Saturn's ionosphere: Electron density altitude profiles and ring shadowing effects from the RPWS/LP

Lina Z. HADID

M. W. Morooka, J.-E. Wahlund, A. M. Persoon, D. J. Andrews, O. Shebanits, W. M. Farrell, W. S. Kurth, H. Waite, R. Perryman,L. Moore, M. M. Heddman, T. E. Cravens, N. J. T. Edberg, E. Vigren, A. Nagy, A. I. Eriksson

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IRF
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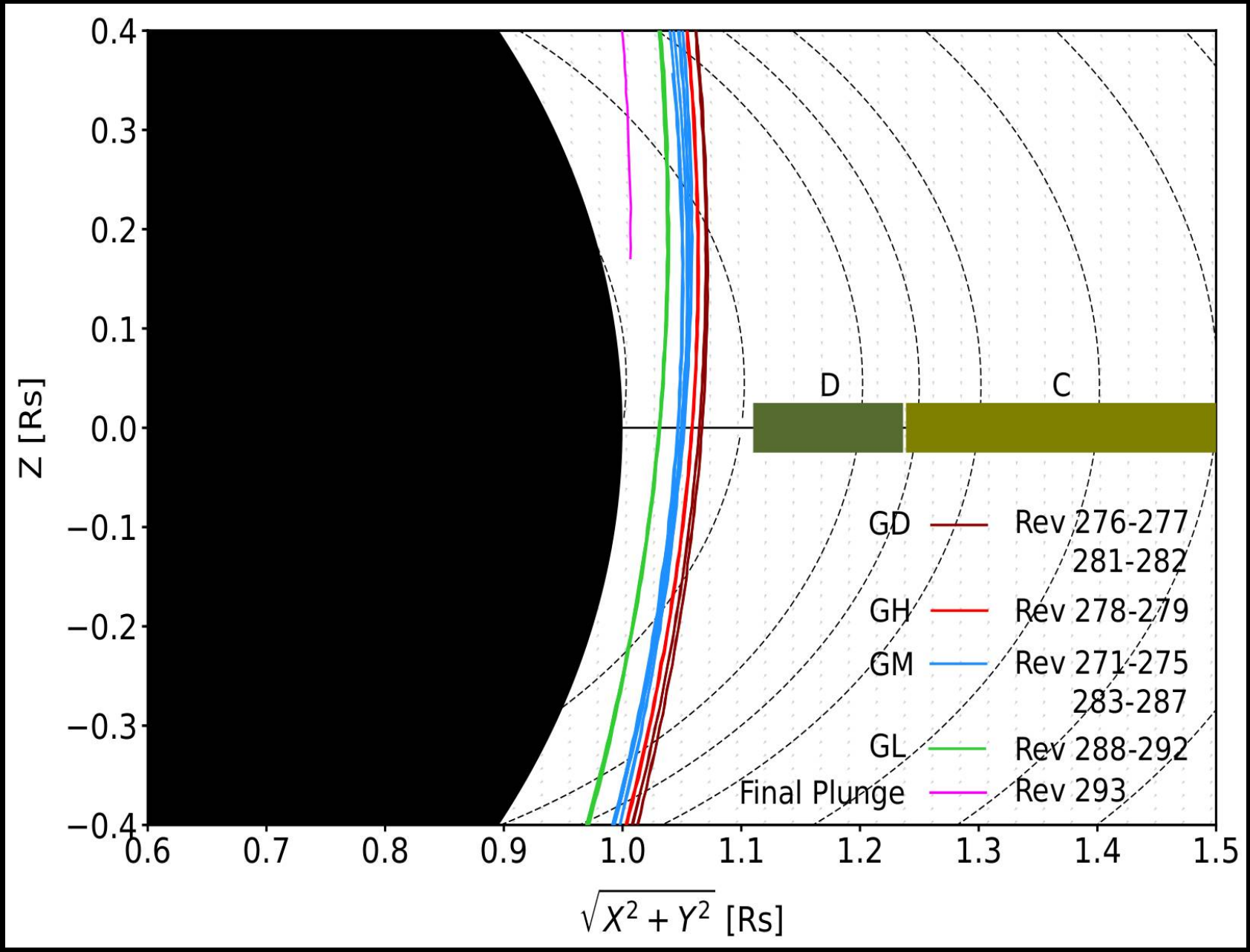
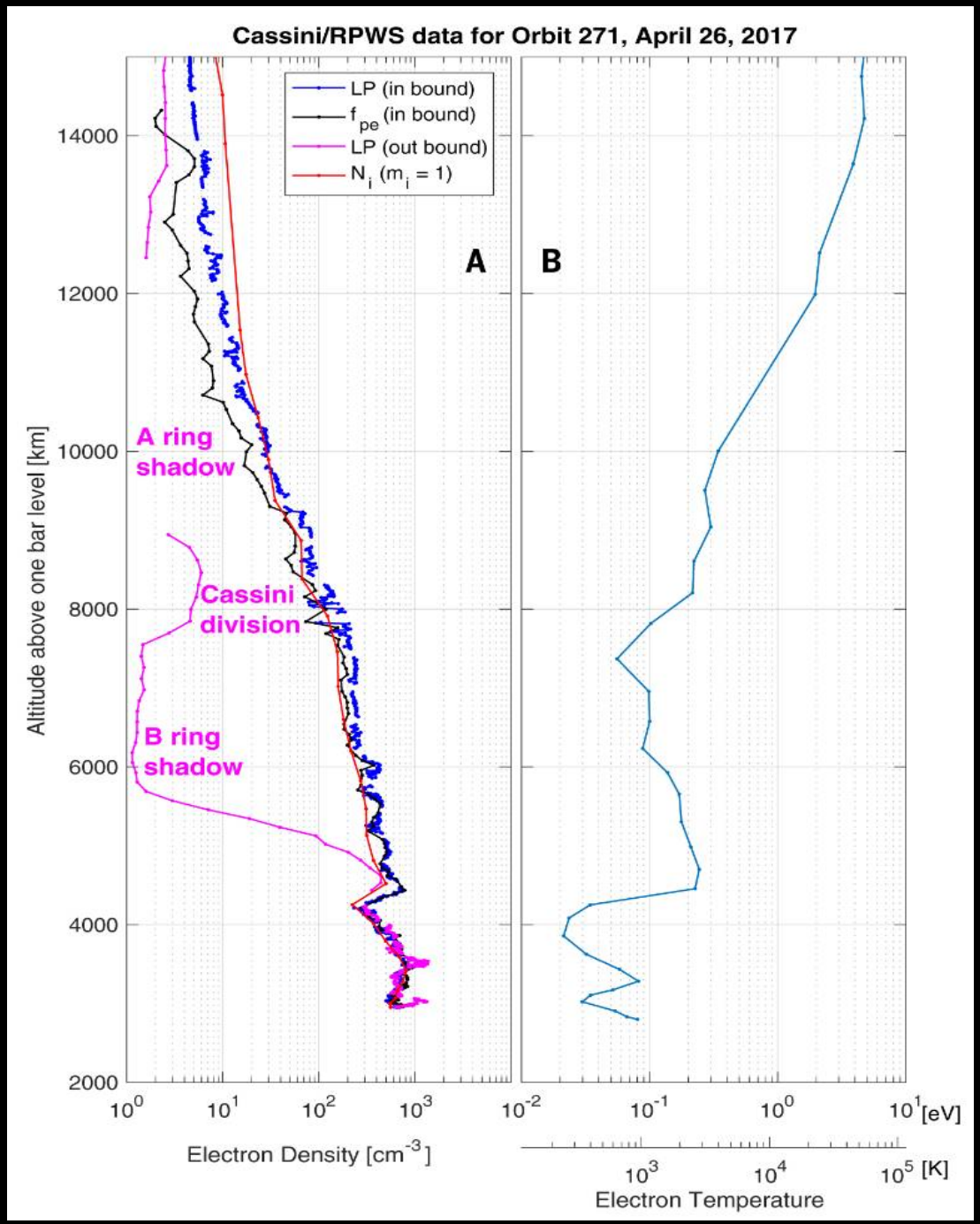
Swedish Institute of Space Physics

Proximal orbits overview



Saturn's topside ionosphere profile (1st proximal orbit)



First *in-situ* detailed detection!

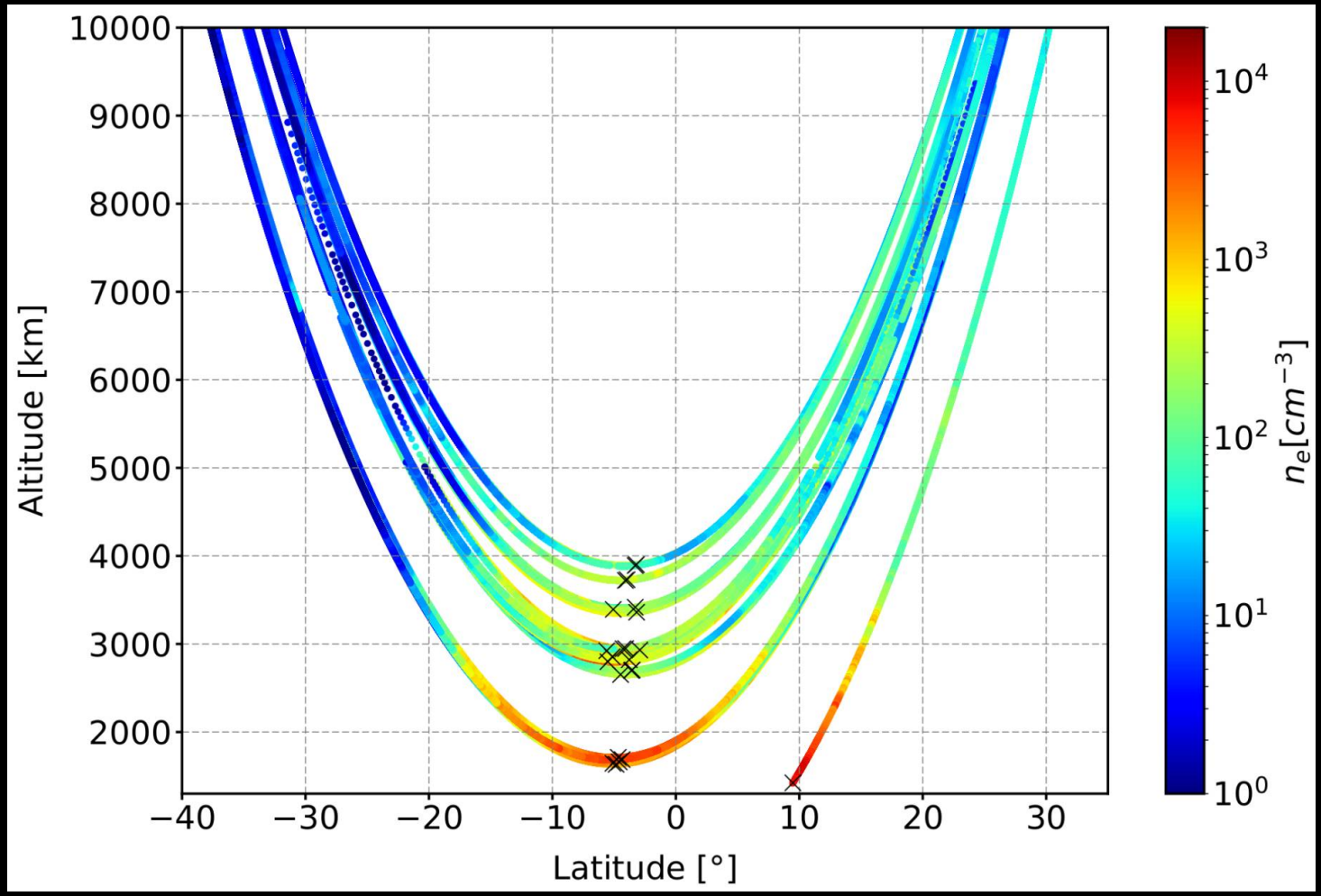
- LP measurements in agreement with:
  → 20 Hz LP current densities
  → Upper cut-off frequency of the whistler waves.
- Dominance of H^+
- Ring shadow effect observed:
  → B- & A- ring optically thick
  → No effect observed from the C- and D- rings.
  → Cassini division less opaque to the EUV ionization.
- Local photoionization of the ionospheric plasma

Dense and cold ionosphere!

→ $N_e > 1000\ cm^3$
→ $T_e \sim 0.1$ eV

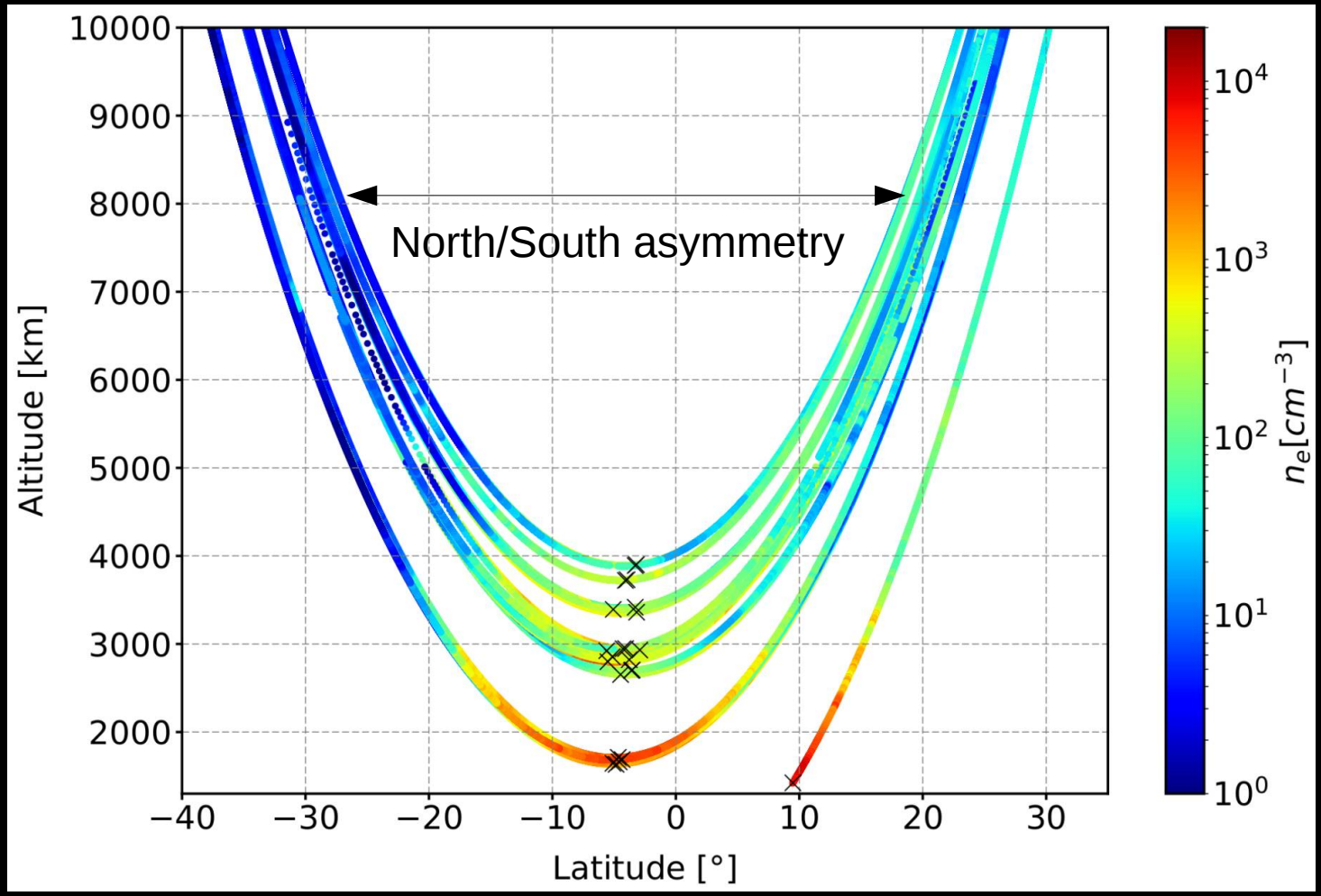
Wahlund et al., *Science*, 2017

Saturn’s topside ionosphere profile (all the proximal orbits)



- Large variability in n_e between the orbits and within one orbit
- North/south asymmetry because of the A and B ring shadows in the southern hemisphere

Saturn’s topside ionosphere profile (all the proximal orbits)



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Electron density altitude profiles and D ring electrodynamic interacttion

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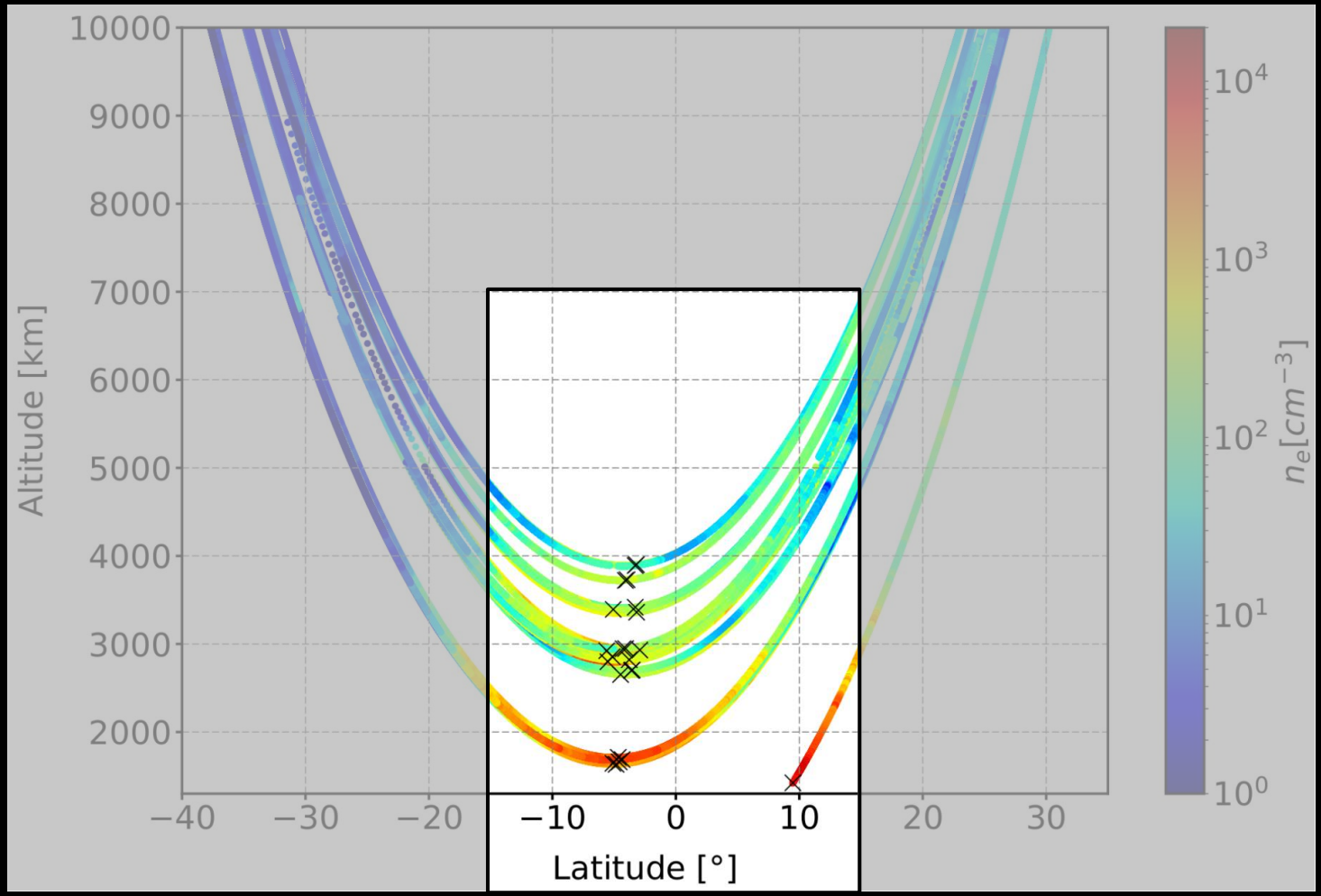
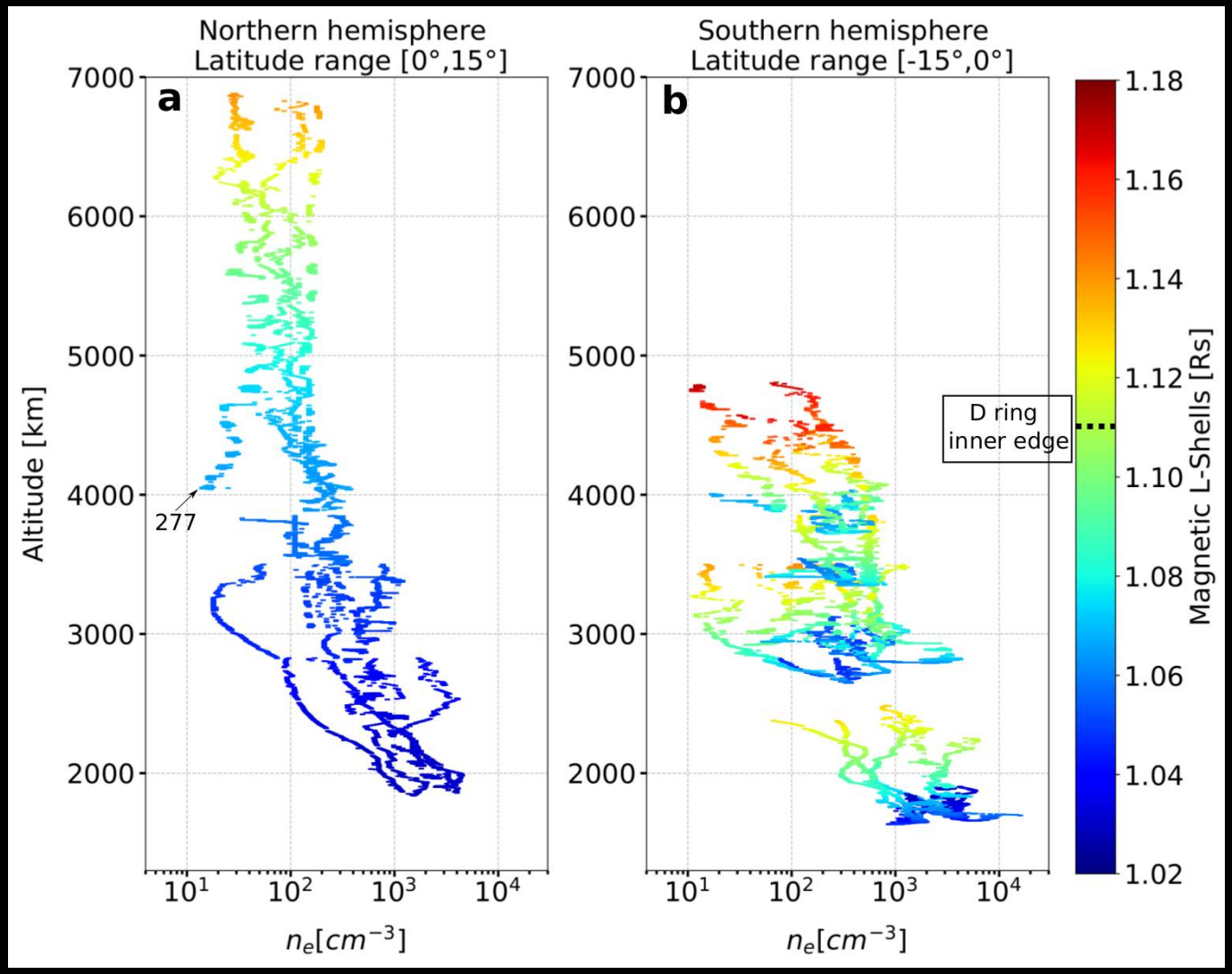


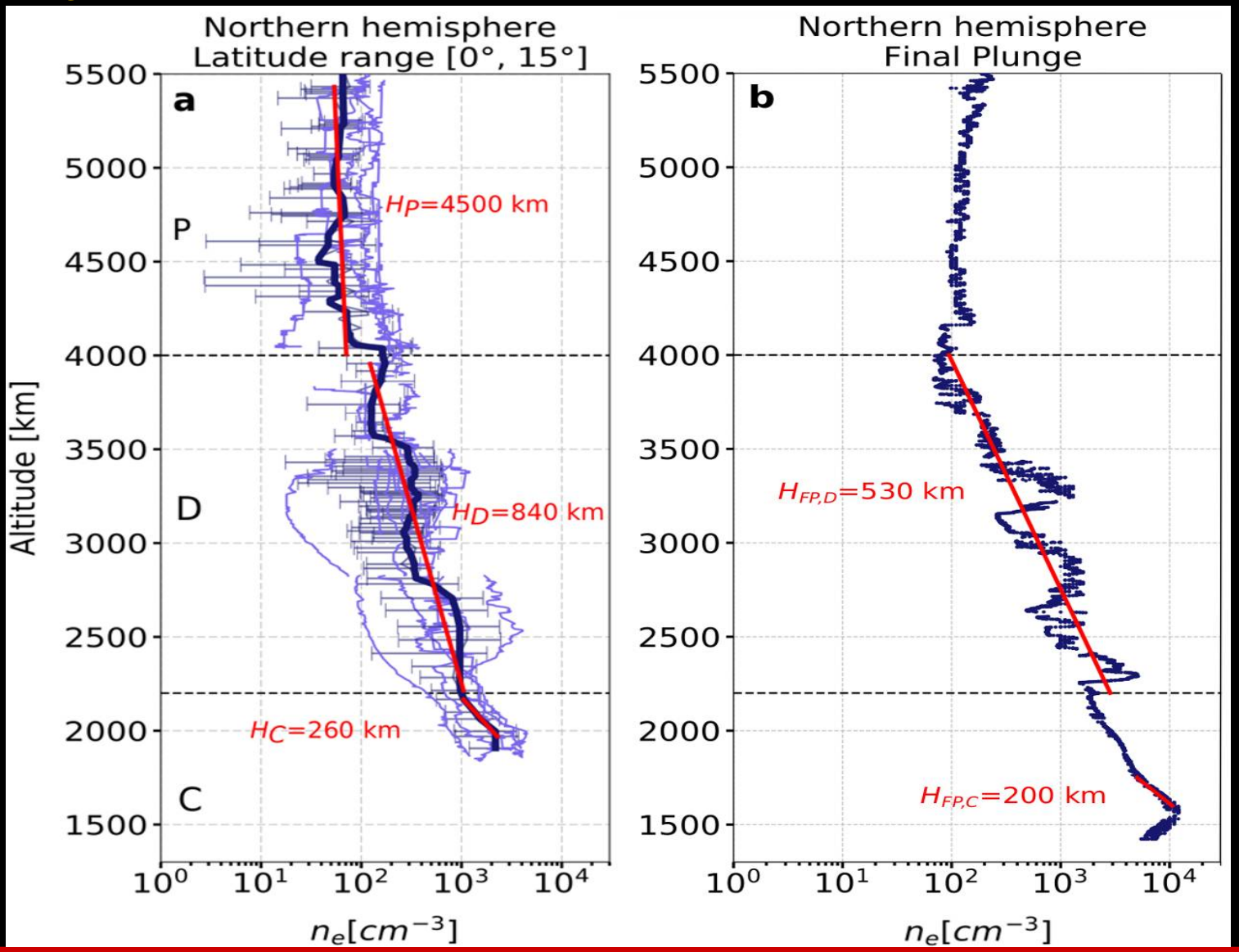
We limit the analysis to near equatorial latitudes [-15º,+15º] in order to exclude the shadowing effects

n_e altitude profiles and D ring electrodynamic interaction



- NH and SH: increase of n_e (x100) with increasing altitude
- NH: more organized n_e profiles
- SH: electrodynamic type of interaction with the D ring

Average n_e altitude profiles



- Similar profiles between the average profile and the Final Plunge
- Evidence of three different layers : P, D and C
- Scale height estimations : consistent with previous estimation from radio occultation and from the wave frequency characteristics [Persoon +, GRL, 2018]

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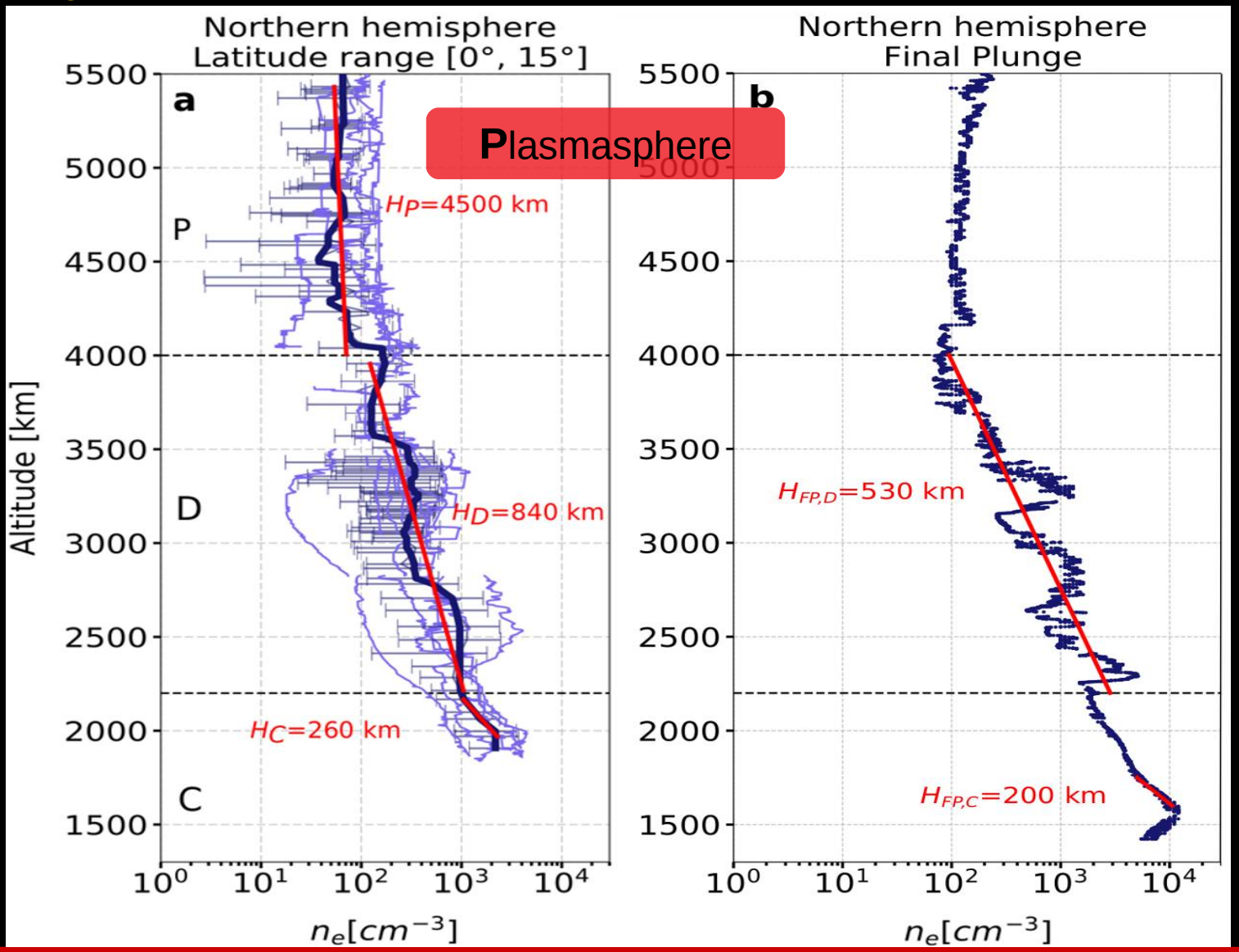

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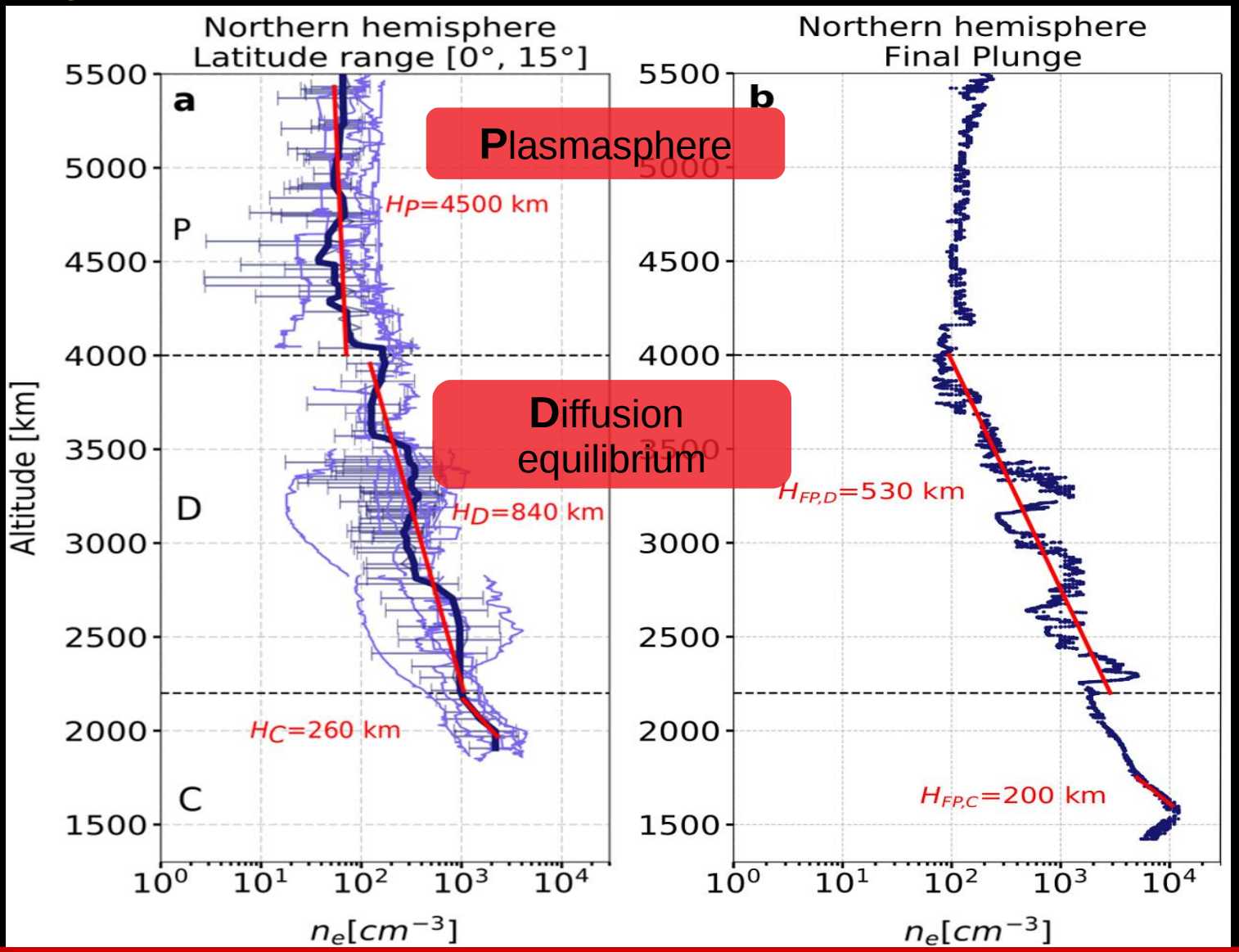

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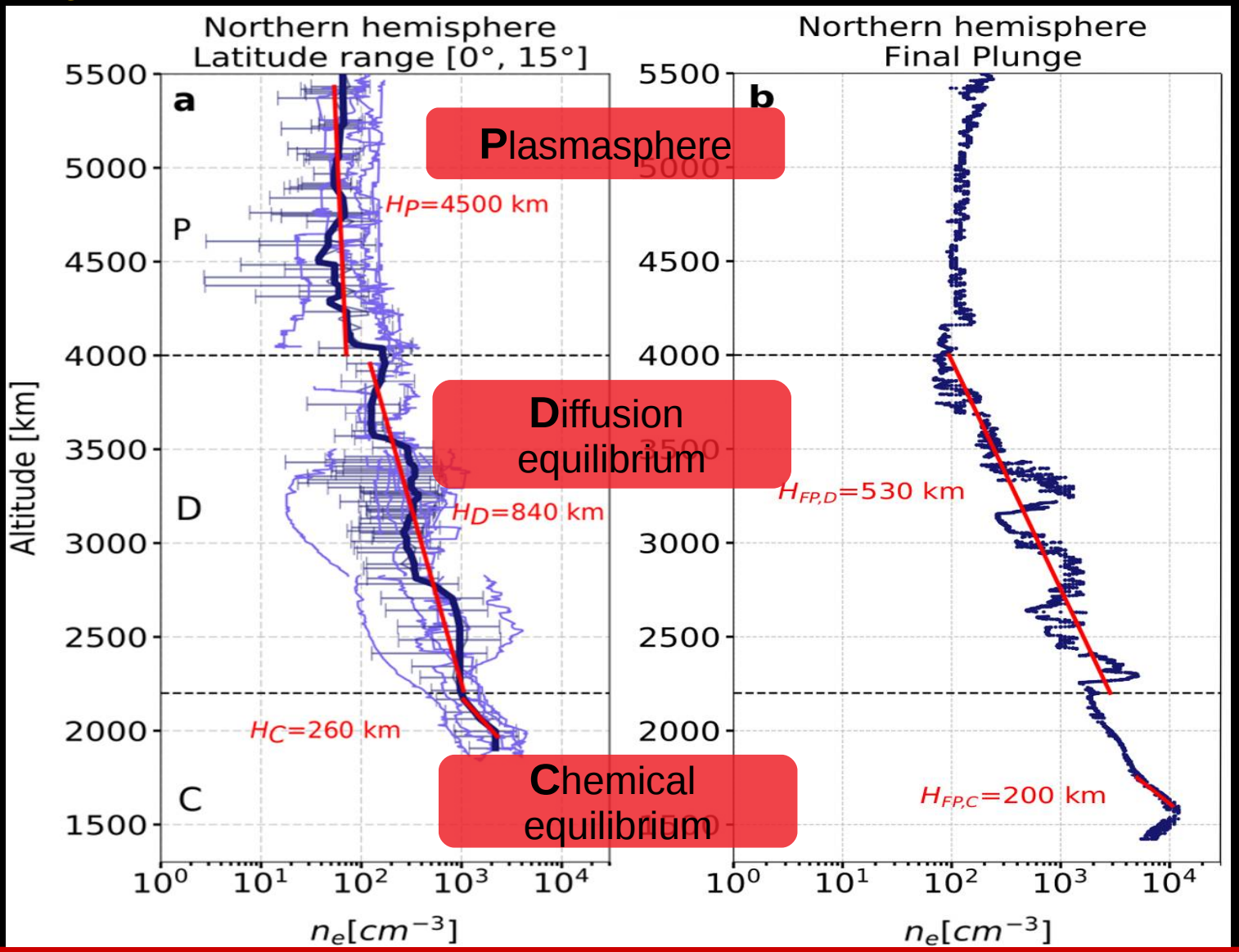

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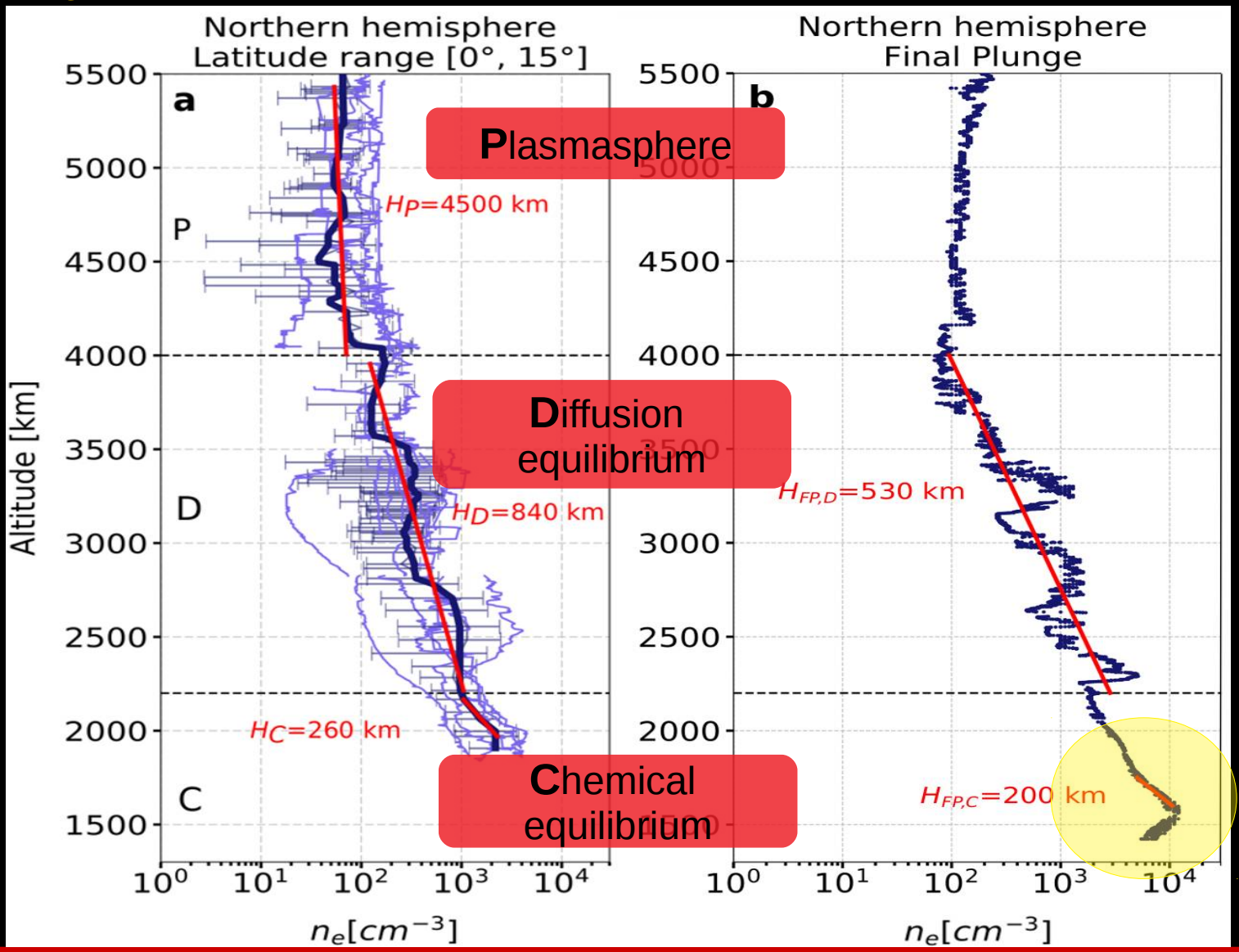

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A and B ring shadowing effects on Saturn's ionosphere

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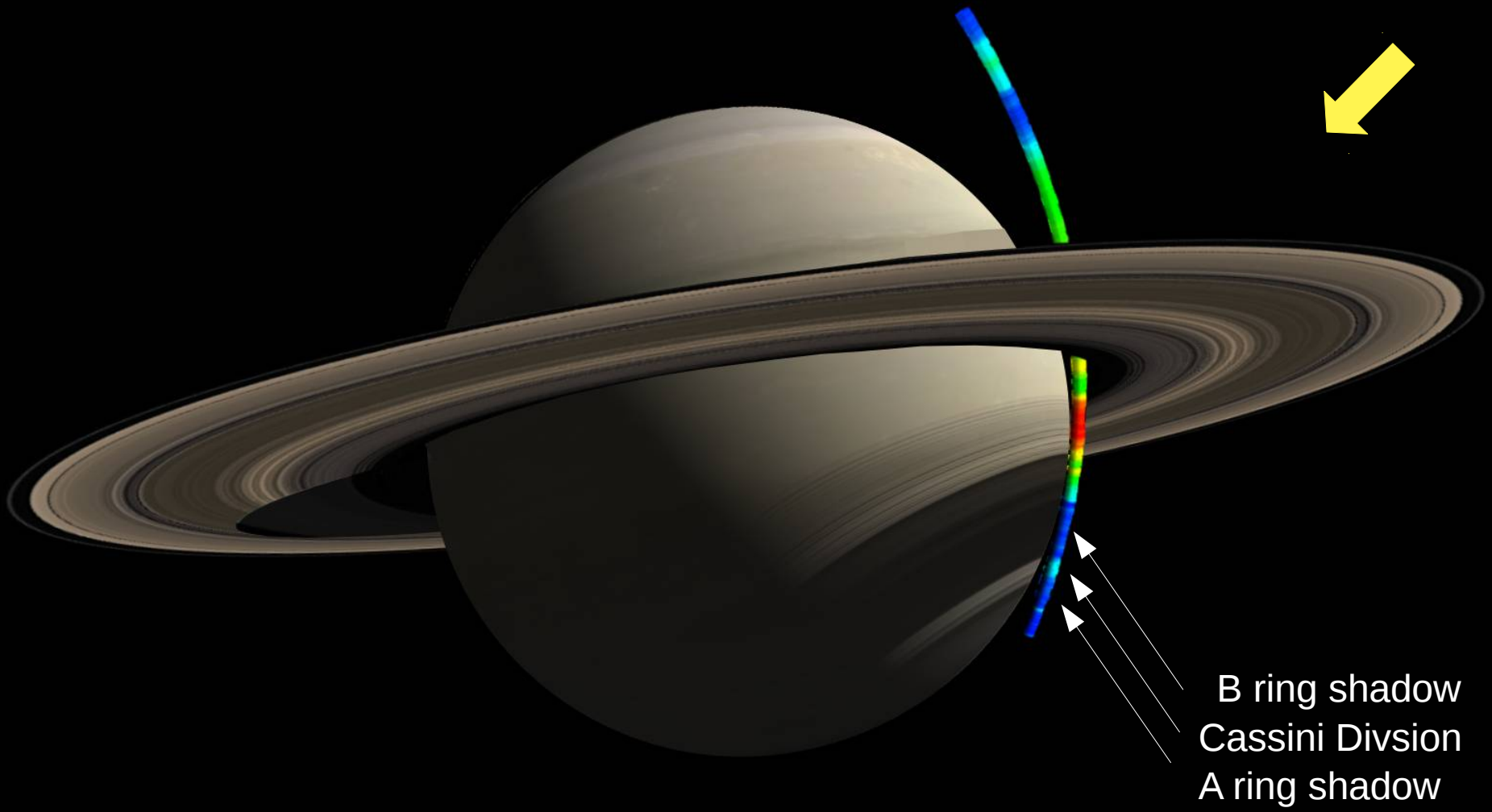
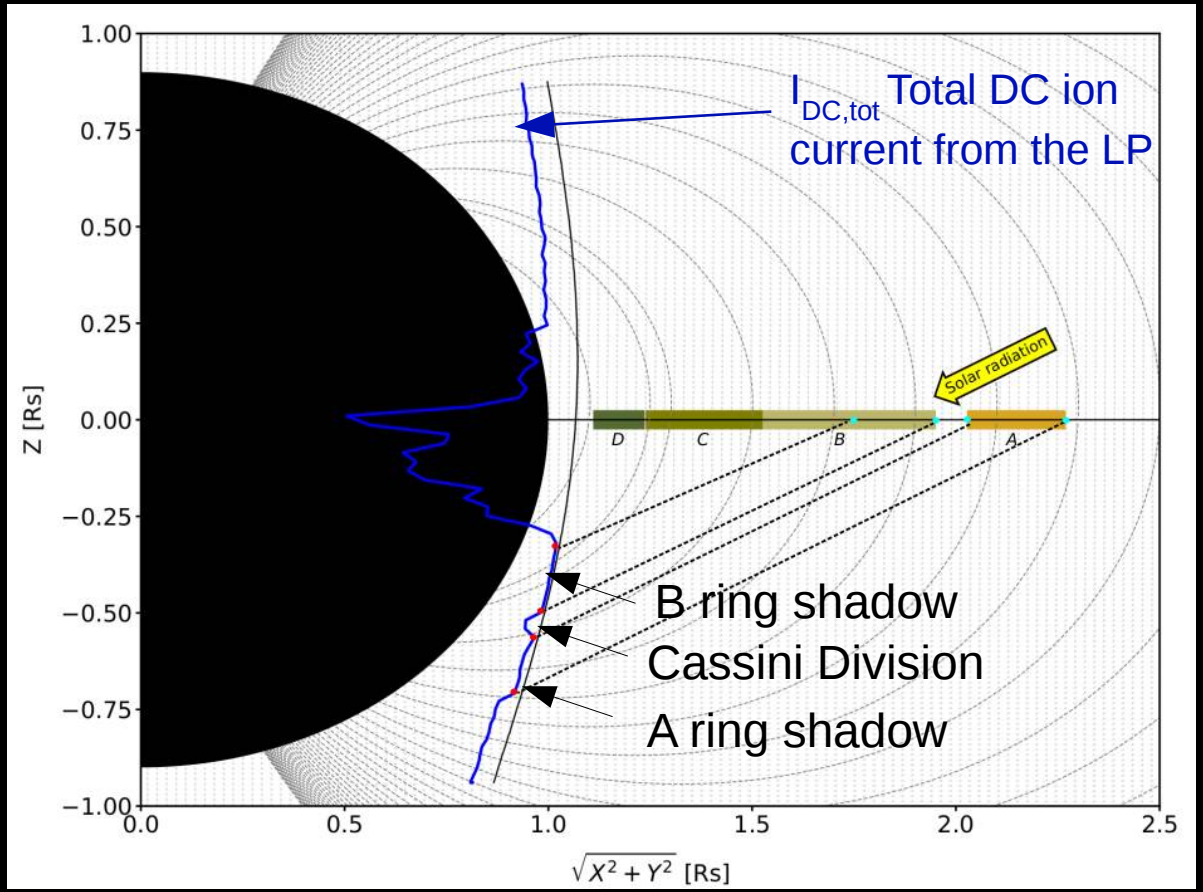
Ring shadows



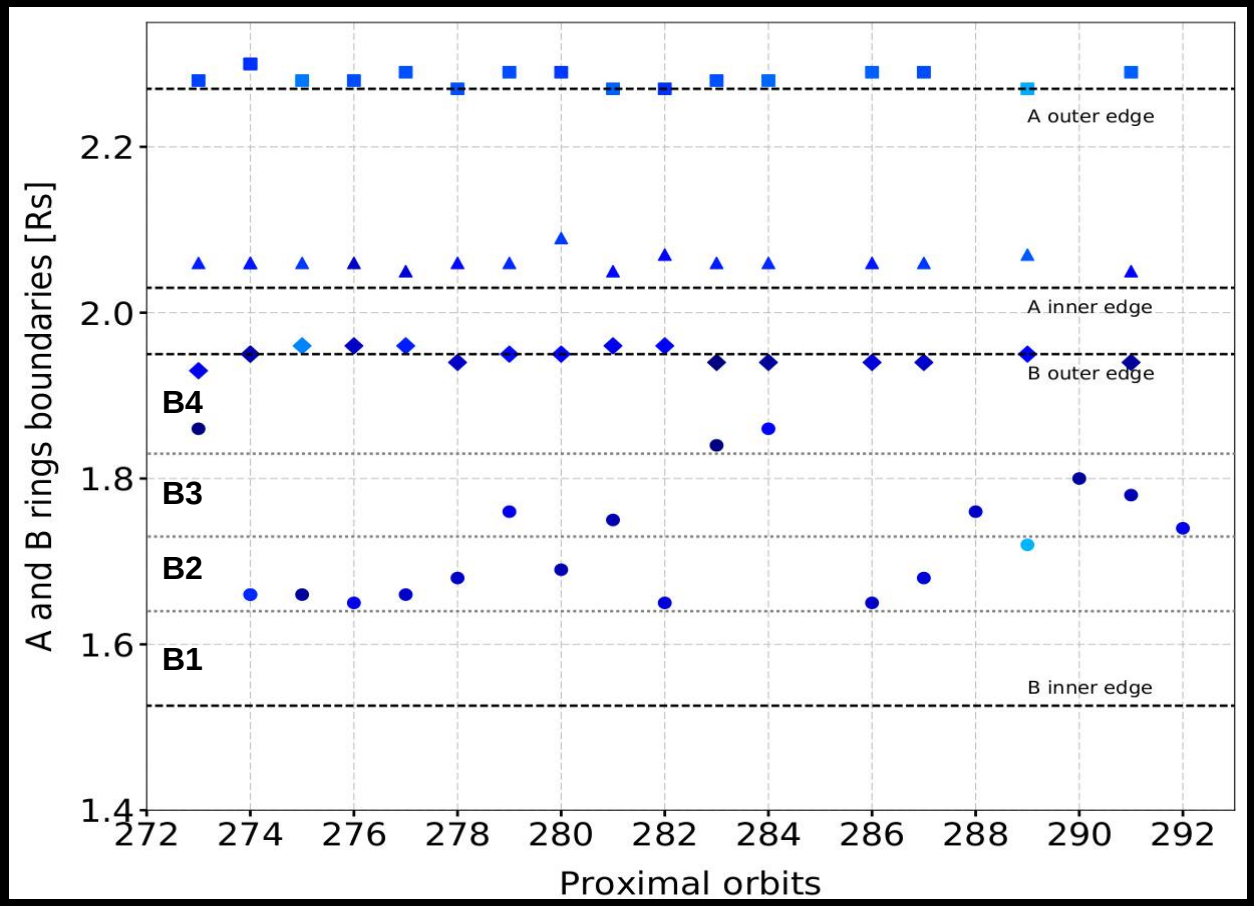
Langmuir probe total ion current

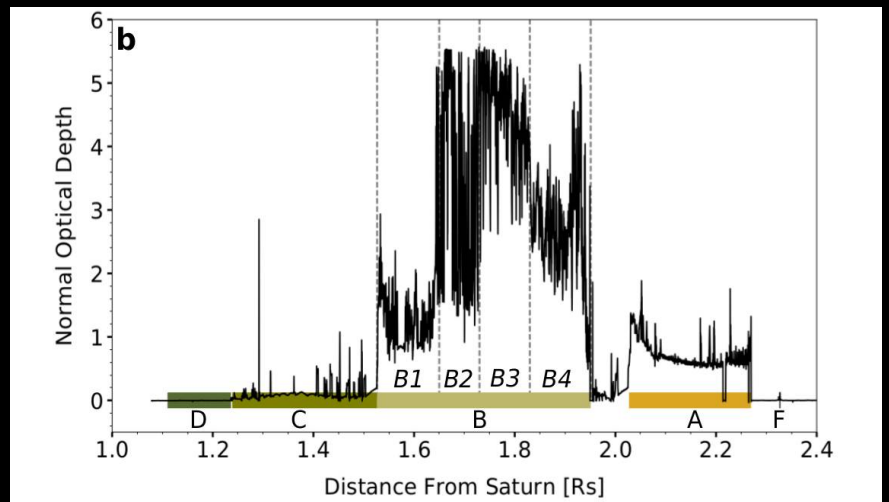
$$I_{tot} = I_{i0}(1 - \frac{U_{float} + U_{bias}}{m_i v_i^2/2e}) + I_{ph} + I_{sec} \quad \Rightarrow \quad \boxed{I_{DC,tot} = I_{i0} + I_{ph} + I_{sec}}$$

Total DC ion current projected on Cassini's trajectory



Shadows boundaries vs A and B rings boundaries





A ring:

- Projected A ring boundaries are consistent with the theoretical one.

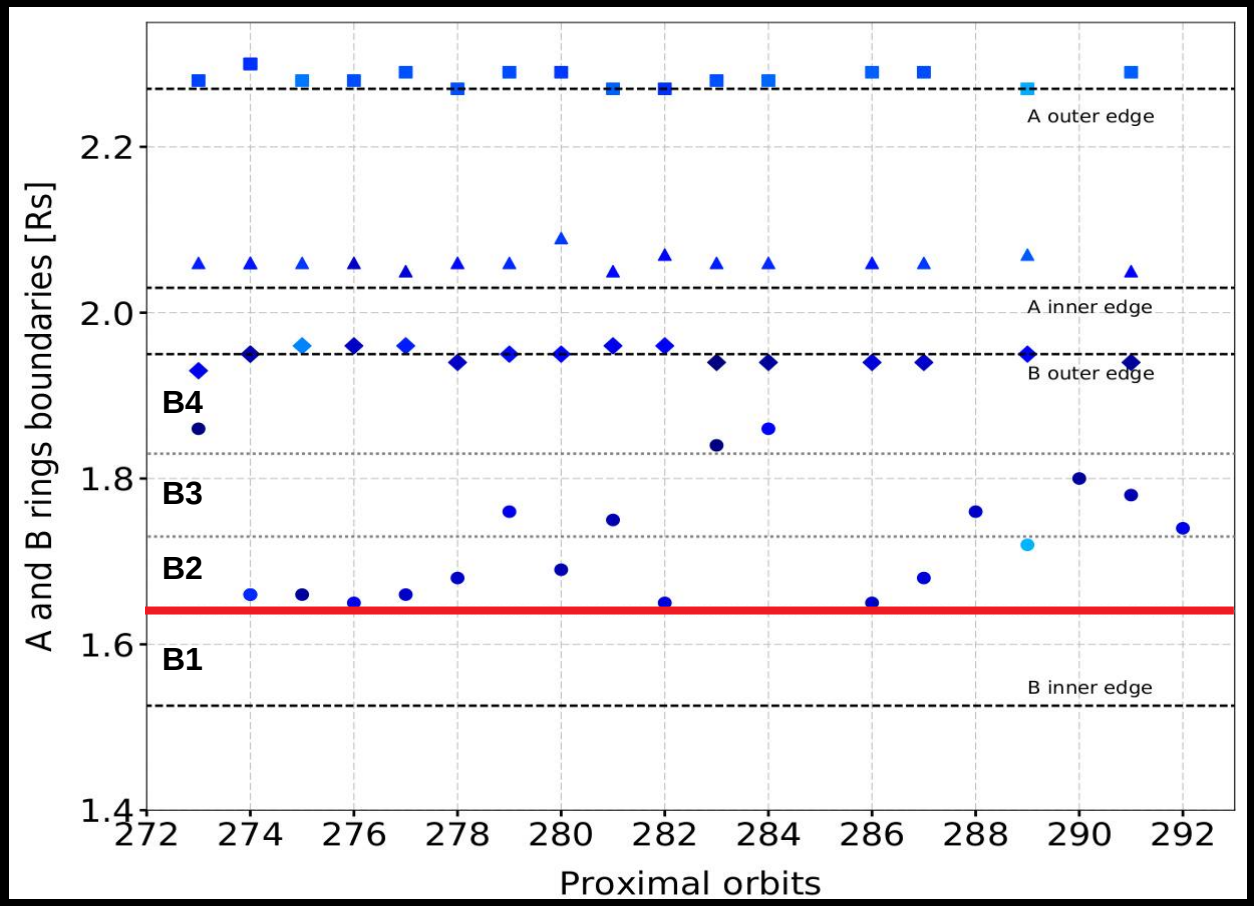
B ring:

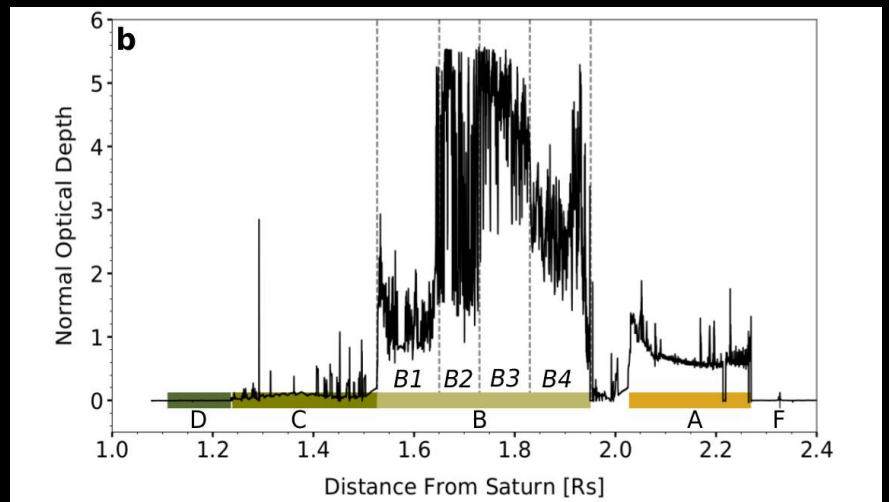
- Observed outer edge of the B ring consistent with the theoretical one.
- Observed inner edge of the B ring not consistent with the theoretical one.
- Total current starts to decrease around the inner edge of the B ring.

→ Plasma transport of H^+ from unshadowed regions to shadowed regions: longer chemical lifetime of H+ compared to H_3^+ and H_2^+

→ Plasma transport from the D and C rings ?

Shadows boundaries vs A and B rings boundaries





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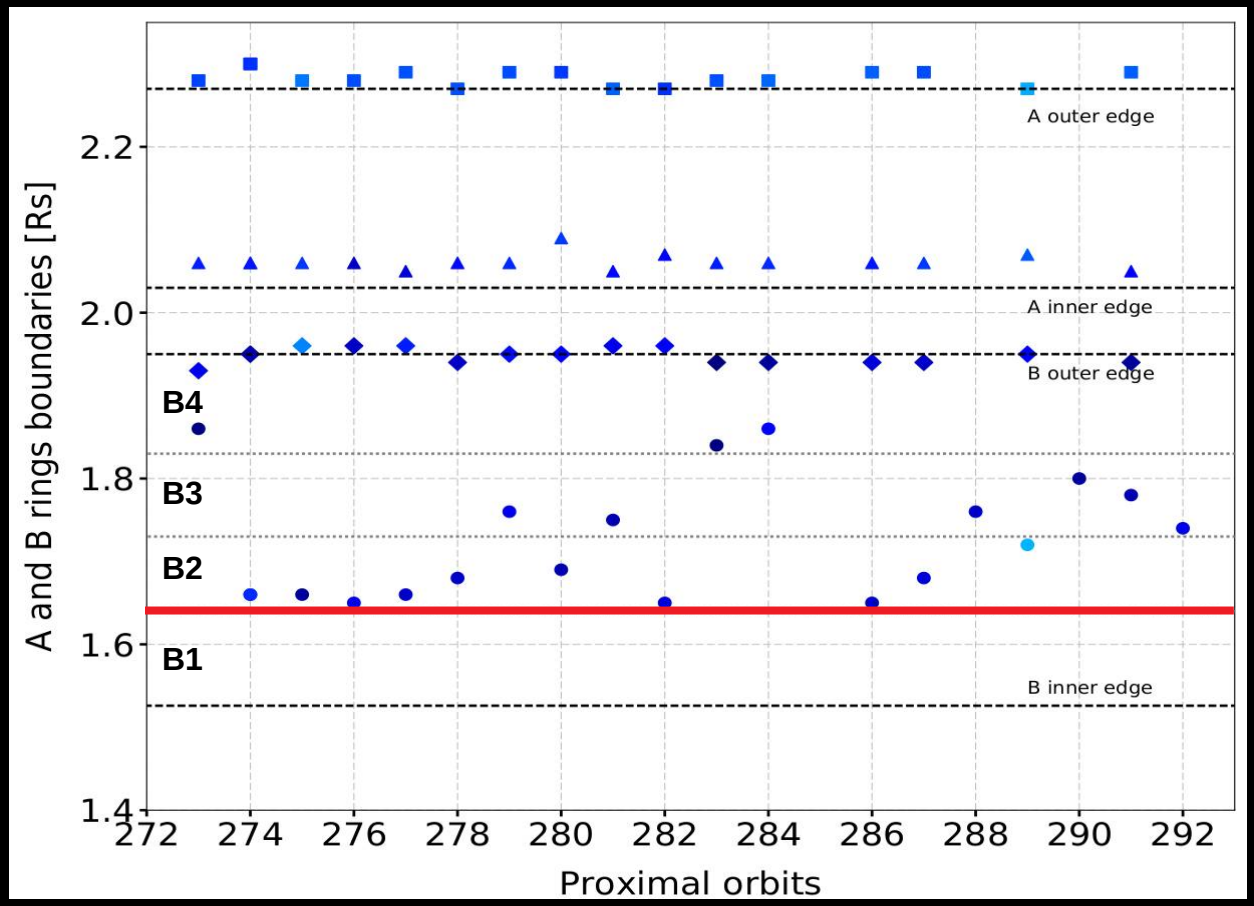

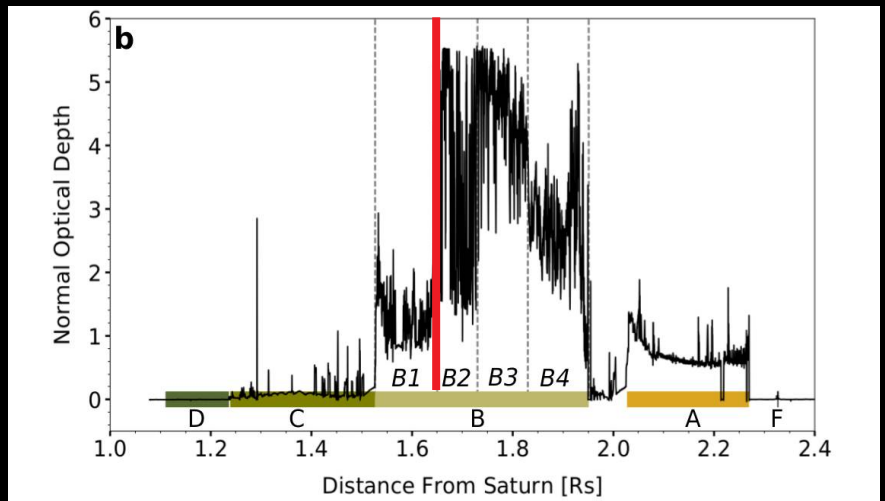

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→ Plasma transport from the D and C rings ?

Conclusions

Electron density altitude profiles and D ring interaction from the Cassini Grand Finale

- Evidence of an electrodynamic type of interaction between the topside ionosphere and the D ring in the southern hemisphere.
- Evidence of a layered electron density profile characterized by at least a diffusive and a chemical equilibrium region
- In-situ observation of the main ionospheric peak in the final plunge around 1550 km.

L. Z. Hadid +, GRL, 2018a

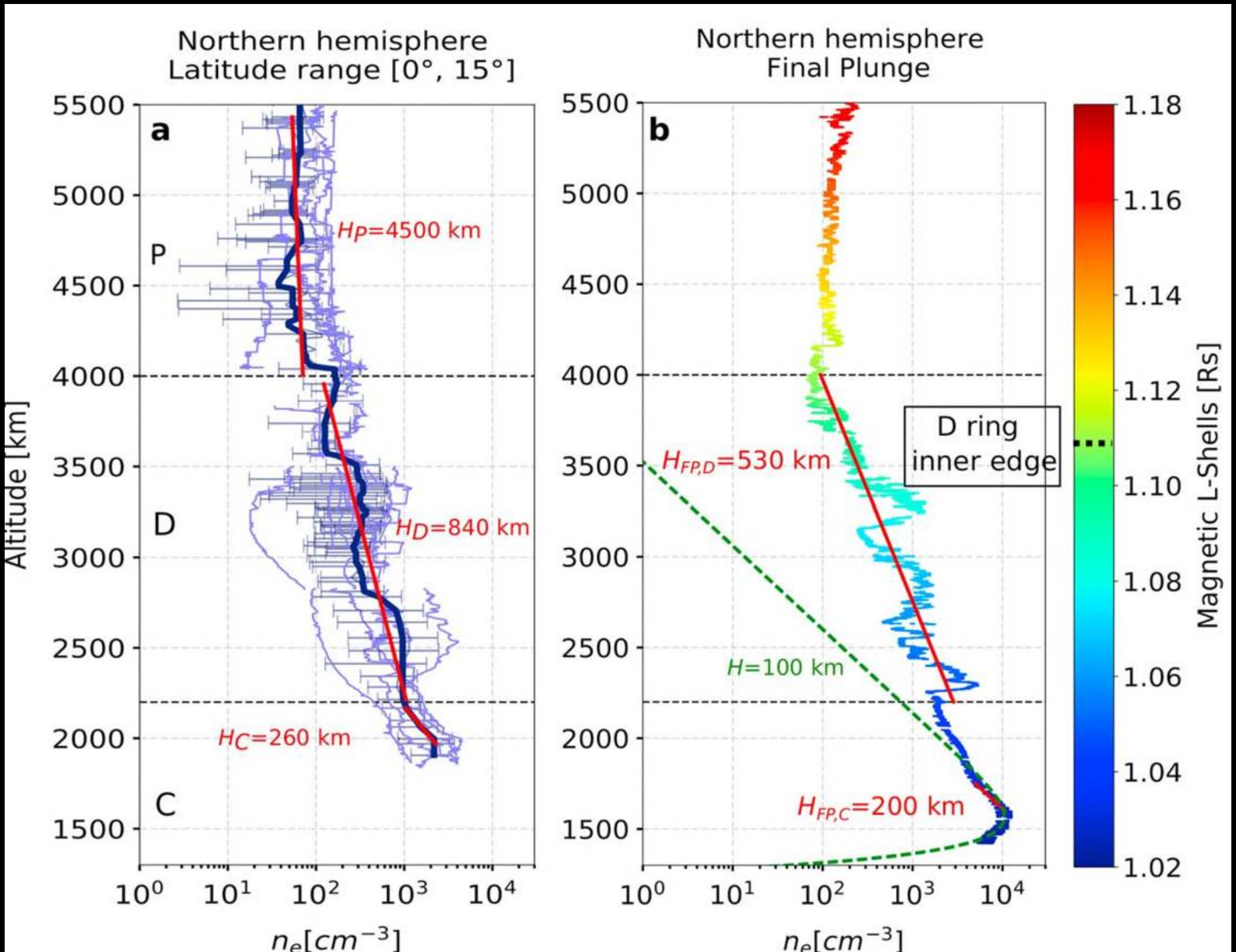
Ring shadowing effects on Saturn's ionosphere:

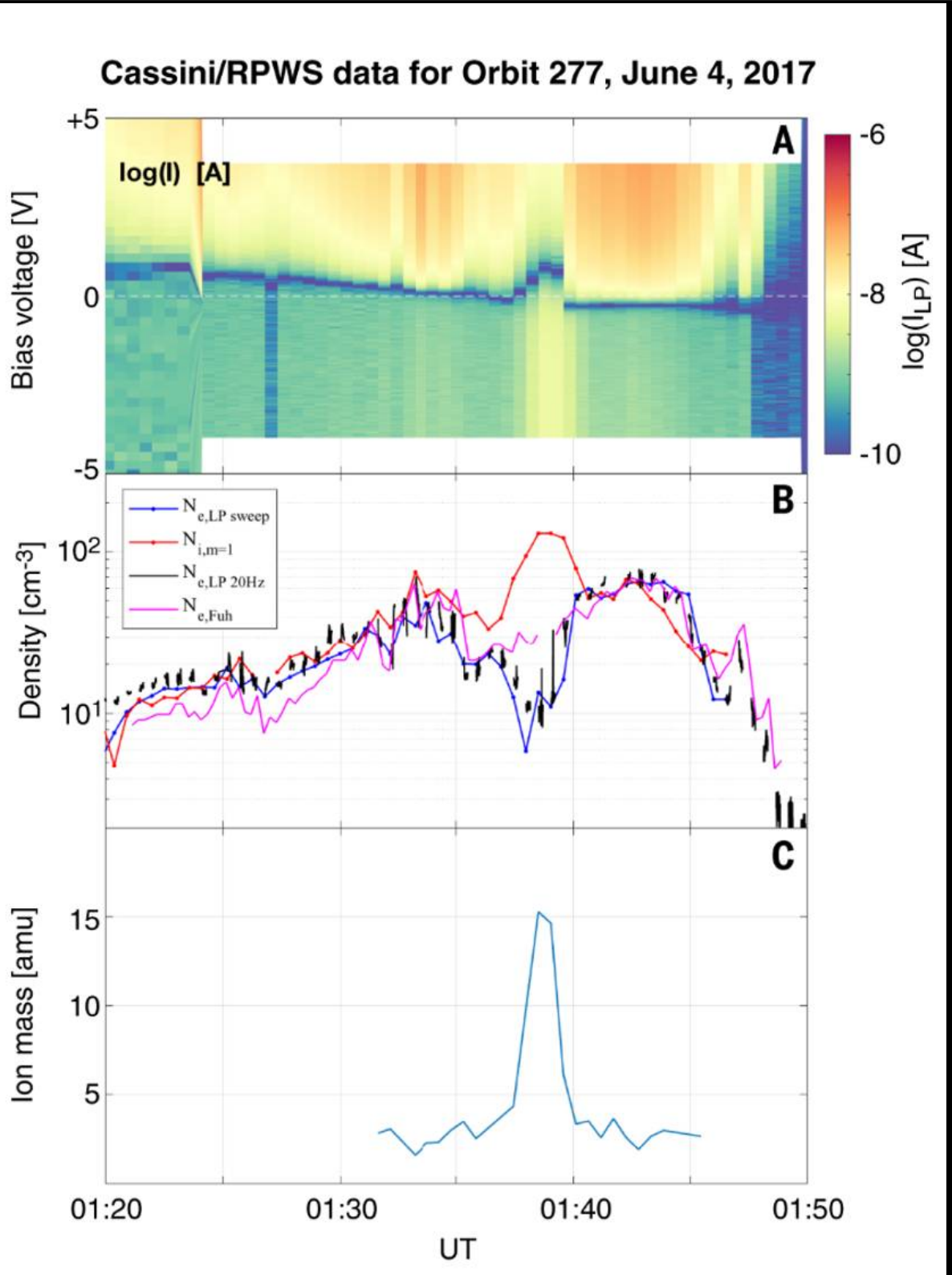
Variations in the B ring shadowing signature below 4000 km:

- Plasma transport of H^+ from un-shadowed regions → longer lifetime of H^+ compared to H_3^+
- Plasma transport from/to C and D rings

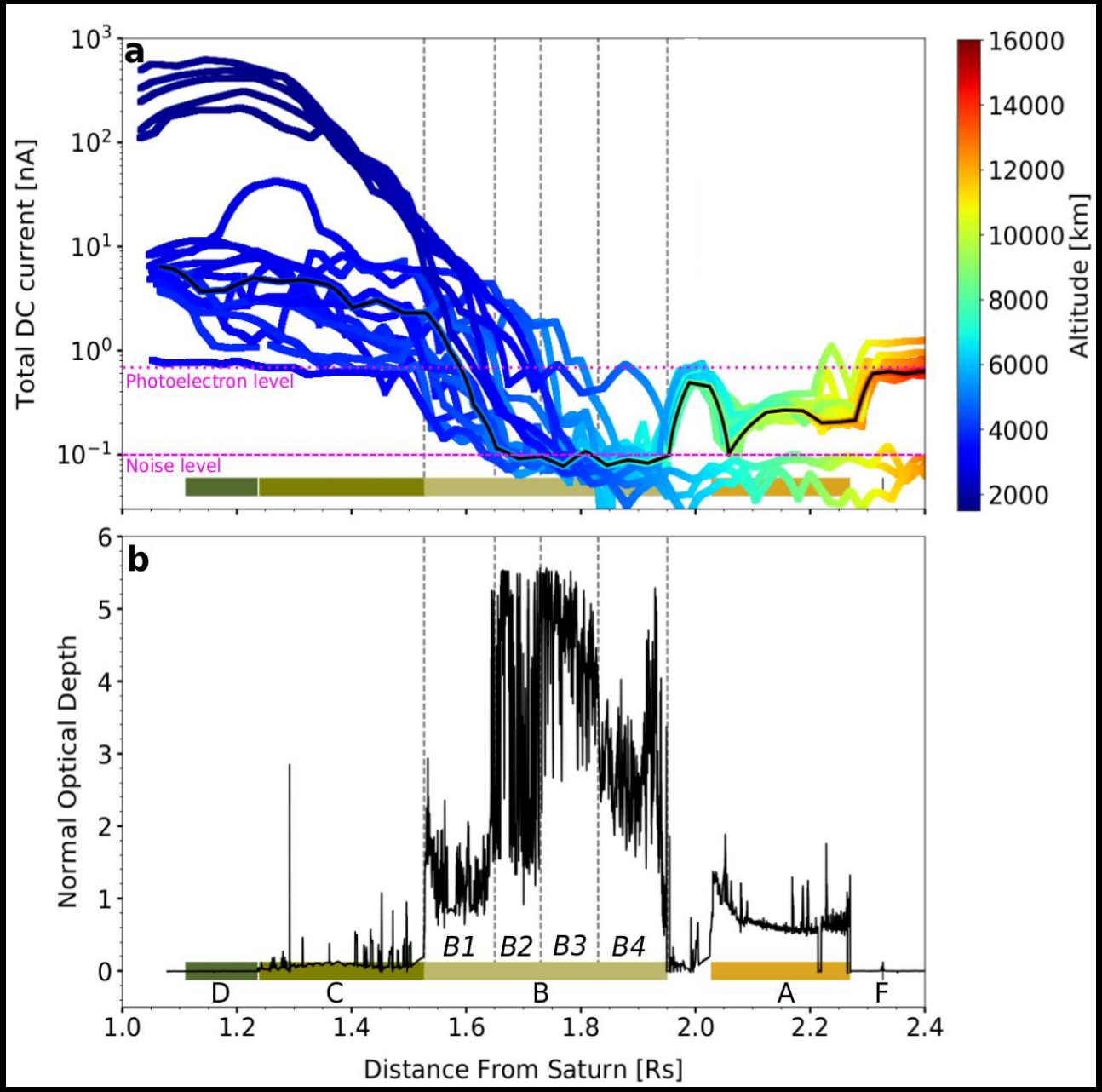
L. Z. Hadid +, GRL, 2018b

Average n_e altitude profiles




Cassini/RPWS data for Orbit 277, June 4, 2017
A
log(I) [A]
Bias voltage [V]
+5
0
-5
-6
-8
-10
log(I_LP) [A]
B
N e,LP sweep
N i,m=1
N e,LP 20Hz
N e,Fuh
Density [cm-3]
10^2
10^1
C
Ion mass [amu]
15
10
5
01:20
01:30
01:40
01:50
UT

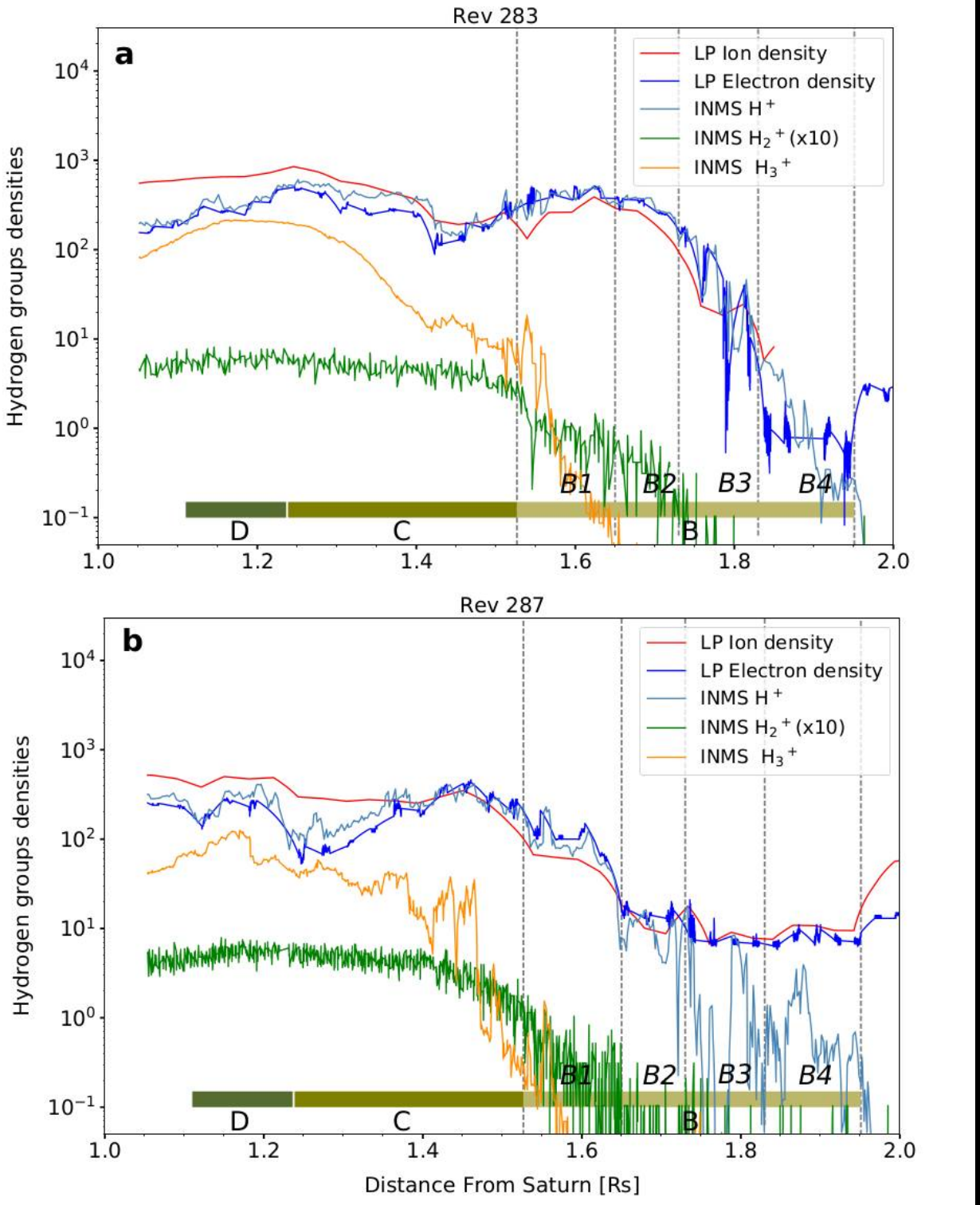
Total ion current versus altitude and normal optical depth



$I_{DC,tot}$ inversely proportional to the altitude and the normal optical depth

High altitudes >7000 km → plamasphere → low densities ~ 10 cm^{-3} → $I_{DC,tot} \approx I_{se} + I_{ph}$ → mapping of the CD and the A ring

Low altitudes < 4000 km → ionosphere → high densities >100 cm^{-3} → $I_{DC,tot} \approx I_0$ → decrease in $I_{DC,tot}$ below the B ring


Rev 283
a
LP Ion density
LP Electron density
INMS H+
INMS H2+ (x10)
INMS H3+
Hydrogen groups densities
B1
B2
B3
B4
D
C
B
Rev 287
b
Distance From Saturn [Rs]