Spectroscopy delivers wide variety of information about our world, from composition of exoplanets atmospheres in service of searching for life in the universe, through pressure, temperature and chemical compounds in the Earth's atmosphere needed for tracking and understanding climate changes, identifying sources and kinds of pollutants, and providing real-time data on air quality, to applications in non-invasive medical diagnostics, detection of trace amounts of explosives and monitoring dynamics of chemical reactions. It provides information on fundamental physical processes and may address questions crucial for our understanding of the world, such as one about invariability of physical constants.

Many of the above as well as not mentioned here applications of spectroscopic measurements require sub-percent measurement accuracy. This cannot be achieved without high quality reference data regarding positions, intensities and shape of spectral lines, which in many cases is unavailable, yet. Over the years huge amount of spectral data has been collected and stored in spectral databases, however their quality is often too low for applications where sub-percent accuracy is required. Most of that data originates from theoretical calculations, which cannot be truly accurate for molecules more complicated from the simplest one, which is hydrogen. Data of experimental origin also in many cases doesn't fulfill accuracy requirements.

Over last years there has been observed substantial progress in experimental techniques, which enables high accuracy data to be obtained in laboratory conditions. In case of very weak absorption lines in gaseous samples, which are considered in this project, the most accurate measurement techniques are those enhanced by high finesse optical cavities, such as cavity ring-down spectroscopy (CRDS), cavity mode-width spectroscopy (CMWS) and cavity mode-dispersion spectroscopy (CMDS), which we intend to apply in our research. However, despite the availability of these techniques, it is literally impossible to experimentally determine reference data for all applications due to its huge amount. On the other hand, *ab initio* methods of determining molecular line intensities were evolving simultaneously with experimental techniques. Presently, they enable highly accurate determination of absorption line intensities for small molecules, supposing that they are supported by high quality experimental data. This approach enables proper prediction of line intensities in spectral regions where laboratory data is unavailable. In the project we will apply this approach, together with our partners from theoretical molecular spectroscopy group, to molecules of great importance for atmospheric studies such as water, carbon monoxide and carbon dioxide.

Another difficulty in collecting spectral data is caused by the fact that spectra of various isotopologues, belonging to the same chemical compound, differ from each other. In this context the question about transferability of highly accurate spectral data between isotopologues is of great importance. In our research we intend do address this problem for the case of carbon monoxide molecule, which is relatively simple from point of view of theoretical calculations. We will experimentally verify whether *ab initio* calculations can be transfered from major to minor isotopologues. Besides that we are going to measure line positions of oxygen minor isotopologues lines, which will be further used for retrieving their energetic structure. This is another problem within our study devoted to minor isotopologues.

In most of applications it is assumed that spectral line area, i.e. absorption coefficient integrated over the line, is proportional to absorber concentration, which is equivalent to independence of line intensity on absorber concentration. This assumption is valid within impact approximation, underlying most of spectral line shape theories and resulting model line profiles. Its validity was confirmed in many experimental investigations for different systems. However, it also has been shown in carefully chosen systems that non-impact effects, going beyond these theories, can be observed. Among them the most important one is collisional decrease of line intensity, which causes that in certain conditions observed line intensity is no longer independent on absorber concentration, as it is reduced due to molecular collisions. In the context of atmospheric research, where accuracy demands are continuously increasing, the question about invariability of line intensities needs to be re-addressed. If this invariability is confirmed with the highest accuracy that can be presently obtained in laboratory conditions, it enables reliable increase of remote observations accuracy. Otherwise, it will indicate present accuracy limits and point out new direction for further research oriented for applications requiring the highest accuracy.