On the variation of the energy scale 8

Primordial Density Perturbations

by

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Summary

The hypothesis has been put forward that the energy scale can vary from location to location. Such energy scale variations can explain the rotation curves of spiral galaxies and the high velocities of galaxies in clusters of galaxies without the need for any dark matter. This paper extends that work and shows that variations in the energy scale can also explain the primordial density perturbations and the observed fluctuations in the cosmic microwave background.

1 Introduction

1.1 The ΛCDM (Λ: cosmological constant; CMD: cold dark matter) theory explains the evolution of the universe as follows: after inflation the Universe was dominated by high temperature radiation, which kept the plasma (electrons, protons, alpha particles) in a uniform state and prevented them from clumping together. However, the cold dark matter was not so affected and could clump together forming over-dense and under-dense regions. The over-dense regions of dark matter acted as gravitational wells that could attract the plasma and so create primordial density perturbations. The interplay of gravity and plasma pressure resulted in baryonic acoustic oscillations being set up, essentially sound waves. At recombination time the electrons and ions joined together to form neutral atoms, the matter became transparent to radiation, and the plasma pressure arising from electron scattering disappeared. The density perturbations gave rise to the observed temperature variations in the cosmic microwave background (CMB). The baryonic acoustic oscillations (BAO) gave rise to the observed peaks in the power spectrum of the CMB.

1.2 The paper "On the variation of the energy scale: an alternative to dark matter" (Jo.Ke, Sep 2015) is referred to in this paper as simply "JoKe1". The paper introduced the idea of variations of the energy scale and used it to explain the rotation curves of spiral galaxies without the need for any dark matter. It used the simple model of a point mass galaxy and a Gaussian energy scale variation.

1.3 The paper "On the variation of the energy scale 2: galaxy rotation curves" (Jo.Ke, Nov 2015) is referred to in this paper as simply "JoKe2". This improved on JoKe1 by replacing the point mass galaxy by a disk with a Gaussian density distribution.

1.4 The paper "On the variation of the energy scale 3: parameters for galaxy rotation curves" (Jo.Ke, 2015) is referred to in this paper as simply "JoKe3". This took the model of JoKe2 and applied it to the rotation curves of a large sample of 74 spiral galaxies.

1.5 This paper looks at how the fluctuations observed in the cosmic microwave background can be explained by energy scale variations without the need for dark matter. Simply put ΛCDM theory invokes dark matter to provide the gravitational wells; JoKe theory invokes energy scale variations to do the same thing.

1.6 We start by considering an isothermal gas sphere as a simple representation of a region of space at the time of recombination. We consider its properties in terms of total mass and density distribution.

1.7 Next we consider the properties of the same isothermal gas sphere but assume it is embedded in a region of dark matter.

1.8 Lastly we consider the properties of the same isothermal gas sphere but this time we assume it is embedded in a region with a Gaussian energy scale variation.

2 Isothermal gas sphere

2.1 It is generally accepted that a small region of the early Universe can be approximated by an isothermal gas sphere sitting in a gravitational well (Lyth & Liddle, 2009).

2.2 Consider a self-gravitating isothermal gas sphere in hydrostatic equilibrium at the time of recombination.

2.3 The equation of state is given by:

$$\boldsymbol{P = \rho \, c_s^2} \tag{1}$$

where $\boldsymbol{P}$ is the plasma pressure; $\boldsymbol{\rho}$ is the density; $\boldsymbol{c_s}$ is the speed of sound.

2.4 Differentiating (1) gives:

$$\boldsymbol{\frac{\partial P}{\partial r} = c_s^2 \frac{\partial \rho}{\partial r}} \tag{2}$$

2.5 The equation for hydrostatic equilibrium is:

$$\boldsymbol{-\frac{1}{\rho} \nabla P - \nabla \varphi = 0} \tag{3}$$

where $\boldsymbol{\varphi}$ is the gravitational potential.

2.6 For spherical symmetry this is simply

$$\boldsymbol{-\frac{1}{\rho} \frac{\partial P}{\partial r} - \frac{\partial \varphi}{\partial r} = 0} \tag{4}$$

2.7 Using (2) this becomes

$$\boldsymbol{-\frac{c_s^2}{\rho} \frac{\partial \rho}{\partial r} - \frac{\partial \varphi}{\partial r} = 0} \tag{5}$$

2.8 Poisson's equation is

$$\boldsymbol{\nabla^2 \varphi = 4 \, \pi \, G \, \rho} \tag{6}$$

2.9 For spherical symmetry this is simply

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial\varphi}{\partial r}\right) = 4\,\pi\,G\,\rho \tag{7}$$

2.10 This can be integrated to give

$$r^2\frac{\partial\varphi}{\partial r} = G\,M(r) \tag{8}$$

where

$$M(r) = \int_0^r 4\,\pi\,\rho(x)\,x^2\,dx \tag{9}$$

2.11 Equations (5) and (8) can be combined to give

$$\frac{\partial\rho}{\partial r} = -\frac{G}{c_s^2}\,\frac{M(r)}{r^2}\,\rho(r) \tag{10}$$

2.12 For a given central density, equations (9) and (10) can be solved numerically to give the density distribution. This would be the density distribution of a small region of the Universe with no dark matter.

3 Isothermal gas sphere in a region of dark matter

3.1 Consider a self-gravitating isothermal gas sphere in hydrostatic equilibrium embedded in a sphere of dark matter.

3.2 The equation of state is unchanged and given by (1):

$$\boldsymbol{P = \rho\, c_s^2} \tag{11}$$

where $\boldsymbol{\rho}$ is the density of the plasma alone, i.e. it does not include the dark matter.

3.3 Similarly for equations (2) through (5); $\boldsymbol{\rho}$ is the density of the plasma alone.

3.4 Poisson's equation is different and becomes

$$\boldsymbol{\nabla^2 \varphi = 4\,\pi\, G\, \rho + 4\,\pi\, G\, \rho_{DM}} \tag{12}$$

where $\boldsymbol{\rho_{DM}}$ is the density of the dark matter.

3.5 As before the mass of plasma inside radius $\boldsymbol{r}$ is given by (9)

$$\boldsymbol{M(r) = \int_0^r 4\,\pi\, \rho(x)\, x^2\, dx} \tag{13}$$

3.5 Corresponding to (13), the mass of dark matter inside radius $\boldsymbol{r}$ is given by

$$\boldsymbol{M_{DM}(r) = \int_0^r 4\,\pi\, \rho_{DM}(x)\, x^2\, dx} \tag{14}$$

3.6 Equation (10) now becomes

$$\boldsymbol{\frac{\partial \rho}{\partial r} = -\frac{G}{c_s^2}\, \frac{\{M(r) + M_{DM}(r)\}}{r^2}\, \rho(r)} \tag{15}$$

3.7 For a given central density of the plasma and for a given density distribution of the dark matter, equations (13), (14) and (15) can be solved numerically to give the density distribution of the plasma.

4 Isothermal gas sphere in an energy scale variation

4.1 Consider a self-gravitating isothermal gas sphere in hydrostatic equilibrium embedded in a Gaussian energy scale variation.

4.2 Following JoKe1 (Jo.Ke 1, 2015) we assume the energy scale can vary from location to location and, for a Gaussian energy scale variation, is given by

$$\boldsymbol{\xi(r) = A + B\ \ exp(-r^2/\alpha^2\ )} \qquad (16)$$

where, for a given variation, $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{\alpha}$ are constants: $\boldsymbol{A}$ and $\boldsymbol{B}$ are pure numbers; $\boldsymbol{\alpha}$ is a distance.

4.3 Equations (1) through (7) hold in their original form.

4.4 Instead of equation (9), the 'effective' mass inside radius $\boldsymbol{r}$ is now given by

$$\boldsymbol{M_J(r) = \frac{1}{\xi(r)} \int_0^r 4\,\pi\,\rho(x)\,x^2\,\xi(x)\,dx} \qquad (17)$$

4.5 The three free parameters of (16) are reduced to just two using

$$\boldsymbol{\frac{\xi(x)}{\xi(r)} = \frac{\{1 + \gamma\ \ exp(-x^2/\alpha^2\ )\}}{\{1 + \gamma\ \ exp(-r^2/\alpha^2\ )\}}} \qquad (18)$$

where

$$\boldsymbol{\gamma = {}^{B}/_{A}} \qquad (19)$$

4.6 Finally equation (10) is replaced by

$$\boldsymbol{\frac{\partial \rho}{\partial r} = -\frac{G}{c_s^2}\,\frac{M_J(r)}{r^2}\,\rho(r)} \qquad (20)$$

4.7 Comparing (15) and (20), it is clear that an energy scale variation can reproduce the effects of dark matter by suitable choice of the $\boldsymbol{\xi(r)}$ function such that

$$\boldsymbol{M_J(r) = M(r) + M_{DM}(r)} \qquad (21)$$

5 Sample Calculation

5.1 We take a spherical region of space of fixed size and containing a fixed mass of baryonic matter. We also assume the sphere is isothermal in hydrostatic equilibrium with the gas pressure balancing the gravitational attraction. We can calculate the density distribution in three ways.

5.2 Firstly we can calculate the density distribution assuming there is only the baryonic gas present (coming from electron scattering); we assume no dark matter and no energy scale variation. The density distribution is found by solving equations (9) and (10) above. The resultant distribution is the blue curve in Figure 1.

5.3 Secondly we can calculate the density distribution assuming the presence of dark matter with five times the mass of the baryonic matter. The dark matter is assumed to have a Gaussian distribution. The density distribution is found by solving equations (13), (14), and (15) above. The density distribution of the baryonic matter is shown as the red curve in Figure 1. The dark matter density distribution is shown as the dashed black line.

5.4 Thirdly we can calculate the density distribution assuming the presence of an energy scale variation. This is chosen to have a Gaussian distribution with parameters that lead to a similar density distribution to that produced by dark matter. The density distribution is found by solving equations (17) and (20) above. The density distribution is shown as the green curve above.

5.5 The blue, red and green curves in Figure 1 are for the same total mass. The red and green curves have a similar central density enhancement, but the blue curve wins out in the outer regions. This is a spherical distribution so the outer regions have a greater volume than the inner regions.

5.6 The parameters behind the calculations for Figure 1 and listed in Table 1 below.

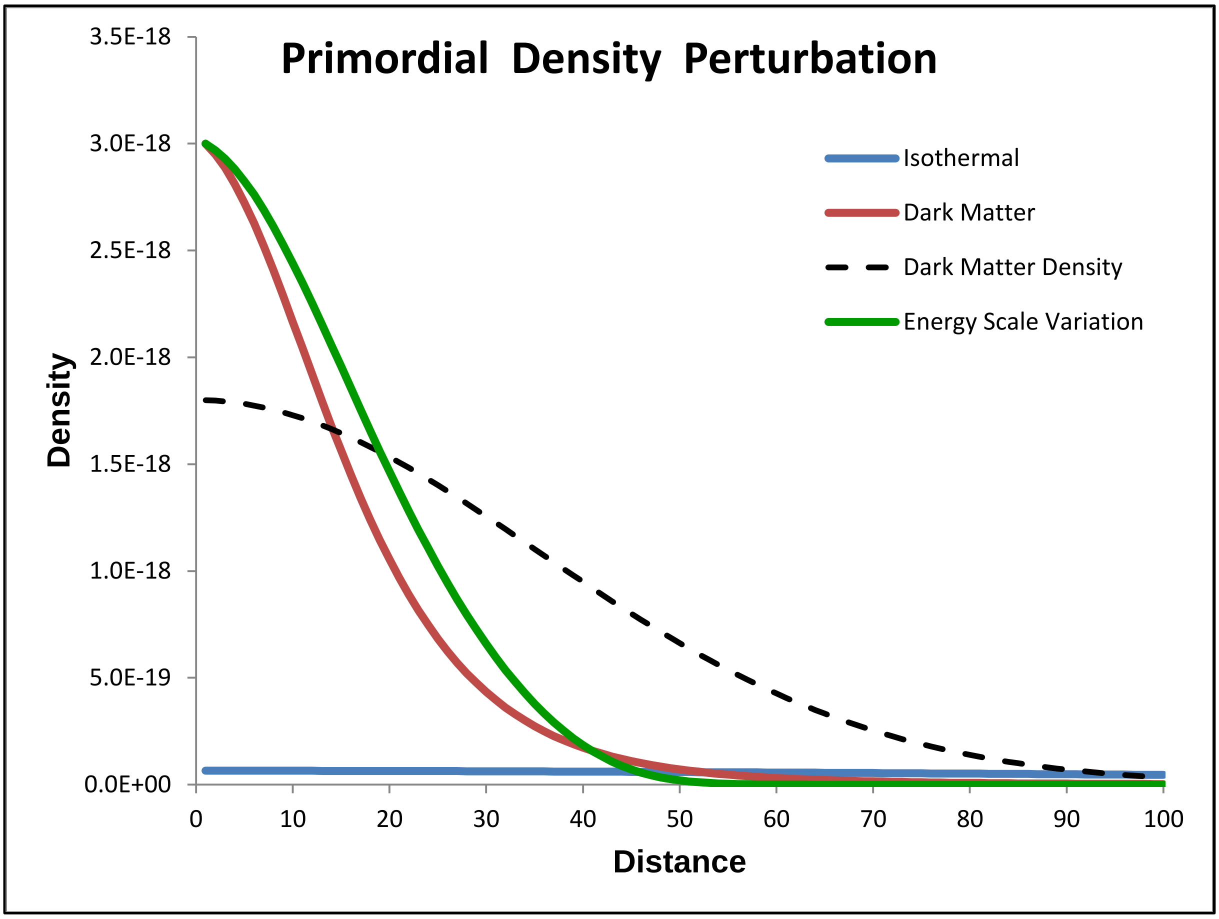

Figure 1. Primordial Density Perturbation. Showing that an energy scale variation can produce a density enhancement similar to that produced by the presence of dark matter. The blue line is the density distribution for a pure baryonic sphere. The red line is for a baryonic sphere embedded in dark matter. The dashed black line is the density distribution for the dark matter. The green line is the density distribution for the baryonic gas with an energy scale variation. All three lines represent the same total mass. The figure shows that an energy scale variation can reproduce the effects of dark matter.

Table 1. Density Perturbation Parameters

Parameter	Value
sound speed, c_s	$1.5 \times 10^{+8}$ m s^{-1}
total mass of baryonic sphere	$6.54 \times 10^{+48}$ kg
Pure baryonic matter	
central density	6.50×10^{-20} kg m^{-3}
outer edge density	4.57×10^{-20} kg m^{-3}
Baryonic matter plus dark matter	
central density (baryons)	3.00×10^{-18} kg m^{-3}
outer edge density (baryons)	3.03×10^{-21} kg m^{-3}
central density (dark matter)	1.80×10^{-18} kg m^{-3}
1/e-width (dark matter)	500 kpc
Baryonic matter plus energy scale variation (ESV)	
central density (baryons)	3.00×10^{-18} kg m^{-3}
outer edge density (baryons)	4.47×10^{-26} kg m^{-3}
ESV height, γ	50
ESV 1/e-width, α	253 kpc

6 Discussion

6.1 One of the key arguments supporting the existence of dark matter is that it provided the gravitational potential wells that led to the primordial density perturbations of the baryonic plasma leading up to the time of recombination. The baryonic acoustic oscillations that resulted were imprinted on the cosmic microwave background.

6.2 This paper demonstrates that similar primordial density perturbations can be produced by variations in the energy scale, without the need for any dark matter.

6.3 Figure 1 and Table 1 are just one example of how an energy scale variation can reproduce the same density enhancement as dark matter. There is nothing special in the values in Table 1; they are just an example. Other researchers may well prefer to work with different values.

7 Conclusion

7.1 We apply the hypothesis of variations in the energy scale to the primordial density perturbations. It is shown that energy scale variations can create density enhancements in the baryonic plasma that closely resemble those created by dark matter.

7.2 There is no need to invoke dark matter for creating the fluctuations observed in the cosmic microwave background nor for the peaks in the power spectrum. Variations in the energy scale can do the job just as well.

6 References

JoKe1. "On the variation of the energy scale: an alternative to dark matter". (Sep 2015). www.varensca.com

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