A Brief Introduction to Bilby

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Overview and Installation

• Bilby is a modular Bayesian Inference code written in Python.
• Primarily for compact binary coalescence parameter estimation, but versatile enough for other problems
• Waveforms from lalsimulation, data processing tools from gwpy
• Out of the box use:
  • `pip install bilby`
• Install from source to contribute to developing:
  • Clone from git.ligo.org
  • Full instructions: https://lscsoft.docs.ligo.org/bilby/installation.html
Structure

bilby

.core .gw .hyper
.core

.prior
- Normal()
- Uniform()

.likelihood
- Likelihood
- GaussianLikelihood
- PoissonLikelihood

.result
- Result(dict)
- plot_corner()

.sampler
- run_sampler()
- Pymultinest()
- Dynasty()
.gw

.prior

.likelihood

.waveform_generator

.source

.detector

GravitationalWaveTransient()

WaveformGenerator()

GW source functions

Interferometer()
Priors

• Other priors: delta function, power law, log-uniform, cosine, etc.
• Interpolate from a file or array
  • Ex: uniform in comoving volume
• Sample, transform from unit cube, calculate probability
• Group individual parameters into a PriorDict
• Set them from a .prior file or directly in the code
• Built-in defaults for CBCs
• Can also set constraints on unsampled parameters
Likelihood

• Common built-in classes like **GaussianLikelihood**, **PoissonLikelihood**, **StudentTLikelihood**

• Write your own likelihood class using the parent **Likelihood**

• For gravitational-wave analyses:
  • **GravitationalWaveTransient**
  • **ROQGravitationalWaveTransient**
Sampling and Output

• Wrapper to external samplers
  • Nested: pynesty, pymultinest, nestle, cpnest
  • MCMC: emcee, pymc3, ptemcee

• Saves both the sampler output and the refactored bilby result object
• Bilby output is json file by default, can also save as hdf5
• Results plotted using corner package
Gravitational Wave Data

- **WaveformGenerator** object computes the waveform polarizations independent of the detector
- **Interferometer** and **PowerSpectralDensity** objects:
  - Load a default IFO or make your own anywhere in the world with any PSD
  - Calculate the PSD from frame data or load it from a file
  - Load GWOSC event data
  - Generate Gaussian noise
  - Inject signals
Gravitational Wave PE

• Generate injections from the default prior
• Sample in any combination of parameters: chirp mass, total mass, symmetric or asymmetric mass ratio, redshift, comoving distance
• Analytically marginalized likelihoods for time, phase, and distance
• Can also conduct hierarchical inference with the built-in module
Additional Resources

• Gitlab repo: https://git.ligo.org/lscsoft/bilby
• Documentation: https://lscsoft.docs.ligo.org/bilby/
• Slack workspace: bilby-code.slack.com
• GWTC-1 analysis: https://github.com/IsobelMarguarethe/Bilby-GWTC-1-Analysis-and-Verification/tree/v2.0
• Papers:
  • https://arxiv.org/abs/1811.02042