DUAL PHOTOSYNTHESIS: EFFICIENCY OF PHOTOSYNTHETIC PIGMENTS IN EXTREME CONDITIONS

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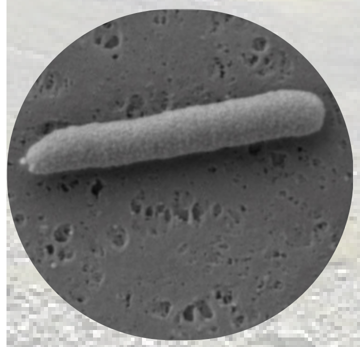
GLOBAL PROBLEM

Organisms in isolated ecosystems with unusual environmental conditions often develop unique structural and functional features as part of their survival strategies. As human activities increasingly impact the environment, significantly reducing biodiversity, studying, the adaptive features becomes crucial for preserving these species. Understanding how those organisms adapt to extreme environments could also have broader implication, including potential uses in biotechnology, such as energy production and environmental monitoring.



INTRODUCTION

This project is devoted to the study of the excited state dynamics of the light-harvesting antenna-reaction center complex of bacteria recently discovered in an Alpine mountain lake at an altitude of 2417 meters. These heterotrophic bacteria are unique because they encode a fully functional bacteriochlorophyll-based photosynthetic apparatus alongside xanthorhodopsin (light-driven proton pump). The bacteria preferentially use one of these systems under specific conditions. Recently it was found out (Kopejtka et al., 2022) that xanthorhodopsin is efficiently expressed at temperatures below 16 °C in the presence of light, while bacteriochlorophyll is expressed between 4°C and 22°C and only under dark conditions. This suggests that dual phototrophy may provide significant advantages, particularly in environments characterized by extreme light and temperature fluctuations. The presented experiments on bacteriochlorophyll complex were performed at varying temperatures and additional illumination to simulate varying environmental conditions. Next, the same series of experiments will be conducted for the second photosynthetic complex - xanthorhodopsin with a nostoxanthin antenna. This comparative study will illustrate the differences in energy transfer and photoprotective mechanisms employed by the two distinct photosynthetic systems.

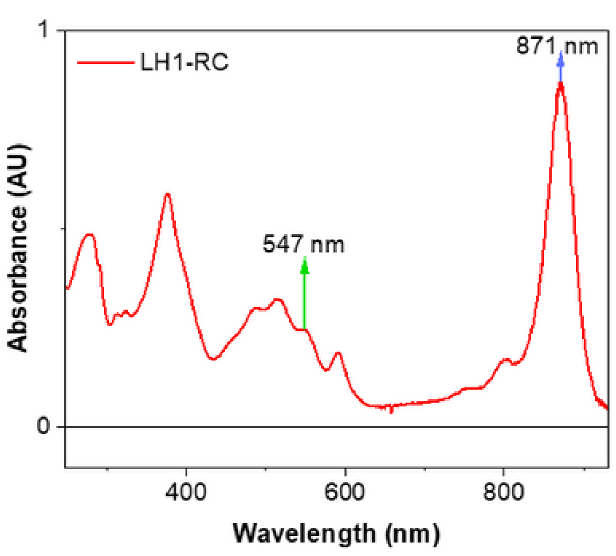
THE METHODOLOGY

One of the most powerful tools for studying photosynthetic complexes is **time-resolved spectroscopy**. This technique allows researchers to track the excited state dynamics following the excitation of specific pigments within the complex. The process involves two ultrashort laser pulses. The first pulse, known as the **pump**, excites the molecules to higher energy states. The second pulse, called the **probe**, is sent to the sample with a variable time delay relative to the pump pulse. The absorption difference spectra are then calculated by subtracting the spectra of the sample in the ground state from those in the excited state. This method provides insights into the efficiency of light-harvesting, energy transfer between states or pigments, and the quenching of reactive pigment species.

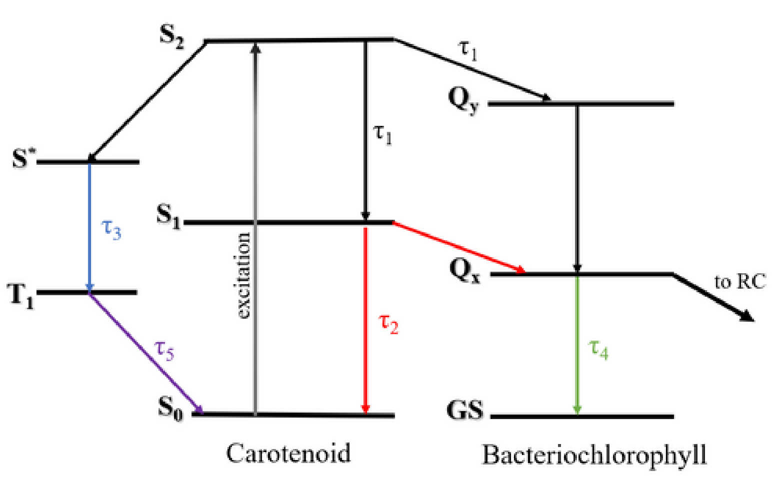
RESULTS

Bacteriochlorophyll-based systems are large pigment-protein complexes that can operate effectively even under low-light conditions due to their high pigment content. These molecules absorb light in the UV and IR parts of the spectrum. The photosystems also include the carotenoid spirilloxanthin, which absorbs **blue**-**green** light—a wavelength not accessible to bacteriochlorophyll—and subsequently transfers this energy to bacteriochlorophyll.

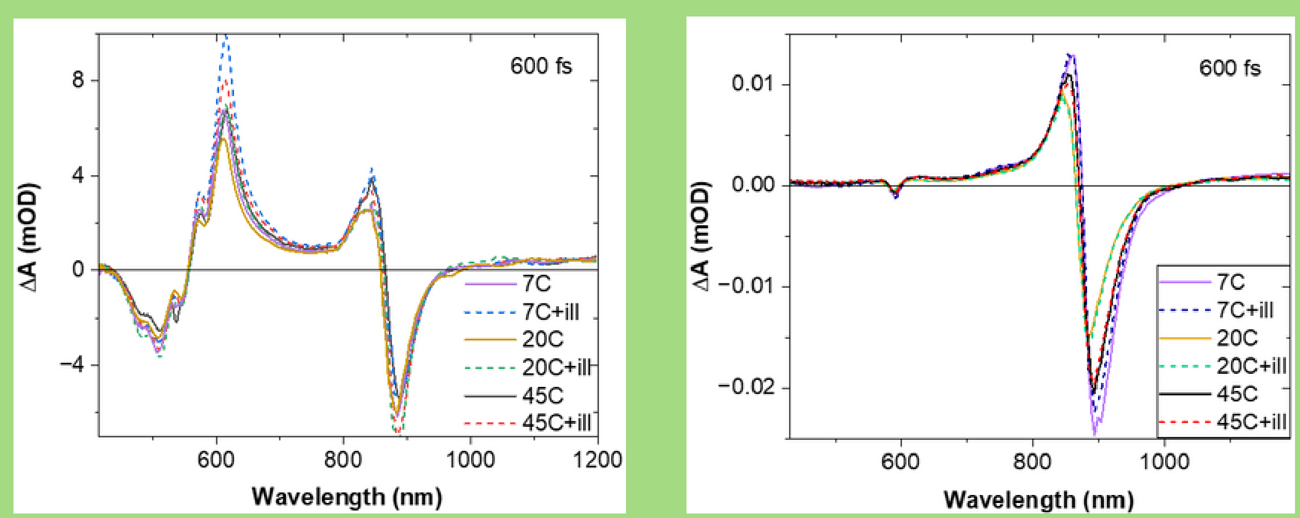
Absorption spectra
Arrows represent the excitation wavelengths used in the experiments.



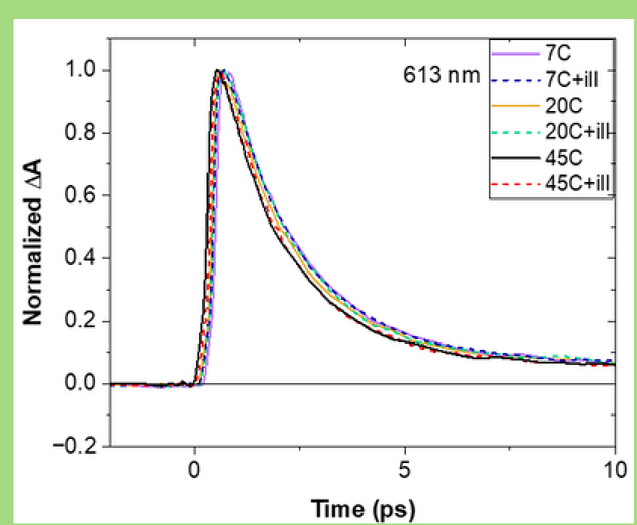
Suggested energy diagram of the studied complex



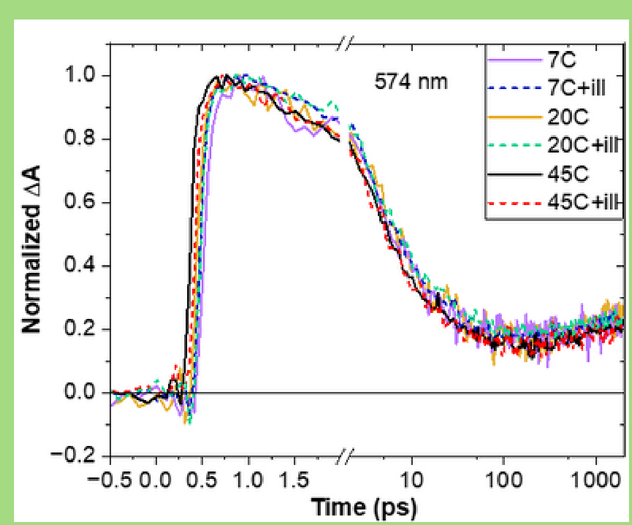
Bacteriochlorophyll complex dynamics after excitation of **S2** state of the carotenoid at a wavelength of **547 nm** at naturel temperature for the mountain lake: 7°C and 20°C, and **extreme** temperature 45°C.



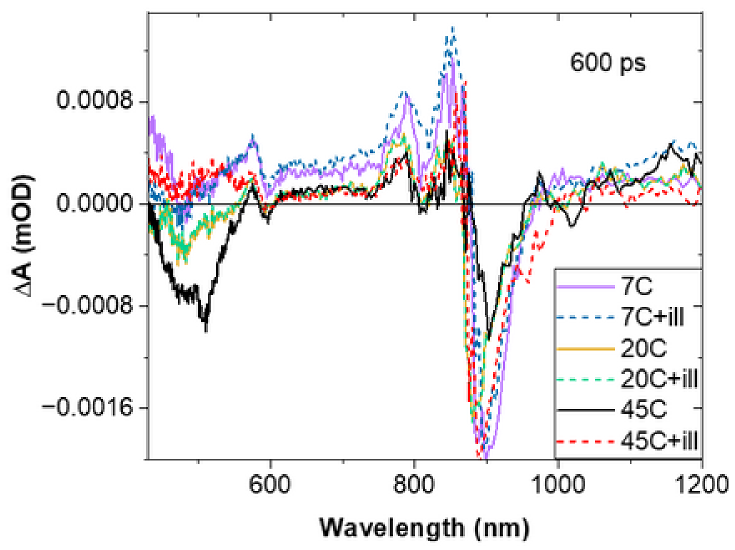
Kinetic traces taken at 613 nm follows the relaxation of carotenoid **S1** state lifetime.



Kinetic traces taken at 547 nm presents the **S*** state of carotenoid at the early timescale and the later rise of carotenoid triplet state.



Bacteriochlorophyll complex dynamics after excitation of **Qy** state at a wavelength of **871 nm** at the same conditions.

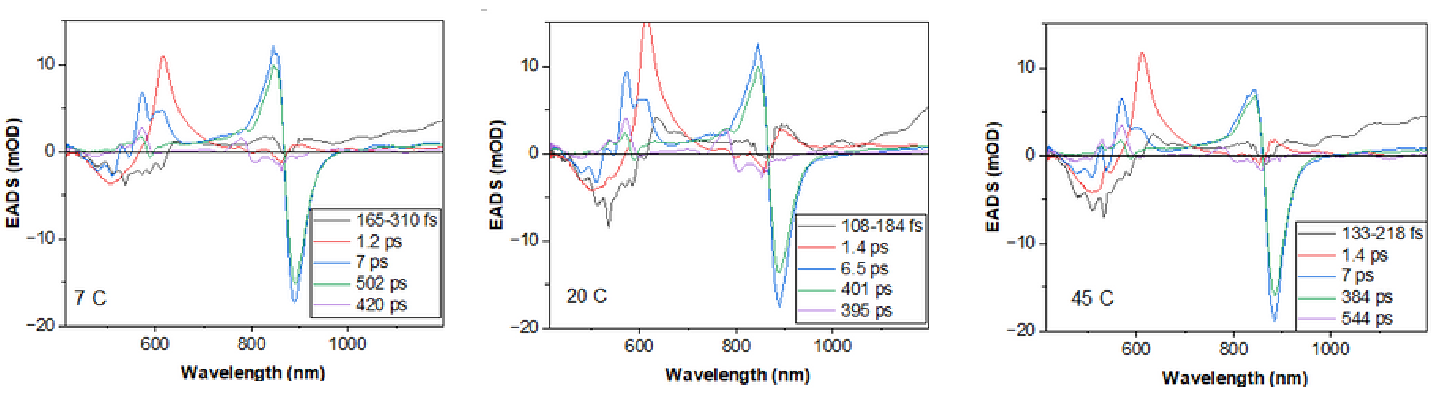


Carotenoid triplet

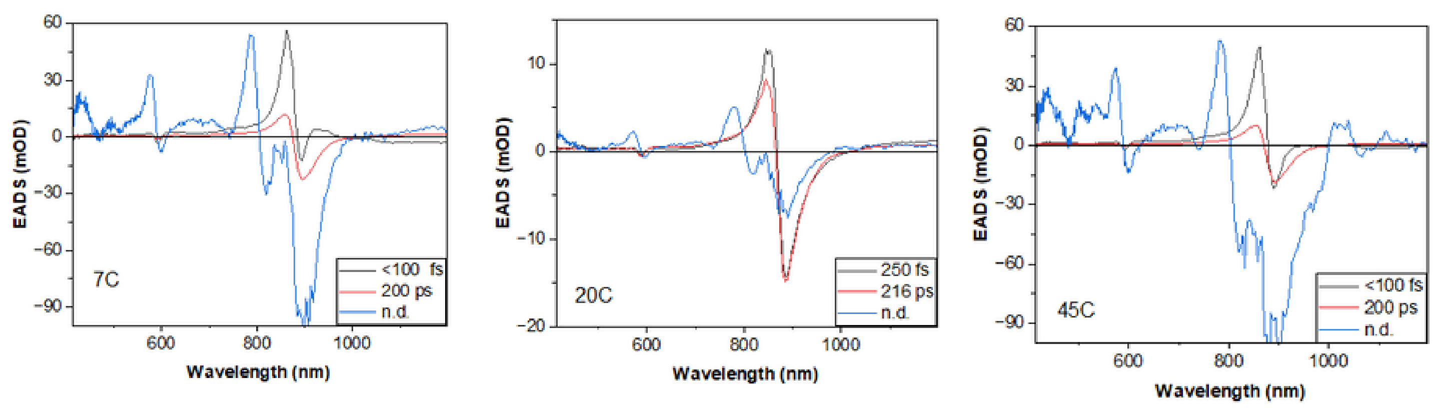
This part of the photosynthetic complex may play a photoprotective role in efficiently quenching the triplet excited state of the BChl, which otherwise may produce deleterious reactive oxygen species.

Global and target analysis of time-resolved spectra following excitation of spirilloxanthin (547 nm) and bacteriochlorophyll (871 nm) of the bacteriochlorophyll complex

547 nm excitation



871 nm excitation



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