schein or 'counterglow' can be seen directly opposite the Sun's position and, under exceptionally good conditions, a faintly luminous band may be observed joining the brighter regions. The total mass of the zodiacal light particles has been calculated at 3×10^{16} kg (comparable with that of a single comet).

Meteorites

A large number of meteorite craters are now recognized on Earth (Table 5·22), although very big bodies causing explosion craters or events such as the Siberian impact of 1908 (pages 156–7) are rare, with perhaps no more than one or two bodies falling on the Earth's land area per century. However, about 100–150 smaller meteorites per year should fall on land, although only about ten of these are usually recovered. In recent years thousands of well-preserved meteorites have been collected in Antarctica, and these have very substantially increased the total quantity of objects available for study. Moreover, it has been possible to collect these meteorites under sterile conditions, in the knowledge that they are free from terrestrial contamination. This is particularly important when dealing with carbonaceous chondrites.

There are three main types of meteorite, described as irons, stony-irons and stones, and from objects which are seen to fall it is possible to state that their percentages are about 6, 1 and 93 respectively. However, the stones have a greater tendency to fragment, are less resistant to weathering and are more difficult to recognize, so that iron meteorites are more frequently recovered. Large numbers of irons are known, ranging in size up to the Hoba West meteorite, which is estimated at 60 000 kg. In contrast to this, only two stony-irons exceed 1 000 kg, the Bitburg, Germany (1 500 kg) and Huckitta, Australia (1 400 kg) meteorites. The largest stone is the Kirin, China 1976 meteorite, weighing 1 770 kg, and only two other falls are known to exceed 1 000 kg.

Composition and origin

The average composition of iron meteorites is about 98 per cent iron-nickel, where the nickel may range from about 4–30 per cent or more, and they have densities of up to 7 900 kg per m^3. The stones are rich in various forms of magnesium and iron silicates, frequently contain a distinctive form of iron sulphide and have densities ranging from 3 450–3 800 kg per m^3, while the comparatively rare stony-irons have intermediate compositions. Stony meteorites have two important sub-classes, **chondrites** and **achondrites**, based upon the presence or absence of tiny, approximately spherical features within the body, which are known as **chondrules**. A rarely recovered but very important type of meteorite is the class designated carbonaceous chondrites, which have densities of 2 200–2 500 kg per m^3. These contain a significant amount of organic (carbon-based) compounds but research has shown that these have not been formed by biological activity. As a class the carbonaceous chondrites have a composition close to that of the Sun, and radio-isotope dating and mineralogical techniques show that they are very ancient and have undergone comparatively little chemical alteration. It is now generally accepted that they are fairly representative of the less volatile material from which the planetary bodies were formed. However, they have been subject to certain chemical changes which suggest that water was present at some time to a significant degree, and that they once formed part of some small bodies (perhaps like minor planets or even comets) from which they were fragmented early in the lifetime of the Solar System. The presence of water (and presumably other volatile materials) at such an early stage supports the general theory of a 'cold accretion' from interstellar material, rather than condensation from a heated nebula.

As far as the other forms of meteorite are concerned, the various minerals have not been produced under very high pressure and temperatures, again indicating that the parent bodies were similar in size to the minor planets. Chondrites appear to have been subjected to temperatures of about 1 100 K, while in other bodies a higher temperature of about 1 700 K would have caused melting and chemical separation similar to those produced in planetary interiors. Later breakup of such bodies would give rise to the achondrites, the stony-irons and the irons. Mineralogical studies suggest that iron meteorites have originated in about ten different masses comparable in size to the larger present-day minor planets (250 km or more), and that there were a similar number of parent bodies for the chondrites, which had rather smaller diameters.

In only one case amongst all the known meteorites is it possible to suggest a body of origin with any degree of certainty. This particular Antarctic meteorite is a quite distinct form, being a breccia (page 107) containing anorthosite, a material highly characteristic of the Moon's highland regions. Theoretical studies show that in certain impacts it should be possible for a very tiny fraction of the ejecta to be given velocities greater than that of escape for the Moon, and that such particles could come from a reasonable depth below the lunar surface. The fact that the meteorite is essentially indistinguishable from any of the lunar samples strongly supports its lunar origin.

An even more surprising body of origin has been suggested for a rare class of meteorites known collectively as the shergottites. These quite closely resemble basaltic lavas, and have been found to have radiometric ages of no more than $1{\cdot}3 \times 10^9$ years – very young for meteorites, and certainly most unlikely to have come from the Moon or the minor planets. A possible body of origin is Mars, although it is difficult to see how an impact could have accelerated any fragments to a sufficiently high velocity for them to escape from the planet's gravitational field, which is much greater than that of the Moon. Their peculiarities, and their source of origin, remain highly problematic.

Some meteoroids which have resulted in very bright fireballs and meteorite finds, such as the Pribram (Czechoslovakia), Lost City (Oklahoma) and Innisfree (Alberta) objects, indicate a close connection with the minor planets (Fig. 5·22). However, the vast