Precise and efficient modeling of stellar-activity-affected HARPS-N solar spectra using SOAP-GPU.

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Stellar activity due to the presence of active regions is the main limitation to the detection of Earth-like exoplanets in radial-velocity time series. Most of the techniques developed until now to mitigate stellar activity are using the time series of the RV and ancillary indicators (FWHM, BIS SPAN, photometry), however, those observables only provide an average information on stellar activity as they are obtained by averaging over thousands of spectral lines. To overcome the limits imposed by this averaging, it is necessary to tackle the challenge of stellar activity at the spectral level, and preliminary results in this direction show significant improvement (e.g. Collier-Cameron+ 2019, Cretignier+ 2022, Zhao, L.+ 22). To test and validate such mitigation techniques, it is extremely important to develop simulations capable of modeling stellar activity at the spectral level. This is the goal of the recently published Spot Oscillation And Planet (SOAP)-GPU code (Zhao, Y. & Dumusque 2022, submitted).

SOAP-GPU can model stellar activity in three different ways. The user can i) configure a basic active region configuration manually, ii) use the spot number data from the Sunspot Index and Long-term Solar Observation (SILSO) database to reproduce the overall statistics of solar observations, or iii) use the intensitygram and magnetogram images from SDO/HMI observation to exactly reproduce solar activity. To demonstrate that all the necessary physics is included in SOAP-GPU, and highlight the precision and efficiency of the code, we propose here to compare the SOAP-GPU modeled RVs based on SDO observations with the ones obtained from the HARPS-N solar telescope. The result shows that SOAP-GPU can precisely model the HARPS-N solar observations on the magnetic cycle as well as on the rotational timescale. Due to this success, SOAP-GPU can be used further to investigate the behavior of spectral line sensitivity to activity or train machine learning algorithms to disentangle stellar activity in the spectral domain.