Kappa distributions and their relation to wave-particle interactions and particle dynamics in space plasmas

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Wave-particle interactions, ion acceleration, and magnetic turbulence are closely interlinked and the physical processes occur on different time and length scales in space plasmas. These scales range from the kinetic scale (ion/electron scales) to the macro/fluid at which the dynamic of single particles is not considered. These processes are likely universal and the same basic processes occur in laboratory settings, at the Earth's environment, the solar wind, around the heliosphere, and likely on astrophysical scales. Undoubtedly, the Earth's environment as well as the close interplanetary space are the best plasma environments to study these processes using satellite measurements. Several operating satellite missions such as, ACE, STEREO, IBEX and Voyager observations clearly showed that turbulence and wave-particle interactions and turbulence are extremely important in interplanetary space and in the heliosphere to understand the underlying physics of these measurements. Measures particle distributions provide information on acceleration, scattering, transport processes but not on the particle dynamics.

Using data from STEREO, Wind, we have investigated the spectral properties of so-called suprathermal ion distributions. The results show that spectral slopes are very variable and depend on the plasma properties and most of them show extended tails at higher energies. To study the particle dynamics on the micro-scale we have performed 3D hybrid simulations. In these simulation ions are treaded as particles following the electric and magnetic fields. The results of these simulations show that the particle dynamics in the turbulent magnetic wave field is Levy-Flight like which leads to a kappa distribution, which is often found in various space environments. In fact, maybe this ion dynamic explains why theses distributions are frequently found in space plasmas. Data of future mission such as THOR and IMAP and currently operating missions such as STEREO, IBEX, and MMS will allow to study this topic in much more detail.

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