AI in Astrophysics at Fermilab

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FNAL AI Jamboree

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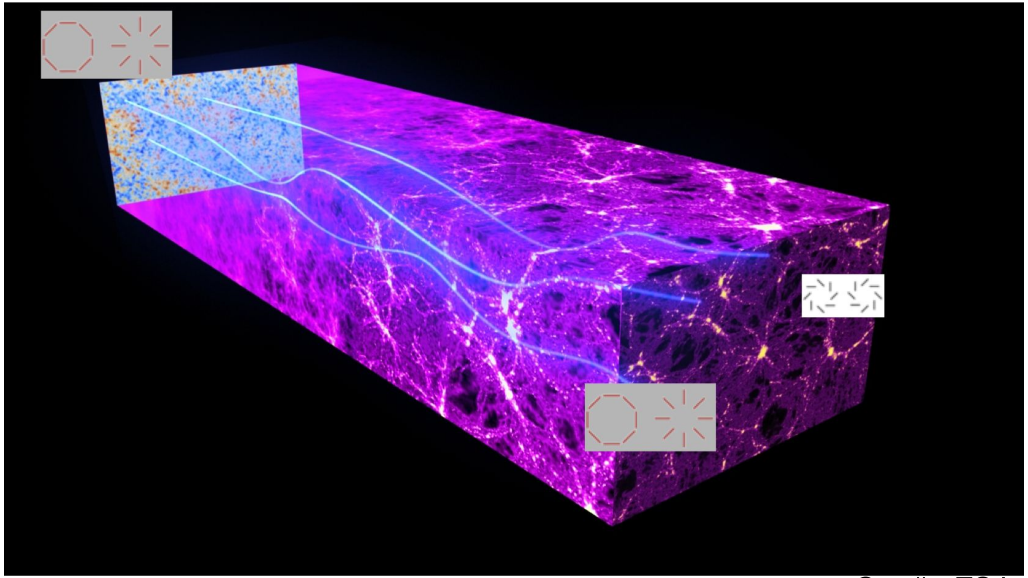
Cosmic Microwave Background polarization lensing



Credit: ESA

- info: provides handle on large-scale structure at low redshift
- nuisance: distorts primordial CMB —> use lensing potential to ‘undo’ the lensing (delensing)

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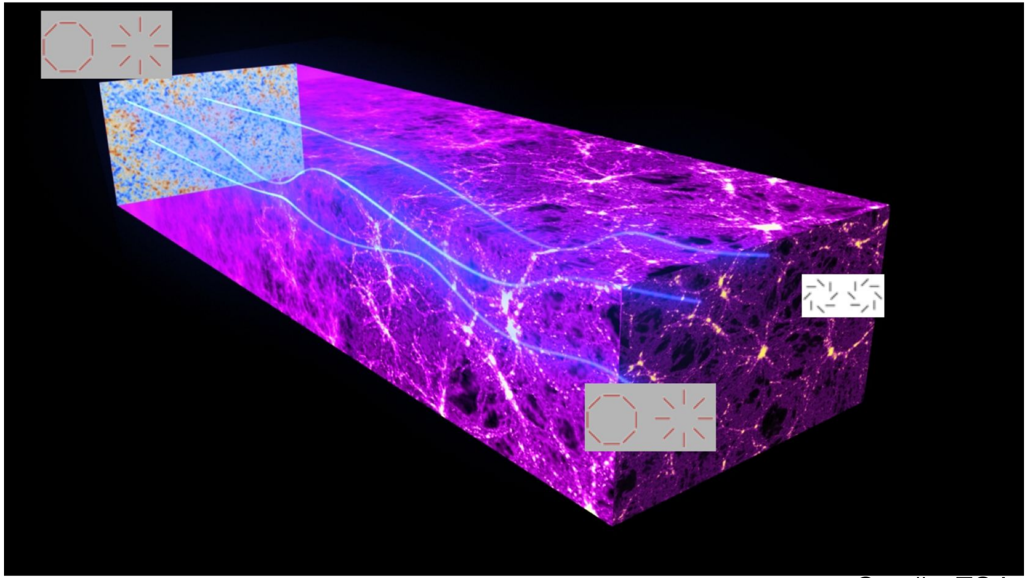

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Why ML?

- current methods are suboptimal at low noise
- it's an image-to-image regression problem

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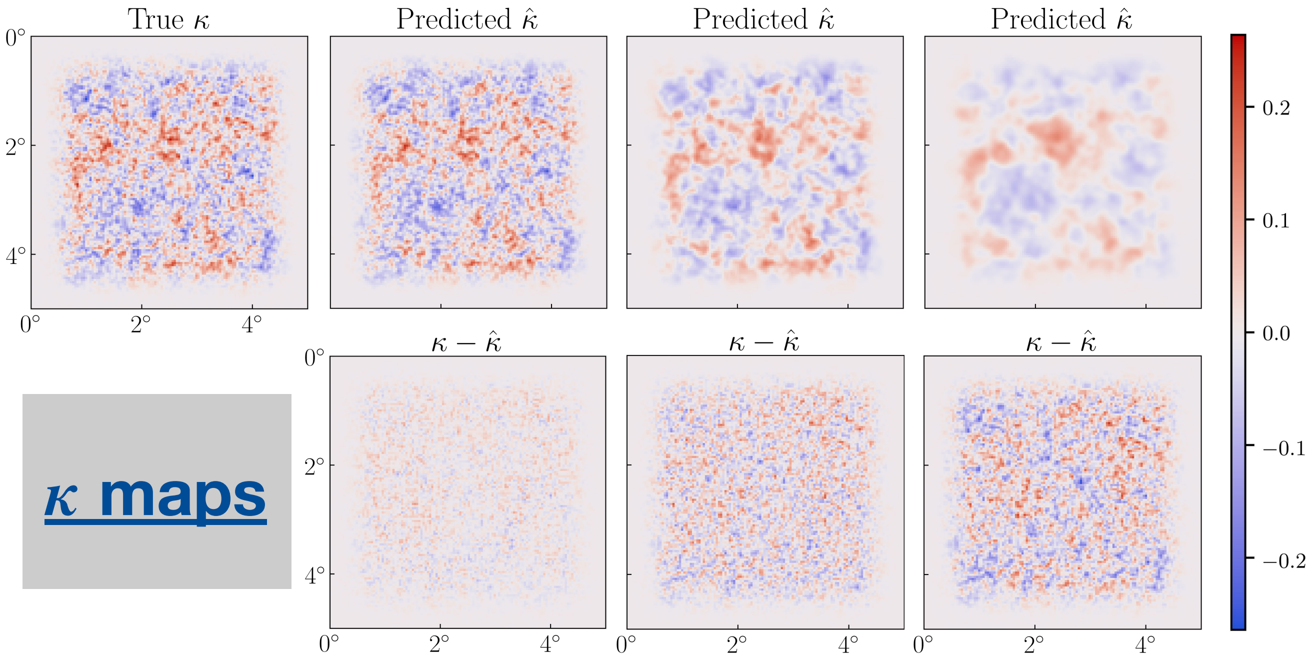
CMB delensing results with increasing noise

For more details, see [1810.01483](1810.01483)

Follow-ups coming!

0 μK-arcmin 1 μK-arcmin 5 μK-arcmin



κ maps

So, it works, but what can you say about uncertainties?

Many methods to determine uncertainties in your deep learning algorithm

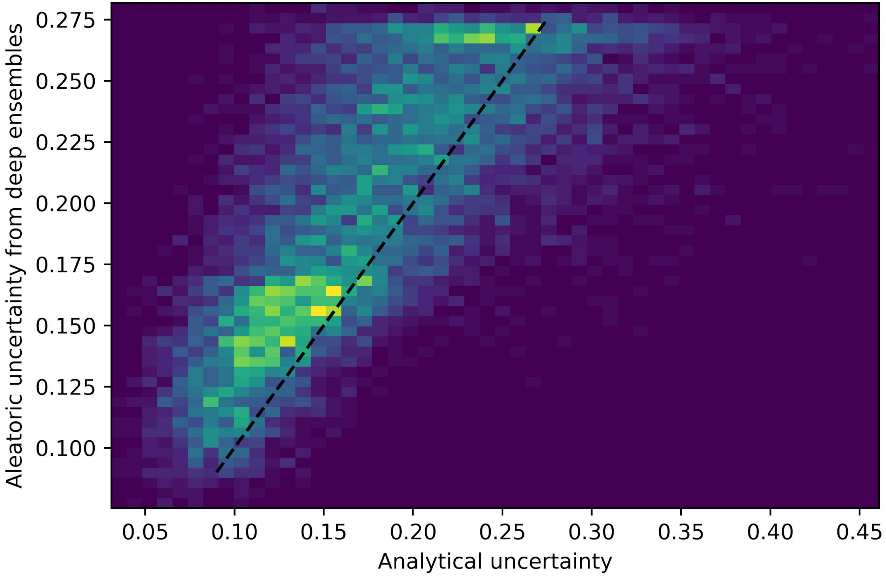
- deep ensembles
- concrete dropout
- bayesian neural networks
- ...

What are the advantages and disadvantages of each?

Working on a guide+comparison

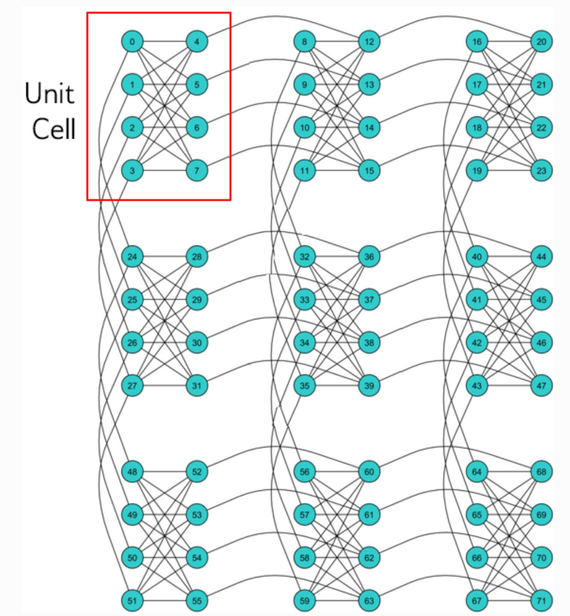
For this, take a simple physics model: a pendulum. Which method reproduces what we expect as physicists?

Coming soon!



Can you use quantum computing to help ML?

A quantum annealer is a type of quantum computer. Think of Ising model with tunable biases and couplings.



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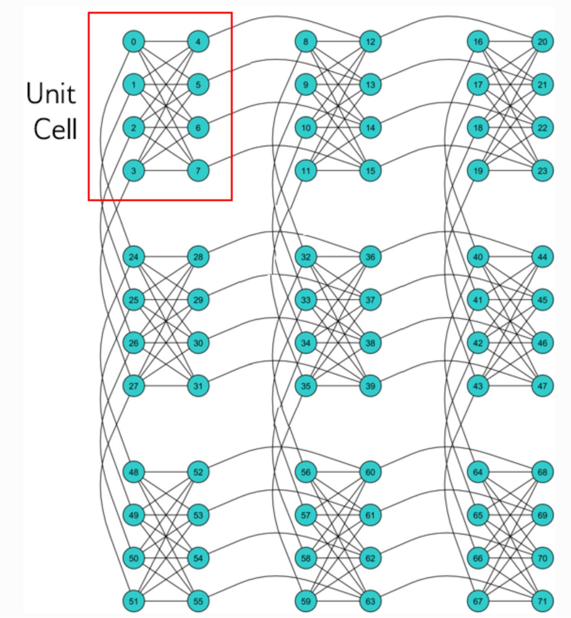
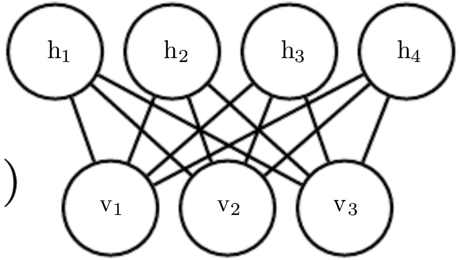


Restricted Boltzmann Machines are an ML algorithm with a similar architecture!



$$P(v,h) = \frac{1}{Z} e^{-E(v,h)}$$

$$E(v,h) = -b_i v_i - c_j h_j - J_{ij} v_i h_j$$

RBM for astrophysics

Can we use a quantum annealer to train a restricted Boltzmann machine to classify galaxy morphology?

Issues:

- you have to compress the data a lot to fit into a current quantum computer (~ 48 bits)
- distribution that comes out of annealer is not quite Boltzmann

Still, we had some success for datasets with few examples of each class! See more at 1911.06259

Conclusions

Just showed you three examples of things we have been working on.

If you have more ideas, let's chat!