Thermal instability in helical magnetic field configurations with flow

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Condensations are observed in many astrophysical environments. In solar physics, common phenomena are coronal rain and prominences. Coronal rain consists of transient dense blobs that form in magnetic loops and rain down along the magnetic field lines [1]. Prominences are cold, dense structures suspended in the hot, tenuous corona by the magnetic field [2]. Solar tornadoes are a class of solar prominences [3], based on their apparent rotating shape, and are in some cases viewed as feet of large, horizontal prominences by which they are connected to the chromosphere. Whether or not they rotate is a topic of debate with two main opposing views: actual rotating magnetic structures [4], versus counterstreaming flows [5]. A process to form condensations without self-gravity is thermal instability, where structures are formed due to energy loss by radiative emission. Thermal instability is a very likely mechanism to form cold condensations, such as solar prominences or coronal rain, in the hot solar corona, as shown by recent multidimensional MHD simulations of prominence formation [6] and spectral analysis of the solar atmosphere [7], alike.

The linear MHD spectrum is investigated for cylindrical equilibria with non-ideal effects and helical flow, extending the work of van der Linden [8]. We show that the only effect of the flow on the thermal continuum is to modify it with a Doppler shift. Hence, the growth rates of the thermal instability remain unaltered. Furthermore, we use an analytic WKB approach to determine a criterion for discrete thermal and slow modes which, if they appear, can destabilise a plasma, i.e. make it thermally unstable.

We use the newly developed spectral eigenvalue code Legolas [9] to study the instabilities of 1D equilibria, which may represent the tornado-like feet of prominences. We compare helical magnetic configurations, under influence of rotational flow, optically thin radiative cooling and anisotropic thermal conduction. This gives us insight into the arising magnetothermal instabilities, which are responsible for the formation of condensations and the dynamics. The spectral study will be followed up by 2.5D numerical simulations using the open-source software MPI-AMRVAC [10]. Modern MHD simulations allow us to study the nonlinear and dynamic evolution of the condensations formed by thermal instability in these rotating magnetic structures at ultra-high resolution.

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