**Abstract**

A key obstacle in the way of productive realistic simulations of the Sun-heliosphere system is the lack of a first-principles understanding of coronal heating. Also, it is still unknown whether the solar wind is "fast" through flux tubes that remain open and are expelled by footpoint-driven void-fill fluctuations or if mass and energy are input dominantly from closed loops into the open field regions. In this presentation, we discuss self-consistent models that assume the energy comes from solar Alfvén waves that are partially reflected, and that are dissipated by magnetic dissipation (MD) turbulence. These models have been found to reproduce many of the observations of the fast and slow solar wind without the need for artificial "heating functions" used by earlier models. For example, the model predicts a variation with wind speed in a commonly measured ratio of charge states and elemental abundances that agrees with observed trends.

This presentation also reviews two recent comparisons between the models and empirical measurements: (1) The model successfully predict the amplitude and radial dependence of Faraday rotation fluctuations (FRFs) observed by the Helios probes for heliographic distances between 2.1 and 15 solar radii. The FRFs are a particularly sensitive test of turbulence models because they depend not only on the plasma density and Alfvén wave speeds but also on the geometric and magnetic correlation length. (2) The model predicts the correct sense and magnitude of changes seen in the polar high-speed solar wind by ITrace from the previous minimum (1996-1997) to the more recent polar minimum (2008-2009). By changing only the magnetic field in the polar magnetic flux tube, consistent with solar and heliospheric observations at two epochs, the model correctly predicts that the wind speed remained relatively unchanged, but the CIV density and temperature decreases by approximately 20% and 10%, respectively.

**Fast & Slow Solar Wind from Varying Flux-tube Expansion**

- For a single choice for the photospheric wave properties, the Cranmer et al. (2007) models produced a radially range of slow and fast solar wind conditions by varying only the coronal magnetic field.

- The superadiabatic flux tube expansion gives rise to multiple "potential walls" in the solar corona in the region of strong vacuum states. The transition criterion is only studied in the narrow case of an adiabatically evolving flux tube (see also Vainio et al. 2006).

- Note that the models produce variations in (1) Bright in situ charge states and (2) FIP-sensitive abundance ratios that very similarly to the in-situ composition measurements. The FIP fractionation was computed using Lavraud’s (2004) wave-velocity theory.

- This seems to contradict the commonly held assertion that slow- and fast- and charge- and composition can only be explained by the injection of plasma from closed-field regions on the Sun (see also Peet et al. 2010).

**Faraday Rotation Fluctuations as a Probe of Turbulent Scales**

- The transition remains on the law of the light (LOT) integral of the product of electron density and the LOT-component of the magnetic field

- The Faraday rotation fluctuations (FRFs) depend on variations in density and magnetic field (see Hollweg et al. 2010)

- The term depends on turbulent correlation length of magnetic fluctuations

- The CRF10 (2007) models used Hollweg’s (1986) assumption that the correlation length scales with the width of the flux tube (i.e., B⊥/B∥), and that it is dominated by the plasma anisotropy of C-band bright points (i.e., B⊥<20% in the photosphere).

- The CRF10 (2007) models used Hollweg’s (1986) assumption that the correlation length scales with the width of the flux tube (i.e., B⊥/B∥), and that it is dominated by the plasma anisotropy of C-band bright points (i.e., B⊥<20% in the photosphere).

**Motivations**

Two distinct classes of theoretical explanation have been proposed for the combined puzzles of coronal heating and solar wind acceleration:

1. **By way turbulently driven (WBD) models**, coronal jets open flux tubes, producing Alfvén waves that propagate up, partially reflect, cascade to smaller scales, and dissipate it.

2. **Constitute loop-opening (LO) events**, in which reconnection at the coronal base is the dominant source of mass and energy into open-field regions, via "inertial" reconnection in the Sun’s magnetic field.

- There is natural appeal to the RLO idea, since only a small fraction of the Sun’s magnetic flux is open at any one time. The magnetic reconnection is continuously evolving a reconnection region (e.g., Plante & Priest 2004).

- However, Cranmer & van Ballegooijen (2009) estimated that the energy lost in loop-opening RLO events is far smaller than that needed to heat the corona or accelerate the solar wind.

- We know that MHD waves and turbulent fluctuations are present everywhere from the photosphere to the base of the corona, so it is worth while to investigate what impact they have on heating acceleration.

**The Peculiar 2008–2009 Solar Activity Minimum**


- **Solar coronal holes** are smaller, with lower field strengths, and there are more coronal holes.

- The latitude spread of the streamer zone is larger.

- The high-speed wind has a lower magnetic flux, lower density, and lower temperatures, but comparable outflow speed.


**Faraday Rotation Fluctuations and Magnetic Correlation Lengths**

- The models predict both the sense and magnitude of the changes seen in the polar high-speed solar wind by ITrace.

- By changing only the magnetic field in the polar magnetic flux tube, consistent with solar and heliospheric observations at two epochs, the model correctly predicts that the wind speed remained relatively unchanged, but the CIV density and temperature decreases by approximately 20% and 10%, respectively.


**Faraday Rotation Fluctuations and Magnetic Correlation Lengths**

- The models predict both the sense and magnitude of the changes seen in the polar high-speed solar wind by ITrace.

- By changing only the magnetic field in the polar magnetic flux tube, consistent with solar and heliospheric observations at two epochs, the model correctly predicts that the wind speed remained relatively unchanged, but the CIV density and temperature decreases by approximately 20% and 10%, respectively.


**Conclusion**

- Despite significant progress in building and validating models of solar wind processes, we still do not have solid evidence that this mechanism is dominant everywhere in the corona and solar wind. For a contrary view, see, e.g., Kall (2010).

- An important next step in testing is to incorporate the proposed heating processes into 3D global simulations of the Sun-heliosphere system. See Cranmer (2010) for an example of a self-consistent "coronal heating subroutine" for this purpose.

- Finally, it is important for future models to take account of the kinetic and multi-fluid nature of coronal heating and solar wind acceleration, e.g., Kall (2010, March 2008).

**Model Inputs**

- CRF10 (2007) computed self-consistent solutions for turbulent fluctuations & the background plasma along flux tubes going from the photosphere to the heliosphere.

- **The only few parameters** were the radial magnetic field (i.e., the flux tube expansion rate) and the photospheric boundary conditions on the wave power spectrum.

- Self-similar "coronal heating functions" were used, just the following physically-motivated ingredients:

  - **Alfvén waves**: Non-WKB reflection with empirical opacity, turbulent dissipation (using phenomenological rates of Hollweg et al. 2009; Matthaeus et al. 1991; Drudek et al. 2001, 2002), and wave-pressure acceleration.

  - **Acoustic waves**: Shock steepening, TAE and conduction, Alfvén wave reflection, 
   above cutoff; A-WKB pressure acceleration.

  - **Radiative losses**: Transitions from an optically thin (EIT) to optically thick (CHANTI + FLOOD) cooling rate.

  - **Magnetohydrodynamical effects**: Collisionless (electron & mirror) I to collisional "free-streaming" electron conductivity.

- The Sun’s mass loss rate was determined self-consistently by allowing the height and properties of the Transition Region to "float" until a static and stable-state solution was found.


- **“interchange” reflect, upper cutoff, A-WKB pressure acceleration.**