The spatial distribution of EUV emission in active regions

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Abstract. The full version of this paper will be published elsewhere. We give here only an extended abstract.

In order to understand fully how active regions are heated we need not only to be able to find a mechanism that will meet the observed energy requirements, but also to be able to explain the thermal structure of the region. Previous studies of active region structure and dynamics have indicated that there are significant differences in the properties and relationships between structures of different temperatures. For example, it has become clear that non-thermal velocities, Doppler flows and dynamics or time variability of high arching cooler loops are much greater than in hotter loops.

Using observations from the Coronal Diagnostic Spectrometer (CDS) on SoHO and the Soft X-ray Telescope (SXT) on *Yohkoh* we investigate how some of the properties of active region loops observed in the EUV and X-ray range vary with temperature. We examine the spatial distribution of the emission using correlation techniques and Fourier methods with which we obtain the two dimensional power spectrum of the intensity distribution for a number of lines at different temperatures. Integrating this over polar angle we find isotropic power-law behaviour at all temperatures in a number of topologically different active regions, with a tendency for flatter spectra at lower temperatures. The existence of power-law spectra indicates that there is no preferred length scale within the regions, while flatter spectra at lower temperatures indicate that the structures are relatively smaller in this temperature range, possibly providing support for the idea of a multi-component transition region (TR).

Our results show that a change in behaviour of the plasma can be found between temperatures of approximately < 5.9 in the log and > 5.9 when we take correlations between intensity maps at adjacent temperatures and relative to the coolest line in our disk studies. This behaviour is seen for four different active regions and appears to be independent of position on the disk. The contrast of loops on the limb and on the disk relative to the background emission also shows a similar difference in these two temperature regimes, remaining uniformly low at higher temperatures. In terms of standard static loop models the behaviour of the correlations could be understood if we assume that the emission at lower temperatures comes from a combination of cool loops and the footpoints of hot loops. In this case we would expect only limited correlation with hotter emission. If the emission in the intermediate temperature range, log T=5.9-6.0, comes exclusively from the footpoints of hot loops, and the emission hotter than this from the coronal parts of the loops, then again we would expect little correlation with hotter material for the intermediate range. The behaviour of the contrast on the disk at coronal temperatures is however not well understood in terms of the standard model. We would expect greater contrast in the corona than in the transition region. The fact that we see the opposite behaviour could be due to a greater filling factor in the corona, as suggested by Schrijver et al. (1999), or it could be that the assumption that all the emission comes from loops well described by the standard model is incorrect.

The existence of broad-band power-law spectra at all temperatures in topologically different active regions indicates that there is no preferred size scale for this emission. It may also indicate that turbulence plays a role in determining the structure and ultimately the heating of the corona. Hollweg (1983) suggested that kinetic energy injected over large scales by sub-photospheric convective motions might cascade down through non-linear interactions to scales where viscosity and resistivity could produce effective dissipation. In Fourier terms this translates into a broad-band isotropic spectrum with energy injected at low wavenumbers and the dissipation region at high wavenumbers. The region between, the inertial regime, is dominated by non-linear interactions, and this region is characterized by the power-law index. However, the value of this index is -5/3 for hydrodynamic turbulence (Kolmogorov, 1941) and -3/2 for the MHD case (Kraichnan 1965), considerably less negative than the -2.1 to -3 reported from NIXT, SXT and EIT observations (Gomez et al. 1993; Martens & Gomez 1992; Benz et al. 1997 and Berghmanns et al. 1998) and the -1.6 to -3.5 that we have found from CDS observations. There may be several reasons for this discrepancy. Firstly, if the coronal magnetic field is passively controlled by the sub-photospheric turbulence, then the power-law index of the coronal emission is not expected to be the Kolmogorov or Kraichnan values (Gomez et al. 1993). But even if turbulence develops in the corona itself, the intertial regime is likely to begin near the smallest observable scales and extend to sub-resolution sizes; most of the observed spectrum is outside of this range. Finally, it is not obvious how the kinetic energy density spectrum of the turbulent eddies - to which the Kolmogorov and Kraichnan indices apply - is related to the power spectrum of the resulting emission pattern.

Our results show that the steepness of the omni-directional spectra changes with temperature, becoming steeper at higher temperatures. The enhanced power at high wavenumbers for low temperatures could be consistent with the bulk of this emission originating in low-lying loops and the footpoints of hotter loops. What this, together with the results for the intensity correlations and contrast, are almost certainly telling us is that the transition region is made up of several components. It appears, when the results of this study are considered in parallel to other investigations, that there are indeed real physical differences between these different temperature plasmas which must be taken into account when modelling potential heating processes. The finer scale structure, sharper contrast and more dynamic behaviour of the cooler plasma suggests a very high degree of both spatial and temporal intermittency in the heating of these structures. The suggestion by Schrijver at al. (1999) that the apparent reduction in contrast with increasing temperature observed by TRACE is in fact due to an increase in filling factor with temperature could be consistent with the possibility that different types of energy release may be occurring. We might expect that a spatially and temporally intermittent energy release process would lead to smaller filling factors than a more homogeneous mechanism.

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