Data Reduction Software for SPIRou

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DRS goals and specifications

- Near-real time automatic data reduction of calibration and science data
- Provide all steps of the scientific reduction from 2D raw frames
to wavelength-calibrated flat-field corrected intensity and polarization
extracted spectra
- Provide RV, Zeeman signature and telluric contents

DRS mainly adapted and optimized from the **HARPS**, **ESPADONS** and **SOPHIE**

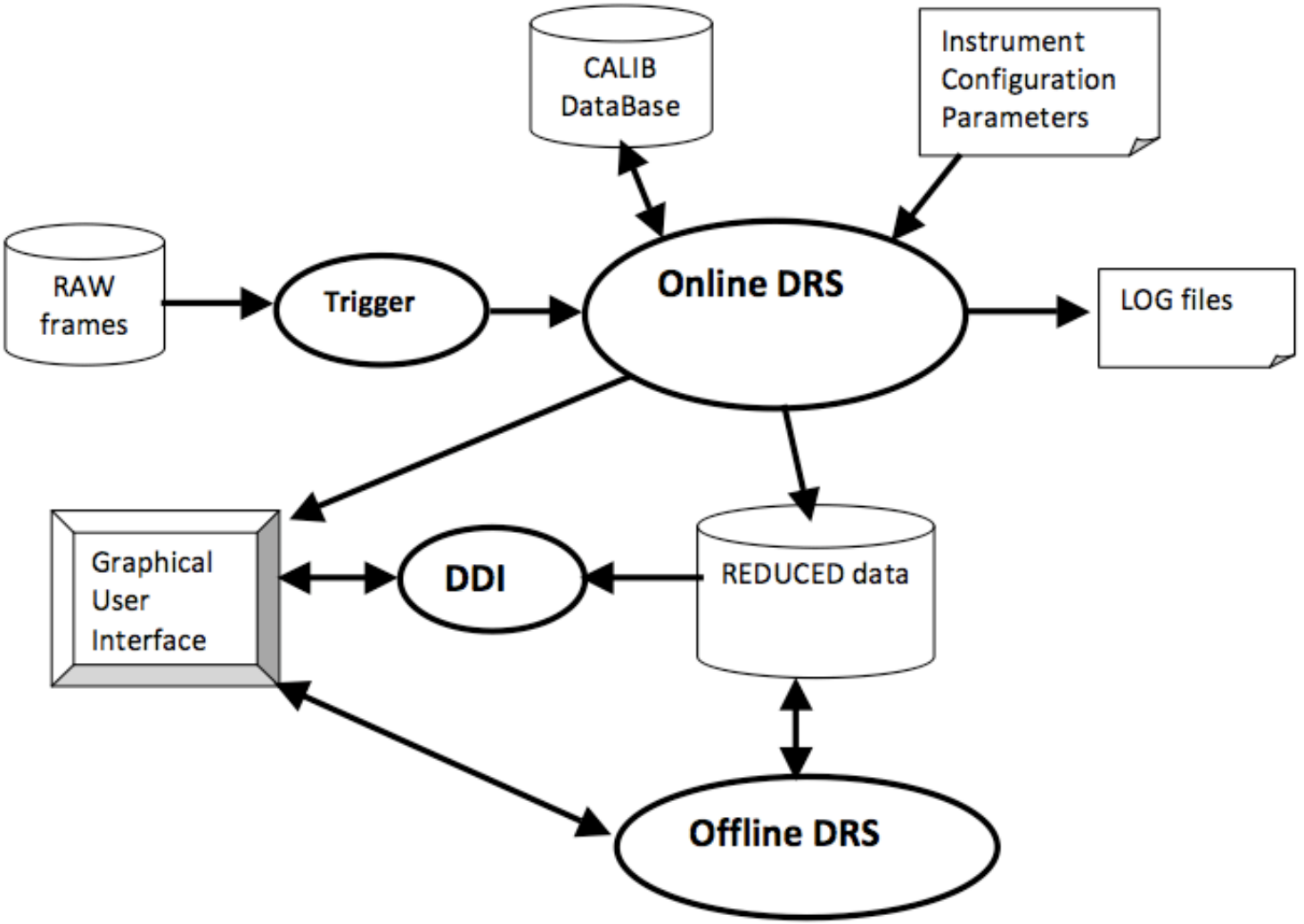
Functions and programs are developed, tested and optimized first
on the **simulated raw frames from SPIrou Pipeline Simulator**

The programming languages are **Python 2.7 and C**. For low-level operations
that requires a higher computation efficiency the routines will be **coded in C**
before being interfaced with the rest of the **Python code v2.7.**

Data Reduction programs

Reduction program	Description
Cal_DARK	Read-out noise, check of the average dark level and cosmic hits rate for short exposures
Cal_DARK_LONG	Read-out noise, average dark level, 2D dark current map, cosmic hits rate, and hot pixel mask for long exposures
Cal_LOC	Localization of spectral orders and slices
Cal_SLIT	Shape determination of slit along spectral orders
Cal_FLAT	Create order profile, flat-field and blaze frames
Cal_WAVE	Wavelength calibration, drift with respect to previous calibration
Cal_FP	Improved wavelength solution, derived width of FP, RV zero point, drift with respect to previous calibration
Cal_FP_WAVE	Wavelength calibration, drift with respect to previous calibration on fiber C Improved wavelength solution + the RV zero point + drift on fibers A & B
Cal_WAVE_FP	Wavelength calibration, drift with respect to previous calibration on fiber A &B Improved wavelength solution + the RV zero point + drift on fiber C
Cal_POL	Full characterization of the waveplate properties and amount of crosstalk
Obj_STAR	Science spectroscopy
Obj_STAR_WAVE	Science spectroscopy + Wave on fiber C
Obj_STAR_FP	Science spectroscopy + RV REF on fiber C
Obj_POL	Science spectropolarimetry
Obj_POL_WAVE	Science spectropolarimetry + Wave on fiber C
Obj_POL_FP	Science spectropolarimetry + RV REF on fiber C

DRS architecture



Data Reduction Products

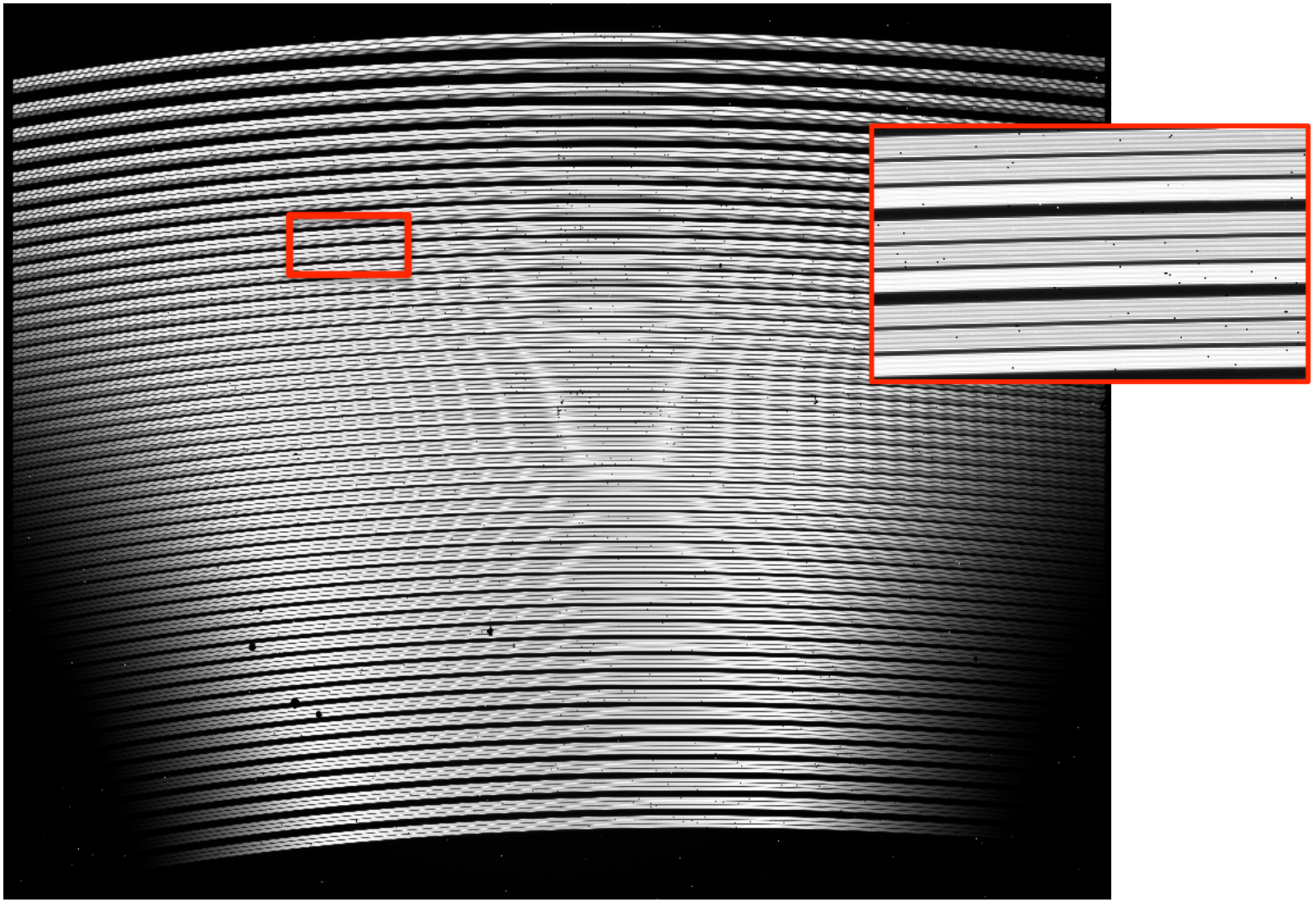
The program related to calibration exposures should have a quality check. The processed products are stored in a local calibration database if they pass the quality control in order to be used for the subsequent reduction of the science exposures.

The program related to the science exposures should deliver:
- S2D extracted spectra with wavelength calibration and flat-field correction for fiber A , B and C
- S2D error maps (photon noise + readout noise) for fibers A, B and C
- 1D re-binned extracted spectra with blaze correction and spectral orders merged for fibers A, B and C
- 1D error maps (photon noise + readout noise) for fibers A, B and C
- Estimation of water vapor column
- Telluric lines free spectrum
- Atmospheric spectrum
- Estimation of the global transmission
- Estimation of the thermal background in K band
- Barycentric Earth Radial Velocity
- Cross-Correlation function using optimum mask
- Parameters of the fit of the CCF (FWHM, Contrast, Bisector, Velocity, Noise)
- Stellar activity index

For the spectropolarimetric exposures, which contains four sub-exposures associated with the different position of waveplates, the program will deliver the extracted spectra and error for each sub-exposure as well as :
- Mean intensity spectrum
- Polarization rate spectrum
- Null polarization spectrum

For the science exposure with simultaneous RV reference, the program will deliver the drift of the spectrograph with respect to the previous calibration if "Wave" or "RV REF" are recorded on fiber C.

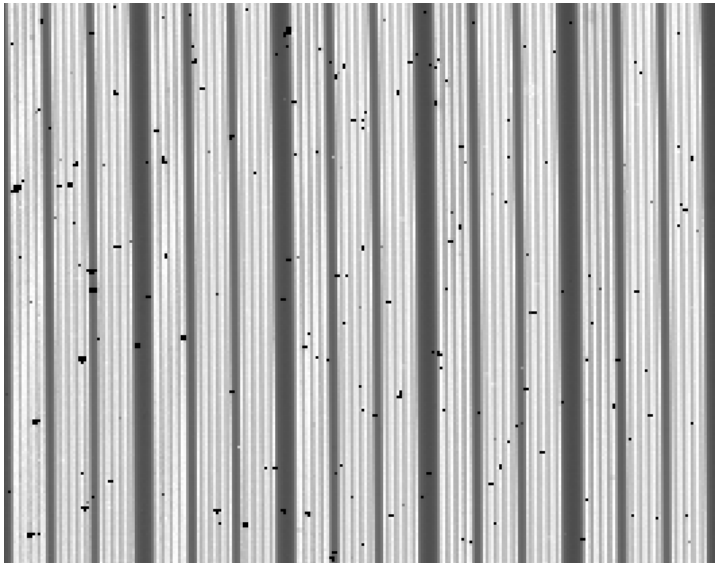
SPirou Data Simulation Pipeline



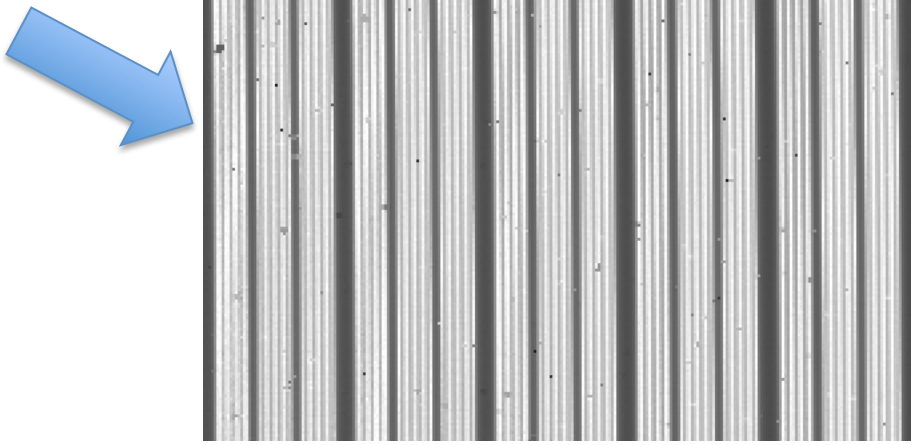
Simulated raw frame with white lamp on fibers AB & C

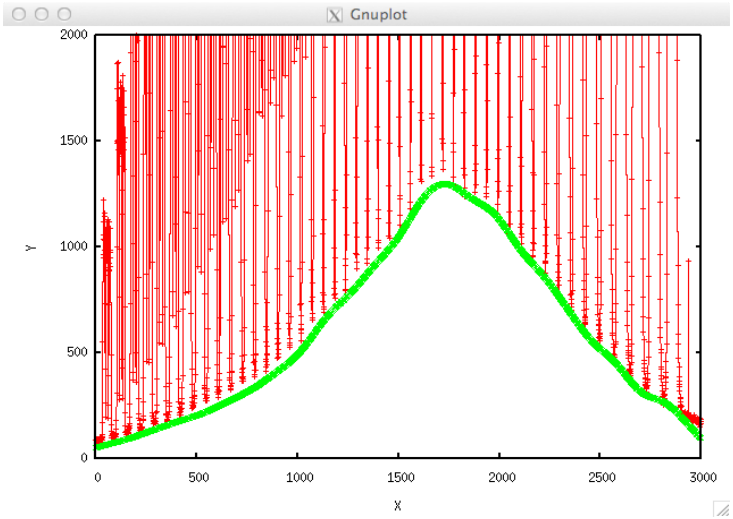
SPirou Data Simulation Pipeline

Portion of the simulated frame of T3000_logg45 star with simultaneous Thorium-Uranium lamp.



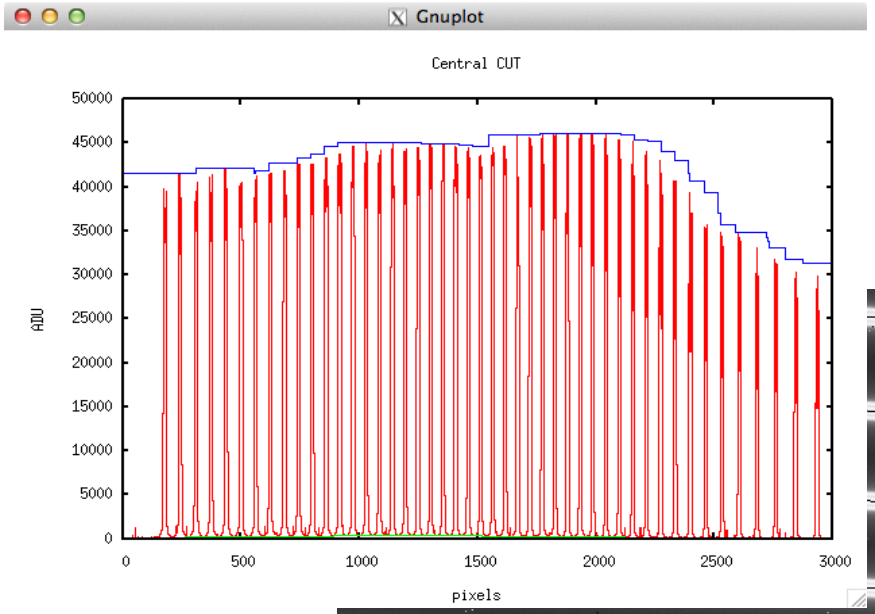
Cosmetics correction

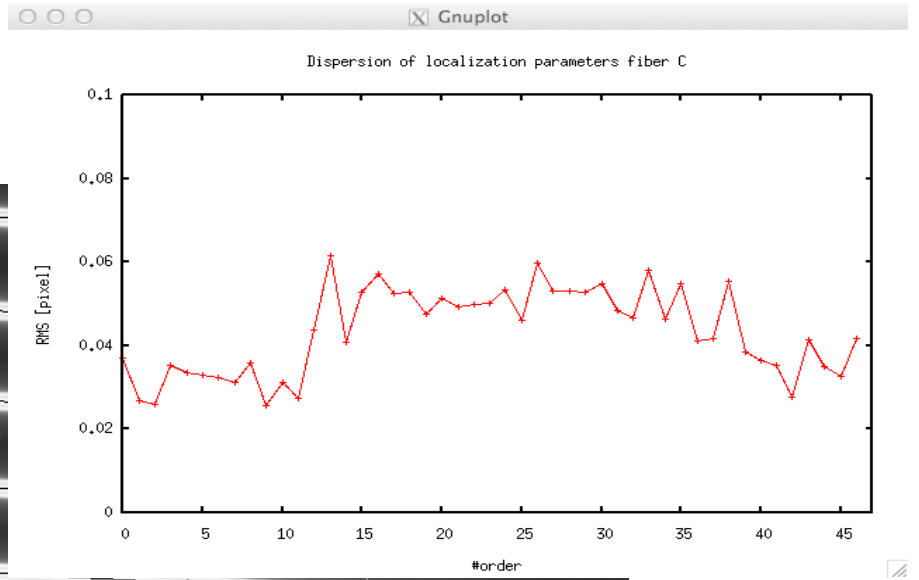


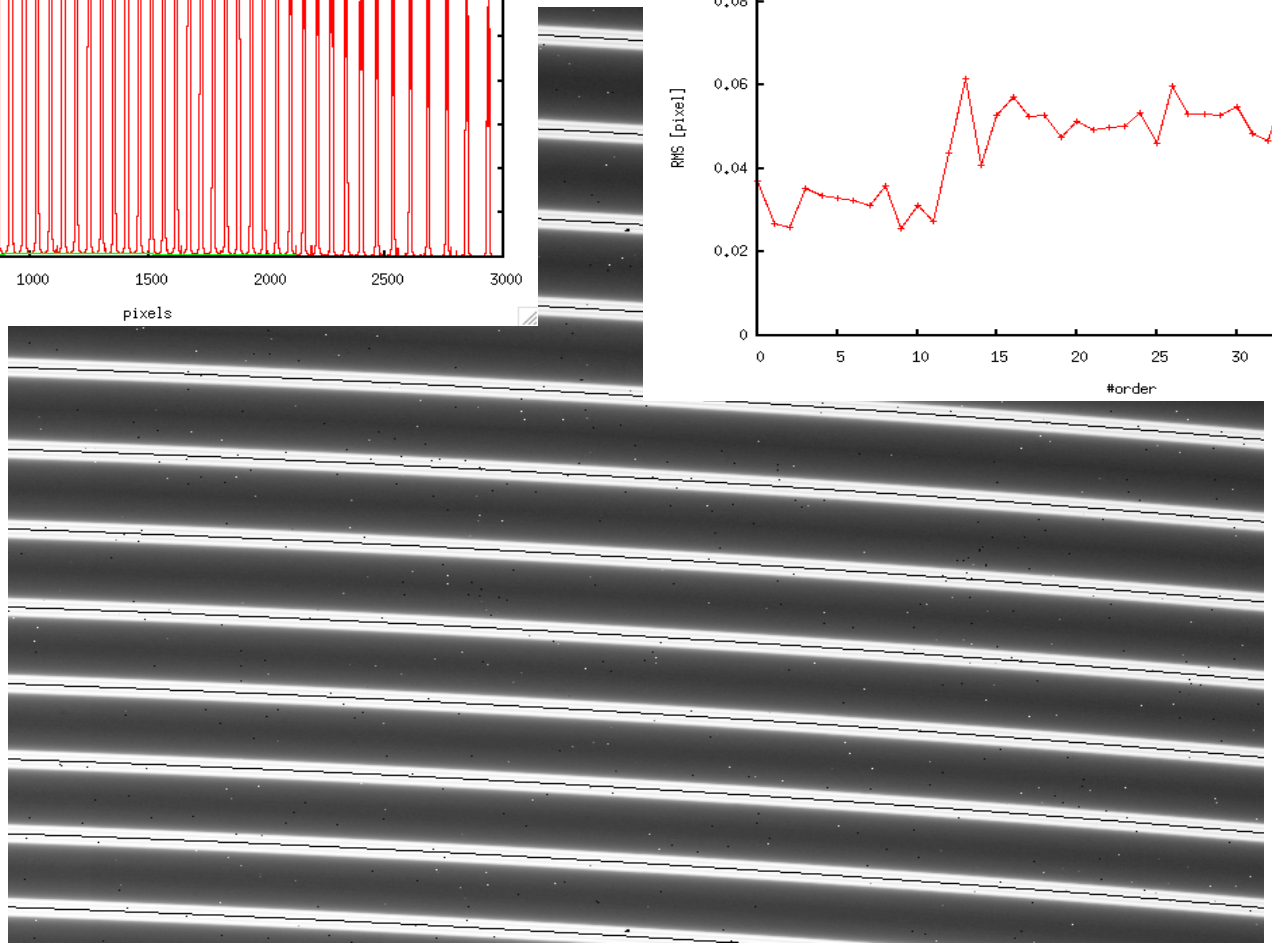


Background correction

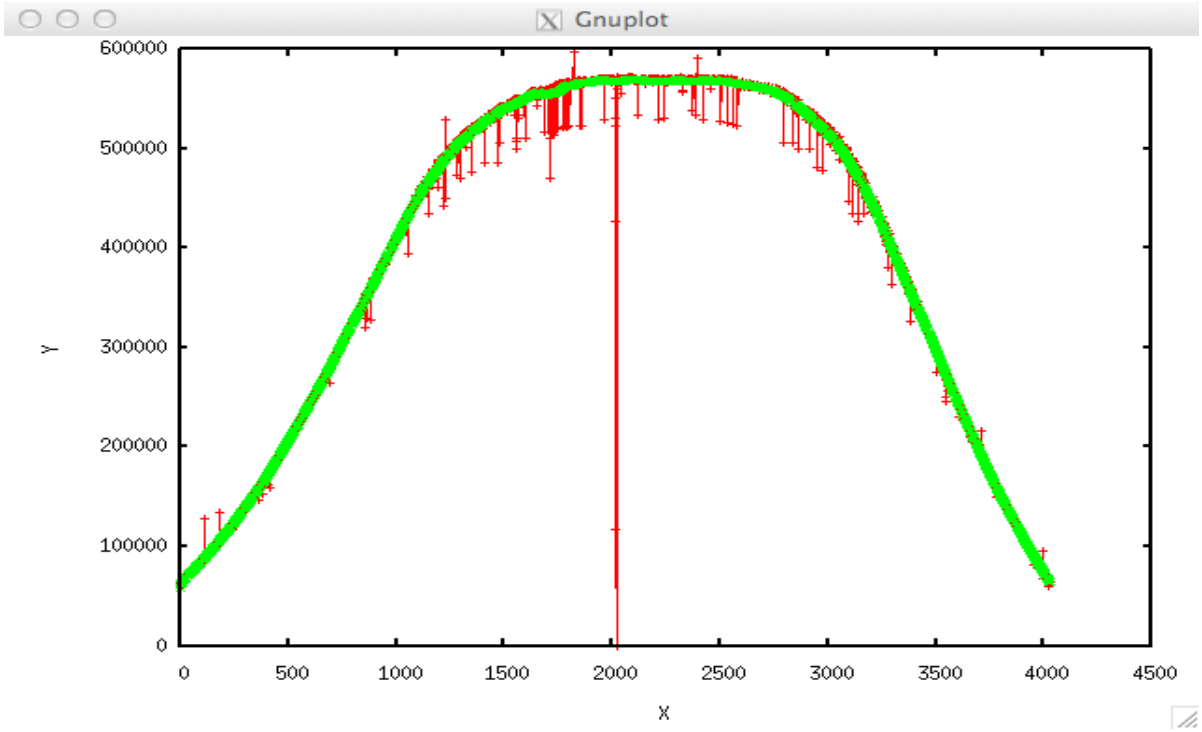
Orders location







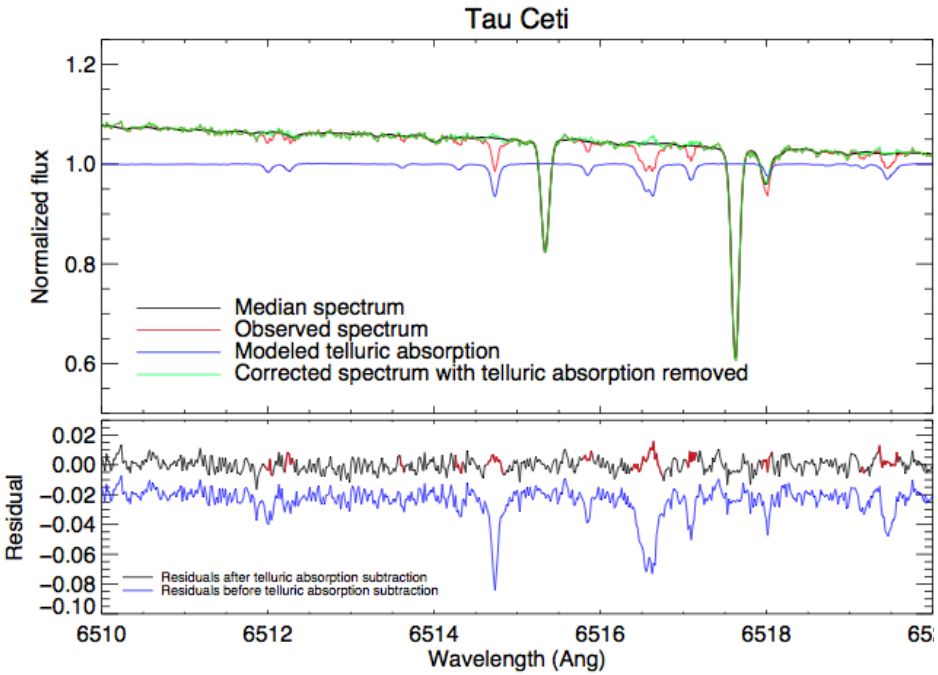
Blaze determination

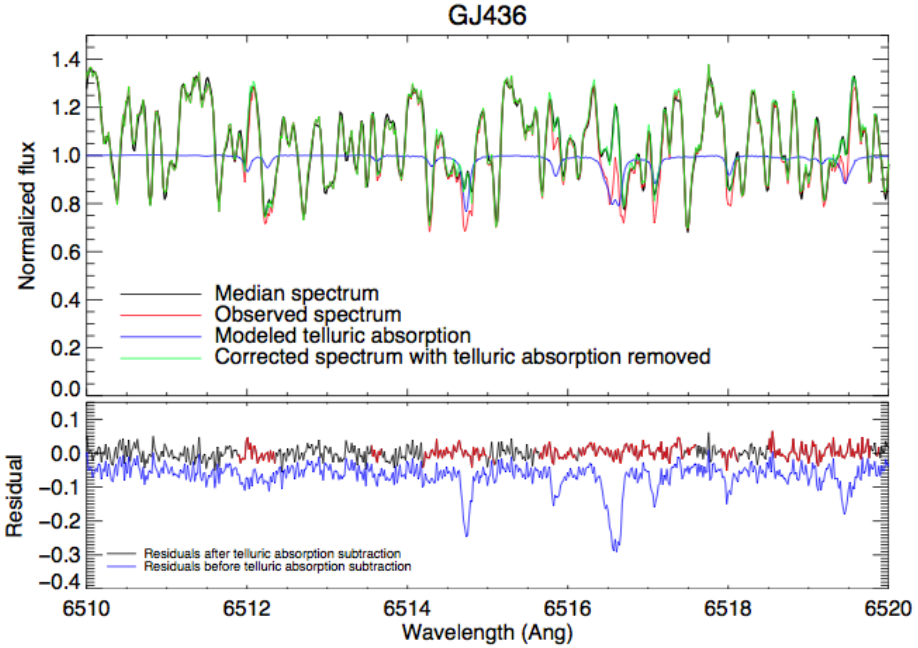


DRS validation on existing spectra

Reduced frames from existing instruments are used to validate the capacity to determine the H_2O column density and the telluric subtraction.

See E. Artigau et al. SPIE ``*Telluric-line subtraction in high-accuracy velocimetry: a PCA-based approach*”





DRS for spectrograph integration @ IRAP

Raw frames **visualization tools** to inspect ghosts and stray light.

Geometry of the spectral orders (localization and profile),
Inter-order gaps, and spectral orders numbering.
Contrast of spectral orders (to help to find the best focus).

Rough wavelength solution based on only few spectral lines
from the low-pressure gas lamps.

Automatically identification of spots on different pre-selected windows and derive the following parameters: gravity center, FWHM, and equivalent width in both axis; orientation, and elongation.

Determination of local and global background light.

Flux at the blaze center in order to derive the relative spectral response of the spectrograph.

2-D correlation of Hollow-Cathode lamp raw frames to check the rough **stability of the spectrograph** on both axis. Stability on the location of spectral orders. **Drift measurements** on extracted spectra of the Hollow-Cathode lamp.

NIRPS Data Reduction Pipeline

It will benefit of all the fine tunings developed for SPIROU on real data

It will benefit of the DRS developed for ESPRESSO

Online DRS will run independently on HARPS and NIRPS

But we may imagine additional tools in the end-of-night
Re-processing using NIRPS and HARPS reduced data