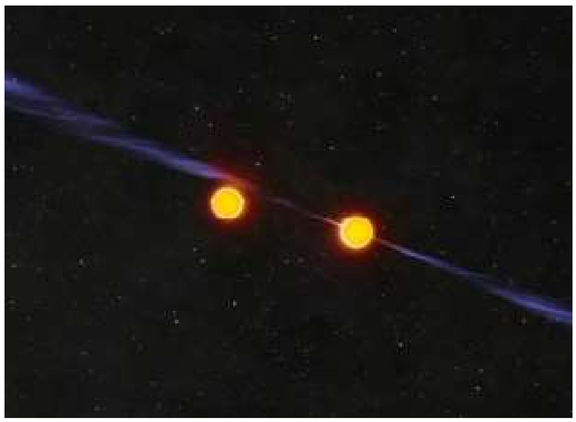
1. **Hulse-Taylor Pulsar:**
    - Firstly looking at a binary pulsar, it is a pulsar with a binary companion, often a white dwarf or neutron star. Pulsars are a type of neutron star which are highly magnetic and emit beams of energy. They have highly precise spin rates. In the standard scenario for binary pulsar formation, the neutron star from the explosion of the primary supergiant moves through the envelope of the companion star. The envelope is then expelled through the hydrodynamic coupling of the dynamical friction. With loss of energy, the orbit of the neutron star tightens. In moving through the companion star envelope, the neutron star accretes a substantial amount of matter.



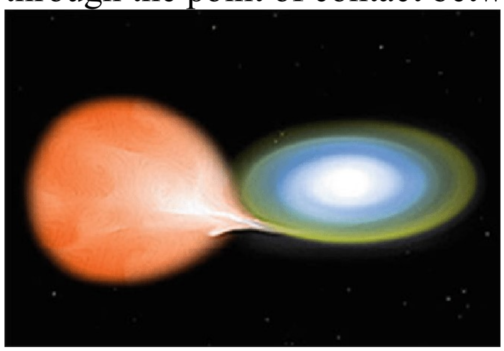
    - The binary pulsar PSR B1913+16 or the Hulse-Taylor binary pulsar was first discovered in 1974 at Arecibo by Joseph Hooton Taylor, Jr. and Russell Hulse, for which they won the 1993 Nobel Prize in Physics. Binary pulsars are one of the few objects which allow physicists to test general relativity because of the strong gravitational fields in their vicinity.
    - Now looking at how exactly this discovery and observation of binary pulsars has helped over time in the study of the following. Stellar evolution is the process by which a star changes over the course of time. Stellar evolution is not studied by observing the life of a single star, as most stellar changes occur too slowly to be detected, even over many centuries. Such a system has usually survived a violent and potentially disruptive supernova explosion that led to the formation of the neutron star, which is indeed a stage which may or may not be attained by an average star.
    - Moving on to gravitational waves and general relativity next, are somewhat interdependent because Gravitational waves were first predicted in Albert Einstein's 1915 theory of gravity, known as general relativity. General relativity is a physical

theory about space and time. According to general relativity, spacetime is a 4-dimensional object that has to obey an equation, called the Einstein equation, which explains how matter curves spacetime. Gravitational waves are tiny ripples in the very fabric of spacetime that propagate outwards from some of the most violent and powerful events in the cosmos. Traveling through the vastness of the universe to reach us here on Earth, these waves gradually lose energy becoming even fainter and more imperceptible. All gravitational systems can create gravitational waves. However, gravitational waves are very weak. Even Einstein believed it would be nearly impossible to detect these waves. the events that make the strongest gravitational waves in the universe are things like compact binary coalescences, such as merging black holes or neutron stars, exploding stars such as supernovas, fast-spinning neutron stars like pulsars, or the leftover gravitational wave background from the big bang.

- Twenty years after the death of Einstein in 1954, physicists Russell Hulse and Joseph Taylor used the Arecibo Radio Observatory in Puerto Rico to discover a tantalizing hint at gravitational waves in the form of a pair of rapidly spinning neutron stars or pulsars. The study led to the first accurate determination of neutron star masses, using relativistic timing effects. When the two bodies are in close proximity, the gravitational field is stronger, the passage of time is slowed – and the time between pulses (or ticks) is lengthened This revealed that the orbits of the pulsars tightened by precisely the amount predicted by general relativity if they were emitting gravitational waves, giving evidence and hence supporting Einstein’s theories.

2. **Mass transfer and orbital dynamics:**

- Mass transfer is the idea that material can move from one star to another. Many binaries orbit slowly with a large distance between the two stars. Radio pulsars in binary orbits often have short millisecond spin periods as a result of mass transfer from their companion stars.
- A Roche surface is the gravitational boundary of the gas in a binary system. Mass can move from one star to the other through the point of contact between the Roche surfaces.



When either star evolves into a red giant state, it expands until it fills its lobe.

- Mass drives stellar evolution, so the evolution of both stars in a binary system will be altered, compared to their destinies had they been single. Later, the second star evolves to the giant state, partly through its normal evolution, but partly because of the added mass.
- Orbital dynamics of binary pulsars involve the gravitational interaction between two neutron stars, where at least one is a pulsar. Their dynamics are influenced by general relativity, causing phenomena such as periastron precession (rotation of the orbit's closest point), gravitational time dilation, and orbital decay due to gravitational wave emission.
- Precise timing of the pulsar's signals allows measurement of orbital parameters, confirming general relativity and providing insights into neutron star properties.

3. **Orbital decay:**

- Orbital decay is a gradual decrease of the distance between two orbiting bodies at their closest approach (the periapsis) over many orbital periods. If left unchecked, the decay eventually results in termination of the orbit when the smaller object in the binary system strikes the surface of the primary. Orbital decay is caused by one or more mechanisms which absorb energy from the orbital motion, such as fluid friction, gravitational anomalies, or electromagnetic effects.

- Looking at the Hulse-Taylor binary pulsar, the measurements made of the orbital decay system were a near perfect match to Einstein's equations. Relativity predicts that over time a binary system's orbital energy will be converted to gravitational radiation. Data collected by them and their colleagues of the orbital period of the pulsar supported this relativistic prediction; they reported in 1982 and subsequently that there was a difference in the observed minimum separation of the two pulsars compared to that expected if the orbital separation had remained constant.
- In the decade following its discovery, the system's orbital period had decreased by about 76 millionths of a second per year, indicating that the pulsar was approaching its maximum separation more than a second earlier than it would have if the orbit had remained the same. Subsequent observations continue to show this decrease.