# Kappa distributions in space plasmas: review of methods and applications

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The valid description and understanding of physical mechanisms in space plasmas often requires the accurate determination of the velocity distribution functions of space plasma particles. Typical space plasmas are weakly collisional systems and the velocities of their particles follow non-Maxwellian distribution functions. Several studies have successfully used kappa distribution functions to describe the velocities of plasma particles in several space regimes, such us the solar wind, planetary magnetospheres, interplanetary shocks, the vicinity of a comet, the inner and outer heliosphere. The determination of the kappa index that labels and governs these distribution functions becomes a vital task, which is required for the complete description of the plasma dynamics. Recent studies demonstrated that inaccuracies in the determination of the kappa index can lead to significant misestimations of all the plasma bulk parameters. In real several applications, distribution functions are determined from particle observations obtained by space plasma instruments. Thus, the accuracy of the derived plasma parameters, depends on the quality of the plasma particle observations and it is affected by instrumental limitations. In this presentation we expose possible misestimations of the plasma bulk parameters when kappa distributions are not accurately determined. We consider realistic plasma instruments and their limitations in order to simulate observations in specific plasma conditions. We analyze the simulated observations in order to present new methods and tools we have developed in order to overcome poor sampling of the plasma distributions. For instance, we simulate the expected electron observations by Solar Orbiter mission and we quantify different fitting methods to calculate the plasma parameters in conditions of extremely low particle flux. In another example, we demonstrate the accurate determination of kappa distribution functions from the analysis of reduced data-sets. Moreover, we discuss the effects of instrument's field of view, sampling and efficiency limitations on the expected observations and the accuracy of the derived plasma parameters. We finally, report the potential use of our methods in a broad range of space plasma analyses, where kappa distribution functions play a significant role.