# PREFACE

This volume contains the detailed text of the lectures delivered at the International Astronomical Union (IAU) Colloquium 132 held in Delhi, India, during October 10–13, 1991. This Colloquium was sponsored by Commission 7 (Celestial Mechanics) and co-sponsored by Commissions 33 (Structure and Dynamics of the Galactic System) and 37 (Star clusters and Associations). The Zakir Husain College, Delhi, was the host institution.

The main objective of the Colloquium was to review the current state of the art in the area of instability, chaos and predictability in Celestial Mechanics and Stellar Dynamics through paper presentation, Key note addresses, lectures and discussions, to expose the participants to more recent developments in various techniques, analytical as well as numerical as applicable to chaotic behaviour of trajectories in the dynamical systems and to establish contact with experts in the field to facilitate the inflow of technical information.

The whole material of this volume has been organized into five basic areas:

(i) Chaos, (ii) Ergodic and Stochastic motion, (iii) Stellar systems and Galaxies, (iv) Triple and Many Body Problem and (v) General Celestial Mechanics and Stellar Dynamics.

(i) Studies on nonlinear dynamics and emergence of chaos are of growing interest at the present time. Chaotic phenomena have brought new mathematical ideas and analytical techniques. The subject is fascinating because of its interplay of Science, mathematica and technology. In this part various aspects of chaotic phenomena have been presented by various Scientists. Bhatnagar in his introductory article on chaos has given the definition of chaos, source and tools of chaos, routes to chaos, measurement of chaos and chaos through resonance. Some problems relating to chaos in the Solar system have been described. Instability of orbits in dynamical systems leading to chaos has been reviewed by Saha. Kurth, by taking a simple nonlinear dynamo model have studied qualitatively the dynamics of the global solar activity exhibiting a rich dynamical behaviour from steady state via some bifurcation to a chaotic regime. Laskar, while establishing the

chaotic nature of the solar system by the numerical computation of the maximum Lyapunov exponent of its secular system over 200 Myr., has given an explanation for the exponential divergence of the orbits. Maciejewski has proven that the problem of perturbed planar oscillations of a rigid body in circular orbit is non-integrable. Nuritdinov has discussed the role of chaos and instability in evolution of nonlinear, non-stationary stellar system. Rajeskar has discussed how chaotic dynamics can be converted into regular motion in Bonhoeffer van del Pol oscillator. Sastry has discussed vector Laypunov functions and stabilities and chaoticities of functional differential equations occurring in Celestial Mechanics and Stellar Dynamics. Subbarrao and Uma in their paper have given a basic research for collisionless of galactic model that collective motion not only introduces Landau damping but also intrinsic chaos of typical star dynamics in the phase plane. Yi-Sui Sun has numerically studied the perturbation extension of area preserving mappings to three dimensional once, in which the fixed points of the area preserving are elliptic, parabolic or hyperbolic respectively.

(ii) Scientists throughout the world have shown an increasing interest to the problem of ergodity (or stochasticity) of motion in the deterministic dynamical system with few degrees of freedom. Here, Agekian has studied the ergodity of the motion in the Dynamical systems with two degrees of freedom and has considered the example of the Henon-Heiles model. Anosova, Kiseleva and Chernin have studied the stochasticity of motions in the Triplets of stars and Galaxies. They have shown that the presence of significant dark matter distributed over the whole volume of system speeds up the rate of stochastisation considerably. Benest, Froechle and Gonezi using mainly Lyapunov Characteristic Indicators have investigated the stochasticity of the orbit of the Asteroid 1989 AC in the framework of three-body, five-body and seven-body restricted models. The orbit of 1989 AC has been found fairly chaotic. Rozgacheva has studied stochastic instability. It is well known that the trajectories with numerous flybies are examples of stochastic motions in classical deterministic dynamical system. It is this problem which has been presented by Krivov, Sokolov and Titov. Stochastic behaviour of planetary orbits during the accumulation process have been studied by Ziglina and Schmidt.

(iii) In the third part papers relating to problems on stellar systems and galaxies are included. Ashok Ambastha has discussed the stability of self-gravitating finite disks in the presence of a massive halo surrounding the disk as an eigenvalue problem. Anosova, Kiseleva and Orlov have studied the behaviour of the virial coefficient K(t) for the triples and quintets of galaxies as a function of time t. It is well known that both early and late type stars are intrinsically polarized. Theoretical modelshave been computed by Burman for

estimating linear polarization from the extended dusty outer layers of the components of close binary stars whose surfaces area disturbed by rotation and tidal effects due to the presence of secondary. Kozhanov has studied the dynamical evolution of stellar clusters and associations in the field of tidal forces of the galaxy. Mirzoyan has studied the dynamical instability of trapezium type multiple stars and Roche instability in ejecting stellar systems have been studied by Narasimhan and Alladin.

Many problems of stellar dynamics have the essential difficulty the divergence of the collision integral. This problem relating to the convergence of collision integral in the stellar system has been studied by Petrovskya.

In classical stellar dynamics it is assumed that Liouville's equation governs the time evolution of stellar systems. The work presented by Sobbouti and Dehghani is a continuation of a series of papers on the symmetries of Liouville's equation by the same authors.

Sridhar has extended the work of Antonov and Nuritdinov which deals with the time dependent solution of the collionless Boltzmann equation (CBE).

This part also includes the paper of Valtonen and Zheng. They have studied scenarios where comets are not original members of the Solar System but have been acquired from the surrounding medium through dynamical evolution. They have also considered the dynamical transfer of Oort cloud comets into short period comets.

(iv) This part deals with Triple and Many Body problems. Bekov's paper deals with the study of the arising and disapperance of collinear (Eulerion)/$L_1$,$L_2$,$L_3$, triangular (Lagrangian) $L_4$,$L_5$ co-planar $L_6$,$L_7$, ring $L_0$ and infinitely distant $L_{\pm\infty}$ solutions in a restricted problem of three variable mass bodies. Nezhinskij has studied the existence of a quasi-integral of areas (similar to an integral of areas in the problem of two bodies) in the plane restricted three body problem. Murtuza has discussed the stability of the photogravitational restricted three body problem.

Brumberg and Ivanova have extended the work of Henon and Petit. They have suggested an algorithm to construct the series representing the general encounter-type solution of the spatial eccentric Hill problem.

This part also includes the paper of Anosova which deals with unstable triple systems. From the statistical material obtained at the Leningrad observatory some basic qualitative results have been summarized.

(v) This part is devoted to various problems relating to Celestial Mechanics and Stellar Dynamics. Papers deal with Hamiltonian systems, satellite motion, Szebehely inverse problem, Fragility in Cosmology and Astrophysics and tidal force on Sun.

Main contributors are Barkin, Manjeet, Ferrandiz, Floria, Sansaturio, Karimov, Sokolsky, Omarova, Kozhanov, Perez, Tavakol, Singh, and Verma.

Several papers are dedicated to the fundamentals such as Hamiltonian Mechanics, KAM theory, Resonance theory and Stability. Lectures on vifurcation, on integrability on manifolds, on Erogodity and Stochasticity, on deterministic and non-deterministic systems etc. are also included.

The most of the lectures delivered were lucid and understandable to the participants who had solid background in Celestial Mechanics and stellar dynamics. Each lecture was followed by free and frank discussions. We do thank all the participants who took keen interest in the deliberations of the Colloquium.

As the readers will agree, the colloquium gave an opportunity to the participants to know the most recent developments in the area of Celestial Mechanics and stellar dynamics and to make contacts with scientists coming from every corner of the world.

The Chairman of the S.O.C. Prof. V. Szebehely could not participate in the colloquium due to some accident which he met a few days before the Colloquium. And I had to take this responsibility as well. I must thank him for his valuable help and advise which he continued to give despite of his bad health.

We are most grateful to the authorities of International Astronomical Union and presidents of IAU Commissions 7,33 and 37 for sponsoring the Colloquuim. We do express our thanks to the Principal, Zakir Husain College, Delhi, the host institution, for giving us his valuable advise in organizing the Colloquium. We also express our thanks to the Department of Science and Technology, Delhi; University Grants Commission, Delhi; Indian National Science Academy, Delhi; Council of Scientific and Industrial Research, Delhi; Inter-University Centre for Astronomy and Astrophysics, Pune; Physical Research Laboratory, Ahmedabad; Mausam Vibhag, Delhi; Bihar University, Muzaffarpur; Bhagalpur University, Bhagalpur and Sahitya Kala Parishad, Delhi which supported our Colloquium. Finally, we do thank all the organizations which supported many participants attend this Colloquium.

At the end, I would like to thank Dr. L.M. Saha who devotedly and tirelessly assisted me in the preparation of this volume. He is my colleague and my friend. My thanks are also due to Drs. P.P. Hallan, U. Gupta, S. Goel, B. Gupta, M. Kaur, S.C. Jethi, Ayub Khan, D.S. Jaggi, R.K. Sharma, V. Mehra, S. Mehra, S. Kumar, J. Shrivastava, M. Arif, A. Aneja and H.R. Mehra for assisting me in organizing the Colloquium. I would also like to thank all the members of the Scientific Organizing Committee, National Committee and the Local Organizing Committee for the valuable advise in planning and successful completion of the Colloquium.

K.B. BHATNAGAR
Chairman,
Local Organizing Committee
and Editor of the Proceedings



https://doi.org/10.1017/S0252921100065854 Published online by Cambridge University Press