ASTRONOMY EDUCATION IN INDIA—AN OPINION PAPER

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Abstract

The important role played by astronomy in the development of physics and mathematics from time to time and recently in influencing new directions of research in chemistry and biology cannot be over-emphasized. When interdisciplinary subjects are in vogue today in the education circle, it is disirable that this relationship between astronomy and other subjects be appropriately projected to science students. Unfortunately, in the education planning in India, astronomy has been relegated to a position of secondary importance. With so many centres of astronomy active in the country today and also the new exciting possibilities being thrown open by fast progress in space and electronics technology, the need of astronomy education has become acute. The paper addresses itself to this problem and suggests a solution. After identifying the basic elements necessary for a viable career in astronomy, it works out in detail a way in which these elements could be introduced into the already existing high school, B.Sc. and M. Sc. (Physics) curricula. A separate degree course in astronomy is not recommended. The need of support to amateur astronomy is also brought up. In the end, the authors request readers for comments.

I. INTRODUCTION

Astronomy has the unique distinction of being at the same time the oldest as well as one of the most modern scientific disciplines. Whereas in earlier centuries, this subject was accepted as a part of the general education, in the more recent past, astronomy has been relegated to a position of secondary importance in the educational planning, particularly in India. With the advent of space age and new electronic techniques, this subject has received a renewed impetus and thus has again come into the forefront of scientific interest, a trend which is encouraging, and needs careful direction along the right lines to ensure a sustained growth and progress.

Astronomy has brought to bear a number of new concepts and ideas in mathematics, physics, chemistry and even biology. Examples are such as, the close link between the growth of optical spectroscopy and the studies of stellar spectra, the relationship between thermonuclear reactions and the stellar evolution as well as developments in plasma physics and magnetohydrodynamics in connection with the investigations of the stellar atmospheres, interplanetary and interstellar media. All these serve to illustrate the role of astronomy and astrophysics in the development of physics. More recently , the studies of neutron stars and black holes have ushered a new interest in the physics of ultradense matter and magnetic fields. Detection of complex molecules in the interstellar space is a new direction of research in astronomy and chemistry—the Interstellar Chemistry. Closely related to this is the aspect of the origin of life and its evolution in the universe, a new direction for biology. In a nut shell, the fundamental problems related to the origin and evolution of the universe on one side and the origin and evolution of life on planetary systems and interstellar space on the other side will have to seek solutions with the help of astronomy.

Besides sustaining these interrelated developments between physics, chemistry, biology and astronomy, it is highly desirable to appropriately project this symbiotic relationship between astronomy and other branches of science to the modern student as a part of his regular academic curriculum in schools and colleges, with an emphasis on interdisciplinary approach. Developing the abilty of a student to apply principles and concepts studied in connection with one branch of science for solving problems in another branch of science is an important element of modern education.

The suggestions/recommendations outlined in this paper in respect of teaching astronomy in schools and colleges have taken due cognizance of the above considerations. Further, the conditions peculiar to India including the available facilities and career opportunities have also been kept in mind.

II. ASTRONOMY IN INDIA

India has a rich tradition in astronomy. The works of illustrious astronomers such as Aryabhata, Varahamihira, Brahma Gupta and Baskaracharya, who dominated the Indian astronomical scene in the 5th, 6th and 7th centuries AD hardly need any introduction. Keeping up to this tradition, India has presently quite a large number of active astronomers and astrophysicists whose interests put together cover the entire span of the electromagnetic spectrum. The cover illustrates the techniques employed at some of the primary centres of astronomical activity in India. These centres could very well serve as nuclei for the growth of a younger generation of astronomers. In planning educational programmes in astronomy for the coming generation of students, it is quite important to ensure a close and effective interaction between these centres and the other educational institutions.

III. BASIC REQUIREMENTS FOR A VIABLE ASTRONOMICAL CAREER

The basic knowledge and skills needed for a viable astronomical career are quite extensive and varied and

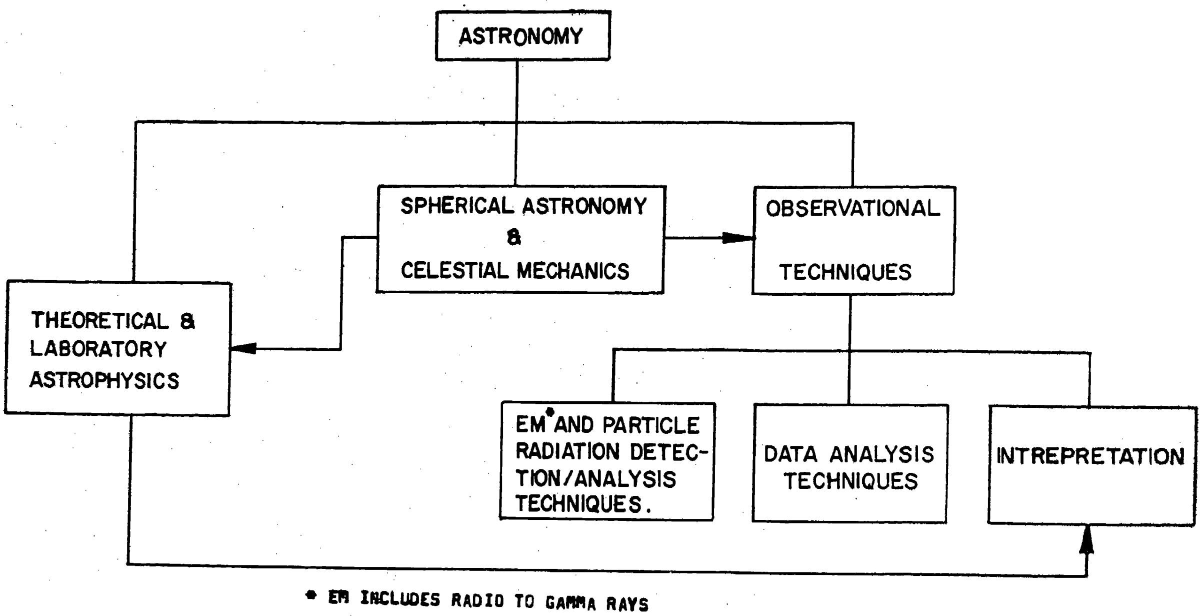

Fig. 1 : Different elements of knowledge for an astronomical career

as such an exhaustive listing of the same is beyond the scope of a short opinion paper of this kind. These could be classified into three broad categories as shown in Fig. 1. We now briefly discuss these.

(a) **Spherical Astronomy and Celestial Mechanics:**

A sound knowledge of these two subjects is a prerequisite for any meaningful astronomical career. Spherical astronomy, where spherical trigonometry finds major application, deals with phenomena related to the apparent positions and motions of principal celestial bodies as projected on the celestial sphere and effects of earth's atmosphere, lunar nutation and precession etc. on these phenomena. Celestial mechanics deals with planetary, stellar and galactic dynamics. Besides being important for theoretical and gravitational astronomy and for the solutions of fundamental problems of galactic structure, stellar dynamics and astrophysics, these are also useful for navigation, surveying and accurate determination of time.

(b) **Observational Techniques:**

Astronomy primarily depends upon observations. Hence the knowledge of the related observational techniques plays an important role in shaping a sound astronomical career. The choice of observational approach is dictated by the wavelength of observation in the case of electromagnetic radiation and by the nature of particles in the case of particle radiation. These are briefly mentioned in the following paragraph.

In the case of radio wavelenghts, from a few tens of metres to a few centimetres, the conventional radio telescopes are employed. A knowledge of the antenna fundamentals, the associated receiver and recording systems, operation in an interferometric configuration, aperture synthesis techniques etc., is essential for a modern radio astronomer. Some of these techniques are also applicable to the microwave region covering 10 cm to 1 mm, even though quantum detectors are coming into vogue for millimetre wave detection. Infrared astronomy calls for cryogenically cooled detectors with appropriate optics. The far and middle infrared astronomy from 1000 microns to about 10 microns have to be implemented essentially with balloons, rockets, or satellites. Astronomy at visible wavelengths, the most ancient of all astronomies, is carried out with reflecting or refracting telescopes. Besides the knowledge of conventional optics, photography, photometry, spectroscopy and imaging systems applications are some of the other important aspects of the optical astronomy. Many of these considerations are also applicable to the ultraviolet astronomy and the near-infrared astronomy. The detection and analysis of X-radiation, as a part of X-ray astronomical research, is dependent on the use of nuclear radiation detectors such as gas proportional counters, inorganic scintillators and solid state detectors. Gamma ray astronomy also employs nuclear radiation detectors like spark chambers. The UV, the X-ray and the gamma ray astronomies can be done using balloon, rocket or satellite based platforms only. Similar considerations apply for particle astronomy too that include the detection of particles such as electrons, protons, alpha particles and heavier elements.

Besides the knowledge of the associated telescope and detector technology, the above observational techniques also need sound familiarity with the modern electronics that include signal conditioning, signal processing and analysing systems.

Another major aspect of observational astronomy is data processing. Apart from conventional data analysis techniques, this may include modern autocorrelation, cross-correlation or image processing techniques for enhancing special features in astronomical photographs, for example, when studying time structure of emissions from celestial bodies; or this may include attitude reduction techniques in case of data generated from detectors mounted on space vehicles. This calls for familiarity with the handling of simple desk calculator on one hand to the most modern computers on the other hand.

(c) Theoretical and Laboratory Astrophysics:

Theoretical astrophysics, which encompasses structure and evolution of stellar, planetary, galactic and extragalactic systems, interstellar and metagalactic media and cosmology, is a discipline that heavily relies on physics and mathematics and is the major tool in interpreting the astronomical data. A sound knowledge of physics and mathematics, including plasma physics, magneto-hydrodynamics, relativity, classical mechanics, thermodynamics, statistical mechanics, nuclear physics and even solid state physics is a pre-requisite to understand modern astrophysics.

Laboratory astrophysics deals with experiments carried out in laboratory to help interpret observational data. These experiments may include spectroscopy at different wavelengths of the electromagnetic spectrum to understand the origin of the cosmic line emissions, or nuclear reaction experiments to calculate such reaction rates in stellar interiors or some controlled experiments in plasma physics and magnetohydrodynamics. Knowledge of such techniques at a basic level should enable a beginner in astronomy to plan his research methods more effectively.

IV. INTRODUCING ASTRONOMY INTO THE EDUCATIONAL CURRICULAM

We discuss this aspect with respect to three different questions. The first question is, what knowledge of astronomy could be imparted to a student at high school, graduate and post-graduate levels considering the degree of his understanding of physics and mathematics? Our answer to this question is summarised in the Appendix from which it is evident that a small amount of knowledge of astronomy can be imparted even at high school level which could then be gradually augmented by details at graduate and post-graduate levels.

This then leads to the second question: how and to what extent do we introduce the appropriate knowledge of astronomy at high school and university levels? Our opinion in this regard is as follows :

At the high school level, topics on astronomy such as the role played by gravitation and nuclear fusion in the stellar evolution, general arrangement and motions of planets in solar system and the relevance of simple telescope to astronomy could be introduced into some of the existing subjects like physics and geography. No special subject on Astronomy need be introduced.

At the graduate level, certain amount of astronomy could be taught on a compulsory basis as a part of Physics, Chemistry and Mathematics. Our recommendations for compulsory portions are the following. PHYSICS—description and elements only—stellar spectra, classification and evolution; interstellar matter, galaxy, elementary cosmology. CHEMISTRY—description and elements only—interstellar moleculs, chemical reactions, factors governing their rates and theories of origin of life. MATHEMATICS—principles of spherical trigonometry; astronomical coordinate systems, their interrelation and also corrections due to parallex etc; time and motion of Earth; Keplar's laws and elementary applications to orbits of planets, comets, artificial satellites; elementary treatment of orbit deterioration and interplanetary orbits.

In the case of physics and chemistry two ways are possible for doing this. Either to introduce topics of astrophysics when relevant topics of physics and chemistry are taught, e.g., stellar photometry and spectroscopy with optics, thermonuclear reactions in stars with nuclear physics etc; or to deliver a set of integrated lectures on these astrophysics topics at the and of the final term.

Another possibility in some of the universities could be a full paper in Astronomy under B.Sc. (Physics). However, this course is recommended only in those universities that have access to some astronomical instruments. In addition to a more detailed treatment of topics included above in the compulsory portion recommended for B. Sc, this full paper could, on the instrumentation side, cover a detailed study of different detection and measurement techniques, covering the entire domain of electromagnetic spectrum, and their use for various types of deductions. Some laboratory exercises on stellar photography and spectroscopy should also be included.

At the post-graduate level, as in B.Sc., a certain degree of teachng in astrophysics could be made compulsory on the lines of the present methodology of teaching nuclear physics or solid state physics. In the last semestar, a full or more preferably half a question paper could be devoted to astrophysics. In the suggested approach of astronomy teaching, as the student would have already gained enough background in descriptive astronomy, spherical astronomy and celestial mechanics in B.Sc., only astrophysics portion upto a maximum of 30 lecture hours is recommended for M.Sc.

Alternatively, at M.Sc. level, astronomy/astrophysics could be taught as an elective subject. This could consist of about 150 teaching hours spread over two full years and covering all the subdisciplines of astronomy and the entire span of electromagnetic spectrum. Topics covered could be spherical astronomy, celestial mechanics; tools, techniques and data analysis for astronomy; theories of stellar, interstellar and galactic processes; cosmology, planetalogy; physics of comets, planetary interior and atmospheres; origin of life, and research conducted by interplanetary and lander space missions. Details of a possible 4-semester elective course at M.Sc. (Physics) level has been worked out along these lines by Tiwari *et al.* (1977). It is strongly recommended that such an elective course be introduced only in a university that can avail of a nearby observatory facility. Appropriate laboratory exercises commensurate with the facilities in the observatory should be made a compulsory part of the teaching.

Finally, it is our considered view that a full fledged course in astronomy/astrophysics leading to a degree in this subject or even a post-M.Sc. diploma is not desirable at this juncture. The approach outlined above is sufficiently intensive and at the same time flexible enough for a student to decide on a professional career in Astronomy on the basis of interest and opportunity.

The third question is, are there some additional approaches that could supplement the regular educational programme outlined above? The answer to this could be the conduct of periodical seminars, workshops and summer schools.

Periodic seminars (at least once in a month) for the benefit of graduate and post-graduate students, especially on topics of current interest and at a level intelligible to them, would be highly stimulating. Senior staff members of the university/special invitees could be requested to give such seminar talks.

The methodology of conducting summer schools and workshops need no elaboration here. However, it is suggested that such workshops and summer schools should be primarily for post-graduate students, the consideration for selection being their past brilliant academic career, varied academic interests and with special stated interest in mathematics and physics.

To illustrate the conduct of a typical summer school, we cite here an experiment described in the March 1977 issue of the magazine *Sky and Telescope*. The students selected for this programme were given a central problem dealing with the observation and calculation of the orbits of selected minor planets. The experiment was done in one of the optical observatories. The flow chart for the entire series of the related activities is roughly as given in Fig. 2. Similar possible problems in the present context could be measurement of atmospheric refraction, finding solar rotation rate, determining the mass of Jupiter from observations of its satellites, etc. Such experimental efforts should be supplemented by a series of lectures on the topic of observational programme by a few well known astronomers.This kind of programme, to quote the authors, provides each student an in-depth exposure to three important aspects of physicsal science : the problems the science in question deals with, the equipment used and the people who work in the field.

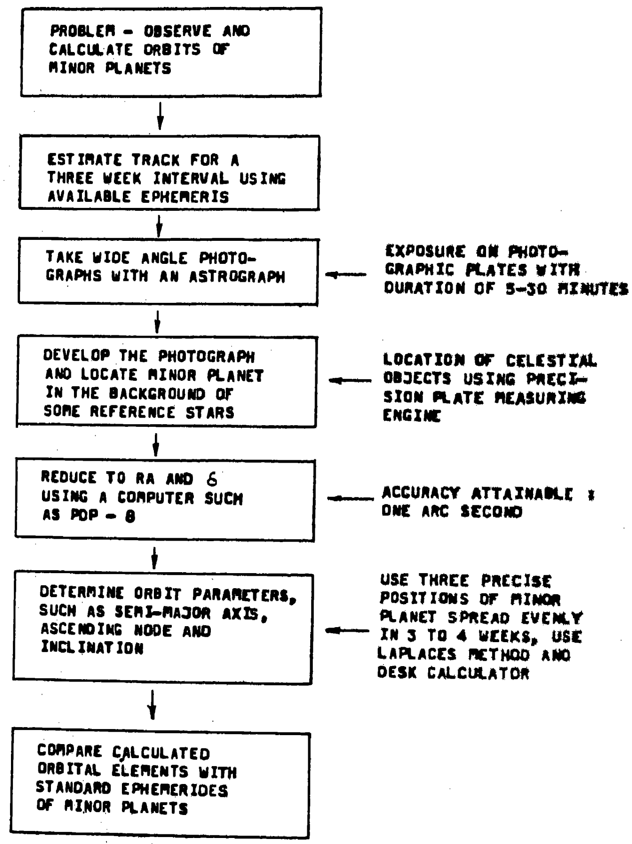

Fig. 2 : A typical Summer School project on Determination of the Orbits of Minor Planets

V. POSSIBLE CAREER OPPORTUNITIES

The career opportunities for a person with specialisation in Astronomy in areas other than astronomy are quite limited presently in our country, if we consider the direct applicability of the astronomical knowledge. It is however not out of context to mention here that certain areas related to space programme such as the orbital mechanics related to artificial earth satellites inlcuding tracking of these bodies, design of inertial navigation systems, attitude determination and control of space vehicles do call for certain degree of knowledge of astronomy. The image processing techniques in astronomy are quite analogous to those employed for earth resources survey. Adequate emphasis on optics, electronics and data processing in the teaching of astronomy should enable a student of astronomy to diversify after M.Sc. into areas such as remote sensing.

However, the limited scope of this subject from the standpoint of job opportunities should not deter a serious student with deep rooted interest in astronomy from making it a professional career. The next decade or two are likely to witness major strides in this branch of science, probably even outbeating what we have seen in the last decade. Research in astronomy with giant radio telescopes, space optical telescope, IR, UV, X-ray and gamma ray investigations with space observatories and un-manned and manned planetary missions are likely to intensify in the next decade, with the attendant exciting possibilities in astronomy, which a modern student should not overlook.

VI. AMATEUR ASTRONOMERS

An aspect normally not considered a part of the educational planning is the possible creation of a large number of amateur astronomers. Towards this, it is felt that the existing observatories and planetaria should play an important role. This could be done by inviting people with interest and a general knowledge of astronomy to observatories and giving them a sound exposure to the observational techniques. The second aspect is to explore the methods of making available simple telescopes to these amateurs. This presently is a problem in our country. Lastly, the possibility of creation of an amateur wing in the existing Astronomical Soceity of India should be explored. It may be mentioned that an important element favourable to the growth of amateur astronomy in India is the avaiability of reasonably clear skies for observations.

It is to be emphasized that besides pursuing their own interests, amateur astronomers could complement the activities of professional astronomers where simple but patient and continuous observations are necessary. In this connection, it may be noted that many of the comets have been discovered by amateur astronomers.

VII. CONCLUSIONS

Now to summarise our recommendations, there is a definite need and scope for introducing/improving astronomy teaching in high schools and colleges. Depending upon the degree of understanding of students, the teaching of small portions of astronomy should be made a compulsory part of the existing physics and geography curricula at high school level, physics, chemistry and mathematics curricula at B.Sc. level, and physics curriculum at M.Sc. level. In addtion, only for universities having access to nearby observatory facilities, a course of one full year paper at B.Sc. level and a course of two full year papers as elective at M.Sc. (Physics) level is recommended. However, a separate degree course in astronomy/astrophysics is *not* recommended. Finally, the amateur astronomy, which has a considerable scope in India, needs special support from the already established astronomy centres in the country.

The purpose of writing this article is to invoke comments from its readers, especially science teachers and education planners, on the approach suggested. The authors understand that the suggested approach is not the only one possible but what they wish to emphasize is the need of astronomy training as a part of the general educational curriculum and the philosophy one should adopt to solve the problem. If the comments received pave a way to a more widely agreeable approach, some of us could appeal to the top echelon among the education planners in the country to consider it. The question as to how this should or would be implemented is a difficult one to tackle at this stage, as the implementation would involve a large number of institutions, all of which may not be favourably disposed to the finalized suggestion. The authors can only hope that some positive steps would be taken in this direction as a result of such an appeal.

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References

Tiwari, M.K., Rajan Y.S., and Kasturirangan, K. 1977, Technical Note ISAC-00-77-12-7-022.

APPENDIX
WHAT ASTRONOMY CAN BE TAUGHT AT SCHOOL AND UNIVERSITY LEVEL

LEVEL	RELEVANT BACKGROUND KNOWLEDGE AVAILABLE	STUDENT CAN BE TAUGHT AT THIS LEVEL	
		GENERAL ASTRONOMY	TECHNIQUES
SSC	Earth's motion and seasons, Gravitation, simple telescope, Elements of Nuclear Fusion.	Star Atlas, Stellar and Galactic Systems, Members of Solar System, their motion and environments.	Applications of Telescopes to Astronomy
B.Sc. (Physics, Chemistry and Mathematics)	Trigonometry, Calculus, Elementary Classical Mechanics. Organic Chemistry, Equation of State, Laws of Radiation, Geometrical Optics, Diffraction, Optical Spectra and Doppler Effect, Electromagnetic theory, Electrical Discharge through Gases, Elementary Nuclear Physics.	Spherical Astronomy, Elementary celestial mechanics, Stellar Spectra and classification, H-R diagram and types of Stars, Life of a Star, Supernovae, Neutron Star, Pulsar, Solar structure and activity, Hubble's law and elementary cosmology. Interstellar Space Physics and Chemistry including elementary concepts of origin of life.	Telescope mounts, Telescopes, gratings and detectors for entire EM spectrum, Techniques of stellar and galactic measurements.
M.Sc. (Physics)	Classical Mechanics, Relativity, Electromagnetic theory and electrodynamics, Thermodynamics, Quantum mechanics, Atomic and Molecular spectra, Nuclear Physics and cosmic radiation, Electronics.	Advanced Spherical Astronomy and Celestial Mechanics, Sources and causes of emission and absorption of all parts of EM spectra, Effects on spectra due to motions, magnetic fields and pressure. Plasma physics, Physics of Stellar and Planetary interiors and atmospheres, Physics of interstellar space, Physics at extremely high densities, neutron stars, pulsars, quasars, Cosmology and relativity, Interpretation of experimental results.	Electronic equipment needed for Astronomy work, Handling of astronomical instrument for various measurements, Platform and vehicle requirements for various astronomy measurements, Autocorrelation techniques, general coordinate transformations and aspect reduction in case of space borne experiments, Error analysis, Image processing for astronomy.