About LIGO India and future in pure Physics

Including views on teaching of Science to children

Q1. Galileo started electromagnetic astronomy and LIGO has opened the age of gravitational astronomy. What will be the significance of gravitational astronomy to the world?

Kip Thorne**:** It is 400 years since Galileo opened electromagnetic astronomy. When we look at the changes in our understanding of the universe, it will come from light, X-rays, gamma rays, radio waves. All of it is magnetic.

All I can do is speculate that there are going to be enormous changes similarly over the next 400 years with gravitational astronomy. It will be referenced for centuries to come and not just decades. It will play a huge role alongside magnetic astronomy over the coming centuries.

I know what kinds of instruments we are likely to have between now and 2050 or 2060, and to me the most exciting thing is to be exploring the birth of the universe, the very earliest moments of the universe, with gravitational waves; (and) observing the birth of the fundamental forces of nature… Those, I believe, will be explored with gravitational waves and we will likely have big surprises that will impact the effort to understand the laws that govern the birth of the universe, the so-called laws of quantum gravity.

Q2. Was the international collaboration for LIGO important to its success?

2.1 The international nature was absolutely critical to its success. The contributions that came from other nations were essential. From India, understanding the shapes of the waves, Bala Iyer, particularly, working hand-in-hand with French physicists… The techniques they devised to solve Einstein's equations and then to predict the shapes of the waves were absolutely critical. The technology transfer… came from Moscow, the complicated aspects of the

suspension system came from Glasgow, much of the laser technology came from Germany, Australia contributed to high-laser power optical issues. This was truly, absolutely international collaboration.

3. On LIGO India, can you explain the value and anticipated role?

India is a very special location. By putting a LIGO detector in India, we will be able to identify far better than we could before locations of sources of gravitational waves in the sky. This is done by looking at the delay in the time of arrival of pieces of the signals at different locations. It is triangulating based on the propagation of gravitational wave signals at different locations on earth. India is a near-ideal location to complement detectors in Europe, North America and the future detector in Japan. This is essential for telling electromagnetic astronomers where the source was. The other thing that LIGO India brings is a capability to better extract the signal and information that comes from the source. There are two wave forms to be measured, and by having this location we can better understand the two wave forms. From the Indian point of view, LIGO brings to India existing advanced measurement technology and participation in developing the next generation of measurement technology.

3.1 When LIGO India begins participating in observations by 2025, perhaps earlier, I hope, LIGO will be making measurements of motions of 40kg mirrors due to gravitational waves at a level of precision that is so accurate that we will be seeing the quantum fluctuations on the positions of the mirrors. For the first time we will deal with 40kg objects behaving according to the law of quantum physics.

3.2 The challenge to build the technology to get the gravitational wave signal through a randomly fluctuating mirror location without the fluctuations demolishing the signal's information is a big challenge. It involves a new technology called quantum non-demolition technology. LIGO India brings with it the first successful steps in doing quantum non-demolition. If they are not successful, we will not be able to make the measurements we need to make.

4. How to create an institution that can reach the top in an index?

4.1 Caltech (California Institute of Technology) is the institution I know best and we pride ourselves in being superb. The big secret to our success is easy communication across fields. In mid- to late 20th century, fields of science and scholarship were quite separate with sharp boundaries. Today, the boundaries are disappearing. Physicists work in biology and engineering, and engineers have a huge impact on physics. One secret of success is to foster cross-disciplinary interactions. A second secret is to hire absolutely superb scientists and help them with resources to succeed. Our LIGO project—gravitational wave detection—it was Caltech that made this field take off because it saw the promise of the field

ABOUT TEACHING SCIENCE

5. How can we teach Indian school children to appreciate science better and take to science more enthusiastically?

Thorne**:** They need to be inspired first, they need to become enthusiastic first. Then the natural human curiosity will drive them to learn. What are your views?

5.1 The best way to help children become enthusiastic about learning science is to perhaps explain the theories behind many of the natural phenomena that they see around them. Why is the sky blue? Is the space blue or black? If I want to (be able to) lift 60 kg of weight somewhere in this planet system, where should I go? In other words, by helping children understand the natural phenomena around them, the daily life around them, using theories, I believe we may be in a position to enthuse them to science.

5.2 The pursuit of pure sciences is a natural extension of a child's curiosity. Curiosity is built into us as children; sometimes it is beaten out of us by the system. We have to foster curiosity and researchers in universities should be encouraged to pursue things just out of curiosity.

5.3 The second part of this is to recognise curiosity based science, which surprisingly often does lead to practical applications.