The sun's magnetic field during the grand minimum is in fact at its maximum

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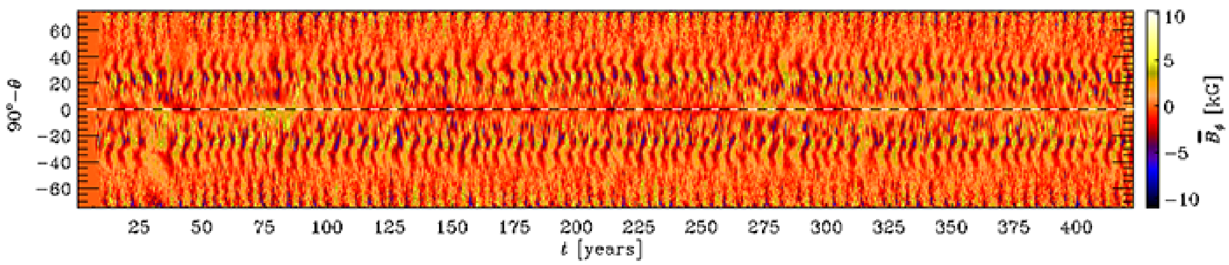

About 80 solar cycles seen from the surface, i.e. more than 1,000 years in solar time, modelled by means of a computer simulation. At 20-50 years in simulation time, a simulated grand minimum occurs, which in actual fact is the maximum of magnetic energy.

The study of the sun's long-term variation over a millennium by means of super computer modelling showed that during a time period of the Maunder Minimum type, the magnetic field may hide at the bottom of the convection zone.

The study conducted by the Aalto University Department of Computer Science, the ReSoLVE Centre of Excellence and the Max Planck Institute for Solar System Research seeks explanation for the mechanisms underlying the long-term variation in solar activity. The research team comprised Maarit Käpylä, Petri Käpylä, Nigul Olspert, Axel Brandenburg, Jaan Pelt, Jörn Warnecke and Bidya B. Karak. The recently published study was carried out by running a global computer model of the sun on Finland's most powerful super computer over a period of six months.

'The sun has an 11-year cycle that involves, among other things, the occurrence and disappearance of sunspots. The phenomena that occur in the sun – including the cycle – change with time, so the solutions need to be integrated over time. Short-term variation is not interesting for the purposes of studying the space climate, for example,' says Maarit Käpylä, head of the DYNAMO team, who conducts astroinformatics or computational astrophysics and data-analysis at the Department of Computer Science.

As a result of the computation carried out, currently the world's longest numerical simulation was created that produces a solar-like dynamo solution complete with its long-term variation.

'The sun as such is impossible to replicate on present-day computers – or those of the near future – due to its strong turbulence. And indeed we are not claiming that this modelling would really be the sun. Instead, it is a 3D construction of various solar phenomena by means of which the star that runs our space climate can be better understood,' Käpylä explains.

What exactly is a grand minimum?

The largest surprise of the study relates to the sun's silent periods known as grand minima, of which the Maunder Minimum is perhaps the best known. The solar magnetic field is thought to wither during it and be so weak as not being capable of generating sunspots or other activity.

'In fact, the magnetic field is at its maximum during the Maunder Minimum. Thus far, we have only been able to examine what is visible on the solar surface, but simulations enable us to see below the surface.

During the Maunder Minimum, the magnetic field sinks to the bottom of the convection zone and is very strong there,' says Käpylä

The outer layer of the sun, the convection zone, is like a boiling kettle with its moving and heat-transferring bubbles, and this not only generates a magnetic field, but also makes the entire area turbulent.

Maarit Käpylä will start as an independent group leader at one of Europe's leading solar research units, Max Planck Institute for Solar System Research, in the summer of 2016. The operations of the Aalto DYNAMO team at the ReSoLVE Centre of Excellence will continue under Käpylä's direction, focusing on even larger simulations using graphical processing units.

More information: M. J. Käpylä et al. Multiple dynamo modes as a mechanism for long-term solar activity variations, *Astronomy & Astrophysics* (2016). DOI: 10.1051/0004-6361/201527002

Provided by Aalto University

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