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CORRELATON OF GRAVITATIONAL WAVES WITH GENERAL THEORY OF RELATIVITY

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ABSTRACT

A Brief discussion of Special theory of Relativity, General theory of Relativity and its consequences. Our aim is to presenting introduction to the basic of theory of Relativity and explanation of gravitational waves from this theory. We build upon user interactive introductory lesson of basic related to these theories .we discussed here how General theory of relativity become central premises for explaining the origin and existence of gravitational waves. In certain circumstances, accelerating objects generate changes curvature of space-time, which propagate outwards at the speed of light in a wave-like manner. These propagating phenomenons are known as gravitational waves. Combine the theory of relativity (the theory of the very large, which describes one of the fundamental forces of nature, gravity) with quantum theory(the theory of the very small, which describes the other three fundamental forces, electromagnetism, the weak nuclear force and the strong nuclear force) in a unified theory of quantum gravity (or quantum theory of gravity), the so-called "theory of everything".

Contents:-

- Special theory of relativity
- General theory of relativity
- Gravitational waves

The "**Theory of Relativity**" generally refers to two theory of Albert Einstein:-

1) Special theory of relativity of 1905
2) General theory of relativity of 1916.

The idea of "relativity "had been studied almost three centuries earlier by Galileo, later by sir Isaac Newton Einstein's theories are somewhat more Involved, even if his starting point was in many respects the same.

His ground breaking theories takes in account the

- Speed of light
- The structure of space time

- The equivalence of acceleration & gravity

They have led to some remarkable consequences, including the

- Dilation of Time
- Contraction of Length
- Mass-Energy Equivalence
- Bending of Light
- Prediction of existence of black holes &wormholes
- Birth of universe in Big Band
- Origin of GRAVITATIONAL WAVE

I. SPECIAL THEORY OF RELATIVITY

In the Special theory of Relativity, published in his 1905, Einstein had the audacity to turn the question around and ask: What must happen to our common notions of space and time so that when the distance Light travels in a given time is measured, the answer is always 3000,000 km/s? For Example, if a spaceship fires a laser beam at a piece of space debris flying towards it at half the speed of light, the laser beam still travels at exactly the speed of light, not at one-and-half times the speed of light. He begun to realize that either the measurement of the distance must be smaller than expected, or the time taken must be greater than expected, or both.

In fact, Einstein realized, the answer is both: space “contracts” and time “dilates”. Some of the motion through space can be thought of as being “diverted” into motion through time and vice versa. Thus the dimensions of space and time affect each other, and both space and time are therefore relative concepts.

In a nutshell, the Special Theory of Relativity tells us that moving objects measures shorter in its direction of motion as its velocity increases until, at the speed of light, it disappears. Its also tells us that moving clocks run more slowly as there velocity increases until, at the speed of light, they stop running altogether. In fact, it also tells us that the mass of a moving object measures more as its velocity increases until, at the speed of light, it becomes infinite.

Thus, one person’s interval of space is not the same as another person’s and time runs at a different rates for different observers travelling at different speeds. To some extent, the faster to go, the slower your age and the slimmer you are! The reason this is not obvious in everyday situations is that the differences at every day speeds are infinitely small and only really become apparent at speeds approaching that of light itself (“relativistic” speeds). The closer the speed of an object approaches to the speed of light, the more warped lengths and time interval become. The amount of length contraction and time dilation is given by Lorentz factor, named after the Dutch physicist Hendrik Lorentz, who had been exploring such transformation equations since as early as 1895, long before Einstein began his work. The Lorentz factor given by the equation$¥=1/(1-v^2 /c^2)^{1/2}$, so that the effect increases exponentially as the object’s velocity (v) approaches the speed of light (c). Thus, the calculations show that at 25% of the speed of light, the effect is just 1.03 (a mere 3% slowing of time or contraction of length); at 50% of the speed of light, it is just 1.15; at 99% of the speed of light, time is slowed by a factor of about 7; and at 99.999, the factor is 224. So, if it were possible to travel in a spaceship at, say, 99.5% of the speed of light, a hypothetical observer looking in would see the clock moving about 10 times slower than normal and the astronaut inside moving in slow-motion, as though through treacle.

A couple of real-life examples may help to make the effects of special relativity clearer. Experiments have been carried out where two identical super-accurate atomic clocks were synchronized, and then one was flown around the world on an airplane while the other stayed at home. The clock which travelled recorded marginally less passage of time than the other (as predicted by the theory), although the difference was of course minimal due to the relatively slow speeds involved. Our fastest military airplanes can only travel at about 1/300,000 of the speed of light, so the dilation effect γ is only about a ten-thousandth of 1%.

At very high speeds, however, the effect is much more noticeable. Experiments have demonstrated that an ultra-short-lived muon particle, which habitually travels at 99.92% of the speed of light, actually lives about 25 times longer and travels about 25 times further than it theoretically should. Particles travelling at speeds up to 99.99% the speed of light in the CERN particle accelerator in Switzerland experience the same kind of relativity-induced time travel, experiencing a γ factor of around 5,000, allowing the artificial persistence of even shorter-lived particles such as phi mesons.

So, travelling at close to the speed of light would theoretically allow time travel into the future, as time slows down for the speeding object in order to "protect" the cosmic speed limit of the speed of light. A corollary of all this is that, if it were possible to exceed the speed of light, then it would also be possible to go back in time, which raises the possibility of time-travel paradoxes (where a person goes back in time and interferes in their own past etc), although some scientists believe that some as yet undiscovered law of physics may intervene to prevent such paradoxes. Actually, special relativity does not specifically forbid the existence of particles that travel faster than light, and there is a hypothetical sub-atomic particle called a tachyon, which would indeed spend its entire life travelling faster than the speed of light, but it is currently still hypothetical.

Essentially, then, the Special Theory of Relativity can be boiled down to its two main postulates: firstly, that physical laws have the same mathematical form when expressed in any inertial system (so that all motion, and the forces that result from it, is relative); and secondly that the speed of light is independent of the motion of its source and of the observer, and so it is NOT relative to anything else and will always have the same value when measured by observers moving with constant velocity with respect to each other

II. GENERAL THEORY OF RELATIVITY

Central premises of the General Theory of Relativity are that the curvature of **space-time** is directly determined by the distribution of **matter** and **energy** contained within it. What complicates things, however, is that the distribution of **matter** and **energy** is in turn governed by the curvature of space, leading to a feedback loop and a lot of very complex mathematics. Thus, the presence of **mass/energy** determines the geometry of space, and the geometry of space determines the motion of **mass/energy.**

In practice, in our everyday world, Newton's **Law of Universal Gravitation** is a perfectly good approximation. The curving of **light** was never actually predicted by Newton but, in combination with the idea from **special relativity** that all forms of **energy** (including **light**) have an effective **mass**, then it seems logical that, as **light** passes a massive body like the Sun, it too will feel the tug of **gravity** and be bent slightly from its course. Curiously, however, Einstein's theory predicts that the path of **light** will be bent by twice as much as does Newton's theory, due to a kind of positive feedback. The English astronomer Arthur Eddington confirmed Einstein's predictions of the deflection of **light** from other **stars** by the Sun's **gravity** using measurements taken in West Africa during an eclipse of the Sun in 1919, after which the **General Theory of Relativity** was generally accepted in the scientific community.

The **theory** has been proven remarkably accurate and robust in many different tests over the last century. The slightly elliptical orbit of planets is also explained by the **theory** but, even more remarkably, it also explains with great accuracy the fact that the elliptical orbits of planets are not exact repetitions but actually shift slightly with each revolution, tracing out a kind of rosette-like pattern. For instance, it correctly predicts the so-called precession of the perihelion of Mercury (that the planet Mercury traces out a complete rosette only once every 3 million years), something which Newton's **Law of Universal Gravitation** is not sophisticated enough to cope with.

Gravity Probe B was launched into Earth orbit in 2004, specifically to test the **space-time**-bending effects predicted by **General Relativity** using ultra-sensitive gyroscopes. The final analysis of the results in 2011 confirms the predicted effects quite closely, with a tiny 0.28% margin of error for geodetic effects and a larger 19% margin of error for the much less pronounced frame-dragging effect.

The **General Theory of Relativity** can actually be described using a very simple equation: $R = GE$ (although Einstein's own formulation of his field equations are much more complex). Unfortunately, the variables in this simple equation are far from simple: R is a complicated mathematical object made up of 16 separate numbers in a matrix or "tensor" that describes the distortion of **space-time**; G is the **gravitational** constant; and E is another complicated number, also represented by a tensor, representing the **energy** of the object (or more accurately the 4-**dimensional "energy momentum density").** Given that, though, what the equation says is simple enough: that what **gravity** really is not a force but a distortion of space and time, and that the geometry of space and time depends not just on velocity (as the **Special Theory of Relativity** had indicated) but on the **energy** of an object. This makes sense when we consider that Newton had already shown that **gravity** depends on **mass,** and that Einstein's **Special Theory of Relativity** had shown that **mass** is equivalent to **energy**.

Gravity is treated as a phenomenon resulting from the curvature of space-time. This curvature is caused by the presence of mass. Generally, the more mass that is contained within a given volume of space, the greater the curvature of space-time will be at the boundary of its volume. As objects with mass move around in space time, the curvature changes to reflect the changed locations of those objects. In certain circumstances, accelerating objects generate changes in this curvature, which propagate outwards at the speed of light in a wave-like manner. These propagating phenomena are known as **gravitational waves.**

As a gravitational wave passes an observer, that observer will find space time distorted by the effects of strain. Distances between objects increase and decrease rhythmically as the wave passes, at a frequency corresponding to that of the wave. This occurs despite such free objects never being subjected to an unbalanced force. The magnitude of this effect decreases proportional to the inverse distance from the source. In spiraling binary neutron stars are predicted to be a powerful source of gravitational waves as they coalesce, due to the very large acceleration of their masses as they orbit close to one another. However, due to the astronomical distances to these sources, the effects when measured on Earth are predicted to be very small, having strains of less than 1 part in 10^{20}. Scientists have demonstrated the existence of these waves with ever more sensitive detectors. The most sensitive detector accomplished the task possessing a sensitivity measurement of about one part in 5×10^{22} (as of 2012) provided by the LIGO (Laser Interferometer Gravitational Observatory). A space based observatory, the Laser Interferometer Space Antenna, is currently under development by ESA (European Space Agency).

III. COMPACT BINARIES

Compact stars like **white dwarfs** and **neutron stars** can be constituents of binaries. For example, a pair of solar mass neutron stars in a circular orbit at a separation of 1.89×10^8 m (189,000 km) has an orbital period of 1,000 seconds, and an expected lifetime of 1.30×10^{13} seconds or about 414,000 years. Such a system could be observed by **LISA** if it were not too far away. A far greater number of white dwarf binaries exist with orbital periods in this range. **White dwarf binaries** have masses in the order of the Sun, and diameters in the order of the Earth. They cannot get much closer together than 10,000 km before they will merge and explode in a **supernova** which would also end the **emission of gravitational waves**. Until then, their gravitational radiation would be comparable to that of a neutron star binary.

Artist's impression of merging neutron stars. This event is **a source of gravitational waves**.

When the orbit of a **neutron star binary** has decayed to 1.89×10^6 m (1890 km), its remaining lifetime is about 130,000 seconds or 36 hours. The orbital frequency will vary from 1 orbit per second at the start, to 918 orbits per second when the orbit has shrunk to 20 km at merger. The majority of gravitational radiation emitted will be at twice the orbital frequency. Just before merger, the in spiral could be observed by LIGO if such a binary were close enough. LIGO has only a few minutes to observe this merger out of a total orbital lifetime that may have been billions of years. in August 2017, LIGO and Virgo observed the first binary neutron star in spiral in GW170817, and 70 observatories collaborated to detect the electromagnetic counterpart, a **kilonovain** in the galaxy **NGC 4993**, 40 mega parsec away, emitting a short **gamma ray burst (GRB 170817A)** seconds after the merger, followed by a longer optical transient **(AT 2017gfo)** powered by **r-process** nuclei. Advanced LIGO detector should be able to detect such events up to 200 mega parsec away. Within this range of the order 40 events are expected per year.

IV. CONCLUSION

The way forward for physics now rests with attempts to combine the theory of **relativity** (the theory of the very large, which describes one of the **fundamental forces** of nature, gravity) with **quantum theory**(the theory of the very small, which describes the other three **fundamental forces**, **electromagnetism**, the **weak nuclear force** and the **strong nuclear force)** in a unified theory of **quantum gravity** (or **quantum theory of gravity**), the so-called “theory of everything”.

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