LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

The 'Horizon' of the Steady-State Universe

IN a recent article on "The Age of the Universe" in *Nature*[1] there has been a call for a further explanation of the nature of the 'horizon' or the 'size' of the universe as it is defined in the steady-state theory. The subject is mathematically quite clear, and geometrical properties follow from the fact that the de Sitter space is the applicable one. Thus in the original papers on the subject by Bondi and Gold[2] and by Hoyle[3] there is no ambiguity. Pirani[4] has published a lucid mathematical discussion of the 'horizon', or the observable size of that type of universe. The present discussion is therefore merely a descriptive supplement.

There is no simple answer to the question: 'How big is that universe?' The theory is concerned only with quantities that can be measured observationally, or that could be so measured were it not for some obviously only technical limitation. Some of the questions that may be asked are discussed below.

(1) 'Out to what distance could we now see galaxies?' With any given observing apparatus of fixed limitations as to the energy density and the frequency of the light required for an observation, this will be a finite range. The number of galaxies that can be seen is then also finite. This will be so whatever the actual limits of the apparatus may be, so long as it requires finite amounts of energy for an observation. An improvement of the sensitivity of the apparatus would always give an increase of the range (but not in proportion).

(2) 'If we continued observations with a given apparatus for a very long time, what changes would we see?' In the course of time, the farthest galaxies that we could see will drop out of the observable set because their light will appear fainter and of lower frequency until it is below the threshold of the apparatus. At the same time other galaxies will become brighter as they grow bigger, and newly formed ones will become visible. Originally bright ones will fade towards the limit of observability. Statistically, the population will remain the same, though there will be losses and gains. The 'observational horizon' will always be at a finite range, constant for any given instrument, but greater the more sensitive the instrument.

(3) 'If we sent out a powerful light pulse now, where could it be received?' Such a signal will reach that set of galaxies which are at present nearer than a certain distance (given by Hubble's constant) from us. That is a finite number. But it will also reach all those galaxies that will have formed within the expanding space defined by the first set, in time to intercept the light. That is an infinite number. If reception is to imply recognition, and therefore a finite amount of energy at the receiver, this would limit the number to a finite one; but there is no limit in principle to the number of galaxies that could be informed of our pulse by the use of intermediate relay stations.

(4) 'Is there a last moment before which a light pulse has to be emitted here to assure its arrival at a specified galaxy?' Yes. If the signal is sent later than that moment it will not get to that galaxy. (This is not a question of observational technique.)

(5) 'Is there a last moment for the reception of light signals from another galaxy?' No. There is no last moment of reception defined in the theory. The last signal emitted by another galaxy that could be received here would, however, be drawn out in time so that it would take an infinite time for it to arrive, however short a pulse it may have been at its emission. This absence of a defined instant at which reception must cease does not mean that the act of disappearance is in doubt, but only that the moment at which it occurs is related to the particular method of observation. A change to more sensitive methods of observation would delay the disappearance of any one galaxy, but provided the method of observation is kept the same, the mean rate of disappearance from view will be constant (and equal to the rate at which new ones are appearing in the realm surveyed by that instrument).

So far as any actual, or in principle possible, observation is concerned, that universe is finite. The flow pattern of information there is analogous to that in a population which has a finite number of members at any instant, but which is in a steady state for all time. If I were a member of such a population I could obtain information (say, in writing) from an unlimited set that have lived before now, and I could leave information for an unlimited set in the future. But there would only be a finite number with whom I could now have a two-way conversation. Any one of that number will also belong to one, or more generally to both, the unlimited sets.

T. GOLD

Royal Greenwich Observatory,
Herstmonceux Castle,
Hailsham, Sussex.

[1] *Nature*, **175**, 69 (1955).
[2] *Mon. Not. Roy. Astro. Soc.*, **108**, 252 (1948).
[3] *Mon. Not. Roy. Astro. Soc.*, **108**, 372 (1948).
[4] *The Observatory*, **74**, 172 (1954).

MR. GOLD's statement is very clear, and those interested in cosmology will be very grateful to him for making it. Unfortunately, however, it only increases the uncertainty which has arisen regarding the actual implications of the theory with respect to the observable horizon, since it appears to be in direct conflict with statements made in the paper by Hoyle which Mr. Gold now cites as one of "the original papers on the subject". In that paper Hoyle says: "Extragalactic nebulæ are continually passing out of the observable universe . . . The oldest condensation within the observable universe . . . has an age of about $1 \cdot 5 \times 10^{10}$ years". If a nebula passes out of the observable universe there must have been a time when it was within it (that is, was observable), and a later time when it was not observable. Hence there must have been a time when it ceased to be observable. But Mr. Gold now says: "Is there a last moment for the reception of light signals from another galaxy? No. There is no last moment of reception defined in the theory".

It is clear from Hoyle's paper that the "passing out of the observable universe" was not introduced as an effect of instrumental imperfections: it has been generally interpreted as an effect of the nebula reaching, at a finite distance and within a finite time, the velocity of light. Statements to this effect are numerous. For example, Dingle, speaking