Stellar distances and Olbers' Paradox

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ABSTRACT

The last remaining bastion of the self-supporting structure that was faithfully thrown together to defend the idea of organic evolution has been the apparent age of the universe. The vast time periods so desperately contrived within uniformitarian geology seemed to be confirmed by starlight that is consistently claimed to be many milliards of years old. Although built merely upon an interpretation of galactic redshift, this area of science has been seized upon by the naturalistic community to bolster their preferred philosophy. Here, though, we present a different view entirely. By ignoring modern cosmological works and going back to basic principles, a perfectly straightforward mathematical model is developed, which is first shown to be sound, via its ability to predict the inverse square law of electromagnetic propagation, and is then used to determine the distances to stars of various visual magnitudes. These stars are shown to sit comfortably within the framework of a very much smaller cosmos, from where they can no longer be claimed to lend support to an enormous age for the universe. Our model is then employed to obtain the resolution of Olbers' Paradox (from which some very interesting parallels and conclusions become apparent) and to infer whether the universe is geostationary or otherwise.

Keywords: Inverse square law, stellar distances, age of universe, cosmology, Olbers' Paradox, geostationary.

1. INTRODUCTION

Consider a point light source, P, situated in a vacuum and producing photons at a constant rate in all directions. Let P be surrounded by a potentially infinite set of virtual, perfectly transparent spheres, all of which are centred on P (as shown in Fig. 1) and let these imaginary spheres be constrained in size such that their radii, r_1, r_2, r_3, etc., obey the relation

$$r_n \quad = \quad nr_1 \ , \tag{1}$$

where n is any positive integer.

Since P is a mathematical point, and the centre of each sphere, the intersection of any photon trajectory with a sphere boundary will form a right-angle. It therefore follows from the constant velocity of light, c, in vacuo and the isotropic nature of free space as far as light is concerned, that there exists a period of time, t, during which all the photons contained within the 1st shell (defined by $r_1 < r \leq r_2$) at an instant, say t_1, have passed into the 2nd shell ($r_2 < r \leq r_3$) by $t_1 + t$. Similarly, because of Eq. 1, all of the photons in the nth shell ($r_n < r \leq r_{n+1}$) at t_1 will be in the $(n+1)$th shell by $t_1 + t$.

The volume, V_n, of the nth shell is simply

$$\frac{4}{3}\pi\left(\frac{n+1}{2}r_2\right)^3 - \frac{4}{3}\pi\left(\frac{n}{2}r_2\right)^3 \ .$$

I.e.,

$$V_n \quad = \quad \frac{(n+1)^3 - n^3}{8}\, S_2 \ , \tag{2}$$

where S_2 is the volume of the *sphere* whose radius is r_2.

Now, by definition, at the instant when the first photon has travelled a distance from P equal to r_n ($n > 2$), there will be exactly the same number of photons in each of the shells 1 to $(n-1)$, inclusive. Let this number be p, then, since $(n+1)^3 - n^3$ reduces to $3n^2 + 3n + 1$, the number of photons per unit volume in the nth shell will be

$$\frac{p}{V_n} \quad = \quad \frac{8p}{(3n^2 + 3n + 1)\, S_2} \tag{3}$$

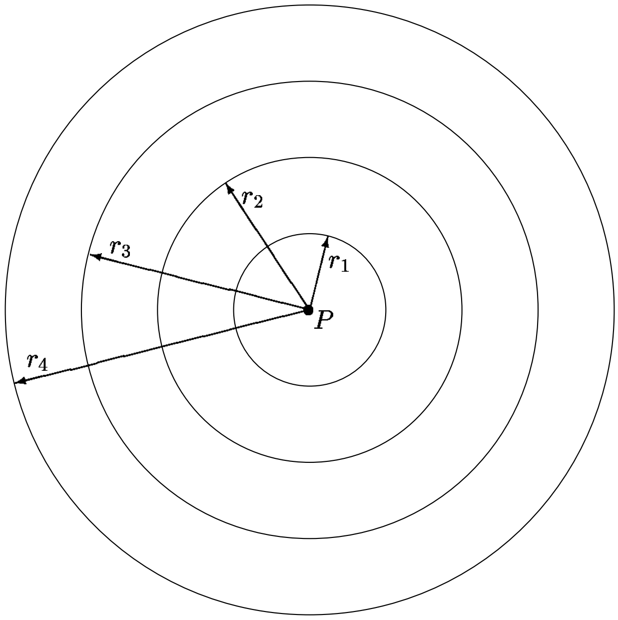

Figure 1. First four, perfectly transparent, concentric spheres surrounding the point light source, P.

and the *inner* radius, r_n, of this shell from P is

$$r_n \quad = \quad \left(\frac{n}{2}\right) r_2 \; . \tag{4}$$

The mnth shell will thus have an inner radius of

$$m \left(\frac{n}{2}\right) r_2$$

and a volume which, from Eq. 2, will be given by

$$\frac{(mn+1)^3 - (mn)^3}{8} S_2 \; .$$

The number of photons per unit volume in this case, namely

$$\frac{8p}{\left[(mn+1)^3 - (mn)^3\right] S_2} \; ,$$

is a measure of the intensity, I, of light in the mnth shell that has emanated from P. Hence,

$$\frac{\text{Intensity in } mn\text{th shell}}{\text{Intensity in } n\text{th shell}} \quad = \quad \frac{I_{mn}}{I_n} \quad = \quad \frac{3n^2+3n+1}{(mn+1)^3 - (mn)^3} \; .$$

In other words,

$$\begin{aligned} I_{mn} \quad &= \quad \frac{3n^2+3n+1}{m^3n^3+3m^2n^2+3mn+1-m^3n^3} I_n \\ &= \quad \frac{3n^2+3n+1}{3m^2n^2+3mn+1} I_n \\ &= \quad \frac{1+1/n+1/(3n^2)}{m^2+m/n+1/(3n^2)} I_n \; . \end{aligned}$$

Therefore,

$$\lim_{n\to\infty} I_{mn} \quad = \quad \frac{1}{m^2} I_n \; , \tag{5}$$

the well-known *inverse square law* of electromagnetic radiation.

2. PHYSIOLOGICAL CONSIDERATIONS OF THE HUMAN EYE

By the manipulation of the ciliary muscles, the lens of the human eye has its shape altered in order to accommodate varying object distances. In this manner, objects in the centre of the field of view are brought to a sharp focus on the coating of *photoreceptors* which form the inner, back lining of the eye. This surface is called the *retina*, its small focal region the *fovea*, with the region around the fovea being referred to as the *parafovea* (Polyak[24]).

The retina consists of two types of photoreceptor, *cones* and *rods*, the former being responsible for detecting colour. Visual pigments within the photoreceptors absorb light of selective wavelengths, which can vary when the pigments are examined in isolation (see Wald and Brown[27]). Both cones and rods *in vivo* exhibit peak spectral sensitivity in the visible green (defined by Hecht[14] as 492-nm $\leq \lambda_g \leq$ 577-nm), the cones at 560-nm and the rods at 510-nm (Hecht and Williams[16]), with rods being between 10 and 25 times more sensitive than cones (Dowling[6]). In Fig. 2, the extent of the green part of the visible spectrum is indicted with dashed lines and the peak sensitivities with two dotted lines.

The diameter of a rod varies with location, being $\approx$ 1-μm when situated near the outer edge of the fovea (no rods are found within the fovea itself). As we go further out across the parafovea, rod diameters increase to $\sim$ 1.5- to 2.0-μm. Their length is about 28-μm and they all contain the same pigment molecule, known as *visual purple* or *rhodopsin* (Wald and Brown[27] and Knowles and Dartnall[18]).

For quite some time now it has been recognized that the lower limit of light-sensitive retinal material to visual-wavelength stimulation is governed by quantum physics (Weale[28] Pirenne[22]), though it should be noted that our use of the term "quantum physics" does not imply all of the probabilistic algebra of the quantum mechanical model, but rather is confined to the concept of radiation as being the transference of energy from one location to another in small, discrete packets, called *quanta*, as suggested by Planck in 1900 and subsequently extended to include light itself by Einstein in 1905. (Quanta, or photons, are reminiscent of Newton's corpuscular theory.)

By way of experiments conducted on subjects whose eyes were completely dark-adapted (i.e., they had undergone extended periods of time in **absolute** darkness), Hecht, Shlaer and Pirenne[15] determined that a 1-ms flash of green light had to deliver at least 54 to 148 photons at the pupil in order for it to be detected. They further calculated that a human rod, under such circumstances, was responsive to a single photon.

However, before coming into contact with the retina, light has to traverse both the atmosphere and the eye itself, experiencing *extinction* (the combined effects of scattering and absorption) in each. A *spectral transparency function*, $\chi(\lambda)$, is defined as being that fraction of the original light which actually gets through to the science instrument and data obtained from the European Southern Observatory (ESO) telescope at La Silla, in Chile, 2,330-m above sea level (as graphically presented in Fluks and Thé[11]) indicate typical values for $\chi_e^a(\lambda)$, in the visible, of between 77% and 95%, where the subscript shows that this is an extinction coefficient and the superscript that it is pertaining to the atmosphere. This agrees with the value we can deduce from the variation in solar energy with altitude plotted by Gates[13] (the important features of which are reproduced in Fig. 2), namely that, over the green region of the visible spectrum, $\chi_e^a(\lambda_g) = 81\%$ for this altitude. At sea level, on the other hand, Gates[13] gives us that,

$$\chi_e^a(\lambda_g) \approx 59.82\% \tag{6}$$

(this value is represented in Fig. 2 by the small section of curve superimposed at an ordinate of 0.12 between the two dashed lines).

Also, from the experiments of Hecht, Shlaer and Pirenne[15] on the fully dark-adapted human eye, we obtain

$$\chi_e^e(\lambda_g) \quad \approx \quad 9.36\% \; , \tag{7}$$

where now we use a superscript of 'e' to indicate extinction within the eye. This means that, in order to obtain N_g green-light photons at our retina, we would need at least

$$\frac{1}{\chi_e^e(\lambda_g)\,\chi_e^a(\lambda_g)} \times N_g \qquad \text{extraterrestrial photons.} \tag{8}$$

3. RELEVANT SOLAR DATA

The Sun subtends 31′ 37″.5 at 1.011443 a.u. (Maris[19]), where the astronomical unit (a.u.) is 1.4959787×10^{11} m, and thus we can determine that the surface area, $A_\odot$, of the Sun must be about 6.087×10^{12} km^2.

The wavelength, λ_{max}, corresponding to peak solar radiation-energy emission is seen from Fig. 2 to be around 490-nm. Hence, the Sun has an *effective temperature*, T, sometimes referred to as its surface temperature, which may be derived via Wien's displacement law (Hecht[14]),

$$\lambda_{max} T \quad = \quad 2.8978 \times 10^{-3} \quad \mathrm{m\ K}\ , \tag{9}$$

to give

$$T \quad = \quad 5,914\ \mathrm{K}\ .$$

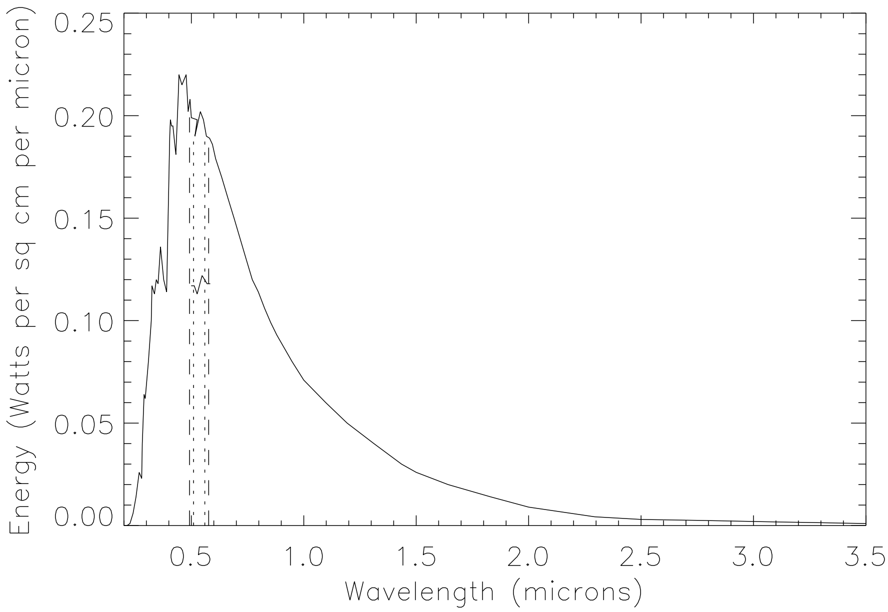

Figure 2. Extraterrestrial solar energy as a function of wavelength (Gates[13]). The dashed lines show the extent of the visible green (Hecht[14]) and the dotted lines show the peak sensitivity of human rods at 0.51-μm and cones at 0.56-μm (Hecht and Williams[16]).

Now, using the Stefan-Boltzmann law,

$$E_\odot \quad = \quad A_\odot \sigma T^4\ , \tag{10}$$

and taking Stefan's constant, σ, as 5.67×10^{-8} W m^{-2} K^{-4}, we see that the Sun's total radiative energy output, or *luminosity*, $E_\odot$, is

$$E_\odot \quad = \quad 4.222 \times 10^{26}\ \mathrm{W} \tag{11}$$

(by specifying a rate of 6.35×10^{10} ergs cm^{-2} s^{-1}, Britannica[9] implies an effective temperature of 5,785 K and a solar luminosity of 3.865×10^{33} ergs s^{-1}, i.e., 3.9×10^{26} W, since 1 J $\equiv 10^7$ ergs).

At a distance of 1.011443 a.u., therefore, total solar energy flux will be

$$\frac{4.222 \times 10^{26}}{4\pi(1.011443 \times 1.4959787 \times 10^{11})^2} \quad = \quad 1,467\ \mathrm{W\ m^{-2}}\ .$$

This quantity, known as the *solar constant*, is usually quoted as 1.36 kW m^{-2}, corresponding to $E_\odot = 3.9 \times 10^{26}$ W, though we will adopt the higher 1.47 kW m^{-2} in this paper. It represents solar radiation flux prior to traversing our atmosphere, as depicted by Gates[13] (see Fig. 2, numerical integration of which shows that 12.22% is in the visible green*). So in each millisecond, the Sun radiates approximately

$$0.001 \times \frac{\int_{0.492\mu m}^{0.577\mu m} E(\lambda)\, d\lambda}{\int_{0.2\mu m}^{3.5\mu m} E(\lambda)\, d\lambda} \times E_{\odot} \quad = \quad 0.001 \times 0.1222 \times 4.222 \times 10^{26} \quad = \quad 5.159 \times 10^{22} \quad \mathrm{J} \tag{12}$$

of energy at wavelengths corresponding to visible green light (in all directions).

The quantum of energy, E_p, carried by a single photon is a function of frequency, ν, a concept 'borrowed' from the wave theory of light. Using the Planck-Einstein relation,

$$E_p(\nu) \quad = \quad h\nu \quad = \quad \frac{hc}{\lambda}\ , \tag{13}$$

where h is *Planck's constant* and c is the velocity of light in a vacuum, and taking the mean wavelength of green light, $\overline{\lambda}_g$, as 534.5-nm, c as 2.99792 $\times 10^{8}$ m s^{-1} and h as 6.6262 $\times 10^{-34}$ J s, we can calculate the energy associated with a single green-light photon as being

$$E_p(\overline{\lambda}_g) \quad = \quad \frac{6.6262 \times 10^{-34} \times 2.99792 \times 10^{8}}{534.5 \times 10^{-9}} \quad = \quad 3.717 \times 10^{-19} \quad \mathrm{J}\ . \tag{14}$$

From Eqs. 12 and 14, the Sun is therefore emitting

$$\frac{5.159 \times 10^{22}}{3.717 \times 10^{-19}} \quad = \quad 1.388 \times 10^{41} \quad \text{photons} \tag{15}$$

of green light per millisecond.

4. DISTANCE TO SIXTH-MAGNITUDE STARS

We now consider the question, "how far away is the faintest star of comparable size and effective temperature to the Sun, that can be seen with our naked eye?" In doing so, we note that "with regard to mass, size, and intrinsic brightness, the Sun is a typical star" (Britannica[8]) and that its radiation output is remarkably constant, fluctuating by less than one percent.

When observing the stars at night, the amount of light around us is minimal and therefore the pupils of our eyes are fully dilated. The diameter of each pupil will then be $\sim$ 7- or 8-mm, but this is not the dimension which is of primary importance. It will be noted that the very faintest stars cannot be observed when looking directly at them, but only by looking slightly to the side. This fact, together with the knowledge that rods in our retina are much more sensitive than cones (found only in the fovea), means that it is rod activation that has led to our visual perception of a faint star. Thus, the aperture we are interested in here is that of a rod and will occupy an area of

$$\pi\,(0.75 \times 10^{-6})^2 \quad \mathrm{m}^2\ , \tag{16}$$

using a rod diameter of 1.5-μm, rather than 1.0-μm, to allow for the greatest distance between the star and our eye.

Feynman[10] (p. 14) states that: "It takes only about 5 or 6 photons to activate a nerve cell and send a message to the brain." Hecht[14] agrees (p. 73). Thus the work of Hecht, Shlaer and Pirenne[15] (mentioned in Section 2) provides us with an upper limit to work with, inasmuch as the threshold for visual detection in mankind seems to be 5 or 6 photons of green light, and this can be achieved with an intensity no greater than 54 such photons entering the eye per millisecond. Since we are investigating the furthest distance to a sixth-magnitude star, we will take this minimum value of 54 green-light photons incident on the pupil. Dividing 54 by the sea level value for $\chi_e^a(\lambda_g)$ (refer to Eq. 6), shows that approximately 91 relevant-frequency photons would be needed at the top of our atmosphere in order to be left with enough photons at the retina to invoke the required mental stimulus. (It should also be noted that this defines the arbitrary time period, t, as mentioned in Section 1 of this paper, as 1-ms.)

Knowles and Dartnall[18] point out that the retina will sum photon absorption over short time intervals. Marriott, Morris and Pirenne[20] found this integration period to be around 130-ms.

*C.f. 11.78% obtained by integrating a 7th-order polynomial fit to the curve in Fig. 2, as returned by IDL's 'poly_fit' function.

Let us assume that a scotopic nerve cell in the retina has been stimulated by the absolute minimum of 5 green-light photons, with no rod absorbing more than one of them (again, this requirement is concerned with maximizing source distance). Then we know that in a 1-ms pulse, these photons will have to be found within a volume of

$$5 \times 0.5625\, \pi \times 10^{-12} \times 2.99792 \times 10^{5} \quad = \quad 2.64888 \times 10^{-6} \quad \mathrm{m}^3 \;, \tag{17}$$

maintaining 5 decimal places for the moment. There are a couple of things to note here. Firstly, these 5 photons do not have to be received by just one rod, they can be incident on up to 5 of the rods that are connected to a particular nerve cell, since each rod is sensitive to a single photon and the brain will sum the resultant impulses over any integration time which does not exceed about 130-ms. Indeed, we obtain a greater stellar distance in this case, because there are fewer photons per unit volume. Secondly, we are considering the **faintest** star visible and thus the limiting scenario of there being **exactly** 5 photons within the volume calculated in Eq. 17.

Now, by taking $r_1 = 2.99792 \times 10^5$ m (i.e., the distance travelled by light in 1-ms), we have from Eq. 2 that,

$$\begin{aligned} V_n \quad &= \quad \frac{3n^2 + 3n + 1}{8}\, S_2 \quad = \quad \frac{3n^2 + 3n + 1}{8} \left(\frac{4}{3}\right) \pi \,(2r_1)^3 \\ &= \quad (3n^2 + 3n + 1) \left(\frac{4\pi}{3}\right) \times 2.69439 \times \; 10^{16} \quad \mathrm{m}^3 \;. \end{aligned}$$

From Eq. 17, there are 5 photons within each 2.64888 $\times 10^{-6}$ m^3 terminating <u>at the retina</u>. These were provided by the minimum 54 green-light photons <u>at the pupil</u> and these, in turn, were all that survived the extinction caused by the World's atmosphere. There must <u>have been</u>, therefore, on the order of 91 such photons <u>outside the atmosphere</u> within every 2.64888 $\times 10^{-6}$ m^3. Hence, we require

$$\frac{91 \times \; (3n^2 + 3n + 1) \times 4\pi \times 2.69439 \times 10^{16}}{3 \times 2.64888 \times 10^{-6}} \tag{18}$$

photons of visible green light in the nth shell, in order that our brain will just detect the extraterrestrial light source.

But this is p, the number of photons in each shell, including, by definition, the initial sphere of radius r_1. Thus, entirely as would be expected, the more photons, p, being generated at visible wavelengths every millisecond by the star ($\equiv P$), the greater will be the value of n (and thus the distance at which the star is able to be seen by an unaided, human eye).

Equating Expression 18 with Expression 15 we get that

$$3n^2 + 3n + 1 \quad = \quad \frac{1.388 \times 10^{41} \times 3 \times 2.64888 \times 10^{-6}}{91 \times 4\pi \times 2.69439 \times 10^{16}} \;,$$

a simple quadratic equation, having the solution

$$n \quad \approx \quad 1.092 \times 10^{8} \;. \tag{19}$$

The *outer* radius of this nth shell, being coincident with the inner radius of the $(n+1)$th shell, is, by Eq. 4,

$$\begin{aligned} r_{n+1} \quad &= \quad \left(\frac{n+1}{2}\right) r_2 \quad = \quad (n+1)\, r_1 \quad = \quad 1.092 \times 10^{8} \times 2.99792 \times 10^{5} \quad \mathrm{m} \\ &= \quad 3.274 \times 10^{13} \quad \mathrm{m} \;. \end{aligned} \tag{20}$$

Light will take 1.092 $\times 10^5$ seconds, or 1.26 days, to travel this distance. This is the **minimum time** predicted by our model for the **maximum distance** to a sixth-magnitude star (of similar characteristics to the Sun).

Sixth-magnitude stars of a size and effective temperature equivalent to our Sun are therefore no more than

$$(\, 1.26 \pm 0.01 \,) \quad \text{light-days} \tag{21}$$

distant from us. This is an upper limit; they can be closer than this.

From the account in Genesis 1 we know that God had created **all** of the stars before evening on the fourth day (Gen. 1:14–19) and Adam and Eve before evening on the sixth day (Gen. 1:24–31), there being no indication that Adam could not see all of God's physical creation during his (i.e., Adam's) first day (or rather, night, in this case).

5. GEOMETRICAL OPTICS APPROXIMATION

At this point, it is worthwhile reiterating our main objective and those aspects of functionality of the human eye which are relevant to it. This is especially important, because otherwise some might suggest that pupil dilation in low-light conditions is evidence against our thesis.

The eye has a converging lens with a maximum diameter (when completely dark-adapted) of 7- or 8-mm. This lens focuses light rays parallel to the optical axis onto a very small region of the retina, called the fovea. The fovea contains only cones (photoreceptors that are sensitive to frequency - i.e., colour). The remainder of the retina, except for a 'blind spot' caused by the connection to the optic nerve, contains rods (sensitive just to intensity). The eye only focuses onto the fovea, it does not focus onto the retina in general (the whole eyeball moves when we change the direction of our gaze). When we look directly at something, therefore, we are detecting light which has been brought to a focus on the fovea. Around this central region we take in an unfocused perception of our surroundings.

Now, 6th-magnitude stars are invisible when we look directly at them, but appear when off-axis (even by a very small amount). The photon flux from them must be the same across the pupil, but is insufficient to register on the fovea cones, even though focused onto these cones by the lens. We need to work out what that flux is.

To emphasize the point, we deal specifically with the off-axis case simply because we can be fairly sure that this gives us a MINIMUM (though CONSTANT) photon flux density across the pupil that is JUST DETECTABLE by the parafovea RODS. Specifically, by virtue of the classical, close approximation of geometrical optics, we can assume that the rays in this vicinity effectively pass straight through the lens. Also, the rod diameter here is well known (1.5 microns) and the photons will enter the rod along its axis (Denton[4] has shown that off-rod-axis photons stand little chance of reaching the rhodopsin). Note that rods are connected locally to their axons, and not from diverse regions of the retina.

Towards the edge of the pupil, the rays are bent much more (light is still unfocused, however), so the photon flux is increased (almost doubled, in fact). To compensate (and this must be true, since the intensity of a faint star does not increase as our view departs further and further from its direction), the rod diameters are of the order of 2.5 microns and the photons are much less likely to enter a rod parallel to the rod axis.

We are dealing with MAXIMUM distances. This is the whole reason why we consider only those stars which, although visible to the naked eye, disappear when we look straight at them. Pupil dilation occurs in order that the amount of light received from nighttime surroundings is maximized. Through this facility, we have far more ability to see where we are going, what is approaching us, etc., but this makes virtually no difference to light entering the pupil along paths that are not parallel to the optical axis. They are bent very little near the line of sight. The dilation of the pupil does not matter, because the observer is not detecting the star via his fovea (which contains only cones). He must, therefore, be detecting the star via rods in his retina. Since these rays are very nearly on-axis, the focusing capability of the eye is not important. It is the light-collecting area of these rods that matters and the eye does NOT focus light onto them. It is the fact that the eye takes a finite time to adapt to low light, rather than specifically the dilation of the pupil, which makes these faint stars slowly become detectable when first the observer goes out at night. Binocular vision, too, is therefore irrelevant in our approach.

Clark[3] has stated that, "Contrary to what nearly every astronomer believes, the eye seems to have an integration capability similar to photographic film, though much more limited. For the detection of the faintest objects, the light must accumulate on the retina for around 6 seconds." It does not take a great deal of thought to realize that this comment is incorrect. Anyone looking to the starry heavens with an already dark-adapted eye will see sixth-magnitude stars slightly offset from the line of sight immediately. It is simply untrue to say that 6 seconds are required for incident light to build up. Try it and see! Also, even if Clark's head were clamped in a vice for his attested six seconds, he would still be unable to have light accumulate on the appropriate photoreceptors, due to the pulsing of blood through his veins (causing slight, involuntary movement of the eye) and the continual rotation of the stars.

Finally, the 'colour' of incoming photons is important only inasmuch as we should match those that we consider with the peak sensitivity of the photoreceptor, again because we are dealing with maximum distance. The sensitivity will fall off on either side of the green (we are considering a Sun-like star, with respect to size and effective temperature - Fig. 2).

6. CONSIDERATIONS PERTAINING TO CERTAIN OTHER CELESTIAL OBJECTS

The observing limit for present-generation, ground-based optical telescopes, in the visible, is $\sim$ 26th-magnitude (Britannica[9]), although this may improve further with the development of laser guide star adaptive optics (Foy and Labeyrie[12]). From the relationship between the intensities, I_a and I_b, of two stellar objects and their apparent visual magnitudes, a and b, respectively, namely that

$$\log\left(\frac{I_a}{I_b}\right) = 0.4\,(b-a)\ , \tag{22}$$

we have, for $a = 6$ and $b = 26$,

$$\frac{I_6}{I_{26}} = 10^8\ .$$

Hence,

$$I_{26} = I_6 \times 10^{-8}\ . \tag{23}$$

But we know from Eq. 5 that

$$I_{26} = \frac{1}{m^2}\, I_6\ ,$$

where the 26th-magnitude star is m times further from the observer than is the 6th-magnitude star. And so here,

$$m = 10^4\ .$$

This means that the distance to a 26th-magnitude star cannot be greater than $\approx$ (34.5 ± 0.3) light-years.

The brightest nighttime object (after the Moon, of course) is Venus, which had an apparent visual magnitude, m_v, of -3.9 on the 18th August, 2000, when it was at a distance of 1.601148 a.u., had an albedo of 0.76 and was 95% illuminated (Maris[19]). Our model will have virtually nothing to say about Venus, because it is bright enough to be seen easily by the cones in the fovea, except that we can still impose an absolute maximum on how far away it could be. Again, from Eq. 22,

$$I_6 = I_{-3.9} \times 10^{-3.96}\ , \tag{24}$$

which means that Venus must be considerably less than (19.0 ± 0.2) light-minutes away (the actual distance, using the above data, was 13.3 light-minutes).

7. TRIGONOMETRIC METHOD

The minimum angular separation, θ_{min}, at the focal plane, of two point objects that can just be identified as distinct by a diffraction-limited telescope of circular entrance pupil is given by the Rayleigh resolution criterion,

$$\theta_{min} \approx \frac{1.22\,\lambda}{D} \quad \text{(rads)}, \tag{25}$$

where λ is the wavelength of the light and D is the aperture diameter. This is equivalent to the angular extent of the central region of the Airy disc.

For the human eye with a dilated pupil of 7-mm diameter and using a green-light wavelength of $\lambda_g = 560$-nm (the Rayleigh resolution formula is relevant for the cones in the fovea, so we choose the value corresponding to their peak sensitivity - see Section 2), we would therefore expect that

$$\theta_{min} = \frac{1.22 \times 560.0 \times 10^{-9}}{7 \times 10^{-3}} = 97.6 \quad \mu\text{rad}$$

$$= \frac{9.76 \times 10^{-5} \times 180 \times 3600}{\pi} = 20''.1 \tag{26}$$

(c.f. p. 415 of Born and Wolf[2] where the lower limit for θ_{min}, at 560-nm, is quoted as 24 arcseconds).

If we imagine the Sun being physically removed from us until its angular dimension reaches the diffraction limit of our dark-adapted eye, then its distance from us would have to be

$$\frac{\tan\frac{1}{2}(31'\,37''.5)}{\tan\frac{1}{2}(20''.1)} \times 1.5131\times10^{11} \quad = \quad 1.42842\times10^{13} \quad \mathrm{m}$$

(taking the astronomical unit as 1.4959787 $\times 10^{11}$ m). Solar radiation would then take 13.24 light-hours to reach us, under the circumstances of being just detectable in the centre of the field of view, i.e., via the activation of cones in the fovea. (Note that the angular resolution of the human eye is $\approx 1'$ under normal daytime conditions, which corresponds to an iris aperture, from Eq. 26, on the order of 2.5-mm.)

As mentioned in Section 2, rods are 10–25 times more sensitive to light than cones are. Intensities could therefore drop to between (1/10)th and (1/25)th of the value at 13.24 lights-hours, before the retreating Sun approached the limit of rod sensitivity. In other words, by this method of analysis, the Sun could be transported to a distance of 1.74 light-days and still just be visible to the naked eye, a value of the same order of magnitude as that obtained in (21), simply by assuming rods to be ten times more sensitive than cones.

Although great accuracy is not claimed for this trigonometric approach, it is certainly noteworthy that we can achieve agreement between the methods of this Section and Section 4, take account of rod sensitivity being up to 13 times that of cones, and even allow for sixth-magnitude stars (of a size and effective temperature equivalent to our Sun) having been created by God in the evening of Day 4 and being visible to Adam and Eve in the evening of Day 6, by adopting a maximum distance to such stars of

$$(\,1.63 \pm 0.37\,) \quad \text{light-days.} \tag{27}$$

8. OLBERS' PARADOX

Any cosmology must explain why the night sky is dark, despite the fact that there seem to be stars and galaxies in whichever direction one cares to look. However, it follows directly from our analysis that, far from being a paradox, the dark night sky is a *consequence* of our model.

Consider Fig. 3 in which, instead of placing a Sun-like star at P and ourselves in a distant shell, we swap positions. The *principle of relativity* (as defined, for example, by Einstein[7]) clearly indicates that both views are equivalent.

We know that when a star exceeds a certain distance, we will not be able to see it. In Fig. 3, stellar objects α, β and γ are each exciting different regions of the observer's retina. The point is, though, that only α is providing its corresponding retinal patch with sufficient photon flux to generate an axon impulse that will subsequently travel along the optic nerve to the brain. The others (β, γ, etc.) will not register with the observer, but they are still there, of course. It's just that insufficient numbers of photons will arrive from them within the 130-ms integration time (see Section 4) of the photoreceptors in our retina. A fact which is demonstrated by way of long-exposure images, such as that shown in Fig. 4, where, even in such a very small field of view, countless numbers of stars and galaxies slowly become visible.

9. AREAS OF CONFLICT WITH LARGE-UNIVERSE COSMOLOGIES

To suggest that the size of the universe is at least 371,000,000 times smaller than popularly taught (35 light-year maximum, as opposed to 13 billion light-years) is somewhat radical. Established interpretations of various astronomical phenomena hence need to be re-assessed in the light of this model.

9.1. Stellar Parallax

Conventional astronomy teaches that the observed parallax effect associated with certain stars can be used to determine their distances from the Sun (see Fig. 5). Distances of up to about 100 light-years can be ascertained in this way (for instance, Berry[1]), before the angle, θ_3 (refer again to the figure), becomes just too small to be measurable. Even for what is considered to be the closest star, *Proxima Centauri*, θ_3 is only about 0.7 of an arcsecond.

If the stars are as close as we claim in this paper, then far larger parallaxes should be observed. Since they are not, then it follows that either our model must be wrong, or else something is seriously amiss regarding the current

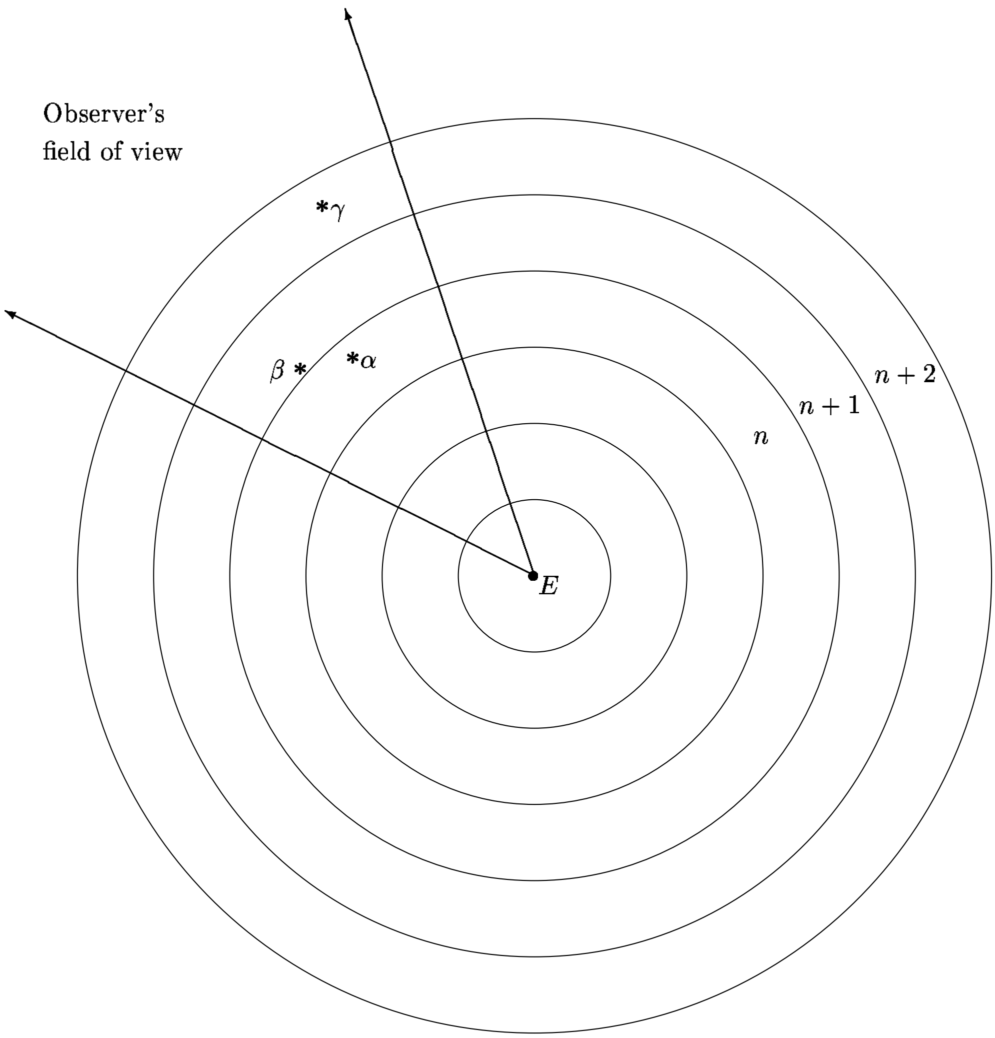

Figure 3. Stellar objects α, β and γ, in relation to the Earth, E.

explanation of stellar parallax. In attempting to preserve the integrity of the paper, we are therefore drawn to the inescapable conclusion that the World does not orbit the Sun.

A geocentric cosmology (see van der Kamp[26] or Jones[17]) accounts for stellar parallax by assigning all movement of the stars to the stars themselves, rather than to the World. Observations will, in this case, document real displacements, rather than apparent ones, but consequently will supply no information as to the distances involved.

Our results are thus only feasible within a geocentric framework.

9.2. Apparent Magnitude Formula

The apparent visual magnitudes, m_1 and m_2, of two objects are linked by the logarithmic relationship

$$\frac{B_1}{B_2} = \left(\sqrt[5]{100}\right)^{(m_2-m_1)} , \tag{28}$$

where B_i are the respective brightnesses and $\sqrt[5]{100}$ is *Pogson's ratio.*

Rearranging Eq. 28 we have that

$$m_2 = m_1 + 2.5 \log \left(\frac{B_1}{B_2}\right) . \tag{29}$$

Figure 4. The Rosette Nebula.

From photometry, a 0th-magnitude star is claimed to have an incident energy flux of 2.84×10^{-8} W m^{-2}. Therefore, by plugging this, together with the solar constant, into Eq. 29 we arrive at the recognised value for the apparent visual magnitude of the Sun,

$$m_2 \quad = \quad 0 + 2.5 \, \log \left(\frac{2.84 \times 10^{-8}}{1467} \right) \quad = \quad -26.8 \; .$$

Equation 29 is basically the same as Eq. 20, which can be written

$$b - a \quad = \quad 2.5 \log \left(\frac{I_a}{I_b} \right) \quad = \quad 2.5 \log \left[\left(\frac{d_b}{d_a} \right)^2 \right] \; ,$$

where I_a is the intensity of a light source situated at a distance d_a from an observer, I_b that of the same source positioned d_b from the observer and

$$I_b \quad = \quad \left(\frac{d_b}{d_a} \right)^{-2} I_a$$

(see Fig. 6).

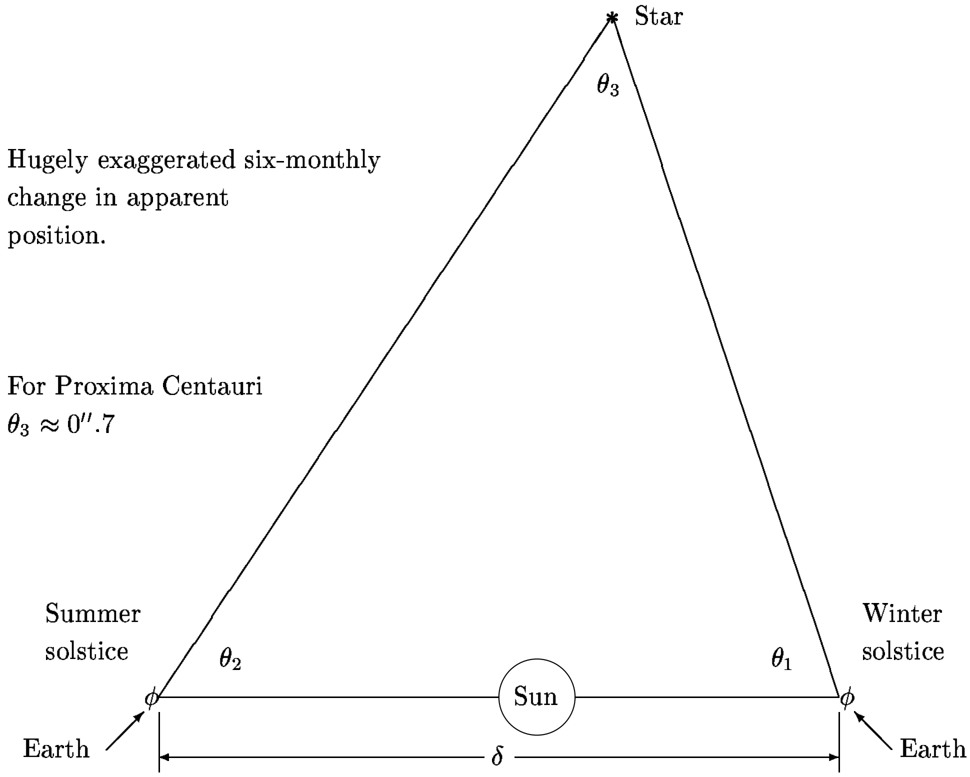

Figure 5. Basis for explaining the observed stellar parallax phenomenon in a heliocentric system.

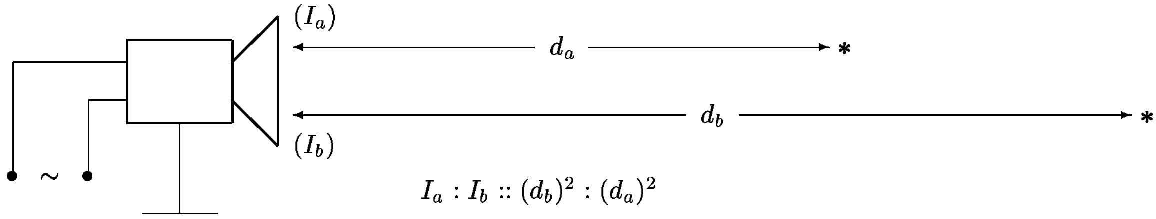

Figure 6. The dependency of light intensity, I_i, with source-observer distance, d_i.

Hence,

$$b - a = 5 \log \left(\frac{d_b}{d_a} \right) . \tag{30}$$

Now, if the apparent visual magnitude of the Sun is -26.8, Eq. 30 decrees that the Sun would need to be located approximately 57.5 light-years away from us before it became a 6th-magnitude star (taking d_a as 500 light-seconds). Clearly this distance is totally at odds with our suggested 1.74 light-days. Indeed, again from Eq. 30, we can predict the Sun's current apparent visual magnitude as

$$a = 6 - 5 \log \left(\frac{158112}{500} \right) = -6.5 . \tag{31}$$

If B_1 in Eq. 29 is correctly given as 2.84×10^{-8} W m^{-2} and the luminosity of this particular star is equal to that of the Sun, then its distance from us would have to be

$$+\sqrt{\frac{4.222 \times 10^{26}}{4\pi(2.84 \times 10^{-8})}} \text{ m} = 3.44 \times 10^{16} \text{ m} = 3.64 \text{ light-years.}$$

But, more to the point, there would be an incident green-light radiation flux over a 7-mm diameter, dark-adapted pupil of only

$$\frac{0.13 \times 0.1222 \times 2.84 \times 10^{-8} \times \pi \times 3.5^2 \times 10^{-6} \times \chi_e^a(\lambda_g) \times \chi_e^e(\lambda_g)}{3.717 \times 10^{-19}} = 2,615 \text{ photons per 130-ms integration period}$$

(ignoring the spectral redshift and assuming the same summation time for both rods and cones), and we recall from Section 2 that this is at the limit of cone sensitivity and definitely not indicative of the brightness one would expect from an $m_v = 0$ star.

Also, at $m_v = -26.8$, the apparent visual magnitude of the Sun would be more than

$$\left(\sqrt[5]{100}\right)^{25} = 10^{10}$$

times greater than that of Sirius ($m_v = -1.5$)! This seems preposterous if we consider the brightness of the Sun through an aperture equivalent in size to Sirius' appearance (i.e., (1/28,703)rd of the usual solar area as perceived from the World, using the angular separation of $11''.2$ for the *Alpha Canis Majoris* visual binary, as given in Maris[19]).

At $m_v = -6.5$, however, and comparing them over areas of equal size, the Sun would be exactly 100 times as bright as Sirius. (The sheer size of the Sun's disc, of course, together with the focusing characteristics of the human eye, would make any attempt to look directly at the Sun extremely dangerous.)

9.3. Redshift

We offer here no alternative explanation for the shifting of starlight, towards either the red or blue ends of the visible region, but hope to research this topic in due course.

9.4. Planetary Perturbation

It has been pointed out by DeYoung[5] that nearby stars would perturb the orbits of the outer planets and that "no such effect is seen."

Stars in such relative proximity might indeed exert some influence, though this would depend upon the universality of Newton's law of gravity, which may not be true. Furthermore, the whole concept of a 'solar system', upon which DeYoung bases his argument, is non-existent in the geocentric universe that our work points to.

Again, this is an area for further study.

9.5. Aberration

According to the late Walter van der Kamp[26] the universe is $\sim$ 58 to 60 light-days in radius. However, his reasoning relies upon a particular interpretation of stellar aberration which would enable us to calculate the star's distance from us.

Although we would certainly agree that such observed movement is real, it is unclear that the effect allows for any distance determination.

10. PRÉCIS OF THE PAPER

There is a sizeable amount of material in this paper, so before giving our conclusions perhaps it would be beneficial to summarize the approach adopted.

Quite a lot of research has been conducted on the limits of human vision. For example, photoreceptor cells in the lining of the back of the eye have been identified and their sensitivities examined in considerable detail.

In astronomy, stars can be classified by their apparent visual magnitude, based on the definition that a stellar object which is only just visible is termed '6th-magnitude'.

Now, if we consider one particular 6th-magnitude star to be similar in both size and effective temperature to the Sun, then we know how much energy is being radiated from it per second (by way of our relatively close observations of the Sun). And, since we know the relationship between distance and the consequential fall off in energy flux, then we can calculate how far light has travelled from such a star in remaining just visible to our eye.

To emphasize this point, which is the central gist of the paper: we assume the total energy radiated (i.e., in all directions) per second by a Sun-like, 6th-magnitude star to be known and reasonably constant. All wavelengths of light are being emitted, of which our eye is sensitive to a narrow bandwidth (the visible spectrum, centred on yellowy-green). We know, by definition, that this star is only just visible (and, highly significantly, not when we look directly at it, but slightly away from it). Light intensity falls off with distance, a fact described in physics by the inverse square law. In other words, there is a very well-known relationship between the strength of electromagnetic radiation emitted and that received by two points at any particular separation. The essence of the paper, then, is that since we know how much is being emitted and we know how much is being received, we can calculate the separation. This separation is the distance from our eye to a 6th-magnitude star.

The paper goes on to investigate various other maximum distances, completely resolves Olbers' Paradox and strongly implies that the universe is geocentric.

11. CONCLUSIONS

'Small' universe models are not new and this work certainly gives added weight to their possible validity, but the obligation placed upon man, by both the source of darkness (Job 38:19) and the central position of the World, are enormous.

According to the evolutionists, light from the brightest star in the night sky, Sirius, has taken 8.6-years to reach us, and that from what they claim is the closest star, Alpha Centauri[†], has taken 4.3-years. Under this scenario, Adam would have gazed towards the heavens and seen the moon, a planet or two and then ... nothing. At some date that is more than four years and three months later, one single star would first have appeared to him. Certain stars (e.g., Deneb, which is quoted as 1,400 light-years away, but is one of the twenty brightest stars in the night sky) would never have been seen by Adam during his 930-year lifespan. This gives a bleak picture of God's heavenly creations as far as His earthly creatures are concerned, which could only result in feelings of isolation, oppression and loneliness. It would also be very misleading, because the appearance of a 'new' star would give the impression that it had just been created, which is incompatible with Genesis Chapter 1. Certainly we read in Psalm 19, verses 1–4 that, "The heavens declare the glory of God, the vault of heaven proclaims his handiwork, day discourses of it to day, night to night hands on the knowledge. No utterance at all, no speech, not a sound to be heard, but from the entire earth the design stands out, this message reaches the whole world[‡]..."

Whether or not we see a particular star depends upon the ability of our eyes to detect it. Those we detect, we see. Those we do not detect, we do not see, but they are still there, they still "give light on the earth" (Gen. 1:15,17 - NIV). Long-exposure images from large, optical telescopes show this to be true.

Job is questioned by God over many things, including "... and as for darkness, where is the place thereof," (Job 38:19, KJV). Job does not know that the source of darkness is **in his own eye**. Despite being bathed in light from countless numbers of stars, Job did not see them. Those stars he could see, however, were unmistakable witnesses of God's glory. In a very similar fashion, evidence of God is all around the naturalists (Rom. 1:20), but they **choose** not to see it. They look through telescopes, painstakingly searching for 'evidence' that can be manipulated (often, 'contorted' would be a better word) to fit their Artificial Big Bang Archetype[§] (see Appendix B of Slusher[25]), while outside the telescope dome a breathtakingly beautiful array of stars is laid out before them. It is no coincidence that, as these telescopes become more and more powerful, the observer's field of view becomes more and more restricted.

The model presented in this paper fits well-known experimental laws, completely resolves Olbers' Paradox and allows for the age of the universe to be measured in thousands, rather than milliards of years. More importantly, though, it is in complete harmony with Genesis, Chapter 1, where we are told by God that the stars were created on the fourth day and Adam on the sixth. Hence, when Adam and his wife looked up at the sky after what was to them the first sunset, they would have marvelled at the sight of the stars appearing one after another, as the sky became darker and darker[¶].

[†] Actually, this is a triple star and it is one of the three, namely Proxima Centauri, which is claimed to be at this distance, but, at 11th-magnitude, is too faint to be seen.

[‡] New Jerusalem Bible (NJB).

[§] I prefer to use 'Archetype' instead of 'Model' here, because the resulting acronym reminds me of what it is that the evolutionists have replaced their real Father with.

[¶] An effect that we can still observe and enjoy on a clear evening.

In addition, our results add weight to a *geocentric* cosmology that countless astronomical observations seem to substantiate.

The stars were put there for our benefit. To gaze at them in awe and wonder is very soothing to the spirit. We can also study them and search deeper and deeper into space. Whatever viewpoint we adopt, however, must always be constrained such as to recognize what God has plainly told us, namely: "**It is I who made the earth and created mankind upon it. My own hands stretched out the heavens; I marshalled their starry hosts.**" (Isa. 45:12, NIV.)

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