JPPIPA 8(6) (2022)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Clothesline Model for Total Eclipses: Shielding Like Effect of Gravity

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Received: August 12, 2022
Revised: November 13, 2022
Accepted: December 20, 2022
Published: December 31, 2022

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DOI: 10.29303/jppipa.v8i6.2006

Abstract: Clothesline Model (CM) has been built. This model tries to explain the strange pattern of variations in the acceleration of Earth's gravity when a total solar eclipse or total lunar eclipse occurs. This model is built on the principle of a usual clothesline. In the CM, the concept of clothesline curvature is introduced due to an object that is hung on it and the ability of the object to reduce or affect the clothesline curvature of other objects that are also hung on the clothesline. In natural phenomena, the curvature of the clothesline in an object is interpreted as the curvature of spacetime which is a manifestation of the acceleration of gravity on the object. The influence or disturbance of an object on the clothesline curvature of another object is interpreted as the gravitational attraction of that object to another object. Based on the results of the CM analysis, the variation pattern of the earth's gravitational acceleration during a total solar eclipse is influenced by the damping factor by the moon against the disturbances from the sun and the earth. Meanwhile, the pattern of variations in the acceleration of Earth's gravity during a total lunar eclipse is influenced by the damping factor by the earth itself against disturbances from the sun and moon. From this damping effect, the moon and the earth act as gravitational shields.

Keywords: Clothesline model; Eclipse; Shielding like effect

Introduction

In general, an eclipse occurs when an object in space, such as a planet or satellite, passes through the shadow of another object in space (Barnett et al., 2020). The types of eclipses consist of solar and lunar eclipses. The solar eclipse is broadly divided into two types, namely total solar eclipse, and partial solar eclipse. Meanwhile, the lunar eclipse is broadly divided into two types, namely penumbral eclipse, and umbral eclipse. The naming of the eclipse is based on the celestial object that is obscured relative to the observer on earth. For example, a solar eclipse is an event where the sun is covered by the moon so that the sun is not visible (partially or totally) to observers from the earth. The same is true for a lunar eclipse, an eclipse that occurs when the moon is covered by the earth so that the sun's light is blocked by the earth which causes the moon to be dark relative to the observer on the earth. When viewed from the positions of the three celestial objects (the sun, the earth, and the moon), a solar eclipse or lunar eclipse occurs when the positions of the three objects are in a straight line.

The phenomenon of eclipses is not just an event that an object in outer space is covered by an object or the shadow of another object. Solar eclipses and lunar eclipses can cause a pattern of variations in the value of the Earth's gravitational acceleration during the event to occur. The variation pattern of Earth's gravitational acceleration is interesting to study because the variation pattern is determined by the type of eclipse. In addition, the pattern of variations in the acceleration of Earth's gravity also appears anomaly. The experimental results related to this anomaly were first confirmed by Maurice Allice based on the behavior of the pendulum swing which indicates the anomaly (ref). In the following year, several experimental results claimed that they have confirmed the Allais effect. However, some other experimental results claimed that this effect is not found

How to Cite:
Heriyanto, L. (2022). Clothesline Model for Total Eclipses: Shielding Like Effect of Gravity. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2689–2696. https://doi.org/10.29303/jppipa.v8i6.2006

(Munera, 2018). So, until now, the existence of the Allais effect is still debated.

One researcher argued that the anomaly or the Allais effect arises due to external factors, for example, factors originating from the earth's atmosphere, namely the rapid movement of air masses for most of the atmosphere above normal cloud levels during a solar eclipse (Flandern et al., 2003). Perhaps this opinion is suitable in locations that contain a lot of water vapor, such as islands. However, experimental results (Laesanpura et al., 2016) located in Poso, Central Sulawesi, Indonesia, which is a coastal area, confirm that the Allais effect is not significant. So it can be said that opinions related to the influence of air mass movements tend to weaken the Allais effect. Thus, this opinion should make the Allais effect weaker**.**

Regardless of the debate, we assume the Allais effect exists. This assumption is based on the experimental results of a total solar eclipse. Based on the experimental results on March 9, 1997, during a total solar eclipse (TSE) as shown in Figure 1, it was confirmed that the value of the Earth's gravitational acceleration decreased when the moon entered the initial phase of the first contact and second contact (4th contact of the figue).

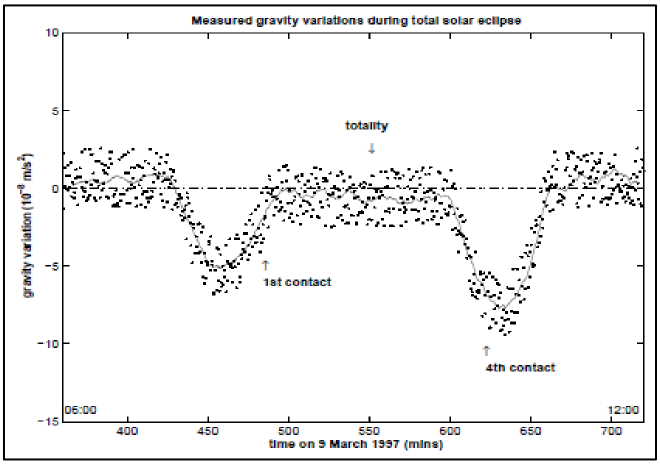

Figure 1. A pattern of variations in the acceleration of Earth's gravity during the total solar eclipse (TSE) on March 9, 1997 (Wang et al., 2000)

Then the value of the earth's gravitational acceleration reaches a minimum value when the moon is in the middle phase of the first and second contact. In the peak or total phase, the value of the acceleration due to gravity is normal. Furthermore, when entering the final phase of the first and second contact, the value of the earth's gravitational acceleration increases until it reaches a normal value when the first and second contact phases are completed. The pattern of gravitational variation that forms the two valleys cannot be explained (Yang et al., 2002).

In contrast to the experimental results of the value of the acceleration of Earth's gravity due to a total lunar eclipse (TLE), based on Figure 2, shows that the lowest point (g=9.7236366301 m/s2 on 31 January 2018 and g=9.7692416374 m/s2 on 28 July 2018) was at at the peak of the lunar eclipse or in the umbra phase (Nugraha et al., 2020).

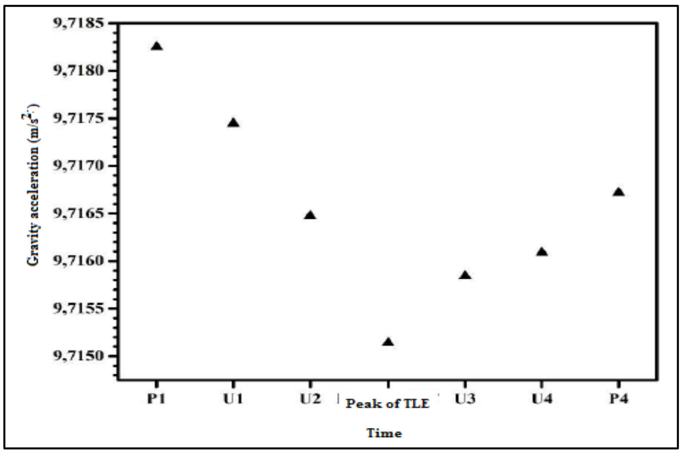

Figure 2. The pattern of variations in the acceleration of Earth's gravity during TLE on January 31, 2018 (Nugraha et al., 2020)

Based on the experimental results, it can be seen that a TSE and a TLE have very different impacts on the Earth's gravitational acceleration pattern. At the peak of TSE, when the moon and sun are both pulling the Earth from the same side (Kurdyaeva et al., 2021), the value of the acceleration of gravity of the earth returns to normal. Meanwhile, the value of the Earth's gravitational acceleration decreased significantly and reached its lowest value at the peak of the TLE when the moon and sun both pulled the Earth from different sides. The difference between the two patterns of Earth's gravitational acceleration, when TSE or TLE occurs, causes an anomaly in the pattern of the Earth's gravitational acceleration value.

The anomaly is quite difficult to explain using Newton's Law of Gravity. This is because it seems as if there is an absorption of the gravitational field by the moon at TSE which can cause a gravitational shielding effect for the earth. So that Newton's law of gravity is inconsistent when applied to the pattern of the Earth's gravitational acceleration value when TSE.

The anomalous phenomenon above may arise because it involves a system governed by several physical laws including Newton's law of gravity. In this article, a model is proposed which hopes to explain the anomalous phenomenon or the strange pattern of the earth's gravitational acceleration during TSE.

Method

In this study, a model is built that explains the pattern of variations in the value of the Earth's gravitational acceleration during a solar eclipse and lunar eclipse. This model is based on Newton's concepts (the nature of the inertia of objects, the gravitational force, and the tidal force) and Einstein's concept of gravity (the relation of mass and the curvature of spacetime). Each object in this model tends to maintain its initial state. An object will maintain its initial state (for example, at rest or moving at a constant speed) if the resultant force ($\vec{F}_R = 0$) acting on the object is zero, (Halliday et al., 2014). This statement is Newton's first law. In essence, Newton's First Law describes the tendency of an object to maintain its initial state. The measure that describes the tendency to maintain its initial state is known as the inertia (moment of inertia, I) or the level of laziness. Mathematically written as equation 1.

$$I = \int r^2 \, dm \quad (1)$$

Where m is the mass enclosed by a surface of radius r.

The interaction between objects in the model is the interaction of Newton's gravity and Einstein's gravity. Newton's gravitational interaction is expressed in the form of tidal forces (Dmochowski et al., 2018). The tidal force is the difference between the force acting at any point on an object and the force acting at the center of the object. Therefore, the tidal force for a point body is zero. The tidal force is also known as differential force. Mathematically, the tidal force on an object m_1 by an object m_2 is written as the first derivative of Newton's gravitational force which can be written as equation 2,

$$F_{tidal} = \int_{r_a}^{r_0} dF_g = \int_{r_a}^{r_0} \frac{d}{dr}\left(-G\frac{m_1 m_2}{r^2}\right) dr$$

$$= \int_{r_a}^{r_0} 2G\,\frac{m_1 m_2}{r^3}\, dr \quad (2)$$

where $F_g = G\frac{m_1 m_2}{r^2}$, r_0 , and ra are Newton's gravitational force, respectively, the distance m_2 to the center of m_1, and the distance m_2 to any point other than the center of m_1.

The measure of the value of the acceleration of gravity of the earth is manifested as a measure of the curvature of spacetime of the earth. The concept of curvature of spacetime is based on Einstein's theory of general relativity which states that objects instruct spacetime on how to bend and spacetime instructs objects on how to move (Misner et al., 1973). For curvature of spacetime that is between two masses (objects), the observed gravitational attraction results from the bending of space and time by the two masses (Adams et al., 2019). The quantitative measure of the value of the gravitational acceleration at a point on the earth is obtained from the tidal force acting at that point.

The concepts or laws of physics above become the glue for the component structures of the model which will be built. In this model, two basic structures form the basis of the model. The two components are the clothesline (Figure 3a) and the object M_1 that occupies the clothesline (Figure 3b).

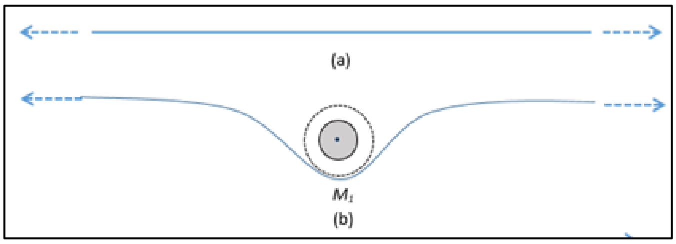

Figure 3. (a) The (ideal) massless clothesline free from objects, (b) The clothesline curvature by the M1 object

Clothesline is a component that becomes a medium of interaction. The strength of the interaction on the clothesline is determined by the size of the curvature of the clothesline. The size of the clothesline is proportional to the size of the mass of the object that occupies it. Changes in the size of the clothesline curvature in an object due to interference from other objects are always destructive or reduce the size of the clothesline curvature in the object (Figure 4). The reduction of the curvature is may be similiar with gravity `bums` theory but in different principle.

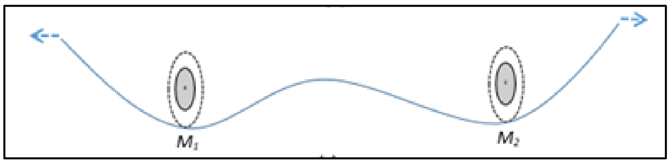

Figure 4. The interaction of two objects

The curvature of the clothesline on an object (M_3) will experience a maximum reduction when two objects (M_1 and M_2) that interfere with the clothesline on the object from two opposite sides with the position of the three objects are in line (Figure 5).

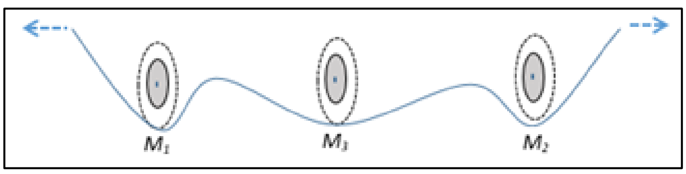

Figure 5. The interaction of three objects in line

Conversely, the curvature of the clothesline in an object will experience a minimum reduction when the two objects that interfere with the clothesline form an angle of 90^0 (Figure 6).

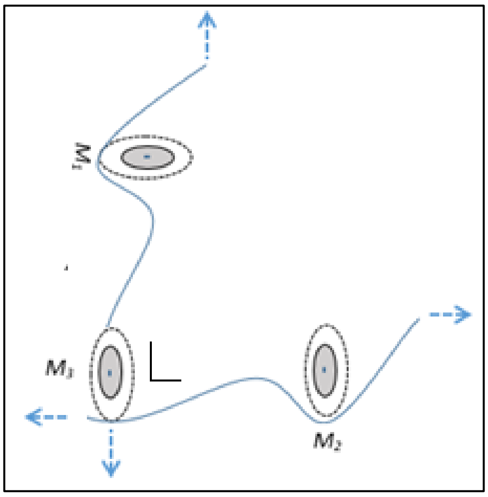

Figure 6. The interaction of three objects with an angle of 90^0

An object can only interfere with the clothesline of other objects that are directly connected to that object. Therefore, from Figure 5, object M_1 can only interfere with the clothesline in object M_3 which is directly connected to object M_1. Meanwhile, the disturbance of object M_1 does not reach object M_2 if object M_2 is covered by M_3. The same thing also applies to disturbances originating from M_2, which can only interfere with the clothesline in object M_3 so that it is not perceived by object M_1. In other words, object M_3 acts as a damper or shield for object M_1 (M_2) from M_2 (M_1) interference. Due to the damping by the M_3 object, the clothesline curvature in the M_3 object decreases drastically. This is because the curvature of the M_3 object is disturbed by the M_1 and M_2 objects.

Based on the explanation above, the physical interpretation of the model that has been built is based on the clothesline behavior when disturbed by an object. The size of the curvature of the clothesline in an object is interpreted as the curvature of spacetime which is the manifestation of the acceleration of gravity in the object. Because this model works based on clothesline behavior, this model is called the "Clothesline Model."

Result and Discussion

An eclipse occurs when the positions of the three objects are aligned (see Figure 7). Based on the picture, the eclipse event can be explained more effectively and more easily. For example, from Figure 7, M_1, M_2, and M_3 are the earth, sun, and moon for a solar eclipse, respectively. Meanwhile, for a lunar eclipse, the positions of the moon and earth are swapped so that M_1 is the moon and vice versa, M_3 is the earth. Due to the exchange of positions between the earth and the moon, we can obtain indirect information about the state of the moon when a solar (moon) eclipse occurs by comparing it with the state of the earth during a lunar (solar) eclipse.

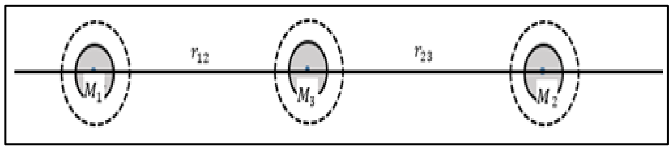

Figure 7. Position of space objects during an eclipse

Lunar eclipse

Based on **Figure 8**, it can be illustrated the force acting on the measuring instrument for the acceleration of gravity of the earth as follows

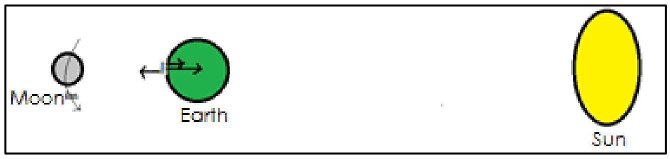

Figure 8. Components of the interaction force of celestial bodies during a lunar eclipse

Based on Figure 8, it appears that the experimental apparatus suffers from a force to the left of the reader from the moon and a force to the right of the reader from the earth and the sun. Because the distance from the earth to the moon is much smaller than the distance from the earth to the sun. So the contribution of the force from the sun can be neglected. Thus, the forces that are quite significant are felt by the experimental apparatus are the forces originating from the earth and the moon. The resultant of the two types of force is destructive because the directions are opposite to each other so the total force that is read is smaller than the components of the total force. As a result, at this position (peak phase) the acceleration of the earth's gravitational force decreases with a minimum value compared to the first and last contact. This is confirmed by experimental results (Figure 3) which show that variations in the acceleration of Earth's gravity during a lunar eclipse form a downward pattern from the first contact until it reaches a minimum point at the total phase, then forms an upward pattern since the last contact and returns to normal when the last contact is completed. Due to the action-reaction force between the moon and the earth, based on the results of the analysis, the pattern of variations in the acceleration of gravity on the surface of the moon facing the earth certainly follows the pattern of variations in the acceleration of gravity of the earth facing the moon. If so, then there is no conflict between the experimental results and Newton's law of gravitation.

The conclusion above regarding the pattern of variations in the moon's gravity when a lunar eclipse occurs needs to be confirmed through measurements. However, we cannot measure the gravitational acceleration of the moon directly. Fortunately, because the positions of the moon and the earth can exchange positions during a solar eclipse and lunar eclipse as previously mentioned, the pattern of variations in the gravitational acceleration of the moon during a solar (moon) eclipse can be determined by measuring the variation in the pattern of the earth's gravitational acceleration during a lunar (solar) eclipse.

Solar eclipse

The components of the forces acting during a solar eclipse can be shown as in Figure 9.

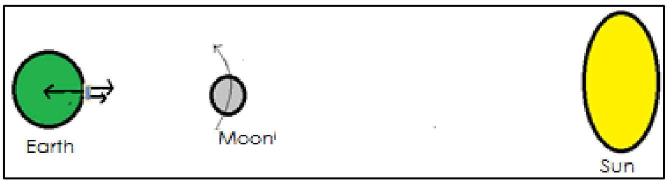

Figure 9. Components of the interaction force of celestial bodies during a solar eclipse

Based on Figure 9, it appears that the experimental apparatus suffers from a force towards the reader's right by the moon and sun and a force towards the reader's left by the earth. Because the earth-moon distance is much smaller than the earth-sun distance, the contribution of the force from the sun is negligible. Thus, the forces that are quite significant are felt by the experimental apparatus are the forces originating from the earth and the moon. The resultant of the two forces is destructive because the directions are opposite to each other, so the total force that should be measured is smaller than the components of the total forces which is similar to the moon eclipse. As a result, at this position (peak phase) the acceleration of the Earth's gravitational force should decrease to a minimum value compared to the first and last contact. Thus, based on this analysis, the pattern of variations in the acceleration of Earth's gravity during a solar eclipse is the same as the pattern of variations in Earth's acceleration during a lunar eclipse.

However, experimental measurements show a very different fact (see Figure 1), namely the pattern of variations in the Earth's gravitational acceleration has decreased since the first contact. The decrease reaches a minimum point in the middle of the first contact, then increases slowly to a normal point again when the first contact is finished or when it enters the peak or total phase. This pattern is repeated when entering the final contact phase until the phase is complete. So, experimental facts show that in the total phase of the gravitational acceleration returns to normal which according to Newton's law of gravity should reach the minimum point of the earth's gravitational acceleration in that phase. In this case, the analysis based on Newton's theory of gravity seems inconsistent the experimental results.

Analysis Using Clothesline Model

A solar (moon) eclipse has three stages, namely the first contact (penumbra 1), total (umbra), and the second contact (penumbra 2). As in the previous assumption, the illustrations for solar eclipses, M_1, M_2, and M_3 are the earth, sun, and moon, respectively. Meanwhile, for a lunar eclipse, the positions of the moon and the earth are swapped so that M_1 is the moon and vice versa, M_3 is the earth.

When the moon enters the early to the mid phase of the first contact of the solar total eclipse as shown in Figure 10, the sun and moon begin to interfere with the curvature of spacetime on earth so that the curvature of spacetime pattern on the earth tends to decrease. This pattern is relevant to the results of partial solar eclipse by Subhan et al. (2022) who state that the earth's gravity is decreased till a certaint point. The same result also was also found by Sholihat at al. (2016).

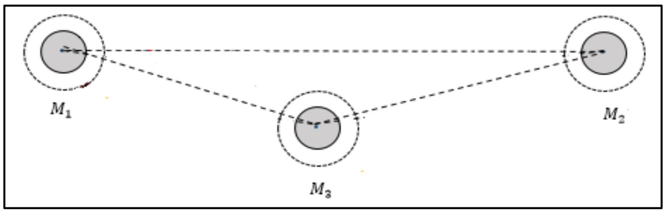

Figure 10. First phase of the first contact of the moon (M_3)

Because the curvature of spacetime on the moon also experiences disturbances from two sides, the curvature of spacetime pattern on the moon also tends to decrease. Likewise, the curvature of spacetime in the sun will follow the pattern of the curvature of spacetime on the earth because the nature of the disturbance is the same as the curvature of spacetime disturbance on earth. The curvature pattern of the three objects will be different when the moon enters the middle of the first contact (Figure 11).

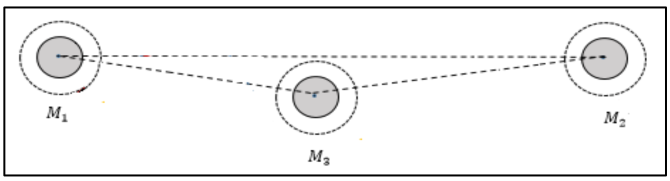

Figure 11. Middle phase of the first contact of the moon (M_3)

The downward pattern of the curvature of spacetime on the earth and sun tends to stop or stagnate at a certain value. However, the the curvature of spacetime pattern on the moon still tends to decline. Based on the CM, this occurs because the damping or shielding effect by the moon begins to work caused by the disturbances from the earth and sun to the curvature of spacetime on the moon getting stronger or bigger. The first contact and the last contact (after total phase) of the moon, the patterns of the earth's gravity indicate by the ocean tides when the ring eclipse occurs (Puspitasari et al., 2022).

The damping effect of the moon increases as the moon begins to enter the first contact to the end of the first contact. During this phase, the curvature of spacetime pattern on the earth and sun tends to rise while the curvature of spacetime pattern on the moon tends to decrease. Both of these patterns stop when the moon enters its peak or total phase (Figure 12).

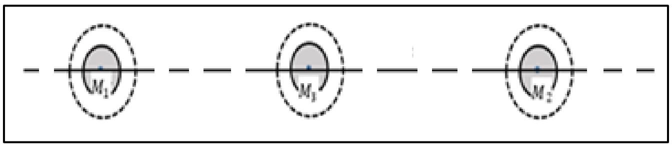

Figure 12. Peak or total phase of the moon (M_3)

In the total phase (peak), the curvature of spacetime on the earth and sun reaches the maximum value while the curvature of spacetime on the moon reaches the minimum value. The maximum value of the curvature of spacetime on earth (the sun) shows the damping of the moon against the disturbances from the sun (earth) is also maximum. The maximum damping from the moon then causes the curvature of spacetime on the moon to reach its minimum value.

The phase of the second contact is the reverse of the first contact phase process. Therefore, the pattern of the curvature of spacetime variation on the earth, the moon, and the sun when the moon begins to enter the initial phase until the end of the second contact phase is similar to the curvature of spacetime variation pattern of the three objects for the reverse process of the first contact phase.

The pattern of the curvature of spacetime variations on the earth and the sun from the first contact, peak (total), to the second contact of a total solar eclipse can be illustrated in Figure 13. The pattern of the earth's gravity which is represented with rhe earth curvature should be able to detect through the behavior of litght wave bending as in Bagdoo's explanation of lunar eclipses and Allais effect (Bagdoo, 2021). These also fit the experiment result mentioned in (Wang et al., 2000).

Meanwhile, the pattern of curvature of spacetime variations on the moon from the moon entering the first contact phase, peak (total), to the second contact of a solar eclipse can be illustrated in Figure 14.

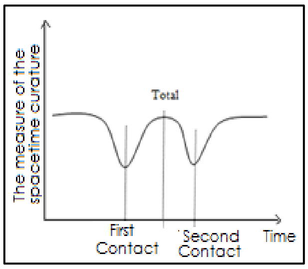

Figure 13. Patterns of variations in the Earth's and sun's curvature of spacetime during TSE

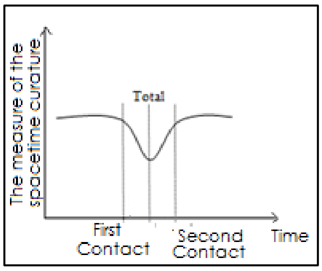

Figure 14. The pattern of variations in the moon's curvature of spacetime during TSE

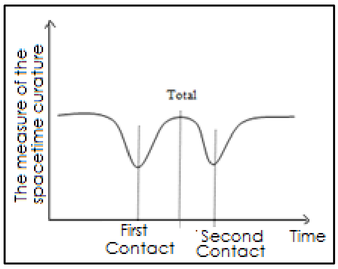

Figure 15. The pattern of moon and solar curvature of spacetime variation during TLE

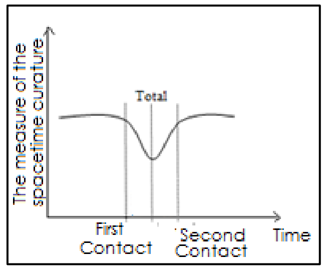

Figure 16. The patterns of variation of the Earth's curvature of spacetime during the TLE

The pattern of curvature of spacetime variations on the earth, moon, and sun during the total lunar eclipse can be explained using the pattern of variations of the three objects during the solar eclipse. Because the position of the earth during a solar eclipse is the same as the position of the moon during a lunar eclipse, so that, the pattern of variations of curvature of spacetime on the earth during the solar eclipse is the same as the pattern of variations of curvature of spacetime on the moon during the total lunar eclipse. Vice versa, the pattern of variations of curvature of spacetime on the moon during a solar eclipse is the same as the pattern of variations of curvature of spacetime on earth during a lunar eclipse. Thus, the pattern of lunar and solar variations during a total lunar eclipse is shown in Figure 15. Meanwhile, the pattern of curvature of spacetime variation on earth during a total lunar eclipse is shown in Figure 16. The patterns of the earth's gravity are the same as experiment result of total lunar eclipse as in obtained by (Nugraha et al., 2020).

Based on the results of the CM analysis of the pattern of variations of curvature of spacetime on the earth, it can be concluded that the pattern of variation of curvature of spacetime or the acceleration of earth's gravity during a total solar eclipse (TSE) shown in Figure 13 is the same as the experimental data (Figure 1). Likewise, the pattern of variations in the curvature of spacetime or the acceleration of Earth's gravity during a total lunar eclipse (TLE) shown in Figure 16 is the same as the experimental data (Figure 2). In other words, the clothesline model is consistent with the experimental data.

The experiment results which directly measured the gravity anomaly during solar eclipses can be found in Gallucci et al. (2018). Based on the article, those results devided in to two results. The first results, 11 of 18 researchers, agree with the shielding effects or such kind of shielding effect and the second results disagree with this effect. The positive, 7 of 18 researcher, results of shielding gravity effect for example come from (Flandern et al., 2003; Kuusela, 1992; Savrov et al., 1995; Saxl et al., 1971). While the negative results of shielding gravity effect for example come from (Chernogor, 2022; Fuchs et al., 2019; Kuusela, 1992). These results are complicated enough because the effect somtime come out but the effect also sometimes does not.

There is an aspect that can distinguish those results that is the surrounding where the experiments take place. The positif results come from the lands which are far enough from oceans or such kinds of it, while the negative results come from the lands which are closed enough from oceans or such kinds of it. These arguments are based on the experiments of the behavior of atmosphere during total solar eclipse which have been conducted by Marlton et al. (2016) and Marty et al. (2013).

Conclusion

Based on the explanation of the clothesline model, it can be concluded that the pattern of variations in acceleration on earth during a solar eclipse is influenced by the damping factor of the moon against disturbances or pulling force from the sun. Meanwhile, the pattern of variations in the acceleration of gravity on earth during the total lunar eclipse is influenced by the damping factor by the earth itself against disturbances or pulling force from the moon and the sun. By these dampings, the moon and the earth behave as a gravitational shielding. The depelovment of this model will be considered quantitatively in the next. Addition, the problem of the Earth's gravitational acceleration pattern during a partial solar eclipse has not been discussed. This issue will be examined in the next article.

Acknowledgements

The researcher would like to thank STKIP Paracendekia NW Sumbawa for providing partial funds to publish this journal. Thank you also to Warda Martia who has taken the time to discuss and provide suggestions and advises to the author.

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