ON THE INTERACTION OF RADIATION FROM DISTANT SOURCES WITH THE INTERVENING MEDIUM

We discuss several ways that a distant radiation source (with a large redshift assumed due to the cosmological expansion) can provide information over a wide range of distances about the intervening medium. As we shall show [cf. Gunn and Peterson (1965)] neutral hydrogen (or other atoms) at various distances between the source and us will give rise to an "absorption trough" in the continuous spectrum of a distant source. If the neutral hydrogen is instead concentrated in clusters of galaxies, this trough is replaced by a number of sharp absorption lines. Besides discussing (i) absorption troughs and (ii) absorption lines from clusters, we also consider (iii) photon scattering by free electrons in the intervening medium and (iv) spreading of a radio beam due to inhomogeneities in the ionized gas that is traversed. Present observations furnish some stringent upper limits, and we suggest other feasible cosmological tests.

Let $z \equiv (\Delta\lambda/\lambda)$ be the "distance" or redshift measure, q_0 the deceleration parameter for the usual cosmological models (with cosmological constant equal to zero) that satisfy the field equations of general relativity (see, e.g., Bondi 1961, or Sandage 1961*a*, *b*), H the Hubble parameter with $H_0 \approx (10^{+10}\text{ years})^{-1}$ (a subscript zero indicates a local value at the present epoch), and N the total density (in nucleons per cm^3). The evolving cosmologies[1] require that the *total* number density satisfy a relation of the form:

$$N(z) = (1+z)^3 N_0\,, \tag{1}$$

where $N_0 = 2 \times 10^{-5}\, q_0\ \text{cm}^{-3}$. The steady-state model requires $N(z) \equiv N_0$ with $N_0 \approx (1 \text{ or } 2) \times 10^{-5}\ \text{cm}^{-3}$ in some versions (Hoyle 1948; Hoyle and Narlikar 1962). We denote the redshift of a distant source by z_s and that of an absorbing layer by z_a.

One can easily estimate (assuming a fairly flat ultraviolet spectrum [Greenstein and Schmidt 1964; Oke 1965; but see also Greenstein 1964]) values of z_s that may be observed in QSS's in the near future. A QSS with the intrinsic brightness of 3C 273 (one of the brightest QSS's) would have an apparent magnitude of 20 for $z_s = 2.0$ on the steady-state model (note that 3C 9 with $z_s = 2.05$ is about seven times brighter than the above value), and for evolving cosmologies the z_s corresponding to apparent magnitude 20 increases monotonically from $z_s = 2.5$ for $q_0 = 0$ to $z_s = 5$ for $q_0 = 1$. We shall see later than an ionized, evolving universe with $q_0 > 1$ is optically thick to Thomson scattering for $z_s > 5$.

i) Consider continuum radiation emitted from a distant source at frequencies $\nu(1+z_s)$, where ν is the received frequency, passing through the dilute gas which is postulated as a "substratum" in cosmology If a constituent of the gas has a resonance absorption line at a frequency ν_{res}, then most of the absorption takes place at distances near z_a, where

$$z_a = (\nu_{\text{res}}/\nu) - 1 \tag{2a}$$

$$= (\nu_{\text{res}}/\nu_{\text{emission}})(1+z_s) - 1\,. \tag{2b}$$

[1] We assume that all physical constants are independent of z_s (i.e., time). In particular, we assume that the relation between energy and wavelength for a photon emitted from a distant source is the same as for a photon emitted locally (constancy of *hc*). Comparison of redshifts measured (e g , for 3C 273) with a diffraction grating (wavelength) and with a prism spectrometer (photon energy via the dispersion relation) or photoelectric detectors would check on the constancy of *hc*. Large effects can already be excluded ($d[\ln hc]/dt < 10^{-10}\ \text{yr}^{-1}$) from the absence of any marked discrepancy for photons from distant sources in the two *wavelengths* for which atmospheric absorption sets in and photographic sensitivity falls off (both involve the photo effect and hence depend on photon *energy*). Similarly one can show from multiplet splittings in, e g., the spectra of 3C 47 and 3C 147 (Schmidt and Matthews 1964), that $d \ln \alpha^2/dt \lesssim 10^{-11}\ \text{yr}^{-1}$ (where α is the fine-structure constant) and therefore the variation of α with z_s cannot account for the redshifts of QSS's (cf. Savedoff 1956).