The tidal force and the solar activity

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Abstract

This paper discusses the important role of centrifugal force in generating tidal forces and argues that solar activity is primarily influenced by the tidal force exerted by Jupiter. Measurement data show that our proposed tidal force equation provides significantly higher accuracy, with errors reduced by a factor of 16 compared with existing models.

Introduction

We propose that centrifugal force roles in maintaining stable planetary motion, contributing to tidal forces [1,2], and influencing solar activity [3–8].

Theory and Discussion

Einstein's general principle of relativity states that the formulation of physical laws should be independent of the choice of coordinate system [9,10]. Consider an idealized experiment involving a rotatable disk with a steel ball of appropriate mass attached to the center by a string. When the disk rotates, friction causes the steel ball to undergo circular motion. According to the conventional interpretation, the tension in the string provides the centripetal force required for circular motion, while no real centrifugal force is considered to exist. However, when the steel ball reaches a sufficiently high rotational speed, the string breaks. Since a centripetal force acts inward and cannot itself produce an outward separation of the string, we argue that the breaking of the string can only be explained by an outward centrifugal effect. This idealized experiment is straightforward to realize.

In this idealized experiment, Newton's second law, $F = ma$, can be applied in the radial direction. When the steel ball undergoes uniform circular motion at a relatively low speed, the inward centripetal force is balanced by the outward centrifugal force in the rotating reference frame. Therefore, the net radial force is $F = 0$, and the radial acceleration is $a = 0$, meaning that the steel ball remains stationary in the radial direction relative to the rotating frame. When the rotational speed becomes sufficiently high, the centrifugal effect exceeds the tensile strength of the string, causing the string to break.

Because the centrifugal force acting on the Moon balances the centripetal force generated by universal gravitation, the net radial force acting on the Moon is $F = 0$ and the radial acceleration is $a = 0$. Therefore, the Moon remains stationary in the radial direction, and we argue that centrifugal force prevents the Moon from falling toward the Earth. By the same reasoning, centrifugal force prevents the Earth from falling toward the Sun. When the tangential velocity of a satellite or spacecraft increases, the centrifugal effect becomes larger than the gravitational centripetal force, causing the orbital radius to increase. Conversely, when the tangential velocity decreases, the centrifugal effect becomes smaller than the centripetal force, causing the orbit to decrease.

We further propose that tidal forces are also related to centrifugal effects. Consider the Earth, with mass *m*, orbiting the Sun, with mass *M*, at velocity *v*. The distance between the center *O* of mass *M* and the center *c* of mass *m* is *l*, and the radius of *m* is *r*. Here, *G* represents the universal gravitational constant. The centripetal force acting on point *c* is directed downward and is given by:

$$\frac{GMm}{l^2}$$

and the centrifugal force acting on point *c* is upward and is given by: $m\omega^2 l$

The resultant force acting on point *c* is: $\Delta f = \frac{GMm}{l^2} - m\omega^2 l$ (1)

When *m* undergoes uniform motion, $\Delta f = 0$, and $GM = \omega^2 l^3$ (2)

The centripetal force acting on point b is downward and is given by : $\frac{GMm}{(l+r)^2}$

The centrifugal force acting on point b is upward and is given by : $m\omega^2 (l+r)$

The resultant force is an upward tidal force:

$\Delta f = \frac{GMm}{(l+r)^2} - m\omega^2 (l + r) = - 3\frac{GMmr}{l^3}$ (3)

The centripetal force acting on point a is downward and is given by : $\frac{GMm}{(l-r)^2}$

The centrifugal force acting on point a is upward and is given by : $m\omega^2 (l-r)$

The resultant force is a downward tidal force:

$\Delta f = \frac{GMm}{(l-r)^2} - m\omega^2 (l - r) = 3\frac{GMmr}{l^3}$ (4)

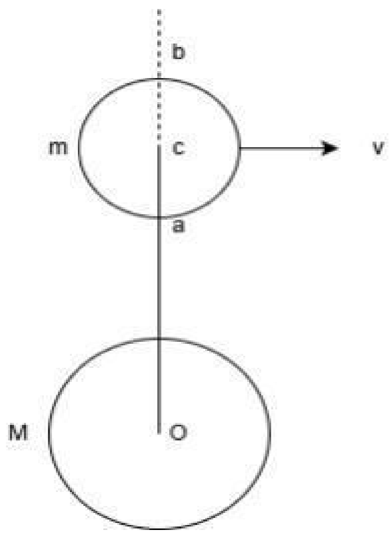

Figure 1. Tidal force of the Sun M acting on the Earth m.

When M_1 is the sun–planet barycenter, the sun-Mand the planet-m move around the barycenter M_1:

$$x_1 = \frac{ml}{M+m}$$

where l is the distance between the Sun and the planet.

When *m* < *M*, the gravitational field loses its symmetry. In calculating the tidal forces acting on both *m* and *M*, if $x_1 < r$, the parameter *r* in Equations (3) and (4) should be substituted with x_1. The tidal force acting on the Sun is therefore:

$$3\frac{GMmx_1}{l^3} \qquad (5)$$

When $x_1 > r$, the value of *r* in Equations (3) and (4) remains unchanged. The tidal force acting on the Sun is:

$$3\frac{GMmr}{l^3} \qquad (6)$$

the tidal forces of Jupiter and Venus are calculated as:

Jupiter : $\Delta f = 3\frac{GMmr}{l^3} = M5.6\times10^{-10}\, m/s^2$

Venus : $\Delta f = 3\frac{GMmx_1}{l^3} = M2.06\times10^{-13}\, m/s^2$

The tidal force exerted by Venus is less than one-thousandth of that exerted by Jupiter; therefore, Venus is expected to have a negligible influence on solar activity. Jupiter produces the strongest tidal effect among the planets and is therefore considered the dominant contributor. Consequently, the period of solar activity is close to the difference between Jupiter's orbital period and Earth's orbital period, because the observations are made from the Earth-based reference frame.

The currently mainstream formula for tidal force is : $\Delta f = 2\frac{GMmr}{l^3}$ (7)

Here r is the radius of the Sun. Using Equation (7), the tidal forces of Jupiter and Venus are calculated as:

Jupiter :$\Delta f = 2\frac{GMmr}{l^3} = M3.73\times10^{-10}$ m/s^2

Venus :$\Delta f = 2\frac{GMmr}{l^3} =M3.57\times10^{-10}$ m/s^2

Using Equation (7), the tidal forces of Jupiter and Venus are calculated to be similar, which does not match the period of solar activity. Therefore, Equation (7) is incorrect.

To calculate the tidal acceleration exerted by the Sun on the Earth, Equation (6) should be used: $\Delta f/M = 75\ \mu Gal$.

To calculate the tidal acceleration exerted by the Moon on the Earth, Equation (5) should be used: $\Delta f/M = 122\ \mu Gal$. Applying the lunar orbital inclination correction factor cos(5.15), gives a corrected value of approximately 121.5μGal

The tidal acceleration exerted by the Sun on the Earth is calculated using the conventional mainstream Equation (7): $\Delta f/M = 50\ \mu Gal$.

Using the conventional mainstream Equation (7), the tidal acceleration exerted by the Moon on the Earth is calculated as follows: $\Delta f/M = 110\ \mu Gal$.

The Earth's obliquity is 23.44°. The latitude of DJ060: Djougou (OSG #060) is 9.74°. On January 1, 2018, when the Sun, Earth, and Moon were aligned, DJ060 recorded a maximum tidal acceleration of 163 Gal [11]. This maximum value was produced by the combined tidal effects of the Sun and the Moon.

Using Equations (5) and (6), the calculated value is:

(75+121.5)$cos\ (23.44 + 9.74)$ =164.46μGal,

This value is approximately 0.9% higher than the measured value.

Using Equation (7), the calculated value is:

(50+110)$cos\ (23.44 + 9.74)$ =133.9μGal ,

this value is approximately 18% lower than the measured value.

Measurement data demonstrate that Equations (5) and (6) are more accurate than Equation (7), with errors reduced by a factor of 18.

On January 24, 2018, when the Sun and Earth were aligned and the Moon was approximately at a 90° angle relative to this direction, DJ060 recorded a maximum tidal acceleration of 61.4 Gal [11]. This value represents the contribution from the Sun alone.

Using Equations (5) and (6), the calculated value is:

75cos(23.44∘+9.74∘)=62.8 Gal.

This value is approximately 2.3% higher than the measured value.

Using Equation (7), the calculated value is:

50cos(23.44∘+9.74∘)=41.8 Gal.

This value is approximately 37.6% lower than the measured value.

The measurement data indicate that Equations (5) and (6) provide higher accuracy than Equation (7), with the error being approximately 16 times smaller.

Solar activity is a tidal–typhoon phenomenon driven by the combined effects of the Sun's rotation and Jupiter's revolution [3–8], with sunspots representing the visible manifestations of these processes. Jupiter has an orbital period of approximately 11.86 years. When solar activity is observed from the Earth, the apparent period becomes approximately 11.86 − 1 = 10.86 years due to the Earth-based observational reference frame, whereas the measured solar activity cycle is approximately 11 years. The active regions where sunspots form have a solar rotation period of approximately 27 days, and sunspot activity also exhibits a cycle of about 27 days.

Solar activity involves not only surface convection but also radial convection within the Sun. Radial convection transports high-temperature material from the solar interior to the surface, generating solar flares, coronal mass ejections, high-speed solar winds, and other predominantly low-energy phenomena. These effects become more significant during periods of solar maximum. During solar maximum, the tidal waves induced by Jupiter become stronger and thicker, and the absorption of particles within these tidal structures reduces the number of medium- and high-energy particles, resulting in an anti-correlation between these particle populations and solar activity. However, higher-energy particles (E > 9 GeV) possess stronger penetrating capabilities and are less affected [7].

The radial convection associated with solar activity plays an important role in maintaining the smooth progression of nuclear reactions within the Sun. Therefore, binary stars may evolve more rapidly and have shorter lifetimes than isolated stars. For stars with the same mass, differences in the surrounding environment, including the presence and characteristics of companion objects (whether stars or planets), may lead to different evolutionary pathways. Consequently, the fraction of stars with exactly identical luminosities is expected to be less than 1%.

Conclusion

1. We propose that centrifugal force plays a major role in the generation of tidal forces. Measurement results indicate that our proposed tidal force equation achieves significantly improved accuracy, with errors reduced by a factor of 16 compared with conventional formulas.
2. We propose that solar activity is primarily influenced by the combined effects of the Sun's rotation and Jupiter's tidal force.

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Author contributions

Yc.T. propose a theory；interpreted the data; and substantially revised the manuscript.

Zy.T. interpreted the data and drafted the manuscript.

Conflict of interest

The authors declare no competing interests.

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