Gravitation - A Mystery?

by Gonit Sora - Tuesday, May 05, 2015

http://gonitsora.com/gravitation/

We all have an intuitive understanding about the force that makes apples fall. This is partly due to the work done by Isaac Newton, who contrary to the opinion of school kids did not “discover” gravity. Newton instead for the first time proposed that the force of gravitation existed between any two masses and gave a nifty expression for this,

This was a big moment in physics when the Heavens and Earth where shown to follow the same laws. Newton's ideas explained the motion of the Earth around the Sun as well as it did the descent of fruit.

There was one little problem though and Newton had written about it in the Principia,

> “Gravity must be caused by an Agent acting constantly and instantly according to certain laws; but whether this Agent be material or immaterial, I have left to the Consideration of my readers ”

In other words, how does one mass know about the other mass? It is incredible that Newton thought of this issue at a time when physics as a subject did not even exist (He called himself a natural philosopher). Electromagnetism had the same issue of “non locality” but this was partially solved by Faraday's introduction of the field concept(...). For clarity let us take an example, let the Sun suddenly be shaken vigorously, will the Earth be affected by this instantly and also will there be any new effects to look out for? How is this pull from the Sun able to travel across the void of space instantly and affect the motion of Earth?

Source : www.astro.cornell.edu

Newton's challenge to his readers lay forgotten for 202 years when it was finally answered by Albert Einstein in 1915. Einstein brought forward the theory of General Relativity(GR) which is currently accepted as how gravitation actually works. The equations of GR reduce to Newton's one for weak fields and slow motions. Einstein developed this theory based on two key ideas. Firstly his special relativity theory showed how no information can transmit faster than the speed of light, and the equivalence principle.

Einstein noted that there was no experiment that could be conducted within a closed, small space that can distinguish between a gravitational field and acceleration. How he managed to work from this seemingly innocuous idea to GR is complicated but Einstein considered this idea the happiest thought of his life.

Before Einstein space and time were not discussed in physics, they were considered to be a constant, inert backdrop with fixed properties upon which all other interactions took place. Einstein proposed that this was not so. Space and time were “connected” and it was possible for this space time to have curvature just like the surface of the Earth. The surface of the Earth from the point of view of a person on it was flat, but we know that on the whole it is not. This curvature can lead to very interesting geometric results that we do not study in our usual high school geometry classes. One example is that it is possible to draw a triangle with three right angles on a sphere.

Source : www.pitt.edu

What about, the shortest path between two points ? By this definition the lines in the diagram are as straight as straight can be since we are only allowed to move on the surface. In summary we have looked at one example of a 2-D surface embedded in a curved 3-D space. One may argue that those lines are not straight. But what is a straight line?

What if our 3-D world similarly was embedded in a curved 4-D space ? This is exactly what Einstein proposed and more importantly the curvature around a body is related to its mass. Now let us see how to explain the motion of the Earth around the Sun using this idea.

Source : www.space.com

Imagine space time as some kind of fabric and the Sun due to its awesome mass creating some kind of depression in it. Now if the Earth where initially moving tangentially it would move along this trough created as seen in the above picture. Another way of looking at it is to say that the Earth is locally moving along a straight path, the space around it is curved . Also any perturbations in the Sun's position or mass would create ripples in this “fabric” which would experience a time delay before arriving at Earth.

Qualitatively Einstein's ideas are not too hard to explain but the real problem comes when you start working with the equation:The above is the general form of Einstein's field equation and the terms and the mathematical ideas that lay behind this one equation is far from trivial. General Relativity forced physicists to study subjects like differential geometry which where at one point a matter of concern only for pure mathematicians. The equation above has been for the last one hundred years been studied and various solutions have been evaluated. The solutions and the properties of this one equation continues to be the subject of active research and many predictions from the equation have been confirmed and some such as gravitational waves are yet to be.

Since the equations of GR are difficult to work with, usually even in cosmology a lot of computations continue to be done with Newton's equation except for when we are studying very strong gravitational fields. The first solution to the Field equation was computed by Schwarschild, a Russian physicist for the case of a black hole. Through his theory of gravity Einstein unified space, time and mass/ energy. This approach to unification using geometric ideas and extra dimensions continues to be used in the new field of String theory which is arguably the strongest contender for the title of the “Theory of Everything”!

Image Source : www.fromquarkstoquasars.com

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