UNIVERSAL RED SHIFT

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ABSTRACT

Paper presents simple model of Solar redshift, based on theory of tired light (Zwicky, 1929). In accordance with measurements of Adam (1959), the dependence of total shift for Fraunhofer lines with $\lambda_o \approx 6300$ Å at Solar equator on distance from center of Solar disk is:

$$\Delta\lambda\text{ , Å} = 6300\times\{10^{-6}/0.1761\}\{((1+0.1761)^2 - x^2)^{0.5} - (1-x^2)^{0.5}\} + 0.03709\times x$$

Here factor $10^{-6} = \Delta\lambda/\lambda_o$ is central scaled red shift, factor 0.1761 is "best-fit" thickness of equatorial Solar Corona (122513 km) divided by radius of Sun (695700 km), 0.03709 is "best-fit" factor for Doppler shift, x is visible distance from center of Solar disk, divided by visible radius of Sun (x is positive at western limb and negative at eastern limb of Solar disk).

What has been is that will be,
What has been done is that will be done,
And there is nothing new under the Sun.
Ecclesiastes

INTRODUCTION

There is an old problem of modern Cosmology with Solar red shift. The most of Solar light comes from lower atmosphere of Sun, so-called Photosphere. Photosphere is relatively thin (~200 km), cold (~ 6000 K), and dense (~10^{20} particles per dm^3). It consists of atomized gas (mainly, hydrogen and helium) with few percents of plasma. Specific absorption of light due to ionization of various elements, which present in Photosphere, leads to formation of dark Fraunhofer lines in Solar spectrum. At the polar radius, all these lines are shifted into the red field. In accordance with Einstein theory, Solar redshift at polar radius may be explained by gravity of Sun. Each photon is specified by relativistic mass:

$$m_{ph} = E/c^2 \quad (1)$$

Here E is energy of photon, and c = 299 792 km/s is velocity of light. Consequently, energy loss of photon in gravity field of Sun is

$$\Delta E = m_{ph}\times(k_G M_S/R_S) = (E/c^2)\times(G_S\times R_S) \quad (2)$$

Here $k_G = 6.67384\times10^{-11}$ $m^2\times N\times kg^{-2}$ is gravity constant, $M_S = 1.98855\times10^{30}$ kg is mass of Sun, R_S = 695700 km is radius of Sun, and G_S = 274 N/kg is acceleration at Solar surface. Thus, scaled "gravitational" red shift of Solar Fraunhofer lines at polar radius may be expected at:

$$Z = \Delta\lambda/\lambda_o \sim \Delta E/E = (G_S\times R_S)/c^2 \sim 2.12\times10^{-6} \quad (3)$$

Here $\Delta\lambda$ is absolute red shift, and λ_o is initial wave length.

It should be noted that the Doppler blue/red shift due to approaching/removing of emitter to/off observer at polar radius is absent. Thus, in accordance with Eq. (3), Solar red shift at polar radius should be independent of position on Solar disk.

In **Fig. 1**, Solar red shift at polar radius for Ca line, 6122.2 Å (most intensive in the range studied), is shown, as measured by Adam (1948). The dashed line in **Fig. 1** was calculated from Eq. (3) and wave length. As may be seen, consistence with data is very weak. Besides, in accordance with Eqs. (1-3), 2.12×10^{-6} part of total energy, emitted by Sun, simply disappears somewhere in the deeps of relativity, which also seems to be not so good for theory.

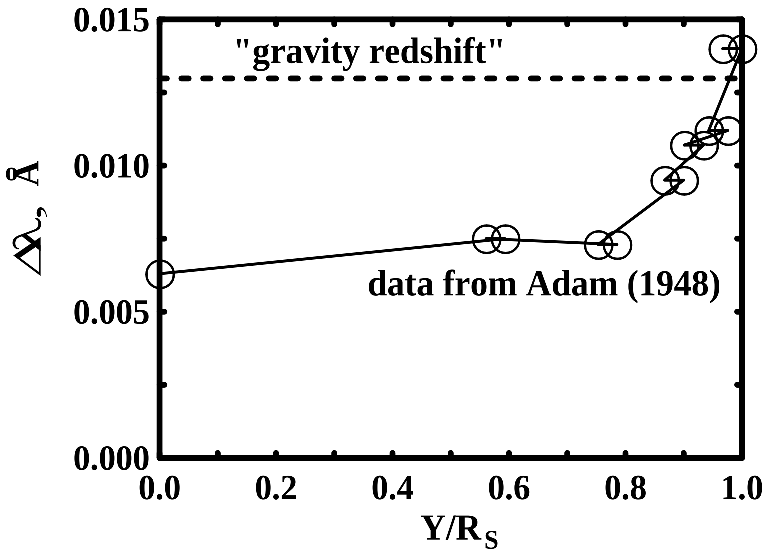

Fig. 1. Solar red shift at polar radius for Ca line, 6122.2 Å, as measured by Adam (1948). Y is visible distance from the center of Solar disk, and R_S is radius of Sun.

So on, let us construct more self-consistent theory of Solar redshift.

THEORY OF TIRED LIGHT

Most important parameter of Cosmology is Hubble constant (Plank Collaboration, 2016):

$$H_U \approx 2.20\times10^{-18}\ \text{second}^{-1} = 67.8\ \text{km/s per Mps} \quad (4)$$

Here Mps is megaparsec:

$$1\ \text{Mps} = 3.0857*10^{19}\ \text{km} \quad (5)$$

The inversed Hubble constant gives “age of Universe”:

$$t_U = 1/H_U = 4.55\times10^{17}\ \text{seconds} = 14.42\times10^{9}\ \text{years} \quad (6)$$

The “age of Universe”, multiplied by light velocity, c = 299792 km/s, gives radius of potentially visible Universe:

$$R_U = c\times t_U = c/H_U = 1.364\times10^{23}\ \text{km} \quad (7)$$

Hubble constant gives relation between red shift and distance to extra-galactic object. However, this relation is dependent on Cosmological theory. For instance, in accordance with theory of tired light, energy photon in the inter-galactic space decreases with passed distance by analogy with Beer-Lambert-Bouguer law:

$$E = E_o\exp(-L/R_U) \quad (8)$$

From Eq. (8), “exact” formula for scaled red shift is:

$$Z = \exp(L/R_U) - 1 \quad (9)$$

As before, scaled red shift is:

$$Z = \lambda/\lambda_o - 1 = \Delta\lambda/\lambda_o \quad (10)$$

Here λ_o is initial wave length of light, emitted by extra-galactic object, and λ is that measured at in the observatory, and $\Delta\lambda = \lambda - \lambda_o$ is absolute red shift. Note that Eq. (10) is exact by definition.

At distances $L<<R_U$, the following relation is true in any cosmological theory:

$$Z = L/R_U = L\times H_U/c \quad (11)$$

It should be noted, that the observations at distances about R_U are almost impossible, and condition $L<<R_U$ is generally satisfied. Thus, in practical sense, Eq. (11) coincides with Eq. (9).

According to theory of tired light, exponent factor $1/R_U = H_U/c$ in Eq. (9) is valid for intergalactic space. In arbitrary medium (again, at $L<<R_U$), scaled red shift is related to particle density:

$$Z = L\times\{D/D_U\}/R_U = L\times\{D/D_U\}\times H_U/c \quad (12)$$

Here D is particle density of medium, and D_U is that for intergalactic space. Estimating particle density of intergalactic space at ~ 1 atom per dm^3 (by author's arbitrary choice) one may estimate optical density of Universe:

$$Q_U = D_U\times R_U = 13.64\times10^{26} \text{ atoms per } dm^2 = 2265 \text{ moles}/dm^2 \quad (13)$$

One cubic decimeter of liquid water contains ~ 111 moles of hydrogen atoms, and thus, optical density of Universe is comparable with 2 m layer of liquid water. Red shift in liquid water is absent, and thus, intergalactic space is filled by plasma.

The temperature range for stability of plasma may be found from thermodynamic data for reaction:

$$H^o \Leftrightarrow p^+ + e^-, \qquad K_{diss} = [p^+][e^-]/[H^o] \quad (14)$$

Here H^o is hydrogen atom, p^+ is proton, and e^- is electron, square brackets correspond to some concentration scale. In **Tab. 1**, the values of dissociation constant of hydrogen atom are given at various temperatures: original data, in atmospheres, from Glushko (1962) and these recalculated to particle density scale. The last column shows calculated fraction of plasma at particle density, $D(H^o) + D(p^+) = 1$ particle per dm^3.

Tab 1 The constant of dissociation of hydrogen atom K_{diss} at various temperatures and fraction of plasma at particle density $D(H) + D(p^+) = 1$ particle per dm^3.

T, K	K_{diss} Atm (Glushko, 1962)	K_{diss} particle/dm^3 recalculated	Fraction of plasma at $D(H^o) + D(p^+)$ = 1 particle/dm^3
2500	3.967×10^{-26}	1.165×10^{-4}	1.07 %
2600	4.950×10^{-25}	0.001400	3.67 %
2700	5.159×10^{-24}	0.01402	11.2 %
2800	4.557×10^{-23}	0.1194	29.1 %
2900	3.474×10^{-22}	0.8791	59.6 %
3000	2.320×10^{-21}	5.767	86.9 %
4000	2.448×10^{-15}	4.491×10^{6}	100 %
6000	3.469×10^{-9}	4.243×10^{12}	100 %

As may be seen, temperature of intergalactic plasma should be, at least, about of 3000 K. Thus, one may suspect significant heat emission from Universe. However, in reality, heat emission from intergalactic plasma is strongly hindered. For instance, effective cross section area of hydrogen atom is:

$$\sigma_H = \pi d^2 \sim 3.14\ \text{Å}^2 \qquad (15)$$

Here $\pi = 3.14159\ldots$, and d is contact distance between two atoms (i.e., diameter of hydrogen atom, ~ 1 Å). Thus, at density of intergalactic space D_U ~ 1 atom per dm^3, one may calculate the length of free path for hydrogen atom:

$$\ell_H = 1/(2^{0.5}\sigma_H D_U) = 1/(2^{0.5}\pi d^2 D_U) \sim 2.25\times10^{13}\ \text{km} \qquad (16)$$

Average velocity of hydrogen atom at 3000 K is

$$\upsilon_H = (3RT/M_H)^{0.5} = 8.62\ \text{km/s} \qquad (17)$$

Here R is gas constant (8.3144 $J\times mol^{-1}\times K^{-1}$), T is absolute temperature (K), and M_H is molar weight of hydrogen atom (0.00100794 kg/mol). Consequently, at particle density ~ 1 atom per dm^3 and T = 3000 K, each hydrogen atom may emit one photon per

$$\ell_H/\upsilon_H = 2.61\times10^{12}\ \text{seconds} = 82\ 700\ \text{years} \qquad (18)$$

Thus, in reality, heat emission from intergalactic plasma is negligible. Because of negligible heat emission, and due to permanent interaction of free electrons with photons, intergalactic plasma may accumulate huge amounts of "dark energy". There are also some reasons to suspect even much higher temperatures for the intergalactic plasma, 10^5 – 10^7 K (Fang et all, 2010).

As may be seen from Eqs. (16-18), emission of "hot photons" from rarified plasma should be much less intensive than that for "cold photons" (see **Fig. 2**). Thus, it is likely, that the application of "black body" model for determination of "spectral temperature" of Universe (~ 2.7 K) leads to huge errors, up to 10^8 percents.

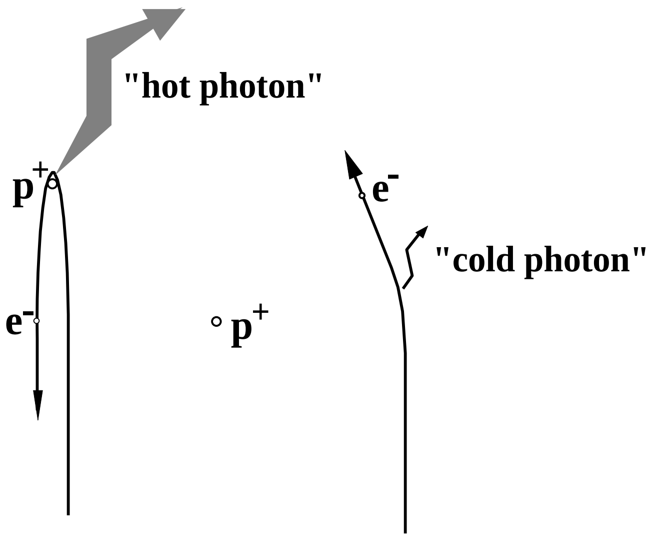

Fig. 2 Emission of "hot" and "cold" photons.

APPLICATION TO SOLAR RED SHIFT

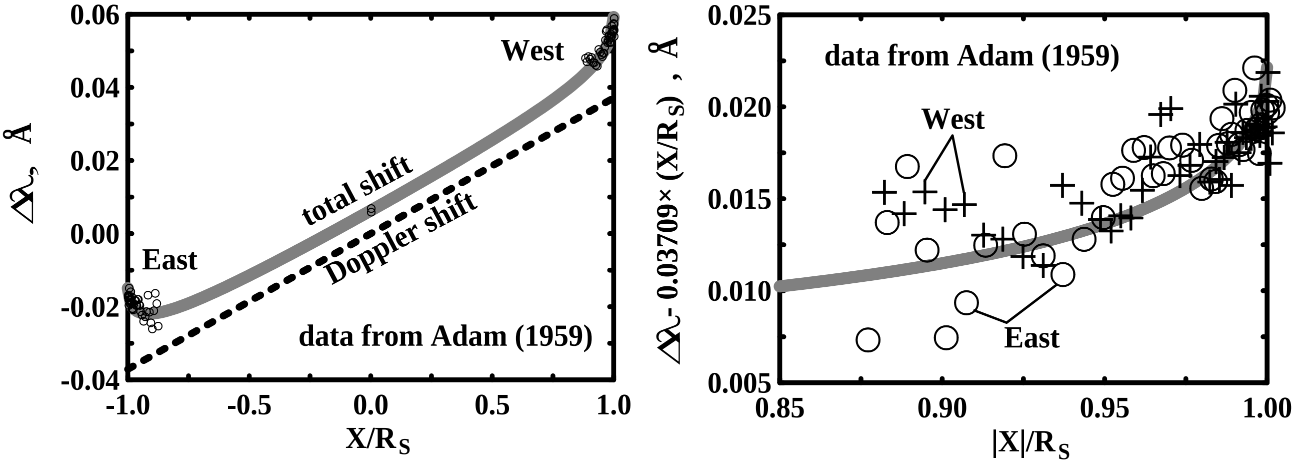

Fig. 3 Total (left panel) and absorptive (right panel) shift for Fe Fraunhofer lines 6297.799, 6301.508, and 6302.499 Å at Solar equator, as measured by Adam (1959). Dashed line (left panel) is Doppler shift (Eq. 21). Grey curve in left panel is total (Doppler plus absorptive) shift (Eq. 21 plus Eq. 28). Curve in right panel is absorptive red shift (Eq. 28).

In **Fig. 3**, the data on blue/red shift at Solar equator are shown, as measured by Adam (1959) for Fe lines 6297.799, 6301.508, and 6302.499 Å. As may be seen, main contribution into total equatorial shift is Doppler shift due to rotation of Sun. There is blue shift at eastern (approaching) limb and red shift at western (removing) limb. Scaled Doppler shift is defined by:

$$Z_{Doppler} = \{\upsilon/c\} \quad (19)$$

Here υ is velocity of removing/approaching of emitter to/off observer (positive for removing and negative for approaching emitter), c = 299792 km/s is light velocity. From elementary geometry, velocity of removing/approaching for element of Solar equator off/to observer is

$$\upsilon = \upsilon_o\{X/R_S\} \quad (20)$$

Here X is visible distance from center of Solar disk (negative at eastern limb and positive at western limb), R_S = 695700 km is visible radius of Sun, υ_o is absolute velocity of Solar equator with respect to observer. Best fit to data from Adam (1959) gives relation (see dashed line in left panel of **Fig. 3**):

$$\Delta\lambda_{Doppler}\text{, Å} = \lambda_o\times\{\upsilon_o/c\}\times\{X/R_S\} = 0.03709\times\{X/R_S\} \quad (21)$$

Thus, visible velocity of Solar equator with respect to observer

$$\upsilon_o = 0.03709\times c/\lambda_o = 0.03709\times 299792/6300 = 1.765 \text{ km/s} \quad (22)$$

From this value, period of visible rotation of Sun (so called "synodic" period) is

$$t_{syn} = 2\times\pi\times R_S/\upsilon_o = 28.71 \text{ days} \quad (23)$$

Taking into account for orbital movement of the Earth, one may calculate period of rotation with respect to "fixed stars" (so called, "sidereal" period):

$$t_{sid} = 1/\{1/t_{syn} + 1/365.25\} = 26.62 \text{ days} \quad (24)$$

This value is close to results of measurements of visible movement of Solar spots, which gives sidereal period of rotation about 24.7-27.3 days at latitudes from – 30 to 30^o (Howard 1984).

So on, let us assume that the difference between total shift and Doppler shift (see right panel of Fig. 3) arises due to absorption of light energy in upper (plasmatic) atmosphere of Sun, so called Corona. Average red shift in center of Solar disk, as was measured by Adam (1959), was about 0.006-0.007 Å. Thus, scaled red shift in center of Solar disk is about

$$Z_o = \{0.006 \div 0.007\}/6300 \sim 10^{-6} \quad (25)$$

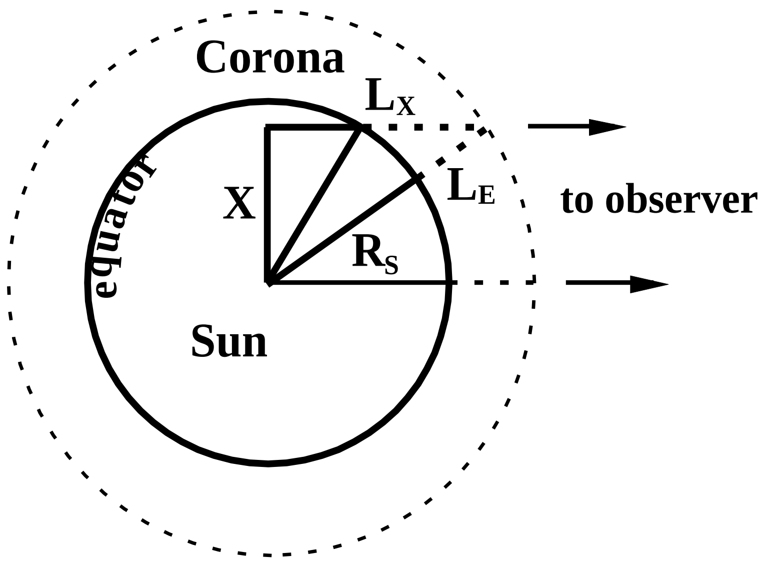

Fig. 4 Geometric relation between absolute L_E and apparent L_X thickness of Solar Corona with visible distance from center of Solar disk, X, at equator.

Apparent thickness of Solar Corona at equator L_X increases with visible distance from center of Solar disk (see **Fig. 4**) in accordance with Pythagorean theorem:

$$L_X = \{(R_S + L_E)^2 - X^2\}^{0.5} - \{R_S^2 - X^2\}^{0.5}$$
$$= R_S[\{(1 + L_E/R_S)^2 - (X/R_S)^2\}^{0.5} - \{1 - (X/R_S)^2\}^{0.5}] \quad (26)$$

Here X is distance from center of Solar disk, L_E is equatorial thickness of Corona. Thus, absorption red shift is:

$$Z_{absorb} = Z_0\{L_X/L_E\} = Z_0\{R_S/L_E\}[\{(1 + L_E/R_S)^2 - (X/R_S)^2\}^{0.5} - \{1 - (X/R_S)^2\}^{0.5}] \quad (27)$$

Gray solid curve in right panel of Fig 3 is:

$$\Delta\lambda_{absorb}/\lambda_o = \{10^{-6}/0.1761\}\{[(1+0.1761)^2 - (X/R_S)^2]^{0.5} - [1 - (X/R_S)^2]^{0.5}\} \quad (28)$$

Gray solid curve in left panel of Fig. 3 (total shift) is sum of Eqs. (21) and (28).

From fitting parameter $L_E/R_S = 0.1761$, average thickness of Corona at equator is

$$L_E = 0.1761 \times R_S = 122\ 513 \text{ km} \quad (29)$$

From Eq. (12), applying central scaled red shift, $Z_o \sim 10^{-6}$, particle density of Universe, $D_U \sim 1$ per dm^3, radius of Universe, $R_U = 1.364\times10^{23}$ km, and equatorial thickness of Corona, L_E = 122 513 km, one may estimate average particle density of Solar Corona at equator:

$$D_E = Z_o\times D_U\times R_U/L_E = 1.11\times10^{12} \text{ protons per dm}^3 \quad (30)$$

This value is close to estimates $10^{12} \div 10^{13}$ particles per dm^3, given by Wikipedia (2016).

In **Fig. 5**, the data on Solar red shift at polar radius for Ca line, 6122.2 Å (Adam, 1948), are shown again. At polar limb, Doppler shift is absent, and results of measurements should be consistent with absorptive red shift, observer at equator. Gray curve in **Fig. 5** was calculated from Eq. (28). As may be seen, absorption red shift at polar limb is smaller than at equatorial limb. This difference may arise due to flattening of Corona at polar limbs. If to assume ellipsoidal shape of Corona, apparent thickness of Corona at polar radius should be consistent with:

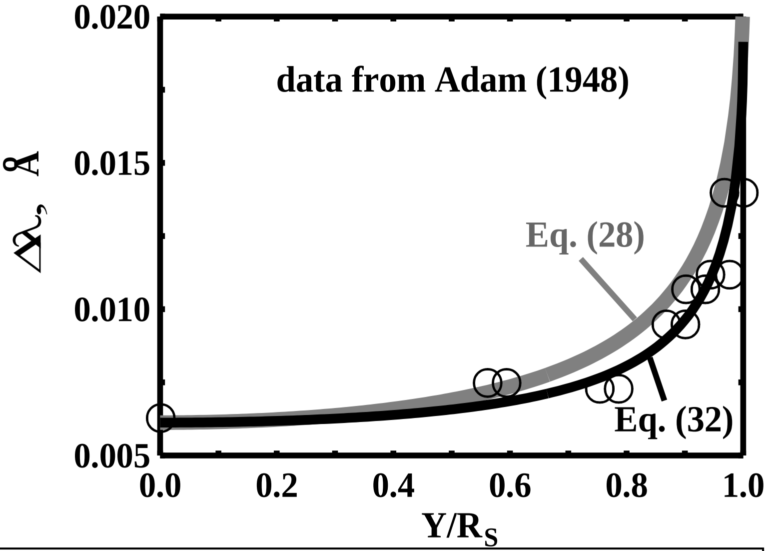

Fig. 5 Solar redshift at polar radius for Ca line, 6122.2 Å, as measured by Adam (1948). Y is visible distance from the center of Solar disk, and R_S is radius of Sun.

$$L_Y = \{(R_S+L_E)^2 - Y^2(R_S+L_E)^2/(R_S+L_P)^2\}^{0.5} - \{R_S^2-Y^2\}^{0.5} =$$
$$= R_S\times[\{(1+L_E/R_S)^2 - (Y/R_S)^2\times(1+L_E/R_S)^2/(1+L_P/R_S)^2\}^{0.5} - \{1-(Y/R_S)^2\}^{0.5}\,] \quad (31)$$

Here Lp is average thickness of Corona at polar limb (see **Fig. 6**).

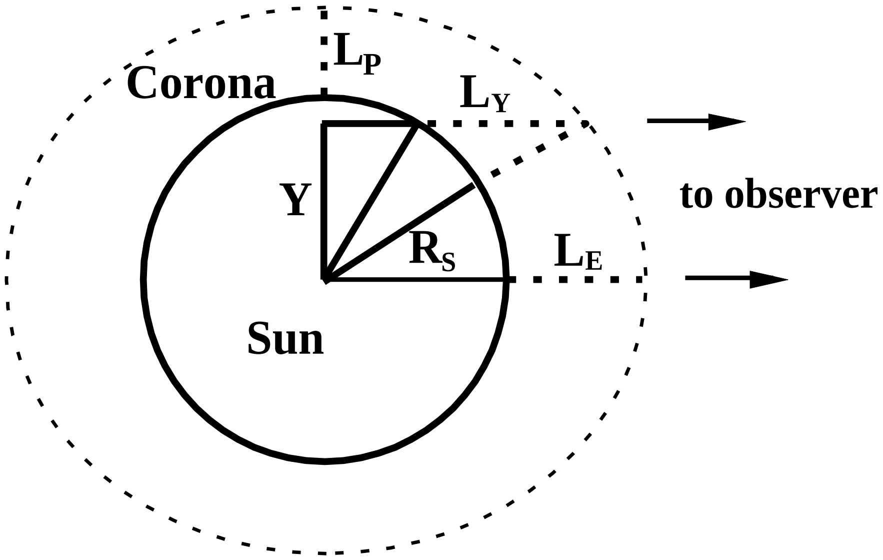

Fig. 6 Geometric relation between absolute thickness of Corona at equator, L_E, that at pole, L_P, visible distance from center of Solar disk, Y (at polar radius), and apparent thickness of Solar Corona at polar limb, L_Y.

So on, the black solid curve in **Fig. 5** is:

$$\Delta\lambda_{absorb}/\lambda_o = \{10^{-6}/0.1761\}\{[(1+0.1761)^2 - 1.08022\times(Y/R_S)^2]^{0.5} - [1 - (Y/R_S)^2]^{0.5}\} \qquad (32)$$

From fitting parameter $1.08022 = (1+L_E/R_S)^2/(1+L_P/R_S)^2$, thickness of Corona at poles is:

$$L_P = (1.1761/1.08022^{0.5} - 1)\times R_S = 0.1315875\times R_S = 91\,545 \text{ km} \qquad (33)$$

It should be noted, that the flattening of Solar Corona at poles is not the only explanation. Smaller red shift at polar limb may be also explained by equivalent depression in particle density. In reality, both effects may coexist due to influence of Solar magnetic field.

In general, theory of tired light gives excellent fit to data on Solar red shift. The same theory gives simple explanation for huge temperature of Solar Corona, $1\text{-}2\times10^6$ K (Wikipedia, 2016). It should be also noted that the energy, absorbed by Solar Corona (~ 10^{-6} part of total energy, emitted by Sun), does not disappears. Upon absorption, this energy is reemitted into the free space, as may be clearly seen during Solar eclipses.

CONCLUDING REMARKS

Even primitive geometric model of Solar Corona, combined with theory of tired light, gives close consistence with measured Solar redshift. Thus, the Universe has no beginning and has no end. NO BIG BANG!!! UNIVERSE FOR EVER!!!

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