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# Feasibility of Conversion of Dark Energy into Useful Energy

Bhuvan Bhasker Srivastava
*Department of Physics, Shia P.G. College (An Associated college of University of Lucknow), Lucknow, U.P. India , PIN- 226020.*

***Abstract***
*The Big Bang gives the universe the force to continue to expand, but it would stand to reason that gravity would eventually slow this force down. When gravity begins to overpower this force the universe would begin to contract. Several cosmological observations demonstrated that the universe is expanding. By studying supernovae type Ia (SNe Ia), it was found that the universe's expansion is speeding up rather than slowing down, as was expected if only matter and radiation were present. This unknown 'anti-gravity' force at work is termed 'dark energy'. Dark energy or cosmological constant or quintessence is an unknown form of energy. This is the dominant component of the physical Universe. This is hypothesized that dark energy permeates all the space, tending to accelerate the expansion of the universe. Although the idea of dark energy is new, the fact that the Universe is expanding has been understood since the late 1920's. Telescope observations show that galaxies, no matter where they are in space, are becoming more distant all the time. The farther away a galaxy is, the faster it is receding in accordance with Hubble's Law. The best current measurements indicate that dark energy contributes 68.3% of the total energy in the observable universe; the mass-energy of dark matter and ordinary matter contribute 26.8% and 4.9%, respectively; and other components such as neutrinos and photons contribute a very small amount. Again on a mass–energy equivalence basis, the density of dark energy (6.91 × $10^{-27}$ kg/m$^3$) is very low, much less than the density of ordinary matter or dark matter within galaxies. However, it comes to dominate the mass–energy of the universe because it is uniform across space. Besides discussing the origin and nature of dark energy, this paper overviews the various models of dark energy and investigates the theoretical options for conversion of dark energy into usable energy.*

***Keywords:*** *Dark energy, Dark matter, ΛCDM universe, Cosmological constant, Supernovae Ia etc.*

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## I. Introduction

Several cosmological observations demonstrated that the expansion of the universe is accelerating. Einstein's General Theory of Relativity predicts that the Universe must not be static, but Einstein refused to believe it. Edwin Hubble began studying the distances of galaxies and compared them to the speed at which they were moving away from Earth. He found that the galaxies that were farther away were moving at a higher speed. This is what led Hubble to the conclusion that the universe is expanding. As evidenced by their red shifts, the distant galaxies in all directions are moving away from the Earth. Hubble's law describes this expansion. He found the following linear relation, between a galaxy's recession velocity, v, and its distance to us, D, called the Hubble law[1] :

$$v = H_0 D$$

where $H_0$ is the present day value of the Hubble parameter, also known as the Hubble constant.
Strictly speaking, the linear Hubble law only holds at non-relativistic speeds where the redshift z can be accurately expressed as z = v/c. The redshift is defined as the wavelength shift of spectral features from the emission wavelength $\lambda_e$ to the observed wavelength $\lambda_o$:

$$z = \frac{(\lambda o - \lambda e)}{\lambda e}$$

**Evidences of existence**
The following evidences establish that dark energy exists:

**(1)Supernova**

Cosmic acceleration was initially discovered by examining the apparent brightness of tens of distant Type Ia supernovae. Supernovae are useful for cosmology because they are excellent standard candles [2] across cosmological distances because of their extreme and consistent luminosity. They allow the expansion history of the universe to be measured by looking at the relationship between the distance to an object and its redshift, which gives how fast it is receding from us. The relationship is roughly linear, according to Hubble's law. It is relatively easy to measure redshift, but finding the distance to an object is more difficult. Usually, astronomers use standard candles. Standard candles are the objects for which the intrinsic brightness, the absolute magnitude, is known. This allows the object's distance to be measured from its actual observed brightness, or apparent magnitude.

Recent observations of supernovae are consistent with a universe made up 68.3% of dark energy and 31.7% of a combination of dark matter and baryonic matter.

**(2)Cosmic microwave background**

Measurements of cosmic microwave background (CMB) anisotropies indicate that the universe is close to flat. For the shape of the universe to be flat, the mass/energy density of the universe must be equal to the critical density. The total amount of matter in the universe (including baryons and dark matter), as measured from the CMB spectrum, accounts for only about 30% of the critical density. This implies the existence of an additional form of energy to account for the remaining 70%. After analyzing the collected data which was collected in seven years by Wilkinson Microwave Anisotropy Probe (WMAP) spacecraft, it was estimated that the universe is made up of 72.8% dark energy, 22.7% dark matter and 4.5% ordinary matter. More precise Work done in 2013 based on the Planck spacecraft observations of the CMB provided a more accurate estimate of 68.3% of dark energy, 26.8% of dark matter and 4.9% of ordinary matter [3].

**(3)Large scale structure**

The study of large scale structure which governs the formation of structures like stars, quasars, galaxies and galaxy groups and clusters in the universe, reveals that dark matter is nearly 30 percent. Then there is a deficit of almost 70 percent; the supernovae observations tell us that the missing component is an exotic form of energy with large negative pressure dubbed as dark energy[4,5,6,7]. The recent observations on baryon oscillations provides yet another independent support to dark energy hypothesis. The Wiggle Z galaxy survey of more than 200,000 galaxies, provided further evidence towards the existence of dark energy. The Wiggle Z survey from the Australian Astronomical Observatory scanned the galaxies to determine their redshift.

**(4)Late-time integrated Sachs-Wolfe effect**

Accelerated cosmic expansion forms gravitational potential wells and hills to flatten as photons pass through them, producing cold spots and hot spots on the CMB aligned with vast supervoids and superclusters. This is called late-time Integrated Sachs–Wolfe effect (ISW). ISW is a direct signal of dark energy in a flat universe [8].

**(5)Observational Hubble constant data**

A new approach to test evidence of dark energy through observational Hubble constant [H(z)] data (OHD) has gained significant attention in recent years. The Hubble constant is measured as a function of cosmological redshift. OHD directly tracks the expansion history of the universe by taking passively evolving early-type galaxies as “cosmic chronometers”. From this point, this approach provides standard clocks in the universe. The core of this idea is the measurement of the differential age evolution as a function of redshift of these cosmic chronometers. Thus, it provides a direct estimate of the Hubble parameter [ $H(z) = -1/(1+z)dz/dt \approx -1/(1+z)\Delta z/\Delta t$ ]. The merit of this approach is clear: the reliance on a differential quantity, $\Delta z/\Delta t$, can minimize many common issues and systematic effects; and as a direct measurement of the Hubble parameter instead of its integral, like supernovae and baryon acoustic oscillations (BAO), it brings more information and is appealing in computation. For these reasons, it has been widely used to examine the accelerated cosmic expansion and study properties of dark energy[9].

**Theories of explanation**

The following theories explain the cause of existence of dark energy.

(1)**Lambda-CDM model**

The most logical and simple explanation of existence of dark energy is that it is simply the "cost of having space". Obviously this volume of space has some intrinsic, fundamental energy. This is the cosmological constant ($\Lambda$). From Einstein’s well known energy – mass relation[ $E = mc^2$] and Einstein's general theory of relativity ,this energy must also have a gravitational effect. Dark energy is also known as vacuum energy because it is the energy density of empty vacuum. In fact, most theories of particle physics predict vacuum fluctuations that would give the vacuum this sort of energy. This is related to the Casimir [10], in which there is a small suction into regions where virtual particles are geometrically inhibited from forming (e.g. between plates with tiny separation). The cosmological constant is of the order of $10^{-29}$ gm/cm$^3$. The cosmological constant has negative pressure equal to its energy density and therefore causes the accelerated expansion of the universe. The reason why a cosmological constant has negative pressure can be seen from classical thermodynamics; Energy must be lost from inside a container to do work on the container. A change in volume dV requires work done equal to a change of energy −P dV, where P is the pressure. But the amount of energy in a container full of vacuum actually increases when the volume increases (dV is positive), because the energy is equal to ρV, where ρ is the energy density of the cosmological constant. Therefore, P is negative and, in fact, P = − ρ. The current standard model of cosmology which is the the Lambda-CDM model, includes the cosmological constant as an essential feature.

**(2)Quintessence**

In this model of dark energy, the observed acceleration of the scale factor is caused by the potential energy of a dynamical field. This dynamical field is referred as quintessence field. Quintessence differs from the cosmological constant in that it can vary in space and time[11].

**(3)Variable Dark Energy models**

Recent observational data have ascertained the density of dark energy. Using baryon acoustic oscillations, the effect of dark energy in the history of the Universe can be investigated and therefore the parameters of the equation of state of dark energy can be constrained. One of the proposed solutions to get closer to answering the question of dark energy, is to assume that it is variable. Several models of variable nature of dark energy like Chevallier–Polarski–Linder model (CPL model), Barboza & Alcaniz model and Wetterich Model have been proposed.

## II. Results and discussions

This has been experimentally established that the Universe is made up of 68.3% of dark energy, 26.8% of dark matter and 4.9% of ordinary matter, Which means that the major portion of energy is in the form dark energy. How this energy which is responsible for the acceleration of the galaxies and thereby expansion of the universe can be utilized for the useful work is a great challenge to the physicists. To extract useful energy from the dark energy, following theoretical models are proposed. We will now discuss the design and feasibility aspects of these models. Let us imagine that we have constructed a 10 billion light year long rope and if somehow we could hook up this rope to a distant quasar and have it pull the rope. Then this pulling force will give useful energy. But for this we must have a 10 billion light year rope, and to reach up to the nearest quasar away ten billion light years. If these conditions are fulfilled, only we can think about extraction of work from such type of system. Moreover, if the above conditions are somehow satisfied, it is definitely not practical unless we have a free supply of very strong ropes that are billions of light years long. Moreover The universe is expanding at 74 km/sec/Mpc. So let's take two heavy objects and place them far from any galaxy cluster or other influence and space them just one parsec apart (3.26 light years). Then they will effectively be moving a part at 7.4 km/sec. Now imagine that the monomolecular filament rope between the objects puts a force on the objects that will decelerate the objects. Then during the time that they are decelerating, one can extract work from the objects. That work per second comes from the force the rope is exerting being applied over the 7.4 cm/sec that the objects are moving apart. However, once the force causes their relative velocity to drop to 0, one will not be able to get any more energy from the objects since they are no longer moving apart. There will still be a constant force on the rope but we need to have a force applied over a distance to get work. Once the rope's force has gotten their relative velocity to zero, the two objects are like a gravitational bound system and it will stop "expanding". Now as the dark energy is causing an accelerating expansion of the universe which means that the two objects are not just "moving" apart at constant 7.4 cm/sec but that this velocity is actually increasing with time. So if the rope is set up such that the force it is exerting on the objects results in an deceleration that is slightly smaller than this cosmic acceleration, then one can extract work continuously and indefinitely. Here this is important to note that if the rope exerts more force that causes a deceleration larger than the cosmic acceleration then the objects will eventually stop moving apart and the work which one can extract will drop to zero again. This is important to note that from just the normal expansion of the universe one can only extract a finite total amount of energy, but that with the accelerated expansion you can extract a small but positive amount of energy per second forever. However, our rope needs to get longer and longer with time at the rate of 7.4 cm/sec. The rope needs to get longer because we have to have our very small force applied to continuously moving objects to get work done. Since it will take continuous energy to make a continuously lengthening rope, and we cannot win this battle by starting with objects that are further apart since then the rope is lengthening at an even faster rate than the 7.4 cm/sec of this example. we can increase the energy per second you extract by making the objects more massive, but then the force on the rope increases so we need to make a thicker rope. The problem that needs to be solved is the energy cost of the continuously lengthening rope. The bottom line is that this free energy project is impractical, even though it is theoretically possible.

There's also an interesting idea of exploring the possibility of using dark energy and dark matter. The idea was that if we could simulate or effect dark matter and dark energy, then we could build a ship which effects dark matter in the front, and effects dark energy at the back. Then the space will contract immediately in front of the ship, while space will stretch behind it. The ship itself however does not move and thus, the ship could travel to places billions of light years away in days/hours /minutes/seconds without breaking any laws of physics, since the ship stayed stationary while space stretched and contracted around it.

## III. Conclusions

According to the best model we have at the moment, dark energy is uniformly distributed across space, and almost all of space is empty. So, if we average across the entire universe, dark energy becomes dominant. However, if we look at a specific part of the universe which also contains matter in it, then the amount of dark energy becomes completely negligible. For example, the volume of Earth is about $10^{21}m^3$, and the mass of the ordinary matter that it is composed of is about $10^{25}$kg. Since the density of dark energy is observed to be about $10^{-27}kg/m^3$, a simple calculation yields that the mass of dark energy inside the entire volume of the Earth is about $10^{-6}$kg or 1milligram. This is 31 orders of magnitude less than the mass of ordinary matter and is completely negligible. We would have to average over a volume of $10^{31}$ times the volume of Earth, and which contains only the Earth and the rest is complete vacuum, in order for the contribution of dark energy to become comparable. This volume would be about 13000 cubic light year.

Dark Energy-Quantum Vacuum Energy- particles which are constantly coming in and out of existence generate energy. The problem is that the calculation of this energy is a problem in quantum mechanics and the expansion of the universe is in terms of general relativity to determine the dark energy properties as well as possible. We know that there must be something else out there, and thus we call it dark matter and dark energy, but for all we know it's not just one energy / force / something, but rather a whole range of different elements working as one, or perhaps separately, only with the end result or effect being that which we observe / measure.

However the Dark Energy Task Force (DETF) was established by the Astronomy and Astrophysics Advisory Committee (AAAC)[12] and the High Energy Physics Advisory Panel (HEPAP) as a joint sub-committee to advise the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation on future dark energy research and for exploring the possibilities of using dark energy as a fuel but as the dark energy is too spread out or scattered more and as there's no way to gather it. Therefore despite of having a large portion of the universe in the form of dark energy , it remains useless as an energy source till date.

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