THE TELESCOPE

RASIK SHAH

CITIZENS OF TOMORROW SERIES, 26

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TWO RUPEES

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1. The Magic Tube

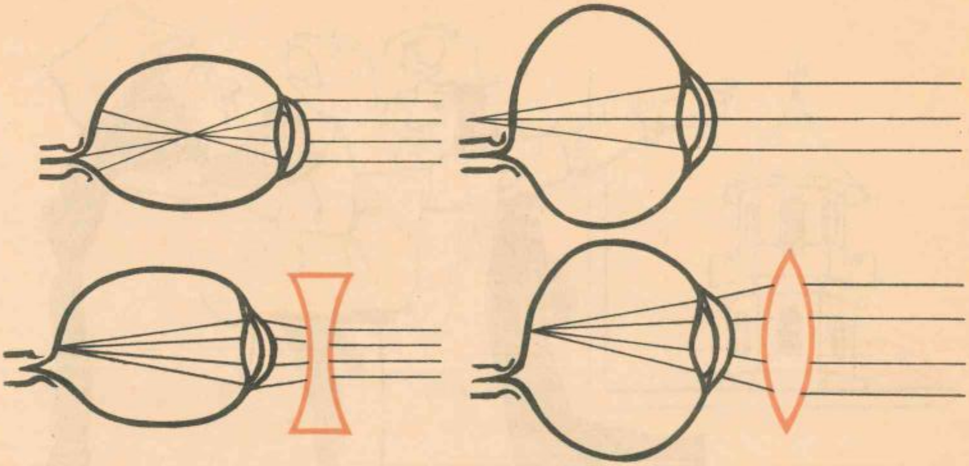
"LOOK, MASTER HANS, look!" shouted the boy-apprentice, "I can see those weather-vanes so far away on the tower!"

"Don't shout so loud," said Hans Lippershey, "I can hear you very well. And what's that rubbish about the weather-vanes?" He came up to the boy and saw the two glass pieces in his hands, held one behind the other.

The boy was right. Though Hans could not see the weather-vanes with his naked eyes, he could see them clearly through the two glass pieces which the boy gave him. "That's very interesting indeed," he said.

This was in Holland in the first decade of the 17th century.

People then were ruled by superstition. It was very common to hear remarks like: "I was sure that their marriage would turn out a



Concave lenses are used to see far–off things;
convex lenses are used for reading purposes.

failure. You see, they were married in May"; or, "Our ears burn when others speak of us." People believed that health and strength varied with the waxing and waning of the moon. Every event was considered to be either a sign of God's pleasure or his wrath. It was common to hear of 'witch' being burnt, or a man with an evil eye being turned out of the village. Questions in the physical sciences were settled, not in laboratories by scientists, but in armchairs by philosophers or in churches by bishops and popes.

But men who were going to change, to revolutionise the entire thinking of mankind, were already on the way. To some scientists it had become clear that the power of human observation was very limited. They had realised that the human eye could not see clearly enough, far enough, and minutely enough. And at the end of the sixteenth century itself the ground had already been prepared to overcome the limitations of the human eye. A scientist in Italy named Porta had already found out that through a concave lens things appear smaller but sharper and clearer, while through a convex lens they appear larger but less distinct. If however, you know how to combine the two types of lenses properly, you will see near and far, both, large and clear. This became the basis of all the optical instruments of the future! As a matter of fact, the spectacle-makers had already started using this principle in making glasses.

Now, Hans Lippershey was himself a well-known Dutch spectacle-maker. Quite often, boys who wanted to learn the trade of spectacle-making came and worked as apprentices under him. He taught them how to grind lenses for the people who could not see far-off things clearly. These lenses were thin in the middle and were called *concave* lenses. Then there were *convex* lenses used by older people to help them to read. These were thick in the middle and were commonly known as reading glasses.

When a lens was ground, the boys had to check whether it was evenly ground, whether there were any scratches on it. To do this, the boys had to look through the lens very, very closely. The boy who showed Hans the weather-vanes actually had two different lenses in his hands, one convex, and the other concave, the latter held right next to his eye and the former some distance away.

Hans held the 'reading glass' close to his left eye and tried to adjust the other lens, the concave lens, to see the weather-vanes.

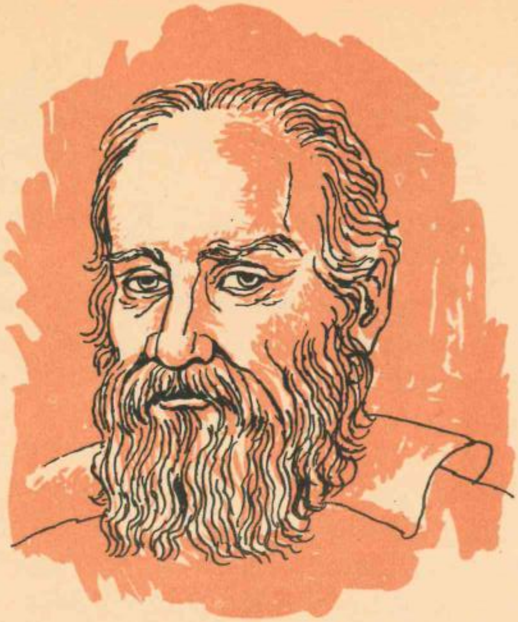
"O no Master! You're holding them wrong," said the boy. "Hold the reading glass away and look through the other lens."

Hans exchanged the positions of the two lenses. Now, he could indeed see the weather-vanes as if they were right on the top of the next building, when, in reality, they were quite far away. Later on, he fixed the two lenses in a tube and called it the Magic Tube.

The Dutch were then at war with the Spaniards. The legislators saw the military value of the Magic Tube. It could help to spy the movements of enemy ships from a great distance. So Lippershey was awarded 900 florins. He must have been extremely happy with this sum. He had considered the Magic Tube to be merely an interesting toy, and 900 florins was not a small sum for a toy!

But the magic tube was not merely an interesting toy. That accident of a boy apprentice holding two glass pieces one behind the other was to have far-reaching consequences. Watching the movements of enemy ships or weather-vanes were not going to be the only uses of this magic tube. Later, it would help the human eye to probe far off distances and solve many mysteries of the starry heavens.

That boy-apprentice in Hans Lippershey's workshop had accidentally made the first TELESCOPE. The prefix *tele* in Greek means far off and *scope-ein* means 'to look'. The whole word *telescope* thus means an instrument for looking at distant objects. Similarly, we have other words too with the same prefix *tele*, e.g. telephone (which conveys sound over a distance), television (which conveys visual images over a distance), etc. All these instruments have helped man to bring far-off places nearer, as it were. With the invention of the telescope this expansion of man's knowledge began. But neither Hans Lippershey nor the Dutch legislators knew this.



Galileo

2. The Magic Tube Becomes A Telescope

LIPPERSHEY thought of the telescope only as an interesting toy and the Dutch legislators considered it merely an imporant aid for spying on enemy movements. Because they were not trained scientists, they did not and could not realize the real importance of the telescope for the future. The first person to realize the importance of this invention was the Italian, Galileo, who lived at Padua. Galileo is often referred to as the 'First of the Moderns', because it was he who ushered in the era of modern science. As mentioned in the first chapter, till his time, scientific questions were 'decided' by the philosophers and the clergy. Regarding this, Galileo had said, "It is not in ancient times, but in close observation and personal consecration that a grain of truth may be found. It is so very easy to seek the significance of things in the papers of this man or that rather than in the works of nature, which, ever alive and active, are constantly before our eyes." He introduced OBSERVATION and EXPERIMENTATION in science. Up to that time it was believed that heavy objects fell faster than light ones. Nobody had proved this, but a great Greek philosopher had said so long ago in the past, in the 4th century B.C., and all had accepted this statement. Making use of a very simple experiment, Galileo, however, proved that "All objects, whether light or heavy, fall the same speed." And since then, these two words: EXPERIMENTATION and OBSERVATION have become the watchwards in all fields of science.

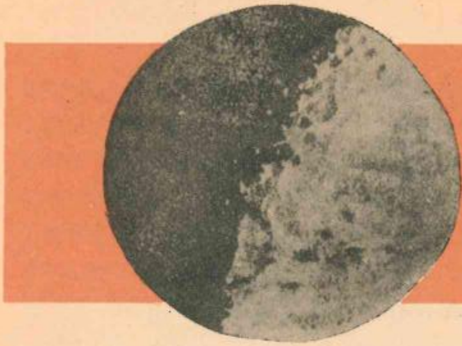
To go back to our story, the news of the Magic Tube reached Galileo. Being a trained scientist, he immediately set himself to improve upon it and make a better instrument of the same kind. He made certain changes in the lenses he used to construct his telescope. Instead of lenses curved on both sides, he used lenses which were flat on one side and curved on the other. And this is what he wrote about his instrument: "I hit upon the idea of fixing two lenses to the ends of a tube, one lens being plane-convex and the other plane-concave ... I obtained an excellent instrument which enabled me to see objects almost a thousand times as large and only one-thirtieth of the distance in comparison with their appearance to the naked eye."

In August 1609 Galileo visited Venice. He carried his telescope with him. Of course he did not call it a telescope. He called it a "spy-glass", and this is what he reported from Venice:

> "Many of the nobles and senators, although of a great age, mounted more than once to the top of the highest church in Venice in order to see sails and shipping... so far off that it was two hours before they were seen without my spy glass... for, the effect of my instrument is such that it makes an object fifty miles off appear as large as if it were only five miles away... The senate knowing the way in which I had served it for seventeen years at Padua,... ordered my election to the Professorship for life."

The moon as sketched by Galileo

A latest photograph of the moon



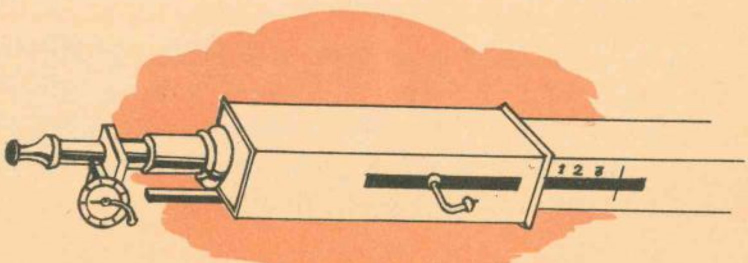
Though Galileo won the professorship for life he was not very much interested in watching the sails of arriving ships. He was a scientist and his interests were wider and of far-reaching consequence. He must have made use of his visit to the port of Venice to direct his telescope to the heavens. He must have watched the moon and the stars from that highest church when the nobles and the senators were fast asleep. He was surprised to observe bright spots and lines on the unlit part of the moon. He soon realised that these could be nothing but the mountain summits and the rims of valleys on the moon.

Back at Padua, Galileo improved his spy-glass till it magnified objects a thousand times! When he directed his improved telescope, rather his improved spy-glass, at the sky he discovered about ten times more stars than can be seen with the naked eye. For instance, he saw that the constellation Pleiades known as Krittika in Indian astronomy, had thirty-six, not just seven stars as was till then believed.

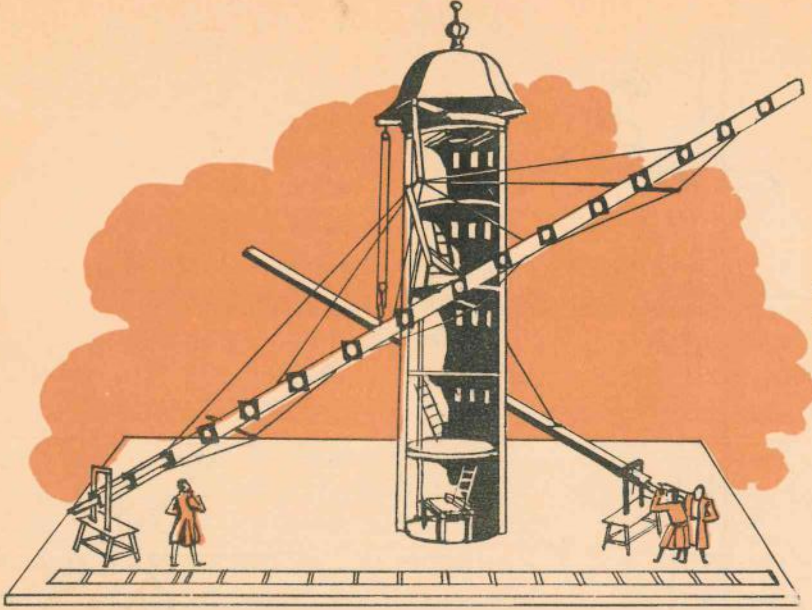
In January 1610, Galileo discovered four bodies going round the planet Jupiter and soon realised that these were nothing but the 'moons' of that planet. With all these observations, he was able to draw correct conclusions regarding the true nature of the Solar System. The spy-glass was proving really useful.

But you will be surprised to know that even learned professors, avele aside the common man, refused to look through the telescope! Possibly they were afraid that there was a devil inside the tube, and that their cherished theories would crumble to pieces. These poor professors hardly realized that the facts of nature would remain the same whether they accepted them or not. Soon afterwards, the use of the telescope as a scientific instrument became common, and many forms of it came into existence. The well known astronomer, John Kepler, suggested certain changes in the type of lenses used by Galileo. Curiously enough, Kepler himself never constructed this telescope, which came to be known as the Astronomical Telescope. Soon this telescope became very popular and astronomers all over Europe started using it.

In 1639 an important invention was made by the English astronomer, Gascoigne. He invented the MICROMETER. The word *micro* means 'small' and the word *meter* stands for 'measure'. With the help of an ordinary metre rule we can measure lengths up to, say, one-tenth or at most one-twentieth part of a centimetre. If the lengths are smaller than this, they cannot be measured. With the help of the micrometer, however, we can measure much smaller lengths very accurately. In modern micrometers we can even measure accurately lengths up to one thousandth part of a centimetre. Astronomers started using these newly invented micrometers to adjust their telescopes. This resulted in unprecedented accuracy.



Micrometer

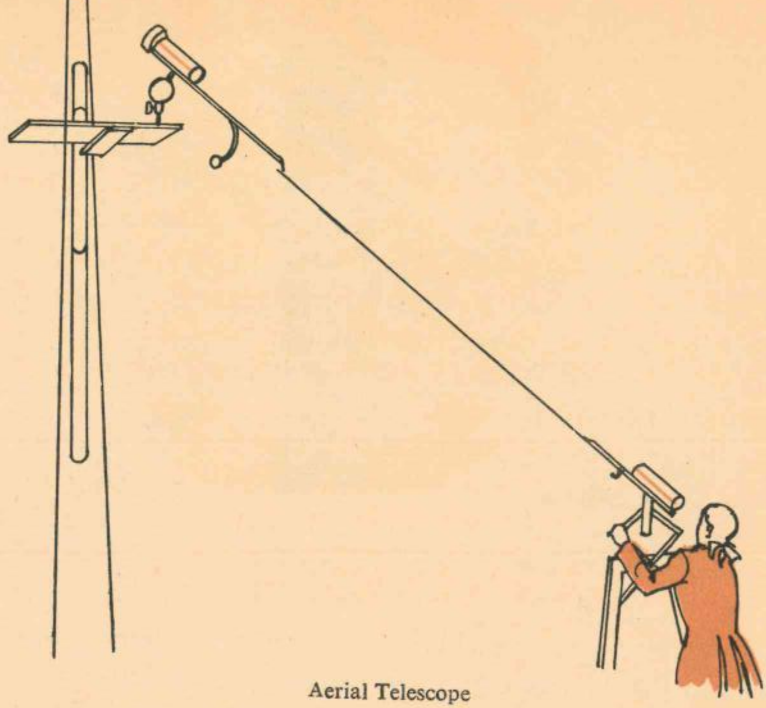


Hevelius's Telescope

Many varieties ot telescopes were construced. Scheiner constructed a telescope similar to the one used by Galileo, but instead of viewing the image directly he obtained it on a white screen. In this way he was able to show that the sun's disc had dark spots which are known as sun-spots. (It has been said that Galileo, in later life, became blind because he looked at the sun direct through his telescope.) Scheiner called his telescope a Helioscope.

Some of the telescopes constructed were very, indeed very, long. Hevelius had a telescope which was more than fifty metres long. A special tower had to be built to support this telescope. The reason for such long telescopes was that the images obtained with short telescopes were always blurred and had coloured edges; with longer telescopes it was possible to overcome these defects partially. However, on the other hand, longer telescopes become very difficult to handle.

One ingenious solution of the problem of handling long telescopes was to get rid of the bulky tube. The first lens was fixed in a small



Aerial Telescope

tube on a pole. The other, the second lens, was fixed in another tube on a stand. The second tube and the stand were adjusted until the star under observation could be seen through both the lenses. This arrangement was known as an Aerial Telescope.

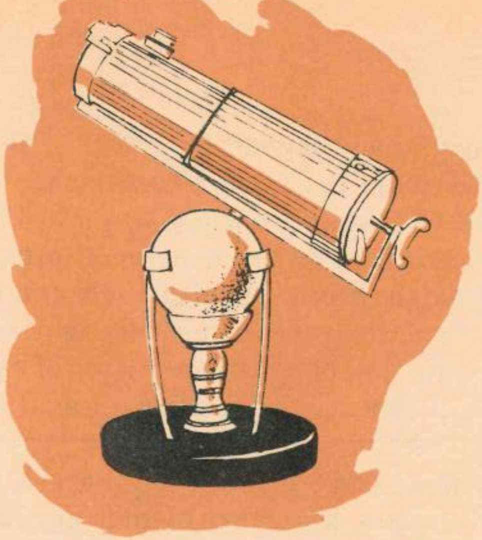
All these telescopes used lenses to collect light rays. Now, when a light ray passes through a lens it *bends*. This *bending* is known as REFRACTION. The telescopes which make use of refraction to form images of heavenly bodies are known as REFRACTING TELESCOPES.

Then, an entirely new type of telescope was introduced by the great scientist, Isaac Newton. It has been said that there are only a very few scientists whose contribution to science had been as great as that of Newton. To honour him, a great poet named Pope composed the famous couplet which ran as follows :

Nature and Nature's laws lay hid in night;
God said, "Let Newton be!" and all was light.

One day in 1666 Newton bought a prism at a fair. He then darkened his room and bored a hole in the window shutter to let in the sun's light. Next he held the prism so that sunlight could pass through it, and what do you think happened when this light passed through the prism? On the facing wall Newton saw a strip of rainbow colours namely, Violet, Indigo, Blue, Green, Yellow, Orange and Red. After many such experiments he proved that the white light of the sun was, in fact, a mixture of these seven colours and that when it passes, or is refracted, through a prism these seven colours are separated. From these experiments he concluded, though wrongly, that it was impossible, with lenses alone, to obtain images without coloured edges.

Newton constructed the first telescope in which a curved mirror was used instead of a lens. The mirror that he used was made from



Sir Isaac Newton's first telescope

an alloy (a mixture) of copper and tin known as speculum. He mounted the speculum mirror and a lens through which the image was seen in a cardboard tube. Later, Newton presented this telescope to the Royal Society of London where it can be seen even today.

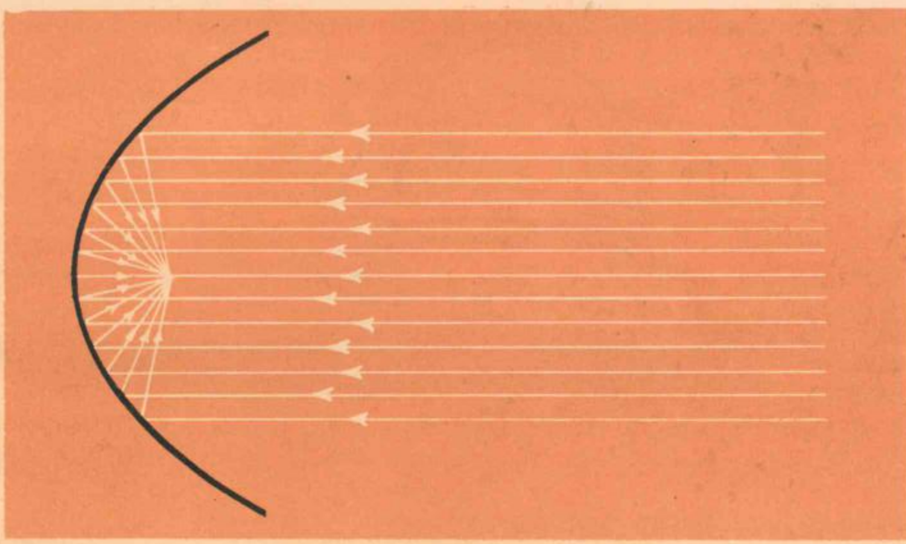
For his reflecting telescope, Newton used a mirror which was the inner surface of a part of a sphere. He described a mirror as CONCAVE. Surfaces which are like the inner side of a spoon are known as CONCAVE surfaces. You must have seen shaving mirrors with concave surfaces. In Newton's telescope, the concave mirror served the same purpose as the convex lens in the earlier refracting telescopes. Just like the convex lens, the concave mirror gathered the light from the heavenly bodies and formed an image.

Now you know that light falling on mirrors is thrown back and that this is called REFLECTION. Just as the telescope which worked on the principle of refraction was called the Refracting Telescope, this telescope, working on the principle of *reflection* was known as the Reflecting Telescope. This reflecting telescope had one great advantage over the old telescope. The image formed by it did not have coloured edges. Hence it was much clearer and sharper.

As time passed, a great many improvements were made in the construction of these two types of telescopes. In the case of the refracting telescopes, the major improvement was regarding the lenses. The major headache here was the colour-edged image. Technically, this defect was known as 'chromatic aberration'. It was found that if, instead of using a single convex lens, known as the OBJECTIVE, to gather the light rays, a combination of two lenses was used, the image did not show any coloured edges. These two lenses were made from two different types of glass: crown glass and flint glass. Such a combination is known as a CHROMATIC COMBINATION. Nowadays, most of the telescopes use such combinations.

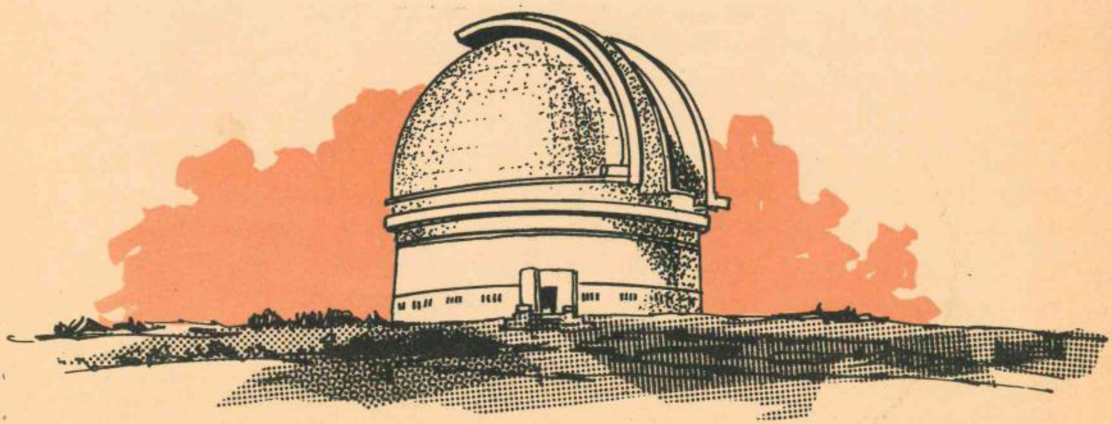
In the case of the Reflecting Telescope, the major improvement was regarding the shape of the concave mirror. Newton's mirror was part of a sphere. An English scientist, John Hadley, changed the shape of the mirror from spherical to parabolic. The shape of the

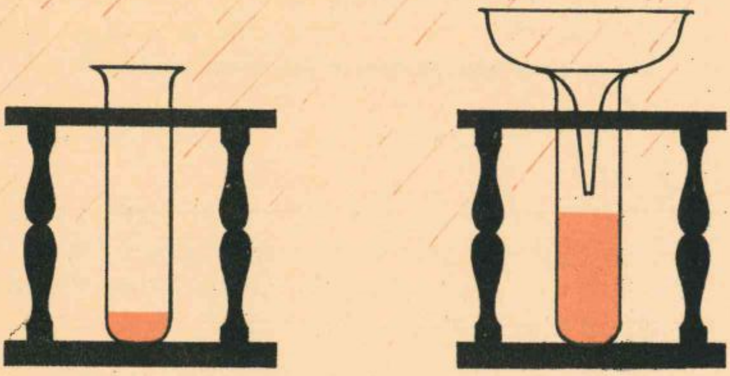
Parabolic reflectors used in headlights



mirrors used in the headlights of motor cars, in torches, searchlights, etc. are parabolic With these parabolic mirrors, very clear images can be obtained.

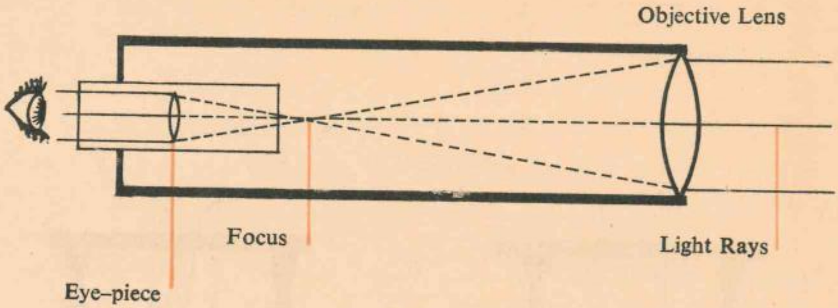
Apart from these, many other improvements also took place in the construction of the telescope. Compared to modern telescopes, the telescopes of Galileo and Newton look like mere toys. Newton's first telescope had a mirror about two and a half centimetres in diameter, whereas the giant telescope on Mount Palomar in the USA has a mirror which is about 500 centimetres across. But the basic principles have remained the same. In the next chapter, we shall birefly discuss these principles.





3. How The Telescopes Work

IF YOU HOLD A testtube in the rain, you would, no doubt, collect some rain water. But if you put a wide-mouth funnel on the test tube you would definitely collect much more water. The reason is obvious. The mouth of the funnel is much wider than the opening of the test tube. In other words, the funnel gathers water from a greater area than the test tube does. An unaided eye and an eye looking through a telescope act in a similar fashion. Both gather light, just as the test tube and the funnel gather rain water. But the eye, which has a very small opening, about half a centimetre in diameter, can gather very few light rays. On the other hand, the telescope, with its large lens or mirror, can collect many, many more light rays. A telescope with a small mirror of 10 centimetres diameter collects 400 times more light than the eye. As a result, the images that are formed

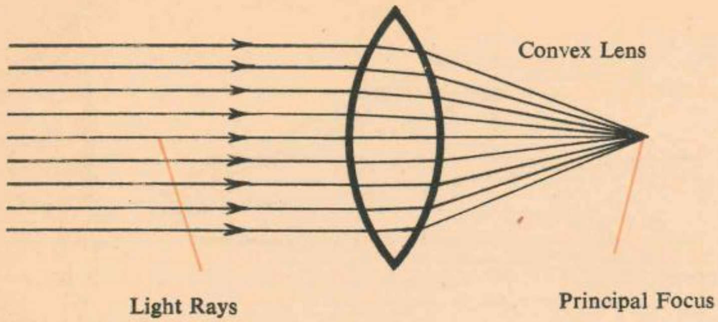


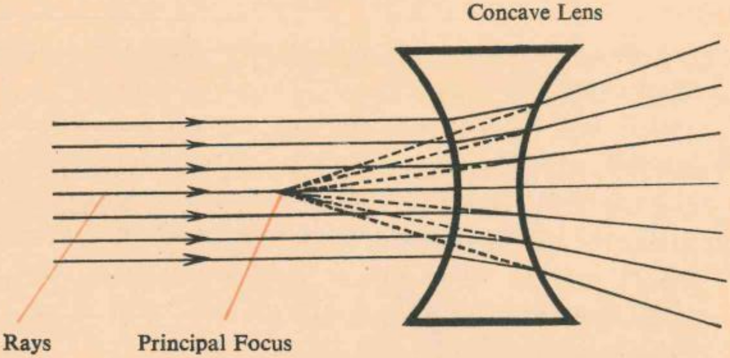
are much brighter than those that we see with the naked eye. The larger the diameter of the lens or the mirror, the brighter the image. This is the reason why the great observatories of the world have telescopes with lenses and mirrors of giant size.

Now, let's try to understand how a telescope forms an image of distant stars. It is better to start with Galileo's spy-glass which, as mentioned in the second chapter, had two lenses. Similarly, all telescopes have two lenses. The one that is directed to the sky is called the objective lens, while the other through which the astronomer observes, is called the eye-piece.

Before we try to understand the combined working of the Objective and the Eye-Piece, let us see how each of them works independently.

The objective lens is convex. Perhaps, you know that a convex lens is also known as a CONVERGING LENS. The reason for this name will soon become clear if you study the illustration alongside. The light rays from very distant objects like the heavenly bodies strike the convex lens on one side and are refracted through it. You will notice that these rays, when they strike the lens, are parallel. But after refraction they meet at a point, known as the PRINCIPAL FOCUS. In other words, they *converge*, which means that they come towards each other and meet at a point. Therefore the lens that brings together these rays is called a *converging* lens.



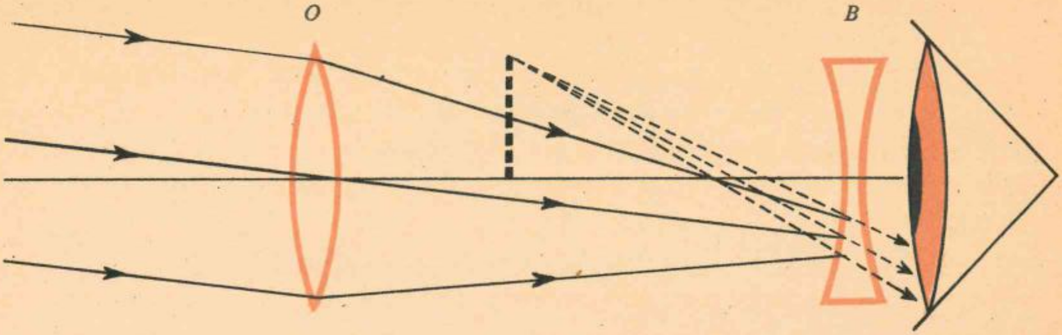


On the other hand, the concave lens is known as a DIVERGING LENS. It does the exact opposite of what the convex or converging lens does; making the parallel rays diverge, or go away from each other when they pass through it. These rays through a diverging lens appears to come from a point *behind* the lens known as the PRINCIPAL FOCUS.

Now it is easy to understand the working of a Galilean telescope. When the rays pass through the objective lens they converge. But before they meet at the Principal Focus they pass through the 'eye-piece' which is a concave lens, and an image is formed as shown in the illustration alongside.

You will notice that the image is erect, i.e. not inverted or upside-down. The Galilean telescope is no longer used to watch the sky, but because of its erect image this combination of lenses is used in bino-

Modern Refracting Telescope



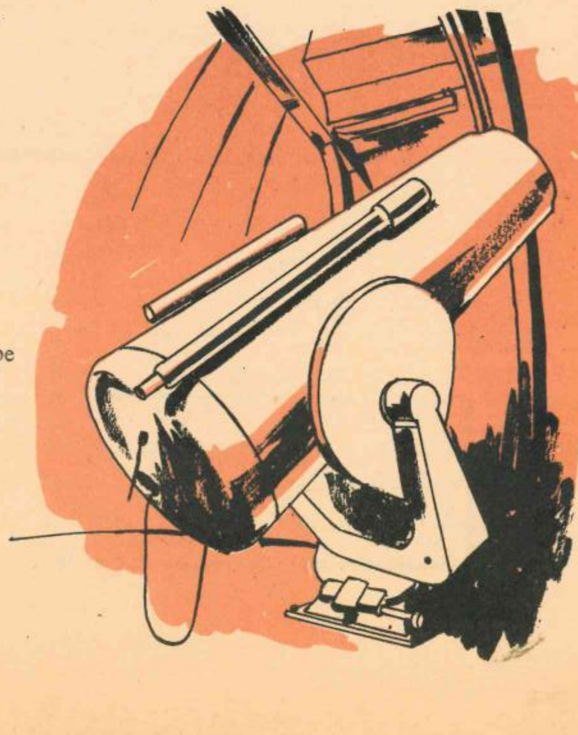
culars or opera glasses where two such telescopes are used, one for each eye.

The principle of the modern refracting telescope or refractor is similar to that of the Galileo Telescope with two major differences: the eye-piece is *not* a concave or a diverging lens but a combination of lenses serving as a *convex* lens; and the objective lens is not a simple convex lens, but a compound one made up of two types of glass as mentioned earlier, so as to give images without coloured edges.

In the illustration above lens *O* is the objective lens and lens *E* is the eye-piece. When light rays from a very distant object strike the objective lens they pass through it. On coming out of the objective lens they bend and form a very small image. As will be seen from the illustration opposite, this image is inverted or upside-down and very small. As a matter of fact, the images of distant stars become just dots. Now, the eye-piece of the telescope works just like the magnifying glass used by old people to read. The eye-piece receives the light rays from the first image formed by the objective lens and, from this, it then forms the final image as shown in the illustration. This final image is inverted or upside-down, but, as this telescope is used for astronomical observations, this makes no difference.

Formerly, the final image was directly viewed by the astronomer at work. But after the great advances in photography, astronomers prefer to photograph the stars instead of looking at them directly. The photographs are permanent records of the stars and are, therefore, much to be preferred to direct viewing. As a result, astronomers nowadays generally take only a casual glance at what the eye-piece shows, just to make sure that the telescope is pointed to the right object. To facilitate the photographing of the stars, most modern observatories have arrangements to attach cameras to the eye-piece of their telescopes. So modern telescopes, in fact, work like giant cameras, photographing objects millions and millions of miles away. In the illustration below is shown the famous Schmidt telescope which was specially constructed for such photography.

Now let us see how the reflector works. As mentioned earlier, the first reflector was constructed by Newton. In comparision with



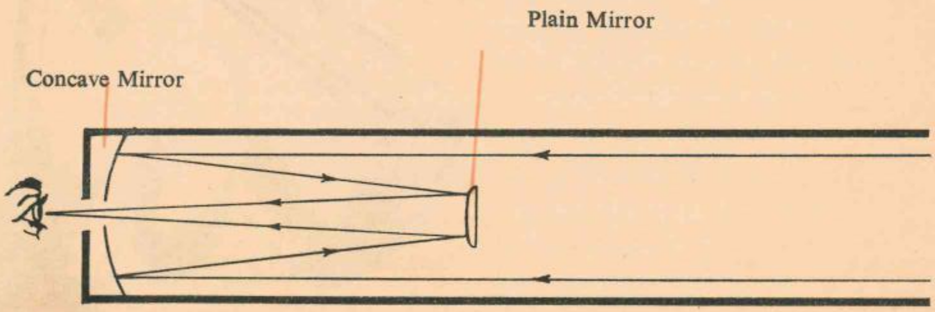
Schmidt's Telescope

modern reflectors, Newton's instrument appears no more than a toy. Yet the basic principle in both is the same.

In the reflector, the objective mirror has an opening in the centre, as shown in the illustration. The place of the plane mirror which diverts the rays is taken by convex mirror, similar to the one you see at the side of bus drivers. The eye-piece is behind the objective mirror. The way in which this type of telescope (the Cassegrain telescope) forms an image is shown in the illustration below.

In order to get clear photographs astronomers have often to expose film for some hours. Now, as we all know, the earth rotates on its axis. So, as time passes, the positions of the stars being photographed change in relation to the earth. This results in blurred images. To overcome this difficulty, a clockwork-like arrangement rotates the telescope in a direction opposite to the one in which the earth rotates. As a result of this, the telescope keeps on pointing at the same stars and very sharp photographs are obtained.

In the last two chapters of this book we shall give some information about the world's largest optical telescope and the latest advance in telescopy—the Radio Telescope.



Cassegrain Reflecting Telescope

G. E. HALE
(1868–1938)

4. The Giant at Palomar

IN THE USA there is a mountain named Palomar. It is not a high mountain. It is only a little more than 1,600 metres high. Yet it has become world famous. Why? Well, there is a road starting at the foot of this mountain known as the "Highway to the Stars". Rather an uncommon name for a road, you'd think. Yes, but, in a sense, this road does lead to the stars. You see, it leads to the Great Observatory of Palomar with its world-famous 200-inch telescope. The Rockefeller Foundation spent millions of dollars in the construction of the observatory and the telescope.

George Ellery Hale (1868-1938), after whom the telescope is named, was the director of a great observatory at Mount Wilson in the USA, which had a telescope with an objective lens of 100-inch diameter. In comparision to the human eye, this mirror gathered about 250,000 times more light. Yet, he was not satisfied.

"While much progress has been made, the greatest possibilities still lie in the future."

Like all the great astronomers who came after the famous Galileo, Hale's eternal cry was for 'more light', or in other words, for better telescopes. This work was guided by two maxims. "Make the peaks higher" was one of them, and "Make no small plans" was the other. And till his last day he tried to live up to them.

In 1917, as soon as the telescope at Mount Wilson Observatory started functioning, Hale started preparing plans and blue-prints for a much larger telescope. After a long waiting period of more than a decade, his dream started taking shape when the International Education Board of the Rockefeller Foundation took an interest in the proposal. Hale wrote to the Board that the further study of the structure and the evolution of the stars, of the spiral nebulae, of the mass, temperature, density, etc. of the heavenly bodies called for a larger telescope. He wrote, "No method of advancing science is so productive as the development of new and more powerful instruments and methods of research."

After a great many set-backs, the whole of Hale's project for a better telescope was approved by the Rockefeller Foundation which agreed to spend $6,000,000 on it. Mr. John D. Rockefeller Jr. had this to say: "I have no competence in the field of astronomy. Six million dollars is a large sum of money, but I have complete confidence in Mr. Rose and the trustees, and if, after careful investigation, they decide that it is a wise thing to do, there certainly will never be any criticism from me."

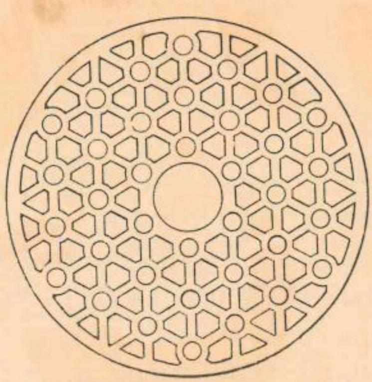
Newspapers all over the world welcomed the project. According to the Allahabad *Pioneer*, the 200-inch mirror of the proposed telescope was such that it could photograph a candle flame at a distance of 40,000 miles !

At last the work on the telescope started. The most important thing in it was, of course, the mirror. Suggestions come from England, Holland and Germany. At first it was decided to cast the mirror from quartz. We are all familiar with sand on sea shores and in deserts. It contains quartz. But after three years of experiments and an expenditure of more than $ 600,000, it was found that quartz was not suitable for the mirror. It was decided to use glass instead.

There were many problems with the glass disc of 200-inch diameter. For one thing, it would weigh more than forty-two-thousand kilograms and, for another, it would take about nine years to cool. It was therefore decided to have a ribbed disc. This design brought down the weight by one-half without sacrificing the strength of the mirror. It also shortened the cooling time considerably.

On 2 December 1934, the final disc was cast and the cooling was completed at the end of the following year. Then came the very important task of coating the disc in order to make the surface a reflecting one. Instead of silver, aluminium was used for coating, as it is far more resistant and much more lasting than silver. Can you imagine the quantity of aluminium that was used to coat the disc? You might think it must be a substantial quantity. But no,

The ribbed disc



The mounting for the
Mt Palomar Telescope

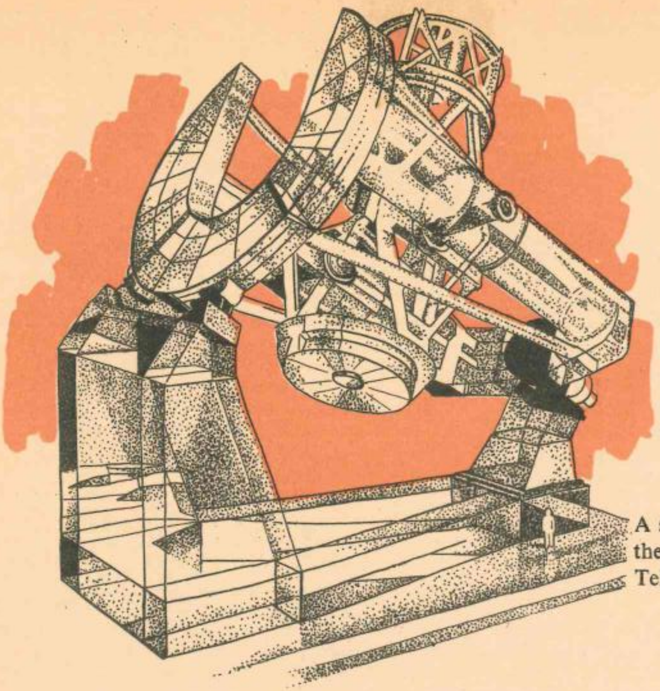
you'll be entirely wrong. Less than 30 grams of aluminium was all that was needed to coat the glass. Indeed the coating was very, very thin, but to coat a surface thinly takes a much longer time than to coat it thickly.

It took three months to complete the preparations for carrying the valuable disc from the factory to the observatory via the optical workshop.

A special car in the shape of a well was built by the railway company and ultimately the mirror arrived at the optical shop for grinding. Because of the interruption in the work caused by World War II, the grinding was not finished for eleven long years! During all these years, not even a speck of dust or any particle of grit was allowed to enter the shop! At last, in 1947, the mirror was ready. Then began its final journey to Mt. Palomar in California.

Where was this mirror to be mounted? What type of throne was to be prepared for this Giant?

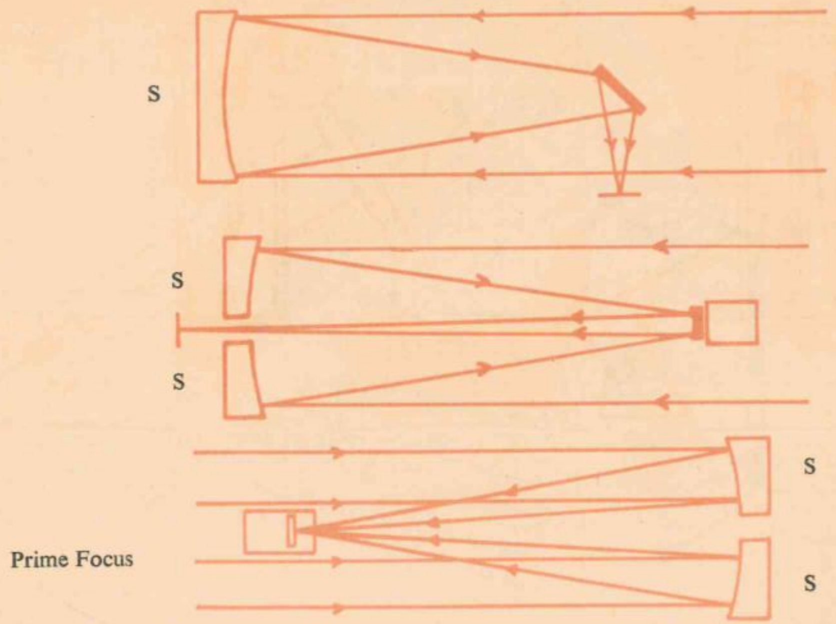
The throne for the mirror was a mounting consisting of two chief parts, namely the tube and the horseshoe. And mind you, it had to be as strong as a bridge, as precise as a watch and as light as a feather! Moreover, when required, it had to be able to move only a tiny fraction of a centimetre. Thousands of preliminary sketches and



A scale model of the Mt Palomar Telescope

models were prepared. Structural engineers who had built bridges, and electrical engineers who had spread telephone lines were consulted. Advice was even sought from engineers who were concerned with the construction of automobiles, locomotives and steamships. A scale model of the mounting was prepared and subjected to every possible test. After the work had started, it took more than two years to complete it. When completed, it was too large to be carried by land and had instead to be carried by river and ocean.

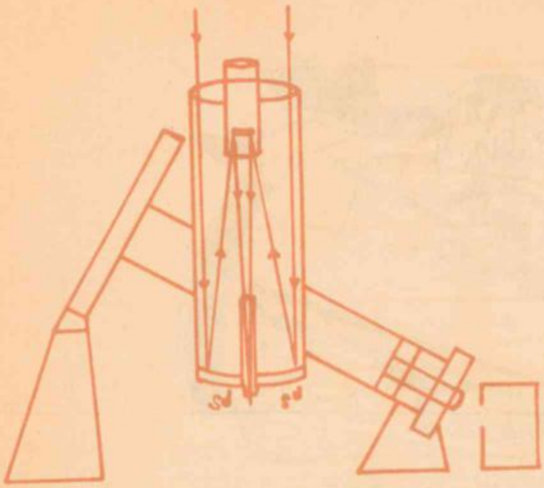
After it was assembled the total weight of the mounting was found to be more than 500 tons. Such was the throne on which the mirror was to rest! Now, what about the palace where this Giant would reside? That, too, was equally majestic, with its enormous dome. The outer wall was made of steel and the inner was made of aluminium. Between these two walls, there was a gap filled with



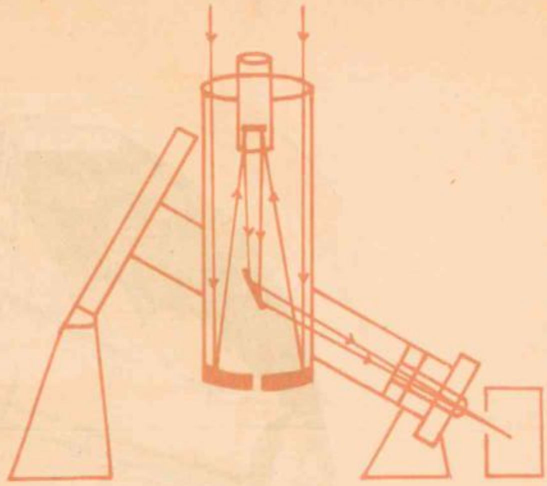
aluminium foil. When a part of the mounting rotates, it rotates so smoothly that no vibrations at all are transmitted to the telescope.

And this Giant at Palomar, as all giants should, takes up work which cannot be done by the other telescopes of the world. At present, it mainly works on nebulae, often described as Island Universes, and on the structure and evolution of stars, their temperatures, pressures, densities, etc.

There are many positions in the telescope from where the astronomer can do his work. If he wants to work from the position where the reflected rays meet, or from the prime focus as it is called, there is a 'cage' right within the tube itself where he can sit. Often an astronomer is interested in the nature of the light emitted by a certain star, in other word, in the *spectrum* of that star's light. He would then like to be in what is called the Cassegrain position, right behind



Cassegrain Position

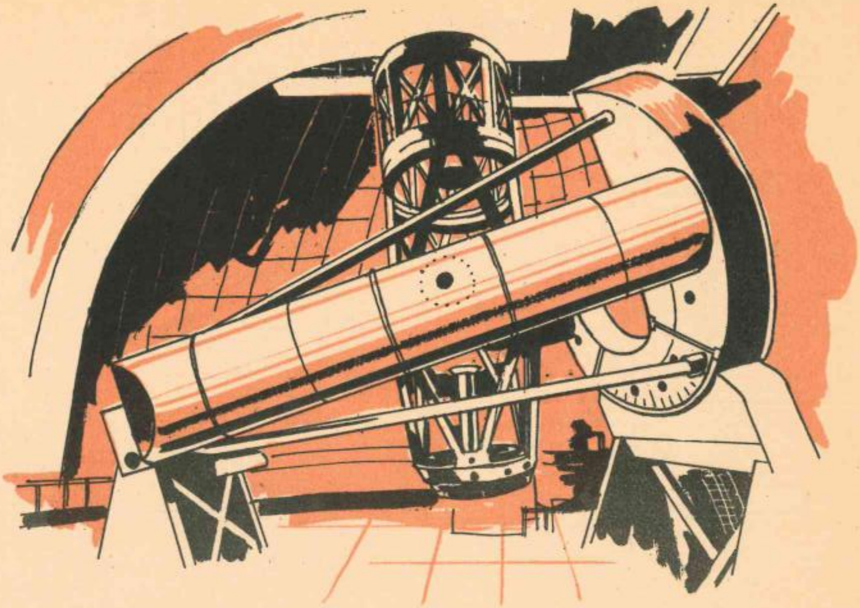


Caude Position

the reflector at the position of the usual eye-piece of a reflecting telescope. Or he might prefer to direct the light from the star into the laboratory where he can use other instruments (Caude position).

The Giant is so constructed that, by means of a remarkable system of controls, the astronomer can make observations regarding his position and the position of the star very, very easily. With the help of the assistant at the control board, the astronomer can easily move the telescope from one position to another without even stirring from his seat.

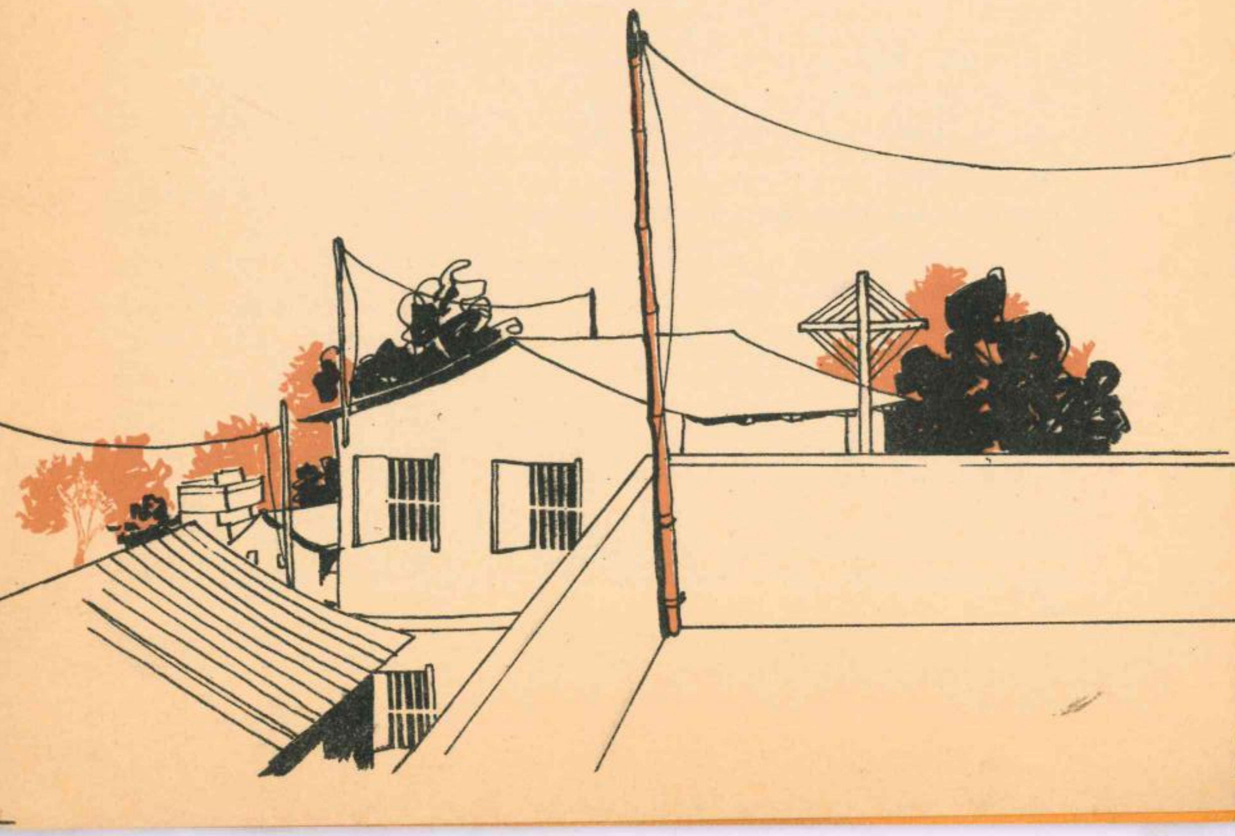
Such is the largest telescope of the world and a most wonderful piece of work it is indeed! The man whose most cherished dream it was, did not live to see it completed. Hale died in 1938, and his dream was fulfilled only at the end of 1947. But Hale will live in the memories of men as long as the Palomar Giant works.



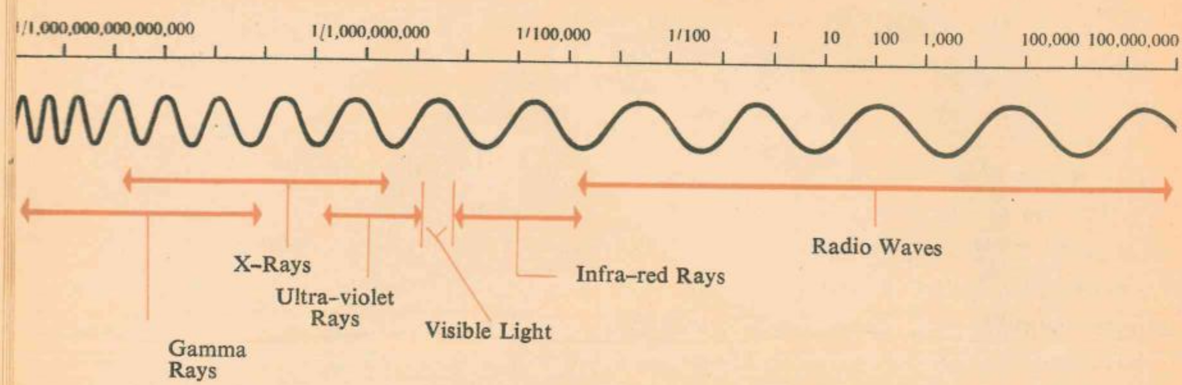
5. Always Better—"Make The Peaks Higher"

FROM NEWTON'S six-inch instrument to the Giant at Palomar is indeed a great stride. But the progess was all in the same direction and no new element came in. However, while the Giant was being constructed, a fundamental discovery was made by Karl Jansky, a radio engineer who was studying the causes of the disturbances which bothered people who sent radio messages to and from ships at sea. There was one disturbance that had really puzzled him. The source of this disturbance moved across the sky along with the sun. Ultimately, he discovered that the source which produced this disturbance was not anywhere on or even near the earth. It was not even near the sun. The source of this disturbance lay far away in the centre of the Milky Way and took thousands and thousands of years to reach the earth. On the day when the radio engineer made this discovery, an entirely new field opened up before astronomers the world over. And that was the field of RADIO ASTRONOMY.

"What has the radio to do with astronomy?" you might ask. Perhaps you know that the aerial that we put up on our housetops receives radio waves which carry broadcasts. These radio waves are also known as ELECTROMAGNETIC WAVES. But you might be surprised to know that light also travels in the form of waves, and that these light waves too are electromagnetic waves. The only difference between the two types is that the radio waves are longer, while the light waves are much shorter. Now our eyes can perceive waves of only a certain range of wave-length. If the wave-length is greater or shorter than this range we cannot see them at all. You might also have heard of X-rays and ultra-violet rays and infra-red rays. All



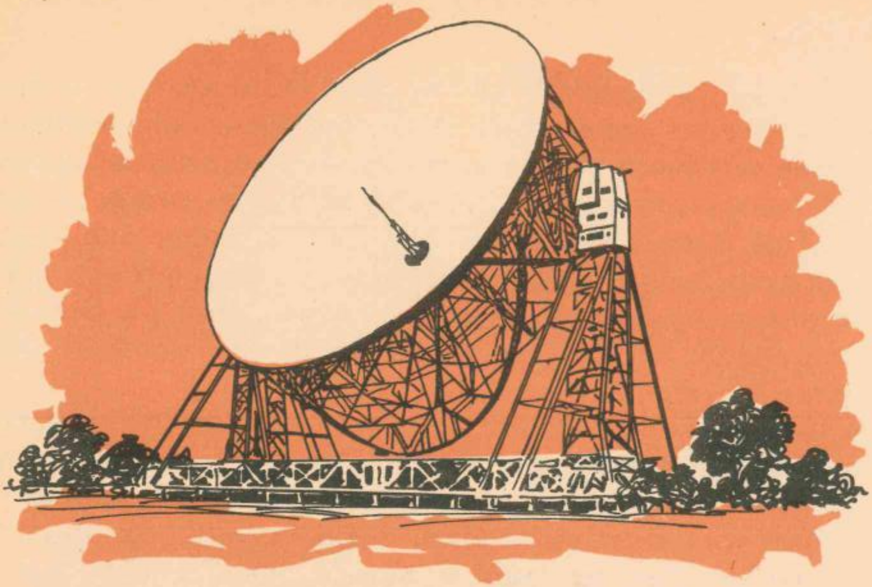
WAVE LENGTH IN METRES



these are also electromagnetic waves, just as the rays of visible light are. X-rays and the ultra-violet rays have wave-lengths shorter than light rays but infra-red rays have longer wave-length. The radio waves that we are discussing have still longer wave-lengths, and that's the reason why we cannot *see* any of these.

Now, the sun and the stars also emit these invisible radio waves along with light rays, which are visible. But until Jansky discovered the means of catching them, they remained unknown. After the Second World War, research regarding these radio waves from the stars gathered momentum. A great many instruments known as Radio Telescopes were constructed to catch and gather the radio waves from the stars of our galaxy, and other galaxies as well.

These radio telescopes vary in shape and size. As a matter of fact, they are nothing but giant aerials which collect radio waves originating from places billions and billions of miles away. Many of these waves have left their source thousands and thousands of years ago! To catch these waves or signals some of these radio telescopes have enormous bowl-shaped discs. Just as the concave mirror of the telescope at Palomar gathers light rays and converges them to a point, the concave disc of the radio telescope also gathers the radio



Giant bowl of a Radio Telescope

waves emitted by stars and converges them to a point called the central aerial. From this aerial, the signals are carried to the observatory where they can be converted into sound, and listened to. But, generally, the signals are recorded on graph paper so that permanent records of them can be maintained. The interpretation of these sounds and records is, needless to say, a most complex business.

The working of the ordinary telescopes which collect light waves depends on the condition of the atmosphere. If the sky is overcast, the telescope will be of little use. Even if the sky is very clear, if the air currents are very strong, the telescope will not be able to function because the images of the star would be, so to say, shaky. In such cases the astronomer complains that the "seeing is not good" and has to close the dome.

But radio astronomers are at an advantage here for, you see, the clouds cannot stop radio waves. So these radio-astronomers can always work, whether the sky be clear or overcast, be it day or night. However, there is one thing that these radio-astronomers complain very much about and that is the 'disturbances' caused by broadcasting stations. Radio astronomy had its origin in investigations of disturbances about which broadcasting and receiving stations complained. And, now, the radio-astronomers complain about the broadcasting stations themselves! Anyway, both the radio-astronomers and the broadcasting stations are doing a wonderful job.

This then, in short, is the story of man's quest for "more light" to recall the immortal words of Galileo once again. Already man is not satisfied with the giant telescope at Palomar nor with the radio telescopes with their giant discs, some extending to more than 70 meters in diameter. Man is already planning telescopes with larger mirrors and bigger discs. But the search, the quest, does not end there. Not satisfied with observatories based on Earth, man has already started planning observatories located on space stations moving round the earth and even observatories on the Moon! Will he be never be satisfied? Let one of Hale's own guiding mottoes, MAKE THE PEAKS HIGHER, be the motto not only of the scientist, but of all of us as well.

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