Non-equilibrium energy transfer in the solar chromosphere

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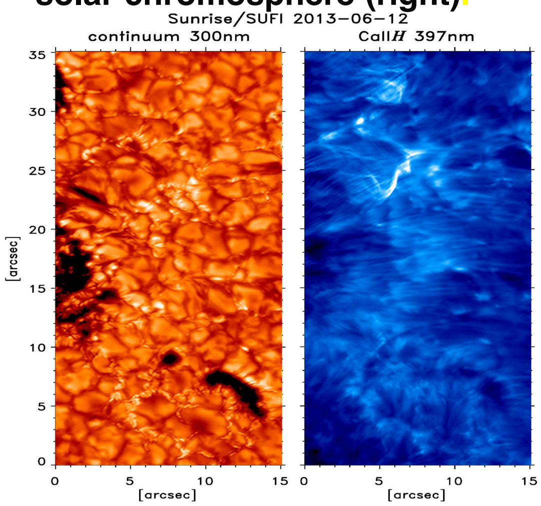
- Solar atmosphere is highly structured and dynamic due to magnetic activity (see Fig. 1).
- Image of the solar photosphere shows granulation as a result of convection below the photosphere, dark pores (small sun-spots) and bright points which are intense magnetic flux concentrations.
- Image of the solar chromosphere shows fine structure called fibrils and a bright region experiencing a dynamic event.
- What is the dynamic event seen in chromosphere? Micro-flare caused by magnetic reconnection? or shock waves? or ohmic dissipation?
- How does the heating of the solar chromosphere (see Fig. 2) happen? → through these dynamic events?
- What is the role of the radiation field in solar chromospheric heating ?

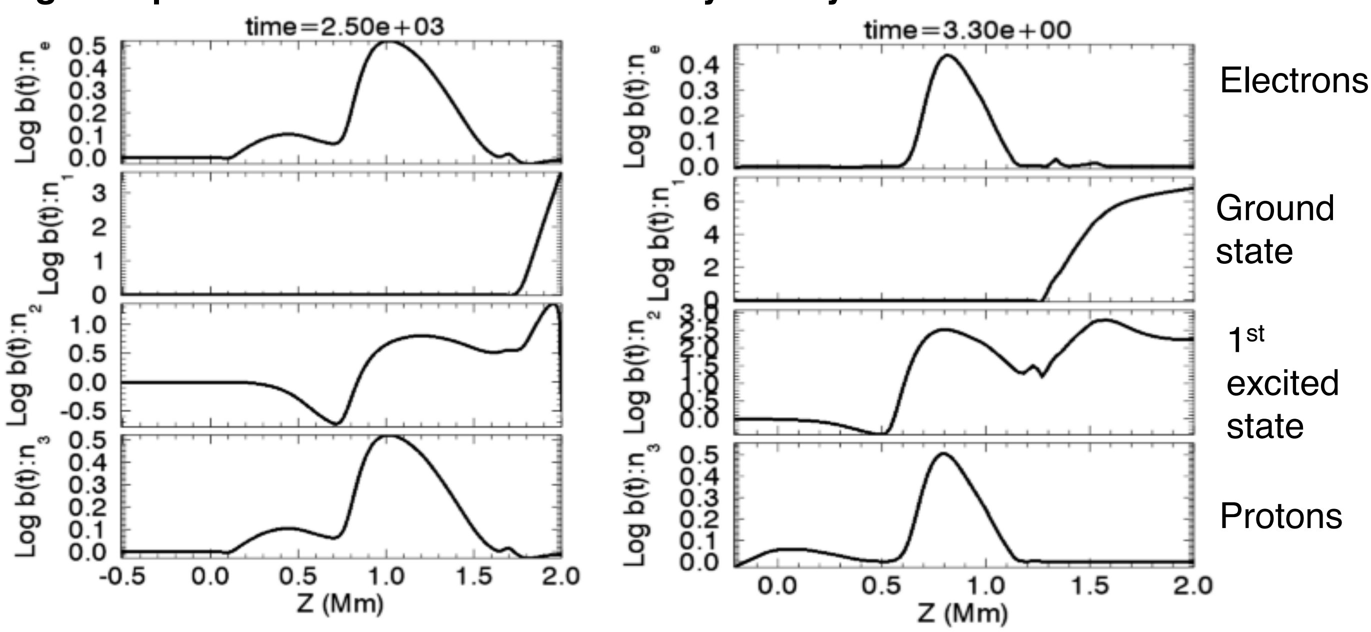
Fig. 1. Sunrise observations showing the solar photosphere (left) and the solar chromosphere (right).



Population Evolution

- A 1D non-equilibrium solver has been developed at the MPS as a module for the MURaM code. It solves the 1D NLTE radiative transfer together with non-equilibrium energy transfer.
- Fig. 2 shows the evolution of hydrogen populations: b[t] is the departure coefficient, showing the departure of the level population of electrons, the hydrogen levels n_1, n_2, n_3 and ionized Hydrogen, from their LTE values, for a 2 Mm chromosphere.

Fig. 2 Departure coefficients for stationary and dynamic cases



Poster

2. Chromospheric heating and dynamics

Non-equilibrium energy balance in solar chromosphere

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The enormous increase in computing resources in recent years has made it feasible to approximate the solar photosphere in great detail using numerical magneto-hydrodynamic (MHD) simulations. Extending these simulations to the solar chromosphere, that lies above, has been challenging, due to the dominant role played by radiative losses there. These losses are driven by a small number of strongly scattering spectral lines, so that the approximation of local thermodynamic equilibrium cannot be used. In addition, the dynamic time scale of the atmosphere is similar or below that of the dominant collisional processes, so that even statistical equilibrium cannot be assumed. We present a time-implicit numerical method that simultaneously solves the atomic population evolution and radiative transfer equations, together with the MHD quantities. The method is being implemented as a module for the MHD code MURaM. We present here, some results from our study of non-equilibrium evolution of hydrogen in a one-dimensional atmosphere.