THE ACTIVE SUN*

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Abstract. A brief summary is given of observations which will be required to investigate further the structure and energy balance of active regions.

1. Introduction

Since around 1970 when observations of coronal loop structures were first obtained in the EUV and X-ray regions there has been an increasing interest in the physics of these systems. The forthcoming NASA-Skylab Active Region Workshop Monograph gives extensive reviews of the current state of our knowledge. Only one or two examples of future work are given here. Apart from the obvious difference in the magnetic field configuration the outstanding problems are similar to those which exist for the quiet solar atmosphere. They concern the source of heating for the hot plasma, the energy transport and dissipation mechanisms. Also, the apparent pressure structure and life-times of the loops pose interesting questions regarding the stability of the systems.

2. Temperature and Density Structure

Present knowledge of the densities and temperatures in active-region loops comes from observations made from rockets and satellites, particularly from the instruments on the Apollo Telescope Mount (ATM) on Skylab, although many current ideas originate from earlier work, (see reviews by Jordan, 1975; Vaiana and Rosner, 1978). Whilst there is not a consensus of opinion regarding methods and details there is broad agreement on the typical range of temperature and density structures to be found in active regions (e.g. Cheng, 1978; Landini and Monsignori Fossi, 1975; Rosner et al., 1978). It seems clear that many of the remaining arguments concerning the structure of active regions could be resolved by improving the spatial scale with which observations are made of fluxes in a wide variety of emission lines formed at different temperatures. The wavelength range proposed for GRIST gives ideal coverage of lines formed above \( \sim 2 \times 10^5 \) K.


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In order to progress from the line of sight emission measures, which can be found from emission line fluxes, to information concerning the temperature gradients it is essential to measure accurately the electron density. Although methods are established and atomic data are available (e.g. Dere et al., 1979) the region of \( \sim 170 \text{ Å} - 350 \text{ Å} \) which contains many density sensitive ratios over the temperature range of interest (\( \sim 10^6 - 3 \times 10^6 \text{ K} \)) has not been fully exploited at high spatial resolution. Most density measurements have been made from lines at longer wavelengths formed at \( T_e \approx 2 \times 10^5 \text{ K} \). Whilst these are valuable in studies of the transition region it is important to measure \( N_e \) directly in individual loops, preferably as a function of height.

The density distribution across active region loops is of particular interest since early measurements (Gabriel and Jordan, 1975) suggested that the material in the core of a loop has a lower electron pressure than does that in the hotter surrounding 'sheath'. Observations from ATM supported this conclusion (Foukal, 1975), but this type of measurement needs to be repeated with much better spatial resolution than the 5 arc sec used so far. The pressure in the loop core plays an important part in considerations of loop stability. (e.g. Hood and Priest, 1979).

3. Energy Balance

If the temperature and density structure can be determined with sufficient accuracy then it is possible to deduce the magnitude of the static terms of the energy balance equation – the radiation loss and net conductive flux. Careful Doppler-shift measurements made with high spatial resolution are required to investigate terms associated with mass flows. The form of the energy-input function required can then be investigated. Or, conversely, the results of assuming particular heating mechanisms can be tested against the observed properties.

One of the most urgent observations required is a search for periodicities in line fluxes or profiles, in emission lines formed above \( 2 \times 10^5 \text{ K} \). By working from typical emission measure distributions it can be shown (Jordan, 1976) that if either pure acoustic waves or pure Alfvén waves are heating the region above \( 2 \times 10^5 \text{ K} \) then a spectrum of wave periods is required. A small amount of energy deposition from waves with periods \( \sim 1-10 \text{ s} \) would be needed at around \( 2 \times 10^5 \text{ K} \), with most energy being deposited at the highest temperatures from waves with periods of up to several hundred seconds. The strong lines of Ne \( \text{ vii} \) and Mg \( \text{ ix} \) formed at \( T_e \approx 6 \times 10^5 - 9 \times 10^5 \text{ K} \) perhaps offer the best hope for measuring waves of period \( \approx 100 \text{ s} \). Consideration of the likely Alfvén velocities and hence the wavelengths shows that useful information should be obtainable with a spatial resolution of \( \sim 1 \text{ arc sec} \).

Over the past few years a variety of considerations has led to the conclusion that pure acoustic waves are unlikely to be heating the corona (Athay and White, 1978; Bruner, 1978; Jordan, 1976, 1980). MHD modes cannot as yet be excluded. It will be difficult to distinguish between D.C. Joule heating and MHD waves except
through a search for periodicities. Even in the absence of evidence for wave motions
the degree of non-thermal mass motions is still an important aspect of the energy
balance of the region.

The above observations made with an instrument such as GRIST plus spectro-
graphic equipment, designed to give high spatial resolution, high spectral resolution
and sufficient photon flux to achieve adequate time resolution should surely be
given the highest possible priority in planning future solar physics payloads.

References