Teaching of Astronomy in Asian-Pacific Region

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TEACHING OF ASTRONOMY IN SCHOOLS OF INDIA

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From the dawn of civilisation, various questions regarding the Sun, the Moon and other heavenly bodies haunted the mankind and that marked the beginning of astronomy. Gradually various mystries of nature have been unveiled by man, initially with the help of naked eye observations and then with the aid of various equipments. Today, when we are approching the 21st century, astronomy has become one of the most fascinating areas of research.

Necessity of learning astronomy ::

One of the aims of teaching science in secondary level in Indian schools is to impart some basic ideas of various scientific arena, viz., Physics, Chemistry, Mathematics, Life science, Agriculture etc. Since we everyday see various heavenly bodies such as the Sun, the Moon, the stars and frequently observe some astronomical phenomena, viz., the eclipses, the stars etc., so it is necessary for the students to acquire some basic knowledge of astronomy in order to get themselves aware of the causes of these and many other astronomical phenomena happening around them. Now-a-days secondary education cannot be complete without some knowledge of astronomy. The most fruitful way of exposing the school students to the topics of astronomy will be to introduce a separate paper on astronomy in the secondary level curriculum. But that's a long term process and requires initiative from various corners of the society. Instead, if some topics on astronomy, which are already in the curriculum, be modified to some extent and one or two new topics be included then that will also be useful.

Topics of theoretical teaching

There are many topics in astronomy which can create interest and enthusiasm among the school students. One of the landmarks in the history of astronomy is the transition from geocentric to helio - centric idea. This topic, along with the obstacles faced by the proponents of this idea (Galileo, Bruno etc.) must be introduced in the syllabus. This will not only help the students to understand the evolution of astronomy but also may help to eradicate various superstitions and religious dogmas. Students will learn to stand in favour of scientific truths daunting heavy odds.

As we are inhabitants of the Solar System, so study of the Solar System must be included in the curriculum. It's true that the study of the Solar System has already been included briefly in the geography course but various data given in the text books regarding this topic are backdated. A few years ago ring systems have been detected around Uranus and Neptune from ground-based observations. Moreover, after Voyager Mission, ring systems have been detected around Jupiter and it has been possible to obtain photographs of ring systems of all the Jovian Planets including that of Jupiter. Also the number of satellites of all the giant planets have increased considerably. These informations must be incorporated to keep the students updated. The above two topics should be included in the geography course.

It is now almost certain that the Earth is the only planet in the Solar System in which living creatures can reside. The students must know why the Earth is a favourable place for the creation of life and why atmospheres of other planets are unsuitable for the formation of life. This will help to eradicate various misconceptions about the formation of life on the Earth. Students will realise that living creatures on the Earth has not been created by any God; life has been formed on the Earth because there were certain favourable conditions in our planet for its formation. If some informations about the search for extraterrestrial life and its consequences be also included in this topic, then that will be of added interest to the stu - dents. This whole topic may be inserted as an introductory chapter into the life science course.

Many laws of theoretical physics such as Newton's laws of motion, Newton's law of Universal Gravitation, principles of shadow formation etc. have direct applications in astronomy. Newton's law of gravitation is included in the physical science curriculum. But the direct consequences of this law has not been included, although it may be a very interesting topic to the students. During the life time of Newton, his friend Sir Edmund Halley calculated the path of the comet which bears his name on the basis of Newton's laws of motion and law of gravitation and predicted correctly that the comet's next visit would be in the year 1758. The discovery of the planet Neptune in the year 1846 was possible by the application of the law of gravitation. Students should learn these triumphs of the law of gravitation and the laws of motion. This will give a better impetus to the study of this law for the students.

Study of eclipses, which are already included in the curriculum, should be done more thoroughly because the Principles of shadow formation have direct application in eclipses. For instance, the scientific importance of observation of eclipses should be included in the curriculum. A few informations regarding the observations of eclipses in the ancient times (both in India and abroad) may also be incorporated.

Ways of practical teaching

No scientific knowledge can be complete without practical demonstration. So teaching of various topics of astronomy must be substantiated with the aid of observation — both with the naked eye and with the help of telescopes and binoculars. Teachers who can identify the planets and some well-known stars such as Sirius, Betelgeuse, Aldebaran, various constellations etc. will take out the students regularly in an open field and will make themselves familiar with those heavenly bodies. Besides regular classes, special observational programmes may be arranged during eclipses, transits etc.

Making of small telescopes must be very interesting to the students. For this purpose, the respective schools will have to contact with a person who is an expert in making of small telescopes against paultry remuneration because most of the schools in India are financially not so sound to spend a huge amount of money for this purpose. If this can be arranged then the students will be benefited in two ways. Firstly, they will be able to make observations with the help of the telescope that they will make. Secondly, in future, they can prepare telescope on a large scale and may sell them to amateur astronomers.

An astronomy laboratory may be prepared in the schools. In that laboratory, various apparatus such as sun-dial, telescope, star map etc. will be kept as teaching aids. A small portion of the school fund may be used for purchasing these materials. During theoretical and practical classes, these teaching aids will be used to make the teaching more fruitful.

Teachers Training

Finally, a few words regarding training of the teachers should be mentioned. Science, mathematics and geography teachers should be trained in astronomy. For this purpose, the Education Department of various states may chalk out large scale programmes in which some resource persons (who are experts in the field of astronomy) will train up a few teachers of each of the Secondary and Higher Secondary Schools who in turn will act as resource persons to train up the teachers of Junior High and Primary Schools. These training programmes should be repeated after every five or ten years so that the teachers can know the advancement in the field of astronomy during the last five or ten years and can keep themselves abreast with the latest knowledge in this field.

Conclusion ::

Thus it is apparent from the above discussion that astronomy can be taught in the schools in India without much altering the present infrastructure of education. As a teacher, it is my personal experience that the students are very much interested to listen discussions on astronomy. The teachers are also willing to do their duty in this matter. So, a bit of sincere and positive approach on behalf of the Government can make the teaching of astronomy in the schools in India very fruitful and significant.

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DETECTION OF EXTRATERRESTRIAL INTELLIGENCE

Why so difficult?

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ABSTRACT

Astronomers and astrophysicists are after SETI for the past few decades. Apart from technical difficulties, the difficulties involving vast time spans are brought out. It is clarified why it is said that any ETI we detect is likely to be more advanced than us. The likely means of communications is also discussed.

INTRODUCTION

Radio waves were produced artificially and instruments for their detection were developed by Hertz and Marcony towards the end of the previous century. In this century, it was realized that radio waves form one of the major components in the radiation and particles that are coming to us from all over the universe.

With advancements in microbiology and biochemistry, an idea emerged that life, leading to the development of intelligent beings, could occur and develop on any planet of a star, with ingredients conducive for growth of complex organic structures. Thus we may not be the only intelligent beings in the entire universe.

For the past 30 years, man has focussed his attention on this question. It is now conjectured that there are a few hundred billion stars in our Milky Way galaxy, and there may well be as many galaxies in this universe. Several questions arise regarding the existence of extraterrestrial intelligence

(ETI). What are the desirable conditions on a planet such that primitive life can develop on it? What are the chances of the existence of such a planet with optimum conditions, in our Milky Way and the whole universe? What are the chances of ETI establishing contact with us?

DELICATE BALANCE

The earth is situated at a distance of 150 million kilometers from the sun. It has an atmosphere mainly containing nitrogen and oxygen and also several other trace gases. It has vast reserves of water, covering more than two-thirds of its surface. The axis of earth's rotation is inclined to the plane of its revolution around the sun by about 67 degrees, giving rise to the phenomenon of seasons on earth. The period of its rotation about its own axis is about 24 hours, giving rise to days and nights. The earth's mass is just right to hold the atmosphere of gases around it. Its atmosphere is sufficiently thick and contains just the right ingredients (such as ozone) to cut out the hazardous ultraviolet and high energy radiations coming from the sun, and yet it is sufficiently thin to allow visible light to penetrate down to the earth's surface. The average temperature on the earth is slightly higher than 0 ^{o}C.

LIFE ON OTHER PLANETS

Compare these factors with some other planets and satellites in our solar system. First, the moon. Its mass it eighty-one times lower than that of the earth, resulting in a weak gravity. It has therefore no atmosphere. Whatever gas was left over when the moon solidified, must have escaped its bonds long ago. Even if we decide to put some gas on the moon's surface, all the gas molecules will escape moon's gravity before long. Due to this, hazardous radiations reach moon's surface and meteorites strike its surface every now and then.

Also the surface temperature on the moon ranges roughly between 150 ^{o}C and -150 ^{o}C. It was earlier conjectured that there might be at least some microscopic form of life on the moon. But with investigations of lunar soil over the past two and a half decades, absolutely no evidence of any life has been found. Even there is no water on the surface of the moon.

Next, we look at our neighbouring planets. Mercury, the nearest planet to the sun, has no atmosphere. Its surface temperature rises to 700 ^{o}C on the day side. Hence there is no possibility of life there. Venus has also a much higher temperature than that on the earth. Moreover, it has a very thick atmosphere, ten to hundred times thicker than our atmosphere. The erstwhile Soviet Union had sent an unmanned spacecraft Venera to land on Venus, which sent us many photographs and a good deal of information about the planet. As it descended Venutian atmosphere, the signals from it stopped coming. Neither light nor radio waves can penetrate its thick atmosphere. Finally, its atmosphere consists of poisonous gases such as methane, ammonia, carbon-dioxide etc.

Mars has an atmosphere much thinner than that of the earth. Its average temperature is also only slightly lower than that of the earth. But many spacecraft that have been sent towards Mars have not been able to collect any evidence of even microbial form of life on it.

Then there are the four giant planets, Jupiter, Saturn, Uranus and Neptune. They are much more massive than the earth and thus have a large gravity on their surface. This results into a very thick atmosphere extending to over a thousand kilometers. No light from the sun reaches their surface. Finally, all of them are extremely cold, with temperatures well below the freezing point of water. They also contain mostly poisonous gases. There is hardly any possibility of life developing under such conditions. We can rule out the farthest planet, Pluto, on the grounds of its surface temperature being below -200 ^{o}C.

Then there are several satellites of other planets, thousands of asteroids and comets. There is no evidence of life on any of these so far, and we can safely rule them out.

LIFE OUT THERE

Now we consider the possibility of life on planets of other stars. It is known that three-fourths of all the stars are binary stars or composites. The orbits of planets around such composite stars are not very stable, and the conditions change much too rapidly for life to grow. We need a planet with stable conditions for millions of years, and the right environment -- the right mass, the right distance from its star, atmosphere, temperature, water and several other things.

Probability estimates of finding life out there in space are made on the basis of various such factors. Needless to say, there are wide margins of error. The basic feeling is that we are not alone in the universe and there could be suitable planets among myriads of stars and galaxies which harbour intelligent life. It is, of course, agreed that extraterrestrial intelligence would be very rare. If there is ETI, according to Drake, the average separation between two such intelligent worlds is likely to be of the order of 10 000 light-years.

DIFFICULTIES IN SEARCH

With the hope that there are other intelligent worlds, man has been sending encoded signals about his existence and whereabouts in all directions for the past 30 years. Again with the hope that ETI would also be broadcasting such signals, there have been tremendous efforts to try to detect any meaningful messages suggestive of life and intelligence, from among the vast amounts of random radiation which are constantly coming to us from all parts of the universe. Even if ETI exists and is broadcasting signals, there are difficulties in their search and communication. For the sake of comparison, let us again review the development of life on the earth.

According to the present normally-accepted view, life began in its elementary forms on this earth about 3500 million years ago. Note that the age of the earth itself is about 5000 million years. Then primitive man came into existence only about 2 million years ago. Then modern man came into existence 500 000 years ago, and the present man (like us) came only 20 000 years ago. The scientific renaissance occurred in the 17th century, only 300 years ago, and finally, only 30 years ago, man has started broadcasting messages of his existence to the universe.

If there is ETI anywhere else, it could be at any stage of this development spanning millions of years, or it could be more advanced than us. Now, if this ETI is even 30 years behind us and if they have not yet started sending signals about their existence, there is no way of knowing about them even if they exist. Therefore it is conjectured that if at all we detect signals from some ETI, they are almost sure to be more advanced than us.

COMMUNICATION

There is another important question needing our attention. Assuming that there is ETI more advanced than us somewhere and assuming that they want to send messages of their existence, what form of, and what medium for, communication will they choose? Conversely, if we wish to send messages out, what should we do?

Electromagnetic waves are the fastest vehicle known to us. Also they follow the maximum possible straight path, except when passing very close to a star, and do not undergo as much scattering as, for example, a beam of electrons or neutrons. Then the question is what frequency or wavelength of the electromagnetic radiation we should choose to carry our messages. The radiation should be able to travel large distances without distortion. Since we have no inkling of the language or the culture of ETI, we have to look for something which will be independent of language and culture. The element that is abundant in the universe is hydrogen. Its atoms emit electromagnetic radiation of wavelength 21 cm. There is a constant influx of this radiation from all directions to us and, in fact, it is used to detect the amount of hydrogen in different parts of the universe. Therefore our scientists have decided to use this radiation to carry the messages about the earth and about man, of course, in a coded language. The thinking is that any other intelligent beings would use similar logic and arrive at the same conclusion of using the 21-cm radiation of hydrogen.

If we detect signals from ETI or they detect our signals, would we be able to communicate with them? That is again a far cry! As noted earlier, the average distance between two ETI is likely to be 10 000 light-years or more, and we have started broadcasting signals only 30 years ago. So if some ETI catches our signals and sends the reply, we would receive it 20 000 years from now! On the other hand, if we succeed in detecting some intelligent signals now and send our reply, they would receive it 10 000 years from now. So each to-and-fro message will take 20 000 years!

Therefore, for all practical purposes, at least for the time being, we are alone in the universe, even if the reality is otherwise.

Logarithmic Relation of Magnitudes

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1 Abstract

Our objective is to enable students to check their eyes are logarithm calculators, observing differences of magnitudes related to distance through logarithm function. Working with stars of different constellations, we aim to verify the relationship $M-m=5-5\log D$ by introducing the apparent magnitude m for each student, and the known values for every star of absolute magnitude M and distance D.

Using several slides of constellations, the students only have to assign apparent magnitude m for some stars in every constellation. Using slides is practical, but of course it is possible to do it by observing the sky with the naked eye.

Afterwards, they have to calculate the right side of equation $\log D = \frac{5+m-M}{5}$ and drawing the point $(D, \frac{5+m-M}{5})$ on semi-logarithmic paper for different stars from various constellations. The result is approximately a straight line, and so consequently the $\log D$ is equal to $\frac{5+m-M}{5}$ as we would like to verify. (If the students are not accustomed to semi-logarithmic paper it is necessary to introduce this paper to check that the graph of $y = \log x$ is a straight line).

2 Contents

To verify the relationship $M - m = 5 - 5\log D$, we present an experiment carried out with a set of several constellations selected depending on seasons.

The selection is made bearing in mind that we want to observe 2 or 3 of them throughout the year.

A good idea is to select some constellations in the north horizon particularly in the pole zone (for example: Ursa Major and Cassiopeia) and others constellations in the south horizon, one for every season (for example, in our latitude: Leo (Spring), Hercules (Summer), Cygnus (Autumn), Orion (Winter)).

For each constellation the students make a table, where they introduce five different stars to which they assign the apparent magnitude m. From these values of m and the values of absolute magnitude M from a star catalogue, they calculate $\frac{5+m-M}{5}$. On the other hand, they also introduce in the table, the distance D in parsecs from the stars catalogue.

Making tables, we start to select some stars (five in this case) of different brightnesses for each constellation. For each one, the students assign the apparent magnitude m from slides or from observations with the naked eye. Also, the students obtain M and D from star catalogue and finally they calculate the fraction $\frac{5+m-M}{5}$. With all this information they make the tables 1, 2, 3, 4, 5 and 6. Code letters in the column of distances are: The values marked "t" show they are based on a trigonometric parallax. A letter "s" denotes spectroscopic parallax. When both of these methods were used, "ts" appears. An "mn" code means the distance is a minimum value compatible with the star's negligible trigonometric parallax. The code "mx" means the distance is the maximum likely value, in view of the star's large space motion.

Ursa Major		m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.
Merak	β	2	(2.37)	+1.2	1.16	19 ts
Dubhe	α	2	(1.79)	+0.2	1.36	23 ts
	χ	4	(3.71)	+0.2	1.76	37 s
Mizar	ξ	2	(2.27)	+1.4	1.12	18 ts
	η	2	(1.86)	−1.7	1.74	33 mx

Tabla 1: Constellation of Ursa Major.

Cassiopeia	m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.
β	2	(2.27)	+1.9	1.02	13 ts
Schedir α	2	(2.23)	−0.9	1.58	37 s
μ	5	(5.17)	+5.8	0.84	7.7 t
δ	3	(2.68)	+2.1	1.18	19 ts
χ	5	(4.71)	+0.2	1.96	80 s

Tabla 2: Constellation of Cassiopeia.

Leo	m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.
Algenubi ε	3	(2.98)	−2.0	1.96	95 s
Regulus α	1	(1.35)	−0.6	1.42	26 ts
τ	5	(4.95)	−0.9	2.18	150 s
υ	4	(4.30)	+0.2	1.76	64 s
Denebola β	2	(2.14)	+1.7	1.08	12 mx

Tabla 3: Constellation of Leo.

Hercules	m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.
β	3	(2.77)	+0.3	1.54	31 s
δ	3	(3.14)	+0.9	1.42	28 s
π	3	(3.16)	−2.3	2.06	120 s
ρ	4	(4.17)	+0.6	1.68	52 s
λ	4	(4.41)	−0.3	1.86	85 s

Tabla 4: Constellation of Hercules.

Cygnus		m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.	
Albireo	β	3	(3.08)	−2.3	2.06	120	s
	δ	3	(2.87)	−0.6	1.72	49	s
	η	4	(3.89)	+0.2	1.76	52	s
Deneb	α	1	(1.25)	−7.5	2.70	560	s
	ν	4	(3.94)	+0.6	1.68	45	s

Tabla 5: Constellation of Cygnus.

Orion		m	from slides (real value)	catalogue M	by calculator $\frac{5+m-M}{5}$	catalogue D in pc.	
	π^3	3	(3.19)	+3.8	0.84	7.7	t
	ρ	5	(4.46)	−0.2	2.04	86	s
Rigel	β	0	(0.12)	−7.1	2.42	280	s
Saiph	κ	2	(2.06)	−0.2	1.43	21	mn
Betelgeuse	α	0	(0.50)	−5.6	2.12	95	s

Tabla 6: Constellation of Orion.

Finally, the students draw the point $(D, \frac{5+m-M}{5})$ on the graphs.

Using semi-logarithmic paper to draw the graph, it is possible to observe equality $\log D = \frac{5+m-M}{5})$, that is to say to observe a logarithmic relation between the coordinates of points $(D, \frac{5+m-M}{5})$. Before this, we have to show students the properties of semi-logarithmic paper. Particularlly using semi-logarithmic paper the graph of $y = \log x$ is a straight line. Then, when students draw on this paper the points $(D, \frac{5+m-M}{5})$ for each star of every constellation they should expect to obtain points like straight line.

3 Conclusions

In every graph, the points obtained are approximately aligned (Fig. 1,2,3,4,5 and 6). The students can observe a clear structure of a straight line in every case, then we verify $\log D$ is equal to $\frac{5+m-M}{5}$. Or, in other words, $M - m = 5 - 5\log D$ which was our objective.

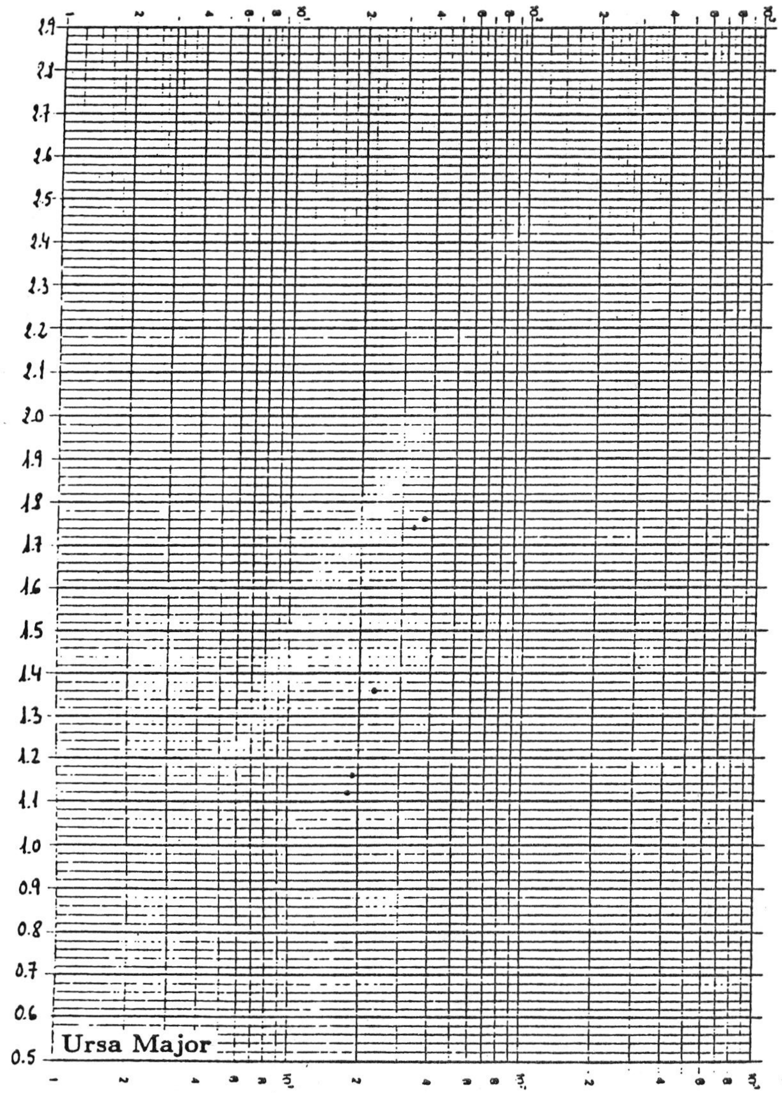

Figure 1: Constellation of Ursa Major.

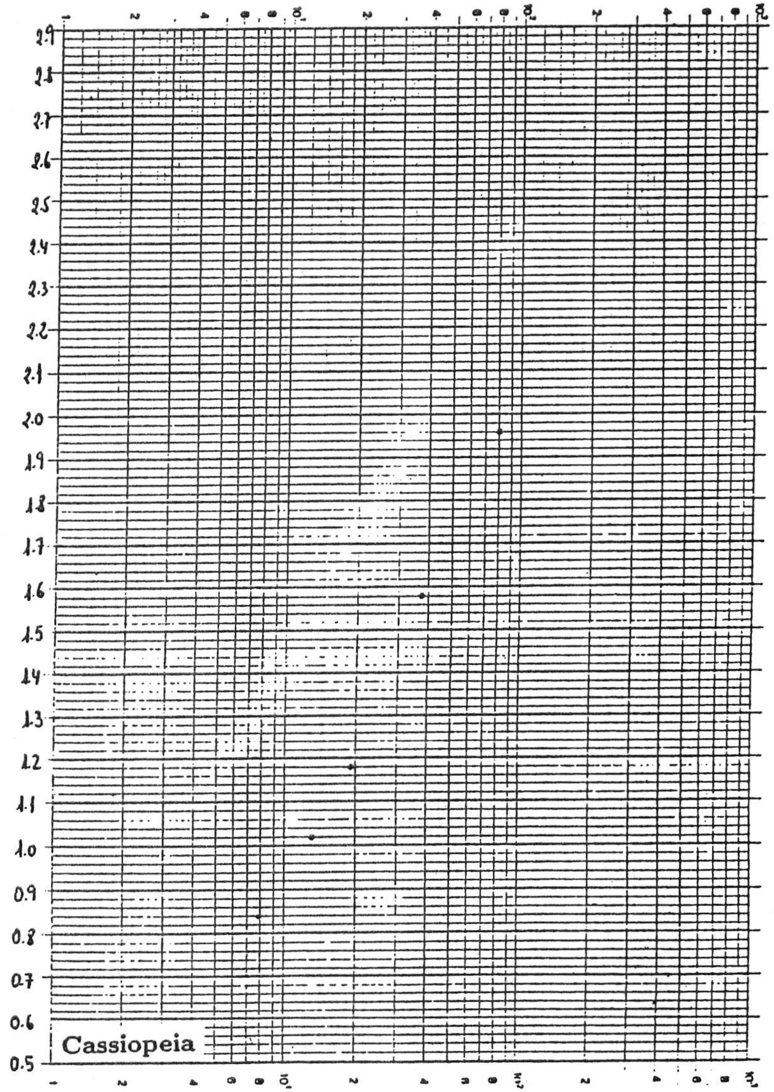

Figure 2: Constellation of Cassiopeia.

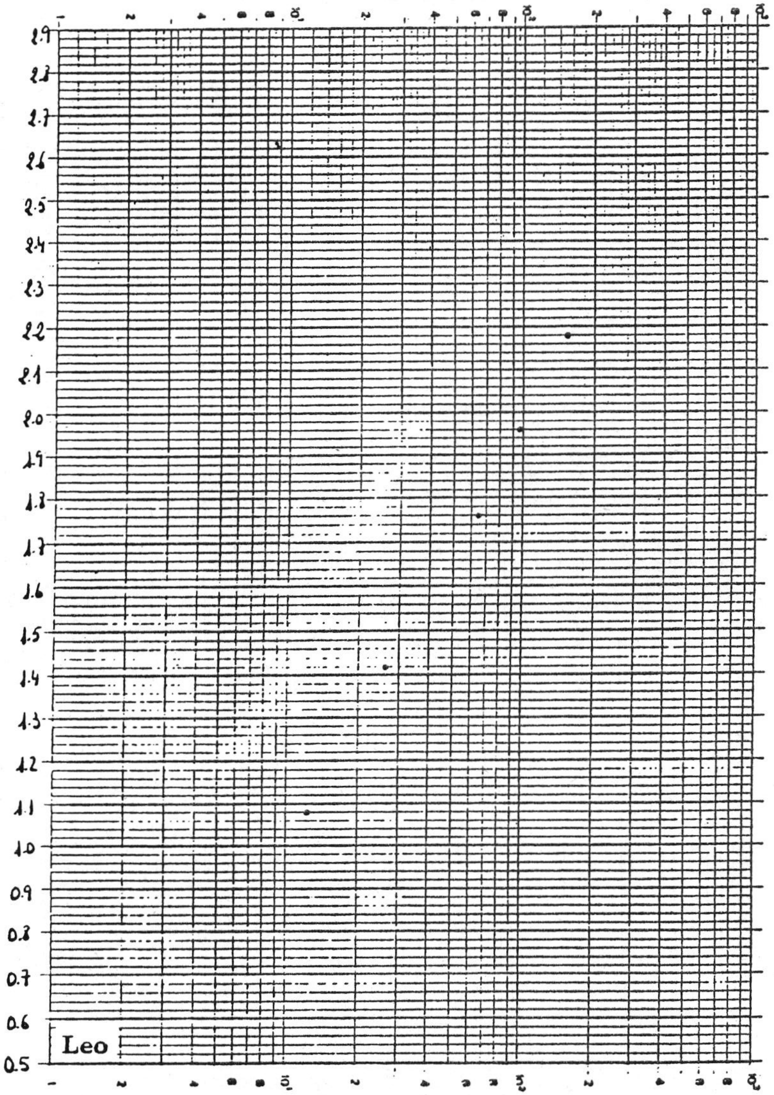

Figure 3: Constellation of Leo.

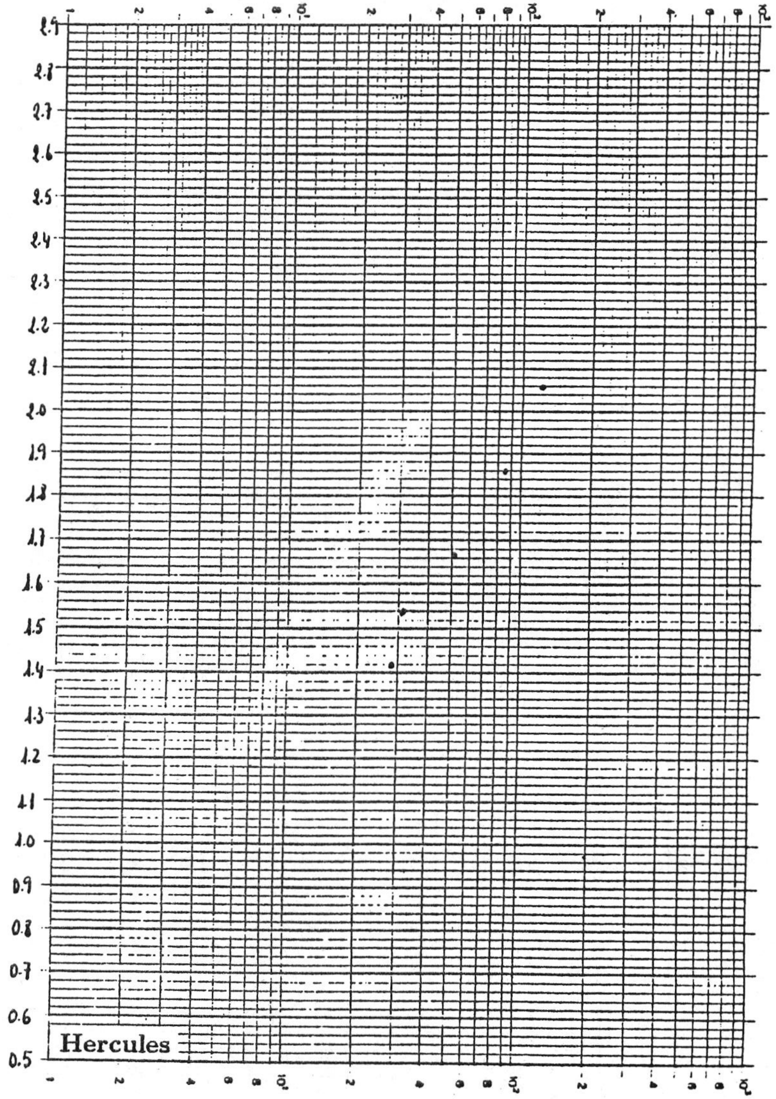

Figure 4: Constellation of Hercules.

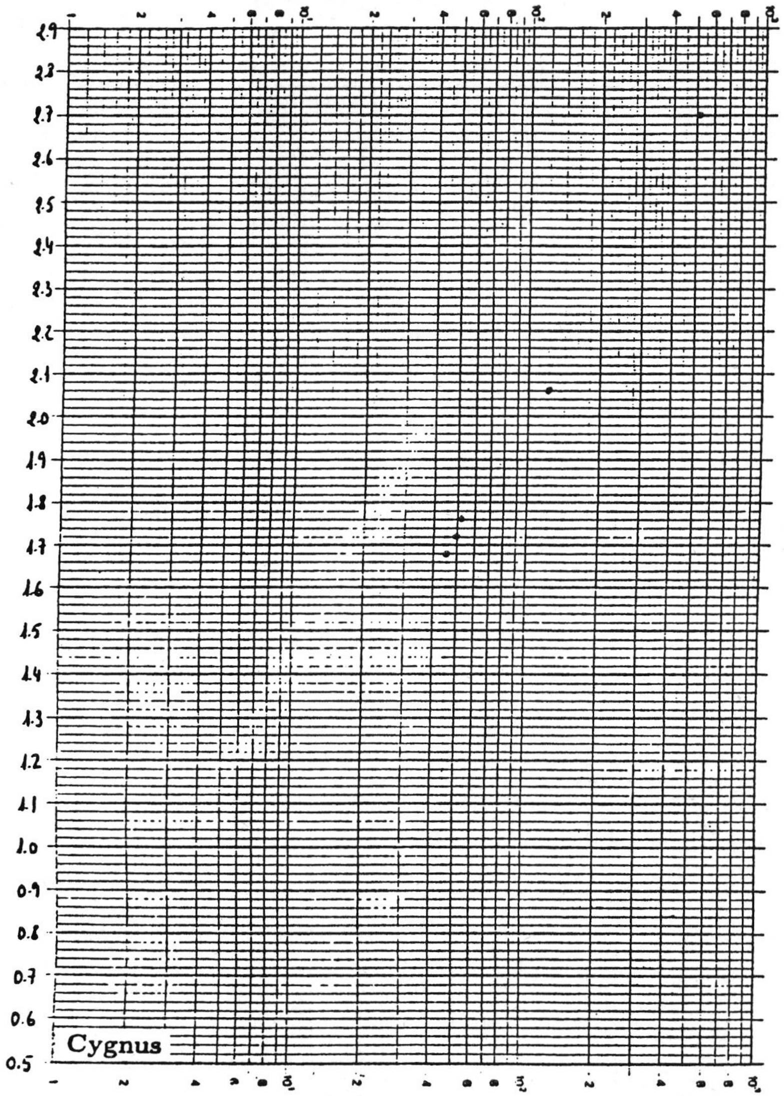

Figure 5: Constellation of Cygnus.

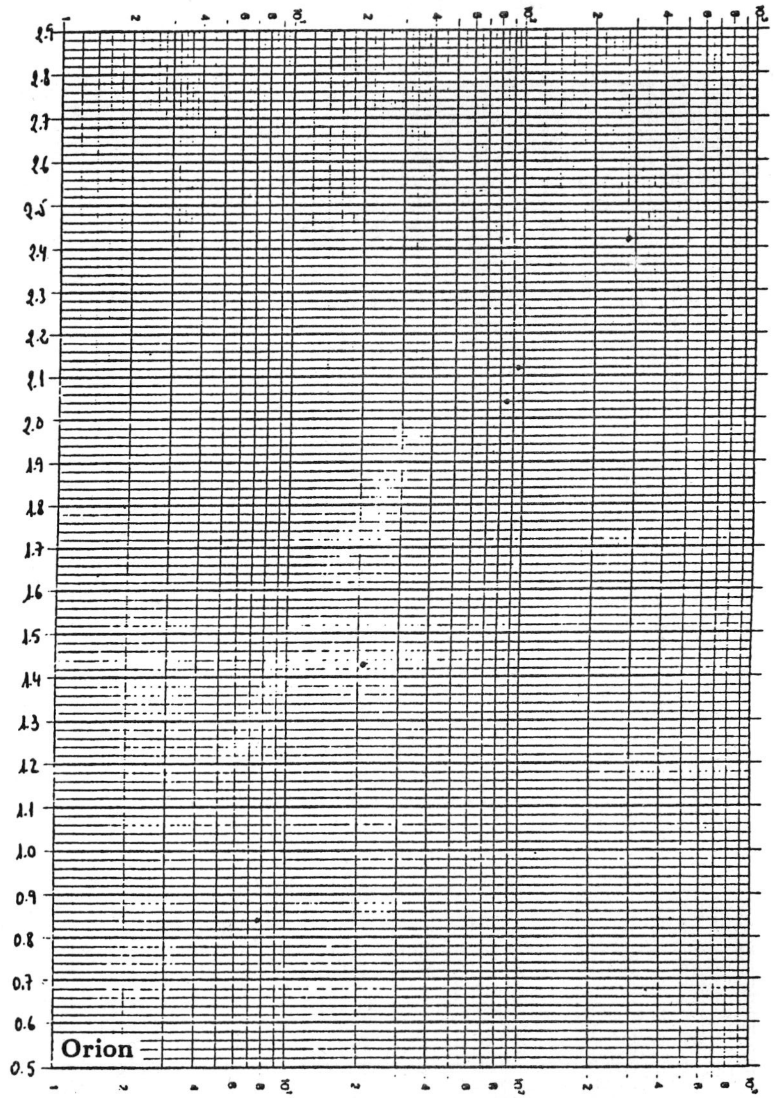

Figure 6: Constellation of Orion.

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WRITING POPULAR ASTRONOMY ARTICLE CHALLENGING FOR FURTHER THAN AMUSEMENT

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ABSTRACT

There is still getting astronomical idea wrong when the public in Indonesia receive news of fascinating astronomical objects in TV or newspapers. It is an indicator of the existence of knowledge or information gab in astronomical news between the public response and it should be. It may be also an indication of shortage time to learn or to get a necessary astronomical information for the public. Short and brief writing of popular astronomy in newspaper or magazine persistently is suggested to fill the necessary information for the public.

I. INTRODUCTION

Indonesia will be 50 years old in August 17, 1995. Nowadays the projected population of Indonesia will be about 200 millions. Half of them are young with the age range between 15 and 50 years old. In the past Indonesian community used astronomical knowledge to determine the farming seasons and solar calendar. Some Indonesian moslem scholar learned practical astronomy as early as in 7th century. Their activities are to determine praying time, the direction of qibla and first visibility of the moon crescent. The beginning of praying time determined based on the zenith distance of the sun or using the length of shadow of the sundials' praying time. The beginning of praying time corresponds to the sun at zenith distance of 109°, 2 minutes after above culmination of the sun, the time when the length of shadow of a straight stick perpendicular to the surface of the earth will be twice the length of the stick, the zenith distance of the sun is 91°, the zenith distance of the sun at 109° after sunset. The direction of Ka'bah in Mekah can be determined by using the position of the sun and knowledge of spherical astronomy. The orientation of the mosque is always to the qibla direction. The prediction the first visibility of moon crescent is important to determine the beginning of the month in Islamic lunar calendrical system. Astronomy with optical telescope formally began in the 1920's. It was started from 1923 when the double refractor Zeiss was constructed. The diameter and the focal length of the objective are 60 cm and about 11 meter respectively. The telescope is located at Bosscha Observatory in Lembang. The altitude of the Bosscha Observatory is 1310 m from the sea level with geographic latitude at south -6°49' and 7 hours 10 minutes east longitude. The telescope is about 22 years older than the country itself. It is understandable that the public mind about astronomy in Indonesia often associated with optical telescope at Bosscha Observatory. It is realized that the optical telescope are only tool in observational science. The formal education in astronomy is undergraduate program. The program was started in 1950 in Bandung Institute of Technology. The educational program conducted in the Department of Astronomy - Faculty of Mathematics and Natural Sciences - Bandung Institute of Technology. Up to now the total number of graduated people from the Department of Astronomy is about 70 peoples. Nowadays about 5 to 10 graduated student per year can be produced by the Department of Astronomy. Less than half of the graduated people is still working in astronomy, related to space research and science education. It is too small number compared with the number of population in Indonesia.

Astronomy is one of human interest. It is apart of human knowledge. It can be used for enrichment and broadening human culture, challenging for technological development and intellectual exercise. Astronomical activities keep human resources in space research. It develops human knowledge about the usefulness of space as well as to remain that there is possible disaster on the biosphere from space.

The progress of astronomical discoveries as well as astronomical knowledge become very fast in the near future. Many bigger optical telescopes with the diameter of main mirror over 5 m, will be constructed at the end of this century (20th century). For example Keck I and II and Subaru. Some astronomical satellites or space telescope will be launched in the near future. More information and explanations of astronomical object from deeper space will be available. Those will enhance astronomical knowledge and information hidden by earth atmosphere. View of a new universe derived from the new observational data will come soon and it will replace the old one. General public needs more effort in imagining about the new idea in astronomy. It is not easy to imagine the system of black hole, pulsar, planet arround pulsar, quasar, blazar, mega maser galaxy, active galactic nuclei. The public just catch the name of fascinating astronomical objects from a short news in TV or perhaps radio or even in news paper. Not all the new information can be explained in detailed directly. Generally astronomers or science writers are not ready to prepare popular writing for the fascinating objects in a short time. In Indonesia the number of people who trained and well equipped with astronomical knowledge too small compared to the country like Japan or America. Due to the limited expert in astronomy there is some demands that each astronomer should know any progress in various fields in astronomy. It is almost impossible that each astronomer follow or to read each astronomical progress.

In Indonesia there are several ways to get further information. Every year, thousands of students from basic to senior high school visit to Planetarium Jakarta in Jakarta (for average it is about 750 people per day) and Bosscha Observatory in Lembang (about 40 people per day). The visit activities are usually to see the telescope, to enjoy popular talk in astronomy and asking further about fascinating astronomical objects or to confirm their astronomical view. It is interesting job but for professional astronomers it may be a time consuming job. In other occasion some people may ask further information by phone or write a letter to the planetarium Jakarta, Department of Astronomy in Bandung or Bosscha Observatory.

Library in Bosscha Observatory or other's library like central libraries in the Bandung Institute of Technology or in the Department of Astronomy are equipped with astronomical books and science magazine. Those libraries are also place to access astronomical knowledge. However, it is rarely visited by the public. It is probably due to the library located "far away" from the public. Furthermore the available information is mostly in English. It is not easy to extract the technical information without some effort and some basic knowledge. Writer or lecturer for public needs an effort to digest the technical information so the astronomical idea can be understood easily by the public. If the public seriously use the library the small number of the library facilities compared with the number of people may not enough to serve or to enrich the knowledge of the public widely. Those library facilities will be a complement of popular article. Such facilities may not replace the role of popular article in newspaper or magazine that appears in unsystematic way to respond the current astronomical issue. Popular article keeps the astronomical knowledge remain fresh for teachers as well as for amateurs and general public.

Inspire writing about the beauty of the universe in popular way and making people can understand easily is a challenge for astronomers and science writer. For higher level astronomers may use mathematics and physics as the language to explain the beauty of the universe. The popular and inspire astronomical writing may induce and strengthen the spirit of religious life to some people in Indonesia.

We thank to many journalists, science writers and amateur astronomers for their effort to make astronomy become popular and enjoyable to the society. Knowledge of astronomy is not only for astronomers, public could obtain the knowledge as far as they can. At the end the astronomical knowledge should become one of the earthling properties.

II. INFORMATION AND REASONING AS GAB INDICATOR

Examine the motivation of some new student in astronomy (10 to 15 students) in the last 5 years by asking question why do they interest in astronomy? Sometimes the answer contains misunderstood conception between astronomy and astronautics or the have wrong perception in astronomy. Astronomy is known as science dealing with the beauty of photograph of galaxies and nebula or the picture of other world taken by space telescope or astronomical satellite. They are often very surprised to have hard course in mathematics and physics during study in astronomy. Some detrimental view about the out of date of ground based optical telescope sometimes appear without knowing the science and the role behind the ground based telescopes or astronomical detectors and astronomical techniques. Some of their interest in astronomy were formed by watching science fiction film. It is a mixed up idea between science and science fiction. They wish to become science fiction writer through study on astronomy. Some of them are getting interest in astronomy by reading popular article and astronomical book. Some others are motivated by religious doctrine and spirit. Their answers of their interest in astronomy reflect that the number of writing popular article and books in astronomy is still useful from generation to the next generation. If we notice a wider public, we may find that some people still have a mixed up idea between astronomy and astrology, planet and stars, planet and the sun.

From oral astronomical questions and answer from visitor in Bosscha Observatory, telephone call and quiz with prize in TV can be drawn qualitatively that the knowledge of public diverse with great variety and surprisingly. There is some information gab between astronomers and general public. For example when there was a news about the discovery a new planet around pulsar in July 1991 and February 1992. The positive reaction of some people in Indonesia about the discovery was wishing to see the planet through their own optical telescope and asking the position and the name of the planet. The journalists were asking for further information about how to discover the new planet. Another example there was a news about the moon at the perigee on December 2, 1990, some people asked the impact of the moon at perigee on the earth and life in the earth. It is similar situation when superior and inferior planetary conjunction happened in October - December 1982. The conjunction caused stronger tidal force on the earth and the planets Some people felt panic due to the news of the planetary conjunction. They were afraid that stronger tidal force would make disaster on the earth. In this situation the public needs professional astronomers to explain the astronomical phenomenon clearly. Another example is when the collision of S-L 9 and Jupiter occurred in July-August 1994. There were some telephone calls asking question whether the S-L9 collisions produce a dangerous X ray for human being in the earth or does it causes some disaster on the earth? There are still some more panic questions concerning the collision's event. Writing popular astronomy with some information and press conference about S-L 9 collision made clarify the situation. Again about the collission, it was broadcasted in TV program in December 1994. In the program there was question asking the date of the collision between S-L 9 and Jupiter with about one million rupiah (about $ 500) prizes. In general, the people in Jakarta or Java were well informed about collision between S-L 9 and Jupiter. It was surprisingly that many of them did not give correct answer. It may be due to degree of awareness or the information is easily forgotten. The people from Aceh in Sumatera gave correct answer for the question within a short time. He got the prize. One more example is some debate among the result of observation on the first visibility crescent by naked eye. One results says it was visible and the others says it was invisible. The very young crescent is very faint and less contrast compared with the brightness of sky background. The object is difficult to resolve among the cloud in west horizon. The observing time or the chance is very short. Astronomers have to clarify the problem.

III. PUBLIC PARTICIPANT FOR ASTRONOMICAL DEVELOPMENT CAN BE EXPLORED?

Training science teachers from basic to senior high school or other university's lecturer may be one among solutions to overcome the existing conception gab between astronomers and society. The flow of astronomical information or idea from science teachers to student may be seen as concept from public to public. The solution may just to eliminate the existing wrong idea of standard conception of astronomy given in the curriculum. The difficulties to imagine a new object and a new idea in astronomy may not easily solved by the method. Professional astronomers should give a proper explanation about the new astronomical idea or astronomical object in popular language.

What kind of connection can be made between writing popular astronomy and astronomical issue on the development of astronomy? The problem of astronomical development is also the problem of the progress astronomical knowledge of the society. The enthusiastic effort to popularize astronomy may not long lasting without development astronomical research center where the deep souls as astronomers exist. With respect to the government and policy makers in Indonesia, some questions to the public arise: Could the society participate to solve the problem facing by development of astronomy in Indonesia? The government and the policy makers support the idea for astronomical development, but astronomers realize that they may not enough budgeting support.

Another issue is looking for appropriate job after passing astronomical education (undergraduate level) is a current issue in Indonesia and probably in many other countries in the world. It rises up a question whether education (including research) in astronomy should be enlarged or kept small. Astronomical education spread from a relatively cheap to very expensive. Cheap mean the education based on the available literature and expensive deals with constructing and maintenance of new instrument and massive data reduction. The cheap astronomical education level may be remain for science education and it hopefully develope frontier of science in theoretical work. The cheap and the most expensive expenditure in astronomical research is still within human achievement. The Indonesian government and policy makers support the development of astronomy in policy level. The supporting budget depends very much upon the available government money which generally enough up to maintenance not for development. The above astronomical issue may become less important as some enough financial support available. It is still possible to develop astronomical research center or to make a new astronomical education before or after the question can be answered properly. It needs rich person with their love to develop astronomy. It is necessary to have a connected idea between professional astronomers and rich person. The rich person may come from domestic and foreign countries or perhaps foreign government.

Another issue is light pollution, radio signal pollution in the surrounding of the observing site as well as space debris far above atmosphere will be the future conflict of interest in modern society. To solve the problem astronomers need some discussion to build up mutual understanding among scientist, government and general public. Without communication with popular writing they may support the idea but they do not know how to operate in practical level.

Some experience happened in June 1983, when the Indonesian government prohibited to watch the total solar eclipse. It was many writings on popular astronomy about the eclipse. However, the government made an over safety decision. The society was the victim of the decision. They loosed a chance and experiences to watch total solar eclipse directly.

IV. TIME FOR PUBLIC

Writing popular astronomy is like an art. The people enjoy in reasoning and satisfying to get a new knowledge by seeing a new and invisible world in the distant place. The purpose of writing popular astronomy is giving an information, awareness, warning, transfer of knowledge, explanation and understanding about the restless of the universe. We can not remove the existing information and explanation gab in astronomy through writing popular astronomy, however we can reduce it. How much time must be spent for popular astronomy writing? It may be varies in views from writing it self may distract a serious concentration in astronomical research up to writing may just take some leisure time. Why do we spend more time for writing popular astronomy since we do not hope that all people become astronomers?. If we do not write popular article, the culture enriched by astronomical knowledge may not be borned. Gradually, it will create knowledge gab in the society. The knowledge gab will isolate astronomy from the society and kill their serious interest gradually. The society knows a little or does not know at all what is going on in the space program and space activities. If the society does not know about the astronomical activities and if they do not enjoy the knowledge from the science of astronomy, it is difficult to see the way how they become fall in love in astronomy. The space program had spend a lot of money and resources to achieve the current frontier of knowledge of distant world. The price of the space program becomes more expensive if the achievement knowledge could not be enjoyed by a lot number of people.

Understand and enjoy the progress of astronomical knowledge is a common target of human interest. A word popular astronomy is some times interpreted cynically as popularization through astronomy (either good or bad reputation). Professional astronomers are professional in astronomical research and education, but not necessary professional in writing popular astronomy. Certainly theirs well trained in writing scientific paper may help in effective writing on popular article. Writing popular astronomy is a kind investment for the future astronomical development. Some amateur, science writer and journalist may have professional in writing popular astronomy, however they need more information and more interaction with professional astronomers to exchange and may be sharpen the new idea. They have more time than professional astronomers. Some students with their astronomical knowledge at the third or fourth grade sometimes have enough knowledge to explain a simple astronomical phenomenon. It is not necessary that someone has perfect and complete astronomical knowledge before writing popular article, but certainly it will be better if they have more knowledge and experiences. The essential thing to write a popular astronomy is to convey a correct idea and correct information in standard writing. For students writing is apart of practicable education. They learn how to absorb, to convey and to organize information. Some astronomical bulletins contain many popular articles written by Indonesian student in Astronomy are also available. That is still useful information for the public.

V. WHY MUST BE PROFESSIONAL ASTRONOMERS INVOLVED?

Astronomers have a professional knowledge in astronomy and astrophysics. They may have vision in astronomy and select a necessary material could be given to the public. They digest technical astronomical information before delivering to the public. Their professions come from their main duty for astronomical research (or reviewing, reading) and the way to report their progress works, so writing a professional and technical paper is a standard experience. They are source person in astronomy to enhance the broad based knowledge of the public.

Writing popular astronomy sometimes need to create a new word for astronomical term. It is not easy without understand astronomy. Professional astronomers may lead to find appropriate word for some foreign astronomical term. The distortion of scientific message is often occurred especially when the interpretation of translated sentences goes wrong. It is also occurred when not easy to find correct word or sentence to convey the content of astronomical message in popular way. In this respect of course to make more training and more educated people are one of the alternative solution. It seems not enough due to the number of new astronomical phenomena and new results of astronomical research often come suddenly like meteor shower, collisions in the solar system. Only people well equipped with astronomical knowledge can give better explanation and more comments for those astronomical phenomena.

The professional astronomers know very well about what they study in depth, so it is hopefully they can write in more broad their vision and more enjoyable. It is true that not all difficult and complicated knowledge possible to be exposed in simple way without technical term. It is necessary to have new spirit to write as popular as we can reach, so it can be understood by many peoples. It inspires to many people, serious but relax in presentation.

The tied schedules make astronomers have limited time. The pressing situation makes astronomers have almost no time for the general public. In Indonesia writing popular article or delivering information in his field for general public is apart of duty for academic staff of government official. Professional astronomers need some time to write popular article in their career. The short popular article can be published in newspaper (in Indonesian) or magazine. Actually there are many options to write a popular article in Indonesia (newspapers, bulletin and magazine). At present, it may be too ambitious to promote the unstructured material of writing popular astronomy as informal education in astronomy without improving systematic dialog and persistent writing in a long time.

The societies do not have enough general knowledge for ordinary or even more complicated nature of astronomical phenomena. They need professional astronomers to explain clearly. To place astronomy knowledge in the public mind is extremely importance. It makes easier to convince that still too many interesting things in the heaven must be explored and must be learned for long time. There are so many unknown things in the deep space. If the member of society knows about all there will be more chance for support. The support may not come directly but as public idea, public opinion and feeling love in astronomy.

Writing a book about popular astronomy will also become important but it may take more time to write understandable, exciting and challenging for public or for student at lower education stages. Writing daily astronomical phenomena, eclipse and other's activities, some experiences to observe astronomical objects in the sky with small telescope will keep some impression of celestial object and universe in human mind.

Teaching General Astronomy at St. Petersburg University

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Abstract. The paper presents the course "General astronomy" which is given to the first year students in astronomy of St. Petersburg University. The course is the basis of the astronomical curriculum. The reader will become aware of the goals, pedagogical principles, specific features, and author's experience of teaching "General astronomy".

1 Introduction

St. Petersburg is one of the largest centres of astronomy in Russia. There are several specialized astronomical institutions carrying out research in various branches of astronomy: Pulkovo Observatory, Institute of Theoretical Astronomy, Institute of Applied Astronomy, Astronomical Institute of St. Petersburg University. In order to maintain normal work of these centres, it is necessary to provide a continuous income of young astronomers. St. Petersburg University is among a few educational institutes in Russia that perform a full-program, specialized training of professional astronomers. This function is carried out by the Astronomical Division, a part of Department of Mathematics and Mechanics. About 20 students graduate from the division yearly, getting the diploma of astronomers and starting their work in astronomical centres of Petersburg. Some graduates replenish the staff of institutes and observatories in other places of Russia, independent states of the former Soviet Union, and several countries of Asia, Africa, and South America.

The educational system of St. Petersburg University leans on the old traditions and, on the other hand, it has been naturally evolving with the progress of astronomical science. More than 150 year history of astronomical education has yielded a rich pedagogical experience and resulted in a number of conclusions on how to train students in the most effective way.

This paper deals with one of the basic ingredients of the astronomical education system, the "General astronomy" course delivered for the 1st year students. "General astronomy", being the first astronomical matter for students just entered the university, provides a systematic introduction to astronomy and lays the foundations for further education. The course has been proving its worth for a long time.

In the subsequent sections, we discuss the place and functions of the course within the overall curriculum of astronomical education; outline its logical organization and describe its various components — lectures, seminars, test papers etc.; present the didactic strategy and give a number of teaching patterns. The paper reflects the author's 5 year experience in teaching "General astronomy". We hope that some material presented in the paper might be of interest to our colleagues involved in astronomical education in other universities or institutes.

2 General features of the course

The course "General astronomy" is the first course over five years of students' training, where astronomy, with its diverse particular subjects and methods, is treated as a united and unique science. It is of particular interest that we join two broad parts of astronomy — classical astronomy and astrophysics — and systematically emphasize that they do have very much in common. Such a juncture expresses our firm belief that both parts essentially interact and penetrate each other, and will fruitlully do that in future. That is why we insist that each young astronomer, whatever his specialization is, must be familiar with the basic principles and main achievements of all the astronomical disciplines — from astrometry to cosmology.

The course aims at setting up a background knowledge in astronomy. One can say that "General astronomy" is the "root of the tree" of astronomical education. Later on the students will proceed their education with a set of more detailed and specialized astronomical courses. At the 3rd and 4th year level, the "educational tree" expands to a set of matters comprising astrometry, celestial mechanics, stellar astronomy, general astrophysics, theoretical astrophysics, radio astronomy. Then, at the 4th and 5th years, it evolves toward the special courses and special seminars, depending on a more narrow specialization chosen by a student. For instance, those who specialize in celestial mechanics may attend lectures on "Theory of lunar motion" or "Relativistic celestial mechanics", whereas astrophysicists are teached in, say, "Radiation transfer" or "Astrospectroscopy".

It is to be noted that "General astronomy" is the only astronomical course in the first year education schedule. This is because during the 1st to 3rd years the accent is placed on the basic mathematics and physics, rather than on the astronomy itself.

The course "General astronomy" lasts for one year (two academic terms) and includes 120 hours teaching (approximately two lectures per week, each being of two hours duration). The basic (and obligatory) forms of training are: a set of special introductory lessons, "main body" lectures (≈ 70 hours), seminars, intermediate tests, and final examination at the end of the course. Besides, there exist some optional parts of the course. In later sections, all forms of teaching will be described in more detail. Notice that the parts of the text below are not proportional in volume to the parts of the course they describe. This is because we concentrate most attention on the non-standard things rather than on those consuming most teaching time.

3 Introductory lessons

A distinctive feature of "General astronomy" is that the main set of lectures is preceded by a special block of lessons (most of then being lectures) called "Introduction to astronomy". It takes 12 academic hours and plays a multifunctional role. It explains, at a quite popular level, what astronomy is and how astronomers work. It draws a general picture of the Universe. Besides, it forms (or at least tries to form) an initial (hopefully positive) impression of students about astronomy and their own future life in professional astronomy. The "Introduction to astronomy" performs therefore both information and psychological functions. It seems worthy describing this part of the course in more detail.

The first lecture, called *"Apology of astronomy"*, presents astronomy as a science; characterizes its subject, methodology, relations to other sciences; demonstrates its fundamental, applied, and cultural importance. This opening lecture may occur the first serious presentation of astronomical science to students' minds; that is why it must be a well-organized talk designed perhaps in a somewhat solemn manner to produce a noticeable psychological response.

The second lesson is not a lecture. Unexpectedly for students, they are requested to pass through a quite extended test. It consists of 50 questions covering all branches of astronomy, of course, at elementary level. The students are required: to indicate values of physical constants (c, G, h); to explain simple terms (say, radio telescope, cepheid, Galaxy); to give elementary evidences of well-known phenomena ("Prove that the Earth does rotate"); to reveal their knowledge of history ("What is the scientific merit of Copernicus?") etc. Note the individual results are not announced publically that allows students to feel free in their answers. This test paper has the dual purpose. First, a lecturer becomes learnt about the initial level of knowledge of a particular group of students and can make corrections to the lectures, if necessary. Second, each student will recognize his own results and at the same time he will know the overall statistics; hence a student is capable of making natural conclusions for himself.

The third lecture is entitled *"Professional astronomy"*. It makes the students familiar with main astronomical institutes and observatories, astronomical societies (such as IAU), astronomical information (libraries, academic publications, computer communications etc.) and so on. The undergraduates also get the first acquaintance with their expected educational and professional career.

The fourth lecture is called *"The Universe in pictures"*. It is, in fact, a special slide session with detailed commentaries. A slide set comprises images (pictures, schemes, plots, diagrams and so on) of the most important (and most beautiful) astronomical objects and phenomena so that the students make a journey across the Universe. The idea is to awake an inspiration and imagination of undergraduates, showing them how nice and perfect the Universe is, to professional investigation of which they orient themselves. Apart from the emotional effect, this visual lecture first demonstrates the hierarchy of astronomical subsystems. Some principal concepts, notions and terms first appear at this slide session, to be more thoroughly reintroduced and reexplained further in the main set of lectures that leads to clearer understanding and keeping in mind ("repeation is the mother of teaching"...).

The subsequent lecture entitled *"The Universe in numbers"* is close to and simultaneously contrast with the lecture just described. Again, the students travel across the Universe. However, another language is employed now to give an insight into the physical reality: we abandon pictures in favour of numbers. The Universe is silhouetted in terms of specially selected (and quite lengthy) set of constants and parameters. They are divided in a meaningful way into the following groups: fundamental constants; atomic nuclei; atoms; man and mankind; environment; Earth-Moon system; Solar system; the Sun; the Sun as a star; stars; interstellar medium; galaxy; Metagalaxy and cosmology; history of astronomy. All the numbers must be known by students by heart. The first reaction of students to this requirement usually resembles a shock and rises questions like this: "What are the reasons for us to keep so lengthy list of numbers in mind instead of making something more meaningful?" However, they find the answer by themselves after a very short time. First, it is evident that the knowledge of these quantities furnishes one a good idea of the structure and properties of the Universe. Second, it is really helpful because, keeping these constants and parameters in mind, one can easily make various estimates, solve simple problems etc. Furthermore, the "Universe in numbers" is quite popular among my colleagues who often use this list of quantities as a mini-version (better to say, caracaturized version...) of famous Allen's book [1].

The introductory part of the course is completed with a special test paper on the "Universe in numbers".

4 Lectures

Lectures constitute the basic element of the overall course. They offer a systematic presentation of investigation methods and research results of astronomy. It should be emphasized again that a distinctive feature of our set of lectures is a wide coverage of all parts of astronomical science, both classical astronomy and astrophysics. The full educational program is given in Appendix 1.

Several pedagogical principles are used throughout the course:

1. We try to combine the "method-oriented" and "phenomenon-oriented" approaches in composing the lectures. So, we exhibit the subject and methodology of each astronomical discipline and at the same time we show an essentially interdisciplinary nature of a number of problems. For example, the lecture on "Earth tides" is not restricted to the description of tides as a classic phenomenon in the Earth-Moon system. We also discuss tidal effects from a general viewpoint and reveal many other cases where they come into play (formation of planetary rings, evolution of close binaries and so forth).

2. We try to combine a clear and rigorous explanation of basic material with an acquaintance with present-day aspects of modern astronomy (including the most exciting unsolved problems). For instance, the lecture on "Time" not only introduces the standard time scales, from sidereal to universal time, but also contains a brief account of contemporary time scales, from TAI to TCB and TCG [2].

Each lecture (sometimes, a couple of lectures) is designed in such a way that it forms a logically complete presentation of a certain issue. As examples, the following lecture titles could be listed: "Celestial sphere", "Two-body problem", "Solar atmosphere and solar activity", "Origin and evolution of stars" and so on.

5 Seminars and current tests

Each chapter of the lecture course (see Appendix 1) is completed with a two-hour seminar, aiming at solution of simple problems. Normally, the students are trained in solving the problems that require estimates and approximate calculations rather than full-accuracy cumbersome computational procedures. It is supposed that students are well familiar with the list of astronomical quantities (described in sect. 3) and with the necessary formulas.

A simple example of a typical problem is: "Estimate the mass of the Earth atmosphere". The answer can be derived from, say, the following constants entering the list of quantites: radius of the Earth, height of the homogeneous atmosphere, and density of air near the surface.

By offering problems, we try to invoke students' abilities of thinking, reasoning, making conclusions rather then merely combining the formulas and numbers. For instance, the teacher addresses to students with the following question: "Could you estimate the time interval, after which the changes in contours of well-known constellations will be visible by a naked eye?". Such a formulation contrasts with typical scholar problems that usually sound as: "Given:... Required:... ". At first students' glance, neither what is given nor what is required is clear . Meanwhile, there exists a good way of reasoning of the following type. One can start with the formula: v_t [km sec^{-1}] = 4.74 D [pc] μ['' yr^{-1}], with v_t, D, and μ being the tangent velocity of a star, its distance, and proper motion, respectively. It is evident that stars forming the well-known constellation figures are among the brightest and hence probably the nearest stars. It allows us to adopt several tens of parsecs as a typical value of D. As to v_t, we can assume it to be several tens of kilometers per second, a typical value of stellar velocities in the galaxy. We conclude that typical $\mu \sim 0.1''$ yr^{-1}. Next, one can assume that a constallation changes in shape appreciably if its constituent stars displace, say, by $1^\circ = 3600''$. Thus, it takes 36000 (to our accuracy, several tens thousand) years for the constellations to alter their contours markedly.

Of course, the difficulty level of problems is steadily growing through the course. Some other examples of problems are given in Appendix 2.

We teach the students to apply several good ideas in solving problems: (i) to keep only necessary accuracy in calculations, consistent with the accuracy of initial data; (ii) to use, where possible, a self-consistent system of units in order to avoid embarrassing mistakes; (iii) to estimate each step of solution and the final result by "common sense": "What I've actually got?". All these recipes, trivial though they may seem, in fact are not to be really used by many students. It takes time and patience of a teacher to make undergraduates accustomed to these rules.

The course also includes several (4 to 5) intermediate tests throughout the academic year. Each test offers 5 to 20 problems to be solved in 2 hours.

6 Examination

Each student must pass an examination at the end of the academic year. (If the results of his/her tests during the year are unsatisfactory, the examination is preceded by a special additional test.) The examination procedure is quite involved and essentially comprises the following steps:

1. A student selects (randomly) a card containing the names of 5 astronomical constants (e.g. speed of light, Earth-Moon distance, luminosity of the Sun, mass of the Galaxy, Hubble's constant) and must write correctly the numerical values of at least 4 of them. If it is done, the student is allowed to the second step.

2. The student chooses by chance one of $\approx$ 30 basic examination cards containing 3 topics of the lecture course (see Appendix 3 for examples). The contents of each issue (ideas, definitions, formulas, schemes etc.) should be presented by the student after 1 hour of preparation (notebooks or textbooks are not accepted). Such a presentation bears some resemblance with a broad scientific discussion between the teacher and student, and never can be just a student's monologue, with teacher as a passive listener.

3. The final step of the examination implies a solution of a problem proposed by the examinator. The problems are similar to those considered in seminars and test papers.

All results are expressed by an integral mark in 5-point scale (5 — excellent, 4 — good, 3 — average, 2 — poor). This scale is standard in Russia. A mark from 3 to 5 officially permits the student to continue his education, whereas 2 is considered unsatisfactory.

Contrary to the wide-spread opinion, we look upon examination procedure as being an important element of teaching. Indeed, during 1/2 hour communication with a student the examinator has a rare opportunity to teach him *individually*, explain him his personal mistakes and supply him with personal advices.

7 Complementary forms of teaching

There are some forms of communication between the teacher and students that play a role of complementary (but quite natural and popular) parts of the course.

Among them, there are several *excursions* arranged from year to year for students in astronomy. Note an excursion to Pulkovo Observatory, one of the well-known astronomical institutions in Russia. Another excursion, always available for our students, is a visit to the Astronomical library of St. Petersburg University. This division combines its basic library functions with the role of a small museum. It contains a number of exhibits — from a fragment of a large meteorite to some samples of XIX century astronomical instrumentation. We treat these excursions to "astronomical places of interest" as a direct continuation of lectures.

A further form of teaching is provided by specially arranged students' *meetings with professional astronomers* working at the University and other Petersburg's astronomical centres alike.

Worthy of mention is also *computer-assisted teaching*. Some topics can be (and really are) explained in the most effective way by means of different kinds of astronomical software.

We always encourage the self-motivated activity of students. Informal *consultations* and answers to diverse questions of students are considered as a creative element of teaching.

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9 References

[1] C.W. Allen, 1973. Astrophysical Quantities. The Athlone Press, Univ. of London.
[2] Reference Systems, 1991. Eds. J.A. Hughes, C.A. Smith, G.H. Kaplan. USNO, Washington, D.C.

Appendix 1: Educational program

1. Astronomy as a field of science. Subject of astronomy. Astronomical observations and experiments. Relation of astronomy to other sciences. Practical, fundamental, and cultural functions of astronomy. Astronomical disciplines.

2. Spherical astronomy. Formulas of spherical trigonomertry. Celestial sphere, main points and circles. Celestial and terrestrial coordinates. Duirnal rotation of the sky. Risings, settings, culminations. Ecliptic and annual motion of the Sun. The principles of measuring time. Sidereal time, true solar time, mean solar time, local time, universal time, zonal time. Contemporary time scales. Calendar.

3. Astrometry. Subject and methodology of astrometry. Reference systems and reference frames. Meridian instruments and astronomical clocks. Absolute and relative methods for determination of celestial coordinates. Reduction of astrometric measurements: refraction, aberration of light, parallax, precession and nutation, proper motions. Astronomical constants. General method of constructing the spatio-temporal refernce frames in astrometry. New observation methods: laser and radar ranging, VLBI, satellite astrometry.

4. The Earth. Shape and size of the Earth. Meridian arc measurements, triangulation, satellite geodesy. Geoid, gravity, Earth's gravitational field. Gravimetry. Earth tides and tidal phenomena in the Universe. Rotation of the Earth. Polar motion and variability of latitude.

5. Celestial Mechanics. Subject and methodology of celestial mechanics. N-body problem. Two-body problem: equations of motion, integrals of area and energy, orbital geometry, dependence on time. Kepler's laws and determination of masses of celestial bodies. Orbital elements. Perturbed motion. Method of osculating elements.

6. Motion of Solar System Bodies. Structure of the Solar system. Motion of planets, satellites, minor planets, comets, meteoric particles. Configurations and synodic motion of planets. Systems of Ptolemy and Copernicus. Motion of Moon and principal inequalities. Apparent motion and phases of the Moon. Solar and lunar eclipses. Motion of artificial satellites and space vehicles. Action spheres. Interplanetary travels.

7. Physical bases of astrophysics. Spectrum of electromagnetic radiation. Astrophotometry. Flux and apparent magnutude. Thermal and nonthermal emission. Planck's law. Wien and Rayleigh-Jeans limits. Wien's law. Stefan's law. Effective and brightness temperature. Astrospectroscopy. Doppler, Zeeman, and Stark effects. Molecular physics. Ideal gas, degenerate gas, and "neutronized" matter.

8. Astrophysical Instruments. Optical, infrared, and ultraviolet telescopes. Opticlal schemes of telescopes and their parameters. Visual, IR, and UV detectors. Spectral devices. Radio telescopes. Telescopes for other wavelengths. All-wave astronomy. Non-electromagnetic observations: cosmic rays, neutrino, gravitational waves.

9. Solar System Physics. Composition and origin of the Solar system. Earth-type planets. Jupiter-type planets. The double planet Pluto-Charon. Planetary satellites. Minor planets. Comets. Interplanetary matter. Meteors and meteorites.

10. The Sun. General characteristics. Spectrum, temperature, chemical composition. Internal structure: nuclear, radiative, and convective zones. Sources of energy. Solar atmosphere: photosphere, chromosphere, corona. Solar activity and its influence on the Earth.

11. Stars. Stars, as the most important objects in the Universe. Mass, luminosity, radius, mean density, chemical composition of stars and direct methods for their determination. Spectral classifications of stars and stellar colorimetry. Realtions between stellar parameters. Hertzsprung-Russel diagram. Stellar structure and equilibrium. Physical conditions inside the stars. Sources of energy. Formation and evolution of stars. White dwarfs, neutron stars, and black holes. Binary and multiple stars. Cepheids and other pulsating variables. Nova. Supernova and their remnants. Pulsars and X-ray sources.

12. Galaxy. Structure and dimensions of Galaxy. Methods of stellar astronomy. Subsystems of Galaxy. Rotation of Galaxy. Spiral structure. Open and globular clusters. Interstellar medium, its properties and role in the formation of stars. Interstellar extinction and polarization of radiation. Gas and dust nebulae. History and evolution of Galaxy.

13. Extragalactic astronomy. Nearby galaxies. Classification of galaxies. Luminosities and masses of galaxies. Determination of distances to galaxies. Hubble's law. Radio galaxies, galaxies with active nuclei and quasars. Clusters and superclusters of galaxies.

14. Cosmology. Observational basis of cosmology: structure and non-stationarity of Metagalaxy, microwave background, abundance of chemical elements etc. Cosmological models. Big Bang and expanding Universe.

Appendix 2: Examples of test problems

1. What are the minimal and maximal midday altitudes of the Sun in your city?
2. What is the reading of your watch today at your site, when the Sun culminates over the meridian?
3. Find the apparent magnitude and the angular diameter of the Sun for an observer at the Pluto.
4. Estimate the width of lines in the solar spectrum.
5. Prove that most of coronal electrons are not held by the solar gravity and would escape from the corona into the interplanetary space.
6. Is it possible to organize ground-based observations of the interstellar hydrogen line 10_α (related to electron's transition from 11th to 10th level)?
7. Are the stars with $L = L_\odot$ in the Andromeda Galaxy accessible to the largest telescopes?
8. The mass of a main sequence B0 star is ten times the mass of the Sun. Evaluate the mean mass density of the star.

Appendix 3: Examples of examination cards

Card 1.

1. Precession and nutation.
2. Optical telescopes.
3. Stellar evolution.

Card 2.

1. Celestial coordinates.
2. Planck's law and its consequences.
3. Open and globular clusters.

DRAWING OF AN ELLIPSE ON THE BLACKBOARD

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If Kepler's laws of planetary motion are to be taught to high school pupils (age group 12+ to 14+) what difficulties a teacher has to circumvent? One of them is the drawing of an ellipse accurately on the blackboard. One can easily get a wooden compass for drawing the circle on the blackboard but for drawing an ellipse no such instrument is available in the market. Of course one can use either a slide projector or an over head projector for this purpose but these instruments are more costly than the blackboard and they can not be used in absence of the electricity. On the other hand, blackboard is present in every classroom. This situation motivated me to make a very simple instrument at home. It was used for teaching these laws to high school pupils in the summer programmes at the I.U.C.A.A., Pune, and in the Vidnyanbharati. Pupils gave good response to it and therefore I am describing below how to make that instrument.

Take a good rectangular wooden plate, ABCD, and fix three nails X, Y and Z as shown in Fig. 1. A plate, about 40 cm long and about 7 cm wide, would be quite suitable. Y nail is to be fixed at the centre of plate and X and Z are to be fixed at a suitable distance from the Y nail, say 10 cm. Also take a cotton string, about 80 cm long, and make two small loops at the ends of string. The plate and string can be used as follows, see the figure.

For drawing the ellipse, put the loops on two nails (say X znd Z) and hold the plate firmly on the blackboard with one hand. Stretch the string tightly with a chalk and move it on the board, a neat and accurate ellipse appears on it. As pupils can directly see the importance of nails in drawing the figure, they can easily understand terms like foci, major and minor axes and then one can also go onto terms like perihelion and aphelion. For the sake of proper understanding, it is necessary to draw a circle also and compare and contrast it with the ellipse. The circle can be drawn by putting both the loops on one nail, say Y, instead of using a compass.

Fig. 1