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Physical analogies between solar chromosphere and earth's ionosphere

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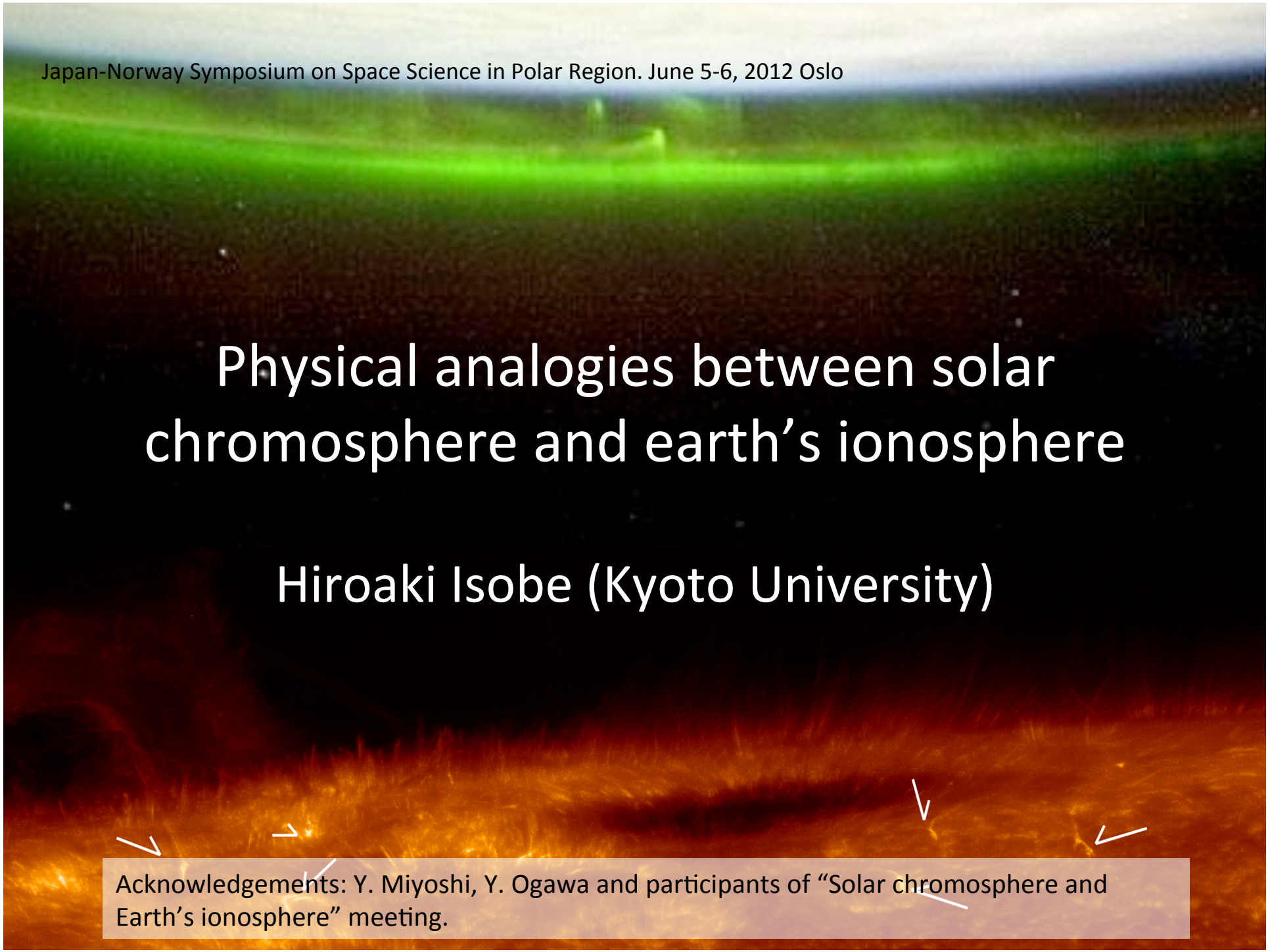
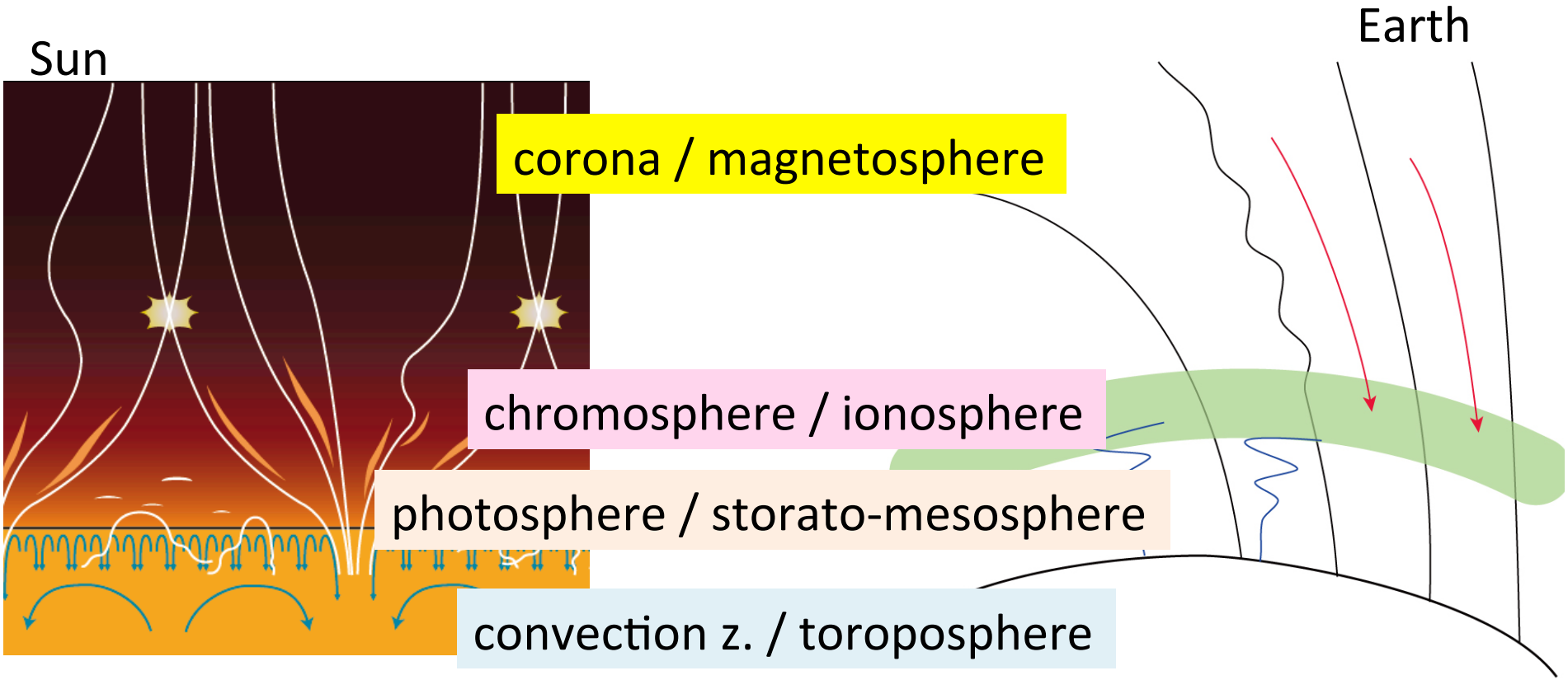


Acknowledgements: Y. Miyoshi, Y. Ogawa and participants of "Solar chromosphere and Earth's ionosphere" meeting.

Why chromosphere is important

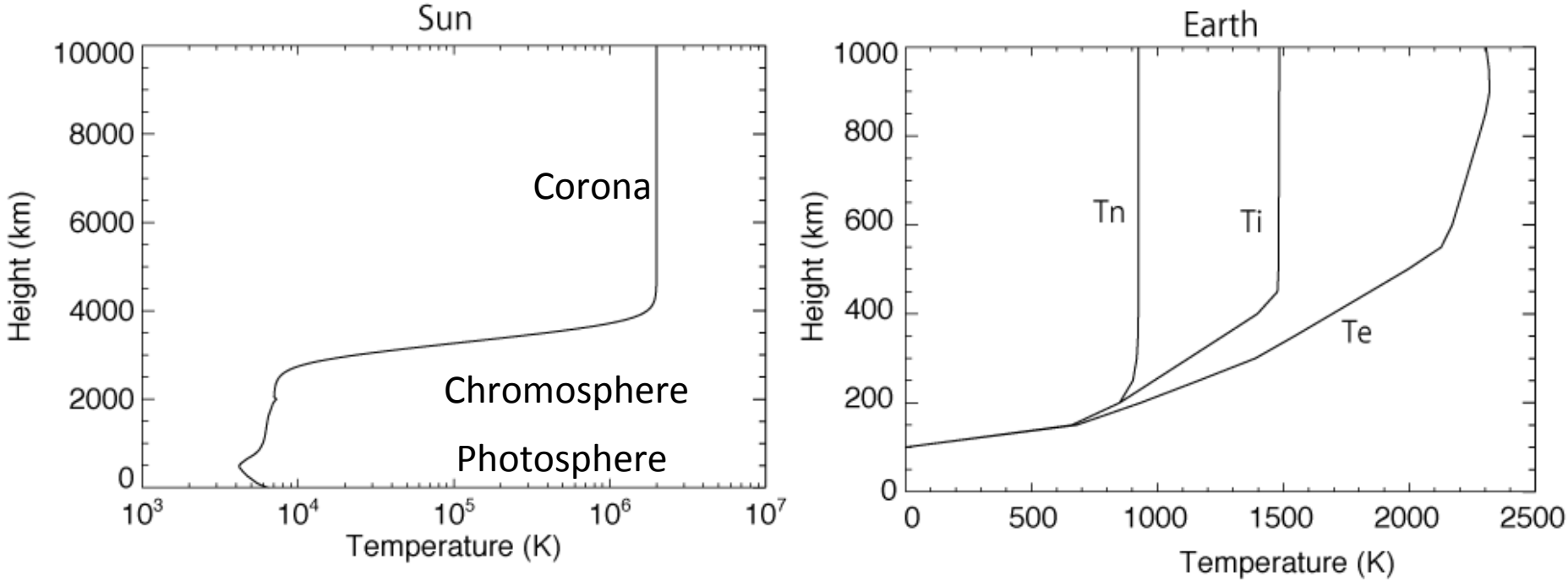
- Intrinsically interesting
- Path of mass and energy to corona, solar wind, and thus heliosphere
- Origin of UV radiation that affects upper atmosphere of Earth
- Unique laboratory of weakly ionized plasma also relevant to molecular cloud, protoplanetary discs and ionosphere

Similarity of chromosphere and ionosphere



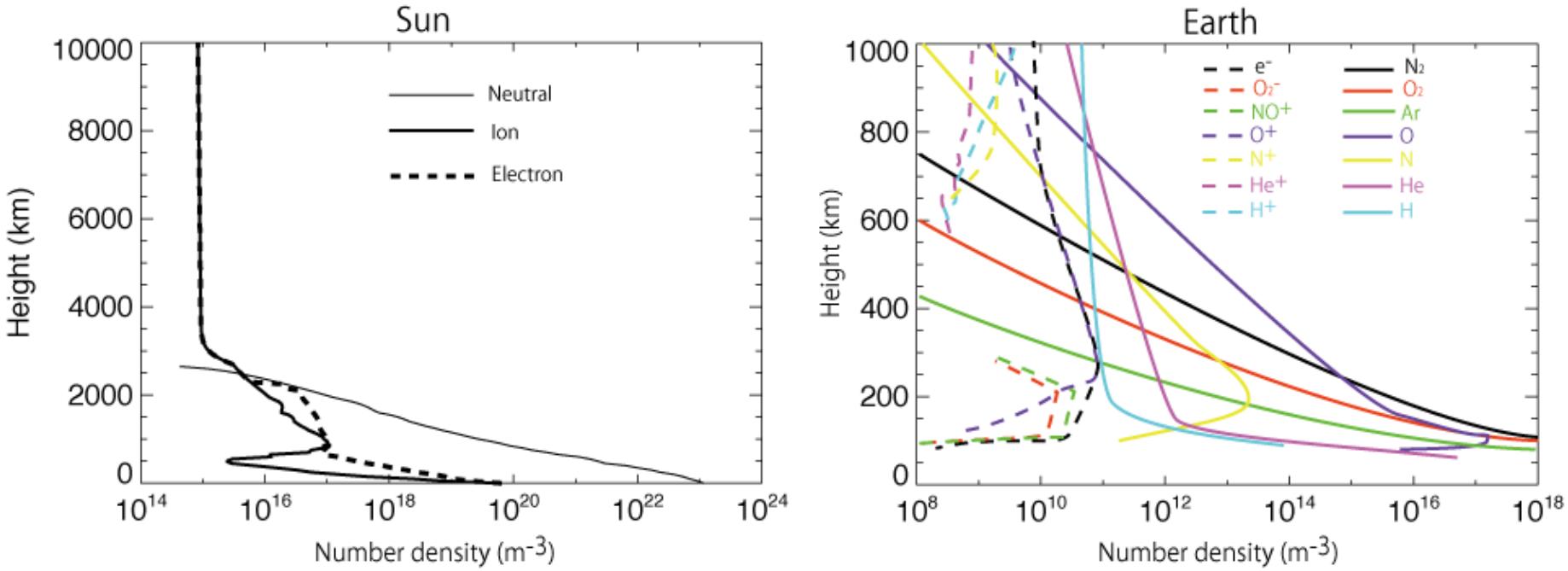
- Interface layer between tenuous, magnetically dominant region above and convecting layer below
- Coupling with by magnetic field and waves
- Gravitationally stratified
- Weakly ionized. Neutral/plasma interaction important

Temperature profile



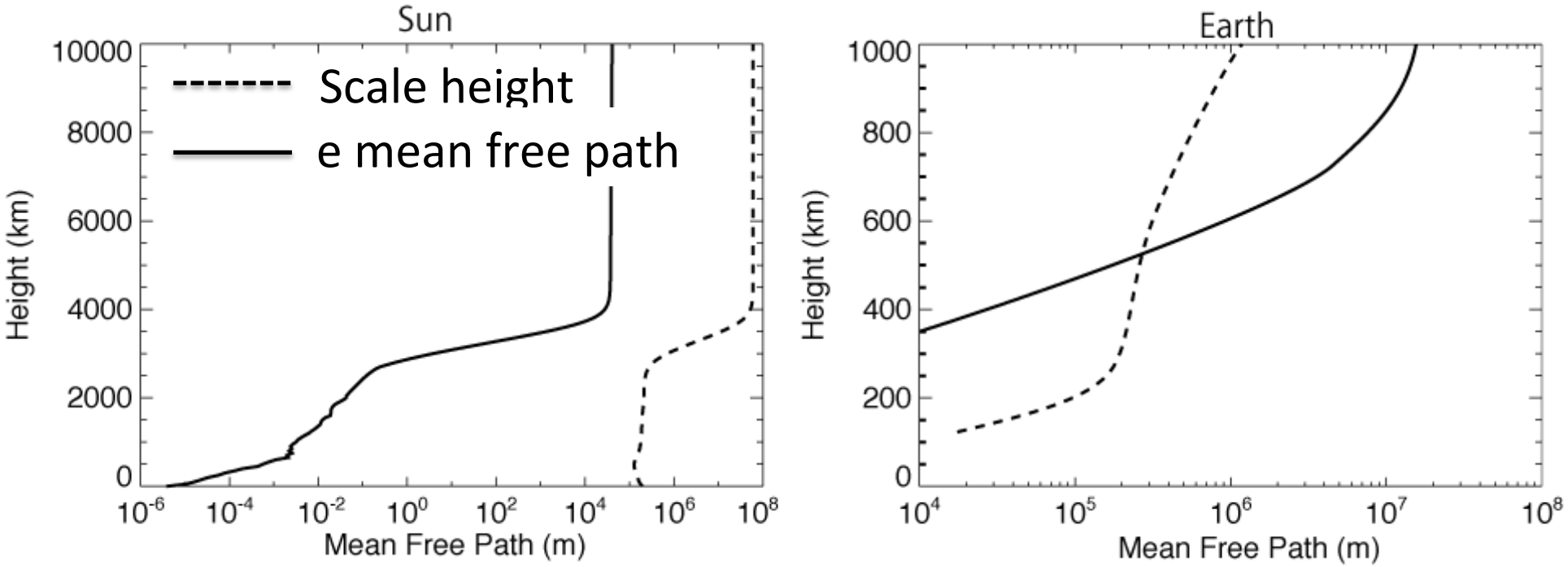
- $T_n \sim T_i \sim T_e$ in solar atmosphere because of collisional relaxation.

Density profile



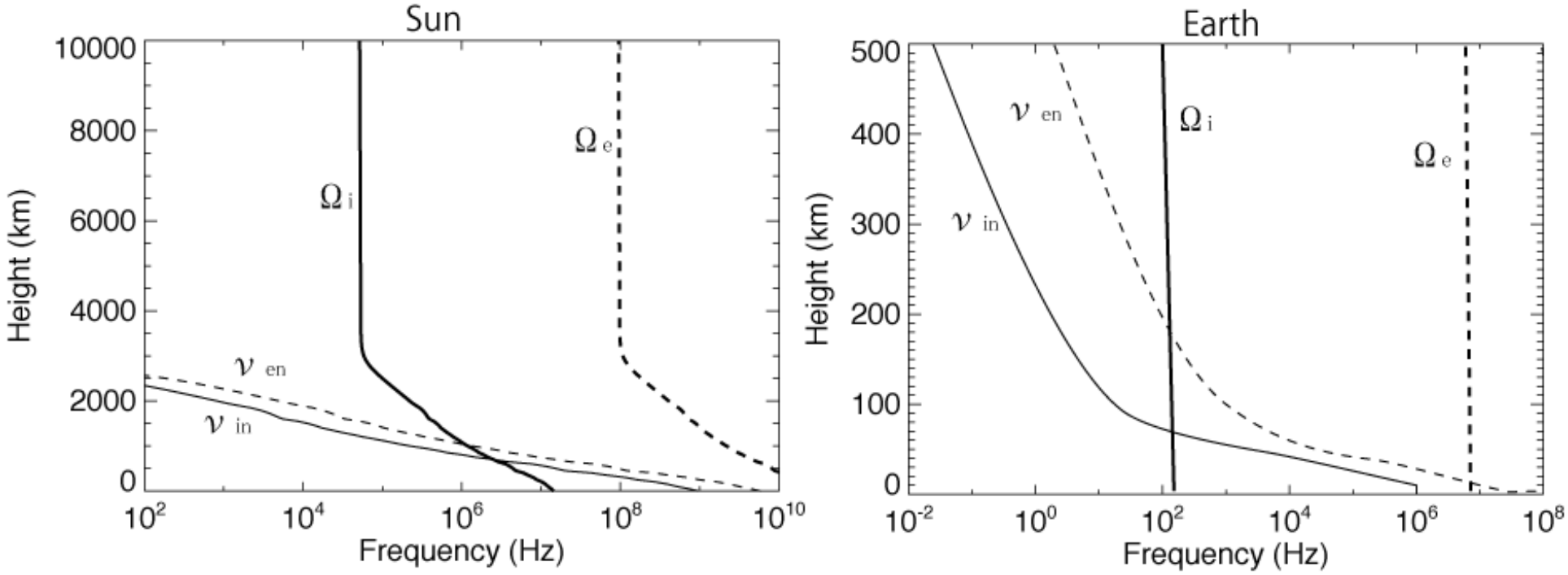
- Strong stratification: density drops many orders of magnitude.
- Weakly ionized (ionization fraction << 1).
- In ionosphere, Dominant ion species change as a function of height.
- In the sun, H~90% , He~10% (number density) and little others.

Collisionality



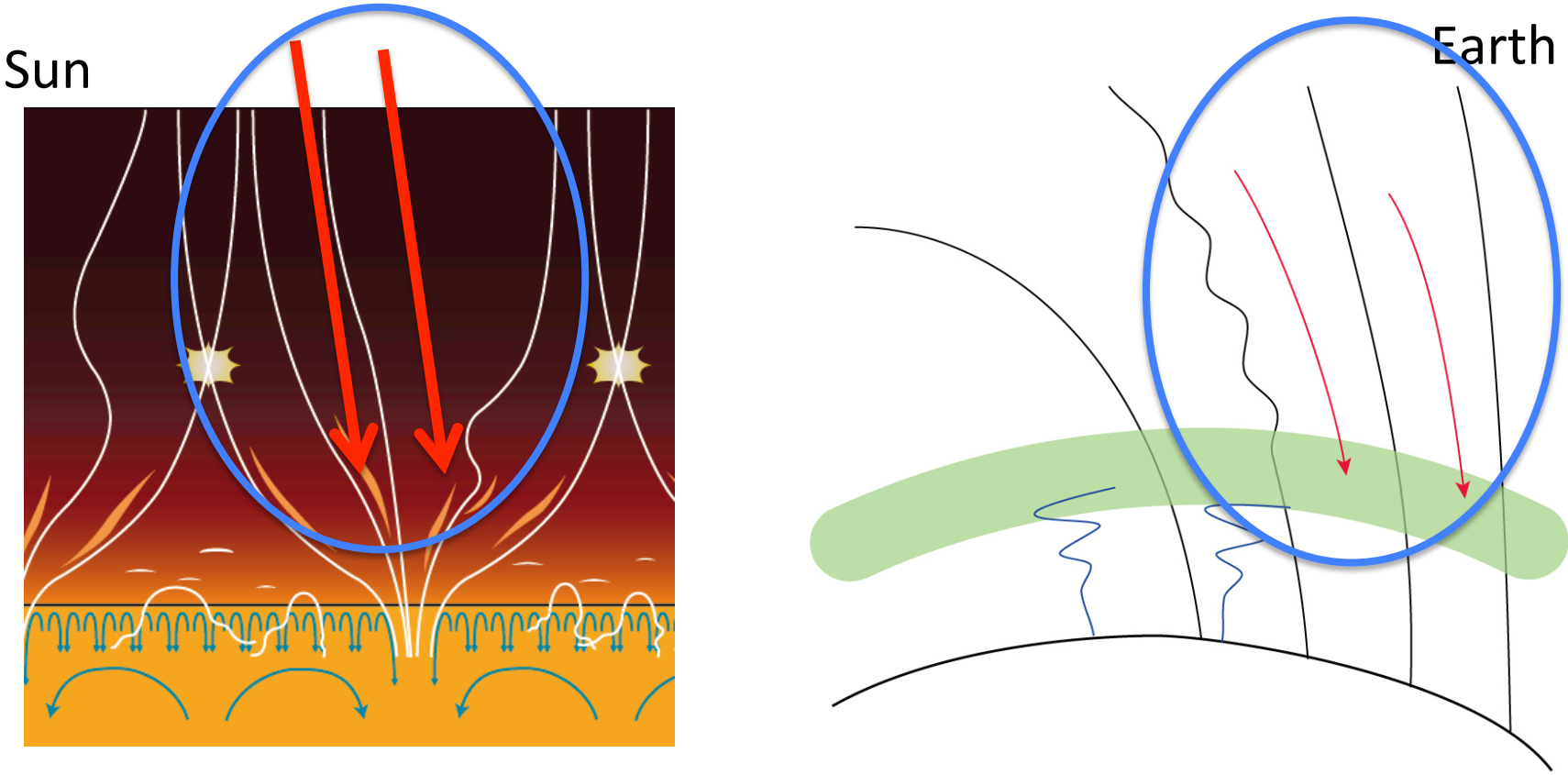
- Chromosphere is collisional. Neutrals and plasma is strongly coupled and behave as a single fluid, except in small (<~10km) scale.
- Lower ionosphere is strongly coupled, while upper ionosphere is nearly collisionless.

Collisional and cyclotron frequencies



- Collisional freq $\nu_{in,en}$ > cyclotron freq $\Omega_{i,e}$ means ion/electron is demagnetized by collision with neutrals.
- If $\Omega_i < \nu_{in}$ and $\Omega_e > \nu_{en}$, ion and electron behave differently, producing electric current.
- Such “dynamo effects” known in ionosphere, but not identified in chromosphere.

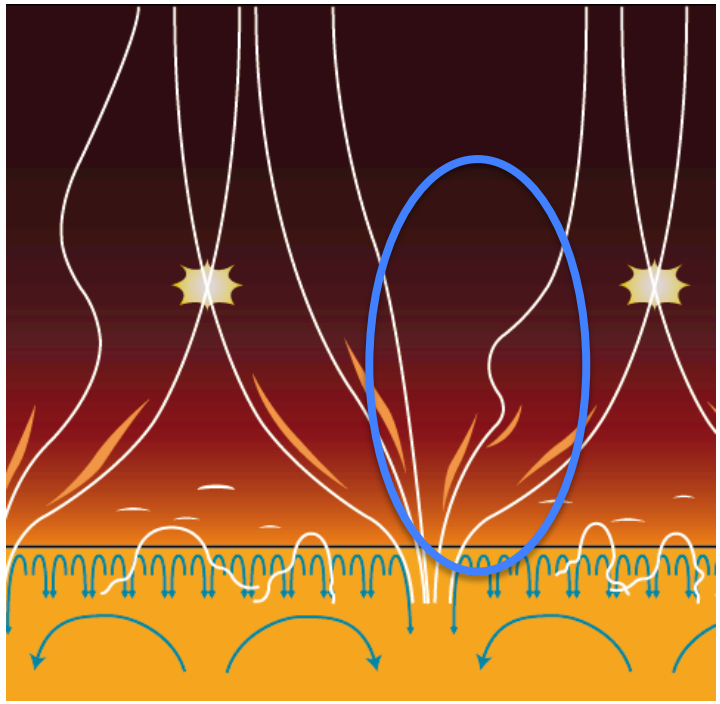
Common physical processes

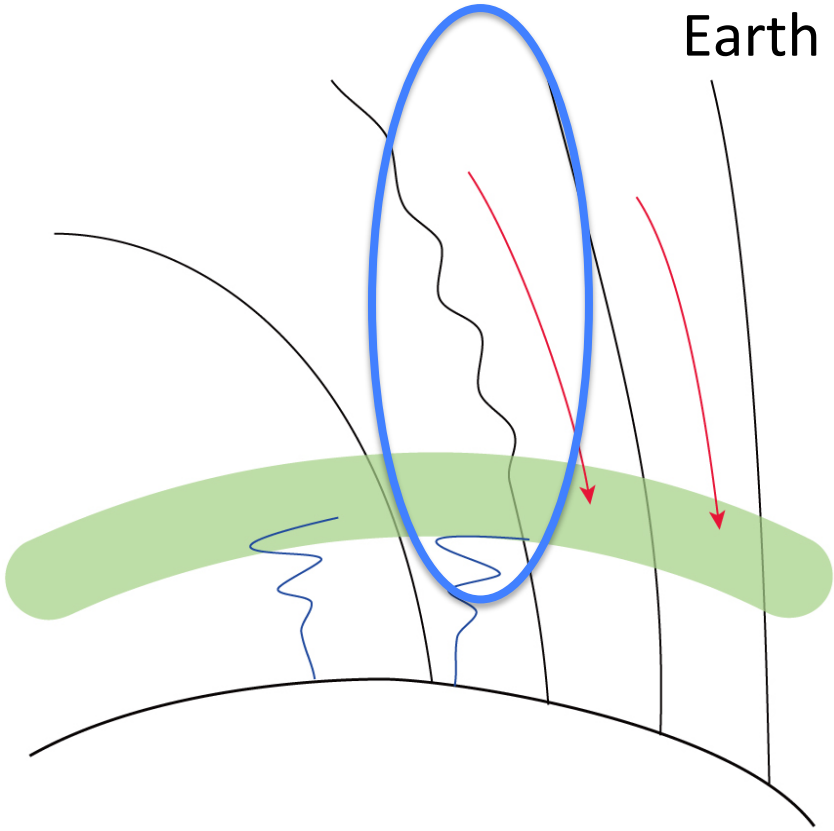


- Precipitation of high energy particles during flare/ substorms

Common physical processes

Sun

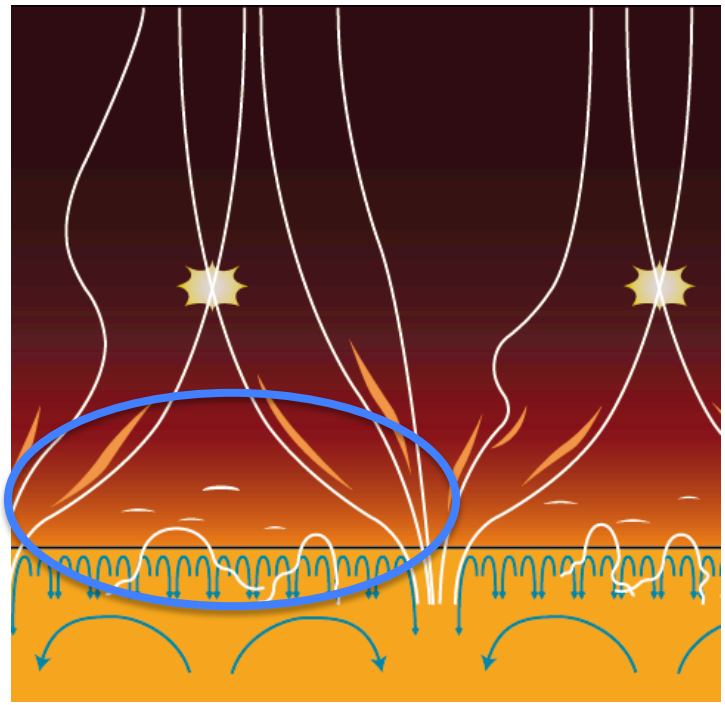




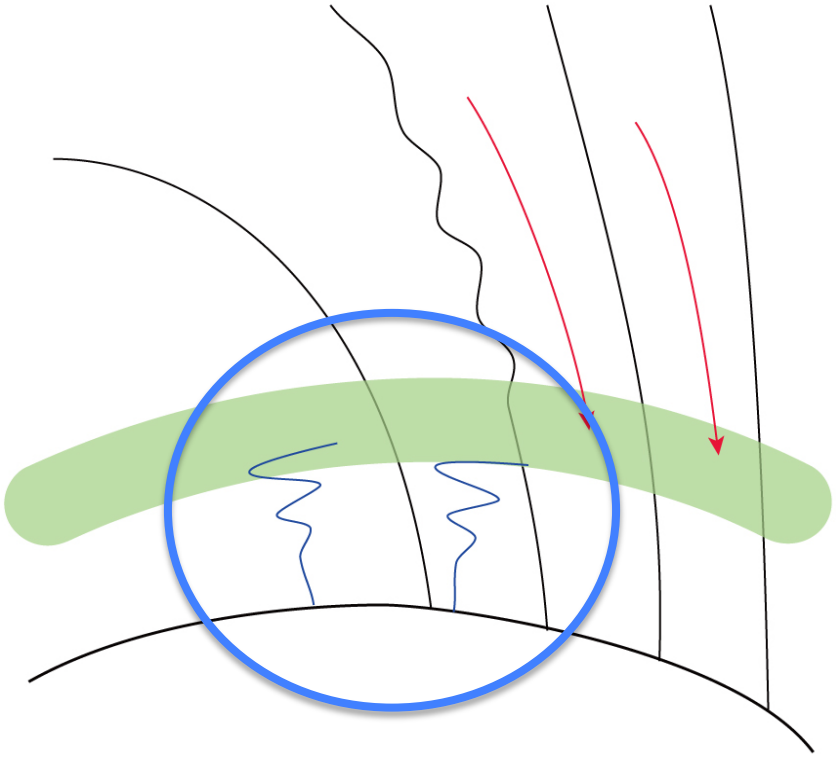
- Magnetohydrodynamic waves
  - In ionosphere they come from magnetosphere (energy source is solar wind)
  - In chromosphere they come both above and below (energy source is photospheric convection)

Common physical processes

Sun



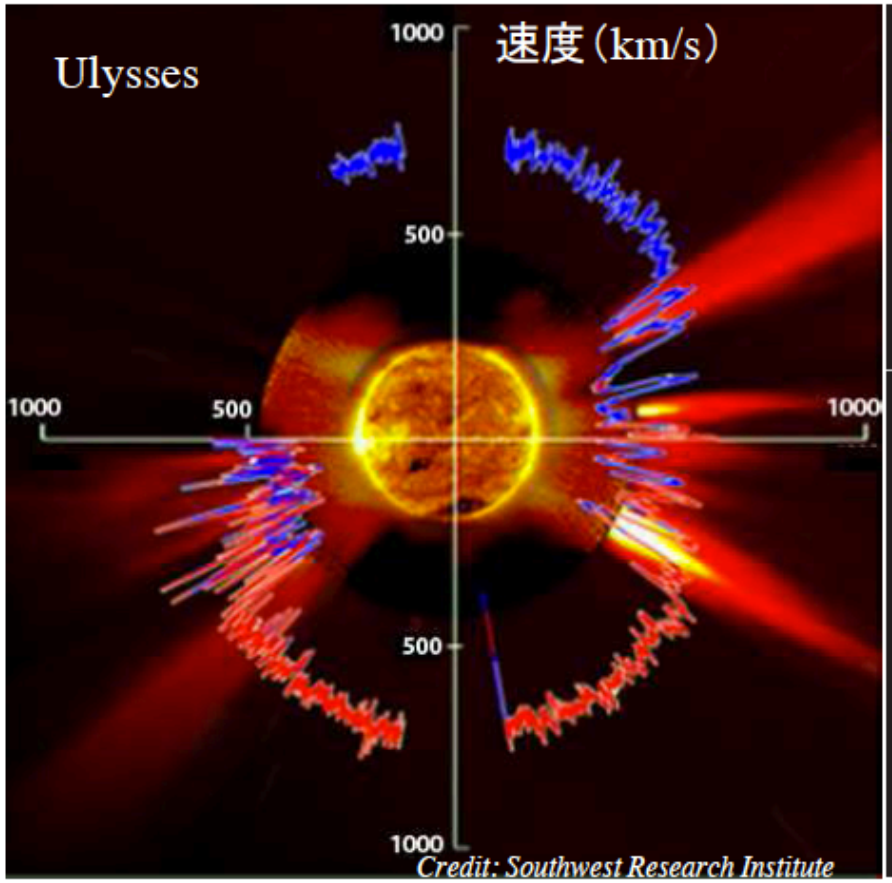
Earth



- Waves from below
  - Stratification causes amplitude growth (shock formation)
  - Gravity wave important in Earth
  - Sound wave (slow-mode shock) important in Sun
  - ...why different?

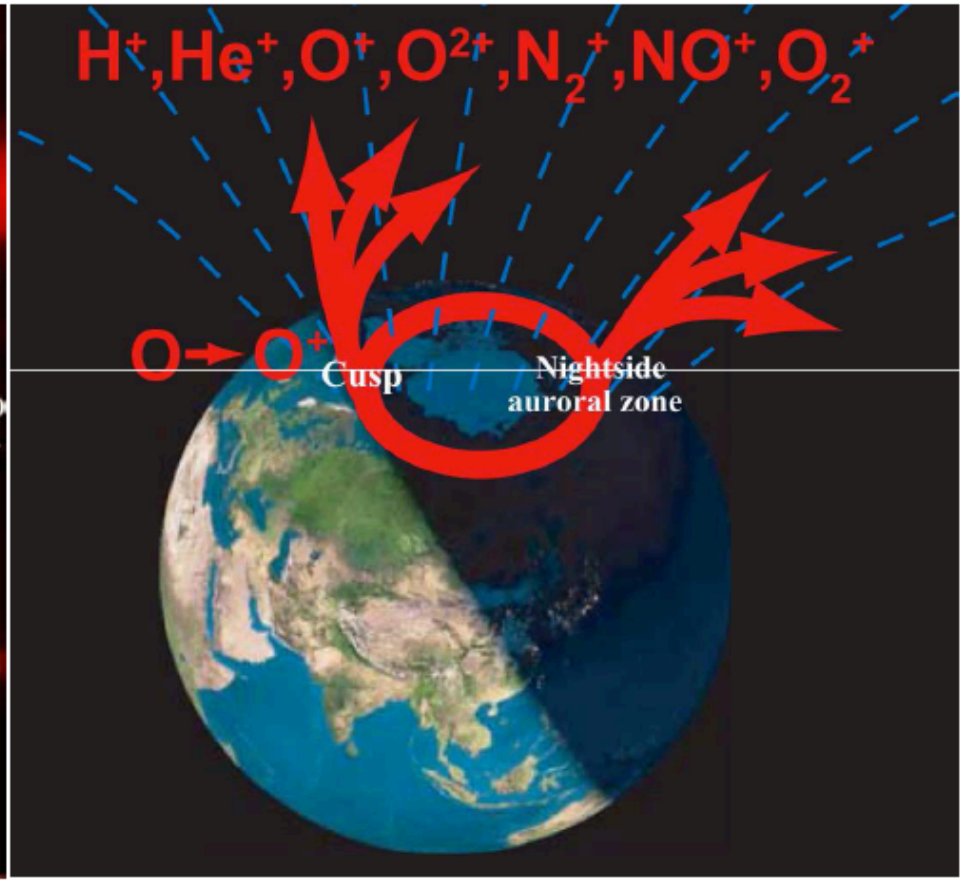
Similar? solar wind and polar wind

Sun



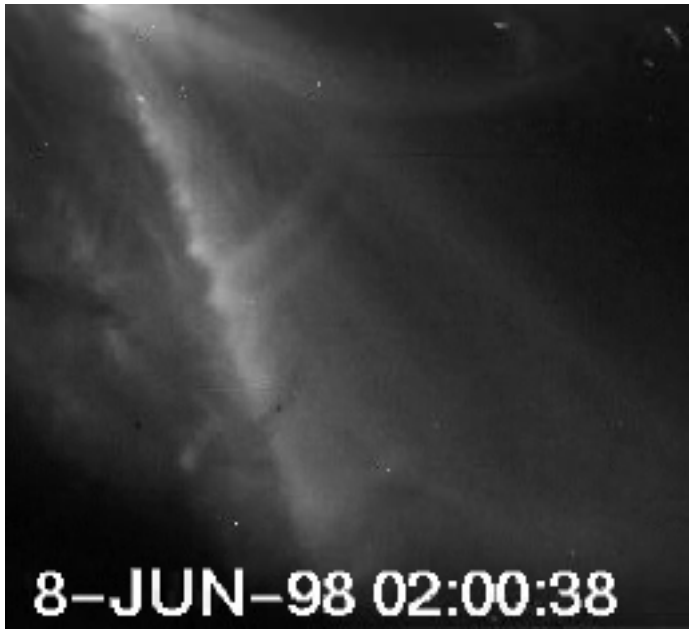
Phil Berardelli, *Science NOW*, 2008

Earth

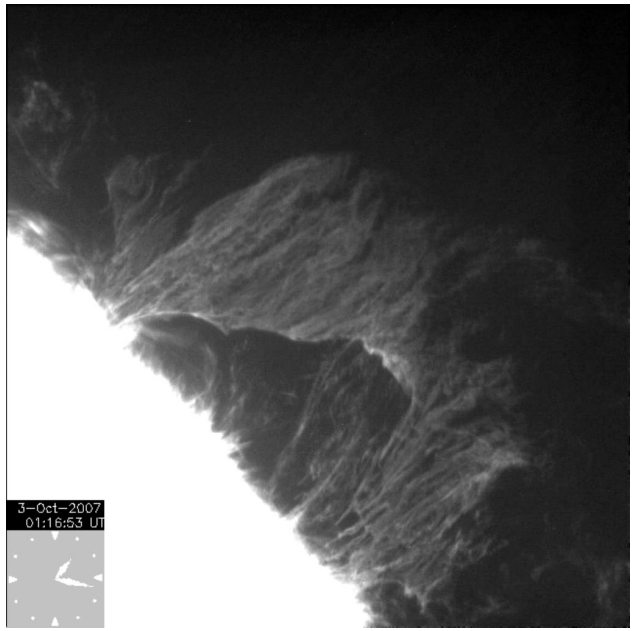


Y. Ogawa, *STEL Newsletter*, 2005

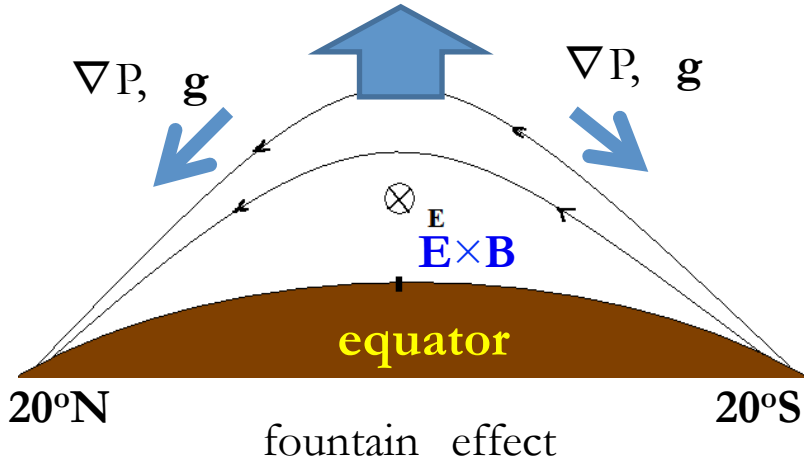
Similar? Emerging flux and plasma bubbles



Emerging flux



"Bubble" in prominence (Berger et al. 2008)



Plasma bubble in Earth atmosphere
(courtesy H. Fujiwara)

Magnetic Rayleigh-Taylor instability

Sun-Earth language barrier larger than that of Norway-Japan?

- Terrestrial people define plasma beta by
  (plasma pressure) / (magnetic pressure)

- Solar people define plasma beta by
  (plasma + neutral pressure) / (magnetic pressure)
  ...because plasma and neutrals behave almost as single fluid

- We need persevering conversation!

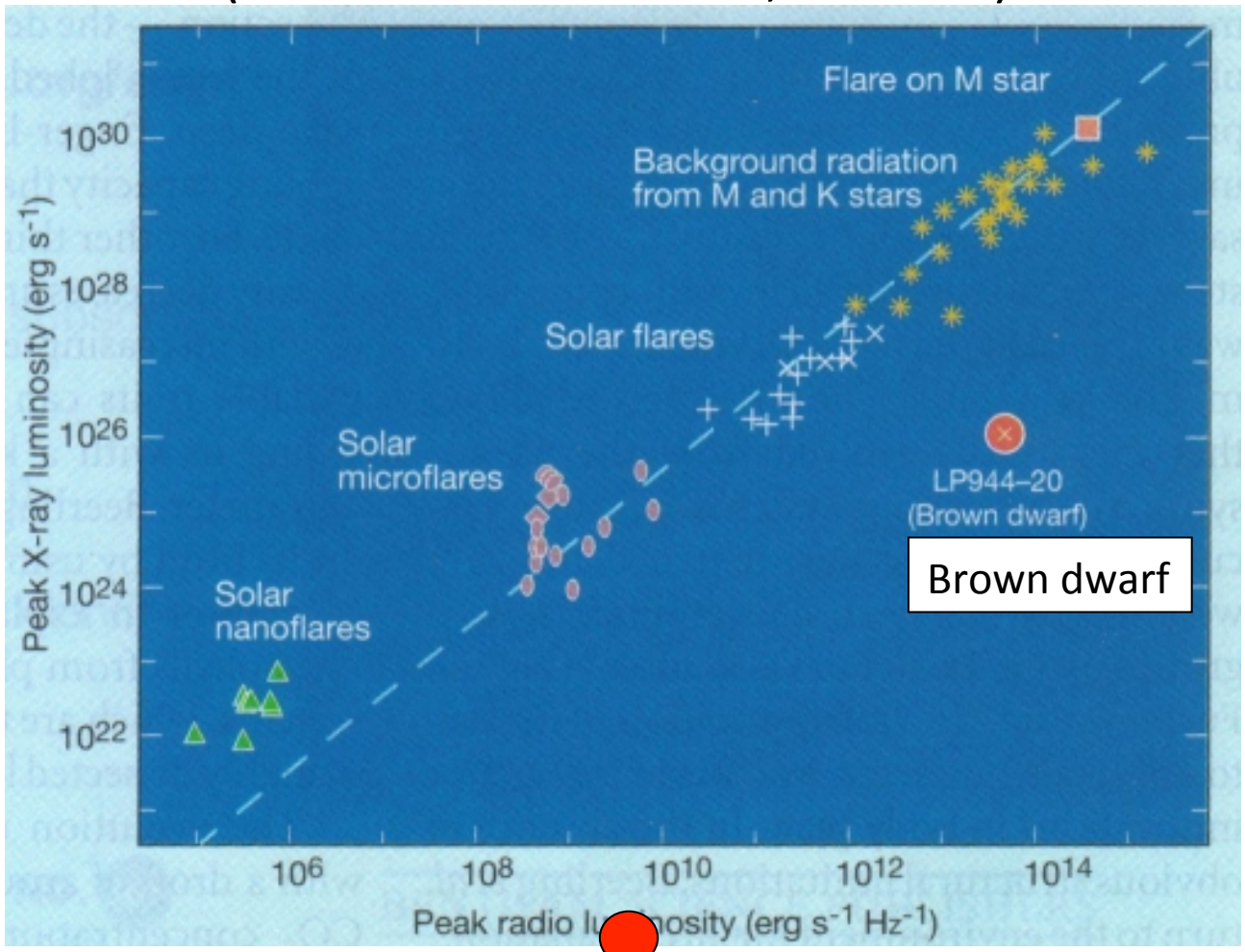
Conclusion

- Lots of similarity (and some differences) in solar chromosphere and Earth's ionosphere:
  - plasma parameters
  - physical processes
- Scandinavian countries and Japan have strong groups in both fields.
- International and interdisciplinary collaboration promising, but we need continuous conversation.

backup slides

X-ray and radio emission in flares

(Guedel-Benz relation, GB1993)



Jupiter aurora

Why 1-fluid MHD is OK in chromosphere

Balancing the Lorentz force and ion-neutral drag

$$\nu_{ni}\rho_n\left(V_n - V_i\right) \approx \frac{J \times B}{c}$$

$$V_n - V_i \approx \frac{B^2}{4\pi L \nu_{ni}\rho_n} \approx 100\left(\frac{V_A}{10\mathrm{km/s}}\right)^2\left(\frac{L}{100\mathrm{km}}\right)^{-1}\left(\frac{\nu_{ni}}{10^3\mathrm{Hz}}\right)^{-1}\mathrm{cm/s}$$

Relative velocity is ~ 1m/s in chromosphere, whereas chromosphere is dynamic and always moving around with V > 1km/s.

Except in small scales (such as high-frequency waves and magnetic reconnection), plasma and neutrals can be considered as single fluid.