Magnetic turbulence trumps collisions to heat solar wind

August 17 2012

(Phys.org) -- New research, led by University of Warwick physicist Dr Kareem Osman, has provided significant insight into how the solar wind heats up when it should not. The solar wind rushes outwards from the raging inferno that is our Sun, but from then on the wind should only get cooler as it expands beyond our solar system since there are no particle collisions to dissipate energy. However, the solar wind is surprisingly hotter than it should be, which has puzzled scientists for decades. Two new research papers led by Dr Osman may have solved that puzzle.

Turbulence pervades the universe, being found in stars, stellar winds, accretion disks, galaxies, and even the material between galaxies. It also plays a critical role in the evolution of many laboratory plasmas, causing diminished confinement times in fusion devices. Therefore, understanding plasma turbulence is essential to the interpretation of a large body of laboratory, space, and astrophysical observations. The solar wind and near-Earth environment provide an excellent laboratory for the study of turbulence, and are the only in-situ accessible astrophysical plasmas.

The solar wind is much hotter than would be expected if it were just expanding outward from the Sun. Turbulence is the likely source of this heating. For neutral fluids such as fast flowing water, energy dissipation occurs through many microscopic collisions. As is the case for many astrophysical plasmas, the near-Earth solar wind is thin and spread out, which means collisions between particles are rare to the point that the plasma is considered collisionless. A major outstanding problem is how, in the absence of those collisions, does plasma turbulence move energy to small scales to heat the solar wind.

The new research led by Dr. Kareem Osman at the University of Warwick's Centre for Fusion, Space and Astrophysics has revealed how turbulence heats the solar wind. He says:

"Turbulence stretches and bends magnetic field lines, and often two oppositely directed field lines can come together to form a current sheet. These current sheets, which are distributed randomly in space, could be sites where the magnetic field snaps and reconnects transferring energy to particle heating. There are also many more ways that current sheets can heat and accelerate the plasma."

The researchers set thresholds in the strength of these current sheets, to determine how proton temperature was related to current sheet strength. The results show convincingly that these current sheets are associated with temperature enhancements, and that the strongest are also the hottest. While each current sheet does not provide a lot of heating, collectively the current sheets account for 50% of the solar wind internal energy despite only representing 19% of all the solar wind data. Even more striking, the strongest current sheets which only make up 2% of the solar wind were found to be responsible for 11% of the internal energy of the system.

The researchers also found that current sheets heat the solar wind in a very interesting manner; the heating is not equal in all directions.

This temperature anisotropy can drive plasma instabilities and the strongest current sheets where preferentially found in plasma that is unstable to particular types of these instabilities called 'firehose' and 'mirror'.

More information: K.T. Osman, W.H. Matthaeus, M. Wan, and A.F. Rappazzo, Intermittency and Local Heating in the Solar Wind, *Phys. Rev. Lett.* 108, 261102 (2012).

K.T. Osman, W.H. Matthaeus, B. Hnat, and S.C. Chapman, Kinetic Signatures and Intermittent Turbulence in the Solar Wind Plasma, *Phys. Rev. Lett.* 108, 261103 (2012).

Provided by University of Warwick