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Fluid Mechanics at Atomic Scale

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Abstract

In this paper, following results obtained at cosmological scale, we tried to use fluid mechanics concepts at atomic scale. A model based on mixing systems mechanics was developed in order to calculate an electron rotational speed. Space-time transport properties i.e., density and dynamic viscosity were needed and their values were carefully chosen in literature. Moreover, we found that gravity acceleration at atomic scale has to be largely greater than the well known Newtonian value. Final results gave a rotational speed in fair agreement with Bohr model value for hydrogen atom indicating that, a fluid mechanics based approach, could be useful in building a physics model available whatever the scale and a quantum gravity theory.

Keywords: Gravity; Energy; Density; Mixing; Kinematic viscosity; Nano scale; Quantum gravity

Introduction

Recent works, Padmanabhan [1] and Delplace [2,3], showed that fluid mechanics could be a promising way to describe physics of very large scale phenomena. Indeed, these authors studied Einstein General Relativity equations available in cosmology and they obtained strong similarities with well known Navier-Stokes equations describing Newtonian fluids flows. In these approaches, Einstein space-time was considered as a liquid having classical transport properties i.e., density and dynamic viscosity.

In the same time, Netchitailo [4,5] developed an approach based on a "medium of the world" called World Universal Medium (WUM) made of elementary particles. Even if this approach is not continuum media physics, results and calculations performed gave energy densities or pressures well in agreement with Delplace [2] values at both astronomic and atomic scales. For example, energy density produced in space-time by a proton or by a neutron star (a macro-object) is in the order of 10^{35} J.m^{-3}. These results showed that coherent values can be obtained at very low (atomic) and very large (astronomic) scales.

Energy density or pressure or stress is a well known quantity in fluid mechanics and it is involved in both General Relativity and Navier-Stokes equations. Moreover, Delplace showed in a recent paper [3] that the rate of strain tensor of fluid mechanics can be related to Einstein tensor giving local space-time curvature. This important result gave a relationship between shear rate, space-time curvature and transport properties combined in kinematic viscosity. All these results seem to confirm a strong link between gravity and hydrodynamics introduced by Padmanabhan [1] and Delplace [3].

The main objective of this paper is then to try to demonstrate that fluid mechanics equations could be available at atomic scale and then could be a promising way to unify large and low scales physics.

In the first part of the article, we will show how an electrons rotational speed could be calculated using fluid mechanics equations. Even if quantum mechanics description of atoms is not today in agreement with the old Bohr atomic model, rotational speed value found by Niels Bohr for hydrogen is always a reference and we will compare it with value obtained through our fluid mechanics approach.

In a second chapter, we will discuss values of transport properties we need to calculate an electron rotational speed. Moreover, following equations obtained in the first part, we will have to introduce and discuss a value of gravity acceleration at atomic scale. In the highly curved space-time found at this scale and caused by huge energy densities [2,4,5], Newtonian gravity constant value G =6.67384 × 10^{-11} m^3.s^{-2}.kg^{-1} will have to be modified.

Finally, we will perform calculations for four atoms chosen in periodic classification: hydrogen (H), aluminium (Al), argon (Ar) and uranium (U). Results obtained will be discussed and interpreted to show their consequences for both physics and chemistry.

A Fluid Mechanics Model at Atomic Scale

As reported by Delplace [2], an average energy density value $\overline{T}$ (J.m^{-3}) can be calculated at atomic scale using the following relationship:

$$\overline{T} = \frac{3c^2}{4\pi R}.\frac{Zm_e + Zm_p + Nm_n}{R_a^2} \quad (1)$$

In this equation, c (m.s^{-1}) is the light velocity, Z is the number of protons or electrons, N is the number of neutrons, m_e, m_p, and m_n (kg) are respectively the mass of electron, proton and neutron, R_a (m) is the atomic radius measured by X-Ray diffraction and R (m) is a reference length or scale length found to be 1fm = 10^{-15} m. It is important, for the following of this paper, to notice that the quantity $3c^2/4\pi R$ (m.s^{-2}) is a centripetal acceleration. Using numerical quantities, equation (1) can be rewritten as followed:

$$\overline{T} = 2.148610^{31}.\frac{M_a}{R_a^2} \quad (2)$$

Where M_a (kg) is the total mass of nucleons and electrons and the constant value 2.1486 × 10^{31}m.s^{-2} can be considered as gravity acceleration at atomic scale. Using this equation, Delplace [2] obtained a strong correlation between $\overline{T}$ and density of all atoms of periodic classification except for seven atoms: the six rare gases and fluorine (this interesting result will be discussed at the end of this publication).

In fluid mechanics, especially in rotating mixing systems, ¯ can be

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related to an average shear rate value $\bar{\dot{\gamma}}$ (s^{-1}) using the following well known relationship [6]:

$$\bar{T} = \eta\bar{\dot{\gamma}} \tag{3}$$

In this equation, η(Pa.s) is the fluid dynamic viscosity. Equalling equations (2) and (3) allows the following expression for $\bar{\dot{\gamma}}$ to be obtained:

$$\bar{\dot{\gamma}} = \frac{k}{\eta}.\frac{M_a}{R_a^2} \tag{4}$$

With $k = 2.1486\times10^{31}$ m.s^{-2}

In a previous paper [3], we showed that a velocity gradient called $\dot{\gamma}\,4D$ (s^{-1}) can be related to space-time curvature C_{4D} (m^{-2}) using the following relationship:

$$\dot{\gamma}^{4D} = \frac{Ks}{4}C_{4D}\,\nu \tag{5}$$

In this equation, ν ($m^2.s^{-1}$) is the well-known kinematic viscosity (the ratio of dynamic viscosity and density) often called momentum diffusivity [7] and K_s a dimensionless number introduced by Metzner and Otto [6] and well known in mixing systems mechanics. K_s is an experimentally determined quantity representative of mixing system shape and of its capacity to diffuse shear rate in the fluid. If we consider now that $\dot{\gamma}\,4D = \bar{\dot{\gamma}}$, we can equal equations (4) and (5) to obtain:

$$\frac{k}{\eta}.\frac{M_a}{R_a^2} = \frac{Ks}{4}C_{4D}\,\nu \tag{6}$$

In a first approximation, corresponding to the atom model used to establish equation (1), we can consider atoms as spheres of radius R_a and then, we can write that $C_{4D} = 1/R_a^2$. Using this assumption, equation (6) allows K_s values for all atomic species to be calculated in the following form:

$$K_S = \frac{4k}{\eta^2}\rho M_a \tag{7}$$

As expressed above, K_s characterises the mixing shape of all atomic species or more accurately of their complex shape electrons orbitals, these atoms being considered as nano-scale mixing systems. In equation (7), K_s is proportional to atomic material mass M_a (kg), proportionality constant depending on space-time transport properties i.e., density ρ and dynamic viscosity η and a centripetal acceleration.

Using mixing system well known equation $\bar{\dot{\gamma}} = K_S.N$ [6], N (rad.s^{-1}) being the rotational speed of the mixing system (for example a turbine at our scale), it is then possible, with equations (7) and (4) to calculate a rotational speed N for all atoms. Of course, these calculations require the knowledge of space-time transport properties which are always a great subject of debates between physicists. But calculation of N and comparison to the value obtained by Niels Bohr for hydrogen i.e., $N = 6.67\times10^{15}$ rad.s^{-1} is of interest to verify if transport properties found in literature could be available.

Space-time Transport Properties and Gravity at Atomic Scale

An important theoretical and experimental work was performed by Galaev [8] in order to obtain a numerical value of space-time kinematic viscosity. This author found the following value: $\nu=6.24\times10^{-5}$ $m^2.s^{-1}$. Another elegant way to calculate momentum diffusivity at atomic scale could be the use of famous Heisenberg uncertainty principle, coming from Schrödinger equation and often written as followed:

$$\Delta x\,.\Delta p_x = \frac{h}{4\pi} \tag{8}$$

Δx and Δp_x are respectively the uncertainty on position and momentum, h is the well-known Planck universal constant: $h=6.6261\times10^{-34}$ kg.m^2.s^{-1}. Applied to an electron of mass $m_e = 0.911\times10^{-30}$ kg (equation (8) being established for hydrogen atom) and introducing momentum diffusivity ν ($m^2.s^{-1}$), we can write:

$$\Delta x\,.\Delta v_x = \frac{h}{4\pi m_e} = \nu \tag{9}$$

Equation (9) could be interpreted as a way to quantify how much electron, considered as an impeller in space-time, diffuse momentum. Numerical calculation using values given above gave $\nu = 5.79\times10^{-5}$ m^2s^{-1}. This value is remarkably close to Galaev [8] result and considering that equation (8) is the product of uncertainties, we can admit that Galaev [8] result is of great interest and great accuracy.

But knowledge of kinematic viscosity is not enough to use equation (7). This equation involves the square of dynamic viscosity and density and we need to calculate one of these parameters. Value of space-time dynamic viscosity is today a subject of debates and we can consider that two tendencies exist: a very low (superfluid) and a very high value.

The very low or null dynamic viscosity hypothesis suppress the viscous term in Navier-Stokes equation reducing to an Eulerian ones (perfect fluid). Considering our approach, based on mixing systems mechanics and equation (7) derived of it, a very low value of η will give a very high value of K_s parameter. From experimental results obtained for mixing systems, we know that K_s values vary in the range 10 to 40 and highest values are obtained for proximity agitators like helical rubans giving the highest shear rates for a given rotational speed [9]. Considering the lacunar structure of atoms, it seems not possible to consider electrons as proximity agitators and then to obtain huge values of K_s dimensionless number.

On the other hand, Delplace [2] proposed a very high dynamic viscosity value available at both cosmological and atomic scales. This very high value: $\eta = 1.54\times10^{11}$ Pa.s will lower K_s value in better agreement with the lacunar atomic structure.

From these considerations, we decided to use Delplace [2] dynamic viscosity value and Galaev [8] kinematic viscosity to calculate space-time density: $\rho = \eta/\nu = 2.468\times10^{15}$ kg.m^{-3}. It is interesting to remark that this value is between the proton density: $\rho_p = 6.23\times10^{17}$ kg.m^{-3} and electron density: $\rho_e = 9.72\times10^{12}$ kg.m^{-3}. This result shows that atoms could be seen as a space-time volume of high density containing denser particles i.e., protons and neutrons constituting the kernel and less dense particles: the electrons. This representation could be interpreted as a hydrostatic atom model.

Finally, the last value of interest in equation (7) is parameter k which can be seen as a centripetal acceleration (equation (1)). At our scale, Newtonian gravity is also a centripetal acceleration and we could consider k as gravity acceleration at atomic scale. Its value is huge compared to earth well known average value: g=9.81 m.s^{-2}, but considering huge energy densities found at atomic scale, this hypothesis appears realistic. It allows calculating values of Newton gravitational constant G as followed:

$$G = \frac{kR_a^2}{M_a} \tag{10}$$

Considering values of R_a and M_a, it is clear that G values will be

very high and much greater than the well-known Newtonian value: G=6.67384×10^{-11}m^3.s^{-2}.kg^{-1}. Moreover, following our mechanics model and doing a dimensional analysis G could be interpreted as a volume acceleration of space-time in m^3.s^{-2} caused by a moving quantity of matter in kg.

Results and Discussion

As expressed in the introduction of this paper, we performed calculations for four atoms of periodic classification: H, Al, Ar and U. The same calculations can be made for all atoms. Using transport properties values given above, equation (7) gives:

$$K_S = 8.943710^{24} \ .M_a \tag{11}$$

Numerical results are given in the following table (Table 1):

The first important result is the value of N found for hydrogen atom. Bohr model predicted $N= 6.67\times10^{15}$ rad.s^{-1} which is close to the value $N= 5.55\times10^{15}$ rad.s^{-1} found using the fluid mechanics based approach. Values of N given for Al, Ar and U are indicative because quantum mechanics does not allow electrons velocity calculation.

K_s Values increase when electron number increases; this result is well in agreement with the mixing model used at our scale giving an increase of shear rate with mixing intensity provided by mixing device.

These important results show that a coherent framework can be built from very large to very low scale using fluid mechanics concepts. The rotational speed result found for hydrogen electron is clearly coming from both well determined transport properties of Einstein space-time and a gravity acceleration being unusual at our scale. It seems that the unique combination of proposed, η and ρ values given in chapter 3 is able to recover the famous Bohr model value. Moreover, this result allows a rotational Reynolds number for hydrogen atom to be calculated. Interesting result is given by the following equation:

$$Re = \frac{\rho N D_a^2}{\eta} \cong 1 \tag{12}$$

This important result means a laminar space-time flow regime which was the fundamental assumption in all this fluid mechanics approach.

It is also important to come back to quantity $3c^2 / 4\pi R$ we defined as gravity acceleration at atomic scale and analogous to earth Newtonian gravity. If the assumption was correct, it should be possible to apply it to earth motion and then to recover the well-known value g =9.81 m.s^{-2}. The problem is extremely complex because earth trajectory through space-time and its velocity are approximate. But using classical values found in literature for earth velocity on itself (v_1), earth velocity around the sun (v_2) and solar system velocity through space-time continuum (v_3), we can calculate a geometric mean velocity v^* as followed:

$$v^* = \left(v_1 \ .v_2 \ .v_3\right)^{1/3} \tag{13}$$

Using classical values: v_1 = 465m.s^{-1}; v_2 =30000m.s^{-1} and v_3 =300000m.s^{-1}; equation (12) gives $v^* = 16115$ m.s^{-1}. Then gravity acceleration on earth is given by $g = 3v^{*2} / 4\pi R$ with R = 6.37814×10^6 m for earth considered as a perfect sphere. Final calculation gives g=9.72 m.s^{-2} which is in fair agreement with our earth gravity acceleration.

	H	Al	Ar	U
A	1	27	40	238
Z	1	13	18	92
R_a **(m)**	0.53 10^{-10}	1.25 10^{-10}	0.71 10^{-10}	1.55 10^{-10}
M_a **(kg)**	0.17 10^{-26}	4.51 10^{-26}	6.68 10^{-26}	39.8 10^{-26}
$\bar{\dot{\gamma}}$ **(s^{-1})**	0.84 10^{14}	4.03 10^{14}	18.49 10^{14}	23.1 10^{14}
K_s	1.52 10^{-2}	40.33 10^{-2}	59.74 10^{-2}	353.96 10^{-2}
N **(rad.s^{-1})**	5.55 10^{15}	10^{15}	3.1 10^{15}	0.65 10^{15}

Table 1: Calculations of electrons rotational speed.

Finally, it is also interesting to come back to the anomaly observed by Delplace [2] in his attempt to correlate $\bar{T}$ values from equation (1) and measured atoms densities. As reported at the beginning of chapter 2, correlation was good except for the six rare gases and fluorine. In Table 1, we can observe that Ar, one of the six rare gases, has a higher value of N compared to Al and U. Moreover, considering first energy ionization of periodic classification atoms, rare gases and fluorine have the highest values, clearly out of the range of all other atomic species. This result could be of interest for chemistry to explain particular behaviours of these atoms.

Conclusion

Using a fluid mechanics approach, we tried to build an atomic model in agreement with large scale physics recent developments. Each atom was considered as a nano scale mixing system in Einstein space-time.

Transport physical properties values of space-time i.e., dynamic viscosity and density were chosen in literature and discussed. It clearly appeared that high values were necessary for calculations having a physical meaning. Moreover, assuming that electrons motion creates a velocity field and a centripetal acceleration of space-time which is gravity acceleration at atomic scale, we calculated an electron rotational speed for hydrogen.

Surprisingly, this rotational speed appeared in fairly good agreement with Bohr model value. This important result could signify that a fluid mechanics approach could be available at atomic scale. We propose to call it nano-scale fluid mechanics (NSFM). Moreover, this model giving also interesting results at astronomic scale; it could be a first step in building the bridge between small and large scale physics.

In this approach, gravity appeared an emergent phenomena coming from space-time motion caused by huge energy densities found at atomic scale. It was then possible to calculate gravity acceleration at atomic and astronomic scales using the same formula. This result could signify that the famous quantum gravity theory could come from Einstein space-time hydrodynamics.

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