Astronomy and Telescope

Saurav Chakraborty*

1. PROLOGUE

Astronomy (not astrology) is one of the oldest scientific and technical hobbies of human being. Telescope, the most important investigating instrument in astronomy, brings the whole universe in front of our eyes.

Ancient India made some significant advances in astronomy. At that time India was in constant contact with European, Arabian and Chinese Astronomy. There are ample proofs to show that Aryabhata (499 A.D.) and Varahamihir were well acquainted with Greek astronomy. The most celebrated astronomer after Varahamihir were Brahmagupta (b.598 A.D.), Lala (8th century), Manjula or Munjala (10th century) and Bhaskaracharya (b.1114 A.D.). In the 15th century one eminent astronomer appeared in Europe named Copernicus (1473 - 1543). After him, an equally famous astronomer, Galileo appeared. He invented telescope and used it efficiently. It is known that first a spectacle maker was able to build an optical instrument through which far distant objects could be seen as if they were near. But Galileo without seeing that instrument built more powerful telescope using glass lenses. He used to observe sky objects with this telescope scientifically and was able to find those objects which could not be seen in naked eye. From there telescope started its journey. But Indian astronomers did not use telescope at that time. Sawai Raja Jay Singh II (1686 - 1743) felt a great urge in reviving the study of astronomy in India. With the aim of preparing a new table, Jay Singh at first started with the traditional brass instruments. Realizing their inadequacy, he discarded them in favour of stone and masonry instrument of huge size. He built observatories in five places: Delhi, Jaipur, Mathura, Ujjain, and Varanasi. The first one was made in Delhi. This observatory later on came to be known as ' Jantar Mantar ', a house of wide variety of masonry and metal instruments. The most important of them were Samrata Yantra, Jai Yantra and Mishra Yantra. Among the metal instruments astrolabe was the most significant. But all those instruments were used to observe those sky objects, which are visible in naked eye.

Fig. 1 : Jantar Mantar

Using this instrument Singh prepared the astronomical treatise 'Zij-I-Muhammad Shahi' and dedicated it to the reigning monarch, Muhammad Shah. Jay Singh had established contacts with Jesuit missionaries in India and came to know all about telescope. But he did not make use of the Copernican revolution ushered in Europe. He followed the geocentric system of India's tradition and that of Ptolemy. Modern astronomy arrived in India along with the European merchant and missionaries. At the end of the 17th century the French Jesuit priests of Pondicherry were already using the telescope. Jesuit priest Fr. Jean Richaud discovered with a telescope from Pondicherry that the southern bright star, a Centauri, is in fact a double star. The merchant of East India Company also brought astronomical instruments to India. They established their first observatory in Madras in 1792. Followed by invention of telescope, its shape and efficiency had gradually changed and become major part of astronomy. But till 1947 India had no facilities of sky observation with a

* *4th year student of Electronics and Communication Engineering*

good telescope. In 1947, the renowned astronomer Harlow Shapley expressed with grief that although India had great astrophysists like Meghnath Saha and Subrahmanyan Chandrasekhar, observing facilities in India were nil. In that first year of independence that remark, indeed, was true. But during the period of last five decades the situation has radically changed. Now India has a few telescopes which are not available in other countries of the world. Beginning its journey from Galilean's age, telescope traversed through various changes in types, shapes, and efficiency. Different types of telescopes are:

2. REFRACTING TELESCOPES

In this type of telescope light rays are refracted through the objective of the telescope, which is made of lens. The different types of refracting telescopes are :

2.1 Galileo's Telescope

It is the first type of telescope made by Galileo. It consists of one convex lens of long focal length as objective and one concave lens of short focal length as eyepiece. It produces erect image; hence, it is especially suitable for viewing terrestrial objects. This kind of telescope is not used for astronomical studies because if its magnifying power (f. l. of objective / f. l. of eyepiece) is increased by increasing the f. l. of objective, spherical and chromatic aberration of the objective lens distort the image, and also its field of view is decreased. Hence when Galileo observed Saturn, due to hazy image he could not identify the ring of Saturn and described it as ears of Saturn in his note.

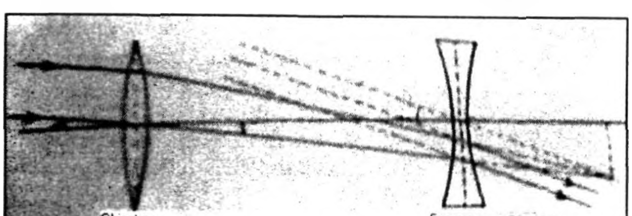


Fig.2: Galileo's Telescope

2.2 Astronomical Telescope

It consists of one convex lens of long focal length as objective and one convex lens of short focal length as eyepiece. It produces inverted image; hence, it is suitable for observing sky objects. To reduce spherical and chromatic aberration the objective generally consists of two lenses in contact with each other. One is biconvex lens of crown glass and other is plano-convex lens of flint glass. The eyepiece is also combination of two lenses separated by suitable distance. There are different types of eyepieces such as:

1. Huygen's eyepieces.
2. Kellner's eyepieces.
3. Ramsden's eyepieces.

Among them Ramsden's eyepieces are mostly used. As this type of telescope has large magnifying power, finding sky object with this is very difficult. So a finder telescope of small magnifying power is placed above the main telescope. Axes of the two

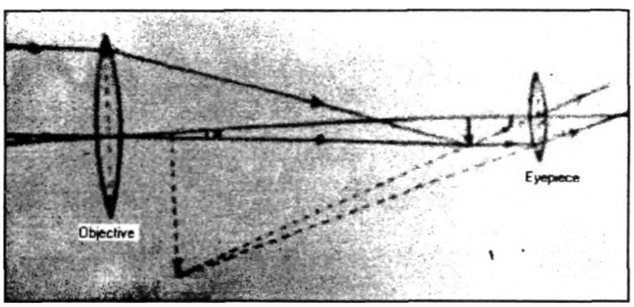


Fig.3: Astronomical Telescope

telescopes are in parallel. The eyepiece of the finder is fitted with cross-wires. Magnifying power of the astronomical telescope is obtained from the following equation:

M.P = (focal length of objective)/ (focal length of eyepiece);

And length of the telescope is given by

L = (focal length of objective) + (focal length of eyepiece);

So for large magnification focal length of the objective lens must be large, but it increases the total length of the telescope. To reduce this problem telephoto lens can be used. In this case a convex lens of short focal length is used along with a concave lens as objective. Here the effective focal length of the complex objective is large.

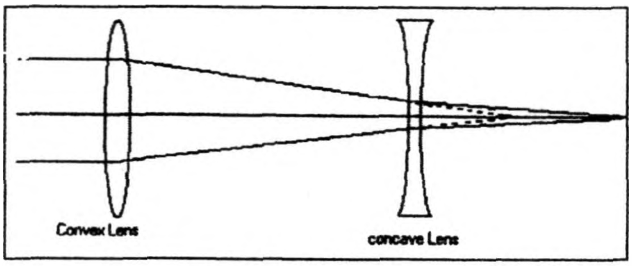


Fig.4: Telephoto Lens

3. REFLECTION TELESCOPES :

In this type of telescopes light rays from distant objects are reflected from a large concave mirror for collecting light and a conventional two-lens eyepiece is used to view the image formed by the mirror. This kind of telescopes is specified as 'x inch f/y value', where 'x' is the diameter of the mir. ɔr in inch, and 'y' is the ratio of the focal length and diameter of the concave mirror. Larger the diameter of the mirror, more light will be collected and therefore faint objects can be seen clearly. With an 8 inch f/8 telescope a star of magnitude +13.5 can be seen. For aberration free image parabolic mirror is used instead of spherical mirror. Through grinding process flat and thick circular glass pieces are given parabolic shape. In this process one glass remains fixed and another glass is moved back and forth on it with proper procedure. The moving glass gets parabolic shape. During grinding process aluminum oxide abrasives are used between the two glasses. After grinding, polishing is done using Bransite, Cerium Oxide or raugh as charge. This is a very laborious process. Generally 50 hours is required to grind and polish properly a 10 inch mirror. Pyrex (2) glass having extremely low temperature coefficient (1/3 of plate glass) of linear expansion is used for mirror. A mirror will perform close to perfection if its curve is smooth and not over 1/4 – wave length of light from the ideal parabolic shape. So to make a mirror with this kind of perfection and of a diameter of 2.5 meters will take 4-5 years for grinding and polishing. After polishing, the mirror is covered with a film of silver or aluminium for producing a surface of high reflecting power.

Most of the big telescopes are of reflecting type. In Nizamia observatory at Hyderabad a 1.2 meter telescope was installed in the year 1968. At Kavalur observatory the first observations with an indigenously built 38 cm telescope were made in late 1967. In Kavalur the one meter Zeiss telescope was installed in 1972. Vainu Bappu planned and worked hard for the erection of an indigenously built 2.3 meter telescope at Kavalur. But he did not live to see the realisation of his dream. This telescope is the largest in Asia and was set up in a big dome at Kavalur in 1985. In 1986, both the observatory and the 2.3 meter telescope, were named after the founder, Vainu Bappu. The first observatory was set up in 1954 at Varanasi and this was shifted to Nainital in 1961. In 1972 it acquired a one meter telescope. The Gurushikhar Infrared Observatory, Mount Abu, houses a 1.2 meter reflector along with stellar and infrared photometers.

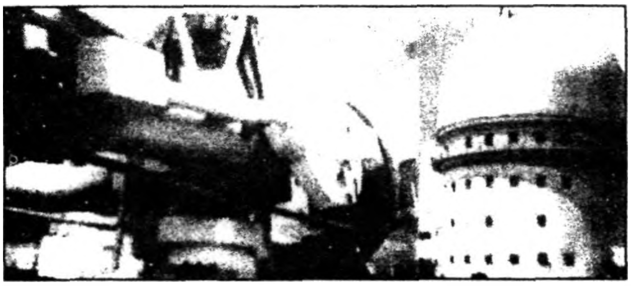


Fig.5: The 23 meter telescope at Vainu Bappu Observatory, Kavalur (left)

The Kavalur dome where the Vainu Bappu telescope is built (right)

3.1 Types of Reflection Telescope

3.1.1. NEWTON'S REFLECTION TELESCOPE

One of the earliest reflecting telescopes built by Newton is shown below. Parallel rays from distant object entering the telescope are reflected by the objective concave mirror and brought to the focus. A small plain mirror of rectangular or elliptical shape deflects the rays by 90 degree so that a real inverted image is formed. The plain mirror is called diagonal. It makes an angle of 45 degree with the main axis of the telescope. Instead of mirror a prism is also used sometimes. The real image formed is then viewed by a usual two-lens eyepiece.

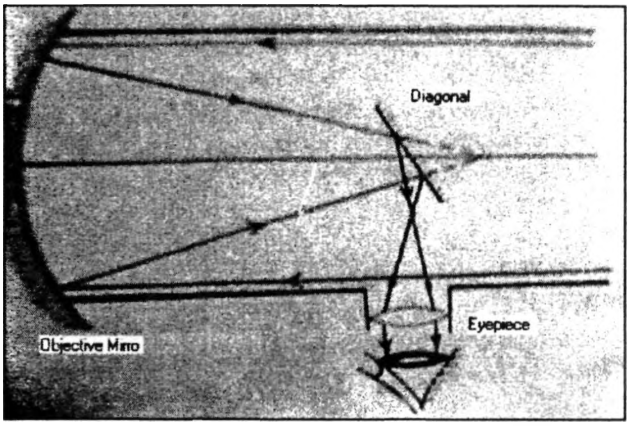


Fig.6: Newton's Reflecting Telescope

3.1.2. CASSEGRAINIAN TELESCOPE :

In Cassegrain's arrangement, the parallel rays coming from distant object are first reflected from the objective mirror and then are doubled back by a small convex hyperbolical mirror on the telescope axis to form the image. This image can be viewed by any eyepiece, which is fitted at the back of the telescope, through the hole in the center of the main objective mirror. Due to the use of a convex mirror the effective length of the telescope is increased.

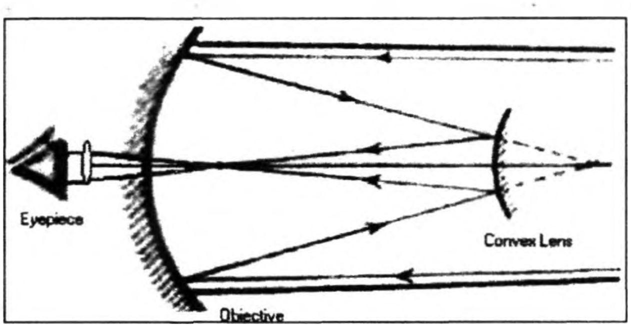


Fig.7: Cassegrainian Reflecting Telescope

The pictures below show a home built Newtonian Reflecting Telescope (left) built by the author at Srirampore, Hooghly and a Schmidt Cassegrainian Telescope of Indian Institute of Astrophysics, Bangalore made by Tejraj and Co. Bombay.

Fig.8: Newtonian Reflecting Telescope

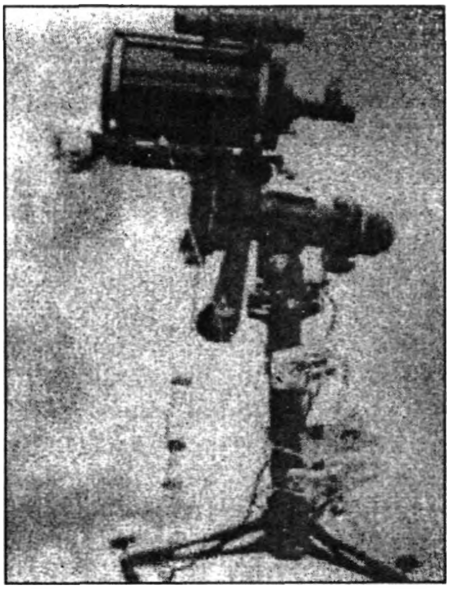
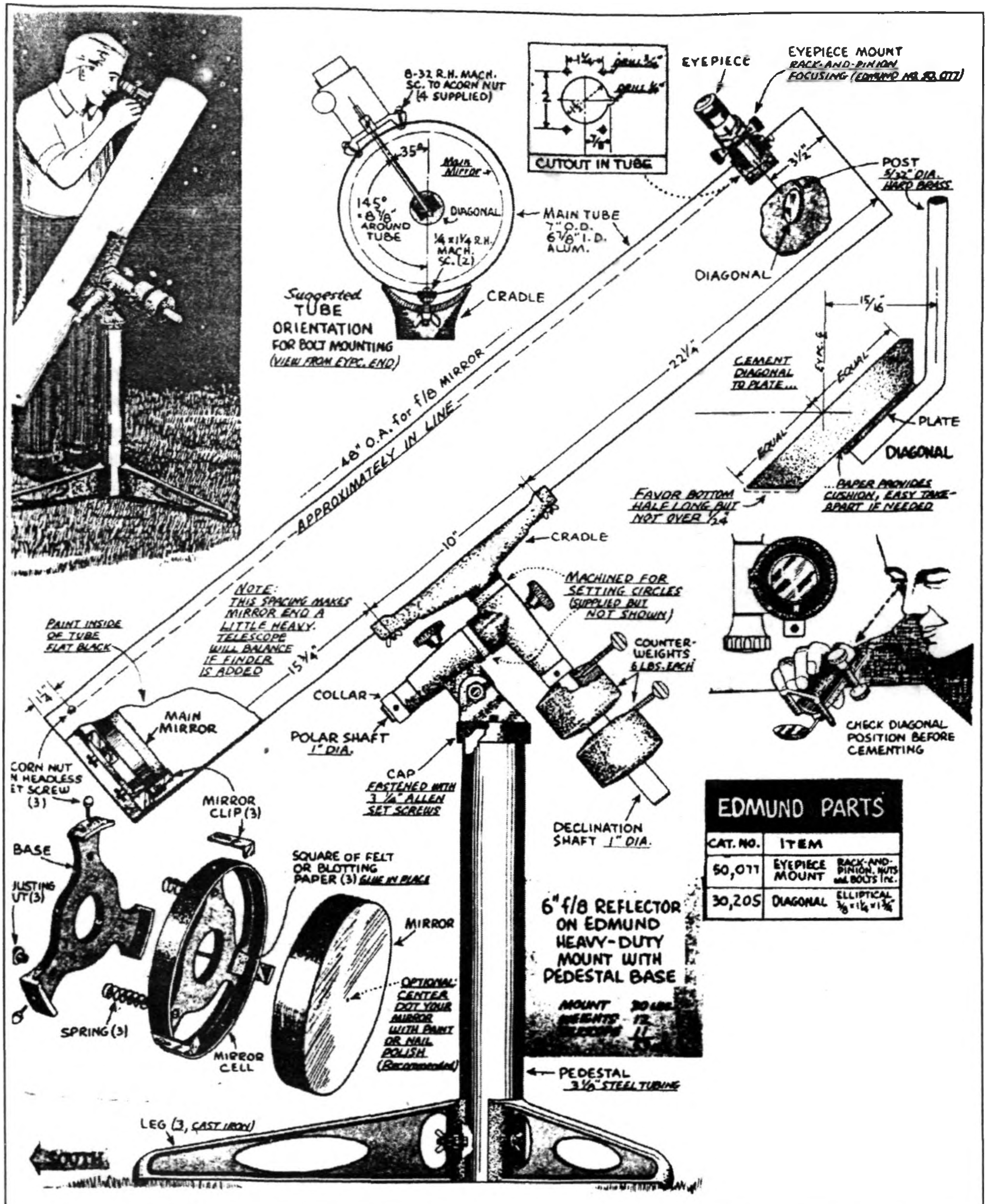


Fig.9: Cassegrainian Telescope

3.1.3 MULTI MIRROR TELESCOPE :

Power of the reflecting telescope can be increased by using concave mirror of large diameter. But it is difficult to make a large mirror. Generally 10 inch diameter mirrors are used by most of the astronomers. Only some big observatories have


EYEPIECE
EYEPIECE MOUNT
RACK-AND-PINION FOCUSING
8-32 R.H. MACH. SC. TO ACORN NUT (4 SUPPLIED)
CUTOUT IN TUBE
35°
Main Mirror
145° = 8 3/8" AROUND TUBE
DIAGONAL
1/4 x 1 1/4 R.H. MACH. SC. (2)
MAIN TUBE 7" O.D. 6 7/8" I.D. ALUM.
Suggested TUBE ORIENTATION FOR BOLT MOUNTING (VIEW FROM EYPC. END)
CRADLE
3 1/2"
POST 5/32" DIA. HARD BRASS
DIAGONAL
15/16"
CEMENT DIAGONAL TO PLATE...
EQUAL
PLATE
DIAGONAL
...PAPER PROVIDES CUSHION, EASY TAKE-APART IF NEEDED
FAVOR BOTTOM HALF LONG BUT NOT OVER 1/24"
48" O.A. for f/8 MIRROR
22 1/4"
APPROXIMATELY IN LINE
10"
CRADLE
NOTE: THIS SPACING MAKES MIRROR END A LITTLE HEAVY. TELESCOPE WILL BALANCE IF FINDER IS ADDED
15 1/4"
PAINT INSIDE OF TUBE FLAT BLACK
MACHINED FOR SETTING CIRCLES (SUPPLIED BUT NOT SHOWN)
COUNTER-WEIGHTS 6 LBS. EACH
CHECK DIAGONAL POSITION BEFORE CEMENTING
COLLAR
MAIN MIRROR
POLAR SHAFT 1" DIA.
CAP FASTENED WITH 3 1/4" ALLEN SET SCREWS
DECLINATION SHAFT 1" DIA.
MIRROR CLIP (3)
BASE
SQUARE OF FELT OR BLOTTING PAPER (3) GLUE IN PLACE
MIRROR
OPTIONAL: CENTER DOT YOUR MIRROR WITH PAINT OR NAIL POLISH (Recommended)
SPRING (3)
MIRROR CELL
EDMUND PARTS
CAT. NO. | ITEM
50,077 | EYEPIECE MOUNT | RACK-AND-PINION, NUTS and BOLTS Inc.
30,205 | DIAGONAL | ELLIPTICAL
6" f/8 REFLECTOR ON EDMUND HEAVY-DUTY MOUNT WITH PEDESTAL BASE
PEDESTAL 3 1/2" STEEL TUBING
LEG (3, CAST IRON)
SOUTH

large mirror telescopes (greater than 1 meter diameter). But they are very costly and take years to build. In multi mirror telescopes, instead of one large mirror several small identical mirrors are used. Here the small identical mirrors are so arranged in a single platform that all the mirrors focus the parallel rays coming from distant objects into a single point. A same power multi mirror telescope is less costly than a single reflector telescope.

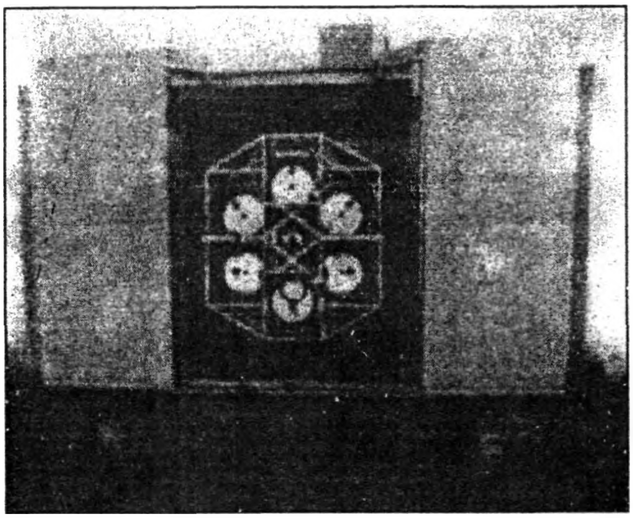


Fig. 10: Multimirror Reflecting Telescope

4. **MERCURY MIRROR TELESCOPE**

In this type of telescope the objective mirror is not a glass mirror, but a big circular disk which can rotate with constant speed without any vibration. The disk is full of mercury. When the disk starts rotating, the surface of the mercury takes the shape of a concave mirror. The major disadvantages of this telescope are that it cannot be tilted and the slightest vibration makes distortion in the image formed by the mirror. It is also very dangerous to work with the poisonous mercury.

There is no mercury mirror telescope in India.

5. **RADIO TELESCOPE**

Radio telescopes are used to study the naturally occurring radio wave emission from planets, stars, galaxies and other astronomical objects between wavelengths of about 30 MHz and 300 GHz. But at frequencies less than 1.5 GHz, irregularities in the ionosphere distort the incoming signals.

Radio telescopes have two components: - (1) a large radio antenna and (2) a radio meter or radio receiver. The sensitivity of the radio telescopes depends on the area and efficiency of the antenna, the sensitivity of the radio receiver used to amplify and detect the signals, duration of the observation and also on the receiver bandwidth. The most familiar type of radio telescope is the radio reflector consisting of a parabolic antenna, which operates in the same manner as TV satellite receiving antenna to focus the incoming radiation onto a small antenna referred to as feed.

Radio telescopes permit us to study many kinds of extraterrestrial radio sources. Astronomical objects emit radio waves by many processes including (1) thermal radiation from solid body like planets (2) synchrotron radiation from relativistic electrons in weak magnetic field (3) pulsed radiation resulting from the rapid rotation of neutron stars surrounded by an intense magnetic field and energetic electrons. This kind of telescopes has been used to measure the temperature of all the planets.

Before independence there was not a single radio telescope in India. At present radio astronomical facilities exist at different places in India. India's first major radio astronomical facility, the Ooty radio telescope, was set up in 1970 at Udhagamandalam in Nilgiri Hills. It consists of 24 parabolic cylinders, 530 meter long and 30 meter wide. The Giant Meter-Wave Radio Telescope (GMRT) erected near Khodad, about 80 km north of Pune, has become operational since 1995. It is the world's largest aperture synthesis radio telescope at meter wavelength. It consists of 30 fully steerable parabolic dishes of 45meter diameter each. In West Bengal, there is a radio telescope in Kalyani University for studying the sun. Thus, India is now very rich in this field.

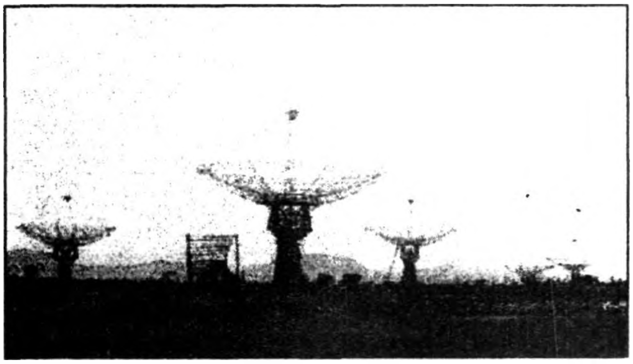


Fig. 11: GMRT

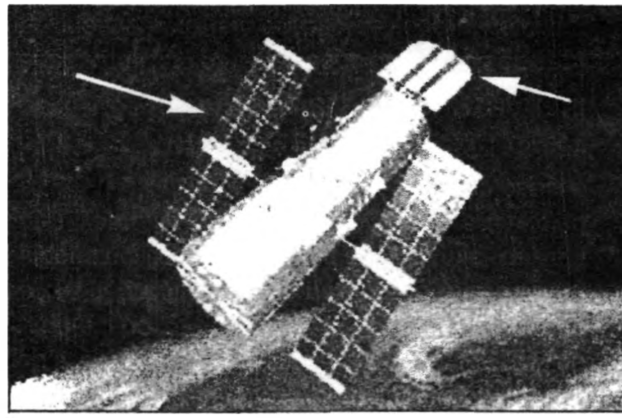


Fig. 12: Hubble Space Telescope

6. SPACE TELESCOPES

While astronomers continue to seek new technological breakthroughs with which to build big ground-based telescope, it is apparent that the only solution to some scientific problems is to make observation from above the Earth's atmosphere. A series of Orbiting Astronomical Observations (OAOs) have been launched by the National Aeronautics and Space Administration (NASA). The most sophisticated observational system placed in the Earth orbit so far is the Hubble Space Telescope (HST). Launched in 1990, the HST is essentially an optical-ultraviolet telescope with a 2.4 meter primary mirror. The HST was launched into orbit from the U.S. Space Shuttle at an altitude of more than 570 km above the Earth. Shortly after its deployment in orbit, scientists found that a manufacturing error affecting the swap of the primary mirror severely impaired the instrument's focusing capability. It is still a mystery how this kind of defect occurred in such a costly project. However, scientists were able to find the solution and the telescope was repaired in space. In space the telescope was held by a robotic hand and then the brave astronauts came out of their spacecraft and repaired the telescope in black, dangerous space condition. HST's images are very clear and help to change many old concepts.

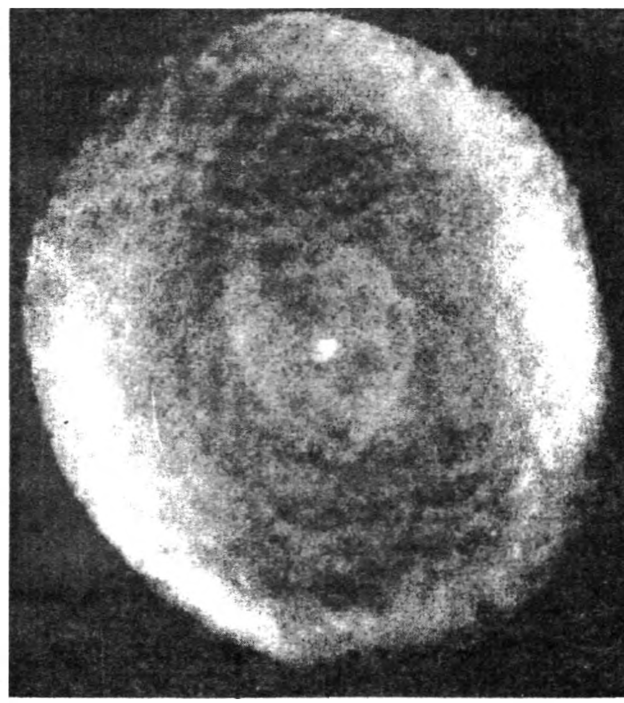


Fig.13: Nebula (HST's Image)

India till now has not entered in this kind of astronomical project, but soon it will also be possible.

There are other kinds of telescopes like gamma-ray telescope, X-ray telescope etc. For gamma-ray astronomy there are two facilities in our country. These are High Altitude Research Laboratory at Gulmarg under Bhabha Atomic Research Centre (BARC) and the High Energy Gamma-Ray

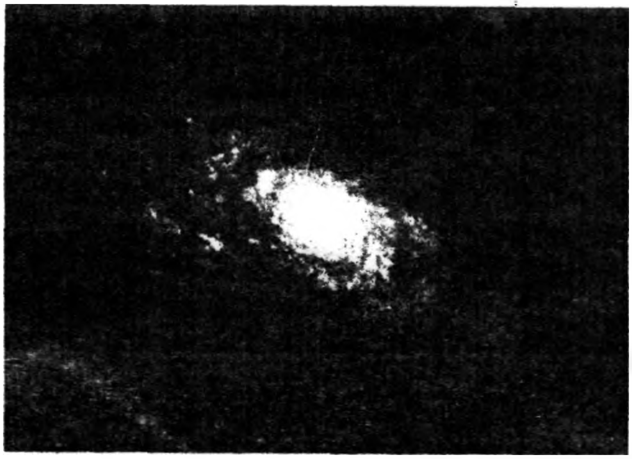


Fig.14: Spiral Galaxy (HST's Image)

Observatory under Tata Institute of Fundamental Research (TIFR) at Panchmarhi, M.P. India has performed very well in cosmic ray studies. Dr Homi Bhabha was the pioneer in this field. Work has also been done in the X-ray astronomy and infrared astronomy. There are many amateur astronomers who use small reflecting telescopes (6,8,10 inch) to observe and study sky objects. Many clubs of amateur astronomers also exist in different cities, universities, colleges etc in our country.

7. ASTROPHOTOGRAPHY

Photography with the big eyes of the telescope is exciting fun whether you go for the moon shots or for other sky objects. It is the only way to preserve as hard copy of what one has seen. For photography generally film based cameras are used. As the sky objects are very faint, very sensitive films are required. Generally two techniques are used for photography. One is **direct objective technique,** where the lens less camera is directly attached with the objective of the telescope and the objective focuses the light directly on the film. This technique offers highest light transmission and best definition. Another popular technique is **afocal technique,** where the camera with lens is attached to the eyepiece of the telescope. In this system any camera can be used, and once the object is focused suiting our eyes there is no need for further focusing of the telescope for photography. That's why it is called afocal technique. For quality photograph the high light sensitive films that are used are very costly and it also takes a lot of time to wash and develop the films.

There is a completely different technique of astrophotography, digital photography, where images are captured with a digital camera and then fed to a computer to view and edit the captured photo. There are two techniques used in digital cameras. One uses CCD sensor and the others CMOS sensor.

For astrophotography CCD cameras are generally used. These cameras either store the digital information of a the image in the inbuilt storage device such as a floppy disk or RAM or directly load the information in the computer. The captured image can be shown on the computer screen and also the print out of the image can be taken. Through proper software, images can be enlarged according to requirement. High-resolution CCD cameras are very costly. To increase the resolution of the camera liquid nitrogen cooling system is used. This is also very costly and beyond the reach of common people.

The CMOS sensor technique emerged in 1995. This technique is not used for astrophotography. But the present author has built one 8inch reflecting telescope where he has used CMOS camera successfully for astrophotography. Both the afocal technique and direct objective technique have been used by the author. Though its resolution is not high enough as that of a CCD sensor, it has other advantages over CCD sensor. CMOS sensors can be made using standard chip making instruments, which makes them a lot cheaper for mass production. For astrophotography CMOS camera does not require extra sophisticated cooling system. If any one is required, ordinary ice-cooling system is enough. A CMOS camera can be attached to the computer through a USB port. Once the driver is loaded, the camera can be operated easily. The camera always gives the live images with a flapper speed of up to 30 fps. Still images can be taken by adjusting the clarity of the live images on the screen and if required, these can be stored in the hard disk. Thus it is possible to study a particular portion of the image repeatedly. This is not possible in CCD camera. Power consumption of CMOS camera is very low. Once the picture is captured it can be edited and enlarged through proper software like Microsoft photo editor, Photoshop 6.0, ms paint etc. As CMOS cameras are cheap, amateur astronomers can use it. Once one has the camera there is no extra charge for photography and can take ample photos. If somebody can discover anything in the sky, he can immediately send the information with photographs anywhere in the world through Internet.

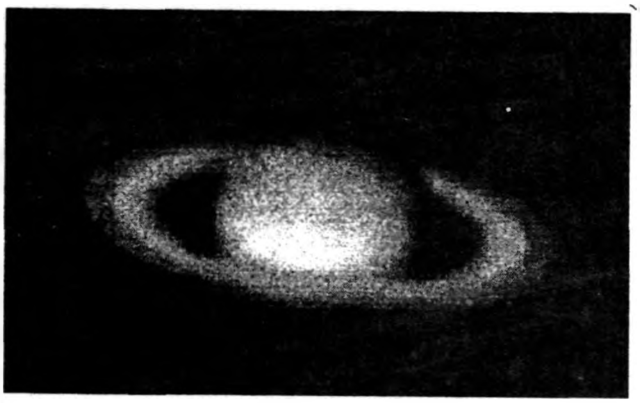


Fig.15: Saturn (From USA)

(High Resolution CCD Camera Image with Liquid Nitrogen Cooling system)

Fig.16: Moon (From Srirampore) CMOS camera image

8. CONCLUSION

At the time of Jay Singh India came in contact with modern European astronomy. India had no facilities for astronomical observations worth the name in 1947. But now we have several top class facilities. The Vainu Bappu Observatory at Kavalur is one of the best in the eastern hemisphere. Also, the GMRT is one of the most powerful observatories in the world. At present, contributions of Indian astronomers are also receiving international recognition.

Watch the stars, and from them learn.

—Albert Einestain