Understanding the oscillations of magnetic white dwarfs

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Researchers at the Paris-Saclay "Astrophysics, Instrumentation, Modelling" laboratory (AIM – CNRS/CEA/Université Paris Diderot), of the CEA's Military Applications Division (DAM) and from the Universe and Theories Laboratory (LUTH – Observatoire de Paris/CNRS/Université Paris Diderot) at the Paris Observatory, have succeeded in modelling an enigmatic phenomenon of quasi-periodic oscillations present on the surface of strongly magnetic "white dwarf" stars, called "polars". By means of these numerical simulations, they were able to study the scale of the plasma instabilities leading to the rapid variations in the brightness of these stars. It will be possible to confirm these results through the use of high-energy lasers which, in the near future, will be able to reproduce physical conditions in the laboratory that are comparable to those encountered on the surface of white dwarfs. This work is the subject of two publications in the 22 June 2015 edition of the *Astronomy & Astrophysics* review.

When it reaches the end of its life, the Sun will have depleted all its nuclear resources. Its core will then collapse under the effect of gravity into an extremely dense star with a mass close to that of the Sun, but in a volume equivalent to that of a planet such as Earth. It will then become what is called a "white dwarf". At present, researchers estimate that nearly 10% of the stars in our Galaxy have already become "white dwarfs". Some of them are highly magnetic, with a magnetic field ten million times more intense than that of the Sun.

When they orbit around another star, magnetic white dwarfs, also known as "polars", attract matter which then free-falls to their poles in an "accretion stream", a cylindrical region with a radius of hundreds of kilometres. In this stream, the free-falling matter reaches supersonic speeds of about 1000 km/s, creating a shockwave phenomenon comparable to the "boom" created by supersonic aircraft. This compression wave leads to a sudden slowing down of the matter, which heats up and can then radiate as much energy as in the heart of a star, primarily in the form of X-days, ultraviolet and visible light.

Between 1982 and 1997, rapid variations in brightness were discovered in the visible light from five of these polars, suggesting the existence of instabilities. The scientists wanted to understand the origin of these instabilities in these strongly magnetic stars. First of all, building on previous work, they produced extremely accurate numerical simulations of the complex physical process involved in the shockwave due to the displacement of matter in the accretion stream of these polars. In most cases, these simulations showed the existence of strong instabilities leading to a significant oscillation in the height of the shock above the white dwarf and thus in the X-ray brightness. For the first time, the researchers were able to reveal the existence of a "secondary" shock, which is "reflected" by the surface of the white dwarf when the matter strikes the star.

Subsequently, the same teams looked for the presence of these rapid oscillations, the period of which can vary between 0.1 and 10 seconds, in a group of polars studied by the European XMM-Newton X-ray observation satellite. However, none of the 24 polars studied revealed any rapid oscillations.

In some cases, an overly strong magnetic field can damp the oscillations and make them undetectable. However, despite the uncertainty surrounding certain parameters (mass of the white dwarf, cross-section of the accretion stream, etc.), at least some of the polars observed by

XMM should have shown signs of rapid oscillations owing to shock variations. These new results and the discovery of the absence of these oscillations would seem to cast doubt on the validity of the standard models for the behaviour of accretion streams, for which the physics is nonetheless considered to be robust.

To obtain these results, the scientists developed numerical simulations of plasma behaviour. Progress in laser physics and the increasing use of high energy density lasers now makes it possible to reproduce conditions in the laboratory similar to those encountered in certain structures in the Universe. Thus, as part of the astrophysics experimentation project named "POLAR", the same group of scientists has already succeeded in partially reproducing in the laboratory the physical phenomena present in the accretion streams on the surface of white dwarfs. The recent commissioning of the Megajoule Laser (LMJ) will enable a real mock-up of the accretion stream to be created in the near future, during the inaugural experiments with LMJ-PETAL, thus opening the door to true laboratory studies of shock instabilities.

More information: "Quasi-periodic oscillations in accreting magnetic white dwarfs I." dx.doi.org/10.1051/0004-6361/201425482

"Quasi-periodic oscillations in accreting magnetic white dwarfs II." dx.doi.org/10.1051/0004-6361/201425483

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