Secondary Slow Shock Front in the Magnetosheath for Strongly Magnetized Solar Wind Conditions

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DASP 2009

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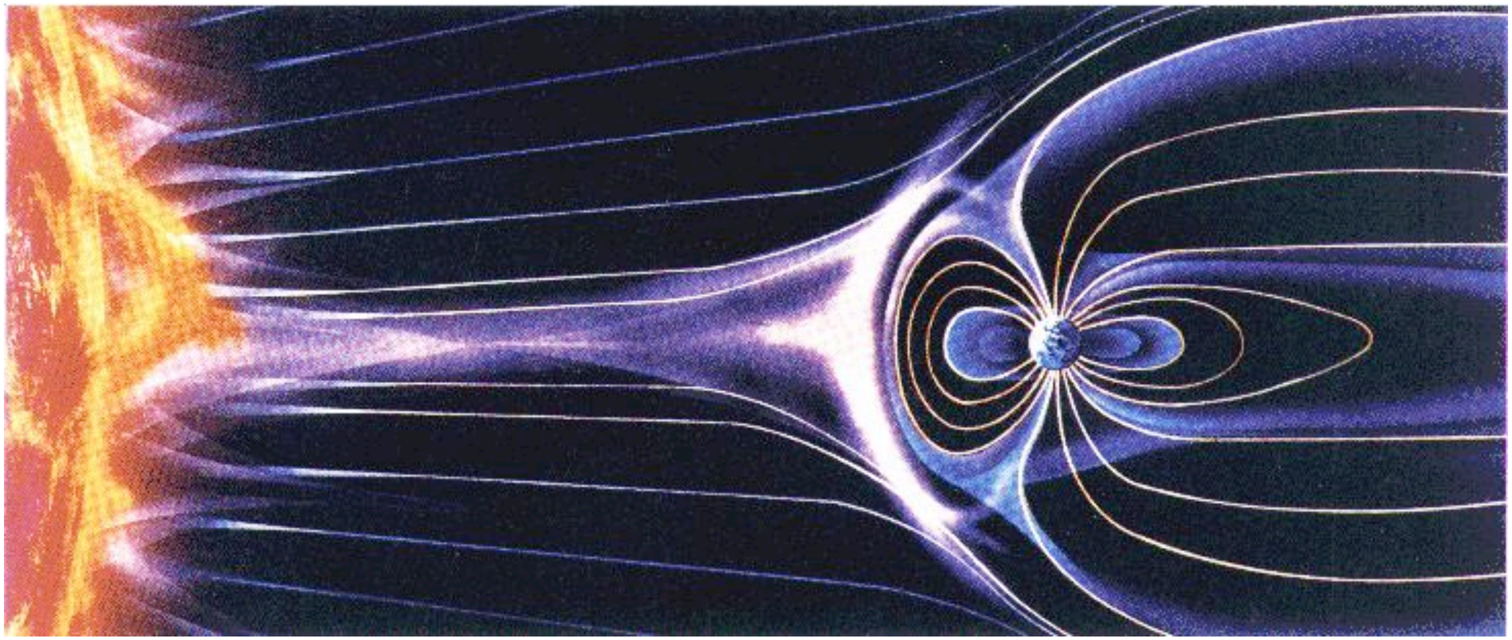
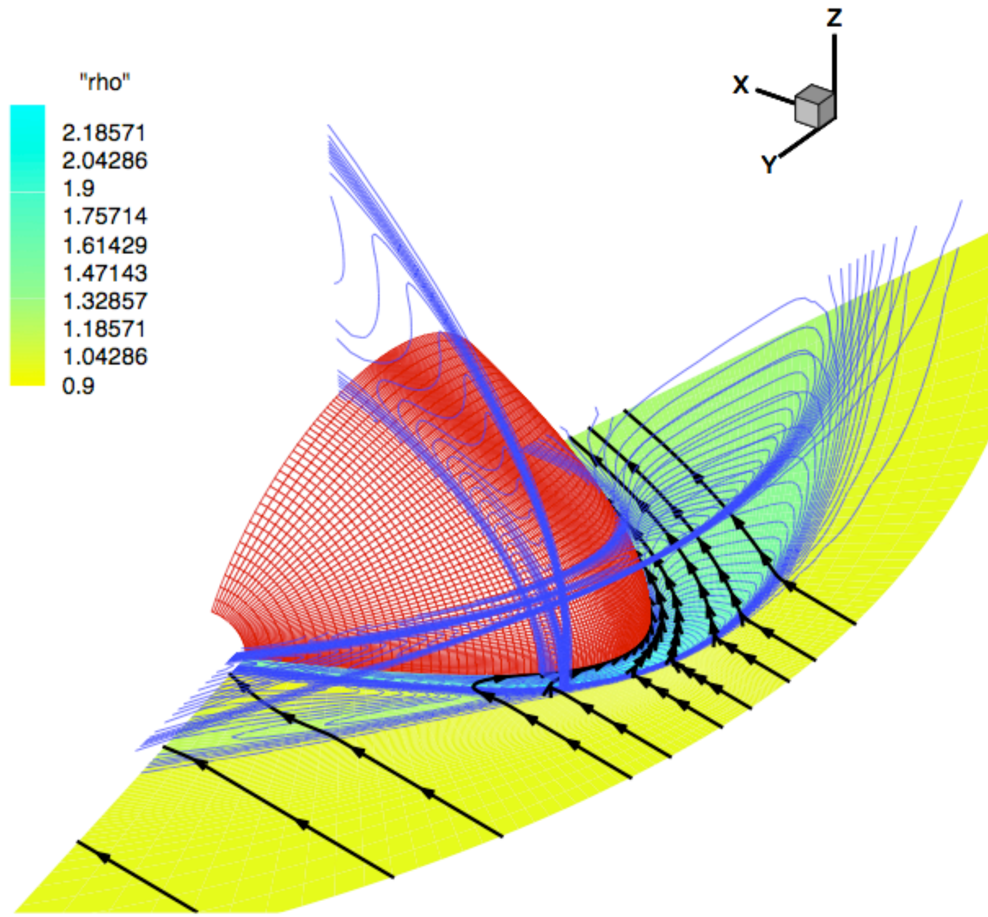
1. magnetohydrodynamic (MHD) bow shocks



- supersonic plasma flow over obstacle (Earth...) produces bow shock
- use continuum simulation model: magnetohydrodynamics (MHD)

2. MHD simulation result



- secondary slow shock forms in magnetosheath
- this happens when solar wind B is large, and the field-aligned Alfvenic Mach number is not too much larger than one
- De Sterck and Poedts, PRL, 2000

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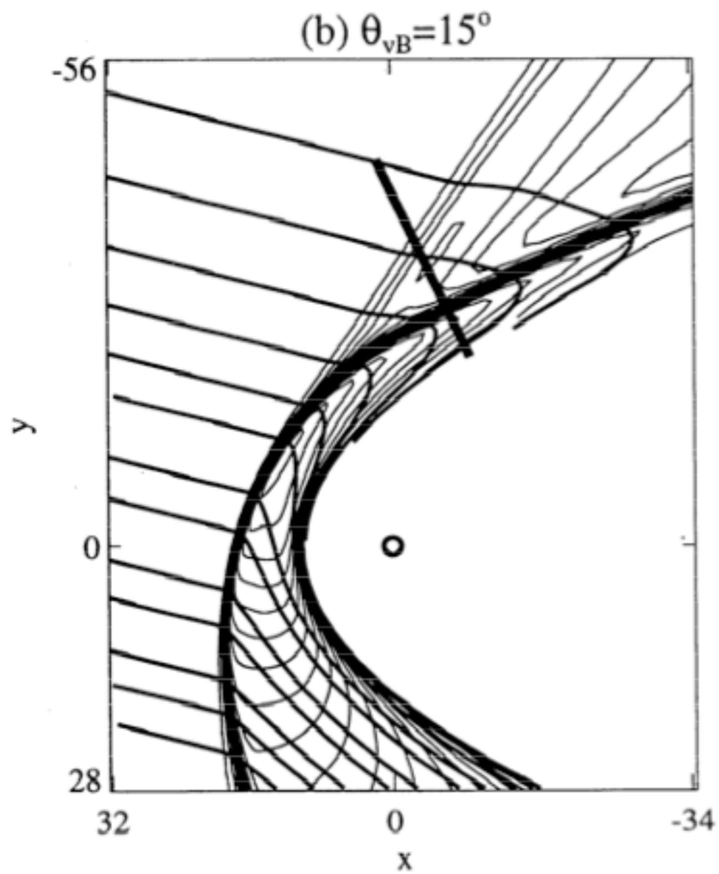
2. MHD simulation result



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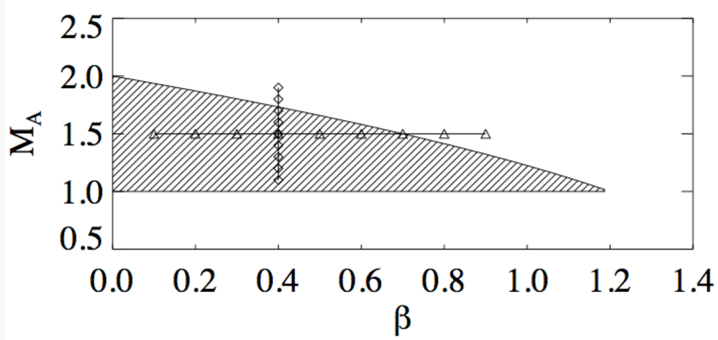
3. secondary shock regime

- magnetic pressure: $P_{\rm mag} = B^2/2\mu_0$
- plasma beta: $\beta = P_{\rm th}/P_{\rm mag}$
- field-aligned alfvenic Mach number: $M_A = v/c_A$

- two conditions for secondary slow shock:

$$\beta < 2/\gamma$$

$$1 < M_{\rm A} < \sqrt{\frac{\gamma(1-\beta)+1}{\gamma-1}}$$



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4. ideal MHD

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0$$

$$\rho \frac{d\vec{v}}{dt} = -\nabla p + (\nabla \times \vec{B}) \times \vec{B}$$

$$\frac{\partial \vec{B}}{\partial t} = \nabla \times (\vec{v} \times \vec{B})$$

$$\frac{\partial p}{\partial t} + (\vec{v} \cdot \nabla) p + \gamma p \nabla \cdot \vec{v} = 0$$

MHD=gasdynamics +
electromagnetics

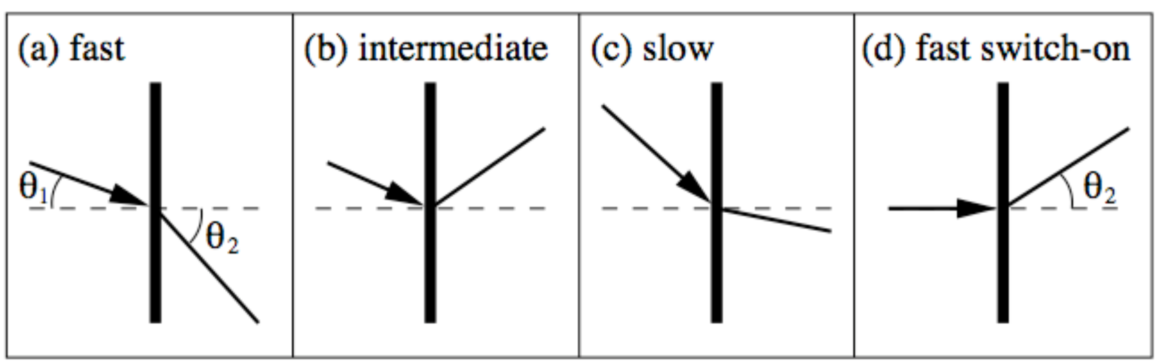
$$\vec{E} = -\vec{v} \times \vec{B}$$

$$\vec{J} = \nabla \times \vec{B}$$

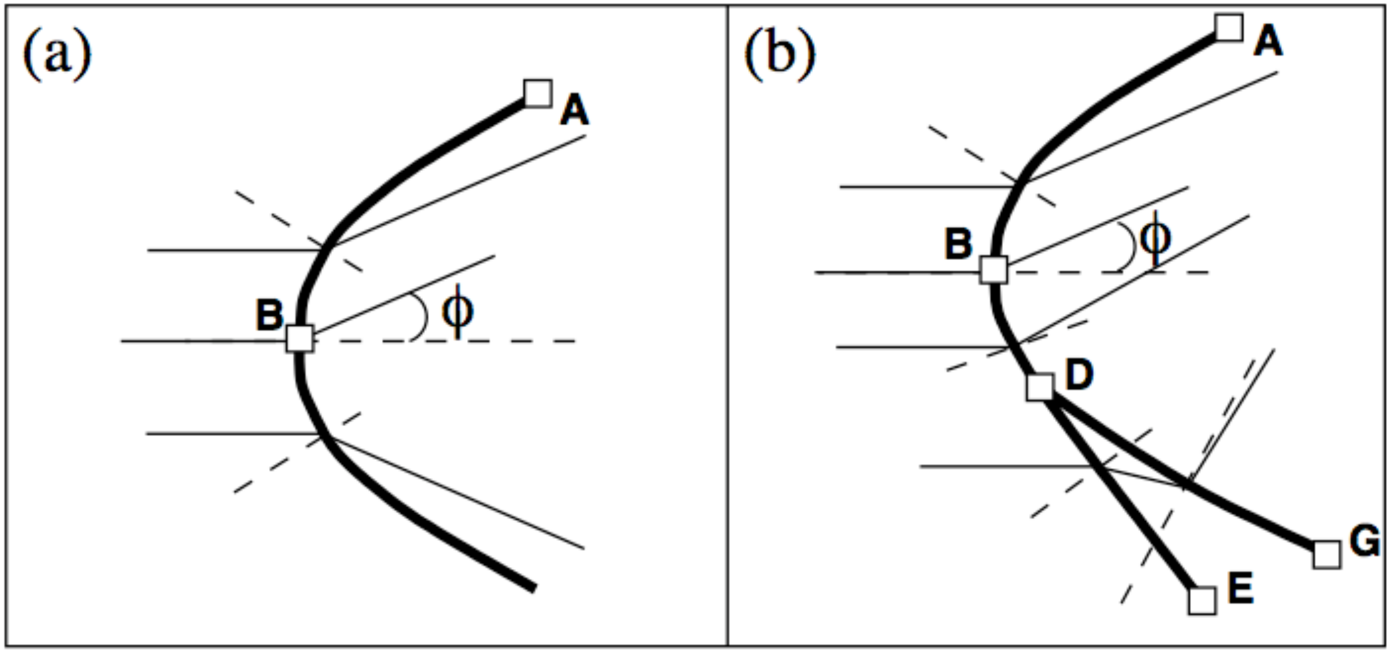
$$\nabla \cdot \vec{B} = 0$$

5. MHD waves and shocks

- MHD has three types of waves:
  - fast
  - Alfven
  - slow
- MHD has three types of shocks



6. why do we get a secondary slow shock?



$$\beta < 2/\gamma$$

$$1 < M_A < \sqrt{\frac{\gamma(1-\beta)+1}{\gamma-1}}$$

(De Sterck and Poedts, PRL, 2000)

7. has this been observed?

- not yet
- reasons
  - how often is the solar wind in the correct parameter regime?
  - MHD validity - kinetic effects?
  - time-dependent - intermittency - how would you observe this?
  - nobody has looked so far

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8. solar wind parameter regime

- De Keyser et al., Space Science Reviews, 2001
- survey of Wind January-March 1995, and Ulysses 1990-2000

$$\beta < 2/\gamma \qquad 1 < M_A < \sqrt{\frac{\gamma(1-\beta)+1}{\gamma-1}} \qquad |\theta_{vB}| < 45°$$

- Wind: 'magnetically dominated' regime
  - 2% of time (near solar minimum)
  - lasts up to 10^4 seconds (a few hours)
  - suggests intermittent slow shocks may form in magnetosheath

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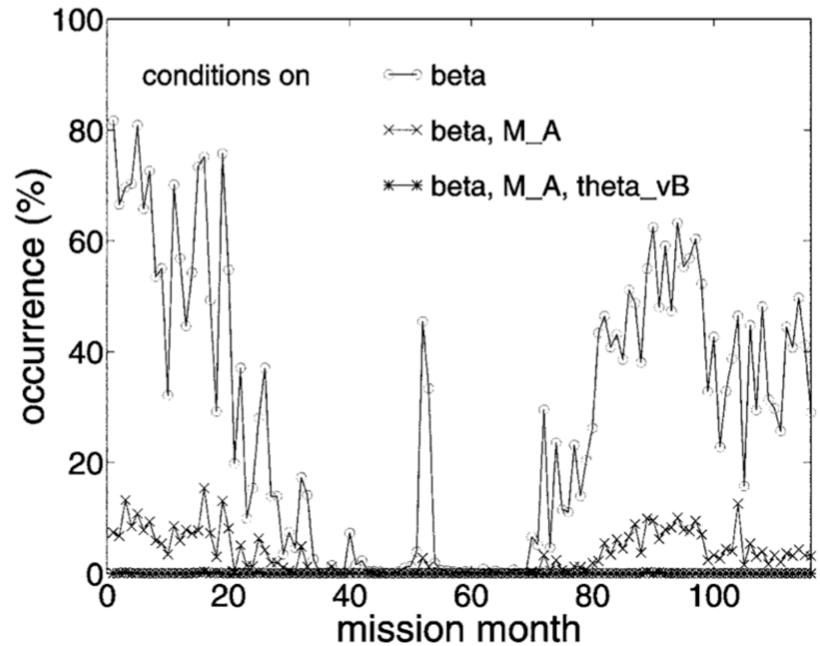
8. solar wind parameter regime

- Ulysses:'magnetically dominated' regime
  - found only at low latitude during solar minimum, but everywhere at solar maximum
  - may be associated with magnetic clouds and corotating interaction regions (have same characteristic rotation)
  - intermittent slow shocks in planetary magnetosheath may be formed



(De Keyser et al., Space Science Reviews, 2001)

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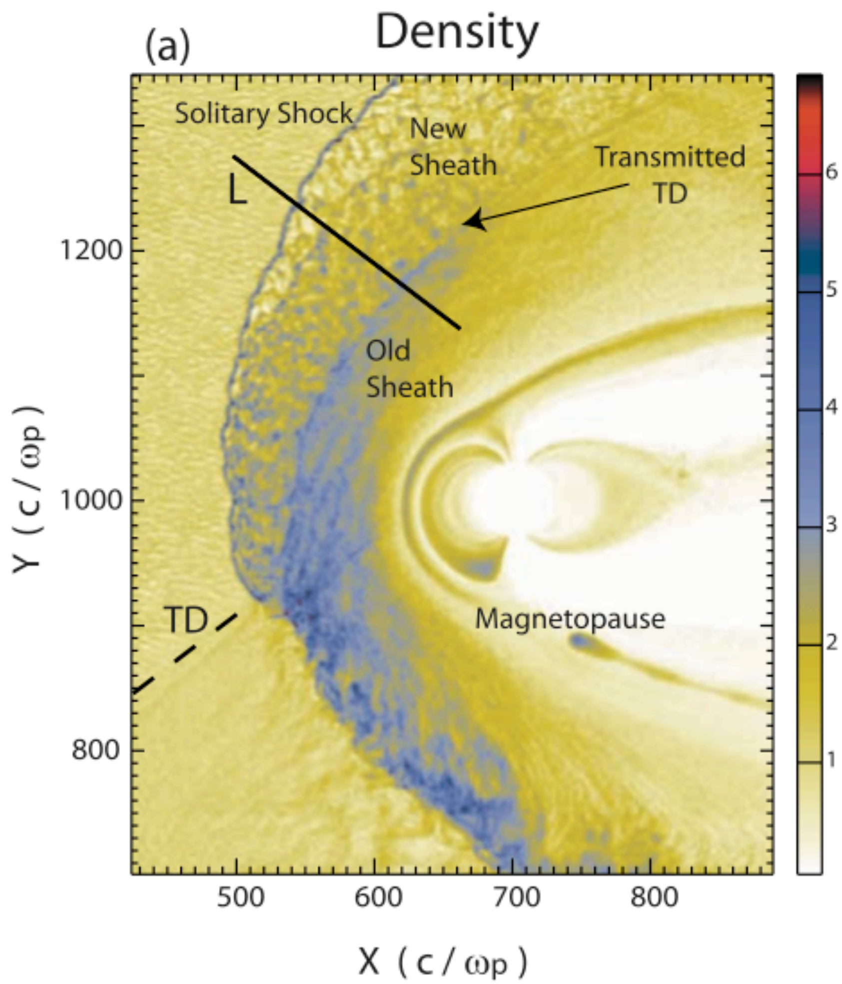
9. MHD validity - kinetic effects?

- Omidi and Sibeck, JGR, 2007
- interaction of a tangential discontinuity with the bow shock forms a 'solitary shock'
- not sure this is related



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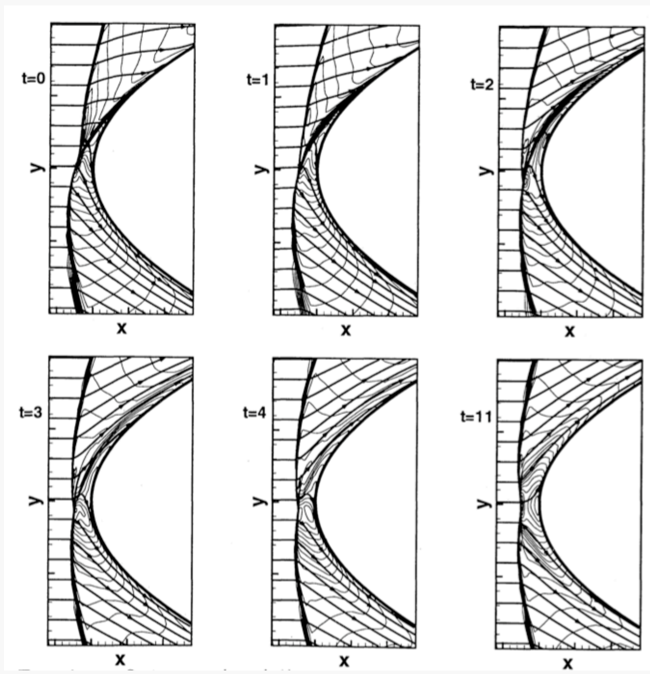
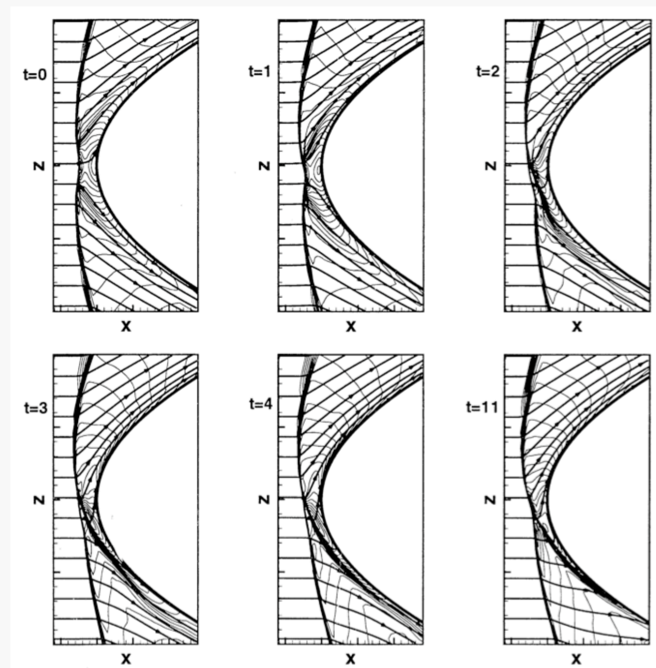
10. time-dependence, intermittency

- secondary slow shock can form and disappear, reconfigure
- De Sterck and Poedts, JGR, 2001





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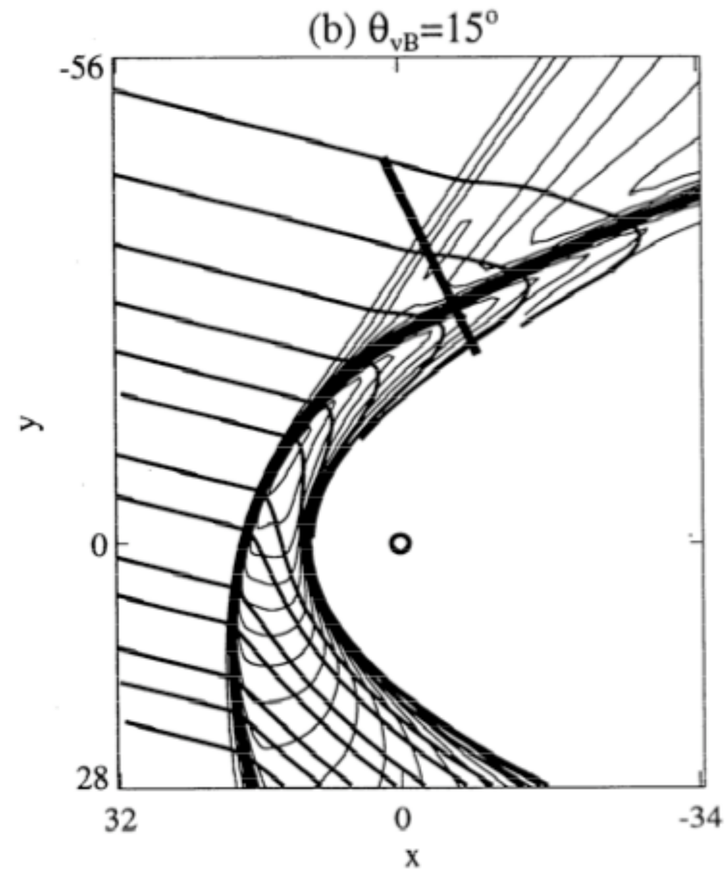
conclusions

- MHD predicts that secondary slow shock may form in magnetosheath
- solar wind conditions: 2% of time for solar minimum, short-lived (hours)
- magnetic clouds?
- how can this be observed? - nobody has looked yet
- may lead to temporary reconfiguration of magnetosphere - large-scale effects? (reconnection, ...)
- acknowledge support from CSA through CGSM program



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questions?

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