# GRAVITOMAGNETICS, THE BASICS OF A SIMPLER APPROACH,

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**ABSTRACT**

Galileo studied bodies falling under gravity and Tycho Brahe made extensive astronomical observations which led Kepler to formulate his three famous laws of planetary motion. All these observations were of relative motion. This led Newton to propose his theory of gravity which could just as well have been expressed in a form that does not involve the concept of force. The approach in this paper extends the Newtonian theory and the Special Theory of Relativity by including relative velocity. This enables the non-Newtonian effects of gravity to be calculated in a simpler manner than by use of the General Theory of Relativity (GR). Application to the precession of the perihelion of Mercury and the gravitational deflection of light gives results which agree with observations and are identical to those of GR. This approach could be used to determine non-Newtonian variations in the trajectories of satellites.

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## NEWTONIAN GRAVITY

Galileo studied bodies falling to Earth under gravity and concluded that all bodies fell with the same acceleration independent of size and material. Tycho Brahe made extensive astronomical observations which led Kepler to formulate his three famous laws of planetary motion relative to the Sun. All of these observations were of relative motion but the mass of one body was, in each case, much greater than that of the other. These led Newton to propose his theory of gravity but he could just as well have presented it in the form

$$a_{B/A} = -\frac{G(m_A + m_B)}{r_{B/A}^2} \tag{1}$$

without invoking the concept of force, and only requiring one definition of mass.
That is, the acceleration of body B relative to A, in the radial direction, is proportional to the sum of their masses and inversely proportional to the square of their separation.

## GRAVITOMAGNETICS

It is now proposed that equation (1) be extended to include the relative velocity. The axioms are.

(a) In a vacuum light travels at a constant speed and
additionally it is assumed that light travels in straight lines, this defines a non-rotating frame of reference.
(b) Because all motion is relative there are no other restrictions on the frame of reference.
(c) Gravity propagates at the same speed as light.
(d) Mass is simply the quantity of matter. It could be a count of the number of basic particles.

The proposed equation is

$$\boxed{\boldsymbol{a} = -\frac{K}{r^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2K}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r)} \tag{2}$$

or

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2Kv_r}{r^2c^2}\boldsymbol{v} \tag{3}$$

where $\boldsymbol{a}$ = acceleration of body B relative to body A , $\boldsymbol{v}$ = the relative velocity, $r$ = the separation and $\boldsymbol{e_r}$ = the unit vector from body A to body B. Also $c$ = speed of light, $K = G(m_A + m_B)$ and $v_r$ is the radial component of velocity. Note that $G$ is a constant which could be incorporated into the definition of the quantity of matter. These equations reduce to equation (1) when $v << c$.

The equation can also be written in terms of the Newtonian part plus the gravitomagnetic part

$$\boldsymbol{a} = \boldsymbol{a}_N + \boldsymbol{a}_V = -\frac{K}{r^2}\boldsymbol{e}_r + \frac{K}{r^2}\left(\frac{v}{c}\right)^2\boldsymbol{e}_{2\phi} \quad . \tag{4}$$

where $\phi$ is the angle between the velocity and the radius.

A convenient definition of force is

$$\boldsymbol{P} = \mu\boldsymbol{a} = -\frac{Gm_Am_B}{r^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2Gm_Am_B}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r) \tag{5}$$

where $\mu = m_Am_B/(m_A+m_B)$ , the reduced mass.

By definition of the centre of mass (or the centre of momentum) the total momentum is zero with reference to the centre of mass. It is now proposed that the motion of the centre of mass of two bodies is not affected by collision. From this it follows that for a group of particles the motion of the centre of mass is unaffected by internal impacts.

The moment of momentum is now a function of the relative position so for an elliptic orbit it remains within bounds. Conservation of moment of momentum results from Newton's third law, but this is not true for electromagnetic or gravitomagnetic reactions. So this result should not be a surprise.

General inferences from equation (2) .

Reverts to Newtonian form when $v << c$.
The second term of (2) is normal to the velocity.
If $v = c$ the first term of (2) vanishes so that there is no change of speed.

Moment of velocity ( or moment of momentum per total quantity of matter) is not conserved. It is shown to be a function of $r$.
The Principle of Equivalence does not arise.

**APPLICATIONS**
Equation (2) will account for the precession of the perihelion of Mercury and will predict the observed value for the deflection of light grazing the Sun. These results were heralded as confirmation of Einstein's General Theory of Relativity. However, equation (2) is very much easier to apply. This equation is equally applicable to the prediction of satellite trajectories. The equation also predicts the accepted value of the Schwarzschild radius but gives a slightly different value for the last stable orbit.

Equation (5) leads to an expression for the precession of a gyroscope in space of the same form, but with a slightly different magnitude, to that quoted for the Gravity Probe B experiment. However, it predicts the same result for the precession of a body in close Earth orbit as that suggested for the LAGEOS I and III experiment. This takes into account the rotation of the Earth. The method also agrees with the quoted measured value for the precession of the periastron of the binary pulsar PSR B1913+16..

The last stable orbit is 2.62 times the Schwarzschild radius instead of the accepted value of 3.0. The numerical differences for Gravity Probe B is that the geodetic value is 2/3 of the quoted value and the motional is ½ . The final results of the experiment have recently been published. The reason for the difference between to two applications of the relevant basic theories is yet to be established.

The decay of the orbit time of binary pulsars is said to be simply due to energy loss caused by gravitational wave emission. This may be the case but energy loss alone will not account for the phenomenon. Application to gravitational wave propagation is similar to that suggested by GR but the difference may have some bearing on the way that waves are to be detected.

**CONCLUSION**
Equation (2) is easier to apply than GR and therefore leaves less room for misrepresentation. The new method agrees with all but one of the measured results. That force is a secondary quantity was strongly advocated by H. R. Hertz who regarded force as "a sleeping partner". Force is to dynamics as money is to commerce. Once force has been demoted to a defined quantity then force fields and inertia are also defined quantities. Equation (2) is loosely modelled on the Lorentz force but this relationship is for guidance only in the same way that Maxwell used a mechanical model to form his equations.

The concept of curved space-time is very erudite and works well but is no more fundamental than the idea of force acting at a distance. The problem still remains that if one body moves relative to another the information has to travel across empty space, this is assumed to be at the same speed as that of light. How one body is aware of the presence of another is an intriguing question but it does not require an immediate answer.

More detailed analysis of this approach is given in reference [19].

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