



ExoData: A Python package to handle large exoplanet catalogue data[☆]



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ABSTRACT

Exoplanet science often involves using the system parameters of real exoplanets for tasks such as simulations, fitting routines, and target selection for proposals. Several exoplanet catalogues are already well established but often lack a version history and code friendly interfaces. Software that bridges the barrier between the catalogues and code enables users to improve the specific repeatability of results by facilitating the retrieval of exact system parameters used in articles results along with unifying the equations and software used. As exoplanet science moves towards large data, gone are the days where researchers can recall the current population from memory. An interface able to query the population now becomes invaluable for target selection and population analysis.

ExoData is a Python interface and exploratory analysis tool for the Open Exoplanet Catalogue. It allows the loading of exoplanet systems into Python as objects (Planet, Star, Binary, etc.) from which common orbital and system equations can be calculated and measured parameters retrieved. This allows researchers to use tested code of the common equations they require (with units) and provides a large science input catalogue of planets for easy plotting and use in research. Advanced querying of targets is possible using the database and Python programming language. ExoData is also able to parse spectral types and fill in missing parameters according to programmable specifications and equations. Examples of use cases are integration of equations into data reduction pipelines, selecting planets for observing proposals and as an input catalogue to large scale simulation and analysis of planets.

ExoData is a Python package available freely on *GitHub*.¹ It's open source and community contributions are encouraged. The package can be easily installed using *pip install exodata*, detailed setup information is provided within.

Program summary

Program title: ExoData

Catalogue identifier: AFAL_v1_0

Program summary URL: http://cpc.cs.qub.ac.uk/summaries/AFAL_v1_0.html

Program obtainable from: CPC Program Library, Queen's University, Belfast, N. Ireland

Licensing provisions: GNU General Public License, version 3

No. of lines in distributed program, including test data, etc.: 21884

No. of bytes in distributed program, including test data, etc.: 608434

Distribution format: tar.gz

Programming language: Python 2.7, 3.4, 3.5.

Computer: Any.

Operating system: Any.

RAM: Less than 200MB

Classification: 1.7.

External routines: numpy, quantities, matplotlib, requests, astropy, seaborn, pandas, six

[☆] This paper and its associated computer program are available via the Computer Physics Communication homepage on ScienceDirect (<http://www.sciencedirect.com/science/journal/00104655>).

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¹ <https://github.com/ryanvarley/exodata>.

Nature of problem: Being able to use exoplanet catalogue values in code including where there may be incomplete and incorrectly formatted values. Also being able to use the whole catalogue data at once, both for user querying, visualisation and in large simulation programs.

Solution method: An interface to access the catalogue including filling in missing values and parsing of the catalogue data. Creating an API useable by both humans and other code, implementation of commonly used exoplanet equations, a plotting library.

Running time: A few seconds depending on task

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1. Introduction

The field of exoplanets is rapidly expanding with the current population now in the thousands and new measurements published increasingly frequently. A catalogue of Exoplanets is necessary to keep track of these systems and their parameters, ideally being open and editable by all with a version history to enable researchers to reproduce results using the exact same values. This is especially important in large scale simulations and other work on multiple targets where a catalogue version may be more easily given over individual values and sources.

A second obstacle lies in the interface between the catalogue and the code. Such an interface can add value in its ability to calculate values using published equations, easily generate plots, estimate parameters, while keeping the catalogue up to date. It can also take into account all the fringe cases which can trip up a standard loading code (such as certain missing values and planets without a host star). The ability to replicate the catalogue is further enhanced through quoting both a catalogue and interface version. The exact parameters used for every target in the catalogue can then be easily obtained including any calculated parameters and estimations by ExoData. This tool then allows instant access to the exact parameters used in a paper.

1.1. Open Exoplanet Catalogue

The Open Exoplanet Catalogue (OEC, [1]) is an open-source, version controlled catalogue of exoplanets and their system parameters. It is hierarchical, preserving the format of the system (including binary star layouts). OEC uses *git* for version control and the catalogue exists as a series of XML files (one per system). This format makes OEC much more diverse than most other exoplanet catalogues by letting users create their own ‘forks’ of the catalogue where they can make their own changes and adaptations whilst still able to receive updates from the original. The advantages of version control include being able to see the exact changes made to each version, easily roll back the catalogue to any previous state and report the exact version of the catalogue your using to other researchers (using the commit SHA-1²).

The open nature of the catalogue means that anyone can download the full database and history of the catalogue, contribute their own changes and set up their own branched versions.

2. Exoplanet background theory

An exoplanet is a planet that orbits a star other than the Sun. We can describe a simple exoplanet system with a planet orbiting a star with a stellar radius of R_* , stellar mass of M_* , planetary radius R_p , planetary mass M_p and semi-major axis of the orbit a .

2.1. Describing the star

The stellar luminosity L_* is given by the Stefan–Boltzmann equation applied to the surface area of a sphere,

$$L_* = 4\pi R_*^2 \sigma T_*^4 \quad (1)$$

where σ is the Stefan–Boltzmann constant. Stellar temperature can be estimated using the stellar mass–radius relation described in [2]:

$$R_* = k M_*^x \quad (2)$$

where k and x are constants for each stellar sequence. We can also describe stellar temperature using the main sequence relationship

$$T_* = 5800 \times M_*^{0.65}. \quad (3)$$

The stars luminosity distance d (with negligible extinction) is given by rearranging the absolute magnitude relation

$$m - M = 5 \log_{10} d - 5 \quad (4)$$

where m is the apparent magnitude and M is the absolute magnitude. Whilst m is easily measured and commonly known M is often undefined. We can estimate M for a star using an absolute magnitude lookup table³ based on spectral type.

In cases where we do not have a measured stellar magnitude in the band required but do have a measured value for another band we can use the conversion factors given in Table A5 of Kenyon and Hartmann [3] to convert between magnitudes based on the stellar spectral type.

² In *git* versions each commit (snapshot) of the code has a SHA-1 hash of the source which is functionally unique and is used to reference that version of the code.

³ http://xoomer.virgilio.it/hrtrace/Sk.htm_SK3 from Schmidt–Kaler (1982).

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