DEPARTMENT OF PHYSICS AND ASTRONOMY

Electron Bulk Heating at Saturn's Magnetopause

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Key Points:

- Electron bulk heating at Saturn's magnetopause is used to test hypotheses about magnetic reconnection.
- Observations suggestive of locally open magnetopause tend to exhibit electron heating closer to the theoretical prediction for reconnection.
- $\Delta\beta$-magnetic shear parameter space discriminates well between events with evidence of energisation and those without.

Background

- **Magnetopause** – interaction between solar and planetary B-field & plasma.
- **Magnetic reconnection-** energises plasma via release of magnetic energy.
- **'Open' magnetosphere-** solar wind enters magnetosphere.
- **Question:** When is reconnection viable at Saturn's MP?
- Plasma β is higher in Saturn's magnetosheath than in Earth's (Masters et al. 2012) => need high magnetic shear (Swisdak et al. 2003)
- When Bshear $< 180°$: Particle drift opposes reconnection outflow.

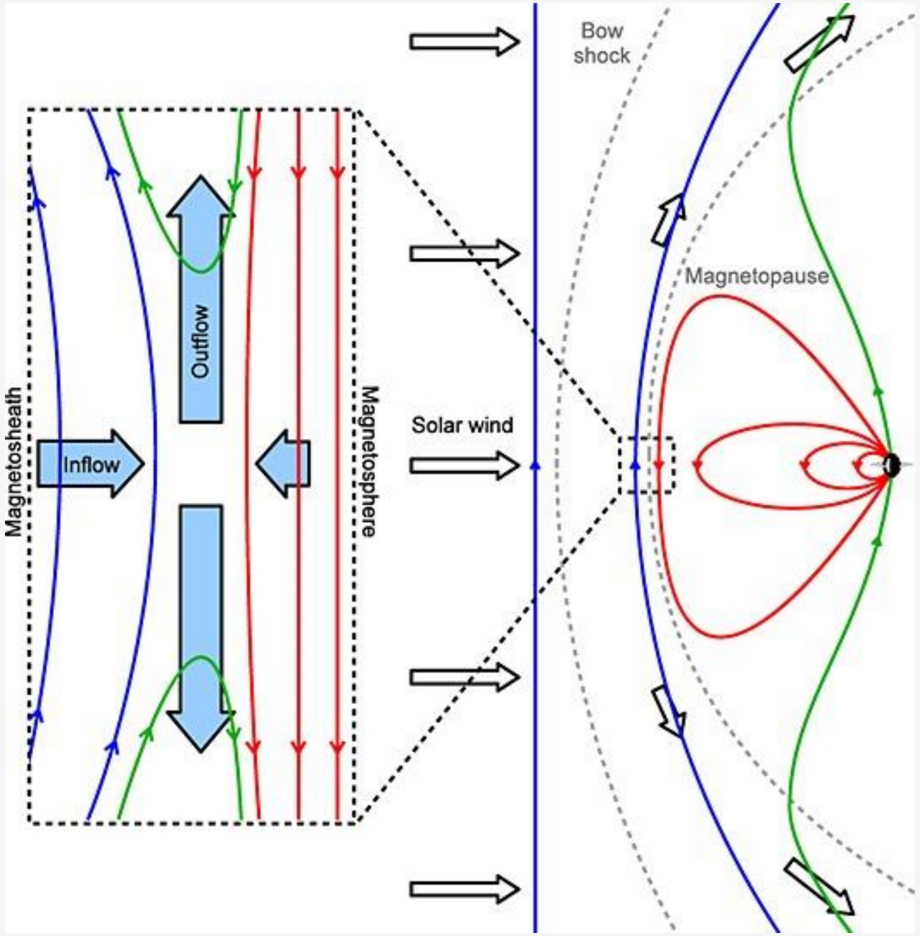

Figure 1. Diagram illustrating magnetic reconnection at Saturn's magnetopause for northward IMF. Interplanetary, planetary and reconnected (open) magnetic field lines are shown in blue, red, and green respectively (Taken from Masters et al. 2014).

Methodology

- Use **bulk electron heating** as a reconnection signature to test the following hypotheses:
  1) 'Closed' boundary => no heating
     'Open' boundary => heating close to theoretical prediction
  2) Events with heating => 'reconnection possible' regime
     Events without heating => 'reconnection suppressed' regime
- 70 MP crossings made by Cassini between April 2005 to July 2007 (Masters et al. 2012), determined using B-field and ELS moments data.
- Determine temperature (Lewis et al. 2008):
  1) 3d method- sum over energy distribution.
  2) 1d method- fit Gaussian to determine Maxwellian parameters (n and T).
- Compare to theoretical prediction (Phan et al. 2013):

$$\Delta T_{e,pred} = 0.017 m_i v_{AL}^2$$

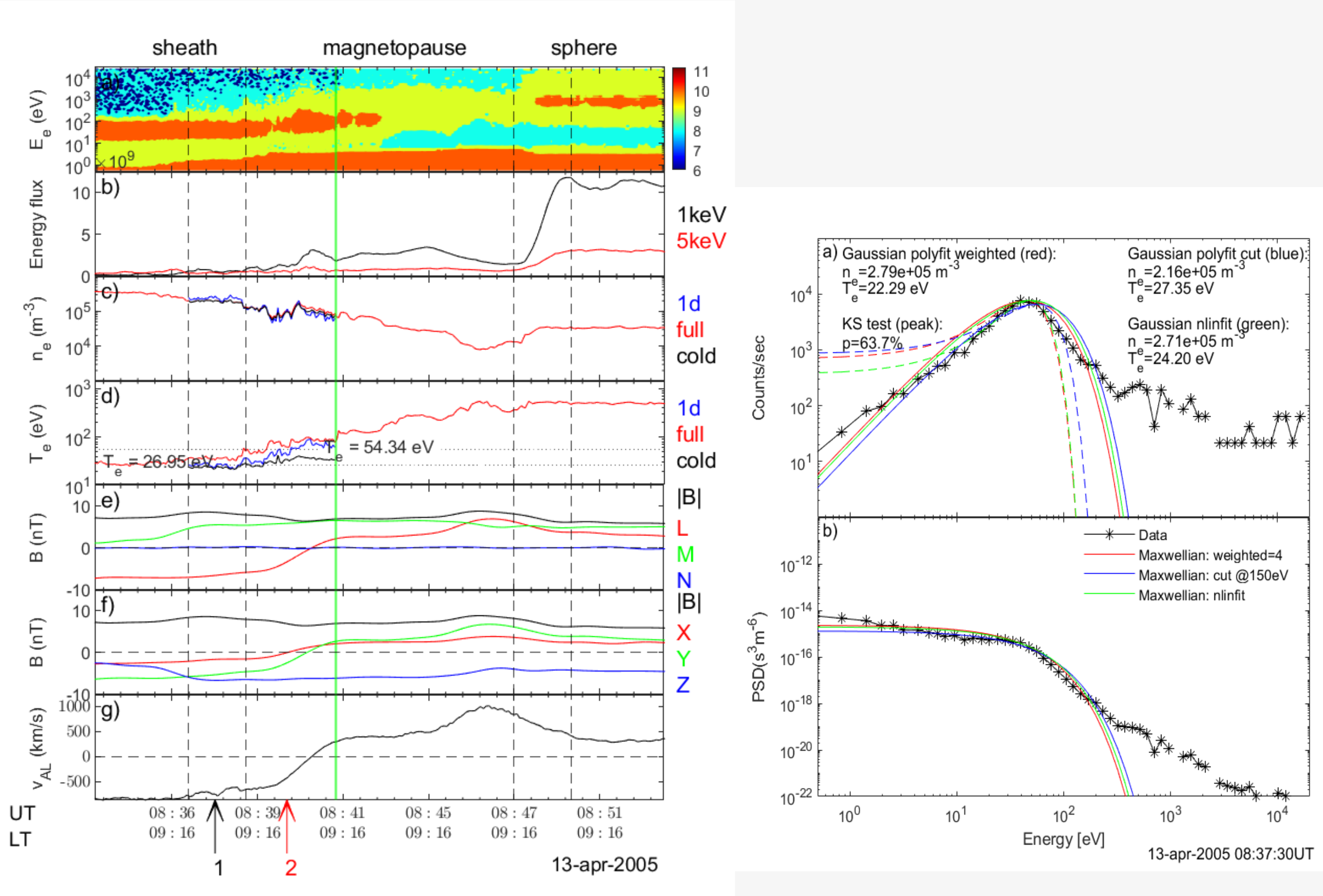

Figure 2. Left: Data from MP crossing on 13 Apr 2005. **Right:** Example of 1d moment method fits.

Results

1. **Figure 3:** Clear **positive correlation** between observed and predicted heating when 1d method used (linear regression: $slope = 0.66; r^2 = 0.99$).
   Open boundary (**bottom**):
   - Tendency of better agreement with prediction.

   Closed boundary (top):
   - Cluster consistent with $\Delta T_e \approx 0$.
   - Numerous cases with poor agreement.

2. **Figure 4:** Events with no heating (left) => 83% in 'reconnection suppressed' regime ($L = d_i$).
   Events with heating (right) => 43% to 68% in 'reconnection possible' regime ($L = d_i$ or $L = 2d_i$).
   L = current layer thickness; d_i = ion inertial length

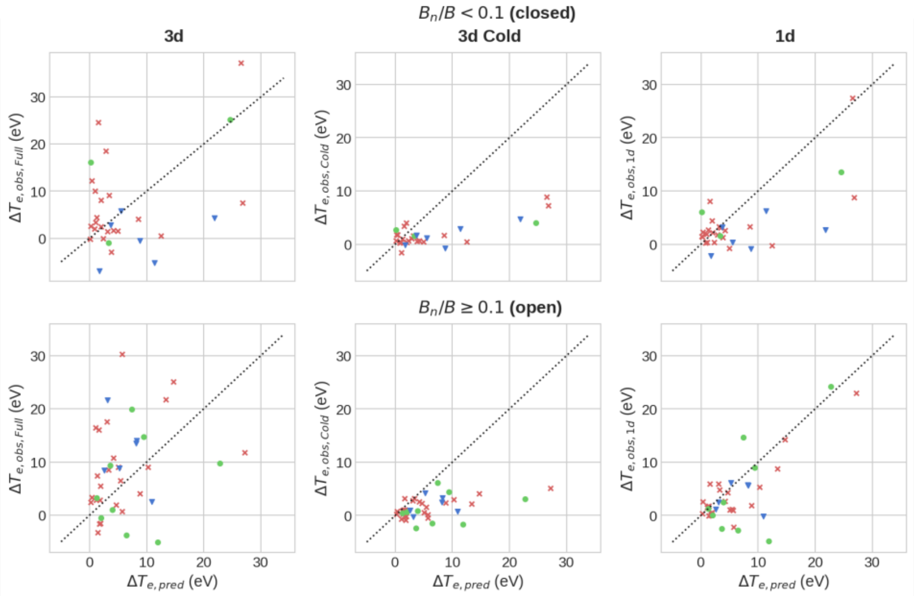

Figure 3. Observed vs. predicted temperature change for open and closed boundary configurations.

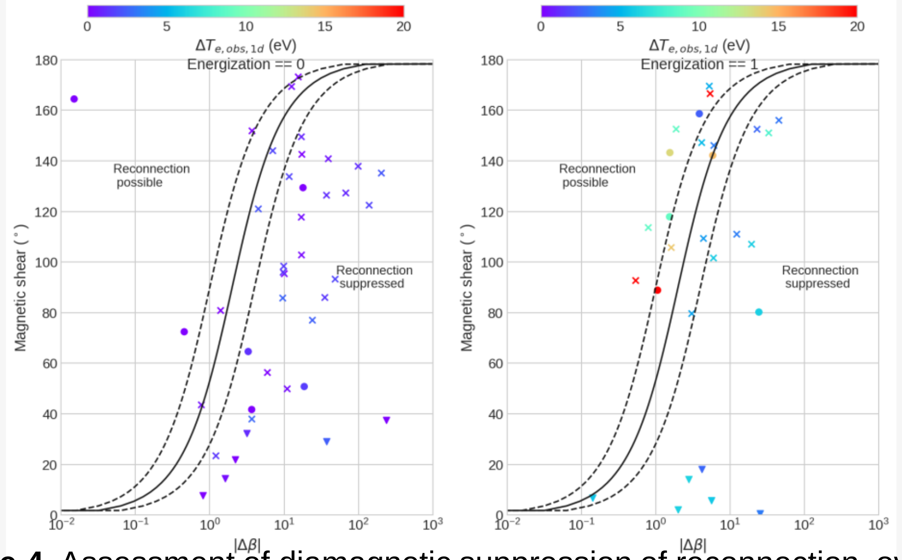

Figure 4. Assessment of diamagnetic suppression of reconnection, overlaid with electron heating ΔT_e shown as colour scale.

Conclusion

1. Statistical study of observed and theoretical electron bulk heating at Saturn’s magnetopause based on 70 MP crossings detected by Cassini.
2. Results support both hypotheses 1 and 2 to some extent:
   ‘Closed’ boundary => no heating
   ‘Open’ boundary => heating close to theoretical prediction
   Events with heating => ‘reconnection possible’ regime
   Events without heating => ‘reconnection suppressed’ regime
3. Possible reasons for disagreement:
   - Assumed local conditions similar to reconnection site.
   - Unknown distance to reconnection site (e.g. up to $51R_s$ Jasinski et al. 2014).
   - Temporal variability in the near-magnetopause environment.
   - Relatively weak electron heating (max $\Delta T_e \approx 20eV$) so large relative uncertainty.
4. Further work: Analyse and augment the dataset utilising the recent MP crossings lists (e.g. Pilkington et al. (2015); Jackman et al. (2019)), and taking the above aspects into consideration.

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