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Heating the Solar Corona

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A typical temperature for the quiet solar corona is $\sim 1.5 \times 10^6$K, whereas the photosphere – the likely source of the thermal energy – has a temperature less than 6×10^3 K. Although many theories have been advanced to explain why the corona is so much hotter than the photosphere, this old problem remains unsolved. However, there is a mechanism based on second-order transport that may provide the answer, or at least part of the answer. This process, described by the author in *Thermodynamic inequalities in gases and magnetoplasmas*, John Wiley & Sons Ltd, 1996, causes heat to be transported across strong magnetic fields *up* temperature gradients.

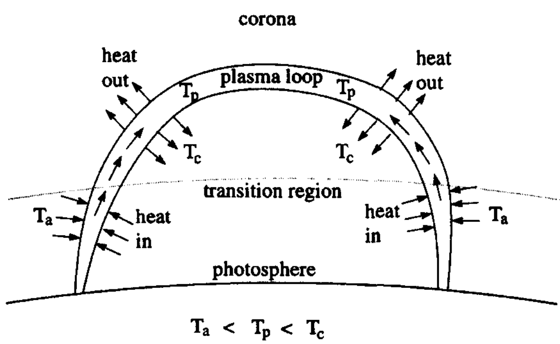

Fig. 1. Transporting heat to the corona via plasma loops

Plasma loops in the solar atmosphere (see Fig. 1) exist with a wide range of temperatures and in particular there are loops that are hotter than ambient in the chromosphere/transition region ($10^4\,\mathrm{K} < T < 5 \times 10^5\,\mathrm{K}$) and cooler than ambient in the corona ($10^6\,\mathrm{K} < T < 2 \times 10^6\,\mathrm{K}$). The theory of second-order transport suggests the mechanism illustrated in Fig. 1; heat is transported *upwards* from the upper chromosphere and transition regions, using appropriate flux tubes as conduits. In the region below the transition region, the loop temperature is greater than that in the ambient plasma and by second-order transport, heat flows up the temperature gradient, across the magnetic field into the loop. This causes a local increase in temperature, and a relatively small temperature gradient is established around the loop that conducts the thermal energy up to that part of the loop high in the corona. This stage is 'normal' heat flux, i.e. along the magnetic fields lines and down the temperature gradient. High in the loop the situation is the reverse of that in the chromospheric region, that is the temperature in the loop is less than that in the ambient corona and heat therefore flows out of the loop into the hotter corona. This mechanism can easily supply the power of about $3 \times 10^2\,\mathrm{Wm}^{-2}$ required for the quiet corona and also the $\sim 10^4\mathrm{Wm}^{-2}$ required for the active corona.

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