The Strange Menagerie at the Magnetopause: High-Resolution Magnetospheric Multiscale Data Reveal Diverse Phenomena near the Boundary with the Magnetosheath

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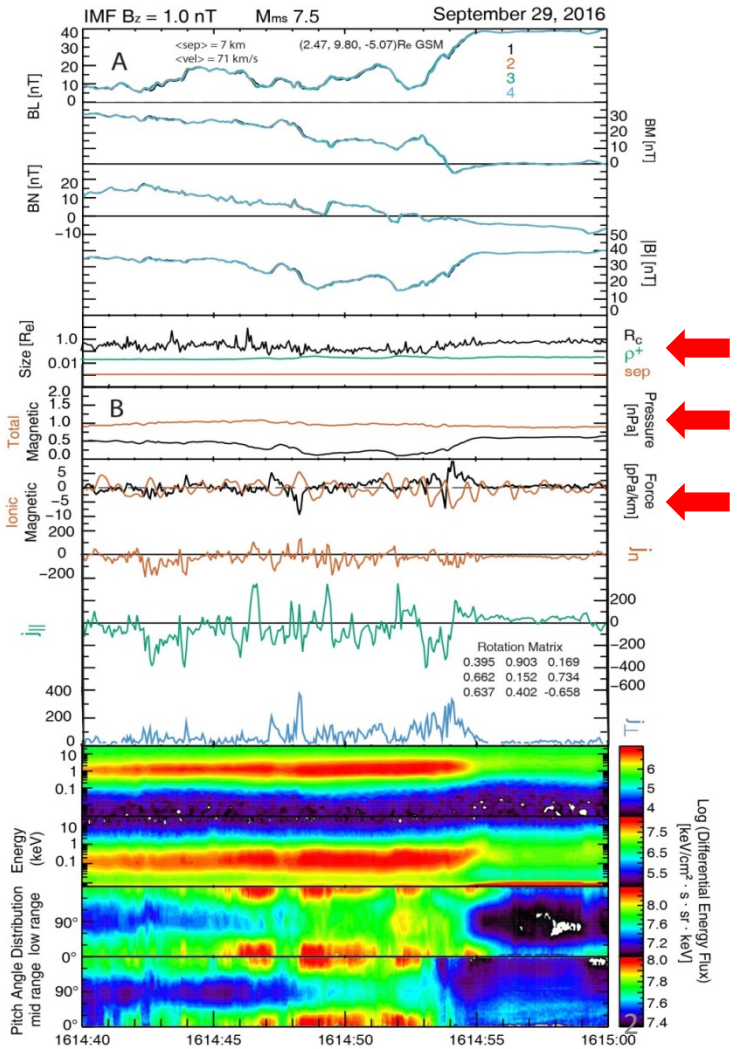
ESLAB 52
Magnetospheres and Space Weather
1420 Wednesday, May 16, 2018
ESTEC, The Netherlands

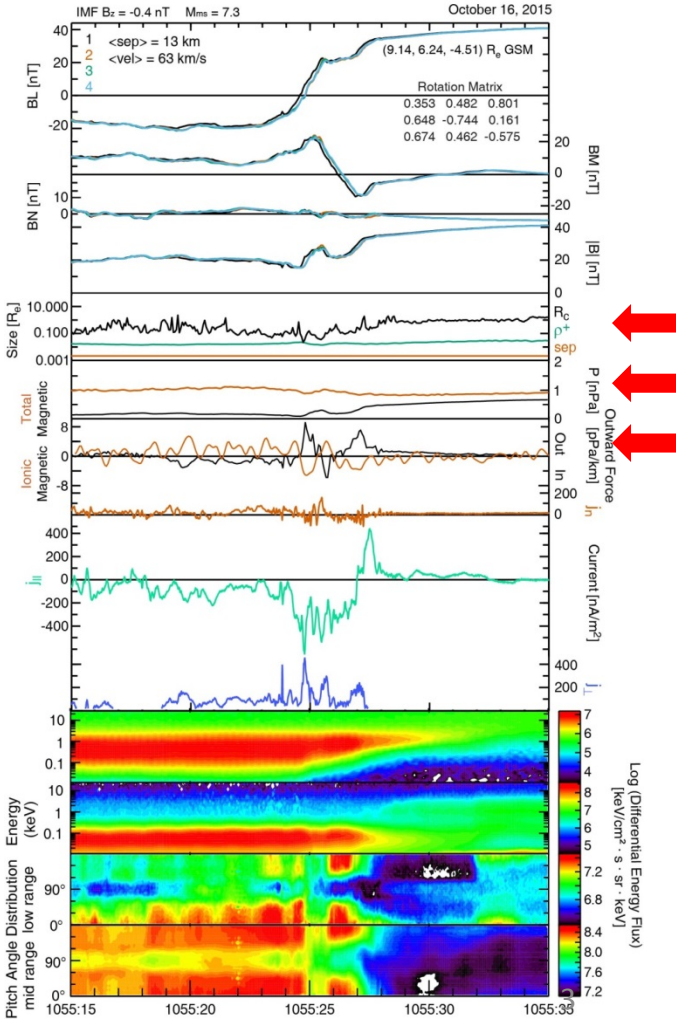
Plasma and Magnetic Field for a Northward Magnetopause

- For a northward IMF magnetopause, the radius of curvature of the magnetopause is about 1 Re
- The total (magnetic and plasma) pressure is constant.
- The plasma and magnetic forces oppose and balance each other.
- There is parallel and antiparallel streaming in the sheath boundary layer.
- The magnetopause is well defined.



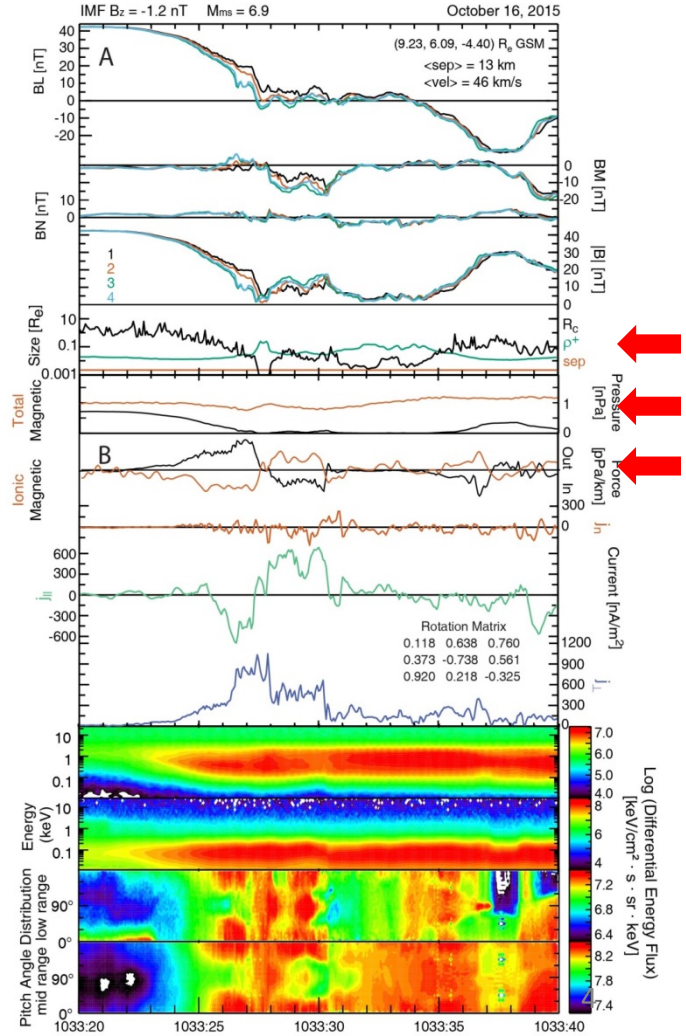
Plasma and Magnetic Behavior for a Southward Magnetopause Crossing

- For a southward IMF magnetopause, the radius of curvature is ~600-6000 km.
- The total plasma pressure is almost constant.
- The plasma and magnetic forces are more complex but still oppose and balance each other.
- There are strong fluxes of parallel and antiparallel electrons in the sheath.
- The magnetopause is well defined.



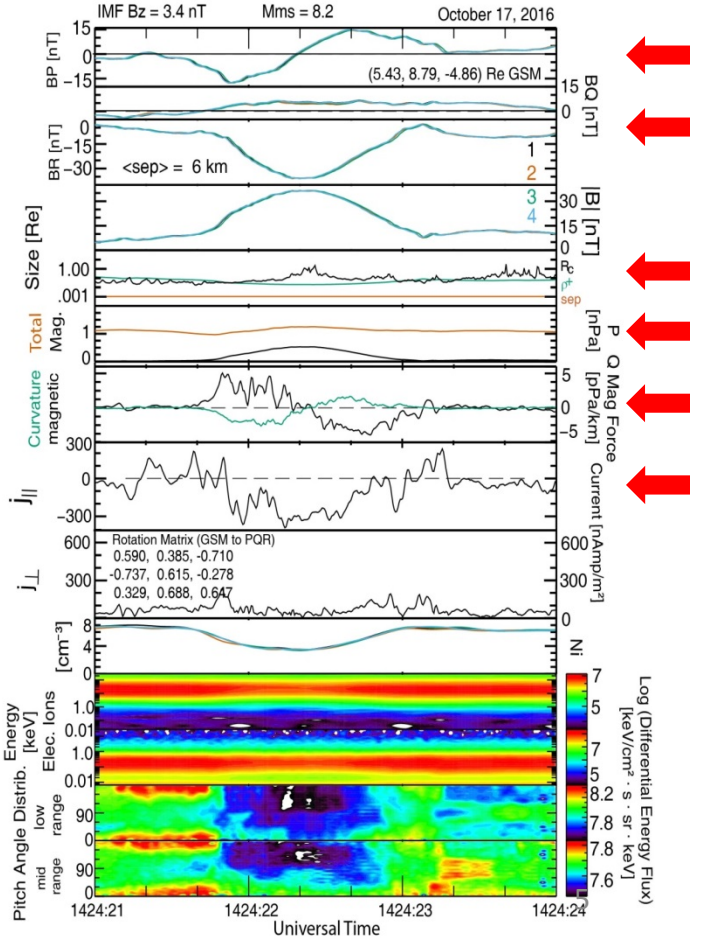
Plasma and Magnetic Behavior for a Strongly Reconnecting Magnetopause

- For a strongly reconnecting magnetopause, the radius of curvature drops below the ion gyroradius and may approach the electron gyroradius.
- The total magnetic and plasma pressure is almost constant.
- The plasma and magnetic forces are complex but are opposed and balance each other.
- Electrons are isotropized.
- Strong fluxes of low and medium energy electrons parallel and antiparallel to the field near the magnetopause.
- The magnetopause is well defined.



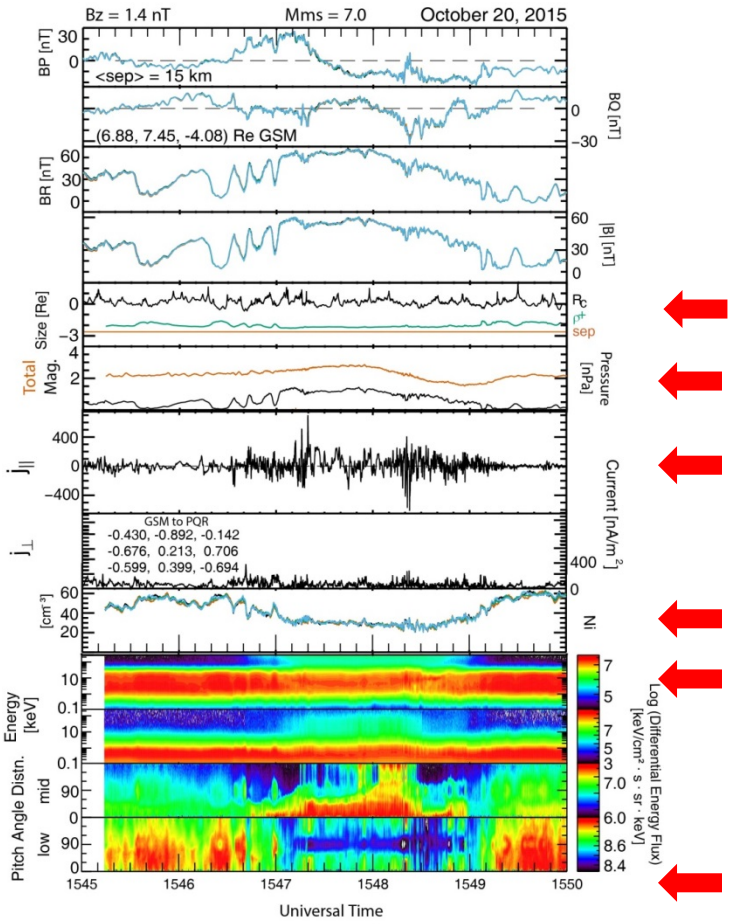
Magnetic Rope

- Identifying properties
  - Magnetic field in PQR system
    - R – Rope axis constant pressure direction
    - P – Curvature force direction at rope center
    - Q – Pressure force direction at closest approach
    - |B| - Smooth rounded maximum
  - Radius of curvature
    - Maximum at center of rope
    - Curvature force balances pressure force
    - Both cross zero in center of rope
  - Current
    - $J_{||}$ dominates $J_{\perp}$
  - Density
    - Minimum in center of rope



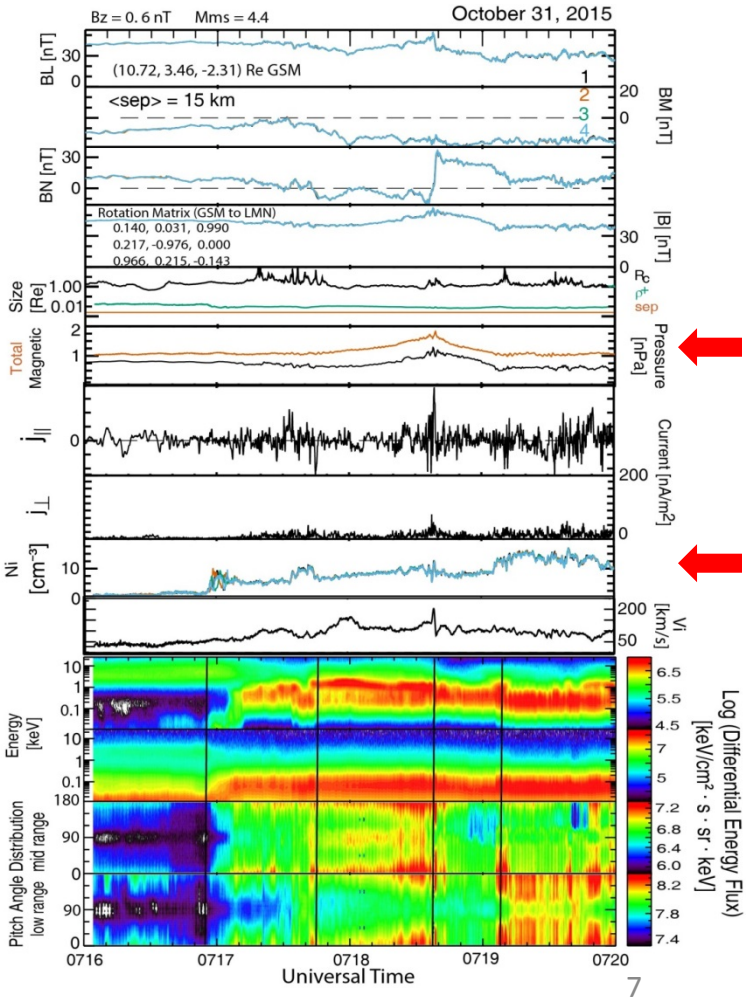
Flux Transfer Event

- This interval is identified as an FTE.
- It has a large radius of curvature.
- It exists for a long (minutes) time.
- It has lower density than the sheath.
- It contains energetic magnetospheric particles.
- It has a total pressure that varies through the event.



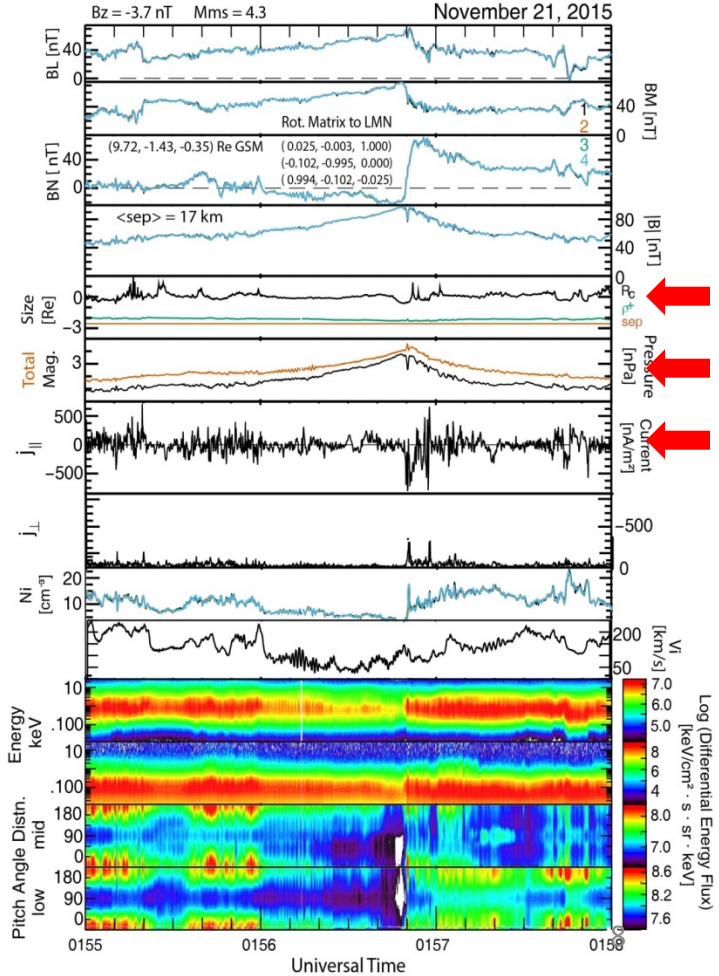
Extraterrestrials in our Menagerie

- Identifying Properties
  - Magnetic field
    - Thin abrupt change in direction near sharp maximum in the magnetic field
  - Radius of curvature
    - About 1 RE through entire crossing
  - Pressure balance
    - No obvious mechanism to balance pressure gradient. Deceleration?
    - Both plasma and field pressure increase. No obvious magnetopause.
  - Current
    - $J_{||}$ strong near center of structure
    - $J_{||}$ can be stronger than in reconnection
  - Plasma
    - Multiple distinct plasma regimes
  - Fluctuations
    - Smaller in rising phase
  - Is this a disturbance moving through the plasma or a stationary spatial structure on the boundary?



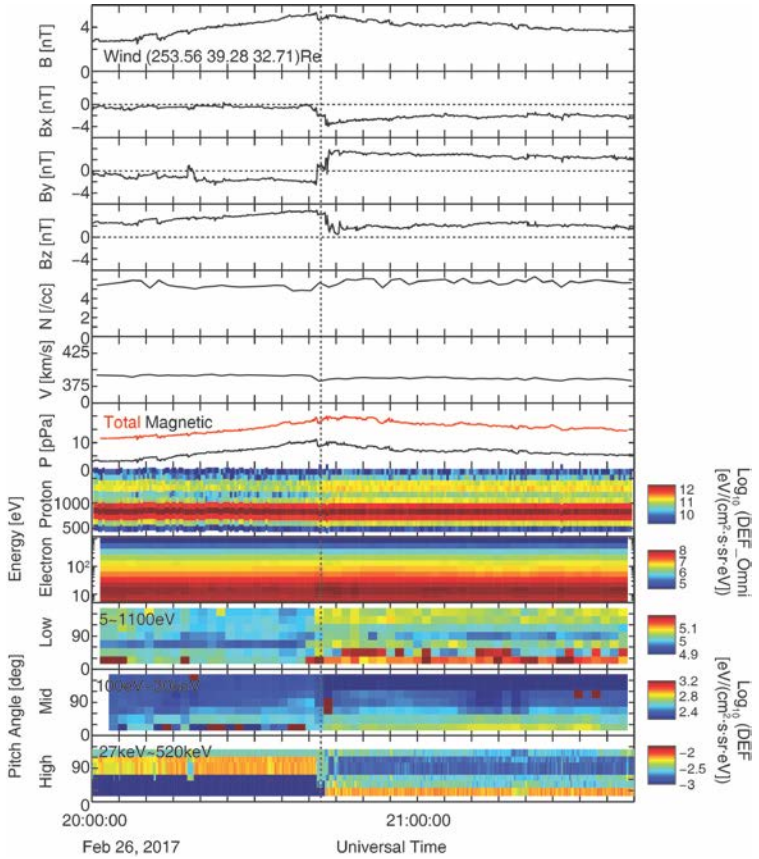
Magnetosheath Field Enhancement

- Identifying Properties
  - Magnetic field
    - Thin abrupt change in direction near sharp maximum in magnetic field strength
  - Radius of curvature
    - About 1 R_E for entire period except near current sheet
  - Pressure gradient
    - Not balanced by pressure forces
    - Low density, low speed on leading side
  - Current
    - Strong $J_{||}$ near center of event
  - Plasma
    - Number density less in rising portion of event. What is providing the mass density?
  - Fluctuations
    - Quieter in rising phase. Plasma instabilities stronger on the RHS.



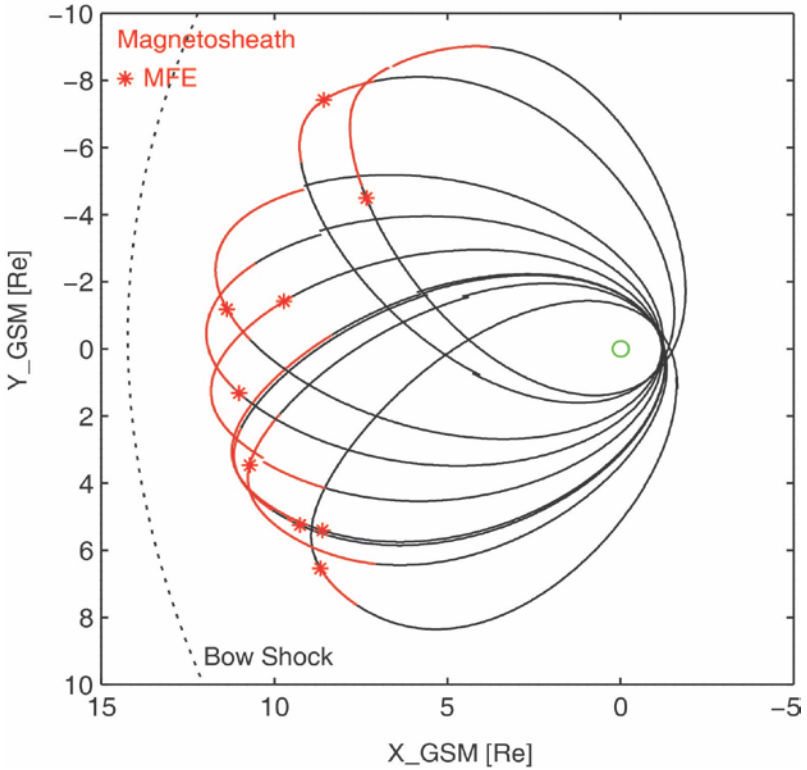
Interplanetary Field Enhancement with Solar Wind Plasma

- IFEs are scale independent magnetic structures in the solar wind.
- They are seen with 12-hour durations to 10-minute durations.
- We have long attributed these to meteoroid collisions.
- MFEs at the magnetopause last less than one minute and have a similar magnetic and plasma structure.
- They seem to be small IFEs slowing down at the magnetopause.
- Could they be small dust comets?



Locations of these Dust Comets

- These strong short-lived pressure pulses are approaching the magnetopause.
- The morphology of the plasma and field is identical to interplanetary structures known as interplanetary field enhancements and attributed to ionized magnetized dust accelerated to the solar wind speed.
- These appear to have passed through the shock front at solar wind speeds and later decelerated near the magnetopause.
- They are seen across the entire front-side magnetopause.



Conclusions

- The magnetopause separates the Earth's magnetosphere from the confining solar wind
- This boundary is very sensitive to magnetic and plasma conditions. Importantly reconnection of the magnetic field on the two sides of the boundary may occur increasing the tangential stress on the boundary
- The boundary may also produce flux ropes and these flux ropes may join on one side to the magnetosphere and transfer magnetic flux to the tail in bursts
- Pressure pulses also appear at the magnetopause with mass that our detectors do not detect. We attribute these clearly massive events to dust comets as their morphology emulates that of apparently collisionally-produced events in the solar wind
- This discussion of the menagerie at the magnetopause is most probably incomplete