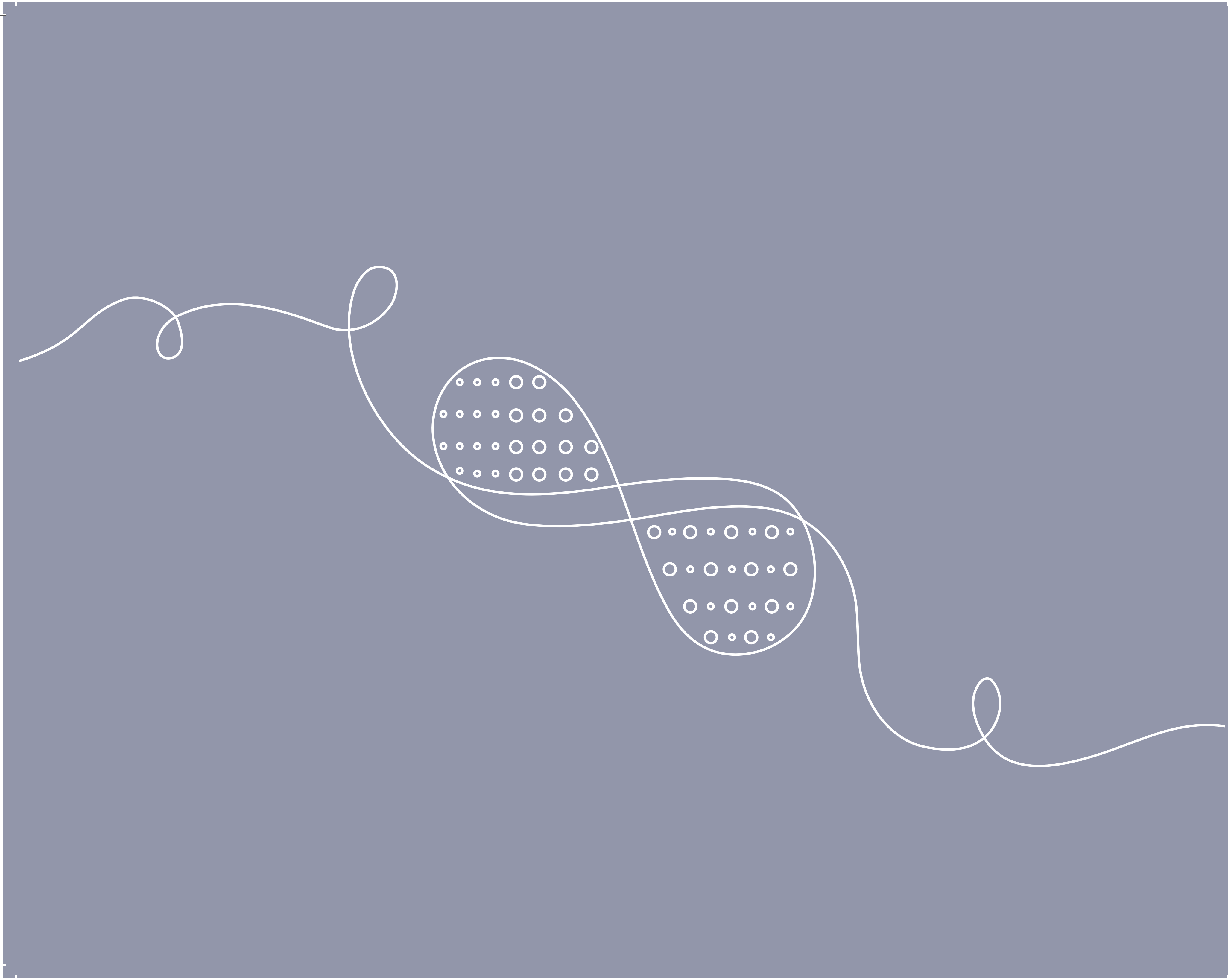

The quest for time crystals: A new phase of matter

The quantum world is an unexplored frontier for scientists. It is a world where the laws of classical physics that we hold inviolable don't apply. Albert Einstein famously was not in favor of quantum physics precisely because the theory defied all commonsense notions of classical physics. It should come as no surprise then that time crystals, objects that defy the second law of thermodynamics exist in the quantum world. It is a world strange enough to make a perpetual motion machine possible—something impossible in the world we live in thanks to friction.

When we think of crystals in the general sense of the word, we usually think of diamonds or other types of crystals. For physicists, crystals are objects of symmetries and the breaking of those symmetries. And time crystals (until recently) were hypothetical structures that move in regular repeating patterns without requiring energy. These structures manage to be both stable and ever-changing at the same time.

Time crystals also defy what we know about phases of matter. For example, water can remain water or become ice, meaning that their thermal equilibrium remains stable and the atoms that make them up remain at the lowest possible energy permitted by the temperature of their environment. A time crystal on the other hand is a phase of matter that remains both at equilibrium and in an excited and evolving state at the same time.

The idea of the time crystal was first posited by the Nobel laureate Frank Wilczek in 2012.

Prof. Vedika Khemani is a condensed matter physicist who helped demonstrate that a time crystal was not just a hypothetical state of matter but something that was actually possible. Prof. Khemani and her collaborators used the quantum computer at Google to experimentally demonstrate the existence of time crystals.

Prof. Khemani's original work on many-body localization is what helped her demonstrate time crystals. The many-body localization theory posits that a one-dimensional chain of quantum particles can get stuck in a fixed state—a state known as many-body localization. This was the first component of a time crystal. The next phase of the experiment was to see what happens when a many-body localized system is hit with a laser. Khemani and her collaborators found that it moves between two different many-body localized states in a repeating cycle without using up or expending energy. In 2019, Google announced that the Sycamore quantum computer had completed a task in 200 seconds that would take a normal computer 10,000 years to complete. Quantum computers are made up of qubits which are quantum particles that can be controlled. Google's qubits are made of superconducting strips of aluminum, which have two possible energy states. Khemani's collaborators at Google used a chip with 20 qubits that could be programmed for different strengths of interactions, making the time crystal possible.

The practical applications of time crystals remain to be seen.