Draft version July 31, 2016
Preprint typeset using LaTeX style AASTeX6 v. 1.0

CONSERVATION LAWS AND ENERGY BUDGET IN A STATIC UNIVERSE

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ABSTRACT

The universe is characterized by large concentrations of energy contained in small, dense areas such as galaxies, which radiate energy towards the surrounding space. However, no current theory balances the loss of energy of galaxies, a requirement for a conservative universe. This study is an investigation of the physics nature might use to maintain the energy differential between its dense parts and the vacuum. We propose time contraction as a principle to maintain this energy differential. Time contraction has the following effects: photons lose energy, while masses gain potential energy and lose kinetic energy. From the virial theorem, which applies to a system of bodies, we find that the net energy resulting from the gain in potential energy and the loss in kinetic energy remains unchanged, meaning that the orbitals of stars in galaxies remain unaffected by time contraction. However, each object in a galaxy has an internal potential energy leading to a surplus of energy within the object. This internal energy surplus should balance with the energy radiated at the level of a galaxy. We illustrate this principle with a calculation of the energy balance of the Milky Way.

Keywords: conservative universe; energy budget; heat death of the universe; static universe

1. INTRODUCTION

We are in a universe governed by energy fluxes and exchanges either in the form of waves or particles in motion. Energy flows in space allow life to exist. The universe is characterized by vast concentrations of energy confined in small spaces such as galaxies in the immensity of a surrounding vacuum. Supermassive black holes at the center of galaxies contain a large portion of this energy. However, we do not understand how such energy segregation came into existence. Most of the energy in the universe radiates outward from these dense galaxies. The supermassive black holes at the center of galaxies may be the cosmic embryos that give rise to the birth of the stars and planets. Massive particles and atoms are attracted by gravitation to the dense points of the universe, a process which maintains the segregation between the vacuum and the dense parts. Because galaxies radiate a large amount of energy, they appear to have energy deficits. Here we investigate the physics of how the energy difference between the vacuum and the dense parts of the universe is maintained.

Many profound questions related to this issue have not yet been answered. Most notably, how did the galaxies come into existence? Do the galaxies have a life time? About 90% of galaxies are dwarf galaxies, and most are elliptical or lenticular in shape. Large spiral galaxies such as the Milky Way are the minority. What are the conditions for galaxies to form stars? For a galaxy to form a spiral it must rotate rapidly. We have observed powerful jets of particles ejected from galaxy central supermassive black holes in the direction of the axis of rotation of the galaxy. These jets, together with a vortex in the black hole, supposedly induce the galaxy to rotate, and then form arms and spirals of stars. A galaxy which has few stars radiates less energy than a galaxy forming stars in abundance. Without a doubt, the lives of galaxies should be considered among the greatest mysteries in the universe.

Nowadays, many people consider the static model of the universe outdated. Nevertheless, we believe there is a lesson to learn when considering the energy balance of the universe. After all, energy conservation is a cornerstone of physics. The elusive dark energy encourages us to inspect the energy balance of the universe from a different angle, in a static universe.

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2. THE ENTROPIC PRINCIPLE

The entropic principle in a thermal context is regarded as an indicator of the effectiveness or usefulness of a particular quantity of energy. Mixing a hot supply of energy with a cold one produces a mix of intermediate temperature, which is less effective. If we apply this principle at the level of the universe, it will eventually lead to the so-called "heat death of the universe", when the outbound and inbound energy fluxes of galaxies reach an equilibrium that should stay at low temperature provided that the universe does not maintain its present energy segregation between the vacuum and its denser parts. The inbound energy flow from cosmic radiations is much lower than the outbound flow radiating from a galaxy, giving galaxies the appearance of an energy deficit. Present theories do not permit us to balance this deficit.

3. PHOTON-PARTICLE INTERACTIONS

We could conceive of a wind of particles that sweeps the remnant undulating energy in the vacuum of the universe in something like the Compton effect and brings it back to the denser parts of the universe to enrich the galactic gas and nebulae where new stars are formed. This scenario appears to be very unlikely as the inbound flux of cosmic rays is very low, and known interactions between low-energy photons and particles do not subtract energy to the photons. In Thomson scattering, the scattered photon energy is left at the same level, and an increase of the scattered photon energy is obtained in the photon-particle interaction of the Sunyaev-Zeldovich effect. Compton scattering, which subtracts energy from the photons, is known to occur for high-energy light sources such as X-rays and gamma rays. Furthermore, there is no evidence that cosmic rays come from outside the galaxy, although most cosmic rays originate from outside the solar system (Gaisser 1990). Cosmic rays are composed primarily of high-energy protons and atomic nuclei. Some cosmic rays originate from supernovae (Ackermann et al. 2013); however, this is not the only source of cosmic rays. Active galactic nulei also ought to produce cosmic rays (HESS Collaboration 2016).

Compton scattering is an interaction between photons and charged particles such as electrons (Motz et al. 1961; Fuchs et al. 2015). During this interaction, part of the photon energy is transferred to the recoiling electron. The scattering of the photons produces a blurring effect of light.

Thomson scattering intervenes between photons having much lower energies compared to the mass energy of the particle (Gell-Mann & Goldberger 1954; Moore et al. 1995; Glenzer et al. 1999). This interaction occurs between free charged particles and photons. Thomson scattering is an elastic scattering, meaning that the energies of the particles and photons remain unchanged in this interaction. However, the wave is scattered, producing a blurring effect. This interaction produces polarization of light in the direction of its motion. The cosmic microwave background ration (CMBR) is linearly polarized and as such must have undergone Thomson scattering.

The Sunyaev Zel'dovich effect is an interaction occurring between the CMBR and high-energy particles, which produces an inverse Compton effect (Sunyaev & Zel'dovich 1972). It is the result of high-energy electrons transferring some of their energy to the photons. This interaction is observed in the hot gases contained in galaxy clusters, which change the frequency of the CMBR.

The images of galaxies we observe in the sky are not blurred, meaning a priori that no photon-particle interactions occur for these wave frequencies. For all these reasons we dismiss photon-particle interaction as a mechanism to regulate photon energy in the vacuum.

4. STATIONARY WAVES

Stationary waves, also called standing waves, are formed by the superposition of two waves of the same amplitude and frequency moving in opposite directions (Born 1980). The result of this interference is a wave with no net propagation of energy. The locations at which the amplitude of the wave intersect with the x-axis are fixed points called the nodes, and the part of the wave contained between two nodes oscillates upside down in a given amplitude range. Because of the vibration of the standing wave, some energy would be stored in the vacuum, but with no energy being transmitted. Because of the isotropy of the universe we can assume that for every wave there exists another wave of same frequency and amplitude moving in the opposite direction. Standing waves may cause an accumulation of energy in the vacuum, but do not explain redshifts. Nevertheless, we would still need additional mechanisms to regulate the energy budget of galaxies and of the universe as a whole.

5. TIME CONTRACTION

5.1. *Gravitational redshift and potential energy*

Another way to look at the problem of energy budget in the universe is by considering gravitational redshift, a phenomenon based on the principle of energy conservation. Einstein imagined the following thought experiment. Let

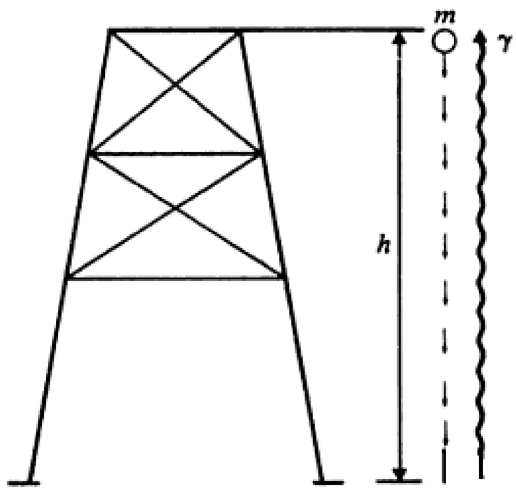

Figure 1. A photon climbs up to a heigh h. Then, the photon is converted at the top of the tower into a mass m, and falls back to the ground. Perpetual motion is created unless the photon loses energy while climbing in the gravitational field.

us consider a photon moving away from the ground surface in the direction of the sky up to a given height h. At this height, the photon is converted into mass according to $E = mc^2$, and then falls back to the ground (see Figure 1).

In this system there is an apparent gain of energy from the time the photon left the ground to the time when the mass came back to its initial position due to the potential energy gain when the photon moved upwards. This energy gain, of course is paradoxical. In terms of energy conservation, when considering the energy of a photon, we associate it with the potential energy of its virtual mass counterpart. In order to maintain the system at constant energy, the photon must lose energy when moving away from a mass in a gravitational field, which causes a redshift. The reciprocal is also true: when a photon moves towards a mass in a gravitational field, it is blueshifted. Another solution of the gravitational redshift is obtained with general relativity using the Schwarzschild metric. Both methods give similar solutions that converge asymptotically when the gravitational field is weak.

The gravitational redshift from mass-energy equivalence, which stems from special relativity, is derived as follows. By converting the photon energy into a rest mass we get $E = h\nu = mc^2$. The gravitational potential energy is:

$$U = -\frac{GMm}{r} = -\frac{GMh\nu_0}{rc^2}\,, \tag{1}$$

where ν is the light-wave frequency, G the gravitational constant, M the mass producing the gravitational field, r the distance between the center of gravity of the mass M and the photon, c the speed of light, and h the Planck constant.

Hence, the frequency change of a photon of frequency ν_0 moving relative to a gravitational mass is $h\nu = h\nu_0\left(1 - \frac{GM}{rc^2}\right)$. Therefore, we get:

$$\frac{\nu}{\nu_0} = 1 - \frac{GM}{rc^2}\,. \tag{2}$$

The equation of the gravitational redshift from general relativity with the Schwarzschild metric is obtained from the equation (Moore 2012):

$$\delta\tau = \left(1 - \frac{2GM}{rc^2}\right)^{\frac{1}{2}} \delta t\,, \tag{3}$$

where $\delta\tau$ is the proper time interval, and δt the Schwarzschild time interval.
Because the light wavelength can be expressed as a function of the time interval, $\lambda = c\delta\tau$, we get the gravitational redshift

$$\frac{\nu}{\nu_0} = \left(1 - \frac{2GM}{rc^2}\right)^{\frac{1}{2}}\,, \tag{4}$$

where ν is the light-wave frequency, G the gravitational constant, M the mass producing the gravitational field, r the distance between the center of gravity of the mass M and the photon, and c the speed of light.

For weak gravitational fields, we can use the Taylor approximation $(1-x)^{\frac{1}{2}} \approx 1 - \frac{x}{2}$ when x is small; hence, we obtain the same equation as the gravitational redshift obtained from mass-energy equivalence.

From general relativity, moving away from the ground surface at increasing altitude causes the clock to tick more rapidly, meaning that time is contracting as in the dichotomous cosmology presented in Heymann (2014a,b, 2015). Based on the principle of time contraction in a static universe, we are able to derive Etherington's distance-duality equation (Heymann 2015). This principle as an explanation of cosmological redshift is worth considering. One way to look at the problem of photon and matter energy is by linking time with energy, meaning that time contraction is causing both a decrease in the photon energy and an increase in the potential energy of a mass. If this is valid in a gravitational field, does it hold in general? From the mass-energy equivalence, there is an implicit duality between photon and mass, in which energies appear to be indissociable from one another.

Emmy Noether proved a theorem according to which every differentiable symmetry of the action of a physical system has a corresponding conservation law. From the Noether theorem, the law of conservation of energy follows from time homogeneity, meaning the Lagrangian is time-translation invariant. Time is preponderant in energy conservation. In special relativity we learn that time dilation has a direct effect on the energy balance between reference frames. In general relativity, the flow of time and gravitational potential are directly linked. This is a very simple principle that nature could use to regulate energy fluxes in the universe. Accordingly, time contraction would allow maintenance of the energy differential between the vacuum and the massive parts of the universe.

5.2. *Effect of time contraction on the photon energy and the energy of a mass*

In the dichotomous cosmology (Heymann 2015), we found that the time-contraction factor is expressed as $\gamma_t = \exp(-H_0 t)$. Therefore, the energy of the photon decreases according to an exponential law of the form:

$$E_{photon}(t) = E_0 \exp(-H_0 t)\,, \tag{5}$$

where H_0 is the Hubble constant, E_0 the initial photon energy, and t the time.

Because the gain in potential energy is in the same proportion as the photon energy loss from mass-energy equivalence, the gravitational potential energy of a mass shall increase according to the law:

$$U_{mass}(t) = U_0 \exp(-H_0 t)\,, \tag{6}$$

where U_0 is a negative potential energy at time zero, H_0 the Hubble constant, and t the time.

We still need to quantify the effect of time contraction on the kinetic energy of a mass. As time contracts, a clock is ticking more rapidly, and an object in motion appears to slow down. The apparent velocity of an object decreases in direct proportion to the time-contraction factor. Because the kinetic energy is expressed as $K = \frac{1}{2}mv^2$, the kinetic energy of a mass decreases by the square of the time-contraction factor. Hence, the kinetic energy of a mass decreases according to the law:

$$K_{mass}(t) = K_0 \exp(-2H_0 t)\,, \tag{7}$$

where K_0 is the kinetic energy at time zero, H_0 the Hubble constant, and t the time.

These are the laws that we propose regulate the energy budget of the universe.

Let us show that for a star in orbit in a galaxy, its orbital radius remains unchanged under time contraction. The total energy of the star with respect to other bodies in the galaxy is expressed as follows:

$$E_{tot}(t) = U + K = U_0 \exp(-H_0 t) + K_0 \exp(-2H_0 t)\,. \tag{8}$$

Let us take the time derivative of E_{tot}; therefore, we get:

$$\frac{dE_{tot}}{dt}(t) = -H_0\, U_0 \exp(-H_0 t) - 2H_0\, K_0 \exp(-2H_0 t)\,. \tag{9}$$

We evaluate this expression at $t = 0$, hence:

$$\frac{dE_{tot}}{dt} = -H_0\, U_0 - 2H_0\, K_0\,. \tag{10}$$

From the virial theorem, which applies to stable systems composed of many bodies, we get:

$$2K_0 + U_0 = 0\,, \tag{11}$$

where K_0 is the kinetic energy and U_0 the potential energy between the bodies.

From (10) and (11), we obtain $\frac{dE_{tot}}{dt} = 0$. Therefore, the total energy of a star in orbit remains unchanged under time contraction, meaning its orbital radius is not affected. This is the condition required to have stable galaxies in the universe.

The virial theorem only considers the potential energy between the bodies of the system. Because each object in a galaxy, either solid or fluid, has an internal potential energy, and that the kinetic energy inside a solid or fluid at rest is negligible, there is a surplus of potential energy from (6). This surplus of potential energy is converted into internal energy within the object. This is the principle we propose to balance the energy radiated by galaxies.

5.3. *Energy balance of the Milky Way*

From this principle, we would expect that the surplus of internal potential energy due to time contraction, at the level of a galaxy, balances with the outbound radiation flux. Let us do a rough estimation for the Milky Way. The luminosity of the Milky Way is estimated to be about $3.8\times10^{10} L_{\odot}$(Flynn et al. 2006), with the Sun radiating about 4.6 $\times10^{26}$ watts, leading to an overall radiation of about 1.74×10^{37} watts. We need to estimate the sum of the internal potential energy of each object contained in the Milky Way.

For a spherical solid, the internal potential energy is given by the equation (Kittel et al. 1973):

$$U_{sphere} = -\frac{3GM^2}{5R}\,, \tag{12}$$

where G is the gravitational constant, M the mass, and R the radius of the sphere.

Let us consider the estimated mass of the Milky Way including dark matter to be about 3.0×10^{42} kg or 1.5 trillion solar masses. According to most recent estimates the apparent mass of the Milky Way is somewhere between 1 to 3 trillion solar masses. In Heymann (2016) we show that the dark matter of a spiral galaxy is due to a correction coefficient applied to Newton's force in a disk. Hence, we need an estimate of the total baryonic mass of the Milky Way, which is approximatly one fifth of the apparent mass or about 6.00×10^{41} kg. The mass of the cental supermassive black hole Sagittarius A* is about 4.0 $\times10^{6}$ solar masses (Boehle et al. 2016), and its radius about 31.6 solar radii. Hence, the potential energy of Sagittarius A* from (12) is -1.15×10^{53} joules. We have used a gravitational constant G of 6.67×10^{-11} $m^3kg^{-1}s^{-2}$.

Because the majority of stars in the Milky Way are red dwarfs, and due to other dense objects such as neutron stars, white dwarfs, and black holes, the average radius of objects in the Milky Way is lower than the radius of the Sun. An estimate of 100 million neutron stars in the Milky Way was obtained by estimating the number of stars that have gone supernova (Camenzind 2007). Let us assume that these 100 million neutron stars in the Milky Way have an average mass of 1.35 solar masses. From the density of neutronium, we can infer that the radius of such a neutron star would be about 15 km. Therefore, from (12), the internal potential energy of those 100 million neutron stars all together is -1.92×10^{54} joules. According to Plait (2009) there are about 10 million black holes in the Milky Way. Let us assume that these 10 million black holes have an average mass of ten solar masses and a radius of 45 km. The radius of a black hole is computed from the "photon sphere" which is 1.5 times the Schwarzschild radius. The internal potential energy of those 10 million black holes all together is -6.42×10^{54} joules from (12). Let us assume there are 2 billion white dwarfs having an average mass of half a solar mass and a radius equal to the radius of the earth. The internal potential energy of those 2 billion white dwarfs is -1.28×10^{52} joules. Let us assume there are 300 billion stars lefts (mainly red dwarfs) having an average radius of 0.3 solar radii and average mass of 8.0×10^{29} kg. The internal potential energy of those 300 billion stars all together is -3.68×10^{52} joules from (12).

Adding together the potential energies of Sagittarius A*, the 100 million neutron stars, the 10 million black holes, the 2 billion white dwarfs, and the 300 billion stars, the overall internal potential energy of the Milky Way is estimated to be about -8.49×10^{54} joules. The densest objects, although not the most numerous, contribute the greatest share of to the internal potential energy of the Milky Way. For this reason, black holes and neutron stars are responsible for most of the Milky Way's internal potential energy. The calculations for the internal potential energy of objects in the Milky Way are summarized in Table 1.

When multiplying the overall internal potential energy of the Milky Way by the Hubble constant of $H_0 = 2.16\times10^{-18}$ per second (corresponding to 67.3 $kms^{-1}Mpc^{-1}$), we obtain a surplus of internal energy of 1.83 $\times10^{37}$ watts. We compare this value with the estimate of the energy radiated of 1.74×10^{37} watts. Of course this is a crude estimate, but from our calculations the internal energy surplus of the Milky Way is the same order of magnitude as the energy radiated by the galaxy.

Table 1. Internal potential energy of objects in the Milky Way

Object	Number	Mass	Radius	Potential energy
Sagittarius A* (central black hole)	1	$4.0\times10^{6}\ M_{\odot}$	2.2×10^{7} km	$-1.15\ \times10^{53}$ joules
Black holes	10 million	$10\ M_{\odot}$	45 km	-6.42×10^{54} joules
Neutron stars	100 million	$1.35\ M_{\odot}$	15 km	-1.92×10^{54} joules
White dwarfs	2 billion	$0.5\ M_{\odot}$	6.30×10^{3} km	-1.28×10^{52} joules
Remaining stars (mainly red dwarfs)	300 billion	$0.4\ M_{\odot}$	2.09×10^{5} km	-3.68×10^{52} joules
Total	–	–	–	-8.49×10^{54} joules

6. CONCLUSION

According to the entropic principle in a thermal context, mixing a hot source with a cold source produces a mix of average temperature that is less useful from a mechanical standpoint. The universe is based on energy fluxes and exchanges, and galaxies radiate a large amount of energy. For the universe to be conservative there must be a mechanism to balance the energy deficit of galaxies, otherwise it will lead to the so-called "heat death of the universe". We analyzed photon-particle interactions, and concluded that such interactions cannot regulate the energy budget of the universe. We propose time contraction as a principle to regulate the energy balance in the universe, which would decrease photon energy, increase the potential energy of a mass, and decrease the kinetic energy of a mass. From the virial theorem, which applies to systems of bodies, we find that the net energy resulting from the gain in potential energy and loss in kinetic energy remains unchanged, meaning that the orbitals of stars in galaxies remain unaffected by time contraction. However, each object in a galaxy has an internal potential energy leading to a surplus of energy within the object. At the level of a galaxy, this internal energy surplus should balance with the energy radiated. We illustrated this principle with a calculation of the energy balance of the Milky Way.

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