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EB-iPic3D: a semi-implicit expanding box model for kinetic solar wind simulations

Maria Elena Innocenti (1), Anna Tenerani (2), and Marco Velli (2)

(1) Interstellar and Heliospheric Physics Division, Jet Propulsion Laboratory, Pasadena, CA 91109, USA (maria.elena.innocenti@jpl.nasa.gov), (2) Department of Earth, Planetary, and Space Sciences, University of California Los Angeles, Los Angeles, CA 90095, USA

The highly anisotropic features observed in proton and electron velocity distribution functions (VDFs) in the solar wind (SW) suggest that it hosts a variety of kinetic instabilities [Pilipp et al 1987, Marsch et al 2012]. These features evolve with heliocentric distance, thus pointing at the fact that solar wind propagation and expansion have a role in the instability onset and saturation [Maksimovic 2005 et al, Stverak et al 2008, Matteini et al 2013]. In turn, said instabilities seem to constrain the evolution with heliocentric distance of SW bulk parameters [Stverak et al 2008, Matteini et al 2013], and are therefore a major target of investigation.

To faithfully reproduce the onset, evolution and saturation of kinetic instabilities in the SW, we have developed the EB-iPic3D code [Innocenti, Tenerani, Velli, in press].
The code is composed of two fundamental building blocks: a semi-implicit Particle In Cell approach, and the capability of modelling SW expansion with heliocentric distance.

The semi-implicit method we use is the Implicit Moment Method [IMM, Brackbill et al 1982, Lapenta et al 2006] implemented in the iPic3D code [Markidis et al 2010]. The IMM allows to simulate larger boxer for longer times with respect to explicit simulations of comparable computational cost. The Expanding Box Model [Velli et al. 1992, Grappin & Velli 1996, Liewer et al. 2001, Tenerani et al 2017] allows to cheaply simulate in a semi-Lagrangian fashion the motion of a parcel of plasma moving away radially from the Sun, while expanding in the non radial directions with an expansion rate proportional to the distance from the Sun.

In this work, we show how including expansion effects in kinetic simulations quickly alters the shape of the VDFs with respect to non expanding simulations. At the current stage, we use as initial conditions in our simulations highly idealised VDFs. In the future, we plan on using as initial conditions Parker Solar Probe observations [PSP, Fox et al, 2016], which will give us a picture of the coronal contribution to ion and electron VDFs.