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Particle acceleration by circularly and elliptically polarised dispersive Alfven waves in a transversely inhomogeneous, 2.5D and 3D plasma in the inertial and kinetic regimes

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Dispersive Alfven waves (DAWs) offer, an alternative to magnetic reconnection, opportunity to accelerate solar flare particles in order to alleviate the problem of delivering flare energy to denser parts of the solar atmosphere to match X-ray observations. Here we focus on the effect of DAW polarisation, left, right, circular and elliptical, in the different regimes inertial and kinetic, aiming to study these effects on the efficiency of particle acceleration. We use 2.5D particle-in-cell simulations to study how the particles are accelerated when DAW, triggered by a solar flare, propagates in the transversely inhomogeneous plasma that mimics solar coronal loop. (i) In the inertial regime, fraction of accelerated electrons (along the magnetic field), in the density gradient regions is $\approx 20\%$ by the time when DAW develops three wavelengths and is increasing to $\approx 30\%$ by the time when DAW develops thirteen wavelengths. In all considered cases ions are heated in the transverse to the magnetic field direction and fraction of heated particles is $\approx 35\%$. (ii) The case of right circular, left and right elliptical polarisation DAWs, with the electric field in the non-ignorable transverse direction exceeding several times that of in the ignorable direction, produce more pronounced parallel electron beams (with larger maximal electron velocities) and transverse ion beams in the ignorable direction. In the inertial regime such polarisations yield the fraction of accelerated electrons 20%. In the kinetic regime this increases to 35%. (iii) The parallel electric field that is generated in the density inhomogeneity regions is independent of the electron-ion mass ratio and stays of the order $0.03\omega_{pe}cm_e/e$ which for solar flaring plasma parameters exceeds Dreicer electric field by eight orders of magnitude. (iv) Electron beam velocity has the phase velocity of the DAW. Thus electron acceleration is via Landau damping of DAWs. For the Alfven speeds of $V_A = 0.3c$ the considered mechanism can accelerate electrons to energies circa 20 keV. (v) The increase of mass ratio from $m_i/m_e = 16$ to 73.44 increases fraction of accelerated electrons from 20% to $30 - 35\%$ (depending on DAW polarisation). For the mass ratio $m_i/m_e = 1836$ the fraction of accelerated electrons would be $> 35\%$. (vi) DAWs generate significant density and temperature perturbations that are located in the density gradient regions. Preliminary 3D simulation results also indicate that re-considering the problem in 3D geometry (a cylindrical, over-dense magnetic flux rope in a 3D box) increases the efficiency of particle acceleration in the density inhomogeneity regions to $60 - 70\%$, commensurate to solar flare observations. In summary, DAWs propagating in the transversely inhomogeneous plasma can effectively accelerate electrons along the magnetic field and heat ions across it.