Diffusion of Selforganized Brownian Particles in the Michelson-Morley Experiment

Jirí Stávek
Laboratory of Diffusion Processes
Bazovského 1228, 163 00 Prague, Czech Republic
e-mail: stavek@volny.cz

The phenomenon of the constant light velocity could be explained classically using the concept of the diffusion of selforganized structures of Brownian particles. In this contribution the length of both arms of the Michelson-Morley instrument is constant. The Fitzgerald-Lorentz transformations were used to describe the contraction of the waves of Brownian particles (diffusion of waves in the direction of the motion) and the extension of these waves (diffusion of waves against the direction of the motion). The Fitzgerald-Lorentz transformation was used to recalculate the periods of these diffusing waves from the moving frame to the observer frame. The product of these wavelengths and frequencies $\lambda' \nu'$ of diffusing selforganized Brownian particles gives *c*.

Keywords: diffusion action, spontaneous formation, selforganized structures, constant light velocity

Received January 24, 2004. Communicated by Y. Baurov.

Diffusion action of chemical waves

G.F. Fitzgerald (in 1889) and H.A. Lorentz (in 1892) independently suggested how to solve the dilemma of the Michelson-Morley experiment. They came with a suggestion that the part of the apparatus which carried the two way wave-train of light became contracted in such a way that it compensated the extra time required for the light to travel along the paths. Lorentz and Fitzgerald estimated that the molecules of every solid substance might compress in the direction of motion and expressed this idea in the mathematical equations now known as Lorentz-Fitzgerald (LF) transformations. In 1905, A. Einstein adopted the Lorentz-Fitzgerald transformation in his approach where the LF transformation is required not only for the length contraction but also for the dilation of time.

This old idea will be used in this contribution for the description of diffusing waves of selforganized Brownian particles from moving source and reflecting from a moving mirror. The length of both legs of the M-M instrument is constant in this contribution. However, the diffusing waves of Brownian particles are contracted in the direction of the motion and extended against the motion of the source. It is proposed to use the LF transformation in order to modify the ordinary Doppler effect into the relativistic Doppler effect.

In order to start with this analogy, it is necessary to summarize some experimental evidences collected during the intensive studies of chemical waves. There is a strong tendency for systems far from equilibrium to create spontaneously selforganized dissipative structures. They can be seen not only within the biological systems but also in physical and chemical world of inorganic substances [1]. Colloidal chemists have frequently observed macroscopic spatial patterns during the past one hundred years. Liesegang [2] observed 2D formation of patterns of inorganic substances in the presence of gelatin termed as Liesegang rings (LR). The discovery of the Belousov-Zhabotinsky (BZ) oscillation reaction catalyzed intensive research of these oscillation reactions [3].

It was found that during the evolution of successive waves the product of instantaneous propagation speed u and the wavelength λ converge to a constant value [4,5,6]. This product $u\lambda$ depends on the type and the concentration of the polymer used in the case of Liesegang rings. There was a tendency to characterize the diffusing front by a characteristic particle mass m that is needed for the estimation of the *diffusion action* of chemical waves. The product of the characteristic mass m, propagation speed u and the wavelength λ was termed as the *diffusion action* [7].

This approach for the characterization of the LR formation was followed repeatedly several times since then [8]. More than one hundred different combinations of cations and anions were employed for the LR formation. Because of the difficulties in the estimation of mass of diffusing particles (reaction between the molecules of outer and inner electrolytes, irreversible formation of clusters) the calculated values of the diffusion action of the order ~ 10^{-34} Js could not be tuned to a certain constant value. Therefore, this concept was considered as very trivial [9]. On the other hand, several theoretical physicists contributed to this topic [10,11,12,13,14,15,16,17], too. Several decades long experimental and theoretical research can be condensed into the following equation:

$$Kkm\,l\,u = h \tag{1}$$

where K is the diffusivity factor, k is the tortuosity factor, m is the particle mass, λ is the wavelength, u is the propagation speed, h is a characteristic constant of the diffusion action. The parameter K – diffusivity factor—describes the geometrical arrangement of the experiment. For one-dimensional space (thin glass tubes) K = 1, for two-dimensional space (thin layer in a Petri dish) K = 2, in case of the three-dimensional experiment the value *K* depends on the space angle available for the diffusion of Brownian particles from their source. If the whole space is available for the propagation of the chemical waves, then K = 4p. Many studies of the dispersion relations were performed in gels, membranes, resin beads, glasses in order to prevent hydrodynamic disturbances from the reacting media. These media help to localize the propagating bands; on the other hand they modify the diffusion path of ions. The diffusion field in these restricted environments changes by a tortuosity factor κ that characterizes the diffusivity in porous media.

In the recent summary of this topic [18] the evolution of the diffusion actions of Liesegang rings formation, Belousov-Zhabotinsky waves and the cAMP (cyclic adenosine 3′,5′-monophosphate) waves were analyzed. The main trend for all three types of chemical waves is similar. During the evolution of successive chemical waves there is a strong tendency to self-organize their diffusion fields in such a way that the diffusion actions converge to a constant value of about $6.6 * 10^{-34}$ Js (stage 1). Diffusion actions of next waves fluctuate around this quantity of action for a long time in dependence on the capacity of the system (stage 2). When the stage 2 is over the successive waves irreversibly decay towards chemical equilibrium (stage 3) until the creation of waves stops.

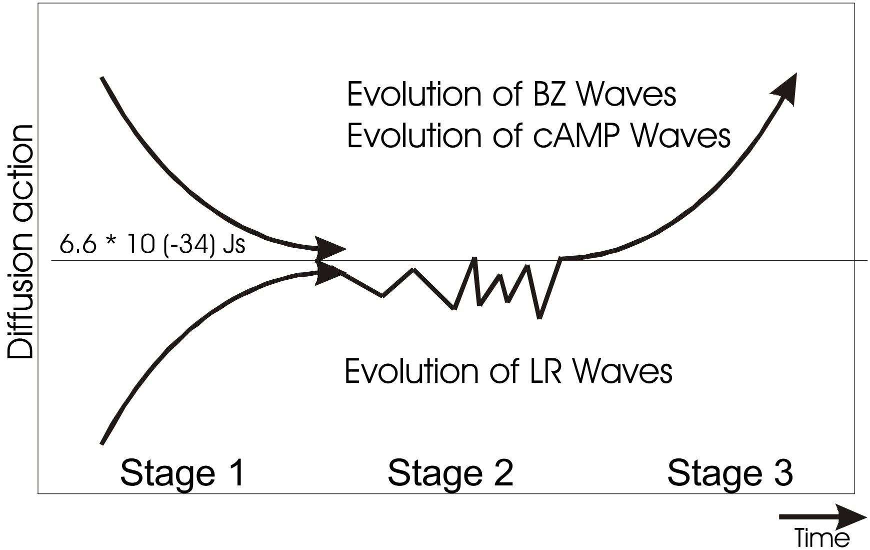

Figure 1 Evolution of diffusion actions of chemical waves

The property of vast collections of Brownian particles to diffuse into their surroundings as local osmotic waves reveals that these waves have a strong tendency to selforganize their diffusion fields. This self-organization of the diffusion field can be done via the characteristic mass m, propagation speed u or the wavelength λ in such a way that their diffusion action tend to fluctuate around the characteristic value $6.6 * 10^{-34}$ Js. This behavior of chemical waves is schematically shown in Figure 1.

Chemical waves consist of many discrete particles that coherently diffuse into their surrounding provided that a certain critical particle concentration is exceeded. These chemical waves behave in a similar way as photon waves. Nikiforov and Kharamenko [19] studied Maupertuis´ as well as Fermat´s principles and the Snell law validity for lead iodate and silver bichromate waves. Raman and Subba

Ramaiah [20] described the wave-interferences in Liesegang patterns. Oosawa et al. [21] investigated refraction, reflection, and frequency change of chemical waves propagating in a non-uniform BZ reaction medium.

Recently, the Doppler effect of chemical waves was intensively studied [22, 23, 24]. The motion of the source leads to a modulation in amplitude, wavelength and frequency of the emitted waves. As a consequence of the Doppler effect, spiral waves in front of the spiral tip are compressed and spiral waves behind the spiral tip are dilated. It was found that the modulation of the nonlinear waves is uniquely determined by the temporal period of the source motion. These experimental evidences reveal the complex behavior of the Doppler effect of these nonlinear waves. The behavior of these chemical waves differs significantly from sound waves that are carried by the molecules of medium. Diffusing selforganized Brownian particles move from the source to the detector. The moving source and detectors act on those waves and contract or extend them in a different way in compare with sound waves.

The vast collection of Brownian particles creates a local osmotic wave that penetrates into its surroundings and self-organizes its diffusion field in such a way that the value of its diffusion action fluctuates around the quantity of action. Properties of these waves of selforganized Brownian particles are compared with those stated by the Copenhagen interpretation of quantum mechanics (CIQM) and by the stochastic interpretation of quantum mechanics (SIQM) [25,26] in Table I. There is one main difference between these three concepts: no wave is associated with single Brownian particles. The wave is associated with the groups of Brownian particles when they exceed a certain critical concentration.

For the case of diffusion of single Brownian particles through double slits [27] the structure on the detector is formed by the interaction of Brownian particles with the spontaneously formed selforganized structure of photon field radiating from the cavity used for these experiments. The Brownian particle seems to be interacting with both slits via the formed selforganized structure of the cavity photon field. This interaction might explain the non-classical behavior of individual particles that adjusts its random trajectory according the geometrical arrangement of the experiment.

Table I Comparison of CIQM, SIQM and the colloidal interpretation of QM

	Copenhagen Interpretation of QM
1	Individual photons are particles or waves, never the two simultaneously
2	Double slit experiment with single particles: individual photons interfere with themselves, one cannot tell through which slit the photon passes
	Stochastic Interpretation of QM
1	Individual photons are real de Broglie´s waves associated with particles
2	Double slit experiment with single particles: the real wave goes through both slits, the photon goes through one slit only
	Colloidal interpretation of QM
1	No wave is associated with single Brownian particles
2	Wave is associated with the vast collection of Brownian particles, diffusion action of these waves fluctuate around the quantity of action
3	Double slit experiment with single particles: individual Brownian particles diffuse through the spontaneously formed selforganized field of photons radiating from the cavity

Diffusion of selforganized Brownian particles from a moving source

The original derivation of the Lorentz-Fitzgerald transformation fails because it is based, like the Michelson-Morley experiment, on two way travel. This original transformation predicts the same length contraction of the leg of the Michelson-Morley instrument to both paths. It is possible to remove this weak part of the original Lorentz-Fitzgerald transformation and to propose the contraction of the diffusing waves of Brownian particles in the direction of the motion of the source instead of the shrinkage of molecules of the legs. On the other side, the waves of selforganized Brownian particles diffusing against the motion are extended. The length of the instrument is constant and not dependent on the motion of the instrument. Therefore, the classical Lorentz-Fitzgerald transformations are used here for the contraction (extension) of wavelengths and for the extension (contraction) of frequencies of those waves. This modification leads from the ordinary Doppler effect to the relativistic Doppler effect. Doppler [28] presented his famous contribution in Prague in 1842.

The product of the contracted wavelength and the extended frequency (based on the Lorentz-Fitzgerald transformations) in the direction of the motion of these waves of selforganized Brownian particles gives the constant value c. Similarly, the product of the extended wavelength and contracted frequency of those waves of selforganized Brownian particles against the motion of the source gives the same constant value c, too. In this concept, there are contracted or extended wavelengths instead of the “curved space” and extended or contracted periods of these waves instead of the “time dilation”.

When the waves of selforganized Brownian particles approach the interface of the detector, their wavelengths and frequencies are adjusted according to relative motion of the moving source and the detector. In the case when the velocity of both the source and the detector is the same, the wavelength and frequency of those waves are restored to the standard values $\lambda_0\,\nu_0$. On the side of the source, waves become contracted in the dependence of motion of the source. At the interface of the detector the wave is extended or contracted according to the relative motion. If the relative motion between the source and the detector is zero, then the same amount contracted by the source will be extended at the interface of the detector. This behavior of diffusing waves can be termed as the selforganization of the 1st kind. The motion of the source modifies the frequency of emitted waves. The wave packet of Brownian particles adjusts its wavelength and frequency in such a way that the product $\lambda'\nu' = c$ is kept constant.

Selforganization of the 1st kind

(Light propagation between moving objects)

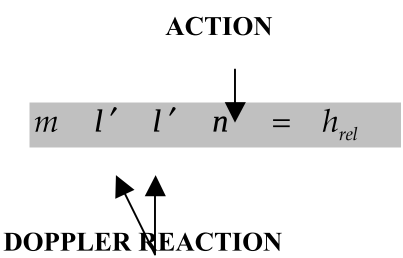

Figure 2 Selforganization of the 1st kind

During the reflection of the wave composed from Brownian particles this wave will be extended or contracted in dependence on the motion of the detector. If the relative motion of both source and detector is zero, then the reflected wave from the detector will be extended in the same amount as the wave diffusing from the source was contracted but with an opposite sign.

The product of the mass of Brownian particles m, their contracted (or extended) wavelength λ' and the velocity c gives a diffusion action h_{rel} that fluctuates around the quantity of action. If the relative motion of both the source and the detector is zero, then $h_{rel} = h$. The propagation of waves of selforganized Brownian particles is described by Equation 2:

$$m \frac{\left(1-\frac{v_{rel}}{c}\right)}{\sqrt{1-\frac{v_{rel}^2}{c^2}}} \, l_0 \frac{\left(1-\frac{v_{rel}}{c}\right)}{\sqrt{1-\frac{v_{rel}^2}{c^2}}} \, l_0 \frac{\sqrt{1-\frac{v_{rel}^2}{c^2}}}{\left(1-\frac{v_{rel}}{c}\right)} n_0 = h_{rel} \tag{2}$$

The positive sign of v_{rel} describes approaching motion of the source and detector. The negative sign of v_{rel} describes the receding motion of the source and the detector.

The concept based on the diffusion of selforganized Brownian particles enables to suggest the selforganization of the 2nd kind, too. In this case the mass of Brownian particles decays (model of the tired light was firstly suggested by Zwicky[29] in 1929) and secondary particles of smaller mass have been formed. This effect could be seen in the existence of background radiation [30] and in the so-called redshift quantization [31]. In the equation of the diffusion action the decreasing mass of Brownian particles is counterbalanced through the extension of wavelength and through the contraction of frequency. This reaction of the system enables to keep the constancy of the light velocity and the value of the diffusion action close to the value of the quantity of action. Behavior of these waves becomes more complicated when the selforganization of the 1st kind and the selforganization of the 2nd kind interplay together.

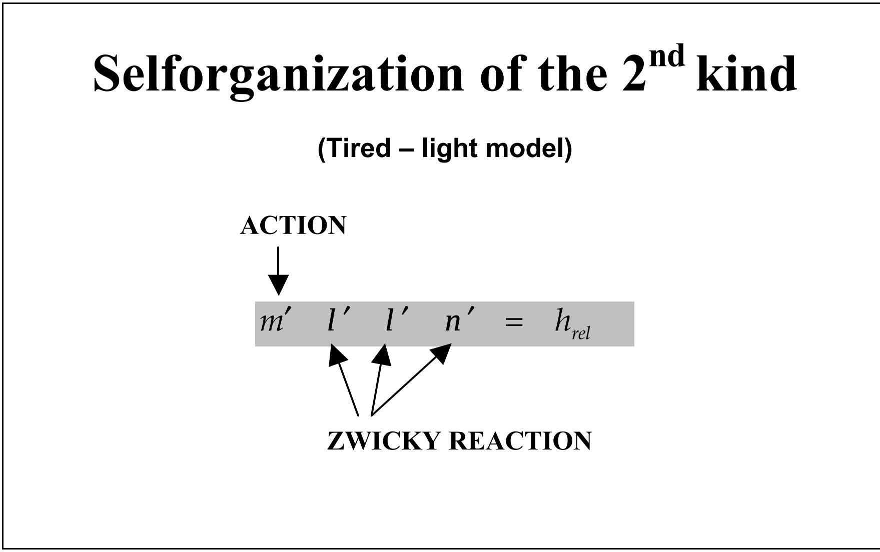

Figure 3 Selforganization of the 2nd kind

Conclusions

This analogy between Brownian particles and photons can be verified in the following observations:

1. Brownian particles can be locked in traps.
2. The periodic translational motion of the source modifies the waves in their wavelengths, frequencies, and amplitudes and forms unique diffusion patterns.
3. The rotational motion of the source modifies the waves in their wavelengths, frequencies, and amplitudes and forms unique diffusion patterns.
4. The selforganization of the 1st kind (frequency action – wavelength reaction) gives the constant product $\lambda'\nu' = c$.
5. The value of the diffusion action of waves between the source and the detector depends on their relative motion. If the relative motion is zero, then $h_{rel} = h$.
6. The selforganization of the 2nd kind (mass action – frequency and wavelength reaction) leads to the formation of the background radiation and the redshift quantization.

References

[1] P. Glansdorf and I. Prigogine, *The theory of structure, stability and fluctuations*, John Wiley & Sons, New York, 1971.

[2] R.E. Liesegang, *Chemische Reaktionen in Gallerten*, Selbstverlag, Dusseldorf, 1898.

[3] A.M. Zhabotinsky, "A history of chemical oscillations and waves," *CHAOS*, **1** (1991) 379 – 386.

[4] P. Michalev, V.K. Nikiforov and F.M. Schemyakin, "Uber eine neue Gesetzmässigkeit für periodische Rektionen in Gelen," *Kolloid-Z.* **66** (1934) 197-200.

[5] J.A.Christiansen and I. Wolff, "Untersuchungen uber das Liesegang-Phänomen," *Z. Physik. Chem*. **B26** (1934) 187-194.

[6] G. Ammon and R. Ammon, "Diffusion in gelatin and rhythmic precipitation of magnesium hydroxide," *Kolloid-Z.* **73** (1935) 204-219.

[7] J. Stávek, M. Šípek and J. Šesták, "The application of the principle of the least action to some self-organized chemical reactions," *Thermochimica Acta* **388** (2002) 441-450.

[8] J. Stávek and M. Šípek, „Interpretation of periodic precipitation pattern formation by the concept of quantum mechanics," *Cryst. Res. Technol*. **30** (1995) 1033 - 1049.

[9] G. Joos, H.D. Enderlein and H. Schädlich, „Zur Kentnis der rhytmischen Fällungen (Liesegang-Ringe)," *Z. Phys. Chem. (Frankfurt)* **19** (1959) 397 - 401.

[10] R. Furth, „Uber einige Beziehungen zwischen klassischer Statistik und Quantummechanik," *Z. Physik* **81** (1933) 143 - 162.

[11] I. Fényes, „Eine wahrscheinlichkeitstheoretische Begrundung und Interpretation der Quantenmechanik," *Z.Physik* **132** (1952) 81 - 103.

[12] W. Weizel, „Ableitung der Quantentheorie aus einem klassischen, kausal determinierten Modell," *Z. Physik* **134** (1953) 264 - 285.

[13] D. Kershaw, "Theory of Hidden Variables," *Phys. Rev. B* **136** (1964) 1850 - 1856.

[14] E. Nelson, "Derivation of the Schrodinger Equation from Newtonian Mechanics," *Phys. Rev*. **150** (1966) 1079 - 1085.

[15] K.L. Chung and Z. Zhao, *From Brownian Motion to Schrodinger Equation,* Springer, Berlin, 1995.

[16] P. Marquardt and G. Galeczki, "Action and Quantum Mechanics," *Apeiron* **2** (1995) 5 – 15.

[17] J.P. Wesley, "Classical Quantum Theory," *Apeiron*, **2** (1995) 27 – 32.

[18] J. Stávek, "Diffusion Action of Chemical Waves," *Apeiron*, **10** (2003) 183-193.

[19] V.K. Nikiforov and S.S. Kharamenko, "On the wave nature of the periodic reaction of silver bichromate," *Acta Physicochimica U.R.S.S.* **8** (1938) 95 – 102.

[20] C.V. Raman and K. Subba Ramaiah, "On the wave-like character of periodic precipitates," *Proceedings of the Indian Academy of Sciences*, Vol. **IX**, Section A (1939) 455 – 473.

[21] Ch. Oosawa et al., "Refraction, reflection, and frequency change of chemical waves propagating in a nonuniform Belousov-Zhabotinsky reaction medium," *J. Phys. Chem.* **100** (1996) 1043 – 1047.

[22] L. Brusch, A. Torcini and M. Bär, "Doppler effect of Nonlinear Waves and Superspirals in Oscillatory Media," *Phys. Rev. Lett***.** **91** (2003) id. 108302.

[23] L. Qun Zhou and Q. Ouyang, "Experimental Studies on Long-Wavelength Instability and Spiral Breakup in a Reaction-Diffusion System," *Phys. Rev. Lett*. **85** (2000) 1650-1653.

[24] Q. Ouyang, H.L. Swinney and G. Li, "Transition from Spirals to Defect-Mediated Turbulence Driven by a Doppler Instability" Phys. Rev. Lett. 84 (2000) 1047-1050.

[25] S. Jeffers et al. Eds., : "*Jean-Pierre Vigier and the Stochastic Interpretation of Quantum Mechanics,"* Apeiron, Montreal, 2000.

[26] Special issue of Apeiron, "Fundamental Problems of Quantum Physics" *Apeiron* Vol. 4, No. 2, 1995.

[27] J. Stávek, "Diffusion of Individual Brownian Particles through Young´s Double-Slits" *Apeiron* **11** (2004) 175-186.

[28] Ch. Doppler, *"On the coloured light of the double stars and certain other stars of the heavens"* Lecture on 25 May 1842 in the Patriotic Hall of the Karolinum building in Prague.

[29] F. Zwicky, *Proc. Nat. Acad. Sci*. **15** (1929) 773.

[30] J. Stávek, submitted and accepted.

[31] H. Arp, *"Seeing red, Redshift, cosmology and academic science,"* Apeiron, Montreal, 1998, Ch. 8.