

Spectropython_English

Overview of Folders and Scripts – Documentation

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1 Overview

The collection comprises 191 Python scripts for the reduction and analysis of astronomical spectra, organised in 28 main folders. It covers the whole chain: reduction of raw images (echelle and slit spectrograph, NRES), preprocessing of spectral series, measurement of line parameters and radial velocities, plotting, and an extensive time-series analysis (folder TSA), which was developed primarily for the Deneb project.

Conventions:

- Developed under Python 3.13 in Spyder (Qt5) on Linux; many scripts use Qt dialogs.
- Almost every script has a documentation file in the same folder, named <script name>_Documentation.docx.
- Shared modules are located in the folder Building_Blocks and are found via the PYTHONPATH (Spyder: PYTHONPATH manager).
- Input data are mostly 1D spectra in FITS format with a linear wavelength scale (CRVAL1, CDELTA1, CRPIX1) or tables of measured values in CSV format (semicolon, decimal comma) or as a FITS table (TFTS).
- Original files generally remain unchanged; results are saved as new files with a name suffix or in subfolders.

2 Folder overview

Folder	Contents	Scripts
Reduce	Reduction of CCD images: master frames, echelle pipeline, classical slit spectrograph	19
NRES	Preparation of LCO/NRES spectra	4
Header	Check, correct and tabulate FITS headers	3
Series	Processing of entire spectral series: cropping, averaging, smoothing, cosmic rays, quality control, BeSS	10
Normalisation	Continuum normalisation	3
BC	Barycentric/heliocentric and telluric correction	2
Drying	Telluric correction with HITRAN	1
Rebinning_Mean_Spectrum_Difference_Spectra	Common grid, mean spectrum, difference spectra	3
Format_Conversion	Time and coordinate conversions	1
ascii	Reading and plotting ASCII spectra	5
RV	Measuring and correcting radial velocity	5
CC	Cross-correlation of spectra and measurement series	3
EW	Equivalent width	1

Folder	Contents	Scripts
Line_Parameter_Determination	Time series of EW, line depth, position, FWHM, bisector	6
Line_Fitting	Profile fits (Gaussian, Voigt, Lorentzian, multi-component)	6
Micro_Macro_Turbulence	$v \sin i$ and macroturbulence using the Fourier method	2
SNR	Signal-to-noise ratio, artificial noise	2
Spectra_Plots	Viewers, comparison and time-series plots, dynamic spectrum, animation	7
Velocity_Space_Plots	Line profiles of a series in velocity space	2
Plots	Plotting and correlating table columns	1
Theoretical_Spectra	Generating and preparing synthetic spectra	2
Convolution	Gaussian convolution and rotational broadening	4
binaries_Period_Determination_Orbital_Elements	Binary stars: period, phase, orbital elements	8
Light_Curves	AAVSO light curves	1
Catalogue_Queries	SIMBAD, ESO archive, NIST	3
astroplanner	Observation planning	1
Building_Blocks	Shared modules	3
TSA	Time-series analysis in 12 thematic subfolders	86

3 Reduce - Reduction of CCD images

From the raw image to the calibrated spectrum. The echelle pipeline was developed for the FLISES spectrometer and is also used for the instruments of Bernd, Daniel and Siegfried; the corresponding verified line catalogues and calibration aids are located in the subfolders `verifiedVersion *`, the ThAr reference catalogues in `ThAr_LineCatalogues`. Complete description: `Echelle_Pipeline_Documentation.docx`.

3.1 Reduce (main folder)

Script	Description
CreateMasters_CCD_2d_fits.py	Master frames (science, dark, calibration light, flat) from several 2D FITS images, dark-current corrected
FITS_2D_Viewer.py	Interactive viewer for 2D FITS images (raw images, flats, darks, calibration exposures)
Telluric_Zero_Point.py	Instrumental RV stability from telluric lines (O_2 and H_2O bands): drift and zero point per spectrum, trend, changepoint step and periodogram

3.2 Reduce/Echelle

Script	Description
Echelle_Extraction.py	Order extraction from flat, ThAr and science

Script	Description
	exposures
ThAr_Calibration.py	Wavelength calibration against bachesLINE.fit: two anchor clicks, echelle model, iterative line assignment per order
Echelle_InstrumentSpecific_LineCatalogue_Creation.py	Instrument-specific identification table (X, ORDER, WAVEC, IDENT, PEAK) for a new spectrograph
Normalisation_Orders.py	Continuum normalisation of the calibrated echelle orders
Merge_Orders.py	Merging of calibrated orders into a complete 1D spectrum
Diagnosis_LineYield.py	Shows, per order, how many ThAr lines each filter step of the assignment costs
ThAr_LineCounter.py	Counts the detected ThAr lines in all extracted orders
ThAr_LineCatalogue_Viewer.py	Interactive viewer for ThAr line catalogues as a synthetic spectrum
ThAr_Image_Show.py	Shows a 2D ThAr exposure and saves it as PNG
live_Reduction/Live_Reduction.py	Live reduction of an observing night with the echelle pipeline

3.3 Reduce/Classical Spectrograph

Script	Description
2._AlignSpectrumStrip_CCD_Images_fits.py	Aligns the spectrum strip of a slit spectrograph horizontally (rotation angle taken from the master)
3._ExtractionAndWavelengthCalibrationNormalisation_withSlit_... _withCalibrationLineOptimisation.py	Extraction, wavelength calibration and normalisation for slit spectra
3a_ExtractionAndWavelengthCalibrationNormalisation_slitless_CCD_Images.py	Extraction, approximate calibration and normalisation for slitless spectra
Reduce_GUI.py	Graphical user interface for the entire workflow: master, alignment, extraction, calibration, normalisation, display
spectro_core.py	Module: common computing functions of the scripts and the GUI
spectro_workflow.py	Module: common workflow of extraction, calibration and normalisation

4 NRES - Spectra of the LCO network

Preparation of spectra from the NRES echelle spectrographs (Las Cumbres Observatory). Sequence: extraction → vacuum/air → barycentric correction → control plot. Background: NRES_Beschreibung_20241207.pdf.

Script	Description
NRES_extract.py	Extracts the 68 orders of the science fibre as individual 1D FITS files (0.05 Å/pixel)
VacToAir.py	Converts the wavelength scale from vacuum to air
heliocentricCorrection_NRES.py	Applies the barycentric correction from the header value BARYCORR
PlotAllOrders.py	Control plot of all orders of a spectrum

5 Header - FITS headers

Script	Description
fits_header_check_correct.py	Checks and corrects FITS headers
jd_header_check.py	Checks the time information of a series and, on request, enters the keyword JD
header_print_series_csv.py	Header of a series as a CSV per file, overall table and comparison report (constant/varying/missing keywords)

6 Series - Processing of spectral series

Script	Description
TimeSeries_Overview.py	Inventory: time, wavelength range, dispersion and flux range for each spectrum
spectra_diagnosis.py	Actual wavelength and JD ranges with recommendations for time-series plots
spectra_quality_control.py	Interactive quality control: S/N, NaN and zero pixels, spikes, continuum level
remove_cosmics.py	Detects and removes hot pixels and cosmic-ray hits in 1D spectra
Crop_Section_TimeSeries.py	Crops a series to a wavelength section
Average_Of_fits.py	Combines any number of spectra into a mean spectrum (even with different grids)
TimeSeries_Spectra_Smooth.py	Smooths a series of spectra
JD_In_Filename.py	Adds the JD and, optionally, the wavelength range to the file names
fits_series_to_csv_and_dat.py	Converts a FITS series into CSV and DAT files
BESS/BESS_fits_header_series.py	Supplements the headers of a series in conformity with BeSS

7 Normalisation

Script	Description
Universal_Normalisation.py	Continuum normalisation of 1D FITS spectra
Normalisation_Single_Lines_20260923.py	Normalisation of the surroundings of individual lines in spectral series

Script	Description
support_point_validator_single_lines_20260923.py	Checks normalisation support points for lines with variable RV

8 BC - Barycentric and telluric correction

Script	Description
barycentric_correction_spectra.py	Heliocentric correction of a series (site from observatories.py), with log CSV
telluric_bc_correction.py	Telluric correction (Hanuschik 2006) and barycentric correction (barycorrpy) in the range 6500–6620 Å

9 Drying - Telluric correction

Script	Description
telluric_drying_hitran.py	Telluric correction without barycentric correction, with H ₂ O lines from HITRAN in the H α gap of the Hanuschik table

10 Rebinning_Mean_Spectrum_Difference_Spectra

Script	Description
newbinning_mean_spectrum_v2.py	Rebinning of a series onto a common grid and mean spectrum
DifferenceSpectra_v2.py	Difference spectra of a series against a reference spectrum
DifferenceSpectra_withPlotAll_v2.py	Calls DifferenceSpectra_v2.py with a collective plot of all differences

11 Format_Conversion

Script	Description
format_conversions.py	Conversions JD/MJD ↔ calendar date, RA/DEC sexagesimal ↔ degrees, HJD, BJD, barycentric RV correction, altitude, azimuth, airmass

The subfolder Building_Blocks no longer contains any scripts, only the documentation of the removed building blocks FixedTargets and SternUndOrtskoordinaten.

12 ascii - ASCII spectra

Script	Description
1d_dat_read_plot_save_csv.py	Reads a spectrum from any two-column ASCII file (format detected automatically) and saves the plot as PNG
1d_txt_plot.py	Simpler version: read an ASCII spectrum, plot it, save as PNG
spectra_stack_plot.py	Several ASCII spectra stacked, in colour or with offset,

Script	Description
	with S/N filter
comparison_plot_2spectra_ascii.py	Overplot of two ASCII spectra as PDF
PlotAndCrop_1d_ascii.py	Plot an ASCII spectrum and save a wavelength section

13 RV - Radial velocity

All scripts use the module `Building_Blocks/rv_tools.py` and write uniform header entries (RVMEAS, RVERR, RVSHIFT ...).

Script	Description
RV_Measurement_OneLineInFitsSeries_Spline.py	RV of a line in a series from the position of the line minimum (or maximum)
RVCorrectionByTemplate_1d_spectra_fits_series.py	RV relative to a template by cross-correlation and shift onto the template
RVCorrection_1d_spectra_fits_series.py	Shifts a series by a given or tabulated velocity
telluricLines_RVCorrection_RBF_1d_spectra_fits_series.py	Zero-point correction on telluric lines, minimum via radial basis function
telluricLines_RVCorrection_Regression_1d_spectra_fits_series.py	Zero-point correction on telluric lines, minimum via polynomial regression

14 CC - Cross-correlation

Script	Description
cross_correlation_fits_series_v2.py	RV of a series by cross-correlation with a template, optionally barycentrically corrected
cross_correlation_fits_series_single_lines_v2.py	Cross-correlation restricted to ranges around individual lines
cross_correlation_measurements.py	Pairwise cross-correlation and correlation matrices of arbitrary time series of measured values (CSV)

15 EW - Equivalent width

Script	Description
EW_absorption_emission.py	Equivalent width with separate absorption and emission components, graphical range selection

16 Line_Parameter_Determination

Script	Description
TimeSeries_EW_LineDepth_LineWavelength_FWHM_MultipleModels.py	EW, line depth, position of the minimum and FWHM of a line over a series; models spline, Gaussian, Voigt, split Voigt or automatic (BIC), with 1σ errors

Script	Description
TimeSeries_EWs_MultipleRegionsInOneLine.py	Equivalent widths of several ranges within one line as a time series
LineArea_VelocityRange.py	Line area within a selectable velocity range
Bisector_RV_TimeSeries.py	Bisector-based RV time series per line at a fixed relative depth (for variability analysis)
Tomography_Single_Lines.py	Tomography from individually chosen lines and their bisectors: travel time of a disturbance through the atmosphere (ICCF with FR/RSS, phase method)
Tomography_Formation_Depth.py	Tomography by formation depth: joint multi-profile LSD in K line masks, RV per layer and travel time (ICCF, phase method), optional external series (H α , H β)

17 Line_Fitting

Script	Description
FitLine.py	Profile fit of a line over a series: Gaussian, double Gaussian, Lorentzian, split Lorentzian, Voigt, double Voigt
FitLine_auto_parametrised.py	Like FitLine.py, with the starting values tracked from spectrum to spectrum
FitLine_PositiveAndNegativeGauss_Version2.py	Emission line with central absorption (e.g. β Lyr, Be stars): emission plus absorption Gaussian
Halpha_Double_Gaussian_Fit.py	H α in Deneb: emission and absorption components, multi-start fit
Halpha_Profile_Fit_Voigt_Gauss.py	Multi-component fit of the H α profile (Voigt/Gaussian)
FWHM_of_one_line_series_fits.py	FWHM and resolving power R from lamp or telluric lines

18 Micro_Macro_Turbulence

Joint documentation of both scripts:

MacroTurbulence_Fourier_Method_Documentation.docx.

Script	Description
MacroTurbulence_Fourier_Method.py	$v \sin i$ and macroturbulence ζ from a spectrum using the Fourier method (Gray 2005), Monte Carlo errors, profile fit
MacroTurbulence_Fourier_Method_batch.py	Batch mode for many spectra and lines from line_lists.py, collective CSV and time-series plot

19 SNR - Signal-to-noise ratio

Script	Description
SNR_Determinatio	S/N of a series of 1D stellar spectra

Script	Description
n.py	
add_noise.py	Adds Gaussian noise to spectra, e.g. to test the robustness of analyses

20 Spectra_Plots - Plotting

Script	Description
1d_fitSpectrum_view.py	Viewer: header, complete spectrum with coupled zoom, paging through the folder
1d_fitSpectrum_view_withLineIdentification_WithSubplot.py	Viewer with markers for selected lines from line_lists.py
Spectra_Comparison.py	Overplot of several calibrated spectra (PyQt5 GUI)
timeseries_Spectra.py	Time series of spectra with offset, JD legend, wavelength and JD range
Dynamic_Spectrum.py	Dynamic spectrum of a line: velocity or wavelength against JD, colour = flux
AnimationFromPlots.py	Image series as an animation, export as MP4 or GIF
fits_to_png.py	Batch export of all FITS files in a folder as PNG (1D and 2D)

21 Velocity_Space_Plots

Script	Description
fits_series_line_velocity_space_jd_range_v2.py	One line in velocity space: overplot, offset time series, dynamic spectrum; selectable JD range
fits_series_lines_velocity_space_jd_range_v2.py	Several lines in velocity space side by side or in one plot

22 Plots

Script	Description
PlotsFromTableColumns.py	Plot columns from CSV, FITS, Excel or ASCII against each other, also across tables via JD; correlation and regression

23 Theoretical_Spectra

Script	Description
Spectrum_GaussBroadened.py	Preparation of synthetic or tabulated spectra (Kurucz, POLLUX and others) for comparison with measurements
CreateArtificialSpectrum.py	Test spectrum with six lines of known position, broadened to R and with added noise

24 Convolution

Script	Description
convol_fits.py	Gaussian convolution of FITS spectra to a resolving power R (or σ , FWHM)
convol_dat.py	The same for tabulated spectra (.dat, .txt, .csv)
Pollux_Ausschnitt_convolve.py	Section and Gaussian convolution of a POLLUX model spectrum
rotation_broadening_fits.py	Rotational broadening ($v \sin i$, limb darkening) with optional Gaussian convolution

25 binaries_Period_Determination_Orbital_Elements - Binary stars

Script	Description
period_analysis.py	Period search with Lomb-Scargle and the string-length method
orbital_elements_from_jd_rv_fit.py	Orbital elements of an SB1 (K, e, ω , T0, γ) from RV measurements for a known period, Lucy-Sweeney test
rv_calculation_from_orbital_elements_and_jd.py	Theoretical RV from orbital elements
phase_calculation.py	Phases and phase plot for a table of measured values with a known ephemeris
phase_calculation_from_spectra_given_t0_and_period.py	Phase and epoch for each FITS spectrum from the header time, as CSV
phase_plot_known_period_20260924.py	Phase plot from arbitrary table formats with column selection in a dialog
sum_and_difference_spectrum_measured_minus_theoretical_per_phase_with_integral_correction.py	Theoretical sum spectrum and difference from the measured spectrum per phase
spectrum_conversion_barycentric_to_stellar_rest_frame.py	Convert barycentrically corrected spectra to the rest frame of one component

26 Light_Curves

Script	Description
aavso_lightcurve_analysis.py	Analysis of AAVSO data: format detection, upper limits, mean values, plot

27 Catalogue_Queries

Script	Description
simbad_query_a.py	Object profile from SIMBAD
eso_query.py	Reduced data (Phase 3) from the ESO archive
nist_line_wavelengths.py	Line wavelengths from the NIST Atomic Spectra Database

28 astroplanner

Script	Description
astroplanner_20260924.py	Observation planning for one night: altitude curve, twilight, Moon, usable window

29 Building_Blocks - shared modules

These modules are imported by many scripts and must be reachable via the PYTHONPATH.

Module	Description	Used by
line_lists.py	Line database (228 lines, 21 ions + telluric) with search, export and selection functions	over 20 scripts
rv_tools.py	Dialogs, reading, Doppler shift, header, log and telluric evaluation for the RV scripts	RV, Dynamic_Spectrum
observatories.py	Observer site coordinates	barycentric_correction_spectra

30 TSA - Time-series analysis

Analysis of time series of measured values (RV, EW, FWHM, line depth ...), mostly irregularly sampled. The numbers of the subfolders indicate the usual order of the working steps. Folder description: README_Folder_Structure.md; method descriptions in 90_Documentation.

30.1 01_Data_Preparation

Script	Description
OutlierAnalysis.py	Four-stage outlier detection with cross-validation over several measurement channels
MedianLoessFilter.py	Time-based median filter and LOESS smoothing
time_range_binning_and_interpolation.py	Binning of a variable onto selectable time ranges
parse_stats_to_csv.py	Combines *_stats.txt files into one CSV

30.2 02_Plotting

Script	Description
Measurement_Plot.py	Time-series plot of a measured quantity from one or more tables
Measurement_Comparison.py	Several measurement series over a common JD axis
PlotsFromColumns_batch.py	Plotting from CSV, FITS, Excel, ASCII; interactive or in batch mode
LOESS_Comparison_Plots_batch.py	Comparison plots of the LOESS-filtered quantities APX, EW, FWHM, RV for all common lines

30.3 03_Test_Data

Script	Description
synthSignal_GUI.py	Generator of synthetic time series for testing the analysis methods

30.4 10_Period_Analysis

Script	Description
GLS/GLS.py	Generalised Lomb-Scargle periodogram (Zechmeister & Kürster 2009)
PDM/PDM_Period_Analysis.py	Phase dispersion minimisation, single file and batch, with bin stability analysis
PDM/amplitude_tracking.py	Tracking of the amplitude of periodic signals over time
CLEAN/CLEAN_Period_Analysis.py	CLEAN algorithm for removing window-function aliases
ACF/ACF.py	Autocorrelation function with confidence band
Prewhitening/ tsa_prewhitener_auto_white.py	Detrending, multi-term Lomb-Scargle, iterative prewhitening down to white residuals, bootstrap FAP
Sine_Fit/SineFit_Period.py	Harmonic sine regression for given periods
Phase_Folding/ Phase_Folding_Single_Line.py	Phase folding of several measured quantities of a line onto a reference period
Epoch_Screening.py	Sliding period screening (GLS or PDM) for episodic short periods

30.5 11_Time_Frequency

Script	Description
WWZ/wwz.py	Weighted Wavelet Z-Transform: single file, batch, synthesis, test against red noise
WWZ/wwz_core.py	Module: computational core of the WWZ
Sliding_GLS/ SlidingGLS_Spectrogram.py	Sliding GLS spectrogram as a gap-robust alternative to the WWZ
EMD/eemd_analysis_final.py	EEMD/CEEMDAN decomposition into intrinsic modes
Synchrosqueezing/ Synchrosqueezing_Analysis.py	Synchrosqueezed wavelet transform
Sliding_SHO/ Sliding_SHO_celerite2.py	Interpolation-free time-frequency analysis by window-wise fitting of SHO kernels (celerite2)

30.6 12_Noise_Models

Script	Description
PSD_plot.py	Power spectral densities of several measured quantities or lines
Structure_Function.py	Structure function of irregularly sampled time series
GPR/ GPR_Time_Series_Analysis.py	Gaussian process regression

30.7 20_Line_Comparison

Script	Description
Influence_Factors/ InfluenceFactor_Analysis.py	Common and individual influences on several measured quantities (PCA/factor analysis and others)
Extrema_Time_Differences/ TimeDifferences_Extrema_TwoLines.py	Time differences between local minima and maxima of two time series
GLS_Comparison/GLS_Line_Comparison.py	GLS periodograms of many lines with a correlation heatmap
Correlation_Regression/ Correlation_Analysis.py	Pearson and Spearman correlations between measured quantities
Correlation_Regression/ Regression_Analysis.py	Regression of two measurement series after JD matching
Cross_Correlation/ DCF_CrossCorrelation_Verification.py	Verification of lags from the cross-WWZ with the DCF (Edelson & Krolik 1988)
Cross_Correlation/ CrossCorrelation_Bandpass_Verification.py	Verification of lags by cross-correlation of band-pass-filtered series
Cross_Spectrum/LSSA_CrossSpectrum.py	Segmented LSSA coherence without interpolation
Cross_Spectrum/WaveletCrossBispectrum.py	Wavelet cross-bispectrum
Lag/Lag_Analysis_Line_Pair.py	Time offset between two RV time series, e.g. to test dispersive wave propagation
Lag/Lag_All_Line_Pairs_CCF.py	CCF lag for all pairs of a line selection
Lag/Lag_Ranking.py	Ranking of the lines by formation depth from the lag matrix
Lag/Lag_Reference_Line_Extraction.py	Lags of all lines relative to a reference line from a lag table
Lag/EW_APX_vs_Lag.py	Mean EW and line depth against the lag
Lag/Eup_Elow_vs_Lag.py	Excitation potentials against the lag
Line_Parameters/ Line_Parameter_Comparison.py	One line parameter across many lines in parallel
Line_Parameters/ Line_Comparison_Clustering.py	Clustering of smoothed RV time series of many lines
Line_Parameters/ Measures_Line_Comparison.py	Time evolution of arbitrary measured quantities of several lines
WWZ_Comparison/ WWZ_Line_Comparison.py	Comparison of the WWZ results of several lines
WWZ_Comparison/ WWZ_Comparison_Multiple_Lines.py	WWZ spectrograms of several lines, with time-offset layout
WWZ_Comparison/ WWZ_Similarity_Analysis.py	Similarity of WWZ spectrograms in four dimensions
WWZ_Comparison/ WWZ_Correlation_Neighbours.py	Lines with a WWZ spectrogram similar to that of an anchor line
WWZ_Comparison/WWZ_Line_Grouping.py	Grouping of WWZ spectrograms by structural similarity

30.8 21_Causality

Script	Description
GrangerCausality.py	Multivariate Granger causality
TransferEntropy.py	Symbolic transfer entropy between RV time series
ConditionalTransferEntropy.py	Conditional transfer entropy

30.9 30_Nonlinear_Dynamics

Script	Description
Phase_Space/PhaseSpaceReconstruction.py	Phase-space reconstruction by time-delay embedding (Takens)
Phase_Space/attractor_encoder/attractor_autoencoder_interactive.py	Attractor reconstruction with autoencoders
Lyapunov/lyapunov_analysis.py	Lyapunov exponents
Lyapunov/NonlinearDynamics.py	Lyapunov spectrum, Kaplan-Yorke dimension, permutation entropy
Multifractal/multifractal_analysis.py	Multifractal dimension spectra
DMD/DMD_Analysis.py	Dynamic mode decomposition
Recurrence/TSA_Analysis_Multiple_Methods.py	Distance matrix, autocorrelation, Lomb-Scargle, wavelet, recurrence plot and FFT in a single run
Recurrence/Phase_Space/PhaseSpace_DistanceMatrix_Analysis.py	Distance matrix and recurrence analysis in the reconstructed phase space
Recurrence/Value_Space/RC_and_DistanceMatrix_valuespace.py	Distance matrix and recurrence plot in value space, optional RQA (static and sliding)
Recurrence/Value_Space/Value_DistanceMatrix_analysis.py	Comprehensive statistical evaluation of distance matrices
Recurrence/Value_Space/rqa_metrics.py	Module: RQA metrics
Recurrence/Cross_RQA/Multi_File_Cross_RQA.py	Cross-recurrence analysis of several files

30.10 40_Statistics

Script	Description
histogram_analysis.py	Histograms and statistics of measured values or observation intervals
Statistics_OneVariable_AllLines.py	Statistics of one variable across all files of a directory
Extrema_Statistics.py	Statistics of extrema of measured values
Changepoint_Analysis_SiII.py	Changepoint detection in the RV time series of SiII 6347/6371

30.11 50_Systematic_Analysis

Five-stage analysis chain without regularisation.

Script	Description
01_Periodicity_Analysis.py	GLS, WWZ, PDM, CLEAN, string length, AoV
02_CrossCorrelation_Lag.py	DCF, ZDCF, cross-WWZ, optional JAVELIN
03_Nonlinear_Recurrence.py	RQA, CRP, JRP, CCM, mutual information
04_Statistical_Dependence.py	Distance correlation, transfer entropy, copula analysis
05_ModelBased_GP_CARMA.py	Gaussian process and CARMA (celerite2), sparse Bayesian learning

30.12 60_Spectral_Analysis

Script	Description
Bisector/Bisector_Analysis.py	Bisector of a line for each spectrum, several displays
Bisector/Bisector_CCF_Depths.py	Cross-correlation of the bisector RV series of all depth levels
HalpHa/HalpHaVariability.py	Systematic analysis of the H α profile variation
Line_Asymmetry/Spectral_line_asymmetry_interactive.py	Line asymmetry by reflection about the minimum
Line_Asymmetry/SpectraDifferenceToReferenceSpectrum_Line.py	Difference of each spectrum from a reference spectrum in the range of a line
Line_Asymmetry/DifferenceAreaPlot.py	Plot of the difference areas (positive, negative, total) against JD
Line_Asymmetry/FluxAtOffset_Line.py	Flux at a fixed velocity offset from the line minimum
Temperature/ExcitationTemperature.py	Excitation temperature from the EW ratio of two lines
Temperature/Boltzmann_Temperature_Fitter.py	T _{exc} (JD) from Boltzmann fits over several ions
Temperature/Boltzmann_Saha_Analysis.py	Simultaneous determination of T _{exc} and electron pressure
Temperature/LDR_Calibration_Hot_Stars.py	Calibration of line-depth ratios (LDR) on model spectra for A supergiants
Temperature/LDR_Batch_Analysis_from_fits.py	Application of the LDR calibration to a FITS series

30.13 90_Documentation

Method descriptions (Analysemethoden.odt, MethodenZurPeriodenfindung.odt), detailed project documentation (Deneb_TSA_Documentation_Detailed.html), notes on the code, and literature on recurrence plots (including Marwan's habilitation thesis).

31 Further documents in the main folder

File	Contents
BeschreibunDerSkripte_20251027.pdf (.lyx)	Complete description of the scripts, as of October 2025

File	Contents
SpektroPython_Einführung_veraltet_aber_informativ.pdf	Older introduction to the collection
Poessel_BeginnersGuideAstronomicalData.pdf	Introduction to astronomical data formats (M. Pössel)
InternetlinksFuerPython.txt	Collection of links
TSA_alt_vor10_2026.zip	Archive of the TSA version before October 2026