Source : www.thehindu.com Date : 2021-10-10

EXPLAINED

Relevant for: Science & Technology | Topic: Science and Technology- developments and their applications and effects in everyday life

Hidden patterns: Syukuro Manabe and Klaus Hasselmann won the prize for the physical modelling of Earth’s climate. Giorgio Parisi has been honoured for the discovery of the interplay of disorder and uctuations in physical systems. Photos: AFP, AP

The story so far: The Nobel Prize in Physics for 2021 has been awarded to climatologists Syukuro Manabe of Princeton University, U.S., and Klaus Hasselmann of Max Planck Institute for Meteorology, Hamburg, Germany, and physicist Giorgio Parisi of Sapienza University of Rome, Italy. The prize has been given for their “groundbreaking contributions to our understanding of complex physical systems”. Professors Manabe and Hasselmann will share half the prize and Professor Parisi will receive one-half of the prize. Professors Manabe and Hasselmann bagged the Prize “for the physical modelling of Earth’s climate, quantifying variability and reliably predicting global warming”. Professor Parisi won “for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales”.

Though the prize-winning work done by the laureates are in different areas, they are broadly linked, as they fall under the umbrella of complex systems, climate on the one hand, and spin liquids on the other, the former a phenomenon that spans length scales ranging from centimetres to the size of the planet and the latter a description of what goes on at a microscopic level. The Nobel is being given to climatologists for the first time since its inception in 1901, and this sends out a message that cannot be repeated too often: there is a solid physics basis to climate science, on which the laureates have spent decades, and many other scientists have striven to establish.

Editorial | Handling complexity: On 2021 Nobel Prize in Physics

The incoming short wavelength radiation from the Sun is absorbed by the Earth and re-emitted outwards as long wavelength radiation. The atmosphere absorbs a part of this outgoing radiation and warms up. This is known as the green-house effect. The green-house effect has been known from the work of French mathematician Joseph Fourier two hundred years ago, although it was given its name much later. This warming of the atmosphere and the ground below it is affected by greenhouse gases — water vapour, carbon dioxide, methane and other such. The greenhouse effect also has a positive impact: it keeps the surface of the earth warm and makes life possible. However, when the percentage of the greenhouse gases in the atmosphere increases, this warming also increases and can rise to a degree that is harmful to life itself. Around the close of the 19th century, Swedish scientist Svante Arrhenius estimated that should the carbon dioxide in the atmosphere double, this would cause its temperature to increase by 5-6 degrees.

In the 1950s and 1960s, Professor Manabe and collaborators made pioneering attempts at modelling atmospheric warming due to the increase in carbon dioxide. He estimated that a doubling of carbon dioxide would lead to a temperature rise of 2 degrees. His model confirmed that the rise in temperature was, indeed, due to the increase in carbon dioxide, because it predicted rising temperatures close to the ground and cooling of outer layers of the atmosphere. If the warming had been due to the Sun’s radiation, it would have been uniform. It was Professor Manabe’s model that pinned the quantitative impact of warming due to carbon dioxide.

The term, weather, refers to day-to-day variations in temperature and rainfall, whereas climate describes long-time effects and also seasonal and average behaviour over a long time. While it is very difficult to predict the former, the latter appears predictable, as for instance, in the anticipated regularity of monsoons year after year. The striking aspect of Professor Hasselmann's work is that he built a connection between the rapid, randomly varying, "noise-like" weather patterns and inferred from these the "signal" of climate. He built a stochastic climate model that connects the two. He did this around 1980. According to information released by the Nobel Academy, Professor Hasselmann later developed methods to identify the human fingerprint on climate change. The models that he built carried information about warming due to solar radiation, the greenhouse gases and other causes, each of which could be separated. His study, followed by that of others, demonstrated the human impact on climate change through several observations.

To understand the work of Giorgio Parisi, it is necessary to understand four concepts with a dash of abstraction to them — spins, frustration, spin glasses and replica symmetry. Spins are like minimalistic line drawings of magnets. Just as magnets point in the north-south direction, spins are arrows that point along one direction. Consider a triangular array of spins that can either point up or down. Let us say that the neighbouring pairs of spins always like to point in opposite directions. In a triangular array with spins A, B and C, if A points up, and to satisfy the condition, B points down, what will be the direction in which C must point — up or down? If C points down, it will be parallel to B, thus violating that bond. If it points up, it will become parallel to A, thus violating the A-C bond. So, the spin C does not know how to align itself. This is the classic situation called "frustration". If you extend the description of a triangular arrangement of spins to a triangular mesh or net (triangular lattice) and place spins on each intersection, you will see that it is impossible to find a state where all neighbouring spins are aligned opposite to one another. This is a frustrated system.

The information released by the Nobel Academy describes how when a gas — which can be pictured as a collection of tiny balls flying around at random — is cooled slowly, it condenses first into a liquid and then a solid which most of the time is crystalline (with the balls being fixed into a periodic array). However, if the gas is cooled rapidly, it just goes into a glass state where some periodicity is present and some random placements. Similarly, frustration can lead the spin systems to form a spin glass.

In the 1970s, many physicists tried to calculate meaningful quantities out of spin glasses by using "a replica trick" — this is a mathematical technique in which many copies of the system (or replicas) are processed at the same time. However, they were not quite successful. Parisi, in a breakthrough in 1979, was able to identify a structure to the replicas and describe it mathematically. This led to the method being used eventually to solve problems in the field of complex systems. This went beyond physics and helped in solving problems in mathematics, biology, neuroscience.

Parisi has also studied other phenomena in which simple behaviours give rise to complex collective behaviour like murmurations of starlings. This is a phenomenon that arises when hundreds or thousands of starlings fly together in co-ordinated patterns across the sky. Phillip Anderson's words aptly describe the philosophy of studying such systems, as quoted in the Academy's release: "The history of spin glasses may be the best example I know of the dictum that a real scientific mystery is worth pursuing to the ends of the Earth for its own sake, independently of any obvious practical importance or intellectual glamour."

weeks. The company expects to submit data of children 2–4 years and 6 months to 1 year by the end of the year.

END