Water, mineral salts and more complex molecules such as amino acids and proteins are undisputedly crucial to our existence. An interesting and important, but not well-explored yet group of molecules, is a family of naturally occurring molecules called *porphyrins*. Various kinds of *porphyrins* are used in a multitude of biochemical processes, including those taking place in our body. They are found in our blood stream, as the main building block of hemoglobin, which is responsible for transporting the oxygen. They are also a part of vitamin D12 complex, which we need for proper functioning of our nervous system. In plants *porphyrins* make up complex molecular systems that absorb the sunlight and thus play an active role in photosynthesis.

The significance of *porphyrins* and the role they play is strongly connected to their structure and dynamics. *Porphyrins* contain mobile hydrogen atoms that constantly change their position within the molecule. This makes the molecule switch continuously and extremely fast between two chemical structures, a process known in chemistry as *tautomerization*. In the proposed research I will use *porphycenes*, structural 'cousins' of *porphyrins*, as a model system that exhibits ultrafast *tautomerization*.

So far, the hydrogen dynamics in *porphycenes* has been studied in solutions, where the interaction between many molecules obscures the observation of the hydrogen motion within one molecule. To see exactly how fast *tautomerization* takes place in a molecule we need to investigate these molecules in isolation, which leads me to the main question of my research proposal:

How fast do hydrogen atoms move and hydrogen bonds rearrange in a single porphycene molecule?

Once this is achieved I will expand the experiment and expose the molecules to different environments. For this I will put them in different polymer films and on different substrates. In addition, I will study various types of *porphycene* molecules, which differ in chemical structure in order to investigate how the intramolecular architecture of *porphycenes* defines the tautomerization dynamics.

Answers to the above questions will give us much needed insight into *tautomerization*, one of the most fundamental chemical processes and will help us to understand why did Nature design these molecules this way and not another; all that with a vision in mind that perhaps one day we will be able to better mimic Nature and harvest its knowledge to our own use. With this research we will at any rate be able to better understand the mechanism behind the hydrogen transfer and hydrogen bond rearrangement, as it is still debated among researchers. Moreover, the proposed experiments will pave the road for the study of hydrogen transfer and hydrogen bonding dynamics in complex biomacromolecules. Fascinated by the properties of naturally occurring *porphyrins*, chemists have been making synthetic variants such as *porphycenes* and using them to build more complex artificial molecular structures. For instance molecule-based circuits capable to perform certain operations using light or charge have been realized. Therefore knowledge about the ultrafast hydrogen transfer dynamics and the ability to measure it in individual *porphycenes* may in the future proof very useful for designing molecular nanophotonic systems.

The challenge of this research lies in how we can monitor a process that lasts only a tiny fraction of a second (picoseconds=millionth of a millionth of a second) and how we can do that with only a single molecule. In order to 'see' a single molecule we need to use a very sophisticated microscope. Nowadays, 26 years after individual molecules were detected for the first time, the field of single molecule microscopy is thriving and we have all the necessary technology to efficiently detect, analyze and even manipulate individual molecules. However, just seeing individual molecules is not enough to investigate the dynamical processes that happen inside a molecule. To achieve our goal we will use ultrashort laser pulses. In analogy, if we want to take a photo of a fast moving object (let's say a racing car) the photo needs to be taken very quickly, otherwise the photograph becomes blurred and we can't distinguish details of the car. In spectroscopy researchers use lasers that can produce very short pulses of light, which allow us to 'freeze' the motion of a fast moving object, like molecules and atoms, and to determine their properties. By taking a series of such ultrashort snapshots of the hydrogen in the molecules I will be able to resolve its motion. This rare experimental combination of single molecule microscopy and ultrafast (femtosecond) spectroscopy, is an emerging new technique, which only a handful of laboratories around the world uses.