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Temporal evolution of an expanding gas-plasma-dust system - application to Enceladus' plume and cometary jets

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Electron depletion caused by dust absorption is a well-known phenomenon in dust-rich plasma systems. It is usually considered as an indication of high local dust density. While many discussions have focused on steady state cases, little is known about the temporal evolution of a fast-evolving plasma-dust cloud. Inspired by the Cassini Langmuir probe measurements in the plume of Enceladus, we develop a numerical model that follows the temporal evolution of the charge state of a gas-plasma-dust system by considering the production/loss of various components as well as the expansion of the system. Using in situ measurements as constraints, our modeling results can provide diagnostics of an expanding plasma-dust cloud. The model is applied to study the plume of Enceladus and cometary jets. For Enceladus' plume, our results show that, the plasma electron depletion has already developed in the high dust density environment near the moon surface and the degree of depletion decreases as the cloud expands and propagates outward. The electron depletion measured at large distances thus may not reflect the local dust-plasma properties but could be a result of the temporal evolution. For cometary jets, the impact of dust on the charge balance of the system becomes only modest if plasma electrons are cooled by water vapor.