
GRAVITATIONAL TIME DILATION

EXPLAINED FOR BEGINNERS

INTRODUCTION

At first the concept of gravitational time dilation may look a bit complicated and it is difficult to figure out the reason. In this paper, I am going to explain gravitational time dilation without the knowledge of any other concept such as the equivalence principle and others. So let me start with what General Relativity (GR) postulates. Suppose we have two clocks, one is placed closer to the surface of the earth while the other high in space. The clock which is closer to the surface of the earth will run slower than the clock placed high up in space. Well at first though, this seems pretty absurd and it is hard to think of a reason for such an awkward behavior. This phenomenon is called gravitational time dilation.

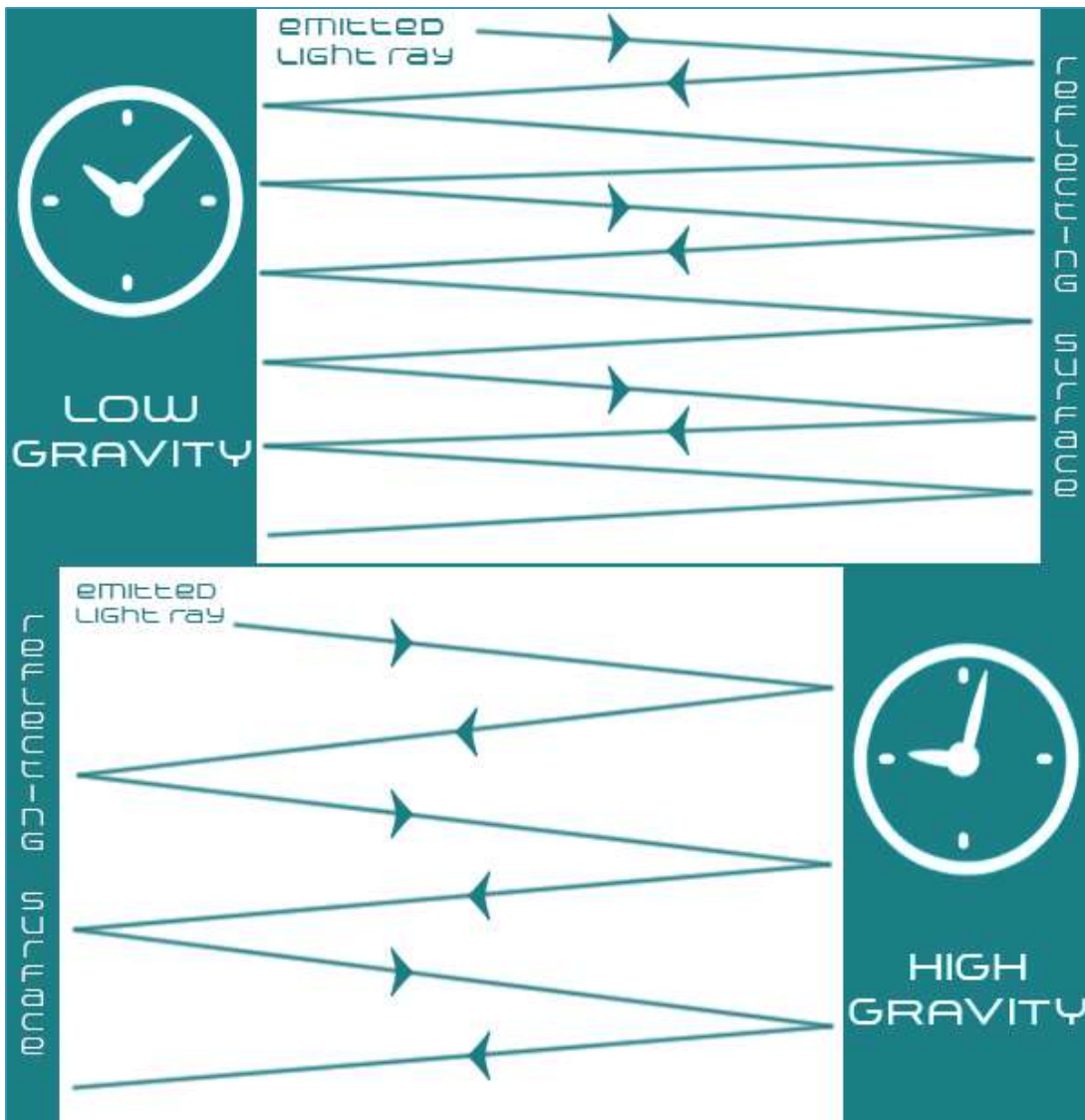
This is what the wiki page says about it: - Gravitational time dilation is an actual difference of elapsed time between two events as measured by observers differently situated from gravitational masses, in regions of different gravitational potential. The lower the gravitational potential (the closer the clock is to the source of gravitation), the more slowly time passes. Albert Einstein originally predicted this effect in his theory of relativity and it has since been confirmed by tests of general relativity.

So that pretty much sums up the concept of gravitational time dilation. Just to clear up the doubts I will give an example. Suppose you are up in space sitting in a stationary space shuttle and your sibling is on earth. When you return back to earth, you will find that you have aged a little more than your sibling in the same time frame. This happens because you were in an area of higher gravitational potential while your sibling was in an area of lower gravitational potential. This difference led to your sibling ageing slower than you. Take note, that this example is an oversimplification in the sense that these effects are very hard to measure when there is only a slight difference in gravitational potential. So actually it will be very hard to measure the actual difference between the ages of you and your sibling.

Now I will move on to why this happens and the reason behind this phenomenon. On the internet you will hardly find a very simple reason which you can understand without any basic prior knowledge.

BEHIND THE SCENES

This image below might seem confusing at first but this is what explains the reason behind gravitational time dilation. So let us try and make sense of the image and discover the reason



behind gravitational time dilation. The image is divided into two parts. The upper part contains a clock placed high above the earth's surface, thus in a region of low gravity while the clock at the bottom of the image is placed closer to the earth's surface. You can also see that the lower clock is running slower by comparing its time in the image. These clocks are not any ordinary clocks. They are called "light clocks". So how do

they work? Well as you can see, a light ray is emitted and as soon as the light ray hits the reflecting surface, the clock ticks. The clock is made up of two reflecting surfaces that also act as detectors. So when a photon hits a reflecting surface the clock ticks and this continues forever. Now we are assuming that the photon never loses energy after reflection and its

reflection can be detected. Making such a clock is impossible at the moment due to the restrictions of QED (quantum electrodynamics) but then this clock is only for explaining the concept. Now we know how the clock works, let us move on. I will introduce you to another very simple concept. Since light has energy and energy is equivalent to mass, it is affected by gravity. As a result light follows a curved trajectory or a curved path when introduced to gravitational forces. Now again this is not actually what happens because gravity curves space-time and light bends because it has to travel through that curved space-time. If this just went over your head, then just think that light bends under gravity and does not follow a straight path. Since high gravity attracts things more towards itself (bends space-time more), light bends more in a region of high gravity. We also know that a straight path is always shorter than a curved path in terms of distance traversed. So a light ray that bends more has to travel a longer distance to reach the destination and therefore takes more time than a light ray that bends lesser. So now back to the image and the two clocks. When a light ray is emitted in the clock placed closer to the earth's surface, the light ray bends and thus takes a longer time to reach the reflecting surface than it should have, if it followed a straight horizontal path. The image shows straight diagonal lines instead of curved paths just to simplify the diagram. Even a diagonal path is longer than a horizontal path. Since light has to follow a curved path (represented as a diagonal in the image), the clock ticks a little slower than usual.

Let us get back to the clock placed up in space. We know that the light ray in that clock bends lesser since it is in a region of higher gravitational potential and experiences less gravity. So the clock will tick faster as the light takes a lesser time to reach the reflecting surface. In the image you can see that in the bottom clock, the light ray has to follow a more curved path (a more diagonal path) than in the clock placed above it. Therefore the clock placed closer to the earth ticks slower.

CONCLUSION

So I showed how and why gravitational time dilation occurs. To sum up, the clock placed in a higher gravitational potential region will run slower because the effect of gravity on light will be minimal and the light will take lesser time to reach the reflecting surface. This will in turn make the clock tick slower.

Citations

Gravitational time dilation. (2014, June 19). Wikipedia. Retrieved July 12, 2014, from http://en.wikipedia.org/wiki/Gravitational_time_dilation