LETTERS TO THE EDITOR

PHYSICAL SCIENCES

Jets in Quasi-stellar Objects

McCrea[1] has raised the interesting possibility that the line spectrum from quasi-stellar objects could arise from a jet aimed toward the observer. McCrea states that this sort of model avoids the intergalactic absorption of Lyman α from 3*C*9 predicted by Gunn and Peterson[2] if the density of neutral intergalactic hydrogen at $z=2$ is of the order of 10^{-11} cm^{-3} or more. Here I shall point out that this model still leads to difficulties with Lyman α absorption of the type predicted by Gunn and Peterson.

If the jet that is supposed to emit the spectral lines approaches the observer so that an observer in the line of sight but near the quasi-stellar object sees the lines with a special relativistic blue-shift $\Delta\lambda/\lambda_s = z_s$, $z<0$, then the local cosmological red-shift z_c must exceed the observed red-shift according to the law $(1+z)=(1+z_s)(1+z_c)$. As stated by McCrea, the light emitted from the jet in Lyman α will be at too high a frequency to be absorbed by the nearby gas, which is at larger red-shift. But there is ample opportunity for the light to be absorbed by gas closer to us along the line of sight. Moving from the quasi-stellar object toward the Earth along this line, the cosmological red-shift varies from the value $z_c > z$ to zero. Thus, in some intermediate region, the narrow intergalactic absorption line must sweep across the emission line. If the density of neutral hydrogen in this region exceeds about 10^{-10} cm^{-3}, the calculation of Gunn and Peterson shows that the entire line would be absorbed. This contradicts the observation that all quasi-stellar objects with suitable red-shifts show Lyman α emission. Thus the gas would have to be highly ionized, or confined to galactic clusters. On the other hand, in an unpublished work I have considered the opposite case, where it is assumed that negligible special-relativistic motion occurs in the source. In this case, the hypothesized absorbing region would be near the quasi-stellar object and would be sufficiently ionized by the quasi-stellar object to raise the extremely low limit of Gunn and Peterson to $\sim 10^{-7}$ atoms cm^{-3}.

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[1] McCrea, W. H., *Nature*, **218**, 257 (1968).
[2] Gunn, J. E., and Peterson, B. A., *Astrophys. J.*, **142**, 1633 (1965).

Distances, Space Distribution and Luminosity Function of Quasi-stellar Objects

The question of the distances of quasi-stellar objects may be dealt with on the basis of the following statistical consideration. Consider a multitude of objects of some sort, distributed according to Poisson's law in an infinite space. The mean density of these objects is D. There is an observer, whose position is chosen randomly, and the objects have been enumerated in order of increasing distance from this observer. The distance of the kth object from the observer is denoted by r_k. Designating the volume of the sphere of radius r_k by V_k it can be shown easily[1,2] that the mean value of V_k is equal to

$$\bar{V}_k = \frac{k}{D} \quad (1)$$

Each of the values

$$D_k = \frac{k}{V_k} \quad (2)$$

can be considered as "density determined by means of the xth object". It can be shown that the dispersion of D_k decreases when k increases. The values of D_k determined using the distances of several neighbours can serve as different approximations to the mean density D.

If we are to apply equation (2) to the actual case, and to determine the density from a group of objects contained in some sphere, we must be sure that no object is omitted, or our enumeration will be erroneous and the application of equation (2) will give a value D much different from the real value. Of course, instead of the whole sphere we can limit ourselves to a part of the sphere confined within a solid angle ω. Then when computing values of V_k we must take this into account. If a sample of the objects with a specific value of absolute magnitude M is considered and if this sample is limited by some apparent magnitude m, then the radius of the quoted sphere is an increasing function of the distance modulus $m-M$.

Now, assuming that red-shifts are cosmological, let us divide the quasi-stellar objects (QSOs) into groups, corresponding to different intervals of absolute magnitude, and try to determine the space densities for each specific group from the distances of its members listed in order of increasing distances. Then the agreement between the different determinations of the density may be considered as evidence of the cosmological nature of the red-shift. Indeed, if the red-shifts are not cosmological, there is no reason to expect the different values of the function D_k for the variable z, which describes the red-shift and which is then independent of distance, to coincide approximately.

The list published recently by Schmidt[3], of thirty-three QSOs from the revised 3*C* catalogue, was used for such a statistical test. This sample of QSOs is held to be complete up to $\log f(2500) = -30\cdot0$, where $f(2500)$ is the flux density at 2500 Å. These objects were divided by Schmidt into four intervals of absolute intensity. Assuming $q_0 = +1$, $H_0 = 100$ km s^{-1} Mpc^{-1} and, using Schmidt's corresponding data, I have calculated the values of D_k for all objects included in the four intervals. Volumes in co-moving coordinates were calculated by the formula given by Roeder and McVittie[4]. This takes into account the fact that the unobscured area covered by the revised 3*C* catalogue is 43 per cent of the celestial sphere. The results are shown in Table 1. The mean values of the density for each group are given under the corresponding sections of Table 1. (It should be noted that the results do not depend strongly on the assumed value of q_0.)

Table 1 shows that the individual determinations of D_k in each group are in rather good agreement. There are only two objects for which D_k differs strongly from the remainder of the corresponding group. The large deviation derived from 3*C* 273 is obviously quite natural for the nearest object. The second object, 3*C* 207, the last one in the fourth group, may be too distant for it is outside the volume containing the other objects of the faintest group. These two objects were omitted when I went on to calculate the mean values of the space densities of QSOs of different intrinsic luminosities. Because the values of D_k in each group coincide well with each other, we may conclude that quasi-stellar objects are actually at cosmological distances.

On the other hand, the data in Table 1 show that the distribution of quasi-stellar objects is rather uniform. Of course, this statement refers only to distances corresponding to $Z<2$.