Leibniz-Institut für Astrophysik Potsdam

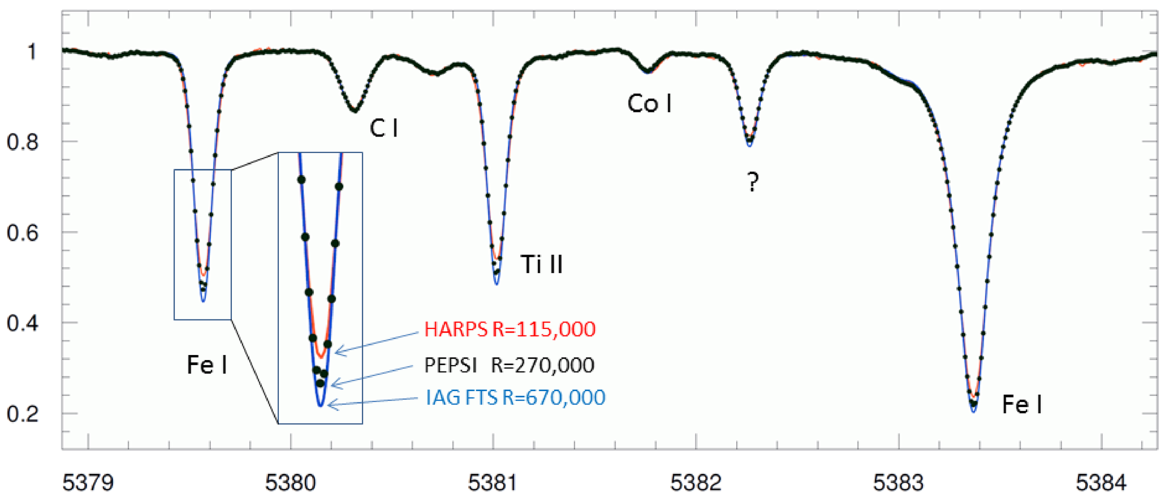
The Sun as a star

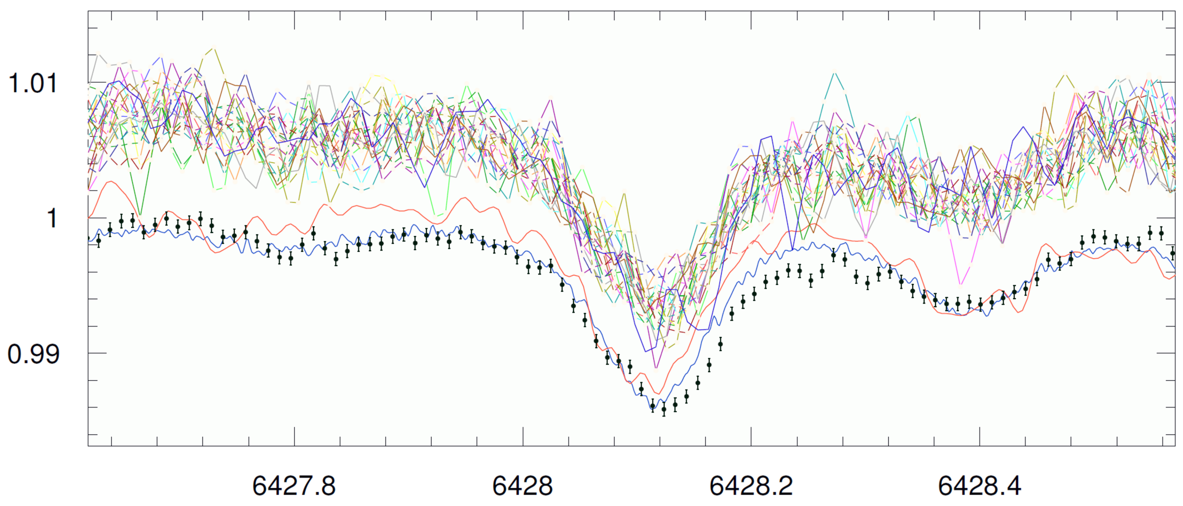
Solar spectra with PEPSI, and why this is news for the LBT community

K. G. Strassmeier, I. Ilyin, M. Steffen, E. Dineva, & C. Denker (AIP)

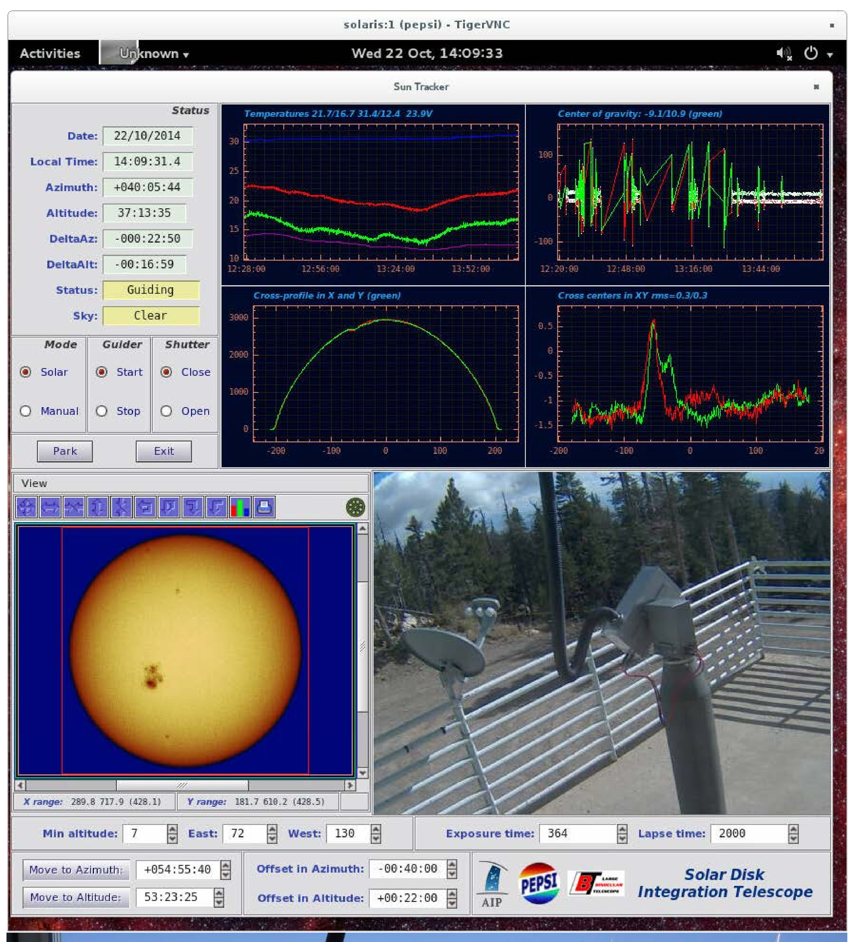
The Potsdam Echelle Polarimetric and Spectroscopic Instrument

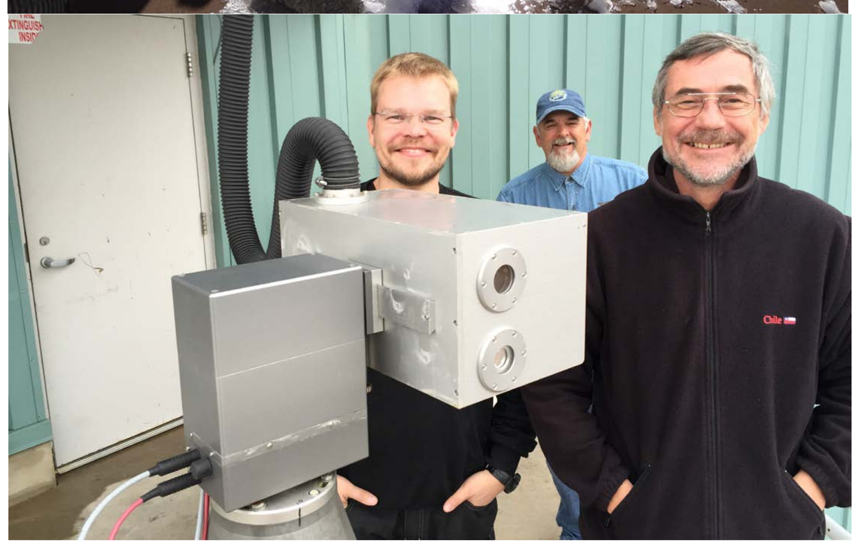
Abstract: The Sun has been monitored with the new Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPSI) of the Large Binocular Telescope (LBT). Instead of the LBT the spectrograph was fed by a small robotic Solar-Disk-Integration (SDI) telescope. The aim is to test the spectrograph and to monitor the Sun-as-a-star. Daily deep spectra are the result from average combining up to 100 consecutive exposures per wavelength setting and are compared with FTS solar flux atlases. Being able to observe the Sun with a night-time instrument allows direct validation of certain stellar parameters that may (or may not) depend on its spatial distribution on the stellar surface; among them the abundance of elusive elements like Lithium or p-mode oscillations.

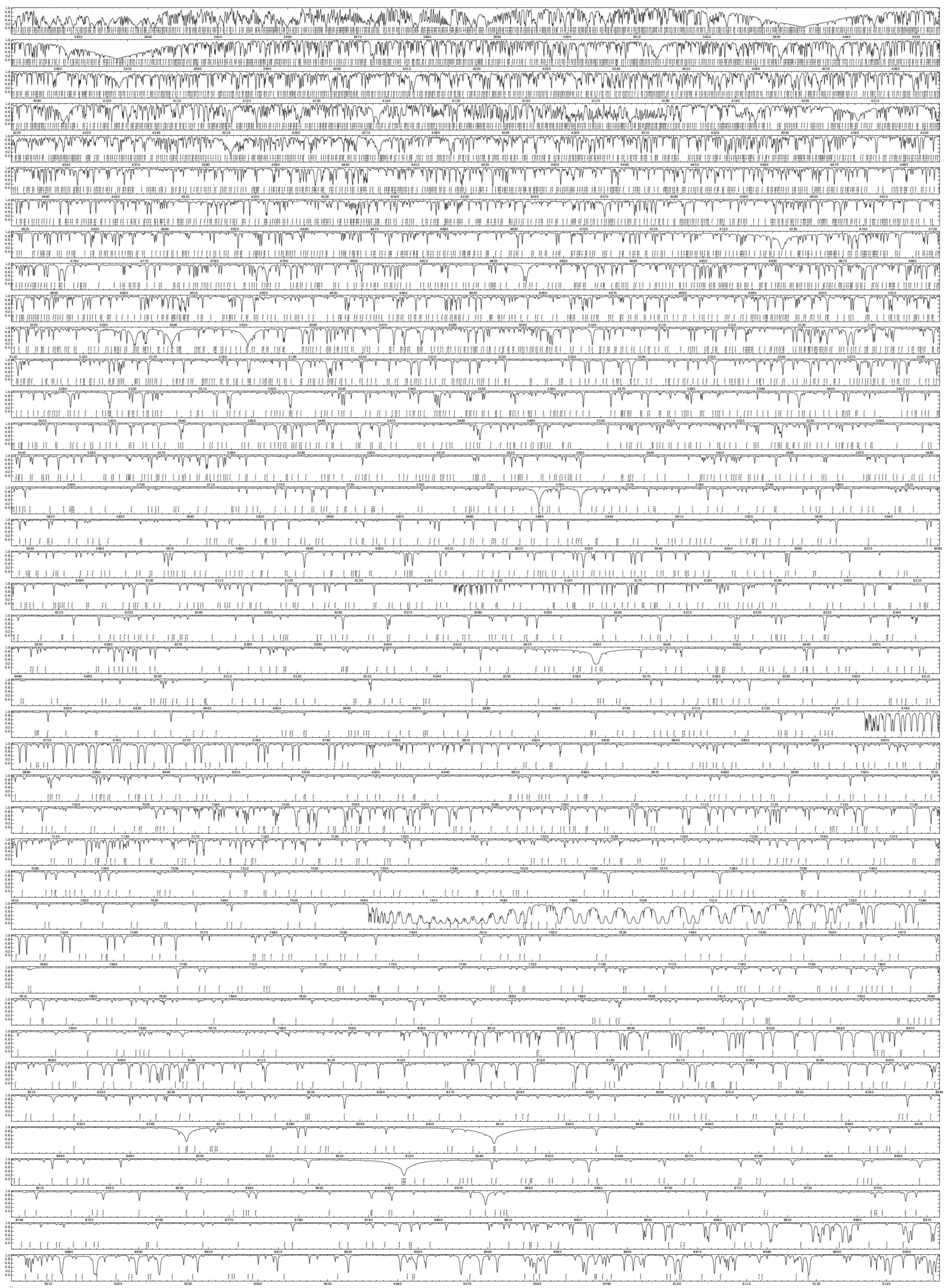




Figs above. Top. Wavelength region around the solar C i line at 5380.3 Å. Dots indicate one of the PEPSI deep spectra and the dark blue and bright red line is the IAG FTS atlas from Reiners et al. (2016) and the HARPS spectrum from Molaro et al. (2013), respectively. The zoom shows the Fe i 5379.6 line. Bottom. A deep PEPSI spectrum (dots with error bars) and its individual 20 exposures (colored lines) for a 1-Å wavelength region around the Cr I 6428.1 line. The twenty individual back-to-back spectra are offset in continuum by +0.01 for better visibility. The deep spectrum is unshifted and directly compared with the IAG FTS (blue line) and NSO FTS (red line) atlases. Note that the equivalent width of the Cr line at 6428.1Å is just 1.8 mÅ.

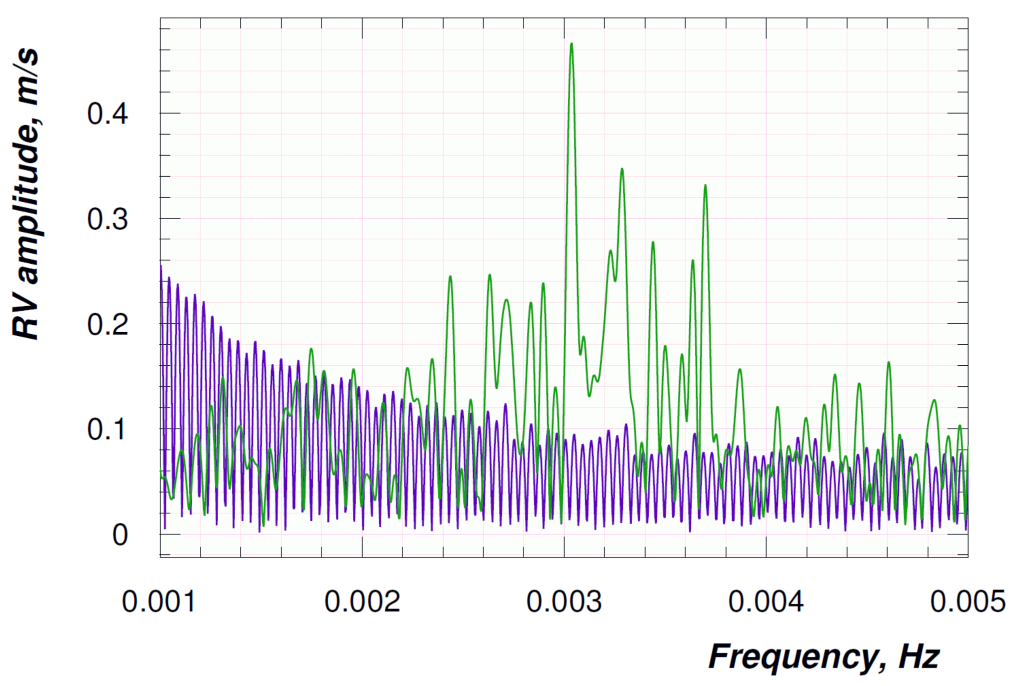




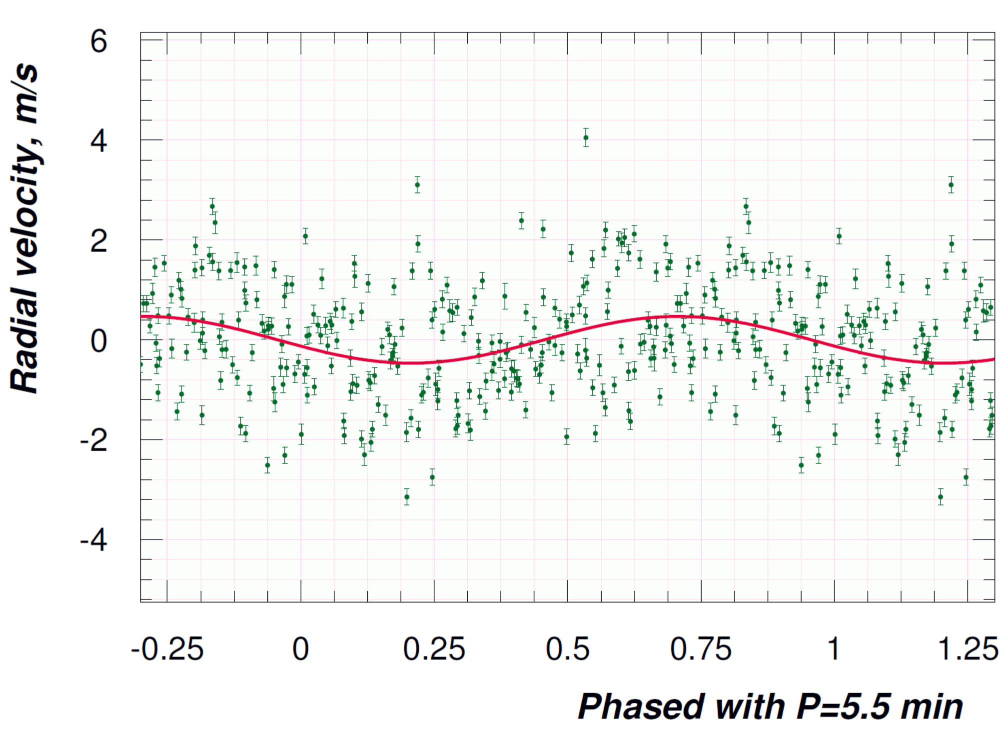


Figs right. Picture series. SDI GUI showing the guider image with a large spot group, the web camera control picture, and the various acquisition and guiding parameters. After a winter storm on the kitchen balcony. SDI telescope version 2 (=current). The top entrance holds the off-axis mirror telescope with its fiber feed, the lower entrance holds the guiding telescope. In the background three stooges ... very right, the full PEPSI solar spectrum.

a.

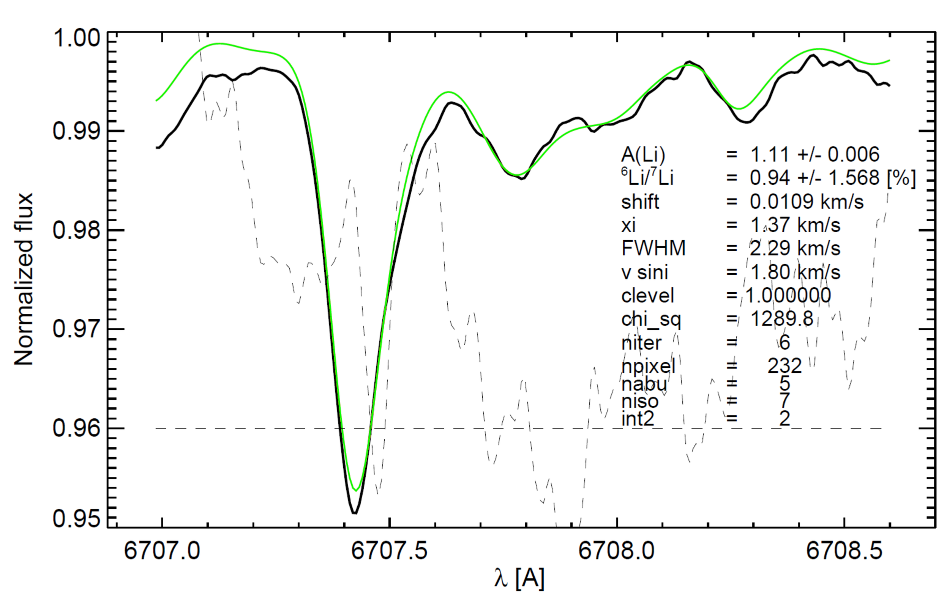


b.

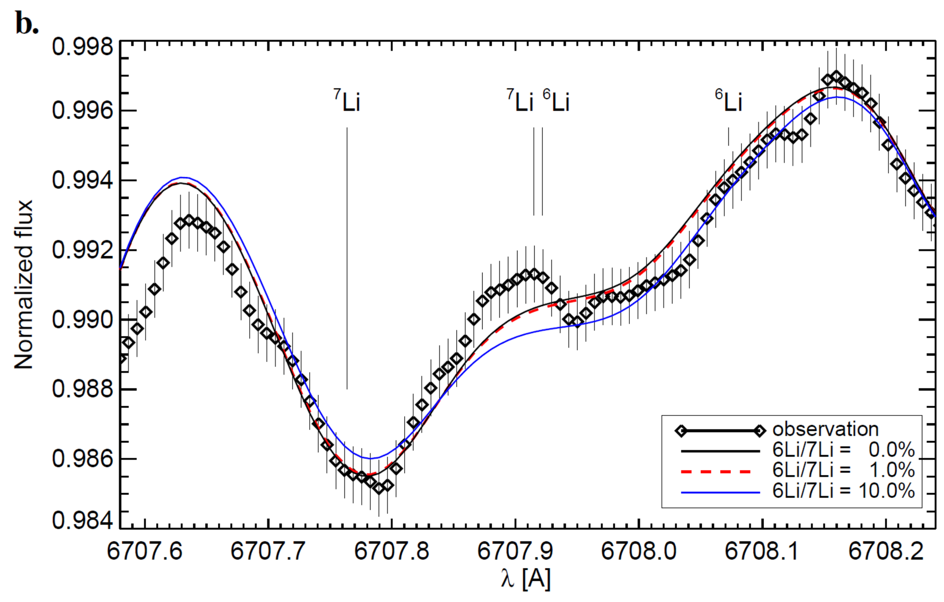


Figs above. Detection of solar p-mode oscillations with Sun-as-a-star PEPSI spectra. A total of 996 back-to-back spectra were taken with CDIII (λ480–544 nm) and resulted in ≈300 radial velocities every day for 8.5 hours. Exposure time was 3s. Air mass varied between 1.4 to 4.4 and S/N ratio between 490 to 410, respectively. The figure shows the results from one day. *a*. Periodogram from the 8.5-hr time series. The peak at 3 mHz (5.5 min) appears with an amplitude of 47 cm s^{-1} (the blue line is the window function). *b*. RV versus phase combined with the best-fit period. Its rms is 1.2ms^{-1}.

a.

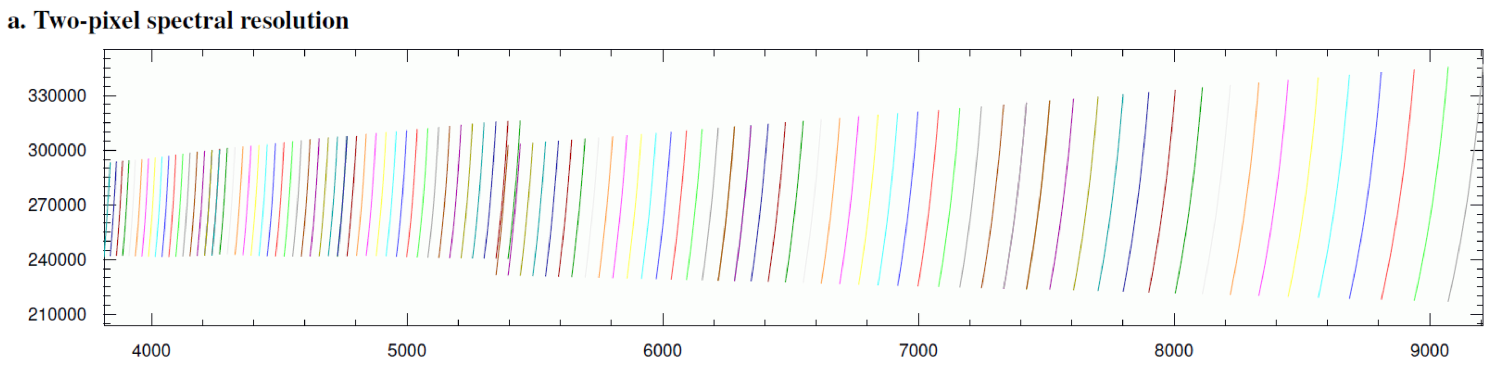


b.

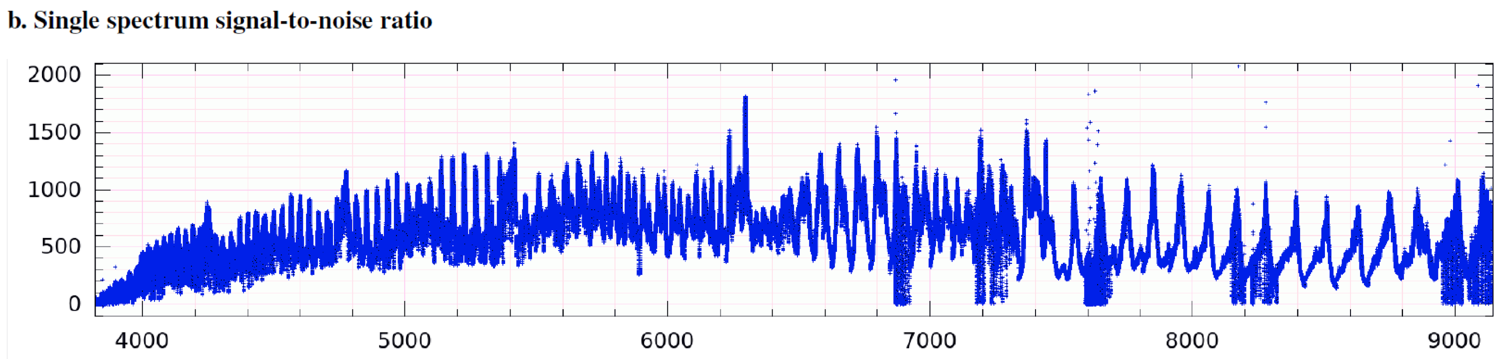


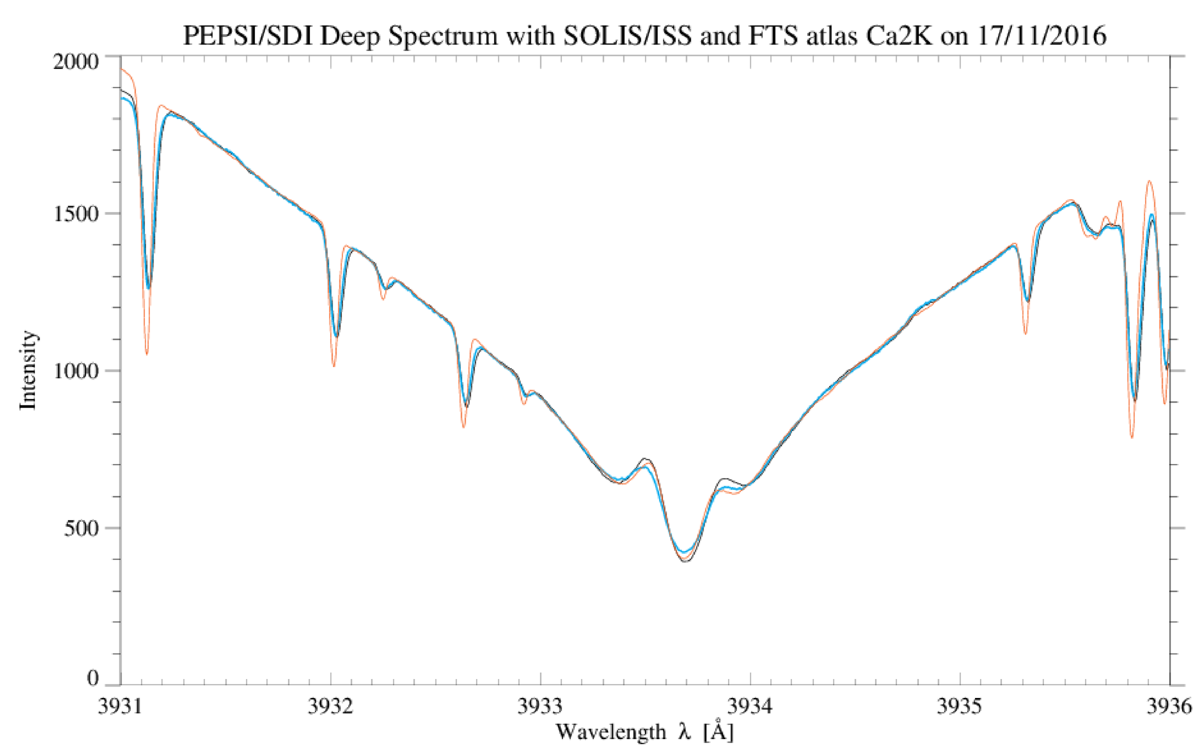
Figs above. The Li I 6707.8-Å line of the Sun. The analysis of isotopic ratios and their relative contributions requires extremely clean, high-quality spectra. Here we present the analysis of a „deep" spectrum of the Sun made up from 100 individual exposures. *a*. A 1.8-Å section of the deep spectrum (dark black line) and the fit with a synthetic 3D NLTE spectrum generated with CO5BOLD and *Linfor3D* (green line). The insert lists the best-fit parameters. The residuals (dashed lines) are enhanced by a factor 10 for better visibility and offset by +0.96 units in flux. *b*. A zoom into a 0.6Å subsection centered on the two Li doublets. Observations are now indicated as open squares with error bars. The colored lines are based on the best fit from panel *a* but for three different isotope ratios as indicated in the insert.

a. Two-pixel spectral resolution



b. Single spectrum signal-to-noise ratio





Figs above. (*a*) The nominal resolution R=λ/Δλ of PEPSI and (*b*) the S/N ratio achieved with a single integration of the Sun (still with the "old" 8mm SDI telescope). The bottom panel is a close-up of the Ca II K line core from PEPSI (black line) in comparison with the NSO FTS spectrum from Wallace et al. (red line) and the SOLIS ISS spectrum from the same day (blue line). Note that the FTS spectrum has a resolution of about 500,000, SOLIS ISS of 300,000 and PEPSI nominally 270,000 (in practice between 220,000-250,000 at that time due to imperfect focus).