The Journal of Open Source Software

Dyad: a binary-star dynamics and statistics package for Python

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DOI: 10.xxxxxx/draft

Software

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Submitted: 03 March 2025
Published: unpublished

Summary

Dyad is a pure-Python two-body dynamics and binary-star statistics package for astrophysicists. It allows the user to compute the kinematic properties of a bound gravitational two-body system given that system's component masses and orbital elements. It also allows the user to synthesize a population of binary stars with component masses and orbital elements that follow a given distribution. Specifically, Dyad allows the user to synthesize primary- and secondary-star masses in a manner consistent with given distributions of stellar masses and mass ratios. It does so by implementing the method of Gration et al. (in preparation). Accordingly, Dyad provides a library of distributions for stellar mass, mass-ratio, and the orbital elements. This library includes (but is not limited to) the distributions for (1) the initial stellar mass published by Chabrier (2003), Kroupa (2001), and Salpeter (1955), and (2) the mass-ratios and orbital elements of binary stars in the Solar neighbourhood published by Duquennoy & Mayor (1991) and Moe & Di Stefano (2017).

Statement of need

I wrote Dyad to implement the work on binary-star population dynamics and stellar population synthesis presented by Gration et al. (2025) and Gration et al. (in preparation). Although binary-star population dynamics is an active area of research (see, for example, Minor et al., 2010; Rastello et al., 2020; and Arroyo-Polonio et al., 2023) there is no publicly available software to implement it. To compute the kinematic properties of binary systems researchers new to the subject must write their own software. I hope that Dyad fills this gap. Stellar population synthesis (i.e. the modelling of the evolution of populations of stellar systems) is also an active area of research (Izzard & Halabi, 2019). However, the software is better developed. In order to run population synthesis programmes the user must provide a description of the initial unevolved population. This can be done by sampling the appropriate random variables. A number of packages allow the user to do this. Some (such as *Binary_c-python* by Hendriks & Izzard, 2023; or *IMF* by Ginsburg, 2021) provide a probability density function, which can be used by an out-of-package sampling routine (such as rejection sampling or Markov-chain Monte-Carlo sampling). Others (such as COSMIC by Breivik et al., 2020; or COMPAS by Riley et al., 2022) do not provide the probability density function explicitly but allow the user to generate samples directly. Uniquely, Dyad implements these distributions as instances of the *Scipy* random variable class `scipy.stats.rv_continous`, allowing the full functionality provided by that class. This includes the evaluation of the probability density function and the generation of samples of a given size.

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