

Gala: A Python package for galactic dynamics

Adrian M. Price-Whelan^{1,2*}, Author Without ORCID^{2*}, Author with no affiliation^{3¶}, and Ludwig van Beethoven³

¹ Lyman Spitzer, Jr. Fellow, Princeton University, USA ² Institution Name, Country ³ Independent Researcher, Country ¶ Corresponding author * These authors contributed equally.

DOI: [10.xxxxxx/draft](https://doi.org/10.xxxxxx/draft)

Software

- [Review](#) ↗
- [Repository](#) ↗
- [Archive](#) ↗

Editor: [Open Journals](#) ↗

Reviewers:

- [@openjournals](#)

Submitted: 01 January 1970

Published: unpublished

License

Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License ([CC BY 4.0](#)).

In partnership with



This article and software are linked with research article DOI [10.3847/xxxxx](https://doi.org/10.3847/xxxxx) <- [update this with the DOI from AAS once you know it.](#), published in the *Astrophysical Journal* <- The name of the AAS journal..

Summary

The forces on stars, galaxies, and dark matter under external gravitational fields lead to the dynamical evolution of structures in the universe. The orbits of these bodies are therefore key to understanding the formation, history, and future state of galaxies. The field of “galactic dynamics,” which aims to model the gravitating components of galaxies to study their structure and evolution, is now well-established, commonly taught, and frequently used in astronomy. Aside from toy problems and demonstrations, the majority of problems require efficient numerical tools, many of which require the same base code (e.g., for performing numerical orbit integration).

Statement of need

Gala is an Astropy-affiliated Python package for galactic dynamics. Python enables wrapping low-level languages (e.g., C) for speed without losing flexibility or ease-of-use in the user-interface. The API for Gala was designed to provide a class-based and user-friendly interface to fast (C or Cython-optimized) implementations of common operations such as gravitational potential and force evaluation, orbit integration, dynamical transformations, and chaos indicators for nonlinear dynamics. Gala also relies heavily on and interfaces well with the implementations of physical units and astronomical coordinate systems in the Astropy package ([Astropy Collaboration, 2013](#)) (`astropy.units` and `astropy.coordinates`).

Gala was designed to be used by both astronomical researchers and by students in courses on gravitational dynamics or astronomy. It has already been used in a number of scientific publications ([Pearson et al., 2017](#)) and has also been used in graduate courses on Galactic dynamics to, e.g., provide interactive visualizations of textbook material ([Binney & Tremaine, 2008](#)). The combination of speed, design, and support for Astropy functionality in Gala will enable exciting scientific explorations of forthcoming data releases from the *Gaia* mission ([Gaia Collaboration, 2016](#)) by students and experts alike.

Mathematics

Single dollars (\$) are required for inline mathematics e.g. $f(x) = e^{\pi/x}$

Double dollars make self-standing equations:

$$\Theta(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{else} \end{cases}$$

34 You can also use plain \LaTeX for equations

$$\hat{f}(\omega) = \int_{-\infty}^{\infty} f(x) e^{i\omega x} dx \quad (1)$$

35 and refer to [Equation 1](#) from text.

36 Citations

37 Citations to entries in paper.bib should be in [rMarkdown](#) format.

38 If you want to cite a software repository URL (e.g. something on GitHub without a preferred
39 citation) then you can do it with the example BibTeX entry below for Smith et al. ([2020](#)).

40 For a quick reference, the following citation commands can be used: - @author:2001 ->
41 "Author et al. (2001)" - [@author:2001] -> "(Author et al., 2001)" - [@author1:2001;
42 @author2:2001] -> "(Author1 et al., 2001; Author2 et al., 2002)"

43 Figures

44 Figures can be included like this: Caption for example figure. and referenced from text using
45 [section](#) .

46 Figure sizes can be customized by adding an optional second parameter: Caption for example
47 figure.

48 Acknowledgements

49 We acknowledge contributions from Brigitta Sipocz, Syrtis Major, and Semyeong Oh, and
50 support from Kathryn Johnston during the genesis of this project.

51 References

- 52 Astropy Collaboration. (2013). Astropy: A community Python package for astronomy.
53 *Astronomy and Astrophysics*, 558. <https://doi.org/10.1051/0004-6361/201322068>
- 54 Binney, J., & Tremaine, S. (2008). *Galactic Dynamics: Second Edition*. Princeton University
55 Press. <http://adsabs.harvard.edu/abs/2008gady.book.....B>
- 56 Gaia Collaboration. (2016). The Gaia mission. *Astronomy and Astrophysics*, 595. <https://doi.org/10.1051/0004-6361/201629272>
- 57
- 58 Pearson, S., Price-Whelan, A. M., & Johnston, K. V. (2017). Gaps in Globular Cluster
59 Streams: Pal 5 and the Galactic Bar. *ArXiv e-Prints*. [http://adsabs.harvard.edu/abs/](http://adsabs.harvard.edu/abs/2017arXiv170304627P)
60 [2017arXiv170304627P](http://adsabs.harvard.edu/abs/2017arXiv170304627P)
- 61 Smith, A. M., Thaney, K., & Hahnel, M. (2020). Fidgit: An ungodly union of GitHub and
62 figshare. In *GitHub repository*. GitHub. <https://github.com/arfon/fidgit>