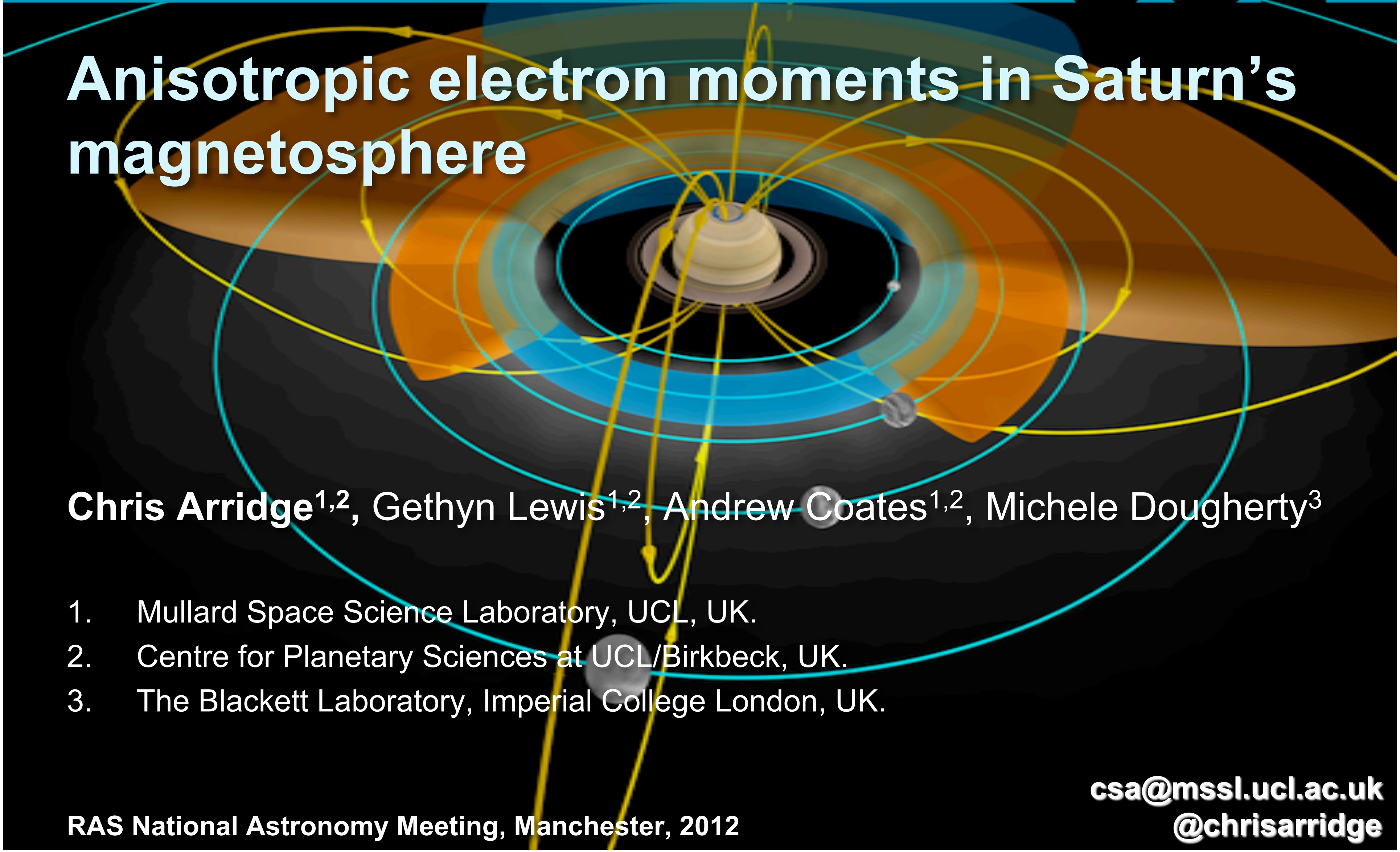
Anisotropic electron moments in Saturn's magnetosphere



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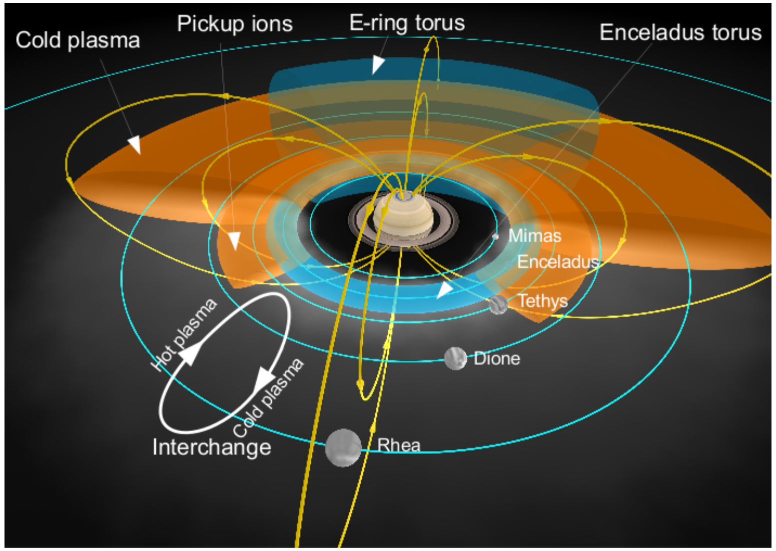
Introduction

- Electron moments are important for characterising the macroscopic properties of the observed electron velocity distribution.

- Important for (e.g.):
  - Understanding plasma transport (Rymer et al., 2007, 2008; Burch 2007).
  - Diffusive equilibrium calculations (e.g., Persoon et al., 2009).
  - Ring current calculations (e.g., Kellett et al., 2010).
  - Calculating plasma wave growth (e.g., Gary and Cairns, 1999; Masood and Schwartz, 2008; Tao et al., 2010; Menietti et al., 2008).

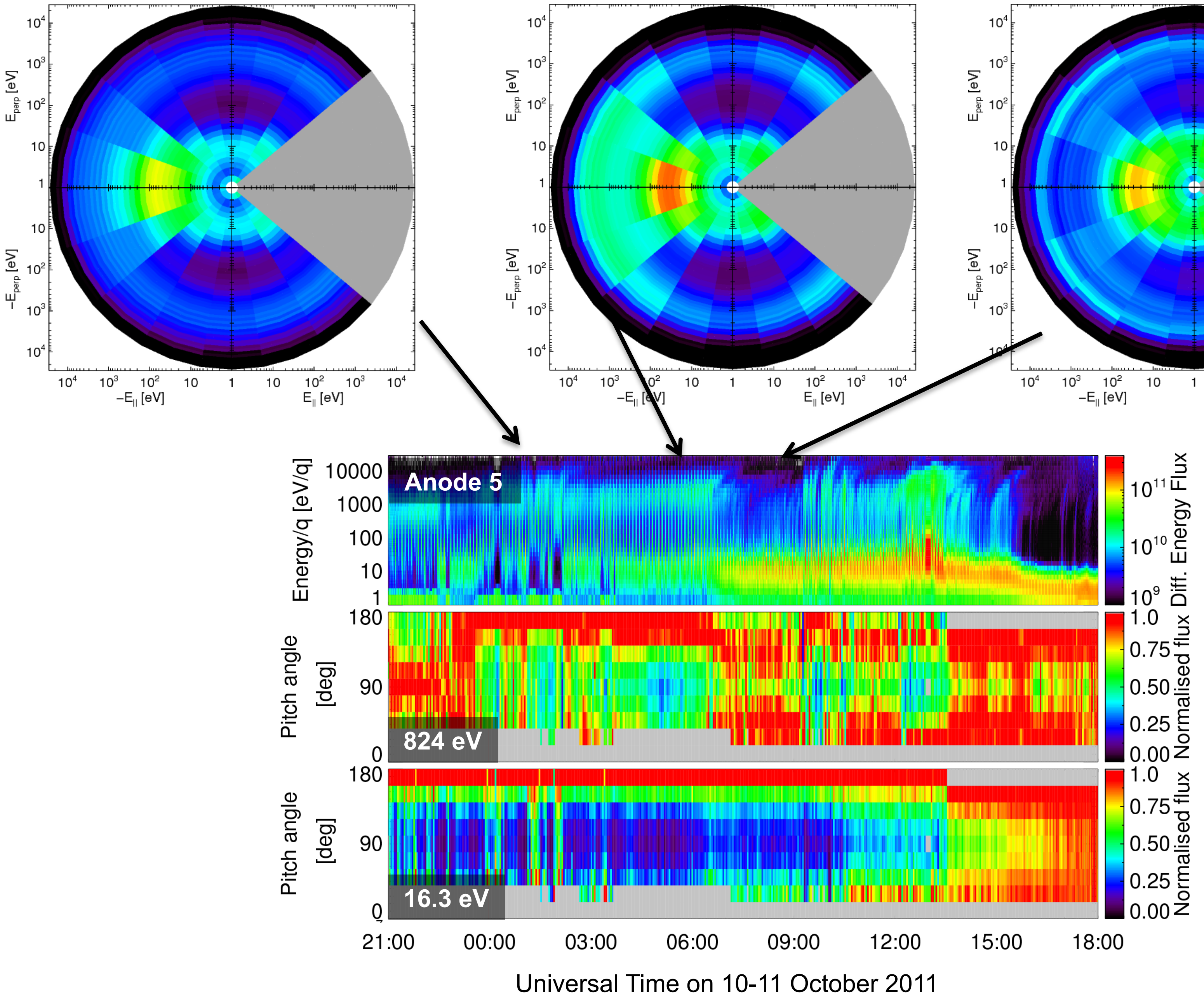


Arridge et al. (2012)

- Existing electron moment calculations for Cassini assume isotropy in the spacecraft frame – we cannot estimate anisotropies such as $T_{\perp} > T_{||}$.

- **We have now relaxed this isotropic assumption.**

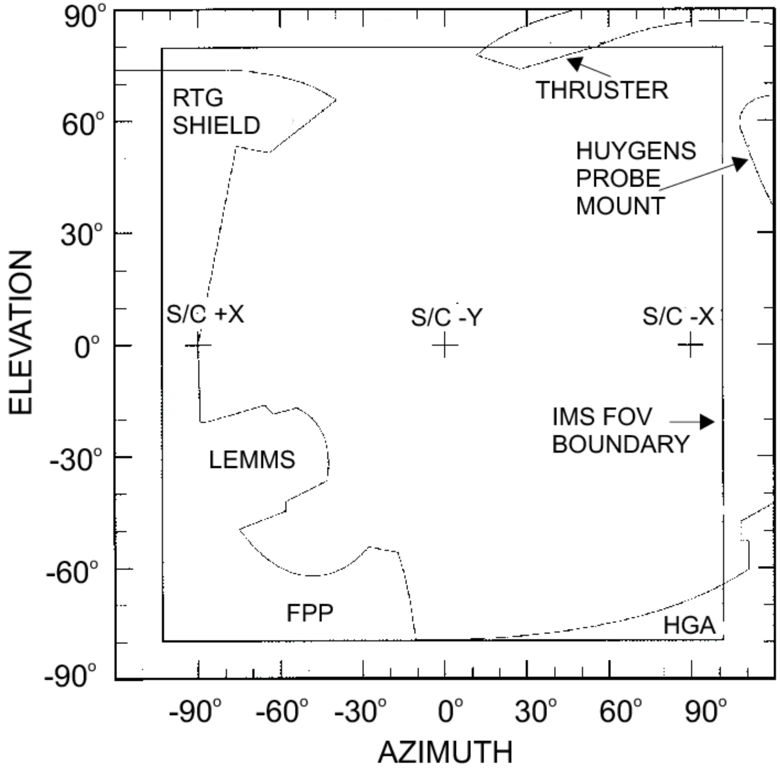
Example data

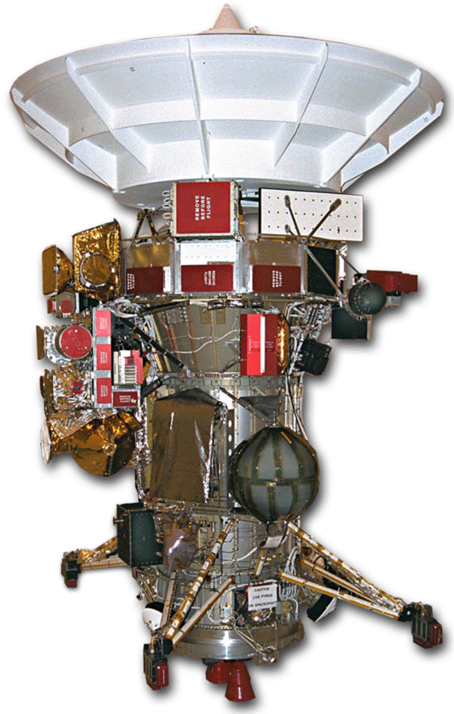


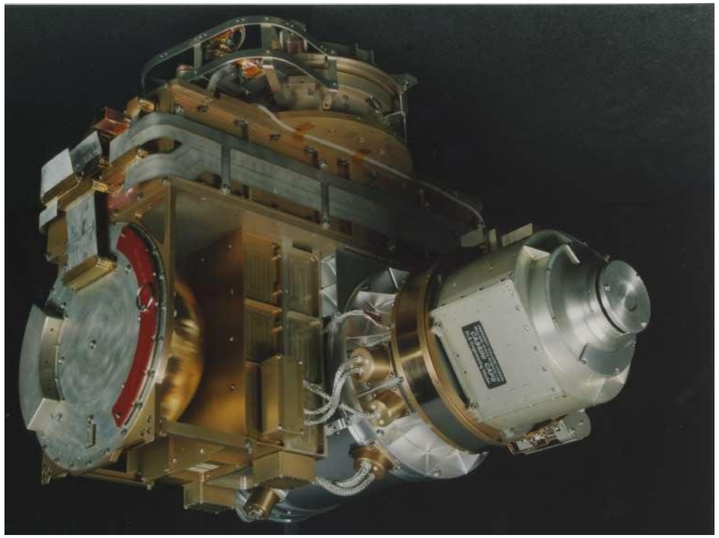
Instrumentation

- CAPS – Electron Spectrometer (ELS).
- Eight 20º x 5º anodes, IFOV 160º x 5º
- Energy coverage: 0.5-28000 eV

- Actuator increases FOV: sweep IFOV by ±100º in 4 min.
- Parts of the platform & other instruments block this FOV.
- Full pitch-angle coverage not necessarily in FOV.

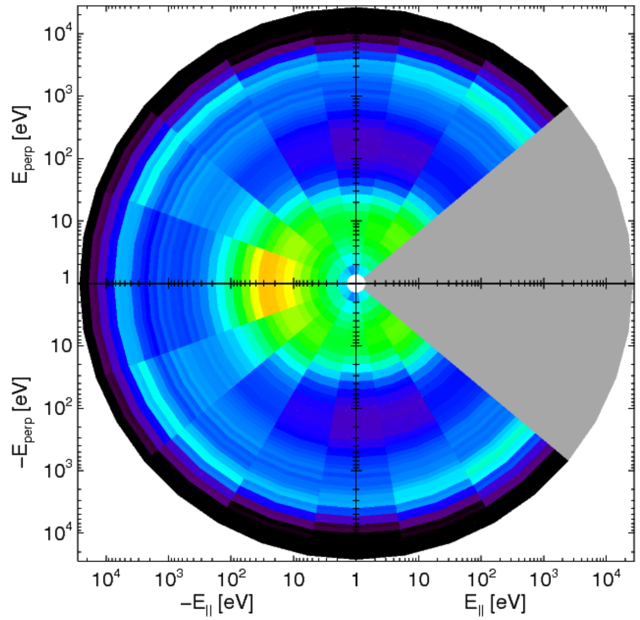


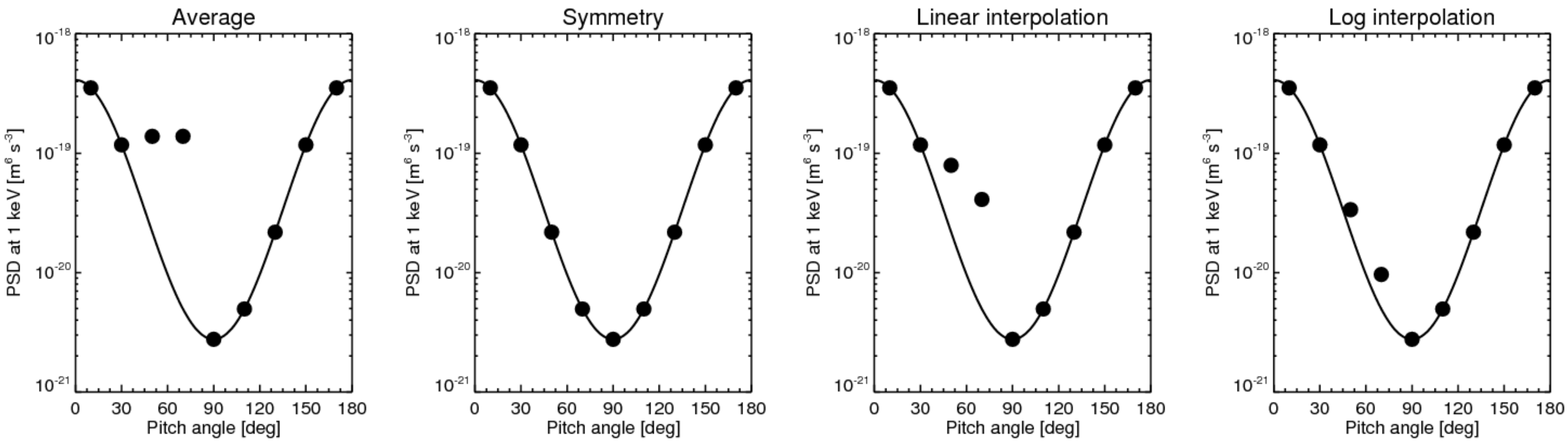




Filling gaps in the distribution

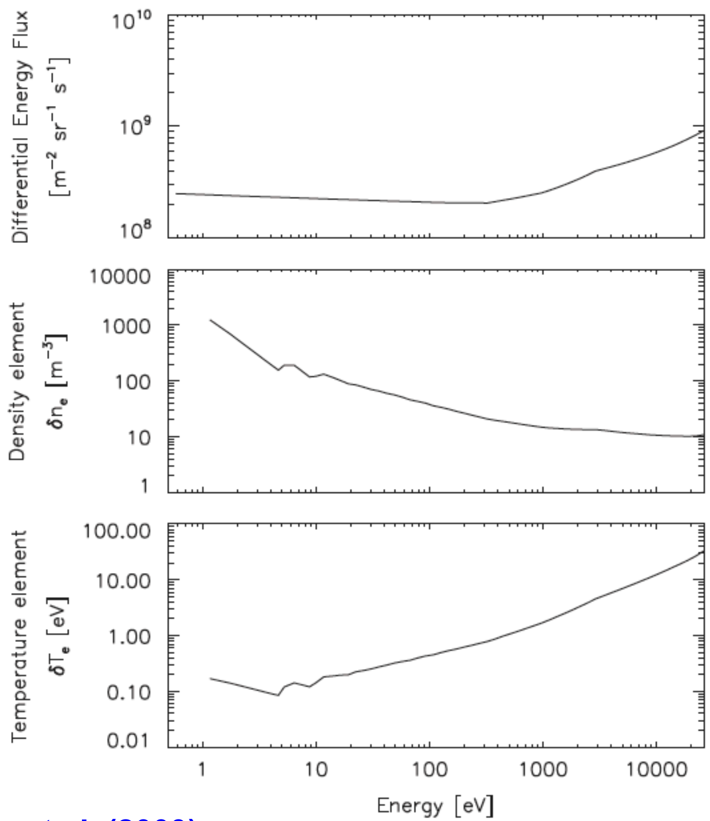
- Because of the restricted field of view of CAPS a full pitch angle distribution is not always available.
- Complete the pitch angle distribution using four **strategies** before moment integration.
- Results of each are stored.
- Cross-comparing moments from different filling strategies provides an idea of the uncertainty in this filling process.

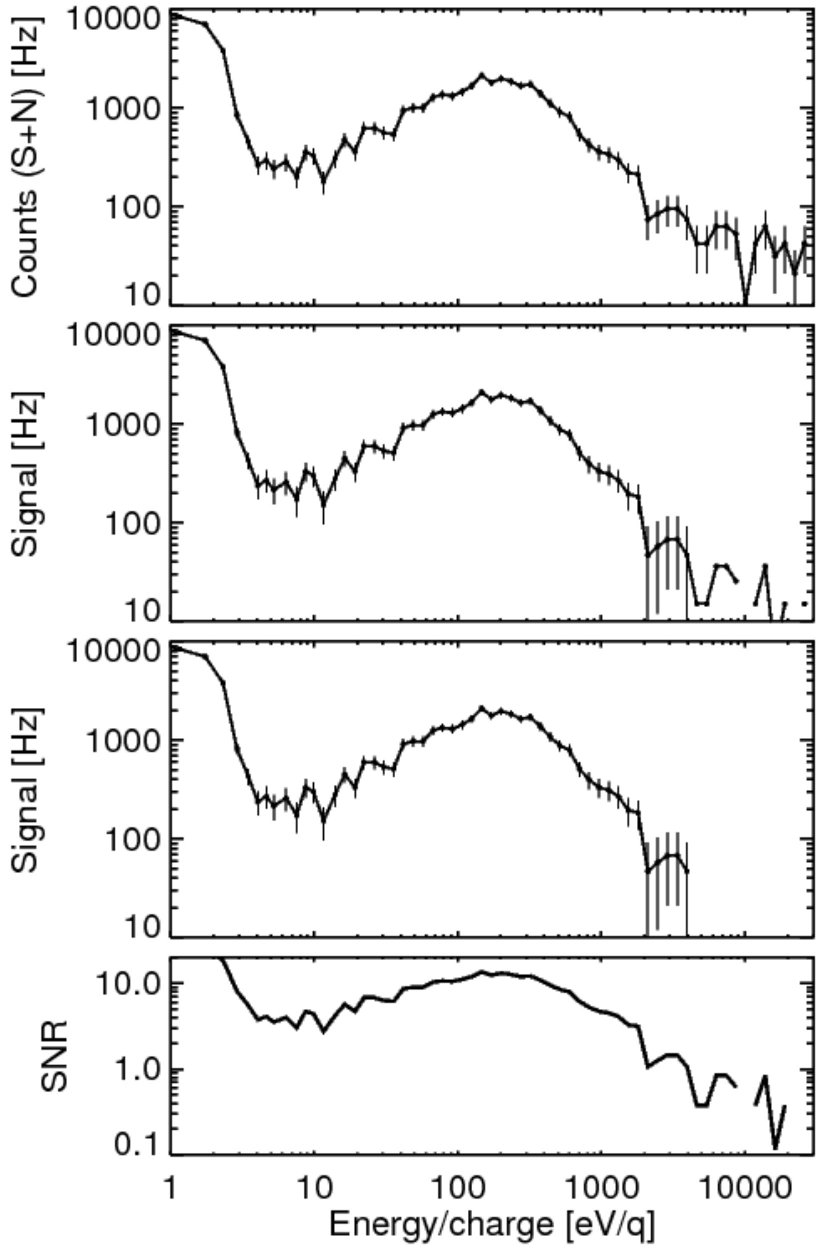




Signal processing

- Moments distorted by noise.
- Large body of astronomical image processing/data reduction literature.
- Lots in common with processing of astronomical spectra.

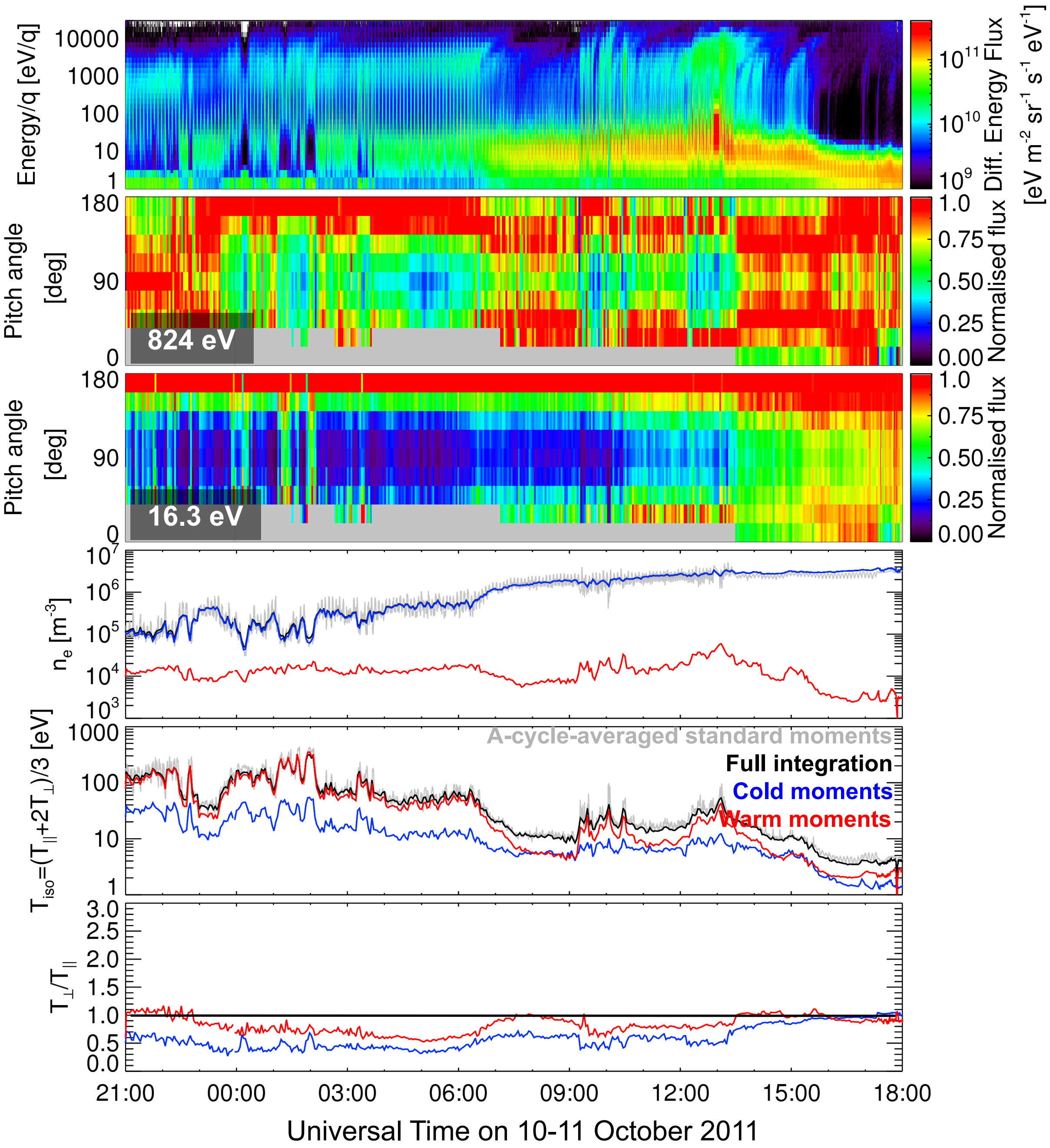




Arridge et al. (2009)

Example time series

- Expect $T_{\perp}/T_{||}<1$.
- Because of cos and sin weighting factors – large (>×5) anisotropies in flux don't give rise to very large T anisotropies.
- Butterfly distributions produce anisotropy – although not very strong.
- See that the standard moment products often vary by factor of 3 from anisotropic.



Error analysis

- Random errors associated with counting statistics and noise.

- Five sources of systematic error:
  1. Velocity space resolution.
  2. Dynamic range.
  3. Non-zero spacecraft potential.
  4. Numerical integrations using Riemann sums.
  5. Gap filling.

- Treat random errors & (1) with a full formal error propagation through numerical integrations.

- Treat (2,3,4) with moment integrations of synthetic spectra.

- Treat (5) with fill strategies.

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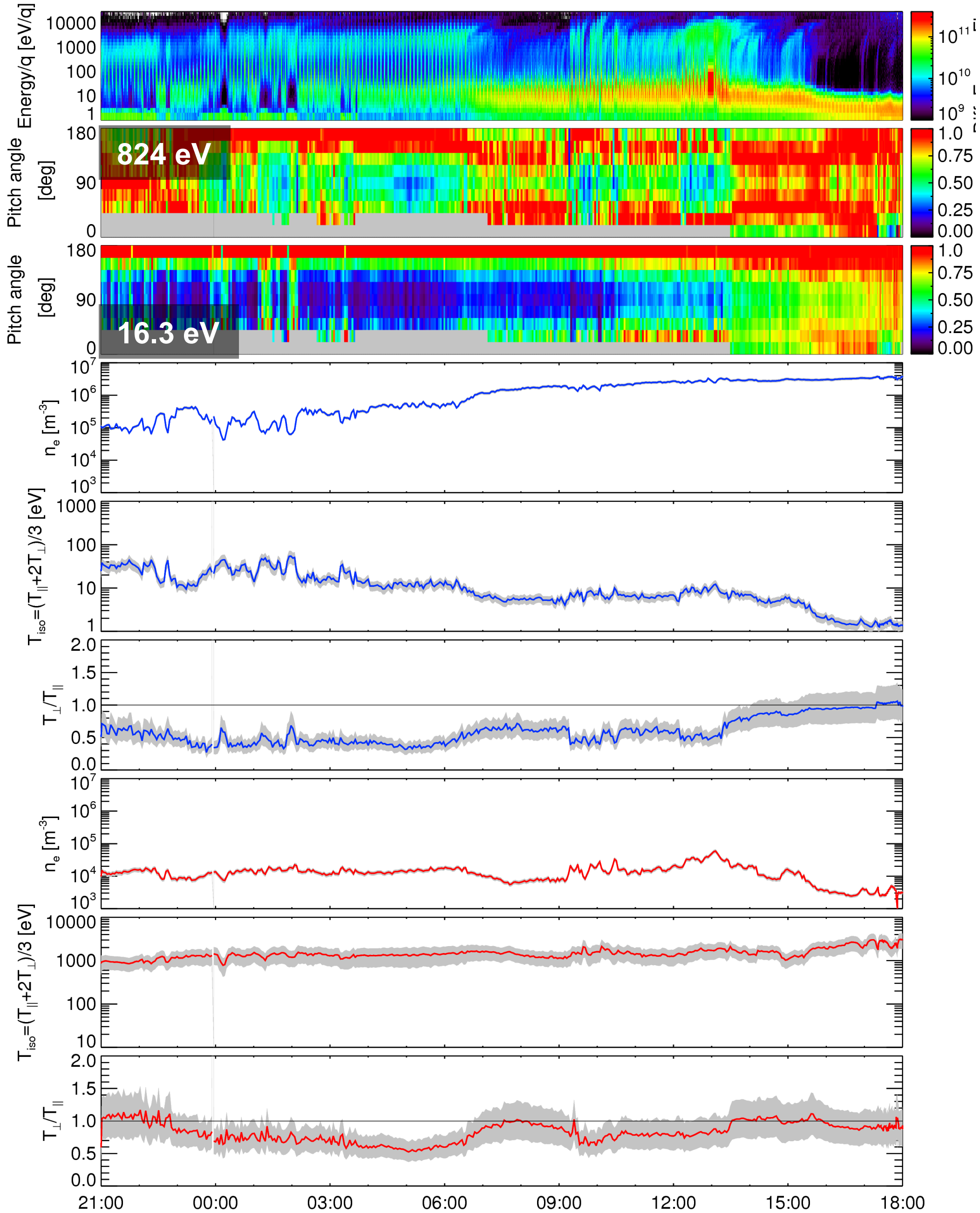
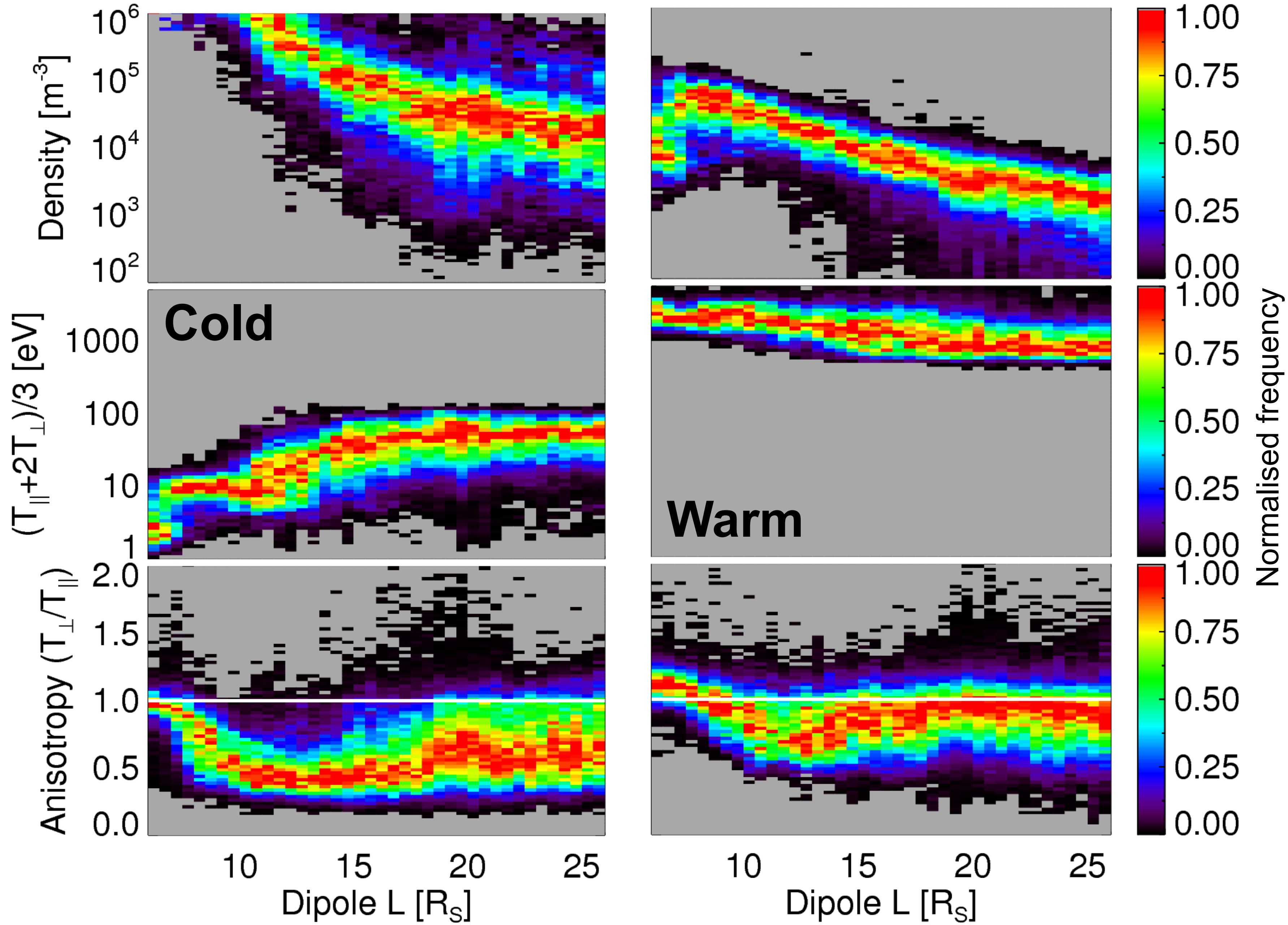


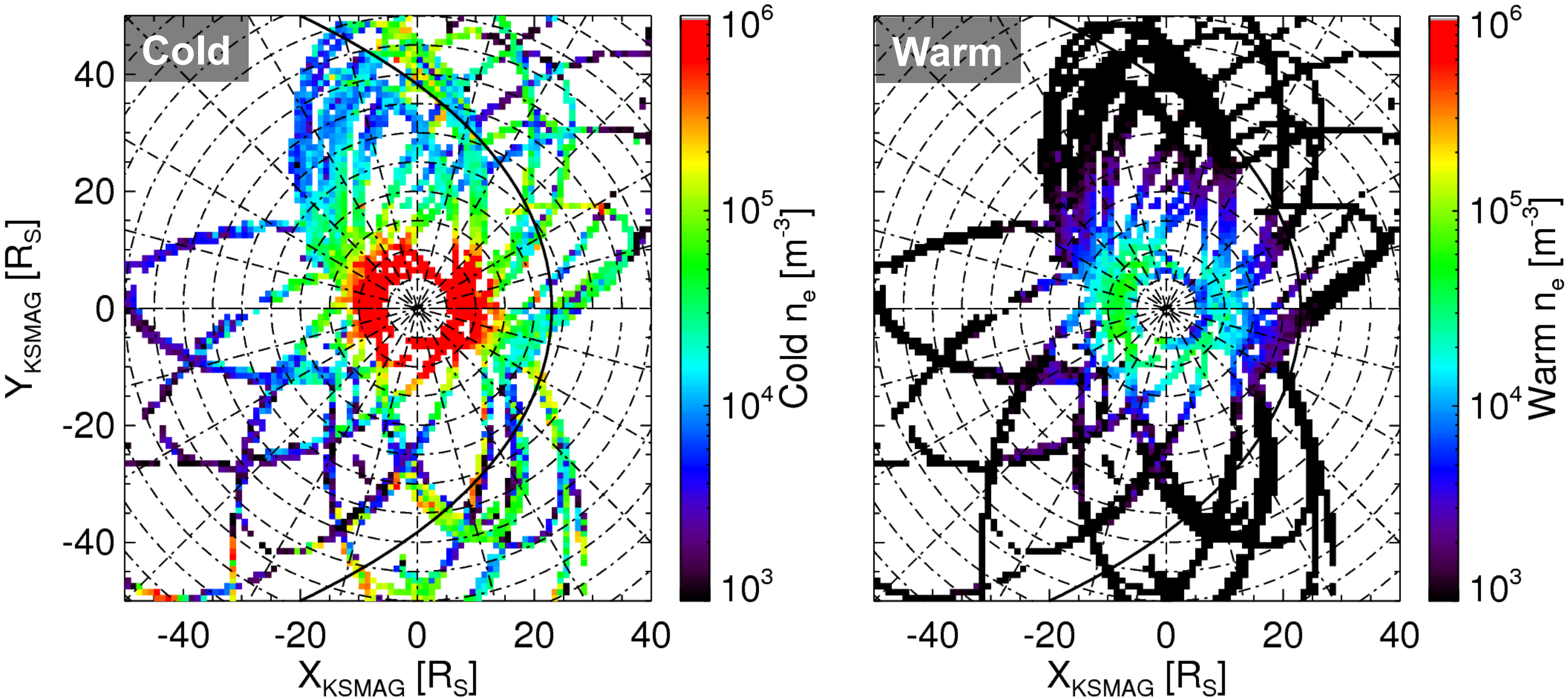
Statistical survey overview



Number densities in SLT

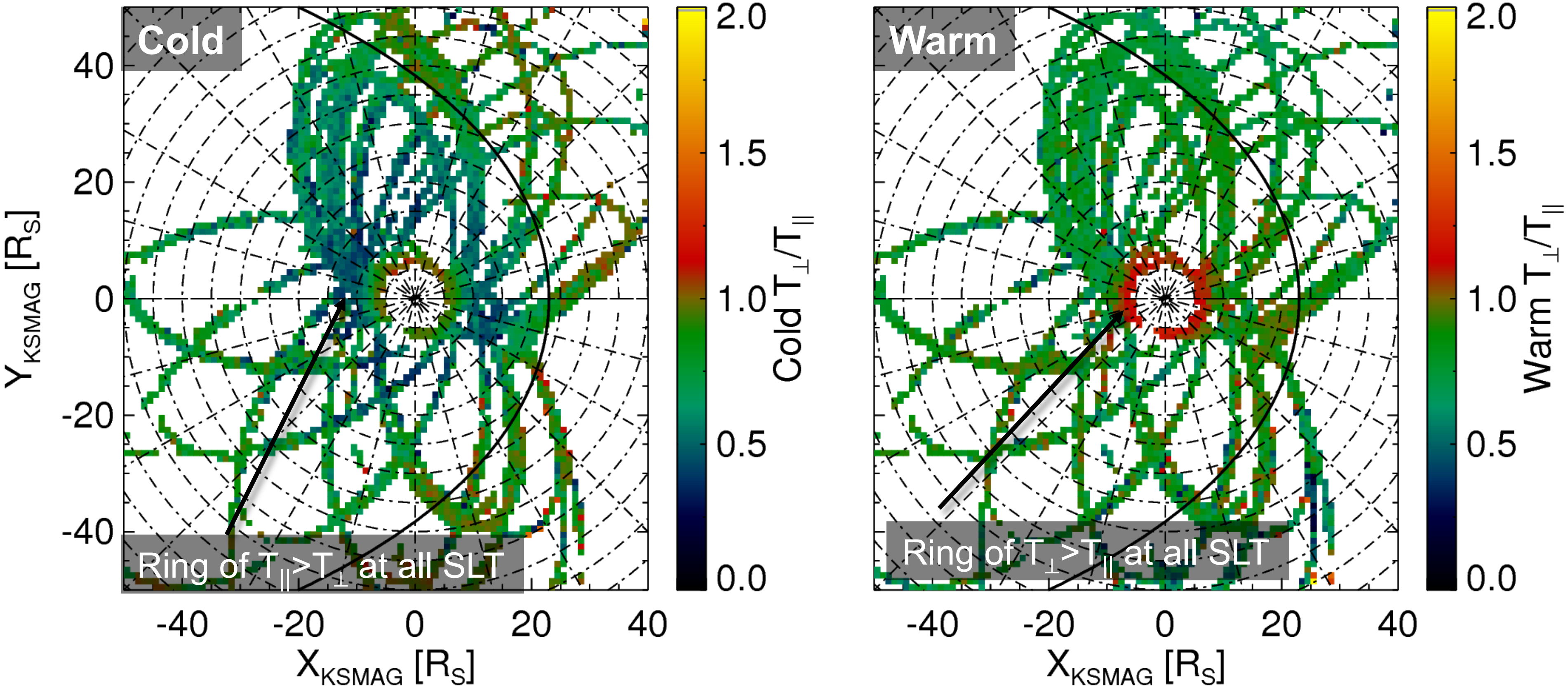
- Evidence for a lobe of cold plasma on the dusk flank – escape of cold plasma?

- Enhanced warm plasma densities on the nightside.



Anisotropies in SLT

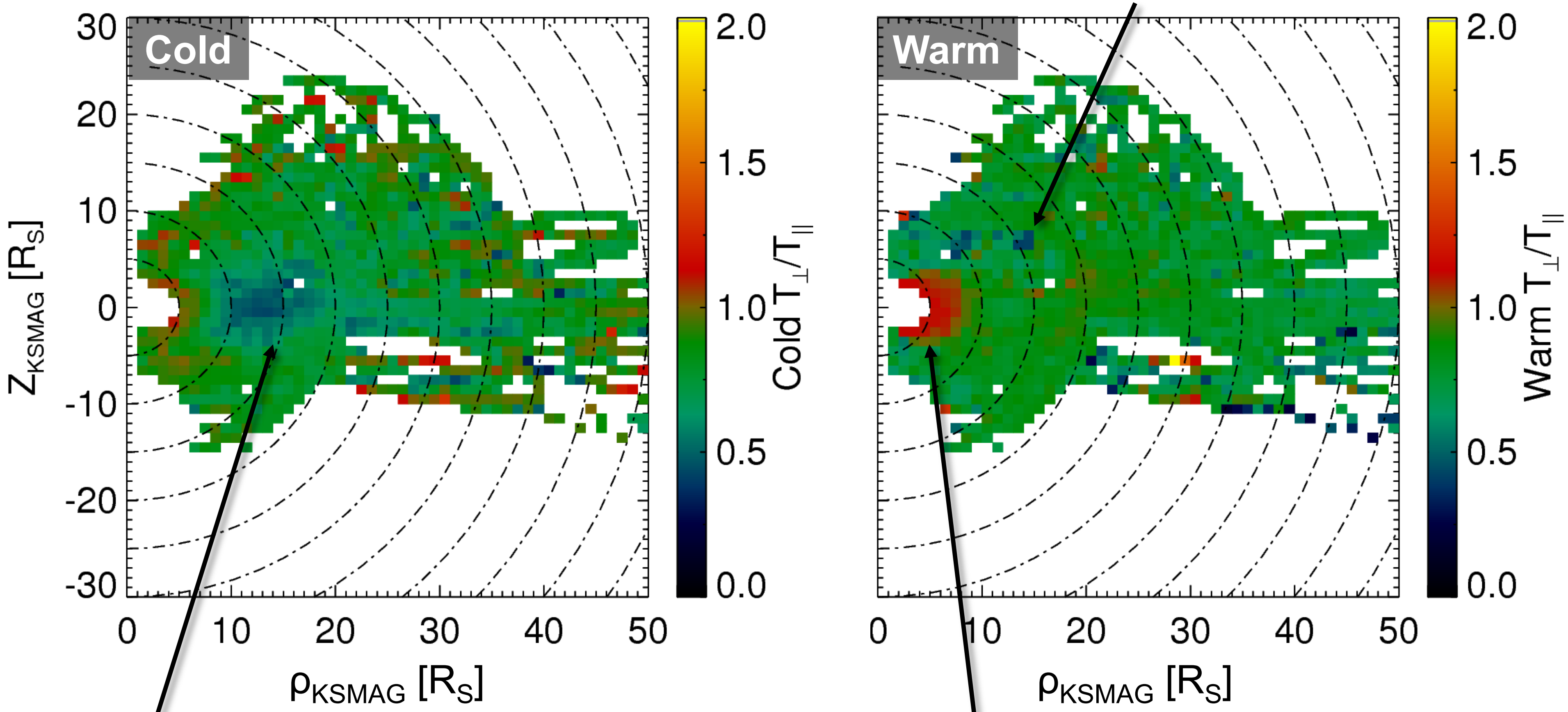
- Cold plasma: ring of $T_{||} > T_{\perp}$ at all local times near 10-15 R_S.
- Warm plasma: ring of $T_{\perp} > T_{||}$ at all local times near 5-8 R_S.



Anisotropies projected in (ρ,z)

UCL

Possible auroral FA electrons?



Cold beams

Warm inward-moving electrons

Summary

- Calculated anisotropic electron moments from Cassini CAPS electron spectrometer.
- Detailed error analysis – can confidently extract anisotropies in the electron temperature.
- Statistical study shows:
  - Equatorially confined region near 10-15 R_S with cold electron $T_{||} > T_{\perp}$. Coincident with cold field-aligned beam (possibly bidirectional).
  - Region of warm $T_{\perp} > T_{||}$ inside 8 R_S, coincident with the inner neutral torus, suggestive of inward transport.
  - Warm/hot electron densities are larger on the nightside.
  - Lobe of cold plasma on the dusk flank possibly related to cold plasma escape from near 9 R_S.
- Future work:
  - New noise model.
  - Ongoing calibration work.
  - Completion of statistical study.