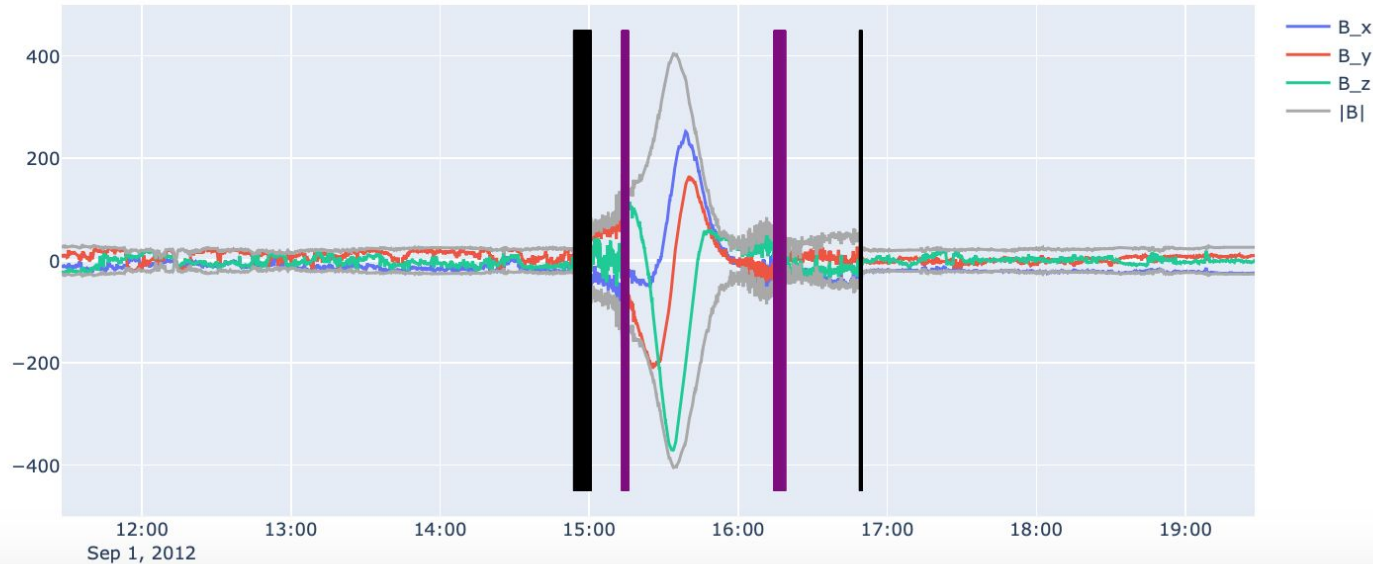


VESPA implementation workshop 2021

David Parunakian - Lomonosov Moscow State University

Use ML to detect magnetospheric boundary crossings

Messenger orbit 1200 [learned]



The original dataset and the overarching goal

MESSENGER spacecraft had a high-frequency (20Hz) magnetometer onboard. 1/5/10/60 second averages are available via [PDS-PPI](#).

Particle detectors EPS and FIPS unsuitable for working with solar wind plasma (partly due to the solar-oriented thermal shield).

Goal: develop a machine learning framework which would allow to determine magnetopause and bow shock crossings solely based on magnetic field measurements and coordinates.

MAG



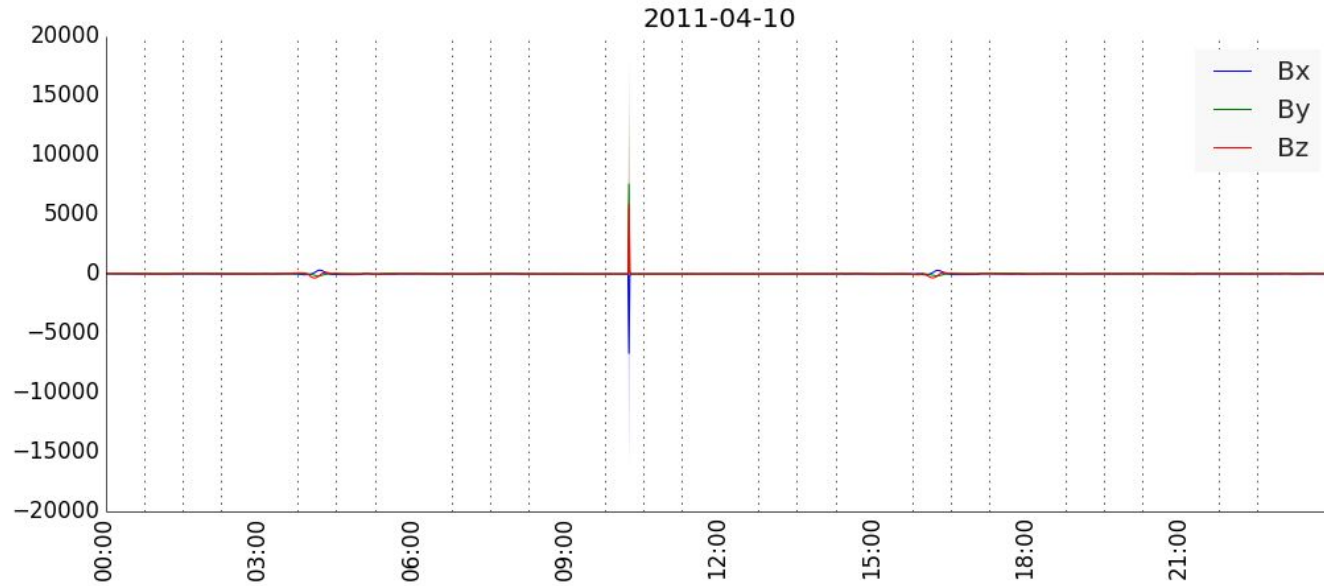
EPS



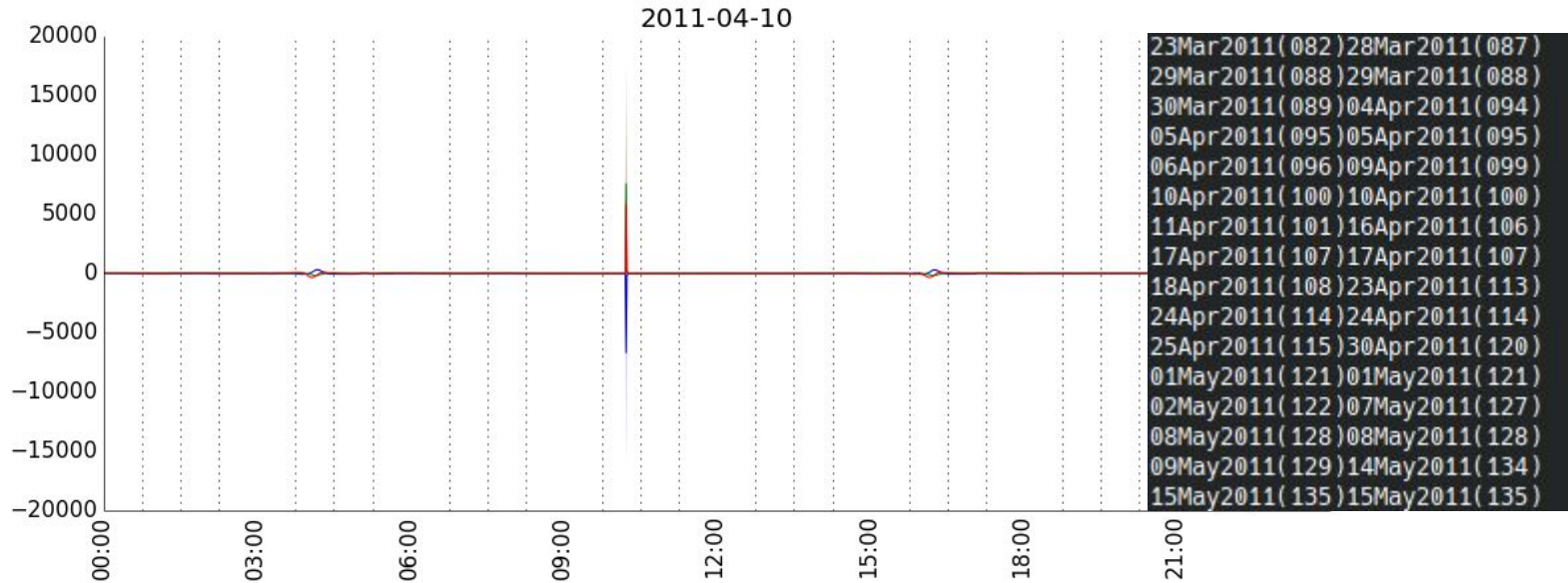
FIPS



Removal of calibration signals

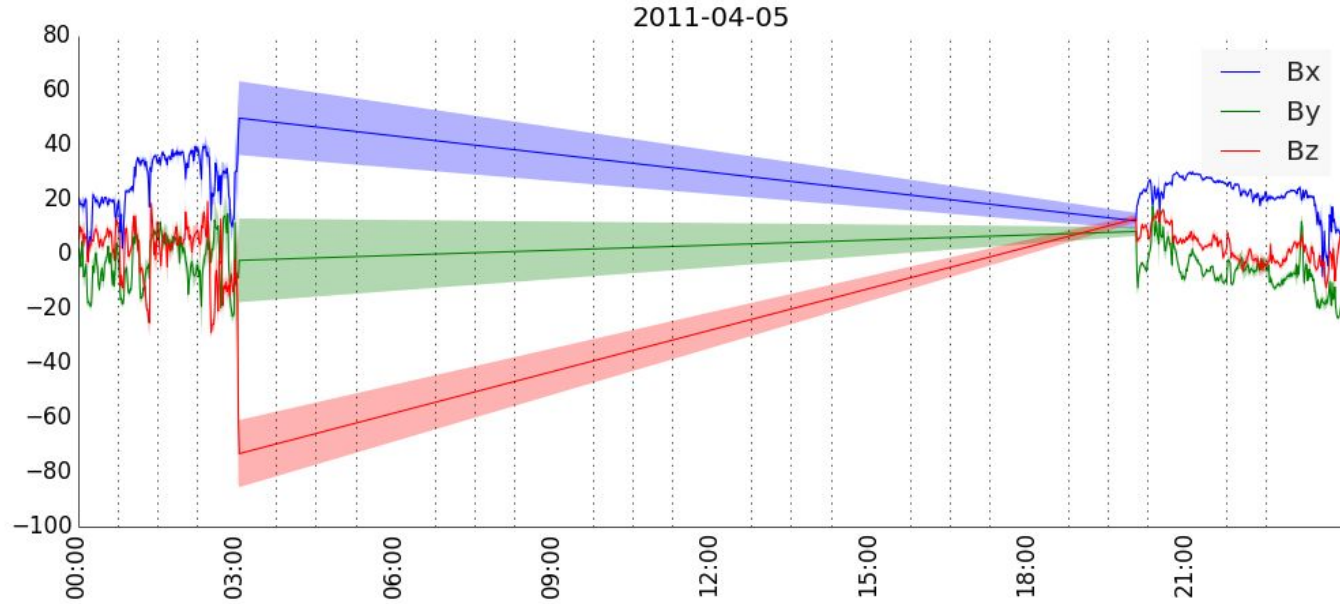


Removal of calibration signals



Calibration / checkout dates available in [PDS-PPI](#)... but only the dates!

Gap detection and processing



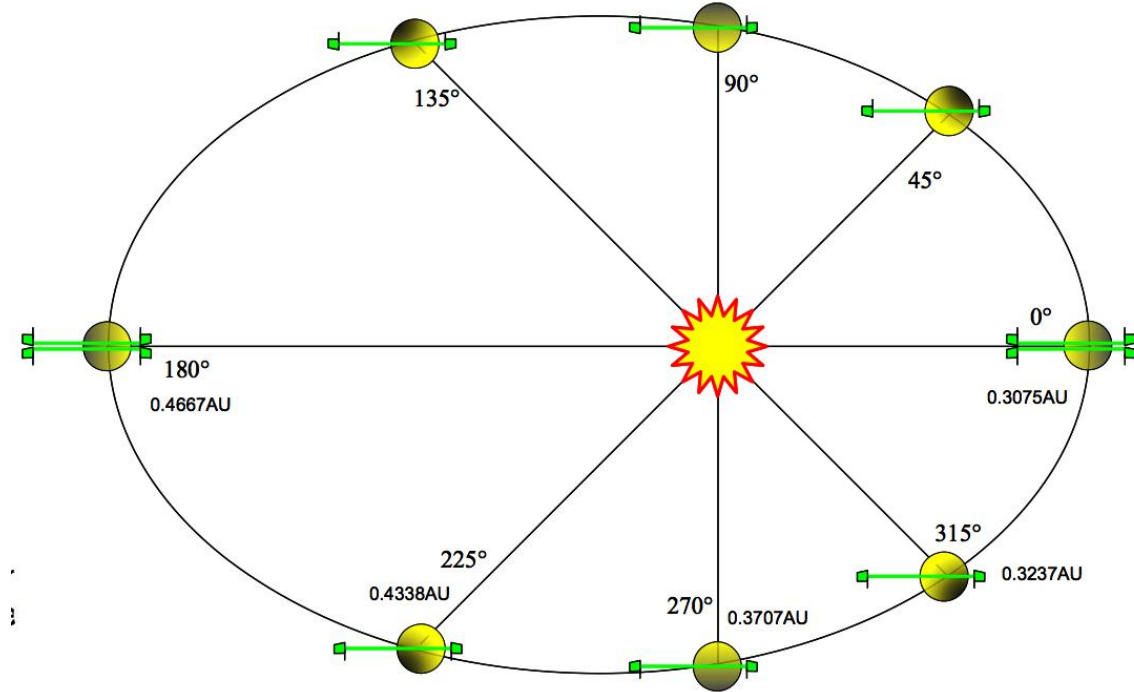
Coordinate system transformation

- Mercury's orbital speed is 40-50km/sec
- Slow solar wind speed is ~400km/sec
- We need to account for the effect Mercury's motion has on the effective direction of solar wind arrival.
- Transformation into aberrated MSO' coordinate system:

$$R_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \theta \sim 7-9^\circ$$

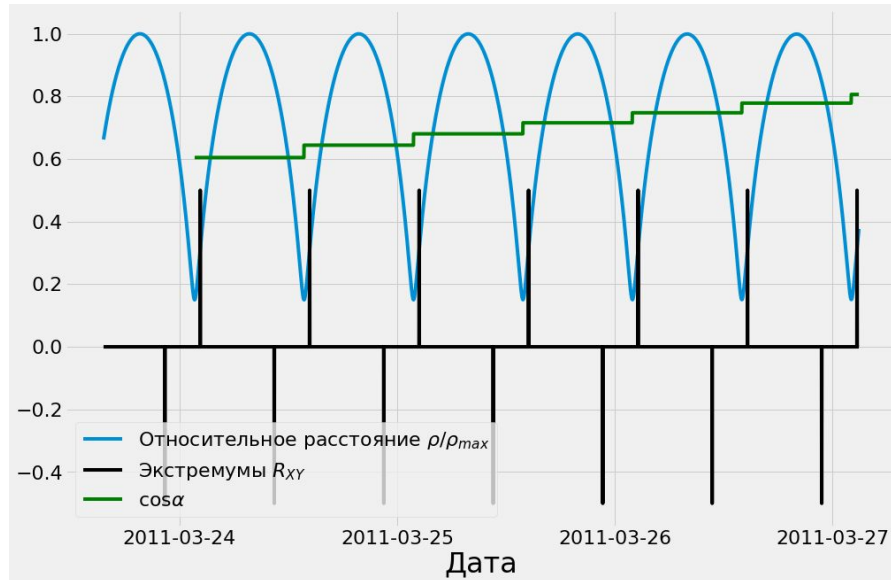
Additional feature: spacecraft orbital plane

Since the magnetosphere is always oriented towards the Sun, and the spacecraft's orbital plane is fixed in heliographic coordinates, we observe very different magnetic field profiles depending on the season of the Hermean year.

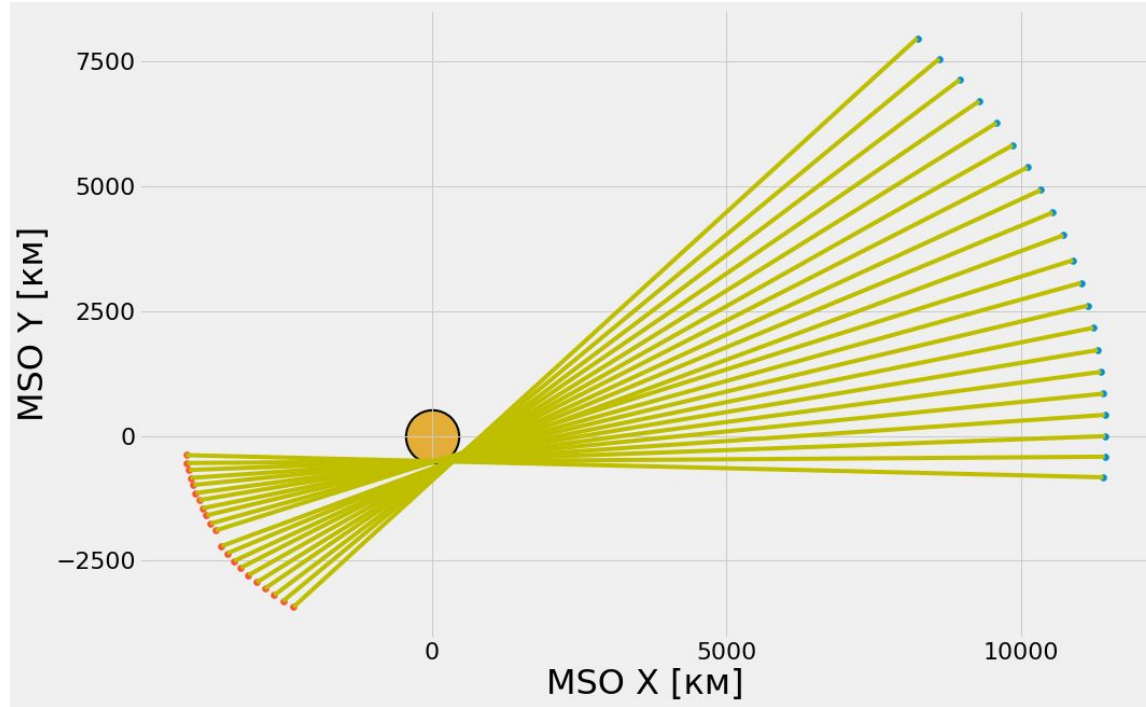


Additional feature: spacecraft orbital plane

1. Find local minima of the ρ planetocentric distance
2. Find local maxima R_{XY} to the both sides from each local minimum of ρ
3. Find the angle α between the X-axis and the line connecting the adjacent R_{XY} local maxima

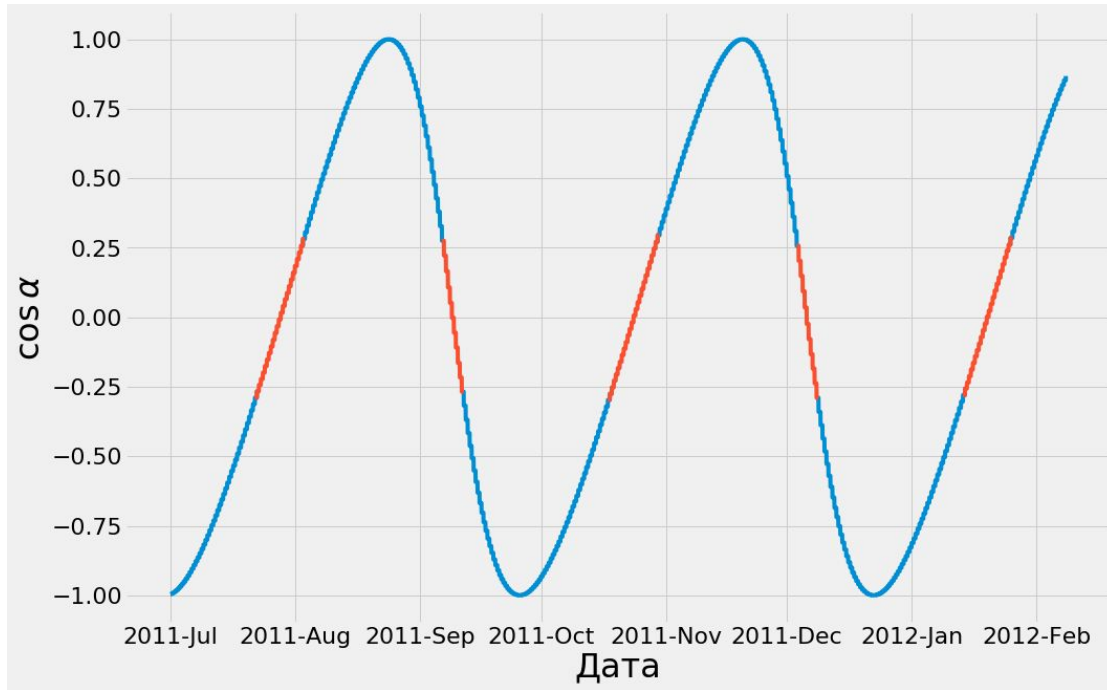


Additional feature: spacecraft orbital plane



R_{XY} local maxima precession

Additional feature: spacecraft orbital plane



Use the $\cos(\alpha)$ value as a feature to determine the current Hermean season

Final notes

- Full list of columns: DATE, TIME_TAG, NAVG, X_MSO, Y_MSO, Z_MSO, BX_MSO, BY_MSO, BZ_MSO, DBX_MSO, DBY_MSO, DBZ_MSO, RHO_DIPOLE, PHI_DIPOLE, THETA_DIPOLE, BABS_DIPOLE, BX_DIPOLE, BY_DIPOLE, BZ_DIPOLE, RHO, RXY, X, Y, Z, VX, VY, VZ, VABS, D, COSALPHA, EXTREMA
- Split based on orbits centered on each periapsis instead of splitting based on Terran days.

