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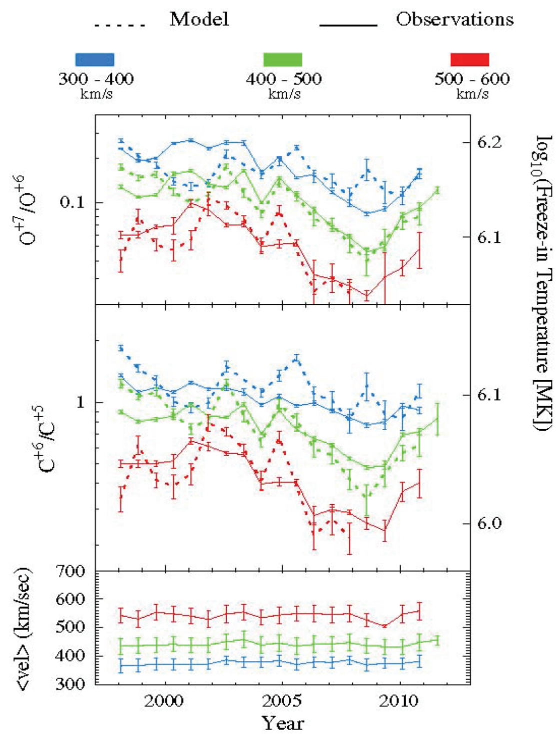
Coronal Electron Temperature in the Protracted Solar Minimum, the Cycle-24 Mini-Maximum, and over Centuries

The acceleration of the solar wind requires an energy source that is today not well understood. Parker's original theory invoked electron heat flux. Many theories make use of wave propagation and several resonant or non-resonant dissipation processes. Still other theories invoke magnetic reconnection or turbulence. At present, our most detailed insights are provided by measurements of the solar wind atomic, isotopic and charge-state composition in union with theoretical treatments that attempt to understand the relative efficiency of acceleration for different particle types.

Charge state composition provides a direct indication of electron temperatures (mean energy) within the acceleration region. Hot electron backgrounds produce solar wind ions with greater charge states. ACE has been instrumental in revealing charge-state variations in association with different wind speeds which strongly indicates that fast and slow winds originate in regions of different electron temperature (called freeze-in temperature). This, in turn, provides insight for theories attempting to describe the altitude above the solar photosphere where the acceleration takes place.



Coronal freezing-in temperature deduced from O^{7+}/O^{6+} and C^{6+}/C^{5+} charge state ratios (solid curves).

The data show that charge states (e.g., the O^{7+}/O^{6+} and C^{6+}/C^{5+} abundance ratios) evolved through the extended, deep solar minimum between solar cycle 23 and 24 (i.e., from 2006 to 2009) reflecting cooler electron temperatures in the corona. Schwadron et al. (2014) extended previous analyses to study the evolution of the coronal electron temperature through the protracted solar minimum and observed not only the reduction in coronal temperature in the cycle 23-24 solar minimum, but also a small increase in coronal temperature associated with increasing activity during the "mini-maximum" in cycle 24. The study went on to use a new model of the interplanetary magnetic flux since 1749 to estimate coronal electron temperatures over more than two centuries. The reduction in coronal electron temperature in the cycle 23-24 protracted solar minimum is similar to reductions observed at the beginning of the Dalton Minimum (~1805 - 1840), when the estimated freeze-in temperature for 500-600 km/s wind dropped to ~1 MK. If these trends continue to reflect the evolution of the Dalton Minimum, then in the future we will observe further reductions in coronal temperature in the cycle 24-25 solar minimum. Preliminary indications in 2013 do suggest a further post-cycle 23 decline in solar activity. Thus, the work of Schwadron et al. (2014) extends understanding of coronal electron temperature using the solar wind scaling law, and compares recent reductions in coronal electron temperature in the protracted solar minimum to conditions that prevailed in the Dalton Minimum. For additional information see Schwadron et al., JGR 119, 1486, 2014.

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