The CPL Wavelength Calibration method using Iterative Cross-Correlation

Yves Jung

yjung@eso.org

Introduction

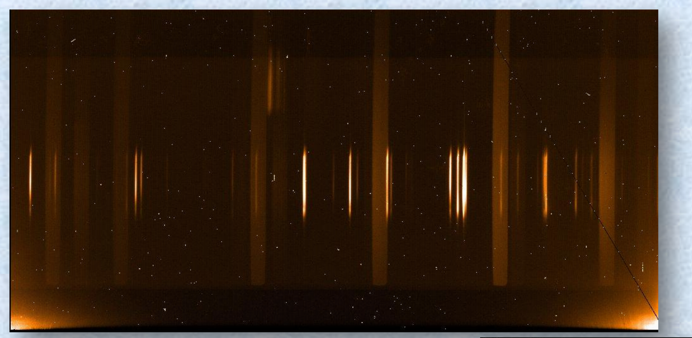
Most of the ESO VLT data reduction pipelines need to calibrate the instruments in wavelength (wavelength = P(pixel)). The generic method described here allows to search iteratively this relation, starting from a first guess, going through a well defined search space identified by wavelength bounds around this first guess.

The way the inputs are changed during the successive iterations depend on the precision of the first guess, the accuracy of the requested calibration, the requested degree of the polynomial solution, the precision of the catalog, etc…

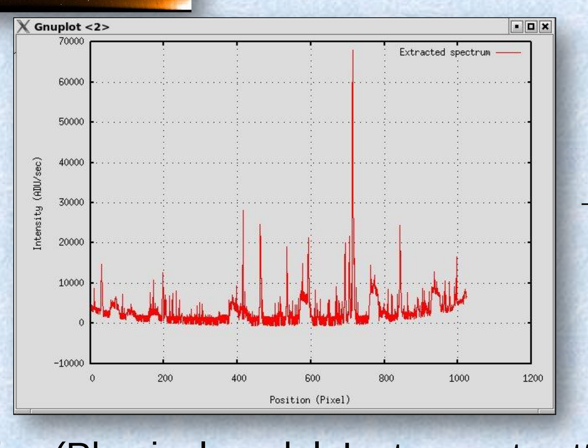
The **CPL** (Common Pipeline Library) function called iteratively has been designed to have a clear and meaningful interface, making it useable in any context.

1. Instrument specific pre-processing

The algorithm inputs (the spectrum to calibrate, the catalog, degree, Po, WL_ERR, nsamples) first need to be prepared.



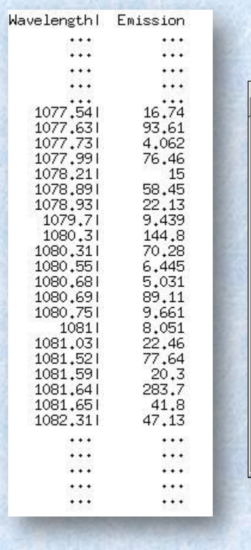
Spectrum Extraction



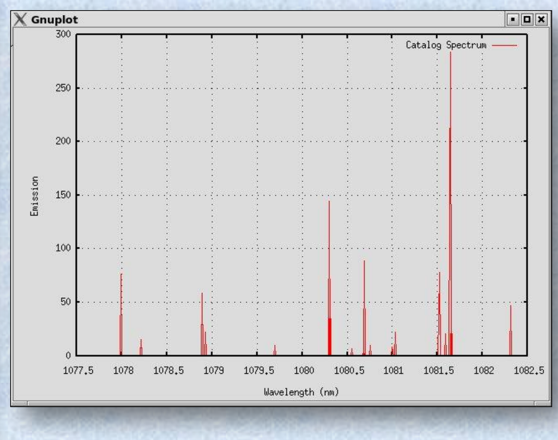
Wavelength range estimation (Physical model, Instrument setting)
wavelength = Po(pixel)

Lines catalog (OH, Argon lines, HITRAN model, Absorption lines)

Po(1)



Po(1024)



Wavelength Error WL_ERR of the estimation

Precision of the wished solution:

- number of samples nsamples for the solution space sampling
- degree of the final polynomial solution

2. Instrument Independent Iterative Wavelength Calibration

http://www.eso.org/cpl

Function Documentation

```
cpl_polynomial* cpl_wlcalib_xc_best_poly ( const cpl_vector *      spectrum,
                                           const cpl_bivector *    lines_catalog,
                                           int                     degree,
                                           const cpl_polynomial *  guess_poly,
                                           double                  wl_error,
                                           int                     nsamples,
                                           double *                xc
                                         )
```

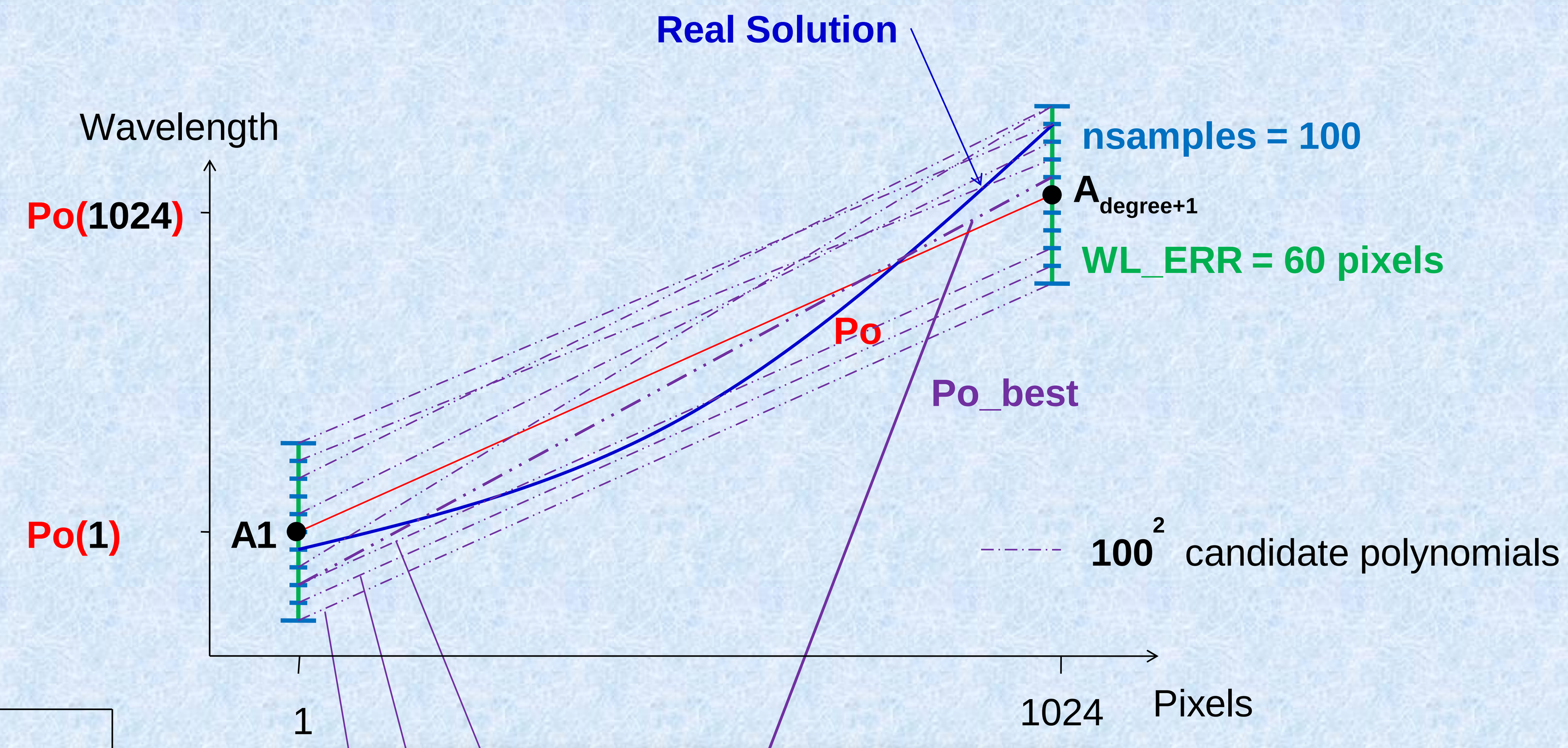
Find the best polynomial in a given range.

Parameters:

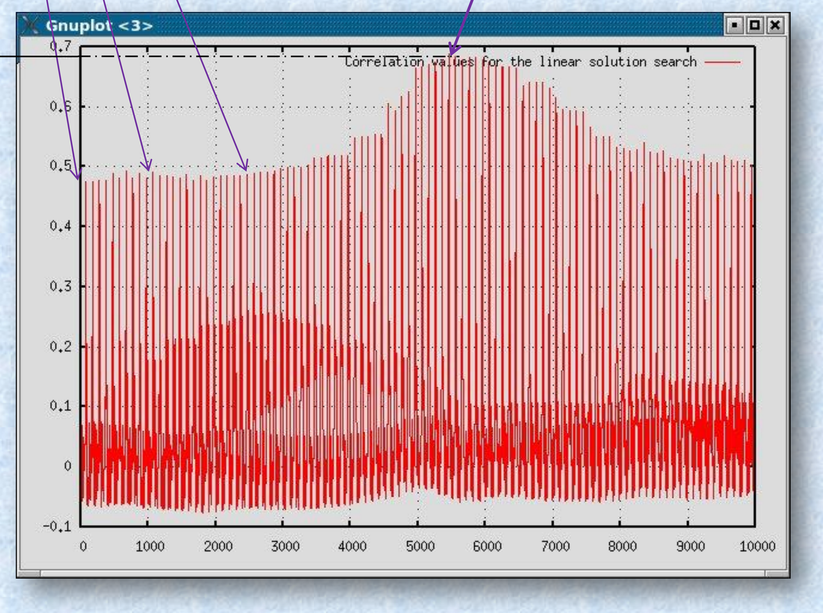
spectrum	The spectrum vector	
lines_catalog	The lines catalog	
degree	The polynomial degree	1
guess_poly	Guess Dispersion Polynomial	
wl_error	Search range around the anchor points	
nsamples	Number of samples around the anchor points	
xc	Cross-correlation factor (returned)	

Returns:

the best polynomial or NULL in error case



0.68



Algorithm

The CPL function first defines the solutions space. This space is defined using Po, WL_ERR, degree and nsamples.
As described by the drawing, a number ($nsamples^{degree+1}$) of candidate polynomials of degree degree are defined passing through the nsamples positions around the points A1, … , $A_{degree+1}$.

Each of these candidates is used to assign wavelengths to the input extracted spectrum. The result is compared to the catalog and a correlation factor is computed. The closer the spectrum and the catalog, the higher the correlation factor, the better the solution.

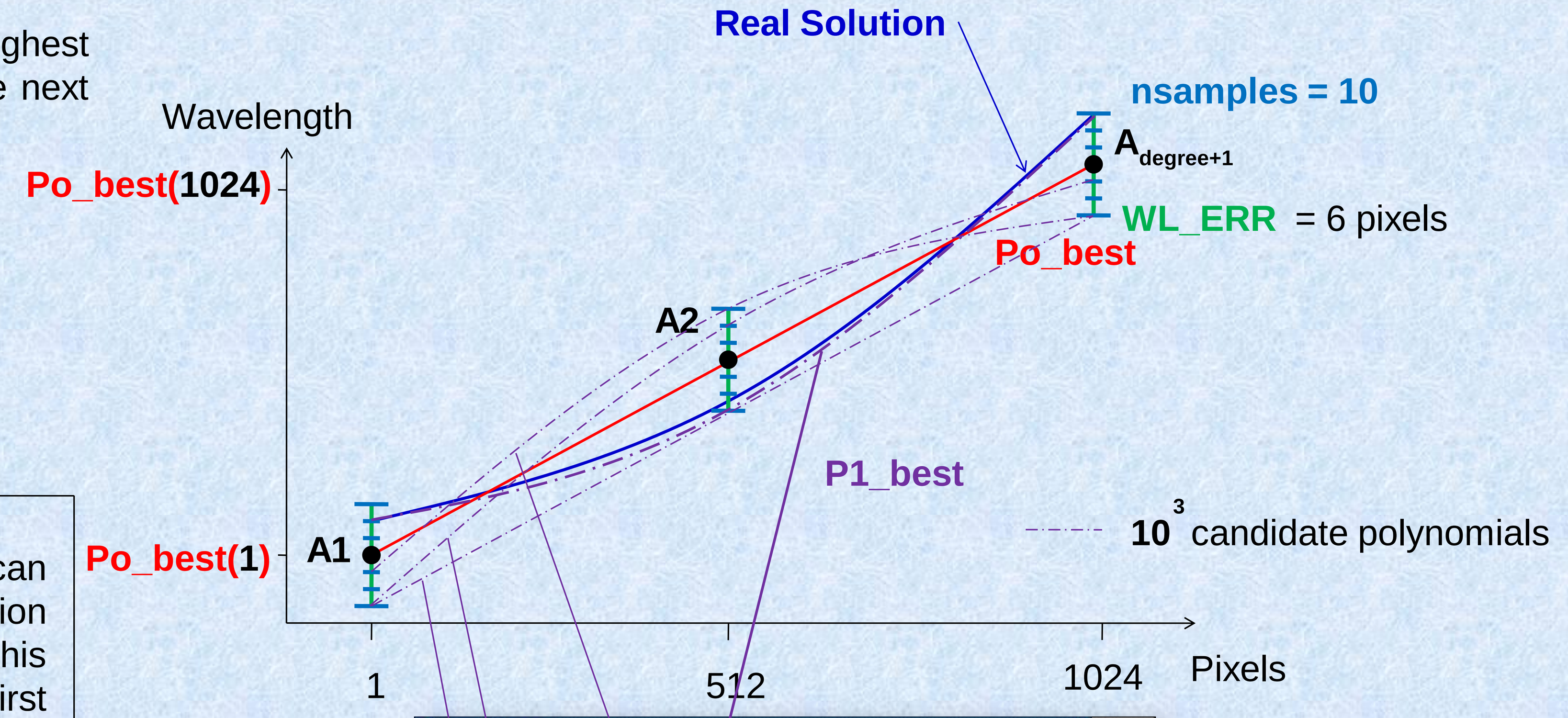
The solution is the polynomial Po_best corresponding to the highest correlation value. This polynomial is used as first guess in the next iteration.

```
cpl_wlcalib_xc_best_poly(spectrum,
                         lines,
                         2,
                         Po_best,
                         WL_ERR/10,
                         nsamples/10,
                         &xc) ;
```

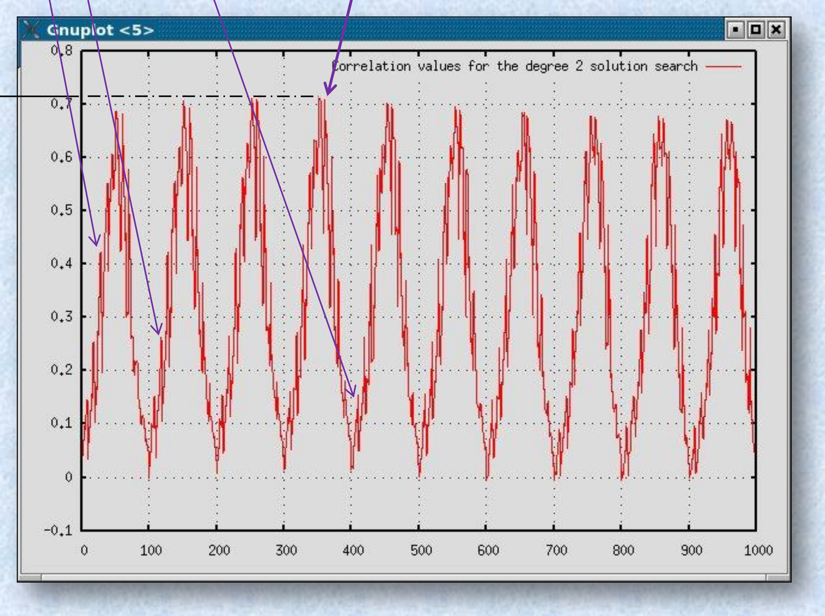
Iteration

The number of candidate polynomials that are evaluated can easily explode ($nsamples^{degree+1}$) especially if a high precision calibration (with a high degree) is requested. To keep this number reasonable, we need to proceed iteratively. The first step refines the guess polynomial (high nsampes but low degree). This refining allows to reduce the WL_ERR in the second step (and thus the nsamples) and to increase the degree.

```
cpl_wlcalib_xc_best_poly(spectrum,
                         lines,
                         degree,
                         P1_best,
                         WL_ERR/100,
                         nsamples/10,
                         &xc) ;
```



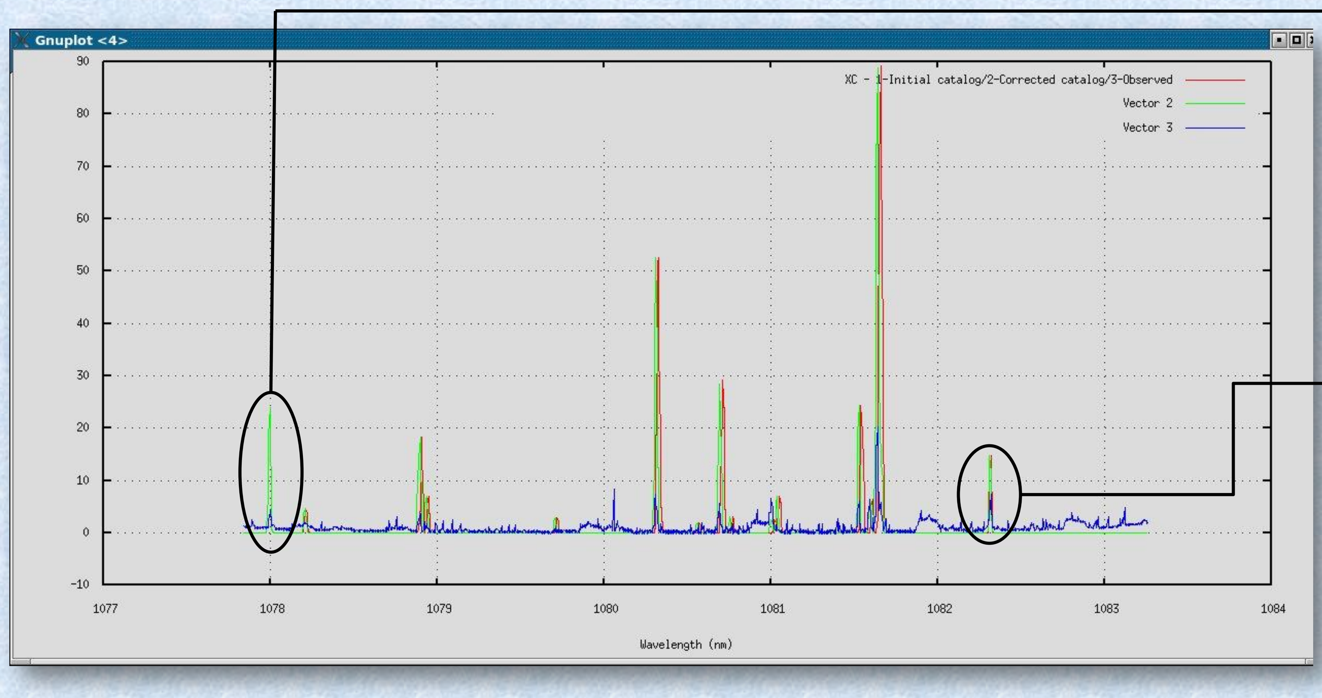
0.71



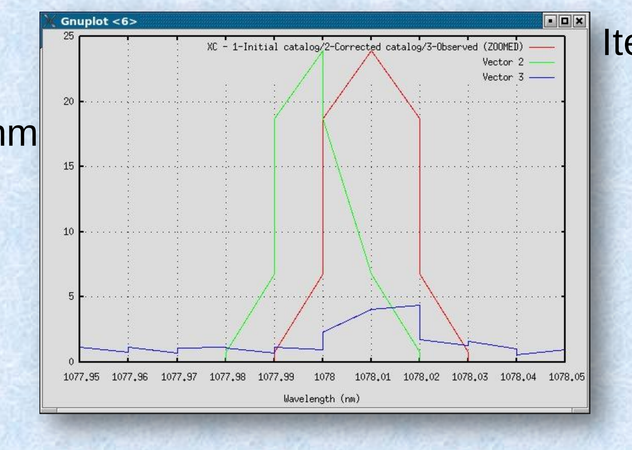
3. Application on CRIRES data through the CRIRES pipeline

http://www.eso.org/pipelines

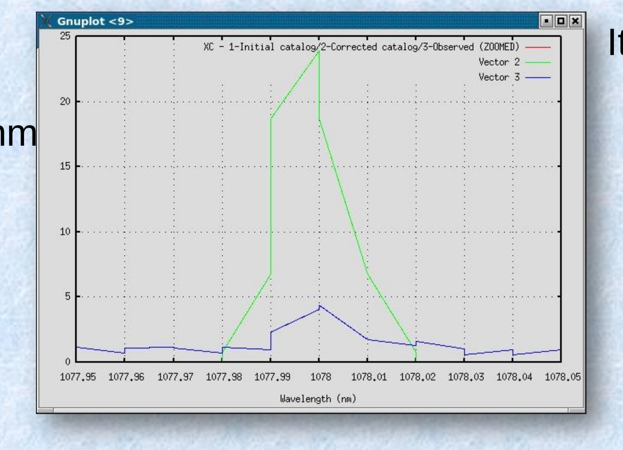
A calibration lamp is used here to calibrate the instrument in wavelength. The plot shows the calibrated extracted spectrum and the catalog emission lines. The red plot shows the catalog position regarding the spectrum using the guess polynomial solution. A good solution is obtained when green and blue are well aligned.



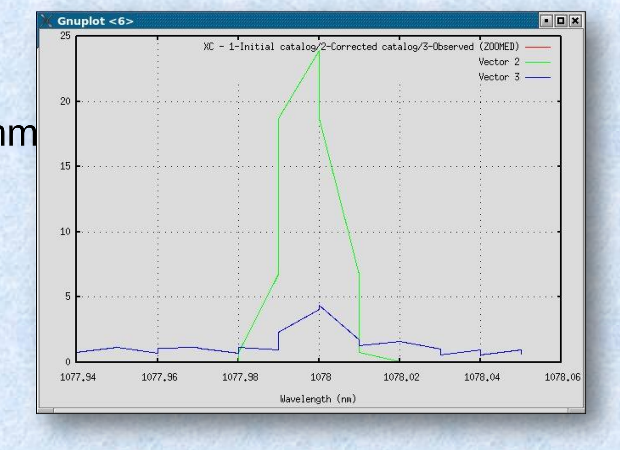
Iteration 1 :
degree = 1
WL_ERR = 0.3 nm
nsamples = 100



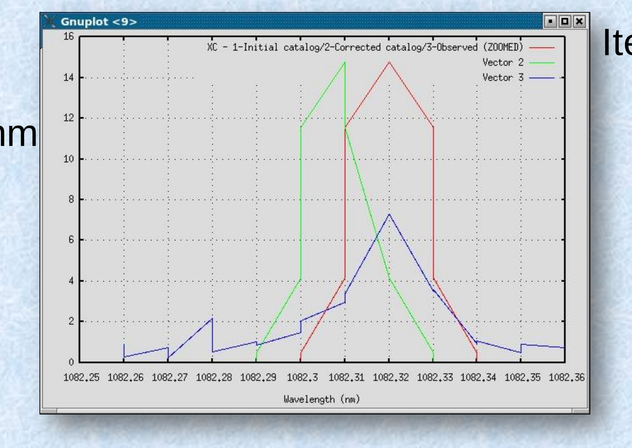
Iteration 2 :
degree = 2
WL_ERR = 0.06 nm
nsamples = 10



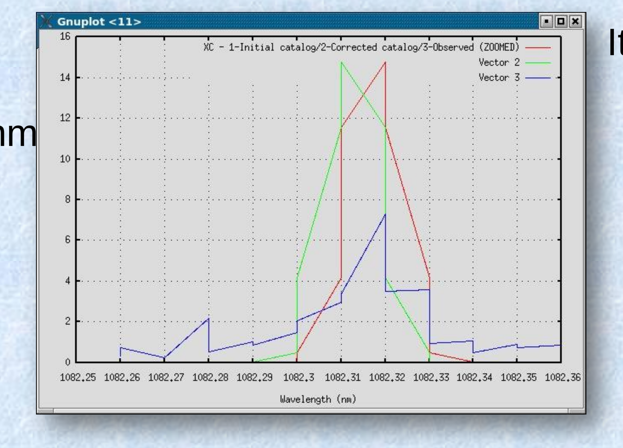
Iteration 3 :
degree = 3
WL_ERR = 0.01 nm
nsamples = 10



Iteration 1 :
degree = 1
WL_ERR = 0.3 nm
nsamples = 100



Iteration 2 :
degree = 2
WL_ERR = 0.06 nm
nsamples = 10



Iteration 3 :
degree = 3
WL_ERR = 0.01 nm
nsamples = 10