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# Blimpy: Breakthrough Listen I/O Methods for Python

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**Software**

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## Summary

The search for extraterrestrial intelligence (SETI) has historically used radio astronomy data as the main venue to search for artificial signals of extraterrestrial origin. The Breakthrough Listen program is the latest large-scale project for the search of technosignatures, and thanks to modern telescopes and instrumentation, as well as significant amounts of dedicated observing time, the program has become the largest SETI endeavour in history. This has also resulted in an unprecedented amount of publicly-available data (Lebofsky et al., 2019). Over 1 PB of data from the Breakthrough Listen program may be downloaded from seti.berkeley.edu/opendata.

The `Blimpy`—Breakthrough Listen I/O Methods for Python—package provides Python 2.7+/3.6+ utilities for viewing and interacting with the data formats used within the Breakthrough Listen program. This includes Sigproc filterbank (.fil) and HDF5 (.h5) files that contain dynamic spectra (aka 'waterfalls'), and GUPPI raw (.raw) files that contain voltage-level data. Python methods for data extraction, calibration, and visualization are provided. A suite of command-line utilities are also available.

The waterfall data product stores an array of detected power across frequency channel (i.e. spectra) over time. These files can be several GB in size, with up to billions of channels and/or hundreds of thousands of time steps. `Blimpy` provides convenient methods to extract frequencies and time slices of interest—without loading the full file into memory–which are presented as `Numpy` arrays (van der Walt, Colbert, & Varoquaux, 2011). Methods for manipulating lower-level voltage data products stored in the GUPPI raw format, as generated by the Green Bank Telescope, are also provided. `Blimpy` uses the Matplotlib library (Hunter, 2007) to provide plotting of spectra, time series, and dynamic spectra; the `Astropy` package for handling of astronomical coordinates (Astropy Collaboration et al., 2013; Price-Whelan et al., 2018); and, the `H5py` package to interact with data stored in HDF5 files (Collette, 2013). The turboSETI package, which conducts doppler acceleration searches for narrowband signals that would indicate the presence of technologically-capable life beyond Earth, uses `Blimpy` for file handling and diagnostic plotting.

`Blimpy` was designed to be used by radio astronomers, students and anyone else interested in accessing Breakthrough Listen data, whether searching for SETI signals, spectral lines, pulsars, fast radio bursts, or other astrophysical phenomena. It has already been used in a number of scientific publications (Croft et al., 2018; Enriquez et al., 2019, 2018; Enriquez et al., 2017; Gajjar et al., 2018; Price, Croft, et al., 2019; Price, Enriquez, et al., 2019).

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