# pyuvdata v3: an interface for astronomical interferometeric datasets in python

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## Summary

pyuvdata is an open-source software package that seeks to provide a well-documented, feature-rich interface for many of the different data formats that exist within radio interferometry, including support for reading and writing the following formats: UVH5 (La Plante & the pyuvdata team, 2024), UVFITS (Greisen, 2016), MIRIAD (Sault et al., 1995), and measurement set (Kemball & Wieringa, 2000) visibility files. It offers read-only support for FHD (Sullivan et al., 2012) and MIR (Qi, 2022) visibility save files. Additionally, pyuvdata supports reading/writing measurement set, CalFITS (Ali et al., 2017), and CalH5 (B. Hazelton & the pyuvdata team, 2024) calibration solutions; and reading of FHD calibration solutions. pyuvdata also provides interfaces for and handling of models of antenna primary beams, including BeamFITS (B. Hazelton & the pyuvdata team, 2018) (read and write), CST (read-only), MWA beam formats (read-only). It also provides interfaces for handling of data flags.

## Statement of Need

There are several standard formats for astronomical interferometric data, but translating between them in a robust and well-understood way has historically been challenging. This is partially due to conflicting assumptions and standards, giving rise to significant (though sometimes subtle) differences between formats. Interfacing with different data formats – like one does when they convert from one format to another – thus requires careful accounting for the complex mathematical relationships between both data and metadata to ensure proper data fidelity. This is required both for leveraging existing community-favored tools that are typically built to interface with a specific data format, as well as analyses requiring bespoke tools for specialized types of analyses and simulations leveraging data in a variety of formats.

pyuvdata has been designed to facilitate interoperability between different instruments and codes by providing high quality, well documented conversion routines as well as an interface to interact with interferometric data and simulations directly in Python. Originally motivated to support new low frequency instruments (e.g. MWA: http://www.mwatelescope.org/, PAPER: http://eor.berkeley.edu/, HERA: http://reionization.org/), the capabilities of pyuvdata have been steadily expanded to support handling of data from several telescopes, ranging from meter to submillimeter wavelengths (including SMA: https://cfa.harvard.edu/sma, ALMA, SMA, VLA, ATCA, CARMA, LWA, among others).

## Major updates in this version

In the time since it was initially published (B. J. Hazelton et al., 2017), pyuvdata has undergone a significant expansion in capabilities. In addition to general performance improvements and restructuring, the newest version of pyuvdata includes several new major features, including:

- The addition of the `UVCal` class, which provides a container for handling calibration solutions (bandpass, delays, and gains) for interferometric data. Supported data formats include MS, FHD, CalFITS, and CalH5.
- The addition of the `UVBeam` class, which provides a container for handling models of the primary beam for antennas within an interferometric array. Supported data formats include BeamFITS, MWA, and CST.
- The addition of the `UVFlag` class, which provides a container for handling flags/masking of bad data for visibility data.
- Drastically improved handling of astrometry.
- Increased speed and accuracy of algorithms used to "phase-up" data (i.e., change the sky position where the interferometer is centered up on).
- Support for several new visibility data formats, including MIR, MS, and MWA/MWAX.
- Support for data sets containing multiple spectral windows.
- Support for data sets containing observations of multiple sources/phase centers.
- Many new convenience methods for working with interferometric data, including splitting and combining data sets, averaging in time and frequency, and applying calibration solutions and flags.

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