

PROFILE

- I am currently a Post-Doc at **Center for Theoretical Physics, Seoul National University**. I completed my PhD at Indian Institute of Science Education and Research - Bhopal, India. My PhD thesis titled 'Anisotropies in Bouncing Cosmology and Analog Gravity' consists of my exploration of breaking of the rotational invariance in the very early universe and search for its signature on the power spectrum. The nature of my research is interdisciplinary. It involves studying the early universe cosmology, constructing their analogs in ultra cold gases and building the cosmic simulators using the Bose-Einstein condensates. Alongside, I also work in the purely theoretical aspects of cosmology, understanding the nature and structure of our universe.

Academic Timelines

- **Doctor of Philosophy - Physics**,
Aug. 2018 - Feb. 2024
Department of Physics
Indian Institute of Science Education and Research - Bhopal
Bhopal, India
- **Master of Science, Physics**
Aug. 2015 - May 2018
IISER Bhopal, India
CPI: 8.4
- **Bachelor of Science (Hons.), Physics**
Aug. 2011 - May 2014
University of Delhi, India
Percentage : 73.6
- **Senior Secondary, BSEH Board**
Haryana(India), GPA:9.6
- **High School, BSEH Board**
Haryana(India), GPA:9.8

Research Experience

- **Analogue Gravity(AG) and Cosmic Simulators using Ultra Cold Gases** : AG is research program in which we try to recreate a system governed by general relativistic gravitational field in some other physical systems. There are many such systems available, Bose-Einstein Condensate being one of them which we are using. There are three projects we have been working on in this direction:
 - **Anisotropic Inflation in Dipolar BEC** : This got recently published here '[New J. Phys 25 \(2023\) 11, 113040](#)'. In this project, we first constructed the analog of anisotropically expanding space time using the anisotropic character of the long range interaction between the dipolar condensate. The motivation to study these anisotropic space-time comes from the theories which suggest them to be causing the observed anomalies in the CMB. These anomalies are studied via the power spectrum. In our work, we were able to verify that given the existence of anisotropy during the pre-inflationary phase, its imprints would be detected in the power spectrum. As there is no way to directly probe this, analog gravity can provide a better insight into that phase. We also used the Truncated Wigner Approximation method to go beyond the mean-field approach and obtained our results.
- **Power Spectrum, Anisotropy and Matter-Dominated bouncing universe** : This is published here: [Eur. Phys. J. C 82 \(2022\) 10, 887](#). In this project, we investigated the effects of the anisotropy on the scale-invariant power spectrum considering the matter-dominated collapsing universe as background and studied the deviations from the scale invariance. Once we set up the background, we considered a test massless scalar field and worked out the correlations for the field, first by using the perturbative approach in which the anisotropic background was approximated with an effective isotropic metric represented by the metric of matter dominated collapsing universe, second by directly solving the field equation numerically, and then obtained the power spectrum for the range of modes which are of cosmological interest. Using both techniques, we got an upper bound on the deviation in the power spectrum from the scale invariance. We also worked out the power spectrum for much smaller modes and looked at whether it was possible to explain the observed anomalies in CMB via the matter bounce scenario or not.

- **Constant Roll inflation, Modified gravity and Palatini Formalism** : This was published at : [Eur. Phys. J. C 83 \(2023\) 4, 297](#). In this project, we have studied a constant-roll inflationary model in the Palatini formalism using modified gravity. Here our action consisted a non-minimal coupling of a scalar field ϕ with Ricci scalar R in a general form of $f(R, \phi)$. Using Palatini approach, we wrote its equivalent scalar-tensor form in the Einstein frame and then applied the constant-roll condition in the equation of motion for the inflaton field. Later the tensor-to-scalar ratio and the spectral index were calculated using the slow-roll parameters and the results obtained were found to be well in agreement with the Planck 2018 data. We found that the results agree nicely with the observations within the parameter regime under consideration.
- **Inflation with an anti-symmetric tensor field** : This can be looked at [Eur. Phys. J. C 78, 887 \(2018\)](#). Inflation is a theory of exponential expansion of space-time in the very early universe. It lasted for a very small interval of time. We have worked on an inflationary model in which there is an anti-symmetric tensor field coupled minimally and non-minimally to gravity. Although the minimal model does not support inflation, the non-minimal models can give rise to a stable de-Sitter solutions with a bound on the coupling parameters. The values of field and coupling parameters are sub-planckian.
- **Perturbation Theory in Cosmology** : I have done my Master's Thesis on this project, it has been one of the interesting topics for me, the reason being the large scale structure of the universe is the result of the very small fluctuations in the very early universe. I have studied perturbation theory in linear regime and have worked out the structure formation for all the components of the universe.
- **Other interesting topics** : I am also familiar with Analog Black Holes (BH), Hawking Radiation, BH Evaporation, Advanced GR and QFT in Curved Space-time, Particle Production, Reheating and Preheating etc.

PUBLICATIONS : ([INSPIREHEP Link](#))

1. Anisotropic Inflation in Dipolar Bose-Einstein Condensate, *New J. Phys.* 25 (2023) 11, 113040
2. Cosmic Duality of Primordial Power Spectrum in Ultra Cold Gases (Manuscript Under Preparation)
3. Constant-roll Inflation in Modified $f(R, \phi)$ Gravity Model using Palatini Formalism, *Eur. Phys. J. C 83 (2023) 4, 297*
4. Imprints of anisotropy on the power spectrum in matter dominated bouncing universe as background, *Eur. Phys. J. C 82 (2022) 10, 887*
5. Inflation with an anti-symmetric tensor field, *Eur. Phys. J. C 78, 887 (2018)*

SKILL

- **Computational software:**
 - Expertise in using XMDS (eXtensible Multi-dimensional Simulator), to simulate the analog cosmic models using BEC and building up a simulator to understand the Early universe cosmology using ultra cold gases. I have used HPC facilities for the same.
 - Familiarity with software packages like Matlab, Mathematica, Maple and xAct (package for Einstein Equation and perturbations involve there in) for advanced analytics.
- **Programming Languages:**
 - Proficient in programming languages such as Python and C++ for scientific computing data analysis and plotting.
- **Documentation Tools:**
 - Skilled in writing a research paper/report using Latex.

Teaching Experience

- Teaching Assistant for one year in Under Graduate Physics Laboratory.
 - Teaching Assistant for two year in tutorial sessions for basic and advance courses in physics
 - Co-supervised two students for their Masters' thesis, one involving the study of Bouncing Cosmology and other one on Analog Gravity.
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WORKSHOPS AND CONFERENCES

- NARIPHY 2022, A National Conference
IISER Bhopal, India.
- Physics In-house Symposium 2022/23
IISER Bhopal, India.
- Cosmologlobe 2021, Mode - Online,
- Conference - Less Travelled Path to Dark-Matter
ITCS 2021/2022, India.
- Physics In-house Symposium 2019
IISER Bhopal, India.
- Workshop on High Energy Physics Phenomenology - 2017
IISER Bhopal, India.

Achievements

- Best Poster Award, Physics In-House Symposium-2019
IISER Bhopal.
- Joint Entrance Screening Test, National Level Exam
All India Rank-121, JEST-2015.
- Joint Admission Test for M.Sc., National Level Exam
Qualified-2015.
- DST INSPIRE Scholar, 2011-2014
Department of Science and Technology, India.
- Among State Board Top - 0.1 Percent Students
BSEH Board 2011, Haryana, India.
- District Representative, Science Conference - 2010
Dr. Homi J. Bhabha Birth Centenary, India.

Languages

- English : Fluent
- Hindi : Native

REFERENCES

- Prof. Dr. Sukanta Panda, IISER Bhopal, India
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 - Prof. Dr. Sebastian Wüster, IISER Bhopal, India
Email : sebastian@iiserb.ac.in.
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