COMPUTATIONAL INSIGHTS INTO THE CHIRAL SUM FREQUENCY GENERATION RESPONSE OF WATER SUPERSTRUCTURES SURROUNDING AN ANTIPARALLEL β-SHEET

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Hydration modulates the structure and function of biomacromolecules. However, probing water structures in hydration shells remains difficult due to a large background signal from bulk water and the dynamic nature of the solvation layer. Chiral vibrational sum frequency generation (SFG) spectroscopy can probe the solvation shell around a chiral solute without interference from the bulk. Computational modeling can guide the interpretation of chiral SFG spectra of water structures in hydration shells. We develop and apply computational methods to predict chiral SFG responses of water around a model protein system, the antiparallel β-sheet $LK_7\beta$, at the air-water interface. The SFG response of chiral water superstructures around the protein is modeled with molecular dynamics simulations and an electric field mapping strategy. Our computed spectra agree qualitatively with experimental results and flip when the amino acids are replaced with their (D-) enantiomeric equivalents. We show that the spectroscopic response of the chiral water assemblies arises from both strong and weak hydrogen bonds between water and protein. Intra- and intermolecular vibrational couplings of water molecules are shown to be necessary for generating the chiral SFG response. These results will improve our understanding of macromolecular solvation, a key factor in protein folding, denaturation, and ligand recognition. This study establishes a computational framework to support further development of chiral SFG in revealing the structure of biomacromolecular solvation shells, complementing current structural biology methods.