Exploring the Power of Fabry-Pérot Calibration with the Spectrographs SOPHIE and CORALIE

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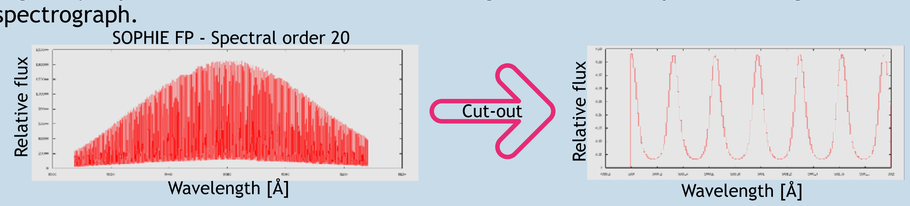
Motivation

Hollow-cathode thorium lamps have successfully served as a source of wavelength calibration and drift measurement in astronomical spectrographs despite their non-ideal characteristics. Fabry-Pérot etalons (FP) are good alternatives that produce regularly spaced calibration lines covering the entire spectral range of the spectrograph.



The spectrographs CORALIE and SOPHIE are both state of the art instruments on telescopes in the 1-2 m class with recently installed stabilised FP calibration units put together at the Observatory of Geneva. The FP etalons is placed in vacuum and temperature controlled to achieve highest intrinsic stability of the produced spectrum.

CORALIE @ EULER 1.2 m in La Silla

Since 1998 CORALIE has been performing high precision radial velocity measurements principally to search for giant planets in the southern celestial hemisphere. A precision of 3 m/s can be achieved, corresponding to the photon noise from a 1 hr exposure on a V-band magnitude 10.5 star.

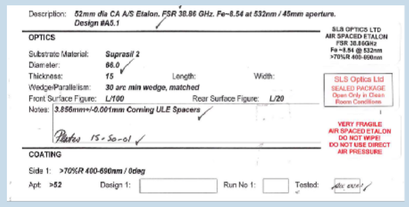
Several updates have been implemented over the previous years, including octagonal fibres, new cross-disperser and a Fabry-Pérot calibration unit. The FP delivers drift measurement better than 0.3 m/s (rms) per night and is now the standard drift calibration.

Resolution	50000
Wavelength range	3900 - 6800 Å
Magnitude limit v-band	14.5

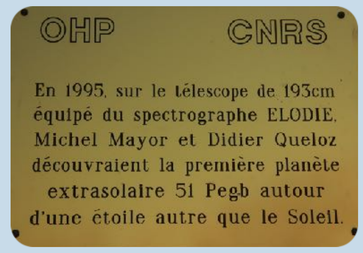
SOPHIE @ OHP 1.93 m in France

The SOPHIE echelle spectrograph at the Haute-Provence Observatory (OHP) is commonly used for radial velocity follow-up of planet-candidates identified through photometric transit-surveys including ground- and space-based projects such as SuperWASP, HAT, Kepler and CoRoT.

A Fabry-Pérot calibration unit was installed through multiple interaction in spring 2017. This has enabled radial velocity precisions of 3 m/s on mV=11 targets observed in high efficiency (HE) mode when used with with simultaneous FP in the calibration fibre.



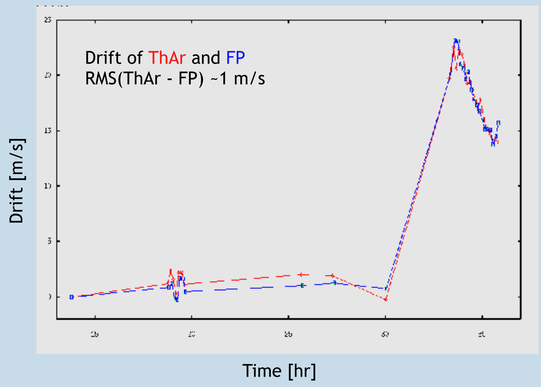
Some key test results are shown here. Not presented are the day-time on sky tests, where the solar 5 min p-mode oscillations easily have been picked up.



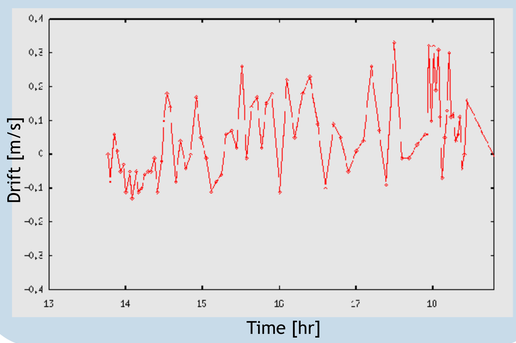
	HR	HE
Resolution	75000	40000
Wavelength range	3870 - 6940 Å	

FP drift

Drift of ThAr in red and FP in blue, monitored over 22h. Both FP and ThAr follow the same spectrograph drift. The dispersion of the difference is close to 1.0 m/s RMS.
Over one full night there is no significant drift of the FP with respect to the ThAr. The drift measured with the FP is at least comparable if not better to the drift measured with the ThAr.

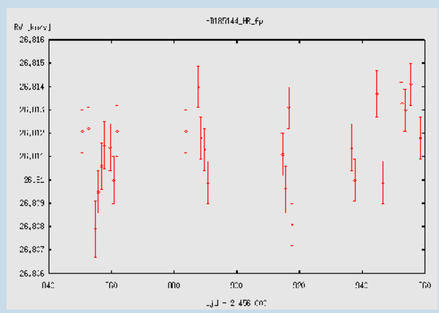


Bellow is the difference between FP in both the science and calibration fibres plotted over a 5 hr sequence. The dispersion of the drift difference is **12 cm/s RMS**.

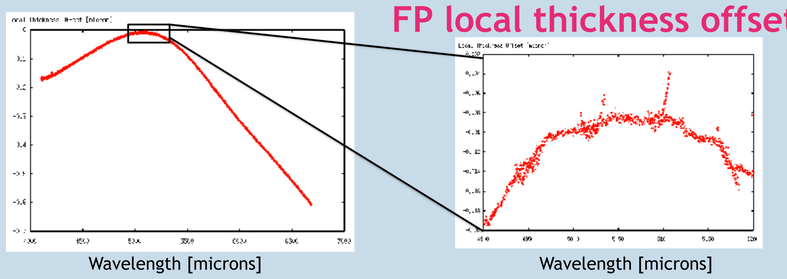


Monitoring of the RV standard star HD185144

The std star HD185144 has been monitored with simultaneous FP over 4 months.
A dispersion of **1.64 m/s RMS** was found. This is on the scale of ~1 m/s more than the same sequence obtained with simultaneous ThAr. This is due to the fact that the two calibrations are not simultaneous (FP-FP is done few minutes after ThAr-ThAr). This will be fixed in operation of the instrument when simultaneous FP is the default observation mode.

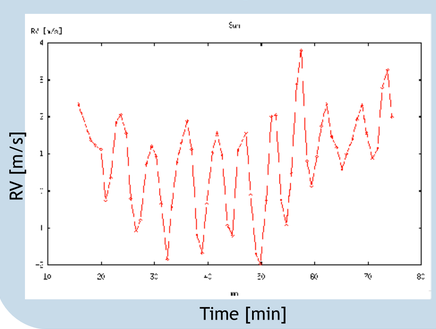


FP local thickness offset



The wavelength dependent optical depth of the dielectric mirrors coatings in of the FP affects the line thickness in the FP spectrum. Using the wavelength solution from ThAr, the offset in line thickness is computed.
The zoom-in around 5000 Å shows strong discontinuities at the edges of some orders due to the poor quality of the ThAr-based wavelength solution.
The FP lines clearly offer an opportunity for improving the calibration process.

5 min solar p-mode oscillations



An RV signal of ~5 m/s due to the 5 minute p-mode oscillations of the sun, have been measured in a short 40 min sequence on blue sky with 30 sec exposures. This kind of precision has been enabled by the Fabry-Pérot calibration unit.

Conclusions - and TESS follow up activities

The SOPHIE HE-mode will be a crucial tool in the TESS follow-up activities on the northern hemisphere, as the high resolution (HR) mode will only be able to observe the brightest few tens of candidates. In the southern hemisphere the spectrograph CORALIE at the Swiss 1.2 m telescope Euler, which has made use of simultaneous Fabry-Pérot spectra since June 2015, will play a similar role. These 1 m class telescopes will be effective and economical tools for followup activities in the era of TESS. Fabry-Pérot etalons ensure stable drift monitoring, sparing the hard-to-come-by hallow cathode thorium lamps while still being affordable and easy to utilise at these smaller observing facilities. Using the information obtained on the local thickness offset, the overall wavelength solution can be improved as well.

For SOPHIE, simultaneous FP will become the default observing mode, leaving ThAr calibrations during the night obsolete. The day time calibration sequence will consist of a ThAr exposure, sandwiched by two FP exposures to ensure best possible correction for instrumental drift between readouts. Another solution would be to enable simultaneous ThAr-FP exposures, which will require a refurbishing of the optical setup of the calibration unit.

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