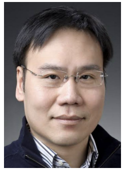
Discussion: Connections to Fundamental Theory

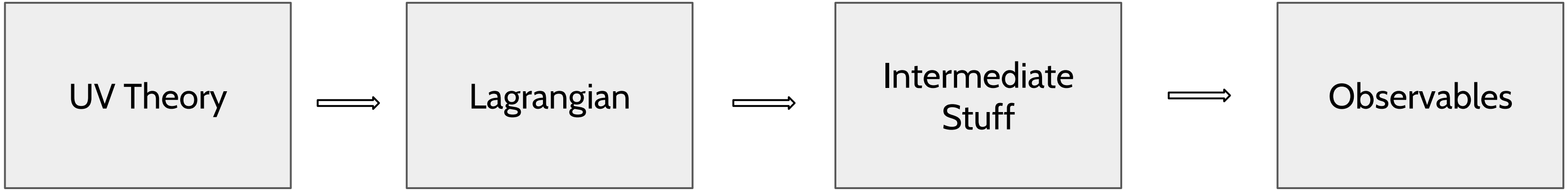
Pitt PACC Workshop on Non-Standard Cosmological Epochs and Expansion Histories

Jim Halverson

Northeastern University

w/ Gary Shiu, who has his own slides!



Charge from the organizers: To what extent do different top-down scenarios for physics beyond the Standard Model, including string theory, predict departures from the standard cosmology?

A probe: what is a string theorist’s prior on Lagrangians?

e.g., as discussed, moduli everywhere, can lead to EMDE.
e.g., towers of states can lead to stasis. (CY KK modes now possible!)

A Concrete Approach

Study biggest known string datasets,
sample them in some way,
look for general patterns.

On Algorithmic Universality in F-theory Compactifications

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"The Tree Ensemble"

We study univer… e in the context of F-theory compactifications. A finite time construction algorithm is presented for $\frac{4}{3} \times 2.96 \times 10^{755}$ F-theory geometries that are connected by a network of topological transitions in a connected moduli space. High probability geometric assumptions uncover universal structures in the ensemble without explicitly constructing it. For example, non-Higgsable clusters of seven-branes with intricate gauge sectors occur with probability above $1 - 1.01 \times 10^{-755}$, and the geometric gauge group rank is above 160 with probability .999995. In the latter case there are at least 10 E_8 factors, the structure of which fixes the gauge groups on certain nearby seven-branes. Visible sectors may arise from E_6 or $SU(3)$ seven-branes, which occur in certain random samples with probability $\simeq 1/200$.

Physics TLDR w/ uniform sampling:

- Dark gauge sectors:
  rk(G) = 1612 +- 17
  # gauge factors = 1457 +- 14
- Axiverse: # axions = 2076 +- 23

Updated code, open source soon

The F-theory geometry with most flux vacua

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Abstract: Applying the Ashok-Denef-Douglas estimation method to elliptic Calabi-Yau fourfolds suggests that a single elliptic fourfold $\mathcal{M}_{\max}$ gives rise to $\mathcal{O}(10^{272,000})$ F-theory flux vacua, and that the sum total of the numbers of flux vacua from all other F-theory geometries is suppressed by a relative factor of $\mathcal{O}(10^{-3000})$. The fourfold $\mathcal{M}_{\max}$ arises from a generic elliptic fibration over a specific toric threefold base $B_{\max}$, and gives a geometrically non-Higgsable gauge group of $E_8^9 \times F_4^8 \times (G_2 \times SU(2))^{16}$, of which we expect some factors to be broken by G-flux to smaller groups. It is not possible to tune an $SU(5)$ GUT group on any further divisors in $\mathcal{M}_{\max}$, or even an $SU(2)$ or $SU(3)$, so the standard model gauge group appears to arise in this context only from a broken E_8 factor. The results of this paper can either be interpreted as providing a framework for predicting how the standard model arises most naturally in F-theory and the types of dark matter to be found in a typical F-theory compactification, or as a challenge to string theorists to explain why other choices of vacua are not exponentially unlikely compared to F-theory compactifications on $\mathcal{M}_{\max}$.

On the Elliptic Calabi-Yau Fourfold with Maximal $h^{1,1}$

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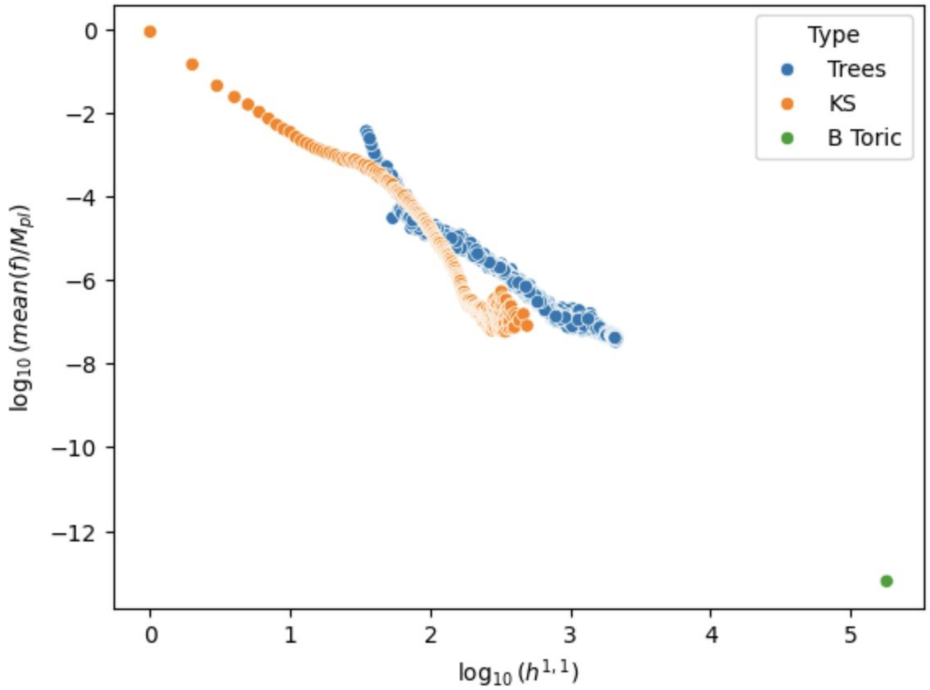
E-mail…

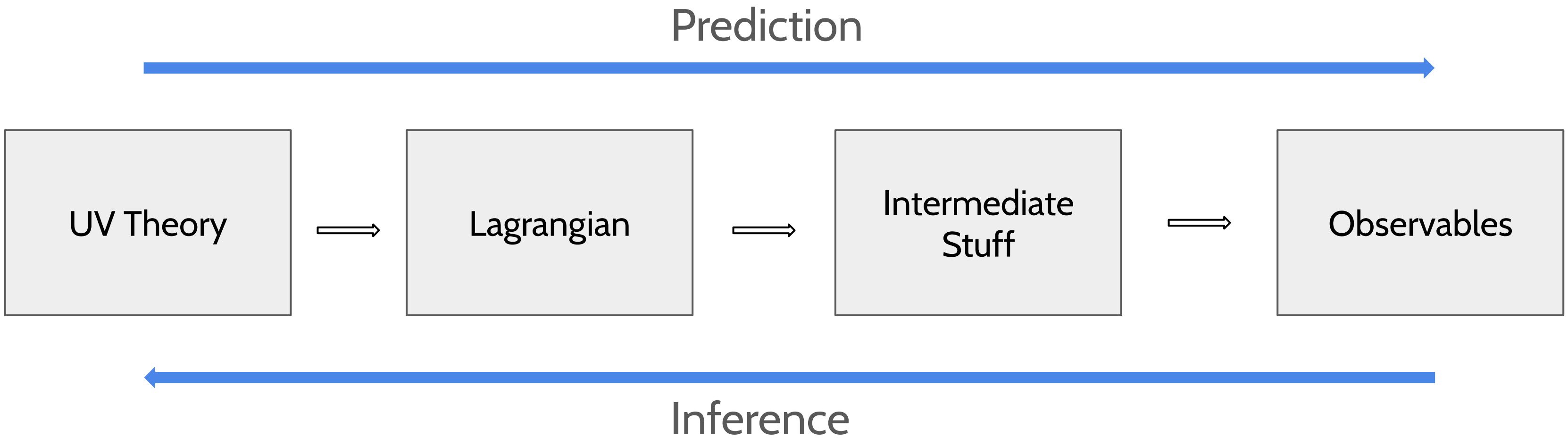
"Btoric"

Abstra… …ld for the ellipt… …erated by blowi… …he 4d F-theory compactification model over it has the largest geometric gauge group, $E_8^{2\,561} \times F_4^{7\,576} \times G_2^{20\,168} \times SU(2)^{30\,200}$, and the largest number of axions, 181 820, in the known 4d $\mathcal{N} = 1$ supergravity landscape. We also prove that there are at least $1100^{15\,048} \approx 7.5 \times 10^{45\,766}$ different flip and flop phases of this base threefold. Moreover, we find that many other base threefolds with large $h^{1,1}$ in the 4d F-theory landscape can be constructed in a similar way as well.

Preliminary: Large Combined Dataset Axiverse Study

- collab with group of L. McAllister, studying axions in "Kreuzer-Skarke" CY3, Trees, and Btoric.
- Look for universality or important differences across datasets.
- First pass: compute (f,m)'s
- Masses: max often within 5-10 OOM of Planck. Many very light.

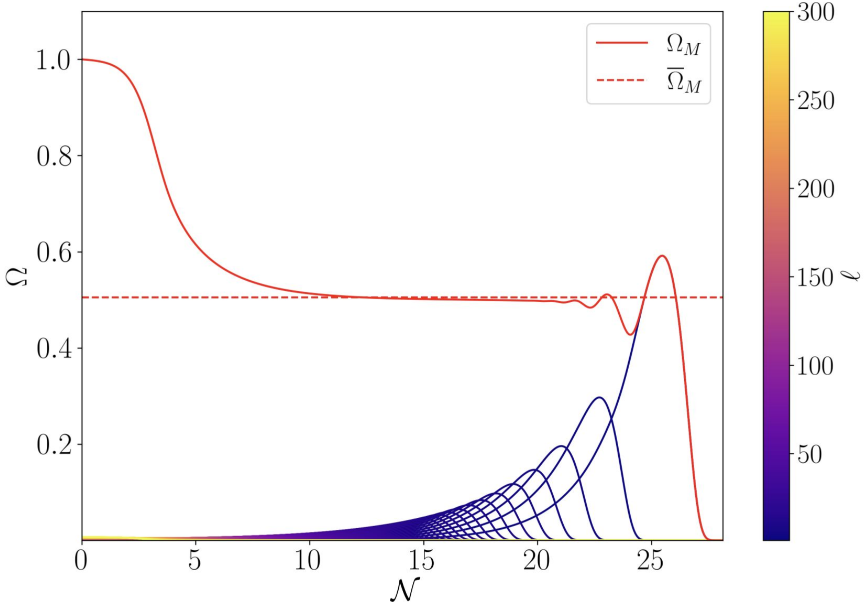




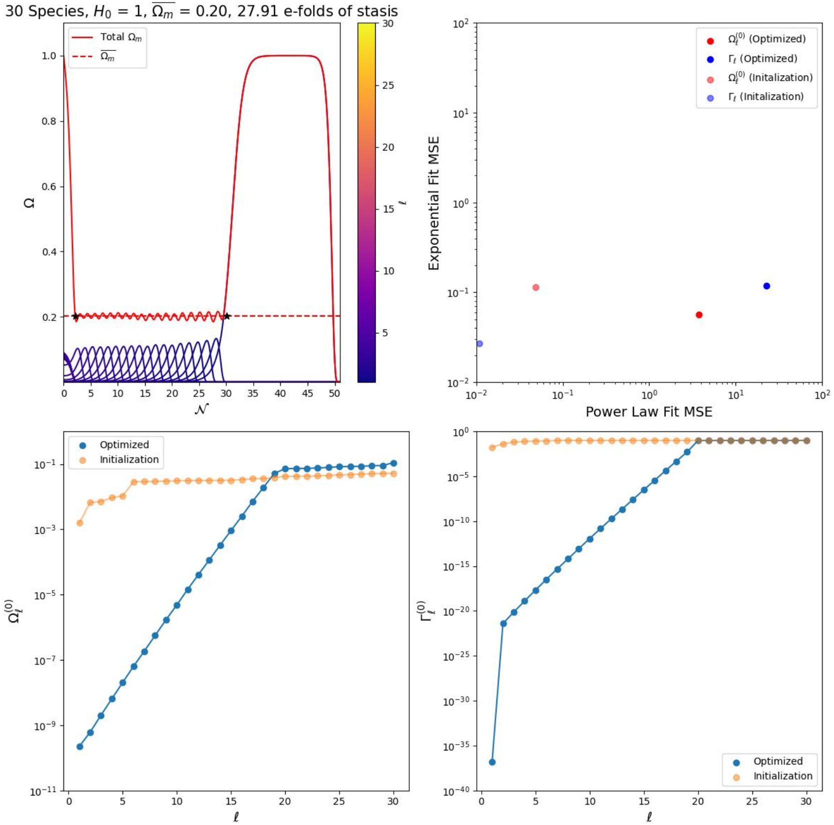
Charge from the organizers: Conversely, were we to obtain observational evidence that indeed the expansion history of our universe differs from that of the standard cosmology, what would this tell us about fundamental physics at high scales?

Running inference backward through the *whole* pipeline at a detailed level, seems *very* hard and requires many observables.

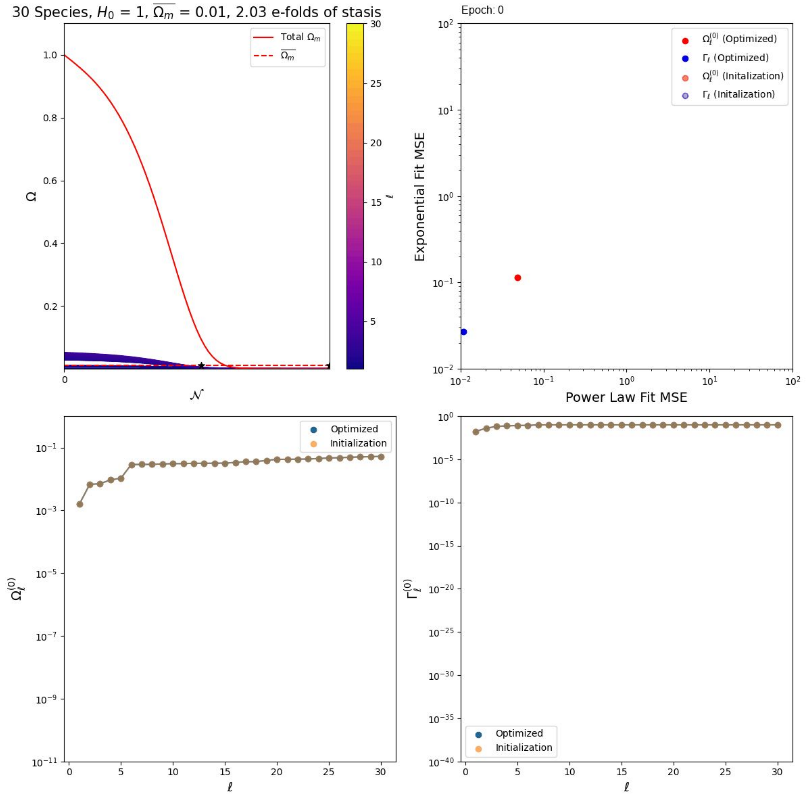
Rates and abundances for N particles $\Longrightarrow$ Stasis e-folds and matter abundance



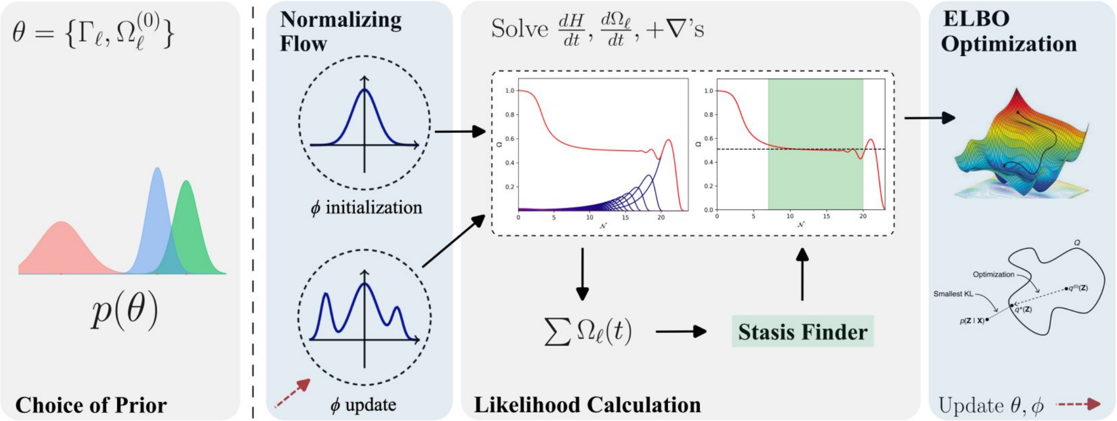
- arrow takes 2N-dim space to 2D space by solving N Boltzmann equations and using algo to extract e-folds, omega.
- with limited info on RHS, probably many points on LHS that recover it.
- if arrow is *differentiable*,
  can more systematically search through / do Bayesian inference on rates, abundances.



30 Species, H_0 = 1, $\overline{\Omega_m}$ = 0.20, 27.91 e-folds of stasis
Total Ω_m
$\overline{\Omega_m}$
Ω
$\mathcal{N}$
ℓ
$\Omega_\ell^{(0)}$ (Optimized)
Γ_ℓ (Optimized)
$\Omega_\ell^{(0)}$ (Initalization)
Γ_ℓ (Initalization)
Exponential Fit MSE
Power Law Fit MSE
Optimized
Initialization
$\Omega_\ell^{(0)}$
$\Gamma_\ell^{(0)}$



30 Species, H_0 = 1, $\overline{\Omega_m}$ = 0.01, 2.03 e-folds of stasis
Epoch: 0
Total Ω_m
$\overline{\Omega_m}$
Ω
$\mathcal{N}$
ℓ
$\Omega_\ell^{(0)}$ (Optimized)
Γ_ℓ (Optimized)
$\Omega_\ell^{(0)}$ (Initalization)
Γ_ℓ (Initalization)
Exponential Fit MSE
Power Law Fit MSE
Optimized
Initialization
$\Omega_\ell^{(0)}$
$\Gamma_\ell^{(0)}$



Example pipeline from 2408.00835

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