Numerical Modeling of “Velocity Redistribution” in the Solar Transition Region

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Introduction

It has generally been found that modeling can reproduce the observed intensities of transition region EUV spectral lines with a few exceptions, among them the 303.8 Å line of He II. One model that may account for the over intensity of this line (between 4 and 13 times the expected value) is the "velocity redistribution" model (Andretta et al., 2000; Jordan, 1975; MacPherson and Jordan, 1999; Jordan et al., 2001). In this model microturbulent flows transport He II atoms to regions of elevated electron temperature, where they may radiate at an enhanced rate. We present a first hydrodynamic simulation of this mechanism.

The Simulation. . .

- Constant, divergenceless, isotropic, homogeneous, 2-D, flow field with Kolmogorov spectrum ($U_k \sim k^{-\frac{5}{3}}$, where U_k is the mean energy/mass in wave-mode k)
- Passively advected He II ionization fraction, X_{He+}, via

$$\frac{\partial X}{\partial t} + \mathbf{v} \cdot \nabla X = 0$$

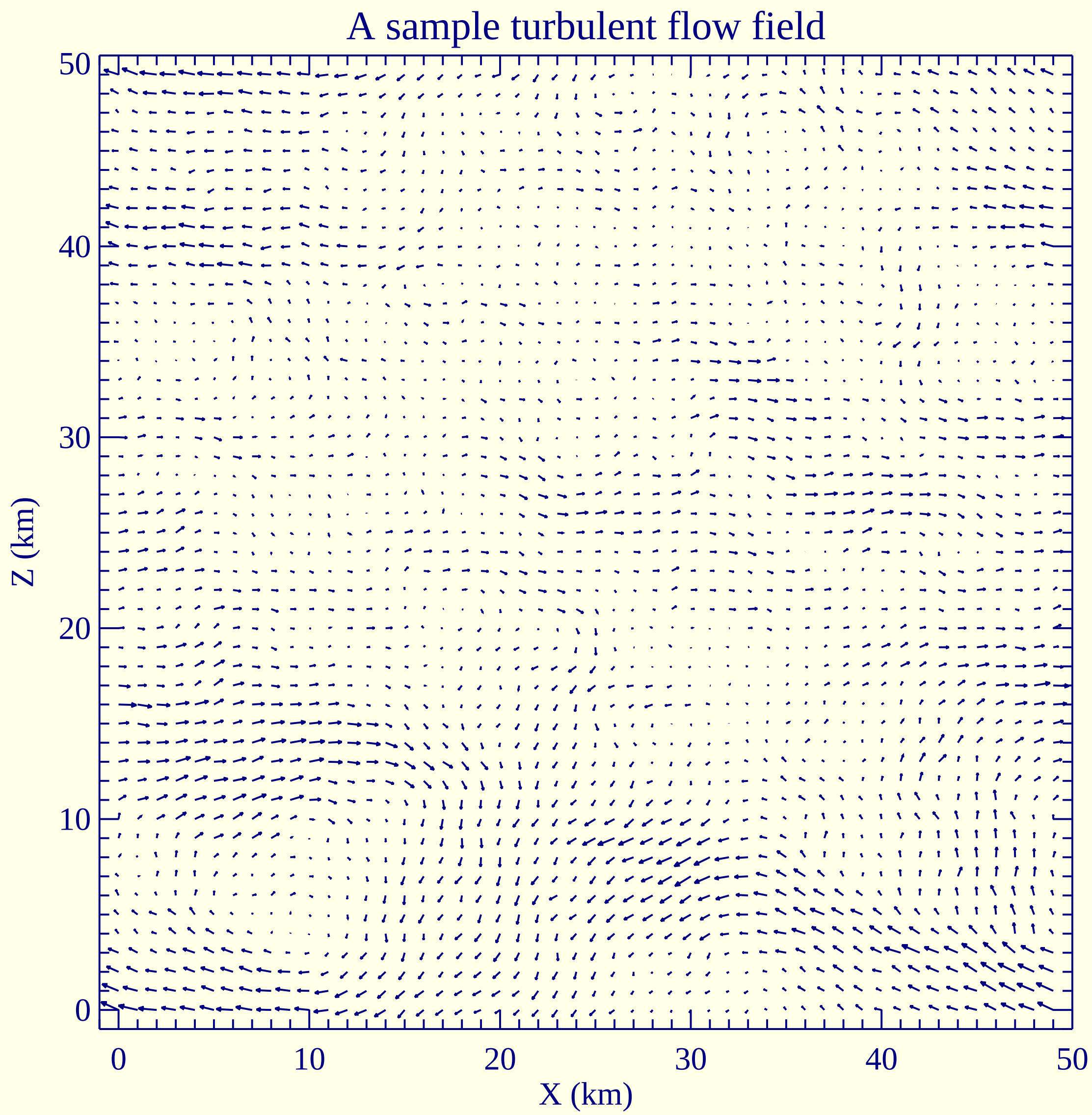
- Spitzer thermal conduction according to the equation

$$\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T = \frac{(\gamma - 1)}{P_0} T \nabla \cdot \left(\kappa_0 T^{\frac{5}{2}} \nabla T \right)$$

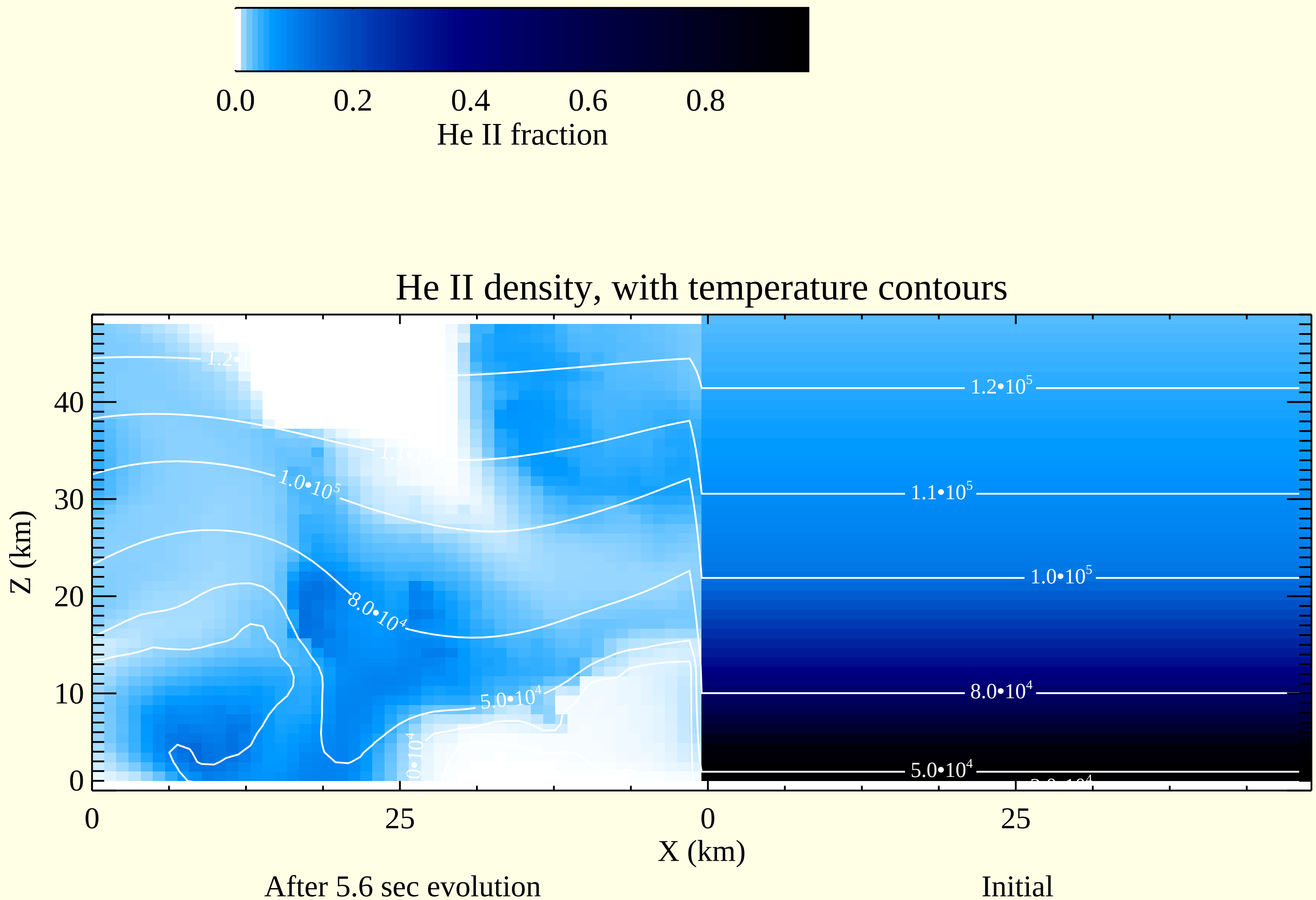
where P_0 is taken to be constant.

Initialization

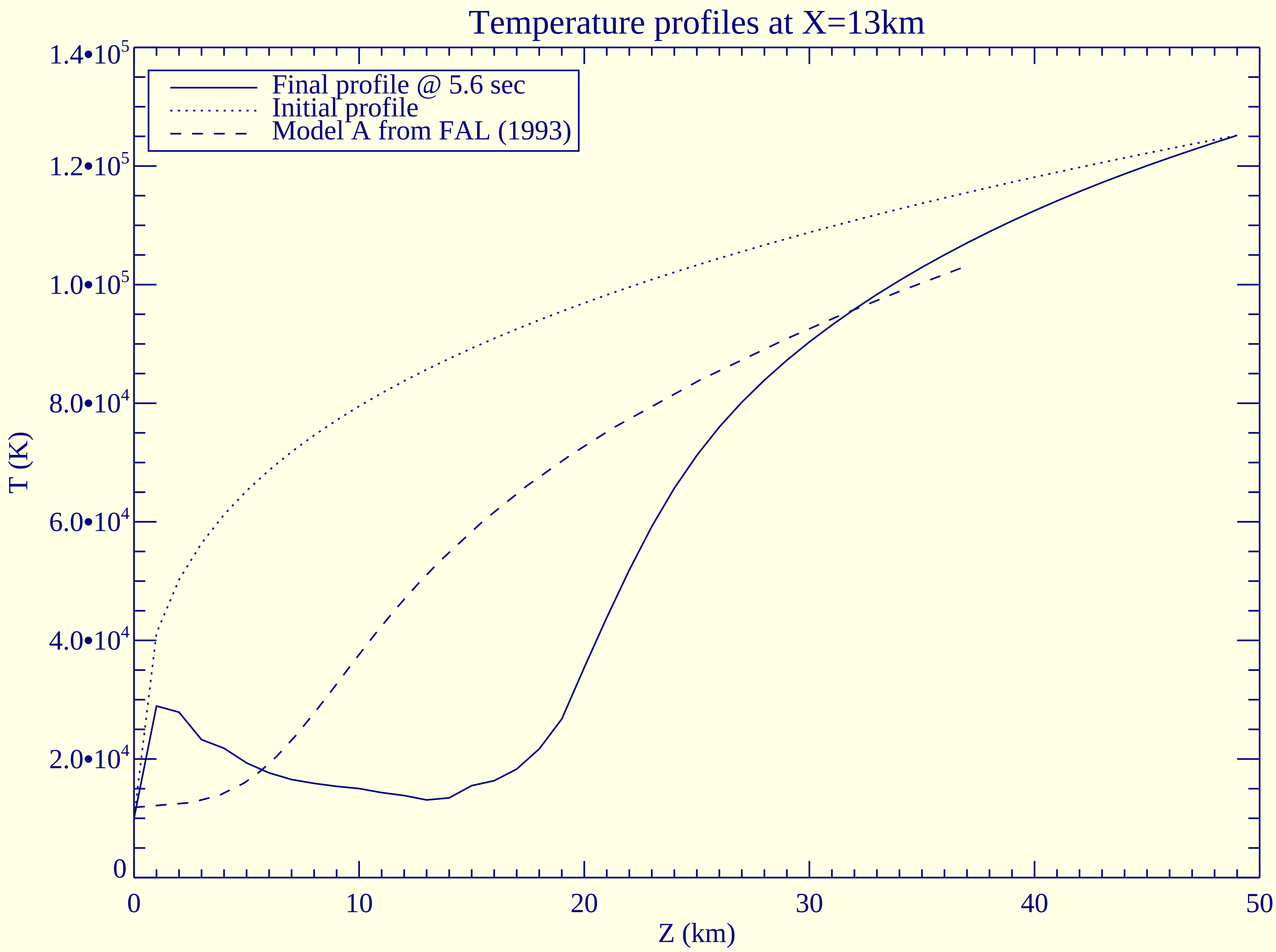
- The velocity field is computed from a stream function generated in Fourier space by $\widetilde{\Psi} = \frac{1}{\sqrt{2}}\zeta(A + Bi)$, where $\zeta^2 \sim k^{-\frac{14}{3}}$, and A and B are zero-mean, unit-variance, gaussian distributed random variables.
- The pressure is taken to be constant, $P_0 = 6 \cdot 10^{14} Kcm^3$ (Smith and Jordan, 2002)
- The initial temperature profile is derived from $T^{\frac{7}{2}} = a + bz$, where a and b are chosen so that the $T = 10,000K$ level is at the bottom of the grid and $\log T = 5.1$ is at the top (Smith and Jordan, 2002).
- The ionization fraction is initialized from Arnaud and Rothenflug, 1985, and the initial temperature profile.



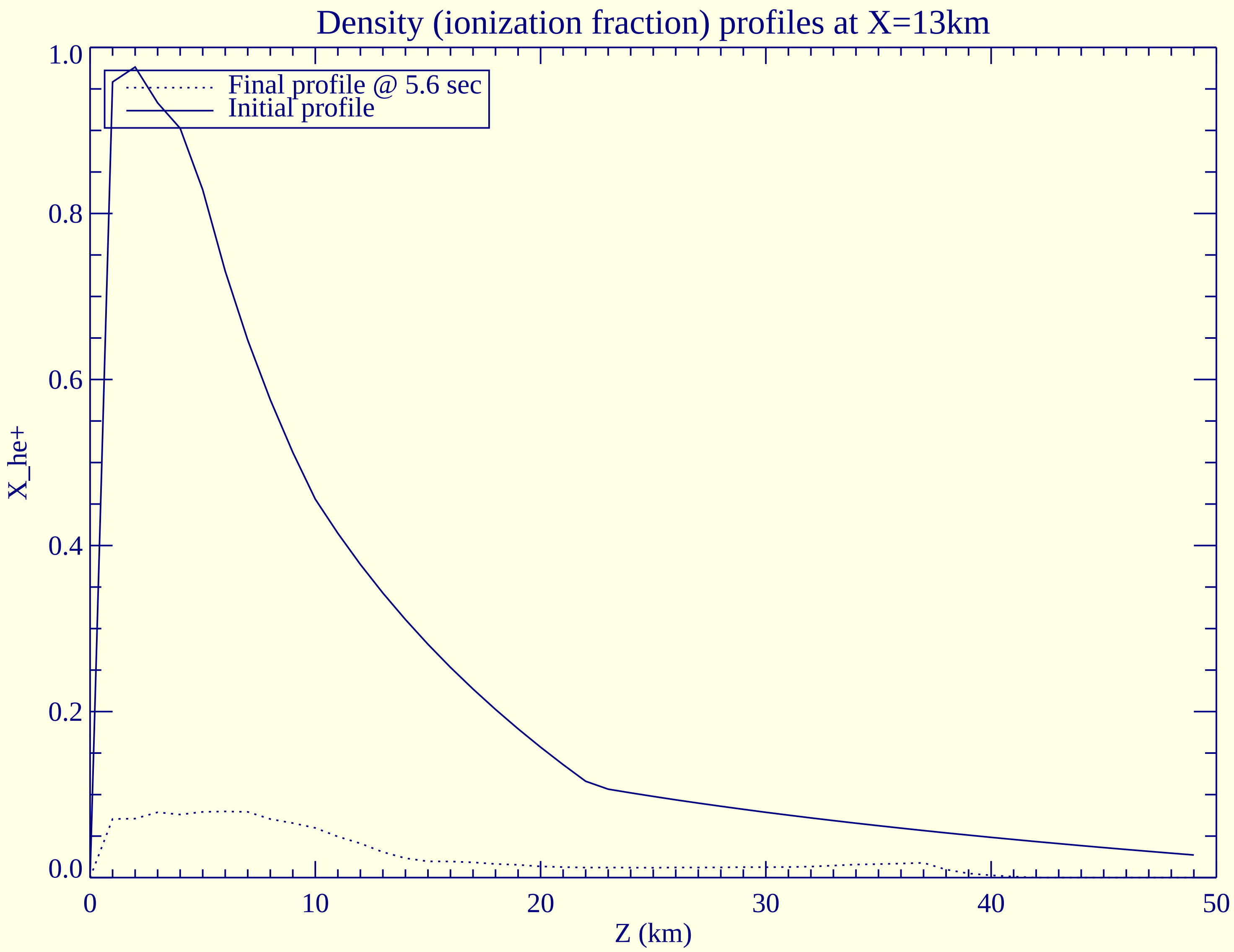
A typical velocity field. The RMS velocity is 10 km/s, corresponding to the results of Andretta et al., 2000.



The He II fraction advected for one excitation time (Smith and Jordan, 2002). The top and bottom boundaries have fixed temperature and He II fraction. The left and right boundaries are periodic. Conduction is thermalizing the plasma as it is mixed by the turbulence. Conduction is clearly more important at higher temperatures, as expected.



The initial and final temperature profiles at a randomly chosen X position, compared the temperature profile of model A from Fontenla et al., 1993.



The initial and final He II fraction. The initial distribution is based on the previous temperature profile.

Discussion

At issue is the extent to which turbulent convection acts to transport He II to regions of higher electron temperature. Larger eddies are more able to transport the ions across the temperature gradient. However, conduction acts to thermalize the plasma most effectively for small size scales and high temperatures. Turbulence on larger size scales will carry its thermal environment with it, and inhibit the exposure of He II ions to hot electrons. Further work with this simulation may allow the calculation of the He II enhancement for turbulence of various characteristic scales.

Acknowledgements

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