

# UNGRAVITY AND APPLICATIONS

N. MEBARKI

Laboratoire de Physique Mathématique et Subatomique, Physics Department, Faculty of Fundamental Sciences, Frères Mentouri University, Constantine, Algeria.

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## Abstract

A model based on the ungravity proposal is presented. Some applications explaining dark energy and dark matter are discussed.

**Keywords:** Cosmic magnetic field, redshift, gravitational waves, cosmological observation.

## Résumé

Un modèle se basant sur une proposition de la ungravitation est présenté. Quelques applications expliquant énergie et matière noires ont été discutées.

**Mots clés :** Champ magnétique cosmique, décalage vers le rouge, ondes gravitationnelles, observation cosmologique.

## ملخص

نموذج يعتمد على فرضية اللاتجاذب و أقترح بعض التطبيقات تفسر الطاقة المظلمة والمادة السوداء نوقشت.

**الكلمات المفتاحية :** الحقل المغناطيسي الكوني، الإنزياح نحو الأحمر، الأمواج الجاذبية، المشاهدة الكسملوجية.

## I. INTRODUCTION

From Hubble's observations of galaxies recession, the redshift of galaxies has made a revolution in our view to the universe. The Hubble law links two important quantities: the cosmological redshift and distance of the observed object (galaxies, quasars, or supernovae...). The distance recalibration has given more accurate determination of the cosmological distances and results a big change of Hubble Constant from 500km/s/Mpc as initial estimation, to around 70km/s/Mpc, the actual accepted value from the cosmic microwave background observations. This latter is one of the key parameters of the modern cosmology.

We investigate a new effect that can be in origin of supplementary redshift contributing with the one of cosmological origin to the total observed redshift of galaxies. Our aim in this work is to prove the origin and estimate the contribution and implications of this non cosmological redshift. This new redshift effect does not result from the universe expansion or the peculiar motion of galaxies. It is due to the photon radiation of high frequency gravitational waves in an external magnetic field. The estimation of this effect on the total observed redshift will serve as another recalibration of the cosmological parameters improving our understanding to the universe.

The following sections are organized as follow: the next section present the methodology to follow; after that, a section to give the results on the non cosmological redshift contribution; then, one for the foundation and argumentation to compare with previous works; finally, discussion and conclusion section to suggest some possible evidence and observational contaminations with this new non cosmological redshift. We take the convention on units as:  $(c, \kappa, \mu_0)$  representing the speed of light, gravitational constant of Einstein equations and the Permeability of the vacuum respectively.

## II. METHODOLOGY: COMPUTE THE REDSHIFT EFFECT

We are interested in the light propagation through spacetime and their gravitational interaction. In the Einstein theory of gravity, the energy momentum tensor part includes the matter and electromagnetic fields contributions. We restrict the study to the vacuum case (absence of matter). The background is a flat spacetime represented by Minkowski metric  $(\eta_{\mu\nu})$ . We treat the weak Linearized gravity [1-3] where the curvature caused by the energy of the electromagnetic waves will be small enough to be a perturbation given by  $(h_{\mu\nu})$  in the first order approximation of the metric as in (1) and the Einstein equations will be as in eq.(2)..

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \quad (1)$$

$$\partial_\alpha \partial^\alpha \bar{h}_{\mu\nu} + \eta_{\mu\nu} \partial_\alpha \partial_\beta \bar{h}^{\alpha\beta} - (\partial_\mu \partial_\alpha \bar{h}^{\alpha\nu} + \partial_\nu \partial_\alpha \bar{h}^{\alpha\mu}) \quad (2)$$

$$= -2T_{\mu\nu}$$

Where  $\bar{h}_{\mu\nu}$  is given by  $\bar{h}_{\mu\nu} = h_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}h^\alpha_\alpha$ . In vacuum and with the traceless transverse gauge as in (3), we define solutions of equations (2) as gravitational waves.

$$\begin{aligned} \partial_\beta \bar{h}^{\alpha\beta} &= 0, \\ h^\alpha_\alpha &= 0 \end{aligned} \quad (3)$$

We assign an energy-momentum tensor  $t_{\mu\nu}$  to the gravitational field itself just as we do for electromagnetism, or any other field theory. Physically, we accept the gravitational radiation that will carry a part of energy-momentum just as any physical radiation does. In the weak Linearized gravity, this contribution can be shown in Einstein tensor as in (4) and (5) by considering the higher orders of the perturbation  $h_{\mu\nu}$ .

$$G_{\mu\nu} = G^{(1)}_{\mu\nu} + G^{(2)}_{\mu\nu} + G^{(3)}_{\mu\nu} + \dots = -T_{\mu\nu} \quad (4)$$

$$t_{\mu\nu} = G^{(2)}_{\mu\nu} + G^{(3)}_{\mu\nu} + \dots \quad (5)$$

We should, at each point in spacetime, average over a small region in order to probe the physical curvature. It is worth a good approximation to take the second order only. For a metric having the form in (1), the gauge invariant measure of the gravitational field will be given as in (6).

$$t_{\mu\nu} = \frac{1}{4} \left\langle \begin{aligned} &\partial_\mu \bar{h}_{\alpha\beta} \partial_\nu \bar{h}^{\alpha\beta} - 2\partial_\alpha \bar{h}^{\alpha\beta} \partial_{(\mu} \bar{h}_{\nu)\beta} \\ &-\frac{1}{2} \partial_\mu \bar{h}_\beta^\beta \partial_\nu \bar{h}^\alpha_\alpha \\ &-(4\bar{h}_{\alpha(\mu} T_{\nu)}^\alpha + \eta_{\mu\nu} h^{\alpha\beta} T_{\alpha\beta}) \end{aligned} \right\rangle \quad (6)$$

The energy carried by the physical gravitational waves is determined by the energy flux  $F$  in the propagation direction that is only the  $t_{0i}$  components of this energy momentum tensor. The energy loss computed with method for the binary pulsar was observed by Hulse and Taylor [4] for PSR1913+16 within an accuracy of 3%. These observations are the evidence of the gravitational waves and give a Nobel Prize to Hulse and Taylor in 1993.

When interested to the gravitational interactions of electromagnetic waves, the methodology to follow is: first, we compute the electromagnetic fields  $F_{\mu\nu}$  energy momentum tensor as in (7), and then compute the solution to the weak Linearized gravity equations as in (2), after that accept solutions with non-vanishing energy momentum tensor of the radiated gravitational waves, finally compute the energy carried by these physically accepted radiations. The energy carried will be seen as a redshift in the electromagnetic wave frequency.

$$T_{\mu\nu} = -(F_{\mu\alpha} F_\nu^\alpha - \frac{1}{4} \eta_{\mu\nu} F_{\alpha\beta} F^{\alpha\beta}) \quad (7)$$

## III. NON COSMOLOGICAL REDSHIFT EFFECT

Following the steps described previously, we have

computed three possible situations. First, plane transverse electromagnetic waves have vanishing energy momentum tensor even for higher orders. Then, plane electromagnetic waves in a transverse magnetic (or electric) mode have non vanishing energy momentum tensor. This situation is more likely to find in electromagnetic waves propagating in a medium. Finally, monochromatic plane transverse electromagnetic waves propagating in the presence of external magnetic fields have a non vanishing energy momentum tensor. This situation can be found in a cosmological context.

Dealing with Minkowski space described by Cartesian coordinates, the external transverse magnetic field  $\vec{B}_{ext} = (B_x, B_y, 0)$  will be static, homogenous and extend in a restricted spatial area where  $(L)$  represents the coherent length of the magnetic fields. The electromagnetic wave is considered to propagate in the  $z$ -direction from  $(-\infty)$ . The electric and magnetic vectors are  $\vec{E}_{photon} = (E_0 \cos(k(t - z)), 0, 0)$  and  $\vec{B}_{photon} = (0, B_0 \cos(k(t - z)), 0)$  where the wave number is  $(k = 2\pi\nu)$  and  $(B_0 = E_0)$  and the photon frequency is  $(\nu)$ . The radiative energy momentum tensor of these electromagnetic fields is only the intersection part of the type fields.

The space of propagation can be decomposed to three parts; the first and the third parts with no magnetic fields and the second where the electromagnetic waves will radiate gravitational waves losing energy in this process. To find this loss in energy, we first solve the equations (2) in the three parts, respecting the continuity condition (8), and then follow the other steps of our methodology.

$$\begin{aligned} \bar{h}_{\mu\nu}^{(I)}(z=0) &= \bar{h}_{\mu\nu}^{(II)}(z=0); \\ \bar{h}_{\mu\nu}^{(II)}(z=L) &= \bar{h}_{\mu\nu}^{(III)}(z=L) \end{aligned} \quad (8)$$

The energy momentum tensor, for the out-going gravitational radiations in the third part, has non-vanishing components, as given in (9), for light waves propagating in an external magnetic field.

$$t_{00} = -t_{03} = \frac{E_0^2 z^2}{4} (B_x^2 + B_y^2) \quad (9)$$

To determine the loss of photon's energy  $E$ , we consider the energy flux  $F$  in the propagation direction that can be given by (10).

$$F = \frac{-dE}{d\Omega dt} = -t^{0i} n_i \quad (10)$$

Where:  $(d\Omega dt)$  represent the variation in time and in the surface perpendicular to the direction of propagation. We set up a new non expansion part of the observed redshift on our result derived from the energy loss due to the gravitational radiation in an external magnetic field from photons. The relation of the non cosmological redshift  $(z_{NC})$ , as in (11), will be exponentially proportional to the transverse external magnetic field strength  $B_{\perp} = \sqrt{B_x^2 + B_y^2}$  and coherent length  $(L)$ .

$$1 + z_{NC} = \exp\left(\frac{1}{12} B_{\perp}^2 L^3\right) \quad (11)$$

The new non expansion part of the redshift must be considered from the widespread magnetic field of galaxies, clusters, filaments in large scale structure [5-6]. The magnetic fields in the universe has take ample evidence in a wide variety of scales and magnitudes: galactic ranges with strength  $1\mu\text{G}$  and coherent length of few kpc, clusters ranges with  $1-10\mu\text{G}$  and coherent length  $10-100\text{kpc}$  and filaments ranges with  $0.3\mu\text{G}$  and coherent length  $1\text{Mpc}$ . This proved redshift has a significant amount for the magnetic field that has, as an average, strength of  $1\mu\text{G}$  that spread on a coherence length of  $100\text{kpc}$ . The magnitude of the redshift  $z_{NC}$  for cosmic magnetic fields will be  $13.45 \times 10^{-3}$  and grow when the field is stronger or have more coherence length. The spacetime curvature of Schwarzschild spacetime will also contribute to our redshift as given in (12) as a first approximation to the situation.

$$1 + z_{NC} = \exp\left[\frac{1}{4} B_{\perp}^2 \left(\frac{1}{3} L^3 + mL^2 + 4m^2 L + 8m^3 \ln[1 - 2m/(2m)]\right)\right] \quad (12)$$

Our amplifier redshift depends on some fundamental properties of galaxies and clusters. These three parameters are the magnetic field strength  $(B)$ , the effective spatial spread or the coherence length  $(L)$  and the total mass of galaxies or clusters  $(m)$  included in the total mass of the luminous object causing the spacetime curvature. We have to associate the two redshifts in the global observed redshift  $(z_{observed})$ , as given in (13), as done by many authors [7].

$$1 + z_{observed} = (1 + z_C)(1 + z_{NC}) \quad (13)$$

$(z_C)$  is the cosmological redshift due to the expansion and  $(z_{NC})$  is the non cosmological redshift or the non expansion origin such as our redshift. This new redshift effect will be like an amplifier of the observed cosmological redshift of galaxies due to their own magnetic field or for galaxies in clusters of filaments by the intergalactic magnetic field.

## IV. FOUNDATION AND ARGUMENTS

The propagation of electromagnetic waves in external magnetic fields is studied previously and referred as Gertsenshtein effect. In some works [8-16], the Gertsenshtein effect and its inverse are viewed as processes of photon graviton conversion. They have used some probability  $P = 4\pi G B^2 L^2$  of conversion depending on the external magnetic field and its coherence length. The photon graviton conversion has been explored as a possible mean to generate the observed anisotropies of the cosmic microwave background. Cillis and Harrari [17] estimate the faint possibility of conversion that will tend to be smaller in the existence of plasma. The plasma will make the probability

depending to the photon frequency and so cannot produce detectable anisotropies in the cosmic microwave background. Ejlli [18] present a new paper in the same subject. Pshirkov and Baskaran [19], contrarily to the previous view and in the presence of a strong enough high frequency gravitational wave background, significant anisotropies in the microwave background will be produced by the inverse Gertsenshtein effect.

The non cosmological redshift effect is believed to clarify some misunderstanding done in the construction of the conversion view. First, The Einstein field equations and the electrodynamics equations in curved space time that describe the Gertsenshtein effect and its inverse are classical theories do not deal with quanta and we cannot deduce a conversion between the photon and the graviton. Second, the probability of conversion was a ratio between the carried energy and the initial energy of electromagnetic waves; representing more a transferred energy than a probability. Third, the non cosmological redshift is computed by the loss energy method that was in origin of the observations of Hulse and Taylor. For the special case of microwave background anisotropies, the high frequency gravitational waves background has no evidence of black body spectrum shape and their conversion to microwave photons will produce a random spectrum. The non cosmological redshift effect is believed to be more coherent and consistent with a method that give observed results.

## V. DISCUSSION AND CONCLUSION

As an application, this effect can be an explanation of some anomalous redshift as a discordant behavior of our amplifier redshift such as: Stephan Quintet the compact interacting galaxy group, the galaxy-quasar associations and the discordant redshifts of some types of galaxies [20-21]. We have found that in all the above mentioned cases, a relation between these anomalous redshifts and the existence of strong sources of magnetic field supporting the nature of our non cosmological redshift.

Other implications are possible observational measurement contamination. Several models predict a primordial cosmic magnetic field from the inflation, given a possible primary and secondary CMB anisotropies can be from the non cosmological redshift origin. The redshift observations of the Supernovae SN Ia have to be amplified by this effect. These two possible observational measurement contaminations affect the cosmological parameters estimations through CMB and SN Ia measurements. The observational measurements of the cosmic magnetic field by the Faraday rotation [22], defined in (14) and (15), have to consider this effect and reconsider the actual measured magnetic fields and electron densities of galactic and intergalactic medium.

$$RM(z_s) = 8.1 \times 10^5 \int_0^{z_s} n_e B_{||} (z) (1+z)^{-2} dl(z) \quad (14)$$

$$dl(z) = 10^{-6} H_0^{-1} (1+z)(1+\Omega z)^{-1/2} dz \quad (15)$$

Where: ( $z_s$ ) source of light redshift, ( $B_{||}$ ) longitudinal magnetic field and ( $n_e$ ) electron density in the medium. The total observed redshift will be amplified compared to the case without magnetic fields in the line of sight trajectory. Due to this non cosmological redshift, objects in the existence of magnetic field will be apparently more distant. This effect on the distance of cosmic objects estimation is crucial in many fields of astrophysical study, such as the ultrahigh energy cosmic rays UHECR, Greisen–Zatsepin–Kuzmin cutoff [23] and the sources identification problem [24].

It is worth to mention that this non cosmological contribution will account for the recalibration of Hubble parameter and the dark matter content of galaxies and clusters.

Our preliminary results are qualitative and not quantitative (more studies are under investigations).

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