The Equestria Solar System

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We explore a question as old as My Little Pony (MLP) itself: what does Equestria's solar system look like? We approach this question using evidences from MLP episodes along with some fundamental laws of physics such as Einstein's theory of relativity. Working with the assumption that Equestria's sun exhibits similar properties as Earth's sun, we argue that Equestria's sun has the same size and is positioned at the same distance from Equestria as its moon. We further propose the three celestial bodies, sun, moon and Earth are not in orbits with each other but stationary relative to each other. Finally, we conclude that Celestia and Luna raise the sun and the moon with their magic in the most literal way by positioning them above the land of Equestria during day and night respectively.

I. INTRODUCTION

Day and night in Equestria are brought forth magically by Celestia and Luna by raising the sun and the moon respectively. Before the time of the princesses, this was achieved by a group of unicorns as shown in [1]. This differs drastically from our world where the orbital motion between the sun, moon and Earth is what gives rise to day and night. This raises the question: what does Equestria's solar system look like?

The easiest models to think of are the heliocentric model (Earth orbiting around the sun) like our solar system and the geocentric model (the sun orbiting around Earth). Detailed discussions on these two models can be found in [2]. However, the only force in *our* universe that plays a significant role on the cosmic scale is the gravitational force. In the Equestria universe this is not the case as magic can also be classified as a long-ranged fundamental force of nature. We will not go over the detailed properties of magic and how to mathematically incorporate it as a fundamental force in this paper. Rather, for the remaining of this paper we will assume Celestia and Luna *do* have the magical prowess to control and move celestial objects such as the sun and moon. With this assumption, we will create a model for the solar system in Equestria in a way that is consistent with the laws of physics and is supported by evidences from the episodes.

II. PHYSICS BACKGROUND

In order for us to make the connection between the physical laws in our universe and Equestria universe, we need to establish some ground rules.

Axiom 1 *The laws of physics in our universe forms a subset of the laws of physics in Equestria universe.*

In other words, the laws of physics that work in our world will work in Equestria as well. However, this does not mean we can't have new physics in Equestria. For example, the introduction of magic forms an integral part of Equestria physics that is absent in our universe.

This axiom allows us to proceed with our analysis using physics and mathematics we already have rather than building everything from scratch. In this section, we will explore some topics in physics that will constrain the kind of models Equestria solar system can be.

A. Angular diameter and Luminosity

How big an object appears in the sky has everything to do with its *angular diameter* (δ). This is why a large object far away appears to be the same size as a smaller object much closer to us. The angular diameter is defined as $\delta = \arctan(R/d)$ where R is the radius of the object and d is its distance from us. But given that we are dealing with celestial objects where $d \gg R$, we have $\delta \approx R/d$ to a very good approximation. This shows a large sun very far away appears to be the same size in the sky as a small sun very near Equestria.

If we were to change the size and distance of the sun, we must check how this would affect its luminosity (L) which is the amount of power (per unit area) ponies receive on Equestria. Luminosity can be computed using the surface temperature of the sun (T), radius of the sun (R) and distance from Equestria (d). For the sun in our universe, this adds up to about $1380\mathrm{Wm}^{-2}$ (where W is Watts, the unit of power). So the three variables T, R, d need to be carefully selected in order for the sun to produce the right amount of light for ponies to survive. Even though ponies may not need exactly $1380\mathrm{Wm}^{-2}$, we will still strive for something at a similar order of magnitude based on the fact that their environment is similar to ours.

The equation for luminosity (L) is:

$$L = \sigma \frac{T^4 R^2}{d^2} \tag{1}$$

for some constant σ. From Equation 1 we see that the luminosity Equestria receives only depends on the ratio R/d (assuming a constant T). So if we were to make the sun smaller and closer to Equestria, the ponies will receive the same luminosity as long as the ratio stays the same.

B. Special Relativity

The theory of special relativity formulated by Einstein was one of the greatest achievements in the 20th century giving rise to what is arguably the most well known equation: $E = mc^2$. But, there is another consequence of special relativity that is more important and fundamental: nothing can travel faster than the speed of light. This is one of the most firmly established and well tested law of physics which we will assume to hold in the Equestria universe as well. Breaking this law would mean overhauling all physical theories we constructed since the 20th century. Faster-than-light travel can also create many paradoxes and issues with causality. Hence, in accordance with Axiom 1, we propose the following:

Theorem 1 *Magic is a fundamental force of nature.*

Corollary 1 *Just like light and gravity, magic cannot travel faster than the speed of light (300,000km/s).*

Now we have all the tools necessary to construct the solar system of Equestria.

III. THE EQUESTRIA SOLAR SYSTEM

In our universe, the moon has a radius $R_{\text{moon}} = 1.7 \times 10^6$m and the distance to Earth $d_{\text{moon}} = 4 \times 10^8$m. The sun has a radius $R_{\text{sun}} = 7\times10^8$m and is positioned $d_{\text{sun}} = 1.5 \times 10^{11}$m away from Earth. An interesting property is that the ratio $R_{\text{sun}}/d_{\text{sun}} \approx R_{\text{moon}}/d_{\text{moon}}$. In fact, this is why the moon and the sun appears to have the same size in the sky! The importance of this will be obvious soon.

In [3-4], there were several incidences where Celestia raises the sun. One thing to notice is that as soon as Celestia uses her magic (indicated by her unicorn shining brightly) the sun moves immediately as well. If we assume the sun is positioned 1.5×10^{11}m from Equestria as in our universe, it will take about 8 minutes for light to reach Equestria. In fact, if we take into account the time for magic to reach the sun and for light from the sun to reach Equestria, it takes 16 minutes in total. From this, we can conclude that Celestia cannot instantly move the sun without violating Corollary 1. The resolution is to make the sun much closer to Equestria.

Scenes from [5] allow us to directly compare the size of the sun and the moon in the sky of Equestria (or in other words their angular diameter δ), showing that they are approximately equal $\delta_{\text{sun}} \approx \delta_{\text{moon}}$. This is similar to the case in our universe. So we have two conditions to meet:

Condition 1: The distance $d_{\text{Equestria sun}}$ between the sun and Equestria must be near enough to *almost* immediately respond to Celestia's magic.

Condition 2: We require $\delta_{\text{sun}} \approx \delta_{\text{moon}}$.

Miraculously, taking inspiration from our own solar system, we can satisfy both of these conditions!

Proposition 1 *The sun in Equestria is just as bright as ours but has the same size and same distance from Equestria as its moon* $d_{Equestria\ sun} \approx d_{moon}$.

By placing the sun at moon distance of $d_{\text{moon}} = 4\times10^8$m , it is now close enough for Celestia's magic to cause a (near) immediate reaction of the sun (with about a 2.5 second delay). Our model is now consistent with scenes in [3-4] and does not violate special relativity!

If we place a slightly larger sun slightly further away we can still meet Condition 2. However, we need it to be as close as possible in order for Condition 1 to hold. Furthermore, due to the appearance of solar eclipses when Luna becomes nightmare moon, the lower boundary on the distance is $d_{\text{Equestria sun}} \geq d_{\text{moon}}$. In other words, we want the sun to be as close as possible but not nearer than the moon. The closest we can get without the sun crashing into the moon is $d_{\text{Equestria sun}} = d_{\text{moon}} + R_{\text{moon}}$. A simple calculation would show the corresponding radius of the sun in order to keep the ratio constant would be $R_{\text{Equestia Sun}} = R_{\text{moon}}(1 + R_{\text{moon}}/d_{\text{moon}})$. Given that the size of the moon is usually much smaller than the distance from Equestria, we have $R_{\text{Equestria Sun}} \approx R_{\text{moon}}$.

When two celestial objects such as the sun and Earth came close to each other, they will be caught in each others' gravitational pull. As a result, they orbit around each other. This is how planets orbit the stars and moons orbit planets in our solar system. However, the reason this works is that out of all the fundamental forces, only gravity is significant in this situation. In Equestria universe, the ability of Celestia and Luna to move the sun and the moon shows magic is significant enough to combat gravity. It could be possible that the initial orbital movement between the celestial bodies is not sufficient to sustain life on Equestria. For example, days can be much longer or much shorter than is preferable. As a result, the first group of unicorns use their magic to allow a reasonable amount of daytime and night time by raising the sun and moon themselves. Now, what happens to the sun and the moon after they raised it? We argue that whenever they are not controlled by magic, the sun, moon and Equestria remain stationary relative to each other.

Now let's see this in detail. There are times in [5-6] where no one to performs the duties of raising the sun and the moon. If we consider the above theory that unicorn magic is what fixes the position of these two celestial objects, wouldn't they collide into each other during its absence via gravitational attraction? The answer in short is yes. However, due to their distance apart, it would take a significant amount of time for collision to occur. The time frame given in [5-6] would result in an insignificant change to their positions in the sky. A more detailed computation can be found in [7] which uses Kepler's laws to show that it will take 5 days for the moon to crash to Equestria.

With these features established, the act of Celestia and Luna raising the sun and the moon is exactly what it is — they used their magic to position the sun and moon

above Equestria, thus creating day and night. Of course, in order for our model to work, we need Celestia and Luna to constantly maintain the motion of the sun and moon respectively. This explains why their absence in [5] results in an immediate halt in the position of the sun and moon. At night, the sun would be rotated to the other side of earth and similarly for the moon during the day.

IV. CONCLUSION:

In our model of the Equestria solar system, the position of the sun is chosen to be $d_{\text{Equestria sun}} = d_{\text{moon}} + R_{\text{moon}}$ so that it is near enough to react almost instantly to Celestia's magic but still further away than the moon. The closer distance of the sun prompts us to adjust its size to be $R_{\text{Equestria Sun}} \approx R_{\text{moon}}$ in order to keep the luminosity around 1380Wm^{-2} to sustain life in Equestria. Furthermore, the sun, moon and Equestria are stationary relative to each other rather than orbiting around themselves. As a result, Celestia and Luna constantly use their magic to reposition the sun and the moon to bring forth day and night in Equestria.

A. Questions to be addressed

The proposition above solves some problems but also raises a few. Firstly, for a star to be the same size of our moon is unheard of in our universe. Secondly, we assumed the temperature of the Equestria sun to be the same as ours which is quite concerning (since it needs to be at a certain size to sustain the fusion reactions in its core in order to generate heat).

Since the mean density of the moon is greater than that of the sun, the moon will be heavier if they were the same size. This is in contradiction with comments made by Celestia in [8]. However, the values we assigned to the size and distance of the Equestria sun is quite flexible. We could just as well have placed it slightly further away, with a larger radius and lower surface temperature and still allows the same luminosity to sustain life on earth while keeping the laws of relativity intact. The exact computations need to be worked out.

There is also the question about whether Equestria is flat or spherical. Such arguments were already made in [9]. Our view is that Equestria is spherical although a flat Equestria would not significantly hurt the arguments above as gravity still works the same way. Celestia simply needs to take the sun to the 'backside' of earth, see [10] for a visualization of this process in a different universe.

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