LETTERS TO THE EDITOR

ASTRONOMY

Cosmological Significance of the Relation between Red-shift and Flux Density for Quasars

THE purpose of this report is to point out that recent measurements[1] of the red-shifts of quasars provide the most decisive evidence so far obtained against the steady state model of the universe. The previous evidence[2,3] consisted mainly of the anomalously[4] steep slope of the log N–log S relation for quasars (N is the number of sources with flux density greater than S). This evidence is ambiguous, however, because one could argue[5] that many of the quasars may have zero red-shifts and be situated inside our Galaxy. Their log N–log S relation would then have a purely local significance. If we can restrict the analysis to quasars of known red-shift we avoid this ambiguity, provided that we interpret the red-shift as being cosmological in origin, which in this communication we shall do.

Red-shifts are now known[1] for thirty-five quasars in the revised *3C Catalogue*[6], which is complete down to 9 flux units at 178 Mc/s (1 flux unit is 10^{-26} W $m^{-2}(c/s)^{-1}$). To analyse the data we study not log N–log S, but the more detailed relation between red-shift z and flux density S for these sources (Fig. 1). A similar diagram was constructed by Hoyle and Burbidge[7], who claimed that the absence of a clear correlation between small S and large z shows that red-shift has nothing to do with distance. We shall see that this claim is not necessarily correct.

To test the steady state theory we draw in the diagram lines of constant intrinsic radio luminosity P evaluated at 178 Mc/s. If the sources are uniformly distributed then the steady state theory requires[8] that the number N of sources in a fixed range of P the red-shift of which is less than z should satisfy the relation

$$N \propto \ln(1+z) - \frac{z}{1+z} - \frac{z^2}{2(1+z)^2} \qquad (1)$$

P is given by

$$P = c^2 \tau^2 z^2 (1+z)^{1+\alpha} S \qquad (2)$$

where τ is Hubble's constant and α is the spectral index of the source ($S \propto \nu^{-\alpha}$). The choice of α is not critical, and so we take the same value of 0·7 (K. I. Kellermann, unpublished results) for all the sources. To illustrate the analysis we draw two lines of constant P, the choice of which is also not critical.

To test the N–z relation (1) we divide the diagram into three regions of z in which we would expect to find equal numbers N of sources in any fixed range of P. Regions 1, 2, and 3 are defined by $z < 1{\cdot}02$, $1{\cdot}02 < z < 1{\cdot}55$, and $1{\cdot}55 < z < 2{\cdot}03$, respectively. We now find that there are five sources with $P > P_1$ in region 3, and because of the cut-off at 9 flux units the actual number may be greater. There is only one such source in region 2, however, and none at all in region 1. We cannot argue that we are dealing with an incomplete sample, and that the observers have a bias in favour of seeking the large red-shifts of region 3, because granted that the five sources exist at all, the corresponding sources in region 1 would have a flux density $S \gtrsim 50$ flux units, and could not have been missed. We find similarly that there are five sources with $P > P_2$ in region 3 (which is now very severely affected by the cut-off), five sources in region 2 (which is somewhat affected by the cut-off), and only two sources in region 1.

These discrepancies appear to be statistically significant and in so far as we may use relation (2) to calculate P they show that there is an intrinsic evolution of either P or N or both, with z, contrary to the predictions of the steady state theory. It is not possible to conclude from Fig. 1 that z has nothing to do with distance, because any reasonable distribution of the points could be accounted for by an appropriate rate of evolution.

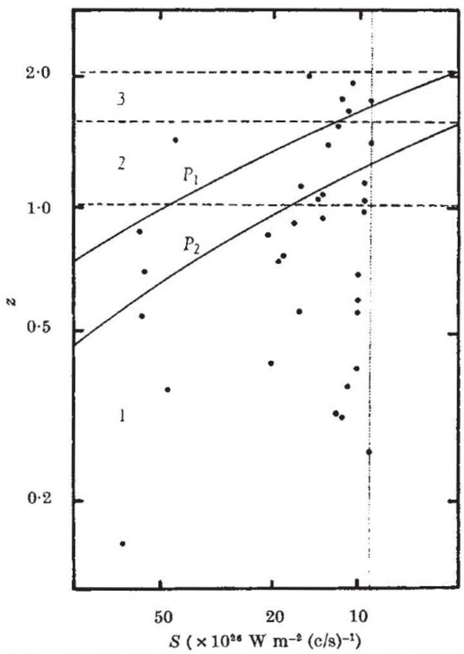

Fig. 1. The red-shift–flux density relation for thirty-five quasars in the revised *3C Catalogue* (which cuts off at 9 flux units). The two curves are lines of constant source power according to steady state cosmology. This cosmology predicts equal numbers of sources of given power in the regions 1, 2, and 3 defined by $0 < z < 1{\cdot}02$, $1{\cdot}02 < z < 1{\cdot}55$, and $1{\cdot}55 < z < 2{\cdot}03$.

We conclude that if the red-shifts of quasars are cosmological in origin, then the present red-shift–flux density relation for quasars rules out the steady state model of the universe.

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