CHAPTER 4

COSMIC DISTANCE AND MASS

Our position x_0 relative to the center

Total mass within x_0

Mass density

Potential energy of matter

Mass and Energy

The Ether

The bending of light by gravity

Of nature's three building blocks, mass (m), time (t) and length (l), length is perhaps easiest to come to terms with. Length cubed, or length × width × height, is volume or space. Space, however, would be meaningless unless filled with something. Space contains gravitational tension produced by all gravitating matter in the Universe. The cosmic gravitational tension in our galactic neighborhood is $f_0 = GM_{univ} / R_{univ} = c^2$. The gravitational tension is the conveyor of force fields and electromagnetic waves. The gravitational tension is the Ether.

4.1 Our position x_0 relative to the center

We have seen that early and recent theoretical models of the Universe tend to place us in a central position from which the distance to its outside boundaries determines the size of the Universe. With the discovery of galactic red-shifts and recession velocities it was believed that the size of the Universe could not go beyond a point where the recession velocity reached its limit of c, the speed of light. Therefore, it was thought that if the recession velocity increases linearly with distance at a Hubble rate of H = 75 km/Mpc, for instance, then the maximum distance of recession had to be c/H which equals about 4000 Mpc or $1.23\times10^{26}\,\mathrm{m}$. This distance or radius turns out to be too small for our Universe and it gives rise to several difficult problems. One such problem occurs when we try to fit the total mass ($M_u = c^3/(GH) = 1.67\times10^{53}$ kg) of the Universe into a volume limited by a 4000 Mpc radius since it generates ten thousand times higher mass density per unit volume than is observed, thus creating an apparent missing mass problem. The observed mass density in the Universe is $r_{obs} \approx 2\times10^{-30}\,\mathrm{kg\ m^{-3}}$. The calculated mass density from Hubble's constant is

$$r = \frac{qH^2}{\frac{4}{3}pG} \approx 2\times10^{-26}\,\mathrm{kg\ m^{-3}}, \qquad (m/l^3) \qquad (19)$$

where q is a dimensionless so called deceleration parameter which could equal 1 or less. G is the universal gravitational constant. The dimensionless deceleration parameter $q = a_0 x_0 / c^2$ is a term invented by cosmologists who favor the “Big Bang” scenario and who need an answer to the question "is the Universe expanding forever or will matter slow down to zero and start to contract again"? In a Universe that obeys the laws of harmonic motion on the other hand, the deceleration parameter has to equal 1 (q = 1) and can be discarded. The discrepancy in mass density from Equation (19) as compared to observed values is caused by Hubble's constant which holds that the recession velocity is linear with cosmic distance rather than numerically proportional to the square root of distance. A discrepancy in mass calculations of individual galaxies or cluster of galaxies can also appear if Hubble's linear constant is used as a distance indicator. As was mentioned before, Hubble's constant is not really a constant because recession velocities relative to us are not proportional to distance. The problem is that Hubble's velocity-distance relation $H = v/x$, has the dimensions of angular frequency and is really a measure of the apparent relative change in angular frequency between us and other astronomical objects in the Universe just as the planets in our solar system have different periods or angular frequencies around the Sun. The true Hubble frequency is therefore obtained by dividing our absolute velocity with the distance to the center of the Universe or $H = c/x_0 = 2\pi/t_0$ rad/s, where t_0 is the period of the Universe. A precise way in which to determine the size of the Universe is to calculate the distance between our position x_0 and the center of mass of the Universe at $x = 0$ using standard equation of harmonic motion. Having established the rate of acceleration a_0 from Planck's constant (Chapter 3, section 3.2) and our velocity in relation to the center of mass of the Universe to equal c, will allow us to exactly determine the distance to the center of mass of the Universe from

$$x_0 = \frac{c^2}{a_0} = 1.17908 \times 10^{28}\,\mathrm{m}. \qquad (l) \qquad (20)$$

This is about one hundred times larger than the distance previously obtained by Hubble's law and it is also about hundred times farther than can be probed by our largest telescopes, which implies that only a small fraction of the Universe is visible to us. It must be emphasized that the parameters c, a_0 and x_0 are derived as they appear to us from our limited field of observation. For this reason, it is impossible to determine the maximum radius or amplitude A of the Universe, but we may assign it a hypothetical distance of $A = 1.667 \times 10^{28}\,\mathrm{m}$, by assuming that our position x_0 is at an angular displacement of $\alpha = 45^0$ (see Fig. 4c Chapter 2, section 2.2). The value obtained for x_0 in Equation (20) is in fact in agreement with estimates performed by Narlikar and Burbidge (1981). The basis for Narlikar's and Burbidge's estimates is Equation (19). Instead of thinking of mass density in its usual form consisting of gravitational matter such as stars and galaxies *etc.* Narlikar and Burbidge argued that the radiation temperature T of the ever prevailing 2.7^0 Kelvin background radiation, discovered by Penzias and Wilson (1965), must have an "equivalent mass" density from which the size of the Universe can be determined.

Knowing the energy per unit volume of the $T = 2.7^0$ K radiation from $U_r = 6\pi T^4 \sigma / c$ and converting this to equivalent mass per unit volume $\rho_r = U_r / c^2$ one can use Equation (19) to solve for the absolute value of H. Inserting the value of ρ_r in Equation (19) yields $H = c/x = 1.5\times10^{-20}$ rad/s. Solving for x allowed Narlikar *et. al.* to obtain a distance of $x = c/H = 1.9\times10^{28}$ m which is very close to the result of Equation (20). Since the distance derived by Narlikar *et al.* is also about 100 times larger than popular belief they suggested that our Universe could be a small island Universe together with several others of the same size making up a super Universe from which the 2.7^0 K would have originated. The question is however, can one assume that the equivalent mass of the 2.7^0 K radiation is gravitational in nature so that Equation (19) would apply? Perhaps it would have been better to estimate the size of the Universe from its average brightness expressed in brightness per unit volume (ℓ) and then determine how large the Universe has to be in order to produce a blackbody temperature of $T = 2.7^0$ K. This is accomplished simply by writing an equation which contains the product of (ℓ) and the spherical volume of the Universe divided by its surface area

$$T^4 = \frac{\ell \frac{4}{3}\pi x_0^3}{4\pi x_0^2 \sigma}, \qquad (none) \qquad (21)$$

and then solve for x_0

$$x_0 = \frac{3T^4\sigma}{\ell} = 1.2\times10^{28}\,\mathrm{m}, \qquad (l) \qquad (22)$$

where $\sigma = 5.670\times10^{-8}$ is Stephan-Boltzmann's constant. The brightness per unit volume $\ell = \rho_{obs}(L_{Sun}/M_{Sun}) = 8\times10^{-34}\,\mathrm{w\,m^{-3}}$ is obtained by multiplying the observed mass density of the Universe with the luminosity to mass ratio of the Sun, *i.e.* if the average star in a galaxy has the same luminosity and mass as our Sun then the luminosity to mass ratio of matter in the Universe must be the same as the ratio L_{sun}/M_{sun}.

The above method, which is similar to that used to estimate the size of a star from its brightness and temperature, yields the same radius as Equation (20) and very close to the size predicted by Narlikar and Burbidge. It appears obvious that if the observed mass density and the observed radiation density, have equal energy density and occupy the same volume within the Universe, the Universe is neither matter or radiation dominated, but in a state of equilibrium. The fact that Narlikar and Burbidge used the equivalent mass density of the 2.7^0 K radiation to determine Hubble's constant is significant because it suggests that the energy density of radiation equals the energy density of matter in the Universe and therefore eliminates the missing mass problem. Secondly, Narlikar's and Burbidge's results show that on a large scale Hubble's constant is not a constant but varies over large cosmic distances. This is consistent with the belief of several investigators including the author, that Hubble's velocity to distance relation is not linear, but follows a quadratic relationship (see sections 3.2 and 7.1).

4.2 Total mass of the Universe within x_0

Since the inward force and acceleration are gravitational in nature we can easily determine the total mass of the Universe within our radius x_0 from

$$M_u = \frac{a_0 x_0^2}{G} = 1.59486 \times 10^{55}\,\text{kg}\,. \qquad (m) \qquad (23)$$

The virial theorem $GM_u = x_0 c^2$ is obeyed (see Chapter 8), which means that standard laws of gravitation apply, the same laws that govern orbital motion of planets and satellites in our solar system. The number of stars in the Universe, within the radius x_0, is about 8×10^{24} assuming the average star having the same mass as our Sun. It is believed that the average galaxy contains about 1.4×10^{11} stars which leaves us with a total of 6×10^{13} galaxies within x_0. The number of galaxies and stars outside x_0 is difficult to estimate since the total mass of the Universe is unknown and cannot be obtained by the cosmological model presented here.

4.3 Mass density

The mean mass density of the Universe within x_0 is M_u divided by the volume within x_0 or

$$r = \frac{a_0}{\frac{4}{3} p G x_0} = 2.32273 \times 10^{-30}\ \mathrm{kg\ m}^{-3}. \qquad (m/l^3) \qquad (24)$$

This is very close to the observed mass density in our part of the Universe (Sandage 1995). Since we can only see about one millionth of the Universe it is not possible to tell whether the mass density is the same everywhere or if it varies with the distance from the center of the Universe. The above mass density corresponds to about 2.5 electrons or positrons per cubic meter.

4.4 Potential energy of matter

Potential energy or absolute energy is, from a cosmological point of view, the total energy that is potentially available and stored in the mass of matter. Potential energy of matter varies along the *x*-axis (radius) of the Universe and its magnitude at our position x_0 is

$$E_0 = f_0 m_0 = m_0 c^2, \qquad (ml^2/t^2) \qquad (25)$$

where $f_0 = GM_{univ}/x_0$ is the cosmic gravitational tension. From the laws of harmonic motion, which involves mathematical functions such as sine and cosine (see Fig. 4. Chapter 2), we may find the potential energy of matter along the *x*-axis by the use of trigonometric functions as follows;

for values between $0-45^0$

$$E = \frac{E_0}{\sqrt{2}\quad \sin a}\ , \qquad (ml^2/t^2) \qquad (26)$$

and from $45^0 - 90^0$

$$E = \sqrt{2}\, E_0 \cos a\ , \qquad (ml^2/t^2) \qquad (27)$$

where E_0 is the potential energy or absolute energy of matter at x_0. Both E_0 and m_0 represent the energy and inertial mass of matter that is at relative rest in our frame of reference at x_0.

4.5 Mass and Energy

We have so far only dealt with energy and velocity but not space. Before assigning certain properties to space it must first be clarified what is meant by energy and field. Energy of matter is confined to mass and comes essentially in three forms:

1. Self energy of matter $E_s = \dfrac{Gm_0^2}{r}$ joules (ml^2/t^2)

2. Potential or absolute energy of matter $E_0 = \dfrac{GM_u m_0}{R_u}$ joules (ml^2/t^2)

3. Radiation $L = \nabla mc^2 n$ watts, $L = \dfrac{2(\nabla m)^2 c^4}{h}$ w/photon (ml^2/t^3)

where ∇m is the inertial mass lost or converted to radiation or into individual photons and n is the frequency of the radiation. Self energy of matter is the energy stored in a body's own gravitational field and potential energy is the energy of a mass stored in an external gravitational field. The self energy of the Earth's own gravitational field equals $(E_s = GM_{earth}^2 / R_{earth})$ and is about 14 times less than the Earth's potential energy stored in the Sun's gravitational field $(E_p = GM_{sun} M_{earth} / R_{sun-earth})$ or 1.5×10^9 times less than its absolute potential energy of E_0 stored in the gravitational field generated by the entire Universe ($E_0 = GM_{univ} M_{earth} / R_{univ} = M_{earth} c^2$). Any change in potential energy of a mass involves radiation. Loss of potential energy produces radiation while an increase in potential energy occurs when matter absorbs radiation. Mass is also equivalent to charge squared since it can be converted to charge and *vice versa* by the relation $m = q^2 m_0 /(4p r)$, where r is the radius of the body and m_0 is the permeability constant. Energy of mass or charge is not confined within the mass or charge itself, but resides in its external field.

What is field? Field is a term often used casually and should really be divided into two categories namely, energy fields and force fields For example, is the Sun's gravitational field at the Earth's surface greater than that of the Earth's own gravitational field? The answer is both yes and no, because if we refer to the energy field or energy per unit mass, which is the same as gravitational tension ($f_{Sun} = GM_{Sun} / R_{Sun-Earth}$), then the Sun dominates the Earth's own field ($f_{Earth} = GM_{Earth} / R_{Earth}$) at the Earth's surface by a factor of 14 (see Fig. 6). If we speak about the force

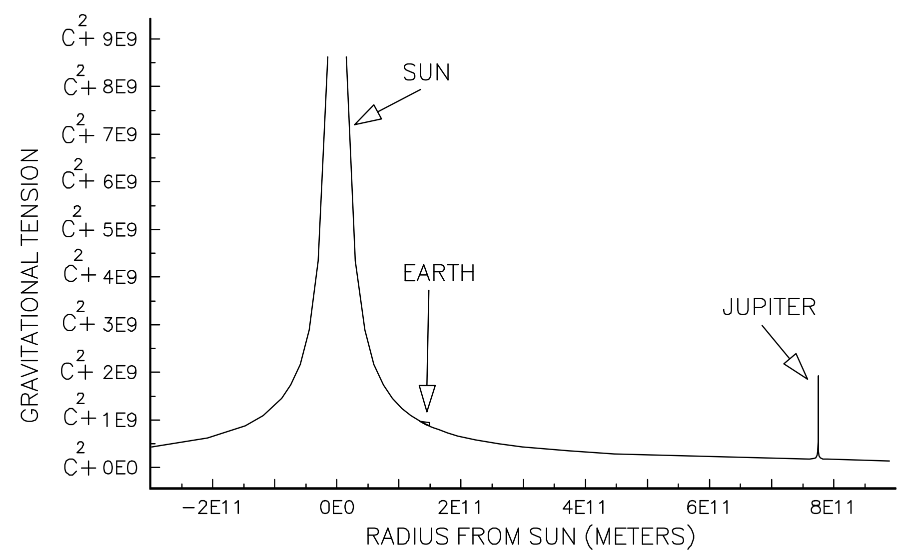

Fig. 6. The gravitational tension of the Sun, Earth and Jupiter superimposed on the gravitational tension $f_{univ} = c^2$ of the Universe.

field on the other hand, or force per unit mass which is acceleration ($a = GM / R^2$), then the Earth's own field at the Earth's surface is greater than that of the Sun by a factor of 1600. The force-field is in fact the same as the gradient of tension. Gravitational tension is also the same as gravitational potential and acceleration the same as potential gradient. Gravitational potential should not be confused with gravitational potential energy. Gravitational potential or tension, from a cosmological point of view, decreases with distance from the gravitating source and reaches zero at infinity. For earthbound observers, it has often been customary to assign gravitational potential a negative sign. This stems from the observation that it requires energy to move a body away from a gravitating source such as the Earth. Problems occur however, if we make gravitational potential and gravitational energy mathematically negative (anti-gravity). A student may try his or her calculator to determine the orbital velocity of an earthbound satellite from $v = \sqrt{-f_{Earth}}$. To avoid confusion, gravitational potential will throughout this book, be referred to as gravitational tension and together with gravitational energy will carry a positive sign.

4.6 The Ether

That the Sun's gravitational tension is 14 times larger at the Earth's surface than that of the Earth's own gravitational tension might come as a surprise, but when we discover that the gravitational tension generated by all matter in the Universe $(f_{Univ} = GM_{Univ} / R_{Univ} = c^2)$ is 1.5 billion times that of the Earth's own gravitational tension we might wonder what impact, such a huge gravitational tension, will have on us here on Earth. In fact, the immense cosmic gravitational tension, in which both the Earth and the entire solar system are immersed, serves as a medium, or ether, for the propagation of photons or ripple of electromagnetic waves. It is the magnitude of the cosmic gravitational tension that determines inertia of mass and, therefore, the rate of time (see Chapter 2, section 2.4) and the speed at which electromagnetic waves propagate through space. The cosmic gravitational tension is also the conveyor of gravitational force fields, since gravitational force is simply the gradient of gravitational tension $(df / dx = f / R)$. Fig. 6

shows the magnitude of the cosmic gravitational tension as compared to that generated by the Sun, Earth and Jupiter. The gravitational tension contributed by the Sun and the planets appear as small bumps on top of the cosmic tension. Summarized in Table 2 are the major components of gravitational and electric fields such as self energy, potential energy, energy between two bodies, tension, force and acceleration.

FIELD COMPONENT	GRAVITATIONAL	ELECTRIC
Self energy E	$\frac{Gm^2}{r}$	$\frac{q^2}{4pe_0 r}$
Potential energy E_0	$\frac{GM_{Univ} m_0}{R_{Univ}} = m_0 c^2$	$\frac{GM_{Univ} q^2 m_0}{R_{Univ} 4p r}$
Energy between two bodies	$\frac{Gm_1 m_2}{r}$	$\frac{q_1 q_2}{4pe_0 r}$
Tension f	$\frac{Gm}{r}$	$\frac{q}{4pe_0 r}$
Force between two bodies F	$\frac{Gm_1 m_2}{r^2}$	$\frac{q_1 q_2}{4pe_0 r^2}$
Acceleration a	$\frac{Gm}{r^2}$	

Table 2. Different components of gravitational and electric fields.

The velocity of electromagnetic waves through the cosmic gravitational tension (ether) is inversely proportional to the magnitude of the gravitational tension just as absolute velocity is inversely proportional to absolute energy (Chapter 3). The additional increase in the cosmic gravitational tension near individual gravitating bodies, such as the Sun for example, will therefore, have the effect of slowing the free space value of c, the speed of light, to an amount determined by

$$v = c\left(\frac{f_{univ}}{f_{univ} + f_{sun}}\right)^2 \cong \frac{c}{1 + \dfrac{2Gm}{rc^2}} \quad , \qquad (l/t) \qquad (28)$$

where f_{sun} is the gravitational tension of the Sun, r the radial distance from the center of the Sun and m the mass within r. The slowdown in velocity causes the wavelength of photons entering the gravitational field to shrink and become blue-shifted by

$$z_{blue} = \frac{\Delta v}{c} = \frac{\Delta l}{l} = 1 - \left(\frac{f_{univ}}{f_{univ} + f_{sun}}\right)^2 \cong \frac{2Gm}{rc^2} . \quad (none) \qquad (29)$$

By the same token photons or rays of light leaving a gravitational field become red-shifted by the same amount, which is an effect that has been observed for light waves emanating from the Sun's surface. The change in velocity of light, entering and leaving a gravitational field, can cause rays of light to bend. The bending of light in gravitational fields is of historical interest since its discovery and prediction by several scientists including Einstein, has had some very important historical implications.

4.7 The bending of light by gravity

The experimental proof that light bends near a gravitational body and the attempts to explain this phenomenon is very interesting, because it led to the impetuous acceptance of Einstein's relativity theories which to some extent has guided us down the wrong path.

Newton himself queried the possibility of light being bent by gravity but it was not before the beginning of the 19th century that a German astronomer, Johann Georg von Soldner (1804), presented calculations based on Newton's corpuscular theory that light weighs and bends like high speed projectiles in a gravitational field, which produced a value of 0.87 arc second bending angle for light grazing the Sun. Fifteen years earlier Sir Henry Cavendish made the same calculations, but his results were never published (Will, (1993)).

Over hundred years later, in the year of 1911, Einstein published his first paper on the bending of light (Einstein, (1911)) based on the equivalence principle which holds that anything, regardless of mass, accelerates equally in a gravitational field. Einstein obtained a deflection angle of

$$a = \frac{2Gm_{Sun}}{c^2 r_{Sun}} \text{ (radians)} = 0.87 \text{ arc second}, \qquad (none) \qquad (30)$$

which is the Newtonian value and the same angle previously published by Soldner. It appears that Einstein and the scientific community at the time were unaware of von Soldner's paper and it was not until the year 1921 when Soldner's work was rediscovered.

About four years after his first paper in 1911, Einstein had developed the General Theory of Relativity (1915) which prompted him to modify the Newtonian value by adding an effect of curved space thus increasing the bending angle of Equation (30) by a factor of two or

$$a = \frac{4Gm_{Sun}}{c^2 r_{Sun}} = \text{(radians)}, \qquad (none) \qquad (31)$$

resulting in a new value of 1.75 arc seconds (1.7505395 arc second).

The new result was published by Einstein on November 18, (1915) and was experimentally verified by Crommelin and Eddington during the solar eclipse expeditions of May 29, 1919. When the sunlight was blocked by the Moon, starlight grazing the Sun's surface became visible and the bending angle of the starlight was revealed. While the expeditions were being planned, Eddington wrote: "The present eclipse expeditions may for the first time demonstrate the weight of light (*i.e.* Newton's value) and they may also confirm the added effect of Einstein's weird theory of noon-Euclidean space, or they may lead to a result of yet more far-reaching consequences of no-deflection" (Eddington, (1919)).

The verification of Einstein's additional bending angle of 0.87" led to instant fame and blind acceptance of his relativity theories.

Einstein's relativity theories, although they produce the right numbers, have often been criticized for being weird since they are conceptually difficult and often impossible to understand. One serious problem with Einstein's bending of light theory is the assumption that light will accelerate and fall closer to a gravitating body according to the equivalence principle, which would account for the first 0.87 arc second of bend, while the rest, or 0.87 arc second, is due to the obscure warping of space. The main objection is that since light is mass less it does not accelerate but, on the contrary, slows down in a gravitational field in accordance with observations. However, the introduction of warped or curved space is what formed the basis for Einstein's General relativity theory which can be classified as mathematical model based on geometry.

The bending of light in gravitational fields is better explained by Snell's law of refraction (see Fig. 7) which is a law that was experimentally established by Willebrod Snell and theoretically by René Descartes over three hundred years ago. Snell's law is based on the discovery that when light enters a medium which retards its velocity of propagation, such as a piece of glass or a gravitational field, it will bend at an angle determined by the combination of its change in velocity and angle of incidence. The advantage of using Snell's law is that it eliminates both the idea that light weighs and the notion of curved space.

Snell's law (or in France, René Descartes' law) can be written as

$$n = \frac{c}{v} = \frac{\sin a'}{\sin a''} \quad \text{and} \quad \frac{\Delta v}{c} = \frac{\Delta(\sin a)}{\sin a'}, \qquad (none) \qquad (32)$$

where n is the index of refraction, a' the angle of incidence, a'' the angle of refraction and c the incoming speed of light and v the retarded speed of light in the refracting medium. Light is a wave and will bend when it enters the refracting medium at an angle and if the velocity of propagation from one medium to the other varies. The diagram in Fig. 7 shows a train of waves entering a glass prism at an angle and how each wave-front breaks at the surface and changes direction due the change in velocity and consequent shrinkage in wavelength caused by a traffic jam effect in the slower refracting medium. Observe that the wave length l'' of the beam inside the prism is shorter than l'

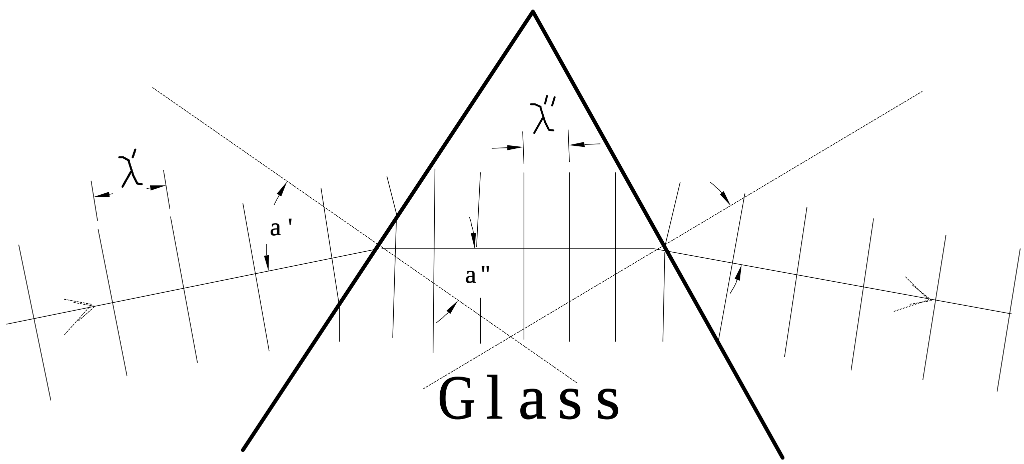

Fig. 7. A beam of light entering and exiting a glass prism showing the wavelength in the glass being shorter because of the slower velocity of propagation.

outside the prism. It is in fact the change in wavelength that causes the light beam to bend. Snell's law can therefore be rewritten as

$$n = \frac{l'}{l''} = \frac{\sin a'}{\sin a''} \quad \text{and} \qquad \frac{\Delta l}{l'} = \frac{\Delta(\sin a)}{\sin a'}, \qquad (none) \qquad (33)$$

Note that the beam of light bends twice, once at the entrance and once at the exit of the diffracting medium. Fig. 8 shows a beam of light entering the Sun's gravitational equipotentials and their associated angles of incidence. The angles of incidence range from $0°–90°$ producing a mean incident angle of $\bar{a}' = 45°$. The change in wavelength Δl, divided by the original wavelength l' of light grazing the Sun's surface, from Equation (29), is

$$\frac{\Delta l}{l'} = 1 - \left(\frac{f_{univ}}{f_{univ} + f_{sun}} \right)^2 . \qquad (none) \qquad (34)$$

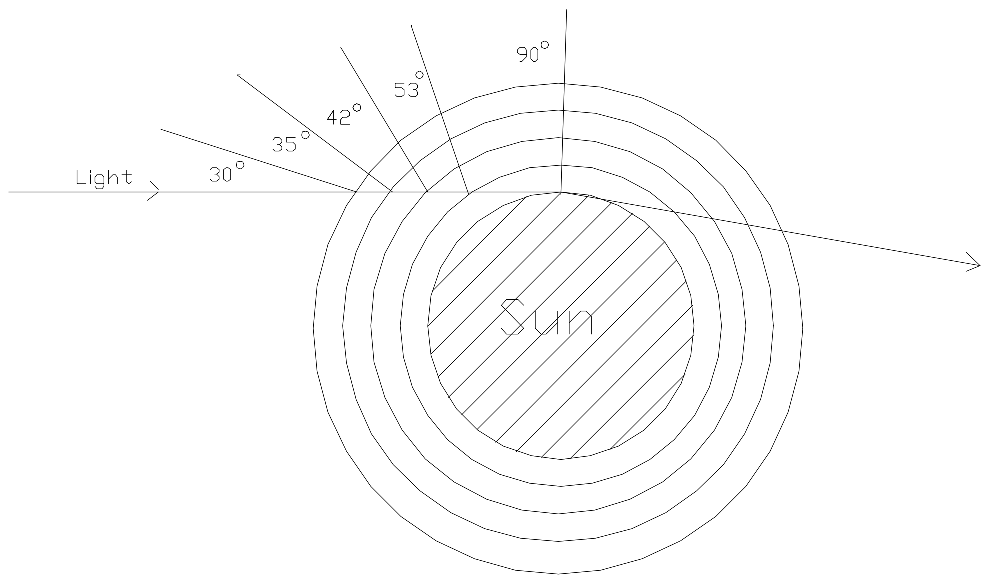

Fig. 8. A beam of light entering the gravitational field of the Sun showing the Sun's different gravitational equipotentials and corresponding angles of incidence.

The optical bending of a light beam grazing the Sun's surface is therefore according to Snell's law $a_{bend} = 2(\overline{a}' - \overline{a}'')$ or

$$a_{bend} = 2\left[\overline{a}' - \sin^{-1}\left(\sin \overline{a}' - \sin \overline{a}'(\Delta l / l')\right)\right] = 1.75053023 \text{ arc second}, \quad (35)$$

where $\overline{a}' = 45^\circ$ is t he mean angle of incidence. The factor of "2" is necessary since light has to pass through two refractive indices, one at the entrance and one at the exit of the gravitational field, produced by the Sun. The solar gravitational deflection of electromagnetic waves has been accurately measured during the last decade for both light and radio waves. One of the latest measurements, which was reported by Lebach *et al*. (1995), and which claims a precision of 0.1% agrees with Equation (35). In fact, Equation 35 yields about 1×10^{-5} arc second less bending angle for the Sun than Einstein's Equation (31).

The velocity of light is constant in a gravitational equilibrium where the gravitational tension is constant and where no potential gradient or acceleration exists. For example, electromagnetic waves produced at Earth travel with a constant velocity relative to Earth regardless of our orbital velocity around the Sun, because the Sun's acceleration at Earth is canceled by the centrifugal acceleration produced by the Earth's circular orbit, *i.e.* the Earth will experience a uniform gravitational tension along its orbit around the Sun thus ensuring a uniform gravitational tension in its path which might be thought of as ether dragging. The Earth's own change in gravitational tension (acceleration), however, will cause a small change in the velocity of propagation which varies with altitude. Light from extra terrestrial objects such as stars and galaxies that intersect the Earth in its orbit, will be subject to aberration. Light from these objects will be tilted just as rain will appear more and more tilted on a windshield screen when traveling at an increasing velocity. The bending due to aberration can be calculated using Snell's law where $n = c / v_{earth}$.

Equation (28) shows that the velocity of electromagnetic waves cannot slow to zero no matter how strong the gravitational tension is, thus most probably ruling out the existence of so called black holes.