Sources of Electron Pitch Angle Anisotropy in the Magnetotail Plasma Sheet

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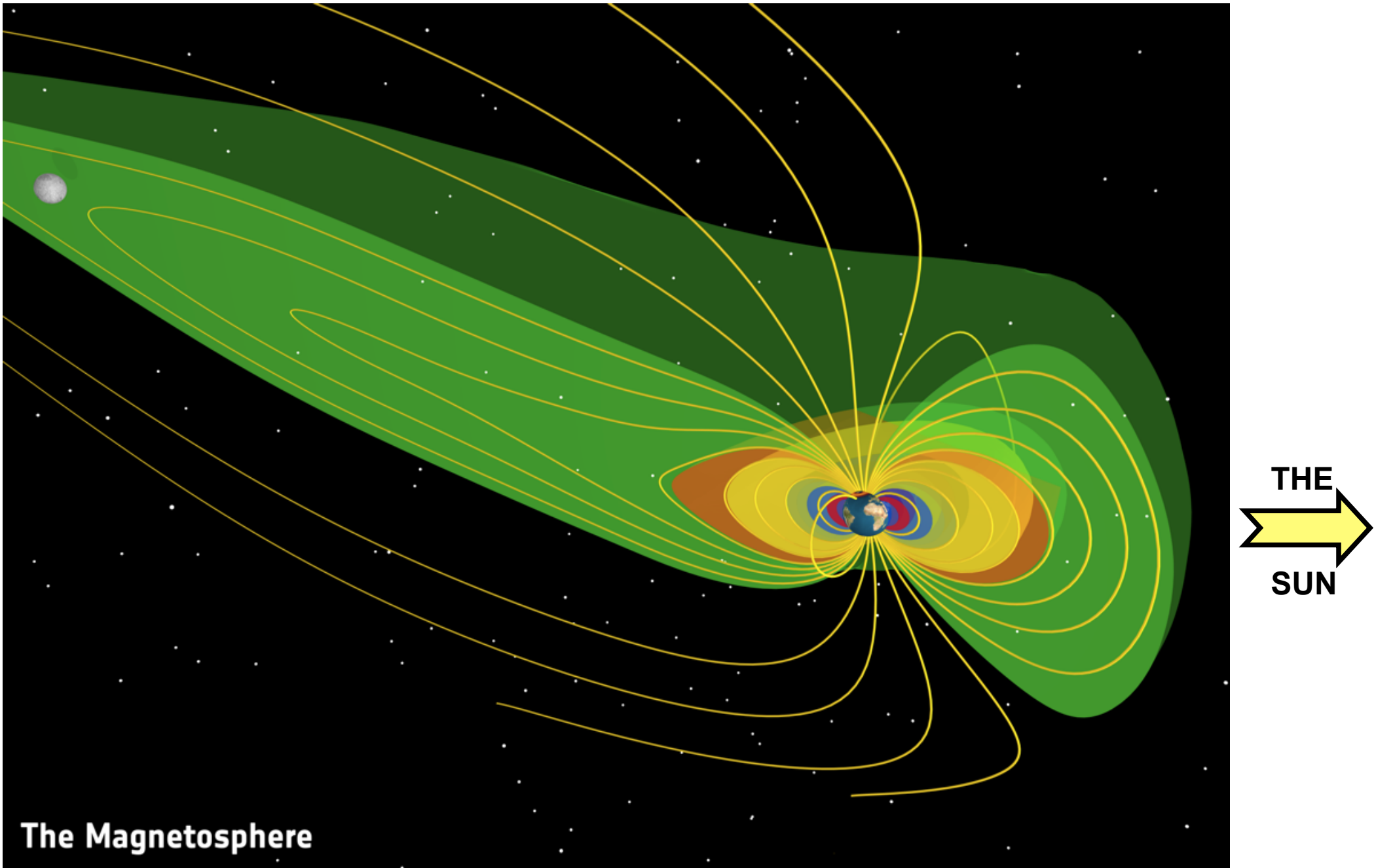
1. ESA/ESTEC
2. UCL-MSSL

IDSW, Aranjuez, 21 November 2013

The Magnetotail Plasma Sheet



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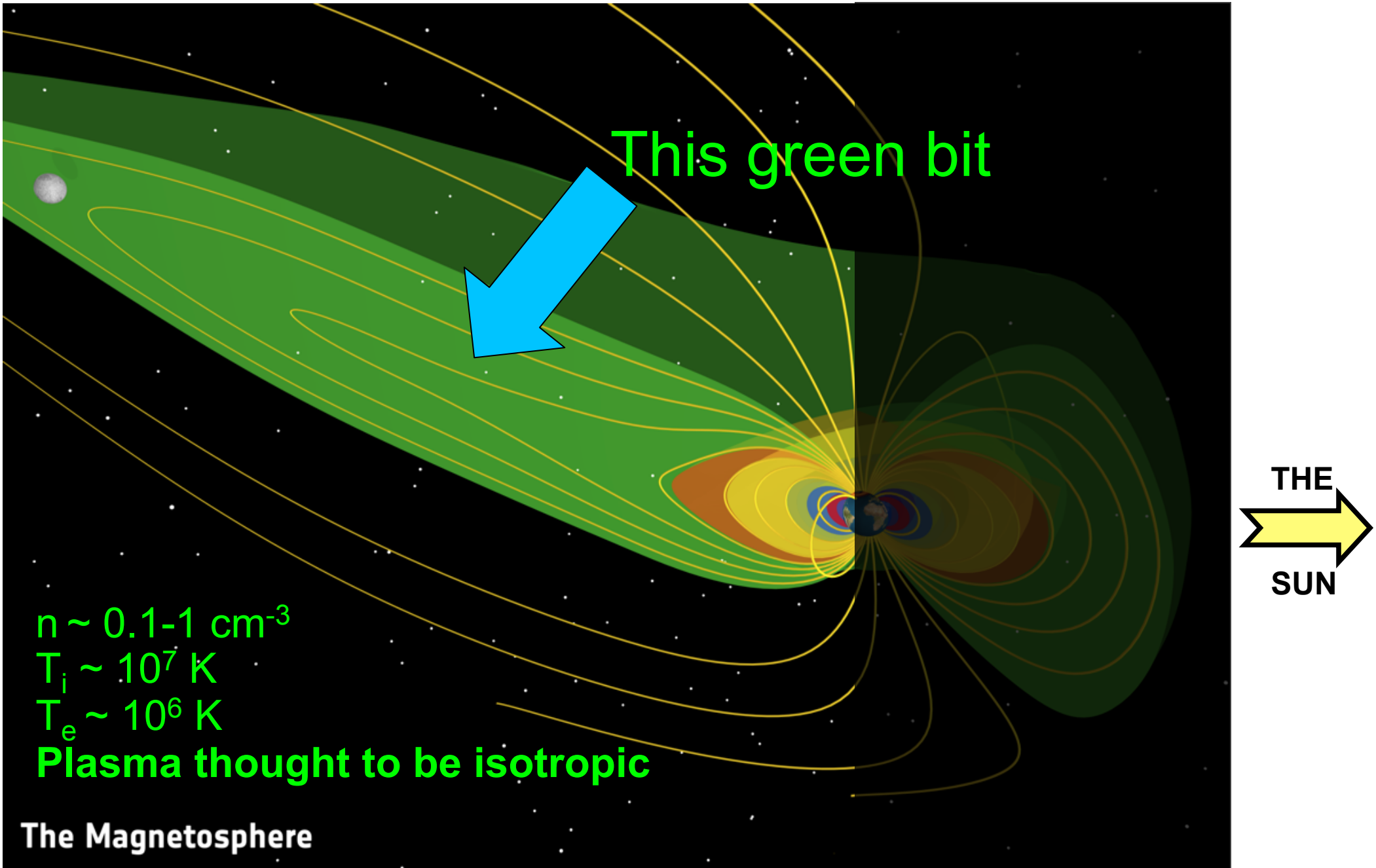
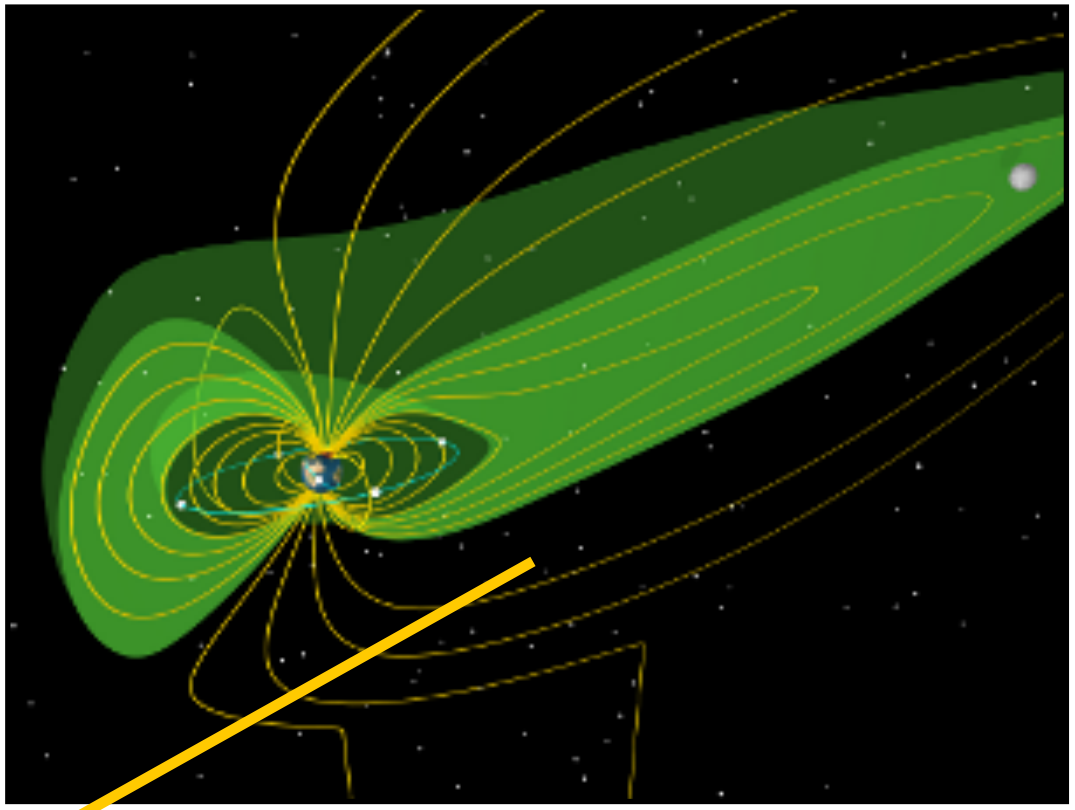
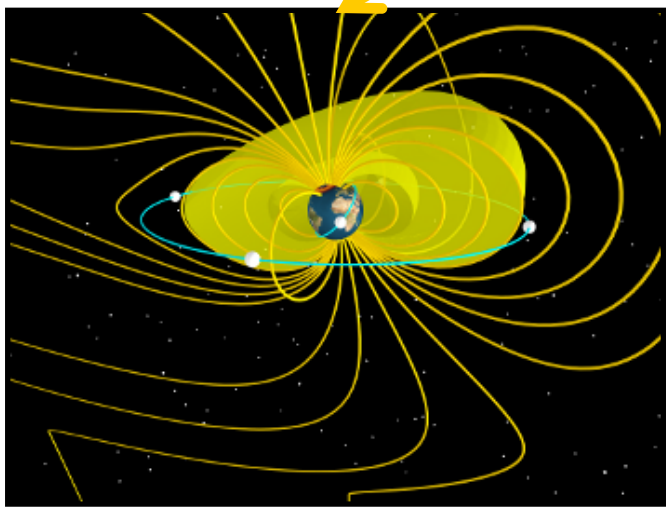
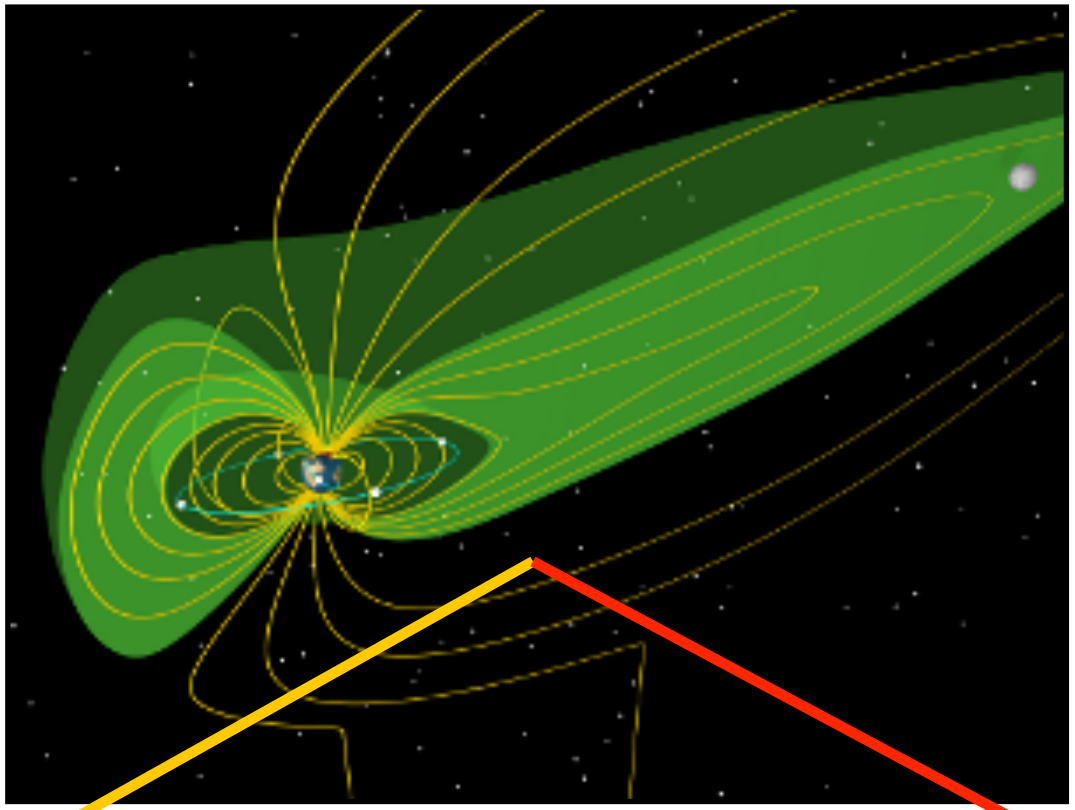




Ring Current



Images: UCL, NASA



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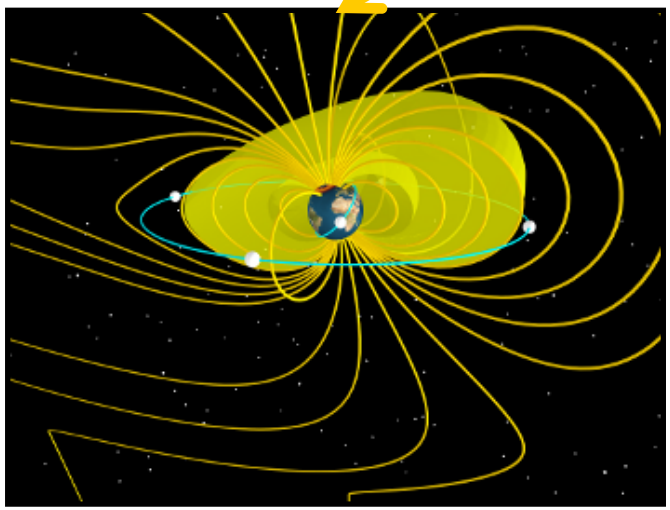
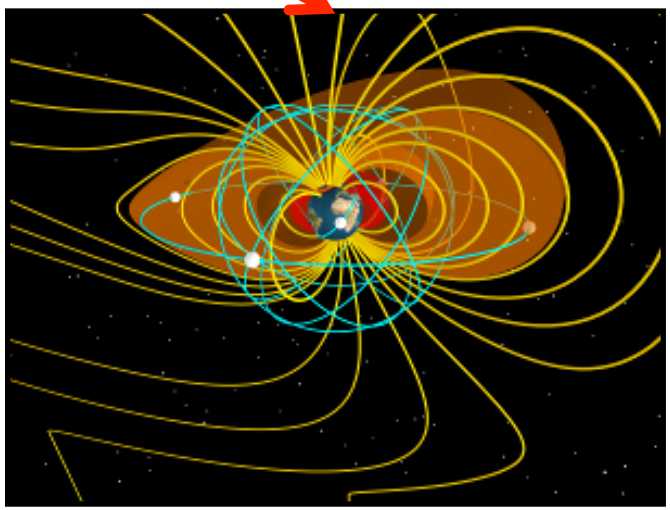


Radiation Belts



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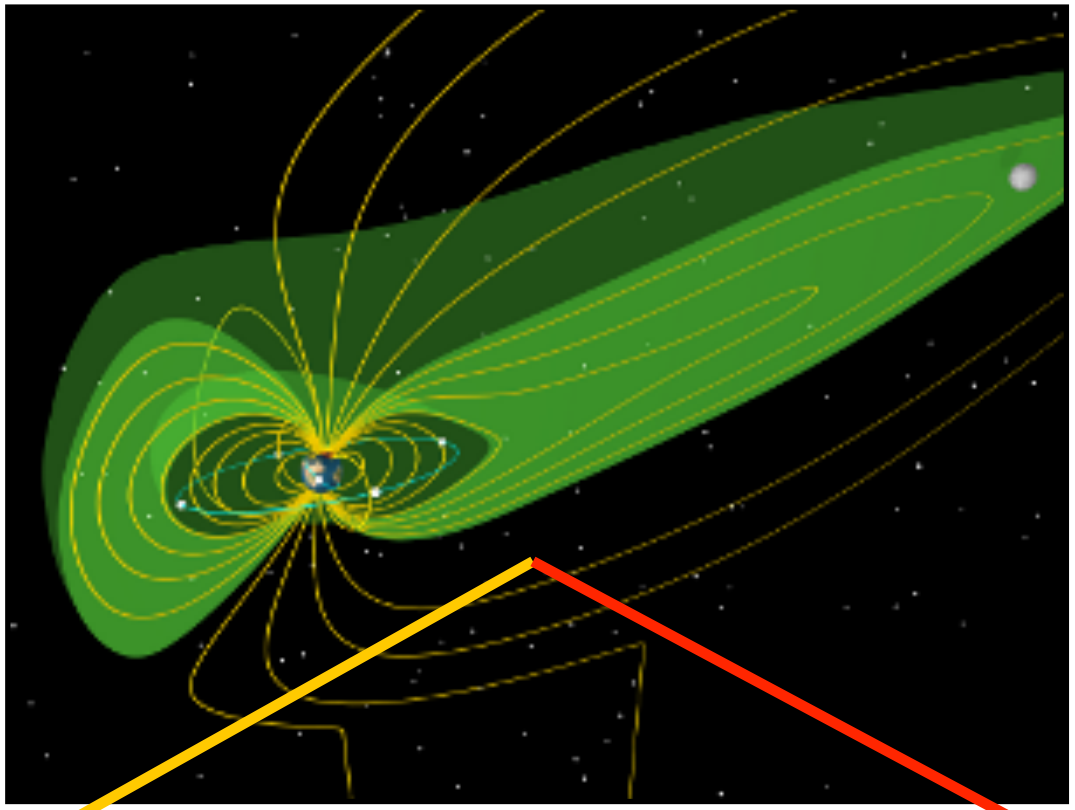

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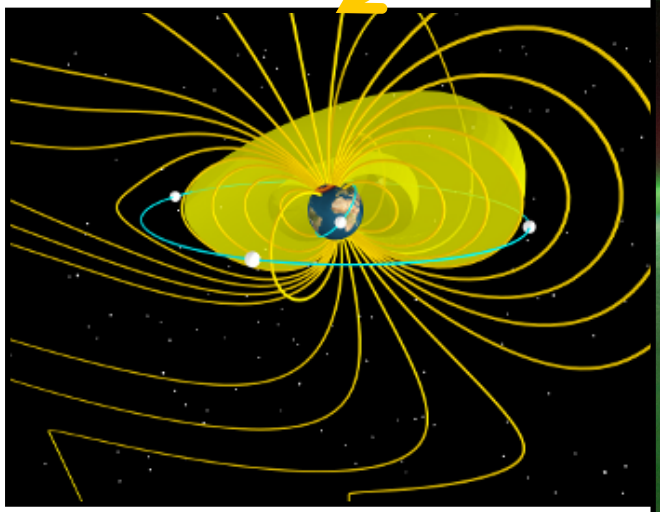

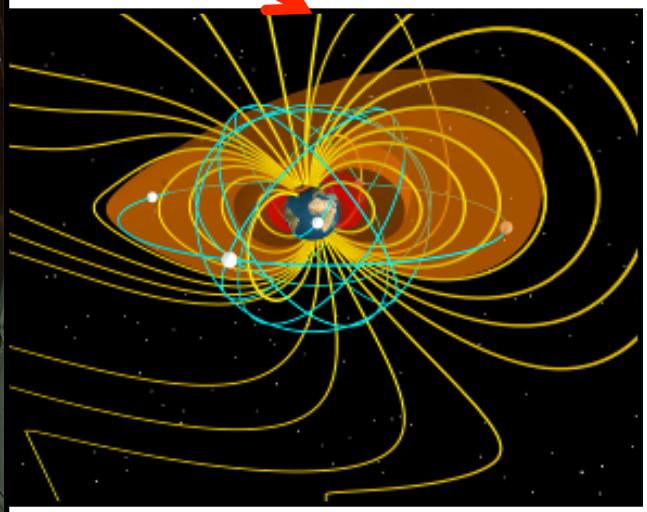

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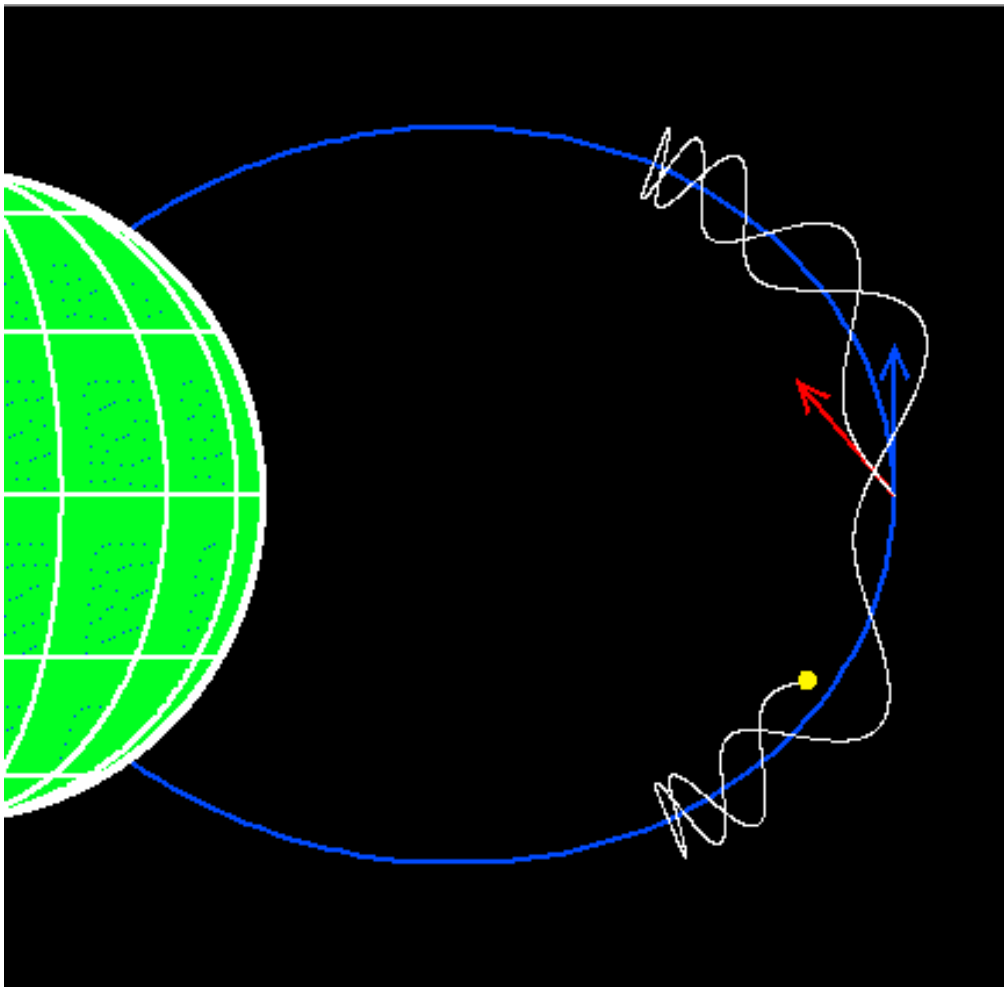
Pitch Angle

- Pitch angle tells us how a particle is moving with respect to the local magnetic field.

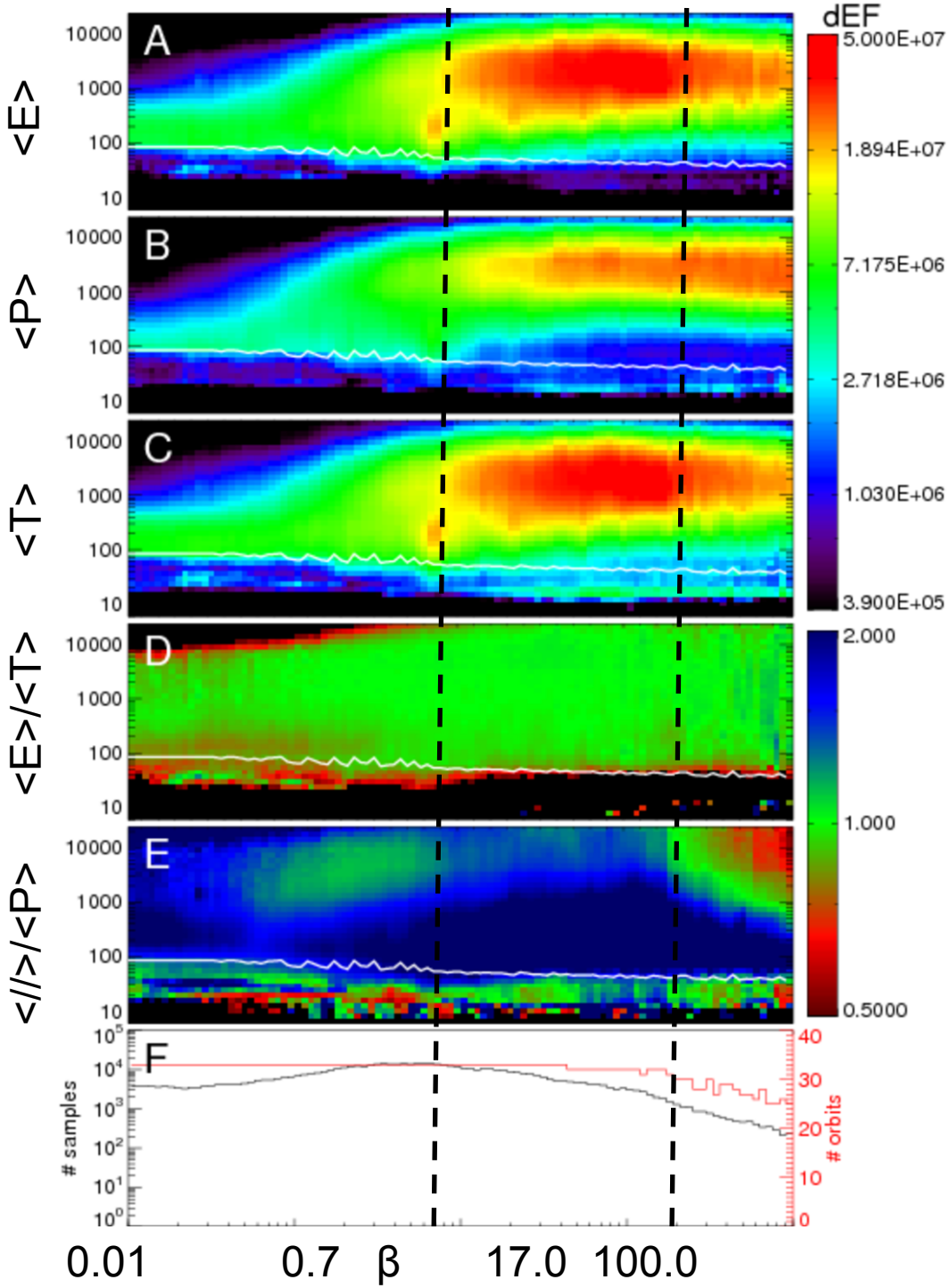
  0 = parallel
  90 = perpendicular
  180 = antiparallel

- Different physical processes produce particles with different pitch angles.

- Comparing the flux of particles with different pitch angles we can learn about the processes that have acted on them.



Plasma Sheet Electron Pitch Angle Distributions



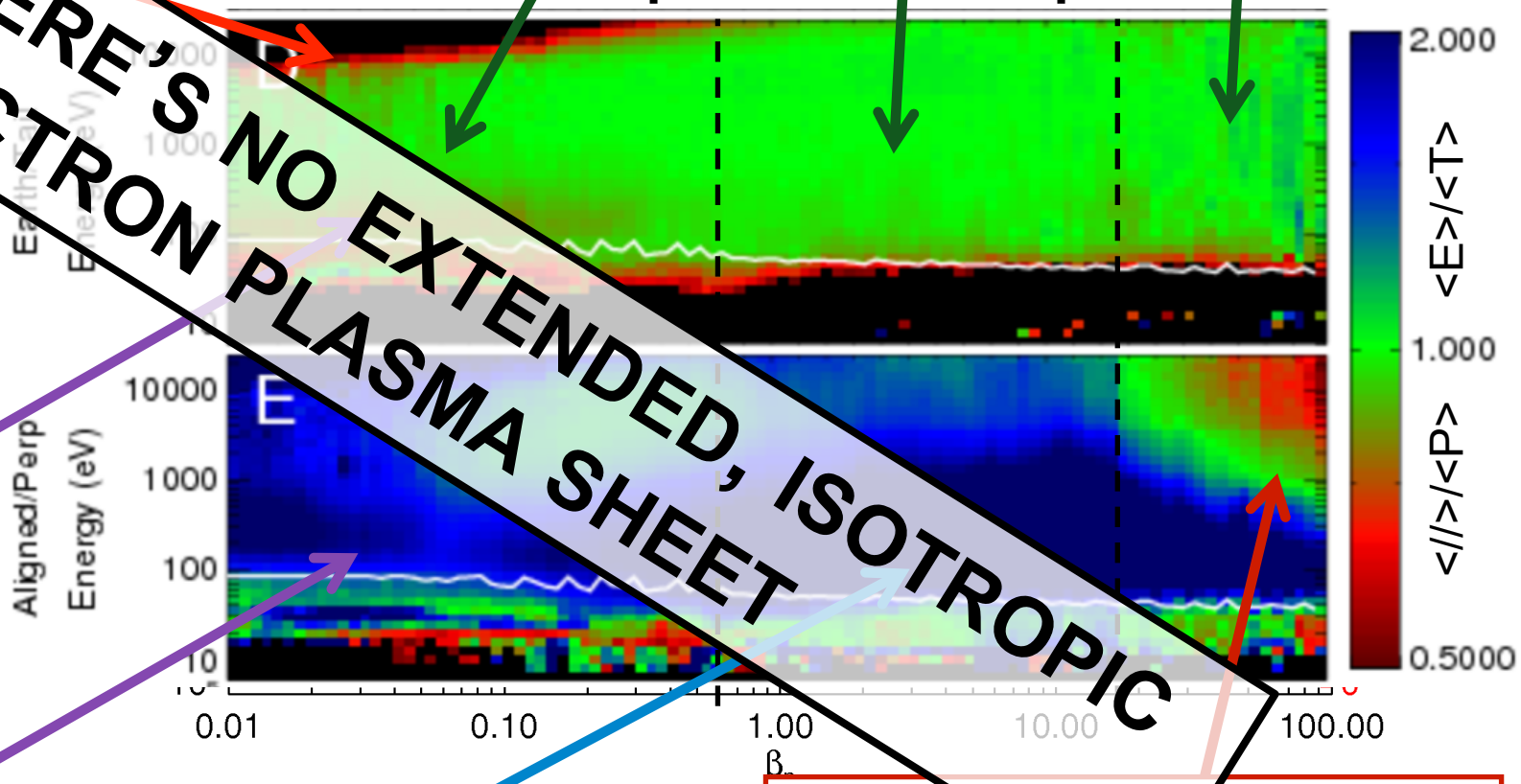
- Are the electrons in the plasma sheet really isotropic?
- Survey of Cluster data.
- ~10^6 electron spectra.
- Examine average electron flux at different pitch angles as a function of distance from the centre of the plasma sheet.
- Examine ratio between average field-aligned flux and average perpendicular flux.

Electron Anisotropy

Field-Aligned electron fluxes are balanced almost everywhere.

Instrument effect at high energy, low β: Sunlight entering the aperture.

THERE'S NO EXTENDED, ISOTROPIC ELECTRON PLASMA SHEET



Net field-aligned, tailward flux at low energy, low β: Mirrored polar rain & ionospheric outflow?

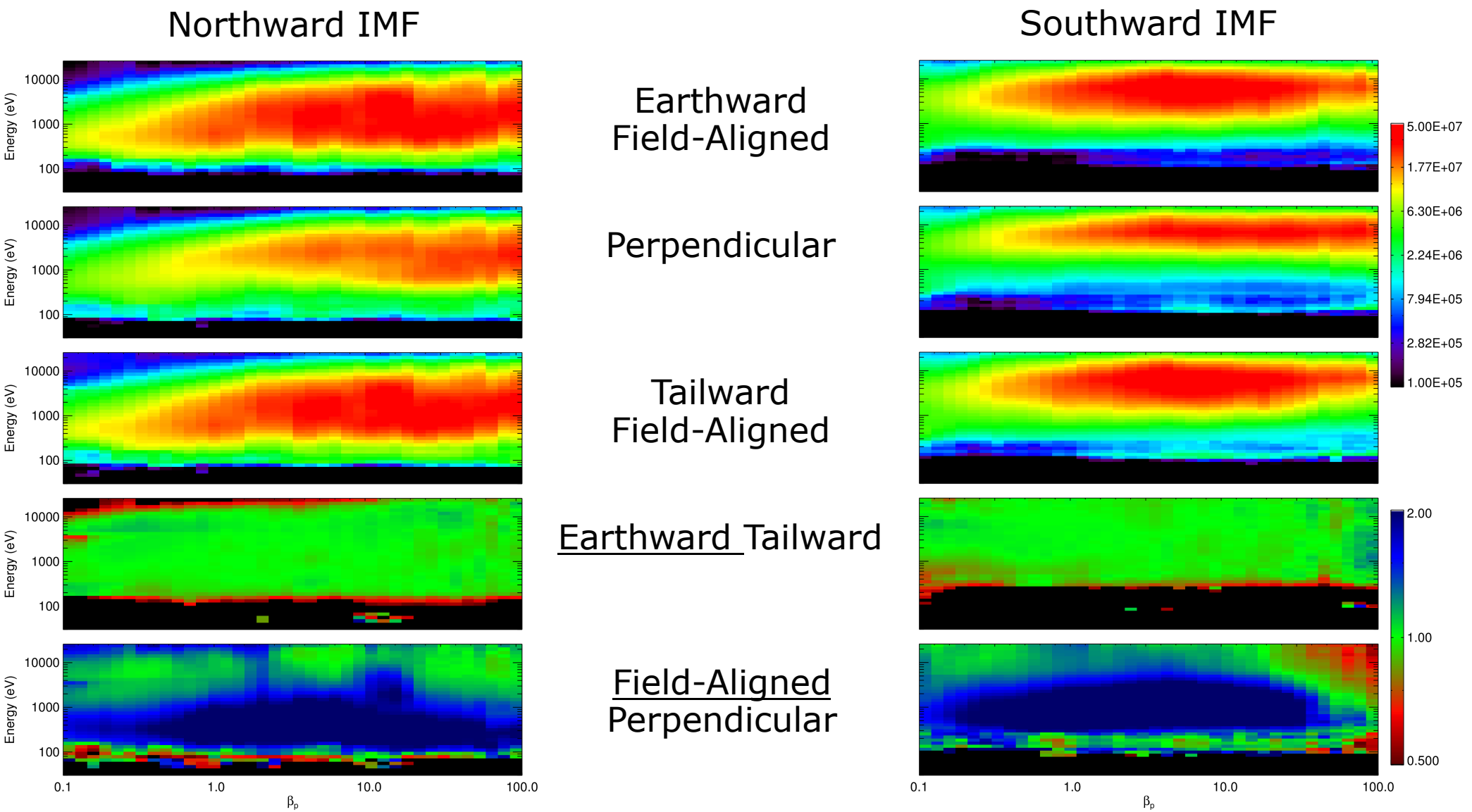
Bidirectional electrons dominate at all energies, moderate β: An "electron PSBL".

Trapped, perpendicular population at high energies; bidirectional at low energies.

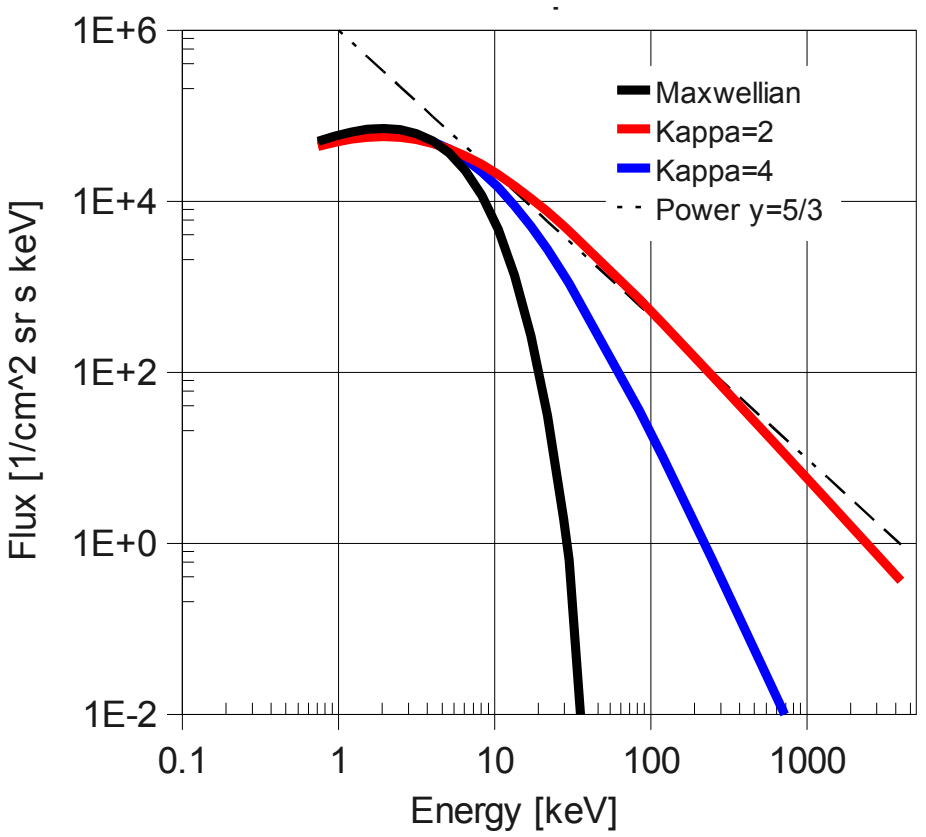
What is the source of the anisotropy?

- There is, on average, an excess flux of field-aligned electrons at sub-KeV energies.
- Is it simply an aliasing effect?
  - Is the electron plasma sheet sometimes colder and more strongly field-aligned?
  - Is it sometimes hotter and more isotropic?
  - Is this controlled by IMF BZ?
- Are there two coexisting components of plasma sheet electrons, similar to the two component proton plasma sheet?
  - If so, what are the sources of these components?

Northward vs Southward IMF



The Kappa Distribution

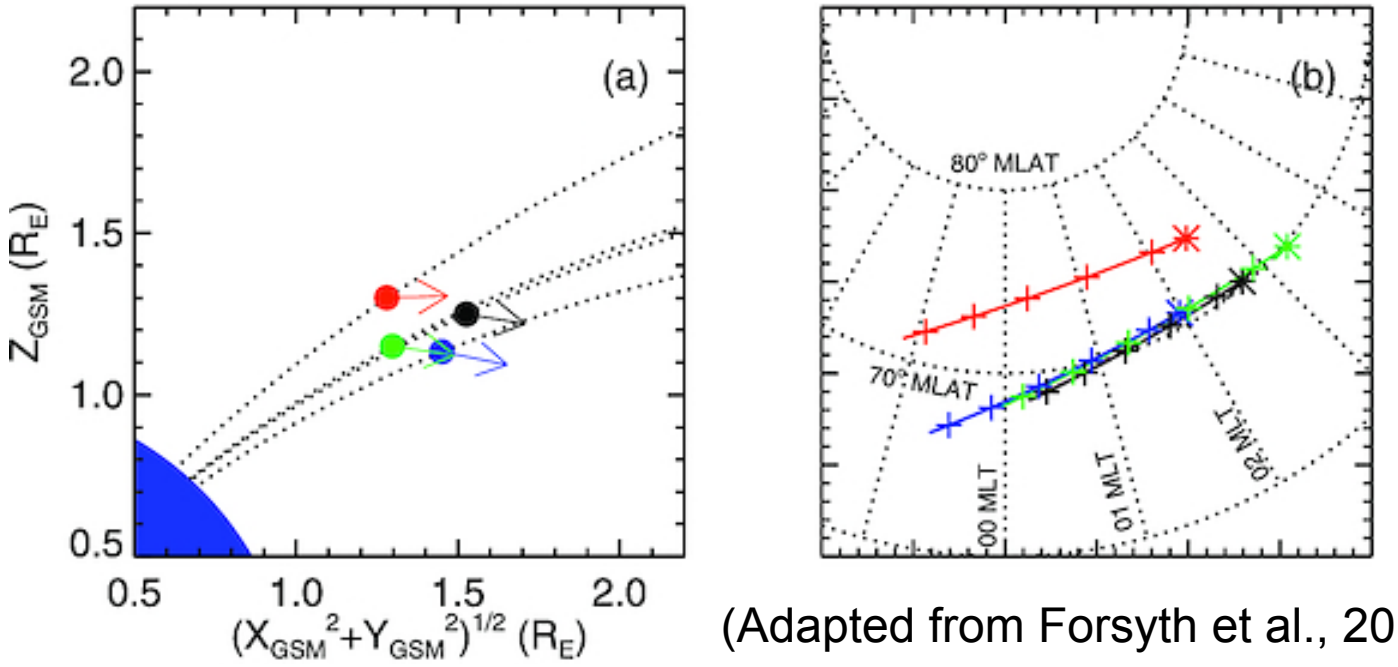


(Haaland et al., 2010)

- Widely used in space plasmas in place of a Maxwellian.
- Models the suprathermal tails of observed particle distributions.
- Can simply sum *n* kappa functions with different parameters to represent an *n* component distribution.

$$J(E) = A_c E \frac{\Gamma\left(\kappa_c + 1\right)}{\Gamma\left(\kappa_c - \tfrac{1}{2}\right)} \left(1 + \frac{E}{\kappa_c E_{0c}}\right)^{-\kappa_c - 1} + A_h E \frac{\Gamma\left(\kappa_h + 1\right)}{\Gamma\left(\kappa_h - \tfrac{1}{2}\right)} \left(1 + \frac{E}{\kappa_h E_{0h}}\right)^{-\kappa_h - 1}$$

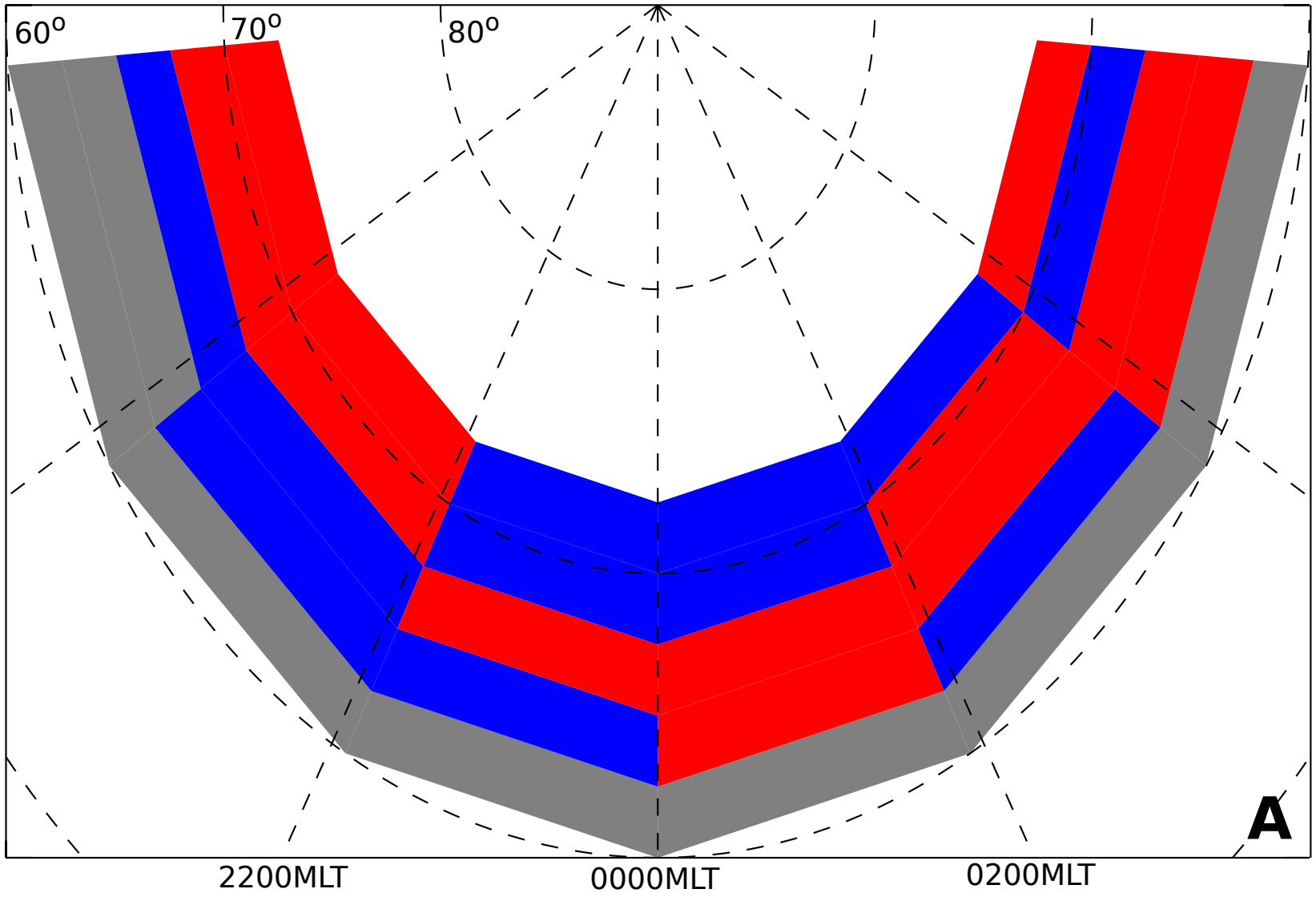
An Ionospheric Source?



(Adapted from Forsyth et al., 2012)

- Using an empirical magnetic field model (Tsyganenko et al., 1989) we can estimate the location in the ionosphere magnetically conjugate to the Cluster spacecraft at any given time.
- We can then determine if there's a pattern to the locations in the ionosphere conjugate to where the cold electrons are most often observed.

An Ionospheric Source?



Cold electrons more likely

Cold electrons less likely

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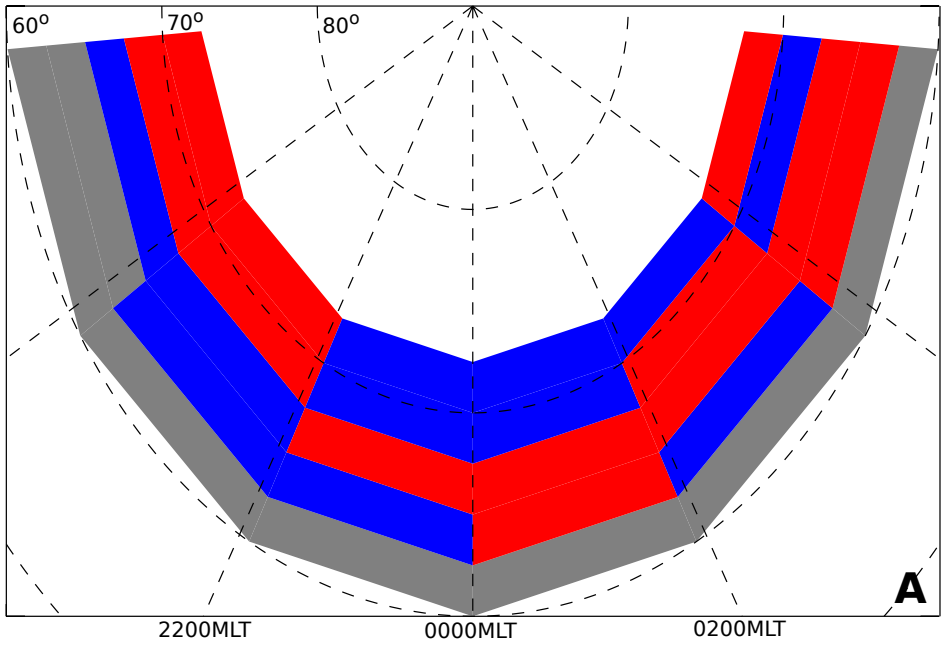

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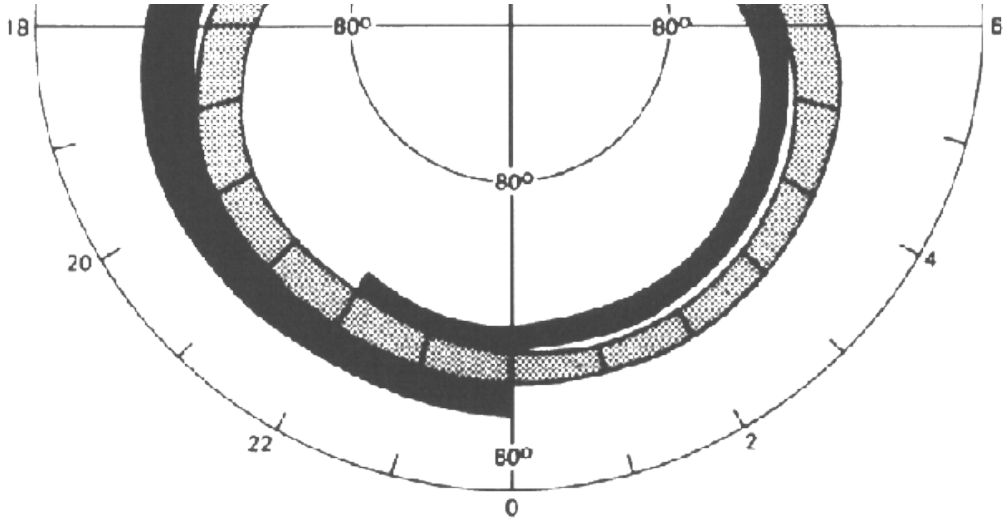

Currents into ionosphere

Currents out of ionosphere

(After Iijima & Potemra, 1978)

Electrons are pulled from the ionosphere into the magnetosphere by the downward Birkeland currents that connect the two regimes.

Conclusions

- The electron plasma sheet is not isotropic as commonly thought.
- The anisotropy is driven by the presence of an additional cold component of electrons.
- Evidence suggests that the cold electrons come from the ionosphere and are transported via field aligned currents.
- This has been postulated in the past and seen in case studies (e.g. Kletzing & Scudder, 1999; Wright et al., 2008), but we've shown it is persistent and significant.
- Walsh et al., GRL, 2011; Walsh et al., JGR, 2013