La emergencia de la irreversibilidad en el tiempo

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Estructura

I. Contando el tiempo
II. Enfoque formal
III. Más allá de Euclides
IV. Conclusión

I. Contando el tiempo

“As logic stands you couldn’t meet a man who’s from the future
But logic broke as he appeared he spoke about the future”

- The Flaming Lips

Moraleja

La evolución dinámica de los sistemas físicos se vuelve de interés filosófico en el momento en que empezamos a tomar en cuenta las consecuencias que tienen nuestros métodos de análisis sobre nuestras nociones de ser, existir y volverse

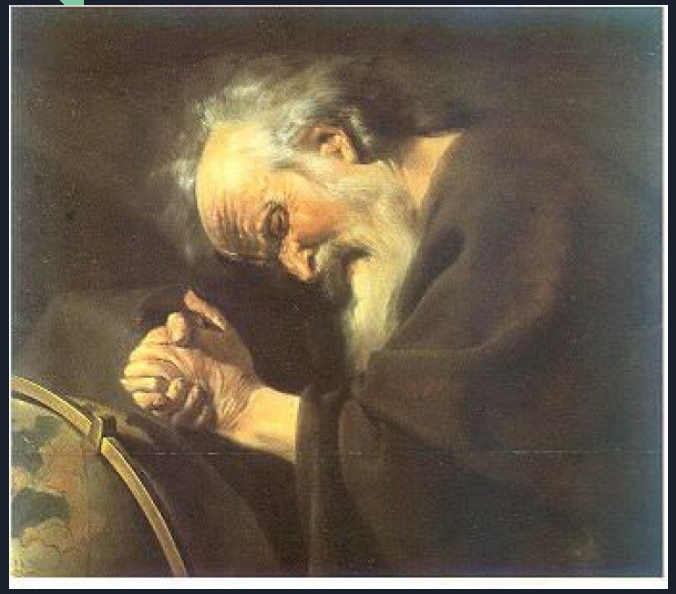
I. Contando el tiempo

Motivación

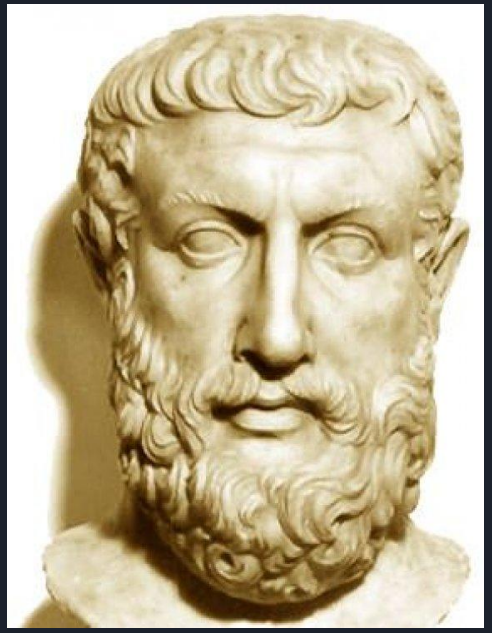
Las tres metafísicas del tiempo

Método y fenomenología

Motivación



PANTA REI
c. 469 BC



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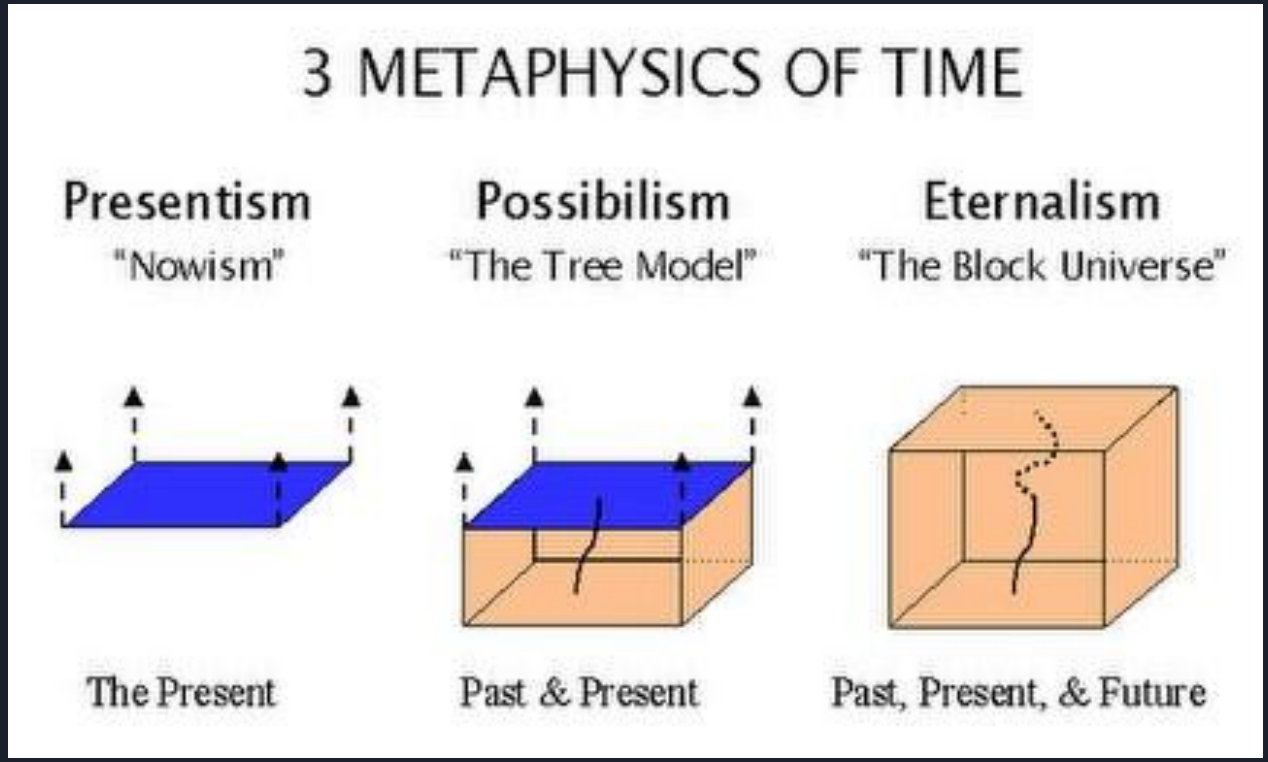
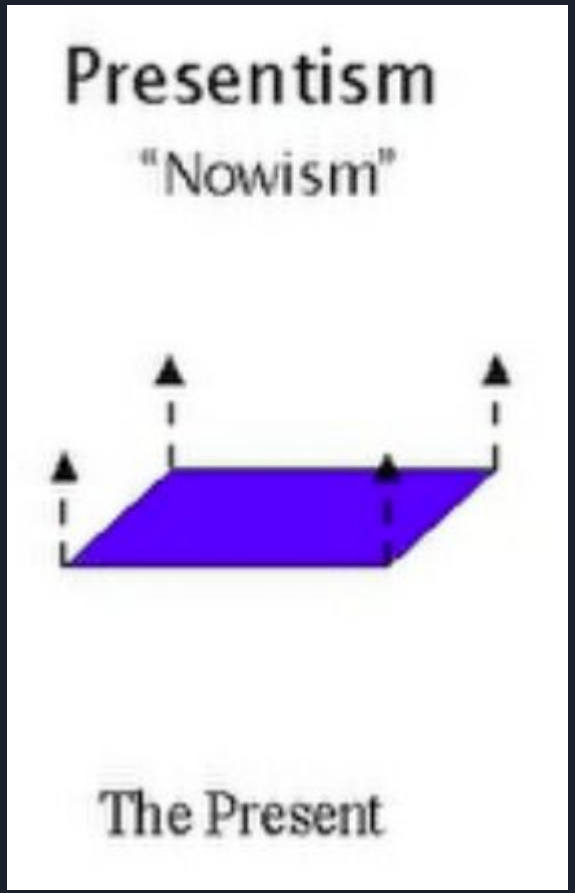
“Volviéndose”

Las tres metafísicas del tiempo



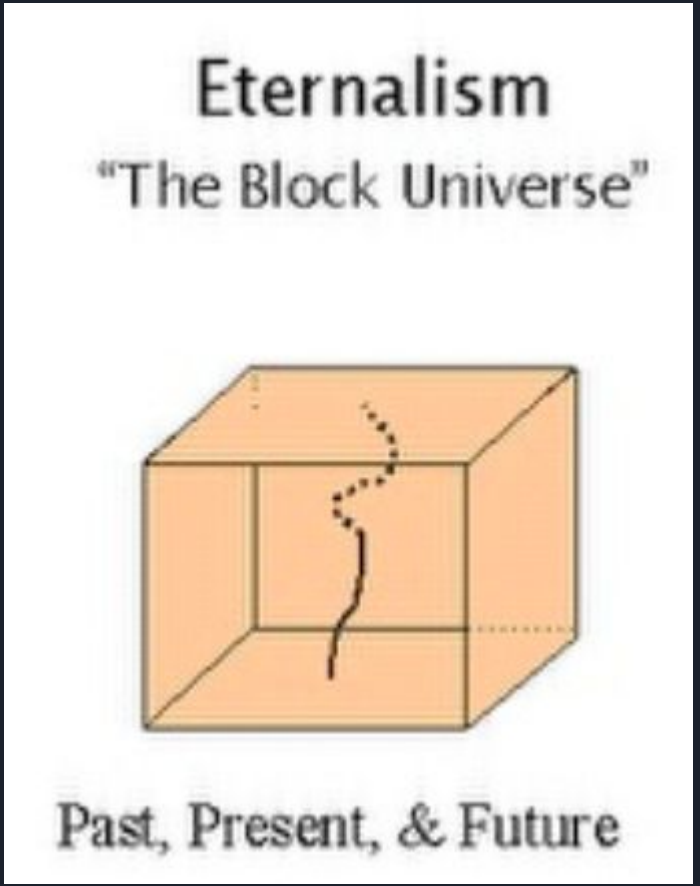


- Heráclito: Sólo el "ya" existe.
- Los eventos pasados perdieron su existencia en el momento que se volvieron pasados
- Los eventos futuros todavía no han llegado a existir
- Un evento existe sólo en términos de la percepción de su ocurrencia.
- Las flechas en el diagrama indican que el momento está desenvolviéndose en un proceso continuo.

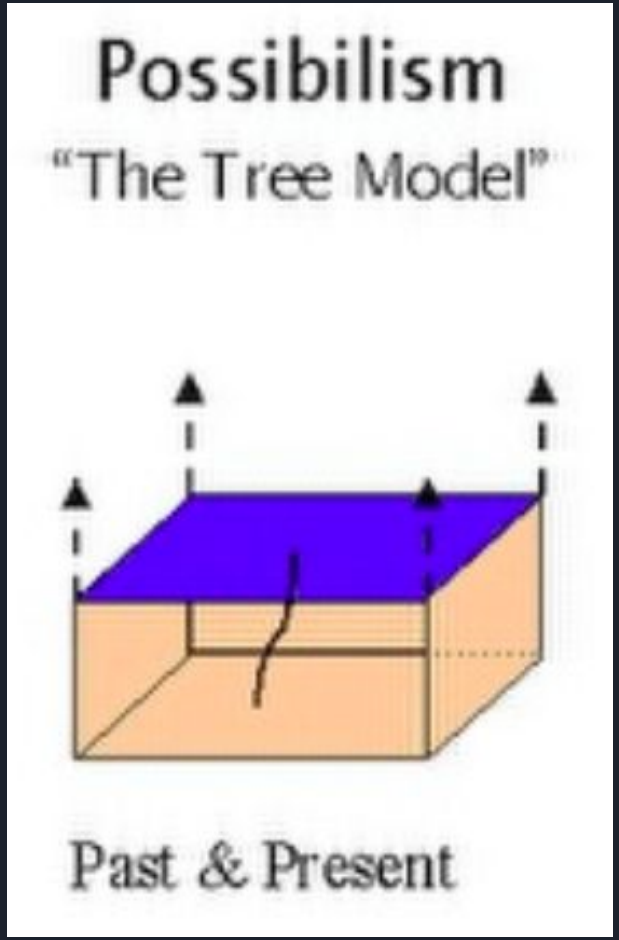
:. El presentista toma como perspectiva la inmersión del sujeto dentro del tiempo, rechazando la existencia de los eventos fuera de su experiencia

- Parménides: El pasado, el presente y el futuro son parte de un todo monádico
- Los eventos pasados son aquellos debajo de un instante determinado
- Los eventos futuros son aquellos encima de un instante determinado
- El diagrama carece de flechas porque la noción de desenvolverse es ilusoria
- Hablar de “antes” y “después” es igual a hablar de “aquí” y de “allá”

:. El eternalista busca comprender al tiempo como independiente de su experiencia, externalizando su perspectiva a un marco despersonalizado fuera del tiempo



- El punto intermedio.
- Los eventos pasados han sido actualizados e influyen sobre el presente
- Los eventos futuros no han sido actualizados, son tan solo posibles



- Las flechas nuevamente indican que el presente está en flujo, pero con su desarrollo al futuro siendo influenciado por el pasado

:. El posibilista reconoce la existencia del pasado como certera y la distingue del futuro debido a su incertidumbre al hacer predicciones

Método y fenomenología

Filosofía: consideraciones lingüísticas

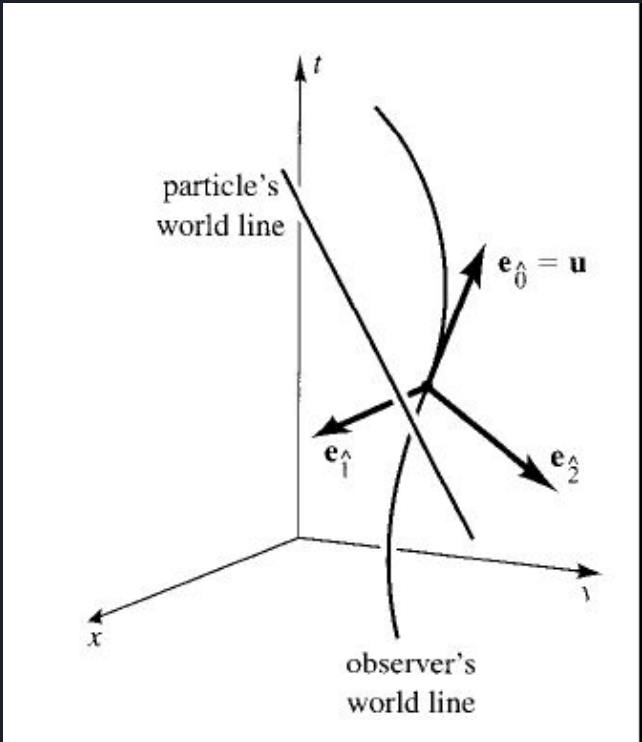
Para un verbo ϕ...

Dígase que el verbo ϕ está **conjugado** si éste refiere a un tiempo verbal definido en el pasado, presente o futuro
e.g. Isaac Newton **nace** en 1642.

Dígase que el verbo ϕ está **des-conjugado** si su tiempo verbal no está definido, es decir, si puede ser cualquiera del pasado, presente o futuro
e.g. El centro del agujero negro **es** una singularidad.

Dígase que el verbo ϕ está **sin conjugación** si éste carece de un tiempo verbal.
e.g. Los eventos **existen** dentro del espacio-tiempo

Física: el evento fenomenológico



II. Enfoque formal

“Tired of lying in the sunshine
Staying home to watch the rain
You are young and life is low
And there is time to kill today”

-Pink Floyd

Moraleja

La reversibilidad del tiempo dentro de los sistemas conservativos clásicos resulta en ecuaciones de tiempo amnésicas, mientras que la mecánica cuántica quiebra con la reversibilidad debido al análisis perturbativo y el colapso de la función de onda cuando hacemos mediciones

II. Enfoque formal

El tiempo en la mecánica clásica

El tiempo en la mecánica cuántica

¿Descripción continua o discreta?

El tiempo en la mecánica clásica

Fuerzas conservativas

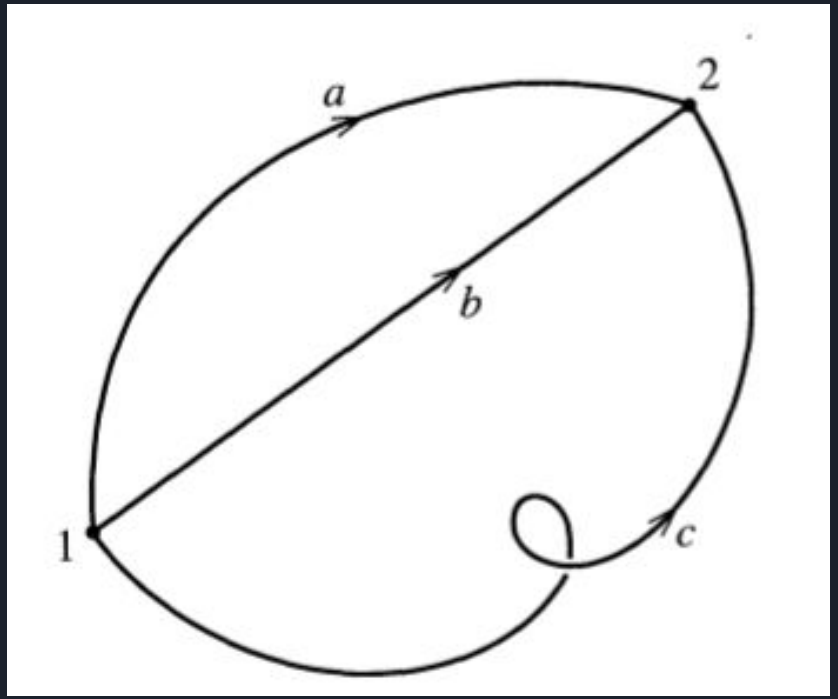
Conditions for a Force to be Conservative

A force **F** acting on a particle is **conservative** if and only if it satisfies two conditions:

(i) **F** depends only on the particle's position **r** (and not on the velocity **v**, or the time t, or any other variable); that is, $\mathbf{F} = \mathbf{F}(\mathbf{r})$.

(ii) For any two points 1 and 2, the work $W(1 \rightarrow 2)$ done by **F** is the same for all paths between 1 and 2.

Independencia de caminos



Conservación de energía

$$\frac{d}{dt}\mathcal{L} = \sum_i \left(\dot{p}_i\dot{q}_i + p_i\ddot{q}_i\right) + \frac{\partial \mathcal{L}}{\partial t}$$

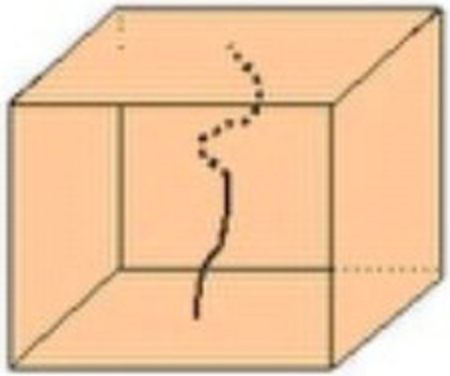
$$= \frac{d}{dt}\sum_i \left(p_i\dot{q}_i\right) + \frac{\partial \mathcal{L}}{\partial t}. \tag{7.89}$$

Now, for many interesting systems, the Lagrangian does not depend explicitly on time; that is, $\partial\mathcal{L}/\partial t = 0$. When this is the case, the second term on the right of (7.89) vanishes. If we move the left side of (7.89) over to the right, we see that the time derivative of the quantity $\sum p_i\dot{q}_i - \mathcal{L}$ is zero. This quantity is so important that it has its own symbol,

$$\mathcal{H} = \sum_{i=1}^{n} p_i\dot{q}_i - \mathcal{L}, \tag{7.90}$$

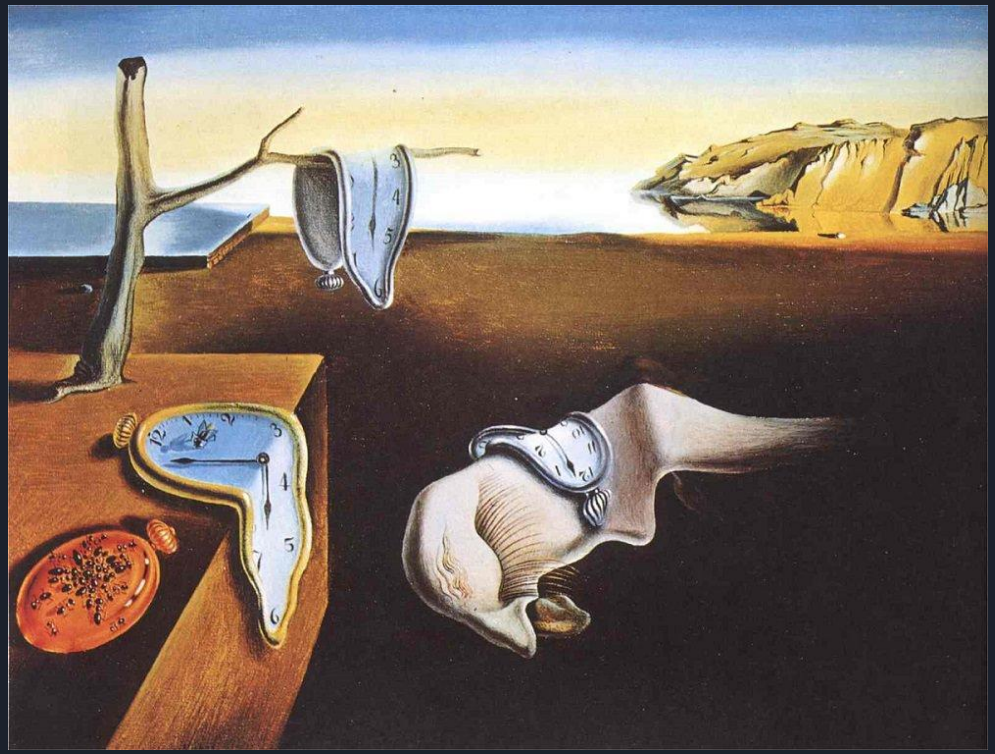
Eternalism

"The Block Universe"



Past, Present, & Future

Amnesia



Excepción: La fuerza de Lorentz

The Lagrangian for a charge q in an electromagnetic field is

$$\mathcal{L}(\mathbf{r}, \dot{\mathbf{r}}, t) = \tfrac{1}{2}m\dot{\mathbf{r}}^2 - q(V - \dot{\mathbf{r}}\cdot\mathbf{A}). \qquad \text{[Eq. (7.103)]}$$

¡La fuerza resultante
NO es conservativa!

El tiempo en la mecánica cuántica

Schrödinger equation:

$$i\hbar\frac{\partial\Psi}{\partial t} = H\Psi$$

Time independent Schrödinger equation:

energías posibles

$$H\psi = E\psi, \qquad \Psi = \psi e^{-iEt/\hbar}$$

número imaginario

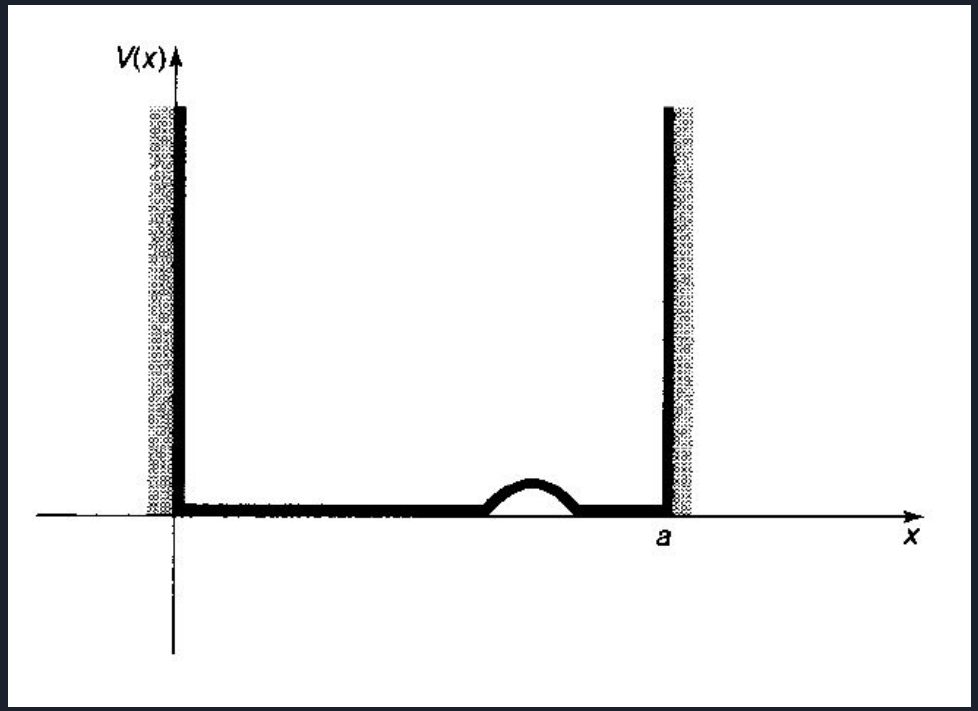
Standard Hamiltonian:

$$H = -\frac{\hbar^2}{2m}\nabla^2 + V$$

Time dependence of an expectation value:

$$\frac{d\langle Q\rangle}{dt} = \frac{i}{\hbar}\langle [H, Q]\rangle + \left\langle \frac{\partial Q}{\partial t} \right\rangle$$

Análisis perturbativo



Colapso de la función de onda

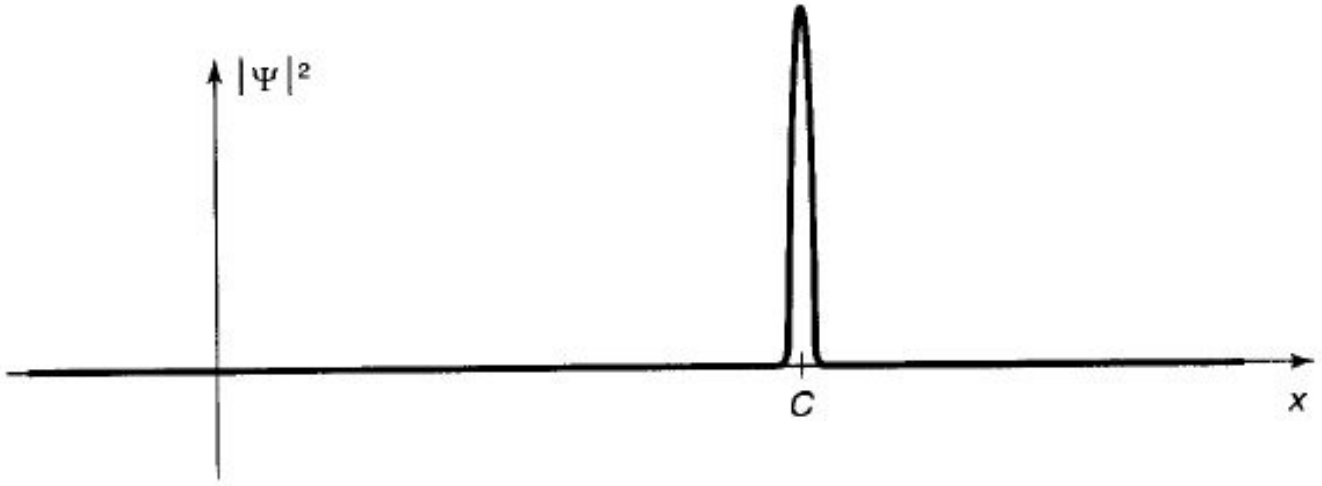
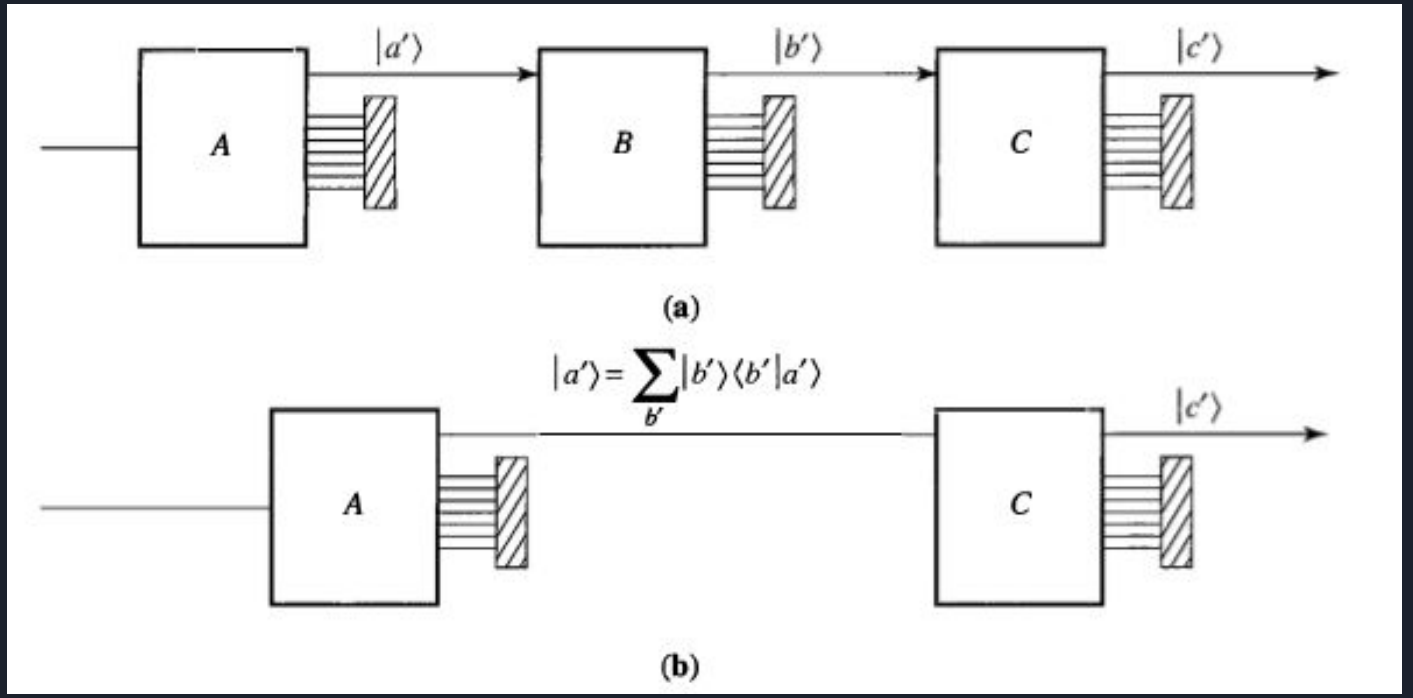


Figure 1.3: Collapse of the wave function: graph of $|\Psi|^2$ immediately after a measurement has found the particle at point C.

La medida filtra los eventos



Presentism

"Nowism"

The Present

Excepción: la interpretación de de Broglie-Bohm

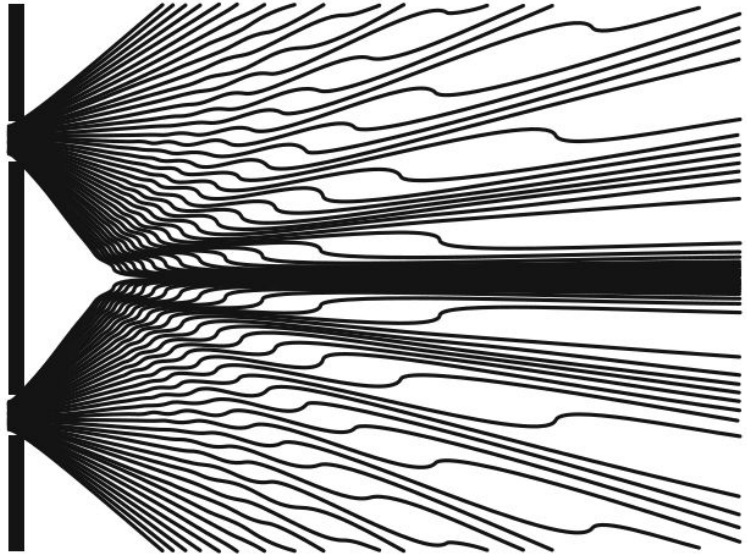
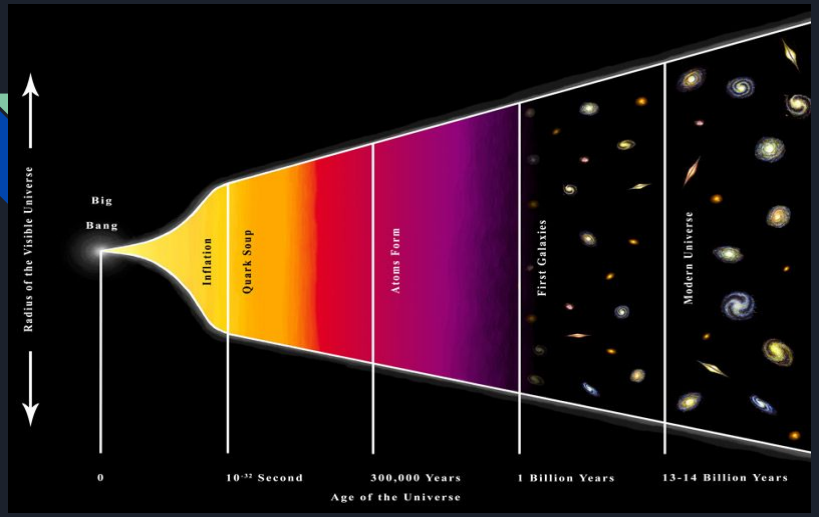
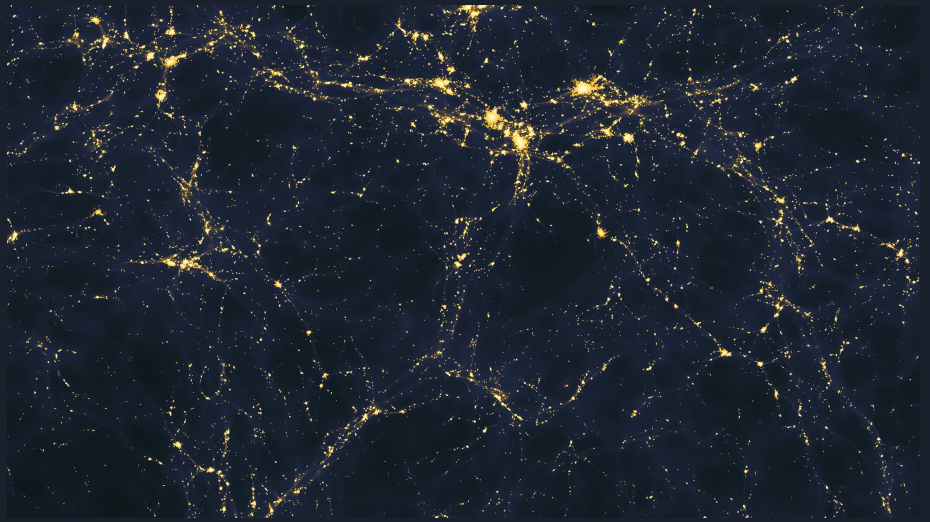
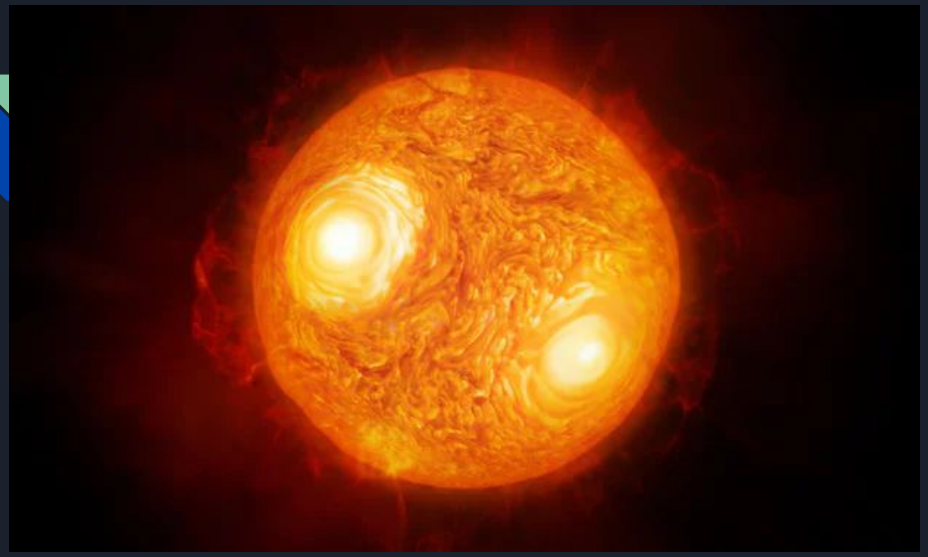


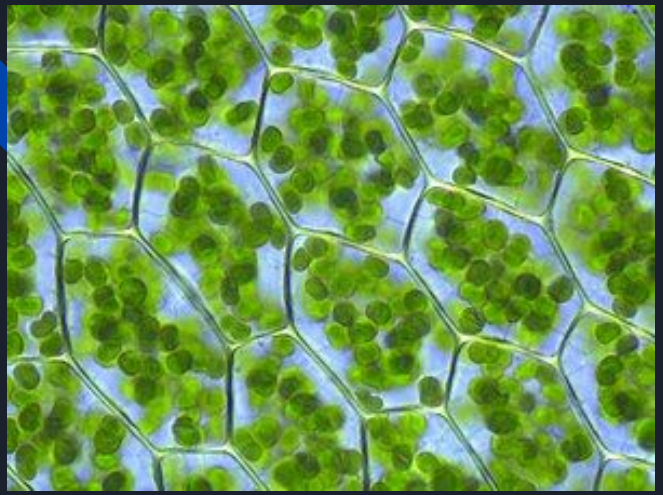
Fig. 1.1 A family of Bohmian trajectories for the two-slit experiment. (Adapted by Gernot Bauer from Hiley, et al. [26].)

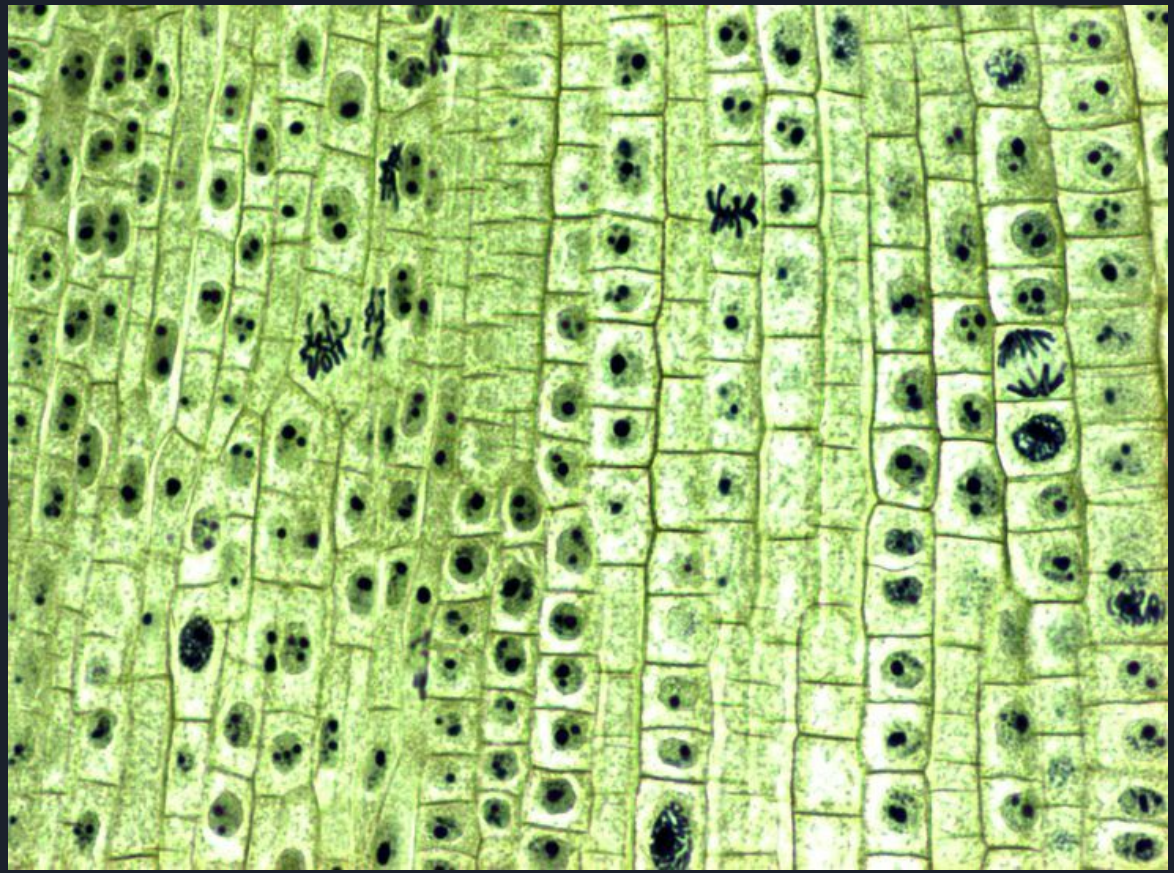
¿Descripción continua o discreta?

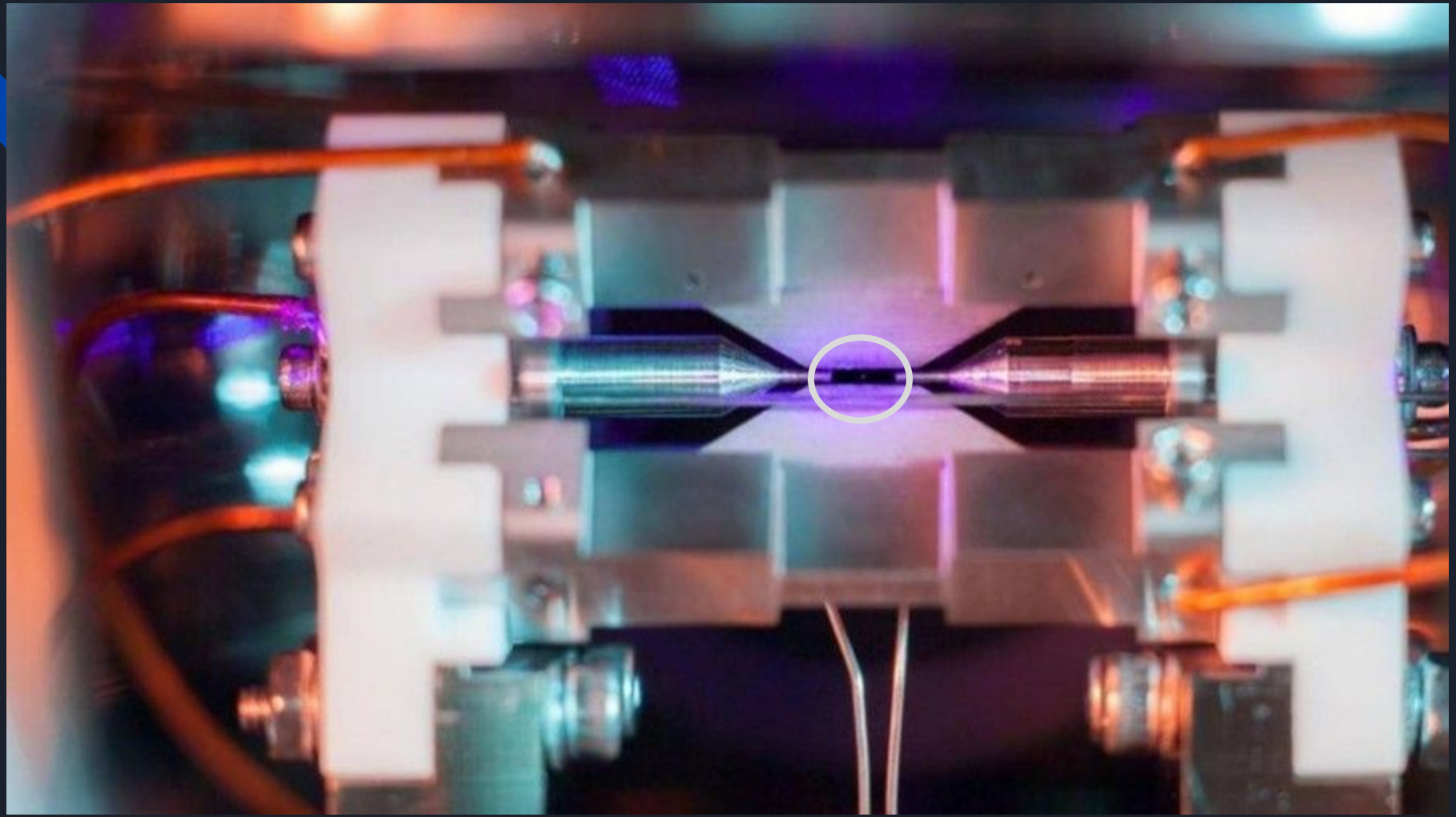

Radius of the Visible Universe
Big Bang
Inflation
Quark Soup
Atoms Form
First Galaxies
Modern Universe
0
10⁻³² Second
300,000 Years
1 Billion Years
13-14 Billion Years
Age of the Universe

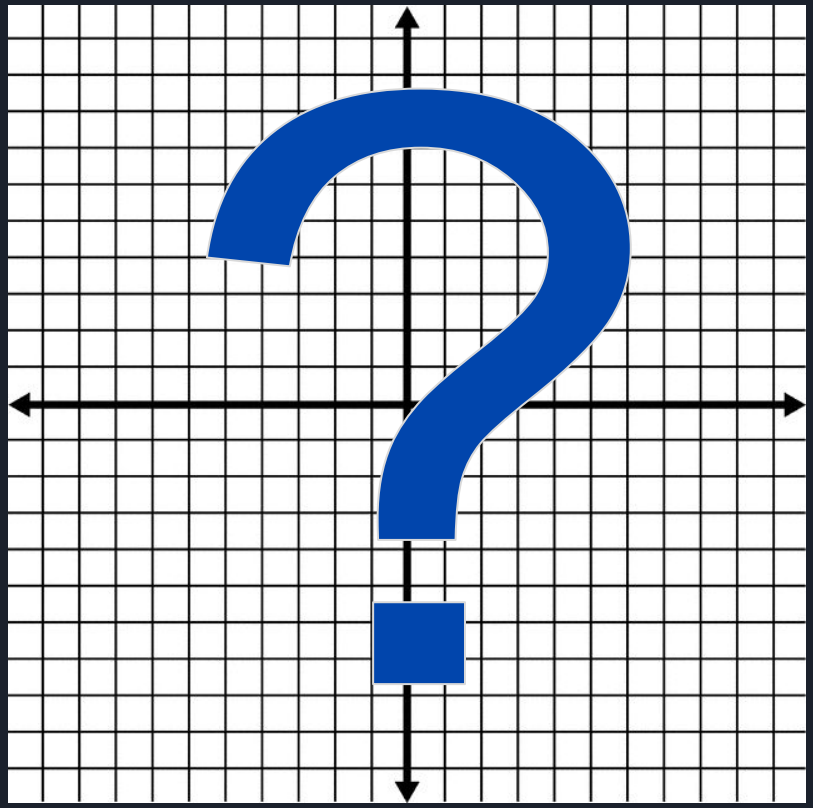












III. Más allá de Euclides

“Everything is changing
And there’s nothing I can do
My world is turning pages
While I am just sitting here”

- Tame Impala

Moraleja

La unión conceptual del espacio con el tiempo nos obliga a reconsiderar todas nuestras intuiciones sobre localidad, causalidad y simultaneidad.

Por otra parte, abandonar la hipótesis de la continuidad de las trayectorias dinámicas nos abre la puerta a las geometrías fractales y su análisis natural como sistemas con memoria.

III. Más allá de Euclides

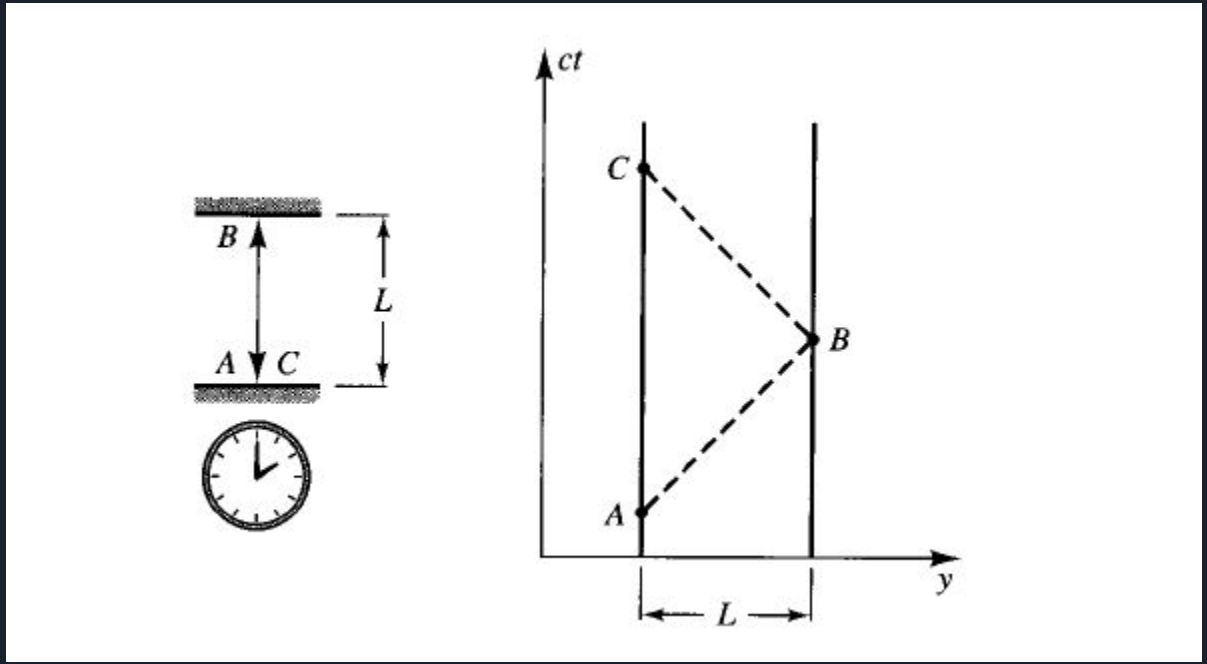
La relatividad especial

La geometría fractal

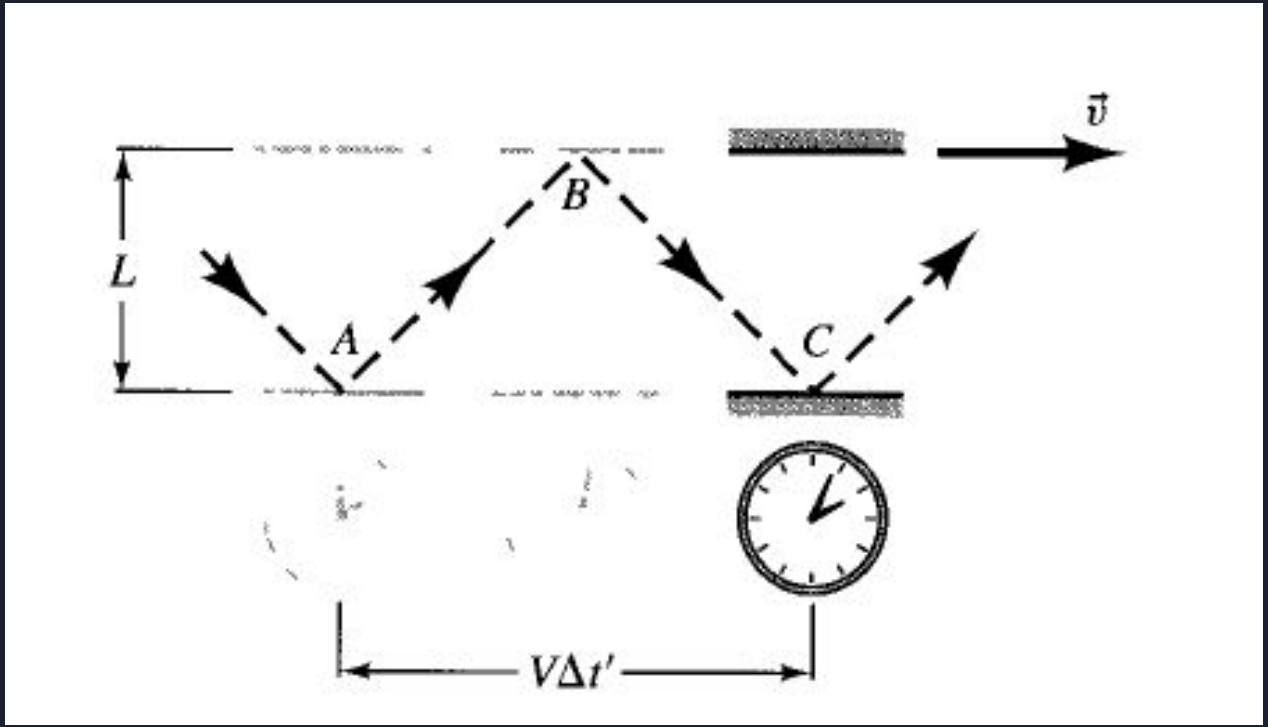
Avenidas sin explorar

La relatividad especial

Relojes de luz



Si la velocidad de la luz es constante...



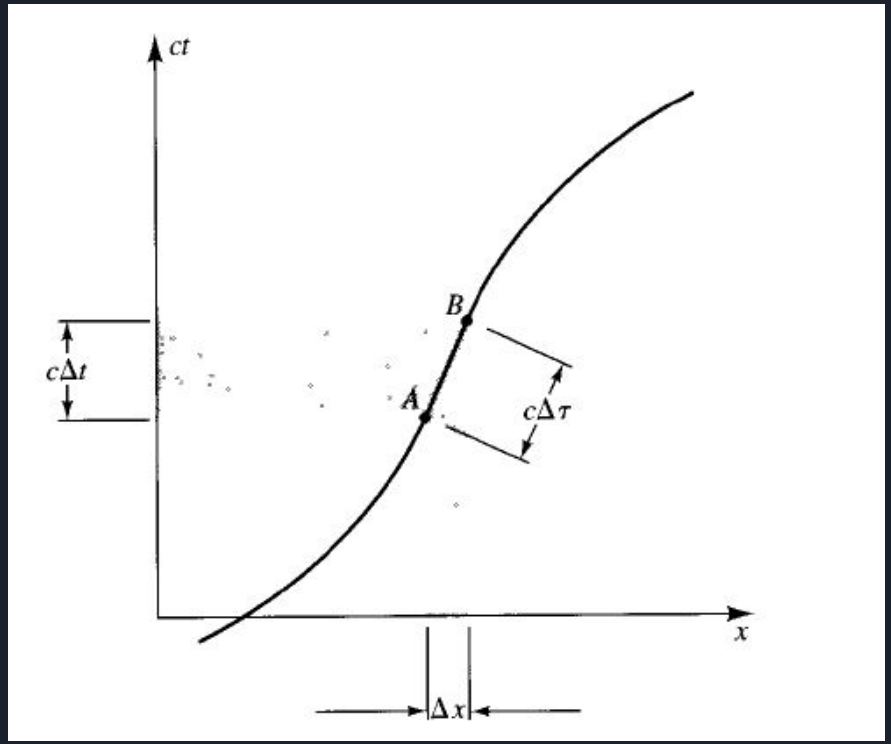
… el intervalo es lo que se preserva

The distance between points defining spacetime geometry must be the same in all systems of coordinates used to label the points. The principle of relativity requires that the line element that defines the distance should have the same form in all inertial frames. The invariance exhibited in (4.7) therefore motivates taking $(\Delta s)^2$ as the squared distance between points in spacetime. More precisely, we will posit the line element[6]

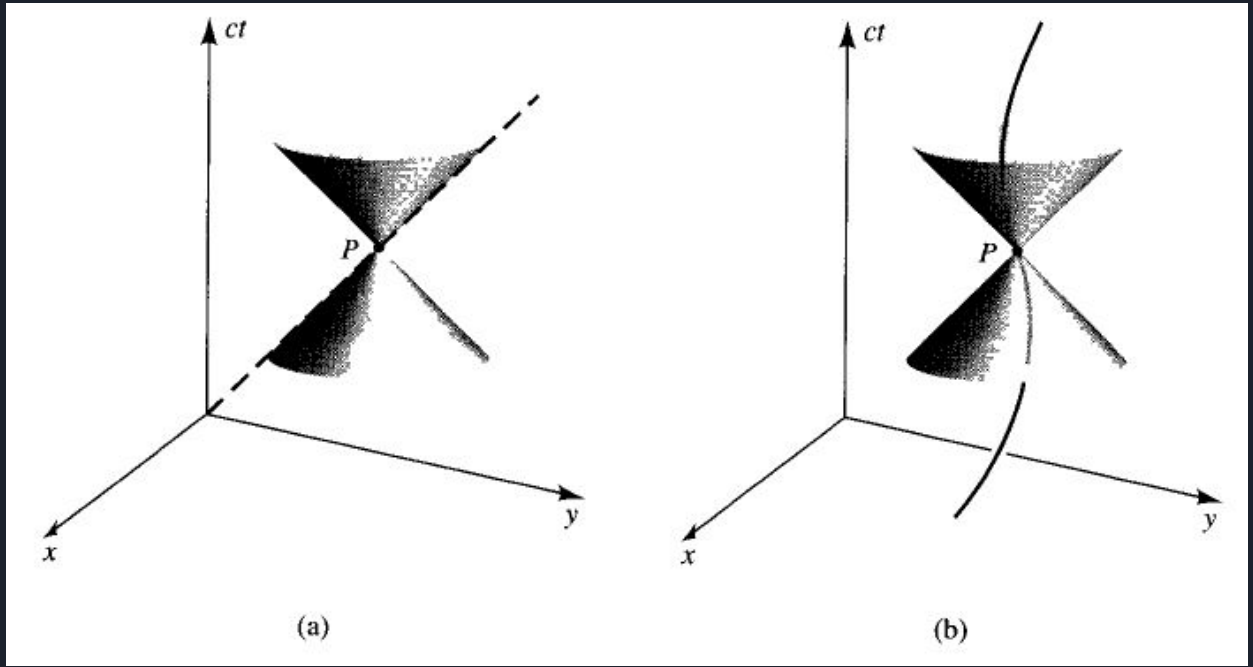
$$ds^2 = -(c\,dt)^2 + dx^2 + dy^2 + dz^2 \tag{4.8}$$

(the infinitesimal version of (4.6)) as defining the geometry of four-dimensional spacetime and the starting point for special relativity. By requiring it take the

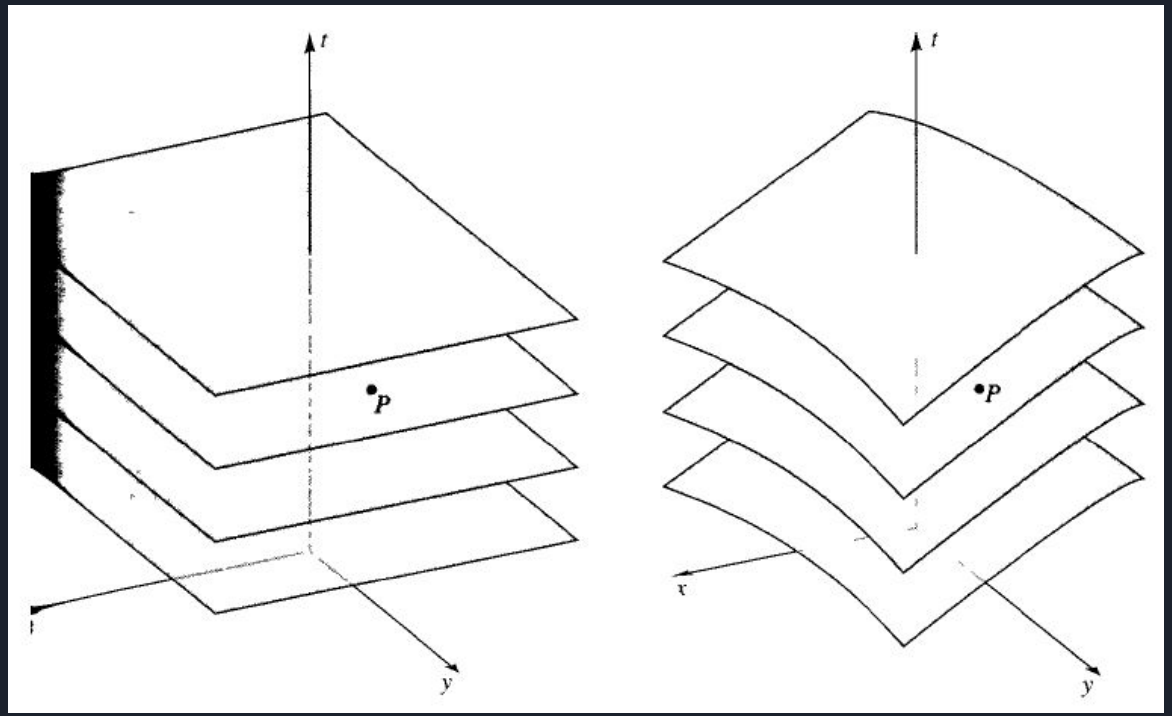
Dilatación de tiempo



Línea de universo

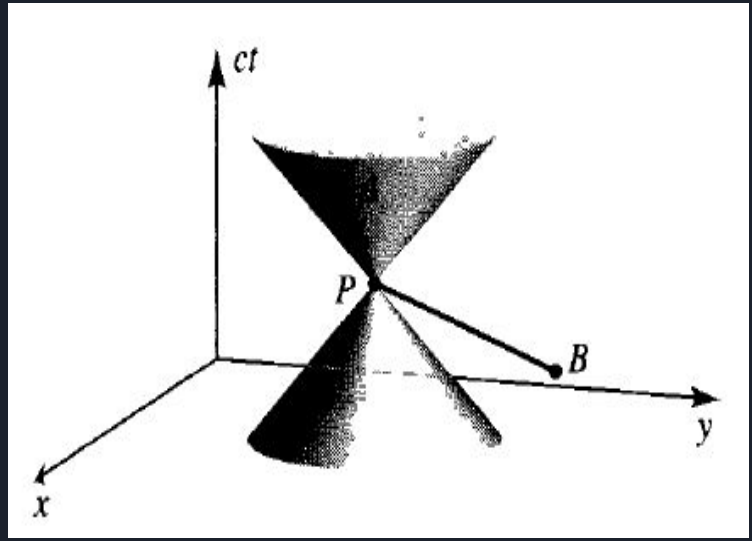


Foliación



Simultaneidad: Putnam vs. Stein

- *“There are good arguments, some of them coming from the philosopher Hilary Putnam, that if you assume the relativity of simultaneity then you can’t objectively distinguish among the past, present, and future. “* -Lee Smolin
- *“If is the case that all and only the things that stand in a certain relation R to me-now are real, and you-now are real, then it is also the case that all and only the things that stand in the relation R to you-now are real.”* - Hilary Putnam
- *“According to Stein, Putnam presupposes notions that are not available in special relativity. He has failed to take note of the changed situation in that context, that ‘definiteness to the present’ has to be replaced by ‘definiteness at a given space-time point’”* -Simon Saunders




Presentism
"Nowism"
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Eternalism

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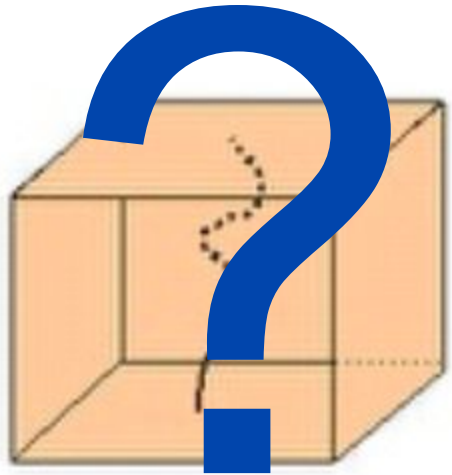
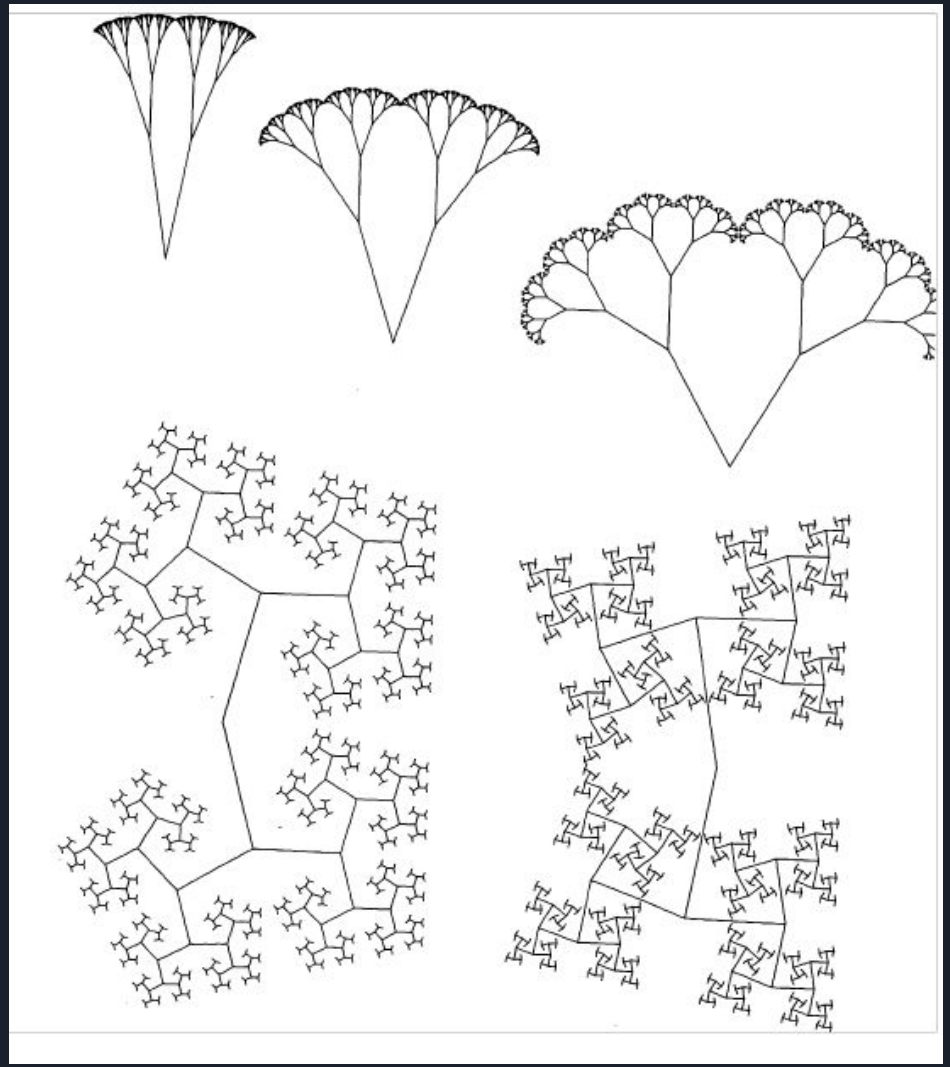


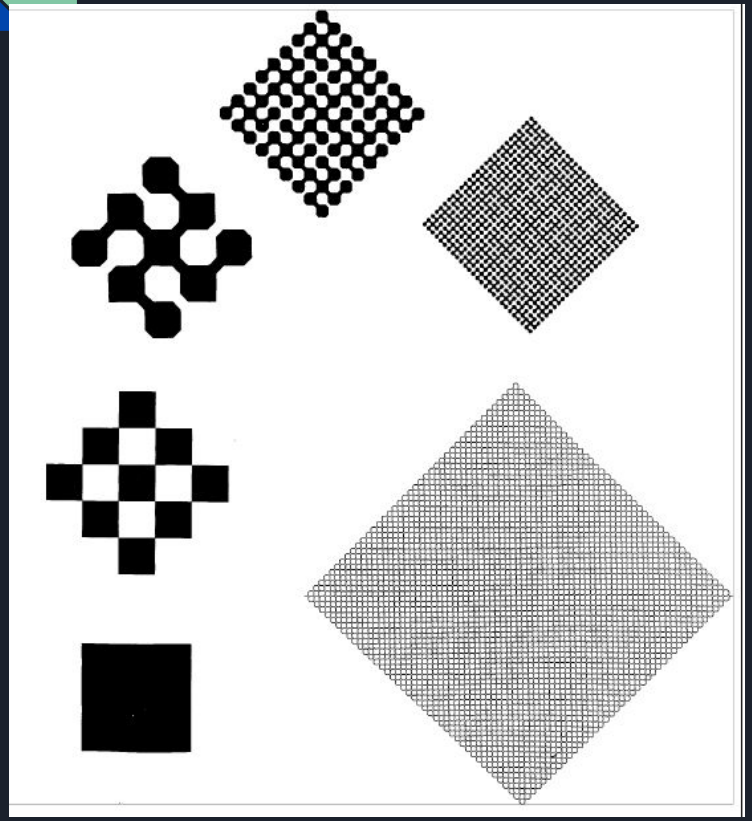
Past, Present, & Future

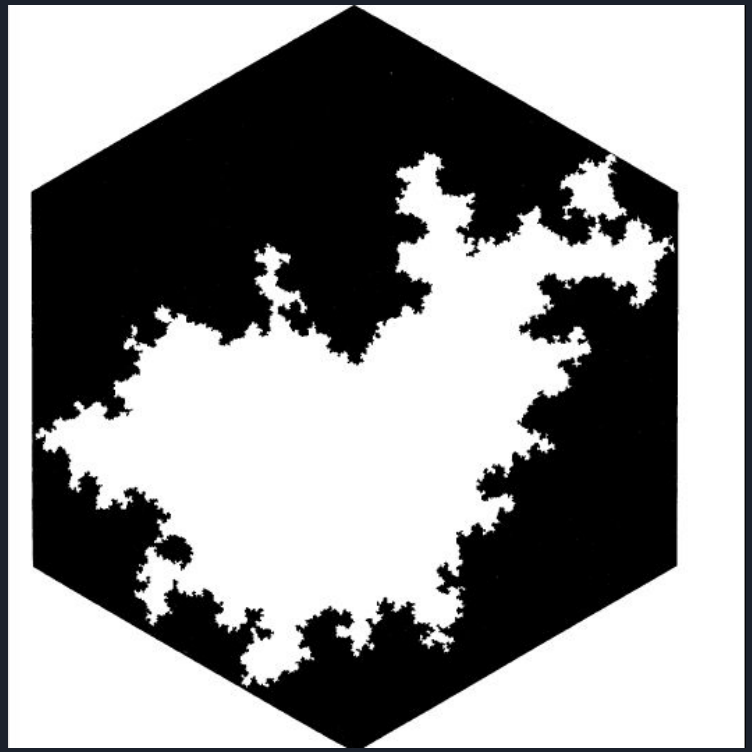
La geometría fractal

¿Qué pasó con el posibilismo?

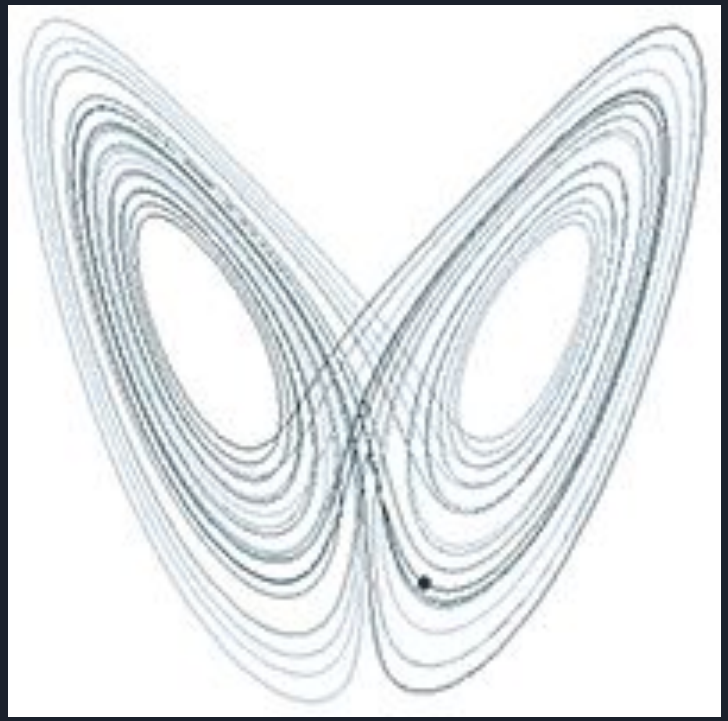


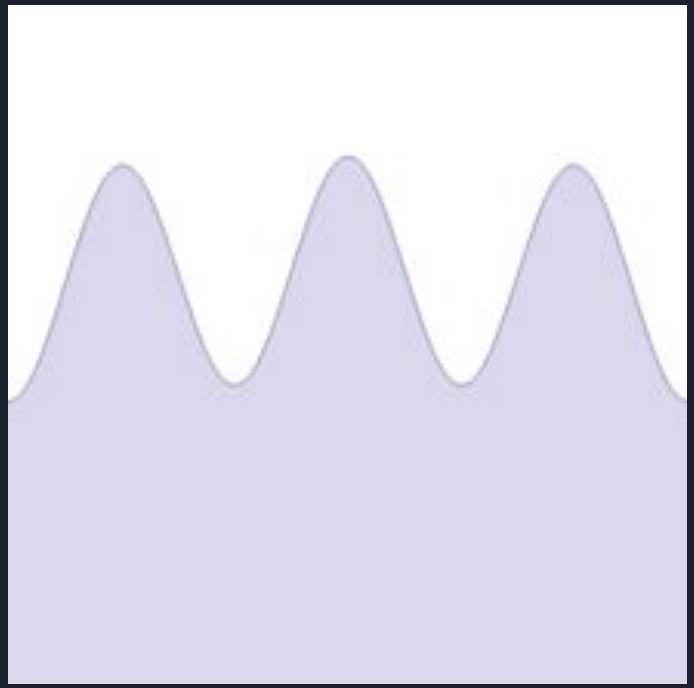
Dimensiones auto-similares



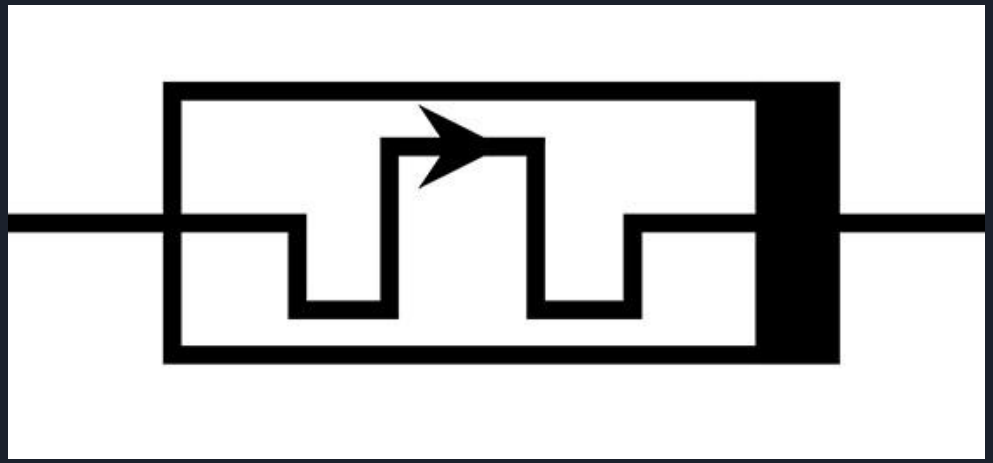


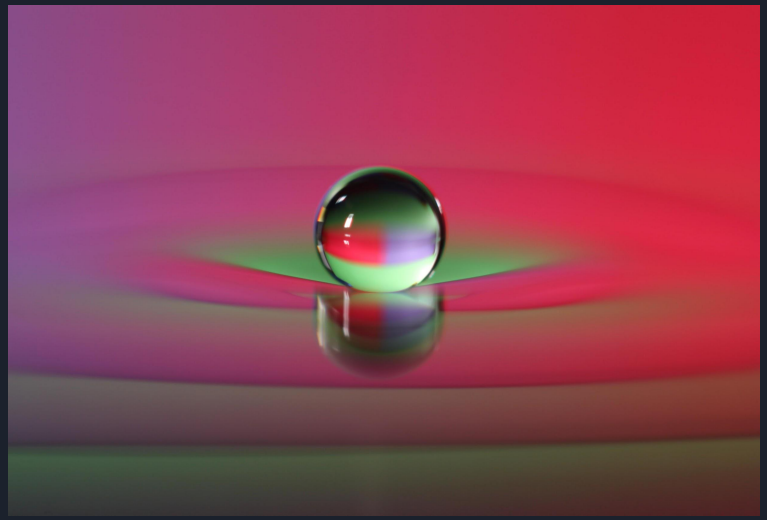
Caos



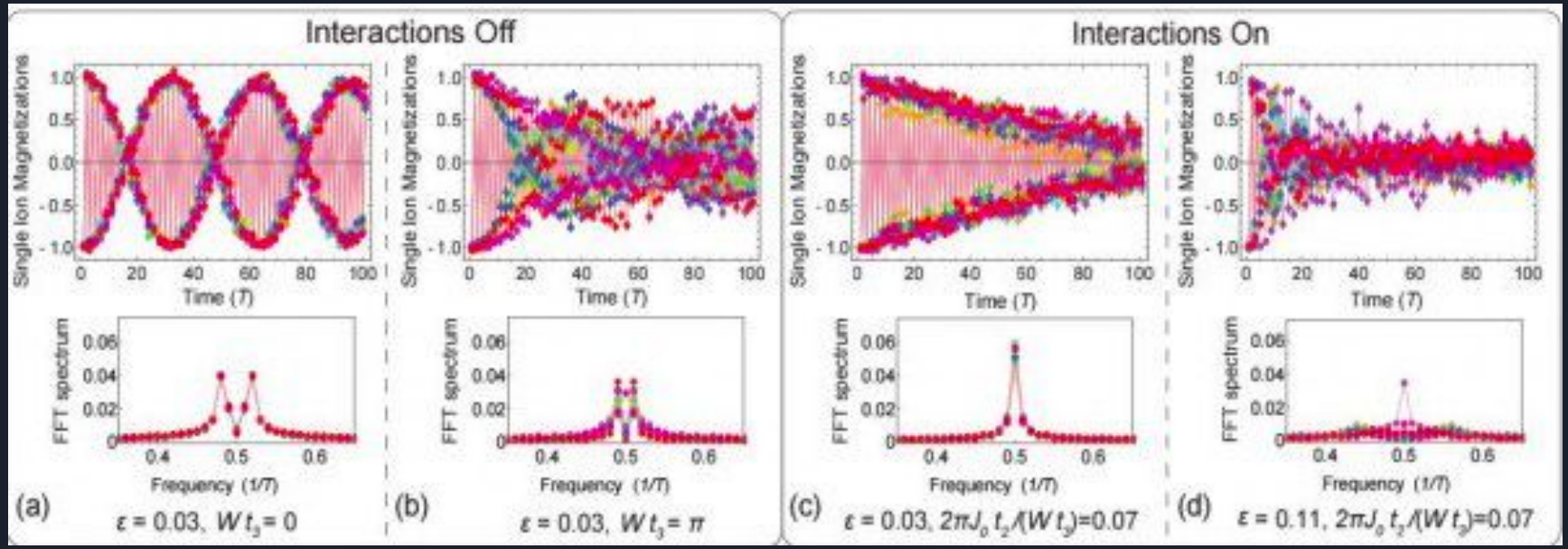


Sistemas con memoria





Cristales de tiempo



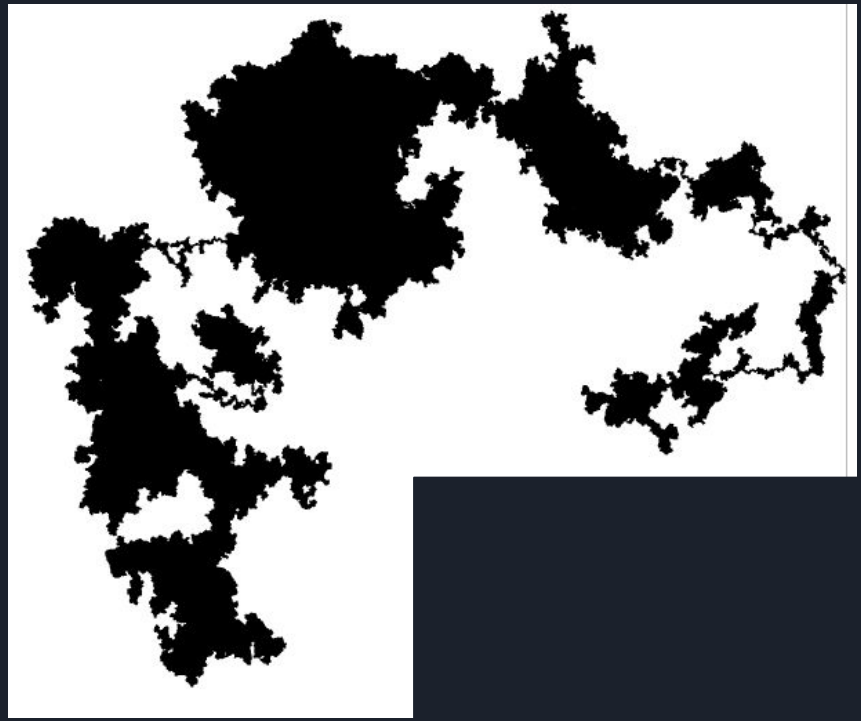
Memoria

Avenidas sin explorar

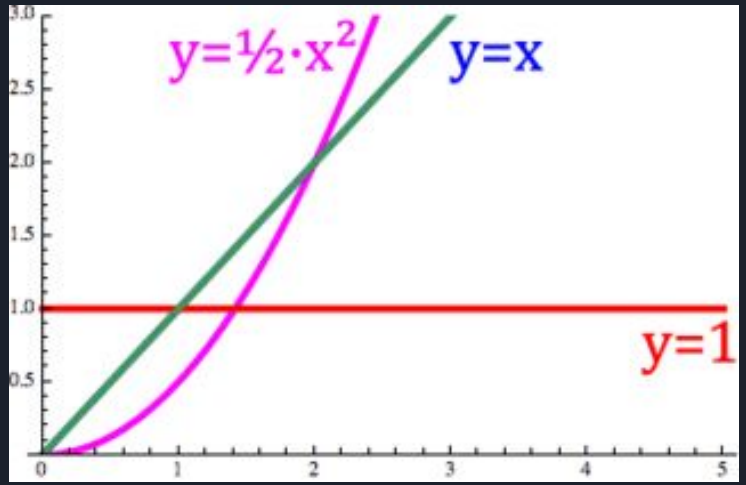
Movimiento Browniano

- "*The direction of the straight line joining the positions at two instants very close in time is found to vary absolutely irregularly as the time between the two instants is decreased. An unprejudiced observer would therefore conclude that he is dealing with a function without derivative, instead of a curve to which a tangent could be drawn*" -Jean Perrin

- "*Feynman & Hibbs 1965 notes that the typical path of a quantum mechanical particle is continuous and nondifferentiable, and many authors observe similarities between Brownian and quantum-mechanical motions (see, for example, Nelson 1966 and the references herein).*" - Benoit Mandelbrot



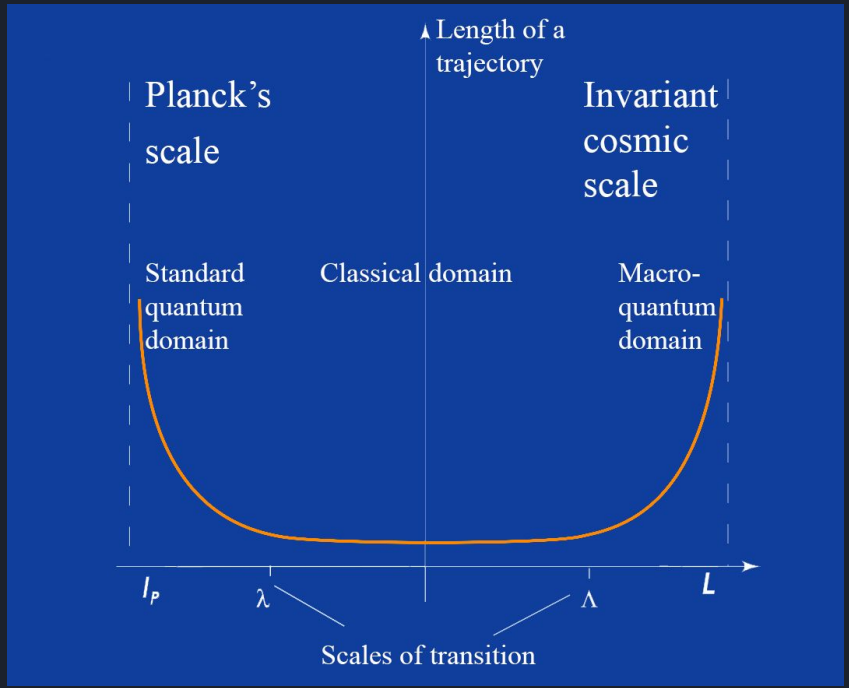
Mecánica fraccional



- "*It is a strange paradox that the most advanced methods of classical mechanics deal only with conservative systems, while almost all classical processes observed in the physical world are nonconservative ... Even at the microscopic level, there is dissipation in every nonequilibrium or fluctuating process*" -Fred Riewe
- "*By using fractional derivatives, it is possible to construct a complete mechanical description of nonconservative systems, including Lagrangian and Hamiltonian mechanics, canonical transformations, Hamilton-Jacobi theory, and quantum wave mechanics.*" - Fred Riewe
- "*The general conclusion is reached that fractional calculus can be used to precisely change or control the fractal dimension of any random or deterministic fractal with coordinates which can be expressed as functions of one independent variable, which is typically time*" -Frank B. Tatom

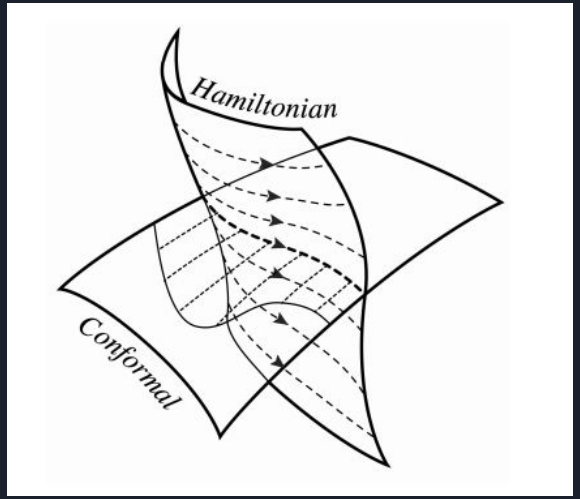
Relatividad de escalas

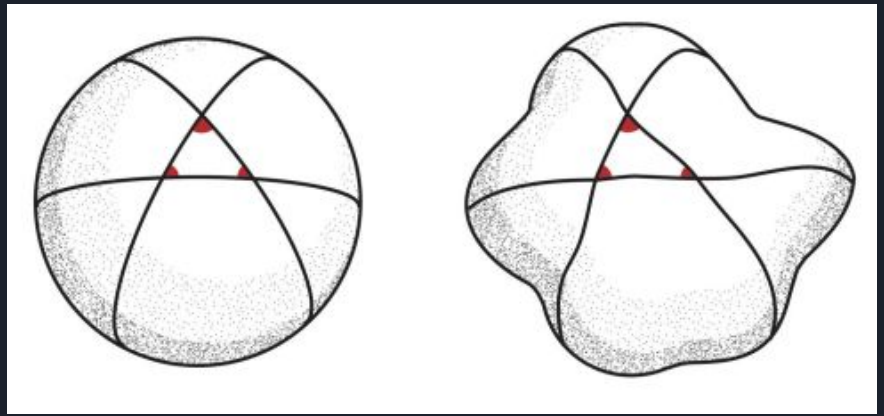
- "*The theory of scale relativity suggests ... quantum mechanics may indeed be founded on the principle of relativity itself, provided this principle (applied up to now to position, orientation and motion) be extended to scales.*" - Laurent Nottale
- "*it is suggested ... that a new generalization of the description of space-time is now needed, toward a still continuous but now nondiffernentiable and fractal geometry*" -Laurent Nottale
- "*the theory's diffusion throughout the scientific field has been limited — albeit real — and its results ... are rarely taken into account by researchers who are not already TSR collaborators.*" - Bontems & Gingras



Dinámica de formas

- *“Then there was a development which was initiated by Julian Barbour himself, it’s a little bit ironic, called shape dynamics. After many, many years of work, he and some colleagues came up with a formulation of a gravitational theory which was almost equivalent to general relativity, but with the difference that size is relative.”* -Lee Smolin
- *“There exists, however, an equivalent formulation of general relativity, called shape dynamics, that is free of the local problem of time. In this approach, there is a single Hamiltonian constraint generating the dynamics of conformal 3-geometry”* - Karim Thebault





Conclusión

“I will keep falling as long as I live
Ah, without ending
And I will remember the place that is now
That has ended before the beginning”

-The Byrds

Moralejas

- Como dice Daniel Dennett, no hay tal cosa como practicar ciencia libre de filosofía, tan sólo hay científicos que ignoran el bagaje filosófico dentro de su disciplina
- La metafísica del tiempo nos invita a reflexionar sobre las condiciones que gobiernan nuestro desarrollo como seres pensantes y actuantes dentro del mundo
- Al evaluar el debate presentista y eternalista dentro de nuestras teorías físicas, descubrimos que la decisión de un tiempo presentista o eternalista depende del sistema bajo consideración
- La métrica de Minkowski tiene implicaciones sobre nuestra experiencia del tiempo que al día de hoy todavía no hemos comprendido del todo
- Finalmente, las geometrías fractales nos ofrecen una noción de “memoria del sistema” que no encontrábamos en los sistemas conservativos reversibles

¿Cuál tiempo y por qué?

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