A new paradigm for the structure of galaxies

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A new paradigm for the structure of galaxies is proposed. The main hypothesis is that a normal galaxy contains a hypermassive black hole at its centre which controls its dynamic and generates the spiral arms. The paradigm gives satisfactory explanations for:

- The rotation curve of a galaxy
- The spherical bulge at the centre of a normal galaxy
- The spiral structure and long-term stability of a normal galaxy
- The age and orbits of globular clusters
- The origin and prevalence of solar systems
- (Partially) the origin of life

The paradigm is compatible with direct observations but not with many of the current interpretations of these observations. It is also incompatible with large swathes of current cosmological theory and in particular with the hot big bang theory.

In a companion paper [14] (joint work with Robert MacKay) we give a new explanation of redshift which is compatible with the main hypotheses of this paper. This is one of the so-called "three pillars of the big bang theory". A second pillar namely the observed distribution of light elements is explained in outline in this paper. The third pillar, the cosmic microwave background (CMB) will be considered in a future paper [15], though for completeness, some remarks about this are made here.

85A15; 85A40, 83F05, 83C40, 83C57

1 Introduction

This paper is part of a program whose aim is to establish a new paradigm for the universe. In this paradigm the universe is long-lived (several orders of magnitude greater than the current estimate for its age) and homogeneous in the large (in both space and time).[1] Other papers in the program (of which several are joint work with

[1] This statement needs some clarification. In our model there are many very heavy bodies and space-time changes dramatically near a heavy body. But at similar distances from these bodies space-time is much the same everywhere.

Robert MacKay) are concerned with redshift [14], observations of very distant galaxies [19], local observations of stellar velocities [20] and the CMB [15]. The underlying geometry used in [14] is discussed in [13].

This research arises from observations of galaxies, Figure 1.

Figure 1: M101 (left) and NGC1300 (right): images from the Hubble site [2]

Most galaxies appear strongly centrally controlled with intricate and strikingly beautiful structure. There is also a near universal rotation curve, Figure 2 (left).

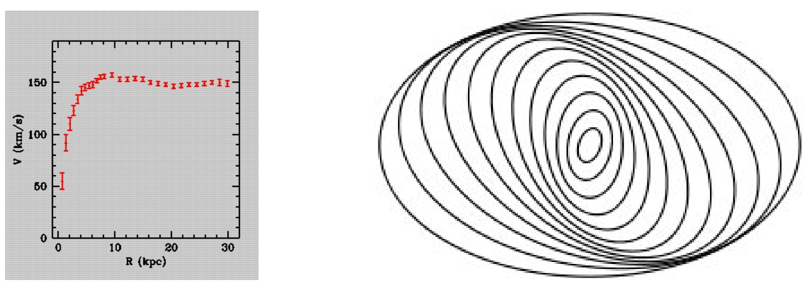

Figure 2: Left: the rotation curve for the galaxy NGC3198 reproduced from [1] (sourced from Begeman [6]). Right: the standing wave theory, reproduced from wikipedia

However, the prevailing cosmology based on the hot big bang (BB) theory has no satisfactory model for the structure of galaxies. One widely publicised theory which attempts to explain the predominant spiral structure is the standing wave theory. For example see Figure 2 (right). No comment is needed when comparing this with Figure 1 (right) or Figure 7 (left).[2]

[2]To be a little fairer to the standing wave theory, there is a rider to the theory which suggests that a shock-wave effect causes short-life stars to appear as the standing wave moves. This rider would carry more force if there was any evidence for such short-life stars in our immediate neighbourhood: after all the sun is part of a spiral arm of the Milky Way.

The situation regarding the universal rotation curve is equally unsatisfactory. In order to explain the curve, it is necessary to hypothesise the existence of a huge amount of dark matter. Indeed if the observation of flat rotation curve extending to great distances is fitted by a suitable distribution of dark matter, then the quantity needed is implausibly large (and tends to infinity with the radius of fit).

Satisfactory explanations, not involving dark matter, for both the spiral structure and the rotation curve will be given in this paper. The main hypothesis is that the centre of a normal galaxy contains a hypermassive black hole[3] of mass around 10^{15} solar masses. The centre generates the spiral arms by a process, which will be outlined, whereby matter is ejected from the centre and condenses into solar systems. This implies that young stars in a galaxy are moving outwards as well as around the centre. This general outward movement has not been observed and the reason for this is that (for an observer on the same side of the centre) the frequency shift due to the outward motion is cancelled by the gravitational frequency shift from the gravitational field of the centre. As will be seen later, in a normal galaxy stars move outwards at near escape velocity, so the two opposing frequency shifts are almost the same. Also the motion of stars is far from Keplerian, being strongly controlled by inertial drag effects from the (rotating) centre. The result is that the outward progress takes a very long time—commensurate with the lifetime of a star and hence the outward velocity is rather smaller than (about one fifth of) the observed rotational velocity. The general picture which emerges is of a structure stable over an extremely long timescale (at least 10^{12} years) with stars born and aging on their outward journey from the centre and returning to the centre to be recycled with new matter to form new solar systems. This timescale is incompatible with current estimates for the age of the universe and entails the abandonment of the big bang theory in its current form. The tentative suggestion is that galaxies have a natural lifetime of perhaps 10^{16} years with the universe considerably older than this.

The paper is organised as follows. Section 2 contains a discussion of galactic rotation curves. This is not the most logical place to start, but it provides by far the clearest evidence for the main hypothesis. The new paradigm gives a natural explanation of the observed rotation curves for galaxies. Section 3 discusses another strong piece of evidence—the spherical bulge at the centre of normal galaxies. Section 4 describes the main proposal, namely the generator for spiral arms and the way in which energy feeds from the central black hole and gives an outline explanation for the observed distribution of light elements. In Section 5 the full dynamic of a spiral galaxy is discussed and the way in which the arms are formed in differing types of spiral galaxies. Section 6 is

[3]The terminology “black hole” is very unfortunate as it is already clear that hypermassive objects are anything but black. However it is well established and I shall continue to use it.

concerned with a further strong piece of evidence, namely the age and orbits of globular clusters. Section 7 discusses the formation of solar systems, which appear in a natural way in the new paradigm and tentatively suggests how life starts on suitable planets. Section 8 concerns a remarkable piece of direct evidence from our own galaxy near Sagittarius A^* and Section 9 (included for completeness) briefly summarises papers [14, 15] on redshift and the CMB. Finally Section 10 contains speculative material on the nature and long-term evolution of galaxies which provides a very tentative explanation for why the tangential velocity in normal galaxies appears similar across many different galaxies.

It is worth remarking that, in contrast to other suggested alternatives to current mainstream cosmology, this program does not propose any new physics. Indeed the whole program can be seen as strong supporting evidence for the correctness of standard Einsteinian relativity.

It is also worth remarking that there is one strong piece of evidence for the main hypothesis that has been known for 77 years. If you estimate the mass of a galaxy from its luminosity you get a mass that is at least a factor 300 times too small to account for the observed galactic and super-galactic clustering, Zwicky (1933) [27] and later observations. Since the estimate of mass based on luminosity is approximately 10^{12} solar masses, this makes the true mass of a galaxy between 10^{14} and 10^{15} solar masses, which is the mass proposed here.

There are two more recent sets of observations that also need immediate comment. Firstly, there is a strong body of observations of local stellar velocities with some quite remarkable properties. Properly interpreted these observations strongly support the galactic dynamics proposed in Sections 2 and 5 of this paper and full details of this can be found in a companion paper [20]. Secondly some detailed observations of the stars near Sagittarius A^* put the mass of the central object at around 10^6 solar masses, far smaller than the central mass proposed here. An alternative explanation for these observations is proposed here. This is the result of gravitational collpase on the majority of the stars in a very old Globular Cluster with the remaining stars observed in Keplerian orbit around it. For more detail here see Section 6 and 8.

Notes A preliminary version of this paper was posted in 2003 [21]. At that time I was unable to find a satisfactory explanation for redshift and did no further work of the program until a couple of years ago when Robert MacKay and I started to collaborate on understanding redshift.

The paper is still largely a preliminary study of the subject and has obvious gaps, notably in the interpretation of observations and in the theory of the spiral arm generator. It is being published in the hope that others will help complete the work.

2 The rotation curve

The observed rotation curves for galaxies are quite striking. Essentially the curve (of tangential velocity against distance from the centre) comprises two approximately straight lines with a short transition region. The first line passes through the origin and the second is horizontal. See Figure 2 (left) above.

Galactic rotation curves are so characteristic (and simple to describe) that there must be some strong structural reason for them. They are very far indeed from the curve you would get with a standard Keplerian model of rotation with any reasonable mass distribution. The current explanation involves a fortuitous arrangement of "dark matter" (ie matter for whose existence there is no other evidence) and begs several questions not least of which are the stability and prevalence of this arrangement. This explanation is strained to the limits by several observations which show that the horizontal straight line section of the rotation curve extends far outside the limits of the main visible part of galaxies.

The explanation given here involves no dark matter. Essentially the rotation curve is a consequence of inertial drag due to rotation of the hypermassive central black hole. Inertial drag is one of the stranger consequences of general relativity. It is a true embodiment of Mach's principle understood in the sense that the matter in the universe determines the concept of inertia. For a discussion of this effect see Misner, Thorne and Wheeler [16, Section 21.12]. Only the most basic properties of inertial drag will be needed:

(1) A rotating body causes the local concept of "inertial frame" to rotate in the same sense as its own rotation.

(2) This effect drops off proportionately with $\frac{1}{r}$ where r is distance from the centre of the body.

Now suppose that there is a heavy rotating body of zero size at the origin.[4] Then the concept of "inertial frame" is formed by superposing the static frame from the universe in general and the rotating frame from the body. The rotating frame dominates totally at the origin and the rotation of inertial frames (measured with respect to a standard frame distant from the origin) can be modelled as the weighted average of the rotating and static frames.

[4] The effect described here does not depend on the mass, so "heavy" is strictly unnecessary. However if the mass is not huge, the effect is negligible in practical terms. Zero size is for simplicity and is also immaterial.

Working in the plane of rotation let r denote distance from the origin. Suppose the rotating frame has angular velocity ω. The rotation effect on inertial frames caused by the heavy rotating body and measured at r from the origin has weight K/r compared with the static inertia due to the rest of the universe. Here K is a constant depending on the mass of the body (roughly equal to the Schwarzschild radius in the case of a black hole).[5] Thus the nett rotation of frames is the average of ω weighted K/r with 0 weighted 1 ie:

$$\frac{\frac{K}{r}\omega + 1 \times 0}{\frac{K}{R} + 1} = \frac{\omega K}{r + K} \qquad (*)$$

Now consider a particle of small mass ejected roughly radially from the origin with respect to the central rotating frame (ie actually rotating with tangential velocity $v \approx r\omega$). Then there are two opposing effects acting on its tangential velocity:

(1) The rotation of the inertial frames tends to increase v. The acceleration is ω for r small and is $\frac{\omega K}{r+K}$ in general.

(2) Conservation of angular momentum causes any excess velocity over that due to rotation of inertial frame to decrease. The excess velocity is $v - \frac{K\omega r}{K+r}$ so the decelleration due to this effect is:

$$\frac{1}{r}(v - \frac{K\omega r}{K+r}) = \frac{v}{r} - \frac{\omega K}{r+K}$$

Adding the two effects:

$$\frac{dv}{dr} = \frac{K\omega}{K+r} - \frac{v}{r} + \frac{K\omega}{K+r} = \frac{2K\omega}{K+r} - \frac{v}{r}$$

Thus:

$$\frac{d}{dr}(rv) = r\frac{dv}{dr} + v = \frac{2r\omega K}{r+K} = 2\omega K - \frac{2\omega K}{\frac{r}{K}+1}$$

Hence:

$$rv = 2\omega Kr - 2\omega K^2 \log(\tfrac{r}{K}+1) + C$$

where C is a constant depending on initial conditions. For a particle ejected with $v = r\omega$ for r small, $C = 0$, and for general initial conditions there is a contribution C/r to v which does not affect the behaviour for large r. Setting $C = 0$ gives the solution:

$$v = 2\omega K - \frac{2\omega K^2 \log(\frac{r}{K}+1)}{r}$$

[5] A calculation of K can be deduced from the discussion in Misner, Thorne and Wheeler (op cit). See section 21.12 and in particular equations 21.155-6: the rotation effect for a body at distance r is $\frac{4}{3r}$ times the angular velocity in units in which the Schwarzschild radius is 2, giving $K = \frac{2}{3}R$ where $R =$ Schwarzschild radius.

There are two asymptotes. For r small $v \approx r\omega$ and the curve is roughly a straight line through the origin. And for r large the curve approaches the horizontal line $v = 2\omega K$. A rough graph is given in Figure 3 where $K = \omega = 1$.

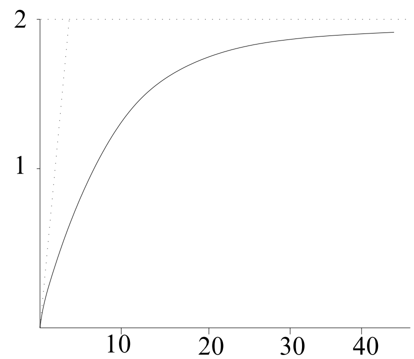

Figure 3

This curve is a good, but not perfect, fit to observed galactic rotation curves. However our analysis so far has been very simple minded and has ignored all effects except inertial drag from the centre. In this sense the result is quite remarkable. The salient features of the rotation curve are entirely explained as the effect of inertial drag.

The most important effect that has been ignored, for a standard spiral galaxy with bilateral symmetry, is the gravitational attraction of the arms. This causes a "flywheel effect": stars in the arms will tend to rotate with the local rotation of the arms. This extends the region where rotation is roughly plate-like and causes the rotation curve to be nearer to a straight-line through the origin of somewhat smaller slope than the asymptote. The flywheel effect breaks down as r increases to the point where the forces required to maintain it are too great and the rotation curve turns fairly sharply towards the horizontal asymptote. This modifies the curve of Figure 3 to something like Figure 4.

Finally note that perturbations to tangential velocity die out like $1/r$ and the limiting horizontal asymptote is highly stable. Perturbation in the flywheel effect (due to non-uniform mass in the arms) will result in fluctuations in the horizontal portion of the rotation curve as illustrated in Figure 5. Figure 5 is a perfect fit for observed rotation curves.

Several comments need to be made.

(1) The analysis in this section has totally ignored radial velocity. Indeed it is a quite remarkable effect of inertial drag that the tangential velocity is controlled asymptotically

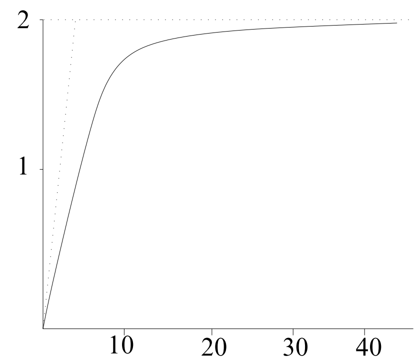

Figure 4

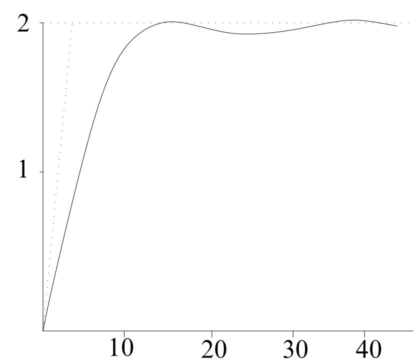

Figure 5

independently of radial velocity or acceleration. In Section 5 the effects on radial acceleration caused by the rotation are discussed (together with other unrelated effects) and the full dynamic of a spiral galaxy is derived in outline. This will explain the familiar spiral structure.

(2) An unholy mixture of relativistic and Newtonian dynamics has been used. For largish r this is justified since inertial drag is then the dominant relativistic effect. However for small r the approximations used are probably very coarse and the analysis needs to be done properly in a fully relativistic setting which may well significantly alter the theoretical rotation curve.

(3) Nevertheless this crude discussion does allow a first estimate of the central mass of a normal galaxy. The observed rotation curves show roughly plate-like rotation extending about to the edge of the central spherical bulge. Comparing with Figure 5, this would give the radius of the bulge as about 10 times the Schwarzschild radius. From

looking at a gallery of galaxy photographs, the radius of the bulge is commonly about 10^{-1} times the galactic radius so the Schwarzschild radius is about 10^{-2} times the galactic radius. Thus for the Milky Way with a diameter of 10^{18}km the Schwarzschild radius is 5×10^{15}km giving a mass of roughly 1.7×10^{15} solar masses.

(4) The control of tangential velocity that has been examined in this section applies most strongly to motion in the galactic plane (and indeed to stars moving outward at the start of their lives). The control gets progessively weaker the further out one goes and random motions and local gravitational effects change the motion. Thus one would expect that the rotation curves obtained in Figures 3 to 5 apply best in the galactic plane, with significant variations outside it. This is indeed what is observed.

As remarked earlier, the effect described in this section is independent of mass. However for rotating bodies of small mass the effect is unobservably small. For example the sun has $K \approx 2$km and $\omega = 2\pi/25$ days. Thus $2K\omega$ is 4km per 4 days or .04 km per hour.

(5) The tangential velocity v can be written as $v = v_{\text{rot}} + v_{\text{inert}}$ where v_{rot} is the tangential velocity due to rotation of the local inertial frame and v_{inert} is the tangential velocity measured in the local inertial frame. From $(*)$ we read that $v_{\text{rot}} = \omega K r/(r+K)$ which tends to ωK asymptotically. Thus the asymptotic limit for v_{inert} is also ωK.

Observational comment Galaxies with poor bilateral symmetry should have smaller flywheel effect and rotation curve should be nearer Figure 3 that Figures 4 or 5.[6]

3 The spherical bulge

The next piece of evidence for the existence of a hypermassive black hole at the centre of galaxies is so obvious and commonplace that, like many commonplace observations, it is easily overlooked. Normal galaxies have a pronounced spherical bulge at their centres. No satisfactory explanation for this has been proposed. If a galaxy is a rotating disc composed of stars and gas with, perhaps, a massive but not hypermassive black hole at the centre (say 10^7) solar masses, then there is no reason to expect the formation of a spherical bulge. One might see a pronounced cluster at the centre, but why should this extend to great distances on either side of the plane of the galaxy?

However if there is a hypermassive black hole at the centre then a spherical bulge is exactly what would be seen, because of gravitational lensing effects. The bulge is not real, but an artifact of the distortion of light caused by the black hole. A graphic

[6] I failed to find any specific observations to support this comment.

demonstration of this effect can be found on the web at:
http://www.photon.at/∼werner/bh/index.en.html

The visible size of the bulge can be used to give a second rough estimate of the mass of the central black hole similar to that given in Section 2. The lensing effects extend to roughly 20 times the Schwarzschild radius. However the expected size of the bulge depends heavily on the actual shape of the galaxy, thus for a given mass of centre, a thin disc will not give such a large bulge as a thicker one. A guess from looking at pictures is that the Schwarzschild radius of the black hole at the centre is commonly about 3×10^{-3} times the galactic diameter. Thus for the Milky Way with a diameter of 10^{18}km the Schwarzschild radius is 3×10^{15}km giving a mass of roughly 10^{15} solar masses.

4 The generator for spiral arms

Here is a sketch of the proposed nature of a normal galaxy. The centre contains all but a small proportion (less than 1%) of the mass. The remainder (10^{11}–10^{12} solar masses) is the visible part of the galaxy. The centre comprises two parts. A central black hole and a surrounding rapidly rotating sphere of matter some of which is in plasma form, which I shall call the *generator*. The generator is mostly concentrated in the equatorial band forming a rotating toroidal belt which I shall call simply the *belt*. The belt has a complex electro-magnetic structure similar to that modelled (see eg Williams [24, 25, 26]) for (lighter) black holes and used to explain Active Galactic Nuclei.[7] The generator is fed from two sources. Dying stars and debris fall into it and get torn apart by the huge tidal forces and broken down into atoms or smaller particles and energy feeds directly into it from the central black hole both in the form of Penrose-process energy and directly from the gravitational field by tidal effects. The result becomes highly unstable as it builds up and it forms sharp bulges which explode outwards flinging elementary particles, energy and heavier particles out into space to condense into solar systems and form the familiar arms.

The generator is highly massive and stratified, with a plasma of small particles at the inside, where the input of energy from the black hole is greatest, and with layers of heavier particles and dust as one moves outwards. The thickness of the generator implies that the polar radiation observed for so-called Active Galactic Nuclei does not escape and explains why this is not observed for normal galaxies.

[7] Again it is clear that the traditional terminology is highly unfortunate here as the burden of this paper is that all normal galactic nuclei are highly active.

The explosions do not occur in random places: most normal galaxies have a pronounced bilateral symmetry with two main opposing arms (eg M101, NGC1300, M83, NGC1365, M51 Figures 1, 6 and 7). There is no instrinsic reason for this to happen, but it is a stable situation. Once two arms have formed, then the gravitational pull of these arms will form bulges at the roots of the arms and encourage explosions there which feed the arms. The bilateral symmetry arises because the bulges are tidal bulges which always have bilateral symmetry.

This tendency to bilateral structure is weak and looking at a gallery of galaxies you can find many examples where it fails to form or where other weak arms have formed as well as the two main arms.

Figure 6: M83 Southern Pinwheel: image from European Southern Observatory

One general observed property of spiral arms is worth commenting on. The roots of the arms are offset. A very clear example is M83 Figure 6 but any gallery of galaxies shows the same phenomenon repeated. This property is related to the apparent size of the central black hole and the belt rotation. A full explanation will have to wait for a good mathematical model for the generator. But this offset, which is clearly a real phenomenon, can be used to explain the general rotation of galaxies: The offset jets contain a deal of lighter particles, eg photons, which are radiated away from the galaxy and this "wind" radiates angular momentum away from the system and causes rotation in exactly the same way that a pinwheel rotates. Later (in Section 10) it will be seen how the rotation stabilises and this will explain the near uniformity of rotation across different galaxies as observed in rotation curves.

The distribution of light elements

Before moving on to discuss the dynamics of galaxies as a whole it is worth mentioning that the hypothesis of a central generator can in principle explain one of the so-called "pillars of the BB theory" namely the observed distribution of light elements. The structure of the belt outlined above is similar to the immediate aftermath of the BB with the earlier times corresponding to layers closer to the central black hole. As we move outward through the layers, we copy the hypothesised history from the BB with the innermost plasma layer corresponding to the earliest matter state. Thus the condensation of this plamsa into elementary particles and thence into light elements has a similar description with the consequence that the resulting distribution is the same.

5 The full dynamic

This section is in very preliminary form and contains an unholy mixture of relativistic and Keplerian dynamics (together with some unrelativised electrostatics). It needs to be recast in fully relativistic form.

Most of the visible part of a galaxy lies within 100 Schwarzschild radii of the central black hole and the part of pre-stars' (and hence stars') orbits which determine the overall picture is the actual ejection from the generator, which is very close indeed to the central black hole. Thus the dynamics are highly relativised and under strong central control including in particular the inertial drag fields used in Section 2 to explain the rotation curve.

The orbit of a star takes it from the centre to the outside and back in roughly its lifetime. In other words the orbit diameter is roughly the radius of the galaxy (say 10^{18} km) and its period is roughly 10^{10} years. A purely Newtonian estimate of the mass of the centre which supports such an orbit is 10^{10} solar masses.[8] The discrepancy from the estimates in Sections 2 and 3 of roughly 10^{15} solar masses cannot be explained by relativistic effects (at least ignoring rotation). There is a simple argument using the geometry established in [13] that shows that, for a body on an radial escape orbit from a black hole, the dynamic effect of the gravitational pull from the centre is exactly the same as in the Newtonian case. (To prove this, I need to refer in detail to [13]. Looking at Section 4 we read $d\rho/d\sigma = \sqrt{1-Q}$ on radial (escape) geodesics in a large class of spherically-symmetric space-times. But ρ is the natural measure of radial distance in the normal (flat) space slices and σ is proper time, so this tells us that escape velocity at distance r is $\sqrt{1-Q} = \sqrt{2M/r}$. ie kinetic energy per unit mass is M/r. But this is the formula in Newtonian dynamics: field energy is $-\int M/r^2 = M/r$. Here Q is the function of r which determines the metric [13, equation (1)] and is $1 - 2M/r$ near a black hole.)

This implies that there must be some other effect that decreases the effective gravitational pull of the centre on stars in a galaxy. Note that, by the Zwicky observations cited earlier, gravitational pull on more distant objects is not diminished so there must be a local effect counterbalancing gravity. Here is a very ad hoc hypothesis that suffices to explain the discrepancy. Suppose that the generating belt carries a large electrostatic charge, for example a positive charge due an excess of protons over electrons (with a compensating negative charge on the polar regions of the generator sphere or in the central black hole itself). Then the matter that is ejected which condenses into stars will also carry a positive charge and there will be a repulsive force away from the centre which opposes the gravitational attraction.

The charge build up could be due to tidal effects causing heavier protons to rise higher up the belt compared to lighter electrons or there could be some electrostatic or electro-dyanamic effect not yet described which causes this charge build-up.

Whatever the cause of this, the effect is that the central gravitational attraction is largely offset by the electrostatic repulsion, and the matter ejected is carried out like a kind of galactic wind (analogous to the solar wind from stars). If the charge density in the ejected matter was not in itself sufficient to overcome gravity for mutual attraction, then gravity would still act to condense clouds of matter into star systems, to provide the flywheel effect described in Section 2

There are two other effects which are worth mentioning briefly:

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[8] Compare with the earth's orbit using "$M = \frac{d^3}{T^2}$" where M is the ratio of central masses, d the ratio of orbital diameters and t the ratio of orbital periods. Both d and t are 10^{10} approx.

(1) The flywheel effect revisted

This is not a relativistic effect. As was seen in Section 2, the tangential motion of stars in the galactic plane is stabilised by gravitational attraction within the arms. This also has an effect on radial motion. The outward gravitational pull of the arms has a tendency to stabilise the outward velocity, in other words to make it more uniform than it would otherwise be.

(2) The slingshot effect

This is another effect of inertial drag and is caused by the decrease of inertial drag as r increases. It is only significant for large r. The best way to think of this is to image that inertial drag causes plate-like rotation of a particle. If the effect were to stop suddenly, the tangential velocity would throw the particle outwards. As the effect decreases there is a corresponding outwards acceleration. To quantify this let $v = v_{\text{rot}} + v_{\text{inert}}$ where v_{rot} is the tangential velocity due to rotation of the local inertial frame and v_{inert} is the tangential velocity measured in the local inertial frame. The effective outward acceleration is v_{inert}^2/r (the familiar "centrifugal acceleration"). For large r, $v_{\text{rot}} \approx v_{\text{inert}} \approx K\omega$ (see Section 2) and the corresponding outward acceleration is $K^2\omega^2/r$. At the edge of the visible galactic disc for a normal galaxy, this outward acceleration is an order of magnitude or more smaller than the inward acceleration due to the attraction of the centre but the effect becomes very significant at larger radii. Indeed there is a definite radius at which it dominates, and matter is "spun off" into outer space. This radius could be regarded at defining the full size of the galaxy. The effect is important for overall control of galactic rotation, see Section 10.

Putting all the effects together the outward motion is close to constant over most of the visible disc and drops off towards zero towards the edge. Combining this with the rotation curve (see Section 2) gives a very good approximation to the observed spirals in the arms of normal galaxies. Assume for simplicity that the rotation curve comprises two straight lines, $v = K\omega r/5$ for $r \leq 10K$ and $v = 2K\omega$ for $r \geq 10K$ (see Figures 3 and 5). The central rotating plate rotates at $\frac{1}{5}\omega$ and this is the apparent fixed frame as far as the shape of the galaxy is concerned. Working in this frame, $\dot{r} = q$ say (the apparent outward velocity) and $\dot{\theta} = 0$ for $r \leq 10K$ and $\dot{\theta} = -\frac{\omega}{5} + \frac{2K\omega}{r}$ for $r \geq 10K$. Hence $\theta =$ constant (zero say) for $r \leq 10K$ and

$$\theta = \frac{1}{q}(-\frac{\omega r}{5} + 2K\omega \log(r) + C)$$

for $r \geq 10K$ where C is a constant such that $\theta = 0$ for $r = 10K$ ie $C = 2\omega K(1 - \log(10K))$.

Without the log term this is a standard "logarithmic spiral". The effect of the log term is to decrease the pitch of the spiral as r increases and the outward decelleration has the same effect. Rather than sketching this curve, two typical examples of galaxies are reproduced in Figure 7, both of which fit the curve extremely well. The first NGC1365 is a typical barred galaxy. The transition between the two intervals for r is very clear. The pitch change in the arms is obscurred by the angle of view. The second M51 is a typical complete open spiral with the plate region coinciding with the central bulge and very clear decrease in spiral pitch as in the theoretical curve.

Figure 7: NGC1365 and M51 images from NASA and Hubble site resp

The various observed shapes of spiral galaxies can be explained by adjusting the basic picture. The key variables are the ratio of the radius of the plate region $r_0 = 10K$ to the overall visible disc radius, R say, which determines the overall extent of the spiral and the size of q compared to the other constants, which determines the pitch of the spiral. For a standard spiral galaxy such as M51, M83 or M101, r_0 is one or two orders of magnitude smaller than R and the arms wrap right round the centre. For a bar galaxy, R is not much bigger than r_0 and the central rotating plate forms most of the galaxy with the arms moving out only a little further. The flywheel effect dominates for this type of galaxy. Indeed for some bar spiral galaxies, the flywheel effect has captured stellar material in advance of the arms to form apparently forward pointing arms as well as the usual trailing arms. A good example of a barred galaxy with very full data can be found in [12] (NGC5383) showing constant rotation along the whole extent of the bar. The data there also show outward motion along the arms and hence directly support the main hypothesis of this paper.

As in Section 2, the analysis of this section applies only to stars moving outward in the galactic plane. The control gets progessively weaker the further out one goes and random motions and local gravitational effects change the motion. Furthermore, the orbits being examined here are in Kerr spacetime and these are known to be chaotic Hartl [10].[9] As stars age their orbits move out of the plane and fill the whole of the galactic halo which leads naturally to the subject of globular clusters.

6 Globular clusters

Another strong piece of evidence for the main hypothesis is provided by globular clusters which are known to be very old objects and have caused some heartache about the age of the universe according to the big-bang theory. In the new paradigm there is a very natural explanation for their age.

The inner arms of a galaxy comprise young stars and star formation regions. As the stars move out along the arms they age and mature. Thus for example our sun was formed about 2×10^9 years ago and has moved about $\frac{3}{4}$ of the way out. The outward movement is by now very gradual and would be difficult to detect even without the masking effect of gravitational frequency shift. It will take perhaps 10 times this period to reach the outer regions of the galaxy, where the spiral arm breaks up and the sun perhaps becomes one star in a globular cluster.

The formation of globular clusters happens when the dynamic stops being strongly controlled by the centre and stars move under a combination of central and local forces. Note that, as outlined in Section 5, the dynamic becomes chaotic and uncontrolled once it stops being determined by the centre. Gravitational and tidal effects cause star clouds to condense into globules forming the familiar globular clusters. The process is analogous to the way in which water vapour condenses into raindrops. This explains why:

(a) Globular clusters comprise old stars.

(b) The orbits of globular clusters are highly elliptical and erratic.

In Section 8 we examine a remarkable set of observations of a particular globular cluster near the end of its life.

[9] Hartl proves this for spinning particles. The spin of stars may not significant, but local random effects are likely to cause similar chaotic effects.

7 Solar systems and life

Eventually stars return to the centre under gravitation. Mostly this happens in complete globular clusters. As they approach the centre the huge tidal forces and the electromagnetic forces in the generator (and in particular the toroidal belt) tear the clusters and the individual stars apart. Most of the matter is then stripped down into small elementary particles. However some of the heavier particles will survive this destruction. Here is a tentative suggestion for how this happens.

As supposed in Section 4, the belt has a complex stratified structure with a plasma of small particles at the inside, where the input of tidal energy from the black hole is greatest, and with layers of heavier particles as one moves outwards. The belt may even be surrounded by an orbiting region of cold dust. There is observational evidence for significant amounts of dust near the centre. As stars feed into the belt, part of their mass will mix with the outer layers and thus some of the heavier atoms resulting from fusion will survive. Thus, when the explosions which create the spiral arms occur, the outgoing matter will comprise a good deal of small particles from the inner layers (which, as remarked earlier, condense to form the observed mix of light elements) together with a sprinkling of heavier matter. When the resulting clouds condense into stars, the heavier matter will condense around them to form solar systems.

Some tentative remarks on life. The timescale for the galaxy is huge. Probably several orders of magnitude greater than current estimates of the age of the universe. This is plenty of time for life to have arisen many times over on suitable planets. When these planets are destroyed (as their sun falls into the centre) some of the molecules may survive and and be recycled into new planets. Thus in a steady state planets will start out seeded with molecules which will help to start life over again. Indeed standard selection processes over a galactic timescale will favour lifeforms which can arise easily from the debris left over from their ultimate demise in the galactic centre. This might explain how life arose on earth rather more quickly than totally random processes can explain.

Observational comments Solar systems should occur around most if not all stars; this is now a reasonably well-established fact. Pre-life molecules (eg long-chain hydrocarbons) should be found on all suitable bodies in the eg meteorites. This is also a well-established fact. There are some very interesting theories advanced to explain how such molecules could be formed in deep space!

8 The globular cluster at Sgr A^*

Starting about 18 years ago, several teams of observers have monitored a group of stars in Sagittarius in tight orbit around a strong radio source Sgr A^*, which is itself at rest as far as we can tell. For a good overview see Gillessen et al [9]. The conclusion that these observers have come to is that Sgr A^* is a massive black hole of mass about 4.3×10^6 solar masses at a distance of about 8.3 kpc. They also conclude that this black hole is the centre of the milky way calling it the "massive black hole in the galactic centre". Since this conclusion directly contradicts our main hypothesis, it is necessary to advance another explanation for these observations.

Globular clusters have total mass varying up to around 10^7 solar masses and central black holes have been detected in many clusters. Moreover there is a well-stablished theory for mass concentration and black hole formation in clusters, see [4]. Indeed this is a natural phenomenon as clusters age. Stars will burn out and collapse and mass concentration will cause a group of collapsed stars to coalesce into a single black hole. The group of stars orbiting Sgr A^*, together with Sgr A^* itself have all the characteristics of a globular cluster near the end of its life with most of the mass coalesced into the central black hole and the remaining stars in orbit around the centre. The reason for this globular cluster being at rest is pure serendipity. As remarked earlier, globular clusters have erratic orbits and there is no reason for such an orbit not to appear at rest for observers on the earth at certain times.

It remains to discuss the steller composition, which is predominantly Wolf-Rayet and type O with a sprinkling of young stars ... [material to be added here, I need to tie this with extreme age]. The young stars could be caused by capture of gas clouds near the generator condensing into new stars. This cluster is clearly near to the generator because of the dusty region where it lies, characteristic of the upper reaches of the generator/belt structure. Most likely it is in front of the generator, which it should be noted, would appear huge in comparison (of a comparable size to the sun or the moon) if we could see it: the thick dust shroud hides it completely from our view. [More material to be added about redshift: if close to the real centre (say within 1kpc) there would be noticeable redshift due to the hypermassive centre: 1kpc gives z approx 1/10.] This globular cluster is close to being captured by the belt and recycled into new solar systems as outlined in Section 4.

9 Redshift and CMB

This section is included for completeness and briefly summarises the contents of [14, 15].

Redshift

Redshift is a feature of the dominant observer field of which we and the main visible parts of all galaxies lie. As explained above, the sun and the stars, which constitute the visible parts of the main galaxies in the universe, are all travelling on near escape orbits from the huge supermassive centres of galaxies which comprise the main mass of the universe. As shown in [13] these orbits fit into natural flat observer fields around each supermassive centre (black hole). In [13] we prove that these fields are expansive and in [14] (following [7]) that (for one black hole) they extend to fit with the standard expansive field in de Sitter space (cf Moschella [17], and [3]). We give two plausibility arguments to show that this extension works with many black holes and therefore for many black holes in de Sitter space there is a (roughly uniformly) expansive field outside the black holes, which implies that the light from distant galaxies is redshifted in a way that fits Hubble's law. There is a dual contractive field and the two are in balance, so that this universe "in the large" is not expanding (the dual expansive/contractive fields on de Sitter space are described explicitly in [17, 3]). Indeed the expansive field only covers the visible parts of the universe. Most of the matter in the universe is contained in the supermassive black holes at the centres of galaxies and this matter is not in any sense in an expanding universe. De Sitter space is infinite but there is no need to assume that the real universe is infinite (merely rather large) for a description along these lines to make sense.

One way of thinking of this expansive field is to compound all the supermassive centres into just one (very) huge mass. It is so huge that it does not fit into any sensible notion of space or time but let's call it the centre. Surrounding the centre is a region where space and time make sense but space is very large. In the expansive field, which is equipped with a coherent sense of time, space flows outwards from the centre and the perception is of an expanding universe. (If you like, think of the massive centre as like the earth, with the surrounding space-time as the atmosphere, and think of the expansion as an outward wind.) There is a dual contractive field which balances this expansion with its own (different) sense of time. An observer in the expansive field can only see as far as the rate of expansion allows, with a natural "horizon" where the rate exceeds the speed of light. Thus the visible universe for any observer is a very small part of the total universe.

Note that the expansion from a heavy centre is not uniform. Near the centre the radial coordinate contracts and the tangential coordinates expand, with the nett effect that is still expansive on average. This is described in detail in [13, Section 6]. When these expansive fields are fitted together to form the global expansive field for the universe, because of the non-uniformity in each piece, the result is highly non-uniform in other words is filled with gravitational waves. There are also very probably many other sources of gravitational waves which add to the non-uniformity.

There is strong direct evidence for gravitational waves in deep observations made by the Hubble telescope, see [19]. It is also worth commenting that there is indirect evidence provided by Gamma Ray Bursts which, as suggested by Robert MacKay are, in all probability, caustics in the developing observer field caused by the same non-uniformity.

CMB

We have now given alternative explanations for two of the three so-called pillars of the BB theory. Finally here is a sketch of how the Cosmic Microwave Background (CMB) might fit into the new paradigm. Full details will be given in [15]. As we have seen, space is not uniform but filled with a background level of gravitational waves.

Gibbons and Hawking [8] show that the cosmological horizon behaves like a black hole event horizon (Hawking effect) and generates an isotropic black body radiation spectrum which is, unfortunately, about 28 orders of magnitude too small to explain the CMB. However the background gravitational waves that fill space-time cause a huge acceleration of this effect and raise the temperature maintaining isotropy. The Hawking effect uses particle pair creation with one half going over the horizon and the other staying this side. Gravitational waves sweep whole dollops of energy over the horizon and vice versa causing a hugely accellerated but still basically Hawking effect.

In [15] we use this explanation and the CMB observations to predict the level of observed instability and (tentatively) to predict the frequency of GR bursts.

10 Long-term considerations and speculation

This section is highly speculative and is essentially a “just-so” story. It is time to consider the long-term history of a galaxy. Suppose just for argument there is a naked hypermassive black hole, with no surrounding matter, floating in inter-galactic space. It will start to accrete matter which will either (a) feed the hole (making it more massive) or (b) start to form a rotating sphere around the hole, mostly concentrated in the plane of rotation forming a disc known as an accretion disc. (The mechanisms for this are well understood, eg [18, 25].) As the mass of the accretion disc builds up it becomes unstable and the mechanism outlined in Section 4 starts to take effect and there are explosions throwing matter outwards. Because of the rotation, these explosions are off centre and lighter particles, eg photons, are radiated away and this loses angular momentum to the system and hence the overall angular momentum starts to build up (the "pinwheel effect"); in other words the black hole starts to rotate. As this happens the effects described in Sections 2 and 4 start to take effect and a full galactic disc begins to form.

To begin with the accretion sphere is weak and does not shield the central black hole effectively and polar radiation escapes as observed in so-called active galaxies (mechanism described in eg [25]) Further, at this early stage, there is a massive "intrinsic" redshift due to the strong gravitational field of the centre. This object has all the characteristics of a quasar or an active galaxy. But note that the redshift means that it is smaller and closer than would normally be assumed when the redshift is taken to be an indicator of distance. Somewhat controversial observations due to Halton Arp (see [5]) provide evidence for the existence of objects of this type.

The accretion sphere continues to build up and so does the overall angular momentum. The full picture of Sections 2 and comes into effect. As the ejection velocity of matter from the centre builds up, the instrinsic redshift decreases and the system becomes a standard galaxy. If the build up gets too large, then ejected stars or smaller bits of matter will escape the system altogether and the system will lose both mass and angular momentum. The slingshot effect mentioned in Section 5 is important here. Once a particle has reached a certain distance out from the centre, it is ejected into outer space. Thus there is a stable limit where furthest out stars are just recaptured and, in this stable limit, matter is ejected from the centre at just below escape velocity for the system, bearing in mind the relativistic effects described in Section 5 which lengthen orbits. Thus the time taken by a star from birth on its outward journey to final recapture by the centre is far longer than accounted by a simple Keplerian orbit and the star has time to live through its full natural lifetime as envisaged in earlier descriptions. This long-term stability explains why observed rotation curves are universal. If rotation exceeds the limiting rate, the generator starts boiling off into outer space!

Finally it is worth remarking that nothing whatever is known about the inner nature of so-called "black holes". There is no such thing in nature as a singularity; black hole is simply the name given to another state of matter about which nothing is yet known. There are some fascinating observations due to Schild et al [22] which hint at a specific inner structure and which may perhaps shed some light here. Or perhaps by observing galactic clusters carefully it may be possible to deduce some of the rules governing this new state of matter—perhaps to begin to build up a proper physics for black holes. One point that needs to be addressed is why galactic centres are not even more massive. Black holes can combine to become more massive. So perhaps there should have arisen a set of super size galaxies grazing on ordinary ones etc. This does not appear to have happened. Why?

The reason may be the mechanism described above which limits size by boiling off excess matter, or the mechanism may be more elementary. Black holes over a certain mass may simply be unstable and spontaneously break up.

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