Assumptions of Physics Summer School 2026

Open Problems in Reverse Physics

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Methodology

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Assumptions of Physics

Status

- Expanding to quantum mechanics forced us to make Reverse Physics more formalized
- Need to
  - Codify the standards for methodology and terminology
  - Make Reverse Physics as much as possible similar to Reverse Mathematics
  - Push the standards of rigor to the maximum attainable
    - Control the informal elements
  - Reformulate results from classical mechanics under the new standard

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Assumptions of Physics

Reverse Physics vs Reverse Mathematics

- Experimenting with new standards in technical briefs
  - Test them on the most complex cases in quantum mechanics
- Similarities
  - Study the discipline by understanding which parts of math/physics are responsible for what results
  - Find results that connect well with established structures/literature, so that insights can be developed by/are of interest to “non-Reversers”
- Differences
  - Currently, Reverse Mathematics is very focused on representation and computability, so the actual techniques and results are not usable by Reverse Physics
  - Reverse Physics cannot be limited to the formal system

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Assumptions of Physics

Methodology and terminology

Conditions. Ideally, each condition represents both a physical intuitive condition and a mathematical specification of that condition. The mathematical specification sets the precise content.

Condition QSUP-MIX (Multiple decomposition of mixtures). *There exists a mixed state ρ that is a mixture of ψ_1 and ψ_2 and also a mixture of ϕ and some other state. That is, $\rho = p_1\rho_{\psi_1} + p_2\rho_{\psi_2} = p_\phi\rho_\phi + p_{\hat{\phi}}\rho_{\hat{\phi}}$ with $\rho_\phi \notin \{\rho_{\psi_1}, \rho_{\psi_2}\}$, $p_1, p_2, p_\phi, p_{\hat{\phi}} \in (0,1)$ and $p_1 + p_2 = p_\phi + p_{\hat{\phi}} = 1$.*

Name. Each condition is given a name, all-caps. Ideally, the same name will be used to identify the same condition within the field

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Assumptions of Physics

Methodology and terminology

Clusters(?). A cluster is a set of conditions that are related by logical equivalence within a theory or conceptual equivalence across theories

In CM

$$\begin{aligned} d_t q &= \partial_p H \\ d_t p &= -\partial_q H. \end{aligned} \tag{HM-1D}$$

The evolution conserves information entropy (DR-INFO)

Densities are conserved through the evolution: $\hat{\rho}(\hat{\xi}^a) = \rho(\xi^b)$ (DR-DEN)

In QM

Condition DR-SCEQ (Schrödinger equation). *The evolution follows the equation* $i\hbar \frac{d}{dt}\psi(t) = H\psi(t)$ *where* H *is a self-adjoint operator.*

Condition DR-INFO (Information preservation). *The evolution is differentiable and preserves von Neumann entropy:* $S(\mathcal{T}(\rho)) = S(\rho)$ *for all* $\rho \in E(\mathcal{H})$.

Same condition is "implemented" differently in the same theory and across theory: hints to a common base theory.

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Assumptions of Physics

Methodology and terminology

Base conditions. Conditions that must be true in any physical theory, and therefore are part of the base theory for all of physics.

Condition [B]EVMIX (Evolution preserves mixtures). *Time evolution preserves statistical mixtures. That is, the time evolution map* $\mathcal{T} : E(\mathcal{H}) \to E(\mathcal{H})$ *is affine:* $\mathcal{T}(\sum_i p_i \rho_i) = \sum_i p_i \mathcal{T}(\rho_i)$.

Condition [B]MUTEX (Mutual exclusivity conditions). *Let* $\psi_i \in P(\mathcal{H})$ *be a countable sequence of states. Then* $p(\psi_i|\psi_j) = 0$ *for all* $i \neq j$ *if and only if* $S(\sum_i p_i \psi_i) = -\sum_i p_i \log p_i$ *for all* p_i *such that* $\sum_i p_i = 1$.

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Methodology and terminology

Types of relationships:

Relationship	Formal Meaning	Natural Language
		Once T is assumed…
A **implies/requires** B over T	$A \wedge T \vdash B$	… if A is true, B is true
A **excludes** B over T	$A \wedge T \vdash \neg B$	… if A is true, B is false
A **equivalent** to B over T	$A \wedge T \vdash B$ and $B \wedge T \vdash A$	… A is true iff B is true
A **independent** of B over T	$A \wedge T \nvdash B$ and $B \wedge T \nvdash A$	… neither forces the other
A **consistent** with B over T	$A \wedge B \wedge T \nvdash \bot$	… A and B can be both true
A **inconsistent** with B over T	$A \wedge B \wedge T \vdash \bot$	… A and B cannot be both true

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Reverse Physics for different theories

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Classical mechanics

$$d_t \xi^a \omega_{ab} = \partial_b H$$

Essentially done, though improvements are always possible

Quantum mechanics

$$\imath \hbar d_t |\psi\rangle = H |\psi\rangle$$

Work is ongoing, core conceptual work done

Thermodynamics

$$\Delta S \geq \int \frac{\delta Q}{T}$$

Some ideas identified, need to be finalized

Classical field theory

$$\mathcal{A} = \int \left[\frac{1}{2\kappa} R + \mathcal{L}_M \right] \sqrt{-g} d^4x$$

Vague general ideas, more technical work needed

Quantum field theory

$$\mathcal{A} = \int \bar{\psi} (\imath \gamma^\mu D_\mu - m) \psi \, d^4x$$

No point in starting now, first finish QM and CFT

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Classical field theory

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Assumptions of Physics

Status

- Actively looking for someone to help generalize Reverse Physics to classical field theory (from finitely many DOFs to continuously many DOFs)
  - Main conjecture: volumes in space provide a count of DOFs, in the same way that volumes in phase space provide a count of states/configurations
- Need to
  - Find a suitable Hamiltonian/symplectic formulation of field theory (starting with electromagnetism)
  - Understand how to generalize count of states/entropy/… to field theory
  - Adapt the arguments from classical mechanics to field theory

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Assumptions of Physics

Geometry of principle of least action (SDOF)

DR

$$\nabla \cdot \vec{S} = 0$$

No state is "lost" or "created" as time evolves

$[p, 0, -H]$

$$\vec{S} = -\nabla \times \vec{\theta}$$

(Minus sign to match convention)

KE $\quad p d_t q + 0 d_t p - H d_t t$

$$\mathcal{S}[\gamma] = \int_\gamma L dt = \int_\gamma \vec{\theta} \cdot d_t \xi^a dt$$

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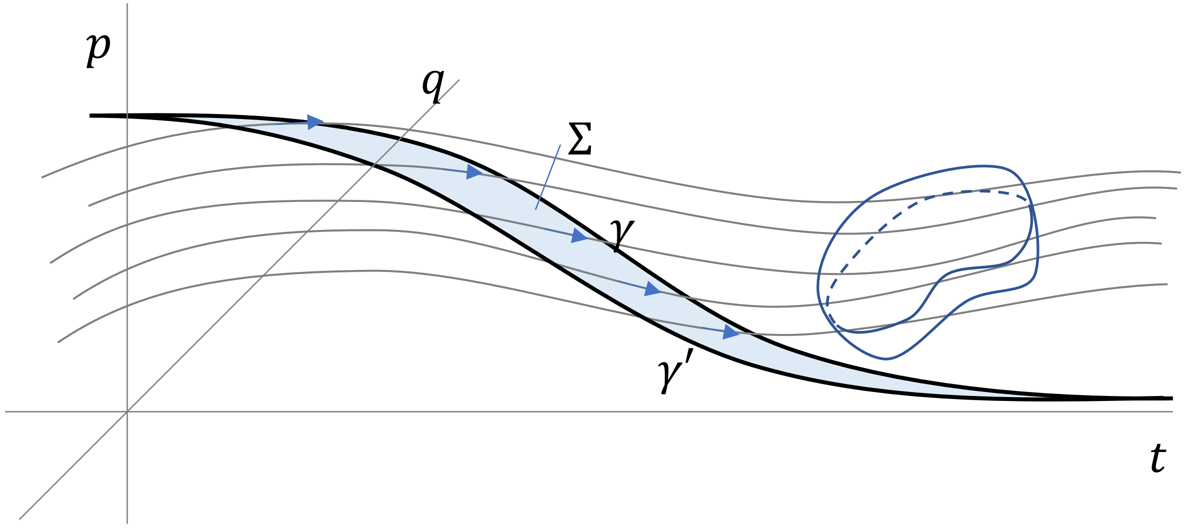
The action is the line integral of the vector potential (unphysical)



Variation of the action

Gauge independent, physical!

$$\delta\mathcal{S}[\gamma] = \oint_{\partial\Sigma} \vec{\theta} \cdot d\vec{\gamma}$$

$$= -\iint_\Sigma \vec{S} \cdot d\vec{\Sigma}$$

Variation of the action measures the flow of states (physical).
Variation = 0 ⇒ flow of states tangent to the path.

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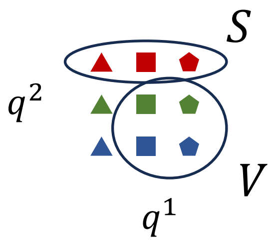
Assumptions of Physics

Counting states and configurations

Discrete case



$\#\text{conf}(S) = \#S \qquad \#\text{states}(V) = \#V \qquad \#\text{DOF}(I) = \#I$

Continuous case

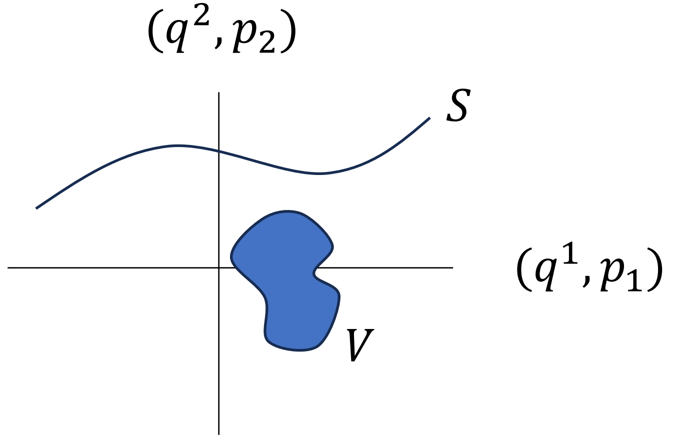
Configuration density

State density

$\neq \#V = \infty$

$\#\text{conf}(S) = \int_S \omega_{ab} d\xi^a d\xi^b \qquad \#\text{states}(V) = \int_V \Lambda\, \omega\, d\xi^{a_1} \cdots d\xi^{a_n}$

$\#\text{DOF}(I) = \#I$



Ham Mech ⇒ Correct count of configurations/states on finitely many dense (i.e. continuous) DOFs

Field theory ⇒ DOFs themselves are dense (i.e. continuous)

$\#\text{DOF}(I) \neq \#I$

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Assumptions of Physics

Conjecture: GR ⟺ det/rev + DOF independence for infinitely many (dense) DOFs

$$\delta \int_\gamma L dt = \oint_{\partial\Sigma} \theta_a d\gamma^a = \iint_\Sigma \omega_{ab} d\xi^a d\gamma^b$$

Flow of states

$$\frac{\#conf}{\#DOFs} =?$$

$$\delta \int_\gamma \mathcal{L} d^4x =???$$

Line integral of the vector potential of the flow of state **density**?

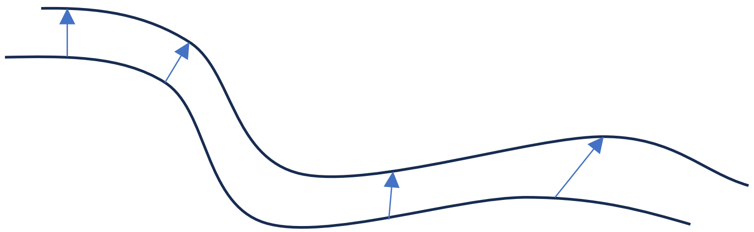
$$\int_U \sqrt{-g}\, d^3x$$

#DOFs?

$$\mathcal{L} = \mathcal{L}_g + \mathcal{L}_{matter}$$

Flow of DOFs?

Flow of configurations?



We are mapping values between Cauchy surfaces,
#DOFs are the points on the Cauchy surface,
#conf are the possible field values at each point

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Thermodynamics

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Assumptions of Physics

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Status

- Key ideas (probably) identified
  - Define physical entropy as logarithm of the count of evolutions (fluctuations)
  - ⇒ Equilibrium maximizes entropy, thermodynamic equilibrium all parts are in equilibrium with each other
- Equilibrium ⇔ dynamics of the system does not depend on the internal dynamics or the environment
  - Required to define physical system: thermodynamics is a more fundamental theory than classical or quantum mechanics
- Need to
  - Create a consistent theory out of these ideas

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Assumptions of Physics

Entropy as logarithm of the count of evolutions

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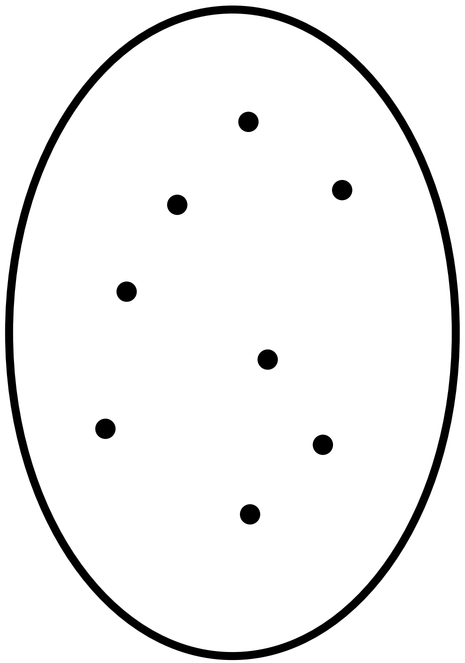
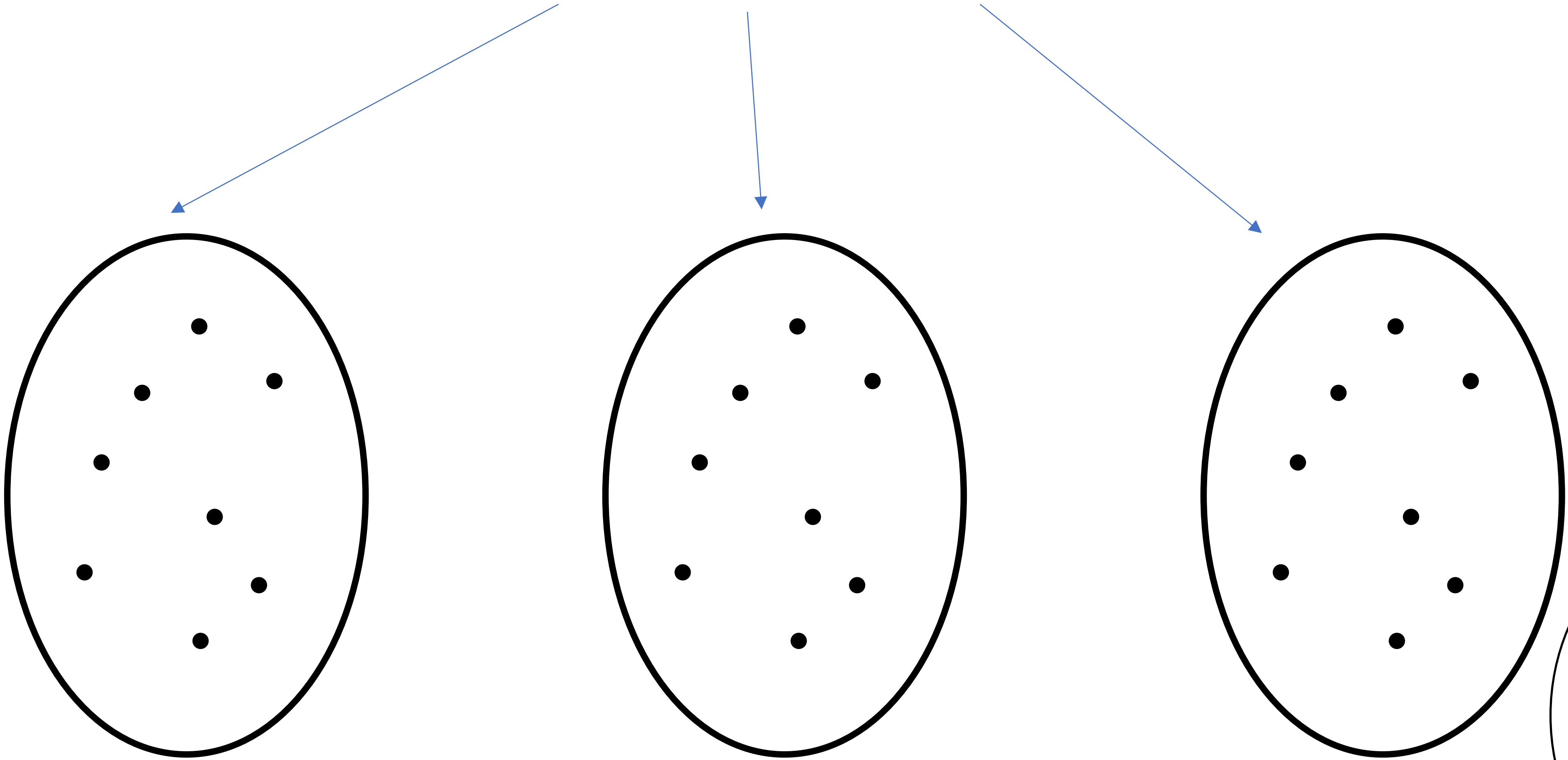
Assumptions of Physics

(e.g. classical microstates, quantum state,
state of a dynamical system, …)

State space of a system



State space of a system at different times



$t - \Delta t$ t $t + \Delta t$

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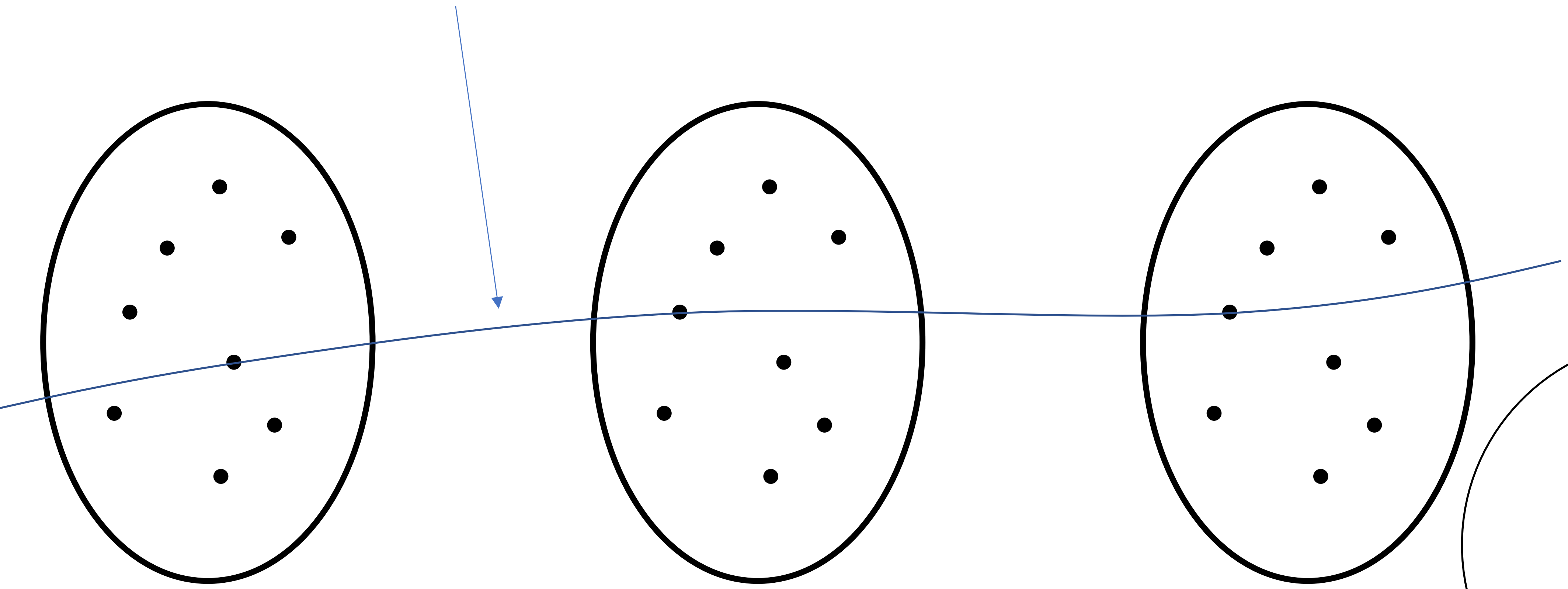
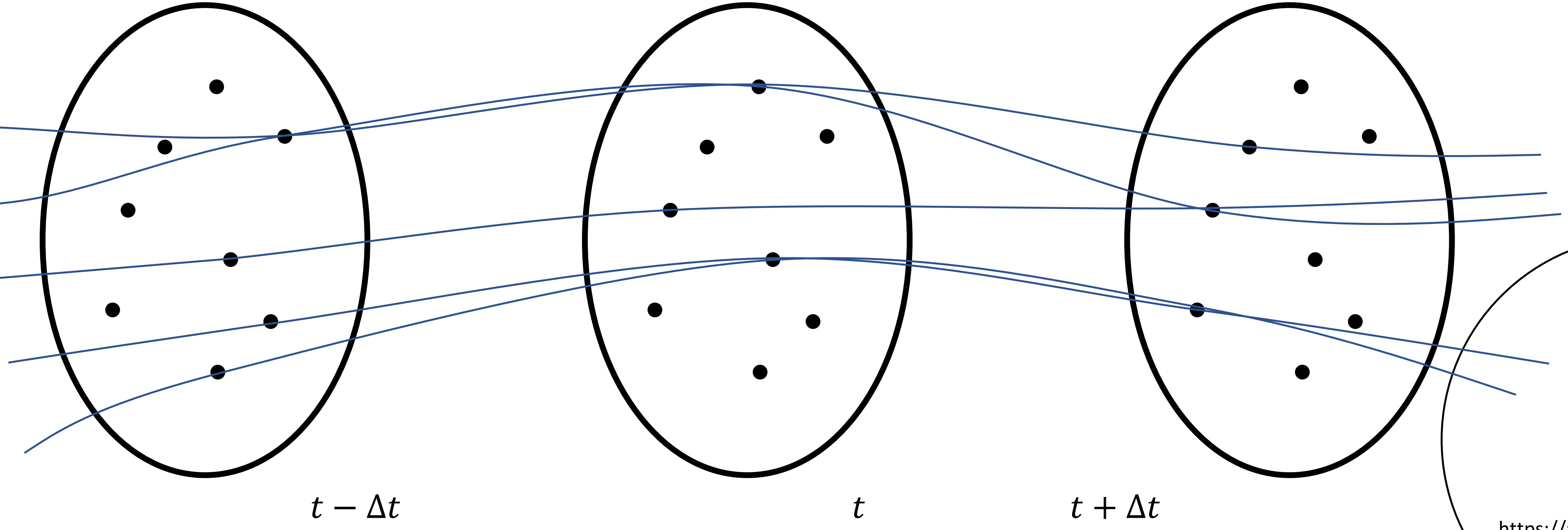
Assumptions of Physics

Evolution: complete description of the system at all times



A process defines the set of all possible evolutions



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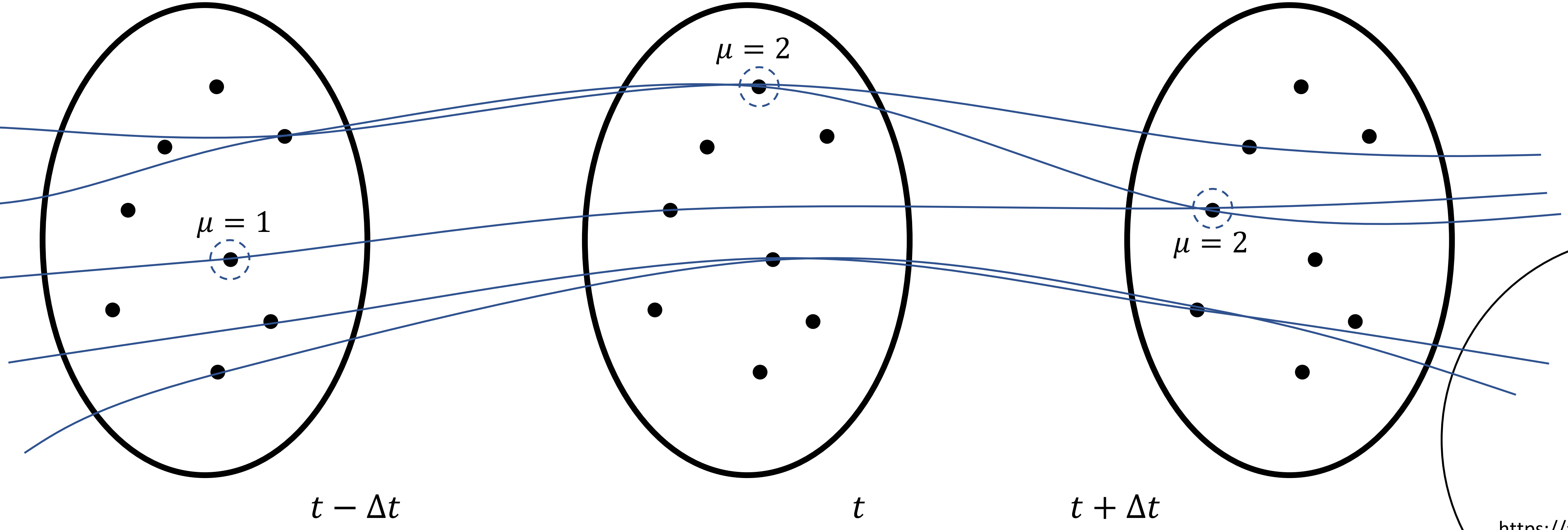
Assumptions of Physics

Each description at each time corresponds to a set of evolutions

We can count the number of evolutions for a particular state s at a particular time with a measure* $\mu(s)$ since s identifies a set of evolutions.



* *The full mathematical characterization may be a bit more complicated (e.g. preorder that leads to a family of measures)…*

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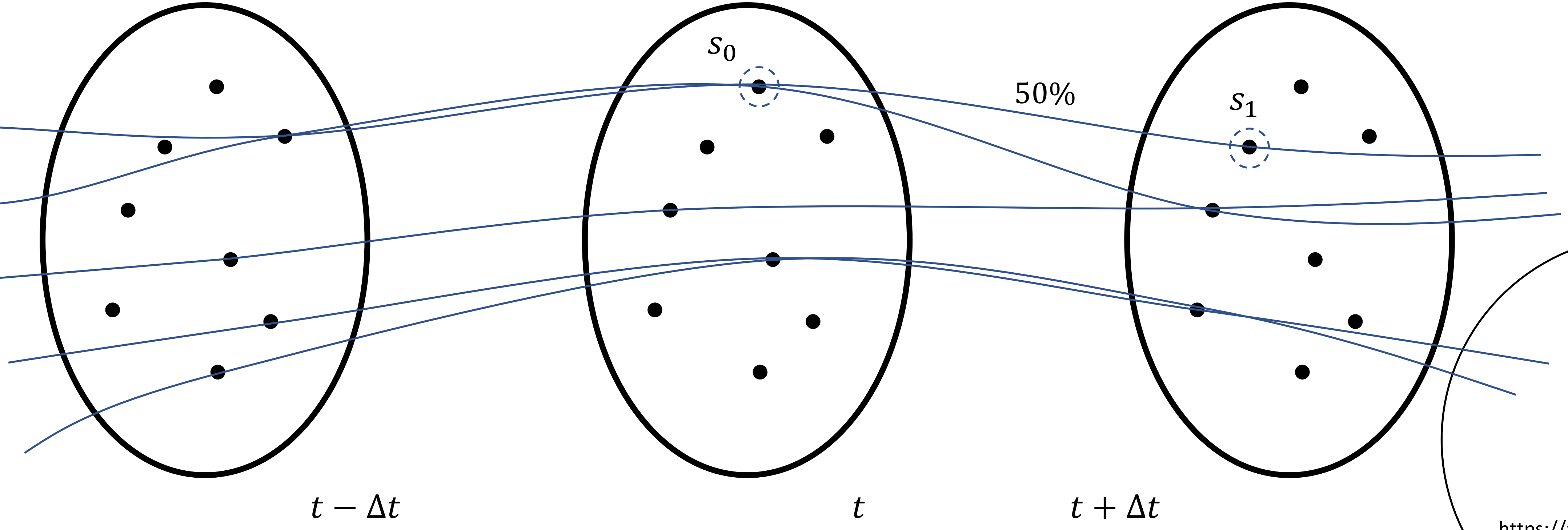
Assumptions of Physics

The probability $P(s_1|s_0)$ of having s_1 given s_0 corresponds to the fraction of evolutions that go from state s_0 to state s_1

That is, $P(s_1|s_0) = \frac{\mu(s_0 \cap s_1)}{\mu(s_0)}$



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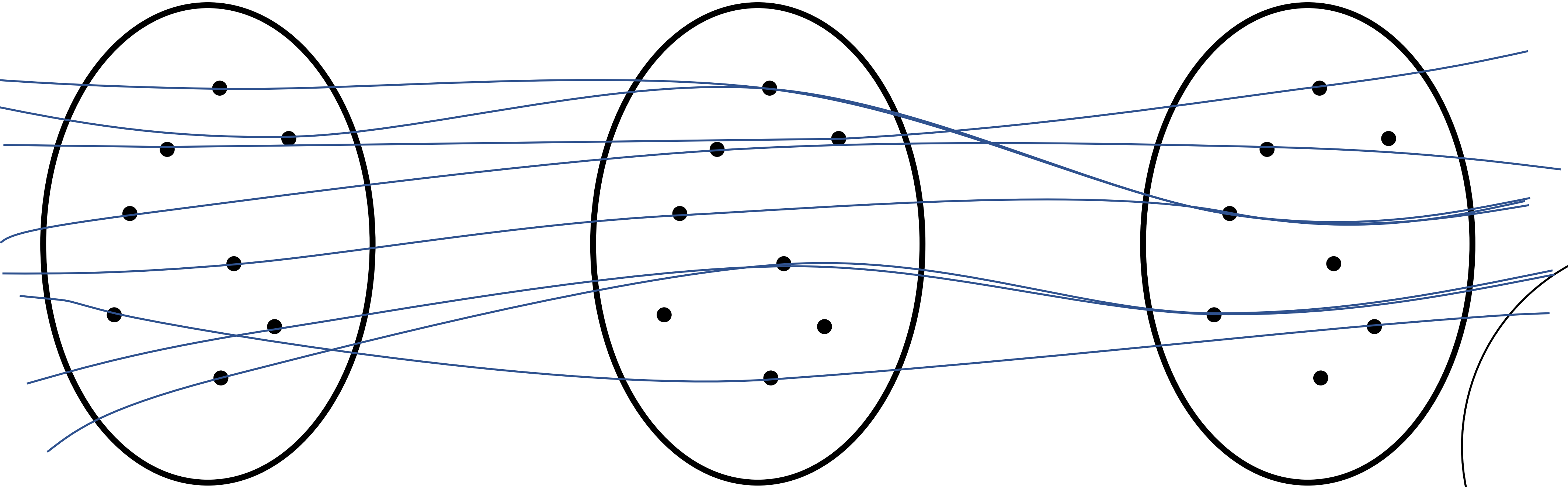
Assumptions of Physics

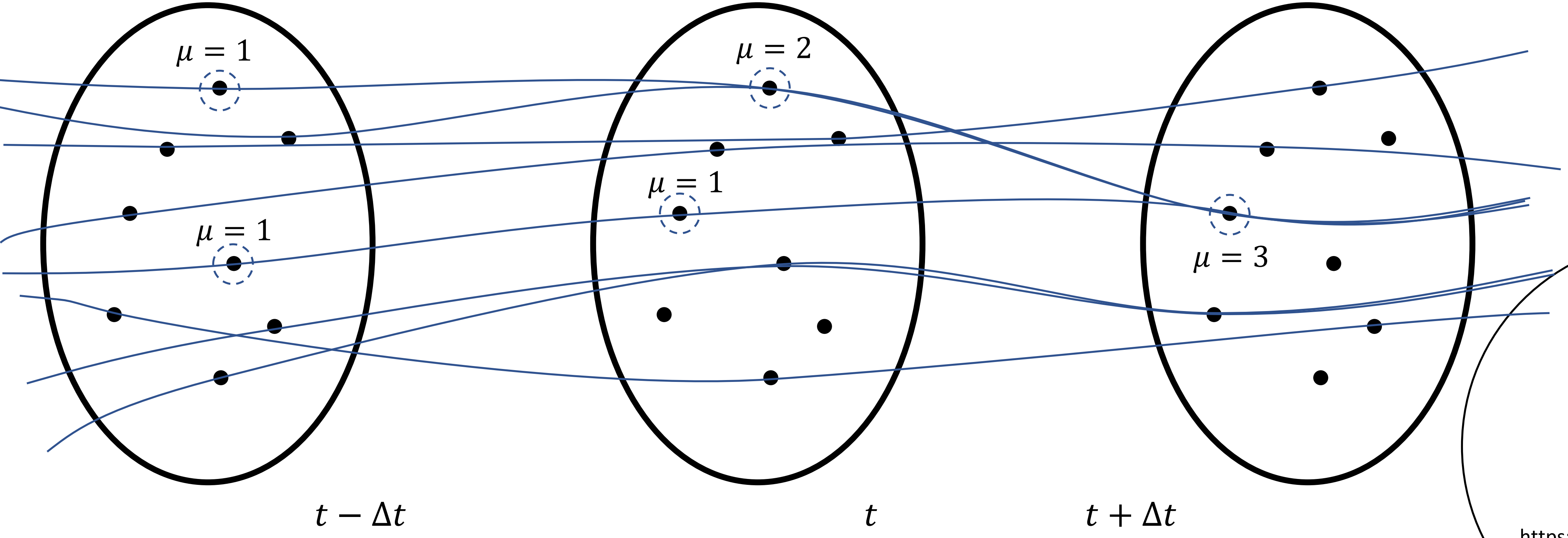
A process is deterministic if knowing the state at a time allows us to predict the state at a future time

For these processes, we can properly write a law of evolution $s(t + \Delta t) = f\big(s(t)\big)$



In a deterministic process, the evolutions can never split, only merge

That is, $\mu\big(s(t+\Delta t)\big) \geq \mu\big(s(t)\big)$



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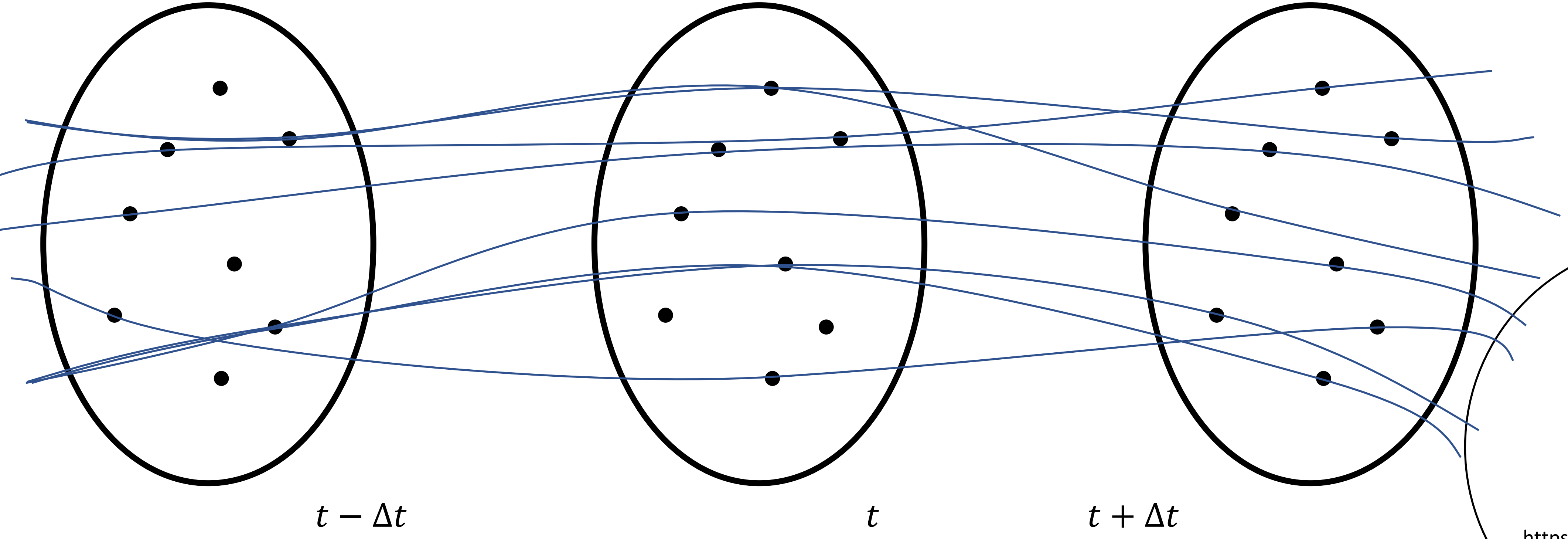
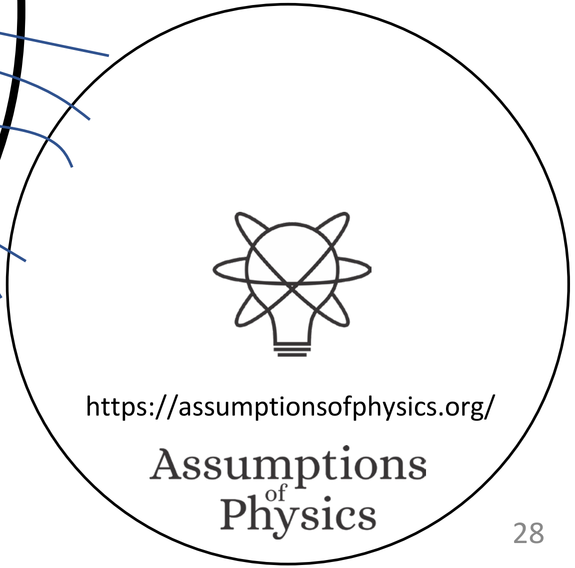
Assumptions of Physics

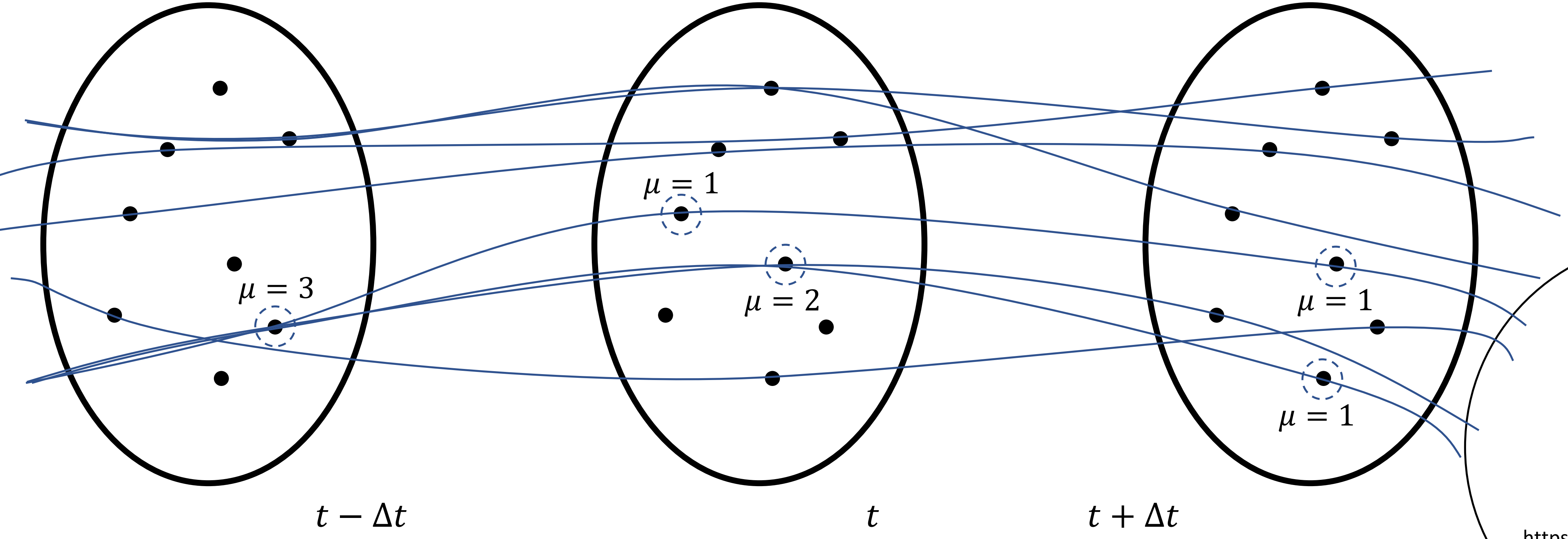
A process is reversible if knowing the state at a time allows us to reconstruct the state at a past time





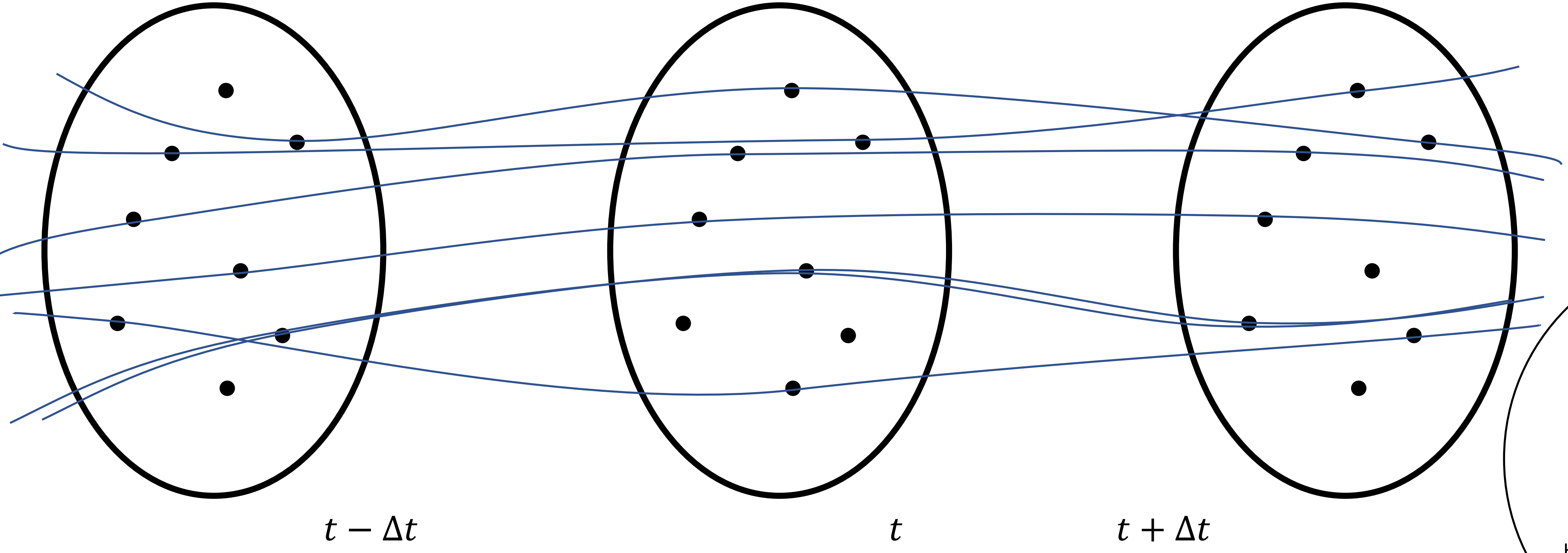
In a reversible process, the evolutions can never merge, only split

That is, $\mu\big(s(t+\Delta t)\big) \leq \mu\big(s(t)\big)$



In a det/rev process, evolutions can never merge nor split

That is, $\mu\big(s(t+\Delta t)\big) = \mu\big(s(t)\big)$



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Assumptions of Physics

For a deterministic process

$$\mu\big(s(t+\Delta t)\big) \geq \mu\big(s(t)\big)$$

(equal if reversible)

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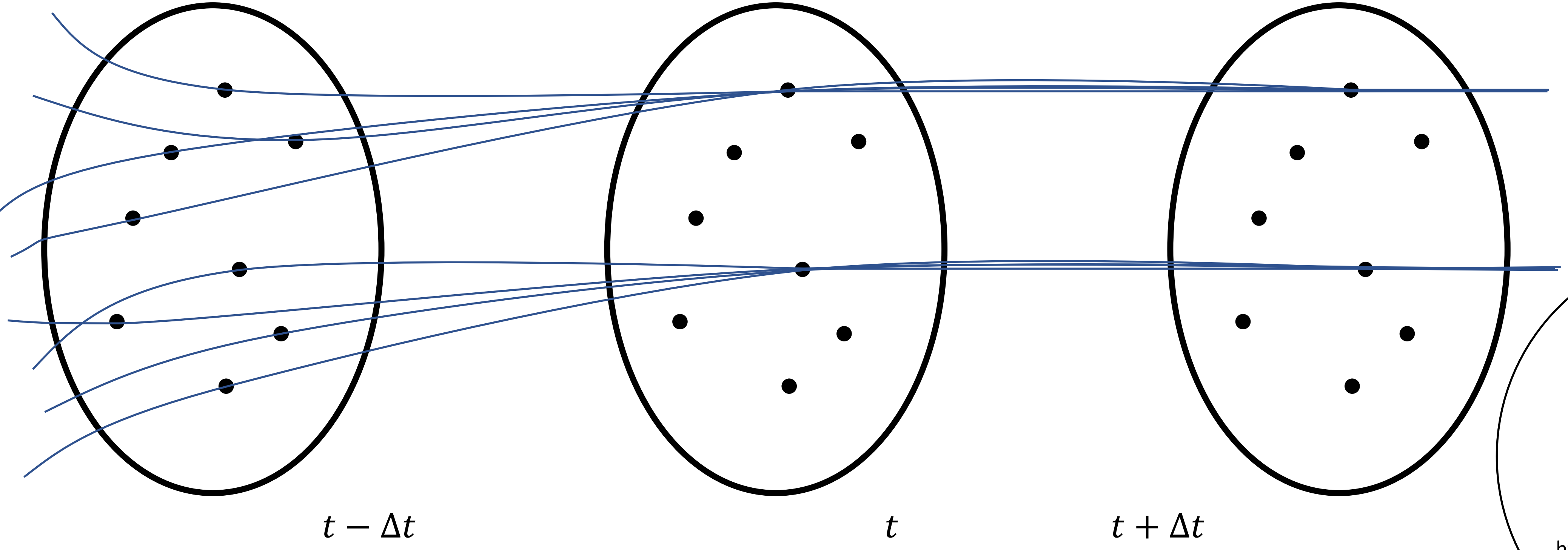
Assumptions of Physics

Consider a process where a system reaches a final equilibrium that can be predicted from the initial state

At equilibrium, evolutions cannot merge anymore



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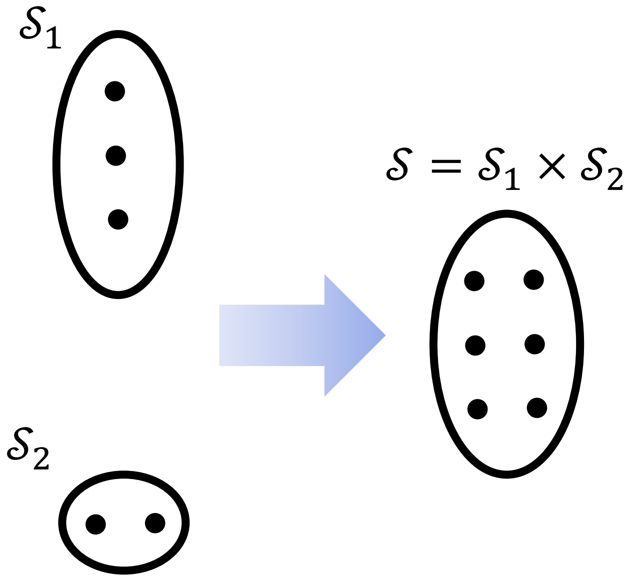
Assumptions of Physics

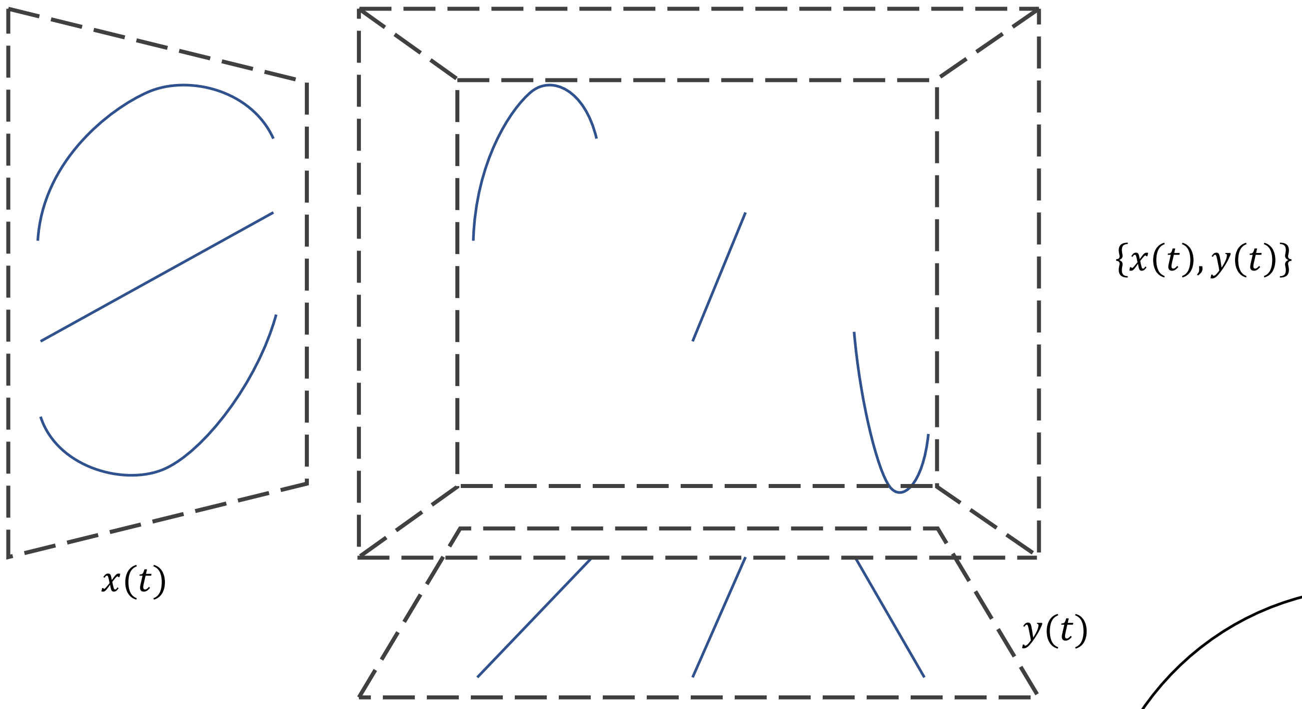
For a deterministic process

$$\mu\big(s(t+\Delta t)\big) \geq \mu\big(s(t)\big)$$

(equal if reversible)
(maximum at equilibrium)

Suppose we have a composite of two systems





State space
is the product

Evolutions, in general, are not the product: there may be correlations

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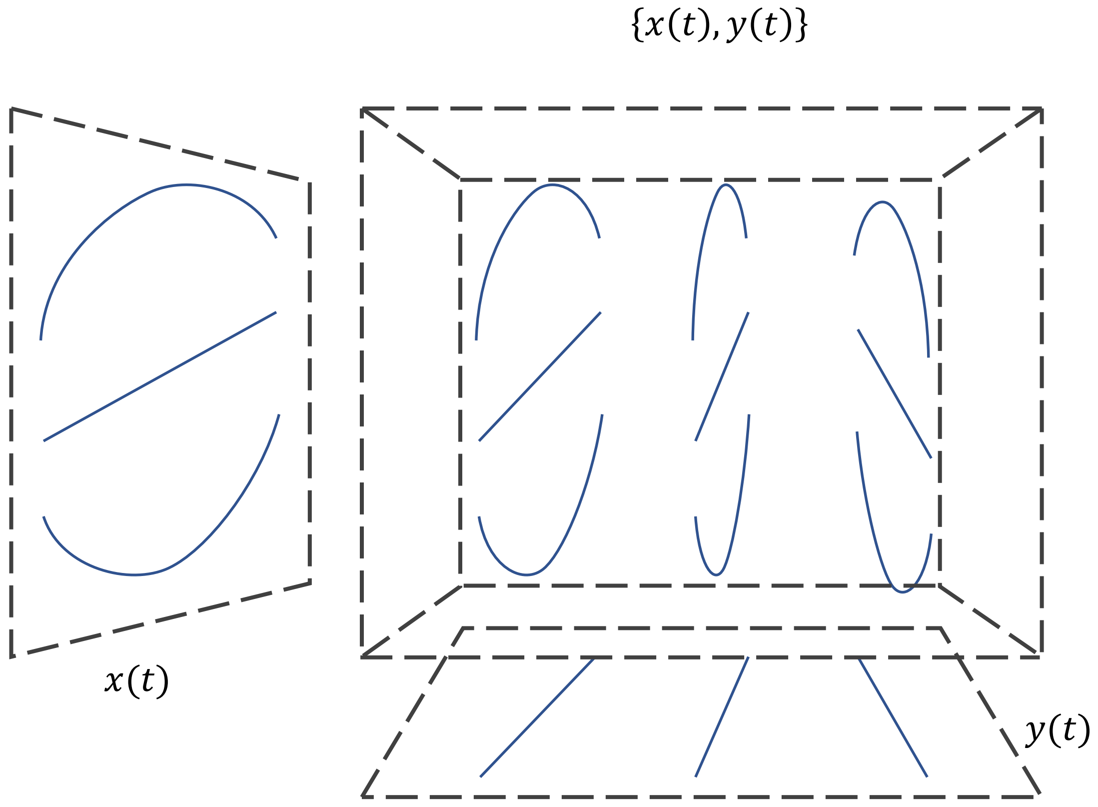
Assumptions of Physics

If the systems are independent, the evolution of one does not constrain the evolution of the other: all pairs are possible

For each pair of states there is a state for the composite system: $\#(\mathcal{S}) = \#(\mathcal{S}_1)\#(\mathcal{S}_2)$

For each pair of evolutions there is an evolution of the composite: $\mu(s_1 \cap s_2) = \mu_1(s_1)\mu_2(s_2)$



Note: $\log \mu = \log \mu_1 \mu_2 = \log \mu_1 + \log \mu_2$
$\log \mu$ is additive for independent systems

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Assumptions of Physics

Define the process entropy as $S = \log \mu$

The log of the count of evolutions per state

It is additive for independent systems

$$S = S_1 + S_2$$

For a deterministic process

$$S\big(s(t + \Delta t)\big) \geq S\big(s(t)\big)$$

(equal if reversible)

(maximum at equilibrium)

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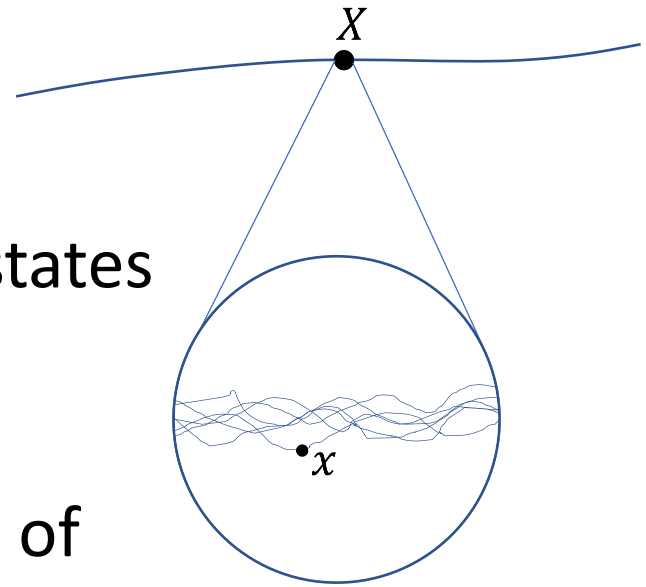
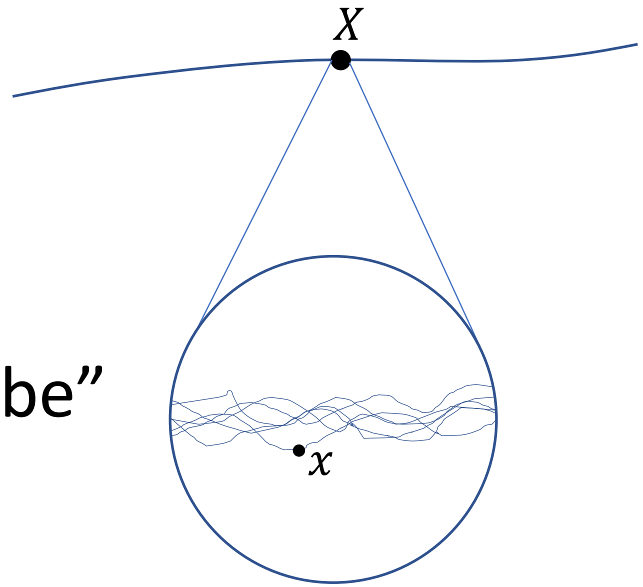
Assumptions of Physics

Recover information entropy



Suppose macrostate X is a dynamical equilibrium of microstates
⇒ Microstate fluctuations can be characterized by a stable probability distribution $\rho(x)$ in each small Δt
⇒ An evolution $\lambda(t)$ for the microstate is a dense sequence of infinitely many microstates whose recurrence matches $\boldsymbol{\rho}$
⇒ Macrostate measurements cannot be sensitive to permutations of microstates: possible evolutions equals all possible permutations
⇒ Shannon entropy counts all possible permutations of an infinite sequence (dense in Δt) which equals all possible evolutions

Macrostate/equilibrium is a “tube” of evolutions at the lower level



Equilibrium means that no evolution enters or exits the “tube”
(i.e. external agents have equilibrated)

The variables describing the macrostate can still change
(i.e. the “tube” moves around in state space)

We can now study the “tube” as if it were single line
(i.e. internal dynamics and environment are decoupled)

Equilibrium = evolution decoupled from environment and from internal dynamics

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Assumptions of Physics

Physical entropy explained?

- We have not mentioned uncertainty, disorder, statistical distributions, information, lack of information, …
  - Therefore those concepts are not fundamental in this context
- We have not discussed what type of state or system we have (classical, quantum, biological, economic, …)
  - Therefore everything we said is valid independently of the type of system, which would explain the success of thermodynamic ideas outside the realm of physics
- The process entropy increase is explained by the definitions and the settings (processes with equilibria that depend on the initial state)
  - The explanation is straightforward (i.e. does not require a complicated discussion)
  - The explanation is not mechanical (i.e. given by a particular mechanism)

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Assumptions of Physics

“Reversing” thermodynamics

Assume states are equilibria of faster scale processes

Assume states identified by extensive properties

Assume one of these quantities is energy U
(conserved by closed system)

$\Rightarrow$ Existence of equation of state $\quad S(U, x^i)$

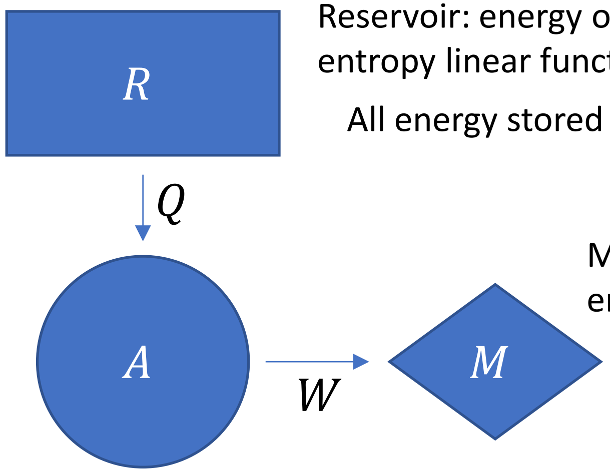
$$\beta = \frac{1}{k_B T} = \frac{\partial S}{\partial U} \quad \text{and} \quad -\beta X_i = \frac{\partial S}{\partial x^i}$$

Define intensive quantities

$$dS = \frac{\partial S}{\partial U} dU + \frac{\partial S}{\partial x^i} dx^i = \beta dU - \beta X_i dx^i$$
$$k_B T dS = dU - X_i dx^i$$
$$dU = T(k_B dS) + X_i dx^i$$

Recover usual relationships

Study interplay of changes of energy and entropy



Reservoir: energy only state variable, entropy linear function of energy

All energy stored in entropy

Mechanical system: same entropy for all states

No energy stored in entropy

$$\beta = \frac{1}{k_B T} = 0$$

$$\Delta U = 0 = \Delta U_A + \Delta U_R + \Delta U_M$$
$$= \Delta U_A - Q + W$$

Recover first law

First law recovered from existence and conservation of energy

$$0 \leq \Delta S = \Delta S_A + \Delta S_R + \Delta S_M$$
$$= \Delta S_A + \beta_R \Delta U_R + 0 = \Delta S_A + \frac{-Q}{k_B T_R}$$

Recover second law

Second law recovered from definition of entropy as count of evolutions

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Assumptions of Physics

Quantum mechanics

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Assumptions of Physics

Status

- Clear that irreducibility/lower bound on the entropy is the only ingredient that makes quantum mechanics different from classical mechanics
- Found the right way to disentangle the math
    - States are ensembles (pure or mixed) at equilibrium (internal dynamics and environment can be ignored)
    - Projections are processes of equilibration
        - Every state is the output of an equilibration process
        - Measurements are special cases
    - Unitary evolution is deterministic and reversible dynamics
        - Can also be recovered as quasi-static evolution
          (i.e. series of infinitesimal projections)
- Need to
    - Write it all down

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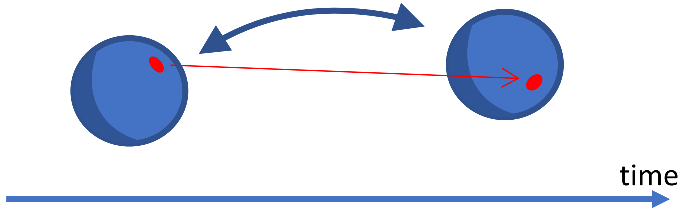
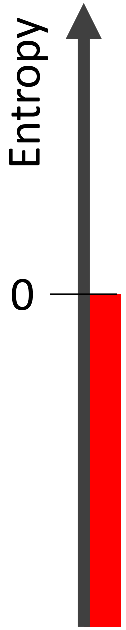
Assumptions of Physics

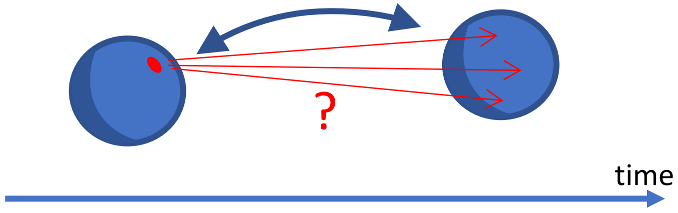
Quantum mechanics as irreducibility

Classical





Quantum



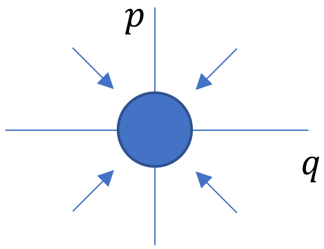
Can prepare ensembles at arbitrarily low entropy: we can study arbitrarily small parts

We always have access to the internal dynamics

Entropy is bounded at zero: we cannot study parts

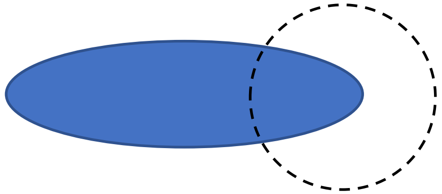
No access to the internal dynamics

Minimum uncertainty



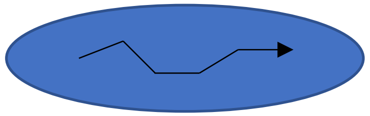
Can't squeeze ensemble arbitrarily

Non-locality



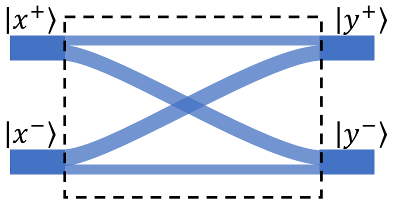
Can't refine ensembles ⇒
Can't interact with parts

Superluminal effects
that can't carry information



Can't refine ensembles ⇒
Can't extract information

Probability of transition



$$p(x^+|y^-) = p(y^-|x^+)$$

Symmetry of the inner product

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Assumptions of Physics

Breaking down “Hilbert” spaces

- QP-RAY: states are rays of a Hilbert space
  - Rays don’t need inner product. Rays by themselves are not enough to pick quantum mechanics.
- QE-DENS: ensembles are density matrices
  - Requires the inner product to define the trace and orthogonal projectors. Excludes classical mechanics, but does not uniquely recover quantum mechanics.
- BR-BORN: conditional probability given by the Born Rule
  - Recovers quantum mechanics. Equivalent to the von Neumann entropy, orthogonality being mutual exclusivity, … That is, once QE-DENS is taken, BR-BORN can be recovered with minimal extra assumptions

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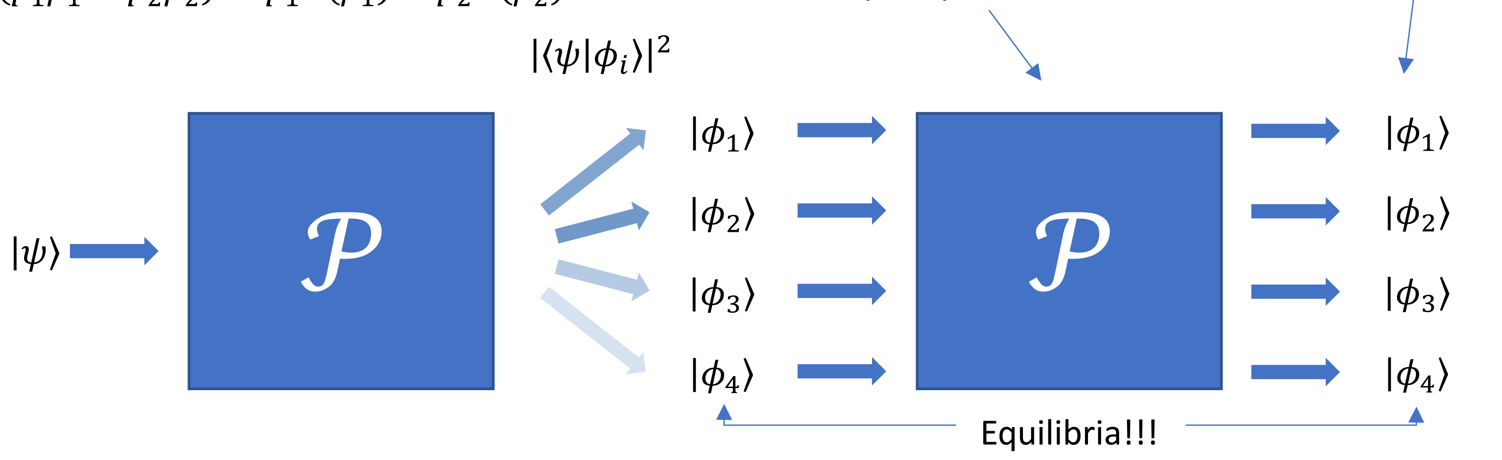
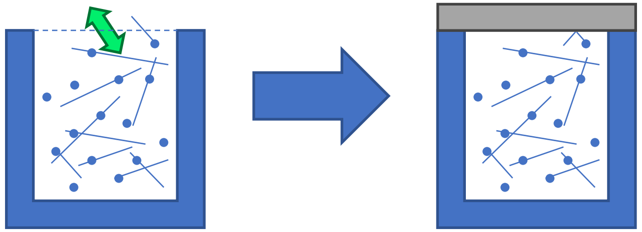
Assumptions of Physics

Projections: linear idempotent operations

Output for a statistical mixture of inputs is the statistical mixture of outputs
$P(p_1\rho_1 + p_2\rho_2) = p_1P(\rho_1) + p_2P(\rho_2)$

Same result if you do it twice

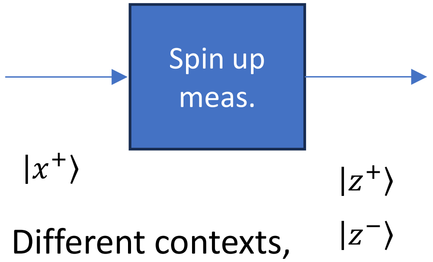




$[\mu, V, T]$

$[N_1, V, T]$
$[N_2, V, T]$
$[\dots, V, T]$

Different equilibria, different variables



Different contexts, different variables

Projections are equilibration processes

Quantum contexts are different boundary conditions

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Assumptions of Physics

Unitary evolution ⟺ det/rev evolution

$$|\psi(t+dt)\rangle - |\psi(t)\rangle = \mathcal{T}(t)dt|\psi(t)\rangle$$

Change of states depends only on previous state (determinism)

$$\langle\psi(t+dt)|\psi(t+dt)\rangle = 1$$

Final state is normalized (reversibility)

$$= \langle(1+\mathcal{T}(t)dt)\psi(t)|(1+\mathcal{T}(t)dt)\psi(t)\rangle$$

$$= \langle\psi(t)\big|(1+\mathcal{T}(t)dt)^\dagger(1+\mathcal{T}(t)dt)\big|\psi(t)\rangle$$

$$= \langle\psi(t)\big|1+\mathcal{T}(t)^\dagger dt+\mathcal{T}(t)dt+\mathcal{T}(t)^\dagger\mathcal{T}(t)dt^2\big|\psi(t)\rangle$$

$$= 1 + dt\langle\psi(t)\big|\mathcal{T}(t)^\dagger+\mathcal{T}(t)\big|\psi(t)\rangle + O(dt^2)$$

$$\Rightarrow \mathcal{T}(t)^\dagger = -\mathcal{T}(t)$$

Also recovered from entropy conservation (like in classical mechanics)

Self-adjoint

$$\mathcal{T}(t)dt = -\frac{H(t)dt}{\imath\hbar}$$

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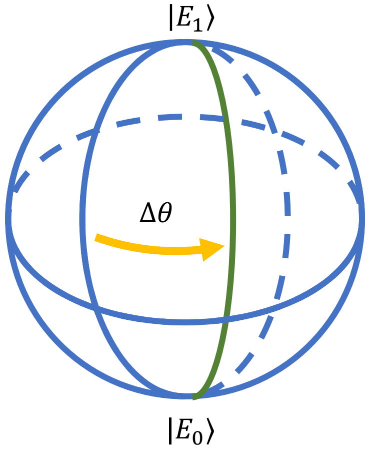
Assumptions of Physics

Any process (deterministic or stochastic) is linear over ensembles

$$\rho_I \longrightarrow \boxed{P} \longrightarrow \rho_O = P(\rho_I)$$

$$P(p_1\rho_1 + p_2\rho_2) = p_1P(\rho_1) + p_2P(\rho_2)$$



complete isolation

Deterministic and reversible

$$\rho_I \longrightarrow \boxed{P} \xrightarrow{\rho_O} \boxed{P^{-1}} \longrightarrow \rho_I$$

Conserves entropy/allows an “inverse”

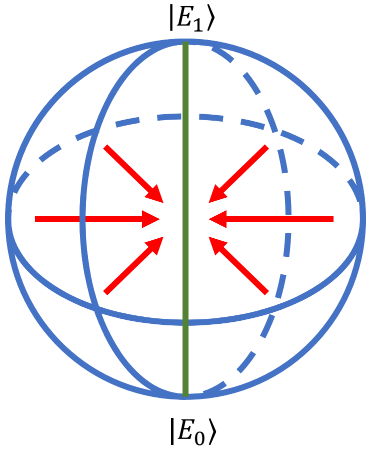
⇒ Unitary operation

Equilibration

$$\rho_I \longrightarrow \boxed{P} \xrightarrow{\rho_O} \boxed{P} \longrightarrow \rho_O$$

Must be repeatable

⇒ Projection



Both are idealizations!

No measurement problem, since unitary evolution is not more “real” than projection

However, “states as equilibria” implies existence of equilibration processes (mathematically, Hilbert spaces are Banach spaces + projectors on each subspace): projections are more “fundamental” as they need to be assumed to exist

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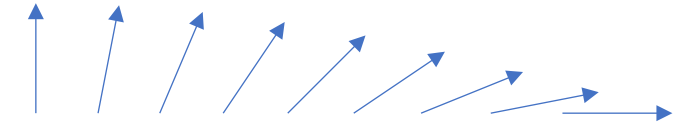
Assumptions of Physics

Unitary evolution $\Leftrightarrow$ quasi-static evolution

Unitary evolution
$\Leftrightarrow$
sequence of infinitesimal projections



$$|\langle\psi(t+dt)|\psi(t)\rangle|^2 = 1$$

$$= \langle\psi(t+dt)|\psi(t)\rangle\langle\psi(t)|\psi(t+dt)\rangle$$
$$= (1 + \langle d\psi(t)|\psi(t)\rangle)(1 + \langle\psi(t)|d\psi(t)\rangle)$$
$$= 1 + (\langle d\psi(t)|\psi(t)\rangle + \langle\psi(t)|d\psi(t)\rangle) + O(dt^2)$$
$$= 1 + dt(\langle\mathcal{T}(t)\psi(t)|\psi(t)\rangle + \langle\psi(t)|\mathcal{T}(t)\psi(t)\rangle) + O(dt^2)$$

$$\Rightarrow \mathcal{T}(t)^\dagger = -\mathcal{T}(t)$$

Projections can be seen as fundamental "black box" processes

Solves the "multilevel problem"

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Assumptions of Physics

Projections $\Longleftrightarrow$ steady states of open evolution

$$\frac{d\rho}{dt} = \frac{[H,\rho]}{\imath\hbar} + \gamma\left(L\rho L^{\dagger} - \frac{1}{2}\{L^{\dagger}L,\rho\}\right)$$

Lindblad equation: evolution of a quantum system
under joint system/environment evolution (+ approximations)

$$\rho_{SE} \longrightarrow \boxed{P} \longrightarrow$$

$$\rho(t) = tr_E[\rho_{SE}]$$

If $L = X$, then ρ is a steady state if and only if $[\rho, X] = 0$

$\Rightarrow$ all steady states are statistical mixtures of eigenvectors of X

(more precisely, ρ is multiplicative in the spectrum of X)

Measurement is the same of a classical measurement
(reveals previously prepared state)

Projections are equilibrations with the environment

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Assumptions of Physics

Equilibration with the environment

Deterministic and reversible evolution

Black-box process with equilibria

Quasi-static evolution

Unitary evolution

Projection

Every preparation is a measurement
Time evolution prepares the system at each time
⇒ Time evolution is a series of measurements

Every measurement is a process
Measurements are repeatable
⇒ Measurements are equilibration processes

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Assumptions of Physics

Let’s wait until both classical field theory and quantum mechanics are done!

Quantum field theory

Should be simply putting a lower bound on the entropy of fields

Quantum gravity?

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Assumptions of Physics

Status

- Not really aiming to solve this… just connecting some trivial bits
- What is quantum mechanics?
  - According to Reverse Physics, it is putting a lower bound on the entropy (lower bound on the count of states)
- What is gravity?
  - In Reverse Physics, it is conjectured to be the proper handling of the count of DOFs and configurations (entropy) over a continuum of DOFs
- Arguably, a lower bound on the entropy/count of states cannot be achieved without imposing a lower bound on the count of DOFs as well
  - Is this what "quantum gravity" is?

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Assumptions of Physics

The problem with counting on the continuum

We'd like to say:

1. Every state is a single case (i.e. $\mu(\{\psi\}) = 1$)
2. Finite continuous range carries finite information (i.e. $\mu(U) < \infty$)
3. Count is additive for disjoint sets (i.e. $\mu(\cup U_i) = \sum \mu(U_i)$)

Incompatible!

Pick two!

Discard 1 ⇒ Lebesgue measure

Discard 2 ⇒ counting measure

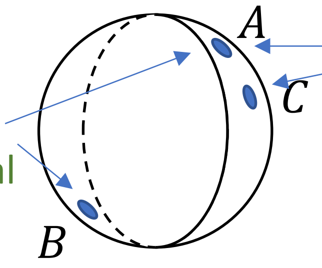
Discard 3 ⇒ "Quantum measure"

$$\mu(U) = 2^{\sup\left(S(\mathrm{hull}(U))\right)}$$

Exponential of the maximum entropy reachable with convex combinations (statistical mixtures) of U (reduces to counting/Liouville measure)

Orthogonal states: different states all else equal

additive



Non-orthogonal states: different states but in different contexts

sub-additive

$\mu(\{A\}) = 2^0 = 1$

$\mu(\{A, B\}) = 2^1 = 2$

$\mu(\{A, C\}) < 2 = \mu(\{A\}) + \mu(\{C\})$

Quantum mechanics ⇒ lower bound on #conf (entropy) on continuous DOF

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Assumptions of Physics

Conjecture: quantum gravity ⇒ lower bound on DOF count

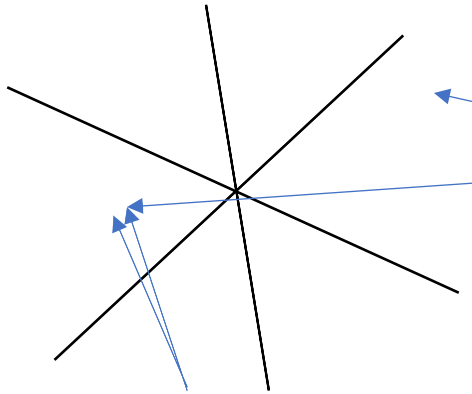
$$\#\text{conf} = \#\text{DOFs} \; \frac{\#\text{conf}}{\#\text{DOFs}}$$

Lower bound on this…

…requires a lower bound on this

Same problem!

1. Every point is a single DOF (i.e. $\mu(\{x\}) = 1$)
2. Finite volume carries finitely many DOFs (i.e. $\mu(U) < \infty$)
3. Count is additive for disjoint regions (i.e. $\mu(\cup U_i) = \sum \mu(U_i)$)



Distant points: independent DOFs additive

sub-additive

Close points: DOFs not independent

From QM: Lower bound on state count requires a severe revisitation of particle state space

Does lower bound on DOF count require an equally severe revisitation of space-time?

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Assumptions of Physics

How to participate and contribute to Reverse Physics

- Prerequisite: share the interest in building a conceptual framework that treats physical theories as models of physical systems and nothing else
  - No theories of everything, interpretations that posit “how the universe works,” …
- Passive contribution: make yourself available as a “consultant”
  - Don’t have to follow the project, called only if there is something relevant that matches your background/expertise
  - Occasional discussion/review of material to make sure things make sense from multiple perspectives
- Active contribution: case-by-case
  - Need to have sufficient background or be able to get it independently
  - Much better chance of success if already working/expert in a research area

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Assumptions of Physics

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Assumptions of Physics