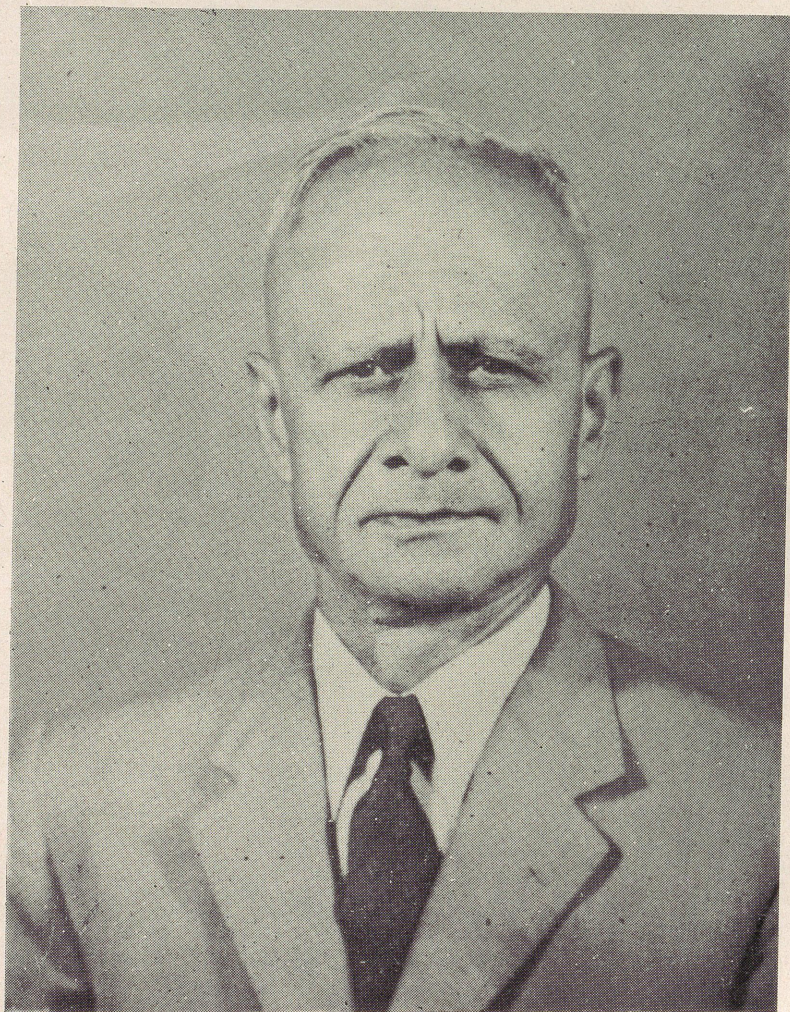


Biographical Memoirs  
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B.S. Mshwaka

## BANGALORE SRINIVASA RAO MADHAVA RAO

(1900-1987)

**Elected Fellow 1953**

### BIRTH AND EDUCATION

BANGALORE SRINIVASA RAO MADHAVA RAO was an eminent Professor of Mathematics, an outstanding teacher of Mathematics, a distinguished Research Scientist, a keen sportsman and a sagacious educational administrator, all rolled into one. He was born on 29th May 1900 at Chamarajanagar, a small town near Mysore City in the State of Karnataka (then the princely State of Mysore). Madhava Rao's ancestors were Sarpeshkars - accountants in the Mahratta army - and his grand father Rama Rao Sarpeshkar, migrated from Poona (Pune) to Mysore province in the early part of the last century. Srinivasa Rao, a son of Rama Rao, opted to the teaching career in preference to accountancy and in due course, became the Head Master of a High School. His wife was Smt Raji Bai. Srinivasa Rao had five sons and Madhava Rao was the third among the five. Madhava Rao was a precocious and disciplined child. He grew to be a brilliant student and invariably scored high positions in all the examinations. He completed the first examination of arts (equivalent to the present Intermediate Examination) of the University of Madras in 1917, securing the first position for the entire province and joined the BSc course with Mathematics as the main field of study. He received the BSc Degree in 1919 from the then new University of Mysore, standing first in rank. He then moved to Calcutta for Post Graduate Study in Pure Mathematics and obtained the MSc Degree from the University of Calcutta in 1921, securing a first class and standing second in rank.

Administrative Services held a great attraction to brilliant young men in those days. For young Madhava Rao however, this was not so and he made a private resolution to seek teaching as a career and advanced study and research in Mathematics as a profession. All through his student-days and even in later life, Madhava Rao was much devoted to out-door games and made mark as a keen sportsman.

The son of a teacher as Madhava Rao was, study and thirst for knowledge were ingrained in him. The two-year sojourn (1919-1921) at Calcutta provided him opportunities to see the great statesman of education Sir Ashuthosh Mukherjee and stalwarts like Professor CV Raman, busily occupied with intense research activity. Madhava Rao's private resolve to devote himself to teaching and research became firmly rooted.

After MSc degree (1921) and a brief stint as a Research Scholar, Madhava Rao secured in 1922 the job of Lecturership in Mathematics in the newly started College of Engineering (the present Visweswaraiiah College of Engineering). In 1926 he was elevated to Assistant Professorship in Central College (of Science), Bangalore and four years later, in 1930, he went back to the College of Engineering as Professor of Mathematics. Hand in hand with his teaching obligations and activities on the sports field, Madhava Rao started research in Mathematics in a big way and this activity received a big fillip with the arrival in Bangalore, of Prof Max Born, the eminent theoretical Physicist (who later became a Nobel Laureate). Madhava Rao drew whatever advantage that was possible from the brief sojourn (October 1935 - April 1936) of Prof Max Born and published a series of research papers on Born's non-linear field theory and obtained the DSc degree in 1938 from the University of Calcutta.

### CAREER

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The classical theory of the electromagnetic field based on Maxwell-Lorentz field equations can satisfactorily explain the propagation of electromagnetic waves in space, the field produced by a given charge distribution and includes a theory of emission of light. The field equations are Lorentz - invariant. However, in the problem of the interaction of the field with elementary particles, difficulties arise since the energy of the field is infinite in the case of a point charge. Also the process of quantization of the field leads to the conclusion that for light of wave length much less than the Compton wave length, electron pairs can be treated even in vacuum. At very high energies the theory does not agree with experiment. Born-Infeld theory of Electro-Dynamics was proposed, basing it on a different action integral and this agrees with Maxwellian theory for weak fields. The electron appears as a point singularity of the field with no divergence or any other difficulties. Madhava Rao examined the ring - singularity model for the electron instead of the point singularity model and showed under suitable assumptions that no model with the possible exception of a point singularity, is appropriate for the representation of elementary particles. He obtained a very general form of the action integral from which the field equations are derivable in a standard way, including certain invariants that had been ignored in earlier treatments.

The German Nobel Laureate J Stark had proposed a ring structure for the electron in a 1938 paper. Madhava Rao's preoccupation with the possible ring structure was earlier to this paper of Stark and Madhava Rao's critical observations on Stark's work and the latter's reply were published in *Phys Z.* (1939). Stark had ignored the principles of Relativity since he did not subscribe to those ideas and in consequence some errors in Stark's proposed ring structure were inevitable. A further reply by Madhava Rao with strong objections to Stark's observations was published in the same journal and there was no further response from Stark (Sl. Nos. 21, 22 of the bibliography, 1937 - the first two reference).

In a paper of 1938 in the *Proc. Indian Acad. Sci.* 7 p. 293 (Sl. No.22; first reference of 1938), Madhava Rao pointed out the inadequacy of the Newtrino Theory of Light to explain many properties of light, thus countering a view held by many upto that time.

Madhava Rao's work on Born's non-linear field theory came to be referred to as Madhava Rao's Theory of Action Functions in the *Poincare Institute Memoirs* of 1938. In a private communication, Prof W Pauli explained how some of the points raised by Madhava Rao regarding Born's non-linear field theory could be satisfactorily explained.

Madhava Rao himself was of the view that his research work regarding the application of the theory of groups and group representations in the theory of elementary particles was the most important of his contributions. This was done over a period of six years (1941-1947). His joint paper with HJ Bhabha (1941) showed that with the latter's idea of allowing elementary particles to exist in all states of integral charge, the scattering of charged mesons shows complex correspondence with the classical theory. Madhava Rao was then led to the study of Dirac's relativistic wave equation of the electron and he saw

that the spin of the electron which had been *postulated* in order to explain spectroscopic data, indeed emerged as a natural *consequence* of the Dirac equation formulated to satisfy relativistic invariance. He also saw later that the particles of higher spin that are either integers or halves of odd integers ( $= n/2$ ,  $n =$  a positive integer or zero) could also be described by a similar equation but with the  $\rho$  matrices satisfying other appropriate commutation relations. He then examined the algebra of the original Dirac  $\beta$  -  $\beta$  matrices and of those corresponding to higher spins. In the algebra of the Dirac  $\beta$  - matrices, he obtained generalizations of certain algebraic identities of W Pauli and also derived certain general types of multi-linear and polynomial identities. To study the commutation relations of  $\beta$ 's for arbitrary spins and give them in a compact form, Madhava Rao developed a method of deriving the commutation relations for arbitrary spin assuming (i) relativistic invariance of the wave equation, (ii) that the spin operator  $S_{uv}$  has the special structure  $\beta_u \beta_v - \beta_v \beta_u$  and (iii) that the eigen values of the spin operator are equal to  $\pm \frac{1}{2} n$  ( $n =$  an integer). For spins  $= 3/2$  and  $2$  the commutation relations were given in a single compact equation. Explicit work of the full algebra of the  $\beta$ - matrices in the case of spin  $= 3/2$  showed that it is the direct product of the algebra of Dirac matrices and another algebra. The general case of S - element  $\beta_u$  was studied and the number and order of the several irreducible representations of the generalized s - element  $\beta$  - algebra corresponding to spin  $= \frac{1}{2} n$  were obtained. In a private communication in April 1949, the eminent algebraist N Jacobson thanked Madhava Rao for drawing the former's attention to the above result and expressed his view that this factorization of the algebra of the  $\beta$  - matrices was very interesting and that the possibility of physical significance of these algebras delighted him.

#### AWARDS AND MEMBERSHIP

That Madhava Rao's research in the field of the algebra of elementary particles constitutes a significant contribution to the subject is beyond doubt. It is appropriate to recall that in the book of EM Corson on spinors, tensors and relativistic wave equations published by Princeton University Press in 1953, reference is made to all the publications of Madhava Rao in the theory of elementary particles. Earlier in 1947, he was awarded the Ramanujan Memorial Prize by the University of Madras for his work in the study of elementary particles.

Madhava Rao was a Life Member of the Indian Mathematical Society and was a member of its council for several years. He was President of the Society for two years (1959-1961) and presided over the conferences of the Society held at Allahabad (1959) and Chandigarh (1960). He was also a member of the Calcutta Mathematical Society. With the Indian Academy of Sciences, Madhava Rao had a deep and lasting association. He was elected a Fellow of the Academy (1936) and was the Secretary as well as Editor

of the Section A of the Proceedings of the of the Indian Academy of Sciences for several years. In 1956, he became a Vice-President of the Academy. He was also a Fellow of the Indian National Science Academy (then National Institute of Sciences of India) from 1953. He presided over the Mathematics Section of the Science Congress, held at Madras in January 1958. He was also a Fellow of the Royal Astronomical Society.

### PERSONAL LIFE

Madhava Rao enjoyed a happy married life. His marriage with Smt Subhadra Bai (an apt name, since Madhava Rao was Arjuna among the five sons of his parents) in June 1922 proved to be a great event in his life. Both of them had a fine sense of aesthetics and love of gardening was a hobby common to both of them. Both of them also enjoyed listening to classical music. They had five daughters and two sons. The eldest daughter Smt Shakuntala is married to Sri V Narayana Rao who headed the Defence Electronics Research Institute, Hyderabad for several years and is now a consultant for Electronic Systems. He has won VASVIK Award in Electronic Sciences and is also the winner of Padma Sri award from the President of India. The second daughter Smt Leelavati is married to Sri DR Jagannatha Rao who was Engineer-in-Chief, in the Public Health Engineering Department of Madhya Pradesh. The elder son Shri Arun M Sarpeshkar works as an Associate Professor in the University of Agricultural Sciences, Bangalore. The third daughter Smt Nalini is married to Lt Col EA Rajanna who is a practising Civil Engineer after retirement from the Army. The fourth daughter Smt Usha has married Shri HY Ramaiah, working as Deputy General Manager, Karnataka State Road Transport Corporation, Bangalore. Smt Usha is the Secretary of Bharat Scouts and Guides Organization and was the first woman from Karnataka to participate in mountaineering in the Himalayas. The second son Dr Ashok M Sarpeshkar is an Organic Chemist and is now in USA as a Research Chemist in Mobay's Organization, West Virginia. The fifth daughter Km Chitra Sarpeshkar is a Medical Doctor and is presently working in USA.

Madhava Rao was an admirer of free India's first Prime Minister Shri Jawaharlal Nehru and appreciated the latter's efforts in stressing the importance of Science and Technology for the progress of the country. He had great faith in the future of the country and was confident that it would rise to prominent position among the advanced countries of the world.

Till the very end of his life Madhava Rao interested himself in the intellectual study of recreational Mathematics, particularly magic squares. The tome on this topic compiled by him was indeed a labour of love and deep study. One may hope that this material will emerge in book form with minimum gestation time.

## ACKNOWLEDGEMENT

I am beholden to my teacher Dr VR Thiruvengkatachar for suggesting the preparation of this biographical memoir. To Shri V Narayana Rao, former Director of Defence Electronics Research Laboratory, Hyderabad I am much obliged for making available the necessary material and information needed for preparing this write-up.

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Madhava Rao was active in research for over three decades and his research publications exceed 60 (an exhaustive bibliography is enclosed). His field of interest in the early phase was the geometry of cubic curves; later he turned his attention to classical analytical mechanics and after his brief association with Prof Max Born (1935-1936), he changed to Quantum Mechanics, specifically the non-linear field theory of Born. In later years he was much interested in the theory of elementary particles, particularly, the algebra of associated matrices.

The classical theory of the electromagnetic field based on Maxwell-Lorentz field equations can satisfactorily explain the propagation of electromagnetic waves in space, the field produced by a given charge distribution and includes a theory of emission of light. The field equations are Lorentz - invariant. However, in the problem of the interaction of the field with elementary particles, difficulties arise since the energy of the field is infinite in the case of a point charge. Also the process of quantization of the field leads to the conclusion that for light of wave length much less than the Compton wave length, electron pairs can be treated even in vacuum. At very high energies the theory does not agree with experiment. Born-Infeld theory of Electro-Dynamics was proposed, basing it on a different action integral and this agrees with Maxwellian theory for weak fields. The electron appears as a point singularity of the field with no divergence or any other difficulties. Madhava Rao examined the ring - singularity model for the electron instead of the point singularity model and showed under suitable assumptions that no model with the possible exception of a point singularity, is appropriate for the representation of elementary particles. He obtained a very general form of the action integral from which the field equations are derivable in a standard way, including certain invariants that had been ignored in earlier treatments.

The German Nobel Laureate J Stark had proposed a ring structure for the electron in a 1938 paper. Madhava Rao's preoccupation with the possible ring structure was earlier to this paper of Stark and Madhava Rao's critical observations on Stark's work and the latter's reply were published in *Phys Z.* (1939). Stark had ignored the principles of Relativity since he did not subscribe to those ideas and in consequence some errors in Stark's proposed ring structure were inevitable. A further reply by Madhava Rao with strong objections to Stark's observations was published in the same journal and there was no further response from Stark (Sl. Nos. 21, 22 of the bibliography, 1937—the first two reference).

In a paper of 1938 in the *Proc. Indian Acad. Sci.* 7 p. 293 (Sl. No.22; first reference of 1938), Madhava Rao pointed out the inadequacy of the Newtrino Theory of Light to explain many properties of light, thus countering a view held by many upto that time.

Madhava Rao's work on Born's non-linear field theory came to be referred to as Madhava Rao's Theory of Action Functions in the *Poincare Institute Memoirs* of 1938. In a private communication, Prof W Pauli explained how some of the points raised by Madhava Rao regarding Born's non-linear field theory could be satisfactorily explained.

Madhava Rao himself was of the view that his research work regarding the application of the theory of groups and group representations in the theory of elementary particles was the most important of his contributions. This was done over a period of six years (1941-1947). His joint paper with HJ Bhabha (1941) showed that with the latter's idea of allowing elementary particles to exist in all states of integral charge, the scattering of charged mesons shows complex correspondence with the classical theory. Madhava Rao was then led to the study of Dirac's relativistic wave equation of the electron and he saw

that the spin of the electron which had been *postulated* in order to explain spectroscopic data, indeed emerged as a natural *consequence* of the Dirac equation formulated to satisfy relativistic invariance. He also saw later that the particles of higher spin that are either integers or halves of odd integers ( $= n/2$ ,  $n =$  a positive integer or zero) could also be described by a similar equation but with the  $\rho$  matrices satisfying other appropriate commutation relations. He then examined the algebra of the original Dirac  $\beta$  matrices and of those corresponding to higher spins. In the algebra of the Dirac  $\beta$  matrices, he obtained generalizations of certain algebraic identities of W Pauli and also derived certain general types of multi-linear and polynomial identities. To study the commutation relations of  $\beta$ 's for arbitrary spins and give them in a compact form, Madhava Rao developed a method of deriving the commutation relations for arbitrary spin assuming (i) relativistic invariance of the wave equation, (ii) that the spin operator  $s_{uv}$  has the special structure  $\beta_u \beta_v - \beta_v \beta_u$  and (iii) that the eigen values of the spin operator are equal to  $\pm \frac{1}{2} n$  ( $n =$  an integer). For spins  $= 3/2$  and  $2$  the commutation relations were given in a single compact equation. Explicit work of the full algebra of the  $\beta$ -matrices in the case of spin  $= 3/2$  showed that it is the direct product of the algebra of Dirac matrices and another algebra. The general case of S - element  $\beta_u$  was studied and the number and order of the several irreducible representations of the generalized s - element  $\beta$  - algebra corresponding to spin  $= \frac{1}{2} n$  were obtained. In a private communication in April 1949, the eminent algebraist N Jacobson thanked Madhava Rao for drawing the former's attention to the above result and expressed his view that this factorization of the algebra of the  $\beta$  - matrices was very interesting and that the possibility of physical significance of these algebras delighted him.

#### AWARDS AND MEMBERSHIP

That Madhava Rao's research in the field of the algebra of elementary particles constitutes a significant contribution to the subject is beyond doubt. It is appropriate to recall that in the book of EM Corson on spinors, tensors and relativistic wave equations published by Princeton University Press in 1953, reference is made to all the publications of Madhava Rao in the theory of elementary particles. Earlier in 1947, he was awarded the Ramanujan Memorial Prize by the University of Madras for his work in the study of elementary particles.

Madhava Rao was a Life Member of the Indian Mathematical Society and was a member of its council for several years. He was President of the Society for two years (1959-1961) and presided over the conferences of the Society held at Allahabad (1959) and Chandigarh (1960). He was also a member of the Calcutta Mathematical Society. With the Indian Academy of Sciences, Madhava Rao had a deep and lasting association. He was elected a Fellow of the Academy (1936) and was the Secretary as well as Editor

of the Section A of the Proceedings of the of the Indian Academy of Sciences for several years. In 1956, he became a Vice-President of the Academy. He was also a Fellow of the Indian National Science Academy (then National Institute of Sciences of India) from 1953. He presided over the Mathematics Section of the Science Congress, held at Madras in January 1958. He was also a Fellow of the Royal Astronomical Society. ←

### PERSONAL LIFE

Madhava Rao enjoyed a happy married life. His marriage with Smt Subhadra Bai (an apt name, since Madhava Rao was Arjuna among the five sons of his parents) in June 1922 proved to be a great event in his life. Both of them had a fine sense of aesthetics and love of gardening was a hobby common to both of them. Both of them also enjoyed listening to classical music. They had five daughters and two sons. The eldest daughter Smt Shakuntala is married to Sri V Narayana Rao who headed the Defence Electronics Research Institute, Hyderabad for several years and is now a consultant for Electronic Systems. He has won VASVIK Award in Electronic Sciences and is also the winner of Padma Sri award from the President of India. The second daughter Smt Leelavati is married to Sri DR Jagannatha Rao who was Engineer-in-Chief, in the Public Health Engineering Department of Madhya Pradesh. The elder son Shri Arun M Sarpeshkar works as an Associate Professor in the University of Agricultural Sciences, Bangalore. The third daughter Smt Nalini is married to Lt Col EA Rajanna who is a practising Civil Engineer after retirement from the Army. The fourth daughter Smt Usha has married Shri HY Ramaiah, working as Deputy General Manager, Karnataka State Road Transport Corporation, Bangalore. Smt Usha is the Secretary of Bharat Scouts and Guides Organization and was the first woman from Karnataka to participate in mountaineering in the Himalayas. The second son Dr Ashok M Sarpeshkar is an Organic Chemist and is now in USA as a Research Chemist in Mobay's Organization, West Virginia. The fifth daughter Km Chitra Sarpeshkar is a Medical Doctor and is presently working in USA.

Madhava Rao was an admirer of free India's first Prime Minister Shri Jawaharlal Nehru and appreciated the latter's efforts in stressing the importance of Science and Technology for the progress of the country. He had great faith in the future of the country and was confident that it would rise to prominent position among the advanced countries of the world.

Till the very end of his life Madhava Rao interested himself in the intellectual study of recreational Mathematics, particularly magic squares. The tome on this topic compiled by him was indeed a labour of love and deep study. One may hope that this material will emerge in book form with minimum gestation time.

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