Binary star population synthesis within a galactic framework

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The present study focuses on the evolution of binary star systems and their contributions to the chemical evolution of galaxies. A first aspect concerns the detailed evolutionary calculation of interacting binaries. The code used for this purpose has been in development and constantly updated for almost four decades. The results of these detailed evolutionary calculations, mainly concerning the amounts of chemical elements that are returned by the binary to the interstellar medium and at what time, are then used in a galactic setting. For this purpose, a binary population number synthesis code was re-written and upgraded. This code uses as input thousands of evolutionary calculations performed with the actual binary evolutionary code (these calculations were not part of this investigation). These data enable to calculate events (e.g. different types of supernovae or mergers) and outputs (e.g. chemical yields) of a starburst with a certain binary fraction and metallicity. The output of this population code is then introduced into a third code, the chemical evolution model. This convolves the pre-mentioned output with a galaxy and star formation model to study the chemical evolution (star formation rate, metallicity, star and gas densities, chemical abundances, supernova rates, etc.) of an evolving galaxy (e.g. the Milky Way) as a function of time. The combination of these three codes allows to study various aspects of the influence of binary stars on the chemical evolution of galaxies, all from first principles. By investigating how the properties or modeling of any (binary) stellar or galactic process affect the macroscopic, observationally testable properties of galaxies, these processes and the parameters that describe them can be constrained. This concerns topics such as the type Ia supernova delay time distribution and Galactic rate, as well as the influence of these events on the metallicity distribution of G-type dwarfs. We find that the 'single degenerate' scenario for type Ia supernova formation alone cannot explain observations, while a combination with the 'double degenerate' scenario can. The method also allows to study the importance of mass return by intermediate mass close binaries for the chemical enrichment in globular clusters, and of merger products created by massive close binaries, such as blue-type core collapse supernova progenitors. Furthermore, the merger rate of double compact objects (neutron stars and/or black holes), their expected gravitational wave radiation signal, and their importance for the enrichment in Galactic r-process elements can be studied. A common topic in all of the mentioned population-wide studies, which links them to detailed underlying calculations, is the uncertainty in some binary evolutionary processes, and the way they are parameterized in population synthesis studies. The most uncertain aspects in all of our studies involve mass and angular momentum transfer between binary components themselves and with their environment. The most important ones, all critical to the outcome of such evolutionary phase, are (1) the stable mass transfer efficiency β, the fraction of mass lost by the mass donor in a binary that is accreted by the mass gainer; (2) in the case of $\beta<1$, the angular momentum loss efficiency, determining how much angular momentum is lost with a fixed amount of mass; and (3) in the case of unstable mass transfer, resulting in both stellar cores rotating within one "common envelope", the efficiency with which rotational energy is converted into kinetic energy used to expel this envelope. Given the fact that neither intense stable or unstable mass transfer are sufficiently long-lasting processes to ever have been observed, many different models exist for them in detailed evolutionary computations, and many different parameterizations in global population studies. In a study comparing four different population synthesis codes, we have shown that when these and other parameterizations in the codes are equalized, this leads to a significant convergence of the codes' predictions concerning single and double white dwarf systems.