Dark Mass is Potential Energy

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Introduction

Since the postulate of the existence of galactic dark mass by Vera Rubin to explain the flatness of galactic rotation curves (1) (2) (3) no convincing explanation for the nature of this dark mass was provided. Attempts to explain this missing mass by an invisible form of ordinary baryonic matter were, for the most part, refuted by the programs AGAPE (4), MACHO (5) and EROS (6). The same is true for explanations using ordinary non-baryonic matter or some form of exotic particle, which could explain this missing mass. The numerous attempts at detection have so far all failed, as have the programs LUX (7), PICASSO (8), PICO (9) or the SuperCDMS (10). Similarly, CERN's new accelerator seems to confirm that physics is limited to the Standard Model, and the existence of an exotic particle is increasingly unlikely. It also seems extremely difficult to explain this phenomenon with current gravitational theory, whether Newtonian gravitation or General relativity.

In cosmology, the standard model remains the ΛCDM model, which postulates the existence of cold dark matter. The concept of mass is inseparable, for most physicists, from that of matter. Moreover, the term “dark matter” is used assertively, whereas in fact, it is only “dark mass”. An alternative to the existence of real dark mass consists of modifying gravitation in such a way as to adapt it to the change of regime at the galactic level. However, such a project comes up against the prodigious adequacy of general relativity to the phenomenological reality and the physical existence of dark mass (11) (12) (13).

The explanation proposed in this article is of an entirely different nature. Dark mass is not any form of real matter, nor is it caused by an alternative theory of gravitation. It is merely an epiphenomenon caused by the current theory of gravitation. This is just the gravitational potential energy stored in the gravitational field. The only axioms used are $E = -GmM / d$ and $E = mc^2$. So, it is just a matter of the judicious application of good old classical physics.

Useful gravitational potential energy

If we consider the equation of Newtonian gravitation $F = GmM / d^2$ we obtain by integration, from d at infinity, the potential energy equation $E_p = -GmM / d$. This equation generates a negative potential energy, useful in practice for calculating the motions of bodies, but totally inappropriate for calculating the total real potential energy of a system. To calculate the “real” potential energy we have to calculate the energy between two states of the system as in raising a mass m from position d by a height h; either $\Delta E_p = E_p(d + h) - E_p(d) = GmM / d - GmM / (d + h) = GmMh / (d^2 + dh)$. This is the “usable” form of gravitational potential energy because negative absolute energy E_p has no “useful” physical interpretation.

This equation (ΔE_p) although useful for calculating the potential energy at the surface of the Earth, for example, becomes unusable when it comes to calculating the potential energy between two planets, two stars or two galaxies. Indeed, if the distance $d + h$, from center to center, is well defined, that of d is totally obscure. We will resolve the ambiguity of d by calculating the energy difference between that of the compact ball state of mass $M_t = m + M$ and that of the state of two balls of masses m and M separated by a center-to-center distance of d. To do this, we need to assign radii r and R and volumes $v = 4\pi r^3/3$ and $V = 4\pi R^3/3$ to our two bodies of volumetric masses m/v et M/V respectively.

The total volume of the compact ball is $V_t = V + v = 4\pi/3\ (R^3 + r^3)$ and its radius $R_t = (R^3 + r^3)^{1/3}$. Assuming equal volumetric masses $m/v = M/V$, that of the compact ball will be identical ($m/v = M/V = M_t/V_t$), otherwise, it will have an "average" density considering the respective contribution of material from the two balls. We know how to calculate the potential energy of a homogeneous ball which is $E_p = -3GM^2 / 5R$ so we have:

Initial state: $E_i = -(3GM_t^2 / 5R_t)$
Final state: $E_f = -(3GM^2 / 5R) - (3Gm^2 / 5r) - (GmM / d)$
Difference: $\boldsymbol{\Delta E_p = E_f - E_i = (3GM_t^2 / 5R_t) - (3GM^2 / 5R) - (3Gm^2 / 5r) - (GmM / d)}$

This equation therefore allows us to calculate the energy difference between the initial state of lowest energy, the compact ball, and its separation into two distinct compact balls. We will note that this is a simple rearrangement of the position of the constituent matter, which preserves the density of the components. This strict condition makes it possible to avoid involving forces other than gravity.

Gravitational potential energy is massive

Gravitational potential energy can be written as $E_p = m_p c^2$ because it must necessarily be stored as mass in the system. This statement can very easily be verified by a very simple thought experiment. Imagine a nuclear reactor transforming a mass m_n in electrical energy allowing a mass m to be raised to a height h. The question of whether the mass of the Earth before the transformation is equal to that after the transformation should not be open to debate. As there is conservation of mass energy m_n in the Earth system, the theory of general relativity guarantees that there is no change in its gravitational effect. The question of whether it is a "real mass" is meaningless because mass is only that which can be measured by its gravitational or inertial effect. Moreover, since the equivalence of inertial and gravitational mass has never yet been violated (14), we can consider, for the moment, the full equality of this potential energy and its massive equivalence.

Calculation of the potential energy of celestial bodies

	m **(kg)**	***M*** **(kg)**	***r*** **(m)**	***R*** **(m)**	***d*** **(m)**	$\boldsymbol{R_t}$ **(m)**
Moon + Earth	7.348E+22	5.972E+24	1.738E+06	6.378E+06	3.844E+08	6.421E+06
Earth + Sun	5.972E+24	1.989E+30	6.378E+06	6.963E+08	1.496E+11	6.963E+08
Jupiter + Sun	1.898E+27	1.989E+30	6.991E+07	6.963E+08	7.780E+11	6.966E+08
Sun + M80	1.989E+30	9.985E+35	6.963E+08	5.534217E+10	4.541E+17	5.534221E+10
Sun + Galaxy	1.989E+30	5.000E+40	6.963E+08	2.040E+12	5.000E+20	2.040E+12

This table contains the standard values of the bodies considered except for the radii of the globular cluster M80 and the typical galaxy (gray boxes). We used a sphere to calculate the initial state R_t of mass $(M + m)$ having solar density, the final state is the sun at distance d with a mass M of solar density. For the sun and galaxy couple, R = 2.03985712710655E+12 and R_t = 2.03985712713359E+12. The logic of this manipulation will be explained later. In any case, we have $R_t = (R^3 + r^3)^{1/3}$.

	$\boldsymbol{E_i}$ **(j)**	$\boldsymbol{E_f}$ **(j)**	$\boldsymbol{\Delta E_p}$ **(j)**	$\boldsymbol{\Delta E_p}$ **(kg)**	$\boldsymbol{m / \Delta E_p}$
Moon + Earth	-2.2795E+32	-2.2413E+32	3.8176E+30	4.2477E+13	0.000000001
Earth + Sun	-2.2751E+41	-2.2751E+41	1.3024E+36	1.4491E+19	0.000002427
Jupiter + Sun	-2.2787E+41	-2.2751E+41	3.5519E+38	3.9520E+21	0.000002082
Sun + M80	-7.2141E+50	-7.2141E+50	2.3949E+45	2.6647E+28	0.013396966
Sun + Galaxy	-4.9079E+58	-4.9079E+58	3.2540E+48	3.6206E+31	18.20

We can see in this table the gravitational energy differences between current physical states and the fusion of bodies into a single body. Thus, knowing that the annihilation of one kilogram of matter corresponds approximately to the power of an H-bomb (2 kg of deuterium associated with 3 kg of tritium, results in a loss of mass of 1 kg, or approximately the Tsar Bomba), the fusion of the moon with the earth would release an energy of forty thousand billion H-bombs. This potential energy has a mass of forty billion tons, which is far from insignificant. If we consider the energy released by the dissolution of the Earth in the Sun, we are talking about more than fourteen million billion tons. This is, however, less than the mass lost by the Sun every hour through nuclear fusion. Thus, depending on its distribution in space, it is quite possible that this mass is perfectly measurable. If we look at the ratio $m/\Delta E_p$ of the mass of the small body on that of the potential energy, we see that it is negligible except in the galactic case, reaching a value in the order of magnitude of the dark mass ratio for this type of system. Continuing for clusters we would be in the order of 1000 and 10,000 for superclusters. However, as we can see for the galaxy, we are at the limit of numerical calculation with 15 significant decimal digits.

The potential energy of celestial systems

The first thing we can see is that the term $-GmM / d$ of ΔE_p is negligible at all scales ($d >> R >> r$). Common physics sense makes this easy to understand; changing the distance between the Earth and the Moon would have little measurable energy impact compared to the cataclysmic fusion of the two bodies. This is true for all celestial bodies. The equation therefore simplifies to $\Delta E_p = (3G/5)[M_t^2/R_t - M^2/R - m^2/r]$. Thus, the relative arrangement of bodies to each other is irrelevant for calculating the total energy. If we consider a system of n masses m_i of radii r_i that we "merge" one after the other, we obtain for each merger $M_i = \sum_{j\leq i} m_j$, $R_i = (R_{i-1}^3 + r_i^3)^{1/3}$, $\Delta E_i = (3G/5)[M_i^2/R_i - M_{i-1}^2/R_{i-1} - m_i^2/r_i]$, the total energy being $\Delta Ep = \sum_i \Delta E_i$. This calculation could be done exactly today even for the largest galaxy (1E5 billion stars). We will note that the order of merger is unimportant because the gravitational field is conservative.

If we reduce the problem to a single value of m and r we can then greatly simplify the calculation for n balls. We then have $M_i = im$ and $R_i = (M_i r^3/ m)^{1/3}$ because we know that the ball M_i has the same density as m. So $\Delta E_i = (3G/5)[M_i^2/R_i - M_{i-1}^2/R_{i-1} - m^2/r]$, $\Delta Ep = \sum_i \Delta E_i = (3G/5)[M_n^2/R_n - M_{n-1}^2/R_{n-1} - m^2/r + M_{n-1}^2/R_{n-1} - M_{n-2}^2/R_{n-2} - m^2/r + \ldots + M_2^2/R_2 - M_1^2/R_1 - m^2/r + M_1^2/R_1 - m^2/r]$, the terms $-M_i^2/R_i + M_i^2/R_i$ cancel each other out, there remains only $\boldsymbol{\Delta E_p = (3G/5)\,[M_n^2/R_n - nm^2/r]}$. It is important to note that ΔE_p is only the potential energy of each of the small balls (m, r) subtracted from the potential energy of the initial ball (M_n, R_n). We have $M_n^2 = n^2m^2$ and so $\Delta E_p = (3G/5)[M_n^2/R_n - M_n^2/nr]$. In addition, $R_n = (M_n r^3/m)^{1/3} = n^{1/3}r$ and so $\Delta E_p = (3G/5)[M_n^2/ n^{1/3}r - M_n^2/nr]$ (implying that the term $-nm^2/r$ is negligible) and as $M_n = nm$, $\boldsymbol{\Delta E_p = (3G/5)\,[(n^{5/3} - n)\ m^2/r]}$. This last equation reduces the expression of energy only as a function of the mass, radius and number of small balls. Thus, a small radius and a large mass of the small balls, i.e. a large density of the latter, will considerably increase the potential energy produced.

In practice, we only know the histogram of the stellar population of a galaxy. We could then separate M_n in n slices of masses (M_i, m_i). We calculate the energy of all slices by $\Delta E_{pa} = \sum (3G/5)[M_i^2/R_i - n_i m_i^2/r_i]$ then we calculate ΔE_{pb} by "merging" all the balls M_i of radii $R_i = (M_i r_i^3/ m_i)^{1/3}$. We then obtain the total energy $\Delta E_p = \Delta E_{pa} + \Delta E_{pb}$. Even simpler, consider the function $f(m, r, M, M_i, R_i) \mapsto (\Delta E_p, M_t, R_t)$ this one takes the definition of small balls (m, r) and their total mass M as well as the definition of an initial compact ball (M_i, R_i) can be zero, it returns the potential energy as well as the new initial compact ball (M_t, R_t). The algorithm is simply:

$f(m, r, M, M_i, R_i) \mapsto (\Delta E_p, M_t, R_t)$:

$$
\begin{aligned}
n &= M / \mathrm{m} \\
M_t &= M + M_i \\
R &= n^{1/3} r \\
R_t &= (R^3 + R_i^3)^{1/3} \\
\Delta E_p &= (3G/5)[\mathrm{M_t}^2/ R_t - n\, m^2/ r]
\end{aligned}
$$

To calculate ΔEp of more massive structures such as a cluster or supercluster of galaxies, we must first compact each of the galaxies using the previous calculation allowing us to obtain ΔEp, M_t et R_t. So, we have the mass of this compact ball given by $M = M_t + \Delta E_p / c^2$ and its radius $R = R_t$. Then, we simply need to reapply the same fusion process with these galactic balls in the cluster or supercluster. We can repeat the process from one scale to another. This is the principle of nesting dolls.

Galactic gas is problematic because we don't have a ball to merge into, however, we know that it has at least as much potential energy as stars because the gas is responsible for star formation by gravitational collapse. We have two phases here, first the collapse of the gas into balls, second the fusion of these balls into an initial compact ball. The young stellar population of a galaxy is representative of the fate of galactic gas and so the simplest thing to do is to consider the gas exactly as if it were contributing to this population. However, if we consider the gas collapsing at the end into the initial ball of stars, it is so comparatively sparse that we could practically consider each of its molecules in isolation. In this case, the conservative displacement of each of the gas molecules in the initial ball only increases the size of the ball while preserving its density. Thus, we should use the gas exactly as if it contributed, in an undifferentiated way, to the stellar mass. Our tests confirm this hypothesis, and this is what we must do to minimize the error in the experimental data.

The initial compact ball problem

We use a compact ball that conserves the volumes of the bodies “fused” with this ball. This strict conservation of volumes allows us to maintain the same state of matter before and after “compaction”. We know that gravity would compact this ball even more in reality, however, in this situation, other repulsive forces would come into play. We would then have to take these forces into account, forces that were not previously considered. Only this strict condition of conservation of volumes allows us to achieve a conservative transformation of all forces.

If we were to use a radius other than the volume-conserving one to obtain a better evaluation of the potential energy, we would have to determine why it is better. We would then enter a form of arbitrariness that seems completely unreasonable. However, it is enough to verify the use of the compact volume-conserving ball with other dense balls to see the experimental adequacy. Less dense would make no sense because the potential energy is at least that found in the bodies as they are. Denser would quickly generate far too much potential energy (see theoretical models), the current quantity of dark mass produced being not a problem of lack.

The fact that no forces other than gravity are involved seems fundamental. In this case, why not use a black hole as the initial compact ball? In fact, to do this, it would be enough to calculate the energy addition of our ball ΔE_b conserving volumes (sum of all stars) with the black hole of equivalent mass. This initial black hole has no spin. Indeed, merged stars have random directions of rotation and therefore the initial ball, conserving volumes, has no rotation by mutual cancellation of angular momentum. Consequently, the energy provided by the collapse of our ball into a black hole (which is in fact the film played backwards) is $\Delta E_{bh} = \Delta E_b - E_{bh}$ but our black hole has as its own mass as its only energy... consequently $E_{bh} = 0$ and so $\Delta E_{bh} = \Delta E_b$. The potential energy of a system is therefore simply ΔE_b, that of our ball conserving volumes.

Theoretical model

We will use our theory to generate the theoretical curves of the dark mass generated by different galaxies in number of stars (NS), each galaxy size being a different curve (Figures 1, 2). On the abscissa we have the different average sizes of stars (MS) expressed in solar mass. Their radii are given by the standard mass-radius relationship of the main sequence. On the ordinate we find the ratio of the total dark mass generated (MG) on the total baryonic mass of stars (MB) so MG/MB. We can see from these graphs that for a galaxy size of 100 billion stars (thin dotted line), this generates a dark mass ratio of 28 for an average star size of (1 $M_\odot$, 1 $R_\odot$). With 200 billion stars, we are at a ratio of 45, and 60 for 300 billion stars. We are therefore above the ratio of 20 now accepted for the Milky Way. However, we must admit that the order of magnitude is good even if we do not consider gas and black holes. One thing is certain: the question of dark mass production is not a problem if we consider that it is the potential energy of the system.

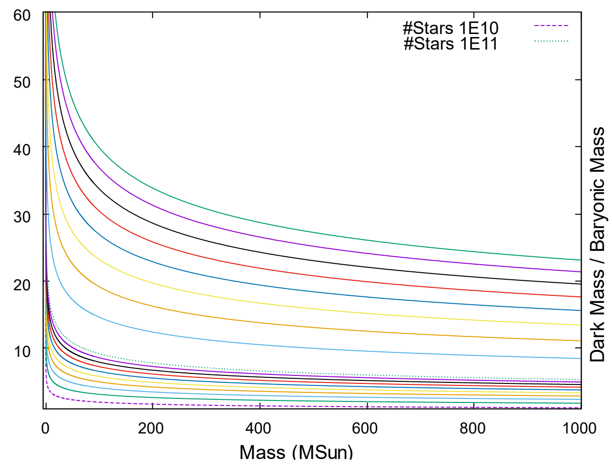

Figure 1

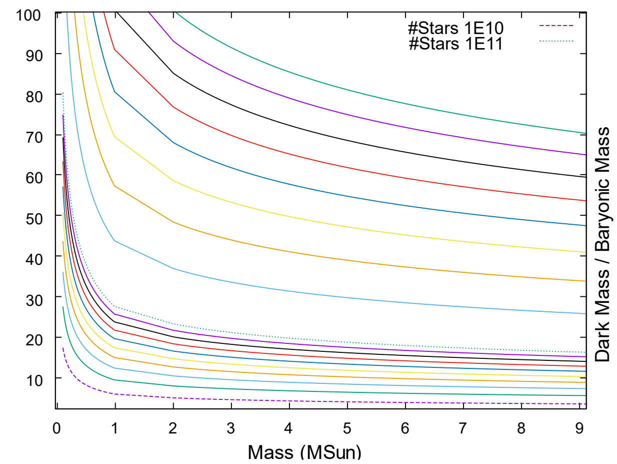

Figure 2

Adding less dense stars like red giants can rapidly decrease galactic dark mass production (Figures 3, 4). This is the same population of stars as before but with a fixed size of one solar mass (1 $M_\odot$, 1 $R_\odot$), to which we mix a fraction of red giants (4 $M_\odot$, 100 $R_\odot$).

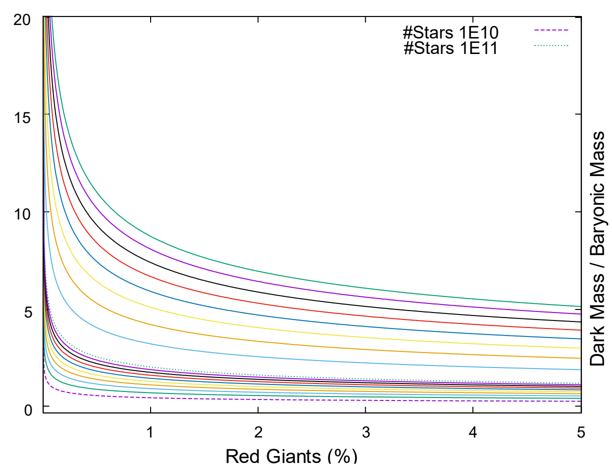

Figure 3

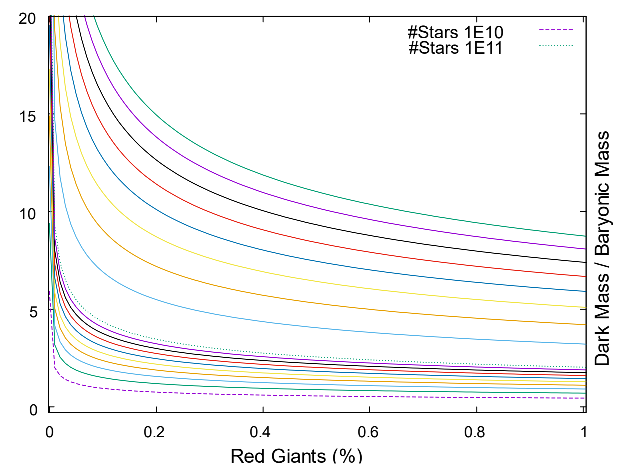

Figure 4

Adding dense stars (Figures 5, 6) like white dwarfs (0.6 $M_\odot$, 0.0084 $R_\odot$) or neutron stars (1.35 $M_\odot$, 10.8 km) produces a spectacular increase in dark mass. This increase will be counterbalanced by the presence of low-density stars and black holes.

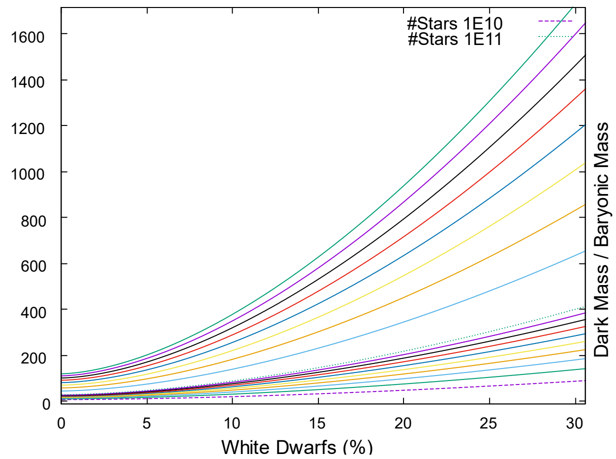

Figure 5

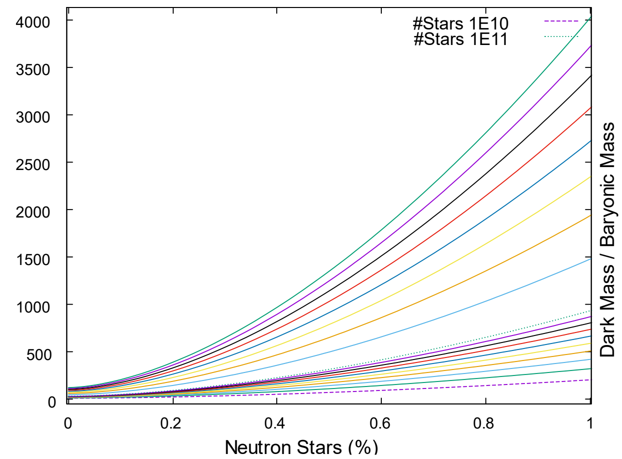

Figure 6

Black holes

While we can now calculate the potential energy of a star's system, moving on to the potential energy of the black holes in that system is more complex. However, the principle remains the same: the stored potential energy is that between the two states, that of the black holes merged into one versus the black holes separated into two separate black holes.

As with stars, we start with the fusion energy of two black holes. The calculation of the potential energy of black hole merger is given (15) (16) by general relativity by the formula $M_f = (M + m)\,(1 - \eta\varepsilon_{rad}(q, \chi))$ with $\eta = Mm / (M + m)^2$, $q = m / M \leq 1$, χ = spin parameter and $\varepsilon_{rad}(q, \chi)$ is an empirical function that gives the efficiency of gravitational emission. For unspinned black holes, a common approximation is $\varepsilon_{rad}(q) = 0.048\,(1\text{-}q)^2 / (1\text{+}q)^4$. The effective spin is $\chi_{eff} = (M\chi_M + m\chi_m) / (M + m)$, considering that we merge black holes with random spins, M will quickly have zero spin and $\chi_a \approx 0$.

Let the function $f(m, M) \mapsto M_f$ allowing two black holes to merge. To move on to the merger of several black holes, we reduce the problem to the merger of n black holes of identical mass m for a total mass of $M = nm$.

$g(n, m) \mapsto M_f$:
IF $n = 2$ THEN $M_f = f(m, m)$
IF $n = 3$ THEN $M_f = f(m, m)$, $M_f = f(m, M_f)$,
ELSE
is*Odd = false*
IF Odd(n) THEN $n = n - 1$, is*Odd = true*
$M_f = 2\, g(n/2, m)$
$M_f = f(M_f, M_f)$
IF is*Odd* THEN $M_f = f(m, M_f)$

This algorithm allows to simply merge black holes two by two with at the base the black holes of mass m, then $2m$, $4m$ and so on. It is then possible to use dynamic programming to memoize the values of $g(a, b)$, this allows the calculation operation to be carried out in $O(\lg_2(n))$.

We will find that the potential energy is extremely small because the energy is strictly drawn from the initial mass of the black holes. Thus, the potential energy can never exceed the total mass of the black holes. Even considering the energy of an aligned prograde spin (the best conditions) using an empirical semi-analytical approximation based on numerical simulations (17) (18) we have $E_{gw} / M \approx \eta(\,1 - 4\eta)[1\text{-}\ 0.0686(1 - \chi_{eff})^2]$. We have managed to produce a maximum of 16% of potential energy with black holes of more than 500 solar masses with a spin of practically 1. We should therefore consider that the contribution of black holes, by fusion, to the potential energy of celestial systems is negligible, especially given their small proportion.

However, it is impossible not to consider the potential energy generated by black holes because they necessarily participate in the potential energy within the galaxy by the equation $E_p = -\, GmM \,/\, d$. Consider the initial ball conserving the volumes of mass *M* and volume *V*, resulting from the fusion of gas and stars. If there remain *n* black holes of mass *m* and volume *v*, then logic dictates that they be treated exactly like the rest introduced into the initial ball and therefore $M' = M + nm$, $V' = V + nv$. However, such a treatment is perplexing because it is not conservative. If we move the black holes within the initial compact ball, they will end up next to each other and then merge, and their total volume will decrease. Black holes have this curious property of not conserving volume through fusion.

Thus, it seems that treating black holes requires treating them exactly like ordinary matter with a volume-conserving ball, but with their volume conservation. We will merge all the black holes into a single black hole. This could have a high density (1000 for a mass of 4.3E6 solar masses) or a low density (0.001 for a mass of 4.3E9 solar masses). Contrary to intuition, the presence of many black holes would therefore decrease the potential energy of the system. This is inevitable because the limit to increasing the proportion of black holes is a single large black hole with zero potential energy by the very definition of a black hole.

This is what our theoretical model gives (Figures 7, 8, 9, 10) for galaxies with the same number of stars as previously but fixing these stars to the solar mass (1 $M_\odot$, 1 $R_\odot$). On the abscissa we have the fraction (%) of the mass of stars in black holes. We can see that at 1.3% the curves of 100, 200 and 300 billion stars converge to values of 19.7, 22 and 23 which is consistent with the value of 95% of dark mass for the Milky Way and the fraction of black holes around 1% (19). This trend toward decreasing dark mass production fades around the billion-star mark, reversing slightly. It is remarkable that with only a 5% proportion of black holes, most galaxies lose all individuality, and only the smallest remain distinguished in terms of dark mass production.

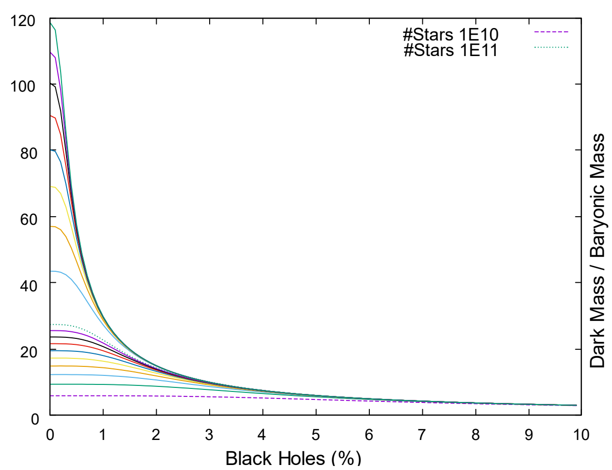

Figure 7

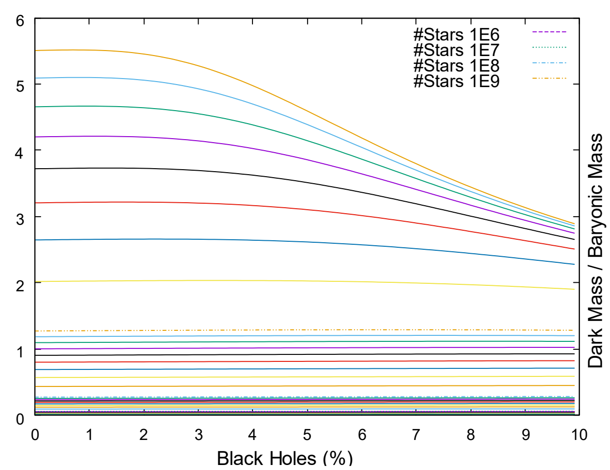

Figure 8

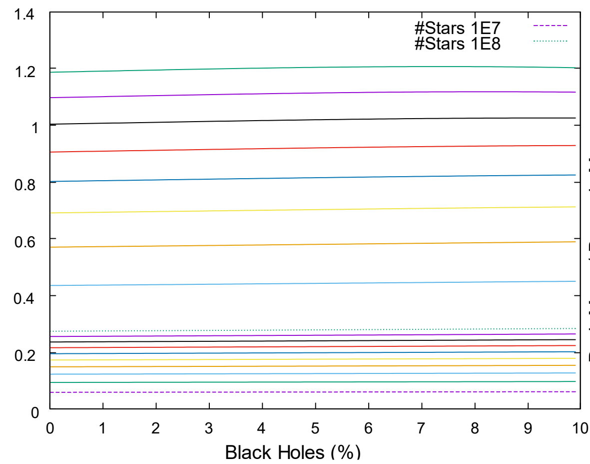

Figure 9

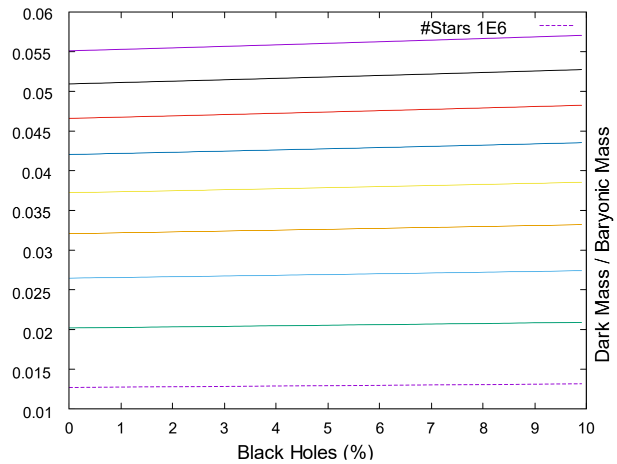

Figure 10

Galactic models

We used the SPARC sample (14) of 175 galaxies to check whether it is possible to produce the necessary amount of dark mass with gravitational potential energy. We rejected two galaxies that did not have acceptable error margins. This sample of 173 galaxies contains 3362 data points, of which 3039 will be kept (90%), points close to the center with no error margin or producing a negative dark mass were removed. For each of these points, we have the baryonic mass (gas and stars) inside the orbit, as well as the orbital velocity. Each of these points also has an estimate of the necessary dark mass M_{dark} by calculating the mass deficit as well as a margin of error eM_{dark}.

For each data point, we use our method to determine what proportion of black holes, white dwarfs (0.6 $M_\odot$, 0.0085 $R_\odot$), red dwarfs (0.4 $M_\odot$, 0.5 $R_\odot$) and red giants (4 $M_\odot$, 100 $R_\odot$), allow to produce a dark mass E_{dark} minimizing the error with M_{dark} ($\Delta_{\text{dark}} = |E_{dark} - M_{dark}|$). This minimization is done by trying, firstly, to enter the margin of error, to obtain $\Delta_{\text{dark}} < eM_{dark}$ or $\Delta_{\text{dark}} < 2eM_{dark}$. It would indeed be more accurate to consider the two margins of error, that of M_{dark} and that of Δ_{dark}; assign margin eM_{dark} to Δ_{dark} is a practical simplification. Second, we are simply trying to minimize Δ_{dark}. Each data point is considered an independent problem. All our errors ($\pm e$) are of a standard deviation.

The fit is excellent, the dark mass of 86% (149 out of 173) of the galaxies (for 81% of the data points) is resolved without any errors with $\Delta_{\text{dark}} < 2eM_{dark}$ and 74% (128 out of 173) galaxies (for 71% of the data points) with $\Delta_{\text{dark}} < eM_{dark}$. A total of 95% of the data points are resolved without error with $\Delta_{\text{dark}} < 2eM_{dark}$ and 92% with $\Delta_{\text{dark}} < eM_{dark}$. Better yet, if we consider the positioning of the value E_{dark} within the margin of error eM_{dark} (100% being the end of the error bar, 0% exactly the value) for our 86% of galaxies without error, the average positioning is 3% ± 9%, it is even of 1.4% ± 1.6% for our 74% of error-free galaxies with $\Delta_{\text{dark}} < eM_{dark}$.

The most interesting thing is that to succeed, the algorithm produced for our 86% of galaxies without error, an average of 5.4% ± 4.6% of black holes, 30% ± 7.7% of white dwarfs, 20% ± 6.7% of red giants and 45% ± 7.7% of red dwarfs. We obtain very similar results with $\Delta_{\text{dark}} < eM_{dark}$ and even in our galaxies with errors. Thus, not only does potential energy allow the observed amount of dark mass to be generated, but this production also requires acceptable relative proportions of the different types of stars and black holes. We will note that the high rate of white dwarfs could probably be reduced by a small fraction of neutron stars. It is probably the same with red giants and hypergiants.

The previous model demonstrates that it is possible to generate all the necessary dark mass with the most common types of stars and black holes. However, it does not guarantee any consistency from one data point to another within a galaxy. To achieve this, during optimization, it is necessary to only allow the proportion of stars and black holes to change within the point itself. This adds constraints to the problem. Thus, we obtain 62% (108 out of 173) of the galaxies (for 49% of the data points) resolved without any error with $\Delta_{dark} < 2eM_{dark}$. But most importantly, this allows us to obtain graphs of the stellar distribution. Here are two examples of results (Figures 11, 12) :

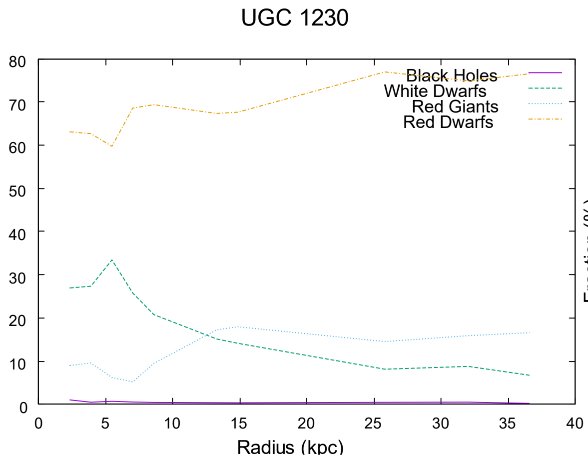

Figure 11

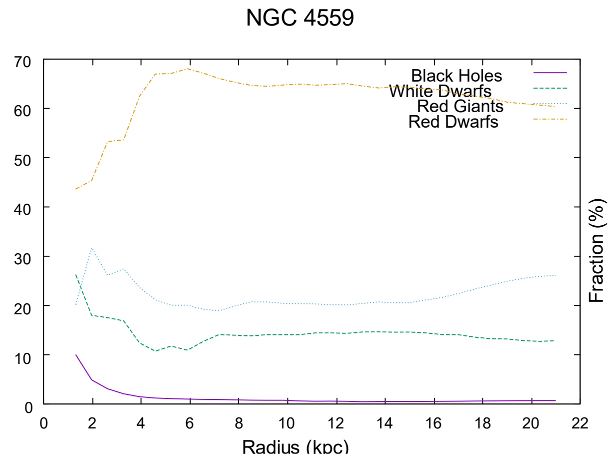

Figure 12

Galactic rotation curves

To understand how our dark mass affects the galactic rotation curves, we would first need to know the position of this invisible mass. This mass-energy is located in the field, the fact that it has remained invisible and intangible for so long is a mystery, however it is possible to quote Leon Brillouin here (21) (22) :

"All energy has mass, but it seems that the case of potential energy has been omitted. The founders of Relativity hardly mention it. In fact, the corresponding energy is spread throughout space, and its mass cannot be exactly localized. The symmetry of the distribution suggests dividing the mass between the various interacting particles. It is therefore necessary, from classical Relativity onwards, to revise the values of the masses. Well before quanta, *renormalization* was essential (and was omitted) in Einstein's Relativity."

Although the problem was clearly posed by Brillouin in 1965, it does not seem to have received a satisfactory answer. We postulate that the mass stored in the field is directly proportional to the intensity of this field. Thus, if at position *a* it is possible to measure a field $\Phi(E_a)$ produced by a dark mass E_a and a field $\Phi(M_a)$ produced by a baryonic mass M_a then to the position *b* of baryonic field $\Phi(M_b)$ we have a field $\Phi(E_b)$ produced by a dark mass E_b subject to the relationship $\Phi(E_b) / \Phi(E_a) = \Phi(M_b) / \Phi(M_a)$. So $\Phi(M_b) / \Phi(M_a) = M_bR_a / M_aR_b$, $\Phi(E_b) / \Phi(E_a) = E_bR_a / E_aR_b$ and consequently $E_b = E_a M_b / M_a$.

In the galactic case, we have seen that we must divide the production of dark mass into several components, each with its own "efficiency". Thus, if the "gas" component produces a total dark mass of E_{gas} from a baryonic mass of M_{gas} and the disc component a total dark mass of E_{disk} from a baryonic mass of M_{disk} then it is essential to calculate separately $e_{gas} = E_{gas}\ m_{gas} / M_{gas}$ and $e_{disk} = E_{disk}\ m_{disk} / M_{disk}$, $e_{tot} = e_{gas} + e_{disk}$. However, the problem is much more complex because we have seen that the potential energy varies depending on the stellar type. An accurate calculation would have to consider a division of mass into several stellar categories and without forgetting black holes.

In the absence of this information, we will only consider the gas and the disk whose respective contribution will be given by a fraction f ; $E_{dark} = E_{gas} + E_{disk} = f\ E_{dark} + (1- f)\ E_{dark}$ and therefore for each data point, $e_{gas} = f\ E_{dark}\ m_{gas} / M_{gas}$ and $e_{disk} = (1- f)\ E_{dark}\ m_{disk} / M_{disk}$. So there is only one parameter f adjustable per Galaxy. With this simple parameter, we can generate the correct proportion of dark mass for all data points of 76 galaxies out of the 175 in the SPARC sample, or 43% of the galaxies. In addition, we have assigned to e_{tot} the same margin of error as E_{dark} which is minimalist. Here are two examples of results:

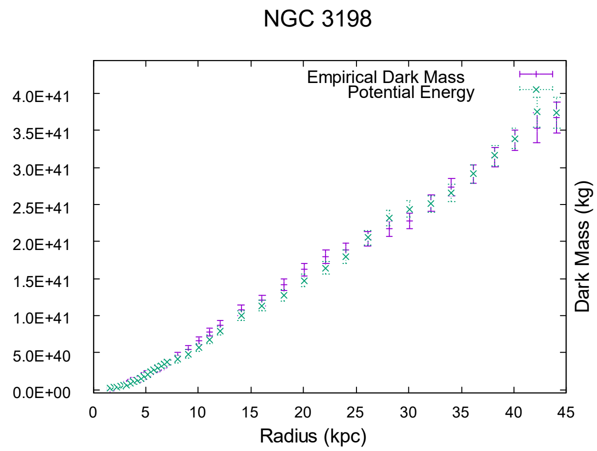

Figure 13

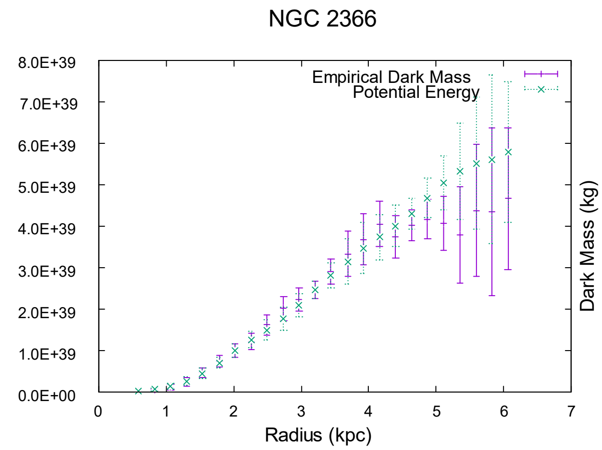

Figure 14

It is possible to add several *f* parameters until the curve is perfectly adjusted or at least until no further improvement is possible. We then obtain 29 additional galaxies with two parameters, without error, and 6 galaxies with three parameters, without error. We thus cover, without error, 111 of our 175 galaxies, or 63%. The existence of this direct relationship between baryonic mass and dark mass seems to be confirmed.

Conclusion

The objective of this article was to prove that gravitational potential energy was the cause of the phenomenon misnamed "dark matter". We demonstrated with the example of an Earth-Moon or Earth-Sun collision that it is not negligible and must therefore be considered. Then we established with simple theoretical models that it allows us to explain the galactic dark mass in the expected orders of magnitude. Already, we are faced with a dilemma; if this potential energy is not responsible for the phenomenon of dark mass, we would have to explain why the mass-energy relationship $E = mc^2$ does not apply in this case. Indeed, potential energy is produced, it exists, and it must necessarily generate mass or at least distort space-time in a way equivalent to an equivalent mass. What we have demonstrated is that enough potential energy is generated to produce the phenomenon of dark mass. This is logically a sufficient condition; dark mass must exist because potential energy exists, and the mass-energy relationship must apply.

Subsequently, we compared our theoretical model with a significant amount of experimental data and obtained an excellent fit, despite the large number of obligatory simplifications. This is logically a necessary condition; potential energy is the cause of the dark mass phenomenon. We completed our demonstration by calculating the galactic curves using the principle of "equal causes, equal consequences". So, if a mass M of a certain type, for example stars of solar mass, produce a dark mass E then a mass m of the same type will produce a dark mass of $e = E\ m/M$. Expressed in the form of a gravitational field, this means that the dark mass perfectly follows the galactic profile of the baryonic mass if the latter is homogeneous (same types of stars, same proportion of gas). This already known relationship (19) (20) between baryonic mass and dark mass finds here the necessary fundamental justification in the nature of the field. Thus, the application of the logical consequences of the fact that dark mass is produced by potential energy makes it possible to shed light on the mystery of its spatial distribution.

Why this phenomenon has gone unnoticed for so long is probably the most interesting question of all. Potential energy has long been known, as has the mass-energy relationship, and their experimental validations are indisputable. We also know that atomic binding energy, sometimes called mass energy, exists, albeit indefinitely, somewhere in the quantum field. The only reason gravitational energy was dismissed out of hand was the belief that it is a weak force. Therefore, it cannot produce mass. We have shown that this is false; while nuclear binding energy barely produces a two-fold increase in mass, gravity can easily reach ten times this value in a galaxy, or thousands on a larger scale. Gravity is weak on the quantum scale but powerful on the galactic scale. Conversely, the strong force is powerful on the quantum level but completely insignificant on the galactic scale.

The other big problem is that Newtonian gravitational theory (GN) is not “The Theory of Gravitation” which is now General Relativity (GR). Potential energy does not exist in GR, worse, Emmy Noether has shown that energy itself is not conserved in GR. Conservation of energy in the presence of a dynamic gravitational field is a very delicate subject in GR. The question of how GN can explain what GR cannot be very boring. In fact, we know that the weak field approximation, or GN, is excellent, it is even much simpler to use than GR. If a phenomenon as major as dark mass is produced by gravity, it should be calculable with GN. Indeed, it is not a detail like the precession of mercury. However, GN only gives us the potential energy of a system, we need to reintroduce it into the system to calculate the correct motions of the bodies. It is hard to believe that GR would prefer better unless we are not calculating the self-induction of the field accurately enough (15) (16) (17) (18). In this case, the simplest solution would be to find the equivalent of a weak field simplification for this self-induction; the potential energy equation should appear. In any case, that gravitation “recognizes” the potential energy produced by all other fields and itself, in a non-discriminatory way, is a miraculous phenomenon for the moment. All fields are here “unified” by this phenomenon. The BEHHGK field seems here a better candidate than gravity to “host” the potential energy; it could transform the potential energy of the other fields into something “recognizable” by gravitation.

Finally, we conclude that the study of dark mass does not require an alternative theory of gravitation, exotic particles, or even general relativity. The good old Newtonian mechanics is sufficient. Better still, we have demonstrated that simple models can accurately explain the phenomenon. It would be possible to improve these models indefinitely by using, for example, stellar population distribution curves or a more precise treatment of gases. It would also be possible to study large structures such as galaxy clusters and superclusters. One thing is certain: it is no longer possible to ignore potential energy. You can find the C++ program used to generate all the calculations and graphics at dark-mass-generator.sourceforge.io.

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