Dancing stars and black holes in a cosmic cloud of gas: New research of the 'common envelope phase'

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Neutron star nebula. Credit: NASA/CXC/SAO: X-ray; NASA/JPL-Caltech: Infrared

Most massive stars are born in binaries (and sometimes triples, quadruples, and so on). As stars age, they grow larger in size by a hundred-fold or even thousand-fold expansion. When stars in binaries expand, parts of them approach the other star in the binary, whose gravity can then pull off the outer portions of the expanding star. The result is mass transfer from one star to the other.

Usually, mass is transferred gradually. But sometimes, the more mass that is transferred, the more mass gets pulled off in a runaway process. The outer layers of one star completely surround the other in a phase known as the common envelope. During this phase, the dense cores of the two stars orbit each other inside the cloud, or envelope, of gas. The gas drags on the stellar cores, causing them to spiral in; this heats up the common envelope, which may get expelled. The cores may end up more than 100 times closer than they started.

This common envelope phase is thought to play a crucial role in forming ultra-compact object binaries, including sources of gravitational waves; however, the process is poorly understood.

In a paper recently accepted to the *Astrophysical Journal*, Soumi De and collaborators from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) explored the common envelope phase through detailed computer simulations. They used wind-tunnel models in which a stellar core, a neutron star or a black hole is buffeted by the wind of gas, representing its orbit through the envelope. While this is a simplification of the full three-dimensional physics of the common envelope, the hope is that this approach makes it possible to understand the key features of the problem.

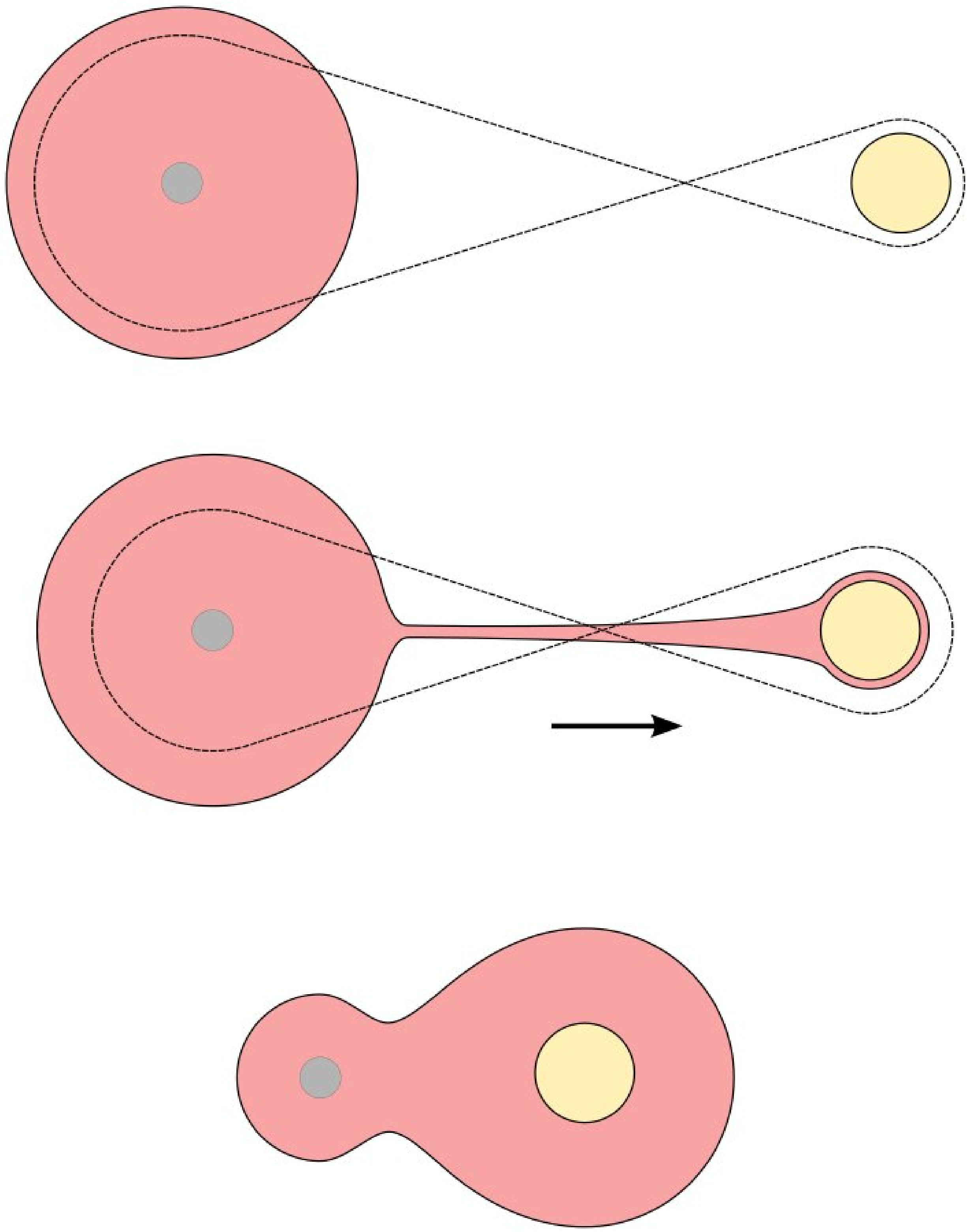

Diagram of how a common envelope is formed between two stars. Credit: Wiki Commons

You can watch an animation of one of the models here.

Co-author and OzGrav CI Ilya Mandel says, "The results revealed the drag forces and the rate of accretion onto the black hole. Together, these allow us to predict how much the black hole will grow during the common envelope phase. While a naive estimate suggests that black holes should gain a lot of mass during this phase, we find that's not the case, and the black holes do not become much heavier. And this has important consequences for understanding the merger rates and mass distributions of gravitational-wave sources."

More information: Common Envelope Wind Tunnel: The Effects of Binary Mass Ratio and Implications for the Accretion-Driven Growth of LIGO Binary Black Holes, arXiv:1910.13333 [astro-ph.SR] , arxiv.org/abs/1910.13333

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