Summary

IRM data over 8 years reveal important features in magnetosphere-ionosphere-thermosphere (MIT) coupling in topside ionosphere (2013/10 – 2021/12) at 325-1500 km: e.g.

- Effects of atmospheric photoelectrons on spacecraft charging
- Molecular and nitrogen (N\textsubscript{2}) ion enhancements in active auroral ionosphere
- Decameter-scale structures at both high and low latitudes (i.e., aurora, equatorial plasma bubbles)

IRM Ion Time of Flight (TOF) Measurements

Swarm-E imaging and rapid-scanning ion mass spectrometer (IRM):

- Combines ion time-of-flight (TOF), hemispherical electrostatic analysis, and 2D positional imaging
- Resolves ion mass-per-charge (M/q), energy-per-charge (E/q), and incident direction
- Simultaneously measures incident plasma current at high (1-mA) cadence

Spacecraft Potential and Ion Composition Analysis

**Spacecraft Potential**

- Significant effects of escaping atmospheric electrons in sunlit ionosphere above source altitude of atmospheric photoelectrons
- Other sources (than ambient electrons) of significant negative (and positive) spacecraft potentials
- Small, non-negligible percentage of cases of highly negative potentials at low and high latitude

**Method:**

- Fit TOA distributions of measured ions in spacecraft ram at peak and adjacent peaks and V\textsubscript{m} (or other species where available).
- Infer spacecraft potential V\textsubscript{sc} from measured ion velocity inside sheath v(m) and corresponding velocity outside sheath v(m) (multi-species analysis)
- or spacecraft ram velocity v\textsubscript{m} (single-species analysis)

\[ V_{SC} = \frac{m}{2q} \left( v(m)^2 - v(m) \right) \]

**Small-scale plasma density irregularities**

- Measured plasma current on sensor surface \( I_e \) (typically) due to ambient electrons and ions, photoelectrons, and (primarily) auroral electrons and proportional to plasma density \( n_e \)
- \( I_e \) used as proxy for \( n_e \) \& \( n_{\text{enh}} \) used to study density irregularities \( n_{\text{enh}} \) down to 10-m scale

- Statistically significant differences in morphological characteristics between:
  - current enhancement and current depletion structures,
  - positive and negative current structures,
  - large-scale and small-scale current structures

- Scale-dependent spectral index, with significant power down to 10's of meters: detailed analysis in progress

**Spacecraft Potential**

- Challenge of measuring \( N^+ \)
- Unique capability of IRM to separate \( N^+ \) from \( O^+ \) (and dependence of capability on S/C potential)
- Occurrence of molecular ions (MI) altitude distribution & interpretation
- Occurrence of \( N^+ \) enhancement: association with MI & interpretation
- Occurrence frequency of MI in topside ionosphere vs. abode: interpretation & MIC implications

**Molecular and nitrogen (N\textsubscript{2}) ions**

- Challenge of measuring \( N^+ \)
- Unique capability of IRM to separate \( N^+ \) from \( O^+ \) (and dependence of capability on S/C potential)
- Occurrence of molecular ions (MI) altitude distribution & interpretation
- Occurrence of \( N^+ \) enhancement: association with MI & interpretation
- Occurrence frequency of MI in topside ionosphere vs. abode: interpretation & MIC implications

**Conclusions**

- Swarm-ECASSIOPE (e-POP) IRM:
  - 8 years of ion time-of-flight (TOF) & plasma current data spanning SC 24 & 25 (2014-2021)
  - Unique measurements for study of (underexplored) ion composition & small-scale irregularities

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