Investigating Loop Quantum Gravity with EHT Observational Effects of Rotating Black Holes

Presented by Shafqat Ul Islam (University of KwaZulu-Natal).

A mathematically consistent rotating black hole model in loop quantum gravity (LQG) is yet lacking. The scarcity of rotating black hole solutions in LQG substantially hampers the development of testing LQG from observations, e.g., from the Event Horizon Telescope (EHT) observations. The EHT observation revealed event horizon-scale images of the supermassive black holes Sgr Aand M87. The EHT results are consistent with the shadow of a Kerr black hole of general relativity. We present LQG-motivated rotating black hole (LMRBH) spacetimes, which are regular everywhere and asymptotically encompass the Kerr black hole as a particular case. The LMRBH metric describes a multi-horizon black hole in the sense that it can admit up to three horizons, such that an extremal LMRBH, unlike the Kerr black hole, refers to a black hole with angular momentum $a > M$. The metric, depending on the parameters, describes (1) black holes with only one horizon (BH-I), (2) black holes with an event horizon and a Cauchy horizons (BH-II), (3) black holes with three horizons (BH-III) or (4) no-horizon (NH) spacetime, which, we show, is almost ruled out by the EHT observations. We constrain the LQG parameter with the aid of the EHT shadow observational results of M87and Sgr A, respectively, for an inclination angle of 170 and 500 . In particular, the VLTI bound for the Sgr A, $\delta \in (-0.17, 0.01)$, constrains the parameters (a, l) such that for $0 < l \leqslant 0.347851\text{M}$ ($l \leqslant 2\times 106\text{km}$), the allowed range of a is $(0, 1.0307\text{M})$. Together with the EHT bounds of Sgr A$*$ and M87$*$ observables, our analysis concludes that a substantial part of BH-I and BH-II parameter space agrees with the EHT results of M87 and Sgr A. While the EHT M87 results totally rule out the BH-III, but not that by Sgr A*.

Energy and Angular Momenta of Periodic Orbits Around Static Black Holes

Presented by Yen-Kheng Lim (Xiàmén University, Malaysia).

We study the distribution of energy (E) and angular momenta (L) of the 'periodic table of orbits' around the Schwarzschild black hole first established by Levin and Perez-Giz. In this formulation, each periodic orbit is classified according to three integers (z, w, v). In the (L, E)-parameter space, the set of all periodic orbits can be partitioned into domains according to their whirl number w, where the limit of infinite w approaches the branch of unstable circular orbits. We show how this distribution can be inferred by perturbing the stable circular orbits. We also show a correspondence between periodic orbit around a pierced Schwarzschild black hole and the motion of charged particles around a Schwarzschild black hole carrying a magnetic monopole. This is joint work with Thomas Yeo and Zoe Chan, partially based on the papers published in Phys. Rev. D 109, 024037 (2024), Phys. Rev. D 106 064023 (2022), and another in preparation.

On the Shear Free Perfect Fluid Conjecture

Presented by Muzikayise Sikhonde (University of Cape Town).

Using a covariant formalism, we present a method for proving shear-free perfect fluid theorems in General Relativity. It establishes the consistency of the Einstein gravitational field equations under the barotropic shear-free perfect fluid condition. Using the Mathematica package xTensor, we prove several cases: constant pressure, parallel alignment of the acceleration vector and vorticity, basic orthogonal components of a rescaled acceleration vector field, and the existence of a Killing vector along the vorticity when the dot product of the rescaled acceleration vector field and the unit vorticity vector is basic.

A Model-independent Approach to Analysing Dynamical Systems in $f(R)$ gravity

Presented by Jess Worsley (University of Cape Town).

Motivated by various issues with the ΛCDM cosmological model, the study of modified theories of gravity has gained increasing popularity in recent years. Modified gravity theories extend Einstein's theory of general relativity to explain poorly understood phenomena. Examples include theories that incorporate extra dimensions, introduce new scalar fields, or propose new gravityrelated particles. These modifications often aim to provide alternative explanations for the accelerating expansion of the universe or the behaviour of dark matter and dark energy. Aiming to provide a simple, geometric explanation for the late-time acceleration of the universe, $f(R)$ modified gravity has garnered significant interest. This model can produce a ΛCDM-like evolution history without the need for a Λ vacuum energy term. In particular, the $f(R)$ model replaces the Ricci scalar in the Einstein field equations with a function of the Ricci scalar. Traditionally, studies of $f(R)$ gravity have either reconstructed a functional form of $f(R)$ to match a specified cosmological solution or specified the form of $f(R)$ a priori and studied the resulting evolution history. While these approaches have provided useful insights, they are time-consuming and limited by the need to analyse each $f(R)$ theory individually. To address these challenges, we introduce a new formalism [1,2] for studying the cosmology of $f(R)$ gravity. Our approach avoids specifying a form of $f(R)$ by using standard model-independent cosmographic parameters — such as deceleration, jerk, and snap — to develop a general dynamical system. This method streamlines the analysis process, offering a more efficient way to explore the cosmological implications of $f(R)$ gravity. By substituting cosmographic parameters into the dynamical system, we create a generalised framework that avoids the arduous process of guessing and testing specific $f(R)$ functions. Our new formalism thus provides an efficient and comprehensive method to study the cosmological implications of $f(R)$ gravity while ensuring its physical viability.

Model-independent Formalism for Analysing Structure Formation in $f(R)$ Modified Gravity

Presented by Kelly MacDevette (University of Cape Town).

Building on the previous talk from Jessica Worsley which details a model-independent approach to $f(R)$ gravity [1] and illustrates the link between a ΛCDM-like evolution history and the cosmographic condition j = 1, this talk will explore structure formation in this generic $f(R)$ gravity. This is achieved by extending the model-independent formalism to the study of linear perturbations using the covariant gauge-invariant approach [2-5] in its exact, semi and full quasi-static forms. By examining matter density perturbations, the growth function and growth index, I will explore perturbative signatures of general $f(R)$ theories which mimic ΛCDM at a background level. This will show that this model-independent formalism is capable of capturing features common to the most viable $f(R)$ theories while avoiding instabilities and producing a realistic evolution history. Finally, I will examine these differences from ΛCDM at the perturbation level and give an outlook on the possibility of their detection in future surveys.

A New Perspective on Kaluza-Klein Theories

Presented by Langa Horoto (Stellenbosch University).

By assuming that the geometry of spacetime is uniquely determined by the energy momentum tensor of matter alone, i.e. without any interactions, enables us to construct the Lagrangian from which the metric of higher dimensional spacetime follows. From the geodesic equations that follow it becomes clear that the incorrect mass of elementary particles predicted by Kaluza-Klein theories arises from the assumption that in the absence of gravity the solution to the Einstein field equations reduces to the Minkowski metric. From construction of a consistent theory of 4D electromagnetism, we find that this assumption does not only result in the incorrect mass of elementary particles, but also the incorrect value of the cosmological constant. This suggests that these incorrect predictions, which are often regarded as major flaws of Kaluza-Klein theories, just reflect the inconsistency of the assumption that the solution to Einstein field equations reduces to Minkowski metric in the absence of gravity and Weyl invariance which is the symmetry of gauge theories in 4D spacetime. Abandoning this assumption results in modifications of general relativity. We show that the unified description of fundamental interactions naturally incorporates the Higgs mechanism. For non-Abelian gauge fields, we find that the manifold comprising the extra dimensions has to be a group manifold and show that the standard model is realised in 16D spacetime. We show that charge and spin are the same concept, but what makes them different is that the former follows from symmetry of 4D spacetime while the latter follows from symmetry of the internal space.

Stability Analysis of Thick Brane Models with Three-Form Fields

Presented by Jenna Bruton (University of Cape Town).

This talk investigates thick brane models featuring three-form fields as the primary gravitational source in the bulk. We explore novel solutions where three-forms interact gravitationally, both with and without matter fields represented by a scalar field proxy. Comparisons with single scalar field thick brane models highlight how the parameterization of three-form fields restricts the choice of warp factor form, leading to a closed system of equations with unstable solutions. Specifically, we find that three-form dominated thick brane models are inherently unstable against metric perturbations, suggesting limitations on their viability in braneworld scenarios. This study contributes insights into alternative gravitational sources in braneworld theories, with implications for cosmology and high-energy physics.

Single-Fluid Approach to Modeling Dark Matter and Dark Energy

Presented by Vineshree Pillay (University of Cape Town).

In this study, we construct a double polytropic model analogous to the Murnaghan equation of state (EoS), which is commonly used in solid-state physics and thermodynamics. We assume a flat FLRW background and derive relationships for sound speed and the background EoS parameter as functions of the scale factor. Our findings indicate that the model is consistent with classical cosmological theory. We also perform a perturbative analysis for various cases of the Murnaghan EoS. In limiting cases, we reproduce other unified dark energy models, including the Generalized Chaplygin gas model, the Logotropic model, and the ΛCDM model. Numerical fitting with observations reveals that the model is highly constrained for specific values for the free parameter α. This model provides motivation for further exploration of unified dark energy models and selfinteracting scalar field models.

Charged Dust Models in Einstein-Gauss-Bonnet Gravity

Presented by Shavani Naicker (University of KwaZulu-Natal).

Dust is considered to be the simplest form of matter composed of pressureless, radiation and is abundant in galaxies, clusters and superclusters. The gravitational behaviour of these pressureless fluid distributions is investigated in Einstein-Gauss-Bonnet (EGB) gravity in the presence of an electromagnetic field. The EGB field equations are generated for this system in arbitrary dimensions. It was found that the governing equation for this static charged dust configuration is classified as an Abel differential equation of the second kind; a complicated nonlinear differential equation. These are difficult to solve in general however we demonstrate a method that reduces the nonlinear differential equation to a simpler form enabling exact solutions to be found. This process of finding exact solutions to the governing equations in any gravitational field theory represents a foundation for analysing the gravitational dynamics of astrophysical objects. Furthermore, we demonstrate that the charged dust model obtained is physically well-behaved in a region at the centre, and dust spheres can be generated. It can be observed that the higher order curvature terms influence the dynamics of charged dust and the gravitational behaviour which is distinct from general relativity.

The Chini Integrability Condition in Second Order Lovelock Gravity

Presented by Mohammed Ismail (University of KwaZulu-Natal).

We analyse second order Lovelock gravity, also known as Einstein-Gauss-Bonnet (EGB) gravity, and generate the field equations in N dimensions for a static, spherically symmetric spacetime, for neutral and charged fluids. We first transform the condition of pressure isotropy, an Abel differential equation of the second kind into canonical form. We review known exact solutions for both charged and neutral matter. We then determine a systematic approach to integrate the condition of pressure isotropy by showing that the canonical form is a Chini differential equation. We find three new general solutions, in implicit form, to the condition of pressure isotropy. We determine new exact specific solutions to the isotropic pressure condition and show that previously obtained exact specific solutions are regained.

Heating effects in the Interaction of Gravitational Waves with Matter

Presented by Nigel Bishop (Rhodes University).

The interaction of gravitational waves (GWs) passing through matter is normally treated as being very weak. In a series of papers, we re-investigated this issue using linearized perturbations within the Bondi-Sachs formalism. We found, as expected, that the effect is very weak when the matter is far from the GW source, but when close to the source the interaction can be very significant. We consider a GW source surrounded by a spherical shell of matter. Previously, it was shown that the shell causes the GWs to be modified both in magnitude and phase; and if the shell is viscous, then the shear induced in the velocity field results in an energy transfer so damping the magnitude of the GWs. This presentation focuses on the effect of GW damping on the matter shell, i.e. that the matter will be heated, and applies this to astrophysical scenarios. GW heating will be significant in the quasinormal mode regime after a binary neutron star merger; it may be respinsible for reviving the stalled shock in a supernova explosion; and if matter is present at a binary black hole merger, it can be heated sufficiently to cause an X-ray or gamma-ray burst.

Unveiling Quantum Entanglement and Gravity-Induced Entanglement Through Gravitational Waves

Presented by Partha Nandi (Stellenbosch University).

This talk delves into the exploration of quantum entanglement and gravity-induced entanglement (GIE) phenomena in the context of quantum harmonic oscillators coupled to gravitational waves (GWs). The first part discusses the potential for generating quantum entanglement between orthogonal modes of oscillators using LIGO's arms as interacting oscillators with GWs. The study reveals unique entanglement dynamics influenced by classical GWs, along with a distinct "quantum memory effect" and temperature effects on oscillators. The second part proposes an improved theoretical model to investigate GIE, circumventing classical communication constraints. The model couples a non-relativistic two-dimensional quantum oscillator detector to linearly polarized GWs, observing GIE within oscillator quantum states. The observed GIE serves as a robust signature of the quantum nature of gravitational waves, satisfying "event" and "system" localities.

The Mass Gap in 5D Einstein-Gauss-Bonnet Black Holes: A Geometrical Explanation

Presented by Chevarra Hansraj (University of KwaZulu-Natal).

In this talk, we study the dynamical black hole formation via the radiation collapse in the radiating Boulware–Deser spacetime in five dimensions. The central zero mass singularity is weak, conical and naked, and the horizon forms only when a finite amount of matter, that depends on the coupling constant of the Gauss–Bonnet (GB) term, falls into the central singularity. To understand this phenomenon transparently and geometrically, we study the radiating Boulware–Deser spacetime in five dimensions using a 1+1+3 spacetime decomposition, for the first time. We find that the geometric and thermodynamic quantities can be expressed in terms of the gravitational mass and the GB parameter and separate each of them into their GB and matter parts. Drawing comparisons with five dimensional GR at every step, we explicitly show how the mass gap arises for a general mass function $M(v)$ and what functions for $M(v)$ make certain geometrical quantities well defined at the central singularity. We show in the case of self-similar radiation collapse in the modified theory, the central singularity is not a sink for timelike geodesics and is extendable. This clearly demonstrates how the GB invariant affects the nature of the final state of a continual collapse in this modified theory.

Lie Group Analysis of the Karmarkar Condition

Presented by Noeleen Naidoo (University of KwaZulu-Natal).

This study investigates the Karmarkar embedding condition in various spherically symmetrical metrics using Lie symmetries. We explore Lie symmetries for conformally flat and shear-free metrics, extending recent findings. Additionally, we derive Lie symmetries for geodesic metrics and general spherical spacetimes for the first time. Through a Lie group analysis, we obtain group invariant exact solutions to the Karmarkar embedding condition in all cases. Furthermore, we demonstrate that the Karmarkar condition can be used to model an embeddable relativistic radiating star with a barotropic equation of state using Lie symmetries.

Study of Dynamical Systems and Large-scale Structure

Presented by Dumiso Mithi (North-West University).

In this study, we employ dynamical systems methods to examine the behaviour of two distinct interaction models (linear and non-linear) within the dark sector, associated with a specific dynamical dark energy model inspired by Veneziano ghost theory in quantum chromodynamics (QCD). In these models, the dark energy density (ρDE) varies with the Hubble parameter (H), expressed as $\rho DE = \alpha H + \beta H2$. Additionally, this work assesses how these models agree with recent cosmic measurements particularly the luminosity distance measurement through supernova survey data, which helps explain the universe’ s accelerating expansion. The best-fit values of the cosmological parameters are calculated through Markov Chain Monte Carlo (MCMC) simulations for these cosmological models, enabling the presentation of Hubble and distance modulus magnitude diagrams for a comprehensive analysis of the accelerating universe.

A Model-independent Compact Dynamical System Formulation for Exploring Bounce and Cyclic Cosmological Evolutions in f(R) Gravity

Presented by Charlotte Louw (University of Cape Town).

Through the use of cosmographic parameters, a model-independent dynamical systems approach for studying $f(R)$ gravity models was recently established. The formulation is model-independent in the sense that one needs to specify not a particular functional form of $f(R)$ a-priori, but rather a particular cosmological evolution, which fixes the cosmography. Therefore this approach avoids the difficulties associated with usual reconstruction methods as well as providing a way to compare models to CDM qualitatively. For a generic $f(R)$, the procedures involved in both the noncompact and compact phase spaces will be shown. The applicability of this formulation will be demonstrated using examples of bouncing and cyclic cosmology. Analysis of these examples reveal the difficulty to achieve such cosmologies without positive spatial curvature. arXiv:2311.18563

Bouncing Cosmologies in the Presence of a Dirac-Born-Infeld Field

Presented by Mariam Campbell (University of Cape Town).

I will present work that has formed part of my PhD and has recently been accepted in PRD, arXiv: https://arxiv.org/abs/2405.06031. It centers around bouncing cosmologies in the presence of a Dirac-Born-Infeld (DBI) field characterised by a potential and brane tension. I will detail the dynamical systems analysis performed when considering power-law and exponential functions for the potential and brane tension. Their physical implications and the initial conditions required to achieve a bounce will also be discussed. While the initial aim of this study was to find if a DBI field would exhibit cyclical behaviour, our analysis concluded that it does not, including the case in which a negative cosmological constant is present.

A Dynamical Systems Formulation for Inhomogeneous LRS-II Spacetimes

Presented by Saikat Chakraborty (Naresuan University).

I will introduce a dynamical system formulation for inhomogeneous LRS-II spacetimes using the covariant 1+1+2 decomposition approach, that we recently proposed in 2404.01161. Our approach describes the LRS-II dynamics from the point of view of a comoving observer. Promoting the covariant radial derivatives of the covariant dynamical quantities to new dynamical variables and utilizing the commutation relation between the covariant temporal and radial derivatives, we have been able to show that it is possible to construct an autonomous system of first-order ordinary differential equations along with some purely algebraic constraints. I will talk about some interesting features in the LRS-II phase space with dust, one of them being that the homogeneous solutions constitute an invariant submanifold. For the particular case of LTB, I show that it is possible to recover some previously known results. The talk will be based on our recent work 2404.01161.

Constraining Viscous-fluid Models in $f(Q)$ Gravity Using Cosmic Measurements and Large-scale Structure Data.

Presented by Shambel Sahlu.

This paper investigates the impact of $f(Q)$ gravity models, including the effects of bulk viscosity, on the accelerating expansion and large-scale structure formation of the Universe using cosmological data. Various classes of $f(Q)$ gravity models, including power-law (f1CDM), exponential (f2CDM), and logarithmic (f3CDM) are considered. In our analysis, we incorporate 57 Hubble parameter data points (*OHD*), 1048 supernova distance modulus (*SNIa*), their combined analysis (*OHD+SNIa*), 14 growth rate (f-data), and 30 redshift-space distortions ($f\sigma_8$) datasets. We highlighted the significance of $f(Q)$ gravity models in understanding late-time cosmic history after constraining the best-fit values$\{\Omega_m, H_0\}$ and exponents $\{n, p, \gamma\}$ including the bulk viscosity coefficient ζ_0, through detailed statistical analysis. We studied linear cosmological perturbations using the 1+3 covariant formalism and computed the density contrast $\delta(z)$, growth factor $D(z)$, growth rate $f(z)$, and redshift-space distortion $f\sigma_8(z)$. Based on the Akaike Information Criterion (AIC) and Bayesian / Schwartz Information Criterion (BIC), a statistical comparison of $f(Q)$ gravity models with the ΛCDM is made. From our analysis, we note that these $f(Q)$ models have good observational support when using *OHD*, *OHD+SNIa*, *f*, and $f\sigma_8$ datasets, but they have less observational support when considering *SNIa* alone

Does the Primordial Universe Exhibit Parity Violation?

Presented by Martin Bucher (Université Paris 7/ CNRS/ University of KwaZulu-Natal).

Most models for the new physics in the Early Universe assume that parity is conserved. However, we know that parity is violated in the Electroweak Standard Model of Weinberg and Salam. While today the details of the electroweak model have been well established, the same is not true for the physics beyond the standard model at play in the early universe. I will discuss how to look for parity violation in the bispectrum of the cosmic microwave background.

Confronting the Chaplygin Gas with Data: Background and Perturbed Cosmic Dynamics

Presented by Heba Abdulrahman (University of KwaZulu-Natal).

In this paper, we undertake a unied study of background dynamics and cosmological perturbations in the presence of the Chaplygin gas. This is done by rst constraining the background cosmological parameters of dierent Chaplygin gas models with SNIa data, and then feeding these observationally constrained parameters in the analysis of cosmological perturbations. Based on the statistical criteria we followed, none of the models has a substantial observational support but we show that the so-called original “andextended/generalized” Chaplygin gas models have some observational support and less observational support, respectively, whereas the modied “andmodied generalized” Chaplygin gas models miss out on the less observational support category but cannot be ruled out. The so-called “generalized cosmic Chaplygin gas” model, on the other hand, falls under the no observational support category of the statistical criterion and can be ruled out. We follow the 1+3 covariant formalism of perturbation theory and derive the evolution equations of the fluctuations in the matter density contrast of the matter-Chaplygin gas system for the models with some or less statistical support. The solutions to these coupled systems of equations are then computed in both short-wavelength and long-wavelength modes.

On Foundations and Generalizations of General Relativity: Theory of Superfluid Vacuum and Its Applications

Presented by Konstantin Zloshchastiev (Durban University of Technology).

Within the frameworks of the logarithmic superfluid model of physical vacuum, we demonstrate the emergence of four-dimensional curved spacetime from the dynamics of quantum Bose liquid in three-dimensional Euclidean space. We derive the metric tensor of this spacetime and study its special cases and limits, such as the linear-phase flow and linearized gravity limit. We show that the value of the speed of light, which is a fundamental parameter in the theory of relativity, is a derived notion in superfluid vacuum theory: its value is a combination of the Planck constant and the original parameters of the background superfluid. As for the gravitational potential, it can be defined in terms of the quantum information entropy of the background superfluid. Thus, relativistic gravity and curved spacetime are shown to result from the dynamics of quantum excitations of the background superfluid being projected onto the measurement apparatus of a relativistic observer. If time allows, we demonstrate some applications of the formalism. For example, the logarithmic vacuum model explains the non-Keplerian behaviour of galactic rotation curves, as well as why their profiles can vary depending on the galaxy. It also makes a number of predictions about the behaviour of gravity at larger galactic and extragalactic scales, which are expected to be seen in the outer regions of large spiral galaxies. To test theory's predictions on a galactic scale, we apply the best-fitting procedures to the rotation curve data of fifteen galaxies from the HI Nearby Galaxy Survey assuming their stellar disc's parameters being fixed to the mean values obtained using photometric methods. Although the fitting results seem to be sensitive to a choice of a stellar disk model, they agree well with observational data. If time allows once again, we discuss logarithmic liquid models of cold dense stars in quantum astrophysics which are motivated by studies of laboratory quantum liquids. We demonstrate the existence of equilibrium configurations of self-gravitating logarithmic liquid minimally coupled to general relativity, described by spherically symmetric nonsingular finite-mass asymptoticallyflat solutions without event horizons. Unlike other boson star models known to date, equilibrium configurations of relativistic logarithmic fluids are shown not to have scale bounds for their gravitational mass or size. Therefore, they can describe large massive dense astronomical objects, such as bosonized superfluid stars or cores of neutron stars, whose stability against the gravitational collapse is enhanced by not only the Heisenberg uncertainty but also superfluidity.

FLRW Transit Cosmological Model in $f(R, T)$ Gravity

Presented by Siwaphiwe Jokweni (University of Zululand).

A Friedmann Lemaitre Robertson Walker space-time model with all curvatures $k = 0, \pm 1$ is explored in $f(R, T)$ gravity, where R is the Ricci scalar, and T is the trace of the energy–momentum tensor. The solutions are obtained via the parametrization of the scale factor that leads to a model transiting from a decelerated universe to an accelerating one. The physical features of the model are discussed and analyzed in detail. The study shows that $f(R, T)$ gravity can be a good alternative to the hypothetical candidates of dark energy to describe the present accelerating expansion of the universe.

New Cosmological Models in Einstein-Gauss-Bonnet Gravity

Presented by Sumeekha Singh (University of KwaZulu-Natal).

This research is devoted to Einstein-Gauss-Bonnet (EGB) gravity in spacetimes which are maximally symmetric. We extend the analysis of general relativity in Robertson-Walker spacetimes to N dimensions. We then generate the field equations in EGB gravity with higher order curvature corrections in N dimensions. The matter distribution is described by a perfect fluid in a comoving N-dimensional spacetime manifold. We then investigate exact solutions to the EGB field equations with dust and pressure. Several new classes of exact solutions are found to the field equations both explicitly and implicitly. Firstly, for dust models with flat spatial curvature, we find new results for all N. When $N = 5$ we obtain new models with no restriction on the spatial curvature. Secondly, in the case of barotropic pressure with an equation of state, a new EGB model is found when $N = 5$. We observe that the dynamics of Robertson- Walker spacetimes in EGB gravity are governed by Abel type differential equations. This is different from general relativity since the higher order curvature corrections in EGB gravity change the gravitational dynamics in the spacetime yielding new and physically relevant models, in all spacetime dimensions.

Barotropic Equations of State in 4D Einstein-Maxwell-Gauss-Bonnet Stellar Distributions

Presented by Siyamthanda Remember Mngadi (University of KwaZulu-Natal).

Although initially beset by several controversies the Glavan-Lin dimensionally regularised proposal to incorporate higher curvature effects through the Gauss-Bonnet invariants in four spacetime dimensions continues to attract attention as it is known to be viable in spherically symmetric spacetimes applicable to the study of stellar structures. In our present work, we investigate for the first time, the consequences of imposing a linear barotropic equation of state ($p = \gamma\rho$) on a charged compact isotropic perfect fluid in 4D scalar Einstein-Gauss-Bonnet theory. Even though mathematically one more choice is available after invoking the equation of state to close the system, finding exact models is nontrivial. The case of constant gravitational potentials corresponding to the defective Einstein universe as well as the isothermal fluid distribution is studied. Neither of these lead to physically interesting cases. Two proposals for the temporal potential, motivated on mathematical grounds, yield physically viable charged star models. Assuming the existence of a one-parameter group of conformal motions in the spacetime geometry, we obtain a governing equation that is solvable exactly in implicit form and explicit solutions are found for the case of a stiff fluid $p = \rho$. On the other hand, if the potential is assumed to vary linearly with the radius, an exact incoherent radiation model $p = 31\rho$ emerges. The physical properties of both these solutions is analysed comprehensively with the aid of graphical plots in conjunction with suitably defined parameter spaces.

Structure Formation with Viscous Dark Matter

Presented by Jaymie van der Merwe (Stellenbosch University).

The ΛCDM model is currently our best description of the universe. However, discrepancies between theory and observation have emerged. Bulk viscosity has been proposed as a possible extension to the CDM model to account for these mismatches. There are two popular frameworks for studying bulk viscosity in cosmological fluids. These are the Eckart and Muller-Israel-Stewart (MIS) theories of dissipative, relativistic hydrodynamics. We study the effects of bulk viscosity on the formation of large-scale structure via the evolution of the dark matter density and metric perturbations. We compare the two competing theories for dissipative hydrodynamics. We investigate changes to the hydrodynamic equations as well as the Einstein equations with the introduction of the bulk viscous pressure. We will then discuss the numerical solutions found for the growth of the dark matter perturbations. The evolution of the gravitational potential in this context is also examined. We compare our results from the two competing theories with those from the ΛCDM model as well as results in the literature from work already done in this field. Future work is also discussed.

Observational Constraints on the Interacting Dark Energy Models

Presented by Rethabile Thubisi (North-West University).

In this paper, we consider the interacting dark energy models (IDE) to study the evolution of dark energy and dark matter. We constrain the interaction between dark energy and dark matter using recent cosmic measurements from the observational H(z) parameter data (OHD) which consists of 57 points in the redshift range $0.070 < z \leqslant 2.36$, and type 1a supernovae from the pantheon sample consisting of 1048 points in the redshift $0.010 \leqslant z \leqslant 2.26$. We further compute the best fit values of parameters $(\Omega dm, H0, \xi, \omega)$ from the emcee and getdist packages. By using the SNIa data we continue to calculate the distance modulus of the considered IDE models to get the optimal luminosity distance values for the constrained parameters and compare them to the standard cosmological model. Finally, we investigate the viability of the IDE models theoretically and observationally.

Interacting Dark Energy Models

Presented by Robert Rugg (North-West University).

In this work, the two linear interactions between dark matter and dark energy is highly emphasised to explain the late time acceleration. Both models are constrained using a Markov chain Monte Carlo analysis (MCMC) using different sets of observational data. The analysis was composed using the Pantheon data set, consisting of 1048 points of SNIa distance moduli measurements from the Pantheon analysis and the Observed Hubble Parameter (OHD) data set using Baryon acoustic Oscillation (BAO), consisting of 57 data points using distance and expansion rate measurement. Both models showed promising results with the OHD data (BAO), with a interaction that results in a higher dark matter content of 56% and 44%, and a Hubble parameter of 65.7 ± 3km s-1 M pc-1 and 65.8 ± 3km s−1 M pc−1 for the interaction dependent on dark matter and dark energy respectively. The pantheon data set however predicted a reverse interaction for both models which does not follow initial assumptions that were made. The pantheon data measured a dark matter content of 18% and 20% with a Hubble parameter of $72.1 \pm 0.003 km$ s-1 M pc-1 and 72.3 ± 0.004km s-1 M pc-1 . The constrained results are used to revisit the coincidence problem and other problems in standard cosmology. The analysis provided a discrepancy between the different data sets with one having a large error margin, leaving the research incomplete and requires further investigation.