Part II Astrophysics Essay 2021

Common envelope evolution in binary stars

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Cataclysmic variables are close binary stars comprising a white dwarf and usually a low-mass main-sequence star. The companion is transferring mass by Roche lobe overflow to the white dwarf. A white dwarf is the remnant of a star that has gone through a giant phase of evolution reaching up to 1 000 $R_\odot$ in size. Yet a CV has an orbital separation of only a few solar radii. Pacyn´ski (1974) proposed that the necessary shrinkage of the orbit comes about when the giant progenitor of the white dwarf overflows its Roche lobe in an unstable manner. The rapid transfer of the giant envelope leads to a common envelope around the much denser main-sequence companion as well as its own core. These two cores spiral together, transferring both energy and angular momentum from their orbit to the envelope. Ultimately, either the cores merge or the envelope is ejected leaving a close binary progenitor of a cataclysmic variable. Similar scenarios are necessary for the formation of X-ray binaries and various merged compact objects including the progenitors of type Ia supernovae and various gravitational wave sources.

The physics of the core spiral in and envelope ejection has been addressed a number of times since. Initially, and very much still the case in population synthesis models, a simple balance between the loss of orbital energy and the binding energy of the envelope is used to estimate the outcome of common envelope evolution. More recently several attempts have been made to address the problem using more realistic three dimensional hydrodynamical simulations. A good review of the state of the art appeared in 2013 (Ivanova et al. 2013) and you might use this as a starting point to understand the limitations of the modelling. Since then there have been a number of improvements both in terms of computer power and physics applied within the models. In this essay you should review what has been achieved while also describing what problems must still be overcome. In particular are we any closer to a quantitative determination of the outcome of any particular common envelope event?

References:

Ivanova N. et al., 2013, A&AR, 21, 59
Paczyn´ski B., 1976, in Eggleton P. R, Mitton S., Whelan J. A. J., eds, Proc. IAU Symp. 73, Structure and Evolution of Close Binary Systems. Reidel, Dordrecht, p. 75