COMPUTATIONAL APPROACH TO THE SELF-ORGANISATION OF FUSION PLASMAS

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Negligible greenhouse gas emissions and high power density make thermonuclear fusion an attractive long-term energy solution. The progress towards these significant benefits has been hampered by challenging practical execution. As the temperatures required by fusion turn the fuel into a plasma, understanding how this state of matter behaves has become a priority.

Tokamaks represent the most mature fusion energy technology at the moment. The toroidal devices utilise powerful magnetic fields to contain the plasma in a vacuum chamber. The cost and viability of a tokamak fusion reactor depend on the efficiency of the magnetic confinement, which is limited by energy losses. [1]

Applying sufficient external heating on the plasma can spontaneously increase the confinement performance of a tokamak by a factor of two. The sudden improvement in confinement is understood to be a product of the interplay between two fundamental phenomena: plasma turbulence and flows. [2]

Temperature and density gradients feed the turbulence that amplifies fluctuations in the plasma, leading to enhanced energy and particle transport. On the other hand, turbulence also participates in driving flows that can suppress it. Due to the complex interactions between vastly varying temporal and spatial scales from single particle motion to reactor size, models have been unable to decipher the details of the confinement transitions.

We conduct massively parallel simulations to understand this self-organisation of fusion plasmas. Our approach combines gyrokinetic theory with the particle-in-cell method to model the turbulence self-consistently. [3] Previously, experimental measurements on various scales have been quantitatively reproduced, while the current focus is on the interplay between turbulence and flows [4].

Recent simulations have demonstrated an increase in flow oscillation amplitude and a decrease in particle transport when fuel isotope is switched from hydrogen to deuterium. With similar experimental observations, the finding can help us understand the improved confinement of deuterium plasmas.

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