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The Kadomtsev-Petviashvili (KP) and MKP equations in Vasyliunas-Cairns distributed dusty plasmas

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The presence of superthermal particles in most of the astrophysical, space and laboratory environments have been confirmed by number of satellite observations. Lorentzian (kappa) distribution function is the most common distribution used to illustrate the superthermal particles. This distribution is observed to provide the best fit for the superthermal particles. First time, Vasyliunas reported details of kappa distribution employed to analyse energy ranges of electrons inside the space environments. The high-energy electrons do not follow the simple well-known Maxwellian distribution but rather follow a non-Maxwellian power law distribution, known as kappa (κ) distribution. In various space plasma situations, the velocity distributions of plasma particles at low energy is Maxwellian, while at high energies it is non-Maxwellian which shows super thermal power-law tail. It has been reported that the investigation of the velocity distributions observed in the solar wind, planetary magnetosphere and magneto-sheath by the spacecraft showed that non-Maxwellian distribution of charged particles are very common. The AZ-distribution (hybrid type distribution) like power law distribution can be used to explain many linear and nonlinear phenomena in space/astrophysical environments more effectively. A more generalized distribution function can be used to understand nonlinear phenomena occurring in such space plasma systems. Therefore, the hybrid distribution function must be more helpful to understand such observed space plasma nonlinear phenomena more effectively. This distribution offers an enhanced parametric flexibility in modelling nonthermal plasmas, as in principle a two-parameter representation of the distribution function could be useful in fitting a wider range of the observed plasmas. For the last few years, numerous researchers have been using hybrid velocity distribution to investigate different kind of nonlinear structures in various plasma systems in the framework of perturbation approach and Sagdeev method. In this investigation, we consider Vasyliunas-Cairns (VC) distribution to derive KP as well as MKP equations in a dusty plasma. The VC distribution function contains two spectral indices κ (given by Vasyliunas) for superthermal case and α (given by Cairns) for nonthermal case. The constraints on these spectral indices are $\alpha < 1$ and $\kappa > 3/2$. The VC distribution becomes kappa distribution in the limit of alpha (α) = 0, and becomes a Maxwellian distribution under the condition $\alpha = 0$ and κ tends to infinity. Most of the space and astrophysical environments such as comets, planetary rings, interstellar molecular clouds, the Earth's ionosphere, and circumstellar disks witness the presence of dust. An electron-ion plasma containing an extra charged dust grains whose sizes range from nanometres to millimetres is called dusty plasma. The presence of charged dust grains in electron-ion plasma generates new different modes such as the dust acoustic (DA) wave, dust-ion acoustic (DIA) wave etc. Over the last many years, dusty plasmas have been gaining tremendous attention of the plasma scientific community to carryout research in this area due to its wide ranging applications in semiconductor technology, fusion devices, plasma chemistry, crystal physics, biophysics, etc. Due to importance of dust and non-Maxwellian distribution, it is interesting to analyse the nonlinear excitations in a multicomponent plasma in presence of charged dust particulates with electrons obeying hybrid velocity distribution. In the present investigation, we have studied the characteristics of two-dimensional small amplitude dust-ion-acoustic waves in Vasyliunas-Cairns (VC) distributed plasma containing inertial ions, dust grains and hot electrons obeying VC distribution. The KP equation has been derived using reductive perturbation technique. From the solution of KP equation, we have studied the characteristics of small amplitude dust ion acoustic solitary waves. We have also investigated the stability of the solitary wave solutions of KP equation. Since for certain critical values of plasma parameters nonlinear coefficient of the KP equation becomes zero, so further we have derived the MKP equation. It is remarked that all physical parameters have great influence on the characteristics (amplitude and width) of dust ion acoustic solitary waves in KP and MKP regimes of equations. The findings of this investigation may be useful in understanding the nonlinear structures in space dusty plasma like Saturn's magnetosphere etc.

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