How to know when an earthquake is coming? Possibility of a New Earthquake Warning.

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Have you ever wished that you knew when an earthquake was coming a little earlier? Earthquakes are a very serious disaster, especially for Japanese people living in this earthquake-prone country. As you know, big earthquakes are usually accompanied by big casualties, for example, the Great Kanto Earthquake that occurred on September 1, 1923, and the Great East Japan Earthquake that is still fresh in our memories. In the Great Kanto Earthquake, many households were cooking when the quake occurred, and it is said to be that the gas stove fires caused a huge fire. If people could have known that an earthquake was coming before the tremors occurred, people who were cooking would have been able to extinguish their gas stoves, and the number of casualties in the Great Kanto Earthquake would have been much lower. Nowadays, earthquake early warning systems are available, and cell phones and televisions will notify you of an earthquake coming just before a big tremor occurs. However, this earthquake alert comes just before the big tremor, so if you notice it even a little too late, you won't be able to turn off the gas stove.

Recent studies gives an possible answer to this problem. They suggest that if we observe the gravitational waves from the earthquake source, we can know that an earthquake has occurred more quickly. Then what is the gravitational waves?

A gravitational wave is a distortion of space-time that propagates as a wave. Let’s think of a tennis ball on a piece of saran wrap that is stretched tight. You can see that the saran wrap is slightly warped. If the tennis ball moves, the shape of the saran wrap will change accordingly. Similar to this, if there is an moving object that have mass, the space-time around it is distorted and the distortion of it changes. This change of distortion of space-time is propagated as a wave, and this is called gravitational waves (GWs).

While the waves currently used to detect earthquakes (called P-waves) travel less than the speed of light, GWs travel at the speed of light. Therefore, if we can measure the space-time fluctuations caused by earthquakes, it will be possible to detect and warn of the occurrence of earthquakes earlier than now. So, is it possible to detect GWs?

GWs was first detected by Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015, and they detected the GW produced when two black holes with masses tens of times the mass of the sun merge at that time. This event was very surprising because it was thought that gravity waves were too small in amplitude to be observed, but LIGO has detected many gravity waves so far.

However, unfortunately, LIGO can't detect the fluctuations of space-time generated by earthquakes. This is because the GWs from the merging two black holes detected by LIGO and those from earthquakes are different in their frequencies. Although the frequency of GWs from earthquakes is around 0.1 Hz, LIGO can only detect GWs with a frequency of 30-7000 Hz, and this is because of the difficulty of detecting GWs with low frequency on the ground. Then why is it difficult to detect GWs with low frequency?

One of the difficulties to detect GWs with low frequency is ground vibration. In fact, the ground on which we stand is constantly vibrating at various frequencies, especially low frequency. Therefore, the ground vibration could be a significant noise in the observation of GWs on the ground, and it is difficult to separate the GWs from the signal that detectors measure. However, some scientist are working to make such a detector that can detect GWs with a low frequency of 1 mHz-10 Hz with high accuracy, called "Torsion-Bar Antenna (TOBA)" ([1]). So, what is new in TOBA compared to LIGO?

Let me tell you about the system of LIGO detector. In LIGO detector, there are two mirrors. The same laser beam is divided into two directions, and the mirrors are placed in each direction to reflect each laser beam. Then, the divided laser beams are gathered together again, and by observing the laser beams, we can see whether GWs are coming or not.

On the other hand, TOBA does not contain two mirrors. In TOBA, two bars (Test-mass bar) are suspended horizontally like Figure. 1, and this two bars will rotate around z-axis when GWs comes, so by measuring the rotation of the two bars, we can see whether GWs are coming or not. The advantage of this system is that this detector is less sensitive to ground vibration ([1]), so it can detect GWs with low frequency with higher accuracy than LIGO.

TOBA is still under development, but if it can detect GWs with a frequency of 1 mHz-10 Hz with sufficient sensitivity in the future, it may be used to detect the occurrence of earthquakes. If this comes true, we will be able to know when an earthquake is coming earlier than we do now, and take action before the big tremor. If we can do this, the number of deaths and injuries caused by earthquakes will be greatly reduced.

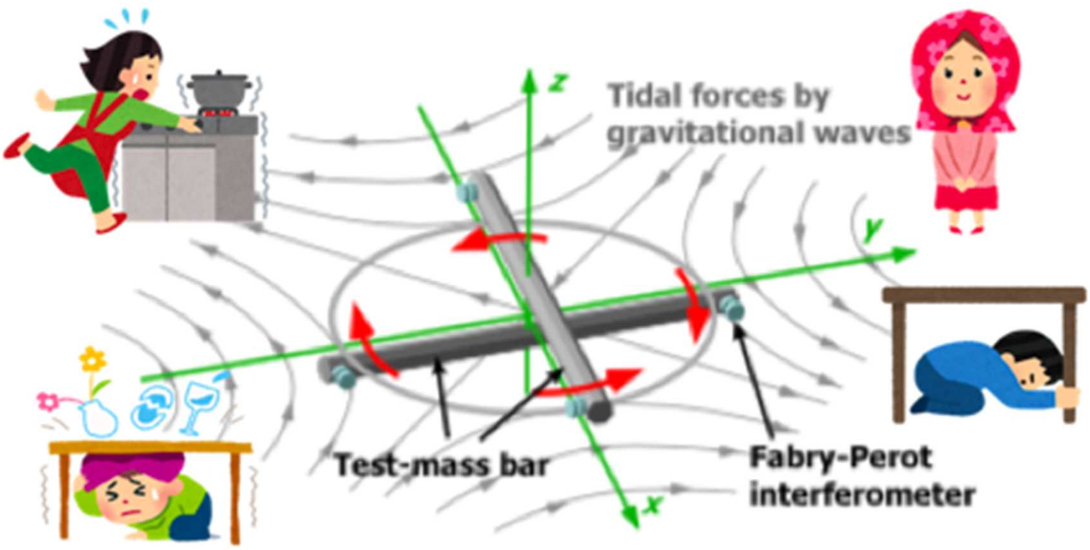

Figure. 1: The cartoon of TOBA and people when an earthquake occur (Cited from [1], partially modified)

References

[1] M. Ando, et al, Phys. Rev. Lett., 105, 161101 (2010)

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