

Time Series Analysis Methods for On-board Detection of Magnetic Field Boundaries by Europa Clipper

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Introduction

The **Plasma Instrument for Magnetic Sounding (PIMS)** on the Europa Clipper mission aims to characterize the properties of the Jovian plasma surrounding Europa, providing insight into Europa's cryovolcanic activity and its subsurface ocean.

Mode-Switching in PIMS

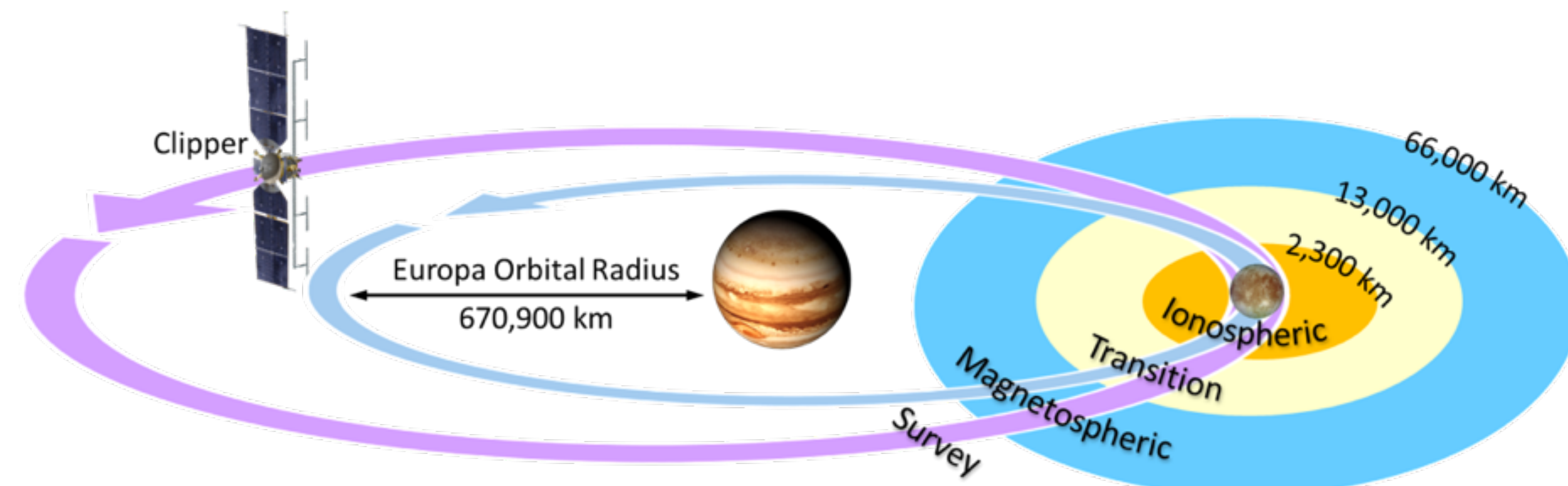


Figure 1: PIMS modes as currently planned.

PIMS operates in 4 different modes, depending on **prior estimates of the magnetic field boundaries** and the distance to Europa. To account for uncertainty in these estimates, PIMS spends significant amount of time in a **transition mode**.

The Key Question

Can we instead make PIMS **responsive**, and **switch modes automatically** based on its current observations?

Detecting Magnetic Field Boundaries

At each time step, PIMS counts the number of particles within energy 'bins':

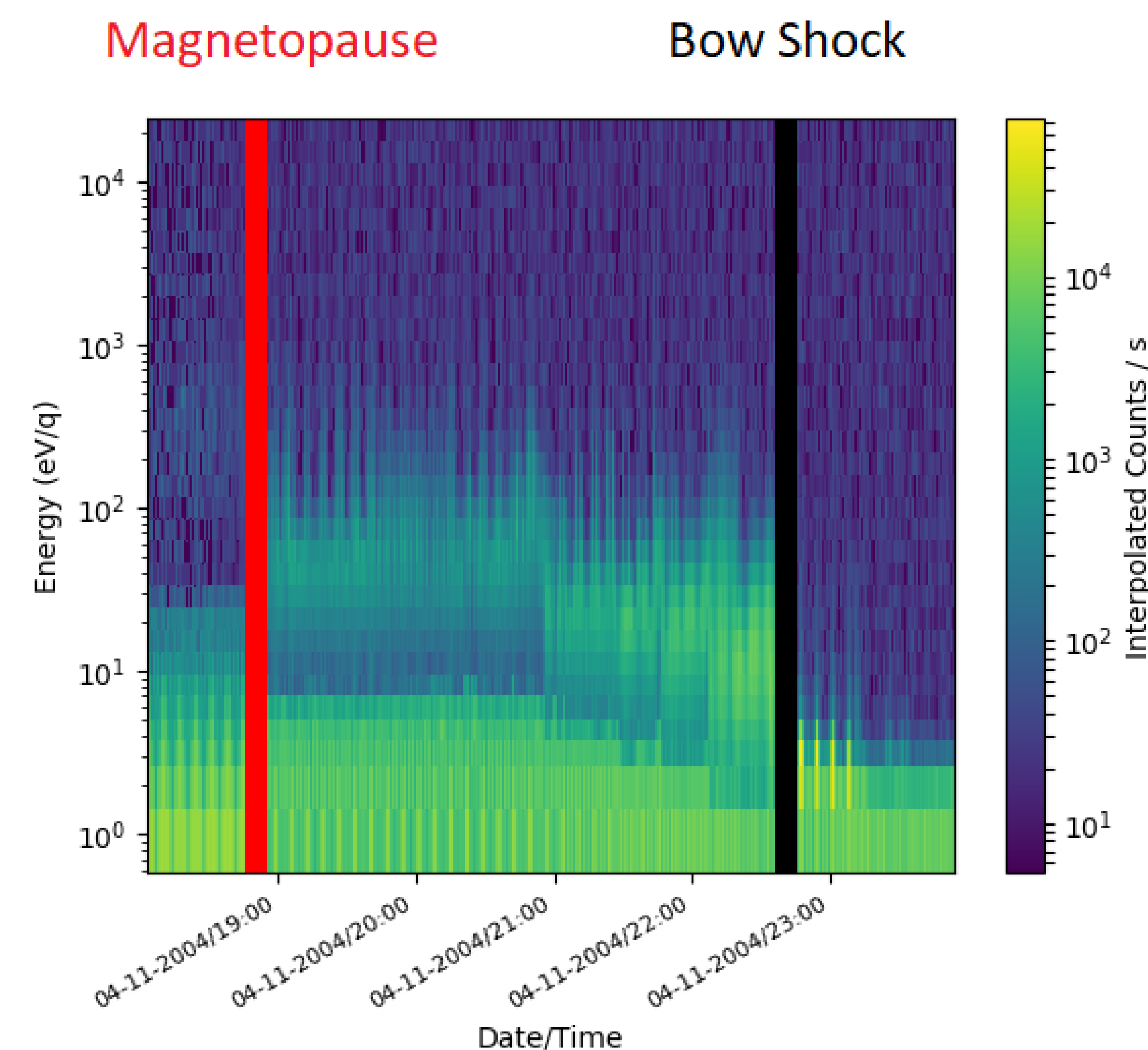


Figure 2: Magnetic field boundaries of Saturn as seen by an analogous instrument, the CAPS ELS on the Cassini mission.

We cast this as an **anomaly detection** problem over **multidimensional time series**.

To deal with the lack of knowledge about the true magnetic field boundaries around Europa, we investigate **unsupervised** methods.

We can evaluate these methods using labelled data from the Cassini mission.

Results on Cassini Data

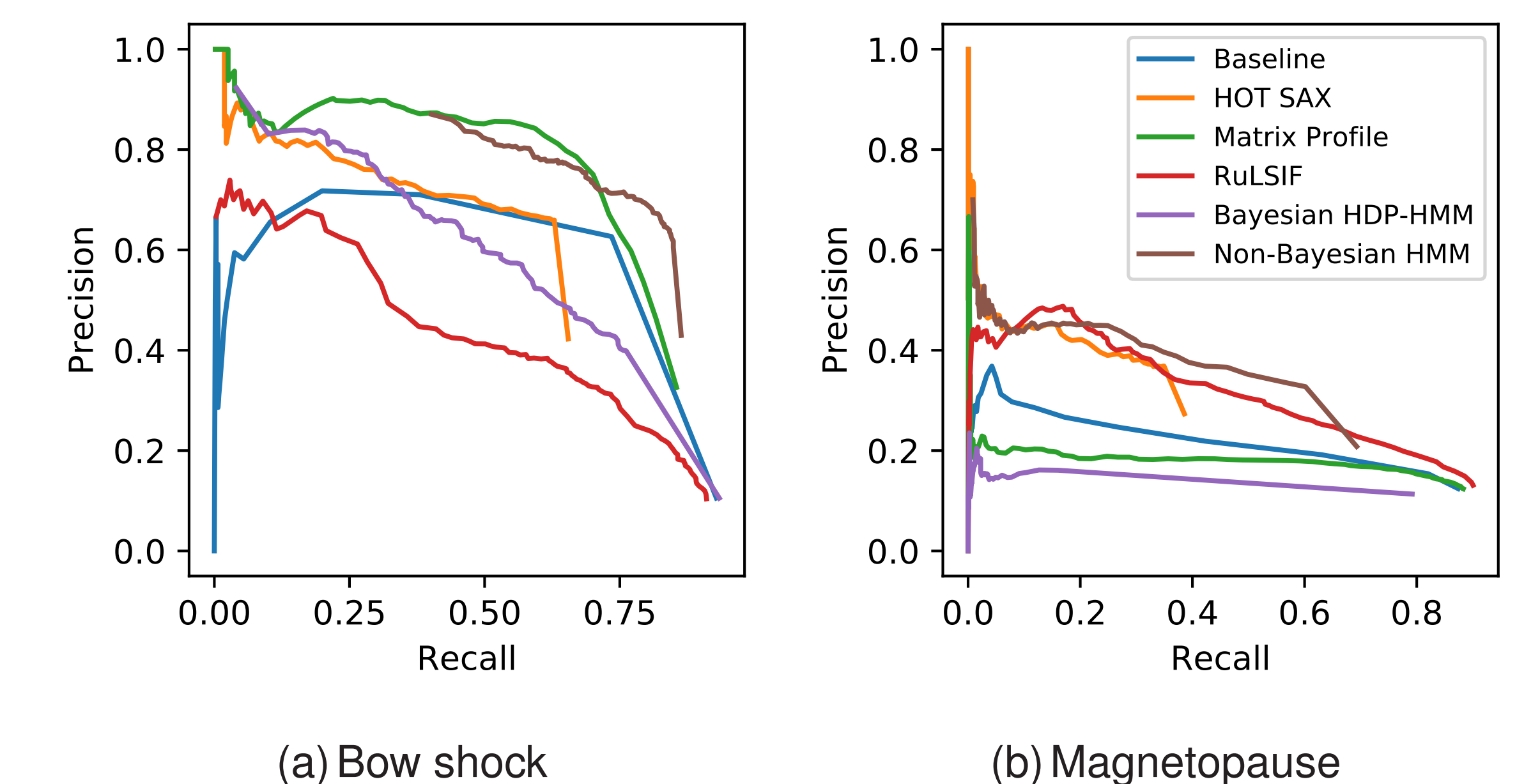


Figure 3: Test performance on around 2300 crossings spread across years 2005 to 2012. Parameters were optimized using 60 crossings from 2004.

Our Key Contributions

- We **evaluate** four unsupervised approaches to identify magnetic field transitions in CAPS data.
- We propose an **extension to the Matrix Profile** for anomaly detection in multidimensional time series.
- We show that **bow shock transitions** from CAPS data can be **detected best** by the **Multidimensional Matrix Profile** and the **non-Bayesian HMM**.
- We find that all four approaches **struggle to identify magnetopause transitions** from CAPS data. Significant differences between spacecraft orbits across years limits the generalizability of parameters optimized on a single year: **online adaptation may be beneficial**.

