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OPTIMIZATION OF PARTICLE-IN-CELL CODE FOR THE STUDY OF SOLAR WIND-SPACECRAFT INTERACTION THROUGH PARTICLE REZONING

Abstract

A software called Solar Corona-Spacecraft Interaction (SCSI) was created in order to study probe surface charging, with the possibility of including complex phenomena that may arise when considering Solar Corona-Probe interactions, and with the versatility to simulate as well different plasma-surface phenomena, such as acceleration channels of electric thrusters and plasma-probe interactions.
Although the code architecture may allow for different types of plasma simulation methods, the current focus of the authors is on developing the Particle-In-Cell method, as its derivation from first principles of Physics allows to study the physical phenomena of the system without conditioning its behavior beforehand, as opposed to other plasma simulation numerical methods. However, a disadvantage of the PIC technique is that it is more computationally expensive, as it requires not only to compute parameters in the nodes of a mesh, but also to simulate particles that fill the space. Usual PIC calculations require around 1 million particles for every species taken into consideration.
In order to optimize the execution of the PIC method, a particle rezoning algorithm has been proposed and implemented into SCSI. This procedure periodically scans the meshes to look up for cells that contain too many or too few particles, and for the selected cells it changes the number of particles while maintaining the average values of the different statistical momenta of the species. This methodology differs from previous particle rezoning methods in that it does not require to sort particles by weight, thence reducing the cost of the algorithm. This type of procedure becomes particularly useful in systems where there is difference of several orders of magnitude in the density values throughout the domain.
The particle rezoning algorithm has been tested with the simulation of a Solar Probe coming into contact with the solar wind at a distance of $8.5\,_{\odot}$ from the Sun's surface. This methodology reduced computational times by ~3x-4x in comparison with the previous version of SCSI without particle rezoning. In comparison with the spacecraft floating potential value of $-14.6 \pm 0.2\,\mathrm{V}$ of SCSI's previous version, the new update yielded $-16.2 \pm 0.4\,\mathrm{V}$. This result and other parameters in the simulation suggest that although the average values and behavior of the system are similar, the particle rezoning method produces bigger temporal changes during the steady state, opening up the possibility for further improvements in the algorithm.