Diffusion Gravity (4): An Alternative to Dark Matter

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Abstract

Diffusion Gravity is a theory based upon established physical principles including Newtonian mechanics, quantum mechanics, and the Principle of Least Action. Radial flows of virtual particles from all masses due to *mass diffusion* is proposed as the fundamental cause of gravity, along with the corresponding quantum mechanisms underlying the macroscopic phenomenon. The Poisson equation for gravity and the corresponding "*sink*" or depletion zone is presented as the attraction mechanism for gravity; this current research installment applies the equation to large scale gravitational equipotential point-surfaces in galactic star orbits, where the acceleration according to Newton-Kepler should fall to $a_0<10^{-10}$ m/sec^2, but observationally does not. By steradial geometry and the Gaussian transform of volume virtual particle flows to equipotential surface fluxes, the diffusion gravity model demonstrates how a gravitational "locking" and "equipotential-locking" at galactic scale affects centripetal acceleration and velocity rotation curves of galaxies, without invoking dark matter.

Introduction

Mass Diffusion of virtual particle streams from all masses can be shown as the fundamental physical cause of gravity[1]. This mechanism supports the tenet that the phenomenon of gravity is an independent entropic force of nature that conforms with and coexists with the accepted laws of physics such as thermodynamics and electromagnetism. Accordingly, the Diffusion Gravity (DG) model is also rooted in the quantum mechanical realm that includes random motion and stochastic probability behaviors, as described in a previous research work[3]. In further correspondence to thermodynamics, DG posits the random microscopic realm determining the outcomes of the macroscopic physics of gravity, to be consistent with classical mechanics. Virtual particle streams thereby act as the gravity "transport" mechanism. Compare this to electromagnetism (radiation), where photon streams (virtual quanta of energy) are the transport mechanism for energy. Evidence will be presented herein to show that mass diffusion in the vacuum invokes the same properties of the vacuum to transmit virtual particles as virtual quanta of mass. The paradigm of "transmission" via the vacuum can apply logically and equally for both electromagnetic energy via photons, and mass (gravity) via virtual particle streams. That is, the model proposes that likewise quanta of electromagnetic energy are transmitted by the vacuum as "information" (wavelength and direction), while gravity sends its "information" (mass and direction) in a very similar way using the same vacuum medium and virtual particles. Electromagnetic radiation propagates through the vacuum with known transmission properties (permittivity and permeability); however vacuum does not "hold" photons, which are virtualizations only for transmission of the "information" about the energy by the active vacuum. The DG model proposes, therefore, to apply the principle of virtual photon transmission to the analogous gravitational "information" transmission by virtual particle streams, i.e., the vacuum transmits the information about the mass, but not the mass itself. Streams of virtual particles provide essential mass and direction information between masses, which then effectively interact and modify the vacuum between masses. The masses then react accordingly (attraction) as shown in the schematic diagram of Figure 1. Conservation laws are upheld since mass does not actually move until gravitational attraction occurs, when energy is expended in movement of the masses. This model should apply at any scale, so this current effort is presenting the case where enormous mass and distance interactions display consistent behavior with the smaller scale model for gravity, but with some added functions that extend the model to explain the observed galactic anomaly of constant velocity for orbiting stars. In doing so, DG aspires to greater insights into the general phenomenon of gravity.

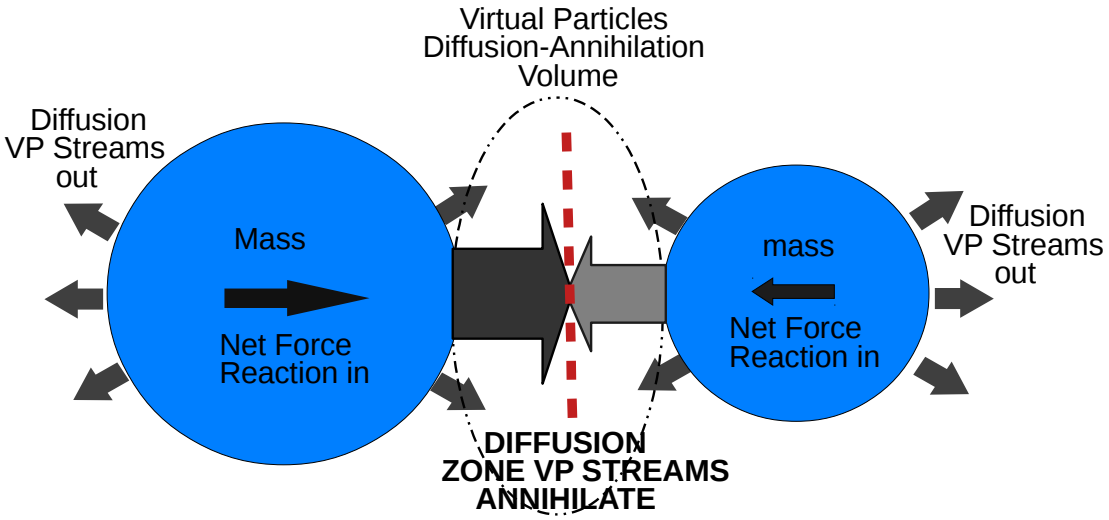

Figure 1: The Diffusion Gravity Depletion-Attraction Mechanism

Physics has never provided an adequate explanation of the underlying *cause* of gravity. The empirical descriptions and observations with ever-finer instruments and measurements continue to multiply, but still there is no clear causality from the quantum level to the larger scale for gravity. Theories based on or around General Relativity (GR) continue proliferating with "tweaking" and variants, but without practical motivating mechanisms for gravity. Curvature of space is a geometric-mathematical concept with no primary mechanism to actually move mass. Hence, the problem of *no prime mover mechanism* begets the problems that include the big bang model of cosmology, dark matter, and dark energy, which all compound upon themselves in a ever-more-complex standard model. Some prominent physicists, such as P. Mannheim [4,5] have analyzed and discussed these problems induced by increasing complexity and even proposed their own alternatives to dark matter. We draw upon resources for this work that include current research by notable scientists M. Milgrom [8] on Modified Newtonian Dynamics (MOND), S. McGaugh [9,10] on galactic rotation curve observations, V. Rubin [12,13], and many others, as well as standard references on the subject, such as Galactic Dynamics [19] and Spherical Astronomy [17].

The mechanism of *diffusion* was suggested in 1997 as a basis for gravity by Roy Britten [7], who published two research papers on the subject; however, his basic model did ***not*** include a prime mover mechanism:

> *"The model that has developed includes: (i) an unspecified agent responsible for the force of gravity, probably traveling at the speed of light over small distances; (ii) for distances more than a few kiloparsecs (kpc), the agent propagates following the diffusion equations; (iii) the effective mean free path is '5 kpc, apparently independent of the local matter density..."*

Without an "agent" specified, the Britten model lacked causality; the DG model, in contrast, proposes an hypothesis and a physical mechanism[1], which together provide a baseline of principles of causality and mechanics toward development of a practical theory. This paper adds further details and observation to substantiate the overall DG model, and is organized into three sections:

(1) Overview of the DG Model with summary of previous work and fundamental principles;
(2) The large distance effects of diffusion gravity in the Milky Way Galaxy (MWG);
(3) Application of the quantum virtual particle streaming model to large scales.

A final section will summarize the overall DG theory to date, project further research toward evidence for the active vacuum DG model, and recommend further observations and research toward integration of the component conceptual models.

Section 1 Overview-Review of the Diffusion Gravity Model

The model is based upon continuous streams of virtual particles from all masses; these streams of virtual particles are agents that interact with streams from other masses to deplete a region of the vacuum between the masses in proportion to their respective masses (at the equipotential point or surface), whereupon the masses are accelerated toward the depleted region to "equalize" or "level" the vacuum, in the same way that nature seeks to equalize both matter and energy through all types of diffusion (for both energy and matter). This manifests as a gravitational attraction mechanism as summarized in the diagram of Figure 1. The agent streams are detected as gravity itself; gravitational potential is therefore a scalar metric of the virtual particle stream flow through a given point with a directional sense, as an "implied" vector. Simple Newtonian gravity defines an equipotential point-surface between two masses M and m, separated by a distance $R + r$, the equipotential point-surface Φ_{EP} is calculated using the mass ratio to obtain the distance of the equipotential point surface:

$$\Phi_{EP} = GM/R = Gm/r \qquad (1)$$

where G is the gravitation constant and r is the distance from the small mass m to the equipotential point-surface; so $R=Mr/m$. Every gravitating pair of masses has an equipotential point-surface between them, where the two potentials (virtual particle streams) add algebraically, i.e., opposite direction streams ***sum to zero***. This is the simple principle of superposition defined for classical electromagnetic and gravitational fields, e.g. in [8]. The equipotential point-surface is caused by the quantum annihilation of the virtual particle streams from each of the masses within a volume around the equipotential point or surface. In typical pairs (e.g. our solar system) of approximately equal masses, the equipotential point-surface lies where the potentials cancel and create a ***zero-potential surface***. This is illustrated in Figure 2 for typical Newtonian gravity as observed in our solar system.

$$\Phi_{EP} = \Phi_M + (-\Phi_m) = 0 \qquad (2)$$

Equation 2 states that potentials add to zero where they are equal and opposite in direction, where direction is referenced toward the larger mass M. This simple classical field principle is illustrated clearly in terms of static vector fields with direction, and applies not just to static electric field potentials, but also to gravitational potentials. Figure 2 shows an example equipotential surface created by the addition of potentials between two masses. This equipotential surface is again consistent with the annihilation-cancellation as described in the Attraction Mechanism[3] underlying quantum diffusion equations for virtual particles. As such, it is not just analogous to the static electric field equipotential surface; it is identical.

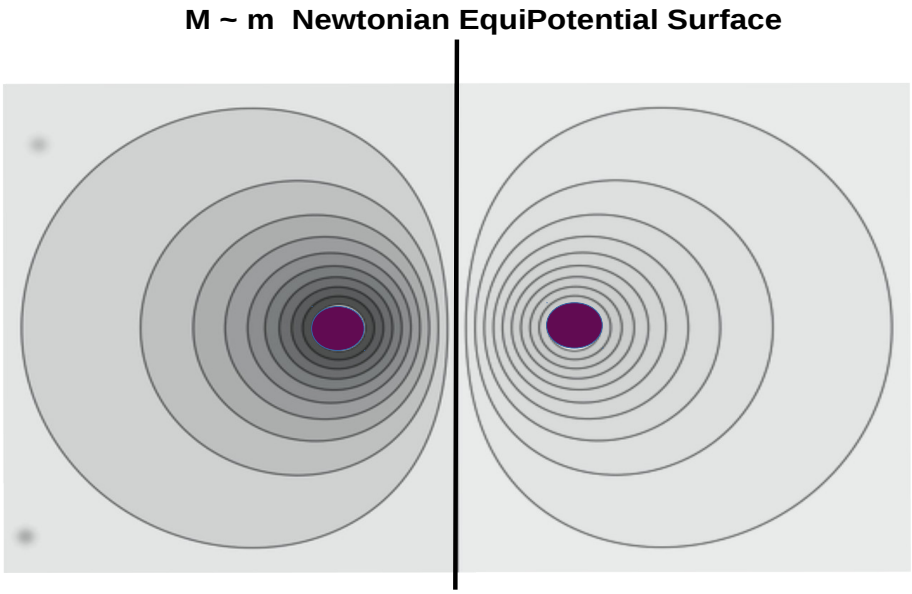

Figure 2 Equipotential Surface for Gravitational Potential

The geometry of gravity can be envisioned in the same way that any radial field is portrayed, i.e., with $1/r^2$ intensity profile, due to radial virtual particle streaming. Gravitational fields can be shown in steradial geometry along with the equipotential surface formed between attracting bodies in typical gravitational configurations of the solar system. The depletion zone for Diffusion Gravity is therefore the surface of intersection between the steradii of the larger mass and the smaller mass, where the virtual streams algebraically add to zero. The ratio of the interface areas, i.e., the steradii r^2, will provide the ratio of the two masses, in accordance with the Gaussian and Poissonian equations for gravity. In fact, mathematically there is no difference in the ratios

$$M/m = R/r = \sqrt{R^2/r^2} = \sqrt[3]{R^3/r^3} = \sqrt[n]{R^n/r^n} \qquad (3)$$

and so the DG model equates the Gaussian surface flux as the equivalent to the steradian volume flux, and works geometrically in that regime. This provides a correspondence between the volumetric radial streams of virtual particles and the equivalent flux from the steradii volumes where they intersect and interact. The basic unit of gravitational action for DG is described using the steradian volume. The streams of virtual particles outflow in the conical path of the steradians from the center of the masses; and their opposing convergence is the depletion zone between the masses.

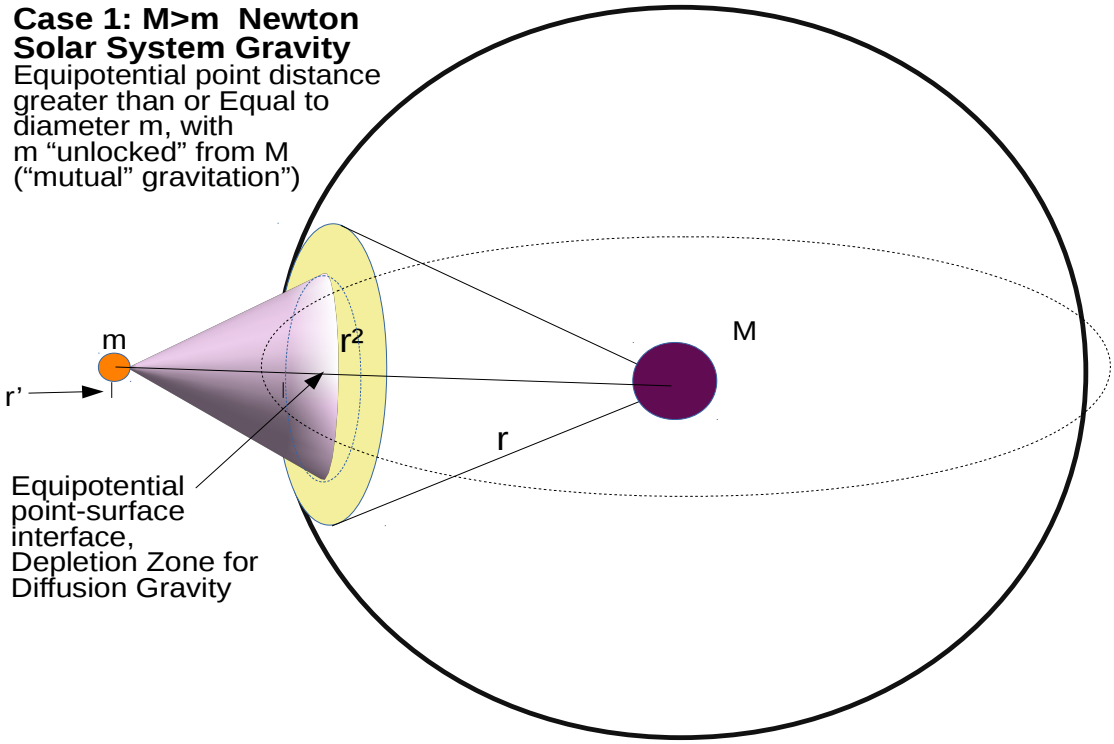

Figure 3 Typical Newtonian gravity steradial geometry depletion zone of virtual particle streams

Figure 3 depicts this corresponding steradial geometry and the equipotential surface formed between attracting masses in typical gravitational configurations of the solar system.

But now at the scale for the very large mass of the Milky Way Galaxy, that mass M is so large that it overwhelms the closer-in individual stars gravitationally, and "captures" them without a "depletion zone" between the star and MWG center, as has been previously defined and illustrated for DG. For a star inside the $\mathbf{a_0}$ orbital distance (~8K light years), the steradian intersection volume for the orbiting star is neglible; so for the very large mass *M* of the MWG "locks" the closer-in individual stars as integral to the "disk" of the galaxy. Diffusion gravity explains this by the cancellation (annihilation) of the virtual particle stream as soon as (or at the surface of m) it emanates from the inward side of the

star mass. The following description will show how the DG model explains this locking of inner star orbits.

The enormous mass ratio at the galactic scale is not encountered at the solar system level where the same ratio of Sun to Earth is M/m = 3.3 x 10^5 and the corresponding balance point (equipotential) is 1.5 million kilometers, or 10^9 meters from earth, or .01 the distance from the Sun, which is beyond the diameter of the earth of 6.4 x 10^6 meters; from this evidence, we postulate that there is a critical point at which the equipotential point-surface of the gravitational potential will occur within the mass *diameter distance* of the orbiting body (toward the MWG center), such that it is "locked" to the larger mass. An example of this locking is the planet Mercury, 1.7 x 10^{-7} solar mass, so M/m = 10^7 with r = 1.7 x 10^7 / 50 x 10^9 meters ≈ .03 x 10^{-2} meters, which shows the equipotential surface is "coincident" upon the planet during much of its orbit around the Sun; in fact, Mercury has no continuously stable equipotential point-surface with the Sun due to its eccentric orbit, but it is gravitationally locked to the Sun during some of its orbit.

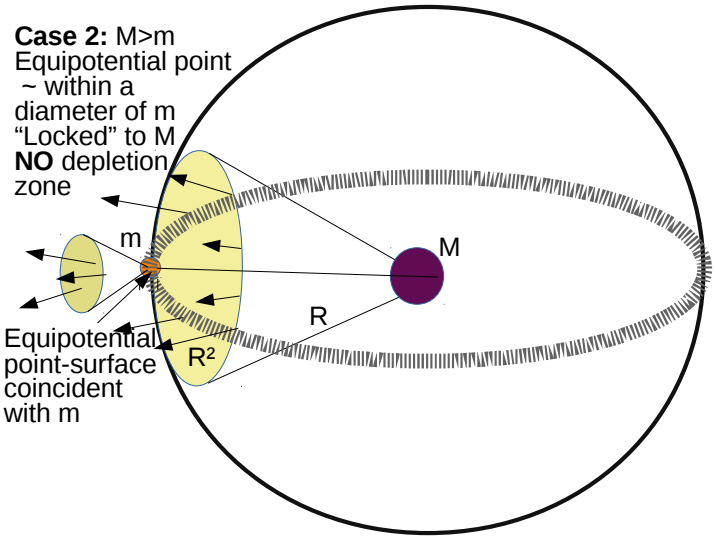

Figure 4: Gravitationally "locked" star within a_0 radius

This example of Mercury in our solar system suggests evidence toward the diffusion gravity locking model, so we apply this approximation as Case 2 to the closer-in stars of the MWG, within the radius of where $a_r \sim a_0 = 10^{-10}$ m/sec^2; this calculates to be around 8K light years from the center of the MWG. The Milky Way Galaxy hypothetically, then, has gravitationally "locked" masses of stars out to approximately 0.8 x 10^{20} meters , where the approximate a_0 radius occurs. The absence of a steradial depletion zone for stars inside the a_0 radius can be summarized mathematically by the Laplacian:

$$J = \nabla^2\phi = 0 \qquad (4)$$

where the gravitational potential of any given mass within that region is "locked" into the galactic disk, and potentials between those stars and MWG add to zero in accordance with equation 4. It is reasonable, therefore to declare this as the Diffusion Gravity *captive* state, whereby tidal forces and the larger M gravitationally controls the smaller m completely. This is depicted in Figure 4, where the equipotential point-surface is coincident upon the orbiting star mass m. From this coincident locking basis then, we can extend and modify this simple locking configuration to describe the behavior of masses *outside* the a_0 point, as their behaviors provide insight to the larger scale effect on the rotation curve of galaxies.

Section 2 Large Scale Effects of Diffusion Gravity; Equipotential Surfaces

Now, by applying this same model and logic to galactic star orbits beyond the a_0 radius, we observe that the equipotential point-surfaces only start to "move away" from "coincidence" orbits with the stars at the cosmic dimension of around R > 8k light years, or 1 x 10^{20} meters. At that distance R, the orbiting star is about one diameter of the smaller mass *m outside* (away from) the equipotential surface between the MWG and the orbiting star. If we consider the stars further out from a_0, such as our Sun, which is well outside the a_0 radius at 26k light years, the acceleration toward the center of the MWG would be calculated to be only .2 x 10^{-10} m/sec^2 using Newtonian gravity ($ma_r = GMm/r^2$), which is considerably less than the required centripetal acceleration, $a_r=mv^2/r$ for the observed velocity (230 km/sec) and distance (2.6 x 10^{20} meters) . The DG model addresses this discrepancy in this third case (Case 3), to show how the equipotential point-surface proximity (but not coincidence) to the small mass m can cause a net outflow, or *source* out of the region or volume of the star mass. This local, or differential effect, is the direct result of the equipotential surface proximity to the star mass m, and the difference $\Delta\phi$ between the potential on the outward vice inward side of m. Please refer to to **Figures 5** and **5a** for the mechanism schematic of this configuration. There will be reduced virtual particle radial streams out of the inward side of m, due to very small diffusion-driver $\Delta\phi$ between m and the equipotential (zero) potential surface, which causes a commensurately larger radial stream of virtual particles out of the outward side of the small mass due to the difference between the inside surface and outside surface potentials from star mass *m*; the radially outward increased flow from the star mass m manifests as an increased centripetal acceleration a_r, which is larger than the $a_r = mv^2/r$ calculated and expected. This DG model extension for the galactic scale thus shows how the Newtonian mechanics can be maintained at very large mass and distance ratios in comparison to the solar system, and the effect of equipotential point-surfaces in close proximity to, but not coincident upon the orbiting star; DG labels this configuration as equipotentially locked, or "EP-locked". Further evidence for this Case 3 for the DG model can be shown by examining the energy of the orbits for the EP-locked stars with flat rotation curves and where the equipotential surface is within about a diameter of the orbiting star. The equipotential surface is a ***zero potential contour***, meaning that a mass traveling along or very close to that *contour* requires ***minimal or zero energy;*** the DG attraction mechanism shown will add centripetal acceleration to direct the star toward the contour in consonance with the **Principle of Least Action** [21, 22, 24]**.**

Application of the geometry of the steradian helps to visualize at this scale to show virtual particle radial streams and the Gaussian-Poisson effects of *volume to surface flux* conversions. The Poisson equation of gravity for the Case 3 just described is thus expressed as

$$+J = \nabla \bullet a_r + \nabla \bullet a_{EP} = \nabla^2\phi \qquad (5)$$

Where J is *positive* as a *net source* of gravity virtual particle streams for the Poisson volume defined around the orbiting star, and therefore provides the additional centripetal acceleration required for

constant velocity *v* as observed, with a_{EP} the added acceleration due to the mechanism described. Please refer to Figure 5a for visualization of this Poisson volume.

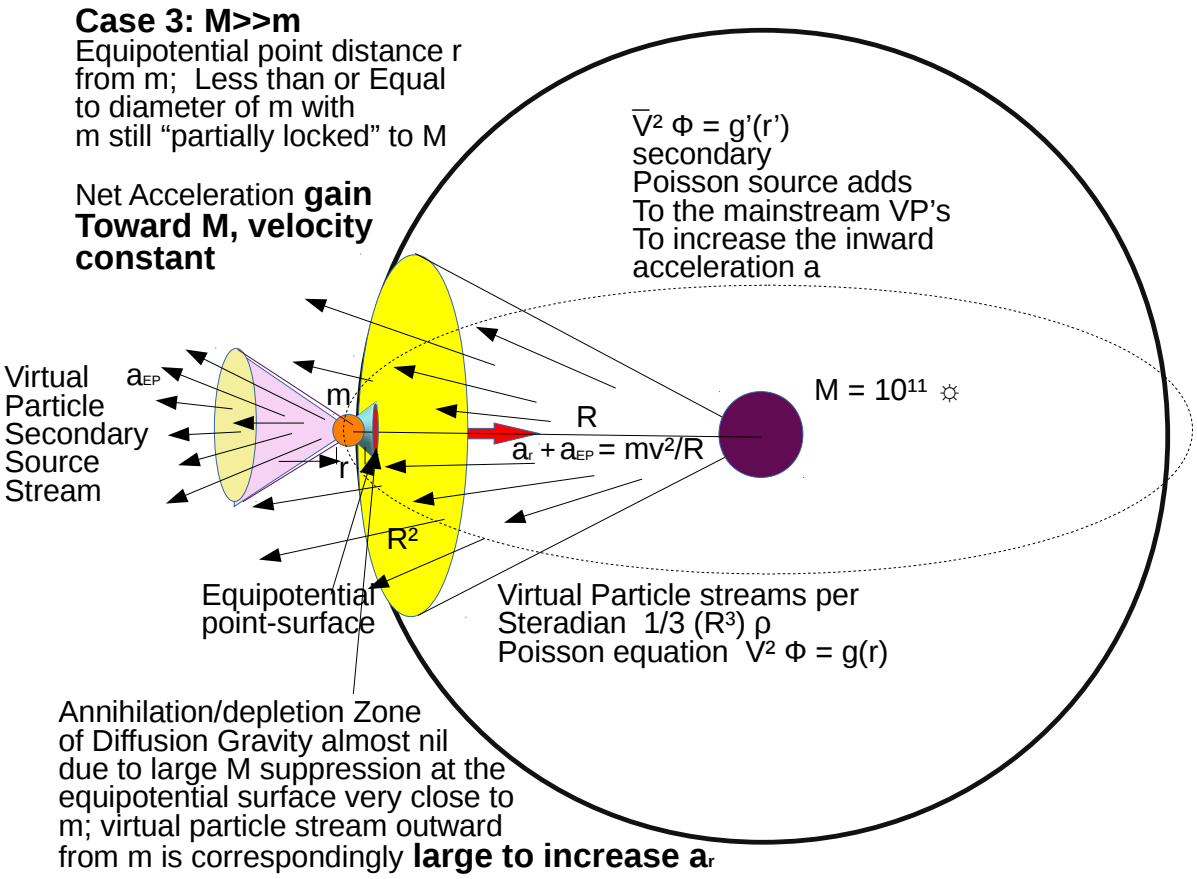

Figure 5: EP-Locked Star with Diffusion Gravity

This DG concept has provided the Poisson equation of gravity that reflects the microscopic *annihilation-creation* and VP stream flow mechanism of virtual particle pairs in the convergence of opposing radial streams from masses (sources) in the steradial geometry; this will be reviewed and summarized in Section 3. The next segment shows the calculations for the MWG and the Sun and relates the enormous potential ratio to the orbital scales of stars beyond the a_0 radius.

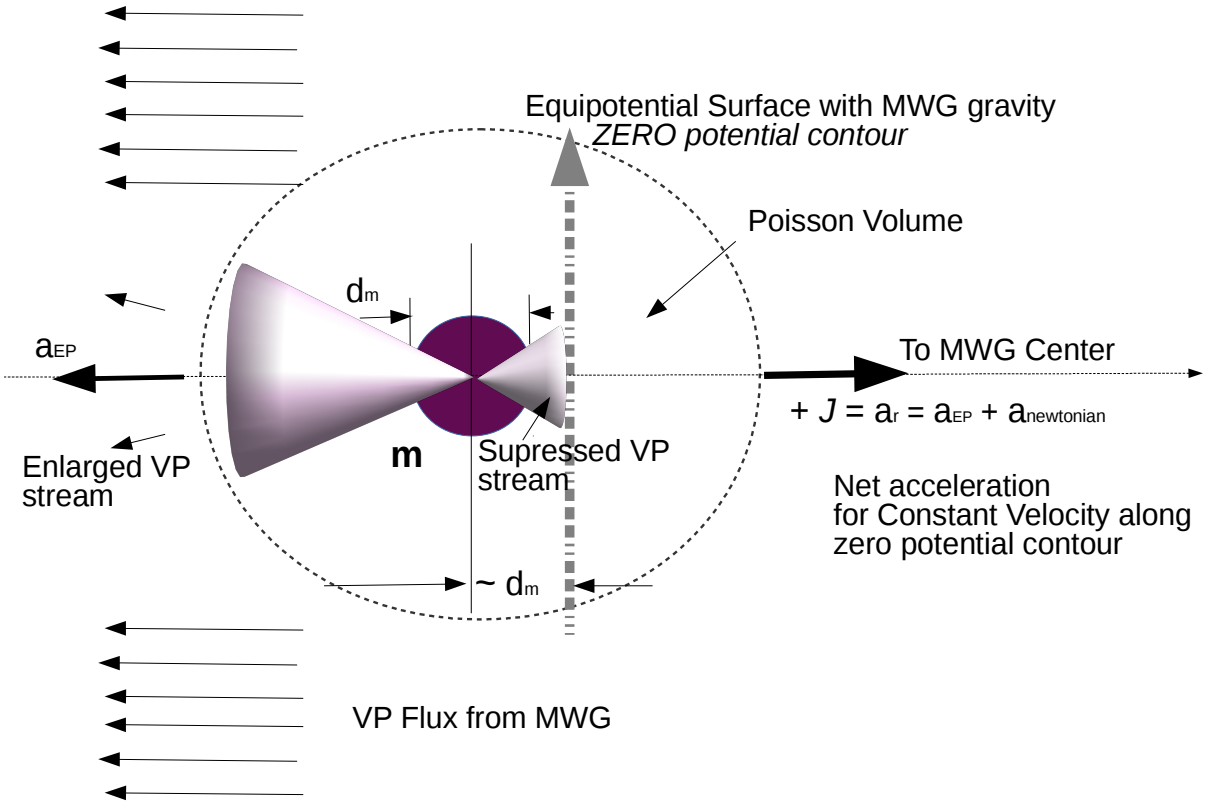

Figure 5a: Detailed schematic of EP-locked mechanism for DG model

Example Calculations for Milk Way Galaxy Diffusion Gravity

The long distance effects (i.e., flattened velocity curves) that have been described by Rubin, et al. [12,13] provide strong clues that gravity may show its diffusion origin more clearly at large scale range and mass ratios. In the simple equation for a equipotential *point-surface* (where gravitational potential is equal) between masses, the distance is directly related to the relative masses by the equation for potential:

$$\Phi = GM/R = Gm/r \qquad (6)$$

therefore,

$$M/m = R/r \approx 10^{11} \quad \text{“potential ratio”} \qquad (7)$$

The simple ratio shows that for very large mass (i.e., the galaxy) of ~10^{11} solar mass, the *r* distance (potential balance point) from a galactic orbiting star will be

$$r = \frac{R}{r} = \frac{10^{20}}{10^{11}} \approx 10^{9} \quad \text{meters from the } \textit{orbiting} \text{ star} \qquad (8)$$

Where R is 10^{20} meters (10^4 light years) [6], the approximate distance of the Sun from the Milky Way center. The "*r*" value of one million kilometers (10^9 meters) is the approximate diameter of the sun (~1.5 x 10^9 m.). DG proposes that beyond the a_0 radius, any star of one solar mass orbiting the MWG center at approximately one solar diameter away from its gravitational equilibrium point-surface, but not co*incident* with it, will induce an additional centripetal acceleration in accordance with the Principle of Least Action. This is a direct result of the enormous difference (ratio) between the mass of the galaxy and the mass of a star (MWG mass estimate $1 \rightarrow 4$ x 10^{11} [28]). Please see Figure 6 for a view of relative size and distance for galaxies, and of *R* and *r*, in the context of diffusion gravity. The a_0 threshold point defines the limit of the "locking" state for the galaxy, since within that radius, the star is captive to the galactic gravity, and so it revolves around the center of the galaxy integral with the disk of the galaxy. The Sun, however, lies beyond that gravitational locking point of the MWG, so it is in contrast "EP-locked" and demonstrates the behavior of constant velocity rotation curve as shown in McGaugh[29]. This DG model concept is relative to and dependent upon the equipotential surface that forms between the Sun and the Milk Way Galaxy center as a consequence of the large mass and distance ratios.

Note on Sensitivity of DG Model to Estimates for MWG

Calculations will show that the distance and mass relations, and the equipotential surface distance to the orbiting star increases over the observed constant velocity curves for galaxies to an *R* distance of 100K light years. For that *R* of 1 x 10^{21}, and assuming a galactic mass estimate of 4 x 10^{11} solar masses (*M* for the model is taken as 4 x 10^{11} solar masses from S. Odenwald and NASA [27] for stars and gas, no dark matter), the calculated *r* distance to the equipotential point would increase to less than two solar diameters (1.5 x 10^9), or 2.5 x 10^9 meters. Galactic mass *M* compares to other estimates generated by P.J. McMillan [26], of 0.6 x 10^{11} and McGaugh [29] at .616 x 10^{11} solar masses; there continues to be uncertainty in the estimates of the mass of the MWG for measured matter excluding dark matter. The Diffusion Gravity model assumes the attraction mechanism will be effective even at equipotential distances that are multiples of the solar diameter to ensure EP-locking out to large distances.

The attractive force of gravity at large scale of the galaxies with regard to the orbit at radius r where centripetal acceleration drops below a_0, i.e., $\mathbf{a_0} < \mathbf{a_r}$ for spiral galaxies has been exhaustively studied by Milgrom [8], McGaugh [9,10], Rubin [12,13], Zwicky [16], and others, concerning the apparent mystery as to why the orbit profiles of stars beyond the $\mathbf{a_0}$ point level-off in velocity, or in some cases even increase in velocity. The key factor that emerges beyond the a_0 radius is reflected by the Poisson equation for the volume that includes the orbiting star and the equipotential point-surface of that star with the MWG mass. Mannheim [4,5,6] explored this idea in his 2005 paper on alternatives to dark matter, with the fourth-order and sixth order Poisson equation, as an attempt to obtain the approximate 1/r observed acceleration profiles, and others such as Kellogg have discussed this as higher order power series in his text on potential theory [14]. Mannheim has even developed this idea to support his conformal theory of gravity as coefficients of 1/r terms that appear in the fourth-order Poisson equation.

However, the DG model applies the normal second order Poisson equation, with the geometry of the steradian volumes showing how an amplification can create a secondary (local) potential that increases the centripetal acceleration. The stronger acceleration thus generated by the mechanism of DG in a *secondary* Poisson equation and steradian geometry extends the attraction mechanism for Diffusion Gravity at this galactic scale to suggest an alternative explanation to the "dark matter" conundrum, wherein more mass is required to explain the constant velocities observed. (dark matter has never been proven to exist). The model indicates that when the distance of the equipotential point surface to *m*,

shown as *r*, becomes larger than approximately a solar diameter, the equipotential point-surface moves sufficiently far to be outside of the star mass itself (size diameter of the orbiting star ~1 solar diameter or 1.5 x 10^9 meters), and therefore is NOT gravitationally "locked" to the central mass of the MWG. This shows that the R distance and R/r ratio governs the equipotential surface-point, and therefore the *Diffusion Gravity* at galactic scale distances (~10^{20} meters). This artifact is further presented, as *observational evidence* for diffusion gravity, by the *proximity* of equipotential point-surfaces at or very near to their respective orbiting stars, where DG Depletion Zones are small and the orbiting star is "EP-locked" to the central MWG mass. The geometry of steradians helps to visualize volumetric DG depletion and annihilation zones between masses, and how a 10^{11} potential ratio can drive the model at very large scale.

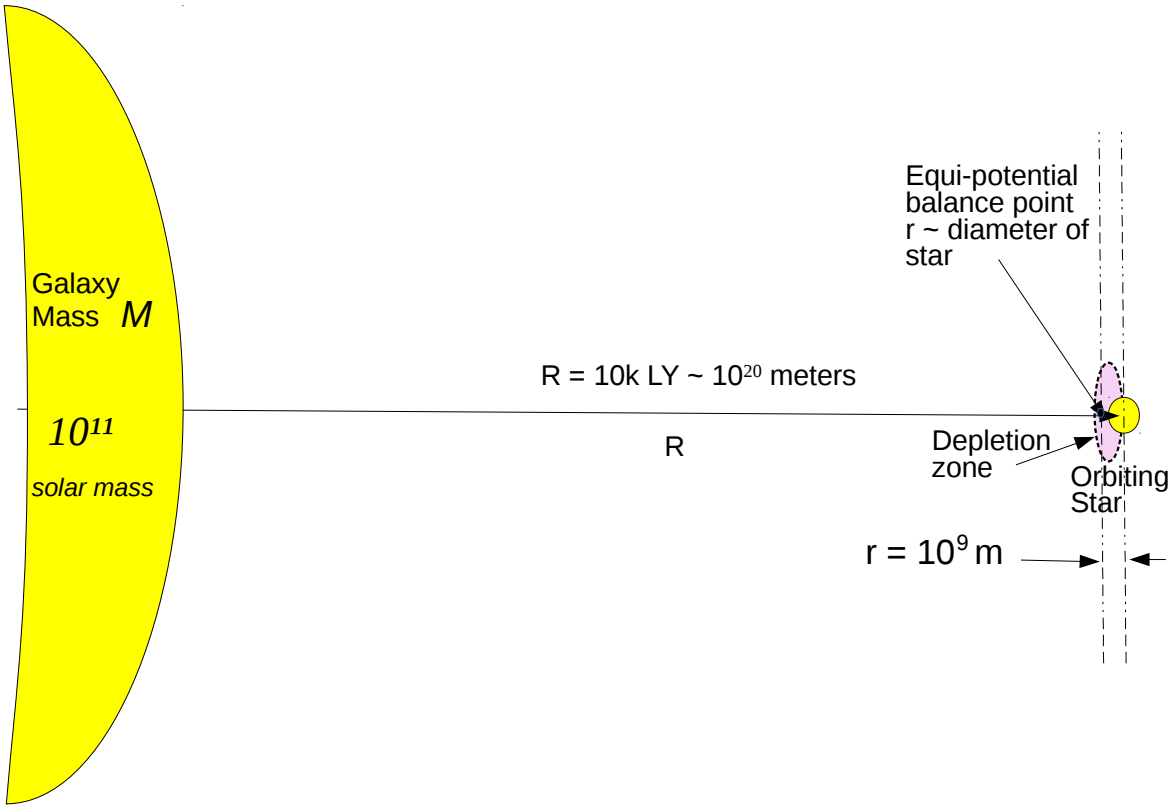

Figure 6: The Scale Difference of Galactic Mass and Distance affects Depletion Zone for DG

The MOND empirical paradigm has been observationally solidified with extensive data and analysis as an empirical relation between the observed behaviors and a corresponding mathematical fit with "function" modifiers for Newtonian equations; Diffusion Gravity has offered a possible causal mechanism and is compatible with the work and research of MOND.

To review, the Diffusion Gravity model describes the attraction mechanism caused by annihilation of virtual particle streams between mass objects, which manifests as a flux into or from a Poisson volume

at the confluence or equipotential point-surface of the streams. This concept was illustrated in the previous work presented [3] that shows the net flux result of the Poisson summation as

$$\pm J = \nabla^2 \phi \qquad (9)$$

where $J = \nabla \bullet \nabla \phi$, and a = $\nabla \phi$, representing the virtual particle stream behaviors, resulting in acceleration from the potentials; therefore *J* can represent either a net sink of depletion-annihilation in the volume around the equilibrium point (negative), or a net source that results in increased acceleration (positive). The driving force for the constant velocity is both the diffusion gravity attraction mechanism, and the Principle of Least Action. Implicit in the the overall model is the ambient quantum vacuum level, to which the net inflow or outflow from the Poisson sample volume is referenced.

Section 3 Diffusion Gravity Distance Quantum Mechanism Effects

The underlying quantum mechanism of diffusion gravity was presented in [3] to provide the theoretical underpinnings for gravity based upon known microscopic diffusion phenomena such as brownian motion and probablistic virtual particle propagation. The quantum vacuum virtual particle equation for depletion-annihilation zones that resulted in the attraction mechanism were shown as a negative flux (sink):

$$\sum a_i^{\dagger} a_i = K \left\{ \int J_{FM}\, dV + \int J_{RM}\, dV \right\} = - J_a \qquad (10)$$

Where $a_i^{\dagger}$ and a_i are the creation and annihilation operators from quantum mechanics, *K* is a diffusion constant (for Diffusion Gravity) and *J* is the net virtual particle flow representing net or resultant acceleration after annihilation. The net flux from annihilation can then be generalized to the Poisson equation for diffusion gravity thus:

$$\pm J_a = \nabla^2 \phi \qquad (11)$$

At galactic scales the Poisson equation was shown in Section 2 to have a positive value for a Poisson *source* resulting from a virtual particle flow outward, which in turn generated an increased acceleration toward the MWG. We showed that the macroscopic gravitation can be derived from the quantum mechanisms, and how this can have specific applicability to the constant velocity of rotation curves beyond the a_0 radius for orbiting stars in a galaxy.

In conjunction with the overall updated DG model, it was also proposed that within the a_0 radius, stars are locked into a disk configuration where the Laplace equation will apply:

$$\nabla^2 \phi = 0 \qquad (12)$$

This equation shows that there is neither sink nor source in the volume within the a_0 radius. Virtual particle creation and annihilation will exactly balance among virtual particle streams from the orbiting star masses within this radius, thus holding them *locked* into the galactic disk configuration.

$$\nabla^2 \phi = \frac{\partial^2}{\partial R^2} \phi_R + \frac{\partial^2}{\partial r^2} \phi_r = 0 \qquad (13)$$

where r is the distance from the star to the equipotential point-surface, *R* is the distance from the center of the galaxy to the equipotential point-surface. At the coincidence of the small mass *m* with the equipotential point-surface, the Laplace equation defines the summation of gravitational potentials, i.e.,

the virtual particle flows where the *r* term vanishes. This does not preclude the Kepler law for $a_r=mv^2/r$ from being valid.

This section has shown and restated the previous research for quantum level diffusion that provides a mechanism for quantum vacuum creation-annihilation via quantum mechanics operators (e.g., Miller [31]. In these aspects, the DG Model depends upon the quantum vacuum and virtual particles behaviors from these well-established quantum mechanics and quantum electrodynamics.

Summary of Diffusion Gravity Large Scale Effects

There are three major evidences offered in this paper for the DG model at galactic scales.

(1) The distance and mass ratios for the gravitational *equipotential point-surfaces* of galactic orbiting stars were shown to be related to the a_0 radius of the galaxy, within which the DG gravitation is described as "locking" of an orbiting star *m* to the galaxy core mass *M*, due to coincidence of the equipotential point-surface with the orbiting star mass *m*.

(2) the equipotential point-surfaces between the MWG and the orbiting star beyond the a_0 radius are in close proximity, but not coincident with the star, resulting in an increased potential difference gradient from that equipotential point-surface to the outside steradial volume of the orbiting star (Case 3) thereby producing a net acceleration inward toward the MWG. This is proposed as the *source of the added acceleration* to explain the constant velocity curves of the orbiting stars outside the a_0 radius.

(3) the equipotential point-surface between the MWG and the orbiting star forms a *contour of zero potential* near (within ~ a star's diameter distance d_m) the orbit of the star. The zero potential contour is a minimum energy state, where, according to the **Principle of Least Action**, that star's orbit is forced to maintain a constant velocity. Diffusion gravity proposes a mechanism (of attraction) to enable and ensure the Principle of Least Action.

The three mechanisms described combine to provide a near constant velocity rotation curve for the galaxy, or even a slightly rising curve (increasing velocity) where the equipotential point-surface may lie close enough to the orbiting stars to create an excess orbital velocity. The principles of Diffusion Gravity therefore can provide the mechanism that works at smaller scale as well as the galactic scale. The active quantum vacuum creation-annihilation of virtual particle streams at galactic scale, the Poisson equation macroscopic sources and sinks as caused by quantum mechanisms, and the overall mass diffusion prime mover comprise the operative DG model as described in this paper.

Conclusion and Further Research

The results from this research improve and substantiate the Diffusion Gravity model.

Application of fundamental physics principles of field theory, quantum virtual particle streams, Newtonian-Kepler mechanics, and the Principle of Least Action combine to account for the constant velocity observed in star orbits beyond the a_0 radius of approximately 8K light years. The Large Scale extensions of the Diffusion Gravity model include the equipotential surfaces, the potential ratio of 10^{11}, and the Principle of Least Action as major determinants at the great distances of the Milky Way Galaxy ($\sim 10^{20}$ meters). Further research and analysis will examine galactic rotation curves and the equipotential point-surfaces for the orbiting stars as further proof of the relations stated in this work. The equipotential point-surface for the Sun and the center of the galaxy strongly suggests that a local observation or measurement of the Sun's equipotential point-surface can be achieved at approximately 1000 kilometers (10^9 meters) from the Sun towards the center of the MWG, on the galactic plane. Such a measurement might determine the distance of the equipotential point-surface to the center of the galaxy and verify its distance from the Sun, to confirm further the ratio of 10^{11} as postulated by diffusion gravity, and to further determine the mass of the galaxy within our Sun's radial distance to the center of the galaxy.

Further investigation using these principles and the zero potential contour between the MWG center and our Sun may also suggest an alternative cause for the solar system planetary perihelion precession anomalies, or even the extra deflection of light near the Sun, which has heretofore been ascribed to space curvature in General Relativity (GR). These questions and others will be addressed to determine if the galactic gravitational influence has a greater effect than has been historically assumed. The implications for this different point of view of gravity may have profound effects on standing theories and cosmology more generally. There is also the role of Mass to Light ratios that have been extensively studied, and should be reconciled with the observed constant velocity curves of the galaxies. This research from this project can help investigate gravity further and deeper than was originally planned; so there will be subsequent additional papers to report the findings of this project, including the effects of DG on light and redshift, as well as the above mentioned GR questions. The primary goal of the DG project remains: the deeper understanding and explanation for gravity.

References

1. Fulton, DH. *Diffusion Gravity: An Heuristic Model*. ResearchGate, March 2019.
2. Fulton, DH. *Diffusion Gravity Dynamics*. ResearchGate, April 2019.
3. Fulton, DH. *Diffusion Gravity Attraction Mechanism*. ResearchGate, September 2019.
4. Mannheim, Phillip D., *Alternatives to Dark Matter and Dark Energy*. August 2005. arxiv.org/abs/astro-ph/0505266v2
5. Mannheim, Phillip D. *Is dark matter fact or fantasy? – clues from the data.* May 2019. arXiv:1903.11217v2
6. Obrien, Mannheim, et al., *Radial Acceleration and Tully-Fisher Relations in Conformal Gravity.* December 2018. arxiv.org/abs/1812.03152v3
7. Britten, Roy. *A gravitational diffusion model without dark matter. 1997.* PNAS doi: 10.1073/pnas.95.7.3351
8. Milgrom, Mordehai. *The MOND Paradigm.* March 2008. arxiv.org/0801.3133v2
9. McGaugh, Lelli, Schombert, *The Radial Acceleration Relation in Rotationally Supported Galaxies*. September 2016. arXiv:1609.05917v1.
10. McGaugh, S. Lelli, Schombert, Pawlowski., One Law to Rule Them All; The Radial Acceleration Relation of Galaxies. January 2017. arxiv.org/1610.08981.
12. Rubin, V. , Ford, Jr., W. Kent . *Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions. The Astrophysical Journal.* ***159****: 379ff. Bibcode:1970ApJ...159..379R. Doi:10.1086/150317.*
13. Rubin, V., Thonnard, N., Ford, W. K., Jr., Roberts, M. S. *Motion of the Galaxy and the Local Group determined from the velocity anisotropy of distant Sc I galaxies. II. The analysis for the motion. Astronomical Journal, Vol. 81, p. 719-737 (1976).*
14. Zwicky, F. wikipedia.org/wiki/Fritz_Zwicky#cite_note-19.
15. Electromagnetics, Kraus and Carver, McGraw Hill, 1973 Second Edition.
16. Foundations of Potential Theory, Kellogg, OD. Dover 1959
17. Spherical Astronomy, Woolard and Clemence. Academic Press, 1966.
18. The Structured Vacuum, Rafelski, Johann. H. Deutsch Publishers, 1985.
19. Galactic Dynamics, Binney, J. and Tremaine, S. Princeton University, 1987.
20. Creation and annihilation operators for reaction-diffusion equations. wikipedia.org/wiki/Creation_and_annihilation_operators. 2019.
21. Forsyth, A.R. Calculus of Variations. Dover Publications, 1960.
22. Principle of Least Action. wikipedia.org/wiki/Principle_of_least_action,
23. Galaxy Rotation Curve. wikipedia.org/wiki/Galaxy_rotation_curve.
24. Gravity equipotential surface. In: Dictionary Geotechnical Engineering/Wörterbuch GeoTechnik. Springer, Berlin, Heidelberg. 2014.
25. Theoretical Physics. Page, Leigh. Van Nostrand 1935. (section on Principle of Least Action).
26. McMillan, P.J. *Mass Models of the Milky Way.* February 2011. arxiv.org/1608.00971.
27. Milk Way Galaxy. wikipedia.org/wiki/Milky Way Galaxy.
28. Odenwald, S. Counting the Stars in the Milky Way. December 2017. www.huffpost.com/entry/number-of-stars-in-the-milky-way_b_4976030
29. McGaugh, S. *A Precise Milky Way Rotation Curve Model for an Accurate Galactocentric Distance*. August 2018. arxiv.org/abs/1808.09435.
30. McGaugh, S. *Milky Way Mass Models and MOND*. April 2008. arxiv.org/abs/0804.1314
31. Quantum Mechanics for Scientists and Engineers. Miller, D. 2008.