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Theoretical models of auroral acceleration

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Abstract

In this short review, I will underline a few features of the theoretical models of the Earth auroral acceleration that might be of interest in the more general context of the magnetized planets.

1. A great phenomenological and theoretical diversity

Many models exist for auroral acceleration. They have been developed mainly to explain Earth auroras, and their development follows remote and in-situ observations. Each model usually puts the emphasis on a peculiar length and time scale. Considering the high variety of auroral structures, we can expect that many of them are relevant, even if the real acceleration process (out of reach of our computational abilities) is probably a complicated mixture of the effects described in each model. In all the models of auroral acceleration considered nowadays, the source of free energy is situated in the magnetosphere. It generally results in a forced current along the magnetic field line. This can be a direct current, or a time dependent current induced by processes occurring in the outer magnetosphere, or by magnetic field line oscillations, or by propagating Alfvén/Magnetosonic waves...

2. Acceleration by quasi-static parallel electric fields

The large scale acceleration models generally invoke the mirror effect induced by the increase of the magnetic field near the planet : to maintain a downward current against the repulsive mirror force, a small population of electrons must gain a high velocity, generally acquired through acceleration by a magnetic-field-aligned electric field. But this model cannot, alone, explain the efficiency of the auroral acceleration, and other effects are considered.

3. Acceleration by waves

In the models based on propagating MHD waves, the accelerating parallel electric field is induced by a distortion of the wave front, or oblique propagation. Actually, this cannot be explained by MHD alone; the difference of inertia between the ions and the electrons plays a key role in the emergence of the accelerating parallel electric field. The reaction of the ionosphere to the growing influx of energetic particles can also destabilize and amplify the acceleration by an Alfvén wave.

4. Interaction between wave acceleration processes

The particles accelerated by quasi-static electric fields and by MHD waves exhibit different signatures: the quasi-static processes tend to produce monochromatic beams while Alfvénic acceleration produces broader ranges of energy. Some observations suggest that beams of particles created by quasi-static processes could destabilise Alfvén waves, that in turn, might trigger wave acceleration. On the contrary, other cases suggest that acceleration by Alfvén/Magnetosonic waves act before the settlement of the quasi-static acceleration. The link between this two families of processes is the object of recent studies.

5. Summary and Conclusions

Each of these acceleration mechanisms have a different signature that could be analysed through the study of the associated auroral display, through diagnostics of the radio-emissions, and, when auroral probes will pass closer to the planets, through in situ measurements.