the general science journal

A Constructive Model of Gravitation

Raghubansh P. Singh
raghu.singh@verizon.net

Abstract

This paper proposes a physical model in which gravitational interaction between masses is mediated by their mass-momentum fields. A mass in the mass-momentum field of another mass experiences two gravitational forces: repulsion due to their separation and attraction due to their motions in the universe. The paper then formulates gravitational interaction between matter and matter and between matter and energy quanta, calculates gravity's effect on spectral lines and clock time periods, and estimates the speed of gravitational wave.

1. Introduction

In General Relativity[1] gravitation is due to the curvature which matter creates in the field of space-time geometry. The curved space-time is the gravitational field, which, as energy quanta, would be the so-called gravitons. Astronomic collisions and interactions among celestial bodies notwithstanding, so far there is no evidence of such gravitons (particles) or disturbances (waves) in the field of space-time geometry.

The physicist's unshakable faith in the underlying simplicity of nature is leading the quest for a unified theory of the fundamental forces. The electroweak theory unifies the weak and electromagnetic forces. The strong force could be next; however, gravitational force defies being unified with the rest.

E. A. Milne holds that geometry can be selected primarily by the nature of underlying phenomenon and the convenience of representing and analyzing that phenomenon; and transformations of coordinates alone are but translations of language and have not necessarily much to do with phenomena. How matter warps (or creates) space is left unexplained.[2]

Space and time neither act nor are acted upon in the strong, the weak, and electromagnetic interactions. Those three fundamental interactions are mediated by respective fields (bosons), which are inherently 'attached' to their interacting matter. So, it would be natural to have gravitational interaction be mediated similarly by gravitationally pertinent fields of interacting matter – without coordinates and observers being a part of the law of gravitation (nature).

Gravitational interaction here will be reformulated as mentioned above at the macroscopic level in the non-relativistic framework. At the macroscopic level, fields are effectively continuous. (Continuous means a value at each space-time point.) Microscopic forces and quantum mechanics will be ignored.

2. Assumptions:

We will base the model on two assumptions:

(a) Matter has an envelope of intrinsic *mass field*.

(b) Motion creates an envelope of *momentum field.*

Mass is a property of matter. The range of mass field is infinity. (The origin of matter or mass is not pertinent here.)

Momentum is a property of mass-in-motion. Momentum field is effective within a *momentum field range*, which varies with the momentum.

3. Characteristics of mass, charge, and the fields

From mechanics, electrodynamics, and the Assumptions, Table I lists the pertinent characteristics of charge, mass, and the fields. Entries in row 2, columns 5-10 are deduced; k_1, k_2, k_3, and k_4 are constants; and $\vec{r}$ extends from the axis of moment of momentum or current to the mass or charge.

Table I. Characteristics of charge, mass, and fields

Charge (Electric charge)	Mass (Gravitational charge)
Charge: e	Mass: m
Current: $\vec{i} = e\vec{u}$	Momentum: $\vec{p} = m\vec{u}$
Moment of current (Angular current): $\vec{L}_e = \vec{r} \times \vec{i}$	Moment of momentum (Angular momentum): $\vec{L}_m = \vec{r} \times \vec{p}$
Charge (electric) field: $k_1 e\, \vec{r} / r^3$	Mass field: $k_3 m\, \vec{r} / r^3$
Current (magnetic) field: $k_2 \vec{L}_e / r^3$	Momentum field: $k_4 \vec{L}_m / r^3$
Repulsive force between charges due to separation: $k_1 e_1 e_2 \vec{r} / r^3$	Repulsive force between masses due to separation: $k_3 m_1 m_2 \vec{r} / r^3$
Attractive force between charges due to parallel motions: $k_2 i_1 i_2 \vec{r} / r^3$	Attractive force between masses due to parallel motions: $k_4 p_1 p_2 \vec{r} / r^3$
Speed of electromagnetic wave: $c = \sqrt{(k_1/k_2)}$	Speed of gravitational wave: $b = \sqrt{(k_3/k_4)}$
Force between charges due to separation and parallel motions: $k_1 (1 - u_1 u_2 / c^2) e_1 e_2 \vec{r} / r^3$	Force between masses due to separation and parallel motions: $k_3 (1 - u_1 u_2 / b^2) m_1 m_2 \vec{r} / r^3$

4. The gravitational model

Figure 1, sector I, shows masses m_1 and m_2 at r_1 and r_2 from the Primordial Point P (at the Big Bang). The angle between r_1 and r_2 at P is α. Figure 2 shows the masses with separation distance r, velocity vectors u_1 and u_2 relative to P, and mass fields (light shades) and momentum fields (dark shades). The ranges of the momentum fields are S_1 and S_2.

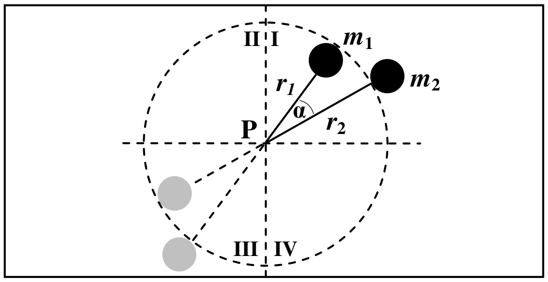

Figure 1. Masses m_1 and m_2 at r_1 and r_2 from P

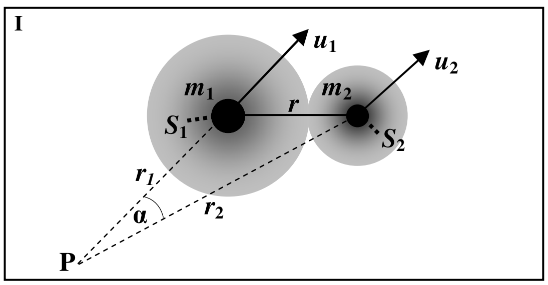

Figure 2. Masses with mass and momentum fields

We define for a mass m its effective momentum field range S_m, which is proportional to its momentum:

$$S_m = \sigma\, m\, u\ , \tag{1}$$

where σ is *momentum field range coefficient*, a fundamental constant. A 1 kg mass with a speed of 1 m/s has an effective momentum field range of σ m.

The inter-momentum field range between m_1 and m_2 is:

$$S_{12} = S_1 + S_2 \tag{2}$$

From (1) and (2), we have:

$$S_i = S_{ij}\, m_i \,/\, (m_i + m_j)\ ; \quad i \neq j \tag{3}$$

From Assumption (a) and Table I, the *repulsive* force between m_1 and m_2, due to their separation in space, is mediated by their mass fields and is expressed in (4):

$$F_s = G_s \frac{m_1 m_2}{r^2}\ , \tag{4}$$

where G_s is the *static gravitational constant*.

From Assumption (b) and Table I, the *attractive* force on m_1 by m_2, due to their momenta p_1 and p_2 relative to the Primordial Point, is mediated by their momentum fields and is expressed in (5). Here $\vec{r}$ extends from m_1 to m_2.

$$\vec{F}_d = G_d \frac{\vec{p}_1 \times (\vec{r} \times \vec{p}_2)}{r^3}\ , \tag{5}$$

where G_d is the *dynamic gravitational constant*.

We will estimate momentum field range coefficient later to be quite small ($\approx 10^{-24}$ s/kg). The age of the universe is close to 14 BY. So, at $r_1 \to \infty$, $r_2 \to \infty$, and $r \leq S_{12}$, $\alpha \approx 0$. From (5), the attractive force is expressed in (6):

$$F_d = G_d \frac{p_1 p_2}{r^2} \tag{6}$$

The dimension of G_s/G_d is of the square of speed. Denoting this speed by b, which would be the speed of mass-momentum (gravitational) wave, we have:

$$\left| G_s / G_d \right| = b^2 \tag{7}$$

Within $r \leq S_{12}$ momentum fields are effective. From (6), the force between m_1 and m_2 is attractive and given in (8). We will set $u_1 u_2 = u^2$ as needed for simplicity.

$$F_{12} = G_d\, u^2 \frac{m_1 m_2}{r^2}; \quad r \leq S_{12} \tag{8}$$

Beyond $r > S_{12}$ mass fields are predominant. From (4), (6), and (7), the resultant force between m_1 and m_2 is expressed in (9), whose sign depends on u/b:

$$F_{12} = G_s \left(1 - \frac{u^2}{b^2}\right) \frac{m_1 m_2}{r^2}; \quad r > S_{12} \tag{9}$$

Eqs. (8) and (9) are of the form of Newton's Law of gravitation. In (8), as $r \leq S_{12}$, the Cavendish experiment yields a value for $G_d\, u^2 \equiv G$, the classical gravitational constant, which now varies with u^2. Both G and $G_s (1 - u^2/b^2)$ depend on u; however, on the human-time scale, as u is constant, they are constant.

Table II has the signs of gravitational interaction, which is attractive in inner regions ($r \leq S_{12}$) regardless of the value of u, and repulsive, attractive, or zero in outer regions ($r > S_{12}$) depending on u/b.

Table II. Interaction signs with respect to b and S_{12}

	$r \leq S_{12}$	$r > S_{12}$
$u < b$	*attraction*	*repulsion*
$u = b$	*attraction*	*zero*
$u > b$	*attraction*	*attraction*

5. Mass-energy gravitational interaction

An energy quantum (E, c) is at distance r from a mass (m, u). The energy quantum has no mass field but has momentum field by its momentum $p = E/c$. The attractive force on the quantum is due to the interaction between the momentum fields, and, from (6), is given in (10):

$$F_{me} = \kappa \frac{m\, E}{r^2}; \quad r = r\ , \tag{10}$$

where κ is mass-energy gravitational constant:

$$\kappa = G_d\, u / c = G / (uc) \tag{11}$$

Eq. (10) holds as well for the gravitational interaction between a mass and a photon.

The angle of gravitational deflection θ of electromagnetic wave with impact parameter d is expressed in (12):

$$\theta = 2\tan^{-1}\left(\kappa \frac{m}{d}\right) \tag{12}$$

To escape a mass m of radius R, an electromagnetic wave must be outside a critical radius R_e:

$$2\tan^{-1}\left(\kappa \frac{m}{R_e}\right) - \cos^{-1}\left(\frac{R}{R_e}\right) = 0 \tag{13}$$

The radius R_e for $\theta = 90^0$ is given by:

$$R_e = \kappa\, m \tag{14}$$

We note that, at $u \approx c/2$, θ in (12) and R_e in (14) agree with General Relativity.

6. Physical data

The following data are pertinent here:

(a) Speed of light (c): 3.0×10^8 m/s;
(b) Deflection of light at the sun (θ): 2.2 arc secs [3];
(c) $G_d\, u^2 \equiv G$ (present-day): 6.672×10^{-11} N kg^{-2} m^2;
(d) Sun's mass: 1.989×10^{30} kg;
(e) Sun's radius: 6.963×10^8 m;
(f) Earth's mass: 5.976×10^{24} kg;
(g) Earth's radius: 6.378×10^6 m;
(h) Mercury's mass: 3.332×10^{23} kg;
(i) Mercury's sidereal period: 87.969 days;
(j) Mercury's perihelion precession: 575 arc secs/century;
(k) Farthest Kuiper-belt body from the sun: ~ 10^3 AU;
(l) Diameter of the Milky Way galaxy: ~ 10^5 l.y.

It is not clear whether the observed deflections of light at the sun were corrected for refraction and other effects through the sun's and the earth's atmospheres.[4]

We will estimate u and b for lack of observations.

6.1 Estimates of G_d, u, and κ

With reference to the sun, Eq. (12) and data 6(a-e) yield:

$$u = 1.191 \times 10^8 \text{ m/s} \tag{15}$$

$$G_d = 4.704 \times 10^{-27} \text{ N kg}^{-2}\text{ s}^2 \tag{16}$$

$$\kappa = 1.867 \times 10^{-27} \text{ N kg}^{-2}\text{ s}^2 \tag{17}$$

6.2 Estimate of σ

For lack of observations, datum 6(l) would be considered as the sun's approximate momentum field range. From (1), (3), (15), and data 6(d, k), we have:

$$S_{sun} = 1.5 \times 10^{14} \text{ m} \tag{18}$$

$$\sigma = 6.3 \times 10^{-25} \text{ s/kg} \tag{19}$$

A 1 kg mass with a speed of 1 m/s has an effective momentum field range of the order 10^{-24} m.

From (1), (3), (14), (15), (19), and datum 6(l), the Black Hole at the center of the Milky Way galaxy has a mass of about 6.3×10^{36} kg and a escape radius of about 1.2×10^{10} m for electromagnetic waves.

6.3 Estimates of G_s and b

We estimate the magnitude of G_s and the speed of gravitational wave (b) based on Ref. [5] and data 6(h-j).

Planet Mercury is under two sets of gravitational forces: one due the sun and the other due to the outer planets. Eq. (8) is applicable to the former, Eq. (9) to the latter.

Price and Rush[5] derive Mercury's apsidal angle ψ to be:

$$\psi = \pi\left(1 - F_p / F_s - f / F_s\right), \tag{20}$$

where force F_s (by the sun), force F_p (by planets Venus through Saturn), and force f (radial oscillations) are:

$$F_s = -1.318 \times 10^{22} \text{ N}; \tag{21}$$

$$F_p = 108.6715\, \pi\, \Gamma\, m \text{ N}; \tag{22}$$

$$f = 77.92565\, \pi\, \Gamma\, m \text{ N}; \tag{23}$$

where m is Mercury's mass, and instead of G we considered Γ in F_p and f in above:

$$\Gamma \equiv G_s\,(1 - u^2/b^2) \tag{24}$$

The precession rate of Mercury's perihelion is 575 arc secs/century (6.7186×10^{-6} rad/sidereal period). So,

$$2\,\psi - 2\,\pi = 6.7186 \times 10^{-6} \text{ rad} \tag{25}$$

Carrying out the calculations with (20) - (25), we get:

$$\Gamma = 7.241 \times 10^{-11} \text{ N kg}^{-2}\text{ m}^2 \tag{26}$$

$$G_s = 1.388 \times 10^{-10} \text{ N kg}^{-2}\text{ m}^2 \tag{27}$$

$$G_s/G_d = 2.95 \times 10^{16} \text{ m}^2\text{ s}^{-2} \tag{28}$$

$$b = 1.72 \times 10^8 \text{ m/s} \tag{29}$$

$$u/b = 0.692 \text{ (present-day)} \tag{30}$$

$$b/c = 0.574 \tag{31}$$

The speed of gravitational wave would be approximately 57.4% of the speed of light.

7. Vibrating particle in gravitational field

We derive the change in frequency v of vibration of a particle as its position relative to a mass m changes. The mass, a perfect sphere of radius R and density ρ, is at $r = 0$. The momentum of the particle is given by $p = E/c$, and its energy E is proportional to v. The attractive force F between the mass and the particle is mediated by their momentum fields and given by (10).

7.1 Vibrating particle outside the mass

As the particle is moved from $r = r \geq R$ to $r = \infty$, the change in its energy is given by:

$$E_\infty - E_r = -\int_r^\infty \vec{F} \cdot d\vec{r} = \int_r^\infty \kappa \frac{m\,E}{r^2}\, dr \tag{32}$$

Carrying out the integration, we have:

$$\nu_\infty = \left(1 + \kappa \frac{m}{r} \right) \nu_r \qquad (33)$$

The expression in the bracket > 1, thus $\nu_r < \nu_\infty$. The particle vibrates at lower frequency closer to the mass.

If the frequency is that of emitted light, its wavelengths, with reference to the sun ($r = R_{sun}$), from (33), (17), and data 6(d, e), are given by:

$$\lambda_R = (1 + 5.33 \times 10^{-6})\, \lambda_\infty \qquad (34)$$

Spectral lines produced on the sun's surface are redshifted by about 5.33×10^{-6} of their wavelengths corresponding to those produced at infinity.

If the vibrating particle serves as an atomic clock, its time periods, with reference to the earth ($r = R_{earth}$), from (33), (17), and data 6(f, g), are given by:

$$\tau_R = (1 + 1.75 \times 10^{-9})\, \tau_\infty \qquad (35)$$

A 1.0 second period at infinity is dilated to 1.0000000018 seconds at the earth.

7.2 Vibrating particle inside the mass

As the particle is moved from $r = 0$ to $r = r \le R$, the change in its energy is given by:

$$E_r - E_0 = -\int_0^r \vec{F} \cdot d\vec{r} = \int_0^r \kappa \frac{m_r\, E}{r^2}\, dr\,, \qquad (36)$$

where $m_r\,(4/3\, \pi \rho\, r^3)$ is the mass within $r = r \le R$. Carrying out the integration, we have:

$$\nu_0 = \left(1 - \kappa \frac{m_r}{2\,r} \right) \nu_r \qquad (37)$$

The expression in the bracket < 1 but > 0, thus $\nu_0 < \nu_r$. The particle vibrates at lower frequency closer to the center.

With reference to the sun ($r = R_{sun}$), electromagnetic wavelengths, from (37), (17), and data 6(d, e), are given by:

$$\lambda_R = (1 - 2.67 \times 10^{-6})\, \lambda_0 \qquad (38)$$

Spectral lines produced at the sun's center are redshifted by about 2.67×10^{-6} of their wavelengths corresponding to those produced at its surface.

With reference to the earth ($r = R_{earth}$), time periods, from (37), (17), and data 6(f, g), are given by:

$$\tau_R = (1 - 8.78 \times 10^{-10})\, \tau_0 \qquad (39)$$

A 1.0 second period at the surface is dilated to 1.00000000088 seconds at the center.

7.3 Vibrating particle near a point-dense mass

An infinitely high point-dense mass may be indicated by $m \to \infty$ as $R \to 0$, or $m/R \to \infty$.

From (33), as $m/R \to \infty$, $\tau_R/\tau_\infty \to \infty$. Time period near the surface tends to infinity; time exists but virtually stops.

From (33), as $m/R \to \infty$, the wavelength of light near the surface tends to infinity ($\lambda \to \infty$, $\nu \to 0$, $\nu\,\lambda = c$). Light virtually ceases to exist in waveform but still propagates.

From (12), as $m/d \to \infty$, $\theta \to 180^0$. Light passing near the mass might go around it and return toward its source.

An example of a mass of infinitely high point-density is a black hole.

7.4 Vibrating particle and no mass

A no-mass may be indicated by $m \to 0$ as $R \to 0$. From (33), as $m/R \to 0/0$, $\tau_R/\tau_\infty \to 0/0$. Time is indeterminate in the absence of mass.

7.5 Fundamental interactions and time

Outside a mass, the run of time is slower as the intensity of gravitational field increases. Inside a mass, time runs slower as the intensity of gravitational field decreases.

The run of time in other fundamental fields is not known.

8. Photon falling in the gravitational field of a mass

We calculate the change in the energy of a photon (E, ν, $p = E/c$) as it 'falls' from a height h in the gravitational field of a mass m of radius R. Their momentum fields mediate their gravitational attractions. As the photon falls from $r = R+h$ to $r = R$, the change in its energy is given by:

$$E_R - E_h = -\int_{R+h}^{R} \vec{F} \cdot d\vec{r} = -\int_{R+h}^{R} \kappa \frac{m\,E}{r^2}\, dr \qquad (40)$$

Carrying out the integration, we have:

$$\nu_h / \nu_R = \left(1 - \frac{\kappa m}{R} \right) \Big/ \left(1 - \frac{\kappa m}{R+h} \right) \qquad (41)$$

As $(R+h) > R$, $\nu_R > \nu_h$. The falling photon is blueshifted.

The Pound-Rebka experiment[6] shows fractional change in the energy of a photon as it falls from height $h = 22.5$ m to the earth to be $\delta E/E \approx 2.5 \times 10^{-15}$.

From (41), we get $\delta E/E = (\nu_R - \nu_h)/\nu_h \approx 6.17 \times 10^{-15}$.

9. Photon-photon gravitational interaction

A photon has no mass field but has momentum field. From (6), absolute gravitational force between photons is:

$$F_{\nu\nu} = \frac{G_d\, h^2}{c^2} \frac{\nu_1 \nu_2}{r^2}\,;\;\; r \le S_{12}\,, \qquad (42)$$

where h is Planck's constant and $(G_d\, h^2/c^2) \approx 0$. There is *no* gravitational force between photons.

10. Antimatter-antimatter gravitational interaction

The model applies to antimatter-antimatter gravitational interaction as well.

11. Matter-antimatter gravitational interaction

The question about matter-antimatter gravitational interaction is wide open. To resolve this question experiments are needed to reveal the sign of antimatter gravitational mass and the sign of matter-antimatter gravitational interaction.

12. Remarks

Gravity exists as repulsion and as attraction. Gravitational repulsion is inherent. Gravitational attraction is acquired, exists at close separations ($r \leq S_{12}$), and has been evolving with the speeds of the masses after the Big Bang. Attraction is weaker than repulsion by a factor of $(u/b)^2$. The classical gravitational constant G is *not* a constant but varies with u^2; however, it is constant on the human-time scale.

We note from (30) that $u < b$ at present. We may then infer from Table II that: the universe has bound systems due to attractions between masses in inner regions ($r \leq S_{12}$); and the universe is expanding due partly to repulsions between masses in outer regions ($r > S_{12}$). The universe might undergo one or more cycles of expansion, steady, and contraction states.

The calculations and inferences here *acutely* depend on the accuracy of the value of the gravitational deflection of light by a mass and of momentum field range coefficient of a mass in motion. Those values ought to come from delicate observations.

13. Addendum

Faraday introduced the concept and utility of 'field' to physics. Classical physics had gravitational field and electromagnetic field; modern physics introduced the strong field and the weak field. General Relativity introduced the field of space-time geometry to explain gravity. This model introduces mass-momentum field to explain gravity. Thus, the strong field, the weak field, electromagnetic field, and gravitational (mass-momentum) field now belong to the same *class* of fields – that is, fields which are inherently associated with and depend on their sources.

The rate or probability of emission or absorption of a quantum is related to the strength of the underlying interaction. The relative strengths of the fundamental interactions are: $\Delta E\,(g : w : e : s) \approx (1 : 10^{30} : 10^{40} : 10^{42})$. A nucleus takes $\Delta t_e \approx 10^{-12}$ sec to emit a photon. So, relatively, a nucleus would emit a graviton in roughly $\Delta t_g = (\Delta E_e / \Delta E_g)\,\Delta t_e \approx 10^{40} \cdot 10^{-12}$ secs $\approx 10^{21}$ years! This is several orders of magnitude higher than the known age of the universe ($\approx 14 \times 10^9$ years)!

The following questions are fundamentally significant to understanding gravity and, very possibly, the fundamental interactions further:

(1) Is mass, as gravitational charge, a property of matter (or antimatter), as are the color, the weak, and electrical charges?

(2) If so, what endows matter (or antimatter) with these fundamental charges?

(3) Do gravitational masses of matter and antimatter have opposite signs?

(4) Do matter and antimatter have the fundamental charges of opposite signs?

14. References

[1] Albert Einstein, *The Meaning of Relativity*, Princeton University Press, Princeton, NJ, 1955.

[2] E. A. Milne, *Relativity Gravitation and World-Structure*, Oxford University Press, Oxford, 1935.

[3] E. Freundlich, H. v. Klüber, A. v. Brun; *Zs. f. Astrophys.*, 3, 171, 1931.

[4] Charles Lane Poor, The deflection of light as observed at Total Solar Eclipses, *JOSA*, v20n4, 1930.

[5] Michael P. Price and William F. Rush, Nonrelativistic contribution to Mercury's perihelion precession, *Am. J. Phys.*, v47n6, 1979.

[6] R. V. Pound and G. A. Rebka, Jr., Gravitational Red-Shift in Nuclear Resonance, *Phys. Rev. Letts.*, 3(9), 1959.

Herndon, Virginia, USA
March 1, 2011