Unified Field Theory: Indians' Part of Research

Raja Kishore Paramguru

Abstract

This paper presents a brief account of contributions of Indian researchers to UFT research. It started with the famous Satyendra Nath Bose in early 1950s, and continued with Gaganbihari Bandyopadhyay, J. R. Rao, Ratna Shanker Mishra, and the USA based Jogesh Chandra Pati. Many others, either in association with them, or independently, also contributed. Indian contribution to UFT research may be termed commendable, though, similar to Einstein's original work, it falls short of achieving a complete unification of forces, leaving the field open for future exploration.

Key Words: *Unified Field Theory, Grand Unified Theory, Field Equations, Affine Connection, Mixed Geometry, Divergence Identities, Empty-Space Solutions, Linear Equations, Tensorial Objects.*

Introduction

More than one hundred years have passed by since Albert Einstein (1879-1955), the initiator of the idea of 'unified field theory (UFT)' made the first announcements on the subject during 1920s. Following it, volumes of research have been conducted. As UFT is highly relevant to the objective of our journal, a series of short reviews on UFT were published by the present author starting with [Paramguru 2025a]. This one presents the activities of Indian scientists on the subject. The motivation for this one arose from the fact that the noteworthy historical coverage on UFT between 1930-1965 in *Living Reviews in Relativity* by the German theoretical physicist Hubert Goenner [2014], besides uttering 'India' and 'Indian' at various places; and quotes like, '(I)in the 1970s and 1980s, many papers on exact solutions of the Einstein-Schrodinger theories and alternatives were published by Indian scientists' [181]; assigns two pages [158 and 159] for Indians' research on this subject. It may also be noted that in the same review a total of 723 references has been cited out of which 37, more than 5 per cent, are authored by 15 Indians. Obviously, this situation calls for a discussion on the subject.

The Indians' contribution to UFT has also been briefly covered in the earlier publication [Paramguru 2025b]. The Indian scientists cited by Goenner [2014] start from Satyendra Nath Bose, to Ratna Shanker Mishra, Gaganbihari Bandyopadhyay and twelve others. It has been found from literature that their contributions were highly significant, and they also continued to research and publish afterwards till they were active.

Therefore, the present review will discuss major parts of the UFT research conducted by these Indian scientists as reported by Goenner [2014], and will also include their contributions afterwards during the 1970s and 1980s as found in literature. In addition, the work of American-Indian physicist Jogesh Chandra Pati will also be added, since his contribution is significant.

Satyendra Nath Bose

Satyendra Nath Bose was probably the most renowned Indian scientist referred to by Goenner, and hence, he went ahead in a note: 'This is Satyendra Nath Bose (1894-1974) of the Einstein-Bose statistics.' Our readers also deserve a brief mention here about the Einstein-Bose statistics fame. During 1924, a thirty-year Bose submitted a four-page research paper titled 'Planck's law and the light quantum hypothesis' to the journal *Philosophical Magazine*, which was rejected for publication; then Bose did the wisest thing possible, sent it straight to Einstein for his comment with a hand-written cover letter. Einstein liked the paper, immediately acknowledged the receipt as well as the worthiness of the same, translated it to German language and sent it to the German journal *Zeitschrift fur Physik*, and it was published in its 1924 August issue [Debnath 1993, 636]. It was the beginning of quantum statistics, and soon Bose's name was reflected in the sub-atomic particle 'boson', and the theoretical term in physics, 'Bose-Einstein condensate.' Bose continued his research as well as his contact with Einstein, the fame of the later facilitated a two-year leave for research and study abroad in Europe with research fellowship and full travel expenses for Bose from his employer Dacca University during 1924; Bose got a chance to work in the laboratory of Madame Curie at Paris, and finally met Einstein at Berlin in 1925 [628]. From Berlin, getting selected for the position of professor and Head of Physics Department of Dacca University, with recommendation of Einstein, Bose came back to India during 1926 and continued working at Dacca University till 1945 when he got a chance to come back to his 'Alma mater' as the renowned Khaira Professor of Physics, then during 1950-56 was Head of the Department of Physics. Amongst the numerous honors received by him include Fellow of Royal Society of London, and the second highest Indian civilian award Padma Bibhushan [629].

During the 1910s and early 1920s Bose was interested in Einstein's hot topic of the time - relativity, and along with M. N. Saha, brought out a book *The Principles of Relativity* in 1920. However, when he met with Einstein during 1925, he learned that Einstein had shifted his interest to unified field theory. Though Einstein spent the rest of his life researching on UFT, Bose never thought of doing any research on this subject. However, since 1948, he revived his early interest and published five papers, four of them in French, during 1953-1955 at various aspects of UFT [Bose 1953a, Bose 1953b, Bose 1953c, Bose 1954, and Bose 1955]. During 1994, S. N. Bose National Centre for Basic

Sciences, Calcutta, has brought out a book, *S N Bose: The Man and His Work – Part I: Collected Scientific Papers*, edited by a group of editors with Santimay Chatterjee as chief editor, where all of these five papers have found place including English translation of the French papers [Chatterjee 1994]. In the first paper, Bose dealt with the divergence identities used in UFT in an easier way, whereas, in the second paper, he dealt with a complicated Lagrangian [26]. The last three papers of Bose were dealing with the field equations and their solutions [30]. Goenner [2014] has referred, not all five, but only three of Bose's papers [Bose 1953a, Bose 1954, and Bose 1955] and has indicated that Bose rewrote the particular field equation into an inhomogeneous linear equation for tensorial objects, which was homogeneous and linear in T [Bose 1955]. He then considered the equation as a matrix equation, went ahead for its solution [Bose 1954 and Bose 1955]. It appears that many others including Einstein and Kaufman have gone in for the solutions. Goenner's final statement on this issue is: "Although the method is more transparent than Tonnelat's, the solution is just as implicitly given as hers [2014, 112]."

To be honest, it is really difficult to understand whether Bose had any contribution to UFT without going technically into his research. Here comes another way out to have some idea of his contribution from the Horse's mouth, i.e., Einstein's mouth. Like his 1924 paper, Bose also supplied his research papers to Einstein at Princeton, and Einstein wrote his own comments through two letters to Bose, one (type-written) on 4th October 1952, and the other (hand-written) on 22nd October 1953; and both are published [Chatterjee 1994, 27-29]. Chatterjee's edited book [1994] also puts Einstein's mind on this issue very precisely, "(T) thus to Einstein the crucial problem was: 'Do the singularity-free solutions of the equation system have physical meaning? Are there at all singularity-free solutions which correspond to the atomistic character of matter and radiation?' From this view point the solution of those equations is not of great help [31]." According to Debnath [1993, 643]: "Indeed Bose had a number of contributions to the unified field theory including some major changes in the field equations. He obtained the general solution of Einstein's field equations connecting the basic field quantities and affinities in the non-symmetric field theory. ---. But, according to Einstein, Bose's work broke no new ground on the subject." This is probably the exact gist of Einstein's two letters to Bose. One thing can be said that Einstein knows exactly what Bose did.

Gaganbihari Bandyopadhyay

Goenner's two pages for section 13.3 describing research by Indians starts with: "In a short note, the Indian theoretician G. Bandyopadhyay[293] considered an affine theory using two variational principles such as Schrodinger [553] had suggested in 1946 [9] [158]." Here, the bracketed numbers 553 and 9 refer to the work of respectively Schrodinger and Bandyopadhyay, the superscript number 293 duly refers to the note 293 which the author considers apt to give a short introduction on Bandyopadhyay. We learn that Bandyopadhyay was associated with Government College, Darjeeling, IIT Kharagpur and then University of Calcutta from where he retired as Professor from Department of Applied mathematics. Goenner [2014] has cited five papers of Bandyopadhyay [1951a, 1951b, 1953, 1960, and 1963]. The first paper provides particular solutions, as the title suggests, for Einstein's then unified field theories. In fact, the symmetry of so called "1-dimensional" gravitational fields of Einstein's general relativity, i.e., those for which the metric components depend on only a single coordinate, is high enough to try and solve for them field equations of UFT. Bandyopadhyay had found such a solution of the *weak* equations [1951a]. The second paper, published in the epic journal *Nature*, analyzed the non-symmetric tensor field variables ($g_{\mu\nu}$) in Einstein's unified field theory, specifically examining isolated singularities [Bandyopadhyay 1951b]. The third paper, the gist of which is quoted in the first line of this paragraph, considered an affine theory using two variational principles as suggested by Schrodinger earlier, generated the field equations, and also gave the solution [Bandyopadhyay 1953].

Bandopadhyay's fourth paper started from his second paper, where one of his claims was that for the *strong* equations m e = 0, here m, e are the parameters for mass and charge, a discussion took place whether isolated mass-less magnetic monopoles could exist. In 1960, he came back to this question in his fourth paper and claimed that the *stronger* equations will not allow isolated magnetic poles with mass whereas the *weaker* equations will allow the existence of such entities [1960, 427]. His fifth paper is development of a theorem on spherically symmetric solutions in unified theory, which holds good for both Einstein's and Schrodinger's unified theories [Bandyopadhyay 1963]. He worked on *para-form* field equations in Schrödinger's unified theory, focusing on static spherically symmetric fields; and showed that for certain plane-symmetric field structures, solutions in Schrödinger's unified theory could be generated from known *empty-space* solutions of the general theory of relativity. His research was notable for extending solutions from *empty-space* conditions to those containing electromagnetic fields, providing insight into how physical situations could be generated in unified theories. As will be shown later, his work has motivated other Indian researchers and they have also extended his research further.

Goenner puts a categorical statement that - "(T) the generation of exact solutions to the Einstein-Schrodinger theory became a fashionable topic in India since the mid-1960s" [158]. Following a suggestion of G. Bandyopadhyay, R. Sarkar published two papers [Sarkar 1965 and Sarkar 1966]. In the first paper, he assumed the asymmetric metric to have the form, where, x^0 is used instead of x^4. Then, as a physical interpretation, he offered the analogue to a Newtonian gravitating infinite plane. The limit in the metric components led back to Bandyopadhyay's solution [1951a] and he brought out the solution; and he could also remove some printing errors from Bandyopadhyay's text. In his second paper [Sarkar 1966], Sarkar used the asymmetric metric again, and found that the solutions are static and with coordinate singularities. No physical interpretation was given.

Physicist N. N. Ghosh from the Department of Pure Physics of Calcutta University has published three papers [1955, 1956, and 1957] which have also been referred to by Goenner [2014, 159]. These papers deal with the general solution of field equations, specifically in the *strong* form, in Einstein's unified field theory, where he has tried products of functions depending on different coordinates for the components of the asymmetric metric in his attempt at solving the *strong* field equations. However, Goenner comments that due to his awkward index notation and use of many ad-hoc additional assumptions, Goenner could not find out what kind of new exact solutions he has found; a clearer presentation might have helped [159].

There are some contributions from many other researchers, mostly one, or two publications by each, which are not being taken up here; however, their names are being mentioned: B. R. Rao, V. V. Narlikar, K. B. Lal and S. P. Singh, S. N. Gupta, S. Datta Mazumdar, and A. R. Roy and C. R. Datta. But one person who could make it to the 'IIT Kharagpur Foundation (USA) Newsletter' (volume 12.22.2024) with the article, 'From IIT Kharagpur to Einstein's Equations: The Story of J. R. Rao' will have a special mention.

J. R. Rao

Goenner has referred to two papers of J. R. Rao [1959 and 1972] but has commented that "(T)there exist a number of helpful review articles covering various stages of UFT like --- Rao [504], ----" [2014, 10]. This mention, in itself, should be considered as praise-worthy. However, there remains a bigger story to be told. J. R. Rao was belonging to the then Department of Mathematics of IIT Kharagpur to which Professor G. Bandyopadhyay was also once belonging before shifting to the University of Calcutta. In one of his papers, Rao expresses his deep sense of gratitude to Professor G. Bandyopadhyay for his helpful discussions and encouragement. This indicates a professional link between the two. However, what is the most significant fact in our context right now is that this mathematician as well as IITKgpean J. R. Rao successfully defended his PhD thesis 'Some Problems in Einstein's Unified Field Theory of 1945' during 1962. And the story in the IIT Newsletter is based on the synopsis of this PhD thesis.

It is a well-known fact that Albert Einstein proposed the UFT in 1945 and scores of research was continuing at that time, because Einstein's original equations contained non-symmetric tensors which raised the questions of mathematical consistency and solvability. Rao did the right thing by doing a deep review of all the issues of Einstein's theory such as derivation of field equations, linear relations, exact solutions, and physical interpretations. He did also look into alternate approaches including works by Schrodinger and Weyl. Finally, he offered three propositions: (i) a special type of symmetry and coordinate system leading to an explicit field structure that resembled the infinite plane analogy in general relativity, (ii) a “rigorous solution”, as well as, (iii) a “restricted weaker form” solution, those were derived by simplifying certain constants. Of course, similar to Einstein’s original work, according to the story of IITKgp Foundation, Rao’s dissertation falls short of achieving a complete unification of forces, leaving the field open for future exploration.

Rao’s contribution to the UFT is not limited to his PhD thesis; rather, it is well extended to several publications mostly in association with his coauthors. Here, not all of them, but just a couple of them are cited [Rao and Tiwari 1974, Mohanty, Tiwari, and Rao 1982]. In the first one, the authors provide a theorem, which in their own words – ‘we may say that we can pass from a special empty-space solution of general theory of relativity to the solutions of unified field theory. It is indeed highly gratifying to be able to build physical solutions either in general theory of relativity or in unified theories from the empty-space solutions which form a solid base for Einstein’s gravitational theory’ [1974, 595]. Similarly, a couple of sentences are cited from the later paper, which describes, in their own words, their own contribution to UFT: ‘(Rao et al [13][14][15]) have obtained a class of solutions for cylindrically symmetric coupled zero-mass and source free electromagnetic fields described by Einstein-Rosen metric and have interpreted these solutions mainly from the view point of their singular behaviour. In a separate investigation they (Rao et al [16][17][18][19]) have extended the study to the case of Brans-Dicke theory’ [1982, 238]. There is also a mention in Rao’s coverage in the IIT Kharagpur Foundation Newsletter – The work connected Rao’s solutions to those obtained in some earlier works by Indian physicists Ghosh and Bandyopadhyay.

Here, one more Indian, Dipak Kumar Sen will be described, because he also appears as flashy as Rao. Goenner has cited four of Sen’s contributions, including one PhD thesis [1958], one book [1968], two papers with one coauthor in each [Sen and Dunn 1971, and Sen and Vanstone 1972]. The specialty of the PhD thesis is that it is in French and submitted to the faculty of science at Paris, which Goenner mentions – ‘In the thesis of D. K. Sen began [174] with G. Lyra in Goettingen and finished in Paris with M. A. Tonnelat, ---’ [175]. The thesis is about a novel unified theory for a static cosmological model of the universe based on Lyra’s geometry [Sen 1958]. Of course, in later developments of the theory by Sen and his coworkers in the 1970s, it was interpreted just as an alternative theory of gravitation (scalar-tensor theory) [1971 and 1972]. The book *Fields and/or particles* [1968] is solely based on the PhD thesis and attracts the comment from Goenner – ‘(T)to my knowledge, the only textbook including the Einstein-

Schrodinger non-symmetric theory has been written in the late 1960s by D. K. Sen [572].' [2014, 10]. By the time the book was published, Sen had shifted to the Department of Mathematics, University of Toronto, Canada.

Ratna Shanker Mishra

Along with Gaganbihari Bandyopadhyay, Ratna Shanker Mishra (1918-1999) also appears (*Ratan* appears in place of *Ratna*) in section 13.3 where research of Indians is described. From amongst Indians, Goenner has cited the highest numbers of publications of Mishra, totaling 13, with 8 as single author [1956a, 1956b, 1958a, 1958b, 1958c, 1959a, 1959b, and 1963] and 5 with coauthors [Husain and Mishra 1956, Abrol and Mishra 1958, Kaul and Mishra 1958, Lal and Mishra 1960, and Mishra and Abrol 1960]. The note number 294 presents his credentials, of which the last but one sentence reads – 'He has been a visiting professor in many countries, and worked and published with V. Hlavaty at Indiana University.' [158]. And Goenner's description of V. Hlavaty reads – 'Hlavaty[272] is the fourth of the main figures in UFT besides Einstein, Schrodinger, and Tonnelat' [144]. This implies Mishra got the opportunity of working with the fourth main figure in the world working in UFT. One of the students of R. S. Mishra, R. B. Misra has brought out a memoir in favor of his guru as posthumously remembered by his students [2018], where it has been mentioned that – "He collaborated with Prof. V. Hlavaty at Indiana University, Bloomington (U.S.A.) twice: 1957-58 and 1961-62" [5]; and another long and big statement – "Prof. V. Hlavaty --- while working on a problem of 'Field equations' left a note on his death bed 'In case of my death or incapacitation, Prof. R. S. Mishra would be willing to complete this work'. It is so heartening that Prof. Mishra was able to complete the work which ran into 100 printed pages" [3].

Goenner's mention of Mishra's work on UFT is also wide and deep, placed at various sections. Mishra, being a mathematician, has looked into mathematical features such as 'affine and/or mixed geometry' [1956a, 1959a, Husain and Mishra 1956], 'lambda transformations' [1956b], and attempted solutions for various cases, as well as derived conditions for equations to have unique solutions [1958a, 1958b, 1959b, 1963, Lal and Mishra 1960]. According to Goenner, Mishra has also studied Einstein's last publication with Kaufman and provided a solution for its connection [1958c]. Mishra's joint paper with Abrol [Mishra and Abrol 1960] is also directed to Einstein-Kaufman version of Einstein's theory, where the authors claim that 'the equations of motion of charged particles found from the system of field equations by applying Infeld's method of approximation, fails in this peculiar theory.' Abrol and Mishra [1958] also re-wrote Bonner's field equations with the help of the connections defined earlier by Bose [1953a and 1954]. In another paper [Kaul and Mishra 1958], Mishra generalized Veblen's identities to mixed geometry with asymmetric connection, where the authors obtained 4 identities containing 8 terms each and with a mixture of ±-derivatives. It is proper, now, to reflect Goenner's overall impression on Mishra's work on UFT – "From my point of view as a historian of physics, R. S. Mishra's papers are exemplary for estimable applied mathematics uncovering some of the structures of affine and/or mixed geometry without leading to further progress in the physical comprehension of unified field theory" [2014, 158]. Such a comment is certainly praise-worthy.

One can mention a bit about Mishra's position in India. Mishra was Professor and Head of the Department of Mathematics at Gorakhpur (1958-1963) and Allahabad (1963-1968) Universities; then Head of the Department of Mathematics and Statistics at Banaras Hindu University in Varanasi from 1968 till retirement in 1978. Subsequently he was Vice-Chancellor of University of Kanpur during 1978-1980 and Lucknow University, his own *alma mater*, during 1982-1985. He was Visiting Professor, besides Indiana University, to Kuwait University, University of Waterloo, and University of Windsor. He was an invited participant in 'International Conference on General Relativity and Gravitation (GR 6)' at Copenhagen during 1971, and also (GR 7) at Tel Aviv during 1974. In India, he held various positions in academic and professional bodies. He has guided more than 50 students for PhD and DSc Degrees, published more than 300 papers and won many awards including Fellowship of almost all the established academic bodies in India. Books published by Mishra are – *Structures in a Differentiable Manifold* in 1978, *Structures on a Differentiable Manifold and Their Applications* in 1984, *Almost Contact Metric Manifolds* and *Hyper-surfaces of Almost Hermitian Manifolds* both in 1994. The Government of India has honored him with the fourth best civilian Award - ***Padmashree***.

Jogesh Chandra Pati

This name does not appear in Goenner's review. It may be because his research on UFT started with his paper along with the Pakistani Nobel Laureate Abdus Salam in 1974 only, much after ca. 1930 – 1965 [Pati and Salam 1974]. Actually during 1974 only, Glashow and Howard Mason Georgi III brought out what is called the Georgi-Glashow model, the first Grand Unified Theory (GUT). According to Goenner, in the beginning, GUTs were 'unifying only the electromagnetic, weak, and strong interactions' that is 'with gauge group SU (5)' [2014, 195]. They would have observable effects for energies much above 100 GeV.

Subsequently, many proposals for GUT have emerged; one of them is the Pati-Salem Model. (Jogesh) Pati (1937-), an Indian-American theoretical physicist, has contributed substantially in collaboration with Abdus Salam to formulate a GUT proposal called Pati-Salam model. John Ellis, from the Theoretical Physics Division of CERN, reports – 'Even before the discovery of neutral currents, the restless spirit of Abdus Salam have led him and Jogesh Pati to propose the idea of grand unification of the strong and electroweak interactions --. They are the first to propose, in a motivated way, that quarks and leptons should be treated together in a common theory' [1996, 3]. The specialty of the Pati-Salem model is its suggestions: (i) the symmetry of SU (4)-color, (ii) left-right symmetry, and (iii) the associated existence of right-handed neutrinos. They provide some of the crucial ingredients for understanding the observed masses of the neutrinos and their oscillations. After discoveries of gauge coupling unification and neutrino-oscillation, Pati himself says – '(I) in this context, it is remarked that with neutrino masses and coupling unification revealed, the discovery of proton decay, that remains as the missing link, should not be far behind' [1998, 1]. Alas, after so many years, proton decay still remains eluded.

Overall, contributions of Indian researchers, as marked above, in moderate words, can be said as commendable. Goenner has once identified five major groups working on UFT in the world through his own words – '(T)the work done in the major "groups" lead by Einstein, Schrodinger, Lichnerowicz, Tonnelat, and Hlavaty ---' [2014, 10]. In case of Indian researchers also, it can be said that five major groups lead by Bose, Bandyopadhyay, Rao, Mishra, and Pati have contributed to UFT.

Conclusion

A brief account of contributions of Indian researchers to UFT research is given. The contribution started with Satyendra Nath Bose in the early 1950s, incidentally, he shared some of the results with Einstein himself who gladly responded with his observations. The other leading researchers were Gaganbihari Bandyopadhyay, J. R. Rao, whose own PhD thesis was on this subject and was highlighted in the IIT Kharagpur Foundation (USA) Newsletter during 2024 (after 62 years of PhD defense in 1962), Ratna Shanker Mishra, who availed the opportunity to work with Professor Hlavaty at Indiana University, and the USA based Jogesh Chandra Pati. Indian contribution to UFT research may be termed commendable, though, similar to Einstein's original work, this research falls short of achieving a complete unification of forces, leaving the field open for future exploration.

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