Nowadays, one of the top-priority subjects in space physics is the problem of the heating of the solar corona and solar-wind plasma. The solar wind is a bubble of globally neutral, very rarefied and almost completely collision-free gas, composed by charged particles, mainly protons and electrons, which is ejected by the Sun and fills the Heliosphere. The most puzzling aspect of the dynamics of the interplanetary medium consists in the empirical evidence that the solar wind is warmer than expected as an adiabatically expanding gas. Then, how does the energy of the Sun heat the corona and the solar wind?

Scientists pointed out that the answer may be hidden in the turbulent character of the solar-wind plasma. Turbulent heating consists both in a progressive energy degradation and disorder increasing, going from large to small scales: the energy injected from the Sun as large wavelength fluctuations (Alfvèn waves) is progressively degraded and carried to shorter and shorter scales, until it can be transferred to the plasma particles in the form of heat. At such short wavelengths, kinetic effects can drive the particle velocity distribution far from thermodynamical equilibrium.
What is a turbulent cascade and how does turbulent heating work? As an everyday experience, when stirring a cup of coffee with a spoon swirls and vortices are produced in the liquid. These vortices split into smaller and smaller eddies (turbulent cascade) until, at the smallest scales, the motions dissipate and the energy turns into heat. It would now seem that stirring heats the liquid, while everybody knows that the effect of stirring is cooling off the coffee. In fact, the vortical motion triggered by the spoon brings layers of hot coffee from the bottom of the cup up to the surface, where they come into contact with the cold air which absorbs the heat. As a final affect, the coffee cools off. But there is no cool air in space, and here is the difference between the coffee and the solar wind. As it happens for the coffee, the energy injected by the Sun stirs the solar-wind, producing vortices and swirls. Along the turbulent cascade, the energy within these vortices eventually reaches the smallest scales at which it dissipates and turns into heat. At this point the temperature shoots up (turbulent heating) and there is no cool air to stop it.

Nowadays, the the modern super computers provides the unique opportunity of running multi-dimensional kinetic simulations of plasma systems. Recently, a massive scientific research activity developed within the project “3D-3V Vlasov simulations of plasma turbulence” (PRACE project 4th Regular call) has been devoted to perform numerical simulations in realistic physical conditions of the solar-wind environment, with the purpose of providing clues for the identification of the physical processes at work in the turbulent interplanetary gas.

The numerical tool adopted to develop this line of research is the hybrid Vlasov-Maxwell (HVM) code, which integrates the Vlasov equation for the protons in 3D-3V phase space configuration. The algorithm is based on a Eulerian approach consisting in discretizing the equations on a fixed in time space-velocity grid. The HVM code has been massively parallelized by using the Message Passing Interface protocol in the physical domain; the parallelization strategy consists in distributing among the processors the array containing the particle distribution function, the largest array involved in the numerical calculation.