Using Unsupervised Machine Learning to Resolve Bow Shock Crossings

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Goal & Source Data

Goal

- Machine Learning is becoming ever the more prominent in space physics
  - Mostly supervised – but not so much unsupervised learning

- Recent results in *Innocenti* 2021 using unsupervised methods (Self-Organizing Maps + KMeans) on classifying simulated magnetospheric regions emboldens more widespread use.
  - Next step: Using similar idea on observations?

Source Data

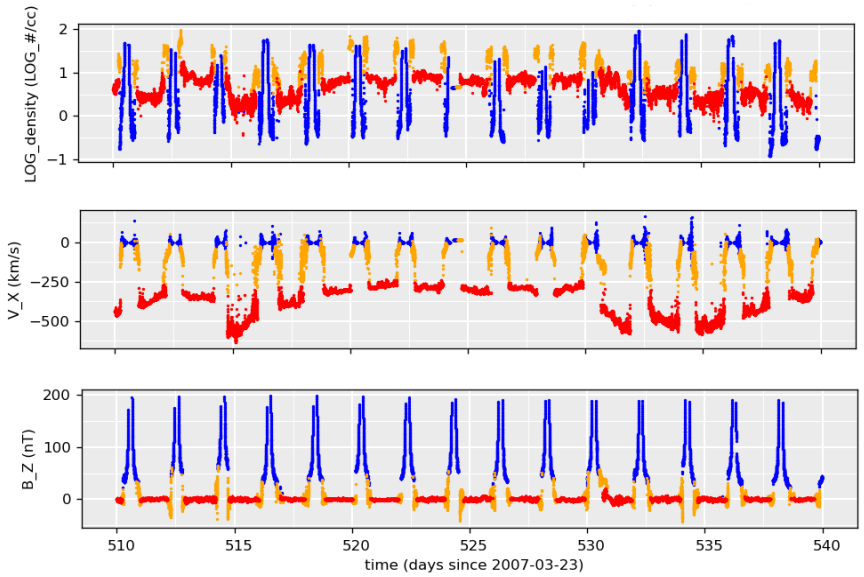
- Combination of THEMIS's ESA-reduced (~3 s), ESA-full (~90 s), and the on-board computed moments (MOM, ~3 s) for all spacecraft (A, B, C, D, E) from March 2007 to end of 2020 at 1-min resolution.

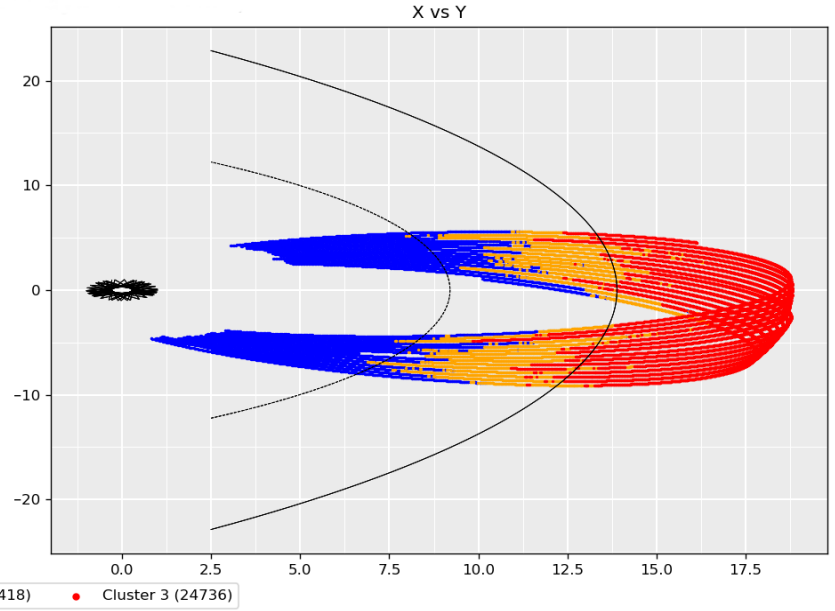
- Use a Gaussian Mixture Model to separate **dayside** magnetosphere based on plasma parameters:
  - **B** [nT], $\mathbf{V}_{ion}$ [km/s], Log-T_{ion} [eV], Log-n_{ion} [#/cc]

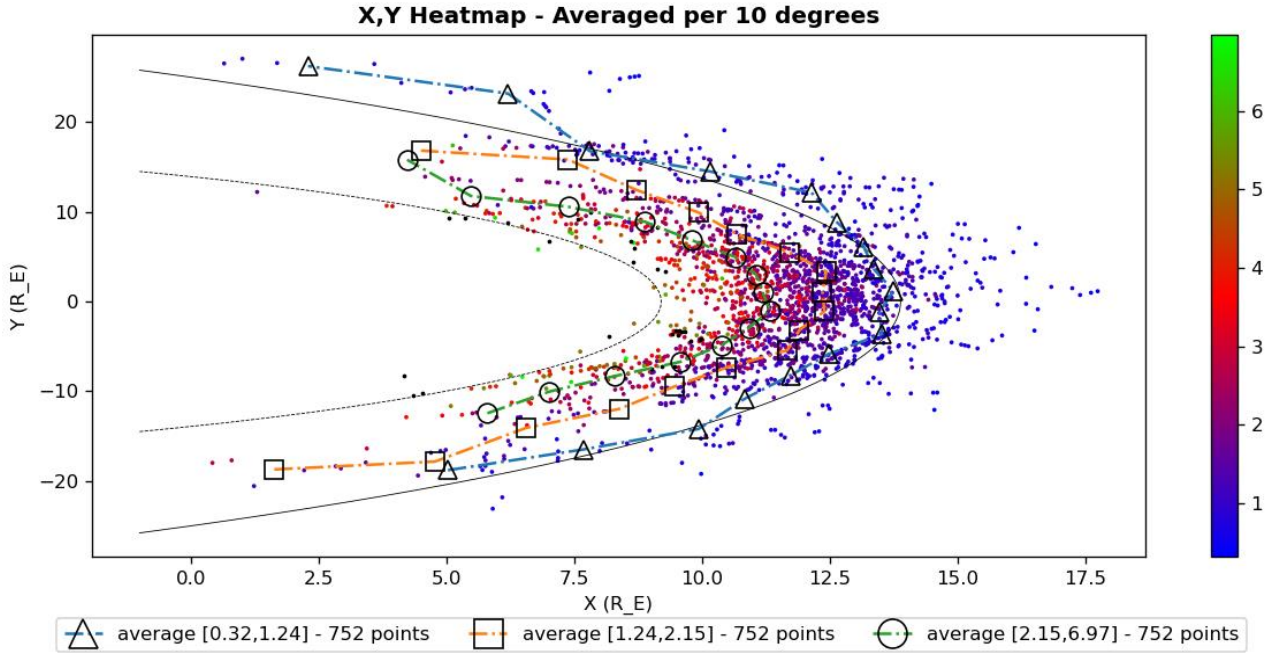
- Constrain data to dayside (X_{GSE} >= 0) and remove close-in magnetosphere (require |**B**| <= 200 nT)

Clustering Results – Data Example

- Can then view clustered data in relation to various parameters
- At right is clustered THEMIS-C data from 14 Aug 2008 (Day 510) to 13 Sept 2008 (Day 540)







Ion Flow Pressure ($\rho_{ion} V_{ion}^2$) [nPa]

Right contour (Bow Shock):
Simple hyperbola -
$25\ R_E / (1 + 0.8*\cos(\phi))$

Left contour (Magnetopause):
Shue 1998 with parameters
$B_z = 0.15$ nT, $D_p = 3.5$ nPa

Summary / Future Work

Summary

- We demonstrated how a GMM can successfully partition plasma regions in the dayside magnetosphere using moments and magnetic field data.
- These crossings can be used as the basis for developing an empirical bow shock model

Future Work:

- Extending the unsupervised model to other dayside s/c (MMS, Cluster, etc)
- Can use the same model to also build catalogue of magnetopause crossings

Main Takeaway:

Unsupervised methods can be used to classify magnetosphere plasma regions

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