PAPER FILE: “paper.md”:

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title: 'Gala: A Python package for galactic dynamics'

tags:

- Python

- astronomy

- dynamics

- galactic dynamics

- milky way

authors:

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orcid: 0000-0003-0872-7098

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affiliations:

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index: 1

- name: Institution Name

index: 2

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index: 3

date: 13 August 2017

bibliography: paper.bib

# Optional fields if submitting to a AAS journal too, see this blog post:

# https://blog.joss.theoj.org/2018/12/a-new-collaboration-with-aas-publishing

aas-doi: 10.3847/xxxxx <- update this with the DOI from AAS once you know it.

aas-journal: Astrophysical Journal <- The name of the AAS journal.

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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] (`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:2017] and has also been

used in graduate courses on Galactic dynamics to, e.g., provide interactive

visualizations of textbook material [@Binney: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] 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) = \left\{\begin{array}{l}

0\textrm{ if } x < 0\cr

1\textrm{ else}

\end{array}\right.$$

You can also use plain \LaTeX for equations

\begin{equation}\label{eq:fourier}

\hat f(\omega) = \int\_{-\infty}^{\infty} f(x) e^{i\omega x} dx

\end{equation}

and refer to \autoref{eq:fourier} from text.

# Citations

Citations to entries in paper.bib should be in

[rMarkdown](http://rmarkdown.rstudio.com/authoring\_bibliographies\_and\_citations.html)

format.

If you want to cite a software repository URL (e.g. something on GitHub without a preferred

citation) then you can do it with the example BibTeX entry below for @fidgit.

For a quick reference, the following citation commands can be used:

- `@author:2001` -> "Author et al. (2001)"

- `[@author:2001]` -> "(Author et al., 2001)"

- `[@author1:2001; @author2:2001]` -> "(Author1 et al., 2001; Author2 et al., 2002)"

# Figures

Figures can be included like this:

![Caption for example figure.\label{fig:example}](figure.png)

and referenced from text using \autoref{fig:example}.

Figure sizes can be customized by adding an optional second parameter:

![Caption for example figure.](figure.png){ width=20% }

# Acknowledgements

We acknowledge contributions from Brigitta Sipocz, Syrtis Major, and Semyeong

Oh, and support from Kathryn Johnston during the genesis of this project.

# References

Bibliography file: “paper.bib”

**@article**{Pearson:2017,

url = {http://adsabs.harvard.edu/abs/2017arXiv170304627P},

Archiveprefix = {arXiv},

Author = {{Pearson}, S. **and** {Price-Whelan}, A.~M. **and** {Johnston}, K.~V.},

Eprint = {1703.04627},

Journal = {ArXiv e-prints},

Keywords = {Astrophysics - Astrophysics of Galaxies},

Month = mar,

Title = {{Gaps **in** Globular Cluster Streams: Pal 5 **and** the Galactic Bar}},

Year = 2017

}

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url = {http://adsabs.harvard.edu/abs/2008gady.book.....B},

Author = {{Binney}, J. **and** {Tremaine}, S.},

Booktitle = {Galactic Dynamics: Second Edition, by James Binney **and** Scott Tremaine.~ISBN 978-0-691-13026-2 (HB).~Published by Princeton University Press, Princeton, NJ USA, 2008.},

Publisher = {Princeton University Press},

Title = {{Galactic Dynamics: Second Edition}},

Year = 2008

}

**@article**{gaia,

author = {{Gaia Collaboration}},

title = "{The Gaia mission}",

journal = {Astronomy **and** Astrophysics},

archivePrefix = "arXiv",

eprint = {1609.04153},

primaryClass = "astro-ph.IM",

keywords = {space vehicles: instruments, Galaxy: structure, astrometry, parallaxes, proper motions, telescopes},

year = 2016,

month = nov,

volume = 595,

doi = {10.1051/0004-6361/201629272},

url = {http://adsabs.harvard.edu/abs/2016A%26A...595A...1G},

}

**@article**{astropy,

author = {{Astropy Collaboration}},

title = "{Astropy: A community Python package for astronomy}",

journal = {Astronomy **and** Astrophysics},

archivePrefix = "arXiv",

eprint = {1307.6212},

primaryClass = "astro-ph.IM",

keywords = {methods: data analysis, methods: miscellaneous, virtual observatory tools},

year = 2013,

month = oct,

volume = 558,

doi = {10.1051/0004-6361/201322068},

url = {http://adsabs.harvard.edu/abs/2013A%26A...558A..33A}

}

**@misc**{fidgit,

author = {A. Smith},

title = {Fidgit: An ungodly union of GitHub **and** Figshare},

year = {2020},

publisher = {GitHub},

journal = {GitHub repository},

url = {https://github.com/arfon/fidgit}

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