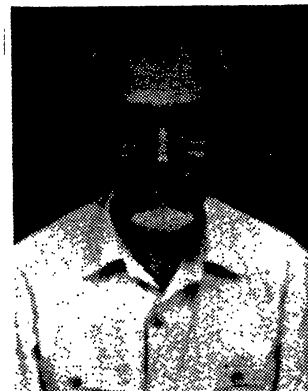


*Silver Jubilee Article***My life as an astronomer****Saleh Mohammed Alladin**

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Abstract. Factors which motivated me to pursue Astronomy are discussed. Dynamics of galaxies has been the principal area of my research. Work done by me and my associates in this field is indicated. Our work on frequency of occurrence of lunar and solar eclipses, which has been motivated by a prophecy in religious books, is described. My experiences in teaching and popularisation of astronomy, are also mentioned.

Key words : dynamics of galaxies - lunar and solar eclipses - teaching of astronomy

1. Astronomy in early years

The spacious firmament with its numerous celestial bodies is very captivating. From time immemorial, it attracted the attention of man and developed his thoughts. In the present age, various other attractions and preoccupations divert the attention of man from this pristine illuminating occupation. By God's grace, I was fortunate to spend my childhood in a house far from the city which had a nice terrace that enabled me to get a good view of the stars. I enjoyed looking at the celestial bodies night after night in solitude and noting their changing positions. Hardly any astronomy was taught in my school. We were introduced to the Solar System but not to the Galaxy. However my interest in stars led me to read whatever popular articles in astronomy I could get.

In my college education, one of my physics teachers in the M.Sc. class was Professor Ravada Satyanarayan. He had a great interest in Astronomy and he freely drew attention to astronomical phenomena in his lectures. He taught us Atomic Physics. I learnt from him, for example, the classification of stellar spectra into types O B A F G K M R N S and the way to remember this order of alphabets. He was an inspiring teacher.

On completing my M.Sc. in Physics in 1955, I wished to work as a research scholar under him in the Physics Department of Osmania University. There was no Astronomy Department in Osmania University at that time. When I approached him, he replied : "If you would like to

get your Ph.D. quickly, you take some other person as your supervisor. If you want to indulge in flights of imagination, you come to me". He asked me to take my time to decide. In my M.Sc. class I was impressed by his teaching and encouragement, and I decided to work under him.

In December 1955, by God's grace I was extremely fortunate to meet a great spiritual luminary, Hazrat Mirza Bashiruddin Mahmud Ahmad, who was the Head of our community (i.e. Ahmadiyya Muslim Jamaat) for more than fifty years (1914-1965). He encouraged me to do my Ph.D. He prayed for me and saw in his dream that I would succeed. He gave me one precious admonition : "Trust in Almighty God".

Professor Satyanarayan asked me to study the dynamics of the solar system and he wished that I should do some work of fundamental importance in dynamical astronomy. Under his supervision, I studied basic astronomy and read books on the history of the development of the concepts in physics. He emphasized that the books written by the pioneers should be studied and that one should try to understand the trends of thought that lead to a great discovery. "The Science of Mechanics" by Mach, was his favourite book. Working with him considerably broadened my outlook and intensified my interest in science. But I was not able to write a thesis or a research paper in four years and the term of my research scholarship approached its end.

I tried for employment without success. Once it appeared that I had a very good chance of getting the position of a Lecturer in Physics in a private Medical College in Warangal but to my surprise I was not selected. However, the admonition which my master had given me, kept me full of hope.

By God's grace, something favourable happened. The Osmania University decided to establish a Department of Astronomy and a couple of persons were to be sent to U.S.A. for a period of eight months for training in Astronomy with grant from India - US Wheat Loan Educational Exchange Program. M.B.K. Sarma who had completed his Ph.D. and was selected as a Lecturer in the Osmania University was an obvious choice for this purpose. My supervisor Professor Satyanarayan strongly recommended that I should also be sent. Dr. Akbar Ali, who was the Director of the Nizamiah Observatory, approved the idea and thus Sarma and I got the opportunity of studying in U.S.A.

2. Education at the University of Chicago (1959–1963)

I had applied for the Ph.D. Programme at the Yerkes Observatory, University of Chicago, earlier. Professor G. Kuiper, who was the Director, wrote to me that I could not be given admission to the Yerkes Observatory with the background I had. But if I could come to U.S.A. at my own expense and take various courses in Physics in the University of Chicago for a year and if my progress was found good, I would be eligible for a Research Assistantship at Yerkes. Since earlier I did not succeed in getting financial support from anywhere for studying in U.S.A. for a year, I had given up the idea of going to U.S.A. Now with funds available under U.S. - India Educational Exchange Program, I was able to go to U.S.A. and study physics for a

year in the Physics Department of the University of Chicago. The books that I studied here were generally the same as those I had studied in India. But in India I was not used to solving problems given at the end of various chapters. In U.S.A. I found that our progress was chiefly assessed by the ability to solve problems. One of my teachers Dr. P. Vandervoort once said : "Here, in the University of Chicago, our policy is not to teach the subject but to teach the student how to learn the subject". I spent many sleepless nights trying to solve the problems which were given as home work. This was the hardest year in my education.

By God's grace I passed the ordeal and was admitted to the Ph.D. program of the Yerkes Observatory. I found that here great emphasis was laid on acquisition of comprehensive knowledge. After taking courses for two years, a comprehensive examination had to be passed. Professor W.W. Morgan, who gave us courses on classification of astronomical objects told us : "The deeper you want to go in any field, the more necessary it is for you to broaden your knowledge". I was Research Assistant of Dr. D. Nelson Limber for three years and I did my Ph.D. research under his supervision. He was an excellent research guide and a very kind and affectionate person. He was a student of Professor S. Chandrasekhar.

For my Ph.D. thesis Limber asked me to compute the orbits of colliding galaxies making use of the polytropic theory to obtain the forces between galaxies when they overlap. I did this in a semi-analytic manner assuming that the galaxies were spherically symmetric configurations and by representing their density distributions by those of polytropes. The orbits were computed by taking into account the departure of the intergalactic force from the inverse-square force due to the effects of overlap but by neglecting the transfer of energy from the translational motion of the galaxies to the stellar motions. The thesis was not accepted and I was asked to resubmit it after investigating the problem of energy transfer to which I had referred in my thesis as a problem for further research. This was very fortunate because the latter work turned out to be considerably more significant than what I had already done. Those who are asked to resubmit the thesis with the addition of more work may keep my case in mind. This may be a blessing in disguise.

Using the technique of impulsive approximation used earlier by Spitzer (1958) for estimating the tidal effects of an interstellar cloud on a galactic cluster, I estimated the energy transfer from galactic motion to stellar motions for penetrating collisions of galaxies. It was found that the energy transfer was considerably greater than what was inferred earlier by Spitzer and Baade (1951) who had estimated it in a crude way without taking into account the non-homologous nature of the energy transfer. The results showed that close penetrating collisions can lead to considerable energy transfer and that even mergers of galaxies would occur (Alladin 1965). I was awarded Ph.D. degree in December 1963.

3. Studies in dynamics of galaxies in India

I joined as a Lecturer in the Department of Astronomy, Osmania University, in May 1964 and retired as Professor of Astronomy in March 1991. Here, I investigated various aspects of dynamics of interacting galaxies with my students who provided me much stimulus for work. I shall give a brief account of the work done by me and my associates.

Sastry & Alladin (1970) estimated energy changes and escape of stars in a galaxy collision for polytrope models of galaxies.

Capture velocities (i.e. maximum velocities required for tidal capture) of galaxies were calculated for various impact parameters under impulse approximation. This work was presented in the IAU Symposium on 'The Dynamics of Stellar Systems' held in Besançon and was well received (Alladin *et al.* 1975). Later, the results of N-body simulations showed that our results were reasonable (Alladin & Narasimhan 1982).

Toomre (1977) gave an elegant analytic treatment of energy changes in a head-on collision of identical spherical galaxies using Plummer models. We realized that if Plummer model is used instead of polytrope of index $n = 4$, as we have been doing, the analysis becomes considerably simpler and elegant. Ahmed (1979), Narasimhan & Alladin (1986), then extended Toomre's treatment to unequal Plummer model galaxies and also investigated further details. Zafarullah *et al.* (1983) obtained analytic expressions for velocity perturbations of stars for penetrating collisions for Plummer model galaxies.

Changes in shapes of spherical galaxies were studied numerically for off-centre collision (Alladin *et al.* 1974) and head-on collision (Ahmed & Alladin 1981). Change in the shape of a satellite stellar system close to Roche density was studied by N-Body simulations and comparisons were made with the predictions of analytical formulae (Devadas Rao *et al.* 1985 : Namboodiri & Kochhar 1990).

Gravitational potential energy of two penetrating galaxies due to their mutual attraction was derived for a pair of two disk galaxies (Ballabh 1973) and for a disk-sphere pair (Ballabh 1975). Collisions between a disk galaxy and a spherical galaxy were studied by Chatterjee (1984) and Zafarullah & Sastry (1987). Chatterjee (1984) investigated conditions under which a ring galaxy is formed and the properties of the rings thus formed.

Subrahmanyam (1980), Subrahmanyam & Narasimhan (1989), computed zero-velocity surfaces in the gravitational field of a pair of interacting galaxies. Both spherical and disk galaxies were considered.

Tidal coalescence and tidal disruption in binary stellar systems were studied analytically under different simplifying assumptions (Alladin & Parthasarathy 1978; Alladin *et al.* 1985, Subrahmanyam 1992). Namboodiri & Kochhar (1992), who studied the tidal effects on a satellite stellar system close to the Roche density, by the method of N-Body simulations, pointed out that the energy changes obtained analytically under adiabatic approximation by Alladin *et al.* (1985) would agree with their numerical results if the half-mass radius in the paper is replaced by the full radius.

The merger time derived under the simplifying assumption that the motion of the stars may be neglected in comparison to galactic motion (Alladin & Parthasarathy 1978) leads to a simple analytic expression which gives valuable insight into the dependence of the merger time on the

parameters of the motion and serves as a reasonable first order approximation against which the results of detailed numerical work can be compared (Alladin *et al.* 1988; Barnes 1990).

Ramamani *et al.* (1985) studied tidal interactions between the Galaxy and the Magellanic Clouds. A tidal model was proposed for the interacting pair of galaxies VV 117 which utilizes both the optical and radio data (Narasimhan & Alladin 1985) which supersedes the earlier model obtained from optical data alone.

Namboodiri *et al.* (1987) studied numerically the formation of bridges and tails in interacting galaxies.

Som Sunder & Kochhar (1986) studied dynamical evolution of a spheroidal cluster using tensor virial equations. Using tensor virial equations tidal transfer of energy and angular momentum to spheroidal galaxies in fast collisions, was studied analytically. (Som Sunder *et al.* 1990).

Energy changes in ejecting stellar systems were studied analytically with the Plummer model. These were used to obtain the conditions for the Roche instability of the systems (Narasimhan & Alladin 1992).

A simple semi-analytic method has been developed for obtaining orbits of colliding galaxies that takes into account both the penetration effects and energy transfer due to tidal effects, which gives results in fairly good agreement with those obtained from N-Body simulations (Narasimha Rao *et al.* 1994).

Classification of galactic collisions was made on the basis of intensity of tidal effects (Sastry & Alladin 1977). Example of each type is given from observed pairs of interacting galaxies (Narasimhan *et al.* 1996).

A review article was written on Galaxy Interactions and Consequent Evolution (Alladin & Narasimhan 1989) which discusses the role of galaxy interactions in galaxy evolution. Some problems of galaxy interactions that may be of interest to plasma physicists have been indicated (Alladin 1992a).

We did not work on gas dynamical aspects of galaxy interactions. This is an important area of research connected with star formation. I would like to mention that research in this area is being done by Chanda Jog at Indian Institute of Science (Jog 1995 and references therein).

The UGC appreciated my work by giving me Meghnad Saha Award for Theoretical Sciences for the year 1981 and encouraged further research by granting me a National Fellowship for two years (1984 - 1986).

4. Visits to other institutes

Visits to other institutes and participation in conferences are very helpful in research. Profs. R.V. Karandikar, K.D. Abhyankar, M.B.K. Sharma, and N.B. Sanwal, who had been Directors of the Centre of Advanced Study in Astronomy, Osmania University, encouraged me in my theoretical research and permitted me to take a leave from the university whenever I got the opportunity and recommended my case for financial support for attending conferences whenever possible.

Prof. M.K.V. Bappu, Director, Indian Institute of Astrophysics (IIA), encouraged me to visit the institute as often as I wished with the understanding that my expenses of travel and stay would be met by the institute. I could therefore visit IIA many times and I had fruitful interactions with the scientists there, particularly with Drs. M. Parthasarathy, R.K. Kochhar, P.M.S. Namboodiri, and C. Sivaram. When Prof. Bappu passed away, Prof. J.C. Bhattacharyya kindly continued the warm hospitality.

Likewise, Prof. J.V. Narlikar, Director, Inter-University Centre for Astronomy and Astrophysics (IUCAA), has been kindly giving me opportunities of working at IUCAA whenever I wish to do so. IUCAA provides excellent opportunity for scientists from various parts of the country to work together. At IUCAA I studied tidal effects and radio emission in compact groups of galaxies with Profs. V.R. Venugopal and K.S.V.S. Narasimhan and scattering phenomena in binary-single star encounters with Dr. K.B. Bhatnagar and Dr. N. Hasan. A very nice Indo-U.S. Workshop on Structure and Dynamics of Elliptical Galaxies was organised by Dr. A. Kembhavi at IUCAA in 1995.

Dr. K.B. Bhatnagar has established the Centre for Fundamental Research in Space Dynamics and Celestial Mechanics (CFRSC) in Delhi, and is at present a source of much encouragement to me in research in Celestial Mechanics. Profs. R.B. Singh and B. Ishwar arranged conferences in the University of Bihar, Muzaffarpur, where I could meet their Celestial Mechanics group.

Prof. B. Basu invited me to Calcutta University several times. Prof. S.M.R. Ansari gave me opportunities for visiting Aligarh Muslim University. I also benefited very much by visiting PRL, TIFR, RRI, I.I.Sc. and MATSCIENCE.

Prof. B. Buti kindly invited me to a Plasma Physics Workshop at Physical Research Laboratory, Ahmedabad, where I came in contact with Dr. D. ter Haar and attended his lectures. Ter Haar then visited the Osmania University and gave a lecture on the origin of the Solar System. Afterwards ter Haar invited me to Oxford. In 1980, I spent three months at the Department of Theoretical Physics, University of Oxford, where I enjoyed the warm hospitality of ter Haar and the excellent academic environment of Oxford. Here I worked on the review paper on "Gravitational interactions between galaxies" (Alladin & Narasimhan 1982).

On the kind invitation of Prof. D. Lynden-Bell, I spent a month at the Institute of Astronomy, University of Cambridge, and attended the NATO Workshop on Normal Galaxies.

Here I met for the first time Drs. Toomre, Tremaine, Binney, White and many astronomers in my area of research, and had fruitful discussions with some of them.

I spoke on Galaxy Interactions in Oxford, Cambridge, Manchester and Newcastle-on-Tyne. I met Prof. Zdenek Kopal at Manchester, Prof. Paul Roberts at Newcastle-on-Tyne and Prof. Nandy at Edinburgh and enjoyed their kind hospitality.

During this visit, I was also very fortunate to meet Hazrat Mirza Nasir Ahmad, who was the reverend Head of our community during 1965 to 1982 who happened to visit U.K. at the same time, and I requested his valuable prayers. He said : "Almighty God will bestow His grace".

In 1985, I spent three months at International Centre for Theoretical Physics, Trieste, on the kind invitation of Prof. Abdus Salam, who was a source of great encouragement to me. Here I studied dynamics of satellite stellar systems (Alladin 1986, Devadas Rao *et al.* 1987). During this trip I also benefited very much by meeting Prof. D.W. Sciama and his associates at SISSA.

Profs. J.P. Ostriker and Y. Sobouti were my classmates at Yerkes Observatory. Both of them visited Hyderabad and gave seminars in our department. I visited Ostriker at Princeton University Observatory and had useful discussions with him and his associates, but I could not visit Sobouti in Iran.

5. Studies in frequency of eclipses

In the last few years I have devoted much attention to an important matter in religion which is related to astronomy.

The religions of the world give glad tidings of the advent of a great Divine Reformer in the Latter Age through whom spiritual regeneration of mankind would be brought about in the world and eclipses of the moon and the sun have been mentioned among Divine Signs for him (Alladin 1989). Valuable details of the prophesied eclipses have been given by the Holy Prophet Muhammad, peace and blessings of God be upon him. Hazrat Ali Bin Umar Albaghdadi Addarqutani, an eminent authority on the Hadees (i.e. on Sayings of the Holy Prophet Muhammad, peace and blessings of God be on him), who lived from 918 to 995 A.D. has recorded the following Hadees, narrated by Hazrat Imam Baqar :

"For our Mahdi (i.e. Divine Reformer) there are two Signs which have never appeared before since the creation of the heavens and the earth, namely the moon will be eclipsed on the first night of Ramazan (i.e. in the month of Ramazan on the first of the nights on which a lunar eclipse can occur) and the sun will be eclipsed on the middle day of Ramazan (i.e. on the middle one of the days on which solar eclipse can occur) and these signs have not appeared since God created the heavens and the earth". (Sunan Darqutani Vol. 1 p. 188; Ansari Press, Delhi).

The month of the Islamic Calendar (Hijri) begins with the sighting of the lunar crescent. If the Hijri Calendar is used, the dates on which a lunar eclipse can occur are 13, 14 and 15 and the dates on which a solar eclipse can occur are 27, 28 and 29. The prophecy therefore implies that lunar eclipse on 13th Ramazan and solar eclipse on 28th Ramazan would serve as signs for the Divine Reformer.

In 1891 Hazrat Mirza Ghulam Ahmad of Qadian, India, claimed to be the Mahdi and Messiah on the basis of Divine revelations which he received. He was a devoted follower of the Holy Prophet (peace and blessings of God be on him) and he made this claim in complete subordination to him. Lunar and solar eclipses occurred on 21st March and 6th April 1894 respectively, over Qadian, exactly on the dates of Ramazan specified in the prophecy. Hazrat Ahmad (peace be on him) repeatedly stated in his books that his claim has been testified by the signs of lunar and solar eclipses.

Objections were raised that lunar and solar eclipses have occurred in the month of Ramazan several times and hence this could not serve as reasonable criterion for the identification of a Divine Reformer. Hazrat Mirza Tahir Ahmad, the present Head of our community, directed me to look into the matter. On my request, A.K. Bhatnagar and his colleagues at Positional Astronomy Centre, Calcutta, kindly helped me by making lengthy calculations. I studied the frequency of occurrence of eclipses in the month of Ramazan with my colleague Prof. G.M. Ballabh, who helped me enormously. We investigated the occurrence of eclipses from 623 A.D. (0001 Hijri) to 2000 A.D. We found that in a period of about 22 years, we have a year, or more commonly two consecutive years, in which both lunar and solar eclipses occur in the month of Ramazan over some part of the earth or the other, but it is quite rare to get both eclipses on the specified dates over a specified place. We have to go back by more than 600 years to the year 1287 A.D. (686 Hijri) to get again the eclipses on the 13th and 28th Ramazan over Qadian (Alladin & Ballabh 1993). The prophecy does not say that eclipses never occurred on the specified dates in the past but it does clearly say that such signs were not shown for any other person before.

The Ahmadiyya Muslim Jamaat celebrated in 1994 the centenary of the fulfilment of the prophecy concerning lunar and solar eclipses. By God's grace I gave lectures in religious conferences in several places in India as well as in U.K. and U.S.A. In U.K., on July 31, 1994, the reverend Head of our community gave an illuminating, lucid lecture on the grand prophecy of the signs of lunar and solar eclipses and its fulfilment. His lecture was telecast all over the world. In his lecture he also mentioned the work done by me and my associates with much appreciation.

In Washington, I was very glad to meet Dr. Bradley Schaefer, who attended my lecture. Schaefer had done research on visibility of the lunar crescent and had written an article on "Solar eclipses that changed the world" (Schaefer 1994). He was not aware of the prophecy regarding eclipses at the time of writing the article, otherwise he would have also mentioned in his article the historic solar eclipse of 6th April 1894.

6. Teaching of astronomy

I taught Astronomy at the M.Sc. level in the Osmania University. The subjects I generally taught were Applied Mathematics, Celestial Mechanics, Stellar Dynamics, Plasma Physics and Galaxies. Some of the students had been very good and teaching had been a very delightful activity. It also helped me in my research by making me understand the subject better. I regret however, that I generally did not succeed in making the students solve problems as home work. Also I intended to write a book on Applied Mathematics for Astronomers but could not devote sufficient attention to do so.

I gave a course on Stellar Dynamics in the IAU School for Young Astronomers held in Osmania University in 1969.

Prof. M.K.V. Bappu kindly invited me to Kodaikanal in 1974 to give a series of lectures on Stellar Dynamics. He took great interest and inspite of his frequent travel, he attended every lecture. Later, he brought out my lecture notes in the form of a book (Alladin 1977) and distributed it to various institutes.

In 1978, Prof. S.D. Sinvhal, Director, U.P. State Observatory, Nainital, kindly invited me to give lectures in Celestial Mechanics and Dynamics of Star Clusters, in his observatory. When the Department of Astronomy and Space Science was started in the Punjabi University, Patiala, Prof. H.S. Gurm, Head of the department, kindly invited me to teach galactic astronomy to M.Sc. students.

I was the national representative of India to IAU Commission on Teaching of Astronomy during 1982-1985. In 1985, when the General Assembly of the IAU was held in Delhi, Prof. C. Iwaniszewska, Vice-President of the Commission entrusted me with the work of arranging a meeting of school teachers with astronomers in Delhi. Many persons, especially Dr. K.B. Bhatnagar, helped me very much in this task. The meeting was held on 19th November 1985 under the Chairmanship of Prof. Iwaniszewska. It was gratifying that many teachers attended the meeting. Teaching astronomy to students in school can be very helpful in broadening their outlook and in improving general education in school.

I was Chairman, Board of Studies in Astronomy, Osmania University, from 1988 to 1991. A good background of Physics is very helpful to an astronomer. We therefore proposed that a two year M.Sc. (Astrophysics) course may be given with the collaboration of the Physics Department in which the students would study physics along with other physics student in the in Physics Department during the first year and would study Astrophysics in the Astronomy Department in the second year. This has been implemented and is getting on well. This is in addition to the usual M.Sc. (Astronomy) course of two years which is being given in our department since 1961.

7. Popularisation of astronomy

Occasionally I got the opportunity of giving a popular talk on a topic of astronomy. I wrote popular articles on the following topics : "The Solar System and the Development of Celestial Mechanics" (Alladin 1980); "The Rotating Galaxy" (Alladin 1981); "The Impact of Astronomy on the Development of Scientific Thought" (Alladin 1983); Interactions of Arab and Persian Astronomers with India" (Alladin 1988); "The Motion of the Moon and the Islamic Calendar" (Alladin and Ballabh 1989); "Galaxy Interactions" (Alladin 1922b).

Sometimes I got chances of talking about the structure of the universe in a religious meeting. Religion encourages the study of nature as the following verses of the Holy Quran clearly show:

"In the creation of the heavens and the earth and in the alternation of the night and the day there are indeed Signs for men of understanding; Those who remember Allah while standing, sitting, and lying on their sides, and ponder over the creation of the heavens and the earth : "Our Lord, Thou has not created this in vain....." (3:191, 192).

I often quote the following words of the great celestial mathematician Henri Poincaré (1958) which I like very much :

"The stars send us not only the visible and gross light which strikes our bodily eyes, but from them also comes to us a light, more subtle, which illuminates our minds".

Acknowledgements

I am grateful to Prof. Vinod Krishan, Editor, BASI for inviting me to write this article. I am also grateful to numerous persons who benefited me with their guidance, encouragement, discussion and prayers. Only some names could be mentioned in this article. "And if you try to count the favours of Allah, you will not be able to number them". (The Quran 14:35). All praise to God.

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