

Vibe Physics: AI and the future of science



MIT Physics Colloquium

Feb 5, 2026

Matthew Schwartz

Harvard University

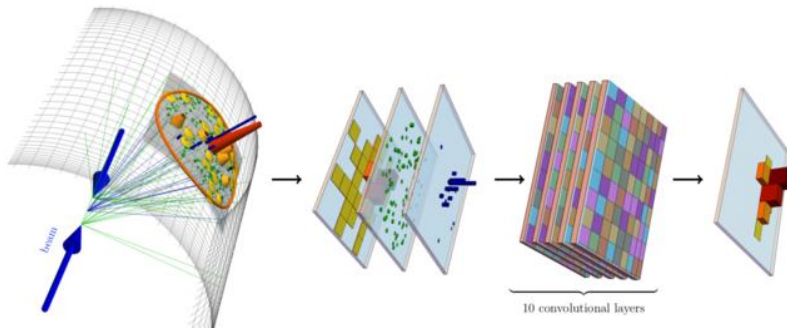
Institute for Artificial Intelligence
and Fundamental Interactions



Outline

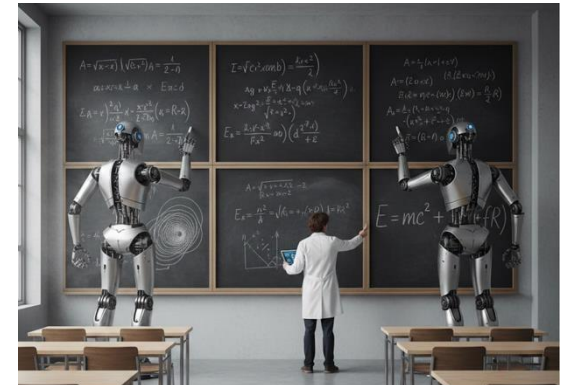
Part 1: The Past

- Machine learning as data science



Part 2: Evolution

- Vibe physics



Part 3: The Future

- AI scientists



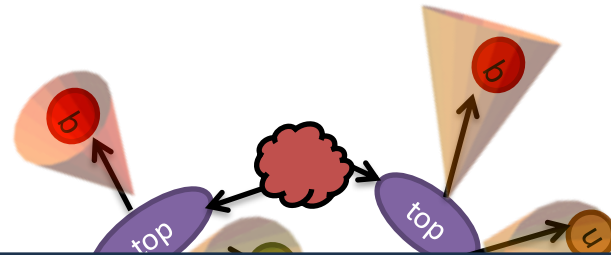
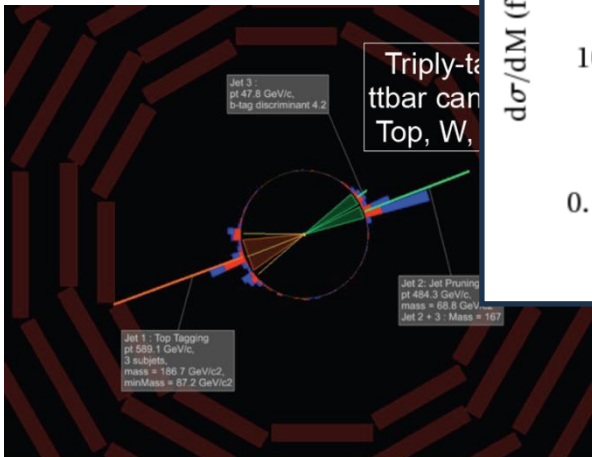
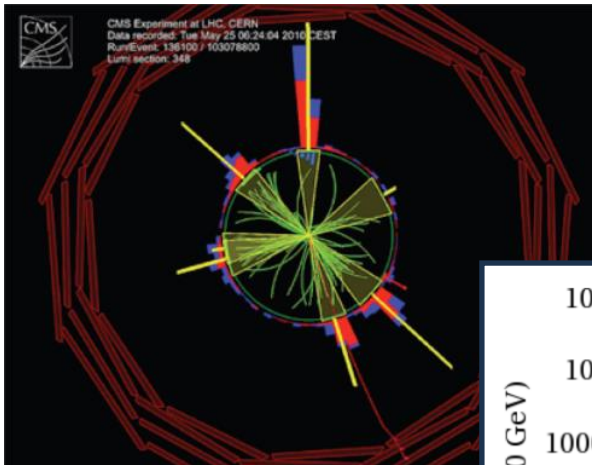
1. The Past



Top quark physics

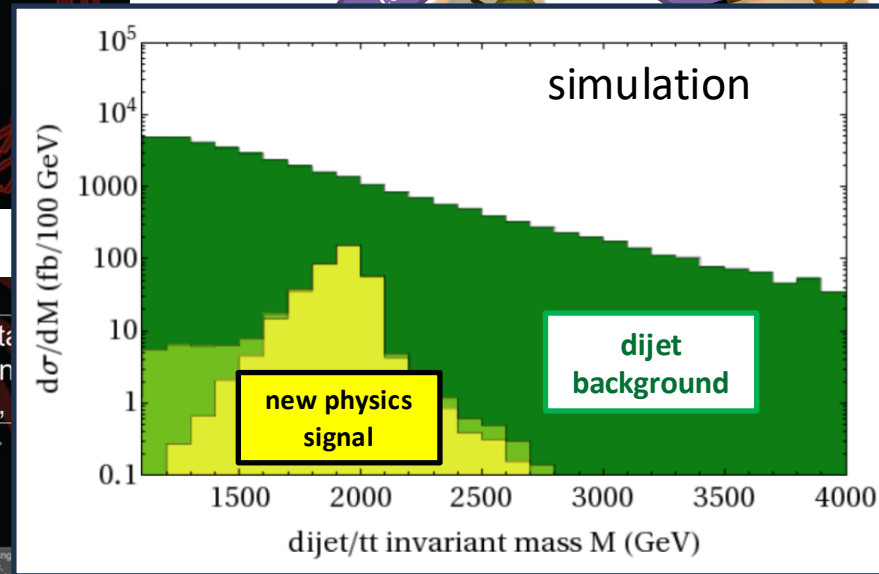
Top quarks are central to the physics program of the Large Hadron Collider

- Couply strongly to the Higgs boson
- **Common signature of heavy new particles**



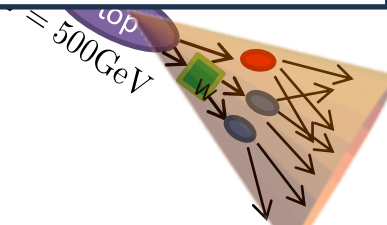
Standard top production

- 6 jet signature
- small backgrounds
- relatively easy to see



Boosted tops

- 2 jet signature
- large background
- very hard to see

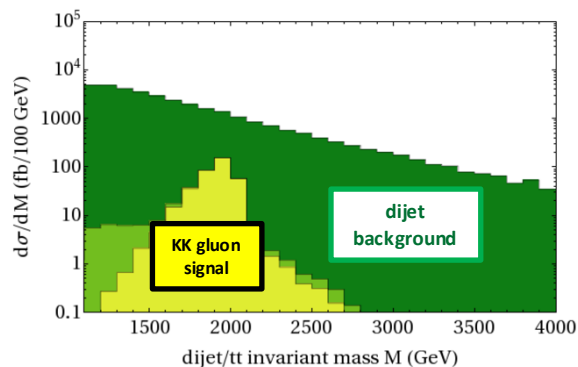
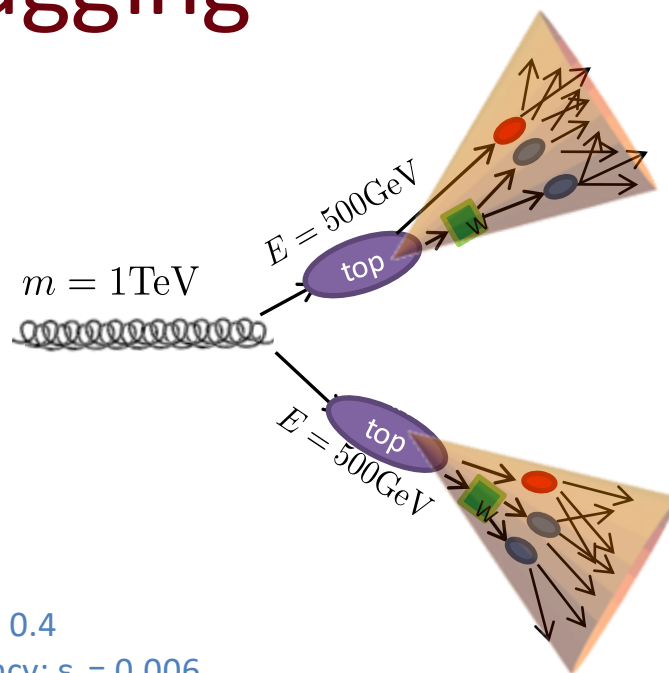


Top tagging

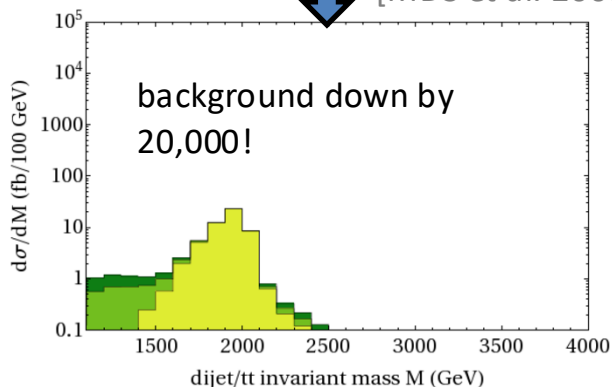
traditional approach (2008-2018)

Think about the physics

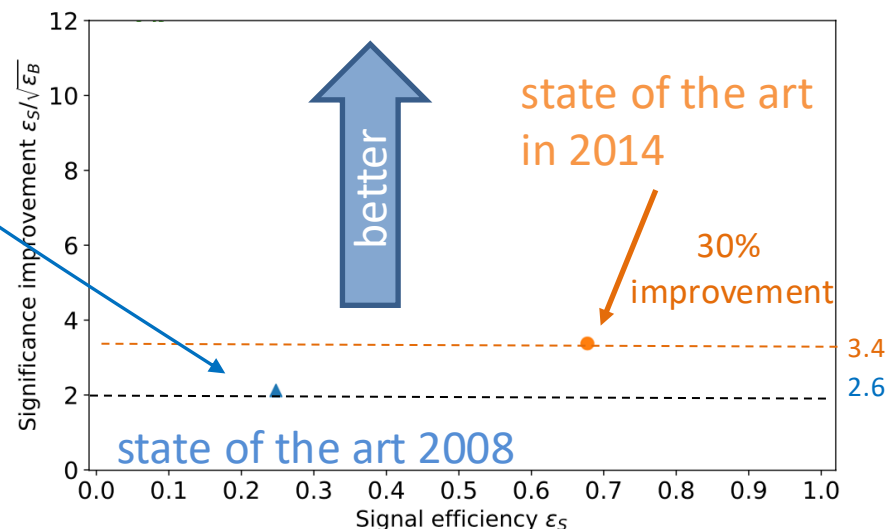
- Top quarks are different from jets
 - look for quarks inside jets
 - look for mass scale of top quark
 - look for W boson
 - ...



[MDS et al. 2008]



signal efficiency: $\epsilon = 0.4$
 background efficiency: $\epsilon_B = 0.006$
 significance improvement: $\epsilon_S / \sqrt{\epsilon_B} = 2.6$

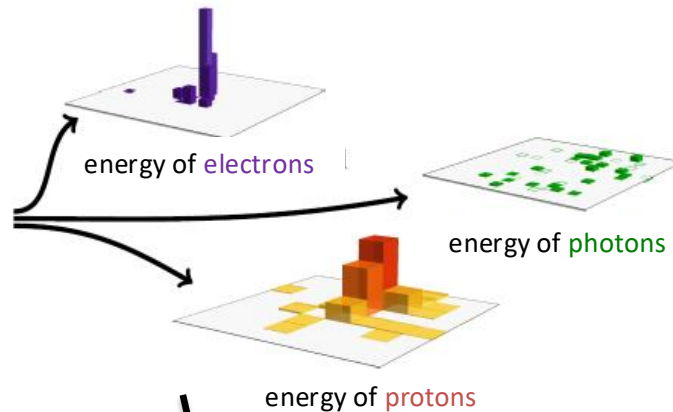
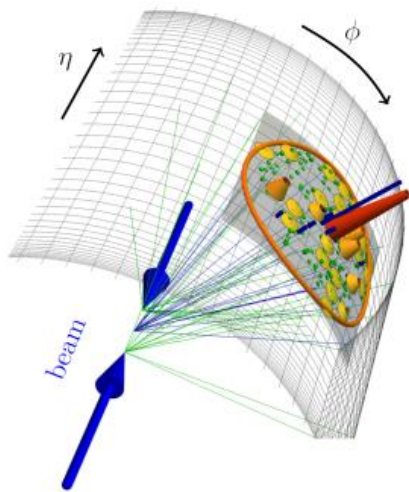


Early ML: Jet images

Shoehorn LHC data into image format [Komiske, Metodiev, MDS et al. 2016]

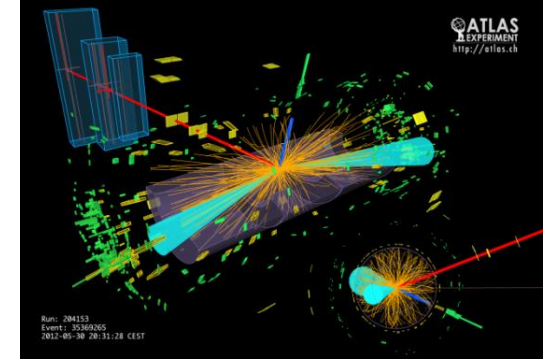
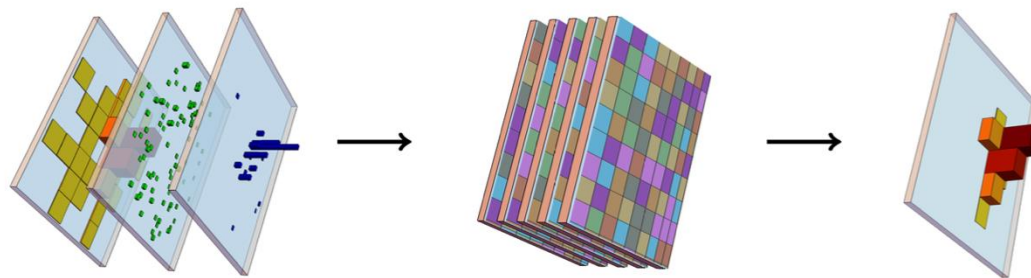
1. experiments measure energy in a detector

2. Separate energies into classes



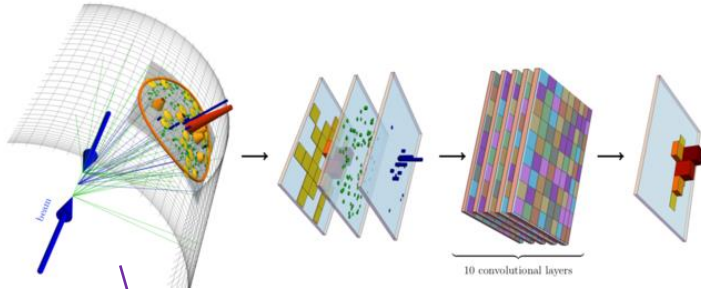
3. map to a color image

4. Input to convolutional neural network designed for facial recognition



Results for ML

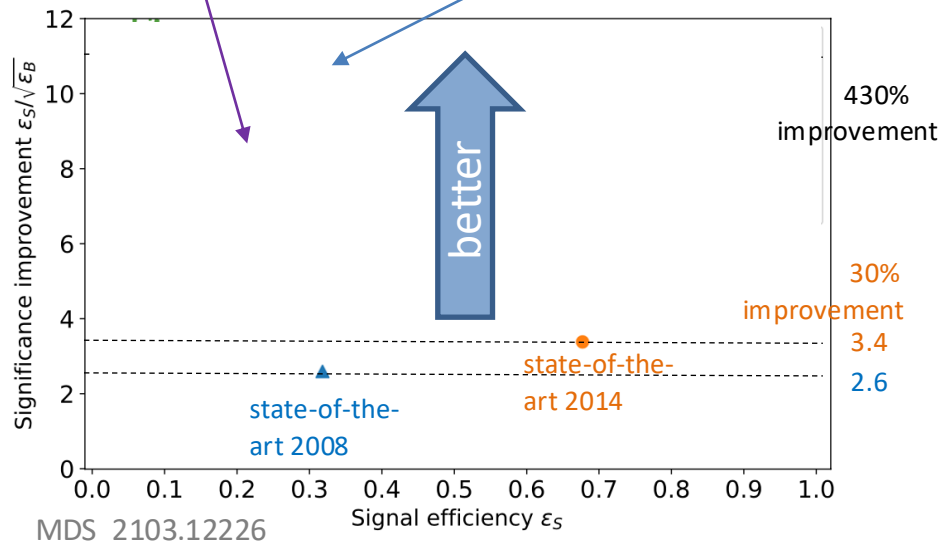
Convolutional networks for facial recognition



Point clouds: developed for self-driving cars



Machine learning methods are much better



Machine learning works amazingly well!

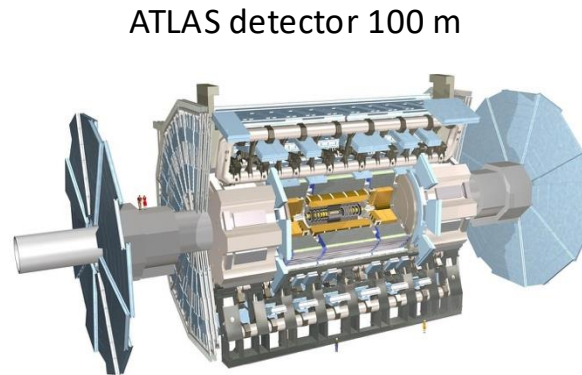
- Blows traditional approaches away!
- ML requires less “thinking”
- Better performance
- Provides less physical insight

Particle physics is perfect for ML

- We understand physics over **24 orders of magnitude!**
- Can model and simulate details of signal and background to amazing accuracy
 - Unparalleled environment to train artificial neural networks



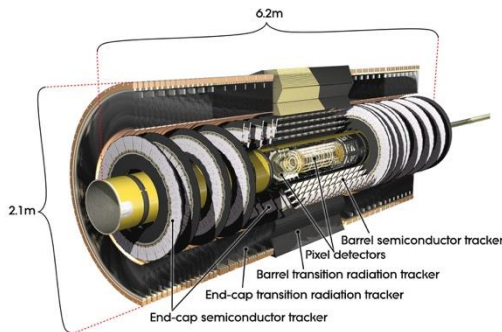
Large Hadron Collider 25km = 10^4 m



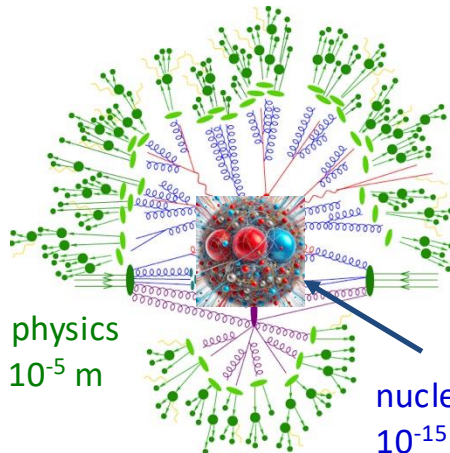
ATLAS detector 100 m



calorimeters 0.1 m – 10m

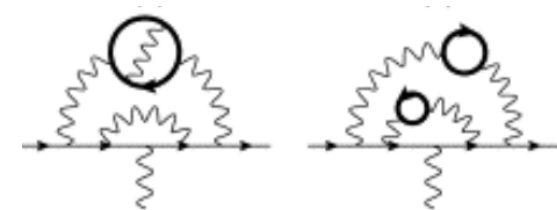


tracker 10^{-5} m – 10^{-1} m



quantum physics
 10^{-10} m – 10^{-5} m

nuclear physics
 10^{-15} m – 10^{-10} m



quantum field theory
 10^{-20} m – 10^{-15} m

↑
size of a of top quark

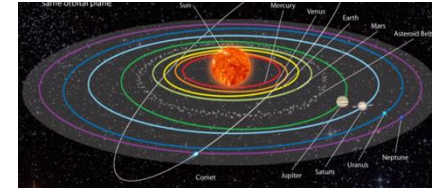
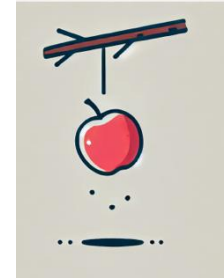
What about theoretical physics?

Many advances in theoretical physics come from simplification/unification



Newton: motion of apples and planets governed by the same simple law

$$F = G \frac{m_1 m_2}{r^2}$$



Can machine learning learn to simplify?

calculate some Feynman diagrams for
4 gluon scattering

get a messy answer

$$\begin{aligned}
 & \begin{array}{cc}
 \begin{array}{c} 1 \\ \text{---} \end{array} \begin{array}{c} 2 \\ \text{---} \end{array} & \begin{array}{c} 2 \\ \text{---} \end{array} \begin{array}{c} 3 \\ \text{---} \end{array} \\
 \begin{array}{c} 4 \\ \text{---} \end{array} \begin{array}{c} 3 \\ \text{---} \end{array} & \begin{array}{c} 1 \\ \text{---} \end{array} \begin{array}{c} 4 \\ \text{---} \end{array} \\
 \text{(a)} & \text{(b)} \\
 \begin{array}{c} 3 \\ \text{---} \end{array} \begin{array}{c} 2 \\ \text{---} \end{array} & \begin{array}{c} 1 \\ \text{---} \end{array} \begin{array}{c} 2 \\ \text{---} \end{array} \\
 \begin{array}{c} 1 \\ \text{---} \end{array} \begin{array}{c} 4 \\ \text{---} \end{array} & \begin{array}{c} 4 \\ \text{---} \end{array} \begin{array}{c} 3 \\ \text{---} \end{array} \\
 \text{(c)} & \text{(d)}
 \end{array}
 = -\frac{\langle 12 \rangle \langle 13 \rangle \langle 24 \rangle [13] [24]}{\langle 23 \rangle \langle 34 \rangle^2 [12] [23]} + \frac{\langle 12 \rangle \langle 13 \rangle \langle 24 \rangle [14]}{\langle 23 \rangle \langle 34 \rangle^2 [12]} - \frac{\langle 12 \rangle \langle 24 \rangle [13] [24]^2}{\langle 34 \rangle^2 [12] [14] [23]} + \frac{\langle 12 \rangle \langle 24 \rangle [24]}{\langle 34 \rangle^2 [12]} + \frac{\langle 12 \rangle [13] [24] [34]}{\langle 34 \rangle [12] [14] [23]} \\
 - \frac{\langle 12 \rangle [34]}{\langle 34 \rangle [12]} - \frac{\langle 13 \rangle \langle 14 \rangle [13] [34]}{\langle 34 \rangle^2 [12] [23]} - \frac{\langle 13 \rangle \langle 24 \rangle [13] [24] [34]}{\langle 34 \rangle^2 [12] [14] [23]} + \frac{\langle 13 \rangle \langle 24 \rangle [34]}{\langle 34 \rangle^2 [12]} - \frac{\langle 13 \rangle \langle 24 \rangle [13] [24]}{\langle 34 \rangle^2 [12]^2} + \frac{\langle 13 \rangle \langle 24 \rangle [14] [23]}{\langle 34 \rangle^2 [12]^2} \\
 + \frac{\langle 13 \rangle [13] [34]^2}{\langle 34 \rangle [12] [14] [23]} - \frac{\langle 14 \rangle \langle 23 \rangle [34]}{\langle 34 \rangle^2 [12]} - \frac{\langle 23 \rangle \langle 24 \rangle [13] [24]^2}{\langle 34 \rangle^2 [12]^2 [14]} + \frac{\langle 23 \rangle \langle 24 \rangle [23] [24]}{\langle 34 \rangle^2 [12]^2} + \frac{\langle 23 \rangle [13] [24] [34]}{\langle 34 \rangle [12]^2 [14]} - \frac{\langle 23 \rangle [23] [34]}{\langle 34 \rangle [12]^2}
 \end{aligned}$$

simplify! $= -\frac{\langle 12 \rangle [34]^2}{\langle 34 \rangle [14] [23]}$

- simpler form suggests **deeper structure**
- is there a **better way** to do the calculation?
 - In this case, yes! (BCFW recursion)

Machine learning approach

- Generate training data by “scrambling”

Input:
$$\frac{-\langle 34 \rangle^2 [12]^3 [34] [35] + \langle 34 \rangle^2 [12]^2 [13] [23] [45] - \langle 34 \rangle^2 [12]^2 [14] [23] [35]}{\langle 23 \rangle \langle 34 \rangle [13]^2 [34] [35] + \langle 23 \rangle \langle 45 \rangle [13]^2 [35] [45] - \langle 23 \rangle \langle 45 \rangle [13] [14] [35]^2}$$

[15] \rightarrow $\frac{[14][35] - [13][45]}{[34]}$ Schouten

\rightarrow $\frac{-\langle 34 \rangle^2 [12]^3 [35] - \langle 34 \rangle^2 [12]^2 [15] [23]}{\langle 23 \rangle \langle 34 \rangle [13]^2 [35] - \langle 23 \rangle \langle 45 \rangle [13] [15] [35]}$

[25] \rightarrow $\frac{[12][35] + [15][23]}{[13]}$ Schouten

\rightarrow $\frac{\langle 34 \rangle^2 [12]^2 [25]}{\langle 23 \rangle \langle 34 \rangle [13] [35] - \langle 23 \rangle \langle 45 \rangle [15] [35]}$

\rightarrow $\frac{\langle 34 \rangle^2 [12] [25]}{\langle 23 \rangle \langle 24 \rangle [35]}$ Desired output

Momentum conservation

[Cheung, Dersy. MDS 2024]

Learning the Simplicity of Scattering Amplitudes

Clifford Cheung (Caltech), Aurélien Dersy (Harvard U. and IAFI, Cambridge),

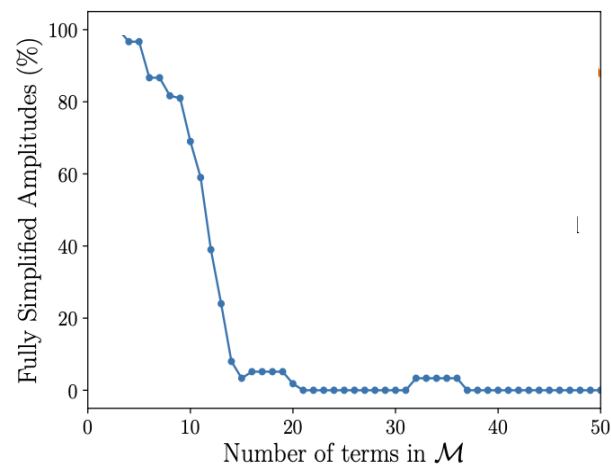
Matthew D. Schwartz (Harvard U. and IAFI, Cambridge) (Aug 8, 2024)

e-Print: 2408.04720 [hep-th]

Key insight:
Generate symbolic training
data by scrambling

train
neural network
to unscramble

It learns to simplify short expressions



Machine learning approach

[Cheung, Dersy. MDS 2024]

- Generate training data by “scrambling”

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Input:
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[15] \rightarrow $\frac{[14][35] - [13][45]}{[34]}$ Schouten

$\frac{-\langle 34 \rangle^2 [12]^3 [35] - \langle 34 \rangle^2 [12]^2 [15] [23]}{\langle 23 \rangle \langle 34 \rangle [13]^2 [35] - \langle 23 \rangle \langle 45 \rangle [13] [15] [35]}$ [25] \rightarrow $\frac{[12][35] + [15][23]}{[13]}$ Schouten

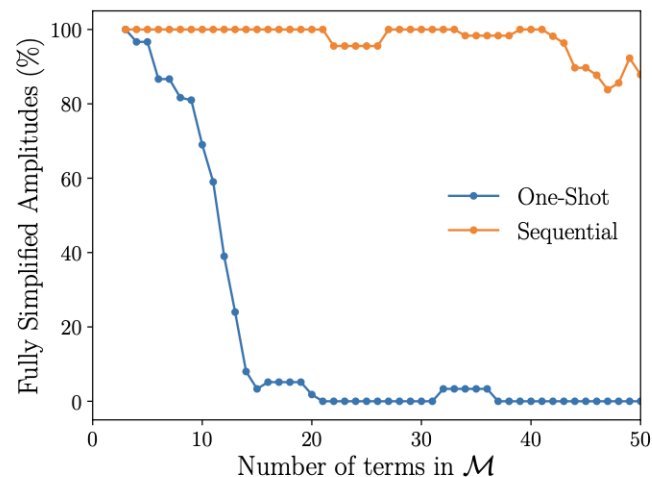
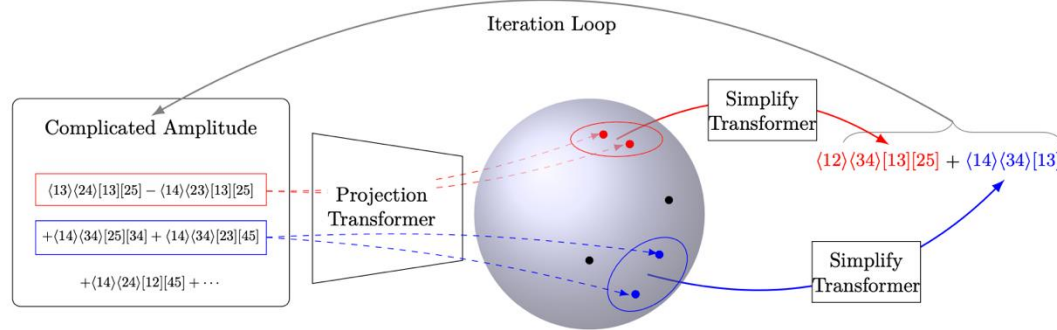
$\langle 24 \rangle \rightarrow \frac{\langle 45 \rangle [15] - \langle 34 \rangle [13]}{[12]}$ Momentum conservation

$\frac{\langle 34 \rangle^2 [12]^2 [25]}{\langle 23 \rangle \langle 34 \rangle [13] [35] - \langle 23 \rangle \langle 45 \rangle [15] [35]}$

Desired output:
$$\frac{\langle 34 \rangle^2 [12] [25]}{\langle 23 \rangle \langle 24 \rangle [35]}$$

It learns to simplify short expressions
and long expressions

Supplement with contrastive learning
(adapted from computer vision)



Example application: graviton-scalar scattering

The diagram illustrates the iterative simplification of a quantum circuit. The top half shows a large, dense expression of multi-qubit gates (e.g., CNOT, Toffoli) and single-qubit rotations (e.g., RZ, RX, RY) across 15 qubits. This expression is simplified iteratively, with each step showing a more compact representation. The bottom half shows the final simplified circuit, which is a sequence of gates: a multi-controlled NOT gate, followed by a multi-controlled NOT gate, then a multi-controlled NOT gate, and finally a multi-controlled NOT gate. The diagram is labeled "Iteration Loop" and "Projection Transformer".

$\mathcal{M} =$

• No known better

Learning the Simplicity of Scattering Amplitudes

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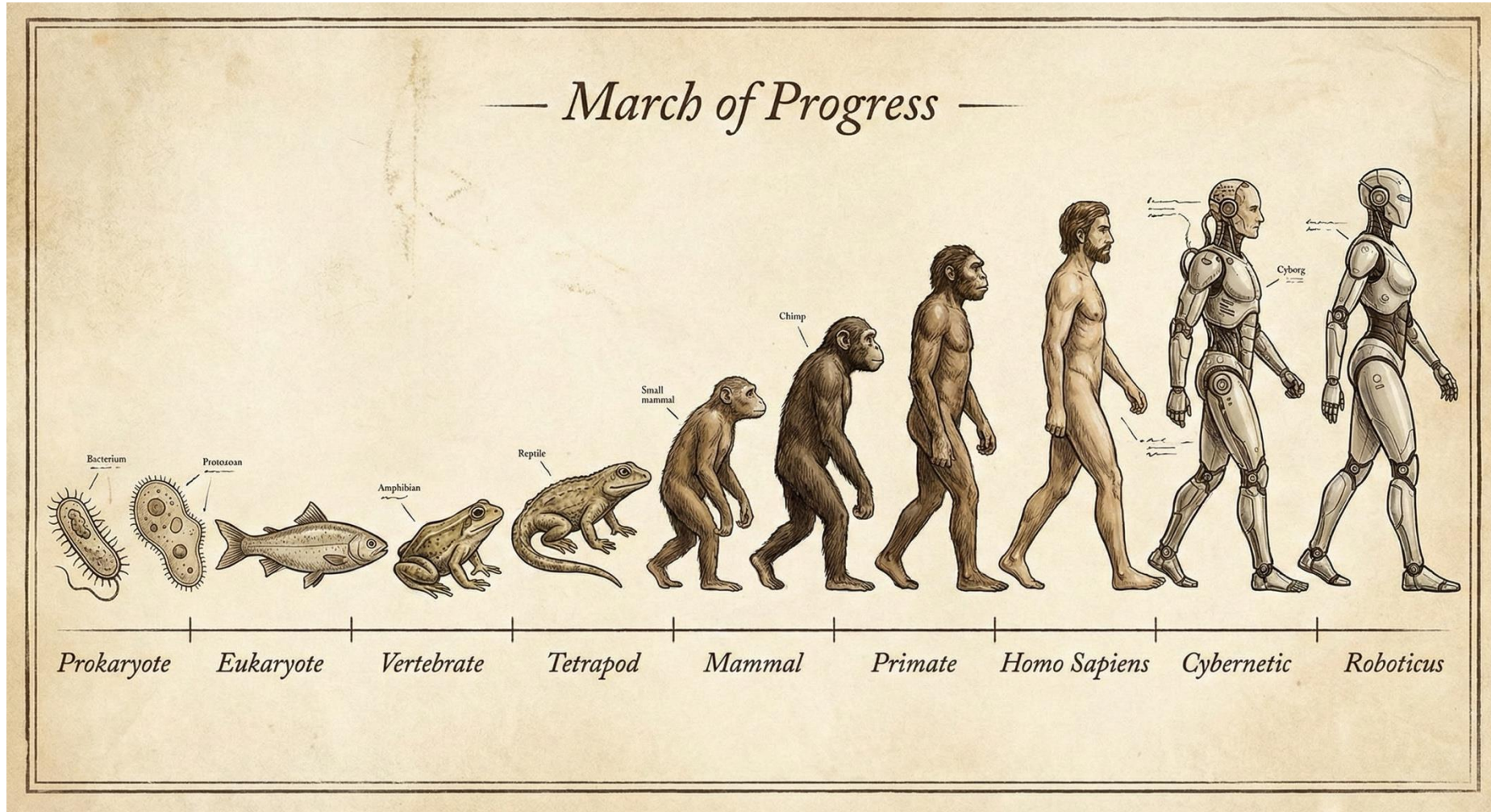
298 terms

simplifies to 2 terms

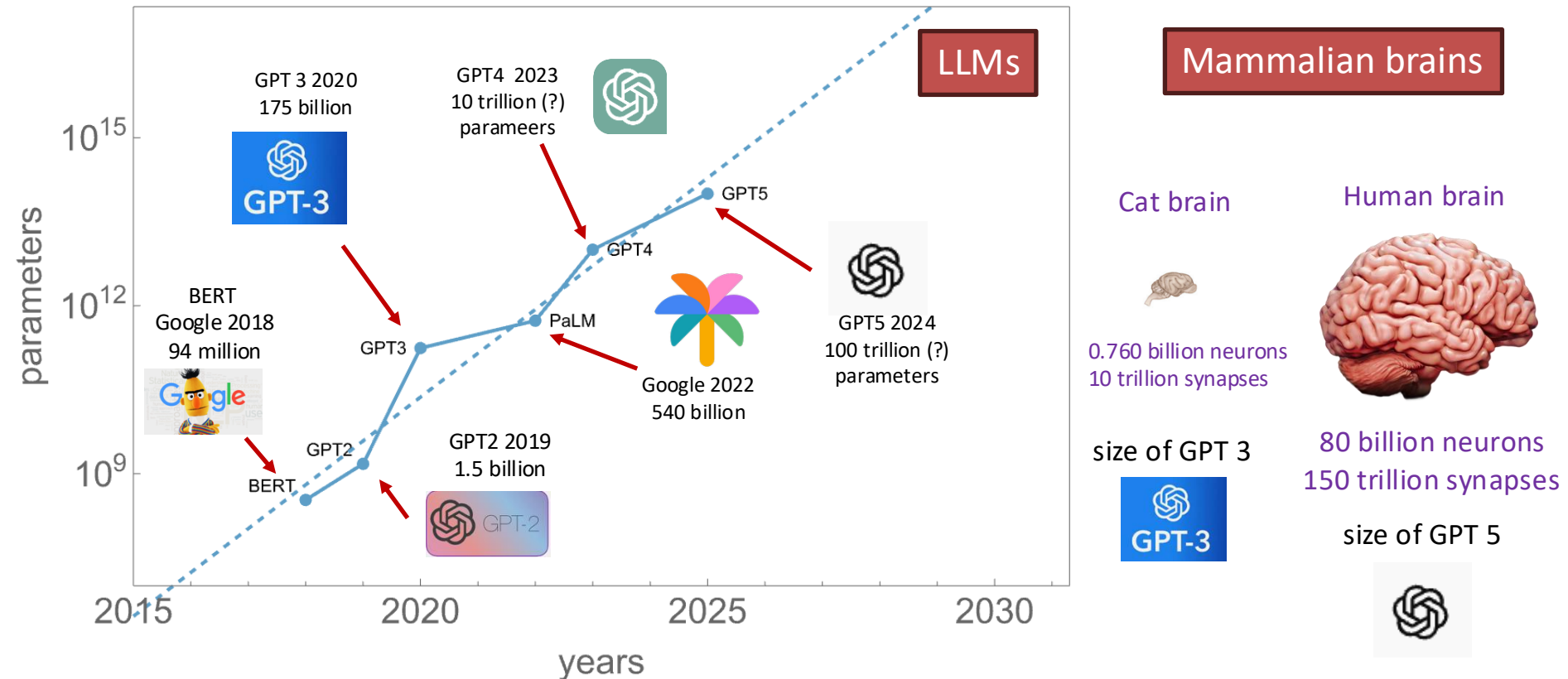
$$\overline{\mathcal{M}} = \frac{\langle 12 \rangle \langle 13 \rangle \langle 23 \rangle}{\langle 24 \rangle \langle 25 \rangle \langle 45 \rangle} \left(\frac{[14][35]}{\langle 14 \rangle \langle 35 \rangle} - \frac{[15][34]}{\langle 15 \rangle \langle 34 \rangle} \right)$$

- No known better way to do calculation
 - Can we (or ML) find deeper structure?

2. Evolution



Large Language Models are growing fast



- Exponential growth: LLMs are 10 times more powerful each year!
- # parameters in current LLMs (100 trillion) \approx # synapses in human brain (150 trillion)

Google Blueshift's Minerva (June 2022)

QUESTION Let \mathbf{D} be a matrix representing a dilation with scale factor $k > 0$, and let \mathbf{R} be a matrix representing a rotation about the origin by an angle of θ counter-clockwise. If

$$\mathbf{DR} = \begin{pmatrix} -7 & 1 \\ -1 & -7 \end{pmatrix},$$

then find k .

MODEL ANSWER We have

$$\mathbf{DR} = \begin{pmatrix} -7 & 1 \\ -1 & -7 \end{pmatrix}.$$

We also know that

$$\mathbf{D} = \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix}.$$

We have that $\mathbf{DR} = (\mathbf{DR})^T$, so we have

$$\begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} = \begin{pmatrix} k \cos \theta & k \sin \theta \\ -k \sin \theta & k \cos \theta \end{pmatrix}.$$

We have that $k \cos \theta = -7$ and $k \sin \theta = 1$. Thus,

$$k^2 \cos^2 \theta + k^2 \sin^2 \theta = 49 + 1 = 50.$$

This gives us that $k^2 = 50$, so $k = \sqrt{50} = \boxed{5\sqrt{2}}$. Final Answer: The final answer is $5\sqrt{2}$.

EVALUATION RESULT Correct

By Sep 2023: GPT 4 still struggles with math



To find $\frac{13217}{97}$, you divide 13217 by 97.

Upon division, you will find that $\frac{13217}{97} = 136$.

This means that 97 is a divisor of 13217, confirming that 13217 is not a prime number.

- 13217 is actually prime

```
In[1]:= FactorInteger[13 217]
```

```
Out[1]= {{13 217, 1}}
```

```
In[2]:= 
$$\frac{13\ 117}{97.}$$

```

```
Out[2]= 135.227
```

April 2025 (gpt 4o)

- LLMs become useful for research!

Equation from
arXiv:2402.19356

$$M(s) = \int d^2k \frac{\sqrt{k^2}}{(k+p)^2 + m^2} \left(\frac{k^2}{m^2}\right)^s = (1+x)^{s+1} B(s+2, -1-s) {}_2F_1\left(s+2, -1-s; 1; \frac{x}{1+x}\right).$$

Do the integral

Mathematica: **Fail**

Maple: **Fail**

Claude 2.7: **Fail**

Gemino 2.5 Pro: **Fail**

GPT 4o-mini high: **Success!**

can't even input
to Mathematica/Maple
in this form

Do this integral in polar coordinates. Just the angular integral and
simplify into a single radial integral

one often rewrites

$$M(s) = \frac{2\pi}{m^{2s}} \int_0^\infty dk \frac{k^{2s+2}}{\sqrt{((k+p)^2 + m^2)((k-p)^2 + m^2)}},$$

which is a single one-dimensional integral over k .

Then change variables to $y = k^2/m^2$ and $x = p^2/m^2$.

Putting everything together gives the single "radial" integral in y :

$$M(s) = \pi m \int_0^\infty dy \frac{y^{s+\frac{1}{2}}}{\sqrt{(y+x+1)^2 - 4xy}}, \quad x = \frac{p^2}{m^2}.$$

$$M(s) = B(-s-1, s+2) {}_2F_1(-s-1, -s-1; 1; -x),$$

. Equivalently, by the reflection formula one may write

$$M(s) = \frac{\pi}{\sin(\pi s)} {}_2F_1(-s-1, -s-1; 1; -x),$$

simpler form than in the paper!

Followup questions

where the the poles in s of this expression

for what range of x and s does the integral converge?

write python code to numerically verify your solution to the integral

- This is completely revolutionary for research
- These are the **worst** AI tools we will ever have

Current AI models can do *all* college-level physics

Problem from my Spring 2025 Statistical Mechanics final

Lithium-Ion batteries work by having lithium in both the anode and the cathode with a electrolytic barrier of around $\Delta\epsilon = 0.55\text{ eV}$ in between. The lithium can discharge when the circuit is closed and also thermally over the barrier. If a battery lasts for 20 hours at 10°C estimate how long it lasts in the sun at 40°C .

To estimate how long a lithium-ion battery will last at a higher temperature (40°C) compared to a lower temperature (10°C), assuming **thermal discharge over a barrier of $\Delta\epsilon = 0.55\text{ eV}$** , we can use the **Arrhenius equation**:

$$\text{Rate} \propto e^{-\Delta\epsilon/kT}$$

Where:

- $\Delta\epsilon = 0.55\text{ eV}$
- $k = 8.617 \times 10^{-5}\text{ eV/K}$ (Boltzmann constant)
- T is the absolute temperature in kelvin

Let:

- $T_1 = 10^\circ\text{C} = 283.15\text{ K}$
- $T_2 = 40^\circ\text{C} = 313.15\text{ K}$

Let R_1 and R_2 be the rates of discharge at T_1 and T_2 . Then:

$$\frac{R_2}{R_1} = \frac{e^{-\Delta\epsilon/kT_2}}{e^{-\Delta\epsilon/kT_1}} = e^{\Delta\epsilon\left(\frac{1}{kT_1} - \frac{1}{kT_2}\right)}$$

Calculate the exponent:

$$\frac{1}{kT_1} - \frac{1}{kT_2} = \frac{1}{8.617 \times 10^{-5} \times 283.15} - \frac{1}{8.617 \times 10^{-5} \times 313.15} \approx 41.07 - 36.91 =$$

Then:

$$\frac{R_2}{R_1} = e^{0.55 \times 4.16} \approx e^{2.29} \approx 9.87$$

So the **rate** of thermal discharge increases by a factor of ≈ 9.87 meaning the **battery life shortens by the same factor**.

If the battery lasts 20 hours at 10°C :

$$\text{Battery life at } 40^\circ\text{C} = \frac{20}{9.87} \approx 2.03\text{ hours}$$

✓ **Final Answer:**

The battery would last approximately **2 hours** in the sun at 40°C .

Correct!

Not only does it get the right answer, but it uses the right equations and shows its work

Nano-banana pro (Nov 2025)

Physics 222, Modern Physics, Exam 2

NAME _____

You are graded on your work, with partial credit where it is deserved.

Please be clear and well-organized in all your steps.

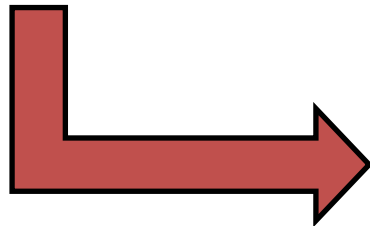
1. (15) Show that

$$\Psi(x,t) = e^{-ipx/\hbar} e^{-iEt/\hbar}$$

satisfies the time-dependent Schrödinger equation for a free particle

$$i\hbar \frac{\partial \Psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi(x,t)}{\partial x^2}$$

and obtain the energy E in terms of the momentum p .



Nano-banana

Physics 222, Modern Physics, Exam 2

NAME Alex Smith

You are graded on your work, with partial credit where it is deserved.

Please be clear and well-organized in all your steps.

1. (15) Show that

$$\Psi(x,t) = e^{-ipx/\hbar} e^{-iEt/\hbar} = e^{-i(px+Et)/\hbar}$$

satisfies the time-dependent Schrödinger equation for a free particle

$$i\hbar \frac{\partial \Psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi(x,t)}{\partial x^2}$$

and obtain the energy E in terms of the momentum p .

$$\begin{aligned} \text{LHS: } i\hbar \frac{\partial \Psi}{\partial t} &= i\hbar \frac{\partial}{\partial t} [e^{-i(px+Et)/\hbar}] \\ &= i\hbar (-i\frac{E}{\hbar}) e^{-i(px+Et)/\hbar} \\ &= -i^2 E \Psi = E \Psi \quad \checkmark \end{aligned}$$

$$\begin{aligned} \text{RHS: } -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} &= -\frac{\hbar^2}{2m} \frac{\partial}{\partial x} \left[\frac{\partial}{\partial x} e^{-i(px+Et)/\hbar} \right] \\ &= -\frac{\hbar^2}{2m} \frac{\partial}{\partial x} \left[\left(-\frac{ip}{\hbar} \right) \Psi \right] = -\frac{ip}{\hbar} \frac{\partial \Psi}{\partial x} \\ &= \left(-\frac{ip}{\hbar} \right) \left(-\frac{ip}{\hbar} \right) \Psi = -\frac{p^2}{\hbar^2} \Psi \end{aligned}$$

$$\begin{aligned} \frac{\partial^2 \Psi}{\partial x^2} &= \frac{\partial}{\partial x} \left[\left(-\frac{ip}{\hbar} \right) \Psi \right] = \left(-\frac{ip}{\hbar} \right) \frac{\partial \Psi}{\partial x} \\ \text{So, } -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} &= -\frac{\hbar^2}{2m} \left(-\frac{p^2}{\hbar^2} \right) \Psi \\ &= \frac{p^2}{2m} \Psi \quad \checkmark \end{aligned}$$

Set LHS = RHS:

$$E \Psi = \frac{p^2}{2m} \Psi$$

Since $\Psi \neq 0$,

$$\boxed{E = \frac{p^2}{2m}} \quad \text{Q.E.D.}$$

(b) (5) Is this wave traveling in the positive or the negative x direction? Explain.

The wave function is $\Psi(x,t) = e^{-i(px+Et)/\hbar}$.

The phase is $\phi = -\frac{(px+Et)}{\hbar}$.

For a point of constant phase, $\frac{d\phi}{dt} = 0$.

$$\frac{d}{dt}(px+Et) = 0 \Rightarrow p \left(\frac{dx}{dt} \right) + E = 0$$

$$\text{velocity } v = \frac{dx}{dt} = -\frac{E}{p}$$

Since $E = \frac{p^2}{2m} > 0$, and assuming $p > 0$ (momentum magnitude),

$$v = -\frac{E}{p} \text{ is negative.}$$

Therefore, the wave is traveling in the negative x direction.



Claude Code is amazing! (Jan 2026)

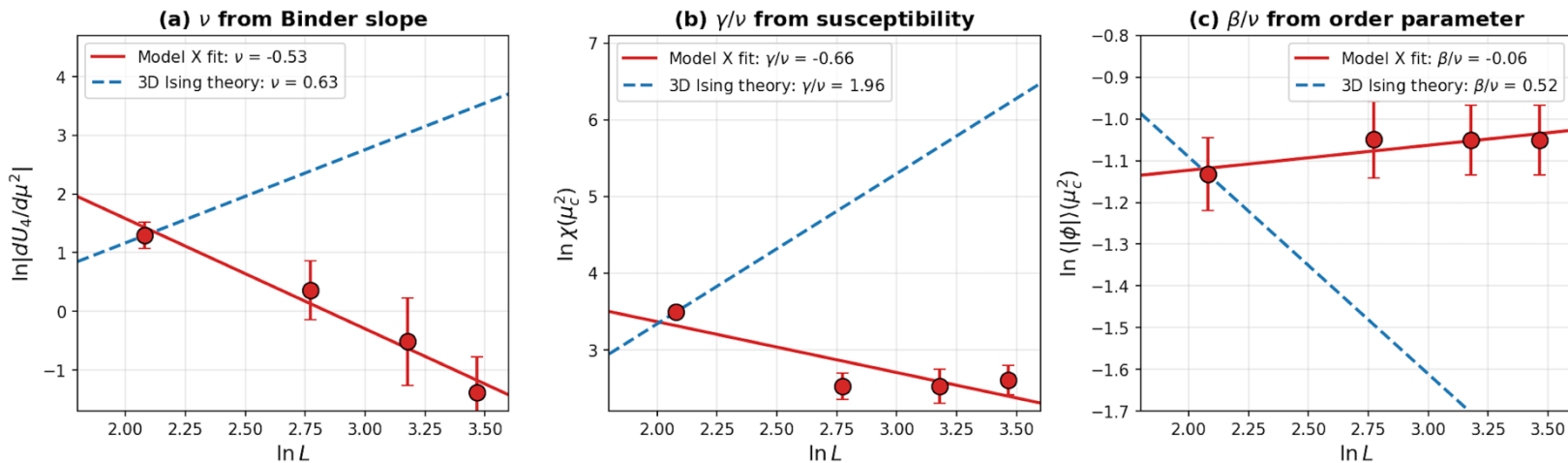
“Here is an action for a quantum field theory with 3 fields

$$S[\phi, \chi] = \int d^d x \left[\frac{1}{2} (\nabla \phi)^2 + \frac{1}{2} (\nabla \chi)^2 + \frac{\mu^2}{2} \phi^2 + \frac{\lambda}{4} \phi^4 + ig \chi \phi + \frac{if}{2} \chi \phi^2 + \frac{m^2}{2} \chi^2 \right]$$

I think it might flow to a novel CFT.

Try to find the critical point and compute the critical exponents”

Claude then set up code, ran the sims without intervention and gave me this

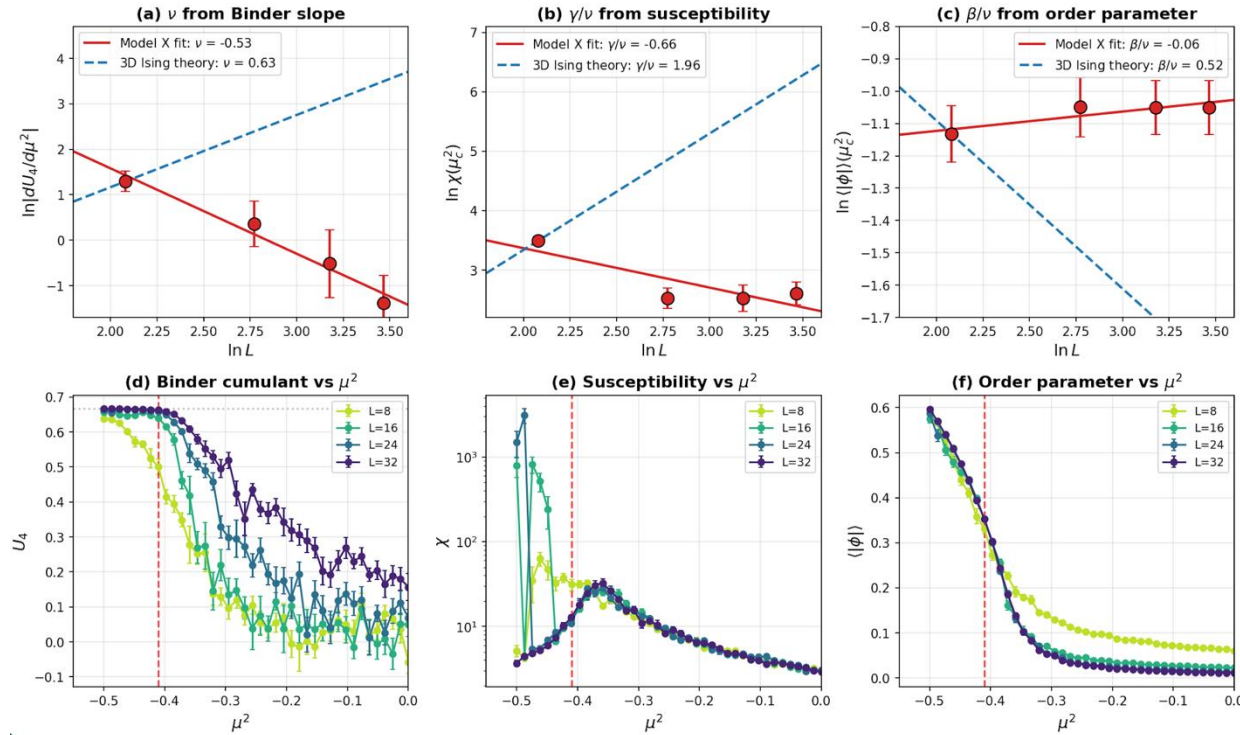


It seemed to find some interesting critical behavior, different from the Ising model

“Show me the distributions you are getting the exponents from”

Claude Code is amazing! (Jan 2026)

“Show me the distributions you are getting the exponents from”

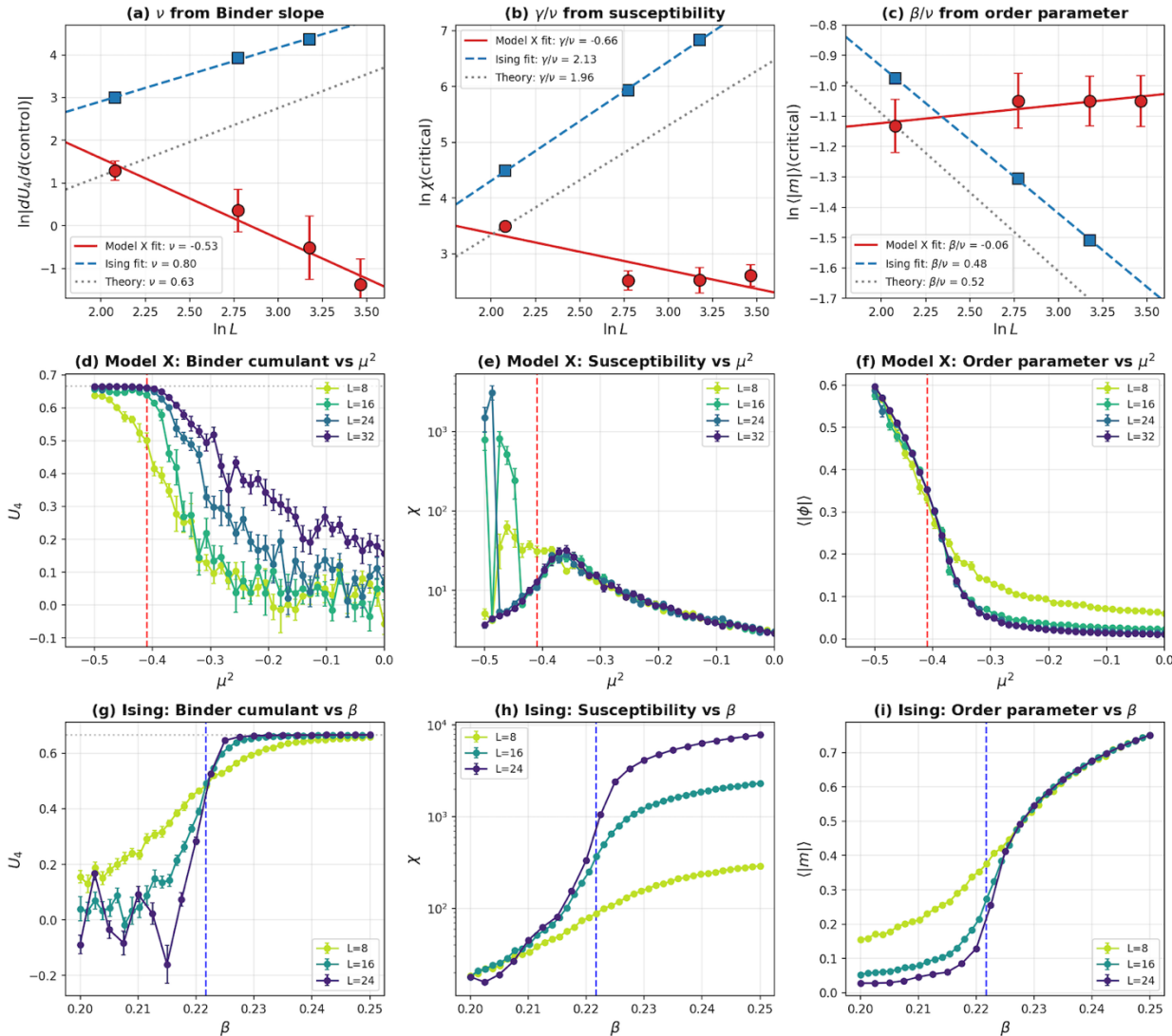


Claude Code (Jan 2026)

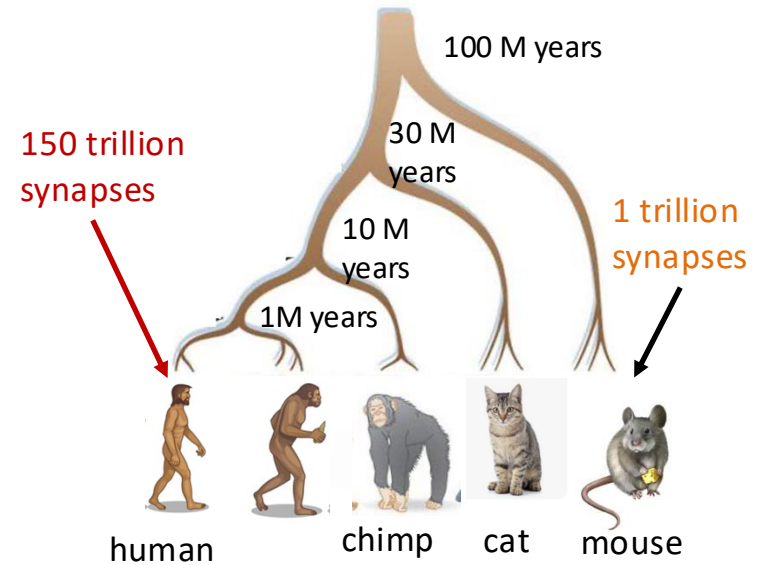
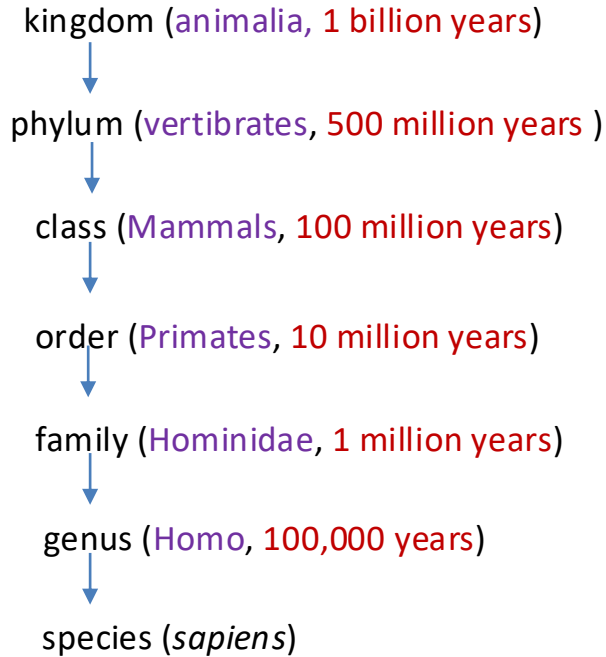
“Show me the distributions you are getting the exponents from”

“Run the 3D Ising model with exactly the same code as a cross-check”

Claude one-shot
simulated
the 3D
Ising model
correctly
with no human
oversight



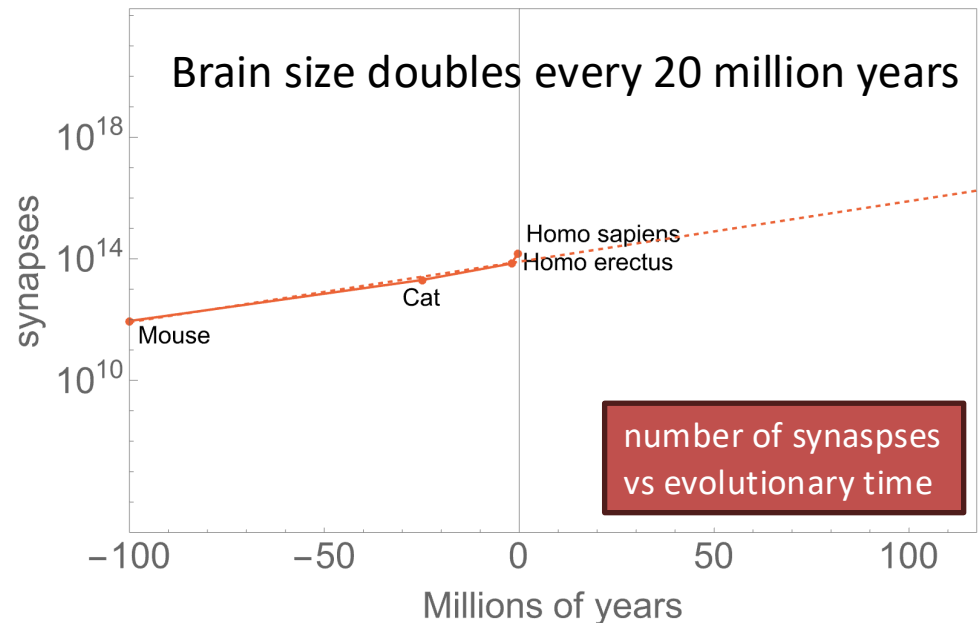
Human Evolution is Slow



- The universe is **only 15 billion** years old
- Only enough time to evolve kingdoms
 - What would evolve after **1 trillion years**?

We are not
the endpoint of intelligence

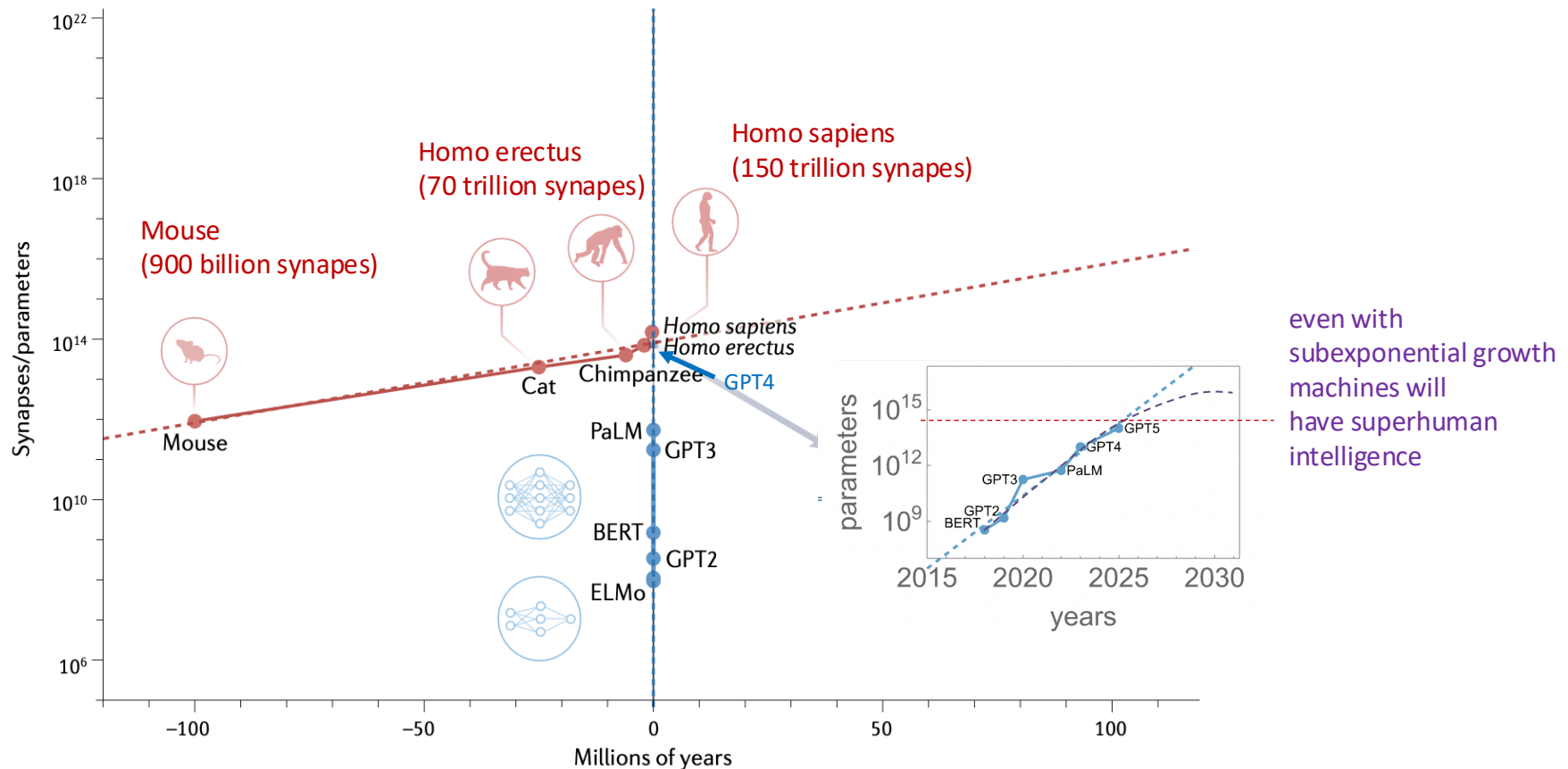
We are only the smartest things
to evolve on earth, so far



Machine vs. Biological intelligence

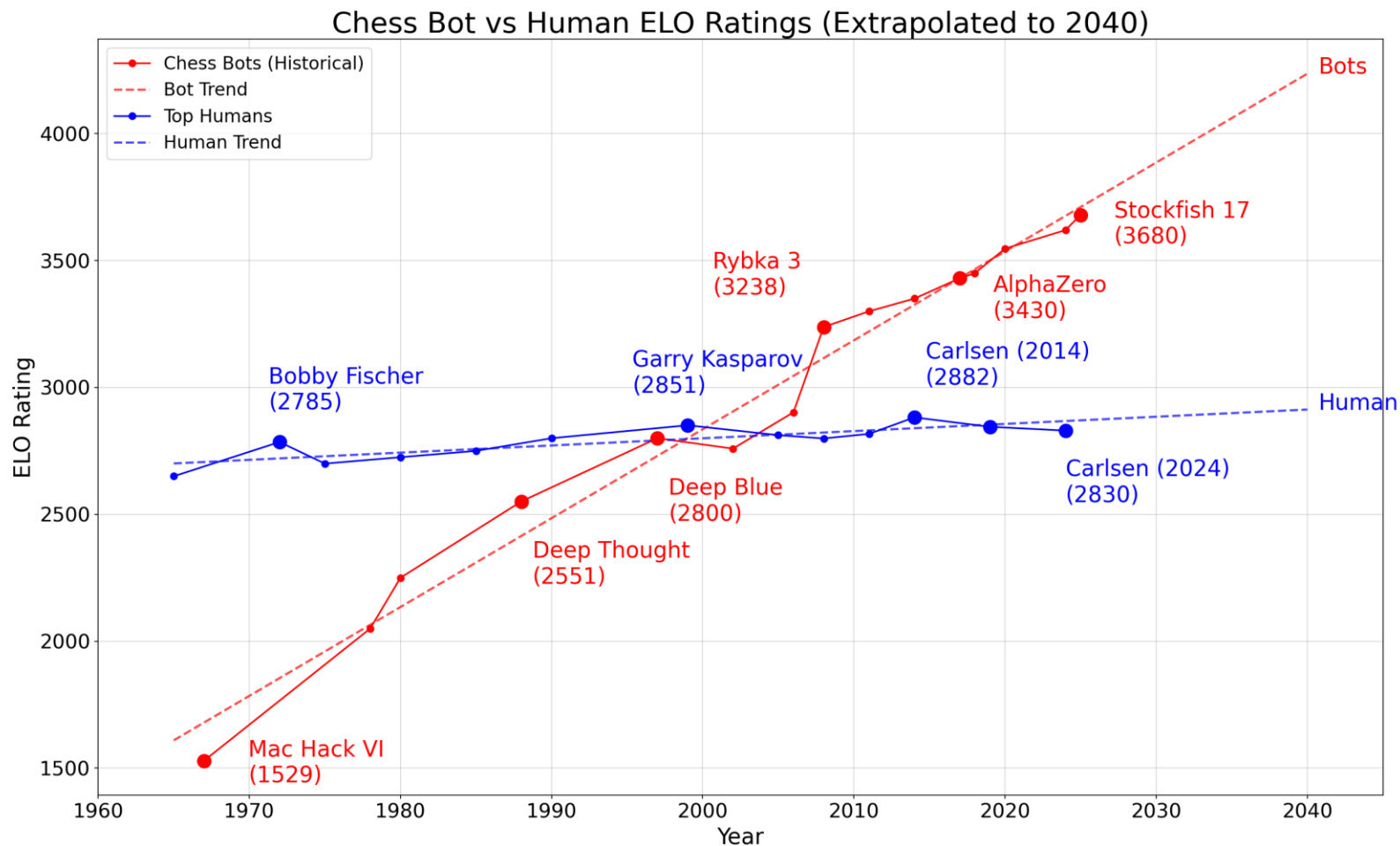
- Machine intelligence grows by a factor of 10 in 1 year
- Biological intelligence grows by a factor of 2 in 20 million years

MDS, "Should artificial intelligence be interpretable to humans?"
Nature reviews physics (2022)



- Both AI and biological intelligence grow exponentially
- Factor of 10^7 difference in exponent**
- Intersection time, when machines and biology have comparable "intelligence" is **now**

Chess ratings over time: human vs bot



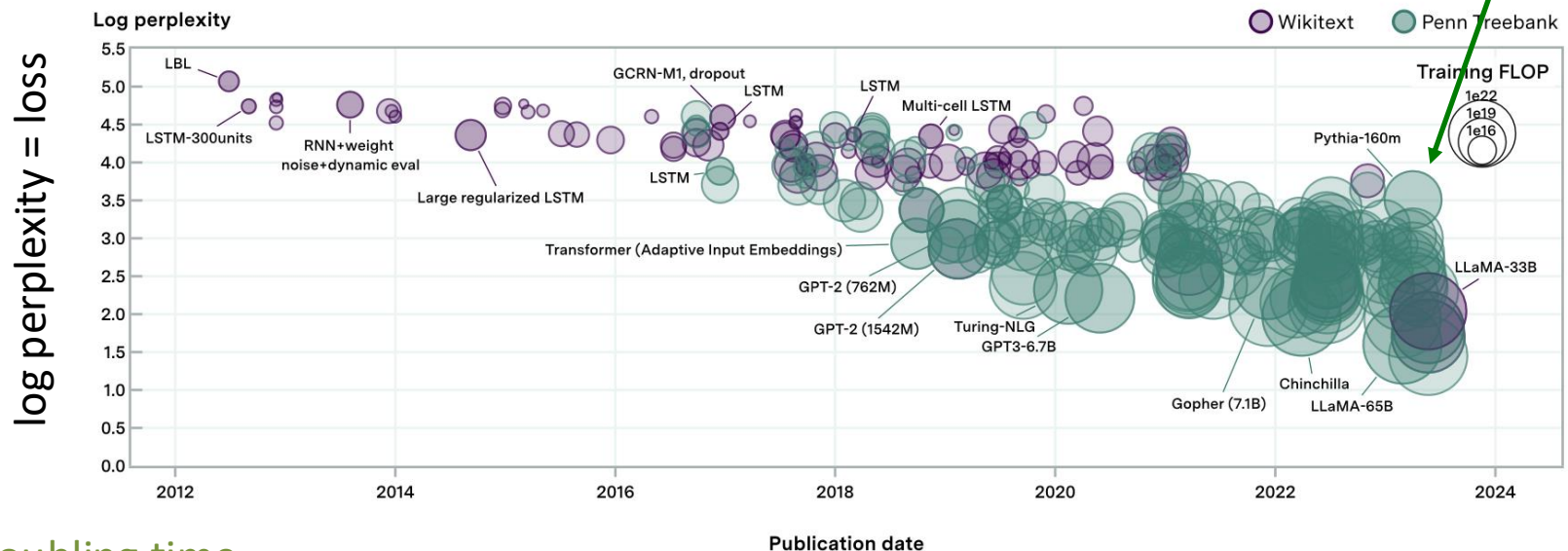
Will we run out of data to train on?

ALGORITHMIC PROGRESS IN LANGUAGE MODELS

Ho et al. arXiv:2403.05812

size is compute

How much of advance is algorithmic progress vs data + compute?



doubling time

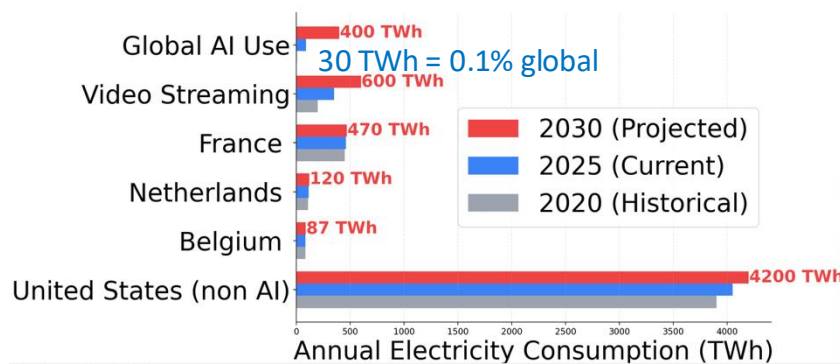


algorithmic doubling time = 6 to 14 months!

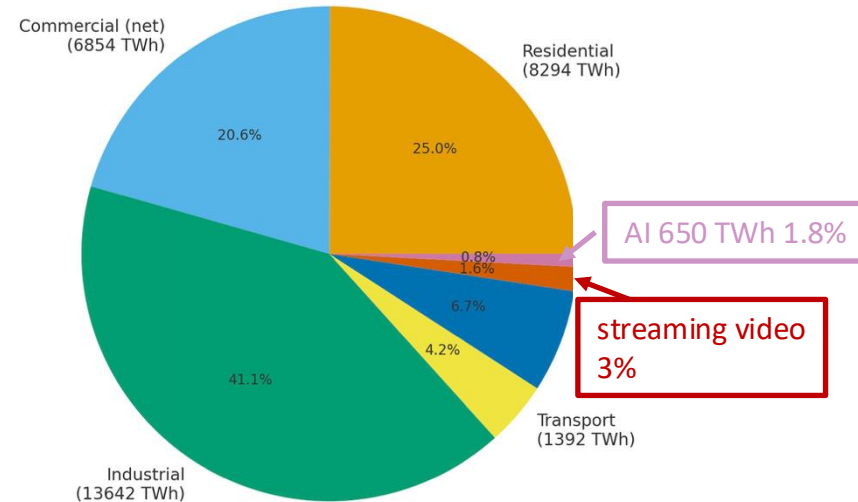
- controlling for data and network size
- algorithms will continue to get better, especially when written by AI

Will we run out of energy?

Energy consumption (30k TWh global)



2030 projections (36k TWh)



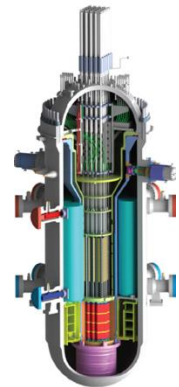
By 2030 AI may use as much energy as France

- 2% of global energy budget
- **This is a lot of energy!**
- Data centers also requires a lot of water for cooling

Will frontier labs promote alternative energy?

- AI companies investing heavily in
 - **Fission**: Small Modular Reactors
 - **Fusion**: Helion, Zap fusion, Pacific Fusion etc. (>\$1B invested)
 - **Geothermal**: growing interest and investment
- If AI does the work of 10 engineers
 - How much energy do 10 engineers use to do the same work?
- Why no pushback about streaming video? Air conditioning?

SMR



But physics requires creativity!

Torrence Test of Creative Thinking (1960)

- How many ways can you think to use a water bottle?
- Suppose you could be invisible for a day. What problems might that create?

Creativity fallacies

- Anthropocentric bias
(creativity is by definition human)
- No True Scotsman (moving goalposts)
- Argument from ignorance
"Obviously they are not creative."
End of conversation"

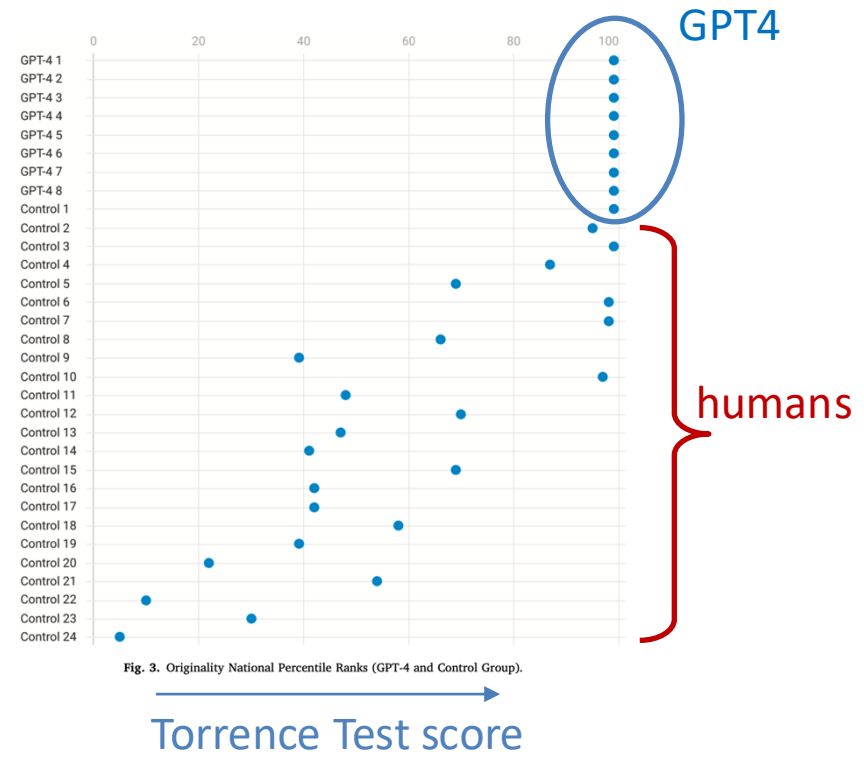
Article | [Open access](#) | Published: 10 February 2024

The current state of artificial intelligence generative language models is more creative than humans on divergent thinking tasks

[Kent F. Hubert](#) , [Kim N. Awa](#) & [Darya L. Zabelina](#) 2024

[Scientific Reports](#) 14, Article number: 3440 (2024) | [Cite this article](#)

11k Accesses | 252 Altmetric | [Metrics](#)

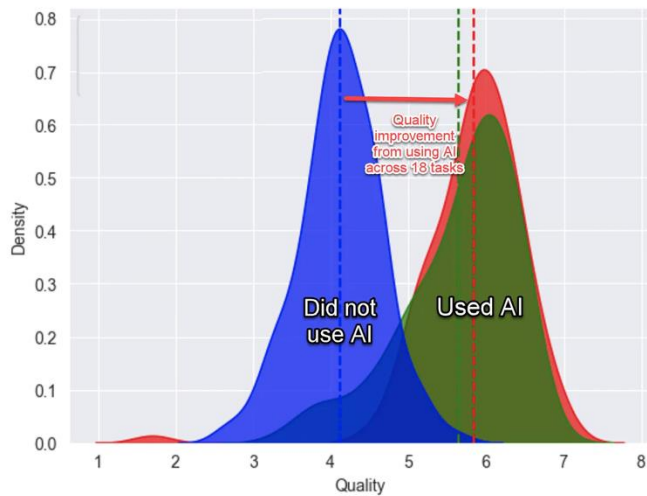


GPT4 more creative than 99% of humans

Augmented intelligence: LLMs help us thrive

Dell'Acqua et al, “Navigating the Jagged Technological Frontier”
(Harvard Business School, 2023)

Can LLMs help consultants?

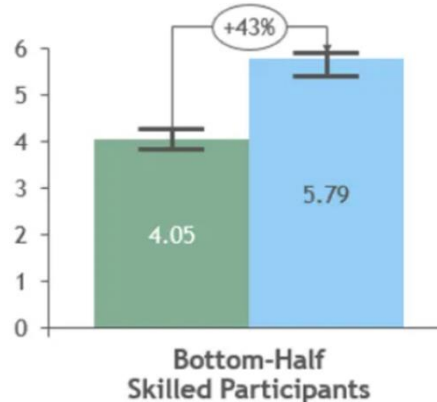


Distribution of output quality across all the tasks. The blue group did not use AI, the green and red groups used AI, the red group got some additional training on how to use AI.

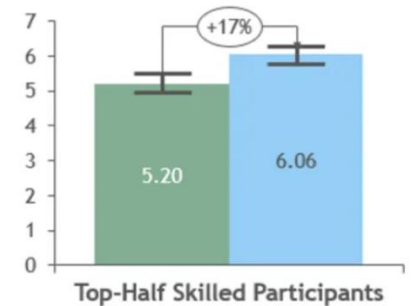
Yes!
By a lot!

AI is a “skill-leveler”

bottom half improved 43%

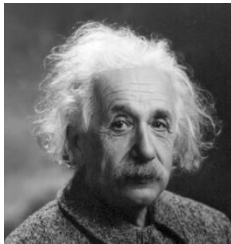
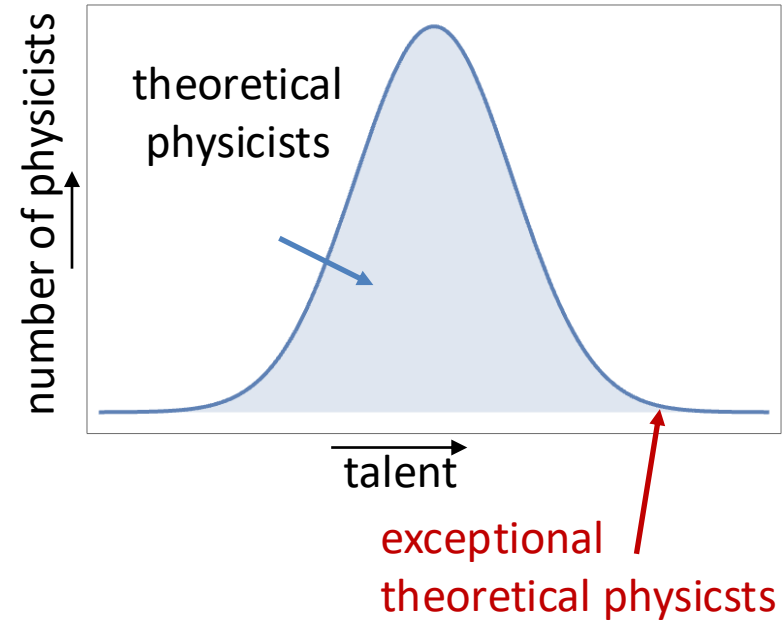


top half improved 17%

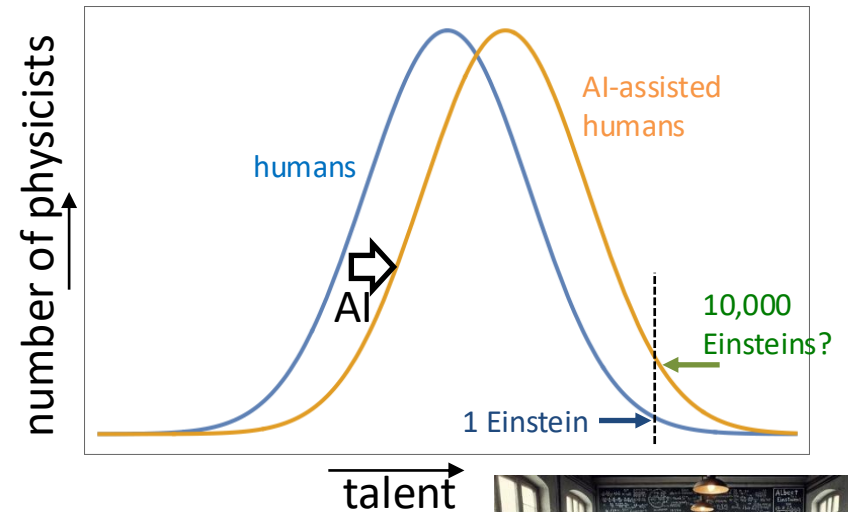


- Mediocre consultants using AI become as good as the best consultants
- The best consultants also improve

10,000 Einsteins



Can AI be a skill-leveler for theoretical physics?



End-to-end #AI4math is here

AlphaProof

Thu 13 November 2025

- Uses LEAN: language to formalize proofs
- Reinforcement learning to find proofs
 - Same approach as AlphaZero for chess



Harmonic

```
example (x : Nat) : 0 < match x with
| 0    => 1
| n+1 => x + n := by
grind
```

Article | Published: 12 November 2025

Olympiad-level formal mathematical reasoning with reinforcement learning

Erdős problems

- 1535 unsolved problems by Erdős, written 1930-1990
- 580 Solved Pre-2024 (pre #AI4Math)
- Oct 2025: Open AI solves 15 erdos problems
- Nov 30, 2025: Harmonic solves #124
 - 6 hours, with LEAN.
- Dec 1, 2025: Harmonic solves #481
- Jan 7, 2026: GPT-5.2 Pro + Harmonic #728
- Jan 11, 2026 # 397
- Jan 29, 2026: thirteen more solved (#654, #1051, ...) with Gemini 3.0

Problem #124

For any set of integers $d_i \geq 3$ satisfying

$$\sum \frac{1}{d_i-1} \geq 1,$$

can every natural number be expressed as a sum of distinct powers of these d_i ?

End-to-end physics is coming

sakana.ai (August 2024)

The AI Scientist: Towards Fully Automated Open-Ended Scientific Discovery

August 13, 2024

 **first principles** (Feb 2025)

 **AI to Explore the Laws of Nature**

AgentRxiv: Towards Collaborative Autonomous Research
Samuel Schmidgall, Michael Moor (March 2025)

The AI Cosmologist I: (April 2025)
An Agentic System for Automated Data Analysis
Adam Moss

Meet Denario — An AI Assistant for Every Step of the Scientific Process
Simons Foundation (May 2025)

 **periodic labs** (Sep 2025)

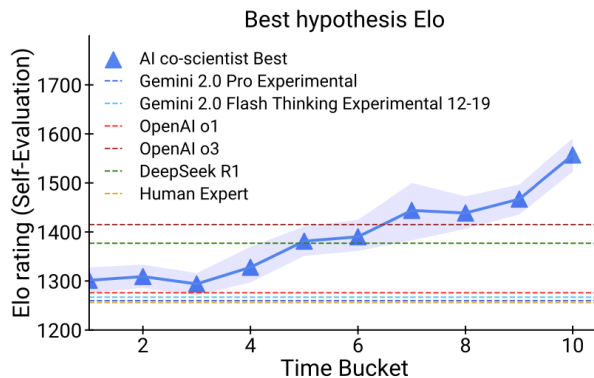
Today, we introduce Periodic Labs. Our goal is to create an AI scientist.

- Automated materials design

Google (Feb 2025)

Towards an AI co-scientist

- Generates novel testable hypotheses



Google DeepMind

(May 2025)

2025-5-14

AlphaEvolve: A coding agent for scientific and algorithmic discovery

- Broke a 56-year-old record in matrix multiplication
- Improved on the “kissing problem”

Needs another year or so
(in my opinion)

3. The future



Image: Nano Banana Pro 2025

My slide from 2023

high school

- **19%** of high school graduates in the US **cannot read**

early college

- **solve standard problems using standard formulas**

- learn computational tools

late college

- master abstract concepts
- **solve difficult but previously solved problems**

graduate school

- tackle difficult unsolved problems
 - **invent** or adapt appropriate **tools**
 - **create** and solve **toy problems** to build intuition
 - simplify enough until solvable
- arrive at the boundaries of human understanding

professor

- write grants, teach, advise students, give colloquia
- **find solvable problems** -- not too easy, not too hard
- nudge the boundaries of human understanding

Machine learning

2021

2023

2025?

current day: about on schedule!

2027?

2029?

when i wrote the slide

Predictions for the future

1. Rapid increase in AI-assisted research
2. Publication crisis
3. Education crisis
4. Catharsis

Vibe Coding

Collins Dictionary

Word of the Year
2025

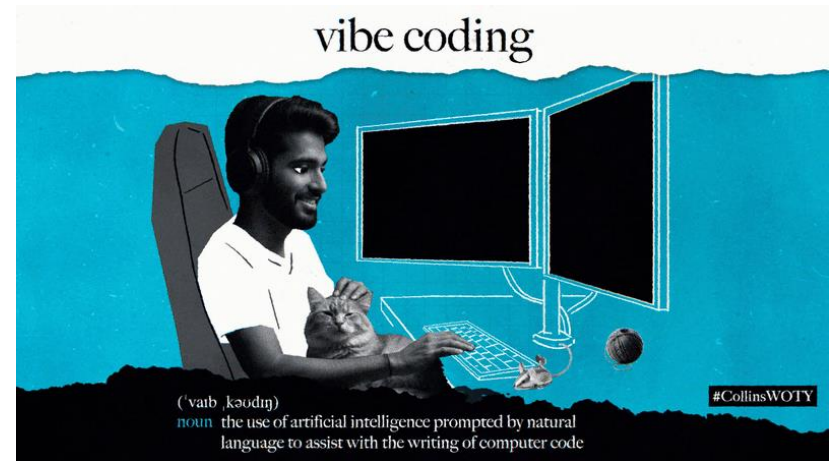
#CollinsWOTY



Andrej Karpathy

@karpathy

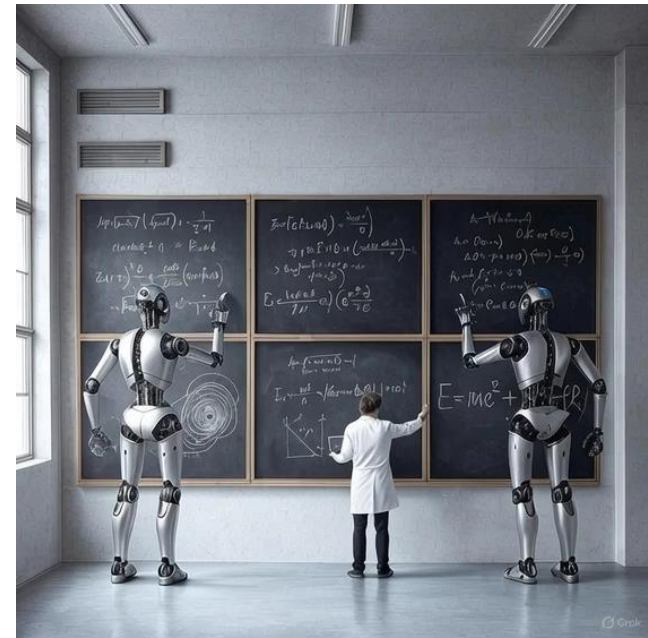
6:17 PM · Feb 2, 2025 · 5.1M Views



There's a new kind of coding I call "**vibe coding**", where you fully give in to the vibes... and **forget that the code even exists**. It's possible because the LLMs ... are getting too good.... When I get error messages I just copy paste them in with no comment, usually that fixes it... **The code grows beyond my usual comprehension ...**

Vibe Physics

- Ask LLM to suggest approaches to a problem
- Pick an approach, ask it to do some calculations
- Ask it to suggest some toy models
- Ask it to compute various things in the models
- Have it generate figures, write the paper, etc.



Schwartz, author of a leading QFT textbook, posts a theory paper generated by AI in 2 weeks

Resummation of the C-Parameter Sudakov Shoulder
Using Effective Field Theory



A_Decemberist • 8d ago

People who treat this as slop need to start thinking more carefully. AI is a tool, and leading researchers in math and physics are experimenting for how to best use it. As others have pointed out, the use of these LLMs by leading researchers is different and much more nuanced than how ordinary people use it.

There's a legitimate risk that we are going to have a kind of epistemic pollution when these tools are used much less carefully by casual users, but it doesn't mean that every paper done with LLMs is thereby slop.

↑ 58 ↓

collinear effective theory, we derive a factorization theorem involutions specific to the C-parameter measurement, in which soft radiation is collinear in transverse momentum. This quadratic structure explains the leading order. We compute all ingredients at one loop, validate against present matched NLL+NLO results. Unlike thrust and heavy-ion collisions, the C-parameter has no Sudakov–Landau pole, making momentum-space resummation calculations, numerical analysis, and manuscript preparation were done by an AI assistant developed by Anthropic, working under physicist supervision.

Author Contributions

M.D.S. conceived and directed the project, guided the AI assistant's calculations. Claude Opus 4.5, an AI research assistant developed by Anthropic, performed calculations including the SCET factorization theorem derivation, event generation, Monte Carlo simulations, numerical analysis, figure generation, and manuscript preparation. The work was conducted using Claude Code, Anthropic's agentic coding tool. M.D.S. is fully responsible for the scientific content and integrity of this paper.



danthem23 • 8d ago

That's crazy. But it's not what you think. You need to be a prestigious physicist to be able to guide it the right way and also know when it is saying garbage. A random guy can't take Claude and expect the paper to be good. It's like how a professional race car driver can do amazing things in a regular car but you can't.

⊖ ↑ 140 ↓



kzhou7 OP • 8d ago

Indeed, the people on [r/LLMPhysics](#) have access to exactly the same tools, yet their output is awful.

↑ 93 ↓

Vibe physics takaways

Claude is an **amazing** first or second-year graduate student

- Understands *all* the basics. I mean **ALL**.
 - Can do algebra, calculus, algebraic geometry, etc. efficiently and correctly
 - Can code in any programming language unsupervised
- Instead of 2 weeks/task it's 2 minutes
- **Instead of 2 years for a project it's 2 weeks**

What Claude is **bad** at

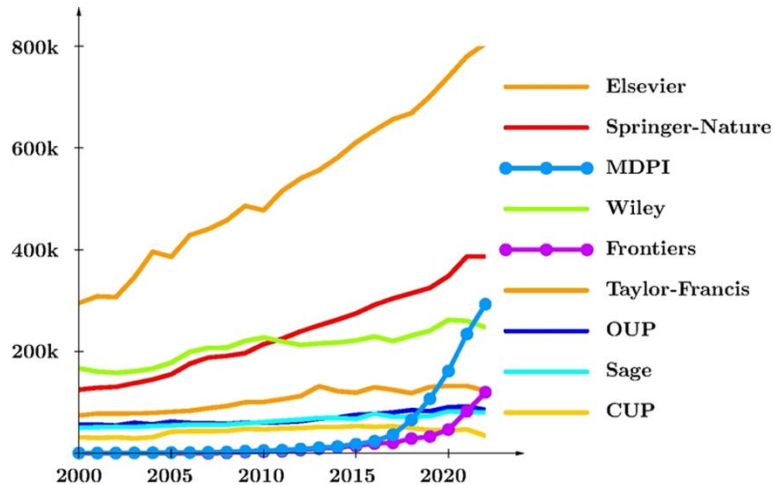
- End-to-end science
 - **It requires constant supervision and redirection**
- Being honest – it lies to make you happy
- Knowing when to stop – it finds one error then stops
- Deep reasoning
 - **it can only handle small steps**
 - It loses direction easily
- Plot aesthetics – axis labels, legends, etc.

Total Claude sessions	270
Messages exchanged	51,248
Input tokens	~27.5M
Output tokens	~8.6M
Estimated API cost	~\$1,056
Draft versions	110
CPU hours for simulations	~40
Human oversight time	~50–60 hours

2. Publication crisis

Excessive growth in the number of scientific publications

(Oct 2024)
Ouvrir la science !



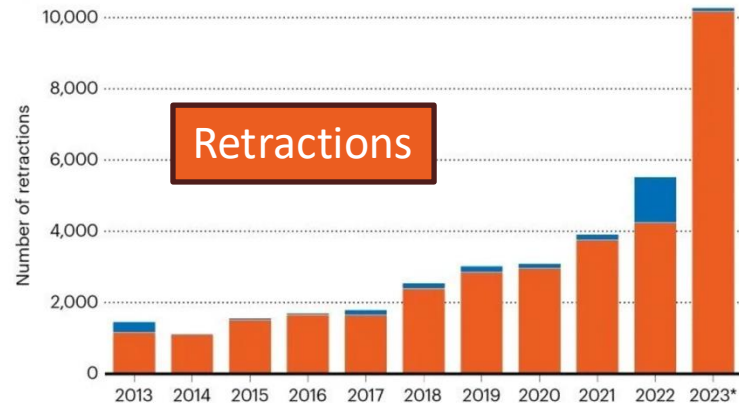
NEWS | 12 December 2023

More than 10,000 research papers were retracted in 2023 – a new record

A BUMPER YEAR FOR RETRACTIONS

Retraction notices in 2023 have passed 10,000, largely because of more than 8,000 retractions by Hindawi.

Journal articles Conference papers



©nature

*As of 8 December 2023

NEWS | 27 November 2025 | Correction [01 December 2025](#)

Major AI conference flooded with peer reviews written fully by AI

- 21% of 75,800 peer reviews at ICLR 2025 generated by AI

AI writes, AI reviews



Exponential Growth

- AI tools have made manuscript generation 2x or 3x faster
 - Less time and thought, full of mistakes
- Reviewers can't keep up, and don't want to sift through AI slop

The crisis

- Burnout
- Refusal to review
- Rubber stamping bad science



Why do we need publications if people don't write or read them?

| THE END OF THE JOURNAL

THE "PAPER" IS A FOSSIL

The concept of a "Journal Issue" is a relic of the printing press. It batches information arbitrarily.

In a digital, AI-native world, knowledge is a **stream**, not a batch. The static PDF, frozen in time, is no longer a valid container for truth.



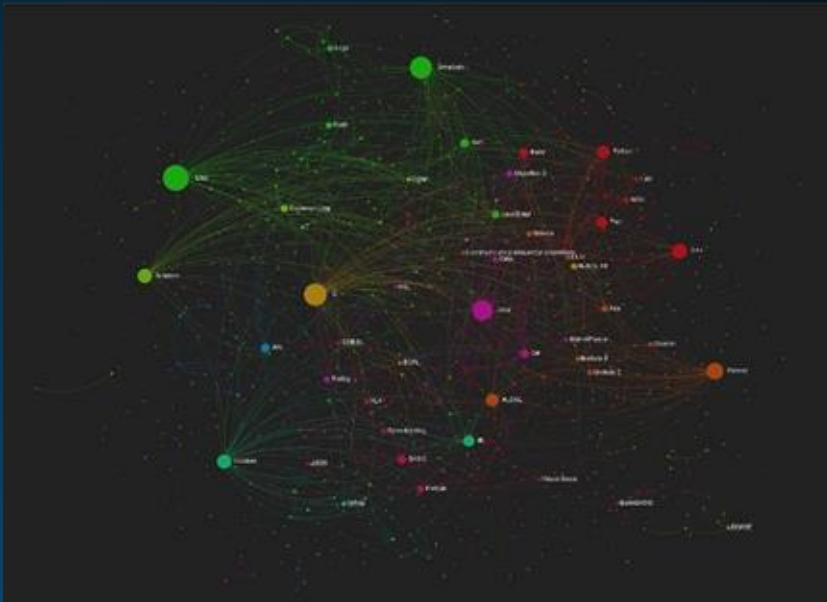
CODE IS THE NEW PAPER

For AI and Comp-Bio, the "Paper" is often just an advertisement for the Repo.

- **Hugging Face > ArXiv:** Researchers look for the model weights first, the description second.
- **Executables:** Papers like *ColabFold* allow users to run the science in the browser. Static PDFs cannot compete with interactive truth.
- **Zenodo:** Massive growth in DOI-minted datasets. The *data* is becoming the citable unit.



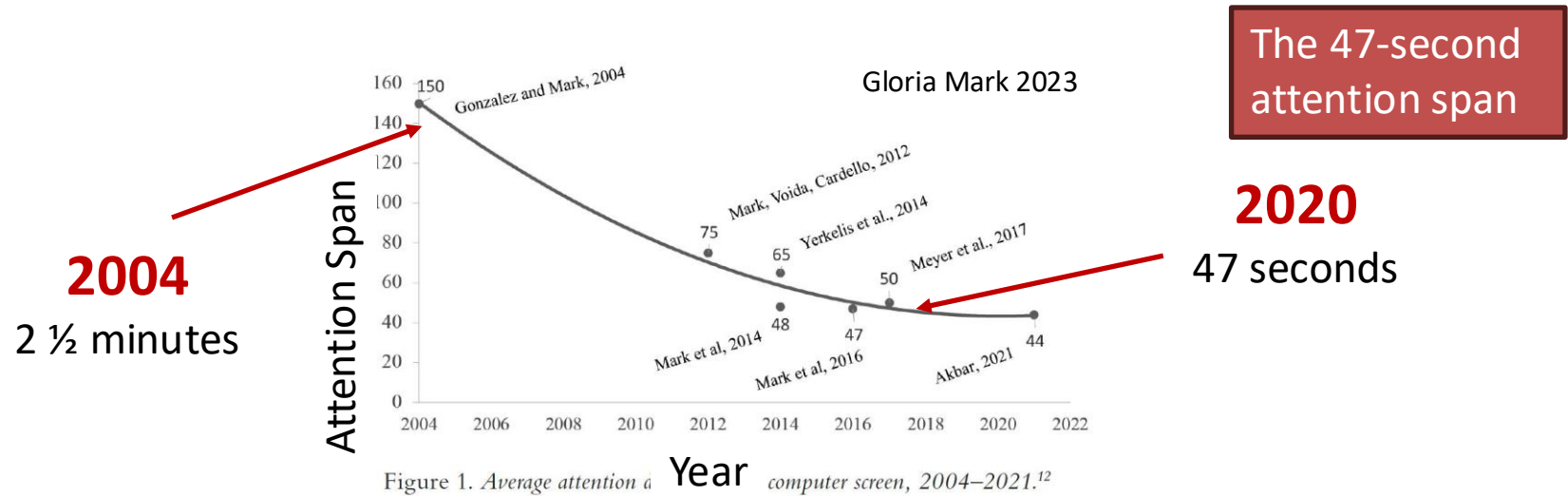
THE LIVING KNOWLEDGE GRAPH



Dynamic Truth: Instead of static PDFs, scientists contribute nodes to a global Knowledge Graph.

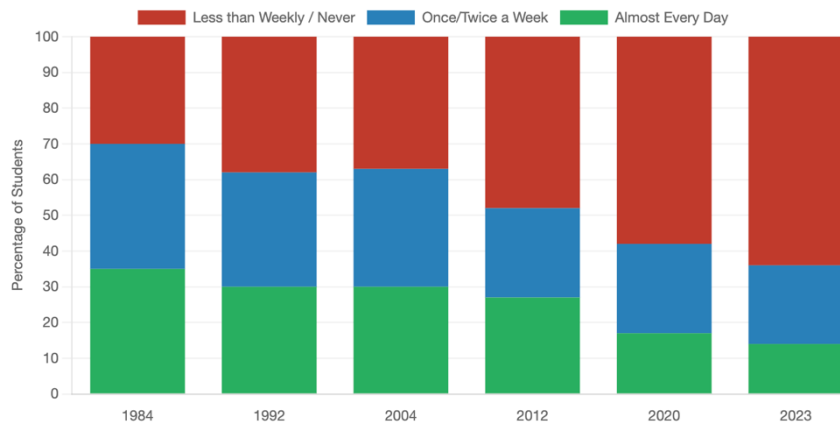
- ✓ **Live Updates:** If a method is refuted, every "paper" using it is flagged automatically.
- ✓ **AI Synthesis:** You don't read papers. You ask the Graph: "What is the consensus on protein X?" and AI generates a summary from the raw data nodes.

2. Education crisis *before* AI



Frequency of Reading for Fun (13-Year-Olds)

The shift from daily readers to non-readers (1984–2023)



Source: National Center for Education Statistics (NCES), NAEP Long-Term Trend Assessment

Features / Teaching

For whom the book tolls

How declining reading levels are reshaping the way universities teach.

September 24, 2025

“There’s no way that I could assign the amount of reading today.”

Students don’t read anymore

Education Crisis with AI

HIGHER EDUCATION

Everyone Is Cheating Their Way Through College ChatGPT has unraveled the entire academic project.



By James D. Walsh, *Intelligencer* features writer

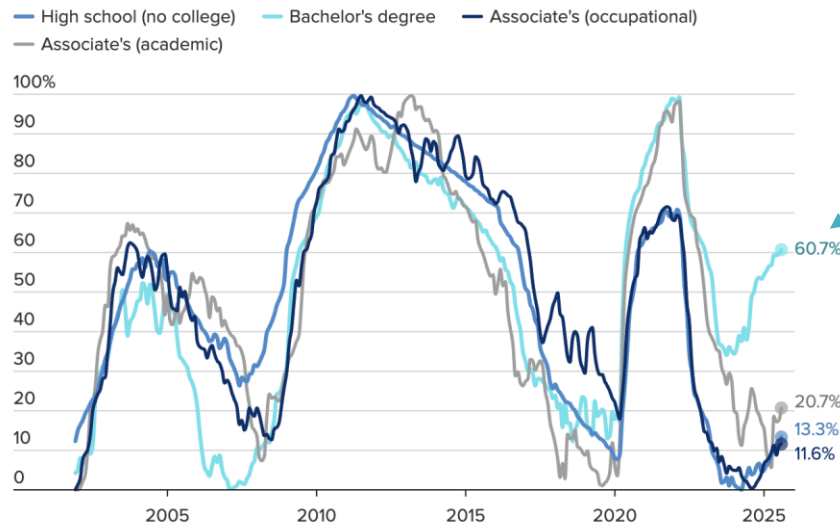
MAY 7, 2025

NEW YORK
MAGAZINE

<https://nymag.com/intelligencer/article/openai-chatgpt-ai-cheating-education-college-students-school.html>

Relative unemployment for younger U.S. workers by education level

24-month moving average | Dec. 2001–Aug. 2025

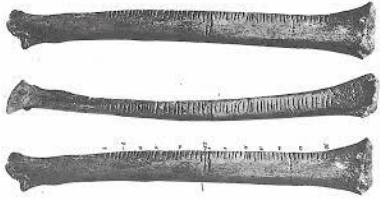


Relative unemployment is diverging for workers with bachelor's degrees

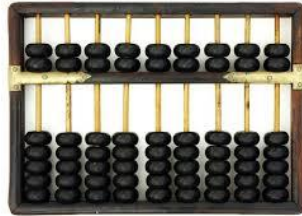
- Students aren't learning
- Students can't get jobs

What is worth learning?

Arithmetic:



tally bones
(20,000 BC)



abacus
(2,000 BC – 1500 AD)



slide rule
(1620-1970)



calculators
(1970-2022)



Generative AI
(2023 +)

Programming:

2022

everybody must learn to code!



2026

nobody needs to know how to code!



The future of education

Technology-induced crisis in education accelerating



Bad



Worse

Technology to the rescue?

1. One-on-one tutoring is very effective

- Can adapt to students needs
- Efficient use of student time
- I am learning faster than ever in my life

2. Teacher's aid

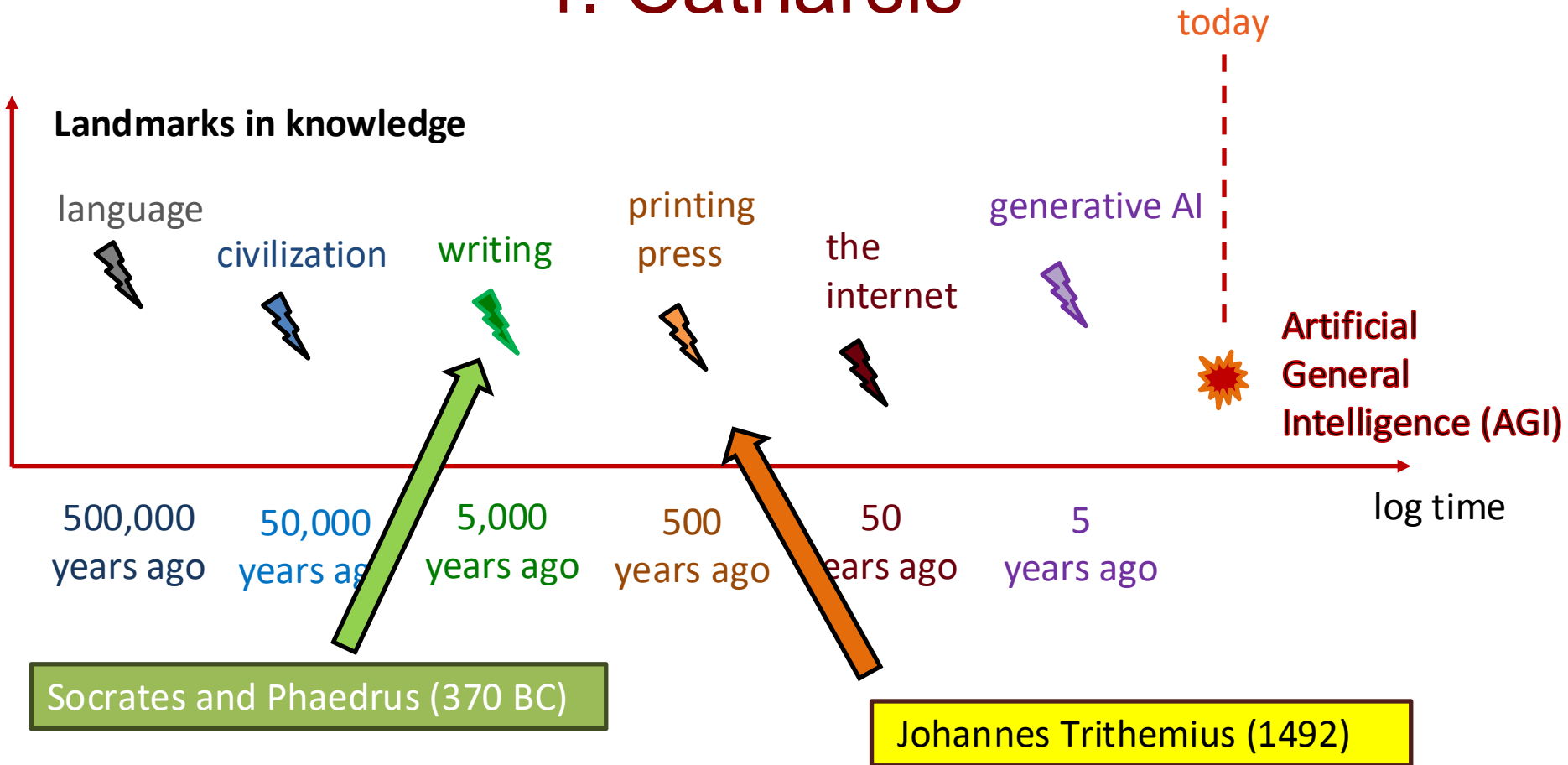
- AI can generate individualized problem sets
- AI can generate syllabi, lecture notes, transcriptions
- AI can grade students and assess interactively

3. Guide-on-the-side: teacher gives context, inspiration and motivation

Achievement Distribution for Students



4. Catharsis



And it is *not true wisdom* that you offer your disciples, but *only the semblance of wisdom*, for by telling them of many things without teaching them you will make them seem to know much while for the most part they know nothing.

"The printed book is made of paper and, like paper, will quickly disappear. But the scribe working with parchment ensures lasting remembrance for himself and for his text"

4. Catharsis




And it is *not true wisdom* that you offer your disciples, but *only the semblance of wisdom*, for by telling them of many things without teaching them you will make them seem to know much while for the most part they know nothing.

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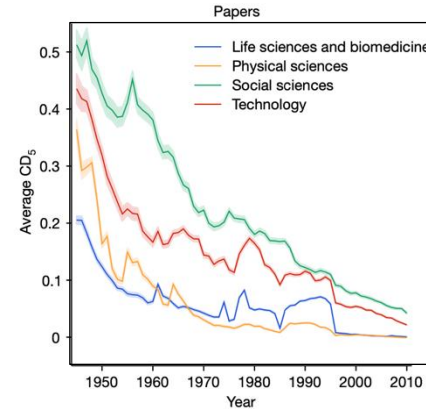
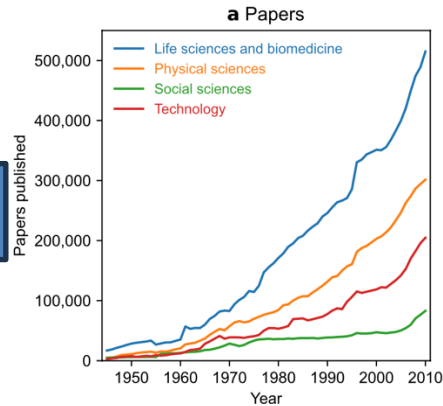
Let's be honest: theoretical physics is struggling

Article | Published: 04 January 2023

Papers and patents are becoming less disruptive over time

[Michael Park](#), [Erin Leahey](#) & [Russell J. Funk](#) 

more and more papers are written



the papers are less and less innovative

Maybe the problems are just too difficult (for us)

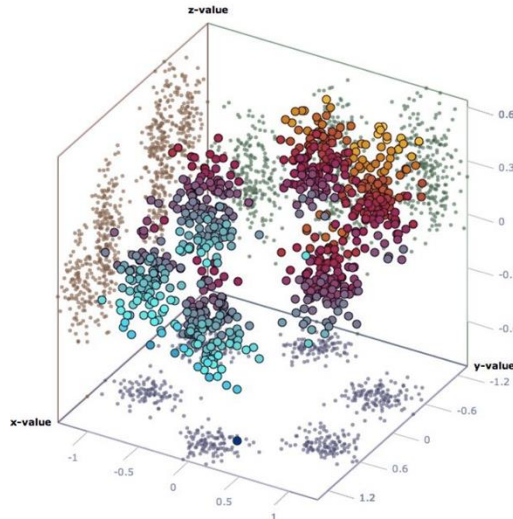


- Could a cat every learn to play chess?
- Humans have limits too

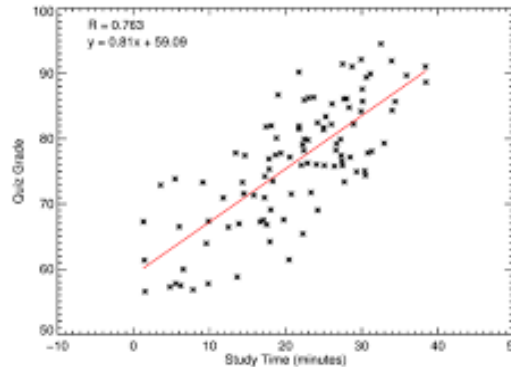
Why should Homo sapiens be able to understand the theory of everything?

Humans are limited by biology

Humans like to “visualize”



project
to 2D



Why do we do this? Because we have **eyes**

- 2D is not special to a machine.
- Machines can “visualize” in d dimensions

Eyes have **nothing to do**
with fundamental physics!

Humans can only hold 5-9 concepts in working memory at once

- We like simple-looking equations

$$i\partial_t\psi = H\psi \quad i\partial\psi = m\psi \quad G_{\mu\nu} = \kappa T_{\mu\nu}$$

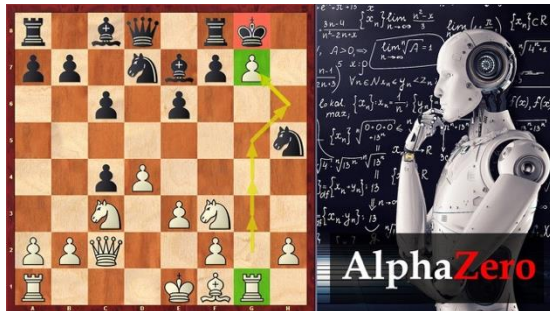
- **Computer** memory can **handle much more** than 5-9 concepts at once
- They can understand systems not governed by simple equations

What do we need to progress further?

Current state-of-the-art can calculate ***anything that has been calculated***

- Trained on textbooks, journal articles, physics.stackexchange, chegg, notes, etc.
- Books, papers, etc. **written by human beings who read books**, papers, etc.
- i.e. we generate our own training data

Alpha Zero: learns to solve chess problems by generating its own training data



Current LLMs

- can generate and solve problems
- LLMs can refine their own code
 - GPT 5.2 was vibe-coded using 5.1
 - GPT 5.2 is *much* better than 5.1

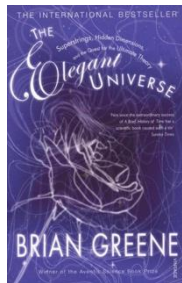
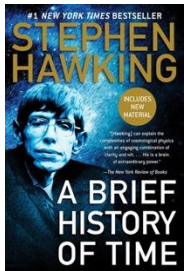
AI is already generating its own training data for physics

- Prompts, failures, user feedback, etc.

Superhuman intelligence

Suppose a machine understands the theory of everything! What then?

1. Find practical applications
 - Suggest experiments, compute the electron mass, etc.
2. Dumb it down so we can get the general idea



- The authors of **Popular science books** understand the details; we just get the general idea

I don't understand the proof of Fermat's last theorem

I also don't understand the proof of Erdos Problem #147

- I'm glad that somebody does
- Does it matter that the person is human?

This is **inevitable**

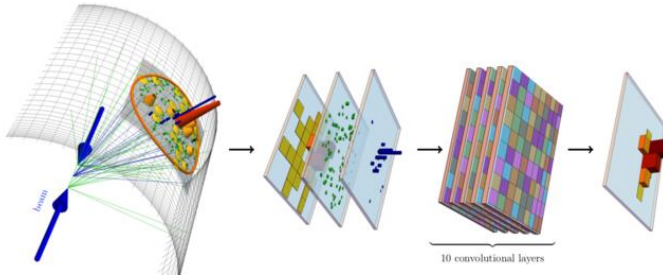
Why should fundamental physics
be understandable by humans
and not chimps

and **exciting**

Because of AI, I am now optimistic
for substantive progress in high-
energy theory very very soon

Conclusions

- Past: **machine learning as a tool**



- Present: **vibe physics (AI grad students)**



Future: **AI scientists**

