Spatially resolved solar spectroscopy as benchmark

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Abstract

For the detection and characterization of exoplanets, observed spectra need to be understood at extremely high detail. Knowledge about the radiation emitted from the host star is of utmost importance, and the Sun is the best available laboratory to understand Sun-like stars. At the Institute for Astrophysics Göttingen, we observe the Sun using a high resolution Fourier Transform Spectrograph (FTS). Our observations of the resolved Sun provide insight into the variable spectral behaviour across different limb angles, which can provide crucial information about limb darkening, convective velocities, and line profile variability relevant for radial velocity (RV) work. We show first results from our atlas of the solar spectrum at different limb angles that can put models of transit observations and stellar RV variability on a firm footing.

Instruments

Figure 1: Siderostat of the Vacuum Vertical Telscope on the rooftop of the Institute for Astrophysics in Göttingen.

The observations get performed with the Vacuum Vertical Telescope in Göttingen, see Fig. 1. The FTS enables us to observe with a resolution of R≈700,000 at λ=600nm. This provides solar spectra at wavelengths between 450 and 1000nm. We obtain spectra from the spatially resolved solar disc with an aperture of 32” in diameter (≈23000 km on the solar surface). For more detailed information about the FTS and the setup see Schäfer et al. (2020)[1]

Observations

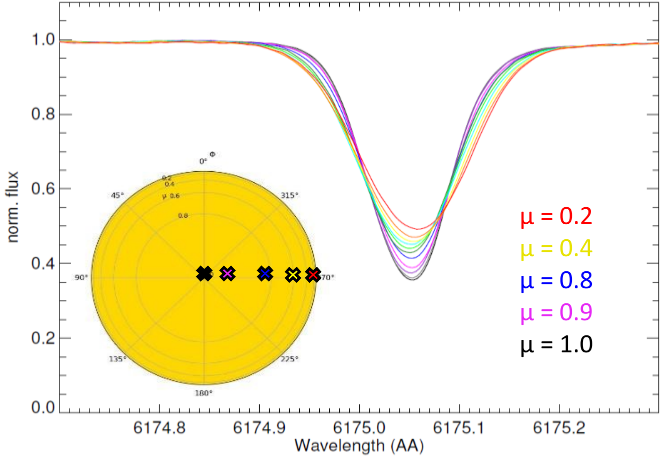

Figure 2: Variation of an iron line over different observing angles. The draft of the Sun in the left lower corner shows exemplary some of the chosen data positions.

To get a dense grid of the resolved solar disc with a predominantly focus on the centre to limb variation our observations try to cover as many μ angles as possible. This angle is defined as μ = cos(θ), where θ is the heliocentric angle. That implies a value of μ=1 for the disc centre and a non linearly decreasing value of μ the farther to the solar rim the position is based. The observed areas are quiet Sun regions and have a scan time of ≈10min. The atlas is free from telluric lines and barycentric corrected. In Fig. 2. the effect of the different observation angles is shown on an example iron line.

Solar Spectra

In Bergemann et al. (2021) a first insight into this data set was shown. They used the atlas as comparison to 3D NLTE line profiles to reanalyse the solar oxygen abundance. In Fig. 3 the atlas data is shown in red for two different μ angles and four different absorption lines.

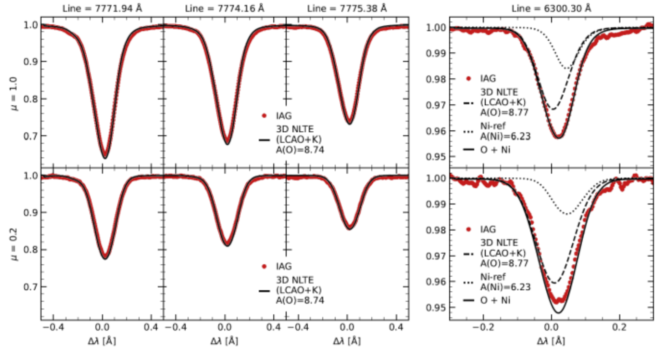

Figure 3: 3D NLTE profiles of model atmospheres compared with the spatially resolved solar observations for different μ angles.

Outlook

Our spatially resolved solar atlases will provide a lot of different opportunities. For example:

- ⊙ Better understanding of the Sun in general
- ⊙ Template for other stars
- ⊙ Improve the detection of exoplanets

References

1. Schäfer, S. et al. 2020, in Ground-based and Airborne Instrumentation for Astronomy VIII, ed. C. J. Evans, J. J. Bryant, & K. Motohara, Vol. 11447, International Society for Optics and Photonics (SPIE), 2187 – 2208
2. Bergemann, M., Hoppe, R., Semenova, E., et al. 2021, MNRAS

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