1

Astronomy and astronomers

What is the conventional idea of an astronomer? The old picture was that of an elderly man with a long white beard, sitting in a lonely observatory throughout the night 'watching the stars'. This picture was never true, and today it could not be less accurate. Your professional astronomer is much more likely to be a youngish, energetic person who spends very little time at the eye-end of a telescope. Instead, all his work is carried out by electronic methods, and he can remain in the comfort of a warm control-room when the telescope is being used. Nowadays it is not even necessary for the astronomer to be in an observatory at all. A large telescope in, for instance, the Mauna Kea observatory on top of a volcano in Hawaii can be operated by an astronomer in his office in London or Boston.

Moreover, professional astronomy is theoretical, and every hour spent in obtaining information from the sky means a great many dozens of hours of desk work. Strange though it may seem, I know a number of eminent professionals who would be quite unable to go out on a clear night and identify the various star-groups!

Yet there is another side to astronomy. The amateur with no professional qualifications whatsoever can still make valuable contributions, simply because he looks at the sky and knows it well. Some amateurs make a hobby out of hunting for comets and exploding stars or novae, while others (such as myself) are much more at home when carrying out telescopic observations of the Moon and planets. Despite all the new techniques, and despite the spacecraft which have caused such a revolution in outlook over the past few decades, there is still a great deal which we do not know.

Remember, too, that those people who have no wish to become 'serious astronomers', either professional or amateur, can enjoy themselves immensely by making the acquaintance of the stars. I began to take a real interest at the age of six (when, admittedly, the situation was very different from that of today), and my first step was to go outdoors with a star map, wait until the sky was dark and clear, and then learn my way around. It did not take long, and in fact it is not in the least difficult.

It is for these casual enthusiasts that I am writing now. Let us assume that you know absolutely nothing about astronomy, and have no wish to spend money on a telescope or even a pair of binoculars. The naked eye alone is quite adequate; so we will begin at the very beginning, with the fundamental facts. Anyone who knows them already has my full permission to skip the next few pages and proceed straight to Chapter 2!

First, there is a common error to be corrected. Some people still confuse astronomy with astrology. Actually, the two are as different as the proverbial chalk and cheese. Astronomy, the study of the sky and everything in it, is an exact science. Astrology is mediaeval superstition. Astrologers claim to link the positions of the Sun, Moon and planets with the characters and destinies of men and women born at different times of the year and in different places, so that a baby born on, say, 1 March in London will have a 'horoscope' quite different from that of a baby who first saw the light of day in Bognor Regis on 10 April. The only polite way to describe astrology in a single word is: 'Rubbish'. It has no basis of fact, and is strictly for the credulous only. The best that can be said of it is that it is fairly harmless when treated as a parlour game.

The Earth, our home in space, is a planet: a globe 7926 miles in diameter, moving round the Sun at a mean distance of 93 million miles. The Sun itself is a star, no larger, brighter or more luminous than many of the stars you can see on any clear night. The only reason why the Sun appears so splendid is that on the astronomical scale it is close to us, and this brings us on to the first difficulty: the problem of visualizing tremendous distances and vast spans of time. Frankly, nobody can really appreciate even one million miles, to say nothing of 93 million, but we know that the figures given are correct, and we simply have to accept them. As I have said often enough, astronomers cannot appreciate vast distances and time-scales any better than anyone else; the only difference is that they don't make the mistake of trying.

A very rough analogy may help. Suppose that we set out to fly to the Sun, moving at a steady 100 m.p.h. and never stopping. In one day we will cover approximately 2400 miles – but it will take us more than a hundred years to reach the Sun.

The Earth is not the only planet. Moving round the Sun there are eight others, of which the best known are Mercury, Venus, Mars, Jupiter and Saturn. They have no light of their own; they shine only because they reflect the light of the Sun, in the same way that a tennis ball will do if you shine a torch on it in a darkened room (though in fact most of the planets are much less reflective than tennis balls). Though the planets look like stars, and some of them are brilliant, they are our near neighbours, and are very junior members of the universe as a whole. Some of them have satellites moving round them; we have only one satellite (the Moon), but Saturn has as many as eighteen. The Sun's family, or Solar System, is completed by various objects of lesser importance such as comets and meteors, which I will describe later.

The Solar System itself is a very insignificant unit. The stars lie at immense distances, measured in millions of millions of miles. Represent the distance between the Sun and the Earth by one inch, and the nearest star will be over four miles away. This is why the stars appear as tiny points of light. It is also why they seem to keep virtually the same positions in the sky relative to each other – a fact which is of such fundamental importance that I must pause to say rather more about it.

Consider two flying objects: a sparrow at tree-top height, and a jet aircraft many miles up. The sparrow will move quickly against its background, while the jet will appear to crawl, but in reality the jet is much the faster of the two (at least, I have no record of any sparrow which can break through the sound barrier). The jet seems to move much more slowly merely because it is so much further away. The rule is: 'The further, the slower', and the stars are so remote that relative to each other they do not move detectably, as seen by the naked-eye observer, even over periods of many lifetimes. The patterns or constellations which we see today are to all intents and purposes the same as those which must have been seen by George Washington, Alfred the Great, Julius Caesar and the builders of the Pyramids. True, the stars do have tiny individual or 'proper' motions, because they are moving through space in all sorts of directions at all sorts of speeds, but for the moment we may regard the stars as 'fixed'.

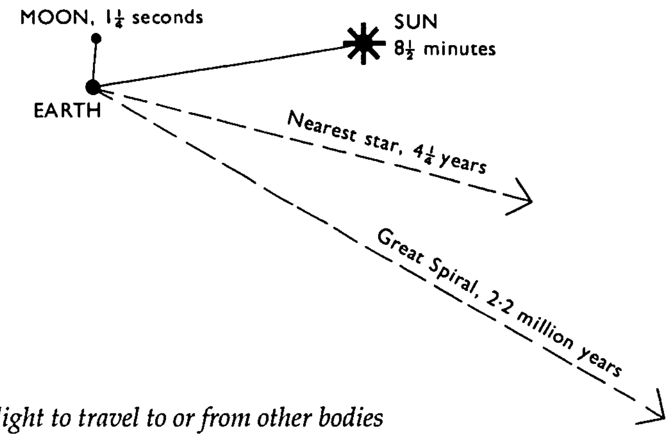
Not so the Sun, Moon and planets, which are much closer to us, and wander slowly around the sky from one constellation to another. They do, however, keep within certain definite limits, and this was how they were identified by the ancient astronomers; the very word planet really means 'wanderer'.

Obviously it is impossible to plot the planets on permanent star-maps. This is also true of the Moon, which is the nearest natural body in the sky and is the only one which revolves round the Earth. (To be accurate, the Earth and Moon are revolving together round the centre of gravity of the Earth–Moon system, but for the moment we are dealing with fundamentals.) The Moon has a diameter of only 2160 miles, and its mean distance from us is 239,000 miles. If you want to make a reasonable though rough model, take a tennis ball to represent the Earth, wrap a piece of string around it ten times, and then unravel the string and put a table-tennis ball on the far end to represent the Moon. A simple calculation shows that the Sun is about 400 times as far away from the Earth as the Moon.

Like the planets, the Moon has no light of its own. It depends upon sunlight, and clearly only half of it can be illuminated at any one moment. This is why the Moon shows its regular phases, or apparent changes of shape from new to full. The mean interval between one full moon and the next is 29½ days, and when nearly full the Moon is brilliant enough to drown all but the brighter stars, even though it would take more than half a million full moons to equal the brightness of the Sun.

How many stars can you see with the naked eye on a dark night? When I put this question recently to a group of newcomers to astronomy, the answers ranged between 'ten thousand' and 'millions'. Rather surprisingly, nobody can ever see more than about 2500 stars at any one time; appearances can be deceptive. Of course, optical aid gives a prompt increase. The total number of stars in our star system or Galaxy is of the order of 100,000 million, and even this is only a beginning. Beyond our Galaxy there are others, each with its quota of stars.

Come back to the question of distance. We have seen that the stars are very remote, and it becomes awkward to give their distances in miles or kilometres, just as it would be clumsy to give the distance between London and New York in inches or centimetres. Fortunately there is a better unit available. Light does not travel instantaneously; it flashes along at 186,000 miles per second, so that in a year it can cover 5,880,000,000,000 or rather less than six million million miles. This is the unit known as the light-year – a unit not of time, please note, but of distance. If you want to convert light-years to miles, multiply by six million million and you will not be so very far out. The nearest star beyond the Sun is 4.2 light-years away, which works out at approximately 24 million million miles. The Galaxy measures 100,000 light-years from one side to the other; the distances of external galaxies range out to thousands of millions of light-years.



Time taken by light to travel to or from other bodies

There is an interesting result of this. Suppose that we look at a galaxy two million light-years away, as we can do with the naked eye; there is one system, the Andromeda Galaxy, which is more than two million light-years away, and is quite clearly visible as a tiny smudge against a dark background. We are seeing the Andromeda Galaxy not as it is today, but as it used to be more than two million years ago. If there are any astronomers in that system (as is highly probable), they will be seeing our Galaxy as it used to be before the start of the last Ice Age.

How large is the universe? Frankly, this is a question which is almost impossible to answer with confidence. The most remote object so far measured appears to be over 12,000 million light-years away. Whether the universe is infinite, or whether it has a definite size, is something which we can postpone for the moment.

I hope that this chapter has not been indigestible, but there was no choice but to cram it with facts. So to clarify matters, I will try to sum up the situation as concisely as possible:

1. The Earth is a planet, moving round the Sun at a mean distance of 93 million miles. The time taken to make one full circuit is, of course, one year – more accurately, 365¼ days.
2. The Sun is an ordinary star, appearing so glorious only because on the cosmical scale it is so close to us.
3. There are eight other planets moving round the Sun, of which five are easily visible with the naked eye. They have no light of their own, and depend upon reflecting the Sun's rays.

4. The Moon, at 239,000 miles, is much our nearest neighbour. It moves around us, and is much smaller than the Earth. Like the planets, it shines by reflected sunlight, which is why it shows its monthly phases. If the Sun were suddenly blotted out, the Moon and planets would disappear too, though the stars would be unaffected. (Let me assure you that nothing of the kind is likely to happen.)
5. The Sun, planets, planetary satellites and various bodies of lesser importance make up the Solar System.
6. The stars are suns in their own right, and are very remote. Even the nearest of them beyond the Sun is over four light-years away – a light-year being the distance travelled by a ray of light in one year, almost six million million miles.
7. Because they are so far away, the stars do not seem to move noticeably with respect to each other, so that the star-patterns or constellations do not change appreciably even over periods of centuries. The members of the Solar System, however, move around from one constellation to another, keeping to one definite band around the sky (the Zodiac).
8. The system of which our Sun is a member is known as the Galaxy. It contains about 100,000 million stars.
9. Beyond our Galaxy there are many other galaxies, most of which are many millions of light-years away.

I hope that this is helpful. And having cleared the basic facts, we can now turn our attention to the way in which the sky appears to move.

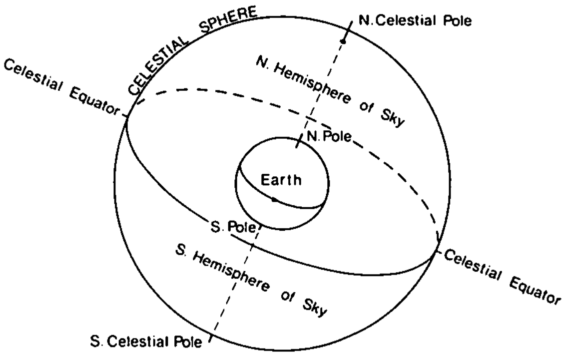
2

The revolving sky

We live upon a spinning globe. The Earth is rotating all the time, carrying us with it; a full turn takes 23 hours 56 minutes, conventionally rounded off to 24 hours. (Throughout this book I propose to deal mainly with rounded-off numbers, which makes things easier without being misleading.) We are not conscious of being whirled around, but the effects are obvious enough when we survey the sky. Since the Earth's direction of spin is from west to east, the sky appears to rotate from east to west, carrying the Sun, Moon, planets and stars along with it. (Most of the other planets spin in the same direction, though Venus rotates from east to west for reasons which remain a total mystery.)

Ancient stargazers believed that the stars were fixed on to an invisible crystal sphere, whose centre was concentric with the centre of the Earth. They called this the 'celestial sphere', and the term is still useful provided that it is not taken too literally. After all, the Earth does give the impression of being in the centre of the universe, with all the other celestial bodies revolving round it once a day.

The Earth's axis is tilted to the perpendicular to its path or orbit by 23½ degrees. It is this tilt which is responsible for the seasons; during northern summer the north pole is inclined towards the Sun, while in northern winter it is the turn of the south pole to be favoured. Actually, the Earth's orbit round the Sun is not quite circular. The distance from the Sun ranges from 91½ million miles in December to 94½ million miles in June, so that we are closest to the Sun when it is winter in London and New York. Still, the difference is not very much, and the effects are more or less masked by the fact



The celestial sphere

that there is so much ocean in the southern hemisphere; water tends to stabilize the temperature.

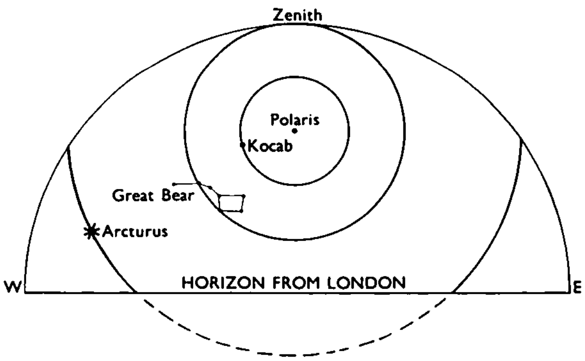
Now let us take a closer look at the so-called celestial sphere. In the diagram, the Earth is shown in the centre, with its two poles, its equator and its axis of rotation. If we prolong the axis line, we can fix the positions of the celestial poles. The north pole of the sky is marked within one degree by a fairly bright star Polaris in the constellation of the Little Bear. Therefore, Polaris seems to remain most stationary, with everything else moving round it in a period of twenty-four hours. This has nothing directly to do with Polaris itself, and neither has it always been the north pole star. The celestial pole shifts slightly over the years, and when the Egyptian Pyramids were being built the pole star was Thuban, in the Dragon. For the moment, however, and for centuries to come, Polaris occupies the position of honour. Navigators have always found it very useful, because its altitude above the horizon is equal to the observer's latitude on the surface of the Earth. Thus from London, where the latitude is 52 degrees, Polaris will be at an altitude of 52 degrees; from New York, latitude 40 degrees, Polaris will be only 40 degrees above the horizon (in round figures, that is to say). There is no bright star near the south pole of the sky, to the constant regret of southern navigators. The nearest naked-eye candidate is the obscure Sigma Octantis, which is so dim that even light mist will hide it.

Quite obviously, the south celestial pole will never be visible from a northern country, such as Britain. The solid body of the Earth gets in the way, so that the southernmost stars never rise above the horizon. On the other hand, the stars close to Polaris will never set, and will always be visible whenever the sky is sufficiently dark and clear. Ursa Major, the most famous of all constellations, comes into this category. (Note that in Britain Ursa Major is called the Great Bear or Plough; in the United States it is known as the Big Dipper.) It sweeps around the pole, and even when at its lowest it is still well above the horizon, so that it is said to be *circumpolar*.

The brilliant orange star Arcturus, which lies further south in the sky, is not circumpolar from Britain or the United States; at its lowest it drops below the horizon, so that it rises and sets regularly.

Anyone who travels from Britain towards the Earth's equator will notice that the altitude of Polaris is becoming less. Go to Mexico or central India, for example, and the angle between Polaris and the horizon will be reduced to

Kocab, a star not far from Polaris, describes a small circle. Ursa Major, further from Polaris, never sets, but can reach the zenith or overhead point. Arcturus can pass below the horizon, and so is not circumpolar.

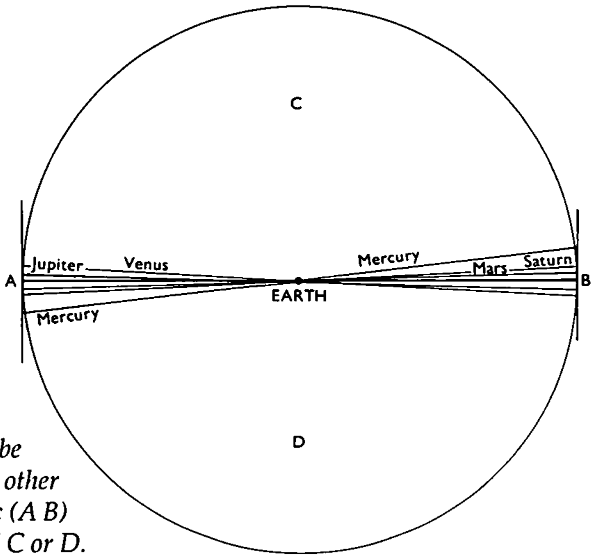


only about 20 degrees. This means that Ursa Major will no longer be circumpolar, since part of its daily circle will lie below the horizon. To compensate for this, southern stars which never rise from Britain come into view – notably the brilliant Canopus, which is never to be seen from anywhere in Europe.

Go to the equator, and you will find that Polaris is right on the horizon; the south celestial pole lies on the opposite horizon, and the celestial equator passes overhead, so that the entire sky is visible at one time or another. In the Earth's southern hemisphere Polaris is lost to view, and from part of Australia and all of New Zealand even Ursa Major has gone. However, in its place are brilliant constellations such as the Southern Cross, which is actually much brighter than Ursa Major although it is smaller, and is shaped more like a kite than a cross.

The members of the Solar System take part in the daily rotation of the sky, but have individual movements of their own. The Sun seems to travel right round the sky in one year. Its light completely drowns that of the stars, although accurately pointed telescopes can show bright stars at any time. (The only time that stars can be seen with the naked eye during the daytime is when the Moon covers up the Sun, at a total solar eclipse.) The Sun's yearly path among the stars is known as the ecliptic. The belt of sky centred on the ecliptic is called the Zodiac, and it is here that the Sun, Moon and bright planets are always to be found.

The reason for this is that the orbits of the planets round the Sun are in much the same plane, so that if you draw a plan of the Solar System on a flat piece of paper you are not very far wrong. The inclination amounts to 7 degrees for Mercury and less than 4 degrees for all the other planets (apart from Pluto, which is much too faint to be seen with the naked eye or even a small telescope). The diagram again shows the celestial sphere, this time with the ecliptic. You can see that planets may appear in directions A or B, but never towards C or D. For example, you will never find a planet anywhere near Ursa Major or the Southern Cross.



All the bright planets have slight orbital inclinations to the main plane of the Solar System (7° for Mercury, 3½° for Venus less than 3° for Mars, Jupiter and Saturn) so that they can be seen only near the ecliptic; in other words they keep to the Zodiac (A B) and can never be seen toward C or D.

Since it is impossible to put the planets into permanent star-maps, the observer has to learn how to recognize them – which is easy enough. Venus and Jupiter are always so brilliant that they far outshine any of the stars. Mars is noted for its strong red colour. Saturn, admittedly, can be confused with a star, but it is a slow mover, and once it has been identified it can be found again with no trouble. Mercury need not concern us for the moment, because it is never conspicuous, and the casual observer is unlikely to notice it at all. (Have you ever seen Mercury? In more than nine cases out of ten, I would be prepared to wager that the answer is 'No'.)

It has often been said that stars twinkle, while planets do not. This is not entirely true, but there is no doubt that a star, which is to all intents and purposes a point source of light, twinkles more than a planet, which shows as a small disk. Twinkling has nothing directly to do with the stars; it is due entirely to the Earth's unsteady atmosphere, which, so to speak, 'shakes' the starlight around. When a star is close to the horizon, its light comes to us through a deep layer of atmosphere, and the twinkling is pronounced; when the star is high up there is less atmosphere to be crossed, and the twinkling is much less marked. You can check this on any clear night by comparing the twinkling of stars at different heights above the horizon.

Apart from the circumpolar groups, the stars are seasonal. Thus Orion, one of the most brilliant of all the constellations, cannot be seen around June, because it is then too near the Sun in the sky and is above the horizon only during the hours of daylight. The monthly maps given in this book will, I hope, show exactly when and where the constellations are on view. Obviously I have had to give two main sets of maps – one for the northern hemisphere and one for the southern.

Most of this chapter has been concerned with the revolving sky, and there is an easy way to demonstrate it. Take an ordinary camera, wait until the sky is clear and dark, load with a fast film and leave the shutter open for a few minutes (or, if you like, an hour or two – though beware of 'fogging' the film by moisture or artificial lights). The stars will appear as trails as they cross the field of view. If you aim the camera at the north celestial pole, you will see that the trails are circular – and that Polaris itself shows a very short, curved trail, proving that it is not exactly at the polar point.

Finally, let me dispose of another common misunderstanding. It has been claimed that you can see stars in the daytime if you go down to the bottom of a mine-shaft, or a deep well, and look up at the narrow circle of light above you. In fact this is quite wrong. Stars are invisible in the daytime because the contrast between their light and the sky background is too low, and the situation to an observer in a coal-mine is exactly the same. No; if you want to see the stars during daylight, you must wait for the fleeting moments of a total eclipse of the Sun.

3

Patterns of stars

The first thing you will note when looking up at the night sky is that the stars seem to form definite patterns. Early men were suitably impressed, and divided the stars into groups, or constellations. Various systems were used; the Egyptians drew up one set of constellations and the Chinese another, but the system we use today comes from the Greeks. (Nobody is quite sure where it originated. There has been a suggestion that the Greek system came from the island of Crete, where the so-called Minoan civilization, named after the legendary King Minos, was highly developed until it was destroyed by a violent volcanic eruption around 1500 BC. Incidentally, there is little doubt that it was this disaster which gave rise to the story of Atlantis.)

Ptolemy, the last great astronomer of ancient times, listed forty-eight constellations, all of which are still to be found on our modern maps even though their boundaries have been modified. The names of the constellations were drawn partly from mythology and partly from everyday life. Thus we find Orion, the great Hunter; Hercules; and Pegasus, the flying horse which carried the hero Bellerophon into battle against a conventional fire-breathing monster, the Chimaera. We also find a Triangle, a Wolf and an Altar. However, Ptolemy lived in Alexandria, and could not see the stars of the far south, which were tackled later; some of the names have a decidedly modern flavour – the Telescope, the Microscope and so on. Moreover, there was a period when astronomers took a fiendish delight in tinkering with the already cumbersome and complicated constellations, adding such atrocities as Sceptrum Brandenburgicum (the Sceptre of Brandenburg), Officina Typographica (the Printing Press) and Globus Aerostaticus (the Balloon). Finally, in 1932, the controlling body of world astronomy, the International Astronomical Union, lost patience and reduced the accepted number of constellations to eighty-eight.

The constellations are of very different shapes, sizes and importance. The largest of all is Hydra, the Watersnake, with an area of 1303 square degrees; the smallest is the Southern Cross, with only 68 square degrees. Some constellations contain many bright stars, while others are so dim and formless that they seem to be unworthy of separate identity. However, the system has become so well established that it will certainly not be altered now. Periodic attempts have been made, perhaps the worst of which was to rename the constellations after prominent politicians. Mercifully, this idea was received with a total lack of enthusiasm.