Spectral calibration & spectrum extraction with AMBER

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Context

- Cepheid pulsating stars
  - Study the effects of radial pulsation in the photosphere
  - Maximum pulsation velocity ~ 50 km/s (R~6000)
- AMBER:
  - HR has R~15000
  - Br Gamma may also be sensitive to the mass loss
- Problems:
  - No usable spectrum exctracted by AMDLIB
  - No accurate spectral calibration (subpixel)
  - "DIT>1s almost impossible to calibrate"

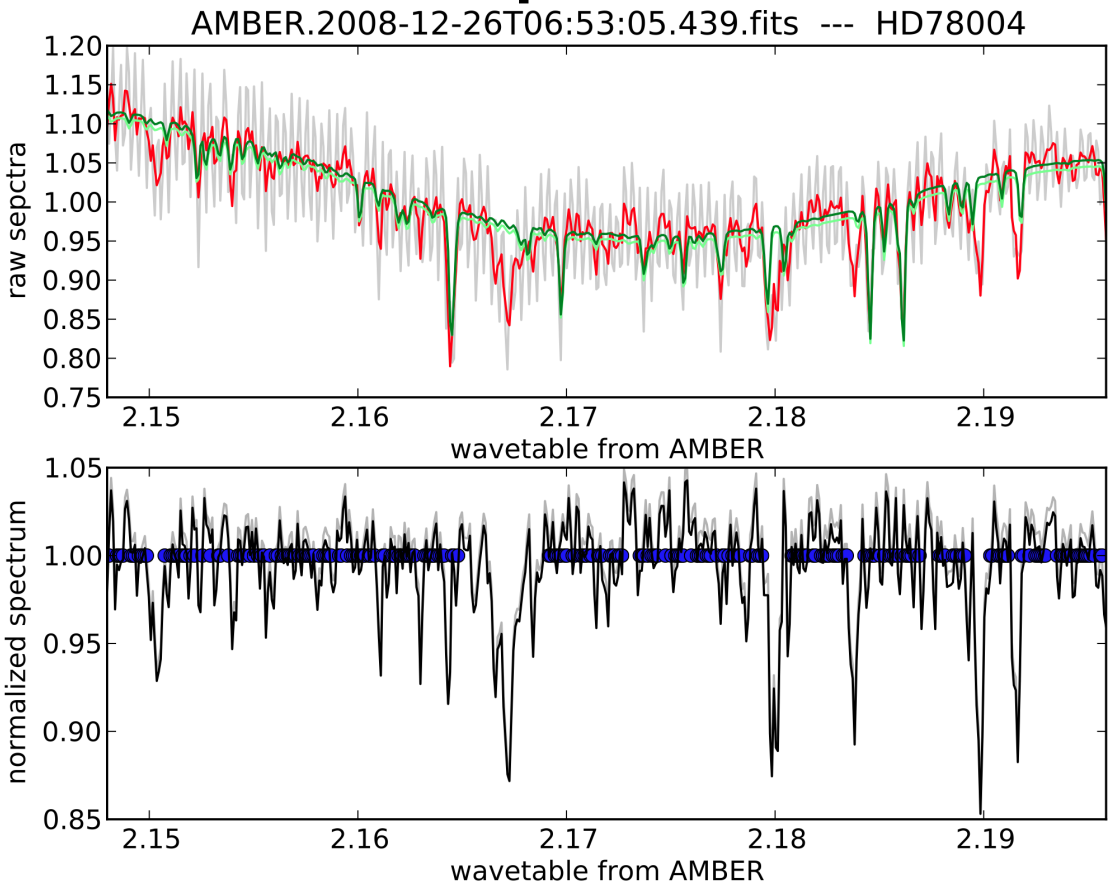
Context (2)

- What do we need ?
  - Both V2 AND Spectrum: simultaneous data are a must for varying objects => get spectrum from AMBER
  - Spectrum extraction: remove telluric lines, correct from continuum
  - Spectral calibration: use telluric lines for accuracy and precision (subpixel)
  - ... Plus we had old data corrected from the Fabry-Perot fringing due to old polarizers
- AMDLIB does many things, but do not address these points

'Minor' problems

- Removing ripples from old polarizers
  - We adoped a 'model / fit / remove' approach rather than notch filtering
  - Advantage: no ripple -> no information loss (not the case for filtering)
  - Adhoc model
  - Result not as clean as new data...
- specCalShifts
  - Critical in our case
  - Correlation using the telluric spectrum
  - Subpixel shifts seem OK

Spectrum extraction



Raw (with ripples)

Telluric model * continuum

Clean (derippled)

Mask (ignore stellar lines to fit the continuum)

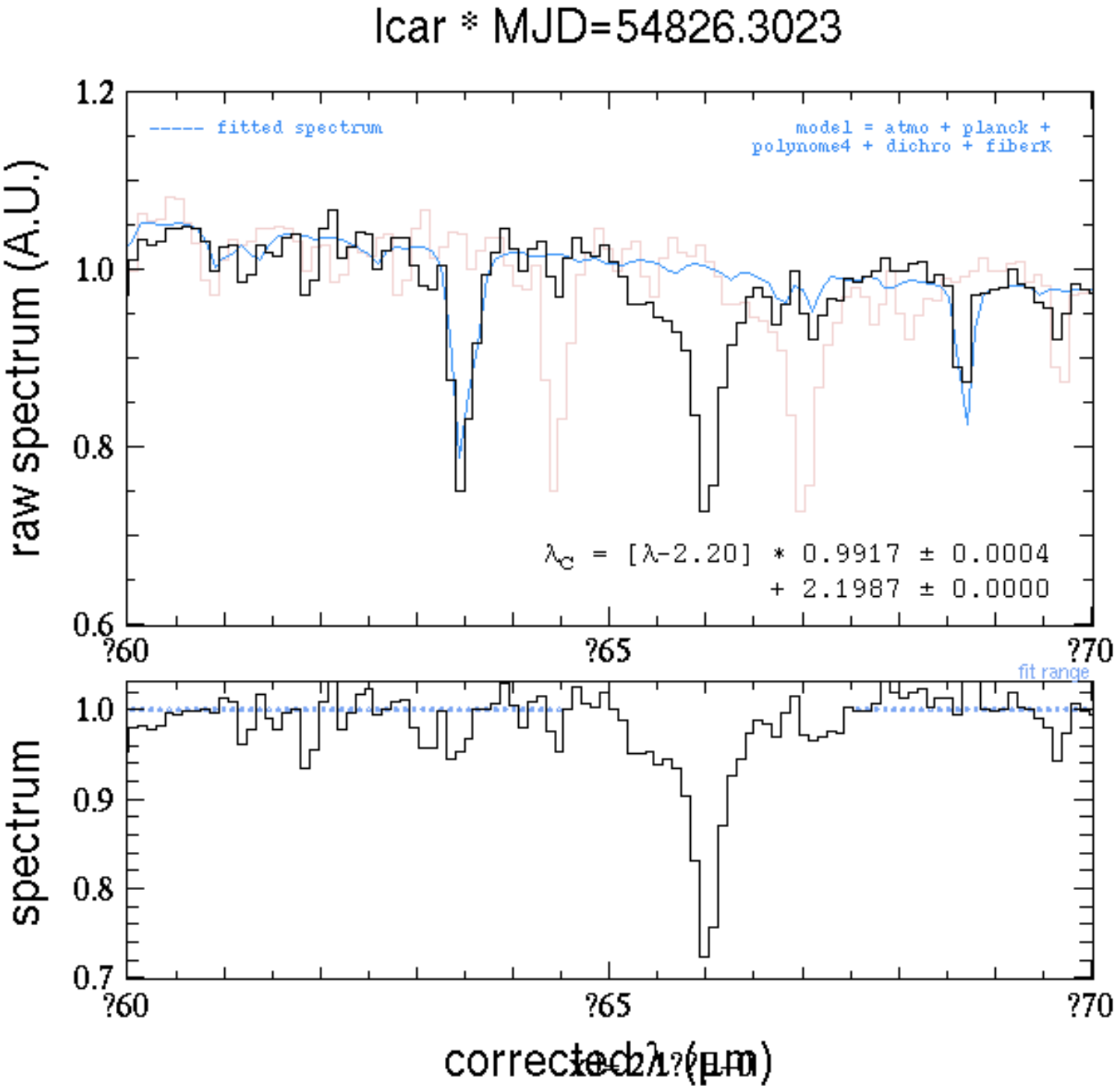
Normalized spectrum

Telluric spectrum?
using HITRANS
(Alain Smette - ESO)

> **Spectral calibration** => Differential channel offset (SpecCalShift)
=> Subpixel dispersion law correction (3rd order)

> **Spectrum extraction** => Ripples HR + Continuum fitting + Sky transmission

> By-product **Precipitable Water Vapor** (PWV)



Zoom in close to BR Gamma

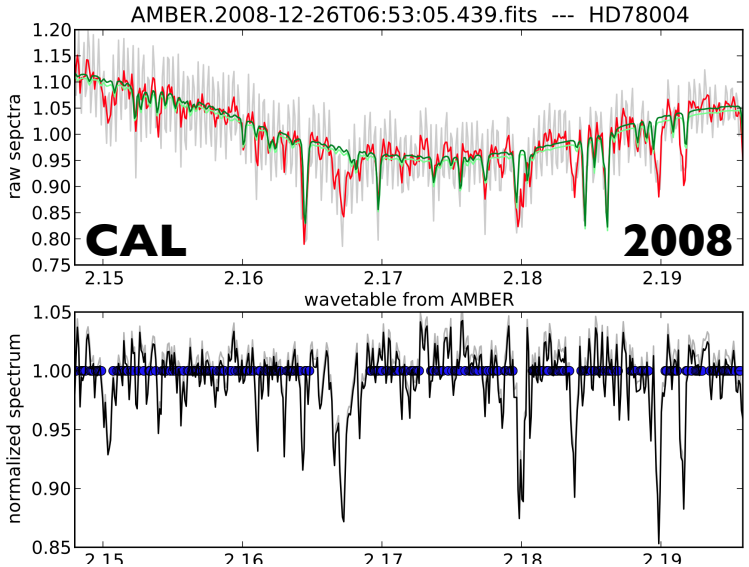
- most features are telluric
- in pink, wave table in AMBER FITS file:

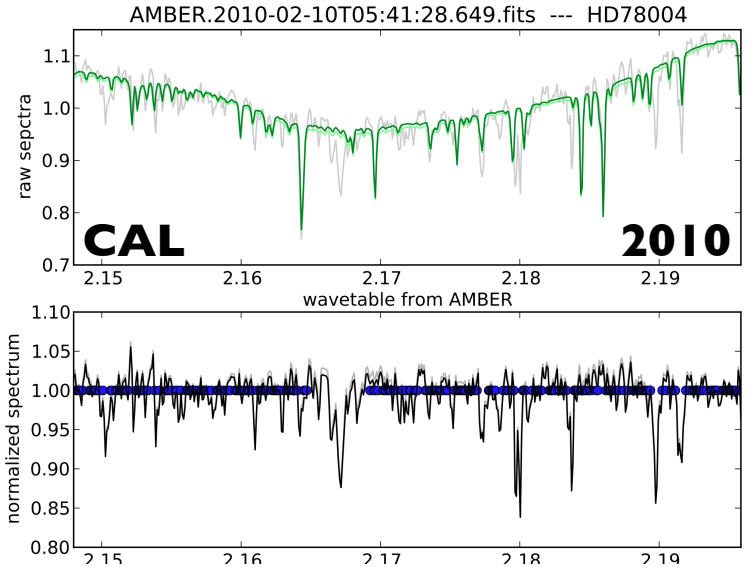
offset >10 pixels

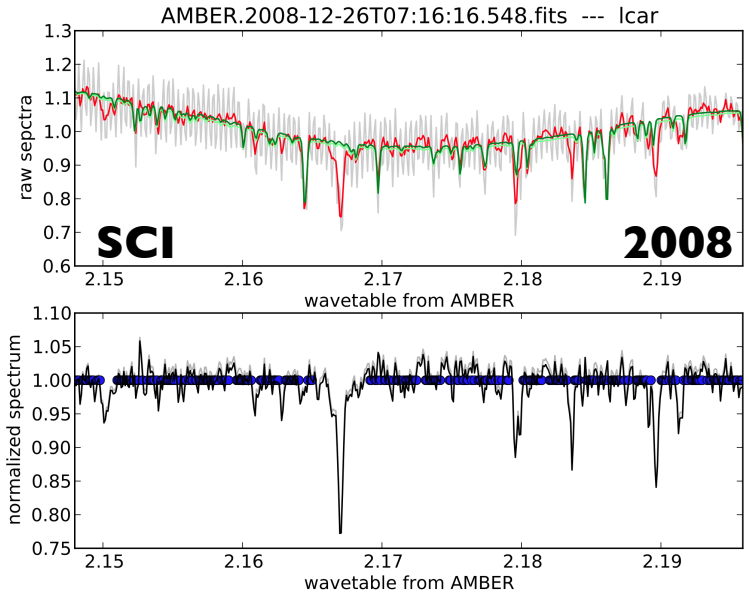
- AMBER slope is accurate to ~1%

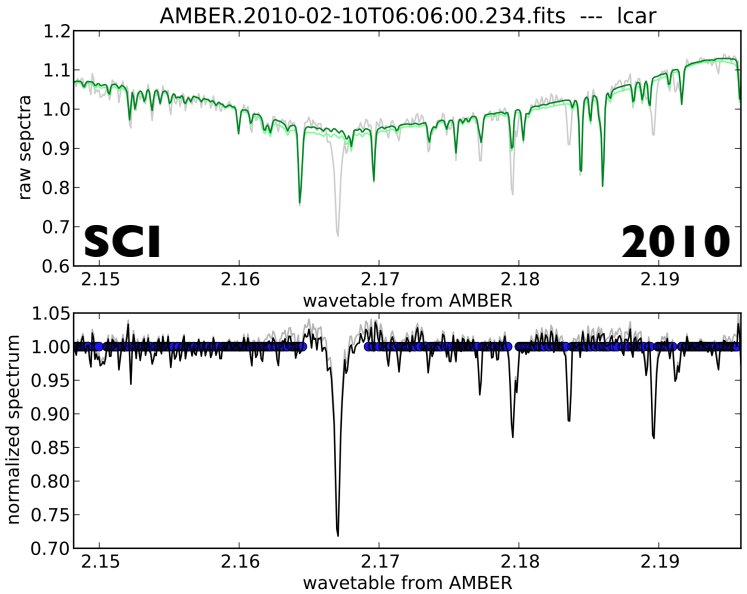
Application to LCar

(Denis Mourard, Nicolas Nardetto, Pierre Kervella)

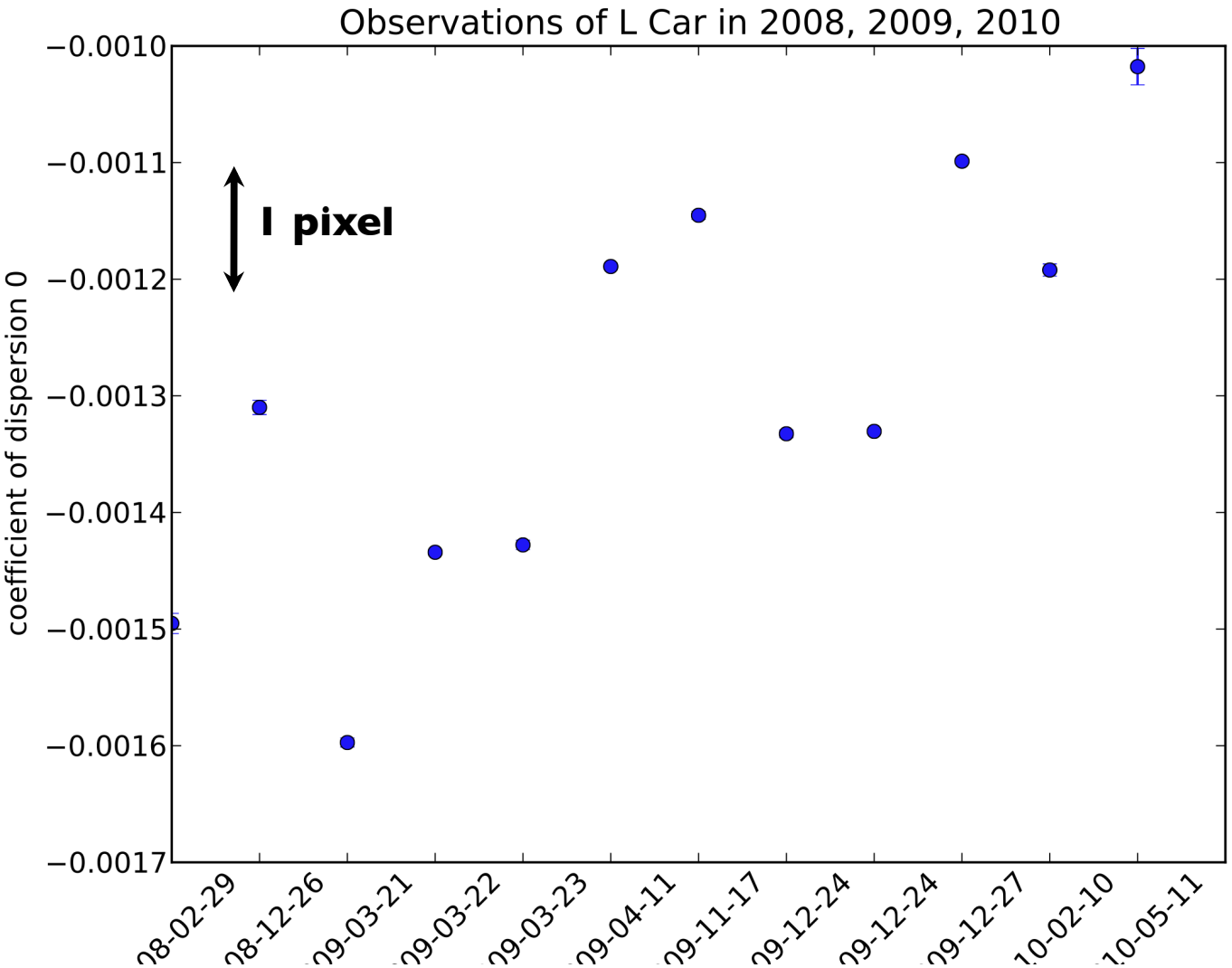








Offset of dispersion (in um)



Offset between:
- wavelength table
- extracted spectrum

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Dispersion
over 2 years:
1.3nm +/- 0.3nm
13pxl +/- 3pxl

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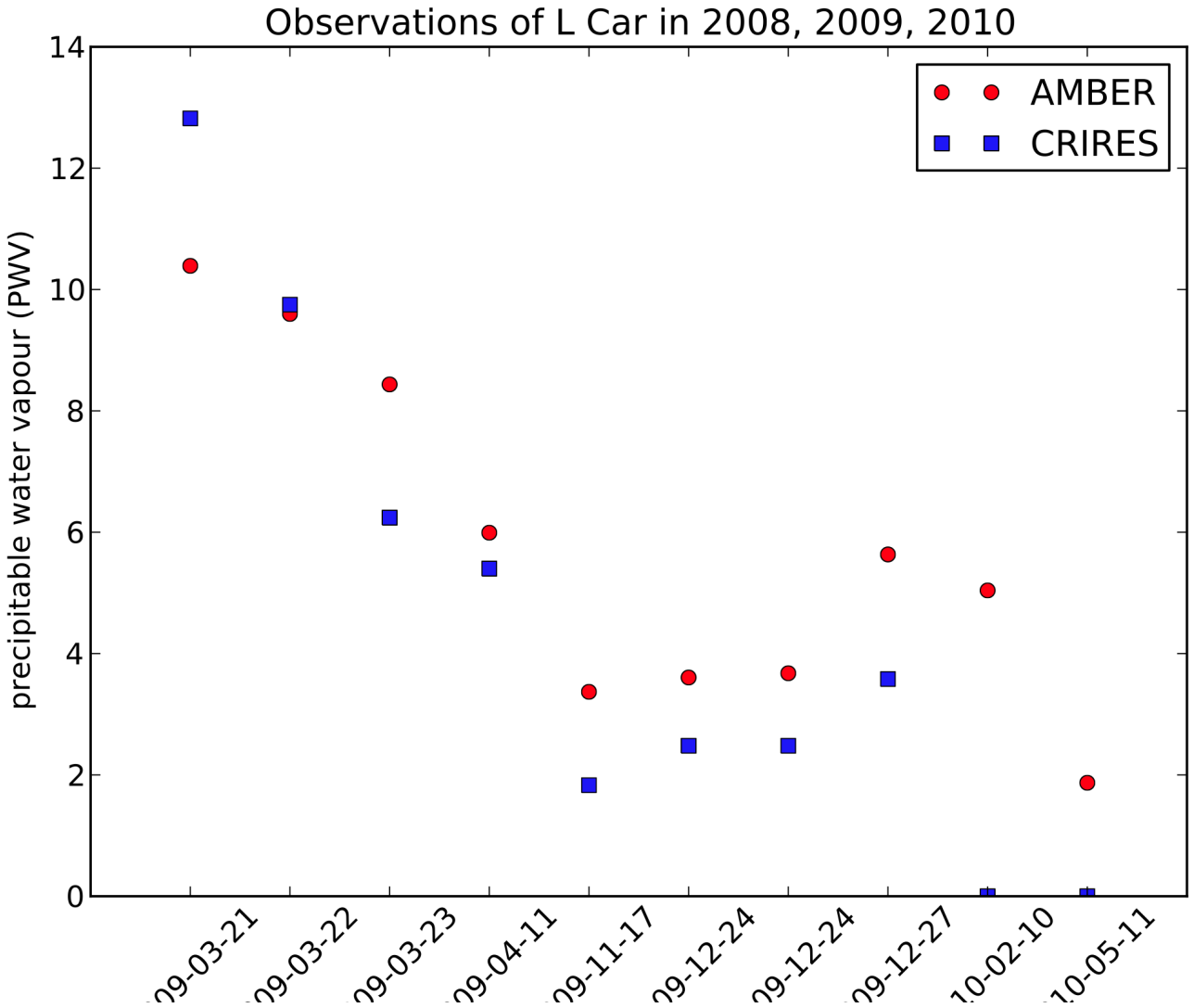
No drift during the night: Highly stable

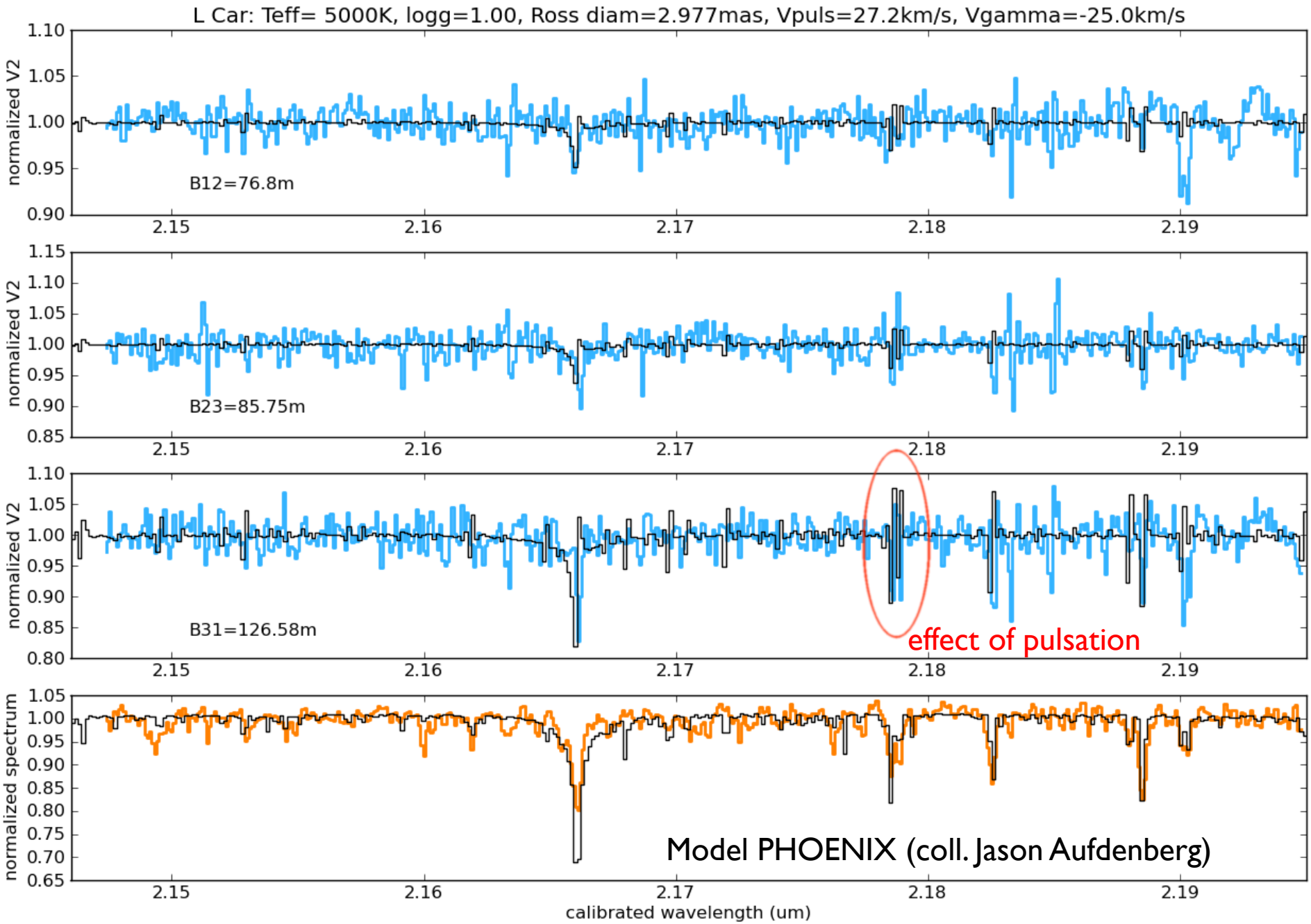
Precipitable Water Vapor



Measuring the amount of precipitable water vapour with VISIR (A. Smette 2007 ESO) using HITRANS

Note:

- PWV will be used in the future at Paranal as a constraint
- Do we want AMBER to use it? *needs to be studied in details*

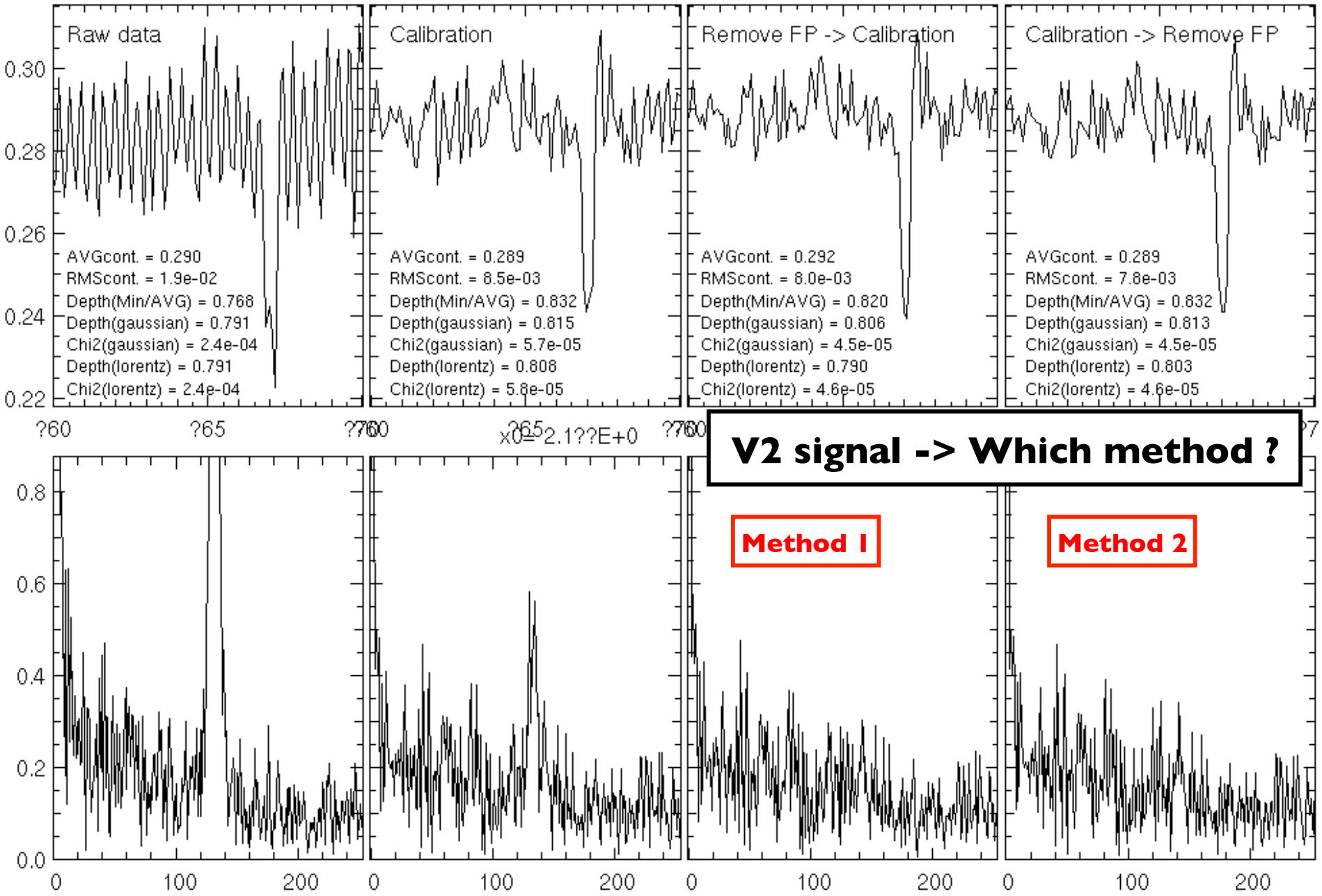

L Car: Teff= 5000K, logg=1.00, Ross diam=2.977mas, Vpuls=27.2km/s, Vgamma=-25.0km/s
normalized V2
B12=76.8m
B23=85.75m
B31=126.58m
effect of pulsation
normalized spectrum
Model PHOENIX (coll. Jason Aufdenberg)
calibrated wavelength (um)

Conclusion

- Motivation: For L Car in HR, effect of pulsation at the limit of AMBER-HR:
    - Radial velocity ~ 10 km/s
    - Differential visibility ~ 1%
- AMBER is a spectrograph. Possibility to extract normalized spectrum contemporaneous to V2 data (important for varying objects!)
- We developed an automated tool for proper spectral calibration, spectrum extraction & continuum correction:
    - Written in *Python*
    - Additional BINTABLE in OIFITS

End

How to remove ripples ?

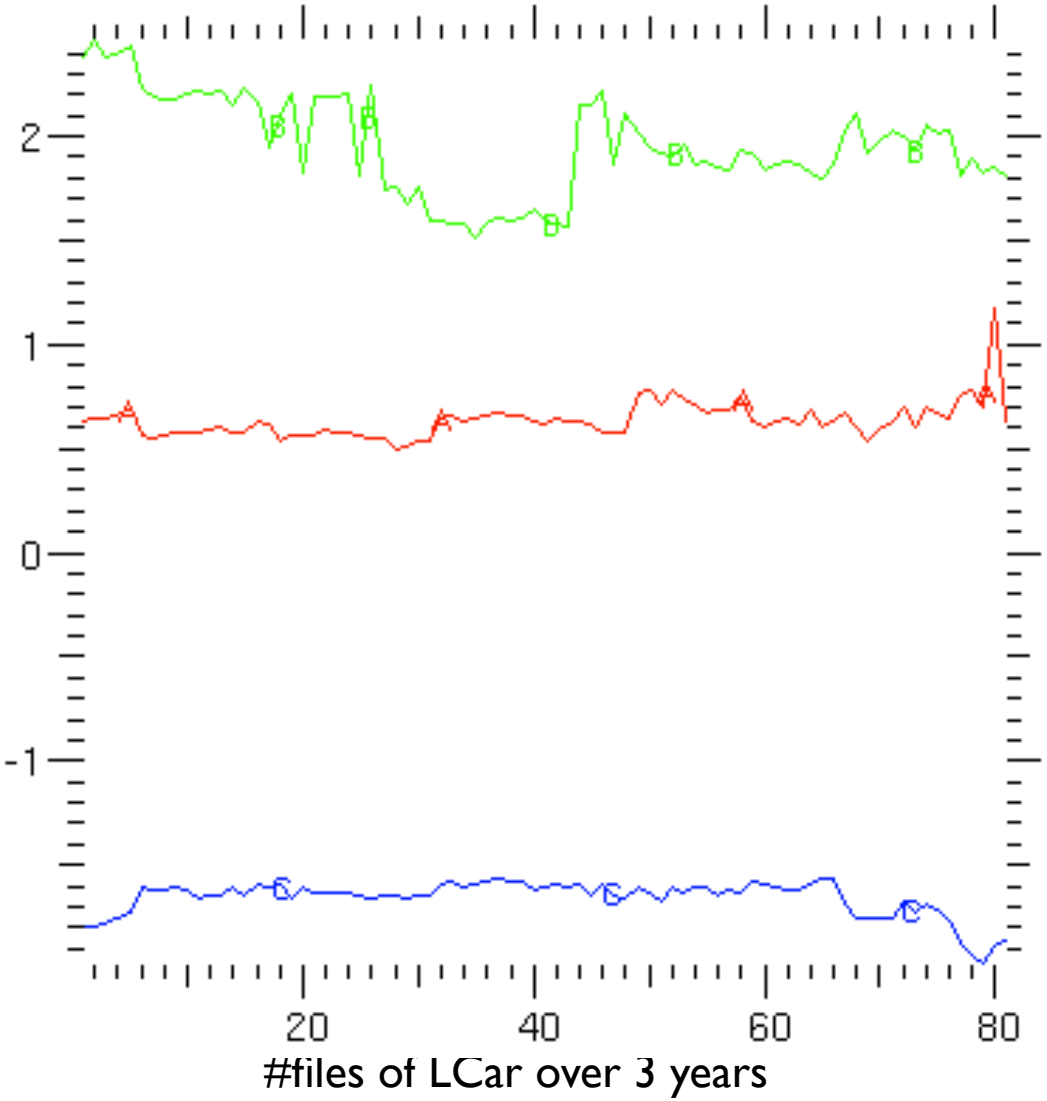


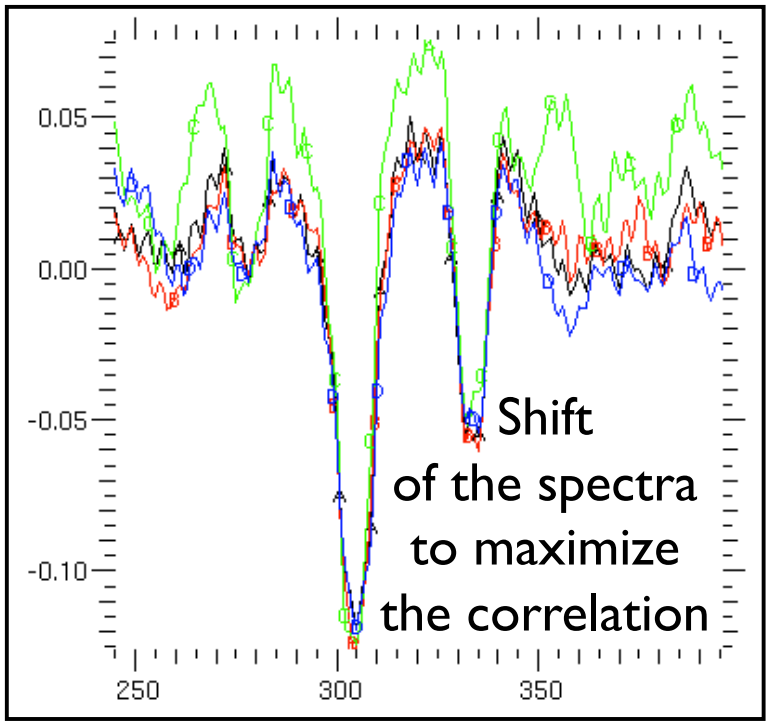
Removing ripples

- Old Polarizer (MJD<55xxx) produced Fabry Pero fringing. Hard to remove and calibrate.
- Algorithm to remove ripple:
  - model y[a,b,c,d,e] = a + b*sin(c*lambda^d + e) (d ~ 3.2 empiric)
  - do a 'ripple transform' with the base e=[0, pi/2]
  - get the maximum power, fit to the data, remove the ripples
  - repeat until ther is no more power in 'ripple transform'
- Advantages compared to the pass-band spatial filtering:
  - do not to affect data
  - relatively stable on a set of data, but can drift during the night
  - take into account the static chromaticity of hte polariser
  - no ripples, no changes

Spectral reshifting (SpecCalShift)

Relative position of the photometric beams / the interferometric beam



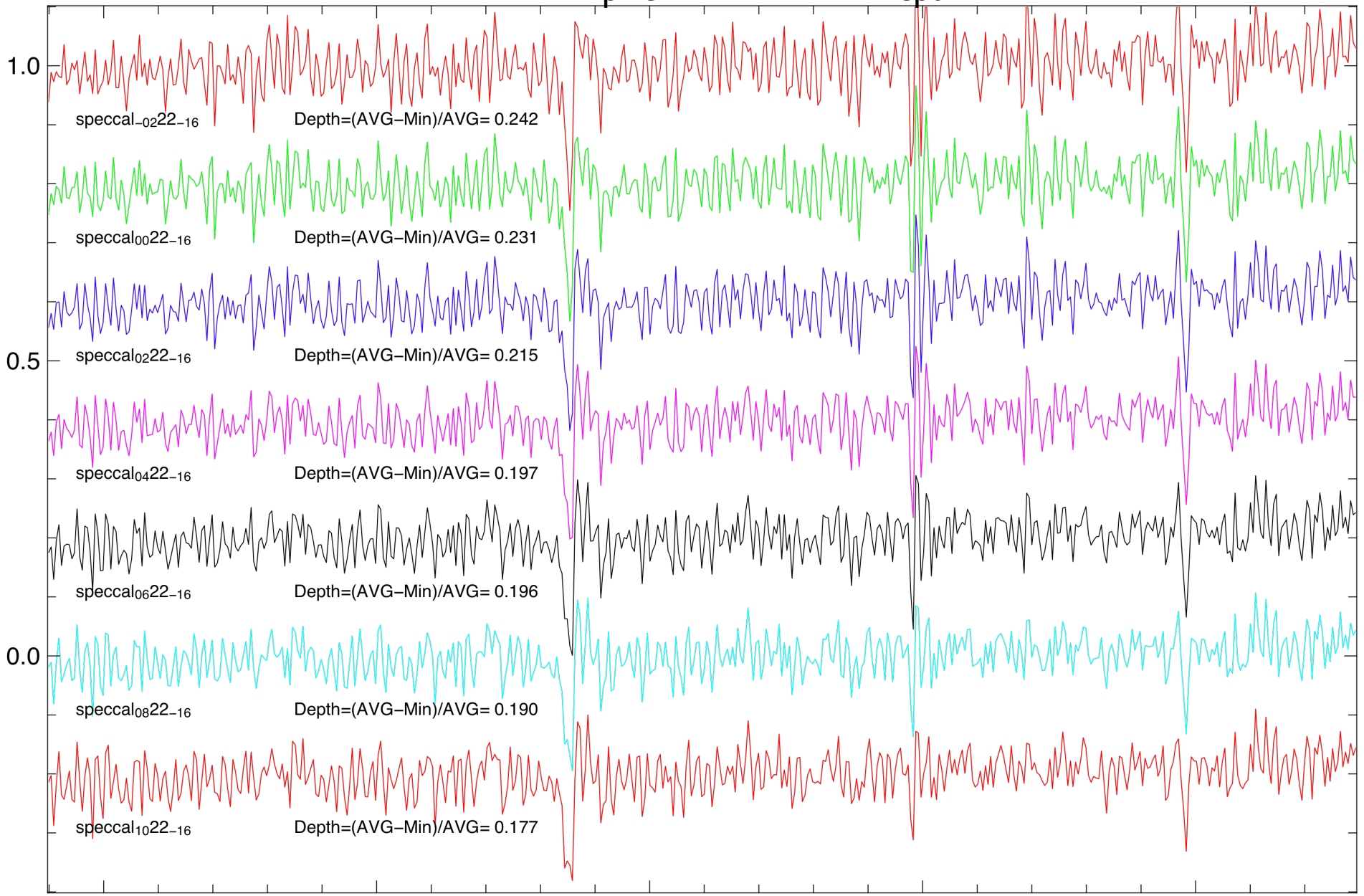


Common offset for all the data :

	MEDIAN	AVERAGE	RMS
1	0.628	0.636	0.088
2	1.956	0.235	0.236
-2	-1.657	0.085	0.085

Comparison V2 vs SpecCalShift Interferometric <–> photometric channels (B31)

Shift of Channel #1 (Δ_{pixel}=1.2 => Δ_{Depth}~25% on B31)

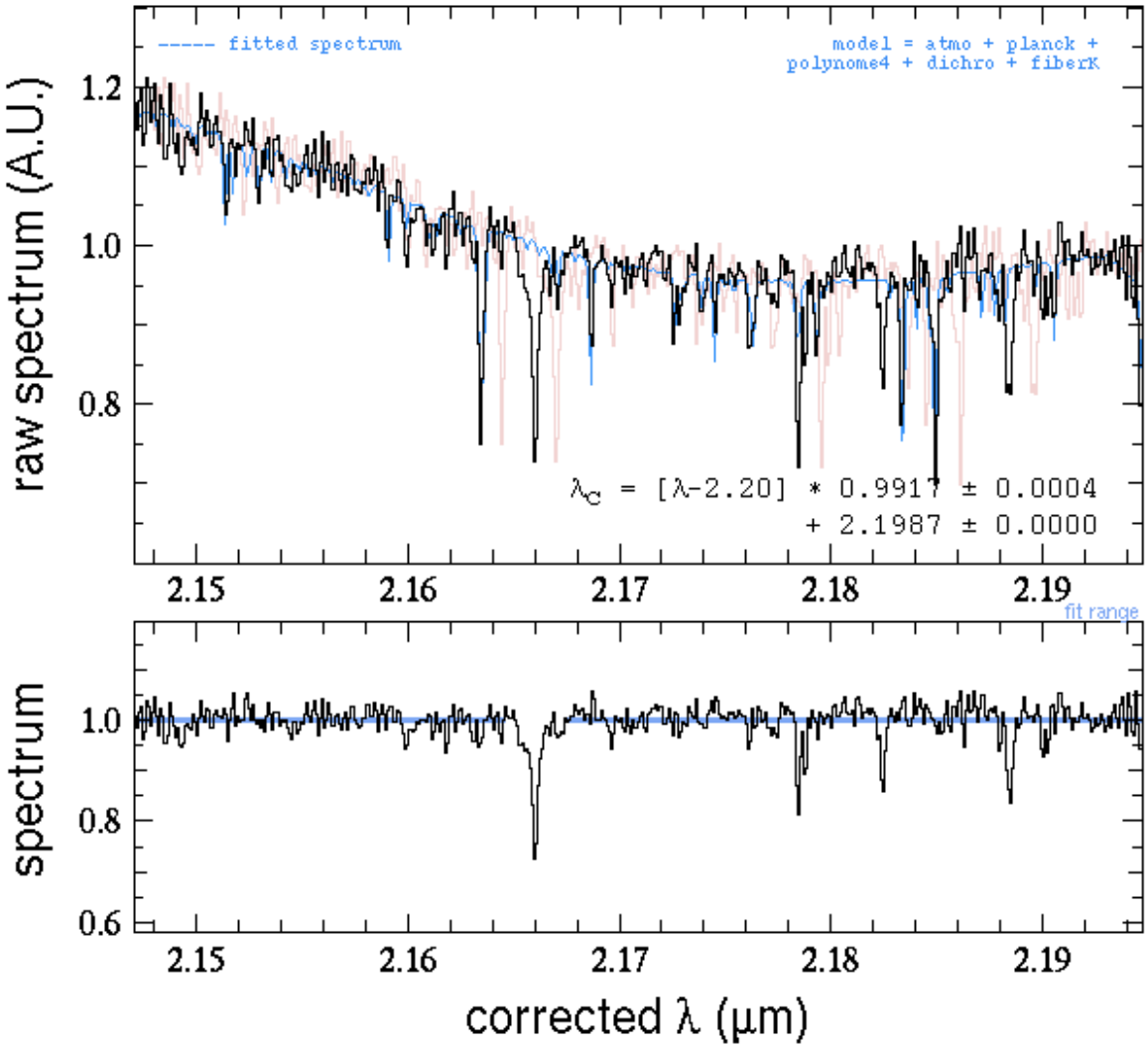


Resume: SpecCalShift

- Spectral shifting => Sensitive! => Error of the line depth
- Using rounded values => Error ~ 1 to 7%
- Shift of 0.2 pixels of one channel => Error ~ 1%
- Shift of 0.02 pixels of one channel => Negligeable
- Infact, the coefficients are almost constant, excepted an unstability over the year of the 2nd one (+/-0.5pixels) compared to the 1st and 3rd ones (+/-0.1pixels)
- Using default AMDLIB3 values => uncertain in HR mode!
- Using specific values for each dataset by maximizing the correlation => seems more accurate!
- ? Maximize the line depth or minimize the lines assymetry on&between the 3 baselines ? ? Gaussian fit on the V2 lines ?

Spectral calibration

=> Routine qui corrige du continuum, fit les raies du ciel
et calibre la dispersion spectrale sur L Car.



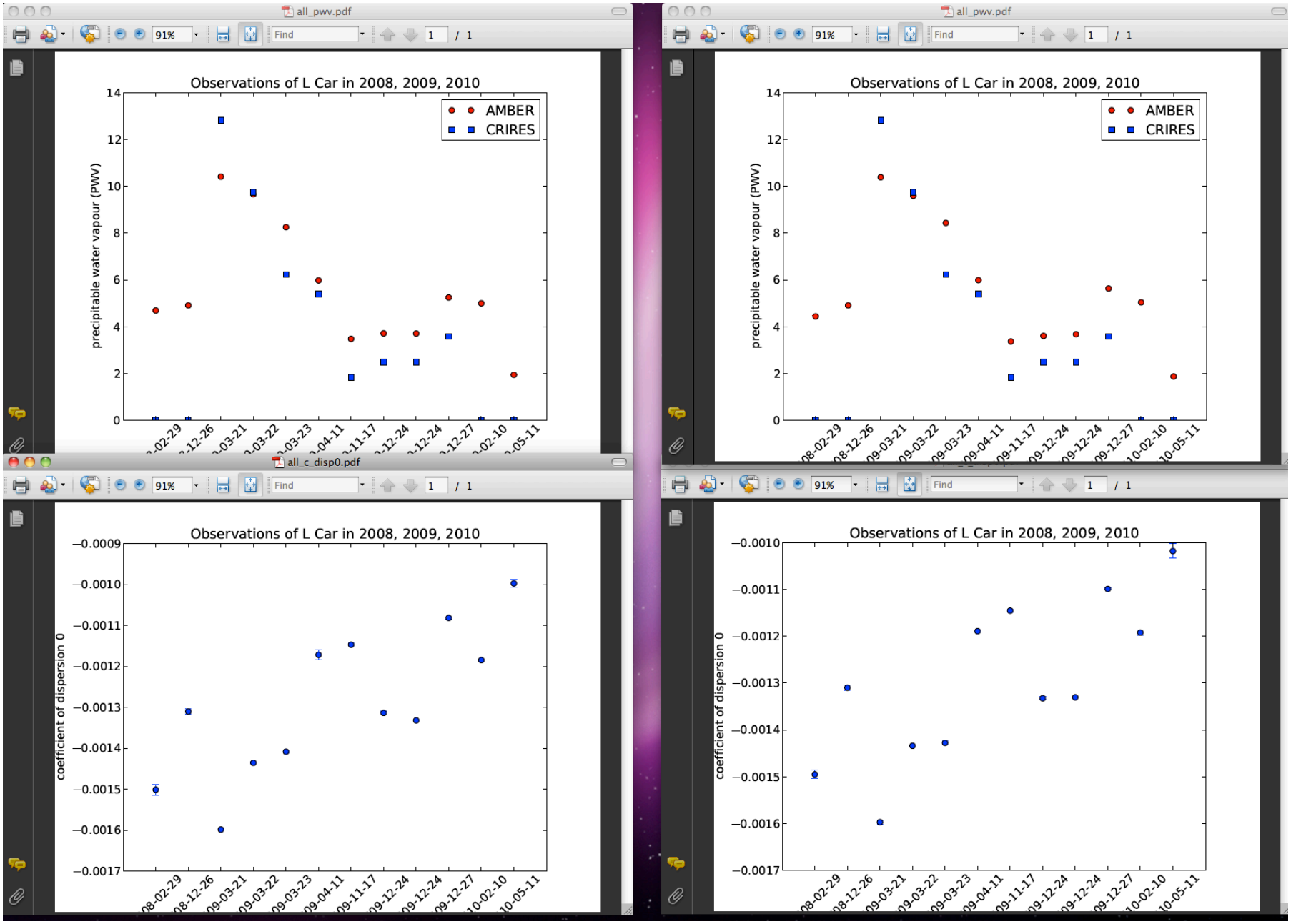
Spectre de-ripplé,
avec la calibration spectrale
et le modèle de transmission/
absorbtion atmosphérique

Spectre normalisé,
avec la belle raie Br_gamma
à 2.166um.

divers

- AMDLIB2 => AMDLIB3
  - same same with L Car
  - spec cal shift ?
  - remove the V2 negative values ?
  - Request: Bootstrapping for error bars

Comparison AMDLIB2 – AMDLIB3



Precipitable Water Vapor (2)