Weber's Planetary Model of the Atom

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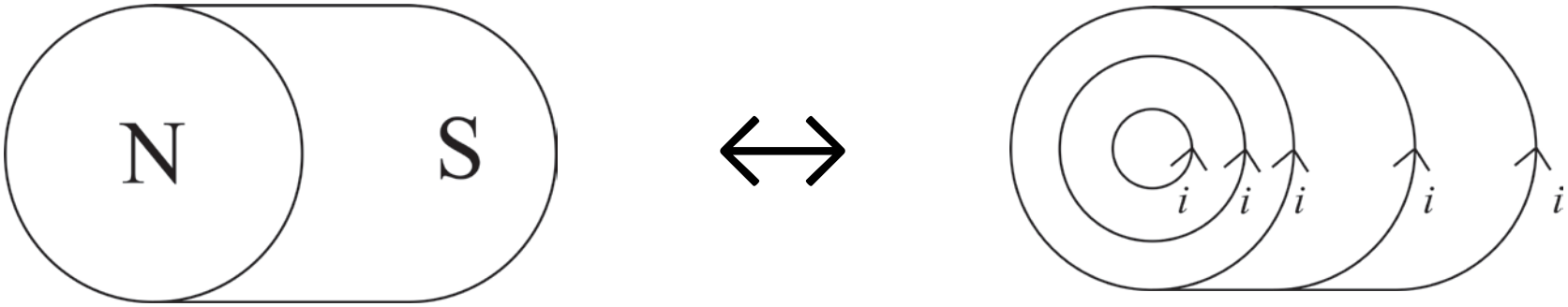
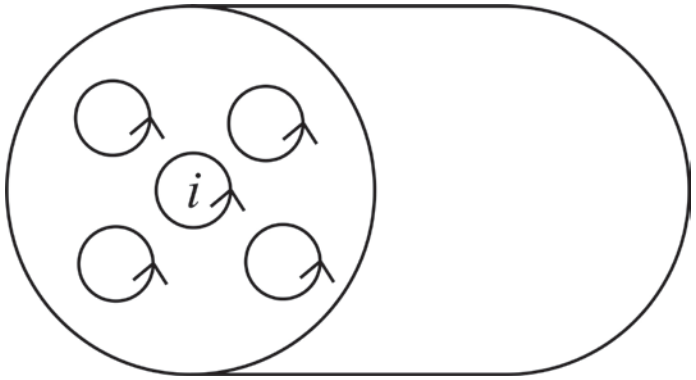
Ampère's supposed in 1820 the existence of permanent electric currents flowing inside magnets and inside the Earth in order to explain their magnetic properties.
Initially he assumed the existence of macroscopic currents describing concentric circles around the North-South axes of these bodies:



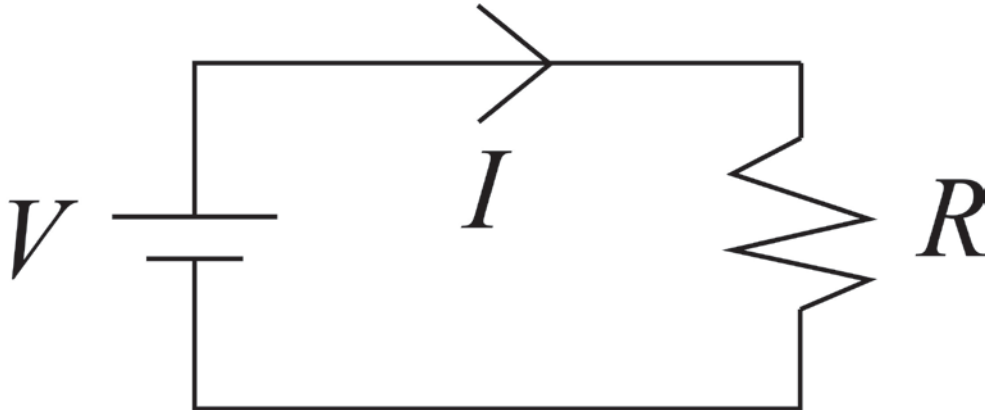
Fresnel suggested in 1821 to replace these macroscopic currents by microscopic or molecular currents flowing around each iron particle of the magnet:



Ampère accepted this suggestion.

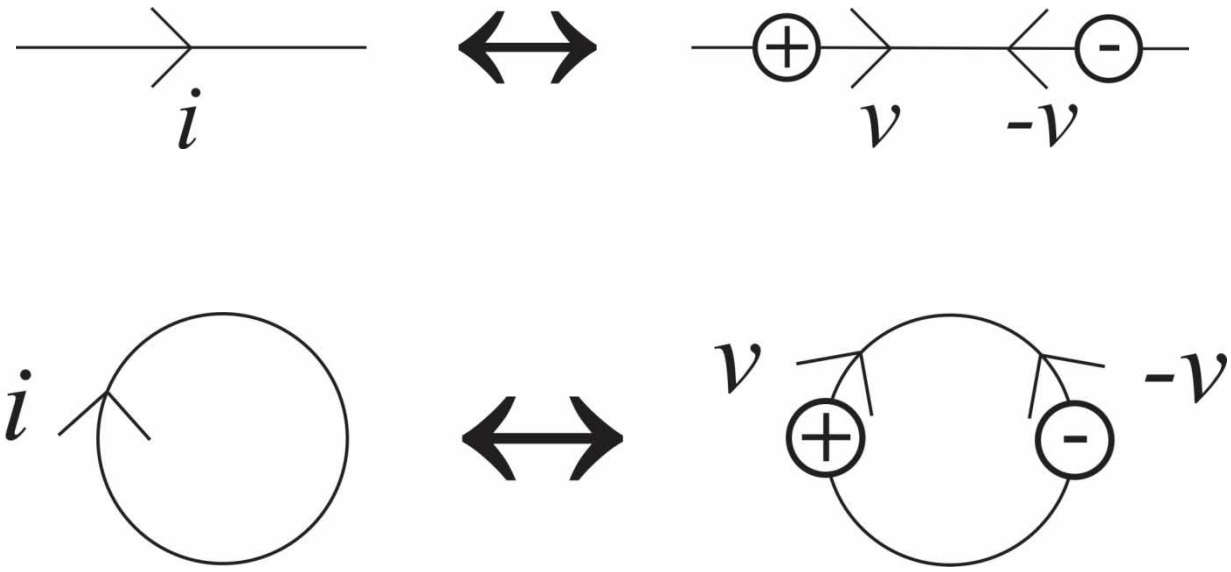
In 1826 Ohm published his law relating the voltage *V* of a battery with the current *I* flowing through a circuit with resistance *R*:

$$V = R\,I$$



Therefore, to have a steady current *I* in a resistive circuit, we need an external source of voltage *V*.

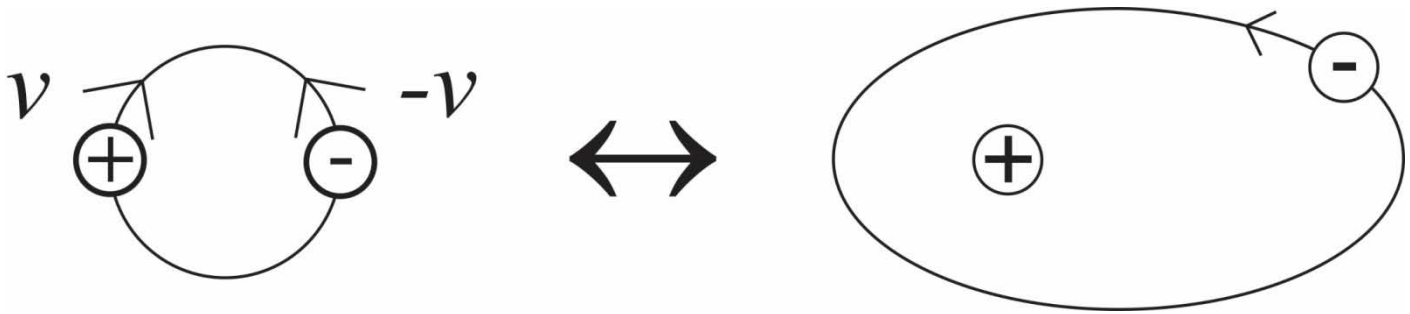
Oersted (1820), Ampère (1820-26) and Weber (around 1846) believed that an electric current was due to a double flow of charges. That is, positive charges moving relative to the wire along the direction of the current, together with an equal amount of negative charges moving in the opposite direction:



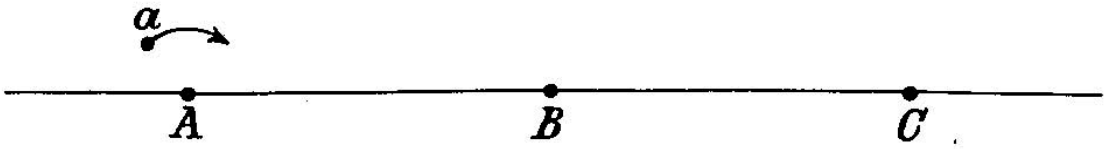
Weber believed that the resistance of metals was due to the collision of positive and negative charges moving in opposite directions inside a current carrying conductor.

This supposition created a problem for Ampère's molecular currents. How to explain the existence of permanent microscopic currents without the existence of a microscopic voltage source, as required by Ohm's law?

In 1852, in order to solve this problem, Weber disintegrated Ampère's microscopic rings into a system of electrical negative satellites moving in elliptical orbits around stationary positive particles. It was like replacing the rings of Saturn by the satellites of Jupiter. With this assumption, there would be no collisions between opposite charges. Therefore, these microscopic currents might be maintained indefinitely without any source of external voltage.



Weber's drawing and words in 1852 considering a negative charged particle ***a*** following an elliptical orbit around a positive ponderable electrical mass ***A*** fixed in the metal lattice:



"Therefore, the mass in *a* will describe, for example, an elliptical orbit according to Kepler's laws."

This supposition is at the origin of Weber's planetary model of the atom.

Weber also changed his initial conception of macroscopic currents. Initially he assumed a double current of positive and negative charges moving in opposite direction. Now he assumed that in the usual circuits the positive charges would be fixed in the metal lattice, and only negative particles would move.

In 1846 Weber presented his law expressing the force between two particles of charges q1 and q2.

$$\vec{F} = \frac{q_1 q_2}{4\pi\varepsilon_0}\frac{\hat{r}}{r^2}\left(1 - \frac{\dot{r}^2}{2c^2} + \frac{r\,\ddot{r}}{c^2}\right)$$

$$\dot{r} = \frac{dr}{dt}, \quad \ddot{r} = \frac{d^2 r}{dt^2}, \quad c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3\times 10^8\, m/s$$

In 1864 he was the first scientist to introduce explicitly the inertial masses m1 and m2 to his electrified particles. He was also the first person who tried to measure the ratio q/m.

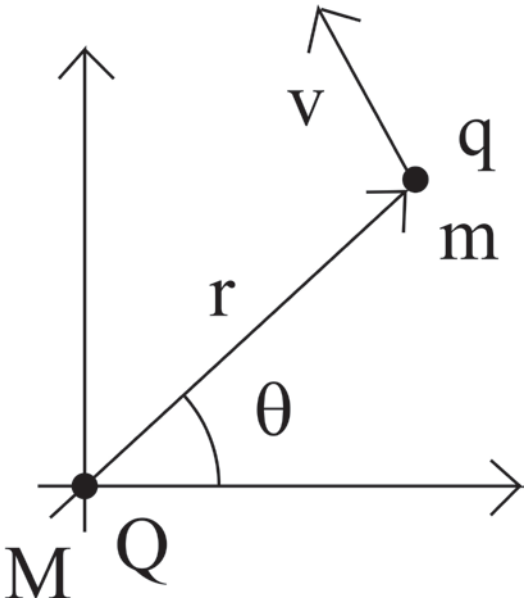
In 1871 he solved approximately the two body problem with his force law. The properties of this solution led to his mature planetary model of the atom.

Some scientists who solved the two-body problem according to Weber's law applied to electrodynamics and gravitation:

- Weber (1846-1871).
- Seegers (1864): Über die Bewegung und die Störungen der Planeten, wenn dieselben sich nach dem Weberschen elektrodynamischen Gesetz um die Sonne bewegen.
- Tisserand (1872 and 1896): Sur le mouvement des planètes autour du Soleil, d'aprés la loi électrodynamique de Weber.
- Zöllner (1872 and 1876): Principien einer elektrodynamischen Theorie der Materie.
- Lolling (1882): Ueber Bewegungen elektrischer Theilchen nach dem Weber'schen Grundgesetz der Elektrodynamik.
- Servus (1885): Untersuchungen über die Bahn und die Störungen der Himmelskörper mit Zugrundelegung des Weber'schen electrodynamischen Gesetzes.
- Schrödinger (1925): The possibility of fulfillment of the relativity requirement in classical mechanics.
- Assis and Clemente (1991 and 1992): Two-body problem for Weber-like interactions.

Two-body problem for Weber' force law.

a) Particles with charges of opposite sign: $qQ < 0$.



Central force: conservation of angular momentum.

$$L = mr^2 \frac{d\theta}{dt} = \text{constant}$$

Weber's law also complies with conservation of energy: the sum of the kinetic and potential energies is constant in time.

$$E = K + U = \frac{m}{2}\left(\dot{r}^2 + r^2\dot{\theta}^2\right) + \frac{qQ}{4\pi\,\varepsilon_o}\frac{1}{r}\left(1 - \frac{\dot{r}^2}{2c^2}\right) = \text{constant}$$

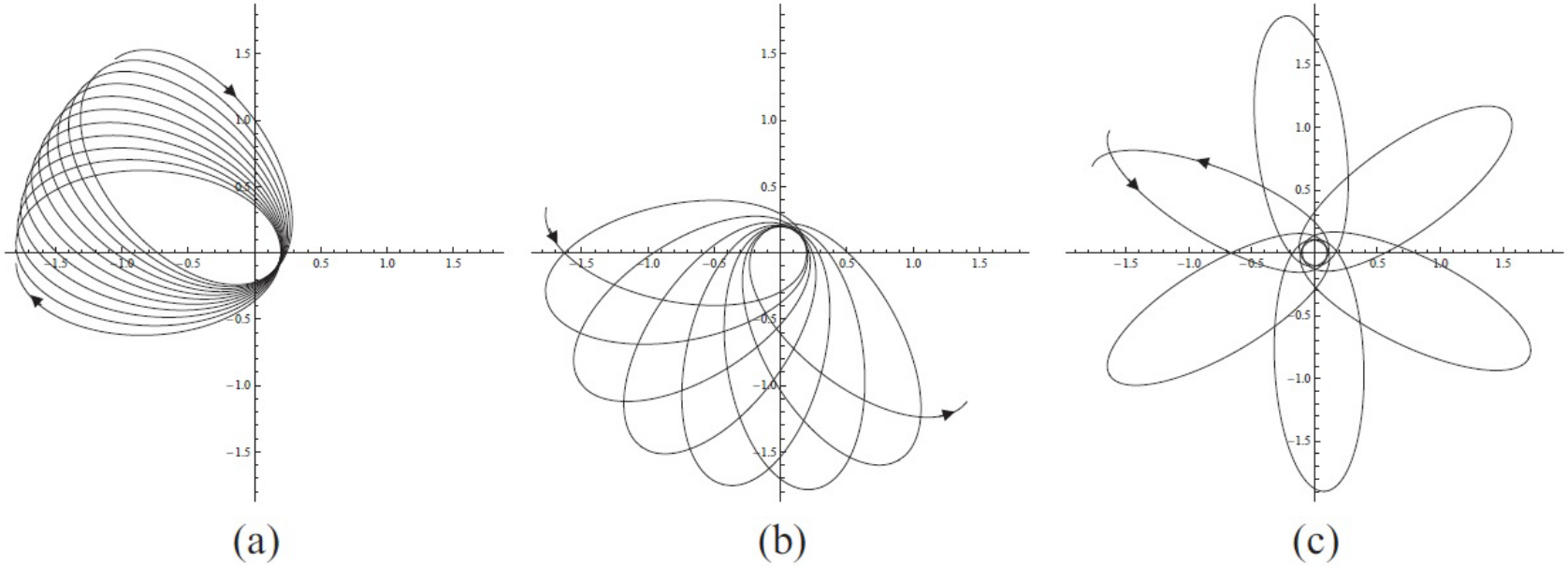
There is a general solution of this equation in terms of the incomplete elliptic integral of the second kind:

$$\theta = \pm 2 x_A E\left(\phi, k\right)$$

$$x_{A,B}^2 = 1 + \left(\frac{qQ}{4\pi\varepsilon_o}\right)^2 \frac{1}{L^2c^2}\left[1 \pm \sqrt{\frac{2EL^2}{m\left(qQ/4\pi\varepsilon_o\right)^2}}\right]$$

$$\phi = \arcsin\sqrt{\frac{x_A^2 - x^2}{x_A^2 - x_B^2}} \qquad k = \sqrt{\frac{x_A^2 - x_B^2}{x_A^2}} \qquad x^2 = 1 - \frac{qQ}{4\pi\varepsilon_o}\frac{1}{mc^2 r}$$

This solution yields a precession of the perihelion:



We now consider the two-body problem for Weber' force law when the particles have charges of the same sign, $q1q2 > 0$.

This case presents the main difference not only with classical electrodynamics (Coulomb's force) but also with modern physics (quantum mechanics and nuclear physics).

Weber's planetary model of the atom (1870-1880):

$$\frac{q_1 q_2}{4\pi\varepsilon_0}\frac{1}{r^2}\left(1-\frac{\dot{r}^2}{2c^2}+\frac{r\,\ddot{r}}{c^2}\right)\approx q_1 E + m_W a_1 = m_1 a_1$$

$$q_1 E = (m_1 - m_W)\,a_1 \qquad \text{where} \qquad m_W = \frac{q_1 q_2}{4\pi\varepsilon_0 c^2}\frac{1}{r}$$

$$m_1 = m_W \qquad \text{when} \qquad r = \frac{\mu_0}{4\pi}\frac{q_1 q_2}{m_1} = r_C$$

Therefore, for q1q2 > 0 we have r_c > 0.
Moreover, if r < r_C then m1 – m_W < 0.

The particles will behave as if they had a **negative** inertial mass.
Therefore, two particles of the same sign will attract one another, instead of repelling each other!!!

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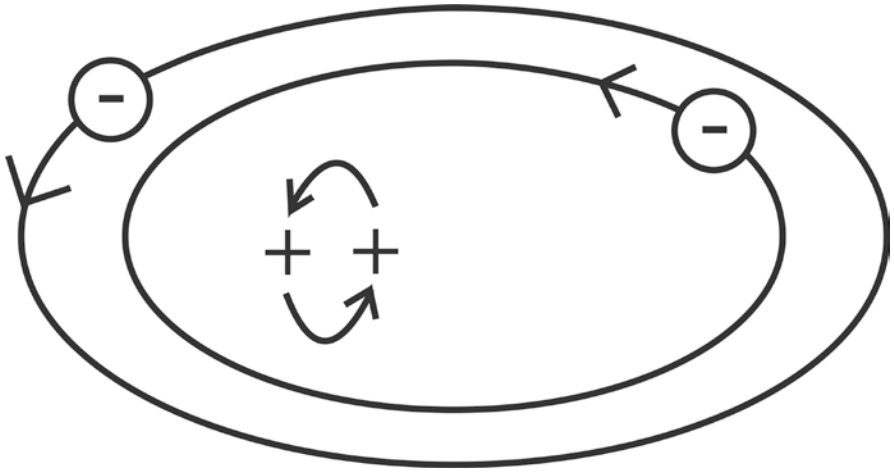
This property gave rise to Weber's remarkable planetary model of the atom:



Weber wrote in the beginning of the 1880's his eighth and last major memoir on Electrodynamic Measurements. It was published posthmously in 1894. It contains his mature planetary model of the atom.

Particles of the same sign would attract one another when they were separated by distances smaller than his "critical or molecular distance" r_C. They would be in "molecular motions". These particles would form "indissoluble molecules". He characterized them in a beautiful way by saying that this group formed an enclosed world for itself, due to the fact that the internal force connecting the group would be so great that it would be extremely difficult to break it apart due to external influences. His words:

"Not only 2 or 3, but a far larger number of similar electrical particles could be together in such a small space, without the distance of any particle from another being greater than or equal to r_C, so that all of these particles together, also form an indissoluble molecule which remains together for ever."

"Each such composite molecule forms an enclosed world for itself."

Optical properties of Weber's planetary model of the atom:

Already in 1862 Weber believed that the wavelengths of emitted light might yield the key to obtain information about the structure of the molecular currents inside the atom:

"Therefore, if the supposed relation between electrical molecular currents and the light ether are corroborated, then it would be possible to obtain from optical experiments a better information about the behavior of the electricity generating a molecular current."

In 1876 Zöllner reversed this reasoning. He predicted that it might be possible to utilize the internal properties of a planetary model in order to derive the spectral lines of the chemical elements! Quotation:

"The laws developed by Weber about the oscillations of an atomic pair will probably lead to an analytical determination of the number and position of the spectral lines of the chemical elements and their connections with the atomic weights."

These words were presented decades before Bohr's model of the atom in 1913!

In 1869 Mendleev published his periodic table of the elements.

$$\begin{bmatrix} +1 \\ -1 \end{bmatrix}$$

In the 1880's Weber tried to explain qualitatively the properties of the elements of the periodic table utilizing his planetary model of the atom. He also tried to explain the chemical bondings between atoms. At the right we have some of his models of the atom:

$$\begin{bmatrix} -2 \\ +1 \\ +1 \end{bmatrix} \quad \begin{bmatrix} +2 \\ -2 \end{bmatrix} \quad \begin{bmatrix} +2 \\ -1 \\ -1 \end{bmatrix} \quad \begin{bmatrix} +1 \\ +1 \\ -1 \\ -1 \end{bmatrix}$$

The modern atom with a nucleous composed of *n* protons surrounded by *n* electrons describing elliptical orbits around the nucleous corresponds approximately to the following Weberian "ponderable molecule":

$$\begin{bmatrix} +n \\ -1 \\ \cdots \\ -1 \end{bmatrix}$$

This Weberian atom has *n* particles of charge +q and mass M attracting each other and moving relative to one another inside a volume of diameter r_C. This positive nucleous is surrounded by *n* particles of charge –q and mass m describing elliptical orbits around the nucleous.

Remarkable properties of Weber's planetary model of the atom:

• Weber's **prediction** (1870-1880) was made before the discovery of the electron (1897), of Balmer's spectral series (1897) and of Rutherford's scattering experiments (1911)! Bohr's model (1913), on the other hand, was **created (invented)** in order to be compatible with these experimental findings.

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• Weber presented a formula for his critical distance r_c below which two charges of the same sign would attract one another. But he could not calculate its value as the electrons and positrons (1932) were unknown. When we utilize the modern values of the mass and charge of two positrons, we obtain that they will attract each other when **r_c < 10^{-15} m**. Therefore Weber's model gives a **justification** for the known size of the atomic nuclei!

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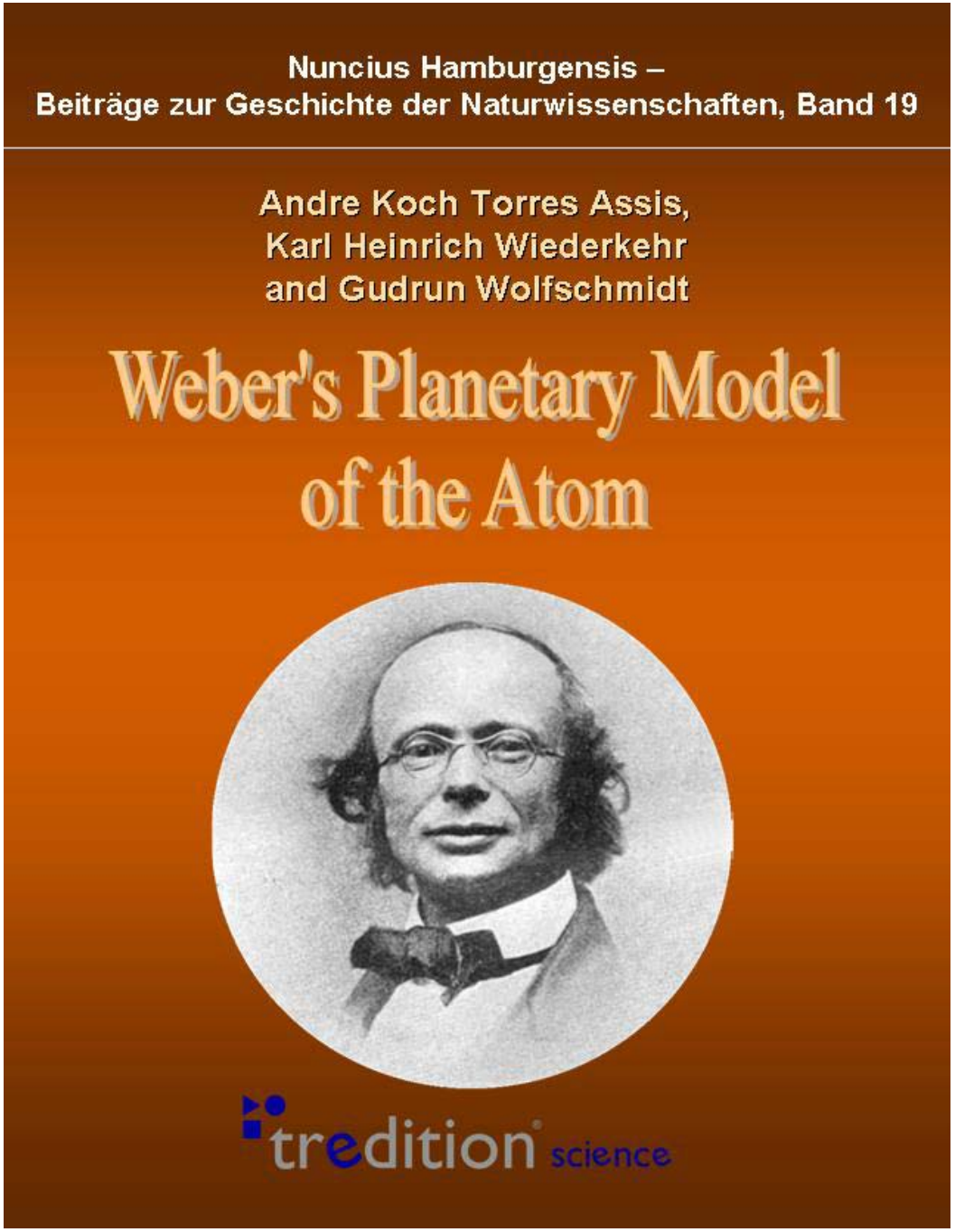
• In modern physics it is necessary to **postulate** the existence of nuclear forces in order to stabilize the positively charged nucleous against Coulomb's repulsive forces. Weber's model, on the other hand, offers an **unification** of electromagnetism with nuclear physics, as the nucleus is held together by purely electrodynamic forces!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Karl Heinrich Wiederkehr
and Gudrun Wolfschmidt
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2011

My next project:

To publish an English translation of Weber's main works on electrodynamics.

I am looking for volunteers willing to translate any of the articles.

Conclusion

Weber's planetary model of the atom is fascinating.

It may represent the essence of the correct explanation of the constitution of real atoms based only on classical electrodynamics!

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