Leveraging Simulation-Based Inference for Precision Cosmology

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mwiet.github.io

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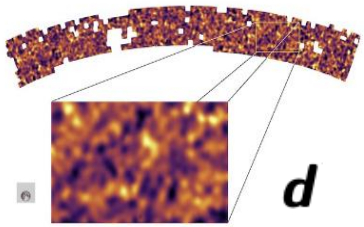
Institute for Computational Cosmology

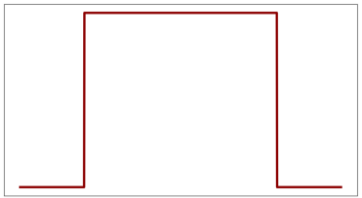
Recipe for Cosmological Inference



d

Data

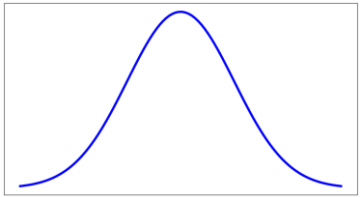
$P(\theta)$



θ

Prior

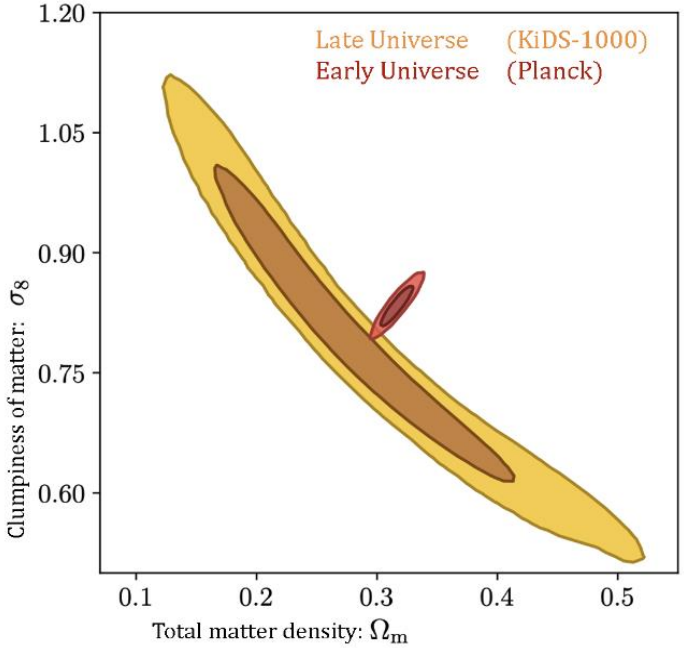
$P(d|\theta)$



d

Likelihood

$P(\theta|d)$: **Posterior**

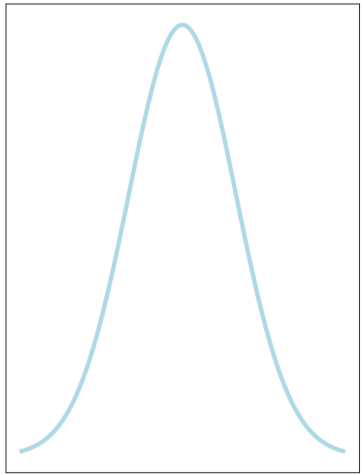


Model: ΛCDM

Modelling Likelihoods

Given a model!

$P(\boldsymbol{d}|\boldsymbol{\theta})$

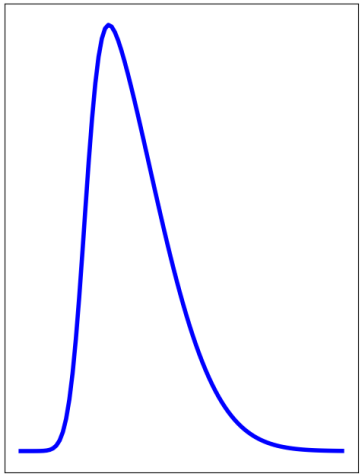


$\boldsymbol{d}$

Analytic

e.g.

$P(d|\theta) \propto e^{-(d-\mu)^2}$

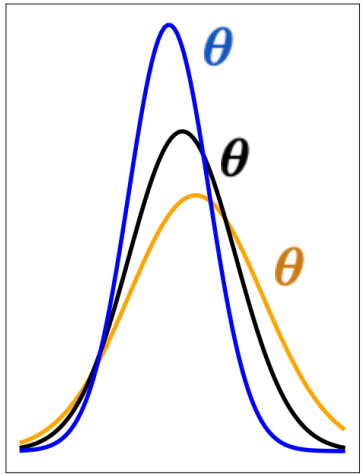


$\boldsymbol{d}$

Biased

e.g.

Instrumental systematics

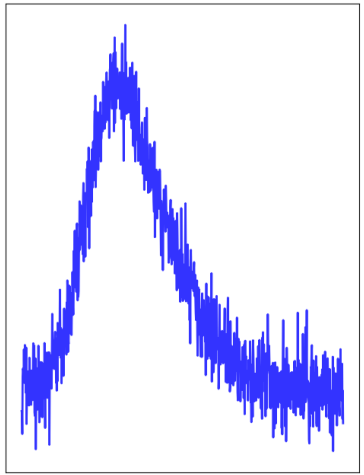


$\boldsymbol{d}$

Signal-dependent uncertainty

e.g.

Cosmic variance



$\boldsymbol{d}$

Intractable

e.g.

Non-trivial selection functions

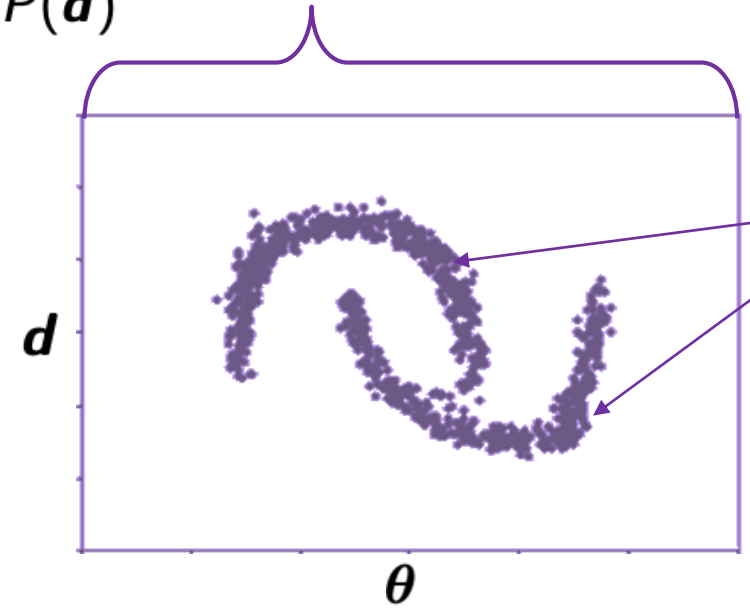
Bayes' Theorem

Posterior — **Likelihood** — Prior — **Joint probability**

$$P(\boldsymbol{\theta}|\boldsymbol{d}) = \frac{P(\boldsymbol{d}|\boldsymbol{\theta}) \cdot P(\boldsymbol{\theta})}{P(\boldsymbol{d})} \propto P(\boldsymbol{\theta}, \boldsymbol{d}) \cdot P(\boldsymbol{\theta})$$

$\boldsymbol{\theta}$: Model parameters

$\boldsymbol{d}$: Data



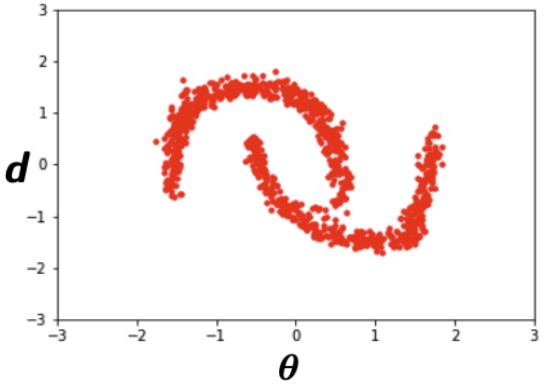
Populate with **simulations** given a model

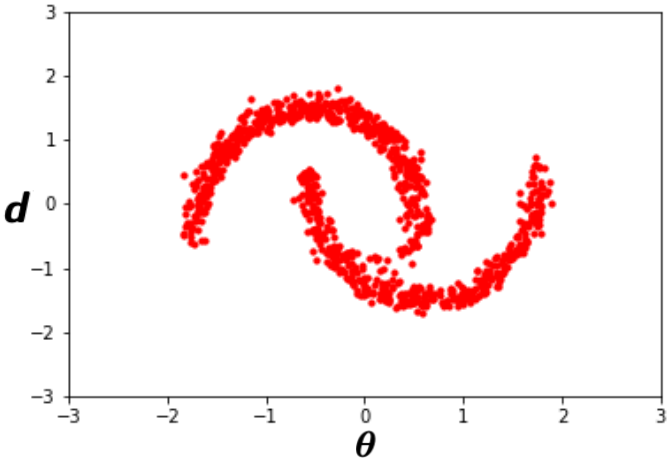
Simulation-Based Inference

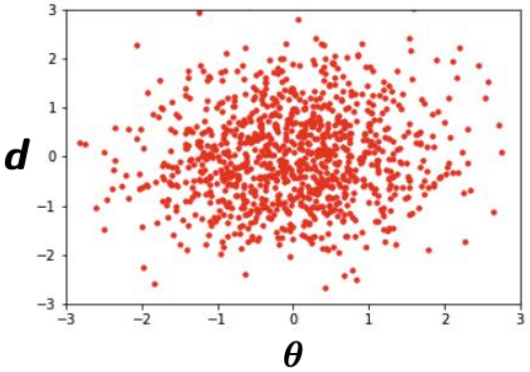
$P(\theta, d)$
from simulations

Learn transformations
to

Gaussian
distribution







Credit: Eric Jang

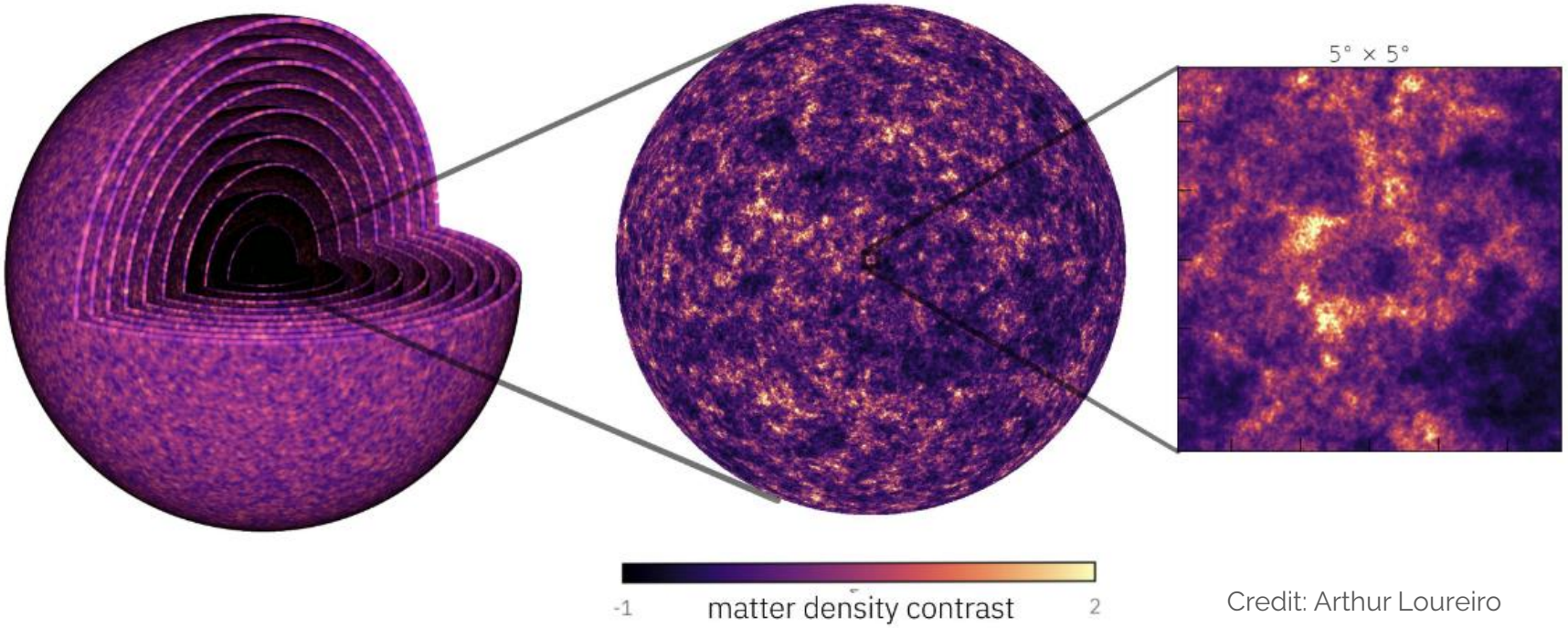
Invertible

Cosmic Shear
& Large-Scale Structure

In collaboration with K. Lin, N. Tessore, B. Joachimi, A. Loureiro, R. Reischke, A.H. Wright

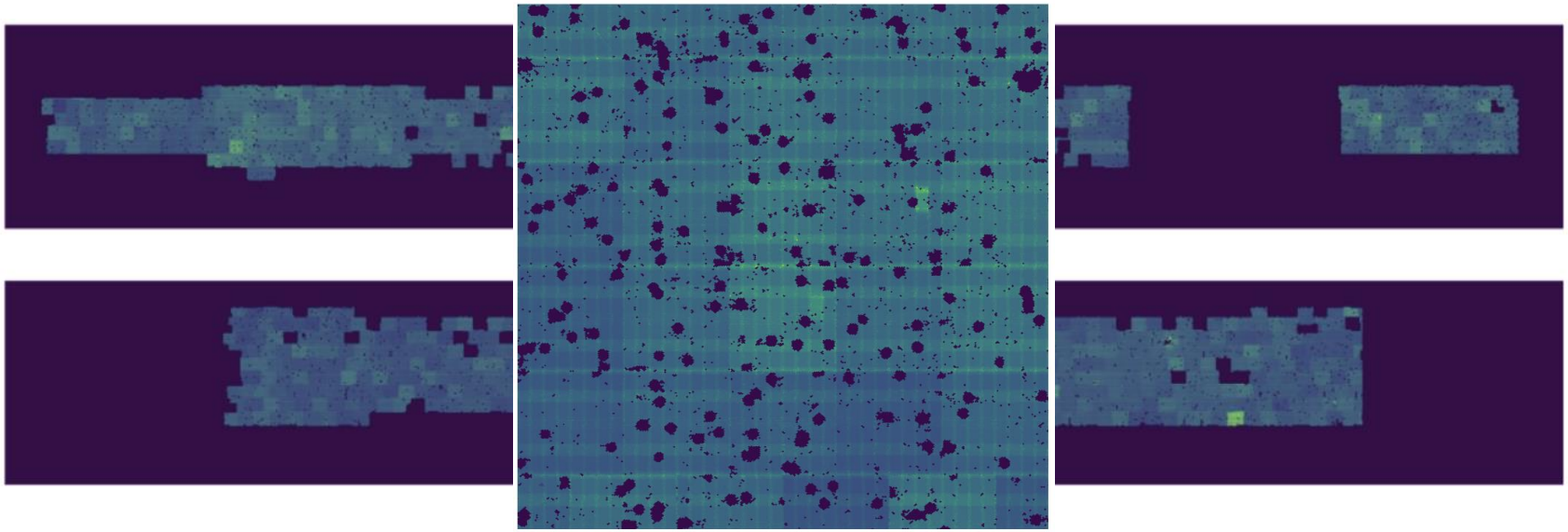
arxiv:**2404.15402**

Simulating Large-Scale Structure



Credit: Arthur Loureiro

Realistic Selection and Systematics



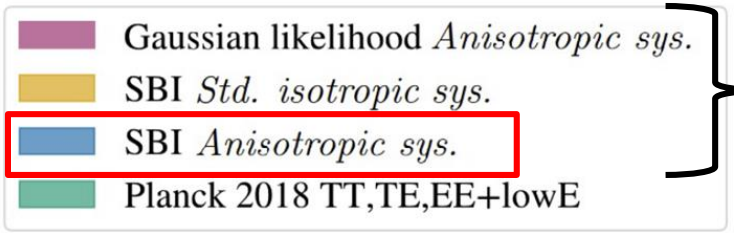
KiDS
Kilo-Degree Survey

Deeper survey

Less deep survey

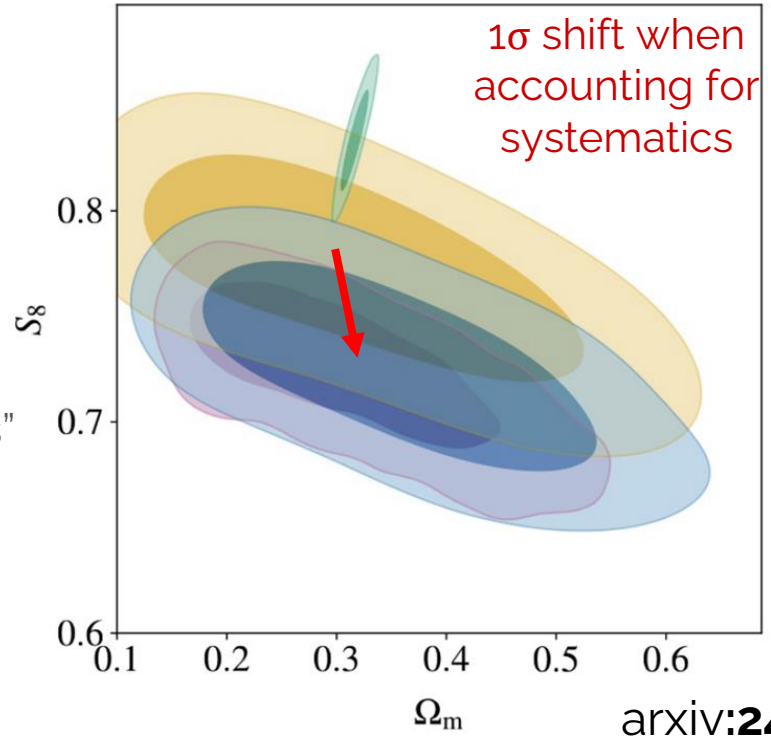
arxiv:**2404.15402**

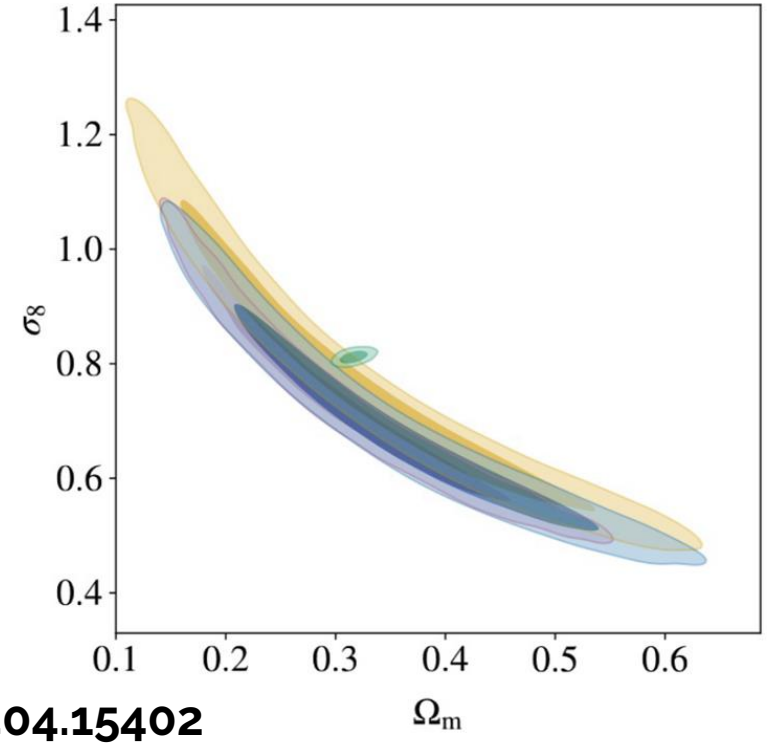
SBI in Cosmic Shear



KiDS-1000 cosmic shear only

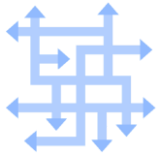
Weak lensing parameter for "clumpiness"



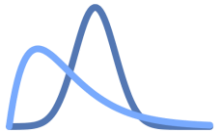


arxiv:**2404.15402**

Conclusions



SBI allows for uncertainty propagation of **arbitrary complexity**



Including a realistic systematics and selections shifts S_8 to **0.731±0.033 (1σ lower!)**

As future surveys become **systematics-limited**, SBI may help address modelling challenges

arxiv:**2404.15402**