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On Fundamentals of Motion under Gravitation in Space

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Abstract *Gravitational interaction* arises out of particles having their property of mass and the motion under gravitation of an individual particle takes place by exchanging its position with virtual particles around it in space, whereas the overall motion of the celestial body, comprising such individual particles only is guided by the principle of superposition. Curvature of the space-time continuum is the result of similar virtual particles around massive celestial bodies causing the motion of other gravitating particles through them along the geodesic appearing as a curved path with accelerated motion. Following the analytical relationship between gravitational radius and the mass, also taking into consideration the average density of matter contained, as stipulated by General Relativity, there exists a high gravitational potential around the periphery of the sphere that results in the observed galaxy rotation curve and the apparent moving away of galaxies. In all probability, a gravitational collapse may happen at any time and at any part of our observable universe, causing a *mini bang*, as opposed to a big bang, to be followed by going through the period of a recycle. Similarly, diverging galaxies and celestial bodies may ultimately converge at the point of the origin of the inflation or at any other diametrically opposite pole causing a *mini bang* and the corresponding recycle once again.

Keywords Gravitation, Quantum mechanical motion, Gravitational collapse

1. Introduction

Humans have been looking into the sky since they first evolved on earth, mesmerized by the opulent mysteries, wondering and craving to learn the whys and hows. The motion of celestial bodies in space has been observed and the study of the same has been actively pursued over centuries, yet the enigma persisted albeit became more complicated despite immense discoveries that followed over time. This is because while there are but a few humble basic principles guiding all this, there are unending probabilities that may transpire making the results seemingly endless. The truth lies in the study of the fundamentals of motion under gravitation in space which contribute to such possibilities.

This article has been chronicled as a continuation of my earlier article [1] on the fundamentals of motion of a particle in space which characterizes the gravitational interaction between and among massive particles; and a study of the fundamentals of motion under gravitation in space would give rise to the solutions of the most intricate problems faced by astrophysics over the past. The same concept has been put forward in case of motion of celestial bodies too.

Gravitation results from an interaction between two massive particles in view of their having the inherent property called *mass*, which allows them to undertake motion carrying energy and momentum. In addition, a system comprising of particles closely spaced together, may manifest internal pressure as well and a density, all of which will contribute towards the overall gravitational interaction, following the basic principles of General Relativity (GR), which predicts the curvature of the space-time continuum causing an accelerated motion as viewed by an observer from an independent frame of reference.

A physical interpretation of motion under gravitation suggests [1] that a gravitating particle undertakes motion by exchanging its position with virtual particles surrounding it, under a quantum mechanical state, following a geodesic along a curved co-ordinate in space, created by the mass-energy-momentum due to the presence of a massive particle responsible for the gravitational potential.

The above simple concept is at the root of all that transpires for the motion of celestial bodies in space, obeying innumerable possibilities and causing in turn the myriad of resulting observations.

2. Gravitational Interaction between Massive Particles

Mass is an intrinsic property of an elementary particle, and gravitational interaction results between two such particles in view of their having the property of mass. This aspect has already been adequately dealt with by the modern day *Quantum Field Theory* (QFT) [2] which vindicates the origin and perpetual endurance of gravitational interaction between any two particles in space over the mutually generated gravitational field [1]. This is irrespective of the particle(s) being elementary or composite as the overall gravitational interaction among them will be a *superposition* of the same only following the *correspondence principle*.

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Consider a hypothetical situation wherein there is one only particle in space, having no other particle in its vicinity and no other form of exogenous interaction with it. Then the particle shall remain perpetually in the same location, without undergoing any motion, and causing or bringing in no change to the environment surrounding it. If instead there is one system with a number of particles, elementary or composite, contained within the system, then the system will also remain stationary in the same location without undergoing any motion, irrespective of whatsoever happens between and among all the particles, elementary or composite, residing inside.

Next consider two elementary particles only in space, and then there will be gravitational interaction between them causing a relative motion. With more particles around, there will be motion under gravitation as explained in my earlier article [1] and gravitational lines of interaction generated by means of virtual particles surrounding the particles in space. A similar phenomenon shall take place in case of composite particles and for everyday massive objects including large celestial bodies too.

3. Quantum Mechanical Motion under Gravitation

We will consider a massive particle of mass (M) at rest having no other particle around it. So it will be surrounded by a sphere of *virtual particles* [1], each corresponding to an amount of energy equivalent of its rest mass energy (Mc^2). Now consider another particle of smaller mass (m) at rest in its vicinity at a distance from it which will also be similarly surrounded by a sphere of virtual particles of its own. Now in accordance with QFT [2] and as postulated in my earlier article [1] the two particles will have a *common gravitational field of attraction* and will be joined by gravitational lines of interaction, causing impending motion under gravitation. We shall further consider the scenario of each particle resting at a point on the circumference of a great circle of the sphere centered on the other particle.

We shall, however, consider the motion of the smaller particle of mass (m) only, neglecting the effect of it on the other more massive particle. In view of the two particles having their property of mass, there will be a negative *gravitational potential* between them [1] [2], and following the path of least action, the smaller particle will tend to move to a position at a point on the great circle, immediately below it, since in space there is no direction as such and so it is alright to consider one above the other, by interchanging its position with a virtual particle of the more massive particle and will acquire an amount of energy (Mc^2), thereby acquiring a momentum causing a velocity towards the other particle. In this way the process will continue and each time the smaller particle will acquire the same amount of energy due to which it will acquire a uniform acceleration under gravitation independent of the value of its own mass. This will be a *free fall motion under gravitation* considered by GR.

Now we will consider the smaller particle to have a *uniform initial velocity*. We shall consider the component of the velocity which is *tangential* to the great circle at its position only, neglecting the radial component through the centre, which will have the effect of superposition of an initial velocity under a free fall, as explained above. Similarly following the path of least action, the particle will now move along the great circle by interchanging its position with a virtual particle of the more massive one and will also acquire an amount of energy (Mc^2) which will give rise to an *acceleration* by directing it to retain its path along the great circle only, causing the smaller particle to fall in a *path of orbital motion* around the more massive particle, and we shall appreciably consider this effect neglecting the initial velocity to be too small or too large, which shall not permit it to be restricted to the above scenario.

An exactly similar situation shall occur, as detailed out later in this article, while considering the thought process in GR, of a cloud of small particles which will start falling towards its center when set in motion under gravitation alone. Also the same principle of *curvature of spacetime* as in GR will be followed by each particle, however, under the *quantum mechanical motion*, as postulated hereinabove.

So this fundamental concept of *quantum mechanical motion under gravitation* may be applied to each consequential motion and effect coming under the purview of the principles and formulations of GR which may be viewed as the *analytical simulation* of the above mentioned quantum motion.

4. Motion of Celestial Bodies in Space

We may consider celestial bodies in space as large objects such as planets and stars that we find in our skies. We may further consider that irrespective of the nature of composition, any such celestial object is composed of a number of molecules and atoms which are in turn composed of a few only classes of elementary particles, which, belonging to the same class are all alike as truly indistinguishable. Moreover, elementary particles and the atoms and molecules are in continued motion under interaction among them which results in preserving the composition and the shape and size of the celestial body.

While the primary interactions causing the above scenario are strong, weak and electromagnetic ones; the overall motion of the body, is due to electromagnetic and gravitational interactions only. The nature of electromagnetic interaction is fairly well understood in terms of exchange of photons, and so in this treatise I shall accentuatemy attention on *gravitational interaction* only which is the primary interaction governing the motion of celestial objects in space.

Since the celestial body is actually comprised of tiny elementary particles in continuous motion in their quantum states, the overall motion of the vast celestial body arises as

the result of the *superposition* of motion of such quantum particles following the *correspondence principle* [1]. But the resultant motion as above can also be successfully vindicated under the principles of GR theory, and so we will continue our discussions on a few specific issues only on the basis of GR.

5. Gravitational Collapse

The concept of *gravitational collapse* [3] [4] and observational facts supporting such a possibility are derived from GR while the true nature of it is yet to be revealed. However, from a purely logical point of view, and apparently supported by analytical workout, a scenario simulating the gravitational collapse is a distinct possibility in terms of the massive particles coalescing together under gravitational interaction alone, as made possible due to the inter-relationship of the radius of the spherical space and the amount of mass contained in it formulated under GR. Since the galaxies and their constituents are in continuous motion in space, a gravitational collapse may occur at any part of the stellar space and at any time. However, whether a *general relativistic gravitational collapse* [4] is true or not, it seems quite apparent that a very *high gravitational potential* around the periphery of the sphere supposedly under a gravitational collapse may result as per the assumptions held true under the GR.

Such a possibility may give rise to remarkable outcomes, offering solutions to many conundrums which are otherwise difficult to answer and explain; the secret therein, however, lies in the study of the quantum mechanical motion [1] of the individual particles comprising the masses within the sphere.

In case of a supposedly gravitational collapse, the gravitating particles will coalesce together within a compact space, till the particles shall no longer remain as such, but shall be disintegrated into energy and space, the constituents that formed the particles [1], and both space and energy shall be dissipated into the environment. The energy shall be conveyed away through photons only [1] in the form of electromagnetic radiation, and the overall mass shall continue to decrease [3] [4] till the total gravitational or baryonic mass shall completely be eliminated.

At the same time another possibility may arise, when the amount of energy released by the gravitating and converging gravitational mass may turn into an *inflation* causing the remaining particles being entirely thrown violently outwards. This will cause a *mini bang*, as discussed herein later.

6. Gravitational Radius

An outcome of the GR shows that for a simplified spherical, uncharged and non-rotating body, there stands an exciting relationship between the radius of the sphere and the mass contained within it such that a limiting scenario may be achieved which may lead to a so-called *gravitational collapse* [3] [4] of the body in case of the mass contained within the sphere attaining or exceeding the limit set by the above analytical relationship. I will extend this correlation by taking into account the property of *density* also, the use of which becomes more apparent and convenient when we will consider the deep outer space where an estimation of mass contained within the intended sphere is impossible to account for.

While in terms of the real world, the celestial object may deviate considerably from being a perfect sphere and may be electrically charged and also rotating being alongside in translational or orbital motion, we will restrict our analysis based on the above simplified version only, because the purpose of our discussion will be so served. The analytical relationships as stated above stand as follows.

$$R_s = \frac{2GM_s}{c^2}$$

$$V_s = \frac{4}{3}\pi {R_s}^3$$

$$\rho_s = M_s/V_s$$

$$R_s * {M_s}^{-1} = \frac{2G}{c^2} = constant$$

$${R_s}^2 * \rho_s = \frac{3c^2}{8\pi G} = constant$$

$$R_s * M_s * \rho_s = \frac{3c^4}{16\pi G^2} = constant$$

Symbols:

R_s = Gravitational radius, M_s = Mass corresponding to R_s, V_s = Volume corresponding to R_s, ρ_s = Density corresponding to R_s, G = Gravitational constant and c = Speed of light.

The above analytical relationship between R_s and M_s and so also with ρ_s in terms of gravitational interaction, thus governing the motion, depends only on the gross value of M_s and not on the actual distribution of the mass within the sphere, contributing to the average value of the density.

Moreover, interestingly as the value of R_s increases, the corresponding value of ρ_s will go on decreasing at a much higher rate. For the real world, therefore, as is prevalent in the observed outer space, it may further be considered realistically that as the radius of the sphere increases, more celestial bodies and so their masses get enfolded within the sphere yet the average density sharply decreases.

I will start with an arbitrarily selected sphere of radius R_s having a corresponding mass M_s under the limiting condition that the celestial body will still hold back from a supposedly gravitational collapse while having created a *very strong gravitational field* in the zone immediately outside the above radius. Now I will go on with an increasing radius and simultaneously enfolding more and more mass while the total amount of mass within the sphere remaining lower than, yet not too far from, the corresponding value of M_s, thereby all the time being safely away from the limiting condition of gravitational collapse but still having a strong gravitational field in the vicinity outside the sphere.

Moreover, in the real world, as I will go on radially

outwards, the value of the enfolded mass will change in its own way, independent of the radius. *However, in all probability, I will certainly meet with several such near-limiting scenarios, at various values of the radius, where the relationship between the radius and the mass will create a strong gravitational field close to the above limiting condition stipulated by the value of the corresponding gravitational radius at that location in space*. The observed real world density of space, the formation of clusters of celestial bodies along with their distribution and the varying measure of proximity among themselves strongly suggest such probable scenarios.

I will furnish a simple analytical example with the following values for the universe as a whole.

$$R^2 * \rho = \frac{3c^2}{8\pi G}$$

G = 6.7E-11 $m^3kg^{-1}s^{-2}$

c = 3E+8 $m\,s^{-1}$

ρ = Average density of space = 9.9E-27 kg/m^3

R = Radius of an arbitrary sphere with average density ρ as above

From the above relation between R and ρ, we get,

R = 1.34E+10 light year, whereas the radius of the observable universe = 4.6E+10 light year.

Since beyond a radius of 300 million light year, the average density of space may be assumed as above, we may consider our arbitrary sphere of radius R to satisfy the relationship of a gravitational radius thereby generating a high gravitational potential around its periphery. In this way, we may reasonably expect more such annular regions of high gravitational potential because the actual average density of space may vary over the regions in order to satisfy the relationship of a gravitational radius.

7. Galaxies and Stars

Similarly, the observed nature of the real world galaxies and the stars inhabiting them, show that a typical galaxy has a lumpy center surrounded by a cluster of stars in a disc like manner and together having rotational cum translational motion. Moreover, the center of the galaxy usually contains a purportedly supermassive gravitationally collapsed mass, passably following the above relationship between its radius and mass values contained within that sub-sphere.

It has further been observed that the *rotational velocity* of the stars remains nearly constant away from the above galactic center. This can be accommodated by assuming a *singular isothermal sphere profile*, which, however, deems to be unphysical while the observed *radial orbital velocity profile* is fairly constant. As indicated above, away from the galactic center, we may encounter several annular sectors at various intervals each having a correlation between its radius and density in view of the mass enfolded within the corresponding sphere arising close to the limiting condition ($R_s^2 * \rho_s = constant$) thereby each annular segment exercising a strong gravitational field and satisfying the above *singular isothermal sphere profile* scenario which may justify the observed *galaxy rotation curve*. The stars inhabiting each such annular sector will be under the above condition of a very strong gravitational field thereby causing the radial orbital velocity equitably constant allowing the galaxy rotation curve to be similar to what has been observed.

Furthermore, each galaxy will end in having an outermost annular sector under the above condition, exercising a strong gravitational field, due to enfolding of the huge entire mass of the galaxy, and so two neighboring galaxies will exchange light with redshifts, causing the observational fact that the galaxies are flying off away from each other at accelerating rates.

The postulate, that I would like to submit here, is that say from our Milky Way galaxy, when we are observing the outer space, we will find that the surrounding galaxies are moving away in the above manner, which is actually the effect of redshift of light between the similar outermost annular sector of each of the galaxies adjacent to our galaxy and the outermost sector of our galaxy.

8. Mini Bangs

As gravitational collapse is apparent from the above discussion, a scenario following such a collapse will eventually *end in a bang at the galactic center*, limiting itself to the specific galaxy or more rationally to a cluster of galaxies. Each such bang, similar to a big bang in every other condition except in its severity and not encompassing the entire universe may conveniently be termed as a *mini bang*, to be happening all the time, and everywhere around, wherever the condition will permit.

The *mini bang* will cause the matter particles to undergo through an inflationary stage, and recreating the lumpy character once again, albeit after many billions of years. Moreover, the cosmic microwave background radiation, will also appear as is being observed in the outer space today.

In addition, the results of the *mini bang* will create a nearly *homogeneous, isotropic and isothermal stellar space* as is observed in the real world today. Since such a mini bang will retain and manifest all the characteristics of a perceived big bang, except limiting its enormity to the quantum of the cluster of galaxies undergoing the cycle, all that may follow will happen again forming the mini universe out of it, as an integral part of the greater universe as it was once earlier, before going through the cycle of a gravitational collapse followed by the mini bang.

9. Cosmology and Singularity

Cosmology in general takes into consideration large scale celestial and stellar bodies, and their formation and continuation; all based on the study of their motion and relative positions only. Theoretical analysis starting with

simple thought processes, however, simulating their motion in the real world of galaxies and stars, is a vital tool in this direction, as will be taken up and studied hereinafter.

A cloud of freely moving gravitating particles around a center will either be converging towards it or in case of moving away from it will be inferred as originating from it, with time scale reversed. This has already been vindicated by the Field equations of GR or Raychaudhuri equation [5] [6] and in each case it will point towards a *mathematical singularity* at the center either in the past or in the future.

Now let us have a closer look at this *singularity* which projects the entire mass of the particles in the cloud to be located at the center thereby raising the mass-energy density and the curvature of space-time to infinity. Taking into consideration *Planck units*, we have the minimum possible length as the *Planck length* (l_P) corresponding to the value of the minimum possible action as *Planck constant* (h) being the result of the motion of a particle from any arbitrary initial space-time event to a final one. Therefore, irrespective of the particle being elementary or composite, it cannot move to a position closer to a particle which is less than the above *Planck length*. This allows the inverse square law of interaction to remain inviolate for both the electromagnetic and gravitational cases.

In case of a repulsive interaction, it is expected that the strength of interaction will even much earlier become too large to let the particle move away with an *inflationary speed*, which is, however, not what we are considering here under gravitational interaction. For an attractive interaction, the particle will continue to move till it entirely fuses with the particle at the center, thereby not remaining as a particle any more but disintegrating into its equivalent amount of space and energy [1] and with a large number of oncoming particles under the above scenario, a very high amount of energy will be released which will impart sufficient kinetic energy to the surrounding particles to move away with an *inflationary speed*, same as the other scenario under a repulsive interaction.

The above conjecture will prevent a *mathematical singularity* to occur physically at the center yet it will condone the anticipated motion of the cloud of freely moving gravitating particles around the center as above for both the converging and diverging scenarios. This will be the case of a *mini bang* similar to what I have conjectured hitherto in this article under gravitational collapse, only to be caused differently. Extrapolating this to the real world of the galaxies we may infer that the observed motion of flying away of the galaxies is the result of an earlier *mini bang* which is again the outcome of an even earlier converging motion of the galaxies under the gravitational interaction alone, provided however, we are in a position to deliberate this convergence other than due to gravitational collapse.

Let us now consider an observer at the pole of a sphere watching all particles moving away from the pole along its great circles simulating the above divergence. We will also consider this pole to be the same as the center of our above sphere from which the particles are diverging out radially, so there will be a large number of spheres all having the common pole at this center, while the radial arms will eventually turn into great circles of the other spheres over a large distance as space-time will begin to curve, reasonably presuming that most of these spheres will attain the necessary mass-energy density at the center. The same motion will cause the particles converging towards the opposite pole of each such sphere, and in case the curvature of the sphere is retained, the motion can be repeated in *endless cycles*. The particles will either actually converge at the pole to be followed by a mini bang or in some way bypass it while moving close to it. So with a mini bang at the other pole or not, the particles will tend to converge at the originating pole again in any case. Moreover, for the observer at the pole, the particles will tend to accelerate away at a higher rate as they move along the increasing curvatures of the great circles as viewed by the observer. For a uniform sphere, such an observer pole may exist at any point on its surface and an identical scenario will also occur considering all other spheres of varying radii so contained within or staying outside of the primary sphere of the observer. Therefore, any arbitrary observer will experience an *expanding universe* around him which will actually *re-converge* after the cycle over space and time at some point in the future. This may seem too simplistic yet a realistic scenario while extrapolating this conjecture for the real world of our galaxies.

Extrapolating the above scenario to the real world of galaxies, we may infer that some of the diverging galaxies will find another massive galaxy at the center of a sphere to curve around it and then to eventually converge at the other pole simulating a mini bang or return to the originating pole and start a mini bang there again. Given the abundance of scattered galaxies with their opulent mass-energy density and the enormity of time available to go through the cycles as above, we may reasonably presume that in all probabilities such a scenario will be a realistic one in our real observable universe.

Since we shall never be able to observe our entire universe from being outside of it [1], we may still be content with a scenario portrayed above, which may happen arbitrarily and continually at one or many locations within our grand universe, taking into consideration the innumerable probabilities due to enormous possible combinations of mass, energy, momentum and relative positions of the vast number celestial and stellar objects contained within our observable universe. As an aside, it may be noted that as living beings we may survive in an observable universe of diverging galaxies only while the converging one is one of a doomsday scenario, not to be considered except for our analysis.

10. The Universe

So I will look at our universe in this way. It is the *observable universe* only that I will consider to be our

universe with all the galaxy clusters contained in it. The galaxies are in continuous motion relative to one another, in the same way as every particle down to the elementary particle is in continuous relative motion in space under the respective interaction. The formation of the massive celestial bodies is the result of all such particles being held in close proximity, as applicable, and then together under gravitational interaction as formulated by GR. Every arbitrarily chosen point in space may be considered as the center of an idealized sphere and an imaginary gravitational radius may be drawn with the entire mass of celestial bodies enfolded in it. At any time and at any part of the space, a condition may so arise that an amount of space bears the relationship of the gravitational radius and mass or density triggering a gravitational collapse that cannot be precisely predicted by any known physical law of nature.

However, such a gravitational collapse, more than one and more than once, is bound to occur taking into account the incalculable number of probabilities and the enormity of the period of time of the existence of the universe. Interestingly, it is sure to occur in a part of the universe rather than happening for the universe as a whole, as is already prevalent from the observational facts supporting the formation of supermassive gravitationally collapsed celestial bodies at galactic centers.

I have already dubbed earlier such a collapse causing a *mini bang*; and so the cycle will be repeated in creating the part of the universe restoring the masses. All our observations will in any case be limited within our observable universe only, as we shall in no way be able to make observations barring mere speculation, what lies, if any, beyond our observable universe.

In our universe, matter and space co-exist while matter is formed out of space by means of energy [1] and as matter disintegrates space is released and energy is liberated. Matter is reformed once again and the cycle thus goes on. Matter is formed out of elementary particles which have real existence while energy manifests itself only during transition from a particle to another particle in motion, taking it from one state of motion to another.

11. Conclusions

Motion of matter particles under gravitational interaction, caused by the virtue of their property of mass, and made effective in every possible way, is the source of creation of all celestial bodies and governs their overall motion in space. Our entire universe with everything contained in it was created by chance, nurtured and endured by chance and has been tantalizingly living on chance only.

A gravitational collapse or convergence of celestial bodies causing a mini bang may take place at any time and at any arbitrary location within our universe. Our observable universe, more probably partially rather than in its entirety, shall perpetually go through a cycle of a mini bang followed by an inflationary stage recreating matter and thus completing the recycle. Based on a few humble principles yet with an incalculable amount of unintelligible probabilities the universe lingers on from a no apparent origin to an end alike. What may happen, will always happen, if not now, some other time, if not here, anywhere. In all probability it will transpire. God does not play dice, yet rolls the dice all the time.

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