K. S. Sreelatha
Varghese Jacob *Editors*

# Modern Perspectives in Theoretical Physics

## 80th Birthday Festschrift in Honor of K. Babu Joseph

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# Foreword by P. P. Divakaran

I first met Babu Joseph sometime in the mid-1970s in connection with the Ph.D. qualifying examination of one of his first students at the then not-so-old Cochin University of Science and Technology. After that, my occasional visits, for various purposes, continued over many years; especially memorable was the decade that followed immediately and I am now happy to remember my friendship and association with several of Babu Joseph's students, some of whom subsequently became stalwart members of the CUSAT physics faculty. It was an exciting time: several of the areas of research in which CUSAT became an active and respected participant were already beginning to produce new results. It was an exciting time also for the values of good science in Kerala. The hard struggle to save Silent Valley from those who would destroy our natural heritage was at its height, a battle in which CUSAT played its due role. My visits gave me, personally, a ringside seat from which to experience the power that a committed community of citizen-scientists can wield.

Babu Joseph's own high standards, both in the choice of problems on which he and his students worked and in the manner in which they were solved and written up, played no small part in making CUSAT such a stimulating place to be at. To this must be added his personal qualities: generousity, open-mindedness and hospitability. This is not just my personal experience; I know many visitors to CUSAT who will heartily endorse it.

Babu Joseph's main scientific interest has always been physics at its most fundamental level which, at that time, was concerned mostly with the description and understanding of the physics of elementary particles. The high point of that period was the organisation of one of the regularly held national high energy physics symposia (in the winter of 1980–81, if memory serves) by him. It was among the very best of these symposia, with a wide participation of distinguished high energy physicists from India (and a few from outside). Among the many memories I have of it, two stand out: scientifically, the several unofficial or informal sessions, full of passion and noise, devoted to a particular theme or a particularly interesting new piece of work; socially, the warm efficiency with which everything was organised and conducted.

Subsequently, Babu Joseph's urge to go to the roots of interesting intellectual/rational issues extended to areas of fundamental physics other than particle physics, quantum field theory, etc. and even to complex systems which are not generally considered part of physics. Along with that came an increased sense of responsibility to his institution where he served first as the head of his department and then as the vice chancellor. Everyone knows that the position of the vice chancellor of a university, starved of essential funding—especially if it is not a central university—and subject to pressure from various institutions and authorities, is not a bed of roses. But CUSAT survived and thrived, as seen most clearly in its collaboration with the Inter-University Centre for Astronomy and Astrophysics (Pune) in the seeding of a culture of top-level research and teaching in various educational institutions across Kerala. It is a tribute to Babu Joseph's role in promoting this very fruitful collaboration in the field of astronomy/astrophysics/cosmology, of which, Kerala must remain forever conscious.

After his retirement from CUSAT, what I think of as Babu Joseph's true vocation has come fully to the forefront of his life. His search for an intellectual understanding of the philosophical–historical foundations of modern science and his love of writing—and of the literary life in its broadest meaning—have come together in his life as a writer, the author of dozens of articles and several books in Malayalam. They have had an impact on Kerala's intellectual life, keeping the flame alive at a time when many in our nation were engaged in a futile search for "science" in the mythical productions of certain periods of our past. These endeavours culminated in his role in the founding and continued health of the Malayalam magazine Ezhuthu. The life of the mind is not dead.

To become 80 years old is not a handicap. Michelangelo was in his mid-80s when he designed and supervised the building of the great dome of St. Peter's Basilica in Rome. Nilakantha, our own great polymath from somewhat earlier, was 80 or more when he completed his masterpiece, his bhasya of Aryabhatiya. Onward!

P. P. Divakaran
Formerly Professor of Physics
TIFR, Mumbai

# Foreword by M. Lakshmanan

Young people often look for a role model to shape their careers. It is more so for people in the field of science. Professor K. Babu Joseph has been one such towering personality for many youngsters in the southern part of the country, particularly for those who are pursuing scientific research. Professor Babu Joseph rose from the ranks of active young theoretical physicists in the early 1970s to a Professor of Physics and Head of the Department of Physics and then as a Vice Chancellor of Cochin University of Science and Technology (CUSAT), Kochi, to reach the pinnacle of his career. It is very apt that his grateful former research students have joined together to bring out this very useful festschrift 'Modern Perspectives in Theoretical Physics' on the occasion of his 80th birthday, and they should all be congratulated for their efforts.

Professor Babu Joseph's scientific interests have been vast and wide in theoretical physics. He explored deeply many areas such as quantum field theory, cosmology, nonlinear dynamics including solitons and chaos, mathematical physics and economics besides other topics and has published more than 150 research articles in his long academic career spanning more than four decades. He has trained more than 20 scholars towards their Ph.D. degrees. Many of them have emerged as leading theoretical physicists on their own and have led or are leading strong teams of active young researchers in different institutions of repute in the country. Professor Babu Joseph should be a satisfied person on this count.

Professor Babu Joseph has been a very successful administrator, both as Head of the Department as well as the Vice Chancellor of CUSAT during1997–2002. His calmness, uprightness, charming smile and friendly disposition towards all have endeared him as a great personality, and he is loved by one and all.

I had the good fortune of knowing personally Prof. Babu Joseph quite well since the late 1970s, and we have mutually visited each other at our institutes (and of course our homes as well). He has been an excellent host, and our research scholars had the benefit of visiting each others' institutions for scientific collaborations. I highly value his friendship and I am grateful to him for his kindness.

Professor Babu Joseph continues to be in active academic pursuit for the cause of higher education, particularly in the state of Kerala, even after his retirement as Vice Chancellor of CUSAT. I wish him continued good health, success and active service to the cause of science and higher education on his 80th birthday. Aspiring young students and researchers will always find Prof. Babu Joseph to be a model to be emulated.

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# Preface

Professor K. Babu Joseph, who held the positions of teacher of physics, head of the department and later the Vice Chancellor of the prestigious Cochin University of Science and Technology (CUSAT), has promenaded into his octogenarian year. On his 80th birthday on 6th July 2020, we are greatly honoured to dedicate this Festschrift to Prof. K. Babu Joseph, our guru and mentor, to whom we all are immensely indebted for making our lives meaningful. This Festschrift is designed as a tribute to his distinguished achievements in various fields of physics and applied mathematics. This book is a compilation of research review articles by his research students to reflect his innovative thoughts that have made his professional life so rewarding. His contributions to popularizing science in the form of writings and lectures are greatly appreciated by the state and central governments.

Professor Babu Joseph is a versatile genius in Physics. His doctoral work was in the area of spectroscopy under the guidance of Prof. K. Venketeswarlu, the founder head of the Department of Physics, CUSAT, and former Professor and head of the Department of Physics, Annamalai University. Then he extended his research to domains of Theoretical Physics, like gravitation and cosmology, quantum field theory and high energy Physics, the areas of nonlinear dynamics—solitons, machine learning, neural networks, chaos, fractals and their applications, limited to not only Physics but also Biology and Economics.

This book is divided into four sections based on the contributions of Prof. Babu Joseph and his students.

The first section is on cosmology in which Moncy V. John, Suresh P. K. and Sivakumar C. present their research work during and after their doctoral research. Suresh P. K. has completed his Ph.D. under the guidance of the late Prof. V. C. Kuriakose, who was a student of Prof. K. Babu Joseph.

The second section deals with contributions to high energy physics and gravitation by Satheesh K. P. and Titus K. Mathew—a student of the late Prof. M Sabir, who, in turn, was a student of Prof. K. Babu Joseph. In the third section, contributions to Mathematical Physics by Vinod G. and Leelamma K. K. are enlisted. The fourth section is on nonlinear dynamics and its applications where the research

works by Lakshmi Parameswar, Ninan Sajeeth Philip, Rose P. Ignatius and K. S. Sreelatha are included.

Along with the contribution to various branches of Physics, Prof. K. Babu Joseph is internationally renowned for his articles and books based on the fundamentals of mathematics and the development of conceptual Physics and their applications in various fields like the relation of the mind and the brain, evolution of species, variation of GDP and its effects, fuzzy logic and neural networking.

Professor K. Babu Joseph is widely appreciated for his associations with various journals, professional bodies and scholarly societies in science and humanities and possesses a seemingly tireless capacity for support and mentoring. We devote this Festschrift for his tangible love and unconditional support and motivation in all our activities.

Our success is due to the combined efforts of many people. We deeply acknowledge Prof. P. P. Divakaran, Tata Institute of Fundamental Research, Mumbai, and Prof. M. Lakshmanan, Centre for Nonlinear Dynamics, Bharathidasan University, for writing 'Forewords' for this Festschrift. We sincerely acknowledge the efforts of the members of the editorial board in sparing their valuable time and energy to compile the book in the $LaTeX$ format. The indefatigable patience and hard work by Dr. Anoop K. Mathew and Dr. Jinchu I., Department of Physics, Government College, Kottayam, to combine all the articles in the present book format and to make our effort in its outright form are deeply appreciated. Special thanks to Suresh P. K., Prof. of Physics, University of Hyderabad, for the eye-catching design of the cover pages. We sincerely acknowledge the co-operation of each contributor to this Festschrift, and also for his/her critical comments and suggestions for enriching the content, presentation and organization of the book in its final form.

Kottayam, India
July 2020

K. S. Sreelatha
Varghese Jacob

# A Tribute to Prof. K. Babu Joseph on His 80th Birthday

*The mediocre teacher tells.*
*The good teacher explains. The superior teacher demonstrates.*
*The great teacher inspires.*

*William Arthur Ward*

In many ways, the art of a teacher is to awaken a learning experience in realizing our true vitality. We all have had our fair share of personal experiences with Prof. K. Babu Joseph, and this book is a humble dedication to the person who has inspired us with the magic of Quantum Mechanics, High Energy Physics, Nonlinear Dynamics and Solitons. He has moulded us, taught us to fight every challenge and encouraged us to adapt to changes with a positive outlook. We are grateful to him for leading by example and enabling us to look up to him as a great mentor. He has left irreplaceable footprints in the areas of Cosmology and Mathematical Physics, especially in understanding Cosmological models and underlying cosmic parameters. Machine Learning for Artificial Intelligence-driven data science platforms is the current trend to predict many nonlinear phenomena. Being a true visionary, Prof. Babu Joseph has opened new pathways for data scientists and Artificial Intelligence enthusiasts via producing the first ever Ph.D. on this topic from a university in the country. His book Padartham Muthal Daivakanam Vare (DC Books) won the Science Literature award in the Science book (In-Depth Science) category in 2019. Furthermore, he has worked alongside legends such as Prof. E. C. G. Sudarshan and Prof. N. Mukunda and also associated with IUCAA Pune. It is indeed fascinating to be exposed to multidisciplinary aspects of research and life from our teacher and we are humbled to have interacted and learnt from his vast abode of expertise. It is an honour to present him this festschrift titled 'Modern Perspectives in Theoretical Physics' based on our work with him that includes excerpts from our research theses, manuscripts and book chapters. We dedicate this collection to Prof. K. Babu Joseph—a great teacher, most importantly a great human being.

Students of Prof. K. Babu Joseph

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**Nonlinear Dynamics**

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# Cosmology

# A Non-empty Bouncing Milne Model for the Universe


**Moncy V. John**

**Abstract** In the late 1990s, a paradigm shift occurred in cosmology when observations of Type Ia supernovae indicated that our universe is undergoing an accelerated expansion at present and that this is possibly due to the presence of some otherwise unknown, mysterious 'dark energy', in addition to ordinary matter and the already speculated 'dark matter'. Just before that, a theoretical model of the universe published by the present author and Prof. K. Babu Joseph predicted a universe expanding linearly (Milne-type coasting evolution), which had a bounce from an earlier contracting epoch. It suggested the presence of dark matter and dark energy in the universe, though with densities different from that estimated by the supernova search teams. It also suggested the possibility that matter is continuously being created in the universe at the expense of dark energy. In addition to broadly agreeing with all major cosmological observations, the model has the advantage that it has no cosmological problems. The linear coasting model has several interesting follow-ups in the literature, such as the $R_h = ct$ cosmological model which are reviewed. In the second part of the present paper, I present a complex extension of the classic Milne model of the universe and show that this can lead to a bouncing non-empty, coasting cosmological model as in the case of the above coasting model. In the new model, the universe had a previous contracting phase and it emerged to the present coasting expansion phase after a bounce that occurred during a very small time of the order of Planck time. The present model has the advantage that the space-time attains the usual Lorentzian signature for the metric tensor after the Planck epoch, though at the minimum radius corresponding to the bounce, the signature is Euclidean.

**Keywords** Physical cosmology · Coasting models · Quantum cosmology

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## 1 Introduction

A cosmological solution to Einstein's general theory of relativity [1–4] was obtained by A. Friedmann in the early 1920s. This first suggested an expanding universe, though the solution was not widely noticed at that time. It is interesting to note that even Einstein himself believed in the prevailing paradigm of 'static universe' during that period and did not heed to the prediction of general relativity that the universe is either expanding or contracting. Hubble's observation in 1929 that the redshifts of galaxies and their apparent magnitudes obey certain relation was interpreted as evidence to an expanding universe. This model was based on only two basic principles in addition to general relativity: (1) the universe is homogeneous and isotropic at large scales and (2) it contains only ordinary matter. But in the 1930s itself, astronomical observations such as that of galaxy rotation curves suggested that the visible matter is not the entire component of the universe. It may contain some invisible matter, which is even now called 'dark matter'. Such a model of the universe that contains ordinary matter, possibly along with some dark matter, provided a satisfactory picture of the universe with an initial singularity and a very hot early phase. This model is now famous as the hot big bang model and had several successes like the prediction of cosmic microwave background radiation (CMBR), which was actually observed in 1964. The two scientists, A. A. Penzias and R. W. Wilson, who made this milestone observation, were awarded Nobel prize in 1978.

The Friedmann model of the universe reigned till the end of last century, though not without opposition. An unmistakable prediction of this model was that the cosmic expansion gradually slows down (decelerated expansion) with time. A paradigm shift occurred in cosmology with the 1998 observation that standard candles such as Type Ia supernovae show exceptional dimming at very high redshifts and this turned the graph upside down and led to the notion that the universe is at present undergoing an accelerated expansion. The reason for this was speculated to be the presence of large amount of some unobservable, repulsive dark energy and this culminated in the currently popular Lambda-CDM model. Adam Riess, Brian Schmidt and Saul Perlmutter, who led the teams that made this observation were awarded Nobel prize in 2011 for their discovery.

Now, after two more decades, when the dust settles, is there evidence laid bare for a universe that is neither accelerating nor decelerating? Was the universe expanding linearly throughout its history, with a constant expansion rate? A universe that expands with a constant expansion rate is said to be 'coasting'. Such a straightening of the graph may mark yet another milestone in the development of cosmology. This is now discussed in a large number of papers published in leading journals of astronomy. In the first part of this paper, we discuss various coasting cosmological models, starting from the first such model by the British astronomer A. Milne. The Milne model is still considered in the literature as an interesting, albeit unphysical model. We also review briefly the first realistic eternal cosmological model with

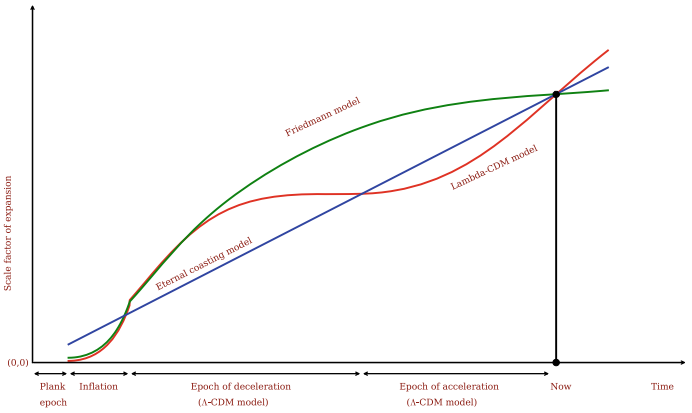


**Fig. 1** Graphs showing expansion of the universe in different models (not to scale). Cosmic time is taken along the x-axis and the scale factor of expansion along the y-axis. There is no graph drawn for the Planck epoch. Following this, there occurs an exponential expansion for a short period in both Friedmann (green colour) and Lambda-CDM (red colour) models. This is referred to as the epoch of 'inflation'. Afterwards, the Friedmann model has only a decelerating phase, but the Lambda-CDM model has a decelerating phase followed by the recent accelerated expansion. The eternal coasting model (blue colour) has the most simple 'linear expansion' all throughout the history of the universe (On the time axis, various epochs for the Lambda-CDM model are marked.)

an initial bounce proposed and studied by the author, along with Professor K. Babu Joseph. In the second part, we present such a new realistic and physical eternal coasting cosmological model obtained through a complex extension of the Milne model (Fig. 1).

## 2 Eternal Coasting Models of the Universe

### *2.1 Cosmological Problems*

Several problems, such as those referred to as the horizon problem, flatness problem, monopole problem, etc., were identified in Friedmann cosmology during the 1980s, but the theory of inflation [5] solved most of them at one stroke. But time and again, some other problems too came up in connection with this model. The theory of inflation, which speculates quantum field theoretical effects in the early epochs, suggests that the present universe is flat. In fact, the most important prediction of the inflationary models is that the universe is almost spatially flat. This in turn implies for a Friedmann model that the combination $H_0 t_0 \approx 2/3$, where $H_0$, the present Hubble constant is a measure of the expansion rate of the universe and $t_0$, the present age of the universe, i.e. the time elapsed since the big bang singularity. A major set back to inflationary models was in fact this prediction. Some observations in the