THE SKY TONIGHT

by Kenneth E.Chilton

The Sky Tonight

Introduction

The Universe is a beautiful mysterious and fascinating place. Its allure has attracted the attention of men from the days of the ancient Chaldean shepherds, lying on their backs in the meadows at night, to the present time, when scientists,with their large and powerful instruments, probe and interpret radiations reaching the Earth from distant galaxies. Public interest in Astronomy, the science of the Universe, has never been higher. This, no doubt, is due, in part, to the tremendous impact of the manned space programmes. Man, at last, has left his home planet and has travelled the relatively short distance to the Moon. Consequently, imaginations have been sparked, with the result that membership in astronomical associations has increased dramatically.

With public interest so high, I began to wonder, in late 1970, if a television series on the subject of Astronomy might not be of value in educating the public with regard to the wonders of outer space. Since community television by means of cablevision, that is, broadcasting by means of coaxial cable instead of through the air, was comparatively new and in need of programmes, I wrote to Cable 8 Ltd., a company producing television by this means in Hamilton,Ontario. The idea was accepted and, on March 31,1971, the first edition of "The Sky Tonight" was produced.

The format of "The Sky Tonight" is simple. Usually, I invite some local amateur astronomer, or a professional astronomer from a nearby university, knowledgeable in the topic of the evening, to the studio. While the guests answer my questions, the control-room staff show pictures and slides at the appropriate moments.

This book contains the material covered in the programme. It is more or less chronological, but I have not tried to include the material from every programme. I have picked what I think are the best and most interesting. Neither is this book a complete astronomical compendium. Rather, it is a series of short essays on astronomical topics.

In the production of this book, the writer owes a great deal to many people. Sincere thanks go to Malcolm Neal, General Manager of Cable 8 Ltd., and director of "The Sky Tonight". He pushes the buttons that make things come out right. Thanks also to the staff at the studio for their encouragement. I would also like to express my appreciation to Mr.Patrick Moore of B.B.C.Television in England, whose programme "The Sky At Night" was a source of inspiration. Patrick's encouragement has made production of "The Sky Tonight" a great deal easier.

Lastly, the writer owes a great deal to his wife, whose tolerance and understanding have made production of television, and of this book, much simpler. Her suggestions and criticisms have been more than valuable.

At the time of this writing, "The Sky Tonight" has completed its 112th half-hour broadcast. Hopefully, the public will continue to view our efforts favourably, for it is their support and interest which make continuance of the programme possible.

Ken Chilton
Hamilton,Ont.
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"The Sky Tonight"

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1. The Universe

Italics:

The first broadcast of "The Sky Tonight" occurred on March 31,1971. My guest in the studio was Rev.Norman Green, National Secretary of the Royal Astronomical Society of Canada, and Assistant Director of the McLaughlin Planetarium in Toronto,Ontario.

The subject for the evening was to be "An Introduction to Astronomy". We hoped to give the viewers an overall picture of the Universe.Despite our initial nervousness, I believe that we succeeded!

Regular Type:

The Universe is an awesome place. For years, men dreaded the sky and the signs they saw in it. Dragons, serpents, monsters and wild animals populated the firmament, if not in reality, then certainly in the minds of primitive men. A few, however, refused to be frightened and tried to interpret the myriad points of light as physical phenomena. These men were the very first true astronomers.

Why do men study the skies? In addition to wanting to know the true composition of celestial bodies, their motions, their distances and sizes, man has built into his nature some tremendous urge to know his own place in the Universe, and his role in the scheme of things. With this in mind, let us make a small trip through the Universe, simply making note of the objects that abound there and learning a bit about them.

To we Earthlings, the brightest object in the sky is the Sun. The Sun is a star. It is slightly smaller than medium-size, but, nontheless, it is much larger than the majority of stars. Its diameter is 864,000 miles, or about 115 times the diameter of our tiny dust-speck, the Earth. It is a seething cauldron of gases whose surface temperature is 10,000^{o}F.. Estimates of the interior temperature usually mention the figure of 22 million degrees. This is extremely difficult to visualize!

The Sun is accompanied through space by a retinue of smaller bodies known as planets . There are nine major planets: Mercury Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto, in that order from the Sun outward. Whereas the Sun is a hot gaseous body, the planets are relatively cool and solid. Jupiter, the largest, has a diameter of 88,000 miles, while tiny Mercury is only 3,000 miles from side to side.

Each of the planets, except Mercury, Venus and possibly Pluto, have smaller bodies revolving around them. These are known as moons or satellites. Jupiter has a retinue of 12 moons, Saturn 10, Uranus 5, Neptune and Mars 2 each; and the Earth has one.

Our Moon has been studied more by amateur astronomers than any other object. Its pitted, cratered, mountainous, rugged surface is a magnificent sight when viewed through a small telescope. Astronauts have visited the Moon with the purpose of depositing scientific instruments there. As a result, scientists here on the Earth can measure "Moonquakes". In recent years, much controversy has arisen as to whether the money spent on space programmes might not be better spent here on the Earth. Of course, all of the money has been spent here on Earth. The astronauts took no money with them. The money was spent in wages, wages for the thousands of men and women who participated, in both science and industry, in placing men on the Moon. In addition, many many modern conveniences, such as Teflon, and transistors, have come from research connected with the space programme.

The Sun and its family occupy only a very tiny part of the Universe. If you were to make a model with the Sun and the Earth being about one inch apart, then the nearest star would be four miles away! In fact, stellar distances are so great that astronomers have had to invent a new unit of length with which to measure the scale of the Universe. That unit is the Light Year. A Light Year is that distance which a beam of light would traverse in one year, travelling at 186,000 miles per second. This comes to nearly six trillion miles, an imagination-defying distance.

Stars are arranged in systems called galaxies. The shape of a galaxy is rather like two fried eggs, glued back to back. They often remind me of children's pinwheels which revolve in the wind. There are millions of galaxies, each containing millions of stars. The stars are suns, huge cauldrons of seething gas, literally exploding, converting Hydrogen into Helium. Our own star-system, or galaxy, is called "The Milky Way". It appears as a faint band of hazy light across the sky. However, even a pair of binoculars will show that it is, in reality, thousands and thousands of stars. It has always been a pleasure for me to lie back on a cool summer's evening and to watch the myriad points of light spread out along the Milky Way.

Also found in the Milky Way system, and in other galaxies, too, are some very interesting aggregations of stars, roughly spherical in shape, called Globular Clusters. Each of these contains several thousand stars. It appears to astronomers that the Globular Clusters form a spherical halo around the entire galaxy.

Some of the most beautiful sights in the galaxy are the nebulae, great clouds of gas, glowing because of stars imbedded in them. It appears that the stars are formed inside of these nebulae, from the material of the nebulae. Two particles of gas attract each other through mutual gravitation.They cling together. Then other particles are attracted until the mass of gas that has accumulated is sufficiently heavy for the atoms at the centre, under tremendous pressure from the other atoms above, to begin atomic reaction. The star then begins its life. Of course, the light given off by the star would illuminate any gases left in the vicinity.

Naturally, dear reader, this has been but a very brief tour of the Universe. I have deliberately avoided getting into detail on the objects mentioned, since I intend to elaborate in later chapters. My object in this particular chapter was to lead you to appreciate the awesome size and variety in our Universe.

2.Astronomers

Italics:

On the evening of April 13,1971, Peter H.Ashenhurst, Secretary of the Hamilton Centre of the Royal Astronomical Society of Canada appeared on the programme. The topic was "The World of the Astronomer". We explained what it is that astronomers do, a bit of how they do it, and the vast difference between professional and amateur astronomers.

Regular type:

Astronomers come in all shapes and sizes, in all temperments and dispositions, and in all philosophies and outlooks. They have one thing in common, however, and that is a love of the skies. One of the basic requirements for becoming an astronomer, either professional or amateur, is that you must have that burning desire to know, that consuming need to find out, that great spirit of exploration.

Amateur astronomers differ from their professional colleagues both in instrumentation and in the types of programmes which they undertake. This is, of course, due to a difference in economics and in education. Whereas many amateur astronomers have purchased or constructed their own telescopes, the professional is on the staff of a university or a research organization, which provides the telescope and other equipment. Further, the professional astronomer has had many years of university education, while his amateur brother learns from books, attending lectures and through association with other amateurs.

This is by no means a criticism of amateur astronomers. They have a very distinct and valuable role to play in their chosen science. In fact, it is safe to say that Astronomy is one of the few sciences where the work of amateurs is desired by their professional colleagues because of its extreme value.

The chief tool of both amateur and professional astronomers is the telescope. But here the similarity ends. The amateur astronomer uses his telescope as an optical aid, making visual observations, whereas the professional astronomer uses his telescope as a light gathering instrument, to feed light into his other instruments.

Generally, special attention is given by professional astronomers to objects beyond the solar system. That is not to say that the Moon and Planets are not studied by them, but rather that the majority of astronomers study the stars, galaxies and nebulae. The reasons for this will be evident later in this chapter.

Much of professional astronomy is photography, either of the stars, directly, or of their spectrae. A spectrum is a band of multi-coloured light obtained by passing starlight through a slit and then through a prism. (A rainbow can be thought of as being an example of a spectrum.) This spectrum is traversed by many bright and dark lines. Through the study of these lines, the professional astronomer can deduce the composition, temperature, speed and magnetic fields of the stars.

Other astronomers measure photographs of the stars. In this way, motion across the line of sight, and brightness of the stars can be measured. I might mention, at this point, and outstanding discovery made by the painstaking measurement of plates, or pictures. Dr.Peter van de Kamp,of Sproul Observatory at Swarthmore,Penna., has discovered, by measuring irregularities in the motion of "Barnard's Star", a star near the Sun, two planets revolving around the star.

Still other astronomers work with photoelectric devices, measuring the brightness of stars, especially those which appear to vary. Others work with radio telescopes, receiving and recording radio noise which originates in the stars and dust clouds.

The amateur astronomer is more restricted in his work, but, nevertheless it is still valued and desired by his professional colleague. While it is true that some amateurs do take very good photographs with their equipment, the vast majority of amateur observations are visual. The useful observations which can be made by amateurs are many.

Amateurs all over the world compile observations of sunspots. This is done by aiming the telescope at the Sun by means of the shadow of the telescope, and then projecting the image of the sun on a card held behind the eyepiece. There, the sunspots may be seen in great profusion. Here, I must sound a very serious warning to any reader who may be a prospective sun-gazer. Never, under any circumstances should you ever look directly at the Sun through a telescope or binoculars. Instant blindness will result! True, there are filters which the manufacturers thereof claim make it safe to look at the Sun. These, however, have been known to crack. Should one crack while you are viewing, and don't forget that a telescope focuses the heat of the Sun as well as the light, you would feel a searing pain, and then never see anything with that eye again. The only 100% safe method is to project the Sun as outlined above.

The Moon has often been a target for the attention of amateur astronomers. With its hundreds of craters, seas, and mountain ranges, the Moon is an interesting object for study. It was customary for astronomers to make maps and drawings of the surface. It must be pointed out, however, that this is now outmoded by the amazing photos which were sent back by the Orbiter spacecraft. Current attention is being paid to Transient Lunar Phenomena, or TLP's for short. TLP's are rather reddish glows which occur on the lunar surface from time to time. They appear to be clouds of rather luminous gas emitted through cracks in the surface when the crust of the Moon is strained by the tides raised in it by the gravitational attraction of the Earth. Amateur astronomers using a series of rotating filters, have detected many of these. As proof of the importance of TLP studies, the National Aeronautics and Space Administration set up a network of amateur and professional observers to watch for them, during many of the early Apollo missions to the Moon.

The planets have been the exclusive field of the amateur astronomers for many years, though in recent times, the professional has paid more attention to them since the prospects of actually visiting them are increasingly less remote. It takes only a small telescope to see the belts of Jupiter, the rings of Saturn or the polar caps of Mars. The crescent phases of Mercury and Venus may be seen with ease. Mere binoculars will suffice to show the moons of Jupiter as they revolve around their parent planet. A few hours observing will reveal their motions. All of the above may be seen, and above all, measured by the amateur astronomer.

One of the most valuable fields in which the amateur astronomer can operate is the study of variable stars, those which are not of constant brightness. The long-period variables and irregular variables have been left to the amateur, for he, with his modest equipment, can do a job equally as good as his professional colleague. This frees the professional astronomer for duties which the amateur cannot undertake.

Observations of variable stars are made by comparing the star to stars which do not vary, and whose brightnesses, or magnitudes, are known. It is amazing how accurate the human eye can be, as, with a little practice, amateur astronomers can plot the magnitudes on a graph, and thus, learn some of the characteristics of the stars that they are studying.

Other amateurs concern themselves with drawings of distant galaxies, nebulae and star clusters. While this in itself is not of great scientific value, it is very good training for the observer.

Astronomers love to gather and chat about their work. For this purpose, astronomical societies have been organized. In the USA, there is the Astronomical League, a loose federation of local amateur astronomy clubs, and the American Astronomical Society. Canadians can belong to the Royal Astronomical Society of Canada, or the Canadian Astronomical Society, which is for professional astronomers. In Britain, there is the British Astronomical Association, largely for amateurs, and the Royal Astronomical Society, mainly for professionals. Of course, there are hundreds of other societies around the world, but space does not allow us to mention them all. I should mention, however, two great international organizations which co-ordinate astronomy on a global scale. Nearly all professional astronomers belong to the International Astronomical Union, while amateurs can join the International Union of Amateur Astronomers.

Astronomy is an inviting science. It is full of mystery, beauty, and power. Every night, thousands of men and women, of all creeds, colours and politics, look skyward. They all share the same Universe for Astronomy knows no frontiers, no politics. Perhaps man's destiny is in the stars, for, if politicians and diplomats could be as friendly and cooperative as astronomers, there certainly would be no wars. Perhaps the motto of all mankind should be as the motto of the Royal Astronomical Society of Canada:"Quo ducit Urania".... which, roughly translated, means: "Where Urania (Muse of Astronomy) leads,I follow".

3.The Sun

Italics:

Since the Sun is the brightest object in the sky, I decided that one of the early programmes in the "Sky Tonight" series would be on the subject of the Sun . Fortunately, I had been present during a recent talk about the Sun, given by Mr.Leslie V.Powis of the Hamilton Centre of the Royal Astronomical Society of Canada. I prevailed upon Mr.Powis to appear before the television cameras on April 27,1971.

Regular Type:

The Sun is the only star close enough to us that its surface features may be studied in detail. Through observations of the Sun, much may be learned about the more distant stars, which remain forever inscrutable because of their great distances.

The Sun has a diameter of 864,000 miles,which is over 110 times the diameter of the Earth. This makes the volume of the Sun so large that it would take 1,304,000 Earths to fill it up if it were hollow. The Sun's mass is 330,000 times that of the Earth. This gives the Sun a density of 1.41 times that of water. It would sink in water, if one could find a glass large enough, even though the Sun is gaseous. At the surface of the Sun, the force of gravity is 27.9 times that of the Earth. A 200 lb. man would weigh over 5500 lb. if transferred to the surface of the Sun.

Actually, when we look at the Sun, we do not see its true surface. What we do see is a layer called the photosphere, ie: light sphere. It is overlain by a transparent layer called the chromosphere. This will be dealt with later, so let us deal first with the photosphere, the visible surface.

Probably the most visible surface of the photosphere is the presence of large black spots. These "sunspots" are not just something astronomers see when they are tired, but are cooler areas on the surface of the Sun. By cooler, we mean cooler in relation to the rest of the surface. Whereas the temperature of the photosphere is 6000°C., the temperature of the spots is 4000°C., and that is still plenty hot!

The spots are huge vortices, ranging from small openings to huge gaping pits into which one could drop the entire planet Earth. Gases flow up from the interior, expand rapidly and then descend violently into the centre. Mixing of the cooled gases with the hot surface causes a grey area to surround each spot. This area is called the "penumbra" while the darker central area is the "umbra".

Sunspots provide a reasonably accurate means of determining the rotation period of the Sun. By observing a spot on the Central Meridian of the Sun throughout one whole rotation, a period of 27 days can be roughly estimated. However, the Earth has moved considerably in its orbit in 27 days, so that a correction must be made. This was done originally by a wealthy brewer, and amateur astronomer,Carrington, over a century ago. He found, however, that one could not speak of <u>the</u> rotation period of the Sun, for spots at high latitudes appear to rotate more slowly than those at lower latitudes. The rotation periods for a selection of latitudes are given in Figure 1.

(Figure 1)

In the 19th century, a German apothecary, Heinrich Schwabe, noticed a regular fluctuation in the number of spots visible in a given year. Through 45 years of observation, Schwabe determined that the spots occurred more frequently in an eleven year period. That is, spots become more and more frequent for 5½ years and then less and less frequent for an equal period.

Some interesting effects of this eleven year cycle have been noted. Trees, for instance appear to grow more rapidly during sunspot maximum, while rabbits seem to multiply faster, if that is possible, at the same time. Indeed, there seems to be some correlation between the sunspot cycle and the Dow-Jones stock market quotations! Perhaps some enterprising astronomer could get very rich by investing at the appropriate moment, determined by the observation of sunspots!

At the beginning of an 11-year cycle, spots appear mostly at 35° North and South latitudes. As the cycle progresses, the spots occur at lower and lower latitudes until, at the time of minimum, they appear mostly on the solar equator.

Sunspots are not the only features on the photosphere, although they are, by far, the most noticeable. High magnifications will show that the surface of the photosphere appears granulated. These grains are, no doubt, the tops of thermals of rising hot gas, while the darker areas around each grain are the cooler sinking gases.

The photosphere is underneath what is generally regarded to be the true surface of the Sun. This is a tranparent layer known as the chromosphere. Normally it is invisible, but during eclipses, when the Moon comes between the Earth and the Sun, it is visible as a fainy rosey ring. The pink colour comes from ionized Hydrogen, Helium and Calcium. The temperature of the chromosphere is 50,000° which makes it about 8 times as hot as the photosphere. The depth of the chromosphere is estimated to be about 6,000 miles.

The chromosphere abounds in interesting features. Near the sunspots appear very bright jets of gas, called faculae. When they surround the sunspots they are called plages, which is French for beaches, and I suppose that they do ressemble beaches around a dark lake.

At other times, very dark streaks appear in the chromosphere. When these reach the edge, or limb, of the Sun, they are seen to be towering columns of gas, thousands of miles high, moving with accelerations of up to 250 miles per second. These are called prominences. At eclipses,they are visible to the unaided eye, glowing fiery red against the pearly glow of the corona.

The corona is sometimes called the atmosphere of the Sun, a term which partially describes it, but is not entirely correct. The corona is far hotter than either the chromosphere or the photosphere, asit has a temperature of 1 million degrees Centigrade! The reason for this extremely high temperature is unknown.

The corona appears to be made of delicate streamers, whose appearance changes from eclipse to eclipse, in a cycle related to that of the sunspot cycle. The corona extends out from the Sun about two solar diameters, or one and one half million miles.

The Sun emits many kinds of radiation. Of course, the one that is most readily apparent,here on the Earth, is light. The main wave-length is in the yellow region of the spectrum, which is why the Sun appears yellowish to us. The light from the Sun takes 8½ minutes to reach us, travelling the 93 million miles at 186,000 miles per second.

Other radiations are equally as fast. Ultra-violet, x-ray, and radio radiations also reach us in 8½ minutes. Fortunately, the damaging ultra-violet and x-ray radiations are filtered out to a large degree by the Earth's atmosphere.

High velocity atomic particles are emitted by the Sun. They reach the earth in about an hour. When they collide with the upper portions of the atmosphere, they cause atoms to release other atomic particles, which upon reaching the surface of the Earth, are called "cosmic rays".

Reaching us in about 30 hours are electrons and protons. When they reach the atmosphere, they cause the aurorae.

The Sun, at the surface of the photosphere, emits 1,550 calories per square centimetre per second. Taken all over the surface of the solar sphere, this is equivalent to 11 million million tons of coal per second, which is about 20 years of U.S. coal production! However, all of this vast amount of energy does not reach the Earth since the Sun is shining in all directions at once. The amount reaching us is 2 calories per square centimetre per second.

What causes the sun to shine? It is an atomic cycle, where Hydrogen is converted into Helium. See figure 2.

(Figure 2)

The reader will note that the cycle begins and ends with an atom of Carbon, this being the reason for calling these reactions "The Carbon Cycle". There are other methods by which stars create energy, but they need not be recounted here, as we are concerned solely with the Sun. The reader will note that 4 atoms of Hydrogen are consumed, with a loss of energy, to make one atom of Helium. This is the source of the Sun's energy.

One cannot say in a few papragraphs, the importance of the Sun. Let us say that, without the Sun, there would be no mankind, no Earth, no food, no fuel. Everything starts with the Sun, and everything will end with the Sun, for eventually the Sun will consume all of its Hydrogen. That will signal the end of the Earth. However, long before that distant age, man will have decided his own fate.

4.Making A Telescope

Italics:

Every person who becomes interested in Astronomy wants to own a telescope with which to view the wonders of the heavens. Many purchase telescopes but the cost of anything but a very small instrument is prohibitive to most beginners. To make and use one's own telescope is a source of pride. Thus, on May 11,1971, my long-time friend, Bill Keating, a professional optical technician, appeared on "The Sky Tonight" in order to demonstrate the basics of making a telescope.

Regular type:

To properly appreciate the majesty of the celestial sphere, one needs some sort of optical assistance. Binoculars are of some aid, but a telescope will reveal the universal splendours in grand profusion. However, the beginner may not know about telescope making, so we offer the following as a general guide.

There are basically two types of telescopes, refractors and reflectors as shown in figure 3.

(Figure 3)

A refractor is a glorified spy-glass. It has a large lens on one end and a small lens, called an eyepiece, at the other. Light rays from the sky are bent by the lens to form an image, or picture, just in front of the eyepiece. The eyepiece magnifies the image so that it looks larger. It is just as simple as that!

A reflector, on the other hand, has the top end open, and a mirror at the bottom end. In the middle is a small mirror, tilted at 45° to the direction in which the telescope is pointing. The secret of the telescope is that the large mirror at the bottom is curved.

Light rays striking its surface are reflected back to form an image, just as in the refractor. However, before they reach the image point, they are reflected through a hole in the side of the tube, where they are magnified by the eyepiece.

The efficiency of a telescope depends, to a great degree, on it diameter. It may be seen that more light will enter a telescope if its diameter is large, than will if its diameter is small. Astronomers refer to their telescopes by their diameters. Most amateurs obtain a three- or four-inch reflector for their first instrument. This is because the cost-diameter ratio sky-rockets as you move towards larger and larger diameters. In the case of refractors, a 3" or 4" is all that the average person can afford. A six-inch refractor costs as small fortune!

Reflectors are much cheaper. Telescopes up to 8 inches diameter are well within the price-range of the average amateur astronomer. Some even go as far as to purchase 10" or 12" telescopes. Beyond this, however, the prices literally go astronomical!

It is practical for a person of average mechanical ability to make his own telescope. The writer is literal proof of this, since I must admit to having very little ability in the mechanical field. Let's first rule out making a refractor. Lenses are difficult to make, as they must have both front and rear surfaces made to the exactly correct curve, as well as being perfectly transparent. To make things more annoying, lenses in a refractor are usally two lenses cemented together, so that the prospective telescope maker must grind four lens surfaces and bond them together so that the glue is totally transparent too!

Mirrors for reflecting telescopes are far easier to grind. I do mean grind, for that is literally what you do! As the reader will note from figure 3, telescope mirrors are concave, that is, they are thinner in the centre and thicker at the edges. The method for making these mirrors is relatively simple. For detailed instructions, the reader is advised to read a copy of one of the many books on amateur telescope making on the market. In this brief essay, I intend to give only the most general instructions so that you, dear reader, will be more or less aware of the technique involved.

The first step is to purchase a mirror-grinding kit from a local supply house. The kit will consist of a number of cans of powders and grits of varying coarseness, and two pieces of glass, which are your "mirror blank" and "tool" respectively. Anchor the tool firmly to a table. A sheet or two of wet newspaper will do this just fine. Then sprinkle on some of the coarsest grade of grit, along with a squirt of water. Put the blank on top and commence moving it in a circle, so that the edge of the blank overhangs the edge of the tool by an inch or two. Also, it is advisable to rotate the blank slightly in your hands while making the circles.

What you are doing is causing more wear in the centre of the blank and at the edges of the tool, so that the blank becomes concave and the tool becomes convex. There are formulae for telling you how "hollow" your mirror should be,but, again, the reader is referred to a text on the subject.

As you approach the proper depth, finer and finer grades of grits are used, so that the mirror takes on a very high polish and is perfectly smooth throughout its entire surface. Other simple steps with pitch, and other compounds will bring the amateur manufacturer to the point where his blank is complete. It must then be aluminized or silvered. There are, in most communities, facilities for doing this.

The making of a telescope tube is very simple. I have used a long wooden box made of plywood. Why beginners insist on a round tube, when a square one is much easier to construct. Some provision must be made for the flat diagonal mirror and the eyepiece holder. It has been my experience that one is far better off to purchase a combination unit for about 10 dollars than to try and make one.

The mirror is fastened into the bottom of the tube. The easiest way to do this is to make a "Chilton Mirror-holder" of parts available at your local hardware store. I have shown how to do this in figure 4.

(Figure 4)

A mount for your telescope is a necessity for good viewing. Again, the reader is directed to a text. However, as a temporary measure, you may wish to construct what is called the "Plumber's Nightmare" mount which may be seen in Figure 5.

(Figure 5)

When all is assembled, you are ready to try your telescope. I recommend the Moon as a good starting place. You will marvel at its rugged mountains and deep circular craters. Next, try Jupiter, noting its moons and belts. You are then on the road to becoming an observer. The first view through one's own self-made telescope is indescribable, as a thrill tingles its way down your spine! (I must admit that my first view was less than thrilling. My telescope was completed during an April thunderstorm and was focused through a window at a nearby streetlight.)

In closing this chapter, let me again give the warning that we gave in a previous chapter. Never point your telescope at the Sun and look through it, even for only a fraction of a second. That fraction will be long enough to blind you permanently. Instead, use the projection method outlined earlier.

Should you, dear reader, attempt, after reading this crudest of outlines, decide to make a telescope, you will need lots of patience and some luck! However, the pride in the finished object is worth all of the work, trials and tribulations.

5. The Moon

(italics)

Since Man has visited the Moon, that object has become, more than ever, a source of interest for the ordinary citizen. Thus, on May 25, 1971, we scheduled a programme about the Moon. At the last moment, however, my scheduled guest had to make other arrangements due to a family matter, Fortunately, I was able to obtain the services of Robert Speck, 2nd Vice-President of the Hamilton Centre of the Royal Astronomical Society of Canada.

(Regular type)

For thousands of years, man has wondered about his nearest celestial neighbour, the Moon. He had no conception of its distance, size, or composition. His imagination peopled the Moon with all sorts of beings, ranging from beautiful Moon-maidens to the most horrible of monsters. He thought that the dark areas visible on the face of the Moon were seas and gave them fanciful names such as The Sea of Tranquillity, The Ocean of Storms and the Bay of Rainbows.

Man has also been attracted to the idea of visiting the Moon and his devised all sorts of schemes for getting there. Ancients believed that tying sufficient wildfowl to one's limbs would get one to the Moon very quickly. An old Norse gaga tells of a shipload of Vikings who were carried to the Moon in the winds of a tornado. H.G. Wells thought that a sphere coated with anti-gravity paint would transport a crew of astronauts to the lunar surface, while another author, Jules Verne proposed to shoot the space travellers across the void in a shell fire from a gigantic cannon!

From the beginning of History, mankind observed the phases of the Moon. In its journey around the Earth, approximately once per month, the Moon exhibits varying portions of its illuminated half to earth-dwellers. The reason for this may be seen in figure 6.

(Figure 6)

The distance to the moon has been known for many hundreds of years, as it may be calculated through relatively simple geometry, through simultaneous observation by two observers whose distance apart is accurately known. This method is, of course, the whole basis of surveying.

Aside from the phases, distance and a few minor variations in motion, little else was known about the Moon until the advent of Galileo and his telescope. When the Italian scientist turned his spy-glass to the Moon, a panorama of mountains, craters and plains met his eye. One can well imagine his excitement as he gazed in rapture at the magnificence of the lunar disc!

As larger and larger telescopes came into being, more and more was learned about the Moon. Maps of the surface were made. It seems that the first was constructed by an Englishman, Thomas Harriott, in 1610. Features were given names. Mountains were named after ranges on the Earth, so that we have lunar Apennines, Caucasus and Carpathians. Craters received nomenclature by being named for famous persons in the past, mainly scientists though a few politicians, explorers and poets have crept in somehow. Thus, on the lunar surface, you will find Tycho, Copernicus and Aristarchus.

Lunar mapping and observation continued until relatively recently. All Earth-bound mapping of the Moon was rendered obsolete in the mid-1960's when five Orbiter spacecraft were put into lunar orbit with the object of photographing the lunar surface in great detail. At the same time, both the United States and Soviet Union landed craft on the surface. These machines sent back close-up views of the terrain and proved that the surface was not filled with great pits of dust into which any spacecraft would sink upon landing. One machine actually excavated a trench in the lunar soil to find out what was underneath.

All of this culminated in July 1969 when astronauts Neil Armstrong and Edwin Aldrin landed their space-ship, Eagle, on the Sea of Tranquillity. As the world watched, spellbound, via television, the two astronauts set up several scientific experiments and gathered a precious cargo of Moon-rocks. With the consequent arrival of the rocks back on the Earth, scientists began their first real analysis of the Moon's soil. Many amazing facts came to light. Further astronaut crews have brought back additional lunar rocks and soil. It may be seen, then,that, in the early 1970's, a virtual explosion of lunar knowledge took place. What, then, does man know about the Earth's satellite?

To give a complete answer would require a book in itself. However in this volume I intend to give a general summary of what we know about the Moon, and to state some of the mysteries still awaiting solutions.

The Moon has a diameter of 2,160 miles, which makes it about $\frac{1}{4}$ of the size of the Earth. However, the Moon weighs only 1/81 as much as the earth. This anomaly leads scientists to believe that the Moon does not have a core of nickel and iron after the fashion of the Earth. Since the Moon is not very massive, the force of gravity at its surface is only 1/6 that of the Earth, which means that a 180 lb. astronaut weighs only 30 lb.. In fact, whereas astronauts move very slowly and in an awkward manner in their cumbersome space suits while on Earth, on the Moon they move with relative ease.

The Moon is almost a quarter of a million miles away. Its actual distance varies somewhat as the orbit of the Moon is elliptical, rather than the circular. At minimum distance, the Moon is only 221,463 miles away, while its greatest distance is 252,710 miles. It revolves around the Earth in 27½ days, though it takes 29½ days for the Moon to go from New Phase to New Phase. The difference is caused by the Earth's motion through space. This is more fully explained in Figure 7.

(Figure 7)

A telescope view of the Moon exhibits a variety of features. Some of the most obvious are the seas. As explained previously, they were named by ancients who thought that they were bodies of water. However, a glance through a telescope or a pair of binoculars will show that the seas are, in reality, great plains, broken only by occasional craters and by ridges. These ridges, often called "wrinkle ridges", appear to be lava flows, remnants of the days when the seas were molten, or so the theory goes. The seas are all roughly circular in shape and are underlain by concentrations of greater density than the rest of the Moon. These mass concentrations, or "mascons", were discovered when unexpected changes occurred in the orbits of the five Orbiter spacecraft. This was a fortunate discovery for, if it had gone unnoticed, the Apollo spacecraft would have landed miles and miles off target. Theory has it that the seas were formed when some large bodies smashed into the Moon at thousands of miles per hour, turning the surface into molten rock, and burying themselves under the Moon's crust. The molten rock flowed back into the wounds, creating the relatively smooth seas. This is not the only theory, but it is an interesting one!

There are also many theories for the formation of the craters. There are over 30,000 recognized craters ranging in size from pits a few feet in diameter to the giant Clavius, some 150 miles from side to side. Generally speaking, the craters are not deep, as compared to their diameters. The outer walls are quite steep while the inner walls appeared to be terraced. Many many craters have a mountain or peak at their centres.

Some scientists think that the craters were formed as a result of a bombardment by meteoritic particles, much like the bodies which were mentioned above with regard to mascons, but smaller. Others believe that the craters were formed by means of volcanism in the days when the Moon was very young. Still others have come to the conclusion that the craters are slowly rising from inside the moon, much like bubbles in a bowl of porridge. They burst, leaving the rim.

Certainly, some of the craters appear to be the result of bombardment. They are surrounded by great radial streaks, or "rays" which extend for miles out of the crater. It may also be argued that the rays could have been created through volcanism. The argument has been going on for years, and, strangely, has not at all been resolved by the Apollo flights, though it would seem that the bombardment advocates are slightly ahead at this point.

The lunar surface is rent by giant cracks, or rilles. These are extremely interesting. It appears that they are the result of the Moon'ssurface being torn by tidal forces, although, in some of the Orbiter photos it looks strangely as if some of the rilles were made by running water! They look like dry river beds!

Conditions on the lunar surface are totally alien and hostile to human life. There is not air. There is not water. There are no plants. In the words of the Apollo XI astronauts, it is "magnificent desolation". In the daytime the temperature of the Moon is about 250°F., while during the lunar night, it drops to almost 300° F. below zero, a temperature range of over 500°.

Lunar nights and days last approximately 14 days (Earth days) each. This is because the Moon rotates once on its axis as it revolves around the Earth. The result of having a one to one ratio between rotations and revolutions is that the same side of the Moon always faces the Earth. Further explanation is given in Figure 8. For this, too, we never see the other side of the Moon.

The lunar far-side was a total mystery to mankind. It was a sort of paradise for science fiction writers who envisaged Martian colonies there, set up for the invasion of the Earth! Other equally weird theories and ideas have come to the fore during recent years. I recall seeing, as a teenager, a cartoon in a magazine showing the first two astronauts going around to the back of the Moon in their spaceship. Much to their surprise, there was a giant label on the back which said "Made in Japan"! Another similar cartoon showed the Moon being hollow on the back, and supported inside by scaffolding. A large sign proclaimed "Property of Warner Bros." (an American film studio)!

On October 4, 1959, the speculation ended. A Soviet Spacecraft, Lunik 3, photographed the back of the Moon and relayed the picture back to the Earth. Although it was a crude picture, it became quite evident that the back of the Moon was remarkable in its absence of seas. The only small sea was aptly named the Sea of Moscow. The biggest surprise of all, however, was the giant "bull's-eye" on the far-side. This is the Mare Orientale, literally the Eastern Sea. A bit of this is visible from the earthward side, but the remainder is hidden from telescopes on this planet. What was revealed was that this sea is actually a series of concentric rings looking remarkably like a target.

We now have detailed knowledge of the other side of the Moon, again through the pictures of Orbiter craft.

Further knowledge of the Moon has been gained as a result of the manned missions. The purpose of these flights is not tourism, but a search for the answers to many age-old questions. One of the prime experiments was to deposit a seismometer on the surface, with the result that many moon-quakes have been registered. Analysis of the data indicates that the surface of the Moon is underlain by a layer of highly fractured rock, almost like rubble. When various lunar modules and booster rockets have been deliberately crashed on the Moon, the seismometers indicated reverberations which lasted nearly 30 minutes. The Moon rang like a bell! This, of course, was totally unexpected.

Astronauts also placed a laser reflector on the surface. This highly polished reflector has enabled scientists to determine the distance to the Moon to a matter of a few feet. A laser was placed at the focus of the 120" telescope at Lick Observatory. This, in effect created a laser "searchlight". Other telescopes watched for the reflection. Since the speed of light is known with considerable accuracy, it was possible to time the interval between the instant when a pulse of light was sent Moonward and when the reflection returned. Computations would indicate the distance travelled, which when divided by two, would give the distance to the lunar surface.

Naturally, the cargos of Moon-rocks were of high interest to scientists. Analysis has shown that much of the surface is a medium to fine-grained vescular crystalline rock of igneous origin. It was probably formed as a part of a lava flow by cooling of the molten basaltic material. It has been subsequantly bombarded by meteorites. The Moon is mineralogically the same as the Earth but differs in detailed chemistry. The age of the rocks appears to be about 3 billion years.

As further flights occur, answers to other questions will be provided. We still know little about the rough highland areas in the southern portion of the Moon, as flights have landed mainly on plains near the lunar equator.

Telescopic observations for transient events will continue. Transient Lunar Phenomena, or TLPs for short, are outpourings of luminous gas, which appear from time to time. They appear to be related to tidal stresses for they occur when the Moon is closest to the Earth. Amateur astronomers the world over patrol the Moon with their telescopes watching for the mysterious glows.

Much of the mysticism concerning the Moon has vanished under the probing of modern science. Fortunately, poets and song-writers still find the soft glow of moonlight a romantic topic. For, to put the Moon into the category of just another celestial object would be cruel indeed. The Moon has acted through the centuries as a challenge to man's intellect, imagination and bravery. No doubt, as we get to know our neighbour better, the Moon will act as a stimulation to man's creativity, for it is a hostile, alien environment. Only time will tell!

6. The Stars

(Italics)

To the unaided eye, stars are the most numerous objects in the firmament. To explain what we know about stars, I appeared without a guest on the programme of June 8, 1971.

(Regular type)

"Twinkle, twinkle, little star. How I wonder what you are". So states the chid's nursery rhyme. From the dark ages of the distant past, curiosity about the glimmering orbs of the heavens has held a place in the culture of mankind. Now, astronomers with their telescopes and other instruments have helped to sate that thirst for knowledge.

For thousnads of years, the scientific community virtually ignored the stars. They were more concerned with the planets, partially because of their brightness and partially because of their rapid motions. The stars appeared to be fixed in place, and, as such, provided a handy frame of reference against which to measure the motions of the planets. They were to remain forever inscrutable.

At this point, it might be proper for me to explain the difference between a star and a planet, for there may be confusion in the mind of the reader, especially the lay reader. Generally, stars are like the Sun. They are very large, very very hot, and extremely bright. They give off light of their own, as well as other forms of energy, by means of conversion of Hydrogen into

Helium and other elements.

Planets are bodies like the Earth. They are cold, measuring temperatures by hundreds of degrees rather than by thousands and millions of degrees as do the stars. They are very tiny, being almost dust-grains as compared to the stars. Planets emit no light of their own and must, therefore, be illuminated by light from other sources.

When you look at the sky, one of the first things that you notice is that some stars are brighter than others. Astronomers refer to the brightness of a star as its magnitude. The system, arising from ancient times, divided the stars visible to the unaided eye into five categories. The brightest stars were of 1st magnitude, the next brightest were of 2nd magnitude, and so on. It so happens that the brightest stars are about 100 times brighter than the faintest, so that each magnitude is about two and a half times brighter than the next faintest magnitude. The reader will note that the fainter stars have the higher magnitude numbers. Of course, with modern instrumentation, it has been possible to measure the magnitude of stars very accurately. For instance, Dubhe, the star at the pouring spout of the Big Dipper, has a magnitude of 1.81 and thus qualifies as a 2nd magnitude star. One anomaly of this system is that certain stars, after examination with photometers and other sophisticated equipment, have been placed in the minus category! Canopus, Sirius and Arcturus all have magnitudes brighter than 0. On the scale of magnitudes the Sun rates as -26.7 and the Moon as -12.7.

With the invention of the telescope and the subsequent discovery of stars invisible prior to that time, the scale of magnitudes had to be extended, keeping to the $2\frac{1}{2}$ ratio. Then, too, photography has extended man's vision to still fainter stars, although photographic magnitudes differ somewhat from visual magnitudes, as the eye and photographic plate are sensitive to different shades of light. However, the faintest objects visible to man, visible naturally with the largest telescope in the world, are of 22nd magnitude.

Above, Dubhe, Sirius, Canopus and Arcturus were mentioned. As with many other things, the naming of stars dates from antiquity. Many stars were named by the Arabs. Consequently there are stars named Alkaid, Menkar and Diphda. However, to name all of the stars with proper names would be impossible. Some other system was a necessity, especially after the invention of the telescope. In 1603, Johannes Bayer, a Bavarian lawyer, and astronomer published a catalogue and atlas of the heavens, called Uranometria. In it, he used Greek letters to denote the order of brightness. The brightest star in each constellation was to be known as "Alpha", the next brightest "beta", and so on. Thus, the brightest star in the constellation of Orion is Alpha Orionis, while the brightest in Bootes is Alpha Bootis. This system was satisfactory for many years, and is still used to name the brighter stars. Its drawback is that there are only 24 letters in the Greek alphabet. If more than 24 stars were extant in a constellation, some other system of naming would have to be used. (At this point, I should mention that some anomalies occurred in Bayer's system, since certain of the stars were assigned letters according to position in the imagined configuration of the mythological character of the constellation instead of by brightness.)

An alternate method was to asign the stars numbers. This was done by the noted English astronomer, John Flamsteed, in 1725. The stars were numbered more or less in order from West to East. Thus, we have star names such as 61 Cygni, 14 Tauri and 4 Hydrae. As star atlasses proceeded to fainter and fainter magnitude, more stars with names like BD + 5^{o}1688, or Ross 154. BD means Bonner Durchmusterung, a catalogue complied between 1859 and 1862 by Father Argelander, a German cleric from Bonn. The number is a catalogue number.

One rather amusing result of all this is that, sometimes, a star will have more than one name. For example, the bright star known as Altair can also be quite properly called Alpha Aquilae or 53 Aquilae!

A problem which intrigued astronomers for many years was how to find the distance to the stars. The solution seemed quite simple.....get a long base-line and use trigonometric principles much as surveyors do when calculating the distance across a river or to a distant mountain peak. Astronomers in widely seperated observatories tried to use this method, but failed. There should have been an apparent shift in direction of the nearby stars compared to the more distant background stars. The reader may approximate this by holding up a finger or a pencil at arm's length and alternately viewing with the left and right eyes. The finger or pencil will apparently shift directions against the background of the room.

Because of the first failures, astronomers realized that they needed a longer base-line. Observatories on opposite sides of the Earth were employed thus using the full diameter of the Earth, almost 8,000 miles. Still there was failure. It was then suggested that one observatory could do the job by measuring the position of the star at six-month intervals. In this time period the observatory itself would have been transported half-way around the Earth's orbit, and would be some 186 million miles from its original position. Surely, that would be sufficient in order to provide a shift in direction. Again, failure was the order of the day. It was soon realized that the instruments being used were not adequate for the job. They just could not measure such a tiny shift. As the years passed better instruments came into being, and at last, in 1838, Friedrich Bessel, using the $6\frac{1}{4}$" telescope at the Konigsberg Observatory, discovered a shift in the direction of 61 Cygni and calculated its distance.

This method was suitable for measuring the distances to nearby stars, but many many stars, the majority, are just too distant to be measured. Beyond 150 light years (A light year is the distance travelled by a beam of light in one year at 186,000 miles per second. It is approximately 6 trillion miles.) the method is unreliable and beyond 600 light years, it is totally unworkable.

Before proceeding on to the other method of determining stellar distances, the reader is requested to think about light bulbs! First of all, light bulbs come in different wattages don't they? A sixty watt bulb is brighter than a forty watt bulb and a forty is brighter than a twenty watt bulb. That is common knowledge. It is also common sense that the closer a bulb is the brighter it will seem. There is a definite mathematical ratio between the distance and the brightness....a bulb twenty feet away will seem four times as faint as a bulb ten feet away. So, by a little mathematics, one could calculate the distance if one knew whether he was looking at a sixty, forty or twenty-five watt bulb. The same is true of stars. If one could know the real luminosity, or wattage, to continue our light bulb analogy, the one could calculate the distance. Conversely if one knew the distance, then the luminosity could be determined. The problem lay in the fact that neither was known accurately for distant stars.

A breakthrough was made in 1912 by Miss Henrietta Leavitt, of the Harvard College Observatory at Cambridge, Mass.. She was studying certain variable stars, known as Cepheids. Variable stars are stars which change brightness over a period of time, growing alternately bright and then faint. Some are regular, some are irregular and some are semi-regular. You could set your watch by them! At any rate, Miss Leavitt was studying Cepheids in the Magellanic Clouds, two nearby galaxies whose distance could be calculated by trigonometric means. For all intents and purposes, any Cepheids in the Clouds were at virtually the same distance from the Earth. Miss Leavitt noted that the longer-period Cepheids were the brightest.

Here, then, was the correlation between distance and luminosity. All the astronomers had to do was note the period of a Cepheid, read the corresponding luminosity, and with a few minutes of calculations with a pencil, calculate the distance.

The importance of this breakthrough is self-evident. At last, astronomers had a real yard-stick with which to measure the Universe. The mileage to star-clusters and distant galaxies containing Cepheids could be determined. Since there is a relationship between distance and apparent size, the true size of these objects became known. Since all of the other stars in the cluster or galaxy were at roughly the same distance as the Cepheid, their luminosities became known. From the luminosity, astronomers could calculate the approximate mass and size of the stars. The "Period-Luminosity Law" is truly one of the fundamental building blocks of modern astronomy.

How are stars formed? Theories abound, but the one currently in vogue has them forming inside those great clouds of Hydrogen gas called nebulae. Imagine, if you will, a huge number of Hydrogen atoms floating in space. Eventually, a collision between two atoms must occur. They adhere together by the force of gravity. Under the laws of gravitation, they have more force to attract other atoms, the force of gravitation being directly proportional to the mass. The probability of their being in another collision is increased. This occurs. Slowly, the size of our cluster of atoms grows, and as it does, increases its power to grow. After billions upon billions of hydrogen atoms have been attracted, we have a very large mass. The atoms in the centre must bear the weight of those further out. In doing so, they are crushed together, so much so that their normal atomic structure is disturbed. The nuclei of the atoms come together and an atomic reaction begins. A star has been born! More and more atomic hydrogen nuclei enter the reaction and the whole process of conversion of hydrogen into helium beins.

Theory? Yes, but observation of the great gas clouds, or nebulae, show very distinct black nodules which look very much like our theoretical forming stars. Further, certain stars in the Great Nebula in Orion, appear to be shining quite differently from most. Proponents of the theory state that these are newly-formed stars which have not yet settled down in the hydrogen-to-helium process.

The life that a star leads after its birth depends a great deal on its mass, and that is dependent on the amount of hydrogen present in the original nebulae. Of course, the star has gravitational forces and continue to do so until all of the hydrogen in its vicinity is exhausted. It must then depend on its collection of atomic fuel.

Let's take the example of a star which is quite massive. Since it has a great amount of hydrogen present, the reaction begins and continues very quickly and violently. The star uses up its supply very quickly, during which time it is a blue-white hot star. Eventually, the star arrives at the point where its hydrogen fuel is very nearly depleted. The fires are banked! Now, while the star has been consuming itself, its mass has grown smaller, since when hydrogen is converted to helium, a loss of mass is involved. The mass is converted into the light, heat and other radiations emitted by the star. Einstein calculated the amount of energy that would be released, in his famous formula $E=mc^2$, where E is energy, m is the mass being destroyed, and c is the speed of light. At any rate, to get to our main theme again, as the mass becomes less, the gravitational pull of the centre on the surface of the star becomes less and less. Hence, the star expands. As it does so, the nuclear reaction shuts down even further and the star cools off, becoming larger and redder. Eventually it becomes a red giant, many many times larger than it was at first.

There are many red giants in the sky. Their size is unimaginable. If Arcturus, a red giant in the constellation of Bootes, or Antares from the constellation of Scorpio, were placed in the location of the Sun in the centre of the solar system, we on Earth would find ourselves in the interior of the star!

After a short period as a red giant, the nuclear fires reach virtual extinction. The light and heat within can no longer sustain the weight of the atoms above and the star collapses in on itself. It becomes very small, very hot, and in a state of gravitational collapse. Only heavier elements are present, carrying on a meager atomic reaction. The star is now a "white dwarf". Slowly, the heavier elements are fused into still heavier elements until no more reactions take place. The star is dead! It is just a burned out cinder.

Less massive stars than in our example follow similar life, though it takes much longer, since the rate of fuel consumption is lower. However, all will end up as derelict cinders.

There are a few exceptions in the evolutionary paths of the stars. When certain stars reach the red giant stage and commence their contraction stage into white dwarfs, an interesting phenomenon occurs if the mass is right. As the star collapses inward, the density of hydrogen increases. The fires are stoked up again. Increased light and heat from below force the surface upward. This, of course causes a decline in the amount of hydrogen available, so that the reaction dies down again, with another inward collapse. This gives another impetus to the reaction. The whole cycle continues, at a slowly diminishing rate, until hydrogen depletion occurs. During this stage, the star is known as a "variable star". Many many variable stars inhabit the firmament, and their study is carried on by hundreds of amateur astronomers the world over. Ninety per cent variables are red, which lends great credence to the above.

Another fascinating example of what can happen to a star is the "super-nova". During gravitational collapse, there is so much violence that, at the critical mass, the whole entity explodes, hurling itself outward into space and nothingness! For awhile, the light is intense, but as the matter expands, the light fades to oblivion. A super-nova was recorded by Chinese astronomers in 1054 A.D.. It was so bright that it was visible, even in the daytime. Its remnants are still visible, a tangle of filaments of glowing hydrogen in the constellation of Taurus. It is called "Crab Nebula" since, with a little imagination, the filaments resemble the legs of a crab.

Astronomers can go so far as to weigh stars! The method is amazingly simple. It was first discovered by Johannes Kepler in 1618. Kepler formulated three laws which he called "Harmonics Mundi". The third of these laws relates orbital paths and periods of revolution to masses. Simply stated, it declares that "the sum of the masses is equal to the cube of the distance between them divided by the square of the period of revolution". Thus, all an astronomer has to do is observe the stars in order to get the necessary data and do a little bit of mathematical computation. It should be noted here that this works only with double stars, stars with two components mutually revolving. Fortunately, most stars are double. The problem of finding the mass of a single star is a bit more complex.

How are stars arranged in space? Astronomers wondered this for centuries and had no inkling of the truth. Ancient scientists believed that the stars adhered to a great dome. Others thought that they were holes in the dome, where the glory of Heaven beyond shone through. With the advent of the telescope, it was realized that stars were actual physical objects at varying distances, although the distance was unknown. When Bessel at last successfully measured the distance to 61 Cygni, one breakthrough was made. Another was made when, with larger and larger telescopes, astronomers realized that galaxies were star systems far beyond the local stars.

Galaxies have a shape somewhat as two fried eggs glued together so that both sides are "sunny-side up". They are somewhat reminiscent of those fireworks which spin round and round. We called them pinwheels, and, in England, they are called Catherine wheels. There are millions of these systems, all composed of stars. We are in one such system, called the Milky Way.

The Milky Way was named long ago in the dimmest of antiquity. Indeed, it does remind one of a smear of milk spread along the sky. Its nature remained inscrutable until Galileo turned his telescope upon it and discovered that it was composed of thousands and thousands of stars. To us it does not look like two fried eggs, or like a pinwheel. This is because we are within the system, about 2/3 of the way out from the centre. Imagine being inside a dinner plate, riding on one of the molecules of clay which compose the plate. If you look toward the top or bottom of the plate, you will see past a few other clay molecules and then into the room beyond. If, on the other hand, you look towards the edges of the plate, there will be hundreds of clay particles in the way, obscuring your view. This is the situation with the Milky Way. If we look along the plane of the galaxy, we see myriads of stars, but if we look at right angles to the plane of the galaxy, we see but a few stars and beyond into intergalactic space.

The Milky Way is thought to resemble a pinwheel with its arms loosely wound. Others have the spiral arms very tightly wound, while still others have no arms at all. Galaxies come in all sizes too, ranging from systems with only a few million stars to systems with multiple billions!

It has taken mankind many centuries to learn of his size and relationship to the stars. Yet, the thousands of years involved are but a few seconds on the vast time-scale of the Universe. The age of the Sun is reckoned to be about 4 billion years, and how long the Universe existed before then is a problem upon which the cosmologists are still working. As the life of one man is infinitesimal as measured against the age of a star, so the life of one star is negligible as measured against the life of the Universe as a whole.

In the few cosmic seconds that mankind has inhabited his dust-speck Earth, he has come to know and understand much of the power and beauty of the cosmos. He will continue to study it to find the answers, for the answers of the vital questions of what man is and where he is going lie beyond amongst the stars.

8. Radio Astronomy

(Italics)

Radio Astronomy is a relatively new science, dating only from the 1930's. Not many persons are aware of what it is, and how it is just as important as optical astronomy. With this in mind, I invited Richard McCallum and Anthony Freeth, two members of the RASC, to the studio, to explain some of the mysteries of radio astronomy and how they built a radio telescope. The programme was telecast on July 6, 1971.

(Regular type)

For thousands of years, men have seen the light from the myriads of stars shining down. He has stood in awe of the majesty and beauty of the Universe as revealed, first to his eyes and then to his telescopes. What mankind did not realize, however, was the fact that the stars emit many other kinds of radiation aside from light.

That stars emit light and heat is quite obvious, for such is the case with the Sun, and that is an average star. The stars, including the Sun, also emit gamma rays, beta particles, electrified particles, and radio waves, to mention a few. Fortunately, the Earth's atmosphere shields us from those radiations which are deadly and harmful to mankind. It admits only light, heat, and radio in any great quantities. Since radio is only a relatively recent invention, man would have been cognizant only of light and heat.

Shortly after the existance of radio waves was established by Hertz, a scientist, Oliver Lodge, began to think that the Sun could be a propagator of radio radiation and consequently set up equipment to detect such waves. This was in 1894. He failed, as his equipment was not sufficiently sensitive.

Little else was done in the field until one of those happy accidents of science that are totally unexpected occurred in 1931. A young radio engineering physicist, Karl Jansky, was employed by the Bell Telephone Laboratories to investigate the interference in radio and telephone circuits caused by thunderstorms.

His equipment was somewhat reminiscent of modern radio telescopes. It involved a highly sensitive aerial which could be turned to face any direction on the horizon, the idea being to scan the horizon for distant thunderstorms and to examine the atmospherics caused by them. Naturally, the antenna was most sensitive in the direction in which it was facing.

Jansky's aerial was supported by a wooden frame which sat upon 4 wheels, which in turn sat on a brick circle some 50 feet in diameter. The whole affair turned around a central pivot so that it could face any horizontal direction. It could not look up, and that is where it differs from modern radio telescopes. Motive power was provided by a motor and chain drive. The whole antenna revolved every twenty minutes, scanning the entire horizon in that length of time.

Due to local interference, Jansky tuned the aerial to 14.6 meters, which is longer than most wavelengths used in radio astronomy today.

Signals picked up by the aerial were relayed by cable to his recording house, some 260 feet away, Here, records were kept of the strength of the signals detected by the aerial.

In January 1932, Jansky discovered an unexpected noise in his headset, a noise which differed from the noises of the thunderstorms that he had been studying. It was a low hiss. At first he nearly disregarded it, but being a true scientist, never overlooking any details, began its study. He noticed that it appeared to rotate around the Earth in nearly 24 hours, and thought at first that it might have been some effect of the Sun. Further investigations showed that the period of rotation was 23 hours and 56 minutes, which led Jansky to find that the centre of our own galaxy, the Milky Way, was the source of these radiations, and not the Sun at all. This was an amazing discovery, and, at the age of twenty-six, Jansky had become the father of a whole new science.

Jansky's work, however, was not stricly in line with the practical needs of the Bell Telephone Co., and he had to put his investigations aside for more pressing needs, amongst them radio direction finders for the U.S. Navy during the Second World War. Jansky died quite suddenly in 1950 at the age of 44.

Fortunately for science, someone came along to take up the torch, since the flame of knowledge can never be extinguished, merely dimmed for awhile. That someone was Grote Reber. Mr. Reber was an electrical engineer and amateur astronomer. He first became interested in radio waves from outside the Earth's atmosphere in 1937.

Reber did what most amateur astronomers do, set up his equipment in the back-yard of his home. Where most amateurs have a telescope some four or six inches in diameter, Reber's equipment was not a small optical telescope, but was, in effect, the first true radio telescope. One can imagine the amazement of his neighbours as the telescope began to take shape. It consisted of a large dish made of sheet metal, some 31 or 32 feet across, surmounted by two twenty-foot steel girders supporting a drum containing the radio antennae. The whole affair faced in a North-South direction and could be tilted up and down to different elevations. As a radio source rose in the east and made its journey to the western horizon, it would at some point cross the line of sight of Reber's instrument.

Reber's work with this instrument was brilliant. He traced the direction and intensity of many radio sources in the sky. He also realized that the sensitivity of his instrument was limited and that larger telescopes would, no doubt, find and measure additional sources. He was right.

I have been fortunate enough to meet and chat with Grote Reber many times. He is friendly and witty, and is able to defend his scientific views against all challengers with great charm coupled with tremendous knowledge of the subject. I am happy to say, that at the time of this writing, he is in good health, and is still probing the mysteries of the Universe, with the 360 foot telescope of Ohio State University.

After the war, Reber's work was followed up by others, with more and more radio sources being investigated. Larger and larger telescopes were built, until, today, radio astronomy is a science in its own right.

(Figure 9)

How do radio telescopes work? The principle is not unlike that of an optical reflecting telescope. (See fig. 9) Radio waves from whatever source strike the parabolic dish, which may be made of sheet metal, as was Reber's, chicken wire, mesh, or mosqito-screening. The choice of materials actually depends on the type and wavelength of the source to be investigated. The dish reflects them back to a "focus", at which point the aerial is located. The signal is then fed into several amplifiers, where it is "magnified", to use optical terminology, and recorded on a pen-recorder, looking like a series of spikes, peaks and squiggles on a piece of graph-paper. When the experts study these graphs, they can make conclusions as to what type of source made the radio noise. I am merely an amateur optical astronomer, and would not venture an explanation as to how they do it!

What do radio astronomers look at, or rather, what do they listen to? First, the Sun! Oliver Lodge was right. With modern equipment we have learned that the Sun is very noisy indeed, in practically all radio wave-lengths. This is quite important to us here on the Earth, since the Sun has been known to jam radio recievers and other sensitive electronic equipment.

While the radio emissions from most individual stars are too weak to detect, the emissions from the great clouds of gas, called nebulae, are not! These great swirling masses of hydrogen give off radio radiation at a fantastic rate, and thus are of great interest to radio astronomers. They have even gone so far as to detect radio waves from other galaxies, millions of light years away, and from visible clouds of gas lying between galaxies.

One of the most exciting discoveries made in recent years was that of Pulsars. The discovery was made at the Mullard Radio Astronomy Observatory in Cambridge, England in 1967. The equipment there was especially designed for the detection of very small radio sources. What was found, very early in the systematic observations was a pulsing signal. The signals lasted about 1/3 second each, with the interval between signals being about 1 1/3 seconds. What an astounding discovery! At first the investigators were reticent to release their findings, for the regularity of these signals was such that it appeared that they could be made only by some intelligent creatures!

Our friends, the science-fiction writers, would have a field-day with such a discovery. At last, man was being contacted by alien beings. Plans would have to be made to send a reply. Spaceships carrying little green men would soon arrive at the Earth, and trade agreements would be set up, as well as cultural exchanges and scientific trades. The reader can see what would have occurred had the discovery been announced prematurely. Thus, the Cambridge investigators kept their secret for a time, until some reasonable explanation could be found.

Let me say that the possibility of little green men up there signaling us was considered! It was not, at that time, beyond the realm of possibility!

The scientists concluded, however, that the pulsations were from some superdense object. It has been refined further into stating that the object must be a "neutron star", a star composed only of neutrons, sub-atomic particles without electric charges.

These neutron stars would be so dense that a mere handful of the material from them would weigh as much as the entire Earth!

On January 15, 1969, an optical source in the Crab Nebula, remnants of a supernova explosion in 1054, was flashing with exactly the same period as a radio source in the same direction. Thus, the first visible pulsar was discovered. This is of great importance, since, obviously, the supernova must have some connection with the pulsar, and may be directly responsible for its formation.

Closer to home, the Moon, Venus, Jupiter and Saturn have proved to be radio sources. The wavelengths of these emissions are very short, so radio astronomers believe that the emissions are heat induced, especially in the cases of the Moon, Venus and Saturn, Jupiter, on the other hand, has some very interesting effects. The radio radiation seems to be coming from specific sources on the planet. Other radiation seems to be bound up somehow with the position of Jupider's satellite, Io. Now, before you go jumping to the conclusion that there may be Jovians, and indeed there may be, let me say that most of the radiation is similar to that produced by thunderstorms. Probably this is the case on Jupiter, as any observer will tell you that the atmosphere of Jupiter is filled with great currents, whirling and swirling, much as thunderstorms do here on Earth.

Other than the purely scientific pursuits outlined above, radio astronomy has several practical aspects. Giant dishes tuned to the right frequencies are used in manned spaceflight for communication with the space-ships. Others monitor unmanned craft, such as weather and communications satellites.

By placing a transmitter instead of an aerial at the focus of the giant dish, scientists have developed an entirely new science, radar astronomy. By sending out pulses and waiting for their return, radar astronomers have measured very accurately the distance to the Moon and Venus. Some have even produced a map of the surface of Venus, by interpreting the type of echo they received from the pulses.

This method is also used to track meteors through the sky, since they, too, reflect radio waves. A continuous beam is sent up, and when a meteor falls through the beam, part of the beam is reflected back causing a signal to be received. Scientists have been able to deduce the height, size and direction of flight of the meteors in this manner.

To the layman, it might seem that radio astronomy is of little practical value. However, this is simply not true. Look out of the window. Is it raining? Is it sunny? The weather for your area has been predicted very accurately by means of specially adapted radio telescopes receiving telemetry from satellites far above your head. These satellites take pictures of weather formations and relay them to the Earth so that the forecasters can see the weather that is approaching, and tell you whether to plan that picinic or not!

Much of the same methodology is used when you make a trans-Atlantic phone call, or watch a television programme from Japan!

Pure research in radio astronomy has given us, among other things, more accurate maps of the world, for when radio telescopes work in unison, their positions have to be known very accurately.

Radio telescopes have also created a demand for better electronic equipment. The advances made in developing this highly technical and specialized equipment soon find their way into radio, television and other electronic equipment found in the average home.

Aside from the practical applications, radio astronomy has given man a clearer picture of the nature of the Universe, a more complete knowledge of what lies beyond. If man is ever to leave the Earth, and even the Solar System, and journey forth to explore the great firmament beyond, he must be furnished with complete knowledge of what to expect, for man is but a fragile creature. This knowledge is being provided daily by optical and radio astronomers alike. Practical applications are not aways readily apparent but today's new discovery can often lead to concrete results in an astoundingly short time.

9. The Motions of the Earth

As we look toward the stars, they seem to be unchanging, night after night. Year after year the amount of change in the sky due to the motions of the stars seems very little. But, indeed, they are moving. Every celestial object is moving, including the Earth. Yes, this celestial platform, our space-ship, the Earth is moving. It is not only moving through space but also has a variety of other motions, some prominent, and some subtle, some having an effect on our daily lives, and some having hardly any effect at all.

To the ancients, it would have seemed incredible that the Earth was in motion, although Aristarchus, years ago in Egypt, reasoned it out. The Earth, through most history, was thought to be the centre of the Universe, about which everything else revolved. This was obvious, since the stars and the Sun rose in the east and set in the west daily. what other conclusion was possible?

Yet, these same people who were so dogmatic in their belief in a geo-centric Universe, never gave thought to one perplexing problem. If the Sun and stars set in the west and passed under the Earth, what held the Earth up?

The idea of the Earth in motion was revived by a Polish monk, whose name was latinized to Copernicus. He was born in 1473, and lived until 1543. He wrote a book called "De Revolutionibus Orbium Coelestium" in which he stated that the Sun, not the Earth, was the centre, and that the Earth and other planets revolved around the Sun. This book was not published until Copernicus died, since all in those times lived in fear of religious persecution, especially if one held the "heretical" view that the Earth was not the centre of the Universe.

Gradually, the Copernican system became accepted, and, today, nearly every schoolboy accepts without much thought, the fact that the Earth does revolve around the Sun, and is indeed, in motion.

The Earth is travelling around the Sun at 66,000 miles per hour, more or less. It is not possible to give a precise figure since the speed of the Earth varies with the time of year. This will be explained later, but let us say for now that one can see this for himself if he has a sundial. The sun-time and the clock-time seem to differ constantly, and this is a direct result of the varying speed of the Earth.

The shape of the Earth's path around the sun, or, its "orbit" is not round. Copernicus has suposed that the Earth revolved around the Sun in a circle, but later on, Kepler proved that the orbits of planets were ellipses. We refer you now to figure 10.

(Figure 10)

An ellipse may be described as the path of a point the sum of whose distances from two fixed points is a constant. In other words, from point M, the total distance to the points F and F' is the same as the total distance from point N to F and F'. These two fixed points are the foci of the ellipse. T e line from A to B, passing though F and F' is called the major axis of the ellipse.

Now let us relate this ellipse to the orbital path of the Earth. The Sun is at one of the foci. Let us say, for argument's sake that it is F, although in reality, both foci are inside the Sun. (A little experimentation will show you that if you bring the foci closer together, the ellipse becomes more nearly a circle, The Earth's orbit is nearly circular.) At point A, the Earth will be closest to the Sun. This point is known as peri-helion, from the two words meaning "near" and "Sun". This distance is 91,400,000 miles and occurs on January 2. Point B is aphelion, a distance is 91,500,000 miles and occurs on July 2.

I can hear you asking, "If we are closer to the Sun in January, why aren't we warmer than in July?" The answer will come later in this chapter.

You can actually see an effect caused by the revolution of the Earth. Imagine yourself on a merry-go-round or carousel. If, as you turn around the centre, you keep your eyes on that centre, the people and objects in the background will seem to move by in the opposite direction.

Relate this to the actual celestial sphere. As we go around the Sun, the objects in the background seem to go in the other direction. If you think of the stars being immovable, then it seems that the Sun moves across the background of the stars. The Sun's apparent motion amongst the stars is eastward, and it has a very interesting effect on the sky that we see.

Suppose for a moment that you could see the stars in the daytime. On the Eastern horizon, you note that a star is rising this morning at exactly the same time as the Sun. Now, during the day and the ensuing night the Sun moves eastward with relation to that star. This means that the star is now west of the Sun and thus will rise slightly before the Sun does. This, in reality, actually happens, since the same stars seem to rise 4 minutes earlier every night.

You will recall that we said that the shape of the Earth's orbit is elliptical, or egg-shaped. It is interesting to note that the amount of "egg-shapedness" of the Earth's orbit is changing slowly. At times, it is circular and ta others, it is pronouncadly elliptical. At the present time, it is becoming more circular and in some 24,000 years there will be no perihelion and no aphelion. This will have an effect on the seasons, and this, too, will be explained later in the chapter.

Now refer back to figure 9. The line AB, or major axis, can be known as the line of apsides. This lineis slowly revolving around the ellepse and as a consequence, the dates of perihelion and aphelion change with it. Some 6,000 years ago, perihelion occurred. On Sept. 23, while in 1250 A.D., perihelion took place on Dec. 21, the first day of winter. Now, as we said, perihelion is on Jan. 2 and in 6400. A.D. in will be on Mar. 21.

There are other changes in the earth's oribit, too. These are known as 'Perturbations'. Remember t at the Earth is not the only planet in orbit around the Sun. There are 8 other major pl nets and several thousand minor ones. All have mass, and thus, gravity. Each of the planets exerts a gravitational pull on the Earth, the amount of pull depending on the mass of t e planet and its distance. These gravitational forces influence the shape of the Earth's orbit ever so s ightly. However, perturbations are one of the minor motion category and need not be explored at depth here.

When we speak of the Earth's orbit as being the path of the Earth in its yearly journey around the sun, we are not quite correct. The orbit is really the path of the centre of gravity of the Earth-Moon system around the Sun. This concept is quite easily grasped.

It must be remembered t at the Moon revolves around the Earth, in nearly the same manner asthe Earth revolves around the Sun. The Earth is at one of the foci of the Moon's orbit, though, again, both foci are inside the surface of the Earth. Imagine, if you will, a balance, or a child's teeter-totter, a long board supported from below by some narrow object so that the board is free to tip. It is ovvious, I think, that if the objects set on the ends of the board are of identical weight, the point of support, or fulcrum will be in the centre and the objects will balance. If one object is heavier than the other, then the fulcrum has to be displaced toward the heavy object in order to make them balance.

This is true of the Earth-Moon system. Both revolves around a common balance point which, because the Earth is 81 times as heavy as the Moon, is inside the Earth about 3,000 miles up from the centre in a moonward direction. It is this centre of gravity which revolves around the Sun in an ellepse, while the Earth and Moon revolve around the centre of gravity. The net result of this motion can be seen in figure 11.

(Figure 11)

Up to this point, we have been discussing the motion of the Earth around the Sun, but there is also another motion which is probably even more obvious, and that is the Earth's daily rotation of the Earth determines the periods of day and night, since we are alternately turned toward the Sun and then away from it. This cycle of light and dark is important in that it regulates most of Man's activities, and recent biological studies have shown that man has a great deal of difficulty eating and sleeping and keeping in top mental condition if this cycle is interrupted, as for example, in submarines, mines and space-ships.

Everyone knows that there are 24 hours in a day, as this is the period of rotation relative to the Sun. That is, it is 24 hours from sunrise to sunrise. We must remember that the day is only 23 hours and 56 minutes long when we look at the stars, since the sun seems to move eastward amongst the stars some 4 minutes per day. The day from sunrise to sunrise is known as the Solar Day, while the day as measured by the stars is the Sidereal Day, and is 4 minutes shorter than the Solar Day. Astronomers, who look at the stars, use Sidereal Time, since their telescopes must follow the stars across the sky. Usually they have some method of speeding up or slowing down the driving apparatus of the telescope if they wish to observe the Sun or any other object, such as a planet or comet, which does not move at a sidereal rate.

The Earth turns $365\frac{1}{4}$ times each year. Our calendar, of course, does not have that quarter day added on after December 31. What we do is save up these days until we have four of them, and since four quarters make a whole, we add that whole day on to the calendar. It is usually added so that the extra day is February 29, and is known as Leap Day, the year being known as Leap Year, which as the ryme says, happens once in four.

Like any rotating object, the Earth has an axis of rotation, or line about which it appears to rotate. In a wheel, we call this the axle, so that the principle is similar. The Earth's axis runs from the North Pole to the South Pole. To the casual observer, this line appears to be fixed in space, that is, it always points in the same direction. At present, the northerly end of the Earth's axis points to the star Polaris, which, accordingly, is called the "Pole Star" or "North Star".

If we construct a diagram showing the Earth, Sun and Polaris, we will find that the Earth-Sun line and the Earth-Polaris line intersect at an angle of almost 61°. See figure 12.

(Figure 12)

It is this tilt of the Earth's axis which is directly responsible for the Earth's seasons. When the Earth's north pole is on the sunward side, as at A, it is summer in the northern hemisphere and winter in the southern hemisphere. When the South Pole is on the sunward side, as at B, the opposite seasons prevail. When the Earth is located at C or D, neither hemisphere is favoured and the seasons are spring and autumn accordingly. Notice, that the direction of the Earth's axis has not changed but remains pointed in the same direction, towards Polaris.

Now let us turn our attention back to some statements made earlier about the shape of the Earth's orbit. You will recall that we said that the Earth was closer to the Sun in January, at perihelion, than it was in July, at aphelion. In January, the northern hemisphere is having winter, while the southern hemisphere is in the midst of summer. Consequently, the northern winters are reasonably mild when compared with southern winters which occur in July when the Earth is farther from the Sun. By the same token, southern hemisphere summers are a great deal warmer than our northern summers.

As the Earth's orbit becomes more circular, with no perihelion or aphelion, the seasons will become more even, until, on achieving circularity, northern seasons will be identical with southern seasons, except, of course, that they will be 6 months apart.

We also said earlier that the axis of the Earth, that line joining north and south poles, always points to the same position in space. But, you should also note that we said that this was true merely for the casual observer. Astronomers have discovered that the axis is moving. If you could imagine the sky as being a solid object, and the axis of the Earth as being a long rod with a pen on the end, the pen would trace out a very large circle on the sky. In effect, the earth is "wobbling" along, much as a top does as it slows down, and for the very same reason. This effect is known as 'precession'.

The length of time required for the axis of the earth to complete one whole circle is 25,800 years. Obviously, this means that the Earth will have different "Pole Stars" as the ages pass. If we look back into the ancient records we find that, in Egyptian times, the star Thuban was the Pole Star, and if we compute ahead, we will find that some 14,000 years from now, the star Vega, a bright blue star will be near the pole of the Earth's axial rotation.

The Third Astronomer Royal, James Bradley, was involved in the measurement of the positions of stars. Through his very careful calculations he determined that precession was not happening as it should. The motion of the pole was not uniform. He analyzed the difficulty and in 1748, announced that, superimposed on the precessional motion, was a further cyclical motion having a period of about 18 years. He deduced that this was somehow connected with the Moon's gravitational attraction for the Earth. This motion is known as "nutation". Later, it was discovered that other bodies played a part in nutation, but it is safe to say that the main cause is the gravitational attraction of the moon.

(Figure 13)

This array of varying motions, rotations and revolutions can be quite dizzying. If you consider that you are moving at 66,000 miles per hour around the Sun, and at a speed approaching 1,000 miles an hour, depending on latitude, because of the Earth's rotation, and if you consider that there are precessions, nutations, variations, and centres of gravity, you might be tempted to say, Why can't I feel it?" The answer is, of course, that the motions are all quite uniform, that is, there are not any rapid accelerations, declerations or bumps, such as you would feel if you were out for a ride in your automobile.

Despite this, there is still one more motion which we must add to the collection. The Sun is moving. The Sun, its retinue of planets, satellites and comets, all, are being carried along in the galactic rotation at about 12 miles per second, roughly in the direction of the previously mentioned star, Vega. This means that the Earth is spiralling along as in figure 14.

We have seen how some of these motions affect daily life on the Earth. Our clocks and calendars record celectial cycles. The passing of the seasons is caused by the tilt of the earth's axis 23 degrees from the plane of its revolution..Nevertheless, these motions do create some problem. Clocks, strictly speaking, are not accurate. Astronomers have to keep revising their coordinate systems. But, for the man on the street, the Earth is a stable platform in space, providing him with a home. So long as the sun continues to rise every 24 hours, and the summer holidays come once per year, man will not consciously think about all of the variations of his own motion and that of his home planet. The effect of all these motions on one individual man is very little, but on mankind, throughout the centuries, the effect must add up.

(Figure 14)

10. Mars

Mars! God of War! .....Mars! Harbinger of disaster!.....Mars! The planet which turns mans minds to hatred! So, this was reputed to be!

Long ago, men noted the fiery colour of the Sun's 4th planet, and attributed all sorts of terrible things, wars, famines, earthquakes, and pestilences to the appearance of Mars. Let us have a closer look at this planet, to determine if all of these things are true.

Mars, as we said, is the 4th planet in order from the sun and, thus, is the first with an orbit outside that of the earth. This orbit, like that of the Earth, is elliptical. In fact, it is more pronouncedly elliptical than that of the Earth. Mars has a perihelion distance of 128 million miles and an aphelion distance of approximately 155 million miles, so that generally speaking, Mars is 1½ times as far from the Sun as the Earth. At this distance from the Sun, Mars' year is naturally longer than that of the Earth, and is 1 year 10 months long.

Mars is smaller than the Earth, too, having an equatorial diameter of 4,218 miles, which is about half the diameter of the Earth, and about twice the diameter of the Moon. In fact, as we shall see later on in this chapter, Mars is like the Moon in many ways.

Long ago, of course, men did not know the size of Mars, or its distance. All they could see was its red colour and its motion across the sky. The noticed, though, an irregularity in the motion of Mars, indeed, in the motions of all of the planets. Mars seemed to move eastward among the stars, then slow down and stop, move westward for awhile, stop again, and then resume its eastward course. This mystified the ancients but is now quite simply known as an effect of the Earth catching up to Mars and passing it. Figure 15 explains this quite satisfactorily.

This backwards, or retrogradem motion caused all sorts of difficulties in arriving at a suitable theory of the Universe, especially for those who believed, as most did in ancient times, that the Earth was the centre of the Universe and that all other objects revolved around it.

(Figure 15)

They had to come up with a system of epicycles, that si, small circles on each circular orbit around the Earth. While Mars, or any other planet travelled around in a circle, the centre of the circle travelled around the Earth. Of course, there was no physical basis for this, but the ancients did not realize this at all.

A Danish astronomer, Tycho Brahe, operating from an observatory on the isle of Ven, between Denmark and Sweden, in the 16th century, measured the position of Mars very carefully over a long period of time. His student and cohort, Johannes Kepler, used these careful observations to verify Copernicus theory of the Universe, that the Sun was in the centre of the Solar System and that the planets revolved around it. He went a step further and formulated three laws of planetary motions. The point is that observations of Mars made possible the modern understanding of the system of things.

From a little mathematics it is possible to see that the Earth catches up to Mars ans passes it every two years, more or less, the exact figure being 780 days. Figure 16 will explain this. Suppose that the Earth and Mars are at A' respectively. The planets start moving

(Figure 16)

counter-clockwise along their orbits. After one year, the Earth arrives back at A, but Mars is not longer there. It has moved around to B. By the time the Earth gets around to B, Mars has progressed to C. However, the Earth slowly an inexorably catches up and at D and D' they are again even. You will note that at A and A' and at D and D' th Earth, Mars and the Sun, are all in a straight line. Since Mars is opposite the Sun as seen from the Earth, this configuration is known as "opposition". All planets, except Mercury and Venus come to opposition. Mercury and Venus cannot as their orbits lie inside that of the Earth and therefore they can never be opposite.

These oppositions are very important as they give us our closest views of the red planet. At perihelic oppositions, that is when Mars is at perihelion and at opposition at the same time, it is but a mere 34½ million miles, whereas at aphelic oppositions it can be as distant as 63 million miles. Remember that we are speaking of oppositions, those times when the Earth, Mars and Sun are in a straight line. It can be seen easily from Figure 16 that if Mars were at A' and the Earth at B, the distance would be much much greater as the two planets would be on opposite sides of the Sun. So, it is at oppositions that astronomers get their closest telescopic views of the planet, although much valuable work goes on at other times as well.

Telescopic observationof the planet must have begun with Galileo, but his instrument was of such low power that it is extremely doubtful that he saw much detail on the surface of the planet. However, rudimentary maps of the surface were made in later years, though these really did not give an adequate picture of the surface of Mars.

In 1877, an Italian astronomer, Schiaparelli electrified the astronomical world by announcing that he had discovered "canali" on Mars. What Schiaparelli meant was that he had discovered "channels", which is the proper translation of the word he had used. However, unthinking people jumped at the thought and translated the word "canals". What in our sense of the word, then they must have been dug by intelligent beings!

In America, Percival Lowell jumped on the canal bandwagon, built himself a large observatory in Arizona, and proceeded to study the canals. Lowell claimed that he had observed the canals to double, thus showing that construction by the Martions was still happening. He observed, he said, dark patches on Mars, at the intersections of the canals. These, he reasoned must be the Martian cities. Lowell deduced that the canals were for transporting water, from the seasonal melting of Mars' polar caps, to the cities throughout the globe, since Mars has always been thought to be dry and arid planet.

What Schiaparelli and Lowell and others were observing were faint lines which seemed to criss-cross the surface of the planet. But what else can the telescopic observer see?

When I go to the eye-piece of my telescope, the first thing that strikes me about the planet is the paleness of the red colour. To the unaided eye, Mars appears fiery red, but in the telescope, one sees a pink disc. I am not sure of the reason for this. At any rate, the first view of Mars is liable to be rahter disappointing, since one expects to see all sorts of things. All you see at first is this pink disc with no discernable detail.

There is, however, a secret to the successful observing of Mars. That is the prolonged stare. The longer you look at Mars, the more detail seems to appear on its surface. The first surface features to come into view are the polar caps, followed by the dark band around the centre. After these features are seen for a few minutes, the eye begins to pick up other fine details, in the form of smaller dark markings scattered throughout the pink areas.

These smaller spots may help to explain the phenomenon of the "canals. At this point the reader is invited to inspect the row of dots in figure 17. You will note that we have a row of dots, approximately one eighth inch in diameter and about one quarter inch apart. Now place this book 50 feet away and look at the row of dots.

(Figure 17)

Amazing isn't it? If you have normal vision, the row of dots seems to blend into one long line of dots. This may, as we said, explain the "canals" that Lowell and others espoused. The eye just naturally seems to connect a series of dots into lines. At any rate, later studies have shown Mars to be completely devoid of anything that might be construed as man-made, or even natural, canals. (Although, what looks suspiciously like a river has been discovered! But more of that later.)

Now, let us return to some of the objects that we have mentioned and examine them in somewhat more detail.

The Martian Polar Caps were reported first in 1666 by th Italian -French astronomer, Cassini. His natural reaction was that they are snow caps, as are polar caps were larger than those of the Earth and this was explained, tentatively, that Mars is farther from the Sun. If the distance from the Sun is greater, then the amount of heat recieved must be correspondingly less, so that the polar caps would be larger.

In 1719, another astronomer pointed out that the polar caps were not opposite each other. This is the case on the Earth, too. The North Pole of the Earth is about centrally located under the ice cap on the Artic Ocean, while the centre of the Antartica ice cap is located many hundreds of miles from the South Pole.

Herschel, the Elder, noted that the caps seemed to shrink and grow according to the seasons. Mars has seasons like the Earth, but nearly twice as long. The reason for this will be explained later in this chapter. Herschel suggested that this must be due to the melting of snow and ice in the Martian spring, and the re-freezing, and snowing, in the Martian winter. This view was held for several years, although it was seriously opposed by astronomers who said that the atmosphere on Mars was not thick enough to hold enough water vapour to cause such a snowfall.

Modern instrumentation has only added fuel to the fires of controversy. Rather than settle the doubts, modern techniques of observations have raised more questions than they have answered.

At the turn of the century, it was suggested that the caps were frozen carbon dioxide. Carbon dioxide is a gas, one which, amongst others, is exhaled by humans. If cooled sufficiently, it can form snow or ice-like substances. In the 1940's and 1950's Gerard Kuiper, working with a very large telescope, and very modern equipment showed that this could not be the case, and announced that his findings showed that the caps were indeed composed of some sort of water, and suggested that ordinary frost would be a likely substance.

We must turn again to Percival Lowell, he of the "canals". We must not dismiss him as a crank, or "crack-pot", since he was an astute and ardent observer. Lowell noticed many phenomena which had been overlooked by previous observers. One of these was his "blue band".

What Lowell discovered was a dark band surrounding each polar cap while it was melting. This he reasoned, was caused by the snows melting into water which soaked into the ground around the caps, turning the soil a darker colour. This would not happen with a cap of carbon dioxide since frozen carbon dioxide does not melt but sublimes, that is, it does not turn into liquid under normal circumstances. Rather, it turns from a solid directly into a gas. Hence, Lowell believed in polar caps made of water-ice or snow, and was later vindicated by the work of Kuiper.

The caps melt very quickly in Martian summer, so we can reason that they must be very thin indeed. An area of more than 4 million square miles of cap has been known to disappear during a Martian summer. Although I have seen the South Polar Cap shrink considerably, I have never seen it disappear totally. On the other hand, I have sometimes found the North Polar Cap difficult to observe. This may be partially due to the fact that I have observed Mars more closely during perihelion oppositions, when the South Pole is turned toward the Earth. At aphelic oppositions, the North Pole is pointed earthward but Mars is not observed so much at that time. This points out the need for consistency in observing. Observations of Mars ought to be carried on at all times, and not just at the most favourable times.

The dark markings on Mars were once thought to be seas, just as the dark markings on the Moon were once thought to be bodies of water. Just as we have Mare Tranquillitatus and Mare Serenatatus on the Moon, we have Mare Erythraeum and Mare Iontum on Mars. Mare, in both cases, means "Sea". These markings undergo what appear to be seasonal changes, and were, until lately, thought to be the beds of dried up oceans, since, being lower elevation, they would receive more moisture than other areas. This would allow vegetation, of a sort, to grow. In fact, when scientists analyze the light from the dark areas of Mars, it looks very similar to light which is reflected off various mosses and lichens.

On that basis, a theory has been put forward, which says that the dark areas on Mars are moss and lichen-covered.

One observational effect is certain. The darker areas seem to become even darker during the spring in that hemisphere, and this has been attributed to the growth of new vegetation during that particular season.

Whatever the cause of this darkening, it is pretty safe to say that it is not vegetation waxing luxurious in the spring warmth and moisture. Vegetation, as we know it, produces oxygen, and no large amounts of oxygen have ever been found in the Martion atmosphere.

As we mentioned previously, the light coming from Mars looks a lot like that which is reflected off mosses and lichens. These tiny organisms do not produce oxygen. Rather, they expire carbon dioxide, which has been found in the Martion atmosphere. Further, mosses and lichens are resistant to extremes of temperature and humidity. Therefore, certain theories have used this to suggest that Mars is a moss-covered planet.

The light reddish-pink areas have the appearance of being deserts, and have always been supposed to be just that. Large dust storms and atmospheric disturbances often swirl through the Martian atmosphere, causing the surface to become obscured. Certainly, this suggests deserts.

One astronomer, McLaughlin, postulaties, however, that all of this dust is due to the smoke and the debris from active volcanos. This will remain to be seen.

We turn now to the Martian atmosphere. This tenuos envelope, as we have seen, is sometimes obscured by dust storms. At other times, there are clouds! They are not extensive or very thick clouds, but they are clouds!

In order to understand the Martian atmosphere thoroughly, we must first realize that it is composed of layers, just like the atmosphere of the Earth. On this planet we have the stratosphere, ionosphere, heaviside layer etc... On Mars, there is the violet layer. This is a layer of ice and dust particles high above the surface of Mars, and it shows up well when photographed with film that is sensitive to ultraviolet light. This is quite handy, since a cloud which shows up on an ordinary photp, and is not evident on a ultraviolet picture, must, by necessity, be below the violet layer.

Two kinds of clouds have been seen on Mars, aside from those which are obviously dust-storms. There are blue clouds and white clouds. Some research has been done on these clouds, but the composition of the white clouds is still uncertain. The blue clouds, though, appear over areas on Mars where the Sun has just risen. They are very thin and wispy, and disappear very shortly after they are exposed to the Sun's rays. For this reason, they are often likened to the morning mist which appears in many areas here on the Earth.

Mars has two satellites. The inner is Phobos, being some 5,800 miles from Mars, while the other satellite, Phobos, orbits at a distance of 14,600 miles. They were discovered in 1877 by Asaph Hall at the United States Naval Observatory in Washington DC., using a 26 insh refractor.

There are several interesting ideas to be told in conection with these tiny attendants of the God of War.

Their existance was foretold in Swif's "Guliver's Travels". You will recall that Gulliver landed in a country of very tiny people, Lilliputians. It seems that they were astronomically minded, as they had an observatory,sstaffed by a handful of miniature astronomers. These scientists claimed that Mars had two Moons, and even gave their distances from Mars. They were surprisingly aocurate, especially since "Gulliver's Travels" was written 150 years before Asaph Hall had discovered them!

In the early 1960's another story about Deimos and Phobos was put foreward by a Russian astronomer, Schlovsky. He was especially concerned about the small sizee fo these Moons, as they are only in the order of 5 to 10 miles in diameter. Schlovsky suggested that perhaps artfivial sarellites, put into orbit by the Martians, as a last refuge for their dying race.

Phobos revolves around Mars in 7 hours and 38 minutes, while Deimos revolves in 30 hours and 18 minutes. To the observer on Mars, the length of these revolution periods would provide some very startling effects. Since the rotation period of Mars is just a little over 24 hours, Phobos would catch up and pass the observer, rising in the west and setting in the east. Deimos on the other hand has a period of only 7 hours longer than Mars' rotation period. It would remain above the horizon for nearly three days, and would go into two complete cycles of phases, from Full Moon, round to Full Moon, round to Full Moon.

I have looked for these tiny objects, but they are extremely hard to see. You have to look at the times when they are farthest from the planet and preferably when Mars is at opposition. This means that the satellites are, along with Mars, closer to the Earth. Once I thought that I glimpsed Deimos, but I am not entirely sure that the object sighted was, indeed, this tiny Moon of Mars.

Space probes have updated our information on Mars, but I have deliberatly avoided mentioning what has been discovered, as this will be included in later chapters. What Ihave tried to do is give the reader an idea of conditions on Mars, and to acquaint with the history of telescopic observation of Mars. I have also tried to show what can, and has, been learned through observing Mars. The Mariner probes have given us the first true picture of the surface of Mars and have answered some of the questions raised here. They have also finished off some of the theories mentioned, including the idea that Deimos and Phobos are artificial satellites. Thus in further chapters we shall show what information has been gained by space probes.

Throughout the years, Mars has sparked man's imagination. Science fiction writers have had a jolly good time imagining what the first expedition to Mars would be like. As we stand on the brink of such a journey, it is good to look back and see what the origional explorations of Mars, using telescopes, were like. we have done, in this chapter.

11. Comets

Italics: During the previous two years a number of very bright comets had appeared in the skies, among them Comet Bennett, one of the brightest comets in this century. Since interest in comets was high, Mr.Robert Speck appeared with me on the 13th of September,1971, for a discussion about comets.

Regular type:

Comets have always been the most misunderstood of celestial objects. They have been regarded as evil omens, portending the death of some personality or other. Nowadays, we regard them as just another celestial body, obeying all of the laws of Physics, but, just the same, they are interesting. This is espeically true of those which reach a brilliance which allows them be seen with the unaided eye. Public interest is always high, with regard to comets, since, although there are many comets, those which reach naked-eye visibility are rather rare.

Let us look closely at comets, then, to see, first, what was thought about them in ancient times, and secondly, to see what is known about them at the present time.

I think that, first, we should describe the visual appearance of comets. Comets look like stars with nebulous tails. In fact, the word "comet" comes from a Greek word which means "Hairy Star". Indeed, they do look like hairy stars, for, behind the starlike luminous head, extends a fainter luminous streak, or "tail".

You will remember that in ancient times, the stars were thought to be affixed to the celestial sphere, never moving. Thus, when some star-like object did move, it meant that the gods were up to something. The became to be associated with death and evil tidings. However, you can look at the date of death of almost any great man and point out that something was transpiring in the sky at that time. This is not due to the malice of the gods, but is a natural consequnece of our glorious heavens being a busy place!

Nevertheless, the great fear was there and the fact that some great man passed away to his reward, or punishment (as the case may be), aroused even greater anxiety in the hearts of the public.

However, not only the public was astounded and frightened by the appearance of a comet. Kings and others, who should have known better, were also scared. One French king, when informed that a comet was now visible in the sky, rushed to his balcony, cursed the comet roundly, and fired his pistol at it several times, in an attempt to frighten the comet away! Nevertheless, the comet sailed on serenely, impervious to the threats of Earthly kings!

More fuel was added to the idea that comets forbode bad times by the appearance of Halley's Comet in 1066.(It was not called Halley's Comet at the time.) This bright comet was in the skies when William the Conqueror stormed ashore at Hastings, in the south of England. William, as we all know, defeated Harold, the last of the Saxon kings, and commenced the Norman dynasty in England. Halley's comet was preserved for all time in the famous Bayeux Tapestry, woven by Matilda, the wife of William. This mammoth tapestry depicts the entire invasion of England. High over the heads of the astonished English, we can see, to this day, Halley's comet.

Other fearful times have been raised by cranks who have predicted that a comet would strike the Earth, wiping out all of civilization. Invariably, they learn that some comet or other will intersect the Earth's orbit around the Sun. So, they get a lot of coverage in the popular press, and people generally run amok, fearing the end of the world. What these cranks fail to state, however, is that the Earth will be elsewhere in its orbit at the time of the comet's passage!

While we are on the subject of comets striking the Earth, let's set the record straight. Certainly, a comet striking a populated area would cause vast devastation of property, but the chances of this are extremely rare. Let's add, too, that comets have passed directly in front of the Sun so that they have been illuminated from behind. Nothing could be seen! So, while a comet striking the Earth may cause some damage, it certainly will not be the end of the world!

One person who got a lot of notoriety out of predicting the end of the world was an Englishman by the name of Whiston. It seems that Whiston was both an amateur astronomer and a theologian, and was a contemporary of Isaac Newton. Therefore, he should have known better. He worked mathematically back through time, and found that a certain great comet had intersected the Earth's orbit in 2349 B.C., at a time when the Earth was close to the collision point. Whiston put two and two together and came up with the idea that this comet caused the great Biblical Flood. According to Whiston, Noah was Chinese and lived in Peking. The point closest to the comet was the Armenian region and the Taurus Mountains. These were ripped upwards, opening up, as the Bible says, "The Fountains of the Deep". Not only that, but a portion of the comet's tail came in contact with the Earth's atmosphere and caused the forty days and forty nights of rain.

You will recall that the Bible says that the second destruction of the Earth will be by fire. Whiston accounted for that, too, by stating that, in the near future, a large comet would come up behind the Earth, causing this planet to slow down. This would cause the Earth to fall into an orbit closer to the Sun, and we would all be burned up. Whiston held out hope to his parishioners, however, by saying that God would intervene and save the faithful. Poor Whiston did not have the first inkling of celestial mechanics. Any student of astronautics knows that if an orbiting body slows down, it moves farther away from its parent body, not closer. After all, Pluto moves much more slowly through space than any of the interior planets. Of course, we must not be too hard on Whiston, since he did not know this. On the other hand, perhaps Newton could have told him.

Another example of the fear caused by comets occurred in ancient France during the reign of an emperor known as Louis the Debonair. (How he got this name, we can only imagine!) At any rate, in 837 AD, a great comet appeared. Louis was told by his astrologers that this signified a change in the reign. He consulted the bishops of the land and they advised him to build churches, monastaries and other church buildings, to repent, to contribute to the finances of the church and to pray often. This Louis did, to the extent that the physical activity exhausted him and he died three years later!

We may laugh at this, but even in this century, fear of comets manifested itself. Halley's comet was to pass very,very close to the Earth in 1910. In fact, it was predicted that the Earth would pass through the tail of the comet. Fearing engulfment by fire,several people committed suicide! Needless to say, the Earth is still here and passed through the tail of the comet unscathed.

So, just what are these objects which have caused so much anguish over the ages? They are celestial objects which revolve around the Sun in orbits, just like all the other members of the Solar System. However, some of their orbits are radically different from those of the planets. Where planets revolve around the Sun in orbits which are very nearly circular, some comets have orbits which are cigar-shaped. Not all comets have these elongated orbits, but most do. Others are in orbits which are nearly circular. Still others appear not to be in any orbit. They come flying in from outer space, pass near the sun and, since their paths are changed by the gravitational attraction of the sun, go flying off in some other direction, never to return.

The problem is that comets are not luminous by themselves and are lit up only by reflected sunlight. Thus, we can see them only when they are close to the Sun, at the time of perihelion passage. Since elliptical, and other orbits look the same near perihelion, astronomers have a difficult time determining the precise shape and direction of a cometary orbit. This may be seen in Figure 18.

(Figure 18)

For centuries, it was not known that comets had orbits. No one ever thought that a comet might return. However, Edmund Halley cam up with the idea when he noted that a bright comet was to be seen in the sky every 74 or 75 years. All of these bright comets seemed to have similar orbits. So, he reasoned, the comets of 1531, 1607 and 1682 were just returns of the same object. He predicted that it would return in 1758. Unfortunately, Halley did not live long enough to see his prediction come true. Nevertheless, he has been immortalized by having this comet named for him!

It should be pointed out here that Halley's computations caused considerable interest in the astronomical community of Europe at that time. Not only did Halley demonstrate that the comet would return, he also showed that it went out away from the Sun to a distance of 3,200,000,000 miles. Since, at that time, Saturn was the most remote member of the solar system at 95 million miles (Uranus was not discovered until 1781, Neptune until 1846 and Pluto until 1930), Halley's comet was distinctive in that it extended the boundaries of the system some 33 times!

At the time of this writing, Halley's Comet is on its return, still out beyond the orbit of Uranus. I am looking forward to its return in 1984. What a spectacle it must be!

Structurally, comets are composed of three distinct sections: the nucleus, the coma and the tail. Sometimes, the comet has more than one tail, but that does not need concern us here.

The nucleus of the comet may be thought of as a dirty "snow-ball".By snow, we do not necessarily mean the kind of snow which falls from the sky on cold winter days. That is water-snow. There are other kinds of snow formed by the solidification, or rather, crystallization, of vapours of gases other than water vapour. Carbon dioxide, for instance, can form a very nice kind of "snow". A comet nucleus, therefore is composed on frozen precipitates of various gases, but this snow contains all sorts of impurities. These are generally in the form of dust and molecules and atoms of various compounds. Cyanogen, helium nuclei, hydrogen atoms, formaldehyde molecules and alcohol may all be found in comets.

Now imagine that the comet is approaching the Sun. While it is some distance away it is tail-less. Then the radiation from the Sun begins to strike the snow. Part of it melts and streams off, carrying with it some of the impurities. These stream backwards along the sides of the nucleus, forming a thin layer, the coma. Then it dissipates into the blackness of space, forming the tail, which, be necessity, always points away from the Sun.It is not the motion of the comet which is the main contributor to the formation of the tail, but is the solar wind, or, radiation from the Sun.

This is why, as the comet recedes from the Sun, the tail goes first!

(Figure 19)

The appearance of a comet in the sky depends largely on the relative positions of the Earth, Sun and comeg at the time. Comets, naturally enough, are brightest when near the Sun. But when they pass directly behind the Sun, or in front of it, when seen from the Earth, they cannot be seen. The best time to see them is when they are near to the Sun, but to the side of it. This means that you can see it just after sunset, when it is east of the Sun, or just before sunrise, when it is west of the Sun. I might add that this is the best place to search for a new comet....near the Sun.

Astronomers do find new comets every year. Many of them are found by amateur astronomers searching with very large binoculars. They sit for hours, often in the pre-dawn darkness, searching a particular section of the sky. They have memorized the appearance of every object in that section of the celestial sphere, so that when a new object appears, it is quite likely a comet. Needless to say, the prospective comet finder may never find one. A figure has been quoted that, for every 150 hours you search, you will find one comet, but I am not sure whether this is true or not. Certainly, diligence is the word when searching for a comet.

Comets usually have two names. It is common practice to name them after the discoveror. But astronomers sometimes find more than one comet. In fact, some have been known to have discovered as many as fifteen! Comets,therefore are given a numerical designation. The first comet to reach perihelion (ie. its closest point to the Sun) in a year is given the number of the year plus the letter "a". Thus, the first comet to reach perihelion in 1972 was 1972a, the second 1972b,etc.....

What happens to a comet when it is all melted away? This problem plagued astronomers for years. A clue was given, however, in 1846. Biela has discovered a comet in 1826, the comet orbiting the Sun in 6.7 years. On its third post-discovery return to the vicinity of the Earth, the comet was seen to have split in two, forming two comets, each with nucleus, coma and tail. On its next return, the comets were extremely far apart, and on the next successive predicted return they were not seen at all. Instead, there was a shower of meteors! Evidently, the melting can go on for only just so long, and then the head breaks up under the influence of solar radiation. The dust particles and other impurities continue more or less along the same orbit. Thus it is that every November 30, wehave a minor meteor shower, formerly known as the Bielids, but known today as the Andromedids, because they appear to be coming from the constellation of Andromeda.

The formation of comets is still a matter of great speculation in the astronomical community. Several theories have been proposed, but none seems to fill the bill. For now, we will have to say that we just do not know.

The planet Jupiter seems to have a great influence on the orbits of comets. Many,many comets have their aphelion (furthest point from the Sun) of their orbits near the orbit of Jupiter. It would appear that Jupiter's great mass has deflected these comets from their original paths and bent them so that they now revolve around the Sun. Speculation has it that when the solar system was formed, there were no comets in it!

A great deal more may be learned about comets in the next few years. Plans are being made to have a space-probe approach a comet and fly alongside it in a parallel orbit. This probe,presumably, would have instruments to photograph, analyze and detect. One lone probe could double our knowledge of comets overnight!

Whatever comets are, they are certainly spectacular sights in the sky. No matter what is learned about them, the man-in-the-street will probably continue to gaze in awe at the great celestial "hairy stars".

12. The End of the World!

Italics: This programme was presented originally on Nov 8, 1971. It raised quite a furor in religious circles. Let me say at the outset that I have no argument with any religious person. Unless there is some intervening circumstance, including the return of Christ, this is the way the world will end.

Regular Type:

How will the world end? By this we mean how will this structure known as the planet Earth cease to exist. We do not mean "How will man end?" but "how will this globe cease to be?"

Man, from the earliest times, has wondered about this problem. He has devised several answers, depending on the state of knowledge in that era, and we shall examine some of these before going onto what we believe to be the ultimate destiny of this globe, based on modern astronomical thought.

To the ancients, the grate flood during the time of Noah must have been the end of the world, but of course it was only the end of that particular civilization. What were some of thier beliefs as to the end of this physical globe?

Of course, until the 1500's we really didn't know that the Earth was a globe, although one ancient Greek has said that it was. No one listened to him. So, the fate of the Earth was held in the hands of the Gods. Theeither Greeks no doubt though that Zeus would end it all in a great storm.

The North American Indians believed that this globe would be shattered by the blow from the hand of an evil spirit, but always held that we were protected by the Great Spirit.

So, generally, we can state that people in former times believed that the world's fate was to be decided by the whim of the gods.

But now we know that the Earth is a planet, 8000 miles in diameter, revolving around a middle-class star, the Sun, at an average distance of 93 million miles. How does this affect our thinking with regard to the end of the world?

Several alarmists have cried out in the past years that the Earth was going to be struck by a great comet and be shattered into pieces. I think that we may discount this happening. As we pointed out in the previous chapter, comets do not have very much mass. If one were to strike the earth, certainly great devastation would result. There would probably be tidal waves, earthquakes and possibly even volcanic eruptions. On the other hand, there may not! You will recall that the head of a comet is made largely of "snow" caused by the crystallization of certain gases. It may be entirely possible that a comet entering the atmosphere of the earth may be melted up by the heat of friction, much as a meteor. The result would be a great storm of meteors.

It has been suggested that the Earth might encounter and asteroid. These are bodies ranging in size from small worlds 500 miles in diameter to mountain sized rockes. Most of them revolve around the sun in orbits between those of Mars and Jupiter. There are a few, however, which, from time to time, approach the Earth. It is these that give the alarmists cause for concern.

Fortunately, the larger ones, those that might disrupt the Earth, remain away out there farther than Mars. That's a good safe distance! The ones that approach the Earth are in the 1 to 10 miles class. Let's suppose for a moment that one of these is on a collision course with the Earth. Certainly, if it were allowed to strike the Earth, a cataclysm would follow. The shock of a body such as this would set up earthquakes, and, most certainly, volcanic eruptions. It could penetrate to the moltem core of the Earth, causing molten magma to spew forth stting huge fires. The fall of a large asteroid could spell doom for a whole continent.

There are several things to consider when looking at the idea of colliding with an asteroid. Although, there are several whose orbits intersect the orbit of the Earth, The Earth and the asteroid must both reach the intersecting point at the same time. The odds against that are colossal.

But suppose some scientists did calculate that a given asteroid and the Earth were to reach the same point at the same time. Certainly the warning would be given and sufficient hydrogen bomb carrying missiles would be despatched to desintegrate the intruder. This smacks of science-fiction, I know, but it does present a very real possibility.

A more real danger lies below our feet. It must be remembered that the core of the Earth is a seething mass of molten iron and nickel. Suppose, somehow that the pressure were to build up in the core to the point where the Earth's crust could no longer stand it. Then the Earth would "go nova". It would split apart in a cataclysmic explosion. The little bits and pieces would all fly off into their own individual orbits around the sun, becoming small asteroids themselves. (One theory for the formation of the steroids had it that a planet did just that!)

But, barring all other possibilities, when one looks for the end of the Earth, one must look toward the Sun. For it is the Sun that holds the key to the fate of our tiny globe. The end of the Sun will hold the ned of the Earth. In other words, when the Sun ends, the Earth will end with it!

So, what are the possible ends of the Sun? One must turn to astrophysics and examine what is going on inside the Sun, so that we can understand the processes there, and from this posulate a possible end to these processes.

The Sun, as we have explained in earlier chapters, is essentially a converter of Hydrogen to Helium, releasing energy in the forms of heat, light, gamma rays and x-rays as it does so. Obviously, the end of the Sun must come when its supply of hydrogen is gone. This is not quite so, since the Sun could exist for awhile, converting some other elements into still heavier elements. As it does so the reaction will become extremely unstable. The sun may begin to pulsate like a variable star, or it may literally explode. If this is so, this tiny globe, and whatever inhabitants still happen to be here will be incinerated into cosmic gas!

If the Sun does not explode, it will certainly get larger, since this is what happens to stars as they get older. Then again, as the surface of the sun approaches, the forests will burn, the oceans will boil, the land will melt, and finally the earth will vapourize!

At this point I must pause to assure my readers that there is no cause for alarm. Astronomers estimate the age of the sun at about 5 billion years, and they tell us that the sun, in all that time has consumed about 30 per cent of its hydrogen fuel. Certainly there is enough left for the forseeable future. So, do not worry that the sun is going to blow up tomorrow. It most likely will not!

If mankind is still around, germ warfare, atomic warfare and other pestilences and cataclysms not withstanding, he will probably by then have mastered the art and science of space travel and will probably migrate to some other planet circling around some other star, far from the death of the Sun, and the end of the World!

13. The Star of Bethlehem

Italics: Each year at Christmas, I presented a programme on the nature of the star of Bethlehem. Was it some sort of astronomical phenomenon or was it really a divine miracle?

Regular type:

What was the Star of Bethlehem? In most astronomical magazines, an article appears on this topic just prior to the Yule season. This topic has always been of interest, not only to the layman, but to the astronomer as well.

Let us examine, then some astronomical phenomena to see if any one, or combination of phenomena, fit the description given. We must, however, before considering any phenomenon, decide for ourselves just what period of time we are examining.

The Bible gives us some clue as to the year in question, since it says that Joseph went down to Bethlehem to be taxed. We know from Roman records that such a tax was levied on the citizens of Judea in 8BC, and another, somewhat earlier in 14 BC.

One may wonder why Christ was not born in the year 0. The confusion stems from the fact that BC actually means Before Caesar. You see, the calendar as we currently use it was originated by Julius Caesar, and he, thinking himself divine, numbered the calendar from the date of his own birth. Thus, Christ was not born in the year 0, for he was not born in the same year as Caesar.

We also know from the Bible, that King Herod died when Christ was two years old. From Roman records, we learn that Herod died just after an eclipse of the Moon and just before Passover. The only eclipse that satisfies the condition of coming just before passover is the eclipse of March 13, 4BC. It would seem, then that Christ, being two years old at the time, must have been born in late 7 BC.

What month was it? The Bible says that there were shepherds abiding in the fields at night. I feel that it must have been a spring month since, in Israel, the autumn nights are wet and the winter and summer nights are quite cold.

What astronomical objects were in the skies in late spring of 7BC? Before we can determine which of the many possibilities may have been the "star", we must look again to the Bible for some of the clues. What does the Bible say?

The first mention of the star is found in Matthew 2:2. In fact, Matthew was the only one of the four gospel writers to mention the star. Does this have any significance? I am not qualified to answer that, although I do know that Matthew was a Roman (he was a tax collector) and from this we might assume that he might have had a better education than the other three writers. Further, he may have had some knowledge of the sky.

But to return to the point, Matthew 2:2 says,"Saying, where is he that is born King of the Jews? for we have seen his star in the east and have come to worship him." Not much help is it? In fact, Matthew, or rather, his translators, for I am taking this from the King James Version, were ambiguous on the point. Was the star in the east? Or were the wise men in the East? You could read it both ways! It would surely help if we could determine whether the star was in the eastern sky or not. This, unfortunately, we cannot tell.

Let us go on,then. In verse 7, King Herod asked the wise men what time the star appeared. Alas, their answer is not recorded! What a shame for we would have a valuable clue if only this question were given an answer in the scriptures.

Verse 9 says;" When they heard the king they departed; and lo, the star which they saw in the east, went before them, till it came and stood over where the young child was."

Verse 10 goes on:"When they saw the star, they rejoiced with exceeding great joy."

Although verse 10 offers no clues, verse 9 certainly does. Again, we have the enigma of "the east". Notice that we cannot tell whether the star was to the east, or whether the wise men had been in the east. But, and this is important, it also says that the star went before them. That is a very powerful clue, because it says that this object moved, or to be more correct, it appeared to move. Remember that we are dealing with a time period when the Earth was thought to be flat and that the Ptolemaic ideas were in vogue.

You can see that the Bible is not of much help. We can say that the description is practically non-existant.

I think that we may safely discount the Moon as being the "star". Perhaps a planet might do. We may safely discard any of the fainter planets, as they would not be worthy of notice. Besides, only Mercury, Venus,Mars, Jupiter and Saturn were known to be planets. The rest were not discovered for over 1700 years later! Mercury was thought to be two planets by the Greeks, but the Romans knew and recognized it.

Mercury revolves around the Sun at a distance of some 30 to 40 million miles, which is not far, astronomically speaking. It is the nearest planet to the Sun, and consequently is never seen in the sky far from the Sun. In fact, the proximity of Mercury to the Sun makes it very difficult to see, unless you know exactly when and where to look for it. When you do see it, it is not very bright. On these grounds, I think that we may safely discount Mercury as a possibility for the "star".

Venus, the next planet out from the Sun, presents a different picture. Venus is exceeding bright and lingers near the horizon for months on end. It is about 67 million miles from the Sun, on the average, and is easily seen. Venus is the third brightest object in the heavens at times, being so bright sometimes that the Sun and the Moon are the only brighter objects. Because Venus is so bright, and easily seen, we can, for the time being, put it on our list of suspect objects.

Mars could be put down too, but is not so suspicious as Venus, since it has been known since antiquity, largely because of the brilliant red hue of the planet when seen in the night sky.

Jupiter is another prime candidate, since it sometimes rivals Venus in brightness and is seen throughout the night for large parts of the year.

Saturn is paler, being almost a golden yellow. It is not likely that

Saturn would provide an inspiration for the wise men to mount their camels and go off looking for the King of the Jews.

Besides, in considering the planets, we must also consider their observers, the wise men. In those days, the wise men were astrologers and as such would have known the planets with familiarity. I think, then, that the possibility of the "star" being a planet is very remote.

Well then, were there any other celestial objects which might have qualified? A comet, perhaps, would do.

Comets are astral bodies which revolve around the Sun in long elliptical, almost cigar shaped orbits. They are thought to be rather like dirty snow-balls, that is, frozen vapors of various gases, laced through with impurities such as dust, small pebbles, grains of sand and the like. As the comet approaches the Sun, a part of the snow-ball melts and is pushed off behind by the radiation from the Sun. This results in a long tail of material, stretching out away from the comet in the anti-solar direction. It looks rather like a star with a glowing head of hair.

In fact, the word "comet" comes from "komete" which is Greek for "hairy star". These were often regarded as omens back in ancient times. More often than not, it was an omen for evil, but perhaps not in ancient Isreal. Perhaps a comet is the "star" that we are looking for!

Add to this the fact that comets appear to move quite rapidly against the background stars. You can notice its motion in just a few hours of looking. This might link up with Matthew 2:9 which, if you will remember, says that the star moved.

Many many comets are known and their orbits have been determined with reasonable accuracy. Astronomers can tell you where and when to look in order to see any given comet. When the question of the "star" came up, information regarding these orbits was fed into a computer. The result was that no known comet fits the bill. Thus, we may discount comets, provided we keep in mind that it could have been an unknown comet. Some comets have periods of tens and hundreds of thousands of years. In that case, a comet could have appeared then and won't appear again for centuries or millenia!

Another type of celestial occurance which might have drawn notice could have been a super-nova. This occurs when stars grow old. Like some humans, some have troubles with their interiors. Sometimes things run amok and the star literally blows up! Thank goodness that does not happen with old humans!

Such an occurance happened in the year 1054, and was recorded by Chinese astronomers,the West being then in the Dark Ages (no pun intended) and astronomy not being in vogue as a science. This colossal explosion was visible even in the daytime. The debris can still be seen in the celestial object known as the Crab Nebula, one of the most interesting objects in the sky, and one which has led to some rather startling advances in astronomy in recent years.

If a supernova occurred in 7 BC it was never recorded. And that exhausts our list of possibilities.

But wait! We have overlooked something ! Recall, if you will, that I mentioned above that the wise men were astrologers. That in itself is a clue which may have escaped our notice.

Suppose that we substitute "sign" for "star". They may have seen his "sign"in the east! After all, we say,"You can thank your lucky stars". What you mean is that your astrological sign was right. (Assume for the moment that we have forgotten that astrology is so much hocus-pocus and mumbo-jumbo which has not rational basis in science.)

What is an astrological sign? One kind is a conjunction of planets.

(Figure 20)

A conjunction occurs when two planets are in the same portion of the sky. They appear to be near each other, though in fact, they are merely in the same direction, and can have no great influence. For example, as I look out the window of my study, I can see a light away across an open field. The light appears to be right beside the tree on my lawn, not more than 15 feet from the house. You could say that the light and the tree are in conjunction, even though the light is nowhere near the tree. This holds true for planets. If Mars and Saturn are in conjunction, they are merely in the same direction since Saturn is about 8 times as far away as Mars.

To return to the point, we may ask,"Was there some sort of conjunction in that era which might have been regarded as auspicious by astrologers?"

Indeed, there was! A triple conjunction of Jupiter and Saturn took place in the summer and autumn of 7BC. What is a triple conjunction? Here, I invite you to look at Figure 20.

You must remember that the laws of science are in effect, and, thus, the planets closest to the Sun move the fastest. So, on our figure, the Earth moves the fastest, Jupiter being second fastest, and Saturn slowest, for all intents and purposes, not moving at all, at least for the purposes of the figure.

I suppose that all of us have gone for a ride of some kind, whether it be in an automobile, bus, train or plane. When you look out of the window, you see something that can be explained in two ways: either you are going forward or those objects outside are going backwards while you are standing still.

As the Earth catches up to, and passes, the planets having orbits larger than the Earth's, these planets appear to move backwards with regard to the fixed background stars.

So, on figure 20, we have the Earth, Jupiter and Saturn, all moving around the sun in a counter-clockwise direction. Mars is in there somewhere, but it does not involve itself in our discussion of the triple conjunction, so I have left it out so as not to complicate things unnecessarily. When the Earth was at A, Jupiter moved, by virtue of its eastward motion, directly south of Saturn, creating the first of the three conjunctions. By the time the Earth got to B, Jupiter was east of Saturn. Now then, as the Earth proceeded towards C, retrograde motion, or the backwards-motion effect, if you will, set in, and Jupiter appeared to move backwards, much as the lamp-posts do when you go for a ride in your car. By the time the Earth arrived at C, the two planets were in conjunction again, causing the second of the three.

Of course, Jupiter was still moving eastward all the time. As the Earth moved towards D, Jupiter's motion carried it in line with Saturn again, causing the third of these triple conjunctions.

A triple conjunction would be something to make astrologers sit up and take notice. In fact, they probably sat up on their camels or donkeys or whatever, and galloped off, looking for the man who would be born under such a sign. Remember, too, that the ancient scriptures foretold many of the happenings, so that, when the conjunction occurred, they were ready for it.

The first occurred on May 27, 7 BC, and probably set them on their way. The second occurred on October 5 of the same year. This might have been when they were talking to King Herod. The third occurred on December 1 and would have caused them the exceeding great joy mentioned in Matthew 2:10 . The planets certainly moved as we saw from the figure, so the idea of a conjunction can be accepted on these grounds.

So far, we have been dealing with the realm of Astronomy, since I do feel most secure when talking or writing about my favourite subject. Facts are facts and cannot be denied. But let us,for a moment, go into the realm of theology. Who can disprove that the star was really a special object put into the skies by the Creator to announce the birth of his son? I cannot! I don't know of anyone who can! It makes one wonder, doesn't it?

14. Jupiter

Italics: On April 14, 1973, I appeared alone to give a discourse on the giant of the solar-system-- Jupiter

Jupiter...... is is solid or gaseous? Is it a star or a planet? What is the red spot? These are some of the questions for which we have yet to get answers with regard to Jupiter. As I write these words in 1973, a Pioneer spacecraft with television cameras and other sensing instruments aboard is nearing the planet, and on passing near it, should provide some of these answers.

But for the present, let us look at Jupiter and determine what we can about the planet.

Jupiter is the fifth planet out from the sun, orbitting around that parent body at a distance of 778 million kilometers. Since this may be a bit difficult to understand, let us say simply that Jupiter, on the average, is about five times as far from the Sun as the Earth. At this colossal distance from the centre of the Solar System, Jupiter takes some 11.9 years to complete one circuit, or one Jovian Year. During this orbit, any hypothetical Jovians would not notice the passage of seasons, for the axis of Jupiter's rotation is inclined only three degrees from the perpendicular. Because of this, the Sun can never appear more than three degrees away from Jupiter's celestial equator, hence doing away with the northward and southward "motions" of the Sun, such as we experience here on the Earth.

Jupiter, generally speaking, is the brightest of planets, being exceeded in brilliance only occasionally by Venus. His disc is a bright white against the starry background. His brilliance pales only when he and the Earth are on opposite sides of the Sun. At those times, the increased distance (the total of the radii of the Earth's orbit and Jupiter's orbit) and the proximily of our line of sight to the sun make Jupiter seem less bright than usual.

Seen with binoculars or a small telescope, Jupiter gives the first-time observer a surprise. Four of his moons are visible. One can imagine Galileo's amazement when he turned his primitive spy-glass on the giant planet for the first time. Four tiny attendants circled around Jupiter as he pursued his course through the starry skies. In fact, these four brightest of Jupiter's twelve known satellites are known as the "Galilean Satellites" after their discoveror. But more of the satellites later.

Again, returning to our binoculars, we might notice that there are some dark streaks across the disc of the planet. With a larger telescope and higher magnification, we see that these streaks resolve themselves into a pattern of bands and stripes. Astronomers believe that these are the tops of atmospheric circulation patterns. It is most interesting to watch the changes that occur in these patterns, often in the course of only a few hours.

These bands and zones have names and for these, the reader is referred to figure 21.

(Figure 21)

Quite often, great disturbances appear in some of the zones. When this occurs, amateur astronomers the world over are ready with telescopes and stopwatches, measuring the progress of these storms. In fact, it is safe to say that most of our knowledge of the motions in Jupiter's atmosphere comes from the efforts of a few dedicated and persistant amateur astronomers who look to Jupiter on every clear evening, and record the changes transpiring there. You might almost think of them as meteorologists for another world!

What the amateur astronomer does is to time the exact instant that a disturbance reaches the central meridian of the planet. The central meridian is that which joins the north and south poles of the planet and would run, naturally down through the centre of the disc. Now, by timing successive returns of a marking to the central meridian, one would deduce that one could calculate the rotation period of the planet. But this is not quite so!

Each of Jupiter's zones and belts has a different rotation period. For example, the Equatorial zone rotates in 9 hours, 50 minutes and 26 seconds, while the North Tropical Zone rotates in 9 hours 55 minutes and 54 seconds. And, to be precise, astronomers should use the exact periods for each and every belt and zone. However, to simplify matters, they have adopted two periods of rotation, referred to as System I and System II. System I has a period of 9 hours 50 minutes and 30 seconds and applies to markings situated on or between the north component of the South Equatorial Belt and the south component of the North Equatorial Belt. System II has an adopted period of 9 hours 55 minutes and 40.65 seconds and applies to all of the rest of the planet.

Now, as you can see, this would mean that the true rotation periods are all slightly different from the average adopted values for systems I and II, which would mean that a marking would arrive at the central meridian slightly ahead of or slightly behind its time, according to the adopted system. Astronomers have to correct for this when making the drawings and calculations with respect to the visible surface of Jupiter.

As the Earth turns on its axis, Jupiter, as we have seen, turns in just under ten hours. This would mean that day and night on Jupiter are only about five hours long each. Hypothetical Jovians must lead extremely busy lives, doing what they have to do in the short periods of feeble daylight available to them. But this rapid rotation has an even more startling effect. Jupiter is some 88,700 miles in diameter which is about 11 times that of the Earth. With his equator rotating in some 10 hours, the centrifugal forces tend to throw the equator out away from the core of the planet. This, in turn, pulls the poles down. Thus, when we see Jupiter, either in photographs or in the telescope, the disc has a decidedly flattened look, much as if it had been sat upon.

In figure 22, the solid line indicates the shape of Jupiter's disc, while the dashed line indicates the shape of a perfect circle. One can readily see the amount of polar flattening. In actual fact, the polar diameter is 82,770 miles, which is some six thousand miles shorter than the equatorial diameter.

(Figure 22)

One of the most interesting features of the Jovian disc is the Great Red Spot. This is a vast oval marking about thirty thousand miles long and some twelve thousand miles wide, which is, by the way, much larger than the Earth! A red spot was observed the R. Hooke in 1664 and was visible for nearly fifty years before it faded away to invisibility. It was re-observed by the famous solar observer Heinrich Schwabe in 1831 and has been visible ever since, although it has gone through periodic fading. On the other hand, it has, at times, particularly in

1920, 1926 and 1936, has become intenely red. Curiously enough, when this has happened, its period of rotation has lengthened.

What could this amazing feature be? Various theories have been put forward. One has it that the Great Red Spot is the top of a mountain protrúding through the clouds which cover the rest of the surface of the planet. Another says that it is a volcanic cloud which erupts from time to time, thus creating the reddining. Still another, put forward by Dr. I. Velikovsky, says that this is a giant scar, left when the planets Mars and Venus were ejected from Jupiter in the form of giant comets!

Naturally, all of the theoreticians have thei facts and figures with which to back up thei arguments, but I rather lide the reaction to the Great Red Spot as voiced by a small boy seeing Jupiter for the first time in a telescope. He said, "Look. There's the label!".

As well as being the largest of the planets, Jupiter is also the most massive. Astronomers have calculated that his bulk is some 317.9 times that of the Earth. Now, it may not have dawned on you, but this figure is amazingly low. If you take the time to calculate the volumn of Jupiter, you would expect that it would be for more massive. However it is not, and from this we can assume that Jupiter is composed from materials which are extremely light. The mean density of the planet is only 1.33 times that of water, compared to a figure of 5.5 for the Earth. So, light materials it must be!

Analysis with a spectroscope shows us that the atmosphere on Jupiter is composed of a rather ghastly mixture-- methane and ammonia. Methane is a component of natural gas, the stüff which warms our houses and cooks our meals. Ammonia, as every housewife knows is that smelly stuff that is good for cutting through grease, washing floors and a myriad of other purposes. Our hypothetical Jovians must have some sort of special breathing apparatus to put up with such a foul smelling and poisonous atmosphere. Not only that, but they must also wear their wool snuggies for the temperature there is some -200F., which is cold, to say the least!

Various theories have been propounded to state what is under the great cloud layers. Some have Jupiter with a rocky core, surrounded by a layer of solid hydrogen metal, surrounded by an atmosphere, while in other cases the atmosphere just gets thicker and thicker and thicker until it becomes solid! 51

Whether or not Jupiter has a core that is hot, like the Earth, remains to be seen, Several professional astronomers have come forward with the idea that Jupiter is more like a star than a planet and may represent some intermediate step. It is known that Jupiter does radiate more energy into space than it receives from the Sun, and this has yet to be explained.

I should add here that it will be a very very long time before astronauts ever land on Jupiter, if indeed, they ever do. Jupiter may not have what we know as a surface and any rocket attempting a landing may just sink in, descending lower and lower and lower into the thickening atmosphere, until it reaches a point of buoyancy. In this case, there is no point in sending missions to Jupiter. Further, the gravity on Jupiter is some 2.6 times that of the Earth, so that you can imagine the size of the rocket which would be necessary to lift off from that planet. More than likely, any manned missions would be to the major satellites of Jupiter, which do appear to have solid surfaces and from which a return would not require such a massive transportation system.

As stated earlier, Jupiter has a family of twelve known satellites. Some are very large, one being larger than the planet Mercury, and some are very tiny being only 10 or 15 miles in diameter at the most!

Number I, II, III, and IV are the Galilean Satellites and are known as Io, Europa, Ganymede and Callisto, respectively. The others, V, VI, VII, X, XII, XI, VIII and IX are known only by mumbers although two sets of names have been proposed, one set being Greek names and the other being Roman names.

The reader may wonder why the Roman Numerals are in such a peculiar order. Ihave given them more or less in order outward from the surface of the planet while they are numbered in order of discovery. V is closer to the planet than the four Galilean Satellites while the others are further away, and are in the order given.

Ganymede is the largest of Jupiter's heavenly retinue, having a diameter of 3,120 miles, which, to repeat, is larger than the planet Mercury. Callisto and Io have diameters of 2770 and 2273 miles respectively,which makes them jsut a little larger than our own moon which has a diameter of 2,160 miles. The rest of the moons are rather inconsequential in size, ranging from the 100 miles diameter of V down to the less-than-10 miles diameter of some of the outer ones.

58 It is interesting to note in passing that XII, XI, VII and IX all revolve around Jupiter backwards, in what astronomers call a retrograde motion. The reason for this is not certain but is generally thought that these tiny moonlets must have, at one time, been asteroids, circling the sun in their own orbits. They may have passed close to Jupiter, close enough for that planet to have affected a capture with its immense gravitational pull.

I like to observe the four Galilean Satellites with my telescope for they are always doing something interesting, such as disappearing before your very eyes! Sometimes only two or three are visible, and it is often a matter of s me detective work to determine the whereabouts of some millions of tons of rock, some two to three thousand miles in diamter.

As we all know, these satellites revolve around Jupiter, and as they e mainly in the plane of Jupiter's equator, they appear to pass in front of, or behind, the disc of the planet. When a satellite passes in front of the disc, its white colour is rather hard to distinguish from the white of the disc itself. However, its shadow is not! It is often visible on the planet, a rather dark circle, which either follows or precedes the disc of the planet and we have what is known as an occultation.

But you must remember too, that Jupiter has a shadow. This shadow extends a bit out sideways from the planet, again depending on the angle of the Sun. It is always a source of amazement to watch one of these tiny moons enter the shadow of the planet, for one minute it is there, and just a few seconds later it is not. This is expecially amazing when the phenomenon takes place at some distance from the disc of the planet. Not only that, it is equally amazing when this happens when the shadow is on the side of the planet where the moons re-appear (again, depending on Sun angle). There is the inky blackness of space, and then, voila, there is a moon.

59 Predictions for these happening may be found in three sources: the Handbook of the British Astronomical Association, the Observer's Handbook of the Royal Astronomical Society of Canada, and the American Ephemeris and Nautical Almanac.

As I write these words, we amateur astronomers are getting a special bonus, for, not only are the satellites appearing and disappearing by ducking behind the disc of the parent planet, they are also passing directly one in front of the other. Thisdoes not happen very often, only at intervals of about 5.3 years, so that it does make for very interesting watching.

In ancient mythology, Jupiter was the greatest amongst the gods. In modern astronomy, he is the greatest amongst the planets. This is true, especially when you consider that Jupiter's gravity dominates the rest of the solar system. Many comets have similar orbits around the sun, this being due to the influence of the gravity of Jupiter. The same is true of certain asteroids, or tiny planets.

I could not end this arcticle without mention of something which I really don't understand. On the other hand, nobdy else really understands it either, so that makes us even! It seems that Jupiter has a huge magnetic field, somewhat similar to that of the earth but many times more powerful. This field has trapped many particles of solar matter, giving rise to radiation belts, again, like those of the Earth. When Io passes through these belts, a great bolt of radio noise is released and can be detected by radio astronomers here on the Earth. Why this is, I cannot say.

I can say that Jupiter is, to me, one of the most interesting planets to observe telescopically. With its belts and zones, with the Red Spot, with its family of moons, Jupiter presents a full evening's viewing for the amatuer astronomer and his telescope.

15. Galaxies

Italics: Galaxies are great star syatems, whose pictures are often spectacular. On March 6, 1972 I appeared alone to tell the viewers about galaxies.

Normal type:

In considering the galaxies, great distances come into play, distances which stagger the mind and boggle the imagination. So before we begin stretching our thoughts to try to comprehend the fathomless reaches of space, let us consider something which we all know very well, namely, our own homes.

I would suppose that it would be safe to say that the majority of the population if this old globe live in some sort of dwelling, whether it be a tent, shack, apartment, mansion or igloo. The point is that most of us live in some sort of house.

A group of houses can be called a neighbourhood. The chances are that we know many people in our neighbourhood, such as the local grocer, the couple next door, the old maid who lives down the street, the lady of questionable repute, the butcher and the milkman. In other words, we know the people who live and work close to our own homes.

If we put together enough neighbourhoods we have a city. My own city, Hamilton, Ontario, has such neighbourhoods as Corktown, Durand, and The Mountain.

Now, what I have been doing, of course, is drawing an analogy. This will help us to understand what a galaxy is. Suppose that we think for a moment that our own individual homes are stars. Then our neighbourhoods become local star clusters, and the cities become galaxies. So, a galaxy is a great number of stars.

But as there is more to a city than houses, there is more to a galaxy than stars. Every city has its shopping districts and major arteries for traffic. Usually the shopping district is in the centre of the city and is composed of some rather high office buildings with shops on the street level. You will find too that the "business section" of a galaxy is in the middle. But what of the traffic arteries?

Traffic arteries in a city usually separate of houses but in a galaxy, you will find that clouds of dust and gas separate the arms of the galaxy, which are, to continue our analogy, are the rows of houses in our city.

Galaxies come in various shapes. The most common kind are round when from "above" or "below" and when seen from the side, look rather like two fried eggs stuck back to back. Bart Bok, a famous astronomer, once said that a galaxy was rather like the shape a middle-aged astronomer, a big tummy sticking out in front, a large posterior in the rear, When you consider the pattern of the dark gas clouds, galaxies appear rather like pinwheels, or for our British readers, "Cathern Wheels".

So what we have is a flattened star system laced through with nebulae (those dust and gas clouds)which appear to spiral in, or out if you wish, from the centre. The number of stars in any one galaxy is stupendous. To say a million might be an understatement!

We'll come back to the structure and composition of the various galaxies later but for now, let's get to those colossal distances that we mentioned earlier.

A beam of light travels at 186,000 miles every second (300,000km) and that in itself is rather hard to imagine. We can put this in its perspective by saying that it is equivalent to about $7\frac{1}{2}$ times around the Earth or, is about two-thirds of the distance to the Moon. This means that light takes about $1\frac{1}{2}$ seconds to reach us from the Moon. So do radio signals for that matter, and that is why there is always a slight delay when astronauts are speaking from the lunar surface.

Light from the Sun takes about 8 minutes to reach us. By comparing 8 minutes to $1\frac{1}{2}$ seconds, you can get some of the distance involved in our own little area of the solar system, especially when it takes an astronaut three days to get to the Moon. And, to get back to our city analogy, we are merely going from one room to another in our own house!

Light from the nearest star, Proxima Centauri, takes 4 years to reach us. Four years! Has your mind boggled yet?

Light takes 160,000 years, just to cross our own galaxy. The light which we detect from the other side of the galaxy started off long before man ever appeared on this planet!

Now we know the size of our own "city". Are you ready for the figure that will really defy your imagination? I takes light, two million years to come from the nearest galaxy? Two million! We find it difficult to get a conception of two million! I propose a little experiment to help you understand how many two million really is.

Sit down to a typewriter and type out a sheet of paper with 50 rows of x's, with 50 x's in each row. Now take it to a duplicator and make 400 copies and you will have one million x's. If you make 800 sheets, you will have two million! Now contemplate one year for each of those x's and you will know how long it takes the light to come from the nearest galaxy. And that's just the nearest one! It does boggle the imagination doesn't it?

You may well ask, how do we know how far away these galaxies are?

There are two methods, one for galaxies that are relatively near, and one for those which are farther away,

Those galaxies which are relatively near to our own, are near enough that they may be resolved into individual stars by large telescopes. That is, we can see the stars.

Now, to draw another analogy, liken a star to a lightbulb. The brightness of a light bulb can depend on two factors, first the wattage of the bulb, and secondly, the distance between you and the light-bulb. To separate the two is a problem. For instance, as I look out the window of my study, I can see a street-light about a quaturter of a mile away. It certainly does not look as bright as the forty watt lamp on my desk, although I know that the street-lamp must have a 500 watt light in it. This is the problem that astronomers faced for many years. You couldn't tell the distance unless you could tell the wattage, and you couldn't tell the wattage unless you knew the distance. Were the stars that appeared bright really high wattage bulb, or were they merely low wattage bulbs close up?

This was the enigma which was finally solved by Miss Henrietta Leavitt of the Harvard College Observatory. She was studying two galaxies whose distances were known through the trigonometric methods, that is, someone had calculated the distance using the same methods as a surveyor. What Miss Leavitt noticed was that there were some stars called Cepheid Variables in these nearby galaxies. Capheid Variables are stars which change their brightness extemely regularly. You can, by making a few simple measurements, determine the variation period. Miss Leavitt also noticed that the brighter Cepheids varied with a longer period than the fainter ones. She worked out, in conjunction with other astronomers "The Period Luminosity Law".

To return our analgy, one could now determine the wattage of our lightbulb by looking at the period. Once the wattage is known it is a simple calculation to determine the distance.

We realize that we have explained this in an earlier chapter, but it is so basically vital to the discussion that we think it worth repeating here.

To state the case in simple words, to find the distance to a nearby galaxy, simply find a cepheid variable and observe its period. But, that anly works for those galaxies which are relatively close and can be resolved into individual stars. The more distant have to have a different technique.

Here we have to turn to the work of the cosmologist, Eddington. He announced that all of the galaxies seemed to be moving away from each other, much as would spots on a balloon that was being inflated. Then another cosmologist, Hubble dtermined that, based on distances deduced through the Cepheid Variable Period-Luminosity Law, the remoter galaxies were receeding from us at a greater rate than galaxies that are closer to us.

Now it was well known that the spectrum of an object can tell whether something is receding or approaching. If you have ever received a speeding ticket through the use of 'radar' you will have been the victim of this sort of analysis.

The whole point is that by looking at the velosity of recession of a galaxy, according to Hubble, you can determine the distance. (If the reader os not clear on spectral analysis, he should refer back to chapter 6 on Stars).

To sum up then, you can tell the distance to a galaxy by looking either at the Cepheid Variables contained therein or at the shift in its spectrum to determine the velocity of recession.

At this point, we must refer to figure 23. This is Hubble's famous "tunig fork" diagram. Hubble could see some sort of sequende in the development of galaxies. This has yet to be proven, and I present it here only as it is a logical sequence to explain the different kinds of galaxies.

At the left of the diagram we have galaxies which are nearly spherical in form. They are condensed toward the centre but have no indication of any kinds of arms.

The next kind are rather elliptical in shape. They are slightly flattened, at the tops and bottoms. This may be due to some sort of rotational effect, rather like the planet Jupiter, but we are not 100% sure on this. It would seem, however, that the faster the rotation the more pronounced the flattening, until eventually you have a rather flat system.

Then we come to the division in the diagram, the crotch of the fork. The galaxies which are first out on the "branches" appear to have very short stubby arms. However, on the upper branch the arms seem to be growing directly out of the nucleus, while on the lower branch are they seem to grow out of a "bar" which extends to some distance on either side of the central core. The galaxies on the upper branch are called "Spiral Galaxies" while those on the lower branch are known as Barred Spirals". You will note of course that the farther out you go on the branches, the more the arms seem to be unwound.

As I said before, this might seem to be some sort of evolutionary sequence, but in which direction? Is it that the older galaxies start off a spherical ar elliptical and grow their arms as they get older? Ot is it that the arms tend to wrap up around the centre as the galaxy, ages? We do not know!

Now, what is going on inside the galaxies? Of course, we might deduce that the stars are all in revolution around the centre of the galaxy, for that is the rule in our universe, everthing seems to rotate around something. Thus it is only fair to assume that the stars rotate around the centres of galaxies. We do know that this is true for our own galaxy, the Milky Way, and I think that we might assume this to be true of other galaxies.

However, when you come to examine the constituent parts of a galaxy, you come upon some things that are not expected. For instance, it would seem that all of the youngest stars are located in the spiral arms. The older stars are in the nuclei. (Does this prove Hubble's evolutionary sequence right?) Also, all of the dust and opaque gases are in the arms, and appear to be concentrated along the inside edges of the arms.

The centres of galaxies are still quite mysterious, since most of the research on galaxies so far has been on the arms. Just recently astronomers have tried to study the centres of galaxies, and their results are amazing. It seems that great explosions and releases of energy are happening in the cores of these celestial systems. Are these stars being anhiliated? Or are other mysterious forces in action? Again, we do not know.

We do know that some galaxies appear to be riddled with great turbulence, as they appear to be wracked with great explosions. Some have shot out great jets of matter, releasing radio signals that can be detected with our great radio telescopes. Our own galaxy, the Milky Way, has suffered a cataclysmic explosion in its interior although the great shock wave will not reach us for many billions of years.

At any rate, you can see that galaxies are star systems, indescribably huge, at distances that defy imagination. We are still learning about them and in years to come, the story of the exploration of the galaxies will probably be the main story in the development of astronomy.

16. Bode's Law

Italics: Bode's Law may be just a coincidence, but it does give a reasonably accurate portrayal of our solar system, and did lead to several scientific discoveries. On April 17, 1972, Michael Bodnar, a member of the Board of Directors of the Hamilton Centre of the Royal Astronomical Society of Canada, appeared with me to explain the workings of Bode's Law.

Regular type:

J.E. Bode was a Berlin Astronomer who lived from 1747 to 1846. Although he was known as quite an astute astronomer, and as the person who first proposed the name "Uranus" for the planet which Herschel had discovered it is more for his "law" that we now remember him.

This may not be fair, both to Bode, who ought to be remembered for more than his series of numbers, but also to a Professor J.B. Titius from Wittenburg who also worked out the "law" at about the same time as Bode. However, it is Bode that is remembered and not particularly Titius.

Now just what is this law? First of all it is not really a law, as it breaks down in several cases as you will see. It has not have any fixed distance from the solar globe, but rather travel in elliptical orbits, and at times are closer to the Sun that at other intervals. So, what Bode's Law does, in effect, is give you an approximation of the mean, or average, distances.

In order for the reader to fully understand Bode's Law, we have to introduce a new unit of measure, the astronomical unit. Feet, inches, yards and miles, millimetres, centimetres, metres and kilometres may be all right for measurements here on the surface of the Earth, but when we come to celestial measurements, a longer yardstick is required. In earlier chapters we have referred to the ligh-year, which is some six trillion miles ling (6,000,000,000,000!). This is too large for measuring distances in the solar system, so astronomers employ a unit of measure known as the Astronomical Unit.

An Astronomical Unit is equal to the average distance between the Earth and the Sun, and thus, is equivalent to 93 million miles, or, 149 million kilometres, approximately. The whole point is that the Earth is 1 Astronomical Unit from the Sun. (Astronomical Unit is abbrieviated A.U.).

Returning to Bode's Law, it gives the approximate distances from the Sun to the planets as measured in Astronomical Units.

The train of thought goes like this:

Start with 0,3 and then double for each successive number so that you end up with the series 0, 3, 6, 12, 24, 48, 96, 192, 384, and 768.

Then add 4 to each one. This gives you 4, 7, 10, 16, 28, 52, 100, 196, 388 and 772.

Finally, divide each one by 10, so that you arrive at this set of numbers: .4, .7, 1.0, 1.6, 2.8, 5.2, 10.0, 19.6, 38.8, and 77.2.

These numbers give very nearly the correct distances to the planets as measured in Astronomical Units. A look at the following table will explain:

Planet	Bode's Law	True Mean Distance
Mercury	.4	.39
Venus	.7	.72
Earth	1.0	1.0
Mars	1.6	1.52
(?)	2.8	----
Jupiter	5.2	5.20

Planet	Bode's Law	True Mean Distance
Saturn	10.0	9.54
Uranus	19.6	19.2
Neptune	38.8	30.1
Pluto	77.2	39.5

As you can see, the series fits remarkably well for the majority of the planets. This is the way I remember the distance to the planets, remembering a lot of figures. All that I have to do is remember the exceptions.

The biggest exception that the reader will have noticed is that there is no planet for the distance 2.8 A.U. This puzzled astronomers for several years. No known planet revolves around the Sun at that distance.

When an astonomer finds something unusual, he usually tries to investigate it. Thus, a search for this new planet was begun in the later part of the 18th Century. The search was conducted by an association of twenty-four astronomers, headed by Bode himself. He asked each one of scrutinize one hour of the Zodiac (Remember that the sky can be thought of as a twenty-four hour circle. It takes the Sun that long to go around it!)

On the first day of the new century, January 1, 1801, an Italian astronomer, Piazzi, was observing at Palermo. He pointed his telescope toward the constellation of Taurus, the Bull and happened to notice a faint object which had not attracted his attention before. Quickly he made a star field.

The next night, Piazzi went excitedly to the telescope. The object had moved! At first he took it for a comet (much as Herschel had taken the planet Uranus for a comet a few years earlier.) He followed it until

January 12, whensuddenly it appeared to change direction and to move the other way in sky. This was definitely not a comer and most certainly appeared to be a new planet!

Quickly, the news was relayed to Bode, who asked a young astronomer (Guass) to calculate the orbit. This was difficult since the observations only covered a few days, but by developing a method of his own, which was later to make him quite famous (He used it to discover the planet Neptune!), he calculated the orbit, and found that its mean distance was 2.77 A.U. from the Sun, which almost exactly fits Bode's Law.

Piazzi named his new world Ceres.

However, in 1802, om March 28, to be exact, Olbers was observing from Bremen in Northern Germany. He spied a faint object in the constellation virgo. It followed a similar orbit, similar to that of Ceres. This body became known as Pallas.

These two discoveries were quickly followed by two more, the discovery of Juno on September 1, 1804, and of Vesta on March 27, 1809. All of the bodies revolve at approximately 2.8 A.U. from the Sun.

It became evident that the gap in Bode's law was not filled by one body, but by a multitude of small bodies, which became known by any one of these three names, Planetoids, Asteroids, or Minor Planets. Just how small they are can be illustrated by the fact that Ceres is the largest and has the diameter of only 485 miles. The rest are all smaller, and some of them have orbits located between the orbits of Mars and Jupiter.

Other than that gap, Bode's Law holds very well out as far as Uranus, Beyond that , it begins to break down with Neptune, and is totally impssible as far as Pluto is concerned. However, Pluto is a very unusual planet.

When we were at school, we learned thatPluto is the most remote planet from the Sun, but, although this is generally true, there are times when it is not! The orbit of Pluto is quite eccentric and deviates highly from the perfect circle. It is so devious, in fact, that at times, Pluto is closer than Neptune. This is the case, as I write these words. Pluto hove closer to the Sun in 1970 and will remain closer than Neptune until 2010.

The point of the argument is that Pluto is exceptional, and to exlain this, we may have to do a little figuring. Suppose that we average the didtances of Neptune (30.1 A.U.) and Pluto (39.5 A.U.)? We arrive at an average distance of 34.4 A.U., which is not really too far off from the figure of 38.8 as given in Bode's Law.

This really set astronomers to thinking. Since Pluto spends about one-sixths of its revolution closer to the Sun than Neptune, and since their orbits very nearly intersect, perhaps Neptune and Pluto had a commom origin. In fact, could it be that Pluto might once have been a satellite of Neptune?

If we look at other indicators, other than the orbital parameters, we see that Pluto has a diameter of 3700 miles (although I have seen figures for the diameter as high as 6000 miles.) Now, 3700 miles is certainly satellite size. Add to this that its period of axial rotation is about 6½ days. Satellites have, often, axial rotation to the period of revolution around thier parent planet. This is certainly true of our own Moon which has rotation and revolution equal at 27½ days.

The argument goes something like this. Pluto was once a satellite of Neptune, revolving and rotating with a period of 6½ days. This brought it in close proximity to another satellite of Neptune, Triton. At one time in the past, they approached too close and Pluto was hurled out away from Neptune, while Triton reversed itself and was flung out into a slightly larger orbit, where it eventually settled down to be an ordinary little

Moon again, except for its backward, or retrograde, motion.

Of course this is all sheer speculation as we have no way of either proving or disproving it. However, averaging the distances does add some accuracy to Bode's Law and provides us with some interesting theorizing.

What about that final figure in Bode's Law? Namely 77.2 Astonomical Units. Could there be another planet there, lurking in the cold dark depths of space, far from the warmth of the Sun? We just don't know at the present time.

However, very recently, a California scientist, Brady, was working with his computer on variations in the orbit of Halley's Comet. This spectacular celestial abject just isn't behaving exactly according to the laws of Pysics. Brady calculated that the discrepancies could be accounted for if you postulated the existance of a planet out beyond Pluto.

Brady gave the dimensions of this object as being somewhat larger than Jupiter, gave the brighteness, and told astronomers to look in the constellation of Cassiopia. They did!

After several weeks of searching, nothing was found. However, this does not mean that there is not a trans-Plutonian planet. It simply means that Brady has to work a bit further with his with his fugures.

I would suggest, on the other hand, that perhaps all these expensive computers are not necessary. What if Bode's Law is not a mere coinidence? What if it is a true but unexplained law with regard to planetary motions? Why not look along the zodian for an object at 77.2 A.U.? Certainly it will not do any harm. I find the idea of an outer planet, at 77.2 A.U., fascinating. What a cold place it must be, icebound all year, with the Sun appearing as nothing more than the brightest star in the sky. Certainly, we Earthlings would be lost to view! What a thrill it would be to discover such a planet!

Bode's Law then, may or may not be a "law". It may be just a set of numbers which just happern to f ll a given set of circumstances. Whether it be law or not, it has certainly added to our knowledge of the solar system, both in reality through the discovery of the Asteroids, and in theory method of remembering planetary distances. If you are interested in amatuer astronomy, remember it!

17. Orion

Italics: Orion is one of the most interesting celestial groups as it is a constellation which contains a diverse selection of objects. On April 3, 1972, I appeared alone to give a short talk about this winter constellation.

Regular type:

If you have ever taken a walk in the winter nights, when the snow crackled under your feet, and your breath hung like a cloud of fog in the air, and the stars seem so close that you could touch them, the chances are that you have probably seen the constellation of Orion.

Orion! Orion is probably the best known of constellations after the Big and Little Dippers (which are not really constellations at all but are parts of the constellations of Ursa Major and Ursa Miner, the big and little bears, respectively). But how much do we really know of Orion? Can we recognize it?

We can refer to figure 24 which shows the princ&pal stars.

(figure 24)

I always like to think of the four brightest stars as a box containing the five others, in the form of a T. Later on, you will see that these have a significance in mythology, and will have some use in locating one of the most interesting objects in the sky. Nevertheless, the box and T do provide a handy way of finding Orion since it is just south of the overhead point, or zenith, for most observers in the United States and Canada, on winter and spring evenings.

In mythology, Orion was a mighty hunter who lived long ago in the days when the world was very young and when the gods walked the Earth. So great, in fact, was his prowess at hunting that he attracted the attention of Artemis, the goddess of the hunt. Soon, the pair were inseparable and went on daily hunting excursions.

One day, however, tragedy struck, and Artemis wounded Orion, quite accidently with an arrow. Orion was angered and struck the goddess with a mighty blow.

Since one does not attempt violence upon the person of a goddess, Orion was banished to the underworld, there to be sentenced to chase wild beasts forever, much as he had done in life, although he was never to be sucessful in the chase.

Fortunately, Apollo, the greatest of the gods, took pity on Orion, as it was not really his fault. After all, Artemis should have been more careful where she was pointing her arrow! Apollo was unable to change Orion's sentence of the eternal chase, but he was able to change its location. Thus, he changed Orion into a starry constellation, placing him in the heavens just beside the constellation Taurus, the Bull. Thus, the hunt goes on, and with a little imagination, you can make in the star patterns Orion standing with shield in front of him club upraised, ready to rap Taurus the Bull on the skull if he should come too close!

Now, do remember that this is all mythology. It does take a great deal of patience even to try and imagine that you can see the bull and hunter in the sky. They are merely star patterns, as are all constellations. Orion is made of a diverse number of objects and virtually all are the same line of sight.

Look again at figure 24. The star in the upper left of the box is a bright red star, Betelguese, which was supposed to represent the right shoulder of our legendary hero. I must say here that quite a lot of controversy goes on with regard to the correct pronunciation of the word "Betelguese. I have heard it said like"Bet-el-geze", "Beat-el-jeez", and "Bet-el-jooz". Myself, I like "Beetle-juice"!

The left shoulder is represented by Bellatrix, a bright white star. Orion's left foot is Rigel, one of the brightest stars in the sky, while his right foot is represented by Saiph, another white star. We shall examine these stars in some detail later.

The T in figure 24, represents the belt and sword of the hunter. The stars of the belt, reading left to right are Alnitak, Alnilam and Mintaka, respectively. (We remind the reader that these are the names given to the stars by the Arabs, who kept astronomy alive through the dark ages).

The stars of the sword are interesting, for one of them is not a star at all. It is that interesting object that I mentioned in an earlier paragraph. The top "star" in Orion's sword is a nebula, a great cloud of gas, glowing in the sky. The other is really a star, which, as far as I know, does not have an Arabic name, but simply goes by its Bayer Letter of Iota Orionis. (The reader is invited to refer back to chapter 6 to refresh his memory on the systems for naming stars).

The other stars of the constellation are not so bright. I am speaking of the one that compose the "shield" and the "club" of the mythological hunter nevertheless, they have some interesting features, and so I have outlined them in figure 25.

(figure 25)

As we said earlier, the stars forming the pattern of the Hunter are merely a line-of-sight effect. In reality, very few of them have a physical connection and are many, many light years apart in space. For instance, if we liik at the four bright stars of the box, we see that Betelguese is at a distance of 520 light years, Bellatrix 470, Rigel 900, and Saiph 2,100. From this we see that Orion has quite a depth, and, indeed, we are closer to Betelguese than is Saiph!

On the other hand, the stars of the "Belt" of Orion may form some sort of association since they are distances of 1600 light years each.

But what are these stars that form such an impressive pattern in our winter sky? Suppose that we examine them one by one to see what a diversity there is, just within one single constellation.

Betelguese is a good place to begin, since we have mentioned it before, and is one of the most prominent stars in the winter sky. Betelguese is a super-giant of a star! It is collosal! In fact it is so large that it almosts presents a visible disc in the telescope, whereas all other stars, no matter how bright always look like pin-points of light. Using a special device known as the interferometer astronomers have measured the diameter of Betelguese as being 450 times that of our parent star, the Sun. Think of the consequences if you were to place this star at the centre of our solar system instead of the Sun.. Our star has a diameter of 864,000 miles. However, if you substited Betelguese, you would find that a star with a diameter of 388,800,000 miles would swallow up everthing out as far as the Asteroids. Mercury, Venus, the Earth, and Mars would be gone, and Jupiter would be about as far from its surface as the Earth is from the sufface of the Sun, namely about 90 million miles.

Betelguese is interesting, further, since it is a variable star. That is, it's brightness varies, whereas the brightness of most stars does not. Strangely enough, when you make a graph of the variations you will notice that the oscillations have two definite periods, one of 180 days and one of 2,070 days. Continued measurements with the interferometer show that there is a correlation between the periods and the diameter. Evidently the whole surface of this star is pulsating, causing the changes in brightness. When the star is largest, physically, it is also brightest.

The reader will recall from chapter 6 that this sort of phenomenon occurs when stars reach old age. Although no specific age can be assigned to the star, we reason that Betelguese is a senior citizen of stellar community, and in the next million years or so, should commence his collapse toward extinction. How sad it will be for inhabitants of the Earth, if there are any left at that time, to look skyward on a winter night, and not see Betelguese!

While we spoke of Betelguese not being a good star for the centre of the solar system, Rigel would not be appropriate either. Rigel, you will recall, represents the left foot of our mythological hero. If Rigel were transported to the Sun's location, we would all be incinerated immediately for Rigel has a temperature of 13,000° C. and is 33 times the size of the Sun. Rigel emits 23,ooo times as much energy as the Sun, since it is a young bluish-white star. With a good telescope, one can see that Rigel is not really one star at all.. The star to which we have been referring is really the largest in a triple star system.

This is really not unusual for it seems that most of the brightest stars are either double or multiple in nature.. In the case of Rigel we have a double star, that is, two stars revolving around a common centre of gravity, which revolves around Rigel in a period of about ten days.

Bellatrix is not the celestial sight that Rigel is, but, strangely enough, it is even hotter, having a temperature of some 20,000° C.. It is a young white star, and, like Rigel, emits many times the Sun's energy, Bellatrix, by the way means "female warrior".

The fourth star, Saiph, is also a hot white star with a surface temperature of some 25,000°C.. You can see that the Sun is rather pale copared to these four stars.

What of the trio in the belt? These, too, are exremely hot stars with temperatures in the range of 25,000°C.. In fact they are all rather like Saiph.

Under the belt, we come to the nebula that we mentioned earlier. Unlike the Viel, Nebula, the Lagoon Nebula and the Crab Nebula, this cloud of gas and dust has no name other than the Orion Nebula, or, sometimes the Great Nebula in Orion. This, I think, is a shame, since there are other nebulae in Orion, including the famous Horsehead with which we shall deal with in a few moments.

The Orion Nebula is the most easily visible, and can be seen with ease by the unaided eye. It is, as we said, the top "star" in the sword of the hunter. It is strange that neither the ancient astronomers, such as Eratosthenes, nor the medieval astronomers, such as Galileo, detected the Nebula. In fact, it is rather amazing that Galileo missed spotting it, since he studied Orion in some detail with his primitive telescope.

The discovery was made by Ziesatus in 1618, and then only through a piece of good fortune. He was observing a comet at the time, and it happened to pass almost in front of the nebula.

In binoculars, the sight becomes more impressive, as the hazy outline is expanded. In a telescope, many of the streaks and irregularities come into view as well as some of the stars imbedded in the nebula.
It has been put forward that the nebula is so large that it covers most of the constellation, and all that we see is the illuminated central

portion.

The Orion Nebula is a part of our own galaxy, the Milky Way, and lies in one of the spiral arms of our stellar system. It is 1500 light years away from us, which, if you will recall, is the same distance as the three stars of the belt, just above the Nebula. It may be that these three young hot stars were recently formed in the Nebula and have moved away from it.

The Nebula is composed mainly of hydrogen gas, which is the stuff from which stars are made. However, it is extemely rarified, having about one milligram of matter per 100 cubic kilometers. This is far and a way more rarified than any vacuum which can be created in a laboratory here on the Earth. Talk about luminous nothing!

Nevertheless, the matter contained in this stupendous cloud is enough to make about a thousand Suns, or, three hundred million planets the mass of the Earth! The reason for this is that the size of the Nebula is collosal, having a diameter of some 16 light years! That's a lot of gas and dust, even in a highly rarified state.

When you examine the Orion Nebula, you notice immediatly that there are stars imbedded in it. Four of these form the corners of an imaginary trapezium. These are, again, very hot young stars. It is this congregation of hot stars, so many in such a small area of the sky, that has led astronomers to believe that stars are formed by gravitation in the nebulae.

The Russian astronomer, Ambartsumyan, has postulated that when stars are formed in such a nebula, they must assume some sort of motion , due to the same laws of gravity which formed them in the first place. When they begin moving, they must leave the cloud, and

Ambartsumyan believes that in the next few tens of millions of years, the Trapezium must break up and will not longer be seen, each star going it's own individual route.

There is a class of stars, T Tauri stars, which are not hot young giants at all. They are very small cool objects, which from time to time, undergo quite spasmodic changes in brightness. It is believed that these stars eject great filaments of matter, and at the same time draw in other filaments of glowing matter. It is believed that these are the stars in the very process of formation.. They have ages of only a few million years. It is interesting to note, too, that the largest concentration of T Tauri stars is right in the middle of the brightest portion of the Orion Nebula.

It ahs been proven recently that the Nebula is in rotation, and that certain stars, in other portions of the sky, are racing madly away from the Orion Nebula. It would seem that some great cataclysm occured there in the not too distant past, cosmically speaking.

So, the Orion Nebula is really some sort of cosmic melting pot, containing raw matter in the form of hydrogen, and in which the stars are brewed up under the hand of Gravity. What a fascinating place!

The Great Nebula is not the only cloud in Orion. Another interesting piece of cosmic gas and dust is located just to the south of Alnitak, the star which marks the left side of Orion's belt. This is the Horse-Head Nebula.

The Horsehead Nebula is aptly named, for it does rather resemble the head of a knight, or horse, such as you would see an a chess table. What it is, in reality, is a dard cloud of gas, which by coincidence, has assumed the background of an illuminated area, which resumably is farther away.

Of course, nebulae are not the only interesting objects in this part of the sky. To me, one of the most interesting, and certainly the most frustrating, is a variable star, U Orionis. Now this star is extemely frustrating since it has a period of variation of 372 days, which as you will note is only twelve days longer than a year. Now, it just so happens that the time of maximum brightness occurs when the Sun is in that portion of the sky, and minimum is so faint that the star is not bright enough to be seen in my telescope. However, that 12 days difference is accumulating and in about 10 years, U Orionis will be visible at maximum in my telescope.

Both U Orionis and W Orionis, another variable star, are red giants, nearing the end of their lives as stars. They make for interesting watching, and this, of course, is the field where amateur astronomers can play such a vital role. W Orionis, particularly is visible with a pair of binoculars, and although it varies quite regularly, sometimes exhibits some interesting changes.

Orion, then, is quite a mixture of stars. It has these great associations of young hot stars, connected with the Orion Nebula, that great cloud from which they were formed. It has a few old-timers, such as Betelguese, which is not really part of the main grouping about 1600 Light Years. The distance to Betelguese, if you will recall, is about 520 light years, and thus, it sits in front of the association of hot stars. The variable stars that I mentioned, too, are in front of the main group, although, it must be admitted that the T Tauri class of variables is imbedded right in the Nebula itself.

The sky, as seen from a hypothetcal planet located in the middle of the constellation, must be an amazing sight, with literally scores of suns in the sky. Certainly it could never get dark.

That is not to disparage the sky as seen from the Earth, since we here are fortunate in having dark skies, so that we may look out, and see all of the fantastic sights in the Universe, including the constellation Orion.

18. Venus

Italics: In the late 1960's and the early 1970's, both the Soviet Union and the United States sent space probes to the vicinity of Venus. In fact, one of the Soviet probes attempted a landing there. In order to bring my viewers up to date on the findings of these probes, and to review what we already knew about Venus, I presented a programme on the subject of that planet on Sept. 18, 1972.

Regular Type:

Venus, the Goddess of Love! Beautiful Morning Star! Inspiration! No other planet has ever been so associated. This association goes far back into the pages of antiquity, and no one knows how many vows of love have been made in the light of this celestial diamond.

We do know however that the ancients were mistaken in one belief. They thought that Venus was not one planet, but two! You see, we are dealing with the days when the Earth was believed to be flat. As the ancient astronomers observed the sky, they saw that at certain times of the year, a bright white object was visible in the evening sky after the sun had gone down. They also noted that at certain other times, a bright white object was visible in the morning sky before the Sun came up. It did not occur to them that these two objects were one and the same.

As a morning star, the planet was known as Lucifer, and was supposed to have been one the steeds pulling the chariot of Apollo the Sun-God, and thus, had to precede the Sun across the sky. As an evening star, it was known as Hesperus, and was to have been the point of the spear carried by Achilles. Not until the time of the Romans was it realized that these two were the same.

The reason for the double appearance is, of course, that Venus is a planet and as such, revolves around the Sun. It is closer to the Sun than we are here on the Earth, revolving at a mere 67 million miles in an orbit which is virtually circular. At this distance, Venus takes 224 days to complete one revolution.

Since Venus is closer to the sun, than we Earthlings, its revolution gives rise to some rather startling effects when you view Venus through a telescope.

All bodies in our solar system are illuminated by the Sun. Like all other opaque bodies, when a light falls upon them they are half dark and half illuminated. The illuminated side is always turned towards the light source. When Venus is at A in figure 26, its illuminated side is pointed towards the Sun, but since it is on the opposite side of the Sun, it is also pointed toward the Earth.

(figure 26)

Naturally, since the planet is now 160 million miles from us (the combined radii of Venus' and the Earth's orbits) the disc of the planet is extemely small. Hence, Venus is very faint, and cannot be seen at all.

When Venus swings around to B, the illuminated portion still faces the Sun, but one half of the illuminated portion is on the side of the Quarter Moon. The reader can see that as Venus progresses farther and farther around its orbit, more and more of that illuminated portion which faces the Sun is turned more and more away from the Earth. Hence the Quarter Moon shape becomes narrower and narrower until it finally fades from view. Then Venus passes between the Sun and the Earth and the whole cycle is reversed with the cresent getting larger and larger, reaching Quarter Phase, and then going on until the whole illuminated disc is seen from the Earth. You can also see that as Venus progresses around its orbit, the apparent size of the disc seems to grow, since the planet is getting progressively closer to us. At its closest point, when the illuminated portion is virtually invisible, the planet is only 26 million miles away (the difference in the radii of the planetary orbits).

Since Venus is largest when the illuminated portion is turned away from the Earth, and smallest when facing the Earth, it is a very difficult planet to study.

Galileo was the first to notice the phases of Venus. He saw them first in September of 1610. To say the least, he must have been rather startled by its appearence, but in order to reserve priority for having discovered this, and in order to avoid getting into more trouble with "The Authorities" he published a small anagram:

"Haec immatura a me jam frustra lenguntur,o.y."

My Latin isn't the best, but translated, it says, "In vain, these things were gathered by me today prematurely."

It ahs been pointed out that if you re-arrange the letters of this to a different order, you get: "Cynthiae figuras aemulatur mater amorum." This means: "The Mother of Loves imitates the phases of Diana."

With a little patience, you can check to see if both sentences contain the same number of a's etc...

Somehow, the "Authorities" did find out about Galileo's discovery and when one of them questioned him about it, he replied that although there were many investigations to be carried out, he was in rather bad health and should be home in bed, rather than out in the open, looking at the stars.

It can be seen from figure 26 that there must be quite a variation in the brightness of Venus, depending on the most favourable combination of distance and illuminated portion. This generally occurs when Venus is about one fourth illuminated as seen from the Earth. When at its brightest, Venus can be seen in the daytime. During World War II, many spotters mistook it for a high-flying aircraft. Back in 1797 it was visible over Paris as Naoleon was being recieved by the citizens of that city. How that must have pleased him.

In more recent times, Venus has been mistaken for a flying saucer, especially when seen through shimmering heat of a summer evening. The heat seems to make Venus dart this way and that, and I recall more than one intance when the police have gone racing down the highway, sirens screaming, in pursuit of the "flying saucer".

It has been said that Venus, at maximum brilliance, can cast a shadow on a clear moonless night. I must confess that I have never seen this happen, but it has been written and said so many times, that I am beginning to suspect that there must be some truth in the statement.

While we are on the subject of Venus' brightness, let me repeat the warning that we give so often. Don't be among those foolish people who, on hearing that Venus is visible in the daytime, go out and look for it with binoculars. They usually begin sweeping around the sky, and invariably encounter the Sun, especially since Venus is so close to the Sun. This results in instant blindness! So don't do it!

The best way is to get some amateur astronomer to calculate haw many minutes ahead of or behind the Sun that Venus is travelling. Then get yourself into the shadow of a north-south wall and wait. At the appropriate time Venus eill be there along the wall, so many minutes away from the Sun. Then you can look with binoculars or a telescope of you wish, for you are in the shadow of the wall and the Sun is not visible from your location.

Venus can be as much as 48° away from the Sun, and this means that it is about three hours behind the Sun when setting or three hours ahead of the Sun when rising.

So, now that you know where Venus is, suppose that you take your telescope and look at it. Most people are disappointed at first, although

I must confess that I was not! The majority of people are disappointed since they can see nothing of the dazzling disc except its cresent shape. There are no surface features or markings such as you would see on Mars or Jupiter, respectively. Only in exceptional cases are there any sort of vague markings on the disc. These are rarely more than dark smudges and whenever you try to draw them, you always make your drawing too contrasty. Nevertheless, these markings do appear from time to time, and rather than try to make a dead-accurate sketch (which would be impossible in any case, since I am no artist), I make a rough outline of the shape of the marking and try to guage its darkness on a scale of 0 for white and 5 for black. In most cases, I have to write 1 or even ½ beside the marking, since, at best it is very slightly darker than the rest of the disc.

The reason why we don't see any of the markings on the true surface is that Venus is covered with a thick veil of clouds, so dense that we cannot see the surface below.

Nevertheless, astronomers maintained for years that they had discovered the rotation period of the planet by observing these markings. Father de Vico, working from Rome in 1839 determined the period at approximately 23 hours 20 minutes, the same as had been determined by Cassini nearly 100 years before. Some others guessed that Venus has a "captured" rotation which means that it always keeps the same face toward the sun, resulting in a hemisphere totally lit, and one perpetually in the stygian darkeness of the Venusian night. In between were "twilight zones", semi-lit. In fact, I remember reading, as a youth, about how moderate temperatures might exist there, resulting, as the scince-fiction writers would have us believe, in civilizations flourishing amid luxurious vegetation. This really is in the realm of science fiction, as we shall see later. The conditions on Venus are not suitable for any sort of life as we know it. But more of that later.

The "captured" rotation of 224 days was supported until recently by most of the professional astronomers. Their opinions were based on the best available data of that time.

Strangely enough, the dark portion of the Venusian disc sometimes displays a gentle glow, which has drawn the attention of astronomers. This glow is known as the "Ashen Light". When this occurs, the entire disc is visible, much as when we earthlings look at our own cresent Moon. We sometimes see the remainder of the Moon bathed in a gentle light. This light comes from the Earth. But what of the Ashen Light? Venus has no Moon to provide any sort of back-light, so what could provide the impetus for such a glow?

Various theories were put forward, Aurorae were considered but now have been dicounted, since Venus has been shown to be lacking a magnetic field. Phosphorescent clouds are another possibility. The one that strikes me as being one of the more interesting is that this is the light from torchlight parades, celebrating the crowning of a new monarch of the planet. In view of the frequency of the ashen light, they must change the rulers frequently. And please remember that I said it was interesting. I did not say that I believed it!

Recently, controversy has raged over whether or not the ashen light is seen merely an optical illusion. Certainly, evidence is strong that it is an instrumental defect, since it is claimed that the ashen light seen only in a refracting telescope, and never in a reflecting telescope.

What is below those clouds in the atmosphere of Venus? We just do not know! Occasionally, clearings do present themselves, but no surface markings have been seen. Whatever is on the surface, we know that it is extremely hot.

This has been reasoned out by two methods. One is a theoretical approach, based on the observational data, and the other is a practical approach.

The theoretical approach is called the "Greenhouse Effest". A greenhouse is a structure with a glass or plastic roof which lets the Sun in and provides a warm place for thr growing of tender young plants before they are set out in the ground where the elements can get at them. The heat and other radiations of the Sun pass through the transparent substance in the roof, and on striking the surfaces of objects within, are changed to longer wave-length radiations, which cannot escape through the roof. Thus the energy is trapped and the temperature goes up. The same is thought to be true with Venus. The Sun shines down through the semi-opaque atmosphere of Venus and strikes the surface below. The radiation is changed to a longer wave-length and cannot escape. Up goes the temperature. Based on this, it was thought that the temperature on the surface must be very warm.

Here again, the science-fiction writers have a field day, envisaging great steaming jungles of tropical plants, inhabited by huge dinasaurs.

The matter was determined, in reality, by Soviet and American space probes, Venera, and Mariner, respectively. These probes either flew by at close range, or attempted to land on the planet. Both types of probes indicated that the temperatures on Venus were in the neighbourhood of 800 degrees Fahrenheit! This would certainly rule out any jungles as we know them.

Further, the rotation period has been determined recently by radar methods. Now, if you know about getting a ticket for speeding, you already know about radar. The police have a little device which points up the road, bounces a radio signal off your car, and tells the offiver how fast you are going. The same is true, in a sense of radar astronomers. They bounced signals off both edges of the Venusian disc. Since one edge is approaching and one is receeding, and we do know the circumference of the planet, We can soon obtain the rotation rate from the rates of the two limbs. Scientists calculate this rotation rate as 243 days, in a backwards direction. That is unusual since the Sun, and all of the other planets, with the exception of Uranus, revolve in the same direction. Why Venus should revolve backwards is a mystery, but this shows the vitality of Astronomy as a science. As soon as you solve one mystery, the rotation period, for instance, you have another one to solve, namely the reverse rotation.

Venus has been called the Earth's sister planet mainly because the sizes and masses of the planets are similar, but there the similarity ends. The diameter of Venus is 7,560 miles, while that of the earth is 7900 miles. The mass of Venus is eight tenths that of our native planet. Whereas we have a perfectly wonderful atmosphere (Pollution notwithstanding!) composed of nitrogen and oxygen, with a few other substances mixed in, Venus atmosphere is totally different. The Venera 4,5 and 6 probes of the Soviet Union have shown that the atmosphere is composed mainly of carbon dioxide with no oxygen or water. The United States Mariner V agrees with this.

These probes also indicate that the Venusian atmosphere is very dense. The pressure at the bottom of it is many times that of the Earth's atmosphere. And, as we have noted earlier, the probes indicated a temperature of 800 to 900°.

Whether or not there are life forms that can tolerate such extremes is not known. Certainly it is not to be expected. On the basis of our present knowledge we can assume that the surface of Venus is probably barren and wind-swept.

From time to time, Venus passes directly in front of the Sun. Then, we see the actual surface silhouetted against the bright background of the solar disc, and surrounded by its atmosphere, which appears like a faint grey ring. This is called a "transit" of Venus. Transits do not happen on every revolution around the Sun, for the orbit of Venus is tilted up at an angle of a little over 3°. This is not much of an angle, but when you realize that the Sun is $\frac{1}{2}^{\circ}$ in diameter, you know that this inclination is enough to carry Venus either above or below the Sun, depending on the circumstances. Transits, therefore, are very rare, occurring at intervals of $105\frac{1}{2}$ and $121\frac{1}{2}$ years. As we shall see, they were very important to astronomers, as they allowed accurate measurement of the Astronomical Unit for the first time.

The first transit to have been observed scientifically was that of 1639, and was monitored by Jeremiah Horrocks and William Crabtree, two English astronomers. What they did was to measure as accurately as possible the exact times of the four contacts.

(Figure 27)

In figure 27, we see at the left, what is known as first contact. The outer edges of the two discs are just touching. This is usually quite difficult to determine since Venus must encroach upon the solar disc for a little way until it is seen. The next diagram shows second contact. This, too, is hard to determine, since when the two discs are very nearly tangential, a "Black Drop" seems to appear, connecting Venus to the limb of the Sun, as shown in figure 28. Third and fourth contacts are the reverse of the second and first respectively, and have the same problems attached.

(Figure 28)

The next transits were to occur on June 6,1761,and on June 3, 1769. Sir Edmund Halley, whose name is associated with a rather bright comet, suggested a rather novel method of finding the distance to the Sun if these transits could be accurately measured. Unfortunately, he did not live to see his method employed, much as he did not live to see the return of the comet, which has since been named after him. In fact, Halley's method has been employed only four times, at the transits previously mentioned and at those of December 9,1874 and December 6, 1882.

As you can see, transit-watching is a rather long-term affair, and I think it safe to say that no astronomer has ever seen three! The next transits of Venus will occur on June 8,2004 and June 6,2012. After that, you will have to wait until December 11,2117 and December 8,2125. While I hope to see the next two, I doubt very much if anyone alive now will see the two after that!

I should like to turn aside now from our academic discussion of Venus, to point out two stories, which may strike you as rather amusing, as the second of the two concerns myself. But, first things first.

I have pointed out how important transits of Venus are, and part of Halley's method requires observers to be widely spaced. Considering this, astronomers go to all parts of the globe to observe transits. One such was a French astronomer, Le Gentil de La Galaisiere.

Le Gentil was asked to observe the transit of 1761 from India, part of which was then a French colony. However, naval warfare on the high seas delayed his ship, and he missed the transit. Being an idea man with a capital "I", he knew that transits came in pairs, about 8 years apart, so he just settled down in India to await the second. In the meantime, he built an observatory, learned the local language, and learned what he could of Hindu astronomy. Finally, after 8 years of waiting, the big day arrived.

But as fate would have it, just before the transit was to occur, a storm blew up and covered the Sun with thick clouds. The storm lasted until just after the transit, when the Sun came out again and shone down in its full radiance.

Totally exhausted by the rigors of the climate, and by the great disappointment, he faded into obscurity for two years, when he returned to France. Much to his surprise, everyone thought that he had died. His seat in the Academy of Sciences had been given to someone else. He was forbidden to reclaim his estate since it had passed into other hands, as the courts had ruled that he was legally dead! Poor Le Gentil!

The other story concerns myself. It is not so tragic. It does not concern a transit, but rather, the moon of Venus. Now most astronomy books will tell youthat Venus has no moon, but I want to relate to you now, how I discovered the attendant of the subject of this essay, the planet Venus.

In the summer of 1965, I was camping with my wife in the campground of Mammoth Cave National Park, Kentucky. It is my habit to carry a small four-inch telescope in my car when I leave home, and this time was no exception. The telescope enables me to carry on my observations of variable stars, but this time I was pointing it toward the planet Venus just after sundown on a warm summer evening. The magnification was quite low, but there beside the planet was a very faint object, twinkling a bit in the twilight. Naturally I was curious about this and decided to watch for awhile. As it got dark, the object became more visible. It did not appear to move with relation to the planet, so I knew that it could not be a high-flying aircraft. I did not say anything to anyone, but simply made a note of it in my book, and then went on with the rest of my observations.

The next night, I set up the telescope again at the same location. Again, I looked toward Venus.The object was still there, but this time, it had moved to the other side! I got very excited,to say the least! I called to everyone in the campground to come and see my newly-discovered Moon of Venus. Everyone lined up and peered through the eyepiece and went away suitably impressed.

Within the next few days, I returned home, and wanting to document my discovery, decided that I had better get some facts and figures with regard to the finding. One of the first things that I had to determine was the position of the planet, so I turned to my catalogue and looked up the location of Venus for that particular date. When I got looking at the figures, I began to laugh, for they looked very familiar indeed!

They were the approximate figures for the location of the star, Regulus, which is one of the brightest stars in the sky! How stupid I had been! I had not waited until it had become totally dark in order to see the star-patterns around the planet! I had jumped to an erroneous conclusion. I suppose that the really funny part of the story is that there are still 50 or 60 people from all parts of the United States and Canada that believe that they were present when I discovered the "Moon of Venus".

Nevertheless, this brings to a conclusion our discussion of Venus. It is a hot hostile place about which we do not know very much. We must resign ourselves, for the time,to humble ignorance.

19. Meteors

Italics: The programme of April 10,1972, began in a most unusual manner, with me, lying flat on my back in a sleeping bag on the studio floor. I remained there for some 5 minutes while I talked to a camera poised directly over my head. I outlined the equipment necessary for the observing of some of the smallest members of the Sun's family, meteors.

Regular type:

The scene is one of idyllic calm. A faint zephyr moves the trees, which rustle gently. Far off, the cry of a loon pierces the night, while, closer, the chirp of crickets provides a musical rhythm for our contemplations. The stars twinkle down in a cloudless sky. There are so many stars that they seem inumerable. At the edge of the lake, small ripples lap gently up against the beach.

Suddenly,the stillness of the August evening is shattered, not by a noise, but by light, as a great yellowish-red object darts across the sky, leaving a trail of fire behind it. As quickly as it had come, it disappears, and you remark,"That was a falling star!"

But it was not a falling star at all. Stars do not fall. The move inexorably through space guided by the laws of physics. No, you did not see a falling star, but a meteorite.

Falling stars, shooting stars, or meteorites are simply fragments which we see. Other than atoms, molecules and dust grains, they are the smallest of the objects which inhabit this great cosmos. What happens is that these tiny fragments encounter the atmosphere of the Earth, and, since they are travelling at a great speed, the friction of the air rushing by them causes them to heat up, glow fiercely, and, as denser air is encountered, to vaporize completely. Occasionally, one does not vanish totally and it lands on the Earth, and is recovered,hopefully, by some scientist for study.

Now, so far we have spoken of meteorites, while the title of this chapter is "Meteors". What is the difference? It is simply a degree of position. While the fragment is in space, beyond the atmosphere of the Earth, it is a meteor, and after it lands, it is a meteorite. There are different classes of meteorites, as we shall see, but we need not go into them at this point. Let it be sufficient to say that the classes are based on the composition of the meteorite.

Since these bodies are not visible until they encounter the upper atmosphere, we can ask,"Just how high are they?" This question can be answered by amateur astronomers, working in teams. Professional astronomers interested in meteorics do the same thing but with cameras instead of teams of observers, though let it be said that the observations made by amateurs are greatly desired by their professional colleagues.

What is done is to set up two observing stations about 20 miles apart. When they object appears, the observers record, as accurately as possible, the path of the object as seen against the starry background. The path will appear slightly different due to the perspective gained by having the observers at two different locations. As we said, the professional astronomer gets his observations on film. When all of the records, both visual and photographic, are in, analysis begins. It takes only a little computation to determine the heights of the objects. The average elevation of the track of a meteor is about 90 miles, the lower end 30 miles, and the average length of path is about 200 miles. Naturally, there is some variation with bigger and smaller, faster and slower, but we have given the average.

A very interesting effect is seen when the tracks of a group of meteors seen on a single night are plotted on a star map. They all point to the same general area of the map. It is from this area that the objects seem to come and this is called the "radiant".

I should point out here that meteors seem to occur in swarms, or showers, and that each shower has its own distinct radiant. It is true that the occasional sporadic meteor occurs, but the great majority are shower meteors and seem to come from the same well-known radiants. Hence we have the Perseids coming from the constellation of Perseus, the Leonids from Leo, and the Orionids from Orion. Where there is more than one radiant in a constellation, the shower is named after a bright star near the radiant point. We have, as examples, the Gamma Aquarids and the Eta Aquarids. I should also point out that the radiants don't emit meteors all of the time, but only during specific periods of the year. The Perseids, for instance, occur during a few nights on either side of August 12th, while the Leonids occur only near November 15.

These two are sometimes really spectacular showers. The Perseids are characterized by very large slow-moving objects, which often have long fiery trails after them. Where the air is ionized by their passage, there is often a streak left in the sky for many minutes. The Leonids are shorter and quicker meteors. However, they are, during some years, particularly numerous, and on some nights, the sky seems literally on fire. As many as 330,000 in one hour have been noted.

Where do they come from? It seems that meteors are the debris left over from the dissolution of comets, and they travel around the Sun in elongated comet-like orbits. A shower occurs when the Earth encounters one of these orbits. The density of the shower depends on how long ago the comet dissolved. For instance, a newly-formed meteor group would still be bunched up in one place i n its orbit, since it was not long since they were all members of the same object. I think that this is probably the case with the Leonids, where we have a relatively heavy shower, with the Earth encountering a large group that is not dispersed. On the particular night when they sky seemed to be "on fire" the Earth probably encountered the remains of the comet head.

On the other hand, a comet that dissolved many years agg would have its fragments spread out along the orbit, so that we will get a light shower every year.

There is some observational data for this. Back in 1852, Biela's comet was seen to split in two. On the following apparition, the two components were a million miles apart. On the next apparition, the two comets were nowhere to be seen, but a particularly heavy meteor shower occurred. A shower has occurred every year since then, but it is only a light one, known as the Andromedids.

Now that we know what they are, where they come from and what causes their appearance in the sky, let us see what the various kinds are. Meteor scientists have classified them into three main groups, namely aerolites, siderites and siderolites. They signify rocky meteors, metallic meteors and rocky-metallic meteors respectively. There is also a fourth classification known as tektites, which are rather glassy in appearance, but we shall say more about these later.

Now, rocky meteors are just that, hunks of rock. The minerals in them are not really unlike those found here on the Earth. In fact, for precisely this reason, it is virtually impossible for the layman to tell whether a certain rock is meteoric or not.

Metallic meteors are composed of (mainly) iron and nickel. Isn't it strange that these two elements are the main elements in the core of the Earth? Could it be that comets and meteors originated in the debris of an iron-nickel planet which exploded? Here, I am merely conjecturing and not offering anything other than ideas. We have no proof for this whatever .

Rocky-metallic meteors contain mostly rock but with a good proportion of iron-nickel.

In numbers alone, the vast majority of meteors, and hence, meteorites, are aerolites, or, the rocky kind. Why this should be, I have no idea!

These visitors from space come in all sizes and dimensions, as we have mentioned before. Many of these have been carefully preserved in museums all over the world, but many others have been left where they have fallen. This is largely because of their massive size. They are too large to be moved. It seems to me that the fall of extremely large meteors was more common in the past than it is today. All that we need to do is look at some of the extremely large craters which dot the Earth and the Moon and realize that these were made by the impacts of celestial visitors.

Meteor craters on the Earth include some that are famous and some that may be rather obscure. I suppose that the most famous is the Barringer crater in Arizona. It is a vast gaping pit located 17 miles north of the city of Winslow. The diameter is some 4,000 feet. There is a rim around the crater which is 150 feet above the surrounding plain and is 600 feet above the deepest part of the crater.

An even larger crater is the Chubb Crater in northern Quebec. It is 850 feet deep and is 2 miles across. It is filled with water, which has filled it to its present depth. Under the sediment, the crater is 1,350 feet deep.

Nearer to home, and completely accessible to the great populated areas of North America are two craters in Northern Ontario. The largest is the Sudbury Basin which is just to the north of Sudbury,Ontario, a great mining centre which produces some 85% of the nickel of the world. This basin is about 38 miles long and 17 miles wide. Its flat arable bottom is certainly a contrast to the rocks and forest around it. Pleasant homes dot the floor of the basin and prosperous farms exist, despite the unfavourable climate at this latitude.

Like large lunar craters, Cpernicus, for instance, the crater comes equipped with concentric ridges surrounding the main ring. It also has a pronounced central peak, the same as lunar craters. This peak is a rocky ridge about one quarter of a mile in width by one half mile in length. I estimated the height to be some 200 feet. It is located near the village of Chelmsford.

The north rim of the crater is heavily forested, but is broken by a magnificent waterfall where the Vermilion River pours into the crater. The south rim is wasteland, where no tree, no bush, no shrub and no grass can grow. It is starkly desolate. In fact, it rather reminded me of the surface of the Moon, as I drove through it in 1973. Because of the great desolation here, it is a training-ground for American astronauts.

What causes this fearful barrenness? Indirectly, the meteor does! Evidently, when this great object fell from the heavens in pre-historic times, it cracked the crust of the Earth. Molten lava, containing iron-nickel concentrates, welled upward through the crack and then solidified. Today, miners work in the bowels of the Earth,extracting this iron and nickel (mainly nickel.) As I said earlier, some 85% of the world's nickel supply comes from Sudbury. It is smelted right there, and it is the gaseous emissions from these smelters which cause the desolation. For miles and miles down-wind from the smelters, there is only stunted vegetation. I wonder what the effect of these gases is on the human and animal population of the area.

The other crater is smaller but is accessible if you wish to have a small automobile adventure. This crater is the Brent Crater and is located in Algonquin Provincial Park in Ontario.

Algonquin Park is a wilderness area od 1,754,240 acres located about 100 miles northwest of Ottawa, the capital of Canada. Originally, there was extensive logging in the area, but this has been stopped and now the park is the exclusive habitat of bears, wolves,beavers and the other animals that are commonly associated with the forests of Northern Ontario. Even the tourist sees very little of the park, since the main tourist road passes through but the southern tip of the park. It really is a wilderness to be preserved for future generations.

The Brent Crater is located in the northern extremes of the park, near an outpost by the name of Brent. This community is accessible only by a one-lane bush road from the highway which passes to the north of the park. This is what I meant when I said that you could have an automobile adventure. It is 25 miles in to the crater, and 25 miles back, over a very rough rocky road, with no gas stations, no stores, no homes and no human beings at all! If you were to suffer an automobile breakdown on this road, you would have two choice.....walk to one of the ends of the road for help, or just wait until someone happened to come along.

Near Brent, there is a lookout tower some 60 feet high, from which you can see the crater. This tower is on the east rim and you can look out over the central peak to the west rim beyond. The crater is two miles across and is circular. On the interior are a lake, Gilmour Lake, and a central peak. I estimated this peak as being 400 feet in height and about three quarters of a mile in diameter. All of the crater and the cetral peak, except the lake of course, is covered with a very dense conifereous forest. The crater is 1400 feet deep but has been filled up with 500 feet of sediment, so that its present depth is 900 feet.

Strangely enough, this circular depression was not recognized as a meteor crater until 1951, when aerial photographs were taken of the region. Following the noting of the area, scientists came to the crater, equipped with drills. By boring down into the crater, they definitely established that the crater is of meteoric origin. It seems that the object fell about 450 million years ago, when the area was covered by a shallow sea. The object struck with the force of 250 megatons of TNT, but the explosive effects were somewhat lessened by the effects of the water.

It may be that there are more meteorite craters in North America. Look at a map. The number of circular features is amazing. Was Hudson Bay caused by a fall? What about Ungava Bay at the northern tip of Quebec? The Gulf of Mexico is circular. It it of meteoric origin?

Of course, the objects which caused these great craters must have been very, very large. They were much larger than the ones that we find in museums today. The largest specimen ever recovered is one found in Greenland by Robert Peary, the explorer who first reached the North Pole. It is 12 feet long, 7 feet wide and 6 feet thick. Its weight is 36 tons!

The smallest meteorites are known as micrometeorites. They are so small that you can see them only through the microscope. Their small diameters prevent them from burning up like the larger varieties. Instead, the settle slowly through the atmosphere. They may be recognized easily under the microscope simce many are perfect spheres, while others show small air bubbles, due to their passage through the atmosphere while still in a molten state.

If you have a microscope, or can borrow one, you may want to try to find some micrometeorites. They are very plentiful and may be found practically anywhere. The best places to look for them are in eaves-troughs and on window-ledges. All that you have to do is scrape up a little dust on a microscope slide, and, voilà, there you are! A friend of mine found some the very first time he looked!

I have purposely left the discussion of tektites, the fourth classification of meteors until last, as there is some doubt as to whether they are really meteors in the true sense of the word. As I said before, they look like pieces of green glass. This is due to the fact that, essentially, they are made of the same materials as glass. They are 80% silicon dioxide, with the rest being composed of metallic oxides.

You don't find tektites spread randomly over the globe, as you do with the other meteorites. They are found in very specific areas; in particular, Australia, Moldavia, Java, Malaya, Indo-china and the Sahara Desert. The first was discovered by Charles Darwin, he of the evolution theory, in Australia,hence the name "australite" for this particular substance, though in some countries, it is known as "moldavite", after Moldavia which is a part of modern Czechoslovakia.

I said that they are not meteorites in the usual sense of the word, since there is some controversy as to their origin. One of the most fascinating theories is that they originated on the Moon! It appears that several of the larger craters, such as Tycho, Copernicus and Kepler, were created by the bombardments of very large meteors. Some scientists calculated that some of the debris splashed out from the creation of these craters would reach the Earth. They postulated that the debris would arrive in showers landing in long narrow strips. This is exactly what we find, but I don't know whether this is making up theory to fit observations, or finding the observed effect after the theory has predicted it! One thing in favour of this theory is that the glassy nature of the tektites certainly matches up with the glassy nature of rocks brought back from the Moon by Apollo astronauts. Whatever their origin, tektites certainly are an interesting class of meteorites.

In fact, all meteorites are interesting to astronomers. They are the only celestial bodies, other than those moon-rocks, that we can actually touch. All other bodies have to be observed instrumentally. Many new facts have been learned by the study of meteorites, including the discovery of some organic compounds! This could be a sign that, indeed, there is Life out there in the Universe. At any rate, meteors will always be a field of study which will interest astronomers for some time to come.

I hope, too, that they will interest you, interest you sufficiently that when you see a "falling star" you will note the time and its direction of travel and report it to some local amateur astronomer or professional astronomical agency.

20. Eclipses

Italics: On July 10, 1972, the spectacle of a great solar eclipse was to be visible in Eastern Canada. It seemed appropriate, therefore, that I inform the viewers about eclipse and with that in mind appeared in the 48th programme of the series on June 12, 1972.

Regular type:

It is a pleasant summer day. The winds wafts through the willows, the birds warble sweetly thier songs and calls, the flowers bloom in a splash of colour along the hedges, and cows low contentedly in thier green pastures. Even though there are no clouds in the sky, it has been growing noticeably darker for the past hour. An uneasy feeling pervades the atmosphere.

Suddenly, the lights falls off and it is dark, not totally dark as you can still see things around you, but dark as an evening shortly after sunset. The flowers clutch in thier petals as if night has descended. Noisily, the cows plod wearily towardsttheir barn. The birds fly crazily to and ffo, looking for their nesting places. The wind grows noticeably cooler. You gaze skyward to see what has happened, and there you are greeted by the most spe ctacular of nature's phenomena, a total solar eclipse.

The sun, evidently, has turned black. Surrounding it is a glow, etched by pearly streamers. Here and there a pale pink protuberance extends out into the glow for a short distance. You watch dumbfounded. For several minutes this grand celestial display continues. Then there is a flash as a diamond of light stabs through at one side of the blackened solar disc. You turn away, dazzled by the brilliance. Quickly you get some sort of protection for your eyes. As you watch the sun returns, first as a cresent, and then as the whole disc. It is over! You have seen a total solar eclipse.

You are lucky! I have not! The above description is drawn mainly from books and from chatting with other amateur astronomers who have been fortunate enough to have witnessed this display of celestial beauty.

Actually, there are two kinds of total eclipses, the Total Solar Eclipse, and the Total Lunar Eclipse. There are also partial eclipses, and a very interesting type known as the Annular Eclipse, about which I shall tell you, gentle reader, later in this chapter. But first, let us dicuss that particular phenomenom which I have already described to you.

Of course, nowadays, we know what causes eclipses, but in ancient times this was not known, although, no one would listen to the sevants of that particular age, who did put forward the correct theory of the mid-day darkness. At any rate, it is written that eclipses caused great fear in ancient man, and I suppose, today, it would cause a rather uneasy feeling in anyone who wasn't prepared for it. In that case, we can imagine that our prehistoric ancestor might have gone screaming in fright to his very safe cave of refuge, peeking out bit by bit until he saw that normal day-light had returned. Or perhaps he might have thrown rocksat the evil demon which had devoured the Sun.

This latter idea is attributed to the Orient. There it was thought that a dragon was devouring the Sun. The residents who happened to be in the eclipse path would rush out, banging on thier pots and pans, screaming, shouting, and making a veritable pandemonium until the dragon spat out the Sun (rather a hot mouthfull, anyway) and the daylight returned to normal Legend has it that the Chinese placed grat astrological significance in eclipses, and that they had worked out a system for predicting them. It seems that two astologers had worked out that an eclipse would occur the very next day. So elated were they by thier success in calculating the precise figures that they decided to have a little party. They got very drunk , and, in doing so, forgot to inform their Emperor what was about to transpire. Of course, panic set in at the Great Imperial Court and Hi and Ho (the alledged names of the astrologers) were hauled before the Emperor. They were summarily sentenced to be executed. Alas! poor Hi and Ho! (good names for drunken astrologers!)

That is legend. But there are real historical facts where people have been terrified by a solar eclipse. Away back in 585 B.C. the armies of Media and Lydia, were having at it. The battle raged for many hours, until the sun grew dark. The two armies were taken agog that they dropped thier weapons and promptly made peace, fearing that they had angered the gods. If they had listened to Thales, a philosopher of a neighboring state, they would have known what was going to happen as he had predicted this eclipse a few months earlier.

In Mark Twain's story "A Connecticut Yankee in King Arthur's Court" an eclipse plays a prominent role. The tale, if you will recall is of a modern man who is somehow transported back to the age of Camelot. He is captured by King Arthur's servants and is challenged to a contest of magic by an evil knight (for the simple reason that he appeared to be a wizard, to thier point of view). He amazed them by lighting a match, a "firestick". Then he caused paper to burn by focussing a magnifying glass to allow the Sun's rays to do thier work. This still did not satisfy them, so he was chained to a stake, to be burned like a steak! Now it is extremely fortunate that he had memorized his almanac, for he was able to boast that he could make the Sun go away! Just at that very moment, a total eclipse was seen. Our hero was released and became very popular Lucky fellow! But enough of history and mythology. What really causes Eclipses?

You can be certain that it isn't dragons. It has all been de-glamorized and has veen simlified down to where it can be explained by the motions of three bodies, or to be accurate, of two bodies, relative to the Sun. Quite simply stated, the Moon passes in front of the Sun, cutting off it's light. See Figure29. It just happens that the Sun and the Moon are of the same apparent size in the sky, although the Sun is really much much larger. Howerver, since the ratios of thier sizes to distance are equal they appear to be the same size.

(Figure 29)

When the Moon transposes itself between the Earth and the Sun, the disc of the Sun is quite nearly covered, and all that remains is the faint pearly glow of the corona. I refer the reader back to chapter 3 for a discussion of the corona. Also the pale pink prominences are visible and these are also discussed in chapter 3.

So, quite simply stated, we can say that as the Moon in it's monthly journey around the Earth, becomes exactly between the Earth and the Sun then a solar eclipse occurs. More exactly, the shadow of the moon falls on the Earth as shown in figure 29. Those people who happen to be within the shadow itself see a total eclipse, while those people in the gray area surrounding the shadow see a partial eclipse, where the Moon covers only a portion of the Sun.

If the Moon revolves around the Earth once a month, why doesn't an eclipse occur every month? That's a fair question and I will try to answer this as best I can although it is going to take some mental gymnastics on your part. To put it simply, the Moon's orbit is tilted but as there are some people who don't like simple explanations, I will take a paragraph and a figure to elucidate. So, dear reader, look at figure 30.

(Figure 30)

Imagine the Moon's orbit to be solid, not mearly a circle, but filled in with material, sort of like a dinner plate. In fact, if you happen to have a dinner plate in your hand it will help to explain this! Now, the Earth is in the middle of the dinner plate and the Moon is somewhere on the rim. Let your coffee cup be the Sun. You know that the Earth, and the Moon go around the Sun once a year. So holding the plate vertical, and keeping the eating surface pointing in the same direction pointing in the same direction, let's say North, move it slowly around the coffee cup. With a little bit of observation, you can see that there are only two places where the coffee cup (Sun), rim (Moon), and the centre of the plate (Earth) are in exactly one line. This is the case in space. However, remember that the Moon could be anywhere on the rim at the time when the rim and centre are lined up so that eclipses don't necessarily occur at every time this alignment happens.

In actual fact, I have oversimpified, since the Moon's orbit (the plate in our anology) is not tilted up vertically but is almost lying flat. Almost but not quite! It is tilted up at 5.2^{o}, a very small angle but enough to make the Moon miss the exact point by sufficient room as not to cause an eclipse. This tilt carries the Moon, apparently, above the Sun or below it in most revolutions around the Earth.

Then there is the case of the one very near miss. This is what causes partial solar eclipses. The Moon does not pass centre-over-centre on the Sun but passes off centre. The entire solar disc is not covered, and we have a partial eclipse.

Somewhat earlier, I referred to an Anular Eclipse. The mechanics for producing an Annlar Eclipse is exactly the same as for the production of a Total Eclipse, except for one factor. Please refer again to figure 29. As you can see, the shadow of the Moon falls on the Earth. But, we have to remember that the orbit of the Moon around the Earth is elliptical. Because of this, the Moon is much closer in one portion of it's orbit than it is in another. When it is at it's farthest portion, the Moon cannot cast a shadow long enough to reach the Earth. Then we have a case such as shown in Figure 31.

(Figure 31)

What the Earthly observer sees, at first, is a partial eclipse. The Moon covers more and more of the Sun, but at maximum it cannot cover the entire Sun. It's apparent size is too small. Remember that apparent size and distance are linked inextricably Mathematics. Since the Moon is apparently too small to cover the entire Sun, what is left is a ring of bright sunlight surrounding the darkened disc of the Moon. A ring is also known as an annulus, hence the name "anular" eclipse.

At this point, let me sound a warning that could save you some pain. Never, under any circumstances, should you look at the Sun without adequate optical protection. I know that the temptation is probably the greatest at the time of an eclipse, and that is why I am including this warning in this particular chapter. The Sun shines with a brilliance that is about one million times that which can be tolerated by the human eye. Therefore, if even one-thousandth of the uneclipsed solar disc is visible, it is still one thousand times to bright for your eye. To look at any portion of the uneclipsed Sun with a telescope or binoculars might even prove fatal. Certainly, it would result in blindness. I dont't trust filters either , since they have been known to crack, since the telescope not only focuses light, but also heat. The safest way, by far, is to line the telescope up, by means of it's shadow, so that the sunlight is passing right down through it. All you need to do is place a sheet of white paper in the path of the light, focus the telescope, and there you will see the Sun, complete with it's spots. This is a totally safe method, since you are looking at a projected image of the Sun.

So far we have been discussung Solar Eclipses, but there is a different kind, namely, the Lunar Eclipse. Now, if you understand what causes Solar Eclipses, you also understand what causes Lunar Eclipses. The mechanism is the same. The only difference is that the Moon is on the other side of the other side of the Earth, so that the shadow of the Earth falls on the Moon. The shadow of the Earth is much bigger than the shadow of the Moon, because the Earth is a much bigger body. The whole Moon is immersed in the shadow of the Earth, and not just a tiny portion as we have in the Solar Eclipse. By the same mechanism, we can have partial Lunar Eclipses, just as we had partial Solar Eclipses.

The Moon does not disappear entirely when it is eclipsed. Rather, it takes on a hue which varies from eclipse to eclipse, At times, it is rather copperu, while at others, it is a rather leaden gray hue. This depends scientists say, on the condition of the Earth's atmosphere. The fact that the Moon is visible at all is due to the fact that the atmosphere retracts some sunlight, that is, bends it, so that it falls on the Moon. If the atmosphere is laden with dust and pollutants, then the eclipse is a dark one, since much of the refracted light is filtered out by particles in the air. If, on the other hand, we are in one of those rare periods when the atmosphere is clear, the eclipse takes on a coppery hue, since the light is not filtered out.

(Figur 32-- Lunar Eclipse)

By comparison of figure 32 with figure 29, you can tell that a Luna Eclipse may be seen from any portion of the moonward side of the Earth, whilst the Solar Eclipse may be seen only from a very narrow strip of territory where the Moon's shadow touches the Earth, This will have some bearing on what follows. Also note that Solar Eclipses may be seen in the daytime only, while the Lunar Eclipses are visible only at night! I once had a friend give me a report on a partial solar eclipse. He said that it happened at 2400 hours, which is the middle of the night! When I pointed this out, he realized that he had seen it at noon!

Since total solar eclipsws are seen only in a very narrow area, the shadow of the Moon, astronomers must travel, sometimes, great distances to intercept the shadow of the Moon as it passes over them. Thus, we hear of scientists packing up and moving off to the Sahara Desert, the Amazon Jungles or the South Pacific in order to see the eclipse. I don't mean that all eclipses are seen from remote locations such as these, but I have merely given you the extremes to show you what lengths astronomer will go to obtain thier data. Often, eclipses pass over inhabited areas, making it possible for millions of people to see the spectacle. I would like to tell you of my experience in eclipse-chasing for I have tried to see three, but have failed to see any!

So as not to risk boring you, I shall dwell only on the last effort which was that of July 10, 1972. This eclipse was to begin in the Northern Soviet Union. The shadow of the Moon would sweep along the coast of Alaska, over the Northwest Territories of Canada, across Hudson Bay, into Quebec, Prince Edward Island, Nova Scotia and then leave the Earth after crossing a wee portion of the Atlantic Ocean.

I had persuaded the management of the television station to let me record the eclipse on videotape, so that I could show it to my viewers back home. They even loaned me a cameraman-technician to look after the equipment. Very carefully, I selected my location, so as to be in the place which over the years had had the best weather on July 10. This I decided, was the small village of Les Mechins, Quebec, on the south shore of the St. Lawrence River.

We arrived at Les Mechins the day before the eclipse. The Sun was shining brightly from a cloudless sky as we set up camp. When night fell, a million stars twinkled down from the sky. I was so excited that I could not sleep. At 4 in the morning, I arose and quietly made myself a cup of coffee. Several cups of coffee later the Sun rose into a deep blue sky. By now I was hopping up and down in expectance of seeing my first eclipse. There was no way anything could ruin such a fine day.

Although the eclipse was not until 2:30 in the afternoon, things began to go awry at breakfast. It seems that I had forgotten to pack any cooking oil. Nevertheless, I cooked some pancakes, but when I started to take them out of the frying pan, they wouldn't come. They were stuck fast! The second batch of pancakes was cooked by Al Bauld (my camera-technician) with some butter borrowed from a nearby tent. Since he had cooked the pancakes, I was elected to do the washing up.

I am naturally inclined to be lazy, so when I saw the messy pot in which I had mixed up the batter for the pancakes, an idea struck me. Why not heat up some water in the pot and soften up the batter remnants, allowing them to just float out of the pot when I emptied it? I didn't realize that batter would cook under water! Not only that, it turns into a black ebony substance when overheated. And this is exactly what happened. Now I had a burned pot to clean instead of a messy one. What to clean it with? All good boyscouts know that you clean pots and pans with pebbles and sand. This I did, occupying myself for the next hour.

Finally, the pot was clean. One more swish of water and.....You silly clot! You poured water down your trouser leg!

By now, I was beginning to get an inkling that this was going to be a disastrous day. Still, the Sun was shining, and with great expectations we set our television equipment. We recorded a few interviews with some of the hundreds of other astronomers who were present, and then we settled back to wait for the totality to occur.

I must underline the fact that all of this happened under the bluest of skies. Not a cloud was to be seen anywhere. But, just twenty minutes before the Sun was to be entirely blotted out, a great bank of clouds rolled in. It was too late to do anything. What had I proposed to do, if it had been clear was to talk my way up to totality, and then at the appropriate minute, Al would swing the camera up showing the spectacle. Now the chance of all this was gone, and all that we could do was to have the camera focus on me. As the lighting failed, I would talk my way through into the inky blackness, even though the viewers could not see me. I would describe what I saw and what I noticed around me. Then, as the eclipse ended, I would magically re-appear on the screen, do a wrap-up, and then we could go home. So, this is exactly what we did. No pictures of a slendid celestial sight. No corona. No pearly streamers. Just me fading into black and back up again. What a disappointment. I should add that Nature added injury to her insult by causing it to rain shortly after the eclipse.

Still, the story does not end here. Ther still remained a 1600 mile drive back home. When we got there, we went to the television studios to look at our tape. Would you believe that it was not in usable condition? Areas of television "snow", lines through the picture. Distortions. It is enough to make a grown man cry. Believe me, that was my last eclipse.

I give up!

While I have been unsuccessful, Imust admit that others have been tremendously lucky at being at the right place at the right time. Professional scientists have learned a great deal by the study of eclipses For years our only knowledge of solar prominences was gained thriugh the study of eclipses, although we nowhave machines that can view the prominences at any time. Our knowledge of the corona come strictly from observations of eclipses. Astronomers have learned to prolong these few fleeting minutes when the corona is visible. They fly along in the Moon's shadow in a jet plane, at some1700 miles an hour! In this way, for instance, professional astronomers were able to prolong the 7 minute eclipse of June 30, 1973 to 70 minutes!.

No longer does modern man fear eclipses, although people in backwards areas may. Modern man knows that eclipses are merely shadows produced by a rare alignment of celestial objects, namely, the Sun, the Moon and the Earth. Even though the fear is gone, the wonderment is still there. An eclipse is truly a spectacle not to be forgotten.

21. Variable Stars

Italics: As an amateur astronomer, the field of variable stars had interested me for some time. In fact, they were, and are, my primary field of research when I am in my observatory. On July 17,1972, I presented a synopsis of what is currently known of variable stars.

Regular type:

How old are you? I am 34 but I suppose that anyone reading this book could be anywhere from 8 to 108! I am asking you to think back to the first time that you noticed the night sky. Do you think that the stars have changed since that first time? Most people, if they remember their first view of the night sky, would probably say that the sky hasn't changed very much. In fact, they would tell you that the sky hasn't altered its appearance much since Biblical times, and, in this, they would be correct.

For a long time, it was thought that the stars were "fixed" while the planets were wanderers. In fact, the word "planet" comes from the Greek word "planete" which means "wanderer". The stars, on the other hand, were thought to be permanently fastened to some sphere or other,far off in the reaches of space. Strangely, even though our knowledge of modern science tells us that the stars are, indeed, in motion, one still finds the term "fixed stars" in the text books.

Even though the stars are in motion, these changes of positions are not noticeable in a lifetime. But, there are changes in the sky which can be seen, even in the course of one hour. These are changes of brightness, and it is these changes that I propose to deal with in this chapter.

Stars which change brightness are called variable stars. When I observe them I have three or four instruments that I use, but I would be safe in saying that the most important of these is my 7 x 50 set of binoculars. Binoculars? Yes, since there are many variable stars which are visible to the unaided eye, or are just slightly too faint to be seen, they can be seen with ordinary binoculars. You don't need to have a giant telescope to study these stars.

At this point, I would recommend that you go back to chapter 6 and look over what we said about magnitudes of stars, for it is magnitudes that we are measuring when we study variable stars. What most astronomers in the field do is measure the brightness of these stars over a period of time. We amateur astronomers use our eyes in the main, while professional astronomers use either photographs or electronic instruments, known as photometers. No matter, they all do the same job, measure the brightness of the star.

A single observation is not of much value and it is only with a series of observations, usually put down in graph form, that we can tell much about the star that is varying in brightness. In figures 33a and 33b we have two such graphs. Vertically, we have plotted magnitude, and horizontally, we have plotted time. In 33a, we have the graph of a star that is not varying. It is of constant brightness, so that as time progresses, the line neither rises nor falls, but remains parallel to the horizontal axis. In 33b, however, we have a variable star. As it grows brighter, the line ascends, and,conversely, descends as the star dims. Through study of these "light curves", astronomers can determine much about the nature of the object that is doing the varying.

(Figure 33a) (Figure 33b)

What have astronomers been able to determine about variable stars? There is much, for these stars are extremely important in astronomy since they provide laboratories where matter can be seen in changing form, as opposed to unaltering form in ordinary stars.

Before going on to the assorted varieties of stars, let's digress long enough to determine the system for the naming of variable stars. I would suggest, too, that you return, once again, to chapter 6 to refresh your memory on how ordinary stars are named.

Variable stars are given a nomenclature which depends on their order of discovery. The first variable star to be found in a constellation is given the letter R followed by the name of the star-group in which it was discovered. Thus, the first variable star to be found in Orion is R Orionis. I should mention that, quite often, R is also the brightest variable star in a constellation. This is logical since one would assume that the brightest would be noticed first,but there are always exceptions, and the first is not always the brightest.

The second to be discovered is S, the third is T, and so on, up to Z, always remembering that there is an R, an S and a T for every constellation. What happens when you get up to Z and all of the letters are used up? Then you go back to RR. So, we have stars like the famous RR Lyrae, which, if you will count, must have been the tenth variable to be found in the constellation of Lyra. Following RR, we have RS, RT,RU etc. to RZ. Then we start all over again at SS and work up to S Z. Eventually you arrive at ZZ in a constellation. What then?

The next star after ZZ is AA, then AB etc. up to AZ. Then BB is the next one. I think by now that we have set up the pattern, so let us simply say that this continues on up to QZ, at which point you have used up some 234 appelations for variable stars in any given constellation. After that, the system is simpler, since the next one in the series is V235. It would have seemed much simpler to have started with V1 in the first place, instead of going through all those letters. R Andromedae would have been V1 Andromedae, and so forth. However, if you want to complicate something, just ask a scientist!

This bring us to the end of that particular digression. Now we know what the astronomers do, and how the stars are named, let's go one and see what astronomers have been able to find out ahout these stars over the years. Fear not. I will not get too technical.

There are two main varieties of variable stars, and each category has several sub-varieties within it. Basically, let's say that the two main types are the "eclipsing variables" and the "intrinsic variables".

Let's deal with the eclipsing variety first since they have been known for a very long time. The Arabs first noticed one of these many centuries ago, and called it Algol, the Demon Star, because it appeared to be winking at them. Of course, they had no way of knowing that it is an eclipsing variable star.

Algol is not one star at all; it is two! (By the way, the reason that it does not have a letter or number apellation as I explained in the last few paragraphs is that it was known from antiquity and was discovered before the system came into effect.) The two stars are in revolution about each other, and in the course of this mutual motion, they pass one in front of the other, as seen from the Earth. Naturally, the light from the rear star cannot come through the mass of the front star, so there is a dimming of the aggregate light that reaches the observer.

(Figure 34)

(Figure 35)

Compare figures 34 and 35. They are conveniently lettered so that you can see the resultant light curve when the stars are at the appropriate points of their orbit. Notice that when both stars are at the points marked A, yu see them both. Hence, the light is brighter that when they are at B, and the rear one is masked from us. This curve keeps on repeating, as the stars keep on revolving. This, then, is what we mean by an eclipsing variable star.

Now, I have given you the simplest case, where the two partners are of equal magnitude and of equal size. Consider now, a very common case where we have a small bright star, such as a white dwarf, in orbit around a larger fainter ordinary star. You are going to have a much different light curve.

(Figure 36)

(Figure 37)

I suppose that the first thing that you will notice about Figure 37 is that you have two differing minima of light. But figure 36 explains this quite suitably.

First, let's realize that most of the light is coming from the white dwarf. When it is at A, we are getting the light from both stars, but when this small companion swings out of sight behind the larger fainter star, its light is lost and we see the greatly diminished light of the primary star alone. The light curve drops down to the deepest, or primary, minimum. The little star re-appears and again we have full illumination. When the dwarf passes in front of the larger star, then part of the giant's light is cut off. This loss, however, is negligible since, remember, it is the smaller of the two which is providing most of the light. Thus, we have a secondary minimum which is not so deep as the first one.

If the situation were reversed, with a very large bright star and a faint companion in orbit around it, then the same pattern would be seen, except that both minima would be very shallow indeed.

Now, let's toss in a complication. So far we have been talking about total eclipses where the light from one or the other has been totally obscured by the mass of the other. This can happen when the orbital plane, the direction of revolution, is pointed at the Earth. But what happens when the plane is tilted and you have a partial eclipse?

(Figure 38)

(Figure 39)

Again, we have two figures to study. I am reverting to our original example, where the two stars are of equal size and brightness. As you can see, the light from one is only partially obscured, and rather slowly as compared to the sudden disappearance that we had in figure 34. The sides of the minimum on the light curve are not so steep. We can follow the same reasoning to see that the special cases of unequal stars can lead to light minima with diminished steepness in their slopes.

Have I confused you? I hope not, but in case I have, let me sum up this way. If you have two identical stars in total eclipse, you will have equal minima with sttep sides. If the eclipse is partial, the slopes will be less severe. If you have unequal stars in total eclipse, you will have a deep minimum followed by a shallow minimum, all with steep slopes. If the eclipse is partial, then the slopes will be less steep and the minima not so deep.

Of course, if the two stars don't eclipse at all, then the light does not diminish and theyare not variable stars, and need not concern us at all in this chapter.

The second main-variety of variable star is the intrinsic variable. It is a star which actually brightens and fades of its own accord due to certain physical processes going on in its interior. In many cases, the size of the star swells and shrinks along with the increase and decrease of magnitude respectively. Why? Well, there are many theories but the one that I like best goes like this.

Most intrinsic variables are older stars that are running out of fuel and are cooling off a bit, hence their predominantly red colour. In their interiors, the chemical "cooking" is not going too well, since hydrogen fuel is not in abundance any more, having been burned up earlier in the star's existance. Because there isn't so much light, heat and radiation pressure coming up from the inside, the exterior begins to collapse a bit. This causes the interior to increase its temperature, pressure and radiative power, to the diminished surface area cannot radiate it all into space. The surface has no other choice but to expand again, providing more radiative surface. But now the fires are banked, since they are no longer under pressure; the heat goes down; and the surface collapses again. Minor varieties in this cycle can occur as local differences in the abundance of hydrogen are accounted for.

These are the great changing chemical laboratories that I mentioned earlier, and when scientists turn their spectroscopes, instruments for analyzing light, on these stars, they can learn a great deal about how matter reacts in these strange environments.

The study of light curves can be quite interesting. You always wonder what has happened in the interior of the star to make these varieties possible. It is the differences in light curves which provide us with all of the sub-varieties of intrinsic variable stars.

(Figure 40)

The first kind of intrinsic variable is the classification known as RR Lyrae stars. I should mention, at this point, that the names of the classifications are according to the first of the type to be discovered. These RR Lyrae stars, as may be seen from figure 40, are extremely regular, the maxima being of identical separation. Generally speaking, the period is less than a day long. These stars have rather large amplitudes, of from 3 to 5 magnitudes change in their brightness. The light curve is characterized by a rapid rise to maximum and a slower decline. The minimum is almost flat and takes up half the period.

(Figure 41)

(Figure 42)

There are two sub-varieties of RR Lyrae stars and they are RR Lyrae-b and RR Lyrae-c stars. Their light curves are shown in figures 41 and 42. These have all of the characteristics that are present in the curves of the main classification. You will note, however, that there are certain differences. The "b" type has a slower rise to maximum and a smaller amplitude of variation. The 'c" type has a light curve which is almost a mathematical sine curve. There is really no flat spot anywhere in the curve.

The next intrinsic variable class is the "Classical Cepheids." The first of this type was Delta Cephei, in the northern constellation of Cepheus. These Cepheid variables, as was explained in chapeters 6 and 15, are really the yardsticks of the Universe. I will not bore you by going through the whole thing again, but just let me sum up by saying that there is a distinct connection between the period of a Cepheid and its intrinsic brightness. Once you know the period, you know the luminosity, and then you can calculate the distance to the star, and thence, to the star system that contains it.

(Figure 43)

There are two distinct kinds of Cepheid stars, the first of which are Delta Cephei stars, the kind which was first known. A typical light curve for these is shown in figure 43. The curve is characterized by a rapid rise to maximum, a slower descent, with a hump on the descending side of the curve. The hump is always at the same level in each period. Why there should be a hump at all, I do not know. It is as if the star were starting to collapse, and the changed its mind. The distance between consecutive maxima is always the same, and in this way, Delta Cephei stars are like the RR Lyrae stars.

Another type of Cepheid is the W Virginis group, again named after their prototype. Whereas the Delta Cephei stars are found in the flat planes of galaxies, the W Virginis stars are found in the halo surrounding a galaxy. A W Virginis light curve can be seen in figure 44. Again, you will see the hump on the descending branch of the curve,but this time, the hump comes at a different level on each one. However, the time between maxima is constant and the Period-Luminosity Law is still in effect.

(Figure 44)

The next main group in our discussion of intrinsic variables is the Beta Canis Majoris stars, named after the second brightest star in Canis Major. There are no sub-varieties here. The fluctuations in magnitude are very small, being of the order of one tenth of a magnitude. These changes die out regularly and do not resume for a year or two. Most of these stars, unlike the red ones we mentioned earlier, are hot white stars and it may be that they are just settling down after being formed. In other words, the periods in which there are no changes indicate to me, that for these times, they are just normal stars. A light curve for these stars is given in figure 45.

(Figure 45)

Another class with no sub-varieties is the Delta Scuti variables. These are visually indistinguishable from the RR Lyrae stars. However, when astronomers look at the motions of the surfaces, they are not synchronized with the light variations. The surface may be expanding, but the light is diminishing. In figure 46, I have shown the light curve as a solid line and the radial velocity curve (ie: the motion of the surface) as a dotted line, with motion towards us being upward in the diagram and motion away from us being downward. As you can readily see, the two lines are almost identical, but with a delay between them.

(Figure 46)

Long-Period variables are by far the most common type. They are easily studied by the amateur astronomer, and,as such, are left for the amateur by his professional colleague, who can turn his attention to more pressing problems. These stars are sometimes called "Mira" stars after their prototype, Omicron Ceti, which was called "Mira" by the Arabs. Thelight curve does not really have an absolutely regular maximum but seems to vary around a mean. Thus, a maximum may be a few days late, a few days early the next time, and also be a bit brighter one time than the next. Some of these variables have periods as short as 10 days, while others are as long as 400 days. Magnitude ranges may be as large as 14 magnitudes or as small as a few tenths of a magnitude. A light curve for a Mira star is given in figure 47.

(Figure 47)

Another main class of intrinsic variables is the "Semi-Regular Variables", of which there are 4 sub-types, a,b,c and d. In general, Semi-Regular Variables are those which have a regular curve for awhile, more like Long-Period variables, and then go totally irregular for a period, with unpredictable ups and downs.

In semi-regular-a stars we have giants of spectral classes K,M,and R. They are most like the long-period variables, except that they have smaller changes in magnitudes.

Semi-regular-b stars are generally recognizable in that they often have a very distinct period with interruptions of constant magnitude. An example of this is the star,U Bootis.

Semi-regular-c stars are characterized by the giant Betelguese. The light changes are on the order of 1½ magnitudes.

Lastly,the Semi-regular-d stars have peculiar curves with alternating deep and shallow minima (much like our previously mentioned eclipsing variables). In this they are like RV Tauri stars, whose description follows, except that these stars have bright emission lines of hydrogen in their spectrae,and RV Tauri stars do not.

A light curve of a Semi-regular star is given in figure 48.

(Figure 48)

RV Tauri stars are both rare and luminous and make up our next class of variable stars. Here we see (in figure 49) that they have the shallow and deep alternating minima. The difference between these and the eclipsing variety is that the minima of eclipsing stars are always of the same depth, while these have varying amplitudes from one period to the next.

(Figure 49)

My favourite variables are the class of Irregular Variables. They vary wildly in their periods and amplitudes and when I go to the eyepiece of my telescope to look at one, I never know what to expect. One night, the star may be bright, standing out from all the others. The next night, it may be so faint that I can hardly find it. Sometimes, it will change perceptibly during the course of one night's viewing. I have several of these stars on my observing programme, as they certainly are worth watching.

Another kind which is worth watching, for the sheer excitement of it, is the class of "Eruptive Variables", which has two sub-varieties, the U Geminorum type and the Z Camelopardelis type. Both classes remain constant for long periods of time, and then suddenly flare up with a several-hundredfold increase in brightness. With a jump of several magnitudes, the observer must be wary lest he think that he has discovered a nova, or new star, about which more will be written later in this chapter.

The U Geminorum type can be further sub-divided into the long-maximum variety and a corresponding short-maximum variety. A glance at figures 50a and 50b will explain exactly what we mean. The long-maximum type spends awhile before returning to obscurtity, while the short-maximum type does not. I often think that the short-maximum U Geminorum stars have curves like those of some RR Lyrae stars, but the difference lies in the regularity of the RR Lyrae stars. U Geminorum stars are spasmodic.

Z Camelopardelis stars are quite like U Geminorum stars, in that they flare into brightness, often in a period of a few hours. They are also like Delta Cephei stars in that they have a hump on the descending branch of the curve. See figure 51.

(Figure 50a)

(Figure 50b)

(Figure 51)

Another general category is the R Corona Borealis type, which are the opposite of the Eruptive Variables. These stars remain at constant brightness, and then, in a few hours, they fade away to obscurity. The unwary observer may believe that the star has "gone out", but after awhile, the star returns to normal brightness just as quickly as it had faded. A typical R Corona Borealis type curve is given in figure 52.

(Figure 52)

Another category of stars that change magnitudes quickly is the UV Ceti, or "flare star" variety. Flare stars are very small red dwarf stars, reaching the ends of their lives as stars. They are, nevertheless, suns, and as such, are likely to have the equivalent of solar flares. Probably all stars do, but in this case, the star is dim and the flare is bright, so that a sudden brightening will occur for 5 or 6 minutes and then the star will fade back to its original magnitude. This happens at very infrequent and irregular intervals, and so, is one of the most frustrating types of observations that one can make. You may have to wait for weeks to see one of these stars flare up!

Nebular variables are still another class of variables. (It seems as if this parade of classes will never end, but it will!) These are variable stars which are imbedded in, or associated with, nebulae, those great clouds of gas in space.The passing gases cause some fluctuations in the light curve but these are rather minor. It must be remembered that these are variable stars and are varying of their own accord.There are three sub-types of nebular variables, and when you see the light curves, you will understand what I mean.

The first of the three sub-types is the class of RW Aurigae stars. It is quite likely that they are some sort of Cepheid with an exceptionally long period. They are reasonably periodic with fluctuations at maximum and minimum, no doubt caused by the nebulosity. This is shown in figure 53.

(Figure 53)

The T Orionis type are still forming under gravitational contraction. All known examples are imbedded in the Great Nebula in Orion. The light curve is quite irregular, but in this case, the main source of the irregularity is the opacity of the surrounding gas, while there is some pulstation due to contraction. See figure 54.

The T Tauri type may not be a true variable, but it is still included in our list of nebular variable stars. Not enough data has been gathered on T Tauri stars to make many definitive statements about them. The light curve is marked by small sinusoidal changes as is shown in figure 55.

(Figure 54)

(Figure 55)

Still another class of variable stars are novae, the "new stars" to which I referred a few paragraphs back. They are not really "new stars" at all. In fact, the liklihood is that they are very old stars. As they degenerate, something cataclysmic happens, and the star increases in brilliancy many thousands of times. Then it becomes fainter and fainter until it reaches near-oblivion. Some novae are recurrent. They undergo outbursts repeatedly. A typical nova light curve is given in figure 56.

Two or three novae are discovered every year by patient observers who are familiar with every square degree of the sky.

(Figure 56)

The last class (at last!) is the Supernova. Whereas a nova throws off a shell of gas and then subsides, the Supernova anhilates itself. It literally blows itself to smithereens. One such was recorded by the Chinese astronomers (definitely not Hi and Ho, whom we mentioned in the last chapter) in the year 1054. It was reputed to have bright enough to be visible in the daytime. When astronomers look at this place now, they see the remains of the catastrophe. There is a large blob of gas and dust with hot hydrogen filaments running off in all directions. This is the famous Crab Nebula.

Another Supernova was discovered by Tycho Brahe, the famous Danish astronomer, in the middle 1500's. He just walked out of his house, looked up, and, being aware of every star in the sky, spotted this strange intruder in the constellation of Cassiopeia. This caused quite a stir at the time, since the skies were supposed to be immutable! There is no visible wreckage at that spot, but there is a source of radio emission quite near, which may be due to the event.

So there you have it. All of the classes of variable stars explained, I hope, in a simple fashion. It is essential to remember that the two main classes are the eclipsing variables and the intrinsic variables. Next, we'll discuss how amateur astronomers go about observing these as I think you'll find it interesting.

When the professional astronomer wants to observe a star, he simply points his telescope in the right direction, plugs in his photometer, or exposes his photographic plate. Very little professional astronomy is done visually any more. His amateur colleague, on the other hand, has to rely on less sophisticated techniques. Generally, he has but a modest telescope or a pair of binoculars. For measuring the magnitudes of stars, he has to rely on his eyes. It might surprise you just how accurate the human eye can be, given a little practice. Differences of a tenth of a magnitude are easily discernable to the experienced observer. How is this done?

When I go to my observatory, a book of star maps accompanies me. There is a map for each variable star on my programme. These maps are available from the American Association of Variable Star Observers, which is the leading collection agency for amateur observations of these objects. I also have a few charts from the British Astronomical Association, which has a very active Variable Star Section. Each map shows the star field surrounding the variable. The non-varying stars have their magnitudes beside them. The variable has a circle around it. It is simply a matter, then, of comparing the variable to the non-varying stars, to determine its magnitude. For instance, suppose that the variable is slightly brighter than a star marked 6.3 and is slightly fainter than a star with a magnitude of 6.1, then you would know that the magnitude of the variable is 6.2. In some cases, it is not this easy, as there is a spread between the brightnesses of the comparison stars. If you have a comparison star which is marked 7.6 and another marked 7.0, and the variable is of intermediate brightness, then you have to be able to estimate if the variable is closer to the brighter or fainter in magnitude, and how much closer. The ability to do this comes from experience. At the end of each month, the observer hands his observations in, and they are pooled with those of all the other observers to make a light curve for the star in question.

This work can be quite exciting. Although the magnitudes of long period and quite regular variables can be predicted, some of these stars have been found to be slowing down. Their periods are changing. I have already mentioned how fascinating it is to watch those highly erratic irregular variables. I also keep track of a few eruptive variables and a few R Corona Borealis types, those which fade to obscurity suddenly. Measuring these changes is sometimes tedious, for nothing will happen for a long period. When it does, watch out ! You really have to scramble to keep track of them all.

Then,too, you might make a discovery. In watching the variable RX Leporis, my colleague, Prof.José M. da Silva, of Brazil, and I, decided that there was something wrong with our estimates. In tracking down the problem, we began to realize that the published magnitude for one of the comparison stars, HD 33162, was in error. In researching this, we found that it had brightened from 6.7 at the beginning of the century to 6.3 when the map was published. Now, we have found that it is sometimes brighter than a nearby star marked 6.1. More observations will be made on this, but we think that we have found a new variable star. Since it is a red giant, a type known to vary, we are reasonably sure that this will indeed be a variabe to add to our programmes.

For me, variable star watching is a pleasant way to spend an evening. To record these changes, to watch the nightly parade of the heavens in the quiet of my garden is a very quick way to get some peace of mind. I know, too, that what I do is of use to science. As the nursery rhyme might have said it,"Twinkle, twinkle little star, now I know just what you are......a variable".

22. The Planet that Lies on Its Side

Italics: *We had already done several programmes on the major planets of the solar system, Jupiter and Saturn, and had done as many as three about Mars. It was time to devote some time to the lesser known planets, so on Feb. 5, 1973, I presented the 80th programme of the series about the planet Uranus.*

Regular Type:

On the night of March 13, 1781, an ardent amateur astronomer went to his telescope. Professionally he was an organist, but in his spare time he devoted himself to the study of mathematics and astronomy. On this particular night, he was going to make a discovery which would make his name and the word 'Astronomy' synonymous for years to come.

He had been born in Hanover, Germany in 1738 and had moved to England at an early age. In those days, there was great migration back and forth between Hanover and England, since the line of Hanoverian kings occupied the English throne. Being interested in the heavens he wished to procure a telescope, but the prices being asked by the London opticians was also astronomical so he set to work to grind his own mirror. Now, in those days, making a mirror was not the simple task that it is today, since the technique had only recently been invented. It is recorded that he had to make over 400 attempts before our hero made one right. "If at first you don't succeed......"

Although he had made larger telescopes, the one that he was employing on this particular night was 6 inches in diameter and was about 7 feet long. He was using an eyepiece which was giving a magnification of 227. Very slowly, he perused a group of stars in the constellation of Gemini. There was one with a circular disc. Could it be a comet? Quickly he changed eyepieces, now employing one giving a magnification of 460. It still looked circular. Indeed, it was a comet, but it appeared to have neither tail nor coma.

After a few hours of observations, this peculiar comet had moved with regard to the background of stars, so, excitedly, our amateur astronomer drew up a paper entitled "Account of a Comet". It was presented to the Royal Society in London on April 26, 1781. It was signed "William Herschel".

Soon the new of the comet discovered by this musician-astronomer began to spread throughout Europe. Professional astronomers began checking its orbit, trying to determine the kind of ellipse that this particular comet was following. Strangely, they had to periodically scrap their calculations and begin anew. Several months passed. Suddenly it was realized that this "comet" was not a comet at all. It was following a nearly circular orbit and was farther out in space than the planet Saturn. This was not a comet; it was a planet!

There was a scramble to examine old records to see if anyone had noticed this object before Herschel had seen it. Several records had been made. The oldest dated as far back as 1690! The French astronomer, LeMonnier had seen the planet 12 times between 1750 and 1769 but did not recognize it for what it was. LeMonnier was noted for his severe criticism of other astronomers, but failed to keep orderly records of his own observations. Two examples come to mind. He was searching for a planet closer to the sun than Mercury. All of his observations were recorded in chalk on a board, which was constantly being washed off. One of his observations of the new planet was written on an old paper bag in which hair powder for the wigs of those days had been stored by a perfumar! Had LeMonnier been more efficient in his note-keeping the discovery of the new planet would have gone to France and not to England.

What to name the new planet? Herschel himself wanted to call it Georgium Sidus, the star of George III, the king of England, but the Europeans would have none of that! Others, wishing to carry on the mythological tradition of naming the planets were in favour of "Neptune" for a name. (That particular planet which we now call Neptune had not yet been discovered.) Others favoured the name "Uranus", who was supposedly the oldest of the gods, and the father of Saturn. Finally, Lalande proposed that it be named "Herschel" in honour of its discoveror. These last two denominations prevailed for some time, but eventually, "Uranus" won out, and today we have the orderly family of son, father, granfather, and great-grandfather in the persons of Mars, Jupiter, Saturn and Uranus.

As a historical note, we might add that Herschel capitalized on his discovery. His fame spread to every nation on the Earth and he became a favourite at the court of King George III. The monarch, it seems, delightedin hearing Herschel's simple accounts of his experiments and researches. Herschel was granted a large pension, and a house at Slough not far from Windsor Castle. Here, Herschel began studying astronomy in earnest, using his money to construct larger and larger telescopes. The largest of these was constructed in 1789, and had a diameter of 48 inches and a focal length of some 40 feet. At that time it was the largest telescope in the world. This titanic instrument was first tried on the night of August 27, 1789, and on the very next night, Herschel made a discovery with it when he found the sixth moon of Saturn. Several weeks later he used it to discover a seventh. I might add as an afterthought, that he had already found two moons of Uranus in 1787. Herschel went on to be the "Father of Modern Astronomy," cataloguing several thousands of stars. He passed away in 1822, after a most distinguished career. He is buried in Westminister Abbey.

But what of the planet he had discovered? It is not a particularly faint object, being of 5th or 6th magnitude. It is a wonder that the ancients hadn't noticed it for it is visible to the unaided eye on a dark night. From my own location, a mere pair of 7x50 binoculars will show it. At any rate, the discovery of Uranus was entirely possible befor the invention of the telescope.

Computations showed that Uranus is about 19 times as far from the Sun as the Earth at a mean distance of 1,782,000,000 miles. The orbit is somewhat eccentric (0.0472) and the planet can approach as close as 1,700,000,000 miles or recede as far as 1,870,000,000 miles. The orbit is tipped up at a very small angle and lies virtually in the plane of the orbit of the Earth. Uranus' orbital speed is some 4.2 miles per second which results in one revolution about the sun in 30,685.1 days, or 84.01 years. This means that Uranus returned to its place of discovery in 1865 and 1949, and will do so again in the year 2033.

As we mentioned earlier, Uranus is visible to the unaided eye, but a small telescope (like that of Heschel) will show its disc. With an instrument of 12 inch diameter, some surface details are visible. In my own telescope, it appears to be a greenish disc with whire belts across it, somewhat similar to those of Jupiter. From the occasional markings astronomers have been able to deduce a rotation period of 10 hours, forty-nine minutes. The equatorial diameter has been computed to be 29,300 miles, about three and a half times that of the Earth. Its volume is 47 times that of the Earth, but calculations show that the mass is 14.6 times that of the Earth. From this we can deduce that Uranus must be made of very light material. Indeed, it is, for the density had been computed as 1.71 times that of water, where the Earth, Venus and Mars all tend to be about 5 times heavier as water. When you combine this with a relatively high albedo (or reflecting ability) it is natural to assume that Uranus is composed mainlyof gases and in this, is like Jupiter and Saturn. On the basis of theiretical models it is thought that the planet must be mainly hydrogen and helium (again like Jupiter) with other light gases such as carbon dioxide, ammonia and methane being in reasonable abundance. In fact, the spectroscope shows that methane is present, but astronomers now think that the other gases have been frozen and have fallen as"snow" to the surface.

I might digress for a moment to recall a science fiction movie that I saw a few years ago. It was, I think, "Journey to the 7th Planet". In it the surface was quite accurately, described, as far as the theory goes,portrayed as being snow covered with fantastic crystals, which may have been crystalline forms of methane or ammonia, or even some unknown substance. Naturally, to liven things up, there was a one-eyed monster in a cavern, but monsters are half the fun of science-fiction, so we will let that pass. The point is that the movie had a reasonable portrayal of what I think the surface of Uranus should look like.

The above was written to show that truth can be even stranger than fiction. There are many, many strange things about Uranus, but the strangest of all is that the planet "lies on its side". That is, it is tipped right over, so that the axis of rotation is almost parallel to the plane of its orbit. See figure 57. The angle is about 8° so that Uranus, indeed, is sideways in its orbit. As far as we know, the direction of the pole remainsconstant so that at times Uranus is moving North Pole first, then rolling along like a ball and then South Pole first, followed by more rolling along, but in the other direction. It must be very strange for any Uranian inhabitants, for the phenomena of sunrises and sunsets would be unequaled anywhere in the solar system with the possibility of an exception being made in the case of the planet Mercury, which we shall discuss in a later chapter.

(Figure 57)

Our hypothetical Uranium would see, supposing he lived at the equator, the Sun spiralling its way north and south in an 84 year cycle (earth-years, that is). The Sun would not be very bright, but would appear to rise farther and farther north each day until it came within 8 degrees of the North Pole, and then it would rise farther and farther south each day until it reached the point 8 degrees from the South Pole. The process would reverse itself, ad infinitum.

Why a planet should have this very strange motion is unknown. Most of the other bodies in the solar system both revolve and rotate in the same direction. Of course there are exceptions, but the rule is generally true. Not only that, but the exceptions generally are 180° reversed that the usual, so that this 98° tilt is really strange. Possibilities that have been suggested are encounters with other bodies, original formation in that way, and disturbances in the core of the planet. Take your choice!

Strangely, the Moons of Uranus share this unusual tilt. They revolve more or less in the plane of the planet's equator. This leads to some very strange observational effects. See figure 58.

When the axis of the planet is pointed toward the observer, the moons appear to move in circles around the planet, and that is nice. That's what you would expect of a nice well-behaved moon. As you watch, however, the axis of the planet will swing away from you over a 20 year period ($\frac{1}{4}$ of 80 = 20) and the orbits of the moons will appear to flatten out, becoming elliptical and then, finally flat. Then the process reversed itself until you are looking at the opposite pole and the orbits are circular again, but this time, the moons are going in the opposite direction from what they were 40 years ago. That's because you are looking at them from the "bottom" instead of from the "top".

(Figure 58)

As was mentioned earlier, two of the moons of Uranus were discovered by Herschel himself. These were Titania and Oberon, which are the fourth and fifth, respectively, in increasing orfer of distance from the planet. They are of 14th magnitude, and are not difficult to see in a moderate telescope.

Following his discovery of the planet, Herschel was most anxious to discover whether or not it had any satellites. He searched for 6 years! "If at first, you don't succeed......" again! On the night of January 11, 1787, he noticed two faint "stars" near the planet. They were not visible on the following night. He suspected that these might have been moons, so he kept watching nightly. On February 7-8, 1787, he sat at the eyepiece of his telescope from 6pm until 3am and during the course of this very long observing session he was able to follow the motion of the moons around the planet. He was successful!

Titania revolves around Uranus in 8 days and 16 hours, at a distance of 275,000 miles, which is just slightly more than the distance of our Moon from the Earth. Oberon is 370,000 miles from the planet and revolves in 13 days, 11 hours and 7 minutes. Their diameters are not known exactly, for it is a very difficult task to determine the diameters of very small objects at very small great distances. I have several sets of figures available and I shall give the means, with Titania being about 700 miles in diameter and Oberon being 1100 miles in diameter. These are highly unreliable figures and should not be taken as facts.

Before going on to describe the rest of the satellites of the planet, I should like to tell you that at one time Herschel was given credit for having discovered 6 moons of the planet. They were Titania and Oberon and 4 more. The first of the extra four was supposed to have been discovered on Jan. 18, 1790. It was 216,000 miles from the planet and revolved in a period of 5 days, 21 hours. Number Two was found but three weeks later, on Feb. 9, 1790. It revolved around the primary at a distance of 751,000 miles in 38 days, approximately. Herschel's discoveries seemed to come in pairs for he discovered another on Feb. 28, 1794 and yet another on Mar. 26 of the same year. The February object was supposed to be 1,500,000 miles from the planet, having an orbital period of 107 days and 16 hours. The March object revolved around Uranus is 10 days 23 hours at a distance of 328,000 miles. What happened to them? They are not there now! It seems to be generally excepted that Herschel was mistaken in these last four observations. Perhaps these "moons" may have been faint stars conveniently in the background. The motion of Uranus itself, with regard to the background could have been mistaken for the motion of a satellite. One of them could have been an asteroid, conveniently floating through the field of vision, much closer than Uranus, but at just the right time to cause Herschel to make a mistake. At any rate, the history books give Herschel discovery rights to Titania and Oberon and the other four are nowhere to be seen.

There is a controversy over the second and third moons in order from the planet. They are Ariel and Umbriel, respectively. Some of my astronomy texts say that they were discovered by Otto Struve in 1851, and others say that they were discovered by Lassell, also in 1851. One book takes a neutral stand and assigns Ariel to Lassell and Umbriel to Struve! I shall stay out of this and say that they were discovered in 1851 by either Lassell or Struve.

These two moons are of 15th and 16th magnitudes, respectively and therefore are very hard to see. Ariel revolves around Uranus in two days twelve hours, at a distance of 120,000 miles, about half of the moon's distance from the Earth. Umbriel has a period of 4 days $3\frac{1}{2}$ hours and revolves at 160,000 miles. Again, we are highly uncertain as to the diameters of these objects, but it would be safe to say that they are both approximately 500 miles in diameter.

The fifth and last of Uranus' moons to be discovered is also the closest. It was found recently, in 1948, and was named Miranda. We definitely know who the discoveror was in this case, as it was found photographically by G. P. Kuiper, using the 82 inch reflector of the McDonald Observatory in Texas. Miranda is of 19th magnitude, revolves around the planet at 84,000 miles distance and has an orbital period of 34 hours. It's diameter must be about 100 miles, and not much more.

The discovery of Uranus was one of the happy accidents of science. Herschel happened to be looking at the right place at the right time. It is fortunate that he did, for he gave us one of the most unusual planets to study. More important, the discovery of Uranus led directly to the discovery of another planet a few years later, but that is another story.

23. Taurus

Italics: One of my favorite cartoons shows Orion, standing with shield and club upraised. He is looking at Taurus and saying, "Same old bull, year after year." We covered the topic of Taurus on January 8, 1973, and it involved discussing the many objects in that particular constellation, and showing their distances on a very long line laid out on the studio floor.

Regular type:

The story of Taurus is linked up with the story of Orion. Since we told that in chapter 17 it need not be repeated here. It should also be noted that this particular constellation was named after the Cretan bull which Apollo rode to Greece. Notice that "Toro" the modern equivalent comes direct from Taurus.

Let me begin in earnest by saying that there is no such thing as Taurus! It is the name given by astronomers to a given geographical area in the sky. It is not a physical object and does not have any mystical powers. (Blah to you astrologers! I'll take care of you in the next chapter!) Like all constellations, Taurus is a group of varying objects, all at different distances. In fact, Taurus has a very interesting array of objects, and it is these which we will discuss in this chapter.

I suppose that the most eye-catching features of Taurus, is the Pleaides cluster. To the unaided eye it is a group of stars shaped like a small question-mark. When seen sideways, it looks like a very small dipper and, often, I have had people say to me, :Oh, look at the Little Dipper!"

It isn't the Little Dipper, which is a part of the far northern constellation of the Little Bear, Ursa Minor. It is what we call an open cluster. The stars of this open cluster are very young hot stars and since they are at a distance of a mere 410 light years (Next astronomically speaking!) they appear quite bright in our nght skies.

In antiquity, they were known as the "Seven Sisters" but some people claim that they can only see six. There are some very interesting legends as to what happened to the seventh one, and I shall digress from the main theme long enough to tell this little story.

It seems that long ago in the western plains, that there were seven Indian maidens, daughters of the chief of a very powerful tribe. The youngest, or seventh, was extremely beautiful and was loved very deeply by a young brave, Falling Rock. The two had to meet secretly since Falling Rock was a member of an enemy tribe, and could not be considered as a legitimate suitor for the hand of the maiden.

Once, they were discovered during a lover"s tryst and Falling Rock was banished from the area, forever to roam the mountains of the west. The seventh sister tried to follow him, so that the pair was never seen again, and we don't know whether she ever found him again. The remaining sisters were chosen for wives for the six sons of Manitou the Indian god, and when they died they were placed in the heavens so that all could admire their beauty. Nothing was ever heard of Falling Rock again, but still, to this very day, you can see signs throughout the mountainous western part of North America which say "Watch For Falling Rock".

Now, dear reader, I am pulling your leg a bit, but my purpose is serious, as it shows one of the many ridiculous stories as to how things got placed in the heavens. This is a modern tale, with, I must admit, a twisting-ending, but it can go right along with other such tales! Back to Taurus and the Pleaides!

As we were saying, some people can see but six stars. With the unaided eye, on a good clear night, I have seen as many as 10. When you look through binoculars, there are 50 to 60, and with a moderate telescope there are literally hundreds of stars in this cluster. The telescope shows that they are surrounded with wisps of nebulosity, of gas, and the modern theory is that these stars have just recently (cosmically speaking) condensed out of nebulosity, and these wisps are the remains left over from their formation. Do have a look at these stars with a pair of binoculars. It is a sight well worth the trouble.

There is another open cluster in Taurus, but it is not so densely packed with stars as the Pleiades. This cluster is the Hyades.

Quite prominent is the giant red star, Aldebaran, but it is not a member of the cluster but sits in front of it at a distance of 68 light years, whereas the cluster itself is 130 light years away. We shall discuss Aldebaran later.

This cluster is interesting to astronomers since it is one of the closest. In fact, some 800 thousand years ago, it was, indeed, the closest. It is so close to us, in fact, that astronomers can determine with great accuracy the individual motions of the stars. They all seem to be moving toward a point in Orion. This is simply an effect of motion since we are speeding away from the cluster, and the cluster is speeding away from us. Suppose that you are going down a very long flat straight highway. Ahead you see a group of motorcyclists. From a distance they are just a block blob coming toward you, but as they get closer you can see the individual members of the group. They pass you, and as you watch them in the rear view mirror, they seem to get closer and closer together until they once again form the black blob in the distance. This is the same thing that is happening with the Hyades cluster. As they go away, they seem to be converging, getting closer together, and it just so happens that the "road" is pointing backwards into the constellation of Orion.

To me, the cluster as viewed with the unaided eye is formed into two lines, which I suppose must have had something to do with the mystical outline of the Bull. I cannot see it, resembling a bull, except that I know that Aldebaran is supposed to be the eye.

Aldebaran is a gigantic red star, something like Betelguese. It is much older than the sun and is about 50 times the size of our parent star. If Aldebaran were placed at the location of the Sun, we would be nearly at the surface, which would be rather uncomfortably hot. The surface temperature of Aldebaran is 7000° F., which is a bit cooler than the 10,000° F. inferno of the Sun. Aldebaran has a faint companion in orbit around it. This little star shines with a feeble 13th magnitude luminosity, and it is probably a white dwarf.

ordinary star!

in 1967, a new radio telescope had been built at the Mullard Radio Astronomy Observatory near Cambridge, England. The purpose of the instrument was to investigate the scintillation of radio sources, which is something akin to the twinkling of starlight. In November of that year, the telescope began to operate systematically, and a graduate student, Jocelyn Bell, made a very important discovery. One certain radio source was emitting a pulsed signal, with each pulse lasting about one third of a second, with a gap of exactly one second between the m! What could it be? Certainly, nothing known to nature could send out such an exact signal. Signal! Could it be some other civilization trying to signal to us? For several weeks the information was withheld, while other further investigations were made.

Within several months, however, three more similar sources were found. No little green men! These pulsating radio sources soon became known as "Pulsars".

A year later, some twenty pulsars had been discovered and the theoreticians were having a field-day trying to explain what these starnge objects could be. The final concensus is that pulsars are some sort of super-dense material sending ou a jet of radiation as they rotate. This radiation reaches our radio telescopes and provides the pulses.

On January 15, 1969, the first optical identification of a pulsar was made. Where was it? In the Crab Nebula! (I'll bet you thought I had forgotten it!) There is an object whose optical light pulses in exact synchronization with the radio pulses. It's that 9th magnitude star with the extremely hot temperature!

This represents, scientists now think, the ultimate form of the degeneration of a star. All of the protons and electrons were blown off the atoms in the explosion and all that is lef is the neutrons. This, then, is a neutron star, collapsing and generating heat due to its own gravitational pull. This atraction must be extremely powerful since the material in a neutron star is extremely dense. It is estimated that one cubic inch of the material would weigh in the neighbourhood of forty tons. Any mountains on the surface of a neutron star would soon collapse under their own weight, so that the ultimate limit is about 3 millimetres high! What a strange place a neutron star must be!

Figure 59--Map of Taurus

Another interesting object in the constellation is Lamba Tauri, a star to be found toward the bottom right figure 59. This is an eclipsing variable, the kind that we spoke of in chapter 20. It is an Algol type, with one deep minimum in its light curve and one shallow one . The sides are steep so we know that this is the case of a bright small star, going around a fainter larger one. The star varies from magnitude 3.5 to 4.0 in a period of 3.95 days.

The most spectacular object in Taurus is the Crab Nebula, which has been mentioned in brief before in this book. It lies near the star Zeta Tauri, but is extremely difficult to locate unless you have a very good observing night.

Back in 1758, the French astronomer, Charles Messier, was scanning this region of the sky, searching for comets, which was really his forte in astronomy. He was confused by this hazy patch in the sky on more than one occasion so he set to work and made up his now-famous catalogue of permanent hazy blobs in the sky. The Crab Nebula is M-1, the first object in Messier's catalogue.

Well, this one Interference with Messier's ,hunting has attracted a lot of attention' from astronomers lately. As we will see, it is one of the strongest sources of celestial radio emission, and for a good reason. Good photographs of the nebula, especially in the red light of hydrogen, show it to be a vast network of filaments, which do resemble the arms and antenna of one of those gigantic tropical land crabs. Hence, the name is "Crab Nebula".

This cosmic mess is the remains of a star which blew up in the year 1054 AD. What is left now is a 9th magnitude star, which is highly unusual, and all of these filaments. These filaments have been photographed over the years and when the prints are superimposed, astronomers have discovered that the filaments are expanding at some 750 miles per second. By tracing the motions backwards, they confirm that it was the deed in 1054 that this expansion began. Since the nebula is 4000 light years away, it is evident that the actual cataclysm took place just over 5000 years ago.

Now let's pay some attention to the strange star in the middle. It has a temperature of over 150,000 degrees which is impossible for an ordinary star. And, indeed, this is no

And with the tale of the Crab Nebula and its associated Pulsar, we come to the end of our story on Taurus. It is certainly a place of varied astronomical objects, ranging from the very young hot stars of the Pleiades to the older Aldebaran to the degenerate matter of the Crab Nebula Pulsar.

Astrology

Italics: I have always believed that Astrology is a humbug. It was a pleasure to present my views on that subject on Feb. 26, 1973. At that time I challenged any astrologer listening to come forward and debate with me. So far, I have had no takers. Are they all afraid? Here are my views.

Regular Type:

Voodoo, mumbo jumbo, hocus pocus, abracadabra! Magic! What place have they in modern life? They should have none, but still there are many people who can't accept rational explanations for phenomena, or who seek to explain the unexplained by use of their special beliefs. Usually their beliefs have no scientific basis in fact, for example, those who believe that toads cause warts. When you have the nerve to ask them, they just shrug and say that they believe. When you ask if they have ever seen it (again, that toads cause warts) they usually won't say that they haven't, but they will either change the subject or get awfully mad at you.

Astrologers are such people. Their pseudo-science is a relic from ancient days. Long ago, people thought that the gods inhabited the sky, and we have givenyou several example of this already in this book. They thought that the Sun was Apollo, driving his golden chariot across the sky. They thought that the planet Venus was Lucifer, and so forth. Eventually the legends grew up, and the first thing you knew, people were attributing all sorts of physical and mental characteristics to the planets and constellations. For instance, if you were born while Jupiter was rising in the constellation of Virgo while Mars was in Scorpio, you would turn out ot be one sort of person, while if the planets were reversed you would turn out to be some totally different type. Ignorant people believe this, and are taken in daily by the charlatans who charge money for drawing up a horoscope and pretend to predict the future. But let's look at this in the light of science, and avoid all the hocus-pocus of astrology. After all, astrologers, I can prove that your subject is phoney. Can you prove that it isn't?

First of all, let's take a close look at some of the objects which astrologers say affect our destinies. Since the Sun is the largest and most powerful object in our solar system, we'll discuss that first. Since we have examined the Sun carefully in chapter 3, there is no need to go into great detail about the Sun and its parts. Let it be sufficient to say that the Sun is a great furnace, converting hydrogen into helium with energy as a by-product. Now, I would be the last one to say that the Sun did not affect us here on the Earth. That would be foolish for everyone knows that all of our energies come in one way or another from the Sun. Oil is liquid sunshine. Coal is fossilised sunshine. Sunshine is free, and it can now be converted directly into electricity through the use of solar batteries. In good weather, it can be focused through lenses or mirrors to heat water into steam with which to turn generators to make electricity. Nor would I deny that the sun has other effect on the Earth, other than the steady downpouring o energy. The sun bombards us constantly with radiation, alpha and beta particles, x-rays, and other assorted rays. Certainly, it must be these radiations which have caused any evolutionary changes to occur on the Earth. I do not believe, though, that I am a differnt person for having been born at 6pm than I would have been had I been born at 6am! No way!

The planets are unlike the sun. They are relatively cold bodies, producing no heat of their own (except Jupiter which radiates three times more heat than it recieves from the Sun.) Their magnetic fields are very weak compared to that of the Sun. They produce no energy, no particles, and no rays with which to bombard the Earth. Their only effect on us has to be gravity. If an astrologer believs that the laws of physics do not apply to him and his science, then let him jump out of an airplane. He will suddenly discover the law of gravity!

What about the Moon? It's just a small planet, which happens to be revolving around the Earth, rather than around the Sun. (Strictly speaking the Earth and Moon are revolving around a common centre of gravity which is revolving around the Sun.) The Moon affects us more than any other body, with the possible exception of the Sun, in that its gravitaional attraction causes the tides to rise and fall.

So let's do a little matmematical calculation to see the relative effects of the various heavenly bodies on us. We shall compare them to the sun, since that is the largest. According to all laws of physics, and astrologers must necessarily believe them, an influence is directly proportional to the mass and inversely proportional to the square of the distance. Don't let the big words frighten you. It simply means that a big object will affect you more than a little object and that a near object will affect you more than a far object. Newton more or less summed this up in his formula for the law of gravitation which reads something like

$$G = \frac{Km_1m_2}{d^2}$$

Now, we can forget about K for that is a constant which is used to determine the force of gravity in ergs. All that we are interested in is the relative strength of forces, so we don't need K. The next two numbers are m_1 which is the mass of the Earth, which we will let equal 1 for the pirposes of our discussion, and m_2, which is the mass of the body whose affect we are compúting. The letter d, of course stands for distance, and in doing these calculations we have to square it. The reason for this is simple. If you are talking about any type of force, and measure it at unit distance, then you will receive one unit of force. If you move twice as far away, the force falls off to 1/4 of its strength. If you move three times as far away, the force falls off to 1/9 of its original strength.

There is a further complication. As the Earth and planets are in motion around the sun, there are two extremes of distance, namely when the Earth and the planet are on the same side of the sun and when they are on the same side of the sun and when they are on opposite sides. Naturally the force, being dependent on the distance, will vary between these two limits. I have taken this into account in preparation of the following table.

Remember that the Earth is thought of as having a mass of 1 unit, and that our unit of distance is one sun distance, about 93,000,000 miles. Good luck in interpreting this, but don't worry about the mathematical aspect as I have used a computer to work it all out, By the way, we shall call our astrological force unit a "sap".

Object	Mass	Minimum Distance	Maximum Saps	Maximum Distance	Minimum Saps
Sun	332,958	1	332,958	1	332,958
Moon	.0123	.0026	1819.52	.0026	1819.52
Mercury	.055	.6	.15	1.4	.028
Venus	.815	.3	9.05	1.7	.282
Mars	.107	.4	.66	2.4	.017
Jupiter	318.	4.2	18.02	6.2	8.272
Saturn	95.	8.5	1.31	10.5	.86
Uranus	14.6	18.1	.04	20.1	.036
Neptune	17.3	29.0	.02	31.0	.018
Pluto	0.111	39	.00007	41	.00006

I think that you can see from this that the Sun has by far the most influence on us, This is because of its great mass and relative proximity. The Moon ranks second. It does not have much mass, only 1/81 that of the Earth, but its distance of only 250,000 miles make uo for this, so that the moon does exert a power of nearly 2000 saps on us Earthlings. Mighty Jupiter, when at its minimum distance, exerts a whole 18 saps of astrological power, a far cry from nearly 2,000 for the moon and well over 300,000 for the Sun. Venus exerts 9.05 saps when closest, and the only other body that can muster up a whole sap is Saturn. The rest are reasonably

"Oh, no! " Thats the cry of the astrologer. "Each planet has a mighty influence on us. If you were born when Uranus was in the seventh house, and the Moon was in Pisces............" Rot!

If you are really going to do this scientifically, then you will have to include every body in the solar system. Let's work the same calculations on the Moons of Jupiter, and see if they influence us.

Moon	Mass	Minimum Distance	Maximum Saps	Maximum Distance	Minimum Saps
Io	.0121	4.2	.00068	6.2	.00031
Europa	.0079	4.2	.00045	6.2	.00021
Ganymede	.0261	4.2	.00147	6.2	.00068
Ballisto	. 0162	4.2	.00092	6.2	.00042

Please notice that I have made the moon of Jupiter at the distance of Jupiter. I realize that they are nearer and farther as they circle around that planet, but the 93 million miles doubled increase of distance (i.e; 186 million miles) is more important to the argument than a few paltry hundreds of thousands of miles, when we are talking on such a colossal scale.

What I want you to do is to compare the maximum and minimum values of Pluto, which the astrologers take into account when making their occult divinations, to the values for these foor moonlets, to whom they pay no attention at all. Notice that at maximum distance, even the smallest of these bodies exerts a pressure, or force, some 3 times greater than Pluto, when it is a minimum distance, and therefore exerting its greatest force, This is true for all of these moons. Even when they are farthest away, they exert more force and influence than Pluto at its closest, and yet, our astrologer friends ignore them. Why?

Similar calculations with Titan, the largest moon of Saturn show that it is 4 times more influential than Pluto. Yet, this moon is also ignored by astrologers. In fact, I'll bet that most of them couldn't even tell you the names of the moons of the Saturn.

We have therefore come to one of the greatest fallacies of astrology, that they pick and choose their celestial bodies incorrectly. Remember, too, that the influence of the Sun and the Moon outweighs all the others put together. (Figure 60)

Astrologers take great care to determine which planet was rising at the time that the person for whom they are casting the horoscope was born. But what does "rising" mean. Simply said, it is the time when that particular object becomes visible over the Eastern Horizon. If you stop to think, however, you will see that the object is not "rising" at all! It is a case of the horizon sinking, due to the rotation of the Earth. Look at figure 60. The observer at A caanot see Jupiter because it has not "risen", the Earth being in the way. The observer at B can just see it on his horizon, and Jupiter is said to be "rising". For the observer at C, Jupiter is overhead, and Jupiter is overhead. Now suppose for a minute that these observers are new-born babies, just at this instant popping out of their mothers' woombs. The case must happen constantly since there are several million babies being born each second. Will Jupiter have more effect on baby B or on baby C. It is evident from the figure that baby B is not as close as baby C. In point of fact, if Jupiter were at its closest to the Earth, and hence, at its most influential, baby C would be only a few tens of miles closer to this planet. Whyshould the fact that Jupiter is being carried into a particular point of view from the Earth be of great significance.

Astrologers also pay special attention to the constellation that a particular planet is in. But, as we have said many times before in this book, a constellation is not real. It is merely a direction in space. I cannot see how Aquarius is a "watery" sign. It is merely a group of stars, all at differing distances, which happen to lie in the same direction from the Earth.

But, if you are going to talk about constellation, my astrologer friends, let's do it right. Astrologers place a great stock in the twelve signs of the Zodiac. The Zodiac is a band of twelve constellations through which the Sun travels in its yearly course. Actually it is the Earth that is moving, causing the Sun to appear against the differing backgrounds of the constellations. The names of these constellations are:- Pisces, Aries, Taurus, Gemini, Leo, Sagittarius, Capricornus, Scorpius, Libra, Virgo, and Aquarius, in no particular order, than the order in which I happened to think of them! Now each of them have some significance, but there is some mistake here. Any good astronomer can tellyou that the sun spends a considerable length of time each year in the constellation of Ophiuchus! In fact it spends more time there than it does in Scorpius. What happens to those poor people who are born when the Sun is in a non-zodical sonstellation? What happpens when Saturn happens to be rising in Orion, (also a non-zodical constellation) as it just is doing as I am writing these very words? What happened last year when Saturn spent a great length of time in Cetus the whale, which is another constellation not in the list above. (All those who said that the Saturnians had a whale of a time, leave the room!)

Another example is Pluto, which has spent several years in the constellation of Bernice's Hair! (No wise cracks!) How can any astrologer cast a decent horoscope if the planets themselves won't follow the rules? Why, the astrologers make up the rules as they go along! That's how!

Have I made my point? Astrology belongs in the same class with old saws like "step on a crack and break your mother's back" that we used to play when we were children. I have stepped on many a crack in the last 34 years, and my mother's back is as strong as ever! Astrology holds no scientific water, because it dates from the days when it was believed that the Earth was flat and was the very centre of the Universe. And, I wonder how they had to revise their tables and charts with the discoveries of Uranus, Neptune and Pluto. There must have been a mad scramble to make up new characteristics for each one.

If anyone wants to cast your horoscope for money, remember that he is a charlatan and a trickster. I can say that on two very safe grounds. One is that astrology is not a science, as I have pointed ou in this chapter and second, that science is free! There is no price for it!

25, Mercury

Italics: In the past few years, some very important discoveries have been made regarding Mercury, The 90th programme of the series, on April 23, 1973, was about that particular planet.

Regular type:

In ancient mythology, Mercury was the winged messenger of the gods, but in modern astronomy, he has been reduced to the status of one of the least of the Sun's family of planets. Nevertheless, Mercury is aptly named for it is certainly the swiftest of planets, having orbital speed of, on the average, 29.8 miles per second. Although it is the smallest of what we call planets, it is one of the most interesting, since there are many mysteries about the planet which have taken centuries to solve.

There is no record of who discovered Mercury, since it seems to have been observed from the ancient times. Like Venus, Mercury can appear both as a "Morning Star" and as a "Evening Star" and although the Romans realized that this was one and the same body, the Greeks did not. When it appeared in the evening it was "Hermes" and in its morning apparitions it was called "Apollo". It has been written that Mercury is a difficult object to see, but I have found that this is not the case. All one needs is a clear horizon, and some knowledge of where to look for the elusive planet. This can be obtained from an almanac or from Observers' Hanbook, such as those published by the Royal Astronomical Society of Canada and the British Astronomical Association.

It has been written in many books that even the great Copernicus, father of our present heliocentric theory of the solar system, died without ever seeing the planet. I really doubt that this is true, for any amateur astronomer worthy of the title would be able to tell you where and when to look. I personally have seen this planet on almost 100 ocasions and I am not particularly noted for having any special powers.

As we said above, Mercury can appear both in the morning and in the evening, but it can never appear overhead at midnight, and the reason for this is because, like Venus, Mercury is an "inferior" planet. By that, I don't mean that there is anything wrong with the material in it, but just that it is closer to the Sun than the Earth. Both Mercury and Venus, therefore, are inferior planets, and the rest are superior planets. Since Mercury is in the same boat as Venus, it exhibits phases just like those of Venus, the only difference being that Mercury exhibits a much smaller disc, and goes through its phases at a much faster rate. But this is only because Mercury is closer to the Sun than is Venus. Mercury is the closest known planet to the Sun. It has been rumoured for centuries that there is another smaller planet which is inferior even to Mercury. It has been called Vulcan, after the god of Fire. Certainly, such a planet, if it exists, must be extremely hot due to its closeness to the solar disc.

Mercury also is hot, and for exactly the same reason. The planet revolves around the sun in 87.969 days, but in an orbit which is highly elliptical, which brings it as close as 28 1/2 million miles to the solar sphere or takes it as far away as 43 1/2 million miles. That's quite a difference in anyone's book. I have tried to show this in figure 61.

(Figure 61)

Notice especially the point marked A, which is 28 1.2 million miles from the solar globe. There is a funny thing about A which caused astronomers for two hundred years to scratch their heads. This point A, and also B, appears to move. If, for instance, Mercury is closest to the Sun at A on this revolution, then 88 days later, it will be closest to the Sun at A'. The next time, it will be closest a little farther around, and so on.

Naturally, I have exaggerated the effect a great deal on our diagram, so that you can see it, since really, it is a very small amount each time. But, it is this very tiny discrepancy which caused consternation in the astronomical community, Many theories were advanced to explain this phenomenon, including the theory of influence by Vulcan. Another theory was that there was a ring of cosmic dust around the Sun, which would have caused this. Any such ring, however, would have been visible at twilight, and would have changed the orbits of comets which pass near the sun. Since this is not so, the ring, in all likelihood does not exist. The mystery was solved in 1915 by no less a person than Albert Einstein himself. He formulated laws that showed that very special things took place close to a very large body such as the Sun. At that time, the book on Vulcan should have been closed forever. It makes a good place for science-fiction writers to have as a local for their stories. If Vulcan does exist, it must be very small, or, if it is large, it will cause a lot of embarassment for atronomers!

Not only is Mercury the closest and fastest of the planets, it is also the smallest, having an equatorial diameter of 3,025 miles. Even one of the moons of Jupiter is larger. Ganymede has a diameter of 3120 miles. Other moons approach it in size. Callisto, the outer of Jupiter's four Galilean satellites is 2770 miles in diameter, while Titan, the largest moon of Neptune is 3000 miles through the middle. So, Mercury is not an outstanding body as far as girth is concerned. As an example, if it were possible to set the planet on the continental United States, it would just nicely fit, with one side near the Atlantic and the other near the Pacific.

It is difficult to determine the mass of Mercury, since it is so close to the very massive Sun and since it has no satellites of its own. Astronomers use the satellite of planets to determine the mass of the planets, but it is a rather complicated tale, so you will have to believe me when I say that the mass of Mercury is .055 that of the Earth. Since the volume is .06 that of the Earth, we can calculate the density of the material that makes up that tiny planet. Càlculations show that it has a density of some 5.41 times that of water, which makes it second only to the Earth in terms of density. Further computations will show that the surface gravity there is 0.37 that of the Earth. A body weighing a pound on Earth would weigh only 5 1/2 ounces on Mercury. similarly, a long jumper who could jump 15 ft. here, could jump almost 45 ft. on Mercury.

This low gravity is significant since it means that Mercury has an escape velocity of 2.6 miles per second. Let me take a minute to explain what is meant by escape velocity. When you throw an object up it falls back down. The harder and faster you throw it, the farther up it goes. On Earth, if you project something upward with a velocity of 7 1/2 miles per second, it will not come back down. It will escape from the Earth and go off in an orbit around the Sun. On Mercury, you would have to project your object at a mere 2.6 miles per second, which is a little over 9,000 miles per hour, in order to escape the planet. That is escape velocity.

Why is this significant? Suppose that you are an oxegen molecule, or a hydrogen molecule in the Mercurian atmosphere. The great solar furnace is nearby, and everone knows that heated molecules speed up. You speed up, colliding with several other atoms and molecules. Pretty soon, you are going faster than 2.6 miles per second, and suddenly you are leaving the planet, floating through the reaches of space. Astronomers think that this has happened to nearly all of the molecules in the atmosphere of Mercury. They have all escaped, driven off by the power of the solar radiation in combination with the low gravity of the planet. If there is any atmosphere remaining, it is probably composed of heavier gases, such as ammonia, or perhaps argon.

During transits of Mercury, when the planet passes directly in front of the Sun, observations tend to confirm what we have written above, that Mercury has very little atmosphere. In 1963, Kozyrev, a Russian astronomer, used the 50 inch telescope at the Crimean Astronomical Observatory to make measurements of Mercury's atmosphere, using a spectrograph. Surprisingly, his work shows that the Mercurian atmosphere is mainly hydrogen gas, the lightest of all gases, but at a pressure of only 1/1000 that of the Earth's atmosphere. He explains this by agreeing that Mercury has a low escape velocity, but postulates that the atmosphere is being constantly replenished by bombardment from the Sun with protons, which are simply the nuclei of hydrogen atoms. These positively charged particles link up with a free electron, and there you have a hydrogen atom.

The surface of Mercury can be seen with a moderate telescope. From time to time there are diffuse grey markings, but generally there are no details visible. From these markings, a rotation period for the planet was determined at 88 days, the same as the Mercurian year. This led to very interesting theories, which I shall explain in a few moments. I want to say, however, that as I am writing this, a Mariner space-probe is on its way to Mercury and will send back our first close-up photos. Perhaps what I have said regarding the Mercurian atmosphere will be proved to be all wrong,but I would like to make a prediction. I'll go out on a limb and say that the surface of Mercury is covered with craters, the same as the Moon and Mars.

The 88 day rotation period was announced away back in 1889 by Schiaparelli after a 7-year study of the surface markings. This has been accepted until recently, but over the years it has given rise to some very interesting theories. If Mercury rotates and revolves in the same period, it always has the same hemisphere pointing toward the Sun. This would mean that one side would be forever exposed to the glare of solar radiation, while the other side would be forever committed to darkness. The sunward hemisphere would probably have rivers of molten metal flowing into lakes of lava. The other hemisphere would be a frozen wasteland of ice, snow and frozen gas crystals. In between, there would be a sort of "twilight zone".

The 88 day period has proved to be erroneous by radio astronomers who bounced signals off the planet. Their findings indicate that the planet turns once on its axis is 58 days 16 hours. Now, this could explain how the same markings were seen, time after time, by astronomers. If you multiply 58 and 2/3 days by 3 you will get 176 days, which is exactly double the old 88 day period. In other words, three Mercurian days equals two Mercurian years. After every second revolution around the Sun, the planet would be back with the same side facing the Earth.

There has been some fancy speculation on the nature of sunrises and sunsets on Mercury. Remember that the orbit is quite elliptical. This will mean that the Sun is not at the centre of the orbit and for this reason the ellipticity can make a difference in the Sun's position in the Mercurian sky. In fact, the Earth's orbit is also slightly elliptical and it is this that makes sun-dials run fast and slow according to electrical clocks. Suppose that you are a Mercurian. You have your rotation and revolution to worry about. Here's the Sun coming over the horizon in the east. Now it changes its mind and sets again in the east. Shortly thereafter it rises again and makes its way across the sky to the western horizon where it sets. Then it changes its mind, rises again in the west for another look, and after finally making up its mind, takes the final plunge for the night.

Earlier, we said that Mercury and Venus exhibit phases. In this, they are somewhat like the Moon. In fact, when Copernicus made up the heliocentric theory of the solar system, he said that one of the tests of it would be that Mercury and Venus would exhibit phases. When Galileo came along and first used the telescope, he noticed that Venus had phases and this confirmed the Copernican theory. Unfortunately, the Inquisition was in full sway, and Galileo thought it prudent to keep quiet about it.

The phases of Mercury and Venus can be explained by reference to figure 62. It doesn't matter which planet you are concerned with for what we are going to say applies to one as well as the other. We shall start with the planet at A. It is directly across its orbit from us, so we are seeing it fully illuminated, but it is a very small disc due to its great distance. As it swings around through B,C and D,we see less and less of the illuminated portion which is always facing the Sun. At D we see only half of it and it looks like the Quarter Moon. By the time it gets to E, we see only a slender crescent, and at F, the planet virtually disappears from view. Notice how the size of the size of the planet has grown as it approaches. This, of course, is due to the decreasing distance. After the planet passes F, the process reverses itself until the planet is again at A.

(Figure 62)

This is quite disconcerting to the observer, for when the planet is illuminated, it appears small, and when it is large, it is not sufficiently lit!

In a previous chapter, we alluded to the fact that Mercury can be quite difficult to see. This is due to Mercury's proximity to the Sun. The best times to see it are when it is between D and E in figure 62. and in the corresponding area on the other side of the diagram. How does this translate into actual seeing conditions? As you can see, the angle between Mercury and the Sun is greatest at these positions. In the sky, Mercury is best seen when farthest from the Sun. This angle is, on the average, 23°. It can be as much as 28° when the ellipticity of the orbit is taken into account. The best time to look is just after sunset when Mercury is at greatest elongation east of the sun, or just before sunrise when Mercury is at maximum elongation west of our parent star. These times, as we said earlier, can be found from a variety of sources.

Another time to see Mercury is when it passes directly in front of the Sun. This is called a "transit". I have already described transits to some extent in chapter 18 on Venus and as I have already repeated some of the material from that chapter in this one, I don't want to bore you, dear reader, than I already have. Let it be sufficient to say that many of the same phenomena occur, the major differences being the smallness of Mercury's disc, and the greater speed as it passes in front of the Sun. Transits of Mercury are much more frequent than those of Venus. I have seen several, although I must admit that I missed the last one which occurred only 20 days before the time when I am writing these words. I arose from my bed to prepare to go off with some other observers to watch the sun rise with Mercury already in transit. When I saw that the sky was cloudy, I went back to bed. Alas, the sky cleared and my fellow observers saw a part of the transit. I did not!

The next transit is scheduled for November 12,1986 and the one after that is on November 14, 1999! Perhaps I should not have missed this one!

I should end this chapter with a warning. Some texts will tell you that with binoculars or a telescope,it is possible to see Mercury in the daytime. Indeed, it is, and this is when many professional astronomers gather their data about the planet. The reason for this is that the sky is less turbulent when Mercury is high overhead in the daytime sky. Near the horizon, "boiling" ruins the seeing. However, professional astronomers don't look through their telescopes; they position them by means of dials. If you are sweeping around with binoculars or a telescope, looking for Mercury, you are likely to encounter the Sun. Good-bye eye! I know that I have given this warning in previous chapters, but it is so important, I think it well to repeat it wherever possible.

Mercury, then, is an interesting planet. Certainly, we'll know much more about it when the Mariner space-craft arrives. When it does, much of what I have written above may be out-dated. I hope not!

26. Mariner IX

Italics: When Mariner IX arrived at Mars in 1971, there were many surprises. Many new facts about Mars were discovered. I was fortunate in obtaining a set of Mariner IX slides, and I showed them in the 62nd programme of the series.

Regular type:

As we pointed out in chapter 10, telescopic observers have never been able to agree about markings on the surface of Mars. Some saw "canals". Some did not. Some saw seasonal changes. Others did not notice this phenomenon. The arguments went on for over a century. In the middle 1960's space technology had advanced to the point where it became feasible to send a machine to another planet. Venus was the first to be visited, by the Mariner II spacecraft on Dec.14,1962. This was a "fly-by" mission. See figure 63. That is, the machine passes by the planet, making its measurements and taking photos, and then flies into an orbit around the Sun.

Mars was first visited on July 15,1965, by the Mariner IV probe. This, too, was a fly-by mission. The results, however, stood the astronomical community on its ear! Mars is covered with craters, much the same as the Moon. This, I think, was a totally unexpected finding. On looking at some of my pre-Mariner pictures and drawings made at the eyepiece of my telescope, I was amused to find so many round features. Perhaps I could have forecast the existance of craters on Mars.

Mariner V was another Venus probe, while Mars was visited in July and August of 1969 by Mariners VI and VII, respectively. These, again, were fly-by missions, but the scientists had co-ordinated the probes so that different areas of the surface were photographed. In addition, the photos were divided into two groups for each Mariner. These were the far-encounter photographs followed by the near-encounter pictures. These photographs proved to provide as many questions as they answered. Obviously, something more than a fly-by was needed since the time available for photography was necessarily limited.

(Figure 63)

The solution to the problem had to be a machine that could spend more time in the Martian environment. It had to be inserted into an orbit around the planet, so that it, like the Orbiter craft that visited the Moon, could make a detailed photographic map of the surface. So as two ensure success, two spacecraft were readied.

As soon as Mariner VIII lifted off the launch pad at Cape Kennedy, it made a very large nose-dive into the sea, and, as far as I know, it is now photographing the fishes! Fortunately, Mariner IX lifted off successfully, and it is the story of this spacecraft that I am going to tell in this chapter.

(Figure 64)

Figure 64 shows the appearance of the Mariner craft. I suppose that the first thing that the reader notices are those big "wings". These are the power-plant of the machine, since they are covered with solar cells. Solar cells are like tiny wafers with wires attached. When the light of the Sun hits these wafers, they generate electricity which can then be used by the various electrical systems aboard the vessel.

The big dish is the radio antenna which sends the pictures and data back to the Earth. This dish is necessary since the radio transmitter is a very weak one, and as we explained in an earlier chapter, the strength of the signal falls off as the square of the distance. Some sort of dish is necessary to aim the signal precisely so that none of it is wasted. This signal is collected on the Earth by gigantic dishes, somewhat akin to radio telescopes. (See chapter 8 to see how these work.) An amazing fact is that if all of the wattage coming from a Mariner transmitter at the distance of Mars or Venus were collected for nearly a million years, it would illuminate a little Christmas-tree light-bulb for a tenth of a second!

At the top of the mast is a smaller dish which is a low-gain antenna. It is used to receive commands from the Earth, commands which orient the spacecraft in the right direction and to turn on the cameras and other instruments on board.

The Mariner carried two television cameras. One was to take rather wide-angled pictures, while the other was to take close-up pictures. These would be analyzed by an on-board computer and sent back to the Earth as dashes of radio signals. An Earth-bound computer reassembled the pictures so that scientists could study them. This complicated process was necessary since the transmission of actual television pictures by ordinary methods over such a long distance would be impossible due to power requirements. The reader knows how hard it is to get a decent picture from a television station that is over 80 miles away! Here,we are talking of 36 million miles, and with an infinitesimal portion of the power radiated by standard broadcast stations.

Mariner IX went into orbit around Mars in November of 1969, and the first thing that it discovered was a controversy! Evidently some sort of fantastic dust-storm was in progress, and the pictures showed only clouds of "sand" being whipped about by furious winds. Nothing like this had ever been seen before. I ask you (tongue-in-cheek, of course) if this might not have been a screen thrown up by Martians to cloke their activities from the prying mechanical eyes of the Earthlings. Eventually the dust storm did die out and the Mariner got on with its job of mapping the Martian surface.

In the last paragraph, I indicated that the dust storm was controversial, and I am afraid that you might have taken, from my flippant remark above, that possible Martians were the centre of controversy. This is definitely not the case. It happens that, at the time of the Mars encounter, the Sun, Earth and Mars were lined up in a straight line. Mars, as we astronomers declare, was at opposition. Not only that, but Mars was at a perihelic opposition. (You can define these terms by re-reading chapter 10.) The question is whether the dust storm had anything to do with the fact that Mars was at its closest point to the Sun, or whether this special alignment of the celestial bodies was the cause of the phenomenon. Arguments went on for as much as two years in the various journals, with neither side winning out. I wonder if they considered the possibility that they might both be wrong!

With the clearing of the Martian atmosphere, Mariner IX was able to make a whole series of astounding discoveries, ranging from towering volcanic cones, to dunes, to "Grand Canyons". Let's take them in that order.

A great number of volcanic cones were found, some of which are thought to be active. The most amazing, however, is the cone known as Olympica. It towers some 15 miles above the Martian landscape. It is three times as high as Mount Everest here on the Earth. It is a circular mountain with a base fully as big as the state of Nebraska, which has an area of 76,522 square miles. This means that the base of the come is nearly 500 miles from side to side. The caldera, or vent, at the top of the hill is 40 miles across! What a fantastic volcano, putting any on Earth to utter shame! There are several others on the planet which are almost as big.

Astronomers have long thought that Mars is a dying world, but now they have changed their tune. It seems that a planet must go through a period of active vulcanism before it develops an atmosphere and oceans. Mars may be a much younger planet than we have thought.

Much of Mars appears to be rather like a dusty sandy desert. There are many square miles of sand dunes, all aligned much like ripples at the beach. These are formed by the fierce Martian winds.

Mars is a place of extremes. If that volcano is the highest point on the planet, then a canyon discovered by the Mariner is certainly the lowest. There is a gigantic crack in the surface which is 75 miles wide. Compare this to the meagre 13 miles of the Earth's Grand Canyon. The depth of this chasm is 9,500 feet, almost two miles, where the earthly canyon is but 5,500 feet deep, a little over a mile. All along the sides of the canyon are tributary canyons, which branch off into still smaller canyons. They really look as if there was water running in them, although the majority of scientists think that they were caused by wind. I think that they were formed by running water which falls occasionally as rain. The fault itself is undoubtedly the result of the shifting of the Martian crust.

There are many faults in the surface of Mars. A fault, to the uninitiated, is a place where the surface has cracked and one section has moved relative to the other. There is one area where there is a series of Martian faults, each a mile wide and 1,100 miles long!

The polar caps of Mars came under the scrutiny of Mariner IX. The pictures indicate that the caps may be no more than an inch thick, although drifts are visible in places. Astronomers think, now, that the caps are made of frozen carbon dioxide, which we know as dry ice. Strangely, there are some frost-free (and I use the word "frost" in the loosest sense) areas in the cap. These showed some evidence of glacial action! What a strange place, this Martian surface!

Naturally the pictures were compared to the drawings that have been made by astronomers ever since the invention of the telescope. This has led to another mystery. Isn't it strange that for each question we answer, two more questions are found?

The dark areas drawn by astronomers don't match up with any of the permanent features photographed by the Mariner. It appears to most scientists that the light and dark areas are merely the results of the surface being covered or uncovered by wind-blown dust. Thus, the areas of "vegetation" seen by early astronomers are not really sections of plant-life at all. The wave of seasonal darkening is merely the blowing away of a layer of light dust.

I have yet to mention what I consider to be the most amazing photograph of all. I am gazing at it as I write these words. It is a Mariner IX picture of Phobos, the larger of Mars' two known moons. We pointed out in chapter 10 how it was discovered by Asaph Hall, using the 26" telescope at the U.S.Naval Observatory at Washington, many many years after it had been described in Swift's"Gullivers Travels". Phobos looks like a big ugly potato! This Martian satellite is definitely potato-shaped, being 13 miles in diameter through the shortest axis, and 16 miles from end to end. They "eyes" of the potato are craters,the largest of which, I would say, is about a mile in diameter. This profusion of craters suggests that Phobos must be ancient indeed, for it would take a long time for an object to be bombarded with so many meteors. It must possess considerable structural strength to have withstood this bombardment.

Deimos, the other Martian moon, also came under the watchful eye of the Mariner. It proved to be 7½ miles long and 8½ miles thick, again, like a potato. It, too, has a few craters, including some of the diameter of one mile.

You may recall from chapter 10, that the Russian, Shlovsky, theorized that Deimos and Phobos were artificial satellites put up by the Martians. Mariner IX has put an end to that theory!

But what about Martians? All we can say is that Mariner IX was not equipped to detect the presence of Martians. The smallest objects visible in the close-up photos is about one quarter of a mile long. Hence, we may have missed some 100-yard-long elephants!

What is next? The Russians have already landed a machine on Mars, the first object to do so. It carried a television system similar to that of the Surveyor craft which made the first soft landings on the Moon. Unfortunately, the television camera failed shortly after landing in the southern hemisphere of the Red Planet. Jokingly, I remarked that perhaps some little green man sneaked up behind it and simply turned it off, but that has got me into a controversial topic, so I wont say any more!

The U.S. has a machine nearing readiness which will land on Mars, hopefully in 1976, and will probe for life, presumably of the microbe and spore variety.I hope it finds some! Naturally, scientists will choose what they feel will be a likely site, using photographs from Mariner IX. If they are successful, then the Mariner will have more than exceeded the purposes for which it was designed.

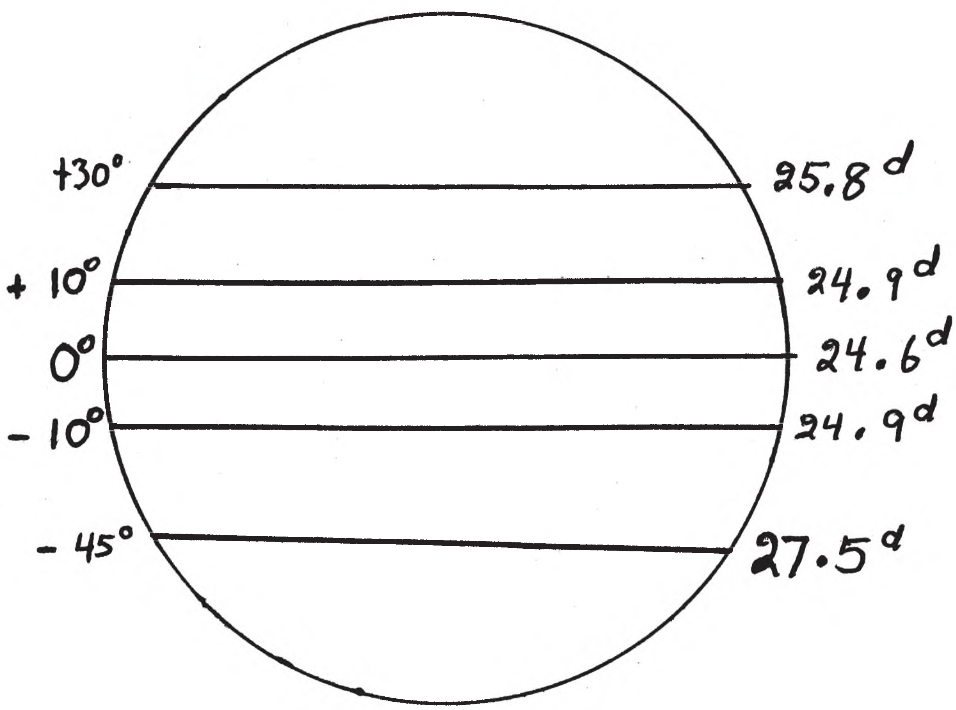


Figure 1 - Rotation Periods of the Sun

$$C^{12} + H^{1} \rightarrow N^{13} + \text{energy}$$

$$N^{13} \rightarrow C^{13} + \text{energy}$$

$$C^{13} + H^{1} \rightarrow N^{14} + \text{energy}$$

$$N^{14} + H^{1} \rightarrow O^{15} + \text{energy}$$

$$O^{15} \rightarrow N^{15} + \text{energy}$$

$$N^{15} + H^{1} \rightarrow C^{12} + He^{4}$$

C = Carbon H = Hydrogen

N = Nitrogen O = Oxygen

He = Helium

Figure 2 - The Carbon Cycle

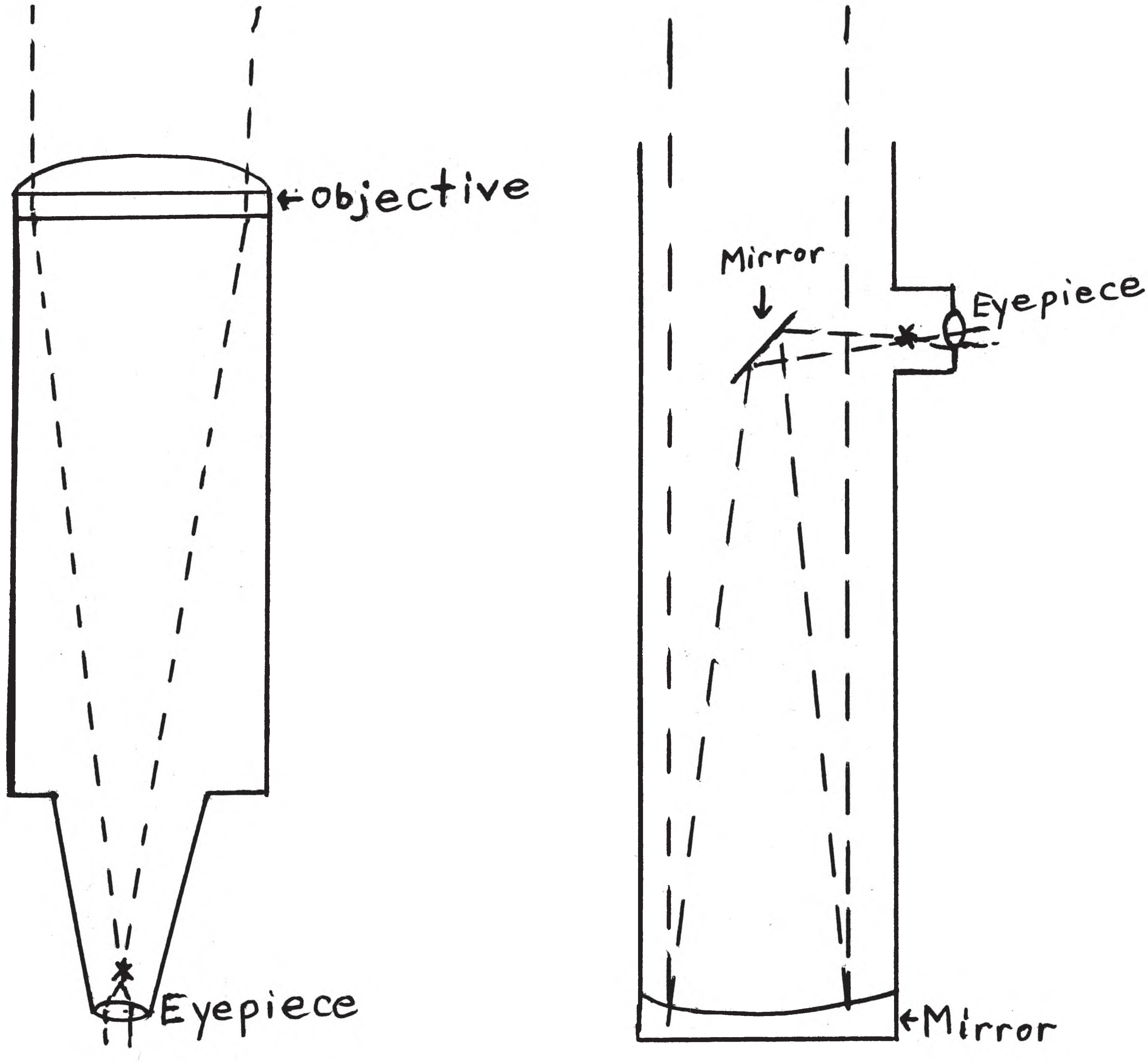


Figure 3 - Optical Systems of a Refractor (left) and
a Reflector

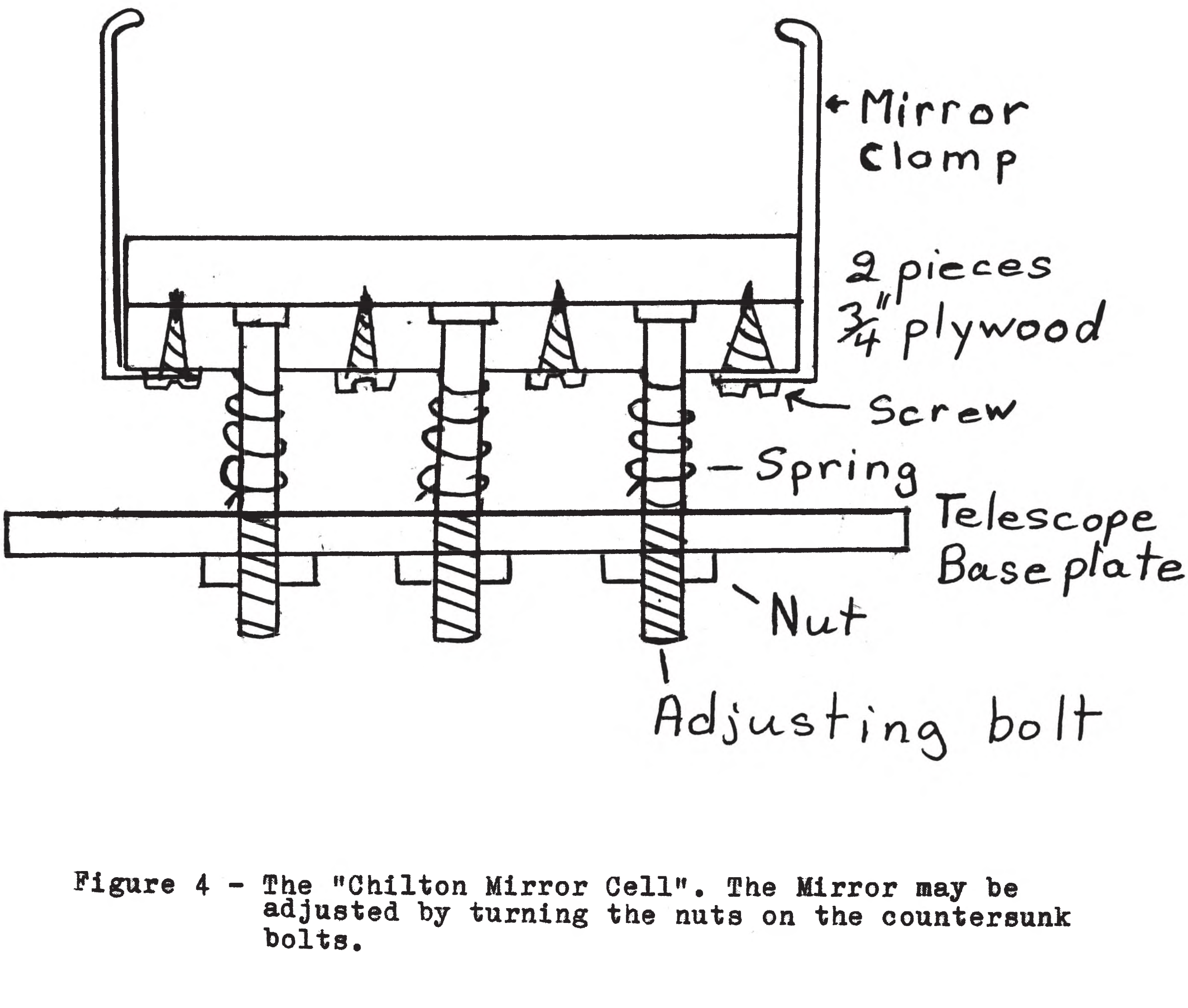


Figure 4 - The "Chilton Mirror Cell". The Mirror may be adjusted by turning the nuts on the countersunk bolts.

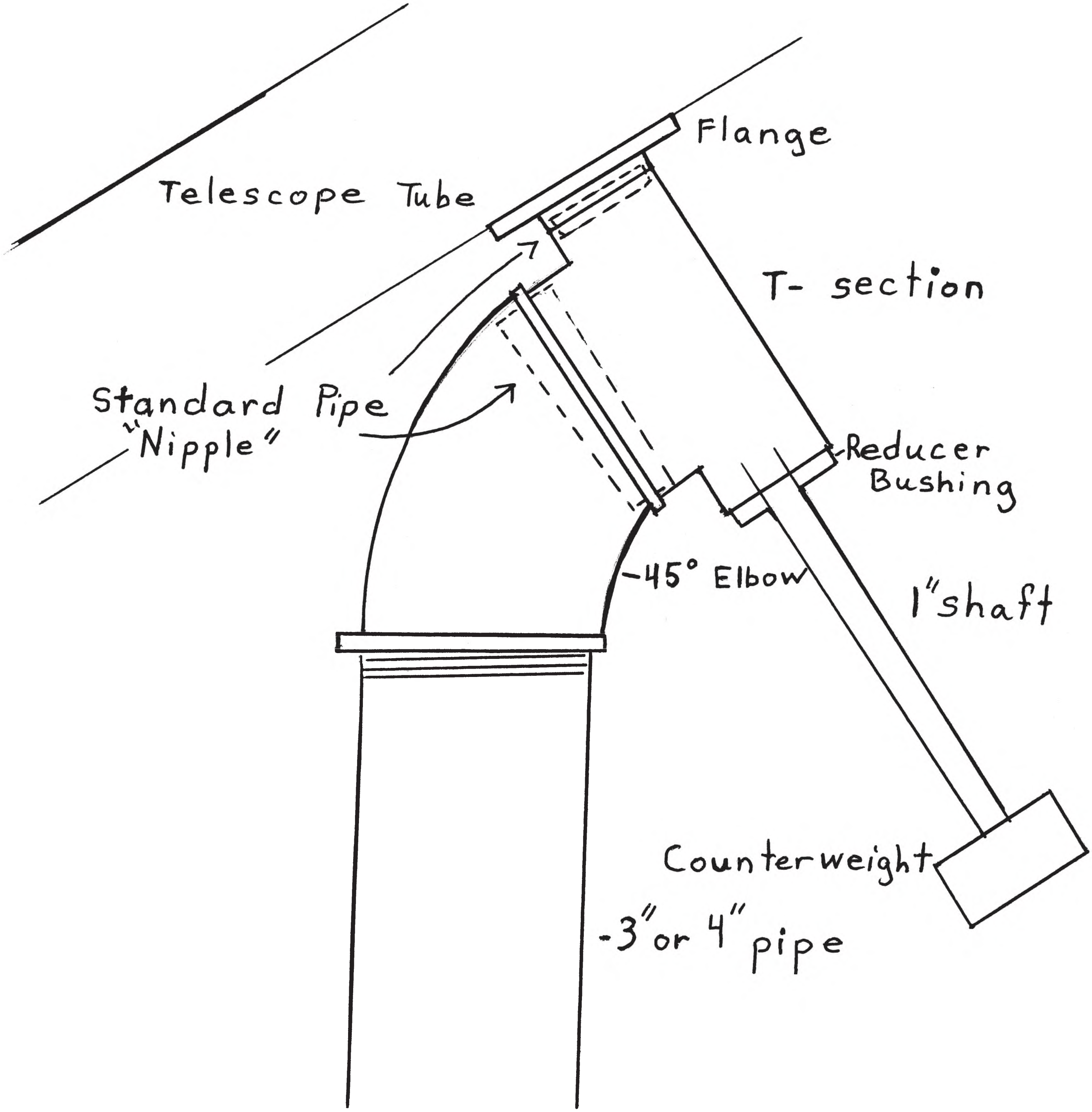


Figure 5 - The "Plumber's Nightmare" telescope mount

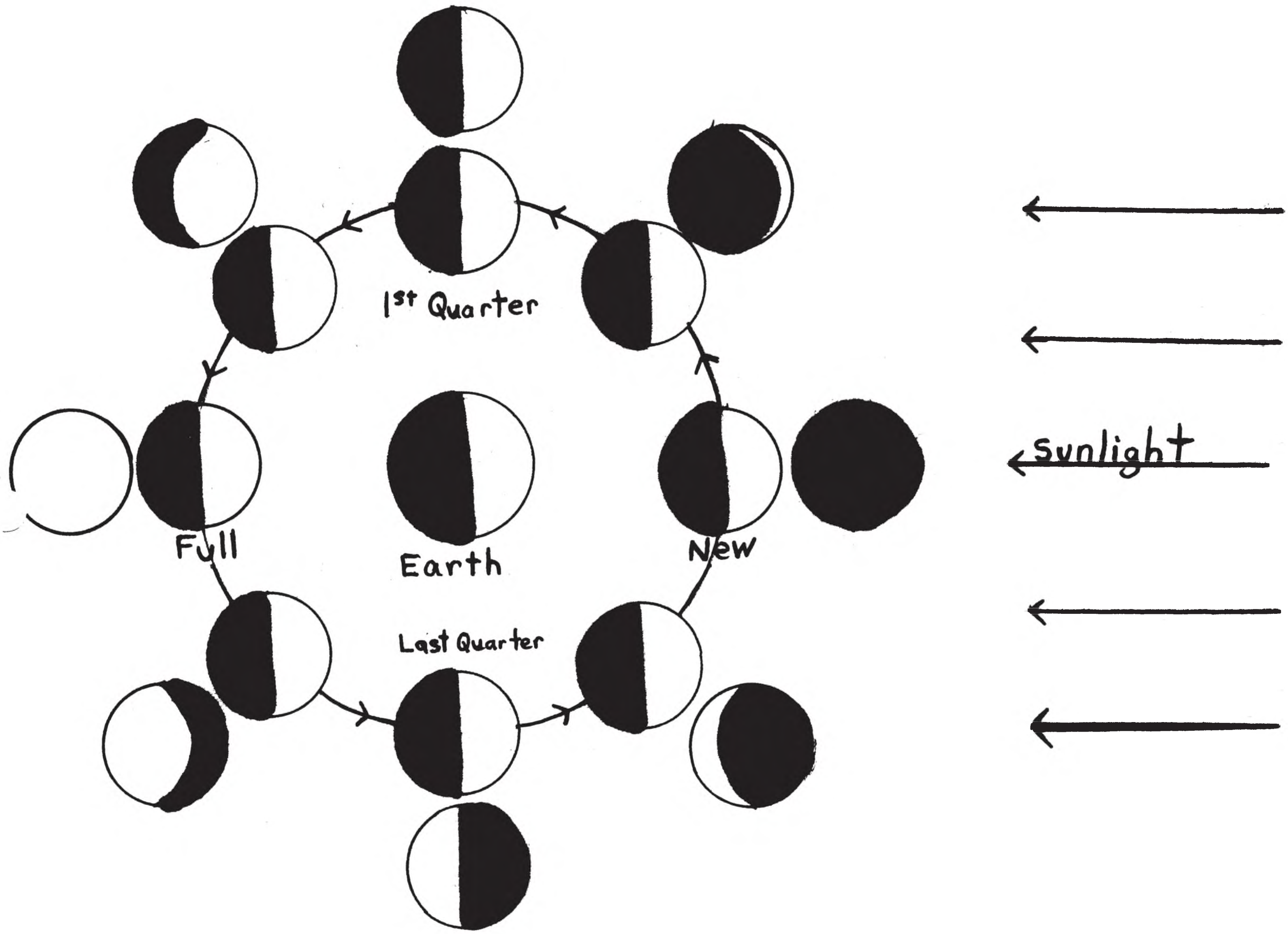


Figure 6 - The Phases of the Moon -

Inner circle - actual illumination of the Moon
Outer circle - what the Earthbound observer sees

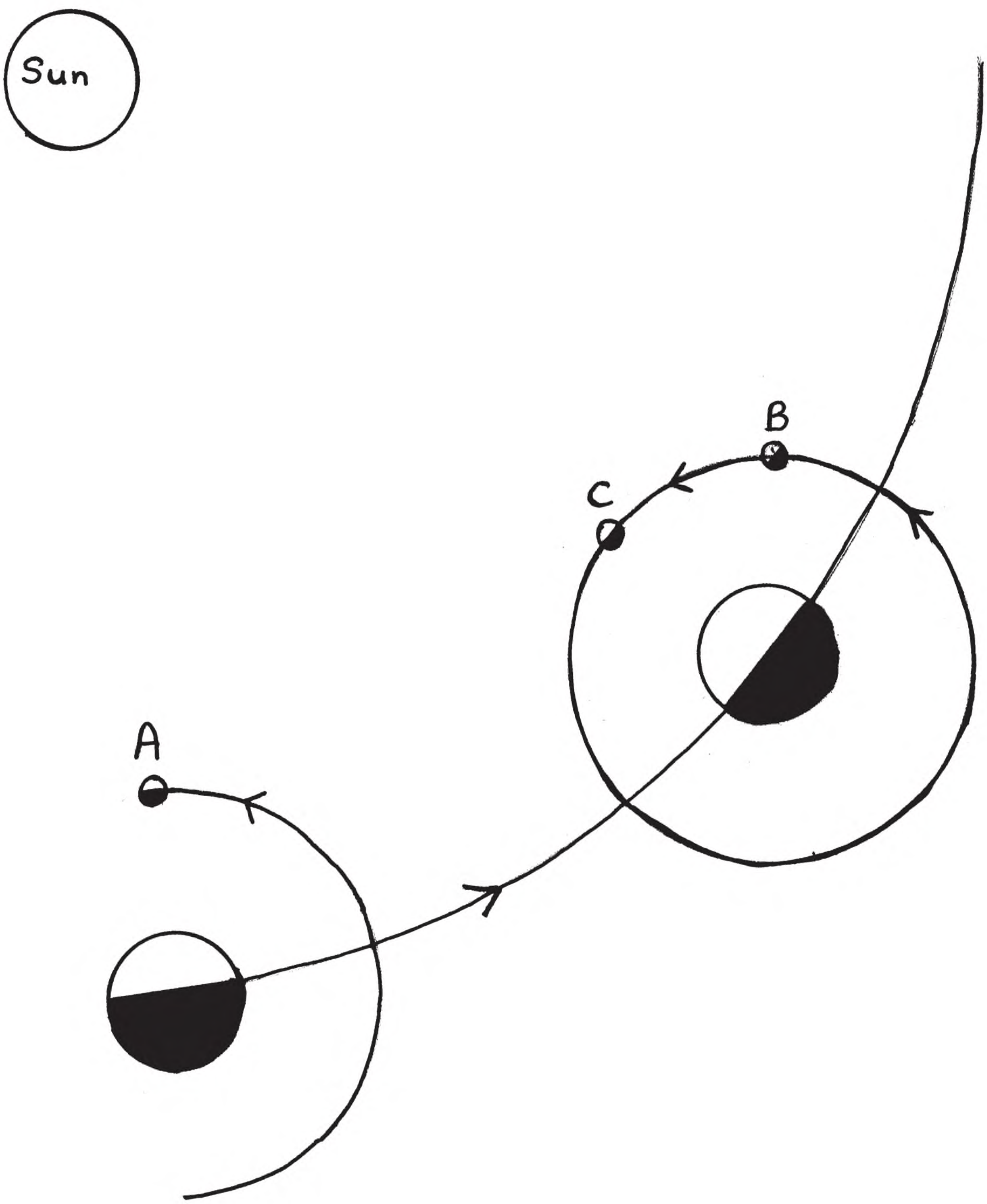


Figure 7 - At A, the moon is at "New" Phase. At B, it has completed one revolution around the Earth, but is not at "New" phase until it arrives at C.

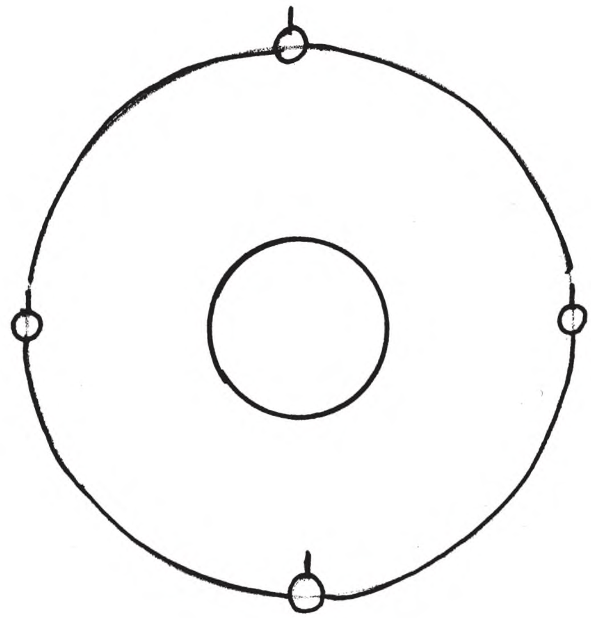


Figure 8a - If the Moon did not rotate (always faced the same direction in space, the little observer would disappear from view as seen from the Earth

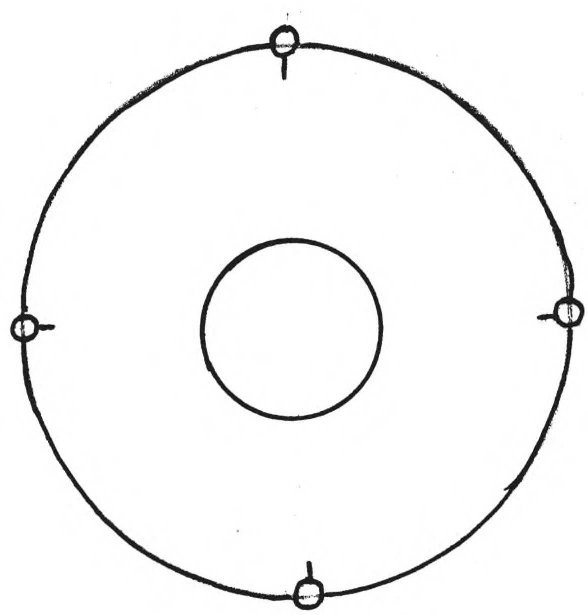


Figure 8b - Since the Moon rotates ¼ turn in ¼ revolution the observer never disappears from view.

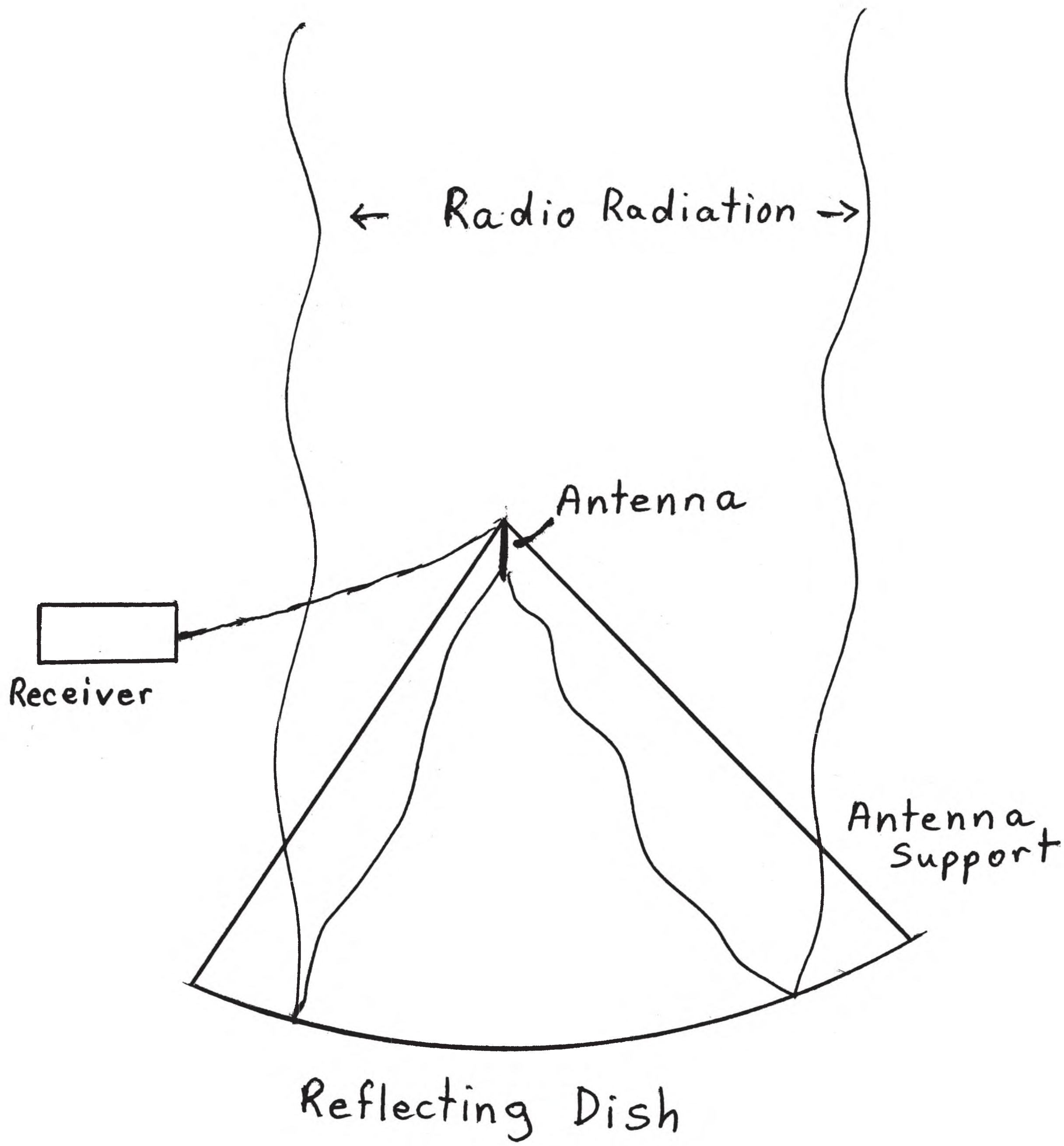


Figure 9 - Principle of the Radio Telescope

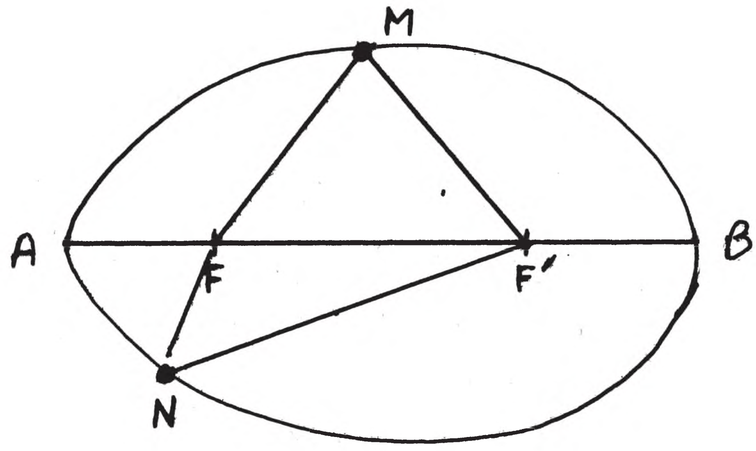


Figure 10 - The Ellipse

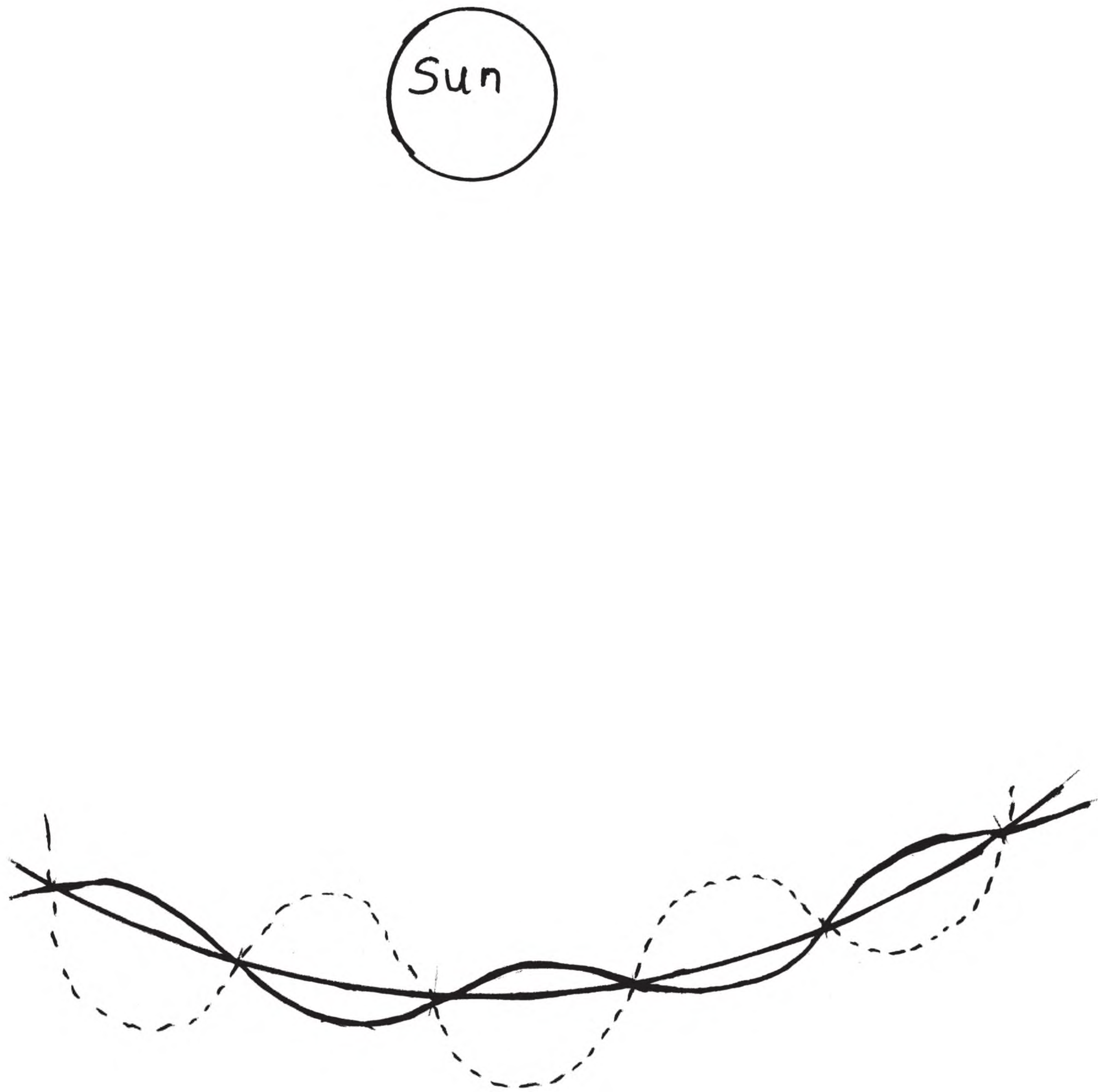


Figure 11 - The path of the Earth around the Sun is shown by the heavy curved line, and the Moon's path by the dashed line. Of course this is not to scale.

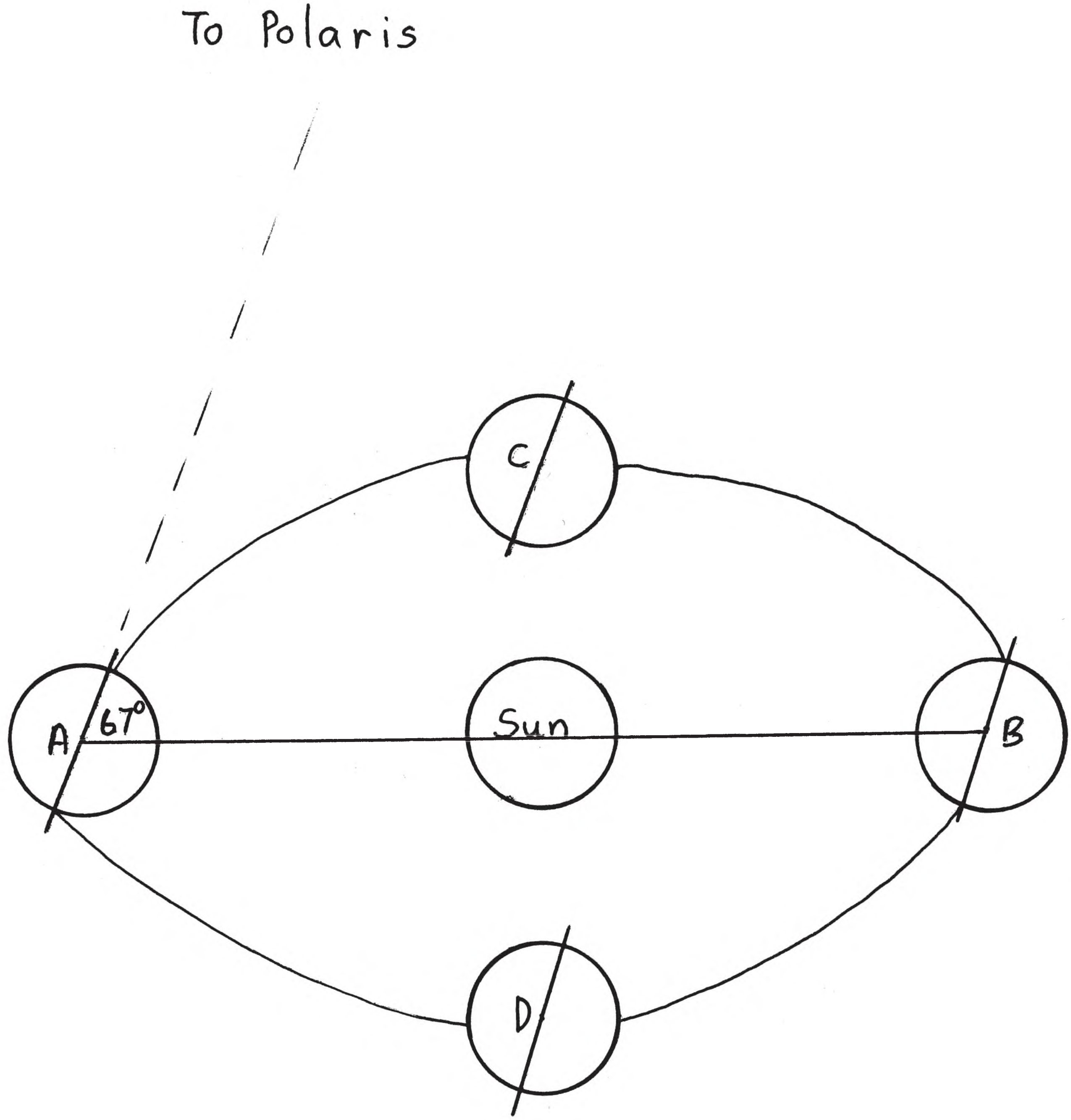


Figure 12 - The angle of the Earth's polar axis causes the seasons.

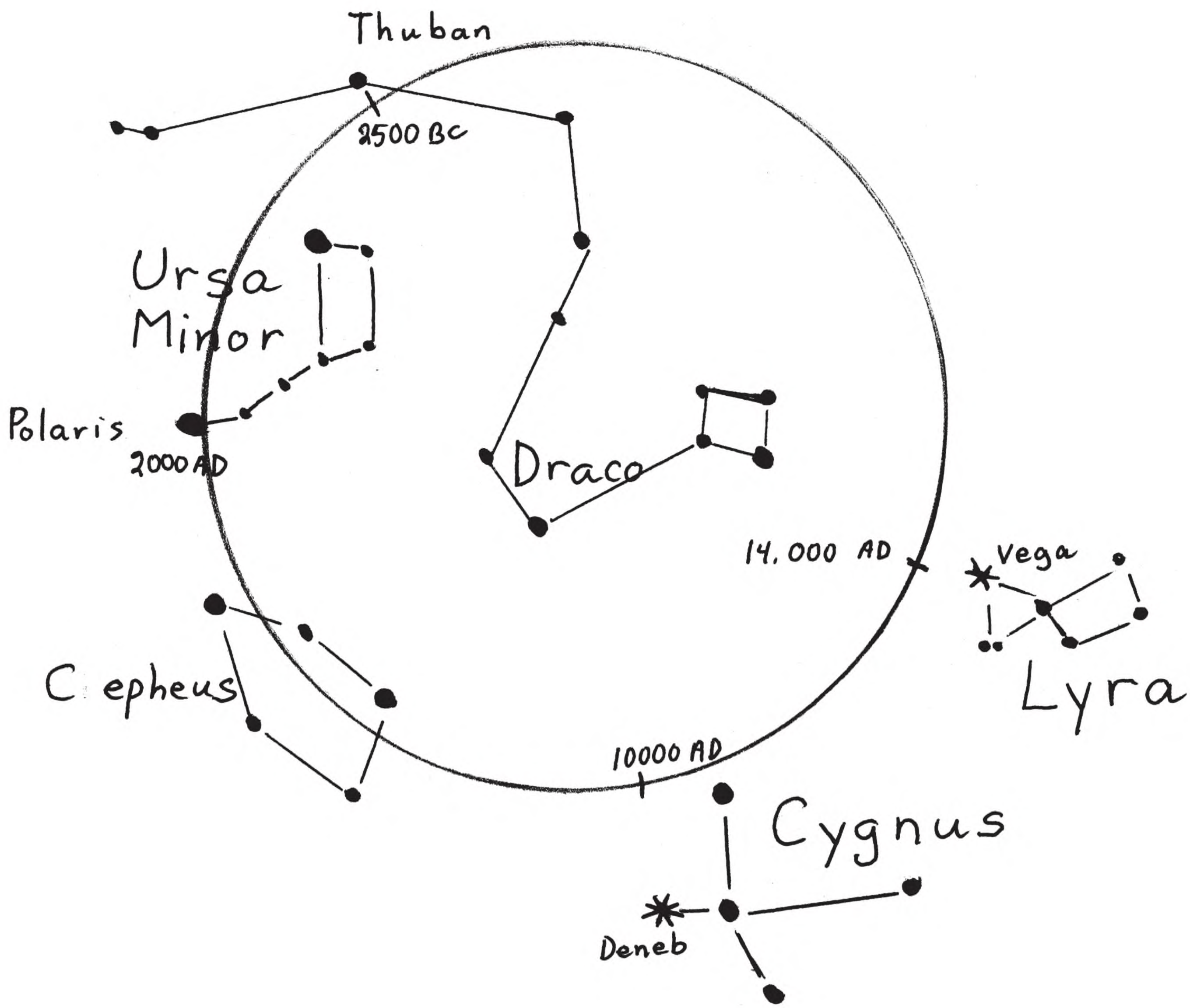


Figure 13 - The path of the Pole through the stars due to Precession. Nutation is a small variation in this path.

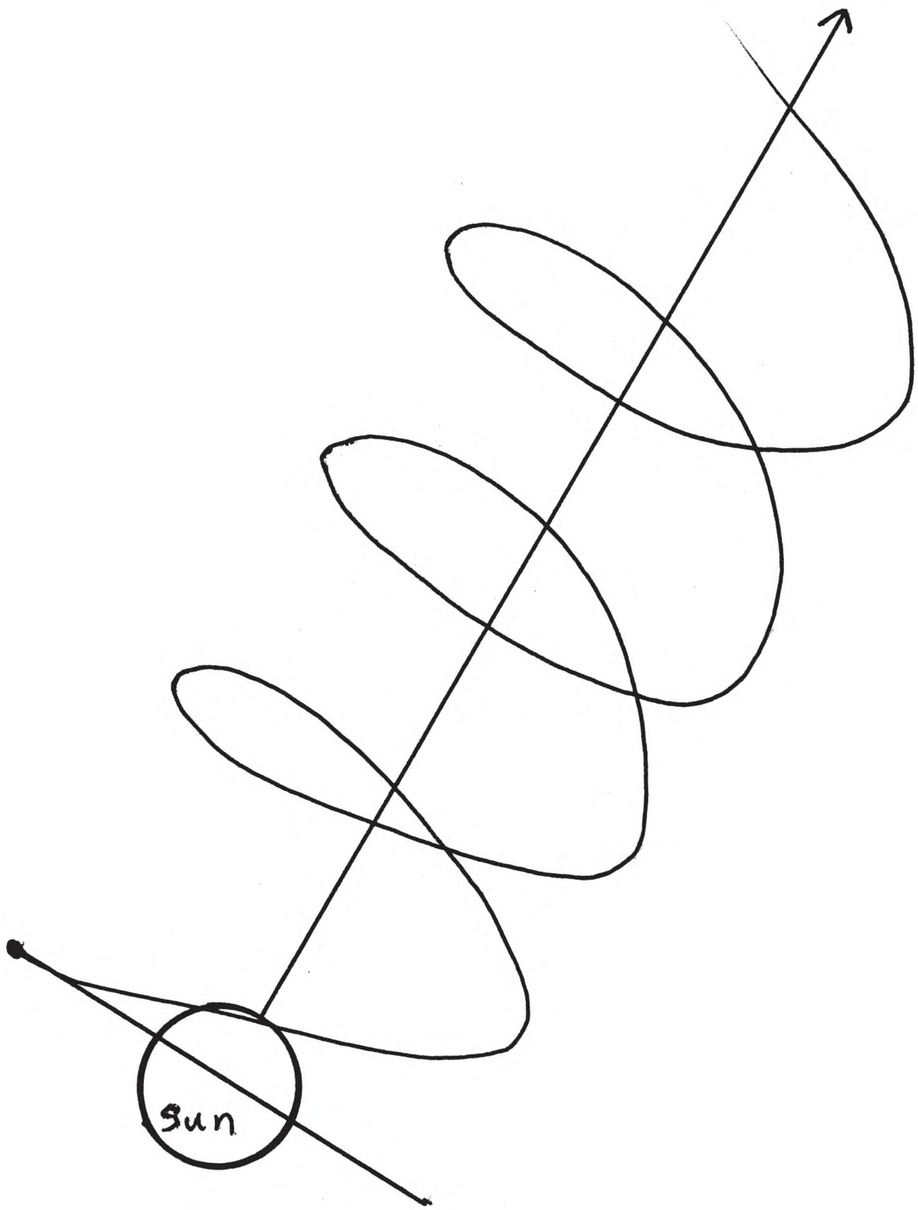


Figure 14 - The true motion of a planet as its star moves through space

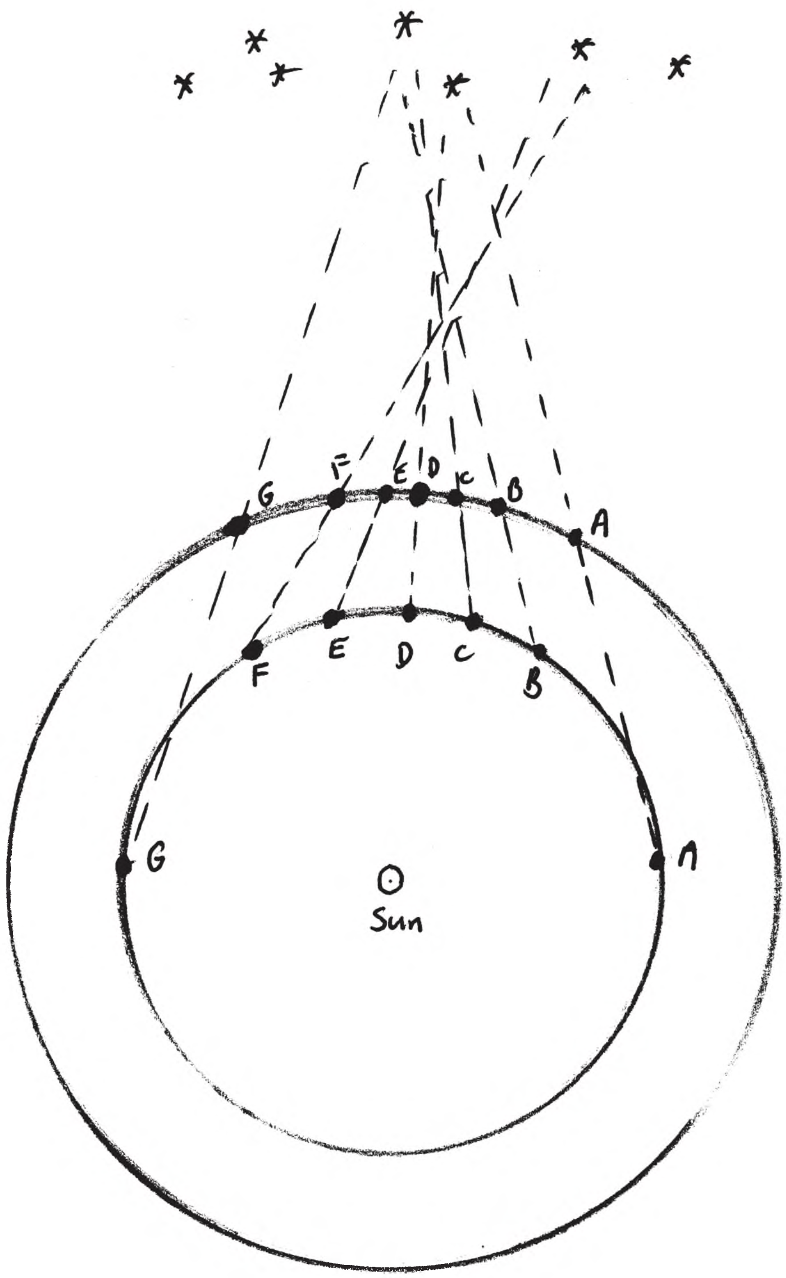


Figure 15 - Why Mars appears to move backwards with regard to the background stars. Note the direction of the line of sight.

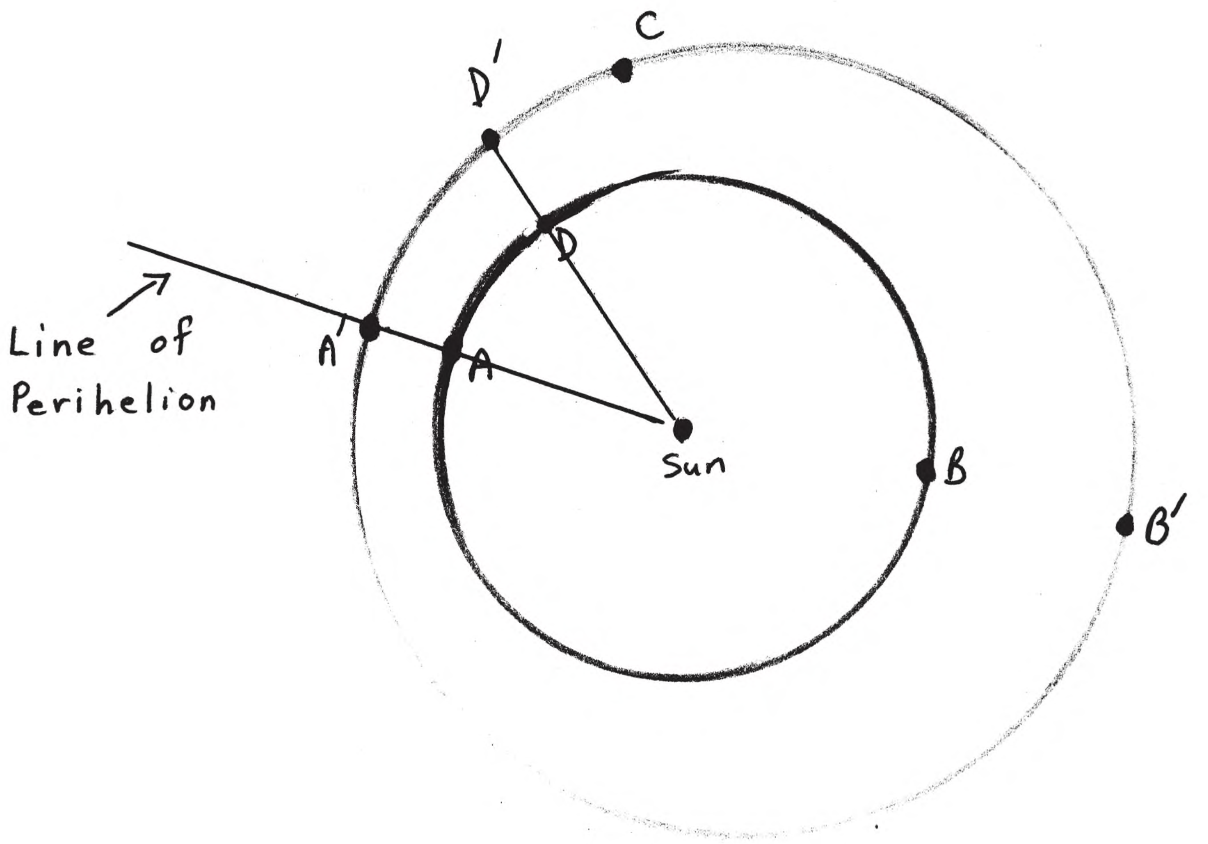


Figure 16 - Relative orbits of Earth and Mars (not to scale)

Figure 17 - Place this 50 feet away from you!

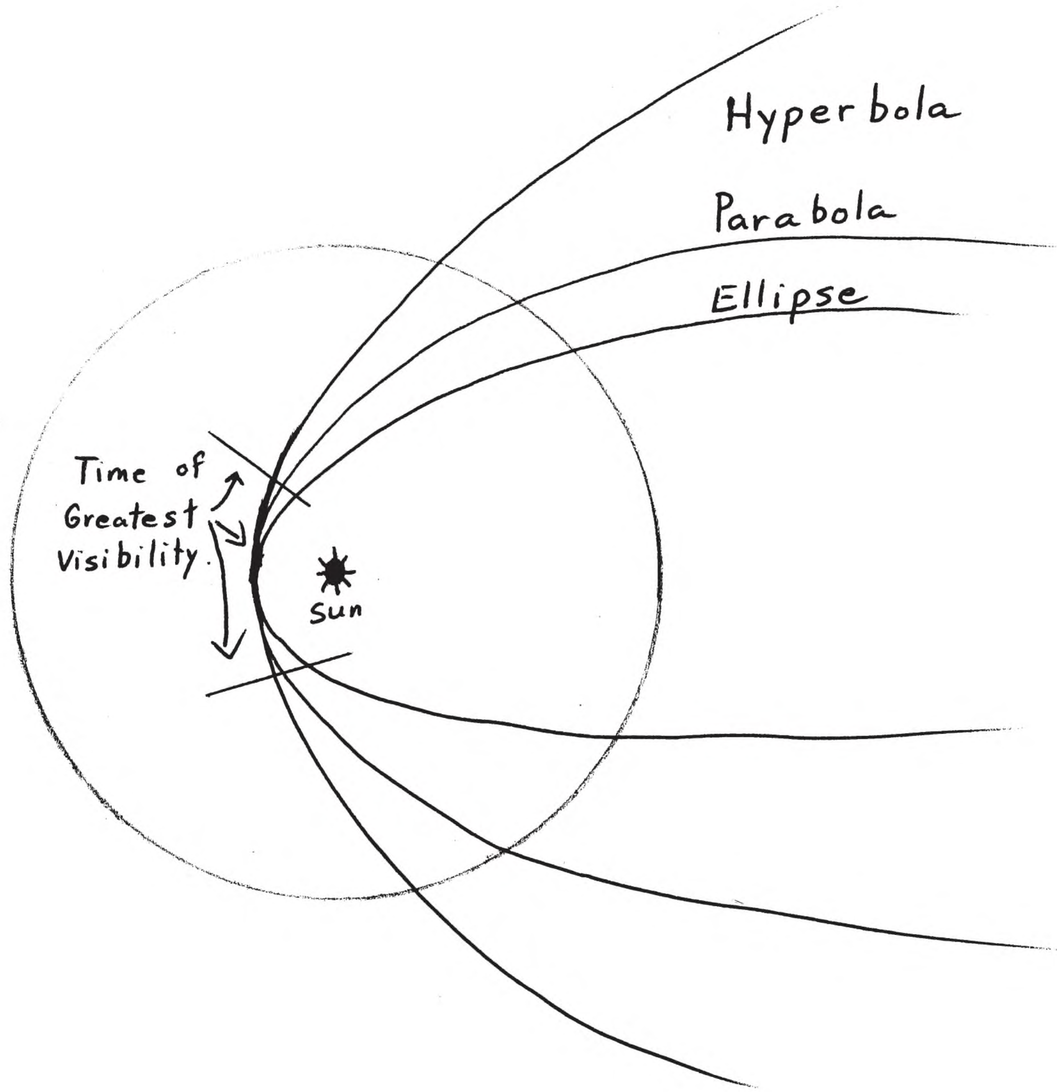


Figure 18 - Some typical comet orbits.

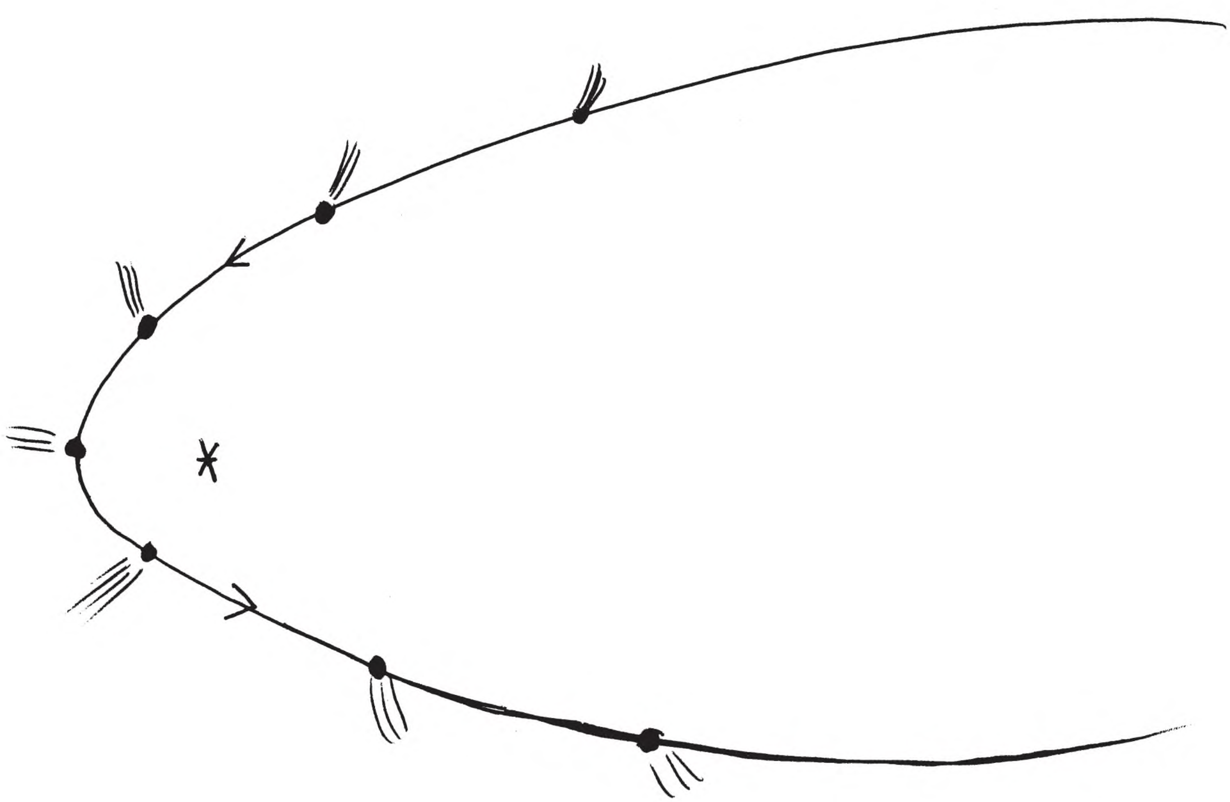


Figure 19 - How Comet Tails point away from the Sun.

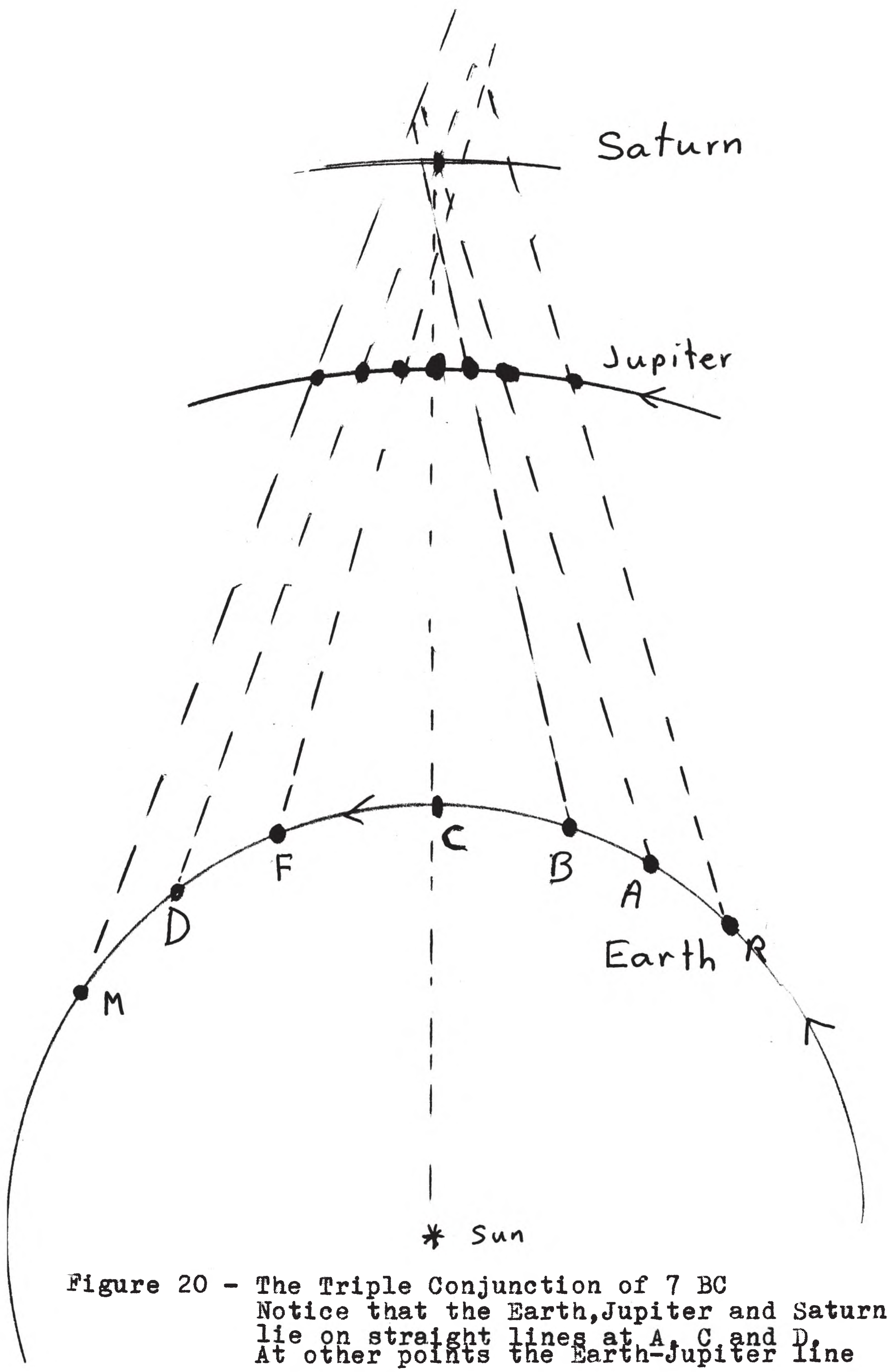


Figure 20 - The Triple Conjunction of 7 BC
Notice that the Earth, Jupiter and Saturn
lie on straight lines at A, C and D.
At other points the Earth-Jupiter line
misses Saturn.

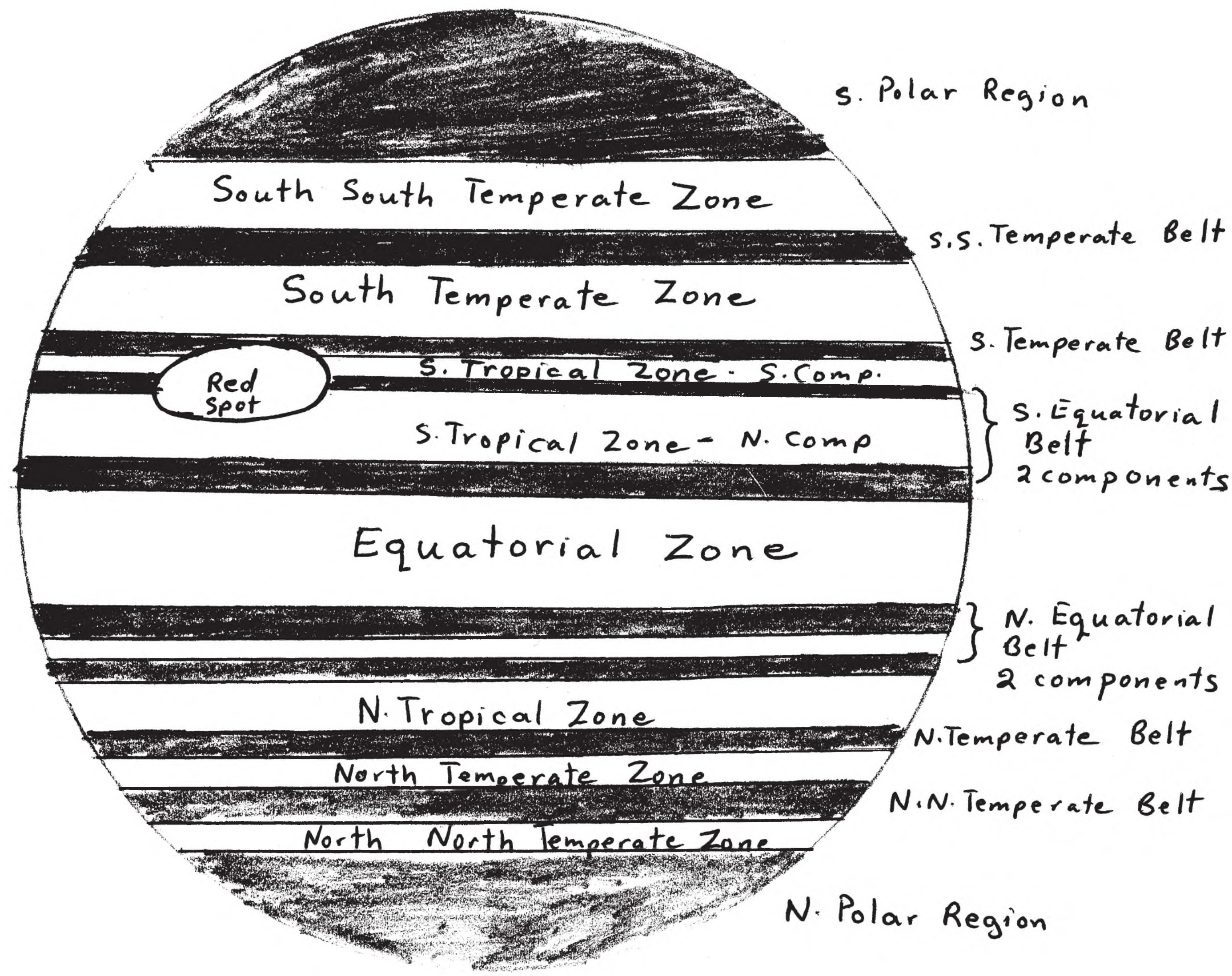


Figure 21 - The Belts and Zones of Jupiter

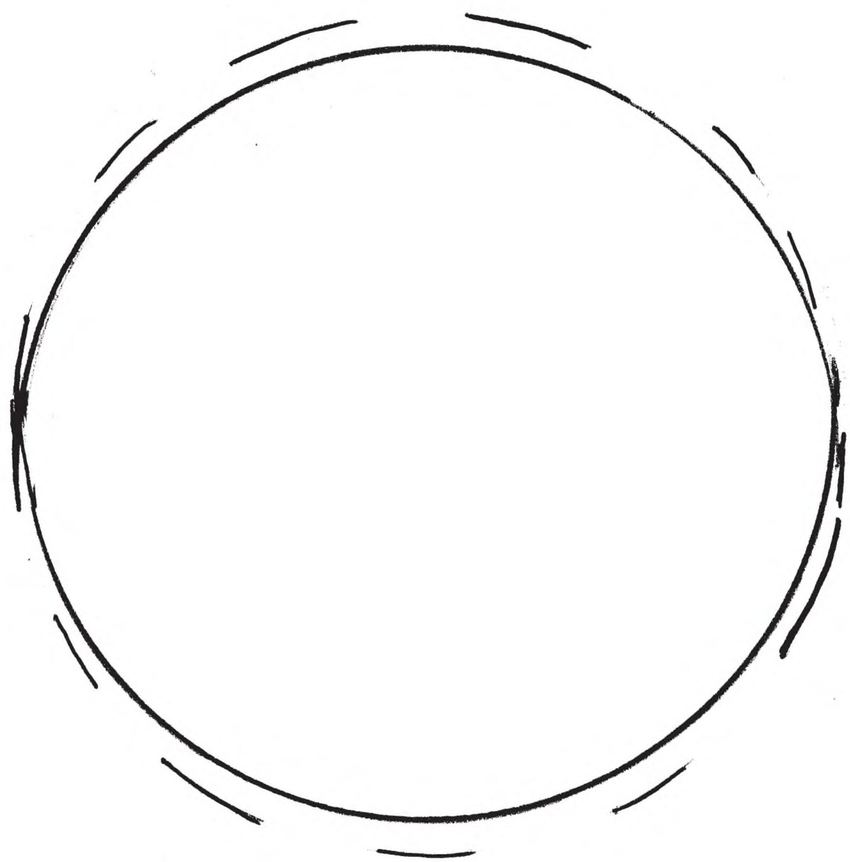


Figure 22 - The Polar Flattening of Jupiter

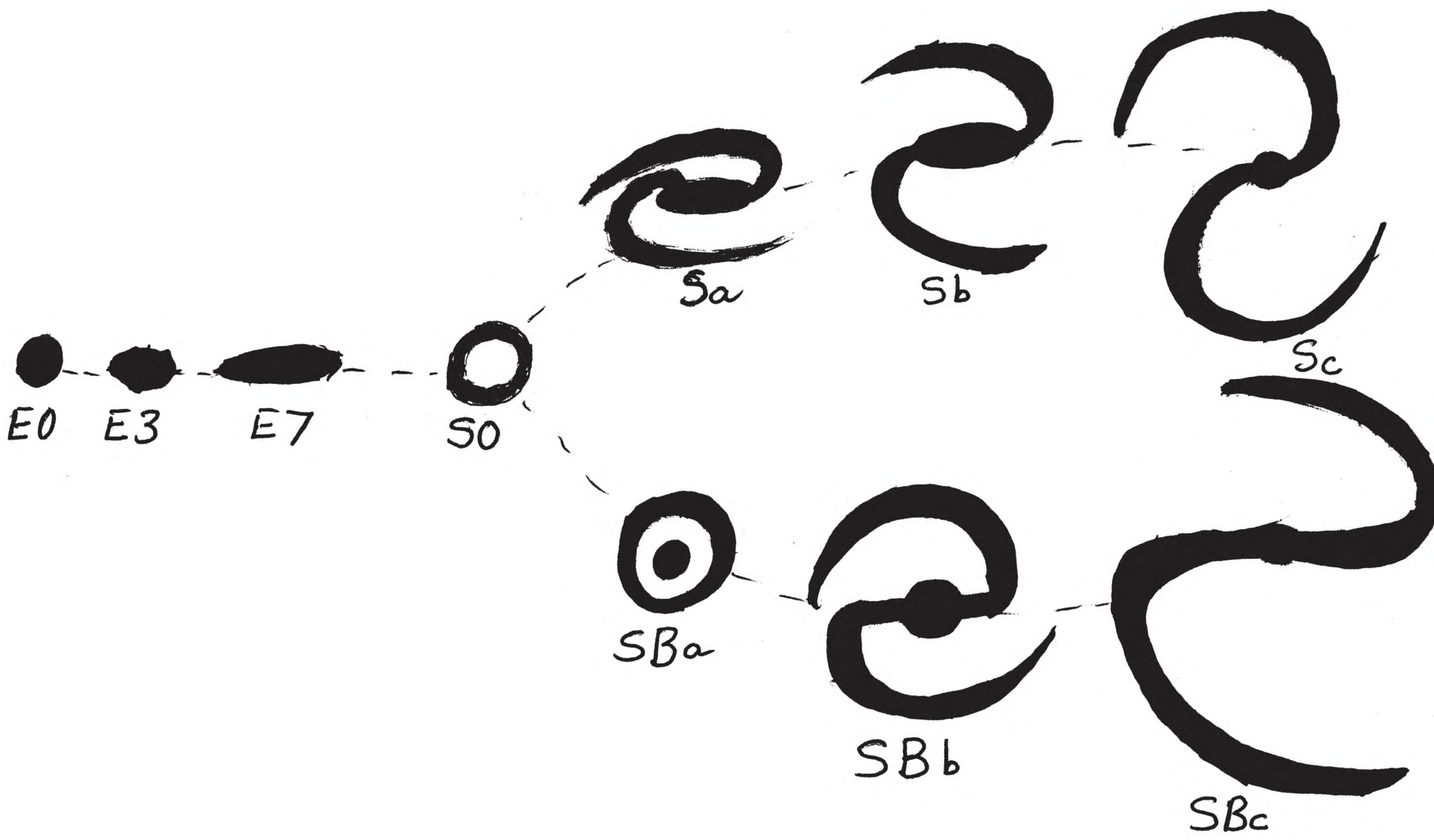


Figure 23 - Classification of Galaxies

E=Elliptical S = Spiral SB = Barred Spiral

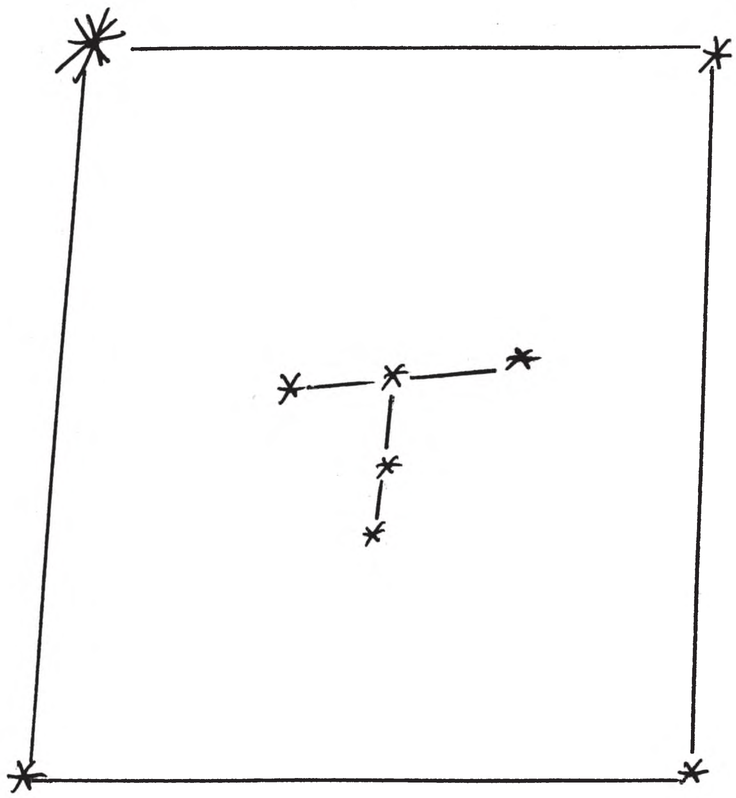
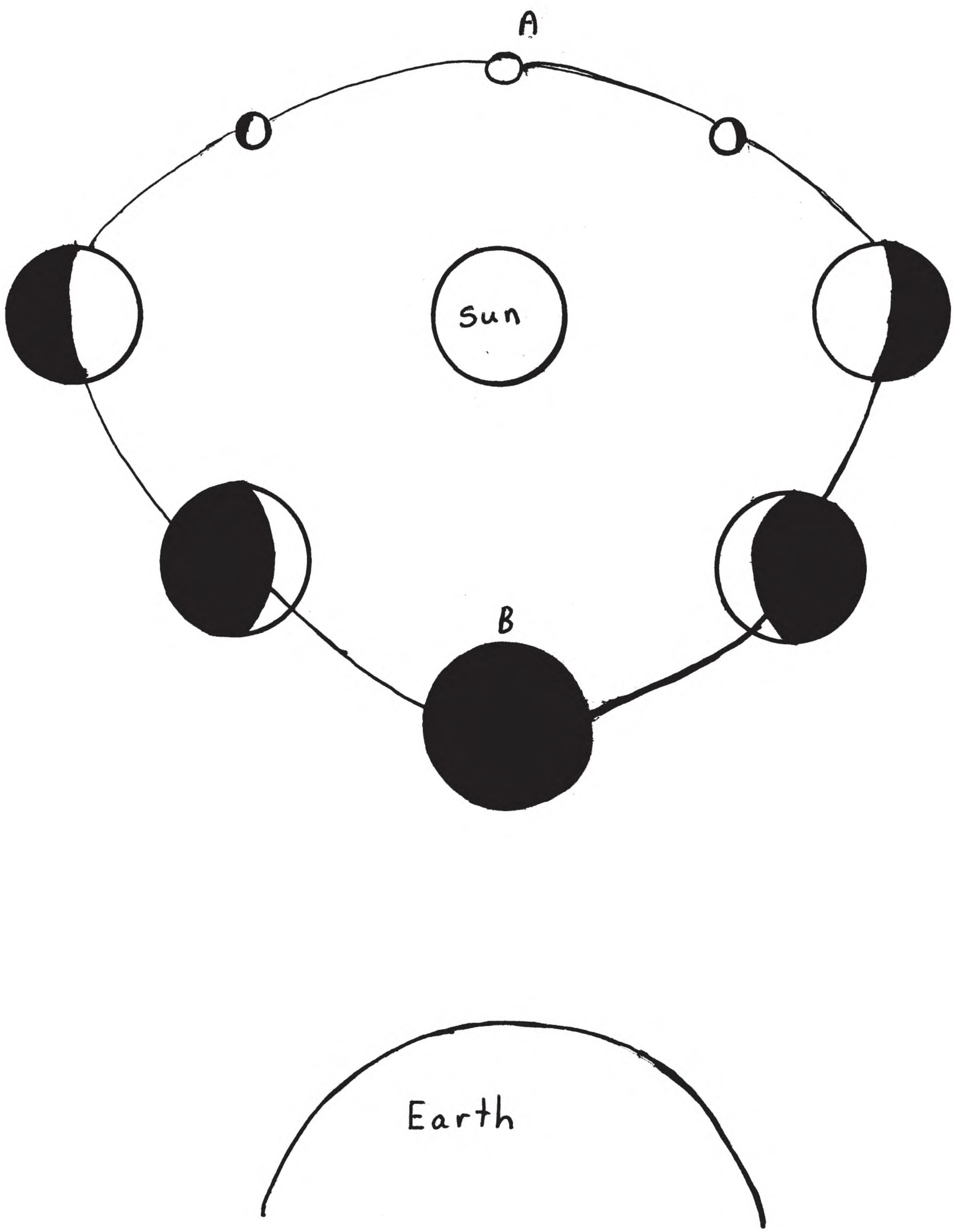
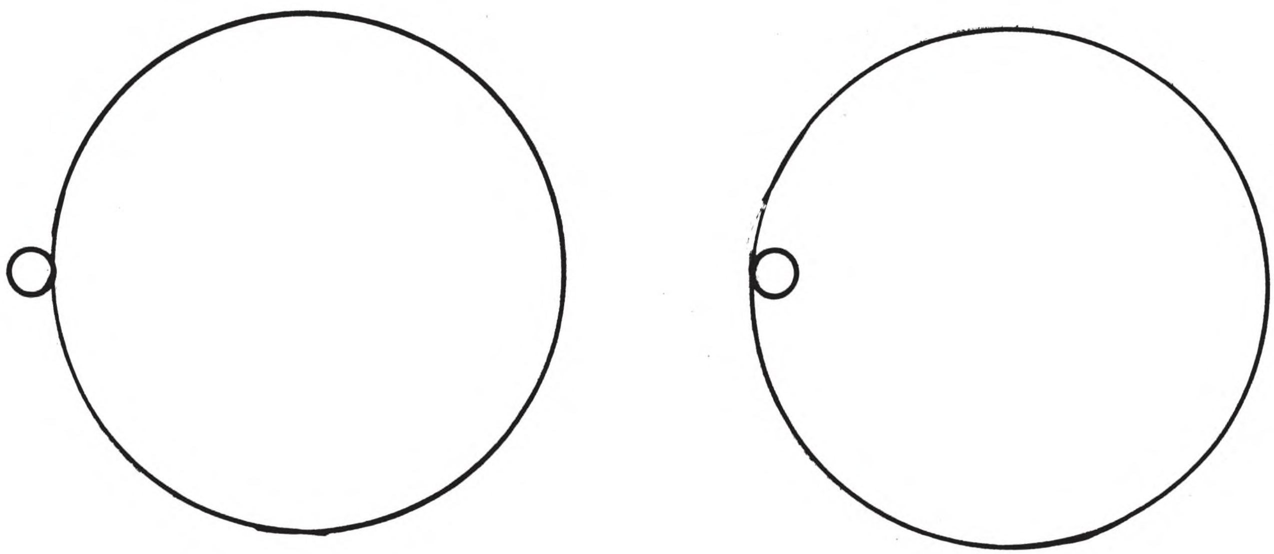


Figure 24 - The Box and T of Orion

Figure 25 - Orion, showing its principal stars

Figure 26 - The Phases of An Inferior Planet





First Contact   Second Contact

Figure 27 - Contacts during a transit of an inferior planet

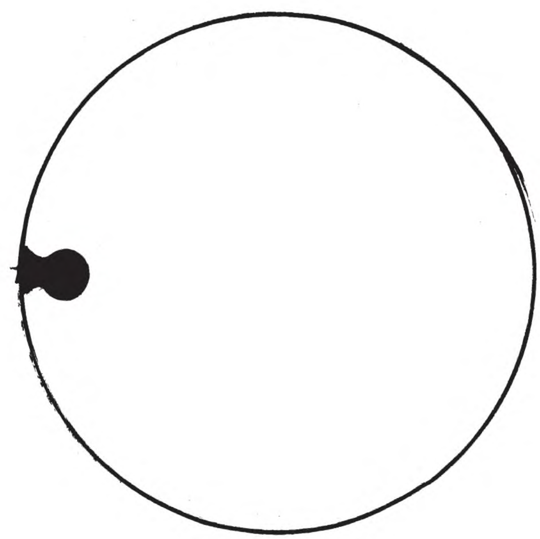


Figure 28 - The "Black Drop" Effect (greatly exaggerated)

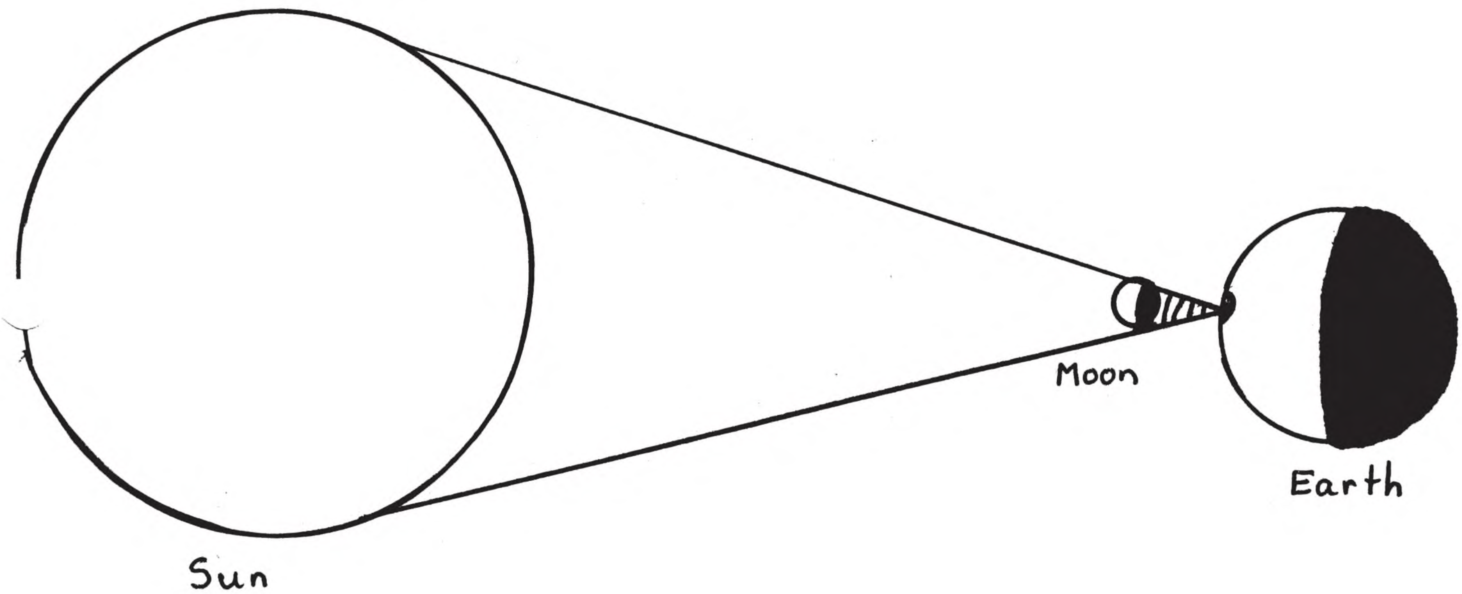


Figure 29- Positions of the Sun, Moon, and Earth in An Eclipse

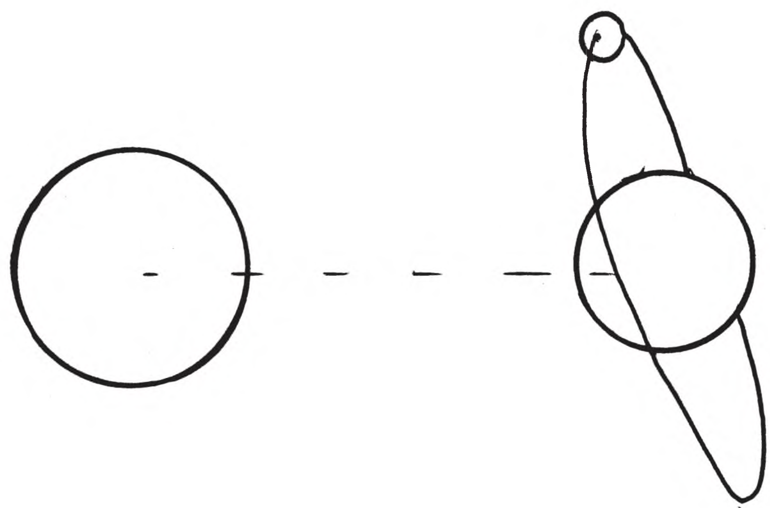


Figure 30 - The Moon's orbit is tilted with
regard to the plane of the Earth's orbit

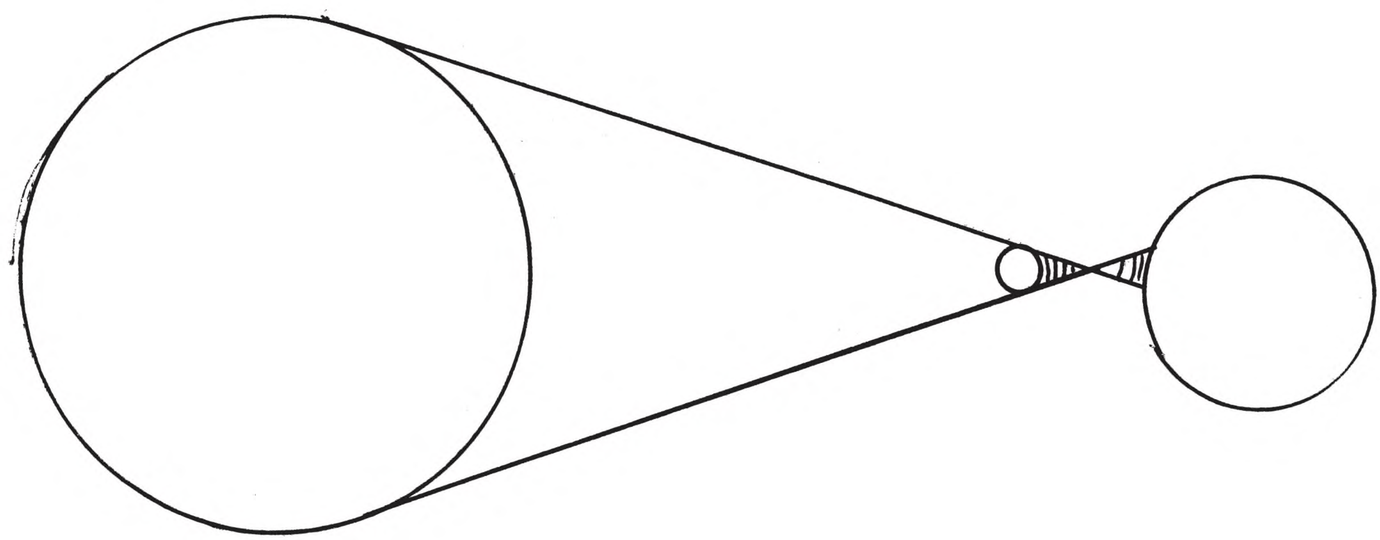


Figure 31 - The Moon's shadow does not reach the Earth

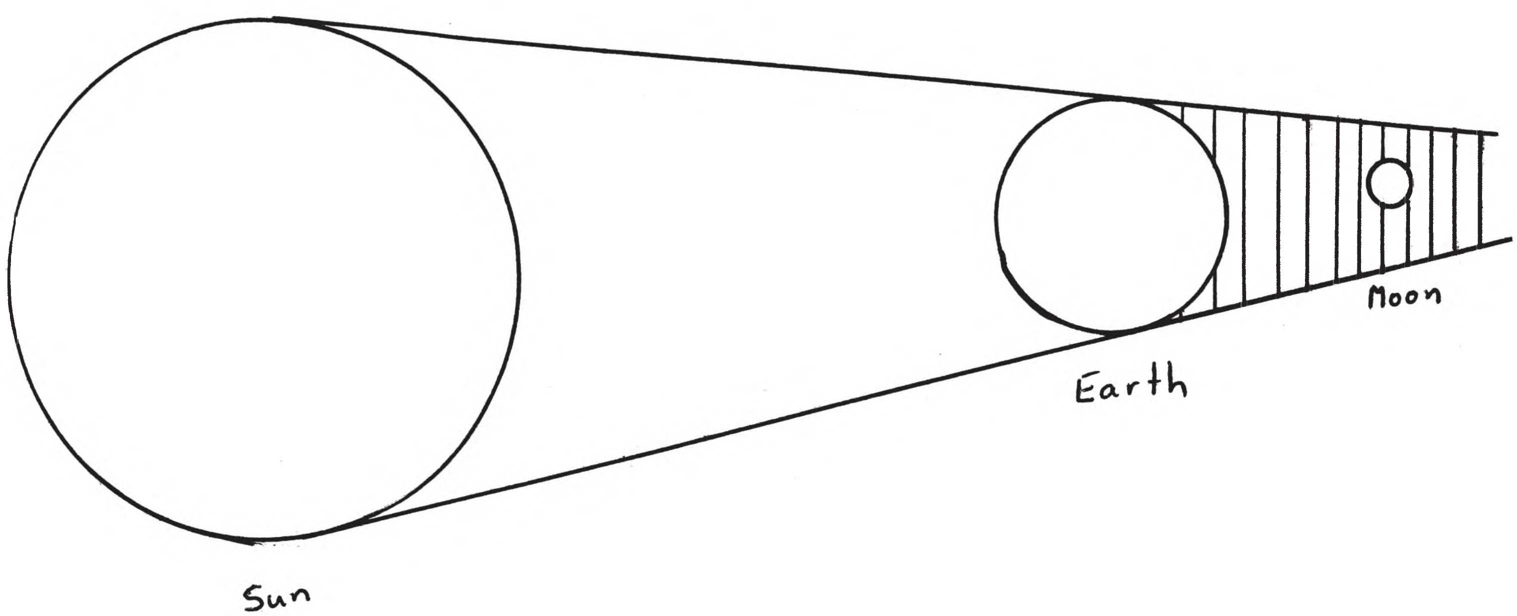


Figure 32 - A Lunar Eclipse

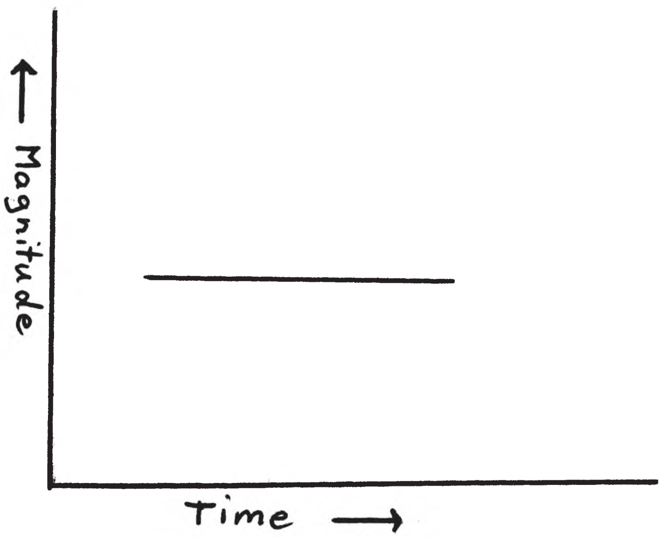


Figure 33a- A Non-varying star

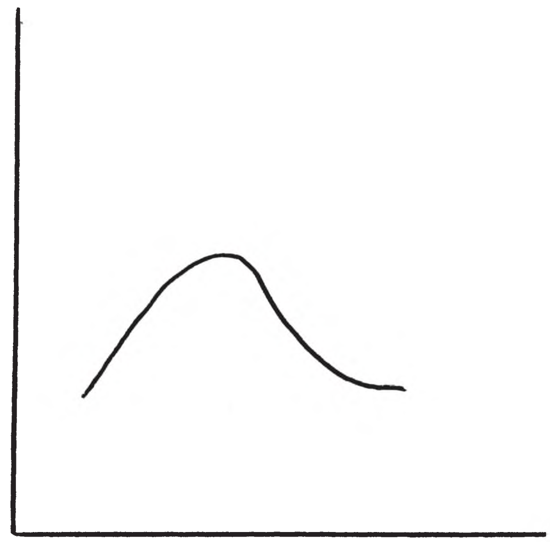


Figure 33b-A variable star

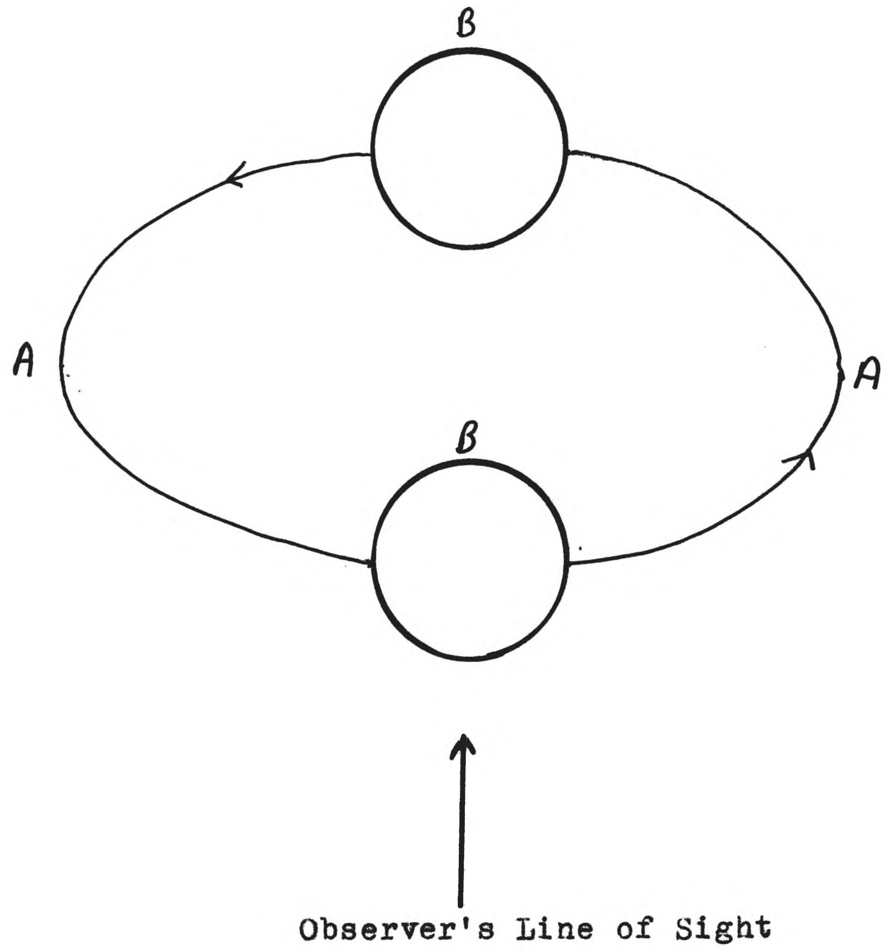


Figure 34 - An Eclipsing Binary System

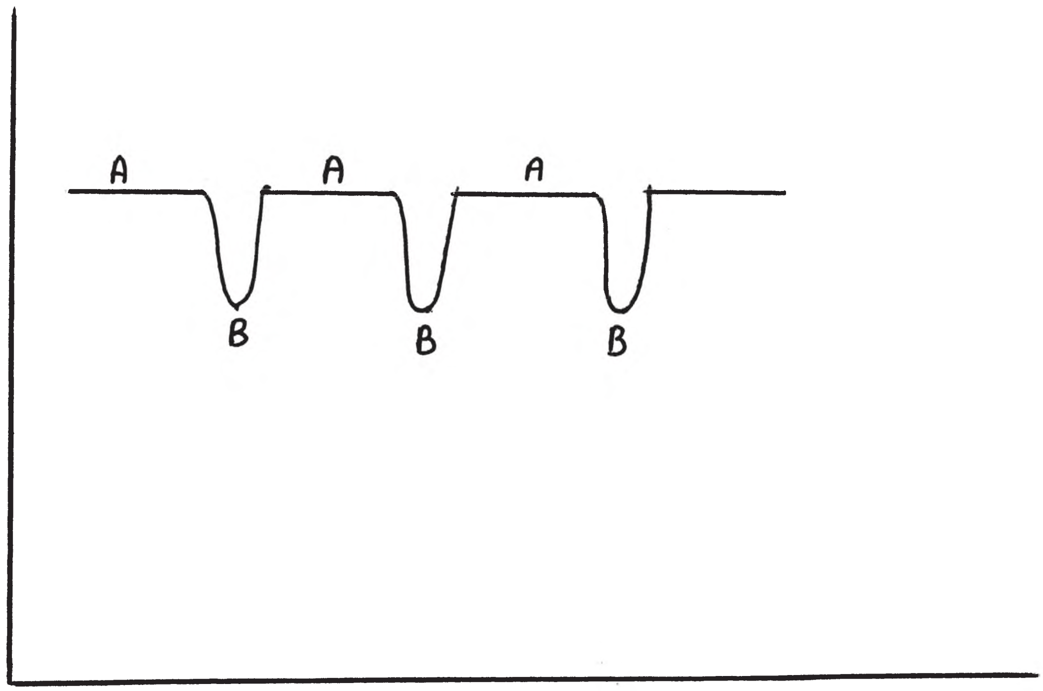


Figure 35 - Light Curve of An Eclipsing Binary

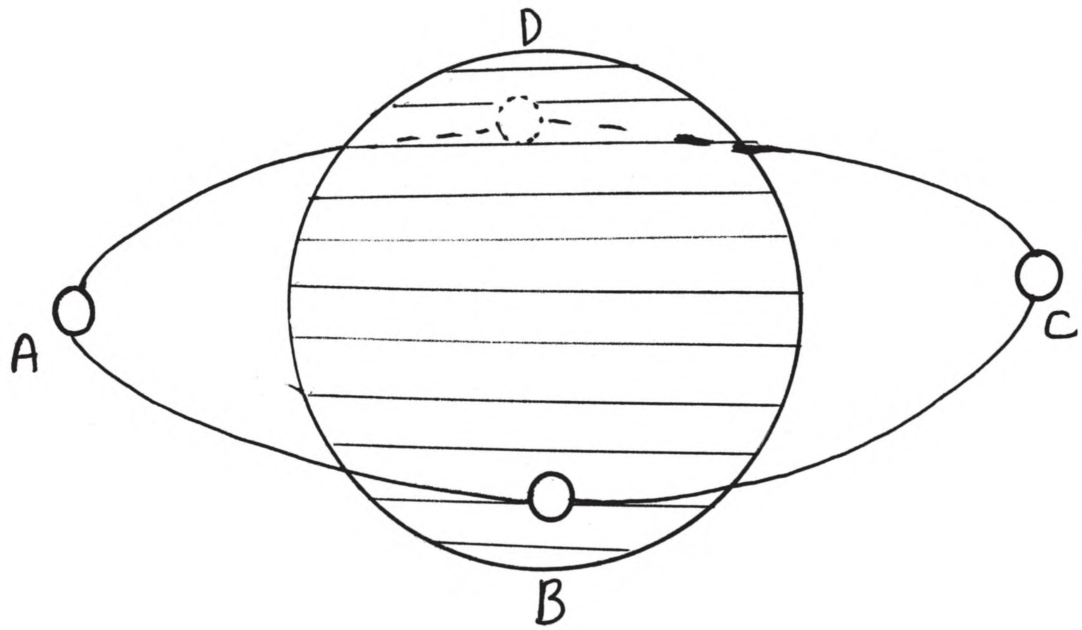


Figure 36 - A Small Bright Star in Orbit Around A Large Faint Star

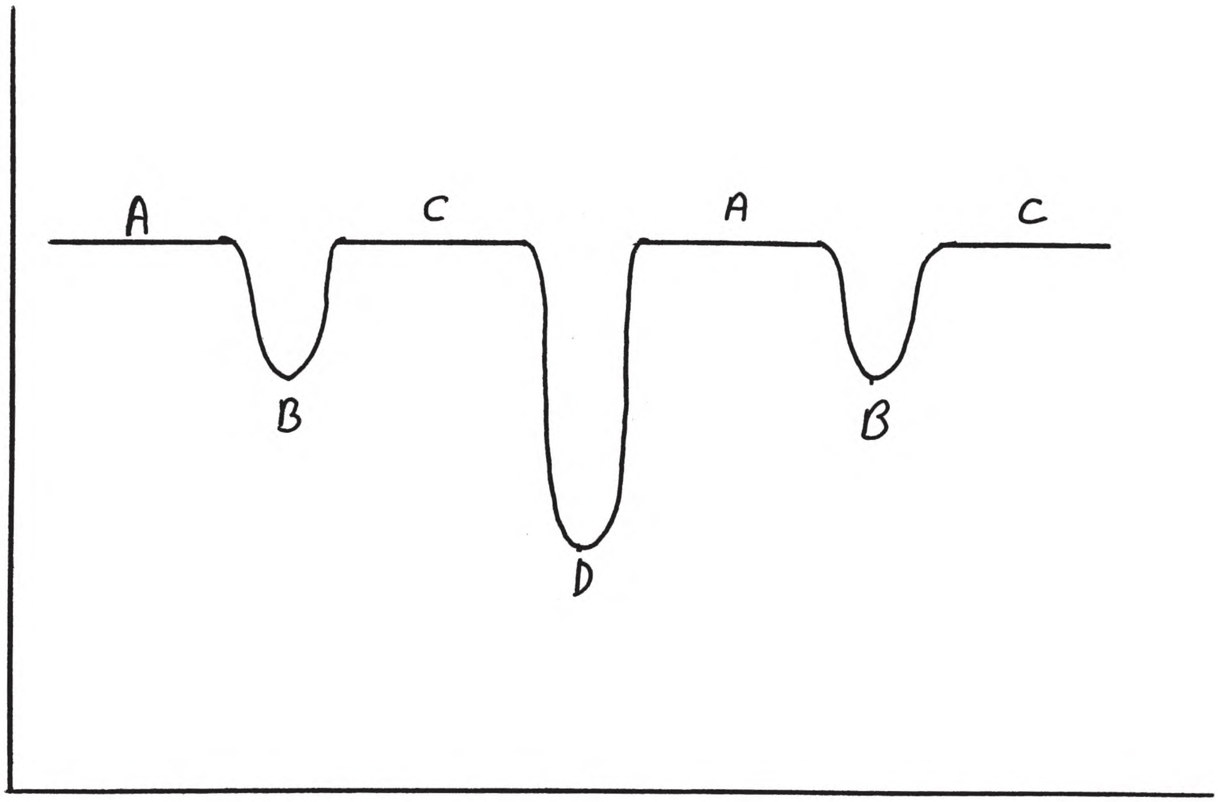


Figure 37 – Light curve for unequal eclipsing stars

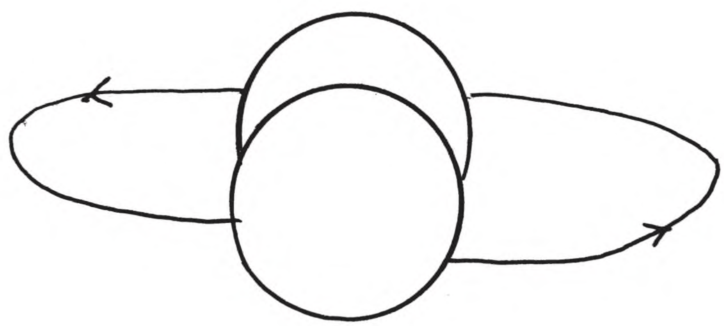


Figure 38 - Partially Eclipsing Binary System

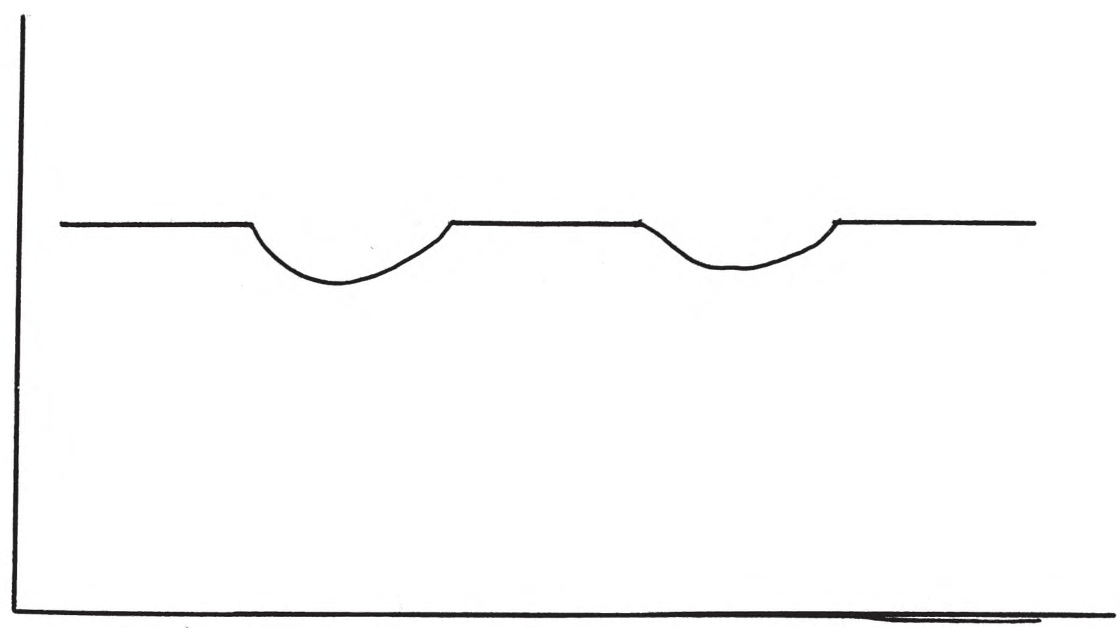


Figure 39 - Light curve of a partially eclipsing binary

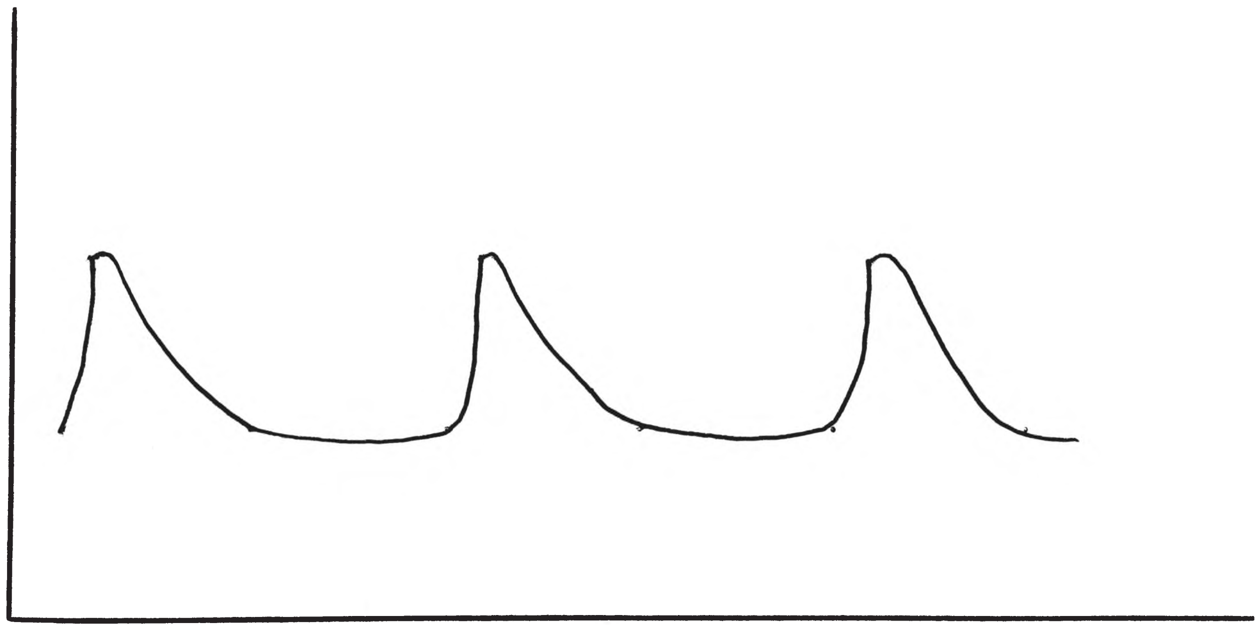


Figure 40 - Light curve of an RR Lyrae-a star

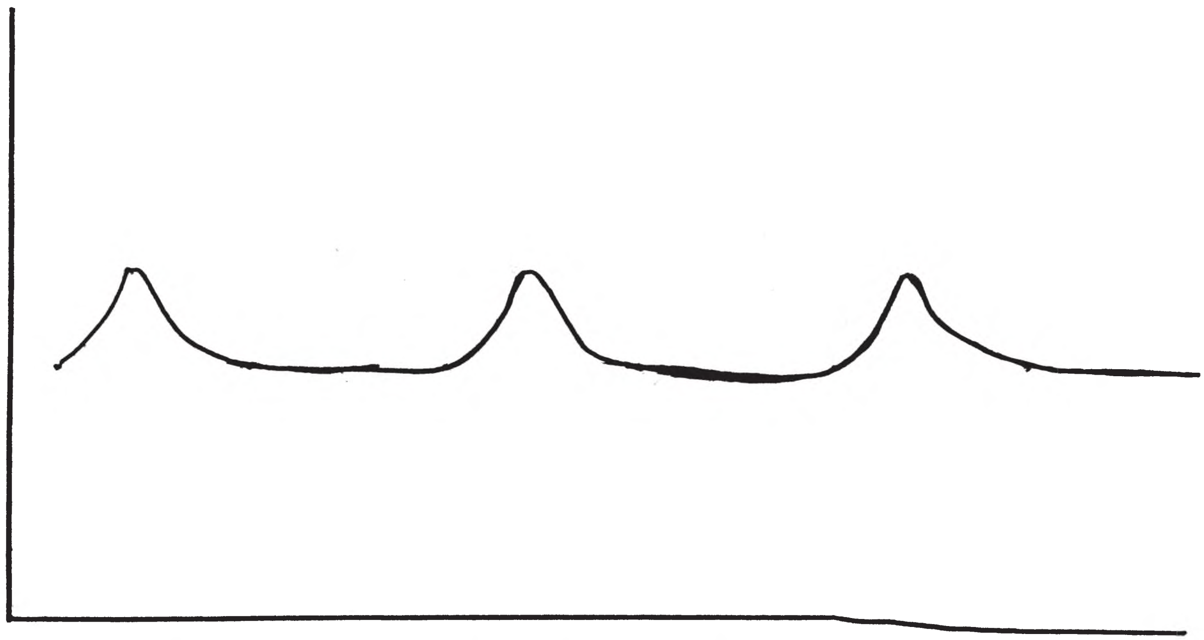


Figure 41 - Light curve of an RR Lyrae-b star

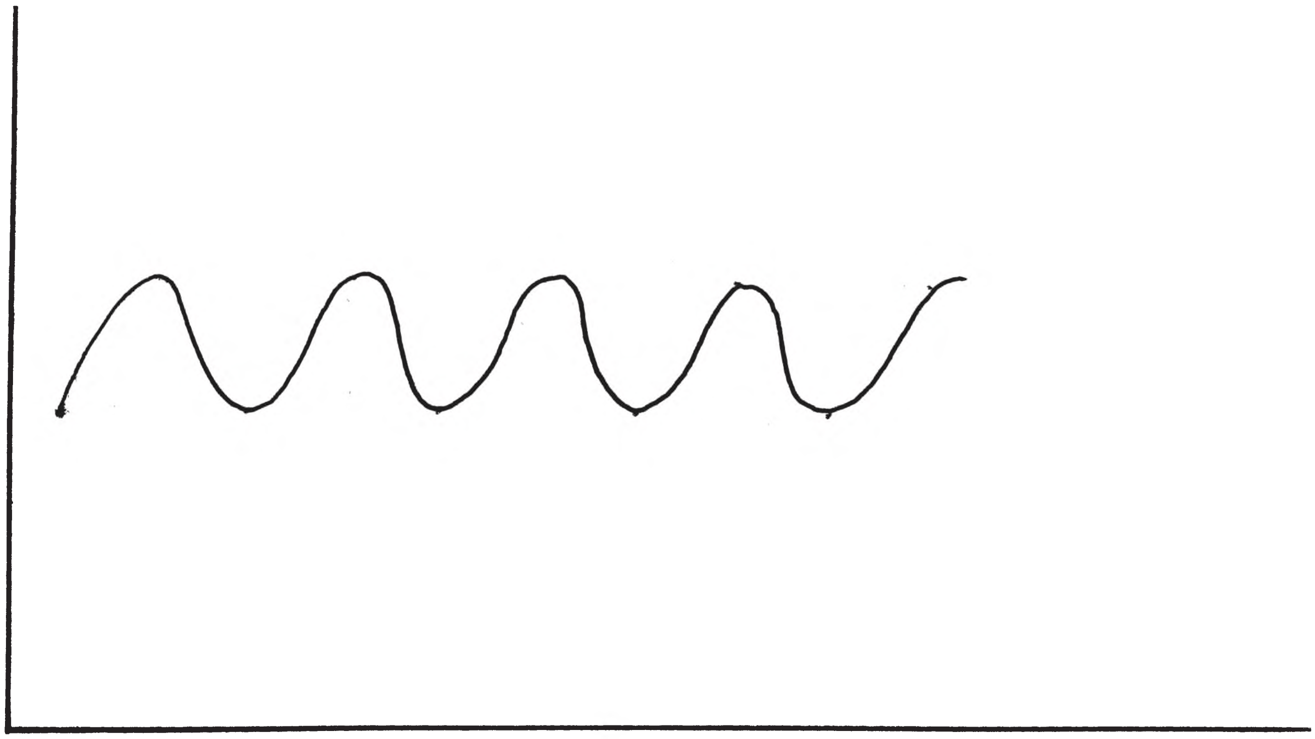


Figure 42 - Light Curve of an RR Lyrae-c star

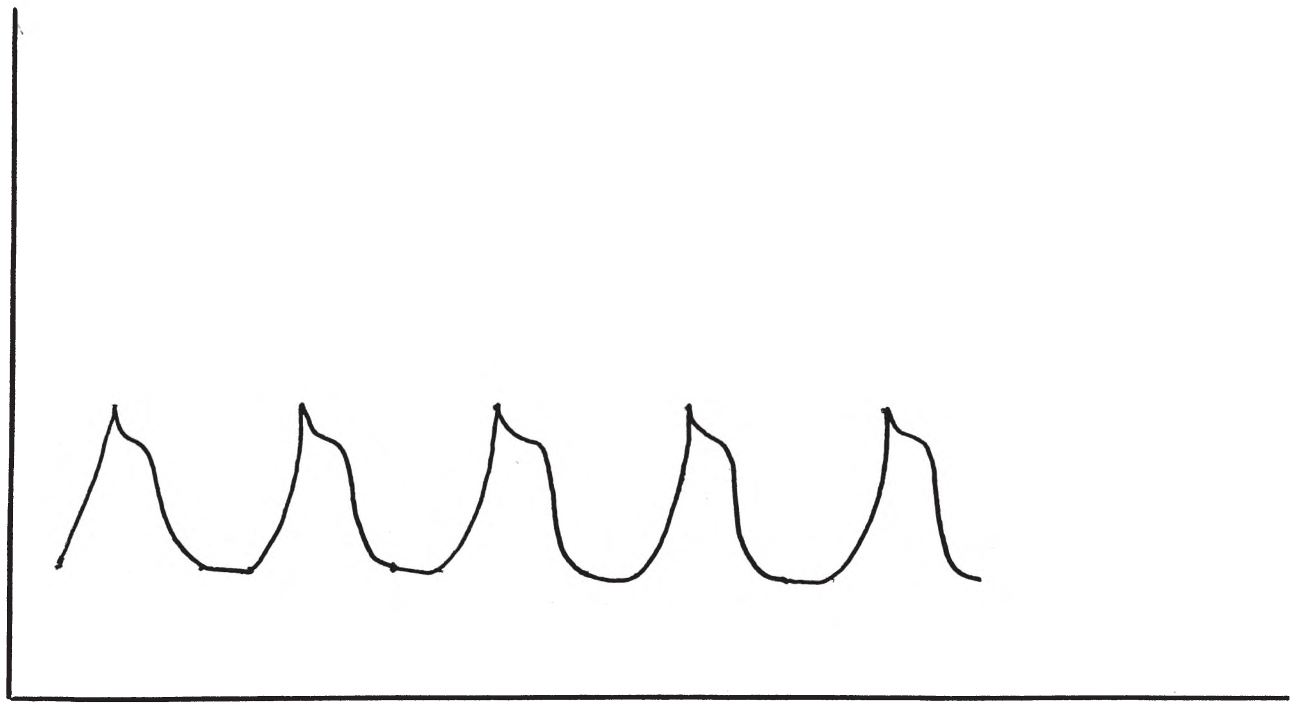


Figure 43 - Light curve of a Delta Cephei star

Figure 44 - Light curve for W Virginis stars

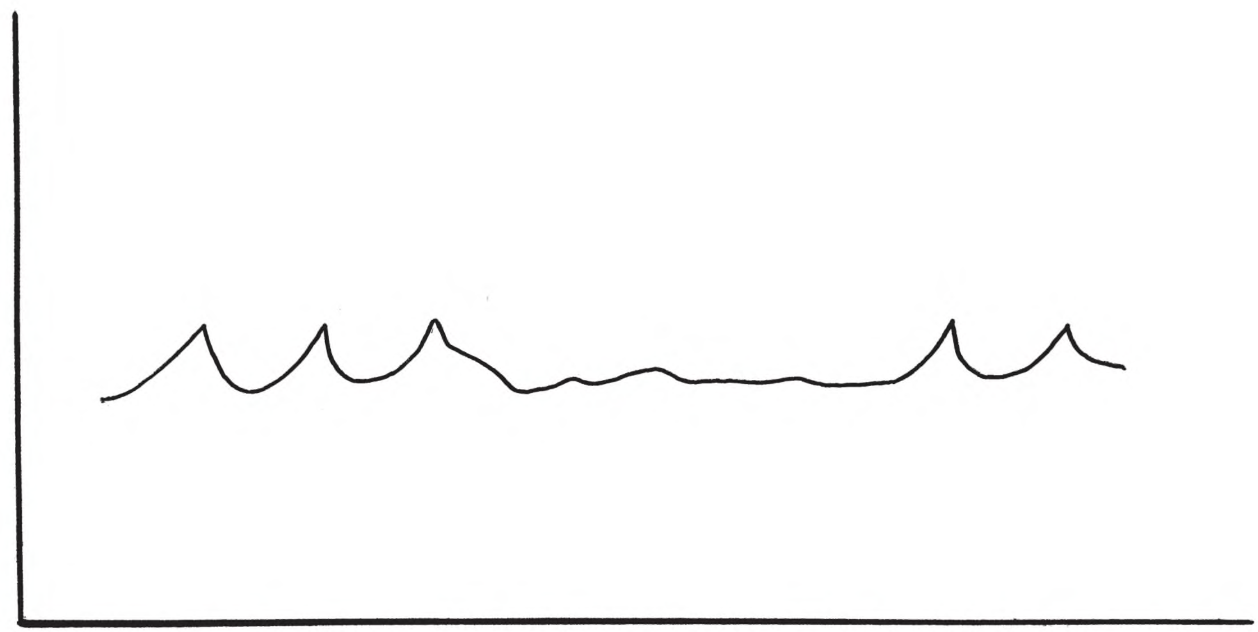


Figure 45 - Light curve for Beta Canis Majoris stars

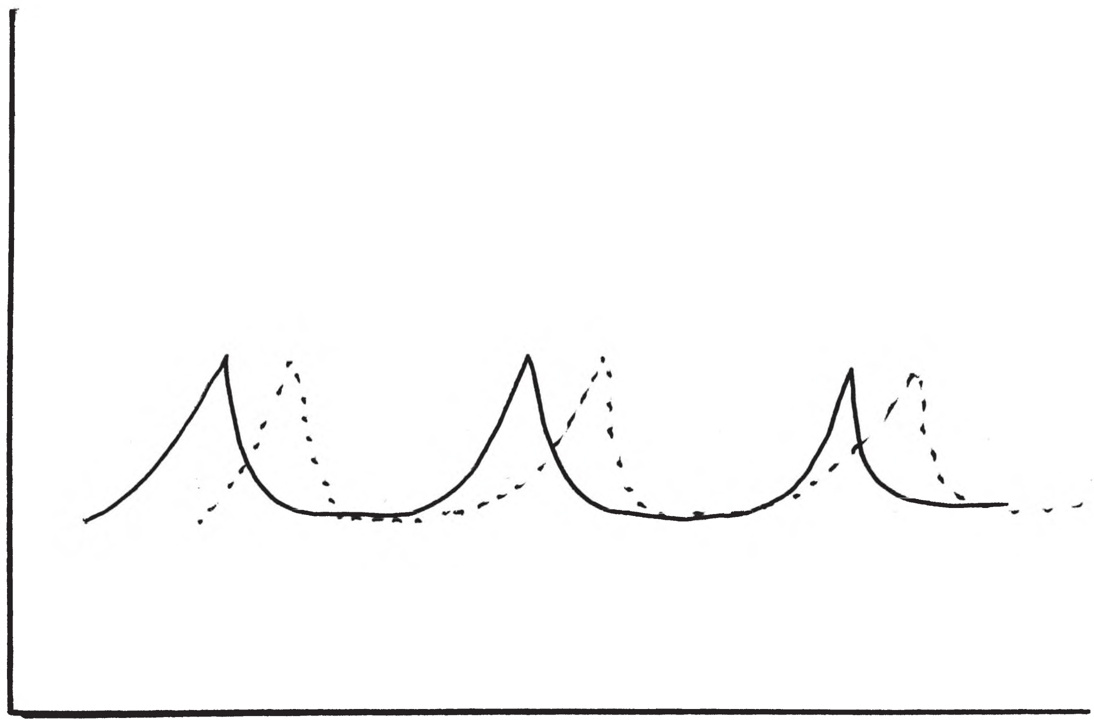


Figure 46 - Light curve for Delta Scuti variables

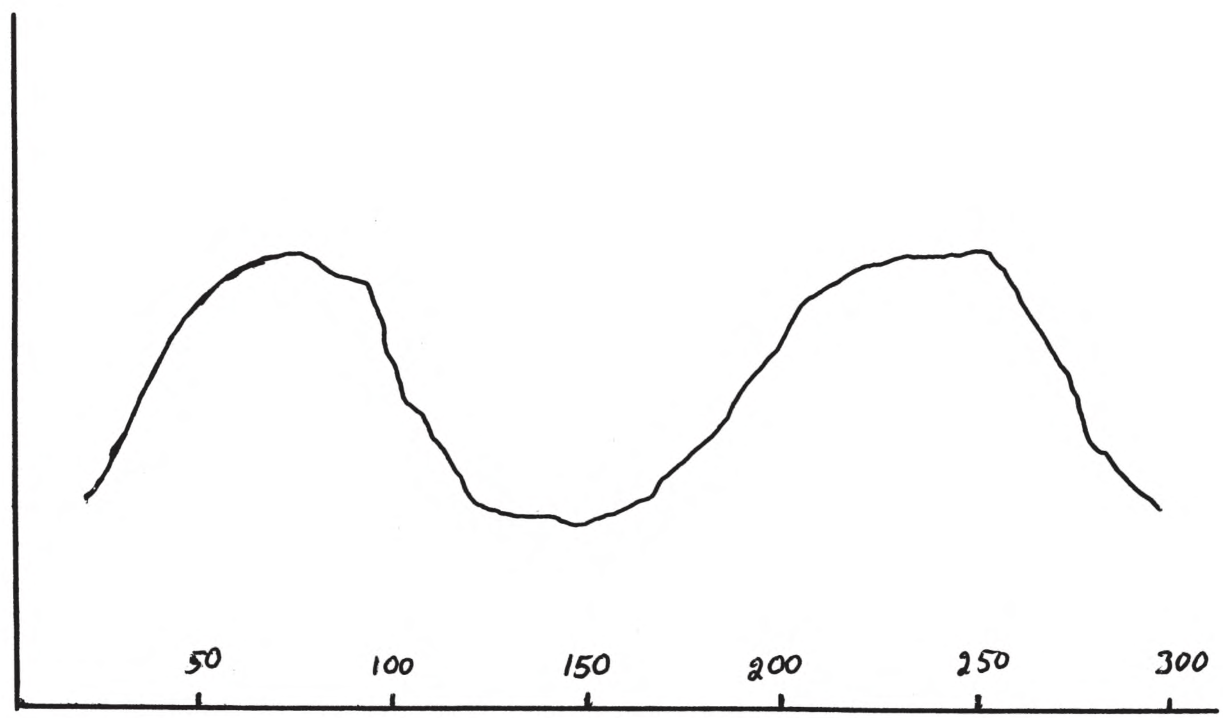


Figure 47 - Light curve of a typical Long-Period variable star

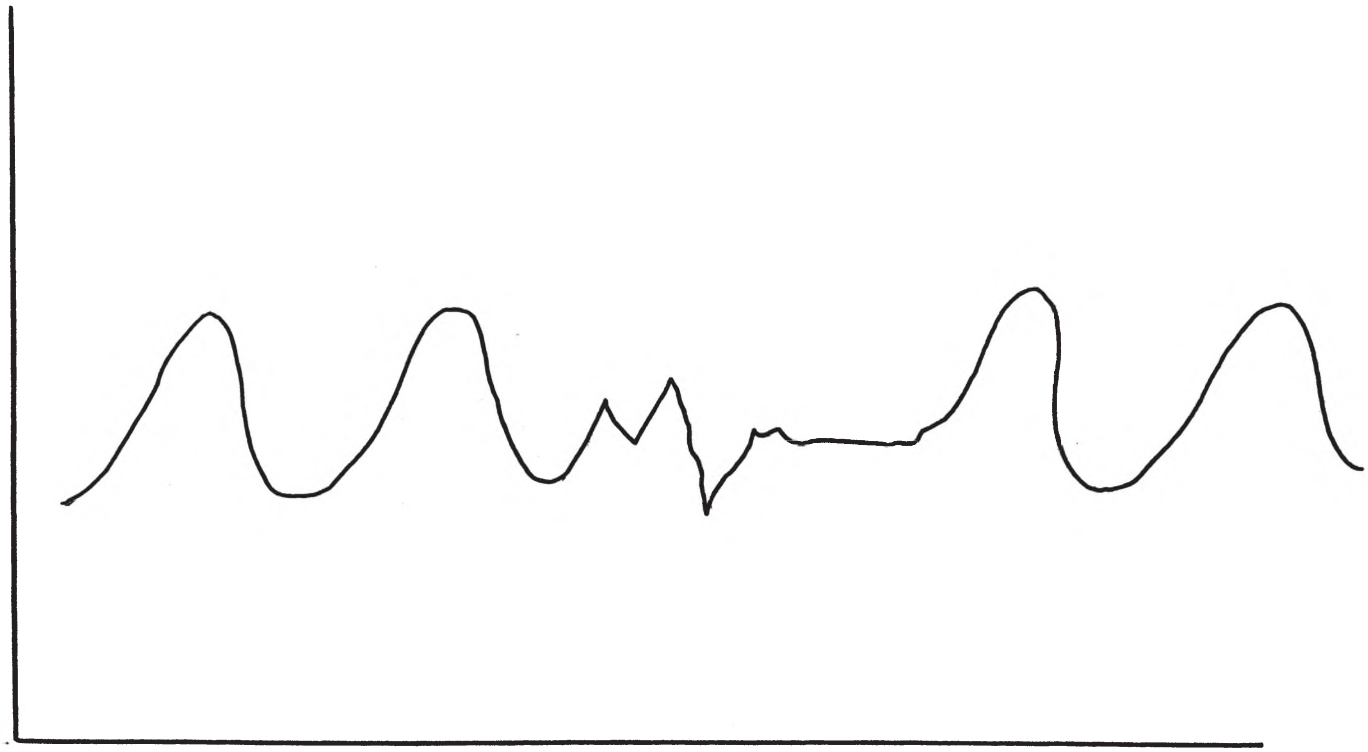


Figure 48 - Light curve for a Semi-Regular Variable star

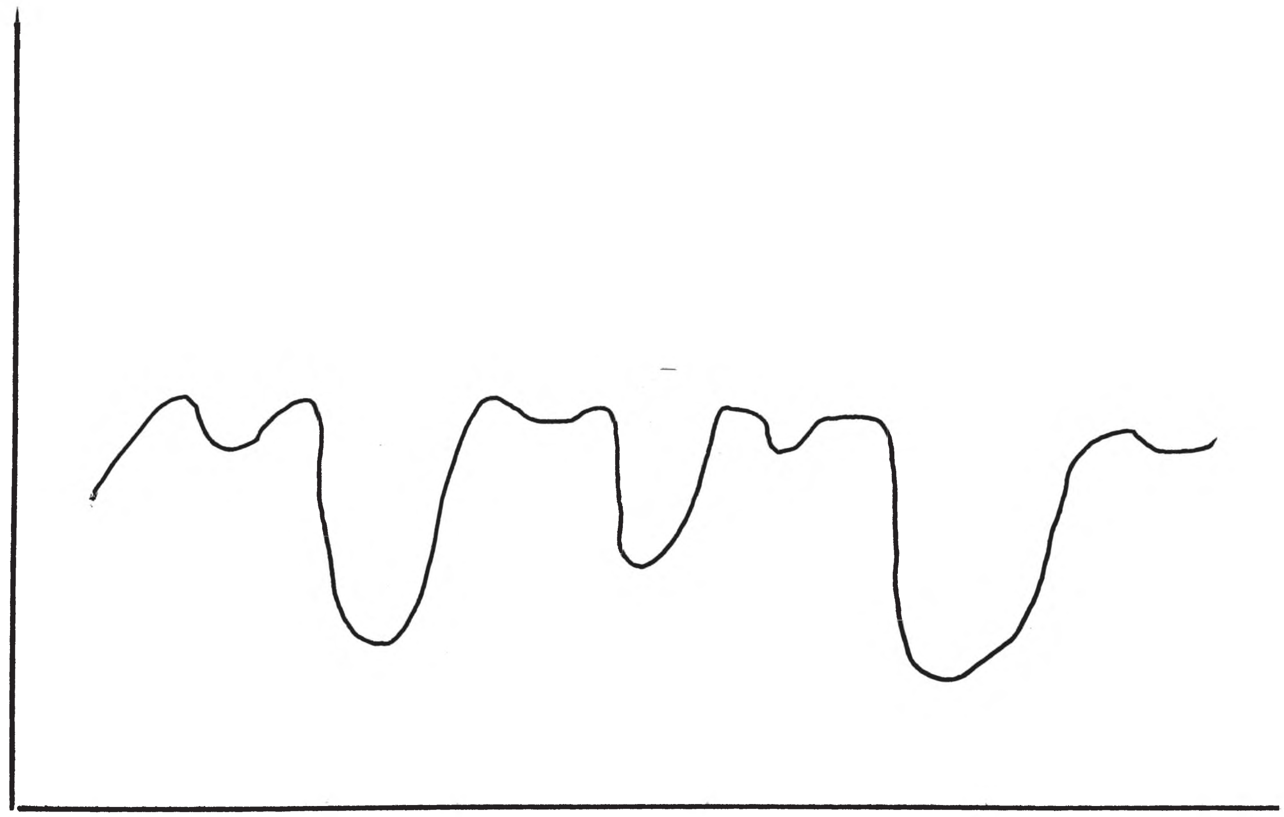


Figure 49 - A light curve for a typical RV Tauri star

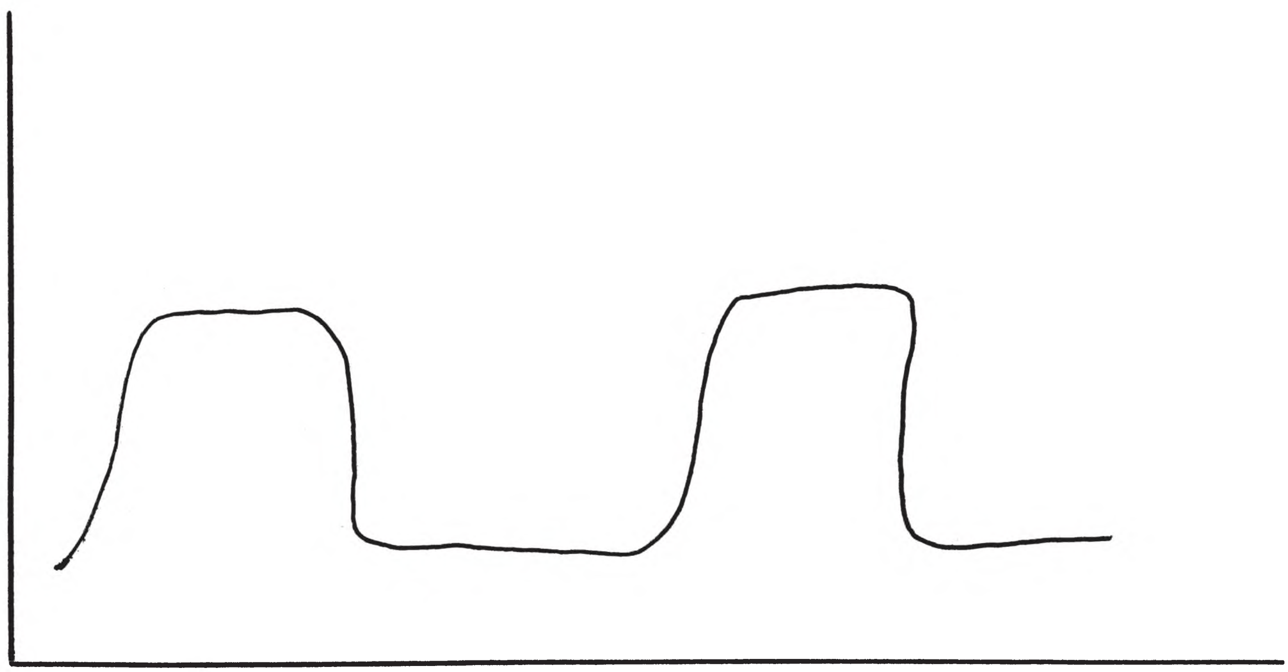


Figure 50a - Light curve for a U Geminorum long-maximum star

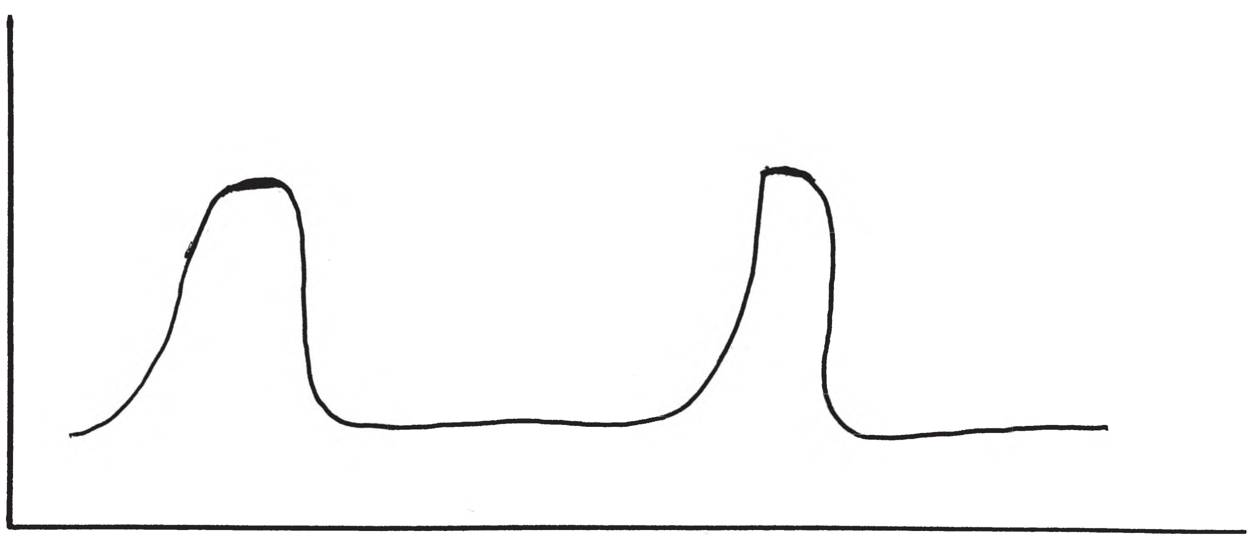


Figure 50b - U Geminorum short-maximum light curve

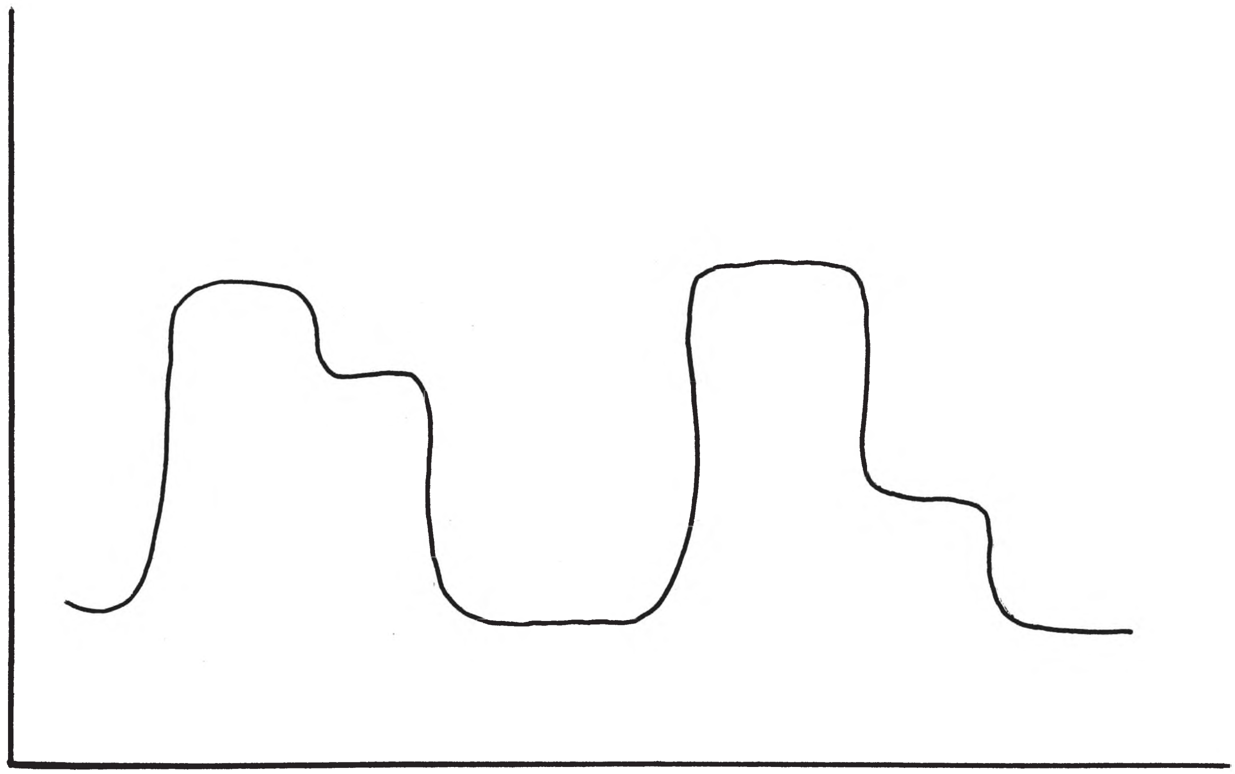


Figure 51 - Light curve of a Z Camelopardelis star

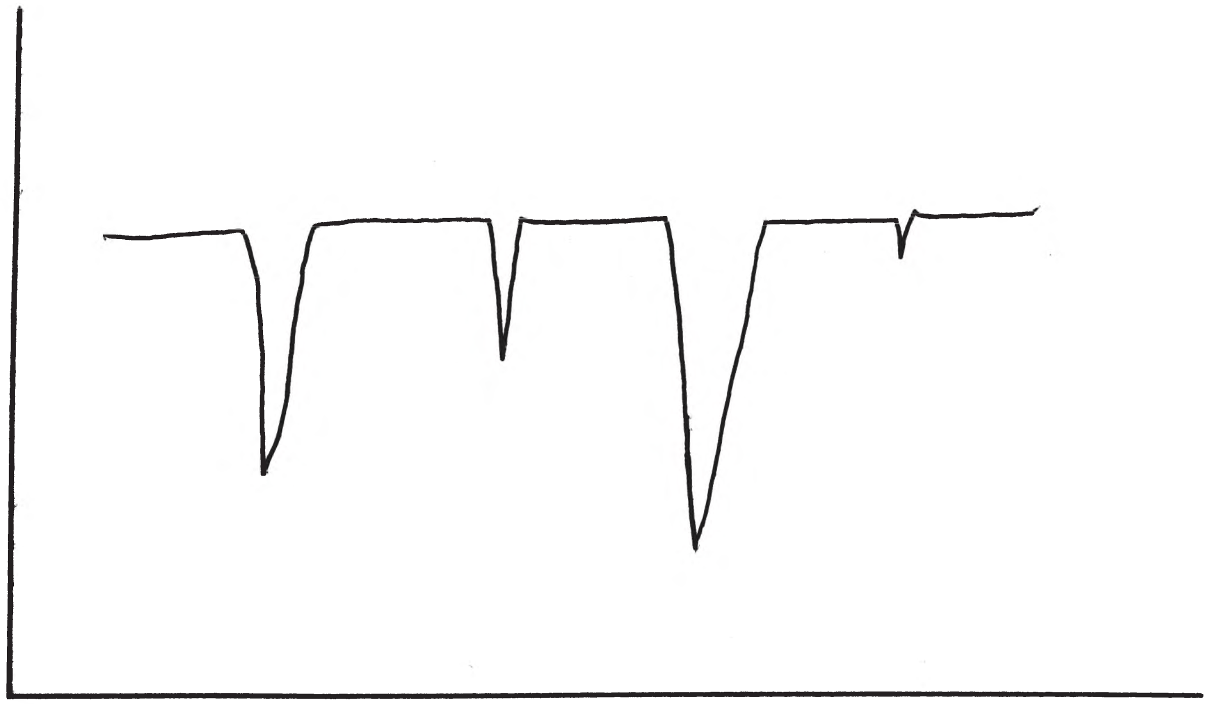


Figure 52 - Light curve of an R Corona Borealis star

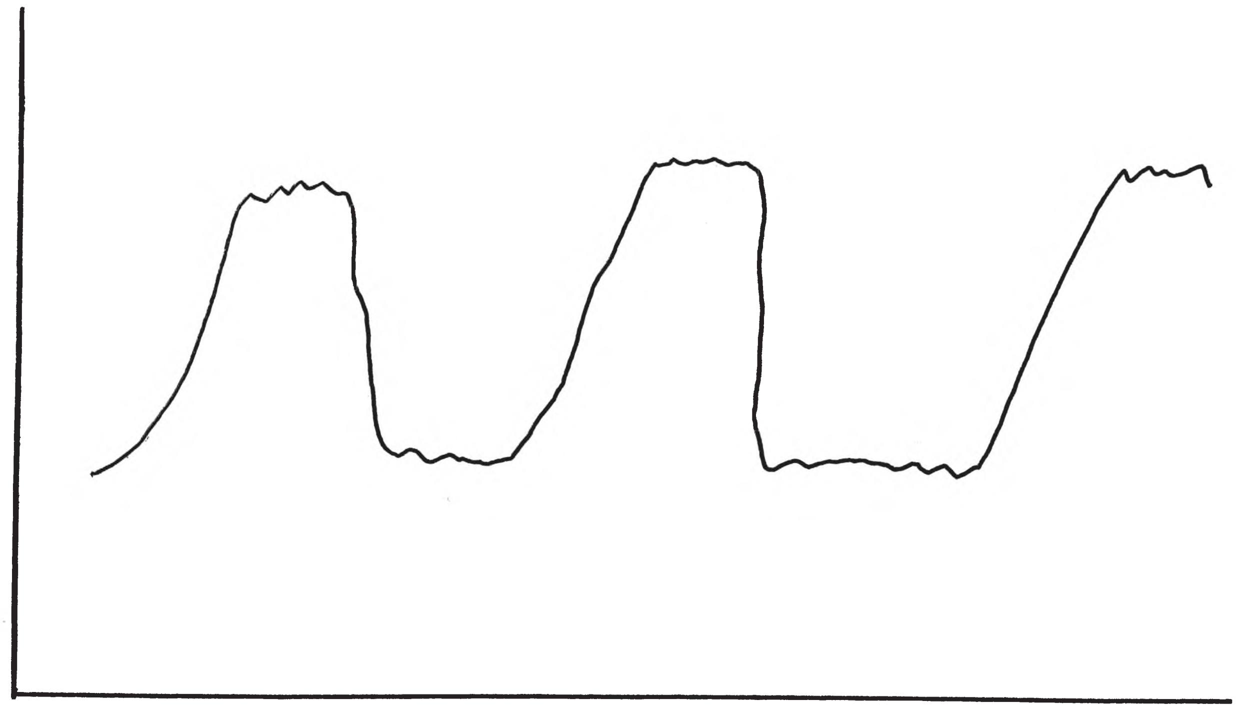


Figure 53 - Light curve of an RW Aurigae star

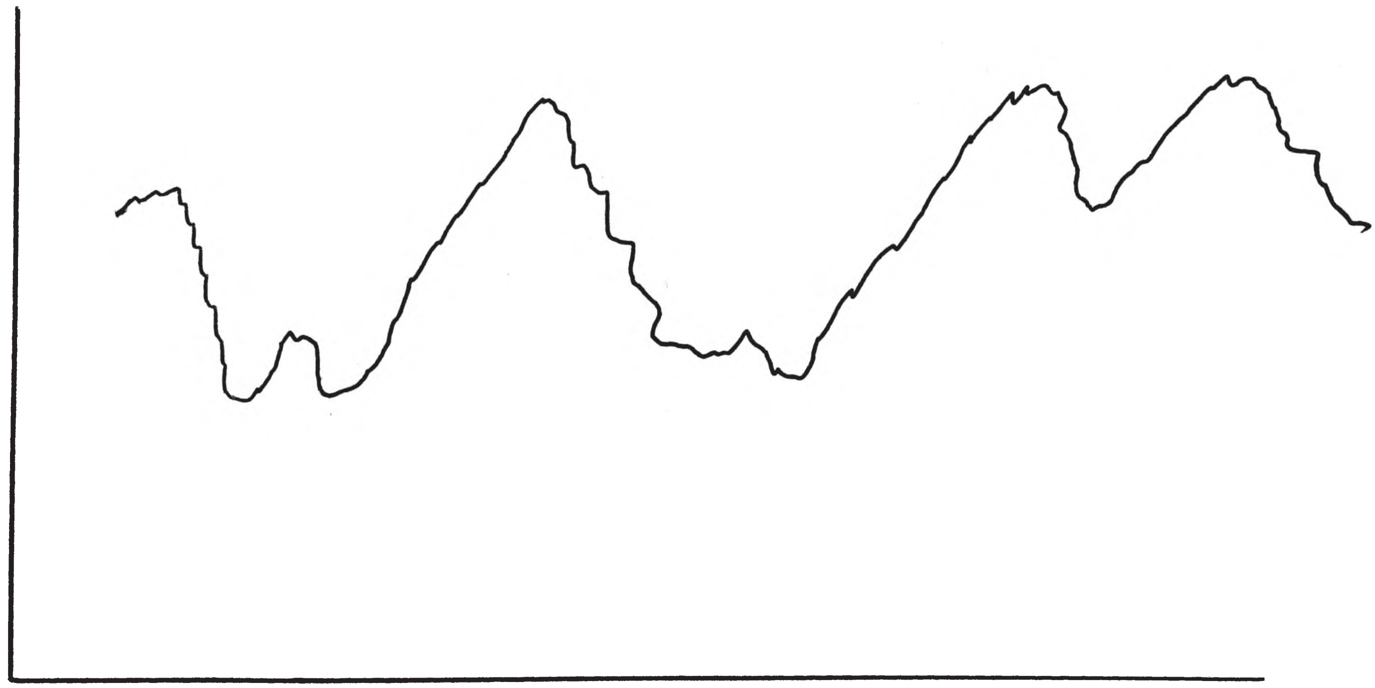


Figure 54 - A T Orionis light curve

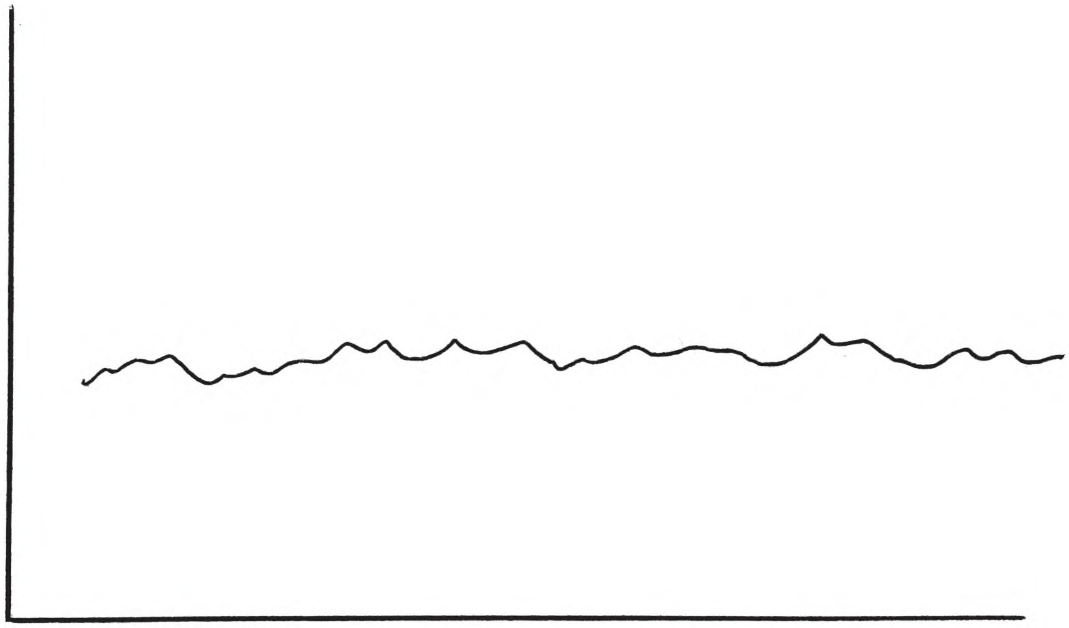


Figure 55 - Light curve of a typical T Tauri star

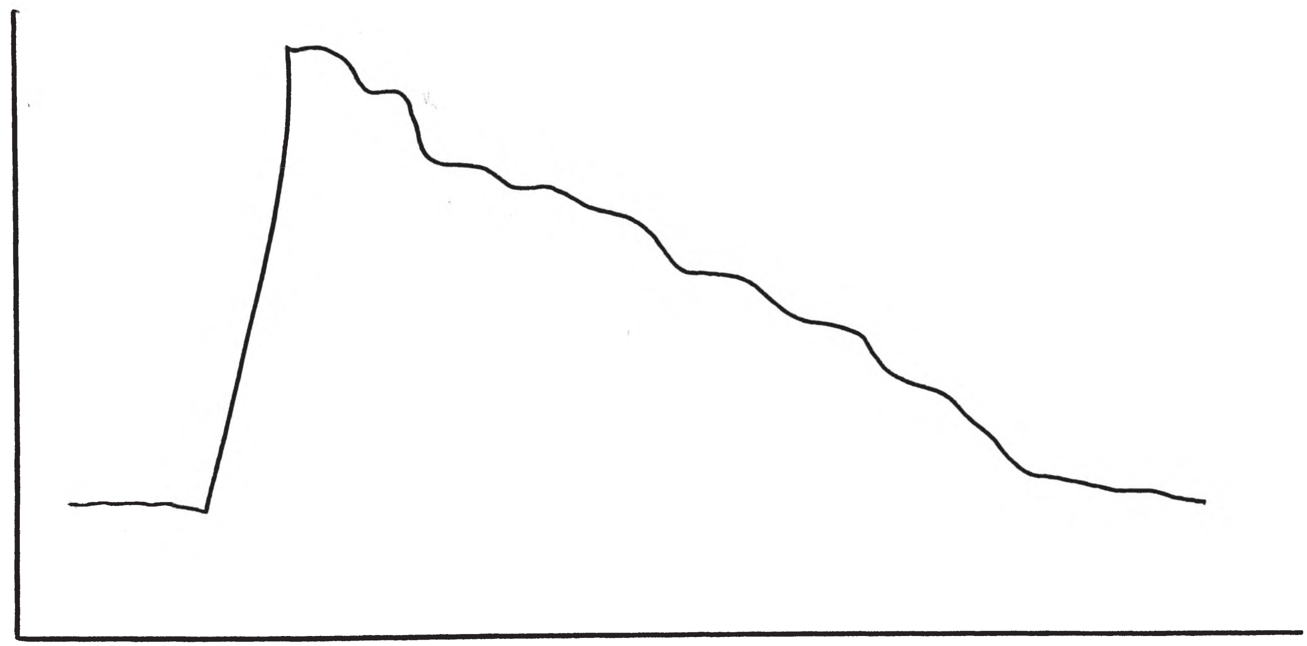


Figure 56 - Light curve of a nova

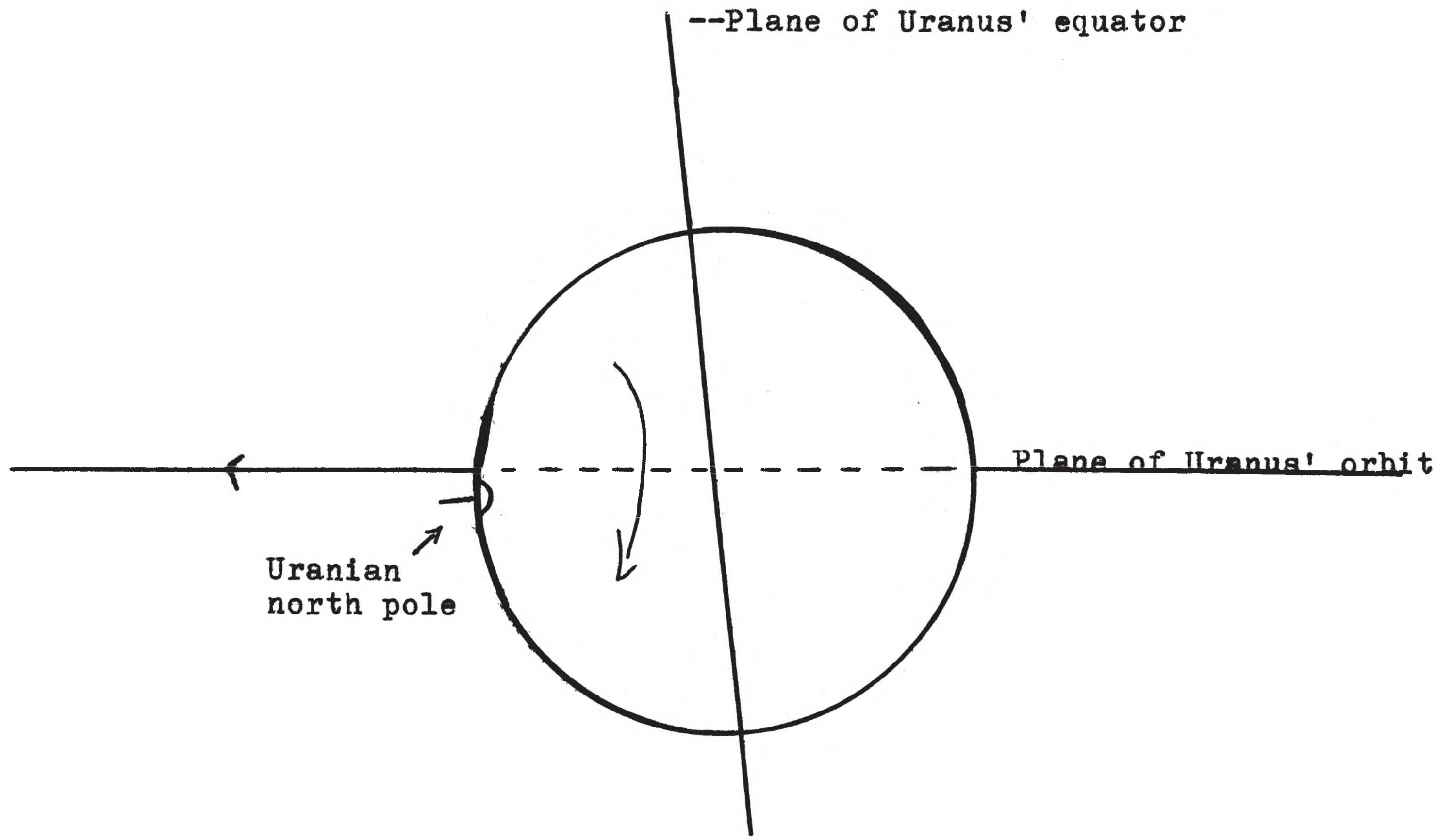


Figure 57 - Tilt of Uranus' axis relative to its orbit

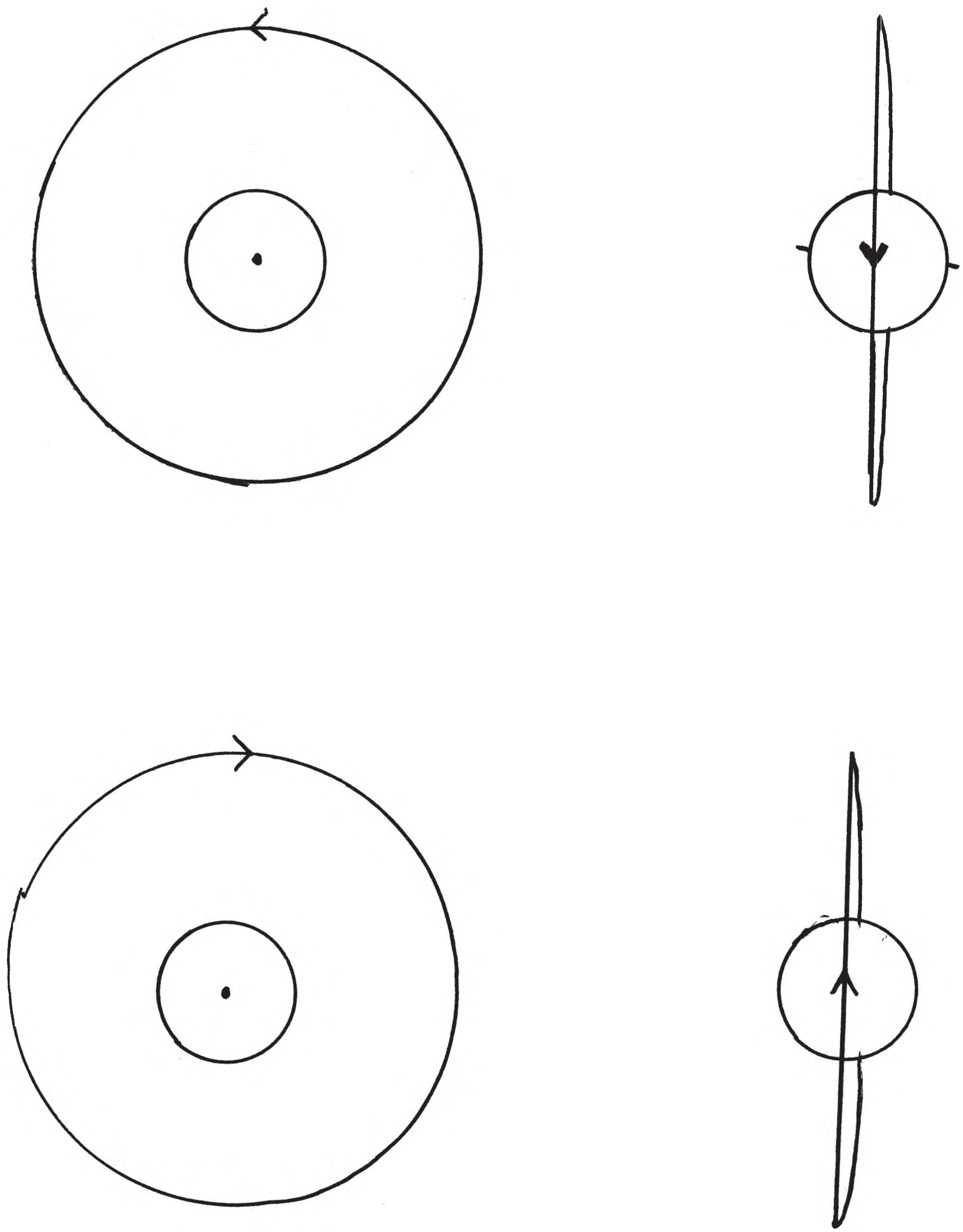


Figure 58 - Varying aspects of the orbits of the moons of Uranus

Figure 59 - Map of Taurus

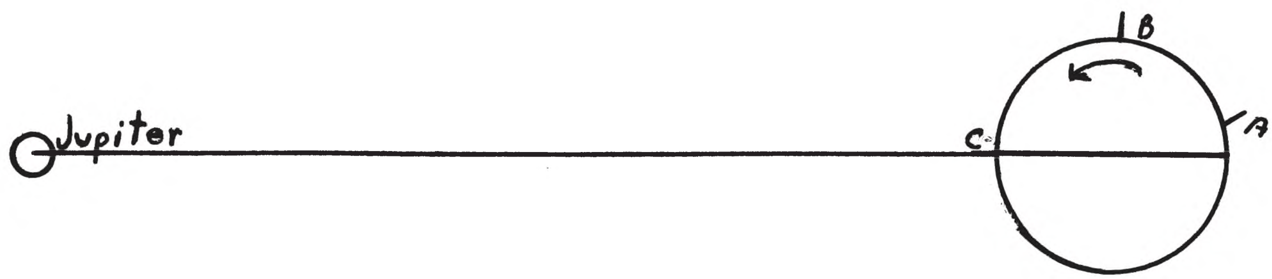


Figure 60 - What "rising" really is.

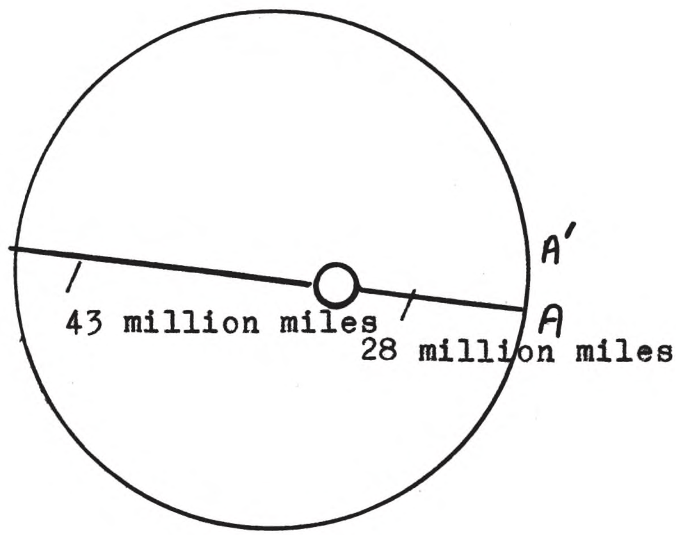


Figure 61 - The orbit of Mercury

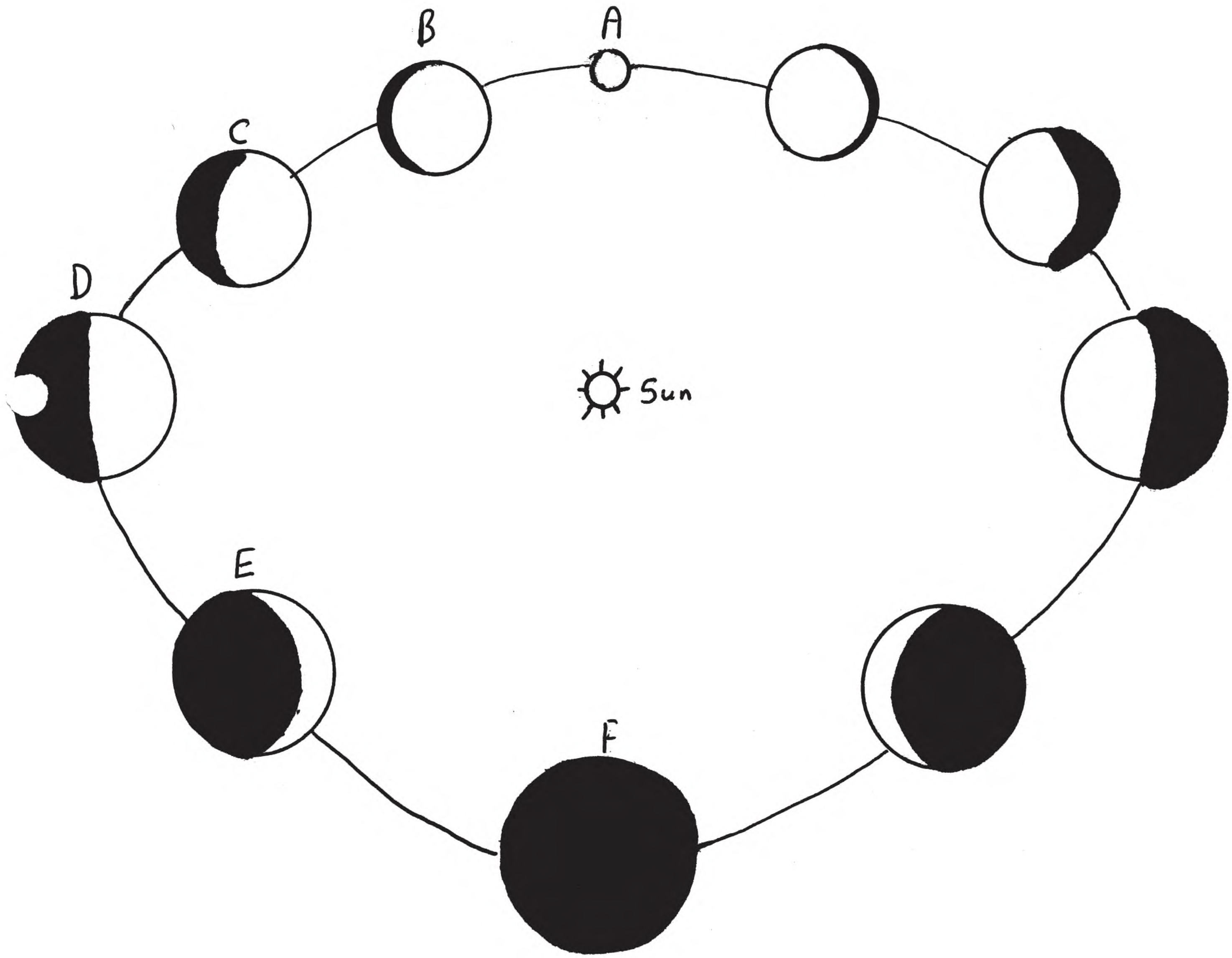


Figure 62 - The phases of Mercury

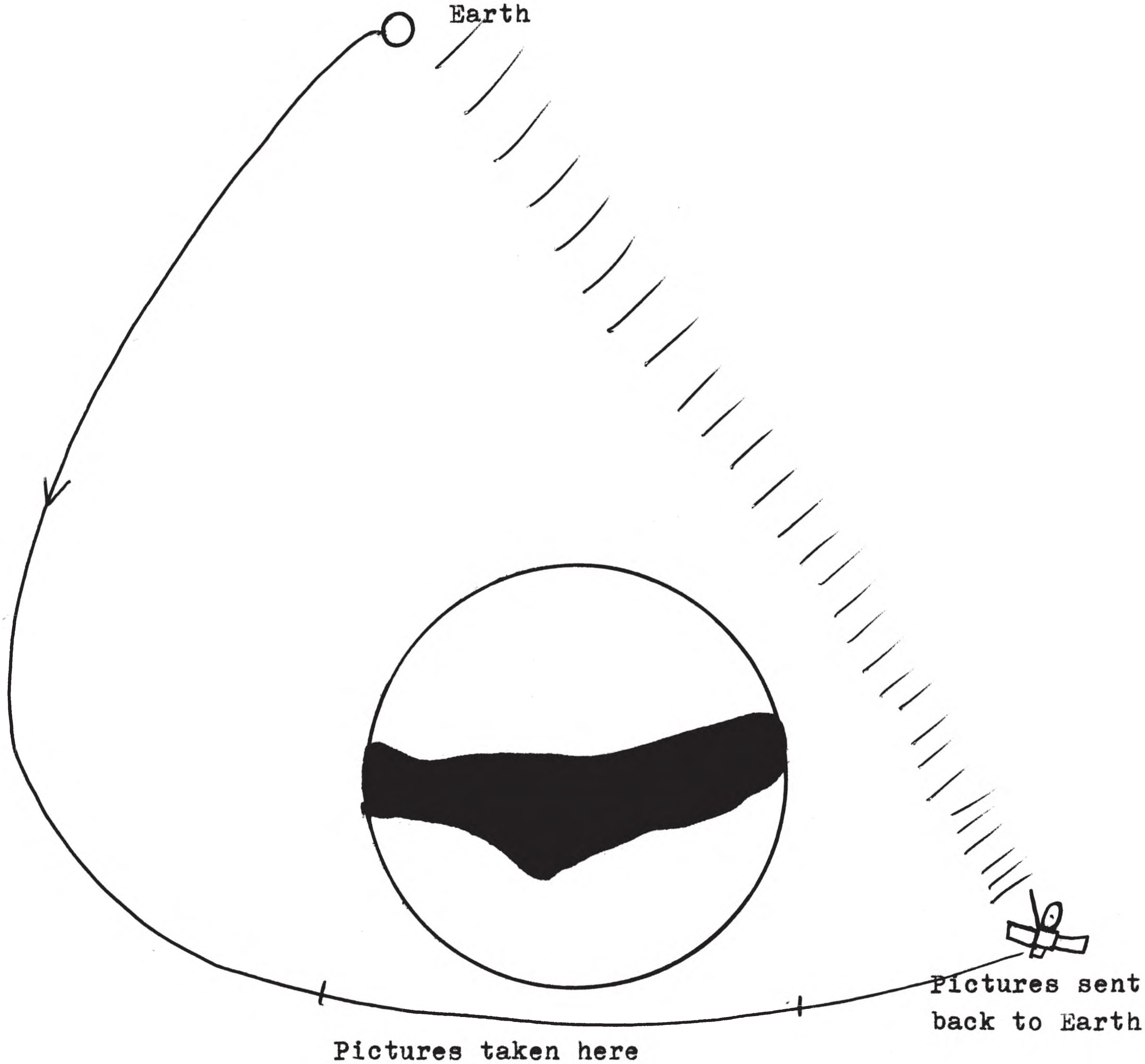


Figure 63 - Trajectory of Mariner on a "Flyby" Mission

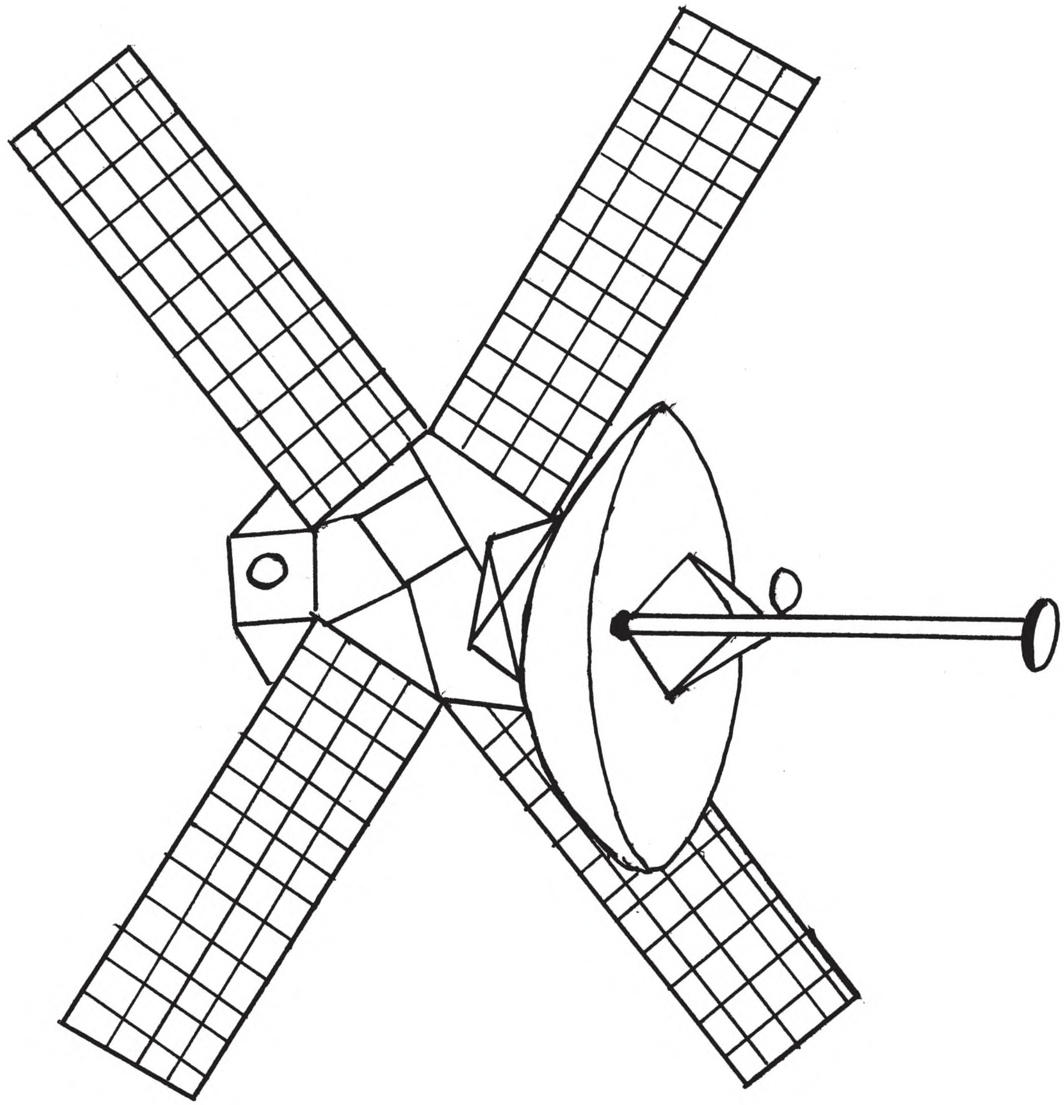


Figure 64 - Sketch of the general appearance of the Mariner

Appendix

This is a complete list of the programmes that have been shown on the "Sky Tonight" to date. The show seems to be surviving well and it is uncertain how long it will continue weekly on the air. I have included the names of the guests on those programmes where astronomers have come along to share their knowledge with the public. Unless other-wise noted, they are members of the Hamilton Centre of the Royal Astronomical Society of Canada.

1. The Universe - Norman Green, Asst. Director, McLaughlin Planetarium Toronto, Ont.
2. Astronomers - Peter H. Ashenhurst
3. The Sun - Leslie V. Powis
4. Making a Telescope - William Keating
5. The Moon - Robert Speck
6. Stars
7. Stonehenge - John W. Macdonald
8. Radio Astronomy - Richard McCallum, Anthony Freeth
9. Motions of the Earth
10. Mars
11. Observing with Binoculars - Garry Pearson
12. Comets - Peter H. Ashenhurst, Robert Speck
13. The Velikovsky Theories - Robert Lang, William Keating, Leslie V. Powis, Gordon Thede, Harold H. Cornfield
14. Flying Saucers & UFO's - Garry Gallant, Henry McKay (UFOlogist, Toronto)
15. The Giant Planets - John W. Macdonald
16. Astronomy in Hamilton - J. Gordon Craig
17. Astronomy in Schools - Daniel F. Wentworth (Science Consultant, Hamilton Board of Education)
18. Astronomy & Astrology
19. The End of the World!
20. Life on Mars
21. Observatories - Francis M. Flinsch (Vice-President, International Union of Amateur Astronomers)
22. Potpourri

23.The Moon - Mrs.Inez N. Beck (Director, Lunar Commission, International Union of Amateur Astronomers)

24.Colonizing the Moon - Roland Packer,Wayne McPhail, Roger Hill,Garry Gallant

25.The Star of Bethlehem

26.Time

27.Pulsars - Roger Hill

28.Moons of Other Planets

29.Astronomy for the Layman - Daniel F.Wentworth (Science Consultant, Hamilton Board of Education)

30.The Nebulae - Michael Bodnar

31.Real and Apparent Motions

32.Life on Other Worlds - Peter H.Ashenhurst

33.Calendars

34.Comets - Paul Ashenhurst

35.Galaxies

36.A quiz

37.Astronomical Photography - Walter Korber

38.History of Astronomy - Norman Green (Asst.Director,McLaughlin Planetarium,Toronto

39.Orion

40.Meteors

41.Bode's Law - Michael Bodnar

42.Saturn - Garry Pearson

43.Navigation - Peter Ashenhurst

44.Potpourri

45.A Chat - Robert Speck *

46.Stellar Evolution - Michael Bodnar, Terry Tick **

47.Basic Astronomy

48.Eclipses

49.Astronomy in Britain

50.Astronomy as a Hobby

51.Motions of the Earth

52.Life of a Professional Astronomer - Dr.Robert F.Garrison (David Dunlap Observatory,Richmond Hill,Ont)

53.Jupiter

54.The Sun
55.Recent Develppments in Astronomy
56.Making A Telescope - William Keating
57.Variable Stars
58.The Milky Way
59.Solar Eclipse of July 10,1972 - Alan Bauld (Cable 8TV Technicial)
60.Venus
61.International Union of Amateur Astronomers
62.Mariner IX
63.Astronomy In Canada - Michael Bodnar
64.Questions Most Often Asked
65.Spectroscopy - Dr.Thomas C.Bolton (David Dunlap Observatory,Richmond Hill, Ont.
66.A quiz
67.Artificial Satellites - John W.Macdonald
68.Messier's Catalogue
69.Double Stars
70.Astronomy in Europe
71.The Star of Bethlehem
72.The Moon Revisited - James Irwin (Apollo 15 Astronaut)
73.Tycho and His Nova
74.Review of the Apollo Programme
75.Craters to Know and Love - Duncan Cruickshank
76.Taurus
77.Unusual & Oddball Theories
78.The Royal Astronomical Society of Canada - Robert Speck
79.The Sun
80.The Planet That Lies on Its Side
81.Chariots of the Gods - Robert Speck, Peter Ashenhurst, Walter Morber, Garry Gallant
82.Astrology
83.The Moon
84.The Life of An Amateur Astronomer - John W.Macdonald ***
85.Comets
86.Cape Kenndy, Skylab & The Space Shuttle

87.The Age of the Universe
88.The Independent Thinkers
89.Jupiter
90.Mercury
91.Stonehenge Revisited - John W.Macdonald
92.Velikovsky Theories,Part 1 -Duncan Cruickshank,Robert Lang,Walter Korber
Robert Speck
93.Velikovsky Theories,Part2 -Duncan Cruickshank,Robert Langg,Walter Korber,
Robert Speck
94.Radio Astronomy - Dr.Ernest Seaquist (University of Toronto)
95.Scale of the Universe - Opportunity Class,Ridge Public School,Hamilton
96.Recent Advances in Astronomy
97.Ancient Astronomical Texts - Michale Bodnar
98.Mysteries of the Solar System
99.A Quiz
100.My Observing Programme
101.Survey of the Solar System
102.Exploration of the Moon
103.Skylab
104.Comet of the Century
105.Meteor Craters in Northern Ontario
106.The Geography of the Moon
107.Flying Saucers,Are They For Real?
108.Elementary Astronomy Projects - Daniel F.Wentworth (Science Consultant,
Hamilton Board of Education)
109.More advances in Astronomy
110.Velikovsky Again - Paddy Doran (Graduate Student,McMaster University)
111.A Quiz
112.The Stars

* At the time of programme 42, I was in St.Joseph's Hospital for a cancer operation. Bob Speck and I chatted in front of a TV camera set up in my hospital room.

**I still had not recovered in time for programme 43, so Mike Bodnar acted as host.

*** John Macdonald interviewed me about my life as an amateur astronomer.