NASA SP-317

STELLAR CHROMOSPHERES

The proceedings of the International Astronomical Union Colloquium
held at NASA Goddard Space Flight Center
February 21–24, 1972

Edited by

S. D. Jordan and E. H. Avrett

Prepared by Goddard Space Flight Center

Scientific and Technical Information Office 1973
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.

Jennings – The loss rates should be proportional to the area under the curves you have drawn for Lyman alpha and H alpha. Do your results imply that Lyman alpha is giving up the largest part of the chromospheric energy loss?

Vernazza – Yes.

Skumanich – In addition to these results based on the divergence of the radiative flux you might find it interesting to compute the contribution of the divergence of conductive flux.

Vernazza – I understand that for a temperature of 10000°, Ulmschneider has computed the conductive flux coefficients in L.T.E. Given the extreme departures from L.T.E. I would be reluctant to base the conductive flux contribution on such results.

Ulmschneider – Using the temperature distribution determined from the Lyman continuum observation (Noyes and Kalkofen 1970, Solar Physics, **15**, 120) one can compute the conductive flux. One finds that this flux is about 2×10^3 erg/cm^2 sec compared with the observed radiation flux of about 6.4×10^3 erg/cm^2 sec, (Friedman 1963, Ann. Rev. Astr. Astrophys., **1** 59), the difference being due to mechanical and radiation heating. The amount of radiation heating through the absorption of Lyα and Lyβ photons in this region between the Ly continuum and Lyα emitting regions appears now to be crucial for the existence of a temperature plateau. This may be seen as follows.

The radiative loss in the Ly continuum, Lyα, Lyβ regions is balanced by 3 competing heating mechanisms, thermal conduction, mechanical heating by shock waves and radiation heating. Of these mechanical heating becomes unimportant at greater height because, first, the increasing sound speed increases the wavelength, decreasing the strength of the shock wave and thus its dissipation, second, the dissipation of shock waves is a slow process and can not rapidly balance strongly increasing radiation losses. If radiation heating were also unimportant then thermal conduction would be the only significant heating mechanism. In the Ly continuum region the coefficient of thermal conductivity K, due to the increasing degree of ionization, is a decreasing function of temperature or height.

$$\frac{d\pi F_{Rad}}{dh} = \frac{d}{dh} K \frac{dT}{dh}$$

Thus through this equation any radiation loss and even zero radiation loss would lead to an increase of the temperature. This argument is especially valid in the main Lyα emission region. In this region we expect a strongly rising temperature due to thermal conduction.

On the other hand if radiation heating is appreciable then it could decrease the conductive flux leading to a temperature plateau between the Ly continuum and Lyα emitting regions. For example if a radiative flux of Lyα photons going toward the sun of about 2×10^3 erg/cm^2 sec were absorbed in the region between Ly continuum and Lyα emission then assuming, for example, no emission in this region one could get

$$\frac{dT}{dh} = 0$$

as seen from the integrated version of the previous equation.

(note added in proof:) A numerical check of the importance of this Lyα back heating was done after the conference by W. Kalkofen. He found that it invariably occurred in various different models so that the existence of a temperature plateau seems to be fairly certain although for reasons different than originally proposed (Thomas and Athay 1961, Physics of the solar chromosphere. Interscience, New York. p. 156).

Vernazza – (Note added in proof:) I referred to the conductive flux coefficient published by Ulmschneider (Astro & Astrophys. 4, 144, 1970 which is calculated assuming L.T.E. Later, however, Ulmschneider kindly provided me with a more general conductive flux coefficient subroutine. The divergence of the conductive flux was calculated and was found to be insignificant.