Radiative Losses in a Flaring Chromosphere: Approximations and Applications

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In the solar atmosphere, radiation plays an important role in the energy balance. Extinctions or emissions of photons from transitions between atomic energy levels can either heat or cool the local atmosphere, and their contributions are expressed as the radiative flux divergence, referred to as the radiative losses. Detailed calculations could be computationally expensive, especially in the chromosphere, where the local thermodynamic equilibrium assumption breaks.

Based on the recipe of approximate radiative losses for the quiet Sun[1], we construct a new recipe for solar flares where the chromosphere undergoes drastic changes. We tabulate the optically thin radiative loss, escape probability, and ionization fraction using a grid of flare models from radiative hydrodynamic simulations as our dataset.

We have also evaluated the performance of different recipes for chromospheric radiative losses in flare simulations (Figure 1). We find that our recipe provides a better approximation of the detailed radiative losses, especially for large flares.

Height-integrated radiative losses imply how much energy is escaped from the deep atmosphere as free photons. Previous studies[2-3] found that there is a good relation between height-integrated radiative losses and the wavelength-integrated emergent intensity of certain spectral lines like Ca II K. Thus, we propose to use height-integrated radiative losses as a proxy to synthesize Lyα images from MHD simulations. We apply this method to a Bifrost simulation[4] and find that the large structures look similar to detailed radiative transfer calculations (Figure 2).

References

[1] Carlsson & Leenaarts, Astronomy and Astrophysics, 539, A39 (2012)

[2] Díaz Baso et al., Astronomy and Astrophysics, 647, A188 (2021)

[3] Yadav et al., Astronomy and Astrophysics, 665, A50 (2022)

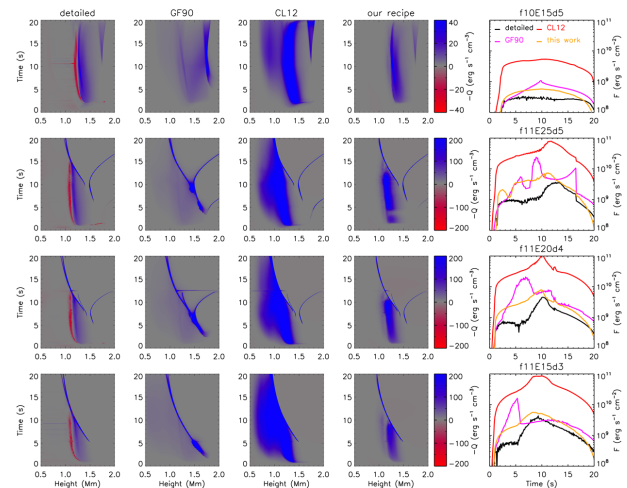[4] Carlsson et al., Astronomy and Astrophysics, 585, A4 (2016)

Figure 1. Comparison of chromospheric radiative losses calculated from detailed solutions and with different approximate recipes for four simulation cases. Blue colors denote radiative cooling, and red colors denote radiative heating. The line plots give comparisons of the evolutions of the radiative cooling rates integrated from 0.5 Mm to 2.0 Mm.
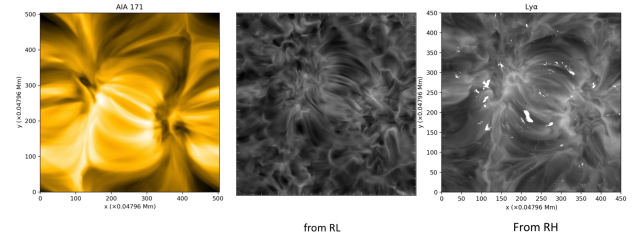

Figure 2. Synthesized AIA 171 Å and Lyα images from a Bifrost simulation of an enhanced network region. The middle panel shows height-integrated radiative losses, and the right panel shows detailed radiative transfer calculations.