Space and time are crucial concepts in our lives. Hence, scientists and philosophers have thought about them since ancient times. Albert Einstein revolutionised our worldview by two remarkable observations at the beginning of the last century: space and time are not different phenomena. They arise from one unified object, spacetime. Moreover, they are not just the rigid stage on which physics plays out but dynamic participants that interact with matter and energy. By formalising these basic ideas in the mathematical framework of Riemannian geometry, one of the two pillars of theoretical physics, general relativity, was born. It shapes physics until today by predicting gravitational waves and black holes with Nobel prices in 2017 and 2020. Even satellite navigation, a key technology of the 21st century, would be impossible without corrections due to general relativity.

Despite this success, our understanding of space and time is far from complete. At the extremely small Planck length scale of $10^{-}35$ m (over 100 billion billion times smaller than a proton), general relativity and quantum field theory, the second pillar of modern physics, contradict each other. Generations of physicists tried to find the solution to this puzzle, a theory of quantum gravity. But despite considerable progress during the last decades, there is much more work to be done. But one thing is certain: our notion of spacetime has to change again dramatically at very small distances and high energies when the weakest of the four fundamental forces, gravity, becomes dominant. In particular, it is impossible to explain the interior of a black hole or the very beginning of our universe without replacing the current geometric notation of space and time with the more elaborate concept of quantum spacetime. At this point, two questions, that form one of the big puzzles of contemporary physics, are imperative:

1) What are the fundamental properties of quantum spacetime?
2) What is the appropriate mathematical framework to describe it?

The proposed research programme will address both. Current experiments can not probe the relevant energy scales. Still, all known laws of physics have to be compatible with whatever one might find. The resulting consistency conditions are very restrictive and guide the search for answers. Due to their dynamic nature, the number of different quantum spacetimes is infinite. While answering the questions above for all of them in one shot is the ultimate goal, it is much too ambitious with the tools at our disposal. Therefore, we instead work on a subclass of examples to lead the way. All of them are distinguished by powerful symmetries. However, symmetry is a two-edged sword: it guarantees the required computational control but can be so constraining that it kills all non-trivial phenomena at the same time. We manage the balancing act by introducing quantum Poisson-Lie symmetry. It is much less restrictive than all other symmetries considered before and permits to analyse a huge number of quantum spacetimes with general features.

Poisson-Lie symmetry is motivated by another change of paradigm where point-like particles are replaced by microscopic closed strings at the Planck scale. The latter provide a consistent UV (ultraviolet = high energy) completion of gravity and are the most developed proposal of what general relativity at arbitrarily high energies might look like. Due to their extended nature, strings probe spacetime very differently from point particles and therefore exhibit the new phenomena of dualities. For example, T-duality states that two seemingly unrelated spacetimes are still indistinguishable from a string's point of view. In its best understood and simplest manifestation, T-duality applies only to spacetimes containing one or more circles. But this case is very restrictive and rules out most of the scenarios where insights into quantum spacetimes are desperately needed these days to

- resolve singularities in black holes and at the beginning of our universe,
- reveal the underlying mechanism behind the AdS/CFT correspondence, another central duality that relates gravity in Anti-de Sitter (AdS) spacetime to a conformal field theory (CFT) on its boundary,
- understand how string theory can accurately describe our universe in terms of flux compactifications,
- and eventually better understand the close relationship between information theory and quantum gravity.

We overcome this problem and expedite progress in all four domains by pushing the most general version of T-duality, Poisson-Lie T-duality and the underlying Poisson-Lie symmetry beyond the classical limit. Thereby, we can systematically derive fundamental properties of quantum spacetimes directly from string theory, understand the implications for the AdS/CFT correspondence and eventually identify the appropriate mathematical framework that supersedes Riemannian geometry. Besides, new and most likely groundbreaking insights into one of the central questions of theoretical physics with high impact across the fields above, we will build a new research direction in Poland and establish it at the top of the international community.