Gauss's Law for gravity and observational evidence reveal no solar lensing in empty vacuum space

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ABSTRACT

Findings show that the rays of star light are lensed primarily in the plasma rim of the sun and hardly in the vacuum space just slightly above the rim. Since the lower boundary of this vacuum space is only a fraction of a solar radius above the solar plasma rim, it is exposed to virtually the same gravitational field. The thin plasma atmosphere of the sun appears to represent an *indirect interaction* involving an interfering plasma medium between the gravitational field of the sun and the rays of star light. The very same light bending equation obtained by General Relativity was derived from classical assumptions of a minimum energy path of a light ray in the plasma rim, exposed to the gravitational gradient field of the sun. The resulting calculation was found to be independent of frequency. An intense search of the star filled skies reveals a clear lack of lensing among the countless numbers of stars, where there are many candidates for gravitational lensing according to the assumptions of General Relativity. Assuming the validity of the light bending rule of General Relativity, the sky should be filled with images of Einstein rings. Moreover, a lack of evidence for gravitational lensing is clearly revealed in the time resolved images of the rapidly moving stellar objects orbiting about Sagittarius A*.

Subject headings: black hole – gravitational lensing – galaxy center – plasma atmosphere – Gauss's law

1. Introduction

We shall examine the evidence for gravitational lensing in our region of space near to us, starting with the nearest star to us, our sun. The light bending rule of General Relativity suggests that a *direct interaction* should take place between the gravitational field of the lensing mass and the rays of light from the stars, whether in a vacuum space or in a plasma atmosphere. If the gravitational lensing is observed only at the plasma rim of the sun, it is evident that the past century of observed solar light bending events were due to an *indirect interaction* between the gravitational field of the sun and the rays of star light. This argument is supported by a calculation which derives the very same light bending equation obtained by General Relativity. The equation was derived from the assumptions of a minimum energy path of light in a plasma atmosphere exposed to the gravitational gradient field of the sun. Appendix A gives a detail calculation and a derivation of the famous light bending equation. We shall take a closer look at the lower boundary of the vacuum space just above the plasma rim of the sun, the nearest star to us, just 8 light-minutes away. We shall examine the nearby stars in our own region of space, less than hundreds of light-years away. There are many cases in the star filled skies where the lenses and the light sources are by chance co-linearly aligned with the earth based observer, presenting vast opportunities for the observation of Einstein rings. We shall examine the collected images and the astrophysical data of the stars orbiting about Sagittarius A*, a region thought to contain a super massive black hole located at the center of our galaxy, the Milky Way, right in our own back yard, just 26,000 light-years away. Research convincingly reveal:

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- a lack of evidence for gravitational lensing in the vacuum space, just a fraction of a solar radius above the solar plasma rim; straightforwardly revealed by applying the Gauss's law of gravity to the solar mass
- a lack of evidence for Einstein rings in a sky of countless numbers of stars, where the candidates for gravitational lenses and the light sources are by good chance co-linearly aligned with the earth based observer
- a lack of evidence for gravitational lensing in the time resolved images of the stars orbiting about presumably a black hole at the site of Sagittarius A*

For nearly a century now, gravitational light bending events have been observed primarily at the rim of the sun during events of solar eclipses. New findings clearly show that with a straightforward application of Gauss's law of gravity, an important fundamental of Mathematical Physics, the light bending rule of General Relativity apparently does not apply to the empty vacuum space above the rim of the sun.

2. Some Misapplied Fundamentals on Gravitational Lensing Concepts

An application of Gauss's law, applied to gravitation as well as to electromagnetism along with the principle of optical reciprocity clearly show that a co-linear alignment of the observer, the lens and the source is unnecessary for an observation of a gravitational light bending effect, as predicted by the light bending rule of General Relativity. The gravitational effect at the surface of an analytical Gaussian sphere due to the presence of a point-like gravitating mass that is enclosed inside of the sphere depends only on the quantity of mass enclosed. The size or density of the enclosed mass particle is not important. [12], [13] Gauss's law of gravity [1], [4] is a Mathematical Physics tool that encloses a gravitating mass particle inside of an analytical Gaussian surface which applies directly to the gravitational field of the enclosed mass. An analogy to this principle encloses an electrically charged particle inside of a Gaussian surface in application to the electric field of the charged particle in the discipline of Electromagnetism [4]. The principle of optical reciprocity [2], [3] simply states that the light must take the very same minimum energy path or least time path, in either direction between the source and the observer. This fundamental principle is an essential tool for the understanding of complex lensing systems in Astronomy and Astrophysics [6]. We shall now correctly apply all of these well founded and proven fundamentals to these gravitational lensing problems.

2.1. Gauss's Law applied to a Point-Like Gravitating Mass

Any gravitational effect on a light ray due to the presence of a gravitating point like mass at the impact parameter R would theoretically depend on the amount of Mass M that is enclosed within the analytical Gaussian sphere of radius R as illustrated in Figure 1. Any gravitational effect that would be noted at the surface of the analytical Gaussian sphere should in principle be totally independent of the radius of the mass particle or the density of the mass that is enclosed within the Gaussian sphere. From Gauss's Law (Equation 2) equal masses of different radii will theoretically have equal gravitational effects at the surface of the Gaussian sphere. The light bending rule

$$\delta\theta = \frac{4GM}{Rc^2} \tag{1}$$

of General Relativity is essentially a localized $\frac{1}{R}$ effect. We are dealing with astronomical distances. Thus, the bulk of the gravitational effect on the path of particles of light would takes place along a segment of the light ray that encloses the impact parameter R. This segment may be only several orders of magnitude greater than the impact parameter R. Thus, the predominant effect of the gravitational field on the bending of the light ray would occur along this short segment of the light path, maximizing at the point where the light ray is tangent to our analytical Gaussian sphere, namely, at the impact parameter R.

A very essential tool of Mathematical Physics known as Gauss's law [1] ,[4],

$$\int_S \vec{g} \cdot d\vec{A} = 4\pi GM \tag{2}$$

is applied directly to the gravitating masses where the gravitational field $\vec{g}$ is a function only of the mass M enclosed by the spherical Gaussian surface S. The gravitational flux at the surface of the analytical Gaussian sphere is totally independent of the radius R of the sphere. [2] The idea here is that the gravitational field at this analytical Gaussian surface is only a function of the mass that it encloses. [1], [4] Any mass M, regardless of the radius of the mass particle that is enclosed inside of the Gaussian spherical surface of radius R will contribute exactly the same gravitational potential at the Gaussian surface. In Figure 1, the gravitational field points inward towards the center of the mass. Its magnitude is $g = \frac{GM}{R^2}$. In order to calculate the flux of the gravitational field out of the sphere of area $A = 4\pi R^2$, a minus sign is introduced. We then have the flux $\Phi_g = -gA = -(\frac{GM}{R^2})(4\pi R^2) = -4\pi GM$. Again, we note that the flux does not depend on the size of the sphere. It is straightforwardly seen that a direct application of Gauss's law to the light bending rule, Equation 1, coupled with the essential principle of *optical reciprocity* (Potton 2004), removes any requirement for a co-linear alignment of the light source, the point-like gravitating mass particle (the lens) and the observer for observation of a gravitational lensing effect as suggested by General Relativity. [12]

From Equation 2, the flux of the gravitational potential at the surface of the Gaussian spheres, as illustrated in Figure 1, is the same for all enclosed mass particles of the same mass M, regardless of the size of the mass particle. As a result, each mass particle will produce the very same gravitational light bending effect $\delta\theta = \delta\theta_1 + \delta\theta_2$, where $\delta\theta_1$ and $\delta\theta_2$ are the bending effects on the ray of light on approach and on receding the lens, respectively. This of course assumes the validity of Equation 1. This symmetry requirement suggests that $\delta\theta_1 = \delta\theta_2$. From Equations 1 and 3 it follows that $\delta\theta = 2\delta\theta_1 = \frac{4GM}{Rc^2}$ and $\delta\theta_1 = \delta\theta_2 = \frac{2GM}{Rc^2}$. This says that the total contribution of the light bending effect due to the gravitating point-like mass particle on any given infinitely long light ray is theoretically divided equally at the impact parameter R, separating the approaching segment and the receding segment of the optical path. A confirmation of this will be clearly seen in the next section with application of the *principle of reciprocity* and a derivation of the equation of the Einstein ring, illustrating the *symmetry requirement* of General Relativity.

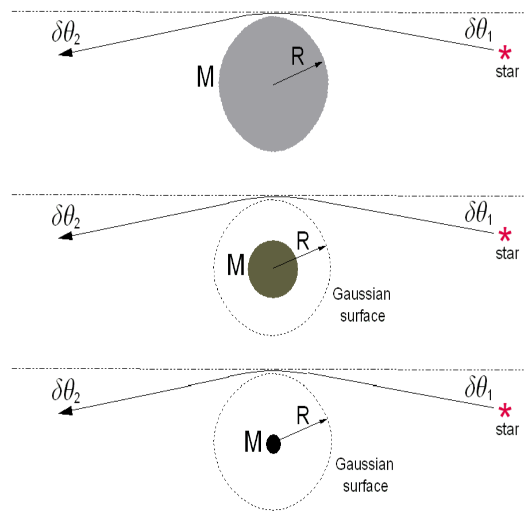

Fig. 1.— Gauss's Law applied to Equal Gravitating Masses of Different Radii Enclosed

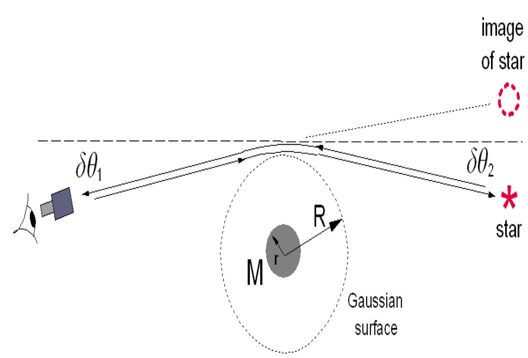

Fig. 2.— Fundamental Principle of Optical Reciprocity Illustrated on a Lensed Light Ray

2.2. Principle of Optical Reciprocity applied to the Lensed Light Ray

In any space, the *principle of reciprocity* [2],[3], a very fundamental principle of optics, must hold as illustrated in Figure 2. The principle simply states that light moving along a **preferred optical path**, from a source to an experimenting observer, must take the very same optical path from the hypothetical light source of the observer back to the distant **real** light source. As a consequence of this fundamental principle, any additional source placed along a preferred optical path will all appear to the observer as a point-like light source sitting on top of the image of the **real** light source. As a consequence of this principle, in the case of an image of an Einstein ring of a single **real** point-like light source, any additional light sources placed on a preferred optical path of the **real** light source would appear as point light sources sitting on the image of the Einstein ring of the distant **real** light source.

The total gravitational light bending effect acting on the light ray upon approach and upon receding a point-like gravitating mass is give by

$$\delta\theta = \delta\theta_1|_{\substack{approaching \\ the\ lens}} + \delta\theta_2|_{\substack{receding \\ the\ lens}} = \frac{4GM}{Rc^2} \quad (3)$$

In this example, for simplicity, the gravitating mass M is chosen to be positioned at the midpoint on the line joining the observer and the light source for the simplified special case $D_L : D_{SL} : D_S = 1 : 1 : 2$. [5] This simplified special case is illustrated in Figure 3.

The astronomical distance D_L is the distance from the observer to the lens, D_{SL} is the distance from the lens to the source and D_S is the distance from the observer to the source. This is a simplified special case, where $D_L = D_{SL}$, presented in most academic textbooks. It is readily seen that the axis of symmetry for a given light ray is perpendicular to the line joining the source and the observer only for the special case where the lens is positioned exactly at the midpoint between the source and the observer. The vast astronomical distances between the stars present much larger impact parameters on a much grander scale to the light passing by the stars. In the plasma free space far above the rim of the stars, an *indirect interaction* certainly could not take place. It is for this reason, the star filled sky reveals a clear lack of gravitational lensing among the countless numbers of stars.

2.3. Symmetry Requirement Demonstrated on derivation of Einstein Ring Equation

From symmetry we have

$$\delta\theta_1 = \delta\theta_2 = \frac{2GM}{Rc^2} \quad (4)$$

Again, the astronomical distance D_L is the distance from the observer to the lens. Since we are dealing with very small angles, from Figure 3, the deflection of the light ray due to the gravitational effect on approach to the gravitating mass is just simply $\delta\theta_1 = \frac{R}{D_L} = \frac{2GM}{Rc^2}$ wherefrom
$\frac{R^2}{D_L} = \frac{2GM}{c^2}$ and $\frac{R^2}{{D_L}^2} = \frac{2GM}{D_L c^2} = {\delta\theta_1}^2$.
Solving this for the radius of the impact parameter of the light ray and thus the radius of the Einstein Ring expressed in units of radians we have

$$\delta\theta_1 = \sqrt{\frac{2GM}{D_L c^2}} \quad (5)$$

which is the radius of the Einstein ring in units of radians for a lens place exactly midway between the source and the observer. This is a special case, where $D_L = D_{SL}$. (See Appendix B for the general case ($D_L \neq D_{SL}$)) Note that the gravitational bending effect on the light ray for the approach segment alone is exactly equal to the radius of the solved Einstein ring expressed in radians and is given as

$$\delta\theta_1 = \frac{2GM}{Rc^2} \quad (6)$$

This effect is exactly one half of the total accumulative gravitational effect acting on the light ray for the approach and receding segments. [12] From symmetry requirement, the integral gravitational effect on a light ray upon approach to a gravitating mass positioned exactly at the midpoint of a line joining the source and the observer, must equal that of the integral gravitational effect on the light ray upon receding the gravitating mass

$$\delta\theta_1|_{\substack{approaching \\ the\ lens}} = \delta\theta_2|_{\substack{receding \\ the\ lens}} \quad (7)$$

as suggested by Equation 4 and the laws of conservation of energy and of momentum. [13] The accumulative gravitational effect along the light ray must sum the total effects of gravity acting on the light ray for both the approach and receding segments of any ray of light passing by a point-like gravitating mass. [12], [13] The total light bending effect is therefore

$$\delta\theta = \frac{4GM}{Rc^2} \tag{8}$$

The principle of optical reciprocity simply states that any light ray or a photon of light must take the very same path, along the same minimum energy path, in either direction between the source and the observer as depicted in Figure 2.

Using the light bending rule of General Relativity, it is theoretically demonstrated and graphically illustrated in Figure 4 that all observers of varying distances from a gravitating mass or lens should see an Einstein ring. Only the mid-field observer depicted in Figure 4 will derive Equation 6 which gives exactly the same value as that given by Equation 5 for a simplified special case, where $D_L = D_{SL}$, which is presented in most academic textbooks. Appendix B gives the general case where D_L is **not** necessarily equal to D_{SL}. In the general case, the lens **may not** be placed exactly midway between the light source and the observer. The near-field and the far-field observers depicted in Figure 4 will also derive Einstein ring equations with coefficients corresponding to their unique geometries. Each observer has distinct sets of lensed light rays, each of the lensed light rays with their corresponding axis of symmetry. As illustrated, the near-field observer would see the largest, most lensed Einstein ring. The far-field observer would see the smallest, least lensed Einstein ring. From symmetry, the axis of symmetry of the lensed curve would lean towards the near-field observer and away from the far-field observer. The axis of symmetry would be perpendicular to the line joining the mid-field observer and the light source only in the case where the lens is exactly midway between the observer and the source.

The lensed light rays depicted in Figure 4 **all** belong to the very same family of equations derived from the light bending rule (Equation 1) of General Relativity. Any light ray that is gravitationally bent by a point-like gravitating mass, as predicted by General Relativity, will always have an axis of symmetry which would be perpendicular to the line joining the source and the observer only when the lens is positioned exactly at the midpoint on the line joining the observer and the source. All observers should see, according to General Relativity, an Einstein ring. Figure 4 depicts the geometry of the lens rays as a function of the position of the observer relative to the lens and the source. [12]

2.4. Condition for Observing of an Einstein Ring using a Lens of 1 Solar Mass and 1 Solar Radius

Table 1: Astrophysical Data of the Sun

Solar Mass	M	$1.99 \cdot 10^{30} Kg$
Solar Radius	R	$6.96 \cdot 10^{8} m$
G Constant	G	$6.67 \cdot 10^{-11} m^3 s^2/Kg$
Velocity of Light	c	$2.99793 \cdot 10^{8} ms^{-}1$
$\delta\theta$ (rad)	$\frac{4GM}{Rc^2}$	$8.4952 \cdot 10^{-6}$ rad
$\delta\theta$ (deg)	$\frac{4GM}{Rc^2}$	0.0004867 deg
Radius of Sun	$R(deg)$	$0.275 deg$
Focal Length	$\frac{R(deg)}{\delta\theta(deg)}$	565.0

We shall use the collected astrophysical data of the sun in Table 1 for this task. Using this data we find that for a stellar system of 1 solar mass and 1 solar radius, the light bending Equation (8) yields an angles of $8.4952 \cdot 10^{-6}$ radians. This angle is 0.0004867 degrees or 1.752 arcsec. The diameter of the solar disk is observed to be 0.55 degrees, a radius of 0.275 degrees. If the radius of the solar disk were compared with the angle of solar light bending of the plasma rim (in degrees), we would have a factor of $\frac{R(deg)}{\delta\theta(deg)} = 565.0$. This means that in order to observe an Einstein ring of a distant stellar light source due the plasma rim of the sun, the observer would have to back away from the sun for at least 565 astronomical units(AU's). This is the **focal length of the plasma rim lensing system** of the sun. It is the distance required for the parallel rays of star light to converge to a point after being deflected by the solar plasma rim.

Note that if the observer were to back off to a dis-

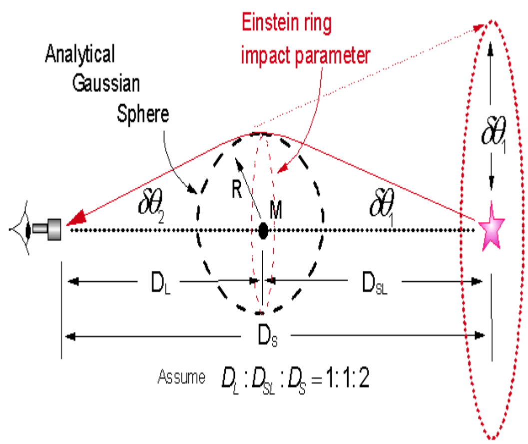

Fig. 3.— Symmetry Requirement of the Accumulative Lensing Effect Illustrated

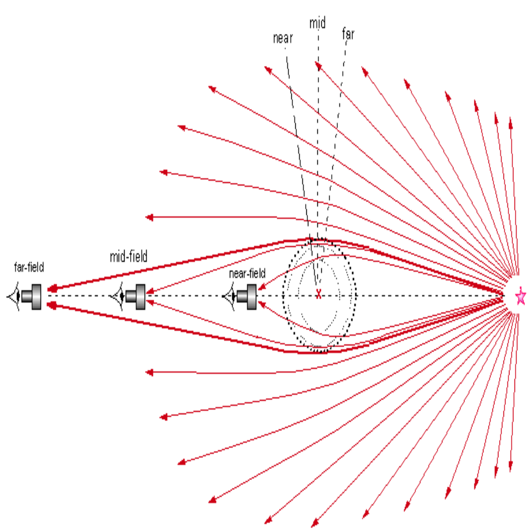

Fig. 4.— The near-field, mid-field and far-field observers and illustration of their corresponding axes of symmetry.

tance greater than 565 AU's then the light rays from the plasma lens would come to a focus before reaching the observer and the Einstein ring would not be detected. Because of the vast distances between the stars in the night skies, any light bending of the light rays, according to General Relativity, would have to have larger impact parameters, extending out well above the plasma rim of the lensing stars into the empty vacuum space where there is apparently **no** gravitational lensing effects taking place at all. Since there is no evidence for Einstein rings among the star-filled skies, this is apparently the case. Consequently, if gravitational lensing in empty vacuum space did not occur, then there can be **no** observations of Einstein Rings due to a co-linearly alignment of the widely separated stellar objects in the night skies.

Historically, the effect of light bending has been noted only at the solar rim, the thin plasma of the sun's atmosphere due to an *indirect interaction* between the rays of star light and the gravitational field of the sun. Appendix A gives a detail calculation for the bending of light rays in a plasma atmosphere exposed to a gravitational gradient field. It is easily demonstrated using the mathematical Physics of the Gauss law of gravity that the light bending effect of the sun varies as $1/R$ at various radii R of analytical Gaussian surfaces, concentric to the center of the sun as suggested by General Relativity. The integrated effect of the solar lensing effect is essentially a $1/R$ effect which is predominant along a segment of the light path that encloses the impact parameter, R, where the light ray is tangent to a spherical Gaussian surface at the impact parameter R. Since the astronomical distances are extremely large, for all practical purposes, the integrated $1/R$ effect of the light bending occurs along a segment of the light ray that is extremely short compared to astronomical distances.

Theoretically, the light bending along the segment due to the gravity of a point-like mass on approach and on receding are virtually equal and divided at the impact parameter R where the relation $\delta\theta_1|_{\substack{approaching \\ the\ lens}} = \delta\theta_2|_{\substack{receding \\ the\ lens}}$ still holds even though the Earth based observer is relatively close to the sun. [12] Remarkably, as it may seem, however, historically the solar light bending effect has been observed only at the solar rim, namely, the light refracting plasma of the solar atmosphere. It is too widely taught solar light bending is observed at the rim to maximize the effect of detection. This has contributed obviously to misapplication of the important fundamentals. We note again, that the thickness of the thin plasma shell of the sun, frequently referred to as the solar rim, is very negligible in comparison to the solar radius R. Table 2 briefly summarizes the observations of gravitational light bending as a function of the distance above the thin solar plasma rim. It is important to note that the bulk of the observed solar light bending events were recorded during solar eclipses. The moon has provided a near perfect masking of the solar disk, allowing only the thin plasma rim of the sun to be exposed for the astrophysical observations.

Table 2: The Observed and Predicted Gravitational Lensing at Distances h (in units of R_{SUN}) above the Solar Plasma Rim

Distance h above Rim (R_{SUN})	Acceleration $1/r^2$ *Effect* (g_{SUN})	Observed Lensing (*arcsec*)	Predicted by Relativity (*arcsec*)
1.0	0.25	none	0.88
0.5	0.44	none	1.17
0.2	0.69	none	1.45
0.1	0.83	negligible	1.59
0	1.00	1.75	1.75

Assuming the validity of the light bending rule of General Relativity, the current technical means of the astronomical techniques should have easily allowed observations of solar light bending of stellar light rays at different solar radii, using the Gauss law of gravity applied to analytical spherical surfaces, namely at the radius of $2R$, $3R$ and even beyond $4R$, where R is one solar radius. For instance, at the analytical Gaussian surface of radius 2R, the predicted light bending effect of General Relativity would have been an easily detectable effect of one half the effect of 1.75 arcsec noted at the solar rim; at the surface of radius 3R, an effect of one third the effect at the solar rim, etc., etc. The equatorial radius R_{SUN} is approximately 695,000 km. The thickness of the solar rim is been recorded to be less than 20,000 km; less than 3 percent of the solar radius R. From this, we can easily see that a gravitational lensing effect in vacuum space several solar radii above the solar plasm rim should be a very noticeable effect to the modern astronomical means.

2.5. The Fundamentals applied to the Orbit of S2 about Sagittarius A*

The past decades of intense observations using modern astronomical techniques in Astrophysics alone reveal an obvious lack of evidence for lensing effects on collected emissions from stellar sources orbiting about Sagittarius A*, believed to be a super massive black hole located at the galactic center of our Milky Way. This is most obviously revealed in the time resolved images collected since 1992 on the rapidly moving stars orbiting about Sagittarius A*. [7], [8], [10], [11] The space in the immediate vicinity of a black hole is by definition an extremely good vacuum. The evidence for this is clearly seen in the highly elliptical orbital paths of the stars orbiting about the galactic core mass. The presence of material media near the galactic core mass would conceivably perturb the motion of the stellar object s16 which has been observed to move with a good fraction of the velocity of light. The presence of any media other than a good vacuum would have caused the fast moving stellar object s16 to rapidly disintegrate. Astrophysical observations reveal that s16 has a velocity approaching 3 percent of the velocity of light when passing to within a periastron distance corresponding to 60 astronomical units from Sagittarius A*, perceived to be a massive black hole. This gives convincing evidence that the space in this region has to be, without a doubt, an extremely good vacuum, no chance of an *indirect interaction* between the gravity of the super massive galactic core mass and the light emitted by these rapidly moving stars orbiting this mass.

Application of the light bending rule of Equation 4 together with considerations of Gauss's Law and the principle of optical reciprocity to the data of the observed orbit the researchers in [11] has shown, it is clear that some gravitational lensing effects should have been detected in the time resolved images of the orbit of S2, owing to the current level of todays observational means.

Selected points of the observed orbit of S2 and the corresponding predicted lensing of the orbit, based on the light bending rule of General Relativity, were tabulated in Reference [12]. From these calculations the predicted magnitude of the lensing effect was found to be orders of magnitude greater than the observed radial separation between the S2 source and the position of the galactic center mass. With current technical mean, this predicted lensing should have been a very noticeable effect. To date, clear evidence of a gravitational lensing effect based on the light bending rules of General Relativity is yet to be revealed in the time resolved images of the stellar objects orbiting about Sagittarius A*, a region under intense astrophysical observations since 1992.

3. Discussion & Conclusions

Historically, the light bending effect has been observed predominately at the thin plasma rim of the sun. A *direct interaction* between the sun's gravity and the rays of star light in empty vacuum space just a fraction of a solar radius above the solar plasma rim, where there is no plasma atmosphere, is yet to be observed. The stellar sky presents vast opportunities to modern Astronomy and Astrophysics to allow for the detection of gravitational lensing events, as predicted by General Relativity, due to the large numbers of stellar objects that just happen to be co-linearly aligned with the earth based observers; again of course assuming the validity of the light bending rule of General Relativity. Because of the vast astronomical distances between the stars, the gravitational lensing effect would have to take place in deep space, at impact parameters far above the plasma rim of the lensing stars. If this were indeed the case and the light bending rule of General Relativity involved a *direct interaction* between the gravitational field of the stars and the rays of light in vacuum space, then the entire celestial sky should be filled with images of Einstein rings.

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A. Appendix: Bending of Light Rays in the Solar Plasma Rim as function of Gravitational Potential; a Minimum Energy Path Calculation

This calculation is based entirely on a conservation of energy concept considering the gradient of the gravitational field of the sun acting directly on the rapidly moving ionized material particles of the thin plasma atmosphere of the sun. The calculation considers a minimum energy path for rays of light. The resulting calculation was found to be totally independent of frequency. The rapidly moving ionized particles of the solar plasma is assumed to be bounded by the gravitational potential of the sun given by

$$\phi(^{r=\infty}_{r=R}) = \int_{r=R}^{r=\infty} \frac{GM}{r^2} dr = \frac{GM}{R}. \tag{A1}$$

It may be assumed that the plasma particles of the ionized solar rim move with random velocities such that their kinetic energies are as dictated by $\frac{1}{2}mv^2 = \frac{3}{2}kT + \phi m$, where m is the mean mass of the plasma particles of temperature $T(K^\circ)$ and v is the velocity of the plasma particle bounded by the gravitational potential ϕ. The random velocity v of the moving ions may be assumed to have an upper bound velocity of $v = \sqrt{\frac{2GM}{R}}$, the escape velocity of the solar gravity at the surface of the sun. The solar plasma particles bounded by gravity in the solar rim may be considered as a dynamic lens under the intense gravitational gradient field of the sun. It is theoretically shown here, and in detail in *Dowdye2 (2007)*, that a minimum energy path for light rays propagating in the solar plasma rim, subjected to the gradient of the gravitational field of the sun, yields the mathematical results of $\frac{4GM}{Rc^2}$.

It is shown that the moving ions acting as secondary sources within the plasma rim, move with random velocities not to accede the escape velocity. The frequency and wavelength of a lensed light ray exposed to the moving plasma are redshifted as:

$$\nu' = \nu_0(1 - \frac{v^2}{c^2}) = \nu_0(1 - \frac{2GM}{Rc^2}) \tag{A2}$$

$$\lambda' = \lambda_0(1 - \frac{v^2}{c^2})^{-1} = \lambda_0(1 - \frac{2GM}{Rc^2})^{-1} \tag{A3}$$

$$\lambda' \approx \lambda_0(1 + \frac{2GM}{Rc^2}). \tag{A4}$$

From this, the number of wavelengths per unit length along the minimum energy path for any given light ray propagating within the plasma rim may be given as

$$n = \frac{1}{\lambda'} = \frac{1}{\lambda_0(1 - \frac{2GM}{Rc^2})^{-1}} = \frac{1}{\lambda_0}(1 - \frac{2GM}{Rc^2}). \tag{A5}$$

Thus, the photon energy density ϵ, joules per unit length of a light ray along the minimum energy path is $\epsilon = \epsilon_0(1 - \frac{2GM}{rc^2})$. Consequently, the number of re-emitted waves per unit length along the photon path and thus the energy per unit length increases as r increases. This translates to a downward, re-emitted path of the bent light ray, along a minimum energy path for the approaching segment of the light ray. Theory and details are published in [13]. If $\frac{d\epsilon}{dr} = +\epsilon_0 \frac{2GM}{r^2c^2}$ or $\delta\epsilon = +\epsilon_0 \frac{2GM}{r^2c^2}\delta R$, then the re-emission of the light ray in the atmosphere of ions will occur such that the total energy along the minimum energy (conservation of energy) path for a given light ray would not change. If ϵ is the energy per unit length along the light ray and $\delta\epsilon$ is the change in energy in the direction of the gradient potential $\phi(r)$, then the angle of change during the approach segment of the light ray is

$$\delta\theta_{app} = \frac{\delta\epsilon_{app}}{\epsilon} = +\int_{r=\infty}^{r=R} \frac{2GM}{r^2c^2} dr = -\frac{2GM}{Rc^2} \tag{A6}$$

and the path change for the receding segment of the light ray is

$$\delta\theta_{rec} = \frac{\delta\epsilon_{rec}}{\epsilon} = +\int_{r=R}^{r=\infty} \frac{2GM}{r^2c^2}dr = +\frac{2GM}{Rc^2}. \tag{A7}$$

The net change in the path of the light ray is

$$\delta\theta = \delta\theta_{rec} - \delta\theta_{app} = \frac{4GM}{Rc^2}. \tag{A8}$$

B. Appendix: The Einstein Ring Equation; the General Case ($D_L \neq D_{SL}$)

The general case for the Einstein ring equation involves all values for the distances, whereby D_L is the distance between the observer and the lens and D_{SL} is the distance between the lens and the source. These are cases where D_L is not necessarily equal to D_{SL}. The general case for the radius of the Einstein ring in units of radians is

$$\delta\theta(rad) = \sqrt{\frac{D_{SL}}{D_L + D_{SL}}\frac{4GM}{D_Lc^2}} \tag{B1}$$

The radius of the Einstein ring at the image location the distance of $(D_L + D_{SL})$ expressed in meters is

$$R(meters) = (D_L + D_{SL})\delta\theta(rad) \tag{B2}$$

where D_L and D_{SL} are also expressed in meters. The impact parameter (IP) corresponding to the Einstein ring is the nearest point of approach of the light rays to the point-like lensing mass, when observed at a distance of D_L meters away from the observer, for the rays of light coming from the light source to the observer. Since this is a 3 dimensional problem, the impact parameter of the light rays that would produce an Einstein ring is also a ring itself. It is a virtual ring for purpose of the analysis of the problem. The impact parameter in meters is

$$R_{IP}(meters) = (D_L)\delta\theta(rad) \tag{B3}$$

where R_{IP} is the nearest point of approach of the gravitationally lensed light rays to the lensing star. It is that distance the lensed light rays will pass over the plasma rim of the lensing star, moving through the empty vacuum space well above the plasma rim of the lensing stars, moving along astronomical distances from the source to the observer. The radius of the predicted Einstein ring, according Equation (B1) and the light bending rule of General Relativity, will be nearly 15 times the radius of a sun-like lensing star, the same mass and radius as the sun, when both are observed at the same distance $D_{SL} = 4$ light years away. Adjusting the parameter D_{SL} would cause the radius of the Einstein ring to change. Increasing D_{SL} would cause the image of the Einstein ring to increase in radius (an increase in magnification), assuming the validity of General Relativity. Setting $D_L = D_{SL}$, Equation (B1) becomes Equation (5), the special case.