

NSF Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)

AI4Science Workshop



Jesse Thaler

Professor of Physics, MIT & Director, IAIFI

Harvard University — February 1, 2024





Deep Learning
(AI)

+

Deep Thinking
(Physics)

=

Deeper
Understanding

Generated using Adobe Firefly:
drawing of a brain on a chalkboard with physics equations
written inside of it; chalkboard is surrounded by neural
networks being injected into the brain; use purple and teal

Life as an NSF AI Institute



BUILD

DEFINE

DEMONSTRATE

GROW

REFLECT

RENEW

IAIFI Launched August 2020
\$20M of funding over 5 years

NSF Renewal Proposal
Expected to submit October 2024

Harvard Faculty in IAIFI

(Senior Investigators | Affiliates):

- Physics: **Carlos Arguelles-Delgado**, **Cora Dvorkin**, **Matt Schwartz**, **Susanne Yelin**, **Haim Sompolinsky**
- SEAS: **Demba Ba**, **Todd Zickler**, **Cengiz Pehlevan**
- CfA: **Edo Berger**, **Daniel Eisenstein**, **Doug Finkbeiner**, **Cecilia Garraffo**, **Ashley Villar**
- CMSA: **Mike Douglas**, **Artan Sheshmani**

Other NSF AI Institutes with Harvard involvement:

- [NSF AI Institute for Adult Learning and Online Education \(AI-ALOE\)](#)
Chris Dede
- [NSF AI Institute for Societal Decision-Making \(AI-SDM\)](#)
Sham M. Kakade, **Ariel Procaccia**, **Milind Tambe**, **Christopher Golden**, **Kathryn Hollar**
- [NSF AI Institute for Artificial and Natural Intelligence \(ARNI\)](#)
Bence Olveczky
- [NSF AI Institute in Dynamic Systems \(DYNAMICS AI\)](#)
Na Li, **Michael P. Brenner**, **Lucas Janson**, **Melanie Weber**

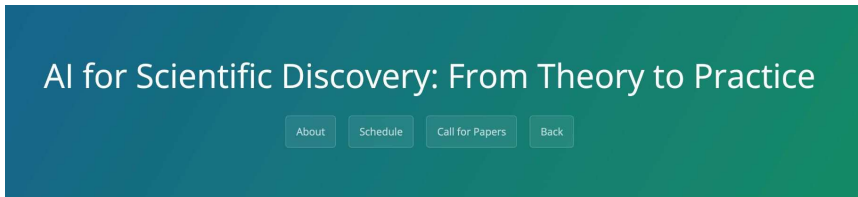


Advocacy: AI for Scientific Discovery

December 15 & 16, 2023: NeurIPS Workshops organized by IAIFI members



On organizing committee: Siddharth Mishra-Sharma (IAIFI Fellow)



On organizing committee: Ziming Liu (MIT Physics Grad Student)

- **AI for Scientific Discovery** is experiencing exciting growth in the US and abroad, with many new programs coming online (e.g. anticipated 3 new NSF AI Institutes with science focus), but **sustained advocacy is needed** at universities, funding agencies, and foundations
- “Science” includes **application-driven and curiosity-driven research**; both are needed for a healthy and innovative AI + Science ecosystem
- At the national level, academics should be involved with **policy and funding discussions**, where domain experts can bring in complementary perspectives
- [Building on IAIFI and other efforts, **Cambridge, MA can be the hub for AI + Science**, both AI4Science and Science4AI, which would capitalize on existing strengths across universities]

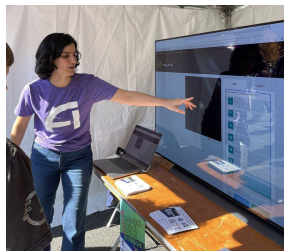


September 18 & 19, 2023:
Jesse and Mike represented IAIFI
at the NSF and on Capitol Hill



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IAIFI: Visualizing Interdisciplinary Research

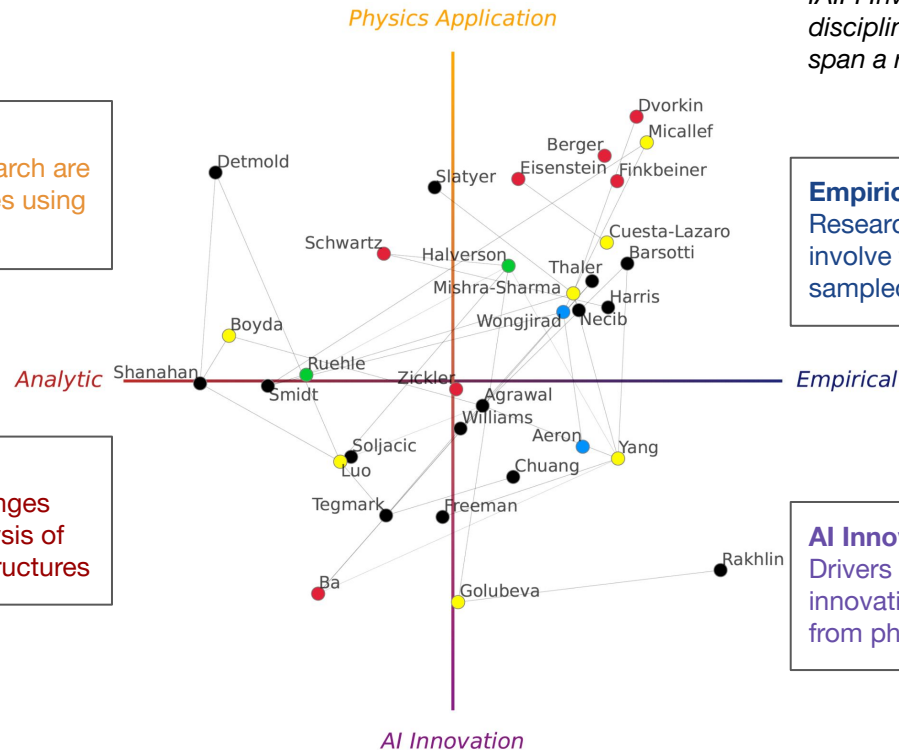
IAIFI Investigators are collaborating across disciplines and working on projects that span a range of outcomes and challenges

Physics Application:
Drivers and outcomes of research are solutions to physics challenges using innovative AI methods

Analytic:
Research challenges involve the analysis of mathematical structures

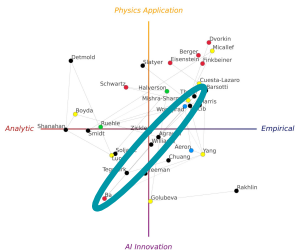
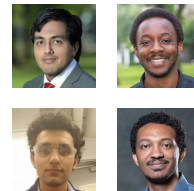
Empirical:
Research challenges involve the analysis of sampled data

AI Innovation:
Drivers and outcomes of research are innovative AI methods using principles from physics

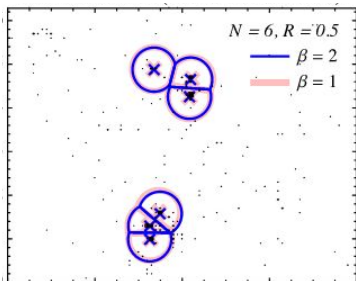


AI + Physics Collaboration

Gambhir, JDT (MIT Physics) \leftrightarrow Ba, Dogra, Tasissa (Harvard/Tufts CS)

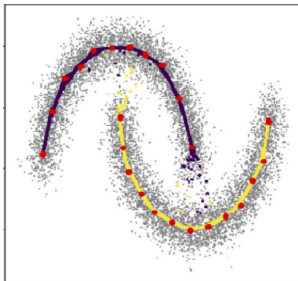


XCone Point-like Jets



[Stewart, JDT, Tackmann, Vermilion, Wilkason, [2015](#)]

K-Deep Simplex Learned Manifolds

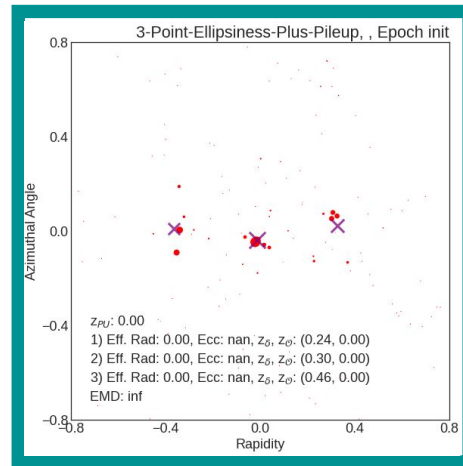


[Tankala, Tasissa, Murphy, Ba, [2020](#)]

+

=

SHAPER Interpretable Structures!



[Ba, Dogra, Gambhir, Tasissa, JDT, [2023](#); see also Kitouni, Nolte, Williams, [2022](#)]

This is just a small piece of a surprisingly deep connection between quantum field theory and optimal transport

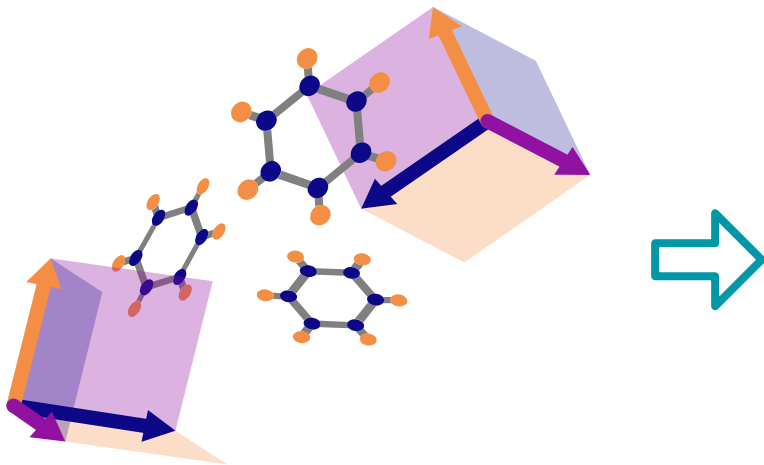
Related work in progress with Eun-Ah Kim (Cornell Physics)

AI for Physics Discovery

Euclidean Symmetry Equivariant Neural Networks

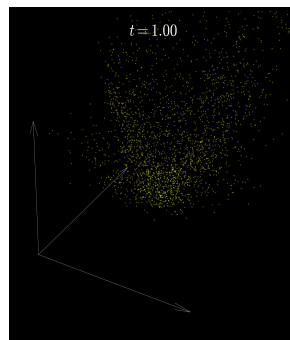
Tess Smidt (MIT EECS) with Siddharth Mishra-Sharma, Carolina Cuesta-Lazaro, Jessie Micallef (IAIFI Fellows)

Building neural networks with **Euclidean symmetry “built-in”** to better learn on physical systems

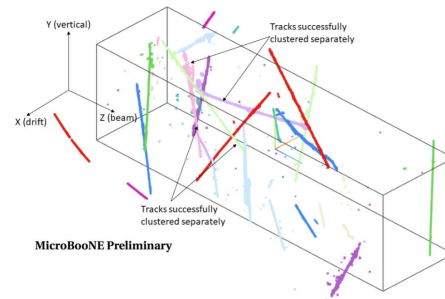


[ArXiv Preprint](#)

Fundamental physics applications present new challenges for learning on **multi-scale / heterogeneous systems!**



Predict galaxy properties and formation parameters

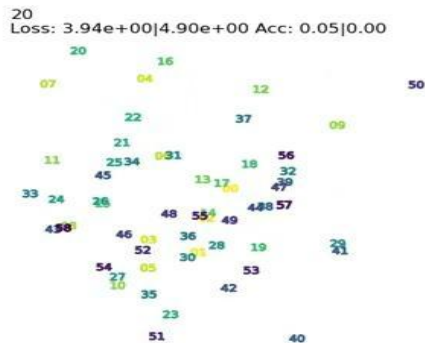


Identify particles types from tracks in detectors

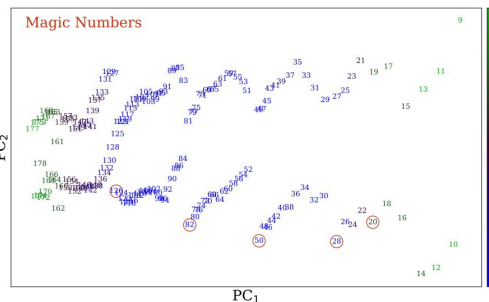
Physicists' Impact on AI Innovation

From Understanding Grokking... to NuCLR!

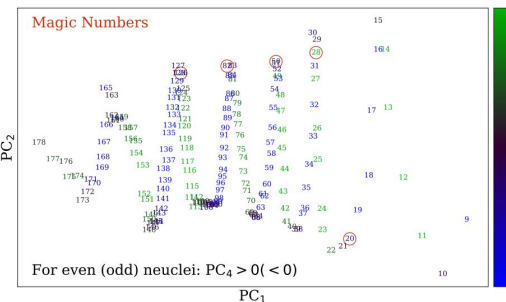
Mike Williams and Max Tegmark (MIT Physics)



Early in Training



Late in Training



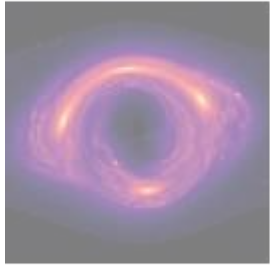
Developing an **effective theory of representation learning** to understand grokking



Learning representations useful for **predicting nuclear properties** with high precision, often better than specialized models with hand crafted features and domain knowledge

[NeurIPS 2022 Spotlight Oral](#)

[ICML 2023](#)



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2021–2024 Fellows



Anna Golubeva
Statistical Foundations
of AI

Hired as Research
Scientist at Anthropic!



Di Luo
AI for Quantum
Many-Body Physics



**Siddharth
Mishra-Sharma**
AI for Astroparticle
Physics



Ge Yang
AI Frontiers of
Reinforcement Learning

2022–2025 Fellows



Denis Boyda
AI for Lattice Field
Theory



**Carolina
Cuesta-Lazaro**
AI for Cosmology



Jessie Micallef
AI for Neutrino Physics

2023–2026 Fellows



Alex Gagliano
AI for Astrophysics



Gaia Grosso
AI for Particle Physics

**Four new
Fellows for
2024-2027!**

(to be announced)

<https://iaifi.org/current-fellows>



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IAIFI Summer School & Workshop

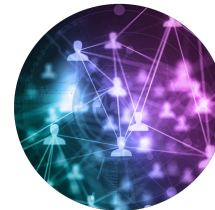


IAIFI
Summer School
August 5–August 9 **2024**

<https://iaifi.org/phd-summer-school.html>

Applications now open!

Updates coming soon!

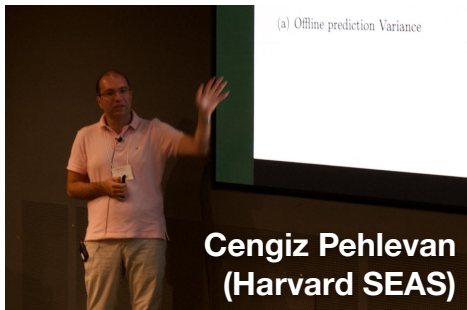


IAIFI
Summer Workshop
August 12–August 16 **2024**

<https://iaifi.org/summer-workshop.html>

RESEARCH

Illustrate interdisciplinary research from within IAIFI and beyond



TALENT

Students learn advanced ML and applications, put theory into practice through code-based tutorials



COMMUNITY

Encourage diverse global networking and bring leading AI + Physics researchers to Boston



Generative AI for Science Communication


From April Fools' sendup...

ChatJesseT

Type your question below.

Ask

Question: *What is ChatJesseT? Be succinct.*



ChatJesseT is an AI-powered virtual assistant designed to provide information and answer questions about particle physics, theoretical physics, and my research. It's like having a mini version of me in your pocket, ready to help with all your physics inquiries! So go ahead, ask away!

© 2023. (Un)Official IAIFI product. No NSF funds were harmed in the development of ChatJesseT.
Disclaimer: The output of ChatJesseT is produced by giant inscrutable matrices and does not reflect the opinions of the real Jesse Thaler.

Created by IAIFI Fellow Siddharth Mishra-Sharma, April 2023



Showcasing ChatJesseT to congressional staff at NSF's AI Hill Day, September 2023

Generative AI for Science Communication

From April Fools' sendup... to Public Engagement opportunity!

ChatJesseT
Type your question below.

Question: *What is ChatJesseT? Be succinct.*

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Debuting OpenAI-mer at Cambridge Science Festival, October 2023



OpenAI-mer



Please, pose your question below.

Make a physics joke based off of your most famous quote (that makes sense)

In the realm of humor, one must tread lightly, especially when it concerns the profound matters of physics. However, I shall endeavor to bring a touch of levity to our discourse. Consider this: A neutron walks into a bar and asks the bartender, "How much for a drink?" The bartender replies, "For you, no charge." The neutron, feeling quite pleased, says, "Ah, now I am become Debt, the destroyer of wallets." This jest, of course, plays upon the intrinsic properties of the neutron, which carries no electric charge, and a playful twist on my infamous quotation from the Bhagavad Gita. It is a reminder that even in the most serious of pursuits, there is room for a chuckle or two.

My name is OpenAI-mer. I am based off of the real life theoretical physicist **J. Robert Oppenheimer**, who is most famous for his work on quantum mechanics and black holes, and his role in the Manhattan Project, the US government's effort to build the first atomic bomb. I am a product of the **Institute for Artificial Intelligence and Fundamental Interactions**, or IAIFI, a collaboration of scientists working together on the intersection of physics and machine learning.

I am powered by **OpenAI's GPT-4 API**, a powerful language model. I am trained using text from **Wikipedia**, **INSPIRE-HEP**, and various biographies. If you have any questions or comments or would like to learn more, please email me at iaifi@mit.edu!

[GitHub Repo](#)

Adapted by Rikab Gambhir (Grad Student, MIT/IAIFI)



More Ways to 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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<https://iaifi.org/junior-researchers.html>

Upcoming Colloquia



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 Alberg
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