Machine Learning for MHD Structures

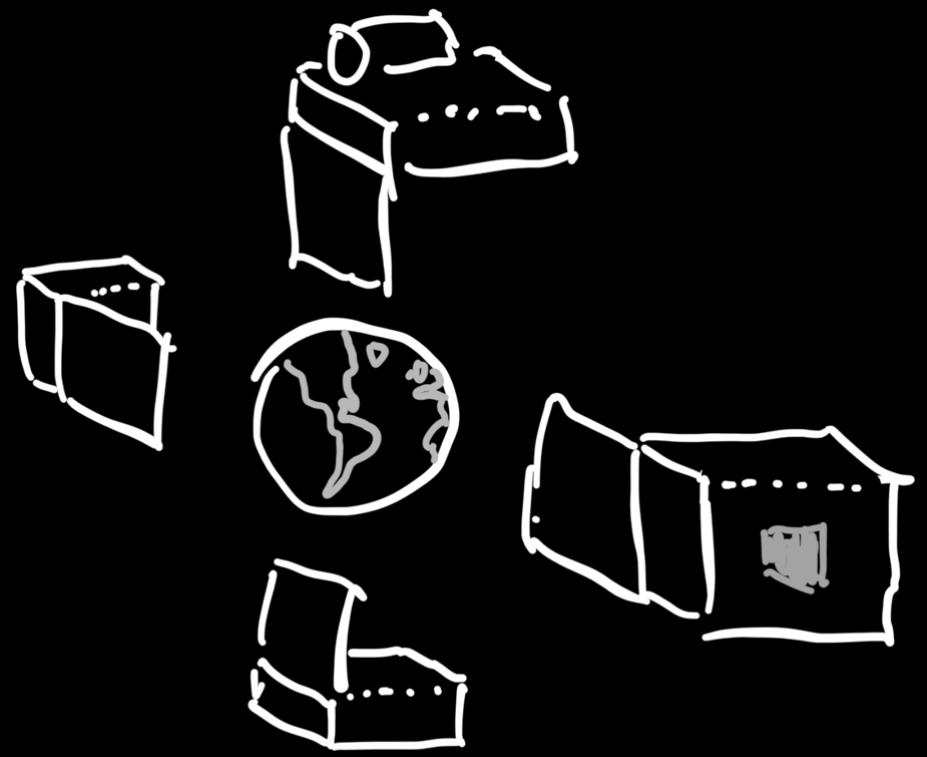
Nat Mathews
they / them

Machine Learning for MHD Structures

- Why Machine Learning for PUNCH?
- What Machine Learning for PUNCH?
- How Machine Learning for PUNCH?
- When Machine Learning for PUNCH?

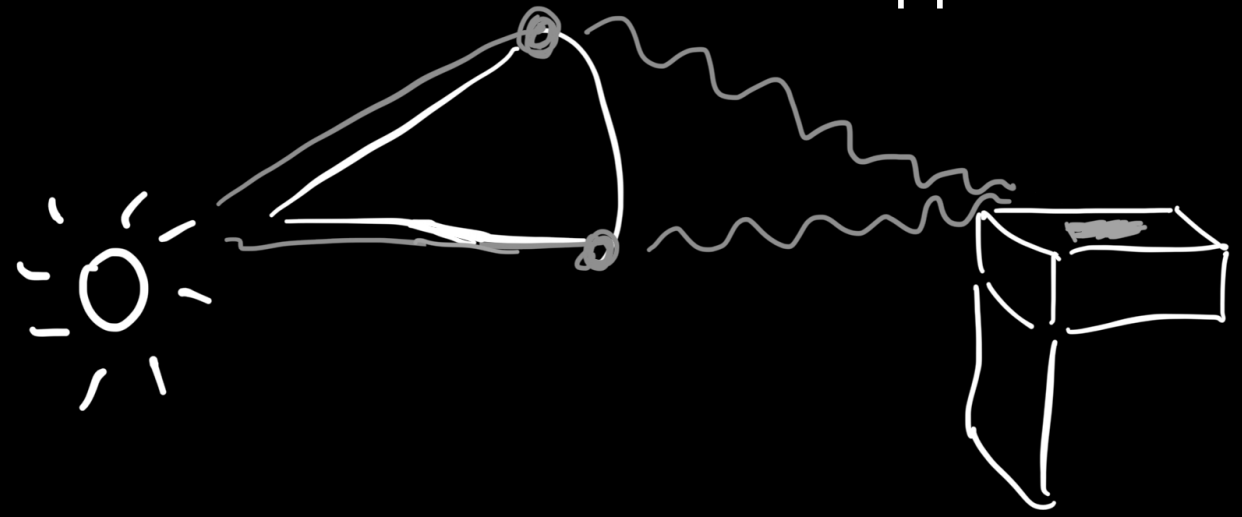
Why?

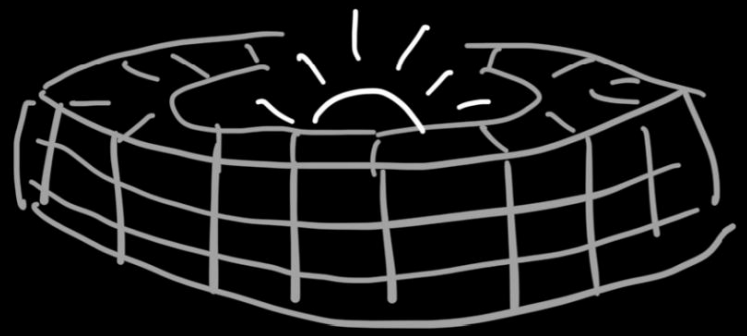
- PUNCH is going to have a LOT of new information for us
- Data taken every four minutes
- Full images every 32 minutes
- An unprecedented FoV for polarimetry
- Multidimensional data!



Why?

- Polarimetry gives PUNCH 3D structure information with a resolution which is difficult to simulate
  - Heliospheric scales are *big* but structures can be *fine*
  - PUNCH resolves down to 140 Mm
- GAMERA simulations with a similar resolution take 11 hours on Cheyenne [Mostafavi et al 22]
- My laptop is not Cheyenne, and 11 hours is more than 32 minutes
- There are cases where a fast approximator is useful





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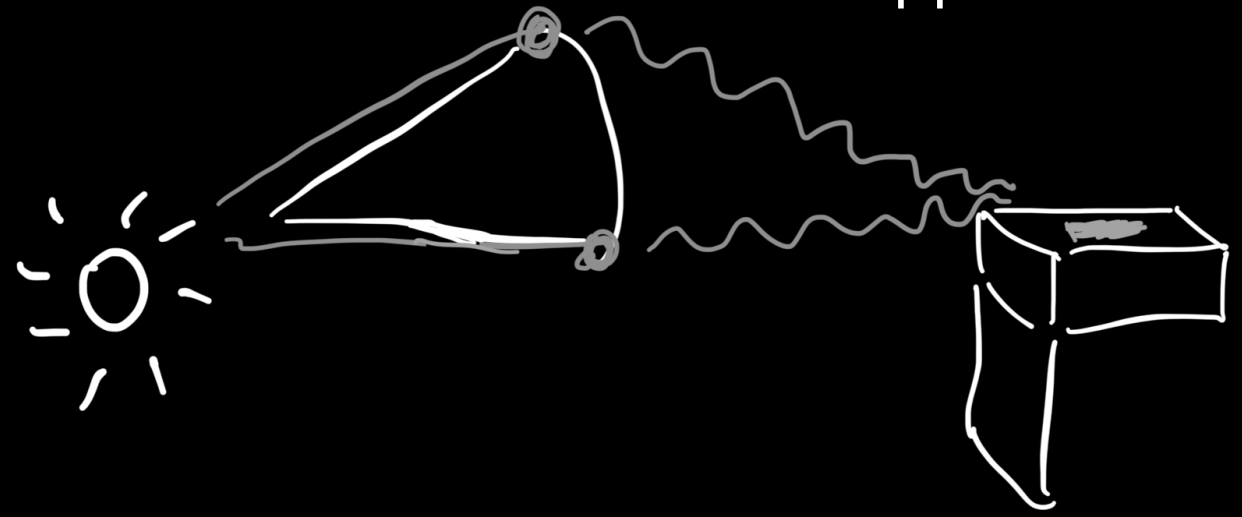
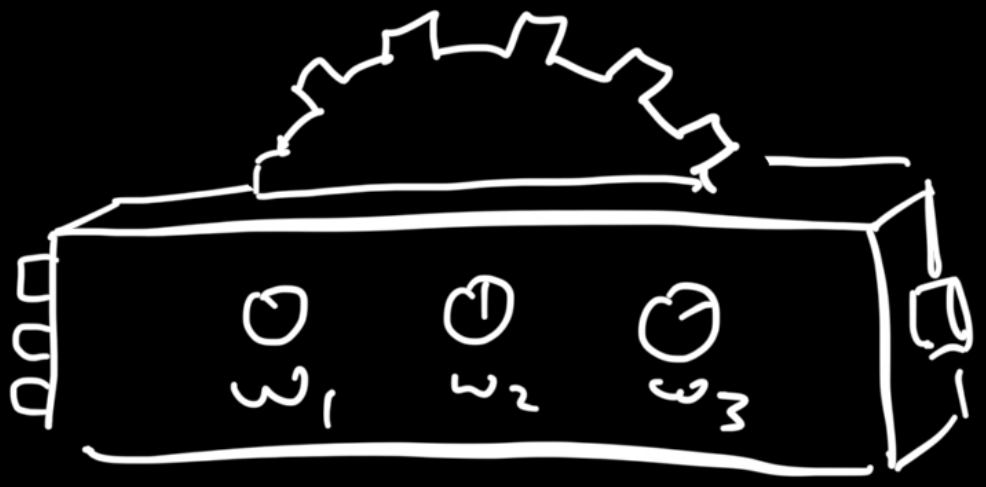


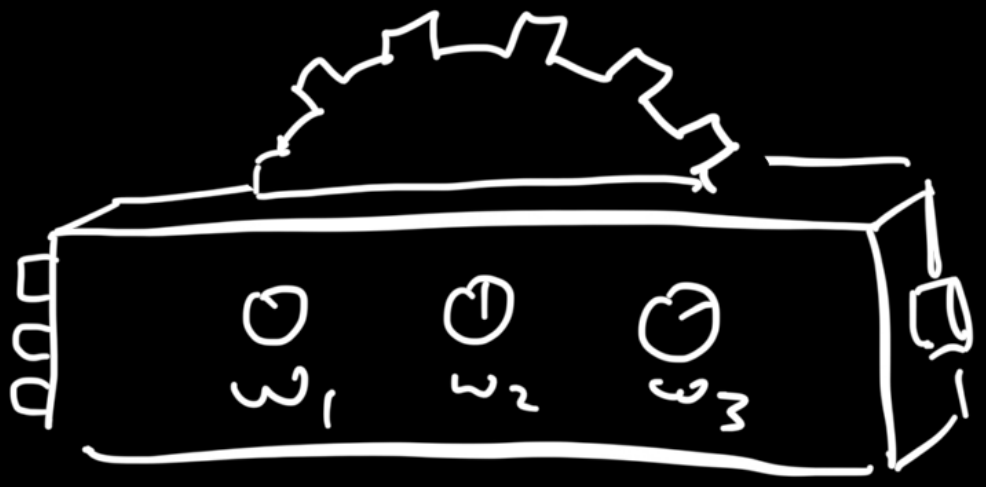
What?

- Machine Learning is a subfield specialty just like instrumentation, observation or theory
- You don’t have to be an expert!
- But it helps to be able to speak the language and understand the powers and limitations of the tools
- Don’t limit your science questions to a conceptualization of pipeline optimization



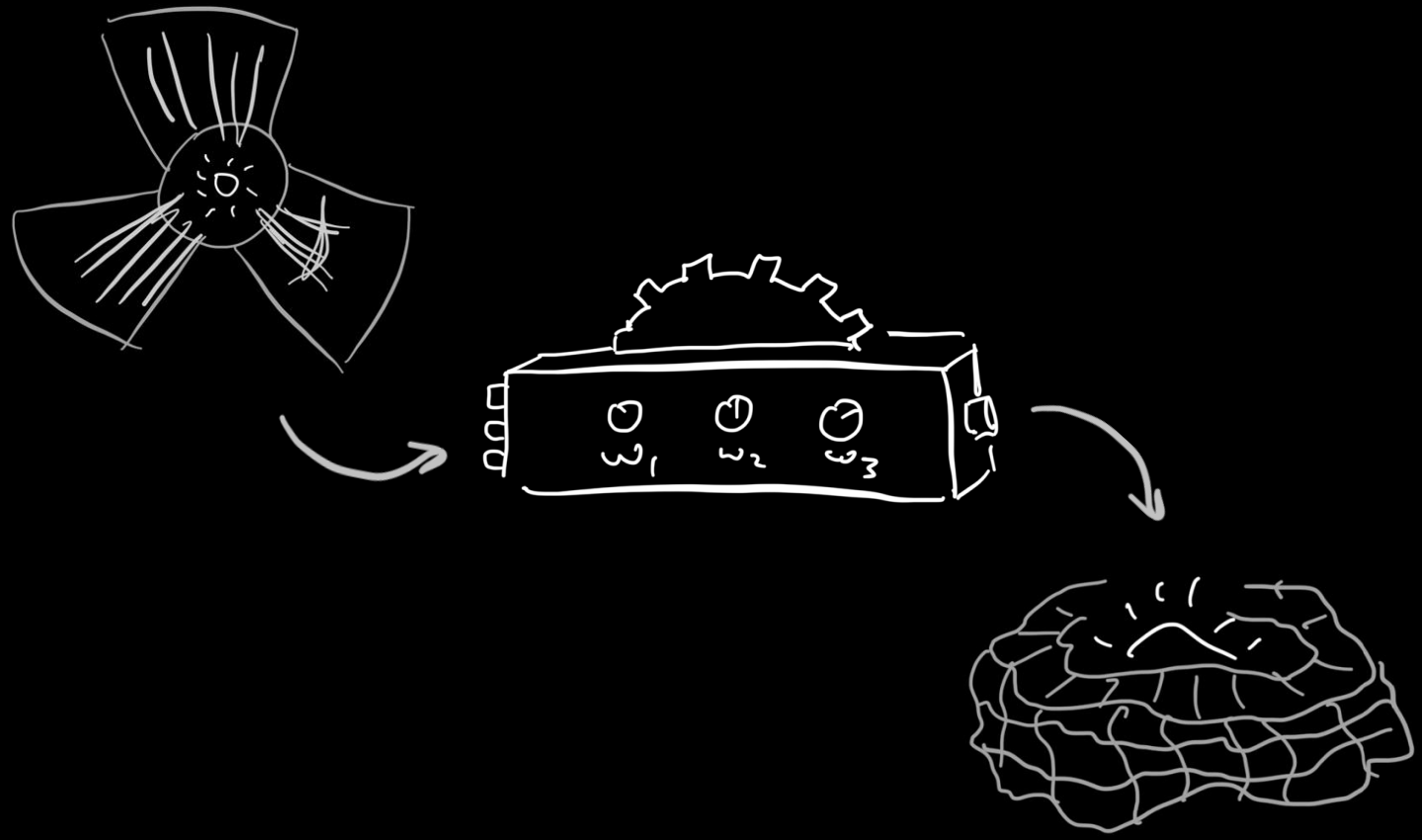
What?

- In Solar Physics, we're used to having a lot of data, so more direct ML approaches can work well
- PUNCH is a new mission without 15 years of data
- There is no large data historicity, no large labeled datasets, very little ground truth simulation



How?

- Physics-Informed Neural Nets [eg, Jarolim et al 2023]
- Architecture-Independent; it’s a difference in how you TRAIN the model



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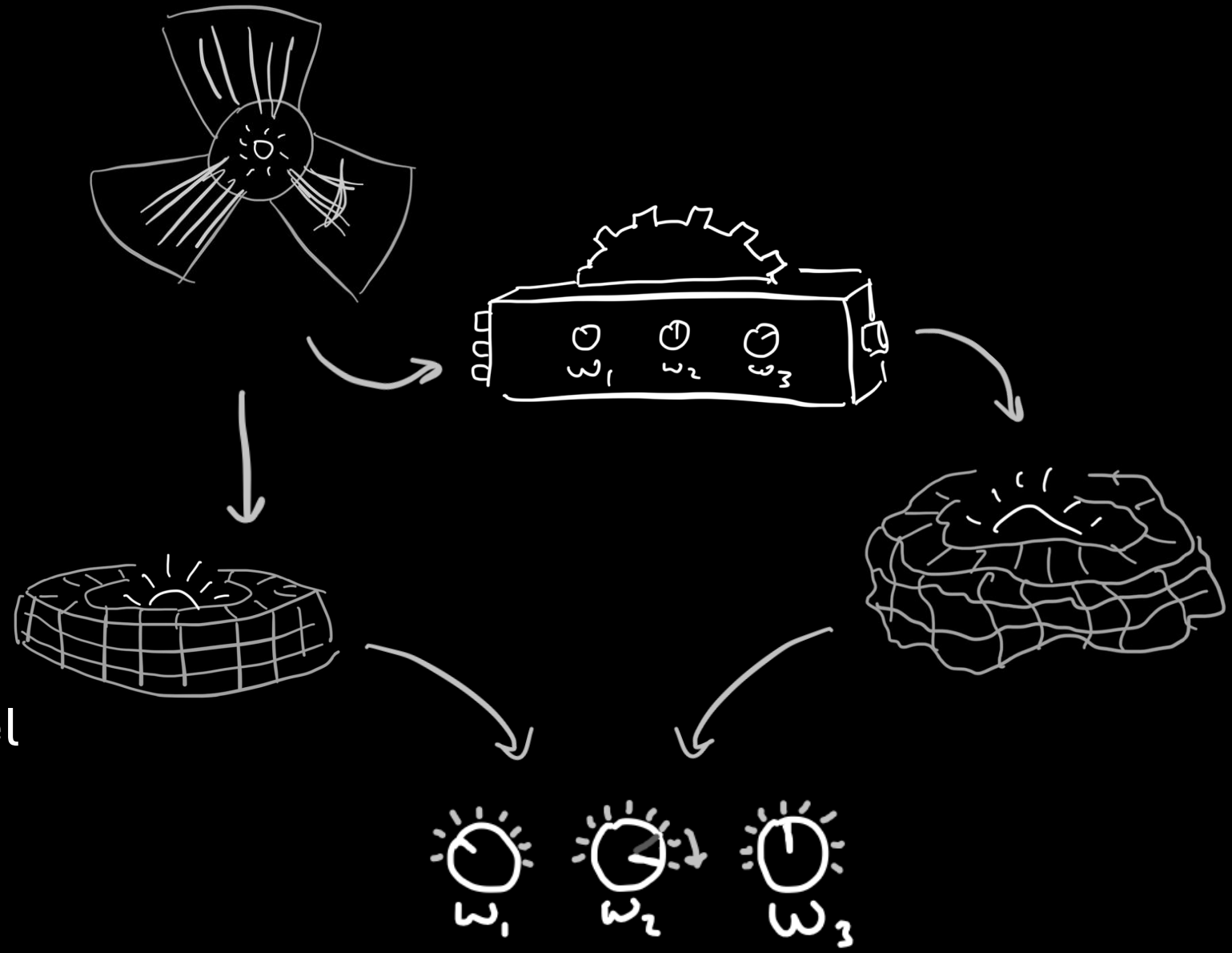
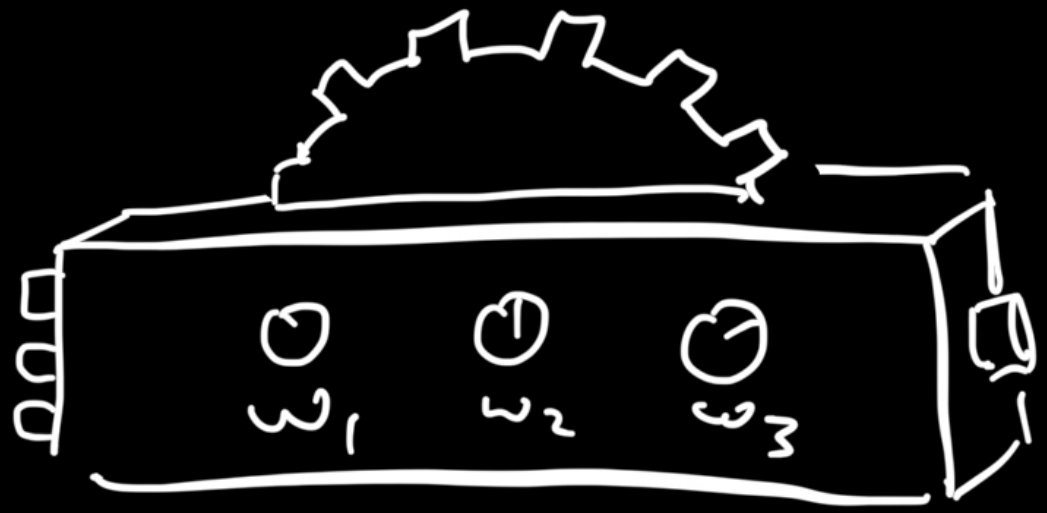
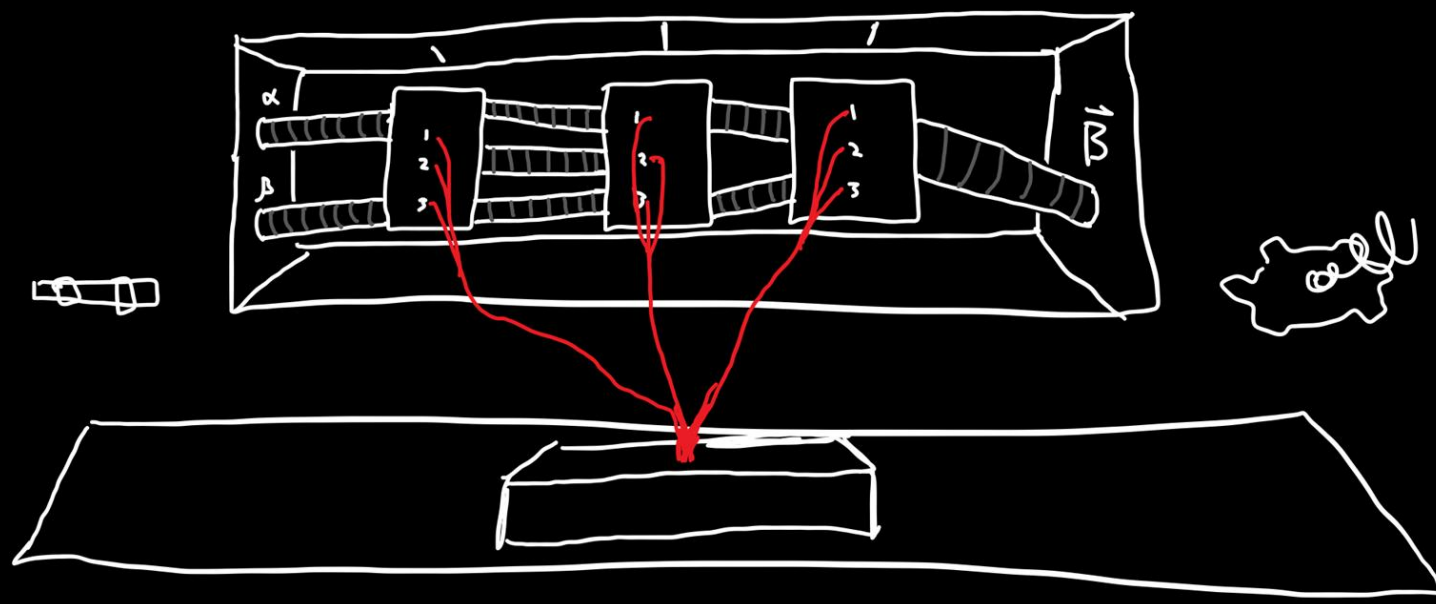


Inside the Box



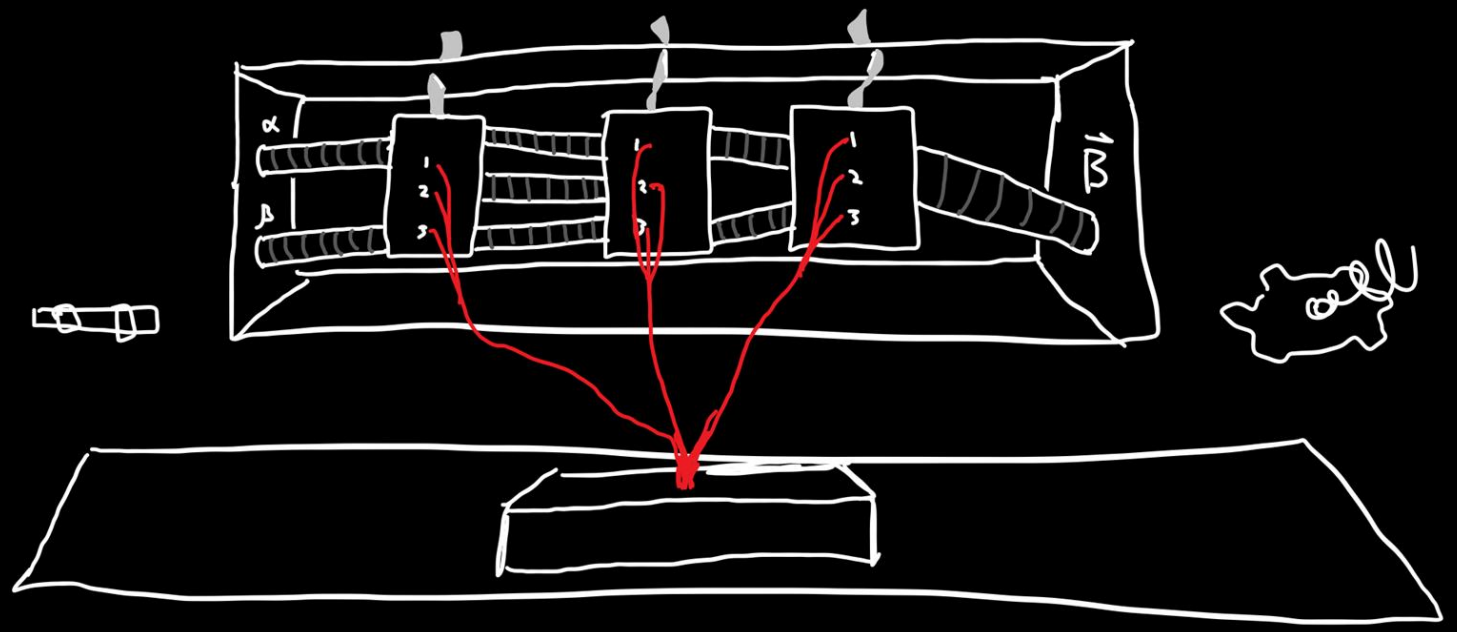
Inside the Box

- Pipeline transforms parameters into magnetic field
- At each step the current values are combined with the weights by a bunch of math



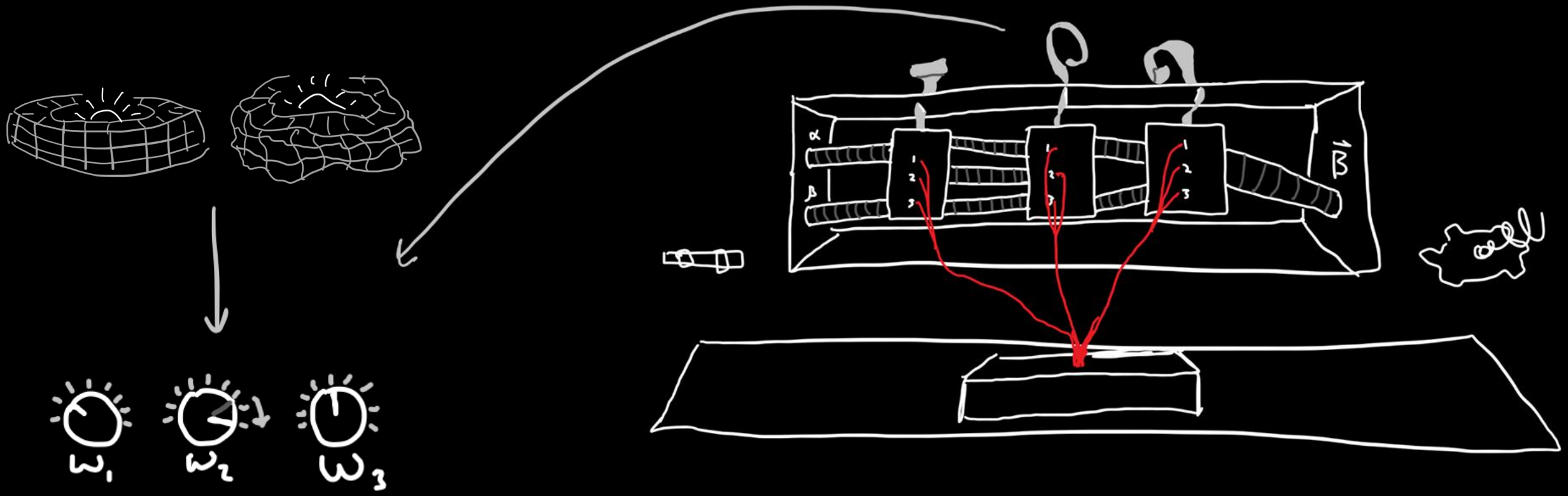
Inside the Box

- Pipeline transforms parameters into magnetic field
- At each step the current values are combined with the weights by a bunch of math
- At every step, the derivative of each operation gets logged



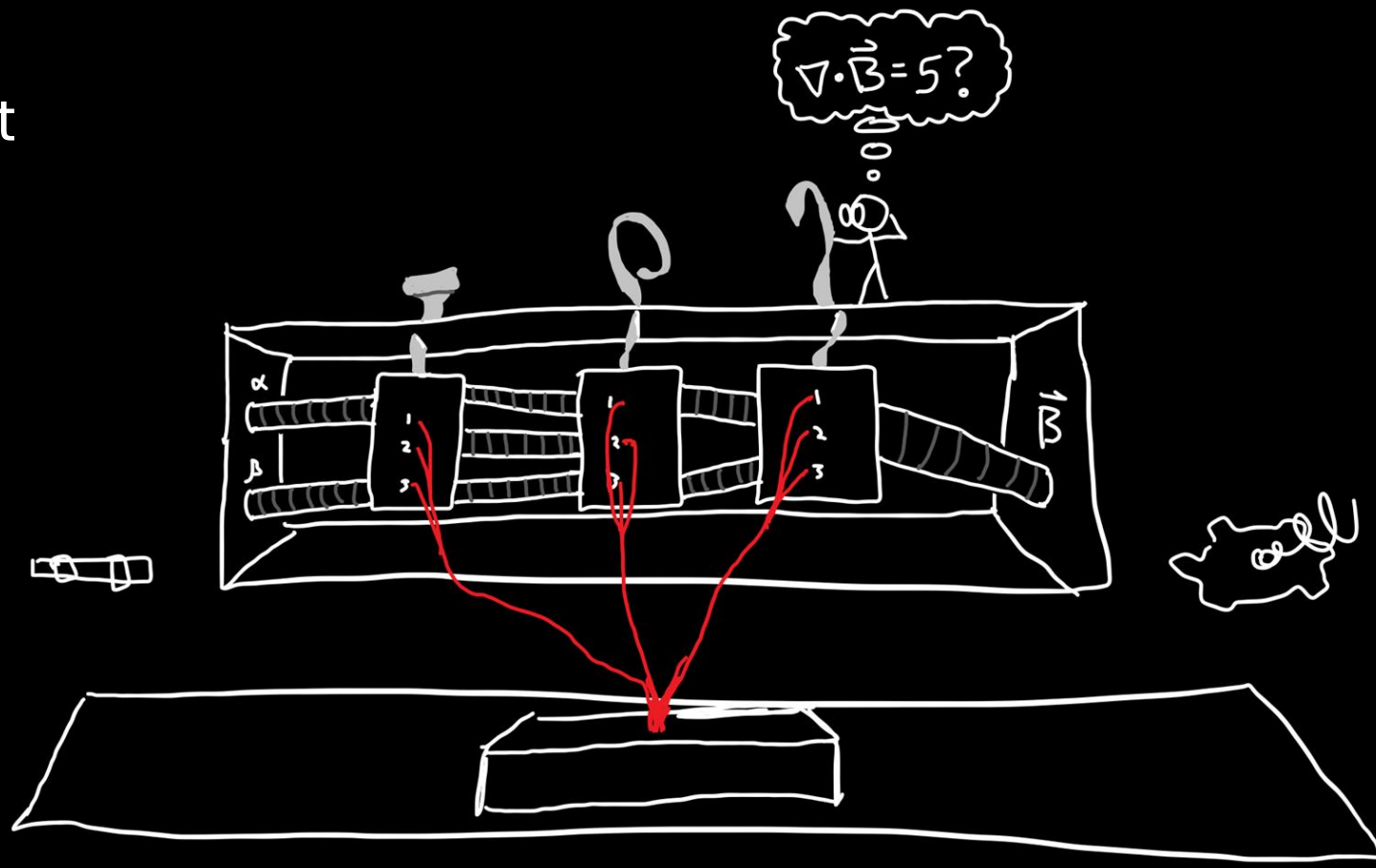
Inside the Box

- These logs are how we know how to update the weights



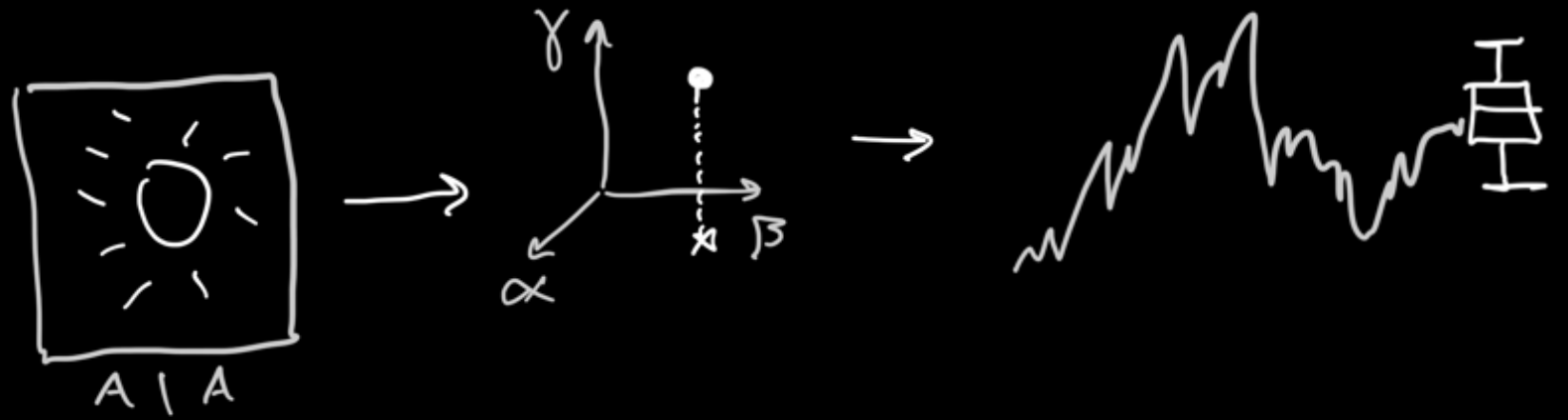
Inside the Box

- We can hijack this process to calculate physical values
- compute derivative of output with respect to spatial locations for little to no overhead
- e.g., the residuals of the governing differential equations
- This is our physical inconsistency



How (else)?

- The SDO-FM Foundational Model is learning about how to encode solar structures *right now* [Lika's poster in the hallway]
- Pretrain the high-dimensional "encoding" so that it's easier to built out specialized heads
- This encoding should be Sun-Driven, and (relatively!!) agnostic to instrumentation
- Could include PUNCH as input – could include all the "fifth eyes" as input!



When?

- Right now!

Index of /mhughes/punch_synthetic_data

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v1/	2024-06-14 20:13	-	
v2/	2024-06-15 07:30	-