Plasma and nanotechnology applications through maths

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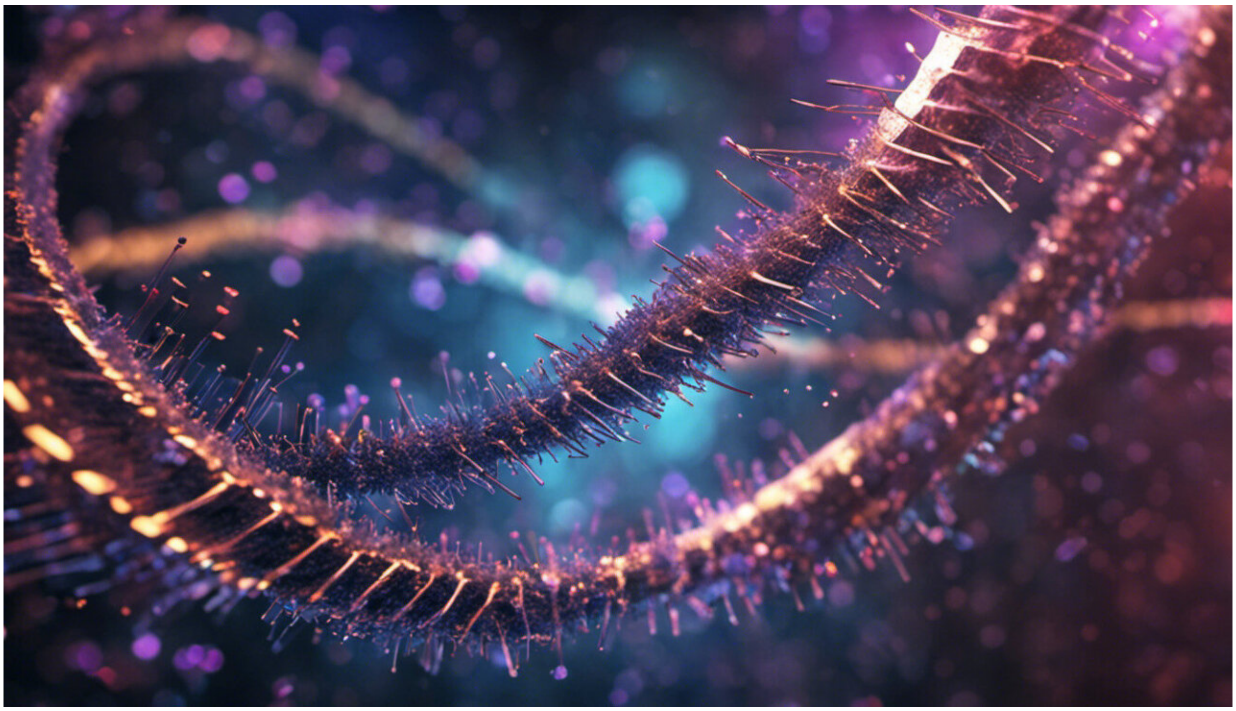

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Plasma is one of the four fundamental states of matter, alongside solid, liquid and gas. Ubiquitous in form, plasma is an ionised gas so energised that electrons have the capacity to break free from their nucleus.

Scientists are keen to shed light on the motion of particles in plasma physics, as well as the dynamics of rarefied gas - a gas whose pressure is much lower than atmospheric pressure. How can this be done? An EU-funded team of researchers has come up with a solution.

Prof. Francis Filbet from Université Claude Bernard Lyon 1 in France decided to tackle the question with mathematical and numerical analyses. He received an European Research Council (ERC) Starting Grant worth almost EUR 500 000 for the NUSIKIMO ('Numerical simulations and analysis of kinetic models - applications to plasma physics and nanotechnology') project. Prof Filbet and his research team modelled non-stationary collisional plasma with supercomputers, putting regimes and instabilities under the microscope.

One of the challenges researchers undertook was to approximate kinetic models and to develop novel techniques that could make numerical analysis in kinetic theory possible.

To do this, the team is working on adapting averaging lemmas (proven statements used for obtaining proof of other statements) to examine kinetic equations, including the Boltzmann equation. Devised in 1872, the seven-dimensional equation is used to model the behaviour of gases, but solving it has proved problematic as numerical capabilities fail to capture the complexities involved.

The NUSIKIMO team is also examining asymptotic preserving schemes, which can be described as performant procedures able to solve 'singularly perturbed problems' - those for which the character of the problem changes intermittently.

Such problems contain small parameters that cannot be approximated by setting the parameter value to zero. For comparison, an approximation for regular perturbation problems can be obtained when small parameters are set to zero.

Asymptotic preserving schemes were established to help scientists deal with singularly perturbed problems. This is especially the case when they are dealing with kinetic models in a diffusive environment.

Prof. Filbet and his team are developing a method to control numerical entropy (classical thermodynamics) production. Being able to control entropy production, which determines the performance of thermal machines, is an important feature for stability analysis - an assessment that helps us understand what happens to a system when it is perturbed. The researchers believe nonlinear equations could therefore be treated with a strategy based on asymptotic preserving schemes.

Applying these equations to plasma physics is one of the NUSIKIMO goals. The team is evaluating energy transport and seeking to determine the efficiency of plasma heating. The researchers are also looking into the measures required to secure fusion conditions through the interaction of intense, short laser pulses, and schemes like inertial confinement fusion or fast ignition.

Another objective is to apply the equations to microelectromechanical systems (MEMS). Prof. Filbet and his team are developing theoretical and numerical methods to investigate gaseous and liquid flows in micro devices. The key element here is the development of numerical methods. The researchers say: using numerical methods, rather than analytical methods, make modelling the three-dimensional flow geometries in MEMS configurations possible.

The project is scheduled to end by December 2013.

More information: Project factsheet: cordis.europa.eu/projects/rcn/93459_en.html