Layman's Description of

High-Frequency Gravitational Waves or "HFGW"

What are high-frequency gravitational waves? Visualize the luffing of a sail as a sailboat comes about or tacks. The waves in the sail's fabric are similar in many ways to gravitational waves, but instead of sailcloth fabric, gravitational waves move through a "fabric" of space. Einstein called this fabric the "space-time continuum" in his 1915 theoretical work known as General Relativity (or GR). Although his theory is very sophisticated, the concept is relatively simple. This fabric is four-dimensional: it has the three usual dimensions of space: (1) east-west, (2) north-south, (3) up-down, plus the dimension of (4) time. Here is an example: we define a location on this "fabric" as 5th Street and Third Avenue on the third floor at 9 AM. We can't see this "fabric" just as we can't see the wind, sound, or gravity for that matter. Nevertheless, those elements are real, and so is this "fabric." If we could generate ripples in this fabric, then many applications become available to us. Much like radio waves can be used to transmit information through space, we could use gravitational waves to perform analogous functions. Still the question arises … how can we generate and detect these gravitational waves in the space-time fabric?

One way we can generate wind waves is by the motion of fan blades. Likewise, gravitational waves (GWs) can theoretically be generated by the motion of masses. We can detect wind waves by the motion of a weather vane. Similarly, we could detect gravitational waves by a transient change in a dimension, such as the distance between two points at the ends of a ruler. Gravitational waves will make the ruler seem to behave, to an outsider observer, as f it was made of rubber, stretching and contracting. However, the change in length would be extremely small, smaller than the diameter of a proton! Ordinarily we would not be able to observe it, but scientists are now testing techniques to detect gravitational waves by very accurately measuring the distance between two points (technically it is called the Laser Interferometric Gravitational Observatory or LIGO).

So, Gravitational Waves are like other waves, but they exist in a rather strange fabric of space-time. Now comes the tough part: how are gravitational waves generated in nature? One possible generation mechanism is a double-star orbit, two stars that circle around or orbit each other. If these stars are very heavy, perhaps black holes, then there exists an incredibly large change in force, called centrifugal force, as they orbit one another. According to Einstein's publication in 1916 (a year after his GR) such a rapid change in force over a brief time generates gravitational waves.

However, the gravitational waves generated by these stars are of very low frequency. So if the stars rotate around each other with a period of, say, one second (for comparison, the period of our motion around the Sun is one year), then the gravitational-wave frequency is two cycles per second or two "Hertz," (2 Hz for short) according to Einstein's theory. For a reference, US house current has a frequency of 60 cycles per second (60 Hz) whereas radio waves have frequencies of thousands of Hz.

These Low-Frequency Gravitational Waves (LFGWs) generated by rapid changes in force (for example, during the orbiting of two black holes), could be detected by LIGO if they exhibited frequencies from 40Hz to 2000 Hz, but what use are they if we can't harness their potential? To be useful we not only need to detect them… we need to generate them. So, could gravitational waves be generated in the laboratory? It's obvious we cannot have two black holes orbiting in a laboratory, but it turns out we really don't need to. The trick is that we don't require gravitational force to generate gravitational waves! It's really the motion of the mass that counts, not the kind of force that produces that motion. How do we obtain a large force change? To make it practical we need a force that is much larger than the force of gravitational attraction. Let's do a thought experiment and think of two horseshoe magnets facing each other (North poles facing South poles). They will attract each other strongly. If we reverse the magnets, put them down back-to-back with their poles facing outwards, then primarily their gravitational force acts due to their masses and we sense little or no attractive pull. As a matter-of-fact, magnetic and other non-gravitational forces are about 1,000,000,000,000,000,000,000,000,000,000,000,000,000 times larger than the gravitational forces! So, if we have our choice, we want to use "electromagnetic force" as our force, not weak little gravity.

How could we make use of this analysis and generate GWs in the laboratory? Instead of the change in "centrifugal force" of the orbiting black holes, let us replace that force change with a change of non-gravitational force, the much more powerful one of electromagnetism. One way to do this is to strike a laser target with a laser pulse. The target could be a small mass. Each laser-pulse strike imparts a force on the target mass acting over a very brief time, commonly defined as a "jerk." Einstein says that each time a mass undergoes a change or buildup in force over a very brief time; gravitational waves are generated – in the laboratory! The duration of these pulses is very short—a very small fraction, perhaps only one billionth of a second, but that short duration leads to an extremely high frequency, on the order of one billion cycles per second (1,000,000,000 Hz) for this pulse duration. The gravitational waves are now "high-frequency gravitational waves" or HFGWs and have wonderful and revolutionary applications that low frequency gravitational waves do not have!

What are those wonderful applications of HFGWs? The successful completion of the experiment in China, Russia, the US, or anywhere else, would be even more important than Marconi's development of the Radio Telegraph. Besides almost assuring a Nobel Prize for whoever successfully accomplishes the HFGW generation/detection experiment, there would be tremendously lucrative commercial and military applications. Some examples: (1) Multi-channel communications (both point to point, for example to deeply submerged submarines, and point to multipoint through all ordinary material things – the ultimate wireless system). One could communicate directly through the Earth from Beijing, China to New York in the US, without the need for fiber optic cables, microwave relays, or satellite transponders – antennas, cables, and phone lines would be things of the past! (2) As discussed in the authoritative text by Landau and Lifshitz, HFGWs provides a remote means for causing perturbations to the motion of objects such as missiles (anything from bullets to ICBMs), spacecraft, rogue comets or minor planets, land or water vehicles or craft – a totally new propulsion system! (3) Remote coalescing of clouds of hazardous vapors, radioactive dust, etc. by changing the gravitational field in their vicinity. (4) The potential for through-earth, or through-water “X-rays” in order to observe subterranean structures, geological formations (such as oil deposits), create a transparent ocean, view three-dimensional building interiors, buried devices, etc.: and (5) the potential for remotely disrupting the gravitational field in a specific region of space and even producing nuclear reactions there! There are no commercial or military secrets here since all of the technology is openly disclosed in patents issued in the United States (6,160,336; 6,417,597; and 6,784,591) and in the 17 pending in the U.S., Europe, Russia, and China. By the way, low-frequency gravitational waves do not have any of the foregoing applications.

The next question that arises is what steps would need to take place, once minute amounts of HFGWs are generated and detected, in order to eventually realize the fantastic possibilities of HFGWs? The first experimental model could be enlarged many fold and still remain within practical funding limits. For example, 200 lasers (rather than two utilized for one possible HFGW generation experimental aparatus) could be positioned on a circle some one-hundred-times larger than the experimental version (say, one kilometer in radius). According to published theory this would increase HFGW power some 100,000,000 fold! (1) Using such an enhanced HFGW generator, HFGW receivers (detectors) could be positioned on the opposite side of the globe to test through-earth communications. (2) First sensitive accelerometers, then massive objects, say 50 kilograms, could be tested for gravitational-field change and movement at the HFGW generator's focus (at the center of the circle). (3) Various aerosols could be tested for coalescence at the focus. (4) The HFGW detectors on the opposite side of the Earth could be moved around over known geological formations to determine if the characteristics of the GWs change depending upon intervening material. In fact, detectors local to the HFGW generator could be utilized to determine the effect of particular object and materials placed between the detector and the more powerful HFGW generator. (5) Even with the less powerful experimental HFGW generator the gravitational-wave intensities are some 5,000,000,000,000,000,000,000 times larger than the intensity of sunlight at the Earth's surface! Strong disruptive events (including nuclear) could result in very small regions of space at the focus and generation of energy is a possibility without hazardous nuclear waste. Actually though, such a question of technology transfer is difficult to answer. The same question put to Marconi, after his successful test of miniscule radio-telephone power, would not have revealed the revolutionary applications of his experiment to microwave ovens, cell phones, radar, television, etc. The same will no doubt be true of the applications of a successful HFGW-generator test. We are, therefore, driven by both scientific curiosity and the prospect of manifest potential practical applications to accomplish the HFGW test. Many technical papers listed below provide the interested scientist a more complete analysis of HFGW, its generation and detection.