Data Science in the Physical Sciences

Feb 2, 2024

Schedule

9:05 - 9:15 Matthew Schwartz, Professor of Physics, Harvard
Introduction

9:15 - 9:45 **Lina Necib**, Assistant Professor of Theoretical Astrophysics, MIT
(Machine) Learning the Genealogy of the Milky Way

9:45– 10:15 **Na Li ("Lina")**, Winokur Family Professor of Electrical Engineering and Applied Mathematics, Harvard
Closing the Loop: From Data to Action in Complex Systems

10:15 – 10:30: break

10:30 – 11:00: **Carlos Arguelles Delgado**, Assistant Professor of Physics, Harvard
Using Machine Learning to Unveil the Invisible Universe

11:00 – 11:45: Panel discussion and Q & A
The future of Machine Learning in the Physical sciences
Matthew Schwartz (moderator), Lina Necib, Na Li, Carlos Arguelles Delgado

Why AI in the physical sciences?

1. Huge amounts of data

2. Important problems

3. Applications to fundamental science and technology

4. AI is able to solve problems people can’t

Physical sciences is a growth area for ML

Share of papers involving AI by field

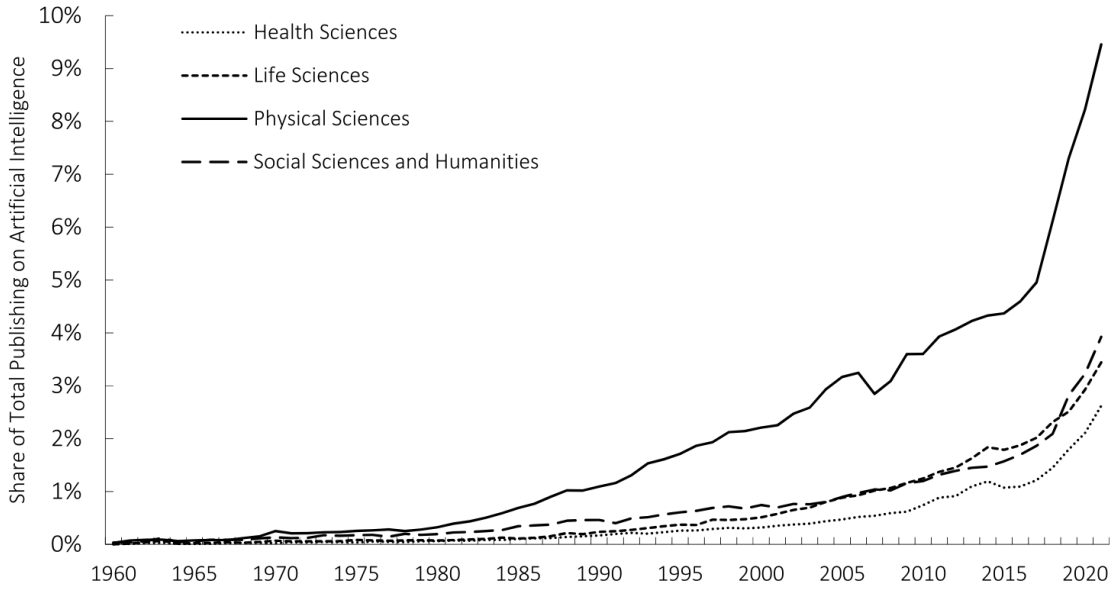
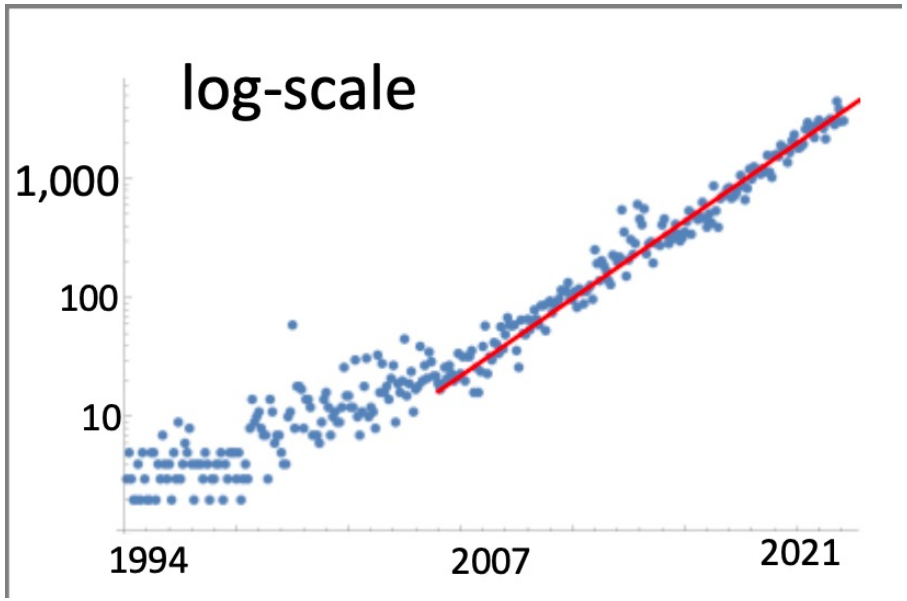


Fig. 5. Artificial intelligence publishing in research domains.

Hajkowicz et al arXiv:2306.09145

Total number of papers on AI

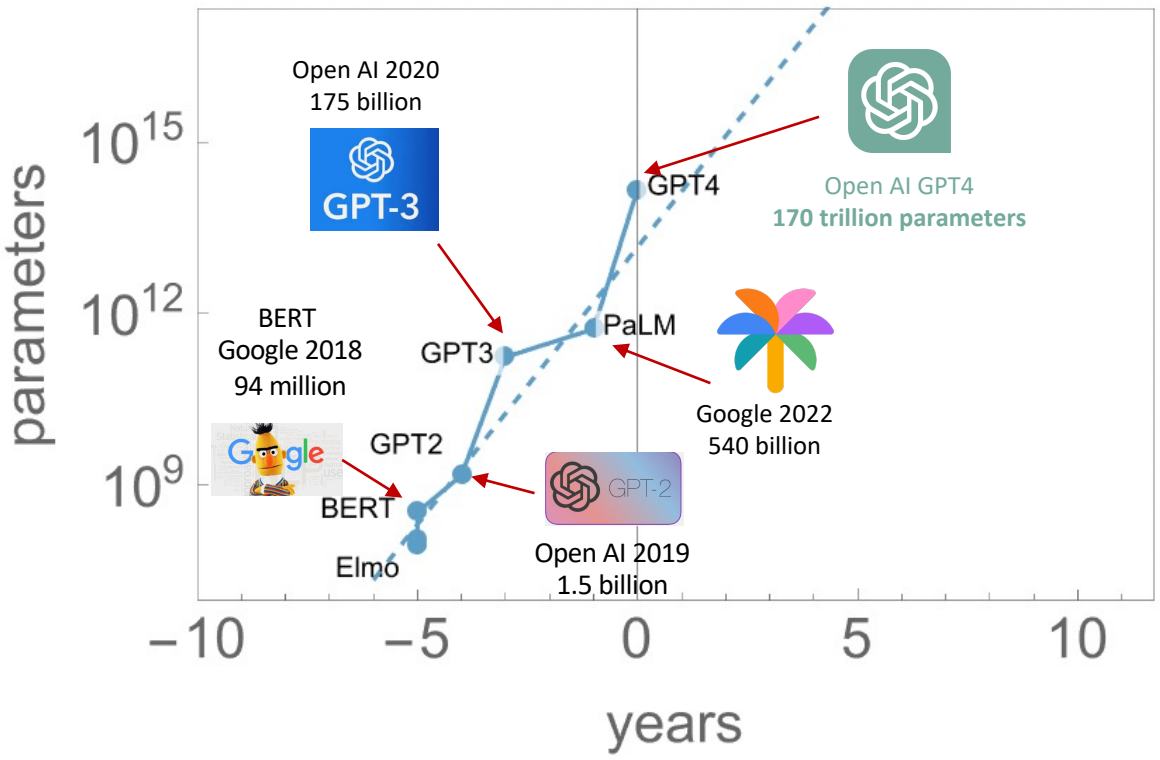
- exponential growth



Krenn et al arXiv:2210.00881

Can AI compete with humans?

Size of AI models (Large Language <odels)



Mammalian brains

Cat brain

0.760 billion neurons
10 trillion synapses

size of GPT 3.5

GPT-3

Human brain

80 billion neurons
150 trillion synapses

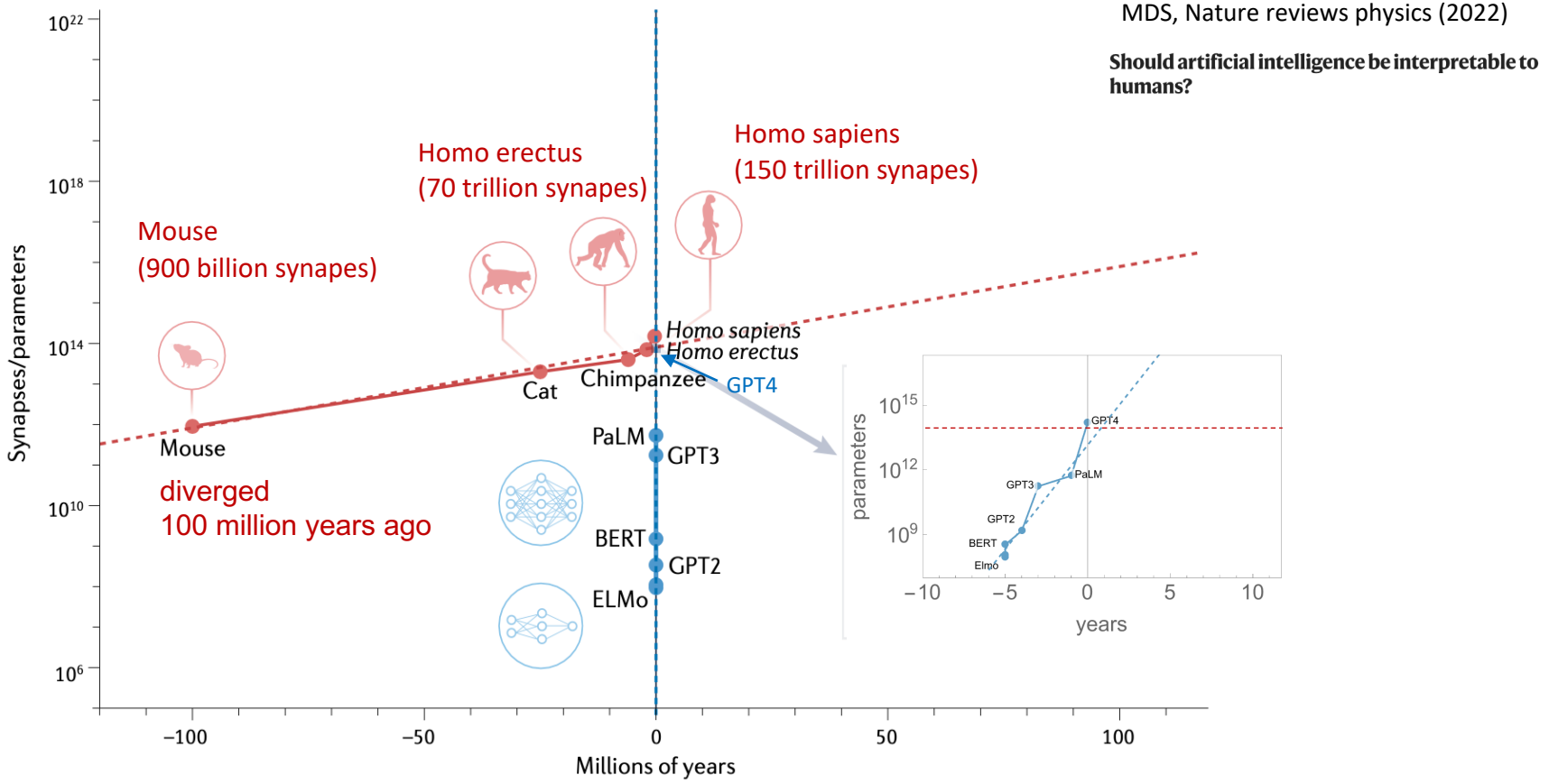
size of GPT 4

Machine vs. Biological intelligence

- Biological intelligence grows by a factor of 2 in one million years
- Machine intelligence grows by a factor of 10 in 1 year

MDS, Nature reviews physics (2022)

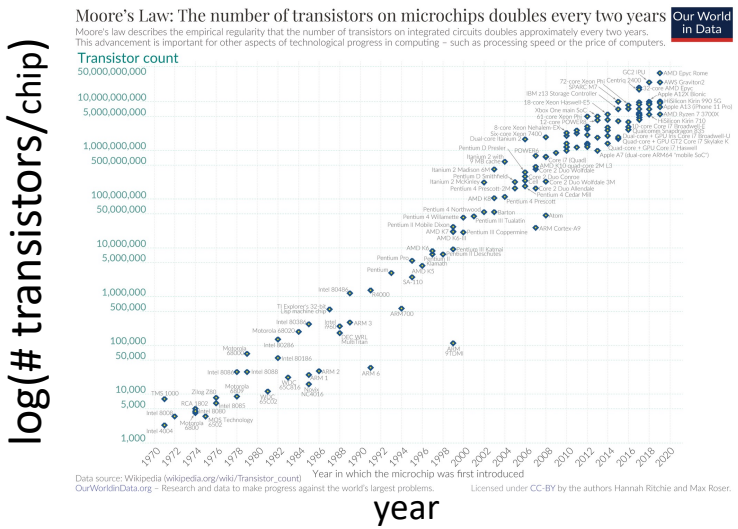
Should artificial intelligence be interpretable to humans?



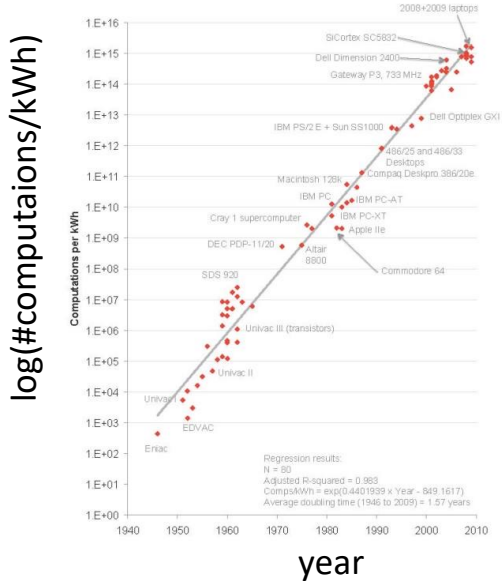
- Both AI and biological intelligence grow exponentially
- **Factor of 10^6 difference in *exponent***
- Intersection, when machines and biology have comparable "intellegence" is 2023

Exponential growth finds a way

Moore's law: computation power/time

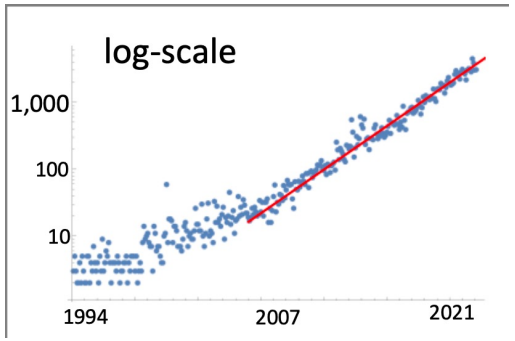


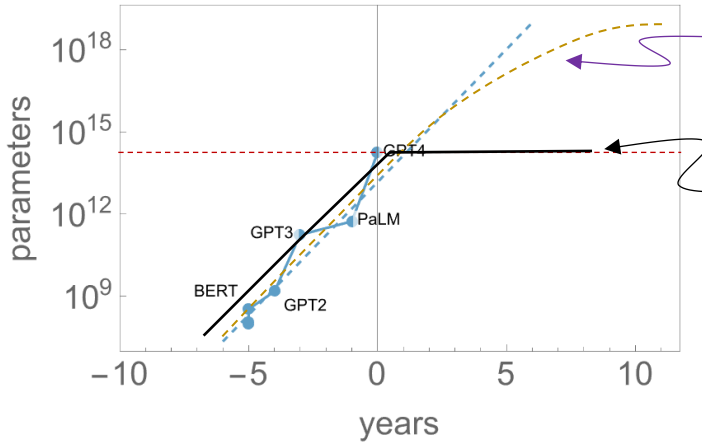
Koomey's law: energy efficiency /time



number of papers about ML or AI

Krenn et al arXiv:2210.00881





- even subexponential growth will soon exceed human capacity

- not going to happen
- impossible to believe this is the endpoint of AI

NSF Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)

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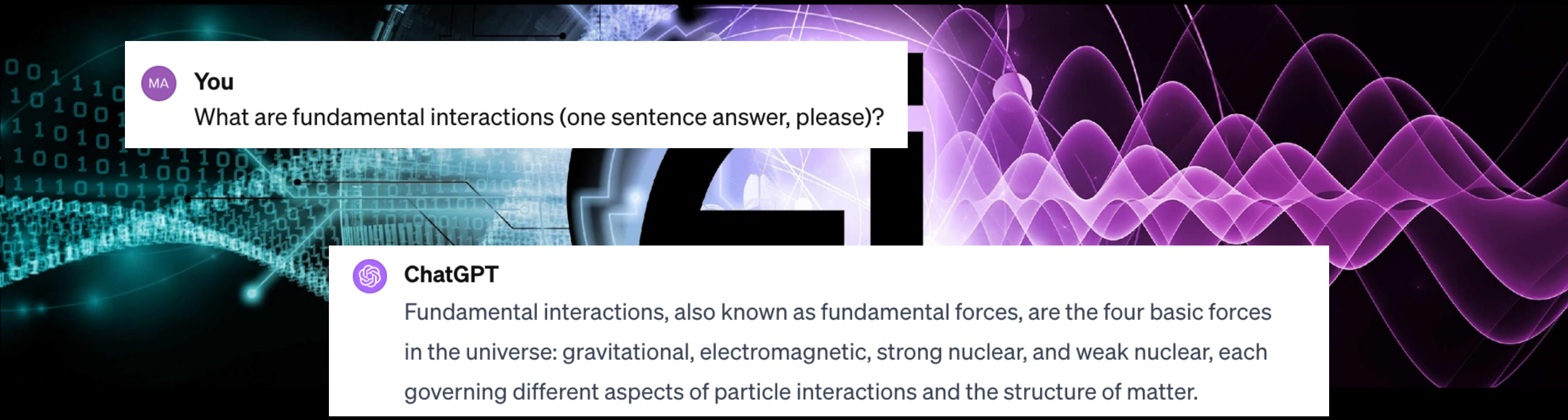
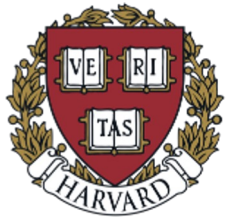


Many Scientists involved

Senior Investigators: 19 Physicists + 8 AI Experts + 17 IAIFI Affiliates
Junior Investigators: ≈31 FTE PhD Students, ≈7 IAIFI Fellows in steady state

Pulkit Agrawal
Lisa Barsotti
Isaac Chuang
William Detmold
Bill Freeman
Philip Harris
Erik Katsavounidis
Lina Necib
Alexander Rakhlin
Dan Roberts

Phiala Shanahan
Tracy Slatyer
Tess Smidt
Marin Soljacic
Washington Taylor
Max Tegmark
Jesse Thaler
Mark Vogelsberger
Mike Williams



Carlos Argüelles-Delgado
Demba Ba
Edo Berger
Mike Douglas
Cora Dvorkin
Daniel Eisenstein
Doug Finkbeiner

Cecilia Garraffo
Cengiz Pehlevan
Artan Sheshmani
Haim Sompolinsky
Matthew Schwartz
Ashley Villar
Susanne Yelin
Todd Zickler

Ning Bao
James Halverson
Brent Nelson
Fabian Ruehle

Shuchin Aeron
Abiy Tasissa
Taritree Wongjirad

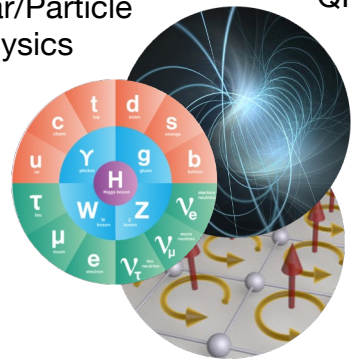
Aram Apyan
An Huang
Tyler Maunu

*Critical mass of **AI** + **Physics** expertise in the Boston area*

IAIFI Research Domains

Nuclear/Particle Physics

QFT & String Theory



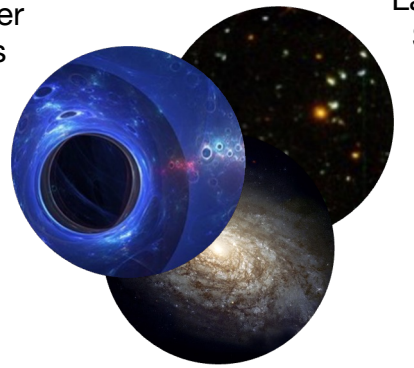
Quantum Many-Body Physics

Theoretical Physics

Leveraging AI to understand the theoretical underpinning of fundamental physics

Dark Matter Searches

Large-Scale Structure



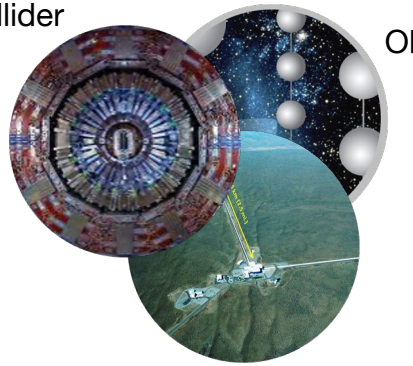
Galaxy Formation

Astrophysics

Using AI techniques to understand the universe on cosmological scales

Large Hadron Collider

IceCube Neutrino Observatory



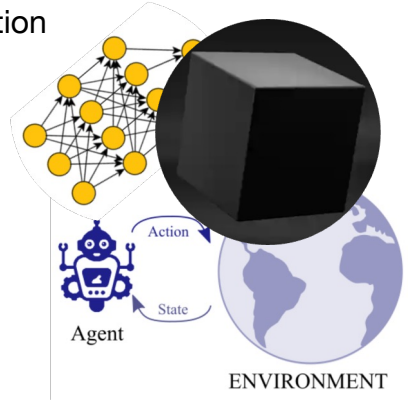
LIGO Gravitational Waves

Experimental Physics

Enhancing the operations and analysis of flagship NSF experiments through AI

Representation Learning

Robust/ Interpretable AI



Reinforcement Learning

Foundational AI

Infusing physics principles into AI to create state-of-the-art AI innovations

Get involved in IAIFI!

Come to Friday "IAIFI Afternoons"!
2:00–3:00 pm ET
Kolker Room (26-414) and Zoom

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Upcoming Colloquia

Xiaoliang Qi
Professor of Physics, Stanford University
Friday, December 8, 2023

Laurence Perreault Levasseur
Assistant Professor, Université de Montréal
Friday, February 9, 2024

Soledad Villar
Assistant Professor, John Hopkins University
Friday, March 8, 2024

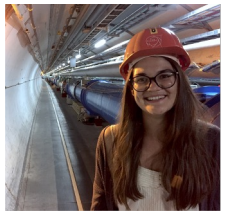
Jennifer Ngadiuba
Associate Scientist, Fermilab
Friday, April 12, 2024

Upcoming Seminars

Susanne Yelin
Professor in Residence, Harvard
Friday, February 2, 2024

Michael S Albergo
PhD Candidate, New York University
Friday, February 23, 2024

Alexander Gagliano
IAIFI Fellow
Friday, March 22, 2024



Gaia Grosso
IAIFI Fellow
Friday, April 26, 2024

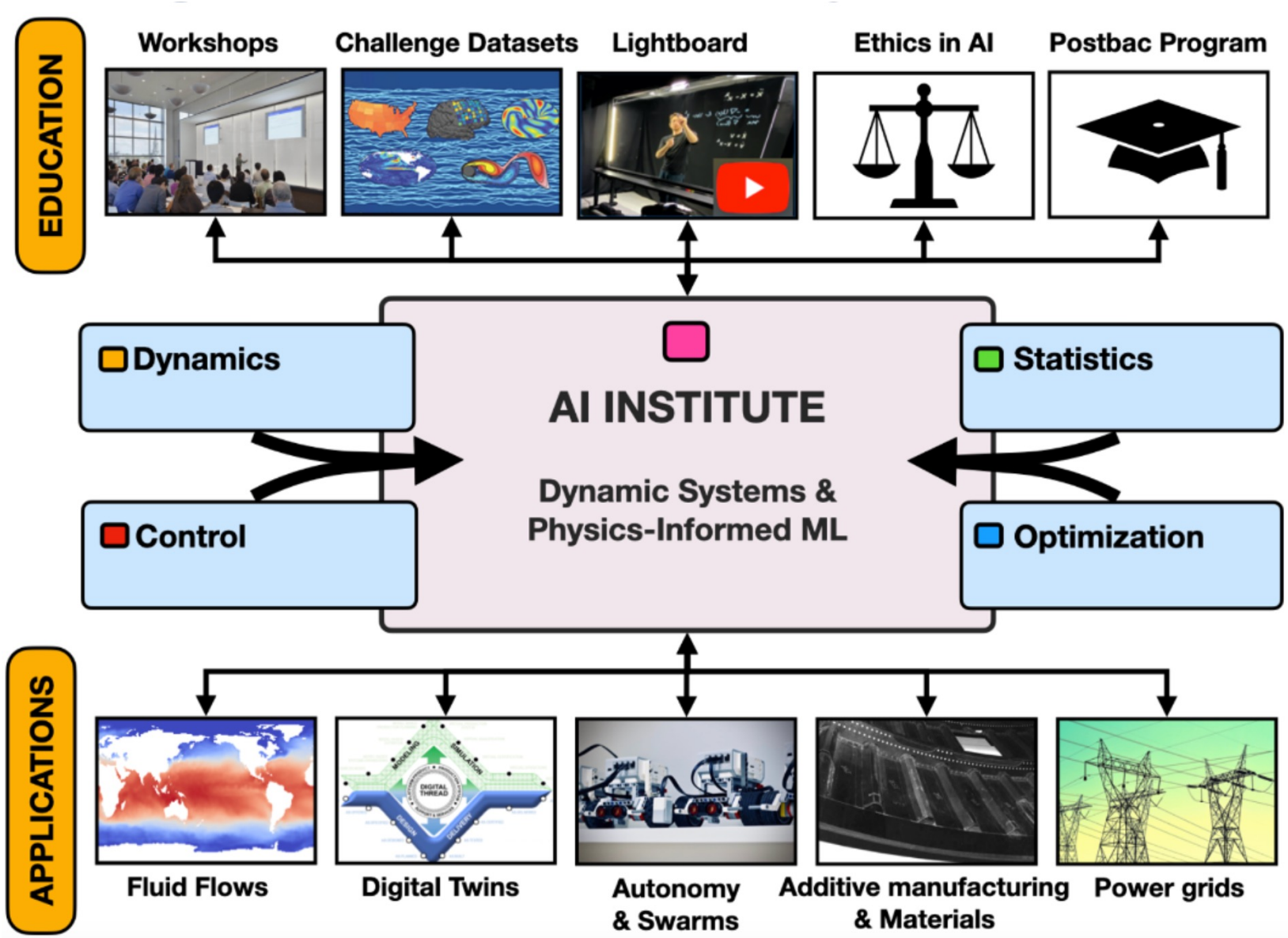

AI INSTITUTE IN DYNAMIC SYSTEMS

MA **You**

What are dynamic systems (one sentence answer, please)?

ChatGPT

Dynamic systems are mathematical models that describe how the state of a system evolves over time due to interactions within the system and with its environment.


EDUCATION
Workshops
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Postbac Program
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Statistics
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Physics-Informed ML
Control
Optimization
APPLICATIONS
Fluid Flows
Digital Twins
Autonomy
& Swarms
Additive manufacturing
& Materials
Power grids

Conclusions

- Data Science in the Physical Sciences is growing fast
- Boston Area has a large concentration of talent
- There are an enormous number of interesting problems
  - Require expertise in science and data science

Welcome to the workshop!