International Webinar
on
Recent Developments in Cosmology and Modified Gravity
(RDCM-2021)
March 9-11, 2021

# Abstract Booklet

## Organiser

Department of Mathematics
Birla Institute of Technology and Science-Pilani
Hyderabad Campus

innovate achieve lead

# International Webinar on Recent Developments in Cosmology and Modified Gravity (RDCM-2021)
# March 9-11, 2021

## *Message from the Vice-chancellor*

I am delighted that the Department of Mathematics, BITS Pilani, Hyderabad Campus, India is organizing an International Webinar on Recent Developments in Cosmology and Modified Gravity (RDCM-2021) during March 9-11, 2021. In recent times, several new findings have been reported on modified theories of gravity and their cosmological consequences. I believe this event will provide an interactive opportunity to the participants to review these new developments stimulating enriching discussions leading to new investigations as well.

I congratulate the organising team for bringing together a galaxy of global stalwarts as speakers. I wish the event a grand success.

(Souvik Bhattacharyya)

## *Message from the Director*

I am delighted that the Department of Mathematics, BITS Pilani, Hyderabad Campus is organizing the "International Webinar on Recent Developments in Cosmology and Modified Gravity" (RDCM-2021) during March 9-11, 2021. The webinar will serve as an invaluable platform for academic exchange between young and emerging researchers, and established experts, perhaps even pioneers in different areas, and thus provide an enriching and refreshing experience. I am sure that this webinar will have special focus on recent experimental findings, and the developments in theory that these have stimulated.

I wish the event all success.

(G. Sundar)

## Message from the Head of the Department

I am delighted to welcome all of you to the International Webinar on Recent Developments in Cosmology and Modified Gravity (RDCM-2021) at the Birla Institute of Technology and Science-Pilani, Hyderabad Campus, India, during March 9-11, 2021. This webinar aims to provide a leading forum for early researchers and academicians to share and discuss their work on various topics such as Cosmology, Relativity, Modified gravity, and many open questions in this area. We are fortunate to have distinguished speakers sharing their enormous ocean of expertise and critical knowledge with us. It will benefit all of us through discussions and collaborations with globally renowned experts.

I am grateful to Prof. Souvik Bhattacharya, Vice-Chancellor; Prof. G. Sundar, Director; Prof. N Swain, Dean; Prof. B Mishra, Convener; and to all members of the Department of Mathematics for their extensive support and guidance in this endeavor.

As the department head, I thank the organizing team along with Axiom members for contributing their valuable time in organizing this webinar. I am sure that the conduct of RDCM-2021 would provide all delegates with remarkable interaction and ideas.

(P.K.Sahoo)

## Message from the Convener

On behalf of the organizing committee and the Department of Mathematics, BITS-Pilani, Hyderabad campus I extend a warm welcome to all the participants and the resource persons to this International Webinar on Recent Developments in Cosmology and Modified Gravity (RDCM-2021).

We all are aware that Einstein's General Relativity with its simple mathematical structure $G_{\mu\nu} = \kappa T_{\mu\nu}$ has a great success in explaining many complex issues in Cosmology and Astrophysics as a whole, the knowledge on the Universe. Since the announcement of a possible late time cosmic speed up phenomenon by Supernovae project group (1998) and high-z Supernovae group (1999) followed by a lot of cosmological observation results, our thought process on the Universe has been changed. This is because cosmological observations revealed "Our Universe is experiencing an accelerated expansion". Since GR has certain limitations in addressing this late time cosmic phenomena, the need of a modification in GR has become inevitable. I must mention here a quote of the great Albert Einstein "Without changing our pattern of thought, we will not be able to solve the problems that we created with our current pattern of thought". Hence there is a need to change in the pattern of thought to theoretically resolve this issue. In this context the great Physicists John A. Wheeler said, "Of all the great predictions that science has ever made over the centuries, was there ever one greater than this; to predict, and predict correctly, and predict against all expectations, a phenomenon as fantastic as the expansion of the Universe".

I hope this event may provide us some lead to the challenges faced by the Mathematicians, Cosmologists, Astrophysicists, Astronomers in modern cosmology. The webinar consists of 9 invited lectures, 70 paper presentations with an overall participation of 270 researchers across the globe. I wish the researchers will experience fruitful and informative sessions to pursue their research further.

My sincere thanks to the invited speakers who have readily accepted our invitation to deliver the talk in the webinar. I thank to the members of Mathematics Department Association Axiom, my department colleagues, Prof. P.K. Sahoo, HoD Mathematics, Prof. G. Sundar, Director BITS-Pilani Hyderabad Campus, Prof. Souvik Bhattacharyya, Vice-Chancellor BITS-Pilani university for the cooperation and encouragement to organise this event. Never the less the participants of the webinar who have shown a lot of interest in participating and presenting their research in the webinar.

(Bivudutta Mishra)

# Schedule of the Webinar

**09.03.2021 (Day-1)**

## 9.10-9.25 A.M.: Inauguration (https://meet.google.com/ipj-drrt-fmo)

## Invited Talk

**Google Meet Link: https://meet.google.com/ipj-drrt-fmo**

| Session | Time | Speaker | Title | Chairman |
|---|---|---|---|---|
| IT 1 | 9.30-10.30 | Prof. T.P. Singh T.I.F.R., Mumbai | Towards the unification of the four fundamental forces | Prof. S. Banik BITS-Pilani, Hyderabad Campus, India |
| IT 2 | 10.45-11.45 | Prof. Emmanuel Saridakis National Observatory of Athens, Greece | Investigation of torsional modified gravity through multi-messenger observations. | Prof. Ali Övgün Eastern Mediterranean University, Cyprus |
| IT 3 | 12.00-1.00 | Prof. Sergei V. Chervon Ulyanovsk State Pedagogical University, Russia | Chiral Self-Gravitating Models as Equivalent of f(R) gravity with higher derivatives. | Prof. A. Beesham University of Zululand, South Africa |

**Lunch Break**

**Paper Presentation: Session I (2.30 PM-4.00 PM)**

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. S.K. Sahu, Arba Minch University, Ethiopia

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | U.Y. Divya Prasanthi, Y. Aditya | Observational constraints on Renyi holographic dark energy in Kantowski-Sachs universe |
| **2.45-3.00** | Z. Yousaf | Complexity Factor of Static Feometric Structures |
| **3.00-3.15** | Faizuddin Ahmed | Quantum effects on spin-0 scalar particle under a Cornell-type potential in the background of Kaluza-Klein theory |
| **3.15-3.30** | Snehasish Bhattacharjee, P.K. Sahoo | Big Bang Nucleosynthesis and Entropy Evolution in f(R,T) Gravity |
| **3.30-3.45** | Reena Tandon, Vaibhav Brock | Cosmological Model in Lyra Geometry |
| **3.45-4.00** | B. C. Paul | Emergent Universe via dynamical wormhole |

## Tea Break

**Paper Presentation: Session II (4.15 PM to 5.45 PM)**

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. Z. Yousaf, Punjab University, Pakistan

| Time | Speaker | Title |
|---|---|---|
| **4.15-4.30** | Gopika K., Shantanu Desai | Scaling relations for dark matter core density and radius from Chandra X-ray cluster sample |
| **4.30-4.45** | Shyam Das | Study of anisotropic compact stellar object accounting tidal Love numbers |
| **4.45-5.00** | Andronikos Paliathanasis | Quantum potentiality in Szekeres geometries |
| **5.00-5.15** | Mohammad Salman | Conharmonic curvature inheritance in spacetime of general relativity |
| **5.15-5.30** | P. B. Krishna, Titus K. Mathew | Emergence of space and horizon thermodynamics in Einstein, Gauss Bonnet and Lovelock gravities |
| **5.30-5.45** | Yashmitha Kumaran, Ali Övgün | Weak Deflection angle of Extended Uncertainty Principle Black holes |

**Paper Presentation:** Session III (2.30 PM-4.00 PM)

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. S.K. J. Pacif. VIT, Vellore

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | Kamal Bora , Shantanu Desai | Constraints on the variation of fine structure constant from joint SPT-SZ and XMM-Newton observations |
| **2.45-3.00** | M. Z. Bhatti. Z. Tariq | Electromagnetic effects on polytropes in f(R) gravity |
| **3.00-3.15** | Daba Meshesha Gusu | LRS Bianchi Type-II Cosmological Model with Time Varying G and Λ in f(R,T) Gravity |
| **3.15-3.30** | S.P. Hatkar, S.P. Saraogi, S.D. Katore | Glimpses of Anisotropic Chaplygin Gas |
| **3.30-3.45** | Deepika Golechha, G. R. Avchar, S. Tade | Transit Cosmological Models of Universe with Perfect Fluid and Heat Flow in f(R, T ) Gravity |
| **3.45-4.00** | Parbati Sahoo, P.H.R.S. Moraes, P.K. Sahoo, Marcelo M. Lapola | Traversable Wormholes in the Traceless f(R,T) gravity |

## Tea Break

**Paper Presentation:** Session IV (4.15 PM to 5.45 PM)

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. R. K. Mishra, SLIET, India

| Time | Speaker | Title |
|---|---|---|
| **4.15-4.30** | Daniel Blixt, María-José Guzmán, Manuel Hohmann, Christian Pfeifer | Viability of teleparallel gravity |
| **4.30-4.45** | N. P. Gaikwad | Locally Rotationally Symmetric Bianchi Type II Magnetized String Cosmological Model with Bulk Viscous Fluid in Rosen's Bimetric Gravity |
| **4.45-5.00** | Karim Mosani, Dipanjan Dey, Pankaj S. Joshi | Local versus global nakedness of a spacetime singularity |
| **5.00-5.15** | Asem Jotin Meitei | Five Dimensional Bianchi Type-III cosmological model with Quadratic Equation of state in Lyra Geometry |
| **5.15-5.30** | Nobleson, Tuhin Malik, Amna Ali, Sarmistha Banik | Comparative study of perturbative and nonperturbative methods of R-squared gravity using Neutron stars |
| **5.30-5.45** | Priyanka | Cosmological model in f(R,T) theory of gravity |

**10.03.2021 (Day-2)**

# Invited Talk

**Google Meet Link: https://meet.google.com/ipj-drrt-fmo**

| Session | Time | Speaker | Title | Chairman |
|---|---|---|---|---|
| IT 4 | 9.30-10.30 | Prof. Shinji Mukohyama Kyoto University, Japan | Minimalism in modified gravity | Prof. P.K. Sahoo BITS-Pilani, Hyderabad Campus |
| IT 5 | 10.45-11.45 | Prof. Aroon Kumar Beesham | Dark Energy and Accelerated Expansion of the Universe | Prof. P.K. Thiruvikraman BITS-Pilani, Hyderabad Campus |
| IT 6 | 12.00-1.00 | Prof. Alessandra SIlvestri Leiden University, The Netehrelands | Probing gravity and dark energy in the era of multi-messenger Cosmology | Prof. B. Mishra BITS-Pilani, Hyderabad Campus |

**Lunch Break**

**Paper Presentation:** Session V (2.30 PM-4.00 PM)

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. Saibal Ray, College of Engineering and Ceramic Technology, Kolkata, India

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | Salam Kiranmala Chanu | Particle Creation In Five Dimensional Cosmological Model With Time Dependent G and Lambada |
| **2.45-3.00** | Ali Övgün | Testing Modified Gravity Theories Using Weak Deflection Angle and Black Hole Shadow |
| **3.00-3.15** | Saikat Chakraborty | Towards a ΛCDM Universe in f(R) gravity |
| **3.15-3.30** | Sankarsan Tarai, Pratik P. Ray. S.K. Tripathy, B.Mishra | Effect of bulk viscosity in cosmic acceleration |
| **3.30-3.45** | Suchita A. Mohta , Prabha Rastogi | Interaction between Baratropic fluid and Dark energy with zero mass scalar field in f(R,T) gravity |
| **3.45-4.00** | M.Z. Bhatti | Influence of Modification of Gravity on The Dynamical Analysis of Self-Gravitating Objects |

## Tea Break

**Paper Presentation:** Session VI (4.15 PM to 6.00 PM)

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. Arun Kenath, Christ College, Bangalore, India

| Time | Speaker | Title |
|---|---|---|
| **4.15-4.30** | Arun Kenath; Louise Rebecca; C. Sivaram | Alternate models of gravity: Consequences for cosmological observations |
| **4.30-4.45** | Saboura sadat Zamani | Gravitational lensing by a black hole in Poincaré gauge theory |
| **4.45-5.00** | Louise Rebecca; Arun Kenath; C. Sivaram | Dark matter conundrum: A case for alternate theories of gravity |
| **5.00-5.15** | S. K. Tripathy, Sasmita Kumari Pradhan,B. Mishra | Unified dark fluid and cosmic transit models in Brans-Dicke theory |
| **5.15-5.30** | Jagat Daimary | Five Dimensional FRW Radiating Models In Presence of Bulk Viscos Cosmological Models In Saez-Ballester Theory of Gravitation |
| **5.30-5.45** | Kazuharu Bamba, Emilio Elizalde, S. D. Odintsov, Tanmoy Paul | Inflationary magnetogenesis with reheating phase from higher curvature coupling. |
| **5.45-6.00** | A.S. Agrawal, S.K. Tripathy, B.Mishra | Gravitational baryogenesis models comparisons in f(R) Gravity |

**Paper Presentation:** Session VII (2.30 PM-4.00 PM)

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. B.C. Paul, North Bengal University, India

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | Ahmed Farag Ali | Black Hole Universal Clock |
| **2.45-3.00** | M.Vijaya Santhi, T. ChinnappalaNaidu | Study on Some Strange Quark Cosmological Models in a Modified Theory of Gravity |
| **3.00-3.15** | Prashant R. Dhongle | Spherically Symmetric Model With Electromagnetic Field In Time – Independent Gravitational Field |
| **3.15-3.30** | Jibitesh Dutta and W. Khyllep | Bifurcations in the general non-minimally coupled scalar field models |
| **3.30-3.45** | Sanjay Mandal, Deng Wang, P.K. Sahoo | Cosmography in f(Q) Gravity |
| **3.45-4.00** | Absos Ali Shaikh | Lorentzian Concircular Structure Manifolds and Ricci Solitons |

## Tea Break

**Paper Presentation: Session VIII (4.15 PM to 5.45 PM)**

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. Daniel Blixt, University of Tartu, Estonia

| Time | Speaker | Title |
|---|---|---|
| **4.15-4.30** | Heena Dua, R. K. Mishra | Accelerating Model of the Universe in Modified Gravity |
| **4.30-4.45** | Musavvir Ali | Computing of soliton on a charged black-hole |
| **4.45-5.00** | Sandhya Mhaske, Y. S. Solanke, V. J. Dagwal, D. D. Pawar | Two fluid Bianchi Type V cosmological model in f(R, T) theory of gravity. |
| **5.00-5.15** | B. Mishra, Fakhereh Md Esmaeili, Pratik P. Ray, S.K. Tripathy | Stability analysis of two-fluid dark energy models |
| **5.15-5.30** | M. Yousaf | Dynamical stability analysis of axial anisotropic geometry in modified gravity theory. |
| **5.30-5.45** | Jerin Mohan N D, Titus K Mathew | Viscous Late Acceleration Universe |

**11.03.2021 (Day-3)**

# Invited Talk

**Google Meet Link: https://meet.google.com/ipj-drrt-fmo**

| Session | Time | Speaker | Title | Chairman |
|---|---|---|---|---|
| IT 7 | 9.30-10.30 | Prof. N.D. Haridass<br>Retd Senior Professor, IMSc Chennai. | Some remarks on dark matter and modified gravity | Prof. Christian Pfeifer<br>University of Tartu |
| IT 8 | 10.45-11.45 | Prof. Francisco S.N. Lobo<br>Instituto de Astrofisica e Ciencias do Espaco, Partugal | Beyond Einstein's General Relativity: Hybrid metric-Palatini gravity and curvature-matter couplings. | Prof. C.P Singh<br>DTU, New Delhi |
| IT 9 | 12.00-1.00 | Prof. Salvatore Capozziello<br>Universita' di Napoli "Federico II", Napoli, Italy | Cosmological Applications of non-local gravity | Prof. S.K. Tripathy<br>IGIT, Sarang |

**Lunch Break**

**Paper Presentation:** Session IX (2.30 PM-4.00 PM)

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. Sankarsan Tarai, Utkal University, India

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | Chinmay Gandevikar | PN Properties of EMRI Using Power Law Potential |
| **2.45-3.00** | Venkata Vasavi | The Study of Anisotropic Perfect Fluid Cosmological Model in f(R, T) Gravity |
| **3.00-3.15** | Simran Arora, S.K.J. Pacif, S. Bhattacharjee, P.K. Sahoo | f (Q, T) Gravity Models With Observational Constraints |
| **3.15-3.30** | Tensubam Alexander Singh | Higher Dimensional FRW Model Universe in Scalar Tensor Theory of Gravitation Using Quadratic Equation of State. |
| **3.30-3.45** | Gargee Chakraborty, Surajit Chattopadhyay | Probing the Cosmological Consequences of Barrow Holographic Dark Energy with Specific Nojiri-Odintsov Cut-off and its Thermodynamics |
| **3.45-4.00** | Nishant Singla, Anil Kumar Yadav, M. K. Gupta | Bulk viscous Universe with dominance of dark energy |

## Tea Break

**Paper Presentation:** Session X (4.15 PM to 5.15 PM)

**Google Meet Link:** https://meet.google.com/ipj-drrt-fmo

**Chairman:** Prof. Pratik P. Ray, VIT-AP, Amravati, India

| Time | Speaker | Title |
|---|---|---|
| **4.15-4.30** | Sagar Dey | Compact objects with Finch-Skea geometry in f(T) gravity |
| **4.30-4.45** | Santosh Kumar Yadav | Constraints on Dark Matter-Photon Coupling Model with CPL Parametrization of Dark Energy |
| **4.45-5.00** | Reginald Christian Bernardo | Gravitational waves from dark sector interactions |
| **5.00-5.15** | P.V. Gayakwad | Bulk Viscous Bianchi Type I Barotropic Fluid Cosmological Model with Varying Λ and Functional Relation on Hubble Parameter in Bimetric Theory of Gravitation |

**Paper Presentation:** Session XI (2.30 PM-4.00 PM)

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. A. K. Yadav, United College of Engineering, India

| Time | Speaker | Title |
|---|---|---|
| **2.30-2.45** | Reena Tandon, Jaya gupta | To Study The Behaviour of Dark Energy in The Accerlating Expansion of Universe. |
| **2.45-3.00** | T. Vinutha, B. Raja Shekar and K. Sri Kavya | Dynamics of Bianchi Type II, VIII & IX Cosmological Models In f(R, T) Theory |
| **3.00-3.15** | A. Chanda and B. C. Paul | Observational constraints on Emergent Universe in presence of Non-linear Viscous Fluid |
| **3.15-3.30** | Debasis Sahu, Bibekananda Nayak | Expansion of the Universe in Interacting Dark Energy Model |
| **3.30-3.45** | Bibekananda Nayak | Black Hole Dynamics in The Universe Having Single Scale Factor |
| **3.45-4.00** | Vipin Kumar Sharma, Ajay Kumar Sharma, Murli Manohar Verma | Diagnostic Signature For GW Scalar Mode Mass and Dispersion Relation in f(R) Background |

## Tea Break

**Paper Presentation: Session XII (4.30 PM-5.15 PM)**

**Google Meet Link:** https://meet.google.com/jbh-zufo-dkf

**Chairman:** Prof. A. K. Yadav, United College of Engineering, India

| | | |
|---|---|---|
| **4.15-4.30** | T. Vinutha, K. Niharika | The Study of Kantowski- Sachs Perfect Fluid Cosmological Model In Modified Gravity |
| **4.30-4.45** | S. H. Shekh, V. R. Chirde, S. V. Raut | Bouncing scenario with energy conditions in modified theories of gravitations |
| **4.45-5.00** | Reena Tandon, Sonia Arora | Study of Cosmological Model With BI-Quadratic Varying Deceleration Parameter in f(R, T) Theory |
| **5.00-5.15** | S. H. Shekh; V. R. Chirde; S. V. Raut | Bouncing scenario with energy conditions in modified theories of gravitations |

## 5.30-5.45 A.M.: Valedictory

## Invited Talks

### Towards the unification of the four fundamental forces

T.P. Singh

Tata Institute of Fundamental Research, Mumbai

**Abstract:** Time is a classical concept, and not an intrinsic part of quantum theory. Hence there must exist a reformulation of quantum theory which does not refer to classical time. We have proposed a prequantum, prespacetime theory, from which conventional quantum field theory and 4D classical space-time are emergent. This eight dimensional underlying theory inevitably lives in a space described by the number system known as the octonions, and is a candidate theory for the unification of the four fundamental forces. The symmetry group is the exceptional Lie group F4. Amongst other predictions, we derive the asymptotic value of the fine structure constant, matching with the measured value to two parts in 10^7. This so-called aikyon theory is a deterministic matrix dynamic, from which quantum indeterminism emerges in a coarse-grained approximation. In this colloquium, we give an overview of the theory and its predictions, and the work that still remains to be done.

### Investigation of torsional modified gravity through multi-messenger observations

Emmanuel Saridakis

National Observatory of Athens, Greece

**Abstract:** We review various theoretical models and scenarios based on modifications of gravity. Then we present the recent possibility of using multi-messenger astronomy, namely data from gravitational waves observations alongside their electromagnetic counterparts, in order to investigate torsional modified gravity and test general relativity.

### Chiral Self-Gravitating Models as Equivalent of f(R) gravity with higher derivatives.

Sergei V. Chervon

Ulyanovsk State Pedagogical University, Russia

We study a gravitational theory with the derivatives of the first and the second order in Ricci scalar with the action $S = \int d^4x \sqrt{-g}\, f(R, (\nabla R)^2, \Box R)$. Such type of gravity models after conformal transformation of the metric can be represented as Einstein gravity with the set of scalar fields provided by the potential of interactions. The former models can be described by Chiral Self-Gravitating Models (CSGM) of special type, where the potential and the target space metric

appropriately defined by the choice of the action for f(R) gravity model with higher derivatives. In the present talk the models with the actions

$S = \int d^4x \sqrt{-g}\, f(R, (\nabla R)^2),\ S = \int d^4x \sqrt{-g}\, f(R,\quad R)\ ,\ S = d^4x \sqrt{-g}\, f(R, (\nabla R)^2, \Box\, R)$

will be considered in cosmology and spherical symmetric spaces. Examples of cosmological and black holes solutions will be demonstrated.

**Minimalism in modified gravity**

Shinji Mukohyama

Kyoto University, Japan

**Abstract:** It is generally believed that modification of general relativity inevitably introduces extra physical degree(s) of freedom. In this talk I argue that this is not the case by constructing modified gravity theories with two local physical degrees of freedom. After classifying such theories into two types, I show explicit examples and discuss their cosmology and phenomenology.

**Some remarks on dark matter and modified gravity**

N.D. Haridass

Retd Senior Professor, IMSc Chennai

**Abstract:** In this mostly pedagogic talk, I will discuss the genesis of the dark matter problem and make various comments. These will include Milgrom's original proposal and some modern perspectives, the particle physicists take on the issue that shall touch upon ideas from supersymmetry and various exotic particles including a discussion on axions as promising candidates, particles with unusual statistics like fermions with integer spin etc. On the gravity side I shall also discuss proposals like emergent gravity, gravity as an entropic force etc. I will briefly discuss the unusual galaxies with no apparent dark matter and proposed resolutions. I shall conclude by listing some important open problems, at least to my mind. My main emphasis will be to provide a clear and coherent exposition for the benefit of the younger audience.

**Probing gravity and dark energy in the era of multi-messenger Cosmology**

Alessandra Silvestri

Leiden University, The Netherlands

**Abstract:** It is now an exceptional time for modern cosmology, when we can observe the universe with high precision and connect cosmological measurements with theory. The excitement about the advances of observational cosmology is accompanied by the awareness that we face some

major challenges: we still lack compelling theoretical models for dark matter, (that accounts for the formation of the structure we see around us) , and dark energy, that drives cosmic acceleration, as well as a deeper understanding of the mechanism that set up primordial conditions, and these puzzles have deep roots in particle theory and gravity.

I will focus on the challenge posed by dark energy and the quest of testing gravity on cosmological scales. I will discuss recent progress in identifying the optimal theoretical framework to tackle these in the context of large scale structure missions as well as direct detection of gravitational waves.

**Dark Energy and the Accelerated Expansion of the Universe**

Aroonkumar Beesham*

Department of Mathematical Sciences, University of Zululand, South Africa; and

Faculty of Natural Sciences, Mangosuthu University of Technology, South Africa

**Abstract:** The discovery of the accelerated expansion of the universe in 1998 has confronted theoretical cosmology with a major challenge, which has so far not been met. Attempts to explain this within general relativity face several difficulties. There are a great variety of models based on dark energy which try to explain the acceleration, but they cannot account for the properties of the vacuum. General relativity could behave differently on the largest scales in cosmology so as the produce this acceleration. Hence, alternative theories of gravity have been explored in great detail, but they also face problems with fine-tuning and an inability to explain why vacuum energy does not gravitate. This lack of a proper theoretical framework to explain late-time acceleration represents a major challenge for cosmology. Perhaps, an entirely new paradigm or even new physics is needed. In this talk, we provide a brief review of dark energy and the accelerated expansion of the universe, and discuss some interesting possible explanations.

*Email: abeesham@yahoo.com

**Beyond Einstein's General Relativity: Hybrid metric-Palatini gravity and curvature-matter couplings**

Francisco S.N. Lobo

Instituto de Astrofisica e Ciencias do Espaco, Portugal

**Abstract:** Einstein's General Relativity (GR) is possibly one of the greatest intellectual achievements ever conceived by the human mind. In fact, over the last century, GR has proven to

be an extremely successful theory, with a well-established experimental footing. However, the discovery of the late-time cosmic acceleration, which represents a new imbalance in the governing gravitational field equations, has forced theorists and experimentalists to question whether GR is the correct relativistic theory of gravitation, and has spurred much research in modified gravity, where extensions of the Hilbert-Einstein action describe the gravitational field. In this review, we perform a detailed theoretical and phenomenological analysis of two largely explored extensions of f(R) gravity, namely: (i) the hybrid metric-Palatini theory; (ii) and modified gravity with curvature-matter couplings. Relative to the former, it has been established that both metric and Palatini versions of f(R)gravity possess interesting features but also manifest severe drawbacks. A hybrid combination, containing elements from both of these formalisms, turns out to be very successful in accounting for the observed phenomenology and avoids some drawbacks of the original approaches. Relative to the curvature-matter coupling theories, these offer interesting extensions of f(R) gravity, where the explicit nonminimal couplings between an arbitrary function of the scalar curvature R and the Lagrangian density of matter, induces a non-vanishing covariant derivative of the energy-momentum tensor. We explore both theories in some several astrophysical and cosmological applications.

**Cosmological Applications of non-local gravity**

Salvatore Capozziello

Universita' di Napoli "Federico II", Napoli, Italy

**Abstract:** Recently the so-called Non-Local Gravity acquired a lot of interest as an effective field theory towards the full Quantum Gravity. In this talk, we sketch its main features, discussing, in particular, possible infrared effects at astrophysical and cosmological scales. In particular, we focus on general non-local actions including curvature invariants like the Ricci scalar and the Gauss-Bonnet topological invariant, in metric formalism, or the torsion scalar, in teleparallel formalism. In both cases, characteristic lengths emerge at cosmological and astrophysical scales. Furthermore, it is possible to fix the form of the Lagrangian and to study the cosmological evolution considering the existence of Noether symmetries.

# Paper Presentations

**Observational constraints on Renyi holographic dark energy in Kantowski-Sachs universe**

U.Y. Divya Prasanthi, Y. Aditya

GMR Institute of Technology, Rajam, India

**Abstract: In** this paper, we discuss the cosmic evolution of the anisotropic and spatially homogeneous Kantowski-Sachs universe with Renyi holographic dark energy in the background of general relativity. In order to find a solution of the field equations we have considered a relation between the metric potentials of the model. Cosmological aspects of the dynamical parameters corresponding to our dark energy model are calculated and their physical importance is studied with reference to the modern cosmological observations. We compute the dark energy equation of state parameter $\omega_{de}$ and construct the $\omega_{de}-\omega^\prime_{de}$ plane (the $\prime$ shows the differentiation with respect to $ln~a$). We include the stability analysis of the model by studying the sound speed and we observe that {\bf the model is stable at initial epoch and unstable at present and late times}. In addition with the deceleration parameter, we also obtain Om-diagnostic and state finder planes. It is clear from their analysis that our model comprises the quintessence, phantom dark energy regions and $\Lambda CDM$ limit.

**Complexity Factor of Static Feometric Structures**

Z. Yousaf

University of the Punjab, Lahore, Pakistan

**Abstract:** The aim of this talk is to explore the complexity factor for those self-gravitating relativistic spheres whose evolution proceeds non- dynamically. In this respect, we have considered radial dependent anisotropic matter content coupled with spherical geometry and determined the complexity factor involved in the patterns of radial evolution. We shall explore the field and a well-known Tolman-Oppenheimer-Volkoff equations. After introducing structure scalars from the orthogonal decomposition of the Riemann tensor, we shall calculate complexity factor. The role of matter variables are analyzed in the structure formation as well as their evolution through a complexity factor.

## Emergent Universe via dynamical wormhole

B. C. Paul

University of North Bengal, Siliguri, India

**Abstract:** We present dynamical wormholes in higher dimensions which admit flat emergent universe model in an elegant way. The emergent universe model was proposed to avoid the singularity of Big Bang cosmology. The basic assumption of emergent universe model was that the present universe emerged out from a static Einstein universe. In the paper we study emergent universe model in four and in higher dimensions and proposed that universe originates from a dynamical wormhole and the throat of the wormhole is the seed of the Einstein Static universe. The shape function obtained here admits closed, open and flat universe in higher dimensions. A class of new cosmological solutions in a higher dimensional flat universe is obtained. We obtain shape functions for flat, asymptotic closed and open universe. The shape function obtained here for asymptotic closed universe is new. It is found that flat emergent universe with a non-linear equation of state can be accommodated with dynamical wormhole. The non-linear equation of state corresponds to three types of fluids in the universe. The equation of state parameter is playing an important role in determining the cosmic fluids. The space-time dimensions determine the rate of change of a particular fluid that varies with the scale factor of a dynamically evolving universe with non-interacting fluids. Considering interaction at a later epoch among the fluids it is possible to describe the observed universe satisfactorily. In higher dimensional universe it is found that near the throat null energy condition is violated, but away from the throat null energy condition is found to obey admitting the observed universe for a flat case. Another interesting aspect of the model is that it permits late accelerating phase. However, in asymptotic closed or open universe, flat emergent universe can be accommodated with null energy condition which is obeyed right from the throat to the present epoch. The tension at the throat of the wormhole is estimated which is found to depend on the initial size of the Einstein static universe and dimensions of the universe. It is interesting to note that null energy condition is not violated to accommodate dynamical wormholes for closed or open universe. Although exotic matter is required at the throat of the wormhole for a flat universe no exotic matter is required for closed or open universe which encompass emergent universe.

## Cosmological Model in Lyra Geometry

Reena Tandon, Vaibhav Brock

Lovely Professional University, Punjab, India

**Abstract.** In this paper, we discuss Cosmological models in the presence of particle creation. The modified field equation in the presence of particle creation is derived. The exact solution is obtained for the FRW model for a specific form of particle creation function. KEYWORDS: Lyra Geometry, Particle creation, variable deceleration parameter

## Big Bang Nucleosynthesis and Entropy Evolution in f(R,T) Gravity

*Snehasish Bhattacharjee, P.K. Sahoo

*IIT Hyderabad, India

**Abstract:** The abstract is based on our paper published in EPJP (Eur. Phys. J. Plus 135(4), 350 (2020)). The work is devoted to constrain the model parameter $\chi$ for the $f(R,T)=R+\chi T$ gravity model by employing the constraints coming from big bang nucleosynthesis. We solve the field equations and constrain $\chi$ in the range $-0.14\kappa^2 \leq \chi \leq 0.84\kappa^2$ (where $\kappa^2=8\pi G c^4$) from the primordial abundances of light elements such as helium-4, deuterium and lithium-7. We found the abundances of helium-4 and deuterium agrees with theoretical predictions, however the lithium problem persists for the f(R,T) gravity model. We also investigate the evolution of entropy for the constrained parameter space of $\chi$ for the radiation and dust universe. We report that entropy is constant when $\chi=0$ for the radiation dominated universe, whereas for the dust universe, entropy increases with time. We finally use the constraints to show that $\chi$ has negligible influence on the cold dark matter annihilation cross section.

## Quantum effects on spin-0 scalar particle under a Cornell-type potential in the background of Kaluza-Klein theory

Faizuddin Ahmed

National Academy Gauripur, Assam, India

**Abstract:** In this work, we investigate spin-0 scalar particle in the presence of a Cornell-type scalar potential in the background of Kaluza-Klein theory. We solve the Klein-Gordon oscillator in the five-dimensional magnetic cosmic string space-time under a scalar potential by modifying the mass term in the equation. We analyze the effects on the eigenvalues and eigen function and a gravitational analogue of Aharono-Bohm effect is observed.

## Emergence of space and horizon thermodynamics in Einstein, Gauss Bonnet and Lovelock gravities

P. B. Krishna, Titus K. Mathew

Cochin University of Science and Technology, Kochi, India

**Abstract:** The accelerated expansion of the universe can be interpreted as a quest for satisfying holographic equipartition. It can be expressed by a simple equation dV=dt (NSurf -NBulk), which leads to the standard Friedmann equation. This novel idea suggested by Padmanabhan in the context of general relativity has been generalized by Cai and Yang et al. to Gauss Bonnet and Lovelock gravities for a spatially flat universe in different methods with different assumptions. We analyze the deep connection between the emergence of cosmic space and the horizon thermodynamics in the context of Einstein, Gauss Bonnet and Lovelock gravities. We have derived both the generalized versions of Padmanabhan's proposal from the first law of thermodynamics. This approach is unique in the sense that both these generalized versions could be derived from a thermodynamic identity that has the same form regardless of the gravity theories. Further, we investigate the consistency of Padmanabhan's proposal and its generalizations with the constraints imposed by the maximum entropy principle. Interestingly, both these generalizations imply entropy maximization even if their basic assumptions are different. Our approach gives a thermodynamic basis and thus provides further support to the emergent gravity paradigm

**Reference:**

1 . P. B. Krishna, Titus K. Mathew, Holographic equipartition and the maximization of entropy, Phys. Rev. D 96 (2017) 063513.

2. P. B. Krishna, Titus K. Mathew, Entropy maximization in the emergent gravity paradigm, Phys. Rev. D 99 (2019) 023535.

3. M. Mahith, P B Krishna, Titus K Mathew, Expansion law from first law of thermodynamics, JCAP 12(2018) 042.

## Conharmonic curvature inheritance in space-time of general relativity

Mohammad Salman

Aligarh Muslim University, Aligarh, India

**Abstract:** Symmetries of space-time are generally called as collineation. In this paper, we have described the geometrical and physical properties of a new type of curvature inheritance symmetry of space-time is called as conharmonic curvature inheritance (Conhci) defined as Lie

derivatives of conharmonic curvature tensor is equal to a scalar multiple of conharmonic curvature tensor. Also we have established its relationship with other known symmetries of space-time. Further, we have proved that a proper Conh CI implies conformal motion along a vector field in fluid spacetime.In particular, we find that no known stiff or unphysical equation of state is singled out for this curvature inheritance symmetry.

**Local versus global nakedness of a spacetime singularity**

*Karim Mosani, Dipanjan Dey, Pankaj S. Joshi

*BITS Pilani Goa Campus, India

**Abstract:** We investigate here the local versus global visibility of a space-time singularity formed due to the gravitational collapse of a spherically symmetric dust cloud having a nonzero velocity function. The conditions are investigated that ensure the global visibility of the singularity, in the sense that the outgoing null geodesics leave the boundary of the matter cloud in the future, whereas, in the past, these terminate at the singularity. Explicit examples of this effect are constructed. We require that this must be a strong curvature singularity in the sense of Tipler, to ensure the physical significance of the scenario considered. This may act as a counterexample to the weak cosmic censorship hypothesis.

**Study of anisotropic compact stellar object accounting tidal Love numbers**

Shyam Das

P. D. Women's College, Jalpaiguri, India

**Abstract:** In this work, we study the tidal deformation of relativistic anisotropic compact stars by computing tidal Love numbers. Anisotropic stresses are ubiquitous in nature and widely used in modelling compact stellar object. Tidal deformability of astrophysical compact objects is a natural effect of gravity such as one produced by a companion in a binary system. In general relativity, the existence of this measurable effect of gravity level can be quantified by their tidal Love numbers (TLN) which characterize the deformability of a neutron star (NS) from sphericity. The tidal deformability or polarizability parameter of a NS depends on its complex internal structure and hence the nature of the compact object can study through measuring the love number (TLN). We choose a particular solution which is the anisotropic generalization of Tolman IV Model as the interior of the compact stellar object. The physical acceptability of the model has been shown graphically by considering the pulsar 4U1608−52 with their current estimated mass and radius. By

computing quadrupole moment, we calculated the tidal love number as a dependent on anisotropy of the compact object. We graphically analyze the variation of tidal love number (TLN) against anisotropy for different compact objects with compactness factor. The numerical value of TLN is given for different compact objects for physically acceptable value of anisotropic parameter.

**Scaling relations for dark matter core density and radius from Chandra X-ray cluster sample**

Gopika K., Shantanu Desai

IIT Hyderabad, India

**Abstract:** A large number of studies have found that the dark matter surface density, given by the product of the dark matter core radius (rc) and core density (ρc) is approximately constant for a wide range of galaxy systems. However, there has been only one systematic study of this ansatz for galaxy clusters by Chan et al. (2015), who found that the surface density for clusters is not constant and ρc∼rc−1.46. We carry out this test for an X-ray sample of 12 relaxed clusters from Chandra observations, studied by Vikhlinin et al. (2006), implementing the same procedure as in Ref. Chan et al. (2015), but also accounting for the gas and star mass. We find that ρc∝rc−1.08±0.055, with an intrinsic scatter of about 18%. Therefore, the dark matter surface density for our cluster data shows deviations from a constant value at only about 1.4σ.

**Weak Deflection angle of Extended Uncertainty Principle Black holes**

Yashmitha Kumaran, Ali Övgün

Eastern Mediterranean University, Cyprus

**Abstract:** In this paper, we have discussed the effects of quantum fluctuations spewed by a black hole on its deflection angle. The Gauss-Bonnet theorem (GBT) is exploited with quantum corrections through the Extended Uncertainty Principle (EUP) and the corresponding deflection angle is obtained. Moreover, we have attempted to broaden the scope of our work by subsuming the effects of plasma medium on the deflection angle as well. To demonstrate the degree of difference, the acquired results are compared with the prevailing findings.

## Constraints on the variation of fine structure constant from joint SPT-SZ and XMM-Newton observations

Kamal Bora, Shantanu Desai

IIT Hyderabad, India

**Abstract:** We search for a variation of the electromagnetic fine structure constant (α ≡ e2/h_cross *c) using a sample of 58 SZ selected clusters in the redshift range (0.2 search. We first obtain a model-independent constraint on α of about 0.7%, using the fact that the aforementioned ratio is constant as a function of redshift. We then look for logarithmic dependence of α as a function of redshift: Δα/α = −γ ln(1 + z), as this is predicted by runaway dilaton models. We find that γ = −0.046 ± 0.1, which indicates that there is no logarithmic variation of α as a function of redshift. We also search for a dipole variation of the fine structure constant using the same cluster sample. We do not find any evidence for such a spatial variation.

## Electromagnetic effects on polytropes in f(R) gravity

M. Z. Bhatti and Z. Tariq

University of the Punjab, Pakistan

**Abstract:** The center of attention of this article is to examine the dynamics of conformally flat anisotropic spheres in the background of electromagnetic field satisfying the polytropic equations of state. We have resorted to the general framework developed in Herrera and Barreto (2013) that helps to inspect the rudimentary attributes of polytropic spheres in the framework of a particular f(R) gravity. We explored physical constraints for couple of families of relativistic polytropes in this scenario. By making use of conformally flat condition, the stability of such polytropes is then checked analytically via the Tolman-mass. We conclude that electromagnetic field produces the same role as that of anisotropic pressure and the configurations made are quite compact.

## Glimpses of anisotropic Chaplygin gas

S.P. Hatkar, S.P. Saraogi, S.D. Katore

Adarsh Education Society's Arts, Commerce & Science College, Hingoli, India

**Abstract:** In this work, we propose anisotropic Chaplygin gas with Bianchi type I metric in the framework of general theory of relativity. The field equations are solved by assuming special form of deceleration parameter and by taking expansion scalar proportional to shear scalar. Some physical parameters are also discussed in detail.

**LRS Bianchi Type-II Cosmological Model with Time Varying G and \Lambda in f(R, T) Gravity**

Daba Meshesha Gusu

**Abstract:** In this paper, we have presented a cosmological model in LRS Bianchi type-$\mathit{II}$ space-time for which the gravitational constant $G$ and cosmological constant $\Lambda$ are dependent on time in the presence of a perfect fluid source in the framework of the modified $f(R, T)$ theory of gravity proposed by Harko et al. \cite{Harko et al. 2011}. For a particular choice of $f(R, T)=R +2f(T)$, where $f(T)=-\lambda T$ and with the help of a variation law between the expansion anisotropy and the scale factor $(a)$, together with a general non-linear equation of state $(p=\omega \rho -\alpha \rho^{n})$, two different solutions of the modified gravity field equations have been obtained. The solution for $n\neo$ belongs to singular model of the universe whereas the solution for $n=0$ corresponds to a non-singular model. Some physical and kinematic properties of the models are also investigated.

**Transit Cosmological Models of Universe with Perfect Fluid and Heat Flow in f(R, T ) Gravity**

*Deepika Golechha, G. R. Avachar, S. D. Tade

*Jawaharlal Nehru College, Nagpur, India

**Abstract:** In this paper, we consider the Bianchi type-V spatially homogeneous space time in presence of perfect fluid and heat flow within the framework of f(R, T) gravity. To obtain the exact solutions of the universe, here we study the special class of functional. In our model, we have used hybrid expansion law, product of power law and exponential law, and studied transition phase of universe from decelerating to accelerating phase. Furthermore, some physical and kinematical properties are also discussed.

**Viability of teleparallel gravity**

Daniel Blixt, María-José Guzmán, Manuel Hohmann, Christian Pfeifer

University of Tartu, Estonia

**Abstract:** General relativity have several formulations which are classically equivalent. Conventionally its action representation is that of Einstein-Hilbert, which is written in terms of the metric and Ricci curvature scalar (depending on the Levi-Civita connection). Alternatively, one can formulate general relativity in terms of tetrads and the torsion scalar. This theory is called teleparallel equivalent to general. This theory only differs to conventional general relativity by a

boundary term. With this as a started point there are new possibilities to write down extended theories of gravity. I will describe the status of the theoretical viability of those theories based on what is known about the Hamiltonian formulation and perturbation theory in those theories. The talk is based on the following article arxiv.org/abs/2012.09180

**f (Q,T) gravity models with observational constraints**

Simran Arora, S.K.J. Pacif, S. Bhattacharjee, P.K. Sahoo

BITS-Pilani Hyderabad Campus, India

**Abstract:** The paper presents late-time cosmology in f (Q, T) gravity where the dark energy is purely geometric in nature. We start by employing a well-motivated f (Q, T) gravity model, f (Q, T) = mQ^n + bT where m, n, and b are model parameters. Additionally we also assume the universe to be dominated by pressure-less matter which yields a power-law type scale factor of the form a(t) = c2(At + c1) 1 A , where A = 3(8π + b) n(16π + 3b) and c1 & c2 are just integration constants. To investigate the cosmological viability of the model, constraints on the model parameters were imposed from the updated 57 points of Hubble data sets and 580 points of union 2.1 compilation supernovae data sets. We have thoroughly investigated the nature of geometrical dark energy mimicked by the parametrization of f (Q, T) = mQ^n + bT with the assistance of state finder diagnostic in {s, r} and {q, r} planes and also performed the Om-diagnostic analysis. The present analysis makes it clear-cut that f (Q, T) gravity can be promising in addressing the current cosmic acceleration and therefore a suitable alternative to the dark energy problem. Further studies in other cosmological areas are therefore encouraging to further investigate the viability of f (Q, T) gravity.

**Quantum potentiality in Szekeres geometries**

Andronikos Paliathanasis

Durban University of Technology, South Africa

**Abstract:** For the Szekeres system which describes inhomogeneous and anisotropic spacetimes we us the point-like Lagrangian, which describes the evolution of the physical variables of the Szekeres model, in order to perform a canonical quantization and to study the quantum potentiality of the Szekeres system in the content of de Broglie--Bohm theory. We find that for a specific family of trajectories with initial conditions which satisfy a constraint equation, there exists additional conservation laws for the classical Szekeres system which are used to define

differential operators and to solve the Wheeler-DeWitt equation. From the new conservation laws we construct a wave function which provides a nonzero quantum potential term that modifies the Szekeres system. The quantum potential corresponds to new terms in the dynamical system such that new asymptotic solutions with a nonzero energy momentum tensor of an anisotropic fluid exist. Therefore, the silent property of the Szekeres spacetimes is violated by quantum correction terms.

**Locally Rotationally Symmetric Bianchi Type II Magnetized String Cosmological Model with Bulk Viscous Fluid in Rosen's Bimetric Gravity**

N. P. Gaikwad

Dharampeth M. P. Deo Memorial Science College, Nagpur, India

**Abstract:** We have presented the solution of LRS Bianchi type II space-time with magnetic field and with string viscous fluid by solving the field equations of Rosen's bimetric theory of gravitation. It is observed that the magnetic field could have the cosmological origin of the model and it is agreed with Harrison (1973). The small value of magnetic field originated the universe and starts evolving it with maximum density and ending with zero density. The strong magnetic field ruled out the existence of the universe. Other geometrical and physical behavior of the model have been studied in the evolution of universe.

**Particle Creation in Five Dimensional Cosmological model with Time Dependent G and Lambda**

Salam Kiranmala Chanu

Maharaja Bodhchandra College, Wangkhei, India

**Abstract:** The effect of particle creation on the evolution of five dimensional cosmological model has been studied. The universe has been considered as an open thermodynamics system when particle creation lead to supplementary negative creation pressure in addition to the thermodynamics pressure. Dynamical behaviour of the cosmological solutions have been studied and an exact solution for matter distribution in five dimensional cosmological models is presented. Corresponding physical interpretations of the cosmological solutions are also discussed.

**Cosmological model in f(R,T) theory of gravity**

Priyanka

Visva-Bharati, Shantiniketan, India

**Abstract:** We have studied spatially homogeneous Bianchi type-III dark energy cosmological model with equation of state parameter in presence of perfect fluid within the framework of f(R,T) gravity theory with the help of special form of deceleration parameter for FRW metric proposed by Singh and Debnath . We have also assumed that the scalar expansion is proportional to the shear and the EoS parameter is proportional to skewness parameter in this model. Some physical and kinematical behaviour of the model are also discussed.

**Comparative study of perturbative and non-perturbative methods of R-squared gravity using Neutron stars**

Nobleson, Tuhin Malik, Amna Ali, Sarmistha Banik

BITS-Pilani Hyderabad Campus, India

**Abstract:** f(R) gravity is one of the modified theories of gravity that is proposed as an alternative to general relativity (GR) in order to explain the accelerated expansion of the universe, dark matter, and dark energy. Neutron stars are very compact objects that exhibit strong gravity. Therefore, they can be used as a tool to study the modified theories of gravity. Firstly, we investigate the structure of neutron stars in R-squared gravity using the non-perturbative method self-consistently by solving the TOV equations for the interior and exterior of the neutron star simultaneously. Secondly, we investigate the structure of neutron stars in R-squared gravity using the perturbative method. The mass-radius relations are obtained for several equations of state (nucleonic, strange, and quark matter) and for a wide range of the R-squared gravity parameter a. A comparison between the methods and the corresponding results will be presented.

**Five Dimensional Bianchi Type-III cosmological model with Quadratic Equation of state in Lyra Geometry**

Asem Jotin Meitei

Pravabati College, Manipur, India

**Abstract:** This article is devoted to the study of the dynamical aspects of the perfect fluid cosmological model with Quadratic equation of state in Five dimensional Bianchi type-III space time in Lyra geometry. An exact cosmological model is presented by solving Einstein field

equations using physically valid conditions. We have evaluated all the dynamical and geometrical parameters of the model and discussed their physical significance in modern cosmology.

**Testing Modified Gravity Theories Using Weak Deflection Angle and Black Hole Shadow**

Ali Övgün

Eastern Mediterranean University, Cyprus

**Abstract:** In this talk, we use spherical symmetric black hole solutions in modified gravity theory to examine the weak gravitational lensing and its shadow. For this purpose, we first calculate the weak deflection angle of these black holes using the Gauss-Bonnet theorem in plasma and vacuum. Then we get its shadow. Next, we discuss the effects of modified gravity theories on the black hole's weak deflection angle and shadow.

**Towards a Lambda_CDM Universe in f(R) gravity**

Saikat Chakraborty

Yangzhou University, Republic of China

**Abstract:** Lambda_CDM model till date remains the best observationally fitting model for late time cosmology. However, this model suffers from the theoretical issue that the quantum vacuum energy, which is the only known candidate for $\Lambda$, gives from QFT calculation a value that mismatches with the observed value of $\Lambda$ by orders of magnitude. This theoretical issue motivated the search for alternative late time cosmological models. Among various alternative models, a broad class of models incorporate modified gravity, within which a significant subclass are f(R) gravity models. A very pertinent question to ask is whether there are some f(R) gravity models that can exactly mimick the Lambda_CDM evolution history. This question is of interest because if there are indeed such f(R) gravity models, then one need to worry about a theoretical issue on \Lambda. In my talk I will discuss some attempts in this direction from the points of view of two frequently used mathematical treatments in theoretical cosmology: the reconstruction method and the dynamical systems approach.

**Interaction between Baratropic fluid and Dark energy with zero mass scalar field in f(R,T) gravity**

Suchita A. Mohta & Prabha Rastogi

**Abstract:** In the last decade, the modified theories of gravitation have preoccupied more attention, especially f(R,T)gravity. In this contingent exploration, we study the spatially homogeneous and isotropic flat Friedman-Robertson-Walker (FRW) universe with zero mass scalar field for the coupled scenario of Baratropic fluid and Dark energy. In this universe, we choose a field equation as f(R,T)=R+2f(T). By applying the volumetric power law and exponential law of expansion, we get exact solution of the field equation. It is observed that equation of state(EoS) parameter ω is a time dependent and it acts as matter dominated once while for small interval at late time for quintessence region ω>-1 it remains present.

**Cosmography in f(Q) Gravity**

Sanjay Mandal, Deng Wang, P.K. Sahoo

BITS-Pilani Hyderabad Campus, India

**Abstract:** Cosmography is an ideal tool to investigate the cosmic expansion history of the Universe in a model-independent way. The equations of motion in modified theories of gravity are usually very complicated; cosmography may select practical models without imposing arbitrary choices a priori. We use the model-independent way to derive f (z) and its derivatives up to fourth order in terms of measurable cosmographic parameters. We then fit those functions into the luminosity distance directly. We perform the MCMC analysis by considering three different sets of cosmographic functions. Using the largest supernovae Ia Pantheon sample, we derive the constraints on the Hubble constant $H_0$ and the cosmographic functions and find that the former two terms in Taylor expansion of luminosity distance work dominantly in f (Q) gravity.

**Influence of Modification of Gravity on the Dynamical Analysis of Self-Gravitating Objects**

M.Z. Bhatti

University of the Punjab, Pakistan

**Abstract:** In this talk, I will discuss the dynamical analysis of self-gravitating stars in the background of a particular modified gravity theory. The analysis would be carried out in a

systematic way by exploring the essential equations, in particular, modified field equations, conservation equations, mass function and evolution equations etc.

**Gravitational lensing by a black hole in Poincaré gauge theory**

Saboura sadat Zamani

Golestan University, Gorgan, Iran

**Abstract:** One of the consequences of Einstein's general theory of relativity is bending of light as it passes through a gravitational field. Examining the path of light in a very strong gravitational field of a black hole can provide a huge amount of information about the geometry and characteristics of the surrounding space. On the other hand, the path of light rays, extent, and shape of gravitational lensing, are directly related to the type of background geometry in which light is emitted. Since the theory of general relativity in very high energies and very strong gravitational fields is expected to be corrected, researchers have been looking at the phenomenon of gravitational lensing in the context of alternative theories for general relativity to find out the needed corrections for the results of general relativity and these corrections are likely to be more significant in a very strong gravitational field of a black hole. Among the various theories that have been proposed for correcting the gravity in high energies, gauge theories of gravity have great importance. One of the important results of these theories is changing the geometry for the background in general relativity, Riemannian space-time, to a non-Riemannian geometry in which, in addition to curvature, there is also torsion. In these theories, the presence of torsion coupled to spin of a matter can affect the path of light rays and correct the results of gravitational lensing. In this work, we want to study the effects of non-Riemannian geometry on the gravitational lensing of a black hole, and in particular the effects of torsion and spin in this context.

**Alternate models of gravity: Consequences for cosmological observations**

Arun Kenath, Louise Rebecca, C. Sivaram

Christ Junior College, Bangalore, India

**Abstract:** In the recent times, with the advent of new technology, the accuracy in measurement of the Hubble constant has improved tremendously. But this has led to a recent tension that could indicate either the need for new physics or as-yet unrecognized uncertainties in the measurements. Hubble constant estimated 'locally' (using Cepheid variables or type Ia

supernovae) differ significantly from the value estimated from the data from the early Universe (from the cosmic microwave background). These observations suggest that either stellar ages or age of the Universe is in serious discrepancy. Several suggestions have been made as to the cause of such a discrepancy. Here we propose a modification of the gravitational field on large scales as an alternate explanation for the discrepancy in the value of the Hubble constant.

We point out that a form of modified gravity (used in recent work to account for non-detection of DM) could in principle account also for the increase in H_0. We invoke a minimal acceleration in the gravitational field which implies a modification of gravity over large scales. At these scales, the matter density is low enough for the gravitational self-energy density to be significant. This modifies the Poisson equation and the solution of which gives an extra term in potential which has a logarithmic dependence on scale (i.e., potential goes as ~ GM/r + const. x ln(r/r_c)). This would suggest that this extra term now manifesting itself (as the Universe expanded and density dropped) would cause an increase of the expansion rate, i.e., a change in Hubble constant by about five per cent. This could perhaps account for the faster expansion rate seen at the present epoch. In the early Universe, the second term was much smaller as it is proportional to ln(r/r_c), hence not important. We also predict, using this model, that the Hubble constant will increase at later epochs.

This extra term in the Poisson equation and its solution could also have interesting consequences for current observations of super spirals, wherein their large extent (450,000 light-years) is associated with large rotation velocities of up to ~450km/s at their periphery. The logarithmic term would now imply that the velocity at the outskirts of these super spirals will also be modified (with again a logarithmic term). This would then imply a higher velocity at the periphery of super spirals without invoking dark matter.

**Dark matter conundrum: A case for alternate theories of gravity**

Louise Rebecca, Arun Kenath, C. Sivaram

Christ Junior College, Bangalore, India

**Abstract:** In view of the negative results from various dark matter detection experiments, we propose alternate models which involve modifying gravity by postulating a minimal field strength (minimal curvature) and also a minimal acceleration. These postulates lead to modified Newtonian dynamics (MOND), modified Newtonian gravity (MONG), and modified relativistic

gravity (MORG). Through these postulates various observed cosmic phenomena usually attributed to dark matter (such as the observed flat rotation curves of galaxies) can be accounted for without invoking any DM.

These modified gravity equations can also set constraints on the size of large-scale structures such as galaxies and clusters, and these constraints are found to be consistent with observations. The model introduces a minimum curvature in general relativity (and consequent modification of the Hilbert action) which leads naturally to a term equivalent to a cosmological constant. This model thus neatly ties up, with this postulate, both the observed flat rotation curves as well as the accelerated expansion of the universe. We also extend these postulates to galaxy clusters and model the dynamical velocity-distance curves for such large-scale structures. The velocity-distance curve (for instance that of the Virgo cluster) obtained from this model is found to be in accordance with that observed.

The sizes of gravitationally bound large-scale cosmic structures can be constrained from the requirement that their gravitational binding self-energy density should at least be equal to the background repulsive dark energy density (for them to be bound). We also point out that the recent observations of baryon-dominated disk galaxies formed about ten billion years ago indicate the consistency of modified gravity with observations.

**Spherically Symmetric Model with electromagnetic field in Time – Independent Gravitational Field**

Prashant R. Dhongle

Seth Kesarimal Porwal College of Arts & Science & Commerce, Nagpur, India

**Abstract:** In this paper, we have studied the spherically symmetric model having charged perfect fluid distribution with electromagnetic field in time – independent gravitational field or stationary space-time. Our model is with negative pressure and it's an accelerating universe in which the negative pressure can prevent the collapse of mass distribution. The geometrical and physical properties of this model are discussed.

## Five Dimensional FRW Radiating Models in Presence of Bulk Viscous Cosmological Models in Saez-Ballester Theory of Gravitation

Jagat Daimary

Bodoland University, Bodoland, India

**Abstract:** Five dimensional FRW cosmological space time is considered in the frame work of Saez-Ballester scalar tensor theory of gravitation in the presence of bulk viscous fluid. We have used a power law between scalar field and scalar factor of the universe to define determinate solution of the field equations. FRW cosmological models corresponding to radiating flat, closed and open models are also presented. Some physical and kinematical properties of the models are also discussed.

## Inflationary magnetogenesis with reheating phase from higher curvature coupling

Kazuharu Bamba, Emilio Elizalde, S. D. Odintsov and Tanmoy Paul*

*University of Burdwan, Bardhaman, India

**Abstract:** We investigate the generation of magnetic fields from inflation, which occurs via breakdown of the conformal invariance of the electromagnetic (EM) field, when coupled with the Ricci scalar and the Gauss-Bonnet invariant. For the case of instantaneous reheating, the resulting strength of the magnetic field at present is too small and violates the observational constraints. However, the problem is solved provided there is a reheating phase with a non-zero e-fold number. During reheating, the energy density of the magnetic field is seen to evolve as $(a^3H)^{-2}$ and, after that, as $a^{-4}$ up to the present epoch (here $a$ is the scale factor and $H$ the Hubble parameter). It is found that this reheating phase --characterized by a certain e-fold number, a constant value of the equation of state parameter, and a given reheating temperature-- renders the magnetogenesis model compatible with the observational constraints. The model provides, in turn, a viable way of constraining the reheating equation of state parameter, from data analysis of the cosmic microwave background radiation. Moreover, we discuss the Schwinger backreaction in the present context and determine the necessary constraints on the reheating equation of state parameter.

## Black Hole Universal Clock

Ahmed Farag Ali

Benha University, Benha, Egypt

**Abstract:** We assume that the black hole forms a universal clock with the space around it. The clock measurements are in terms of relative gravitational red-shift which is a property of general covariance. In this way, we found special relativity preferred frames match with general relativity Rindler frame. From the perspective this preferred frame, we found a geometric/gravitational interpretation of speed of light, mass and uncertainty principle. This lead to an emergence of a timeless state in a mathematically consistent way. The entanglement may be a support for this timeless state.

## Study on Some Strange Quark Cosmological Models in a Modified Theory of Gravity

M.Vijaya Santhi, T.ChinnappalaNaidu

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**Abstract:** In this article, we analyze Bianchi type II, VIII and IX spatially homogeneous and anisotropic space-times, in the background of f(R) theory of gravity, with a strange quark matter attached to string cloud. We have achieved the deterministic solution of the filed equations, using the following conditions: (i) the shear scalar σ is proportional to expansion scalar θ, which leads to a relation between metric potentials, (ii) a power-law relation between the scalar function F(R) of the theory and average scale factor a(t) of the universe and (iii) a special from of the average scale factor obtained from the time-varying deceleration parameter. Furthermore, all the models obtained and presented here are expanding, non-rotating and accelerating. Also, we have discussed some of the dynamical parameters of obtained models through graphical representation which are significant in the discussion of cosmology.

Keywords: Bianchi type II,VIII and IX metric, Strange quark matter, Cosmic strings, Modified theory of gravity, Time-varying deceleration parameter.

## Unified dark fluid and cosmic transit models in Brans-Dicke theory

S. K. Tripathy, *Sasmita Kumari Pradhan, B. Mishra

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**Abstract:** Some dark energy cosmological models are constructed in the framework of a generalised Brans Dicke theory which contains a self-interacting potential and a dynamical coupling parameter. The dark sector of the universe is considered through a unified linear

equation of state. The parameters of the unified dark fluid have been constrained from some physical basis. Since the universe is believed to have undergone a transition from an early deceleration to a late time acceleration, the deceleration parameter should have a signature flipping behaviour at the transition redshift. We have used a hybrid scale factor to simulate the dynamical behaviour of the deceleration parameter. Basing upon the observational constraints on the transition redshift, we have constructed four different transitioning dark energy models. The constructed models are confronted with observational data. For all the models, the behaviour of the dynamical scalar field, Brans-Dicke parameter, Self-interacting potential are investigated. Also, on the basis of the generalised Brans-Dicke theory, we have estimated the time variation of the Newtonian gravitational constant.

Keywords: Unified Dark Fluid, Generalised Brans-Dicke theory, Hybrid Scale factor

**Accelerating Model of the Universe in Modified Gravity**

Heena Dua and R.K. Mishra

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**Abstract:** This study deals with the investigation of the dynamical behavior of LRS Bianchi type-I bulk viscous cosmological model in f(R,T) gravity. In recent research findings, it is observed that many authors have studied the history of cosmic evolution and found the solution of modified field equations using variable deceleration parameter. Here in this communication, we have considered bilinear varying deceleration parameter (BVDP) $q=(\alpha-\beta t)/(1+\beta t)$, $\alpha$ and $\beta$ are positive constants (as suggested by Mishra et al. in Astrophys. Space Sci. 361:259, 2016). The presented model shows decelerated expansion phase in the past and the accelerated expansion phase at present. We have also presented the time-variation of cosmological parameters such as Hubble parameter, deceleration parameter, jerk parameter, etc. graphically. In addition, the behavior of (s-r) trajectories has also been examined to discuss different dark energy models and for a better understanding of the universe as a whole. We may say that the outcomes of the study are in good agreement with present observational data.

## Lorentzian Concircular Structure Manifolds and Ricci Solitons

Absos Ali Shaikh

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**Abstract:** This paper is delineated with the study of Lorentzian concircular structure (briefly, LCS) manifolds and Ricci solitons. A CS-spacetime is a 4-dimensional connected smooth LCS-manifold. It is shown that in a CS-spacetime, the fluid has vanishing vorticity and vanishing shear. It is found that in an LCS-manifold gradα is an irrotational vector field, where α is a non-zero smooth scalar function. It is proved that in a CS-spacetime with generator vector field ξ obeying Einstein equation, T(ξ; ξ) > 0 or α2 or ρ 0 if and only if r > 2 Λ (resp. r 2Λ), and further T(X;X) = 0 if and only if r = 2Λ. The nature of the scalar curvature of an LCS-manifold admitting Yamabe soliton is obtained. Also, it is proved that an LCS-manifold admitting η-Ricci soliton is η-Einstein and its scalar curvature is constant if and only if α is constant. Further, it is shown that if β is a scalar function with β = - (ξρ) and 2αρ - β vanishes, then the gradients of α, β, ρ are co-directional with the generator ξ. In a perfect fluid CS-spacetime admitting η-Ricci soliton, it is proved that the pressure density p and energy density σ are constants, and if it agrees Einstein field equation, then the scalar curvature is constant if and only if the energy density is constant. If such a spacetime possesses Ricci collineation, then it must admits an almost η-Yamabe soliton and the converse holds when the Ricci operator is of constant norm. Also, in a perfect fluid CS-spacetime satisfying Einstein equation, it is shown that if Ricci collineation is admitted with respect to the generator ξ, then the matter content can not be perfect fluid, and further κ(p - σ) ≠ 2Λ with gravitational constant κ implies that ξ is a Killing vector field. Finally, in an LCS-manifold, it is proved that if the CL-curvature tensor is conservative, then scalar potential and the generator vector field are co-directional, and if the manifold possesses pseudosymmetry due to the CL-curvature tensor, then it is an η-Einstein manifold.

## Effect of bulk viscosity in cosmic acceleration

Sankarsan Tarai, Pratik P. Ray. S.K. Tripathy, B. Mishra

Utkal University, Bhubaneswar, India

**Abstract:** In this work, we have studied an accelerating cosmological model in an extended theory of gravity by taking anisotropic space-time. The extended gravity considered as f(R, T) gravity with the matter field as a viscous fluid. The role of the viscous coefficient has been discussed on

the cosmic expansion issue. In the developed formalism a variable Hubble parameter has been incorporated to express the dynamical parameter with respect to redshift. The model is observed to be compatible with recent observational data.

**Bifurcations in the general non-minimally coupled scalar field models**

Jibitesh Dutta and W. Khyllep

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**Abstract:** Non-minimally coupled scalar field models are well-known for providing interesting cosmological features. While the usual stability analysis helps us determine the evolution of a model geometrically, bifurcation theory allows us to precisely locate the parameters' values describing the global dynamics without a fine-tuning of initial conditions. Using the center manifold theory and bifurcation analysis, we show that the general model undergoes a transcritical bifurcation, which predicts us to tune our models to have certain desired dynamics. We obtained a class of models and a range of parameters capable of describing a cosmic evolution from an early radiation era towards a late time dark energy era over a wide range of initial conditions. There is also a possible scenario of crossing the phantom divide line. We also find a class of models where the late-time attractor mechanism is indistinguishable from that of a structurally stable general relativity-based model; thus, we can elude the big rip singularity generically.

**Computing of soliton on a charged black-hole**

Musavvir Ali

**Abstract:** Present research paper focuses on the study the gravitational field of Reisnerr-Nordstrom distorted metric. The technique of six dimensional formalism making an eigen equation gives rise to some decisive conclusions for the Gaussian curvature of Reisnerr-Nordstrom soliton. Further, we comparatively analyse the results for two and three dimensional hyper-surfaces.

**Two fluid Bianchi Type V cosmological model in f(R, T) theory of gravity**

Sandhya Mhaske, Y. S. Solanke, V. J. Dagwal, D. D. Pawar

Shri. R. L. T. College of Science, Akola, India

**Abstract:** In the present paper Bianchi Type V space time is investigated in the context of f(R, T) gravity. To obtain the deterministic model, we have used the fact that scalar expansion is

proportional to shear scalar. We have examined the nature of physical parameters and also discussed the kinematical properties of the model.

**Dynamics of Bianchi Type- II,VIII &IX Cosmological Models in f(R, T) Theory**

T. Vinutha, B. Raja Shekar, K. Sri Kavya

Andhra University, Visakhapatnam, India

**Abstract:** Bianchi type-II, VIII and IX perfect fluid cosmological models are studied in generalized theory of gravity with the quadratic functional form. Here we consider $f(R, T)=f_{1}(R)+f_{2}(T)$ with $f_{1}(R)=R+\nu R^{2}$ from Starobinsky model and $f_{2}(T)=\mu T$, where $R$ is the Ricci scalar, $T$ is the trace of the energy momentum tensor and $\nu, \mu$ are real constants. The required solutions of field equations for three models are obtained by assuming hyperbolic scale factor and the proportionality of shear scalar with expansion scalar. In this paper the nature of the obtained model is discussed thoroughly with the help of the plots of various physical and kinematical parameters w.r.t. redshift(z). In addition to this the energy conditions are studied, the analysis of $\{r, s\}$ and $\{r, q\}$ planes of this model supports the accelerating expansion of the universe. The results obtained here coincides with present modern cosmological observations.

**The Study of Kantwoski-Sachs Perfect fluid Cosmological Model in Modified Gravity**

T. Vinutha, K. Niharika

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**Abstract:** Kantowski-Sachs perfect fluid cosmological model is explored in $f(R,T)$ gravity with functional form $f(R,T)$=$f_1(R)$+$f_2(T)$ where $R$ is Ricci scalar and $T$ is the trace of energy momentum tensor. With this functional form, three different cases have been formulated, namely negative and positive powers of curvature, logarithmic curvature and exponential curvature given by $f_1(R)=R+\gamma R^2-\frac{\mu^4}{R}+\lambda T$, $f_1(R)=R+\nu ln(\tau R)+\lambda T$ and $f_1(R)=R+\kappa e^{-\iota R}+\lambda T $ respectively, and for all these three cases $f_2(T)=\lambda T$ . Here $\gamma$, $\lambda$, $\mu$, $\nu$, $\tau$, $\kappa$ and $\iota$ are constants. While solving the field equations, two conditions i) Expansion scalar is proportional to shear scalar ii) Hyperbolic scale factor are assumed. By using these assumptions the required optimum solutions are obtained. The physical parameters are calculated and geometrical parameters of three cases are analyzed against redshift($z$) with the help of pictorial representation, also energy conditions are discussed thoroughly. The results obtained in this

paper are in persistent with the present cosmological observations and the model represents an accelerating universe.

**Viscous late acceleration universe**

Jerin Mohan N D, Titus K Mathew

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**Abstract:** We investigate the dynamics of a flat FLRW universe filled with a bulk viscous fluid in the context of recent acceleration of the universe. The truncated Israel-Stewart theory is used to incorporate the evolution of the bulk viscous pressure. We analytically obtained the Hubble parameter evolution equation and the model parameter are constrained using the Pantheon sample of Supernovae type Ia data, Observational Hubble parameter data, CMB and BAO data sets. The evolution deceleration parameter and equation of state parameter indicates the transition from a prior decelerated to the current accelerating phase of expansion, possessed with a far future de Sitter phase. For the best estimated values of the model parameters the age of the model deduced in this truncated viscous model is around 13.66 Gyr, which is consistent with recent observations. The phase space analysis of the model shows the evolution towards a stable de Sitter phase. The present study shows that a finite and very small value of the causality parameter, equivalent to the square of bulk viscous speed perturbations in this model, has a major role in the dynamics of the bulk viscous universe. We also compared the present truncated Israel-Stewart model with the full causal and the Eckart viscous models of the universe. The truncated viscous model appears more adaptable with astronomical observations than the Eckart and full causal viscous models.

**PN Properties of EMRI using Power Law Potential**

Chinmay Gandevikar

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**Abstract:** There are many astrophysical scenarios where extreme mass ratio inspiral (EMRI) binaries can be surrounded by matter (esp. dark matter) distribution. The distribution of mass can gravitationally affect the dynamical properties (e.g. orbital frequency, orbital velocity, etc.) and the energy radiation rate of the EMRI. To incorporate such effects, one may consider a more general form of potential i.e. power law potential instead of Kepler-Newton potential. Moreover, due to the power law potential, the velocity profile of a lighter object does not fall as much as

that predicted by Kepler-Newton potential and this feature of the velocity profile may be observationally important. In this presentation, I would discuss the first post-Newtonian (1PN) expressions for dynamical quantities and the average energy radiation rate from the circular orbit EMRI. I would also briefly talk about the energy radiation rate and orbital frequency of EMRI which can be significantly different in the presence of power law potential as compared to that in the Kepler-Newton potential. Signatures of this can be observed in gravitational waves from the EMRI.

**Stability analysis of two-fluid dark energy models**

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*Vellore Institute of Technology- AP University, Amravati, India

**Abstract:** The presentation focuses on investigating the stability of the universe within a framework of a spatially homogenous Bianchi V space time filled with combination of two sources of fluids; i.e., matter fields and dark energy fluid. we have studied the stability of the cosmological models with dark energy and combination of matter fields and dark energy in an anisotropic space time. The pressure anisotropy along the spatial directions are derived and its stability in each direction has been examined. The four models presented here (w.r.t all combinations), show their stability on certain spatial direction. The role of matter field on the stability analysis has been obtained. The positive and negative value of cosmic string completely changed the stability behavior of the model. The presence of a magnetic field disturbs the stability aspects of the models at least in an early epoch.

**The study of anisotropic perfect fluid cosmological model in f(R, T) gravity**

Venkata Vasavi

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**Abstract:** In this paper, we have studied anisotropic axially symmetric perfect fluid cosmological model in f(R, T) gravity. Using quadratic functional form, the field equations are obtained and solved. For the obtained model the geometrical and physical parameters as well as energy conditions are discussed deeply with the help of their plots with respect to redshift(z). The cosmological parameters like state finder parameters {r, s}, jerk parameter are also investigated to study the model in detailed manner. We have plotted graphs by taking three different values

for n namely n = 2, 3, 4 and finally observed that the obtained model represents an accelerated expanding universe.

**Traversable Wormholes in the Traceless f(R; T) gravity**

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*University of KwaZulu-Natal, South Africa

**Abstract:** We present a traversable wormhole solution using the traceless f(R, T) theory of gravity. In the f(R, T) gravity, the Ricci scalar R in the Einstein-Hilbert action is replaced by a function of R and trace of the energy-momentum tensor T. The traceless version of the f(R, T) gravity gives rise to a possible wormhole geometry without the need for ``exotic matter'', which violates the principle of causality. Using a physically plausible ansatz for the wormhole's shape function, the traceless field equations lead to compliance with the weak energy condition at very well-defined intervals of the coupling constant $\lambda$ in the $f(R, T)=R+2\lambda T$ form. Our solution leads to other well-behaved energy conditions considering some possible values of the parameter $\omega$ in the equation of state $p_r=\omega \rho$, with $p_r$ being the radial pressure and $\rho $ the density. The energy conditions are obeyed in the ranges $\lambda -1$.

**Higher Dimensional FRW Model Universe in Scalar Tensor Theory of Gravitation using Quadratic Equation of State**

Tensubam Alexander Singh

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**Abstract:** a five dimensional frw space-time is considered in the scalar-tensor theory of gravitation using quadratic equation of state. to obtain determinate solution of the field equations we have used quadratic equation of state between scalar field and the scale factor of the universe.some physical and kinematical properties of the solution are also discussed.

**Probing the Cosmological Consequences of Barrow Holographic Dark Energy with Specific Nojiri-Odintsov Cut-off and its Thermodynamics**

Gargee Chakraborty and Surajit Chattopadhyay

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**Abstract:** Motivated by the work of Saridakis [1], the study reports a reconstruction scheme of Barrow Holographic Dark Energy (BHDE) with specific Nojiri-Odintsov (NO) cut-off and its thermodynamics. We have incorporated bulk viscous pressure in BHDE. The quintessence

behaviour of Equation of State (EoS) parameter is observed for viscous BHDE. We have reconstructed the density of BHDE and have seen that under a condition we can study the evolution of universe at its large due to BHDE. By studying the BHDE with specific NO cut-off [2, 3], we get the suggestion of Big-Rip singularity. This model also satisfies the generalised second law of thermodynamics [4, 5].

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**Gravitational baryogenesis models comparison in f(R) Gravity**

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Abstract: We have studied the gravitational baryogenesis in f(R) theory of gravity with an anisotropic Bianchi I space-time. The matter field is considered to be that of perfect fluid. Two models pertaining to specific form of Ricci scalar have been presented. The baryon-to-entropy ratio has been derived with some specific form of Ricci scalar in the anisotropic background. The gravitational baryogenesis is examined and its behaviours are studied.

**Bulk viscous Universe with dominance of dark energy**

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**Abstract:** In this paper, we have investigated a bulk viscous accelerating Universe with dominance of dark energy at late time and constrained its model parameters with recent H(z) and Pantheon compilation of SN Ia data. Using cosmic chronometric technique, we estimate the present value

of Hubble's constant by bounding our derived model with recent H(z) data and joint H(z) and pantheon compilation SN Ia data respectively. The present age of the universe is specified as t = 13.89 Gyrs. The model favours a transitioning universe with the transition red shift. We have reconstructed the jerk parameter using the observational data sets. From the analysis of the jerk parameter, it is observed that, our derived model shows a marginal departure from ^CDM model.

**Dynamical stability analysis of axial anisotropic geometry in modified gravity theory**

M. Yousaf

**Abstract:** I will discuss stability criteria under the influence of modified gravity theory. I explore the stable behavior of the axial symmetrical fluid. I will discuss modified field equations, mass function, conservation equations in the background of MGTs. I constituted the collapse equation, which follows from the perturbation technique by applying it to the geometrical and material quantities for the systematic analysis. Furthermore, to determine stability criteria I imposed physical conditions on adiabatic index at N and pN domains.

**Bouncing scenario with energy conditions in modified theories of gravitations**

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*S. P. M. Science and Gilani Art's Commerce College

**Abstract:** In the present paper, we have analyzed the bouncing Scenario of purely accelerating anisotropic LRS Bianchi type-I cosmological model with energy conditions in the context of different modified theories of gravitation. The paper consists of main three parts in which the bouncing scenario of accelerating model with energy conditions in f(R), f(G) and f(R, G) gravity are described (where R and G are the Ricci scalar and Gauss-Bonnet scalar respectively). We govern the features of the purely accelerating cosmological model in view of bounce form. The derived model forecasts that the anisotropy of the model will damp out and the Universe will turn out to be isotropic one. Also discussed the singularity of the model, some physical and kinematical parameters of the bouncing model is also discussed in details.

**Constraints on Dark Matter-Photon Coupling Model with CPL Parametrization of Dark Energy**

Santosh Kumar Yadav

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**Abstract:** The standard $\Lambda$CDM is well-fitted with the observations from cosmic microwave background (CMB), baryonic acoustic oscillations (BAO), Supernovae type Ia (SNIe);

and also successful in explaining the large scale structure (LSS) of the Universe. But this model suffers from some serious theoretical problems such as {\it fine-tuning problem} and many {\it small scale problems} which are related to cosmological constant $\Lambda$ and cold dark matter (CDM), respectively. Also, some parameters of $\Lambda$CDM model are found to be in a serious disagreement with CMB and LSS observations.

The well-known and widely discussed discrepancies in the literature are in the measurement of present Hubble constant $H_0$ and amplitude of present matter density fluctuations at $8h^{-1}$ Mpc scale, characterized by $\sigma_8$. Although, there is no clear explanation so far that this disagreement is due to systematic errors in data or the ignorance of some new physics beyond the standard model.

In this paper, we consider a minimal extension of the $\Lambda$CDM model where the dark matter is coupled to photons via a coupling parameter $\Gamma_{\gamma }$. This coupling induces a non-conservation of the numbers of particles for both species, where the dark matter particles are allowed to dilute throughout the cosmic history with a small deviation from the standard evolution decaying into photons, while the associated scattering processes are assumed to be negligible. In addition to this, we consider CPL parametrization for equations of state of dark energy and the presence of massive neutrinos with $N_{\rm eff}$ as a free model parameter.

The model parameters are constrained by using the data from CMB, BAO, local value of Hubble constant from Hubble space Telescope (HST), and LSS information from the abundance of galaxy clusters. The main objective in this work is to investigate the observational constraints on the free parameters of the considered coupling model by using above mentioned data sets in four different combinations.

We obtained the upper bound on coupling parameter as $\Gamma_{\gamma } \leq 7.7 \times 10^{-6}$ at 95\% CL, from joint analysis using all the datasets. The upper bounds on sum of the neutrino masses are obtained as $\sum m_{\nu} \sim 0.9$ eV and $\sum m_{\nu} \sim 0.45$ eV, both at 95\% CL with and without inclusion of LSS data, respectively. We found that this coupling model yields high values of $H_0$ (as compared to $\Lambda$CDM) with all the data combinations used. Particularly, we have found $H_0 = 72.6 \pm 1.5$ Km/s/Mpc, at 68\% CL from joint analysis, which is in agreement with the local measurements, and thus alleviates the tension on this parameter. In all cases ( except with CMB + BAO + HST), we obtained a lower value of $\sigma_8$, and with

the joint analysis, we have $\sigma_8 = 0.77 \pm 0.15$ at 68\% CL. Hence this coupling model alleviates both $H_0$ and $\sigma_8$ tensions of the standard model.

**Gravitational waves from dark sector interactions**

Reginald Christian Bernardo

University of the Philippines, Philippines

**Abstract:** We show that the gravitational waves generated by the perturbations of general relativistic black holes can be used to probe of the existence of dark sector interactions. Working within the framework of Horndeski theory and linear perturbations, we show that dark sector interactions effectively reduce to an interaction charge that influences both scalar and tensor modes. Furthermore, we show that the total dark matter field, including the effects of dark sector interactions, satisfies a conservation equation reminiscent of the noninteracting case. We exploit this realization and present the waveforms generated by a dark matter particle falling straight into a Schwarzschild black hole.

**Bulk Viscous Bianchi Type I Barotropic Fluid Cosmological Model with Varying Λ and Functional Relation on Hubble Parameter in Bimetric Theory of Gravitation**

P.V. Gayakwad

R.T.M. Nagpur University, Nagpur, India

**Abstract:** In this paper, Bianchi type I model is considered in presence of bulk viscous barotropic fluid along with varying cosmological term and functional relation on Hubble parameter and solved in bimetric theory of gravitation. The model at early stage of the universe attains zero values so that volume V and the scale factor admits zero values at early stage and then they starts increasing with increase in time t. This infers that initially the model starts with zero volume and zero scalar factor and then model expanding exponentially and has infinite volume at final epoch of time. Other physical and geometrical properties are also explored.

**Study of Cosmological Model with Bi-Quadratic Varying Deceleration Parameter In F(R, T) Theory**

Reena Tandon, Sonia Arora

Lovely Professional University, Jalandhar, Punjab

**Abstract:** In this paper, we proposed a generalization of the deceleration Parameter as bi-quadratic function of cosmic time t to study the Bianchi type-1 cosmological model filled under perfect fluid sources in f(R, T) gravity theory. We find the exact solution of Einstein field equations

under the constraint of flat, diagonal and Bianchi type-1 metrics. With the help of extended form of deceleration parameter, we explore early time deceleration and obtain the exact solution of field equations. In addition, we study geometrical and physical properties of our model and the behavior of deceleration parameters is shown by the graph. Deceleration parameter have been analyzed and considered in terms of red shift. We have also analyzed the cosmic models of variable G to obtain a homogenous structure of the FRW condenser Device.

Keywords: Deceleration Parameter, FRW Condenser Device, Bianchi Type-1 Metric

**To study the behaviour of Dark energy in the acerbating expansion of universe.**

Reena Tandon, Jaya gupta

Lovely Professional University, Jalandhar, Punjab

**Abstract:** In this paper,we have investigated the nature of dark energy in the expansion of universe using BAO(Baryon Acoustic Oscillation)and constraint parameters of EOS(Equation of state).we proposed as universe is expanding with negative pressure and low density but dark energy density remains unaffected while dealing with its different models which signifies it doesn't get diluted with the expansion of universe.

Keywords: Dark energy, Expansion, Density, Pressure, Accelerating.

**Compact objects with Finch-Skea geometry in f(T) gravity**

Sagar Dey

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**Abstract:** We present relativistic solutions of anisotropic compact objects with Finch–Skea (FS) metric in f(T) gravity. The modified FS geometry is considered to obtain stellar models for a given mass and radius obeying all the conditions necessary for a realistic star. The EoS is predicted. As the EoS is not known, we also consider a MCG to obtain stellar models. In this case, we have predicted some interesting features. It is found that compact star formation may be possible with a repulsive core when MCG EoS is taken. In the case of MCG in f (T ) gravity compact stars may be obtained with anisotropic fluid (pt > pr ), with maximum anisotropy at the center of the star, which however is not found when MCG is absent.

## Observational constraints on Emergent Universe in presence of Non-linear Viscous Fluid

A. Chanda and B. C. Paul

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**Abstract:** We present a flat emergent universe with a non-linear equation of state considering bulk viscosity. The equation of state (EoS) considered in this case is highly non-linear and is described by parameters A and B. The objective of this work is to investigate the bounds on the model parameters for which EU scenario can be obtained from the observed Hubble data (H(z) - z). We obtain a cosmological model with viscous fluid described by truncated Israel-Stewart theory. Using autonomous system of field equations the stability of the solutions are analyzed. The solutions are new and interesting. The observational constraints on the model parameters are determined for different matter energy compositions of the universe using the Stern H(z) - z data set and the SNe Ia data. The present value of Hubble parameter is considered for the study as determined from the PLANCK mission. According to the analysis the class of EU solutions considered here with bulk viscosity cannot be ruled out by the present observations.

## Expansion of the Universe in Interacting Dark Energy Model

Debasis Sahu, Bibekananda Nayak

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**Abstract:** In this work, we study the evolution of the universe by assuming an interacting dark energy model, where dark energy interacts with matter. Using this model, we have picturised the expansion of the universe. From our analysis, we found that presently observed accelerated expansion of the universe can be explained by interacting model, if the dark energy is quintessence type. Though equation of state parameter of dark energy $\gamma_\varphi$ for quintessence varies between 0 and -1, our results predict that accelerated expansion is only possible for $\gamma_\varphi$ less than -0.166. It is also found that in early time the universe was undergoing a decelerated phase of expansion and transition from deceleration to acceleration would occur in recent past. Further, our model predicts that in near future again expansion of the universe will undergo a second transition from the accelerated phase to a decelerated one and finally deceleration parameter will take a constant positive value 0.5 as early universe indicating a constant rate of deceleration in far future like distant past.

**Black Hole Dynamics in The Universe Having Single Scale Factor**

Bibekananda Nayak

Fakir Mohan University, Balasore, India

**Abstract:** To explain recently observed accelerated expansion of the universe, theoretical cosmology demands that the present universe should be dominated by an unknown form of energy having negative pressure, known as dark energy. Again, for satisfying the early observational facts, starting from primordial nucleosynthesis to formation of large scale structure, it is considered that the universe had passed through radiation-dominated and matter-dominated eras, before it reached the present state. Corresponding to the three different eras, three different types of scale factors are used in literature. But for the exact evolution of the universe, there must be a common scale factor.

In this work, we design a single scale factor for describing the whole evolution of the universe. Using this scale factor, we calculated different cosmological parameters like density of the universe, Hubble's parameter and deceleration parameter etc. and found that their values are in agreement with observations. From our analysis, we also reached at the conclusion that the present universe is dominated with quintessence type dark energy. Again we study the black hole dynamics in this environment by considering both Hawking evaporation and accretion of energy matter from the surroundings. Our result predicts that in the present case black holes will live longer due to greater rate of accretion in comparison with standard model of cosmology, scalar-tensor theory and modified theory of gravity. Thus for the universe having common scale factor, more number of black holes are thought to be exist today than any other models, which strengthens the conjecture that the black holes are the proper candidates for dark matter.

**Diagnostic signature for GW scalar mode mass and dispersion relation in f(R) background**

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**Abstract:** In the context of power-law f(R) gravity, we obtain the dispersion relation for the scalar mode (perturbed extra scalar degrees of freedom) gravitational wave (GW) in the f(R) galactic background. The observational signature of scalaron mass is recently explored by us under the published research work. However, the signature of scalar mode GW is imprinted in the modified

dispersion relation (subject to the future observational evidence). We discuss the scalar mode mass of GW with reference to the chameleon mechanism.

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**Diagnostic signature for scalar mode mass and velocity in f(R) background**

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**Abstract:** In the context of power-law f(R) gravity, we obtain the dispersion relation for GW scalar mode in the galactic f(R) background. The observational signature of scalaron mass is discussed by us via combined analysis of rotational curves and lensing profile of galaxies. The modified signature of GW scalar mode is imprinted in the dispersion relation (subject to the observational evidence). We discuss the scalar mode (perturbed extra scalar degrees of freedom (d.o.f.)) GW mass via chameleon mechanism.

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