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A Unique Formula for Calculating the Rotational Period of Planet and Star

Xiaozhong Zhai *

Odense Kommune. Orchid Id: https://orcid.org/0000-0002-0004-4260 ,Odense, Denmark.

***Corresponding author**: Xiaozhong Zhai, Odense Kommune, Orchid Id: https://orcid.org/0000-0002-0004-4260, Odense, Denmark, E-mail: zxzdcoyk@yahoo.com

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Abstract

This paper reports a formula derived from two assumptions: amplification factor X and rotational resistance. The amplification factor and rotational resistance are expressed in the process of a celestial body changing from its inherent state to its non-inherent rotation state. So-called non-inherent state of object is its orbital motion state. The rotational mass, the rotational radius and the gravity on the its surface are three decisive factors that determine the rotational period of an object.

Keywords: ***Acceleration; Mass; Period; Rotation***.

Introduction

Thus far, a unique formula for calculating the rotation period of planet in the solar system and star, for example, the sun in the Milk Way system remains a challenge. This puzzles astronomer for centuries. The next section represents my attempt to derive such an formula and uncover the nature of rotation.

Theory and Equations

Suppose an object is a sphere with a uniform distribution of matter. If we let the rotational speed of an object in the tangential direction, for example, a planet in solar space, be equal to its orbit velocity, its radius would expand by X times. Then, according to traditional physical theory and Newton's law, we have the following equation:

$$2\pi rX = tv \tag{1}$$

The x can be called an amplification factor. The value of amplification factor of plane or star may be calculated by the following equation (**TABLE 1**):

$$X = \sqrt{\frac{v^2 r}{Gm - gr^2}} \quad \text{or} \quad X^2 = \frac{v^2 r}{Gm - gr^2} \tag{2}$$

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TABLE 1 **The X value calculated by the formula, the rotation period (t) in second calculated by the formula, the rotation period in second by Observations (t_b) and the accuracy rate between the calculating value and the observed value.**

	Mercury	**Venus**	**Earth**	**Mars**	**Ceres**	**Jupiter**	**Saturn**	**Halley**	**Urania**	**Neptune**	**Pluto**	**Moon**	**Sun**
x	15824.4389	19340.18538	64.111262	100.43637	196.81311	1.0618081	0.9988631	19,395.20	2.6472635	2.0355607	350.75203	221.249568	108.82816
t	5067975.87	21129193.49	86164.1	88645.68	32669.457	35724.137	37983.278	190062.13	62062.469	57955.746	551856.67	2360591.51	2164318
t_b	5,067,098.35	20,998,885.78	86,164.10	88,645.67	32,669.46	35,724.14	37,983.28	190,062.13	62,062.47	57,955.75	551,865.15	2,363,258.46	2192832
$t/t_b\times100$%	100.00377%	100.62052%	100%	100%	100%	100%	100%	100%	100%	100%	100.0015%	99.8876%	98.69967%

Note: The accuracy rate ($t/t_b\times100\%$)

So, t, the rotation period of planet or star may be calculated by the following formula (**TABLE 1**):

$$t = 2\pi r\sqrt{\frac{r}{Gm-gr^2}} \quad \text{or} \quad t^2 = \frac{4\pi^2 r^3}{Gm-gr^2} \tag{3}$$

The term of $Gm-gr^2$ in 3 represents the product of the effective mass (m_e) of rotational body and the gravitational constant. In the above formula, t represents the rotation period of an object, r is its radius, m its mass and v its orbit average velocity. The value of g represents the gravity on the surface of object. The value of gravity is equal to the difference $\left(\frac{Gm}{r^2}-\frac{v^2}{rx^2}\right)$ between the centripetal acceleration $\left(\frac{Gm}{r^2}\right)$ (coming from mass or mass distribution) and the centrifugal acceleration $\left(\frac{v^2}{rx^2}\right)$ (coming from the rotation) (**TABLE 2**) [1]. G is the gravitational constant. So, this gravity may be called net gravity.

TABLE 2. **The value of the centripetal gravitational acceleration** $\left(\frac{Gm}{r^2}\right)$**, of the centrifugal gravitational acceleration** $\left(\frac{v^2}{rX^2}\right)$ **and of the net centripetal gravitational acceleration (g) calculated by formula.**

	Mercury	Venus	Earth	Mars	ceres	Jupiter	Saturn	Halley	Urania	Neptune	Pluto	moon	Sun
Gm/ r^2	3.7014956	8.8700943	9.8202581	3.7278544	0.2802034	25.920302	11.186036	1.2134691×10^{-4}	9.0076017	11.274566	0.617212	1.6233275	273.69813
v^2/r X^2	3.7512628×10^{-6}	5.4181597×10^{-7}	0.0338778	0.0170287	0.0174959	2.1626277	1.5934431	1.2021572×10^{-5}	0.2599472	0.2893944	1.5386666×10^{-4}	1.2192456×10^{-5}	0.0058687
g	3.70149184	8.8700937	9.7863803	3.7108257	0.2627075	23.757674	9.5925931	0.0001093	8.7476545	10.985172	0.6170582	1.6233153	273.69226

Note: The unit of acceleration is $\frac{m}{s^2}$ and of mass is kg. g: gravity or net gravity. G=6.67408e-11m^3•s^{-2}•kg^{-1}

The rotational speed of an object in the tangential direction, v_t may be directly calculated by the following equation:

$$v_t=\frac{2\pi r}{t}=\frac{2\pi r}{\frac{2\pi rX}{v}}=\frac{v}{X} \quad \text{or} \quad {v_t}^2=\frac{v^2}{X^2}=\frac{GM}{Rx^2} \tag{4}$$

Let X^2 be divided by $\frac{Mr}{mR}\left(\frac{v^2 r}{Gm}\right)$ and combing 1, the following equation is obtained:

$$\frac{X^2}{\frac{Mr}{mR}}=\frac{t^2v^2}{4\pi^2r^2\frac{GMr}{GmR}}=\frac{t^2v^2}{4\pi^2r^2\frac{v^2r}{Gm}}=\frac{t^2}{\frac{4\pi^2r^3}{Gm}} \quad \text{or} \quad t^2=\frac{X^2}{\frac{Mr}{mR}}\frac{4\pi^2r^3}{Gm} \tag{5}$$

Ordering:

$$t_0^2=\frac{4\pi^2r^3}{Gm} \tag{6}$$

Combing (5) and (6), we obtain the following equation:

$$t^2=\frac{X^2}{\frac{Mr}{mR}}t_0^2 \quad \text{or} \quad t=\frac{X}{\sqrt{\frac{Mr}{mR}}}t_0 \tag{7}$$

And then

$$\frac{t}{t_0}=\frac{x}{\sqrt{\frac{Mr}{mR}}} \tag{8}$$

The letter M in the above equation is the mass at the orbital center and R is orbital semi-major axis of the object that moves around the orbital center.

t_0 can be here considered as an inherent rotation period of an object. The values of t_0 for planet and Sun in solar system are listed in **TABLE 3**.

TABLE 3.**The value of object's mass, effective mass and inherent rotational period.**

	Mercury	**Venus**	**Earth**	**Mars**	**Ceres**	**Jupiter**	**Saturn**	**Halley**	**Urania**	**Neptune**	**Pluto**	**Sun**	**Moon**
m(kg)	3.3011e+23	4.8675e+24	5.97237e+24	6.4171e+23	9,393e+20	1.89819e+27	5.6834e+26	2.2e+14	8.6813e+25	1.02413e+26	1.303e+22	1.9885e+30	7.342e+22
G_m	2.2031805 5E+13	3,24860844E+14	3,9860075E+14	4.28282388E+13	6.26896334E+10	1,26686719E+17	3,7931466E+16	14682,976	5,79396907E+15	6,83512555E+15	8.69632624E+11	1.32714081E+20	4.90010954eE+12
m_e (kg)	3,34612344E+17	2,93667705E+17	2,06033779E+22	2,93129878E+21	5,86499851E+19	1,5837309E+26	8,09596383E+25	2.17949169E+13	2,50530573E+24	2,62872593E+24	3,24838795E+18	4,26377198E+25	5,56706252E+17
Gm_e m^3s^{-2}	2.2 326343E+7	1.9599627E+7	1.375085924E+12	1.95637226E+11	3.91434713E+9	1.05699466E+16	5.40331027E+15	1.45461019E+3	1.67206109E+14	1.75443271E+14	2.1680001E+8	2.84567553E+15	3.7155 0206E+7
$t_0(s)$	5 100,5614177818	5 222,0913707308	5 060,8368874965	5 991,2594484675	8 163,4487150928	10 318,901713508	14 335,822394208	59 821,289448945	10 543,068576194	9 285,2077561585	8 713,4494849326	10 021,656579492	6 679,1696124998
r(m)	2.4397E+6	6.0518E+6	6.371E+6	3.3895E+6	4.73E+5	6.9911E+7	5.8232E+7	1.1E+4	2.5362E+7	2.4622E+7	1.187E+6	6.96342E+8	1.7374E+6

Note: m represents mass, m_e effective rotational mass. G is gravitational constant. t_0 is inherent rotational period, r is radius.

The equation for calculating the object's inherent rotational speed in the tangential direction is as:

$$v_0 = \frac{2\pi r}{t_0} = \frac{2\pi r}{\frac{t\sqrt{\frac{Mr}{mR}}}{x}} = \frac{2\pi rX}{\frac{2\pi rX}{v}\sqrt{\frac{Mr}{mR}}} = \frac{v}{\sqrt{\frac{Mr}{mR}}} \quad \text{or} \quad {v_0}^2 = \frac{v^2}{\frac{Mr}{mR}} = \frac{Gm}{r} \tag{9}$$

The ratio between inherent speed and rotational speed in the tangential direction is calculated as following:

$$\frac{v_0}{v_t} = \frac{v}{\sqrt{\frac{Mr}{mR}}}\frac{x}{v} = \frac{x}{\sqrt{\frac{Mr}{mR}}} \tag{10}$$

$\frac{X}{\sqrt{\frac{Mr}{mR}}}$ is referred to as a slow factor of the object's rotation from the inherent state to no-inherent state.

The rotation period of an object changes from t_0 to t. Then, we have: $t > t_0$, $v_0 > v_t$, and $X > \sqrt{\frac{Mr}{mR}}$.

In words, the tangential rotation speed of an object slows down as it shifts from an inherent state to a non-inherent.

If the reason for this slowing down is attributed to a result of a resistance (F_r) according to Newton's law, the work, E_f, done by this resistance is equal to the difference between the rotational kinetic energy in the inherent state (E_0) and that in the non-inherent (E_r). This energy can be calculated using the following equation:

$$E_f = E_0 - E_r = \frac{1}{2}mv_0^{\ 2} - \frac{1}{2}mv_t^{\ 2} \tag{11}$$

Combing 7, 9 and 11, we have the following equation:

$$E_f = \frac{1}{2}mv^2\left(\frac{Gm}{rv^2} - \frac{1}{X^2}\right) \tag{12}$$

So, the rotational resistance (F_r) as it shifts from an inherent state to a non-inherent may be calculated by the following equation:

$$F_f = \frac{E_f}{r} = \frac{1}{2r}mv^2\left(\frac{Gm}{rv^2} - \frac{1}{X^2}\right) \text{ or } F_f = \frac{1}{2}\left(\frac{\text{Gmm}}{\text{r}^2} - \frac{m\text{v}^2}{\text{rX}^2}\right) \tag{13}$$

$\frac{Gmm}{r^2}$ represents the Centripetal gravity of an object that comes from its mass. $\frac{mv^2}{rX^2}$ represents the centrifugal force that come from object's rotation. The rotational resistance is exactly half the difference between the two forces.

Discussion

The item of $Gm - gr^2$ in formula 3 is equal to Gm_e. m_e is called net effective rotational mass. Obviously, the net effective rotational mass (m_e) of an object is smaller than its inherent mass (m). Their values are shown in **TABLE 3**. This is why the rotational period (t) of an object is greater than its inherent period (t_0).

So, the formula 3 may be rewritten as following: $t^2 = \frac{4\pi^2 r^3}{Gm_e}$.

The gravity (g) on the Earth's surface varies around from 9.7639 ms^{-2} on the Nevado Huascarán Mountain in Peru to 9.8337 ms^{-2} at the surface of the Arctic Ocean because the earth is a sphere with uneven distribution of matter [2]. In 1901 the third General Conference on Weights and Measures defined a standard gravitational acceleration (g) for the surface of the Earth: g = 9.80665 ms^{-2} [3-7].

However, according the result calculated by the equation $\left(g = \frac{Gm}{r^2} - \frac{v^2}{rx^2} \right)$, the net average gravitational acceleration or the net gravity (g) at the surface of the Earth is 9.78638037 ms^{-2} in **TABLE 1** [8].

The centripetal gravitational acceleration $\left(\frac{Gm}{r^2} \right)$ of a rotation object depends on inherent mass, mass distribution and radius. The centrifugal acceleration $\left(\frac{v^2}{rx^2} \right)$ of a rotation object coming from its rotation depends on the rotational radius, orbital velocity and X value.

If the rotation speed is equal to its orbital velocity of the solid planets in the solar system (at which, X value is equal to 1), the centrifugal acceleration $\left(\frac{v^2}{r} \right)$ would be very larger than the centripetal acceleration $\left(\frac{Gm}{r^2} \right)$ $\left(\frac{v^2}{r} > \frac{Gm}{r^2} \right)$. Then, they should lose their ability of cohesion and tend to break down into pieces. This is why solid planet has a big X value and a long rotation period or a slow rotation speed.

Although the X value of the Jupiter and Saturn is nearly to 1, the value of $\frac{Gm}{r^2}$ for them is still bigger than that of $\frac{v^2}{rX^2}$ because of their mass is particularly large. Therefore, the gas planet is stable.

The above phenomenon is summarized as a principle that is, the principle of mutual adaptation of celestial body between rotational period and orbital speed. The principle is, t cannot be smaller than t_0 or v_t cannot be greater than v_0.Otherwise, the celestial body will disintegrate into pieces. It is advisable to use t is close equal to t_0 or v_t close equal to v_0 as the critical point for the disintegration of celestial bodies. This may explain the formation of asteroid belt, Kuiper belt and planetary rings, as well as why large mass of planets and moons must be located in the middle zone of the system.

The cause of rotational resistance is unknown. It may be related to gravitational field viscosity.

The inherent rotation period is a new concept. The inherent rotation period and the rotation period are two aspects of thing.

The rotation resistance is the reason why the value of rotation period of an object on orbit is greater than its inherent period. The slow factor describes the quantitative difference between the rotation period and the inherent rotation period.

Orbital motion is the premise of rotational resistance for rotational objects. Amplification factors (X) play a key role in calculating the centrifugal acceleration and centrifugal force generated by rotation.

In different spaces, the size of the rotational resistance is different. If two objects of the same mass are located in different spaces, they encounter different rotational resistances. This is why the rotational periods of the Mercury and Mars are very difference, although their masses are very close.

Because there is an inherent rotational period, it can be said that rotation is one of the properties of objects in space.

The rotation period of object can be accurately calculated by the formula 3. The value of the rotational period of planet and Sun, including asteroids and comet, for example Ceres and Halley comet , calculated by the formula is 100 percent consistent with observations in the literature in an accurate to seconds. So, this formula applies not only to planets and stars, but also to asteroids and comets. The rotational period of Saturn calculated by formula is equal to 10 hours 33minuts 3.28 second. In other words, this formula applies to all rotational objects in space [9-11]. This also shows that the theoretical assumptions of amplification factor and spin resistance are correct.

Conclusion

The rotational period of planet and Sun, including asteroids and comet, for example Ceres and Halley comet, calculated by the formula is 100 percent consistent with observations. This formula applies not only to planets and stars, but also to asteroids and comets. In other words, this formula applies to all rotational objects in space. The square of an object's rotational period in space is proportional to the cube of its radius and inversely to its net effective rotational mass.

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