Solar Active Region:Heating and Dynamics

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ABSTRACT

It has been frequently observed that in solar active regions the measured line widths are larger than those based on thermal equilibrium widths. This excess width (characterised as non-thermal velocity, V_{nt}) has been proposed as a signature of the heating mechanism. We analyse the difference in V_{nt} and dynamics of the hot (> 1MK) loops and cool (< 1MK) loops.

1. Introduction

It is well observed that in flaring and non-flaring active regions the line widths are found to be in excess of the thermal width as derived from the assumed equality of the electron and ion temperatures. This excess width has been termed *non-thermal velocity* (V_{nt}) and it is thought to be an indicator of the coronal heating mechanism. Transition region observations (eg Boland et al, 1975, Doschek et al, 1976 and Mariska et al 1978) show that the non-thermal velocity (V_{nt}) increases with increasing temperature ($V_{nt} \propto T_e^{1/4}$). This behaviour is predicted from an Alfvén or acoustic wave propagating without energy dissipation. This is also seen in stars with hot coronae as observed with IUE (Jordan, 1991). However as coronal temperatures are reached the relationship becomes less clear with values ranging between 0 → 100 km/s.

The so-called transition region material in active regions frequently takes the form of loops and not the region which separates the chromosphere from the corona. It is now well known that cool "transition region" loops (< 1MK) are in general more dynamic than the hotter loops (> 1MK).

The purpose of this work is to investigate V_{nt} at coronal temperatures and the relationship this has to the dynamics of the different temperature loops.

2. Observations

For the calculation of the V_{nt} at coronal temperatures we employed data from an observing campaign which took place from the 23 August → 31 August 1997 using the 25 cm coronagraph at the Norikura Solar Observatory and the Coronal Diagnostic Spectrometer (CDS) onboard SOHO (Solar and Heliospheric Observatory). Figure 1 shows the active region as observed by Norikura Observatory and CDS. The values of V_{nt} were determined by using the accurate line widths from Norikura alongwith the temperature diagnostics available from CDS. The range in V_{nt} is from 10-20 km/s which is lower than most of the values previously determined, which emphasizes the difference in behaviour in the hot corona and the cooler transition region (Figure 2).

As mentioned in the introduction it is now well observed that not only do cool ($<$ 1MK) loops exist, but they are also more dynamic than their hotter counterparts. We quantify how dynamic the behaviour is in each temperature regime and relate this to the values of V_{nt} that are now well established. We used a 7 min cadence time sequence of an active region on the limb over a period of 5 hours to calculate the variability. The variability is defined to be the the standard deviation of the derivative of the correlation with respect to time ($\sigma(d(corr)/dt)$) which is shown in Figure 3.

3. Conclusions

For active regions the V_{nt} values previously determined from "transition region" temperatures cannot be assumed to be from layers in the loops, but can be considered to arise from separate entities (Matthews and Harra-Murnion (1997), Feldman (1983)). This subsequently means we cannot think of a wave travelling through this loop which is stratified in temperature, but we must consider each temperature loop as a separate structure. Why then are the larger values of V_{nt} observed in loops that contain lower temperature material?

It is known that for cold OV loops, large flows of order 50-100 km/s have been observed whereas measurements from FeXIV indicate small flows on the order of a few km/s. Wilhelm (1997) discovered Doppler velocities of up to 40 km/s in an active region observed in O VI and the velocity maps are indicative of the presence of whirling motions. We found that the V_{nt} correlates strongly with the variability of the active region loops. This is suggestive of the excess line broadening below 1 MK being caused by multi-directional flows due to the rapidly changing structures.

There are two options to explain the dynamic cold loops. The first is that they exist as a progressive stage to the hotter loops and secondly that they are entirely separate entities. These two options are now being further analysed with data from the Transition Region and Coronal Explorer (TRACE).

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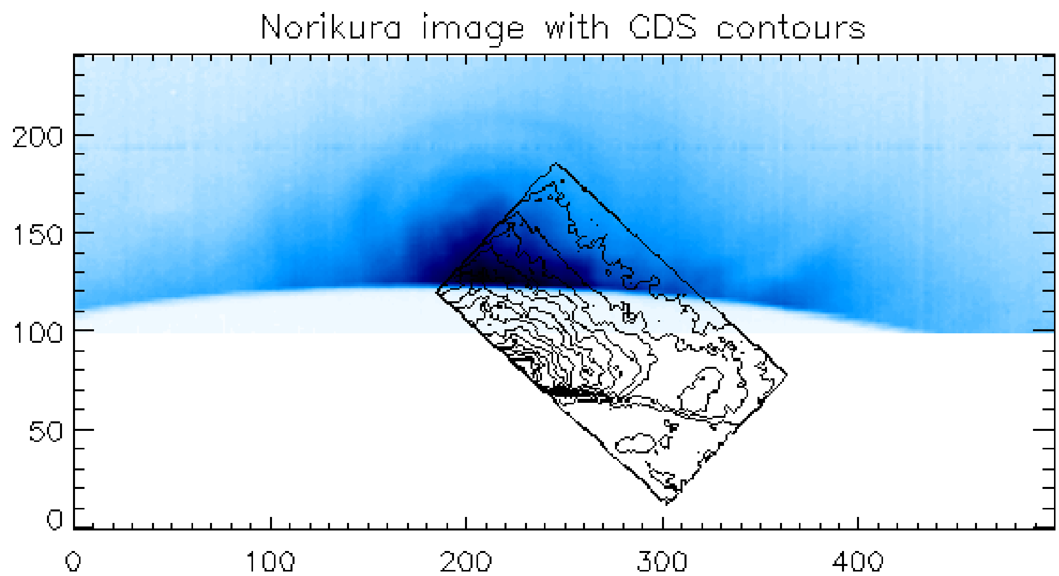

Fig. 1.— Image of AR NOAA 8073 at the limb from the Norikura coronagraph on the 26 Aug 1997 in the coronal green line. The image is 768 × 225 arcsecs. The CDS image is shown in contours (240 × 100 arcsecs). The units are in Norikura pixels.

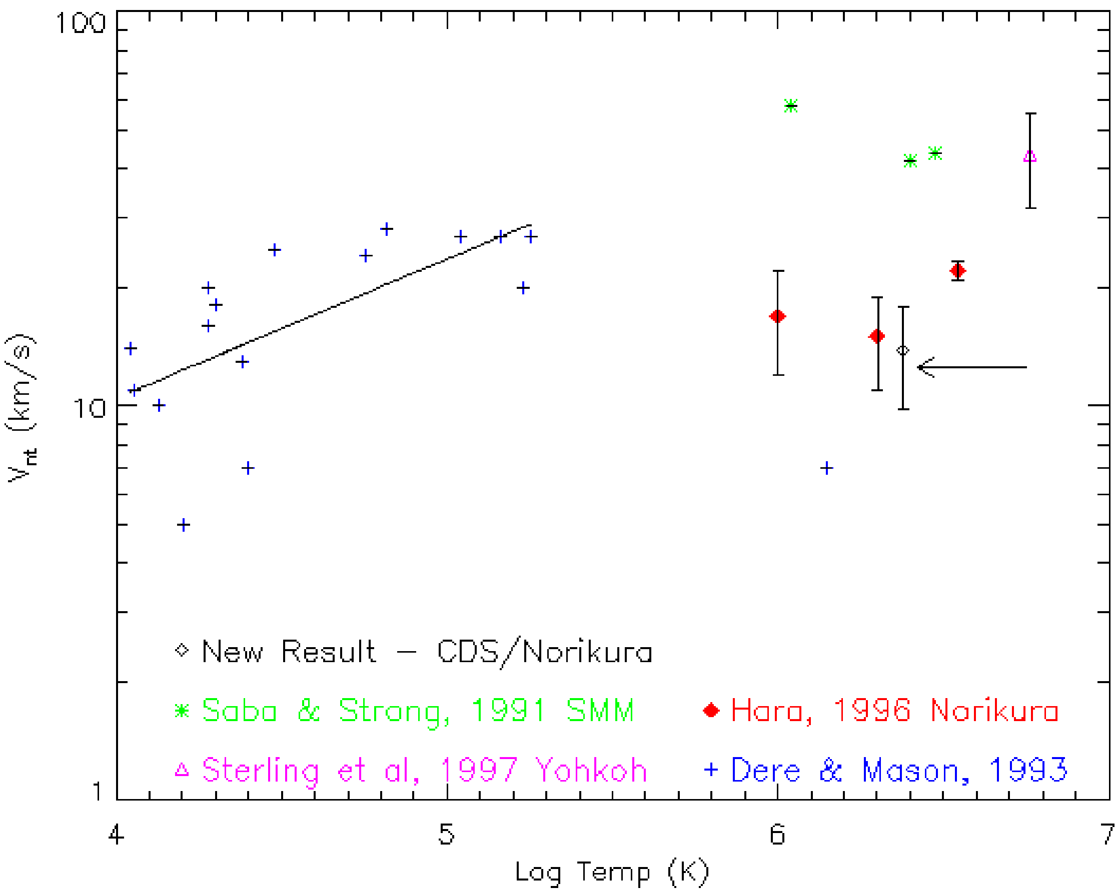

Fig. 2.— This plot illustrates the variation of V_{nt} with temperature. Values of V_{nt} from previous observations are shown alongwith our new result (indicated with an arrow).

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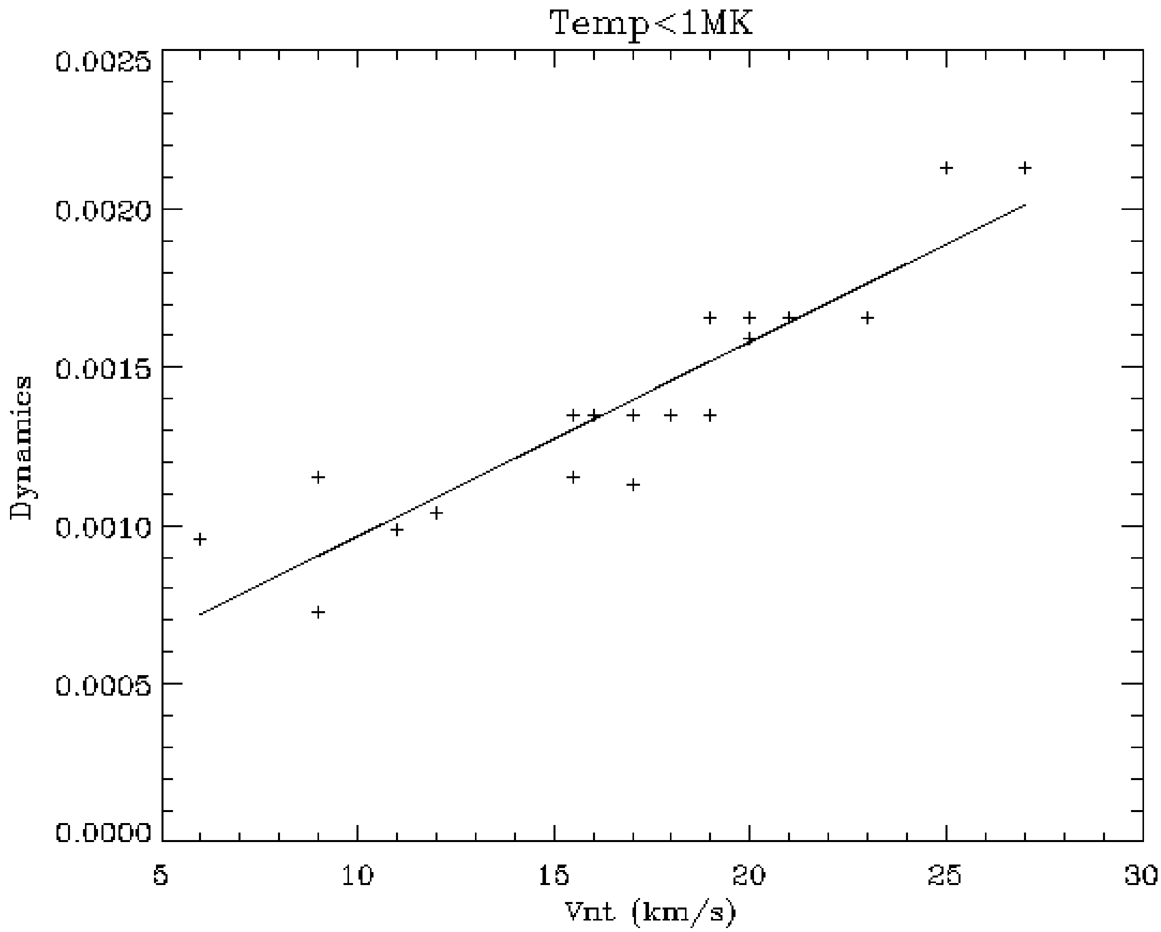

Fig. 3.— The time varibility (dynamics) as a function of non-thermal velocity.