STRUCTURE OF THE CHROMOSPHERE-CORONA TRANSITION REGION

R. L. MOORE and P. C. W. FUNG
Institute for Plasma Research, Stanford University, Stanford, Calif., U.S.A.

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Abstract. The structure and energy balance of the chromosphere-corona transition region is investigated by means of a static, planar model which is compared with the results of XUV-resonance-line observations. In this model, the transition region is heated by thermal conduction from the corona and cooled by radiative losses. Comparison of the model with observational results implies that this is the dominant process in the energy balance of the transition region, and that the base of the transition region is inherently non-static and/or non-planar. The model explains the observational finding of Noyes et al. (1970) that the number density and the downward heat flux both increase by the same factor from quiet regions to active regions. The implications of these results are discussed with regard to spicules.

1. Introduction

The purpose of this article is to examine the extent to which a static, planar model may be used to describe and explain the structure and energy balance of the chromosphere-corona transition region. In this section we shall briefly present the salient features of the transition region which motivate such a study.

In this paper, following Pottasch (1964), we shall use the term 'chromosphere-corona transition region', or just 'transition region', to designate the region of the solar atmosphere in which the temperature increases from about 10^4 K (typical temperature of the upper chromosphere) to about 10^6 K (typical temperature of the lower corona). This is the region from about 2000 km to about 10000 km above the photosphere (Athay, 1969; Dupree and Goldberg, 1967). Observed energy fluxes of extreme-ultraviolet resonance lines emitted from the outer solar atmosphere imply (see Section 3.2.1) that above the 10^5 K level the atmosphere is approximately planar, and that the

Fig. 1. Schematic representation of the transition region.

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flux of heat flowing from the corona down to the chromosphere remains roughly constant from the $10^6$ K level down to the $10^5$ K level. We term this upper part of the transition region the 'constant-heat-flux region'. The part of the transition region below the constant-heat-flux region will be called the 'base region'. This schematic picture of the transition region is summarized in Figure 1.

A major function of the base region is to absorb the downward flowing heat which passes through the constant-heat-flux region. The value of this heat flux which enters the base region is not accurately determined by the ultraviolet line data, but a value greater than $10^5$ erg cm$^{-2}$ is indicated (see Section 3.2.1). At the $10^4$ K level and below, the heat conductivity and the temperature gradient are so small that less than $10^2$ erg cm$^{-2}$ can be conducted out of the bottom of the transition region. Therefore, the heat entering the base region from the constant-heat-flux region must be absorbed in the base region.

Optical eclipse spectra indicate that spicule-like inhomogeneities begin to appear in the chromosphere at heights above about 1500 km (Suemoto and Hiei, 1962), and spicules often extend to heights of 10000 km or more. Thus, some spicules extend through the height range of the chromosphere-corona transition region. Since spicules are transient and must have a temperature well below $10^5$ K (Beckers, 1968), the constant-heat-flux region cannot be completely static and horizontally uniform. However, above 3000 km spicules occupy less than a few percent of the horizontal surface area (Allen, 1963; Beckers, 1968). This suggests that the static, planar constant-heat-flux region implied by the ultraviolet emission-line data corresponds to a hot, static background atmosphere which is penetrated here and there by the cooler spicules. Thus, although the constant-heat-flux region appears to be inhomogeneous and fluctuating when viewed optically at the limb in a chromospheric emission line, in terms of overall structure and average heat flow from the corona to the chromosphere, a static, planar model is still reasonable.

In view of the static, planar nature of the constant-heat-flux region (despite the presence of spicules), it is reasonable to consider a static, planar model for the base region which absorbs the heat which passes through the constant-heat-flux-region. A static, planar model of the base region is ‘possible’ if the downward heat flux passing the $10^5$ K level can be radiated away above the $10^4$ K level. However, Kuperus and Athay (1967) have suggested that the base region is so thin that the inflowing heat cannot be balanced by radiation alone, and that the excess energy goes into the kinetic energy of spicules. Hence, a quantitative study of a static, planar model of the transition region may be relevant to the origin of spicules, and their role and importance in the energy balance of the base region.

2. Model and Formulation

2.1. Basic Physical Assumptions

The model of the transition region studied in this paper is based on the following assumed physical conditions and approximations.