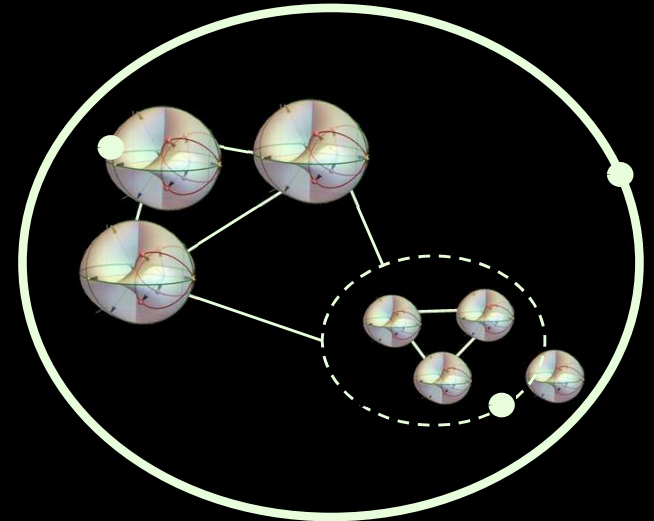




Fernandez-Guasti, M. 2021. Roots of Elliptic Scator Numbers

Galois Capsules: Computational Symmetry and the Problem of Time

The “annihilation of space and time ... [as] the railways' operation
... causes distances to diminish ... Lille suddenly finds itself
transported to Louvres; Calais to Pontoise; le Havre to Poissy”
– Schivelbusch, 1978, Railroad Space and Railroad Time

London UK, 26 Oct 2026

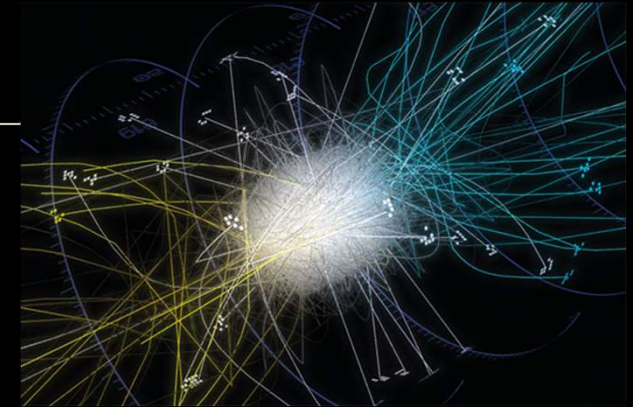
Slides: <http://slideshare.net/LaBlogga>

Dr. Melanie Swan, PhD, MBA
University College London (Research Associate)
DIYgenomics.org Longevity Studio (Research Lead)



Agenda

- Galois Smart Network Field Theory
 - Formal Verification
- Galois Capsules Dynamics Theory
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- Gal-Caps Transport in the STEM Infrastructure
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CERN: testing times for space-time symmetry

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Infrastructure

Why
Smart Networks
Formal Verification

What
Transport Math
Revolution

What
STEM Infrastructure
Examples

Thinking Infrastructure



Physical Infrastructure



Mindset: Kardashev Type I, II, III
leveling up to greater capacity

Philosophy: Epistemic Fragments into Ontological Unity

Ontology: What exists?

Epistemology: How do we know?

Axiology: What is valorized in aesthetic and ethical practice?

Global Terrestrial Networks & Extraterrestrial Space Networks

Transport, Energy, Water, Food, Resources, Healthcare, Sanitation

ITC: Information Technology and Communications

Global fiber-optic telecommunications networks; Internet, Quantum Internet

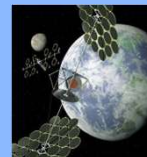
Scientific Method: STEM Infrastructure

Science
(Physics)

Technology
(Computation)

Engineering
(Quantum)

Mathematics

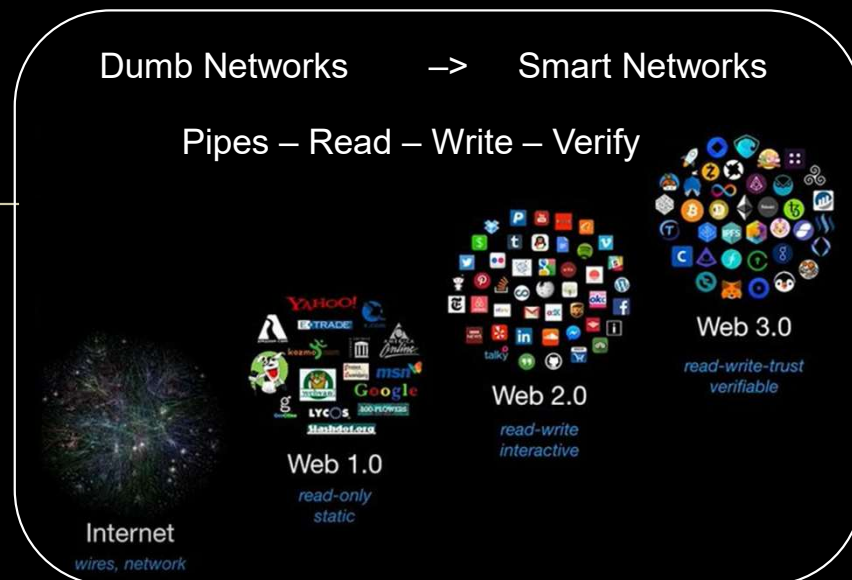


Kardashev energy
marshalling; Earth
Dx: Kardashev 0.72

Type I	Type II	Type III
Planet	Star	Galaxy
10^{16} W	10^{26} W	10^{36} W

Formal Verification

Formal Verification: the act of proving or disproving the correctness of a hardware or software system against a formal mathematical specification



Blockchains

PKI Cryptography
Zero-Knowledge Proofs
Proof of Storage
(Time/Space)
Smart Contracts



Crypto Agents
Chainanalysis

AI Foundation Models

SLSA (Supply-chain
Levels for Software
Artifacts)
ML-BOM (Machine
Learning Bill of Materials)
Model Context Protocol
(MCP)
Prompt Attestation
Agent Executables

AI Agents
Maxim

Mathematics

Formal Proof Assistants
Curated Mathematical
Datasets (axioms,
definitions, theorems)
Auto-Formalization Tools
Neural-Symbolic Solvers
Distributed Compute
Clusters (RL/Tree Search)

Math Agents
Ax-Prover

Physics

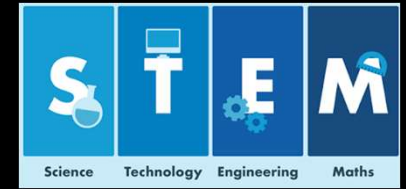
Neuro-Symbolic AI
Lean Certificates

Reasoning Accelerators
for High Energy Physics

Automated Pipeline:
Model Building Agent
Event Generation Agent
Collider Analysis Agent

Physics Agents
SciML Agents
FERMIACC, Lanyon.AI

STEM Infrastructure as a Whole



■ Formal Verification focus

Formal verification tools for software correctness: compilers, type checkers, static analyzers



Computational Reasoning

Computation

Formal verification tools for mathematical correctness: proof assistants, automated theorem provers, interactive theorem provers (Lean, Agda, Rocq)



Mathematical Reasoning

Mathematics

Internal consistency (mathematical consistency)

Formal verification tools for physical theory correctness: in development



Physics-based Reasoning

Physics

External consistency (with other physical theories)

Formal verification tools for experimental correctness: in development



Experimental Reasoning

Quantum

Robotics

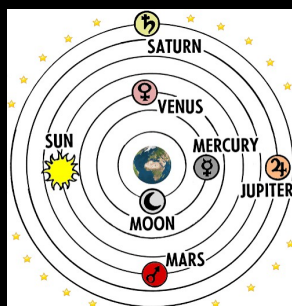
Experimental consistency (with real-world conditions)

Formal Description Language Progression

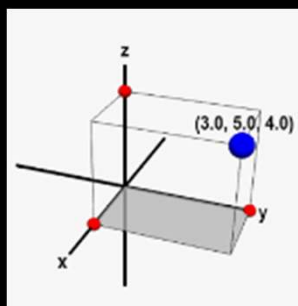
Natural Language:
Pre-Socratics
Anaximander



Geometry:
Ptolemy,
Alhazen



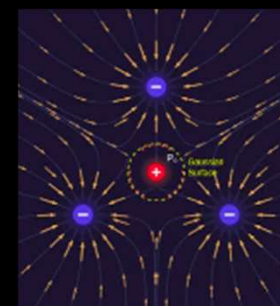
Analysis:
Descartes,
Newton



Computation:
Turing, Zuse,
Fredkin, Wolfram
Information:
Shannon



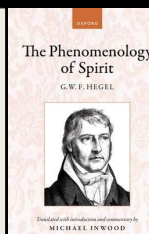
AI:
Math Agents
Physics Agents
SciML Agents



- Evolutionary progression: intractability in previous description language becomes trivial in next
 - E.g.; Maxwell's demon, thermodynamics as entropy not PDEs

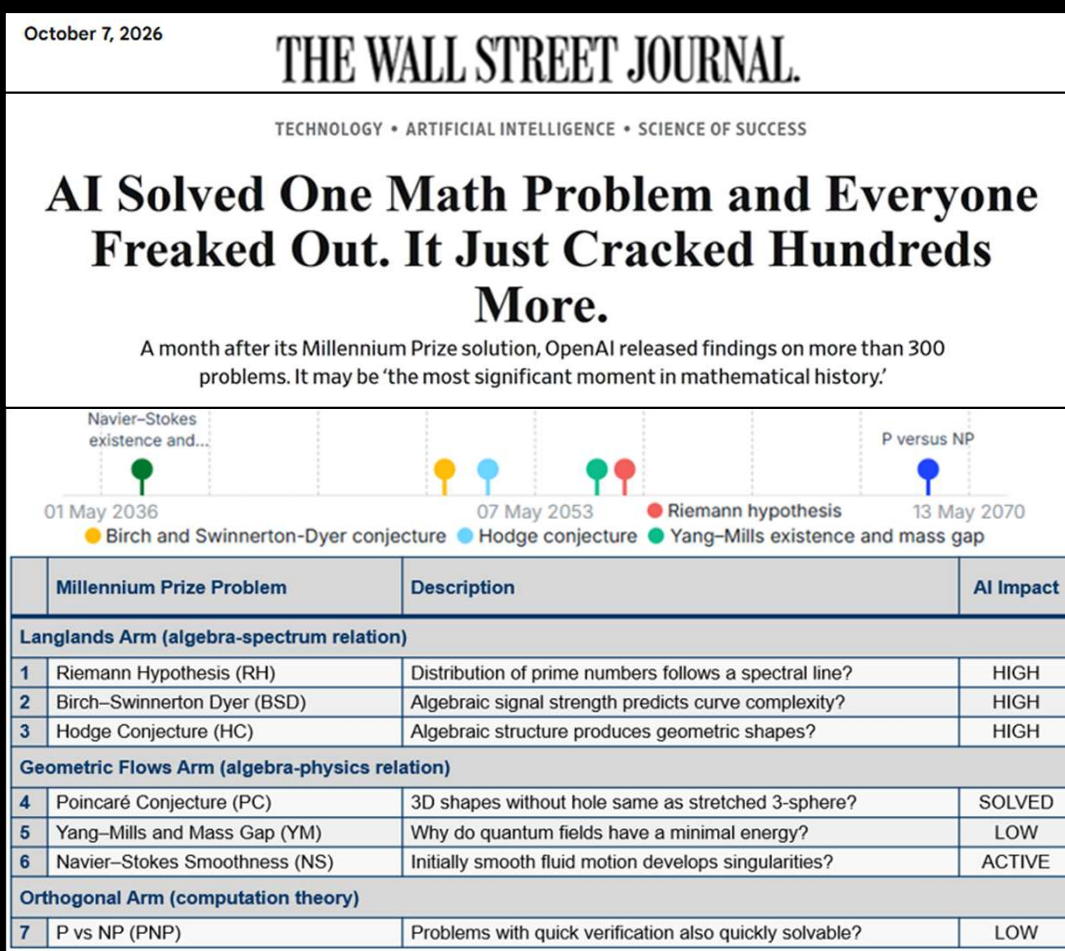
Same kind of self-knowing progression in formal description languages and shapes and concepts of consciousness as in Hegel's PS

Hegel's <i>Phenomenology of Spirit</i> (1807)					
Subjective Spirit (Individual)			Objective Spirit (Collective)		Absolute Spirit
A. Consciousness	B. Self-Consciousness	C. Free Concrete Mind			
		(AA). Reason	(BB). Spirit	(CC). Religion	(DD). Absolute Knowing



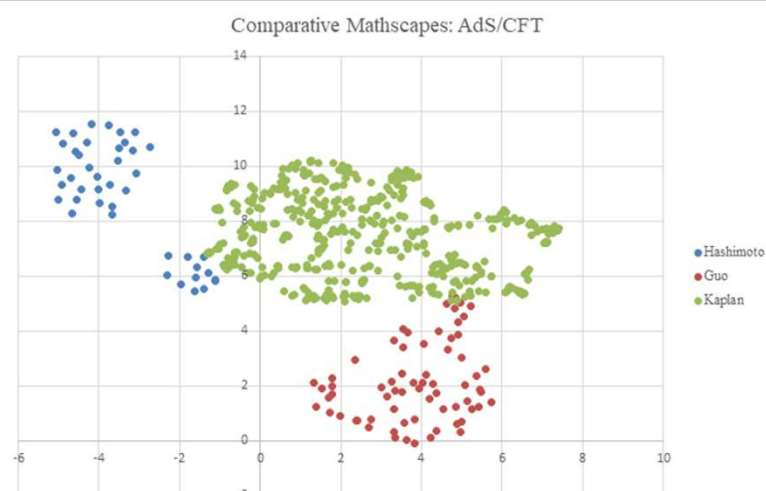
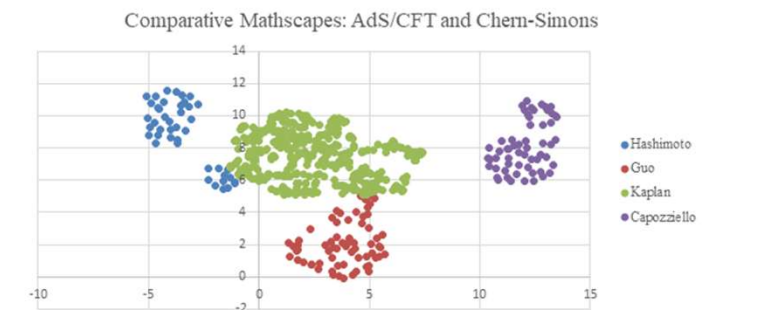
Mathematical Knowledge Production

■ AI science products



New fields of Mathematics

Mathematical Informatics: novel forms of consistency unification at scale: comparative mathsapes, mathematical embedding



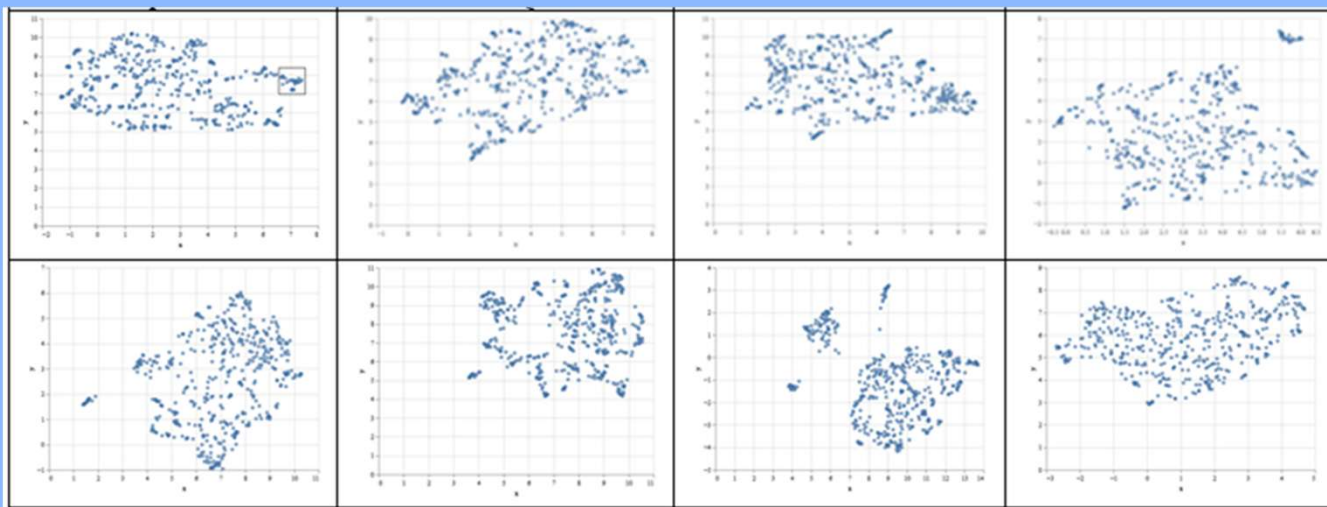
Capozziello, S. et al. (2018). The Chern-Simons current in systems of DNA-RNA transcriptions. *Annalen der Physik*. 530(4):1700271.
 Guo, M. et al. (2016). Modave Lectures on Applied AdS/CFT with Numerics. 11th Modave Summer School. arXiv:1601.00257v2 [gr-qc].
 Hashimoto, K. et al. (2021). Neural ordinary differential equation and holographic quantum chromodynamics. *ML Sci Tech*. 2 (2021) 035011.
 Kaplan, J. (2016). Lectures on AdS/CFT from the bottom up. Johns Hopkins Lecture Course.

Industrialization of Mathematics

- Automated assembly lines, math as informatics field
 - Implication: demand for mathematics informatics workers

“We haven't had tools that can systematically study large populations of mathematical problems until now.”
The implication is to conduct “population surveys of thousands of mathematical species with statistical analysis” – Terry Tao, Fields Medalist, UCLA, 2026 (paraphrase)

Mathscape Embeddings: visualize a body of mathematics as equation clusters grouped by like species of mathematics



Mathematical Embedding: AdS/CFT

Annotated equation clusters illustrate

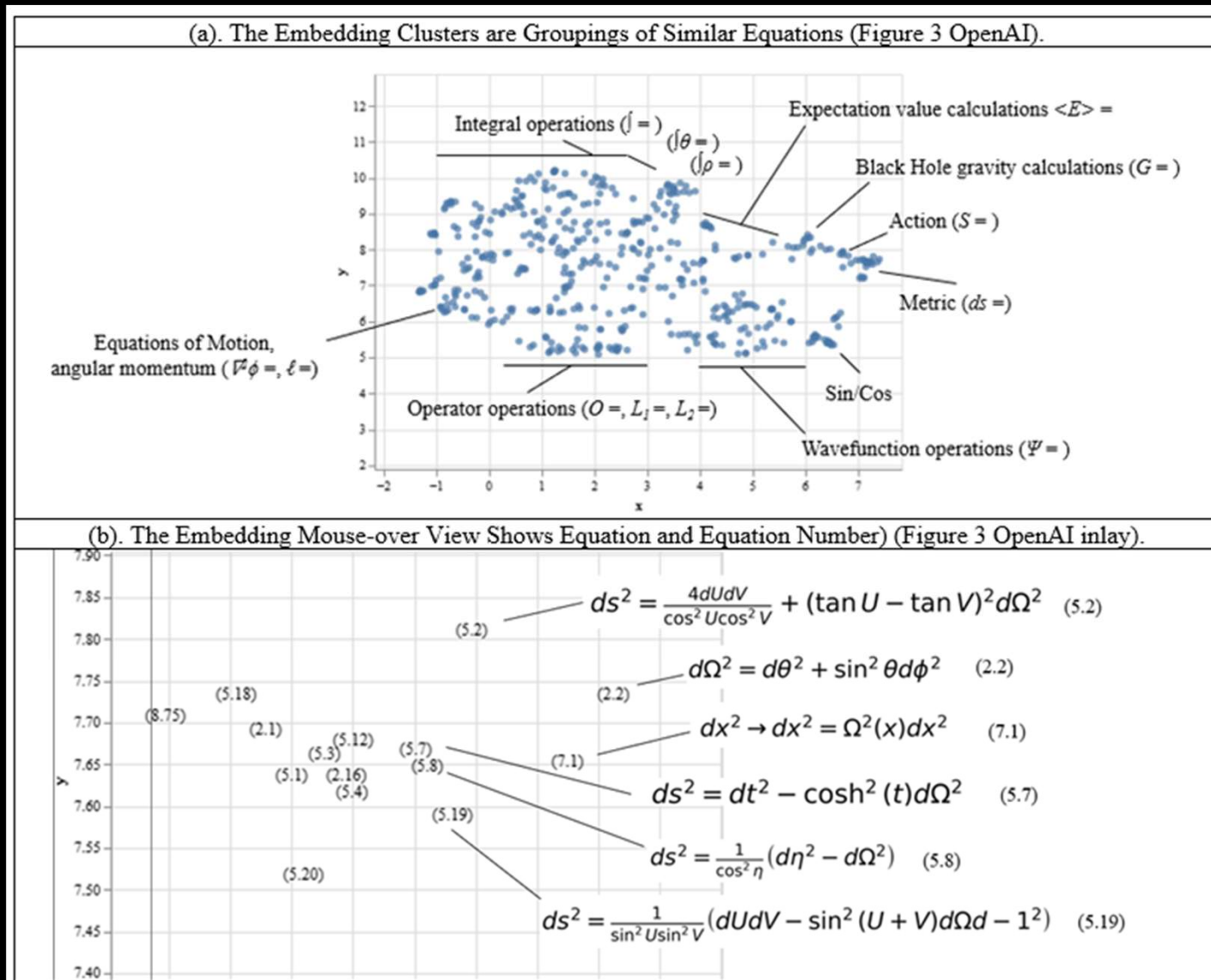
(a) how similar groups of equations are grouped in the embedding method and

(b) mouse-over view of equation images by equation number

Mathematical embedding: math entity (symbol, equation) represented as a character string in vector space for high-dimensional AI analysis

Mathscape: mathematical landscape of related equations

Equation Cluster: similar equations grouped in mathematical ecology embedding visualization



Robotic Lab Knowledge Production

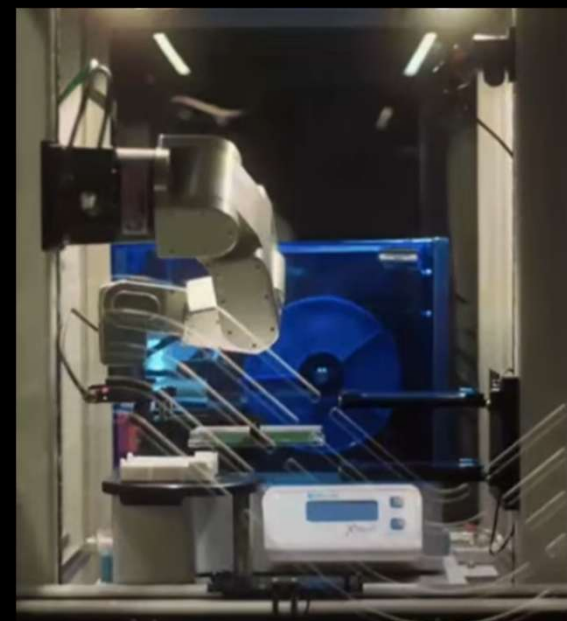
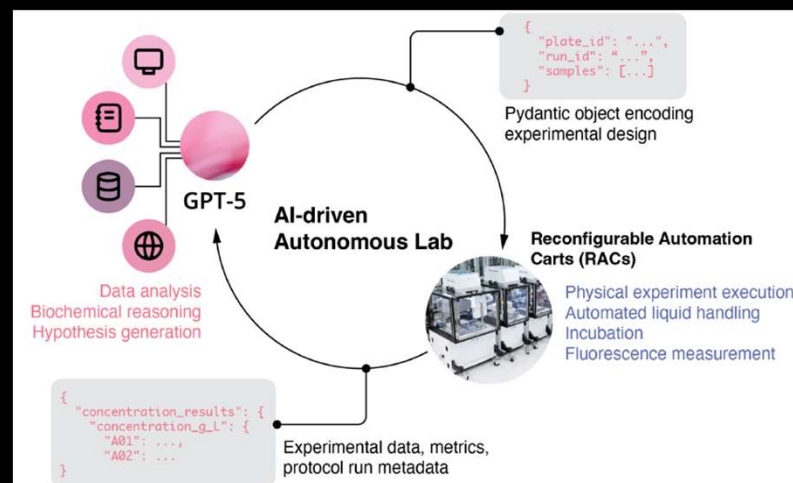
- GPT-5 lab runs 36,000 experiments
 - LLM automated cloud laboratory optimizes the cost efficiency of cell-free protein synthesis (CFPS)

Using a GPT-5-driven autonomous lab to optimize the cost and titer of cell-free protein synthesis



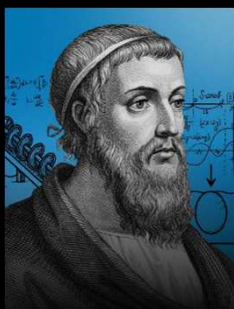
“We connected our autonomous lab to GPT-5 and let it run 36,000 experiments.

The result was a new state-of-the-art for Cell-Free Protein Synthesis that **cut costs by 40% per gram of protein.**”



Mathematics: Artisan -> Industrialization

- Gorard: Math is the limit case of an extremely niche art form
- Venkatesh: In the future, human mathematicians will be hobbyists because automated reasoning is far superior
- Tsimmerman: I'm grieving for taking 10 years to work on a problem
- 3 Blue 1 Brown: There's never been a better time to go into math



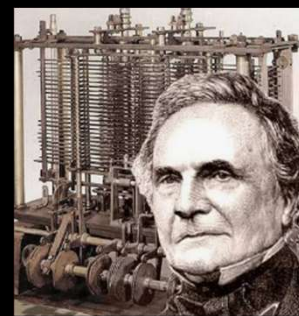
Archimedes: siege
engineer (claw)



Leibniz, Descartes:
trained as lawyers



Babbage, Lovelace:
Aristocratic class



AI Renaissance: Scribe to Vibe

Technology

Specialist

->

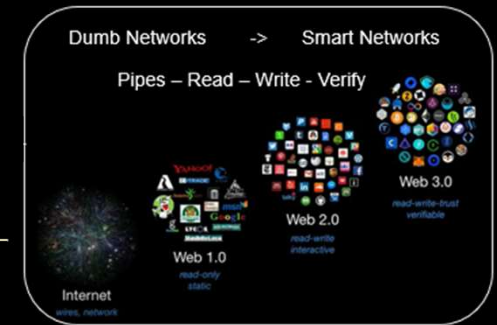
Generalist
All Humans

Explosion in Creative
Expression and
Knowledge Discovery



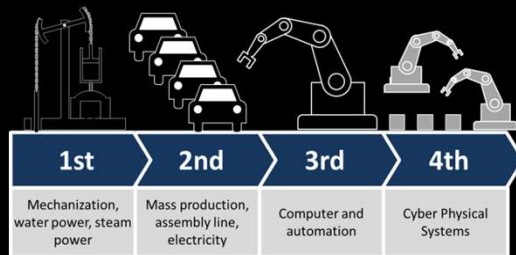
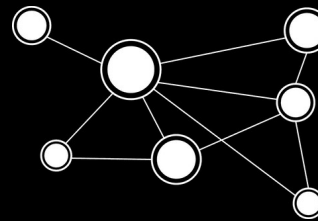
Computing Platform Shifts

Smartnetwork Technologies

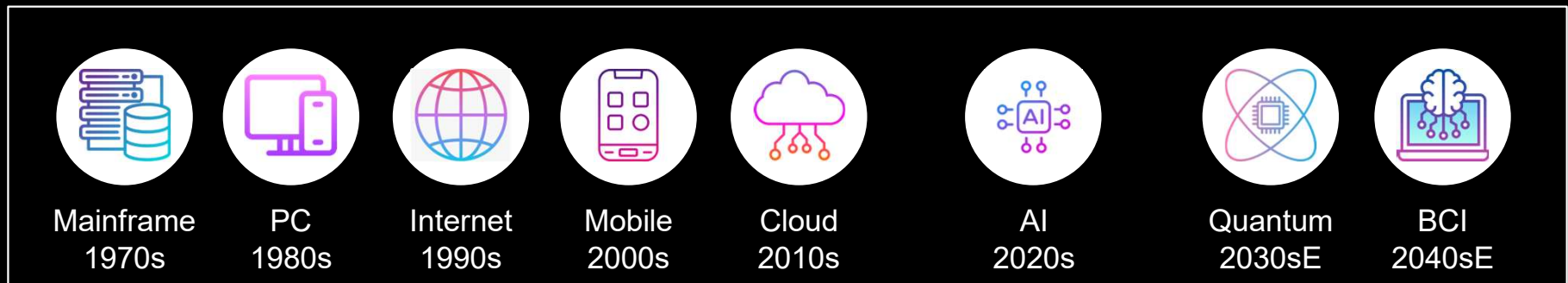


Smart Network (4th Industrial Revolution): formally-verified technological entity with its own space and time regimes, global internet-connected, auto-updating, self-acting, increasingly intelligence-imbued

Examples: blockchains, quantum, artificial intelligence, robotics, IoT, additive manufacturing (3D/4D printing), biotech, neurotech (BCI), AR/VR, digital twins, automotive networks, global healthcare equivalency



Computing Platform Shifts: 1970s-2040s



AI: computing becomes a revenue-generator not a cost center; freedom of Personal Computer -> Personal AI



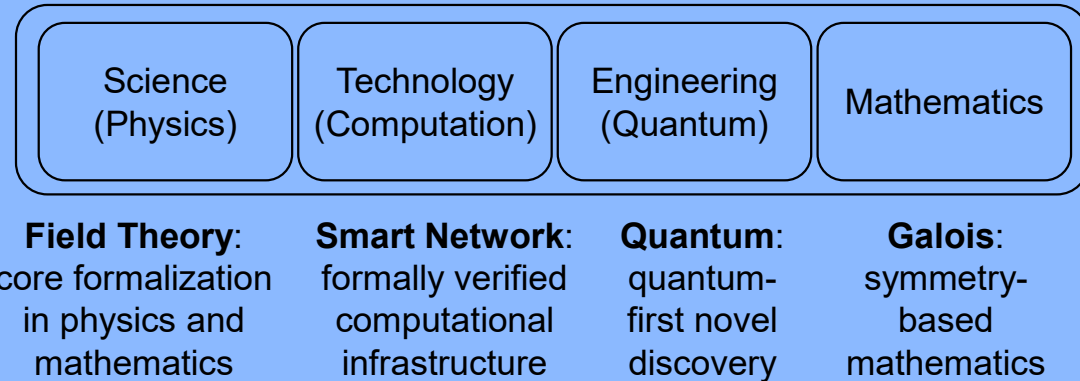
Galois Smart Network Field Theory: a symmetry-based formally verified theory of “particle-many” systems

Galois SNFT

Theory-building for the STEM infrastructure:

Galois Smart Network Field Theory

Scientific Method: STEM Infrastructure



Galois Smartnetwork Field Theory Examples

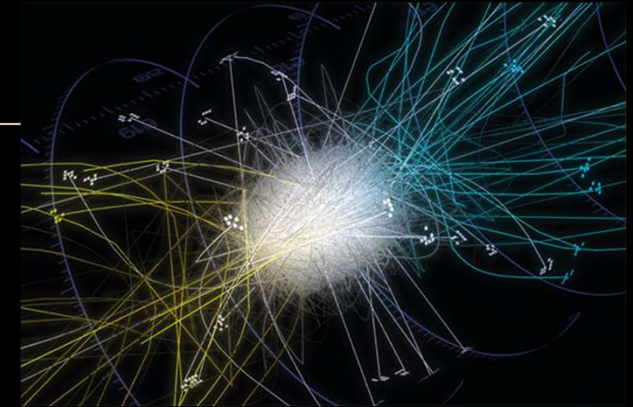
Theme of symmetry implementations in AI Transformers and NNFT definitions

Galois SNFT extends NNFT NNFT (Neural Network Field Theory) is field-theoretic formulations of NN with QFT. NNs and QFT have the same structural form of describing probability distributions over functions (fields) by joining statistics and dynamics

	Topic	Description	Reference
Galois SNFT Formulations (Research-math NNFTs)			Mathematics Computation Physics
1 2	NNQFT	Transformer attention heads as symmetry-breaking Transformer parameter redundancy as gauge symmetry	2026, Silverstein [1]; 2026, Ageev [2] 2024, Hashimoto et al. [3]
3 4	INFT	Fisher information-theoretic fine-tuning Categorical info flow-matching (Fisher, Ricci, Riemann)	2026, Halverson et al. [4] 2026, 2025, Bronstein et al. [5,6]
5	KTNN	Knot-theoretic NN: ribbon disk bounding & Ricci flow	2025, 2024, Gukov et al. [7,8]
6	STNN	Sheaf-theoretic NN: poset sheaf cohomology	2025, Gebhart et al. [9]
Foundational Formulations (NNFTs)			Computation Physics
1 2 3	NNFT NNQFT	Proof: any QFT has a NN description Gaussian processes and tangent kernels Statistical field theory for NN	2026, Halverson et al. [10] 2021, Halverson et al. [11] *KEY REF 2019, Helias & Dahmen [12]
4	SNFT	Smartnetwork field theory	2018, 2020, Swan et al. [13,14]
5	NSFT	Neural statistical field theory	2007 Buice & Cowan [15]

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Galois Smart Network Field Theory: a symmetry-based formally verified theory of “particle-many” systems

Galois Capsules (Gal-Caps): Galois Smart Network Field Theory modules: symmetry-based glocal transport framework for dynamical subsystem modeling

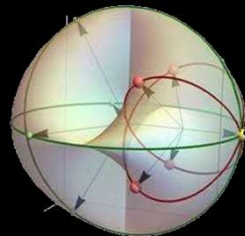
Galois Capsules

Galois

Galois = Symmetry

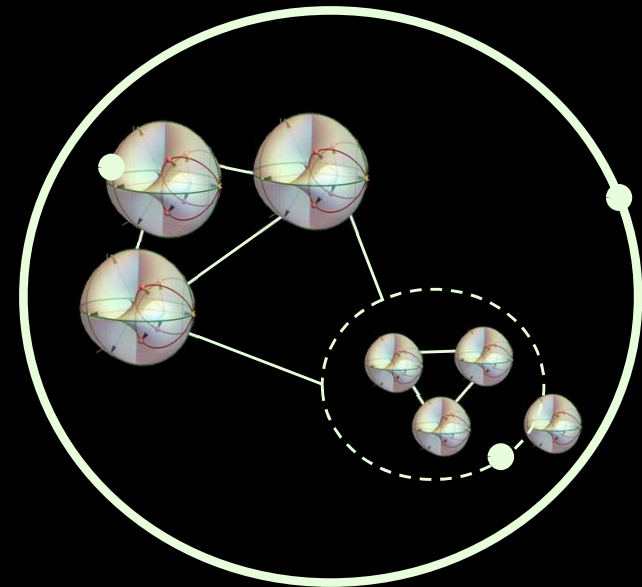
- (1): shorthand for symmetry or other foundational mathematics principles
- (2): Galois formalisms as the strictest constraint-based system solution
- (3): method to detect hidden information in higher dimensions (higher-form symmetries)
- (4): symmetry-breaking as phase transition

Galois's idea: identify solvable equations (with x^5) by looking at the permutations of the symmetry properties of roots (group)



Capsules

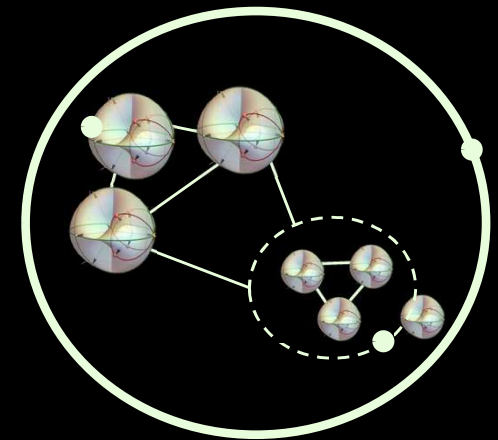
Dynamical modeling of subsystems with their own clocks and geometry; space and time regimes locally transported into coherent glocal (global and local) wholes



Galois Capsules Thesis

Galois Capsules (Gal-Caps): the dynamical regime of G-SNFT: symmetry-based global transport framework for dynamical subsystem modeling

1. Transport as 3rd Mathematical Revolution in the STEM infrastructure
 - Set Theory Entities -> Category Theory
Relations -> Active Transport
2. Galois Capsules: transport framework across the STEM infrastructure
3. Time integration as the native temporal regime of transport
 - Simultaneous snapshot and trajectory
 - Process with beginning, middle, end



3rd Mathematical Revolution: Transport



- Active Transport: intrinsic time, flow, and transformation built directly into the foundational syntax of transport (non-existent in set theory and category theory)
 1. Process: Real-life systems are processual not object-centered
 2. Cyclic Change & Phase Transition: loop-diffs capture cumulative change of cycles and break-out to phase transition
 3. Glocal Coherence: consistency link between local and global
 4. Need a unified transport theory incorporating
 - Green's theorem, Stokes' theorem (BB integrals), Wilson loop

Table 3. Galois Capsules: Set Objects and Categorical Relations lift to Loop Transport.

	Entity	Objects	Math Approach	Stance	Galois Form	Temporality	Episteme
1	Set	Elements	Set theory	Passive	Galois groups	Past	Classical
2	Category	Relations	Category theory	Potential	Galois categories	Present	Transcendental
3	Loop	Transports	Loop-transport theory	Active	Galois capsules	Future	Tr Topology

Category: set equipped with relations; Transport: category equipped with loop dynamics

Transport

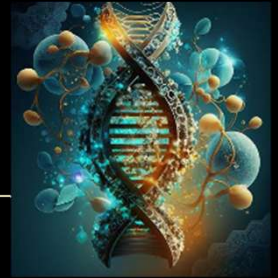
- Shift to active transport visible as prominent emerging method across the digital STEM infrastructure

	Topic	Description	Reference
I. Physical Transport (QCA: Quantum Cellular Automata)			
1	Galois QCAs	Categorical, Clifford & non-Clifford QCAs	2026 Sun; Yang
2	Lattice QCAs	Local symmetry of non-invertible fusion-categories	2026 Wen (Nameki)
3	Lattice QCAs	Local symmetry of lattice anomalies ('t Hooft)	2026 Tu (Else)
4	Lattice QCAs	Bulk-boundary QCA formulation for "GSE"	2026 Tu (Else)
5	Lattice QCAs	FTQC: 3D+ bosonic-fermionic generalization	2026 Tu (Else)
6	Galois QCAs	FTQC: bosonic-fermionic symmetry	2026 Tu (Else)
7	QTP	Lindblad grid instability entanglement	2026 Tu (Else)
8	Galois QC/QIS	Galois qudits: finite-field automorphisms	2026 Tu (Else)
9	Galois QC/QIS	Galois multi-partite entanglement classification	2026 Tu (Else)
10	TQFT	Galois-twisted fusion category lift to 3D TQFT	2026 Johnson-Freyd
11	QFT/TFT	Geometric stack-categories for Lie group symmetry	2025 Stockall (Yu)
12	MZV-QFT	MZV Feynman diagram knot-theory motivic Galois theory	26 Brown/Wakhare21
II. Mathematical Transport (Holonamy, Monodromy, Exodromy)			
1	Holonomic RL	Neural holonomy: action paths in curved space	2026 Singh
2	Holonomic QC	Time evolution: holonomic and dynamical parts	2026 Sjoqvist
3	Entanglement	Entangling holonomy as a transport property; QIE	2026 Ikeda, 2024 Lusk
4	Black Holes	Gravitational Faraday holonomy black-hole light	2026 Lusk
5	Cosmology	Perfectoid QFTs for non-archimedean spaces	2026 Shabir (Faizal)
1	Renormalization	Galois coaction for Feynman amplitude symmetries	2023 Kreimer-Yeats
2	Stacks	Monodromy group, Galois-width homotopy paths	2026 Duff; 2025 Landi
3	Category theory	Higher loops deform path-level surface	2026 Duff; 2025 Landi
4	Cosmology	Axion monodromy ultra-high gravity	2026 Duff; 2025 Landi
5	Cosmology	Torsion monodromy dimension counting	2026 Duff; 2025 Landi
6	Cosmology	Multi-field quantum monodromy for inflation	2026 Duff; 2025 Landi
7	Molecular gas	Quantum monodromy obstructs global	2026 Duff; 2025 Landi
8	Defects	Restore associativity with domain-wall codimension	2026 Copetti
9	Defects	Chern-Simons holography braided tensor categories	2026 Ambrosino
1	Exodromy	Beyond Noetherian-finite stratified spaces	2026 Porta
2	Exodromy	Beyond conical section stratified spaces	2026 Haine
3	Exodromy	Condensed math proofs of exodromy theorems	2026 van Dobben
4	Exodromy	Stratified RL through temporal-logic strata	2026 Curry
5	Exodromy	Arithmetic Dynamics: Arboreal Galois groups	2026 Ulkem
III. Computational Transport (AI, NN, ML, Diffusion Transformers)			
1	Wasserstein OT	Sliced 1-Wasserstein, RL 2-Wasserstein geodesics	2025 Carlier; Ito
2	Wasserstein RL	Wasserstein-metric RL policy regularization	2026 Fan; Nahim
3	AdS/Wasserstein	Wasserstein-metric quantum-chaos transport	2026 Fan; Nahim
4	Symmetry OT	Canonical symmetries & recursive flow	2026 Fan; Nahim
5	Galois OT	Galois flows: prime-number system	2026 Fan; Nahim
6	Category theory	Categorical flow maps: functorial flow	2026 Fan; Nahim
7	Flux-matching	Path-geometry (flow) + mass-density	2026 Fan; Nahim
8	Quantum FM	Density matrix interpolation & quantum continuity	2025 Cui
9	Riemannian OT	Riemannian and Ricci metric OT	2026 Bamberger
10	Riemannian OT	Entropic Riemannian neural optimal transport	2026 Micheli-Bhatt

Physics

Mathematics

Computation



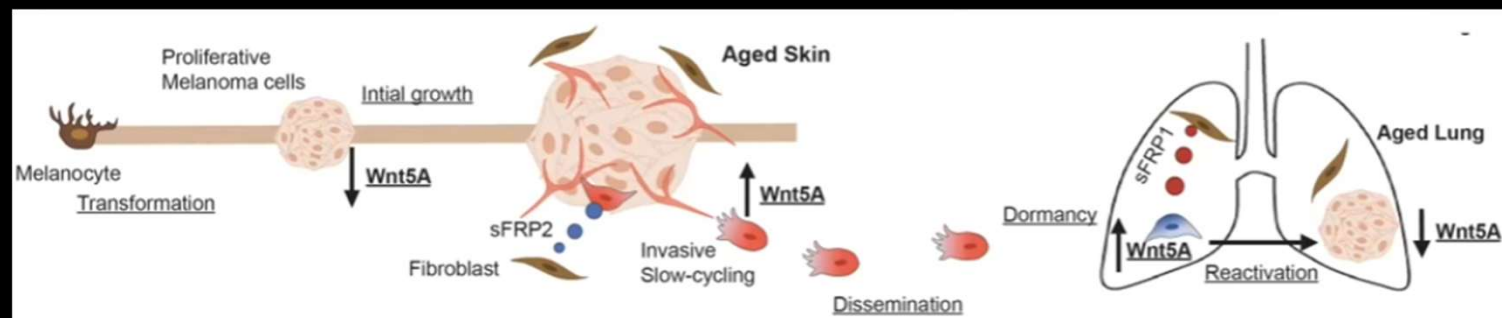
Gal-Cap Subsystem Modeling

- Aging: Cell-Tissue-Organ-Organism-Population
 1. Melanoma transport and dormancy activated in aging remodeling
 2. Loop-transport of Differentially Methylated Positions (DMPs) showed tissue-specific dynamics vs static methylation profiles
 3. Loop-twist highlighted fibroblasts vs epidermis and CD4 cells dynamics compared to raw change in methylation patterns in CpG island Low-Methylated Regions

Aging remodels the lung microenvironment:

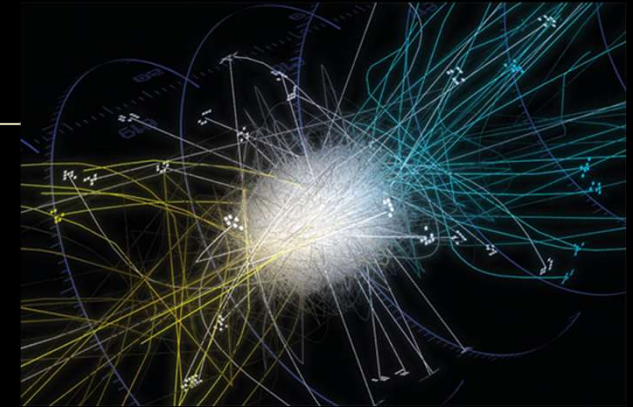
1. Aged fibroblasts secrete factors (sFRP1)
2. Suppress the melanoma dormancy program (WNT5A/AXL)
3. Activate a reawakening program (MER/PROS1) towards lung metastases

The body as a
Turing machine:
runs programs



Agenda

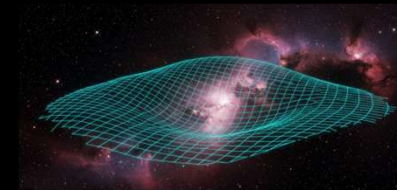
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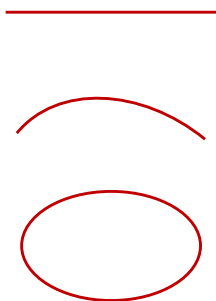
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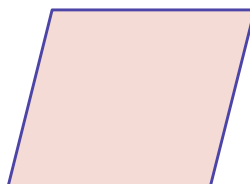
Loop Transport



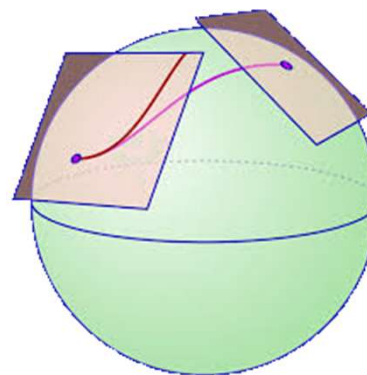
0D: Point



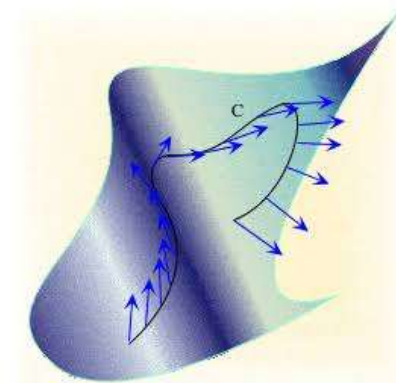
1D: Line,
Curve,
Loop



2D: Surface



3D: Sphere

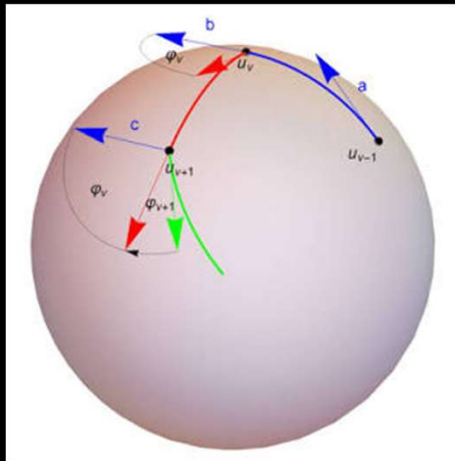
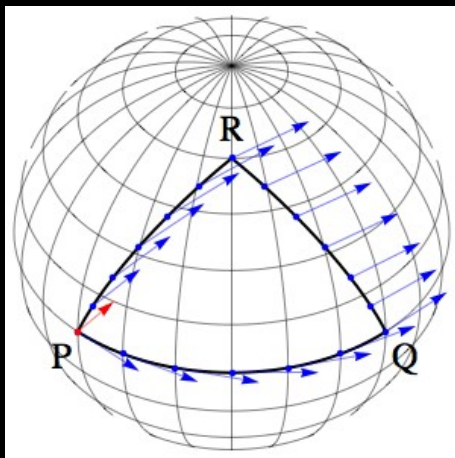
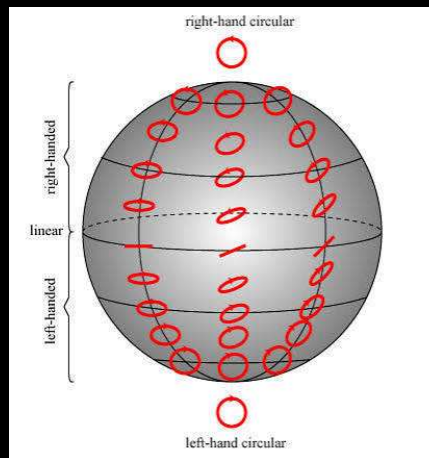
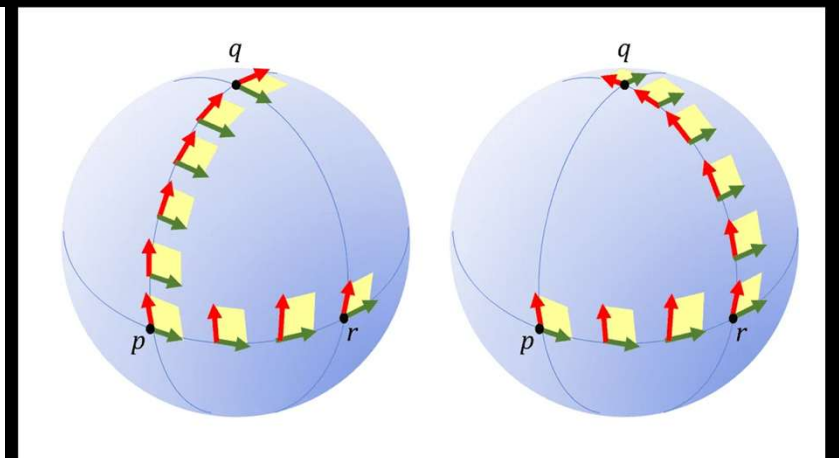


2D Manifold embedded
in a 3D Space

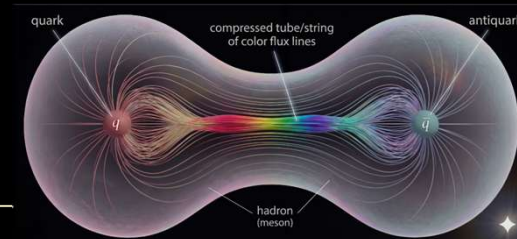
A loop is a line that bends around to return to its starting point

A loop is the minimal object needed to measure curvature; a known object (like an arrow (vector)) is transported around a closed loop to compare its initial, intermediate, and final orientations

Loop Transport

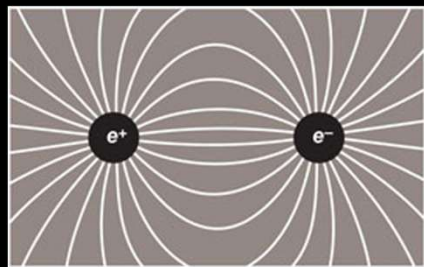


Wilson Loop

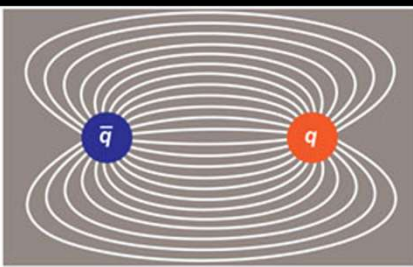


- EM (QED): electromagnetic interactions computed using perturbative QFT theory and Feynman diagrams
- Strong force (QCD): confinement arises from gluon-gluon self-interactions, requiring nonperturbative methods such as lattice QCD
 - In lattice QCD, Wilson-loop expectation values are computed, and their scaling behavior is used to determine confinement and extract the confining string tension

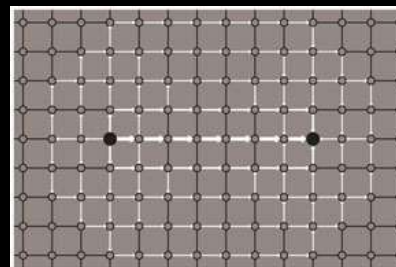
EM force lines spread through space



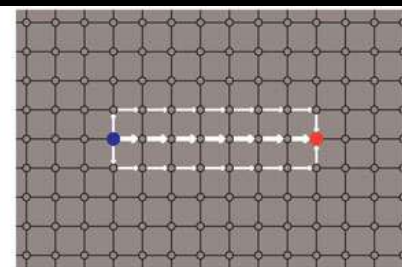
Strong force between quarks confined to flux tube



Lattice QED easy to apply



Lattice QCD necessary with Wilson loop



Green's & Stokes' Theorems

■ Loop transport in Vector Calculus

$$\oint_C P dx + Q dy = \iint_D \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y} \right) dA$$

Green's Theorem

Bulk-Boundary Duality Relation:

A line integral around a closed curve =
A double integral over the flat region
enclosed by the curve (curl)

$$\oint_C (Ldx + Mdy) = \iint_D \left(\frac{\partial M}{\partial x} - \frac{\partial L}{\partial y} \right) dxdy$$

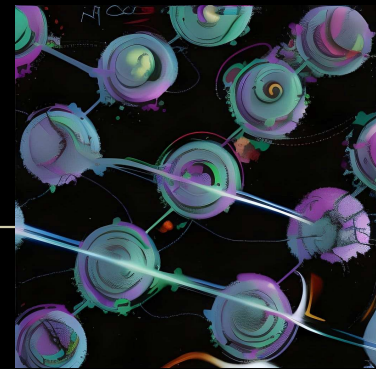
Stokes' Theorem Divergence Theorem

Same idea in higher-dimensions

The surface integral of the curl of a
function over a surface bounded by a
closed surface = The line integral of
the vector function around the surface

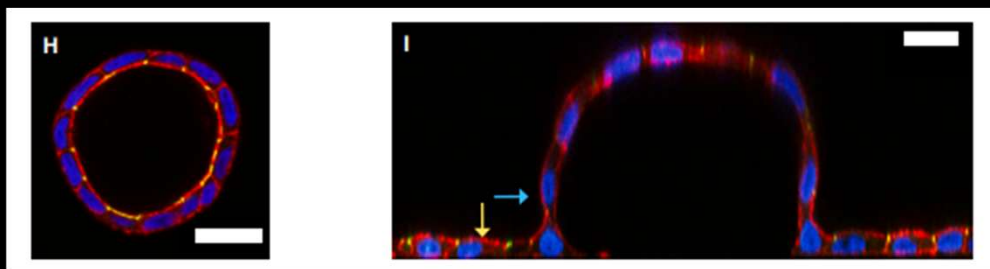
$$\oint_C \vec{F} \cdot d\vec{r} = \iint_S (\nabla \times \vec{F}) \cdot d\vec{S}$$

Loop Examples

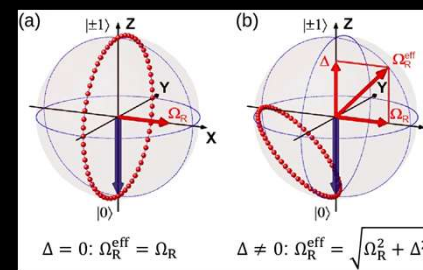


- Goal: measure unknown space, curvature
 - Most real-life situations are not in flat Euclidean space
 - Cells, tumors, black holes, exoplanets
- Loop Quantum Gravity
 - Loop is minimal object to measure curvature
- Wilson loop: cannot use force fields, must circuit a loop
- Camping perimeter tour: measure differences in a loop
- Quantum Computing: accumulated phase transport

Biological Tumor Growth Mechanics



Qubit Bloch Sphere



How does Quantum Computing work?

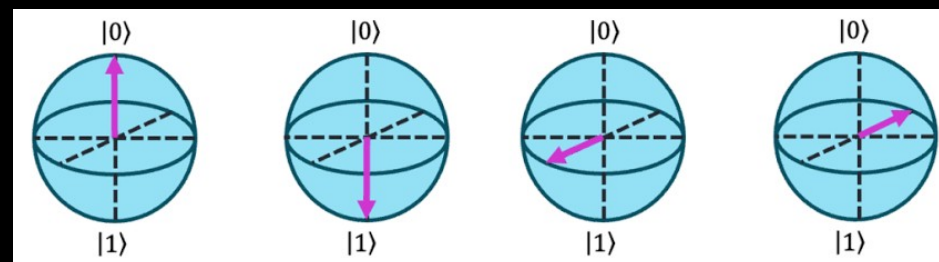


Quantum Computing: the circuit is a spacetime “blanket” across which every possible combination (qubit) is run physically simultaneously, measured as the accumulation of phase changes, interpreted as the “best” answer (blue) at the ending gate (most end states cancel each other out (orange))

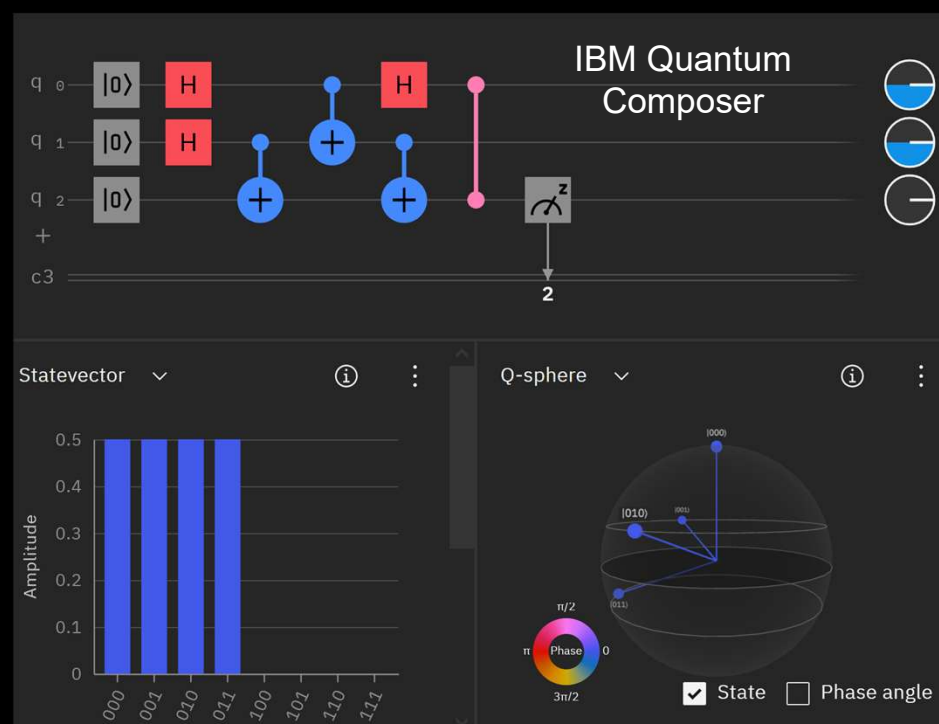
Classical Computing:
Sequential Iteration



Quantum Computing:
Simultaneous Analysis

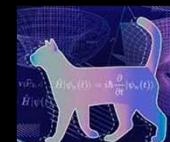
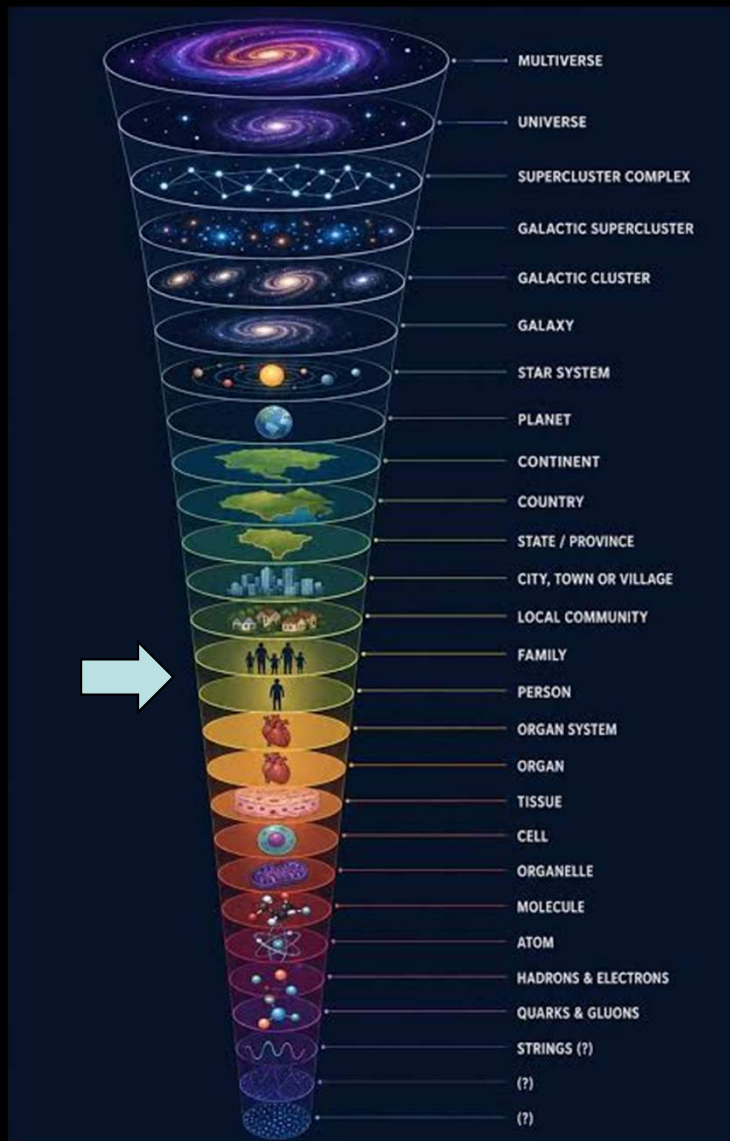


Qubit circuit “loop” around Bloch sphere stored as accumulated phase change



The Scale of Things

Copernican decentering: developing a quantum-first scientific stance, contra Kantian googles of classical mechanics



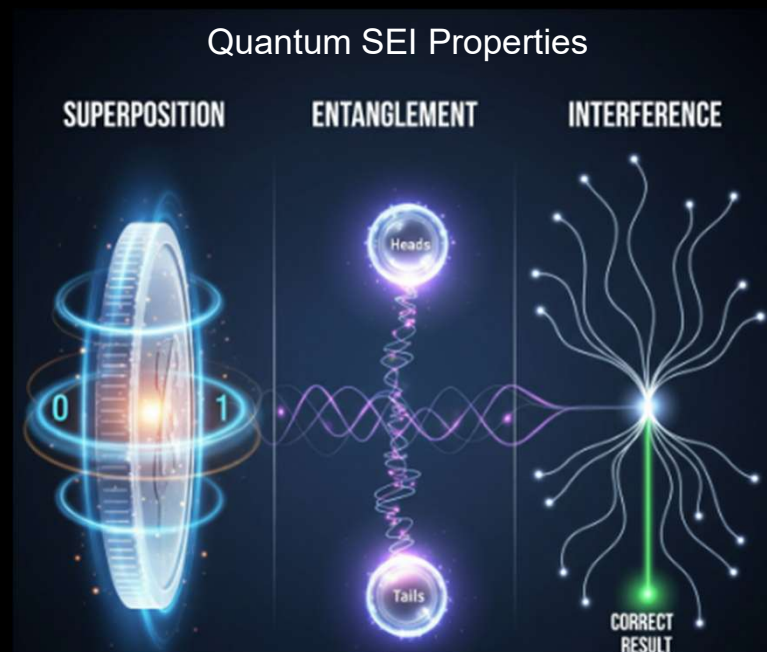
General Relativity

Relativistic effects occur at all scales, but most apparent in galactic and cosmological distances, velocities, gravitational fields, and long timescales

Classical Mechanics

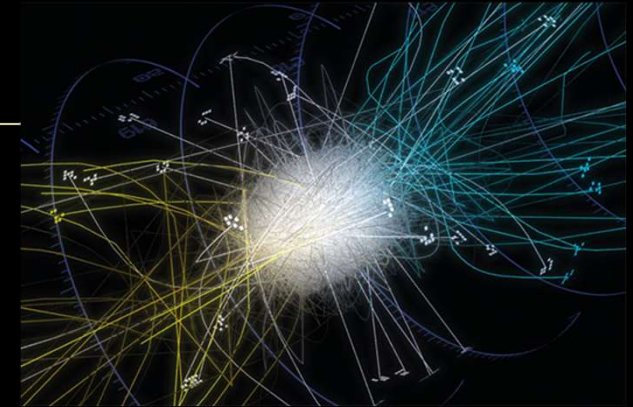
Classical Mechanics of Earth:
10,000 feet of life support

Quantum Mechanics



Agenda

- Galois Smart Network Field Theory
 - Formal Verification
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CERN: testing times for space-time symmetry

Renaissance: Uncover hidden rationality in a stable natural world with Knowledge Production
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Modern Age: Kantian Transcendental: Human is Subject and Object of Knowledge Production
Information Age/Intelligence Age: AI is Subject and Object of Knowledge Production

Transport

- Shift to active transport visible as prominent emerging method across the digital STEM infrastructure

	Topic	Description	Reference
I. Physical Transport (QCA: Quantum Cellular Automata)			
1	Galois QCAs	Categorical, Clifford & non-Clifford QCAs	2026 Sun; Yang
2	Lattice QCAs	Local symmetry of non-invertible fusion-categories	2026 Wen (Nameki)
3	Lattice QCAs	Local symmetry of lattice anomalies ('t Hooft)	2026 Tu (Else)
4	Lattice QCAs	Bulk-boundary QCA form	
5	Lattice QCAs	FTQC: 3D+ bosonic-fermion	
6	Galois QCAs	FTQC: bosonic-fermion	
7	QTP	Lindblad grid instability	
8	Galois QC/QIS	Galois qudits: finite-field	
9	Galois QC/QIS	Galois multi-partite entanglement	
10	TQFT	Galois-twisted fusion category lift to 3D TQFT	2026 Johnson-Freyd
11	QFT/TFT	Geometric stack-categories for Lie group symmetry	2025 Stockall (Yu)
12	MZV-QFT	MZV Feynman diagram knot-theory motivic Galois theory	26 Brown/Wakhare21
II. Mathematical Transport (Holonomy, Monodromy, Exodromy)			
1	Holonomic RL	Neural holonomy: action paths in curved space	2026 Singh
2	Holonomic QC	Time evolution: holonomic and dynamical parts	2026 Sjoqvist
3	Entanglement	Entangling holonomy as a transport property; QIE	2026 Ikeda, 2024 Lusk
4	Black Holes	Gravitational Faraday holonomy black-hole light	2026 Lusk
5	Cosmology	Perfectoid QFTs for non-archimedean spaces	2026 Shabir (Faizal)
1	Renormalization	Galois coaction for Feynman amplitude symmetries	2023 Kreimer-Yeats
2	Stacks	Monodromy group, Galois	
3	Category theory	Higher loops deform path	
4	Cosmology	Axion monodromy ultra-	
5	Cosmology	Torsion monodromy dim	
6	Cosmology	Multi-field quantum mon	
7	Molecular gas	Quantum monodromy ob	
8	Defects	Restore associativity with domain-wall coaction	2026 Copetti
9	Defects	Chern-Simons holography braided tensor categories	2026 Ambrosino
1	Exodromy	Beyond Noetherian-finite stratified spaces	2026 Porta
2	Exodromy	Beyond conical section stratified spaces	2026 Haine
3	Exodromy	Condensed math proofs of exodromy theorems	2026 van Dobben
4	Exodromy	Stratified RL through temporal-logic strata	2026 Curry
5	Exodromy	Arithmetic Dynamics: Arboreal Galois groups	2026 Ulkem
III. Computational Transport (AI, NN, ML, Diffusion Transformers)			
1	Wasserstein OT	Sliced 1-Wasserstein, RL	2026 G. et al.
2	Wasserstein RL	Wasserstein-metric RL p	
3	AdS/Wasserstein	Wasserstein-metric quan	
4	Symmetry OT	Canonical symmetries &	
5	Galois OT	Galois flows: prime-num	
6	Category theory	Categorical flow maps: f	(in)
7	Flux-matching	Path-geometry (flow) + m	
8	Quantum FM	Density matrix interpolation & quantum continuity	2025 Cui
9	Riemannian OT	Riemannian and Ricci metric OT	2026 Bamberger
10	Riemannian OT	Entropic Riemannian neural optimal transport	2026 Micheli-Bhatt

Physics

Mathematics

Computation

Physical Transport

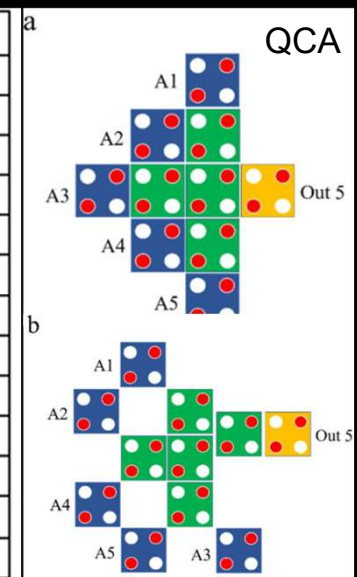
Feynman
Diagram

Object	Diagram	Symbol
Incoming particle		1
Outgoing particle		0
Photon		$\frac{-ig_{\mu\nu}}{p^2}$
Vertex		$ie\gamma^\mu = \nu$

$$(O_1 i e \gamma^\mu l_1) \left(\frac{-ig_{\mu\nu}}{p^2} \right) (O_2 i e \gamma^\nu l_2)$$

- QFT (Quantum Field Theory)
 - Feynman diagrams complicated to compute at scale
- Alternatives
 - QCA (Quantum Cellular Automata), Lattice QCA, TFT/TQFT (SymTFT), Amplituhedrons, MZV (multiple zeta value) motivic Galois periods, Quantum Turing Patterns, tensor networks

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4	Lattice QCAs	Bulk-boundary QCA formulation for all SPTs	2025 Fidkowski
5	Lattice QCAs	FTQC: 3D+ bosonic-fermionic generic QCAs	2026 Kwan (Haah)
6	Galois QCAs	FTQC: bosonic-fermionic symmetry-based QCAs	2026 Jones
7	QTP	Lindblad grid instability entanglement-generation	2026 Ikeda
8	Galois QC/QIS	Galois qudits: finite-field automorphism operators	2026 Wills
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Mathematical Transport

Glocal Primitives (local rules -> coherent global structure)

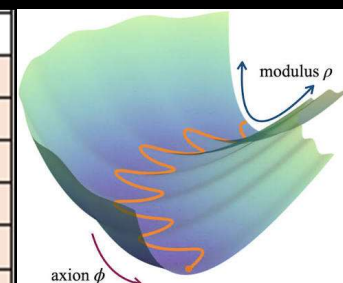
1. Holonomy: net transformation produced by transporting an object around a closed loop in a space (continuous)
2. Monodromy: net transformation produced by transporting an object around a singularity in a space (discrete)
3. Exodromy: exit paths out of a stratified space (endodromy: paths into a stratified space)

1

2

3

II. Mathematical Transport (Holonomy, Monodromy, Exodromy)			
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1	Renormalization	Galois coaction for Feynman amplitude symmetries	2023 Kreimer-Yeats
2	Stacks	Monodromy group, Galois-width homotopy paths	2026 Duff; 2025 Landi
3	Category theory	Higher loops deform path-level surface-level top	2025 Pascaleff
4	Cosmology	Axion monodromy ultra-high gravitational waves	2026 D'Amico
5	Cosmology	Torsion monodromy dimension compactification	2026 Allaby
6	Cosmology	Multi-field quantum monodromy for beyond-FRW	2026 Ghorai
7	Molecular gas	Quantum monodromy obstructs global symmetry	2023 Tokaryk
8	Defects	Restore associativity with domain-wall codimension	2026 Copetti
9	Defects	Chern-Simons holography braided tensor categories	2026 Ambrosino
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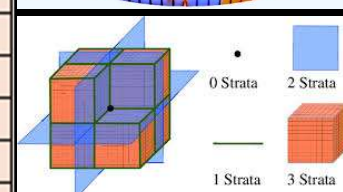
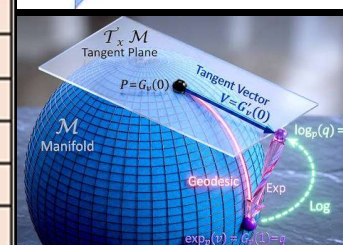


$$g_{jk}(\theta) = \int_X \frac{\partial \log p}{\partial \theta^j} \frac{\partial \log p}{\partial \theta^k} p(x, \theta) dx$$

$$\mathcal{L}(Z, Z') = \lambda \text{Ins}(Z, Z') + \nu [C(Z) + C(Z')]$$

$$\text{Ins}(Z, Z') = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^m \log \left(\frac{1}{\lambda} \frac{p_i(Z)}{p_j(Z')} \right)$$

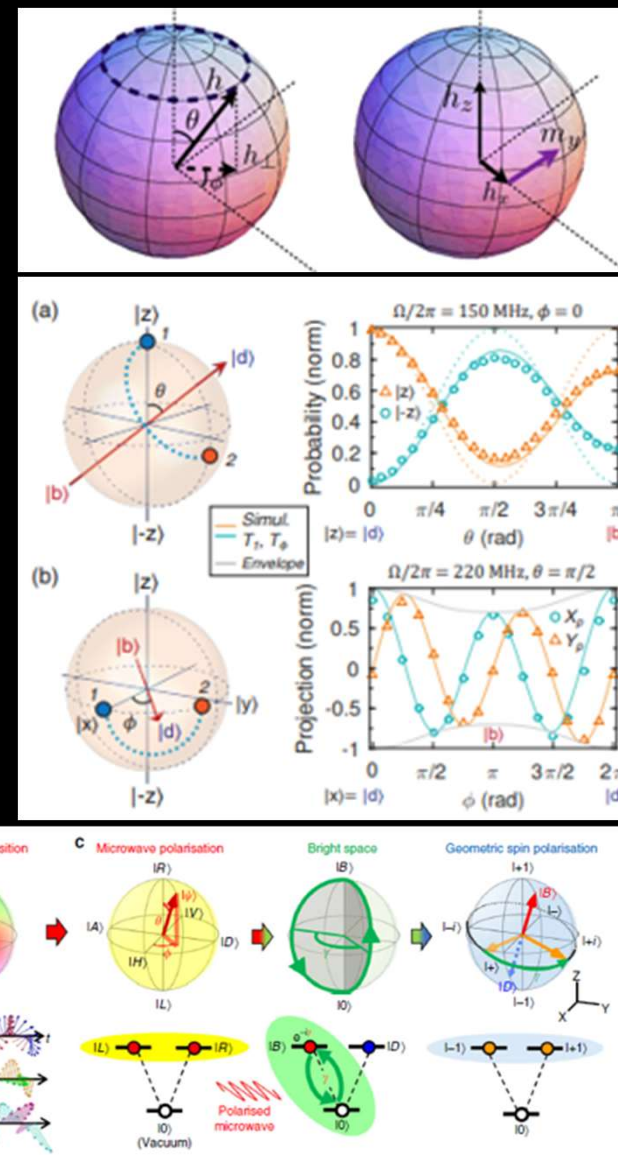
$$v(Z) = \frac{1}{n} \sum_{i=1}^n \log \left(\frac{1}{\lambda} \frac{p_i(Z)}{p_j(Z')} \right)$$



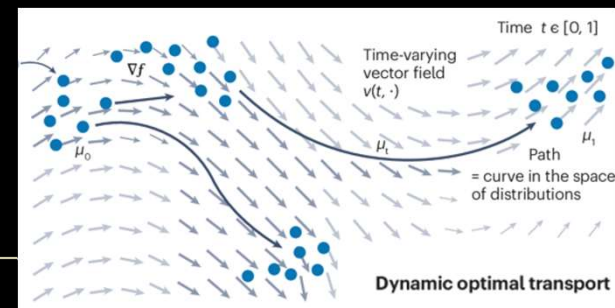
Holonomic QC

Holonomy: tracks the geometric phase a system accumulates during a cyclic evolution; e.g.; polarization holonomy
Entangling holonomy: additional holonomic structure as the geometric effect of the entangled state of multiple qubits

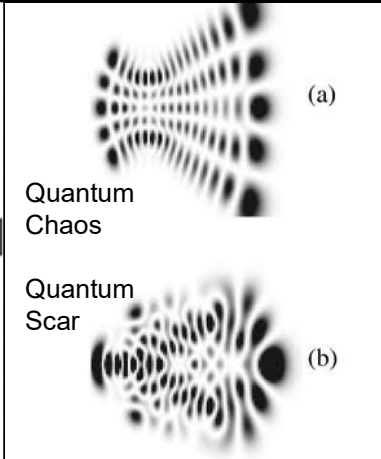
- Geometric phase (Berry, Zee, Wilczek 1984)
- Quantum particle evolution split
 - Geometric component (space)
 - Time-energy component (dynamics)
- Holonomic Quantum Computing
 - Fast robust geometric gates without the overhead of detailed dynamical control of Hamiltonians
 - Holonomic Gates: holonomies (geometric phases) perform logical operations directly within quantum error-correcting code spaces



Computational Transport



- Diffusion Transformers large-scale shift to Optimal Transport (flow matching) for probability flow efficiency
 - Replace random, noisy diffusion paths with straight, mathematically optimal trajectories
 - Accelerate 3D generation speeds while reducing cost
- Wasserstein geometry measure shortest, straightest continuous paths (geodesics) in data distributions

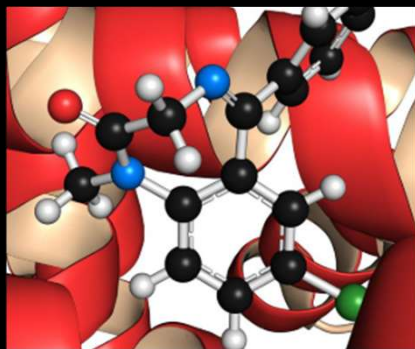
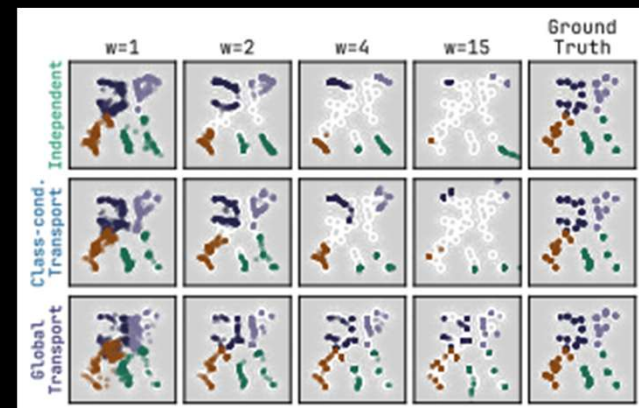
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2	Wasserstein RL	Wasserstein-metric RL policy regularization	2026 Fan; Nahim	
3	AdS/Wasserstein	Wasserstein-metric quantum-chaos transition	2026 Hashimoto	
4	Symmetry OT	Canonical symmetries & recursive flow-matching	2026 Zhou; Huang	
5	Galois OT	Galois flows: prime-number system transport	2021 Pappas	
6	Category theory	Categorical flow maps: functorial flows	2026 Roos (Bronstein)	
7	Flux-matching	Path-geometry (flow) + mass-density (flux)	2026 Pao-Huang	
8	Quantum FM	Density matrix interpolation & quantum continuity	2025 Cui	
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Transport in Biology

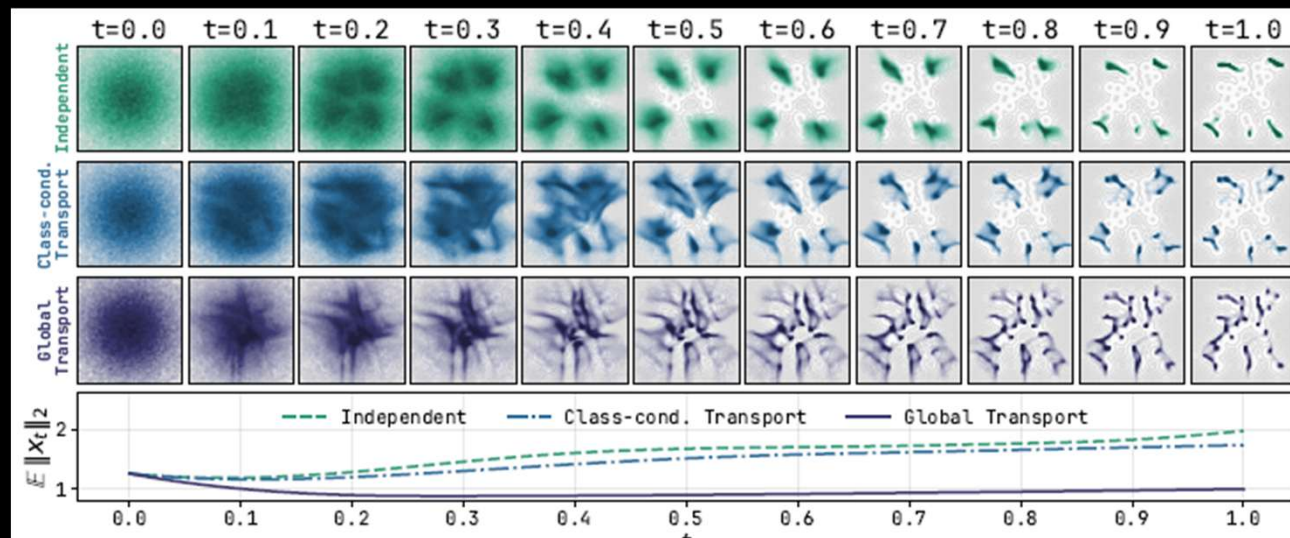
Global Transport: a single transport geometry linking the entire noise distribution to the entire data distribution in molecular space, reused across all target properties and design objectives

- Better design space exploration
- Handle multiple conditional properties simultaneously
 - Binding affinity, toxicity, solubility, and target class
 - Avoid property-specific transport schemes

Molecularly-precise
Drug Design

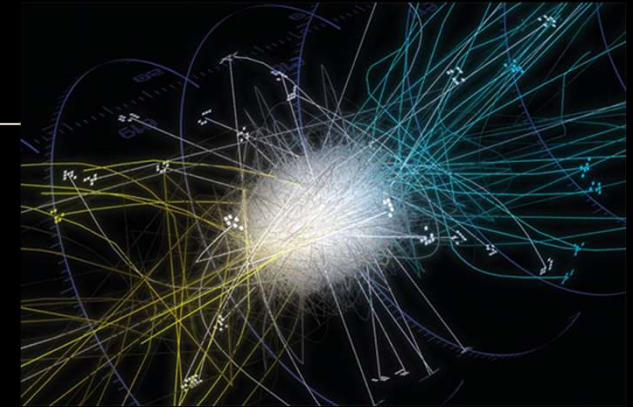


Global Transport in Molecular Drug Design



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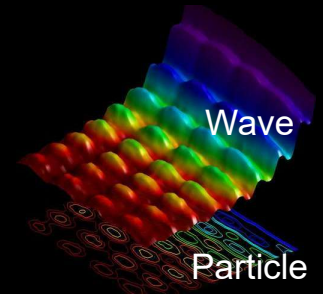
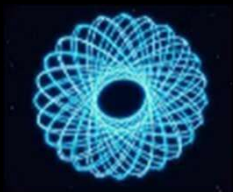
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Information Age/Intelligence Age: AI is Subject and Object of Knowledge Production

Gal-Cap Time Integration

Capsular time: time integration as the native temporal regime of Gal-Caps: a temporal object that is simultaneously the glocal duality of event log and trajectory

- Transport: intrinsic time, flow, and transformation built directly into the formal syntax of process
 - Integrals and derivatives: rate of change
 - Time integration: infinitesimal moments consolidated into whole
 - Duality: particles, light, time: discrete and continuous
- A richer temporal object is needed to model complex dynamical systems
 - Glocal: events only acquire meaning through their embedding within a larger system
 - Intrinsic regimes: subsystems possess distinct internal clocks, feedback loops, and rates of change
 - Dependency: memory, hysteresis, adaptation, and learning are functions of cumulative histories not instantaneous states

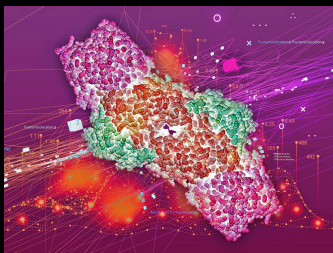


Examples

Gal-Cap Integrated Time



- Time integration: temporal object that is the simultaneous duality of event log and trajectory
 - Inherent smart network feature of all social media
 - Smart network tech with their own spatial and temporal regimes
 - Blockchains: block height, blocktime
 - AI foundation models: network space, diffusion and training time
 - Quantum computing: entangled qubit cloud chamber, circuit time
 - Biology: embryonic development, immune memory, aging
 - An embryo's present form is simultaneously the latest developmental event and the accumulated record of every prior differentiation decision
 - A memory immune cell embodies both its current state and the entire history of pathogen encounters that shaped it
 - An aged stem-cell niche reflects current damage and the integrated trajectory of decades of repair, stress, epigenetic change, exhaustion



The biological object: event log and trajectory

“Time is the most used noun in the English language, but does not have a foundational definition” – Sean Carroll, paraphrase

Time

“...the classic culture of Tlön ... conceive[s] the universe as a series of mental processes which do not develop in space but successively in time” - Borges

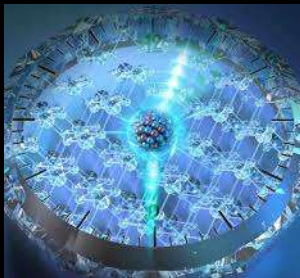


Thinking Infrastructure



Time Transport in the Brain:
the anterior cingulate cortex
(ACC) forms specific patterns
to log sequential actions from
the beginning to the middle to
the end of an activity

Physical Infrastructure



Nuclear Clocks

Philosophy of Time

Kant: transcendental aesthetic of time and space
Hegel: time introduced into philosophy as history
Husserl: internal time consciousness with “long now”
Heidegger: future touches past to determine present
Derrida: non-present is present in the present

Philosophy of Transport

Freedom, Enablement, Possibility

Time Technology Primitives

Floquet periodicity, Fourier transforms

Atomic clocks

Entanglement (ghost) imaging

Quantum Time: time-reversal symmetry-breaking, time-
energy uncertainty relation, out-of-time-order correlators

Anisotropic scaling (time and space scale at different rates):
e.g.; crystals, Haldane phases, quantum Hall effects

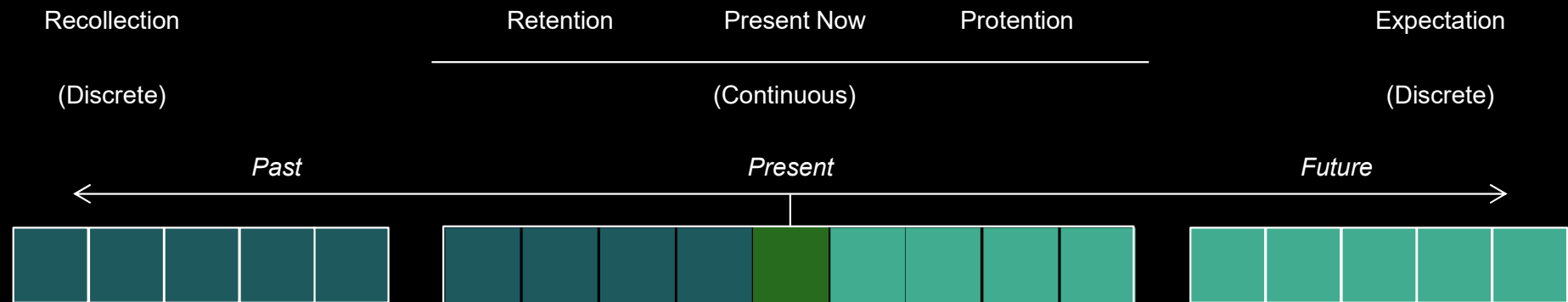
Quantum Chaos: beginning, bullet, saturation, stability
Lyapunov exponents in time and space

Philosophy of Time

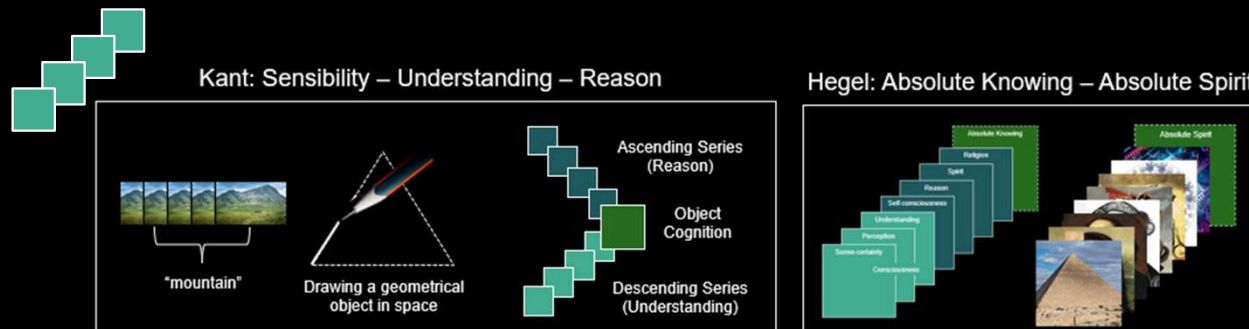
Bergson:
Durée (qualitative time) (*Kairos*)
Clock time (quantitative time) (*Chronos*)



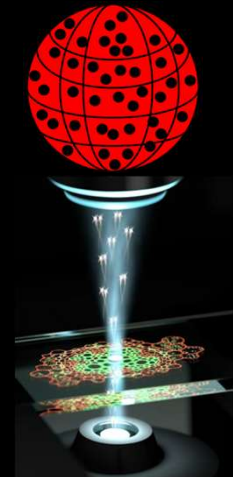
Time: simultaneously discrete and continuous, uncollapsed until measured



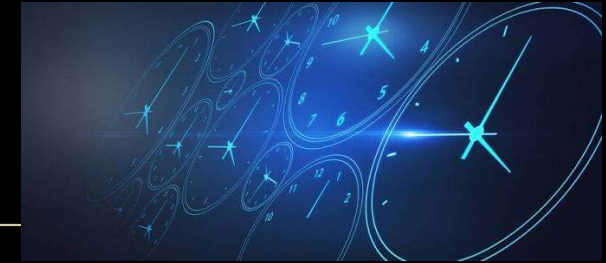
Husserl: Internal Time Consciousness



Kant: time and space are internal and external sensibility configuring all experience
Hegel: time introduced to philosophy in the form of history



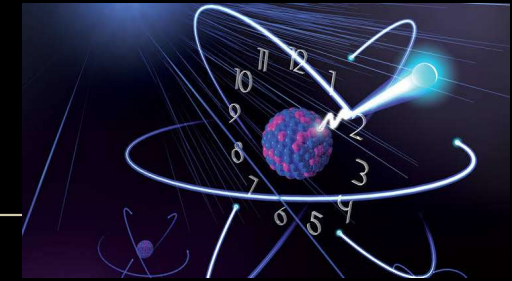
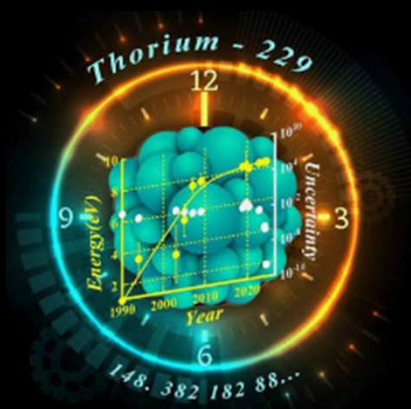
Time Technology Overview



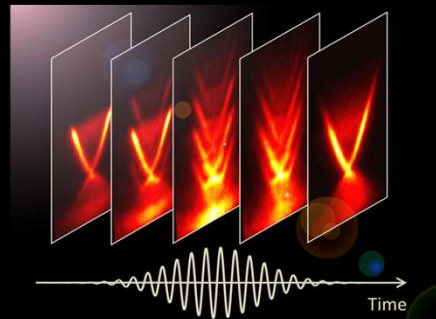
Classical Time <ul style="list-style-type: none"> • Newtonian absolute time • Periodic time (oscillators, pendulums) • Fourier time-frequency duality • Floquet-periodic time • Time-reversal symmetry • Dynamical systems and Lyapunov time • Relativistic proper time • Light-cone causal time • Thermodynamic arrow of time • Poincaré recurrence time 	Quantum Time <ul style="list-style-type: none"> • Heisenberg time-energy uncertainty relation • Quantum evolution (Schrödinger time) • Quantum speed limits (Mandelstam-Tamm, Margolus-Levitin) • Out-of-time-order correlators (OTOCs) • Time-reversal symmetry breaking • Loschmidt echo • Quantum recurrence time • Decoherence time • Relaxation time (T1) • Dephasing/coherence time (T2) • Quantum Zeno effect • Tunneling time • Entanglement growth time • Scrambling time • Heisenberg time (spectral resolution timescale) 	Precision Timekeeping <ul style="list-style-type: none"> • Atomic clocks • Optical lattice clocks • Ion clocks • Frequency combs • Ramsey interferometry • Clock synchronization • Relativistic clock shifts • Quantum metrology • Quantum-enhanced clocks
Geometric and Topological Time <ul style="list-style-type: none"> • Berry phase evolution • Quantum holonomy • Adiabatic time evolution • Geometric phases • Topological time pumping • Cyclic quantum evolution 		Quantum Chaos A recognizable progression: <ul style="list-style-type: none"> • Initial growth (chaos onset) • Lyapunov regime (operator growth) • Scrambling regime (mixing) • Saturation regime (spectral) • Long-time stability/recurrence
Many-Body and Condensed Matter Systems <ul style="list-style-type: none"> • Anisotropic scaling • Critical slowing down • Aging dynamics • Nonequilibrium relaxation • Floquet time crystals • Topological pumping • Fractional quantum Hall dynamics • Haldane phase dynamics • Prethermalization 	Quantum Information and Entanglement <ul style="list-style-type: none"> • Entanglement imaging (ghost imaging) • Entanglement entropy growth • Scrambling dynamics • Quantum teleportation latency • Quantum memories and coherence lifetimes • Causal structure in quantum networks 	Emerging and Exotic Time Concepts <ul style="list-style-type: none"> • Time crystals • Floquet engineering • Synthetic time dimensions • Temporal waveguides • Temporal metamaterials • Discrete versus continuous time • Emergent time in quantum gravity • Thermal time hypothesis • Causal set time

Time Technology Highlights

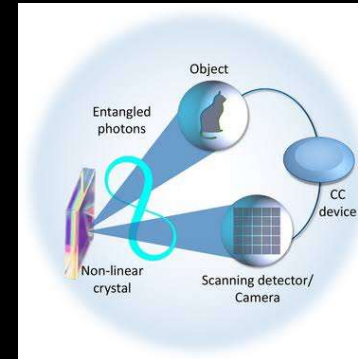
STEM infrastructure examples: Engineers arrive first in many quantum technologies



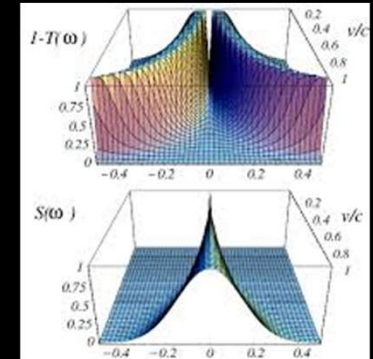
Nuclear Clocks



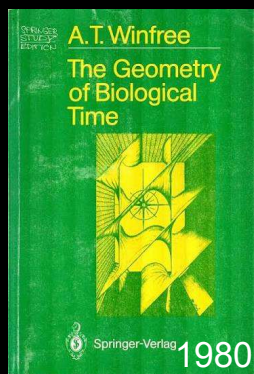
Fourier transforms
Floquet-periodic time



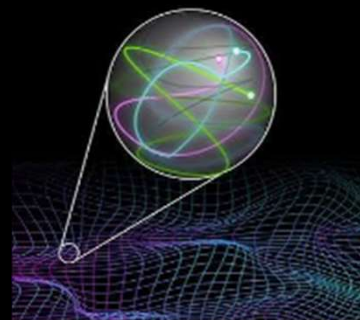
Entanglement
Ghost Imaging



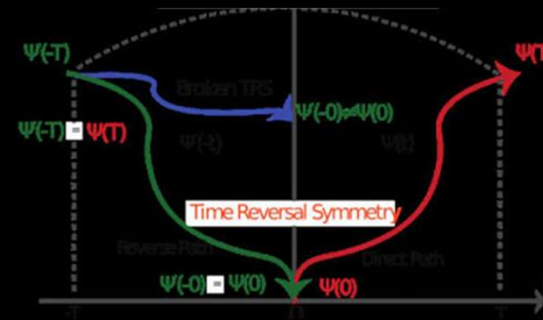
Dark-State Polaritons
Quantum Memory



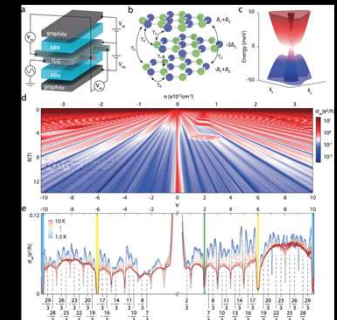
Biological Time Cycles



Quantum Chaos



Time-reversal Symmetry-breaking



Anisotropic Scaling

Gal-Cap Time Integration

- Gal-Cap Philosophy of Time
 1. Present due to transport performativity
 2. Capsular beginning, middle, end duration of processes
 - E.g., quantum chaos regime signatures
 3. Futural since most events are simulated in the digital twin STEM infrastructure but do not occur
- Flexible multifaceted time stance

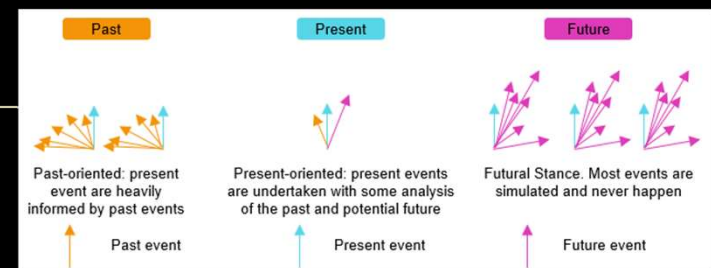
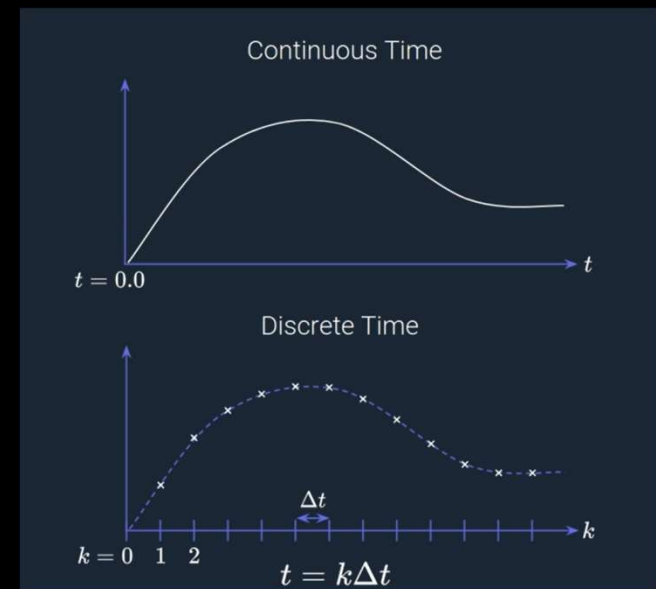
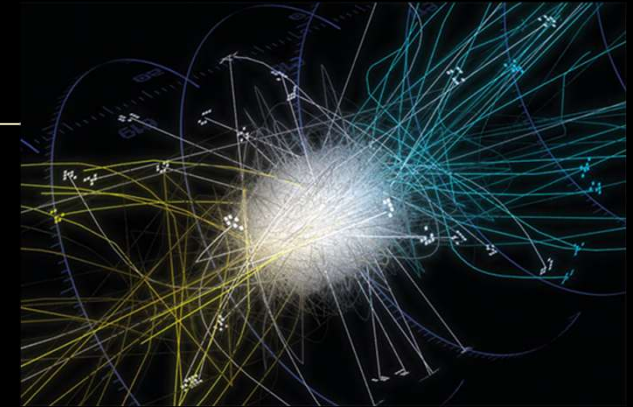


Table 3. Galois Capsules: Set Objects and Categorical Relations lift to Loop Transport.

	Entity	Objects	Math Approach	Stance	Galois Form	Temporality	Episteme
1	Set	Elements	Set theory	Passive	Galois groups	Past	Classical
2	Category	Relations	Category theory	Potential	Galois categories	Present	Transcendental
3	Loop	Transports	Loop-transport theory	Active	Galois capsules	Future	Tr Topology

Agenda

- Galois Smart Network Field Theory
 - Formal Verification
- Galois Capsules Dynamics Theory
- 3rd Mathematics Revolution
 - Set theory -> Category theory -> Transport Theory
 - Transport in the STEM Infrastructure
- Gal-Caps Transport in the STEM Infrastructure
- Time
 - Gal-Cap Time Integration: Events + Trajectory
- Conclusion
 - Episteme



CERN: testing times for space-time symmetry

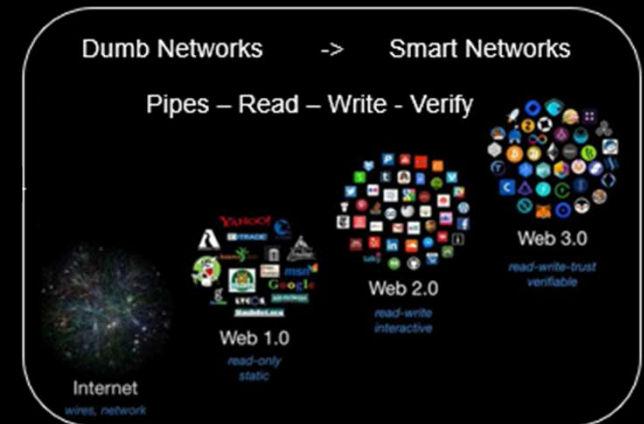
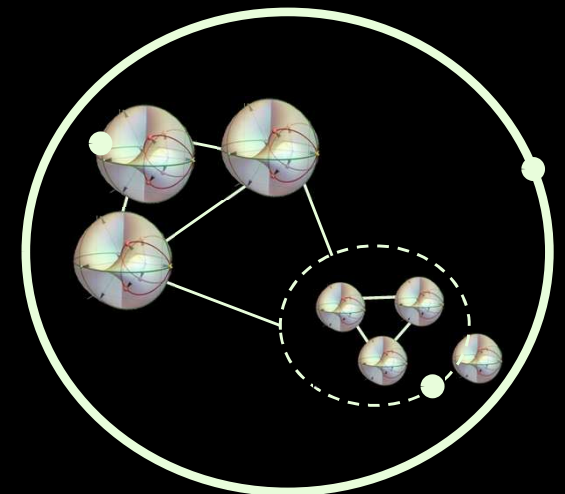
Renaissance: Uncover hidden rationality in a stable natural world with Knowledge Production
Classical Age: Classify, order, categorize the natural world in Scientific Knowledge Production
Modern Age: Kantian Transcendental: Human is Subject and Object of Knowledge Production
Information Age/Intelligence Age: AI is Subject and Object of Knowledge Production

Galois Smart Network Field Theory (SNFT): a symmetry-based formally verified theory of “particle-many” systems

Galois Capsules (Gal-Caps): Galois SNFT modules: symmetry-based glocal transport framework for dynamical subsystem modeling with their own clocks and geometry

Conclusion

- State of the World
 - Dumb pipes -> Smart networks
 - Third mathematical revolution
 - Set theory -> Category theory -> Transport
 - Quantum-first scientific stance
 - New fields: Mathematical Informatics
- Need for overarching theories
 - STEM transport, symmetry, field theory
 - Galois Smart Network Field Theory (SNFT): symmetry-based particle-many system orchestration in formal-verification smart networks
 - Galois Capsules: glocal transport-based dynamical subsystem modeling

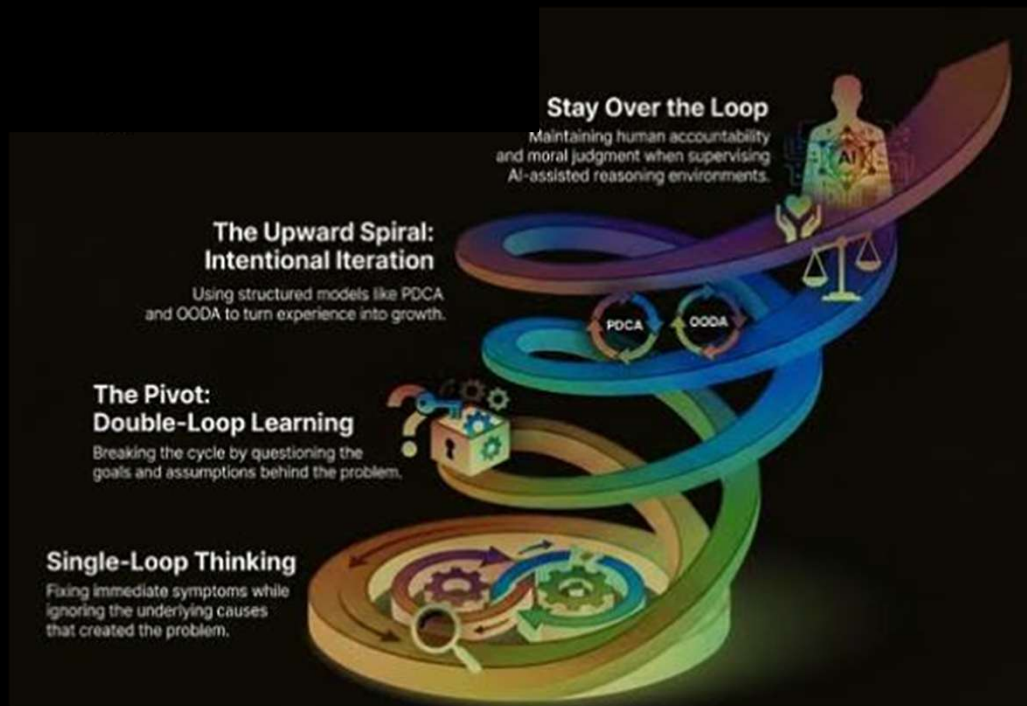


Galois Capsules

Conclusion

Transport~!

	Entity	Objects	Math Approach	Stance
1	Set	Elements	Set theory	Passive
2	Category	Relations	Category theory	Potential
3	Loop	Transports	Loop-transport theory	Active



Loop Transport

Scientific Method: STEM Infrastructure

Science
(Physics)

Technology
(Computation)

Engineering
(Quantum)

Mathematics

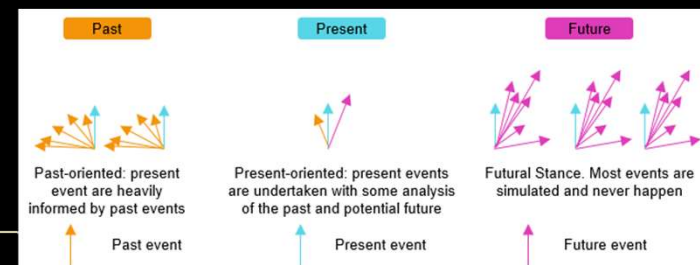
Physics

Mathematics

Computation

	Topic	Description	Reference
I. Physical Transport (QCA: Quantum Cellular Automata)			
1	Galois QCAs	Categorical, Clifford & non-Clifford QCAs	2026 Sun; Yang
2	Lattice QCAs	Local symmetry of non-invertible fusion-categories	2026 Wen (Nameki)
3	Lattice QCAs	Local symmetry of lattice anomalies ('t Hooft)	2026 Tu (Else)
4	Lattice QCAs	Bulk-boundary QCA form	
5	Lattice QCAs	FTQC: 3D+ bosonic-fermionic	
6	Galois QCAs	FTQC: bosonic-fermionic	
7	QTP	Lindblad grid instability	
8	Galois QC/QIS	Galois qudits: finite-field	
9	Galois QC/QIS	Galois multi-partite entanglement	
10	TQFT	Galois-twisted fusion category lift to 3D TQFT	2026 Johnson-Freyd
11	QFT/TFT	Geometric stack-categories for Lie group symmetry	2025 Stockall (Yu)
12	MZV-QFT	MZV Feynman diagram knot-theoretic motivic Galois theory	26 Brown/Wakhare21
II. Mathematical Transport (Holonomy, Monodromy, Exodromy)			
1	Holonomic RL	Neural holonomy: action paths in curved space	2026 Singh
2	Holonomic QC	Time evolution: holonomic and dynamical parts	2026 Sjoqvist
3	Entanglement	Entangling holonomy as a transport property; QIE	2026 Ikeda, 2024 Lusk
4	Black Holes	Gravitational Faraday holonomy black-hole light	2026 Lusk
5	Cosmology	Perfectoid QFTs for non-archimedean spaces	2026 Shabir (Faizal)
1	Renormalization	Galois coaction for Feynman amplitude symmetries	2023 Kreimer-Yeats
2	Stacks	Monodromy group, Galois	
3	Category theory	Higher loops deform path	
4	Cosmology	Axion monodromy ultra-	
5	Cosmology	Torsion monodromy dim	
6	Cosmology	Multi-field quantum mon	
7	Molecular gas	Quantum monodromy ob	
8	Defects	Restore associativity with domain-wall commensuration	2026 Copetti
9	Defects	Chern-Simons holography braided tensor categories	2026 Ambrosino
1	Exodromy	Beyond Noetherian-finite stratified spaces	2026 Porta
2	Exodromy	Beyond conical section stratified spaces	2026 Haine
3	Exodromy	Condensed math proofs of exodromy theorems	2026 van Dobben
4	Exodromy	Stratified RL through temporal-logic strata	2026 Curry
5	Exodromy	Arithmetic Dynamics: Arboreal Galois groups	2026 Ulkem
III. Computational Transport (AI, NN, ML, Diffusion Transformers)			
1	Wasserstein OT	Sliced 1-Wasserstein, RL	2026...
2	Wasserstein RL	Wasserstein-metric RL p	
3	AdS/Wasserstein	Wasserstein-metric quan	
4	Symmetry OT	Canonical symmetries &	
5	Galois OT	Galois flows: prime-num	
6	Category theory	Categorical flow maps: f	(in)
7	Flux-matching	Path-geometry (flow) + m	
8	Quantum FM	Density matrix interpolation & quantum continuity	2025 Cui
9	Riemannian OT	Riemannian and Ricci metric OT	2026 Bamberger
10	Riemannian OT	Entropic Riemannian neural optimal transport	2026 Micheli-Bhatt

Epistemes



Philosophical

History 3.0: a new level of self-reflective sensibility among forms of intelligence: a multi-temporality in which some active-transport events are necessarily enacted, but the vast majority of events are simulated in the digital infrastructure and do not occur

History 2.0: self-reflective sensibility of the Kantian transcendental and Hegelian introduction of time into philosophy in the form of history; realization that events are contingent and could have been otherwise

Mechanical

History 1.0: simple event elapsing; History 2.0 labels History 1.0

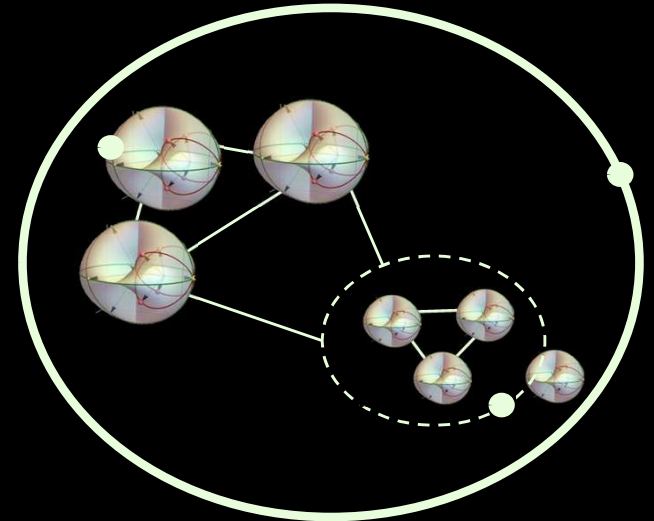


Foucauldian Epistemes: Power-Knowledge Production Eras

	Historical Era	Episteme (Exemplary Figure)	Organizing Paradigm	Parameter
1	Renaissance Age (1300-1650)	Resemblance (Vermeer)	Uncover hidden order, belief in the existence of a stable, knowable world, wholistic system	Literal
2	Classical Age (1650-1800)	Representation (Linnaeus)	Categorize and classify the natural world in tables and diagrams; scientific method; objective truth	Object is abstracted
3	Modern Age (1800-present)	Subject (Kant)	Transcendental Subject: a thing in the world and the condition of possibility for there being a world of things; human is the subject and object of study	Subject is abstracted
4	Information Age (1950-present) Intelligence Age (2020+)	Digitization (Turing) Generativity (ChatGPT)	Knowledge as a dynamical epistemic field (manifested with mathematical well-formedness); AI (not the human) is the Subject and Object of Knowledge Production	Subject and Object are abstracted

***Thank you!
Questions?***

Collaborators:
Takashi Kido
Renato P. dos Santos



Fernandez-Guasti, M. 2021. Roots of Elliptic Scator Numbers

Galois Capsules: Computational Symmetry and the Problem of Time

The “annihilation of space and time ... [as] the railways' operation
... causes distances to diminish ... Lille suddenly finds itself
transported to Louvres; Calais to Pontoise; le Havre to Poissy”
– Schivelbusch, 1978, Railroad Space and Railroad Time

London UK, 26 Oct 2026

Slides: <http://slideshare.net/LaBlogga>

Dr. Melanie Swan, PhD, MBA
University College London (Research Associate)
DIYgenomics.org Longevity Studio (Research Lead)



STEM Systems Theories Needed



- WHY – attain the next level of explanation
 - Unify disjoint knowledge and methods across fields
- Resolve epistemic gridlock
 - Prevent systemic errors by harmonizing the conflicting definitions of truth—such as science’s provisional facts versus mathematics’ absolute axioms—inside computational code
- Unify ontological architecture
 - Establish a singular, coherent framework for reality that treats natural systems (S), human-made tools (T/E), and abstract logic (M) as interconnected dimensions of the same universe
- Overcome reductionism
 - Acknowledge that complex modern crises exhibit emergent properties that cannot be understood in isolation

STEM Systems Theories Needed



- Eliminate epistemic silos
 - Move toward unified, interoperable digital ecosystems
 - Reconcile conflicting definitions of "truth" across STEM
- Prevent data fragmentation
 - Harmonize disparate data formats and software pipelines
- Govern ethical scaling
 - Establish universal frameworks for equitable access, data privacy, and global security
- Secure lifespan sustainability
 - Insulate critical research infrastructure from obsolescence and shifting funding cycles



Individual STEM Theories



- Science (S): The Nature of Reality and Knowledge
 - Scientific Realism vs. Anti-Realism / Instrumentalism
 - Reductionism vs. Emergence / Holism
 - Frequentist vs. Bayesian Inference
- Technology (T): Human Agency and Determinism
 - Technological Determinism vs. Social Construction of Technology
 - Instrumentalism vs. Substantivism
 - Cybernetics / Systems Theory vs. Actor-Network Theory (ANT)
- Engineering (E): Methodology and Problem Solving
 - Rationalistic / Analytical Design vs. Pragmatic / Evolutionary Design
 - Technocratic Efficiency vs. Human-Centered / Socio-Technical Design
 - Heurism / Rule-of-Thumb vs. Applied Science Paradigm
- Mathematics (M): The Foundations of Truth
 - Platonism / Mathematical Realism vs. Formalism
 - Intuitionism / Constructivism vs. Classical Mathematics
 - Logicism vs. Structuralism

STEM Systems Theories



- Transdisciplinary Systems Theory
 - Systems Transdisciplinarity Metatheory (Jantsch, 1972)
 - Dissolves disciplinary boundaries to model physical reality, artifacts, and abstract logic as a unified, non-isolated ecosystem
 - Convergence Theory Framework (NRC, 2014)
 - Organizes disciplines to co-create entirely new fields focused on solving complex, large-scale societal crises
- Performative Systems Theory
 - Integrated STEM Content & Context (Moore, 2014)
 - Anchors interdisciplinary integration within a structured engineering design process driven by real-world constraints
 - Social-Constructivist iSTEM Theory (Vygotsky, 1978)
 - Posits that cross-disciplinary knowledge is dynamically built through collaborative, iterative cycles of prototyping and failure