it, to an inbuilt human physical and psychological mechanism which operates on any stimulus from outside. This – the Weber-Fechner law – shows that we recognize changes on a LOGARITHMIC scale. Thus, the brightness differences between one magnitude and the rest are not simply one, two, three, four and five times a given amount; they differ in a more complex way. In his six magnitudes Hipparchus responded to this law: his magnitude 1 was 100 times brighter than his magnitude 6, with the result that each magnitude is 2·5119 – or just over two-and-a-half times – brighter than the one below it, since 2·5119 multiplied by itself four times is 100. (Mathematically $\sqrt[5]{100} = 2{\cdot}5119$.)

Hipparchus numbered stellar magnitudes backwards – or so it seems – since stars of magnitude 2 are 2·5119 times dimmer, not brighter, than those of magnitude 1. However, this is purely a consequence of saying that stars of the first importance are stars of the first magnitude, those of secondary importance of second magnitude, and so on. Astronomers have found it convenient to continue this approach, only now, after Norman Pogson's establishment in 1856 of precise numerical relationships between one magnitude and the next, it is found that some stars are in fact brighter than those which Hipparchus designated as first magnitude. The magnitude scale therefore goes to 0 for stars 2·5119 times brighter than magnitude 1, and −1 for stars 2·5119 times brighter than magnitude 0. Thus while the star Spica is magnitude 1, Vega is magnitude 0, and Sirius is −1·4. On the same scale, the full Moon has a magnitude of −12·5 and the Sun −26·7.

The ancient idea that the stars are fixed to the inside of a sphere persisted for a very long time, at least from the time of Homer until the 1570s, a span of some 2 300 years. However, in the late sixteenth century this belief was replaced by the concept of an infinite universe, and the face of astronomy changed. When this was coupled with other new ideas about the heavens, the problem of determining the distances of the stars became very pressing: it was a challenge which had to be met. The basic principle of determining distances in space was not in doubt, but the only problem was how to make observations with sufficient precision to detect the very small angles involved. In the event it was not until more than two centuries after the invention of the telescope in about 1608 that the first stellar distance was successfully measured, although some inspired guesses were made before this. In 1839 Friedrich Bessel found the distance of 61 Cygni, but the angle he had to measure to do this was only 0·35 arc seconds (arc sec., modern value 0·29 arc sec.) One arc sec. is $\frac{1}{60}$ of one arc minute, which itself is $\frac{1}{60}$ of a degree, so Bessel's angle was only one ten thousandth part of a degree. Yet this was only a beginning: today determinations are 100 times more precise, involving angles equivalent to measuring the thickness of a human hair at a distance of 300 metres (m).

The successful principle was based on the surveyor's method of triangulation, originally devised for determining distances on Earth to inaccessible points. The astronomical adaptation is shown in Fig. 1·1. Observations of a star are made at six-monthly intervals – that is, from opposite sides of the Earth's orbit round the Sun, giving a base-line of almost 300 million kilometres (km). From each point, measurements are taken of the observed position of the star against the background of more distant stars. Since two different positions are used, the star appears to shift its position with reference to the background stars. (You can obtain a similar effect by holding up a finger at arm's length, and looking at it first through one eye, and then through the other. Your finger will appear to shift in relation to background objects.) This 'parallactic shift' can be measured and the angle SXE_1 (or SXE_2) is known as the **parallax** of the star. Once known, this, together with the base-line distance E_1E_2, allows the star's distance to be calculated.

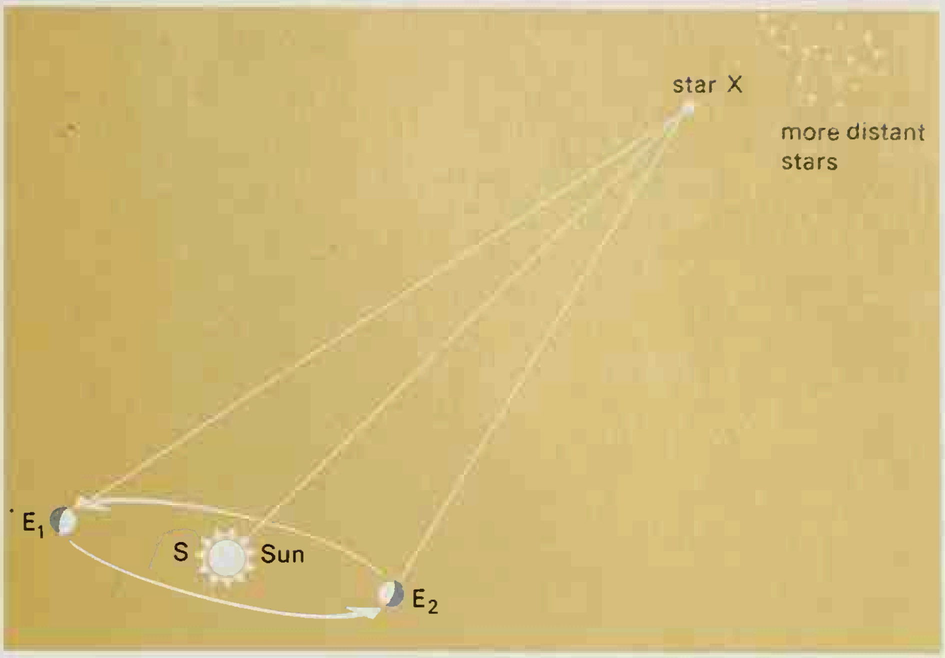

Fig. 1·1 Determining the distance of a nearby star using the ends of the Earth's orbit as a base-line.

The distances of stars are so great compared with distances on Earth that miles or kilometres are too small to be convenient. For instance, if we express the distance to the nearest star, α Centauri C, or Proxima Centauri, in kilometres, we find we are dealing with the number 40 570 700 000 000, which is cumbersome. Even if we write it in the index notation where 100 is expressed as 10^2, 1 000 as 10^3, 1 000 000 as 10^6 and so on, we still have $4{\cdot}057 \times 10^{13}$ km which is hard if not impossible to imagine. We need to have some way of scaling the number down, and one of the most convenient ways is to replace kilometres by **light-years**. A light-year is a distance, not a period of time: it is the distance light travels in one year, and to all intents and purposes is $9{\cdot}5 \times 10^{12}$ km. On this scale, the distance of Proxima Centauri is 4·3 light-years.

The professional astronomer tends to favour a different, and slightly larger unit, the **parsec** (pc). The parsec is that distance at which a star would have a parallax of one second of arc, and it is equal to 3·26 light-years. For the more distant stars the **kiloparsec** (kpc), a unit of one thousand parsecs, is used; and for the most distant realms of space, there is the **megaparsec** (Mpc), one million parsecs.

The method of determining parallax using six-monthly sightings from Earth – trigonometrical parallax – is only effective for the nearer stars.