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Numerical Moduli Stabilisation towards Calabi-Yau Data Exploration

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All In All

- **Calabi-Yau** data (CYD) $\rightarrow$ 1411.1418
  Aim: phenomenology-based classification
- **How?** Bayes factors & Jeffreys' scale w.r.t. **LVS AdS**
  Via: Multi modular fields stabilisation & nested sampling
- **Outlook:** Machine-learn the Calabi-Yau data,
  Guide: phenomenology, stringy remnants $\rightarrow$ 1801.03503
- **This talk:** P_{11169} AdS vs dS scenarios comparison
  Based on: explorations towards minimal V_0

P_{11169} Effective Potential

$4D$ **Compactification**

+ fluxes + non-pertubative effects + α'-corrections

generates super, Kähler, and $N = 1$, $D = 4$ scalar potentials

$$\begin{aligned} W &= W_0 + A_i e^{-a_i T_i}, \quad i = 1, 2 \\ K &= -2\log(\mathcal{V} - \frac{\xi}{2}) + 2\log g_s + K_{cs}, \\ V &= e^K \left[K^{i\bar{j}} D_i W D_{\bar{j}} \overline{W} - 3|W|^2 \right] \\ \text{where } D_i W &= \partial_i W + (\partial_i K) W, \quad K^{i\bar{j}} = (\partial_i \partial_{\bar{j}} K)^{-1} \end{aligned}$$

LVS: two moduli stabilised & break SUSY at large volume

Parameters, θ**:** $\{g_s, W_0, a_i, A_i\}$

Possible Scenarios: $\mathcal{H}_0 \equiv$ **Anti-de Sitter or**

$\mathcal{H}_1 \equiv$ **de Sitter (withou upliftment)**

Numerical Moduli Stabilisation

Given θ**, Find** T_i at (deepest) minimum of $V(\theta, T_i)$
Genetic **or** Dlib C++ Library minimisation algorithm

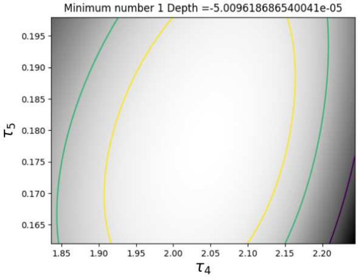

Figure: Deepest of 6 minima found using Genetic algorithm. A check for Dlib minimiser used.

Bayesian Inference Machinery

Apply towards Calabi-Yau data pheno-based classification

- **Bayes:** **evidence**, Z $\times$ **posterior** = **prior** $\times$ **likelihood**

$$p(d|\mathcal{H}) \times p(\theta|d,\mathcal{H}) = p(\theta|\mathcal{H}) \times p(d|\theta,\mathcal{H})$$

$$Z = p(d|\mathcal{H}) = \int p(d|\theta,\mathcal{H})p(\theta|\mathcal{H})\, d\theta \quad \text{[MultiNest]}$$

Consider: $d \equiv$ cosmological constant(Λ) is very small

Likelihood function, $\mathcal{L}(\theta) = p(d|\theta,\mathcal{H})$
With V_0 from numerical moduli stabilisations, get Z using

$$\log\, \mathcal{L} \sim -|V_0| \quad \text{or, alternatively,} \quad \mathcal{L} \sim \exp^{-(V_0-\Lambda)^2}$$

- **Comparison:** Bayes factor, $K = \frac{\mathcal{Z}_0}{\mathcal{Z}_1}$
- **Jeffreys' scale:**

Bayes factors, K	Comparison Remarks	Classification
1 to 3.2	Inconclusive	1
3.2 to 10	Weak	2
10 to 100	Moderate	3
$>$ 100	Decisive	4

Table: Jeffreys' scale for the interpretation of Bayes factors. Classification, say w.r.t. LVS AdS. 0, comparison not possible. 5, 6 or 7, compared geometry wins weakly, moderately or decisively respectively.

LVS de Sitter vs Anti-de Sitter [preliminary]

P_{11169} parameters, θ	Range
g_s	10^{-3} - 0.3
W_0	10^{-11} -10^2
$a_{1,2}$	$2\pi/10$ - 2π
$A_{1,2}$	10^{-1} - 10^1

Scenario	$log_e Z$	K	Class
AdS	-0.366	-	reference hypothesis
dS	-3×10^{-14}	3×10^3	7

de Sitter vacua are obtainable without need for uplit terms

LVS de Sitter vs Anti-de Sitter [preliminary]

Figure: de Sitter scenario.

Summary & Outlook

- **Demonstrated:**
  Multi moduli stabilisation is within reach [dedicated to Joe Polchinski]

- **Proposed:** reference point model/CY. Only Λ used.
  Extend to include inflaton or particle physics constraints

- **Classification:** Bayes factors-based. Something else ?

- **de Sitter Vacua:** found many, without uplifting terms.

Thanks for Listening!