THE NOBEL PRIZE

Speaker's manuscript – Physics prize 2021
Hidden patterns in the climate and in other complex phenomena

The Nobel Prize in Physics

- The Nobel Prize in Physics is one of the five prizes founded by Alfred Nobel and awarded on 10 December every year.
- Before Alfred Nobel died on 10 December, 1896, he wrote in his will that the largest part of his fortune should be placed in a fund. The yearly interest on this fund would pay for a prize given to "those who, during the preceding year, shall have conferred the greatest benefit to humankind."
- The interest would be divided into five equal parts, with one part awarded to those who "shall have made the most important discovery or invention within the field of physics".

Who is rewarded with the physics prize?

- This prize rewards important discoveries or inventions in the field of physics.
- Wilhelm Conrad Röntgen was awarded the physics prize in 1901 for the discovery of x-rays, and Roger Penrose, Reinhard Genzel and Andrea Ghez were awarded the prize in 2020 for their research on black holes.

The 2021 physics prize

- Our world is full of complex and disordered phenomena and processes. The 2021 physics prize is awarded for models that describe the earth's climate and other complex systems.

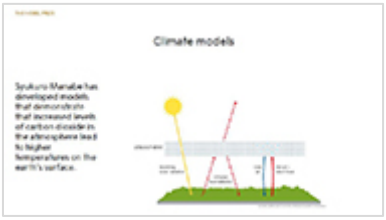
The 2021 physics laureates

- One half of the prize is awarded jointly to Syukuro Manabe and Klaus Hasselmann, who developed models for the earth's climate and produced reliable predictions of global warming.
- The other half of the prize is awarded to Giorgio Parisi, who demonstrated how disorder and fluctuations interact in physical systems at different scales.

The greenhouse effect

- The climate is an example of a complex system. It is made up of a vast number of components - all of the molecules in the air, land and sea - that interact with one another and are influenced by a multitude of different factors.
- One important factor for the climate is the greenhouse effect. When the sun's rays strike the earth, they are converted into infrared light and radiant heat emitted from the ground. The greenhouse effect is when so-called greenhouse gases in the atmosphere - such as carbon dioxide, methane and water vapour - absorb this outgoing infrared radiation and convert it into heat.

Climate models



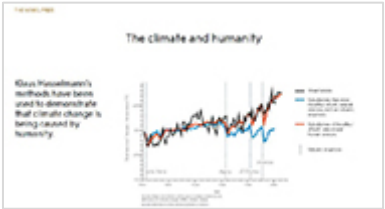
- During the 1960s, Syukuro Manabe led the development of physical models of the earth's climate. These models gave a clearer picture of how elevated levels of carbon dioxide in the atmosphere give rise to higher temperatures on the surface of the earth.
- Manabe explored the balance between the solar radiation that strikes the earth and the radiation it emits as infrared light and radiant heat. He also explored the vertical transport of air masses due to warm air rising and cold air falling, and accounted for the importance of water vapour in the air. Water vapour is a powerful greenhouse gas.

Weather and climate

- Weather is essentially impossible to forecast far in advance. That is partly because it is impossible to determine weather data for every point in the atmosphere and partly because weather phenomena are chaotic - even small changes can end up leading to much larger changes later.
- Klaus Hasselmann demonstrated how the climate, unlike the weather, can be predicted. The chaotic fluctuation of the weather can be described as data noise, which can be accounted for in modeling the climate. These random variations are built into Hasselmann’s climate model.
- This can be illustrated by taking a dog for a walk. The dog runs all over, back and forth around you as you follow a mostly straight path. The dog behaves like the weather, and you behave like the climate.

The climate and humanity

- Hasselmann developed methods for distinguishing the impacts that natural phenomena have made on the climate from those made by humanity. His methods have been used to demonstrate that climate change is the result of emissions caused by human activity.

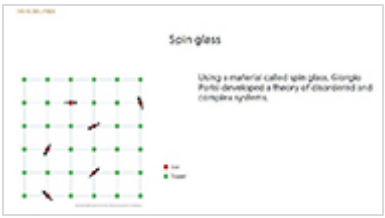


Disordered and complex materials

- When the particles in a gas are cooled down or pressed together, they condense first into a liquid and then into a solid. The result is often a crystal in which the particles form a regular pattern. But if the change happens rapidly, an irregular pattern is formed instead - and a different pattern every time. What controls the results?
- The game "Booby-trap" can be used to illustrate this phenomenon. When the different-coloured wooden pieces are pressed together, a different pattern is formed every time.
- Giorgio Parisi discovered that there is a hidden structure within such complex systems, and he found a way to describe them mathematically.

Spin glass

- Giorgio Parisi studied a material called spin glass. Spin glass is a type of metal alloy in which iron atoms, for example, are randomly distributed among copper atoms. The iron atoms are like little magnets, each one affected by the other nearby atoms.
- In a spin glass, these magnets all point in unpredictable directions. Based on his studies of spin glass, Parisi developed a theory of disordered and complex systems.



Broad applications

- Parisi's theories can be applied to many different areas of physics, mathematics, biology, climate research and computer science. For example, the theories can be used to describe the patterns in a flock of flying starlings.