**Title**: Mass wave model and speed propagation estimation.

**Author**: Enrique Dominguez Pinos. 

Industrial Engineer.

**Address**: Málaga (Spain)

**email**: enrique.pinos@gmail.com

## Abstract

Full analogy between electromagnetism and gravity, with mass wave calculation through solar system simulation sourced with ephemeris data from horizons. Argument of mercury perihelion precession against general relativity.

## Highlights

- We've proposed a parallel theory to electromagnetism, concluding De Broglie's prediction of a waveform associated with a moving mass.
- We've shown how this mathematical relationship is.
- We've calculated wave speed whose value is less than light speed, according to the astronomical data.
- We finally set out a possible refutation of the theory, through the gravitational repulsion.

Málaga, 8 November 2013

## Contents

## Introduction

The aim of this work is to establish a relationship between a moving mass and its associated wave such as De Broglie settled. De Broglie states: "every particle of matter with mass m and velocity v a real wave must be 'associated'", without establishing an equation of the particle-associated waves as electromagnetism does.

We'll set an analogy between electric charges and inertial mass. This analogy was previously observed from Heaviside since 1922 [(1)]; we'll show a new point of view which will explain mercury perihelion precession without general relativity introduction. That analogy between mass and charge will help us to discover a new force law.

We're showing this analogy in Table 1, using the expression of magnetic force for moving charges to search for this new force law.

| Mass field | Electromagnetic field |
|---|---|
| $\vec{F}_M^{M\to m}=-G\frac{Mm}{r^2}\hat{r}$ | $\vec{F}_e^{Q\to q}=\frac{1}{4\pi\epsilon_o}\frac{Qq}{r^2}\hat{r}$ |
| ? | $\vec{F}_m^{Q\to q}=q\vec{v}_q\wedge\frac{\mu_o}{4\pi}\frac{Q\vec{v}_Q\wedge\hat{r}}{r^2}$ |

*Table 1: Electromagnetic and mass analogy*

In this line of thinking, being the expression of force on moving masses,

$$\vec{F}_{mv}^{M\to m}=m\vec{v}_m\wedge\gamma\frac{M\vec{v}_M\wedge\hat{r}}{r^2}$$

We set the constant value that relates the forces known constants, if this quotient is 'cte',

$$cte=\frac{|\vec{F}_e|}{|\vec{F}_m|}=\frac{1/(4\pi\epsilon_o)}{\mu_o/(4\pi)}=c^2=\frac{G}{\gamma},$$

$$\gamma=\frac{G}{c^2}$$

getting our table with the four forces,

| Mass field | Electromagnetic field |
|---|---|
| $\vec{F}_M^{M\to m}=-G\frac{Mm}{r^2}\hat{r}$ | $\vec{F}_e^{Q\to q}=\frac{1}{4\pi\epsilon_o}\frac{Qq}{r^2}\hat{r}$ |
| $\vec{F}_{mv}^{M\to m}=m\vec{v}_m\wedge\frac{G}{c^2}\frac{M\vec{v}_M\wedge\hat{r}}{r^2}$ | $\vec{F}_m^{Q\to q}=q\vec{v}_q\wedge\frac{\mu_o}{4\pi}\frac{Q\vec{v}_Q\wedge\hat{r}}{r^2}$ |

As we told, we'll test the expression through the calculation of the perihelion of Mercury.

Should be noted that the electric field is identified with the gravitational field, likewise that the magnetic field is identified with what we called field mass movement or motion gravitational field. Another papers named it gravitomagnetic field[(1)].

As a result of the model calibration in the expression of the movement gravitatory force (MGF), the force lacks the minus sign, which has the expression of the gravitational force of Newton.

# Start data

## Planets data

Eight planets of solar system and the sun are considered for calculations; getting ephemeris data[2] without stellar aberration correction (geometric states).

NOTE: Arbitrary data couldn't be selected because Mars, we set a valid range for all planets.

Initial conditions used for ODEs were showed in Append I: Ephemeris data. The product of (G*m), collected in DE405[5], was used for setting each planet equation. Instead of the values of horizons constants we have used values of DE405, so we don't need individual data of planets, only (G*m) product.

## Previous results

On literature we can find perihelion precession of 574.10±0.65 arc-seconds by century (ICFR reference -mean values-). 532 arcsec of them are from solar system planets influence and 42.98 arcsec must being of general relativity contribution[3],[4].

Calculations referred to sun reference frame (in it's center), so we need to get precessions at this reference frame and set how to perform this calculation.

For precession calculation Mercury position vector when perihelion come at each cycle, starting form first gained vector and determining angle between current and this first vector we get precessions. For angle between vectors calculation we are using scalar product formula,

Mercury position vector, when perihelion comes at each cycle, is needed for precession calculation. Starting form first gained vector and determining angle between current, and this first vector, we get precessions. The angle between the vectors is computed using the formula for the scalar product,

$$\vec{r}_1 \cdot \vec{r}_n = |\vec{r}_1||\vec{r}_n| \cos(\alpha)$$

Alpha being angle between vectors, $\vec{r}_1$ being first gained perihelion vector and $\vec{r}_n$ being position vector of $n^{th}$ perihelion.

The angle must be averaged because the actual value fluctuates, so that, we are using cumsum octave function. In an extended period of observation, the value stabilizes and gets the real value of the precession. We can't use all simulated data for performing perihelion calculation because stabilization; in each graph will show current promediated years and predicted perihelion precession.

# Octave simulations

## Hardware

We're using octave for planets state simulation on an amd64 computer (1GB RAM) and gentoo linux optimized for this architecture.

## Tolerances

Getting 1e-4 precision in alpha, needing around 1e4 precision tolerance in the positional vector.

Performing mercury trajectory needing absolute tolerance about 1e-80 for positions and about 1e-100 for speeds, as relative tolerance we are using octave epsilon (~1.49e-8). Other planets getting absolute tolerance in function about it's stellar cycle to mercury cycle ratio.

## Newton equations (model 32)

Cumsum results for the perihelion precession in the model of the solar system by Newton's laws are showed in Illustration 1. We got 265 arcsec (simulated one century, last 50 years for getting real tendency)

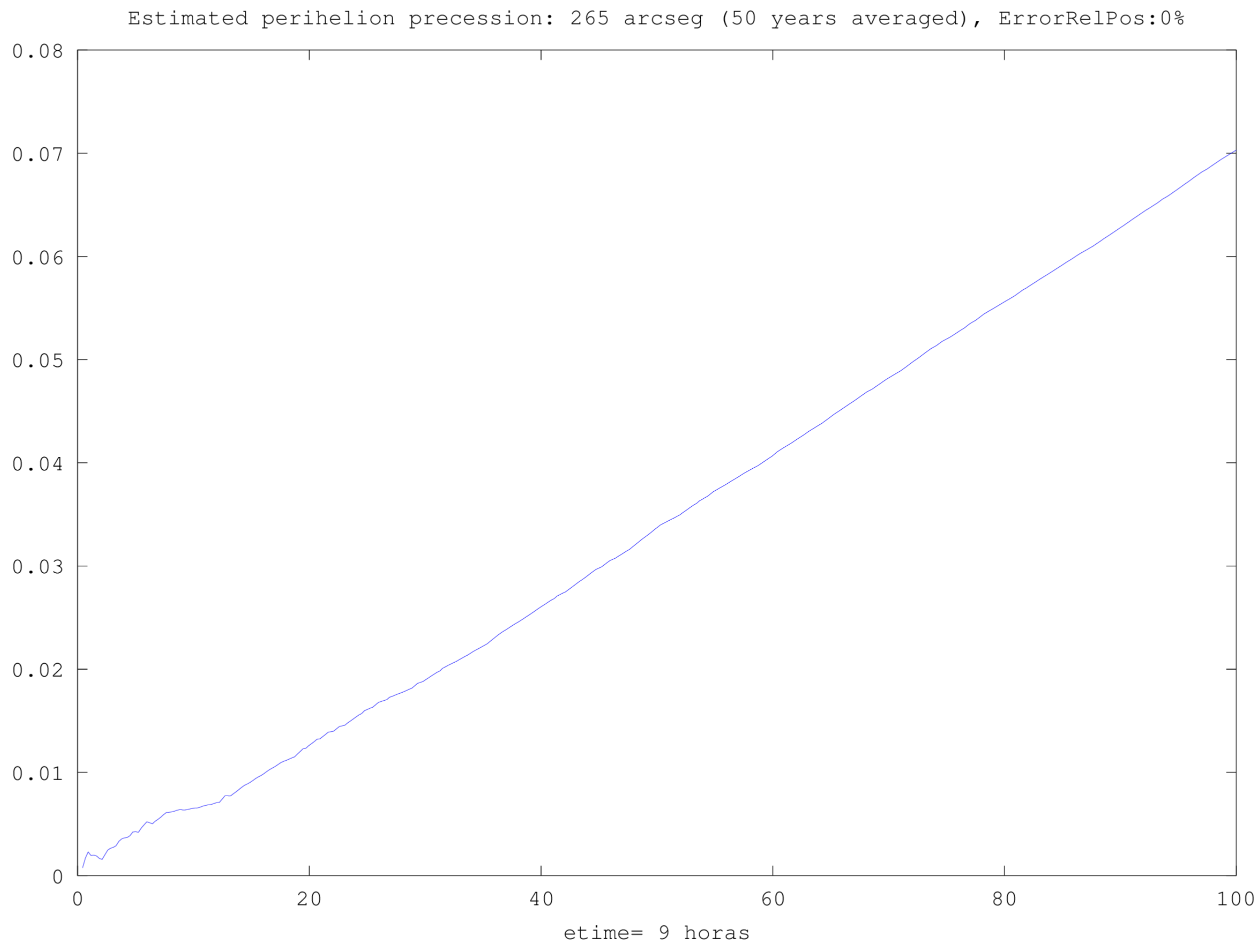


*Illustration 1: Newton model of solar system (one century)*

We compare positional calculated vector with ephemeris tables in last simulated perihelion for validating this model. We got few minutes of error (ephemeris: 17-Feb-2013 02:25:41; simulated: 17-Feb-2013 02:11:41)

| Date | Range |
|---|---|
| 2013-Feb-17 02:15:41.0000 | 4.600028652353445E+07 |
| 2013-Feb-17 02:20:41.0000 | 4.600028430206786E+07 |
| **2013-Feb-17 02:25:41.0000** | **4.600028324139002E+07** |
| 2013-Feb-17 02:30:41.0000 | 4.600028334150112E+07 |
| 2013-Feb-17 02:35:41.0000 | 4.600028460240115E+07 |

*Table 2: Perihelion calculation date via ephemeris*

Relative error in positional vector was about 0.38%-0.11%.

We're tried getting data from other sources (NAIF kernels for example) but can't get all necessary data from there and compared data as sourced by horizons seems a little different.

## Measured astronomic data comparison (model 33)

Last result was evaluated using ASCII kernel form JPL and ephemutil utility called from octave. We need to get the same position vectors already obtained by the simulation with data from JPL kernel data.

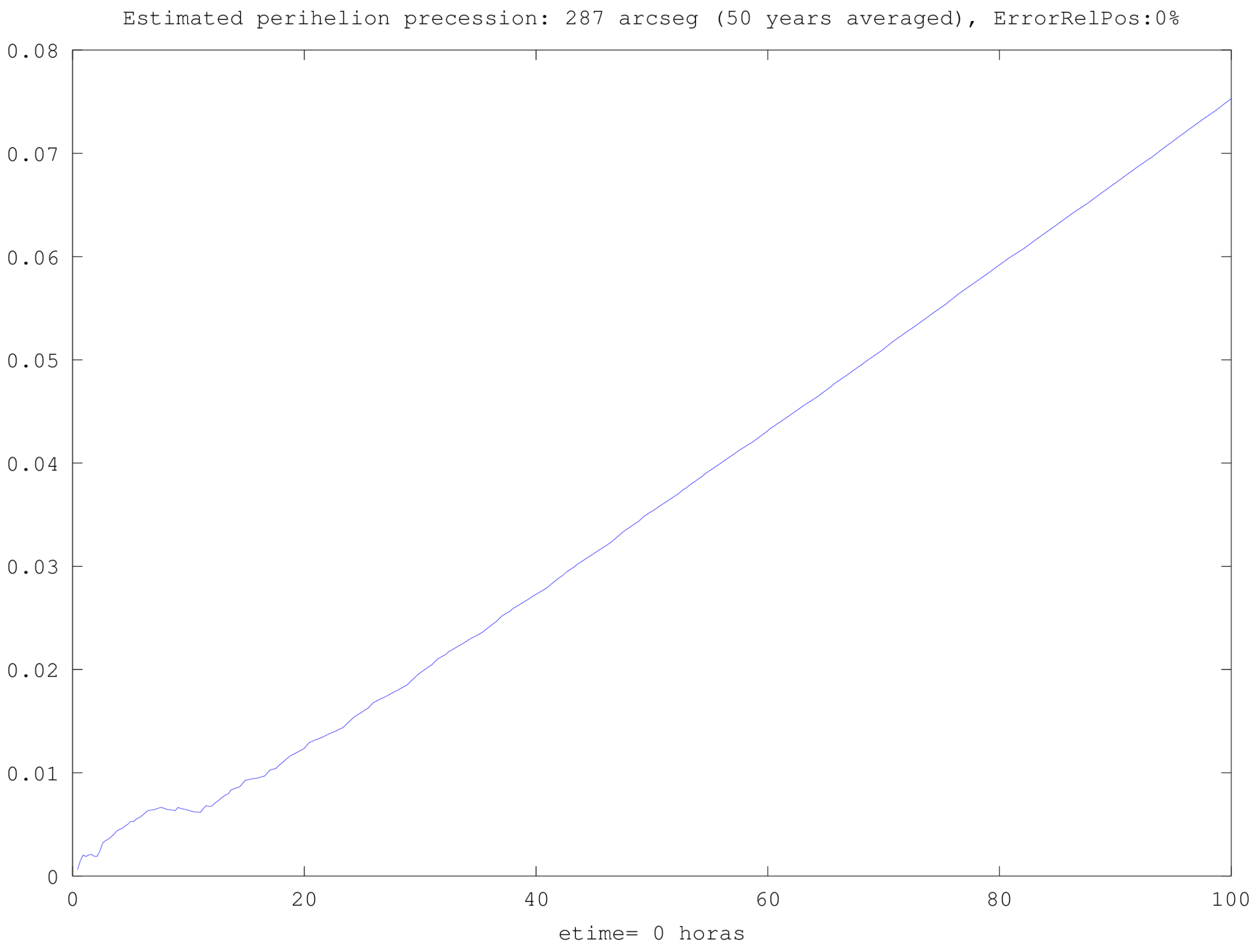


*Illustration 2: Perihelion precession data shown from EphemUtil*

We got 287arcseg by century. We have to remove a pair of data gained from ephemutil (seems out of range)

So we get a measured reference value that will allow us to perform the calibration of the model in this reference system. Model has to supply 22 arcsec.

## MGF model (model 34)

Initially, we get a null effect of this force on the system, consisting of point masses,

$$\vec{F}_{mv}^{M\to m} = m\vec{v}_m \wedge \vec{g}(\vec{r})$$
$$\vec{g}(\vec{r}) = \frac{G}{c^2}\frac{M\vec{v}_M \wedge \hat{r}}{r^2}$$

Sun speed is lower (~5km/s) than mercury speed (~59km/s)

But we may consider the force exerted by sun rotating mass; and as in electromagnetic analogy, rotating charges produce a magnetic field and rotating masses produce a moving mass field (and a MGF from sun to mercury)

Rotational data of sun are in Append II: Sun rotation.

Field equations are, (go to Append III: Magnetic field equations for deduction),

$$\vec{g}(\vec{r}) = \frac{G \cdot M_S}{c^2 V_S}\int_{V'} \frac{\vec{\omega}(\varphi') \wedge \vec{r}\,' \wedge \vec{R}}{R^3} dV'$$
$$\vec{R} = \vec{r} - \vec{r}\,'$$

Being $M_s$ y $V_s$ mass and volume of sun. And $R_s$ it's radius.

This equation could be set for i^th^ planet as,

$$\vec{g}_i(\vec{r})=\frac{G\cdot M_S}{c^2 V_S}\left(\int_{V'}\frac{\vec{\omega}(\varphi')\wedge\vec{r}\,'}{R^3}dV'\right)\wedge\vec{r}_i$$

And,

$$\vec{g}_i(\vec{r})=\frac{G\cdot M_S}{c^2 V_S}\left(\int_0^{R_S}\int_0^{2\pi}\int_0^{\pi}\vec{\omega}(\varphi')\sin^2(\varphi')\frac{(-\hat{x}\sin(\varphi')+\hat{y}\cos(\varphi'))r'^3}{R^{3/2}}d\varphi'd\theta'dr'\right)\wedge\vec{r}_i$$

With,

$$R=[x_i-r'\cos(\theta')\sin(\varphi')]^2+[y_i-r'\sin(\theta')\sin(\varphi')]^2+[z_i-r'\cos(\varphi')]^2$$

Being i coordinates from planet under MGF force.

We have to introduce an additional hypotesis to get an appreciable effect: mass wave propagation speed being less than light propagation speed. From simulations we got $c_m$~3,966.470 km/s (286.61arcsec). Simulation data at Illustration 3.

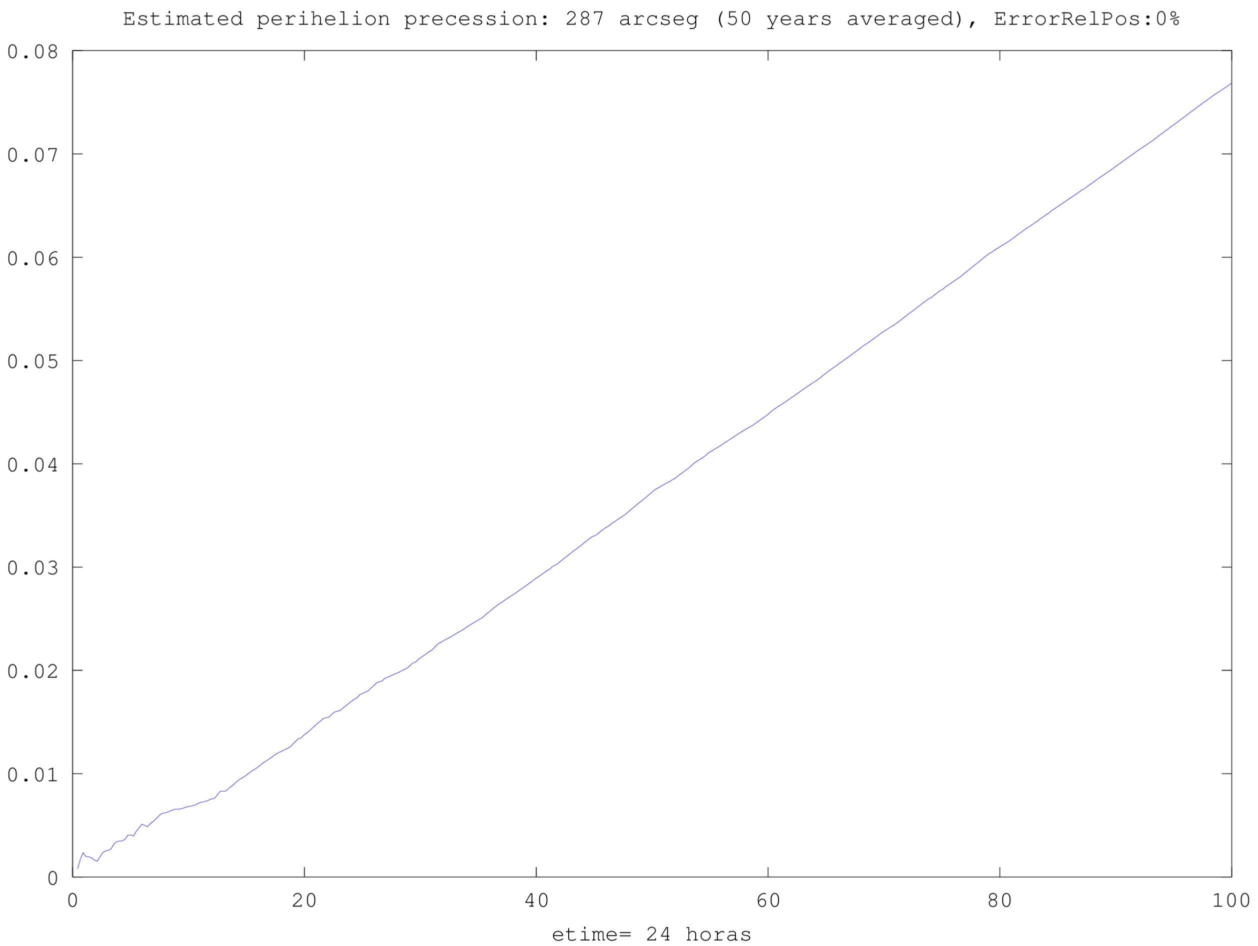


*Illustration 3: Limited velocity of mass waves simulation*

Relative error of simulation was about 0.48%.

## Especial relativity (model 45)

Analyzing contribution of special relativity as explained in Append IV: Special relativity, we got no appreciable influence (few arcsec, but can't explain perihelion precession of 22 arcsec)

But we can introduce it for accounting its effect in mass wave speed. In this way, we got 4,687.756 km/s (286.43 arcsec, Illustration 4)

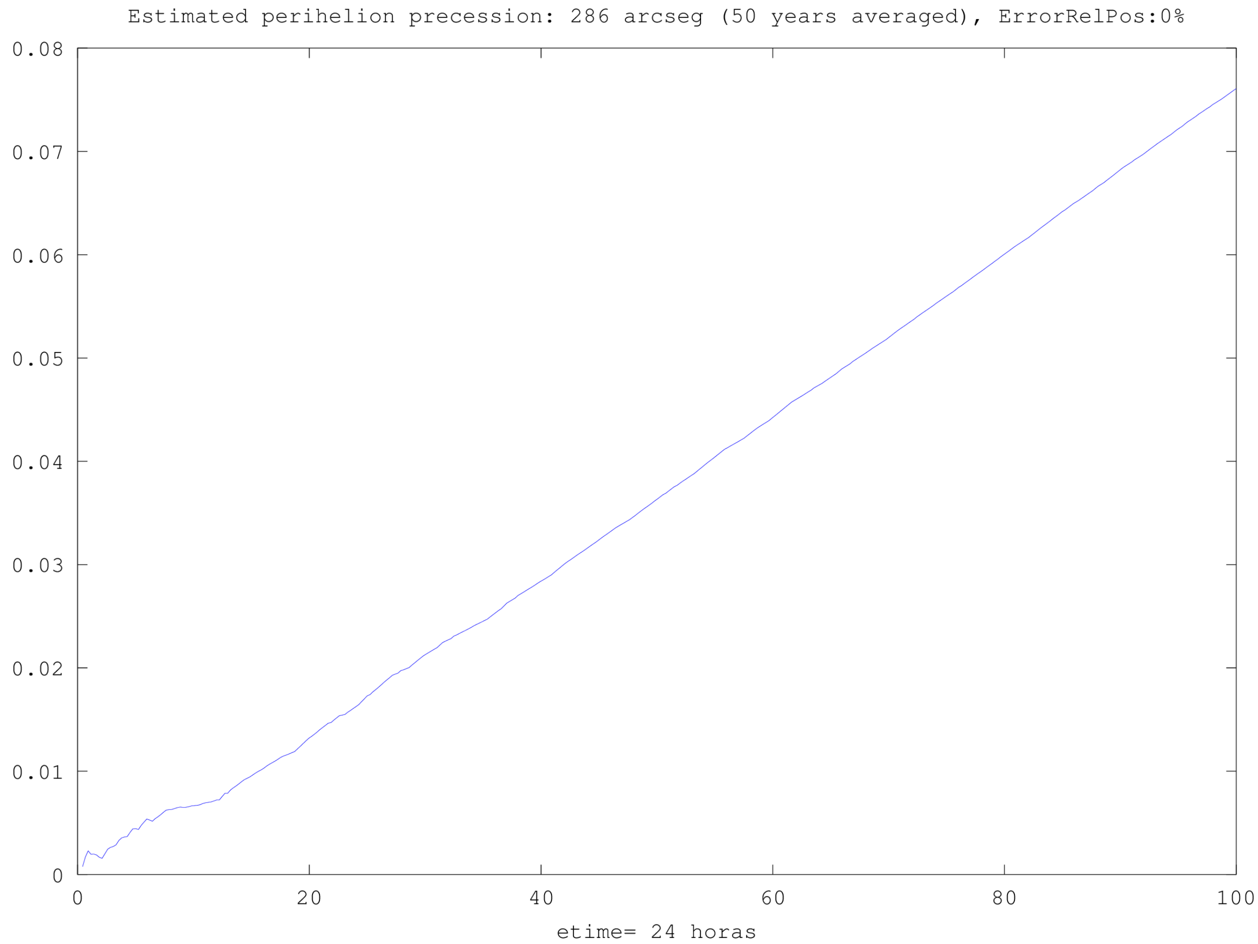


*Illustration 4: Especial relativity effect consideration*

# Remarks

## Positional vector errors

We've compared final positions of planets got from horizons ephemeris and simulated ones for checking simulation results. Those data have been checked for one century (error increase as we increase simulation time to two centuries) but wasn't able to get appreciable arcseg deviation in a single direction.

## Other planets effect

We've checked MGF wasn't able to produce appreciable effect in other planets. Venus was simulated and effect was negligible.

## Central force aberration for wave propagation time

We've seen this effect in [6], Tome II, chap 21, page 21-2, for electromagnetic field. Extrapolation would require us to test the contribution between planets (maybe Venus on Mercury) but we wouldn't consider sun influence, because other planets feeling sun influence as static (they don't see a moving sun) So there is no wave emission.

### Mass wave theory implications

This analogy has more implications. Now the gravitational field propagates with movement mass field as electromagnetic waves do, matching a wave equation like Maxwell one, but with $c_m$ speed (lower than light speed)

Proposed equations were placed in Append V: Mass field equations.

### Appreciable differences

We have to emphasize that the terms of the force will cause, on a body rotating around the sun, in the opposite direction to it, a repulsion force (against the attractive force would predict theory of general relativity) This effect could be used for testing this theory.

## Conclusion

We've proposed a parallel theory to electromagnetism, concluding De Broglie's prediction of a waveform associated with a moving mass. We've shown how this mathematical relationship is.

We've checked that mercury precession can't be explained for special relativity and we have calibrated this new theory with astronomical data.

We've calculated wave speed whose value is less than light speed, according to the astronomical data.

We finally set out a possible refutation of the theory, through the gravitational repulsion (because results are against general relativity ones)

# Append I: Ephemeris data

| | |
|---|---|
| Ephemeris Type | VECTORS |
| Coordinate Origin | Sun (body center) [500@**10**] |
| Table Settings | Output units=KM-S; quantities code=2; labels=YES; CSV format=YES |
| Units | Km y km/s |
| Reference frame | IRCF/J2000.0 |
| Reference plane | Ecliptic and mean equinox of reference epoch |

**Coordinate system description**:

Ecliptic and Mean Equinox of Reference Epoch

Reference epoch: J2000.0

xy-plane: plane of the Earth's orbit at the reference epoch

x-axis : out along ascending node of instantaneous plane of the Earth's orbit and the Earth's mean equator at the reference epoch

z-axis : perpendicular to the xy-plane in the directional (+ or -) sense of Earth's north pole at the reference epoch.

**Symbol meaning**

JDCT Epoch Julian Date, Coordinate Time

X x-component of position vector (km)

Y y-component of position vector (km)

Z z-component of position vector (km)

VX x-component of velocity vector (km/sec)

VY y-component of velocity vector (km/sec)

VZ z-component of velocity vector (km/sec)

Geometric states/elements have no aberration corrections applied.

Computations by ...

Solar System Dynamics Group, Horizons On-Line Ephemeris System

4800 Oak Grove Drive, Jet Propulsion Laboratory

Pasadena, CA 91109 USA

Information: http://ssd.jpl.nasa.gov/

Connect : telnet://ssd.jpl.nasa.gov:6775 (via browser)

telnet ssd.jpl.nasa.gov 6775 (via command-line)

Author : Jon.Giorgini@jpl.nasa.gov

## Sun

Target Body Sun [Sol] [10]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 07:13:25 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Sun (10) {source: DE405}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00, 0.000000000000000E+00,

$$EOE

*******************************************************************************

## Mercury

Target Body Mercury [199]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:18:18 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Mercury (199) {source: DE405}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, -5.360665730052117E+07, 1.243397368572870E+07, 5.946675013560415E+06, -2.109596483753719E+01, -4.533775271587504E+01, -1.757353935106772E+00,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, -4.440290472706281E+07, -5.110440497487431E+07, -1.014449602649391E+05, 2.688550693766266E+01, -2.970018707156070E+01, -4.893508405499786E+00,

$$EOE

*******************************************************************************

## Venus

Target Body Venus [299]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:20:44 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Venus (299) {source: DE405}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, 1.018158177530931E+08, 3.703243858802129E+07, -5.386891016958820E+06, -1.208964619890154E+01, 3.275601387483020E+01, 1.138416084527058E+00,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, -8.364393681148392E+07, -6.847969524311861E+07, 3.889032485377138E+06, 2.193837392533697E+01, -2.726409897743777E+01, -1.639716487601144E+00,

$$EOE

*******************************************************************************

## Earth

Target Body Earth [Geocenter] [399]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:22:13 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Earth (399) {source: DE405}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, -1.045637425163494E+07, 1.467385967490118E+08, 2.835631451258451E+04, -3.018886665393219E+01, -2.222940110022601E+00, -8.140263107061256E-04,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, -8.773033517291984E+06, 1.468674792713496E+08, -4.466184044525366E+03, -3.021116715750096E+01, -1.892934819525167E+00, 1.158502276269857E-03,

$$EOE

*******************************************************************************

## Mars

Target Body Mars [499]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:24:47 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Mars (499) {source: MAR097}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, -7.966999905665824E+07, -2.100334861412445E+08, -2.420085859665400E+06, 2.358431013255164E+01, -6.523457368354225E+00, -7.205749072795029E-01,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, 1.514168902923513E+08, -1.419468950342833E+08, -6.691719661214531E+06, 1.749190756063776E+01, 1.974805640407604E+01, -1.571815631304356E-02,

$$EOE

*******************************************************************************

## Jupiter

Target Body Jupiter [599]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:26:01 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Jupiter (599) {source: JUP230}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, -2.325226589284961E+07, -7.864938001501033E+08, 3.721909619674553E+06, 1.291728188825723E+01, 2.232228774062441E-01, -2.905863315990377E-01,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, 2.208900533351294E+08, 7.241860827237822E+08, -7.950563422672395E+06, -1.266535090043849E+01, 4.437528423714215E+00, 2.650446010224173E-01,

$$EOE

*******************************************************************************

## Saturn

Target Body Saturn [699]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:26:55 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Saturn (699) {source: SAT351}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, 6.160627576702619E+08, 1.208915824575386E+09, -4.573515710213210E+07, -9.121766092721035E+00, 4.363134726154207E+00, 2.856552635915862E-01,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, -1.211851731764423E+09, -8.201413680424271E+08, 6.250905459656192E+07, 4.879229156365631E+00, -8.019271442359987E+00, -5.486570783853705E-02,

$$EOE

*******************************************************************************

## Uranus

Target Body Uranus [799]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:27:45 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Uranus (799) {source: URA095}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, 1.672795478653011E+09, -2.443857810328711E+09, -3.084987609136089E+07, 5.577499124725859E+00, 3.531952557946183E+00, -5.938484056216033E-02,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, 2.976113012338417E+09, 3.810762353106240E+08, -3.713403980800174E+07, -9.245322750052556E-01, 6.439861688192399E+00, 3.586407160501116E-02,

$$EOE

*******************************************************************************

## Neptune

Target Body Neptune [899]

Coordinate Origin Sun (body center) [500@10]

Time Span Start=1912-12-25, Stop=2012-12-25, Step=100 Y

### Results

*******************************************************************************

Ephemeris / WWW_USER Fri Dec 14 06:28:42 2012 Pasadena, USA / Horizons

*******************************************************************************

Target body name: Neptune (899) {source: NEP081}

Center body name: Sun (10) {source: DE405}

Center-site name: BODY CENTER

*******************************************************************************

Start time : A.D. 1912-Dec-25 00:00:00.0000 CT

Stop time : A.D. 2012-Dec-25 00:00:00.0000 CT

Step-size : 100 calendar years

*******************************************************************************

Center geodetic : 0.00000000,0.00000000,0.0000000 {E-lon(deg),Lat(deg),Alt(km)}

Center cylindric: 0.00000000,0.00000000,0.0000000 {E-lon(deg),Dxy(km),Dz(km)}

Center radii : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}

Output units : KM-S

Output format : 02

Reference frame : ICRF/J2000.0

Output type : GEOMETRIC cartesian states

Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch

*******************************************************************************

JDCT , , X, Y, Z, VX, VY, VZ,

*******************************************************************************

$$SOE

2419761.500000000, A.D. 1912-Dec-25 00:00:00.0000, -1.945382209325346E+09, 4.040882875978233E+09, -3.840489086570295E+07, -4.918386519161444E+00, -2.321455648483695E+00, 1.606763346689215E-01,

2456286.500000000, A.D. 2012-Dec-25 00:00:00.0000, 3.971948263325485E+09, -2.085811431212152E+09, -4.856478539988586E+07, 2.480996673642879E+00, 4.845946535939160E+00, -1.576431831611057E-01,

$$EOE

*******************************************************************************

## Append II: Sun rotation

http://en.wikipedia.org/wiki/Solar_rotation

Latitude dependent rotation,

$$\omega = A + B\sin^2(\phi) + C\sin^4(\phi)$$

constants being,

A= 14.713 deg/day (± 0.0491)

B= –2.396 deg/day (± 0.188)

C= –1.787 deg/day (± 0.253)

and maximum in the equator plane. Equation relating latitude and third spherical coordinate being,

$$\sin(\phi) = \sin\left(\frac{\pi}{2} - \varphi\right) = \cos(\varphi)$$

so, rotation module become,

$$\omega = A + B\cos^2(\varphi) + C\cos^4(\varphi)$$

and constants in rad/s are,

$$A' = A\frac{\pi}{180 \cdot 24 \cdot 3600}$$

Getting,

A'= 2.9721098709e-06 rad/sec

B'= –4.84005658308e-07 rad/sec

C'= –3.60984186726e-07 rad/sec

As reference frame is in the sun, z axis match sun rotation axis.

## Append III: Magnetic field equations

Starting from magnetic field equations for a point charge, and a volumetric charge (ρ) spinning, with rotation vector $\vec{\omega}$, and producing a volumetric current $\vec{J}=\rho\vec{\omega}\wedge\vec{r}\,'$,

$$\vec{B}=\frac{\mu_o}{4\pi}\frac{Q\vec{v}_Q\wedge\hat{r}}{r^2},$$

$$\vec{B}=\frac{\mu_o}{4\pi}\int_{V'}\vec{J}(\vec{r}\,')\wedge\frac{\vec{R}}{R}dV',$$

where $\vec{R}=\vec{r}-\vec{r}\,'$. And making the analogy with the mass field, we get,

$$\vec{B}_g(\vec{r})=\frac{G\cdot M_S}{c^2V_S}\int_{V'}\frac{\vec{\omega}(\varphi')\wedge\vec{r}\,'\wedge\vec{R}}{R^3}dV'$$

## Append IV: Special relativity

Followed from (7).

Relativistic equations of a space state system are,

$$\frac{d\vec{x}}{dt}=\vec{v},$$

$$\frac{d\vec{v}}{dt}=\frac{1}{m}\left(\vec{F}-\frac{(\vec{v}\cdot\vec{F})\vec{v}}{c^2}\right)\sqrt{1-\frac{v^2}{c^2}},$$

Being $\vec{F}$ force executed against the body and being speed vector referenced to selected reference frame.

## Append V: Mass field equations

Followed from (8).

Maxwell equations set,

$$\nabla\cdot\vec{E}=\frac{\rho}{\epsilon_0}$$
$$\nabla\cdot\vec{B}=0$$
$$\nabla\wedge\vec{E}=\frac{-\partial\vec{B}}{\partial t}$$
$$\nabla\wedge\vec{B}=\mu_0\vec{J}+\frac{1}{c^2}\frac{\partial\vec{E}}{\partial t}$$

and mass field ones become,

$$\nabla\cdot\vec{E}_g=-4\pi G\rho_g$$
$$\nabla\cdot\vec{B}_g=0$$
$$\nabla\wedge\vec{E}_g=\frac{-\partial\vec{B}_g}{\partial t}$$
$$\nabla\wedge\vec{B}_g=\frac{4\pi G}{{c_m}^2}\vec{J}_g+\frac{1}{{c_m}^2}\frac{\partial\vec{E}_g}{\partial t}$$

## References


(1) Biemond, J., "The gravitomagnetic field of a sphere, Gravity Probe B and the LAGEOS satellites", arXiv:0802.3346v1, 22 Feb 2008.

(2) http://ssd.jpl.nasa.gov/?horizons

(3) http://en.wikipedia.org/wiki/Mercury_%28planet%29

(4) http://www.mathpages.com/rr/s6-02/6-02.htm

(5) http://iau-comm4.jpl.nasa.gov/de405iom/de405iom.pdf

(6) Richard P. Feynman et al. “The Feynman Lectures on Physics”, Addison–Wesley, 1964.

(7) http://en.wikipedia.org/wiki/Relativistic_mechanics

(8) http://en.wikipedia.org/wiki/Gravitoelectromagnetism