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The Nature of the Expansion of the Universe from the Study of the Gravitational Red- Shift

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Abstract: The theoretical calculation of the gravitational red shift requires the combination of Newtonian gravity, particle theory of light and weak equivalence principle of gravitating mass equals inertial mass. According to this theory, the light emitted by the distance stars get stretched and this phenomenon is known as gravitational red shift. The wavelength of the light emitted by the stars are increased and consequently the frequency of the light received by us on earth is decreased. In this paper, we apply Newton's gravity to theoretically study the gravitational red shift and theoretically calculate the distance and the distance modulous of the white dwarf and neutron stars. Interestingly, it is observed that the distance modulous and the galaxy rotation curves of the stars resemble qualitatively that of the experimental curves. The study of the gravitational red shift helps us to determine the mass and density of the stars provided we know the distance. The gravitational red shift data is important in case of white dwarf and neutron stars, where the surface gravity is very large value of the order of $10^{12}\ m/s^2$ and the density of these stars are comparable to the nuclear density. The radius of the white dwarf stars is of the order of kilometer range and masses are greater than the mass of the sun.

Keywords: Gavitation, Red shift, Galaxy, Distance Modulous, Rotation curve

1. Introduction:

The discovery of accelerating universe by studying the SNe Ia supernova explosion data is remarkable in relation to the experimental achievements in cosmology. The explanation relating to these path breaking observations assume the existence of a hitherto unknown dark energy and dark matter. Einstein general theory of relativity along with the cosmological constant representing dark energy of lambda CDM model is believed to be responsible for the accelerated state of the universe. The challenges of this model are to prove and explain the existence of dark matter and dark energy of the universe. In this context, it is worth mentioning that we can alternatively attempt the classical Newtonian model of gravity to check whether it can explain the qualitative features of these discoveries. Under these circumstances, we think that the study of gravitational red shift[1] can be useful in many ways. The theory of red shift[1] predicts that the wavelength of electromagnetic waves is lengthened when it passes from a lower gravitational potential well to a higher potential level. As the velocity of the electromagnetic waves remains same, the energy of the photons will decrease and hence the frequency of the photons decrease. Therefore, the wavelength of the photons increase. For example, if a photon of energy $h\frac{c}{\lambda}$, where h is the planck constant, c is the velocity of light and λ_0 is the wavelength of the photon when it is emitted from the surface of the stars, then the increase of the wavelength of the photon or shift of the wavelength towards the red end of the electromagnetic spectrum is known as the gravitational red shift. The gravitational red shift was confirmed experimentally first by Robert Pound and his graduate student Glen. A. Rebka Jr. in 1959[2]. It is a gravitational red shift experiment, which measures the redshift of light moving in a gravitational field. It is considered to be the experiment that ushered in an era of precession measurements of cosmological parameters[3-10]. The converse is also true. The observed wavelength of a photon falling into a gravitational well will be shortened, or gravitationally 'blueshifted', as it gains energy.

According to the cosmological principle, the universe is thought to be isotropic and homogenous when looked at it from any point of observation in the universe. So we can think the observable universe to be a homogenous sphere of radius equivalent to the Hubble radius R($= \frac{c}{H_o}$), where c is the velocity of light and H_0 is the Hubble constant. If we consider a mass inside this sphere of radius R, then according to the Newtonian mechanics , the potential contribution on it will come from two parts. One part is due to the inner sphere of radius say r, and the other part will come from the spherical shell of radii between R and Rs, where Rs is the sphere of photon emitting star. Here we consider the universe centered around the star , and the observer is situated at a large distance r on earth from the star.

The situation is similar to the case of the quantum mechanical description of an electron[1] bound to an atom in an excited state. When a revolving electron in an excited state jumps from a higher energy state to a lower energy stats it emits photon with frequency corresponding to the difference of the energy states. In the reverse case, when an electron goes up to a higher energy state from a lower energy state, it absorbs a photon of energy appropriate to the difference of the energy between the states.

Now consider two copies of this electron-atom system, one in the excited state (the emitter), the other in the lower energy state (the receiver). If the two systems are stationary relative to one another and the space between them is flat (i.e. we neglect gravitational fields) then the photon emitted by the emitter can be absorbed by the electron in the receiver. However, if the two systems are in a gravitational field then the photon may undergo gravitational redshift as it travels from the first system to the second, causing the photon frequency observed by the receiver to be different to the frequency observed by the emitter when it was originally emitted. Another possible source of redshift is the Doppler shift. If the two systems are not stationary relative to one another then the photon frequency will be modified by the relative speed between them.

In the Pound-Rebka experiment[2], the emitter was placed at the top of tower with the receiver at the bottom. The gravitational field of the Earth will cause a photon emitted downwards (towards the Earth) to be blueshifted (i.e. its frequency will increase). To counteract the effect of gravitational redshift, the emitter was moved upwards (away from the receiver) causing the photon frequency to be red shifted, according to the Doppler shift. In this paper, Newtonian mechanics is applied to calculate the gravitational redshift of a star and show how accurately we can determine the distance of the stars which is a very difficult task in cosmology. The supernova type Ia explosion has characteristic light curves which are the plot of the luminosity versus time after the explosion of the stars. The luminosity curves indicate the presence of intermediate elements characteristic spectra corresponding to the mass ranging from oxygen to calcium forming the outer layesr of the stars. After several months of the star's explosion, the outer layers of the stars fade away to the point of transparency and the characteristic spectra corresponding to the core layers of the stars formed mostly by iron dominate the energy release of the stars . The use of type Ia supernovae to measure cosmological distances precisely was done by the pioneering works of the collaboration of the Chilean and US astronomers. Their study shows that the peak luminosity of the light curves of the stars do not reach the same peak value and a single parameter measured from the curves of the type Ia supernovae[10-16] can be used to correct standard candle values. Here we also compare with their results, the distance modulous versus redshift curves which qualitatively are consistent with the observed experimental results. The Newtonian mechanics is quite able to explain the observed experimental results so far without the assumption of the dark matter and dark energy.

2. Theory and Formula:

In Classical Newtonian mechanics, the gravitational potential inside the solid sphere at a point r from the center O as shown in Fig.1, we can write the energy conservation formula for a photon being emitted in a gravitational field and received at a distance in different gravitational field as,

$$h\upsilon_0 - \frac{GM_u}{2c^2R^3}(3\,R^2 - r^2)h\upsilon_0 = h\upsilon_e - \frac{GM_u}{2c^2R^3}(3\,R^2 - R_s{}^2)h\upsilon_e \quad (1)$$

Where υ_0 and υ_e are respectively the observed and emitted photon frequency and M_s and M_u are the masses of the photon emitting star and the universe respectively. R_s is the radius of the emitter of the photon, R is the radius of the observable universe and r is the distance between the center of the star and the point at which the observer on the earth is situated. From the above formula we can calculate the gravitational redshift as

$$1 + z = 1 - \frac{GM_u}{2c^2R^3}(3\,R^2 - r^2)/(1 - \frac{GM_u}{2c^2R^3}(3\,R^2 - R_s{}^2)) \quad 2)$$

or alternatively we can calculate the distance of the star from us as,

$$r = \left[z\left(1 - \frac{GM_u}{2c^2R}\right)\left(\frac{2c^2R^3}{GM_u}\right)\right]^{\frac{1}{2}} \quad (3)$$

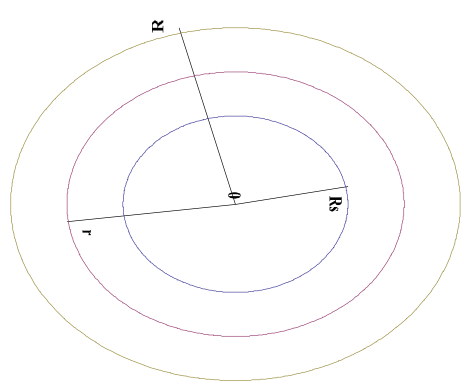

Fig.1 The central sphere represents the star itself. The outer sphere is the sphere of Hubble radius ($\frac{c}{H_0}$). The potential inside point of a sphere at a distance r is shown.

If the condition for $1-\frac{GM_u}{2c^2R^3}(3R^2-R_s^2) = 0$ is satisfied, then there will be no emission of photon of the stars, and for this condition we get $1 \sim \frac{3GM_u}{2c^2R} = \frac{2\pi G R^2 \rho}{c^2}$, where ρ is the density of the universe at this point of the star. So the relation $\rho R^2 = \frac{c^2}{2\pi G} =$ constant which can be used to explain the flat rotation curves of the stars of spiral galaxy (see Fig.3).

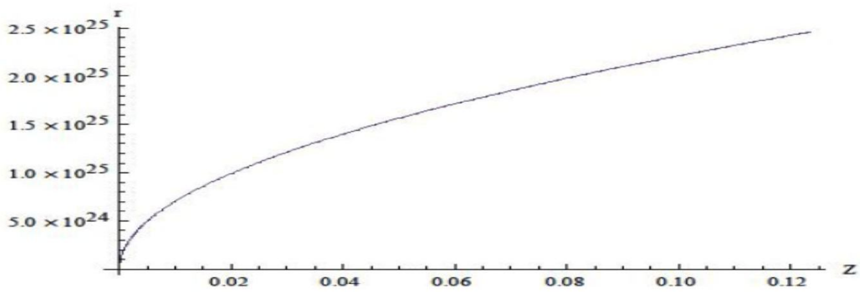

Fig2. The distance r vs. gravitational red shift (z) of the binary stars.

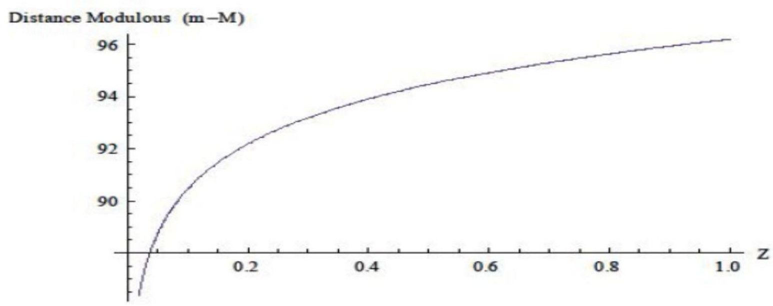

Fig.3 The distance modulous vs. red shift (Z) of stars from the centre.

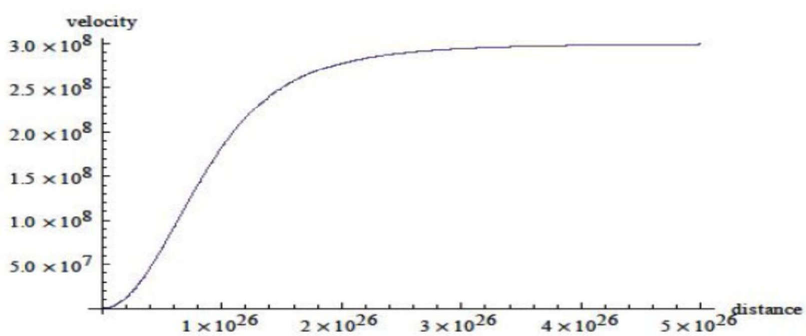

Fig 4 The Distance Modulous (m-M) vs. Redshift (Z)

3. Results and discussions.

In this presentation, we have calculated the distance of the stars from the earth as a function of the gravitational red shift (z). The nature of the function ‘r’ is plotted against z and it has been shown in Fig.2 which has remarkable similarity with the commoving distance of λCDM model[17].The curves qualitatively resembles the observed flat rotation curves (Fig.4).

Another interesting features of the stars are the distance modulous (m-M) vs. redshift graph. It is quite interesting that the curves (Fig.3) are similar to that observed by the others Perlmutter, S. et al[11]. Again we have observed that the product of the critical density and radius of the observable universe satisfies the relation $\rho R^2 = \frac{c^2}{2\pi G} = 2.14655\ 10^{26}\frac{kg}{m}$. Now if we take the standard value of R as $R = 10^{26}$ m then we can find the density of the universe of the order of $10^{-26}\frac{kg}{m^3}$ and the mass of the universe comes out to be of the order of 10^{53} kg.

4. Conclusions:

In this paper, it has been shown that the gravitational red shift plays an important role in the explanations of the cosmological observations . The isotropic and homogenous space in cosmological scales along with Newtonian gravity can explain the observed phenomena qualitatively and becomes vital tools in the study of cosmology. The nature of the distance modulous (m-M) , galaxy rotation curves and the cosmological distances can be well explained by the Newtonian gravity and it does not require any assumptions of the dark energy and dark matter. Our theoretical calculations suggest that the universe is a static rotating object with a time varying angular velocity. This changing angular velocity is equal to the Hubble constant (H_0) at present.

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