ON THE EXISTENCE OF HOT CORONAE AROUND COOL STARS

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ABSTRACT. A star cannot have a solar-like corona if the available mechanical energy flux in the chromosphere is either too large or decreases outward more rapidly than the pressure. This result might be relevant for hybrid stars and cool giants.

The canonical explanation for the existence of the hot solar corona is based on a discussion of the local energy balance between radiation and heating in the chromosphere. The effectively optically thin emission can be approximated by pressure squared times an emissivity function f(T). Theoretical arguments and empirical models show that the heat input into the solar chromosphere, and thus also the available energy flux F itself, decreases outward less rapidly than linearly with p (case C in Fig. 1). Nevertheless, initially the chromosphere can achieve energy balance by means of a gentle outward temperature rise, since f(T) increases steeply with T for small temperatures.

Finally, however, a critical temperature is reached where the emissivity has a maximum. Beyond this point, which is marked by the asterisk on curve C in Fig. 1, energy balance at cool chromospheric temperatures is no longer possible. Therefore, the transition region to the solar corona, which is governed by a different type of energy balance since thermal conduction is important, must lie at or below this critical position. Its actual location is determined by the intersection of the curve F(p) with another curve that specifies the total coronal energy losses as a function of the coronal base pressure (cf. Hammer et al. 1982). Theoretical models of closed (e.g. Rosner et al. 1978, eq. (4.4)) and open (e.g. Hammer 1982, Fig. 2) coronal regions as well as semi-empirical studies (e.g. Jordan 198o, Fig. 4) show that the coronal energy losses increase with the base pressure to some power that is slightly larger than one.

It is interesting to apply this picture to stars near the dividing "line" that appears to separate the solar-like stars with hot coronae from the cool giants with massive winds and extended chromospheres. When we go from the Sun (case C in Fig. 1) towards these stars, it is well possible that the run of energy flux vs. pressure changes. Recently, Böhm-Vitense (1986) discussed the possibility that in the cool giants

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 361–362.

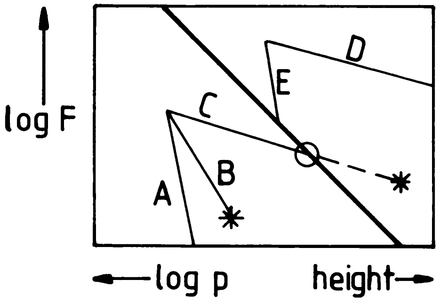

Figure 1. Available energy flux F in a stellar chromosphere as a function of height or pressure (thin curves) and energy requirements of a hot corona (thick curve).

F decreases more rapidly than pressure squared (case A), so that the chromospheric temperature decreases outward, and a corona is not formed. If that is true, however, we should also find stars in which F varies with p to some power between 1 and 2 (case B). In such a star, the chromospheric temperature increases outward, and beyond a certain critical height the heat input can no longer be radiated away at cool temperatures. On the other hand, a solar-like hot corona is also not possible because at any height F is far too small to balance the coronal losses. Such a star would need other means of solving its energy dilemma. Its outer atmosphere could, e.g., oscillate temporally between the cool (overheated) and the hot (underheated) state. Or it could have a warm envelope (with T near the maximum of f(T), beyond which energy is transported outward by means of convection. Such stars, should they exist, might exhibit some characteristics of hybrid stars.

Fig. 1 suggests another possibility for a star to have no corona; namely, if at some chromospheric level F is larger than the energy losses of a given type of corona. If now F drops slowly with p (case D), no equilibrium solution exists. And if F drops rapidly (case E), the equilibrium solution can be shown to be thermally unstable (Hammer et al. 1982).

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https://doi.org/10.1017/S0074180900156712 Published online by Cambridge University Press