Universal behavior is the fundament of statistical physics. Different physical systems belonging to the so-called universality class can show similar global behavior when crossing the phase transition point regardless of the microscopic mechanisms governing the physics of the phase. It is exciting when studying lower-dimensional systems, especially in 2D, where an infinite-order phase transition of Berezhinskii-Kosterlitz-Touuless is expected. This physics is currently relatively well understood in systems in thermal equilibrium, and existing theories describe experimental results well.

Description of universal behavior is captured within the so-called Kibble-Zurek mechanism. This theoretical framework describes universal laws of the formation of defects in a system, which rapidly crosses a critical point of a continuous phase transition. This theory succeeded in the broadest range of applications, starting in describing the universe's properties after the cosmic inflation period and ending at various other classical and microscopic quantum systems. In the experiment, crossing the phase transition point with a controllable rate is important to see how the system responds to different transition rates when reaching the phase transition. This experiment is often called a quench. This principle is similar to what a blacksmith is doing when rapidly quenching very hot steel in cold water. If done correctly, it improves its macroscopic mechanical properties because of specific freezing out of phase and buildup of desired strain in the system microscopically.

In this project, we will study a system of a widely unexplored class, the driven-dissipative quantum fluids of light. Our system is made of hybrid quasiparticles, called microcavity exciton-polaritons, which are bosons characterized by properties of light and matter together. This enables them to form superfluid Bose-Einstein condensate at high temperatures compared to ultracold atomic gases. Due to the escape of light out of the microcavity sample, their open and dissipative nature differs them from systems in complete thermal equilibrium. We aim to determine if the known theories and universal laws describing equilibrium systems still apply to the polariton condensate.

We will develop new experiments to study the hydrodynamic properties of polariton quantum fluid in detail. We will deterministically excite sound waves in the condensate or excite specific oscillations, causing sloshing of the superfluid in an optical trap. This will allow us to study the subtle properties of the system by checking the speed of sound wave propagation in the system. Additionally, we will perform the quantum quench by ramping the excitation power at different rates and see how our system responds to these experimental circumstances.

It is believed that the results of our project will lay a foundation for understanding phase transitions in nonequilibrium systems, pushing forward the frontier of this field of physics. We also aim to trigger new research by utilizing novel experimental techniques that have never been used previously.