

A NOVEL BELT MODEL OF THE ATOM, COMPATIBLE WITH QUANTUM DYNAMICS

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ABSTRACT

Here we provide a novel atomic, paraxial model in which a single belt of electrons surrounds the nucleus. The electronic belt is depicted in terms of broken lines and split wavy trajectories that intersect an axis, giving rise to small angles that can be accurately calculated. We demonstrate that the probabilistic electronic cloud of the atom described by quantum mechanics can be depicted in terms of an electronic belt, because its sizes closely match the descriptions given by de Broglie and Heisenberg. In touch with the claims of the two latter Authors, the wavy trajectories around the nucleus come back to a starting point, so that their orbits are stationary.

Keywords: geometry; nucleus; electron; trajectories; geometrization of physics.

For descriptive purposes, the models of atoms [1 – 3] and molecules are generally represented as spheres. Thomson [12] was the first to provide, in 1904, an atomic model in terms of the motion of a ring of negatively-charged particles inside a uniformly electrified sphere. Another atomic nuclear model, in which an atom consists of a nucleus and electron shells, was then proposed by Rutherford in 1911 [13]. A geometric planetary model of the atomic structure was offered in the form of circle orbits of electrons around a nucleus by Bohr in 1922 [14], and in the form of elliptic orbits by Sommerfeld [1]. Here we propose a novel atomic model described on a two-dimensional manifold that can be generalized in terms of a three-dimensional spherical model.

Concerning the geometrical size [2] of the first atomic shell, the Bohr radius R_B is approximately:

$$R_B \approx 5,3 * 10^{-11} \text{ [m]}. \quad (1)$$

The speed v of the movement of an electron [3] on such first circular orbit is:

$$v \approx 0.0073c \approx 2,2 * 10^6 \left[\frac{\text{m}}{\text{s}} \right]. \quad (2)$$

The wavelength of this electron [3], in agreement with de Broglie's formula, is:

$$\lambda_e = \frac{2\pi\hbar}{m_e v} \approx 3,1 * 10^{-10} \text{ [m]}, \quad (3)$$

where Plank constant is $\hbar \approx 1,05 * 10^{-34} \text{ [J * s]}$ and the mass of an electron is $m_e \approx 9,1 * 10^{-31} \text{ kg}$.

The power of levels, that in Bohr's theory depends on the term n , are defined by the formula [2]:

$$E_n = -\frac{m_e e^4 Z^2}{2\hbar^2 n^2} \sim \frac{1}{n^2}, \quad (4)$$

where the main quantum number is $n = 1, 2, 3, \dots$, e is a charge of an electron and Z is the atomic serial number.

De Broglie, due to his interpretation of the quantization rule in case of one-electron atom, took into account the phase wave running around an atomic nucleus on a circular orbit of an electron [3]. *If, in an orbit wavelength, λ_e keeps within an integer number of times, then the wave surrounding the nucleus will come back every time to a starting point equipped with the same phase and amplitude. In this case, the orbit turns out to be stationary.* De Broglie wrote down the formula of an orbit's stationarity, or the rule of quantization:

$$\frac{2\pi R}{\lambda_e} = n, \quad (5)$$

where R is the radius of a circular orbit and n is an integer which stands for the main quantum number.

For an orbit of Bohr's radius of $R = R_B$ and $n = 1$, the expression (5) will turn out to be:

$$\frac{2\pi R_B}{\lambda_e} = 1, \quad (6)$$

where

$$\lambda_e = 2\pi R_B. \quad (7)$$

The atomic nucleus' radius is accurately defined by the formula [3, 4]:

$$r = 1,3 \cdot 10^{-15} A^{1/3} \text{ [m]}, \quad (8)$$

where A is the number of nucleons in a nucleus. Thus:

$$R \gg r. \quad (9)$$

In our previous binomial atomic model [5], we provided a novel framework termed the *one belt model of the atom*. In [6], we described the required relationships among trajectories, angles and the four quantum numbers, demonstrating that our geometrical model does not contradict the Pauli principle. Further geometrical properties of this model were described in earlier works [7, 8]. In [5], a geometrical explanation of the splitting of atomic spectrum was provided. In [9], the possibility to transfer such geometric model to biology was suggested. The paper [5] also provides images of various trajectories, illustrating how they match the known models of electronic clouds in an atom [1]. The geometrical interpretation of particles' trajectories with integer and half-integer spin values has been separately given in [10], where attention was called to the ancient atomists Epicurus and Lucretius. This approach differs from Ishkhanov [4], who referred just to the ancient atomist Democritus.

In the present work, we build our model on the basis of both the de Broglie's hypothesis of the wave nature of particles [1-3] and the Heisenberg's uncertainty relation [1-3]. Our model displays a circular scale that is stretched six times, compared with the different treatment provided in [5, 9]. As well as in the previous works, we give a geometrical atomic description by using simple tools, such as compasses, a ruler and the same paraxial approach widely used for the calculation of optical instruments. Also, our model does not contradict the probabilistic approaches of quantum theory [1-3]: indeed, the binomial distribution that stands for the main tenet of the probability theory [11], is also the cornerstone of our model [5].

The one belt model is nuclear, but not planetary. Nevertheless, it is possible to draw an analogy with our solar system, but without planets. Our model predicts one nucleus in the center of the atom (similar to the Sun), surrounded by an electronic belt (similar to a belt of asteroids between Mars and Jupiter).

The projection of our model to the drawing plane is provided in **Figure 1**. The general view of the belt model is represented in **Figure 1a**; a wavy trajectory for the first electronic orbit ($n = 1, K - shell$) is displayed in **Figure 1b**; the same trajectory extended in a horizontal tape is depicted in **Figure 1c**.

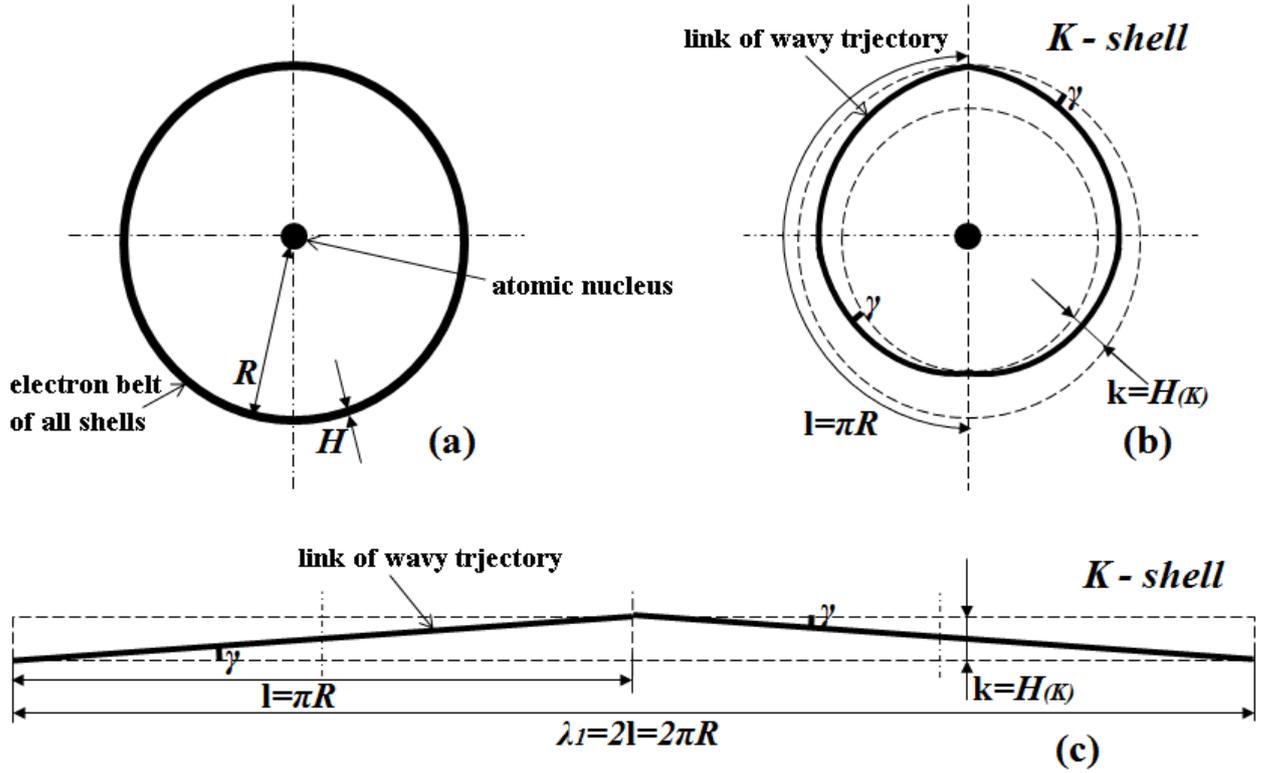


Figure 1. Belt model of the atom. The plane of the drawing provides a general view of the projection displayed in (a). A wavy trajectory is illustrated in terms of curves (similar to the curves shown in [9]) of the first orbit (b). Note that the radial scale is here increased, compared with the picture (a); furthermore, the wavy trajectory is located in a concentric coordinate grid with cells of $l = \pi R$ length along a circle and a radial height of $k = H_{(K)}$. The same trajectory described in (b) can be displayed on a horizontal tape (c); in this case, the wavy trajectory is located in a rectangular coordinate grid with cells length of $l = \pi R$ and shells height of $k = H_{(K)}$.

In our model, the electronic belt displays thickness H and is located at R distance from the nucleus. We assume that:

$$R \gg H. \quad (10)$$

In our paraxial approach, we also assume that the speed of the movement of all the electrons on the orbits is identical according to the formula (2), and the length of the shortest wavy trajectory λ_1 equals the electron wavelength for the first electronic orbit ($n = 1, K - shell$):

$$\lambda_1 = \lambda_e \quad (11)$$

according to the formula (3).

Generally, the electronic belt consists of several (up to eight [6]) electron shells termed K, L, M , etc., where $H_{(K)}, H_{(L)}, H_{(M)} \dots$ stand for the shells' thickness. The trajectories displayed by these shells settle down in every layer, as shown in [6]. Therefore, we will consider that all the shells are located within a thin electronic belt, where H is the belt thickness.

Our model consists of wavy trajectories. *In our paraxial model, we assume that wavy trajectories going around a nucleus come back to a given starting point, so that the orbits are stationary in touch with the de Broglie's assumption given above.* These trajectories have the appearance of cycles in homology theory, each with its own homology group [15-16].

In **Figure 2**, a pattern similar to **Figure 1a** is provided. In a reduced scale, projections to the drawing plane for $K - shell$ (a), $L - shell$ (b), $M - shell$ (c), and $N - shell$ (d) are provided.

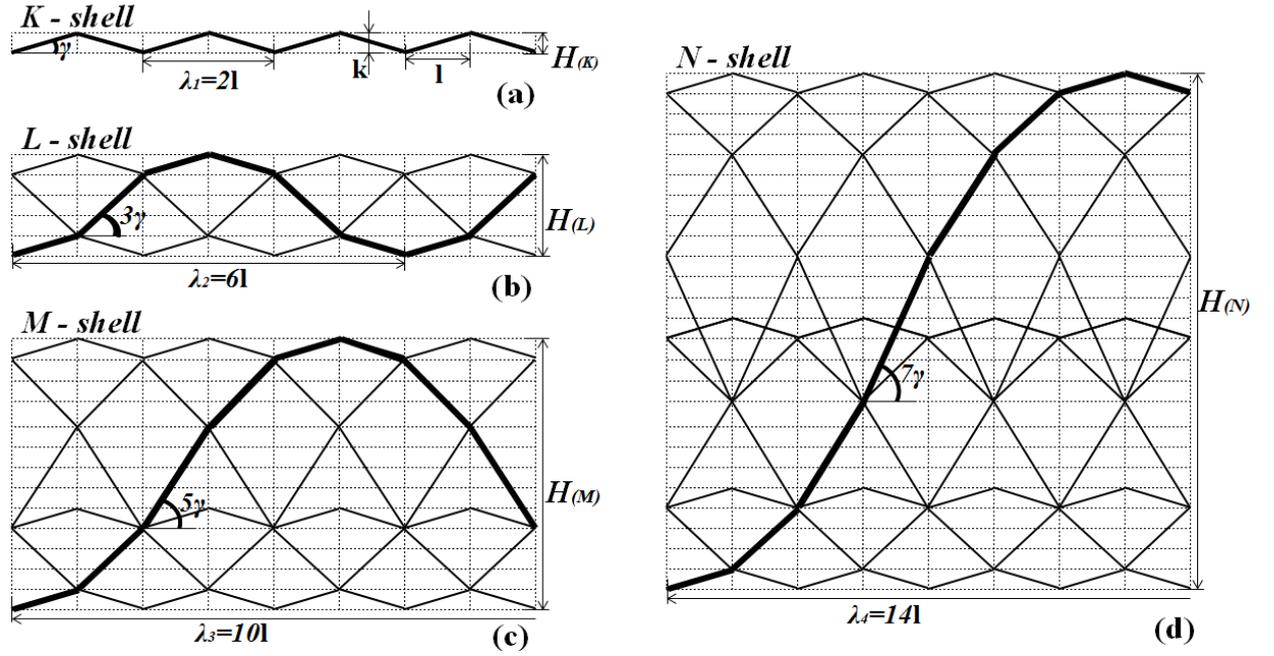


Figure 2. The first four shells of the atom. The thick lines depict wavy trajectories with a length of “waves” of λ_1 (a), λ_2 (b), λ_3 (c), λ_4 (d) of λ_{max} .

From **Figure 2**, some conclusions can be drawn:

- The *K – shell* contains only one wavy trajectory with a length of “wave” $\lambda_1 = \lambda_{max} = 2l$, an height $v_1 = v_{max} = k = H_{(K)}$, and an angle p of inclination $p_1 = p_{max} = \gamma$.
- The *L – shell* contains two types of wavy trajectories with lengths of “waves” $\lambda_1 = 2l$ and $\lambda_2 = \lambda_{max} = 6l$, height $v_1 = k$ and $v_2 = v_{max} = 5k = H_{(L)}$ and angles $p_1 = \gamma$, $p_2 = p_{max} = 3\gamma$.
- The *M – shell* contains three types of wavy trajectories with lengths of “waves” $\lambda_1 = 2l$, $\lambda_2 = 6l$ and $\lambda_3 = 10l = \lambda_{max}$, height $v_1 = k$, $v_2 = 5k$, $v_3 = 13k = H_{(M)}$ and angles $p_1 = \gamma$, $p_2 = 3\gamma$, $p_3 = p_{max} = 5\gamma$, etc.

The length of wavy trajectories [6] depends on the number n and grows linearly:

$$\lambda_n = 2(2n - 1)l \sim n. \quad (12)$$

The height of wavy trajectories and the thickness of a belt of electrons depend on the number n and grows quadratically:

$$v_n = (2n^2 - 2n + 1)k \approx H(n) \sim n^2 \sim \lambda_n^2. \quad (13)$$

This corresponds, in Bohr’s theory, to the square dependence of the distance from a nucleus to the orbits of an hydrogen atom [1].

The tilt angle of the links that gives rise to trajectories depends on the number n and grows linearly:

$$p_n = (2n - 1)\gamma \sim n \sim \lambda_n. \quad (14)$$

If we take into account that the greatest number of shells in atom does not exceed the number of eight [6], then for the eighth shell (for *R – shell*) we will have:

$$\lambda_{max} = 30l, \quad (15)$$

$$v_{max} = 113k, \quad (16)$$

$$p_{max} = 15\gamma. \quad (17)$$

It is feasible to assume that, at further increases in the specified parameters characterizing an electronic belt, the system of trajectories goes beyond small angles, and the paraxial model won’t take place. *In this case, our wavy*

trajectories around a nucleus won't come back to a starting point and the orbits won't be any more stationary. Therefore, the atom becomes unstable.

As showed by our geometrical constructions and numerical calculations in [5, 6], the stationary distribution of energy among the trajectories' links gives rise to a dependence similar to the formula (4):

$$E_n \sim -\frac{1}{n^2}. \quad (18)$$

We are also allowed to write down the approximate dependence between the size of an atomic nucleus (8) and the elements of atomic shells:

$$p_n \sim \lambda_n \sim v_n^{1/2} \sim r. \quad (19)$$

The uncertainty of a coordinate Δx and an impulse Δp of a micro-particle is defined by Heisenberg's relation:

$$\Delta x * \Delta p \gtrsim 2\pi\hbar. \quad (20)$$

The coordinates uncertainty of an interatomic electron [1] is commensurable with the atomic sizes and, more precisely, with the size of the first (Bohr's) orbit:

$$\Delta x \approx 10^{-10} \text{ [m]}. \quad (21)$$

The probability to find an electron near a Bohr's orbit is defined by expression (21). We assume that the thickness of an electronic belt in our model is:

$$H \approx \Delta x \approx 10^{-10} \text{ [m]}. \quad (22)$$

According to the formulas (13), (16) and (22), the height of a cell (**Figures 1, 2**) of a coordinate grid in which the trajectories are placed will be:

$$k \approx H/100 \approx 10^{-12} \text{ [m]}. \quad (23)$$

Because $\lambda_1 = 2l$ (**Figures 1, 2**) therefore, due to (1) and (11), the length of a cell (**Figures 1, 2**) of a coordinate grid in which the trajectories are placed will be:

$$l = \pi R_B \approx 10^{-10} \text{ [m]}. \quad (24)$$

In view of (23), the angle

$$\gamma \approx k/l \approx 10^{-2} \text{ [rad]}. \quad (25)$$

Then, a change of the values (23–25) in (12–14) allows the numerical estimation of the other elements of our model.

In sum, through a simple geometrical construction achieved with compasses, a ruler and a paraxial approach, it is feasible to build a belt model of the atom with short height and long wavy trajectories (in comparison with the atomic radius) around the nucleus. In this paper, we limited ourselves to project our system of trajectories to the two-dimensional plane of the drawing. However, also three-dimensional pictures could be easily built: they would look like a thin (in paraxial approach) disk, or an almost flat toroidal shape with a nucleus in the center of this sphere.

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