On the variation of the energy scale 6

Galaxy interactions

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. Currently it is generally assumed that dark matter is the cause of these observations.

It is shown here that the interactions between galaxies in near miss collisions are substantially different between galaxies with dark matter and galaxies with energy scale variations. Computer simulations of these differences should provide a test to distinguish between the two hypotheses.

1 Introduction

1.1 The paper "On the variation of the energy scale: an alternative to dark matter" (Jo.Ke, 2015) is referred to in this paper as simply "Jo.Ke 1". This paper introduced the idea of variations of the energy scale to explain the rotation curves of spiral galaxies. It used the simple model of a galaxy point mass and a Gaussian energy scale variation.

1.2 The paper "On the variation of the energy scale 2: galaxy rotation curves" (Jo.Ke, 2015) is referred to in this paper as simply "Jo.Ke 2". This improved on Jo.Ke 1 by replacing the galaxy point mass by a disk with a Gaussian density distribution.

1.3 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 "Jo.Ke 3". This took the model of Jo.Ke 2 and applied it to the rotation curves of a large sample of 74 spiral galaxies.

1.4 The paper "On the variation of the energy scale 4: clusters of galaxies" (Jo.Ke, 2015) is referred to in this paper as simply "Jo.Ke 4". This applied the idea of variations in the energy scale to clusters of galaxies. It showed that it could explain the high velocities of galaxies in the clusters.

1.5 The paper "On the variation of the energy scale 5: collisions between clusters of galaxies" (Jo.Ke, 2015) is referred to in this paper as simply "Jo.Ke 5". This suggests that cluster collisions provide a test to distinguish between the hypotheses of dark matter and energy scale variations.

1.6 This paper investigates the interaction between galaxies with a view to providing a second test between the hypotheses of dark matter and energy scale variations. We look at near misses (interactions) rather than full blown collisions.

2 Interactions with dark matter

2.1 When pairs of galaxies pass close to one another they will interact gravitationally and both may be disturbed. The interaction is tidal in nature where, relative to the galaxy centre, gravitational tides are raised on opposite sides of the galaxy. This is exactly the same process as that producing ocean tides on Earth.

2.2 The position during a near miss collision is illustrated in Figure 1 below.

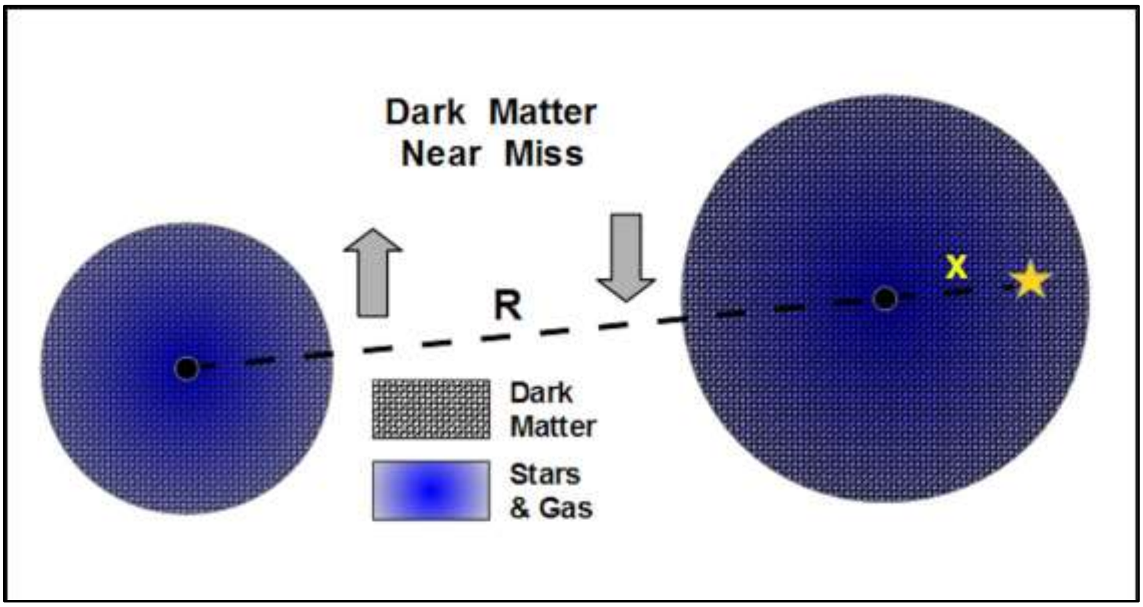

Figure 1. Two disk galaxies in a near miss fly-by. The galaxies (blue) are embedded in dark matter (black hatching).

2.3 If the two galaxies are separated by distance $\boldsymbol{R}$ then the force on a star a distance $\boldsymbol{x}$ from its galaxy centre due to the other galaxy is given by

$$\boldsymbol{F_d(x) = \frac{G(M+H)}{(R+x)^2}} \quad (1)$$

where $\boldsymbol{M}$ is the mass of the other galaxy; $\boldsymbol{H}$ is the mass of its dark matter halo. This assumes the star lies on the line between galaxy centres; $\boldsymbol{x}$ can be positive or negative.

2.4 Similarly, the force at the galaxy centre is given by

$$F_d(0) = \frac{G(M+H)}{R^2} \tag{2}$$

2.5 The tidal force is simply the force on the star relative to the force on the galaxy centre

$$T_d(x) = F_d(x) - F_d(0) \tag{3}$$

2.6 The effect of the tides on the galaxy is illustrated in Fig 2 below.

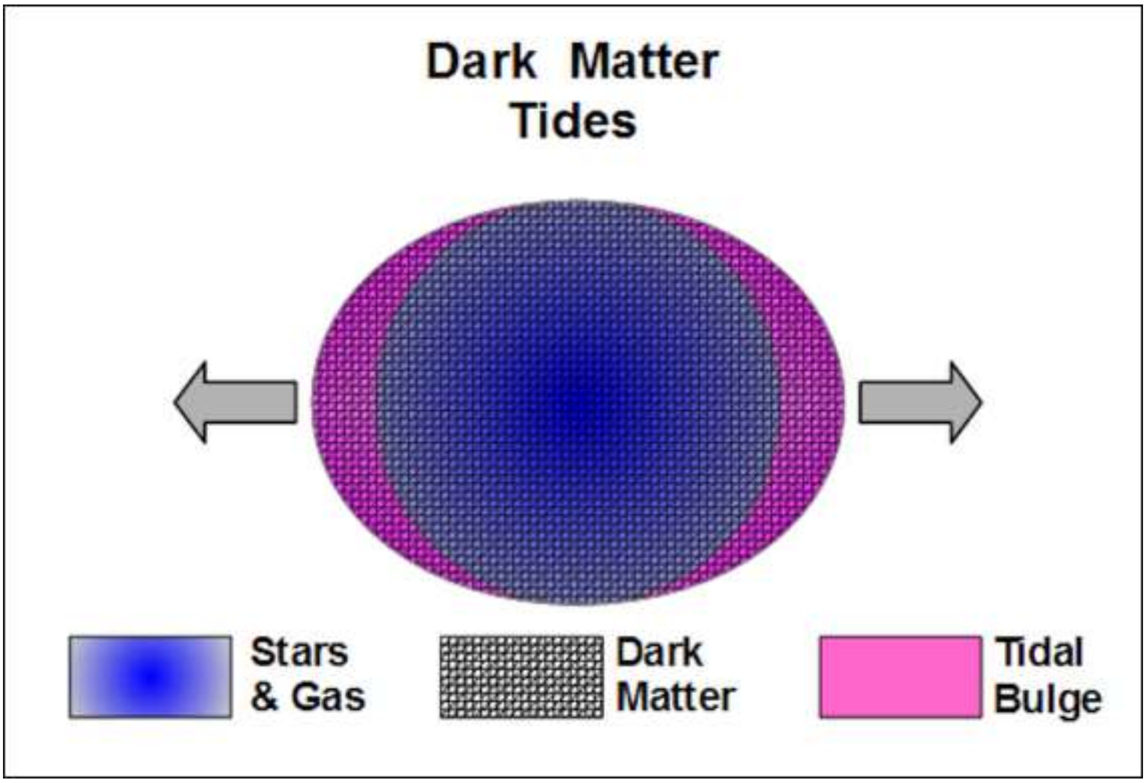

Figure 2. The tidal effect caused by another galaxy passing nearby. There are two tidal bulges (represented in pink): one on the side nearest the passing galaxy; one (smaller) on the opposite side.

2.7 Relative to the galaxy centre the tidal pull of the other galaxy results in a stretching apart of the galaxy with tidal bulges on both sides.

3 Interactions with energy scale variations

3.1 With energy scale variations the galaxies still interact with one another gravitationally. But the details of the interaction are different from the situation with dark matter.

3.2 The position during the same near miss collision is illustrated in Figure 3 below.

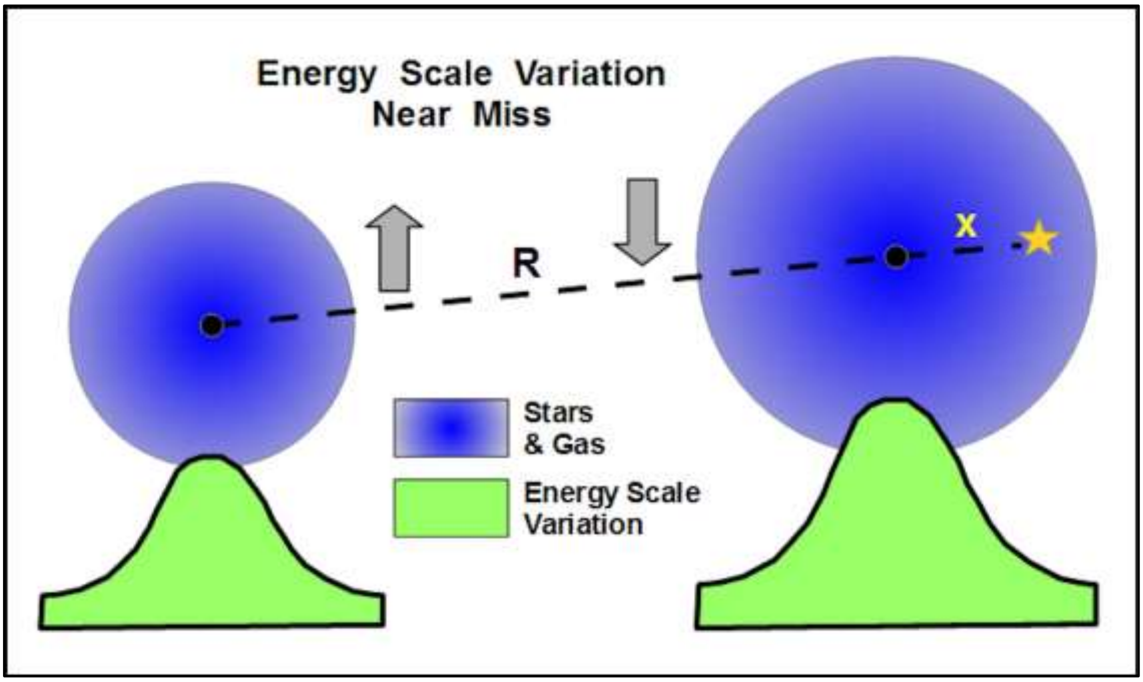

Figure 3. Two disk galaxies in a near miss fly-by. The galaxies (blue) are embedded in energy scale variations illustrated by the green Gaussian curves. There is no dark matter.

3.3 It is assumed that the energy scale variations for both galaxies are simple Gaussians. Following previous papers (Jo.Ke 1 2015) the strength of the energy scale variation at point $\boldsymbol{X}$ as distance $\boldsymbol{x}$ from the centre of galaxy $\boldsymbol{A}$ is given by

$$\xi(x) = 1 + \beta_A \, exp\left\{-\frac{x^2}{\alpha_A^2}\right\} + \beta_B \, exp\left\{-\frac{(R+x)^2}{\alpha_B^2}\right\} \qquad (4)$$

where α_A, β_A characterise the energy scale variation of galaxy $\boldsymbol{A}$; α_B, β_B characterise the energy scale variation of galaxy $\boldsymbol{B}$.

3.4 The force on a star a distance $\boldsymbol{x}$ from the centre of galaxy $\boldsymbol{A}$ due to galaxy $\boldsymbol{B}$ is

$$\boldsymbol{F_e(x) = \frac{G\,M}{(R+x)^2}\ \frac{\xi(R)}{\xi(x)}} \tag{5}$$

3.5 The force at the galaxy centre is similarly given by

$$\boldsymbol{F_e(0) = \frac{G\,M}{R^2}\ \frac{\xi(R)}{\xi(0)}} \tag{6}$$

3.6 The tidal force is simply the force on the star relative to the galaxy centre

$$\boldsymbol{T_e(x) = F_e(x) - F_d(0)} \tag{7}$$

3.7 The effect of the tides on the galaxy is illustrated in Fig 4 below.

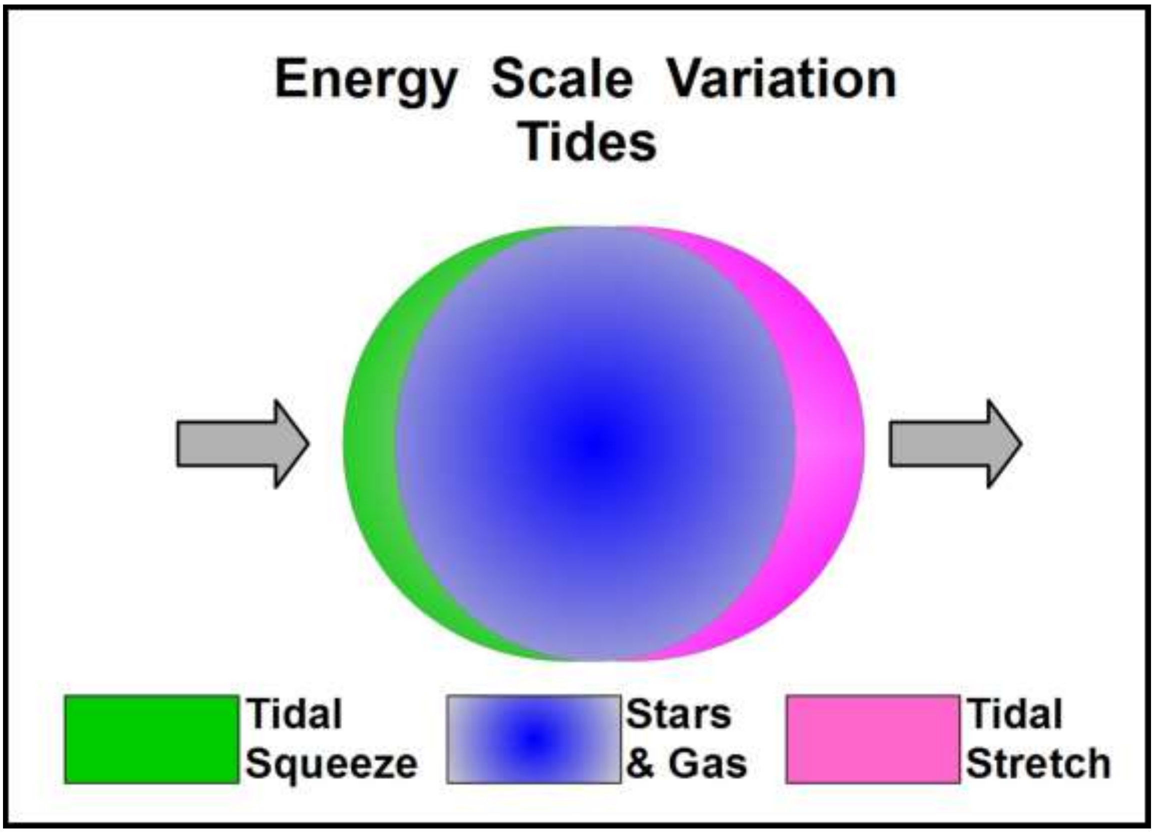

Figure 4. The tidal effect caused by another galaxy passing nearby. There is a tidal bulge (pink) on the side nearest the passing galaxy, and a smaller tidal compression (green) on the opposite side.

3.8 There is a tidal bulge, i.e. a raised tide, on the side of the galaxy nearest to the passing galaxy. This is similar to that produced in a galaxy with dark matter.

3.9 There is a tidal depression, i.e. a lowered tide, on the side of the galaxy away from the passing galaxy. This is completely different from a galaxy with dark matter where there is a tidal rise.

3.10 The reason for the tidal depression is illustrated in the next section where the numbers for some close encounters are presented.

4 Example interaction

4.1 We can examine the differences in the tidal interactions by looking at a typical near miss fly-by of two galaxies.

4.2 We take two identical galaxies with the following characteristics

Mass	$M = 1000$
Dark Matter halo mass	$H = 5000$
Energy scale variation	$\alpha_A = \alpha_B = 12.5\ kpc$
Energy scale variation	$\beta_A = \beta_B = 3.5$

So the effective mass in the dark matter scenario is 6 times that of the energy scale variation scenario.

4.3 Equations 3 and 7 give the strengths of the tidal forces in the two scenarios.

4.4 Figures 7, 8, 9 show the tidal forces on galaxy A, relative to the centre of galaxy A, caused by passing galaxy B. The different plots are for galaxy separations of 50kpc, 100kpc, and 150kpc.

4.5 In the figures the solid line (red) is the tidal force for the energy scale variation scenario; the dashed line (blue) is the tidal force for the dark matter scenario.

4.6 The dashed lines (blue) show that dark matter generates raised tides on both sides of the galaxy.

4.7 The solid lines (red) show that energy scale variations generate raised tides on the side nearest the passing galaxy, but depressed tides on the side away from the passing galaxy.

4.8 There are clear differences between the two scenarios.

4.9 Numerical simulations would show how interactions progress under the different hypotheses. This is not a simple task as there are many arbitrary parameters involved, including: galaxy masses; galaxy rotation curves; speed of interaction; orientation of interaction.

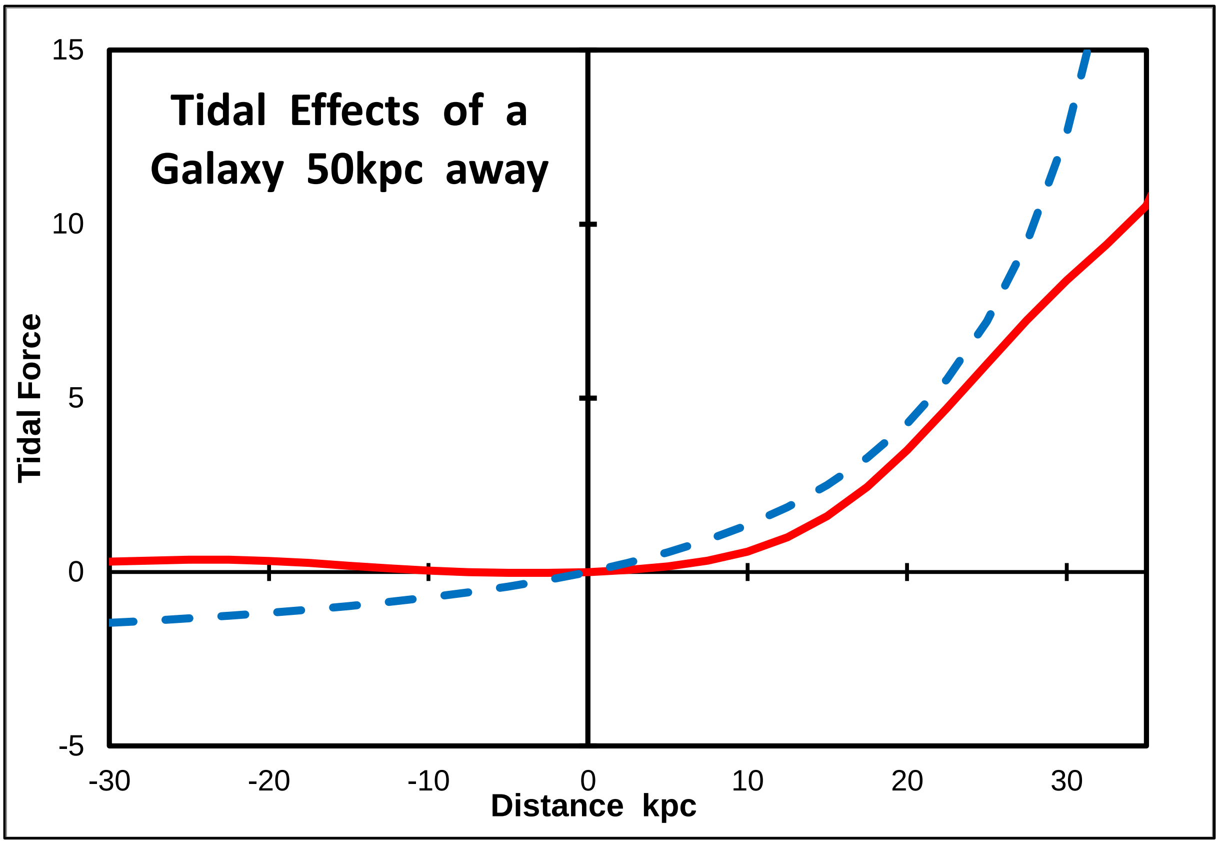

Figure 5: Relative tidal effects of a galaxy 50kpc away.

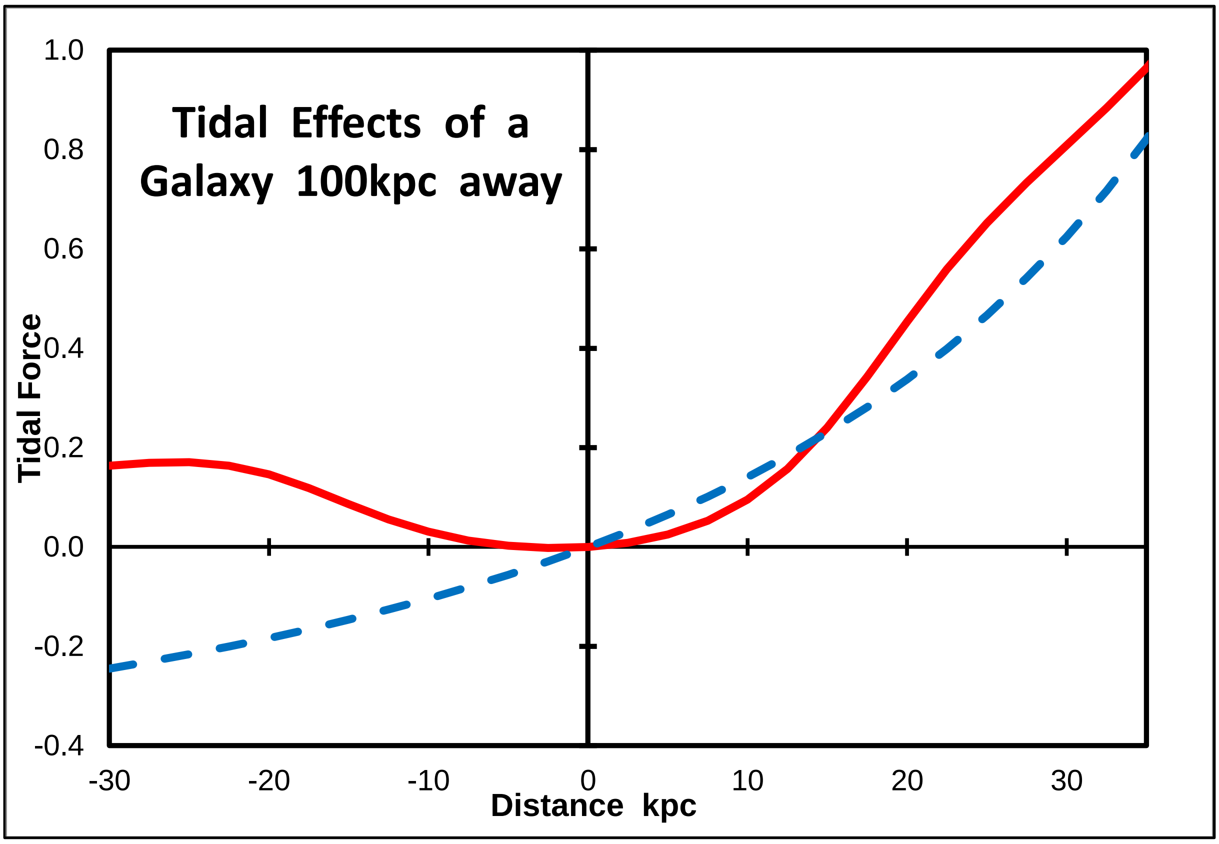

Figure 6: Relative tidal effects of a galaxy 100kpc away.

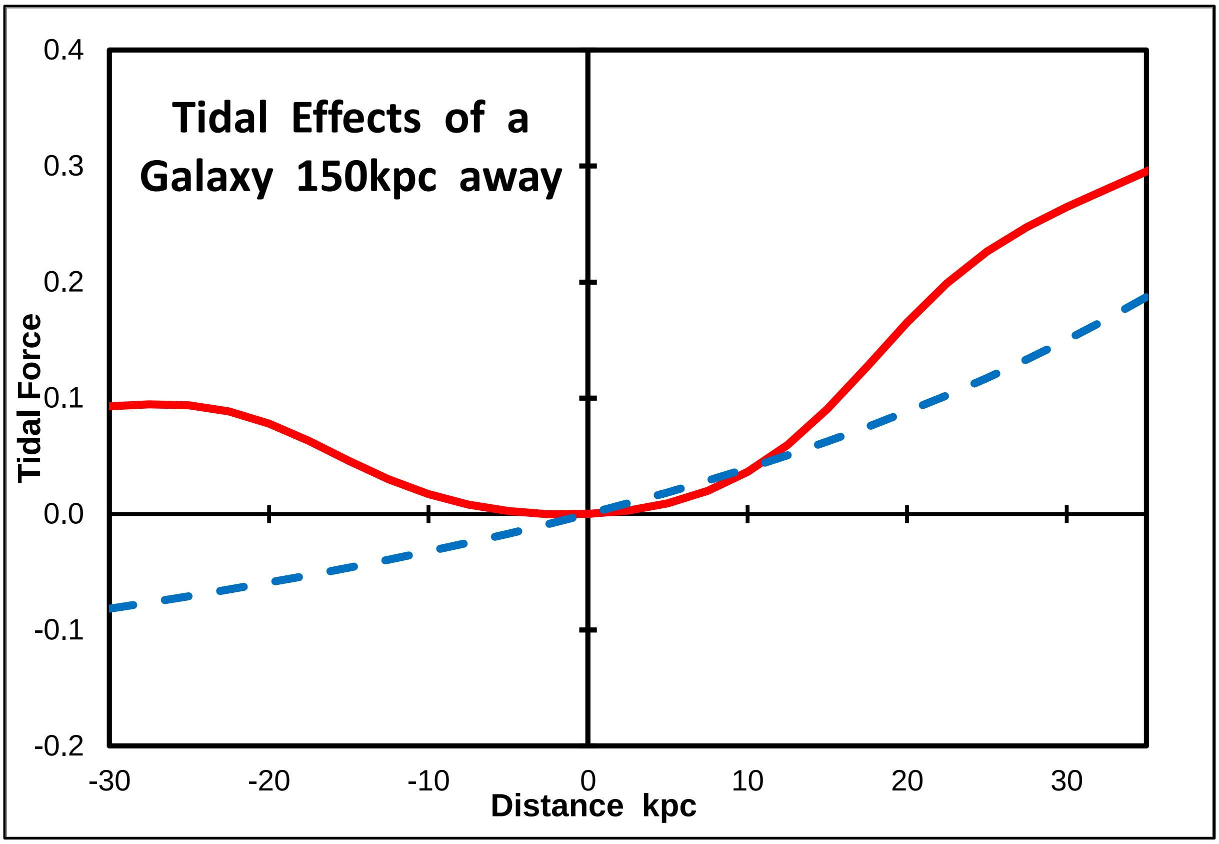

Figure 7: Relative tidal effects of a galaxy 150kpc away.

5 A comment on dark matter interactions

5.1 If dark matter is so prevalent throughout the Universe then we would expect concentrations of dark matter to exist without any normal matter galaxies inside them.

5.2 Such dark matter concentrations should collide with galaxies from time to time and the effects of such collisions should be evident. As far as is known there are no peculiar galaxies observed where the peculiarity has been put down to interaction with a dark matter object.

5.3 All peculiar galaxies have been interpreted as the result of an encounter with another galaxy. There are a tiny number of cases where there is no apparent second galaxy (e.g. Hoag's Object), but other explanations are available.

5.4 The proponents of dark matter need to explain this apparent anomaly.

5.5 For energy scale variations there is no such problem. Variations in the energy scale may well exist on their own, but with no matter content there is nothing to cause any interaction.

6 Conclusion

6.1 We apply the hypothesis of variations in the energy scale to the interaction between pairs of galaxies. There are clear differences between this and galaxies with dark matter.

6.2 Numerical simulations should be able to distinguish between the hypothesis of dark matter and the hypothesis of energy scale variations.

6.3 We do not have access to computer models that simulate galaxy collisions. We must leave it to others to carry out such tests.

6 References

Jo.Ke 1. "On the variation of the energy scale: an alternative to dark matter". (Sep 2015). www.varensca.com

Jo.Ke 2. "On the variation of the energy scale 2: galaxy rotation curves". (Nov 2015). www.varensca.com

Jo.Ke 3. "On the variation of the energy scale 3: parameters for galaxy rotation curves". (Nov 2015). www.varensca.com