Resolving physical line profiles from Bragg X-ray spectra using Withbroe-Sylwester deconvolution

Janusz Sylwester

Ż. Szaforz, M. Stęślicki, B. Sylwester, PL

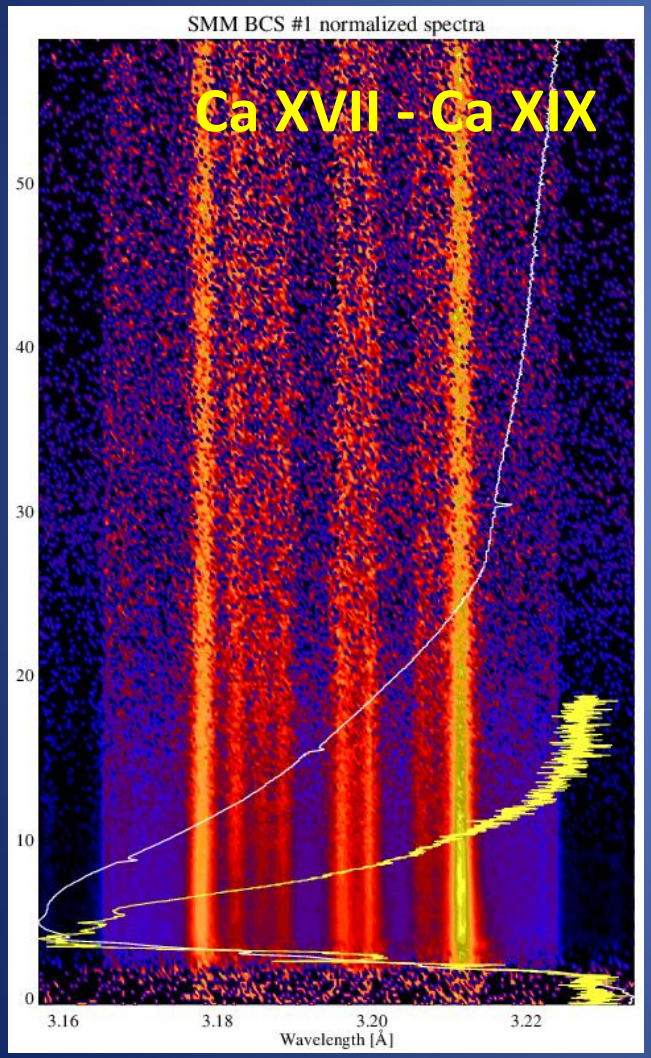
K.J.H. Phillips, UK

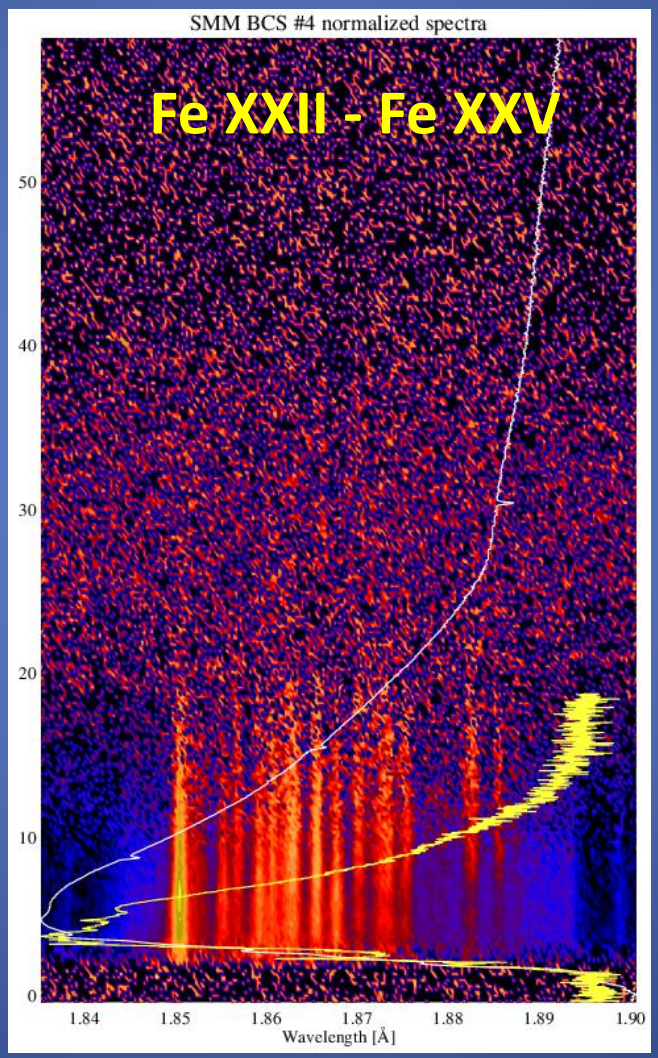
Outline

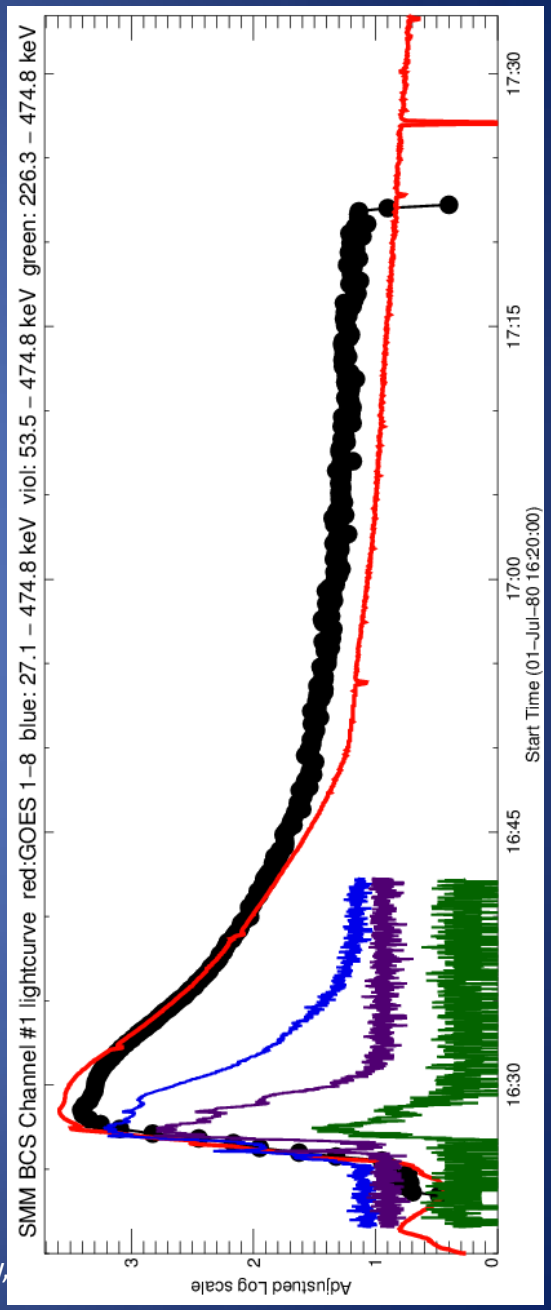
- The problem & rationale (SMM BCS, Diogeness)
- Creating test „observed spectra & datacube
- Typical approach: Theory + instrumental profile→ best fit to observations → physical parameters
- Suggested approach: observed spectra

  - instrumental profile
- Steps of inversion analysis on example event
- Future work & applications

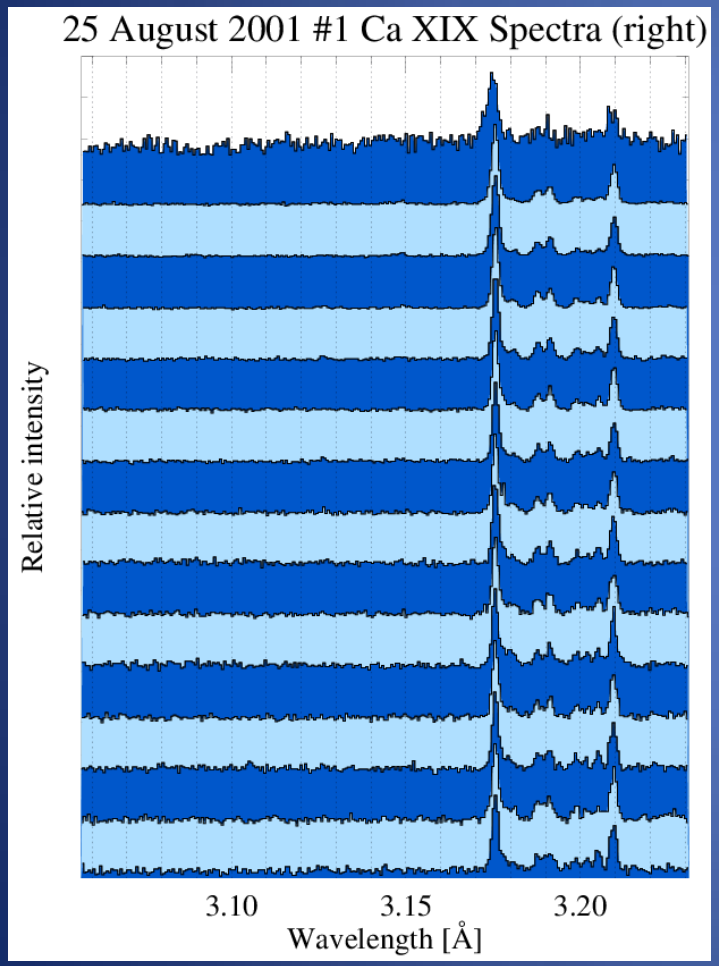
What data are in mind: SMM- 1980-1989

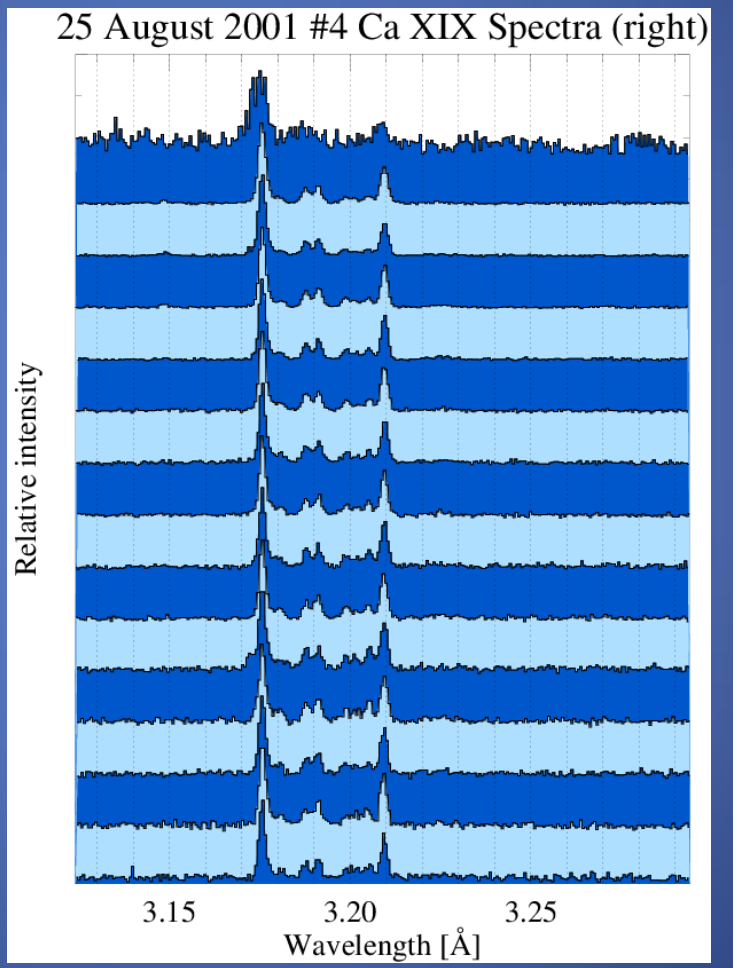


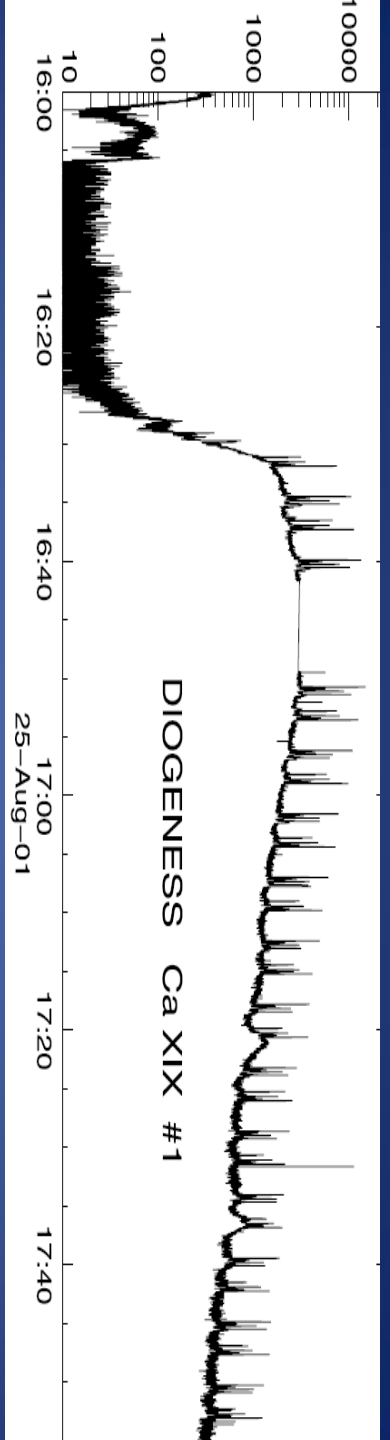




What data are in mind: Diogeness: 2001



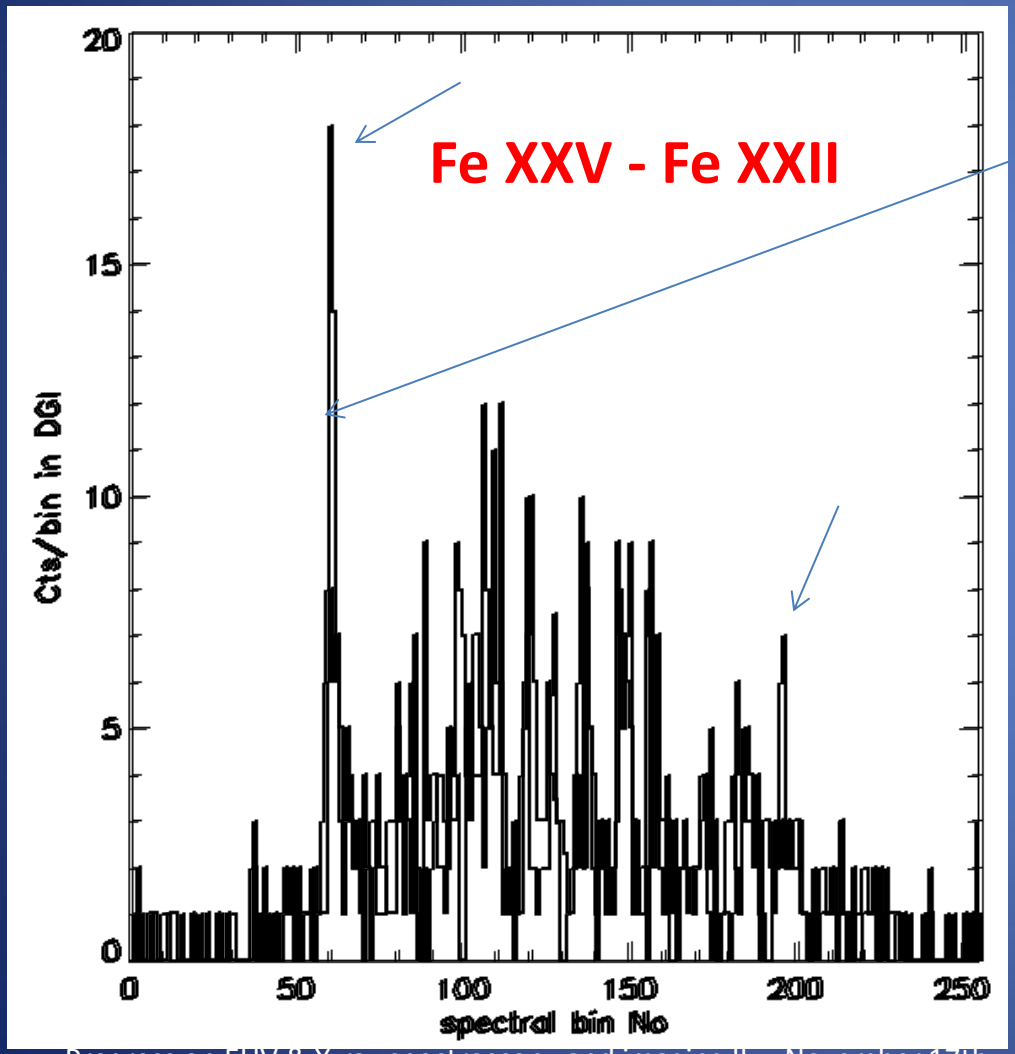




Ca XVII - Ca XIX

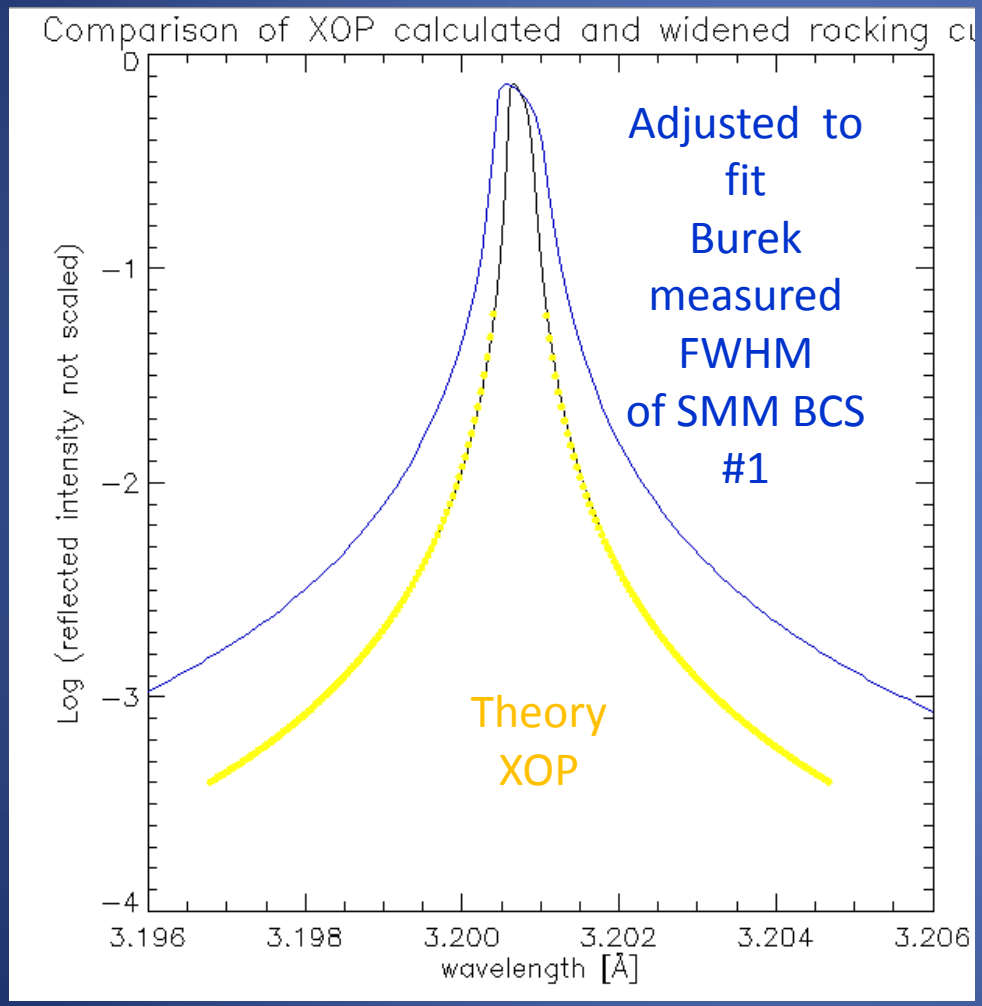
Ca XVII - Ca XIX

Are there any lines in this spectrum?



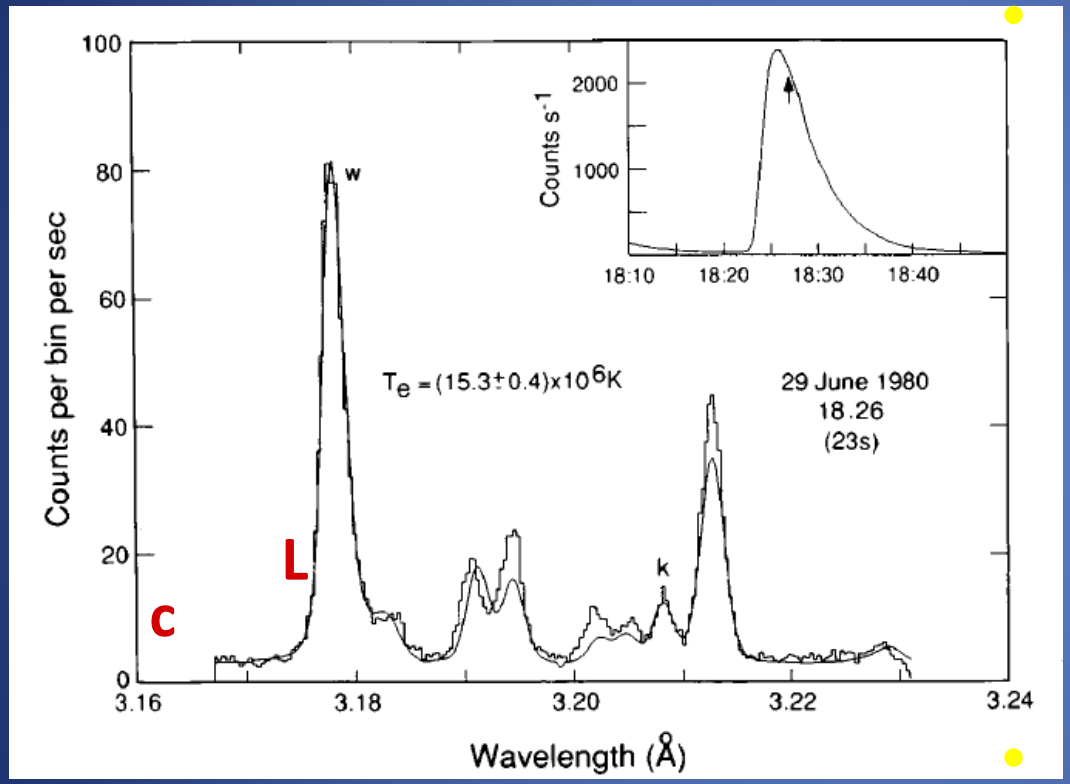
- Info on expected line widths [bins]
- Info on time variability
- Always non-negative spectral signal

What additional information is available?



- Instrumental profile
  - rocking curve
  - Detector linear resolution
  - Electronic resolution
- (presentation by Zaneta Szaforz)

„Classical approach" fitting modelled spectra



Values for physical parameters

Physical model of plasma conditions in the source

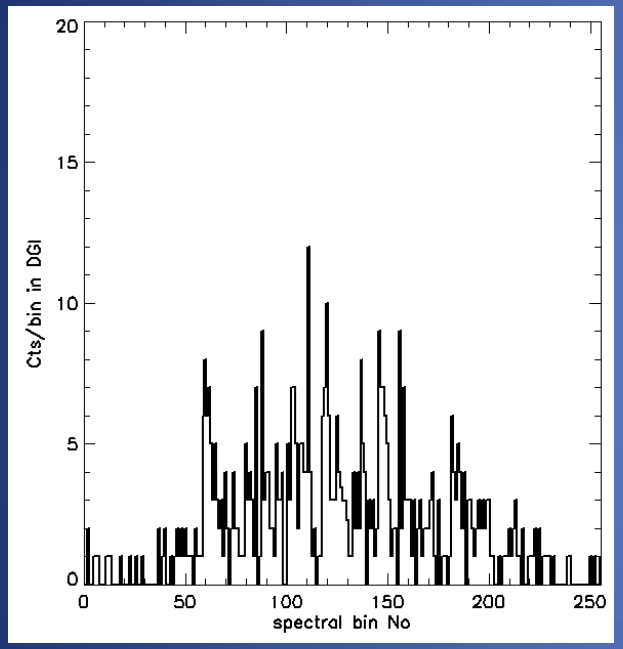
- Distribution of electrons, protons with E

+ (convolve with)

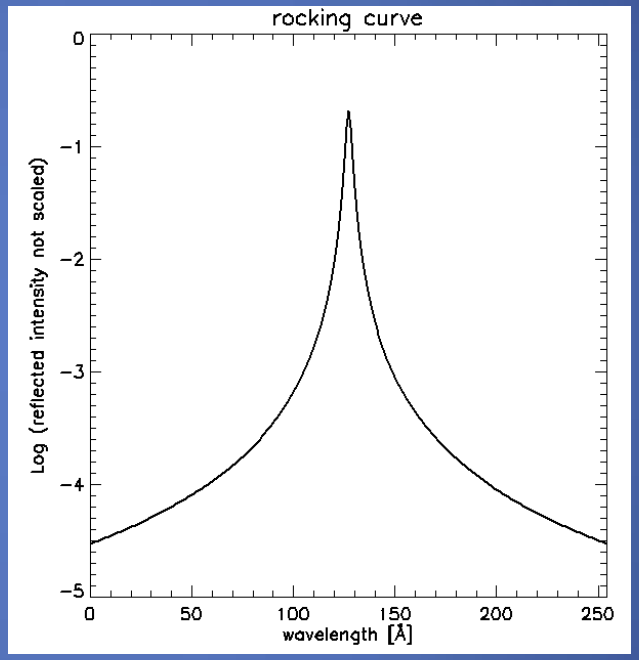
Instrumental profile

- Crystal +
- Detector +
- electronics

The alternate approach



−



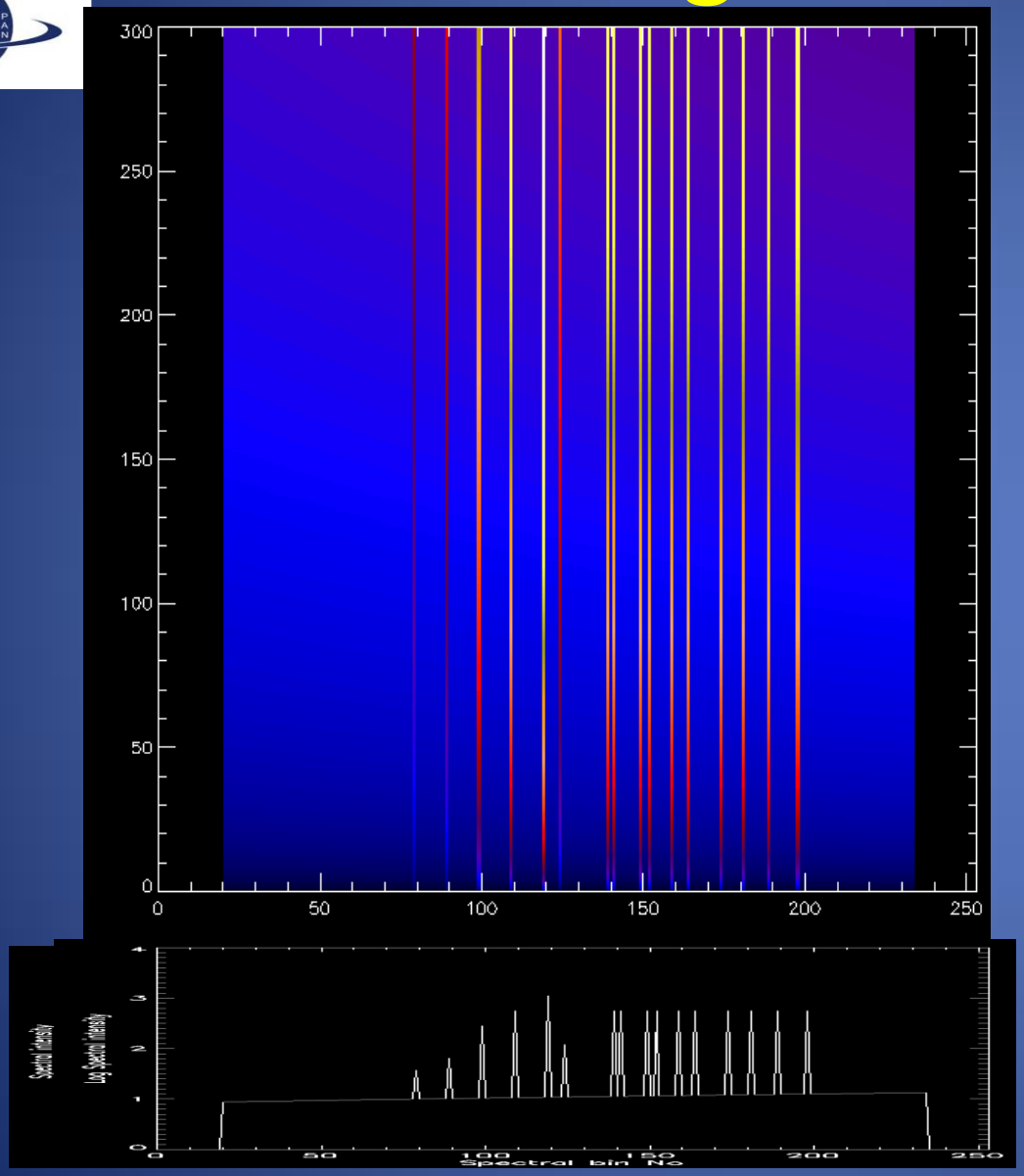
= ?

Observations - instrumental profile = input ??

The test outline

- Create the spectral data cube resembling the observational cubes (time variability allowed)
- Convolve (multiple δ–spectral peaks+continuum, Gaussian smoothed) with the instrumental profile to get „ideal input spectra”
- Add statistical noise
- Apply inversion procedure (W-S algorithm)
- Compare ideal input with the output from deconvolution

Creating test data cube

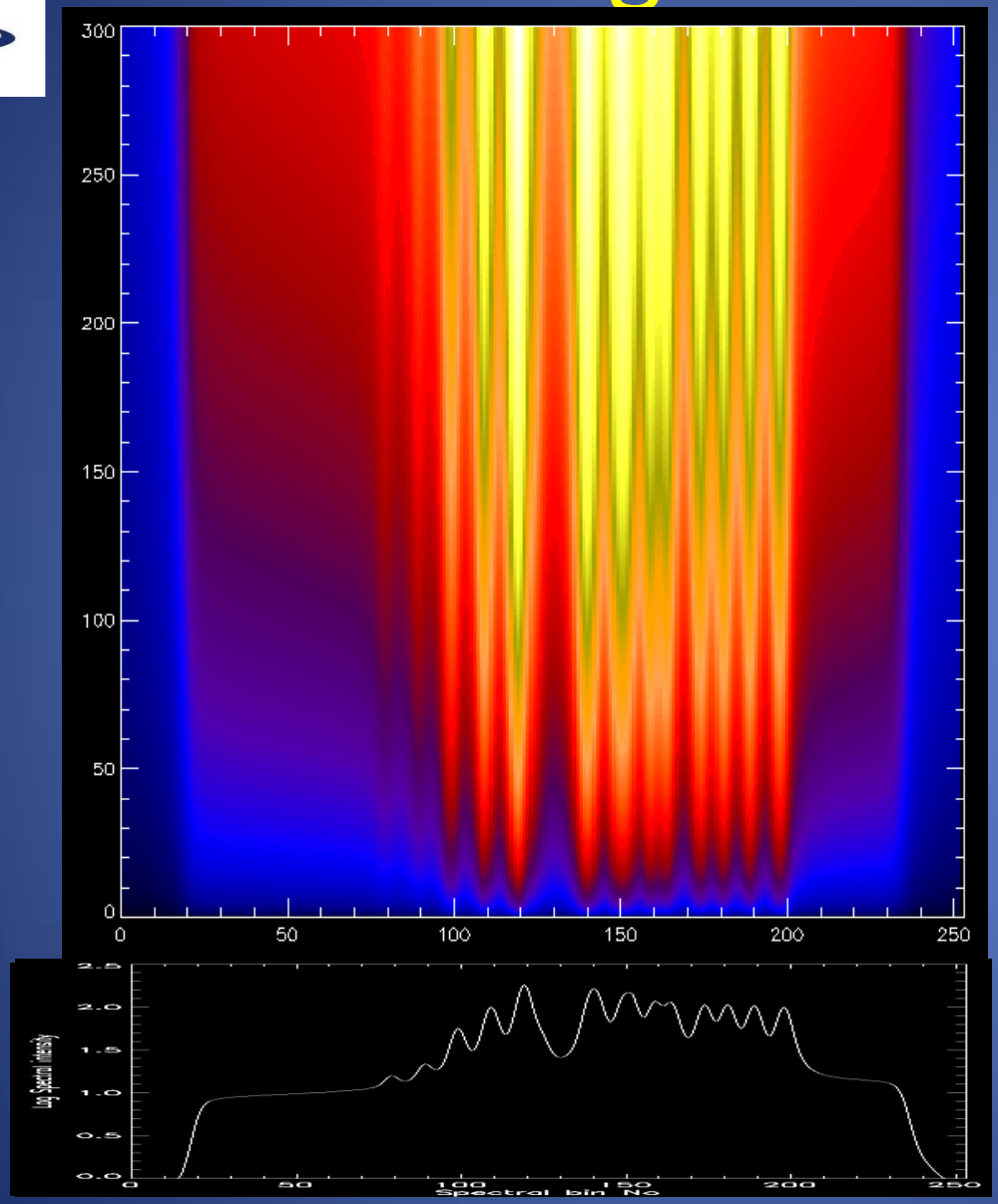


60 000 cts

10 cts

- **Gaussian** line shapes
- Various line to continuum levels ½ to 1000
- Various line separations
- 2, 3, 5, 7, 9 bins 1 - 4 FWHMs
- Weak line next to strong

Convolving with rocking curve

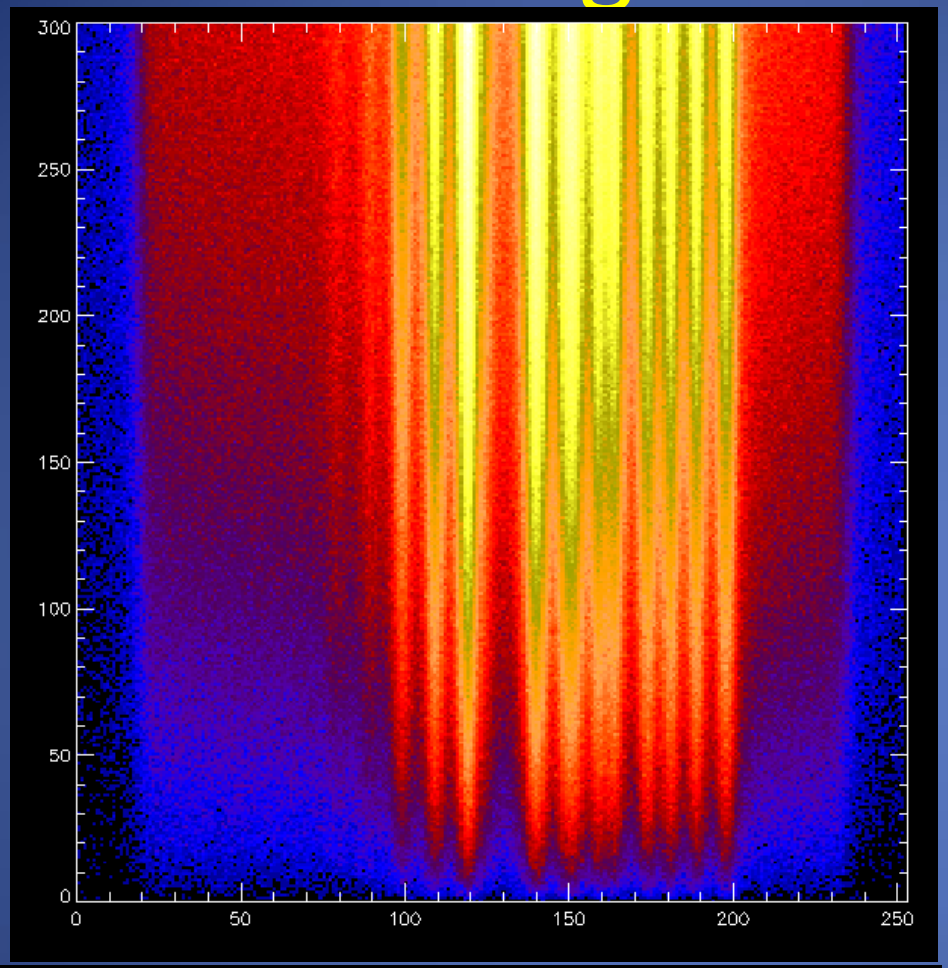


60 000 cts

10 cts

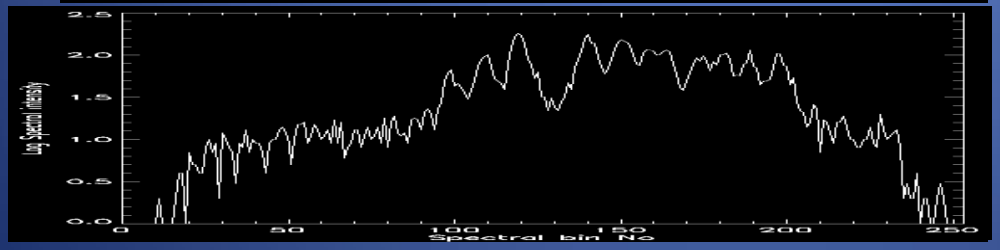
- **Gaussian** line shapes
- Various line to continuum levels ½ to 1000
- Various line separations
- 2, 3, 5, 7, 9 bins 1 - 4 FWHMs
- Weak line next to strong

Adding Poisson noise



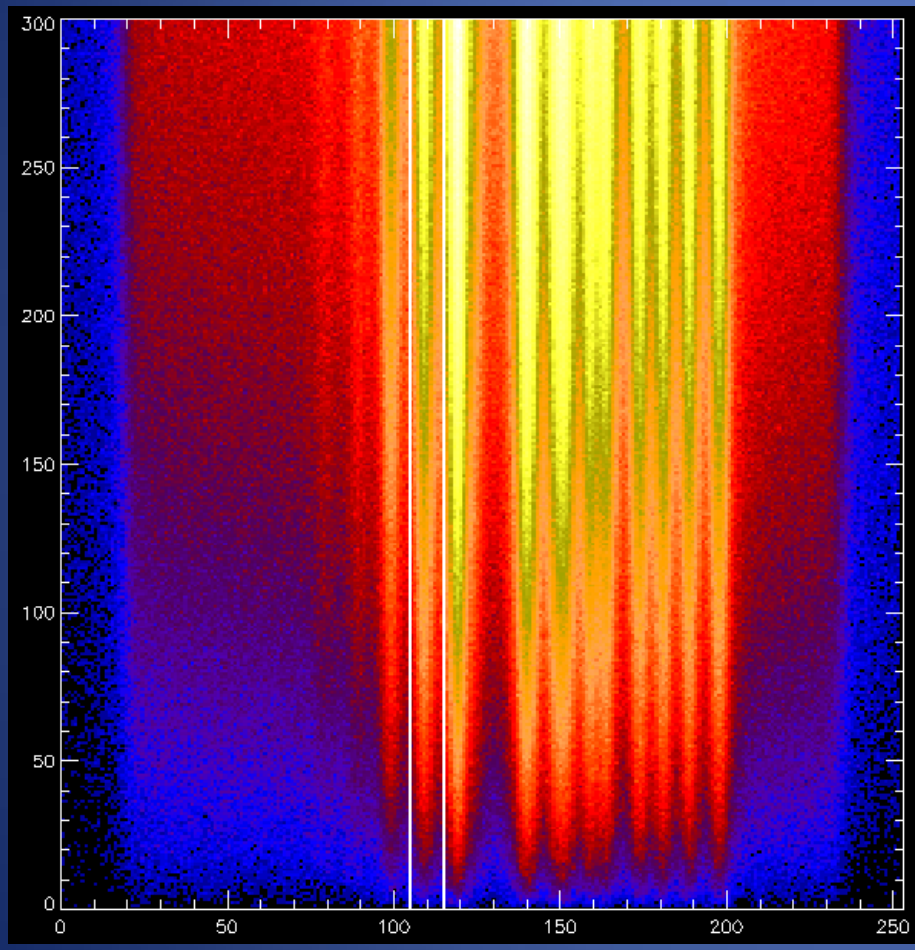
60 000 cts

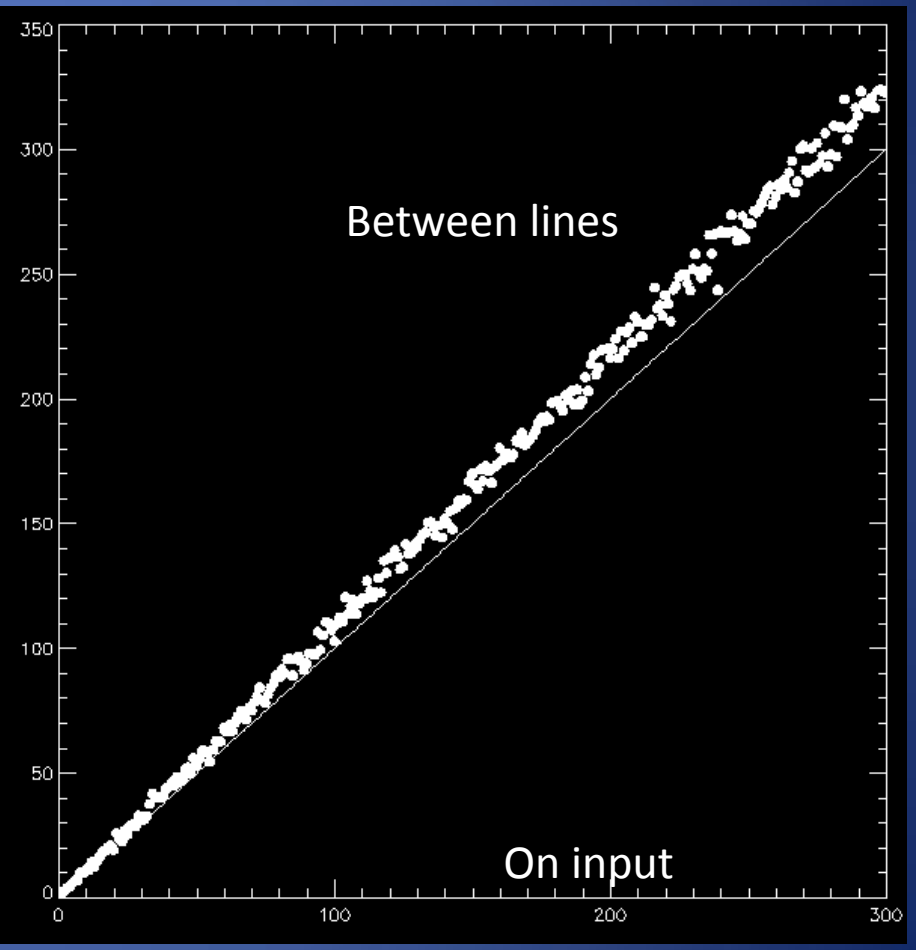
10 cts



- **Gaussian** line shapes
- Various line to continuum levels ½ to 1000
- Various line separations
- 2, 3, 5, 7, 9 bins 1 - 4 FWHMs
- Weak line next to strong

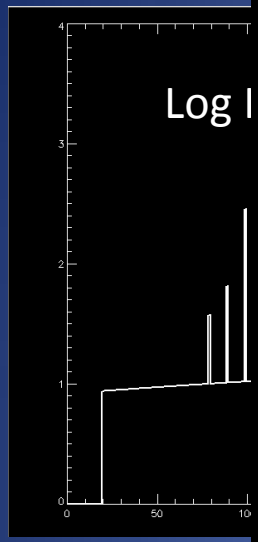
How broadening limit „easy” study of the lightcurves in lines

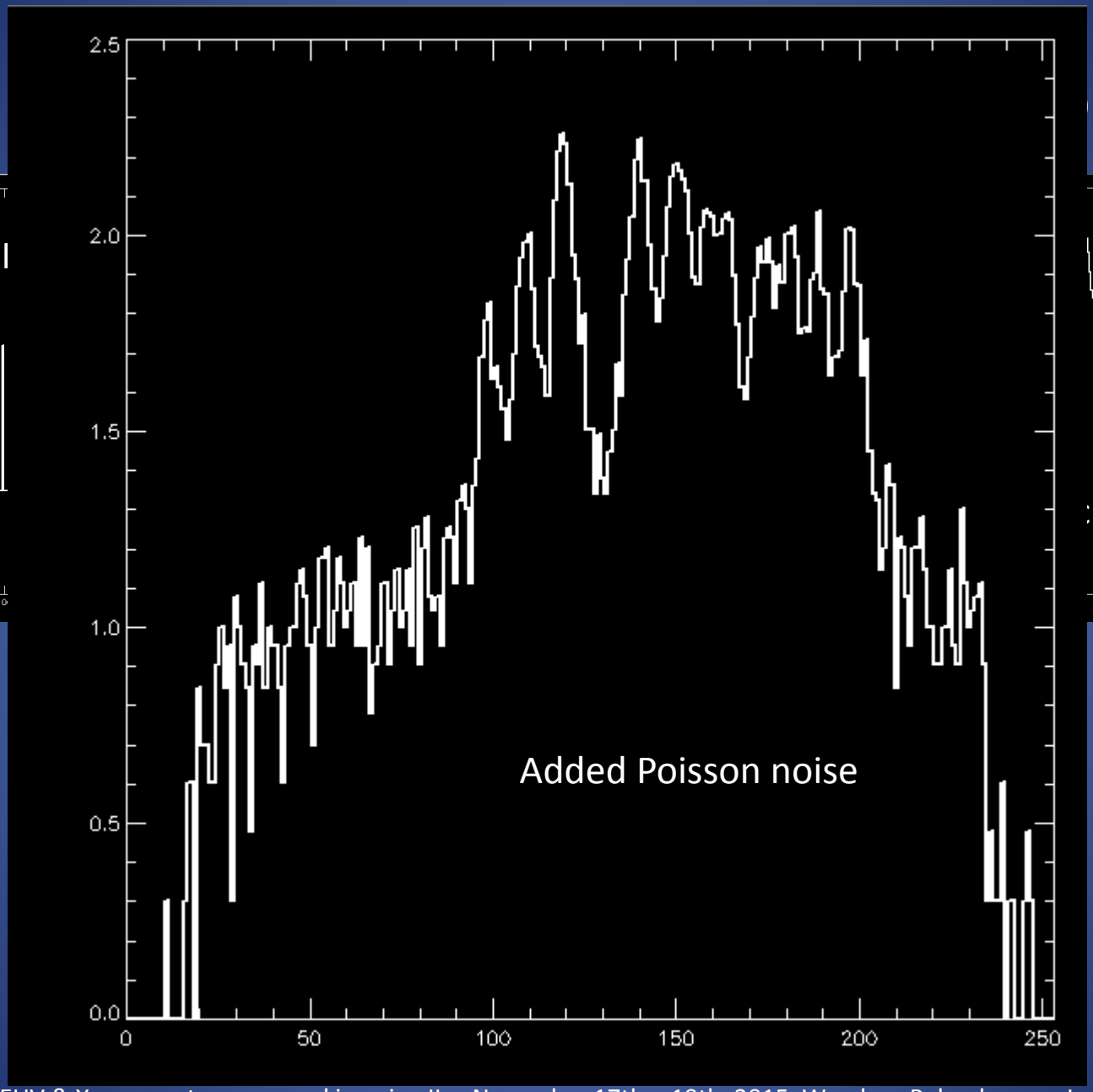




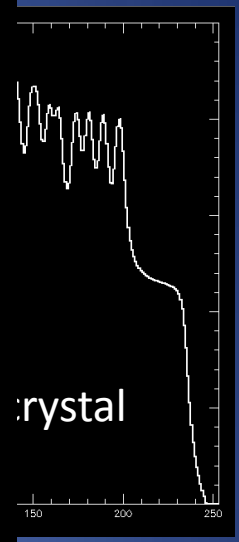
n”

Log I





rystal

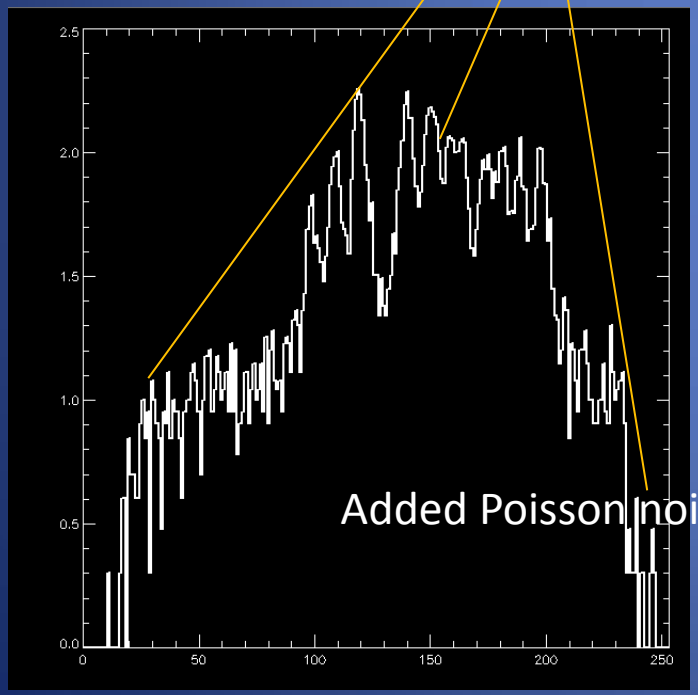


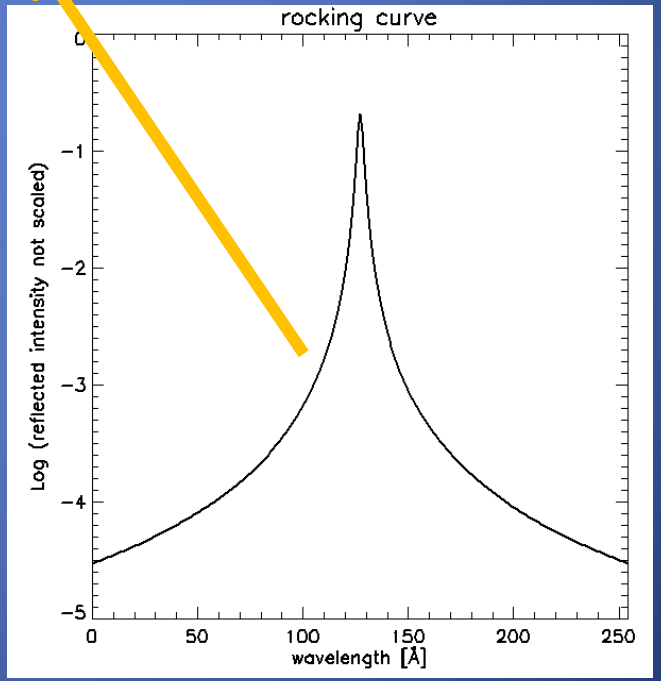
How to invert the true spectral profile? Use the „classical” WS

Deconvolved profile

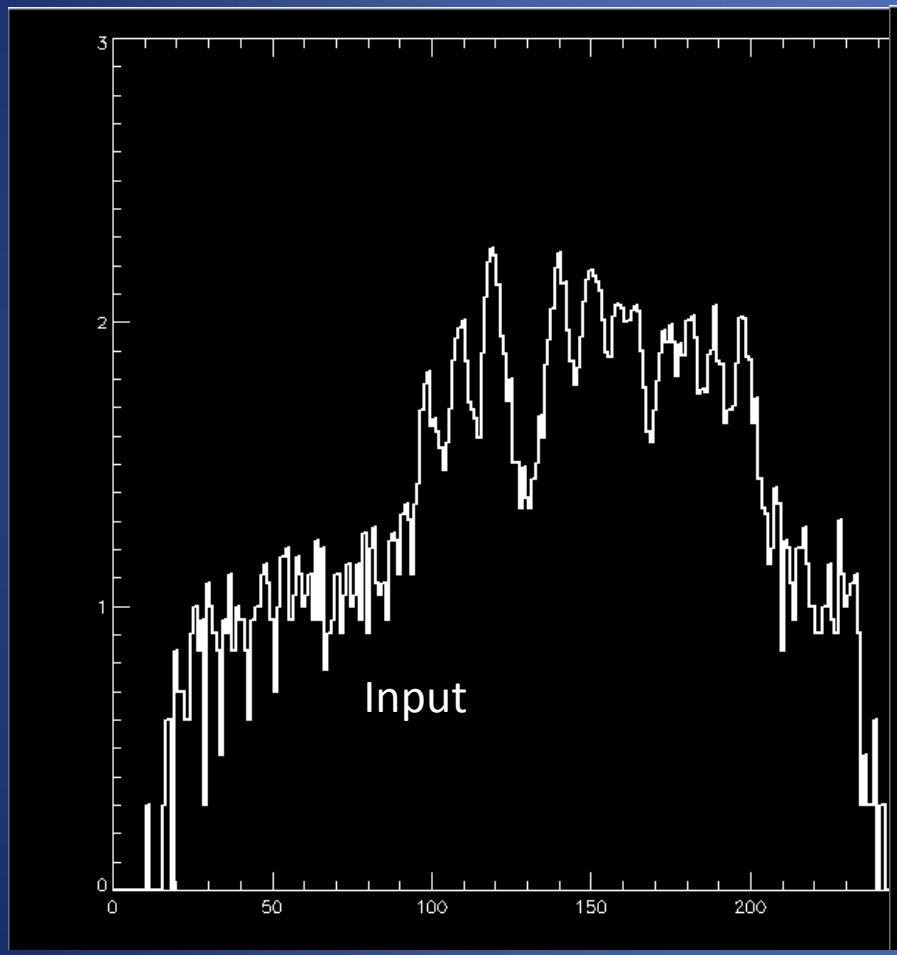
$$F_i = A_i \int_{T=0}^{\infty} f_i(T)\varphi(T)dT,$$

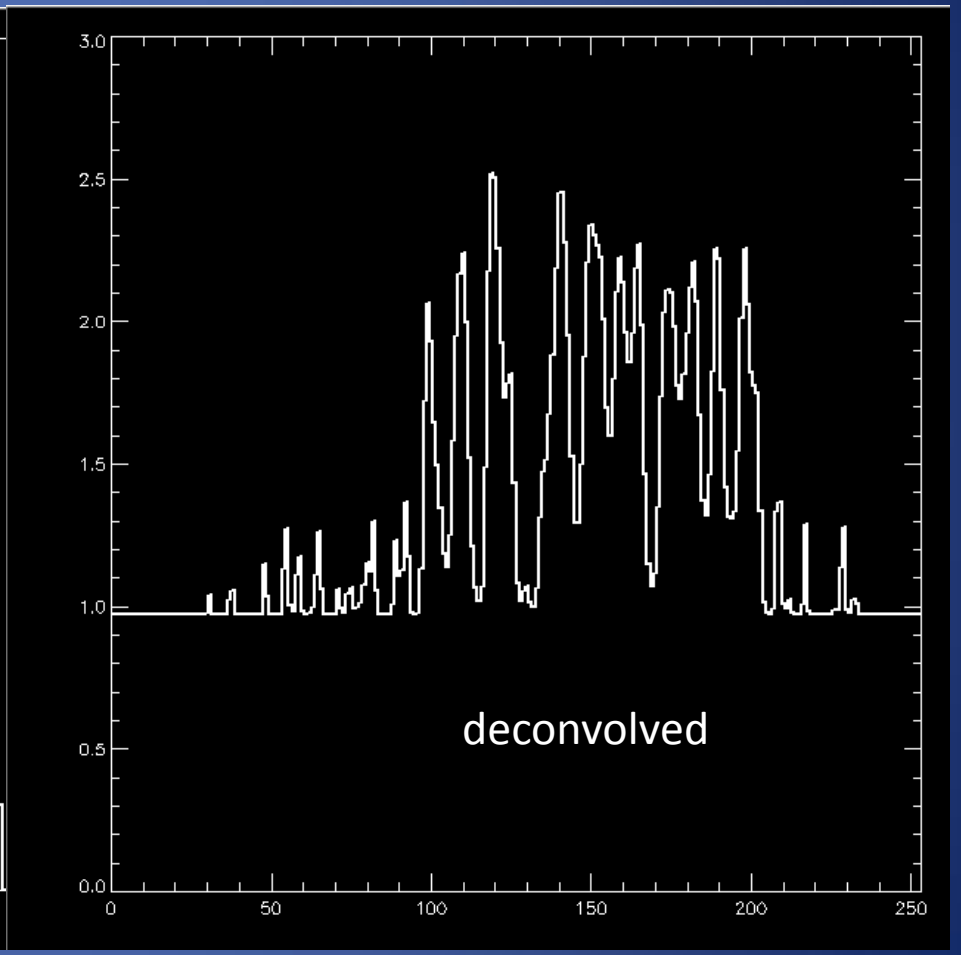
1





Examples, examples

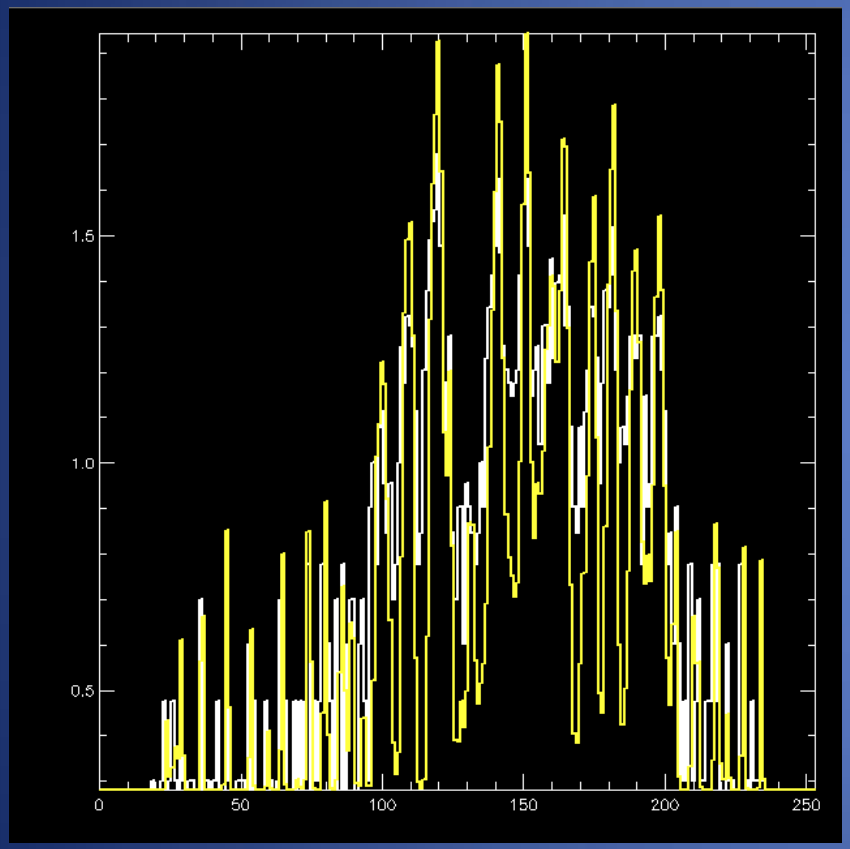


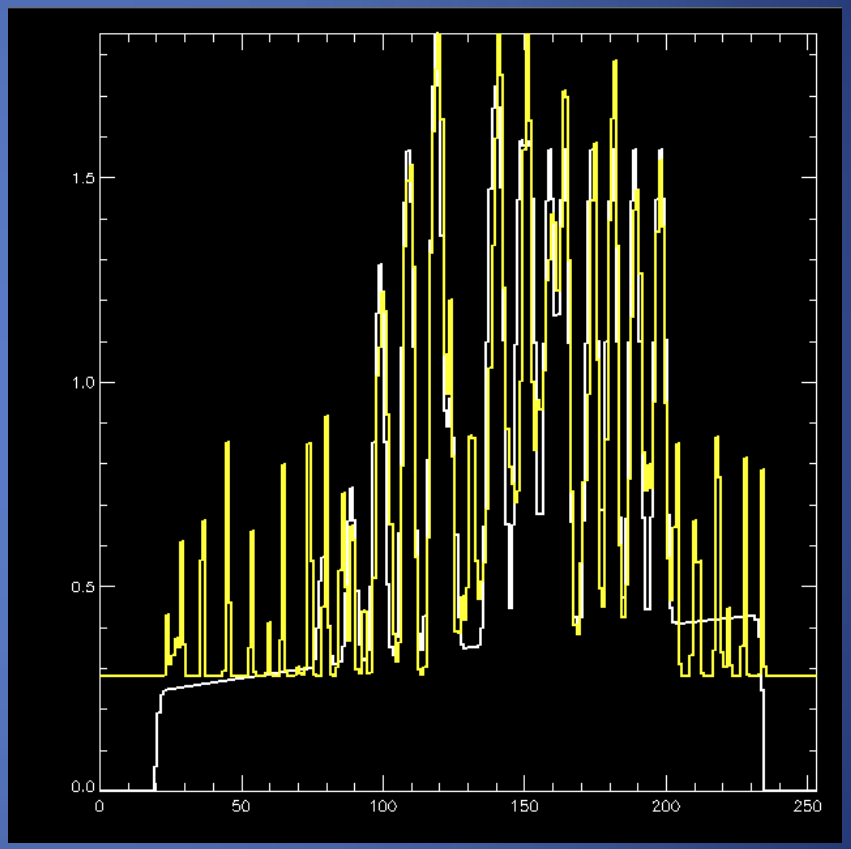


Stages of deconvolution

- Remove the continuum by interpolating from side bins [where no lines are present]
- Make the spectral signal always positive by making it (+1) for all non-positive bins. WS accepts only positive „signal”
- Make deconvolution, usually 30 iterations
- Remove what was added (+1) X No of bins
- Make sure the total signal is preserved

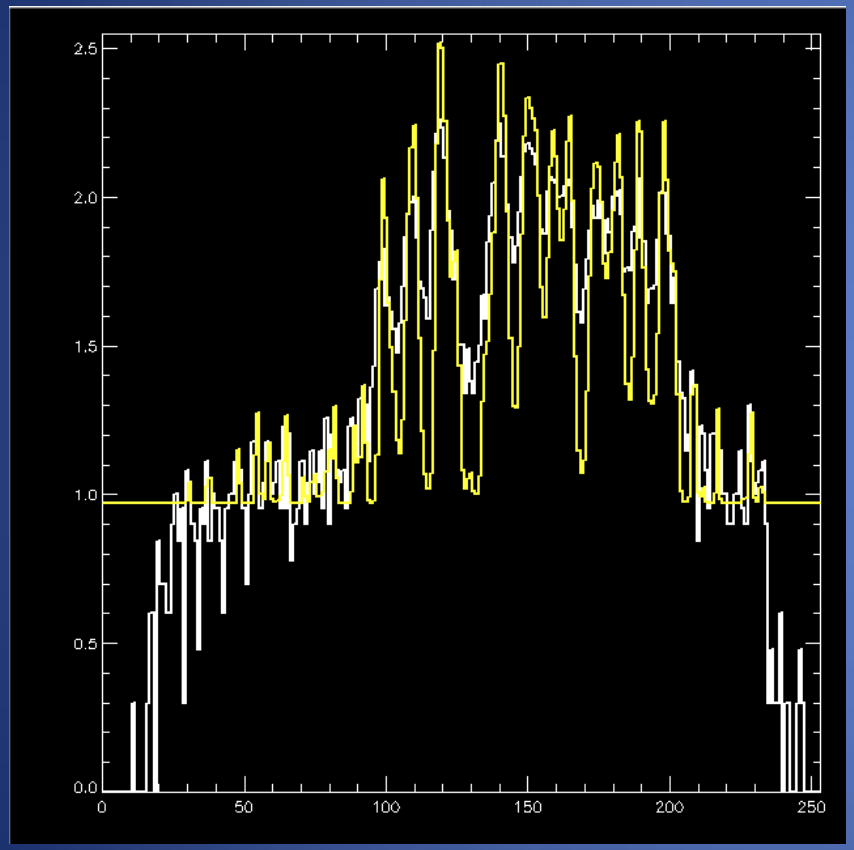
Comparison input/deconvolved

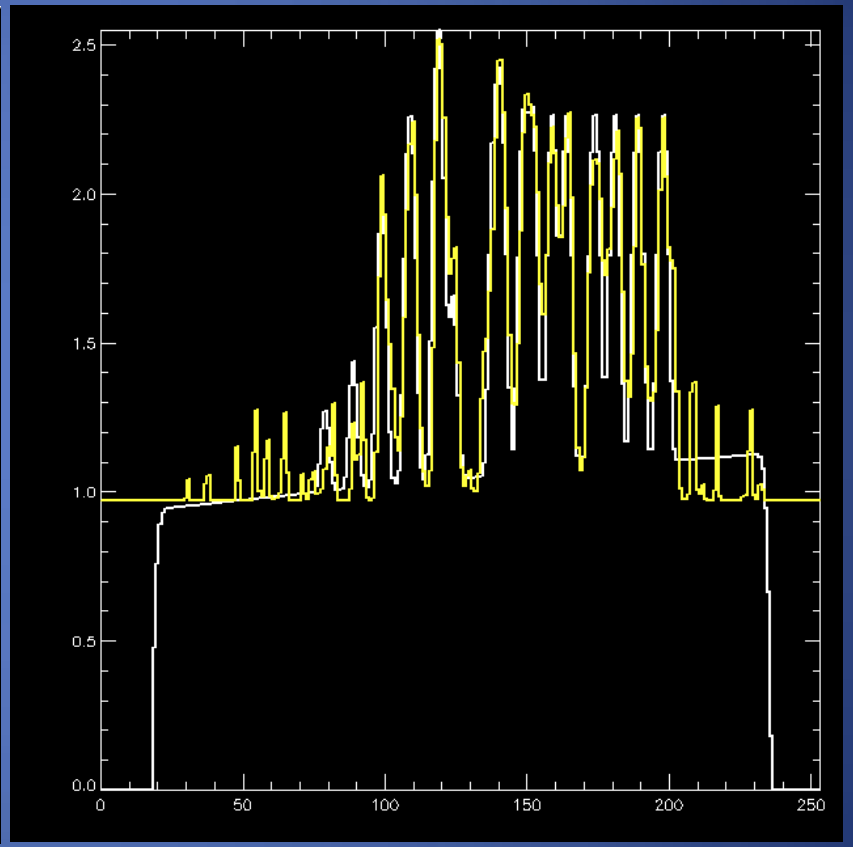




Total counts in the spectrum: 2000

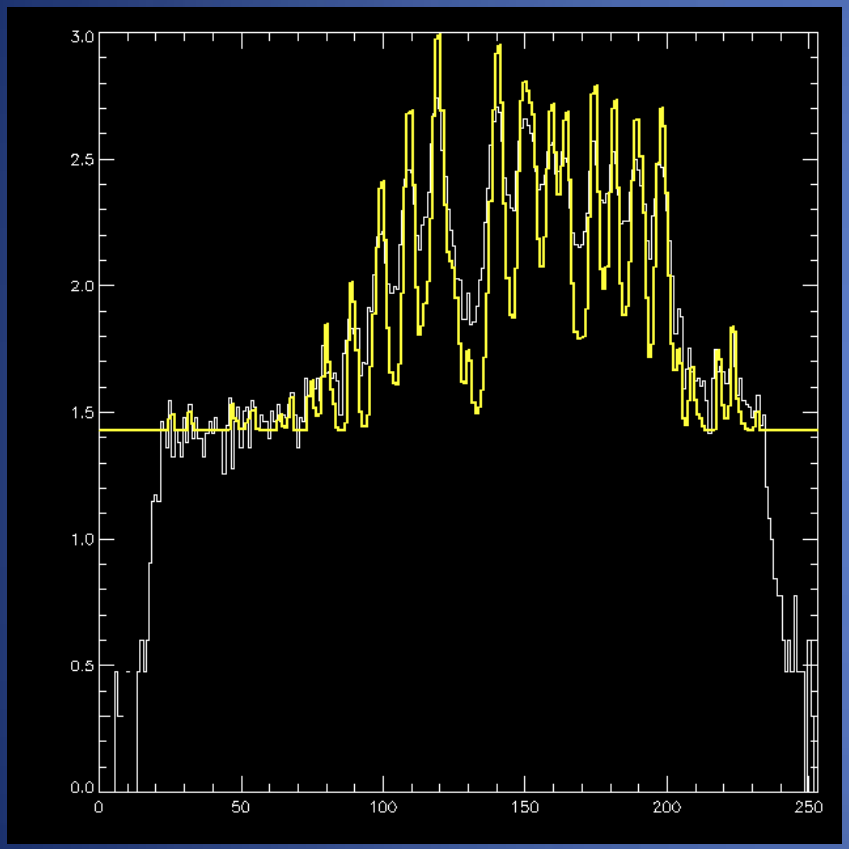
Comparison input/deconvolved

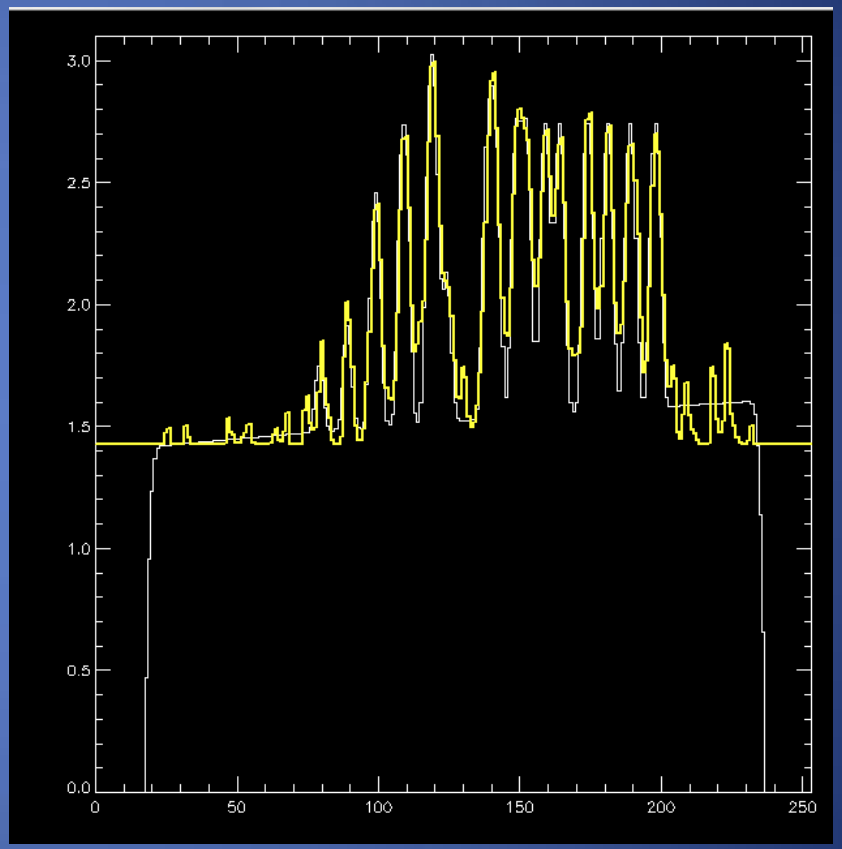




Total counts in the spectrum: 10000

Comparison input/deconvolved



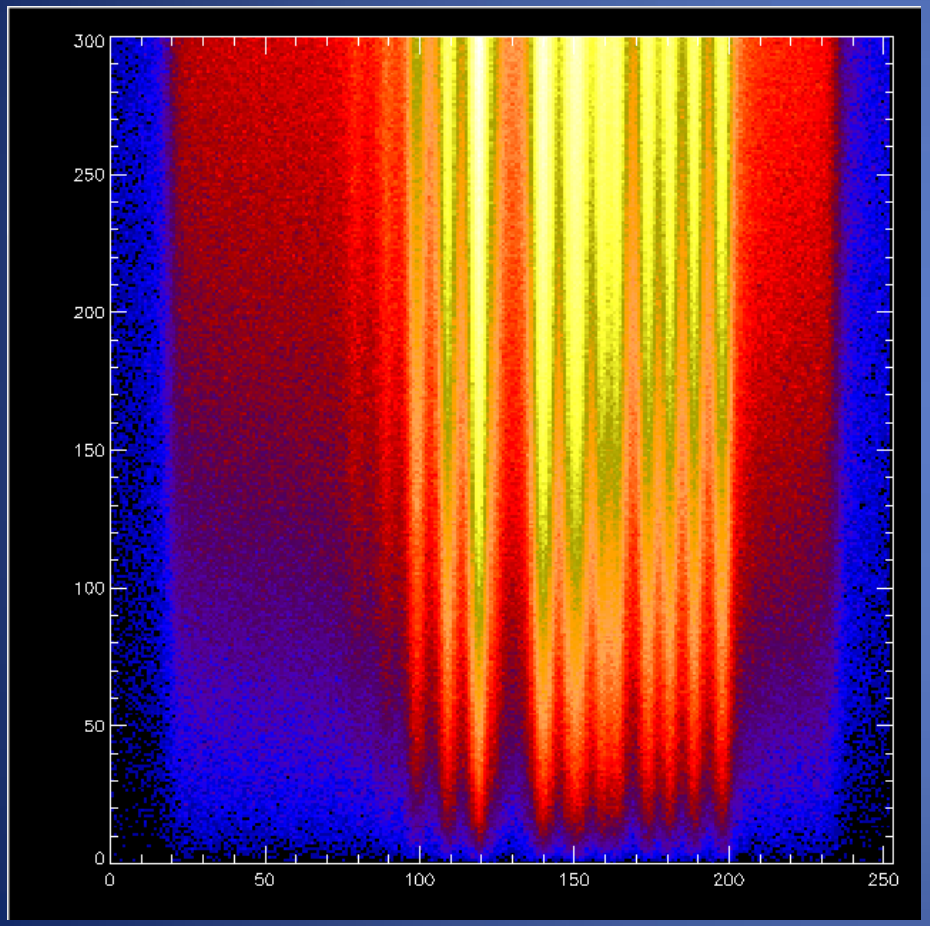


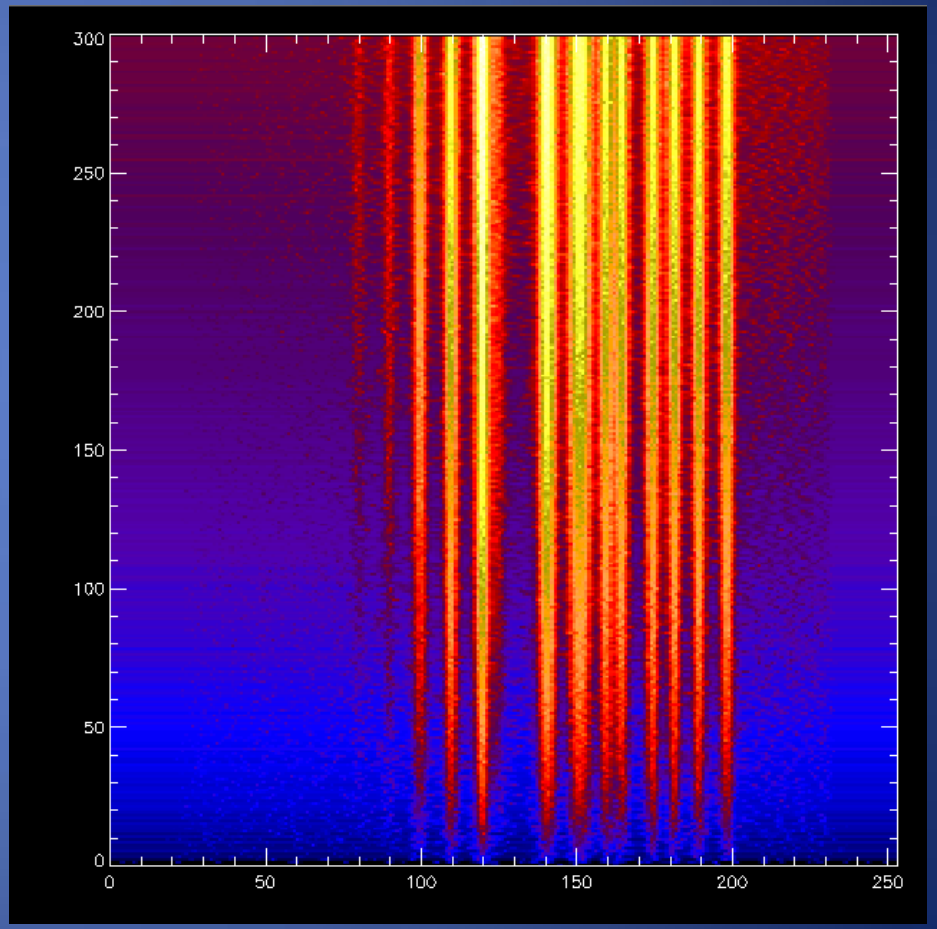
Total counts in the spectrum: 30000

Summary

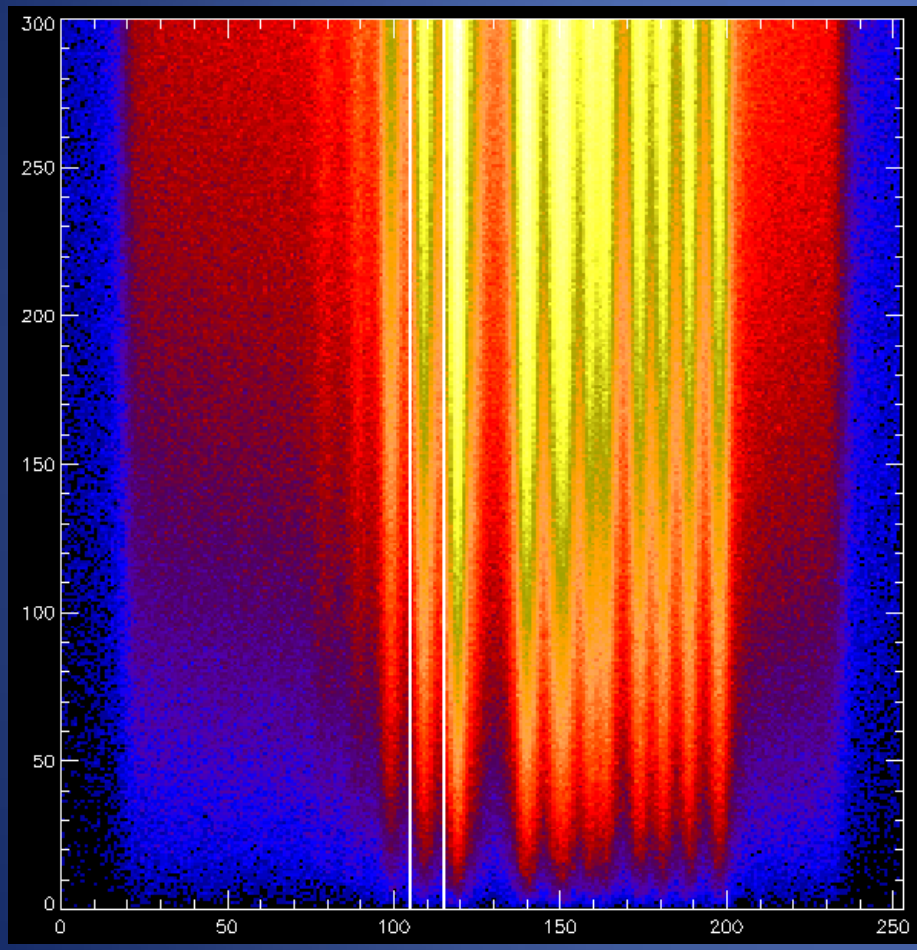
- Deconvolution make lines narrower
- „Detects” weak lines
- Detection threshold depends on „statistics”
- For given line profiles, detection thresholds can be provided and presence of lines supported by statisticsl arguments
- Work is in progress to use the best known rocking curves, detector & electronic widths (Chris Rapley, Ken Phillips, Zaneta Szaforz)

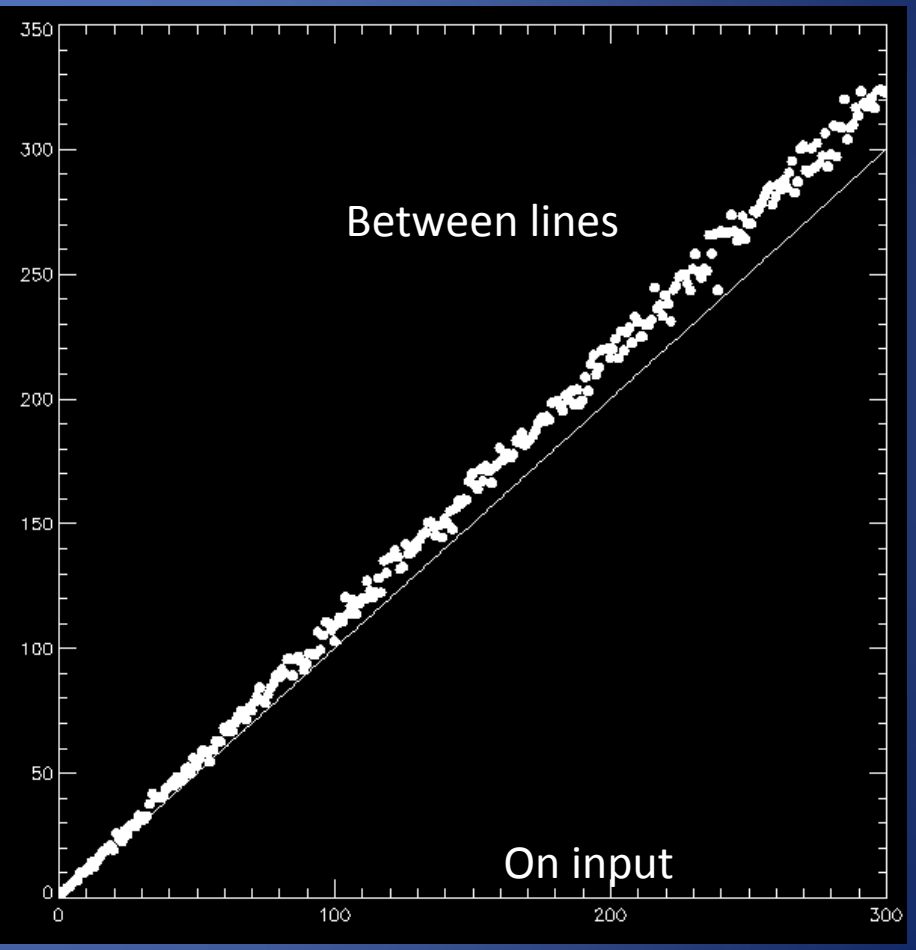
Comparison of test datacubes „as observed” & deconvolved



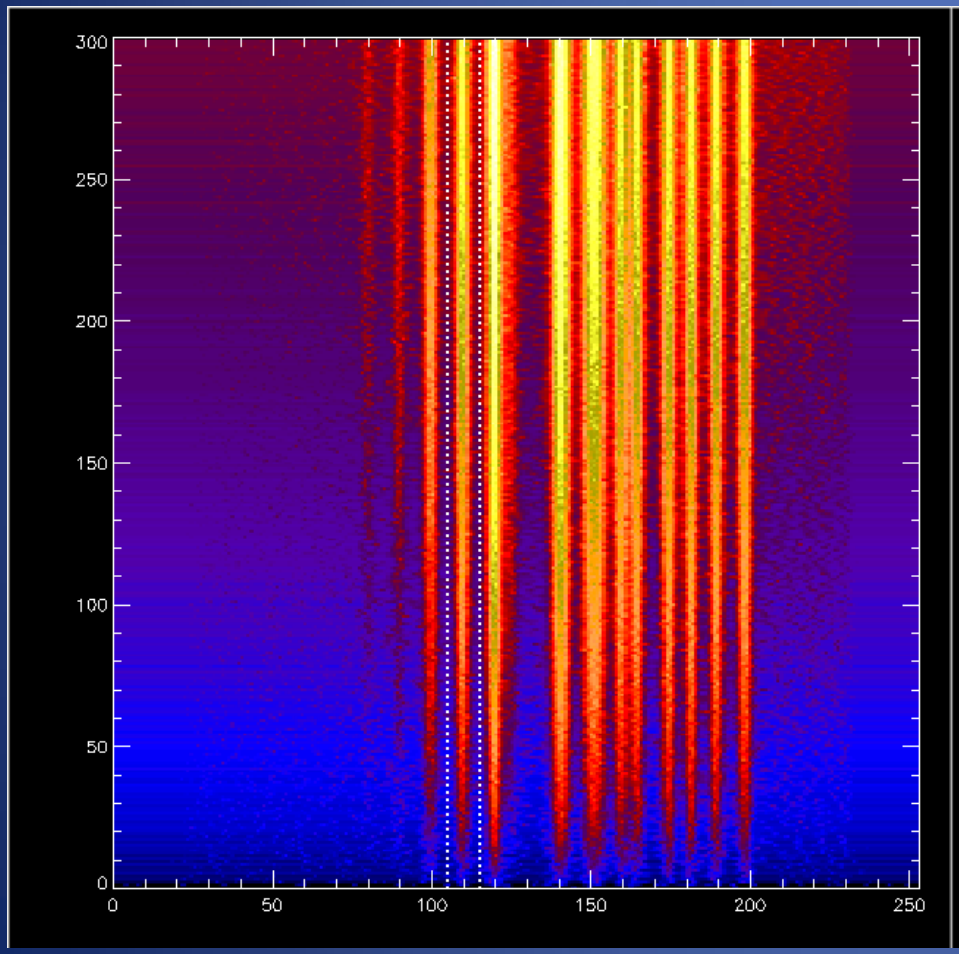


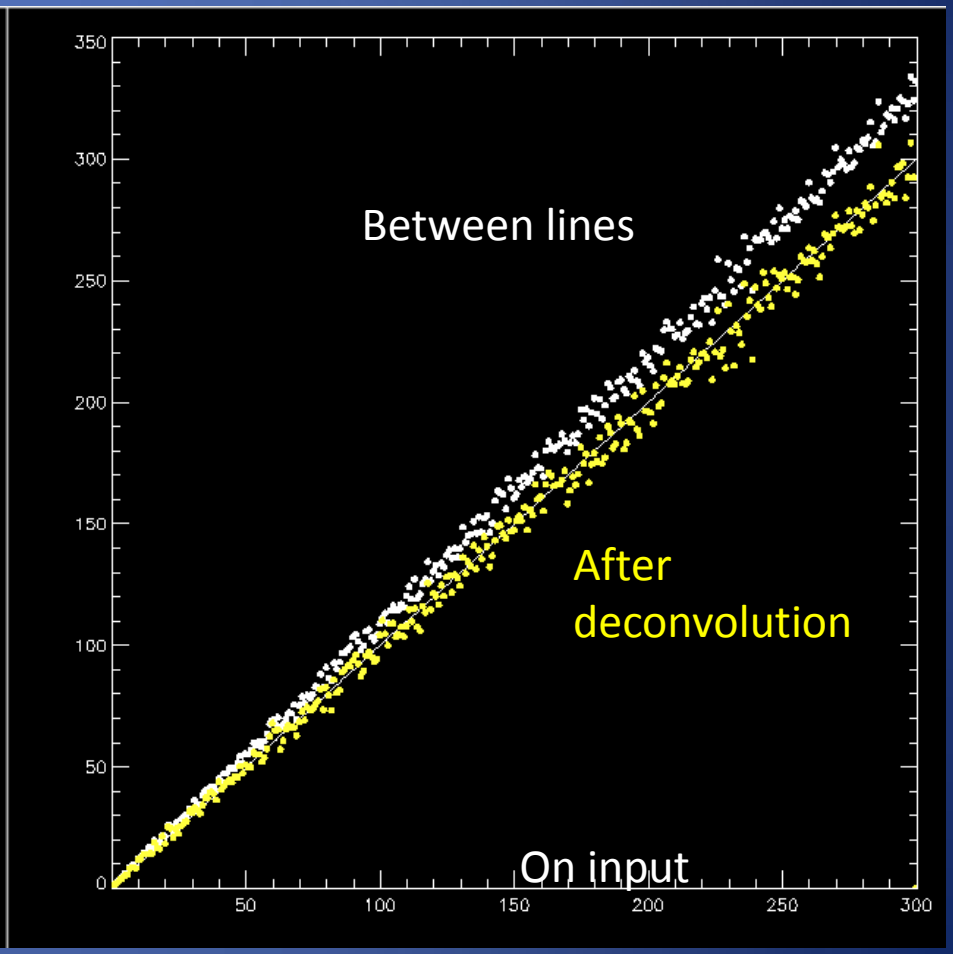
How deconvolution helps in a simple lightcurve in line



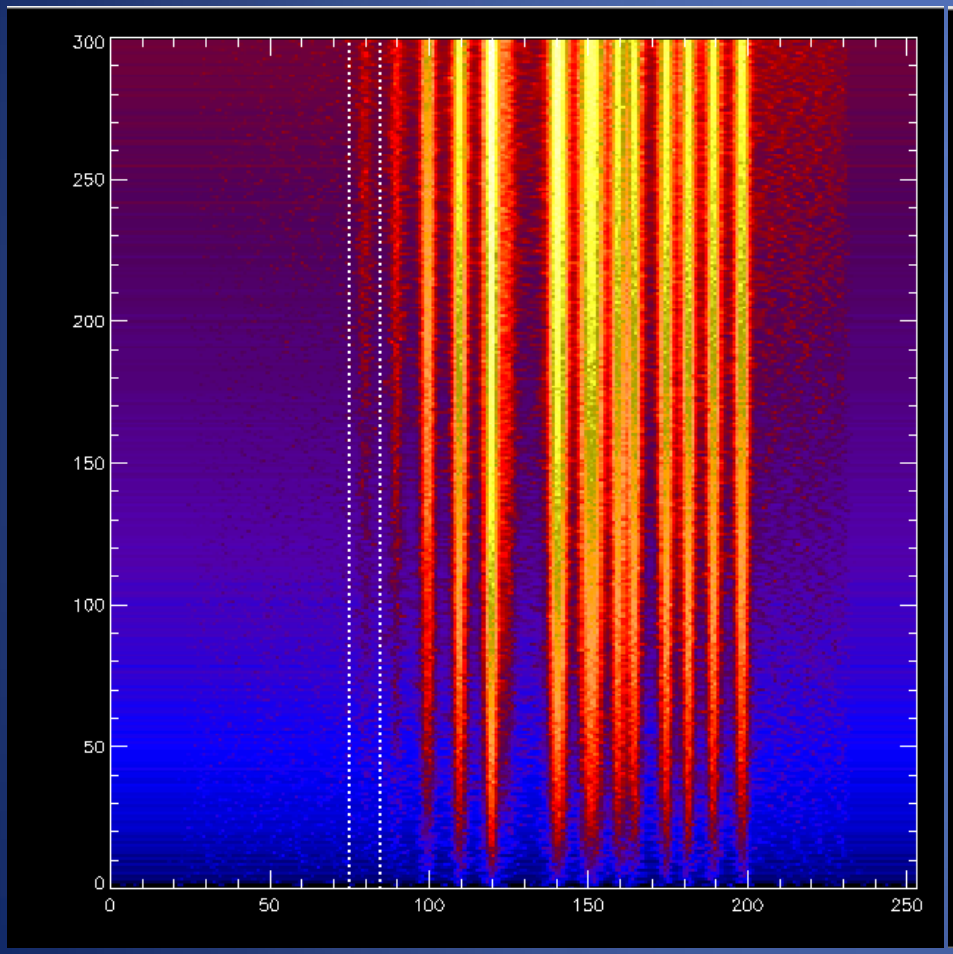


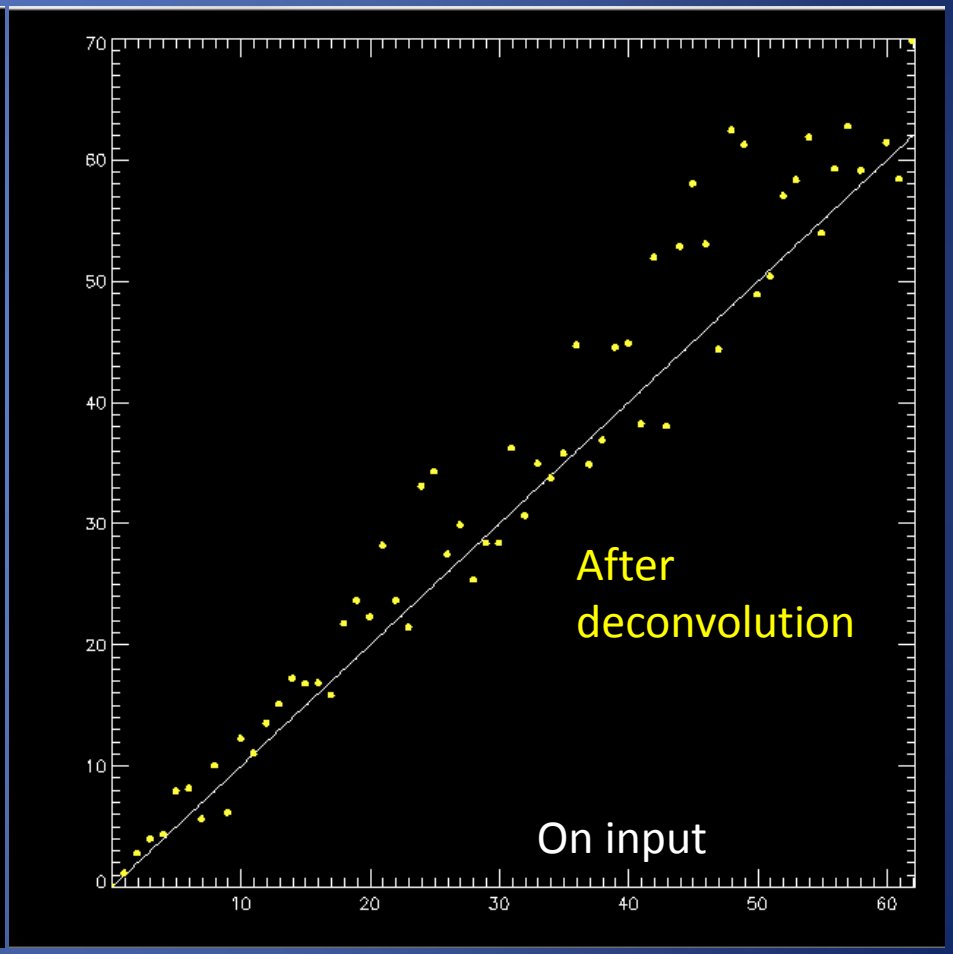
How deconvolution helps in a simple lightcurve in line



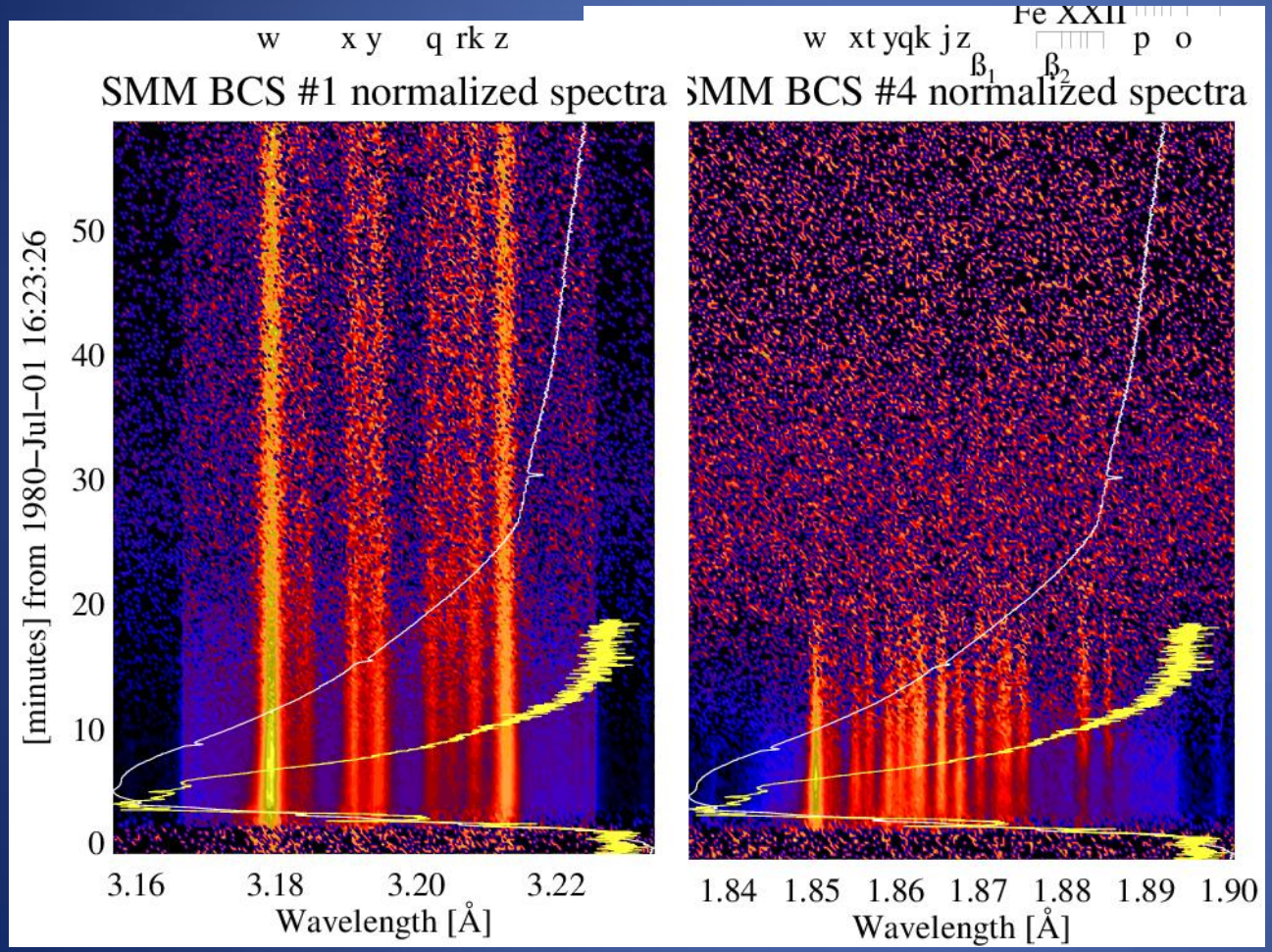


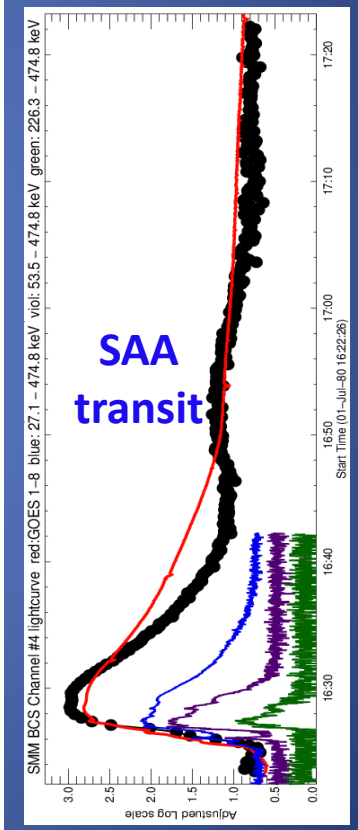
How deconvolution helps in a simple lightcurve: weak line





Real data SMM BCS channels 1 & 4, 1 July 1980 X1.8 flare





Step 1: remove orbital background

Step 2: Remove fluorescence important for iron channels 2 ÷ 8

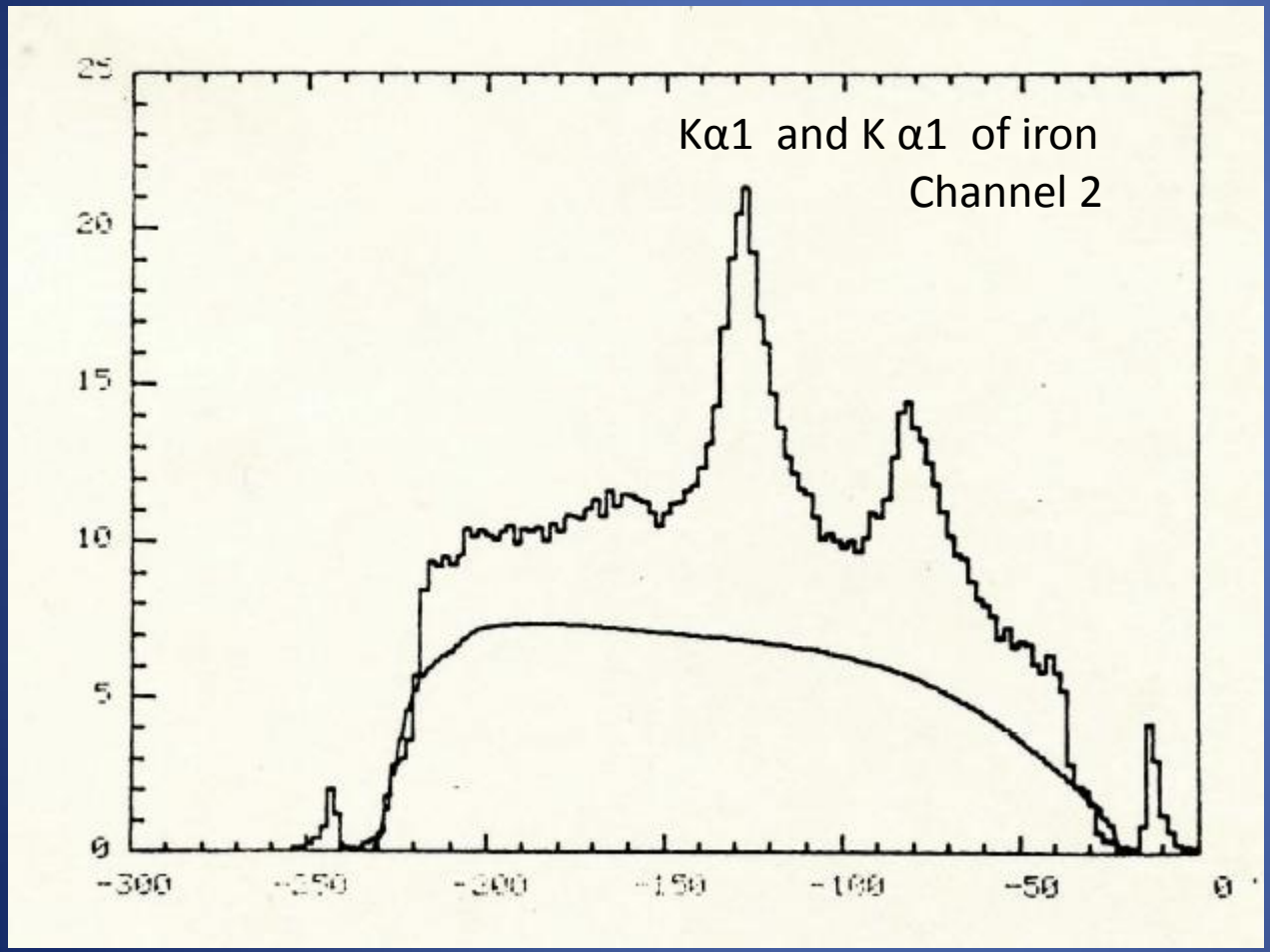
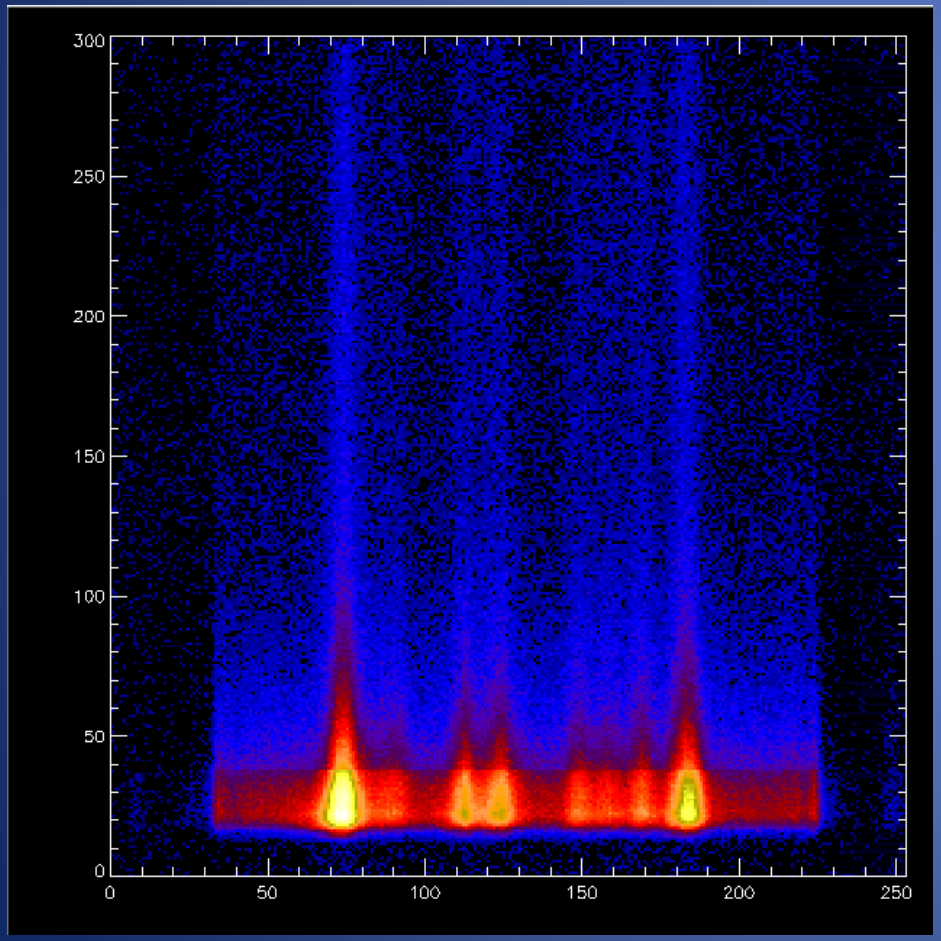


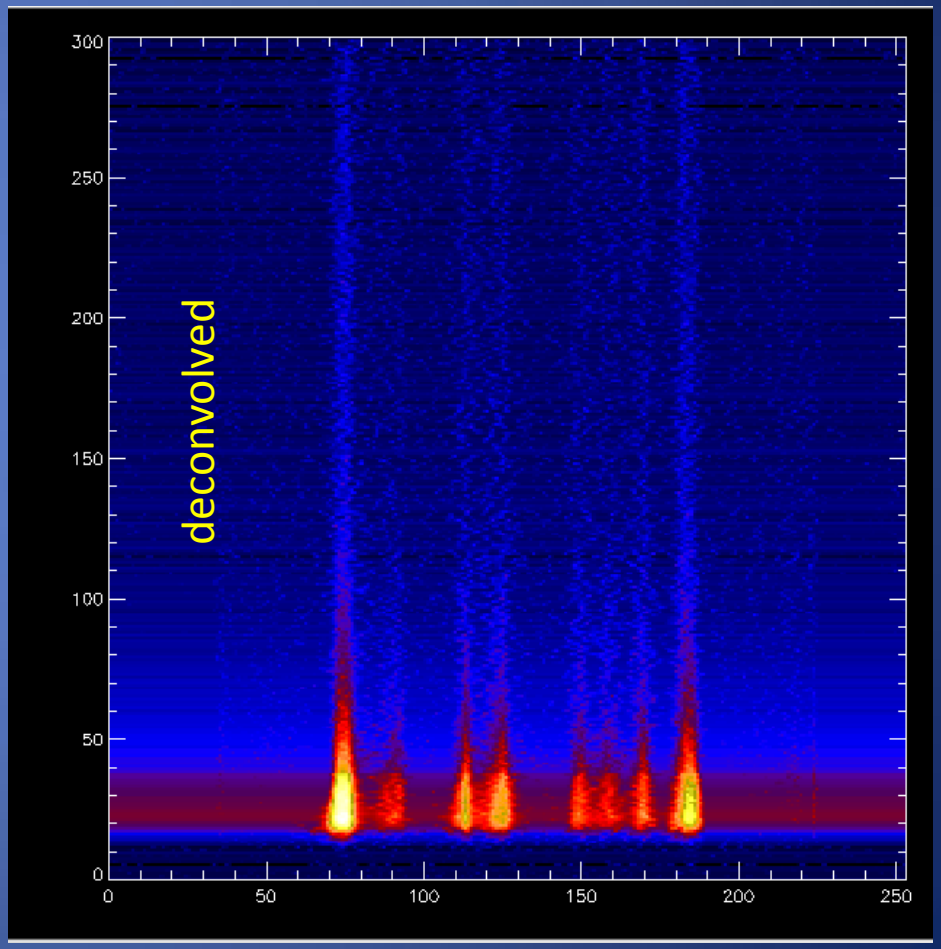
Fig. 4.11
Arvind Parmar Thesis, MSSL, 1982.
This work is to be repeated by our Team using Monte Carlo **Geant 4** package Jaromir & Aleksandra Barylak

How deconvolution works on data: SMM BCS channel 1

1 July 1980

assumed „optimum” instumental profiles

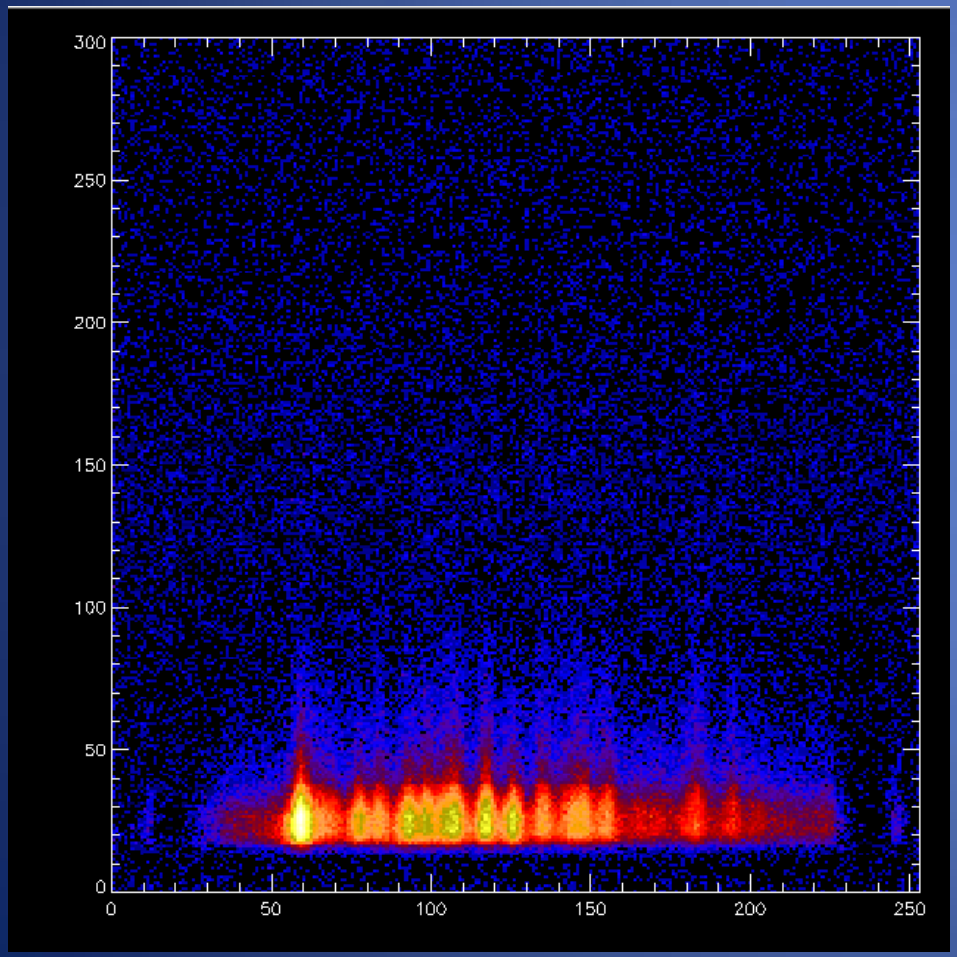


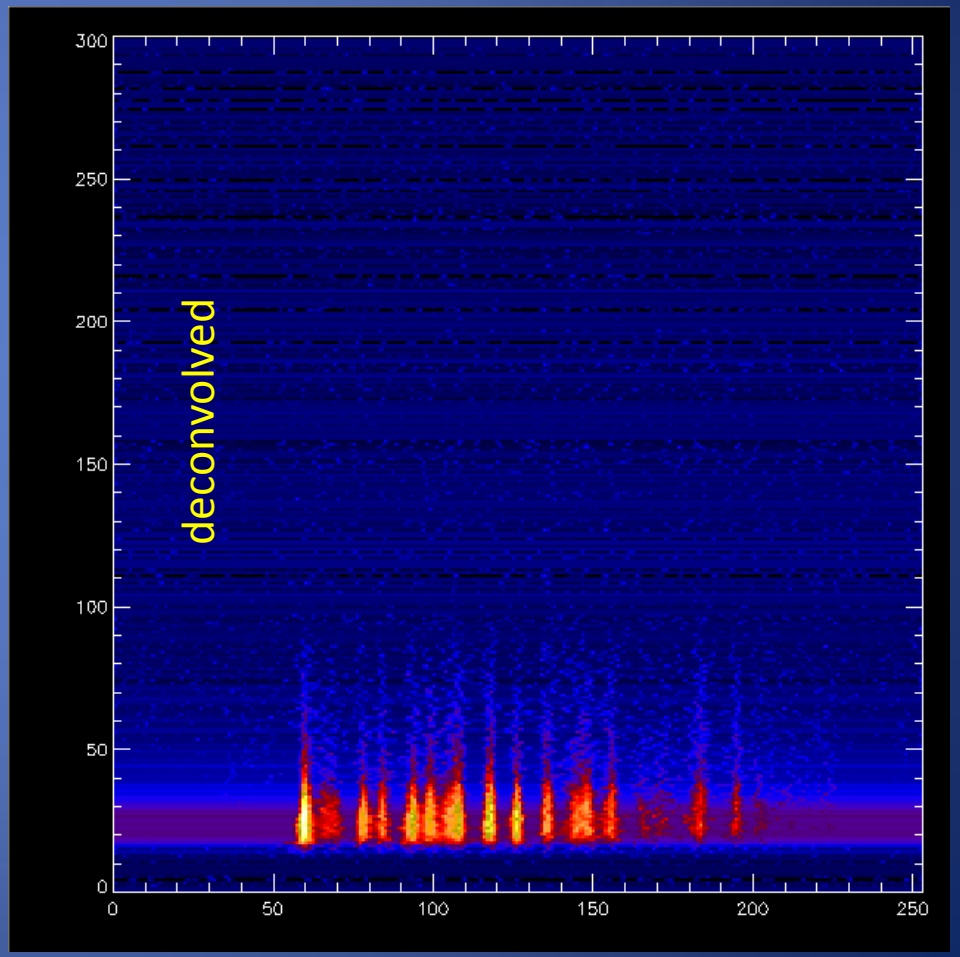


How deconvolution works on data: SMM BCS channel 4

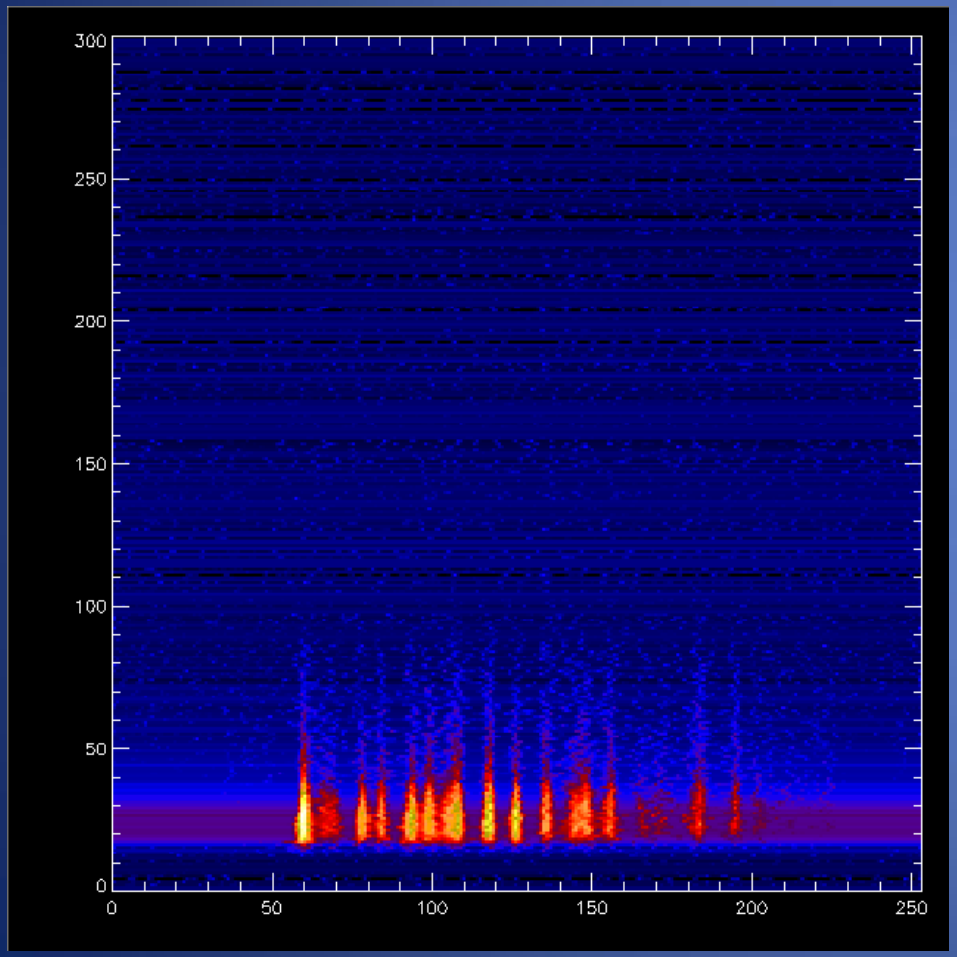
1 July 1980

assumed „optimum” instumental profiles





Step 3: wavelength assignment BCS has no absolute calibration ☹



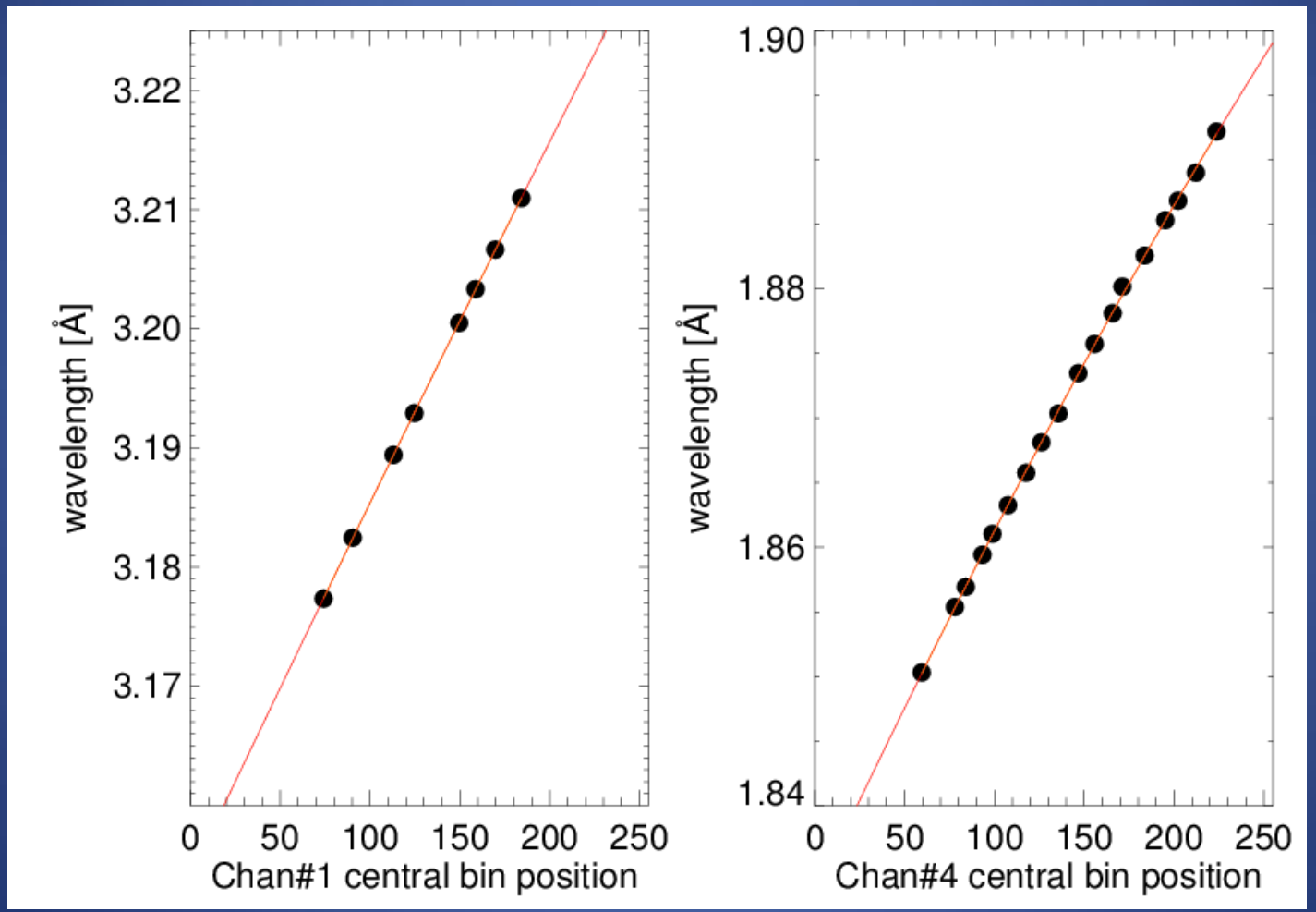
- Use doconvolved spectra
- Fit Voigt profile to every line 8-Ca, 17 Fe
- Identify lines and find best „observed” theory wavelengths from other experiments

Plot „observed” central line bin positions vs „known” wavelengths

THE ASTROPHYSICAL JOURNAL, 338:567–577, 1989 March 1

MEASUREMENT OF WAVELENGTHS FOR INNER-SHELL TRANSITIONS IN Ca XVII–XIX

J. F. SEELY AND G. A. DOSCHEK

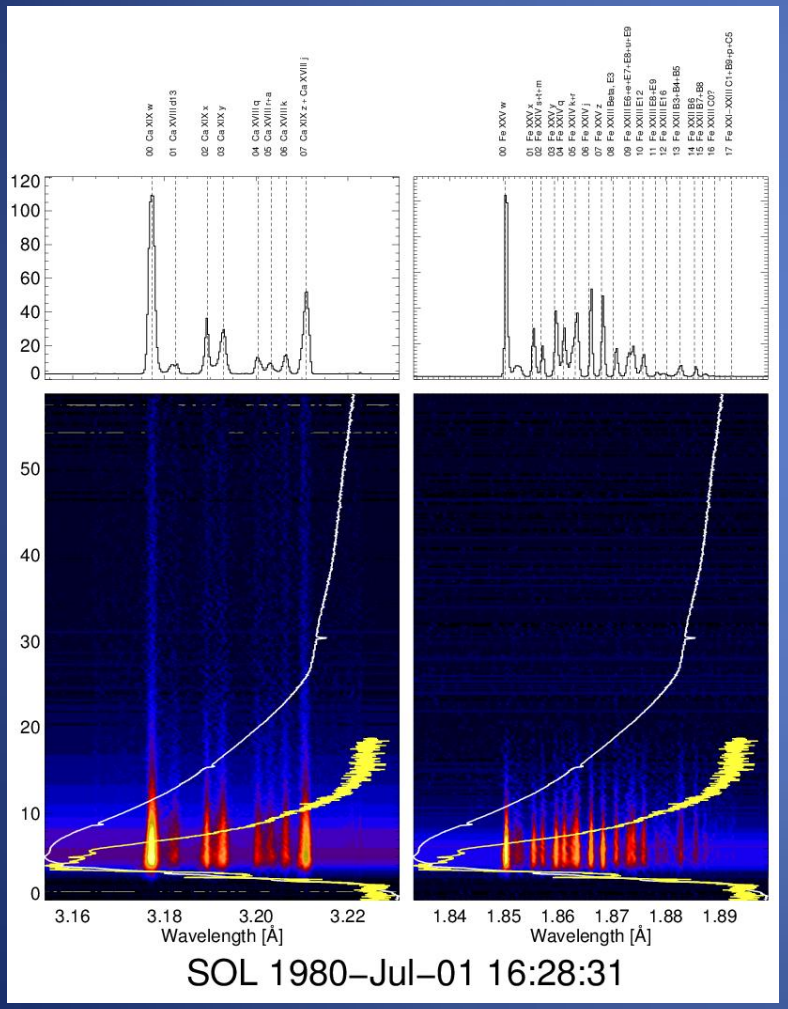


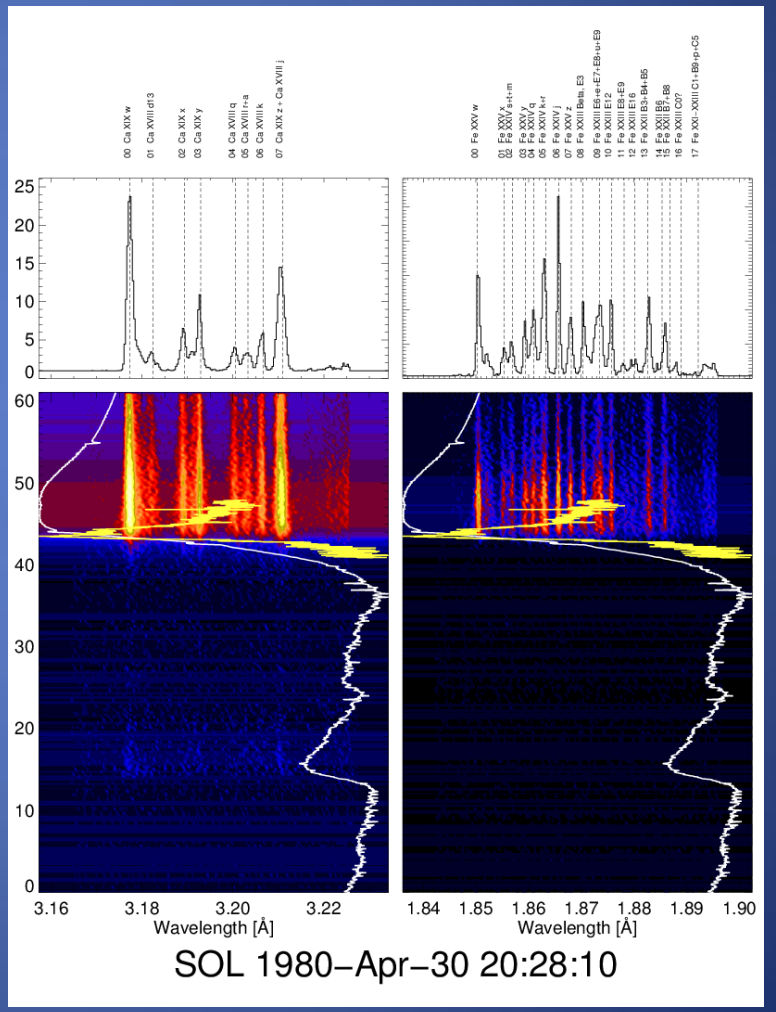
HIGH-RESOLUTION MEASUREMENTS, LINE IDENTIFICATION, AND SPECTRAL MODELING OF Kα TRANSITIONS IN Fe XVIII–Fe XXV

P. BEIERSDORFER AND T. PHILLIPS
Lawrence Livermore National Laboratory, University of California, Livermore, CA 94550

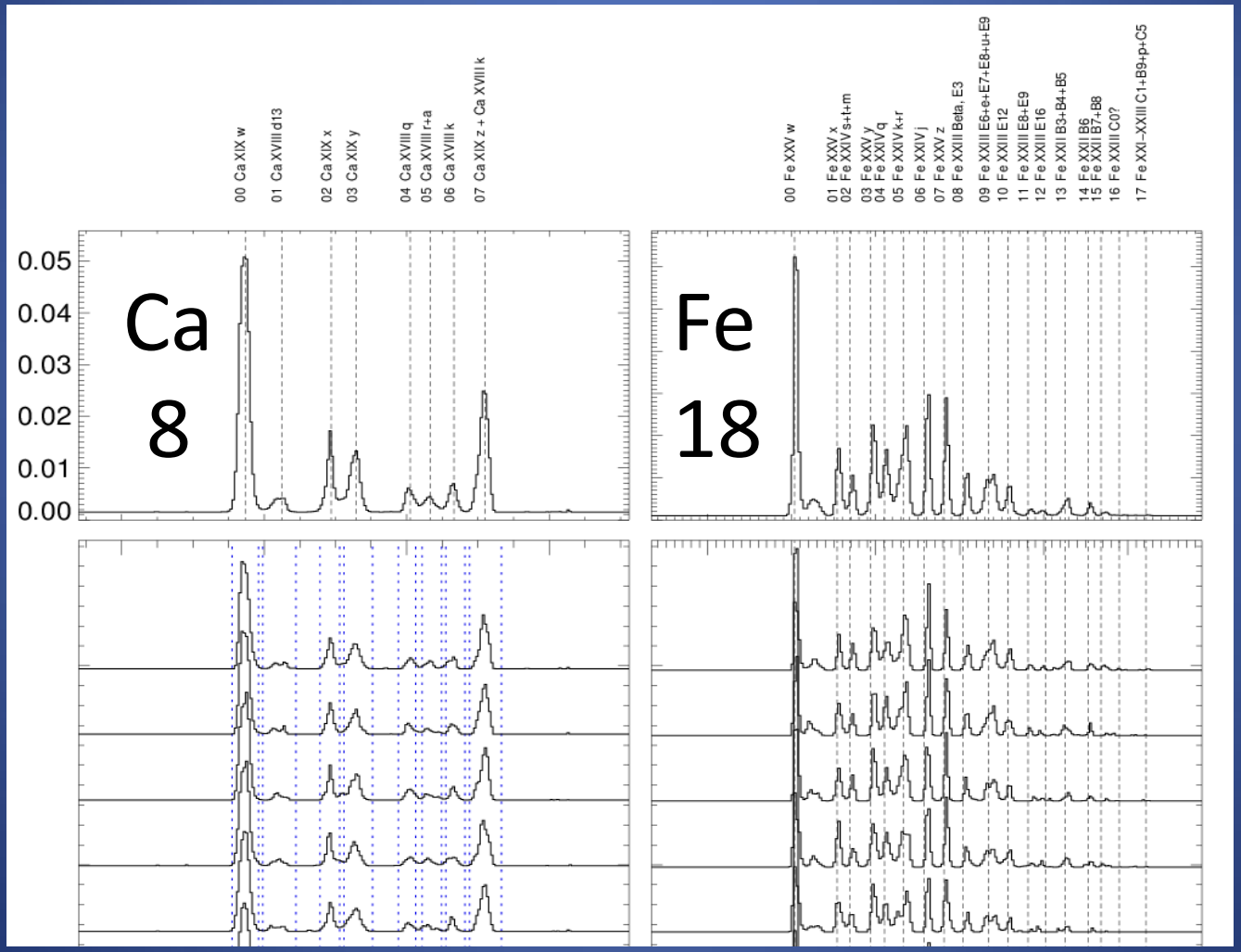
THE ASTROPHYSICAL JOURNAL, 409:846–859, 1993 June 1

Ready to do some simple analysis
Example deconvolved sequences





Time dependence of Fluxes in individual lines (blends)



Data to be available for the further analysis

- Original and deconvolved spectral cubes (#1 & #4) ~100000 spectra in the database, for more than 100 flares SMM; 150 spectra for Diogeness, 7 flares
- Lightcurves of
  - GOES in 2 X-ray bands, 3s resolution
  - HXRBS in 7 channels, 1 s resolution
  - BCS Ca 8 line fluxes & cont, 10-20s resolutiom
  - BCS Fe 18 fluxes, same resolution & time binning
  - Orbital bckd, 10-20s resolutiom
- SMM S/C Pointing available from FCS & UVSP
- However, scarce ground base, radio etc., some data available from publications on selected events
- Location of event within the FOV unknown, rough estimates possible
- Time dependence of sources X-ray morphology (double footpoin?) missing

Summary

- The collaboration established for the reinforced reduction of SMM BCS and Diogeness spectra
- Better instrumental profiles & calibrations will be determined
- Instrumental profile will be deconvolved, resulting in „cleaner” spectra
- The catalogue of deconvolved spectra will be created
- Events will be searched through to identify „interesting” cases for further detailed analysis

We are looking for collaborations

THANK YOU !