5,G Addendum Appendix G
Causes of Redshift

Adrian Bjornson (May 2009)

This appendix discusses issues that relate to spectral redshift. Section G.1 examines the concept that gravitational redshift may explain the extreme redshift of the quasar. Section G.2 discusses the spectral redshift theory of Paul Marmet, which indicates that collisions of photons with hydrogen atoms can produce spectral redshift. The Marmet redshift effect gives a promising explanation for the intrinsic redshifts of quasars and some galaxies. Paul Marmet also proposes his redshift effect as an explanation for the Hubble redshift.

1, Cause of Quasar Redshift

When the extreme quasar redshift was discovered in 1963, two concepts were considered to explain it: (a) redshift due to the Doppler velocity effect, and (b) gravitational redshift. The gravitational redshift possibility was quickly dismissed for reasons that we will now discuss, and this left the Doppler velocity explanation. It was concluded that quasars must be receding at extremely high velocities, and so must be billions of light years away. There were two reasons for rejecting gravitational redshift, which are:

(1) Analyses based on the Einstein theory indicated that a star would become unstable if it has a sufficient mass-to-radius ratio to achieve a large gravitational redshift.

(2) The spectra of quasars display "forbidden" spectral lines of oxygen and other elements. Forbidden spectral lines are not seen on earth, and have only been observed in the radiation from a hot gaseous nebula, which has a gas density very much lower than can be achieved on earth. At this low density, an enormous volume of gas is required to generate appreciable power. It was concluded that the volume of an atmosphere of a star exhibiting large gravitational redshift would be far too small to radiate the energy that is observed in the forbidden spectral lines of quasars.

The following discussion shows that these reasons do not invalidate the gravitational redshift possibility. Consequently, gravitational redshift remains a strong candidate for explaining the very large redshift of the quasar.

Instability of Stars with Large Mass-to-Radius Ratios

The normalized mass m of a star is defined as MG/c^2, where M is the star mass in conventional units, G is the gravitational constant of Newton's theory, and c is the speed of light. Normalized mass has the units of distance. The normalized mass m of our sun is 1.475 kilometers. The m/r ratio at the surface of our sun is 2.12×10^{-6}, where r is the radius to the sun surface.

The Einstein Schwartzschild solution indicates that the density of matter should be infinite at certain points within a star if the m/r ratio at its surface exceeds 4/9. Therefore it was concluded that a star would become unstable and collapse into a black hole if its m/r ratio is greater than 4/9. According to the Einstein theory, a star with an m/r ratio of 4/9 would exhibit a gravitational redshift of 2.

S. Chandrasekhar [5] extended this concept by showing with analysis of the Einstein theory that a star should exhibit strong radial oscillations unless its m/r ratio is much smaller than 4/9. This indicates that the maximum gravitational redshift that can be displayed by a stable star should be much less than 2. Under this constraint, the quasar redshift cannot be explained as a gravitational effect.

These arguments against the gravitational explanation for the quasar redshift are refuted by the Yilmaz theory. The stability problems exhibited by the Einstein theory are related to the black hole singularity, which is merely a mathematical flaw of the Einstein theory. As shown in Fig. 1.3-2 of the Summary portion of this website (Section 1.3), the slopes of spatial contraction and clock rate for the Einstein theory are extremely steep for large values of the m/r ratio, and this property suggests instability. The slope for the Yilmaz theory is gradual, and so the Yilmaz theory does not exhibit instability at large values of the m/r ratio.

Therefore, we conclude that the analysis by Chandrasekhar [5] does not apply to the Yilmaz theory. The Yilmaz theory predicts that a stable star can exhibit sufficient gravitational redshift to explain the redshifts of all quasars.

Analysis of Quasar Spectra by Greenstein and Schmidt

In Feb. 1963, Maarten Schmidt and Jesse Greenstein discovered that quasars exhibit extreme redshift. The first quasars that they studied were 3C48 (with a redshift of 0.367) and 3C273 (with a redshift of 0.158). Their analyses of these quasars were reported in their classic 1964 paper in the *Astrophysical Journal* [6].

Greenstein and Schmidt [6] observed "forbidden" spectral lines of oxygen and neon in the quasar spectra. These forbidden lines are never experienced on earth, and are observed only in the radiation from gaseous nebula, which are extremely thin clouds of ionized gas. Gas density in these nebulae is usually less than 10^5 electrons per cubic centimeter, whereas the density of a high vacuum on earth is about 10^{15} electrons per cubic centimeter. To generate these forbidden lines, it is believed that an enormous volume of hot gas of very low density is required. Gaseous nebulae are heated to a temperature of about 10,000 degrees Kelvin by the radiation from stars.

An extensive theory of the processes involved in the generation of forbidden spectral lines has been developed from observations of gaseous nebula, combined with theoretical analyses. Greenstein and Schmidt [6] applied this theory to the lines they observed in the spectra of quasars 3C48 and 3C273. They concluded that the forbidden spectral lines of these quasars cannot be explained by a viable stellar model that has a large gravitational redshift, and so the redshifts of these quasars must be Doppler effects produced by extremely high velocities. With such high velocities, the quasars must be at enormous distances, and must radiate enormous amounts of power.

Let us examine the findings that Greenstein and Schmidt [6] derived from their studies of the spectra of quasar 3C48, which has the larger redshift of the two quasars. We will see that the physical model of 3C48 that they predicted is inconsistent with the observed time variation of the radiation from this quasar.

The theory of forbidden spectral lines evolved from observations of spectra radiated from gaseous nebulae. Most of the observed nebulae have electron densities less than 10^5 electrons per cubic centimeter. Seaton and Osterbrock [7] studied some gaseous nebulae that may have electron densities as large as 7×10^6 electrons pet cubic centimeter, which appears to be the upper limit to the observed values of electron density. The ratios of the intensities of different spectral lines were found to give indications of the density of the nebulae atmospheres.

Based on the presence of forbidden spectral lines and the ratios of the line intensities, Greenstein and Schmidt [6] estimated the electron density N_e of the atmosphere of quasar 3C48 to be 3×10^4 electrons per cubic centimeter. In their Eq. 3b, they estimated .that the power radiated in the hydrogen spectral line Hβ per unit volume of gas should be $10^{-25} N_e^2$ erg/sec per cubic centimeter, where N_e is the number of electrons per cubic centimeter. Since 1 watt is 10^7 erg/sec, this can be expressed as

$$P/v = 10^{-32} N_e^2 \text{ watt/cm}^3 \qquad (\text{H}\beta \text{ line}) \qquad (1)$$

where P is the power radiated within a volume v of the gas. Setting N_e equal to 3×10^4 electrons gives the following for the power per unit volume radiated by 3C48 in the Hβ spectral line:

$$P/v = 0.9 \times 10^{-23} \text{ watt/cm}^3 \qquad (\text{H}\beta \text{ line, 3C48}) \qquad (2)$$

The redshift $\Delta\lambda/\lambda$ of 3C48 is 0.367. For small Doppler redshifts, the velocity ratio V/c is approximately equal to the redshift 0.367, where V is the galaxy velocity. With this approximation, Greenstein and Schmidt calculated the velocity V of 3C48 to be 0.367c, which is 110,000 km/sec. They assumed a Hubble constant of 100 km/sec per Mpc (megaparsec). This gave a distance of 1100 megaparsecs. Since one parsec is 3.26 light years, this represents 3.6 million light years.

In the Special Relativity theory published in 1905, Einstein showed that the exact formula for the velocity ratio corresponding to a given $\Delta\lambda/\lambda$ spectral redshift is

$$V/c = [(1 + \Delta\lambda/\lambda)^2 - 1]/[(1 + \Delta\lambda/\lambda)^2 + 1] \qquad (3)$$

Applying this formula to the 0.367 redshift value for 3C48 gives a V/c ratio of 0.3028, which represents a quasar velocity of 90.8 km/sec. The best average value for the Hubble rate today is about 65 km/sec per magaparsec, which is equivalent to 20 km/sec per million light years. With this Hubble constant, the calculated distance of 3C48 is 1400 megaparsecs. However, there is still appreciable uncertainty in the value of the Hubble constant. The 3C48 distance of 1100 megaparsecs calculated by Greenstein and Schmidt is consistent with our present knowledge of the Hubble constant.

Based on the measured values of spectral lines of 3C48, Greenstein and Schmidt calculated the power levels that must be radiated in the observed spectral lines of 3C48 assuming that 3C48 is at a distance of 1100 megaparsec, or 3.6 million light years. These are given in Table 1. The intensity of spectral line [OIII] was too small to be measured accurately, and so its calculate emitted power is indicated as "present". The lines in brackets [] are forbidden spectral lines, which are not observed on earth. Lines [O II] and [O III] are spectral lines of oxygen, and [Ne V] is a spectral line of neon.

Based on the expression in Eq. 2, a volume of $7.11\text{x}10^{58}$ cm^3 is required to generate the power of $6.4\text{x}10^{35}$ watts given for the Hβ line in Table 1. Since there are 10^5 centimeters per kilometer, there are 10^{15} cubic centimeters per cubic kilometer. Hence this volume is $7.11\text{x}10^{43}$ km^3. One light year (Lyr) is $9.47\text{x}10^{12}$ km, and so the gas volume in cubic light years is

$$v = 7.11\text{x}10^{43}\ \text{km}^3 = 83{,}700\ \text{Lyr}^3 \qquad (4)$$

This is equivalent to the volume of a sphere with a radius of 27 light years, or 8.3 parsecs. Greenstein and Schmidt [6] (p. 1) estimated the gas volume for 3C48 to have a radius of about 10 parsecs, which is consistent with our calculation. Our calculated diameter of this gas sphere is 54 light years.

Table 1: *Power in spectral lines emitted from 3C48, assuming it is at a distance of 1100 megaparsecs, or 3.6 million light years.*

spectral line	power in watts
Hβ	$6.4\text{x}10^{35}$
Mg II	$3.1\text{x}10^{35}$
[Ne V]	$1.7\text{x}10^{35}$
[O II]	$3.3\text{x}10^{35}$
[O III]	present

Greenstein and Schmidt [6] (p. 19) state that the absolute visual magnitude of 3C48 is about -25. Absolute visual magnitude is the magnitude that an object would have if it were viewed at a distance of 10 parsecs (32.6 light years). The absolute visual magnitude of our sun is 4.85. The difference in absolute visual magnitude of 3C48 and our sun is therefore about 29.9. A magnitude difference is defined as 2.5 times the logarithm. Hence the logarithm of the power ratio is 11.96, which represents a power ratio of $9.1\text{x}10^{11}$. Thus the optical power radiated from 3C48 (assuming it is at its redshift distance of 1100 megaparsecs) is 910 billion ($9.1\text{x}10^{11}$) times the power radiated from our sun.

Thus, Greenstein and Schmidt [6] calculated that quasar 3C48 is radiating a power level equivalent to 910 billion suns. To generate the forbidden spectral lines, this power is illuminating a cloud of thin gas equivalent in volume to a sphere with a diameter of 54 light years.

A serious problem with this quasar model is that the brightness of 3C48 varies with time. Greenstein and Schmidt [6] (p. 16) report that the optical flux from 3C48 "has changed by a factor of 1.4, apparently independently of wavelength, over a period of 600 days". This implies that the amplitudes of the forbidden spectral lines vary in this manner. To achieve this rapid variation, the gas cloud should have a diameter of about 5 light years, not 50 light years. Hence the study predicted a gas volume that is too large by about a factor of 1000.

Implications of Rapid Variations of Quasar Brightness

After this early study of quasars, many more quasars were rapidly discovered. Redshift values increased from 0.367, for 3C48, to over 5. Many quasars vary greatly in brightness over periods of months, weeks, days, and even hours. This indicates that some quasars are no larger than our solar system.

Greenstein and Schmidt deduced from the presence of forbidden spectral lines in the quasar spectra that these lines are generated within an enormous volume of very thin gas. However, even for the 3C48 quasar that they studied, their predicted gas volume was 1000 timers greater than is allowed by the time variation of the quasar brightness. When we consider the much more rapid brightness variations observed in quasars discovered since that time, the predictions derived from forbidden spectral line theory become completely meaningless.

Therefore, it is clear that the forbidden lines observed in quasar spectra cannot be explained even in a crude sense by the theory that evolved from the study of forbidden lines in gaseous nebulae. A quasar definitely does not behave in any sense like a huge gaseous nebula containing very thin gases.

How can we explain the forbidden spectral lines in the quasar spectra? Let us reconsider the possibility that the quasar redshift is caused by an intense gravitational field. Gasses in an intense gravitational field probably behave quite differently than they do in a weak gravitational field. Consequently forbidden spectral lines may be generated in an intense gravitational field at much higher gas densities. Besides, an extremely compact star should have a very large magnetic field, which would induce enormous currents in the ionized stellar atmosphere. These currents may strongly affect the generation of forbidden spectral lines.

An atom emits a photon when an electron drops from one state to a lower state. An emitted photon can be readily absorbed if it strikes a similar atom, which is tuned to its wavelength. However, in the presence of a strong gravitational gradient, the wavelength of an emitted photon decreases rapidly with radial distance from the center of the star. Therefore a photon moving away from the center of the star soon encounters atoms tuned to a shorter wavelength, which do not readily absorb the photon. Thus the absorption of photons can be much less in an intense gravitational field.

Considerations such as these suggest that the generation of forbidden spectral lines should be radically different in the presence of a very large gravitational field. This possibility offers a promising explanation for the forbidden spectral lines in quasar spectra.

If we assume that intense gravitational fields are not involved in generating forbidden spectral lines in quasar spectra, we are left with an enigma. The theory of forbidden spectral lines that has evolved from studies of gaseous nebulae is not even remotely adequate to explain the forbidden spectral lines in quasar spectra, when we consider the rapid variation of brightness displayed by many quasars.

Summary of Arguments against Quasar Gravitational Redshift

When quasars were first discovered, the evidence against gravitational redshift seemed to be overwhelming. Analyses of stellar instability appeared to eliminate this possibility, and the presence of forbidden spectral lines in the quasar spectra also appeared to eliminate it.

However, we have seen that the predictions of stellar instability at large mass-to-radius ratios, which are derived from the Einstein theory, are definitely refuted by the Yilmaz theory. This leaves the issue of forbidden spectral lines.

When we consider the variation of radiation power displayed by many quasars, which are extremely rapid in some quasars, the explanations of forbidden spectral lines, based on present forbidden line theory, are not even remotely adequate. Therefore, analyses based on this theory cannot be used to dismiss the possibility that the quasar redshift is produced by gravity. In fact, there does not appear to be any viable explanations for quasar spectral lines unless we assume that the quasar has an intense gravitational field.

2, Marmet Analysis of Redshift Caused by Hydrogen Cloud

The following analysis is based on an article by Paul Marmet [8]. Equation 12 of Reference [8] gives the following formula for the redshift produced by one collision of a photon with a hydrogen molecule:

$$\Delta f/f = R = MT^2 \qquad (5).$$

I have substituted the symbol f to represent frequency, instead of ν. The following value is given for the constant M:

$$M = 2.73\text{x}10^{-21}\ K^{-2} \qquad (6)$$

In the discussion following Eq. 19 of Reference [8], the following value is given for the assumed blackbody temperature T of the radiation:

$$T = 50{,}000\ K \qquad (7)$$

The Doppler redshift $\Delta f/f$ produced by a receding velocity V is approximately equal to V/c. Hence this redshift $\Delta f/f$ is equivalent to the following velocity V:

$$V = (\Delta f/f)c = cMT^2 \qquad (8)$$

Substitute Eqs.6, 7 into Eq. 8, and set c equal to $3\text{x}10^{8}$ meter/sec. This yields the following

$$V = 2.05\text{x}10^{-3} \text{ m/sec} = 2.05 \text{ mm/sec.} \approx 2 \text{ mm/sec} \tag{9}$$

Thus, the theory predicts a Doppler shift of approximately 2 mm/sec per photon collision.

Let us determine the number of photon collisions during a path length L of one light year. By Eq. 14 of Reference [8], the number of collisions N is equal to

$$N = DL\sigma \tag{10}$$

where D is the density of hydrogen molecules, L is the length of one light year, and σ is the effective cross section of the hydrogen molecule. The values for L and σ are

$$L = 1 \text{ light year} = 9.47\text{x}10^{15} \text{ meter} \tag{11}$$

$$\sigma = 3.14\text{x}10^{-20} \text{ meter}^{2} \tag{12}$$

The value for σ is given in Appendix B, Eq. B8 of Reference [8]. Let us assume a density of hydrogen molecules equal to 1 molecule per cubic centimeter, or 1 million molecules per cubic meter:

$$D = 1 \text{ cm}^{-3} = 10^{6} \text{ meter}^{-3} \tag{13}$$

Substituting Eqs. 11 to 13 into Eq. 10 gives the following number of photon collisions per light year of path length:

$$N/L = 297 \approx 300 \text{ collisions per light year} \tag{14}$$

Multiplying Eqs. 9 and 14 gives the following effective Doppler velocity corresponding to the redshift produced by a path length of one light year

For density of 1 H molecule per cm^{3}:

$$V/L = 60 \text{ (cm/sec) per light year} \tag{15}$$

Section 3.10 of Reference [8] shows that clouds of molecular hydrogen have been measured with densities of 200 hydrogen molecules per cubic centimeter, or 200 million hydrogen atoms per cubic meter. Assuming this density, there are 60,000 photon collisions per light year. Hence the effective Doppler velocity corresponding to the redshift produced by a path length of one light year is 200 times the value of Eq. 15, which gives

For density of 200 H molecules per cm^{3}:

$$V/L = 120 \text{ (meter/sec) per light year.} \tag{16}$$

Paul Marmet has postulated that this effect can explain the Hubble redshift. Recent studies have yielded an average Hubble expansion rate of about 20 km/sec per million light years, which is equivalent to 65 km/sec per megaparsec. This expansion rate is equivalent to 2 cm/sec per light year. Comparing this rate with Eq. 15 (which corresponds to a density of 1 hydrogen atom per cm^3}, shows that the Hubble redshift could be explained by an average concentration of 1/30 hydrogen atom per cubic centimeter throughout the universe. This is equivalent to 33,000 hydrogen atoms per cubic meter.

Paul Marmet [9] gives information that relates to this redshift effect. This article shows that there is at least 10 times as much molecular hydrogen in our universe as atomic hydrogen. There is probably very much more, because molecular hydrogen (H_2) is extremely stable.

References

[5] S. Chandrasekhar, "The Dynamic Instability of Gaseous Masses Approaching the Schwartzschild Limit in General Relativity", *Astrophysical Journal*, vol. 140, No. 2, 1964, pp. 417-433.

[6] Jesse l. Greenstein and Maarten Schmidt, "The Quasi-Stellar Radio Sources 3C 48 and 3C 273", *Astrophysical Journal*, vol. 140, No. 1, July 1964, pp. 1-34.

[7] M. J. Seaton and D. E. Osterbrock, "Relative [O II] Intensities in Gaseous Nebulae", Astrophysical Journal, 1957, vol. 125, pp. 66-83.

[8] Paul Marmet, "A New Non-Doppler Redshift", in website www.newtonphysics.on.ca, specific website address is www.newtonphysics.on.ca/HUBBLE/Hubble.html.

[9] Paul Marmet, "Discovery of H_2 in Space Explains Dark Matter and Redshift", *Twenty-First Century Science and Technology*, Spring 2000, also published in website at the address, www.netwonphysics.on.ca/hydrogen/index.html.