DIRECT ORBITAL DYNAMICS: USING INDEPENDENT ORBITAL TERMS TO TREAT BODIES AS ORBITING EACH OTHER DIRECTLY WHILE IN MOTION

Daniel S. Orton
email: dsorton1@gmail.com

Abstract: There are many longstanding problems associated with orbital systems at all scales. Direct Orbital Dynamics applies a set of independent orbital terms to the Newtonian orbital equations, in place of the standard combined orbital terms. This results in a number of surprisingly successful applications. The standard orbital equations treat the bodies in a two-body system as orbiting their mass center point at the combined orbital period. These orbital terms are all combined terms containing the influence of both bodies. The direct orbital system treats each body as orbiting the other body directly at the full radius distance, with each body also orbiting the other at its own natural, independent orbital period (which is a portion of the combined period). The orbital velocity of each body is now based solely on the mass and radius distance of the body being orbited. It is no longer affected by the mass of the orbiting body, as in the standard system, because the effects of the combined orbital terms are removed from the calculations. The orbital equations remain balanced when using the terms of the direct orbital system frame of reference, with some additional equations balancing. The direct orbital set of equations initially treats the bodies as orbiting each other independently rather than as a combined system. The two bodies are treated as being the orbital center points of each other. However, these two orbital center points are also in motion and are constantly altering the orbital direction of the two bodies. The orbiting bodies must therefore be treated as responding to both the gravitational acceleration and the physical motion of each other. This additional motion factor of the orbital center points is then applied to the direct orbital system. This results in the same mass and velocity to the fourth power relationship found in the excessive orbital velocities and flat rotation curves of disk galaxies, as seen in the Baryonic Tully Fisher Relation ($M \propto V^4$). These excessive velocities are thought to be caused by either halos of dark matter, or by a change in gravitation at low accelerations (MOND). Direct Orbital Dynamics is shown to be the source of this fourth power radial force law. This same mass-velocity relationship of galaxies is found to also exist in smaller orbiting systems within the high acceleration Newtonian regime. The direct orbital system goes on to provide successful application to well known orbital problems.

Keywords: cosmology: dark matter – galaxies: kinematics and dynamics – galaxies: structure – planets and satellites: dynamical evolution and stability – gravitation

1 Introduction

There are many well known problems associated with orbital systems at all levels, from the flyby anomaly of spacecraft swinging around the Earth, to the excessive velocities of galaxies orbiting within clusters [1, 2]. Other notable examples include problems with the formation and evolution of orbiting systems, the many orbital angular momentum distribution problems [3], specific problems with the formation of the moons of both Pluto and the Earth [4], and the flat rotation curves and excessive orbital velocities of stars within disk galaxies [5,6]. This last example led to the theories of dark matter halos and Modified Newtonian Dynamics (MOND) in an attempt to account for these observations [7-12]. The Direct Orbital Dynamics System uses a set of independent orbital terms in the standard Newtonian orbital equations with successful results in addressing a number of orbital problems.

The standard orbital equations use the observed orbital period and the radius distance of each body to the mass center point for the orbital terms of a two-body system. These are combined orbital terms that are dependent on the mass of both the orbiting body and the body being orbited. If an orbiting body is increased in size, its orbital terms are altered by an increase in its orbital radius to the mass center point, and by a decrease in the combined orbital period of the system. A change in the size of the mass of the orbiting body affects its orbital radius, period, and velocity, because these are all combined, dependent terms. This system will be referred to as the combined orbital system because it uses combined orbital terms. The alternative system will be referred to as the direct orbital system because it uses direct orbital terms.

In the direct orbital system the orbital terms are no longer combined orbital terms that are dependent on the orbiting body's own mass. This system treats both bodies as orbiting each other directly at the full radius distance between them, but at the reduced individual orbital period each body would have if the other body was not in motion, or if the mass of the orbiting body was negligible in comparison to the mass of the larger body. The individual orbital periods of the two bodies each comprise part of the observed orbital period of the system (within the terms for the square of the orbital period in the centripetal acceleration equations). If an orbiting body is increased in size, its orbital terms are no longer altered. In the direct orbital system a change in the size of the mass of the orbiting body does not affect its orbital radius, period, or velocity, because the direct orbital terms are all independent terms. Each body is treated as being the orbital center point and direct frame of reference of the other body, and these frames of reference are in motion as will also be addressed.

2 The Independent Orbital Terms of Direct Orbital Dynamics

It would seem that the direct and combined orbital systems should be equivalent in all the orbital calculations, and that the orbital terms in the two systems would be proportional. Both systems yield the same result for the centripetal acceleration of each of the bodies in a two-body system. However, the orbital velocities of the two bodies in the direct orbital system are not equivalent or proportional to the orbital velocities in the combined orbital system, and this is seen within the equivalent sets of centripetal acceleration equations. This difference between the two systems is a crucial factor and has application to many of the orbital problems that are observed.

In order to calculate the velocities of orbiting bodies in the direct orbital system, the individual orbital periods of the two bodies must first be calculated. This can be done by using the F=Ma equation of Newton's Second Law of Motion, inserting the full radius term into the acceleration formula, and solving for the orbital period (T). Circular orbits are assumed for simplicity in all calculations of examples. For the equivalence of the gravitational force and the centripetal force of the smaller body, F=Ma simplifies to

$$GM_1M_2/r^2 = M_2 4\pi^2 r_2^2/T^2 r_2 \quad (\text{or } M_2 4\pi^2 r_2/T^2) \tag{1}$$

and for the equivalence of the gravitational force and centripetal force of the larger body it simplifies to

$$GM_1M_2/r^2 = M_1 4\pi^2 r_1^2/T^2 r_1 \quad (\text{or } M_1 4\pi^2 r_1/T^2) \tag{2}$$

where G is the gravitational constant ($6.67 \times 10^{-11} m^3 kg^{-1} s^{-2}$), M_1 is the mass of the larger body, M_2 is the mass of the smaller body, r is the full radius distance, r_1 is the distance of the larger body to the center of mass of the two-body system, and r_2 is the distance of the smaller body to the center of mass.

Equation 1 can be used to solve for the individual orbital period (T_2) of the smaller body if the mass of the smaller body (M_2) is on the right hand side. In the centripetal acceleration portion of the equation on the right, the terms for the radius distance to the center of mass (r_2) must be replaced with the terms for the full orbital radius distance between the two bodies (r). Now that all the other terms are identified, the individual orbital period of the smaller body (T_2) can be solved for in the equation below

$$GM_1M_2/r^2 = M_2 4\pi^2 r^2/T_2^2 r \quad (\text{or } M_1 4\pi^2 r/T_2^2) \tag{3}$$

where T_2 represents the orbital period that the smaller body has relative to the larger body when the larger body is used as its frame of reference. This is the same as the orbital period the smaller body would have around the larger body if the larger body was not in motion, or if the smaller body had negligible mass relative to the larger body. Solving this equation for T_2 would then give the individual orbital period of the smaller body relative to the frame of reference of the larger body.

Equation 2 can be solved for the individual orbital period of the larger body (T_1) if the mass of the larger body (M_1) is instead placed on the right hand side of the equation as

$$GM_1M_2/r^2 = M_1 4\pi^2 r^2/T_1^2 r \quad (\text{or } M_1 4\pi^2 r/T_1^2) \tag{4}$$

where T_1 represents the orbital period that the larger body has relative to the smaller body when the smaller body is used as its frame of reference. Solving this equation for T_1 would then give the individual orbital period of the smaller body relative to the frame of reference of the larger body.

The two independent, individual orbital periods of the bodies in the direct orbital system (T_1 and T_2) appear in the acceleration portions of the equations above (Equations 3 and 4) as inverse squares: $1/T_1^2$ and $1/T_2^2$. These two components within the centripetal acceleration calculations combine together to form the inverse square of the combined orbital period ($1/T^2$) of the two-body system. This combination of terms appears as

$$1/T_1^2 + 1/T_2^2 = 1/T^2 \tag{5}$$

or

$$T_2^2 + T_1^2 = (T_1^2 \cdot T_2^2)/T^2 \tag{6}$$

The combined orbital period is therefore composed of the individual orbital periods of the two bodies. This shows that the two bodies really are orbiting each other directly as their frames of reference in the direct orbital system, because the two individual orbital periods of the bodies (T_1 and T_2) are actually present as components of the combined orbital period of the system (T).

The full radius distance and individual orbital period terms of the Direct Orbital Dynamics System can now be inserted into the standard Newtonian orbital equations. The orbital terms in the direct orbital system are dependent only on the mass of the body being orbited and the full radius distance. These direct orbital terms are not dependent on the mass of the orbiting body, as in the combined orbital system. Each body's set of direct orbital terms is mathematically independent from their own masses.

The orbital velocities within the centripetal acceleration equations represent each body's orbital response to the gravitational acceleration (GM/r^2) of the other body. The full radius distance term and the individual orbital period terms in the direct orbital system are used in place of the combined orbital terms to calculate the orbital velocity that a body of any size would have when orbiting another body as its frame of reference. This provides a single orbital velocity that any orbiting body would have as a result of the gravitational acceleration of the body being orbited.

In the combined orbital system this cannot be done because the combined orbital terms, the radii distances to the center of mass and the combined orbital period, are dependent on the masses of both the orbiting body and the body being orbited. This dependent orbital velocity is calculated to be different for orbiting bodies of different mass located at the same radius distance from the body being orbited. A change in the mass of the orbiting body causes a change in its orbital velocity in the combined orbital system . This does not happen with the orbital velocities using the orbital terms of the direct orbital system.

3 The Proportionality Contradiction of Orbital Velocities in the Direct and Combined Orbital Systems

The orbital velocity of a body calculated in the direct orbital system is neither equivalent nor proportional to the velocity of a body in the combined orbital system due to a proportionality difference in the orbital terms. In the combined system the radius distance of each body to the center of mass (r_1 and r_2) is variable in the two centripetal acceleration equations for the two bodies. In the direct orbital system, it is the the inverse squares of the orbital periods ($1/T_1^2$ and $1/T_2^2$) that are variable in these two acceleration equations. So when the orbital velocity ($2\pi r/T$) of each body is calculated, the velocity varies as the radius r in the combined orbital equations (Equations 1 and 2), and it varies as the inverse square of the orbital period $1/T^2$ in the direct orbital equations (Equations 3 and 4). The set of variables in the direct system is based on a squared term, and the set of variables in the combined system is not based on a squared term. This disproportionality in the sets of variables causes the proportionality difference in the calculation of the orbital velocities in the two systems. The calculated velocities in the direct orbital system could never be equivalent to those in the combined orbital system because of this proportionality difference in their terms.

In the direct orbital system the velocities of the two bodies are inversely proportional to the square roots of the masses. In the combined orbital system the velocities of the bodies are inversely proportional to the masses directly. This difference affects the calculations of all the orbital equations containing the velocity terms.

The calculation for the centripetal accelerations of the two bodies yields the same result in both the direct and combined systems. Simplifying the centripetal acceleration term (a) in the force equation (F=Ma) gives the equation

$$a = v^2/r \tag{7}$$

The equivalence of the centripetal acceleration calculations for the smaller body in the combined and direct orbital systems (using their respective orbital terms) appears as

$$v^2/r_2 = v_2^2/r \tag{8}$$

where v is the velocity of the smaller body in the combined orbital system, and v_2 is the velocity of the smaller body in the direct orbital system. The equivalence of the acceleration calculations for the larger body in the combined and direct orbital systems appears as

$$v^2/r_1 = v_1^2/r \tag{9}$$

where v_1 is the velocity of the larger orbiting body in the direct orbital system.

In comparing these equivalent sets of centripetal acceleration equations for the direct and combined orbital systems (Equations 8 and 9), each body has different radius (r) terms in the denominator, and each body has different velocity squared (v^2) terms in the numerator. The velocity terms of both of the bodies in the combined orbital system are made variable by the variable term for the radius distance to the mass center point located in the denominator of their centripetal acceleration equations. The velocity terms of both of the bodies in the direct orbital system are not variable because the radius terms in the denominators of their acceleration equations are always the full radius distance between the bodies, which is not variable (at a given radius distance). In this comparison of the the direct and combined orbital systems, the lack of equivalence and proportionality in the velocities of the bodies between the two systems will be shown to be the key to many of the problems that are currently seen in orbital systems.

4 Comparison of the Centripetal Acceleration Equations in the Direct and Combined Orbital Systems

The formula for centripetal acceleration is v^2/r (Equation 7) which simplifies to

$$4\pi^2r^2/T^2r \quad (\text{or } 4\pi^2r/T^2) \tag{10}$$

The centripetal acceleration formula for the larger body in the combined orbital system appears as

$$4\pi^2r_1/T^2 \tag{11}$$

and the centripetal acceleration formula for the smaller body in the combined orbital system appears as

$$4\pi^2r_2/T^2 \tag{12}$$

where r_1 and r_2 are the radius distances of the larger and smaller bodies to the center of mass of the combined system. These are the centripetal acceleration equations in the combined orbital system.

The centripetal acceleration formula for the larger body in the direct orbital system appears as

$$4\pi^2 r/T_1^2 \tag{13}$$

and the centripetal acceleration formula for the smaller body in the direct orbital system appears as

$$4\pi^2 r/T_2^2 \tag{14}$$

where T_1 and T_2 are the individual orbital periods of the larger and smaller bodies relative to the opposite body. These last two equations are the acceleration equations in the direct orbital system.

The variables that differ in the centripetal acceleration equations of the two systems are the orbital radii to the mass center point in the combined orbital system, and the individual orbital periods in the direct orbital system. If the two centripetal acceleration equations in the combined orbital system are added together, the radii distances to the center of mass combine to form the full radius distance. If the two centripetal acceleration equations are combined in the direct orbital system, the inverse-squares of the two individual orbital periods of the bodies combine to form the inverse square of the combined orbital period of the system.

The gravitational acceleration of the body being orbited is equal to the centripetal acceleration of the orbiting body in both the combined orbital system and the direct orbital system. The equivalence of the larger body's gravitational acceleration to the two equivalent centripetal accelerations of the smaller body (in Equation 8)

$$GM_1/r^2 = 4\pi^2 r_2^2/T^2 r_2 = 4\pi^2 r^2/T_2^2 r \tag{15}$$

The equivalence of the smaller body's gravitational acceleration to the two equivalent centripetal acceleration calculations of the larger body (in Equation 9) in the combined and direct orbital systems, respectively, appears as

$$GM_2/r^2 = 4\pi^2 r_1^2/T^2 r_1 = 4\pi^2 r^2/T_1^2 r \tag{16}$$

The two portions of the equation on the right side in Equation 15 express the equivalence of the centripetal accelerations calculated for the smaller orbiting body in both the combined orbital system and direct orbital system, respectively. This equivalence is

$$4\pi^2 r_2^{\,2}/T^2 r_2 = 4\pi^2 r^2/T_2^{\,2} r \tag{17}$$

and like terms can be cancelled out on each side to give

$$r_2/T^2 = r/T_2^{\,2} \tag{18}$$

which is the same radius and orbital period relationship as in Equation 8. The two portions of the equation on the right side in Equation 16 similarly express the equivalence of the centripetal accelerations calculated for the larger orbiting body in both the combined orbital system and direct orbital system, respectively. This equivalence is

$$4\pi^2 r_1^{\,2}/T^2 r_1 = 4\pi^2 r^2/T_1^{\,2} r \tag{19}$$

and like terms can be cancelled out on each side to give

$$r_1/T^2 = r/T_1^{\,2} \tag{20}$$

which is the same radius and orbital period relationship as in Equation 9.

If Equation 18 is then divided by Equation 20 in order to give a ratio of the smaller body's orbital terms to the larger body's orbital terms in the two systems, the equation appears as

$$\frac{r_2/T^2}{r_1/T^2} = \frac{r/T_2^{\,2}}{r/T_1^{\,2}} \tag{21}$$

and by deleting like terms on both sides it becomes

$$\frac{r_2}{r_1} = \frac{1/T_2^{\,2}}{1/T_1^{\,2}} \tag{22}$$

or the expression on the right can be inverted to give

$$\frac{r_2}{r_1} = \frac{T_1^{\,2}}{T_2^{\,2}} \tag{23}$$

which gives the relationship between the radius variables in the combined orbital system to the squared orbital period variables in the direct orbital system.

5 Comparison of the Mass-Velocity Relationship in the Direct and Combined Systems

In the combined orbital system, the terms for the radii distances of the smaller and larger bodies to the mass center point (r_2 and r_1) are in the ratio on the left side of Equation 22. The ratio of the masses of the two bodies (M_1 and M_2) is inversely proportional to the ratio of these two mass center point distances in the combined orbital system, therefore

$$\frac{M_1}{M_2} = \frac{r_2}{r_1} \tag{24}$$

Because of the equivalency of terms in Equation 22, this means that the ratio of the masses of the two bodies is also inversely proportional to the ratio of the inverse squares of the individual orbital periods of the two bodies in the direct orbital system, therefore

$$\frac{M_1}{M_2} = \frac{1/{T_2}^2}{1/{T_1}^2} \tag{25}$$

If both of the r terms in Equation 24 are each multiplied by 2π/T, then the velocity of the smaller body in the combined orbital system appears in the numerator and the velocity of the larger body appears in the denominator on the right hand side of the equation. This equation now appears as

$$\frac{M_1}{M_2} = \frac{2\pi r_2/T}{2\pi r_1/T} \tag{26}$$

This equation shows that the velocities of the two orbiting bodies in the combined orbital system are inversely proportional to the masses of the bodies. The velocities in this system are relative to the center of mass.

If both of the $1/T^2$ terms in Equation 25 are multiplied by $4\pi^2 r^2$, then it is the square of the velocity of the smaller body that appears in the numerator and the square of the velocity of the larger body that appears in the denominator on the right hand side of the equation for the direct orbital system. The equation appears as

$$\frac{M_1}{M_2} = \frac{4\pi^2 r^2/{T_2}^2}{4\pi^2 r^2/{T_1}^2} \tag{27}$$

or this equation can be also be expressed as

$$\frac{M_1}{M_2} = \frac{(2\pi r/T_2)^2}{(2\pi r/T_1)^2} \tag{28}$$

It is the squares of the orbiting velocities of the two bodies that are inversely proportional to the masses of the bodies in the direct system. This is very different from the velocities in the combined orbital system shown in Equation 26. If we take the square root of each side of Equation 28, then the velocities of the bodies in the direct orbital system are inversely proportional to the square roots of the masses. This equation appears as

$$\frac{\sqrt{M_1}}{\sqrt{M_2}} = \frac{2\pi r/T_2}{2\pi r/T_1} \tag{29}$$

Both the combined orbital system and the direct orbital system calculate the same centripetal accelerations for the bodies in a two-body orbital system. But they do so with different sets of orbital terms. This difference in terms causes the velocities in the combined orbital system to be inversely proportional to the masses of the bodies, while it causes the squares of the velocities in the direct orbital system to be inversely proportional to the masses (before the inclusion of the additional motion factor of the orbital center points in Section 7).

6 The Application of Direct Orbital Dynamics to the Orbital Equations

The terms used in the orbital equations for the Direct Orbital Dynamics frame of reference are the full radius distance between the bodies (r), the individual orbital period of the smaller body relative to the larger (T_2), and the individual orbital period of the larger body relative to the smaller (T_1). These terms can be inserted into all the standard Newtonian orbital equations with successful results that balance the equations. These calculations provide the direct orbital response of each body to the gravitational equations without using the combined terms of the standard system.

This set of equations is important because it shows the gravitational action and orbital reaction taking place in the direct orbital system before the factoring in of the interactive motion of the two bodies and their orbital center points in the next section. This set of gravitational and orbital equations with actual calculations is located in the middle column of Table 2 below, with the first column containing the combined orbital system calculations for comparison, and the third column containing the direct orbital system with the application of the additional motion factor. The calculations for the orbital angular momentum of the two bodies will be addressed separately in the next section as well, as they carry another important difference. Below are the gravitational and equivalent orbital equations of the direct orbital system.

The orbital equations using the terms of the Direct Orbital Dynamics System:

Gravitational Force = Centripetal Force or F = Ma
(For both the larger body M_1 and the smaller body M_2)

$$GM_1M_2/r^2 = M_2v_2^2/r = M_2 4\pi^2r^2/T_2^2r \tag{30}$$

$$GM_1M_2/r^2 = M_1v_1^2/r = M_1 4\pi^2r^2/T_1^2r \tag{31}$$

Gravitational Acceleration = Centripetal Acceleration (For both M_1 and M_2)

$$GM_1/r^2 = 4\pi^2r^2/T_2^2r \quad \text{(Centripetal Acceleration of the smaller body)} \tag{32}$$

$$GM_2/r^2 = 4\pi^2r^2/T_1^2r \quad \text{(Centripetal Acceleration of the larger body)} \tag{33}$$

Gravitational Potential Energy + Kinetic Energy M_2 + Kinetic Energy M_1 = 0 (For M_1 and M_2)

$$-GM_1M_2/r + (\tfrac{1}{2})M_2 4\pi^2r^2/T_2^2 + (\tfrac{1}{2})M_1 4\pi^2r^2/T_1^2 = 0 \tag{34}$$

Kinetic Energy of the Smaller Body (M_2) = Kinetic Energy of the Larger Body (M_1)

$$(\tfrac{1}{2})M_2 4\pi^2r^2/T_2^2 = (\tfrac{1}{2})M_1 4\pi^2r^2/T_1^2 \tag{35}$$

Negative ½ Gravitational Potential Energy = Orbital Kinetic Energy (For both M_1 and M_2)

$$+(\tfrac{1}{2})GM_1M_2/r = (\tfrac{1}{2})M_2 4\pi^2r^2/T_2^2 \tag{36}$$

$$+(\tfrac{1}{2})GM_1M_2/r = (\tfrac{1}{2})M_1 4\pi^2r^2/T_1^2 \tag{37}$$

$\sqrt{GM/r}$ = Orbital Velocity (For both M_1 and M_2)

$$\sqrt{GM_1/r} = 2\pi r/T_2 \quad \text{Velocity of the smaller body} \tag{38}$$

$$\sqrt{GM_2/r} = 2\pi r/T_1 \quad \text{Velocity of the larger body} \tag{39}$$

Notice the balancing of the orbital kinetic energies of the larger and smaller bodies in Equation 35. In the direct orbital system the masses are inversely proportional to the squares of the velocities (Equation 27 and 28). So the $(½)M_1v_1^2$ and $(½)M_2v_2^2$ formulas of the orbital kinetic energies of the two bodies now balance. These equations contain the mass term for each body multiplied by the velocity squared term of that same body, and these are equivalent calculations in the direct orbital system. This does not happen in the combined orbital system because of the influence of the combined orbital terms on the calculated orbital velocities, and because of the resulting velocity proportionality difference between the two systems. Equations 36 and 37 further show that the positive (or absolute) value of ½ of the gravitational potential energy is now equal to the kinetic energy of either orbiting body in the direct orbital system.

Notice also that in Equations 38 and 39 the gravitational form of the velocity equation appears, which is usually only used for calculating the velocity of a body of negligible mass (such as a satellite) around a larger body. Equation 38 does not work in the combined orbital system when the smaller orbital body (M_2) is increased in mass and thereby causes the radius term to the center of mass (r_2) on the right hand side of the equations to decrease significantly from the full radius term. There is no term on the left hand side of this equation that can compensate for a change in the orbital velocity due to an increase in the mass of the smaller body in the combined system. For the larger body, Equation 39 could not work at all in the combined system for the same reasons. In the direct orbital system Equations 38 and 39 do work and do balance the velocity equation for two bodies having masses of any size. This is because the radius terms in the equations are the full radius terms, and the orbital period term on the right hand side of the equations is balanced by the mass terms on the left hand side of the equation.

These are examples of some of the equations that are balanced by using the terms of the direct orbital system, and which do not balance in the standard orbital system using combined orbital terms. All of the above gravitational and orbital calculations work successfully in practice as can be seen in the actual calculated examples in Table 2.

7 The Interactive Motion Between the Two Bodies in the Direct Orbital System

In the direct orbital system both bodies orbit each other as their orbital center points, and each body carries the orbital path of the other body around with it. This interactive motion continuously changes the orbital direction of each body as the bodies move, and this creates two smaller apparent orbits of the bodies around a combined orbital center point (Figures 1 and 2). Since each body is orbiting the other body as a moving orbital center point, the motion of each body is affected by both the gravitational acceleration and the physical motion of the other body. Each body not only exerts gravitational attraction on the other body, it also alters the orbital path of the other body with its own orbital motion. The physical motion of the two orbital center points located at each of the bodies presents an additional motion factor for the two bodies in the direct orbital system.

Figure 1. The Two-Body System in Direct Orbital Dynamics: each body orbits the other body directly and carries the orbital center point of the other body around with it. This interactive motion of the two orbital paths (in black) continuously alters the direction of each body on its own path, and creates the two apparent orbits (in red) around a combined orbital center point.

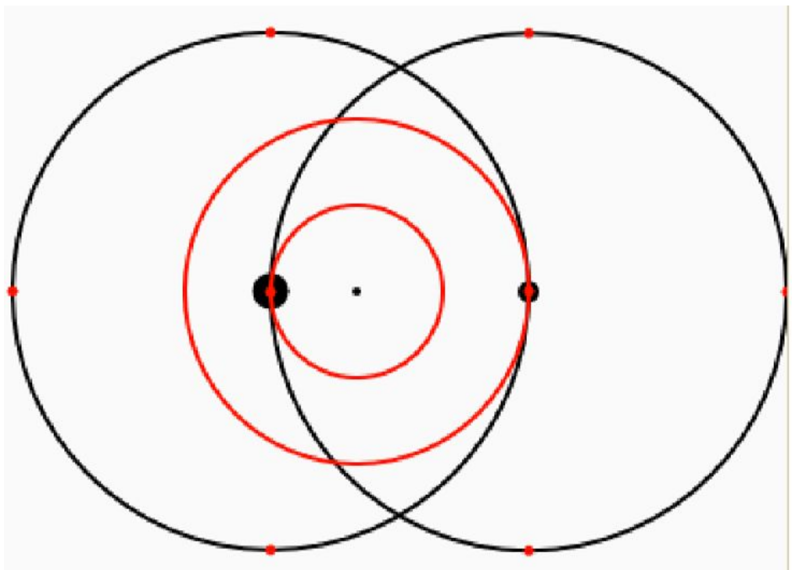
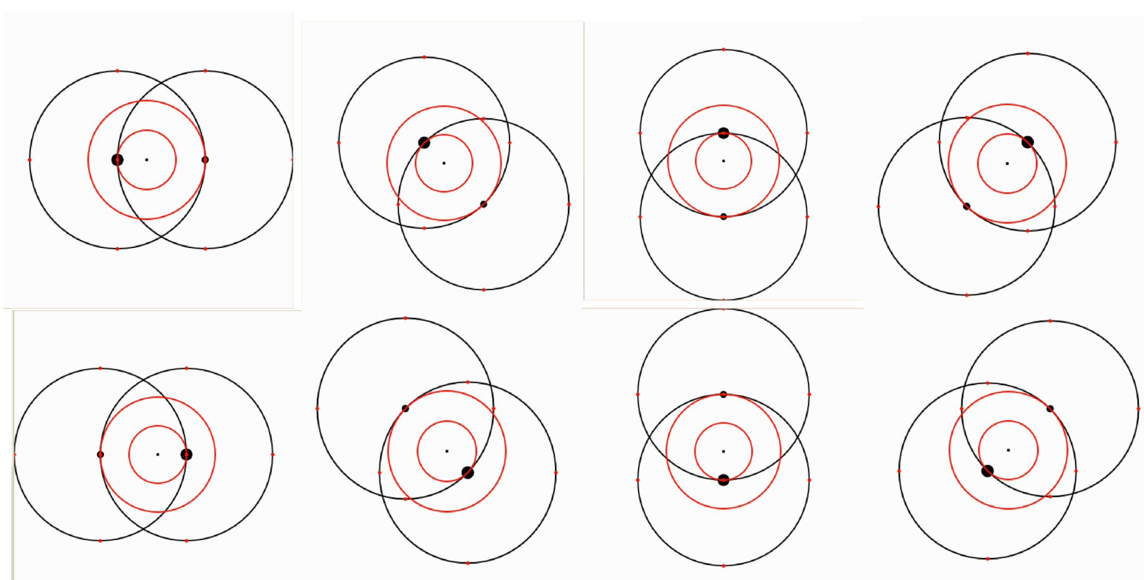


Figure 2. Sequential motion of a two-body system in Direct Orbital Dynamics: a series of diagrams showing the interacting motion of the two bodies and their orbital paths (in black) creating the two apparent orbital paths (in red) around the combined orbital center point.



The orbital motion of each body due to the gravitational attraction of the other body has been accounted for in the equations of the direct orbital system. Now the physical motion of the two orbital center points of the bodies have to be accounted for as an additional interactive motion effect on the two bodies. Since the orbital center points are located at the two bodies, they have the same orbital velocities as the bodies themselves. The individual orbital velocities calculated for the bodies in the direct orbital system can be applied to the motion of the two orbital center points to account for the additional motion factor. These additional velocities of the orbital center points can then be included into the direct orbital system to get the combined interactive motion of the two bodies.

The two bodies are now referred to as having a combined motion and a combined orbital center point, and this sounds like a description of the combined orbital system examined previously. The important difference here is that the individual orbital velocities of the direct orbital system are now being applied to the orbiting bodies rather than the orbital velocities of the combined orbital system, which are neither equivalent nor proportional to the orbital velocities of the direct system. The two bodies in the direct orbital system interact differently in their orbital motion than they would in the combined system due to the two systems having different orbital velocities. The difference in the orbital velocities, caused by the difference in the terms used in the calculation of the velocities, is the key difference in the motion of the two bodies in the direct and combined orbital systems. In the direct system, the direct orbital velocities of the two bodies relative to each other are determined first, and then those two velocities are applied to the two orbital center points that are in motion to determine the combined orbital motion of the two-body system.

The ratio of the two individual orbital velocities of the bodies determines the location of the combined orbital center point of the system. In the direct orbital system the masses of the two bodies are inversely proportional to the squares of the orbital velocities as seen in Equation 28:

$$\frac{M_1}{M_2} = \frac{(2\pi r/T_2)^2}{(2\pi r/T_1)^2} \tag{28}$$

If the two orbiting bodies (in Figures 1 and 2) had masses of 4 and 1 units in the equation above, their orbital velocities (T_1 and T_2) would be 1 unit and 2 units of velocity respectively in the direct orbital system. The squares of these velocities would be 1 and 4, and it is these squares of the velocities that are inversely proportional to the masses in the direct orbital equation.

In the combined orbital system it is the velocities of the bodies, not the squares of their velocities, that are inversely proportional to the masses. So in this scenario the two bodies in the example above would instead have velocities of 1 and 4 units and would therefore orbit the center of mass of the system. This is actually what is observed in multiple body planetary systems within the solar system. However, in all these systems the planetary bodies are locked into orbit around the Sun, and the Sun is the primary source of their gravitational acceleration. The center of mass of a planetary system would orbit the Sun, and the planetary system would naturally appear to orbit the center of mass of the system. The planetary body is not part of a freely orbiting independent system with respect to the smaller body or bodies orbiting it, and so the bodies in such a system are not observed to be operating according to the direct orbital system. Most planetary systems orbiting the Sun do not represent the freely orbiting systems of the direct orbital system (the Pluto-Charon system may be an exception).

The Earth and Moon do not orbit each other freely because the gravitational force of the Sun on the Earth is far greater than that of the Moon on the Earth. The gravitational force of the Sun on the Moon is also greater than that of the Earth on the Moon. And so the Earth and the Moon simply orbit their own center of mass while the two orbit together around the Sun. The effects of the direct orbital system would not be visible in a system gravitationally locked within another system like the Earth and Moon in relation to the Sun.

It is a completely different situation with a freely orbiting body in the direct orbital system. In the above example of a direct system with masses of 1 and 4 units, the masses of the bodies were stated to be proportional to the squares of their orbital velocities (Equation 28). The smaller body with 1 unit of mass would therefore have 2 units of orbital velocity, and the larger body with 4 units of mass would have 1 unit of orbital velocity. With the ratio of 2 units of orbital velocity for the smaller body and 1 unit of orbital velocity for the larger body, the two bodies would have an orbital center point that is located one third the distance from the larger body to the smaller body, as in Figures 1 and 2. This is not the location of the mass center point that is currently viewed as being the orbital center point of a two-body system. The mass center point would have a 4 to 1 radius distance proportionality to the two bodies as in the combined orbital system, with the radii being inversely proportional to the masses directly.

In the direct orbital system, freely orbiting bodies have an inverse square ratio relationship of their masses to their individual orbital velocities (Equation 28). This results in an inverse square ratio relationship of their masses to their radii distances to their orbital center point located at the center of gravity. This "distance squared" gravitational center point in the direct orbital system is located at a point directly opposite the Lagrangian L1 point between the bodies. This point is the same distance from the larger body that the L1 point is from the smaller body. The square of the radius distance of each body to this distance squared center of gravity orbital center point is inversely proportional to the mass of each body. The distance squared radii of this gravitational center point reflects the inverse square law of gravitation. Each body is still gravitationally orbiting the other body directly in the direct orbital system, but the interactive motion of the bodies and their orbits causes the two bodies to also jointly orbit the distance squared gravitational center point. The center of mass in the direct orbital system is located closer to the larger body than the distance squared center of gravity orbital center point, and so it would revolve around this gravitational center point with the orbital motion of the two bodies.

Both the body and its orbital path are in motion, and together this combined orbital motion causes each body to actually traverse the entire orbital path around the other body during the observed orbital period of the system (Figure 2). Part of this orbit is due to the forward motion of the body, and part is due to the reverse motion of its orbital path. The ratio of these combined motions of the body and its orbital path is the same as the ratio of the radii distances of the bodies to the distance squared center of gravity. The result of this interactive motion is that the direction of each body's orbit on the moving orbital path is continuously changing, causing each body to orbit a smaller apparent orbit around the combined orbital center point (with the circumferences of these smaller orbits having the same ratio as above). This combined motion incorporating the additional motion factor also has an important effect on the calculation of the centripetal acceleration of each body relative to the combined orbital center point, with an important application to the excessive rotation of disk galaxies (Section 9).

8 Orbital Angular Momentum in the Direct Orbital Dynamics System

In the direct orbital system the bodies in a two-body system were shown to engage in an orbital interaction around an orbital center point located at the distance squared center of gravity, and not around the center of mass which is used in the combined orbital system. When the orbital angular momentum of a two body or multiple body system is calculated relative to the center of mass in the standard system, the smaller body is always calculated to have the vast majority of the orbital angular momentum (not taking into account axial angular momentum). For example, Jupiter is calculated to have 60% of the orbital angular momentum of the solar system, and the four Jovian planets together account for over 99%. This is referred to as the angular momentum problem, and this problem appears at all scales in the universe [3].

The basis for this problem is the combined orbital terms, and the resulting velocities, of the combined orbital system that are used in the calculations for orbital angular momentum. The equation for angular momentum (L) is

$$L = Mvr \tag{40}$$

or, when simplified

$$L = M2\pi r^2/T \tag{41}$$

In the combined orbital system the r terms are the radii distances of the larger and smaller bodies to the mass center points, r_1 and r_2. The equations for the two bodies in this combined system therefore appears as

$$M_1 2\pi r_1^2/T \tag{42}$$

for the larger body, and

$$M_2 2\pi r_2^2/T \tag{43}$$

for the smaller body. For the combined orbital system, we will use the example from above where M_1 is equal to 4 units of mass, and M_2 is equal to 1 unit of mass. The radius distance of the larger body (r_1) to the mass center point will be 1 unit, and the radius distance of the smaller body (r_2) to the mass center point will be 4 units. We will set $2\pi/T$ equal to 1 in both equations so that these terms will cancel out for comparison purposes. The variable terms in the first equation are therefore $M_1(r_1^2)$, and when the numbers above for the larger body are inserted the resulting quantity is $4(1^2)$ or 4. The variable terms in the second equation are $M_2(r_2^2)$, and when the numbers above for the smaller body are inserted the resulting quantity is $1(4^2)$ or 16. The orbital angular momentum of the smaller body is four times as large as that of the larger body in this example of how the combined orbital system works.

When the mass is multiplied by the distance squared in the orbital angular momentum equations of the combined orbital system, the radius distance of the bodies to the mass center point will always give such a disproportional result. The orbital angular momentum of the smaller body will always be calculated to be greater than that of the larger body by an amount that is inversely proportional to their masses. If Jupiter and the Sun are treated as a two-body system, Jupiter will be calculated to have about 1047 times the amount of orbital angular momentum as the Sun (not taking into account the axial angular momentum of the bodies). The Sun in turn has about 1047 times the amount of mass as Jupiter.

In the direct orbital system, different orbital terms are used that give different results for the calculated orbital angular momentum of each of the bodies. As in the above examples, the masses will be equal to 4 and 1 units again. In the direct system the masses of the bodies are inversely proportional to the squares of their radii to the distance squared center of gravity orbital center point. The radius distance of the larger body (r_{g1}) to the distance squared center of gravity would be 1 unit, and the radius distance of the smaller body (r_{g2}) to the distance squared center of gravity would be 2 units in this example (these quantities of distance are used in this example only and are not comparable to the last example). We will set $2\pi/T$ equal to 1 again in both equations so that these terms will cancel out for comparison purposes. In the direct orbital system the variable terms in the first equation are $M_1(r_{g1}^2)$, and when the terms are inserted the quantity is $4(1^2)$ or 4. The variable terms in the second equation are $M_2(r_{g2}^2)$, and when the terms are inserted here the quantity is $1(2^2)$ or 4. In the direct orbital system the larger and smaller bodies are calculated to have equal amounts of orbital angular momentum. The orbital angular momentum of the two-body system is balanced between the two bodies in these equations.

This is another example of an equation balancing with the orbital terms used in the direct orbital system, that did not balance with the terms used in the combined system. This also occurred with the balancing of the kinetic energies of the two bodies (Equation 35) and with the balancing of the two types of velocity equations (Equations 38 and 39). The orbital angular momentum of the larger body (M_1) equals the orbital angular momentum of the smaller body (M_2). In the orbital angular momentum equations for the direct orbital system this appears as

$$M_1(2\pi r_{g2}/T)r_{g2} = M_2(2\pi r_{g1}/T)r_{g1} \tag{44}$$

which reduces to

$$M_1 r_{g2}^{\ 2} = M_2 r_{g1}^{\ 2} \tag{45}$$

where r_{g1} is the radius distance of the larger body to the distance squared center of gravity orbital center point, and r_{g2} is the radius distance of the smaller body to this distance squared orbital center point. The combined orbital period term (T) is now being used in the orbital angular momentum equations, along with radius distance terms of each of the bodies to the distance squared center of gravity orbital center point of the direct orbital system.

9 The Application of the Additional Motion Factor to Direct Orbital Dynamics

The orbital radius terms of the larger and smaller body to the distance squared gravitational center point (r_{g1} and r_{g2}), along with the combined orbital period (T) of the two-body system, can now be applied to the other orbital equations in the direct orbital system. These terms replace the full radius term (r) and the individual orbital period terms (T_1 and T_2) used up until now in this direct system. These direct terms were used to calculate the individual orbital response of each body to the gravitational attraction of the other body, with each body being treated as the the orbital center point of the other body. The reason for applying the new set of orbital terms is to incorporate the orbital velocities of these two orbital center points, which are located at the bodies. The motion of these orbital center points represents an additional motion factor affecting the combined orbital motion of the two bodies. The proportionality of the orbital velocities in the direct orbital system defined the location of the combined orbital center point to be at the distance squared center of gravity.

The newly defined radius terms to the distance squared gravitational center point were applied to the orbital angular momentum equations, along with the combined orbital period term of the system. The orbital angular momentum of each of the two bodies was calculated to be equivalent and balanced when using these terms (Equation 44). If these terms of the direct orbital system are applied to the orbital angular momentum calculations for Jupiter and the Sun as an example, these quantities are also calculated to be equal and balanced (in the third column of Table 2). This result would be the same for a binary star system, a pair of orbiting galaxies, a star and its planet, or any two-body system.

The balanced relationship between the orbital kinetic energies of each of the bodies in the direct orbital system was given in Equation 35:

Kinetic Energy of the Smaller Body M_2 = Kinetic Energy of the Larger Body M_1

$$(½)M_2 4\pi^2 r^2/T_2^{\,2} = (½)M_1 4\pi^2 r^2/T_1^{\,2} \tag{35}$$

If the new orbital terms for the radii and orbital period in the direct orbital system are inserted into this equation it becomes

$$(½)M_2 4\pi^2 r_{g2}^{\,2}/T^2 = (½)M_1 4\pi^2 r_{g1}^{\,2}/T^2 \tag{46}$$

The orbital kinetic energy of each body is still equal to that of the other body in this equation even though the orbital terms have changed. The application of the additional motion factor changes the quantities on each side of the equation slightly, as it does in all the equations (Table 2), but the equation itself remains equivalent.

The relationship between the gravitational acceleration and centripetal acceleration of each body in the direct orbital system was given in Equations 32 and 33:

Gravitational Acceleration = Centripetal Acceleration (both M_1 and M_2)

$$GM_1/r^2 = 4\pi^2 r^2/T_2^{\,2} r \tag{32}$$

$$GM_2/r^2 = 4\pi^2 r^2/T_1^{\,2} r \tag{33}$$

where the centripetal acceleration of the smaller body is on the right side of the top equation, and the centripetal acceleration of the larger body is on the right side of the bottom equation. If the new orbital terms for the radii and orbital period in the direct orbital system are inserted into these equations they become

$$GM_1/r^2 \neq 4\pi^2 r_{g2}^{\,2}/T^2 r_{g2} \tag{47}$$

$$GM_2/r^2 \neq 4\pi^2 r_{g1}^{\,2}/T^2 r_{g1} \tag{48}$$

These equations are no longer equalities once the new terms are inserted. This would at first appear to invalidate the incorporation of the new terms into the direct orbital system, but it instead leads to the explanation for the increased velocity and acceleration problem that is observed in galactic rotation curves (the dark matter problem). The total sum of the two centripetal accelerations on the right hand side of the equations remains the same in the top set and bottom set of equations (as will be seen in the examples below in Table 2). This equivalence appears as

$$(4\pi^2r^2/T_2^{\,2}r) + (4\pi^2r^2/T_1^{\,2}r) = (4\pi^2r_{g2}^{\,2}/T^2r_{g2}) + (4\pi^2r_{g1}^{\,2}/T^2r_{g1}) \qquad (49)$$

The equivalence of the gravitational acceleration to the sum of the right hand side of the centripetal acceleration equations of Equation 47 and 48 would appear as

$$GM_2/r^2 = ½(4\pi^2r_{g2}^{\,2}/T^2r_{g2}) + ½(4\pi^2r_{g1}^{\,2}/T^2r_{g1}) \qquad (50)$$

Newton's second law is preserved in the orbital system because of this equality. The total sum of the centripetal acceleration of the two body system remains the same when the new orbital terms of the direct orbital system are used. However, a shift occurs in the proportionality of the individual accelerations of the bodies. The larger body in the direct orbital system is now calculated to have a large increase in its acceleration, and the smaller body has an equivalent decrease in acceleration. This is caused by the interactive orbital motion of the bodies, and the motion of their orbital center points and orbital paths.

Some of the acceleration of the smaller body transfers to the larger body in their interactive orbit around the distance squared center of gravity. This transfer of acceleration causes the average acceleration of the mass of the system (per unit of mass) to increase to the relationship $M \propto a^2$, or $M \propto V^4$ (instead of the relationship of $M \propto a$, or $M \propto V^2$ which exists in the static direct orbital system before the additional motion factor is applied). The total sum of the centripetal acceleration of the system remains the same, conserving Newton's second law of motion. But this transfer of acceleration between the two bodies causes a greatly increased acceleration of the larger body, resulting in a large increase in the amount acceleration per unit of mass within the system.

The last equation (Equation 50) is similar to the situation of the kinetic energy calculations in the standard orbital equations. The absolute value of the gravitational energy is equal to the sum of one half the kinetic energy of each of the two bodies.

10 Mass is Proportional to the Velocity to the Fourth Power in Both Disk Galaxies and the Direct Orbital System with the Additional Motion Factor

In the first set of centripetal acceleration equations (Equations 32 and 33) the accelerations of the two bodies are inversely proportional to their masses in the direct orbital system. Now a new set of orbital terms is being used to incorporate the motion of the orbital center points that represents an additional motion factor in the bodies. These new orbital terms are the radius distances of the bodies to the distance squared gravitational point, and the combined orbital period (which is the observed period of the system).

When these terms are inserted into the centripetal acceleration equations, the accelerations of the bodies are no longer inversely proportional to the masses directly. The accelerations are now inversely proportional to the square roots of the masses in the direct orbital system containing the additional motion factor. When each side of this proportionality is squared, **the masses of the bodies are inversely proportional to the squares of their accelerations.** This would mean that the total mass of the system is proportional to the total sum of the accelerations squared, which has an important application to the excessive rotational velocities found in disk galaxies. Acceleration carries the velocity squared term within it, so the mass would be also proportional to the velocity to the fourth power.

Here is the equation for centripetal acceleration showing the velocity squared term:

$$a = v^2/r \tag{51}$$

so the acceleration squared would appear as

$$a^2 = (v^2/r)^2 \tag{52}$$

or

$$a^2 = v^4/r^2 \tag{53}$$

which contains the term for velocity to the fourth power on the right hand side.

Since the squares of the accelerations of the bodies are now inversely proportional to the masses, this means that the velocities to the fourth power are also inversely proportional to the masses, as in the equations below:

$$M_1/M_2 = (v_2^2/r_2)^2 / (v_1^2/r_1)^2 \tag{54}$$

or

$$M_1/M_2 = (v_2^4/r_2^2) / (v_1^4/r_1^2) \tag{55}$$

and by inserting the new orbital terms incorporating the additional motion factor for the direct orbital system this appears as

$$M_1/M_2 = v_2^4 r_{g1}^2 / v_1^4 r_{g2}^2 \tag{56}$$

The mass of the system is therefore proportional to the acceleration squared

$$M \propto a^2 \tag{57}$$

or the mass is proportional to the velocity to the fourth power

$$M \propto v^4 \tag{58}$$

A comparison of the sets of orbital equations using actual orbital terms (of Jupiter and the Sun as an example) is given in the three columns of Table 2. The three columns represent the calculations of the combined orbital system, the direct orbital system, and the direct orbital system incorporating the additional motion factor of the two orbital center points.

This velocity to the fourth power effect is also seen in the flat rotation curves of disk galaxies where it is observed that the mass of the galaxy is proportional to its acceleration squared, or to the velocity to the fourth power. This mass-velocity relationship is charted in the Baryonic Tully Fisher Relation between the baryonic masses of disk galaxies and the fourth power of their rotational velocities (v^4) [14,15]. The rotation curves of disk galaxies contain this mass-velocity relationship and are asymptotically flat at large radial distances [5,6]. This observation is what led to the theories of dark matter and Modified Newtonian Dynamics or MOND. A halo of dark matter is theorized to account for the excessive rotational velocities of disk galaxies [7,11,20]. MOND theorizes a change in gravitation at low accelerations to account for these excessive velocities [8-12].

The Direct Orbital Dynamics System also contains the mass and velocity to the fourth power relationship ($M \propto v^4$) in small orbiting systems within the high acceleration Newtonian regime (Equation 58). This is exactly the same as the same radial force law that is found in the mass-velocity relationship of disk galaxies charted in the Baryonic Tully Fisher Relation [13-15]. Application of the direct orbital system with the revised orbital terms provides the physical basis for the velocity to the fourth power law that is observed in disk galaxies. The basis for this lies in this additional motion factor incorporated into the direct orbital system. The bodies are orbiting each other directly in this system as their orbital center points, but the fourth power relationship only appears after incorporating the additional velocities of these orbital center points relative to the distance squared center of gravity.

In the direct orbital system, a body in a two-body system orbits the other body directly as its orbital center point, but as that orbital center point moves the orbiting body follows it and its orbit is altered. The orbiting body therefore has an additional motion factor apart from its gravitational motion. A star orbiting within a disk galaxy would behave the same way in the direct orbital system. The star would react to both the gravitational acceleration of the galaxy and to the motion of the other stars orbiting in its section of the galaxy. The star would be orbiting the galaxy, but it would also respond to the movement of the other orbiting stars around it, just as the bodies in the two-body system follow their moving orbital center points. The additional motion of these other moving stars has to be factored in with the gravitational motion of the star orbiting the galaxy. This is the apparent reason for the flat rotation curves seen in all disk galaxies. The stars are all orbiting at the same velocity because each star is tied in to the orbital velocities of all the stars around it, like a mass of moving orbital center points. Each star is orbiting the galaxy, but is also being pulled along at the same velocity as all the other stars. Both gravitation and motion have an effect on the velocity of a star in a disk galaxy.

This is the essence of the Direct Orbital Dynamics System, treating bodies as orbiting each other directly while in motion. A body orbits due to gravitational acceleration, but there is this additional motion factor involved with the body also responding to the motion of other bodies. This occurs in two-body systems, in disk galaxies, and at all scales.

11 Other Possible Applications of Direct Orbital Dynamics

Pluto and Charon and the proportionality of their masses

Pluto and its moon Charon comprise one of the only systems in the solar system where the larger body has a moon proportionally large enough to surpass the gravitational attraction of the Sun. The bodies are also far enough away from the Sun so that the Sun has much weaker gravitational attraction than in the inner solar system. Pluto's gravitational attraction to Charon is stronger than Pluto's gravitational attraction to the Sun (in the equation for gravitational acceleration). Pluto is primarily orbiting Charon and Charon is primarily orbiting Pluto, with both bodies secondarily orbiting the Sun. This is very different from the Earth-Moon system where both bodies primarily orbit the Sun. Pluto and Charon would be orbiting the distance squared gravitational center point of their system rather than the mass center point. This would cause the masses of Pluto and Charon to be in different proportion that is currently calculated, though the total mass of the system would be the same. This difference may be observed when the New Horizons spacecraft passes the Pluto system and its major moon Charon. Pluto should be found to contain about 10% more mass than expected ($1.44\text{x}10^{22}$ kg), and Charon should be found to contain far less mass than expected ($1.95\text{x}10^{20}$ kg). Precessional effects in the Pluto-Charon orbit could alter these mass estimates somewhat. The system would have approximately the same total mass as expected, but the mass ratio will be different due to Pluto and Charon orbiting the distance squared gravitational center point of the direct orbital system. This would also mean that the orbital angular momentum of Pluto and Charon would be balanced, as well as the orbital kinetic energy. It would also mean that the velocity of the New Horizons spacecraft should be increased slightly more than expected, and the trajectory should also be slightly affected as it passes Pluto. This is due to the current incorrect mass proportion estimates, since the Pluto-Charon system is currently treated as orbiting its mass center point and would instead be orbiting the distance squared gravitational center point.

The formation and the orbital angular momentum of the Earth and the Moon

The Earth and the Moon are both gravitationally locked to the Sun and so cannot engage in the balance of orbital angular momentum that they would have if they were a freely orbiting system. It is thought that this system must have been created by the giant impact of another body because the Earth-Moon system only has about half of the angular momentum that it should have if the system formed out of a rotating nebula of gas and dust [4]. However, the Earth-Moon system would have about twice as much orbital angular momentum if they were orbiting freely and not gravitationally locked to the sun. The large portion of the Earth's orbital angular momentum relative to the Moon that the Earth should have in the direct orbital system is not present. Since angular momentum is conserved, this missing angular momentum may be showing up instead as the small secular increase in the astronomical unit (AU) distance of the Earth from the Sun each year [16]. This would gradually increase the orbital angular momentum of the Earth and the Sun. The Earth and Moon do not require the giant impact hypothesis of a third body to form this system because they would have initially had the required angular momentum necessary when forming out of a rotating nebula. The missing orbital angular momentum would have been transferred to the Earth-Sun relationship because the Earth and Moon are gravitationally locked to the Sun.

This same argument is applicable to the formation of the Pluto-Charon system as well. Here again a giant impact hypothesis is given for the same reason that there does not appear to be enough orbital angular momentum present in the system to allow for the formation of the system out of a nebula [17]. Direct Orbital Dynamics provides the necessary orbital angular momentum just as with the Earth-Moon system formation, and a giant impact hypothesis in not necessary.

Two-body formation with angular momentum transfer to a second coalescing body

When a spinning nebula of gas and dust is collapsing into a large central body (star, planet, etc.) the formation of a secondary body or bodies around it would transfer angular momentum out from the central body. There would be a balance of orbital angular momentum between the two bodies in Direct Orbital Dynamics. This would allow the larger body to shed a large amount of axial angular momentum and further contract into a star, planet, etc.

As the secondary body formed, the combined orbital period of the two bodies would be smaller (and the velocity faster) than the orbital periods of smaller bodies at the same radius distance from the larger body. The secondary body would therefore move faster in the same orbit than the rest of the mass orbiting at that radius, and it would gradually collect all the additional mass in that zone and grow into a much more massive secondary body. As a result, yet more orbital angular momentum would be gained by both this body and the primary body, with this orbital angular momentum balanced out by the two bodies orbiting the distance squared gravitational center point. The larger central orbiting body would shed more angular momentum and contract further. And so a binary star, or a solar system, or Pluto and Charon, or the Earth and its Moon could form out of the same nebula with balanced orbital angular momentum, without having to resort to a giant impact hypothesis in the case of the last two.

The Flyby Anomaly

Direct Orbital Dynamics treats orbiting bodies as orbiting each other directly, and as having the motion and acceleration of each body affected by the motion of the other. The influence of moving bodies may have impact in areas other than those mentioned above. The axial rotation of a massive body may influence a body orbiting or passing it. This may be the cause of the flyby anomaly, where spacecraft at times have an unexpected increase in velocity when swinging around the Earth [1]. The axial rotation of the Earth may cause the increase in this velocity as the spacecraft passes, which has already been suspected in the past.

The Retrograde Orbit of Triton

The moon Triton orbits Neptune, and it is in a retrograde orbit relative to the planet's rotation. The orbit of Triton is gradually slowing and decaying so that eventually Triton will crash into Neptune. The motion of the enormous mass of the planet that is rotating opposite to Triton's orbit may be causing the moon to slow as is observed.

The Impossible Triple Star KIC 2856960

A star system was recently discovered that is being called "The Impossible Triple Star" because it defies the laws of physics [18]. The researchers were unable to find a set of masses and radii for the stars that could explain the system. This may be due to the incorrect orbital terms and velocities used in the combined orbital system. Application of the direct orbital system may yield results to explain the masses and orbits of this triple star system.

The Calculation of Stellar Masses

The calculated masses of stars in binary systems are proportionally affected when the bodies are calculated to be orbiting the distance squared gravitational center point of the direct orbital system. For example, Cygnus X-1 would no longer be required to contain a black hole, as this object now would fall within the required mass parameters of a neutron star.

The Cosmological Redshifting of Light

Direct Orbital Dynamics may also have an application to the cosmological redshifting of light. Since the motion of mass has an affect on the motion of a body in its gravitational field, the motion of the mass of the universe passing in the opposite direction relative to a moving wave of light may be expected to have an effect on that wave. This effect would be in addition to the expected slight gravitational redshifting. The light wave cannot slow down in response to the effect of the motion of the mass of the universe passing by it, so the light would instead have to exhibit a redshifting in response to this effect. If the effect is large enough to account for the observed redshifting of light in the universe, then the cosmological interpretation of the redshifted light of distant objects would be in question. If the cosmological redshifting of light is caused by the effect of the motion of the mass in the universe moving past the light wave, then there will be more or less redshifting of the light based on the density of the portion of the universe that the light is passing through.

When light waves pass near a massive body such as a star (or galaxy, or cluster of galaxies, or the Sun specifically) the gravitation of that mass bends the light wave. The effect of the motion of the massive body passing the light wave should cause an additional acceleration in the direction of the mass. This would be represented by an additional bending of the light wave beyond what is currently expected.

Large Scale Structures in the Universe

Since dark matter is no longer required as an explanation for the increased rotation of galaxies in Direct Orbital Dynamics, it should not be used as an explanation for how the extremely large scale structures of the universe formed in only 13.7 billion years. If the effect of the motion of the mass of the universe passing a light wave is responsible for the redshifting of light in the universe, then the cosmological interpretation of a Big Bang at a point 13.7 billion years in the past is also in question, as well as cosmological inflation. The formation of the large scale structures in the universe (such as large superclusters of galaxies, walls and filaments, and immense voids) would therefore not be constrained by time or by the existence of dark matter to accomplish this task [19].

The Advanced Precession of Mercury's Perihelion

Mercury is precessing faster than expected in its orbit around the Sun. The extra 43 seconds of precession of perihelion per century is currently accounted for by General Relativity. But the motion of the axial rotation of the enormous mass of the Sun may be expected to cause additional motion in the orbit of Mercury around the Sun. If any of the advanced precession of Mercury is due to this motion factor, then General Relativity would have a problem since the theory must account for 43 seconds of precession exactly.

12 Explanation of Tables 1 and 2

Table 1, below, contains the orbital terms for the planet Jupiter and the Sun. These two bodies are treated as if they are a two-body system test model. Their real orbital terms are used in the equations in Table 2 to compare the combined orbital system that is currently used, the direct orbital system treating the bodies as orbiting each other directly, and finally the direct orbital system incorporating the additional motion of the orbital center points (located at the two bodies) around the distance-squared gravitational center point. The orbital angular momentum of each of the bodies balance in the third column, as do the kinetic energies of the bodies. The centripetal acceleration of the two bodies in the third column have the same relationship between their masses and velocities as that observed for the flat rotation curves of disk galaxies charted in the Baryonic Tully Fisher Relation: mass is proportional to velocity to the fourth power ($M \propto V^4$).

Table 1. Orbital Terms Used for Jupiter and Saturn in the Table Below

	Mass (Jupiter includes Moons)	Full Radius Distance	Orbital Period	Individual Orbital Period	Center of Mass Radius	Distance Squared Center of Gravity Radius
Jupiter	1.8987×10^{27} kg	7.7857×10^{11} m	3.7434×10^{8} s	3.7451×10^{8} s	7.7783×10^{11} m	7.5523×10^{11} m
Sun	1.9886×10^{30} kg	7.7857×10^{11} m	3.7434×10^{8} s	1.2120×10^{10} s	7.4266×10^{8} m	2.3336×10^{10} m

Table 2. Calculation Comparison: The Sun as M_1 and Jupiter as M_2 in a Two-Body System

	Standard Newtonian System (Combined Orbital System)	Direct Orbital System Before Motion Factor Added	Direct Orbital System With r^2 Center of Gravity Orbits
	Gravitational Acceleration (GM/r^2)		
1 2	$GM_2/r^2 = 2.091 \times 10^{-7}$ (of the Sun) $GM_1/r^2 = 2.189 \times 10^{-4}$ (of Jupiter)		
	Centripetal Acceleration (v^2/r) $m \cdot s^{-2}$	Sums of sets are equivalent	$M_1/M_2 \propto (a_2)^2/(a_1)^2$ or $(v_2)^4/(v_1)^4$
3 4	$4\pi^2 r_1^{\ 2}/T^2 r_1 = 2.092 \times 10^{-7}$ (Sun) $4\pi^2 r_2^{\ 2}/T^2 r_2 = 2.191 \times 10^{-4}$ (Jupiter)	$4\pi^2 r^2/T_1^{\ 2} r = 2.092 \times 10^{-7}$ $4\pi^2 r^2/T_2^{\ 2} r = 2.191 \times 10^{-4}$	$4\pi^2 r_{g1}^{\ 2}/T^2 r = 6.574 \times 10^{-6}$ $4\pi^2 r_{g2}^{\ 2}/T^2 r = 2.128 \times 10^{-4}$
	Gravitational Force (GM_1M_2/r^2) N		
5	$GM_1M_2/r^2 = 4.157 \times 10^{23}$		
	Centripetal Force (Mv^2/r) $kg \cdot m \cdot s^{-2}$	= Newtons (N)	
6 7	$M_1 4\pi^2 r_1^{\ 2}/T^2 r_1 = 4.161 \times 10^{23}$ (Sun) $M_2 4\pi^2 r_2^{\ 2}/T^2 r_1 = 4.161 \times 10^{23}$ (Jupiter)	$M_1 4\pi^2 r^2/T_1^{\ 2} r = 4.162 \times 10^{23}$ $M_2 4\pi^2 r^2/T_2^{\ 2} r = 4.161 \times 10^{23}$	$M_1 4\pi^2 r_{g1}^{\ 2}/T^2 r_{g1} = 1.307 \times 10^{25}$ $M_2 4\pi^2 r_{g2}^{\ 2}/T^2 r_{g2} = 4.040 \times 10^{23}$
	Grav. Potential Energy ($-GM_1M_2/r$) J		
8	$-GM_1M_2/r = -3.237 \times 10^{35}$		
	Kinetic Energy (½Mv^2) $kg \cdot m^2 \cdot s^{-2}$	= Joules (J)	Balanced Equations Below
9 10	$(½)M_1 4\pi^2 r_1^{\ 2}/T^2 = 1.545 \times 10^{32}$ (Sun) $(½)M_2 4\pi^2 r_2^{\ 2}/T^2 = 1.618 \times 10^{35}$ (Jup.)	$(½)M_1 4\pi^2 r^2/T_1^{\ 2} = 1.620 \times 10^{35}$ $(½)M_2 4\pi^2 r^2/T_2^{\ 2} = 1.620 \times 10^{35}$	$(½)M_1 4\pi^2 r_{g1}^{\ 2}/T^2 = \mathbf{1.526 \times 10^{35}}$ $(½)M_2 4\pi^2 r_{g2}^{\ 2}/T^2 = \mathbf{1.526 \times 10^{35}}$
	Angular Momentum (Mvr) $kg \cdot m^2 \cdot s^{-1}$	= L	
11 12	$M_1(2\pi r_1/T)r_1 = 1.841 \times 10^{40}$ (Sun) $M_2(2\pi r_2/T)r_2 = 1.928 \times 10^{43}$ (Jupiter)	$M_1(2\pi r/T_1)r = 6.249 \times 10^{44}$ $M_2(2\pi r/T_2)r = 1.931 \times 10^{43}$	$M_1(2\pi r_{g1}/T)r_{g1} = \mathbf{1.818 \times 10^{43}}$ $M_2(2\pi r_{g2}/T)r_{g2} = \mathbf{1.818 \times 10^{43}}$
	Velocity Equivalent ($\sqrt{GM/r} = v$)		
13 14	$\sqrt{GM_1/r} = \mathbf{4.034 \times 10^2}$ (Sun) $\sqrt{GM_2/r} = \mathbf{1.306 \times 10^4}$ (Jupiter)		
	Velocity (v) $m \cdot s^{-2}$		
15 16	$2\pi r_1/T = 1.246 \times 10^1$ (Sun) $2\pi r_2/T = 1.306 \times 10^4$ (Jupiter)	$2\pi r/T_1 = \mathbf{4.036 \times 10^2}$ (Sun) $2\pi r/T_2 = \mathbf{1.306 \times 10^4}$ (Jupiter)	$2\pi r_{g1}/T = 3.917 \times 10^2$ $2\pi r_{g2}/T = 1.268 \times 10^4$

G = gravitational constant, M_1 = mass of larger body, M_2 = mass of smaller body, T = measured orbital period of the system, T_1 = individual period of the larger body relative to the smaller, T_2 = individual period of the smaller body relative to the larger, r = full radius distance, r_1 = radius distance of the larger body to the center of mass, r_2 = radius distance of the smaller body to the center of mass, r_{g1} = radius distance of the larger body to the distance squared center of gravity, r_{g2} = radius distance of the smaller body to the distance squared center of gravity

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