Quantum transport in proteins: An experimental tale

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Modern non-linear science got started in 1952 when Enrico Fermi, John Pasta, Stan Ulam and Mary Tsingou Menzel discovered a remarkable effect about non-linear system dynamics while exploring the dynamics of a chain of masses connected by anharmonic springs via a computer simulation (in 1952!). To their great surprise, the system was not ergodic under certain initial conditions but periodically returned to its original conditions. The Fermi-Pasta-Ulam-Tsingou discovery of what could be called non-thermalization took awhile to get into the public domain, and during this time the mathematician Martin Kruskal at Princeton with Norman Zabusky at Bell Labs discovered that there were integrable solutions to a nonlinear differential equation called the Korteweg–de Vries equation (KdV) equation that came out of studies of nonlinear dispersive waves [1]. These solutions had remarkably robust properties and Kruskal coined the term "soliton" to describe them, a wonderful term that immediately entered the public domain. Solitons are particularly interesting phenomena and important to physics at many different levels because they act as "particles" with an identity as they move through an anharmonic region. An excellent introduction to solitons can be found in the book by Drazin and Johnson [2].

I'll present a summary of picosecond pump-probe and photon echo experiments in the mid-IR at 6 microns on the protein myoglobin looking for these solitons [3,4]. The intriguing temperature dependence of the amide I band in Mb is rather similar to the temperature dependence of the amide I band of acetanilide, the molecule that launched Al Scott done the road of looking for Davydov solitons in biology. Alas, after much effort we believe the data shows that there is no long-lived Davydov soliton at least in myoglobin, but perhaps I am wrong [5].

[1] Zabusky, N.J., Kruskal, M.D., Interaction of Solitons in a Collisionless Plasma and Recurrence of Initial States. Phys. Rev. Lett. 15, 240-244 (1965)

[2] Drazin, P.G., Johnson, R.S., Solitons: An Introduction, Cambridge Texts in Applied Mathematics (1989)

[3] Xie, A., van der Meer, L., Hoff, W., Austin, R.H., Long-Lived Amide I Vibrational Modes in Myoglobin. Phys. Rev. Lett. 84, 5435-5438 (2000)

[4] Xie, A., van der Meer, L., Austin, R.H., Excited-State Lifetimes of Far-Infrared Collective Modes in Proteins. Phys. Rev. Lett. 88, 018102-1 - 018102-4 (2002)

[5] Penrose, R. The Emperors New Mind - Concerning Computers, Minds, and the Laws of Physics. Behavioral and Brain Sciences 13, 643-654 (1990)