Possibility in physics, the relevance to quantum mechanics

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90 years of uncertainty

Uncertainty?

Undetermination?

The position and the velocity of an object cannot both be measured exactly, at the same time, even in theory

impossible?

It's time to think about the concept of possibility in quantum mechancis

Content

- **Basic modal intuitions**
- **Subjective vs objective possibility**
- **Actualism vs possibilism**
- **Possibility and probability**
- **Possibility in physics**
- **Possibility in quantum mechanics**

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Basic modal intuitions

Middle Ages → true judgements → ***necessary*** / ***contingent*** } ***modes*** *of truth* ⇓ **Modality**

- Concepts involved in modal discourse:

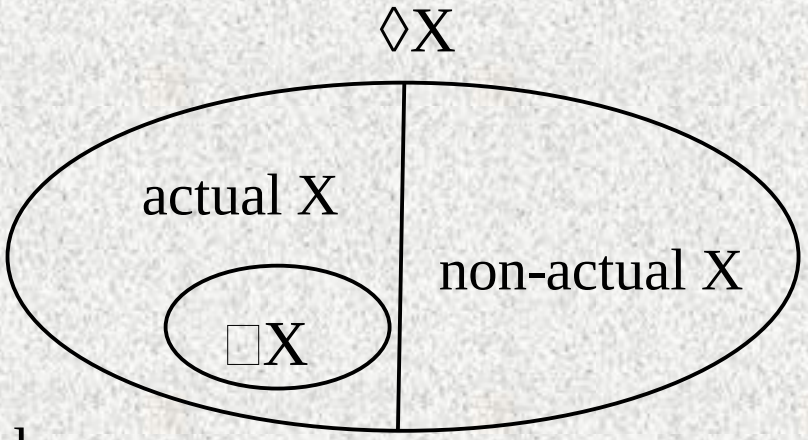
Possible: ◊X

Impossible: ¬◊X

Necessary: □X= ¬◊¬X

Contingent: ¬□X= ◊¬X

- Possible → ***actual*** / ***non-actual***



X→◊X : whatever is actual is possible

□X→X : whatever is necessary is actual

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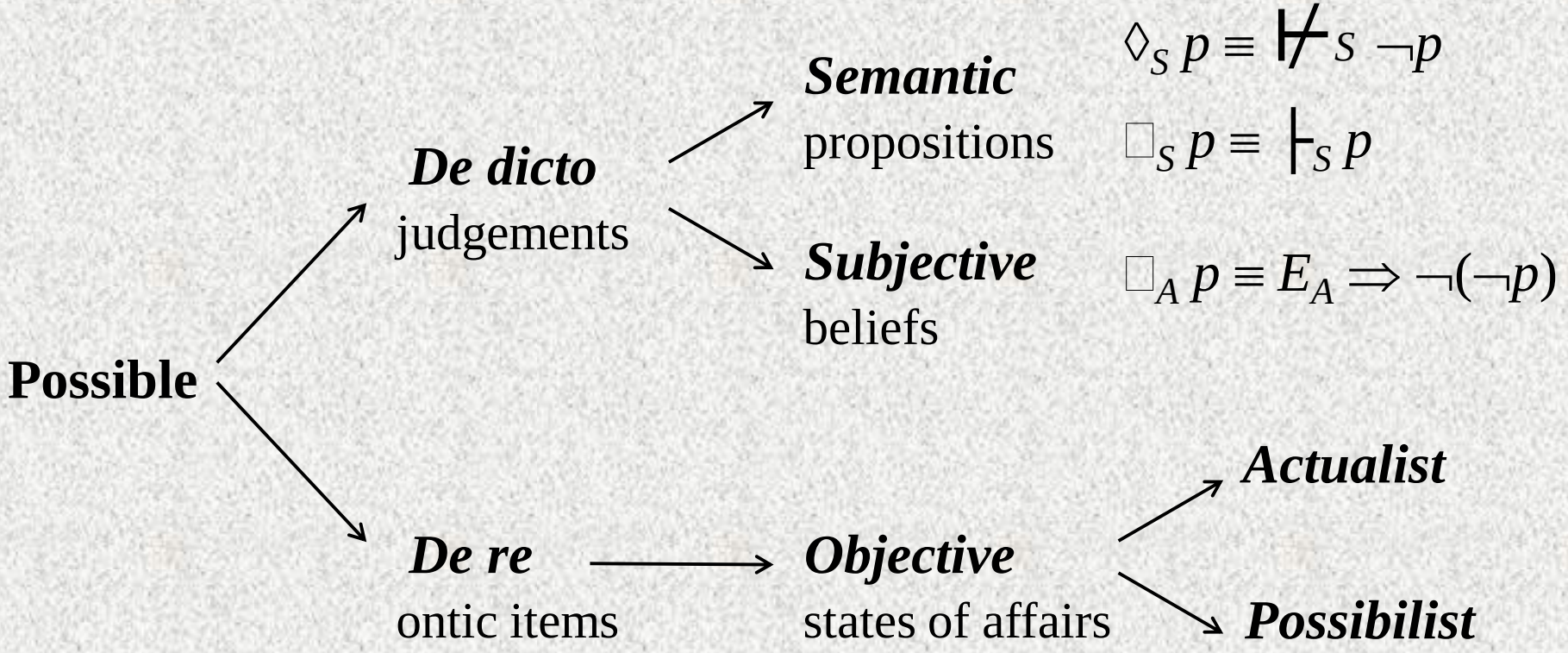
Subjective vs objective possibilities

What the predicate ‘possible’ is applied to?



Abelard XII century

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Actualism vs possibilism

- **Actualism**: Everything that is real is actual

  Diodorus Cronus: “the possible is that which either is or will be”

  Bertrand Russell: “possible means sometimes, necessary means always”

  Reduces possible to actual
  Actuality and possibility are coextensive

- **Possibilism**: Not everything that is real is actual

  Philo of Megara : “possible is that which is capable of being true by the proposition’s own nature”

  Chrysippus : “even thought something is not true and may never be true, it may nevertheless be possible”

  There are possible states of affairs that never become actual
  Actuality is a subclass of possibility

Actualism vs possibilism

XX Century: actualism prevails ⟶ influence of logical-positivism ↓ verificationist theory of meaning

↓

Problem of determinism

- Popper: "scientific" concept of determinism,"the doctrine that the state of any closed physical system at any given future instant of time can be predicted, even from within the system, with any specified degree of precision"
- Russell: "a system is said 'deterministic' when, given certain data e_1, e_2, ..., e_n at times t_1, t_2, ..., t_n respectively, concerning this system, if E_t is the state of the system at any time t, there is a functional relation of the form $E_t = f(e_1, t_1, e_2, t_2, ..., e_n, t_n)$."

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Possibility and probability

Probability

- ***Logical*** (*a priori*) → probability is a mathematical concept
- ***Subjective*** (*Bayesianism-ignorance*) → measure of the degree of belief of a rational agent
- ***Objective***
  - ***Frequentist*** → relative frequencies
  - ***Propensivist*** → measure of an objective tendency, propensity, potentiality, disposition

Possibility

- **Semantic**
- **Subjective**
- **Objective**
  - **Actualist**
  - **Possibilist**

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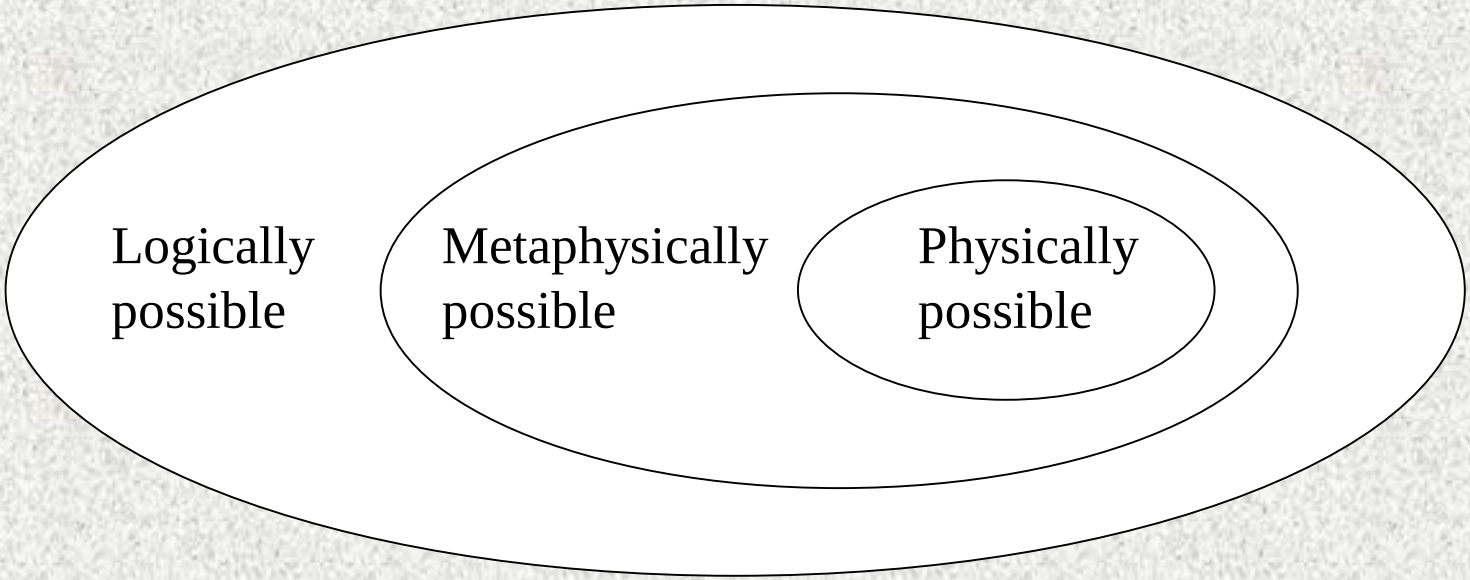
Possibility in physics

Objective possibility: What is not prevented from happening by X

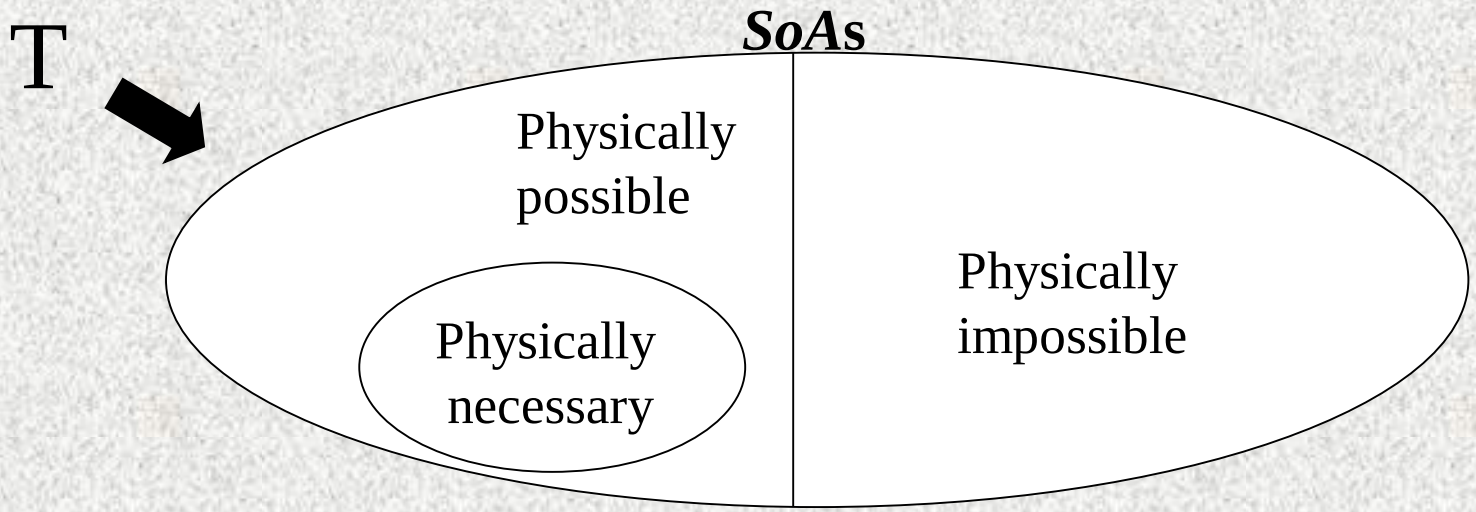
?



Possibility in physics

A state of affairs (*SoA*) is ***physically possible*** iff it is not prevented by a physical theory *T* from happening.

- A particle moves at a velocity $v>c$ → possible in CM
  → impossible in SR
- A photon moves at a velocity $v=c$ ⟶ necessary in QFT



Conditional possibility: $\Diamond(SoA_1/SoA_0)$.

Synchronic: Thermodynamics $PV/T=k$

- SoA_1 : "the gas has a pressure P_1 and a temperature T_1
- SoA_0 : "the gas is confined in a volume V_1

Possibility in physics

Conditional possibility: $\Diamond(SoA_1/SoA_0)$.

Diachronic: Classical physics

- SoA_1 : "the body is in state s_1 at time t_1
- SoA_0 : "the body is in state s_0 at time t_0

Determinism: $\Diamond(SoA_1/SoA_0)$, and also $\Box(SoA_1/SoA_0)$

Indeterminism: $\Diamond(SoA_1/SoA_0)$, but $\neg\,\Box(SoA_1/SoA_0)$

Actualism: given SoA_1 actual, the actualist cannot say if it is conditionally necessary or not

(reduction of indeterministic evolutions to underlying deterministic dynamics)

Probability in physics:

- It does not apply to necessary or impossible *SoA*s
- Reference class: possible but not necessary *SoA*s
  - *Pr*(*SoA*)=1 does not mean necessary
  - *Pr*(*SoA*)=0 does not mean impossible
- In general, probability conditional to another *SoA*

  (when all the probabilities are conditioned on the same *SoA*, conditionalization can be put into parenthesis)

Frequentism prevails over propensivism

(influence of logical positivism)

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Possibility in quantum mechanics

➔ **Copenhagen & GRW**: indeterminism, but probabilities always referred to measurements (frequentism)

➔ **Bohmian mechanics**: determinism and subjective probability

➔ **Many worlds**: determinism, actualist

➔ **QBism**: subjective probabilities

➔ **Wave function realism**: the wave function is a concrete field of matter

Subjective or Objective-actualist

Possibility in quantum mechanics

Challenge: interpretation based on an ***objective possibilist*** view of possibility and probability

- Given an observable, it has possible values:
  - only one is actual
  - the remaining may never become actual
- "Quantum state realism": $|\psi\rangle$ measures propensities as real as actualities
- Reality unfolds into two realms: possibility and actuality

  In Aristotelian terms: "being can be said in different ways: as possible being or as actual being"
- This explains how non-actual possibilities may have effects on actuality

  "Non-interacting experiments"

Possibility in quantum mechanics

There are at least two interpretations of QM of this sort:

- **The Modal-Hamiltonian Interpretation**
  (Olimpia Lombardi & Mario Castagnino)

- **The Transactional Interpretation**
  (Ruth Kastner, based on John Cramer)

Thank you!!!