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pyphot: A tool for computing photometry from spectra

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Summary

Pyphot is a Python package designed for performing synthetic photometry in astronomy. It provides a comprehensive set of tools for calculating fluxes and magnitudes of astronomical objects given their spectral energy distributions (SEDs) and filter transmission curves. Key features include a library of commonly used filter systems (e.g., Johnson-Cousins, SDSS), the ability to define custom filter systems, tools for handling SEDs, and integration with other astronomical Python packages. Pyphot also extends to calculations of spectral line indices from the Line Index System, which is commonly used for determining ages, mass distribution properties, and metallicities of unresolved (integrated light) stellar populations. Pyphot is targeted towards astronomers and astrophysicists working with photometric data.

Statement of need

Synthetic photometry is a crucial task in astronomy, used to estimate the flux an object would have if observed through a given transmission curve. Prior to Pyphot, a standardized, readily available tool for performing synthetic photometry in Python was lacking. Researchers often relied on ad-hoc scripts or software with limited flexibility and interoperability, hindering reproducibility and collaboration. Pyphot addresses this need by providing a user-friendly, well-documented, and versatile package for synthetic photometry. It simplifies the process of calculating magnitudes and fluxes, enables the use of standard and custom filter systems, and promotes reproducible research practices within the astronomical community. By offering a centralized resource for synthetic photometry, Pyphot facilitates collaboration and ensures consistent results across different studies.

Photometry involves measuring the flux or intensity of light emitted by astronomical objects. It is a fundamental technique used in astronomy to study any object that emits light, such as stars, galaxies, and quasars. Photometry provides information about the brightness, color, and spectral energy distribution of these objects, which is essential for understanding their physical properties and evolutionary history.

The type of detector and the units of flux can vary depending on the wavelength range being considered. One of the challenges in computing photometry is ensuring that one performs the calculations in the correct units and handling conversions between different units (e.g., Vega to AB magnitude or vice-versa).

The Pyphot package

To address this challenge, the Pyphot tool provides a comprehensive set of functions and utilities for computing photometry from spectra. The online documentation[1] of Pyphot provides the mathematical details and references. It includes built-in support for unit handling and conversions based on either the implementations of physical units in the Astropy package (Astropy Collaboration et al., 2013) (`astropy.units`) or in the Pint package[2]. Users can define their transmission curves but we also provide a database of pre-defined filter transmission curves[3], and interfaces with the SVO filter profile service (Rodrigo & Solano, 2020) to enable a broader range of publicly available photometric filters.

In addition to calculating photometry, Pyphot provides a set of tools to define and calculate lick indices. The Lick system of spectral line indices is one of the most commonly used methods for estimating ages and metallicities of unresolved (integrated light) stellar populations (Worthey et al., 1994). They are essentially specific combinations of three tophat passband filters but the subtleties come with the dependence on the spectral resolution that varies across different indices (Vazdekis et al., 2010). Pyphot provides a compilation of Lick indices, in particular those of Rose (1985), Worthey et al. (1994), Worthey & Ottaviani (1997), Korn et al. (2005), Cervantes & Vazdekis (2009), Vazdekis et al. (2010), Thomas et al. (2011), and Spiniello et al. (2014). Pyphot deals with adapting the spectral resolution internally to match the definitions and provides a pre-defined compiled list of indices[4].

Comparison with Other Similar Tools

Several Python packages offer tools for synthetic photometry in astronomy. Synphot (STScI Development Team, 2018) is a powerful library for simulating photometric data and spectra, incorporating custom filters and spectra. Astrolib PySynphot (STScI Development Team, 2013), initially designed as an object-oriented successor to IRAF's `STSDAS.SYNPHOT`, is now out of support. Both Synphot and PySynphot are closely tied to the Space Telescope Science Institute (STScI) ecosystem and define their own data format. A key difference between these and Pyphot lies in their scope and integration with the broader astronomical Python ecosystem. Another notable package is sedpy, which initially intended to provide a suite to forward model photometry is now tool to calculate photometry through an extensive list of passbands.

While Synphot, PySynphot, and sedpy may be feature-rich for specific analyses (e.g. Synphot offers more advanced features for spectral manipulation and analysis.), Pyphot offers a more streamlined and flexible approach, readily integrating with packages like Astropy and the SVO-profile service and focusing on ease of use for general synthetic photometry tasks. Pyphot also prioritizes simplicity and integration into larger projects.

By using Pyphot, researchers and students can perform photometric computations with confidence, knowing that the units are handled correctly and conversions are applied accurately. This ensures the reliability and reproducibility of scientific results in the field of astronomy. Pyphot has supported 41 scientific publications[5] since 2019.

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[1] pyphot mathematical details on predicting photometry
[2] https://pint.readthedocs.io/en/stable/
[3] pyphot description of the internal photometric passbands
[4] pyphot description of the provided lick indices
[5] Nasa ADS search for "pyphot"

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