Casting a light on nonequilibrium phenomena

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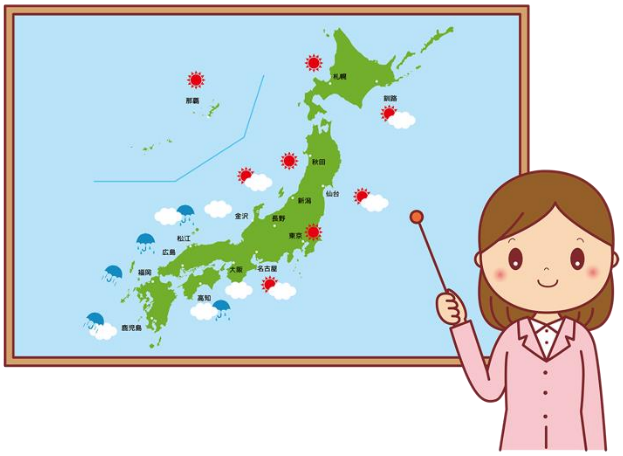

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There are predictions everywhere in our daily lives, and they are so commonplace that we are often making use of them unconsciously. For instance, I took trains to the university today instead of riding a bicycle, trusting the weather forecast saying it would rain in the afternoon. Besides the weather forecast, there are a variety of predictions that our society relies on, such as earthquake warnings, solar activity prediction for forecasting radio disturbances, and so on. The encounter with these technologies marked the beginning of my journey into the world of physics.

In my childhood, my family used to turn on the TV around 7 pm and watch the weather forecast while having dinner together. At that time, the weather forecast seemed like a magic box full of mysteries. Fascinated by the graphical visualization of the moving clouds and precipitation, I was totally absorbed in it every day. But then, I gradually began to wonder how it worked. How can you predict the appearance, the disappearance, and the movement of clouds? How can you calculate the chance of rain? Also, I wondered why it sometimes gave wrong predictions (actually, the weather forecast accuracy is only around 80%). I was so curious about the principles behind the weather forecast, and at that time, I wanted to be a meteorologist. Since then, I have always been excited about how science empowers humankind.

The road of life is not straight, full of hills and curves, and my life was no exception. Starting from meteorology, my interest has changed a lot over time up to now. One time I was obsessed with chemistry, and at another time I was also interested in mathematics. Some of you might have wavering interest, but I believe studying what you are interested in at each point of your life is the best, as you never know how your experience in the past affects your future.

In graduate school, my interest finally converged to nonequilibrium statistical physics, which I will explain later. Let me briefly introduce my research field, "nonequilibrium statistical physics", and why it is important. Before explaining what "nonequilibrium" is, let us start from "equilibrium". Consider a water bottle with a closed lid. If you leave it alone for a while, it reaches a certain state, where no changes seem to happen. There is no flow of water, and the temperature, pressure, and volume become constant. This static state realized after leaving the closed system for a long enough time, is called the "equilibrium" state. On the other hand, all the states other than equilibrium are called "nonequilibrium". Flowing water in rivers, the tides of the ocean, life, and even the whole universe are good examples of nonequilibrium phenomena. Among diverse phenomena happening around us, most of them are classified as "nonequilibrium".

Subsequently, I must explain what "statistical physics" is. Statistical physics is a theory to calculate macroscopic quantities from the microscopic details of a system using probabilities. When you think of gas, it consists of numerous molecules, typically around 10^{23}. The number is enormous, so it is impossible to track the motion of each molecule. Instead, we consider the probability distribution of the energy/velocity of the molecules, which enables us to calculate macroscopic quantities such as the total energy and pressure.

Statistical physics is classified into two kinds. One is equilibrium statistical physics to explain the equilibrium state, and the other is nonequilibrium statistical physics to explain the nonequilibrium state. Equilibrium statistical physics was a quite successful theory constructed from the end of the 19th century to the beginning of the 20th century. However, as I mentioned, the equilibrium state is just the tip of the iceberg, compared to all kinds of natural phenomena. Therefore, extending it to nonequilibrium has been one of the central topics of physics.

Through a series of research for almost a century, various innovations have been made. Nevertheless, there are still many open questions to be solved by the next generation of scientists. I am one of the scientists working on one of these, and my main interest is the relationship between fluctuation and dissipation of the quantum nonequilibrium steady states. There is a famous theorem called the fluctuation dissipation theorem which is an equality between the fluctuation and the dissipation which holds in thermal equilibrium state. However, the theorem is known to be violated in nonequilibrium steady states, and the amount of violation is expected to have a relation with some kinds of flows, such as energy flow and spin current.

My research is fundamental, rather than applicational, so there won't be a direct application to our society. However, I believe this research will deepen our understanding of the nature of the nonequilibrium steady state, which enlarges the range of phenomena that we can explain. Also, the finding may have experimental significance, as it might enable us to measure some flows by measuring the fluctuation and the dissipation. This new measurement technique can further lead to the advance of nonequilibrium statistical physics. Ultimately, I hope we become clever enough to foresee weather disasters.

Declaration:
Grammarly is used to correct spelling, typo and grammar mistakes.