Diagnostics of Solar Wind Processes Using the Total Perpendicular Pressure

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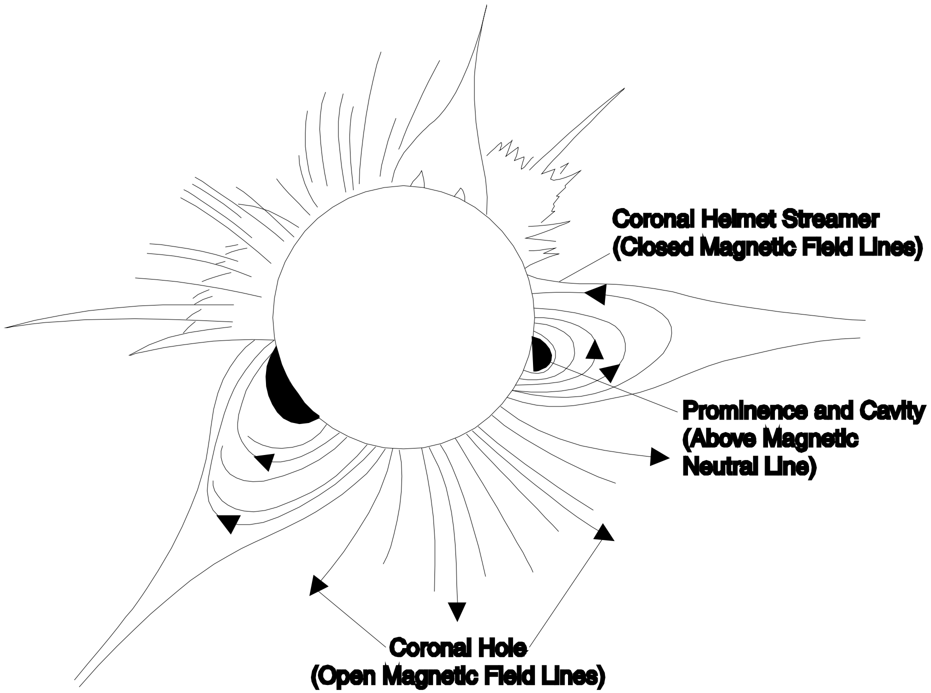
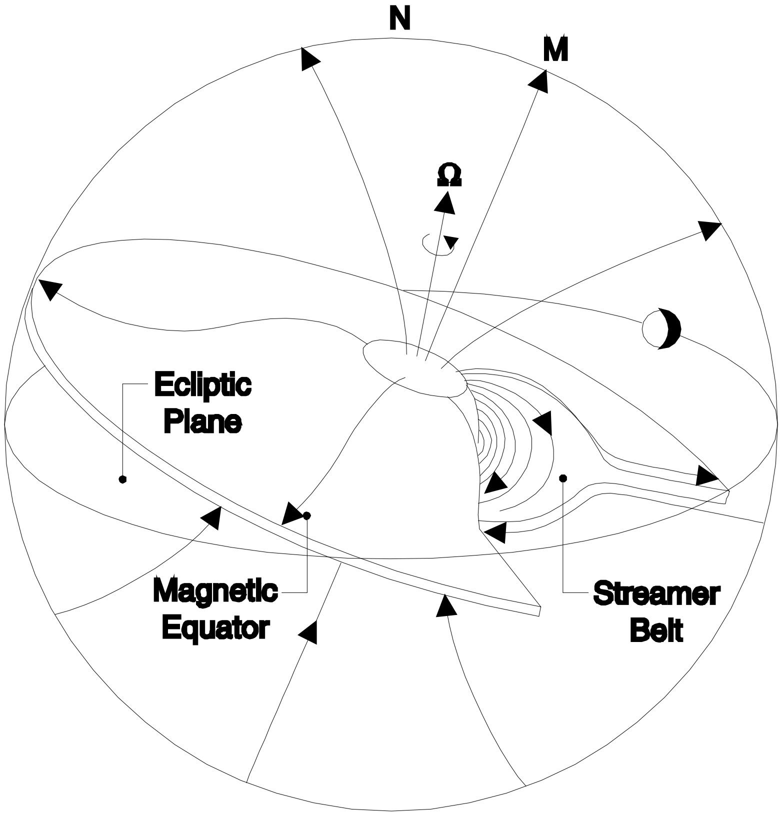
- How does the magnetic structure of the Sun lead to stream interaction regions (SIRs)?
- What are interplanetary coronal mass ejections (ICMEs)?
- Total perpendicular pressure as a solar wind diagnostic parameter
- Examples of SIRs
- Examples of ICMEs
- Conclusions



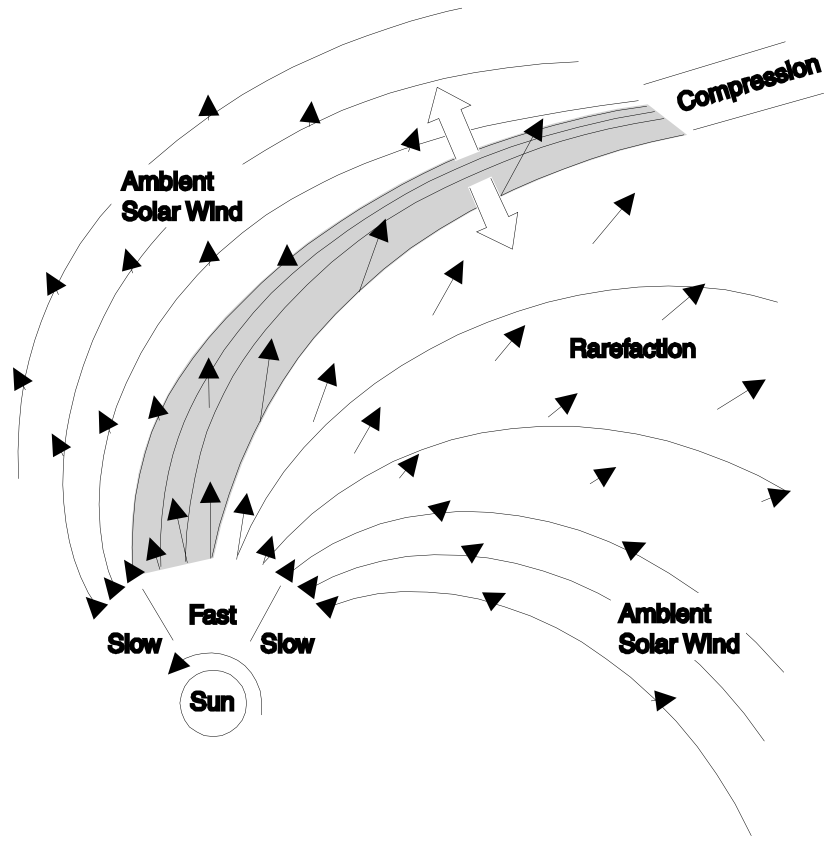
Formation of Stream Interaction Regions

- Magnetic structure of corona controls solar wind velocity
- Solar wind speed is slowest near the heliospheric current sheet
- If current sheet is in rotational equator, there would be no fast-slow stream interaction
- When magnetic axis rotates away from rotation axis, the fast plasma can take over slow plasma
- Fast stream should be encountered after heliospheric current sheet crossing



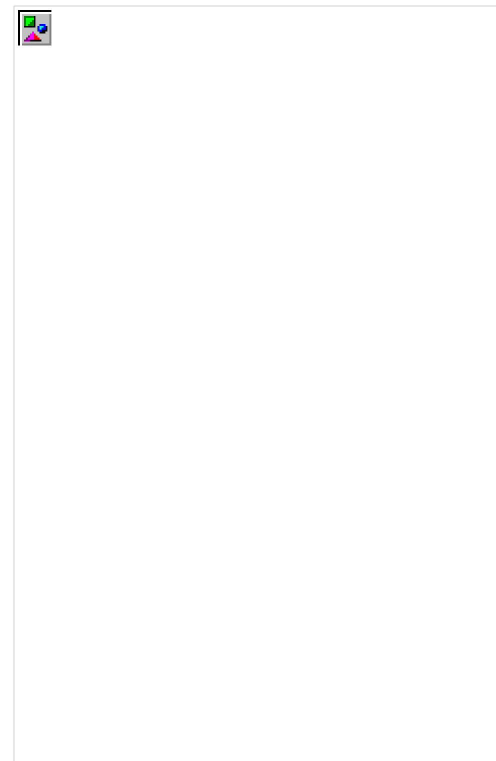
Evolution of Stream Interaction Regions

- SIRs arise from steady state streams on the solar surface
- As the streams move away from the Sun and collide, their signature evolves
- The density and magnetic field between the streams are compressed. The plasma temperature is increased
- If the velocity jump is sufficiently large relative to the compressional wave speed, then one or more shocks may arise: one forward, one reverse
- Far from the Sun, the SIRs coalesce



Structure and Evolution of Interplanetary Coronal Mass Ejections

- Interplanetary Coronal Mass Ejections (ICMEs) arise from transient disturbances on the Sun
- ICMEs may play an important role in the evolution of the photospheric magnetic field during the solar cycle
- Magnetic structures (clouds, flux ropes) are seen in the center of many of these disturbances
- ICMEs often have leading shocks, declining velocity profiles, low proton temperatures



Observational Characteristics of SIRs and ICMEs

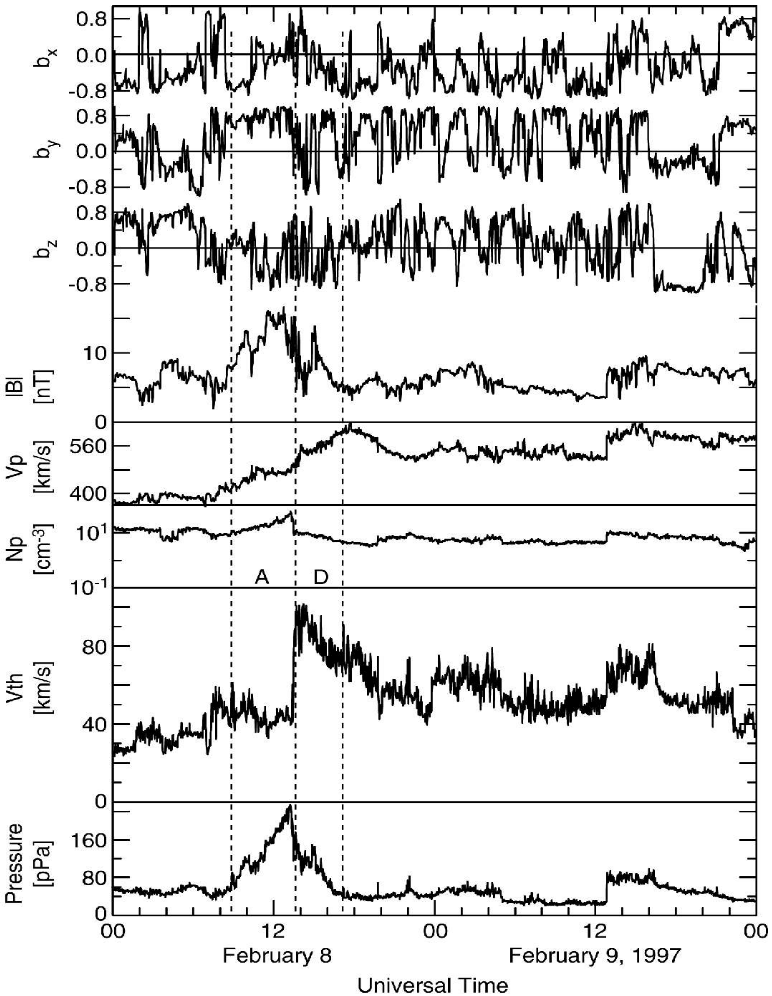
1. SIRs occur where V_{sw} is increasing, not decreasing
2. ICMEs often occur where V_{sw} is decreasing because they are expanding
3. SIRs often occur near the heliospheric current sheet
4. SIRs should result in density and temperature maxima on the SIRs
5. ICMEs often have magnetic flux rope signature, strong rotating field
6. SIRs and ICMEs both strongly affect the direction of the solar wind flow

What is total Perpendicular Pressure?

- Magnetic field exerts no pressure along its length but plasma does
- Magnetic field and plasma both exert a pressure force perpendicular to the field direction
- Total perpendicular pressure is $B^2/2\mu_o + n_i kT_i + n_e k T_e$
- Signatures of processes in the perpendicular pressure are usually much simpler than the signatures of the constituent components
- Irregularities in perpendicular pressure are smoothed by compressional waves
- Sudden discontinuities are caused by shocks

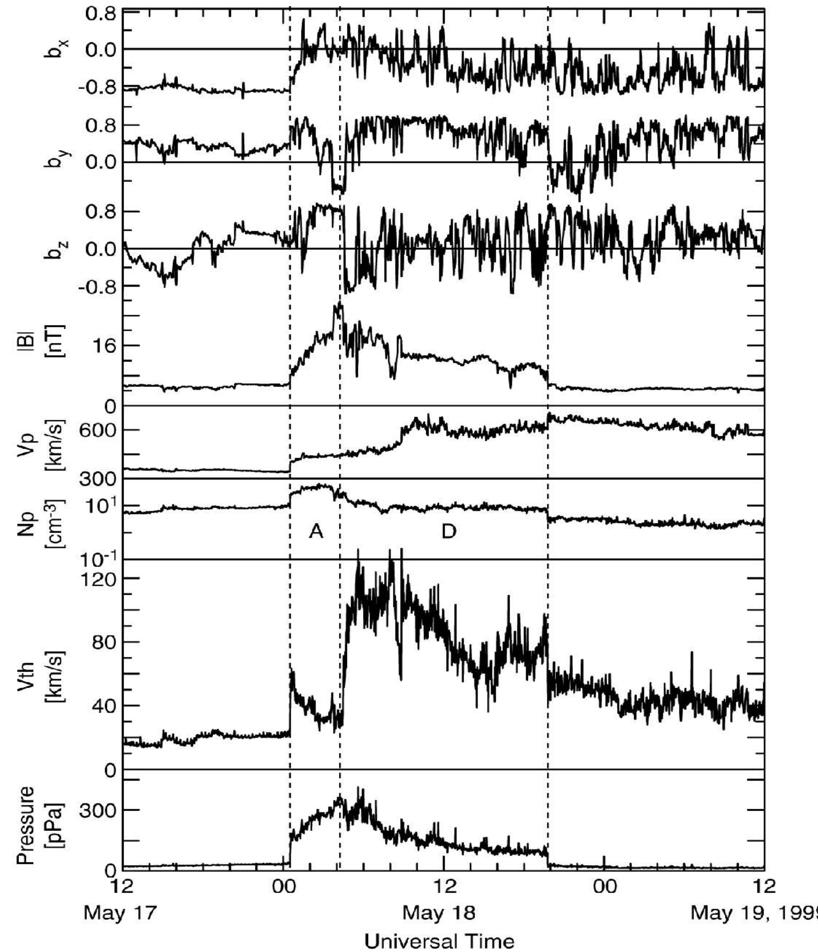
Example 1: Perpendicular Pressure of a SIR

- Simple profile: acceleration phase followed by deceleration phase on increasing speed profile
- Component variations complex:
  - magnetic pressure irregular
  - thermal speed constant and density rise in acceleration phase
  - sharp density drop at interface; density and thermal speed gradually decline in deceleration phase



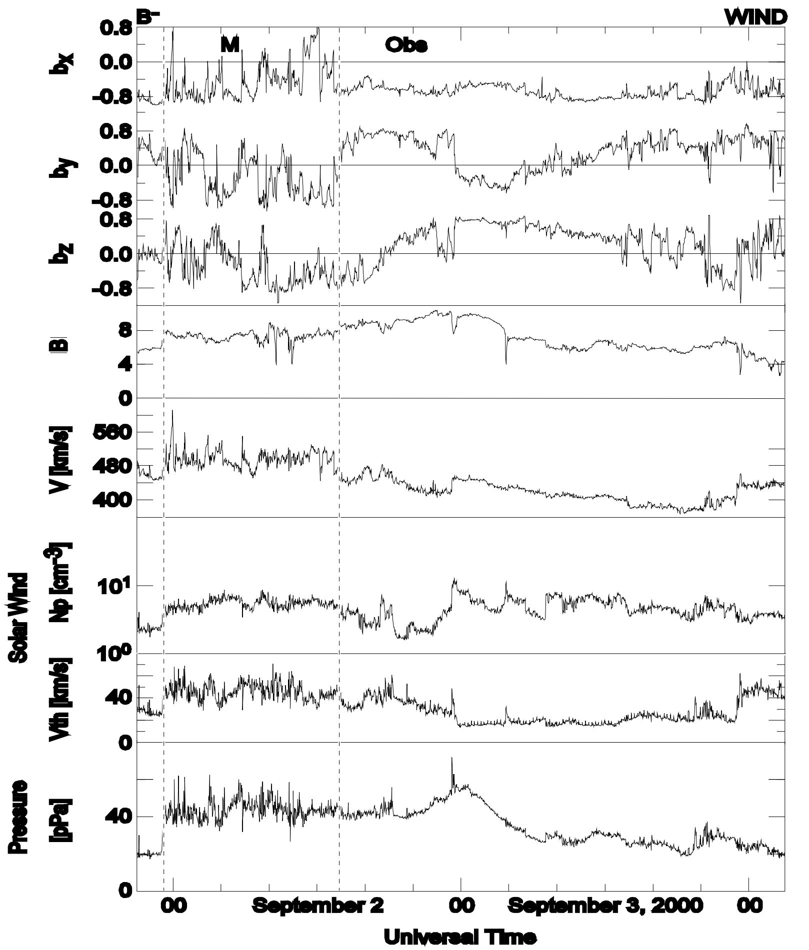
Example 2: Perpendicular Pressure of a SIR

- Perpendicular pressure enhancement bounded by shocks
  - Acceleration phase has temperature decrease while pressure increases.
  - Deceleration phase has declining thermal speed and density.
  - Magnetic field qualitatively similar to pressure
- Lack of rotation in field and occurrence on increasing speed profile mark this as a SIR
- Pressure and field strength profile mimic those of ICME



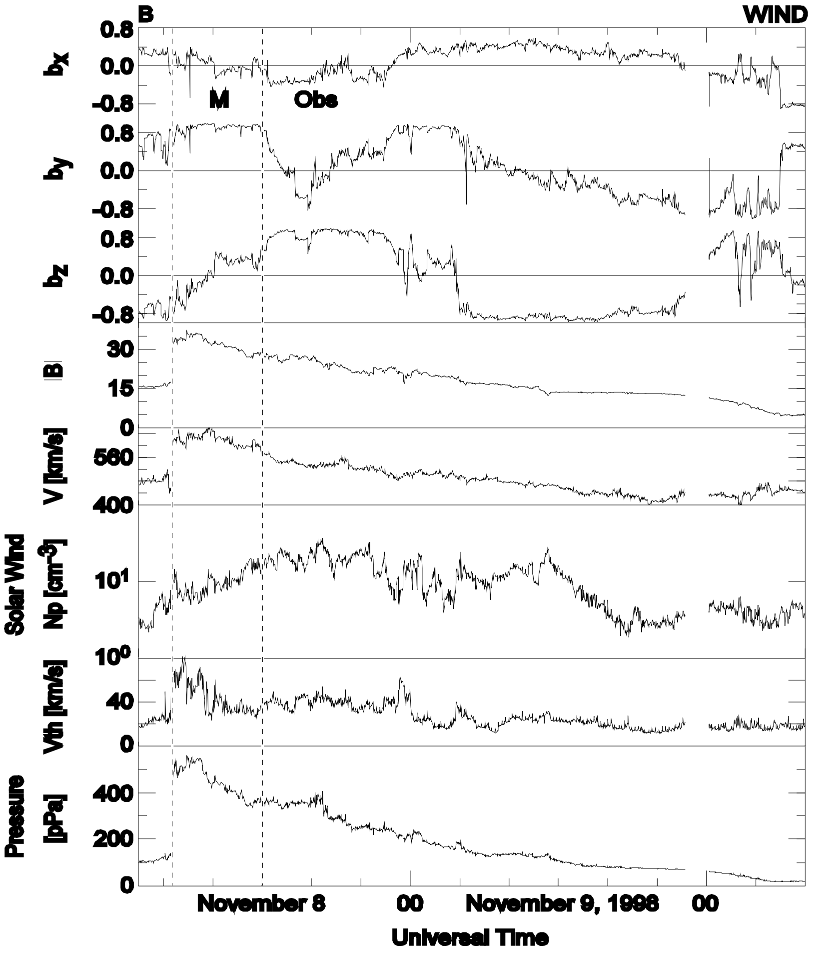
Example 3: Perpendicular Pressure of an ICME

- Leading shock followed by magnetosheath and magnetic obstacle
- Pressure profile much simpler than variations in components
- Declining velocity profile
- Rotating field in obstacle



Example 4: Perpendicular Pressure of an ICME

- Leading shock with possible magnetosheath
- Pressure decreases monotonically after shock
- Obstacle beginning not clear
- Density increases initially while pressure decreases



Conclusions

- It is force that drives the evolution of solar wind structures. The force is the gradient of the total perpendicular pressure.
- Total perpendicular pressure generally has a simple temporal variation, smooth except for shocks.
- The temporal variations of the components of total pressure are not simple.
- The perpendicular pressure can simplify the identification of different types of interactions.
- We recommend total perpendicular pressure as a useful diagnostic parameter for solar wind interactions.