ZodiPy: A Python package for zodiacal light simulations

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Software

- Review
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Summary

`ZodiPy` is an Astropy-affiliated Python package for zodiacal light simulations. Its purpose is to provide the astrophysics and cosmology communities with an accessible and easy-to-use Python interface to existing zodiacal light models, assisting in the analysis of infrared astrophysical data and enabling quick and easy zodiacal light forecasting for future experiments. `ZodiPy` implements the Kelsall et al. (1998) and the Planck Collaboration et al. (2014) interplanetary dust models, which allow for zodiacal light simulations between $1.25 - 240\mu$m and $30 - 857$GHz, respectively, with the possibility of extrapolating the models to other frequencies.

Statement of need

Zodiacal light is the main source of diffuse radiation observed in the infrared sky between $1 - 100\mu$m. The light comes from scattering and re-emission of sunlight by dust grains in the interplanetary medium. Zodiacal light is one of the most challenging foregrounds to model in cosmological studies of the Extragalactic Background Light (EBL) in the infrared sky, primarily due to its seasonal nature.

Traditionally, observers of the infrared sky have had to build their own zodiacal light tools (see the LAMBDA foreground models page for a list of existing tools). However, these programs are either only usable for specific experiments or otherwise difficult to access by requiring licensed programming languages or usage of web interfaces. Modern astronomy and cosmology pipelines are commonly built in Python due to the wide range of available high-quality tools and open-source projects and communities, such as the Astropy project (Astropy Collaboration, 2013). The lack of a general-purpose zodiacal light tool in this space was the primary motivation behind the development of the `ZodiPy` package.

`ZodiPy` can be used to simulate zodiacal light for arbitrary Solar system observers, meaning that researchers no longer have to spend time developing their own tools from scratch. To use `ZodiPy`, the user is required to provide the following data:

1) A sequence of pointings, either in ecliptic or galactic coordinates. These can be specified as angles on the sky or as HEALPix (Górski et al., 2005) pixel indices.
2) A center frequency or an instrument bandpass.
3) Time of observation, corresponding to the pointing sequence.
4) The heliocentric ecliptic position of the observer. If the observer is located at a major Solar system object, such as the Earth or the Sun-Earth-Moon barycenter L2, the position is instead queried through the `astropy.coordinates` Solar system ephemerides.

The predicted zodiacal light is then obtained by evaluating a sequence of line-of-sight integrals from the position of the observer and through a model of the three-dimensional interplanetary dust distribution. For implementation details and examples of how to apply `ZodiPy` to a real-world dataset, see San et al. (2022).

`ZodiPy` has been rapidly adopted by the astronomy community, and the package has already been used by several research projects (see Aldering et al., 2023; Avitan et al., 2023; Hanzawa et al., 2024; Rose et al., 2023; Tsumura et al., 2023), for instance, in assisting the coming NASA Roman Space Telescope in determining its observational fields or modeling the data obtained aboard the Hayabusa2 JAXA satellite.

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This project uses the following Python packages: Astropy (Astropy Collaboration, 2013), NumPy (Harris et al., 2020; Walt et al., 2011), healpy (Zonca et al., 2019), SciPy (Virtanen et al., 2020), and jplephem (Rhodes, 2011).

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