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Climate modellers and theorist of complex systems share physics Nobel

Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi split the award for their work on complex systems — including modelling Earth's climate and global warming.

- Davide Castelvecchi & Nisha Gaind
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2021 Physics Nobel laureates Klaus Hasselmann, Giorgio Parisi and Syukuro Manabe.Credit: J J Guillen/EPA/Shutterstock; Tania/Contrasto/Eyevine; Markus Marcetic, the Royal Swedish Academy of Sciences

Three researchers have won the 2021 Nobel Prize in Physics for their work on describing complex physical systems — including foundational research that created a pioneering mathematical model of Earth's climate and predicted that increasing levels of carbon dioxide in Earth's atmosphere would raise global temperatures.

Syukuro Manabe and Klaus Hasselmann share half of the 10-million-Swedish-kronor (US$1.15-million) prize for this modelling. Theoretical physicist Giorgio Parisi at the Sapienza University of Rome receives the other half for his contributions to the theory of complex systems. His work has affected many areas, from neuroscience to how granular materials pack, the Nobel committee said in its announcement on 5 October.

"These are two different prizes, but there is the common theme that has to do with this order, these fluctuations together that can give rise to something that we can understand and predict," said Thors Hans Hansson, chair of the physics Nobel committee. "We can predict what is happening with the climate in the future if we know how to code the chaotic weather."

Climate models

Manabe, now at Princeton University in New Jersey, showed in the 1960s how increased levels of carbon dioxide in Earth's atmosphere lead to increased temperatures at the surface, and developed early mathematical models of the planet's climate. Around a decade later, Hasselmann, at the Max Planck Institute for Meteorology in Hamburg, Germany, built on this work to create a model linking weather and climate.

“Manabe showed us how and why increasing CO_2 leads to global warming. Hasselmann showed that it is happening,” says climate scientist Bjorn Stevens, also at the Max Planck Institute for Meteorology. He adds that the institute is “thrilled” that the pair have been awarded the “first Nobel prize for the science underpinning our understanding of climate change”.

Early climate models successfully predicted global warming

Jürgen Kurths at the Potsdam Institute for Climate Impact Research in Germany says that a "genius contribution" of Hasselmann's was the 1970s introduction of the first 'conceptual model' for Earth's climate[1] — a simple set of equations that captures global phenomena with just a few variables. This approach has given insights complementary to those from global circulation models, which are brute-force, geographically detailed calculations. "Usually you need a computer to simulate [conceptual models], but it's much faster and easier," Kurths says.

At the age of 89, Hasselmann continues to actively follow the field, and encourages researchers to try unconventional approaches, Kurths adds.

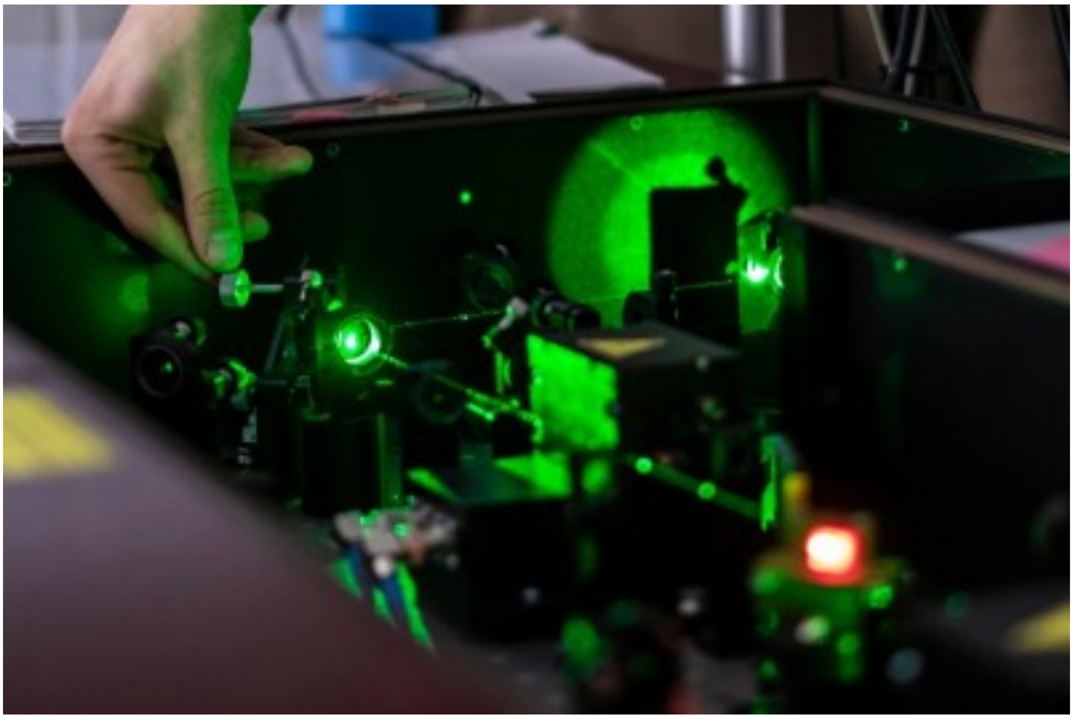
Gabriele Hegerl, a climate modeller at the University of Edinburgh, UK, who worked with Hasselmann as a postdoctoral researcher, says he was a "fantastic" mentor and supervisor, who was "full of ideas and enthusiasm".

"I am really pleased that Suki and Klaus were chosen together, as they both contributed hugely in different ways and are two giants of climate science," she adds. "I still use Suki's old figures from the early papers on absorption and physics of the atmosphere in my classes, and his work is fundamental to understanding climate and, with it, climate change."

Manabe was "gobsmacked" when he heard he had won the prize, said John Wettlaufer, an Earth and planetary scientist at Yale University in New Haven, Connecticut, and a member of the physics Nobel committee. "He said, 'But I'm just a climatologist.'"

Hidden order

Parisi started his career in particle physics, but his research has since touched many other subfields. In the late 1970s[2], he switched his attention to the theory of complex systems, where he discovered a hidden and counter-intuitive type of order in the interactions of many objects[2]. In some systems — such as magnetic materials, for example — atoms tend to align parallel to their neighbours, but complex systems are less predictable. Still, Parisi discovered that they satisfy a kind of symmetry that is noticeable only when comparing how the individual atoms arrange over different scales, says physicist Federico Ricci-Tersenghi at Sapienza.



Giorgio Parisi: Optical system solves computational riddle

"He opened up a way to see and interpret complex phenomena that until then had been missed," says Ricci-Tersenghi, who is a former student and long-time collaborator of Parisi's. The theory turned out to be useful even for systems that at first sight seem to be completely random, such as the structure of glass, he adds.

Parisi's research looks at underlying disorder and fluctuations and predicts emerging behaviour, said Wettlaufer. The link between his work and that of Manabe and Hasselmann is that fluctuations are key for predictability, he said. "We're recognizing that emerging phenomena sometimes require you to look at all the individual complicated physical mechanisms and knit them together to make a prediction."

Kurths is pleased that Parisi — and with him the study of complex systems, which is crucial to understanding the climate — has received recognition from the Nobel committee.

Parisi fosters a "happy environment" in his research group, Ricci-Tersenghi says, and has always encouraged his mentees to follow their curiosity and intellectual interests.

Reacting to news of his Nobel win, Parisi told reporters during the announcement: "I was very happy and I was not really expecting it." He continued: "But I knew I had some chance — so I kept the telephone near me."

The award comes before a pivotal climate meeting — the 26th United Nations Climate Change Conference, due to take place in Glasgow, UK, in November. "It's very urgent that we take a very strong decision and move at a very strong pace," said Parisi, of the climate negotiations. "For the future generations, we have to act now in a very fast way."

Asked if the Nobel committee was sending a message to world leaders with the award, Göran Hansson, secretary-general of the Royal Swedish Academy of Sciences in Stockholm, which awards the prize, said: "What we are saying is that the modelling climate is solidly based in physical theory and solid physics." He added: "Global warming is resting on solid science. That is the message."

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Additional reporting by Quirin Schiermeier, Tosin Thompson and Emma Stoye.

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Trio of scientists win Nobel prize for physics for climate work

Sykuro Manabe, Klaus Hasselmann and Giorgio Parisi share award for advancing climate knowledge

Nobel committee for physics members sit in front of a screen displaying 2021 winners (left to right) Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi. Photograph: Jonathan Nackstrand/AFP/Getty Images

Linda Geddes
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Three scientists have won the 2021 Nobel prize in physics for their groundbreaking contributions to our understanding of complex physical systems – including how humanity influences the Earth's climate.

The winners, Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi, will share the award, announced on Tuesday, presented by the Royal Swedish Academy of Sciences and worth 10m Swedish kronor (£870,000).

One half of the prize was jointly awarded to Manabe and Hasselmann for their physical modelling of Earth's climate, quantifying variability and reliably predicting global heating. The other half went to Parisi for his discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales.

Characterised by randomness and disorder, complex systems are difficult to understand, but this year's prize recognised new methods for describing them and predicting their long-term behaviour.

Paul Hardaker, the chief executive of the Institute of Physics, said: “Whilst complex systems are difficult to deal with mathematically they are all around us and affect our lives in many different ways, not least through the way they affect the nature of our weather and climate.

“Their work has laid the foundations for our understanding of the Earth system and the impact of our interactions with it. Never has this been more important than in what we are doing now to tackle the challenges of our changing climate and move toward a new green economy.”

Manabe, a senior meteorologist at Princeton University, demonstrated how increased levels of carbon dioxide in the atmosphere can lead to increased temperatures at the Earth’s surface. During the 1960s he also led the development of physical models of the Earth’s climate, laying the foundations for the climate models in use today.

About 10 years later, Hasselmann, a professor at the Max Planck Institute for Meteorology in Hamburg, Germany, created a separate model that linked together weather and climate, helping to answer the question of why climate models can be reliable despite the weather being changeable and chaotic.

He also developed methods for identifying specific signals that natural phenomena and human activities imprint in the climate, demonstrating that increased atmospheric temperatures can be linked to human carbon dioxide emissions.

Professor Ralf Toumi, co-director of the Grantham Institute at Imperial College London, said: “It is almost impossible to imagine that there would be such widespread call for action on climate change without the work of many modellers, but particularly Manabe and Hasselman.”

Parisi’s groundbreaking work focused on identifying hidden patterns in disordered complex materials called spin glasses, making it possible to understand and describe many different and apparently entirely random materials and phenomena.

“[He] tamed this complicated landscape by building a deep physical and mathematical model which was so broad that it has impacted a vast range of fields far beyond spin glasses, from how granular materials pack, to neuroscience, to how we compute to random lasers, and to emergent phenomenon far beyond what he envisioned in the 1970s when he started this work," said the Nobel committee member John Wettlaufer, a professor of earth and planetary sciences at Yale University in the US.

Thors Hans Hansson, the chair of the Nobel committee for physics, said: "Although the prize is divided into two parts, there is the common theme that has to do with how disorder and fluctuations together – if you understand it properly – can give rise to something that we can understand and predict.

"The discoveries being recognised this year demonstrate that our knowledge about the climate rests on a solid scientific foundation, based on a rigorous analysis of observations. This year's laureates have all contributed to us gaining deeper insight into the properties and evolution of complex physical systems."

Asked about the timing of the award, Parisi, a professor at Sapienza University of Rome, Italy, said: "We are in a situation where we can have a positive feedback that may accelerate the increase of temperature. It is clear that for the future generations, we have to act now in a very fast way and not with a strong delay."

Physics was the prize area that Alfred Nobel mentioned first in his will from 1895, dictating that his entire remaining estate should be used to endow "prizes to those who, during the preceding year, have conferred the greatest benefit to humankind".

The other awards are prizes for physics and chemistry, physiology or medicine, literature, and the championship of peace.