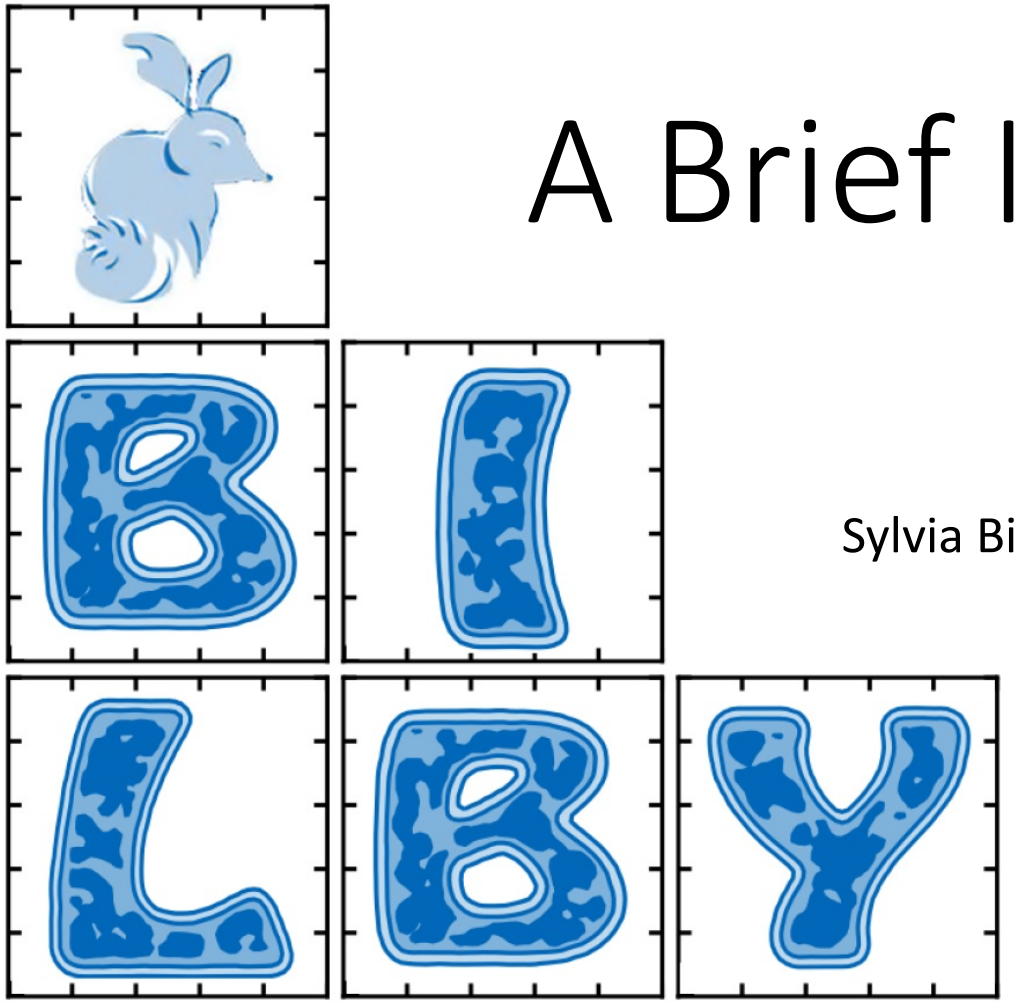

A Brief Introduction to Bilby

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ICERM Workshop

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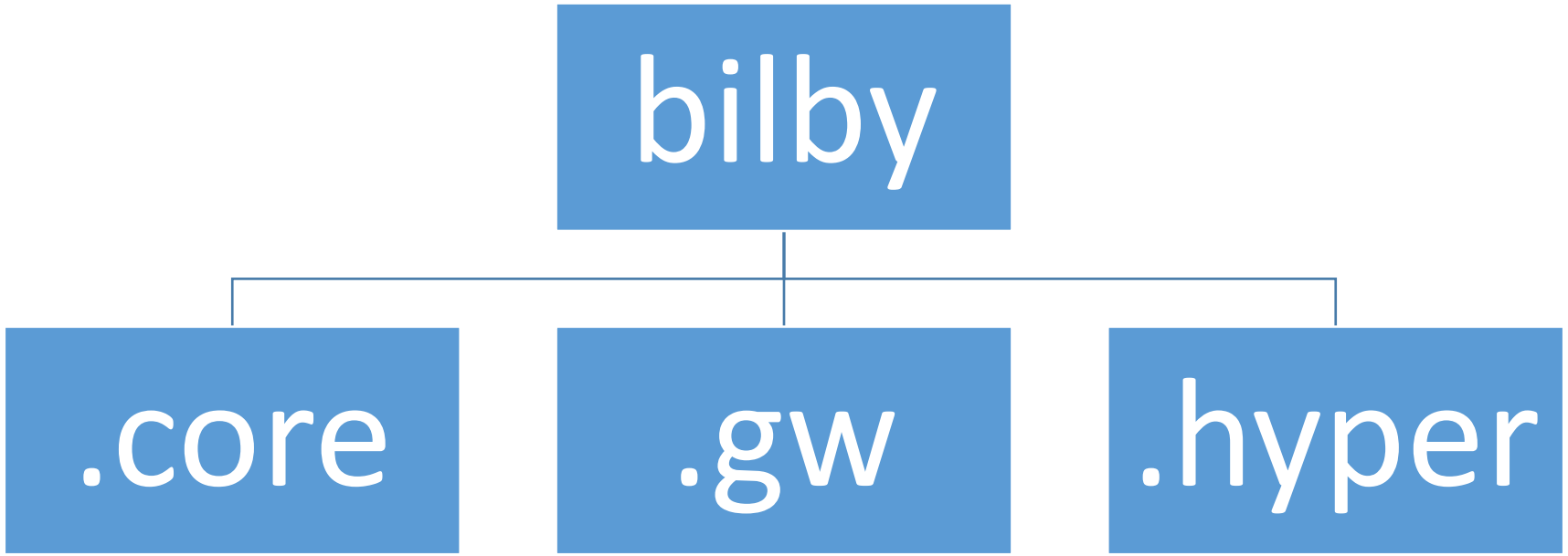
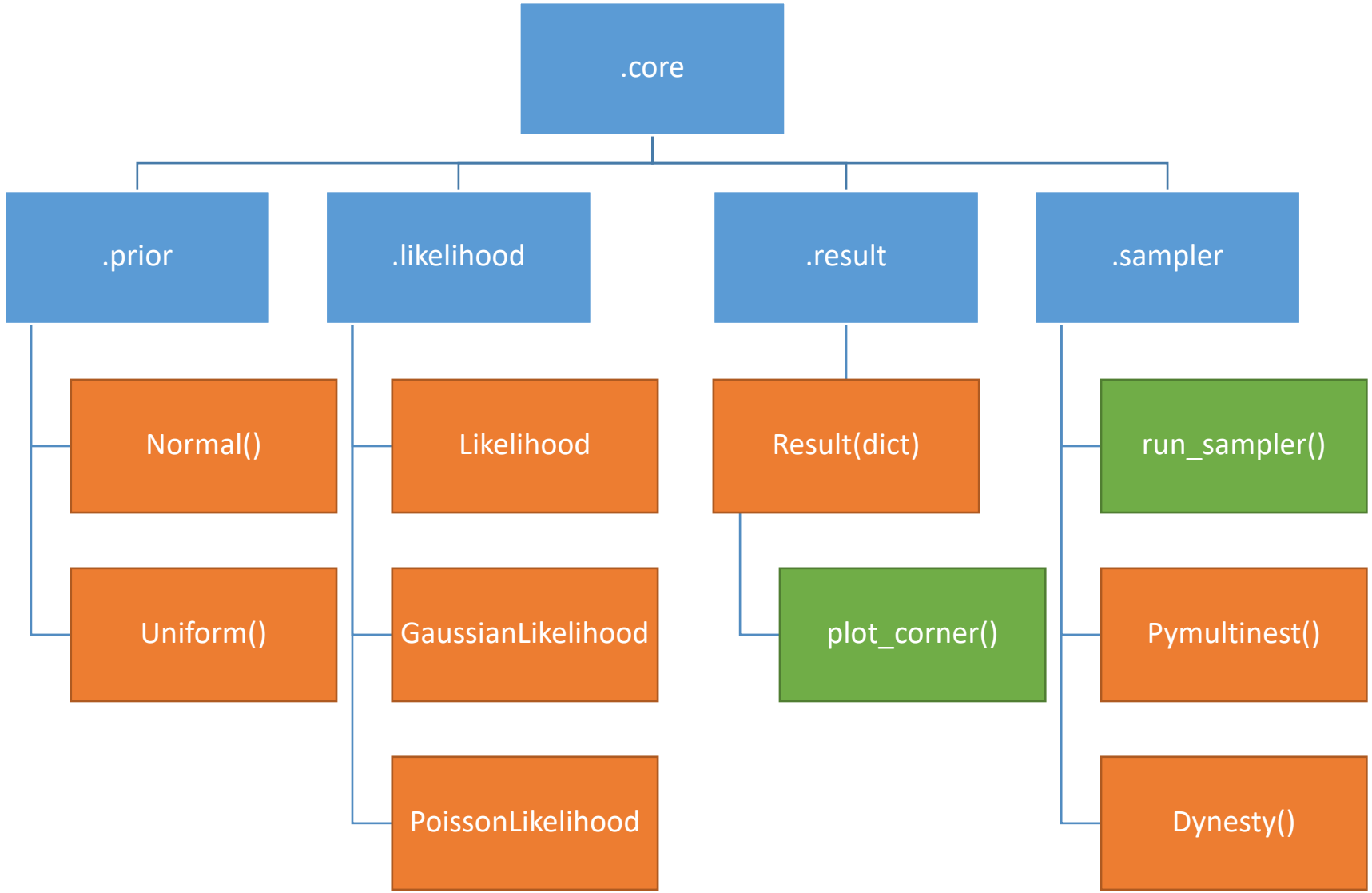
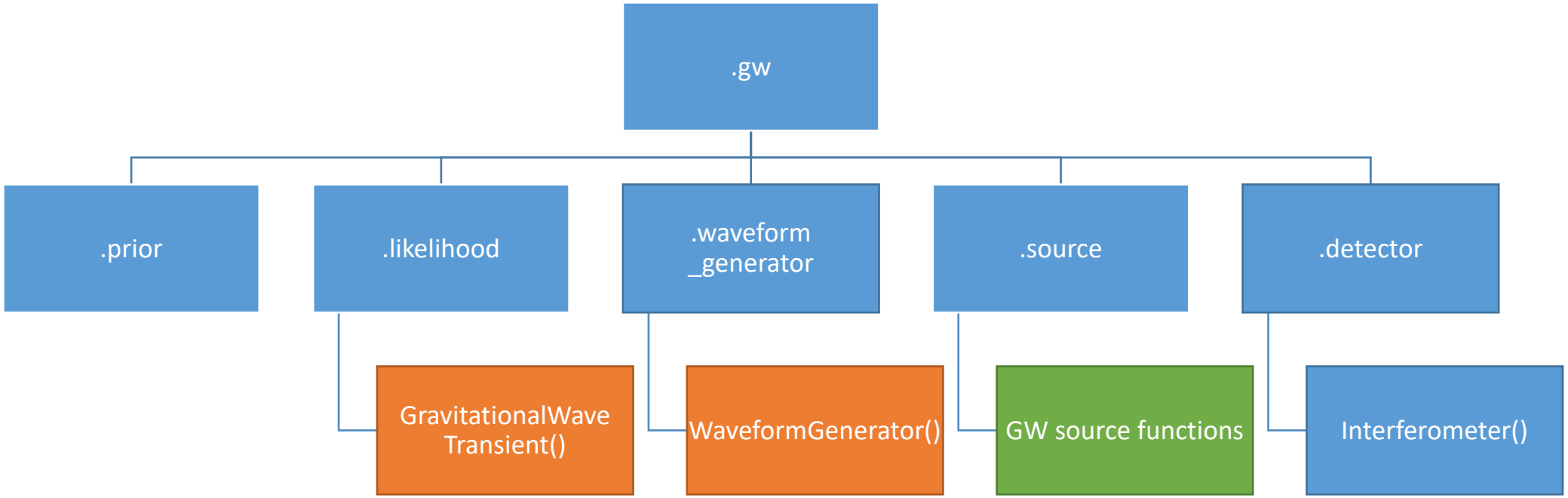
Overview and Installation

- 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




.core
.prior
.likelihood
.result
.sampler
Normal()
Uniform()
Likelihood
GaussianLikelihood
PoissonLikelihood
Result(dict)
plot_corner()
run_sampler()
Pymultinest()
Dynesty()


.gw
.prior
.likelihood
.waveform
_generator
.source
.detector
GravitationalWave
Transient()
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
  - https://arxiv.org/abs/2006.00714