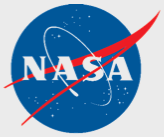
Amy Braverman

(Jet Propulsion Laboratory)

Inference and Uncertainty

Sponsored by the Jet Propulsion Laboratory and by the Keck Institute for Space Studies, California Institute of Technology



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Before we begin, the goal of these modules is to:

- Present statistical inference and its role in data analytics in the simplest terms possible.
  - Fewest number of topics.
  - Least amount of math (but assuming knowledge of some calculus and limits).
  - Not intended to be comprehensive or thorough.
- Three broad topic areas:
  - Review of basic probability.
  - Basic concepts of inference.
  - Introduction to two popular resampling (non-parametric) procedures for inference.

Outline

Goal of this part is to introduce some basic definitions:

- Inference
- Populations and samples.
- Exploratory and confirmatory analysis.
- Massive data sets: populations or samples?

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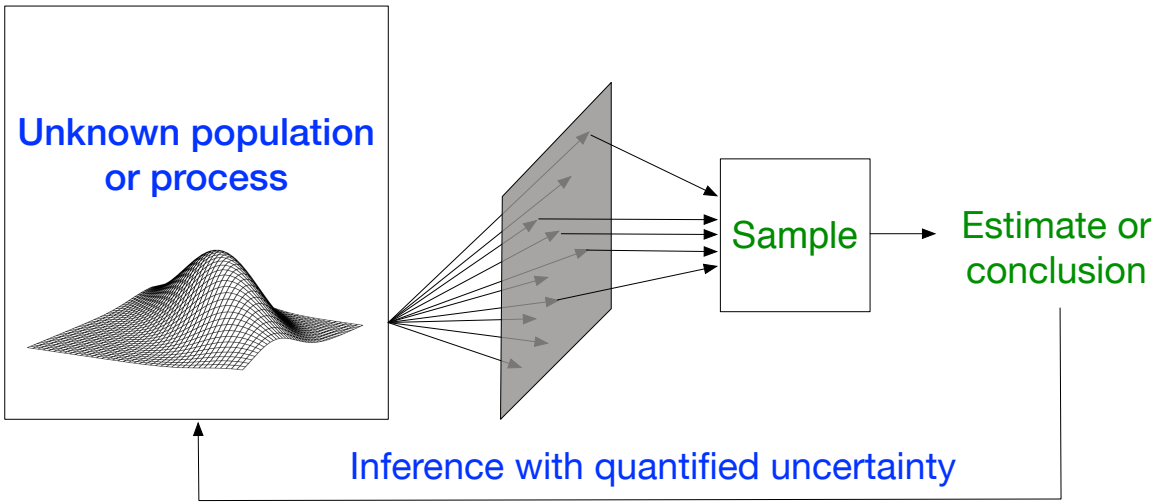

- True population or process is modeled probabilistically.
- Sampling supplies us with realizations from the probability model.
- Compute something, but recognize that *we could have just as easily gotten a different set of realizations*.

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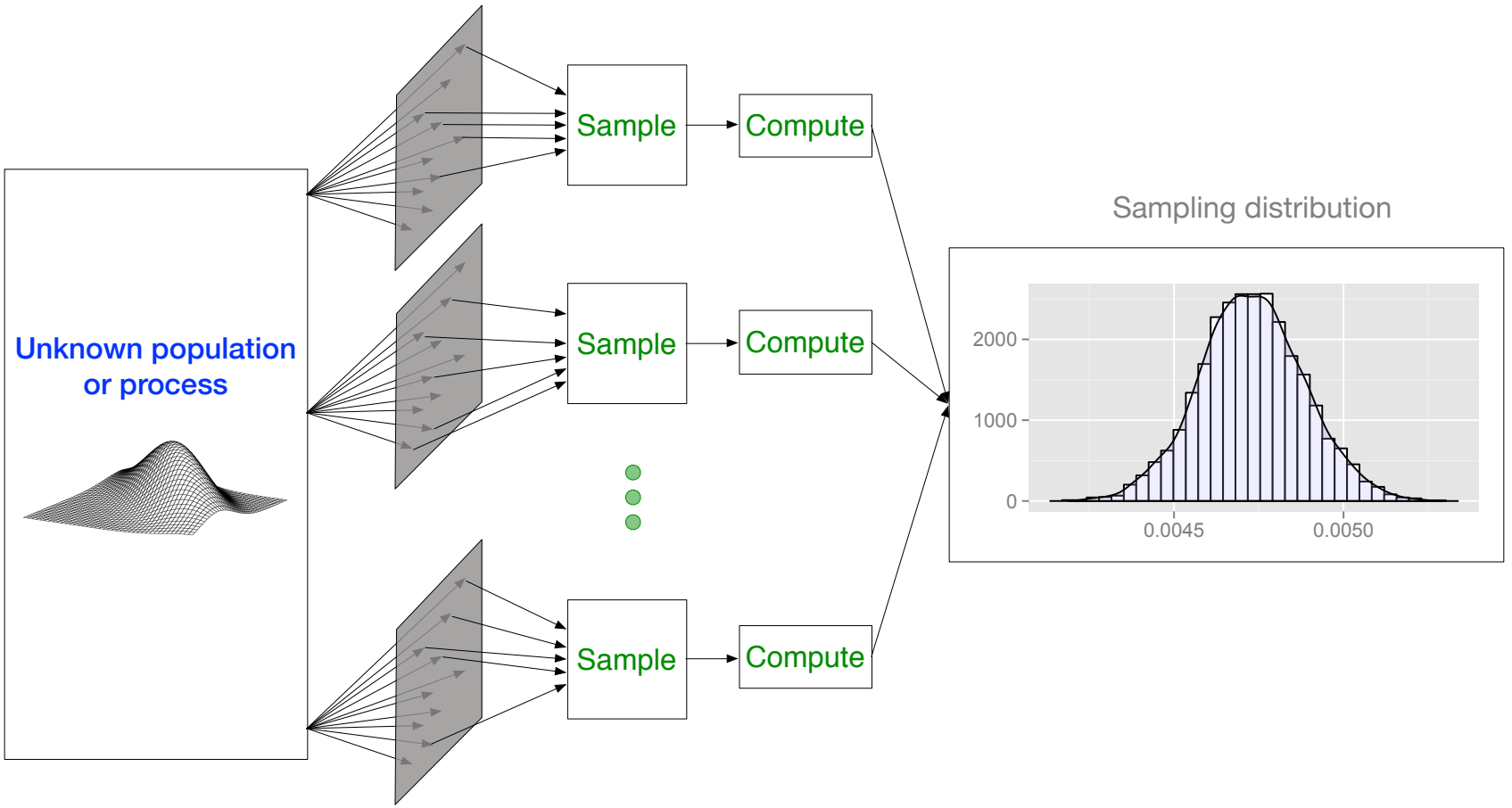

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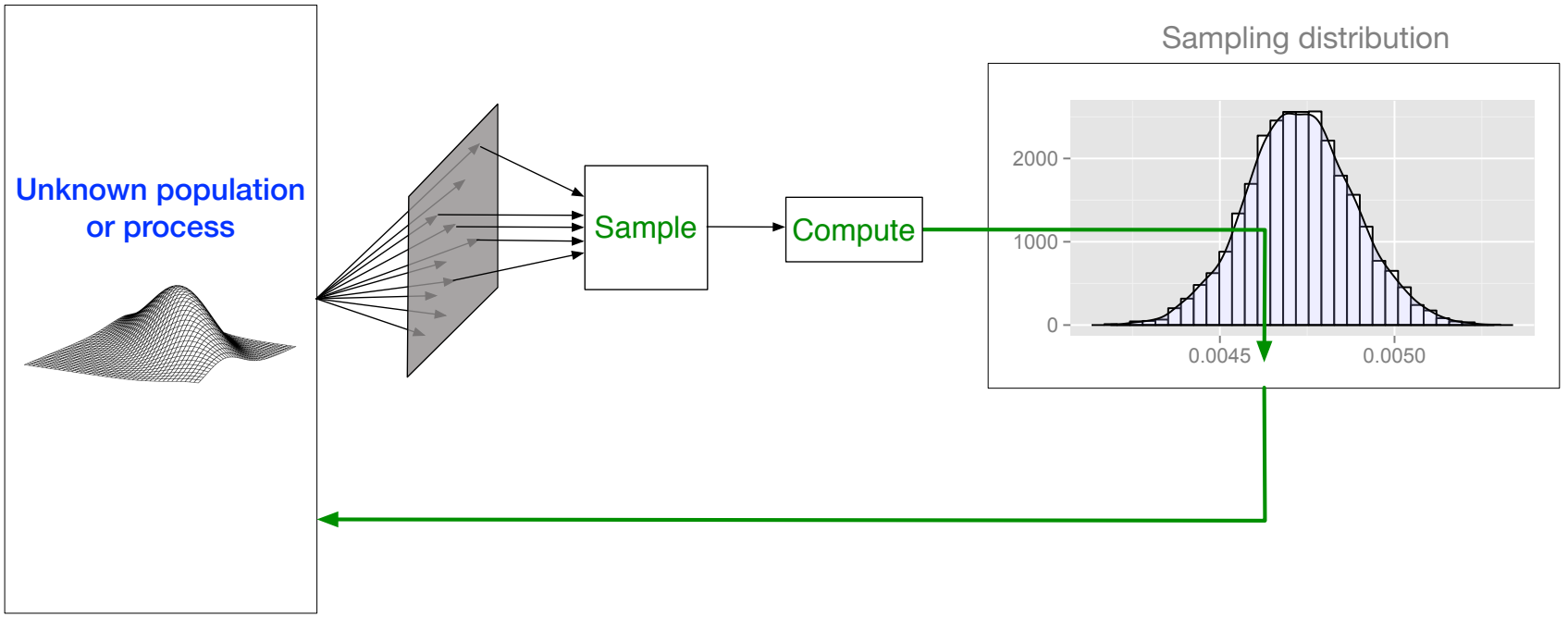

- We want to infer the characteristics of the true probability model from our *one* sample.
- There are generally two approaches: Frequentist and Bayesian. We'll come back to that.

Populations and samples

- An *observational unit* is an object about which we want to know something.
- A *variable* is a quantity we measure on an observational unit.
- A *population* is a collection of observational units.
  - Populations can be finite (e.g., all citizens of the US that are alive today) or infinite (all citizens of the US that were ever or will ever be alive).
  - A physical process or mechanism can be thought of as generating an infinite population (temperature at every moment in time at some location).
- A *parameter* is a quantity computed from all units in the population.

Populations and samples

- An *sample* is a subset of the population.
- A *statistic* is a quantity computed from a sample.

Sidebar: observational study vs. experiment.

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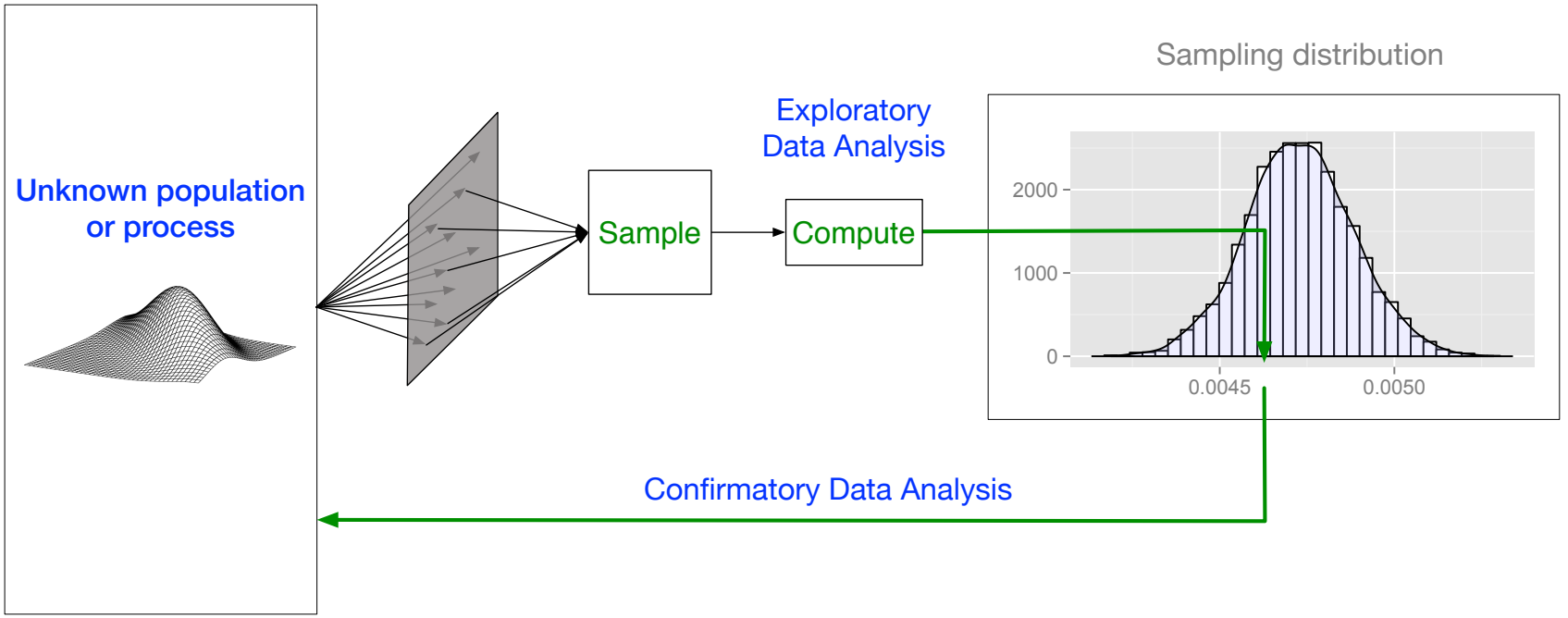
Exploratory vs confirmatory analysis



Exploratory vs confirmatory analysis

- EDA illuminates structures (patterns, relationships, etc.) in the sample. EDA is often necessary to formulate hypotheses about the unknown population. These hypotheses will be tested using confirmatory data analysis.

- In confirmatory data analysis (CDA), we use the tools of statistical inference to make definitive probabilistic statements about the population based on the sample.

- Tools of statistical inference: *hypothesis testing* and *estimation*.

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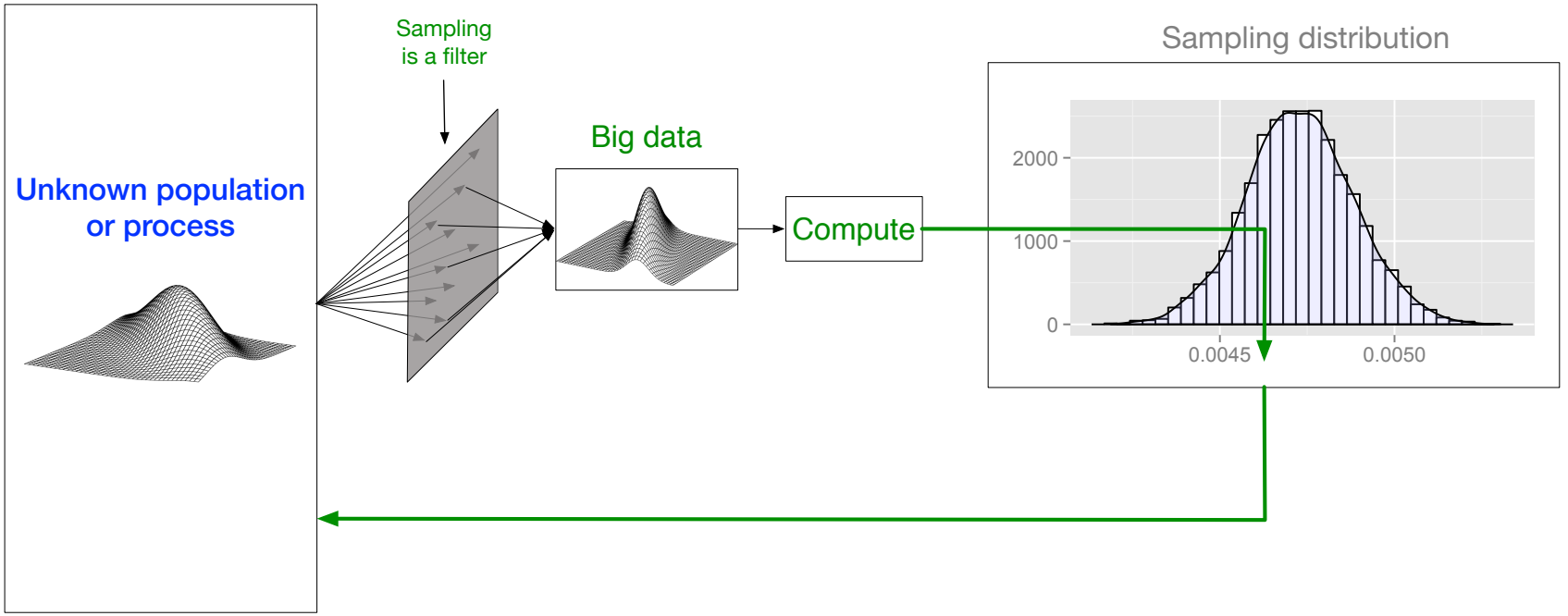
Massive data sets: populations or samples?



- These days the sample can be “big"; too big to compute with using traditional methods.
- Two strategies: bigger, better, faster algorithms (machine learning) or make the data smaller (another stage of sampling, data reduction).

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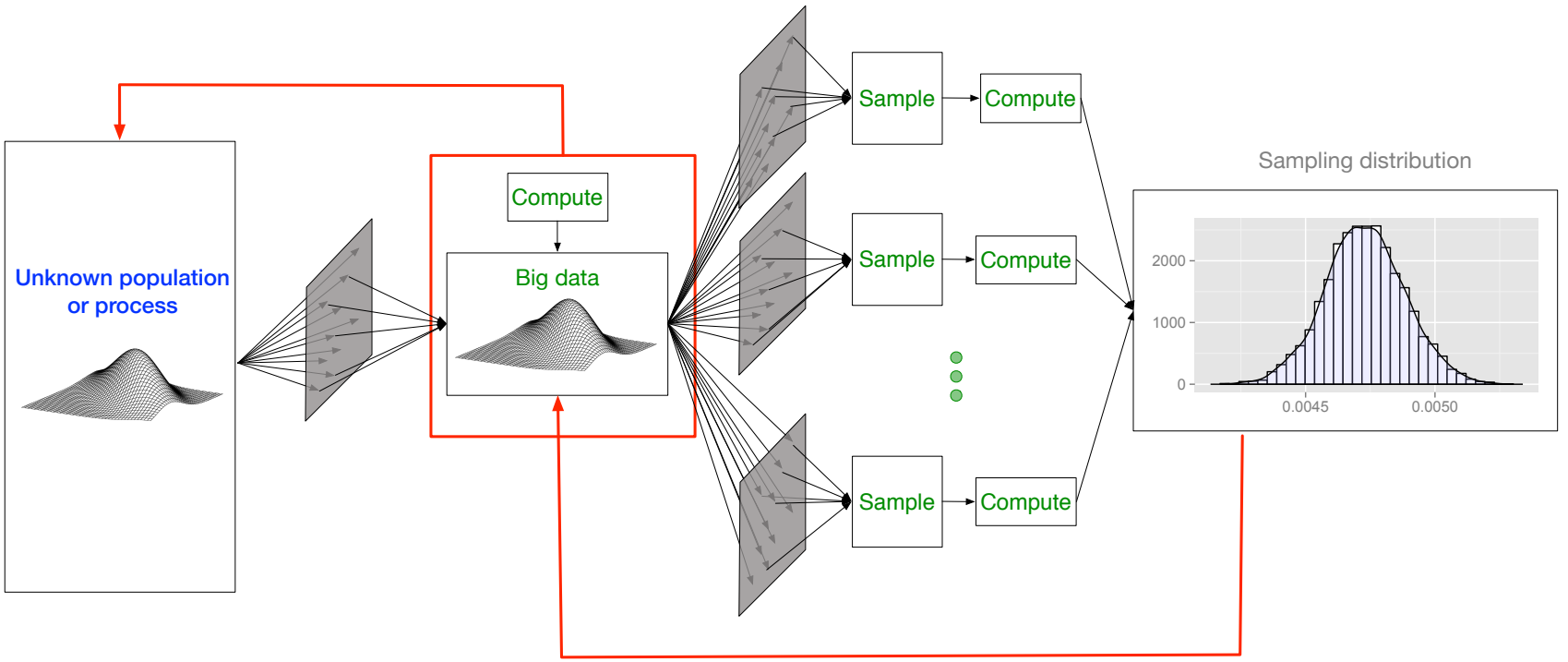

- Both. Surely we should be able to exploit this to provide probabilistic uncertainties for things we compute from big data.

Next

In the next module, we start the discussion with a brief review of basic probability.