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Open questions on particle acceleration in strongly magnetized plasmas and how to answer them

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Particle acceleration mechanisms in solar system plasmas usually imply the conversion of electromagnetic energy into particle kinetic energy. These processes may take different forms depending on plasma magnetization but in most cases they involve multi-scale phenomena that cannot be described by ideal MHD. Little evidence has been gathered on how particle acceleration works in strongly magnetized plasmas. We will show how Earth's auroral regions provide the unique opportunity to address the open questions on particle acceleration in low beta plasmas.

Single point observations in the auroral regions have suggested that acceleration by Alfvén waves would be responsible for filamentary acceleration along magnetic field lines. In the auroral regions, this mechanism would be associated with the generation of the sub-km scale auroral arcs. However single spacecraft measurements cannot evaluate the energy exchanged over a large volume of space between waves and particles. They cannot assess the efficiency of this mechanism, nor can they tell us where and when it is effective and how it relates to the evolving boundary conditions of the system. Numerical simulations alone cannot fully describe this multi-scale and non-local process in the inhomogeneous auroral plasma.

Alternatively, it has been proposed from high-time resolution particle measurements in the auroral regions that localized parallel electric fields would explain the larger scale arcs that can be observed by onboard imagers. Single spacecraft measurements cannot follow the formation and evolution of these transient structures or the complex transport phenomena associated with the strong plasma turbulence that develop along magnetic field lines around these structures. Multi-point CLUSTER observations have shown how these potential acceleration structures were distributed in space and time. However we still miss the dynamic picture of how these structures are created on how they can be maintained in space and time.

We will show that the only way to distinguish between these models describing acceleration processes in strongly magnetized plasmas is to combine advanced numerical simulations with high-time resolution in situ measurements, multi-point measurements, and auroral arc imaging. We will describe how the Alfvén mission concept, that will be proposed to the ESA M5 AO, will allow a major breakthrough in our understanding of particle acceleration mechanisms in solar system plasmas.