THE EVANS ECKARDT EQUATIONS OF MOTION

by

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ABSTRACT

The Evans Eckardt (EE) equations of motion are defined and developed in m theory. They are of general applicability in all branches of physics and are very fundamental because they are based on the well known fact that the hamiltonian and angular momentum are constants of motion. They are compared with the lagrangian development of m theory. The application of m theory is exemplified with galactic dynamics, in which Einsteinian general relativity (EGR) fails completely. The m theory is used to define an effective mass, confirming the work of UFT419, and its Cartesian representation developed; and m theory is applied to the Sagnac effect.

Keywords: ECE unified field theory, m theory, The Evans Eckardt equations of motion.

UFT 420

1. INTRODUCTION

In recent papers of this series {1 - 41} the m theory has been developed and applied to physics and cosmology. In Section 2 of this paper the Evans Eckardt (EE) equations of motion are defined directly from the fact that the hamiltonian (H) and angular momentum (L) of any well defined system are constants of motion. The EE equations can be applied to all branches of classical, relativistic and quantum physics, to any system in which H and L are well defined in m space, the most general spherically symmetric space. The EE equations are compared with the lagrangian methods of immediately preceding papers of this UFT series. It is found that the EE equations are more fundamental than the lagrangian method.

This paper is a short synopsis of extensive calculations and computations described in the notes accompanying UFT420 on www.aias.us. In Note 420(1) the m theory is applied to galaxies, in which Einsteinian general relativity (EGR) fails completely and is refuted entirely. The m theory produces the shape of any galaxy in terms of the m (r) function defined in immediately preceding papers of this series. In Note 420(2) the m theory is used to define the effective mass of an attracting orbit, and replaces black hole theory in this way. In Note 420(3) the Cartesian representation of m theory is developed. In Note 420(4) the m theory of the Sagnac effect is developed. Finally in Notes 420(5) to 420(7) the Evans Eckardt equations are defined and applied to relativistic classical dynamics. They are compared with the lagrangian methods of immediately preceding papers and shown to be more fundamental. They can be coded up and results produced from them in any branch of physics, chemistry and engineering.

2. DEVELOPMENT OF THE EE EQUATIONS

The Evans Eckardt equations of motion are:

$$\frac{dH}{dt} = 0 \qquad -(1)$$

and

$$\frac{dL}{dt} = 0 \qquad -(2)$$

where H is the hamiltonian and L the angular momentum of any well defined system in any branch of physics. The EE equations are based on the well known fact that H and L are constants of motion, and produce force equations from H and L. Consider the coordinate system used in immediately preceding papers, (r_1 , ϕ), where

$$r_1 = \frac{r}{m(r)^{1/2}}. \qquad -(3)$$

In this coordinate system:

$$H = m(r_1)\, m c^2 \gamma - \frac{mMG}{r_1} \qquad -(4)$$

and

$$L = \gamma m r_1^2 \dot{\phi} \qquad -(5)$$

where the generalized Lorentz factor is:

$$\gamma = \left(m(r_1) - \frac{\dot{\underline{r}}_1 \cdot \dot{\underline{r}}_1}{c^2} \right)^{-1/2}. \qquad -(6)$$

Here m is a mass orbiting a mass M and separated from it by a distance $\underline{r}_1$ in m space.

In Eq. (6):

$$\dot{\underline{r}}_1 \cdot \dot{\underline{r}}_1 = \dot{r}_1^2 + r_1^2 \dot{\phi}^2 \qquad -(7)$$

Using computer algebra produces the equations:

$$\frac{d^2 r_1}{dt^2} = \frac{c^2}{2}\frac{dm(r_1)}{dr_1}\left(1-\frac{1}{\gamma^2 m(r_1)}\right) - \left(\frac{d\phi}{dt}\right)^2 r_1 - \left(\frac{d\phi}{dt}\right)\left(\frac{d^2\phi}{dt^2}\right) r_1^2 \Big/ \frac{dr_1}{dt}$$
$$- \frac{mG}{\gamma^3 r_1^2 (m(r_1))^{1/2}}\left(1-\frac{dm(r_1)}{dr_1}\frac{r_1}{m(r_1)}\right) \quad -(8)$$

and

$$\frac{d^2\phi}{dt^2} = \left(\gamma^2 c^2 \frac{d\phi}{dt} r_1 \frac{dr_1}{dt}\frac{dm(r_1)}{dr_1} - 2\gamma^2\left(\frac{d\phi}{dt}\right) r_1 \frac{dr_1}{dt}\frac{d^2 r_1}{dt^2} \right. \quad -(9)$$
$$\left. -2\gamma^2\left(\frac{d\phi}{dt}\right)^3 r_1^2 \left(\frac{dr_1}{dt}\right) + 4c^2\left(\frac{d\phi}{dt}\right)\left(\frac{dr_1}{dt}\right)\right) \Big/ \left(2\gamma^2\left(\frac{d\phi}{dt}\right)^2 r_1^3 + 2c^2 r_1\right).$$

which may be integrated simultaneously to produce forward and retrograde precession of orbits. EGR fails entirely to produce retrograde precession. Eqs. (8) and (9) define shrinking orbits and several other effects described graphically in Section 3. They go well beyond the standard model of physics. In Note 420(7) it is shown how the Newtonian force equations are defined by the Evans Eckardt equations, in Cartesian and plane polar coordinates. In Newtonian physics the EE and lagrangian methods produce the same results, as shown in Note 420(9). This is also true in special relativity.

However, in m theory the EE equations from the hamiltonian (4) and angular momentum (5) are more fundamental than the lagrangian method. From Eqs. (1) and (4):

$$mc^2 \frac{d}{dt}\left(m(r_1)\gamma\right) = \frac{d}{dt}\frac{mMG}{r_1} = -\frac{mMG}{r_1^2}\dot{r}_1. \quad -(10)$$

Now use:

$$\frac{d}{dt}\left(m(r_1)\gamma\right) = \frac{d}{dv_1}\left(m(r_1)\gamma\right)\dot{v}_1 \quad -(11)$$

to find the EE equation of motion:

$$mc^2\frac{d}{dv_1}\left(m(r_1)\gamma\right)\dot{v}_1 = -\frac{mMG}{r_1^2}\,r_1 \quad -(12)$$

The Leibniz theorem gives:

$$\frac{d}{dv_1}\left(m(r_1)\gamma\right) = \gamma\frac{dm(r_1)}{dv_1} + m(r_1)\frac{d\gamma}{dv_1} \quad -(13)$$

where

$$\frac{d\gamma}{dv_1} = \gamma^3\frac{v_1}{c^2} \quad -(14)$$

so:

$$\left(m(r_1)v_1\gamma^3 + c^2\gamma\frac{dm(r_1)}{dv_1}\right)\frac{dv_1}{dt} = -\frac{mMG}{r_1^2}\,r_1 \quad -(15)$$

Now note that:

$$\begin{aligned}\frac{d}{dt}(\gamma v_1) &= \frac{d}{dv_1}(\gamma v_1)\frac{dv_1}{dt} \\ &= \left(\gamma + v_1\frac{d\gamma}{dv_1}\right)\frac{dv_1}{dt} = \left(\gamma + \gamma^3\frac{v_1^2}{c^2}\right)\frac{dv_1}{dt} \\ &= \gamma^3\frac{dv_1}{dt}\left(\frac{1}{\gamma^2} + \frac{v_1^2}{c^2}\right) \\ &= m(r_1)\gamma^3\frac{dv_1}{dt} \quad -(16)\end{aligned}$$

and use a Cartesian coordinate system in which:

$$v_1 = \dot{r}_1 \quad -(17)$$

to find that the EE equation of motion is:

$$\frac{d}{dt}\left(\gamma m \dot{r}_1\right) = -\frac{mMG}{r_1^2} - \frac{mc^2}{v_1}\frac{dv_1}{dt}\frac{dm(r_1)}{dv_1}\gamma \quad -(18)$$

Finally use:

$$\frac{dm(r_1)}{dr_1} = \frac{dm(r_1)}{dt}\frac{dt}{dr_1} = \frac{1}{v_1}\frac{dm(r_1)}{dt} \quad -(19)$$

and

$$\frac{dm(r_1)}{dt} = \frac{dm(r_1)}{dv_1}\dot{v}_1 \quad -(20)$$

to find that the EE equation of motion is:

$$\frac{d}{dt}\left(\gamma m \dot{r}_1\right) = -\frac{mMG}{r_1^2} - mc^2\gamma\frac{dm(r_1)}{dr_1} \quad -(21)$$

which correctly reduces to the well known Newtonian orbit force equation in Cartesian coordinates:

$$\ddot{r} = -\frac{MG}{r^2} \quad -(22)$$

in the limit:

$$\frac{dm(r_1)}{dr_1} \rightarrow 0, \; r_1 \rightarrow r, \; \gamma \rightarrow 1. \quad -(23)$$

The vacuum force of the EE equation (21) is:

$$F(\mathrm{vac}) = -\frac{\partial E}{\partial r_1} = -mc^2\gamma\frac{dm(r_1)}{dr_1} \quad -(24)$$

where the relativistic total energy of m theory is

$$E = \gamma m(r_1) mc^2 \quad -(25)$$

As shown in UFT417 the vacuum force becomes infinite under well defined conditions.

Note carefully that the lagrangian method used in UFT417 produces the result:

$$\frac{d}{dt}\left(\gamma m \dot{r}_1\right) = -\frac{mMG}{r_1^2} - \frac{mc^2}{2}\gamma \frac{dn(r_1)}{dr_1} \quad -(26)$$

from the lagrangian:

$$\mathcal{L} = -mc^2\left(n(r_1) - \frac{1}{c^2}\dot{\underline{r}}_1 \cdot \dot{\underline{r}}_1\right)^{1/2} + \frac{mMG}{r_1} \quad -(27)$$

and the Euler Lagrange equation:

$$\frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{\underline{r}}_1} = \frac{\partial \mathcal{L}}{\partial \underline{r}_1} = \underline{\nabla}\mathcal{L} = \frac{\partial \mathcal{L}}{\partial r_1}\underline{e}_r \quad -(28)$$

which in Cartesian coordinates is equivalent to

$$\frac{d}{dt}\left(\gamma m \dot{r}_1\right) = \frac{\partial \mathcal{L}}{\partial r_1}. \quad -(29)$$

The EE equations of motion produce a vacuum force which is twice that produced from the lagrangian method. Therefore in m theory the EE equations are the more fundamental equations and a lagrangian must be found to give the results of the EE equations. One way of finding the correct lagrangian is to add a lagrangian defined by:

$$\frac{\partial \mathcal{L}_1}{\partial r_1} = -\frac{mc^2}{2}\gamma \frac{dn(r_1)}{dr_1} \quad -(30)$$

and

$$\frac{\partial \mathcal{L}_1}{\partial \dot{r}_1} = 0 \quad -(31)$$

The lagrangian:

$$\mathcal{L}_2 = \mathcal{L} + \mathcal{L}_1 \quad -(32)$$

gives the EE equation (21) with the Euler Lagrange equation (28), given the constraint equations (30) and (31).

It is well known that the weak point of the lagrangian method is that the lagrangian must be chosen by inspection. On the other hand the EE equations are well defined from the beginning, and are based directly on the fact that H and L are constants of motion.

A possible solution of Eq. (30) is:

$$\mathcal{L}_1 = -\frac{mc^2}{2}\gamma m(r_1). \quad -(33)$$

Therefore Eq. (31) is:

$$\frac{\partial}{\partial \dot{r}_1}\left(\gamma m(r_1)\right) = 0 \quad -(34)$$

i. e.

$$m(r_1)\frac{\partial \gamma}{\partial \dot{r}_1} + \gamma \frac{\partial m(r_1)}{\partial \dot{r}_1} = 0 \quad -(35)$$

Therefore:

$$\frac{\dot{r}_1}{c^2}\gamma^3 + \gamma \frac{dm(r_1)}{\partial \dot{r}_1} = 0 \quad -(36)$$

Using:

$$\frac{dm(r_1)}{dt} = \frac{dm(r_1)}{dV_1}\dot{V}_1 \quad -(37)$$

it is found that the constraint equations (30) and (31) are equivalent to:

$$\frac{dm(r_1)}{dr_1} = -\frac{\dot{v}_1}{c^2}\gamma^2 \quad -(38)$$

which is a small quantity which vanishes self consistently in the non relativistic limit:

$$c^2 \rightarrow \infty . \quad -(39)$$

This finding is consistent with the fact that radiative corrections are very small corrections.

It could be argued that the lagrangian method produces results that are as fundamental as those from the EE equations, so results from both methods can be graphed and compared directly. However, the procedure that is almost always adopted in physics is to choose the lagrangian to give the results of the hamiltonian. There is also a well known general theorem linking the hamiltonian and lagrangian:

$$\mathcal{L} = \sum_i u_i p_i - H . \quad -(40)$$

It is considered however that it is possible to use the EE equations for any problem in physics, so that the lagrangian method is not needed, and there is no need to choose a lagrangian by inspection.

The EE equations and m theory entirely supercede Einsteinian general relativity. An example of this is given in note 420(1), in which it is shown that Newtonian and Einsteinian orbit theories fail completely to describe the velocity curve of a whirlpool galaxy. The reader is referred to the details in Note 420(1). In galaxies the EE equations are used to find the orbit function $dr/d\phi$, so the velocity curve can be calculated from:

$$v^2 = \frac{L^2 m(r)}{\gamma^2 m^2 r^2}\left(1 + \frac{1}{r^2}\left(\frac{dr}{d\phi}\right)^2\right) . \quad -(41)$$

Another example is given in Note 420(2), where the EE equations are used in a theory in which:

$$\frac{dm(r)}{dr} = 0. \quad -(42)$$

This theory defines an effective attracting mass and confirms the conclusions of UFT419 concerning the orbit of the S2 star. This orbit refutes EGR by a factor of a hundred, and is an ellipse which is non Keplerian. For details the reader is referred to Note 420(2) in which it is shown that m theory gives the most general type of orbit that results in a constant velocity at infinite r. In Note 420(3) the Cartesian representation of m theory is developed, and in Note 420(4) it is shown that the Sagnac effect in m theory is:

$$\Delta t = \frac{4 A r \Omega}{m(r) c^2} \quad -(43)$$

where Ar is the area of the Sagnac ring, Ω the rotational angular velocity of the platform, and Δt the time difference for clockwise and anticlockwise light travel. Therefore $m(r)$ can be measured directly in the Sagnac effect.

3 COMPUTATION OF THE EE EQUATIONS AND GRAPHICS.

Section by Dr. Horst Eckardt

The Evans Eckardt equations of motion

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3 Computation of the equations and graphics

3.1 Comparison between Hamiltonian and Lagrangian method in plane polar coordinates

The equations of motion have been derived by computer algebra for two coordinate systems of m space: the rest system of the orbiting mass (r_1, ϕ) and the observer system (r, ϕ). The equations of motion based on the Hamiltonian have been derived from

$$\frac{dH}{dt} = 0, \quad \frac{dL}{dt} = 0 \tag{44}$$

with the Hamiltonian in the rest system

$$H = m(r_1)\gamma\, m\, c^2 - \frac{mMG}{r_1} \tag{45}$$

and angular momentum in Z direction

$$L = \gamma\, m\, r_1^2\, \dot{\phi}. \tag{46}$$

The generalized Lorentz factor γ is defined in this case by

$$\gamma = \left(\mathrm{m}(r_1) - \frac{\dot{r_1}^2 + {r_1}^2\dot{\phi}^2}{c^2} \right)^{-1/2}. \tag{47}$$

The equations of motion obtained by computer algebra from (44) are

$$\boxed{\begin{aligned}
\ddot{\phi} =& \dot{\phi}\, \dot{r}_1 \left(\frac{1}{\mathrm{m}\,(r_1)} \frac{d\,\mathrm{m}\,(r_1)}{dr_1} + \frac{GM}{\gamma\, c^2\, {r_1}^2\, \mathrm{m}\,(r_1)} - \frac{2}{r_1} \right), & (48)\\
\ddot{r}_1 =& \frac{d\,\mathrm{m}\,(r_1)}{dr_1} \left(-\frac{\dot{\phi}^2\, {r_1}^2}{\mathrm{m}\,(r_1)} + c^2 \left(-\frac{1}{\gamma^2\ \mathrm{m}\,(r_1)} + \frac{1}{2} \right) \right) & (49)\\
& - \frac{GM\,\dot{\phi}^2}{\gamma\, c^2\ \mathrm{m}\,(r_1)} - \frac{GM}{\gamma^3\, {r_1}^2\, \mathrm{m}\,(r_1)} + \dot{\phi}^2\, r_1. &
\end{aligned}}$$

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For the alternative calculation, the Lagrangian is defined by

$$\mathscr{L} = -\frac{mc^2}{\gamma} + \frac{mMG}{r_1} \tag{50}$$

with the same γ factor (47). The Euler-Lagrange equations give the equations of motion

$$\ddot{\phi} = \dot{\phi}\,\dot{r}_1 \left(\frac{1}{2\,\mathrm{m}\,(r_1)} \frac{d\,\mathrm{m}\,(r_1)}{dr_1} + \frac{GM}{\gamma\, c^2\, {r_1}^2\, \mathrm{m}\,(r_1)} - \frac{2}{r_1} \right) \tag{51}$$

$$\begin{aligned} \ddot{r}_1 =& \frac{1}{\mathrm{m}\,(r_1)} \frac{d\,\mathrm{m}\,(r_1)}{dr_1} \left(-\frac{\dot{\phi}^2\, {r_1}^2}{2\,\mathrm{m}\,(r_1)} - \frac{c^2}{2\,\gamma^2} \right), \\ & - \frac{GM\,\dot{\phi}^2}{\gamma\, c^2} - \frac{GM}{\gamma^3\, {r_1}^2\, \mathrm{m}\,(r_1)} + \dot{\phi}^2\, r_1. \end{aligned} \tag{52}$$

For the $\ddot{\phi}$ component there is a difference of 1/2 in the first term, compared to the Hamiltonian solution. For $\ddot{r}_1$ there are some more differences. For a clean mathematical treatment, a Lagrangian had to be found which gives the same result as (48, 49).

A similar difference is found for the equations of motion in the observer coordinate system (r, ϕ). Then we have the γ factor

$$\gamma = \left(\mathrm{m}(r) - \frac{\dot{r}^2 + r^2\dot{\phi}^2}{c^2\,\mathrm{m}(r)} \right)^{-1/2}, \tag{53}$$

the Hamiltonian

$$H = m(r)\gamma\, m\, c^2 - \frac{mMG\sqrt{\mathrm{m}(r)}}{r}, \tag{54}$$

and the angular momentum

$$L = \frac{\gamma\, m\, r^2\, \dot{\phi}}{\mathrm{m}(r)}. \tag{55}$$

Eqs. (44) lead to the equations of motion

$$\boxed{\begin{aligned} \ddot{\phi} =& \dot{\phi}\,\dot{r} \left(\frac{1}{\mathrm{m}\,(r)} \frac{d\,\mathrm{m}\,(r)}{dr} \left(2 - \frac{GM}{2\gamma\, c^2\, r \sqrt{\mathrm{m}\,(r)}} \right) \right. \\ & \left. + \frac{GM}{\gamma\, c^2\, r^2 \sqrt{\mathrm{m}\,(r)}} - \frac{2}{r} \right), \qquad (56) \\ \ddot{r} =& \frac{1}{2} \frac{d\,\mathrm{m}\,(r)}{dr} \left(\frac{\dot{r}^2 - 3\dot{\phi}^2\, r^2}{\mathrm{m}\,(r)} + c^2 \left(\mathrm{m}\,(r) - \frac{2}{\gamma^2} \right) + \frac{GM}{\gamma^3 r \sqrt{\mathrm{m}(r)}} \right. \qquad (57) \\ & \left. + \frac{GM\dot{\phi}^2 r}{\gamma\, c^2 \mathrm{m}(r)^{3/2}} \right) \\ & - \frac{GM\,\dot{\phi}^2}{\gamma\, c^2\, \sqrt{\mathrm{m}\,(r)}} - \frac{GM\sqrt{\mathrm{m}\,(r)}}{\gamma^3\, r^2} + \dot{\phi}^2\, r. \end{aligned}}$$

The Lagrangian

$$\mathscr{L} = -\frac{mc^2}{\gamma} + \frac{mMG\sqrt{\mathrm{m}(r)}}{r} \tag{58}$$

with the γ factor (53) leads to the Euler-Lagrange equations

$$\begin{aligned}\ddot{\phi} =&\dot{\phi}\,\dot{r}\left(\frac{1}{\mathrm{m}\,(r)}\frac{d\,\mathrm{m}\,(r)}{dr}\left(2-\frac{GM}{2\gamma\,c^2\,r\sqrt{\mathrm{m}\,(r)}}\right)\right. \\ &\left.+\frac{GM}{\gamma\,c^2\,r^2\sqrt{\mathrm{m}\,(r)}}-\frac{2}{r}\right),\end{aligned} \tag{59}$$

$$\begin{aligned}\ddot{r} =&\frac{d\,\mathrm{m}\,(r)}{dr}\left(-\frac{2\dot{\phi}^2\,r^2}{\mathrm{m}\,(r)}+c^2\left(\mathrm{m}\,(r)-\frac{3}{2\gamma^2}\right)+\frac{GM}{2\gamma^3 r\sqrt{\mathrm{m}(r)}}\right. \\ &\left.+\frac{GM\dot{\phi}^2 r}{2\gamma\,c^2\mathrm{m}(r)^{3/2}}\right) \\ &-\frac{GM\,\dot{\phi}^2}{\gamma\,c^2\,\sqrt{\mathrm{m}\,(r)}}-\frac{GM\sqrt{\mathrm{m}\,(r)}}{\gamma^3\,r^2}+\dot{\phi}^2\,r.\end{aligned} \tag{60}$$

The equation for $\ddot{\phi}$ is identical to (56) but the equation for $\ddot{r}$ contains less terms for $d\mathrm{m}(r)/dr$, besides differences in constant factors.

Inspecting Eqs. (57) and (60), we find that the leading term for $d\mathrm{m}(r)/dr$ is that with the factor c^2 in the numerator, leading to a behaviour known from chaos theory as mentioned earlier. The results are extremely sensitive to $d\mathrm{m}(r)/dr$. Assuming a realistic case with

$$\gamma \approx 1, \quad m(r) \approx 1, \tag{61}$$

the leading factor of $d\mathrm{m}(r)/dr$ is approximately

$$-\frac{d\,\mathrm{m}\,(r)}{dr}\frac{c^2}{2} \tag{62}$$

in both equations. Therefore, for realistic systems as the S2 star, both sets of equations lead to the same results. This has been checked numerically. For the example shown in Fig. 10 of UFT419, both orbit plots are indiscernible. Test with model parameters always gave the same result, even in ultrarelativistic cases. This may indicate that the important terms of the Hamiltonian and Lagrangian method are equal in their effect.

3.2 Comparison between Hamiltonian and Lagrangian method in cartesian coordinates

In earlier work we had derived the relativistic Lagrange equations of motion in cartesian coordinates which are

$$\ddot{\mathbf{r}} = \frac{M\,G}{\gamma\,r^3}\left(\frac{\dot{\mathbf{r}}\,(\dot{\mathbf{r}}\cdot\mathbf{r})}{c^2}-\mathbf{r}\right) \tag{63}$$

with position vector

$$\mathbf{r} = \begin{bmatrix} X \\ Y \end{bmatrix} \tag{64}$$

and its modulus

$$r = \sqrt{X^2 + Y^2}. \tag{65}$$

The γ factor in m space with rest system coordinates X_1, Y_1 is

$$\gamma = \left(\mathrm{m}(r_1) - \frac{\dot{X}_1{}^2 + \dot{Y}_1{}^2}{c^2} \right)^{-1/2} \tag{66}$$

with

$$r_1 = \sqrt{X_1{}^2 + Y_1{}^2}. \tag{67}$$

Instead of writing $\mathrm{m}(X_1, Y_1)$ we maintain the the dependence of the m function in the form $\mathrm{m}(r_1)$ because m is defined for a spherically symmetric spacetime. Hamiltonian and angular momentum then read

$$H = m(r_1)\gamma\, m\, c^2 - \frac{mMG}{\sqrt{X_1{}^2 + Y_1{}^2}}, \tag{68}$$

$$L = \gamma\, m\, (X_1 \dot{Y}_1 - \dot{X}_1 Y_1). \tag{69}$$

Solving Eqs.(44) gives quite complicated expressions. For $\mathrm{m}(r_1)$=$\overline{\mathrm{m}}$=const. The solution is

$$\ddot{\mathbf{r}}_1 = \frac{M\,G}{\gamma\, r_1{}^3 c^2 \overline{\mathrm{m}}} \begin{bmatrix} -X_1 \dot{Y}_1^2 + Y_1 \dot{X}_1 \dot{Y}_1 \\ -Y_1 \dot{X}_1^2 + X_1 \dot{X}_1 \dot{Y}_1 \end{bmatrix} - \frac{M\,G}{\gamma^3\, r_1{}^3 \overline{\mathrm{m}}} \mathbf{r}_1. \tag{70}$$

In the oberver system (X, Y) we have

$$\gamma = \left(\mathrm{m}(r) - \frac{\dot{X}^2 + \dot{Y}^2}{c^2 \mathrm{m}(r)} \right)^{-1/2} \tag{71}$$

$$H = \mathrm{m}(r)\gamma\, m\, c^2 - \frac{mMG\sqrt{\mathrm{m}(r)}}{\sqrt{X^2 + Y^2}}, \tag{72}$$

$$L = \frac{\gamma\, m\, (X\dot{Y} - \dot{X}Y)}{\mathrm{m}(r)}, \tag{73}$$

and the equations of motion for constant $\mathrm{m}(r)$=$\overline{\mathrm{m}}$ are

$$\ddot{\mathbf{r}} = \frac{M\,G}{\gamma\, r^3 c^2 \sqrt{\overline{\mathrm{m}}}} \begin{bmatrix} -X\dot{Y}^2 + Y\dot{X}\dot{Y} \\ -Y\dot{X}^2 + X\dot{X}\dot{Y} \end{bmatrix} - \frac{M\,G\sqrt{\overline{\mathrm{m}}}}{\gamma^3\, r^3} \mathbf{r}. \tag{74}$$

These are equal to Eq. (70) except for the factor $\overline{\mathrm{m}}$.

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