Comparing 3D solar model atmospheres with observations: Hydrogen lines and centre-to-limb variations

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Three dimensional hydrodynamical stellar model atmospheres represent a major step forward in stellar spectroscopy. Making use of radiative-hydrodynamical convection simulations that contain no adjustable free parameters, the model atmospheres provide a robust and realistic treatment of convection. These models have been applied to several lines in the Sun and other stars, yielding an excellent agreement with observations (*e.g.*, Asplund et al. 2000).

The present work aims to provide additional observational tests to the 3D solar model atmospheres: hydrogen lines and continuum centre-to-limb variations. The Hα and Hβ lines are good probes of the temperature of a model (in their wings, as they are mainly sensitive to temperature). The continuum limb-darkening profile (center-to-limb variations) is a useful tool to probe the atmospheric structure as a function of depth. By changing the viewpoint, one effectively probes for different depths in the atmosphere and continuum intensity yields information about the model's temperature structure.

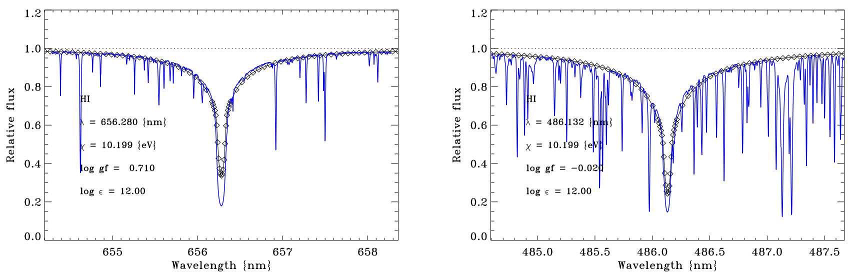

Fig. 1. The predicted spatially and temporally averaged flux profiles of the Hα and Hβ lines (left and right panel, respectively). Diamonds and thin line: 3D model; thick line: solar flux atlas of Kurucz et al. (1984).

We present preliminary results for the normalized flux profiles of Hα, Hβ and for the centre-to-limb variations of the continuum disk-centre intensity. For these results, we used a 3D solar model atmosphere taken from a sequence

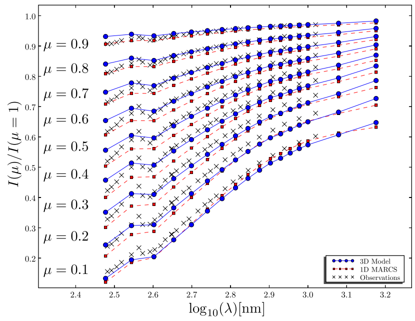

Fig. 2. The limb-darkening profile for the 3D solar simulation in the range of 3000-20000 Åcomputed for the continuum intensity. The μ parameter defines the angle of the viewpoint ($\mu = \cos\theta$). Solar observations data taken from Neckel & Labs (1994).

of snapshots (covering 50 min of solar time) from the full solar convection simulation.

The results for Hα and Hβ are plotted in Fig. 1. A reasonable agreement can be found in the wings but not at the core (which is believed to be formed at chromospheric layers under non-LTE conditions). In the wings, the line profiles from the 3D model seem to be a bit stronger than the observed line profiles.

For the centre-to-limb variations, results are plotted in Fig. 2. While generally the agreement with observations seems to be better than for the 1D MARCS model, it is clear that there is a systematic difference between the 3D model and the observations, in the sense that the 3D has a slightly too steep temperature gradient.

Both these two preliminary results give us some hint that the temperatures and temperature structure of the 3D model might not be exactly the same that one observes in the Sun. Despite the excellent agreement of the 3D solar model atmospheres with many spectral lines, it is clear that there is still room for improvement. We are currently working on improving the radiative transfer in the 3D models.

References

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