

UNRAVELING THE CORONAL HEATING PROBLEM USING HPC SIMULATIONS

MARENOSTRUM5 GPP

Led by

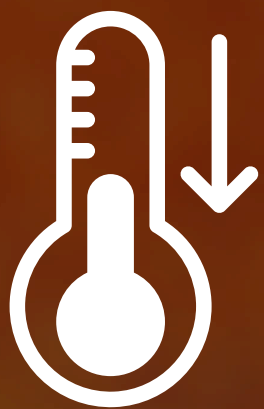


E. KHOMENKO

Instituto de Astrofísica
de Canarias

1 WHY IS THE SOLAR ATMOSPHERE SO HOT?

In the Sun, **temperature progressively decreases** from the core to the surface



The core reaches 15,000,000 °C, while **the surface is about 5,500 °C**

Above it, the **solar atmosphere exceeds 1,000,000 °C**



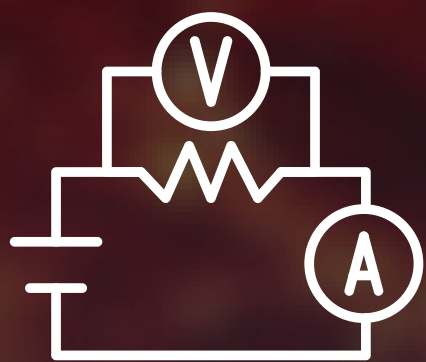
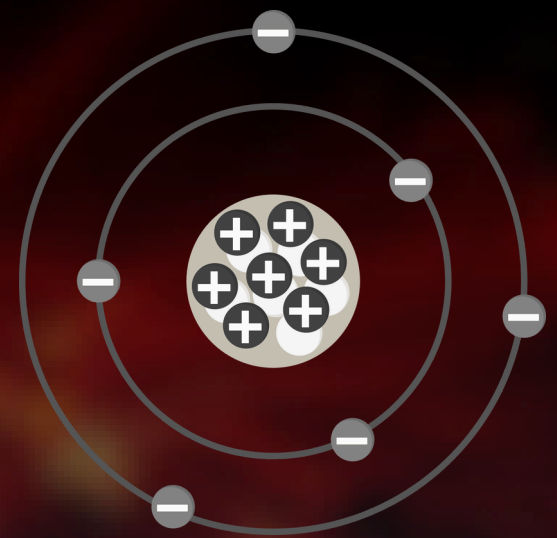
This **unexpected increase** is one of the main **unresolved questions** in solar physics

WHAT IS **HAPPENING** IN THE SUN'S ATMOSPHERE? **2**

The Sun is made of **plasma**, a state of matter where atoms are broken into **free electrons** and nuclei and **energy can move easily**



However, where **temperatures are lower**, some particles recombine into **neutral atoms**

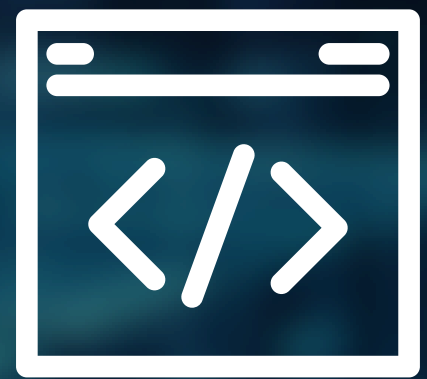


This introduces **resistance** in the plasma, transforming part of the **energy into heat**

This **may be the reason why** the solar atmosphere is **hotter** than the surface

3 MODELLING THE SOLAR ATMOSPHERE USING HPC

Since we cannot directly experiment with the Sun, we study it through **simulations on supercomputers**



First, **2D simulations** reproduce the **atmosphere's structure**, and then high-resolution 3D simulations capture **more complex plasma behaviour**

These models reveal **vortex structures connecting** the surface with the upper atmosphere

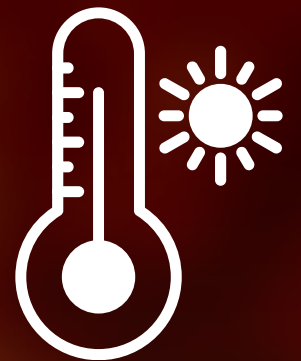


WHAT DO **SIMULATIONS REVEAL?** 4



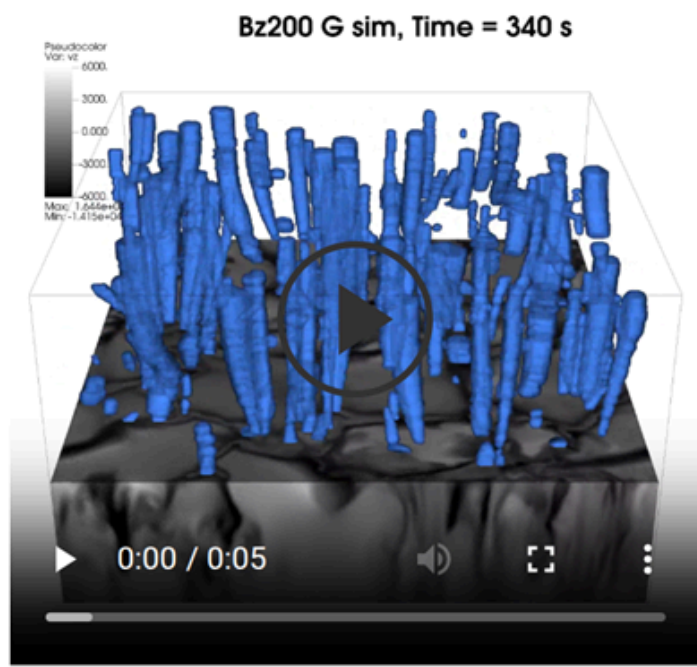
The simulations show that **vortices form in the solar surface and persist across** different atmospheric layers

These structures are **hotter than their surroundings**, highlighting their **energetic role**

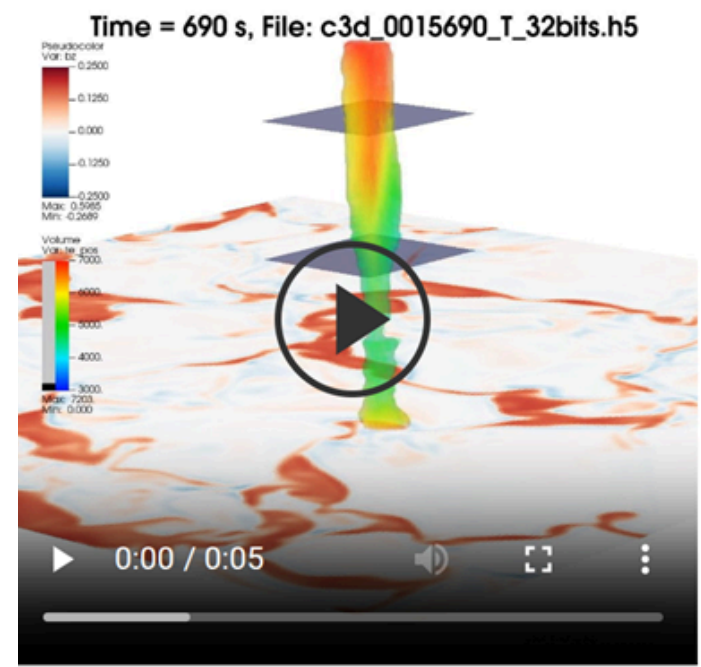


They act as **channels that transport energy** from lower layers to the upper atmosphere

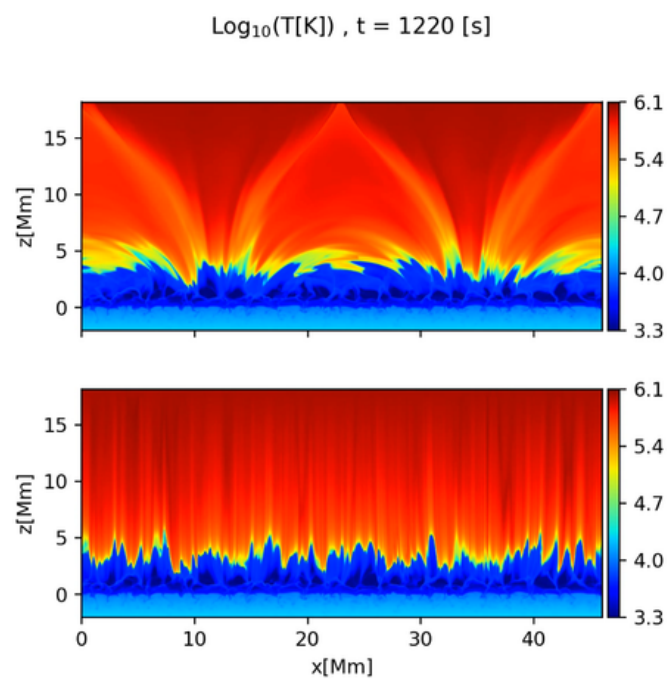
This **upward energy transfer** may help explain the **extreme temperatures** of the solar atmosphere



Temporal evolution of vortices, showing how they persist and connect different regions over time.



Evolution of an isolated vortex from its formation to its dissipation, including a hot perturbation propagating upwards.



Temperature evolution of two different solar atmospheres with different magnetic field “shapes”. The top panel shows two arcades, while the bottom panel shows a vertical magnetic field.



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