:** jumila@utu.fi

The presence of a gravitational field modifies significantly particle decay rates compared to the usual Minkowski space results. Because of the lack of energy conservation, new particle processes, forbidden in Minkowski space, are to be considered leading to new Feynman diagrams even at first order. I will give a brief introduction to the problems one encounters when trying to calculate decay rates using quantum field theory in curved spacetime in FLRW-spacetimes. I will focus on conceptual issues, show methods of calculation to overcome some of these issues and present few explicit results of modified decay rates which show that in the early Universe a massive scalar particle tends to decay into fermionic rather than to scalar channel.

Based on:
arXiv:1805.09620
arXiv:1904.05084

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## Discrete scale invariance in holography revisited

**Author:** Mario Flory[1]

[1] *Jagiellonian University*

**Corresponding Author:** mflory@th.if.uj.edu.pl

In 2013, Koushik Balasubramanian presented a 5+1 dimensional holographic toy model that allows for an exact solution to Einstein's equations in the bulk in which the isometries of ⊠⊠5 appear to be broken to an isometry group describing a discretely scale invariant and Poincare invariant setup [arXiv:1301.6653]. By analytically solving the Killing equations, we prove that the full ⊠⊠5 isometry group is still present, although in a somewhat hidden way. We also comment on the prospects of finding other holographic models which allow for solutions with discrete scale invariance or scale invariance without conformal invariance in the future. This talk is based on arXiv:1711.03113.

**Parallel Sessions** / **69**

## Discrete scale invarinace in holography revisited

**Corresponding Author:** mflory@th.if.uj.edu.pl

**Student's Talks** / **54**

## Extended quantum uncertainty in the presence of horizons

**Authors:** Mariusz Dabrowski[1] ; Fabian Wagner[2]

[1] *University of Szczecin*

[2] *Universytet Szczecinski*

**Corresponding Authors:** fabian.wagner@usz.edu.pl, mpdabfz@onet.eu

Space-time curvature affects quantum uncertainty. This effect is commonly known as the Extended Uncertainty principle. In this talk I briefly present a method to calculate the influence of curvature on the uncertainty relation. Moreover I apply it to cosmological and Rindler horizons and interpret the results in the context of horizon thermodynamics.

**Parallel Sessions** / **76**

## Extra Dimensions in Light of GW170817

**Author:** Sumanta Chakraborty[1]

**Co-authors:** Sukanta Bose ; Soumitra SenGupta ; Kabir Chakravarti

[1] *IUCAA*

**Corresponding Author:** sumantac.physics@gmail.com

I will present a computation of the tidal Love numbers of black holes and neutron stars in the presence of higher dimensions. The perturbation equations around an arbitrary static and spherically symmetric metric for the even parity modes will be presented in the context of an effective four-dimensional theory on the brane. Surprisingly, even for black holes the tidal Love numbers are non-zero and, more importantly, negative. I will also discuss the tidal Love number of neutron stars in a spacetime inheriting extra dimensions and I will demonstrate that, in the context of effective gravitational theory on the brane, they are different from that in general relativity. Finally I will comment on possible constraints on the parameters inherited from higher dimensions from the GW170817 event as well.

**Parallel Sessions** / **64**

## Fierz theory vs Linear Gravity

**Author:** Marian Wiatr[1]

[1] *Universtity of Warsaw*

**Corresponding Author:** m.wiatr@student.uw.edu.pl

One of the most popular points of view on Linearized Gravity is a Massless Spin-2 Particle Theory. This theory often serves as a starting point to formulate a quantum version of gravity theory. The Spin-2 Field has a well defined local energy density equal to $\frac{1}{2}(E^2 + B^2)$ in analogy to Maxwell Electrodynamics. However, obtaining this energy formula from Hamiltonian formulation is not obvious, so to clarify it, I will present a new formulation of Classical Electrodynamics analogical to Fierz formulation of the Spin-2 Field Theory. The relations and differences between Linearized Gravity and the Spin-2 Field Theory will be discussed.

**Plenary Session** / **83**

## Gravitational Waves Observations by LIGO and Virgo

**Author:** Vivien Raymond[1]

[1] *Cardiff University*

**Corresponding Author:** raymondv@cardiff.ac.uk

On September 14th, 2015 the LIGO-Virgo collaboration made the first direct detection of gravitational waves, nearly one hundred years after Einstein first predicted them. Since, several gravitational waves have been detected, and we have been able to study new black holes and analyse the collision of two neutron stars. Now the Advanced LIGO and Advanced Virgo observatories are on their third science run. Many more gravitational-wave candidates have been announced since its start in April 2019.
In this talk, I will review the detections and their physical and astrophysical implications as of the end of the second science run, and I'll give and update on the progress of current observations.

**Parallel Sessions** / **50**

## Gravitational wave Memory Effect

**Authors:** Sebastian Szybka[1] ; Syed Naqvi[1]

[1] *Astronomical Observatory of Jagiellonian University*

**Corresponding Author:** umair.kmc@gmail.com

Gravitational waves offer a unique window to study the strong-field regime of general relativity. In 1916-18, Einstein showed their existence in linearized approximation which was followed by a period of confusion. Finally cemented theoretically by Bondi, Sachs, Trautman gravitational waves are an important tool to discover new information about fundamental gravity effects.

One of the persistent gravitational wave effect called memory effect forms an interesting proposition theoretically and astrophysically. It is essentially a permanent displacement between particles after GW passes. It's linear and non-linear form will be important for the future GW detections from compact binary sources. This effect gives information about the asymptotic nature of spacetime and is relevant for a large number of detections by LIGO/VIRGO. The linear part discovered by Zel'dovich & Polnarev and the nonlinear part discovered by Christodoulou help us understand the nature of spacetime and explore further the nonlinear part of general relativity.

We plan to study the linear memory effect for different wave profiles under the exact plane wave solution of Einstein's vacuum equations and then look for other solutions. The displacement and velocity memory effects are studied by analyzing the geodesic equation for test masses under exact plane wave spacetime. The aim is to look for different gravitational spacetimes and study the memory effect within them.

**Student's Talks** / **31**

## Holographic SQUID and detection of dark matter

**Authors:** Bartłomiej Kiczek[None] ; Marek Rogatko[1] ; Karol Wysokinski[2]

[1] *Maria Curie-Skłodowska University, Lublin, Poland*

[2] *Maria Curie Sklodowska University*

**Corresponding Author:** bartlomiej.kiczek@gmail.com

The gauge/gravity duality has constituted as a powerful tool for analysis of strongly coupled condensed matter systems on a weakly coupled gravitational side in AdS spacetime.
It has been shown that the holographic theory reproduces several properties of superconducting/superfluid state known from conventional quantum mechanical considerations and experiments.
This has been extended by possibilities of modeling Josephson junctions in a holographic approach in various scenarios – different pairing types or in modified gravity, which opened a new branch of research that can be named as Applied AdS/CFT.
Treating these efforts as an inspiration we propose bringing the superconducting devices into the field of the detection of specific kind of dark matter (DM), namely the dark photon.
In our model we construct a holographic SQUID (superconducting quantum interference device) whose one of Josephson junctions is affected by the dark sector. This interaction is realized by kinetic mixing term resulting a photon-dark photon coupling.
We have shown that mixing has an impact on properties of Josephson junction such as current-phase relation.
Our results show that proposed SQUID remains trivial with zero signal when the DM is not affecting it, however if DM is present in the system an interference occurs and possible signal is created.
Furthermore we have investigated the dependence of the DM wavepacket length on the critical current serving as a sensitivity of SQUID for particular mass of a dark particle.
We find that the analyzed properties of the device may be used in the future experiments aimed at the detection of the dark sector of our Universe.

**Parallel Sessions** / **38**

## Hopf-algebraic deformations of 3d spacetime symmetries

**Author:** Tomasz Trzesniewski[1]

[1] *Jagiellonian University*

**Corresponding Author:** tbwbt@ift.uni.wroc.pl

It is widely argued, especially in the phenomenological approach to quantum gravity, that at the Planckian scales the geometry of spacetime may become noncommutative. A closely related effect is the generalization of classical spacetime symmetries into quantum-deformed algebras and groups, which are expected to have the structure of Hopf algebras and be characterized by the (classical) $r$-matrices - solutions of the Yang-Baxter equations. The best known example is the $\kappa$-Poincare algebra. Such quantum algebras and groups actually arise in the convincing way in 2+1 dimensions, where gravity can be described as a Chern-Simons theory with the gauge group given by the isometry group of spacetime, the latter depending on the metric signature and cosmological constant. For non-vanishing cosmological constant the relevant algebras are $\mathfrak{o}(4)$, $\mathfrak{o}(3,1)$ and $\mathfrak{o}(2,2)$. They can also be treated as real forms of the complex algebra $\mathfrak{o}(4;\mathbb{C})$, which has recently been applied to classify all of their possible quantum deformations. We have further expanded this line of inquiry by studying the quantum Inonu-Wigner contractions, i.e. calculating the limit of vanishing cosmological constant of deformations of the $\mathfrak{o}(4)$, $\mathfrak{o}(3,1)$ and $\mathfrak{o}(2,2)$ algebras, which leads to either deformed 3d inhomogeneous Euclidean algebras or deformed 3d Poincare algebras. The obtained algebras form a subclass in the known classification of quantum 3d inhomogeneous symmetry algebras and can be compared with e.g. the recent results concerning deformed symmetry algebras that are associated with the Drinfel'd double structures (the latter are claimed to be a necessary ingredient in the quantization of 2+1d gravity).

**Student's Talks** / **60**

## Hubble tension: a gravitational wave lensing approach

**Author:** Paolo Cremonese[1]

[1] *University of Szczecin*

**Corresponding Author:** paolo.cremonese@usz.edu.pl

In light of the promising and imminent multi-messenger observational era, we suggest a method to constrain the cosmological background by future observation involving gravitational lensing of radiation emitted by a gravitational wave source.
We measure the impact of different cosmological parameters in the value of the time delay due to gravitational lensing. The measured time delay is between the gravitational radiation (in the wave optics regime) and the electromagnetic counterpart (in the geometrical optics approximation). Through this method we constrained the precision of the cosmological parameters involved. The results are promising and will give a considerable contribution in clarifying the Hubble tension problem.

**Parallel Sessions** / **19**

## Instability of a RNAdS black hole under perturbations of a scalar field coupled to the Einstein tensor

**Author:** Bertha Cuadros-Melgar[1]

**Co-authors:** Elcio Abdalla [2] ; Jeferson De Oliveira [3] ; Rodrigo Fontana [4] ; Eleftherios Papantonopoulos [5] ; Alan Pavan [6]

[1] *USP*

[2] *University of Sao Paulo*

[3] *Federal University of Mato Grosso*

[4] *Federal University of Fronteira Sul*

[5] *National Technical University of Athens*

[6] *Federal University of Itajuba*

**Corresponding Author:** berthaki@gmail.com

We study the instability of a Reissner-Nordström-AdS (RNAdS) black hole under perturbations of a massive scalar field coupled to Einstein tensor. Calculating the potential of the scalar perturbations we find that as the strength of the coupling of the scalar to Einstein tensor is increasing, the potential develops a
negative well outside the black hole horizon, indicating an instability of the background RNAdS. We then investigate the effect of this coupling on the quasinormal modes. We find that there exists a critical value of the coupling that triggers the instability of the RNAdS. We also find that as the charge of the RNAdS is increased towards its extremal value, the critical value of the derivative coupling is decreased.

**Plenary Session** / **6**

## Loop quantum gravity: developments and recent results

**Author:** Jorge Pullin[1]

[1] *Jorge*

**Corresponding Author:** pullin@lsu.edu

We present a largely non-technical review of loop quantum gravity, describing its basic principles and recent results in applications to cosmology and black holes.

**Parallel Sessions** / **23**

## Magnetized self-gravitating tori around black holes

**Author:** Patryk Mach[None]

I will discuss recent models of stationary, self-gravitating, magnetized tori (disks) around black holes. They are constructed by solving the coupled set of Einstein equations and the equations of ideal general-relativistic magnetohydrodynamics. In the first part of the talk, I will focus on the impact of the magnetic field on the properties of such tori. If time permits, I will also discuss general-relativistic effects characteristic for very massive tori: bifurcations in the parameter space of solutions, toroidal ergoregions connected with the tori, the appearance of local maxima of the circumferential radius.

**Parallel Sessions** / **56**

## Mass and spin constraint on black holes associated with long GRB's in Collapsar model.

**Authors:** Ishika Palit[1] ; Agnieszka Janiuk[2] ; Petra Sukova[3]

[1] *Center for theoretical Physics , PAS*

[2] *Center for theoretical physics, PAS*

[3] *Instytut Astronomii Czeskiej Akademii Nauk,Praga*

**Corresponding Authors:** lvicekps@seznam.cz, agnes@cft.edu.pl, ishi2694@gmail.com

Gamma ray bursts are highly energetic and brightest explosions that have been observed in EM spectrum. These can last from few seconds to few hours. The progenitors of long GRBs are believed to be massive stars exploding due to the collapse of their cores. Matter from the star around the core falls down towards the center forming a gaseous envelope and (for rapidly rotating stars) swirls into a highly density accretion disk.
In my talk, I will present our results showing how much mass and spin a newly formed black hole should possess during collapsar to launch long GRB. In our model, We start with a newly formed black hole whose mass and spin are going to evolve depending on the rotation of the collapsing cloud. We set a critical angular momentum of the cloud at certain circular radii and we further study the growth of black hole in sub critical, critical and super critical regime. In addition to metric change effects on the evolution, mini disk formation has also been investigated and have been accounted for variability in accretion rate. Our results also testify that the massive BH detected by LIGO till date was never able to launch a powerful GRB because as per our results such massive BH should not have required high spin to support such event.

**Parallel Sessions** / **67**

## Mass, density and circumferential radius in general-relativistic Keplerian disks around black holes

**Author:** Wojciech Kulczycki[None]

**Corresponding Author:** wojciech.kulczycki@doctoral.uj.edu.pl

In my talk I consider self-gravitating toroidal disks around black holes that rotate according to the general-relativistic Keplerian rotation law. During our research on the problem of mass estimation in such systems new effects have been discovered. They concern density and circumferential radius and appear, when disks are massive enough. In my talk I would like to present these effects.

**Parallel Sessions** / **53**

## Massline and other recent results of CDT quantumgravity

**Author:** Dániel Németh[1]

[1] *Jagiellonian University*

**Corresponding Author:** dnemeth@th.if.uj.edu.pl

Causal Dynamical Triangulations is a nonperturbative approach to quantum gravity based on Regge calculus, which uses lattice regularization in the form of a triangulation. To describe the theory for dimension higher than 2 only numerical simulations are available. It is well known through the numerical simulations, that for certain values of bare coupling constants the de-Sitter Universe emerges as a dynamically created background solution around which quantum fluctuations are observed, which agrees with the solutions of the Minisuperspace model. The effects of including scalar-/vector- fields or particles in the theory is less understood. In our new research we are analyzing the effect of introducing closed timelike loops for point particles of various masses and lattice volumes, for spherical and toroidal topologies. The massline is minimally coupled to the geometry through the action dependent on its mass and length $S_m = m * L$. The next step will be to measure the possible behavior of two or more such masslines to see their interaction may produce any noticable gravitational effect. These massline measurements and some other new approaches help us understanding the underlying structure of the generated triangulations.

**Plenary Session** / **8**

## Merger and mass ejection of neutron star binaries (tentative)

**Author:** Masaru Shibata[1]

[1] *Max Planck Institute for Gravitational Physics at Potsdam*

**Corresponding Author:** mshibata@aei.mpg.de

On August 17th, 2017, merger of binary neutron stars was observed for the first time by gravitational-wave and electromagnetic telescopes. Optical and infrared observations in particular agree broadly with the prediction by numerical relativity. From this April, advanced LIGO and VIRGO will start observation again and we expect a few more observations of neutron-star mergers (including black hole-neutron star merger). I will review our current understanding for neutron-star mergers and related mass ejection that are obtained by numerical relativity simulations and summarize predicted observational (optical and infrared) features for next events. (Content could be changed if new events are observed.)

**Parallel Sessions** / **37**

## Modeling General- relativistic disk in OJ 287

**Author:** Wojciech Dyba[1]

**Co-authors:** Patryk Mach ; Edward Malec

[1] *Jagiellonian University*

**Corresponding Authors:** wojciech.dyba@doctoral.uj.edu.pl, edward.malec@uj.edu.pl

We have modelled the accretion disk around the primary black hole in the binary black hole system OJ 287 as a self-gravitating, stationary torus of barotropic matter in Keplerian motion. Using a consistently general-relativistic approach, we found solutions that satisfy either geometric requirements on the disk or the requirements on its mass density
found by Lehto, Valtonen, and their co-workers. It seems that the most important observable features of OJ 287 may be consistent with the model based on the Bondi-Hoyle-Lyttleton transit of the secondary black hole through the disk. This talk is based on paper: W. Dyba, P. Mach and E. Malec, MNRAS 486, 3118-3123 (2019).

**Selected Talks** / **55**

## Modeling short gamma ray bursts from binary neutron star mergers with general relativistic magnetohydrodynamics

**Author:** Agnieszka Janiuk[1]

[1] *Center for Theoretical Physics PAS*

**Corresponding Author:** agnes@cft.edu.pl

I will present the recent development of numerical tools for GR MHD modeling of the black hole accretion flows.
The black hole appears as the result of a binary neutron star merger, and is surrounded by a remnant debris torus.
The code named HARM_COOL is our implementation of the existing algorithm
for a conservative GR MHD scheme.
The newly added modules cover the neutino cooling and the nuclear equation of state for dense matter, as relevant for the physics
of accretion flows in a gamma-ray burst (GRB) central engine environment. We also implement
further post-processing with a nuclear reaction network, and reproduce the nucleosynthesis of heavy, neutron-rich isotopes.
These elements are synthesized within the magnetically driven outflow from the remnant torus.
These fast wind outflows (v/c~0.11–0.23) appear with a broad range of electron fraction Ye~0.1–0.4.
The total mass loss from the post-merger disk via unbound outflows is between 2\% and 17\% of the initial disk mass.
The results are in agreement with the scenarios that explain the blue and red kilonova components, detected in optical lightcurves
after the gravitational wave event GW 170817.

**Parallel Sessions** / **11**

## Multidimensional dynamics of the brane - dilaton black hole system

**Authors:** Anna Nakonieczna[1] ; Łukasz Nakonieczny[1] ; Marek Rogatko[2]

[1] *University of Warsaw, Poland*

[2] *Maria Curie-Skłodowska University, Lublin, Poland*

**Corresponding Authors:** nakonieczna.anna@gmail.com, lukasz.nakonieczny@fuw.edu.pl

Interactions among black holes and branes could have been relevant in the early stages of the evolution of the Universe. Primordial black holes could have formed out of matter density perturbations, while phase transitions in the cooling Universe may have resulted in an occurrence of extended topological defects. There can exist two types of static configurations within the brane - black hole system. The first one corresponds to the brane which intersects the event horizon, the second one represents unlinked objects. In the case of an extremal black hole, the former does not form. Our research was devoted to examining the dynamical behavior of the brane - dilaton black hole system. The evolution of a brane of a nonzero initial velocity was traced with respect to the position of a black hole. The dynamics was described in multiple dimensions and for various values of parameters of the theoretical setup.

**Parallel Sessions / 49**

## New insight into the Taub-NUT space-time

**Author:** Remigiusz Durka[1]

[1] *Univesrity of Wrocław*

**Corresponding Author:** remigiusz.durka@uwr.edu.pl

The Taub-NUT metric represents quite intriguing space-time configuration supposedly possessing gravitational analog of the magnetic monopole. We will deal with the new approach to this subject. Starting from realizing that the source of many inconsistencies lies in neglecting the effects of the wire singularities present in that solution, we are able to explain the existence of the NUT parameter by the means of quite peculiar rotation. Among many things, this leads to the consistent description of the black hole thermodynamics for the Lorentzian Taub-NUT space-time with the essential contribution to the angular momentum and the total entropy.

**Selected Talks / 65**

## On the precanonical structure of the Schroedinger wave functional in curved space-time

**Author:** Igor Kanatchikov[1]

[1] *U St. Andrews & KCIK*

**Corresponding Author:** ik25@st-andrews.ac.uk

I outline the approach of precanonical quantization applied to a scalar field on curved space-time. It leads to the description of quantum fields as sections of the Clifford bundle over the bundle of field variables over space-time. The approach does not require 3+1 decomposition and the corresponding description of quantum fields is a hypercomplex rather than an infinite-dimensional generalization of quantum mechanics. I show how the classical field equations are obtained from the precanonical analogue of the Schroedinger equation as the equations for expectation values of the corresponding operators. I discuss the relationship between the precanonical description and the standard formulation of quantum scalar fields on a curved space-time background in the functional Schroedinger representation. The canonical description is shown to emerge from the precanonical one in a singular limiting case in which, after the 3+1 decomposition, the canonical functional derivative Schroedinger equation is derived from the partial derivative precanonical Schroedinger equation and an explicit formula is obtained which relates the Schroedinger wave functional with the trace of the product integral of precanonical wave functions taken along the surface of initial data.

**Parallel Sessions** / **57**

## On the relation between the canonical Hamilton-Jacobi equation and the De Donder-Weyl Hamilton-Jacobi formulation in general relativity

**Author:** Natascha Riahi[1]

[1] *Universität Wien*

**Corresponding Author:** natascha.riahi@univie.ac.at

We discuss the relation between the canonical Hamilton-Jacobi theory and the De Donder-Weyl Hamilton-Jacobi theory known in the calculus of variations using the examples of a scalar field on curved space-time background and general relativity.

We show that the canonical Hamilton-Jacobi equation of general relativity which preceded the Wheeler-De Witt formulation of quantum gravity can be derived from the De Donder-Weyl Hamilton-Jacobi reformulation of the Einstein equations. The timelessness of the canonical Hamilton-Jacobi formulation appears as a consequence of the split into space and time in the Donder-Weyl Hamilton-Jacobi equation where no space-time decomposition is required. The result is crucial for the understanding of the relation between various formulations of canonical quantum gravity and the results of precanonical quantization of general relativity based on the De Donder-Weyl Hamiltonian theory.

**Parallel Sessions** / **48**

## Palatini stars

**Author:** Aneta Wojnar[1]

[1] *Espirito Santo University*

**Corresponding Author:** aneta.m.wojnar@gmail.com

I will briefly show how low mass stars (<0.08 of the solar mass) allow to test modified theories of gravity. Palatini stars will be the main example.

**Parallel Sessions** / **16**

## Perturbations of the Kerr metric in modified gravity

**Author:** Arthur Suvorov[1]

[1] *University of Tübingen*

**Corresponding Author:** arthur.suvorov@tat.uni-tuebingen.de

The Kerr metric, which describes the geometry surrounding an isolated, rotating compact object, is unique in general relativity (GR), in the sense that all asymptotically flat, stationary, vacuum black holes must be locally isometric to the Kerr spacetime. As such, probing the Kerr metric is one of the best means to test GR. However, because modified theories of gravity are often built such that they contain GR in some limit, the Kerr metric is also common to many of these theories. This means that, in the absence of 'smoking-gun' type deviations, a validation of the Kerr metric does not necessarily favour GR amongst all possibilities. But, since perturbations are tied to the gravitational action, disturbances behave differently in different theories. We discuss, using the Newman-Penrose

formalism, how the field equation structure manifests in the properties of distorted black holes in non-Einstein theories of gravity. This paves the way for future precision tests of GR in the strong field regime using, for example, gravitational waves.

**Student's Talks / 61**

## Quantum Big Bounce scenario and primordial gravitational waves

**Author:** Artur Miroszewski[1]

**Co-author:** Przemyslaw Malkiewicz

[1] *National Centre for Nuclear Research*

**Corresponding Authors:** pmalkiew@gmail.com, artur.miroszewski@ncbj.gov.pl

In my talk I will present a method to quantise and solve the dynamics of gravitational waves in a quantum Friedmann-Lemaitre-Robertson-Walker spacetime filled with radiation.
The classical model is formulated in the ADM formalism. The system is then de-parametrised and reduced phase space is found. With the use of phase space symmetry respecting quantisation map the perturbed quantum FLRW cosmology is obtained. As a result of such procedure the initial singularity is replaced with a quantum bounce, which can act as a mechanism for generation of primordial gravitational waves. The properties of Big Bounce scenario and emitted gravitational waves will be presented, both in the coherent states approximation and using the exact results.

**46**

## Quantum corrections in rigidly-rotating thermal states on anti-de Sitter space

**Author:** Victor Eugen Ambrus[1]

[1] *West University of Timisoara*

**Corresponding Author:** victor.ambrus@e-uvt.ro

Rigid rotation has gained a lot of interest in the field of relativistic heavy ion collisions due to the experimentally observed polarization of the Lambda hyperons [1]. This polarization can be explained via various mechanisms (spin-orbit coupling [2], axial chemical potential [3]) using quantum field theory at finite temperature. On Minkowski space, exact expressions can be obtained for massless fermions [4]. All thermal expectation values diverge as the speed of light surface (SOL) is approached. This prompts the analysis of similar states in bounded domains [5], or in bounded space-times, such as the anti-de Sitter (adS) space [6], which exclude the SOL. In this talk, the rigidly-rotating thermal states (RRTS) of fermions at finite chemical potential on the anti-de Sitter space are discussed, highlighting the formation of the SOL when the rotation parameter $\Omega$ exceeds the inverse radius of curvature $\omega$. A comparison with classical relativistic kinetic theory results is presented to highlight the role of quantum corrections.

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[5] V. E. Ambrus, E. Winstanley, Phys. Rev. D 93 (2016) 104014.
[6] V. E. Ambrus, E. Winstanley, Class. Quantum Grav. 34 (2017) 145010.

**Parallel Sessions** / **68**

## Quantum corrections in rigidly-rotating thermal states on anti-deSitter space

**Corresponding Author:** victor.ambrus@e-uvt.ro

**Parallel Sessions** / **32**

## Quantum cosmology with compact phase space

**Author:** Jakub Mielczarek[1]

[1] *Jagiellonian University*

**Corresponding Author:** jakub.mielczarek@uj.edu.pl

The kinematical phase space of classical gravitational field is flat (affine) and unbounded. Because of this, field variables may tend to infinity leading to appearance of singularities, which plague Einstein's theory of gravity. During the talk the idea of generalizing the theory of gravity by compactification of the phase space will be discussed. The procedure of compactification of the phase space of a minisuperspace gravitational model with two dimensional phase space will be introduced. The model will be analyzed at both classical and quantum level.

**Parallel Sessions** / **73**

## Quantum cosmology with compact phase space

**Corresponding Author:** jakub.mielczarek@uj.edu.pl

**Selected Talks** / **47**

## Quantum creation of a universe-antiuniverse pair

**Author:** Salvador Robles-Perez[1]

[1] *EEBM*

**Corresponding Author:** salvarp74@gmail.com

If one analyses the quantum creation of the universe, it turns out that the most natural way in which the universes can be created is in pairs of universes whose time flow is reversely related. It means that the matter that propagates in one of the universes can be seen, from the point of view of the other universe, as antimatter, and viceversa. They thus form a universe-antiuniverse pair. From a global point of view, i.e. from the point of view of the whole multiverse ensemble, the creation of universes in universe-antiuniverse pairs restores the matter-antimatter asymmetry observed in each individual universe and it might provide us with an explanation for the baryon asymmetry of our universe.

**Parallel Sessions** / **26**

# Quantum gravity on a torus - an update

**Author:** Jakub Gizbert-Studnicki[1]

[1] *Jagiellonian University*

**Corresponding Author:** jakub.gizbert-studnicki@uj.edu.pl

During last POTOR's conference I discussed a quantum gravity model defined by Causal Dynamical Triangulations (CDT) where spatial slices of equal proper time have fixed topology of a 3-torus. Identification of phase structure and order of the phase transitions constitute first steps in the quest for a continuum limit of CDT where, following the asymptotic safety conjecture, the resulting theory of quantum gravity becomes nonperturbatively renormalizable. Initial study of the toroidal model, presented last year, showed that one can identify the same phase structure as earlier observed for the spherical spatial topology, including phase 'C', where quantum fluctuations of spatial volume are well described by mini-superspace like models. Now I will also discuss the recent study of the order of phase transitions in the toroidal case, which is crucial in defining the continuum limit of CDT. If time permits I will comment on the possibility of reintroducing spatial coordinates in the CDT model and on the impact of scalar fields with non-trivial boundary conditions on the toroidal CDT results.

**44**

# Quantum-gravity footprints in the inflationary power spectrum

**Author:** David Brizuela[None]

A framework to obtain quantum-gravity corrections to the inflationary power spectrum will be presented. The geometrodynamical quantization of an inflationary universe will be performed. The wave function will then be decomposed into its infinite set of moments. In order to implement a semiclassical approximation, the infinite set of equations and constraints obeyed by these basic variables will be truncated at second order. In the next step the scale factor of the universe will be chosen as an adequate internal time variable. Finally, this general framework will be applied to a de Sitter model, which will allow us to solve explicitly the evolution equations of the fluctuations and correlations of different variables and to obtain the specific quantum-gravity corrections for the power spectrum. In particular, it will be shown that these corrections are more relevant for large scales.

**Parallel Sessions / 40**

# Relativistic Lagrangian perturbation theory in spherical symmetry.

**Author:** Jan Ostrowski[1]

[1] *NCBJ*

**Corresponding Author:** jan.jakub.ostrowski@ncbj.gov.pl

Perturbation theories play an important role in general relativity and cosmology. Depending on the framework and the quantities we perturb we can distinguish two main approaches in perturbation theories: Eulerian and Lagrangian. Like in the Newtonian theory, relativistic Lagrangian perturbations allow us to get insight into a mildly non-linear stages of structure formation, substantially exceeding the Eulerian regime. However, there is an inherent level of ambiguity when it comes to evaluating certain functionals (e.g. density, spatial curvature, expansion) within the Lagrangian framework, coming from more than one definition of these fields in terms of governing equations. One possible work-around is to compare the perturbative expectations with some exact relativistic

solutions. In my talk I will present such comparison for spherically symmetric dust solutions, the Lemaitre-Tolman-Bondi metrics, with an emphasis on the evaluation of spatial curvature, extending previous works focusing mostly on density field.

**Parallel Sessions** / **24**

## Riemannian geometry imposed on Friedmann and more general spacetimes

**Author:** Janusz Garecki[1]

[1] *University of Szczecin*

**Corresponding Author:** janusz.garecki@usz.edu.pl

At first we define Riemannian geometry in general relativity (GR) as geometry determined by Riemannian, Finsler-like metric
\begin{equation}
h_{ab}(x;v) :=2V_a V_b - g_{ab}(x).
\end{equation}
Here $g_{ab}$ is the Lorentzian metric of a spacetime and $\vec{v}$ is an unit timelike vector field: $v = \sqrt{g_{ab}v^a v^b} = 1$. Then, we compare this Riemannian geometry with original, Lorentzian geometry in the case of Friedmann and more general spacetimes

**Selected Talks** / **84**

## Searching for non-Riemannian signatures in cosmological data

**Author:** Krzysztof Bolejko[1]

[1] *University of Tasmania*

The Einstein's theory of gravity, General Relativity was build on the theory of Special Relativity. This generalisation required utilising the full generality of the Riemannian geometry. Many of the present-day cosmological tests of GR are still based on the assumption of the Riemannian geometry. However, in order to fully study and test various extensions of GR one is also required to move beyond the Riemannian geometry. In my talk I will focuses on light propagation and discuss what signatures in cosmological observational data could point to non-Riemannian effects. This talk will not be a comprehensive review of the issue - it will only focus on the distance and redshift relations. I will discuss observational constraints and talk how future surveys could provide a better insight into the underlying geometry of our Universe.

**Parallel Sessions** / **62**

## Simple SUGRA inflation

**Author:** Michal Artymowski[1]

[1] *Jagiellonian University*

**Corresponding Author:** artymowski@fuw.edu.pl

In my talk I will present a simple idea of Supergravity with flat Kahler geometry. I will show how it may lead to simple scalar potentials, which in principle may lead to inflation or dark energy. Furthermore, I will show how a simple generalization of a simplest flat Kahler leads to generic inflationary potentials from the simplest, linear Superpotentials.

**Parallel Sessions** / **28**

## Solar system analysis of a polynomial class of Palatini f(R) gravity

**Authors:** JUNIOR TONIATO[1] ; Aneta Wojnar[1] ; Davi Cabral Rodrigues[1]

[1] *Federal University of Espirito Santo*

**Corresponding Author:** junior.toniato@ufes.br

It is made a post-Newtonian analysis of a class of Palatini $f(R)$ theories of gravity where the lagrangian density is assumed to be a polynomial function of the Ricci scalar. The resulting metric is not covered by the classical parametrized post-Newtonian formalism (PPN) since new gravitational potentials emerges. I will then discuss post-Newtonian equations of motion of massive bodies and light rays to see whether deviations from general relativity can be used to determine upper bound limits to Palatini $F(R)$ gravity according to tests performed in the solar system.

**Parallel Sessions** / **82**

## Solutions in Teleparallel Gravity: Gravitomagnetism and Rotational Effects

**Author:** Gabriel Farrugia[1]

**Co-authors:** Jackson Levi Said [2] ; Andrew Finch [3]

[1] *University of Malta*

[2] *University of Malta-Unknown-Unknown*

[3] *Institute of Space Sciences and Astronomy, University of Malta*

**Corresponding Authors:** andrew.finch.12@um.edu.mt, gfarr02@um.edu.mt, jackson.levi.said@cern.ch

The theory of $f(T)$ gravity shall be discussed in the context of gravitoelectromagnetism (GEM) where the modified GEM equations are discussed and derived. Through use of linearisation and perturbation techniques, specific metric solutions are obtained which are then used to investigate specific GEM effects such as the de Sitter and Lense-Thirring precessions. Following observations from Gravity Probe B, the $f(T)$ models are constrained and compared against cosmological constraints.

**Parallel Sessions** / **39**

## Solutions in Teleparallel Gravity: Gravitomagnetism and Rotational Effects

**Author:** Gabriel Farrugia[1]

**Co-author:** Jackson Levi Said [2]

[1] *University of Malta*

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**Plenary Session / 9**

## Space-Based Gravitational Wave Observations in the Mid-Band Frequency Region

**Author:** Massimo Tinto[1]

[1] *UCSD*

**Corresponding Author:** mtinto@ucsd.edu

The opportunity exists to scientifically explore the intermediate Gravitation Wave (GW) frequency detection band, a region that is in between those accessible by LISA and LIGO. A GW mission operating in this part of the GW band will complement and enhance the scientific capabilities of both LIGO and LISA. Such a mission entails three drag-free satellites in a geosynchronous trajectory resulting in a triangle formation of arm-length equal to 73000 km and an observational frequency band that is "blue-shifted" with respect to that of LISA by about a factor 70. Because of the complementarity of the observational bandwidths and sensitivities of the two missions, their joint operation will result in an enhanced scientific return over those obtainable by each observatory operated as stand-alone.

**36**

## Spacetime Singularities in Inflationary Universe

**Author:** Daisuke Yoshida[1]

[1] *Kobe University*

**Corresponding Author:** dyoshida73@gmail.com

Despite the fact that the exact de Sitter space is free of spacetime singularity, the absence of singularity in inflationary universe is still non-trivial. I will focus on singularity problem of two kinds of inflationary universe: past asymptotic de Sitter space and torus compactified de Sitter space. In the former case, I find that the presence of the singularity depends on how fast the scale factor approaches to that of exact de Sitter space toward the asymptotic past. In the latter case, I find that the end point of an incomplete geodesic in compactified de Sitter space is locally extendible but there is no globally consistent extension of spacetime. In other words, compactified de Sitter space has so called quasi regular singularity.

**Parallel Sessions** / **72**

## Spacetime singularities in inflationary universes

**Corresponding Author:** dyoshida73@gmail.com

**Parallel Sessions** / **59**

## Standing gravitational waves

**Author:** Sebastian Szybka[None]

**Corresponding Author:** sebastian.szybka@gmail.com

I will discuss existence, properties, and an effective description of standing gravitational waves in general relativity.

**Parallel Sessions** / **27**

## Static, spherically symmetric black holes in quadratic gravity

**Author:** Vojtech Pravda[None]

**Co-authors:** Jiri Podolsky ; Alena Pravdova ; Robert Svarc

It can be shown that all Robinson-Trautman spacetimes are conformal to Kundt spacetimes. For spacetimes with constant Ricci scalar, all quadratic gravity corrections to Einstein gravity can be combined into the Bach tensor which is well behaved under conformal transformations.

Combining these results leads to a considerable simplification of the vacuum field equation of quadratic gravity for static, spherically symmetric spacetimes.
This allow us to study non-Schwarzschild static, spherically symmetric black holes in four-dimensional quadratic gravity using analytical methods.

Based on:

V. Pravda, A. Pravdová, J. Podolský, and R. Švarc, Phys. Rev. D 95, 084025 (2017),
J. Podolský, R. Švarc, V. Pravda, and A. Pravdová, Phys. Rev. D 98, 021502(R) (2018),
R. Švarc, J. Podolský, V. Pravda, and A. Pravdová, Phys. Rev. Lett. 121, 231104 (2018),
and papers in preparation.

**Parallel Sessions** / **74**

## Strength of singularities in varying constants theories

**Corresponding Author:** k.marosek@wmf.univ.szczecin.pl

**Parallel Sessions** / **79**

## Strength of singularities in varying constants theories.

**Author:** Konrad Marosek[None]

We consider a specific type of the bimetric theory of gravitation with the two different metrics introduced in the cosmological frame. Both metrics respect all the symmetries of the standard FLRW solution and contain conformally related spatial parts. One of the metric is assumed to describe the causal structure for the matter. Another metric defines the causal structure for the gravitational interactions. A crucial point is that the spatial part of the metric describing gravity is given by the spatial part of the matter metric conformally rescaled by a time-dependent factor $\alpha$ which, as it turns out, can be linked to the effective gravitational constant and the effective speed of light. In the context of such a bimetric framework we examine the strength of some singular cosmological scenarios in the sense of the criteria introduced by Tipler and Królak. In particular, we show that for the nonsingular scale factor associated with the matter metric, both the vanishing or blowing up of the factor $\alpha$ for some particular moment of the cosmic expansion may lead to a strong singularity with infinite value of the energy density and infinite value of the pressure.

**Parallel Sessions** / **66**

## TBA

**Parallel Sessions** / **71**

## TBA

**Parallel Sessions** / **63**

## The solution to the Petrov type D equation on the non-trivial bundle topology and its embeddability

**Authors:** Jerzy Lewandowski[1] ; Racz Isvan[None] ; Denis Dobkowski-Ryłko[None]

[1] *University of Warsaw*

We consider 3-dimensional isolated horizons (IHs) generated by null curves that form non-trivial $U(1)$ bundles and the Petrov type D equation. From the $4$-dimensional spacetime point of view, solutions to that equation define isolated horizons embeddable in vacuum spacetimes (with cosmological constant) as Killing horizons to the second order such that the spacetime Weyl tensor at the horizon is of the Petrov type D. From the point of view of the $U(1)$-bundle structure, the equation couples a $U(1)$-connection, a metric tensor defined on the base manifold and the surface gravity in a very non-trivial way. We focus on the $U(1)$-bundles over 2-dimensional manifolds diffeomorphic to 2-sphere. We have derived all the axisymmetric solutions to the Petrov type D equation. For a fixed value of the cosmological constant they set a 3-dimensional family as one could expect. A surprising result is, that generically our horizons are not embeddable in the known exact solutions to Einstein's equations. It means that among the exact type D spacetimes there exists a new family of spacetimes that generalize the properties of the Kerr- (anti) de Sitter black holes on one hand and the Taub-NUT spacetimes on the other hand.

**Parallel Sessions** / **43**

## Toda system approximation to quantum Mixmaster universe

**Author:** Ewa Czuchry[1]

[1] *National Centre for Nuclear Studies*

**Corresponding Author:** ewa.czuchry@ncbj.gov.pl

Quantum dynamics of the Mixmaster universe is approximated by the explicitly integrable periodic 3-particle Toda chain. Such approach is based on a covariant Weyl-Heisenberg integral quantization which naturally amplifies the dynamical role of the underlying Toda system by smoothing out the three canyons of the anisotropy potential. Energy levels of the quantum Mixmaster are explored in the first approximation.

**Parallel Sessions** / **12**

## Top-down approach to the curved spacetime effective field theory (cEFT) – theory and examples

**Author:** Lukasz Nakonieczny[1]

[1] *University of Warsaw*

**Corresponding Author:** lukasz.nakonieczny@fuw.edu.pl

The effective field theory (EFT) turns out to be an instrument of an immense value in all aspects of modern particle physics being theory, phenomenology or experiment. In this talk I will show how to extend the systematic top down approach to construction of the EFT proposed by Hitoshi Murayama (LBL, Berkeley) and separately by John Ellis (King's Coll. London) groups to the curved spacetime. To this end, I will take advantage of the heat kernel method so far extensively used in obtaining the one-loop effective action in curved spacetime. After an introduction of the formalism I will discuss its application to the problem of an influence of gravity on the stability of the Higgs effective potential. The talk is based on JHEP01(2019)034.

**Student's Talks** / **22**

## Topologically Supported Cosmological Constant

**Authors:** Paweł Klimasara[1] ; Jerzy Król[2] ; Torsten Asselmeyer-Maluga[3] ; Krzysztof Bielas[2]

[1] *Institute of Physics, University of Silesia in Katowice*

[2] *University of Information Technology and Management*

[3] *German Aerospace Center (DLR)*

**Corresponding Authors:** p.klimasara@gmail.com, krzysiek.bielas@gmail.com, torsten.asselmeyer-maluga@dlr.de, iriking@wp.pl

We present a cosmological model where the cosmological constant is a topological invariant. The cosmological constant is derived from the curvature of exotic $R^4$ embedded in $K3\#\overline{\mathbb{C}P^2}$. Both of the manifolds are perfectly smooth however the 3-diemnsional slices they generate contain topological changes. Then the value of cosmological constant is expressed via Chern-Simons, volume, and Euler invariants of the 3-submanifolds. Moreover, this cosmological model predicts realistically the neutrino masses and inflation parameters, including Starobinsky potential and the number of e-folds.

References:

[1] Król, J., Asselmeyer-Maluga, T., Bielas, K., & Klimasara, P. (2017). From Quantum to Cosmological Regime. The Role of Forcing and Exotic 4-Smoothness. Universe, 3(2), 31.
[2] Asselmeyer-Maluga, T., & Król, J. (2018). How to obtain a cosmological constant from small exotic R4. Physics of the dark universe, 19, 66-77.

**Parallel Sessions / 25**

# Universal black holes

**Author:** Marcello Ortaggio[None]

**Corresponding Author:** ortaggio@math.cas.cz

We consider a generalized Schwarzschild-like ansatz and prove that it can be consistently employed to construct $d$-dimensional static vacuum black hole solutions in any metric theory of gravity for which the Lagrangian is a scalar invariant constructed from the Riemann tensor and its covariant derivatives of arbitrary order. After describing the ansatz and the corresponding (reduced) field equations, we exemplify it in particular theories such as Gauss-Bonnet, quadratic and $F(R)$ gravity, and certain conformal gravities.