

# Gala: A Python package for galactic dynamics

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## 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](#)).

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- 41 ▪ @author:2001 -> "Author et al. (2001)"
- 42 ▪ [@author:2001] -> "(Author et al., 2001)"
- 43 ▪ [@author1:2001; @author2:2001] -> "(Author1 et al., 2001; Author2 et al., 2002)"

## 44 Figures

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

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

## 49 Acknowledgements

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## 52 References

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