EMISSION MEASURES AND HEATING MECHANISMS FOR STELLAR TRANSITION REGIONS AND CORONAE

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ABSTRACT. In order to determine the heating mechanisms for stellar transition regions and coronae we try to determine the damping lengths for the mechanical flux(es) responsible for the heating. For the lower part of the transition regions ($30{,}000 < T \leq 100{,}000$ K) the damping lengths are consistent with shockwave damping. This appears to be also true for the upper part of the transition region in Procyon, while for the upper part of the solar transition region the damping length is much larger.

1. THE LOWER TRANSITION LAYER

In the Lower Transition Layer (L Tr) 30,000 K<T<100,000 K we find an equilibrium between the mechanical energy input and the radiative losses Erad, i.e.,

$$(1) \quad -\frac{d\,Fm\ell}{dh} = \frac{Fm\ell}{\lambda_\ell} = E_{rad} = n_e^2 \cdot f(T) = n_e^2 \cdot B \cdot T^\beta \quad \text{where } \beta \sim 2$$

Here $Fm\ell$ is the mechanical energy flux in the L Tr and λ_ℓ its damping length. $f(T)$ is the radiative loss function which in the L Tr increases approximately as T^2. B is a constant. Assuming $\lambda_\ell = \lambda_o T^\alpha$ equation (1) leads to

$$(2) \quad T^{\beta+\alpha-2} = \frac{Fm\ell}{\lambda_o} \cdot \frac{1}{B} \cdot \frac{1}{P_e^2} \quad \text{with } P_e = n_e \cdot T$$

For the emission measures we find

$$(3) \quad Em = 0.35\, P_{eo}^2 \, \frac{(\beta+\alpha-2) \cdot R}{\mu\, g_{eff}} \cdot \frac{1}{T} \left(\frac{T_o}{T}\right)^{\beta+\alpha-2} \frac{e^{-\int dh/\lambda_\ell}}{1-H/2\lambda_\ell}$$

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with $H = \frac{RT}{\mu g_{eff}}$ and R=gas constant, g_{eff}=effective gravity
μ=atomic weight,

The observed Em(T) permit the determination of $P_e^2(T)$, which in turn permits the determination of $Fm\ell/\lambda_o$ from equation (2). The observed temperature dependence of the Em determines $\alpha=0.4 \pm 0.5$, in agreement with expectations for shockwave damping.

2. THE UPPER TRANSITION REGION

In the Upper Transition zone (U Tr) with $10^5K<T<10^6K$ the radiative loss function f(T) decreases for increasing T, a stable equilibrium between mechanical energy input and radiative losses is therefore not possible. The temperature stratification is governed by the conductive heat flux Fc(h). The energy equation tells us that the downward flowing conductive flux must equal the upward flowing mechanical flux Fmu(h) reduced by the amount of energy lost above the height h due to radiation and the stellar wind. For the emission measure in this layer we obtain

$$(4) \quad E_m(h)=(P_e^2(h)/F_c(h)\ T^{1.5}\cdot 0.7\ \ e^{-2\Delta h/\overline{H}}$$

For constant $P_e^2(h)/Fc(h)$ the observed increase of Em with $T^{1.5}$ is recovered (see also Jordan 1980). From the observed Em only the conductive flux Fc can be determined which relates to Fmu but not to λ_u.

3. THE CORONAL TEMPERATURES

Integration of the equation for the conductive flux from the base of the U Tr with $h=h_2$ and $T=T_2$ to the height h_c, where the conductive flux becomes zero and $T=T_c$, leads to the equation for the coronal temperature

$$(5) \quad T_c^{7/2}-T_2^{7/2} = -\frac{7}{2}\,\eta\cdot\lambda_u\cdot Fmu(h_2)\cdot[1-e^{-\Delta h_c/\lambda_u}(1+\Delta h_c/\lambda_u)]-E_r$$

where E_r describes the integral over the radiative losses in the U Tr. The coronal temperature T_c increases with increasing λ_u. The observed coronal temperatures thus permit a determination of the λ_u. For Procyon (Jordan et al. 1986) the derived value agrees with expectations for shockwave damping while for the sun the value is at least an order of magnitude too large for this heating mechanism.

REFERENCES

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