The discovery of an efficient process to carry out artificial photosynthesis seems to be the philosopher's stone of modern civilization. Developing such highly advanced technologies without an accurate description of phenomena occurring on the atomic scale seems impossible. The theory of open quantum systems comes to our aid, thanks to which we can understand how the smallest components of the matter that surrounds us interact with their surroundings. In particular, it allows describing quantum systems in a dynamical way, that is, to predict changes in their state in the time domain. However, if the environment is too complex, an accurate description of the entire system becomes impossible, and we can only rely on a statistical description, i.e., effective and approximate.

The theory of open quantum systems itself, despite its great successes, has also been burdened with some problems so far. Its leading equations either had limited applicability (GKLS master equations), or their predictions had unclear interpretation (Bloch-Redfield equation). To this day, researchers are engaged in a lively discussion about which type of equations should be used and in what situations. However, recently, it has been proposed how to get rid of these problems, in a general way, by using yet another type of dynamic equations (regularized cumulant equations).

The research task carried out in this project is to analyze the performance and reliability of the newly proposed dynamic equations. To achieve this, we use the most effective method possible, i.e., use them to describe two carefully selected physical systems and compare the obtained results with other approximate or accurate methods whenever possible.

The first of the selected systems is a structure consisting of three energy levels. We describe it using the "first principles" of quantum mechanics so that it reflects the three selected energy levels in an atom interacting with an external electromagnetic field (e.g., visible light). It is worth adding that this system has already been studied in the context of artificial photosynthesis. The second system is a well-known case in physics of a quantum (damped) harmonic oscillator interacting with an environment consisting of a large collection of other similar oscillators. We chose this case because of the possibility of comparing the newly proposed method with the exact results.

Our research hypothesis suggested that a new type of dynamic equations may prove to be an effective and efficient way of describing the dynamics of open quantum systems, free from problems arising in other approaches. If our research hypothesis confirms true, the new dynamic equations may replace the existing methods of describing open quantum systems. Moreover, they can be used by other scientists as new, better working tools and contribute to discovering hitherto unknown physical phenomena, a deeper study of already known phenomena, and, consequently, the development of new technologies.