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A note on Gravitational red shift and deflection of emitted thermal radiation

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Abstract » It is known that black holes loses a small amount of energy and therefore it's mass by emitting thermal radiation. Due to prevalent action of gravity, the outgoing radiation is red-shifted and their trajectory path is bent slightly towards the surface of the black hole. These gravitational effects on radiation are manifested in a single reference frame. The aim of the paper is to combine the radiation physics with gravitational effects on the radiation.

Key words » thermal radiation, black hole, red shift, wavelength, angle of deflection, observer

Back in the 1900s, black holes were treated classically with zero temperature and no entropy. The discovery of hawking effect strengthened the reason to look for a deep analogy between gravity, quantum and thermodynamics. In other words, the black holes are not entirely black, they shine after hawking — they emit energy in the form of thermal radiation due to quantum mechanical effects. Can we actually measure the gravitational effects on emitted thermal radiation? The purpose of this paper is to describe how can this be done .American astrophysicists have experimental results that support that black hole radiate in the spectrum of UV ,roentgen and gamma photons . The few interesting issues concerned about the dominant measurable gravitational effects on light are — gravitational red shift of the wavelength, inward bending of trajectory path of light and gravitational lensing. This paper can be viewed as the manifestation of the 2 predominant gravitational effects – bending of light and red shift. The paper fails to account for the gravitational lensing. The following section represents theoretical analysis

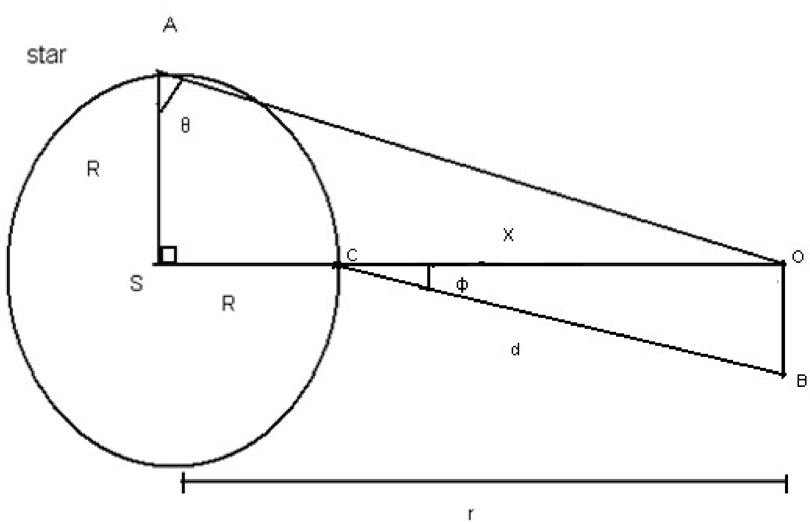

Fig.1

Brief description of the fig.1

S is center of the star
R is radius of the star
r is classical distance of the distant observer from the center of the star
r =X+R
d is distance travelled by the photon to reach the distant observer
OB is the proper length of the distant observer
CB = d
CO=X
AS=SC=R
SO= r
Φ is angle of deviation of the photon from the straight line motion. The strong gravitational field of the star changes the trajectory path of the photon .Specifically the path of the light is bent slightly towards the surface of the star.

From the right-angled triangle OAS

$$\tan\theta = r / R \qquad .... (1)$$

It is known that r =X+R

$$R \tan\theta = R+X$$

$$X=R\,[\tan\theta - 1] \qquad .... (2)$$

From the right-angled triangle OCB

$$\cos\phi = X / d \qquad ..... (3)$$

The use of the eq. (2) together with the eq. (3) leads to the following relationship:

$$d= R\,[\tan\theta - 1] / \cos\phi \qquad ..... (4)$$

The photon at the surface of the star travels a distance d to reach the observer

The work done W in moving the photon from the surface of the star to the distant observer could be determined with using of the eq. (5)

$$W= -(F_p \cdot d) \qquad ..... (5)$$

Here F_p is force, which moves the photon, d is distance travelled by the photon to reach the stationary observer and negative sign indicates the work done against the gravitational field of the star.

We can determine the force F_p, which moves the photon by of dividing its energy hυ by its wavelength λ

$$F_p= h\upsilon / \lambda \qquad ...... (6)$$

Here h is Planck's constant

The frequency of photon υ could be determined with using of the eq. (7)

$$\upsilon = c / \lambda \qquad .... (7)$$

Here c is the speed of light in vacuum

$$F_p = h \cdot c / \lambda^2 \qquad .... (8)$$

Let W= δE=h$\delta\upsilon$

Here δE =energy spent in moving the photon from the surface of the star to the observer

$$W = h\delta\upsilon \qquad .... (9)$$

Here $\delta\upsilon$ is the change in the frequency of the photon

The eq. (5) turns out to be:

$$h\delta\upsilon = -(h \cdot c / \lambda^2) \cdot d \qquad .... (10)$$

It is known that the eq. h$\delta\upsilon$ in turn implies h c/ $\delta\lambda$ in case of photon

Here $\delta\lambda$ is change in the wavelength of the photon

The eq. (10) appears in the form:

$$\delta\lambda / \lambda = -\lambda / d \qquad .... (11)$$

The red shift z could be calculated with using of the eq. (12)

$$z = \delta\lambda / \lambda \qquad .... (12)$$

Here $\delta\lambda$ is change in the wavelength of the photon and λ is original wavelength of the photon

The eq. (11) becomes:

$$z = -\lambda / d \qquad .... (13)$$

From (4), we know that

$$d = R\,[\tan\theta - 1] / \cos\phi \qquad .... (4)$$

The eq. (13) appears in the format:

$$z = -\lambda \cos\phi / R\,[\tan\theta - 1] \qquad .... (14)$$

It is known that tan θ = r / R

$$z = -\lambda \cos\phi\, R / R\,[r - R] \qquad .... (16)$$

$$z = -\lambda \cos \phi / [r - R] \quad \text{........... (17)}$$

An essential assumption of $R=R_G$ is considered. It is clear that if $R=R_{G,}$ the star compresses to form a black hole. In order to include the eq. (17) to black holes, we recall the phenomenon of hawking effect.

$$z = -\lambda \cos \phi / [r - R_G] \quad \text{........... (18)}$$

In an interesting paper entitled "THE GRAVITATIONAL RADIUS OF A BLACKHOLE", Professor Ph. M. Kanarev concludes that idea of equality between force moving the photon and gravitational force yields an expression for photon wavelength in terms of gravitational radius.

The force of gravitation of the black hole [F_G] experienced by the photon could be determined with using of the Newton's law of universal gravitation

$$F_G = G\, M\, m/R_G^2 \quad \text{......... (19)}$$

Here G is universal gravitational constant, M is black hole mass, m is photon mass and R_G is gravitational radius of the black hole.

We can determine the force F_p, which moves the photon by of dividing its energy hυ by its wavelength λ

$$F_p = mc^2 / \lambda \quad \text{...... (20)}$$

Here h is Planck's constant

$$F_G = F_p$$

$$G\, M\, m/R_G^2 = mc^2 / \lambda \quad \text{...................... (21)}$$

In 1916, Karl Schwarzschild came up with an solution (22) for the determination of the gravitational radius of a black hole.

$$R_G = 2GM/c^2 \quad \text{....................... (22)}$$

The eq.(21) becomes

$$R_G = \lambda / 2 \quad \text{.............................. (23)}$$

The eq. (18) turns out to be

$$z = -2\lambda \cos \phi / [2r - \lambda] \quad \text{................................. (24)}$$

By applying mathematical logical operation
the eq. (24) becomes : $z = 2\lambda \cos \phi / [\lambda - 2r]$ **................................. (25)**

Here λ is wavelength of the outgoing thermal radiation

Φ is angle of deviation of the radiation from the straight line motion

r is classical distance of the observer from the center of the black hole

z is red shift of the outgoing thermal radiation

An introduction to dominant gravitational effects on emitted thermal radiation is amplified with emphasis on wavelength of the outgoing thermal radiation. This paper helps clarify a residual puzzle in the discussion of the gravitational effects on emitted thermal radiation.

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