above was performed almost 300 days after the fallout particles were collected, and the radioactivities were many orders of magnitude less than the levels shortly after the nuclear explosion. Nevertheless, the experimental results presented in this report demonstrate the usefulness of this type of experiments. It is clear from these experiments that one single particle, instead of 20 particles, can easily be used to study the fission mass-yield pattern if the analysis is done shortly after the nuclear explosion.

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29 April 1966

Doppler Interpretation of Quasar Red Shifts

Abstract. *The hypothesis that the quasistellar sources (quasars) are local objects moving with velocities close to the speed of light is examined. Provided there is no observational cutoff on apparent bolometric magnitude for the quasars, the transverse Doppler effect leads to the expectation of fewer blue shifts than red shifts for an isotropic distribution of velocities. Such a distribution also yields a function* N(z), *the number of objects with red shift less than* z *which is not inconsistent with the present data. On the basis of two extreme assumptions concerning the origin of such rapidly moving sources, we computed curves of red shift plotted against magnitude. In particular, the curve obtained on the assumption that the quasars originated from an explosion in or nearby our own galaxy is in as good agreement with the observations as the curve of cosmological red shift plotted against magnitude.*

Arp (*1*) has suggested that the quasars are not located at cosmological distances, as previously argued (*2*), but rather that they appear to be associated with a class of peculiar galaxies falling within a range of distances of 10 to 100 megaparsecs from our own galaxy. If further investigation supports this interpretation, the large red shifts of these objects cannot be cosmological in origin. In that event, there remain two explanations. Either the red shifts are due to large gravitational fields in the emitting regions of the quasars, or they are Doppler shifts caused by large velocities of the objects.

If the shifts are gravitational, the quasars must be extremely dense for their sizes. Taking one second of arc as an upper limit to the angular diameter of the quasars, we find that their radii would range from 30 to 300 parsecs if we place them at the distances suggested by Arp. For the observed shifts ($z \equiv \Delta\lambda/\lambda \simeq 1$) to be gravitational, we must require

$$\frac{GM}{Rc^2} \simeq \frac{\rho R^2 G}{c^2} \simeq 1,$$

where R is the radius, M the mass, ρ the mean density, G the gravitational constant, and c the velocity of light. This gives a lower limit to the mean density of a quasar, $\rho > 10^{-10}$ g/cm^3. The globular clusters, with which we are more familiar, have sizes of the same order of magnitude, but mean densities ranging from 10^{-18} to 10^{-20} g/cm^3.

Arp's suggestion that the red shifts might be a consequence of high collapse velocities of the emitting material towards the centers of the quasars implies densities of the same order of magnitude, since the requirement that escape (and hence "collapse") velocities be close to c is the same as $GM/Rc^2 \simeq 1$. We do not suggest that the gravitational hypothesis be discarded on these grounds, but rather wish to point out some logical consequences of the second, the Doppler shift, hypothesis, which is usually abandoned too easily, as judged from reading the literature.

The Doppler shift theories may be divided roughly into two classes. One can assume that the quasars are shot out with relativistic velocities from many explosion centers more or less isotropically distributed with respect to our own galaxy, or, following Terrell (*3*), one can postulate that the quasars have been ejected from the center of our own galaxy in perhaps just one catastrophic explosion. Burbidge and Hoyle (*4*) have proposed a modification of this second scheme, which would place the explosion outside our galaxy but sufficiently close so that quasars initially approaching us at the time of explosion would have long since passed us by. The discovery by Koehler (*5*) of absorption in atomic hydrogen by a hydrogen cloud associated with Virgo cluster and in the line of sight to quasar 3C273 casts some doubt that this object, at least, could have come from an explosion in or near our own galaxy. The motivation for postulating such a local explosion has been the lack of any observed blue shifts. One of the consequences of the Doppler shift hypothesis, however, is that even if the explosion responsible for accelerating the quasars did not occur in our own galaxy, their velocities must be so relativistic that one does not expect to see as many blue shifts as red shifts.

The theory is quite elementary. Suppose a source is moving with dimensionless velocity $\beta = v/c$ (velocity speed of light) in a direction characterized by an angle θ between its velocity vector and the line of sight from the source to the observer, so that $\theta < \pi/2$ corresponds to motion towards the observer. The Doppler shift is given by the well-known formula from special relativity,

$$1 + z = (1 - \beta \cos\theta)\,(1 - \beta^2)^{-\frac{1}{2}} \quad (1)$$

This formula displays the so-called "transverse" Doppler effect, which is a consequence of the relativistic time dilation. Even for a source with no component of velocity toward or away from the observer, there is a red shift. For any value of β, there is a critical angle θ_c, for which the red shift is zero. This critical angle is given by

$$\cos \theta_c = [1 - (1 - \beta^2)^{-\frac{1}{2}}]/\beta \qquad (2)$$

In the limit of $\beta \rightarrow 1$, $\theta_c \rightarrow 0$, and there is a blue shift only if the source is traveling directly towards the observer. The angle θ_c defines a cone of directions for the source velocity which will lead to blue shifts, and the solid angle, $\Omega(\theta_c)$, subtended by this cone, is always less than 2π steradians. For simplicity, let us assume that the quasars can all be characterized by the same speed, but their directions of motion with respect to the observer are distributed uniformly in solid angle. Then $\Omega(\theta_c)/4\pi$ is the probability of seeing a blue shift. If we call $N(z)$ the number of expected red shifts less than z (normalized to unity at z_{max}), then it is a trivial calculation to obtain the result

$$N(z) = \tfrac{1}{2}[1 - \frac{1-(1+z)\,(1-\beta^2)^{\frac{1}{2}}}{\beta}] \quad (3)$$

$$N(z_{max}) = 1, z_{max} = \left(\frac{1+\beta}{1-\beta}\right)^{\frac{1}{2}} - 1$$

$$N(z_{min}) = 0, z_{min} = \left(\frac{1-\beta}{1+\beta}\right)^{\frac{1}{2}} - 1$$

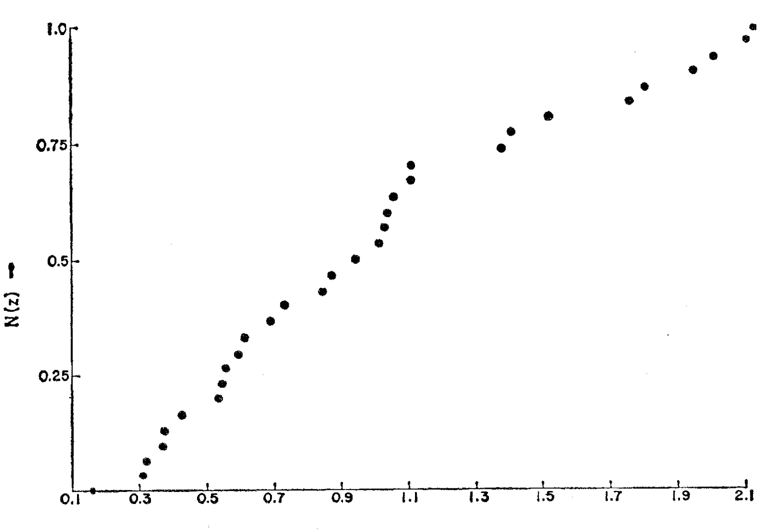
where z_{max} corresponds to the source moving directly away from the observer, and z_{min} to the source moving directly towards the observer. After initially submitting this report, I received a preprint by L. Woltjer (*6*) in which the same intrinsic integral distribution is derived. Woltjer goes on to point out, however, that because of the relation between red shift and apparent magnitude (which I also discuss below) blue-shifted objects will be brighter, and an observer making a survey of all objects extending out to some limiting apparent bolometric magnitude will in fact sample these objects over a larger volume of space. This effect, with Woltjer's assumptions, is sufficient to lead to a predominance of blue shifts. In this report, we explore the implications of the opposite extreme; namely, the assumption that the observational data are governed by a straight volume cutoff, and not one based on apparent bolometric magnitude. Such an assumption is favored if the quasars are not uniformly distributed in space, but are contained in a rather localized region of small enough size so that the the apparent magnitude restriction is not important.

On the basis of this assumption, $N(0)$ is to be interpreted as the total fraction of blue shifts, $\Omega(\theta_c)/4\pi$, we would expect to observe. This number is given for several values of β in Table 1. In order to account for the largest reported (*7*) red shift at present, $z = 2.118$ (object 1116 + 12), we would have $\beta \cong 0.8$, or only 25 percent blue shifts according to Eq. 3. At present, approximately 30 quasars have been shown to have spectroscopic shifts, all of them toward the red. From the above hypothesis, one would expect to have seen eight blue shifts, and the probability of seeing none at all would be about 1/6000. We have neglected any selection effects which might occur if the present techniques of finding the quasars favor large red shifts (*6*), or if, for any reason, spectroscopic blue shifts are more difficult to detect (*4*). This is to be contrasted with the probability of 10^{-9} based on the assumption that there are equal numbers of red shifts and blue shifts.

Table 1. $N(0)$, the fraction of quasars having blue shifts, on the assumption of an isotropic distribution of velocities with fixed magnitude, $\beta = v/c$.

β	$N(0)$
0.6	0.333
.8	.250
.9	.185
.95	.138
1.0	.0

Another consequence of the above assumptions is that the function $N(z)$ is linear in z. In Fig. 1 we plot the observed $N(z)$ for 31 quasar red shifts which have been reported (*7*). Admittedly, the data are still sparse for purposes of plotting this curve, and an integral curve with such a few points is inherently biased toward a straight line. However, we think it is fair to say that the data do not rule out either a single straight line, or a superposition



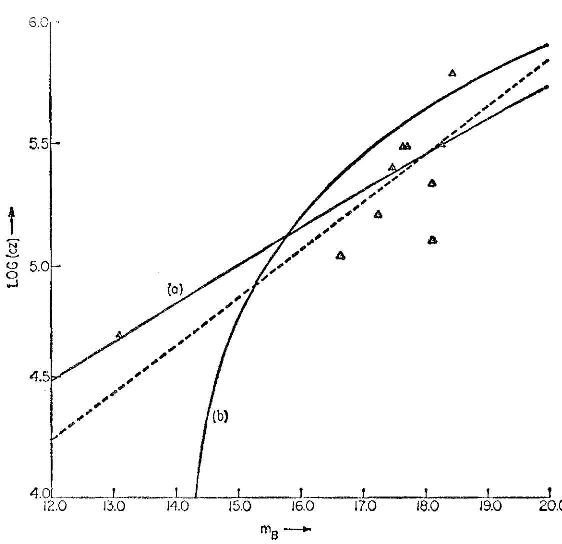


Fig. 1 (left). The observed $N(z)$, number of quasars with red shift less than z, normalized to unity and plotted as a function of z, for 31 red shifts reported in the recent literature (*7*). The points should fall on a straight line or a sawtooth if the quasars arise from one or several explosions near our own galaxy, and the integral distribution of Eq. 3 applies. Fig. 2 (right). Logarithmic plot of cz ($c = 3 \times 10^5$ km/sec, the velocity of light), against m_B, the photoelectric magnitude uncorrected for K-dimming. The ten triangles are the quasistellar sources analyzed by Sandage (*14*), and the dashed line is his best fit, assuming a cosmological model with $q_0 = 1$. The curves (*a*) and (*b*) show the predicted red-shift–magnitude dependence given by the Doppler shift and assumptions (i) and (ii), respectively, in the text. Curve (*a*) corresponds to the Terrell hypothesis (*3*).

of several such lines which would result from several distinct explosions having different values of β.

If the quasar red shifts are cosmological, one can attempt a comparison of the data in Fig. 1 with the function $N(z,q_0)$ for various theoretical universes. Here q_0 is the "deceleration parameter" which is, loosely speaking, proportional to the negative time derivative of the expansion rate of the universe. For a steady state universe, $q_0 = -1$, while for evolving Einstein universes, $q_0 > 0$, and, in particular, for the closed, oscillating models, $q_0 > \frac{1}{2}$. Using the tables computed by Sandage (*8*), we find that a reasonable fit to a straight line in the range $0.15 < z < 2.0$ could be obtained for $8.5 < q_0 < 13$. These values of q_0 would correspond to an effective mass density of 10^{-28} g/cm^3 for the universe as a whole, as compared with the present estimated value (*9*) of 10^{-31} g/cm^3. Such a comparison must be taken very skeptically, however, since there is an appreciable selection effect in the observations for large values of z. The effect is due to the fact that the apparent luminosity of a distant source decreases as a function of increasing z. Thus, a steeply rising $N(z)$ distribution, of the sort predicted by reasonable values of the deceleration parameter, would appear to level off towards a straight line, simply because it is difficult to obtain spectra for the fainter sources. It is for this reason that astronomers follow the practice of using the relation between red shift and apparent magnitude to convert the function $N(z,q_0)$ to the function $N(m,q_0)$, the number of objects brighter than apparent magnitude m.

If the quasars are in fact local objects moving with high velocities, and at random distances from us, there should be no correlation between their red shifts and apparent magnitudes. If, on the other hand (i) the source of the quasars was a galacto-centric explosion (or one which occurred nearby a sufficiently long time ago); or (ii) the distances were approximately the same, as would be the case for a group of quasars originating from an initial explosion at some large, but not cosmological, distance from our own galaxy, then we do indeed find such a correlation (*10*). If we start with the assumption that all sources of interest have the same intrinsic luminosity, both the cosmological theories, and the Doppler effect coupled with assumption (i) or (ii), yield a definite relation between the red shift, z, and the apparent bolometric magnitude, m_{bol}. In the case of assumption (i), which is really a "local big-bang theory", it is simplest to utilize the standard formulas of cosmologies described by Robertson-Walker metrics (*11*). The world line of any particle participating in the explosion can be specified by its dimensionless velocity, β, which we employ as a co-moving coordinate In terms of this coordinate, and the observer's clock time, t, the Lorentz metric of special relativity becomes

$$ds^2 = c^2(1-\beta^2)\,dt^2 - 2c^2\beta t\,d\beta\,dt - c^2t^2\,d\beta^2$$

$$= c^2\,(dt')^2 - \frac{c^2t'^2}{(1-\beta^2)^2}\,d\beta^2 \qquad (4a)$$

where

$$t' = (1-\beta^2)^{\frac{1}{2}}t \qquad (4b)$$

Hence, in t', the metric has the Robertson-Walker form, with the scale factor,

$$R(t') = ct'.$$

For a null geodesic, $ds^2 = 0$, and we have

$$\int_{t'}^{t_0'} \frac{dt'}{t'} = \int_0^\beta \frac{d\beta}{1-\beta^2} \qquad (5a)$$

or

$$\ln\left(\frac{t_0'}{t'}\right) = \ln\left(\frac{1+\beta}{1-\beta}\right)^{\frac{1}{2}} \qquad (5b)$$

Recalling that $R(t_0')/R(t') = 1 + z$ for such a model, the above result simply yields the red-shift–velocity relation of special relativity. The luminosity distance, D, is given by

$$D = R(t_0')(1+z)\,\frac{\beta}{1-\beta^2} = ct_0(1-\beta^2)^{\frac{1}{2}}(1+z)\,\frac{\beta}{1-\beta^2} \qquad (6)$$

where t_0 is the time of observation, measured on the observer's clock and taken equal to zero at the instant of explosion. The apparent luminosity, L, of a given source, is proportional to $1/D^2$, or

$$L \propto \frac{1}{(1+z)^2}\,\frac{(1-\beta^2)}{\beta^2} = \frac{4}{[(1+z)^2-1]^2} \qquad (7)$$

and, converting to astronomical units, we have

$$m_{\text{bol}} = 5\log_{10}[(1+z)^2 - 1] + C \qquad (8)$$

where C is a constant which depends on the intrinsic luminosity of the source and the time interval elapsed from the beginning of expansion. We stress that the integral distribution, $N(z)$, of Eq. 3 does not apply to this case. To obtain the relevant function, we must further specify the velocity distribution which results from the initial explosion.

If we start with assumption (ii) instead, the apparent luminosity of a source is proportional to $1/(1+z)^4$. Two factors of $1/(1+z)$ account for the relativistic time dilation and Doppler shift, and are contained explicitly in the cosmological theories also (*12*). The other two factors enter because of the abberration effect of special relativity (*13*). This is the same effect that causes synchrotron radiation from a relativistic electron to peak in the forward direction. Keeping this in mind, one can derive Eqs. 7 and 8 using more standard techniques in the theory of special relativity. Converting the astronomical magnitudes, we then have

$$m_{\text{bol}} = 10\log_{10}(1+z) + C' \qquad (9)$$

where the constant C' again depends on the intrinsic luminosity of the source and the distance from the observer at the time the light was emitted.

In Fig. 2 we plot the points for the ten quasars analyzed for red shift against apparent magnitude by Sandage in his recent paper (*14*). In that paper, he finds a best fit to the curve

$$m_B = 5\log_{10} z + 18.16 \qquad (10)$$

which is consistent with a cosmological model having $q_0 = 1$ ($\rho \simeq 10^{-29}$ g/cm^3); m_B is the measured photoelectric magnitude, corrected for galactic absorption, but not for the heterochromatic K-dimming discussed by Sandage in his classic 1961 paper on observational cosmology (*8*). His best fit is plotted as a dashed line in Fig. 2, while the curves predicted by Eq. 8 and Eq. 9 above (labeled by (*a*) and (*b*)) are plotted as solid lines. We take as constants, $C = 15.84$, $C' = 14.23$, and, following Sandage, we make the assumption that the K correction can be taken as constant over the range of magnitudes plotted—not a really drastic assumption because of what we consider a large scatter of the data points. The curves can be shifted to the left or right by decreasing or increasing the values of C and C'. In particular, we note that curve (*a*) is in as good agreement with the data as the suggested cosmological curve.

The Doppler shift hypothesis, if "artfully" handled, can also account for the observed $d[\log N(m)]/dm$ values for the quasars. We do not advocate such a succession of *ad hoc* hypotheses at present, nor have we discussed some of the formidable hurdles (*15*) involved in explaining the physics of explosions which would be capable of accelerating large coherent bodies to relativistic velocities. The origin and nature of the quasars appear difficult to explain whether they are distant, dense, or rapidly moving. But on the basis of extant observational data it is not a trivial matter to rule out the Doppler shift hypothesis (*16*).

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10. Because of the apparently isotropic distribution of the quasars, if we adopt alternative (ii), we are forced to postulate many such explosions within a spherical shell surrounding the observer, of thickness small compared to its mean radius. Clearly this is an extreme assumption.
11. See, for example, G. C. McVittie, *Fact and Theory in Cosmology* (Macmillan, New York, 1961).
12. The physics here is clear if we think of the source as emitting pulses of photons. The observer sees each photon diminished in energy by a factor $\nu_0/\nu_s = 1/(1+z)$, and the arrival rate of pulses at his telescope is also diminished by the same factor.
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16. After this report was accepted for publication, I read that F. Hoyle and G. R. Burbidge, *Astrophys. J.* **144**, 534 (1966), also arrived at the red-shift versus luminosity relation given in my Eq. 7.
17. I thank C. W. Misner and D. M. Zipoy for criticism and advice. Work supported by NASA grant NsG-436.

12 May 1966

Thyroid Hormone: Effects on Electron Transport

Abstract. *Thyroidectomy markedly reduces the oxidative capacity of rat liver mitochondria. After the injection of triidothyronine about half of the lost capacity is recovered within 3 hours. This rapid recovery is not associated with any change in the amounts of electron transport components, although the activities of cytochromes* b *and* c *are significantly increased by the hormone.*

One of the characteristics of the action of the thyroid hormones in vivo is the lag period between the administration of the hormone and the stimulation of metabolic rate or of growth (*1*). It has been assumed by some (*2, 3*) that the existence of this lag period makes it unlikely that direct effects of thyroid hormone on oxidation in vitro (*4, 5*) are physiologically significant. However, a direct stimulation of electron transport capacity could occur without causing an immediate change in metabolic rate or in growth (*6*). I find that when T_3 (3,3′,5-triiodo-L-thyronine) is injected into rats 6 to 8 weeks after thyroidectomy nearly half of the lost electron-transport capacity of rat liver mitochondria is restored within 3 hours of the time of injection.

Data from studies of the electron transport system during the recovery period indicate that there are no increases in the amounts of the components of the electron transport chain, although the activities of cytochromes *b* and *c* are substantially increased. These data make it clear that one of the initial effects of the thyroid hormones in vivo is to increase the capacity of the mitochondrial electron transport system. However, the increase does not result from the synthesis of new respiratory assemblies as suggested by Tata (*7*); in fact, the hormonal stimulation of oxidative activity can be separated from the stimulation of amino acid incorporation by treating the animals with actinomycin D. Thus, the increase in electron transport capacity does not result from increased demands for energy for protein synthesis.

Male Wistar rats were surgically thyroidectomized (*5*). Six weeks after thyroidectomy their growth rates had declined to less than 15 percent of normal (*8*). Mitochondria were prepared from liver (*9*), oxygen consumption was measured polarographically (*10*), and incorporation of C^{14}-leucine was estimated as previously described (*6*). The kinetic behavior of the components of the electron transport chain was followed with the Chance dual-wavelength spectrophotometer (*11*).

The first part of Table 1 shows the recovery of mitochondrial oxidative activity following the injection of a single dose (30 μg) of T_3. As reported earlier (*6*), the capacity to oxidize either succinate or a mixture of substrates with dehydrogenases linked to NAD (nicotinamide-adenine dinucleotide) is almost completely recovered within 48 hours. Also, about half of the lost activity is recovered 3 hours after the hormone is administered; this increase is statistically significant whether succinate or the mixture of six substrates is used. As in previous studies (*3, 6*) injection of T_3 causes no change in phosphorylation efficiency. The total reducible amounts of the various components of the electron transport chain did not change during the recovery period. However, the amounts of all of them, except cytochrome *b*, are significantly depressed by thyroidectomy; Drabkin (*12*) first showed this to be true of the amount of cytochrome *c*. Using different methods, Roodyn *et al.* (*13*) found that the amounts of cytochrome in liver mitochondria from thyroidectomized rats do not change during the first 48 hours after injection of T_3.

A characteristic percentage of each of the electron transport components is reduced during phosphorylation (state 3) and after the depletion of ADP [state 4 (*11*)]. Taken together these percentages provide a measure of the activity of each of the electron transport chain components. Changes in these percentages indicate changes in the activity of the component in question, but to be meaningful the changes must be related to any alteration in the rate of electron transport. Thus, hormonal treatment increases the rate of electron transport; consequently, an increase in the percentage of reduction in states 3 and 4 indicates a disproportionate increase in the rate of reduction of the particular component being studied. Thyroidectomy significantly reduces the activities of cytochromes *b*, *c*, and a_3. Three hours after administration of T_3 there are significant increases in the activity of cytochrome *b* and of subsequent components of the electron transport chain, although there is no change in the ac-