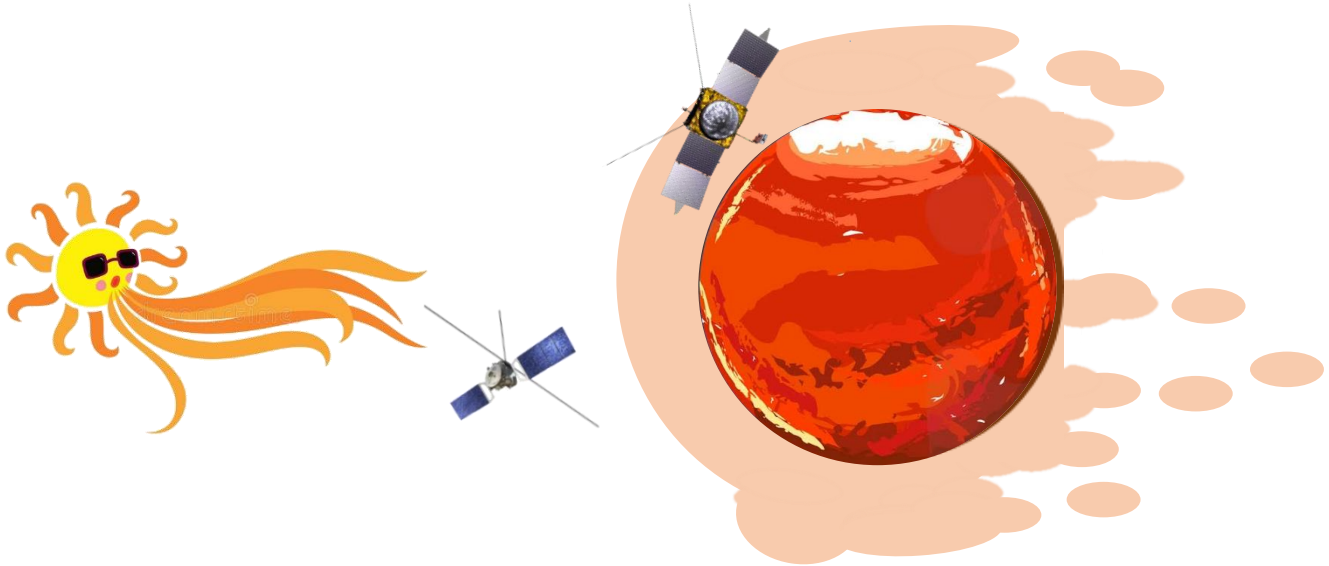
Mars' ionopause

A game of pressures

EGU 2020



Beatriz Sánchez-Cano, Clara Narvaez, Mark Lester, Michael Mendillo
Majd Mayyasi and Mats Holmstrom

UNIVERSITY OF LEICESTER
BOSTON UNIVERSITY
IRF

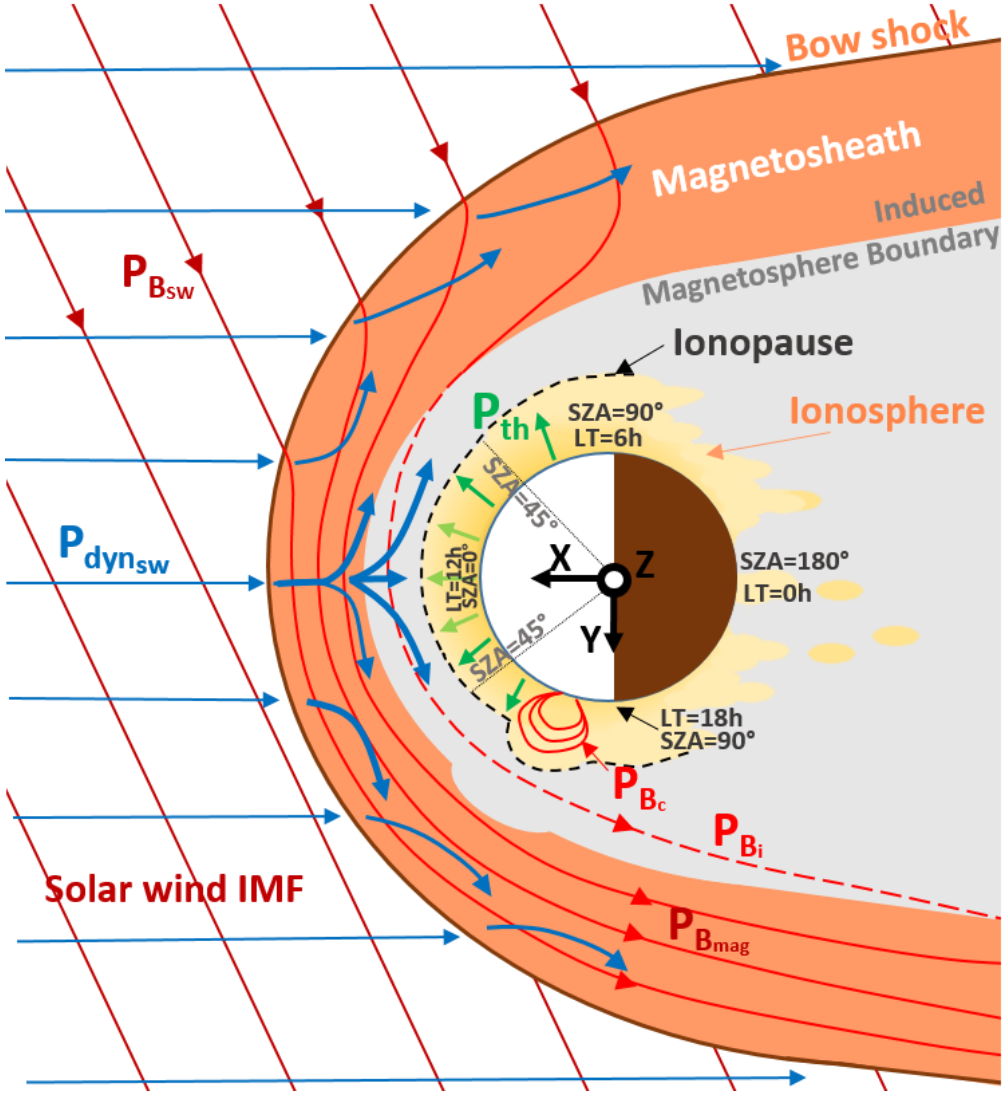
Ionopause definition

The ionopause is the tangential discontinuity in a planet's thermal plasma density profile, $N_e(h)$, that marks the end of the ionosphere for unmagnetized planets.

Ionopauses thus identify the interface between the shocked solar wind and the ionospheric plasma.

The figure on this slide shows a schematic of the solar wind-Mars plasma system interaction (not to scale).

The ionopause (black dashed line) is formed when a balance between the ionospheric thermal pressure (P_{th}), different magnetic pressures ($P_{B_{sw}}$ pressure of the solar wind, $P_{B_{mag}}$ pressure at the magnetosheath, P_{B_i} pressure at the ionosphere, P_{B_c} pressure from crustal fields) and the upstream solar wind dynamic pressure ($P_{dyn_{sw}}$) occurs.



bscmdr1@leicester.ac.uk

Sánchez-Cano et al., 2020 *(under review at JGR)*

Motivation: why Mars ionopause is different to Venus?

- Venus ionopause formation is well-characterised thanks to the Venus Pioneer Orbiter. It is formed at the altitude in which the thermal and magnetic pressure are balanced (left figure). Since the ionopause separates hot and cold plasma, the electron temperature is a good indicator for this boundary (right figure) .

- However, this balance seems to **NOT** occur at Mars at the ionopause altitude because Mars' ionosphere is typically found in a magnetized state (the thermal pressure at Mars is lower than at Venus). Moreover, Mars' ionopause is only formed between 9-50% of the time.

→ **We use MAVEN in the ionosphere and Mars Express in the solar wind to investigate the role of the different pressures on the ionopause formation at Mars.**

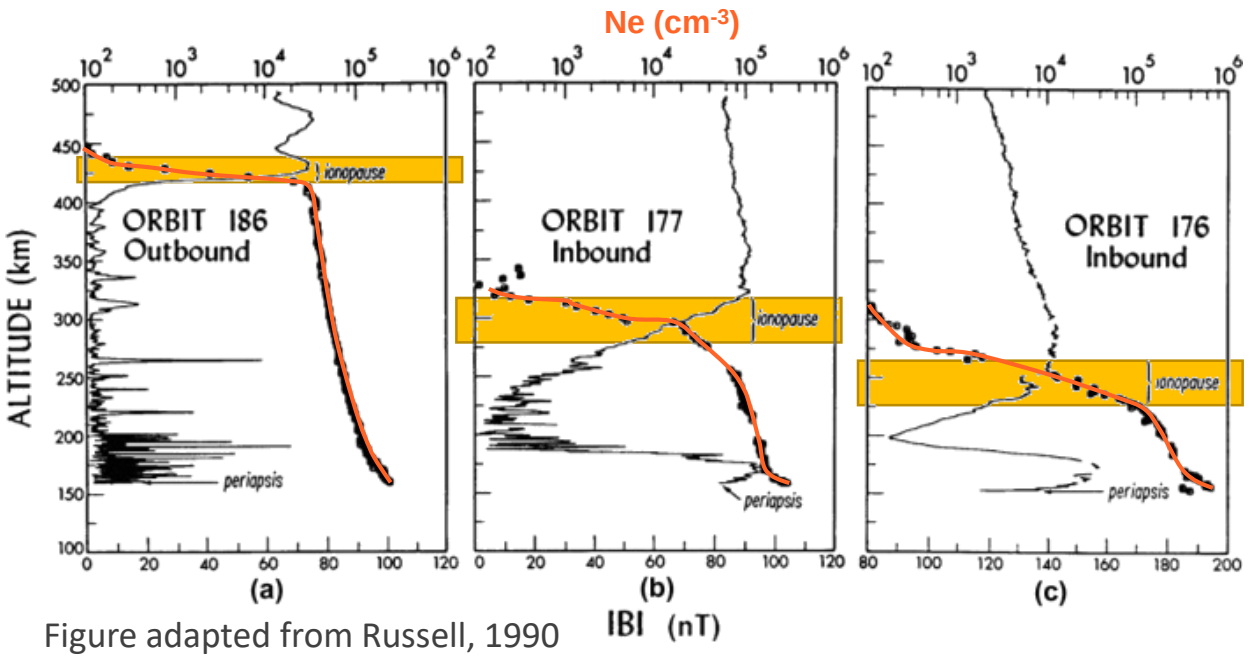


Figure adapted from Russell, 1990

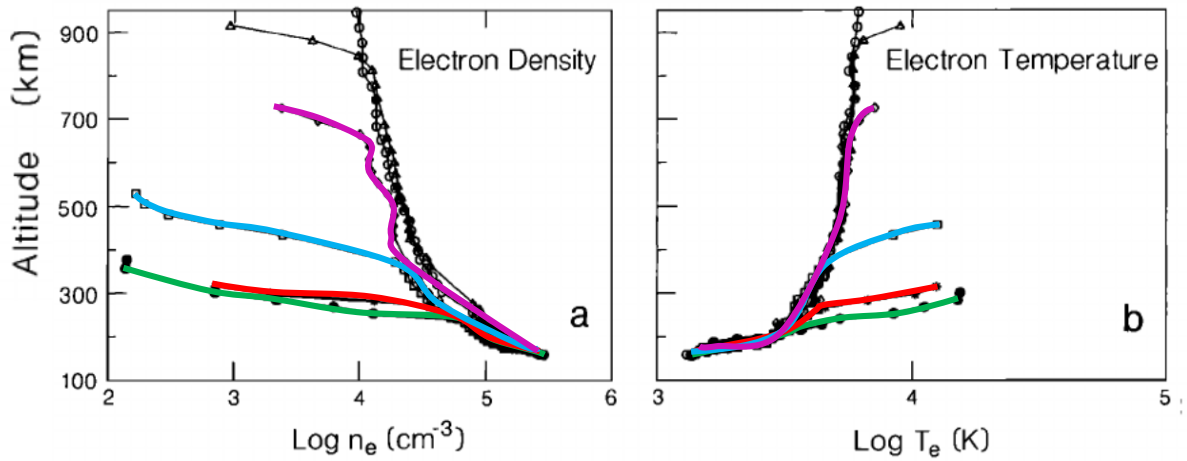


Figure adapted from Luhmann et al., 1987

bscmdr1@leicester.ac.uk

Sánchez-Cano et al., 2020 *(under review at JGR)*

UNIVERSITY OF LEICESTER

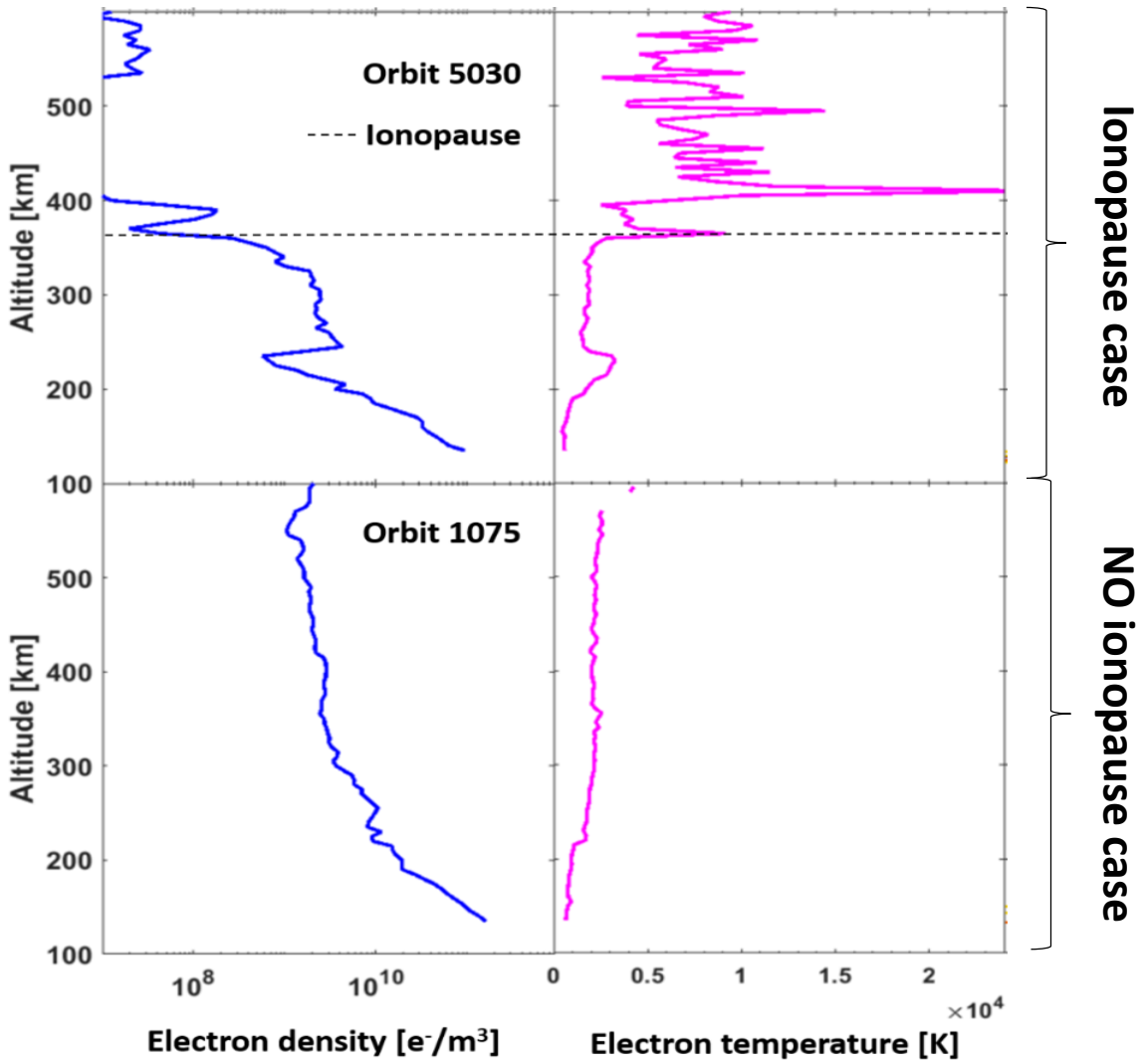
Ionopause identification

We use three MAVEN deep dip campaigns (DD) on the dayside of Mars (DD2, DD8 and DD9).

During a DD campaign, the periapsis is lowered from ~150 km to ~130 km, which gives the opportunity to sample the ionosphere close to the altitude of the maximum plasma density.

→ An ionopause is identified (dashed-line) as the onset of a sudden electron density reduction, coincident with the onset of a sudden electron temperature increase (from ~2000-3000 K to ~8000 K), and onset of large electron temperature fluctuations.

- We find that 45% of the profiles have an ionopause.
- If only profiles far from crustal field are considered, the rate is 54%.
- If only profiles over crustal fields are considered, the rate is 36%.



bscmdr1@leicester.ac.uk

Sánchez-Cano et al., 2020 *(under review at JGR)*

UNIVERSITY OF LEICESTER

Solar wind-ionopause pressure balance

We have calculated the magnetic and thermal pressure of the ionosphere based on MAVEN LPW and MAG observations.

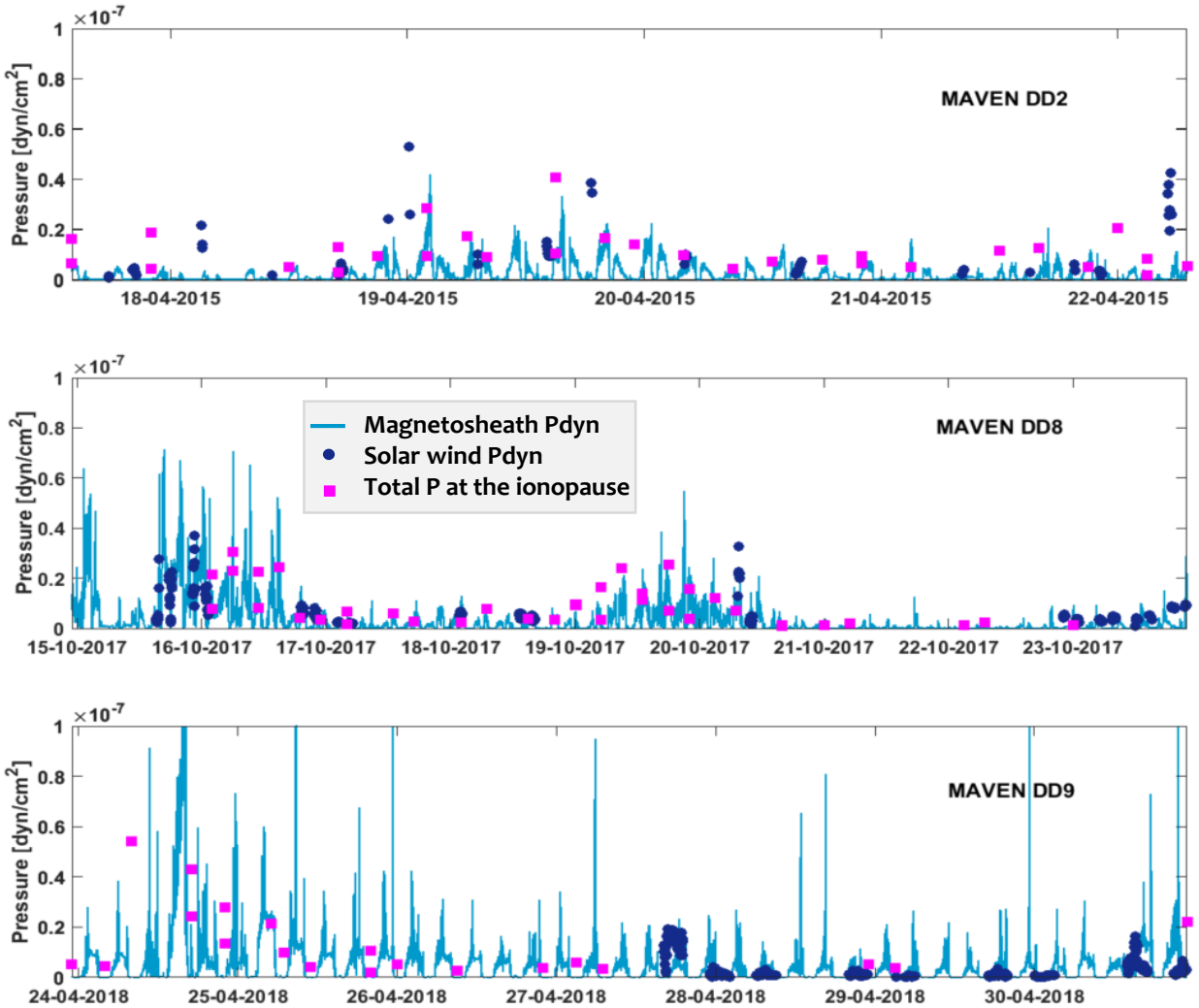
The total pressure at the ionopause altitude is calculated as the thermal + magnetic pressure at that altitude (**pink squares**).

The *in-situ* solar wind dynamic pressure is obtained from Mars Express ASPERA-3 observations (**blue dots**).

For temporal context, the MAVEN-SWIA magnetosheath dynamic pressure observations are also plotted (**blue lines**).

The 3 pressures follow the same patterns with similar order of magnitudes.

→ The ionopause is the region in which there is a balance between the upstream solar wind dynamic pressure outside the system, and the total pressure of the ionosphere.



bscmdr1@leicester.ac.uk

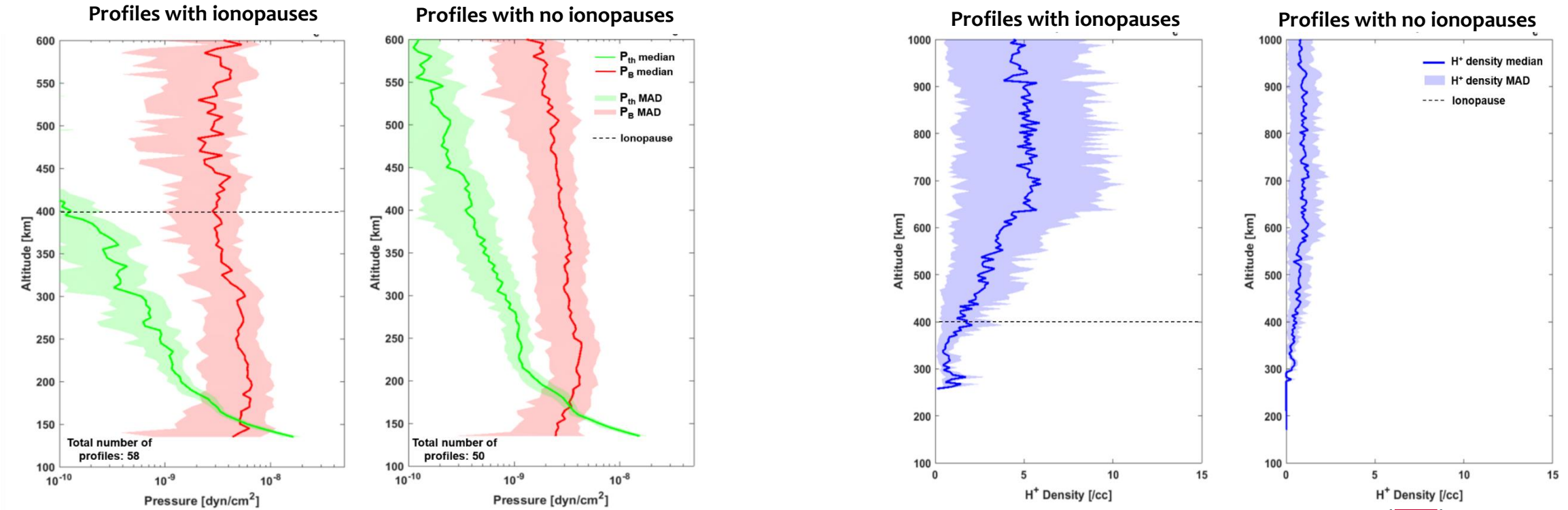
Sánchez-Cano et al., 2020 *(under review at JGR)*

UNIVERSITY OF LEICESTER

Thermal and magnetic pressure balance

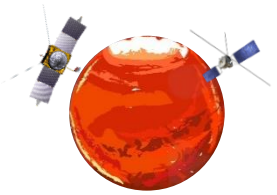
In order to understand the general role of the magnetic and thermal pressures, we have performed a statistical analysis for profiles with and without ionopauses.

- Left plot: The magnetic pressure is larger than the thermal pressure for most altitudes except below ~180-200 km, where the thermal pressure dominates → At Venus, this balance occurs at the ionopause height.
- Right plot: MAVEN-STATIC data show that solar wind protons (proxy for dynamic pressure) are found up to the ionopause altitude for those cases with an ionopause, while for non-ionopause cases, the ionosphere extends and 5 time less solar wind protons are found.



bscmdr1@leicester.ac.uk

Sánchez-Cano et al., 2020 *(under review at JGR)*



Conclusions

- Mars' ionosphere is typically magnetized.
- The thermal and magnetic pressure balance occurs between the peak of the ionosphere and ~180-200 km (well below the region of the ionopause formation)
- For an ionopause to be formed, the upstream solar wind dynamic pressure has to be comparable to the total pressure of the ionosphere (thermal + magnetic) at the ionopause altitude.
- We found that 45% of MAVEN $N_e(h)$ profiles had an ionopause. The occurrence was lower (36%) over crustal magnetic field regions, and higher (54%) far from these regions.
- **Paper under review → stay tuned! ☺**

bscmdr1@leicester.ac.uk

Sánchez-Cano et al., 2020 *(under review at JGR)*

UNIVERSITY OF LEICESTER