BART-Lagrangian

When Transformers Write Particle Physics Lagrangians

[Based on arxiv: 2501.09729]

Koay Yong Sheng, Rikard Enberg, Stefano Moretti, Eliel Camargo-Molina

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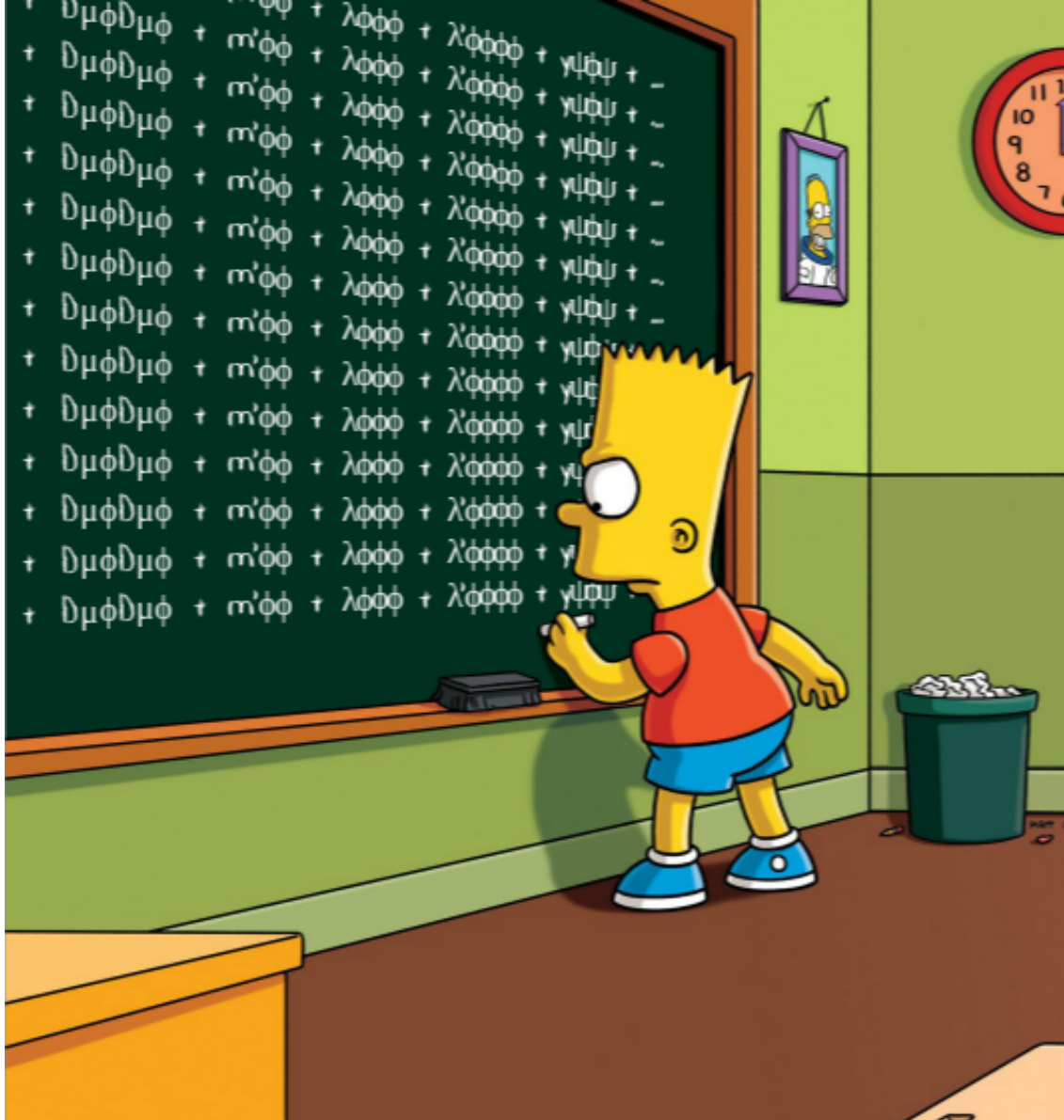
Poster

A38



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If we are building
a foundation model for particle physics,
How should theory come in?

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Do we want...

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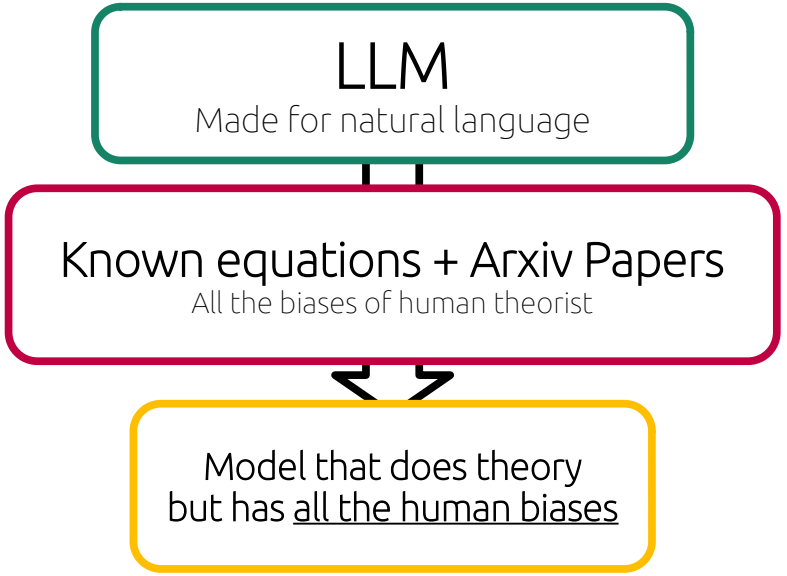
Do we want...

an AI-replacement of human physicists?

If yes, Finetune!



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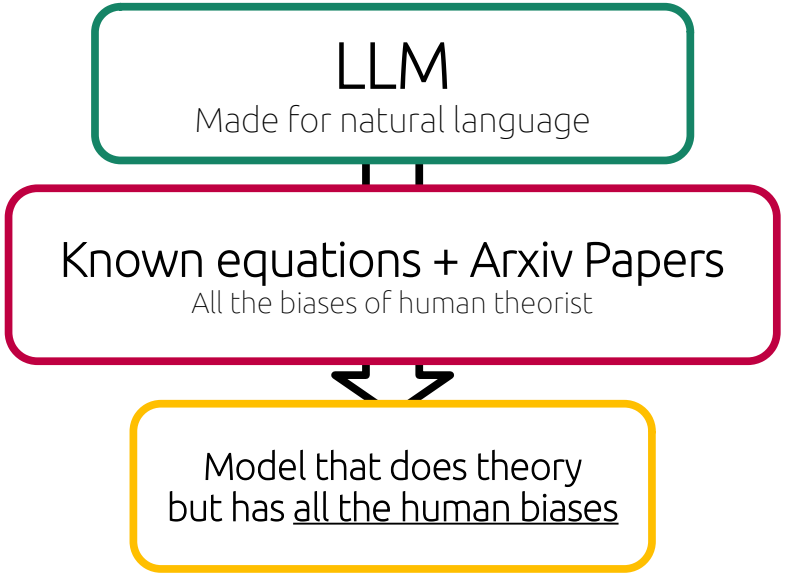
Do we want...

an AI-replacement of human physicists?

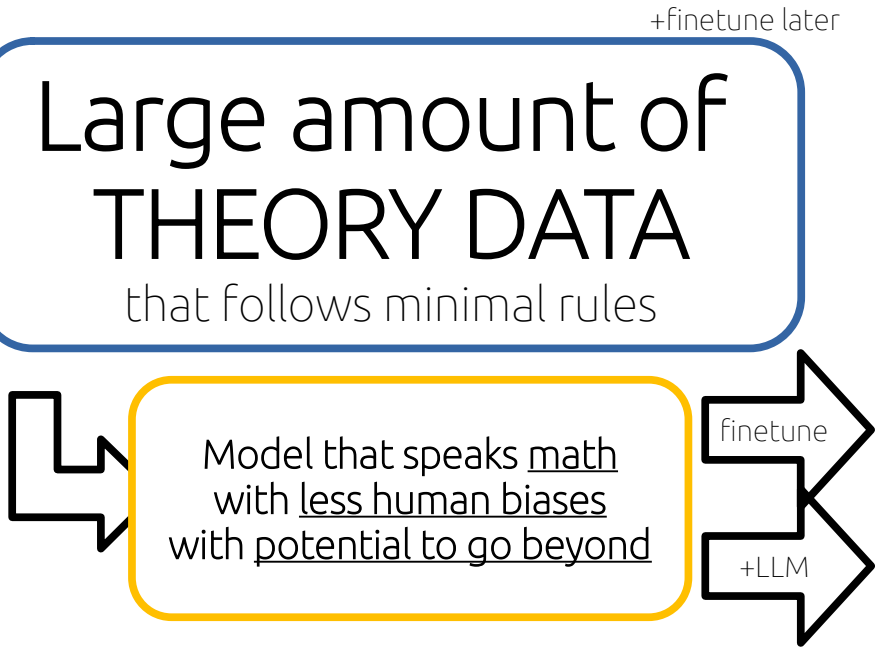
or

an AI that can go beyond human biases?

If yes, Finetune!



If yes, train our own model!



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Do we want...

an AI-replacement of human physicists?

or

an AI that can go beyond human biases?

If yes, Finetune!

LLM
Made for natural language

Known equations + Arxiv Papers
All the biases of human theorist

Model that does theory but has all the human biases

If yes, train our own model!

+finetune later

Large amount of THEORY DATA
that follows minimal rules

Model that speaks math with less human biases with potential to go beyond

finetune

+LLM

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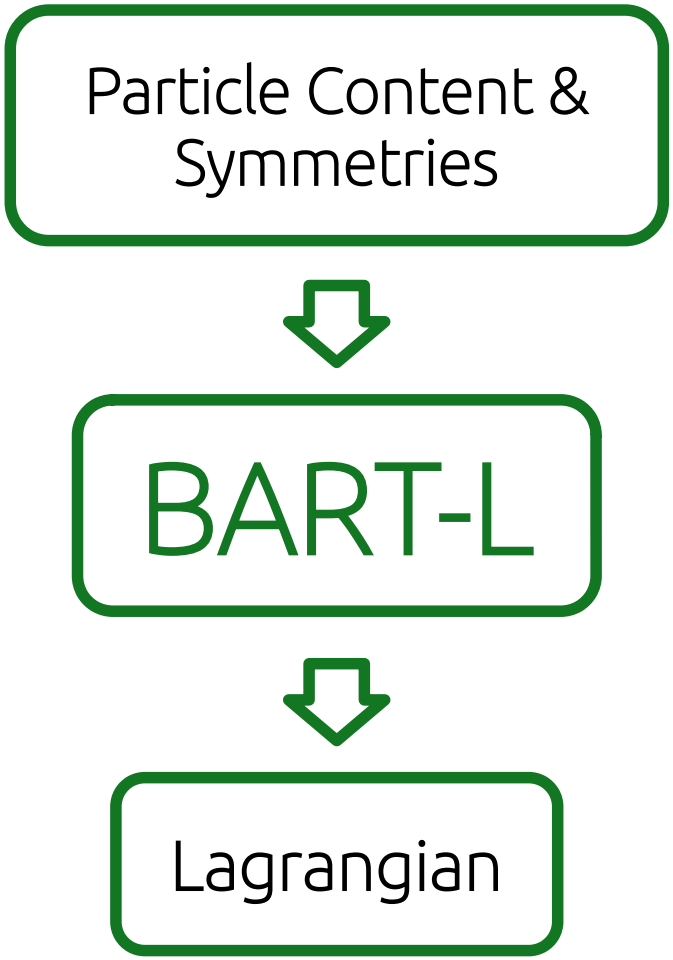

Model Task: LAGRANGIAN GENERATION

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Standard Model
[Q,u,d,L,e,H & SU3xSU2xU1]

BART-L

Standard Model Lagrangian

$$\mathcal{L}_{SM} = -\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g^2_s f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c^2_w}M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\nu A_\mu \partial_\nu A_\mu - igc_w(\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu)) - igs_w(\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu \partial_\nu W^-_\mu - W^+_\mu \partial_\nu W^-_\mu) + A_\mu(W^+_\nu \partial_\nu W^-_\mu - W^+_\nu \partial_\nu W^-_\mu)) - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\nu W^-_\mu + g^2 c^2_w(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) - g^2 s_w c_w A_\mu Z^0_\nu(W^+_\mu W^-_\nu + W^+_\nu W^-_\mu) - 2A_\mu A_\mu W^+_\nu W^-_\mu) - \tfrac{1}{2}\partial_\mu \phi^+ \partial_\mu \phi^- - \tfrac{1}{2}M^2(\phi^+\phi^- + \phi^-\phi^+) - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \tfrac{1}{2c^2_w}M^2 \phi^0\phi^0 - \beta_h\left(\tfrac{2M^2}{g^2}\alpha_h + \tfrac{2M}{g}\alpha_h H + \tfrac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-)\right) + \tfrac{2M^4}{g^2}\alpha_h - \tfrac{1}{8}g^2\alpha_h(H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2) - gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c^2_w}Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig\left(W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)\right) + \tfrac{1}{2}g\left(W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) + W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)\right) + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) + M(\tfrac{1}{c_w}Z^0_\mu\partial_\mu\phi^0 + W^+_\mu\partial_\mu\phi^- + W^-_\mu\partial_\mu\phi^+) - ig\tfrac{s^2_w}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_wMA_\mu(W^+_\mu\phi^- -$$

OUR WORLD

(to the best of our knowledge)

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Toy Model
Particles & Symmetries

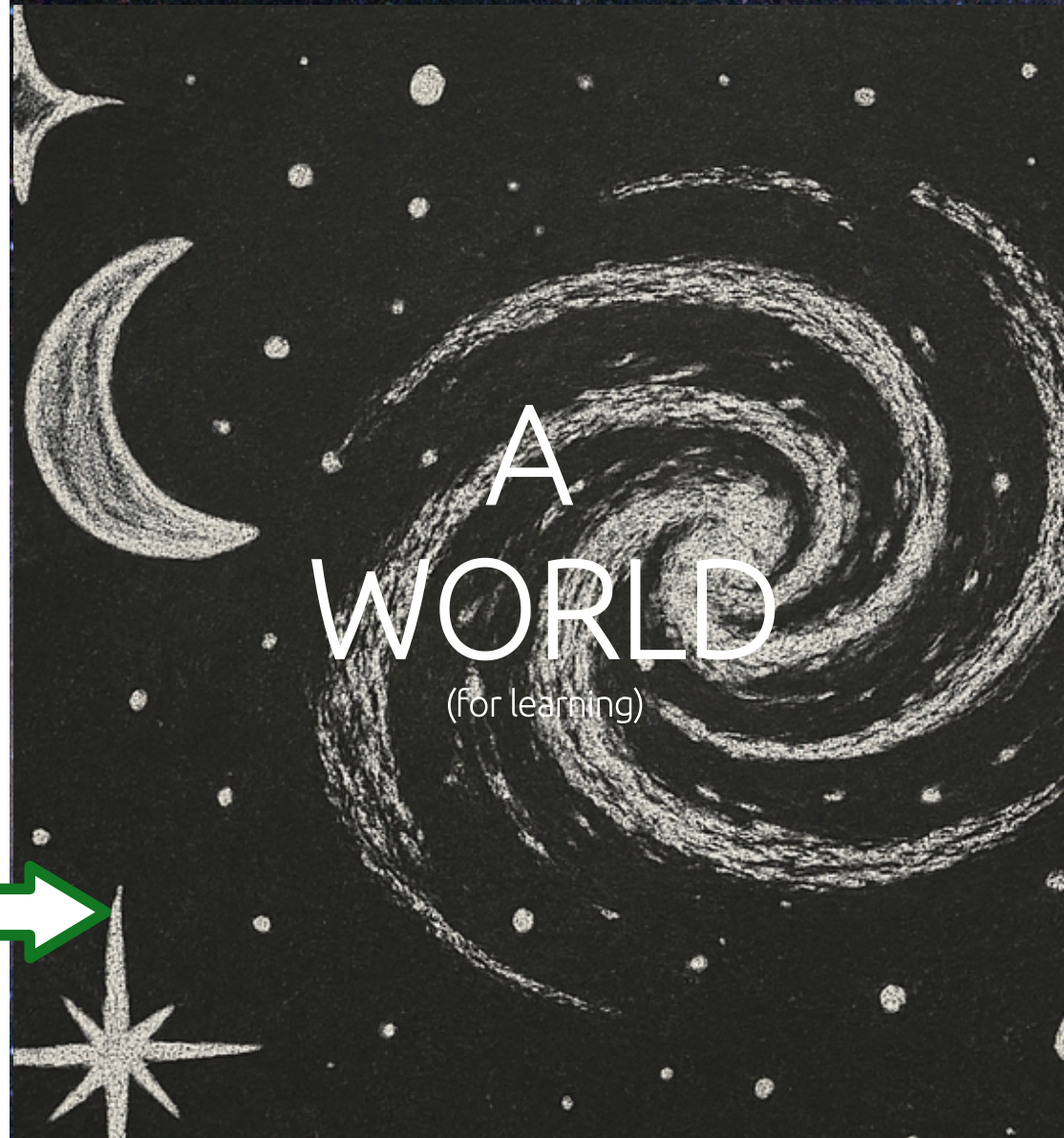
↓

BART-L

↓

Toy Model
Lagrangian

→



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BSM
Particles & Symmetries

BART-L

Beyond Standard Model Lagrangian

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Beyond Standard Model Lagrangian

Does it work?

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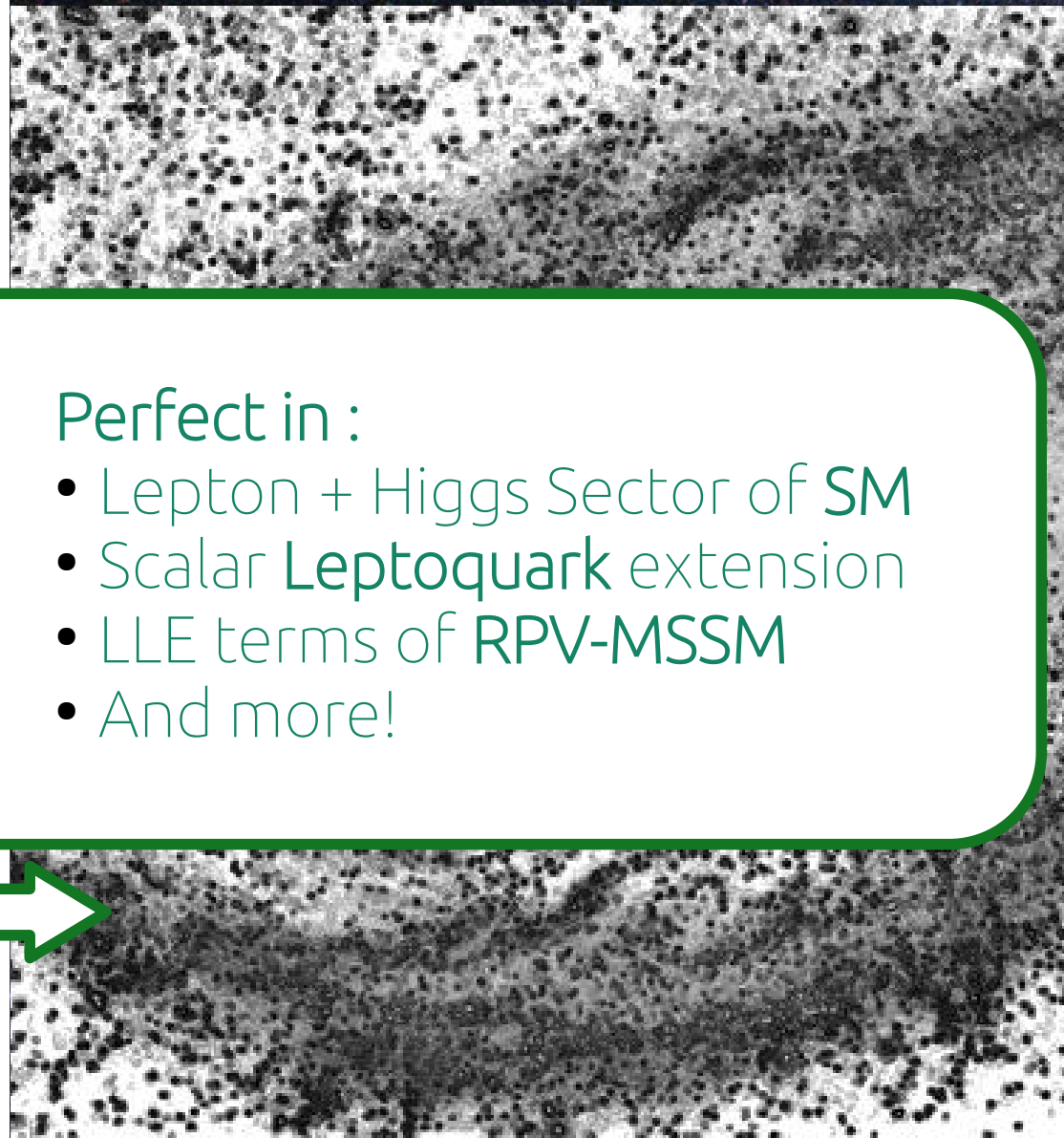
Particles & Symmetries

Works!
~90-97%

Perfect in :

- Lepton + Higgs Sector of **SM**
- Scalar **Leptoquark** extension
- LLE terms of **RPV-MSSM**
- And more!

Beyond
Standard Model
Lagrangian



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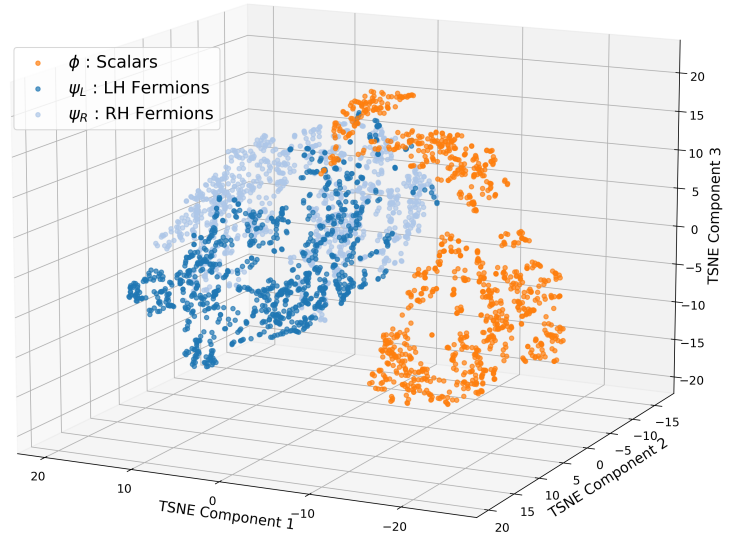
Standard Model Lagrangian

Even Learned :

Symmetry Representation and Conjugations !



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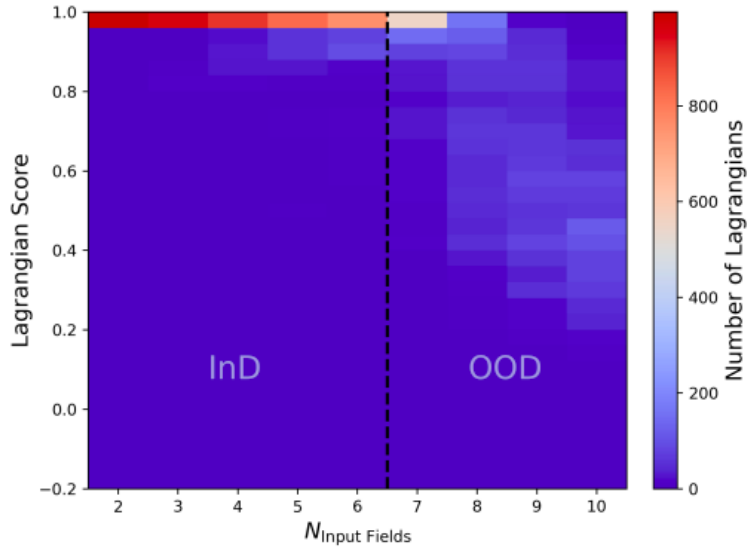
Beyond Standard Model Lagrangian

Generalize Beyond Training Distribution!

(within architectural constraints)



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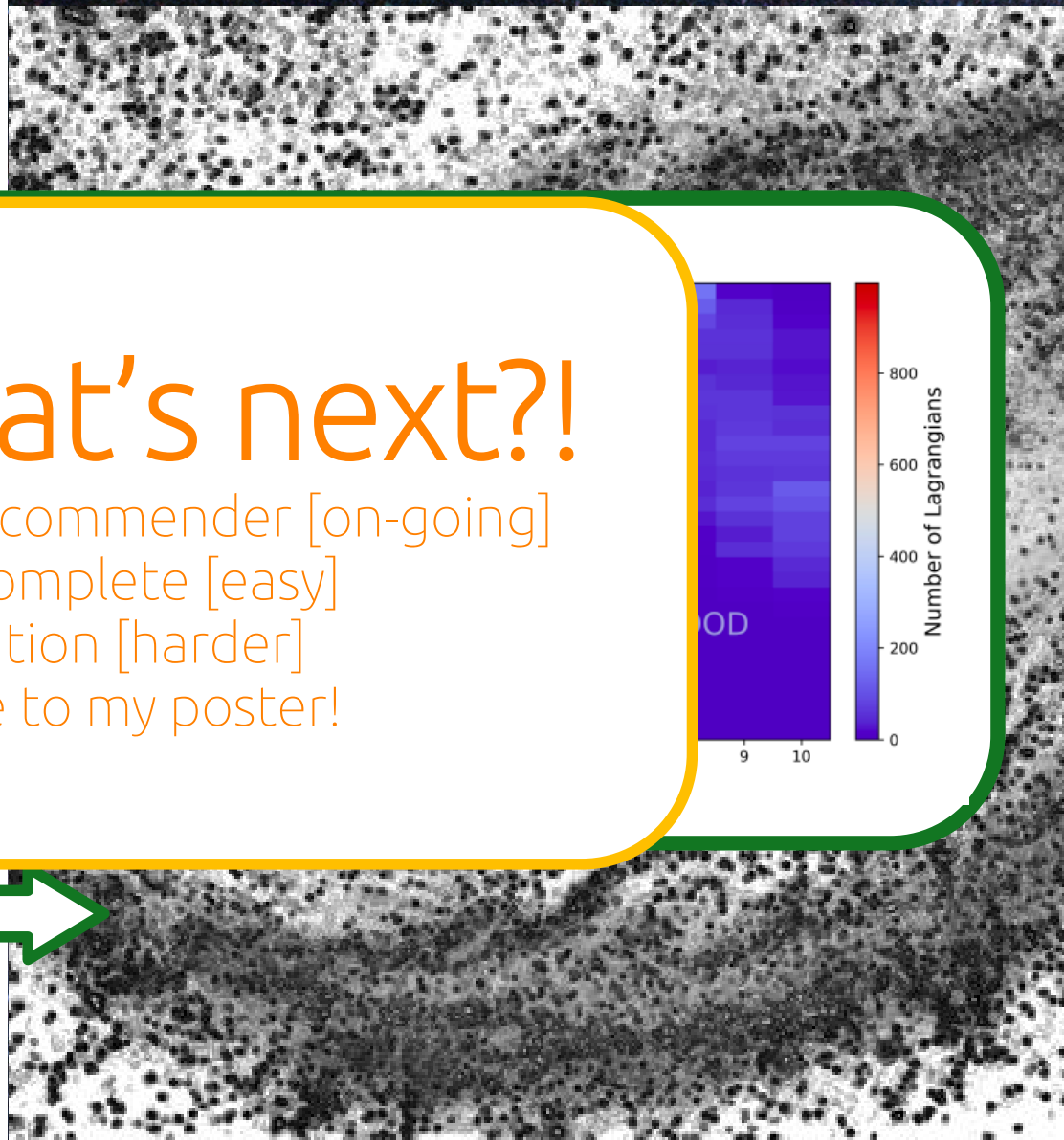
Standard Model Lagrangian

But what's next?!

- BSM Extension Recommender [on-going]
- Lagrangian Autocomplete [easy]
- Symmetry Restoration [harder]
- Much more! Come to my poster!



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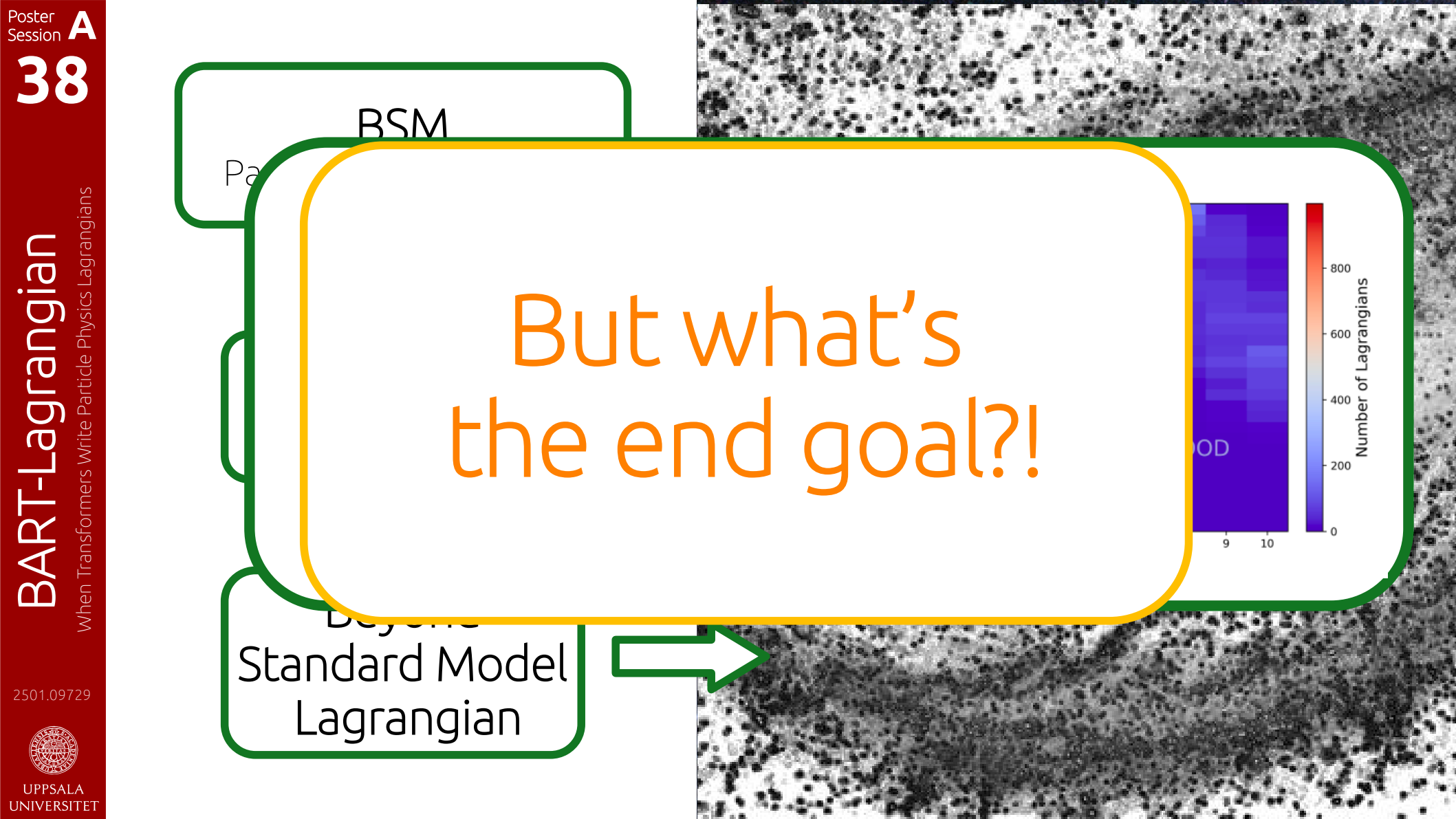

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Come find me at

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for BART-L

or

Just talk to me!

yongsheng.koay@physics.uu.se

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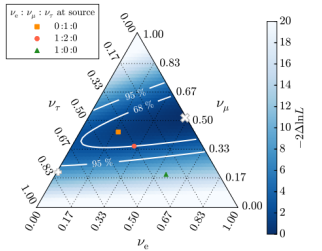
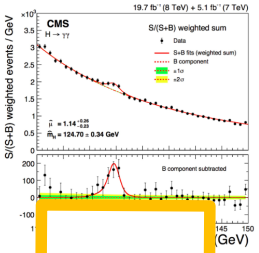
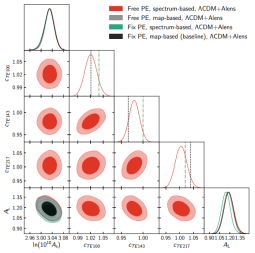
Goal : Data to Theory Inference

Experimental Data







AI

The NEXT Standard Model Lagrangian