4·1 seconds (s) of mean solar time. This is why the stars appear to rise about 4 minutes earlier each night, and it is the time reckoning frequently used by the astronomer.

In this century the Earth's rotation has been found to be somewhat irregular. Time determination using the Earth's axial rotation is, therefore, not entirely satisfactory. In consequence **ephemeris time** is now used, so called because it is based on the orbital motion of the Sun, Moon and planets whose positions are given in an ephemeris or set of tables. Since there are 31 556 925·9747 mean solar seconds in a tropical year of 365·2422 mean solar days, the duration of one second of ephemeris time is 365·2422 divided by 31 556 925·9747.

In the past, observatory clocks and the Earth's rotation made time determination solely the astronomer's responsibility, but now the physicist is involved because mechanical clocks have been replaced by atomic clocks. These have helped to give the precision which has led to irregularities in the Earth's rotation being not only recognized but also measured. Atomic clocks give UNIVERSAL TIME, which is the same as **Greenwich mean time**: it differs slightly from ephemeris time by an amount which, in 1979, amounted to 50s.

An additional consequence of being on the moving space-platform Earth, is that we are surrounded by a blanket of atmosphere. While this is very necessary for supporting life – and so supplying astronomers! – it does mean that our observations are limited. One reason is that the air is always in motion, thus distorting the images of celestial bodies. The twinkling of the stars is one result that can readily be seen, but the telescopic observer finds other effects too, and is never able to use his telescope to full effect. The second main reason for the limitation of observations is that the atmosphere only lets through some of the radiation from space, not all. As human beings we are accustomed to studying the heavens by observing the light emitted by celestial bodies or, more recently, by observing the radio waves emitted too. Yet there is other radiation which the atmosphere absorbs. That other radiation exists we already know: the Sun's heat radiation (infrared) is a common experience, while its ultraviolet light, which cannot be seen, is detectable by the discoloration of our skin we call sun-tan. Yet there are other radiations that do not reach us.

Light, it has been found, may best be described as a wave, or rather as a series of waves, light of different colours having different wavelengths. The shortest waves give us the sensation of violet light, those a little longer, blue light, and so on through the ELECTROMAGNETIC SPECTRUM – green, yellow, orange – to the longest wavelength light which we see as red. According to the wave theory of light, these are electromagnetic waves, all of which travel at the speed of light, but it turns out that light waves are but a tiny fraction of the entire range of **electromagnetic radiation**. Thus, examining the universe with light alone means that we are confining ourselves to a minute fraction of the whole range that should be available. Our atmosphere does let some non-visual radiation through, as we have already seen, but for complete coverage we must go out into space.

Now, at last, in the latter decades of the twentieth century, we may receive and analyse the entire radiation available from space. This gives us a richer and more fantastic universe than man has ever known or imagined, a universe which covers an astounding range of sizes, from the minute electron with a diameter of only 5·6 thousand million millionths (10^{-15}) of a metre, up through man ($1\frac{3}{4}$ metres), the Earth ($12\frac{3}{4}$ million metres), the Sun (14 thousand million metres) to the Galaxy (9 thousand million million (10^{15}) metres) and to the most distant observable depths of space (17 hundred million million million million (10^{26}) metres): a total range of 1 to 10^{41} (or 100,000,000,000,000,000,000,000,000,000,000,000,000,000 or one hundred thousand million million million million million million) – a staggering number however one writes it. This is the universe we shall now examine in some detail.

Fig. 1·8
Diagram of the way the Earth's axis moves with respect to the celestial sphere. The inset shows how this causes different stars to do duty as a pole star.