From noise to music: How the LIGO team heard the famous ‘chirp’

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With the 2017 Nobel Prize for physics going to the LIGO-VIRGO collaboration for having directly observed gravitational waves for the first time, black hole mergers have become a byword. The instrumentation to differentiate and detect this faint signal from the noise was a crucial contributions made by Nobel Laureate Rainer Weiss.

The first gravitational waves that were detected were small fluctuations of spacetime caused by a violent merging of two black holes about 1.3 billion light years away. We know that light bends due to a change in refractive index of the air near hot objects like a heated asphalt road. Light also bends when spacetime curves due to the presence of massive gravitational fields. When a gravitational wave is incident on the detector, the laser beam behaves in a similar manner. One main difference is the magnitude. The difference between bending of light in cool air and hot air is about 1%, whereas the bending caused by a gravitational wave is about one billion times smaller than the thickness of a human hair.

“That’s pretty small. How can we turn something like this into a signal that’s measurable to us?” asks Rana Adhikari, Professor of Physics at Caltech, who has been involved in the construction and design of the detectors since 1997. He explains, “From my PhD advisor, Rai Weiss, I got the strong impression that it was embarrassing to not understand in exacting detail all the constituents of the noise in the experiment. Once we went down the road of making the detailed study of noise a science in itself, we realized that there are no limits to measurement. Everything that we wish to understand about the universe can be revealed by careful design of experimental apparatus.”

The photodetectors are sensitive to the brightness of the incoming signal. When there is no signal, the two arms of the LIGO detector are arranged so that there is cancellation of contribution of light. There is still some small amount of light coming through. When there is a signal, this light shows a variation. “We measure how much light is seen when it is very dark [that is, there is no signal]. This is about the same as a small handheld laser pointer. On top of that brightness, we are trying to measure a variation in brightness level of about one part in one billion. This is manageable. This is just what can be done with the best electronics that we have today,” he says.

The electronics converts photons into electrons. Like in the human ear, there is an electrical signal which has to be turned into sound. The detection is in the range of frequencies from about 20 Hz to 10 kHz. “The challenge is how to reduce the vibration from the ground at those frequencies,” Prof Adhikari says.

“[The relevant] ground vibrations are about 1% of the diameter of the hydrogen atom, or one hundred million times larger than we can handle. We need this vibration to be reduced by a factor of one hundred million. We do this by using many, many springs” The arrangement is that of some six layers of heavy metal beds connected by strong springs. At every layer the vibrations of the ground are cut off by a significant factor.

LIGO’s interferometers are a ten orders of magnitude improved as compared to the first interferometer made by Albert Michaelson in 1881, which was able to measure a displacement in nanometres.

Under the high degree of vacuum needed, stainless steel has the problem that the hydrogen separates out. So a special stainless steel called low-hydrogen stainless steel was needed. The steel tubes are also used to house the lasers and have to be very clean. These are being made at Institute for Plasma Research in Ahmedabad.

In all, the tubes measure 8 km in length and have a diameter of 1.2 m. “So it’s quite a large empty space, and it’s all one piece. No one had made such a large vacuum chamber earlier, so this is the largest empty space in the world,” Prof. Adhikari smiles.

A study of nearly 300 people living in different parts of India found that nine single-base variants (single-nucleotide polymorphisms or SNPs) account

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