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Prof Varma started working in plasma physics in 1958 while at the Tata Institute, and carried out some work on the acceleration of cosmic radiation. In 1961 he joined ~~the~~ Prof Marshall Rosenbluth as a Ph.D student at the University of California, San Diego (UCSD), La Jolla, ~~CA~~, completing a thesis on the theory of mirror machine plasmas. He ~~of~~ received his Ph.D in 1965. ~~A new model of~~

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Though Prof Vanna has worked on a number of different topics in plasma physics and astrophysics including the theory of mirror plasmas, tokamak plasmas, ~~in acoustic and sub~~ solutions in plasmas of various kinds, plasma-neutral gas interaction, spiral structure of galaxies, ~~large scale~~ galactic magnetic fields (a dynamical theory), etc there are two areas which represent ^{his} major thrusts and achievements.

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One of them is his work on the mirror machine plasmas, ~~wherein he first published in Nuclear Fusion (1967) wherein he~~ ^{predicted} a new mode of oscillation ~~with~~ which has come to be known as the "Vanna mode" and the "Vanna branch". The equations ~~of~~ given by him which led to this prediction have come to be known as the "Vanna equations". ~~It was~~ ^{It} has been reported by

(1972)

Prof. Varma started working in plasma physics in 1958 while he was a Research Assistant at the Tata Institute of Fundamental Research (TIFR), Bombay. As a result of this, he became familiar with and got attracted to the problem of charged particle dynamics in a magnetic field. Of particular interest was the concept of the "adiabatic invariance" which is used repeatedly in the theory of magnetized plasmas.

In 1961, Prof. Varma joined Prof. Marshall Rosenbluth as a Ph.D. student at the University of California, San Diego (UCSD), La Jolla, completing a thesis on the theory of mirror machine plasmas. A new mode of plasma oscillation reported in Nuclear Fusion (1967), which has come to be known as the "Varma mode" or the "Varma branch", was discovered by him during this period. The set of equations given by him, which gave this mode, have come to be known as the "Varma equations". This innocent looking mode with a density independent frequency of oscillation was found to be crucial to explain the observed nonlinear behaviour of mirror machine plasmas. This new mode has also motivated considerable amount of further work inter alia that involving the feedback stabilization of the mirror flute modes, where this mode has been found to be very crucial. There has been very important work carried out involving the coupling of this mode with Alfvén mode and convective cell modes, by Shukla and Stenflo, while

Abhyankar and Simon have further generalized the Varma equations.

During the period of his graduate studies at the UCSD,

Again it was noted by Zhiltsov et al that the Varma branch makes the feedback stabilization of the mirror flute mode a little more difficult, while Gribkov has shown that the incorporation of the Varma mode leads to a successful interpretation of the experimental results.

It was found by Simon and Wang that the observed nonlinear behaviour could not be explained unless this explosive mode was coupled to the other flute modes.

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somewhat mystified by the then generally accepted Copenhagen interpretation of quantum mechanics, he began to consider the question of the concept of trajectories in quantum mechanics. He was encouraged in these considerations by the Nobel Prize address of Richard Feynman which ^{came to his notice} appeared in print around 1965-66, and wherein ^{Feynman} he had recalled the development of the path integral formulation starting from Dirac's 1933 paper on the "Lagrangian in quantum mechanics". This address of Feynman served as a great inspiration. ^{Furthermore,} Two papers which appeared in the same issue of the Reviews of Modern Physics (July 1966) around that time—one by J.S. Bell questioning the von Neumann "impossibility proof" on the existence of the hidden variables, and the other by Bohm and Bub on a proposed solution of the measurement problem in quantum mechanics by a hidden variable theory—gave him confidence that the ^{reservations about} unhappiness with the current interpretation and questioning it was not so heretical after all. Such an inquiry into the quantum formalism, however, has led ^{Prof Varma} him, as is described below, to unravel hitherto unknown and rather astonishing behaviour of a classical mechanical system, ^{by} predicted ^{ing it} by him theoretically ^{and by} as well as observed ^{ing} experimentally. This ^{behaviour} is characterized by the existence of certain quantum ^{-like} properties as follow from a Schrodinger-like formalism given by him for the particular classical mechanical system.

^{Prof Varma} He began by posing to himself the rather heretical question (not posed by ^{earlier} anybody else): Is it possible for at least some classical mechanical system to have a quantum-like probability amplitude

description? It turned out, rather astonishingly, that it is. The answer came through a problem that he was engaged in during that period of time, namely the problem of the determination of residence times of charged particles in an adiabatic mirror trap. It is a challenging problem of classical mechanics, because the residence time is a nonanalytic function of a small parameter of the system. The problem was noted by Prof. Varma to be somewhat analogous intuitively to that of life time in a finite barrier potential well in quantum mechanics, where the Planck quantum \hbar is the small parameter. This led him to ask the question, whether charged particles in an adiabatic potential well of a magnetic trap could be governed by a Schrodinger-like equation in which an action associated with the system (the gyroaction μ) plays the role of \hbar .

Such a Schrodinger-like formalism was constructed by Prof. Varma in 1971 (Phys. Rev. Lett.). However, the derivation was a heuristic one, but it yielded, not one, but an infinite set of uncoupled Schrodinger-like equations for a set of probability amplitudes $\Psi(n)$ with (μ/n) , $n = 1,2,3,\dots$ in the role of \hbar . It should, perhaps, be clarified that while \hbar is a fundamental constant, the initial value of the gyroaction μ which plays its role is only a constant of motion of the system for a particular preparation. An immediate consequence of this set of equations is the existence of a multiplicity of residence life times in the adiabatic magnetic trap, corresponding to $n = 1,2,3,\dots$. Upto three such distinct residence times were experimentally identified subsequently

corresponding to $n = 1, 2, 3, \dots$. These results were reported in a series of papers in 1979, 1980, 1982 by him and his collaborators. The residence times so obtained were found experimentally to have the dependence on the strength and scale length of the magnetic field, as well as the initial pitch angle, as predicted by the equations, for the various n values.

A few comments relating to these results are in order. First, quite clearly, the Schrodinger-like formalism referred to above, represents a new paradigm for the consideration of the residence life time problem as against the conventional one which is based on the "overlap of resonances" and resulting chaotic behaviour leading to the diffusion of particles out of the trap. It may be mentioned that the existence of the multiple life times could not have been foreseen nor has it been possible to obtain them even post facto, with the experimentally found characteristics, using the conventional procedure.

To be able to predict the multiplicity of life times which were observed later with the predicted characteristics, is, of course, a triumph of the Schrodinger-like formalism. However, it was still based on a heuristic derivation whose conceptual basis was not entirely clear. This shortcoming was amended later when a derivation of these questions was given in 1985, starting from the Liouville equation for the system. This derivation may be described as a Hilbert space representation of the Liouville ^equation. It is interesting to note that

this 'deductive derivation' yielded the same set of equations as obtained earlier through the heuristic derivation.

There is, however, yet another unusual prediction that these Schrodinger-like equations make. This is the existence of interference phenomena in the classical mechanical parameter regime which inevitably follow because of the probability amplitude character of the description. They would manifest themselves in the existence of "allowed" and "forbidden" energy states if the interference takes place in the energy (frequency) domain. Such "allowed" and "forbidden" energy states have indeed been observed, astonishingly, in the classical mechanical domain of parameters and reported in a set of papers in 1993 by him and his collaborator, A.M. Punithavelu. †

These observations are, ^{therefore,} quite enigmatic when ^{looked at} viewed from the point of view of the standard classical mechanical paradigm which permits a continuum of allowed states emanating from a continuum of allowed initial conditions. It has, however, been shown by Prof. Varma in a recent paper (1994) that these effects may have their origin in the topology of the configuration ^{space} of the system induced by the magnetic field. It is also suggested by him in this paper that the Schrodinger-like description incorporates these topological effects automatically which is not obvious in the Liouville equation description.

What has been shown by Prof. Varma through these

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investigations both theoretical and experimental that there exists, even in the classical mechanical parameter domain, a probability amplitude Schrodinger-like description of an ensemble (coherent system) of charged particles in a magnetic field which has experimentally verified quantum-like consequences, such as the existence of discrete 'allowed' and 'forbidden' states.

He is now proceeding to apply these ideas and concept in the problem of the quantum mechanics itself, the quest for the understanding of whose enigma provided the motivation for the above work.

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One of them is his work on the mirror machine plasmas, published in Nuclear Fusion (1967) wherein he predicted a new mode of oscillation which has come to be known as the "Varma mode" and the "Varma branch". The equations given by him which led to this prediction have come to be known as the "Varma equations". This innocent looking mode with a density independent frequency of oscillation ^{was indeed observed and} was found to be crucial in explaining the observed nonlinear behaviour of mirror machine plasmas. It

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* The second area of his major thrust and achievement is his study of the motion of charged particles in a magnetic field and his discovery of some new and hitherto unknown properties of this motion. This development is described historically as follows:

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was found by Simon and Weng that the observed explosive nonlinear behaviour could not be explained unless this mode was coupled to the other flute modes. The new mode has also motivated considerable amount of further work interalia that involving the feedback stabilization of the mirror flute modes. Again it was noted by Zhiltsov et al (1977) that the Varma branch makes the feedback stabilization of the mirror flute mode a little more difficult, while Gribkov (1977) has shown that the incorporation of the Varma mode leads to a successful interpretation of the experimental results. There has been ^{other} very important work carried out involving the coupling of this mode with Alfvén mode and convective cell modes, by Shukla and Stenflo (1988) while Abhyankar and Simon (1974) have further generalised the Varma equations.

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measurement problem in quantum mechanics by a hidden variable theory--gave him confidence that the reservations about the current interpretation and questioning it was not so heretical after all. Such an inquiry into the quantum formalism, however, has led Prof. Varma, as is described below, to ^{some novel and} unravel hitherto unknown and rather astonishing behaviour of a classical mechanical system, by predicting it theoretically and by observing it experimentally. This behaviour is characterized by the existence of certain quantum-like properties as follow from a Schrodinger-like formalism given by him for the particular classical mechanical system.

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