Theories of the universe

Cosmology is the study of the universe as a whole. It is an overview which allows us to formulate a general picture of the cosmos, and to construct theories about its earliest stages and its ultimate fate. At the basis of this study are two physical theories: the quantum theory – the theory which states that energy is absorbed, emitted or transformed in discrete units or quanta; and the theory of relativity. Quantum theory, coupled with the contemporary picture of atoms and sub-atomic particles, affects all phenomena, as does relativity theory, but the latter has particular cosmological implications, and deserves further explanation.

Relativity theory

Relativity theory falls into two parts – the special theory and the general theory, the first being published by Albert Einstein in 1905, the latter by him in 1916. The special theory is concerned primarily with electromagnetic phenomena and the way electromagnetic waves travel in time and space, while the general theory was developed mainly to deal with gravitation; both are obviously important from a cosmological point of view and it will be convenient to deal with them in turn.

Relative and absolute motion

Before special relativity was formulated, Newton's theory of universal gravitation and his laws of motion were accepted. According to Newtonian theory there must be a basic 'frame of reference': for instance, Newton's first law of motion states that a body must be in either a state of rest or a state of uniform motion in a straight line, unless the body is being acted upon by some outside force. The basic frame of reference is necessary because if we talk of a body being at rest, it must be at rest with reference to something – its surroundings if you like. Again, if it is in motion then its motion must be relative to a frame of reference, which, again, we may specify as its surroundings. We should note that such a frame of reference involves time as well as space, for velocity is a concept which incorporates both space (distance travelled) and time (the time taken). By the end of the nineteenth century it had become clear that there was a problem in choosing an absolute frame of reference: should one choose the Earth, or the Sun (about which the Earth orbited), or the whole gigantic system of stars through which the Sun was moving?

Other research had led to the discovery that light is part of the electromagnetic spectrum, all wavelengths of which travel at the same speed, 3×10^5 km per s. It was clear too that light is a wavelike disturbance, and since one could not have a disembodied wave, there was a new problem – to discover the nature of the substance or medium in which the waves travelled. The medium, whatever it might be, was called the 'aether', and in 1887 Albert Michelson and Edward Morley set up an experiment to determine the velocity of light with respect to this aether. Because of its result, this experiment proved to be one of the most important in the whole history of physics.

The Michelson-Morley experiment

In order to avoid using clocks of any kind to time the motion of a beam of light, Michelson and Morley used two simultaneous beams of light from the same source, sending one in a direction at right angles to the other, then reflecting them back so that they interfered (Fig. 8·1). Because of the movement of the Earth through the aether there should be a difference in the time taken by the two light beams, the light beam perpendicular to the Earth's motion taking a shorter time than the light beam out and back in the direction of the Earth's motion. The difference is very small, but by rotating the whole interferometer, a shift in the interference lines due to this difference

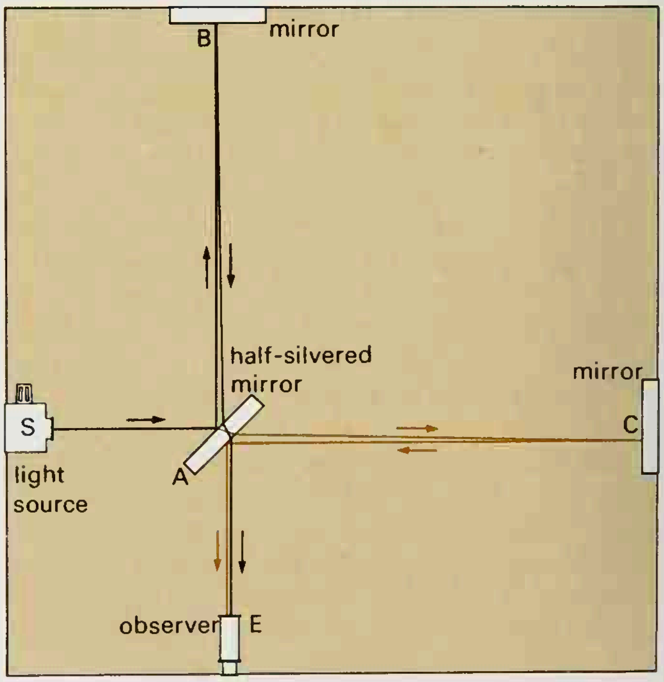

Fig. 8·1 far right: *The optical layout of the Michelson-Morley experiment. The light beam from the source S moves to a half-silvered mirror A, where it is split into two components. One component (black) is reflected to the mirror B and back again to A, when it passes through to the observer at E. The second component passes through the half-silvered mirror A and on to the mirror C; here it is reflected back to A and down to the observer at E. The two sets of waves interfere at E and produce a series of bright and dark fringes.*