Applied Physics Research; Vol. 7, No. 6; 2015
ISSN 1916-9639 E-ISSN 1916-9647
Published by Canadian Center of Science and Education

The Origin of Dark Energy and Cosmic Expansion and Contraction

Bin Liang[1]

[1] College of Science, Chongqing University of Posts and Telecommunication, Chongqing 400065, China

Correspondence: Bin Liang, College of Science, Chongqing University of Posts and Telecommunication, Chongqing 400065, Chin. E-mail: liangbin@cqupt.edu.cn

Received: November 5, 2015 Accepted: November 15, 2015 Online Published: November 26, 2015

doi:10.5539/apr.v7n6p134 URL: http://dx.doi.org/10.5539/apr.v7n6p134

Abstract

This article proves that the photons of lower energy are annihilated into dark energy due to the destructive interference of light, and the increase of dark energy makes the universe expand, the Hubble formula could be derived based on it. The energy level of matter reduces, more and more matter becomes the dark matter in the process. The universe stops expanding and starts to contract in the action of gravity when the energy density of radiation field becomes small enough in it.

Keywords: photon's annihilation, dark energy, cosmic expansion and contraction

1. Introduction

Astronomical observations show the universe is expanding now. Why does it expand? Will it expand forever? To answer these questions we have to solve an old problem firstly: does the entire incident light go through the film when the two beams of reflective light destructively interfere in the anti-reflecting film experiment? The answer is no. We will prove that the photons of lower energy are annihilated into dark energy due to the destructive interference of light, and the increase of dark energy makes the universe expand, the Hubble formula could be derived based on it. The energy level of matter reduces, more and more matter becomes the dark matter in the process. The universe stops expanding and starts to contract in the action of gravity when the energy density of radiation field becomes small enough in it.

2. Photons of Lower Energy Annihilate into Dark Energy

A beam of monochromatic light, as shown in Figure 1, strikes vertically down to a film of thickness e with medium refractive index n $(n>1)$, and two beams of reflective light destructively interfere. Now we ask: does the entire incident light go through the film?

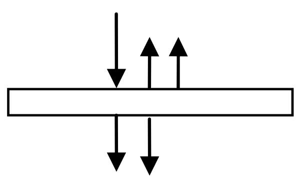

Figure 1. Anti-reflecting film

Without missing generality, assume the number of incident photons is n_0, and the film has two interfaces, as shown in Figure 1. The reflected and transmitted rate of light from the vacuum to the film is α_1 and β_1, where $\alpha_1+\beta_1=1$, and that of light from the film to the vacuum is α_2 and β_2, where $\alpha_2+\beta_2=1$. According to the Lambert's law, if the optical absorption coefficient $k\neq 0$ of the film, notice the two beams of reflective light are out of phase and the two beams of transmitted light are in phase, the number of photons of the reflective light is

$$n_1=\left|\alpha_1-\alpha_2\beta_1\beta_2 e^{-2ke}\right|n_0\,, \tag{1}$$

that of the transmitted light is

$$n_2=\beta_1\beta_2 e^{-ke}\left(1+\alpha_2^2 e^{-2ke}\right)n_0\,. \tag{2}$$

So we have

$$\Delta n \equiv n_0 - \left(n_1 + n_2\right)$$
$$= \begin{cases} \left[\beta_1\left(1-\beta_2 e^{-ke}\right) + \alpha_2\beta_1\beta_2 e^{-2ke}\left(1-\alpha_2 e^{-ke}\right)\right] n_0 > 0, & \alpha_1 > \alpha_2\beta_1\beta_2 e^{-2ke} \\ \left\{1+\alpha_1 - \beta_1\beta_2 e^{-2ke}\left[1+\alpha_2\left(1+\alpha_2 e^{-ke}\right)\right]\right\} n_0 > 0, & \alpha_1 < \alpha_2\beta_1\beta_2 e^{-2ke} \end{cases} \quad (3)$$

This shows that there are always some photons annihilated due to the reflective light out of phase. When $\alpha_1 = \alpha_2\beta_1\beta_2 e^{-2ke}$ there are $n_1 = 0$, $n_2 = \frac{\alpha_1}{\alpha_2} e^{ke}\left(1+\alpha_2^2 e^{-2ke}\right) n_0 > 0$ and

$$\Delta n = \left[\beta_1\left(1-\beta_2 e^{-ke}\right) + \alpha_1\left(1-\alpha_2 e^{-ke}\right)\right] n_0 > 0 . \quad (4)$$

Therefore, it is wrong to believe the entire incident light goes through the film when the two beams of reflective light destructively interfere. Obviously, the conclusion is correct even if when $k = 0$, namely the film does not absorb the energy of light. What does those annihilated photons become then? They will do not transform into pair of electron-positron if they are not high-energy photons. Since those annihilated photons cannot be detected by electromagnetic detector, the only reasonable explanation should just be that they are transformed into dark energy according to the law of conservation and transformation of energy.

3. Dark Energy, Cosmic Expansion

There are always some of electromagnetic waves that are transformed into dark energy due to destructive interference in the universe. In this way, the dark energy accumulates in the cosmic long evolution process. According to the astronomical observations, the dark energy distributes almost uniformly and doesn't agglomerate completely (Hinshaw et al., 2009; Planck reveals an almost perfect universe, 2013) in the universe space, so the increase of dark energy makes the universe expand. This can be proved as follows.

According to Stefan-Boltzmann law of blackbody radiation，the energy flow density of electromagnetic radiation field in the radial direction is

$$J = \sigma T^4 , \quad (5)$$

And the corresponding energy density is

$$\rho_e = \frac{4}{c} J = \frac{4}{c}\sigma T^4 , \quad (6)$$

where σ is the Stefan-Boltzmann constant, c is the light speed in the vacuum and T is the thermodynamic temperature.

Assume the conversion rate from electromagnetic wave into dark energy per unit time is η and the density of dark energy is ρ_d, we have

$$\rho_d = \int_0^t \mathrm{d}t\left[\eta\rho_e - f\left(\rho_d\right)\right], \quad (7)$$

where $f\left(\rho_d\right) > 0$ is the dissipation of dark energy density caused by the resistance of dark energy to gravity or the addition of energy density of gravitational field per unit time. From the above equation we obtain

$$\frac{\mathrm{d}\rho_d}{\mathrm{d}t} = \eta\rho_e - f\left(\rho_d\right). \quad (8)$$

As said previously, the dark energy distributes uniformly in the universe, so， according to the cosmological principle—that the universe is uniform and isotropic—the following equation can be written:

$$\left(\rho_d + \mathrm{d}\rho_d\right) r = \rho_d\left(r + \mathrm{d}r\right), \quad (9)$$

where the r is the co-moving radial coordinate of the Robertson-Walker metric, and

$$\frac{\mathrm{d}r}{r}=\frac{\mathrm{d}\rho_d}{\rho_d}. \tag{10}$$

So the cosmic expansion rate, namely the Hubble constant, can be written as

$$H=\frac{1}{r}\frac{\mathrm{d}r}{\mathrm{d}t}=\frac{1}{\rho_d}\frac{\mathrm{d}\rho_d}{\mathrm{d}t}=\frac{1}{\rho_d}\left(\eta\rho_e-f\right). \tag{11}$$

According to the cosmic standard model (Peacock, 1999; Weinberg, 2008), the universe had experienced inflation with high temperature in the first stage and then gradually entered into the long slow expansion period. The inflation is 17.5×10^4 years approximately and far smaller than the cosmic age, its influence could be neglected and the integrand $\left(\eta\rho_e-f\right)$ in equation (7) could be considered as a constant, so there is

$$\rho_d=\left(\eta\rho_e-f\right)\Delta t. \tag{12}$$

Substitute the equation above into the equation (11) we obtain the Hubble formula:

$$H=\frac{1}{\Delta t}. \tag{13}$$

This shows that the argument above is reasonable.

According to the observations of the Planck satellite in 2013 (Hinshaw et al., 2009; Planck reveals an almost perfect universe, 2013) the Hubble constant $H_0=74.3km/sMpc$, so the cosmic age at present is about

$$\Delta t=131.35\times10^8\,\mathrm{y}. \tag{14}$$

Notice $\rho_d=0.683\rho_c c^2$, the critical mass density $\rho_c=3H_0^2/8\pi G$ and there should be $f\ll\rho_e$, the conversion rate at present is

$$\eta=\frac{\rho_d}{\rho_e\Delta t}+\frac{f}{\rho_e}\approx\frac{\rho_d}{\rho_e\Delta t}=5.95\times10^{-5}T^{-4}/y. \tag{15}$$

If take $T=2.7K$ which is the temperature of microwave background radiation, there is $\eta\approx1.12\times10^{-6}/y$.

4. Dark Matter, Cosmic Ground State

The equation (13) shows the cosmic expansion will not last forever. In fact, from equation (11) we see that the universe expands when $\eta\rho_e>f$, the universe stops expanding when $\eta\rho_e=f$ and contracts when $\eta\rho_e<f$. That is to say the universe stops expanding and starts to contract in the action of gravity when the energy density of radiation field becomes small enough. Especially, when $\rho_e\to0$, there is

$$H\to-\frac{f}{\rho_d}<0. \tag{16}$$

It must be noted that the reduction of energy density of radiation field means the energy level of matter reduces, and more and more matter has become the dark matter in the universe, because said dark matter is without radiation of electromagnetic wave and in the lowest energy state. Therefore, the energy density of radiation field tends to be zero, at which point that almost all matter has become the dark matter and the universe is in the lowest energy state or the cosmic ground state. With the continuous dissipation of dark energy the universe contracts continuously in the action of gravity, at the same time, the matter density and temperature gradually rise in it—the next big bang is brewing. Thus, the relationship of the dark energy and dark matter to cosmic expansion and contraction has been illuminated.

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