On the variation of the energy scale

An alternative to dark matter

by

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Summary

We propose a new physical principle whereby:

> **the value of a scalar quantity depends both on the location of the observer and on the location of the object.**

This means the scales for length, time, mass and charge can vary from location to location. We switch from mass to energy and only consider variations in the energy scale. We do not require changes to any of the constants of physics nor any change to General Relativity. Variations in the energy scale from location to location mean that conservation of energy holds locally but not globally.

The variations in the energy scale eliminate the need for dark matter in galaxies and produce flat rotation curves. A simple Gaussian model for such variations reproduces the main features of observed rotation curves.

We suggest that the missing matter in clusters of galaxies is also unnecessary. We suggest that the variations in the energy scale may be the same as the fluctuations that arose during the inflationary era of the universe. We suggest that there is no dark matter particle and that dark matter will never be discovered in particle accelerators.

1 Introduction

1.1 The rotation curves of many spiral galaxies remain flat in their outer regions and do not show the expected fall off in speed if the majority of the mass is concentrated in the galaxy centre. The widely accepted explanation for these observations is that galaxies are embedded in large haloes of dark matter.

1.2 The velocity dispersion of many clusters of galaxies show that the velocities of individual galaxies are far too high for the cluster to remain gravitationally bound. The clusters should have dispersed billions of years ago. Again the current explanation is that there must be large amounts of dark matter in the clusters holding the galaxies together.

1.3 No dark matter is required to explain the velocities of planets in the solar system. The planets follow Newton's law of gravitation (and Einstein's general theory of relativity) with most of the mass concentrated in the Sun at the centre of the solar system.

1.4 There is no requirement for dark matter in the standard model of particle physics. Observations from particle accelerators (including the Large Hadron Collider) confirm the standard model and, so far, have not detected any dark matter particles.

1.5 Gravity on an astronomical scale is concerned with the effect of masses that are separated by large distances, i.e. it is all about non-local effects. Particle physics experiments are concerned with collisions that occur in the same place, i.e. they are all about local effects.

1.6 Observations of distant objects show that they are made of the same elements and follow the same physical & chemical processes. The constants of physics appear to be the same throughout the observable universe; although in the past suggestions have been made for variations in the constant of gravitation, the fine structure constant, and the speed of light.

1.7 The use of dark matter to explain gravitational effects is somewhat reminiscent of the proposal (well over one hundred years ago) for an "ether" to explain light propagation.

1.8 This paper puts forward a very simple idea for explaining the large scale gravitational effects without the need for any dark matter.

2 A new physical principle

2.1 We propose the following new principle of physics:

The value of a scalar quantity depends on both the location of the observer and the location of the object

2.2 Mathematically this is expressed as

$$\kappa_A S_{AX} = \kappa_B S_{BX} = \kappa_X S_{XX} \tag{1}$$

where S is the scalar quantity; the first subscript is the location of the observer; the second subscript the location of the object; κ is a dimensionless function that depends only on the units of the scalar S.

2.3 S_{AX} is the value of scalar S for an object at location X as measured by an observer at location A.

E.g. M_{AX} is the rest mass of an object at X as measured by an observer at A.

2.4 Current physical theories do not have a κ function, which means

$$\kappa_A = \kappa_B = \kappa_X = 1 \tag{2}$$

everywhere and that

$$S_{AX} = S_{BX} = S_{XX} \tag{3}$$

i.e. all observers measure the same values for all scalar quantities.

2.5 Consider a length l and a volume V. For the length we have

$$\varphi_A\, l_{AX} = \varphi_B\, l_{BX} = \varphi_X\, l_{XX} \tag{4}$$

where φ is the dimensionless function for lengths. For the volume we have

$$\beta_A\, V_{AX} = \beta_B\, V_{BX} = \beta_X\, V_{XX} \tag{5}$$

where β is the dimensionless function for volumes.

But volume is simply length cubed. So

$$\boldsymbol{\beta_A = \varphi_A^3} \tag{6}$$

2.6 It is clear from this that there is only one dimensionless function for every scale. There are just four dimensionless functions for the four scales of: length; time; mass; charge.

3 A switch of scales

3.1 Most of science works with the four scales of: length; time; mass; charge. In this paper we are not going to discuss charge at all. We can, of course, work with any set of independent units and for this paper the most appropriate set for the remaining three scales is: length, speed; energy.

3.2 Relativity teaches us that the speed of light is a special quantity, especially because neither matter nor information can travel faster than it. Also many of the arguments in support of dark matter are based on the observed speeds of remote objects. Hence we switch from using time as a scale to using speed as a scale.

3.3 Relativity also teaches us that energy is a broader concept than mass, with mass contributing to just one form of energy. And particle physics tends to work with the energies of particles rather than their masses. Hence we switch from using mass as a scale to using energy as a scale.

3.4 In section 2 above, we introduced the notion of dimensionless functions that depend only on the units. We clearly need three functions, one for each of the units (scales) we are considering. We choose the following symbols

- $\boldsymbol{\varphi}$ for length
- $\boldsymbol{\sigma}$ for speed
- $\boldsymbol{\xi}$ for energy

3.5 Much theoretical work does so in units where the velocity of light, $\boldsymbol{c}$, is set to unity. And much theoretical work with General Relativity also sets the constant of gravitation, $\boldsymbol{G}$, to 1. These are the so-called geometrized units and to some extent they mask our ability to consider that some physical scales may vary. We make no such substitutions in this paper and work explicitly with all physical constants in their standard form.

4 Restriction to variations in the energy scale

4.1 The existence of dark matter is invoked in scenarios where gravity is the dominant force. The best theory we have for gravitation is the astonishing General Relativity by Albert Einstein. So whatever we do we should keep General Relativity on our side and, if possible, not make any changes to it.

4.2 The field equations for General Relativity can be written as (Weinberg, 1972)

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = - \frac{8\,\pi\,G}{c^4} T_{\mu\nu} \tag{7}$$

where $R_{\mu\nu}$ is the Ricci curvature tensor; R is the Ricci scalar; $g_{\mu\nu}$ is the metric tensor; $T_{\mu\nu}$ is the stress-energy tensor.

4.3 The left-hand side of equation (7) deals with the curvature of 4-dimensional space-time. It covers lengths and times, and by extension speeds through the involvement of the speed of light. Any suggestion that there may be changes to the length scale or to the speed scale will clearly mean substantial changes to General Relativity itself. We really do not want to go there and we accept that part of General Relativity in full.

4.4 The right-hand side of equation (7) deals with energy and we are at more liberty to consider changes in the energy scale without going anywhere near the real structure of General Relativity.

4.5 The metric in the weak-field limit is

$$ds^2 = 1(1 + 2\Phi)dt^2 + (1 - 2\Phi)(dx^2 + dy^2 + dz^2) \tag{8}$$

where

$$\Phi = \frac{G\,(M\,c^2)}{r\,c^2} \tag{9}$$

M is the remote mass causing the local curvature, and Mc^2 the energy of the remote mass.

4.6 From the above it is clear that any considerations of variations in either length scale or speed scale mean serious changes to the General Theory of Relativity. In this paper we are simply going to consider what happens when a change in the energy scale causes a scaling up or down in the value of this remote energy. So in terms of equations (8) & (9) we are simply going to consider changes in $\boldsymbol{\Phi}$, the observed gravitational field.

4.7 If the speed scale changes then not only would the apparent speed of light change between locations but the apparent time scales for various physical processes would also change. In particular, the light curves for supernovae would change. No such anomalous variations are observed.

4.8 This work could be considered as just another paper on "scale invariance" or "scale relativity" (Nottale, 1991). However, scale relativity appears to restrict itself to changes in length scales and has not addressed changes in the energy scale.

5 An interpretation of energy scale changes

5.1 We need to say something about what a change in the energy scale means in practice.

5.2 Locally everything will be exactly the same; there will be no apparent changes in the values of any local measurements.

5.3 Locally, every physical equation, if expressed with a scale function following equation (1), will have exactly the same units on both sides. The scale functions will always cancel out and there will be no changes in any locally measured values.

5.4 The only possibility for variations is where some objects are with the observer in one location and other objects are in a separate remote location. This is exactly the scenario for gravitational interactions.

5.5 When objects move from one location to another their physical attributes automatically adjust to the new location.

5.6 If we observe a remote region where the energy scale is twice that here then we would interpret Lyman alpha photons in the region as having an energy of 20.4 eV. But when such photons arrive at Earth their measured energy would be 10.2 eV exactly the same as every other Lyman alpha photon on Earth.

5.7 For photons we have the relation $\boldsymbol{E} = \boldsymbol{h}\,\boldsymbol{\nu}$ which, following our scale functions and subscript notation of equation (1), can be written as

$$[\boldsymbol{\xi_A}\ \boldsymbol{E_{AX}}] = [\boldsymbol{\xi_A}\ \boldsymbol{\varphi_A}\ \boldsymbol{\sigma_A^{-1}}\ \boldsymbol{h_{AX}}]\ [\boldsymbol{\varphi_A^{-1}}\boldsymbol{\sigma_A}\ \boldsymbol{\nu_{AX}}] \tag{10}$$

where $\boldsymbol{E}$ is the energy; $\boldsymbol{h}$ is Planck's constant; $\boldsymbol{\nu}$ is the frequency. Equation (10) is for a photon in remote region $\boldsymbol{X}$ as measured by our observer at $\boldsymbol{A}$. It can be seen that the scale functions ($\boldsymbol{\varphi}$, $\boldsymbol{\sigma}$, $\boldsymbol{\xi}$) are balanced and cancel out. So observers remain unaware of any change in the remote energy scale.

5.8 An analogy may also help. We have all probably had the experience of receiving a gift that arrives in a large box. We sense we are getting a big present and are attracted to it. On opening the packing box we find a smaller box inside and upon opening this find the gift itself, much smaller than anticipated. The present, whether chocolate, game or jewellery, ends up satisfying the desire but not as initially expected.

6 The paradox of varying constants

6.1 Locally all observers will measure exactly the same value for all the constants of physics. The speed of light will still be 3 x 10^{8} m s^{-1}; Planck's constant will still be 6.63 x 10^{-34} Joule seconds; Newton's gravitational constant will still be 6.67 x 10^{-11} N m^{2} kg^{-2}

6.2 However, observers looking at physical processes in remote locations, where the energy scales are different, will deduce different values for those constants of physics involving energy. We end up with the apparent paradox that the constants of physics have the same values everywhere and yet vary from location to location. This is a natural consequence of equation (1).

6.3 Consider locations $\boldsymbol{A}$ and $\boldsymbol{B}$, where the energy scale of $\boldsymbol{B}$ is twice that of $\boldsymbol{A}$.
Observer $\boldsymbol{A}$ will measure a local value for Planck's constant of 6.63 x 10^{-34} Joule seconds, but deduce a value of 1.33 x 10^{-33} Joule seconds for distant location $\boldsymbol{B}$, i.e. double the local value.
On the other hand Observer $\boldsymbol{B}$ will also measure a local value for Planck's constant of 6.63 x 10^{-34} Joule seconds, but deduce a value of only 3.32 x 10^{-34} Joule seconds for location $\boldsymbol{A}$, i.e. half the local value.

6.4 Of course, neither observer $\boldsymbol{A}$ nor $\boldsymbol{B}$ will notice the variations as every local measurement (or constant) involving energy will be affected in exactly the same way by the change in the energy scale.

7 The rotation curves of galaxies

7.1 Consider a star of mass $\boldsymbol{m}$ orbiting a galaxy with central mass $\boldsymbol{M}$ at a distance $\boldsymbol{r}$ and orbital speed $\boldsymbol{v}$. Newtonian gravity and mechanics mean gravity provides the centripetal acceleration through the relation

$$\frac{m\,v^2}{r} = \frac{G\,M\,m}{r^2} \tag{11}$$

or simply

$$v^2 = \frac{G\,M}{r} \tag{12}$$

7.2 If the star is at $\boldsymbol{X}$, the galaxy centre at $\boldsymbol{G}$, and an observer at $\boldsymbol{X}$, equation (12) after introducing the subscript notation of equation (1) is

$$v_{XX}^2 = \frac{G_{XX}\,M_{XG}}{r_{XX}} = \frac{G_{XX}\left(M_{XG}\,c_{XG}^2\right)}{r_{XX}\,c_{XG}^2} \tag{13}$$

where $\boldsymbol{v_{XX}}$ is the speed of the star at $\boldsymbol{X}$ as measured by an observer at $\boldsymbol{X}$; $\boldsymbol{G_{XX}}$ is the gravitational constant at $\boldsymbol{X}$ as measured by an observer at $\boldsymbol{X}$; $\boldsymbol{M_{XG}}$ is the mass of the galaxy at $\boldsymbol{G}$ as measured by an observer at $\boldsymbol{X}$; $\boldsymbol{r_{XX}}$ is the distance from star to galaxy centre as measured by an observer at $\boldsymbol{X}$; $\boldsymbol{c_{XG}}$ is the velocity of light at $\boldsymbol{G}$ as measured by $\boldsymbol{X}$.

7.3 We need to take into account the fact that the mass of the galaxy is at the galaxy centre $\boldsymbol{G}$ and not at the star $\boldsymbol{X}$. Using equation (1) for the energy scale ($\boldsymbol{\xi}$) gives

$$\xi_G\left(M_{GG}\,c_{GG}^2\right) = \xi_X\left(M_{XG}\,c_{XG}^2\right) \tag{14}$$

where $\boldsymbol{\xi_G}$ is the value of the dimensionless function for energy at the galaxy centre $\boldsymbol{G}$; $\boldsymbol{M_{GG}}$ is the mass of the galaxy centre at $\boldsymbol{G}$ as measured by an observer at $\boldsymbol{G}$; $\boldsymbol{c_{GG}}$ is the speed of light at the galaxy centre as measured by an observer at $\boldsymbol{G}$; similarly for the other quantities.

And for the speed of light

$$\boldsymbol{\sigma_G\, c_{GG}^2 = \sigma_X\, c_{XG}^2} \qquad (15)$$

7.4 Equation (13) can now be written as

$$\boldsymbol{v_{XX}^2 = \frac{G_{XX}\, M_{GG}}{r_{XX}} \left\{\frac{\xi_G}{\xi_X}\right\} \left\{\frac{\sigma_X^2}{\sigma_G^2}\right\}} \qquad (16)$$

7.5 In this paper we are not considering variations in the length and speed scales. So we can drop the subscripts on $\boldsymbol{v}$, $\boldsymbol{c}$ and $\boldsymbol{r}$. And $\boldsymbol{\sigma_X = \sigma_G = 1}$. We are also assuming that the values for the constants of physics as measured by local observers are always the same. Hence equation (16) becomes

$$\boldsymbol{v^2 = \frac{G\, M_{GG}}{r} \left\{\frac{\xi_G}{\xi_X}\right\}} \qquad (17)$$

7.6 If the dimensionless function $\boldsymbol{\xi_X}$ decreases away from the galaxy centre, roughly as $\boldsymbol{r^{-1}}$, then the orbital speed will be constant and a flat rotation curve will be possible.

7.7 We have not modified Newtonian gravity, we have not changed any physical constants, and we have not introduced any dark matter. What we have done is introduce a new physical principle that the observed value of a quantity depends on the location of the object and the location of the observer. For galaxy rotation curves it is the fact that the star and galaxy centre are not in the same location that provides the alternative explanation to dark matter.

7.8 Of course what we have done is introduce an arbitrary function with no justification and no explanation. And, of course, by suitable choice of function we can reproduce the shape of any rotation curve. We address these criticisms next.

8 Gaussian fluctuations in the energy scale

8.1 In many physical situations, deviations from the mean are characterised by a Gaussian distribution. Therefore we look at what the result would be for Gaussian fluctuations in the energy scale from location to location. We assume the energy scale has a base value $\boldsymbol{A}$ with Gaussian variations superposed having a central height $\boldsymbol{B}$ and width (length) $\boldsymbol{\alpha}$. This is similar to thermal fluctuations, where there is a base temperature, $\boldsymbol{T}$, with fluctuations of size $\boldsymbol{\Delta T}$. Our dimensionless function, $\boldsymbol{\xi}$, for the energy scale then has the form

$$\boldsymbol{\xi = A + B \;\; exp(-r^2/\alpha^2\,)} \qquad (18)$$

where for any given fluctuation $\boldsymbol{A}$ and $\boldsymbol{B}$ are dimensionless constants.
This is illustrated in Figure 1, below.

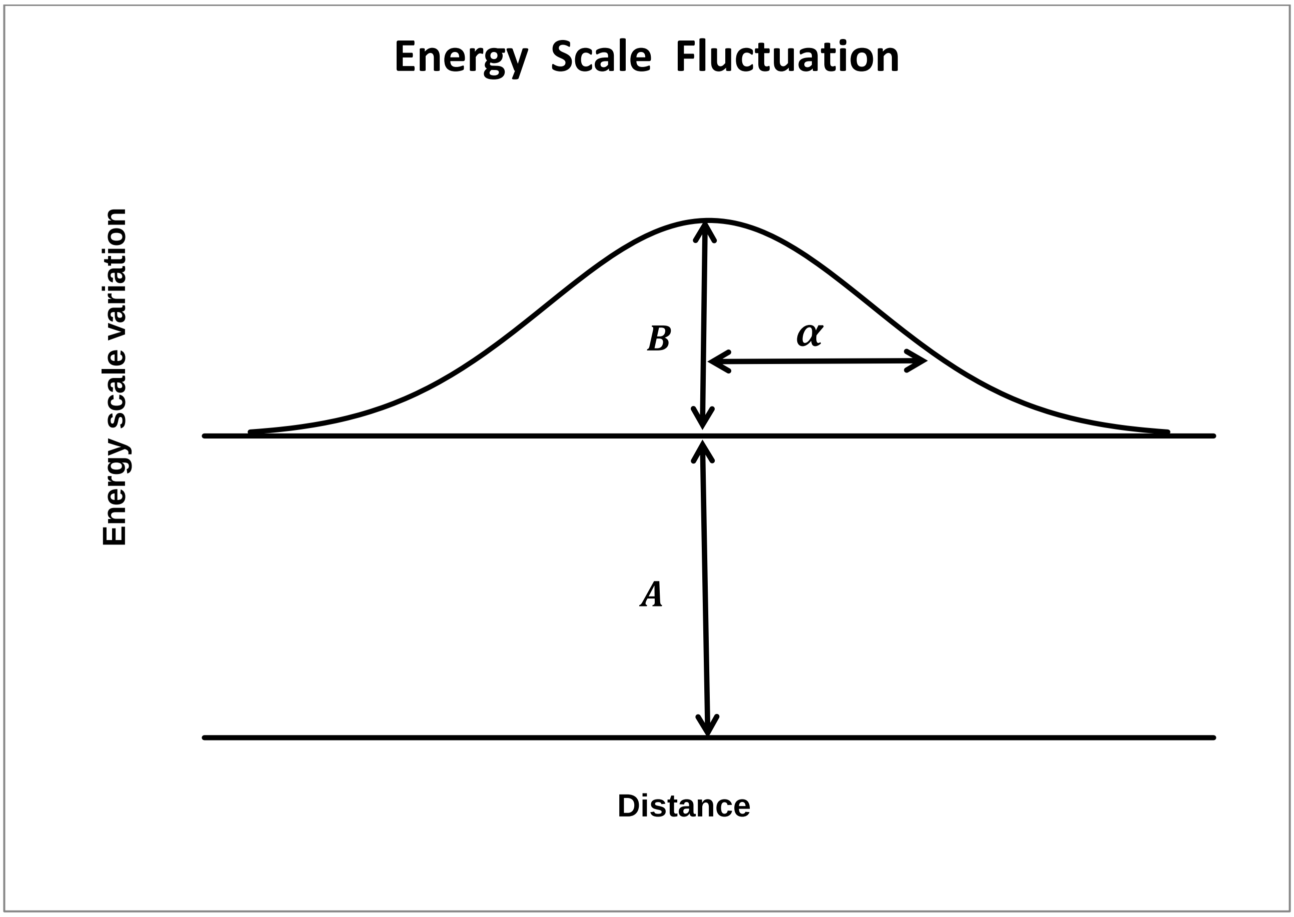

Figure 1. Energy scale fluctuation. $\boldsymbol{A}$ is the base value of the energy scale; $\boldsymbol{B}$ the height of the fluctuation; $\boldsymbol{\alpha}$ the half-width distance of the Gaussian.

8.2 As $\boldsymbol{\xi}$ appears in both numerator and denominator of equation (17) we do not need both $\boldsymbol{A}$ and $\boldsymbol{B}$. Instead we introduce

$$\boldsymbol{\beta} = \boldsymbol{B}/\boldsymbol{A} \tag{19}$$

Equation (17) then becomes

$$\boldsymbol{v}^2 = \frac{\boldsymbol{G}\,\boldsymbol{M}_{GG}}{\boldsymbol{r}} \left\{ \frac{\mathbf{1} + \boldsymbol{\beta}}{\mathbf{1} + \boldsymbol{\beta}\,\boldsymbol{exp}(-\boldsymbol{r}^2/\boldsymbol{\alpha}^2)} \right\} \tag{20}$$

$\boldsymbol{\beta}$ is a dimensionless constant and $\boldsymbol{\alpha}$ a characteristic distance, which for galaxy rotation curves will be of the order of several kilo-parsecs.

8.3 $\boldsymbol{\beta} = \mathbf{0}$ corresponds to current physics with no variation in the energy scale, i.e. equation (20) reverts to equation (12).

For small $\boldsymbol{r}$, i.e. $\boldsymbol{r} \ll \boldsymbol{\alpha}$, the exponential term in the denominator is close to 1 and we again revert to the normal physics of equation (12). So for small distances we are back, as we must be, with Newtonian gravity.

, At the other extreme, when $\boldsymbol{r}$ is large, the exponential term becomes negligible; the bracketed term is close to the constant value $\{\mathbf{1} + \boldsymbol{\beta}\}$; and we revert to the expected $\mathbf{1}/\boldsymbol{r}$ fall off in $\boldsymbol{v}^2$. This is usually put as $\boldsymbol{v} \sim \sqrt{\mathbf{1}/\boldsymbol{r}}$.

8.4 We set

$$\boldsymbol{\rho} = \frac{\boldsymbol{r}}{\boldsymbol{\alpha}} \tag{21}$$

and rewrite equation (20) as

$$\boldsymbol{v}^2 = \frac{\boldsymbol{G}\,\boldsymbol{M}}{\boldsymbol{\alpha}} \frac{\mathbf{1}}{\boldsymbol{\rho}} \left\{ \frac{\mathbf{1} + \boldsymbol{\beta}}{\mathbf{1} + \boldsymbol{\beta}\,\boldsymbol{exp}(-\boldsymbol{\rho}^2)} \right\} \tag{22}$$

This simply enables us to work with distances in terms of $\boldsymbol{\alpha}$, the characteristic distance.

8.5 Finally equation (22) can be expressed in terms of the rotational speed as

$$\boldsymbol{v} \propto \sqrt{\frac{\mathbf{1}}{\boldsymbol{\rho}}\left\{\frac{\mathbf{1}+\boldsymbol{\beta}}{\mathbf{1}+\boldsymbol{\beta}\,\boldsymbol{exp}(-\boldsymbol{\rho}^{\mathbf{2}})}\right\}} \tag{23}$$

We can now plot the predicted rotation speed, as given by the right hand side of equation (23), against distance from the galaxy centre, as given in terms of the characteristic distance $\boldsymbol{\alpha}$.

8.6 Figure 2 shows plots of equation (23) for $\boldsymbol{\beta}$ taking values: 0.0; 1.0; 2.0; 3.0; 4.0; 5.0.

$\beta=0.0$ is the curve for Keplerian orbits with the standard $1/\sqrt{\boldsymbol{r}}$ fall off in speed with distance.

The innermost region, distance <0.5, shows the steep gradient arising from assuming all the mass is in a single central point. Galaxies do not show this as their mass is spread out over a sizeable disk.

At large distances all the curves revert back to a $1/\sqrt{r}$ fall off as they must; albeit at different levels.

Curves with $\boldsymbol{\beta} \approx \mathbf{2.0}$ are flat in their central region and are the ones that match the flat rotation curves observed in many galaxies.

Curves with $\boldsymbol{\beta} \geq \mathbf{3.0}$ show a rise in speed with distance before eventually falling off. Again some galaxies show this behaviour.

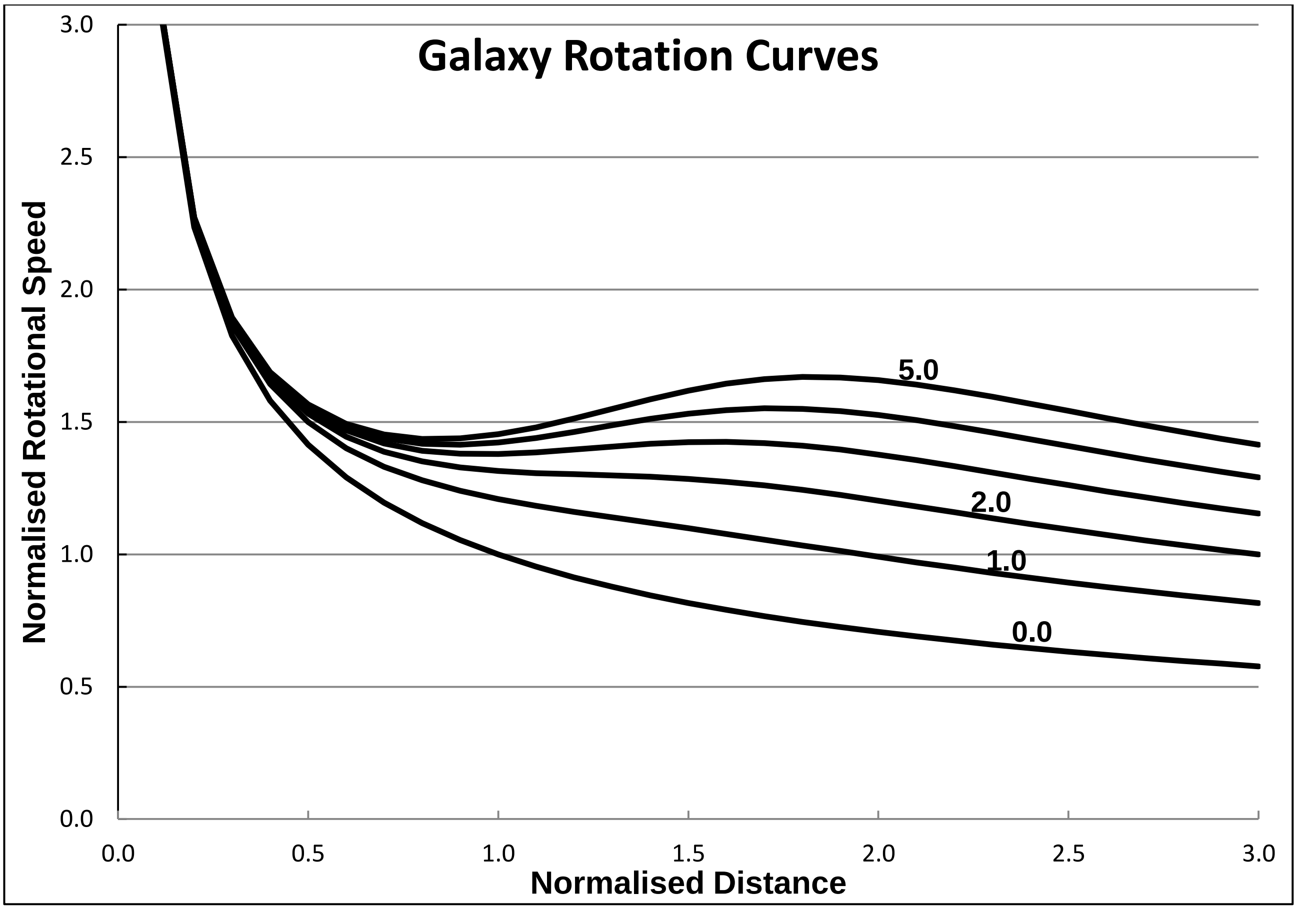

Figure 2: Galaxy rotation curves for Gaussian fluctuations in the energy scale, for different values in the size of the fluctuation. Zero represents no fluctuation and is the standard Keplerian fall off in speed with distance.

9 A sample of galaxy rotation curves

9.1 Equation (22) can be written as

$$\mathbf{v} = \boldsymbol{\gamma} \sqrt{\frac{\mathbf{1}}{\boldsymbol{\rho}}} \sqrt{\left\{\frac{\mathbf{1} + \boldsymbol{\beta}}{\mathbf{1} + \boldsymbol{\beta} \exp(-\boldsymbol{\rho}^{2})}\right\}} \tag{24}$$

where

$$\boldsymbol{\gamma} = \sqrt{\frac{\boldsymbol{G\ M}}{\boldsymbol{\alpha}}} \tag{25}$$

$$\boldsymbol{\rho} = \frac{\boldsymbol{r}}{\boldsymbol{\alpha}} \tag{26}$$

$\boldsymbol{\alpha}$ is the characteristic distance; β is a pure number.

9.2 We take a sample of published galaxy rotation curves and see how well equation (24) fits. The equation assumes all the mass is concentrated at the galaxy centre so we only expect a very rough fit. Equation (24) has three adjustable parameters ($\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$) so some sort of fit is not surprising. (In practice $\boldsymbol{\gamma}$ is determined by the speed $\boldsymbol{v}$; so there are really only two free parameters.)

9.3 Table (1) gives the values of the parameters in equation (24) as measured from the fits to the following rotation curves.

Table (1)

Galaxy	$\boldsymbol{\alpha}$ kpc	$\boldsymbol{\beta}$	$\boldsymbol{\gamma}$ km/s	$\boldsymbol{v}$ km/s	$\boldsymbol{M}$ solar masses
NGC 2403	9	3.5	91	128	2.1×10^{10}
NGC 2841	15	2.0	225	296	1.8×10^{11}
NGC 2903	15	1.9	150	196	4.7×10^{10}
NGC 3198	20	2.4	113	152	6.0×10^{10}
NGC 3621	15	4.5	97	140	1.7×10^{10}
NGC 5055	20	2.2	149	198	1.0×10^{11}

Table 1. Parameters for equation (24) as derived from fitting the observed rotation curves for the listed galaxies. The rotation speed, $\boldsymbol{v}$, is measured at the point corresponding to the characteristic distance, $\boldsymbol{\alpha}$.

9.4 The following figures show the rotation curves for six galaxies. The data points, shown as black diamonds, are the values taken from de Blok et al (2008). The solid line through the data points is an eye fit (not a best fit) found by varying the free parameters in equation (24). The lower line is the Keplerian curve for the same mass as for the eye fit.

9.5 In all the figures the eye fit fails to fit the central regions of the galaxies, but neither does Keplerian rotation. This is simply a reflection of assuming a central point mass rather than a spread out disk.

In all the figures the eye fit curves revert to the expected $\mathbf{1}/\sqrt{\boldsymbol{r}}$ fall off at large distances, but at a higher level than the Keplerian curves.

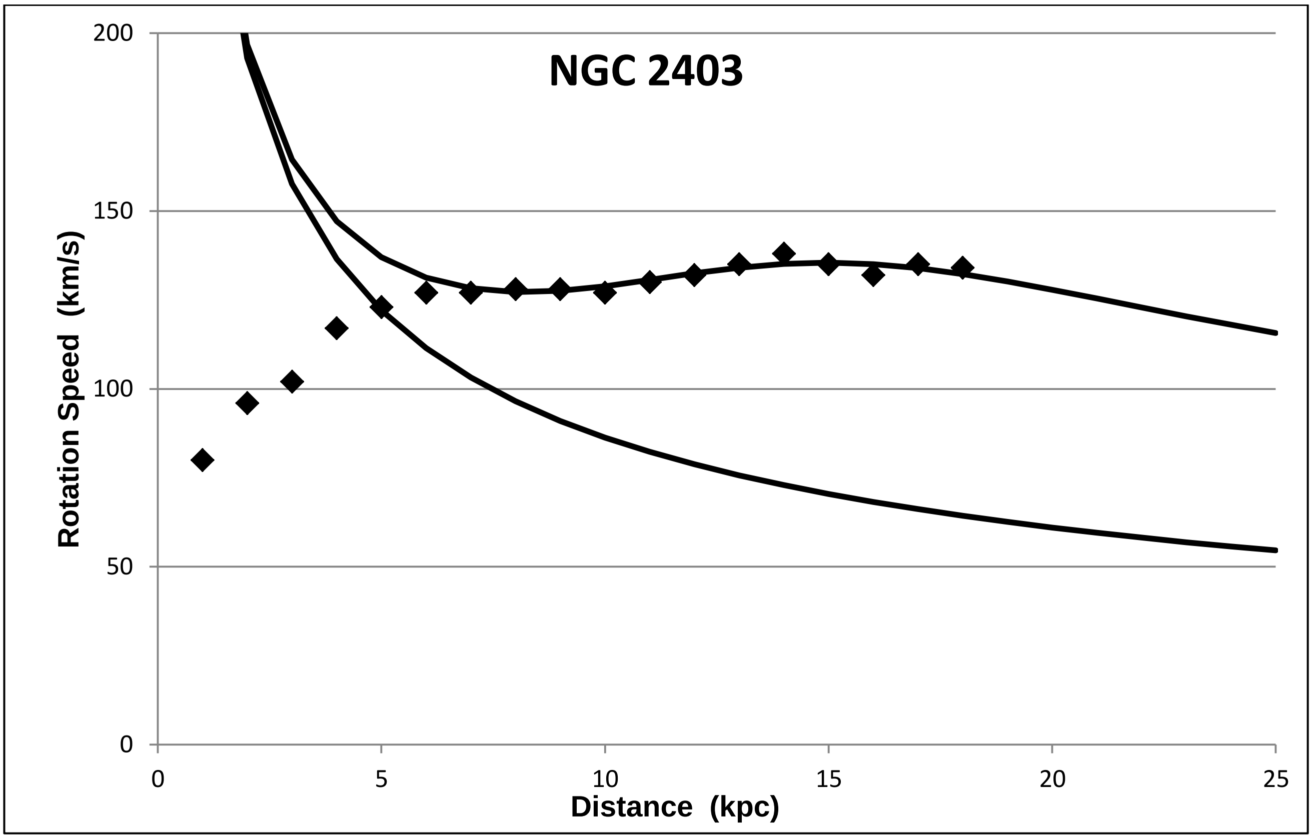

Figure 3: Rotation Curve for NGC 2403.

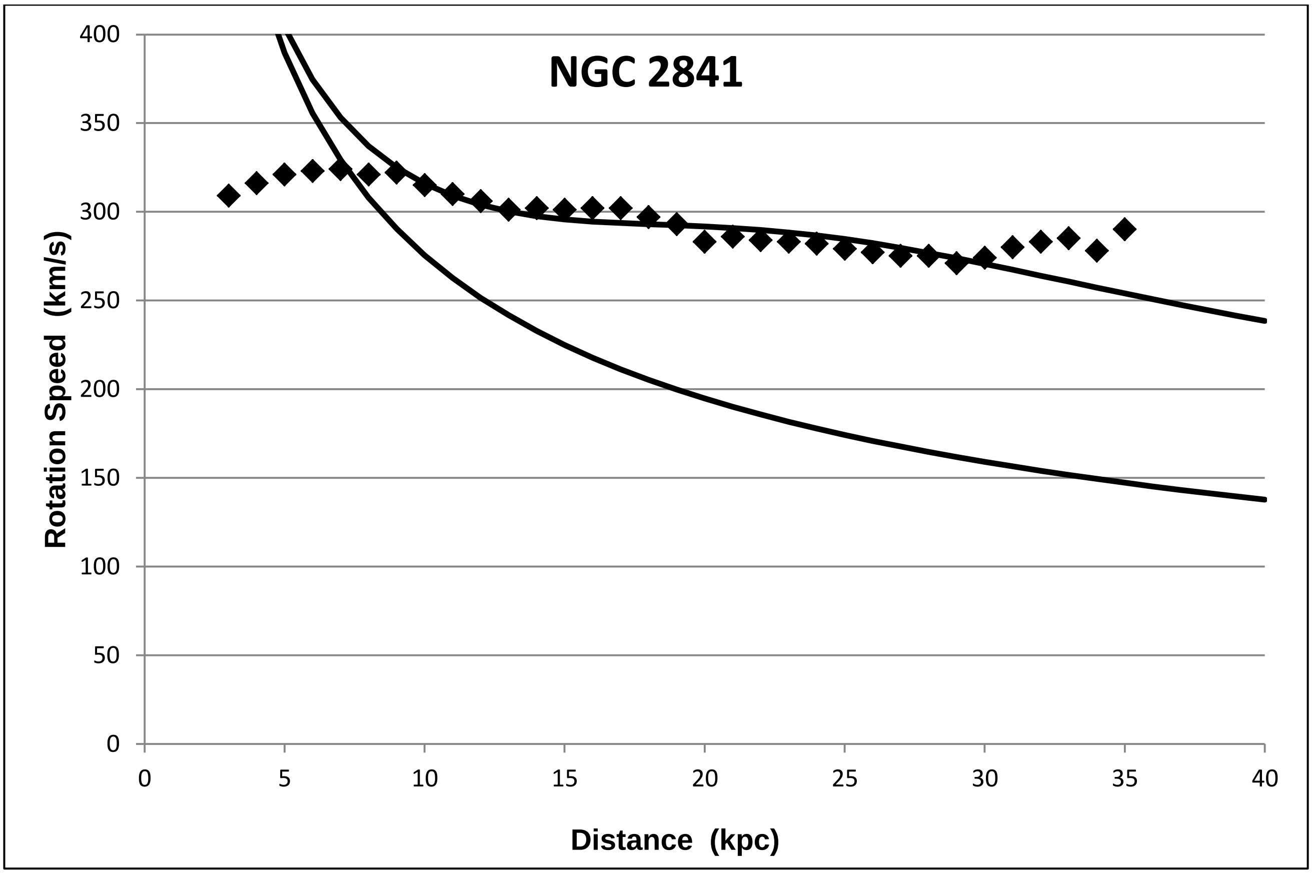

Figure 4: Rotation Curve for NGC 2481.

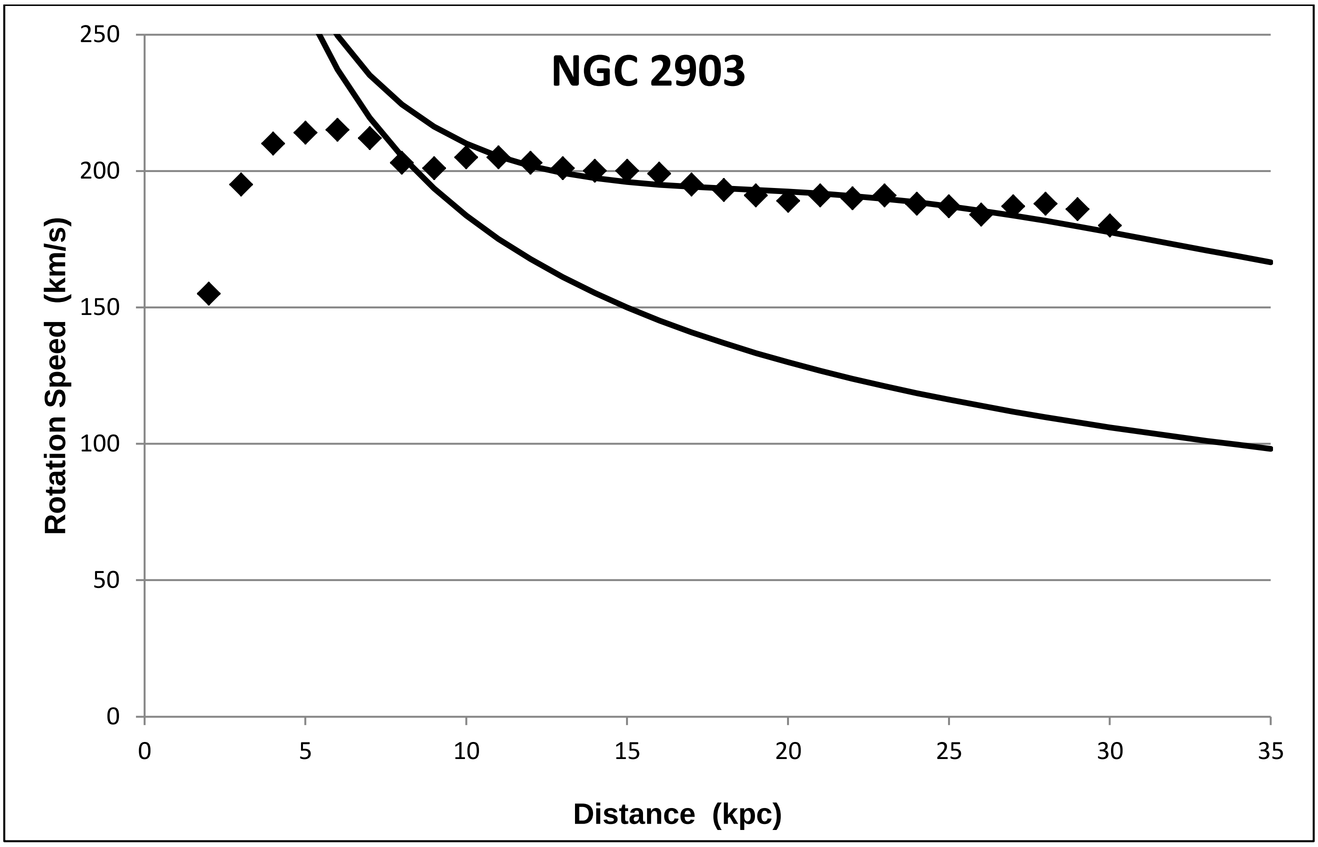

Figure 5: Rotation Curve for NGC 2903.

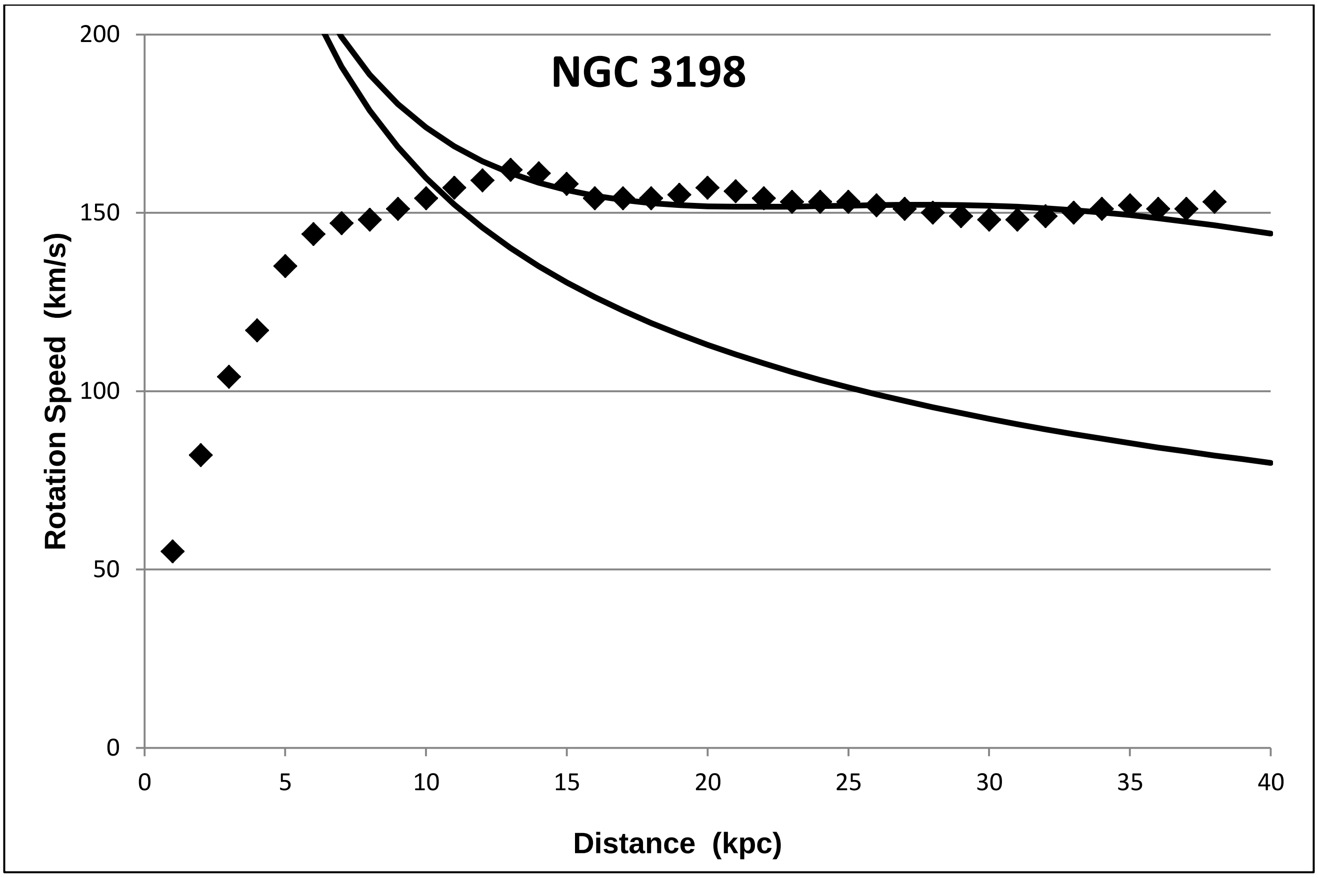

Figure 6: Rotation Curve for NGC 3198.

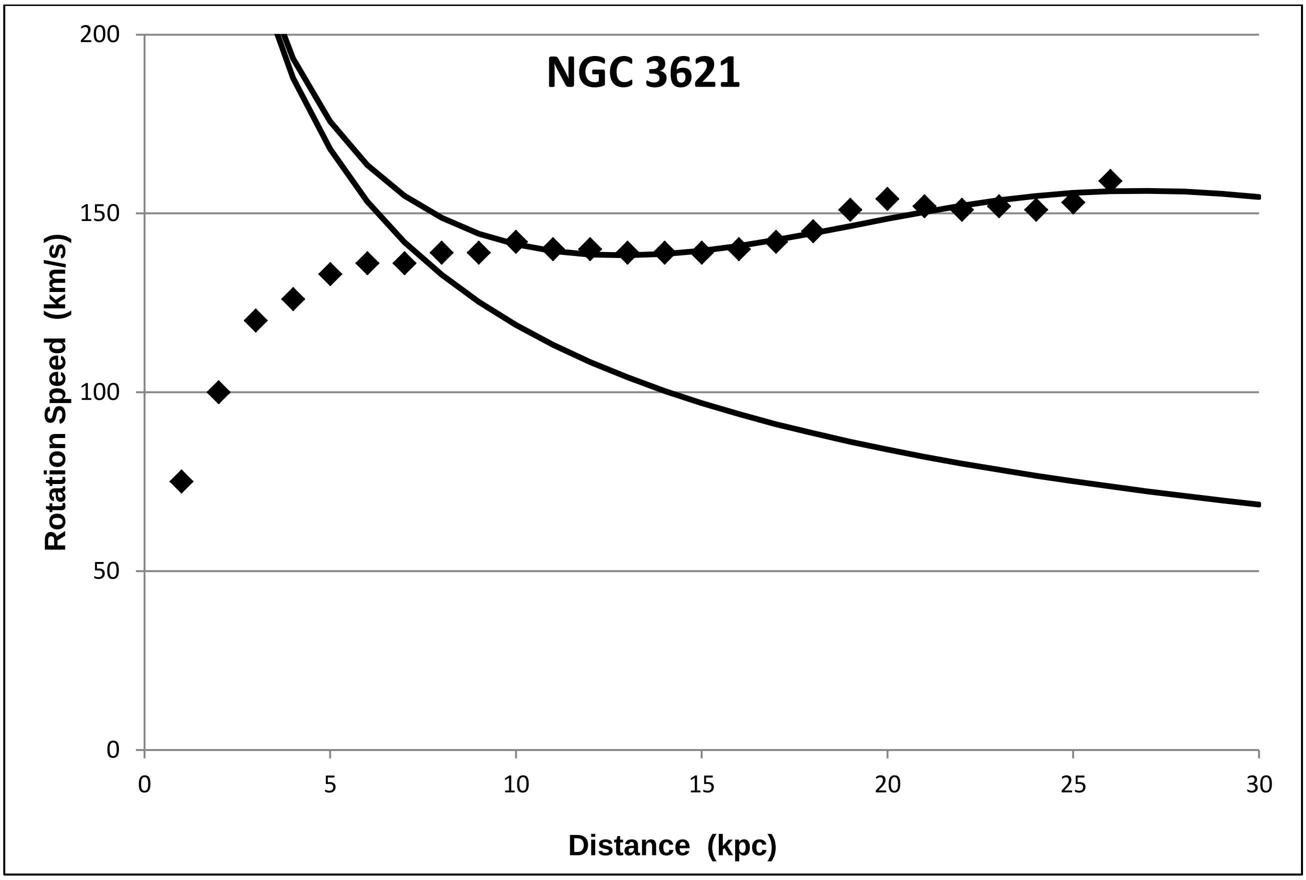

Figure 7: Rotation Curve for NGC 3621.

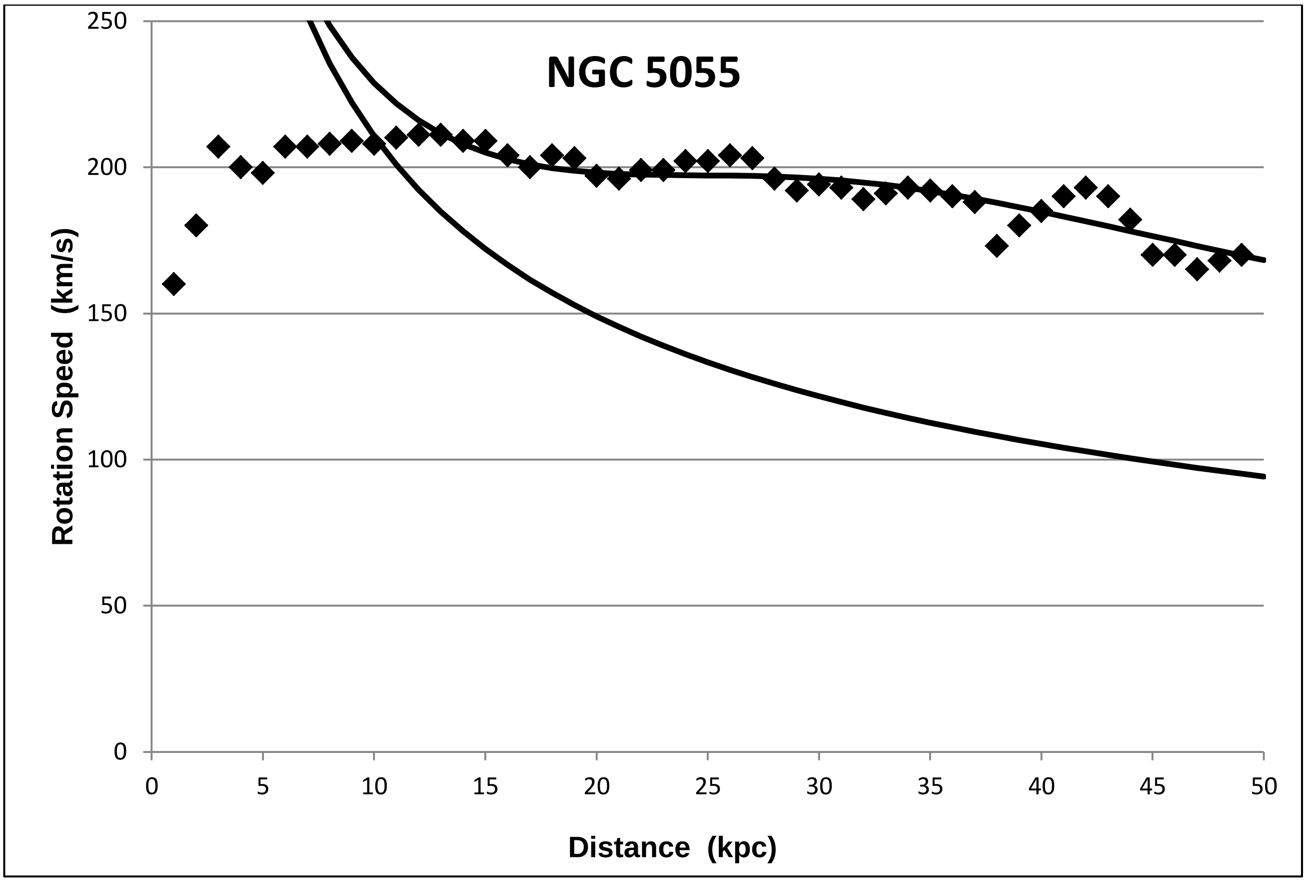

Figure 8: Rotation Curve for NGC 5055.

10 Galaxy masses

10.1 Equations (24) and (25) can be inverted to give an estimate of the galaxy mass, $\boldsymbol{M}$. For the case when $\boldsymbol{\rho = 1}$ we have, in units of solar masses

$$\boldsymbol{M = 2.33 \times 10^5\, v^2\, \alpha \left\{\frac{1 + \beta/e}{1 + \beta}\right\}} \tag{27}$$

10.2 Table (1) also lists this estimated mass for the six galaxies examined. It is somewhat reassuring that the masses are in reasonable agreement with what might be expected for the masses of the spiral galaxies.

10.3 The Tully-Fisher relation is an empirical relationship between the mass and rotational speed of spiral galaxies. The data for our six galaxies are plotted in Figure (9) using the data in Table (1), i.e. the rotation speed at the characteristic distance against the estimated mass. A relationship is clear which is again reassuring.

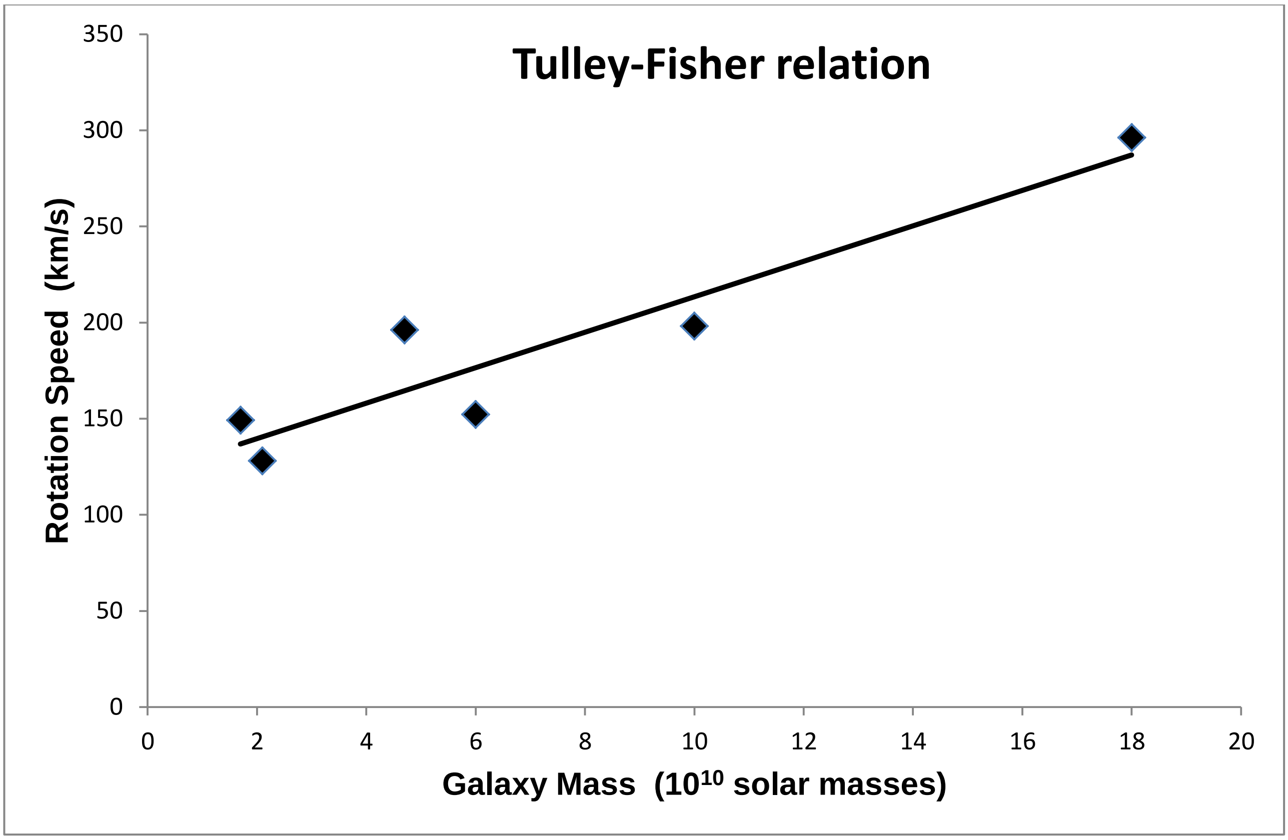

Figure 9. Plot of rotation speed at the characteristic distance against estimated mass. Data taken from Table (1).

11 Clusters of galaxies

11.1 We need to examine whether changes in the energy scale can also account for the missing matter in clusters of galaxies.

11.2 From equation (20) it is clear that, at large distances from the galaxy, the effective mass of the galaxy, $\boldsymbol{M_{eff}}$, is given by

$$\boldsymbol{M_{eff}} = \boldsymbol{M_{GG}}\,(\mathbf{1} + \boldsymbol{\beta}) \tag{28}$$

where $\boldsymbol{M_{GG}}$ is the 'intrinsic' mass of the galaxy, i.e. the mass of the galaxy as measured by an observer at the centre of mass; $\boldsymbol{\beta}$ is the pure number listed in Table (1) for the sample of galaxies.

11.3 Table (1) shows that the average value for $\boldsymbol{\beta}$ is around 2.5, or that the effective mass of galaxies at large distances is a factor 3.5 greater than their intrinsic mass.

11.4 Current estimates for clusters of galaxies puts the visible matter at only 15% of the baryonic matter required to hold the clusters together. Our factor of 3.5 means the galaxies could account for around 50% of the mass. So the discrepancy now is only a factor of 2 rather than a factor of 7.
We have so far ignored the gas in the cluster and, when this is added in, it could possibly remove the discrepancy completely.

11.5 This is, of course, a somewhat superficial and simplistic approach. Nevertheless, the numbers suggest that more detailed work in this area should be undertaken.

12 Conservation of energy

12.1 Any scientific paper that suggests conservation of energy is violated is usually met with instant rejection.

12.2 Changes in the energy scale from location to location mean that conservation of energy is violated as can be seen from the following argument.

12.3 Consider two separate locations where the energy scale at location $\boldsymbol{A}$ is twice that at location $\boldsymbol{B}$, and where there are identical lumps of matter with the same rest mass, $\boldsymbol{2M}$.

The observer at $\boldsymbol{A}$ will measure his lump as $\boldsymbol{2M}$ and the remote mass at $\boldsymbol{B}$ as $\boldsymbol{1M}$, giving a total rest mass of $\boldsymbol{3M}$.

The observer at $\boldsymbol{B}$ will measure his lump as $\boldsymbol{2M}$ and the remote mass at $\boldsymbol{A}$ as $\boldsymbol{4M}$, giving a total rest mass of $\boldsymbol{6M}$.

If observer $\boldsymbol{A}$ takes his lump to $\boldsymbol{B}$, or if observer $\boldsymbol{B}$ takes his lump to $\boldsymbol{A}$, or if $\boldsymbol{A}$ and $\boldsymbol{B}$ meet elsewhere, then both will measure the same rest mass for both lumps, giving a total of $\boldsymbol{4M}$.

12.4 This apparent breakdown in conservation of energy (mass) is simply due to the comparison of measurements made in different locations.

12.5 There is no problem with conservation of energy (mass) at the local level, where objects and observers are at the same location.

12.6 Exactly the same problem occurs in General Relativity where the conservation laws are usually expressed as the covariant derivative of the stress-energy-momentum tensor being zero

$$\boldsymbol{T_{\mu\nu;\alpha} = 0} \tag{29}$$

This works fine at the local level where the conservation laws hold. The problem for global conservation arises when trying to compare tensors at different locations.

13 Fluctuations in the energy scale

13.1 The basic premise for explaining the flat rotation curves of galaxies is that the energy scale varies from location to location. Galaxies are locations where the ξ value for the energy scale is much higher than the surrounding intergalactic regions.

13.2 Regions of high ξ value will act as attractors; once matter has approached it will find it hard to leave. In this sense such regions behave similar to gravitational wells. If there is already substantial mass in this region then we have a win-win situation.

13.3 The fluctuations in temperature observed in the cosmic microwave background (CMB) are thought to have arisen in the inflationary era. These fluctuations are thought to be the seeds of structures in the universe that eventually evolved into galaxy clusters and perhaps individual galaxies. There is currently no accepted theory of inflation, but nevertheless it is tempting to suggest that the fluctuations invoked in this work are the same as those seen in the CMB.

13.4 In this work the scale of the fluctuations is of the order of 10 kpc in length and an energy enhancement over the background value of around a factor of 3. We put forward no reasons why fluctuations in the energy scale should be of these sizes. Indeed at earlier epochs the separation between fluctuations would have been much smaller, possibly even down to microscopic levels. Although we argue against the existence of any dark matter particle we do not rule out the possibility that the effects of energy scale variations might show up in particle accelerators.

13.5 Of course, we would expect fluctuations to be negative as well as positive. There should be regions where the energy scale is depressed as well as regions where the energy scale is enhanced. It maybe that the universe is less smooth as a consequence and in fact much lumpier than we think.

14 Some comments

14.1 We are old and our intellectual abilities are somewhat limited, being no better than first year university in maths and physics. Therefore, we must defer to more able researchers to carry this work forward or to rule it out as a possibility.

14.2 Changes in the energy scale lead to more work on the nature of the stress-energy-momentum tensor in General Relativity. Again others more able than us may wish to pursue this.

14.3 We have discounted changes in the length and speed scales. Others may want to pursue this but we are clear that we do not have the technical abilities required to refactor General Relativity to cover this. If there are variations in the length and speed scales then there must be a conspiracy between these two scales simply because no variations are seen in the times of physical processes.

14.4 We predict that our own galaxy should show variations in the energy scale, declining away from the galactic centre. It should be possible to test this using existing data on binary stars. The derived masses for stars of given spectral type should show a decline with distance from the galactic centre. Alternatively a substantial reduction in the residuals for the mass determinations should appear.

14.5 We see no reason why the proposition put forward in this work should not also apply to elliptical galaxies. We do not mean that elliptical galaxies should have rotation curves, but rather that elliptical galaxies should exist in regions with varying energy scales and show some indications of this.

14.6 Our proposal is that the energy scale can vary from location to location. The variations can be anything from zero to some moderate value (possibly less than 10). We have no difficulty in explaining those galaxies (and globular clusters) that apparently have little or no dark matter as these would simply be in regions having little or no energy scale variation.

14.7 We have worked with energy scale fluctuations that are simple Gaussians. This is just one idea. More able physicists will surely come up with better and more appropriate suggestions.

14.8 Many researchers have access to computer codes that simulate individual galaxies; galaxy collisions; clusters of galaxies; cluster collisions; evolution of the universe. It would be really interesting to remove the dark matter from these models and replace it with some form of energy scale variation.

14.9 Many clusters of galaxies show gravitational lensing. This is often reverse engineered to reveal a dark matter distribution. It should also be possible to carry out a similar analysis but instead end up with a distribution of energy scale variations.

14.10 At an algebraic level others may well be able to recast this work in the framework of Modified Newtonian Dynamics, MOND (Milgrom, 1983). However, the basic idea of MOND is a modification of gravity at low accelerations, and that is completely different from the basic idea here of variations in the energy scale. Nevertheless there may be some algebraic similarities.

14.11 The apparent accelerating expansion of the universe as derived from observations of remote Type Ia supernovae is interpreted as evidence of a "dark energy", which permeates the whole of space. Understanding the nature of "dark energy" is a completely different problem to understanding "dark matter" and we have nothing to say about it in this paper.

14.12 This paper is highly speculative and we would like to indulge ourselves by putting forward one final suggestion, namely that gravitational waves do not exist. Our introduction of the dimensionless $\boldsymbol{\xi}$ function for the energy scale means that (at a simplistic level) the gravitational potential becomes

$$\boldsymbol{\xi\,\Phi = \xi\,\frac{G\,(M\,c^2)}{r\,c^2}} \tag{30}$$

Gravitational waves arise when one considers the time rate of change of $\boldsymbol{\Phi}$. However, the $\boldsymbol{\xi}$ factor means that such changes could be absorbed into changes in $\boldsymbol{\xi}$. So instead of energy being radiated away by gravitational waves, the depth of the energy scale variation would change. By extension this means that there is no need for a graviton particle.

This paper has concerned itself with the "how" rather than with the "why". A "why" now presents itself. There is no graviton particle; therefore gravitational waves do not exist; therefore there must be variations in the energy scale from location to location.

15 Conclusion

15.1 We put forward the proposition that the observed flat rotation curves in spiral galaxies arise through changes in the energy scale from location to location. Gaussian fluctuations in the energy scale go some way to reproducing the observed rotation curves.

15.2 Although this idea is new to us, it is such a simple idea that we feel sure many others must have had same idea in the past. However, we have not come across this suggestion in recent literature and it does not appear to be mentioned as an alternative to dark matter.

15.3 This work is somewhat speculative. We know that we have probably got many of the details wrong and that others will no doubt find better ways of presenting the material. However, we are in no doubt as to the general thrust of the argument.

15.4 We have provided only a few references. This is a new idea and previous references do not exist. We do not have ready access to primary sources in scientific journals; we are limited to the Internet and the likes of Wikipedia for which we are grateful. A simple search of the Internet will retrieve many (non-peer-reviewed) articles supporting the background material referred to here.

15.5 We have resisted the temptation to use the idea of energy scale variations to explain all the outstanding problems of astronomy and cosmology. It is a simple idea and may well have a simple rebuttal. We have deliberately kept this paper simple. We have put forward a simple idea explaining galaxy rotation curves, worked out some simple details using Gaussian fluctuations, and made simple comparisons with observations. We simply leave it at that.

16 References

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