Mesoscale processes in magnetosphere–ionosphere coupling – Part II

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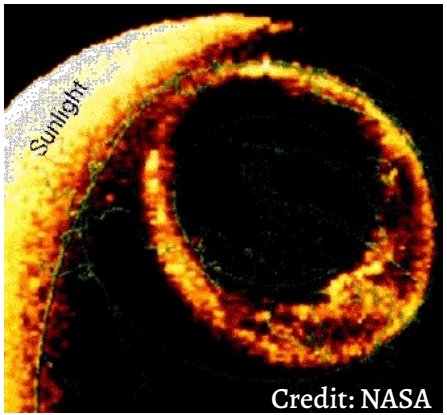
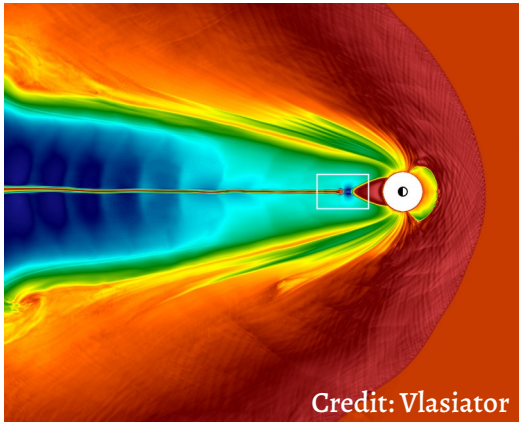
Reminder: Mesoscales in this lecture

- **Temporal scales:** minutes / tens of minutes
  - Way shorter than geomagnetic storms (days)
  - Also shorter than substorms (couple of hours)





- **Spatial scales in the ionosphere:** 10–1000 km
  - auroral arc width: ~5–30 km
  - auroral oval latitudinal extent: from ~3° (~300 km, quiet time) to > 10° (~1100 km, storm)
  - 1 h in magnetic local time (MLT) at auroral latitudes (~65°): ~700 km
- **Spatial scales in the magnetosphere:** hundreds of km to a few Earth radii (1 R_E = 6371 km)
  - dayside magnetopause standoff distance: ~10 R_E
  - magnetotail extent on the nightside: > 100 R_E
  - magnetotail current sheet thickness: 0.1–1 R_E (depending on conditions)

What are we looking for?

- Structures in various ionospheric observables, e.g.
  - electron density
  - ion flows
  - magnetic field
  - optical emissions
  - field-aligned currents
  - electric field
- …with a corresponding signature in the magnetosphere
- (though sometimes we don't understand what we are looking at!)

Outline

Part I: Introduction to magnetosphere–ionosphere (MI) coupling

1. Brief overview of ionospheric physics
2. MI coupling mechanisms
3. Studying mesoscale processes in the ionosphere

Part II: Examples of mesoscale processes in MI coupling

1. Dayside couplings
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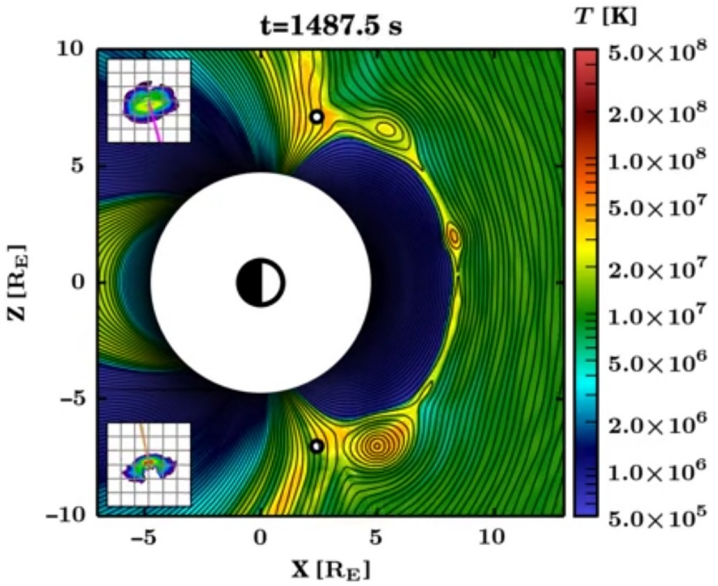
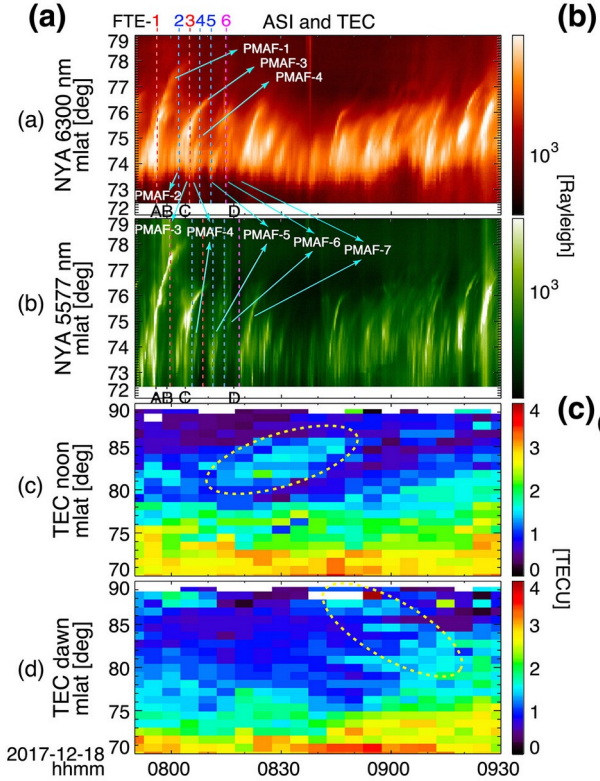
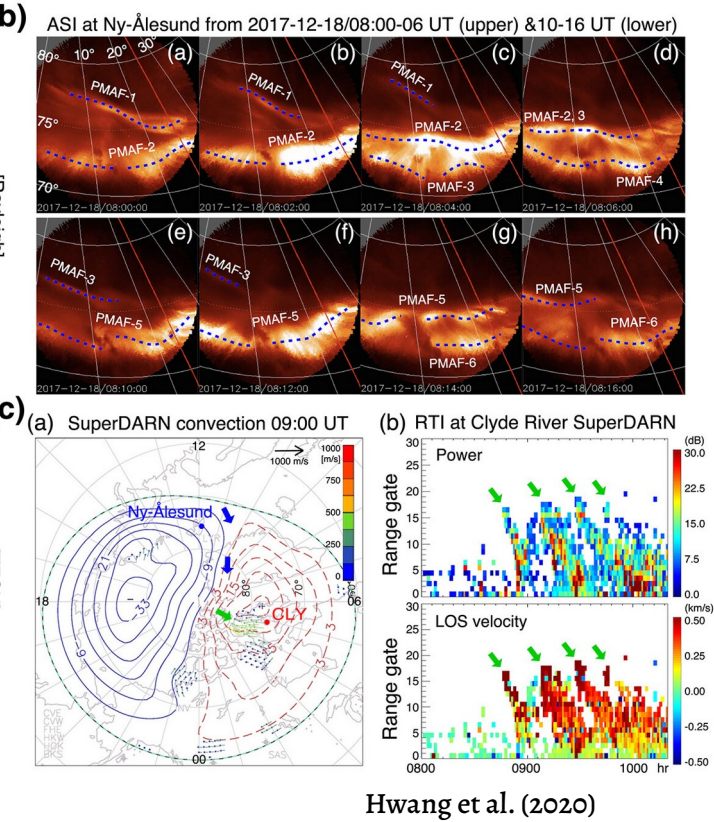
5. Concluding words

Flux transfer events (dayside magnetopause) and poleward moving auroral forms (ionosphere)



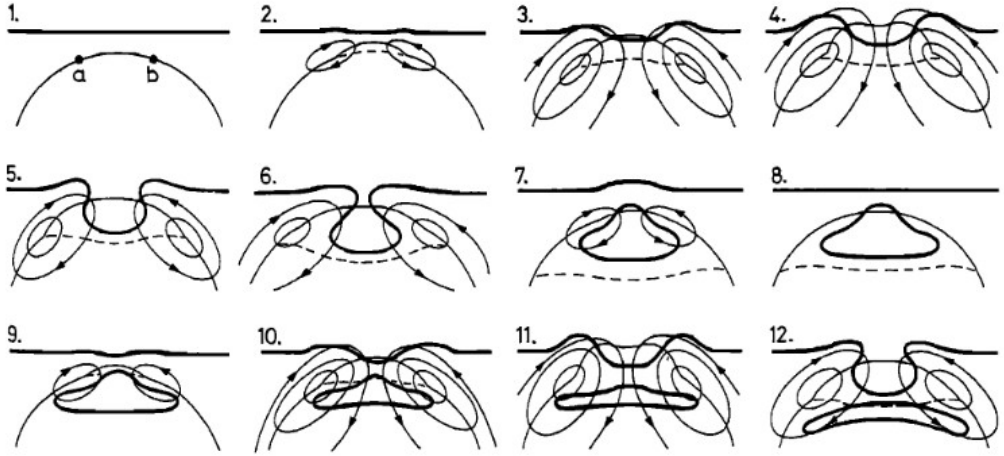
Grandin et al. (2020)



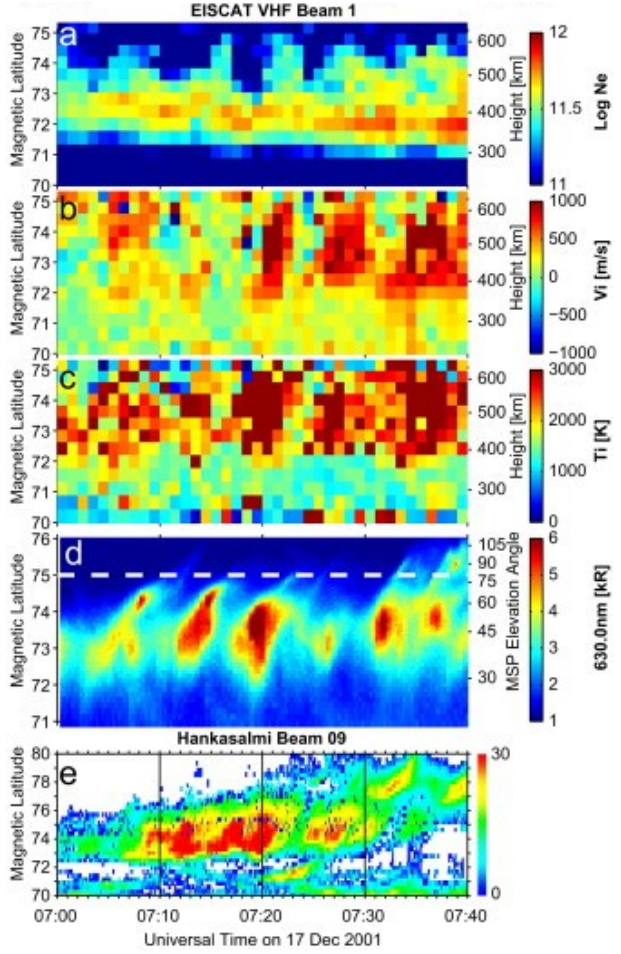


Hwang et al. (2020)

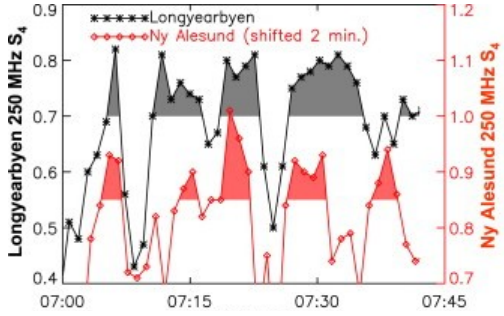
Bursty dayside reconnection (magnetosphere) and polar cap patches (ionosphere)



Lockwood & Carlson Jr. (1992)



Moen et al. (2012)



- signatures in n_e, v_i, T_i (radar), 630.0 nm emission (optics)
- effect on GPS signal (scintillation)

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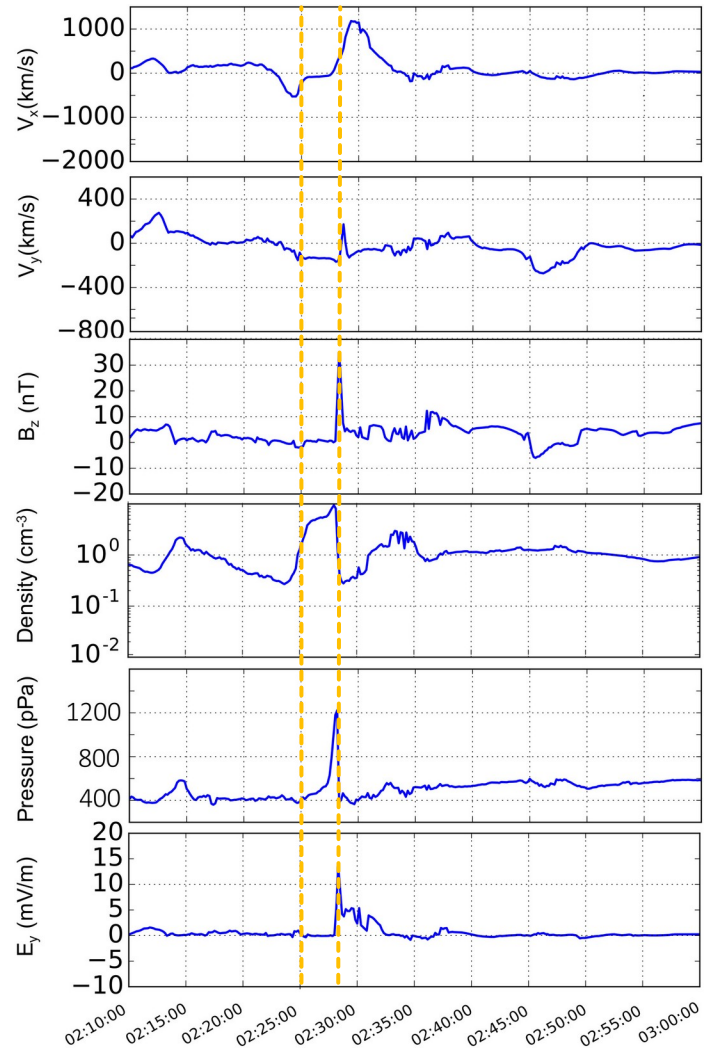
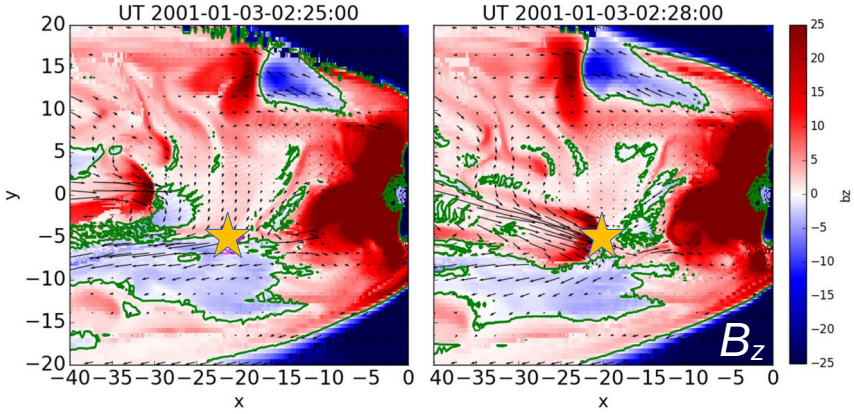
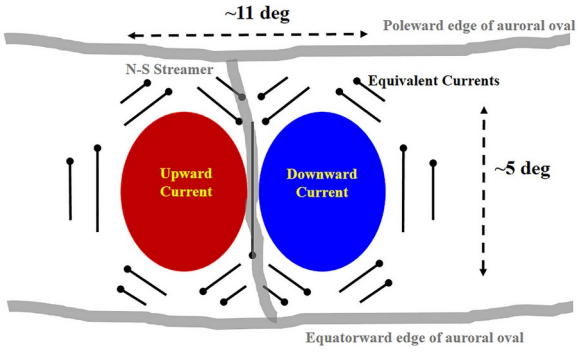
Bursty bulk flows (magnetotail) and auroral streamers (ionosphere)

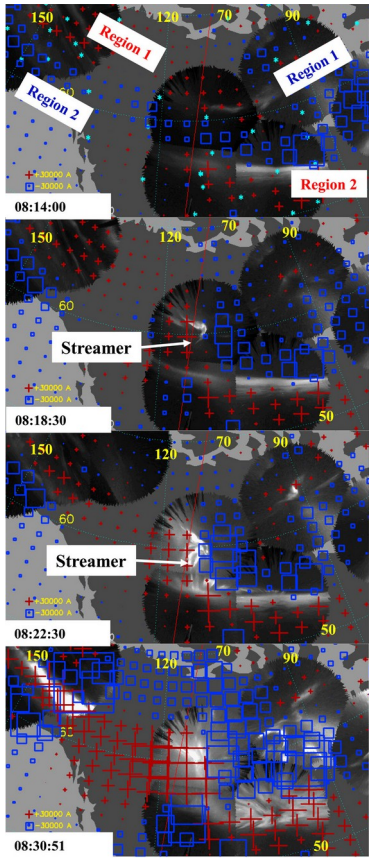




Adapted from Ferdousi et al. (2021)

Adapted from Weygand et al. (2022)





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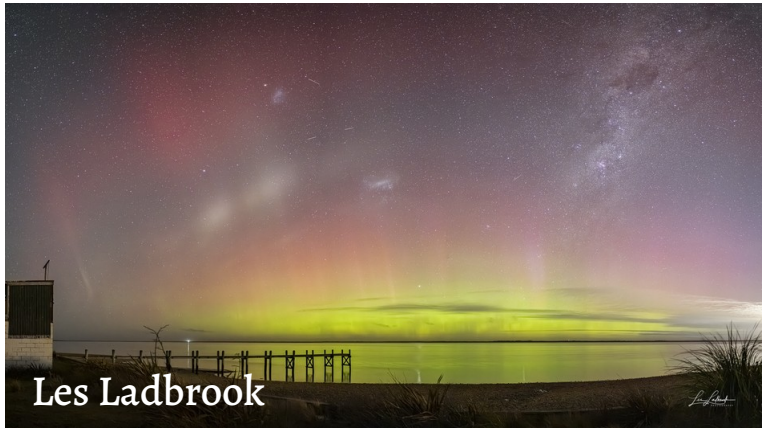
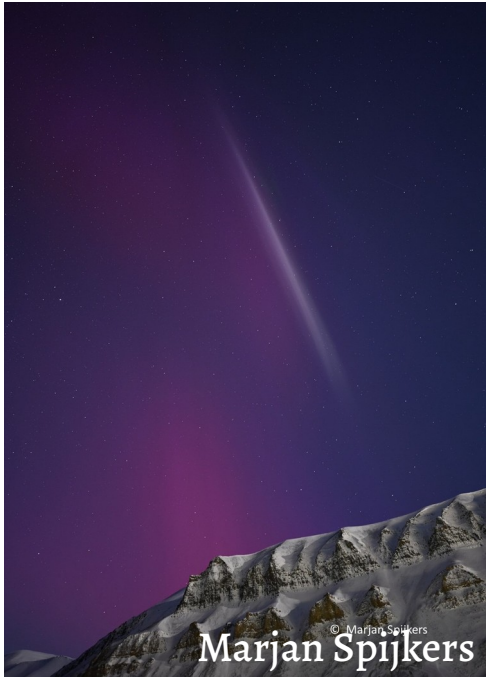
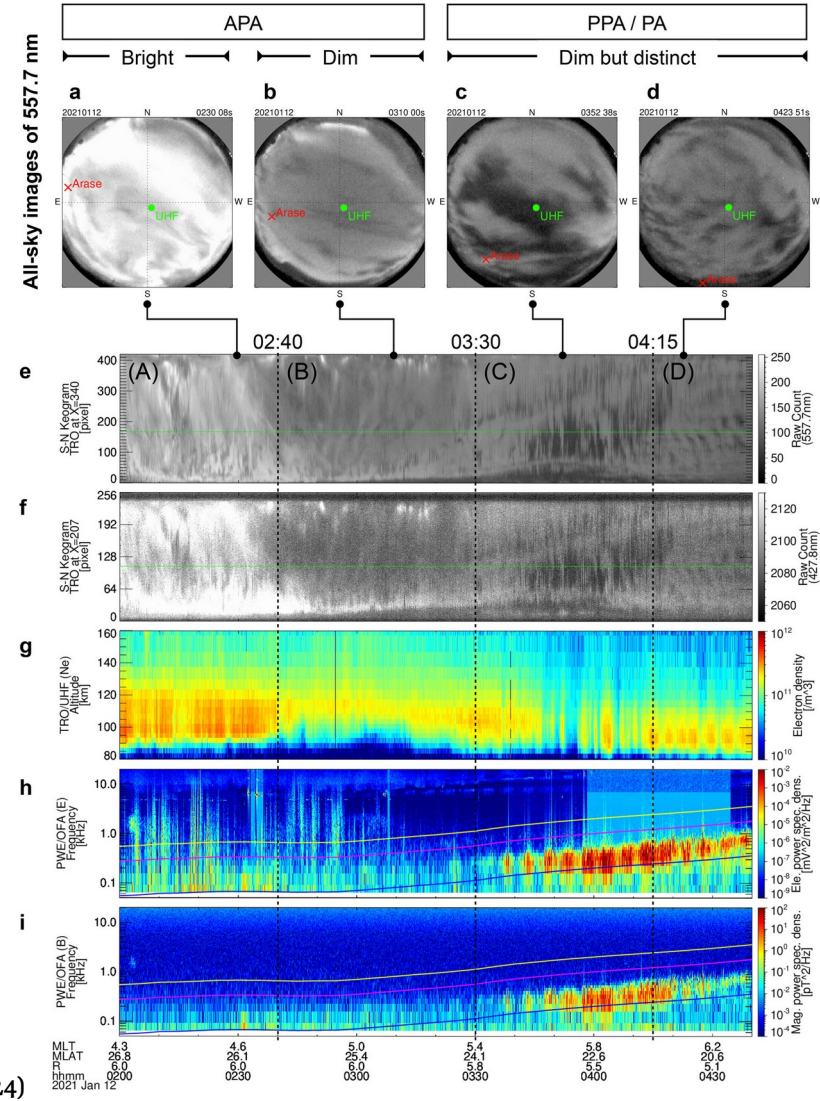
Mesoscales are all over in optical data!





Chorus waves (inner magnetosphere) and pulsating aurora (ionosphere)

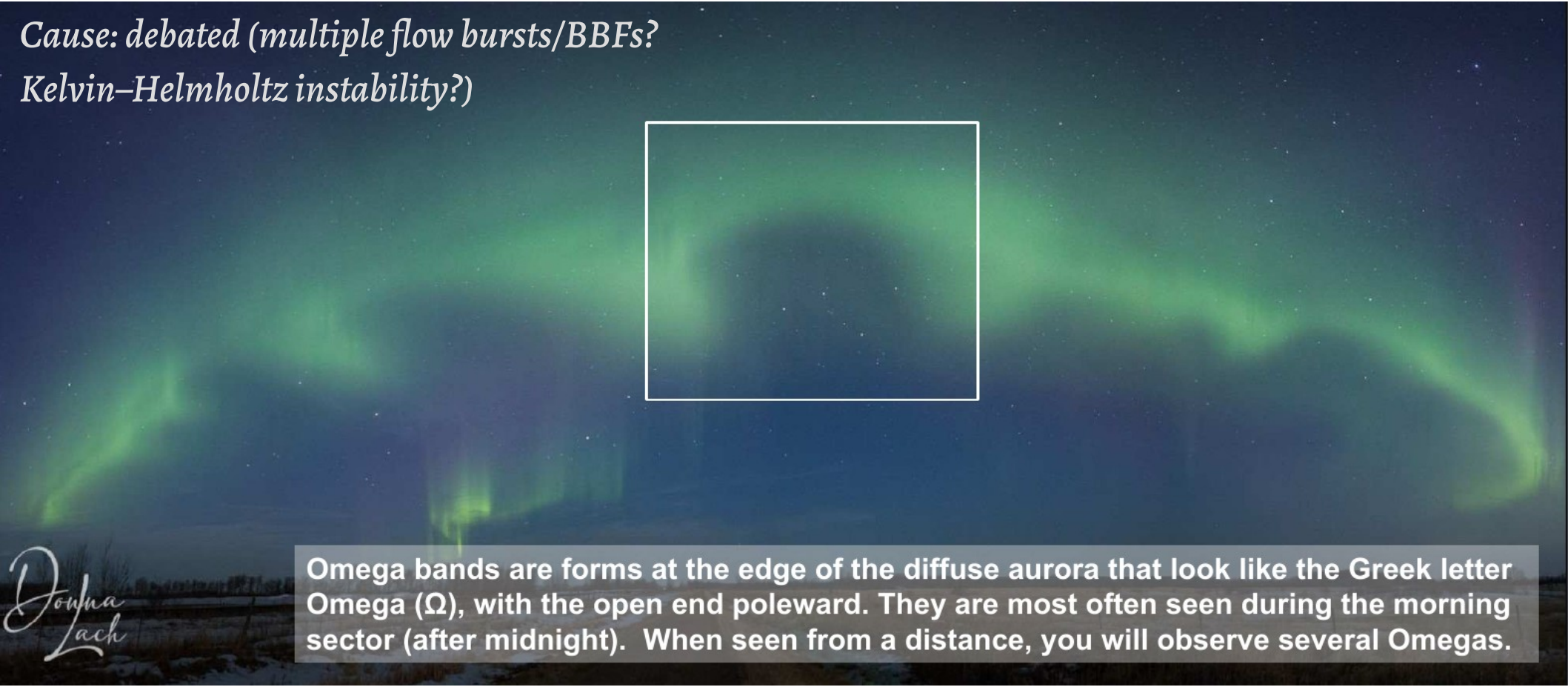
Time lapse credit: Donna Lach (Canada)



Ito et al. (2024)

Omega bands

Herlingshaw et al. (2024, ARCTICS Aurora Field Guide)



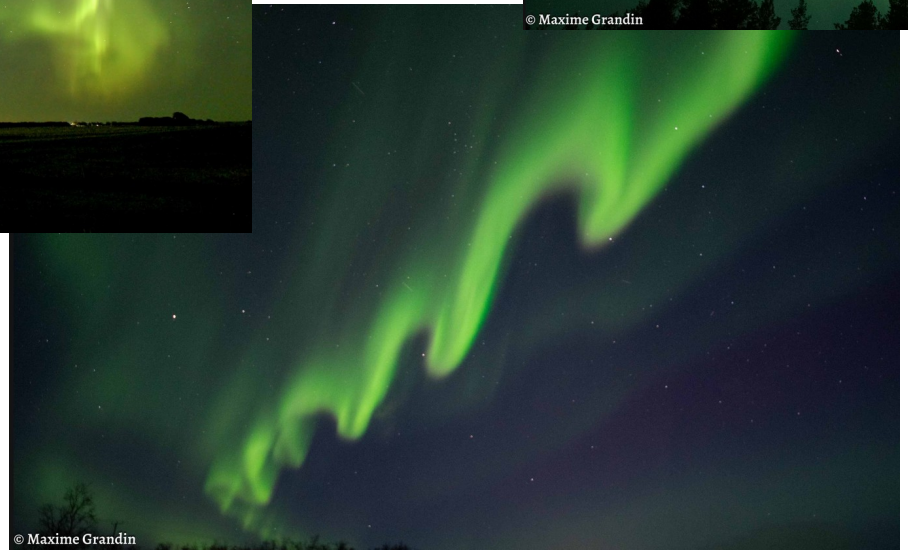
Curls, folds, spirals

Curls

Photo: D. Lach

Sheared flows?

Kelvin–Helmholtz instability?



Spiral

Photo: M. Grandin

Rotational flows?

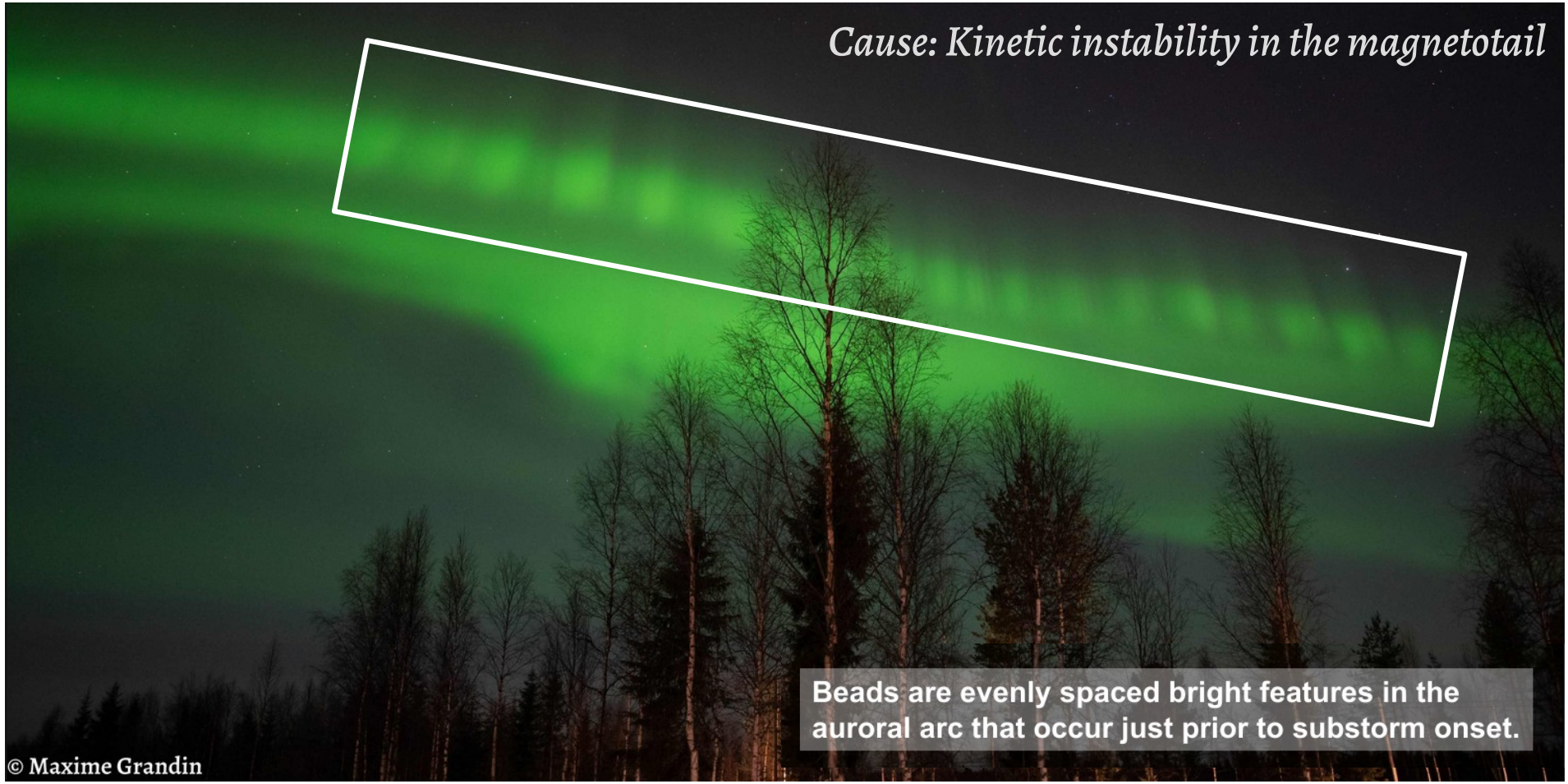
Magnetosphere or ionosphere?

Folds

Photo: M. Grandin

Sheared FAC?

Beads



Herlingshaw et al. (2024, ARCTICS Aurora Field Guide)

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STEVE, picket fence, and SAID

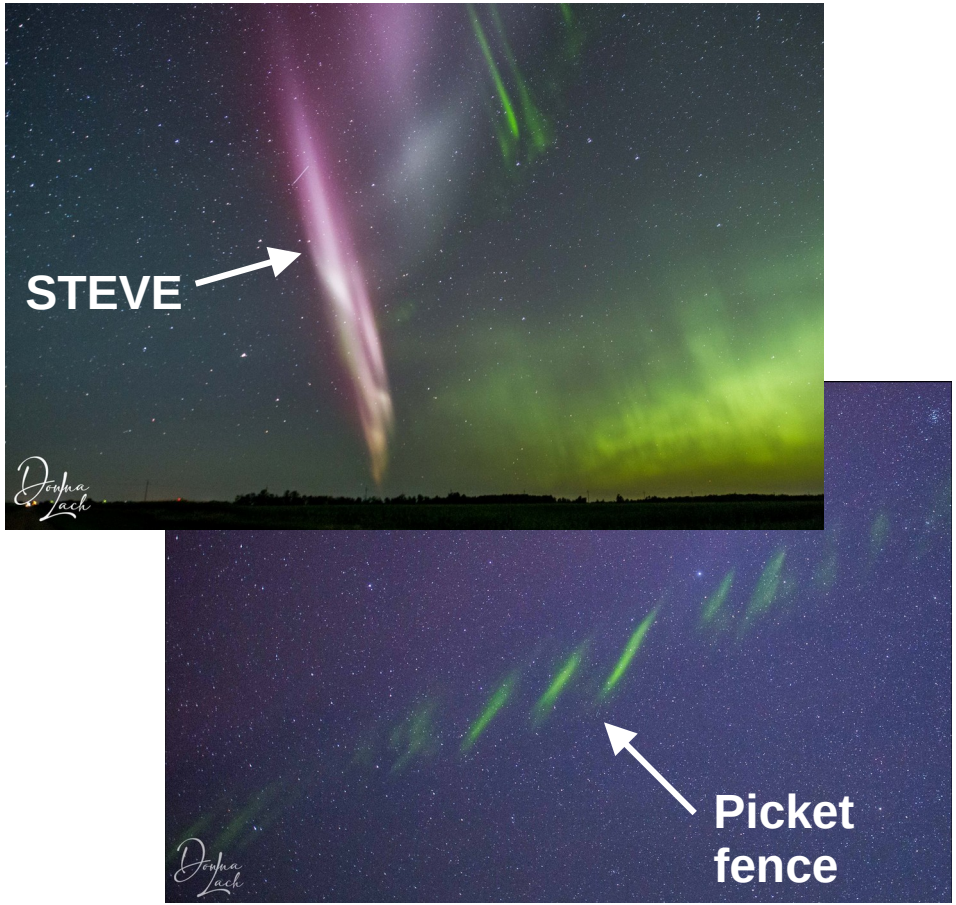
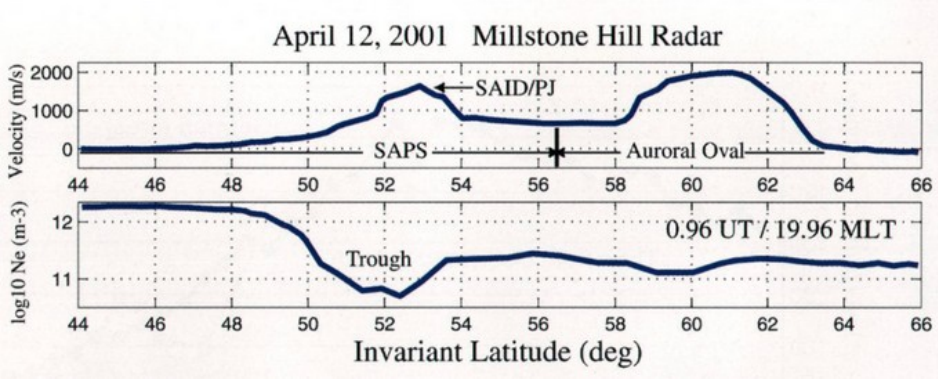


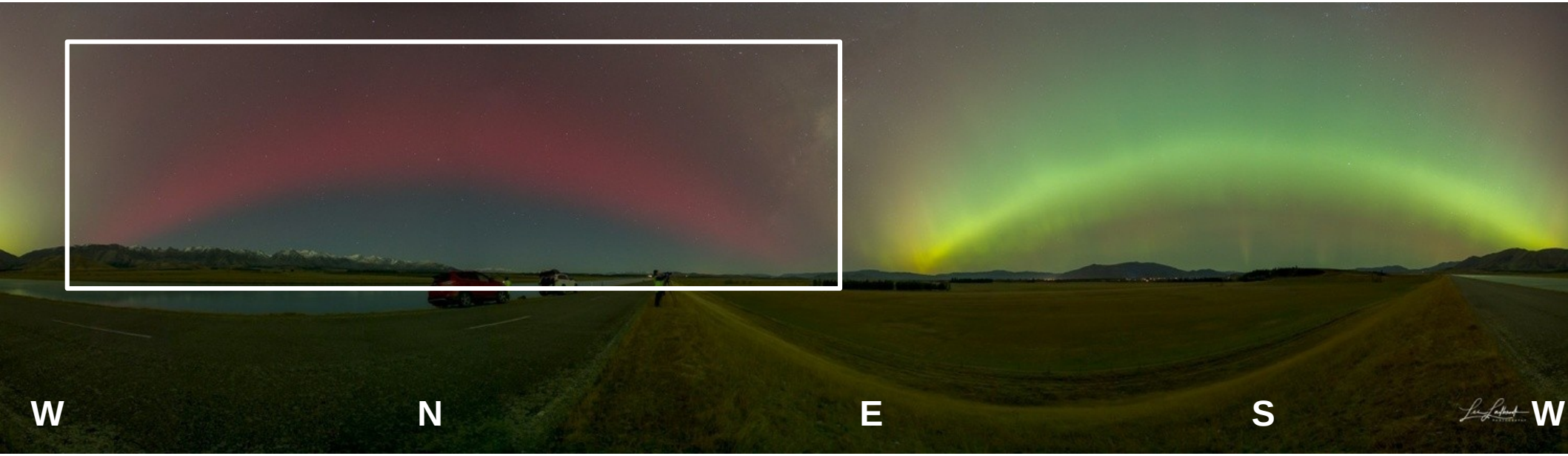
Photo credit: Donna Lach (Canada)

- STEVE: "Strong Thermal Emission Velocity Enhancement"; white/mauve arc-like structure
- SAID: Subauroral ion drift; > 1 km/s westward flow
- Clearly linked together and to inner-magnetospheric processes, though we don't yet know exactly how
- Green emissions called "picket fence" are often seen alongside STEVE. We don't know what they are…



Adapted from Foster & Burke (2002)

Stable auroral red (SAR) arcs



NB: Southern-hemisphere picture!

Photo credit: Les Ladbrook (New Zealand)

- A SAR arc is a subauroral ionosphere process, i.e. it is found equatorwards from the auroral oval
- It consists of red emission from atomic oxygen at ~400 km altitude
- Its location maps near the plasmapause; heating from the ring current

Dune aurora

- Wave-like structure in the diffuse green emission
- Barely visible to the naked eye
- Peak emission at ~100 km altitude (Palmroth et al., 2020)
- Possible association with proton precipitation and the presence of an atmospheric wave near the mesopause (Grandin et al., 2021)

Photo credit: Pirjo Koski (Finland)

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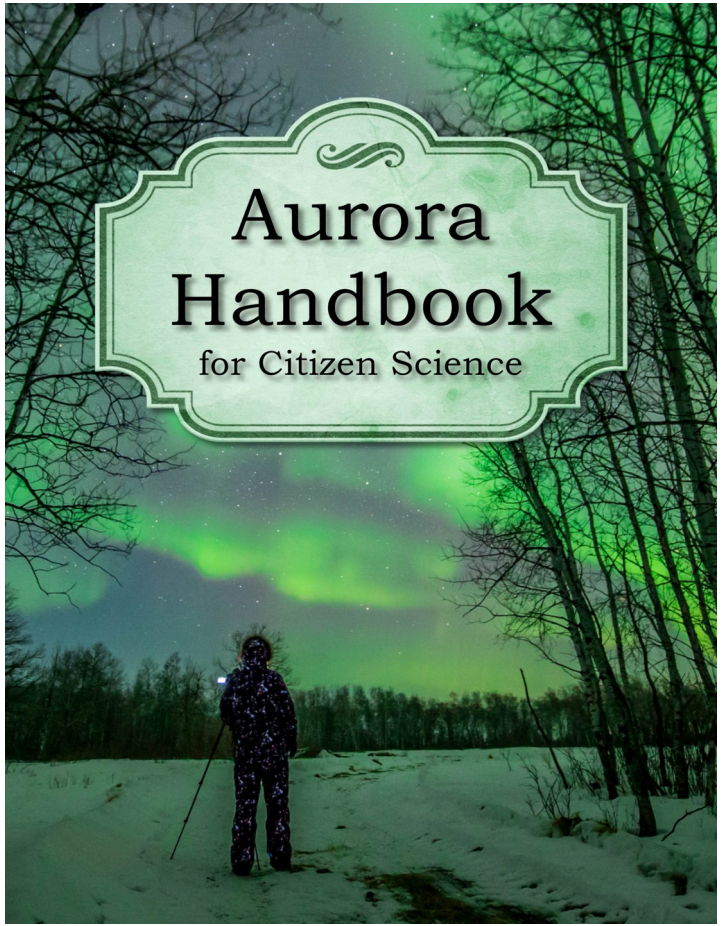
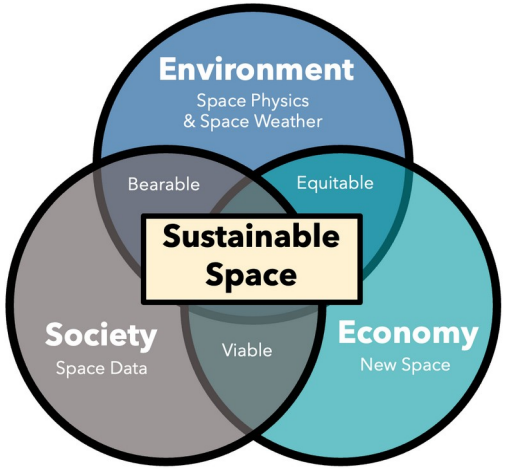
Aurora Field Guide & Handbook for Citizen Science



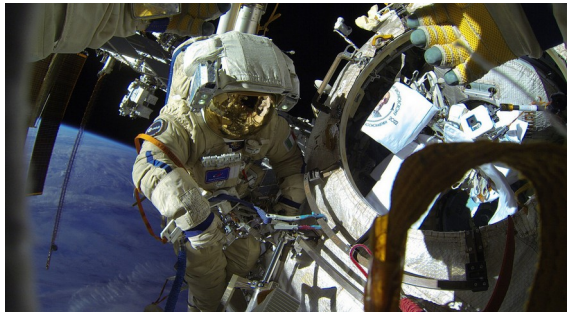
Herlingshaw et al. (2024), doi:10.5281/zenodo.13931939

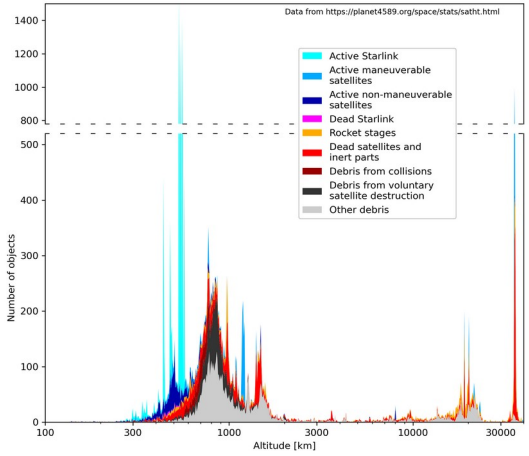
HTML: https://kherli.github.io/Aurora-Field-Guide-And-Handbook/index.html

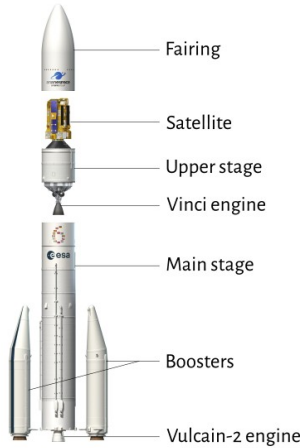
Cover pictures: Donna Lach



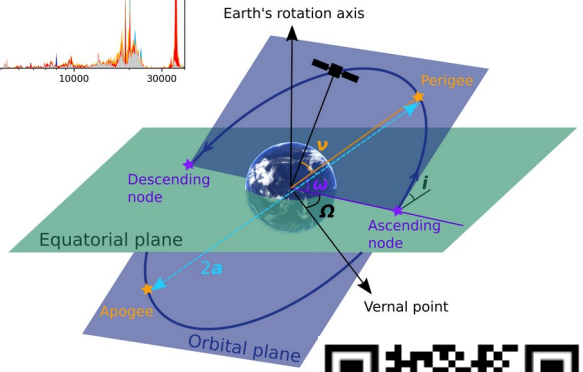
Sustainable Space MOOC







- Free online course by Univ. Helsinki since October 2024 (2 ECTS credits)
- Basics on
  - Sun–Earth interactions
  - Space technology
  - Human activities in space
  - Space law and space ethics
  - **Sustainability challenges: Kessler syndrome, atmospheric effects, resource exhaustion…**



https://courses.mooc.fi/org/uh-physics/courses/sustainable-space

Video credit: SpaceX/Fram2, Jannicke Mikkelsen

Final thoughts

Write one thing (take-home message or specific example) that you learnt from this lecture.

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