# Optical Properties and Dynamic Behaviour on Mammalian Erythrocytes Subjected to Mechanical Stress

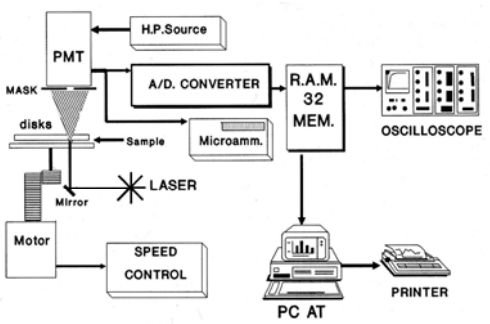
**A. M. Korol** **M.D'Arrigo** and **O. A. Rosso**
*Universidad Nacional de Rosario, Facultad de Ciencias Bioquímicas, Departamento de Matemática y Estadística, Departamento de Inmunohemtología, Suipacha 531, (2000) Rosario, Argentina.*
*Instituto de Física Rosario-CONICET*
*Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Ciudad Universitaria (1428), Ciudad de Buenos Aires, Argentina*

**Abstract**

Since traditional erythrocytes viscoelastic analysis is mostly qualitative, the nanoscale interaction between protein and lipids, and the development of new quantitative nonlinear methods is crucial for restricting the subjectivity in the study of the cell behaviour. These nonlinear methods, are particularly fruitful when they are strongly correlated with cells sensitive to initial conditions and allow a better understanding of their dynamics. An electro-optic mechanic system called erythrodeformeter has been developed and constructed in our laboratory, in order to evaluate the nanoscale interaction.
A numerical method formulated on the basis of fractal approximation for ordinary (OBM) and fractionary brownian motion (FBM), is proposed to evaluate sensitive dependence on initial conditions, based on the assumption that diffractometric data involves both deterministic and stochastic components, so it could be modelled as a system of bounded correlated random walk. The Correlation Coefficient, the Normalized total wavelet entropy, and the Jensen Shannon Complexity are nonlinear parameters, and are presented for samples from: healthy donors, diabetic and/or hypertensive, and α/β thalassaemia patients erythrocytes population.

**Background**

The basic idea of our application of time series analysis is to extract fractals parameters from the series that could reflect the nano interaction dynamical properties of the erythrocytes.
The experimental determination were carried out in a home made device called Erythrodeformeter, which has been developed and constructed in our laboratory for rheological measurements on red blood cells subjected to definite fluid shear stress. A laser beam (He-Ne laser), transverses the layer of shear deformed erythrocytes producing an elliptical pattern, the diffracted intensity falls onto a photomultiplier tube (PMT), after passing through a thin straight slot in a mask placed exactly on the corresponding axis of the elliptical pattern when the erythrocytes are subjected to fluid shear stress and also it is circular the red cells are at rest. This photometric readings are stored in files and used to calculate the sensitive dependence on initial conditions.

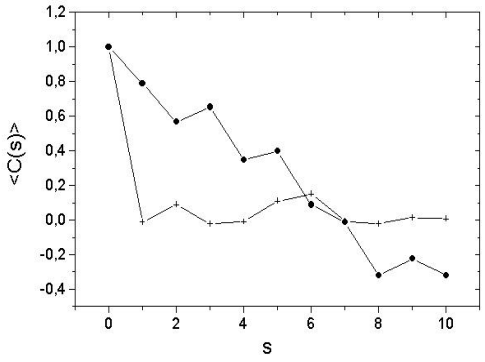


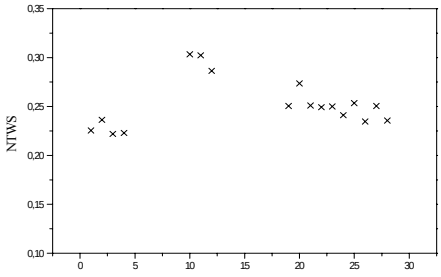

**Data analysis and methods**

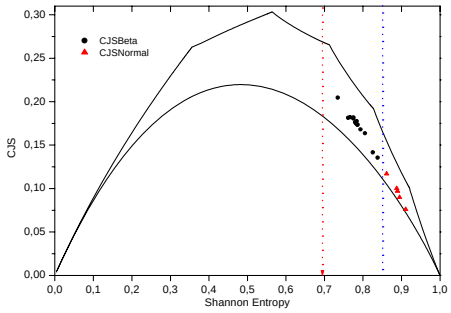
We hypothesize that the photometric readings could be modelled as a system of bounded correlated random walk. This approach is based on the assumption that diffractometric data involves both deterministic and stochastic components. A very convenient way, to reconstruct the dynamics of the process is to unfold the time series by successively higher shifts defined as integer multiples of a fixed lag τ ($\tau = m.\Delta t$), and taking N (N = 256x10), equidistant points for creep and recovery process.
In order to analyze the sensitive dependence with initial conditions, we generated two three dimensional phase space, the first one with diffractometric data corresponding to the process while the erythrocytes become deformed, which will be the creep space, and the second one with diffractometric data while the erythrocytes become relaxed and the first ten steps were studied and very different behaviours appears.

## Results and discussion

Here we report studies on healthy controls non alcoholic non smoker individuals, diabetics and/or hypertensive, α/β thalassaemic patients.
In order to compress information contained in the diffractometric data, in such a way that emphasizes the most significant characteristics, we must use not merely the observers' judgment but objective methods of analysis. The most simplest one is the Fourier transform, but it does not distinguish between chaos involving a small number of degrees of freedom and white noise, so this limits its application and leads us to turn to other method, notably that of a studying phase space trajectories, which offers significant advantages.
We shall argue that the red blood cells viscoelastic properties behave as a complex dynamical system, in which, under certain conditions, spatio-temporal patterns emerge spontaneously and techniques derived from non linear dynamics and chaos theory can be adapted to quantify their dynamical behaviour.
The *Correlation Coefficient* results suggests that in dyslipidemic patients without medical treatment it decreases while we increase the steps, in other words, the stress process gives us some special information of the relaxation one and the series exhibit a great sensitivity to initial conditions. On the other hand, on healthy donors, as well as on patients that received medical treatment, it seems to be independent of the steps and intrinsically unpredictable.
The *Normalized Total Wavelet Entropy* was also applied to measure the order/disorder degree of the process and three different clouds could be distinguish.
The *Complexity-Entropy plane* provides information about the different clouds of samples population of healthy individuals and β-thalassaemic patients which could not be found otherwise.
The evidence of the influence of the changes in the erythrocytes viscoelastic properties that could be detected by light diffraction patterns and by the fractals parameters, show a good deal of promise and the possibility of a better understanding of the rheological erythrocytes aspects and also could help in clinical diagnosis.




## References

1. A.Korol, and R. Rasia, . "Signatures of deterministic chaos in dyslipidemic erythrocytes under shear stress" *CHAOS*, Vol. **13**, N1, pp 87-93. (2003)
2. A.Korol , R. Rasia and O. Rosso. *Alterations of thalassemic erythrocytes detected by wavelet entropy.* Physica A, **375** pp. 257-264 (2006)
3- A.Korol , P. Foresto and O. Rosso. *Self-organizing dynamics of human erythrocytes under shear stress.* Physica A, **386** pp. 770-775 (2007)
4.- A.Korol , P. Foresto and O. Rosso. *Diabetic Erythrocytes Test by Correlation Coefficient* The Open Medical Informatics Journal,**2**, pp.105-110. (2008).