Redshift Components of Apparent Quasar-Galaxy Associations: A Parametric Model

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The components that are known to physically contribute to an object's observed redshift are reviewed. Then, using a postulated galactic ejection model for quasars, and previously derived results from electromagnetic scattering theory which have been experimentally verified, a parametric extrapolation of these redshift components is presented. The model shows that high quasar redshift magnitudes, relative to the low redshift galaxies that eject them, can be obtained. Further, above a parametric threshold, the quasars exhibit only *redshifts*, despite the assumption of isotropic ejection from the galaxies. The differences in redshift between the quasars and galaxies obtained are consistent with astronomical observations of apparent physical associations. A mechanism consistent with the scattering theory and known astrophysical plasmas is suggested.

Keywords: Quasars, redshifts, galaxies, scattering

1. Introduction

The so-called *redshift controversy* is almost forty years old, having originated in reporting of high redshift radio loud quasars in proximity to, and with apparent symmetry about, low redshift galaxies [1, 2] The *controversy* revolves around interpretation of observational data* that, on one side, suggests an apparent physical association, as evidenced in radio to gamma-ray wavelengths between quasars and nearby galaxies. Or, on the other side, the astronomically politically correct one, that redshifts *only* represent cosmological distances as first proposed by Hubble. In this latter view, sometimes called the *Cosmological Hypothesis*, the literally hundreds of quasars that have been catalogued† appearing near to, and with symmetry about, galaxies is simply an artefact of the particular field of view. Statistics have been used and argued about by both sides. As summarised by Kembhavi and Narlikar [3], the study done by Burbidge *et al* [4] identified 472 high redshift quasars “close” to (defined as less than 600 arcsec) low redshift galaxies. A chance projection hypothesis within that limit was determined to have a probability of less than 10^{-2}. The nature of these observational data, in many cases showing connecting filaments or *bridges*, have suggested to the first side of the *controversy* that ejection of quasars by nearby

* See: *The Redshift Controversy*, ed. G. Field, W.A. Benjamin, Inc., Reading, Mass. 1973; *Quasars, Redshifts and Controversies*, H. Arp, Interstellar Media, Berkeley, Calif. 1987; *Seeing Red*, H. Arp, Apeiron, Montreal, Quebec, 1998; *Quasars and Active Galactic Nuclei*, A. Kembhavi and J. Narlikar, Cambridge, UK, 1999; and *A Different Approach to Cosmology*, F. Hoyle, G. Burbidge, and J. Narlikar, Cambridge, UK, 2000, for extensive summaries and presentation of the data, the controversy, its sociology and history, including additional references to journal articles, papers, and other publications.

† See: Arp, Halton , *Catalog of Discordant Redshifts,* Apeiron, Montreal, 2003, for an extensive summary.

galaxies is a hypothesis that should be investigated. The other side, however, has rejected any consideration of such a hypothesis and has been successful in denying the funds and telescope time to others to investigate it further[‡]. This paper reviews the components that both physically and theoretically can determine the redshift using the parametric quasar-galaxy ejection model described below.

2. Redshift Components

The postulated quasar-galaxy ejection model used in this study is shown in Figure 1. Redshifts of objects are defined as the wavelength or frequency difference[§] ($\Delta\lambda$, or $\Delta\nu$) in spectra between that measured in the laboratory (λ_o, ν_o) and that observed emitted from the object (λ,ν):

$$z = \frac{\lambda - \lambda_o}{\lambda_o} = \frac{\nu_o - \nu}{\nu} \tag{1}$$

The components that physically affect the observed quasar redshifts, assuming that they have been ejected by a host galaxy, are four:

‡ With respect to Arp these activities on the part of his colleagues at the Mount Wilson and Palomar Observatories are well documented in *Quasars, Redshifts and Controversies* (1987). It even made the local papers: *Astronomers Warn Maverick: Quasar Heretic May Lose Access to Observatories*, G. Alexander, *Los Angeles Times*, Orange County Edition, Monday, February 15, 1982.

§ For the purposes of calculation, all redshifts were derived from frequency differences ($\Delta\nu$), where ν_o was taken at the quasar emission line for Mg II (2798 Å) as given in: *Allen's Astrophysical Quantities*, Fourth Edition, ed. A. Cox, Springer, New York, 2000; Table 24.9, pg. 599.

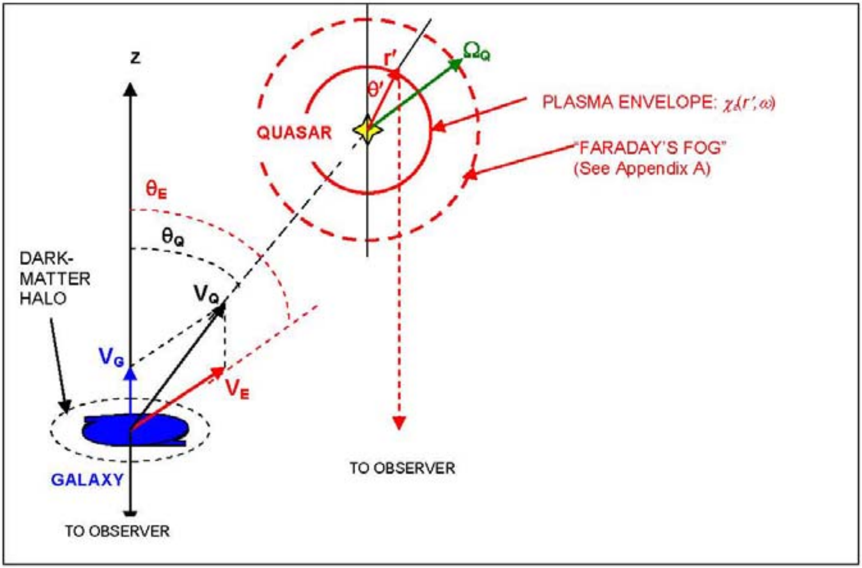

Figure 1. Postulated Quasar-Galaxy Ejection Model

- **Galactic (z_1):** Arising from cosmological expansion, or time dilation in a curved space-time universe, of the light from the galaxy which is receding at velocity $V_G = cz_1$ along the positive z-axis relative to the observer (see Fig. 1).
- **Gravitational (z_2):** Resulting from the energy lost by photons escaping the gravitational field of a massive body of mass M_G and radius R_G: $V_{esc}=(2GM_G/R_G)^{1/2}$.
- **Translational Doppler Shift (z_3):** Determined from the component of linear velocity ($V_Q\cos\theta_Q$) along the line-of-sight of the observer as shown in Fig. 1.
- **Rotational Doppler Shift (z_4):** Due to photon orbital angular momentum (POAM), not linear velocity of rotation, in the quasar environment. It is determined by the component of angular velocity towards the observer ($-\Omega_Q\cos\theta_E$, see below and also Appendix A).

In the model shown in Figure 1, quasar ejection angles (θ_E) are taken as the independent variable, that is, isotropically. The *minimum* quasar ejection velocities must be greater than the escape velocity of the host galaxy ($V_E > V_{esc}$). To define a *nominal* host galaxy and the minimum escape velocity in this model, 63 galaxies of known luminous mass (M_G) and radius (R_G) were used**. The luminous mass was increased to account for the presence of any so-called *dark matter*†† ($M'_G = 27.5\ M_G$). The 63 escape velocities so obtained were then averaged (< >). The resulting $< V_{esc}>$, as well as minima and maxima of the set, were used to define a range of V_E, V_Q, and the quasar ejection geometry (θ_Q) as shown in Figure 1. This determines z_2 and z_3. The rotational Doppler shift described by Allen, Padgett, and Babiker [5], which determines z_4, is derived from POAM, which was suggested by Harwit [6] as having astrophysical applications, specifically in the radiation from quasars. No explicit formulation of the POAM Doppler shift for quasars was presented there, so one is derived in Appendix A.

As shown in Figure 1, the postulated quasar ejection model assumes that a rotational velocity vector (Ω_Q) if it is present, is parallel with the direction of the ejection velocity vector (V_E). The calculated magnitude of z_4 was found to be orders of magnitude less than the translational Doppler shift (z_3), hence negligibly contributes to the overall redshift. The total redshift can be expressed in terms of

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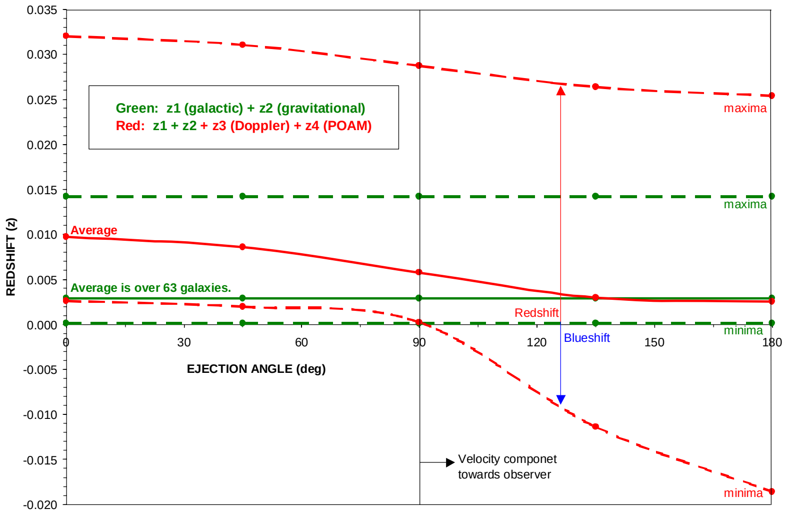
** These were selected from *Astrophysical Formulae*, Second Corrected and Enlarged Edition, K. Lang, Springer-Verlag, 1980; Table 61, pgs. 549-552, for galaxies whose luminous total mass and radius were given and where $z_1 > 0$ as listed in the NASA Extragalactic Data Base (NED).

†† Using "The mass ratio of dark halos to stars and cold gas, 11 to 0.4," from: *The Hunt for Dark Matter in Galaxies,* K. Freeman, *Science* magazine, 12 December 2003, VOL 302, pg. 1902.

the independent contributions that were calculated separately at each stage as described in §:

$$z_T(n) = \left[\prod_{i=1}^{n} (z_i + 1) \right] - 1 \tag{2}$$

Figure 2. Total Redshifts for z_1 to z_4.



The total redshift for n = 2 (galactic and gravitational), and n = 4 (adding Doppler and POAM), are shown in Figure 2. As expected, the first two redshifts are relatively small ($z_T < 0.015$) and are, of course, independent of the quasar ejection angle. The minimum Doppler redshifts are actually *blueshifts* for ejection angles greater than ninety degrees. The average redshift, predominately Doppler, however, remains *red* since the average value of the quasar velocity angle from the galactic data set, $< \theta_Q >$, relative to the observer, was less than ninety degrees. The redshifts described above are now extrapolated using a fifth redshift component:

- **Wolf's Shift (z_5):** This component, as described below, is based on the scattering of radiation from a source (the quasar) by a medium whose dielectric susceptibility, $\chi_e(r', \omega)$ is a random function of position (r′, θ′), represented by a postulated plasma envelope about the quasar as shown in Figure 1.

Emil Wolf, as early as 1986, described the theoretical modification in the far-field spectra from a source whose fluctuations are correlated within the source region [7], [8], [9]. The predicted spectral variations were subsequently verified by experiments (Boko, Douglass, and Knox [10]; Faklis and Morris [11]; and Gori, Guattari, and Palma [12]). In close analogy, Wolf then applied the same type of spectral analysis to the *scattering* of source radiation by a medium whose dielectric properties are spatially random but also correlated within the source region [13], [14], [15]. The development summarised below is based on Wolf [13].

Wolf derived an expression for the spectral frequency ($\omega' = 2\pi\nu'$) of the radiation in the scattered field as a function of the source spectral frequency, its scattering angle, linewidth, and correlation length (ω_o, θ', Γ_o, σ) as:

$$\omega' = \frac{\omega_o}{2\alpha^2(\theta')}\left\{1+\left[1+\alpha^2(\theta')\left(\frac{4\Gamma_o}{\omega_o}\right)^2\right]^{1/2}\right\} \tag{3}$$

Where:

$$\alpha^2(\theta') = \left\{1+\left[2\left(\frac{2\pi\sigma}{\lambda_o}\right)\left(\frac{\Gamma_o}{\omega_o}\right)\sin\left(\frac{\theta'}{2}\right)\right]^{1/2}\right\} \tag{4}$$

Let $m = (2\pi\sigma/\lambda_o)$ be called the *Wolf correlation parameter*. The ratio of linewidth to frequency, taken as a positive constant, can be expressed as:

$$\frac{\Gamma_o}{\omega_o} = \left|\frac{\Delta\omega}{\omega_o}\right| = \left|\frac{\Delta\nu}{\nu_o}\right| \rightarrow \left|\frac{\Delta\lambda}{\lambda_o}\right| = \frac{27}{2798} \approx 10^{-2} \text{ (similar to [13])}$$

After these substitutions, $\nu'(\nu_o, m, \theta')$ in the quasar-observer plane was calculated for a set of scattering angles: $0 \le \theta' < 2\pi$, at $\Delta\theta' = 10$ degree increments, and averaged over the 36 values obtained:

$$\left\langle \nu'(\nu_o, m)\right\rangle = \frac{1}{36}\sum_{i=1}^{36}\nu_i'(\nu_o, m, \theta_i') \tag{5}$$

The total redshift z_T was then found for n = 5 from the set of 63 galaxies, again providing a minimum, maximum, and average value. The *minimum* (*bluest*) total redshifts are shown in Figure 3 as a function of the ejection angle and a set of *Wolf correlation parameters* (m).

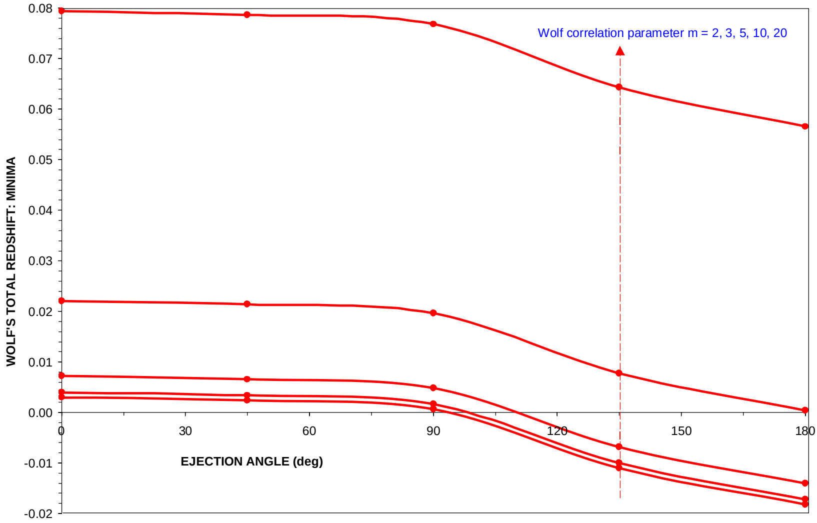


Figure 3. Total (Including Wolf's) Minimum Redshifts.

In Figure 3 note that as the ejection angle increases past 90 degrees, the value of *m* must increase to keep z_T in the *red*, that is, to obtain *red*shifts for $\theta_E > 90$ degrees: $3 \le m \le 10$ as can be seen in the Figure. The general condition of what *m* values are necessary to ensure that z_T will *always* be observed as a *red*shift for increasing magnitudes of escape or ejection velocities can be examined:

- First, require that z_T (n = 4) = $z_D < 0$ (*i.e.* primarily a Doppler *blue*shift).
- Then *m* needs to be determined such that z_T (n = 5) > 0.

- From: $z_D + 1 = \frac{\nu_o}{\nu_4}$, and $z_T + 1 = \frac{\nu_o}{\nu_5}$,
- Then: $\nu_5 < \nu_o < \nu_4$, or $\frac{\nu_5}{\nu_4} < \frac{\nu_o}{\nu_4} = z_D + 1$.

Using equation (3) and substituting for m and Γ_o/ω_o:

$$\frac{\nu_5}{\nu_4} = \frac{1}{2\alpha^2(m,\theta')}\left\{1 + \left[1 + \frac{\alpha^2(m,\theta')}{625}\right]^{1/2}\right\} < \left(z_D + 1\right) \tag{6}$$

Taking the average value for $\alpha^2(m,\theta')$ over all scattering angles (θ') gives:

$$\left\langle \alpha^2(m) \right\rangle = \frac{1}{2\pi}\int_0^{2\pi}\left[1 + \frac{m^2}{2500}\sin^2\left(\frac{\theta'}{2}\right)\right]d\theta' = 1 + \frac{m^2}{5000} \tag{7}$$

Substituting this expression into equation (6) and solving for *m* gives the minimum value required to have the total redshift $z_T > 0$ as required:

$$m > \left\{5000\left[\frac{1}{2500(z_D+1)^2} + \frac{1}{(z_D+1)} - 1\right]\right\}^{1/2} \tag{8}$$

Taking the quantity v/c as an independent variable, the Doppler *blue*shift $-1 \le z_D < 0$ can be calculated and the minimum *m* for a total *red*shift $z_T > 0$ found. These quantities are presented in Figure 4.

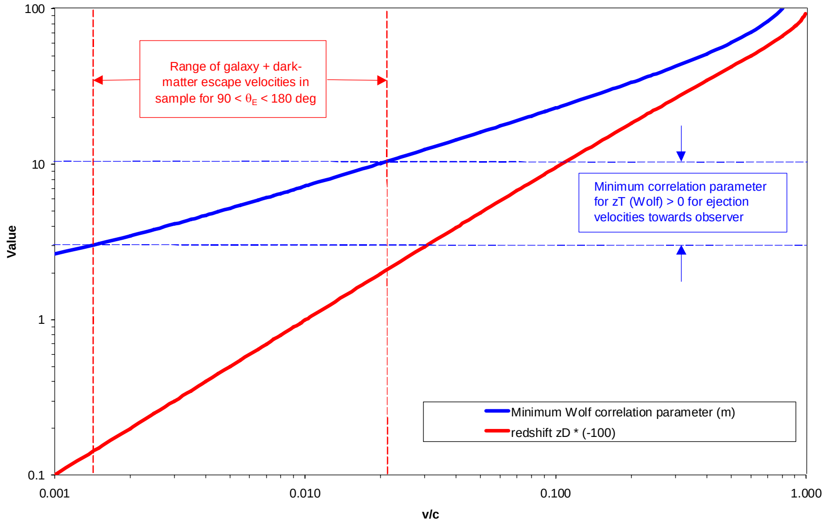


Figure 4. Minimum *Wolf Correlation Parameters* for Total Redshift $z_T > 0$.

Note that for the range of escape velocities in the set of 63 galaxies used, $m \leq 10$, consistent with Figure 3. Also, as v/c increases, or $V_E >> V_{esc}$ in the direction of the observer (that is, z_D becomes more negative, or *bluer*), the minimum value of *m* increases accordingly.

The *average* values of the total quasar redshift z_T (n = 5) over the galaxy set are shown in Figure 5 for an extended set of *Wolf's correlation parameters*. The average galactic redshift z_1 is also shown. In the astronomical database of apparent quasar-galaxy associations discussed in the Introduction (see *), the quasars have redshifts on the order of about $0.2 < z_Q < 2.7$. The nearby galaxies have redshifts around $0.001 < z_G < 0.005$. Figure 5 shows that for a similar separation of redshifts between z_T and z_1, the average *Wolf correlation parameter* is about: $30 < m < 200$.

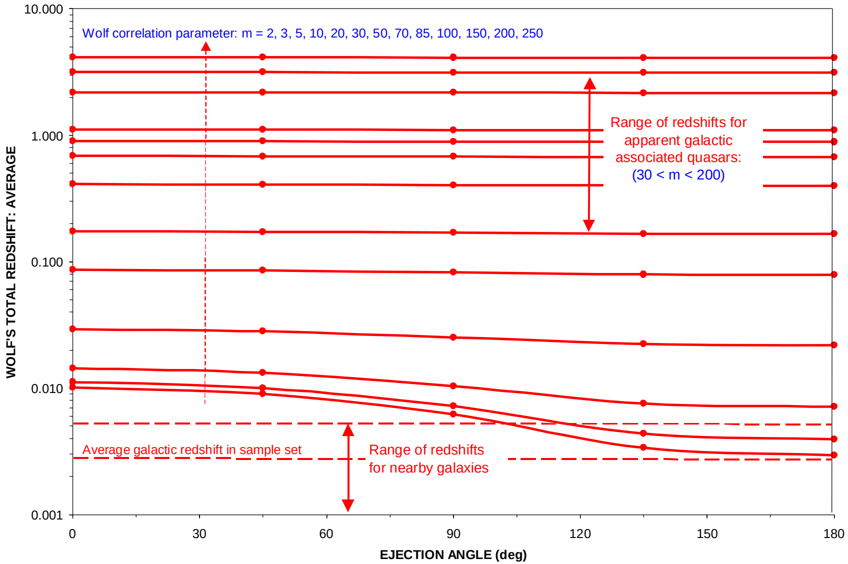


Figure 5. Total Average Quasar Redshifts Using *Wolf's Correlation Parameter*

The remaining question to be answered is, can any physical significance be attached to *the Wolf correlation parameter* that might be consistent with the source environment of quasars. There is, of course, no observational data to determine or characterize this environment.

Wolf's scattering analysis requires a quasar source region whose dielectric susceptibility is a random function of position. This suggests some type of plasma environment or envelope as illustrated in Figure 1. This is not an unreasonable or unphysical conjecture: a plasma environment in the source region of a quasar is quite reasonable *and* parsimonious.

A further conjecture that can be made is that the plasma or dielectric susceptibility correlation length (σ) is probably less than, or on the order of, the Debye plasma screening length or radius (r_D). That is, the correlation length in cm for T in degK and N_e in cm^{-3} is:

$$\sigma = m\left(\frac{\lambda_5}{2\pi}\right) \leq r_D \approx 6.9\left(\frac{T}{N_e}\right)^{1/2} \tag{9}$$

The value of σ is shown in Figure 6 over the range of m values necessary to achieve the quasar redshifts shown in Figure 5. Also shown for comparison are calculated values[‡‡] of r_D for known types of astrophysical plasmas.

Figure 6 of course, is only suggestive. However, the correlation lengths shown are intermediate to Debye lengths for known astrophysical plasmas. In particular, for $30 < m < 200$, the correlation distance is within an order of magnitude of the Debye length for the solar chromosphere.

[‡‡] Using values of T and N_e from Lang's *Astrophysical Formulae*, (see **), Table 4, pg. 52.

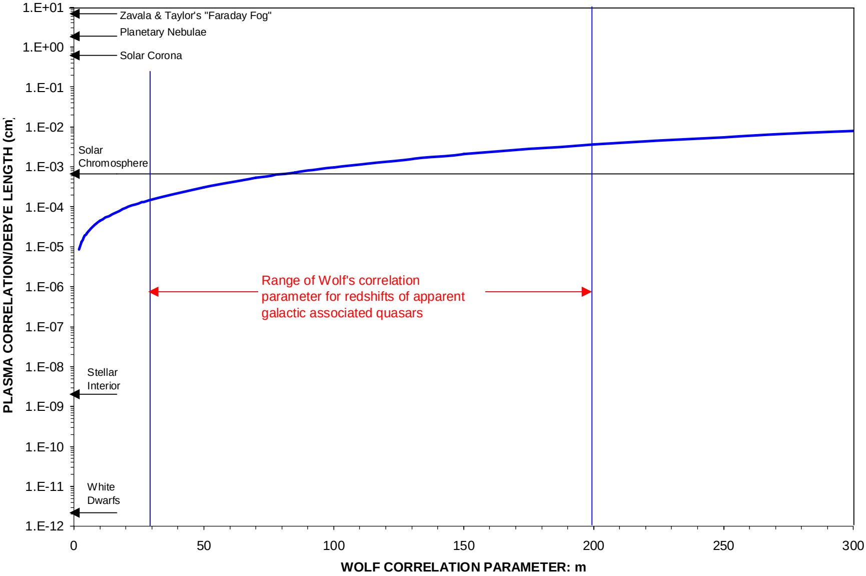


Figure 6. Wolf Plasma Correlation and Debye Screening Lengths

3. Discussion

The so-called *redshift controversy* has been disputed for forty years, but has not been conclusively refuted, either physically or statistically. If just *one* of the hundreds of examples of high redshift quasars *is* physically associated with a nearby low redshift galaxy, then the *Cosmological Hypothesis* is at risk. This is, and has been, politically unacceptable within the astronomical community (see * and ‡). As related in Hoyle, Burbidge, and Narlikar [16], a "leading observer" expressed the opinion that "if no theory is available to explain the observations [of apparent quasar-galaxy associations], then the observations must be in error." This pretty much sums up the continuing state of affairs. It is *not* science. In this paper an attempt *has* been made to apply a “theory” [Wolf scattering] to those “observations.” This particular theory is supported by experimental results and its application to the radiation from quasars both accounts for their redshift and appears physically reasonable.

Appendix A. Development and Application of POAM to Quasar Redshifts

Allen *et al* ([5], pgs. 326-328) defined the Doppler shift arising from photon orbital angular momentum as:

$$\Delta\nu = -\left(\Omega_Q \cos\theta_E\right)\frac{L}{\hbar} \qquad \text{A.1}$$

Where:

Ω_Q = rotational velocity of a beam of light in the source region.

θ_E = angle between the rotational velocity vector and the observer (see Figure 1).

$L/\hbar = s(n\text{-}1)/\lambda$ is the angular momentum per photon.

s = the radial step height of a spiral phase plate.

n = index of refraction of the phase plate.

λ = wavelength of the radiation.

Harwit [6] suggested that this effect might have a number of astrophysical applications, specifically in the radiation emitted by quasars. The working assumption is that the immediate quasar environment may include density discontinuities in a turbulent plasma similar to that described by Zavala and Taylor [17] as “Faraday’s Fog,” which could be envisaged as a screen of spiral phase plates.

Since Ω_Q was not explicitly defined, it is estimated here as:

$$\Omega_Q = \frac{(RM)\lambda^2}{\Delta t} \qquad \text{A.2}$$

Where:

(RM) = the rotation measure observed by Zavala & Taylor (≤ 1 [rad/cm^2]).

Δt = an unspecified time interval [sec].

The time interval for transition through the phase plate was estimated from the index of refraction as: $\Delta t = s/cn$. Substituting into equation A.1:

$$\Delta \nu = (RM)\lambda cn(n-1)\cos\theta_E \qquad \text{A.3}$$

Using the approximation: $n(n-1) \approx -\frac{1}{2}\,(\omega_p/\omega)^2$, with $\omega = 2\pi\nu$ and again substituting:

$$\Delta \nu = \frac{(RM)c^2\omega_p^2}{8\pi^2\nu^3}\cos\theta_E \qquad \text{A.4}$$

Using $\omega_p{}^2 \approx (3\ 10^9)\ N_e$, where N_e is the plasma electron density, also estimated by Zavala & Taylor as: $N_e \leq 10^4$ [cm^{-3}], and substituting into A.4, the order of (negligible) magnitude for $\Delta\nu$ is:

$$\Delta\nu \leq (10^{32}/\nu^3) \approx 10^{-13}$$

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