Mitigating Granulation Noise with GRASS: Lessons from Synthetic Spectra

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Although astronomers have shown success in reducing the RV contributions of pulsations via empirically-motivated observation schemes and magnetically-active spots via multivariate time-series analysis, granulation continues to produce correlated RV noise at the tens of centimeters per second level. Without new advances in EPRV instruments and analyses, granulation is expected to preclude the detection of Earth-twins despite advances in spectrograph stability and precision (Luhn et al. 2022). Because granulation is non-stationary and changes the shape of spectral lines differentially, it should be modeled at the spectral level (as opposed to CCF or RV level) in order to characterize and then mitigate its effects on RV measurements. To support this need, we have developed an open-source, GPU-enabled package, GRASS (Palumbo et al. 2022) - the GRanulation And Spectrum Simulator - which uses disk-resolved, high-resolution (R ~ 700,000) observations of ~20 solar absorption lines to model disk-integrated, “Sun-as-a-star” line profiles while preserving the 15-second temporal resolution of the input spectra. Comparing the resulting synthetic line profiles against the IAG solar flux atlas, we show that GRASS accurately reproduces time-averaged disk-integrated solar line profiles and bisectors. We apply GRASS to produce synthetic spectra at varying temporal and spectral resolutions, and show that the extent of line shape variations due to granulation is significantly reduced at spectral resolution below R ~ 200,000. These results suggest that the ability of current EPRV instruments to characterize and correct for granulation will be limited by their spectral resolution. We describe how we are using GRASS to quantify the granulation barrier, the minimum detectable RV amplitude for an EPRV survey in the presence of granulation. We use these results to inform which current strategies for mitigating stellar variability are likely to be useful for recognizing, and potentially mitigating, variability due to granulation.