Modern Tools for Robust Cosmological Parameter Inference

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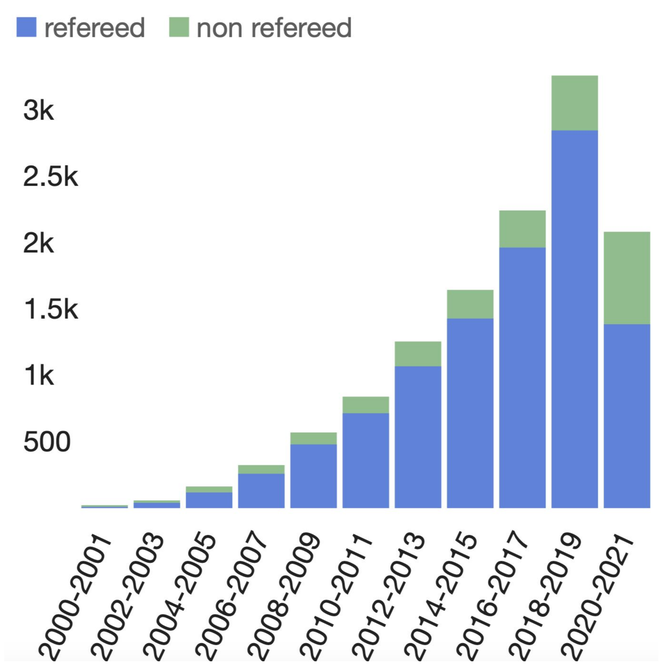
Abstract

We introduce Ensemble Slice Sampling (ESS) and its Python implementation **zeus**. ESS is an efficient parallel black-box Markov Chain Monte Carlo (MCMC) method that can rise to the challenges that modern astronomical datasets and astrophysical models pose.

Introduction

MCMC methods for sampling probability distributions have transformed the physical sciences and astronomy in particular.



Astronomy papers with “MCMC” mentioned in them.

Ensemble Slice Sampling

Despite their common use, most MCMC methods employed in astronomy are inefficient, subject to the *curse of dimensionality*, in need of tedious hand-tuning, difficult to parallelise, and often incapable of handling highly correlated and strongly multimodal cases.

To this end, we introduce ESS, a method specifically designed to address those issues and meet the standards of modern astronomical analyses. ESS relies on an ensemble of parallel chains, called walkers. Each walker moves in parameter space by slice sampling along directions constructed by the current distribution of the ensemble.

The result is an efficient algorithm that:

- Requires no hand-tuning (black-box),
- Is insensitive to linear correlations (affine invariant),
- Is trivially parallelizable (up to 1000s of CPUs),
- Can handle strongly multimodal cases even in high dimensions,
- Produces Markov chains of very low autocorrelation time,
- Is locally adaptive and thus can handle strong non-linear correlations efficiently.

GitHub minaskar/zeus | arXiv 2002.06212 | arXiv 2105.03468

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zeus

Lightning Fast MCMC

We also present **zeus**, a publicly available Python implementation of ESS. We tested ESS’s and zeus’s performance by fitting, among other examples, the Baryon Acoustic Oscillation (BAO) feature using data from the BOSS survey. We used a model that includes 22 free parameters. **zeus** converges after running for less than 30 minutes. As a comparison, state-of-the-art methods such as *emcee* and *dynesty* require more than ~10 hours to produce these results. We conclude that **zeus** is a powerful and useful tool for modern astronomical analyses.