

Artificial Intelligence for Medical Imaging and Data Discovery

Qian Tao, PhD

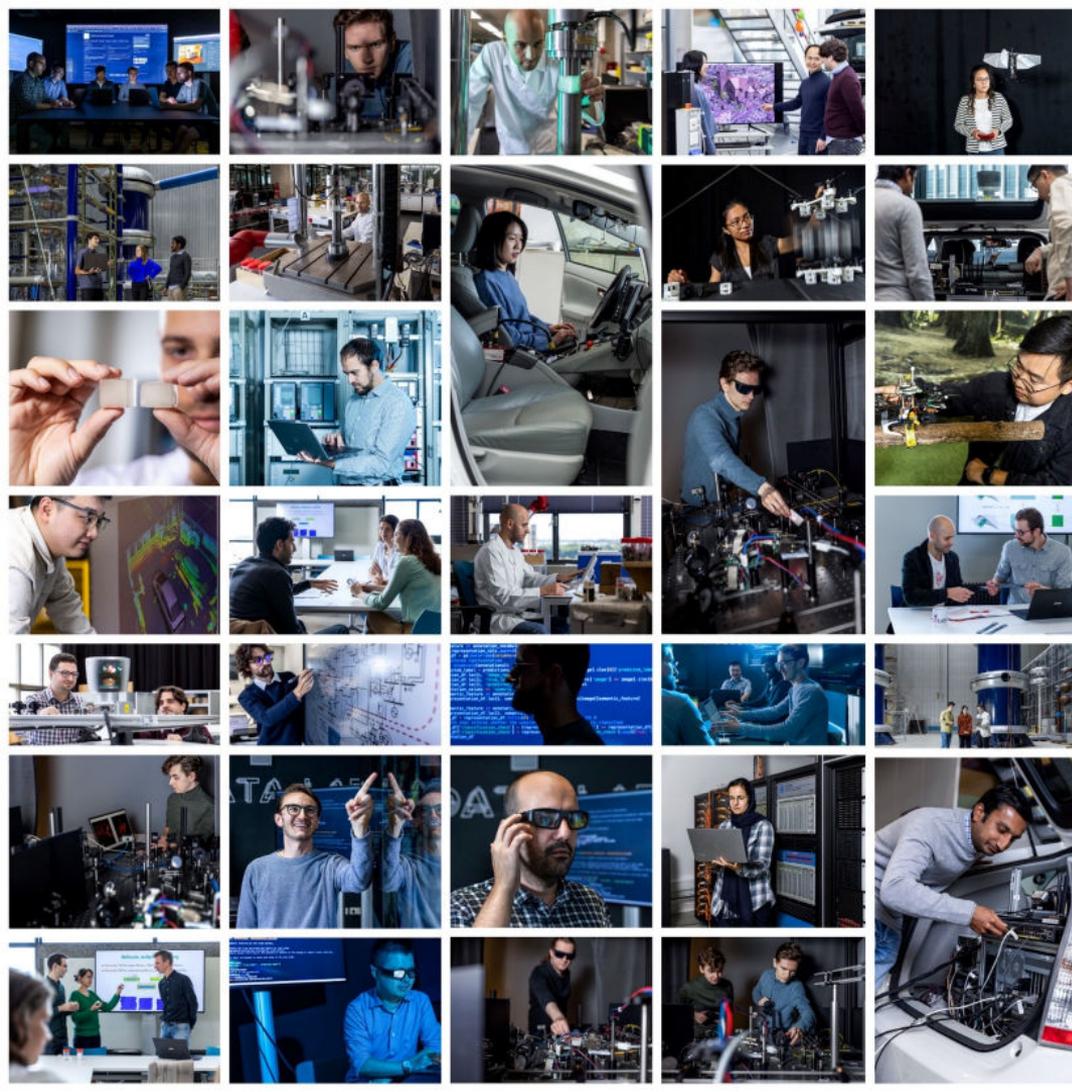
Delft AI Lab for Medical Imaging

Department of Imaging Physics
Faculty of Applied Science, TU Delft

Sep 2025



DutchPhotonicsEvent



About me

- Delft AI Lab for Medical Imaging
- Disclaimer: not a physicist! 😊

Outline



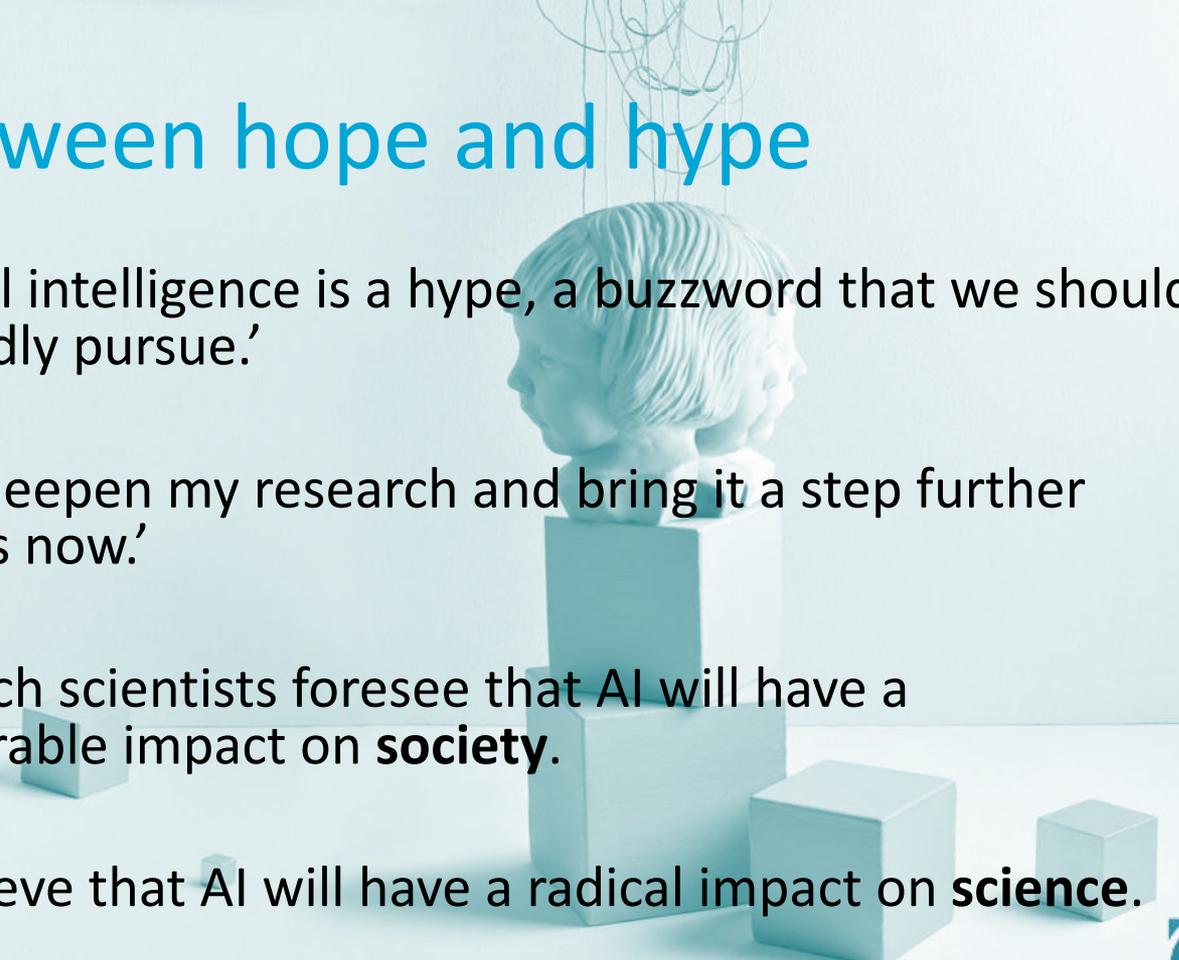
- Artificial intelligence
 - Hope and hype
 - AI for Medical Imaging
 - Trustworthy AI
 - AI and Photonics
 - Sustainable AI

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AI: between hope and hype



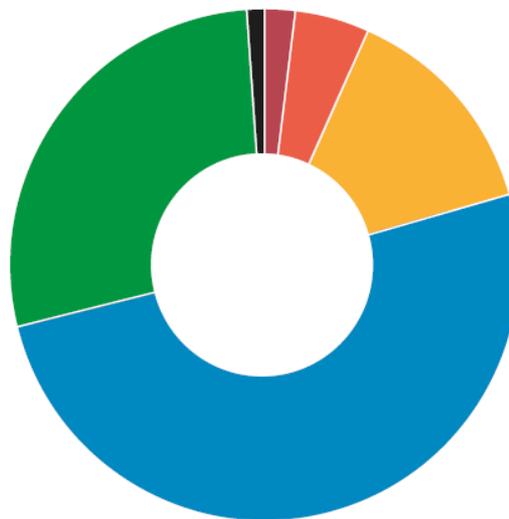
- ‘Artificial intelligence is a hype, a buzzword that we should not blindly pursue.’
- ‘AI will deepen my research and bring it a step further than it is now.’
- **4/5** Dutch scientists foresee that AI will have a considerable impact on **society**.
- **2/3** believe that AI will have a radical impact on **science**.

AI: between hope and hype

'AI gaat de samenleving ingrijpend veranderen'

(n=1484)

■ Zeer mee oneens	2%
■ Mee oneens	5%
■ Neutraal	14%
■ Mee eens	51%
■ Zeer mee eens	28%
■ Weet niet/geen indruk	1%



Survey of around 1500 Dutch researchers

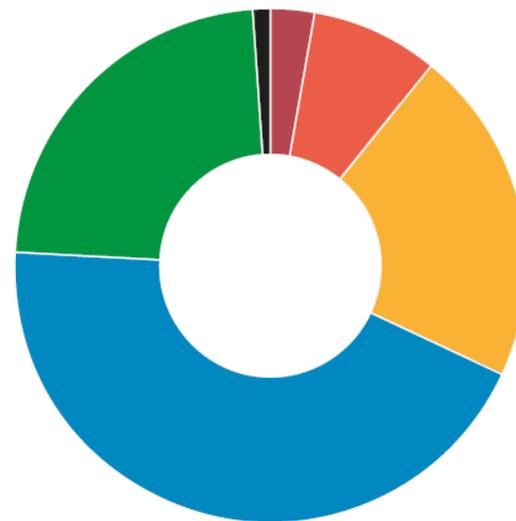
<https://www.nwo.nl/en/between-hope-and-hype> 2020

AI: between hope and hype

'AI gaat de wetenschap ingrijpend veranderen'

(n=1484)

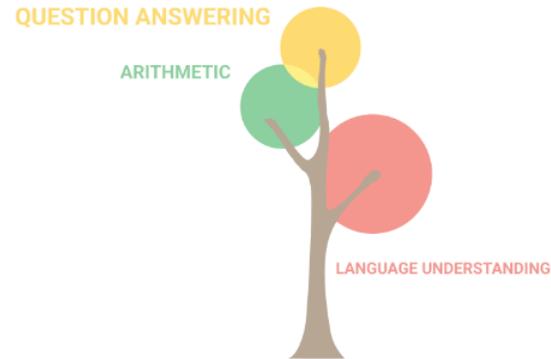
■ Zeer mee oneens	3%
■ Mee oneens	8%
■ Neutraal	21%
■ Mee eens	44%
■ Zeer mee eens	23%
■ Weet niet/geen indruk	1%



Survey of around 1500 Dutch researchers

<https://www.nwo.nl/en/between-hope-and-hype> 2020

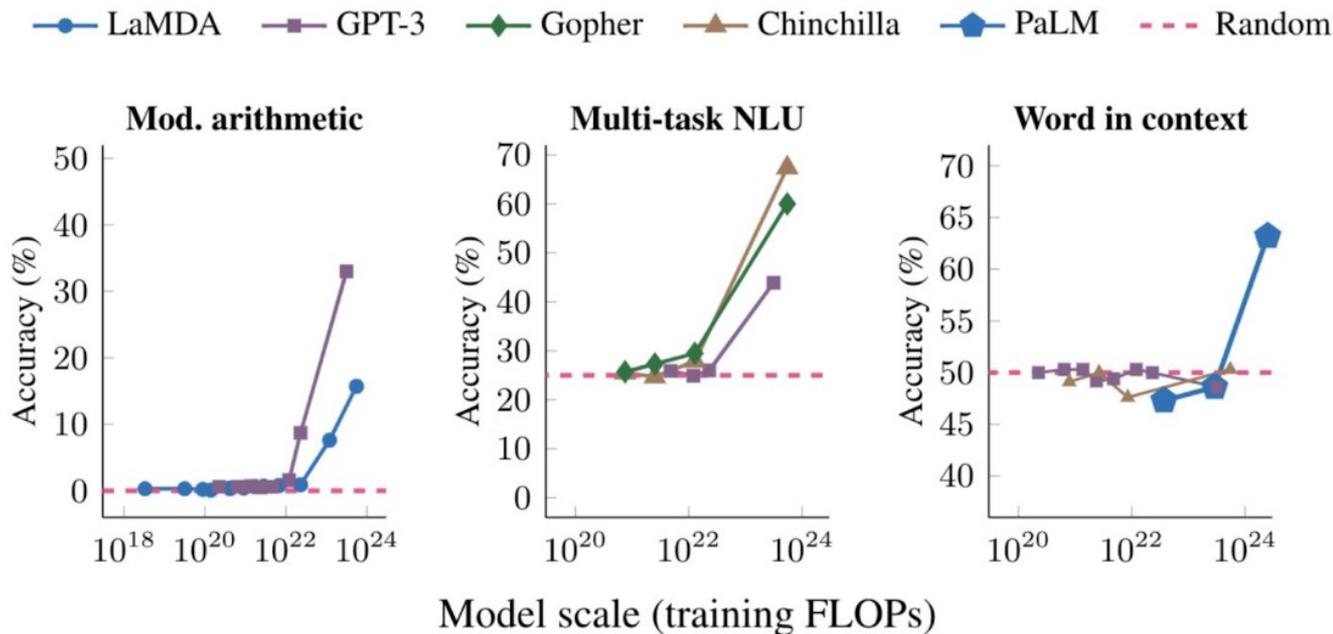
Scaling laws and emergent abilities of Large Language Models (LLMs)



8 billion parameters

<https://cthriet.com/blog/scaling-laws> 2023

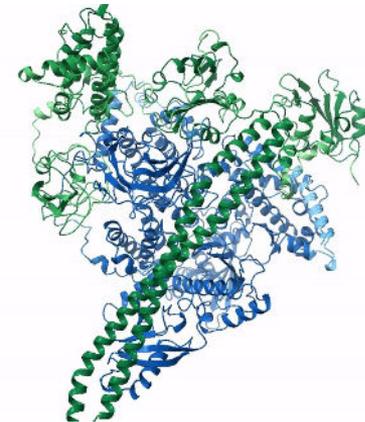
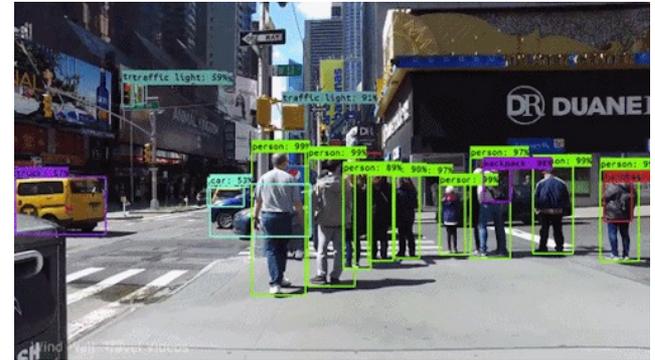
Scaling laws and emergent abilities of Large Language Models (LLMs)



Wei et al. Emergent abilities of LLMs, TMLR 2023

Beyond LLMs

- Real-world applications
 - Autonomous vehicles
 - Healthcare
 - Energy
 - Design and manufacturing
 - etc.
- Scientific discoveries
 - Protein Structure Prediction
 - Drug Discovery
 - Physics
 - etc.



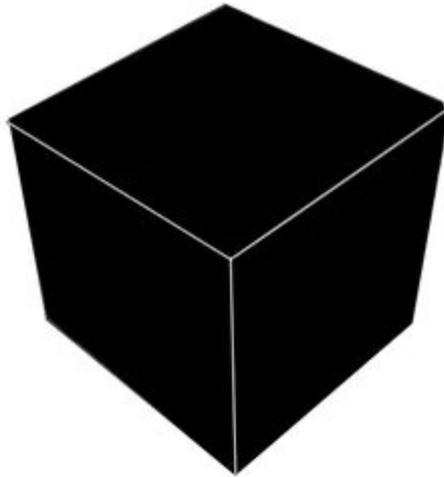
Physics Nobel Prize

- The Nobel Prize in **Physics** 2024 was awarded jointly to John J. Hopfield and Geoffrey Hinton
- "for foundational discoveries and inventions that enable machine learning with **artificial neural networks**"



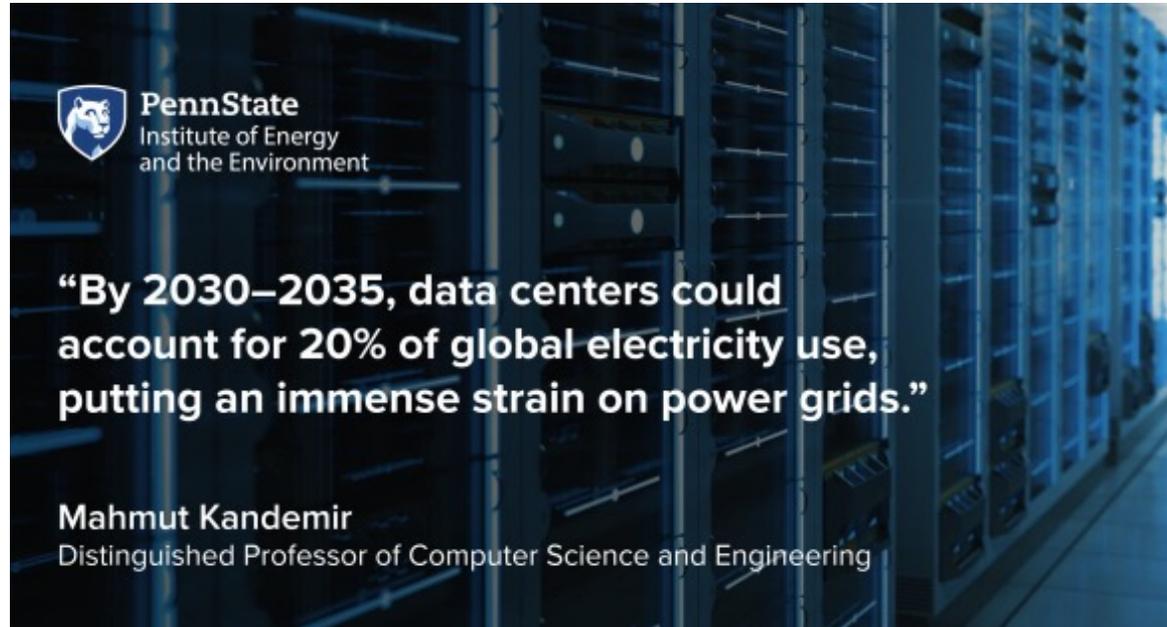
Problems of AI?

- Trustworthiness: is 'black box' reliable for patients?



Problems of AI?

- Sustainability: will we have enough power?

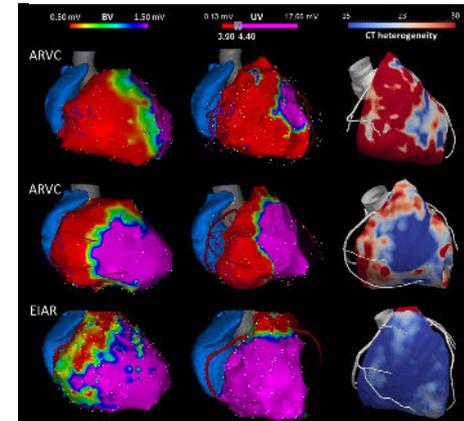
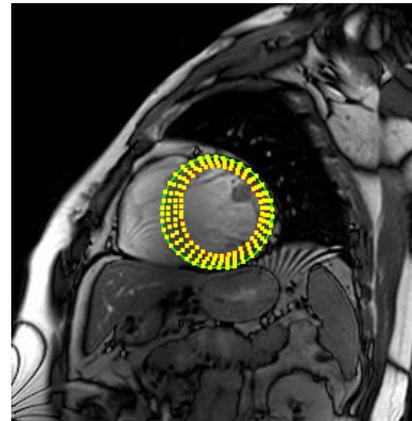
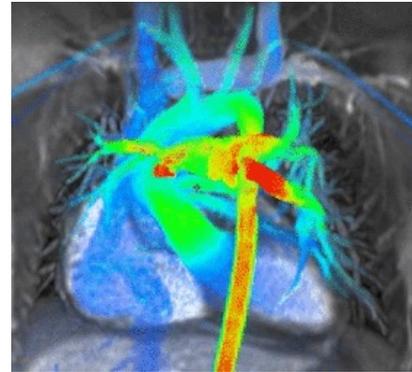
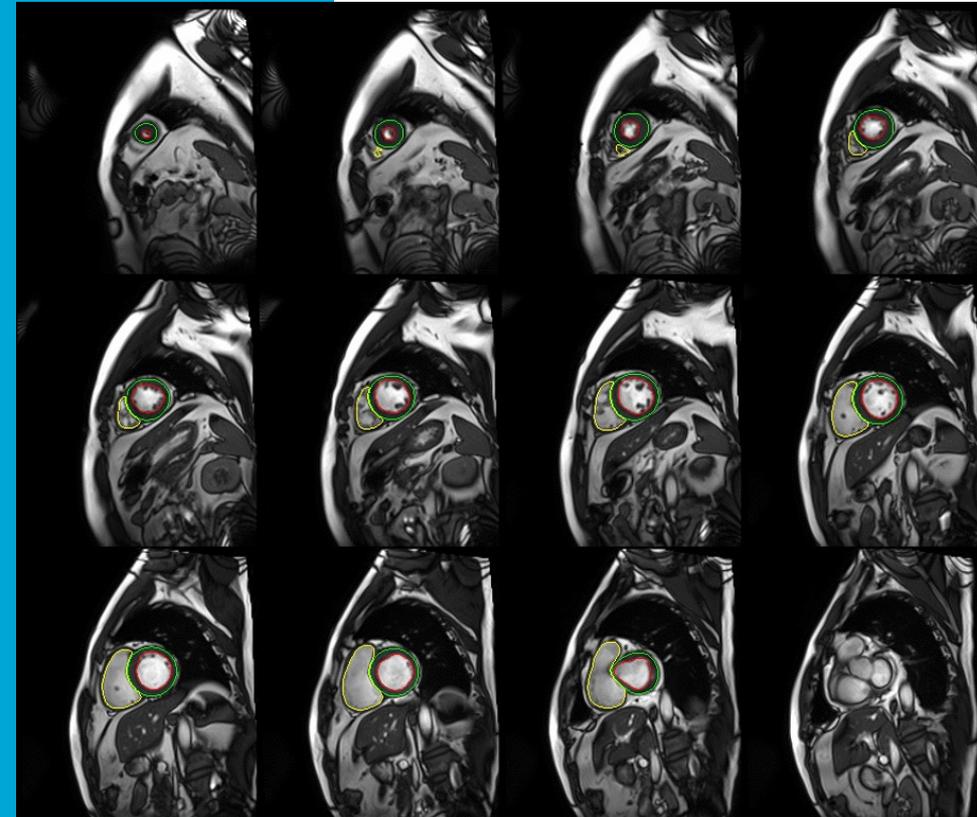


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AI for Medical Imaging



Trustworthy AI for Medical Imaging

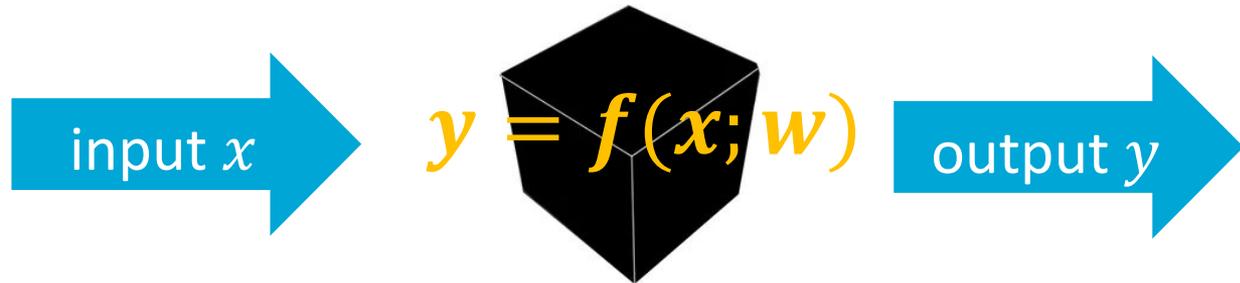
- Towards trustworthy AI



Thomas Bayes

- Probabilistic vs. deterministic modelling of the AI black box

deterministic



Trustworthy AI for Medical Imaging

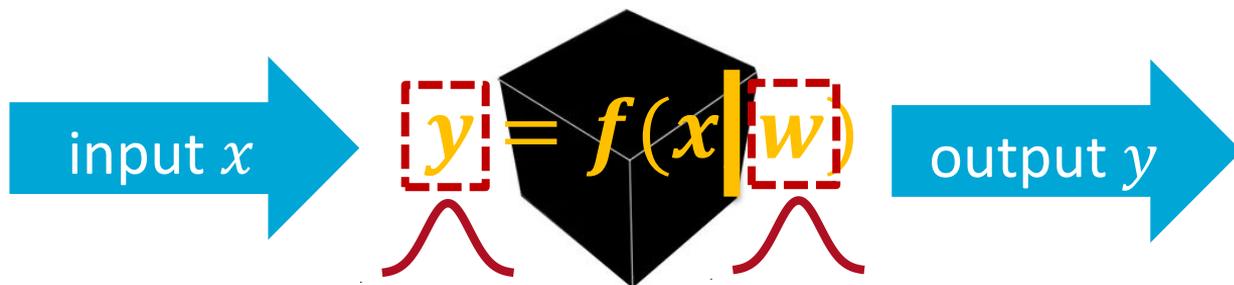
- Towards trustworthy AI



Thomas Bayes

- Probabilistic vs. deterministic modelling of the AI black box

probabilistic

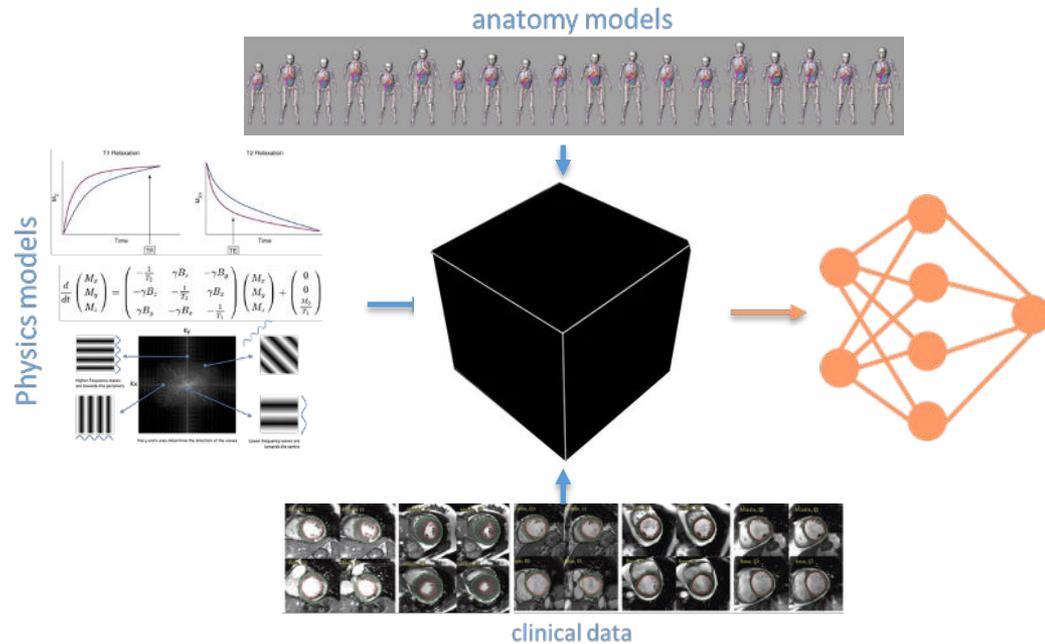


Trustworthy AI for Medical Imaging

- Towards trustworthy AI



- Knowledge-driven + data-driven in training AI

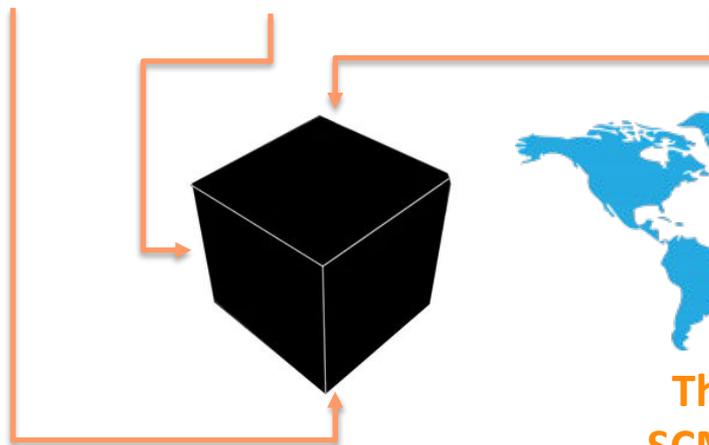


Trustworthy AI for Medical Imaging

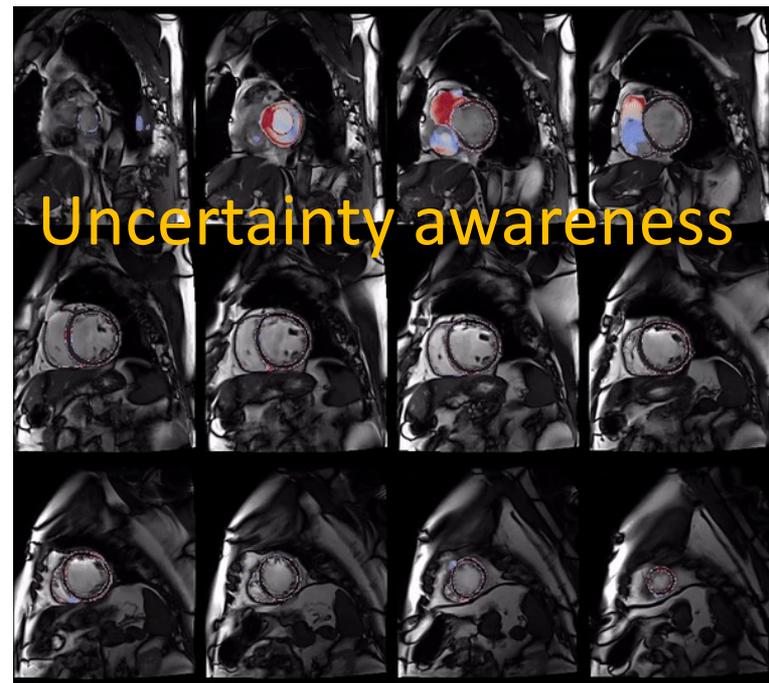
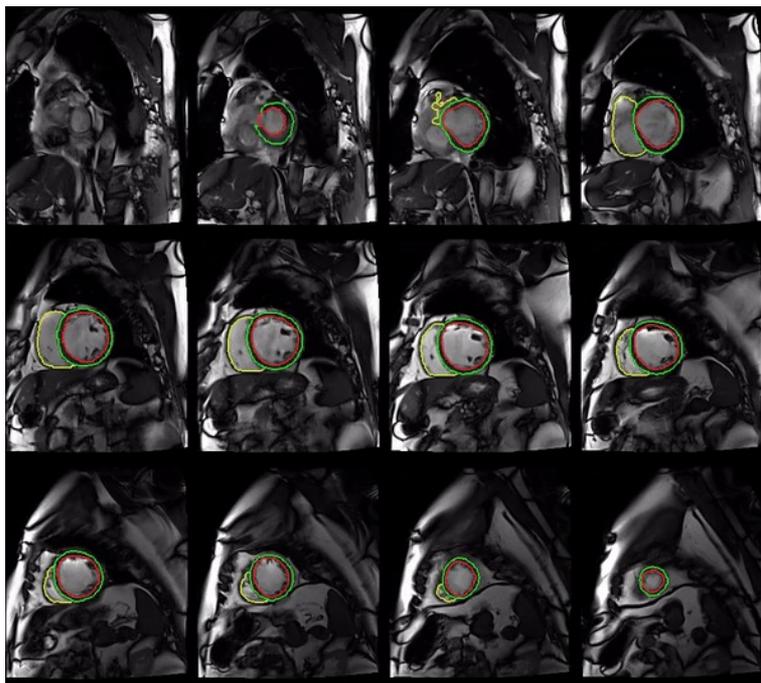
- Towards trustworthy AI



- Collaborations, collaborations, and collaborations
clinical experts imaging physicists epidemiologists



**The International
SCMR Data Registry**



Uncertainty awareness

Bayesian Uncertainty Estimation by Hamiltonian Monte Carlo: Applications to Cardiac MRI Segmentation

Yidong ZHAO¹[0000-0003-3953-6921](#), João TOURAIS¹[0000-0002-1388-4023](#), Iain PIERCE^{2,3}, Christian NITSCHKE^{2,3}, Thomas A. TREIBEL^{2,3}, Sebastian WEINGÄRTNER¹[0000-0002-0739-6306](#), Artur M. SCHWEIDTMANN⁴[0000-0001-8885-6847](#), Qian TAO¹[0000-0001-7480-0703](#)

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Discovery from Data



Enabling scientific discoveries that improve human health

nature machine intelligence

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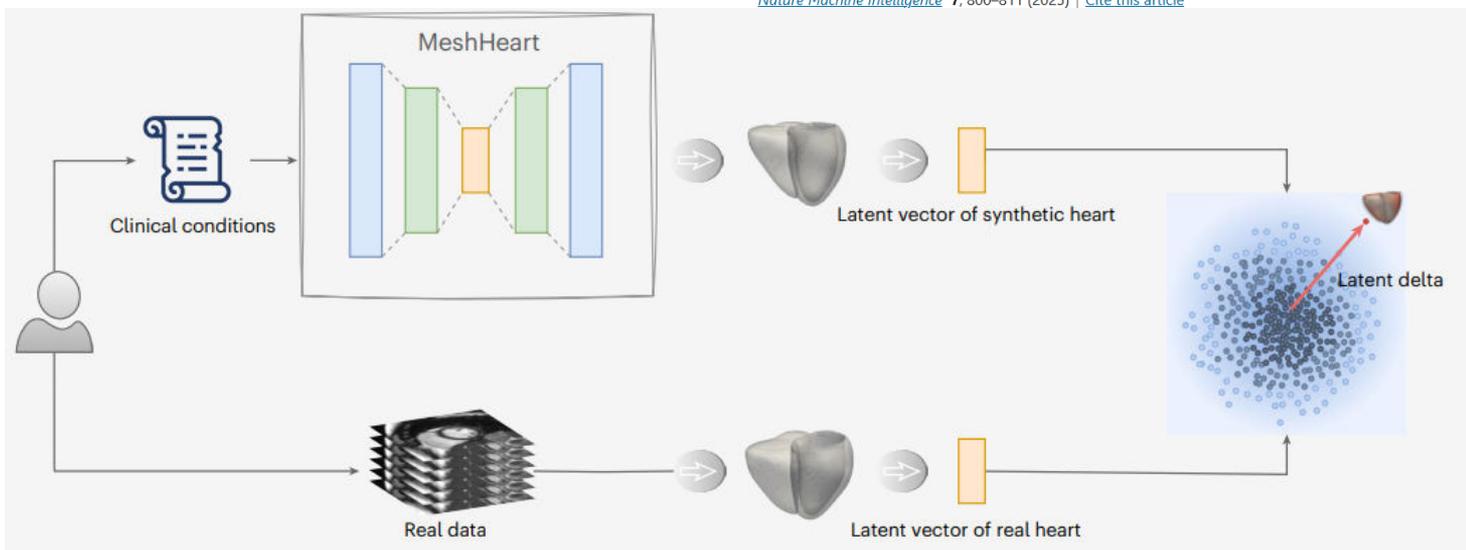
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Article | [Open access](#) | Published: 19 May 2025

A personalized time-resolved 3D mesh generative model for unveiling normal heart dynamics

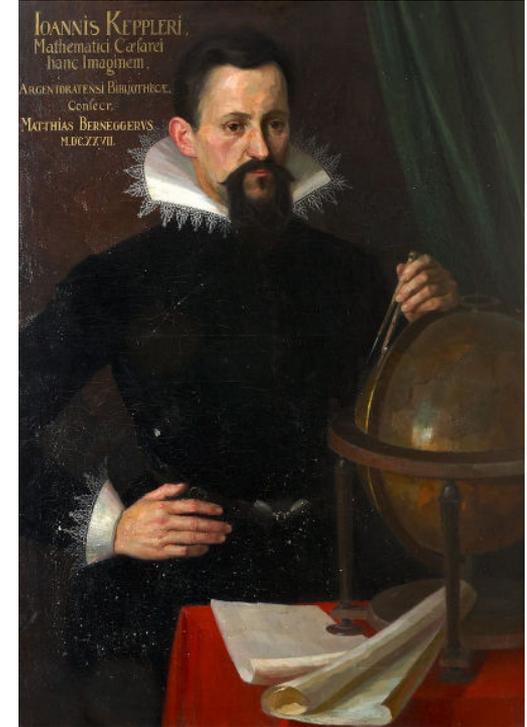
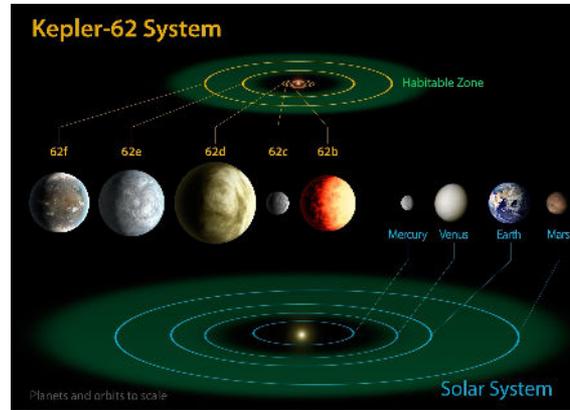
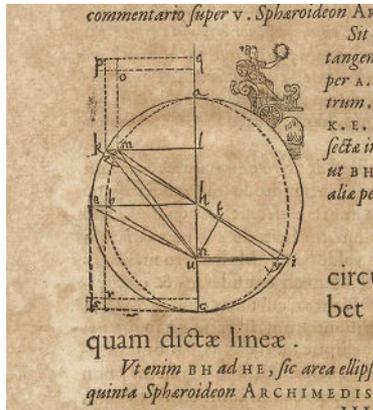
[Mengyun Qiao](#)  [Kathryn A. McGurk](#), [Shuo Wang](#), [Paul M. Matthews](#), [Declan P. O'Regan](#) & [Wenjia Bai](#)

Nature Machine Intelligence **7**, 800–811 (2025) | [Cite this article](#)



Discovery from Data

- In 1601, Kepler discovered that Mars' orbit is an ellipse, after 4 years of analysis on the observational data



Johannes Kepler, 1571-1630
German astronomer, mathematician,
astrologer, natural philosopher and writer
on music. (Wikipedia)

Discovery from Data

SCIENCE ADVANCES | RESEARCH ARTICLE

COMPUTER SCIENCE

AI Feynman: A physics-inspired method for symbolic regression

Silviu-Marian Udrescu¹ and Max Tegmark^{1,2*}

A core challenge for both physics and artificial intelligence (AI) is symbolic regression: finding a symbolic expression that matches data from an unknown function. Although this problem is likely to be NP-hard in principle, functions of practical interest often exhibit symmetries, separability, compositionality, and other simplifying properties. In this spirit, we develop a recursive multidimensional symbolic regression algorithm that combines neural network fitting with a suite of physics-inspired techniques. We apply it to 100 equations from the *Feynman Lectures on Physics*, and it discovers all of them, while previous publicly available software cracks only 71; for a more difficult physics-based test set, we improve the state-of-the-art success rate from 15 to 90%.

Discovery from Data

- AI Feynman
- Discovered 100 equations from the *Feynman Lectures on Physics*, from observation data, with noise resilience!
- Discovered Kepler's equation in ~10 seconds from observation data

Feynman Eq.	Equation	Feynman Eq.	Equation
L6.20a	$f = e^{-\theta^2/2}/\sqrt{2\pi}$	L26.2	$\theta_1 = \arcsin(n \sin \theta_2)$
L6.20	$f = e^{-\frac{x^2}{2\sigma^2}}/\sqrt{2\pi\sigma^2}$	L27.6	$f_f = \frac{1}{\frac{1}{k} + \frac{1}{z}}$
L6.20b	$f = e^{-\frac{(x-\mu)^2}{2\sigma^2}}/\sqrt{2\pi\sigma^2}$	L29.4	$k = \frac{g}{z}$
L8.14	$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$	L29.16	$x = \sqrt{x_1^2 + x_2^2 - 2x_1x_2 \cos(\theta_1 - \theta_2)}$
L9.18	$F = \frac{Gm_1m_2}{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$	L30.3	$l = l_2 \frac{\sin^2(\theta/2)}{\sin^2(\theta_2/2)}$
L10.7	$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$	L30.5	$\theta = \arcsin\left(\frac{\lambda}{\lambda_d}\right)$
L11.19	$A = x_1y_1 + x_2y_2 + x_3y_3$	L32.5	$P = \frac{a^2 a^2}{6ac^2}$
L12.1	$F = \mu N_n$	L32.17	$P = \left(\frac{1}{2} \epsilon c E_f^2\right) (8\pi r^2/3) (\omega^4 / (\omega^2 - \omega_0^2)^2)$
L12.2	$F = \frac{q_1 q_2}{4\pi \epsilon r^2}$	L34.8	$\omega = \frac{qvB}{P}$
L12.4	$E_f = \frac{q_1}{4\pi \epsilon r^2}$	L34.10	$\omega = \frac{\omega_0}{1 - v/c}$
L12.5	$F = q_2 E_f$	L34.14	$\omega = \frac{1 + v/c}{\sqrt{1 - v^2/c^2}} \omega_0$
L12.11	$F = q(E_f + Bv \sin \theta)$	L34.27	$E = \hbar \omega$
L13.4	$K = \frac{1}{2} m(v^2 + u^2 + w^2)$	L37.4	$l = l_1 + l_2 + 2\sqrt{l_1 l_2} \cos \delta$
L13.12	$U = Gm_1m_2\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$	L38.12	$r = \frac{4\pi \epsilon k^2}{mq^2}$
L14.3	$U = mgz$	L39.10	$E = \frac{3}{2} p_f V$
L14.4	$U = \frac{k_{spring} x^2}{2}$	L39.11	$E = \frac{1}{\gamma - 1} p_f V$
L15.3x	$x_1 = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$	L39.22	$p_f = \frac{nk_f T}{V}$
L15.3t	$t_1 = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}}$	L40.1	$n = n_0 e^{-\frac{mgh}{kT}}$
L15.10	$p = \frac{m_0 v}{\sqrt{1 - v^2/c^2}}$	L41.16	$L_{rad} = \frac{\hbar \omega^3}{c^2 (e^{\hbar\omega/kT} - 1)}$
L16.6	$v_1 = \frac{u + v}{1 + uv/c^2}$	L43.16	$v = \frac{\mu_{eff} q V_f}{d}$
L18.4	$r = \frac{m_1 r_1 + m_2 r_2}{m_1 + m_2}$	L43.31	$D = \mu_e k_B T$
L18.12	$\tau = rF \sin \theta$		
L18.16	$L = mrv \sin \theta$		

Discovery from Data

- **AI Kepler:** from data to discovery



“We look forward to the day when, for the first time in the history of physics, a computer, just like Kepler, discovers a useful and hitherto unknown physics formula through symbolic regression!”

Udrescu and Tegmark 2020, Science Advances

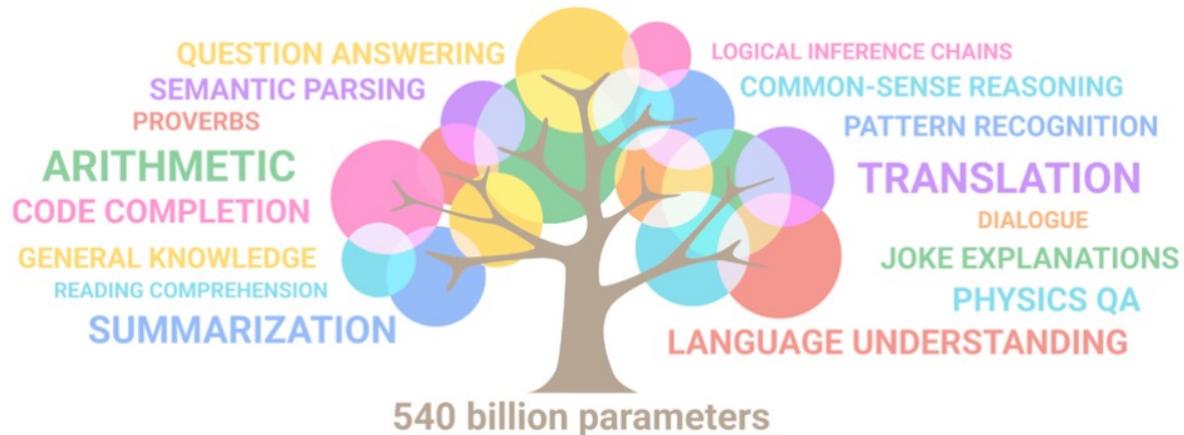
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Photonics and AI

- The explosive computational footprint of AI is creating an unsustainable energy crisis
 - Data centers consuming terawatts globally with exponential growth



Photonics and AI

- **Photonic computing**
 - A latest breakthrough
 - uses light waves produced by lasers or incoherent sources for data processing, data storage or data communication
- **Advantages:**
 - Zero electrical resistance
 - Massively parallel processing
 - Speed of light operation

Photonics and AI

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 Open Access

8 September 2025

Near-energy-free photonic Fourier transformation for convolution operation acceleration

Hangbo Yang, Nicola Peserico, Shurui Li, Xiaoxuan Ma, Russell L. T. Schwartz, Mostafa Hosseini, Aydin Babakhani, Chee Wei Wong, Puneet Gupta, Volker J. Sorger

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¹University of Florida (United States)

²University of California, Los Angeles (United States)

³The George Washington University (United States)

**Light-powered chip makes AI
100 times more efficient**

Researchers have developed a silicon chip that uses light with electricity to perform convolution operations for AI, dramatically reducing energy use and increasing speed.

Photonics and AI

nature

Article | [Open access](#) | Published: 27 August 2025

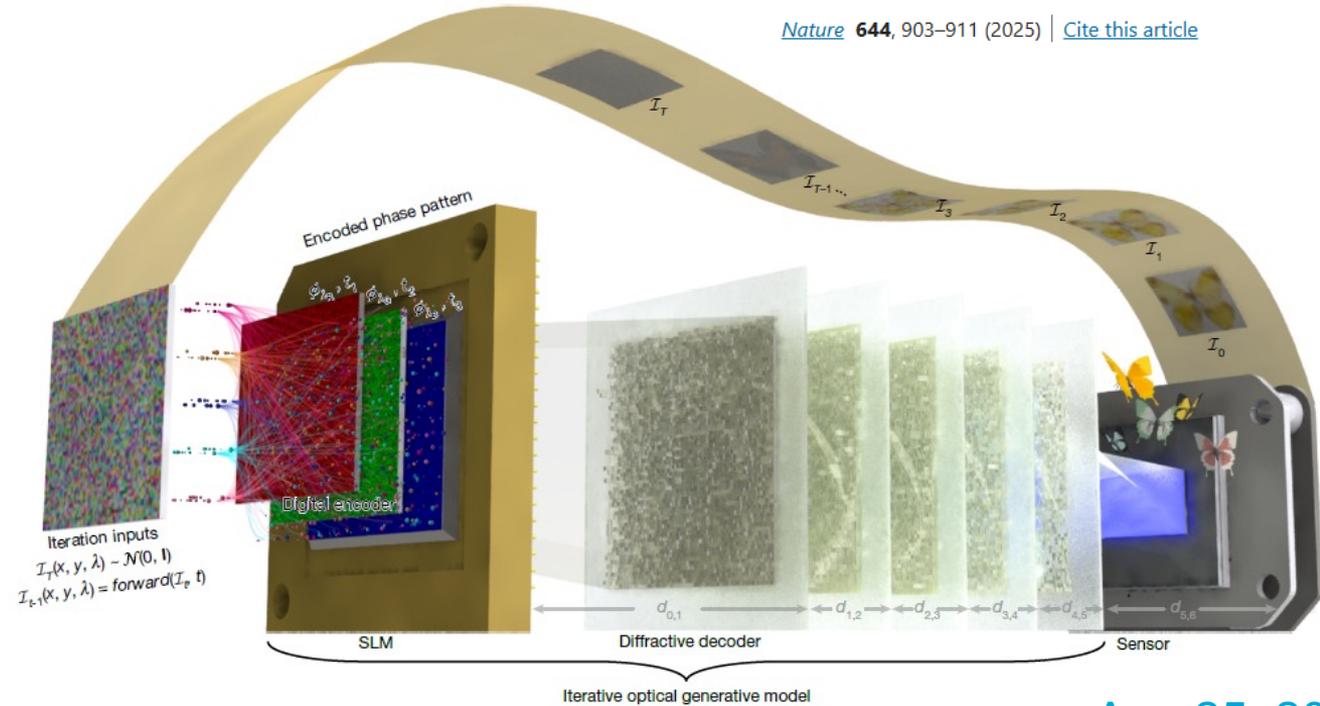
Optical generative models

[Shiqi Chen](#), [Yuhang Li](#), [Yuntian Wang](#), [Hanlong Chen](#) & [Aydogan Ozcan](#) 

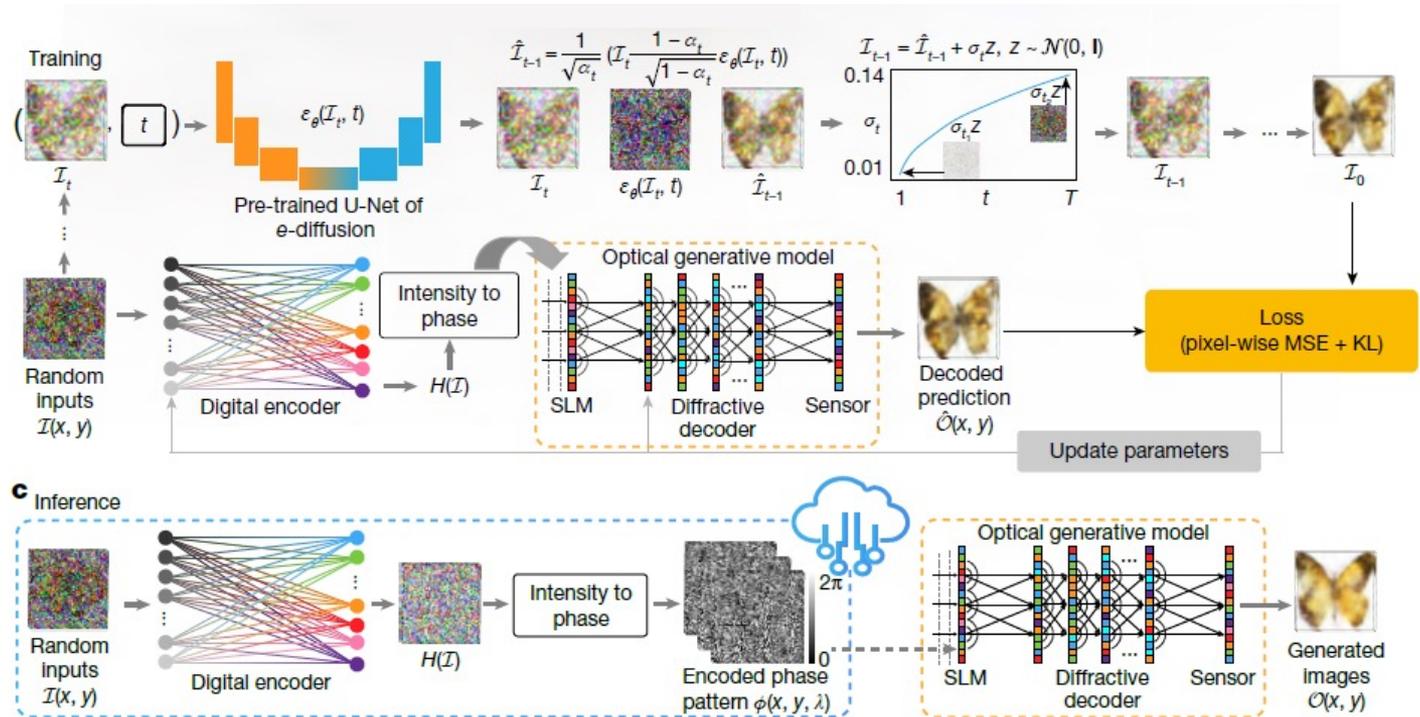
[Nature](#) **644**, 903–911 (2025) | [Cite this article](#)

AI-generated images

a

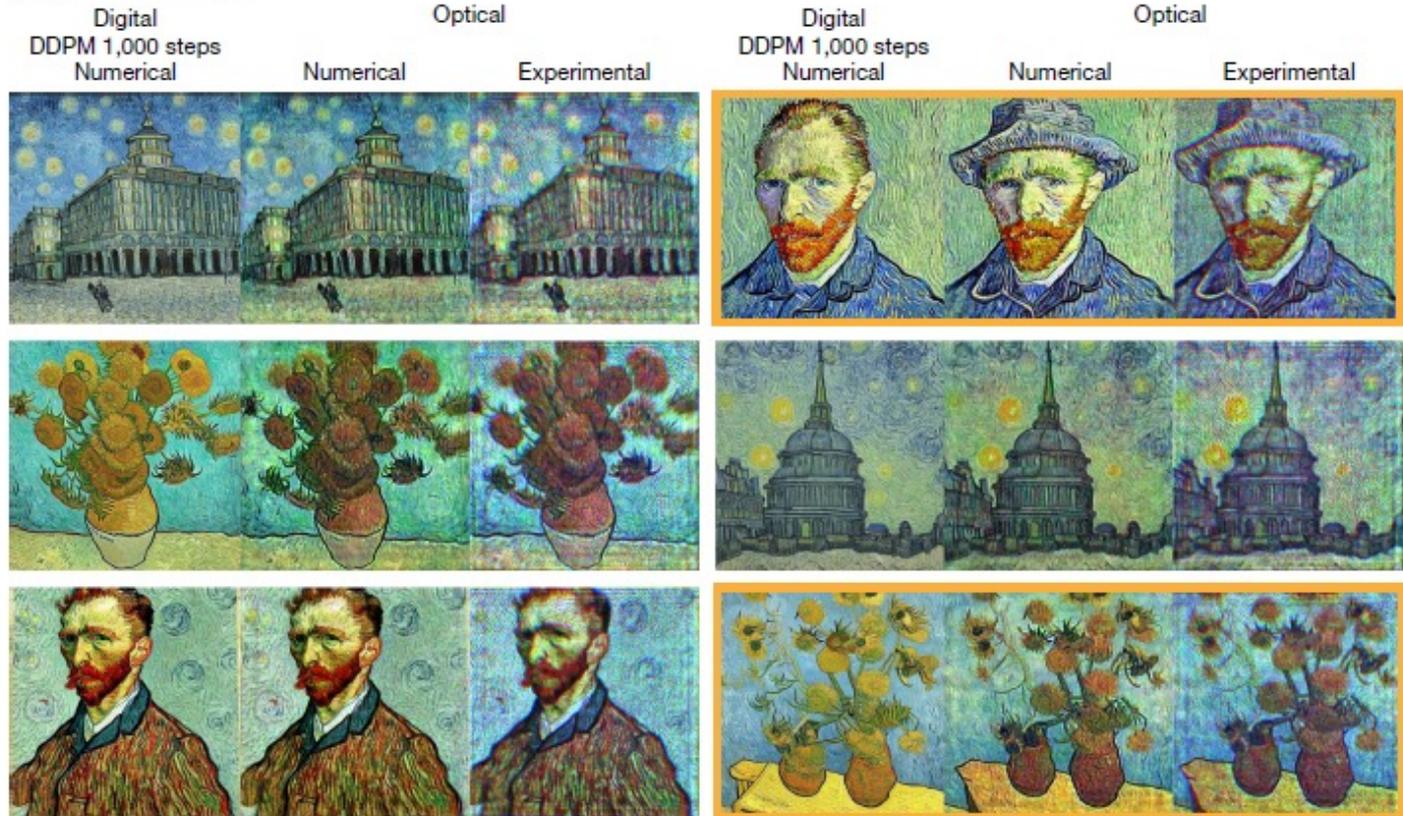


Photonics and AI



Photonics and AI

AI-generated images



Summary

- AI is not a hype, but *the* way to compute
- Trustworthiness & data discovery
- Sustainability and photonic computing

Thank you!

