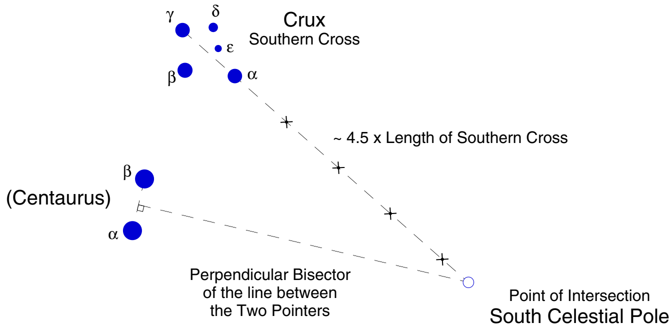
7.1.2 STAR TRAILS[M4]

Astronomy, the study of our heavens, was probably the first branch of science to attract the attention of our earliest natural philosophers. Men learned to chart the sky long before they were able to chart the Earth, and they knew most of the constellations in the sky of the Northern Hemisphere before they knew most of the countries on the Earth. Indeed, the older methods worked out in charting the stars were *later* adapted and used to chart places on the Earth.

7.1.2.1 The Southern Cross[1]

The Southern Cross, also known as Crux, is one of the more prominent constellations in the southern night sky. Although it is the smallest of all the constellations, it is probably the best known to most Australians.

With the lack of a significant pole star in the southern sky, two of the stars of Crux (α and γ, Acrux and Gacrux respectively) are commonly used to mark south. Following the line defined by the two stars for approximately 4.5 times the distance between them leads to a point close to the South Celestial Pole. Alternatively, if a line is constructed perpendicularly between the Two Pointers (α Centauri and β Centauri, in the constellation of Centaurus), the point where the above line and this line intersect marks the South Celestial Pole (see figure below).



The Southern Cross actually comprises five stars, four of which are so situated that they depict the extremities of a Latin cross. Due to precession of the equinox the stars comprising Crux were visible from the Mediterranean area in antiquity. In the Biblical days they were just visible at the horizon. It was last seen from the latitude of Jerusalem at the time of the crucifixion of Christ. It is no longer visible at latitudes north of 25°N. The constellation was again discovered in the early sixteenth century by European navigators and explorers who used it to steer by and also to calculate the time of day.

Originally considered part of Centaurus, Crux was described as a separate constellation in 1679 by the French astronomer Augustine Royer.

7.1.2.2 Recording Star Trails

The Earth rotates (approximately) once, *i.e.* 360°, every 24 hours, or about 15° per hour. Star trails recorded over a 10 minute period thus yield trails with an arc of approximately 2.5°. Even though this is a relatively short arc, it is sufficient to see the apparent curvature of the paths of stars in the different parts of the sky, enabling us to identify the South Celestial Pole and the location of the Celestial Equator.

1 http://en.wikipedia.org/wiki/Crux

7.1.2.2.1 The Southern Cross

The Southern Cross (Crux) can be used to locate the South Pole, as discussed above. The arced paths of the stars in the star trail below clearly indicate the proximity of the South Celestial Pole. In the image on the right, the trails of the Southern Cross and Two Pointers have been enhanced so that they can be readily identified.

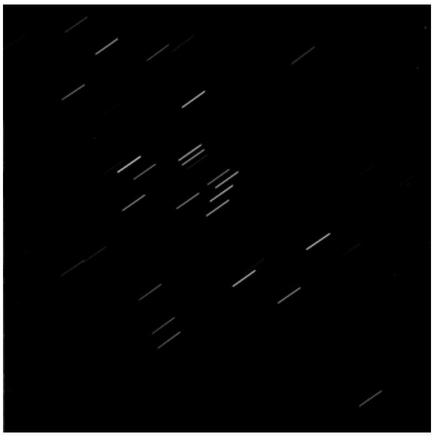
The South Celestial Pole
Pole at lower right
(Wamboin 29-Mar-2006 21:34–21:48)

The Southern Cross (Crux) & Two Pointers (α- & β-Centauri)
(Enhanced in the adjacent image)

7.1.2.2.2 Orion

The constellation of Orion (actually, the three stars comprising the belt of Orion) is located on the celestial equator. The stars in Orion's belt divide the sky into two regions—a region lower in the northern sky where star trails *curve one way*, and a region higher in the northern sky where , in which the trails *curve the other way*.

Since we are in the southern hemisphere, we see Orion upside down relative to the way the constellation is traditionally drawn.



Orion (NW)
(Wamboin 24-Mar-2006 20:55–21:05)

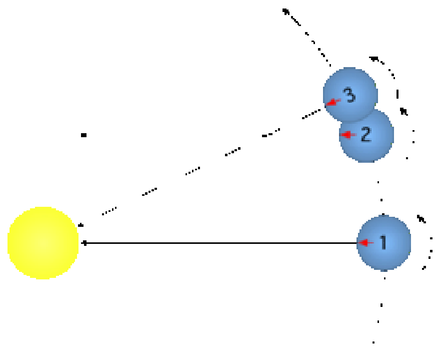
Sirius (at top) & Orion (lower left)
The Celestial Equator passes from lower left to upper right
(Wamboin 29-Mar-2006 21:19–21:29)

7.1.2.2.3 Sirius

Note that the trails of stars above and below 'the belt of Orion' curve in opposite directions. Orion's belt lies on the Celestial Equator, so the stars above and below it in the second image above are in opposite celestial hemispheres. Although the paths are only very slightly curved, the stars in the upper part of the image (Sirius, the brightest star in the sky, is near the top of the image) are rotating around the South Celestial Pole. Those in the lower part are rotating around the North Celestial Pole. Of course, it is the earth that is rotating inside the 'celestial sphere', not the stars at all.

7.1.2.3 Time and Clocks

Regularly recurring events and objects with apparent periodic motion have long served as standards for units of time. The stars, planets and our moon have all served this purpose through time to this very day. The Earth's orbit around the Sun defines our year, and its rotational period essentially defines our day. This is known as *solar time*. We can also measure a day by the time it takes the stars in the sky to return to the same position. This is known as *sidereal time*. Because the Earth is orbiting the Sun, a solar day is slightly longer (3 minutes 56 seconds) than a sidereal day—there are 366.24 sidereal days in a[tropical] year, but only 365.24 solar days. The illustration[2] below helps to explain this situation. The time between positions 1 and 2 is a sidereal day, while a solar day is the time between positions 1 and 3.



For many years, the movement of the Sun across the sky was the primary measure of the hour of day, and the phases of the Moon defined the months. The first clocks that did not depend directly on observations of the heavens were water clocks that measured time by the emptying of filling of a vessel as water flowed through a small opening. From these beginnings, mechanical clocks were ultimately developed.

One of the most important developments in clock construction was the introduction of the pendulum. Its use as a regular timekeeper was described by Galileo (1564–1642) in 1581, although the Dutch mathematician and physicist Christian Huygens (1629–1695) is credited with the invention of the first pendulum clock, patented in 1656.

Whatever the method used to measure time, clocks had always been synchronised with the cycle of the Earth's rotation around its axis. In the late nineteenth century it was found that the rotation of the Earth (*i.e.* the length of a day) was both irregular on short time scales, and was slowing down on longer time scales. While this had been of little consequence in the past, when Man had primarily been concerned simply with the time of day or year, it was unacceptable in the new world of science, where the accurate measurement of very short time intervals was becoming increasingly important.

Caesium atomic clocks became operational in 1955, and quickly made it evident that indeed the rotation of the Earth fluctuated randomly. In 1960, the SI (Système Internationald'Unités) second was defined as 9,192,631,770 cycles of the radiation corresponding to the transition between the two hyperfine levels of the ground state of

2 http://en.wikiedia.org/wiki/Sidereal_day

the caesium-133 atom, equal to 1/31,556,925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time[3].

The time now measured by atomic clocks is known as Terrestrial Time. The time we refer to when setting our clocks and watches is known as Universal Time (UT, formerly Greenwich Mean Time, or GMT), which still follows the somewhat unpredictable rotation of the Earth. The (small but accumulating) difference is relevant for applications that refer to time and days as observed from Earth, like calendars.

Whatever it is being measured, be it time, distance, volume or any other quantity, it is important to recognise the need to use instrumentation with appropriate accuracy. There is no point using an atomic clock to measure the time between the seasons, or even the time from sunrise to sunset. Trying to use a wristwatch to measure the frequency of vibration of atomic particles would be equally pointless.

3 http://en.wikipedia.org/wiki/Second