Precise and accurate wavelength calibration of echelle spectrographs with and without laser frequency combs

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Today, high-precision radial velocity measurements are essential for exoplanet research. While improving the precision to detect rocky planets in the habitable zone remains a challenge, even more demanding applications appear on the horizon: One of the key science drivers for the future ELT/ANDES spectrograph will be the direct observation of cosmic expansion in real time, also known as the Sandage test, requiring an extreme RV stability of 1cm/s over decades. Achieving this order-of-magnitude improvement over current EPRV spectrographs will only be possible by developing novel calibration sources and data processing techniques. I will present some of our ongoing efforts to improve the wavelength calibration of ESPRESSO and work aimed towards ANDES:

Fabry-Perot etalons (FP) have been established as relatively simple, reliable and cost-efficient solution to achieve a high-quality wavelength calibration. However, we recently demonstrated that the ESPRESSO FP exhibits -- in contrast to previous assumptions -- a chromatic drift of up to a few cm/s per day that varies as function of wavelength (Schmidt et al. 2022). Together with very similar findings at HET/HPF it becomes clear that probably every FP etalon used to calibrate astronomical spectrographs suffers from chromatic drifts. I will present our characterization of the Espresso FP and our solution to correct for it based solely on standard ThAr exposures.

However, achieving the highest precision will require the use of laser frequency combs (LFC) as calibration sources. These complex devices offer totally new opportunities but also come with their own difficulties. For ESPRESSO, the LFC allowed to test the wavelength calibration accuracy in unprecedented detail and to identify several so-far not noticed systematics (Schmidt et al. 2021). One particular application I will present is to use the LFC for a detailed characterization of the line-spread function and how incorporating this information in the data reduction flow ultimately leads to improved accuracy and stability.

Finally, I will briefly touch upon our efforts to develop a blue laser frequency comb. Currently, astronomical LFCs are limited to the spectral range >490nm and pushing to shorter wavelengths poses substantial technical challenges. In our interdisciplinary BLUVES collaboration, we are developing novel technologies that will facilitate LFC operations in the blue and near-UV range, down to the atmospheric cut-off at 350nm.