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▶ **To cite this version:**

Andrea Zonca, Leo Singer, Daniel Lenz, Martin Reinecke, Cyrille Rosset, et al.. healpy: equal area pixelization and spherical harmonics transforms for data on the sphere in Python. Journal of Open Source Software, 2019, 4 (35), pp.1298. 10.21105/joss.01298 . insu-03747945

HAL Id: insu-03747945
https://insu.hal.science/insu-03747945

Submitted on 9 Aug 2022

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The Journal of Open Source Software

healpy: equal area pixelization and spherical harmonics transforms for data on the sphere in Python

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DOI: 10.21105/joss.01298

Software

- Review
- Repository
- Archive

Submitted: 28 February 2019
Published: 27 March 2019

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Summary

Recent experiments measuring the temperature and polarization of the Cosmic Microwave Background, like WMAP (Bennett et al., 2013) and Planck (Planck Collaboration, 2018), produce all-sky maps at higher and higher resolution. Handling those datasets efficiently and studying their statistical properties requires a discretization scheme on the sphere. The Hierarchical Equal Area isoLatitude Pixelization, `HEALPix` (Górski et al., 2005), scheme (see Fig. 1) has proven to be an excellent mathematical framework to store map-domain data and efficiently compute their Spherical Harmonics Transform, whose Angular Power Spectrum is one the most powerful tools to understand the early Universe.

The `HEALPix` team provides FORTRAN, C++, IDL/GDL and Java implementations of the framework with simulation, analysis and visualization functionalities, format definitions for FITS files, and extensive documentation of each routine and facility.

`healpy` is a wrapper to the multi-threaded `HEALPix` C++ library in Python, it implements a user-friendly interface for all `HEALPix` functionalities, most importantly a fast nearest-neighbor search and the decomposition into Spherical Harmonics coefficients. It also adds utilities to read/write maps, Spherical Harmonics coefficients, and Power Spectrum values as FITS files based on `astropy.io.fits`. Finally it provides extensive plotting functionality, i.e. Mollweide, Gnomonic and Cartographic projections based on Matplotlib. We also release a `conda` package on `conda-forge` and wheels on PyPI for Linux and MacOS. These packages also bundle the `HEALPix` C++ library. Moreover, `healpy` is distributed as part of the `HEALPix` release package; within the installation script, a single

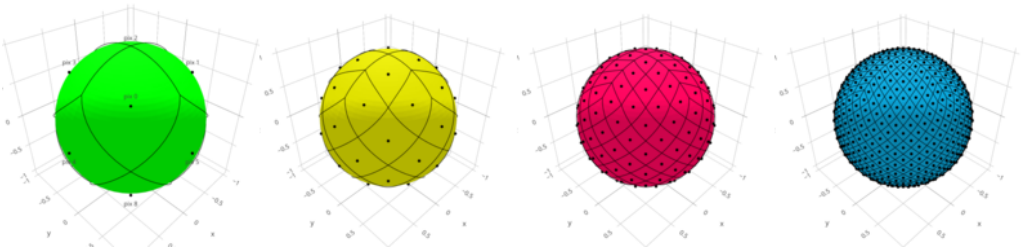


Figure 1: See how a sphere is first split into 12 base pixels of equal area whose centers are aligned at three different latitudes. Then, each is further subdivided to achieve higher and higher resolution.

C++ dynamic library is installed in the target system and used both by the C++ binaries and by `healpy`.

`healpy` was designed to be used by professional cosmologists and students to analyze outputs of Cosmic Microwave Background experiments. WMAP, Planck and many other experiment in the field release their maps in `HEALPix` FITS format that can be accessed, visualized, and analyzed with `healpy`. More recently, its usage spread to other branches of Astrophysics including galaxy surveys e.g. Sloan Digital Sky Survey depth maps, Gamma-ray astronomy e.g. Fermi (Deil & others, 2018), and gravitational waves measurements e.g. LIGO (Singer et al., 2016).

How to cite

If a publication is based on work that used `healpy`, please add the acknowledgement statement: "Some of the results in this paper have been derived using the `healpy` and `HEALPix` packages" and cite this paper and the original `HEALPix` paper (Górski et al., 2005).

Acknowledgements

We acknowledge the Planck collaboration and in particular Peter Meinhold, Julian Borrill and Charles Lawrence for supporting Andrea Zonca's work on the project. We thank all past and current contributors. For a full overview, see the latest list of contributors on Github.

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