Leibniz-Institut für Astrophysik Potsdam

LARGE BINOCULAR TELESCOPE

PEPSI

The Potsdam Echelle Polarimetric and Spectroscopic Instrument

PEPSI data acquisition and image processing

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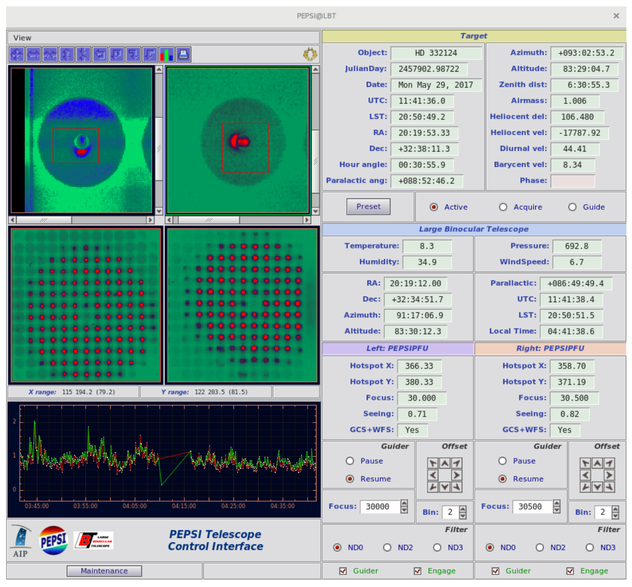
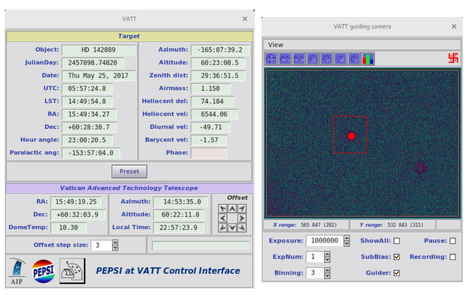
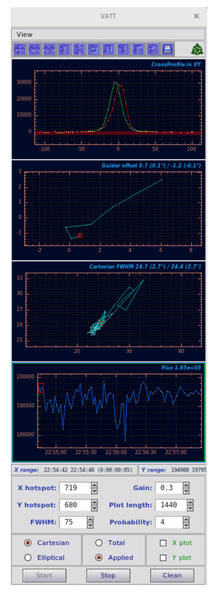
Abstract: The Spectroscopic Data Systems (SDS4PEPSI) is a generic C++ software package based on a numerical template library and graphical toolkit. It is designed and implemented as the control system for various distributed units of the PEPSI spectrograph and polarimeter, as well as for comprehensive echelle image processing and analysis of the resulting spectra.



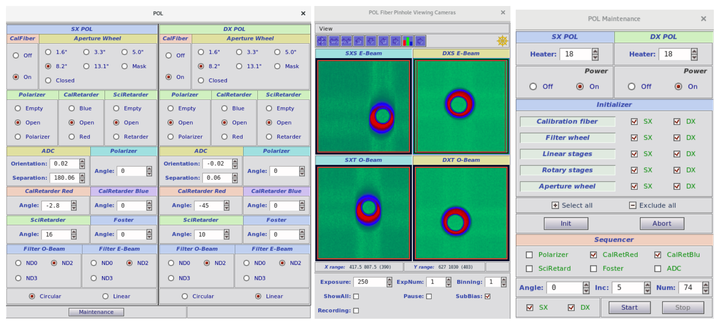
PFU IIF control interface with LBT for presetting to the target and keepeing it centered on the fiber pinhole during integration.



Telescope control interface with the VATT for target preset and guding on the direct-reflected image during integration.

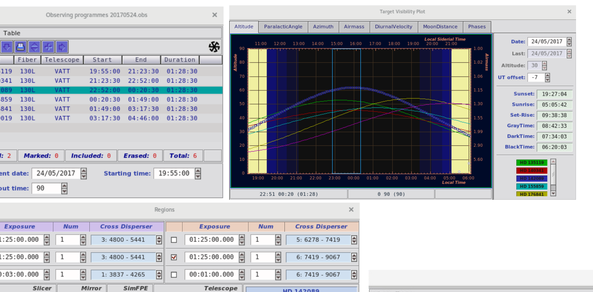


PEPSI guider facility which analyses the guider image and sends the correction offsets to the telescope once its statistical significance is above predefined FAP level.

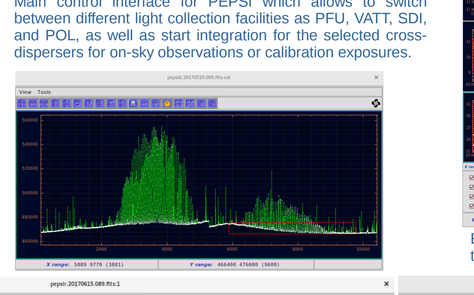


Control interface for the polarimeters which shows the status and current position of its devices. It has four GigE Vision fiber pinhole viewing cameras for two polarimeters and each polarized beam for centering the target on the pinhole during integration. The maintenance windows initializes instrument and runs the polarimetric calibration sequence.

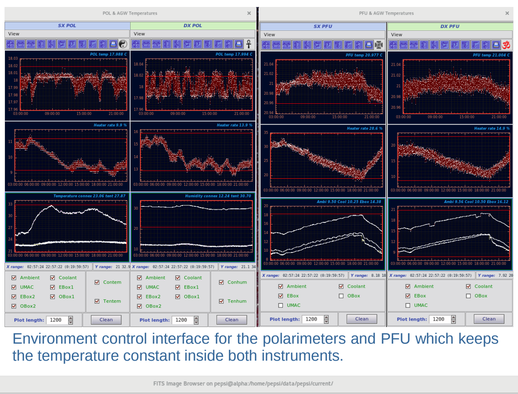
Low level control interface for PFU and spectrograph which shows the status and positions for each device, as well as for the manual control. The maintenance window initializes instrument and changes the set points.



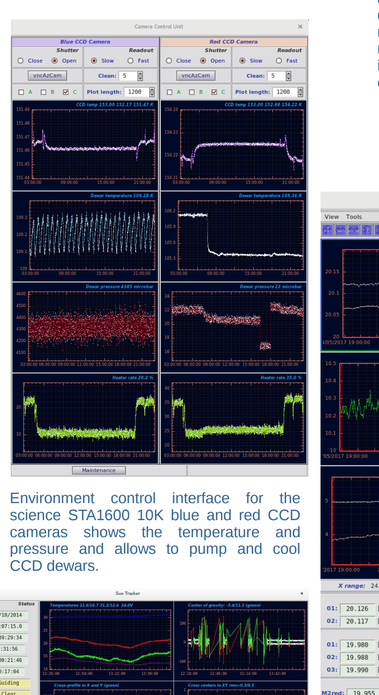
The observing blocks interface is for selecting observing targets according to their visibility and priority with spectral settings selection and exposure times.



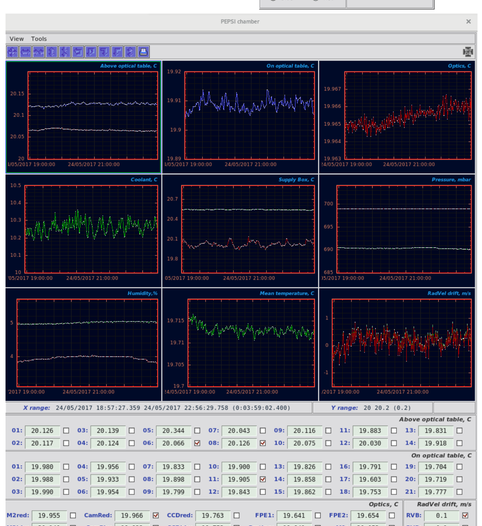
Main control interface for PEPSI which allows to switch between different light collection facilities as PFU, VATT, SDI, and POL, as well as start integration for the selected cross-dispersers for on-sky observations or calibration exposures.



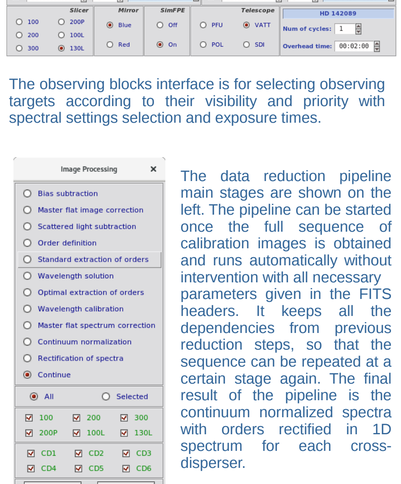
Environment control interface for the polarimeters and PFU which keeps the temperature constant inside both instruments.



Environment control interface for the science STA1600 10K blue and red CCD cameras shows the temperature and pressure and allows to pump and cool CCD dewars.



The PEPSI chamber environment control interface shows the current temperatures, pressure, and humidity. The three parameters are used to calculate the refractive index of air and predict the expected radial velocity offset.



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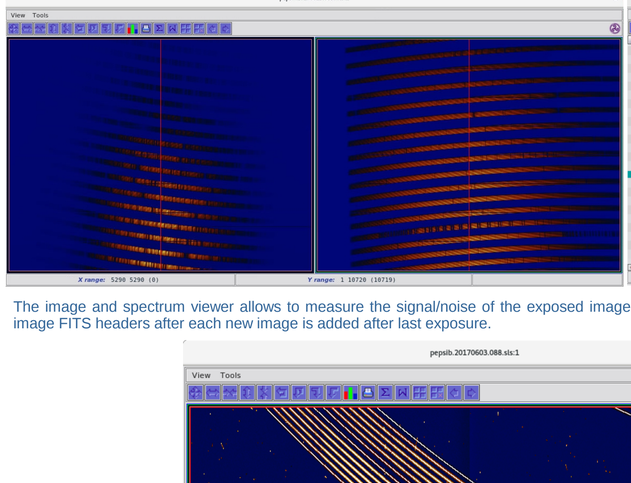
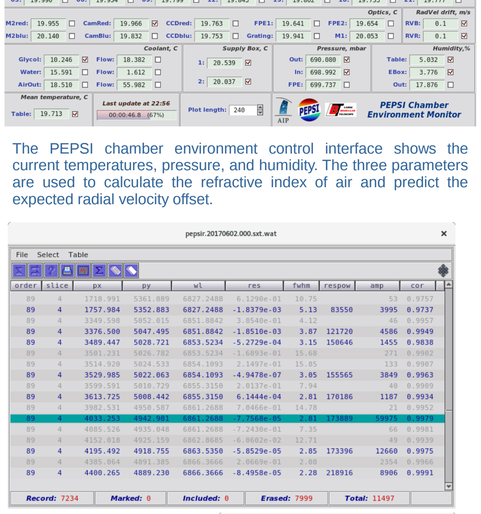
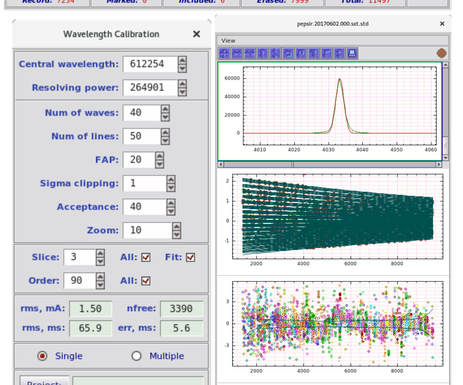
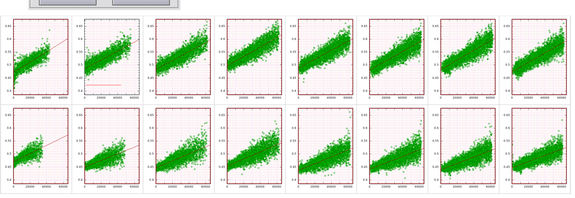


The image and spectrum viewer allows to measure the signal/noise of the exposed images at the selected region of interest. The table shows the selected parameters from the image FITS headers after each new image is added after last exposure.

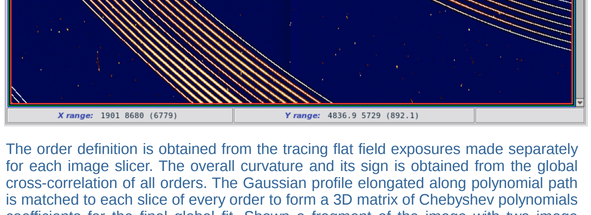


The Solar Disk Integrated Telescope (SDI) is a robotized facility to take spectra in all wavelength regions with 250 000 spectral resolution every day over the solar cycle.

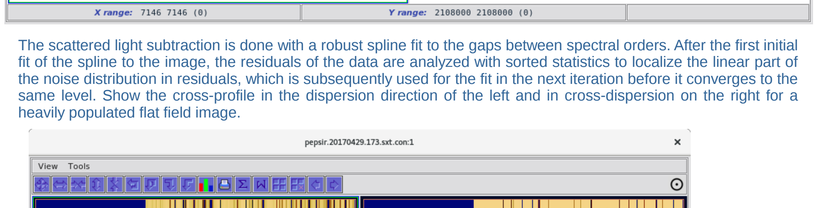




The STA1600 CCD gain calibration is done for each of its 16 amplifiers by using the ratio of two de-focused images of master flat field images repeated at different illumination levels. The conversion factor is the intercept of the fitted line to the gain factor as a function of ADUs. The variance for each pixel is estimated according to the linear fit.

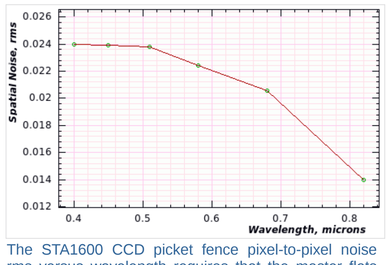


The order definition is obtained from the tracing flat field exposures made separately for each image slicer. The overall curvature and its sign is obtained from the global cross-correlation of all orders. The Gaussian profile elongated along polynomial path is matched to each slice of every order to form a 3D matrix of Chebyshev polynomials coefficients for the final global fit. Shown a fragment of the image with two image slicers and their traces.

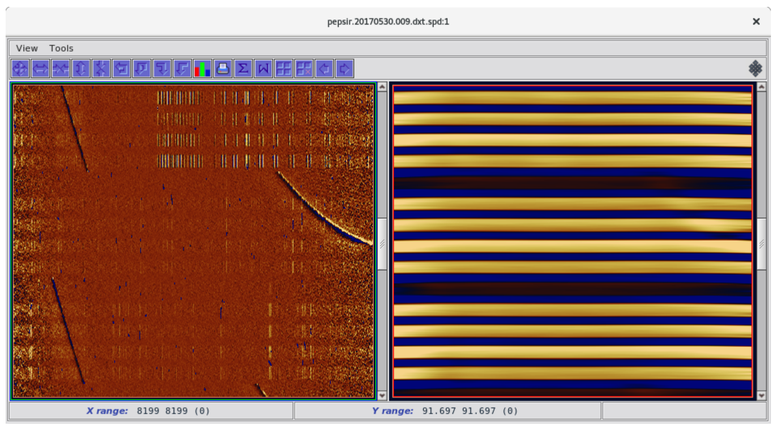


The scattered light subtraction is done with a robust spline fit to the gaps between spectral orders. After the first initial fit of the spline to the image, the residuals of the data are analyzed with sorted statistics to localize the linear part of the noise distribution in residuals, which is subsequently used for the fit in the next iteration before it converges to the same level. Show the cross-profile in the dispersion direction of the left and in cross-dispersion on the right for a heavily populated flat field image.

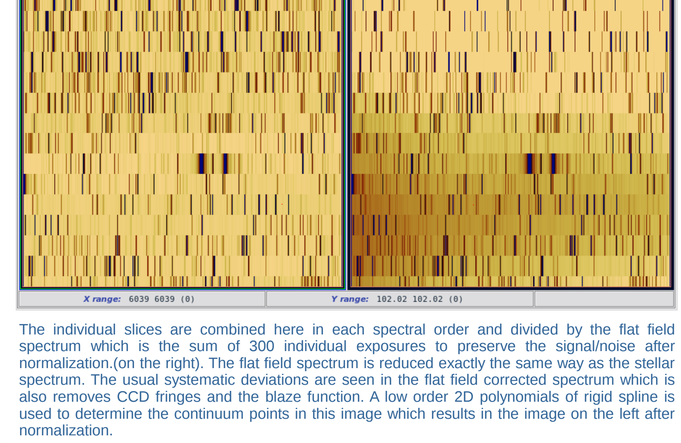
The wavelength calibration is done for each image slicer separately by forming a 3D Chebyshev polynomial fit of each ThAr line position to its normalized wavelength, order number, and slice number as shown in the second from the top panel. The middle panel shows the residuals of the fit, it follows with the FWHM of spectral line distribution along the field, and the resolving power plot derived from the wavelength solution and the measured FWHM of each line. A typical error of the fit in the central part of the image is 3-5 m/s. The initial starting point for each image is given by the approximate value of the wavelength in the first echelle order of the spectrograph and the central order number for a given cross-disperser. With the use of the robust polynomial fit, it finds the best match of spectral lines to the wavelength table.



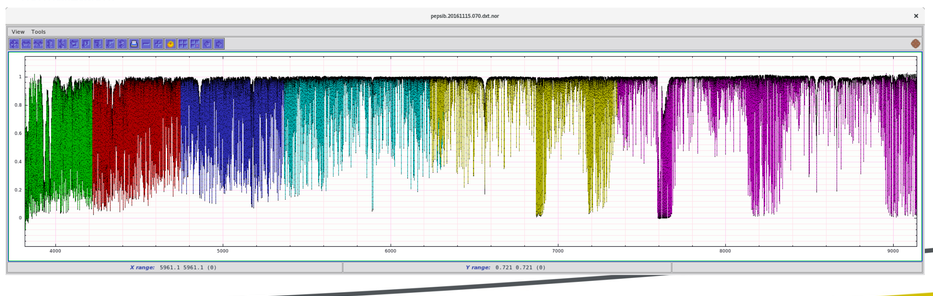
The STA1600 CCD picket fence pixel-to-pixel noise rms versus wavelength requires that the master flats are taken for each cross-disperser separately as the sum of hundreds of exposures. Furthermore, each pixel shows it own non-linear response to different illumination levels, therefore, a polynomial approximation is used to for a super-master flat versus illumination level in order to correct for the CCD spatial noise pattern for each pixel.



The optimal extraction of spectral orders is done by fitting the spatial profile function to the raw data with subsequent elimination of the cosmic ray outlayers. The spatial profile or illumination function is derived from the raw image for every wavelength pixel in each spectral order after normalization to the total flux. The robust spline fit is used to smooth the spatial profile along dispersion for all orders in a global fit with a number of iterations to eliminate outlayers in the data. A fragment of the smoothed spatial profile for three orders is shown on the right and the residual image of the left with the black stretches coming from the cross-line between two amplifiers and the residuals of the telluric lines are seen. The flux in every wavelength pixel is formed as an average weighted with their variances for all slices after the wavelength calibration.



The individual slices are combined here in each spectral order and divided by the flat field spectrum which is the sum of 300 individual exposures to preserve the signal/noise after normalization.(on the right). The flat field spectrum is reduced exactly the same way as the stellar spectrum. The usual systematic deviations are seen in the flat field corrected spectrum which is also removes CCD fringes and the blaze function. A low order 2D polynomials of rigid spline is used to determine the continuum points in this image which results in the image on the left after normalization.



The final spectrum for the Sun from SDI for all cross-dispersers after continuum normalization. Individual regions are partially overlapped which makes it possible to combine them all into one continuous 1D spectrum. The spectra from LBT mirrors has to be also combined together at the final stage of image processing.