Magnetic hot spots on neutron stars survive for millions of years

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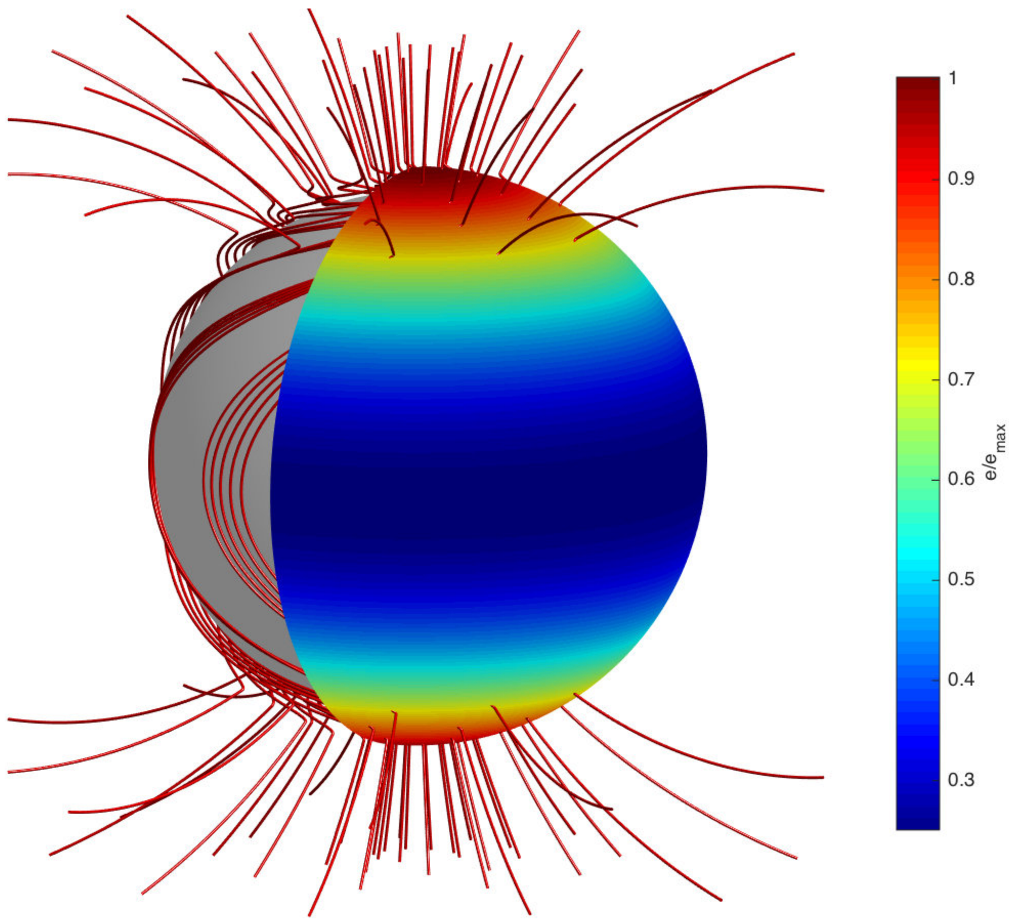


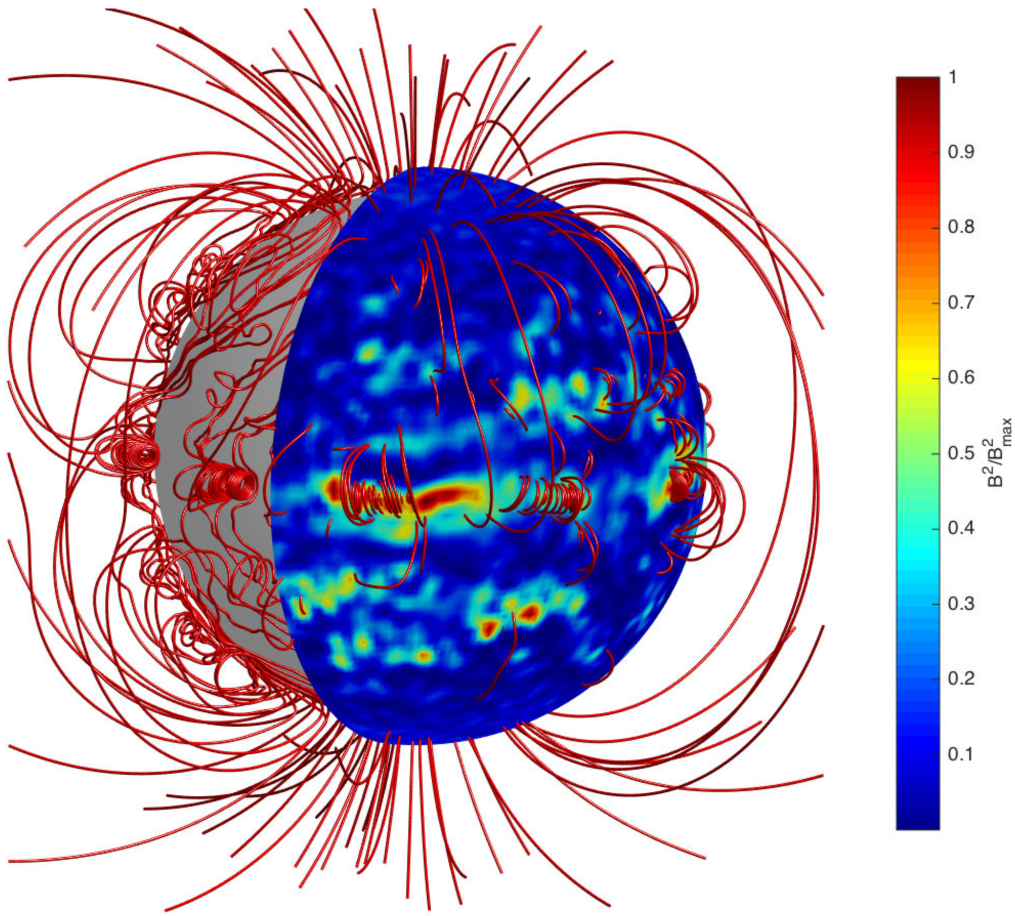
A tightly wound-up magnetic field used as initial state in the simulation. Credit: K. Gourgouliatos, R. Hollerbach, U. Durham, U. Leeds

A study of the evolution of magnetic fields inside neutron stars shows that instabilities can create intense magnetic hot spots that survive for millions of years, even after the star's overall magnetic field has decayed significantly. The results will be presented by Dr Konstantinos Gourgouliatos of Durham University at the European Week of Astronomy and Space Science (EWASS) in Liverpool on Wednesday, 4th April.

When a massive star consumes its nuclear fuel and collapses under its own gravity in a supernova explosion, it can result in a neutron star. These very dense objects have a radius of about 10 kilometres and yet are 1.5 times more massive than the Sun. They have very strong magnetic fields and are rapid rotators, with some neutron stars spinning more than 100 times per second round their axis. Neutron stars are typically modelled with a magnetic field that has a north and south magnetic pole, like the Earth's. However, a simple 'dipole' model does not explain puzzling aspects of neutron stars, such as why some parts of their surface are much hotter than their average temperature.

Gourgouliatos and Rainer Hollerbach, of the University of Leeds, used the ARC supercomputer at the University of Leeds to run numerical simulations to understand how complex structures form as the magnetic field evolves inside a neutron star.

Gourgouliatos explains: "A newborn neutron star does not rotate uniformly - various parts of it spin with different speeds. This winds up and stretches the magnetic field inside the star in a way that resembles a tight ball of yarn. Through the computer simulations, we found that a highly wound magnetic field is unstable. It spontaneously generates knots, which emerge from the surface of the neutron star and form spots where the magnetic field is much stronger than the large-scale field. These magnetic spots produce strong electric currents, which eventually release heat, in the same way heat is produced when an electric current flows in a resistor."



The magnetic field structure after it has become unstable leading to the formation of knots and magnetic spots. Credit: K. Gourgouliatos, R. Hollerbach, U. Durham, U. Leeds

The simulations show that it is possible to generate a magnetic spot with a radius of a few kilometres and a [magnetic field strength] in excess of 10 billion Tesla. The spot can last several million years, even if the total magnetic field of the neutron star has decayed.

The study may have wide implications for our understanding of neutron stars. Even neutron stars with weaker overall magnetic fields could still form very intense magnetic hot spots. This could explain the strange behaviour of some magnetars, for example the exotic SGR 0418+5729, which has an unusually low spin rate and a relatively weak large-scale magnetic field but erupts sporadically with high-energy radiation.

More information: Magnetic axis drift and magnetic spot formation in neutron stars with toroidal fields, Gourgouliatos K. and Hollerbach, R., The *Astrophysical Journal*, Volume 852, Number 1, published 28 December 2017. arxiv.org/abs/1710.01338

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