PARADOXO EPR

Leonel Queimada e Nuno Santos

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Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. Einstein, B. Podolsky and N. Rosen, *Institute for Advanced Study, Princeton, New Jersey*

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In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In quantum mechanics in the case of two physical quantities described by non-commuting operators, the knowledge of one precludes the knowledge of the other. Then either (1) the description of reality given by the wave function in quantum mechanics is not complete or (2) these two quantities cannot have simultaneous reality. Consideration of the problem of making predictions concerning a system on the basis of measurements made on another system that had previously interacted with it leads to the result that if (1) is false then (2) is also false. One is thus led to conclude that the description of reality as given by a wave function is not complete.

Princípio da complementaridade de Bohr

> *[...] impossibility of any sharp separation between the behaviour of atomic objects and the interaction with the measuring instruments which serve to define the conditions under which the phenomena appear [...]*

REALIDADE VS. MODELO

Condição de completude
[...] every element of the physical reality must have a counterpart in the physical theory.

Critério de realidade
If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.

$$\left\{\begin{array}{l}\text{Condição de completude}\\ \text{Princípio da incerteza de Heisenberg}\\ \text{Realismo}\end{array}\right.$$

$$\downarrow$$

(1) A descrição dada pela função de onda é incompleta.

(2) Quando operadores correspondentes a duas quantidades físicas distintas não comutam, estas não têm realidade simultânea.

GRANDEZA FÍSICA A

$$\begin{array}{ccc} a_1 & \longrightarrow & u_1(x_1) \\ \vdots & & \vdots \\ a_n & \longrightarrow & u_n(x_1) \end{array}$$

$$\Psi(x_1,\, x_2) = \sum_{n=1}^{\infty} \psi_n(x_2)\, u_n(x_1)$$

$$\downarrow$$

$$a_k : u_k(x_1),\, \psi_k(x_2)$$

GRANDEZA FÍSICA B

$$\begin{array}{ccc} b_1 & \longrightarrow & v_1(x_1) \\ \vdots & & \vdots \\ b_n & \longrightarrow & v_n(x_1) \end{array}$$

$$\Psi(x_1,\, x_2) = \sum_{n=1}^{\infty} \varphi_n(x_2)\, v_n(x_1)$$

$$\downarrow$$

$$b_r : v_r(x_1),\, \varphi_r(x_2)$$

As funções $\psi_k(x_2)$ e $\varphi_r(x_2)$ referem-se à mesma realidade – o sistema II. Em certos casos, estas funções podem ser funções próprias de operadores que não comutam.

Ou seja, é possível, sem perturbar o sistema II, determinar duas grandezas a ele associadas correspondentes a operadores que não comutam entre si.

$$\downarrow$$

PARADOXO