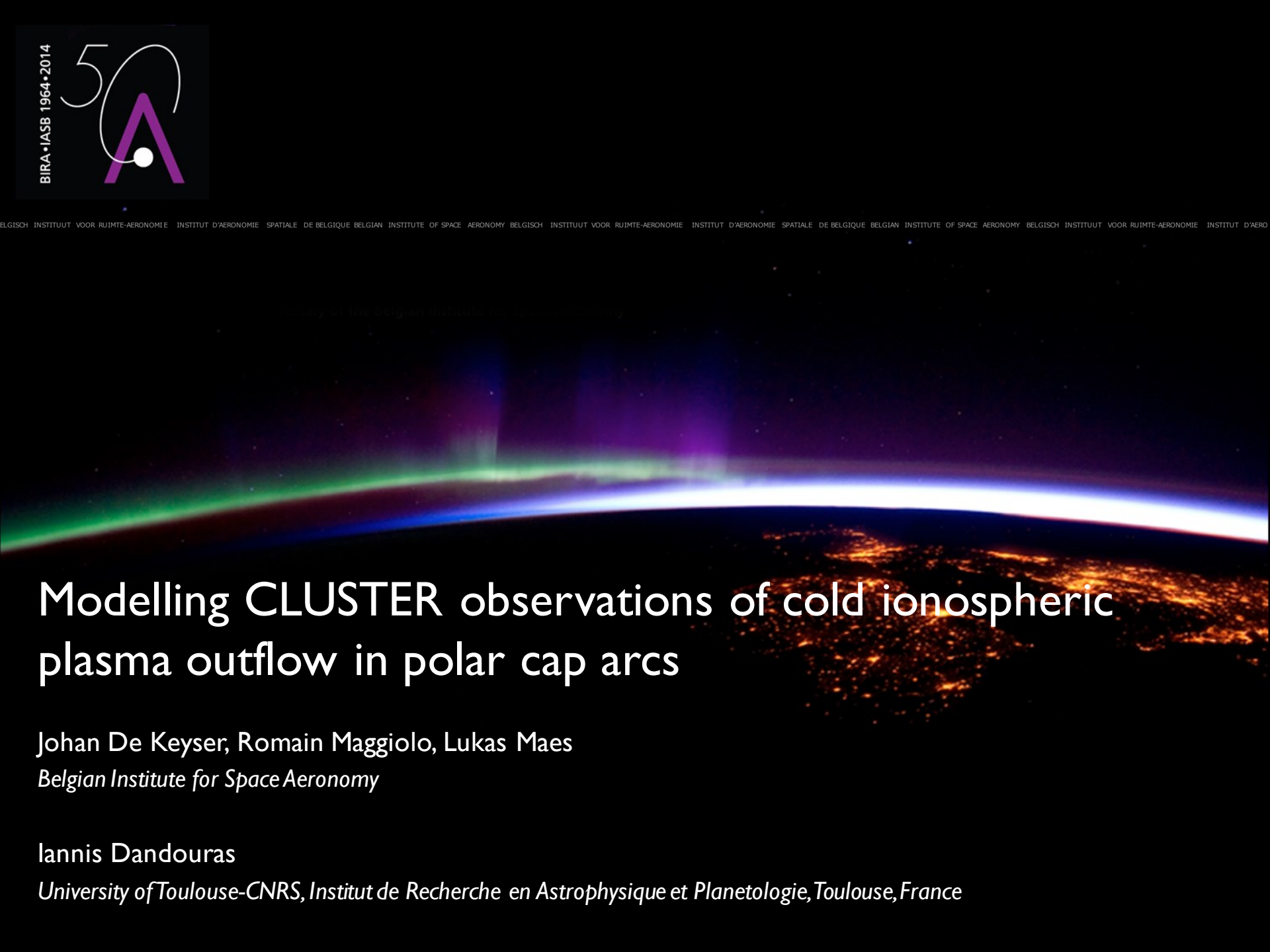

Modelling CLUSTER observations of cold ionospheric plasma outflow in polar cap arcs

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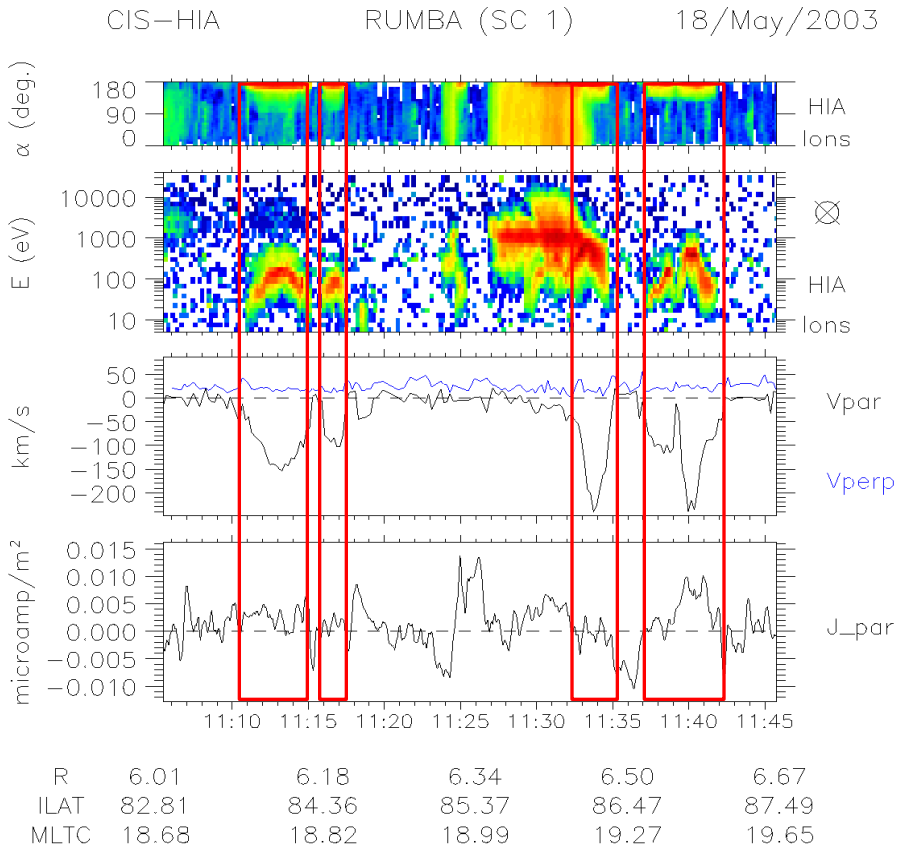
Polar cap ion beams

Flying above the polar caps at an altitude of 4-5 R_E, above the auroral acceleration region, Cluster observes upgoing ion beams of ionospheric composition, with upward flows of up to 200 km/s.

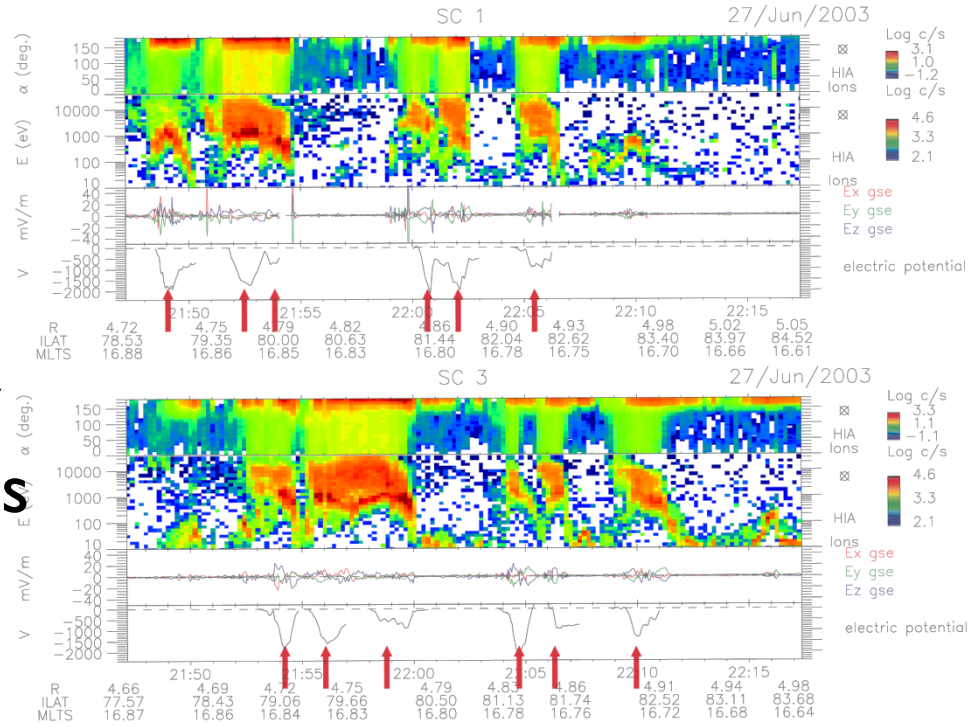


[Maggiolo et al., Ann. Geophys., 2006,2011]

Associated electric potential

When integrating E along the spacecraft trajectory, one finds that potential structures are associated with these beams.

The beam energy roughly traces this potential, and is typically 100-1000 eV.



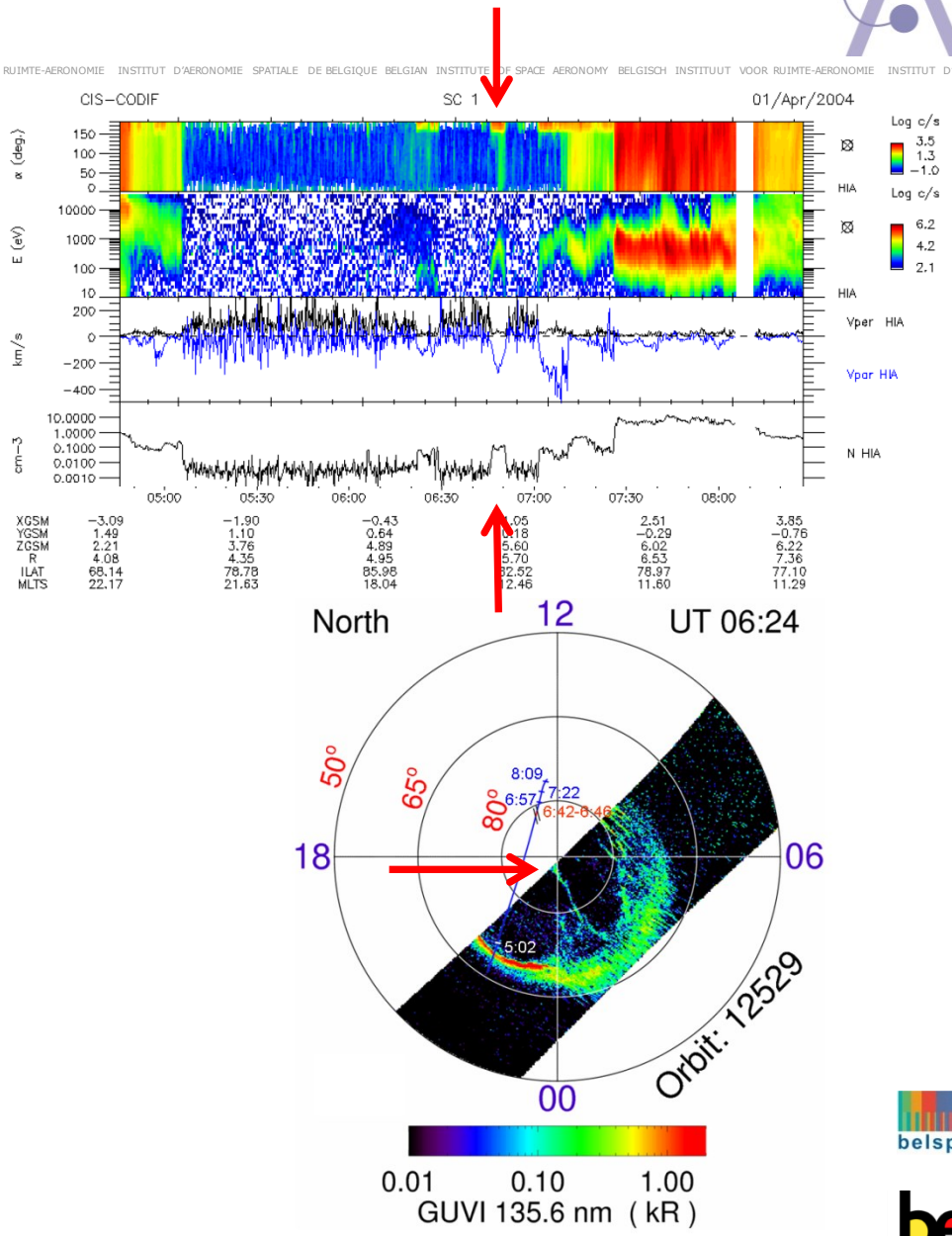
[Maggiolo et al., Ann. Geophys., 2011]

Polar cap arcs

Such polar cap ion beams appear to be connected to polar cap arcs, as shown in a coordinated Cluster – DMSP study.

Such arcs appear shortly after the IMF turns North.

[Maggiolo et al., Ann. Geophys., 2012]

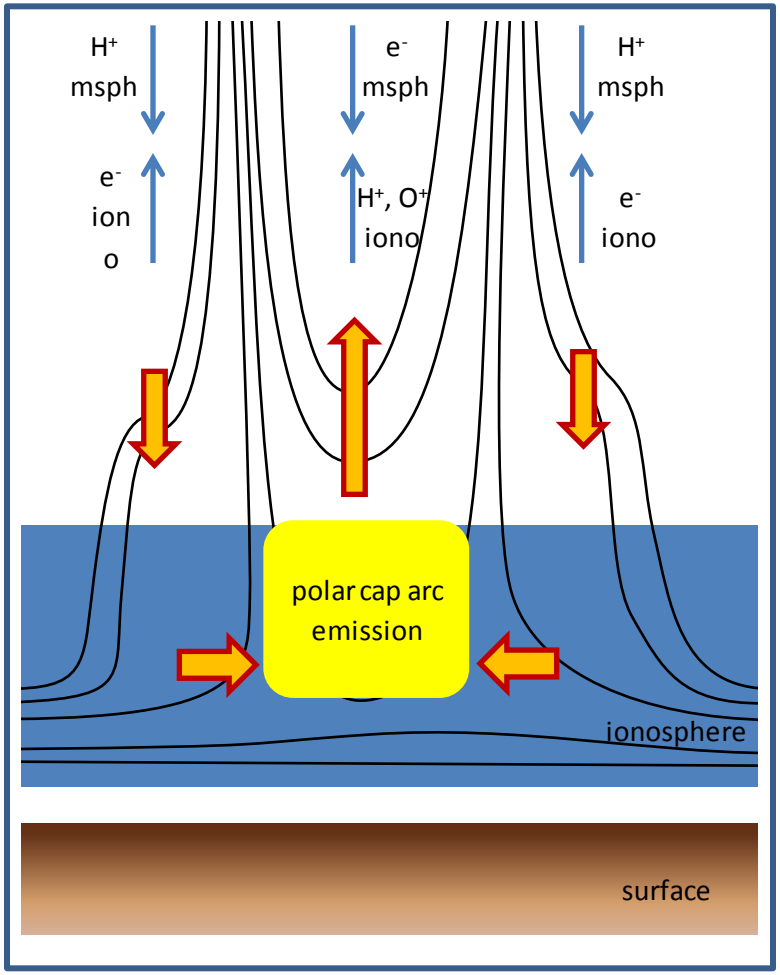


Conceptual Model

If the electric circuit is quasi-static with local current closure, such events can be seen as caused by a bipolar msph E-field, i.e. a potential well. M-I coupling produces an upward current with a parallel potential that accelerates

- e^- down : polar cap arc
- H^+ and O^+ up : beams

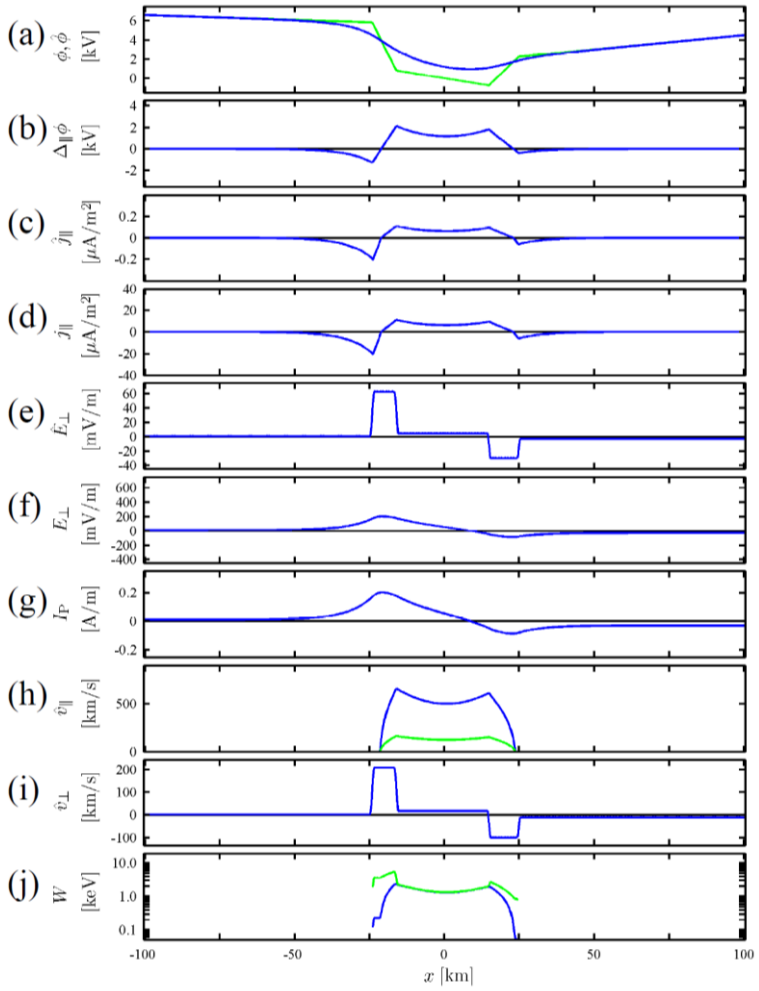
with return current at the edges.



A simple M-I coupling model

For linear I-V and constant Σ, a simple current conservation model describes the physics:

- $\Delta\phi$>0 inside, $\Delta\phi$<0 at edges;
- as $K_- > K_+$ reverse $\Delta\phi$ is smaller (50-100 V);
- $v_{||}$ (H^+ blue, O^+ green) traces $\Delta\phi$ rather than ϕ_{msph};
- additional $E \times B$ drift.



[De Keyser et al., Ann. Geophys., 2010]

The magnetospheric driver

What creates the magnetospheric potential structure?

We model the generator as a plasma slab embedded in the lobe, using a self-consistent 1-D kinetic TD model.

Difficulties:

- lobe plasma has low energy and low density and thus easily escapes detection.
- slab plasma : sometimes – but not always – a hot isotropic ion component is observed.

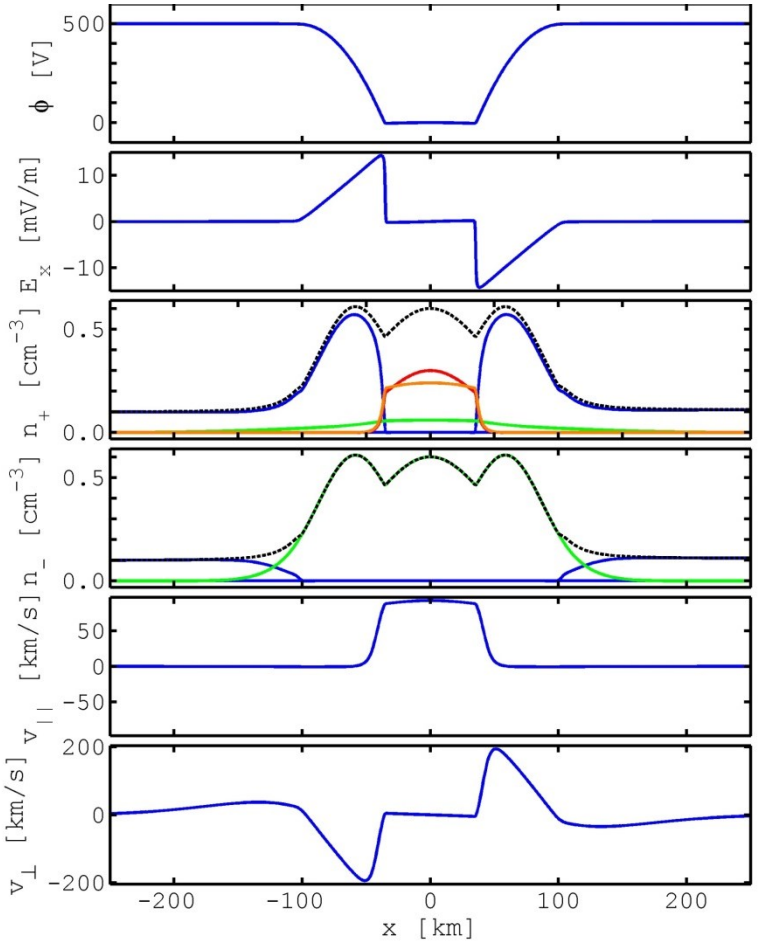
[De Keyser et al., Ann. Geophys., 2013]

Magnetospheric structure

Slab: rather hot plasma (400 eV e^-, 1 keV H^+) plus H^+ and O^+ beams accelerated through 500 V.

Environment: cold lobe plasma (1 eV e^-, 2 eV H^+).

Strong bipolar E-fields are found at the interfaces. This matches with the observed structures.



Conclusions

Cluster has shown us that polar cap arcs and polar cap ion beams are two sides of the same coin. We have a good understanding of M-I coupling in polar cap arcs.

We begin to understand magnetospheric structure thanks to Cluster observations. Still missing:

- a coupling of the beam energy to the $\Delta\phi$ that results from the magnetospheric potential;
- computation of the beam density from the energy deposited in the ionosphere by precipitating e^-.
- the electron beams in the return current regions.

Outlook

We do not have a satisfactory answer (yet) about

- the origin of the potential difference between slab and environment;
- the mystery of the hot isotropic ions : why are they not always observed? where do they come from?
- how do these structures evolve in time?

In conclusion: we are still looking for the process at the origin of polar cap arcs – and that has to do with the overall magnetospheric configuration upon a turning of the IMF from S to N.

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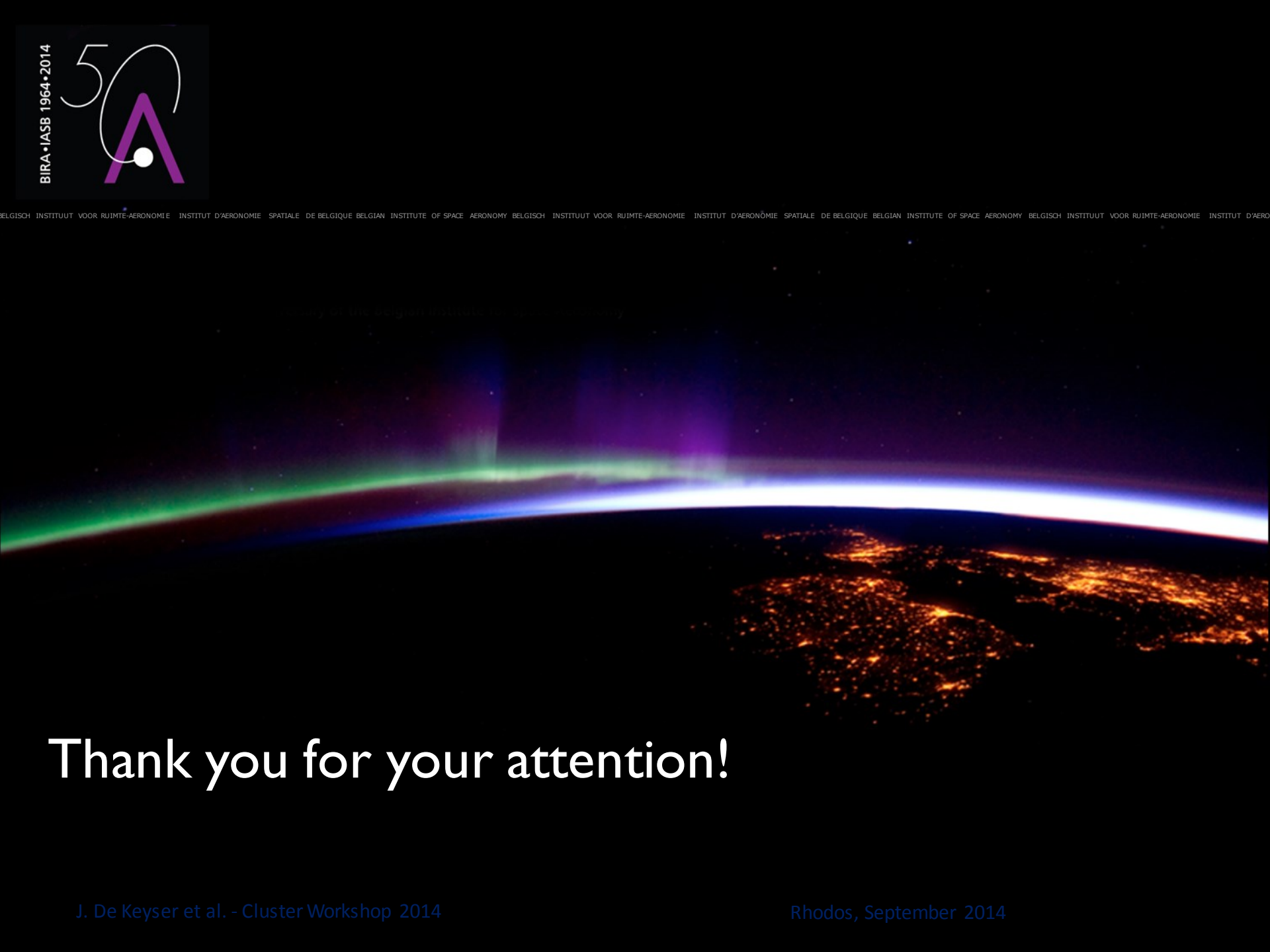
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Thank you for your attention!