New Perspectives on Solar Prominences, IAU Colloquium 167
ASP Conference Series, Vol. 150, 1998
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Observations of the Association of Prominences and the Surrounding Corona

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Abstract. Emission-line coronal images in Fe XIV (530.3 nm) and FeX (637.5 nm) show faint enhancements at the location of quiescent prominences. Such enhancements can appear in the outer portions of a prominence, similar to the high-temperature sheath surrounding prominences as inferred from UV and EUV observations. The observational evidence supports the interpretation that this enhanced coronal emission is due to energy carried by the prominence threads and dissipated in the adjacent coronal region. Also, observed coronal loop interactions involving partial magnetic reconnection have associated Hα structures. These structures can have the appearance of an active prominence, similar to those typically observed in post flare loop systems. It appears that the association of such active prominences with the adjacent corona is fundamentally different from that of quiescent prominences. The observations indicate that these types of active prominences arise simply as a consequence of reconnection processes in the corona itself.

1. Introduction

Observations of quiescent prominences in UV and EUV lines reveal critical information about the prominence-corona transition region (PCTR). It is inferred that the outer layers of a prominence form a transition zone in a shell-like structure, or sheath, between the cool prominence itself and the hot corona. It is assumed that individual threads within a quiescent prominence also have a PCTR (e.g., Orrall and Schmahl 1976, Chiuderi Drago et al. 1992). But regardless of the exact distribution of sources of the PCTR within, or around, a typical quiescent prominence, the data lead to estimates of very small scale thicknesses (<100

https://doi.org/10.1017/S0252921100047242 Published online by Cambridge University Press

km) for the separate layers, each corresponding to one temperature regime as characterized by a given line emission (Schmahl et al. 1974).

Observations with a 20-cm aperture emission-line coronagraph reveal occasional anomalous emission associated with quiescent prominences. The coronagraph records images in FeXIV (530.3 nm; $T\sim2\cdot10^6$), FeX (637.5 nm; $T\sim10^6$), and Hα. A particular case from these data that showed relatively strong prominence–associated coronal emission has been described (Smartt and Zhang 1984). As seen in the red-line image, the initially faint emission gradually changed in form over several hours to become concentrated around the periphery of this compact prominence, appearing as an enhanced band of coronal emission outlining the prominence. While much weaker, the green-line image also evolved to a similar form. The half-widths of the legs of these coronal enhancements were $\sim4\cdot10^3$ km for the red-line image, and $\sim3\cdot10^3$ km for the green-line image.

Since the PCTR, as observed in UV and EUV lines, spans the temperature transition between the cool prominence material and the ambient corona, it appears that the above visible-line coronal observations are not strictly part of the PCTR, except perhaps for some contribution from the low-temperature tail of the ionization equilibrium curve for FeX. Therefore it was concluded that these enhancements were evident primarily because of an enhanced density and/or temperature in this region. Density estimates for the PCTR for quiescent prominences have been found to be only marginally greater than those of the ambient corona (Wiik et al. 1994). For example, using line-sensitive line ratios of CIII, an average value of 1.3 10^9 cm^{-3} was found for the density within the interface where CIII is formed (T = $9\cdot10^4$K) (Orrall and Schmahl 1976). Hence, it was further concluded that the observed visible coronal emission is due principally to a significant increase in the temperature in this region resulting from energy dissipation from the prominence to the adjacent coronal volume.

The observed relationship between visible coronal emission and quiescent prominences is extended to post-flare loop systems and the associated active prominences.

2. General Characteristics of Visible Corona/Quiescent Prominence Observations

a) In about 80% of the cases studied, red-line emission is evident, but mostly extremely weak, and typically showing only as fine features at the location of one or more of the central pillar-like structures in the prominence. These features can evolve in form and brightness, but such changes are usually evident only on time scales of hours.
b) If a red-line image is brighter, a corresponding green-line image is then evident, but is invariably weaker than the red-line image.
c) In most, but not all cases, the structure is similar in the two images.
d) Occasionally a red-line image appears to be surrounded by a coronal cavity, possibly a circumstance where the line-of-sight is along the long axis of the prominence. Such a cavity is usually only marginally apparent in the green-line image, the difference due possibly to the greater number of loops that appear in the green-line corona in general, as compared with the red-line corona, and hence the greater likelihood that foreground and background loops will obscure

such a cavity.

2.1. Interpretation

Coronal emission observed in association with quiescent prominences is due to energy released through processes intrinsic to the prominence structure and hence complex field configurations, but at a level that barely excites red-line emission and rarely green-line emission. The possible contribution to coronal heating by the propagation and damping of slow-mode, fast-mode, and Alfven MHD waves in a prominence has been investigated (Smartt and Zhang 1984). We have also considered the possibility that resonant absorption of surface Alfven waves produces the observed prominence-related coronal enhancements. In brief, surface Alfven waves generated at the photosphere propagate upwards along a magnetic loop. Energy flux conservation implies that the amplitude of a surface Alfven wave, δV, is proportional to $B^{-1/2}$ (Hollweg 1990) and, therefore, rapidly increases as the waves travel from the photosphere, through the chromosphere and into the transition region and beyond. For such a wave, δV reaches a maximum at the surface of the loop (prominence) and decreases rapidly towards the center, forming a velocity shear. Eventually, if the velocity shear associated with the Alfven waves becomes sufficiently large, a Kelvin-Helmholtz instability will be initiated in the outer parts of a loop, as shown numerically by Ofman and Davila (1994). This process converts the wave energy into MHD turbulence, the fluid motions directed primarily perpendicular to the magnetic field. The consequent large-scale turbulence is then expected to cascade to smaller sizes that are efficiently damped through viscous and ohmic dissipation processes. Our estimates of the heating rate show that large-scale motions initiated by a non-linear Alfven wave would introduce non-thermal broadening in high-temperature lines, $\sim$15 km/s for typical parameters in the thin outer layers of a prominence, which could be checked observationally.

3. Characteristics of Visible Corona/Active Prominence Systems

a) Coronal structures can differ between the two coronal line images, and these are often substantially different from the prominence Hα structure itself.
b) The green-line image is invariably brighter than the red-line image.
c) In one case where there was a small, detached portion of a prominence at a height $\sim 140 \cdot 10^3$ km (highest part), there was a corresponding red-line feature at a height $\sim 180 \cdot 10^3$ km, and a similar, but fainter green-line feature at a height $\sim 230 \cdot 10^3$ km.
In the case of post-flare loop prominence systems:
d) Hα and coronal loops are typically present, but the loops are not coincident.
e) Faint, extensive diffuse emission can also appear in association with these systems in both coronal images.
f) Localized transient brightenings in the form of coronal loop interactions (CLI) are observed in visible coronal loop systems, especially evident in association with post-flare loops. Following a loop interaction, Hα can appear at the site of the interaction, typically increasing slowly in size and eventually linking with the surface.

3.1. Interpretation

The appearance of faint coronal emission at sites above a small detached portion of a prominence (as seen in Hα) suggests reconnection occurring higher in the corona (Schmeider et al. 1995). A CLI is interpreted as partial magnetic reconnection involving the coalescence instability (Smartt et al. 1993, Airapetian and Smartt 1995). At the onset of a CLI, it is found that the local plasma volume at the interaction site increases abruptly in density and temperature, followed by gradual cooling, with a maximum in the green-line image followed a few minutes later by a maximum in the red-line image and the eventual appearance of Hα, an obvious consequence of the interaction. It is noted that loop prominences associated with post-flare loops systems are usually interpreted as a result of reconnection via the Kopp-Pneuman (1976) model. In general then, for this class of active prominences, where the green-line signature is invariably brighter than the corresponding red-line component, we suggest that the Hα material is a direct outcome of reconnection in the corona.

4. Conclusion

Enhanced visible coronal emission observed in association with quiescent prominences is due to the dissipation of energy, associated with the prominence threads, into the immediate coronal environment. The level of this dissipation energy is biased towards the lower-temperature 637.5 nm (FeX) coronal line, rather than the higher-temperature 530.3 nm (FeXIV) line. In the case of post-flare loop systems, active prominences arise principally as a bi-product of reconnection in the corona itself. These can involve reconnection associated with the whole loop system, or simply local reconnection within the loop system at the site of a coronal loop interaction.

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