Fórum do Futuro 2017

9 November 2017

Professor David Shoemaker

Gravitational waves: new messengers from the Cosmos

In November 1915, Albert Einstein he established the foundations of the Theory of General Relativity through the submission of four communications to the Prussian Academy of Science. This theory, regarded by many physicists as one of the most beautiful of physics, describes the intertwined dynamics of space-time geometry and of matter/energy in a way that is completely independent of the frame of reference. In the third communication, dated November 18th, he explained the advancement of Mercury's perihelium, which was not properly accounted by Newton's Theory of Universal Gravitation. In the last communication, dated November 25th, Einstein presented the field equations of the theory, a decisive step to fully understand the geometric features of space-time given a matter/energy configuration.

Some months later, in June 1916, Einstein searched for solutions of the field equations at lowest order, actually, at level of small ripples around a given space-time geometry and showed that these perturbations would propagate in space-time at the speed of light as waves, gravitational waves. In 1918, he was forced to get back to the issue, given some incorrect assumptions about the properties of the waves made in 1916. Already at Princeton, United States of America, in 1936, (let me remind you that he left Germany after Hitler took charge in January 1933), and in collaboration with a young researcher, his assistant, Nathan Rosen, he questioned whether wave solutions would exist beyond the lowest order approximation, and concluded that they would not! However, in 1937, he realized how to overcome a tricky technical point in his calculation with Rosen, and in a new version of their previous paper, he eventually concluded that gravitational waves were a legitimate solution of General Relativity.

Since then the detection of gravitational waves has become one of the holy grails of experimental physics. From the very start it was understood that, due to the weakness of the coupling of gravity to matter, detection would be extremely difficult and that detectable sources would require dramatic cosmic events involving very compact astronomical objects such as neutron stars and/or black holes.

Indeed, the first evidence of the gravitational waves, actually an indirect evidence, was found in 1974, when Russell Hulse and Joseph Taylor observed the change of the orbital parameters due to the emission of gravitational waves of the binary pulsar 1913+16, a system composed by two fast rotating neutron stars. For their discovery, Hulse and Taylor were awarded the Nobel Prize of Physics in 1993.

For decades scientists have been eagerly waiting for the improvement of various detection techniques, till that in 2014, the Advanced LIGO Interferometer fitted at the two twin observatories, one at Hanford in Washington State, and another at Livingstone in Louisiana, achieved the impressive capability of measuring a displacement 10000 times smaller than the size of an atomic nucleus! How this incredible technological feat was achieved involved the development of the most precise interferometer ever built as it is going to be explained by our guest Professor David Shoemaker, Spokesperson of the LIGO collaboration.

Furthermore, he will tell us about the five events involving the merging of black holes already detected by LIGO (one of them also observed by the French-Italian Virgo collaboration), and a sixth one involving the merging of neutron stars. Actually, these events were detected at frequencies accessible to the human ear. Hence, one could say that one is hearing the sound of space-time.

The importance of the LIGO collaboration discovery and achievement was highlighted by the Nobel Committee by the attribution of the 2017 Physics Nobel Prize for the pioneers of the LIGO collaboration: Barry Barish, Kip Thorne and Rainer Weiss.

Tonight we have the privilege to hear about these exciting developments from someone who is at the forefront of the events. But, before passing the word to our guest, let me give you an idea about his impressive credentials. Indeed, Professor David Shoemaker is a Senior Research Scientist at the Kavli Institute at the prestigious Massachusetts Institute of Technology (MIT). He graduated at MIT in late 1970's after working with Rainer Weiss at the FIRAS (Far-Infrared Absolute Spectrophometer) at the Cosmic Background Explorer, the satellite which established the black body nature of the Cosmic Background Radiation, for which John Mather, guest of the Fórum do Futuro in 2015, was awarded the Nobel Prize in 2006, together with George Smoot. From 1989 onwards, Professor Shoemaker moved on to work on the interferometric detection of gravitational waves. He has led the Advanced LIGO Project and was elected LIGO Spokesperson in 2017. He is a fellow of the American Physical Society and shared the Milner, the Gruber and the Berkeley Prizes as well as the Princess of Asturias Award for Technical and Scientific Research for the detection of the gravitational waves with his LIGO colleagues.

Please, let us welcome, our guest, Professor David Shoemaker.

Orfeu Bertolami

Departamento de Física e Astronomia

Faculdade de Ciências, Universidade do Porto