Ultrafast Dynamics of Carboxy-Hemoglobin: Two-dimensional Infrared Spectroscopy Experiments and Simulations

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We present high-resolution 2D-IR measurements and detailed simulations of HbCO with a good agreement between theory and experiment. The simulation shows the strong effect of the distal histidine through a hydrogen bond, which is responsible for the slow decay of the frequency-frequency correlation function.

Understanding the structure and dynamics of proteins is an important research challenge that needs to be addressed in order to understand their physiological function. The development of two-dimensional IR spectroscopy (2D-IR) in the past decade has allowed for the study of the real-time dynamics of proteins from femtosecond to picosecond timescales. Hemoproteins are important in physiology because they are responsible for transport and storage of oxygen. Hemoproteins-CO complex have been widely studied in the past, both experimentally and theoretically as a probe of the Hemoproteins dynamics. In particular, it is known that carboxy-myoglobin (MbCO) exhibits complex dynamics with inter-conversion between different sub-states [1]. Fewer spectroscopic studies have been performed to resolve the dynamics of the carboxy-hemoglobin (HbCO), which is known to have different dynamics than the more frequently studied MbCO [2].

Here, we present high-resolution 2D-IR measurements of HbCO at equilibrium as well as detailed simulations based on a semi-classical model. The model describes directly the fluctuations of the potential energy surface (PES) originating from the electrostatic environment and the heme group, and was previously used to simulate vibrational ladder climbing and coherent control experiments [3]. The agreement between theory and experiment (see Fig. 1) is achieved without using any adjustable parameters, which demonstrates the ability of our model to describe the internal protein dynamics [4]. Our simulations show the strong effect of the distal histidine through a hydrogen bond, which is responsible for the slow decay of the frequency-frequency correlation function.

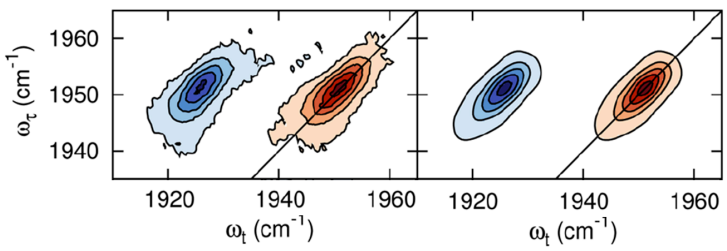

Fig.1 Experimental (left) and simulated (right) 2D-IR spectrum of HbCO obtained for a waiting time T = 0.5 ps. The horizontal axis shows the probe frequency, resolved by use of Chirped-Pulse Upconversion [5,6] whereas the vertical axis is the pump frequency, obtained as Fourier conjugate of the time delay τ continuously scanned from 0 up to 30 ps.

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