Plasma temperature misestimation when the Maxwell distribution is assumed for the analysis of plasma that follows the kappa distribution

G. Nicolaou[1], G. Livadiotis[2]

[1]Swedish Institute of Space Physics (IRF), Kiruna

[2]Southwest Research Institute (SwRI)

The fluid properties of the plasma can be derived from plasma instrument observations following various methods of data analysis. Typically, the form of the plasma distribution has to be defined prior the analysis, whereas two common methods that are used to derive the plasma fluid properties are the fitting i) directly to the distribution function, and ii) to the forward modeling of the instrument's response in given plasma conditions. In this work, we examine how the plasma temperature can be misestimated if the Maxwell distribution is assumed for the analysis of a plasma that actually follows the kappa distribution. We simulate several observations of plasma populations that follow kappa distributions and then derive the plasma properties using the two fitting methods above by forcing them to fit Maxwell distributions instead. We show that under this procedure, the plasma temperature can be significantly misestimated. We quantify the temperature misestimation for the two fitting methods as a function of the kappa index, the temperature and the flow direction of the observed plasma; the instruments field of view plays also an important role in the analysis when the forward modeling is being used. It is shown that the misestimation of the derived temperature is highly depended on the kappa index of the distribution function. The temperature can be significantly lower than the actual plasma temperature as the kappa index approaches its limit value ~ 1.5. In the case of forward modeling, we have detected high correlation between the temperature misestimation and the instruments field of view. On the contrary, however, there is only a minor dependence on the plasma temperature and flow direction. For each case, we examine the goodness of the fitting by calculating the reduced chi-squared value and other statistical measures, showing that the temperature misestimation is always accompanied with relatively large reduced chi-squared values, indicating how the choice of the wrong distribution could lead to misinterpretation of the plasma states, even when the fitting is restricted in the core of the distribution.

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