ture of 3° K. Brightness is measured in units of ergs $sec^{-1}$ $cm^{-2}$ $(c/s)^{-1}$ ster [1]. The experimental measurement at the peak of the curve is that representing measurements of absorption of light from the stars by cyanogen molecules. The lowest experimental measurement on the solid curve was made at the Mullard Radio Astronomy Observatory, and the other points in the United States at Princeton and the Bell Telephone Laboratories. To the left of the solid line are a number of points representing background microwave radiation from the galaxy which must be expected to swamp the cosmological microwave background at frequencies lower than about 1,000 mc/s. One study of this kind has already been described[5]. There seems at least to be a possibility, much in need of confirmation before it can be considered as anything like a fact, that the effective temperature of the microwave radio background is greater in two directions in the Universe, one above and one below the galactic equator, and there is just a possibility that these apparently preferred directions may somehow be linked with places in the sky at which certain exceptional quasars are located (see page 1059).

What does all this mean? The most immediate value of these new developments is that they provide a further means of access to cosmological questions. One possibility, for example, is that the mere existence of the microwave background will set a limit to the energy with which protons in the cosmic radiation can reach the Earth. Too much energy will imply too great a chance of interacting with some photon from the microwave background. Fortunately the discovery that energetic cosmic ray showers in the atmosphere produced by the arrival of single energetic particles from outside are accompanied by the emission of pulses of radio waves may provide a means of testing whether the limit of energy lies at $10^{21}$ electron volts, $10^{22}$ electron volts or at some other level. Another possibility, being followed energetically at Princeton and elsewhere, is that it may be possible to measure directly the motion of the Earth through the microwave background by a sufficiently sensitive measurement of the apparent intensity of the radiation from various directions fixed in space. Although to a first approximation the radiation is isotropic, the velocity of the Earth within the Solar System should be enough to produce a detectable imbalance, leading to a greater flux of radiation from the direction towards which the Solar System is moving, even if this galaxy as a whole is at rest with respect to the microwave background. But what if this galaxy is itself moving relative to the background? Studies like these, in other words, could provide direct evidence about the way in which the galaxy was formed.

Whether the existence of the microwave radiation will quickly help to resolve the differences between competing cosmologies is another matter. But on the face of things, the microwave background does seem to be a piece of evidence that the Universe has changed in the course of time, which seems to argue against steady state theories in which the local character of the Universe remains unchanged from one millennium to the next. It is, however, worth remembering that there may conceivably be other explanations of the microwave background than the degradation of the radiation in an initial big bang—and that the supporters of steady state theories are resourceful people. But even if the Universe is at present ageing, it does not follow that the origin was a big bang. It could also have been the extreme phase of a huge oscillation. As yet it is not clear how far the microwave radiation will help to distinguish possibilities such as these.

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*RADIO-ASTRONOMY*

# Smaller Quasars

THE radio sources which are quasars are distinguished from other radio sources in the sky by their small angular diameter. The precise measurement of an extremely small radio source requires a radiotelescope of great size operating as an interferometer, and techniques for doing this have been worked out over the past several years at the Nuffield Radio-astronomy Laboratories at Jodrell Bank by a group of people under Dr H. P. Palmer[1]. Over a period of several years the components of a pair of radiotelescopes have been moved further and further apart until the distance separating them was as great as half a million wavelengths of radiation at 21 cm. The technique consists of comparing the signals from two separate radiotelescopes so as to extract information not merely about intensity but phase as well. Where the distances are so great, it is necessary to use radio links for comparing the signals. By this means radio sources smaller than a quarter of a second of arc have been measured. But is there any possibility of making interferometers with a still greater base length? One difficulty is that even the best microwavelengths and landlines tend to lose quality after some hundreds of kilometres.

It now appears that a way round the problem does exist. A group of radio-astronomers from Canada[2] have been able successfully to use magnetic tape recorders capable of recording accurately a wide band of radio frequencies in such a way as to produce records from two independent radiotelescopes which can later be accurately compared with each other. The standard of time is provided by independent local oscillators controlled by rubidium frequency standards. In one series of observations, two radiotelescopes were separated by 3,000 kilometres or the equivalent of more than 4·5 million wavelengths at a frequency of 448 megacycles per second. With this arrangement, it has been demonstrated that the diameter of at least one quasar (3*C* 273*B*) is less than 0·02 seconds of arc.

Plainly this is an important development of technique which is certain to lead to still more refined measurements of the diameters of quasars.

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