GENERAL ORBIT THEORY IN SPHERICALLY SYMMETRIC SPACETIME.

by

M. W. Evans and H. Eckardt

Civil List and AIAS / UPITEC

(www.aias.us, www.upitec.org, www.et3m.net, www.archive.org , www.webarchive.org.uk)

ABSTRACT

The most general type of orbit theory is developed in spherically symmetric spacetime. This theory is developed from the fact that the relativistic hamiltonian (H) and relativistic angular momentum (L) are constants of motion. The coordinate system is defined for the general orbit and the equations of motion solved numerically. The resulting orbits precess and in general can decrease, so that a particle m orbiting a particle M eventually collides with M. This theory can describe all observable orbits without the use of the Einstein field equation.

Keywords: ECE2 theory, general orbits in spherically symmetric spacetime.

UFT416

1. INTRODUCTION

In immediately preceding papers of this series {1 - 41} an ECE2 covariant theory of orbits has been developed with the aim of describing precession and orbit shrinking without the incorrect Einstein field equation. The latter fails experimentally in S star systems by an order of magnitude and has been refuted in nearly a hundred different ways in the ECE and ECE2 theories. In Section 2 a rigorously self consistent coordinate system is defined and used to define the lagrangian and hamiltonian. This is the only coordinate system that is rigorously self consistent. The hamiltonian and angular momentum in this coordinate system are rigorously self consistent constants of motion, and this property is used to construct a powerful and simple new cosmology in which orbits can in general both precess and shrink, as observed for example in binary pulsars. The new cosmology can describe S star systems, in which Einsteinian general relativity (EGR) fails by an order of magnitude. S star systems entirely refute the claimed precision of EGR and indeed refute the entire twentieth century thought in gravitational physics. In Section 3 an extensive numerical and graphical analysis is given of the first results from this new cosmology.

This paper is a short synopsis of extensive calculations in the notes accompanying UFT416 on www.aias.us and www.upitec.org. Note 416(1) gives a short review of the properties of the most general spherically symmetric line elements and metrics, and gives the equations of motion of UFT415 using the plane polar coordinate system (r , ϕ). Note 416(2) develops the rigorously self consistent coordinate system used to produce the orbits of Section 3. This coordinate system is the one defined by the most general spherically symmetric spacetime and must always be used. Note 416(3) double checks Note 416(2) using the geodesic method.

2. RIGOROUSLY SELF CONSISTENT THEORY

Consider the plane polar coordinate system (r_1, ϕ) where

$$r_1 = \frac{r}{m(r)^{1/2}} . \qquad -(1)$$

In this system of coordinates the infinitesimal line element of spherically symmetric spacetime is:

$$ds^2 = c^2 d\tau^2 = m(r)\, c^2 dt^2 - dr_1^2 - r_1^2 d\phi^2 \qquad -(2)$$

in which the Newtonian velocity v is defined by:

$$v^2 dt^2 = dr_1^2 + r_1^2 d\phi^2 . \qquad -(3)$$

It follows that the Lorentz factor is generalized to:

$$\gamma = \left(m(r) - \frac{v^2}{c^2} \right)^{-1/2} . \qquad -(4)$$

The free particle kinetic lagrangian {1 - 41} is:

$$\mathcal{L} = \frac{1}{2} m c^2 = \frac{1}{2} m \left(\frac{ds}{d\tau} \right)^2 = \frac{1}{2} m g_{\mu\nu} \frac{dx^\mu}{d\tau} \frac{dx^\nu}{d\tau} \qquad -(5)$$

where $g_{\mu\nu}$ is the metric and:

$$x^\mu = (ct, \underline{r}_1) \qquad -(6)$$

is the position four vector. It follows from Eqs. (2) and (6) that:

$$\mathcal{L} = \frac{1}{2} m \left(m(r) c^2 \left(\frac{dt}{d\tau} \right)^2 - \left(\frac{dr_1}{d\tau} \right)^2 - r_1^2 \left(\frac{d\phi}{d\tau} \right)^2 \right) = \frac{1}{2} m g_{\mu\nu} \frac{dx^\mu}{d\tau} \frac{dx^\nu}{d\tau} . \qquad -(7)$$

Therefore:

$$\frac{1}{2} m g_{00} \frac{dx^0}{d\tau} \frac{dx^0}{d\tau} = \frac{1}{2} m n(r) c^2 \left(\frac{dt}{d\tau}\right)^2 \quad -(8)$$

$$\frac{1}{2} m g_{11} \frac{dx^1}{d\tau} \frac{dx^1}{d\tau} = \frac{1}{2} m \left(\frac{dr_1}{d\tau}\right)^2 \quad -(9)$$

$$\frac{1}{2} m g_{22} \frac{dx^2}{d\tau} \frac{dx^2}{d\tau} = \frac{1}{2} m \left(\frac{d\phi}{d\tau}\right)^2 r_1^2 \quad -(10)$$

The Hamilton principle of least action is:

$$\delta \int \mathcal{L} \, d\tau = 0 \quad -(11)$$

and the Euler Lagrange equation is:

$$\frac{d}{d\tau} \frac{\partial \mathcal{L}}{\partial \dot{x}^\mu} = \frac{\partial \mathcal{L}}{\partial x^\mu} \quad -(12)$$

where:

$$\dot{x}^\mu = \frac{dx^\mu}{d\tau}. \quad -(13)$$

From the Euler Lagrange equation:

$$\frac{d}{d\tau} \frac{\partial \mathcal{L}}{\partial \dot{x}^0} = \frac{d}{d\tau} \frac{\partial \mathcal{L}}{\partial \left(\frac{dt}{d\tau}\right)} = 0 \quad -(14)$$

it follows that:

$$\frac{dE}{d\tau} = 0 \quad -(15)$$

where the total relativistic kinetic energy E of the free particle is

$$E = \frac{\partial \mathcal{L}}{\partial \left(\frac{dt}{d\tau} \right)} = m(r) mc^2 \frac{dt}{d\tau} = m(r) \gamma mc^2 \quad -(16)$$

and from Eq. (15) is a constant of motion of a free particle. The hamiltonian of an interacting particle of mass m is therefore:

$$H = E + U. \quad -(17)$$

Note carefully that in the curved m space the potential energy of interaction between m and M in an orbit is:

$$U = -\frac{mMG}{r_1} \quad -(18)$$

Here M is the mass of the particle about which m orbits, and G is Newton's constant. The hamiltonian is a constant of motion in general:

$$\frac{dH}{dt} = 0 \quad -(19)$$

The Euler Lagrange equation:

$$\frac{d}{d\tau} \frac{\partial \mathcal{L}}{\partial \dot{x}^1} = \frac{d}{d\tau} \frac{\partial \mathcal{L}}{\partial \left(\frac{dr_1}{d\tau} \right)} = 0 \quad -(20)$$

gives:

$$\frac{dp_1}{d\tau} = 0 \quad -(21)$$

where

$$p_1 = \frac{\partial \mathcal{L}}{\partial \left(\frac{dr_1}{d\tau} \right)} = m \frac{dr_1}{d\tau} \quad -(22)$$

p_1 is the conserved linear momentum of a free particle in the most general spherically symmetric spacetime. By definition:

$$p_1 = m\frac{dr_1}{d\tau} = \frac{\gamma}{m(r)^{1/2}} m\frac{dr}{dt} \quad -(23)$$

as in UFT415, so the coordinate system and theory is rigorously self consistent, Q. E. D.

Finally the Euler Lagrange equation:

$$\frac{d}{d\tau}\frac{\partial \mathcal{L}}{\partial \dot{x}^2} - \frac{d}{d\tau}\frac{\partial \mathcal{L}}{\partial\left(\frac{d\phi}{d\tau}\right)} = 0 \quad -(24)$$

gives:

$$\frac{dL}{d\tau} = 0 \quad -(25)$$

where:

$$L = m r_1^2 \frac{d\phi}{d\tau} = \frac{\gamma m r^2}{m(r)}\frac{d\phi}{dt} \quad -(26)$$

is the conserved angular momentum in the most general spherically symmetric spacetime.

This is the same angular momentum as in UFT415, but the plane polar coordinate system (r, ϕ) does not give the correct linear momentum derived from fundamental kinematic considerations as in UFT415. The equations of motion of the new cosmology are therefore:

$$\frac{dH}{d\tau} = 0 \quad -(27)$$

and

$$\frac{dL}{d\tau} = 0 \quad -(28)$$

Finally use:

$$\frac{dH}{d\tau} = \frac{dH}{dt}\frac{dt}{d\tau} = \gamma\frac{dH}{dt} \quad -(29)$$

and

$$\frac{dL}{d\tau} = \frac{dL}{dt}\frac{dt}{d\tau} = \gamma \frac{dL}{dt} \quad -(30)$$

to find that:

$$\frac{dH}{dt} = 0 \quad -(31)$$

and

$$\frac{dL}{dt} = 0. \quad -(32)$$

These are integrated numerically in Section 3 to give any observable orbit. The numerical method checks that H and L are rigorously conserved, so the numerical and analytical techniques are correct and H and L are rigorously conserved, Q. E. D.

The orbital lagrangian in (r_1, ϕ) is

$$\mathcal{L} = -mc^2\left(n(r) - \frac{1}{c^2}\dot{\underline{r}}_1 \cdot \dot{\underline{r}}_1\right)^{1/2} + \frac{mMG}{r_1} \quad -(33)$$

$$= -mc^2\left(n(r) - \frac{1}{c^2}\left(\dot{r}_1^2 + r_1^2\dot{\phi}^2\right)\right)^{1/2} + \frac{mMG}{r_1}$$

and has the well known fundamental property:

$$\frac{d\mathcal{L}}{dt} = 0. \quad -(34)$$

The linear momentum from Eq. (33) is:

$$\underline{p}_1 = \frac{\partial \mathcal{L}}{\partial \dot{\underline{r}}_1} = \gamma m \dot{\underline{r}}_1 = \frac{\gamma m}{n(r)^{1/2}}\dot{\underline{r}} \quad -(35)$$

and is the same as the result obtained in UFT415 from the fundamental definition of the position vector $\underline{r}_1$ in the most general spherically symmetric space:

$$\underline{r}_1 = r_1 \underline{e}_r = \frac{r}{n(r)^{1/2}}\underline{e}_r \quad -(36)$$

The conserved angular momentum from Eq. (33) is:

$$L = \frac{\partial \mathcal{L}}{\partial \dot{\phi}} = \gamma m r_1^2 \dot{\phi} = \frac{\gamma m r^2}{m(r)} \dot{\phi} \quad -(37)$$

which is the same as the result from the geodesic method, Eq. (26), Q. E. D.

Furthermore, from Eqs. (35) and (36):

$$\underline{L} = \underline{r}_1 \times \underline{p}_1 = \frac{\gamma m r^2}{m(r)} \frac{d\phi}{dt} \underline{k} \quad -(38)$$

which is the same result again for the conserved angular momentum, giving a triple cross check on the angular momentum.

The Leibniz equation in the most general spherically symmetric space is:

$$\underline{\dot{p}}_1 = \frac{\partial \mathcal{L}}{\partial \underline{r}_1} \quad -(39)$$

i. e. :

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \underline{\dot{r}}_1}\right) = \frac{\partial \mathcal{L}}{\partial \underline{r}_1} \quad -(40)$$

and

$$\frac{d}{dt}\left(\frac{\gamma m \underline{\dot{r}}}{m(r)^{1/2}}\right) = -mMG\frac{\underline{r}_1}{r_1^3} \quad -(41)$$

The equations of motion (31) and (32) are developed numerically in Section 3 and in the coordinate system (r , ϕ) can be written as:

$$\ddot{r} = \left(\frac{dm(r)}{dr}\right)\left(c^2 m(r) + \frac{MG}{2\gamma^3 r\, m(r)^{1/2}} - \frac{3c^2}{2\gamma^2}\right) - \frac{dm(r)}{dr}\frac{\dot{\phi}^2 r^2}{m(r)}\left(2 - \frac{MG}{2\gamma c^2 r\, m(r)^{1/2}}\right) - \frac{MG\dot{\phi}^2}{\gamma c^2 m(r)^{1/2}}$$

$$+ \dot{\phi}^2 r - \frac{MG\, m(r)^{1/2}}{\ldots} \quad -(42)$$

$$-(43)$$

and

$$\ddot{\phi} = \frac{\dot{\phi}\,\dot{r}}{m(r)}\,\frac{dm(r)}{dr}\left(2 - \frac{MG}{2\gamma c^2 r\, m(r)^{1/2}}\right) + \frac{MG}{\gamma c^2 r^2 m(r)^{1/2}} - \frac{2}{r}\Bigg)$$

These are integrated as simultaneous equations giving a vast amount of new information about any observable orbit. A small sample of such information is presented in Section 3.

3. SOME RESULTS FROM EQS. (42) AND (43).

Section by Dr. Horst Eckardt.

General orbit theory in spherically symmetric spacetime

M. W. Evans[*], H. Eckardt[†]
Civil List, A.I.A.S. and UPITEC

(www.webarchive.org.uk, www.aias.us,
www.atomicprecision.com, www.upitec.org)

3 Some results from Eqs. (42) and (43)

3.1 Euler-Lagrange equations

We first present the equations of motion based on m space in extension of the computer algebra work of UFT 415. The velocity of an orbiting object in observer space is

$$v = \dot{r}^2 + r^2\dot{\phi}^2 \tag{44}$$

and the radial coordinate and velocity in m space are

$$r_1 = \frac{r}{\sqrt{\mathrm{m}(r)}}, \tag{45}$$

$$v_1 = \frac{v}{\sqrt{\mathrm{m}(r)}}. \tag{46}$$

In addition, the time is transformed inversely to r:

$$t_1 = \sqrt{\mathrm{m}(r)}\, t. \tag{47}$$

As worked out in section 2, the potential energy is

$$E_{\text{pot}} = -\sqrt{\mathrm{m}(r)}\,\frac{mMG}{r} \tag{48}$$

and the total relativistic energy is

$$E = (\mathrm{m}(r)\,\gamma - 1)\; mc^2 - \sqrt{\mathrm{m}(r)}\,\frac{mMG}{r} = \text{const} \tag{49}$$

with the γ factor of non-constant, spherically symmetric spacetime:

$$\gamma = \left(\mathrm{m}(r) - \frac{v_1^2}{c^2}\right)^{-1/2} = \left(\mathrm{m}(r) - \frac{\dot{r}^2 + r^2\dot{\phi}^2}{\mathrm{m}(r)\,c^2}\right)^{-1/2}. \tag{50}$$

*email: emyrone@aol.com
†email: mail@horst-eckardt.de

The conserverd angular momentum is

$$L = \gamma\, m\, r_1^2\, \dot\phi = \frac{\gamma}{\mathrm{m}(r)}\, m\, r^2\, \dot\phi = \text{const.} \tag{51}$$

The equations of motion are derived as Euler-Lagrange equations from the relativistic Lagrangian

$$\mathscr{L} = -\frac{mc^2}{\gamma} + \sqrt{\mathrm{m}(r)}\,\frac{mMG}{r}. \tag{52}$$

The Euler-Lagrange equations in normalized form are obtained from the analytical calculation by computer algebra:

$$\boxed{\ddot\phi = \dot\phi\, \dot r \left(\frac{\frac{d}{dr}\mathrm{m}(r)}{\mathrm{m}(r)} \left(2 - \frac{GM}{2\gamma\, c^2\, r\, \sqrt{\mathrm{m}(r)}} \right) + \frac{GM}{\gamma\, c^2\, r^2\, \sqrt{\mathrm{m}(r)}} - \frac{2}{r} \right),} \tag{53}$$

$$\boxed{\begin{aligned} \ddot r = & \left(\frac{d}{dr}\mathrm{m}(r)\right) \left(c^2\, \mathrm{m}(r) + \frac{GM}{2\gamma^3 r\, \sqrt{\mathrm{m}(r)}} - \frac{3c^2}{2\gamma^2} \right) \\ & - \frac{\frac{d}{dr}\mathrm{m}(r)}{\mathrm{m}(r)}\, \dot\phi^2 r_1^2 \left(2 - \frac{GM}{2\gamma c^2 r\, \sqrt{\mathrm{m}(r)}} \right) - \frac{GM\, \dot\phi^2}{\gamma\, c^2\, \sqrt{\mathrm{m}(r)}} \\ & + \dot\phi^2 r - \frac{GM\, \sqrt{\mathrm{m}(r)}}{\gamma^3\, r^2}. \end{aligned}} \tag{54}$$

The m function is to be predefined as a parameter of calculation. The equations and their results are very similar to the temporary version provided in UFT 415. Numerical examples are discussed in the next subsection.

Instead of executing the calculations in observer space (r, ϕ), we can completely switch to the m space coordinates (r_1, ϕ). With (45-47), all r-dependent quantities are transformed to r_1-dependent quantities, giving

$$E_{\text{pot}} = -\frac{mMG}{r_1} \tag{55}$$

$$E = (\mathrm{m}_1(r)\,\gamma - 1)\; mc^2 - \frac{mMG}{r_1} \tag{56}$$

$$\gamma = \left(\mathrm{m}(r) - \frac{v_1^2}{c^2} \right)^{-1/2} = \left(\mathrm{m}(r) - \frac{\dot r_1^2 + r_1^2 \dot\phi^2}{c^2} \right)^{-1/2} \tag{57}$$

$$L = \gamma\, m\, r_1^2\, \dot\phi \tag{58}$$

and the relativistic Lagrangian reads

$$\mathscr{L} = -\frac{mc^2}{\gamma} + \frac{mMG}{r_1}. \tag{59}$$

Since thisv Lagrangian is simpler structured than for the observer coordinate system (Eq.(52)), the resulting Euler-Lagrange equations are simpler:

$$\boxed{\ddot\phi = \dot\phi\, \dot r_1 \left(\frac{1}{\mathrm{m}(r_1)} \left(\frac{d}{dr_1}\mathrm{m}\,(r_1) + \frac{GM}{\gamma c^2\, {r_1}^2} \right) - \frac{2}{r_1} \right),} \tag{60}$$

$$\ddot{r}_1 = \left(\frac{d}{dr_1}\,\mathrm{m}\,(r_1)\right)\left(c^2\left(\frac{1}{2} - \frac{1}{\gamma^2\,\mathrm{m}\,(r_1)}\right) - \frac{\dot{\phi}^2 \dot{r}_1^2}{\mathrm{m}\,(r_1)}\right) - \frac{GM\,\dot{\phi}^2}{\gamma\,c^2\,\mathrm{m}\,(r_1)} + \dot{\phi}^2\,r_1 - \frac{GM}{\gamma^3\,{r_1}^2\,\mathrm{m}\,(r_1)}. \tag{61}$$

The last term of $\ddot{\phi}$ and the two last terms of $\ddot{r}$ are the non-relativistic expressions, where the gravitational potential has a factor of $1/\gamma^3$ as already observerd in UFT 415. In addition, the m function appears in both last terms.

3.2 Results of numerical calculations

The simultaneous equation set (53, 54) has been solved numerically. The results are essentially similar to those presented in UFT 415. In Fig. 1 the orbits $r(\phi)$ and $r_1(\phi)$ are graphed for a mass colliding with the centre where the m function of the extended Schwarzschild metric was used:

$$\mathrm{m}(r) = 1 - \frac{2MG}{c^2 r} - \frac{\alpha}{r^2}. \tag{62}$$

The r_1 orbit is slightly larger than the r orbit because m(1)=0.94 for the initial point r=1. When the r orbit collapses, m(r) goes to zero, letting r_1 go to infinity. The mass is repelled from the centre in the (r_1, ϕ) frame but falls into the centre in the observer frame (r, ϕ). As explained in UFT 415, the motion ends where m(r)=0.

In the subsequent calculations the exponential m function was used because it is not based on Einsteinian general relativity. Fig. 2 shows the counterpart of Fig. 1 calculated with the exponential m function

$$\mathrm{m}(r) = a - \exp\left(b\exp(-\frac{r}{R})\right). \tag{63}$$

The orbit spirals inwards for the r as well as the r_1 trajectories. Their time dependence is graphed in Fig. 3 and their velocity behaviour in Fig. 4. The velocities first rise when the orbiting mass comes near to the centre but then drop down sharply. The value v goes to zero, indicating that the orbiting mass comes to rest in the observer frame, but the velocity v_1 remains final in the frame (r_1, ϕ).

The relativistic angular momentum (Fig. 5) for the same motion remains constant until r approaches zero where the calculation diverges. The Newtonian values go to zero before this point because $v = 0$ and, consequently, $\dot{\phi} = 0$ at this point. The relativistic and Newtonian total energy are graphed in Fig. 6. In the Newtonian case the kinetic energy vanishes at the end point $r = 0$ and the potential energy diverges. As a consequence, the Newtonian total energy diverges to $-\infty$. In the relativistic case the divergence of the $1/r$ term is counteracted by the γ factor and the m function, as can be seen for example in the last term of Eq. (54). Therefore the total energy does not behave singular in this case.

In the following we investigate effects of an event horizon. It is not clear if such an entity exists in nature but from m theory such a structure is possible. We have introduced a zero point in m(r) at $r_0 = 0.3$ as shown in Fig. 7. The m function then reads

$$m(r) = a - \exp\left(b \exp(\pm\frac{r - r_0}{R})\right) \tag{64}$$

where the plus sign holds for $r < r_0$ and the minus sign for $r > r_0$. We first consider the outer space $r > r_0$. If the mass orbits at sufficient distance from the event horizon at r_0, we obtain, in the periodic case, the precessing ellipses and curves oscillating between two radii. Such a case is graphed in Fig. 8. If the initial velocity of the calculation goes below a certain value, the mass stops at the event horizon and stays there, see Fig. 9. The r_1 orbit diverges similarly to the case of Fig. 1. The reason may be that the m function (62) implicitly contains an event horizon, called the Schwarzschild radius.

The periodic motion of a mass within the horizon is graphed in Fig. 10. This is a precessing motion as long as the mass does not come too near to the event horizon. It is seen that the orbits r and r_1 become different in the outer region where they are nearer to the horizon. This is inverse to motion with a central m function (see for example Fig. 2). When the initial velocity exceeds a certain value, the mass is caught by the event horizon, leading to an end of motion. This case is graphed in Fig. 11. Interestingly, the r_1 orbit crosses the horizon and pertains infinitely but the r orbit ends at $r = r_0$. Obviously an event horizon is an insurmountable limit. This is different from obsolete black hole theory where a mass can freely fall through the event horizon.

The last calculations were done with the equation set (60, 61) which describes the motion a priori in (r_1, ϕ) space. Fig. 12 shows an orbit with forward precession. Since the orbit has always a larger distance to the centre, there is no visible difference between the r and r_1 trajectories. When the initial velocity is chosen smaller, i.e. the total energy is smaller in amount, we obtain retrograde precession, see Fig. 13 (observe the different length scales of both diagrams). Finally in Fig. 14 it is proven that also for the equation set (60, 61) the total energy is conserved, as is the angular momentum.

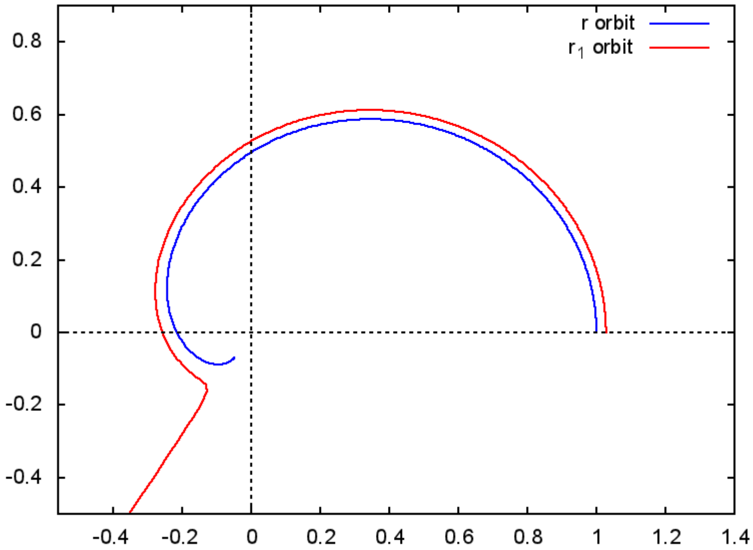

Figure 1: Orbits with Schwarzschild-like m function (62).

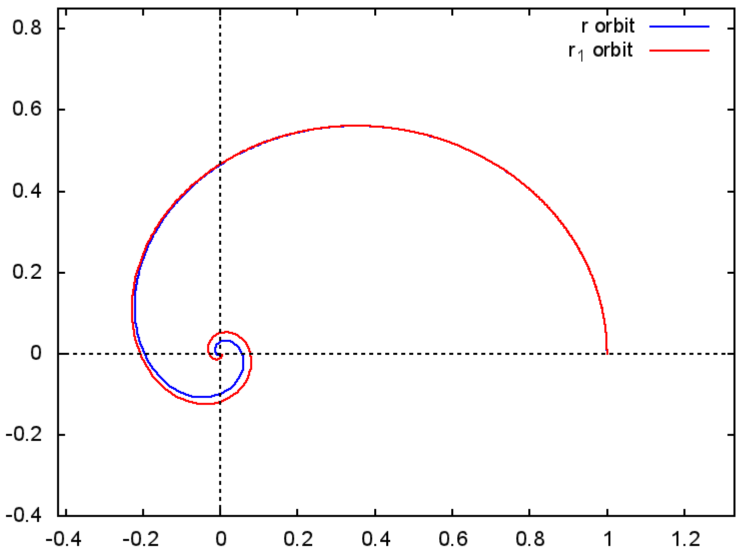

Figure 2: Orbits with exponential m function (63).

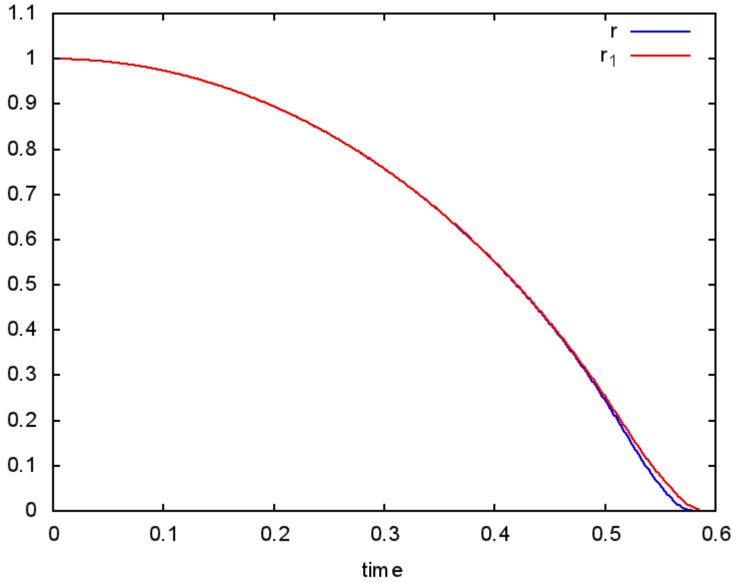

Figure 3: Trajectories $r(t)$ and $r_1(t)$.

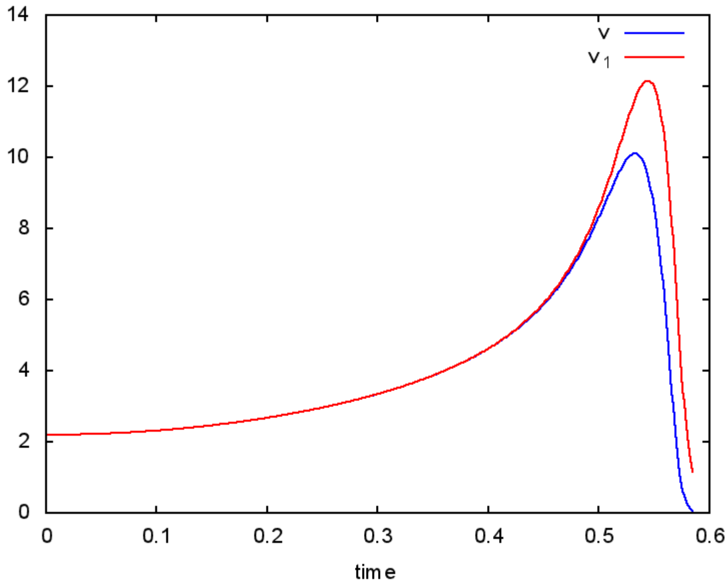

Figure 4: Trajectories $v(t)$ and $v_1(t)$.

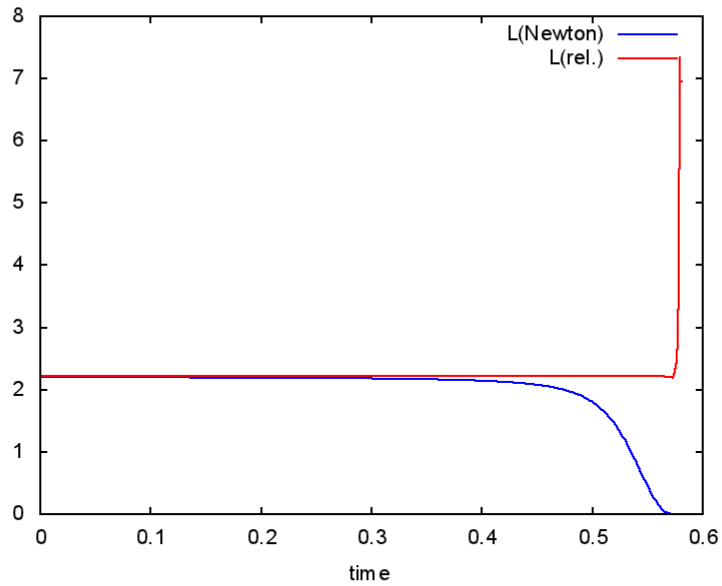

Figure 5: Angular momenta of motion.

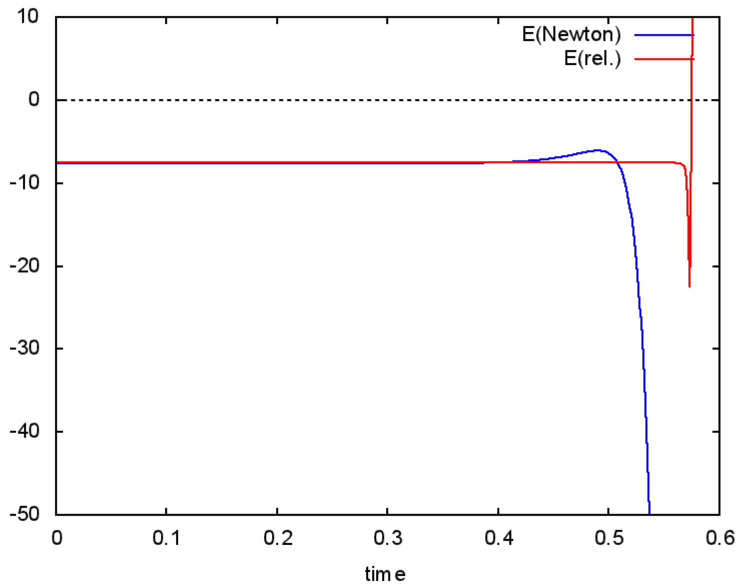

Figure 6: Total energy of motion.

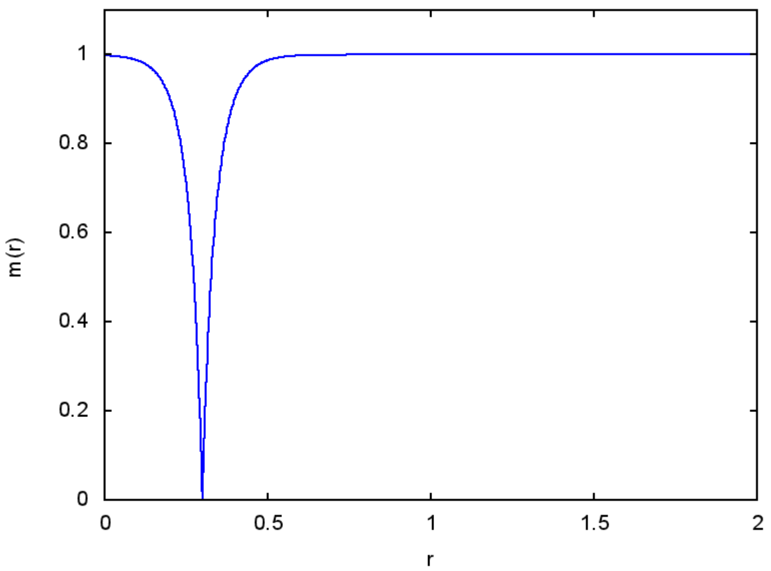

Figure 7: m function with event horizon at $r = 0.3$.

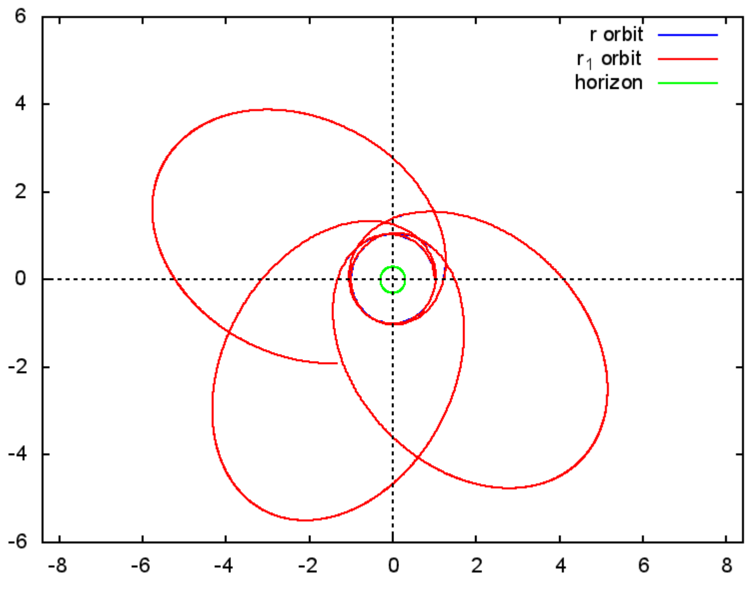

Figure 8: Periodic orbits outside of event horizon.

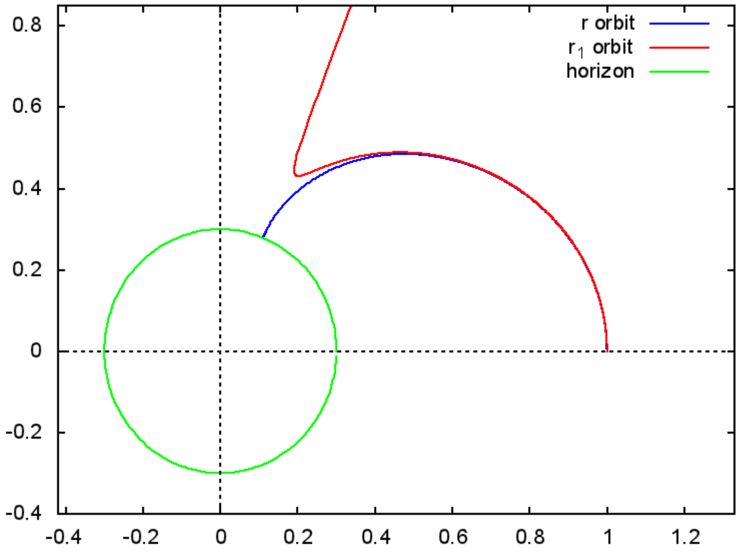

Figure 9: Collapsing orbits outside of event horizon.

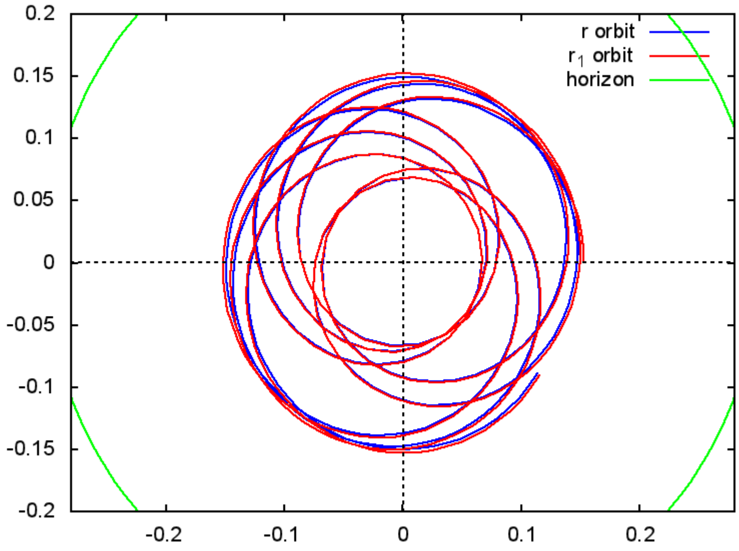

Figure 10: Periodic orbits inside event horizon.

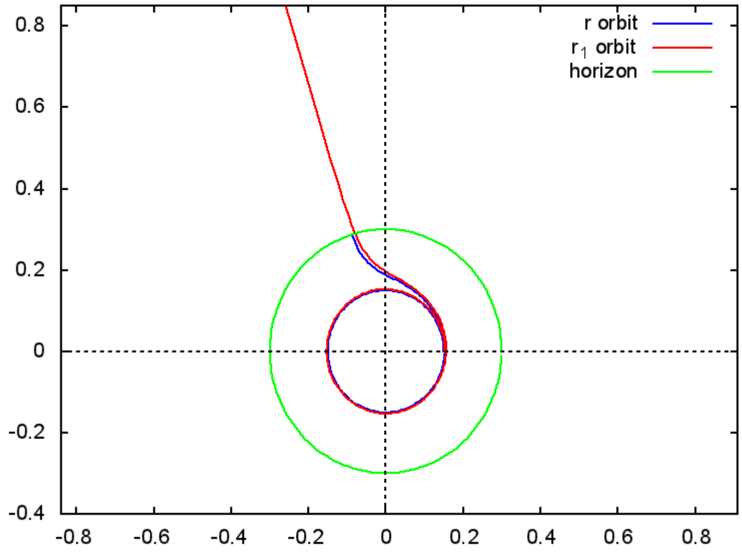

Figure 11: Collapsing orbits inside event horizon.

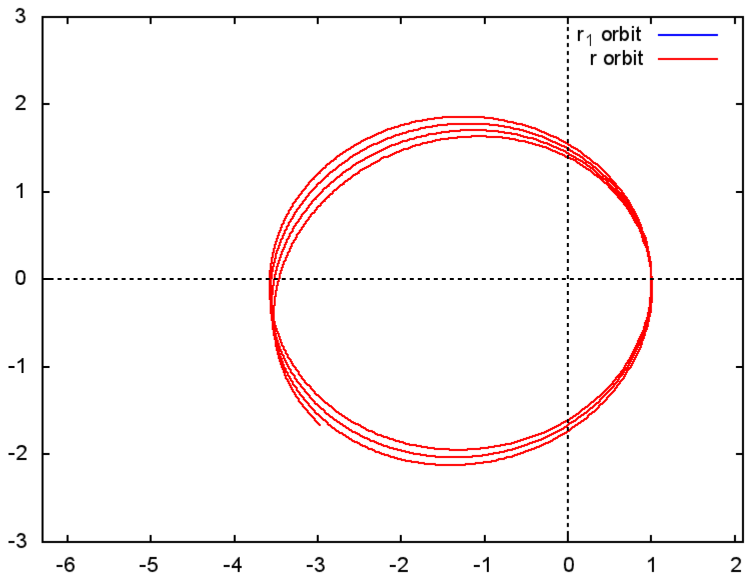

Figure 12: Orbit of equation set (60, 61) with forward precession.

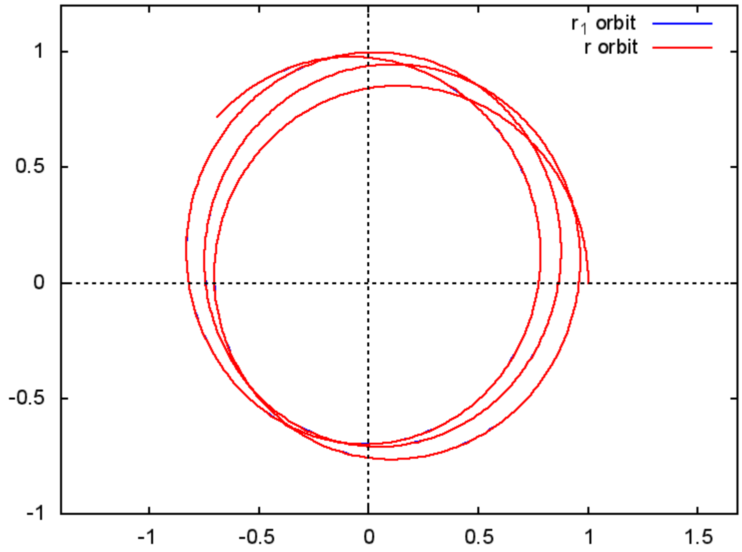

Figure 13: Orbit of equation set (60, 61) with retrograde precession.

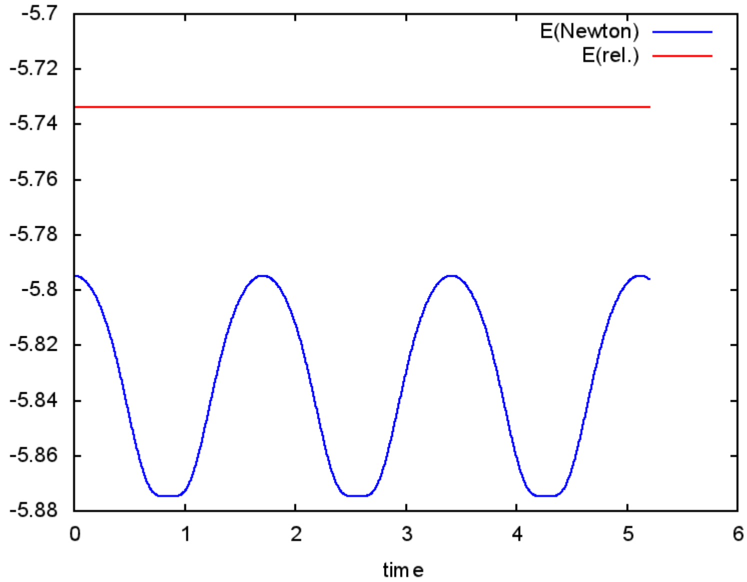

Figure 14: Total energy of motion with retrograde precession.

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