Gravitational Waves Created by Neutron Star Mountains

1. Research

On 14th September 2015, gravitational waves were directly observed for the first time. This detection, by the LIGO collaboration, came 100 years after Einstein's prediction in his General Theory of Relativity. For the universe to be seen in this new way, the gravitational wave signatures of known objects must first be understood. Once a gravitational wave database has been compiled, the information can be used to light up the universe and discover aspects that have never been seen before with traditional electromagnetic radiation.

Figure 1: Image of a mountain range with the milky way galaxy as a backdrop.

I am researching how neutron stars emit gravitational waves by growing mountains. For mountains to grow, hot spots must develop in the neutron star's crust. I am investgating how these hot spots arise, how quickly they develop and how long they live for. I do this by creating computer models of a neutron star crust. From these models, I establish the size of the mountains produced and how long they are sustained for. Finally, I will calculate the amplitude of the gravitational wave signal produced from these mountains.

2. Neutron Stars

Neutron stars are incredibly dense stars that are formed when a massive star dies in a supernova explosion. These star remnants have incredibly strong gravitational and magnetic fields that create an extreme environment. These powerful conditions make neutron stars excellent laboratories for testing the laws of physics and sources of gravitational waves.

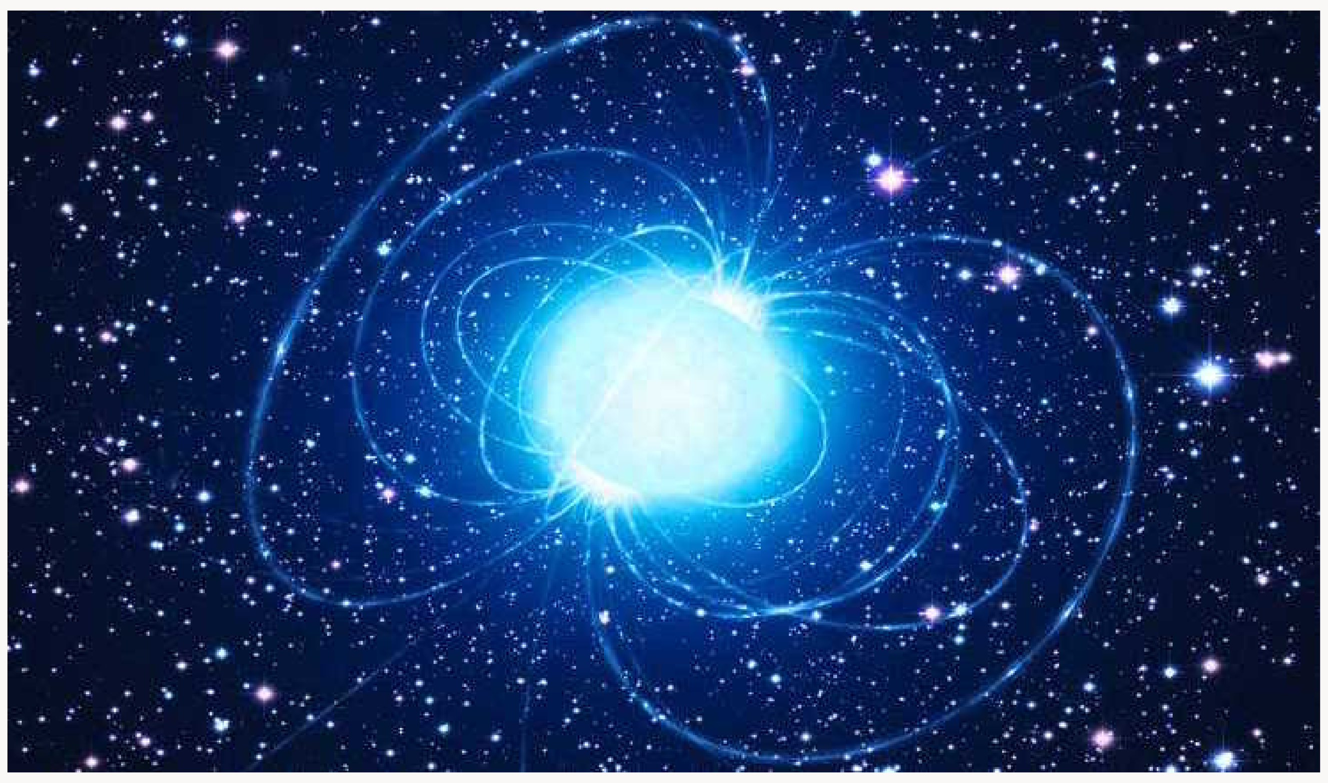

Figure 2: Artists impression of neutron star [ESO/L. Calada].

3. Gravitational Wave Sources

Neutron stars emit gravitational waves when they deform from their spherical symmetry. One way this can occur is through mountain growth. A mountain on a spinning neutron star can produce a gravitational field that changes with time. How fast the star is spinning determines the frequency of the signal. The gravitational wave signal produced by a spinning neutron star has a frequecy in the range that can be detected on earth by Advanced LIGO, the gravitational wave detectors in America.

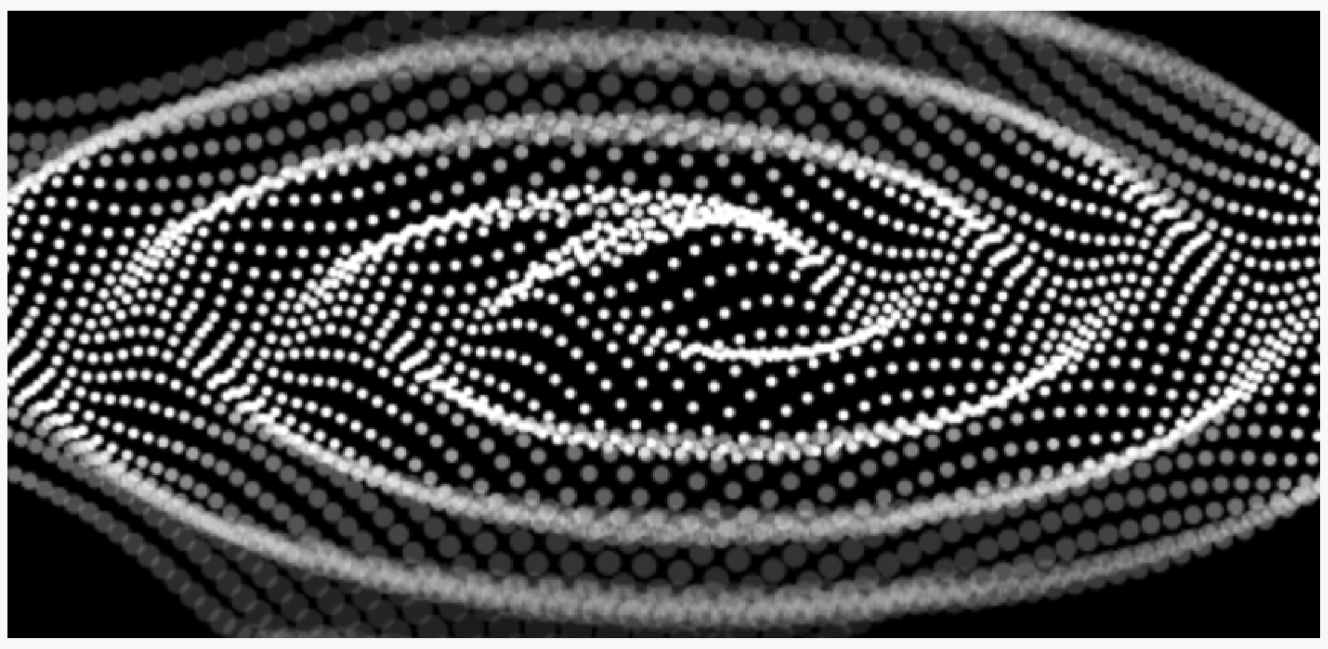

Figure 3: Depiction of a gravitational wave [www.habib.edu.pk].

4. Neutron Star Mountains

Mountains grow when hot spots exist in a neutron star crust. The density of the crust increases from the surface of the star toward the centre. Material in the crust undergoes nuclear reactions at different densities. If a hot spot is present, these nuclear reactions start to occur at lower densities than is usually required. This causes areas of higher density to form closer to the surface. The crust deforms around these dense regions giving rise mountains.

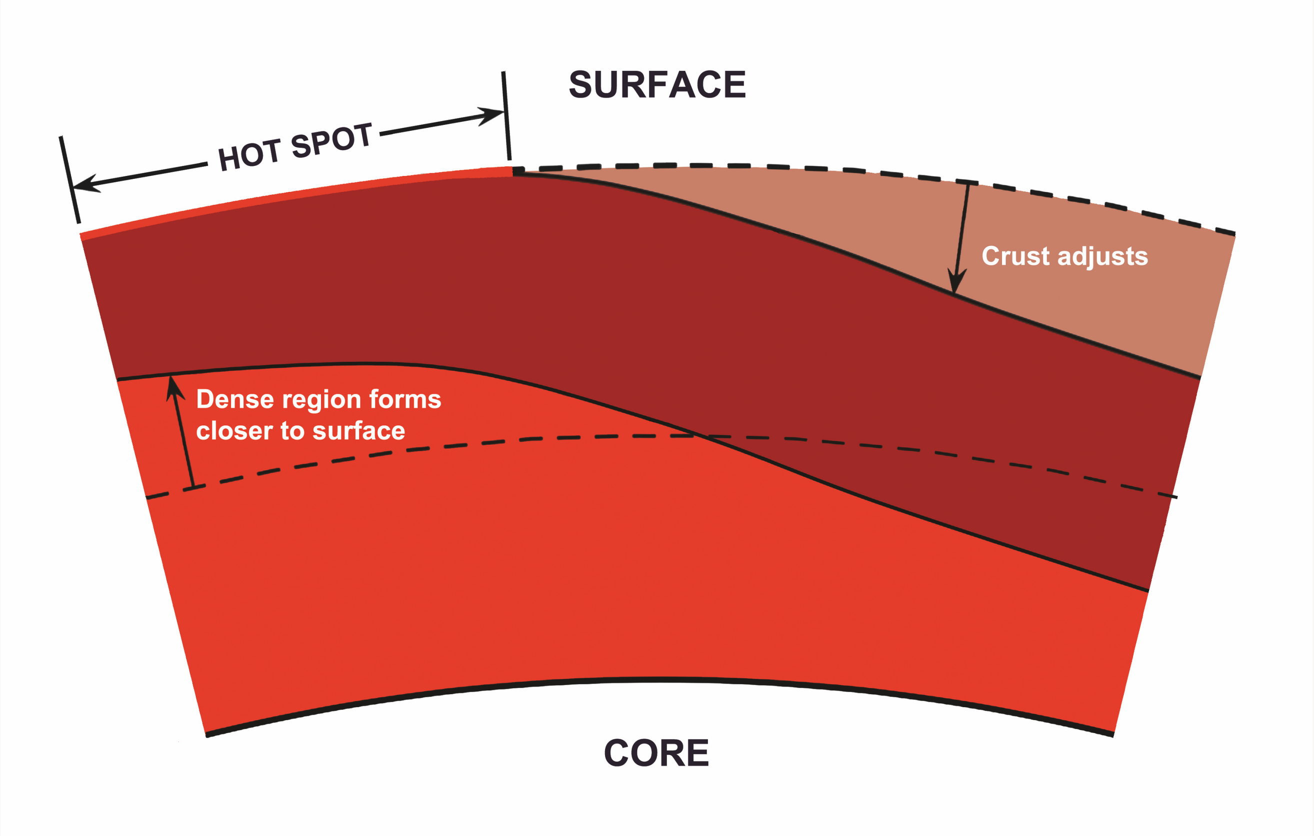

Figure 4: Schematic depiction of mountain growth in a neutron star crust [Oliver Dean].

5. Accretion Hot Spots

One way hot spots may develop in a neutron star crust is through accretion. Accretion is a process where the neutron star's gravitational field draws matter onto its surface from a companion star. This matter gets compacted by more accreted matter falling on top of it. As the matter is compacted, it increases in density and nuclear reactions start to occur. These nuclear reactions release heat energy into the neutron star's crust. If the accreted matter falls onto the star unevenly, then areas where more matter has been accreted will produce more heat, giving rise to hot spots.

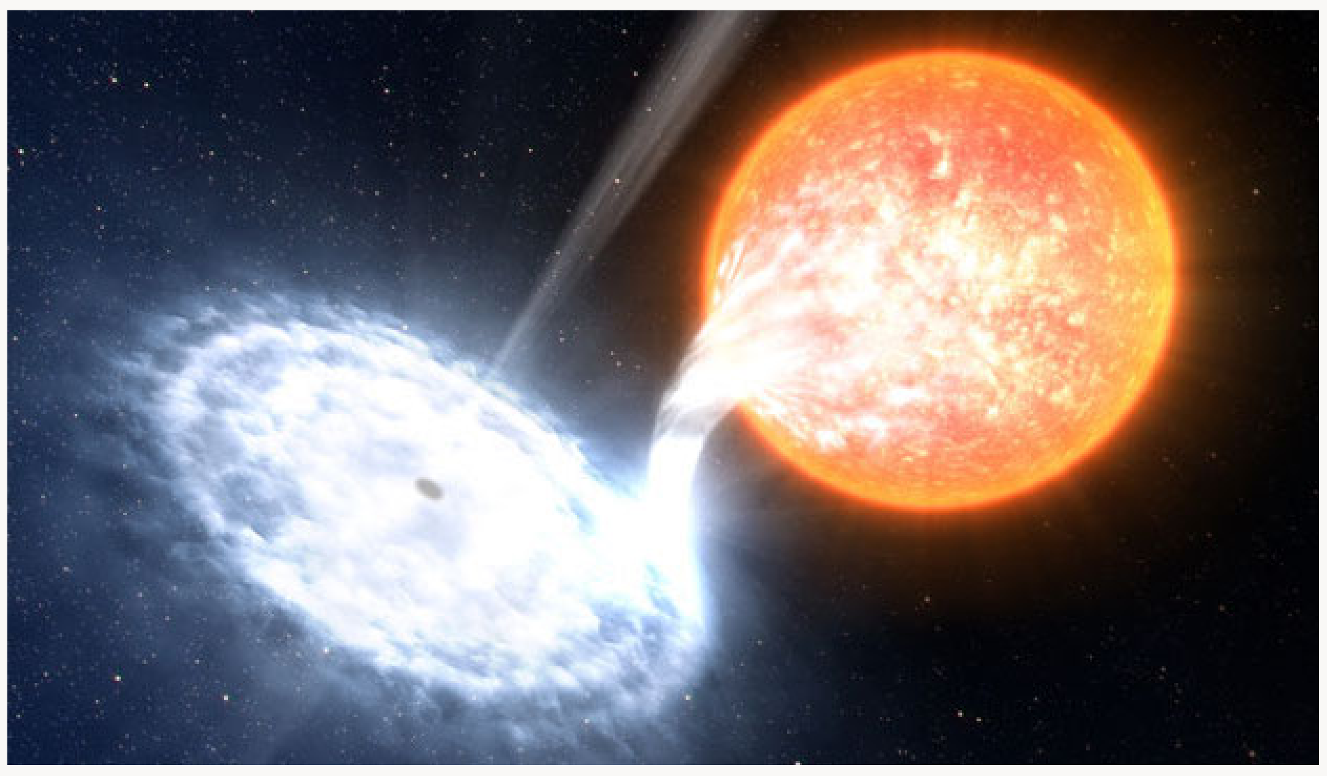

Figure 5: Artists representation of an accreting neutron star [ESO/L. Calada].

6. Magnetic Field Hot Spots

The magnetic field of a neutron star can also give rise to hot spots. Neutron star crusts have very powerful electrical currents. The motion of these currents generate magnetic fields. This in turn causes the electrical currents to lose energy in the form of heat radiation. As materials increase in temperature, so does their resistance. If the heat cannot dissipate quickly enough, a temperature runaway effect occurs.

Figure 6: Artist's illustration of hot spots in a neutron star's crust [Oliver Dean].

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