CosmoGravitas II

Monday 16 November 2026 - Friday 20 November 2026

D Varee Jomtien Beach Pattaya Hotel

Book of Abstracts

Book of abstract

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Contributory: Dynamical analysis of Bianchi type-IX cosmology with a scalar field mediated dark sector interaction

Authors: Ashmita .[1]; Daris Samart[None]; Jaturaporn Watanakampolkij[None]

[1] *Khon Kaen University*

The recent DESI DR2 preference for a time-varying dark-energy equation of state, together with the long-standing difficulty of explaining why an initially anisotropic universe should evolve toward isotropy, motivates the study of interacting dark-sector models in anisotropic backgrounds. We investigate the dynamics of Bianchi type-IX cosmologies containing pressureless dark matter coupled to dark energy in the form of a quintessence scalar field ϕ with exponential potential $V(\phi) = V_0\, e^{-\lambda\phi}$. Energy exchange between the two dark components is mediated by the scalar field through the interaction term $Q = \kappa\beta\dot{\phi}\,\rho_{\rm DM}$, where $\kappa^2 = 8\pi G$ and β is a dimensionless coupling. Because Bianchi-IX models generically recollapse, the Hubble scalar H vanishes at the moment of maximum expansion, where the expansion-normalized variables of the standard Wainwright-Ellis formalism diverge. We therefore adopt the D-normalized phase-space formalism of Hewitt, Uggla, and Wainwright, which compactifies the state space and remains regular through the recollapse, including the moment of maximum expansion at which $H = 0$. Together with the modified conservation equations for the two dark components, the Einstein Klein Gordon system reduces to a closed autonomous polynomial dynamical system, whose fixed points we classify by linear stability analysis, supplemented by center-manifold theory for the non-hyperbolic points. The fixed points shows the kinetic-dominated, coupling modified matter dominated, curvature scalar, scalar field dominated and coupled scaling families; the last is the anisotropic analogue of the Amendola scaling attractor. Restricting to the initially expanding, isotropizing trajectories, we map the region of the (λ, β) plane in which anisotropic Bianchi-IX models approach an accelerating Friedmann Robertson Walker state.

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Flash talk: Chaotic scattering in binary black hole systems

Authors: Sampurna Bhar[1]; Subhodeep Sarkar[None]

[1] *Indian Institute of Technology, Madras*

When we consider the the case of chaotic scattering in a region described by a potential or a massive object, we see that the behavior of particle trajectories are heavily dependent on initial conditions, which eventually decide whether particles stay in the scattering region or exit it through different exits. Initially, the H\'enon-Heiles potential is taken as a model to study these trajectories, where we can find that a scaling relation exists between the fraction of particles trapped in the potential as function of relativistic parameter β, when each of these particles are projected with a different set of initial conditions. We then try to investigate if similar scaling relations could be found for null geodesics propagating around a binary black hole system described by the Majumder-Papapetrou (MP) binary black hole solution. Our study can thus be able to demonstrate the use of nonlinear dynamics to find such an example of the existence of scaling laws in gravitational systems.

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Contributory: f(R) gravity scalarons near black hole horizon

Authors: Pranjali Bhattacharjee[1]; Sanjeev Kalita[1]; Debojit Paul[1]; Rajibul Shaikh[2]

[1] *Gauhati University*

[2] *Indian Statistical Institute*

The Galactic Center (GC) black hole Sgr A* gives us an opportunity to perform horizon scale tests of black hole physics and deviations from General Relativity, thanks to observations carried out by the Event Horizon Telescope (EHT). In this work we study the impact of the scalar degree of freedom (scalaron) of f(R) gravity theory on the size and shape of GC black hole by using a recently developed stationary, axisymmetric and vacuum metric of f(R) theory. We encounter a minimum bound of 10^{-17} eV for the scalaron mass using 1σ upper bound on the deviation parameter produced by EHT-Keck and EHT-VLT measurements. Lighter scalarons increase the shadow size beyond that measured by the EHT. The displacement and asymmetry in the shape of the black hole shadow are employed to test the no-hair theorem and it is observed that 10^{-16} eV scalarons yield the exact Kerr like shadow and a 6% departure from the Kerr quadrupole. We infer preservation of the no-hair theorem for such scalaron mass and further examine the possibility of violation of the theorem. The same mass scale reproduces the PPN parameter γ constrained in the weak field limit of the solar system. This is for the first time we report a convergence of horizon scale test and solar system test of f(R) gravity by using the scalaron mass. The prospect of constraining the scalaron mass using gravitational waves is an exciting avenue to be highlighted.

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Contributory: A unified framework to study f-family of modified gravity theories

Authors: Saikat Chakraborty[1]; Christian Boehmer[2]

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[2] *University College London*

I will introduce a neat mathematical framework that can be utilized to study, in a unified manner, different aspects of $f(R), f(T), f(G)$ or $f(Q)$ gravity. As an example of the application of this framework, I will show it's applicability for a comparative analysis between $f(R)$ gravity and the trivial FLRW connection branch of $f(Q)$ gravity, with respect to the two following questions: (1) provide a purely cosmographic measure on the deviation from GR based on the current data and (2) the behaviour of the underlying theory (more precisely, of it's deviation from GR) given a certain cosmological evolution. Time permitting, I will briefly introduce the direction of a further interesting application of this framework.

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Contributory: JWST-informed Cosmological Inference from 21-cm Tomography

Author: Madhurima Choudhury[1]

[1] *Birla Institute of Technology and Science, Pilani - Hyderabad campus.*

The redshifted 21-cm line of neutral hydrogen provides a unique probe of the high-redshift Universe, tracing the evolving state of the intergalactic medium (IGM) during the Epoch of Reionization (EoR). The 21-cm signal, however, depends on both the underlying cosmological density field and the astrophysical properties of the sources driving reionization, leading to potentially strong degeneracies between cosmological and astrophysical parameters. This degeneracy presents a fundamental challenge for extracting robust cosmological information from 21-cm observations alone. Observations of high-redshift galaxies with the James Webb Space Telescope (JWST) provide complementary information on the population of sources responsible for ionizing the IGM. In this work, we investigate a JWST-informed framework for extracting cosmological information from 21-cm tomography. We

construct simulated EoR lightcones spanning a joint parameter space of cosmological and astrophysical parameters and generate corresponding galaxy observables, including UV luminosity functions, together with the 21-cm signal. We first use the JWST-like galaxy observables to constrain the properties of the underlying galaxy population and use these constraints as informative priors on the astrophysical parameters entering the 21-cm forward model. We then employ machine-learning-based inference to recover cosmological parameters from the 21-cm field while marginalizing over the remaining astrophysical uncertainties. By comparing 21-cm-only and JWST-informed inference, we quantify how external information on the high-redshift galaxy population changes the cosmological posterior and the associated astrophysics–cosmology degeneracies.

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Contributory: The Ringdown and the Tide: Fingerprints of Dark Matter Halo Profiles

Author: Avijit Chowdhury[1]

[1] *Indian Institute of Astrophysics*

Astrophysical black holes are expected to reside in environments enriched by dark matter, raising the possibility that environmental effects may leave observable imprints on gravitational-wave signals. We investigate how the structure of a surrounding dark-matter halo modifies both the ringdown and tidal response of a static, spherically symmetric black hole. The halo is modelled using a generalized (α, β, γ) density profile within the Einstein cluster framework. We compute the quasinormal mode spectrum and static axial tidal Love numbers, and examine their dependence on the halo compactness and density profile. We show that the halo induces a characteristic redshift of the quasinormal frequencies and damping rates, with the strongest influence arising from the inner halo structure. Time-domain evolutions confirm the frequency-domain results and exhibit late-time tails whose behaviour is governed by the outer density profile. We further demonstrate that the tidal Love number probes the halo through a different radial weighting than the ringdown spectrum, making the two observables complementary. Our results suggest that combining ringdown and tidal measurements can help constrain the spatial distribution of dark matter around black holes and distinguish environmental effects from genuine deviations of the vacuum black-hole geometry.

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Flash talk: Beyond ΛCDM: Probing Structure Growth and Observational Viability of Generalized f (Q, Lm) Gravity

Author: RAJ KUMAR DAS[1]

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$f(Q, \mathcal{L}_m)$ gravity is a well-known extension of $f(Q)$ gravity, obtained through non-minimal or additive minimal coupling in the action's Lagrangian density. Existing literature within the framework of $f(Q, \mathcal{L}_m)$ has explored the cosmographic scenario through various approaches, including background-level analyses and comparisons with ΛCDM (Myrzakulov et al., Phys.\ Lett.\ B 139506, 2025; Hazarika et al., Physics of the Dark Universe 50, 102092, 2025). In this work, we investigate the additive minimal coupling in a generalized power-law form, $f(Q, \mathcal{L}_m) = -Q^{\mu} + \alpha \mathcal{L}_m^{\nu} + \beta$, where μ, ν, α, and β are the extra degrees of freedom introduced by the model. We derive the key cosmological evolution equation, the Hubble function $H(z)$, by adopting a suitable novel parametrization. A distinctive feature of this theoretical framework is the non-conservation of the matter sector (a non-conserved continuity equation), which we highlight and study under the condition $\nu \neq 1$; this non-conservation is significant, as it effectively mimics a particle creation scenario. We constrain the model's free and extra parameters, and examine their effects on the cosmographic scenario, using Observational Hubble Data (OHD), Baryon Acoustic Oscillation (BAO) measurements from DESI

DR2, and three Type Ia Supernovae (SNe Ia) catalogs (Pantheon+, Union3, and the Dark Energy Survey). Since our framework inherently involves non-conservation, we extend the analysis beyond the background level to the perturbative regime, deriving the perturbed field equations of $f(Q, \mathcal{L}_m)$ together with the perturbed Euler and continuity equations, and study the growth of structure and the impact of the non-conservation term on the growth equation, further performing a joint observational analysis incorporating the $f\sigma_8$ probe. To statistically assess our results, we performed a Bayesian evidence analysis, treating ΛCDM as the reference model; based on this analysis, our non-conservative model shows a statistical edge over ΛCDM in several cases, depending on the dataset combination used. These results position non-conservative $f(Q, \mathcal{L}_m)$ gravity as a physically motivated and observationally testable alternative to ΛCDM, rooted in an effective particle-creation mechanism.

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Contributory: From CPL to Canonical Fields: Constraining Quintessence with the Tomographic AP Test

Authors: Zahra Davari[1]; Changbom Park[None]; Kin-Wang Ng[2]

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The nature of dark energy remains one of the central open questions in cosmology. While observational analyses commonly constrain phenomenological equation-of-state parametrizations such as the Chevallier–Polarski–Linder (CPL) model, theoretical interpretations require translating these constraints into physically motivated scalar-field models.

We present a computational framework that directly maps observational likelihoods in the (Ω_m, w_0, w_a) parameter space onto the parameter spaces of canonical quintessence potentials without recomputing the full observational likelihood. The method employs likelihood-guided mapping based on the tomographic Alcock–Paczyński test combined with Type Ia supernova and baryon acoustic oscillation observations. For each potential, we solve the scalar-field background evolution numerically and determine an effective CPL representation over the observed redshift range, allowing observational constraints to be projected efficiently onto the underlying theoretical parameters.

We apply this approach to exponential, pseudo–Nambu–Goldstone boson (PNGB), and inverse power-law (IPL) quintessence models. The resulting constraints reveal that viable scalar-field models occupy only a narrow region of the effective CPL parameter space, considerably smaller than the full phenomenological CPL posterior. This demonstrates how theoretical consistency substantially reduces the allowed dark-energy parameter space and provides a practical route for confronting fundamental dark-energy models with current and future cosmological observations.

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Flash talk: A Potential Black Hole Mimicker From Curvature-Matter Coupled Theory of Gravity

Authors: Debanjan Debnath[1]; Rikpratik Sengupta[1]; Kaushik Bhattacharya[1]

[1] *Indian Institute of Technology Kanpur*

I wish to give a presentation, in which I will talk about a class of horizonless, regular ultra-compact objects which may arise in a theory of gravity where fluid variables may couple to the curvature scalar of the spacetime. This kind of non-minimal interaction between fluid variables and the Ricci scalar generates a vacuum-like equation of state in the interior, while the exterior remains exactly Schwarzschild. The interior and exterior spacetimes are glued through a infinitesimally thin-shell

at the boundary of the spacetimes. The interior metric is regular everywhere and the shell has given a stiff-matter equation of state, and near-horizon compactness can potentially mimic black-hole phenomenology without a event horizon. Unlike the Mazur-Mottola gravastar and its variants, the present model predicts a typical ultra-compact mass-radius window, with masses in the range $1.4 - 2.1 M_\odot$ and radii in the range $5 - 7$ km. In addition, this framework also predicts a unique geometric-thermodynamic shell temperature in the ultra-compact limit distinctly different from the Hawking temperature.

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Flash Talk: Fermion condensate at the event horizon

Author: Vladimir Dzhunushaliev[1]

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Some arguments are considered in favor of the idea that the canonical anticommutation relations for fermions should be modified in curved spacetime near the event horizon of a black hole. Such a modification is expected to lead to a change in the source term of the inhomogeneous Dirac equation describing the two-point Green's function. By introducing an {\it ad hoc} source into the Dirac equation that mimics the modification of these anticommutation relations, stationary solutions are obtained and interpreted as two-point Green's functions of fermions located near the event horizon. Owing to their stationarity, these Green's functions describe a fermion condensate near the event horizon.

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Flash Talk: Observational constraints on Fractional Holographic Dark Energy in $f(T)$ gravity

Author: Chingkheinganba Meetei Elangbam[1]

Co-authors: Samaddar Amit [2]; Surendra Singh S. [2]

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We explore the cosmological implications of Fractional Holographic Dark Energy within the context of $f(T) = \beta(-T)^n$ gravity, in which the Hubble parameter is determined implicitly. The model incorporates fractional corrections through a generalized entropy-area relation, allowing for the inclusion of nonlocal effects in the dark energy sector. The model parameters are optimized using Hubble parameter measurements, DES supernova data 5 year, and BAO observations for DESI DR2 via a MCMC analysis. Our results show that the model remains consistent with current observational data and provides a viable cosmological scenario. The dynamical analysis indicates that the model maintains a positive energy density and a negative pressure throughout the cosmic evolution, ensuring physical consistency. The equation of state parameters exhibit a quintessence-like behavior at the present epoch and gradually evolve toward a cosmological constant-like phase at late times. The deceleration parameter confirms a transition from deceleration to acceleration at a redshift $z_t \approx 0.78$. Furthermore, the statefinder diagnostic reveals noticeable deviations from the ΛCDM model at intermediate redshifts, while approaching the standard fixed point $\{r, s\} = \{1, 0\}$ in the asymptotic future. The estimated age of the Universe is also found to be consistent with observational constraints. Overall, the FHDE model within $f(T)$ gravity provides a physically consistent and observationally viable description of late-time cosmic acceleration, and may serve as a promising alternative to the standard ΛCDM paradigm.

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Contributory: Homothetic Killing Horizons in Vaidya and Kerr–Vaidya Black Holes

Authors: Ritwika Ghoshal[1]; Nilay Kundu[2]; Srijit Bhattacharjee[3]

[1] *Indian Institute of Technology Kanpur*

[2] *IIT Kanpur*

[3] *IIIT Allahabad*

I would like to give a presentation in which I will discuss the existence and physical implications of homothetic Killing vectors (HKVs) in a broad class of dynamical Vaidya spacetimes, including generalized spherically symmetric Husain-type solutions and rotating Kerr–Vaidya geometries. By solving the conformal Killing equations, it can be demonstrated that these spacetimes admit a unique class of HKVs only when the dynamical parameters, namely the mass, charge, and rotation parameter, evolve linearly with the advanced null coordinate. For Kerr–Vaidya spacetimes, the existence of an HKV requires both the mass and angular momentum to be dynamical and satisfy a definite relation between their rates of evolution. The null hypersurface where the HKV becomes null defines a homothetic Killing horizon (HKH), providing a natural generalization of the Killing horizon for nonstationary black holes. The presence of an HKV allows the original dynamical spacetime to be conformally mapped to a stationary spacetime, thereby enabling the application of standard geometric methods associated with Killing horizons. Using this framework, we analyse the geometric and thermodynamic properties of HKHs by evaluating different notions of surface gravity and identifying the conformally invariant surface gravity relevant for dynamical black-hole thermodynamics. Finally, a maximal analytic extension of a self-similar charged Vaidya spacetime is constructed the HKH framework provides a suitable setting for investigating the particle creation by Hawking radiation in dynamical backgrounds. These results establish homothetic symmetry as a powerful organizing principle for understanding horizon geometry, thermodynamics, and quantum phenomena in a wide class of nonstationary black-hole spacetimes.

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Contributory: Background and Perturbation Constraints on Spinor Field Dark Energy from Recent Cosmological Observations

Authors: Mahendra Goray[1]; Bijan Saha[2]

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We investigate a nonlinear self-interacting spinor field as a dynamical dark-energy candidate capable of driving the late-time accelerated expansion of the Universe. The model is formulated within a spatially flat Friedmann–Lemaître–Robertson–Walker framework, where the spinor field is minimally coupled to gravity and generates an effective dark-energy equation of state through its self-interaction potential. We study both the background and perturbation dynamics of the model, deriving the evolution of the Hubble parameter (H(z)), equation-of-state parameter (w(z)), deceleration parameter (q(z)), and the growth of matter density perturbations. The background parameters are constrained through a Markov Chain Monte Carlo (MCMC) analysis using recent observational datasets, including cosmic chronometers, Pantheon supernovae, and baryon acoustic oscillation measurements. To assess the impact on structure formation, we implement the model at the perturbation level and examine its predictions for the growth rate ($f\sigma_8$(z)), matter power spectrum, and the evolution of density fluctuations. We find that the spinor dark-energy scenario successfully reproduces the observed expansion history while remaining compatible with current large-scale structure measurements. The effective equation of state evolves dynamically and approaches the cosmological-constant limit at late times, while allowing mild deviations at intermediate redshifts. Statistical model comparison shows that the spinor-field framework provides a viable and competitive alternative to the standard ΛCDM cosmology, motivating further investigation with forthcoming high-precision surveys such as DESI, Euclid, and Rubin Observatory.

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Contributory: Model-Independent Evidence for a Localized Anomaly in the Late-Time Expansion History

Authors: Shibendu Gupta Choudhury[1]; Purba Mukherjee[2]; Eleonora Di Valentino[3]; Anjan A. Sen[4]

[1] *Indian Institute of Astrophysics*

[2] *Korea Astronomy and Space Science Institute*

[3] *University of Sheffield*

[4] *Jamia Millia Islamia*

In this talk, I present a model-independent spline reconstruction of cosmological distances using latest low-redshift datasets to investigate the late-time expansion history of the Universe. Comparing the reconstructed expansion history with the prediction of the Planck ΛCDM model, I demonstrate a localized deviation over a certain redshift interval which reaches a maximum significance of approximately 3.5σ near $z = 0.47$. I further demonstrate that this feature persists under substantial variations of the reconstruction methodology, dataset composition and sound-horizon calibration. I argue using mock analyses that the reconstruction is unbiased and that the observed anomaly is unlikely to arise from reconstruction bias or miscalibrated uncertainties. If confirmed by future observations, this localized feature could point to previously unrecognized late-time physics or reveal subtle inconsistencies between early and late Universe cosmological probes.

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Contributory: Aspects of Spontaneous Symmetry Breaking in Cosmology

Authors: Malavika K[1]; Soumya Chakrabarti[2]

[1] *Vellore Institute of Technology*

[2] *Vellore Institute of Technology, Vellore*

We explore if a late-time cosmic acceleration and a mild variation of fundamental constants can be accommodated within a common scalar-tensor framework. The fundamental constants we focus on are the Newtonian gravitational coupling G and the electron mass m_e. The scalar-tensor framework under consideration is a generalized Brans-Dicke theory with an additional matter field. The viability of this framework is explored in the context of well-established late-time cosmic expansion history, namely, a standard ΛCDM expansion and an extended ΛCDM expansion (where a rational (Pad\'e-like) deformation is considered). We reconstruct and show that the resulting effective potential of the matter field naturally develops a Higgs-like symmetry-breaking structure with a redshift-dependent mass term, leading to a mild evolution of the vacuum expectation value. This variation leads to an evolution of proton-to-electron mass ratio μ which is compared with observational bounds derived from quasar absorption spectra. We find that in order to accommodate a reasonably mild variation of μ, the Brans-Dicke scalar field must behave as a chameleon.

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Contributory: Breaking the Taylor Barrier in Cosmology

Author: SAI SWAGAT MISHRA[1]

[1] *BITS PILANI, Hyderabad Campus*

We present a unified analysis of the late-time cosmic expansion by bridging model-independent cosmography with modified gravity, using the latest DESI DR2 BAO data. A comparative study of Taylor, Padé, and Chebyshev expansions shows that while Taylor breaks down beyond low redshift, Padé approximants, especially (2,1), deliver stable, high-redshift reconstructions and are strongly preferred by information criteria, closely tracking LCDM. Leveraging this, we embed the Padé (2,1) framework within f(T) gravity and contrast it with direct dynamical solutions of the modified Friedmann equations. A comprehensive MCMC analysis with DESI DR2 and complementary probes reveals remarkable agreement between the two approaches, with both outperforming LCDM. Our results establish Padé cosmography as a powerful and reliable interface between data-driven reconstruction and fundamental gravity.

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Contributory: Classical Eikonal for Binary Black Hole Scattering in Dark Matter Backgrounds

Author: Arpita Mitra[1]

[1] *CTP NAS, Mahidol University, Nakhon Sawan campus*

Despite significant advances in post-Minkowskian gravity, scattering-amplitude methods, and gravitational-wave modeling, existing frameworks largely assume vacuum binary dynamics and do not systematically incorporate coherent environmental effects. We develop a unified Hamiltonian framework for compact binaries embedded in coherent ultralight dark matter, combining post-Minkowskian gravity with Hamiltonian deformation theory, the classical interaction picture, and the Magnus expansion. The resulting eikonal captures dark matter–induced corrections to gravitational-wave observables, providing a systematic framework and potential avenue for probing ultralight dark matter with gravitational-wave observations.

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Flash Talk: Geometry and Stability of Wormholes in Symmetric Teleparallel Gravity with Dark Energy and Rotation Profiles

Authors: Jitendra Kumar[1]; Sourav NA[1]; Sunil Kumar Maurya[2]

[1] *Central University of Haryana*

[2] *University of Nizwa*

This work investigates wormhole geometries in the framework of symmetric teleparallel (f($\mathcal{Q}$)) gravity by incorporating holographic and mixed dark energy density profiles. Exact wormhole solutions are obtained using rotational velocity profiles to construct the redshift function and dark energy density profiles to determine the shape function. For suitable parameter choices, the solutions satisfy the flare-out condition and exhibit asymptotically well-behaved geometries. We further analyze the energy conditions, with particular emphasis on the null energy condition (NEC) at the wormhole throat, and demonstrate that the coupling parameter (γ) plays a significant role in governing NEC violation. In addition, the physical properties of the obtained wormholes are explored through the complexity factor, anisotropy, exoticity, and embedding diagrams, highlighting the viability of these solutions in modified gravity.

1

Contributory: Can Gravity Take Us Beyond the Standard Picture of the Universe? Cosmology in Extended Proca-Nuevo Gravity

Authors: Avik De[1]; Kavya Nagarakodige Shashikantha[1]; Tee-How Loo[1]

[1] *Universiti Malaya*

The success of the ΛCDM model is tempered by unresolved questions surrounding the nature of dark energy and the cosmological constant. These challenges motivate the exploration of modified theories of gravity as viable alternatives to General Relativity. In this talk, I present the Extended Proca-Nuevo (EPN) framework, a ghost-free vector–tensor theory in which a massive spin-1 field drives the late-time evolution of the Universe. I will discuss the background cosmology and its implications for possible aspects of alleviating cosmological tensions. I will highlight recent observational constraints from current cosmological datasets, demonstrating the potential of the EPN framework as a promising candidate for cosmology beyond the standard model.

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Contributory: Nature of the dark matter distribution near the Galactic Center black hole: Insights from stellar orbital precession

Author: Debojit Paul[1]

Co-author: Sanjeev Kalita [1]

[1] *Department of Physics, Gauhati University*

Abstract:
The stellar orbits near the Galactic Center black hole provide a unique probe for understanding the nature of mass distribution as well as carrying out tests of gravity. Inferring the nature of mass distribution in the region is crucial for understanding the formation history of the black hole and how it interacts with its environment. In this work we consider several viable dark matter models and constrain the parameters of the models which are consistent with the latest bound on dark mass near the Galactic Center. The pericenter shift of stellar orbits in presence of such mass distributions are worked out. We compare the dark matter precession with general relativistic precession and identify regions where dark matter induced effects might be dominant. We consider 13 S-stars that have passed or expected to pass their pericenter within the next decade. The prospect of detection of the dark matter effects in these stellar orbits through existing and upcoming large telescopes have been explored. In the orbit of S2, the effect of the different dark matter profiles along with some modified gravity models is investigated. It is seen that the orbit of S2 is insensitive to dark matter distribution but provides a good probe for testing modified gravity theories. Additionally, other stellar orbits with low eccentricity and large semi-major axis are found to be prominent probes for distinguishing different dark matter distributions. We identify five S-star orbits that can be used to distinguish between these mass profiles using observational facilities like Keck, Very Large Telescope and upcoming Thirty Meter Telescope.

References:

1. Paul D., Kalita S., 2026, MNRAS, 547, 2
2. GRAVITY Collaboration et al., 2024, A&A, 692, A242

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Contributory: Inflationary trispectrum of gauge fields from scalar and tensor exchanges

Authors: Jishnu Sai Puthiyedath[1]; Rajeev Kumar Jain[2]; Haridev S. R [None]

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[2] *Indian Institute of Science*

In this paper, we compute the inflationary trispectrum of primordial gauge fields generated through the scalar and tensor exchanges in models with spectator U(1) gauge fields which are kinetically coupled to the inflaton. Focusing on the connected four-point autocorrelation function of gauge fields, we derive exact analytical expressions for the full trispectrum of both electric and magnetic fields using the in-in formalism and cosmological diagrammatic rules, and explore their respective contributions in specific momentum configurations. For the scalar exchange, we find that the trispectrum signal in the equisided configuration grows with the exchange momentum and reaches its maximum in the flattened limit. However, in the counter collinear limit, we show that the non-linearity parameter associated with the trispectrum scales quadratically with the corresponding parameter of the cross-correlation bispectrum of magnetic fields and curvature perturbations, thereby establishing a hierarchical relation between the higher- and lower-order correlation functions. For the tensor exchange, the trispectrum displays a richer angular dependence, reflecting the sensitivity to the orientation of the momentum quadrilateral with respect to the tensor polarisation, producing characteristic angular modulations in the trispectrum. Detecting such angular signatures in future high-precision cosmological observations would provide a novel window into tensor-mediated interactions in the early universe.

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Flash talk: Late-Time Dynamics in Accelerating Nonlinear f (T) Gravity via Hybrid Scale Factor : Bayesian Analysis and Cosmological implications

Author: Pratik P. Ray[1]

[1] *Vellore Institute of Technology-AP University*

This study offers a comprehensive reconstruction of modified Teleparallel (f(T)) gravity model with three distinct non-linear as well as novel forms employing a hybrid scale factor to depict the expansion history of the universe. We investigate a physically motivated cosmological parametrization through this hybrid scale factor that can explain a smooth transition from an early decelerated epoch to the present accelerated evolution. This scale factor is then used to derive the corresponding model parameters. These parameters are rigorously constrained using the Monte Carlo Markov Chain (MCMC) analysis with the help of Bayesian statistics and incorporating late-time observations from Hubble, Baryon Acoustic Oscillations (BAO) and Patheon+SH0ES datasets. The investigation of dynamical parameters such as the equation of state parameter and cosmological parameters indicates alignment with an accelerated expansion phase in both the present and late time epochs. Validation is conducted by assessing the energy conditions, verifying the feasibility of the model forms with particular emphasis on the violation of the strong energy condition that indicates dark energy dominance in modified gravity scenarios. This investigation has been instrumental in determining models that remain consistent with cosmological observations and theoretical requirements. The reconstructed forms of the model effectively mimic ΛCDM at late times, providing significant insights into possible extensions of general relativity and bolstering f(T) gravity theory as a robust explanation for cosmic acceleration.

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Flash talk: Phantom divide crossing with interacting scalar fields

Authors: Akshara S B[1]; SOUMYA CHAKRABARTI[1]

[1] *VELLORE INSTITUTE OF TECHNOLOGY, VELLORE*

The accelerated expansion of the Universe poses a serious challenge to our understanding about the dark sector, motivating the investigation of dark matter and dark energy within a unified framework. In this work, we deal with the analysis of two-interacting scalar field model inspired by the hybrid inflation potential. We initially perform the cosmographic reconstruction of the Hubble parameter utilising a modified parametrisation which is constrained by the Bayesian Markov Chain Monte Carlo (MCMC) method. The cosmographic parameters are estimated using the Observational Hubble Data, Baryon Acoustic Oscillation, Type Ia Supernovae, Cosmic Microwave Background, Cosmic Chronometers and Dark Energy Spectroscopic Instrument data. The reconstructed Hubble parameter is used as an input to numerically solve the coupled scalar field equations, analysing the evolution of the interacting scalar fields. The reconstructed scalar field dynamics are then utilised to explore the dark energy equation of state. Further, the evolution of deceleration, jerk and snap parameters are also studied to understand the cosmological aspects of the model. This work demonstrates a cosmographic approach in connecting the observational constraints with interacting scalar field dynamics, paving a way for understanding the unified dark energy models.

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Contributory: Testing Sub-Horizon Approximations in Interacting Dark-Sector Cosmology

Author: Priyanka Saha[1]

[1] *IIT kanpur*

Sub-horizon and quasi-static approximations are widely employed in cosmological simulations to efficiently model the evolution of perturbations in theories beyond ΛCDM. However, their validity can depend on the underlying dark-sector physics and the scales being considered. In this work, we investigate these approximations in an interacting scalar-field dark-sector model, where dark matter and dark energy are coupled. We derive the full linear perturbation equations and obtain their sub-horizon and quasi-static limits, allowing a direct comparison between the approximate and full dynamics. We study the resulting evolution of matter perturbations and compare the interacting model with ΛCDM and a non-interacting scalar-field scenario. This provides a systematic assessment of when the approximations accurately capture the underlying perturbation dynamics and how dark-sector interactions can modify their validity. Our results are relevant for interpreting and improving the treatment of interacting dark-sector models in cosmological simulations and large-scale-structure studies.

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Phantom-Divide Crossing: Geometry and Stability

Author: Prasanta Sahoo[1]

[1] *Midnapore College*

Phantom-divide crossing is examined in single-clock cosmology through phase-space geometry and scalar perturbative stability. For a locally unique autonomous flow, tangency everywhere on the regular divide \(w_{\mathrm{DE}}=-1\) makes it invariant, preventing finite-time crossing, whereas

transversal evolution yields local crossing. Supplementary effective-field-theory and k-essence calculations illustrate the distinction between this geometric obstruction, and ghost and gradient stability conditions. Dynamically allowed crossing alone therefore does not establish a physically viable dark-energy model.

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Flash talk: Dark Energy and Black Holes

Author: Bisweswar Sen[None]

Co-author: Nandan Roy

We study aspects of black-hole spacetimes in the presence of dark-energy components, focusing on how the equation of state and associated curvature diagnostics constrain physically distinct regimes. Starting from the Schwarzschild geometry, we derive the Kretschmann scalar as a coordinate-invariant measure of curvature and use it to characterize the behavior near the horizon and at the central singularity. We then discuss how dark-energy motivated modifications can be incorporated and how they affect invariant quantities and horizon structure. Our results provide a compact set of analytic expressions and checks that are useful for comparing different dark-energy/black-hole models.

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Contributory: Non-Trivial Cosmology from Fractal Spacetime, Memory Effects, and Modified Gravity

Author: Aarav Shah[None]

The success of the ΛCDM model and General Relativity has established the standard paradigm of modern cosmology, yet the fundamental nature of spacetime remains an open question. This talk explores three complementary directions for extending the geometric foundations of modern cosmology. I first consider inflation in a fractal spacetime, where non-integer spatial dimensions modify the inflationary dynamics and the Mukhanov–Sasaki equation through an effective momentum $k_{\rm eff}$, leading to corrections in the scalar power spectrum and spectral index n_s. Confronting the Starobinsky model with Planck 2018 observations constrains the effective dimension to the range $D \approx [2.7, 3]$, while fractal corrections render Natural Inflation phenomenologically viable with sub-Planckian axion decay constants. I then extend the semiclassical Wheeler-DeWitt framework by incorporating a causal non-Markovian memory, leading to an effective non-integer temporal dimension that introduces an additional contribution to the primordial power spectrum with a $k^{3/4}$ scaling, enhancing high-ℓ CMB temperature anisotropies and producing scale-dependent modifications of primordial non-Gaussianity. Finally, I present a De Donder-Weyl formulation of Einstein-Cartan cosmology, where torsion generalizes the underlying spacetime geometry, yielding torsion-modified Friedmann equations and demonstrating the limitations of conventional power-law cosmological solutions. Together, these studies investigate the cosmological consequences of extending spacetime through non-integer spatial and temporal dimensions and torsion, providing new perspectives on physics beyond the standard cosmological paradigm.

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Flash Talk: Probing Energy Flow in the Dark Sector with DESI DR2

Author: Vipin Kumar Sharma[1]

[1] *Universty of Punjab, Lovely Professional University*

We investigate the possibility of energy exchange in the dark sector for interacting dark energy models, using the latest DESI DR2 baryon acoustic oscillation measurements. Our finding suggest that current observations do not provide significant evidence for dark sector interactions, but they allow the possibility of a weak energy flow that can be further tested with future high-precision cosmological surveys.

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Flash Talk: Modified Chaplygin gas with recent observations in f(Q,B) gravity

Author: Dr. Sanasam Surendra Singh[1]

[1] *NIT MANIPUR*

In this work, we explore the cosmological dynamics of a modified gravity framework based on the function $f(Q, B) = \delta Q^2 + \beta B$, where Q denotes the nonmetricity scalar and B is the boundary term that relates Q to the Ricci scalar. The matter sector is modeled using the Modified Chaplygin Gas (MCG) with the equation of state $p = A\rho - \frac{D_1}{\rho^\alpha}$, allowing the model to interpolate between early-time matter behavior and late-time cosmic acceleration. By deriving an analytical expression for the Hubble parameter $H(z)$, we perform a parameter estimation using Markov Chain Monte Carlo (MCMC) techniques in conjunction with the latest cosmological observations: 46 Hubble parameter measurements, 15 BAO data points, DESI DR2 BAO data and the Pantheon+ Type Ia supernovae compilation. The best-fit values are obtained as $H_0 = 72.2814^{+3.4702}_{-4.5209}$ km/s/Mpc, $A_s = 0.6964^{+0.0779}_{-0.1258}$, $\alpha = 0.0027^{+0.0225}_{-0.0209}$ and $A = 0.0024^{+0.0702}_{-0.0464}$. The deceleration parameter transitions at redshift $z_{tr} \approx 0.946$, while the present-day value is $q_0 = -0.789$. The model yields an age of the Universe $t_0 \approx 13.53$ Gyr and a present EoS parameter $\omega_0 \approx -0.691$, which reflects the late-time acceleration consistent with observational bounds. These results demonstrate that the MCG scenario within $f(Q, B)$ gravity provides a viable and observationally consistent framework for explaining the late-time accelerated expansion of the Universe.

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Flash Talk: Kuchowicz gravastars in Horava gravity and Einstein-aether theory

Authors: Meghanil Sinha[1]; S. Surendra Singh[1]

[1] *National Institute of Technology Manipur*

This work introduces a new gravastar model inspired by the Mazur-Mottola framework within Lorentz-violating gravity, specifically Hořava gravity and Einstein-aether theory with the help of Kuchowicz metric function. The proposed gravastar consists of three distinct regions: a de Sitter-like core, a thin shell filled with ultra-relativistic matter, and an exterior vacuum spacetime. Exact solutions obtained for each region demonstrate the consistency and viability of the model. A detailed investigation of the shell's physical properties, along with the other conditions confirms its stability and physical plausibility. The resulting gravastar solutions are free from singularities and event horizons, offering a compelling alternative to the conventional black hole paradigm in Lorentz-violating gravity theories.

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Contributory: Quintom dark energy: Future attractor and phantom crossing in light of DESI DR2 observations

Author: Phusuda Thanankullaphong[1]

[1] *Centre for Theoretical Physics and Natural Philosophy, Mahidol University*

We study the late-time cosmological dynamics of a two-field dark-energy model consisting of a canonical quintessence scalar field and a phantom scalar field in a spatially flat Friedmann-Lemaître-Robertson-Walker universe. The fields are minimally coupled to gravity and uncoupled at the level of the potential, with the quintessence sector governed by an exponential potential and the phantom sector by an inverse power-law potential. By reformulating the background equations as a five-dimensional autonomous dynamical system, we identify and analyze the fixed points and their stability properties, revealing stable late-time attractors corresponding to phantom-dominated accelerated expansion. We confront the model with observations through a Bayesian parameter estimation performed using the cobaya framework, employing several combinations of recent cosmological datasets, including Pantheon+ supernovae, compressed cosmic microwave background distance priors, DESI DR2 baryon acoustic oscillation measurements, and DES year-5 supernova data. The observational constraints favor a dynamical dark-energy sector moderately and are consistent with deviations from a cosmological constant at the present epoch. The regions of parameter space preferred by the data are compatible with the stable accelerating solutions identified in the dynamical analysis, establishing a direct connection between phase-space stability and observational viability. A notable feature of the model is that the effective dark-energy equation of state undergoes phantom divide crossing in a gradual and asymptotic manner, rather than as a sharp transition.

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Flash Talk: Kaluza-Klein inspired a model of inflation with the inverse power-law potential in a Bianchi type-I universe

Author: Jaturaporn Watanakampolkij[1]

[1] *Khon Kaen University*

This work considers the dynamics of the gauge vector and inflaton (dilaton) fields inspired by Kaluza-Klein theory in an inflationary universe with Bianchi type-I spacetime. The inverse power-law potential of the inflaton field is used to study dynamical system analysis. As a result, all fixed points in the autonomous system are non-hyperbolic fixed points, and one cannot determine their stability. Therefore, a center manifold theory is required to properly analyze the stability of the dynamical system. Interestingly, we found an isotropic attractor point which means that the universe undergoes accelerated expansion (inflation) from an anisotropic phase to an isotropic phase of the universe. According to the dynamical system analysis of the anisotropic Bianchi type-I universe with the inspired Kaluza-Klein model, our results supported the isotropization of the observed universe.

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Plenary — Peera Simakachorn: Tracing the cosmic history with gravitational waves: it's not so simple!

A century after Einstein predicted gravitational waves (GW), they have become a way of observing the Universe rather than merely a confirmation of relativity. Light and GW both cross the Universe to reach us, but they do not carry us equally far back in time. Light carries no record of the cosmos from earlier than a few hundred thousand years after the Big Bang, while GW interact so weakly that they arrive essentially unchanged from the first fraction of a second — from energies far beyond the reach of any particle accelerator.

This talk gives an overview of how primordial GW backgrounds arise — from the hot thermal plasma, from inflation, from phase transitions, from cosmic strings, from axions — and what each of them can tell us about physics beyond the Standard Model. These backgrounds record not only the processes that produced them but also how the Universe expanded afterwards: across their range of frequencies, from 10^-18 to 10^11 Hz. Each band probes a different epoch, so the expansion history can be read directly from the shape of the spectrum. I will illustrate this with cosmic strings, whose GW spectrum can reveal the reheating phase after inflation and a possible era of kination, such as one driven by a rotating axion. Finally, I will turn to a more practical question addressed in my recent work: since these primordial backgrounds are so faint that they typically lie beneath the far louder signals from astrophysical binaries, can future detectors like LISA still extract them and read the underlying physics of the early Universe?

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Plenary — Avik De: The Non-Metricity Gravity Approach

General Relativity formulates gravitation through spacetime curvature using the Levi-Civita connection, which assumes both vanishing torsion and zero non-metricity. However, alternative geometric descriptions exist within the Geometric Trinity of Gravity. Among these, Non-Metricity Gravity, specifically \(f(Q)\) gravity and its scalar-tensor extensions, attributes gravitational interactions strictly to the non-metricity tensor, setting curvature and torsion tensors to zero while introducing coupled scalar fields to unlock rich, dynamical behaviors.

A crucial feature that makes modified non-metricity theories particularly intriguing is that the affine connection is no longer uniquely fixed by the metric tensor alone. In isotropic and homogeneous spacetimes, such as the FLRW universe, the requirement of zero curvature and zero torsion yields three distinct classes of affine connections. Similarly, applying these geometric constraints to static spherically symmetric systems reveals two independent classes of connections.

These non-trivial connection classes transform the study of non-metricity gravity from a simple metric modification into a deep structural probe of spacetime geometry. Depending on which connection branch is realized, the underlying non-metricity scalar \(Q\) acquires completely different dynamic expressions. This mathematical degree of freedom allows identical spatial metrics to yield dramatically different field equations, influencing late-time cosmic acceleration, inflationary dynamics, and black hole or stellar solutions. This work highlights how exploring these distinct connection choices opens up compelling new pathways for understanding fundamental gravity.

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Plenary — Atsushi Naruko: Understanding Cosmological Perturbations through the Separate-Universe Approach

How much can we learn about an inhomogeneous universe from homogeneous background solutions? The separate-universe approach offers a remarkably simple way to address this question: on sufficiently large scales, different regions of the universe can be treated approximately as homogeneous universes, allowing us to follow the nonlinear evolution of cosmological perturbations without solving the full inhomogeneous equations.

In this talk, I will introduce the basic physical picture of the separate-universe approach and its formulation in terms of the spatial gradient expansion. I will then explain how this leads to the δN formalism, which relates large-scale curvature perturbations to differences in the local expansion history. I will also discuss the assumptions underlying this description, why it works, and where its limitations become important. Finally, I will briefly touch upon extensions of the standard framework and recent developments in the study of nonlinear cosmological perturbations. The aim is to provide an accessible overview of the subject, emphasizing physical intuition and its usefulness for understanding the early universe.

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Plenary — Masashi Kimura: Black Hole Quasinormal Modes and the Non-Uniqueness of Effective Potentials

Quasinormal modes (QNMs) describe the characteristic oscillations of black holes and play an important role in observations of the ringdown phase. These modes are determined by the effective potential in the master equation for gravitational perturbations, raising the question of to what extent the potential can be uniquely determined from the QNM spectrum. In this talk, we explore this question using Darboux transformations of the wave function. We examine under what conditions Darboux transformations yield physically reasonable effective potentials. We also discuss the implications of these transformations for interpreting black hole QNM spectra.

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Online Plenary — Kent Yagi: Gravitational-Wave Tests of String-Inspired Gravity

Gravitational waves provide a unique window into the strong-field regime of gravity, offering unprecedented opportunities to test general relativity and search for signatures of new physics. In this talk, I will focus on Einstein-dilaton-Gauss-Bonnet gravity, a quadratic modification of general relativity motivated by string theory. I will first discuss the post-Newtonian corrections that arise during the inspiral phase of compact binary coalescences and review current observational constraints obtained from inspiral signals. I will then describe how black hole ringdown frequencies are modified in this theory and the corresponding constraints from ringdown observations. Accurately modeling the merger phase requires numerical relativity simulations, which are computationally expensive and time-consuming. To address this challenge, I will present new approaches for constructing inspiral-merger-ringdown waveforms in Einstein-dilaton-Gauss-Bonnet gravity more efficiently, paving the way for stronger tests of string-inspired modifications to gravity with current and future gravitational-wave observations.

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Plenary — Ryo Saito: Probing the Early Universe with Gravitational-Wave Background Anisotropies: Universal Structures at Large Angles

The stochastic gravitational-wave background (SGWB) offers a new window onto the early Universe. While its sky-averaged spectrum is the primary target of current searches, distinct primordial and astrophysical mechanisms can produce similar spectra over a finite observational band. Angular anisotropies provide complementary information that may help identify the origin of a signal.

The importance of such information is familiar from the cosmic microwave background (CMB). In particular, large-angle CMB anisotropies trace primordial perturbations that were superhorizon at recombination and therefore provide a relatively direct window into inflationary initial conditions. SGWB anisotropies may offer a similar probe, potentially retaining information from epochs far earlier than recombination. At the same time, important differences exist between CMB and SGWB observations. I will discuss how these similarities and differences determine which angular information can be extracted from SGWB observables and how it should be interpreted.

To organize primordial SGWB anisotropies, I will introduce the Cosmological Form Factor (CFF), a model-independent framework describing their response to cosmological long-wavelength perturbations. The CFF characterizes how long modes modulate local short-scale GW statistics and connects observable anisotropies to cosmological correlation functions. This connection allows general principles, including statistical isotropy and locality, to determine the angular and polarization

structures, while amplitudes, frequency dependence, and source-time dependence retain information about the underlying mechanism. Both propagation and fossil effects arise as representative realizations of this common framework. As an application, I will show that nearly scale-invariant scalar long modes yield a universal Sachs–Wolfe-like large-angle scaling.

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Online Plenary — Elisa G. M. Ferreira: Probing the Particle Physics of Ultralight Dark Matter: From Galaxies to the Solar System

Small-scale astrophysical observations provide a powerful window into the particle physics properties of dark matter. In this talk, I will focus on ultralight dark matter and discuss how its distinctive predictions for different astrophysical systems can be used to constrain the particle mass. I will highlight the current observational bounds and the assumptions and systematic uncertainties affecting their interpretation. I will also discuss how these observations can provide information about other fundamental properties of ultralight bosons, including their spin, self-interactions, and fractional abundance. Finally, I will discuss how our own Solar System can provide new ways to probe the particle physics properties of ultralight dark matter.

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Online Plenary — Eleonora Di Valentino: Cracks in the Standard Cosmological Model: Tensions, Robustness, and Hints of New Physics

The ΛCDM model has been extraordinarily successful in describing the Universe, but increasingly precise observations are beginning to expose cracks in this remarkably simple picture. The Hubble constant discrepancy remains the most striking example, while recent measurements of the expansion and growth histories of the Universe, together with cosmological constraints on neutrino masses, are adding new pieces to the puzzle. But which of these tensions are robust, and which depend on our choice of datasets, methodology, or cosmological assumptions? In this talk, I will examine the evidence behind the main cosmological tensions and ask what remains when these choices are varied. I will then explore whether the surviving discrepancies can be accommodated by extensions of the standard model, including dynamical dark energy, new early-Universe physics, and interactions in the dark sector. The emerging picture may not yet tell us what lies beyond ΛCDM, but it is beginning to tell us where (and how) we should look.

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Plenary — Antonio De Felice: From Data to Dynamics: A Simple Phantom-Crossing Dark Energy Parametrization

Is the time dependence of dark energy genuinely complicated, or can current observations be described by a much simpler expression?

I will present a data-driven approach to this question within VCDM, a minimally modified theory of gravity that allows a consistent treatment of cosmological perturbations even when the effective dark-energy equation of state crosses the phantom divide.

We begin by reconstructing the dark-energy equation of state using Bayesian splines constrained by cosmic microwave background, baryon acoustic oscillation, and Type Ia supernova observations.

The reconstruction favors relatively smooth histories, while Bayesian evidence does not justify introducing excessive functional complexity. We then employ exhaustive symbolic regression to identify compact and interpretable analytic expressions compatible with the reconstructed evolution.

A particularly interesting outcome is the one-parameter form \(w(a) = w_0/\sqrt{a}\), which provides a competitive fit compared with conventional two-parameter parametrizations, including CPL.

Its simplicity leads to concrete predictions: the phantom-crossing redshift is determined by the single parameter \(w_0\), the effective dark-energy density is suppressed at early times, and the phantom phase is transient, avoiding a future big-rip singularity.

I will discuss the observational implications of this result and explain how the underlying VCDM dynamics can accommodate phantom crossing without introducing an additional propagating scalar degree of freedom.

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Plenary — Shinji Tsujikawa: Dark Energy with Stable Phantom-Divide Crossing: Model Construction and Observational Constraints

Recent cosmological observations have revived interest in dark energy whose equation of state evolves from below -1 to above -1 at low redshift. In this talk, I will discuss how to construct theoretically consistent models realizing this transition and test them against observations. I will first explain the obstacles to achieving such a crossing in shift-symmetric Horndeski and generalized Proca theories with luminal gravitational-wave propagation and no direct dark-matter couplings. I will then present two ways to overcome these obstacles: introducing a scalar potential that breaks shift symmetry in a Horndeski model, and combining a generalized Proca vector field with a canonical scalar field. Particular attention will be paid to the conditions ensuring the absence of ghost and gradient instabilities, as well as the implications for matter clustering and gravitational lensing. I will also present constraints on a scalar-vector-tensor dark-energy model using the DES five-year supernova sample, second-release DESI baryon acoustic oscillation measurements, compressed cosmic microwave background constraints, and growth data from redshift-space distortions. The results allow stable crossing histories and improve the best-fit likelihood relative to flat ΛCDM. I will discuss Bayesian model comparison, including its sensitivity to theoretical viability conditions and prior normalization, and the prospects for distinguishing these models through cosmic expansion and structure growth.

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Online Plenary — Laura Iacconi: Primordial black holes from inflation: on the decoupling between large and small scales

Primordial black holes can be produced from the collapse of large perturbations generated from inflation on scales much smaller than those seeding the large-scale structure formation.

It is possible that the large peak in scalar power at high wavenumbers might induce corrections to the scalar power spectrum on large scales, e.g. in the form of loop corrections, endangering the success of inflation in explaining the observed statistics of primordial perturbations.

In this talk, I will give an update on recent debates on the viability of such inflationary scenarios.

I will demonstrate that the 1-loop correction to a large-scale adiabatic mode due to a band of enhanced short-scale perturbations decouples from all detailed properties of the peak, including its maximum amplitude, and does not lead to an observable effect.

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Plenary — T.R. Govindarajan: Ultra light dark matter and Primordial balckholes

Dark matter is one of most important unsolved puzzles in Cosmology.
This is where Classical gravity, Quantum mechanics and Particle Physics
interact closely.
The center of the galaxies have supermassive blackholes whose presence
have remained an unanswered question. Now we have evidence
of galaxies existed even as early as 400 million years after
the bigbang. We also know Dark matter aids the formation of
galaxies as well as holding them together.
A novel proposal is made to account for the dark matter
component of the Universe. Ultralight dark matter with mass
\cal{O}}(10^{-18 to -22})~eV is one of the strong candidates for the
missing mass. We propose to answer questions linking primordial Blackholes
Supermassive BHs and Ultralight Dark matter. We will provide
some primafacie evidences and the estimates.

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Online Plenary — Roy Maartens: Testing the Standard Model of Cosmology

The standard LCDM model of cosmology has been highly successful in fitting the data from numerous cosmological surveys. Nevertheless, it is always good physics to test the standard model. In addition, various tensions are emerging in the data, especially the Hubble tension, which may indicate problems with the standard model. I will give an overview of the key features of the model that can be tested. Then I will give examples and updates on some of these tests.

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Plenary — Takashi Hiramatsu: Cosmological Constraints on Extended Theories of Gravity from CMB Observations

The late-time accelerated expansion of the Universe, revealed by observations of Type Ia supernovae and other cosmological probes, may be explained by extensions of general relativity. Various extended theories of gravity have been proposed to explore gravitational physics beyond general relativity. In this talk, I will focus on constraining such theories using observations of the cosmic microwave background (CMB). In particular, I will consider degenerate higher-order scalar-tensor (DHOST) theories, generalised Proca theories, and a model propagating only two tensor degrees of freedom. To investigate these theories, we have developed a Boltzmann solver incorporating the effective field theory (EFT) approach to gravity. Using this solver, we perform Markov chain Monte Carlo (MCMC) analyses with the Planck 2018 likelihood to derive observational constraints on the EFT parameters characterising each model.

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Plenary — Luis Ureña López

19

Efficient computation of non-Gaussian Scalar-Induced Gravitational Waves

Author: Ameek Malhotra[1]

[1] *Swansea University*

Large density perturbations in the early-universe may lead to the formation of primordial black holes and source at 2nd order, scalar-induced gravitational waves (SIGW). The spectrum of the SIGW depends on the statistical properties of the density fluctuations, providing an opportunity to constrain small-scale density perturbations via GW observations. In particular, non-Gaussianity of the scalar perturbations leaves characteristic imprints in the SIGW, highlighting the importance of such GW observations. However, the computation of these non-Gaussian effects is challenging due to the high-dimensional integrals involved, especially as one considers higher and higher order effects. Drawing from CMB/LSS techniques, we present a multipole space method to efficiently and accurately compute such SIGW for local type non-Gaussianity. We discuss applications of this technique and compare it against other methods to evaluate such non-Gaussian SIGW, highlighting its strengths and weaknesses.

5

Modified Gravity and the Complexity of Compact Stellar Structures

Authors: Shyam Das[1]; Farook Rahaman[2]

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[2] *J.U*

This work investigates anisotropic compact stellar models in the framework of modified $f(R,T)$ gravity using the Vaidya-Tikekar metric ansatz. A linear functional form, $f(R,T) = R + \beta T$, is adopted, where β represents the matter-geometry coupling parameter. By imposing the vanishing complexity condition on an anisotropic matter distribution, an exact interior solution is obtained. The stellar interior is smoothly matched with the exterior Schwarzschild spacetime through the continuity of the metric functions and the vanishing of radial pressure at the boundary.

The pulsar $4\mathrm{U}\ 1608\text{-}52$ is used as the primary case study for graphical analysis, while several other observed compact stars are examined numerically to assess the applicability of the model. The influence of the coupling parameter β and the spheroidal parameter K is studied independently. The resulting solutions exhibit regular metric potentials, positive and monotonically decreasing energy density and pressures, and a vanishing radial pressure at the stellar surface. A positive anisotropy factor provides additional support against gravitational collapse.

The model satisfies the null, weak, strong, and dominant energy conditions and fulfills the essential criteria for physical acceptability. Stability is verified through the causality condition, Herrera's cracking criterion, the adiabatic index, and the Tolman-Oppenheimer-Volkoff equilibrium equation. The analysis indicates that negative values of the coupling parameter β lead to denser and more compact stellar configurations while maintaining stability. Stable solutions are also obtained for different values of the spheroidal parameter K, demonstrating the robustness of the proposed model.

Overall, the developed solutions are physically viable and consistent with current observational data, emphasizing the potential of modified $f(R,T)$ gravity as a framework for describing realistic compact stellar objects.

6

Cosmological Dynamics in Covariant f(Q) Gravity with Dynamical Coupling Functions

Authors: Siddheshwar Kadam[1]; Shubham Narawade[None]

[1] *DY Patil International University Akurdi Pune*

We investigate the cosmological dynamics of the Universe within the framework of covariant $f(Q)$ gravity by considering a dynamically evolving coupling function proportional to the Hubble parameter. Two representative models, namely power-law and logarithmic forms, are examined to explore their viability in describing the large-scale evolution of the Universe. The cosmological field equations are reformulated into an autonomous dynamical system, allowing a systematic analysis of the corresponding critical points and their stability properties. The dynamical analysis reveals that both models successfully reproduce the standard sequence of cosmic evolution, encompassing radiation, matter, and dark energy-dominated epochs, together with smooth transitions between these phases. The cosmological behavior at each equilibrium point is characterized through the total equation-of-state parameter, density parameters, and the deceleration parameter, providing a comprehensive understanding of the underlying dynamics. For non-hyperbolic critical points, the stability is further investigated using center manifold theory, enabling a rigorous assessment of their asymptotic behavior. Phase-space trajectories are presented to illustrate the global evolution of the system, while numerical evolution of the radiation, matter, and dark energy density parameters, together with the effective equation-of-state parameter, demonstrates consistency with the observed expansion history of the Universe. The results indicate that the considered covariant $f(Q)$ gravity models naturally accommodate the observed transition from decelerated to accelerated expansion without introducing additional exotic components. These findings highlight the potential of covariant $f(Q)$ gravity as a viable modified gravity framework for explaining the late-time acceleration of the Universe and provide new insights into the dynamical behavior of non-metricity-based cosmological models.

13

Study of DBI Fields: From Exact Results to Gaussian Process Reconstruction

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Dirac-Born-Infeld (DBI) scalar fields offer a compelling framework for modeling dark energy. In this talk, I will present a comprehensive analysis of DBI fields, transitioning from theoretical exact solutions to data-driven reconstructions. First, I will discuss the dynamical system analysis of DBI fields in a modified gravity context, identifying exact fixed points for polynomial and exponential potentials and establishing conditions for the cosmic transition from deceleration to late-time acceleration. Next, I will shift to an observational perspective, using Gaussian Processes to non-parametrically reconstruct the DBI dark energy sector from the latest Hubble, BAO, and DESI datasets. This yields a fully model-independent Hubble constant estimate of H0 = 69.53 +/- 2.68 km/s/Mpc, offering a valuable data point for the Hubble tension. Finally, I will show how we constrain and test the viability of various scalar potentials using MCMC analyses, providing a unified view of DBI cosmology from exact dynamical results to modern observational constraints.

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FROM EARLY INFLATION TO COSMIC ACCELERATION : A UNIFIED SCENARIO IN HOLOGRAPHIC f(Q) GRAVITY

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In this work, we present a unified cosmological scenario within the framework of holographic f(Q) gravity, addressing both early-time inflation and late-time cosmic acceleration. For the inflationary epoch, we reconstruct the Hubble parameter using holographic dark energy (HDE) and derive the key inflationary observables, namely the scalar spectral index and the tensor-to scalar ratio. Our results demonstrate excellent consistency with the latest Planck satellite data, validating the viability of the model during the early universe. For the late-time cosmology, we incorporate a matter sector and employ the Chevallier-Polarski-Linder (CPL) parameterization to characterize the dark energy equation of state. We perform a comprehensive Bayesian sta tistical analysis using a joint dataset of 31 Cosmic Chronometer (CC) and 26 Baryon Acoustic Oscillation (BAO) observations. Markov Chain Monte Carlo (MCMC) sampling is utilized to constrain the free parameters, and we present the corresponding confidence contour plots. The combined analysis reveals that the holographic f(Q) gravity model successfully accom modates both inflationary and late-time accelerated expansion phases within a single theoretical framework, offering a compelling alternative to standard ΛCDM cosmology

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Quintessence model in the late Universe

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Scalar fields have shown great potential in inducing tailored modifications compared to cosmic evolution in the ΛCDM model. We investigate a quintessence model with five physically motivated scalar field potentials: the general power-law, quadratic, fifth-power, hyperbolic sinh, and axion-like potentials. The model parameters are constrained by using the late-time cosmological observations, including Cosmic Chronometers (CC), Pantheon$^+$, BAO, and DESI DR2 data. To assess the influence of the local distance-ladder calibration, we additionally perform a separate analysis using the Pantheon$^+$\& SH0ES compilation. Our analysis shows that the inclusion of the SH0ES calibration systematically shifts the inferred Hubble constant toward higher values, whereas the addition of BAO and DESI DR2 data prefers comparatively lower values and significantly reduces parameter degeneracies. We center the action of these models in the late Universe which leaves early ΛCDM cosmology unchanged. Across all five potentials, an inverse correlation between H_0 and Ω_{m0} is consistently observed, indicating that higher values of the Hubble constant are associated with a lower present-day matter density and a stronger contribution from dark energy to the current accelerated expansion.

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White Dwarfs as Astrophysical Probes of f(Q) Gravity

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White dwarfs provide a complementary laboratory for testing gravity in a density regime distinct from neutron stars and black holes. We investigate their equilibrium structure within the covariant formulation of symmetric teleparallel $f(Q)$ gravity, where gravitational interactions are described through the nonmetricity scalar Q rather than spacetime curvature. Static, spherically symmetric configurations of cold, completely degenerate electron matter are considered using the quadratic model $f(Q) = Q + \alpha Q^2$, with α controlling deviations from general relativity. The resulting modified stellar structure equations are solved numerically together with the Chandrasekhar equation of

state. We analyse the effects of nonmetricity corrections on the metric potentials, pressure, density, enclosed mass, nonmetricity scalar, and mass–radius relation. Negative values of α generate unstable or nonphysical high-density configurations, whereas nonnegative values yield regular stellar solutions. Increasing α produces increasingly significant departures from general relativity at high central densities and systematically lowers the maximum supported mass relative to the Chandrasekhar limit, while also modifying the corresponding radius and internal profiles. For $\alpha = 5 \times 10^{18}\,\mathrm{cm}^2$, the model predicts a maximum mass of $1.3519\,M_\odot$ and a radius of $2228.85\,\mathrm{km}$, compatible with the observational constraints associated with the ultra-massive white dwarf ZTF J1901+1458. These results demonstrate that precise mass–radius measurements of white dwarfs can constrain quadratic nonmetricity corrections and provide an independent astrophysical test of modified gravity.

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Gravastar Model in f(\mathscr{T},\mathcal{T}) Gravity with Vaidya–Tikekar Geometry

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In this study, we construct a gravastar model based on the Mazur–Mottola proposal within the framework of f(\mathscr{T},\mathcal{T}) gravity. Gravastars are considered promising alternatives to black holes, as they provide compact, horizon-free objects that eliminate the occurrence of spacetime singularities. The proposed model consists of three distinct regions: an interior core, a thin shell, and an exterior vacuum region. The interior is characterized by a constant negative energy density that produces an outward repulsive pressure. This repulsive force is counterbalanced by the thin shell, which is filled with ultra-relativistic stiff matter obeying the Zel'dovich equation of state, thereby ensuring the equilibrium and stability of the configuration. The exterior region is described by the Schwarzschild vacuum solution. Within this framework, we obtain a physically viable and singularity-free gravastar solution, where the gravitational dynamics are governed by the combined effects of the torsion scalar and the trace of the energy–momentum tensor.

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Probing the Imprint of Dark Sector Dynamics on Evolution of Black Hole

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One of the feasible theoretical explanations for the currently observed accelerated expansion of the Universe is the inclusion of the dark sector in the standard cosmological model. Further extension of this idea can't be an exaggeration, if we thought the interaction between dark energy and matter contents of the universe. In this work, we investigate the cosmological evolution in a dynamical dark sector and its influence on the mass evolution of Schwarzschild black holes devoid of any charge and rotation. We analyze the cosmic expansion through relevant cosmological parameters like scale factor, Hubble parameter, deceleration parameter, redshift and the type of dark energy during transition and present time. Our focus also attributes to study black-hole mass dynamics governed by the competing effects of Hawking radiation and accretion of the surrounding cosmic medium. Our results show that the black hole mass increases significantly during the radiation-dominated era, remains nearly constant for an intermediate period, and eventually decreases during the matter-dominated era, ultimately leading to complete evaporation depending on the accretion efficiency and initial formation mass. We further examine the population of such black holes in connections

with constraints arise from several astrophysical phenomena like the present matter density, photon spectrum, CMB spectral distortions, and Big Bang nucleosynthesis. Within the framework of the interacting dark sector, we evaluated these constraints and found that they are more flexible than standard cosmology and Brans-Dicke theory counterparts.

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Logarithmic correction to entropy of near-extremal de Sitter black holes

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I will briefly review logarithmic corrections to black hole entropy. Following that, I will focus on thermodynamics of de Sitter black holes and our recent work (https://arxiv.org/abs/2503.08617) on log T corrections to the entropy of de Sitter black holes. I will establish the result that at leading order, the small temperature corrections to the extremal entropy are universal in the cold and Nariai limit. In particular, in the Nariai limit, the near-horizon throat geometry is 2-dimensional de Sitter space with two possible ways of capping the geometry – the usual Hartle-Hawking contour and the Maldacena contour, both leading to the same universal coefficient of 3/2 for log T correction to the entropy of de Sitter black holes. This machinery paves the way for similar such computations and tests in higher dimensional dS black hole spacetimes, including rotating Kerr-dS black holes.

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Tracers of Primordial Black Holes through Dark Matter and Neutrino Interactions

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We investigate the astrophysical and cosmological tracers of the Primordial Black Hole (PBH) through neutrino and 21-cm signal observations. We consider two mechanisms for neutrino production from PBH. An intermediate dark matter process, in which the PBH evaporates into superheavy dark matter in the early universe through Hawking Radiation. These dark matter particles resist the energy depleting interactions before decaying into high-energy neutrinos at late time. We compare the neutrino flux coming from this metastable dark matter mechanism with the high-energy neutrino observatories like KM3NeT and IceCube. The second neutrino production mechanism is through the direct evaporation of PBH into neutrinos. We study the neutrino interaction of these PBH induced neutrinos with Cosmic Neutrino Background (CνB) producing secondary photons, heating the Intergalactic gas, thereby changing the global 21-cm brightness temperature of the universe from the standard cosmological processes near redshift of $z \sim 17$. From the new absorption feature, we constrain the PBH fraction relative to the mass of the PBH. Overall, our study motivates the observation of multi-messenger signatures like neutrinos as well as 21-cm radio photons to probe the exotic phenomenon in the universe.

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The PAU Survey: the i-band galaxy luminosity function from the present day to z = 2, implications for the galaxy-halo connection

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We present a measurement of the i-band galaxy luminosity function (LF) from the present day to z = 2, using over 1.1 million galaxies from the Physics of the Accelerating Universe Survey (PAUS). PAUS combines broad-band imaging from the Canada–France–Hawaii Telescope Lensing Survey with narrow-band photometry from PAUCam, enabling high-precision photometric redshifts with an accuracy of $\sigma_{68}(\Delta z) = 0.019$ down to i_AB = 23. A synthetic lightcone mock catalogue built with the GALFORM semi-analytic model applied to the Planck Millennium N-body simulation is used to simulate PAUS selection effects and photometric uncertainties, and to derive a machine-learning estimate of the k-correction. Rest-frame luminosities are recovered using a random forest regressor trained on simulated ugriz photometry and redshifts, and LFs are estimated with the 1/Vmax method and validated against the mock. We find good agreement between observations and models at z < 1, with increasing discrepancies at higher redshift driven by photometric redshift outliers. The bright end flattens with redshift, primarily as a consequence of redshift errors, while the faint end becomes progressively more incomplete yet remains useful for constraining models. Analysing red and blue galaxies separately, the model overpredicts the abundance of faint galaxies in both populations. Because the LF is the one-point statistic that anchors the galaxy-halo connection, these results carry directly into how galaxies are assigned to haloes: photometric redshift errors propagate into both the inferred luminosity and Vmax, systematically distorting the recovered abundances and hence biasing halo occupation inference unless they are forward-modelled. Looking ahead, narrow-band surveys of this kind measure the faint-end abundance across a wide redshift baseline, the regime where alternatives to cold dark matter predict a suppressed halo mass function, offering a route to constrain the nature of dark matter, provided the degeneracy with baryonic feedback is controlled using realistic galaxy formation models.

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Testing W_{50} as a halo-mass proxy through H I galaxy clustering in ALFALFA + FASHI DR1

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We present measurements of H I galaxy clustering for a combined sample of ALFALFA and FASHI galaxies, hereafter **AF+FS**, and compare them with mock galaxy catalogs derived from the MultiDark–Planck simulation, hereafter **MDPL**. The analysis used the two-point correlation function, $\omega_p(r_p)/r_p$, in differential $\log W_{50}$ bins to test whether the clustering length r_0 increases with the observed linewidth proxy W_{50}, while W_{50} was calculated for **MDPL**. We found a positive $r_0 - \log W_{50}$ relation in **AF+FS**, the full **MDPL**, and an observed distribution-matched mock, $\textbf{MDPL}_{\rm sub}$. The latter was constructed by downsampling the full mock in the joint distance-$-\log W_{50}$ plane to match the observed distribution while preserving galaxy positions. The inferred trends were consistent within the current uncertainties, with **AF+FS** and $\textbf{MDPL}_{\rm sub}$ showing good agreement. Additional monopole, threshold, and halo-spin parameter split tests are presented as robustness checks.

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The f(Q,T) gravity and affine EoS: observational aspects

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In this paper, we investigate the cosmic expansion scenarios within the framework of $f(Q,T)$ gravity by using the affine equation of state (EoS) parameter. Specifically, we consider the linear form of $f(Q,T) = Q + \beta T$, where β is a free model parameter. We use the Bayesian statistical methods, specifically the χ^2 minimization technique to constrain the model parameters using the Cosmic Chronometer (CC) data, Pantheon+SH0ES and DESI BAO data. We further analyse the characteristics of the derived cosmological model. A comprehensive study of the energy density, pressure, equation of state parameter, cosmographic parameters and Energy condition are carried out to understand the universe's evolution in the model and H_0 tension also discuss for this model. The determination of the universe's present age for this model is within 1σ with the planck results.