Collisionless electron dynamics in the expanding solar wind

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Observations of solar wind electron properties, as displayed in the $T_{\text{perp}}/T_{\text{par}}$ vs $\beta_{\text{par}}$ plane, appear to be constrained both in the $T_{\text{perp}}/T_{\text{par}} < 1$ and in the $T_{\text{perp}}/T_{\text{par}} > 1$ regimes by the electron firehose instability (EFI) and by the whistler instability respectively [Štverák 2008]. The onset mechanism of the EFI is established: solar wind expansion results in an electron thermal anisotropy, which in turn promotes the development of the instability that contributes to limit that same anisotropy [Innocenti 2019a]. However, if this were the only mechanism at work in the expanding solar wind, electron observations would pool at the EFI marginal instability line. Instead, they populate the “stable” interval bound by EFI and whistler marginal instability lines. It is not fully clear which role fully kinetic processes have in lifting the observed data points above the EFI marginal stability line and into the “stable” area. Other competing processes redistributing excess parallel energy into the perpendicular direction, such as collisions, may be at work as well [Yoon 2019].

We investigate this issue with Particle In Cell, Expanding Box Model simulations [Innocenti 2019b] of EFI developing self consistently in the expanding solar wind. Our results show that after the EFI marginal stability line is reached, further collisionless evolution brings our simulated data points in the “stable” area. We thus demonstrate that, at least under certain circumstances, purely collisionless processes may explain observed solar wind observations, without the need of invoking collisions as a way to channel excess parallel energy into the perpendicular direction.


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