GYROSCOPIC BEHAVIOR OF TOROIDAL FRACTAL PROTONS IN NMR

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Abstract: *We tried to explain the basic principle of nuclear magnetic resonance without a virtual magnetic dipole. We used the vortex-ring-fractal structures of the basic particles with their vortex electromagnetic fields.*

Keywords: *toroidal proton, vortex-fractal ring theory, spin, magnetic resonance imaging, gyromagnetic ratio, precession, Larmor frequency .*

1 Introduction

Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body. MRI is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. MRI started out as a tomographic imaging technique, that is it produced an image of the NMR signal in a thin slice through the human body.

Magnetic resonance imaging is based on the absorption and emission of energy in the radio frequency range of the electromagnetic spectrum. The human body is primarily fat and water. Fat and water have many hydrogen atoms which make the human body approximately 63% hydrogen atoms. Hydrogen nuclei have an NMR signal. For these reasons magnetic resonance imaging primarily images the NMR signal from the hydrogen nuclei comprised of a single proton. The proton possesses a property called spin which will cause the nucleus to produce an NMR signal.

2 Spin

Spin is a fundamental property of nature like electrical charge or mass. Spin comes in multiples of 1/2 and can be + or -. Protons, electrons, and neutrons possess spin. Individual unpaired electrons, protons, and neutrons each possesses a spin of 1/2.

In the deuterium atom (2H), with one unpaired electron, one unpaired proton, and one unpaired neutron, the total electronic spin = 1/2 and the total nuclear net spin = 1.

In the next figures are shown ring (torus) structures of hydrogen and deuterium atoms with the levitating electron [1-5].

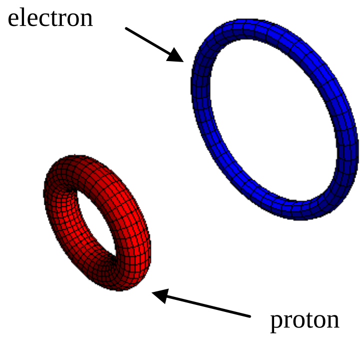

Fig.1 Structure of hydrogen atom

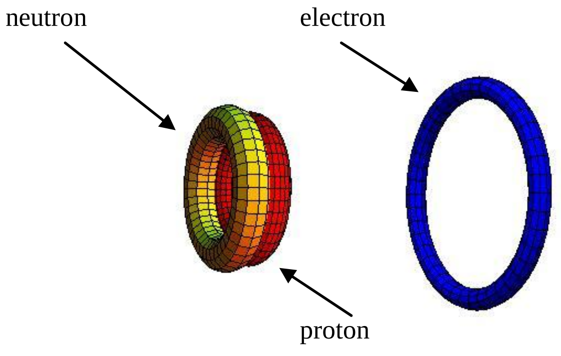

Fig.2 Structure of deuterium atom

Two or more particles with spins having opposite signs can pair up to eliminate the observable manifestations of spin. An example is helium. In nuclear magnetic resonance, it is unpaired nuclear spins that are of importance.

Nuclei are composed of positively charged protons and uncharged neutrons held together by nuclear forces. Both protons and neutrons have approximately the same mass, which is about 1840 times as large as the mass of an electron. Neutrons and protons are referred as nucleons.

The electron can undergo a transition between the two energy states by the absorption of a photon. A particle in the lower energy state absorbs a photon and ends up in the upper energy state. The energy of this photon must exactly match the energy difference between the two states. The energy, E, of a photon is related to its frequency, ν, by Planck's constant (h = 6.626x10-34 J s).

$$E = h\nu \qquad (1)$$

In NMR and MRI, the quantity ν is called the resonance frequency and the Larmor frequency.

When proton is placed in a magnetic field of strength B, a particle with a net spin can absorb a photon, of frequency ν. The frequency ν depends on the gyromagnetic ratio, γ of the particle.

$$\nu = \gamma B \qquad (2)$$

For hydrogen, γ = 42.58 MHz / T.

NMR can only be performed on isotopes whose natural abundance is high enough to be detected, however some of the nuclei are of interest in MRI are listed below.

Table 1: Suitable atoms for MRI

Nuclei	**Unpaired Protons**	**Unpaired Neutrons**	**Net Spin**	**γ(MHz/T)**
^{1}H	1	0	1/2	42.58
^{2}H	1	1	1	6.54
^{31}P	1	0	1/2	17.25
^{23}Na	1	2	3/2	11.27
^{14}N	1	1	1	3.08
^{13}C	0	1	1/2	10.71
^{19}F	1	0	1/2	40.08

The energy of the two spin states can be represented by an energy level diagram. We have seen that $\nu = \gamma B$ and $E = h\nu$, therefore the energy of the photon needed to cause a transition between the two spin states is:

$$E = h\gamma B \qquad (3)$$

When the energy of the photon matches the energy difference between the two spin states absorption of energy occurs.

In the NMR experiment, the frequency of the photon is in the radio frequency (RF) range. In NMR spectroscopy, ν is between 60 and 800 MHz for hydrogen nuclei. In clinical MRI, ν is typically between 15 and 80 MHz for hydrogen imaging

Angular velocity of precession for classical (Newtonian) gyroscope is given by:

$$\boldsymbol{\omega}_p = \frac{mgr}{I_s\boldsymbol{\omega}_s} \qquad (4)$$

In which I_s is the moment of inertia, $\boldsymbol{\omega}_s$ is the angular velocity of spin about the spin axis, and *m*g* and *r* are the force responsible for the torque and the perpendicular distance of the spin axis about the axis of precession. The torque vector originates at the center of mass.

3 Precession and nutation

Precession is a change in the orientation of the rotation axis of a rotating body. It can be defined as a change in direction of the rotation axis in which the second Euler angle (nutation) is constant. In physics, there are two types of precession: torque-free and torque-induced.

Torque-free precession occurs when the axis of rotation differs slightly from an axis about which the object can rotate stably: a maximum or minimum principal axis.

Torque-induced precession (gyroscopic precession) is the phenomenon in which the axis of a spinning object (e.g., a part of a gyroscope) "wobbles" when a torque is applied to it, which causes a distribution of force around the acted axis. The phenomenon is commonly seen in a spinning toy top, but all rotating objects can undergo precession. If the speed of the rotation and the magnitude of the torque are constant, the axis will describe a cone, its movement at any instant being at right angles to the direction of the torque. In the case of a toy top, if the axis is not perfectly vertical, the torque is applied by the force of gravity tending to tip it over.

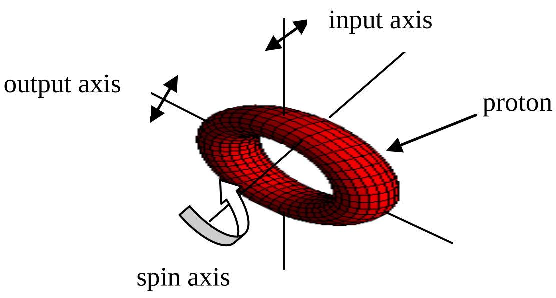

Fig.3 Behavior of gyroscope

Behavior of a gyro wheel (proton) is shown on Fig.3. Reaction arrows about the output axis correspond to forces applied about the input axis, and vice versa.

Nutation (from Latin: nūtāre, to nod) is a rocking, swaying, or nodding motion in the axis of rotation of a largely axially symmetric object, such as a gyroscope, planet, or bullet in flight, or as an intended behavior of a mechanism. A pure nutation is a movement of a rotational axis such that the first Euler angle (precession) is constant.

4 Model of hydrogen with a levitating electron

The new model of the hydrogen atom with a levitating electron was introduced in [2,3]. There is attractive (electric) force F+ and (magnetic) repellent force F- :

$$F = F_+ - F_- = \frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d^2} - \frac{d_o^2}{d^4}\right) \tag{9}$$

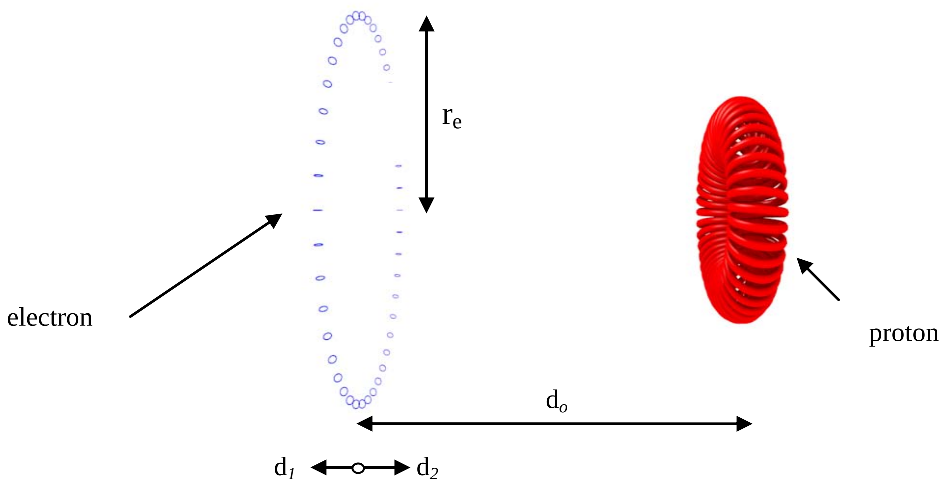

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Fig.4. The levitating electron in the field of the proton (the fractal structure model of hydrogen H is simplified)

The hydrogen atom can have the electron on left side or on right side. The attractive force F+ is Coulomb's force. The repellent force F- is caused with magnetic fields of the proton and the electron. A distance between the electron and the proton in (9) is d. The electron levitates around d_o with end points d_1 and d_2. The energy E_i required to remove the electron from the ground state to a state of zero total energy is called ionization energy. The energy of the hydrogen atom in the ground state is $E = -13.6\ eV$. The negative sign indicates that the electron is bound to the nucleus and the energy 13.6 eV must be provided from outside to remove the electron from the atom. Hence 13.6 eV is ionization energy E_i for hydrogen atom. Calculation of ionization energy from (9) was introduced in [2]:

$$E = -E_i = -\frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d} - \frac{d_o^2}{3d^3}\right) = -\frac{e^2}{4\pi\varepsilon_o}\frac{1}{d}\left(1 - \frac{d_o^2}{3d^2}\right) \tag{10}$$

The quantum number n that labels the electron radii r_{en} also labels the energy levels. The lowest energy level or energy state, characterized by $n=1$, is called the ground state. This state is described in equations (9) and (10). Higher energy levels with $n>1$ are called excited states. For excited states we presuppose following equations (11) and (12) [4]:

$$F_n = F_+ - F_- = \frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d^2} - \frac{n^2 d_{on}}{d^4}\right) = \frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d^2} - \frac{n^4 d_o^2}{d^4}\right) = \frac{e^2}{4\pi\varepsilon_o}\frac{1}{d^2}\left(1 - \frac{n^4 d_o^2}{d^2}\right) \tag{11}$$

$$E_n = -E_{in} = -\frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d} - \frac{n^2 d_{on}}{3d^3}\right) = -\frac{e^2}{4\pi\varepsilon_o}\left(\frac{1}{d} - \frac{n^4 d_o^2}{3d^3}\right) = -\frac{e^2}{4\pi\varepsilon_o}\frac{1}{d}\left(1 - \frac{n^4 d_o^2}{3d^2}\right) \tag{12}$$

where

$$d_{on} = n^2 d_o \tag{13}$$

To calculate quantum model of hydrogen we use radius r_e of the electron, which was derived in [1]:

$$r_e = \frac{\mu_o e^2}{4m_e}\frac{v_o^2}{v_e^2} \tag{14}$$

for

$$v_o = \frac{c}{\sqrt{2\pi}} \qquad v_o^2 = \frac{c^2}{2\pi} = \frac{1}{2\pi\varepsilon_o\mu_o} \tag{15}$$

$$r_e = \frac{\mu_o e^2}{4m_e}\cdot\frac{v_o^2}{v_e^2} = \frac{\mu_o e^2}{4m_e}\cdot\frac{c^2}{2\pi\mu_o\varepsilon_0 v_e^2} = \frac{e^2}{8\pi\varepsilon_0 m_e}\cdot\frac{1}{v_e^2} \tag{16}$$

$$d_o = \frac{\varepsilon_o h^2}{\pi m_e e^2} \approx 5.29\cdot 10^{-11} m \tag{17}$$

$$d_{on} = n^2\frac{\varepsilon_o h^2}{\pi m_e e^2} = n^2 d_o \tag{18}$$

$$r_{en} = \frac{1}{2}n^2\frac{\varepsilon_o h^2}{\pi m_e e^2} = \frac{1}{2}n^2 d_o \tag{19}$$

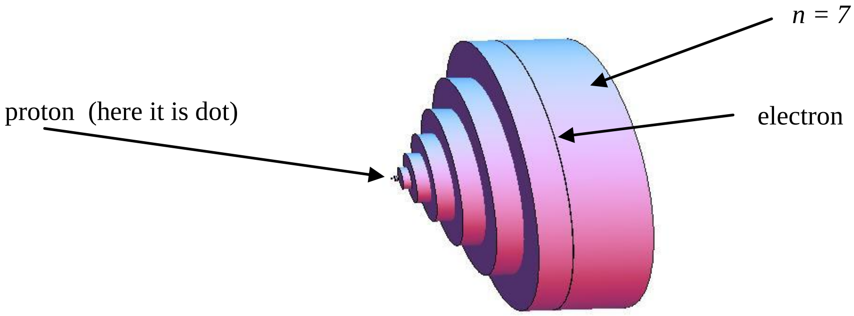


Fig. 5. The position and size of the electron depending on quantum number n

5 Ring structure of the water molecule

The ring structure of water consists from ring structure of the oxygen and two atoms of hydrogen that are held with the covalent bond.

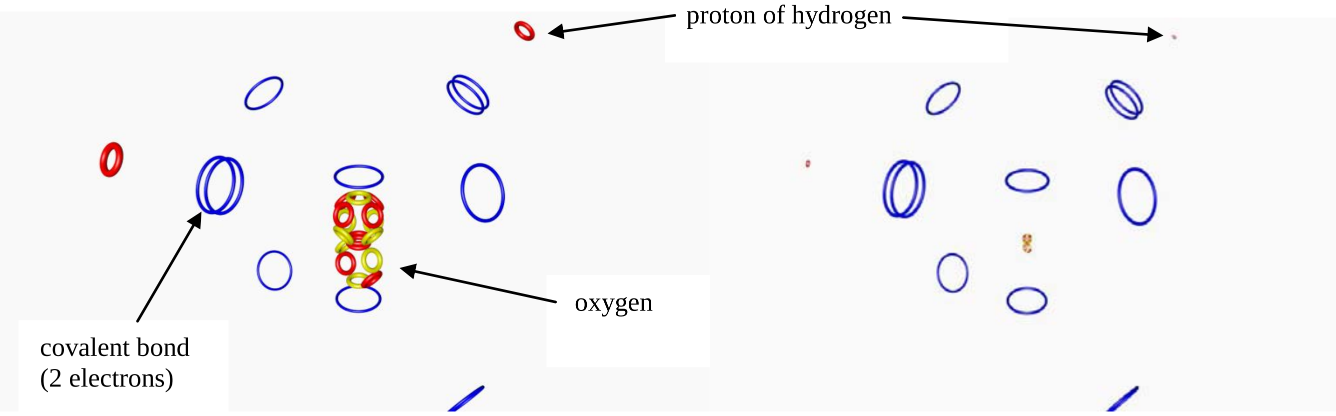


Fig.6. The structure of water (nucleus of oxygen and hydrogen is enlarged)

Fig.7 The structure of water in more real scale

6 Magnetic field of proton and its magnetic momentum

The proton is surrounded with magnetic lines that have the same axis of rotation. The density and the influence of this magnetic lines is decreasing very quickly with the radius r [$1/d^4$ in (11)]. It means that magnetic field is concentrated in near neighborhood around the proton with effective distance r_{ef} and with an effective magnetic field of strength B_{ef} (see Fig.9). The vector of magnetic moment $\boldsymbol{M_{mg}}$ can be express as:

$$\vec{M}_{mg} \approx \vec{B}_{ef} \times \vec{r}_{ef} \tag{20}$$

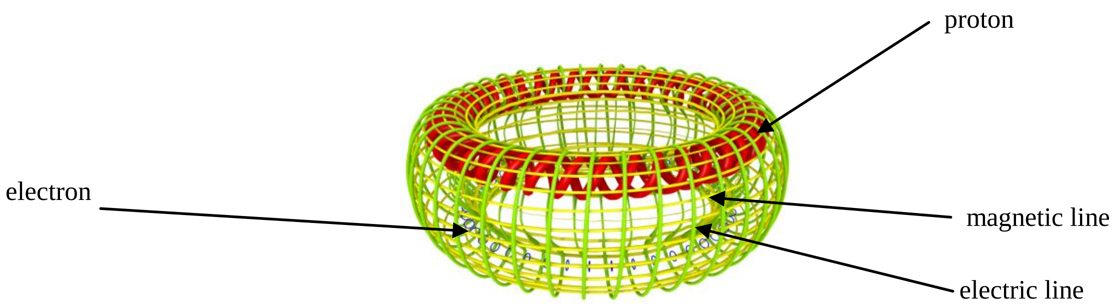
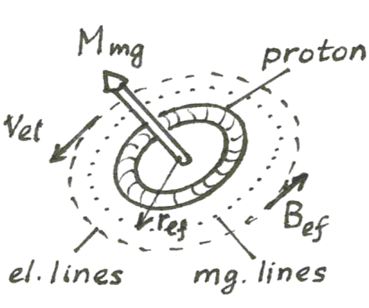


Fig.8 Structure of the hydrogen atom with electromagnetic field
(The proton is highly increased to see the structures)



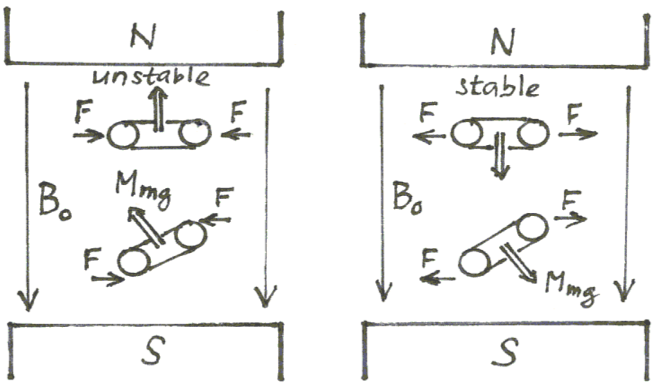


Fig.9 Magnetic moment of the proton

Fig.10 The protons inside magnetic field of the permanent magnet

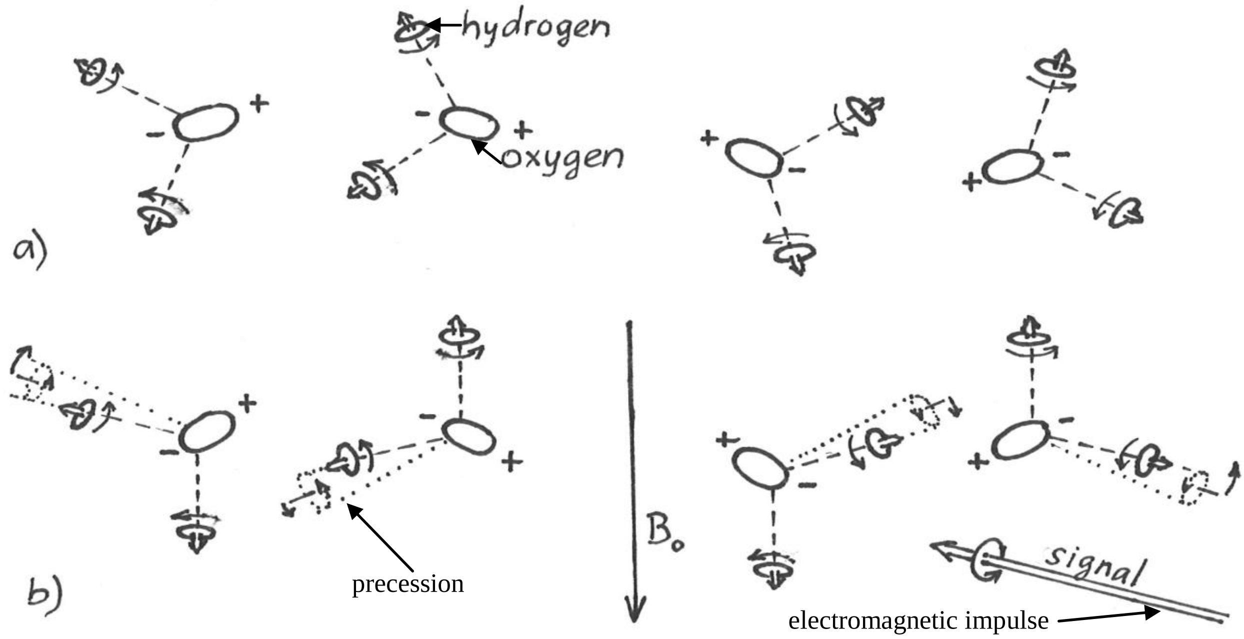


Fig.11 Gyroscopic behavior of the protons in water molecules
a) without outer magnetic field
b) in the magnetic field of the magnet

$$\vec{F}_{mg} \approx \vec{M}_{mg} \times \vec{B}_o \quad (21)$$

$$\vec{F} \approx \vec{v}_{el} \times \vec{B}_o \quad (22)$$

where F_{mg} is a force that translates the proton and F is a force that turns the proton, v_{el} is velocity of electric lines which are parallel with magnetic lines of the proton (see Fig.9 and Fig.10). Those electric lines have not influence on the charge of the proton and they can receive energy of the electromagnetic signal with Larmor frequency. It is the new speculative explanation of basic principle NMR. On Fig.11 is shown the influence of magnetic field of the permanent magnet on the change of position of protons in the water molecules. Some protons are fixed in the direction of outer magnetic field. Other protons are turned and increase their precession (see Fig. 11b).

7 Conclusion

In the future there will be necessary to continue in more precise calculation of gyro-magnetic behavior of the proton. It can better explain basic principle of NMR and then we can find new approaches how to increase the quality of MRI. Theoretically, we can expect further significant qualitative improvement in the onset of new technology, called "electron-nuclear double resonance", which advantageously exploits the fact that the spin of electrons is related to the nuclear spin based on dipole principle. This fact, using electron-nuclear Overhauser effect can bring up multiple increase in MR signal intensity and thus the sensitivity of the whole method.

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