Binary Stars – And The Science Behind Their Cosmic Dance

The current model of our solar system comprises of the 8 planets along with the bodies of asteroids, floating in an orbit around the Sun, located at the solar system's centre. When we consider its true scale, the Sun may seem a lonely star. After all, it holds more than 98% of the mass in our solar system. However, most of the stars in our universe are not alone – they typically form groups. Some have companions, forming an orbital relationship between two stars, and we call these stellar bonds 'Binary Star'.

The Cosmic Dance

You may be used to thinking that our sun is a stationary object in our solar system. Though if we look close enough, the Sun moves a little – like the 8 planets, it's also in an orbit around a centre. This is the case for these binary stars, though their orbital motion is more apparent due to the smaller fractional difference in mass compared to our sun and the planets.

They orbit a common centre called the 'barycentre'. They revolve around it in such a way that they are always opposite each other, mirroring each other's positions – they have equal 'angular speeds'. The heavier star orbits closer to the barycentre than the lighter star; think of sea-saws, where a heavier person must position themselves closer to the pivot to maintain its balance.

The three main types of Binary Stars:

1. Visual Binaries

Visual binaries are star systems whose light from stars could be distinguished from one another simply by looking at them, with or without the aid of a telescope. Imagine yourself in a car on a highway in a dark, cozy night. You look behind you, and you watch the city lights from houses, buildings, skyscrapers and streetlamps fade as you move further away – the lights are bunched into a singular dot. The same concept applies to star systems when we look up the sky. Alpha Centauri, our closest neighbouring star system, is a perfect example; the two main stars in Alpha Centauri, Alpha Centauri A and Alpha Centauri B, seem to be one single star with the unaided eye. But use a telescope with enough resolution, and you'd see the separation of the stars. This makes Alpha Centauri A and Alpha Centauri B form a visual binary!

2. Eclipsing Binaries

Stars, like the sun, emit light in all directions. For binary stars, it may just so happen that their orbits and our line of observation are within the same

plane, meaning the stars passes one another, like the moon blocking the sun during a solar eclipse. We call these events ‘transits’. Astronomers can measure the light intensity we receive from stellar objects using ‘interferometry’, so during a transit, we observe a dip in their total brightness.

3. Spectroscopic Binaries
Suppose that an ambulance passes you. As the ambulance is approaching, you’ll notice that its sirens have a higher pitch than when it drives away. This is called a “Doppler Shift”. Light from stars undergo the same phenomenon. Their wavelengths (which controls the pitch of the sirens) get squashed or elongated depending on the direction of motion relative to an observer. Using spectroscopic analysis, we also see the same pattern in binary stars when we detect their spectral lines; they alternate between back and fourth towards the red and blue spectrum, which depends on the wavelength of the radiation of the star. This has a periodic pattern as they circle around the barycentre.

Stellar Combinations
A binary star system is a combination of any two types of stars. For example, Alpha Centauri A and Alpha Centauri B are main-sequence stars.

In some instances, a white dwarf and a main-sequence star form the binary pair. The white dwarf is a lot denser than the main-sequence star and can draw matter, mainly hydrogen gas, from its companion. The region in which the “stolen” matter flows is called the ‘Roche Lobe’, named after the French astronomer, Édouard Roche. It blankets onto the surface of the white dwarf, producing a series of nova explosions as it ignites due to intense temperature and pressure.

Cygnus X-1 and HDE 226868
An interesting binary pair is located in the constellation Cygnus. When we point our telescopes in the direction of the blue supergiant HDE 226868, we detect a strong source of X-rays – a very energetic type of radiation. However, blue supergiants are not energetic enough to emit such large intensity of x-rays. We also happen to detect an alternating Doppler shift in its spectral lines. With this information, astronomers have deduced that HDE 226868 has a hidden companion; only an extremely dense object can emit such strong radiation. But its companion, given the name Cygnus X-1, is not a white dwarf from our previous example. It is, in fact, a black hole!

Death of the Dance
The stars will continue spiralling down towards the barycentre as they lose energy due to radiation. They revolve faster the closer they are to each other. The common analogy is an ice skater; drawing one’s arms inwards causes a greater rate of revolutions, substituting the skater’s hands as the stars. Eventually, the pair’s orbital radii will be so small that the two stars collide. For massive stars, their collision brings cosmic cataclysm in a

‘kilonova’ event, producing a gamma ray burst (GRB) out into interstellar space, where the energy exploded can reach magnitudes greater than the energy our Sun will ever produce throughout its lifetime.

However, this is not an uncommon occurrence in our universe. In fact, we have seen this happen. On 17th August 2017, ALIGO detectors and the Fermi Gamma-ray Space Telescope detected a collision between two neutron stars in the galaxy NGC4993. Fortunately, this explosion took place more than 100 million light years away, too far to cause any serious impact.

Conclusion

There truly is something poetic about how these binary stars live through their lives; dancing gracefully, ending their cosmic choreography with an explosive finish. Watching how these binary stars dance have no doubt contributed to my passion in astronomy. Seriously, right after reading this article, I urge you to watch an animation of these binary star systems, and I hope you’ll find the same fascination as I did!

References:

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