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Numerical simulations of MHD instabilities in the Kippenhahn-Schlueter prominence model

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Abstract. The launch of SOT on the Hinode satellite, with it's previously unprecedented high resolution, high cadence images of Solar Prominences, led to the discovery of small scale, highly dynamic flows in quiescent prominences. Berger et al. (2008) reported dark upflows that propagated from the base of the prominence through a height of approximately $10Mm$ before ballooning into the familiar mushroom shape of the Rayleigh-Taylor instability . As well as these dark upflows, there have been observations of bright and fast ejections from inside the prominence. These could be viewed as evidence of bursty reconnection, driven by the tearing instability, occurring in quiescent prominences. Whether such phenomena can be driven by instabilities and, if so, how these instabilities evolve is yet to be fully investigated.

In this study, we use the Kippenhahn-Schlueter prominence model as the base for 2-D and 3-D numerical MHD simulations. The Kippenhahn-Schlueter model is linearly stable for ideal MHD instabilities, but can be made unstable through nonlinear perturbations and the inclusion of diffusive terms. Our simulations follow the linear and nonlinear evolution of both the magnetic Rayleigh-Taylor instability (3-D) and the tearing instability (2-D) in the Kippenhahn-Schlueter prominence model. Using the results from these simulations, we discuss how the instabilities are affected by the geometry of the Kippenhahn-Schlueter model and how these results can be applied toward understanding prominence dynamics. We will also discuss the possible effects of ambipolar diffusion.
We found the following results in our simulations. For the Rayleigh-Taylor instability: The linear growth rate has a different dependence on the physical parameters ($\omega \propto (\frac{\rho_+ - \rho_-}{\rho_+ + \rho_-}^{0.7} - C)k^{0.22}$) to that predicted by theory ($\omega = \sqrt{\frac{\rho_+ - \rho_-}{\rho_+ + \rho_-} kg}$), the rise velocity of the upflows in the nonlinear stage was constant and the most unstable wavelength was around $200km$. These final two points are consistent with observations. For the tearing instability: the linear growth rate of the instability was reduced due to the non-uniform density distribution and, in the nonlinear phase, fast plasmoid ejection occurred.