Van Allen Probes and Mass Density Monitoring

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Plasma Mass Density, ρ

– The most fundamental quantity
  - Serves as a medium that sustains plasma waves
  - Controls the time response of the magnetosphere to internal and external force
  - Controls coulomb collision

– Direct measurement is difficult as opposed to electron density.

– Alternative: Infer ρ from the toroidal mode Alfvén waves
  - Technique has been refined for several decades
  - Added advantage: full field line mass variation can be resolved

– Van Allen Probes can monitor the plasma mass density

Magneto-seismology

– Standing waves
  - Tension = B
  - Mass = plasma (ρ)

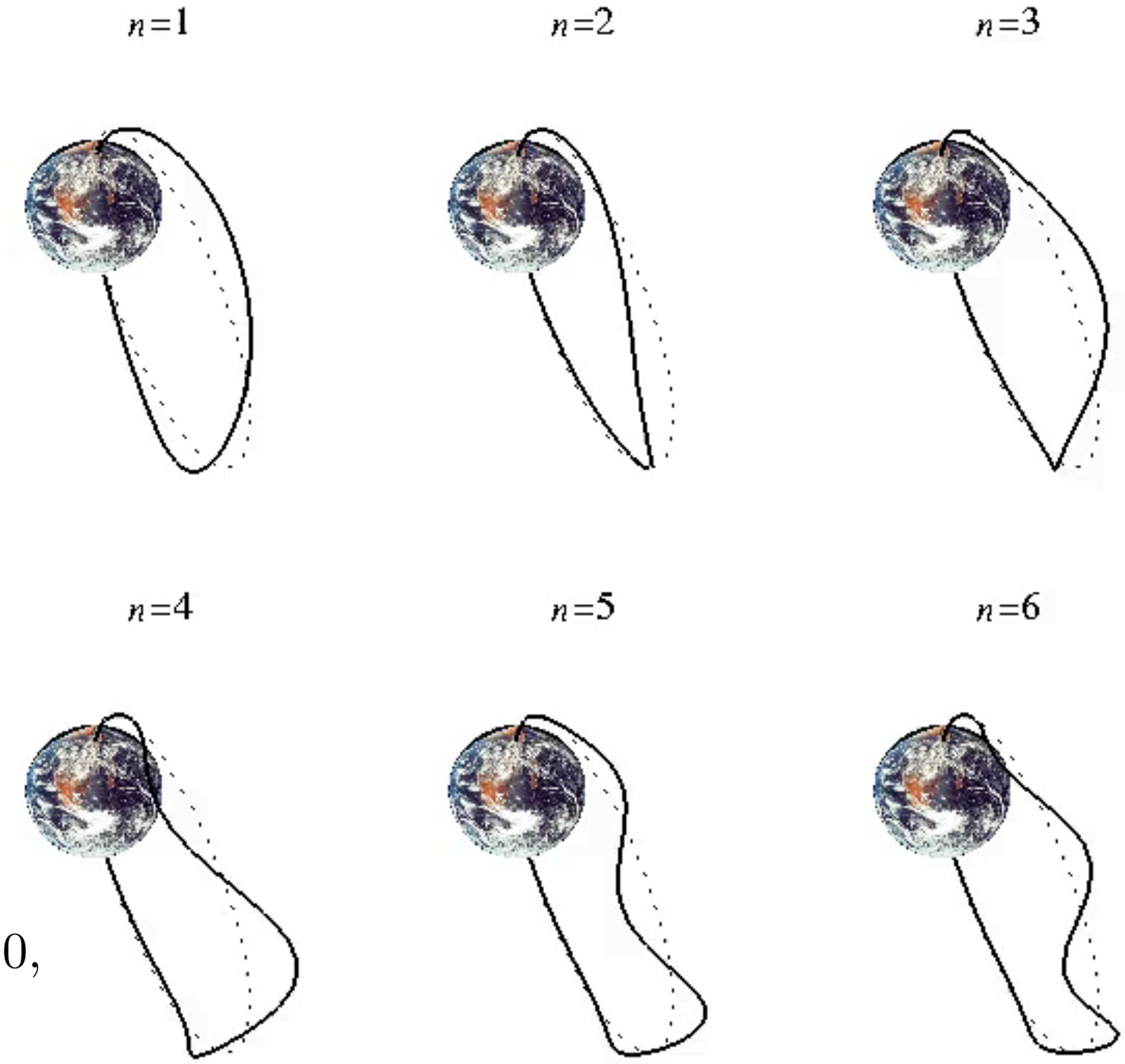
– B and ρ ($V_A \sim B/\sqrt{\rho}$) → complete set of resonant f

– Conversely, resonant f and $B \rightarrow \rho$

– Analogous to seismology

$$\frac{\partial^2}{\partial s^2}\xi' + \frac{\partial}{\partial s}\left(\ln(h^2 B)\right)\frac{\partial}{\partial s}\xi' + \frac{\omega^2}{V_A^2}\xi' = 0,$$

Singer et al. [1981]



EMFISIS and Toroidal Waves

– EMFISIS L3 1sec Bsm Oct 13 ~ Nov 17 (about 95 orbits per SC)

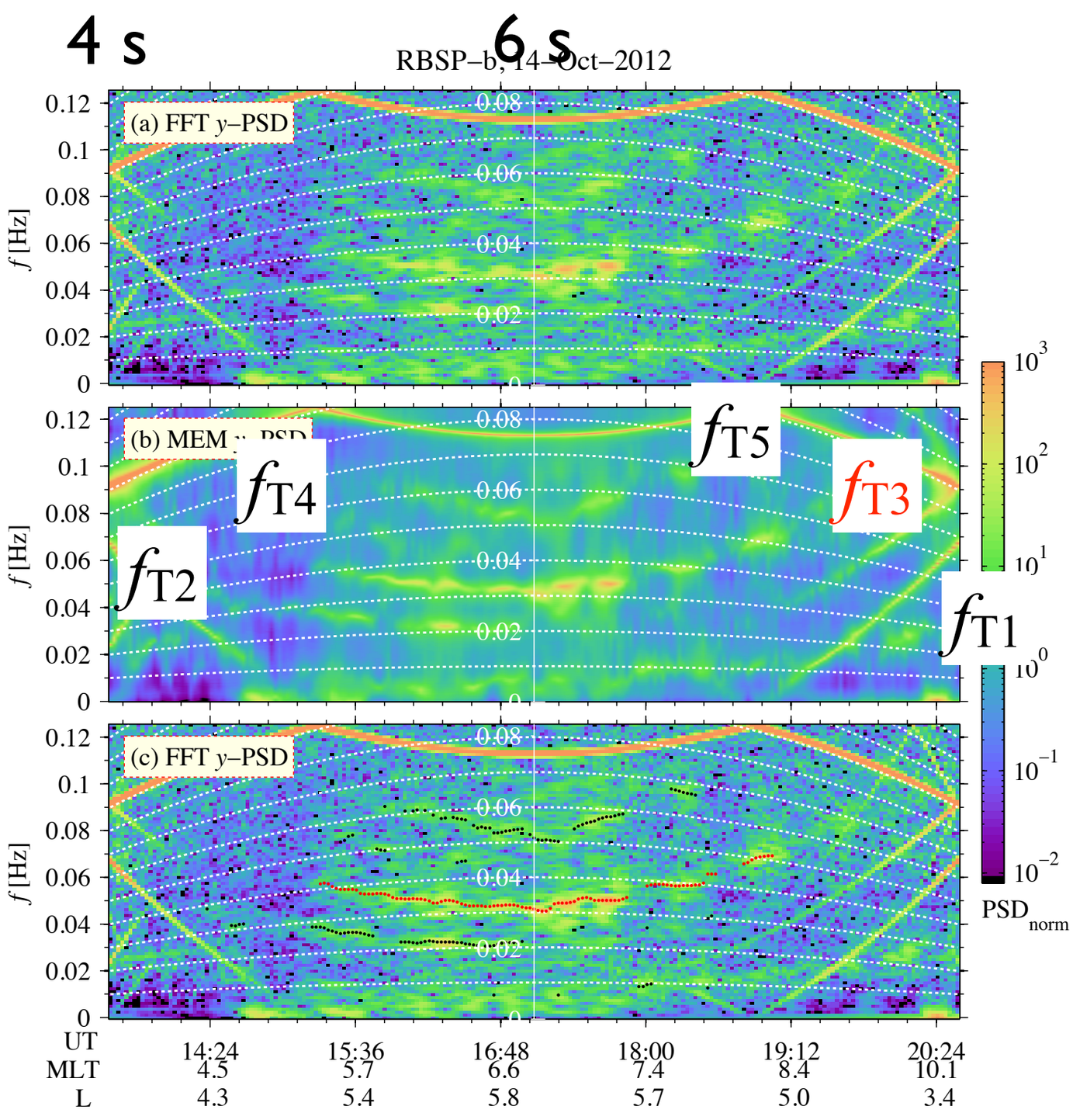
– Data processing following Takahashi et al. [2007, 2010]

– Adaptive sampling

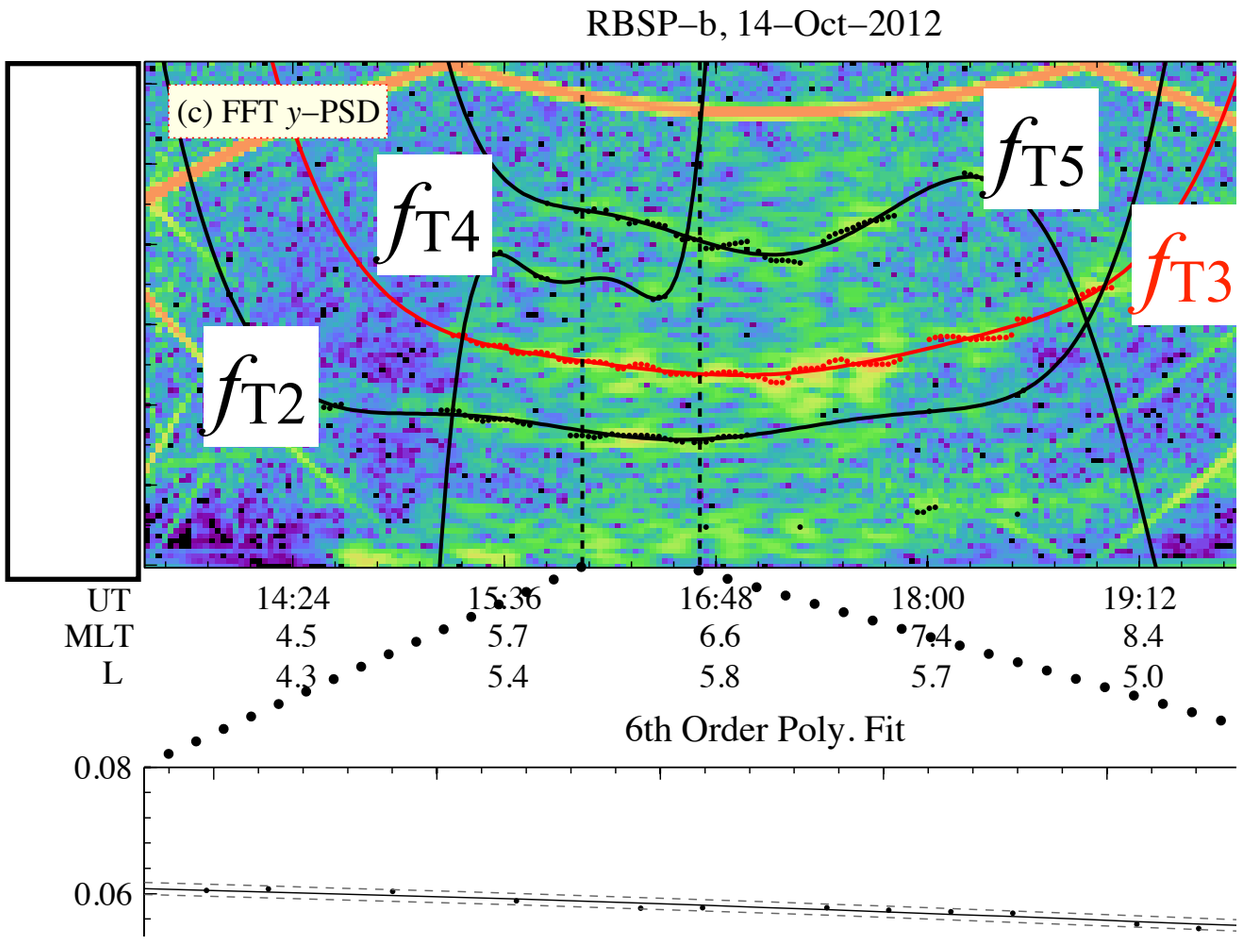
– Maximum Entropy Method gives well defined peaks

– Criteria [Takahashi et al., 2007, 2010]:

1. $P_{yy}(f_T) > P_{zz}(f_T)$
2. $P_{yy}(f_T) > 3\ P_{xx}(f_T)$
3. Δf_T (FWHM) < 3 mHz



Mass Density Inversion for Event 2012-10-14 RBSP-B

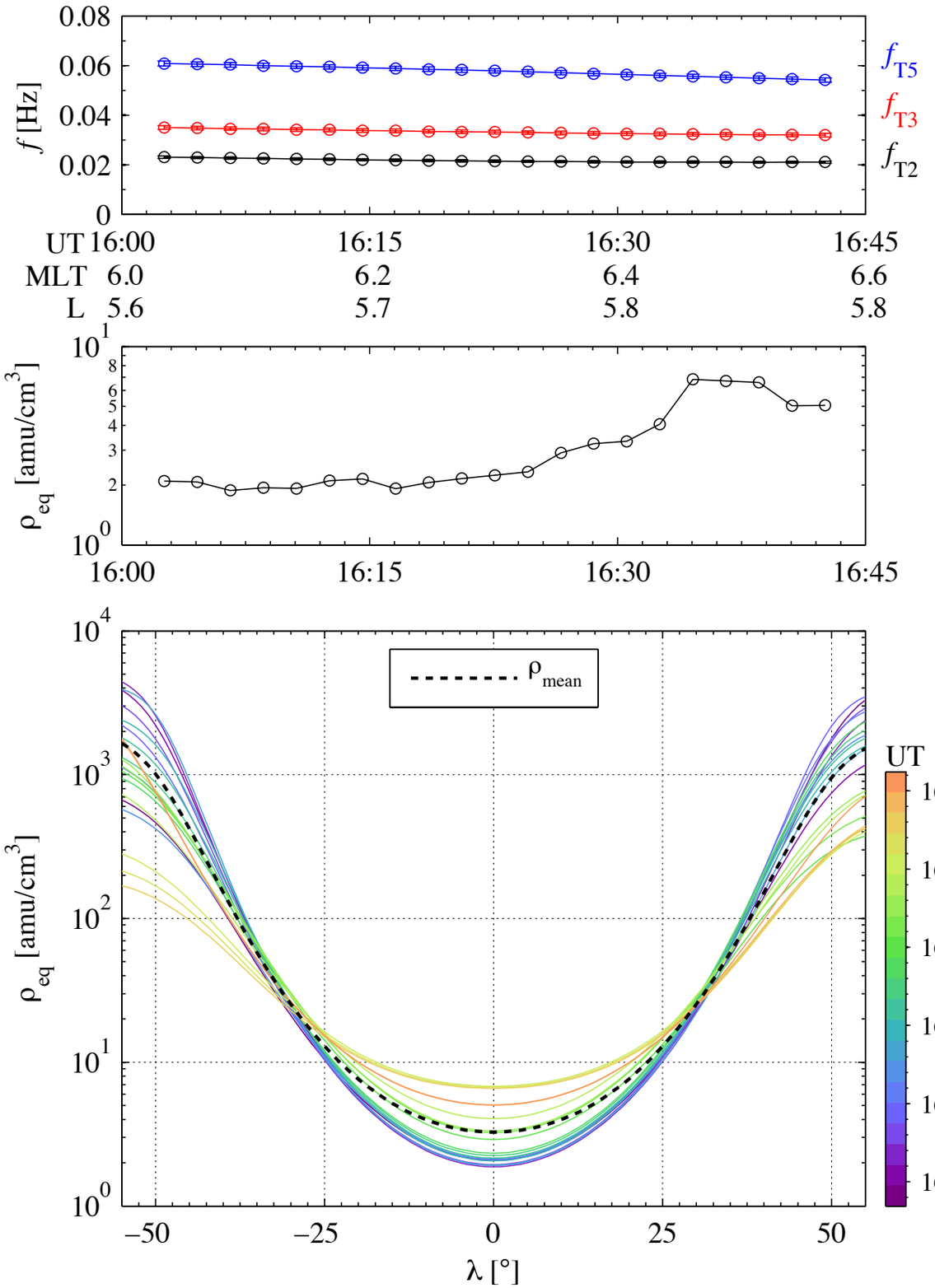


- ρ(λ) Model:

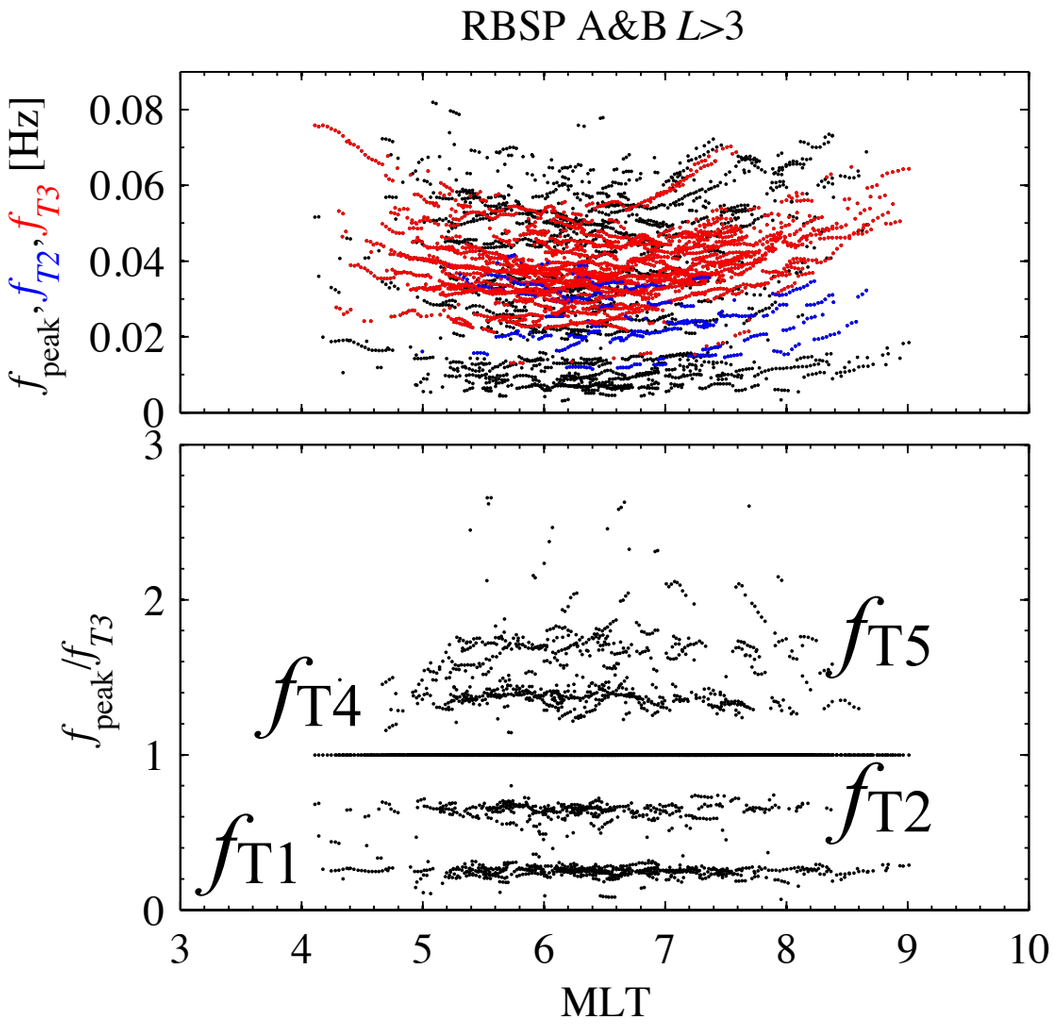
$$\log_{10}\rho = c_0 + c_2\tau^2 + c_4\tau^4 + \ldots$$

$$\tau \equiv \int \frac{ds}{V_A}$$ Alfvén crossing time

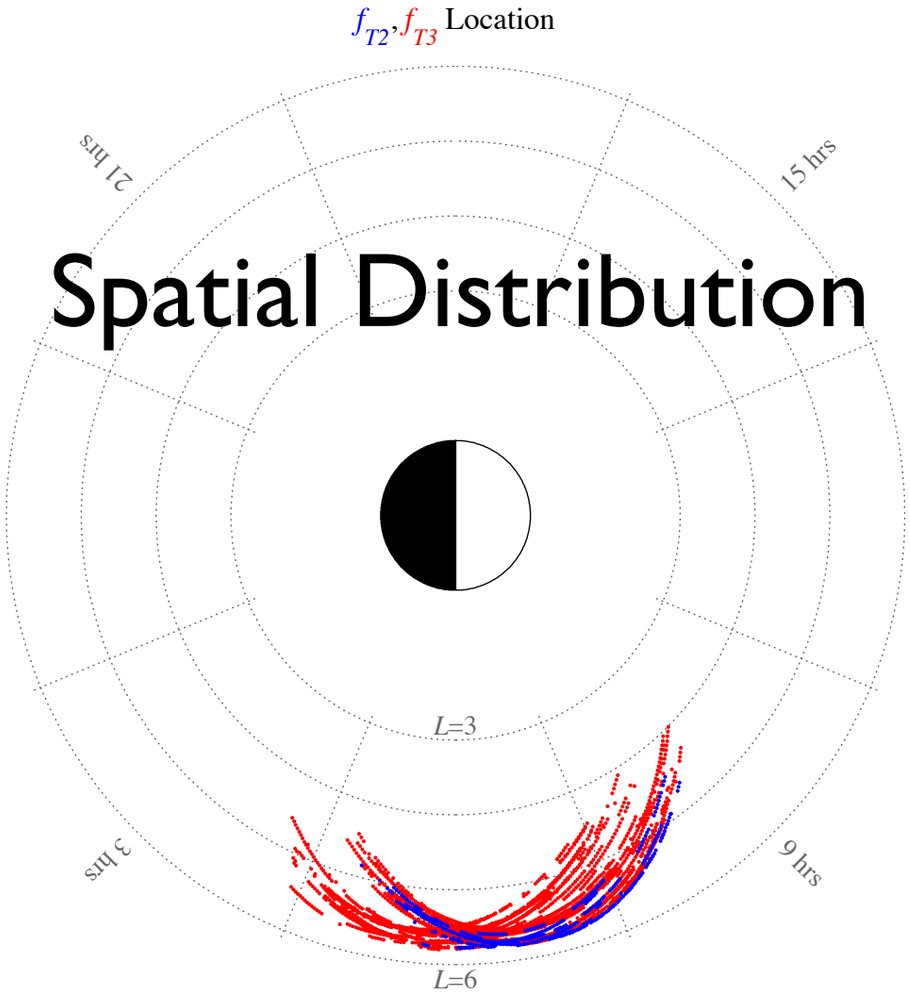
Denton et al. [2001, 2004]



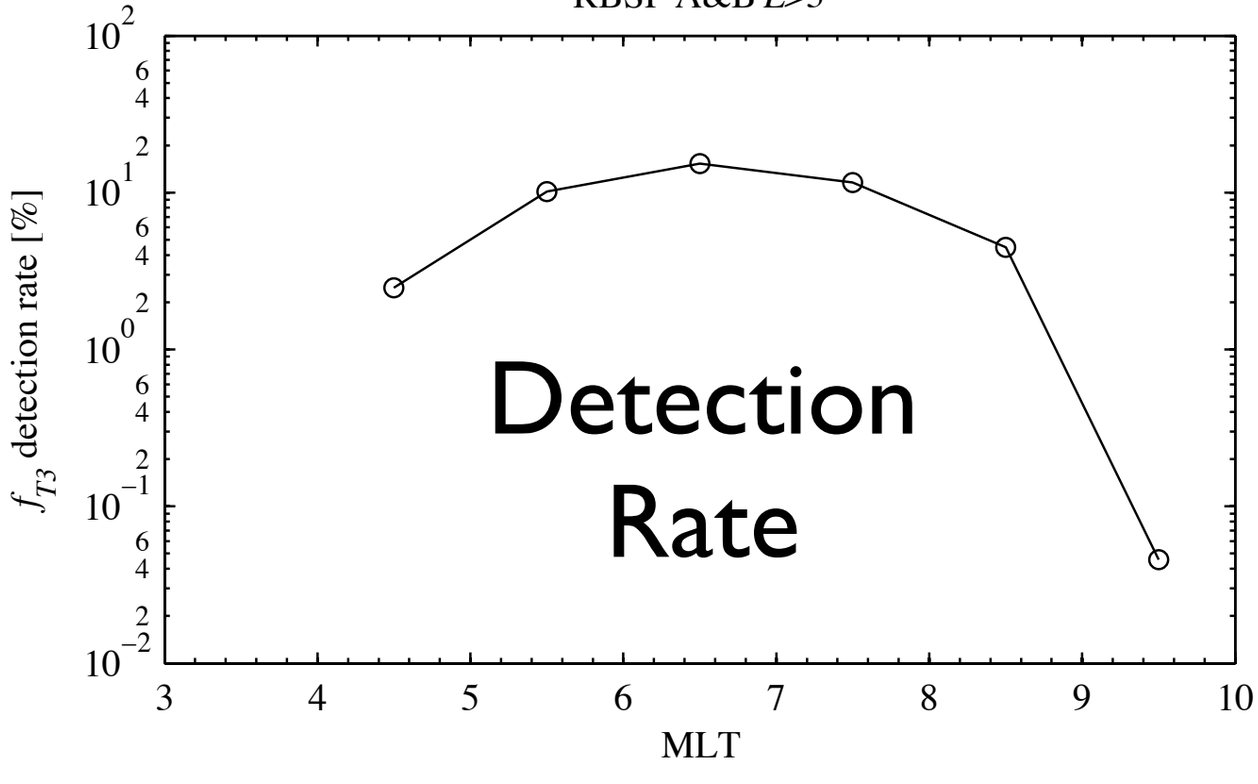
Toroidal Frequencies:
(~ 95 orbits per SC)



Harmonic Structure



Spatial Distribution



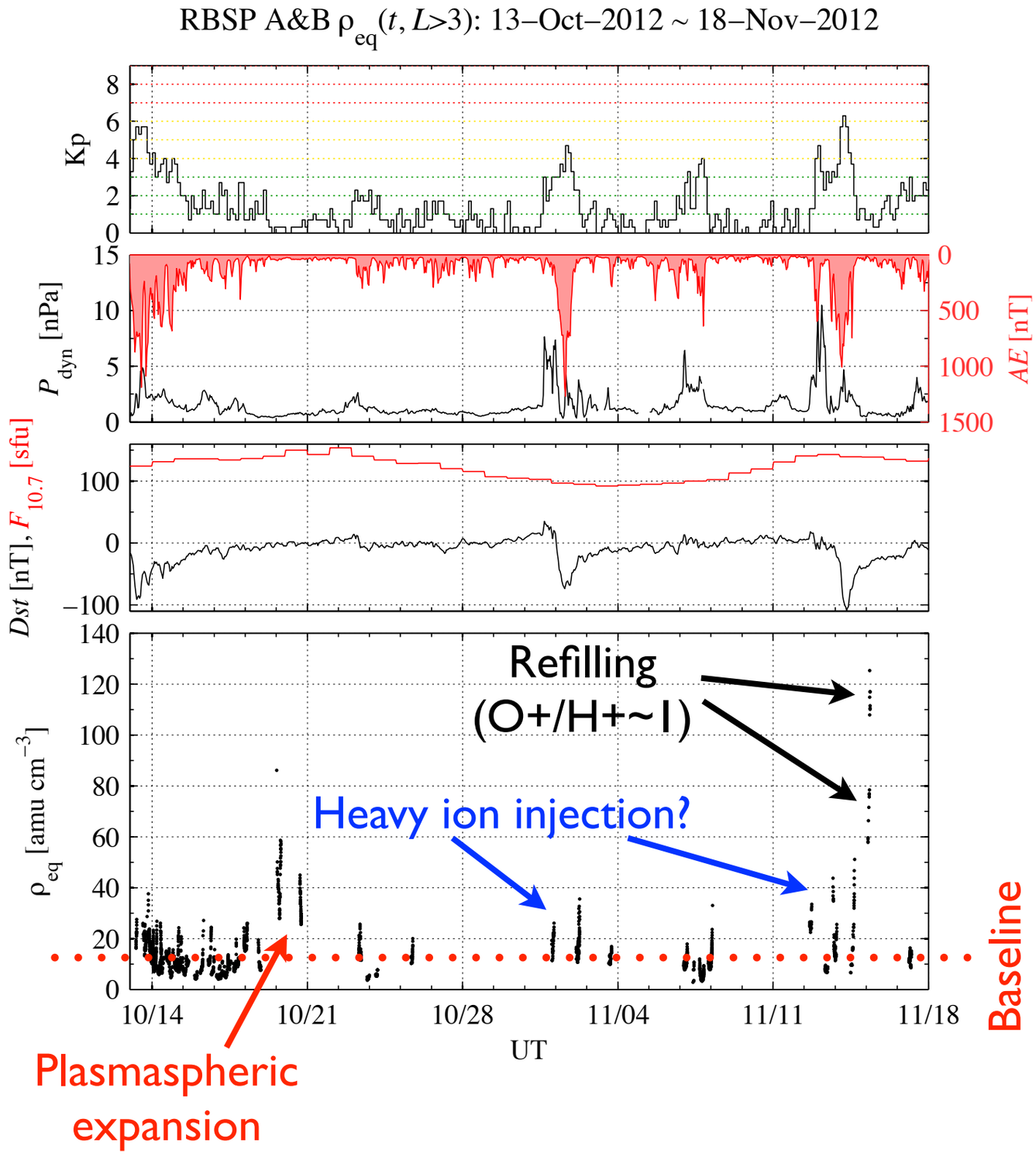
Detection Rate

Equatorial Mass Density, ρ_{eq}

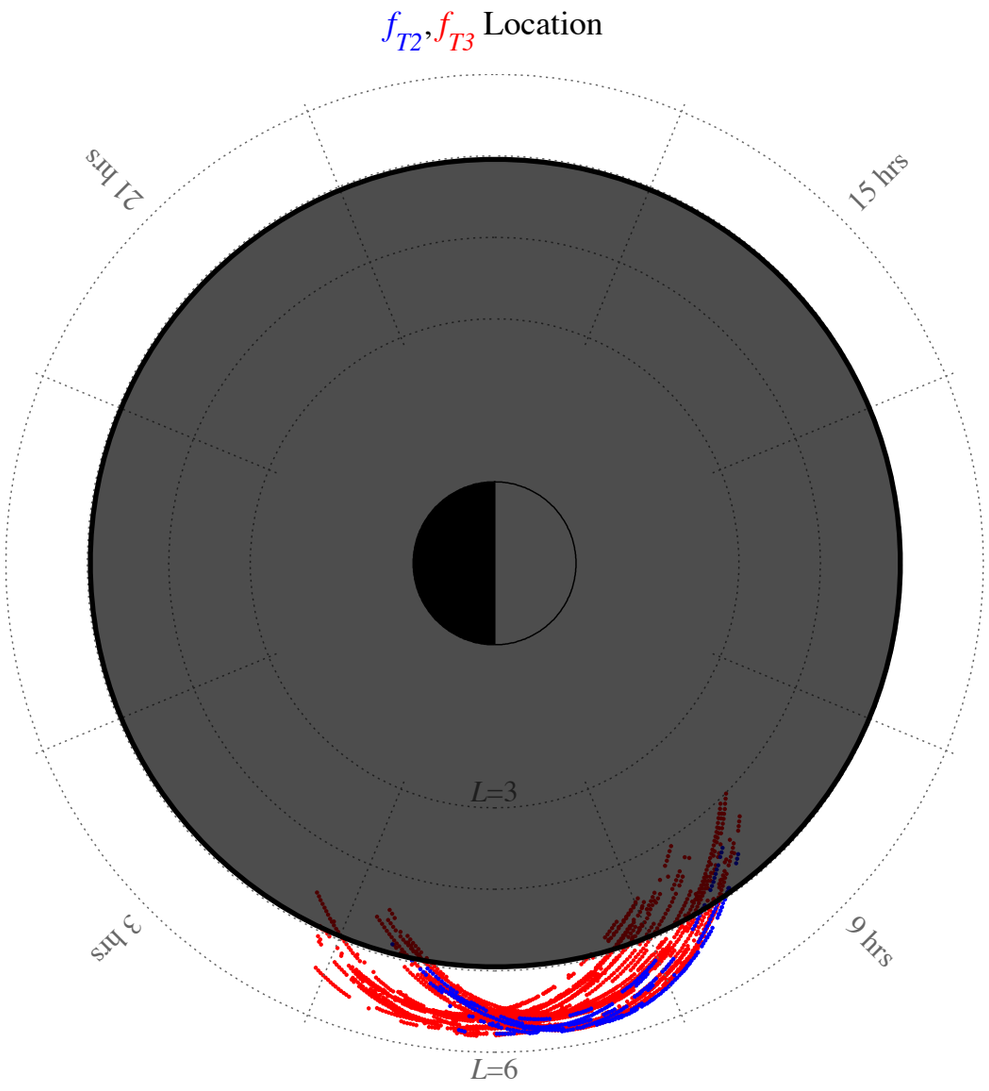
$$\rho = \rho_{eq}\left(\frac{LR_E}{R}\right)^{\alpha}$$

with α = 1 (e.g. Denton et al. 2006)

ρ_{eq} from RBSP



Statistical $\rho(\lambda)/\rho_{eq}$ Variation



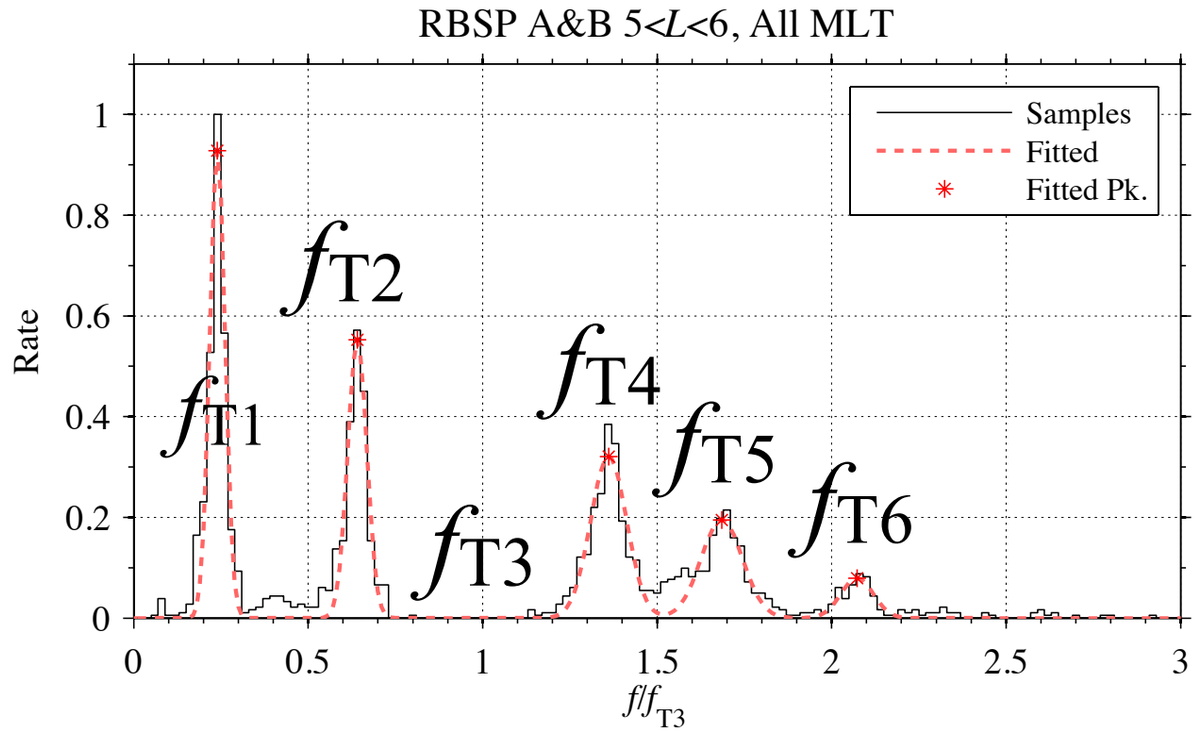
- Use samples from all MLT but 5<L<6
- ρ(λ) Model:

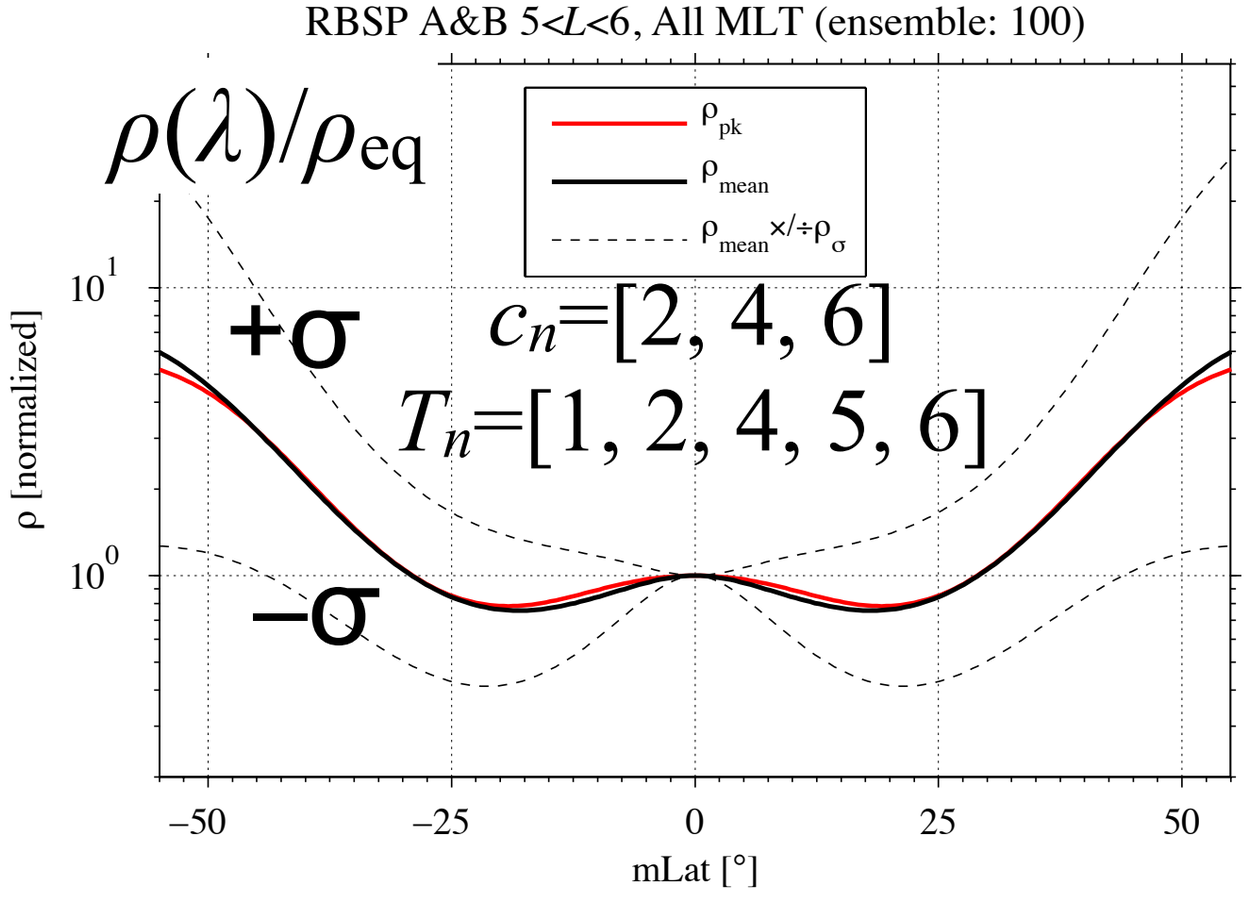
$$\log_{10}\rho = \quad c_2\tau^2 + c_4\tau^4 + \ldots$$

$$\tau \equiv \int \frac{ds}{V_A}$$ Alfvén crossing time

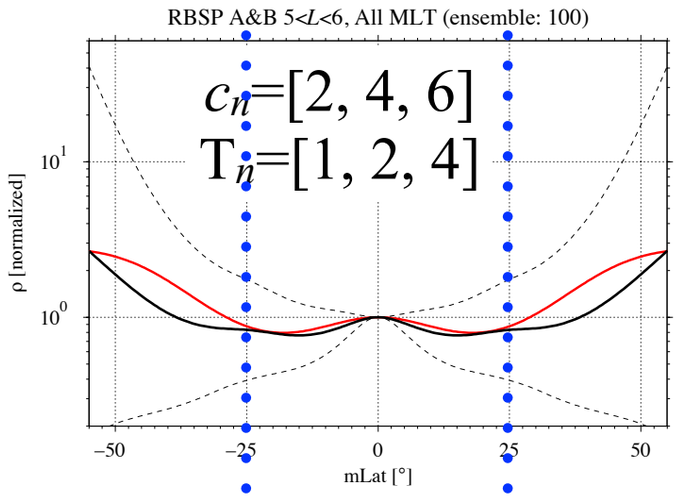
Denton et al. [2001, 2004]

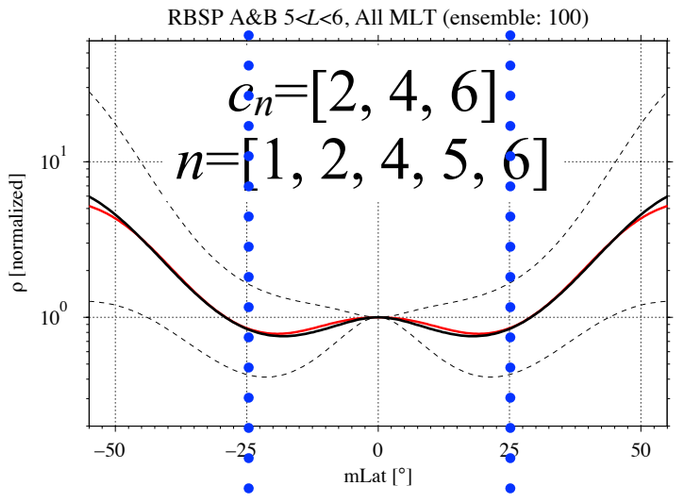
f/f_{T3} Histogram

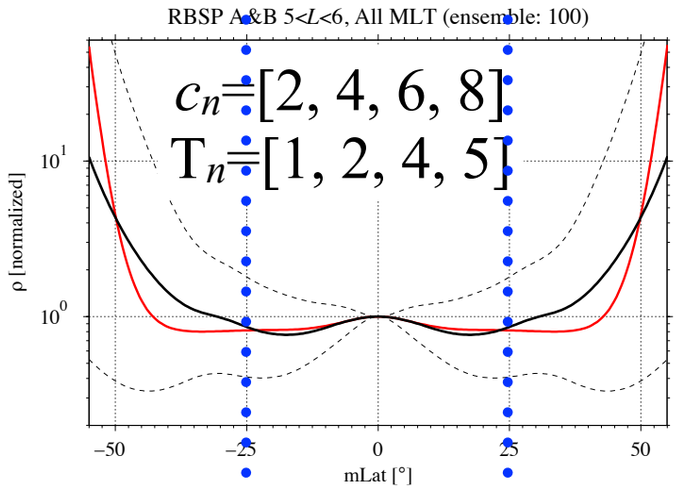


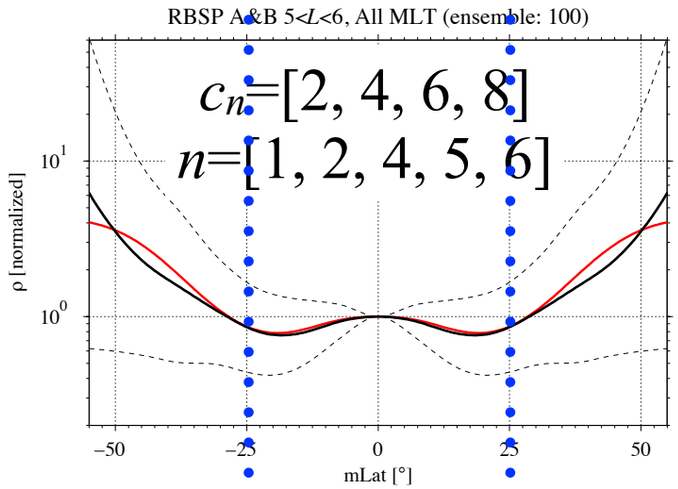


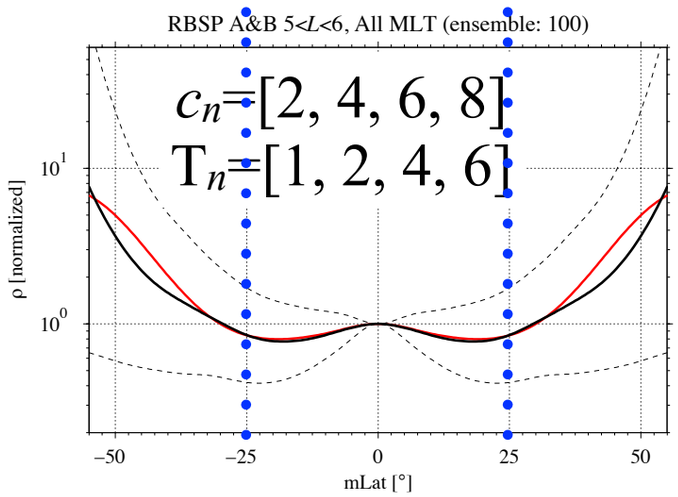
Statistical $\rho(\lambda)$ Variation (Cont'd)

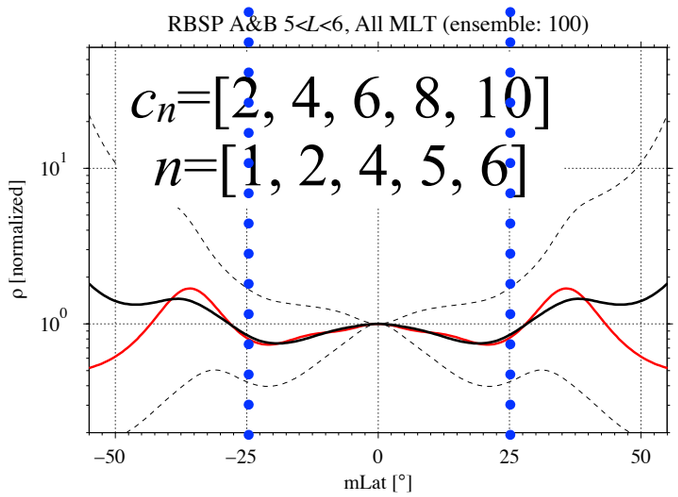












Summary

– Explored the potential of the magneto-seismology and the potential of RBSP to derive the mass density distribution

– With the electric field from EFW, the detection rate will significantly increase

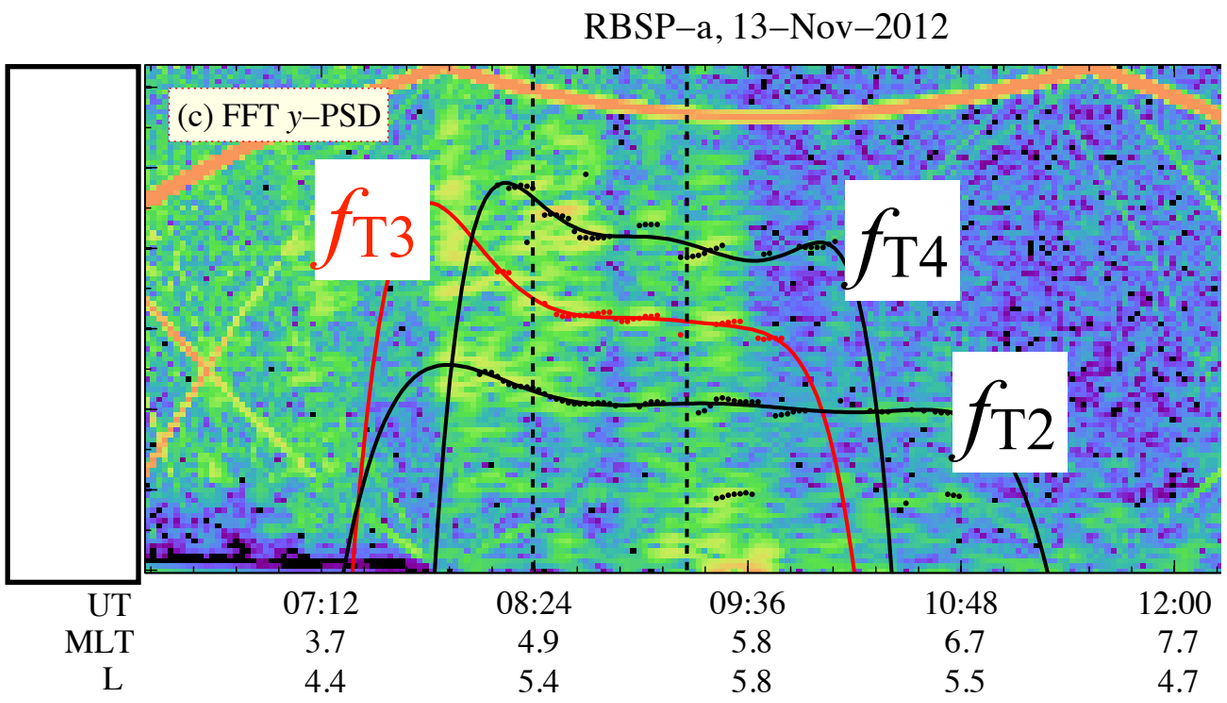
– In-situ electron density information will be very useful for interpretation

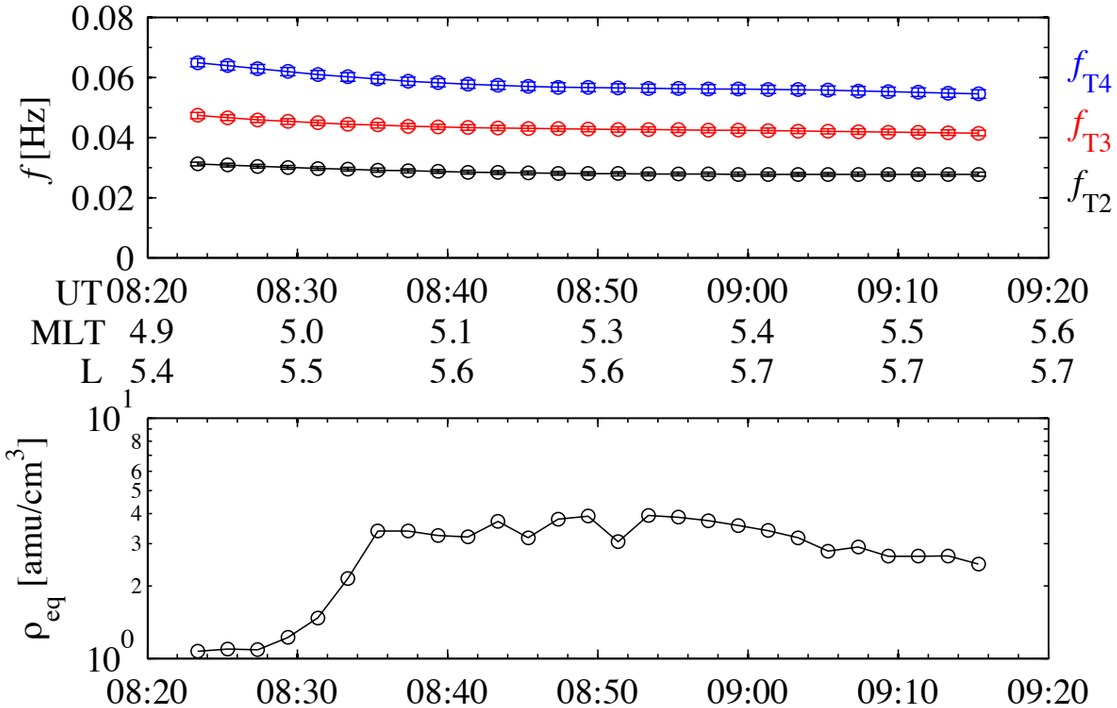
– Cross-calibration with particle measurement from HOPE instrument

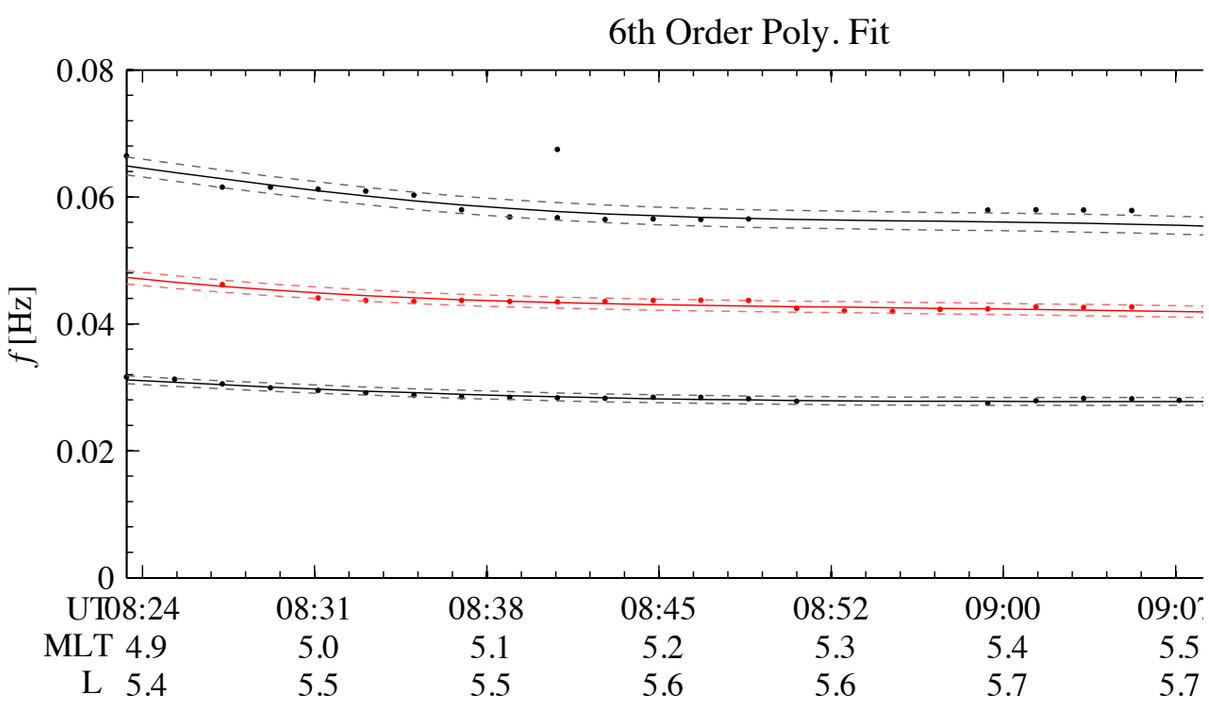
– Fundamental quantity and should be understood. RBSP will help us

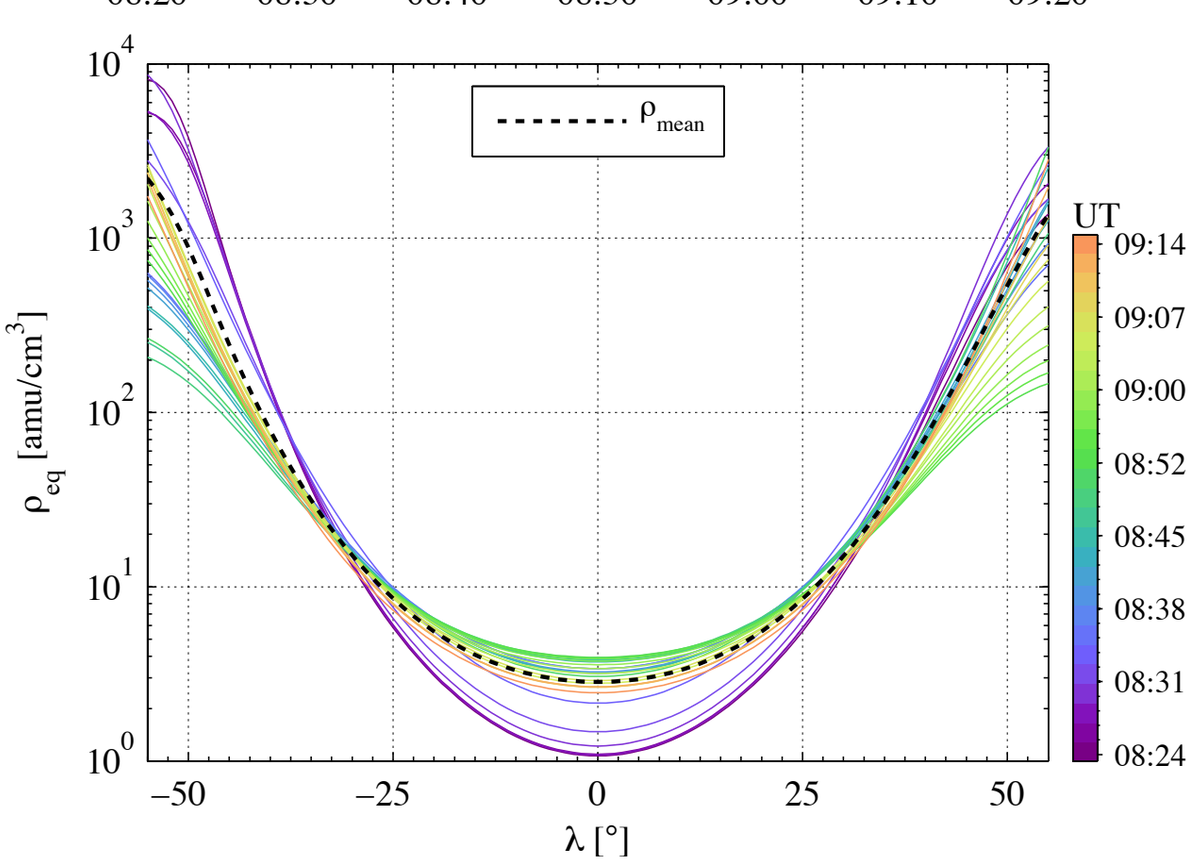
Back-up

Mass Density Inversion for Event 2012-11-13 RBSP-A







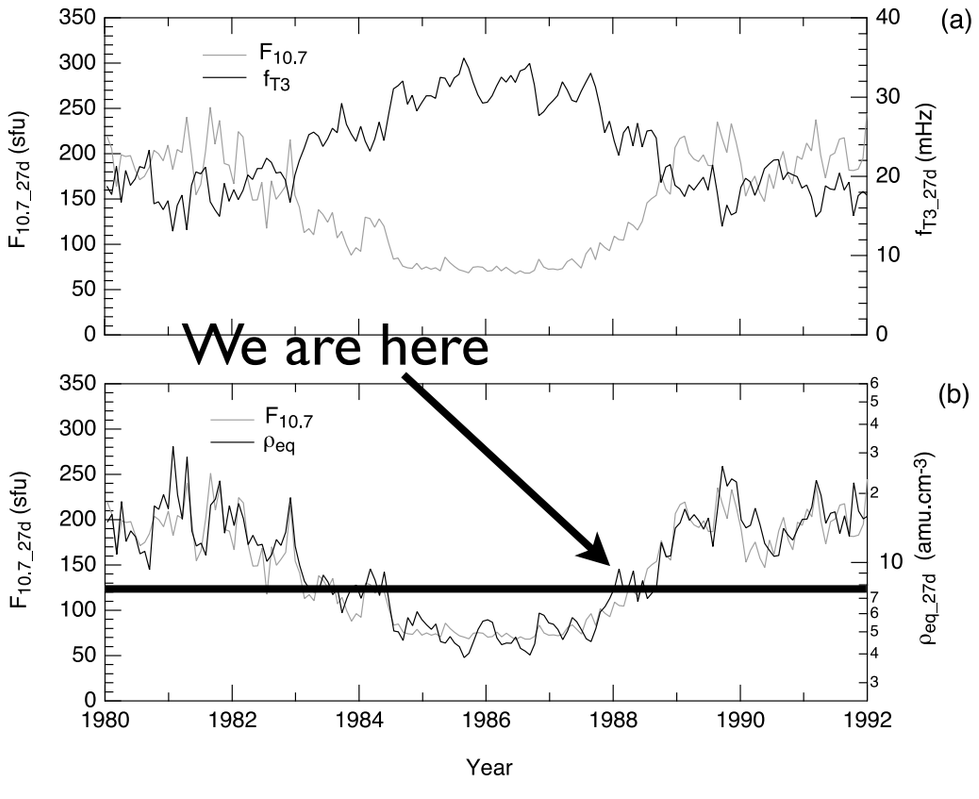


Equatorial Mass Density, ρ_{eq}

$$\rho = \rho_{eq} \left(\frac{L R_E}{R} \right)^{\alpha}$$

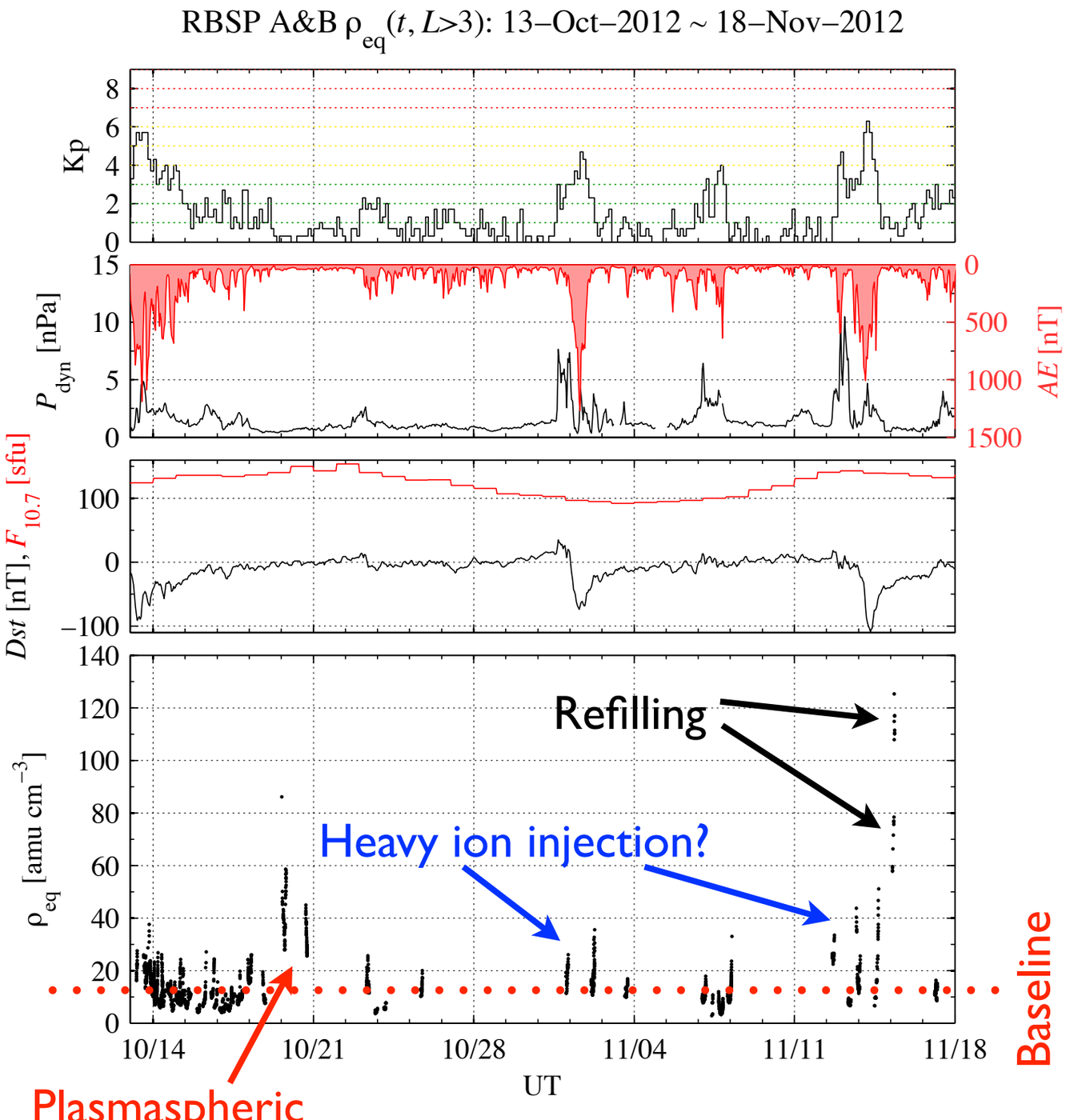
with α = 1 (e.g. Denton et al. 2006)

ρ_{eq} at GEO



Takahashi et al. [2010]

ρ_{eq} from RBSP



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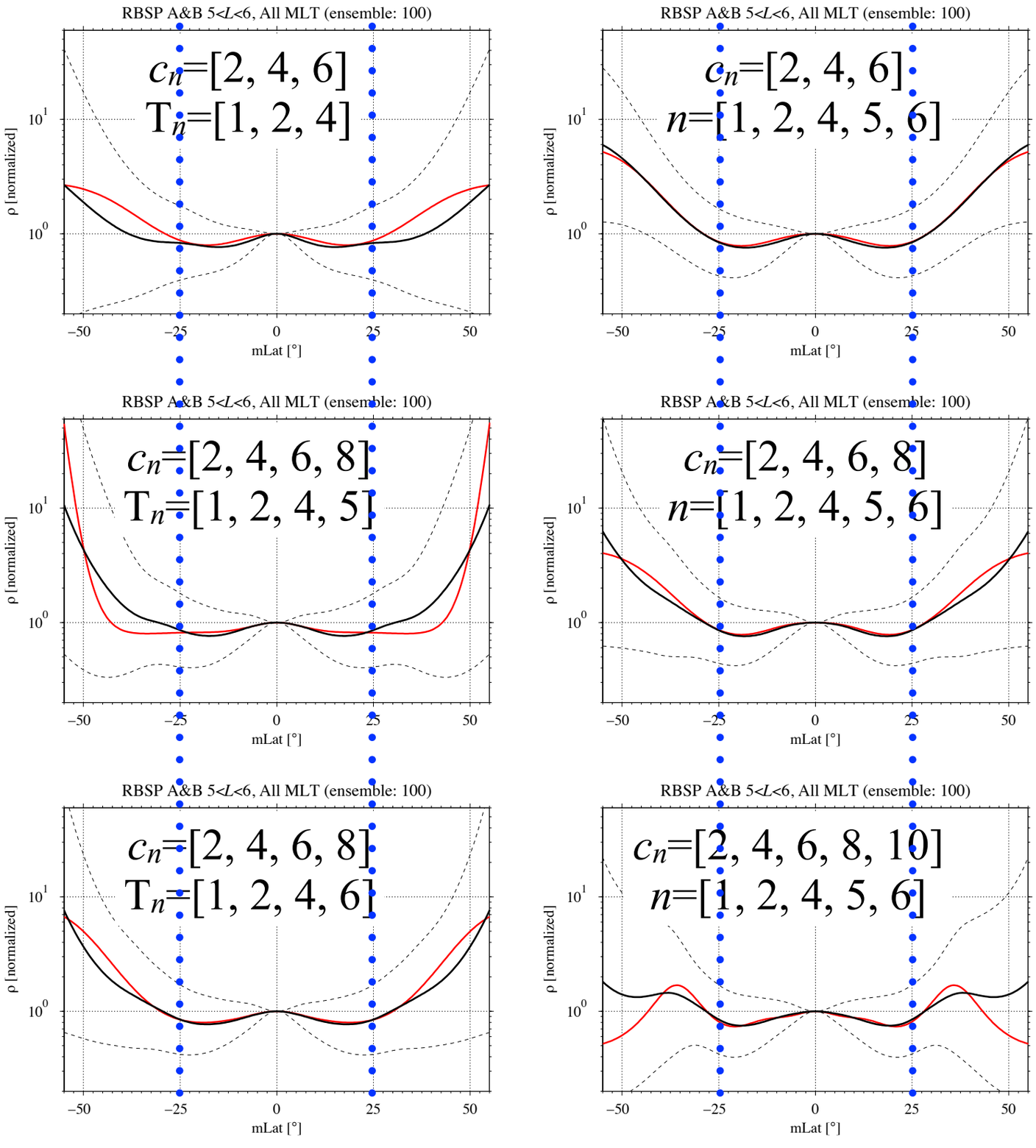

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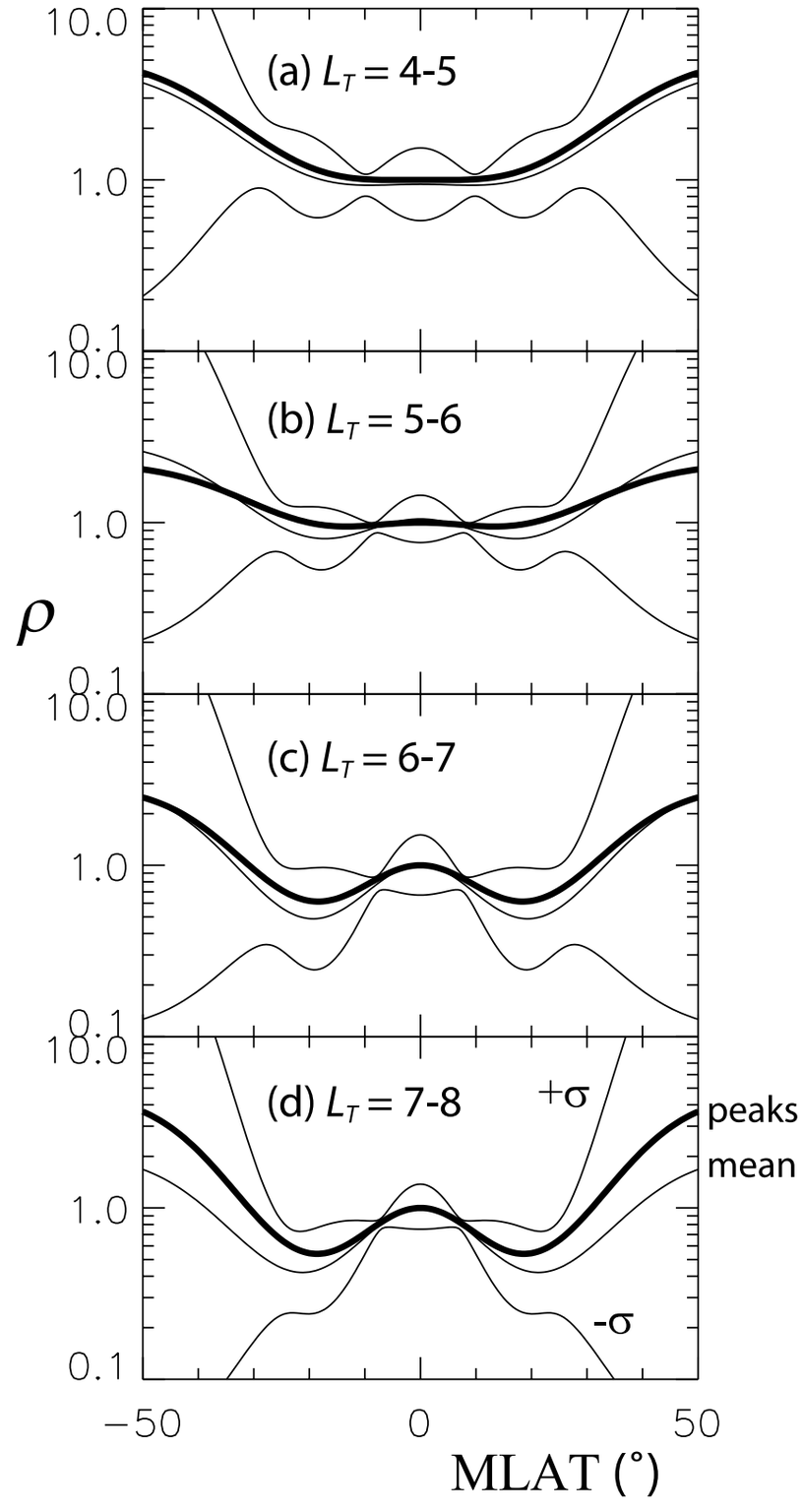

Denton et al. [2006]