From photon to neuron: the molecular mechanism of the primary event in vision

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The activation of rhodopsin, the light-sensitive G-protein coupled receptor responsible for dim-light vision in vertebrates, is driven by an ultrafast excited state double-bond isomerization with a quantum efficiency ($\Phi_{cis\text{-}trans}$) of almost 70%. The origin of such a high light sensitivity, ultimately allowing the human eye to detect even single photons, is not understood. A key unanswered question is whether and how the level of synchronization between different receptor vibrational modes controls the $\Phi_{cis\text{-}trans}$ value. Here, we employ hundreds of quantum-classical trajectories to show that, 15 femtoseconds after photon absorption the excited state population of rhodopsin splits into subpopulations reacting with different velocities and leading to distinct contributions to $\Phi_{cis\text{-}trans}$. We find that each subpopulation and $\Phi_{cis\text{-}trans}$ contribution, is associated with a different phase relationship between specific critical vibrational modes. We also show that the population splitting is modulated by the protein electrostatics, thus linking amino acid sequence variations to $\Phi_{cis\text{-}trans}$ modulation.

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