Aesthetic dimension of physics

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Cartographies of sensation

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Abstract

Aesthetics as a sensual perception plays an important role in the construction of a physical theory and is not considered to be in contrast to mathematical rationalism.

On the basis of quantum theory the aesthetic dimension of physics will be demonstrated. In particular, it will be shown how the quantum states of modern quantum information, the entangled states of the observers Alice and Bob, can be illustrated in an abstract space which exhibits an amazingly simple and elegant geometry.

Aesthetic view

aesthetics as sensual perception

plays important role in construction of physical theory

representatives of view of aesthetics:

Einstein
Dirac
Feynman
Chandrasekhar
Penrose

"it's better to develop beautiful equations than just to adapt equations to experiment"

aesthetics

- no beautiful byproduct
- but essential part of scientific theory

Science – aesthetics

in science

- feeling for aesthetics "no science without beauty" similar to art
- connection between correctness – beauty

aesthetics

as sensual form of knowledge or cognition ⟺ awakening eros

creativity, inspiration

is not in contrast to rationality

or logical construction of theory

mathematical rationality per se

is highly aesthetic !

not just the abstract symbols

with their emotional content

mathematical construction

symbols

geometric illustration

Aesthetics in science

aesthetics in science

- **elegance** — in constructions, solutions, proofs
  don't construct an ugly theory,
  solutions & proofs beautiful, i.e. clever idea behind !
- **simplicity** — in description
  don't describe theory in complicated way,
  do it most simple !
- **economy** — theory concise, optimal
  theory must contain all elements – nothing is missing,
  but without unnecessary frills !
- **efficiency** — in reaching aim
  solutions must be found without detour – straightforward !

Quantum theory

quantum theory

highly aesthetic satisfying requirements for aesthetics

although not understood

from an “anschaulich” physical point of view

from everyday experiences

but as mathematical formalism – just perfect

in accordance with experiment

formalism is complete

there is no element of reality missing

theory

the more abstract – the more correct **! ?**

Schrödinger Equation

fundamental theory of quantum mechanics

Schrödinger equation

$$H\psi = i\hbar \frac{\partial}{\partial t}\psi$$ time dependent

$$H\psi = E\psi$$ stationary

E … total energy
- calculable
- to be compared with experiment

Hamilton operator

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

↑ kinetic ↑ potential energy

Δ … Laplace operator
double differentiation

Quantum state

$\psi_{(x)}$ **wavefunction**

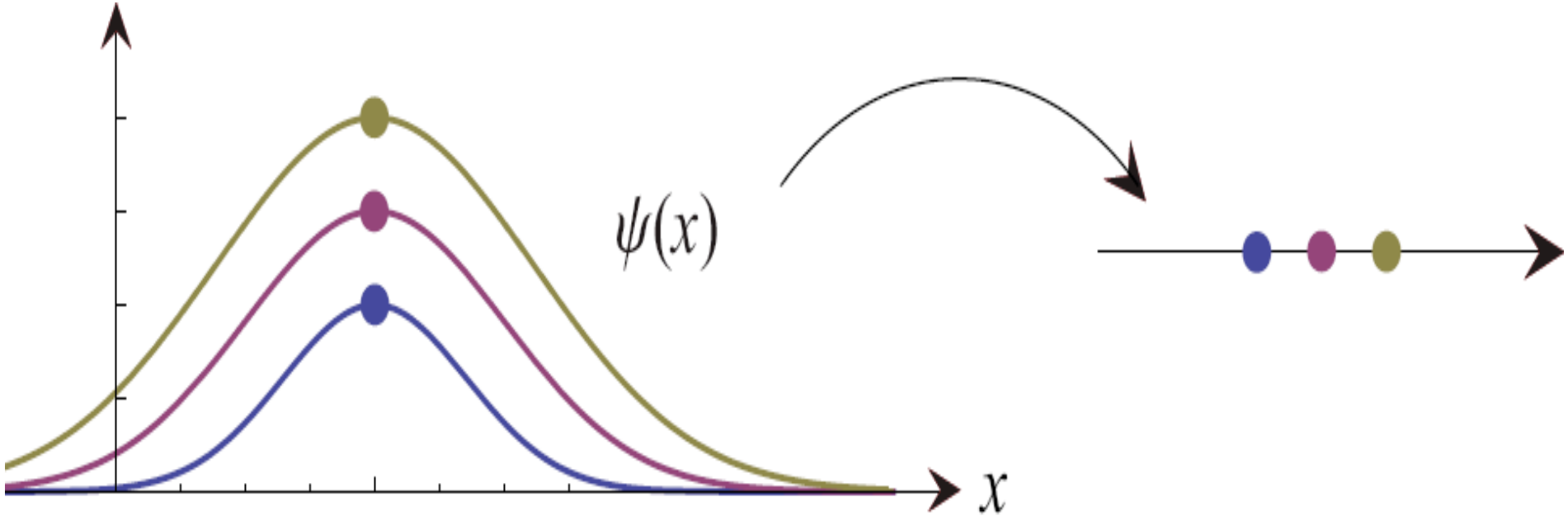
represents state of quantum system
contains all information about system

$\psi^* \psi$ probability for finding system in quantum state

$\psi^* H \psi$ expectation value for energy

States as points

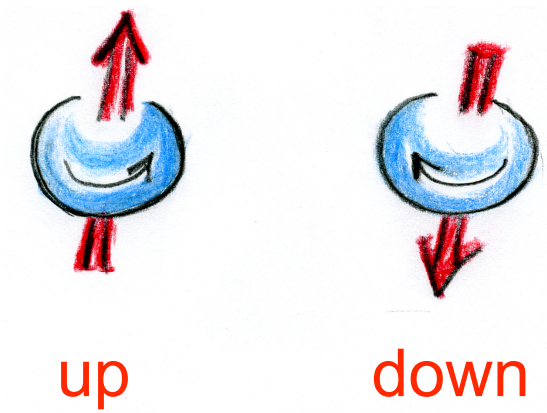
representation of state – wavefunction
as points in Hilbert space



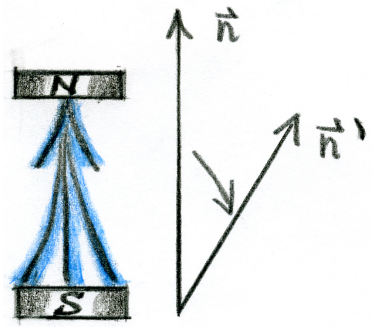
mapping of wavefunctions into points of a line, 1– dimensional space
or into points of 3– dimensional space (more general)

Spin

spin of particle



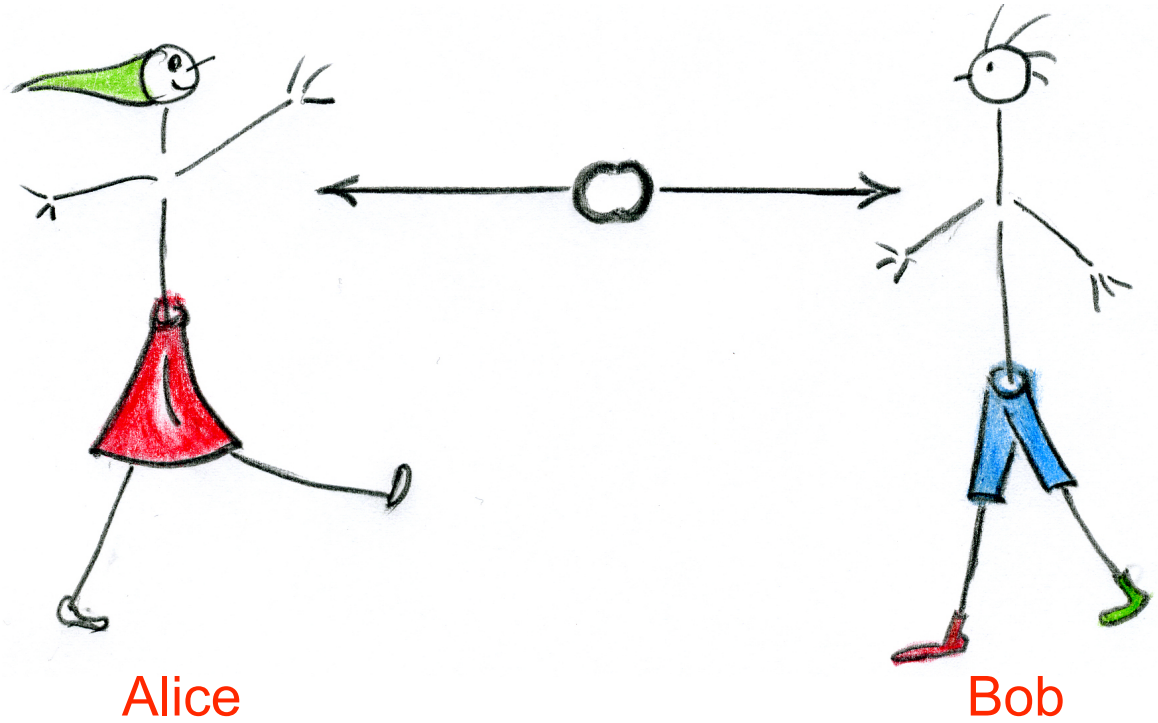
rotation
as classical analogue



spin measured by magnets
along 2 directions

Two particle quantum state

quantum state of 2 particles with spin



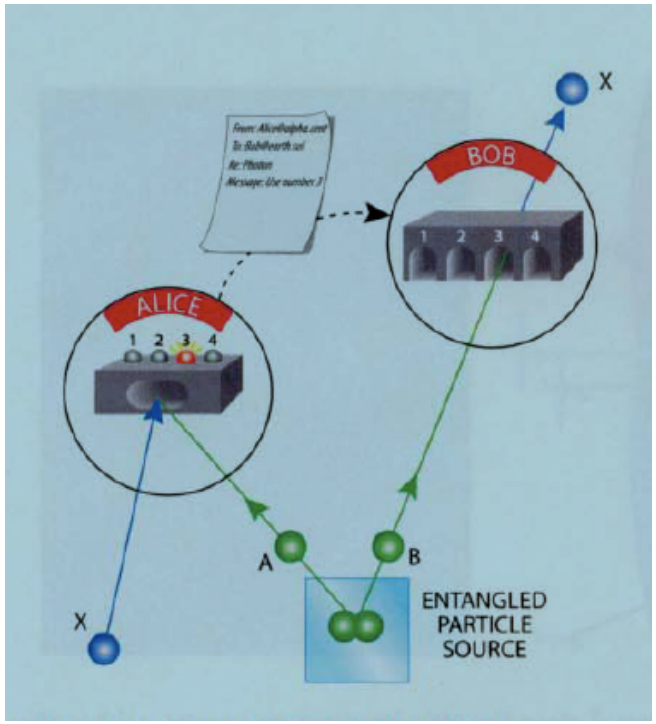
particles measured by Alice and Bob

Quantum information

quantum information & quantum communication

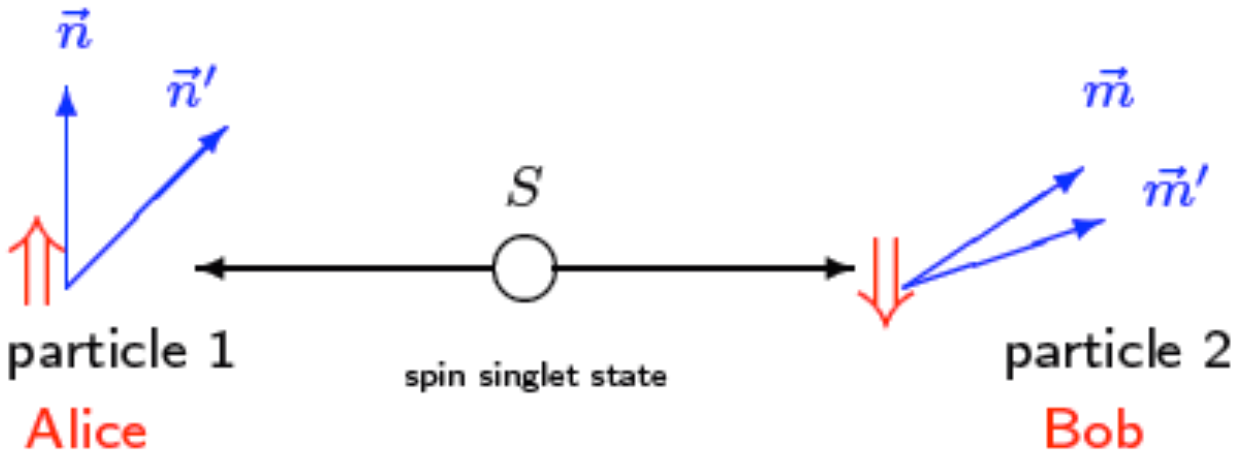
new kind of phenomena like
quantum teleportation

ingredient:
entangled quantum states



Entangled states

entangled states of quantum information



EPR-type experiment Einstein-Podolsky-Rosen

possible states:

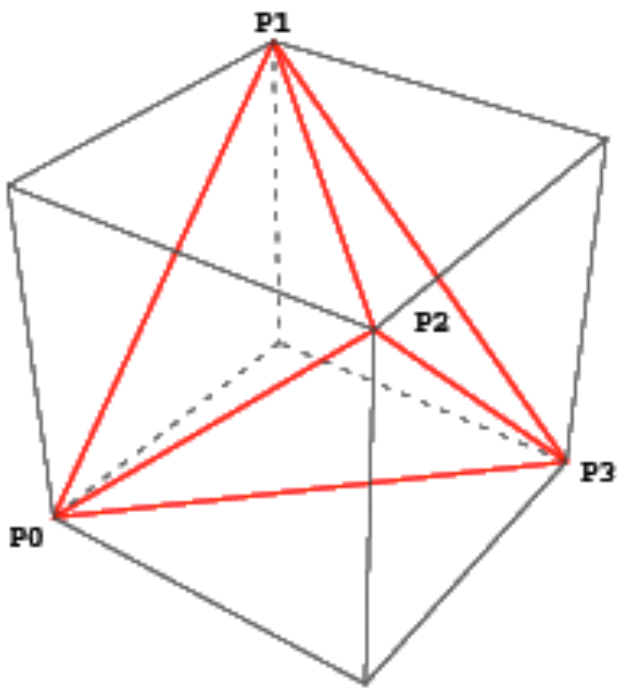
entangled	outcome of Alice influenced by Bob
separable	not influenced

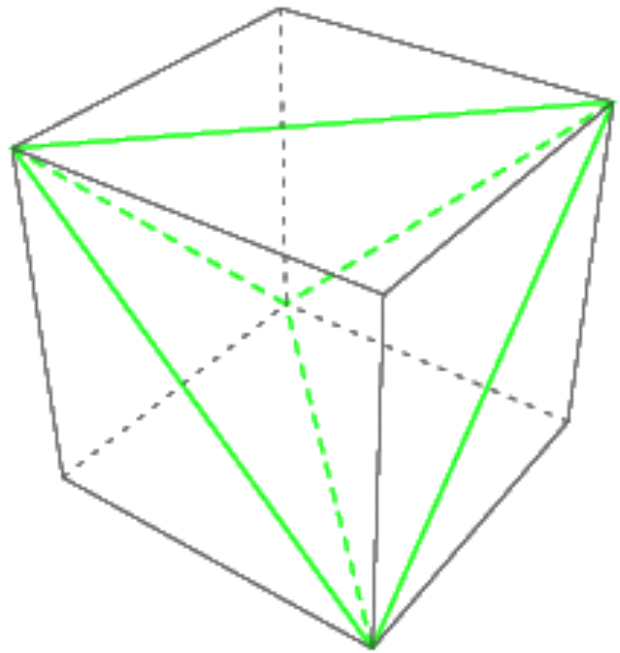
Illustration of geometry

geometry of space of quantum states

in 2x2 -1 = 3 dimensions

quantum states within tetrahedron

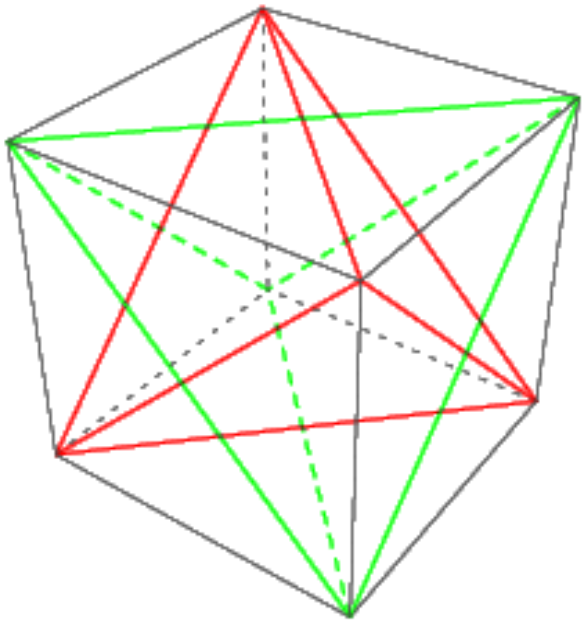


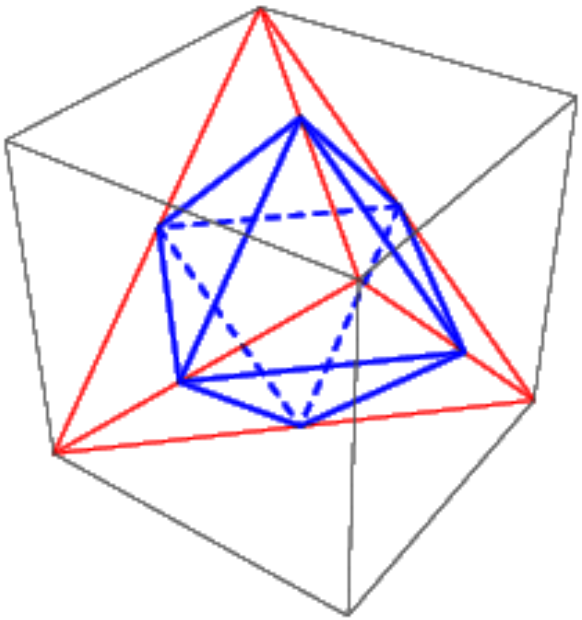


time reversal on one spin – Bob
separable states invariant

Geometry of quantum states

in 2x2 -1 = 3 dimensions





intersection of tetrahedrons → separable states – double pyramide

entangled states – outside

simple & elegant geometry !