Coherent structures in liquid water close to hydrophilic surfaces

Emilio Del Giudice

Centro Studi Eva Reich,Via Orti 5, I-20122 Milano, Italy

E-mail: `emilio.delgiudice@mi.infn.it`

Alberto Tedeschi

WHITE Holographic Bioresonance, Via Francesco Petrarca 16, I-20123, Milano, Italy

E-mail: `gowhite@usa.net`

Giuseppe Vitiello

Dipartimento di Fisica "E.R. Caianiello" and Gruppo Collegato I.N.F.N., Università di Salerno, I-84100 Salerno, Italy

E-mail: `vitiello@sa.infn.it`

Vladimir Voeikov

Lomonosov Moscow State University, Faculty of Biology, Vorobevy Gory, Ru-119995 Moscow, Russia

E-mail: `v.l.voeikov@gmail.com`

Abstract. Quantum Electrodynamics (QED) predicts the occurrence of a number of coherent dynamical phenomena in liquid water. In the present paper we focus our attention on the joint coherent oscillation of the almost free electrons produced by the coherent oscillation of the electron clouds of water molecules, which has been described in previous publications, and of the negative electric charges lying on the solid surfaces wet by water. This joint coherent oscillation gives rise to a number of phenomenological consequences which are found to exist in the physical reality and coincide with the layers of Exclusion Zone (EZ) water experimentally observed close to hydrophilic surfaces.

1. Introduction

In the last decades the structure of liquid water has been investigated in the framework of Quantum Electrodynamics (QED) [1]-[4]. It has been shown that an ensemble of water molecules in a gaseous state, above a density threshold and below a critical temperature, transits to a lower energy coherent state where the electron clouds oscillate between their individual ground configuration and an excited configuration where one electron per molecule is almost free (the binding energy is about 0.4 eV). The coherent state is a superposition of the ground configuration, with a weight of almost 90%, and of the excited configuration with a weight of

about 10%. The molecule coherent oscillation is in tune with an electromagnetic field (emf), trapped within the molecule ensemble and therefore unable to be irradiated outwards. The molecules and the trapped emf are confined within a region (termed Coherence Domain (CD)), whose size is the wavelength of the emf. In the case of liquid water this size is 0.1 microns. Each CD is a pool of quasi-free electrons, which, as in a semi-conductor, can be coherently excited giving rise to a CD spectrum of coherent excited levels produced by the coherent ("cold") vortices of quasi-free electrons, whose magnetic dipoles are aligned with the external (e.g. the terrestrial) magnetic field. Because of the coherence the vortices have no internal friction and therefore have a very long lifespan, so that it is possible to pile up within the CD a large number of excitations which sum up to a unique vortex whose rotational frequency is just the sum of the frequencies of the component vortices. In this way, as it has been shown in [5], the CD becomes a device able to transform ambient noise, namely an ensemble of a large number of low frequency excitations, into a unique high frequency excitation. This property implements the intuition of Albert Szent-Gyorgyi [6], who traced back the presence in living organisms of excitations at molecular scale to the capability of biological water to sum up the small perturbations contained in ambient noise.The molecule condensation produced by coherence is counteracted at any non vanishing temperature T by thermal collisions which push some molecules out of tune. Consequently at each T there is a coherent fraction $F_c(T)$ of molecules and a non-coherent fraction $F_{nc}(T)$ whose sum is 1. Molecules cross over continuously between the two fractions leaving constant the total number of coherent and non-coherent molecules. Besides the above coherence which involves electron clouds, another coherent dynamics has been shown [7] to involve the molecule rotational levels producing a coherent oscillation between the molecule ground state and the low lying states at about 20 wave-numbers. This coherence spans a length of slightly less than 500 microns and gives rise to an extended oscillating polarization field since it is able to correlate together the individual molecule electric dipoles. In the absence of an external electric field, the time average of the above polarization field is zero. However in the presence of an electric field E, the polarization field acquires a permanent component along E. In aqueous systems macromolecules suspended in water or solid surfaces on the boundary could be sources of electric fields so that according to QED layers of polarized water as deep as some hundreds of microns can be expected. We will see in the following that this prediction is corroborated by laboratory observations. Furthermore an additional coherent dynamics can be found in aqueous systems. As shown in [8] plasmas, which are ensembles of charged particles (either negative like electrons or positive like protons) can give rise to coherent oscillations when suitable conditions are met. We examine the dynamics in aqueous systems of the ensemble of quasi-free electrons of water CDs coupled with the ensemble of negative charges lying on the solid surface of the walls. In the present paper we will investigate the condition for the emergence of coherence in the above plasmas and compare the predictions with the observed facts.

2. Plasma coherent oscillations

Stable matter is electrically neutral, made up, however, of constituents electrically charged. Plasma dynamics starts with the small oscillations of charges with a pulsation ω_R around their equilibrium positions. Charges are kept correlated by the emf. As shown in Chapter 5 of Ref. [8], the plasma driven by the coupled emf could "run away" from the initial perturbative regime and transit to a coherent state where all charges oscillate in unison, in tune with a coherent resonating emf at a common pulsation

$$\omega_r = |1 - \dot{\phi}| \, \omega_R < \omega_R \,, \tag{1}$$

where ϕ is the change of the phase of the emf induced by the onset of coherence and the symbol $|...|$ denotes, as usual, the absolute value.

Furthermore, a relevant parameter is the plasma oscillation amplitude α, connected to the emf amplitude A by the equation

$$A^2(1 - \dot{\phi}) + \alpha^2 = 0 \,. \tag{2}$$

When it is assumed that each set of charges moves within a homogeneous ensemble of the opposite charges we have the simplest case of the "ideal plasma", whose pulsation is

$$\omega_P = \frac{e}{\sqrt{m}}\sqrt{\frac{N}{V}} \,, \tag{3}$$

where the natural unit system ($\hbar = 1 = c$) is used, e and m are the charge and the mass of plasma constituents, respectively, and N/V their density. An ideal plasma can be shown to meet always the condition for coherence, namely the existence of the runaway. However, in ideal plasmas the oscillation amplitude is not bounded from above so that, as discussed in Ref. [8], there is no energy minimum; ideal plasmas therefore cannot exist as physical systems. Real plasmas, which are real physical systems, should consequently exhibit dis-homogeneities; the oscillating charges should stay confined within finite volumes, for instance the matrices of opposite charges.

In this case the analysis of the Chapter 5 of Ref. [8] shows that the oscillation amplitude is bounded from above, so that the system has an energy minimum. The condition for coherence is:

$$\frac{\omega_R}{\omega_P} < 1.88 \,, \tag{4}$$

where ω_P is the pulsation of the ideal plasma having the same average density.

If condition (4) is not met, there is no runaway so that the field amplitude does not increase; however, the field, although weak, becomes coherent and "weak coherence" is produced.

When coherence emerges, the energy of the system decreases and consequently the new coherent configuration is protected against instabilities by the energy gap produced by the emergence of coherence. The physical requirement of minimization of energy implies that a physical system could always reach a coherent configuration provided that spontaneous fluctuations allow the suitable change of its parameters necessary to meet the requirement for the onset of coherence.

By using the above concepts, let us examine what happens when liquid water, made up of Coherence Domains containing a pool of almost free electrons and correspondingly an ensemble of almost free protons (the widows of the quasi free electrons), becomes close to a solid surface (a wall, or a suspended microsphere surface, or a molecular backbone) on which electric charges able to oscillate are distributed. We denote by r the size of the charge spot on the surface, δ the depth of the charge layer, z the total number of the charges contained in the spot, λ a parameter measuring the dis-homogeneity of the charge distribution. The pulsation ω_R of the surface plasma is

$$\omega_R = \frac{e\,\lambda}{\sqrt{m}} \sqrt{\frac{z}{4\pi\,r^2\delta}} \,. \tag{5}$$

According to Ref. [8] the energy gain of the energy spot is

$$\Delta E = -15\pi\sqrt{\frac{2\pi}{3}}\,\omega_R. \tag{6}$$

The above coherent oscillation of the solid surface charges occurs close to a corresponding coherent oscillation of the quasi free charges of the water CDs. The parameters (pulsation and amplitude) of this last oscillation depend on the excitation levels where the CD finds itself due to its own dynamics. As a matter of fact, as said in the Introduction, vortices can be induced

in the ensemble of quasi free electrons of CDs by the uptake of energy from the environment. Such vortices control the maximum displacement of the oscillations of quasi free electrons in the CD and therefore the maximum amplitude and the pulsation ω_r of the coherent oscillation (see Eqs. (1) and (2)). It is then possible for the system to self-adjust these parameters in order to produce a resonance between the two charge ensembles and consequently the onset of a compound coherence of the two plasmas on a common frequency, producing the advantage of a larger energy gap due to the larger number of correlated oscillators. The larger energy gap would weaken the binding of the charges oscillating on the surface to their matrix, making possible a charge separation. On the other hand, the increased energy gap enhances the protection of the water CDs against the assaults of thermal collisions, responsible for the formation of the water non-coherent fraction. Water close to surfaces should therefore exhibit a much larger coherent fraction than bulk water. Its coherent inner structure should remain stable in time, allowing, contrary to bulk water where a continuous cross-over between the two fractions occurs, a direct observation of the consequences of the presence of coherence. The depth of the coherent layer close to a surface is governed, according to [7], by the strength of the electric field emitted by the surface, which correlates coherently the CD electric dipoles. The depth of the layer could therefore reach values as high as hundreds of microns, much larger than the depths of a few molecular layers predicted by conventional theories based on H-bonding [9].

Finally, the charge dynamics on the interface water-solid surface should exhibit a feature totally unexpected in the usual framework, namely the attraction among like charges produced by the coherent dynamics which overcomes the repulsion expected according to the Coulomb law of electrostatics. In the next section, we will compare the above predictions of the QED analysis with the results of observations.

3. Phenomenology of interfacial water

In the last years Gerald Pollack and his coworkers [10] - [12] have reported that water adjacent to hydrophilic surfaces (interfacial water) is dynamically different from bulk water. Solutes and microspheres are excluded from this kind of interfacial water which has been termed for this reason exclusion zone (EZ) water. The depth of the layer of EZ water on the solid surface is in the order of tens and hundreds of microns, up to 500 microns. With respect to bulk water, EZ water has higer (up to tenfold) viscosity, diminished infrared emissivity, shorter spin-lattice T_1 relaxation time, retarded spin-spin T_2 relaxation time, as probed by NMR and smaller self-diffusion coefficient [10, 11]. All these features are compatible with the presence of coherent water as described in [1] - [4]. Actually, in a coherent system one could not touch a single molecule without touching also the other correlated molecules, so that viscosity becomes higher as well as the correlations detected by NMR, whereas self-diffusion which depends on the mutual independence of molecules is also depressed. The decrease of infrared emissivity is justified by the presence of the infrared oscillations of CDs which absorb energy in this frequency range.

EZ water is electrically charged with respect to bulk water, which is well known to be neutral. If EZ water is close to a surface bearing a net negative charge, it acquires a negative charge, too, whereas it acquires a positive charge near a surface bearing a positive charge [12]. It is interesting to observe that when EZ water becomes negatively charged near a negative surface, positive charges (protons) appear beyond EZ water on the side of the EZ layer facing bulk water. On the contrary, negative charges appear on the side of the layer facing the bulk water when EZ water is positively charged. It is also interesting to realize that no electric opposite charges have been detected in the interstice between the solid surface and the aqueous surface, suggesting that the attraction water-solid surface underlying the hydrophily of the surface is not produced by electrostatics but by a dynamic collective attraction such as the one produced by QED coherence. **Like likes like**, contrary to the Coulomb law of electrostatics.

Moreover, the expulsion of non-resonating particles from coherence domains oscillating on a

definite frequency accounts for the phenomenon of the exclusion of solutes and also of opposite electric charges since

$$\frac{\omega_{neg}}{\omega_{pos}} \propto \sqrt{\frac{m_{proton}}{m_{electron}}} \simeq 45\,. \tag{7}$$

The charge separation occurring at the interface is understood in the QED framework by the weakening of the binding of the oscillating charges to their matrices as a consequence of the energy gap produced by the combined coherence of the quasi free charges of the water CDs and of the solid surfaces.

Additional evidence for the existence of charge separation on the interface between water and solid surface comes from a recent report [13] that almost all the water droplets constituting the aerosols present in the waterfalls in Austrian Alps were electrically charged (85 % negatively, 15 % positively). It is conceivable that the charge separation occurred on the interface between the flowing water of the river and its rocky banks and the turbulence of the river stripped the charged droplets from the banks.

4. Conclusions and outlook

The predictions of the QED analysis are in striking agreement with the findings of experimental investigations on interfacial water. The so far mysterious features of EZ water have found an explanation which on the contrary cannot be found in the framework of models of water based purely on electrostatics. The attraction among like charges finds a rationale in the context of a long range many-body dynamics emerging above a critical density threshold and below a critical temperature. This result is particularly useful when we try to understand the dynamics existing in living organisms. Since no point of them is more distant than a fraction of a micron from a surface or a molecular backbone, we can safely presume that the whole of biological water is interfacial water. Therefore, all the conclusions of the present article apply to biological water. In particular, we can understand why cells, whose surface is negatively charged can attract each other giving rise to tissues.

Finally, another application of the present analysis could explain the stability of clouds constituted by negatively charged water droplets.

References

[1] Arani R, Bono I, Del Giudice E and Preparata G 1995 *Int. J. Mod. Phys.* B **9** 1813-1841
[2] Del Giudice E, Preparata G 1998 In: Sassaroli E, Srivastava Y, Swain J, Widom A (eds) *Macroscopic Quantum Coherence* (Singapore: World Scientific) pp. 108-129
[3] Del Giudice E, Spinetti P R, Tedeschi A 2010 *Water* **2** 566-586
[4] Bono I, Del Giudice E, Gamberale L and Henry M 2012 *Water* **4** 510-532
[5] Del Giudice E, Pulselli R M, Tiezzi E 2009 *Ecological Modelling* **220** 1874-1879
[6] Szent-Gyorgyi A 1957 *Bioenergetics* (New York: Academic Press)
[7] Del Giudice E, Preparata G, Vitiello G 1988 *Physical Review Letters* **61** 1085-1088
[8] Preparata G 1995 *QED, Coherence in Matter* (Singapore:World Scientific)
[9] Franks F 1972-1982 *Water, a Comprehensive Treatise* (New York: Plenum)
[10] Zheng J M and Pollack G H 2003 *Phys. Rev.* E **68** 031408.10.1103
[11] Zheng J M , Chin W C , Khijniak E, Khijniak E Jr and Pollack G H 2006 *Adv. Colloid Interface Sci.* **23** 1927
[12] Zheng J M , Wexler A and Pollack G H 2009 *J Colloid Interface Sci.* **332** 511-514
[13] Madl P, Kolarz P, Del Giudice E, Tedeschi A, Hartl A, Gaisberger M, Hofmann W 2013 The formation of coherence domains for aerosolized water molecules at alpine waterfalls, submitted to *Water*, online Journal