machine learning for science and humanities postdoctoral program

Co-funded by The European Union

Characterizing the *Fermi*-LAT high-latitude sky with simulation-based inference

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30th of April 2024

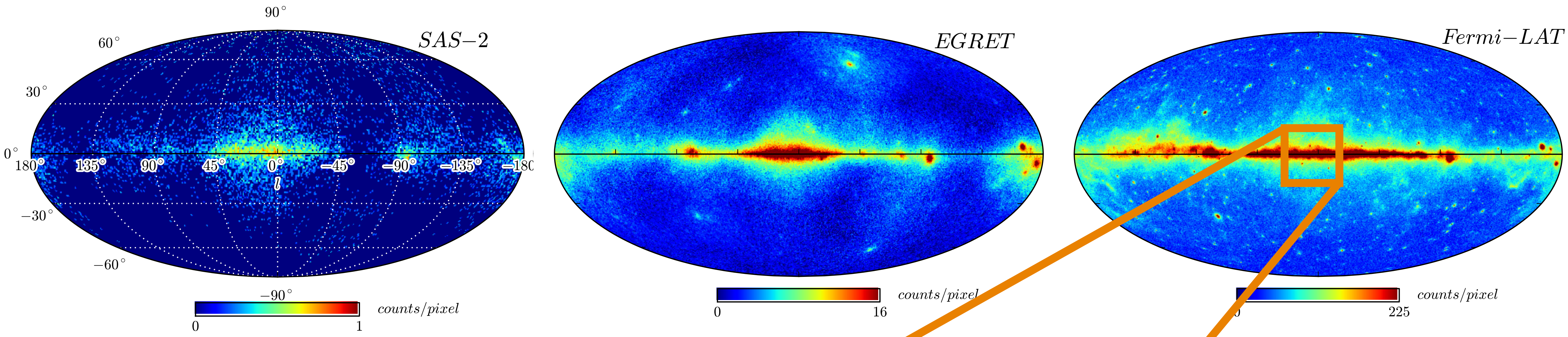
$$p(Z|X) = \frac{p(X|Z)p(Z)}{p(X)}$$

European AI for Fundamental Physics Conference (EuCAIFCon)
Amsterdam, Netherlands

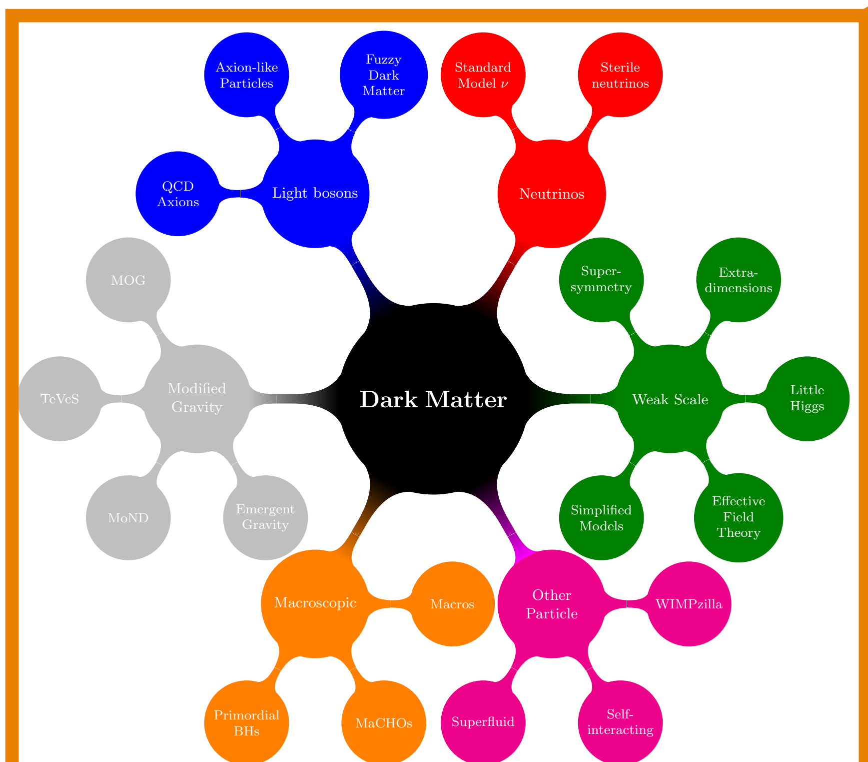
Fundamental physics with gamma rays is hard

The high-energy gamma-ray sky seen over the decades (space-borne telescopes).

1972-73 **1991-2000** **2008-now**



[Fermi-LAT collaboration, ApJS 223 (2016) 2]



[Bertone, Tait, *Nature* 562 (2018) 7725]

Signatures of fundamental physics are potentially hiding there!
→ How to deal with the **complexity** of all the astrophysics?
There is a lot to model …

Simulation-based inference brings back physics

Ratio estimation as a form of simulation-based inference (SBI):

Bayes' Theorem

parameters Z, data X

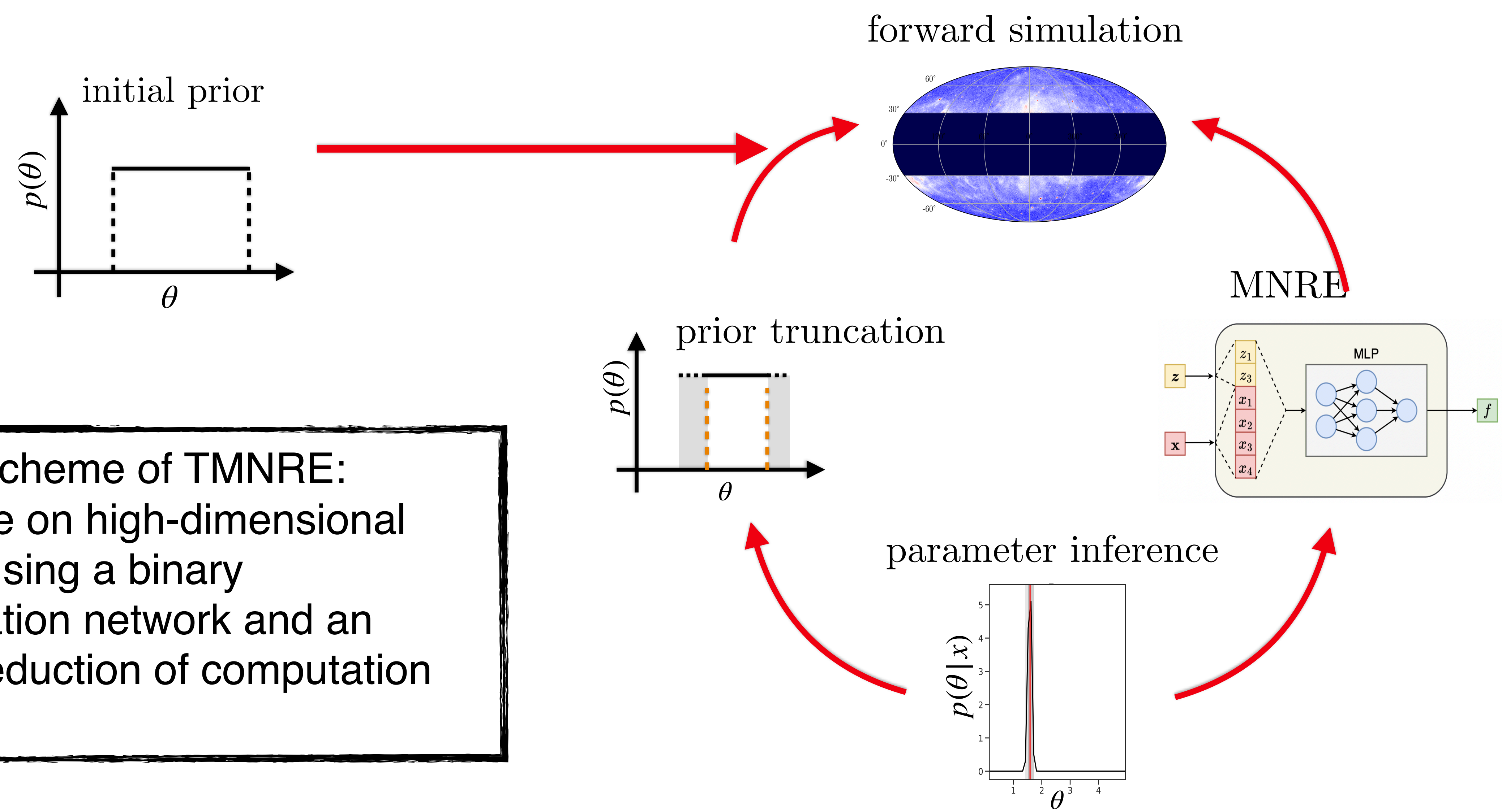
posterior · **prior** · **Likelihood-to-evidence ratio**

$$\frac{p(Z|X)}{p(Z)} = \frac{p(X|Z)}{p(X)} = \frac{p(X,Z)}{p(X)p(Z)}$$

swyft

Truncated
Marginal
Neural
Ratio
Estimation

[B. Miller et al., J. Open Source Softw. 7 (2022) 75]

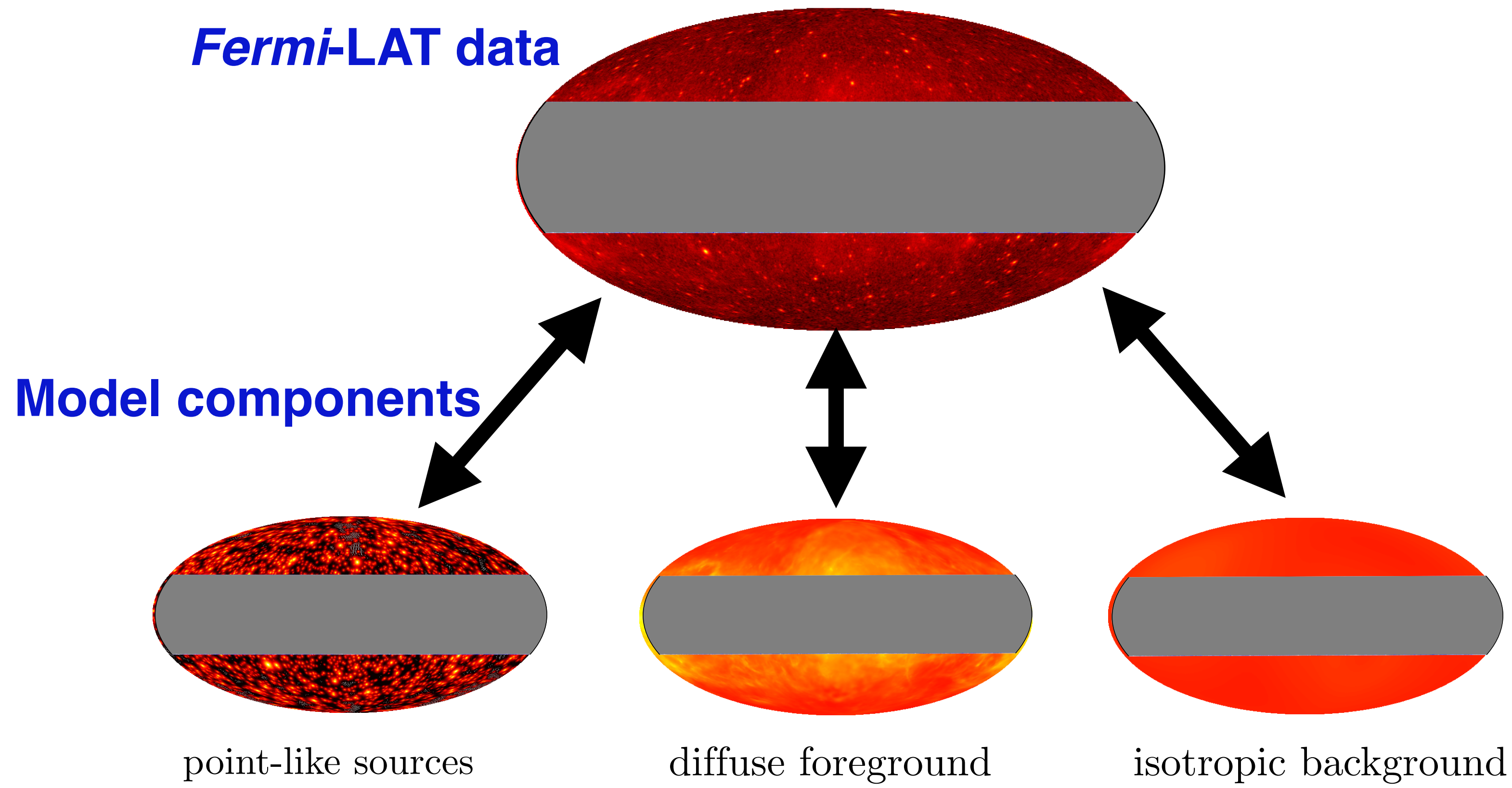


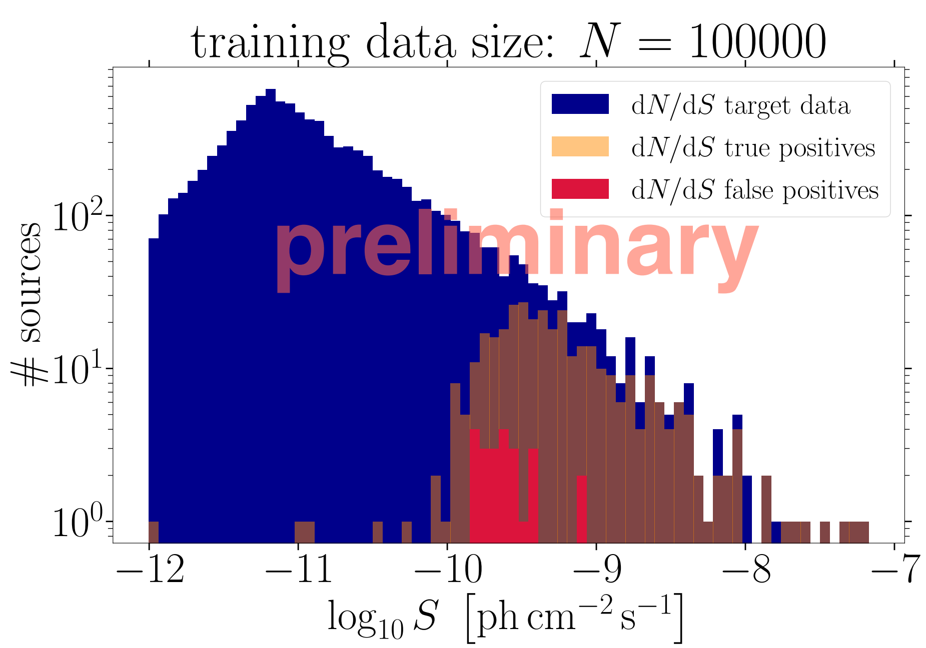
The great scheme of TMNRE:
→ Inference on high-dimensional models using a binary classification network and an overall reduction of computation costs.

First Application to Gamma Rays: High-Latitude Sky

We tune our SBI approach to gamma-ray data with observations of the high latitudes
→ Less backgrounds and more opportunities to cross-check with literature results!

Scientific Objectives:
(1) What is the distribution of point-like gamma-ray sources as a function of their flux?
(2) Which of them can we robustly detect?





You may wonder:
1. How does it work?
2. What does the astro model look like?
3. What are your plans?

Let's have a chat, Wednesday 12 - 3 pm in poster session A!

Neural Simulation-Based Supernova Ia Cosmology

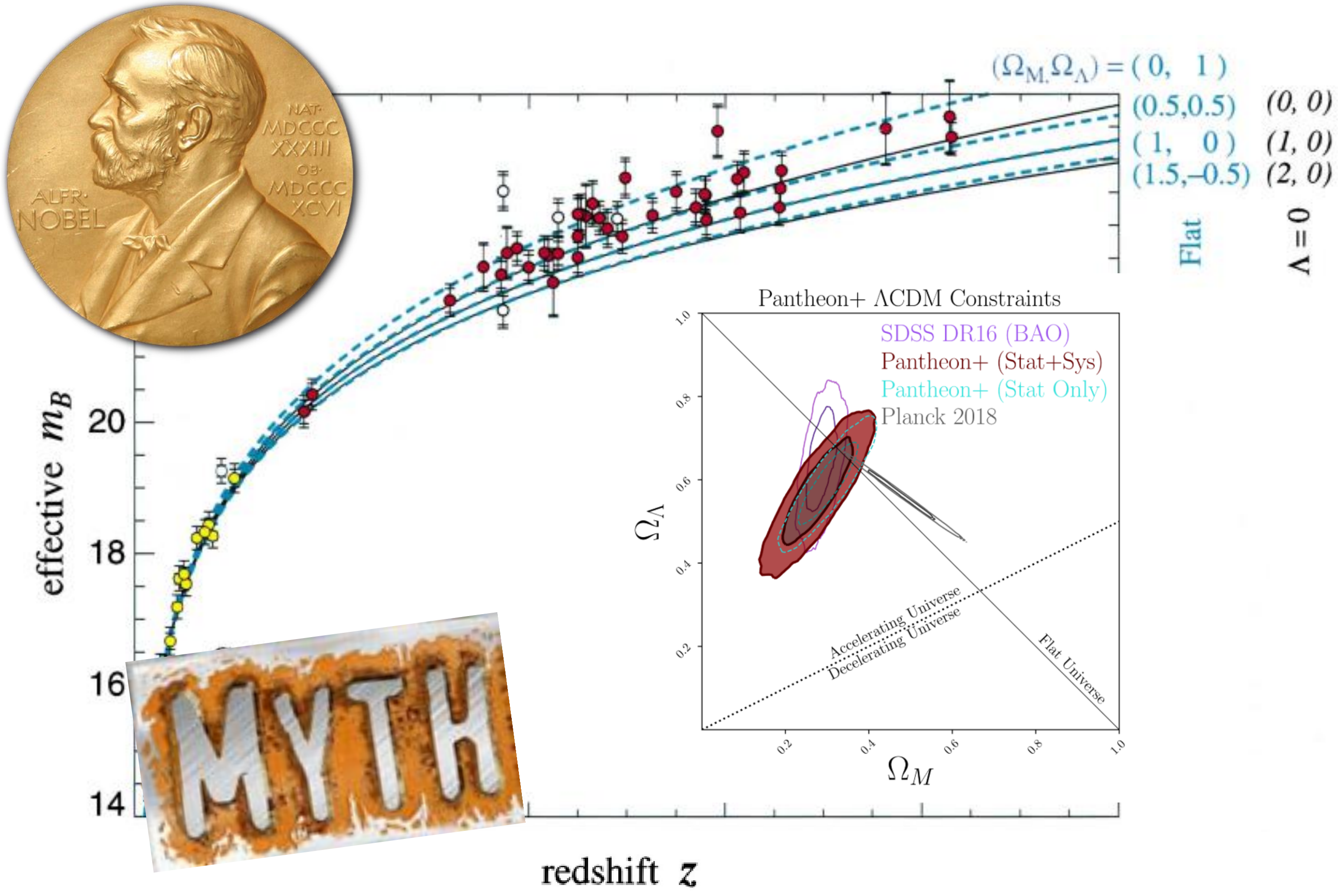
Kosio Karchev

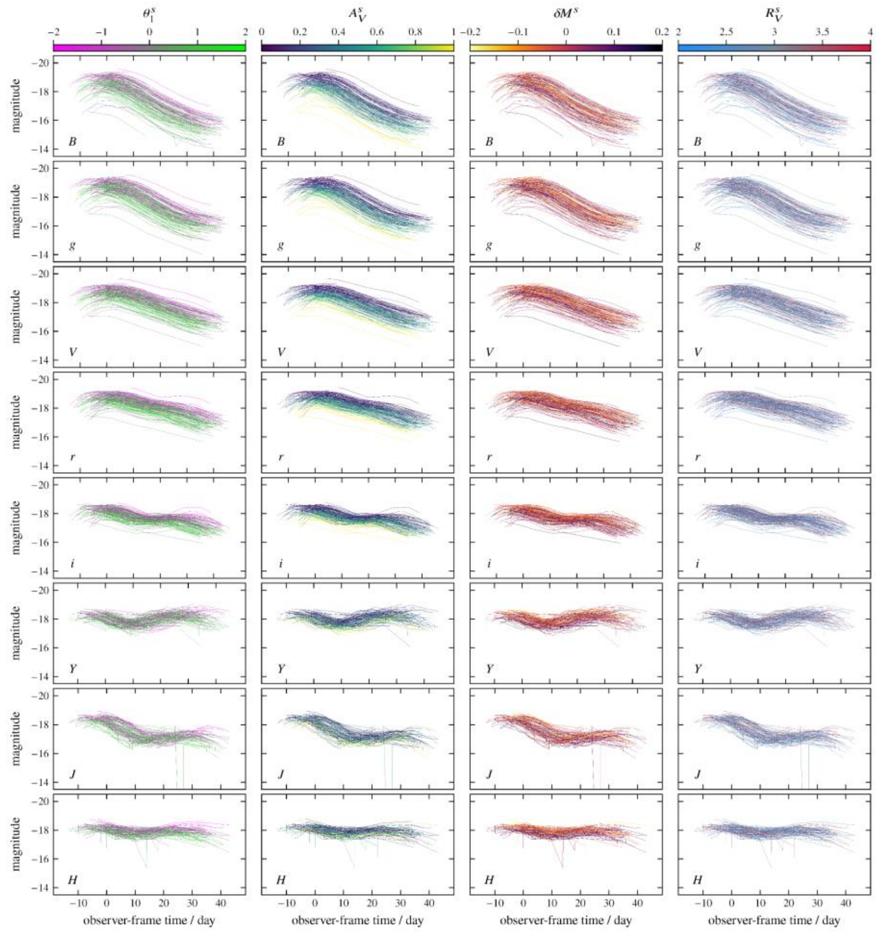
Roberto Trotta, Christoph Weniger

SISSA DATASCIENCE
Machine Learning for the Natural Sciences

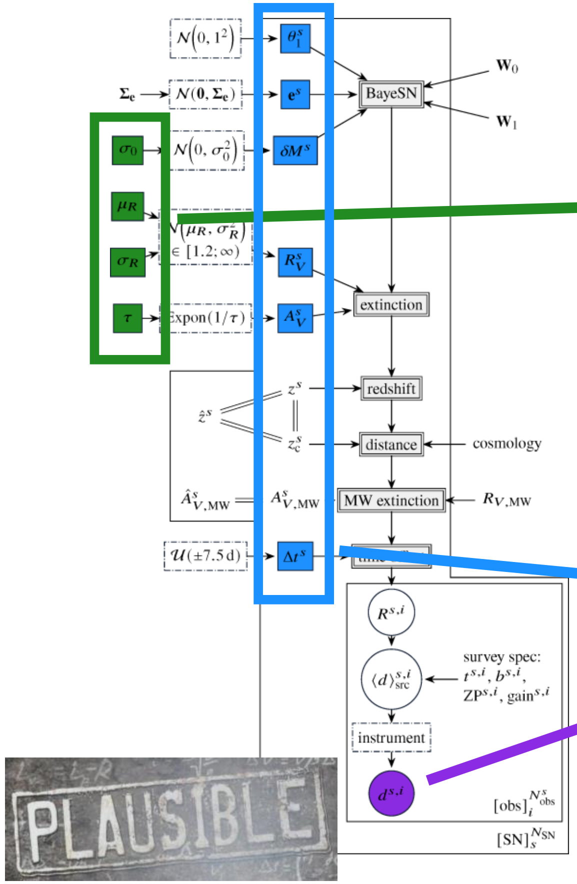
EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE
EuCAIFCon 2024

Supernova Ia cosmology

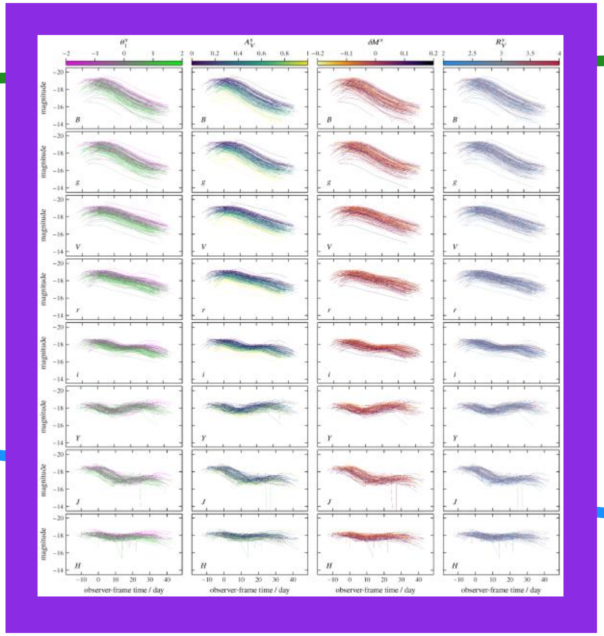


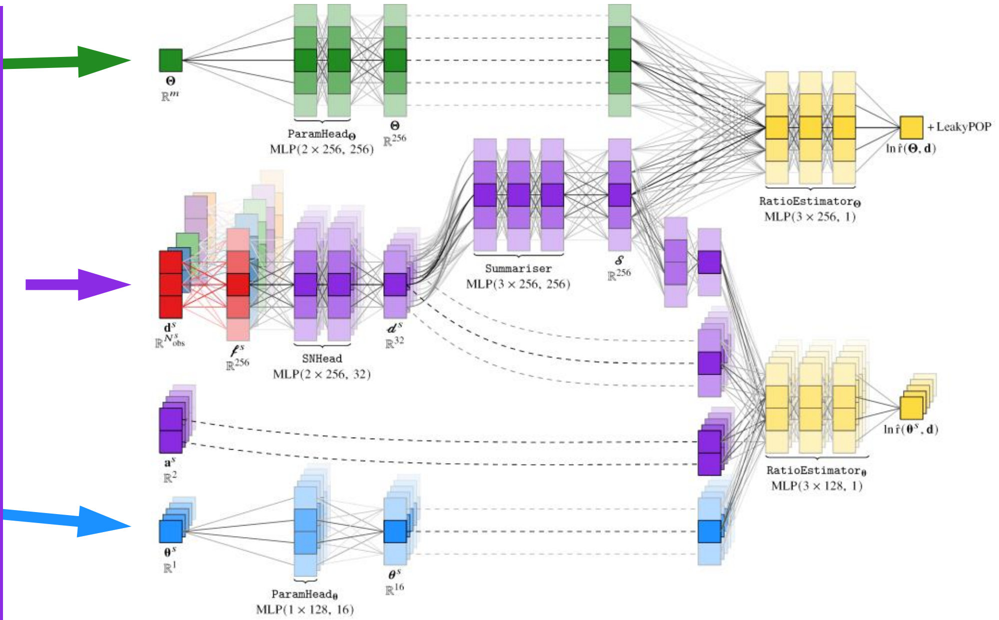


TMNRE for supernova light curves



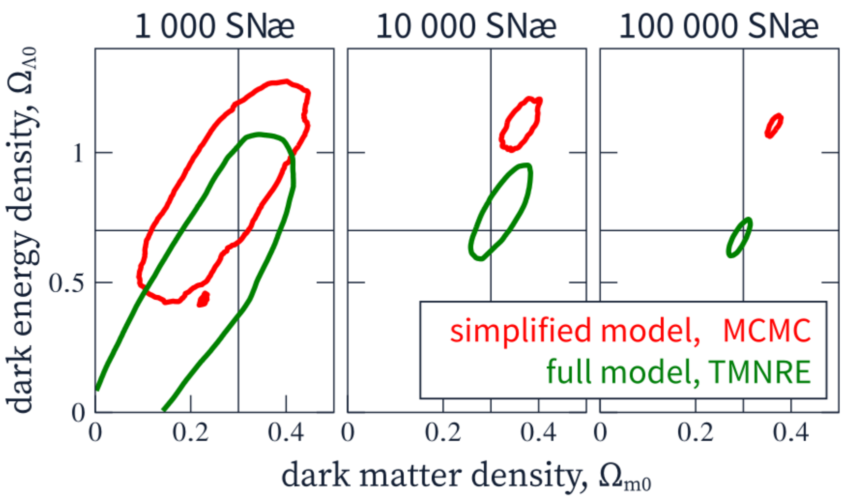
SLiCsim



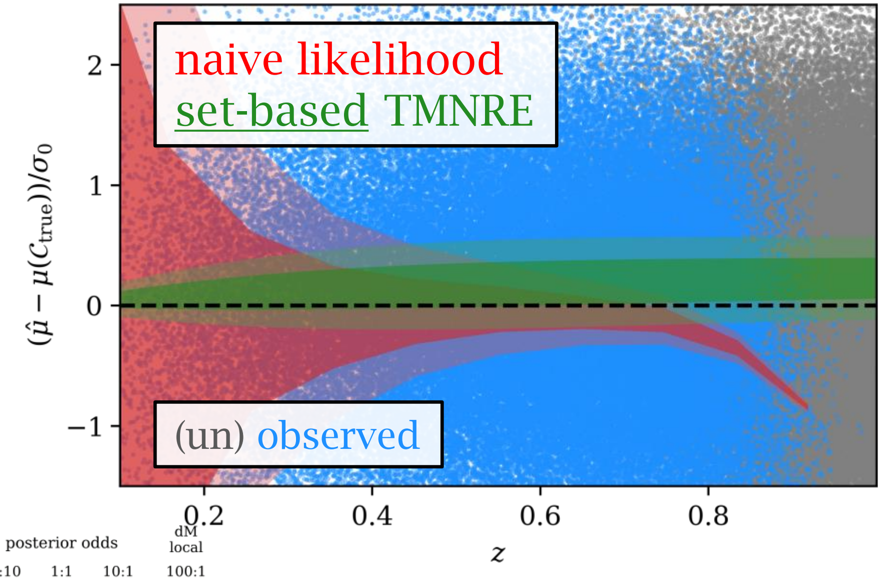


Tuple-based NN:
global and local
NRE

The importance of being principled



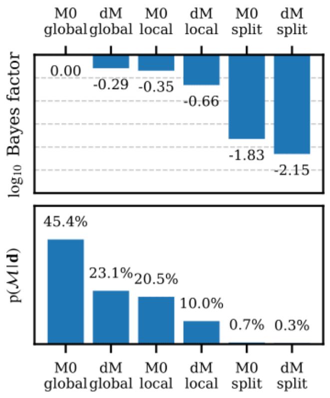
10^5
SNæ

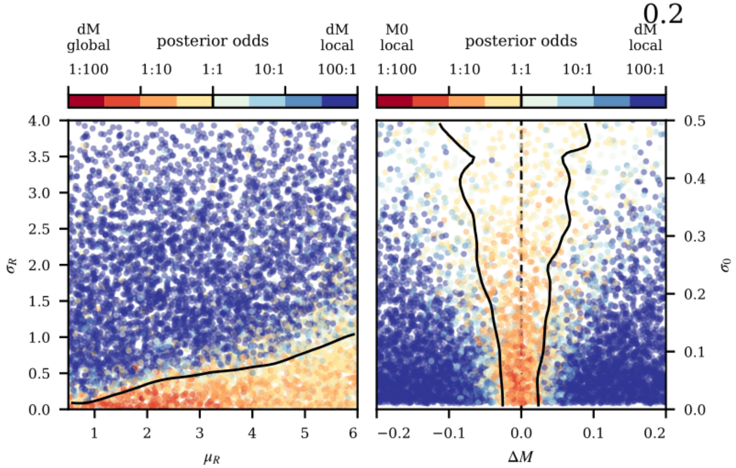


systematics

selection effects

Bayesian model selection





Fast likelihood-free inference in the LSS Stage-IV era

Guillermo Franco Abellán

GRAPPA
GRavitation AstroParticle Physics Amsterdam

Euclid consortium

Based on arXiv:2403.14750

with Guadalupe Cañas-Herrera,
Matteo Martinelli,
Oleg Savchenko,
Davide Sciotti,
& Christoph Weniger

EuCAIFCon - 30th April 2024

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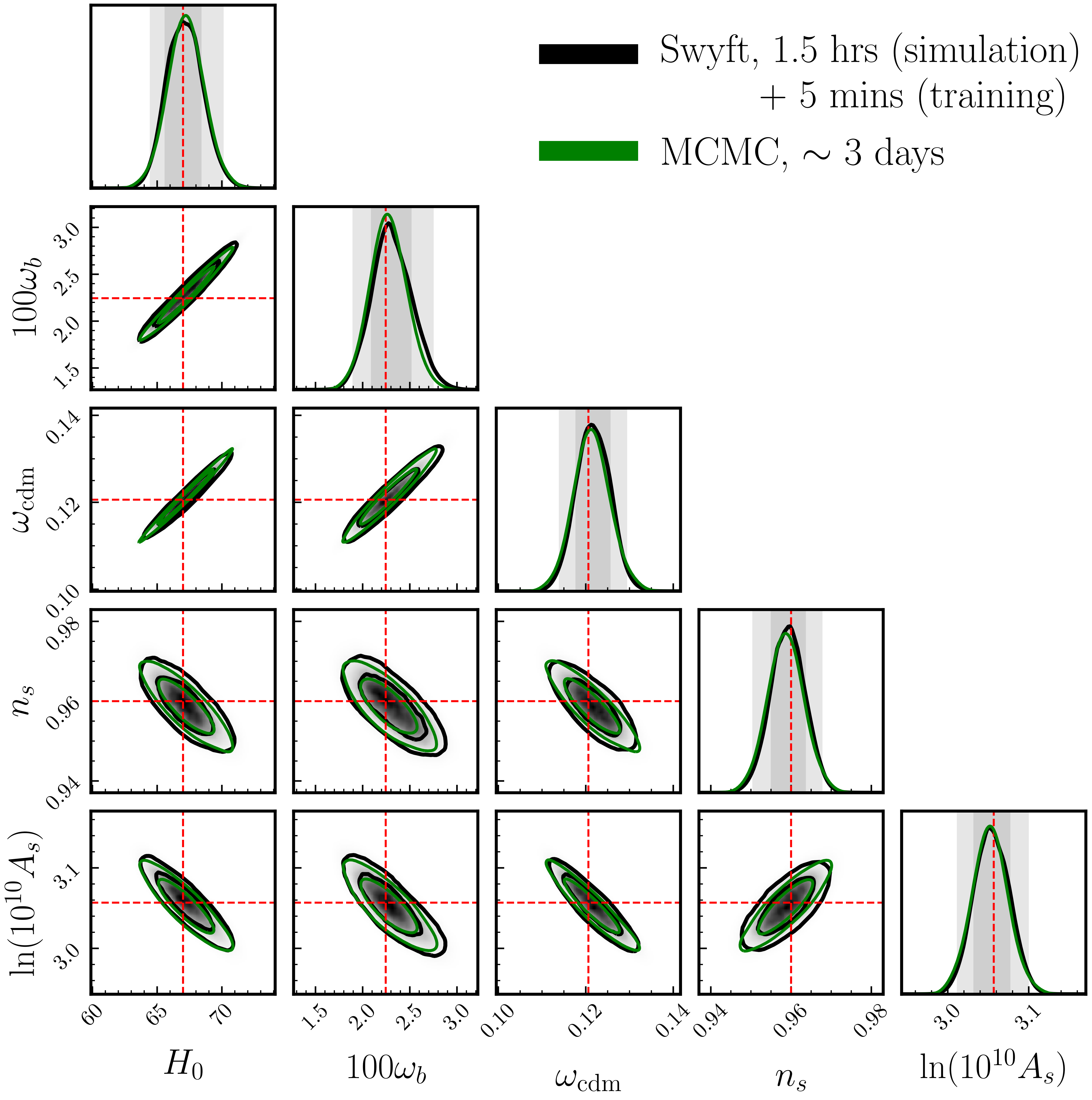
Our **GOAL**

Accelerate parameter inference from Stage-IV photometric surveys (i.e. **Euclid**) using **Marginal Neural Ratio Estimation*** (MNRE, a new approach in **SBI**)

*Implemented in **Swyft** [Miller+ 20]

Forecast ΛCDM posteriors



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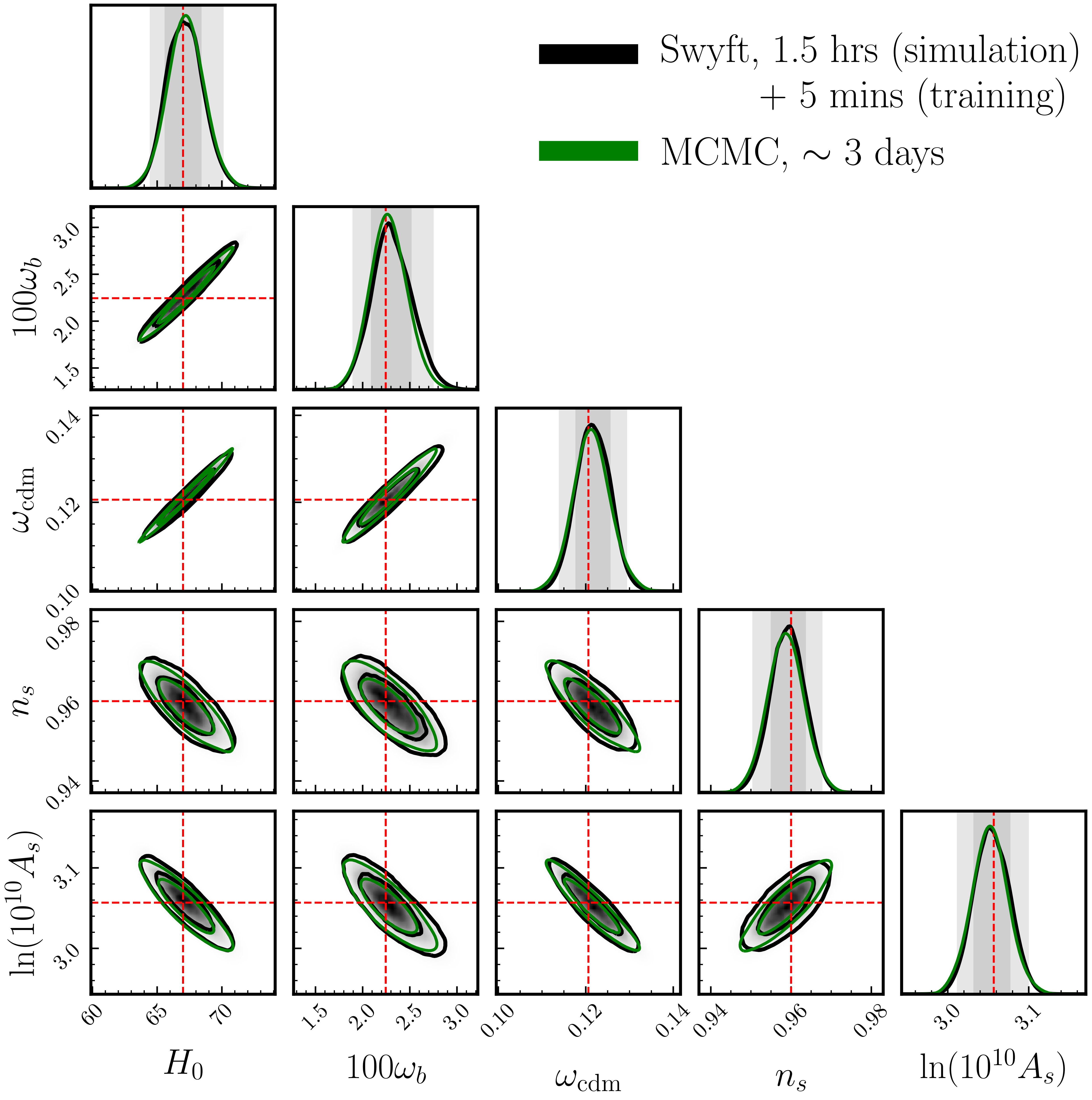

MNRE & MCMC are in excellent agreement!

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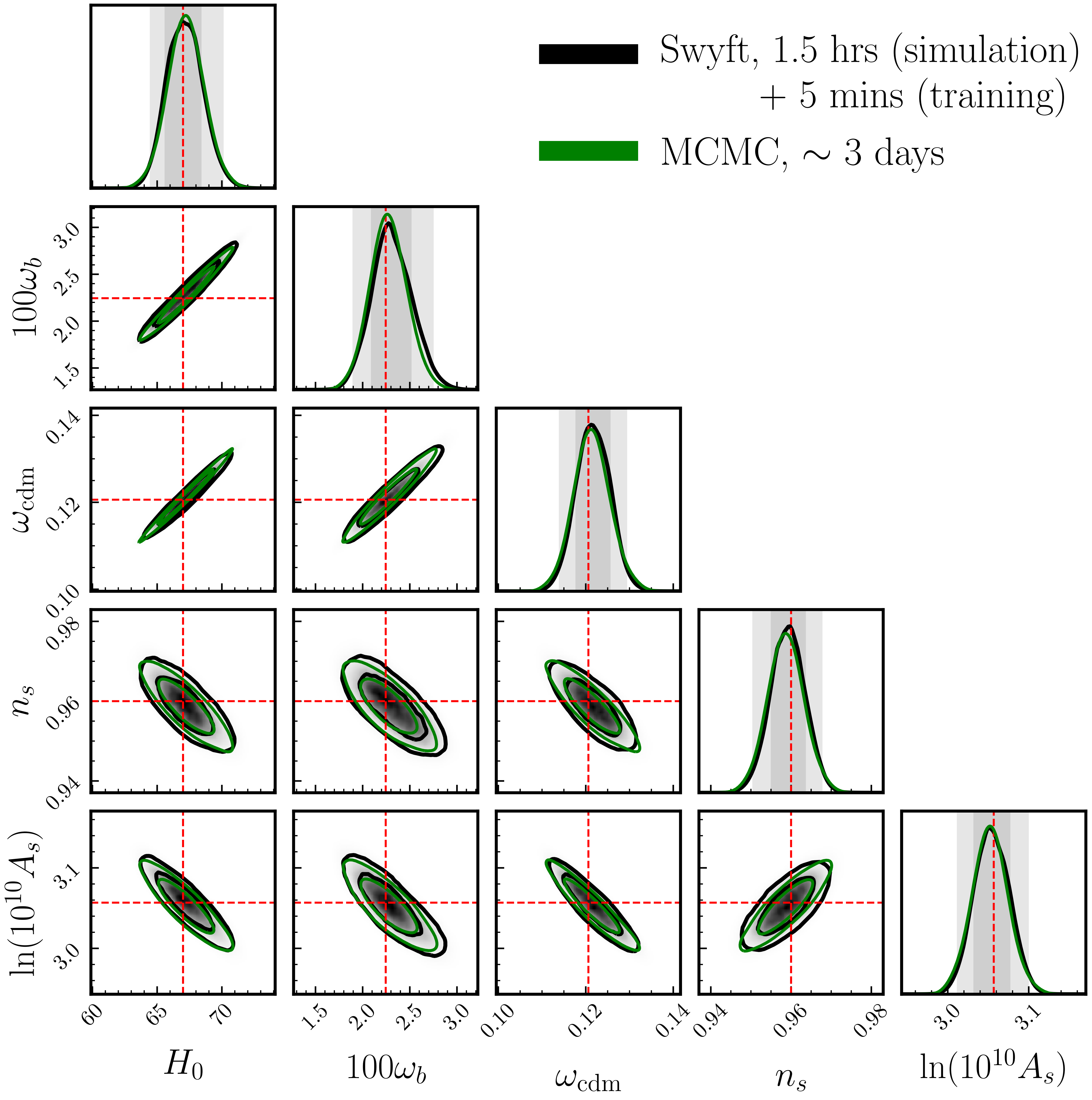
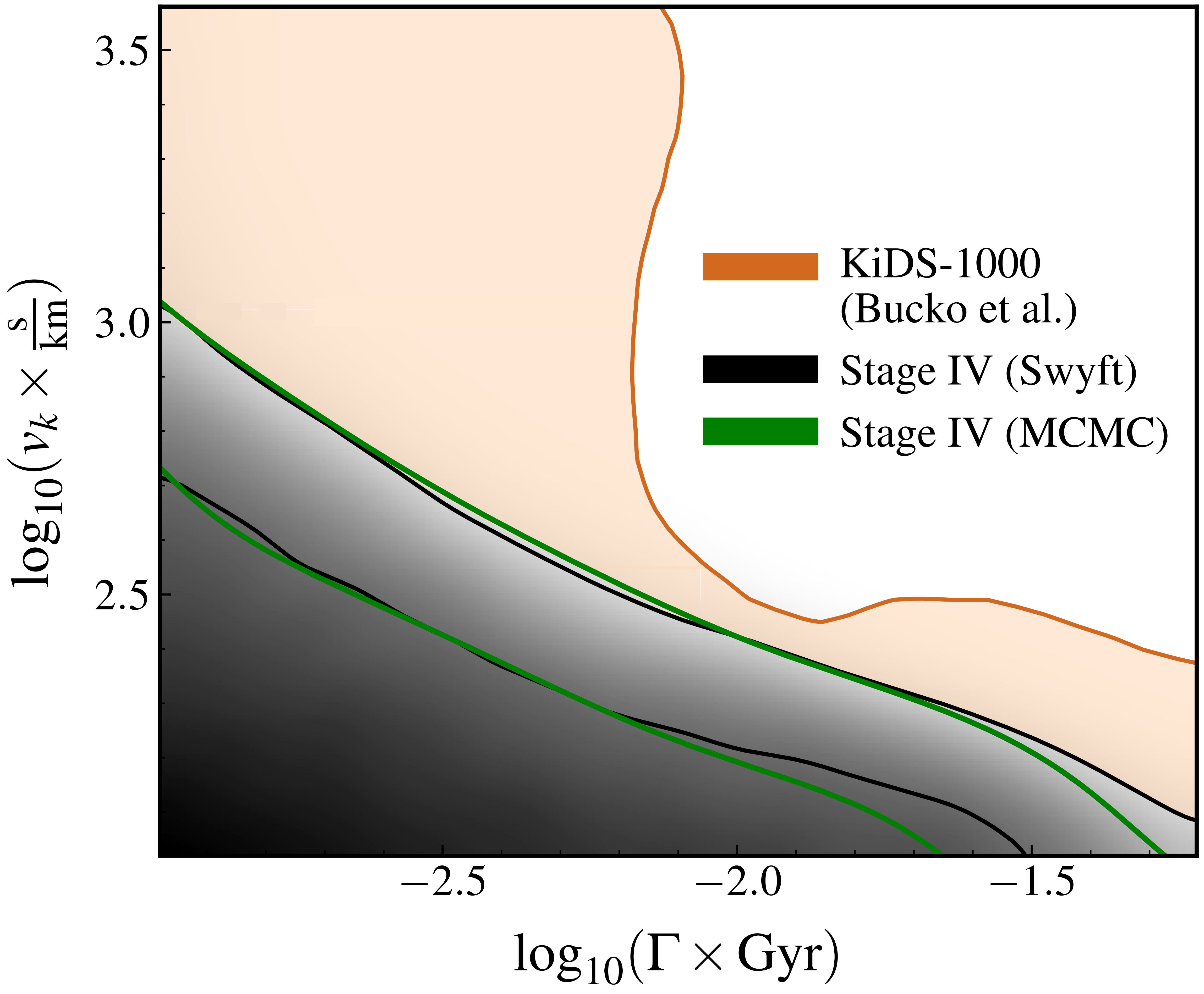


Dramatic reduction in CPU time!

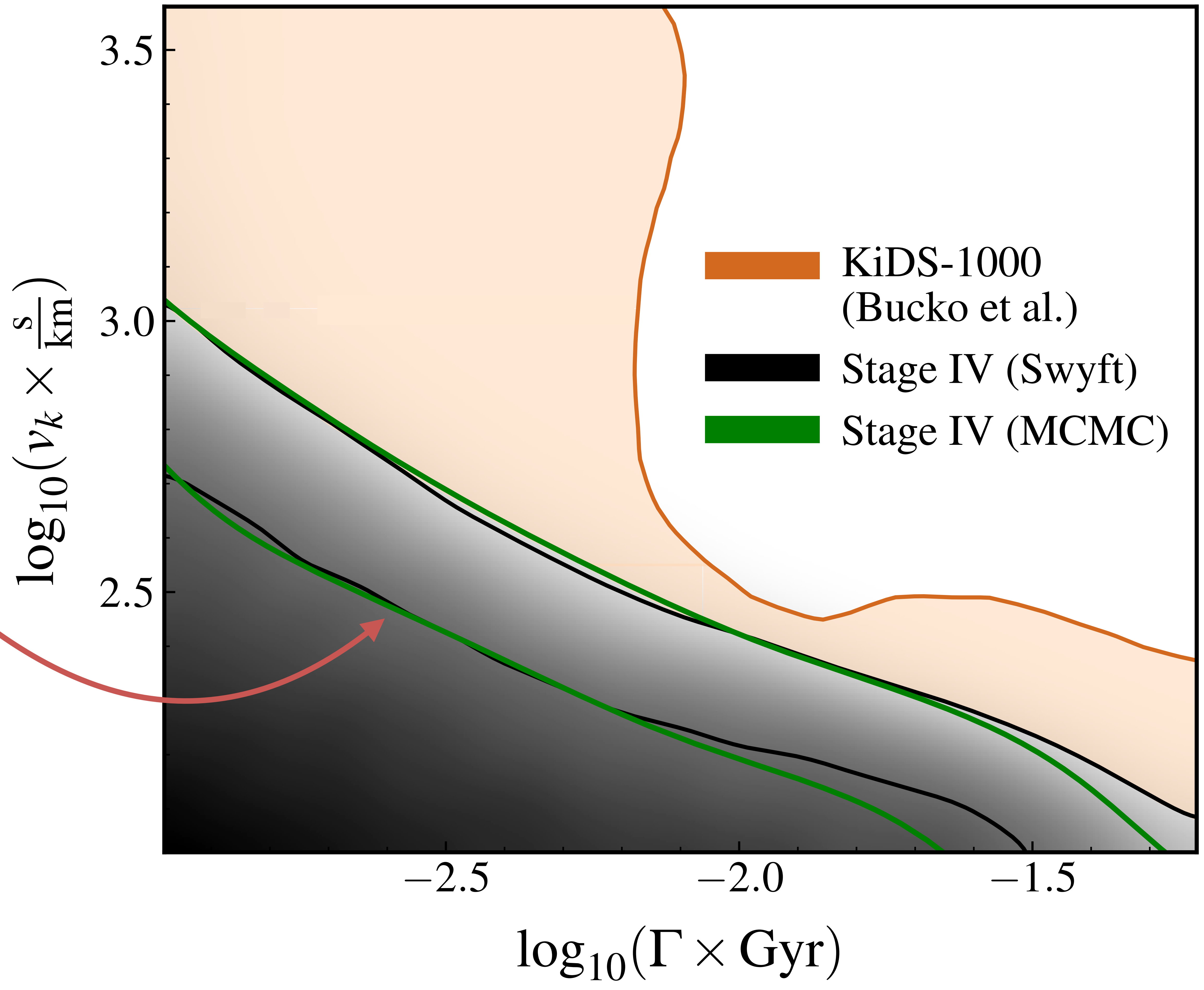
MNRE & MCMC are in excellent agreement!

Forecast constraints on decaying DM



Forecast constraints on decaying DM

MNRE & MCMC in good agreement



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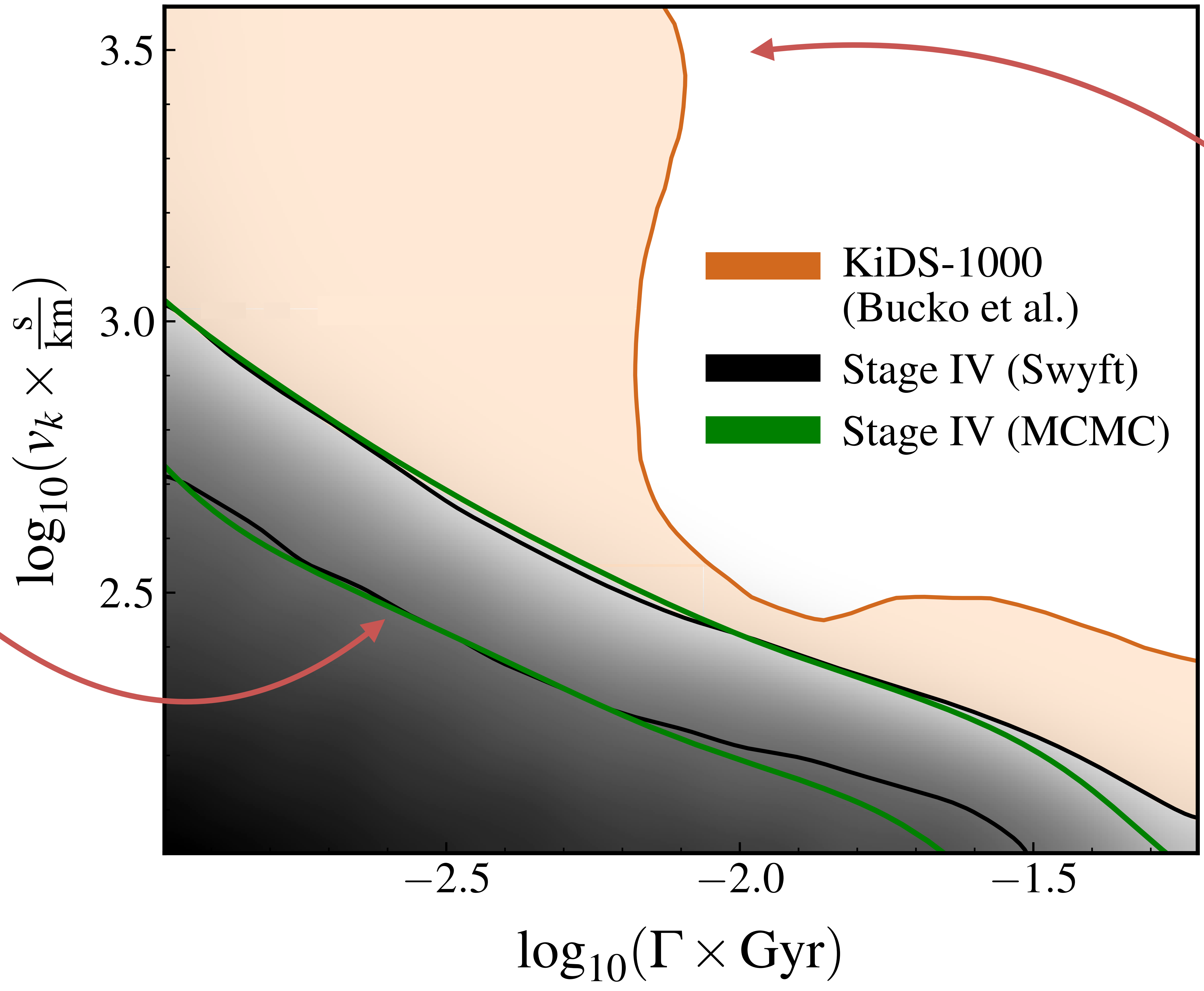

Improve current limits by ~1 order of magnitude!

MNRE & MCMC in good agreement

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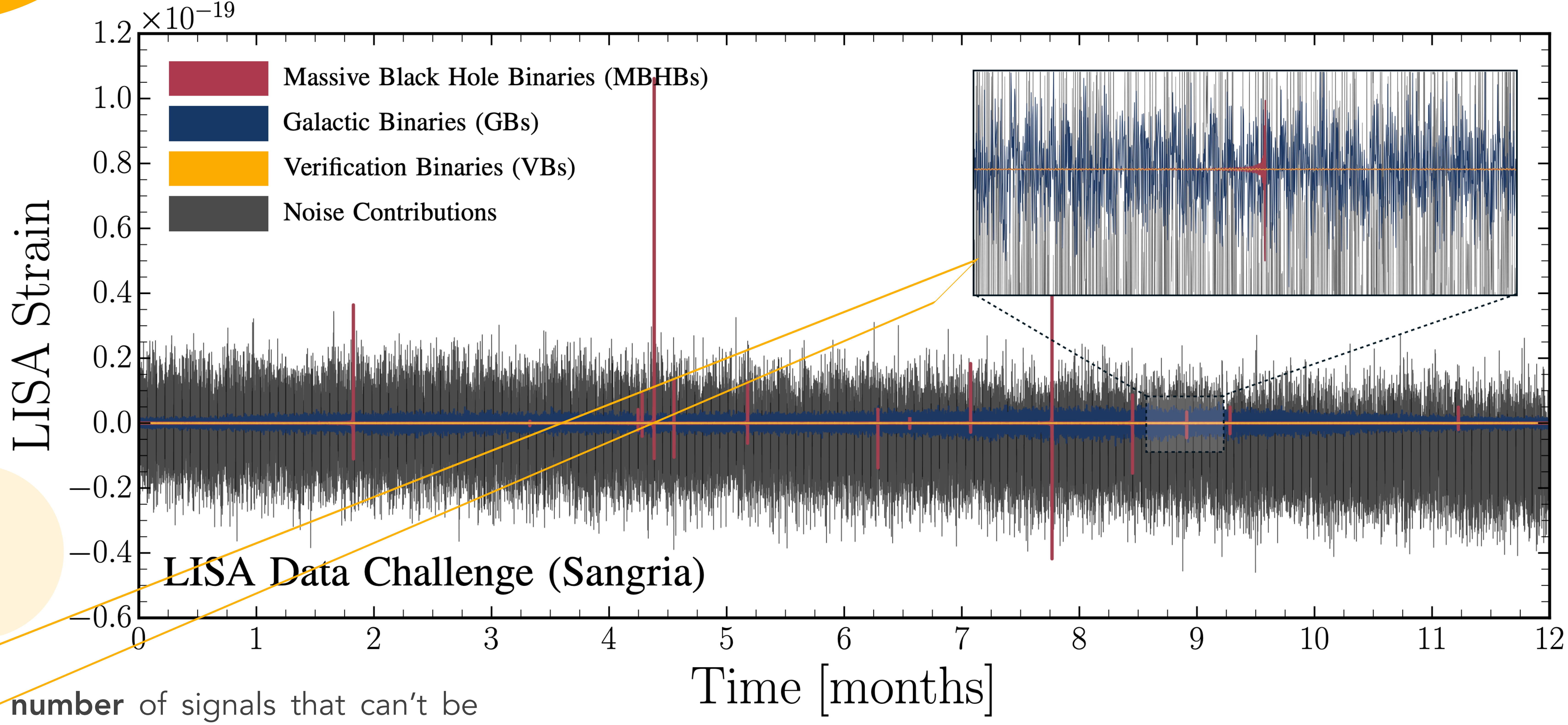
EUCAIFCON 2024 | UNIVERSITY OF AMSTERDAM | MAY 2024

SIMULATION BASED INFERENCE

FOR THE STOCHASTIC GW BACKGROUND



Loads of **different signal classes**, all in the same data stream

THE EVERYTHING ALWAYS ALL-AT-ONCE PROBLEM

Unknown number of signals that can't be separated (highly **overlapping,** unlike LIGO)

So, (someone) has to carry out a joint analysis, naively **10000s of parameters**

POSTER: LOC 15, WEDNESDAY

STATEMENT #1 **LISA DATA ANALYSIS IS A BIG CHALLENGE**

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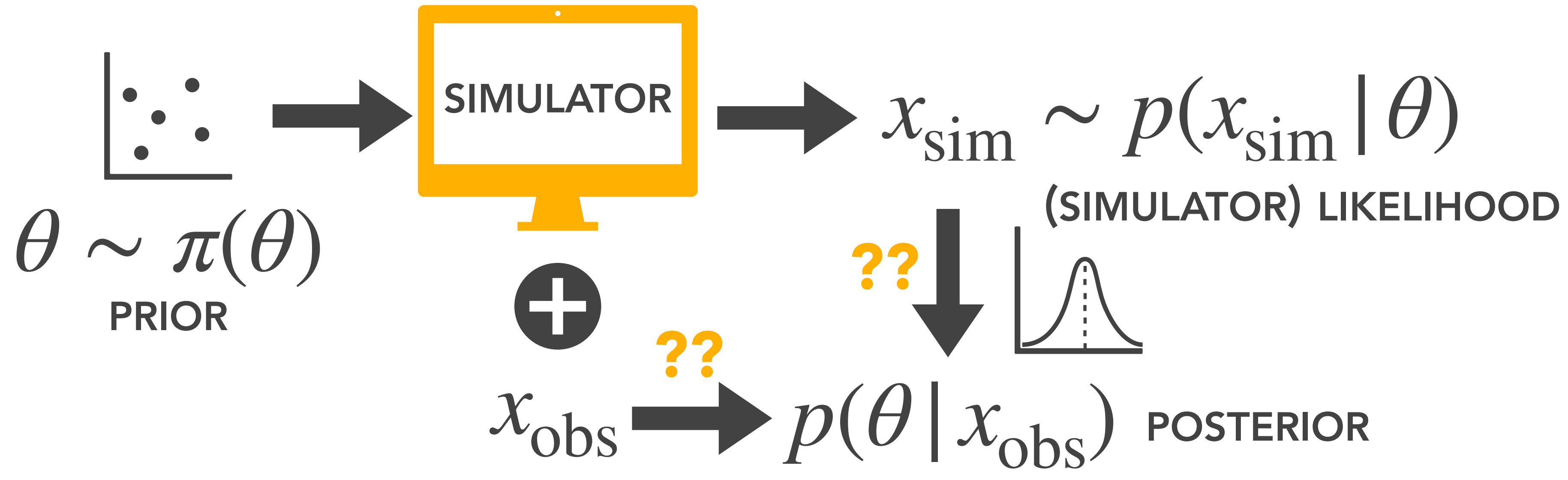
SIMULATION BASED INFERENCE

FOR THE STOCHASTIC GW BACKGROUND

- **MARGINALISE** | SBI is naturally able to marginalise
  "Turn the 10000-dim problem you don't want to solve into the 10-dim one you do"
- **AMORTISE** | SBI can *(sometimes)* be fully amortised
  "Do the hard work once, and do it right"
- **TRANSFORM** | SBI can *(in principle)* look at the data in whatever *(compressed)* form you want
  "Don't be constrained by data likelihoods"



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POSTER: LOC 15, WEDNESDAY

STATEMENT #2 **SBI CAN HELP**