



**BAA**  
Variable Star Section  
British Astronomical Association

**Spectroscopy Workshop**  
**N.L.O. 10<sup>th</sup> October 2015**

**Download from dropbox at <http://tinyurl.com/NLO-workshop>**

# Low Resolution Slit Spectroscopy

Robin Leadbeater

[www.threehillsobservatory.co.uk](http://www.threehillsobservatory.co.uk)

# The slit spectrograph

## Advantages

Collimating the beam at the grating eliminates aberrations at higher dispersion, allowing potentially much higher resolutions

Fixed sampled width of target means extended objects can be measured and the resolution is constant and controlled

Excludes sky background improving SNR and eliminating interference

Provides a fixed reference point for wavelength calibration

Diffuse lamps can be used as calibration sources

Flat correction simpler (flats will also remove small scale instrument sensitivity variations)

# The slit spectrograph

## Disadvantages

Increased cost and complexity over a simple non-objective slitless grating setup

Need to acquire, focus and guide the star on the slit (key to success and not trivial)

Proportion of light through slit not controlled, preventing absolute flux measurement

# Transmission grating slit spectrograph

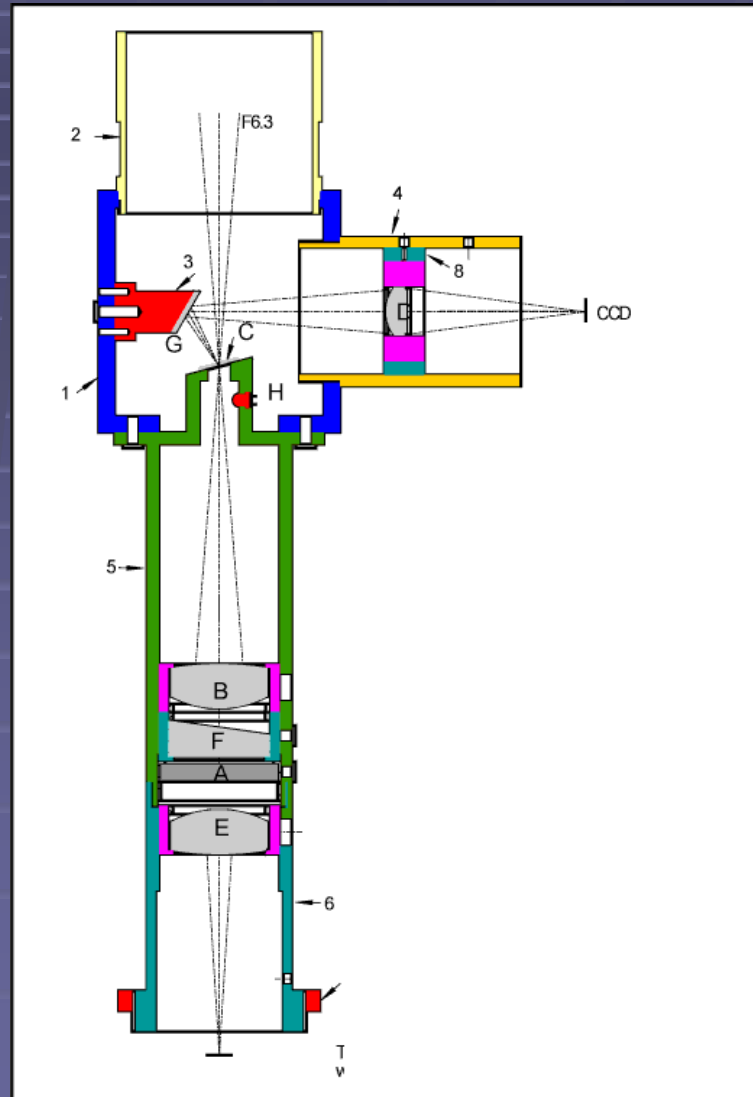
Open University TRAGOS (Vadim Burwitz 2004)

Mirror slit guider

Collimator lens

Grism

Camera lens

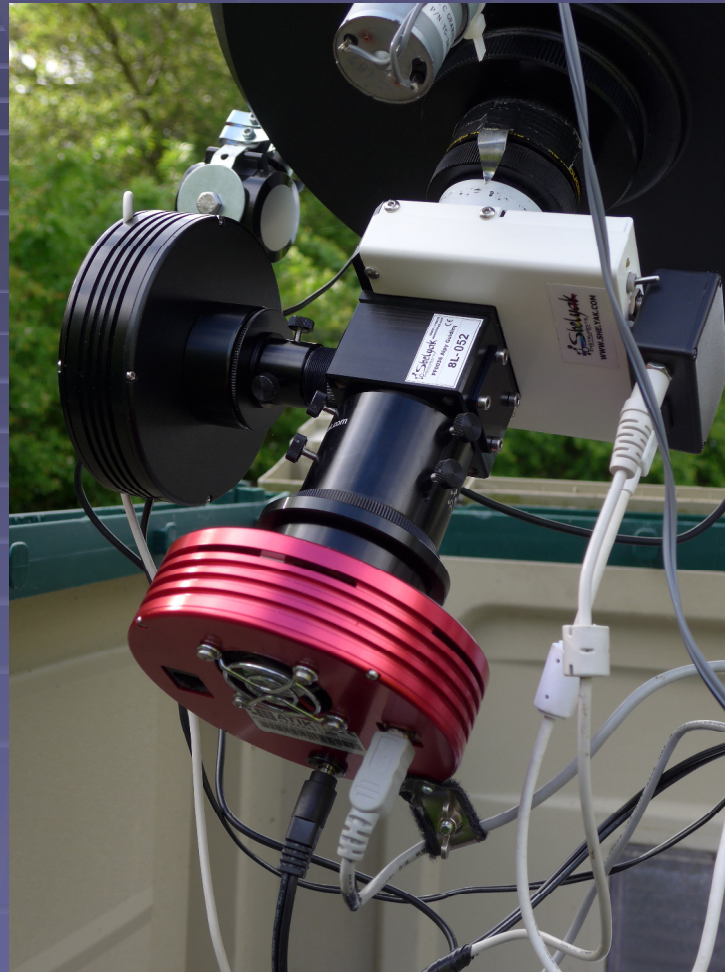


# ALPY 600 at Three Hills Observatory

Celestron C11

Guider camera

Imaging camera



.63 focal reducer

Calibration module

Guider module

ALPY core module

Measuring the spectra of MILES stars of various spectral types  
using an ALPY 600 2013-08-02

The Targets and observation details

star	spec type	Vmag	time	az	alt	air mass	exposure
HD214994	A1v	4.8	22:05	93	40	1.6	20x10s
HD217014	G5v	5.4	22:20	100	34	1.8	10x10s
HD218031	K0iii	4.6	22:39	72	55	1.2	13x10s
			refocused				
HD218031	K0iii	4.6	22:43	73	55	1.2	10x10s
HD183324	A0v	5.8	22:56	179	38	1.6	20x 5s

(Intermittent thin cloud)

# raw reference star spectrum HD214994 A0v

ISIS - V5.5.1

1. Image | 2. General | 3. Calibration | 4. Go | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Image name : HD214994\_1

Display [Left Arrow] [Right Arrow] Next

Save

Header

Graticule

FWHM

Statistic

Tilt

Slant

Line PSF

X : 8  
Y : 473  
I : 288

Displayed image : c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy\_miles\_isis\_reduction\hd214994\hd214994 Exposure : 10.0 s


Hi : [Slider] 10200 20000

Low : [Slider] 0 0

# Neon / Argon lamp spectrum

ISIS - V5.5.1

1. Image | 2. General | 3. Calibration | 4. Go | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Image name : lamp    Display    <    >    Next        Save

Header

Graticule

FWHM

Statistic

Tilt

Slant

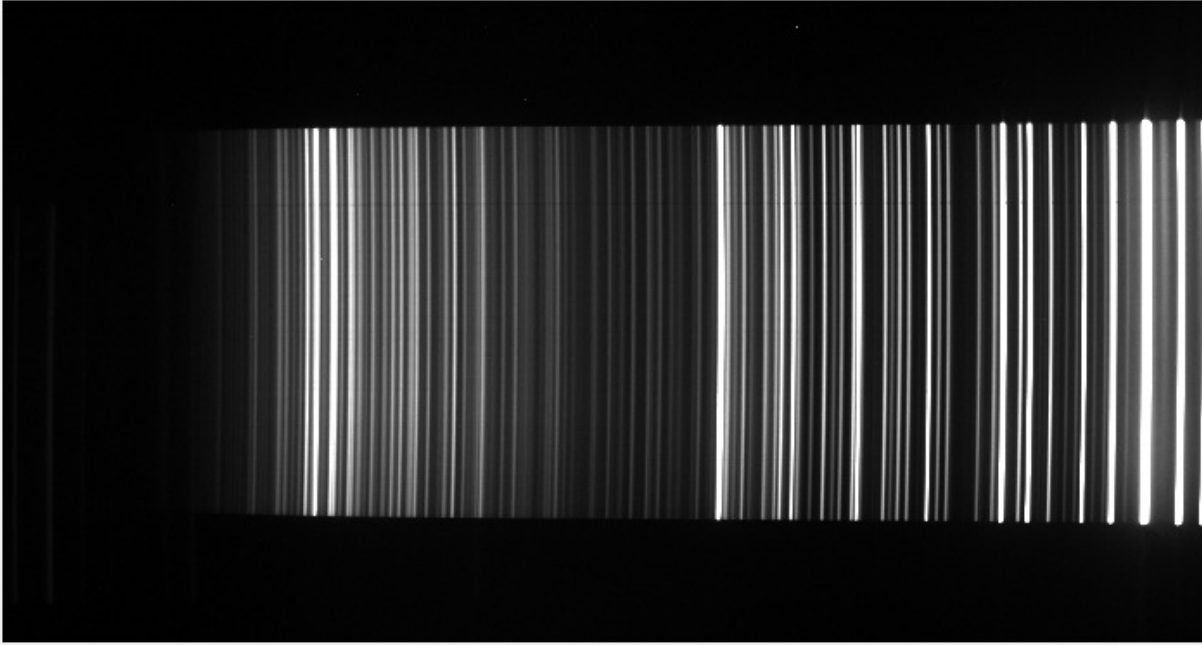
Line PSF

X : 641  
Y : 104  
I : 332

Displayed image : c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy\_miles\_isis\_reduction\calib\_frames\lamp.fit Exposure : 5.0 s

Hi :     Domain

Low :    





# Tungsten Halogen lamp flat

The screenshot displays the ISIS V5.5.1 software interface. At the top, a menu bar includes options: 1. Image, 2. General, 3. Calibration, 4. Go, 5. Profile, 6. Gnuplot, Masters, Tools, Misc, Instruments, and Settings. Below the menu bar, the 'Image name' field contains 'flat\_master'. To its right are 'Display', navigation arrows, and a 'Next' button. A toolbar with a folder icon is also present. The central area shows a grayscale image of a Tungsten Halogen lamp flat, which appears as a dark horizontal band across a lighter background. To the right of the image is a vertical toolbar with buttons for 'Save', 'Header', 'Graticule' (unchecked), 'FWHM', 'Statistic', 'Tilt', 'Slant', and 'Line PSF'. Below these buttons, a status box displays 'X : 21', 'Y : 433', and 'I : 155'. At the bottom, a status bar shows the file path: 'Displayed image : c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy\_miles\_isis\_reduction\calib\_frames\flat\_ma Exposure : 1.0 s'. Below this are sliders for 'Hi' (set to 25800) and 'Low' (set to 0), and a 'Domain' section with input fields for '200000' and '0'.

# Prepare master flat and offset images

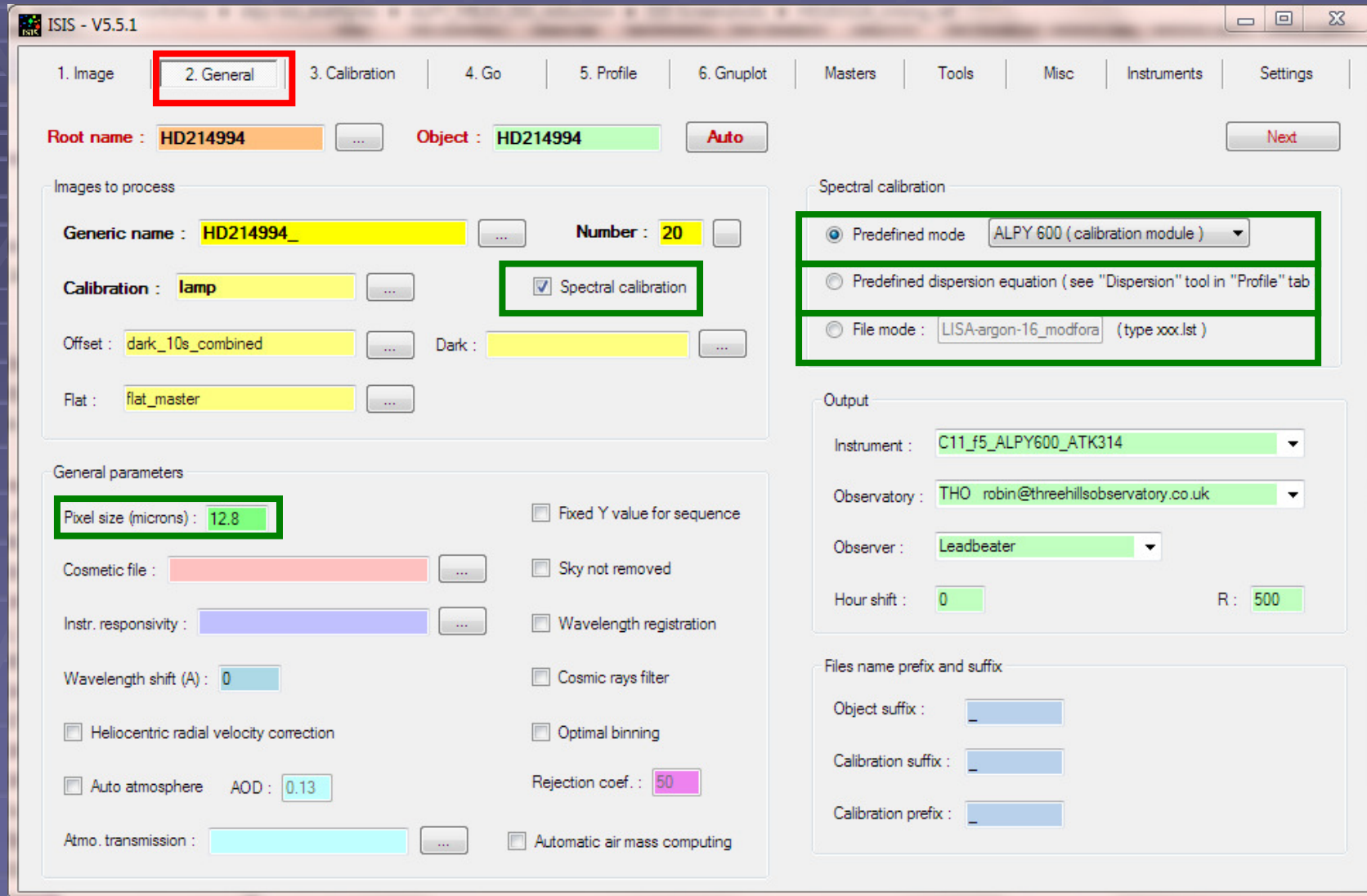
The screenshot shows the ISIS V5.5.1 software interface with the 'Masters' tab selected. The interface is divided into several sections for different calibration tasks:

- Compute an offset image:** Generic name: dark\_10s\_, Image number: 23, Result: dark\_5s\_combined. A green box highlights this section.
- Compute a dark image:** Fields for Generic name, Offset image, Dark coef. (1), and Image number (18). A 'Go' button is present.
- Compute a flat-field image:** Generic name: flat\_, Dark image: dark\_1s\_combined, Offset image: synth\_offset. Includes a checkbox for 'Vertical gain correction' and fields for 'Coordinate Ymax of validity zone' and 'Coordinate Ymin of validity zone' (both set to 0). Image number: 62, Result: flat\_master. A green box highlights this section.
- Compute a cosmetic file:** Fields for Dark image, Threshold (500), and Cosmetic file. A 'Go' button is present.
- Compute an uniform image (synthetic flat-field):** Name: synth\_offset, Constant: 0. A 'Go' button is present.
- Compute a mean image:** Generic name: calib\_, Image number: 26, Result: lamp. A green box highlights this section.
- Compute a PRNU map:** Fields for Generic name, Dark image, Offset image, Image number (1), and Result. A 'Go' button is present.

A terminal window at the bottom left shows the following commands and output:

```
\calib_frames\calib_24.fit
Load image c:\users\user\desktop\spectroscopy
workshop\alpy-isis_examples\alpy_miles_isis_reduction
\calib_frames\calib_25.fit
Load image c:\users\user\desktop\spectroscopy
workshop\alpy-isis_examples\alpy_miles_isis_reduction
\calib_frames\calib_26.fit
Processing...
Save image c:\users\user\desktop\spectroscopy
workshop\alpy-isis_examples\alpy_miles_isis_reduction
\calib_frames\lamp.fit
Ok.
```

# Wavelength calibration options



For this example use predefined mode

## Correct spectrum tilt and select binning and sky background zones

ISIS - V5.5.1

1. Image | 2. General | **3. Calibration** | 4. Go | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Image to process : HD214994\_1

Calibration image : lamp

Tilt angle : -0.2 Smile Y : 137 Radius : 5937 Vertical coordinate : 288  Auto

X coordinate of line at wavelength 5852.49 A = 416 (pixels)

Displayed image : c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy\_2013-08-02T22:05:10\_id214994\hd214994\_1.fit sure : 10.0 s

Seuil haut :   Domain

Seuil bas :

## Correct for smile/slant of lines and enter location of reference line

ISIS - V5.5.1

1. Image | 2. General | **3. Calibration** | 4. Go | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Image to process : HD214994\_1 [Display] [Next]

**Calibration image : lamp [Display]**

Tilt angle : -0.2 | **Smile Y : 137** | Radius : 5937 | Vertical coordinate : 288 [Auto] [Binning zone adjustment]

X coordinate of line at wavelength 5852.49 | **A = 416 (pixels)** [Calibration assistant] [Response assistant]

Displayed image : c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy 2014-03-14T00:32:29 id214994\lamp.fit Exposure : 15.0 s

Seuil haut : 6660 | 20000 | Domain

Seuil bas : 0 | 0

# Run the spectrum processing from raw images to wavelength calibrated profile

The screenshot shows the ISIS V5.5.1 software interface. The '4. Go' tab is selected and highlighted with a red box. The 'Go for process' section contains a 'Go' button highlighted with a green box. The 'Display profile' button at the bottom is also highlighted with a green box. A red arrow points to the 'RMS : 0.355586' value in the output text.

1. Image | 2. General | 3. Calibration | **4. Go** | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Object name : HD214994  
Instrument : C11\_f5\_ALPY600\_ATK314  
Observatory : THO robin@threehillsobservatory.co  
Observer : Leadbeater

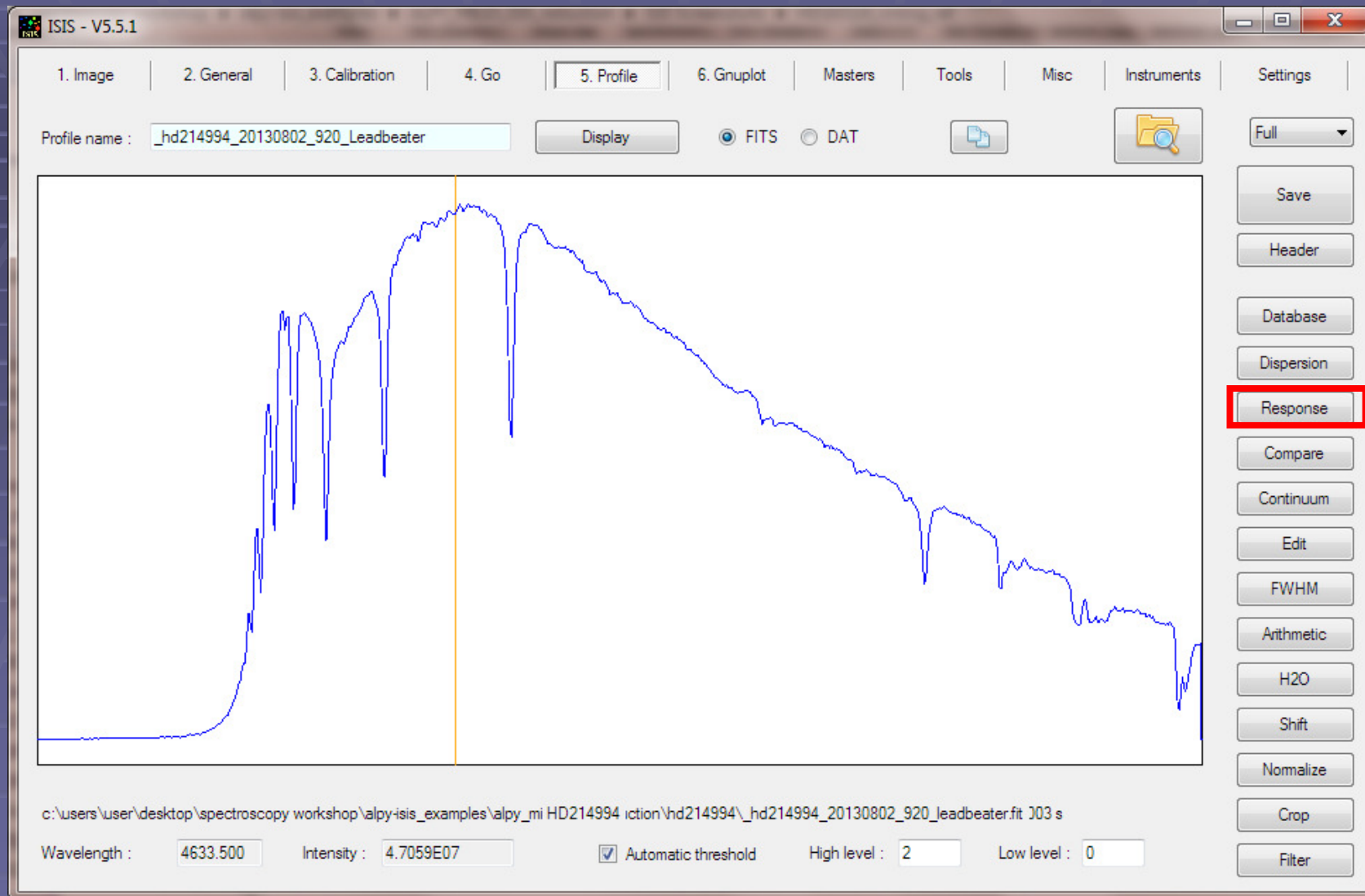
**Go for process**

**Go** Stop

Coefficient a0 : 2916.984  
-----  
RMS : 0.355586 (in angstroms)  
-----  
Wavelength fit deviation  
point #1 x = 147.548 lambda = 3946.154 dlambda = -0.054  
point #2 x = 177.495 lambda = 4158.603 dlambda = -0.013  
point #3 x = 227.058 lambda = 4511.099 dlambda = -0.369  
point #4 x = 231.728 lambda = 4544.335 dlambda = 0.715  
point #5 x = 247.697 lambda = 4657.958 dlambda = -0.058  
point #6 x = 262.707 lambda = 4764.712 dlambda = 0.158  
point #7 x = 290.982 lambda = 4965.575 dlambda = -0.495  
point #8 x = 352.491 lambda = 5400.616 dlambda = -0.056  
point #9 x = 416.988 lambda = 5852.292 dlambda = 0.198  
point #10 x = 476.934 lambda = 6266.365 dlambda = 0.125  
point #11 x = 512.170 lambda = 6506.655 dlambda = -0.125  
point #12 x = 608.070 lambda = 7147.135 dlambda = -0.095  
point #13 x = 644.364 lambda = 7383.910 dlambda = 0.070  
-----  
Coefficient a4 : 8.106786E-10  
Coefficient a3 : -2.406552E-06  
Coefficient a2 : 1.388208E-03  
Coefficient a1 : 6.82011  
Coefficient a0 : 2916.984  
-----  
RMS : 0.355586  
-----  
Warning : The spectral profiles are not normalized.  
-----

Display image **Display profile** Plot

# The wavelength calibrated profile



# Calculate raw instrument response

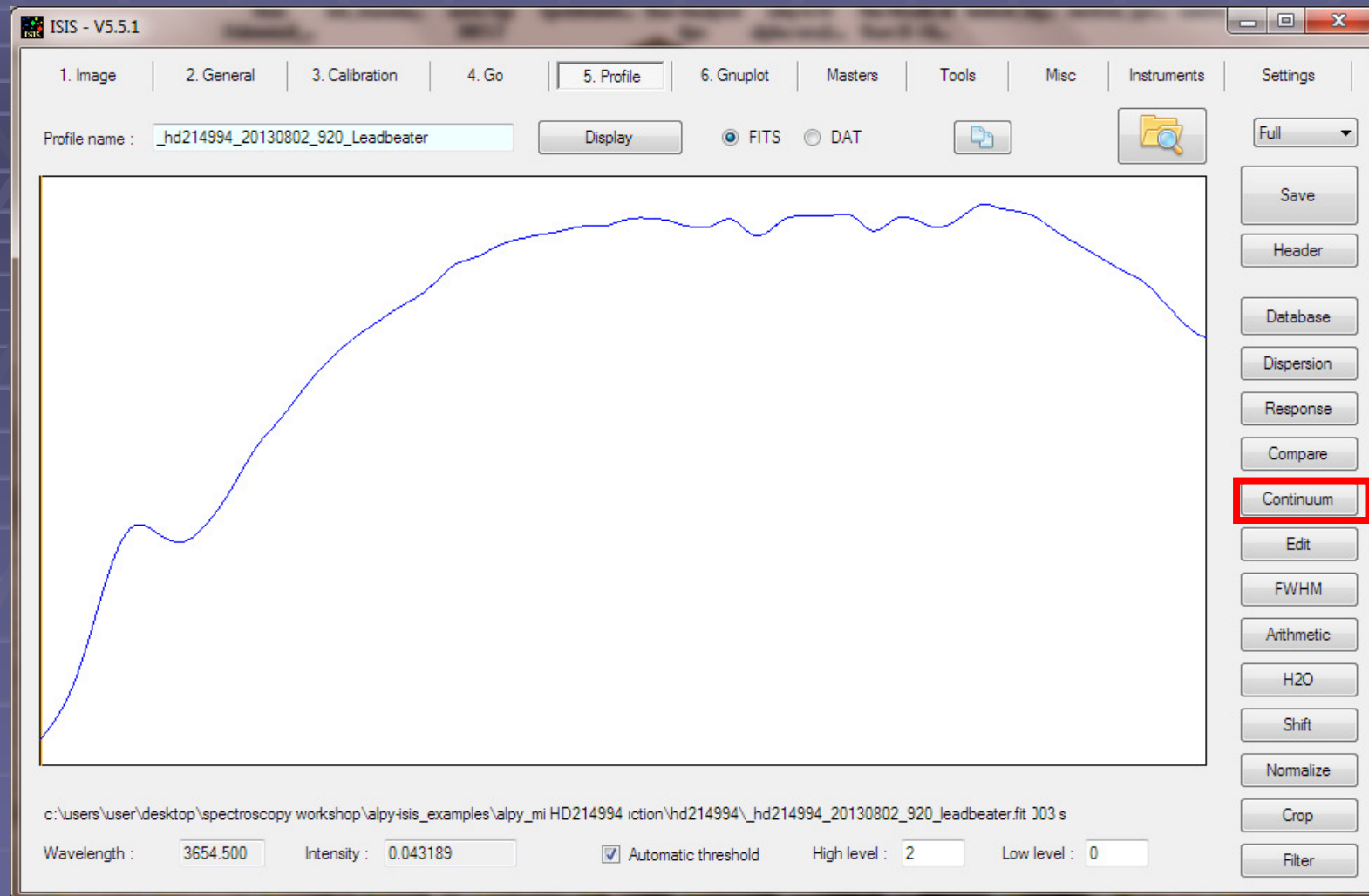
The screenshot displays the ISIS V5.5.1 software interface. The main window shows a spectral plot with three traces: a red trace labeled "MILES", a blue trace labeled "Measured", and a green trace labeled "Raw response". The plot shows intensity versus wavelength, with a vertical yellow line at approximately 3713.000 Å. The "Instrumental response" dialog box is open, showing the following settings:

- Reference spectrum: `c:\program files (x86)\isis\isis_database\m_hd214994.fit`
- Threshold up: 5
- Shift: 0 A
- Threshold down: 0
- Filter: 15

The dialog box includes buttons for "Select a reference spectrum", "OK", "Cancel", and "Response". The main window also features a menu bar (1. Image, 2. General, 3. Calibration, 4. Go, 5. Profile, 6. Gnuplot, Masters, Tools, Misc, Instruments, Settings) and a toolbar on the right with various processing options like "Save", "Header", "Database", "Dispersion", "Close", "Compare", "Continuum", "Edit", "FWHM", "Arithmetic", "H2O", "Shift", "Normalize", "Crop", and "Filter". The status bar at the bottom shows the file path: `c:\users\user\desktop\spectroscopy workshop\alpy-isis_examples\alpy_mi HD214994 iction\hd214994\_hd214994_20130802_920_leadbeater.fit 303 s` and current parameters: Wavelength: 3713.000, Intensity: 0.144789, Automatic threshold checked, High level: 2, Low level: 0.



## Final instrument response curve



Save it!

# Re-run processing including instrument response correction

ISIS - V5.5.1

1. Image | 2. General | 3. Calibration | 4. Go | 5. Profile | 6. Gnuplot | Masters | Tools | Misc | Instruments | Settings

Root name : HD214994 ... Object : HD214994 Auto Next

Images to process

Generic name : HD214994\_ ... Number : 20

Calibration : lamp ...  Spectral calibration

Offset : dark\_10s\_combined ... Dark : ...

Flat : flat\_master ...

Spectral calibration

Predefined mode ALPY 600 ( calibration module )

Predefined dispersion equation ( see "Dispersion" tool in "Profile" tab )

File mode : LISA-argon-16\_modfora ( type xxx.lst )

Output

Instrument : C11\_f5\_ALPY600\_ATK314

Observatory : THO robin@threehillsobservatory.co.uk

Observer : Leadbeater

Hour shift : 0 R : 500

Files name prefix and suffix

Object suffix :

Calibration suffix :

Calibration prefix :

General parameters

Pixel size (microns) : 12.8  Fixed Y value for sequence

Cosmetic file : ...  Sky not removed

Instr. responsivity : \_hd214994\_20130802\_920\_respi ...  Wavelength registration

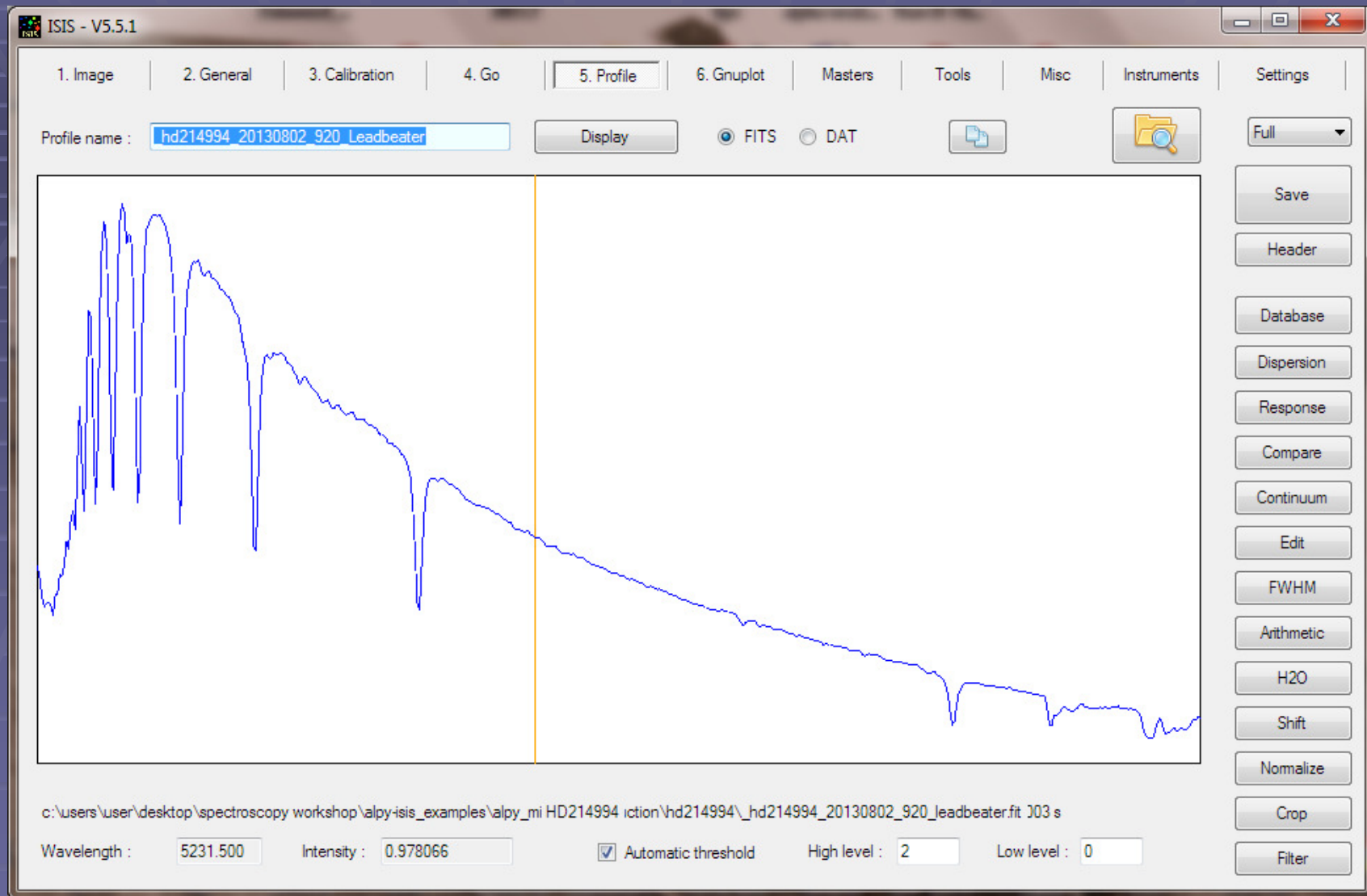
Wavelength shift (A) : 0  Cosmic rays filter

Heliocentric radial velocity correction  Optimal binning

Auto atmosphere AOD : 0.13 Rejection coef. : 50

Atmo. transmission : ...  Automatic air mass computing

## The final result calibrated in wavelength and relative flux



# ISIS enters information about the observation in the FITS header

The screenshot displays the ISIS V5.5.1 software interface. The main window shows a spectral profile plot with a blue line representing intensity versus wavelength. The plot has a vertical orange line at approximately 5496.000 Angstroms. The plot area is titled "Profile name : \_hd214994\_20130802\_920\_Leadbeater". Below the plot, the file path is shown as "c:\users\user\desktop\spectroscopy workshop\alpy-isis\_examples\alpy\_mi HD214994 iction\hd2". At the bottom of the main window, the "Wavelength" is set to 5496.000 and "Intensity" is 0.851680. There is a checked "Automatic" checkbox.

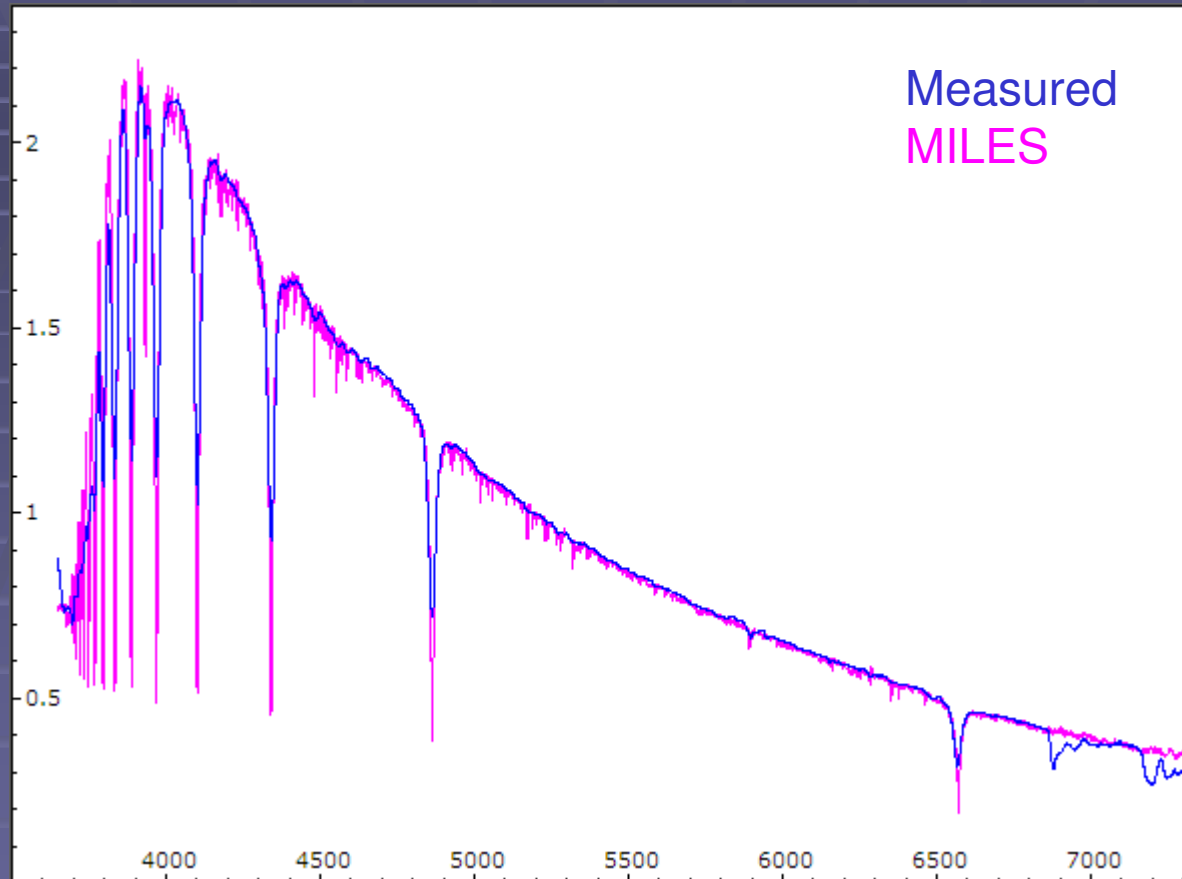
The "FITS header (profile)" dialog box is open, showing the following parameters:

BITPIX :	-32	CRPIX1 :	1
NAXIS :	1	CUNIT1 :	Angstrom
NAXIS1 :	7400	CTYPE1 :	Wavelength
CRVAL1 :	3650.5	OBSERVER :	Leadbeater
CDELTA1 :	0.5	BSS_VHEL :	0
OBJNAME :	HD214994	BSS_COSM :	Removed
DATE-OBS :	2013-08-02T22:05:10	BSS_TELL :	None
EXPTIME :	240.003	BSS_NORM :	None
EXPTIME2 :	20 x 10 s	VERSION :	ISIS V5.5.1
BSS_INST :	C11_f5_ALPY600_ATK314	OBJRA :	
BSS_ESRP :		OBJDEC :	
BSS_SRPW :		OBJBMAG :	0
BSS_ITRP :		OBJVMAG :	0
BSS_SITE :	THO robin@threehillsobservat	SPTYPE :	
BSS_ORD :		OBJRV :	0
SPE_RPOW :	470		
GEO_LONG :	-3.241	GEO_LAT :	54.746
GEO_ELEV :	135		
JD-OBS :	2456507.4203	JD-HEL :	0
JD-MID :	2456507.4216		
COMMENT :			
COMMENT :			

The dialog box has a "Close" button at the bottom right.

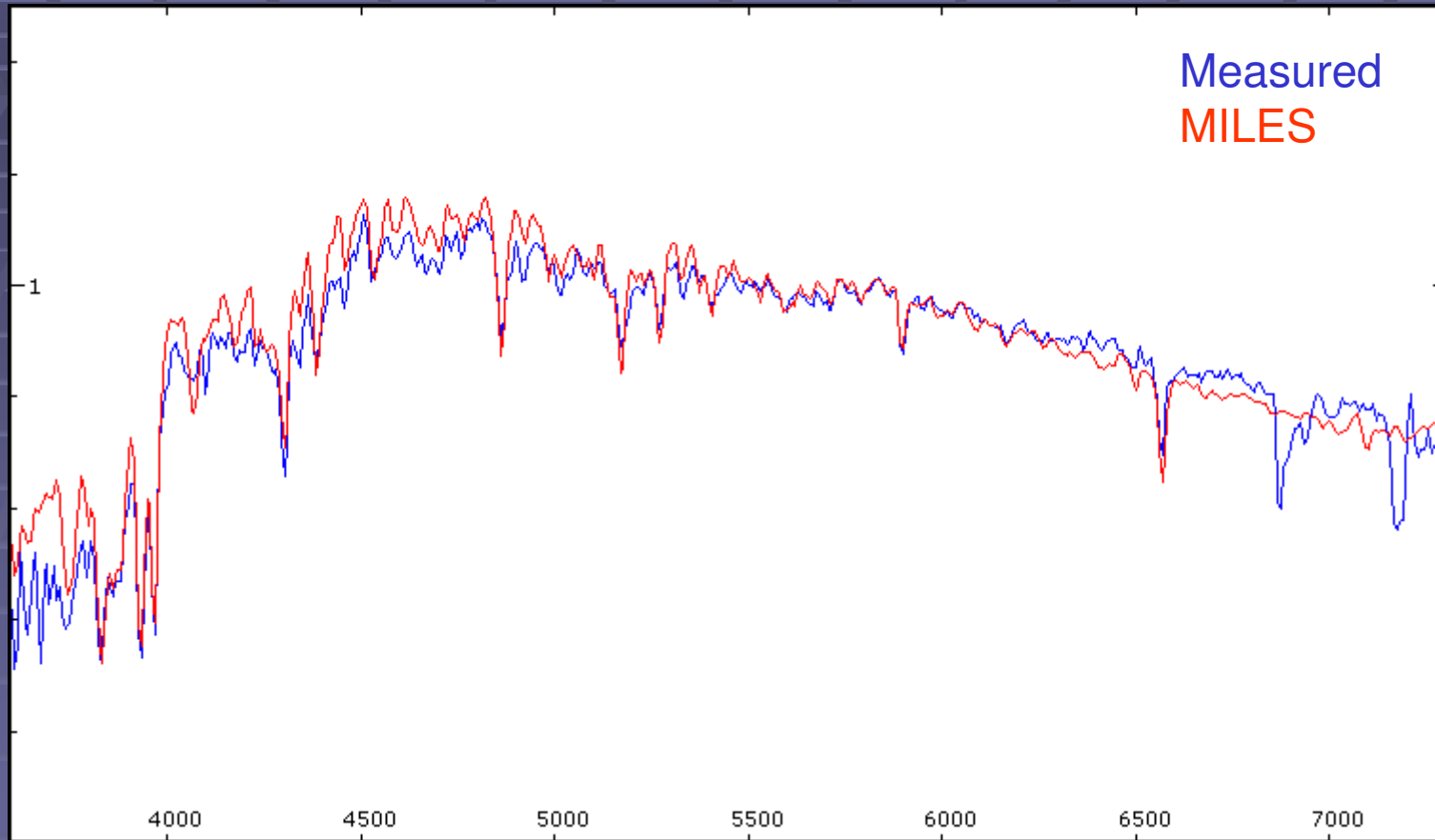
HD214994

A1v



HD217014

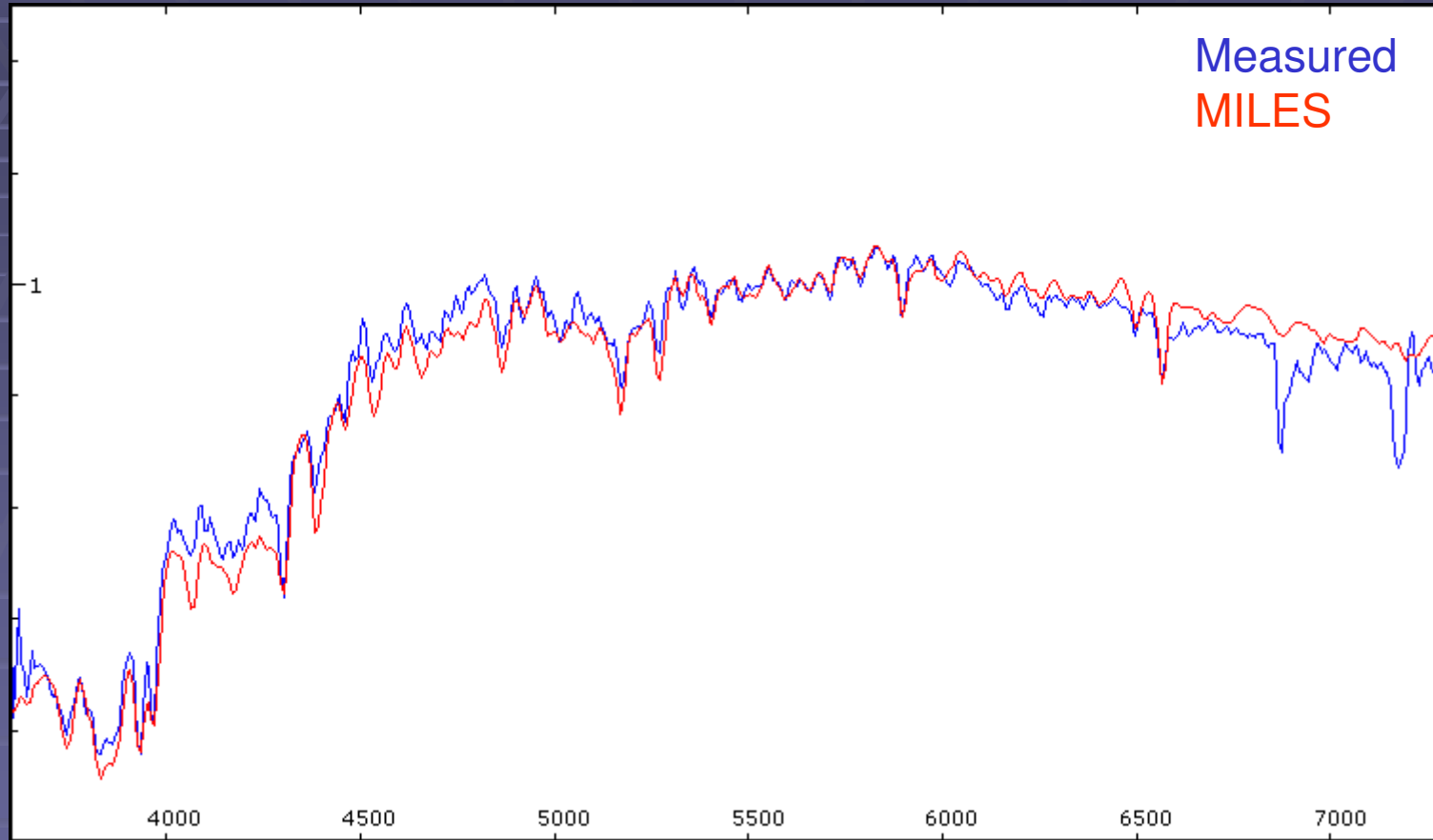
G5v



Note slight error in continuum (high air mass 1.8 v 1.6 for ref star ?)

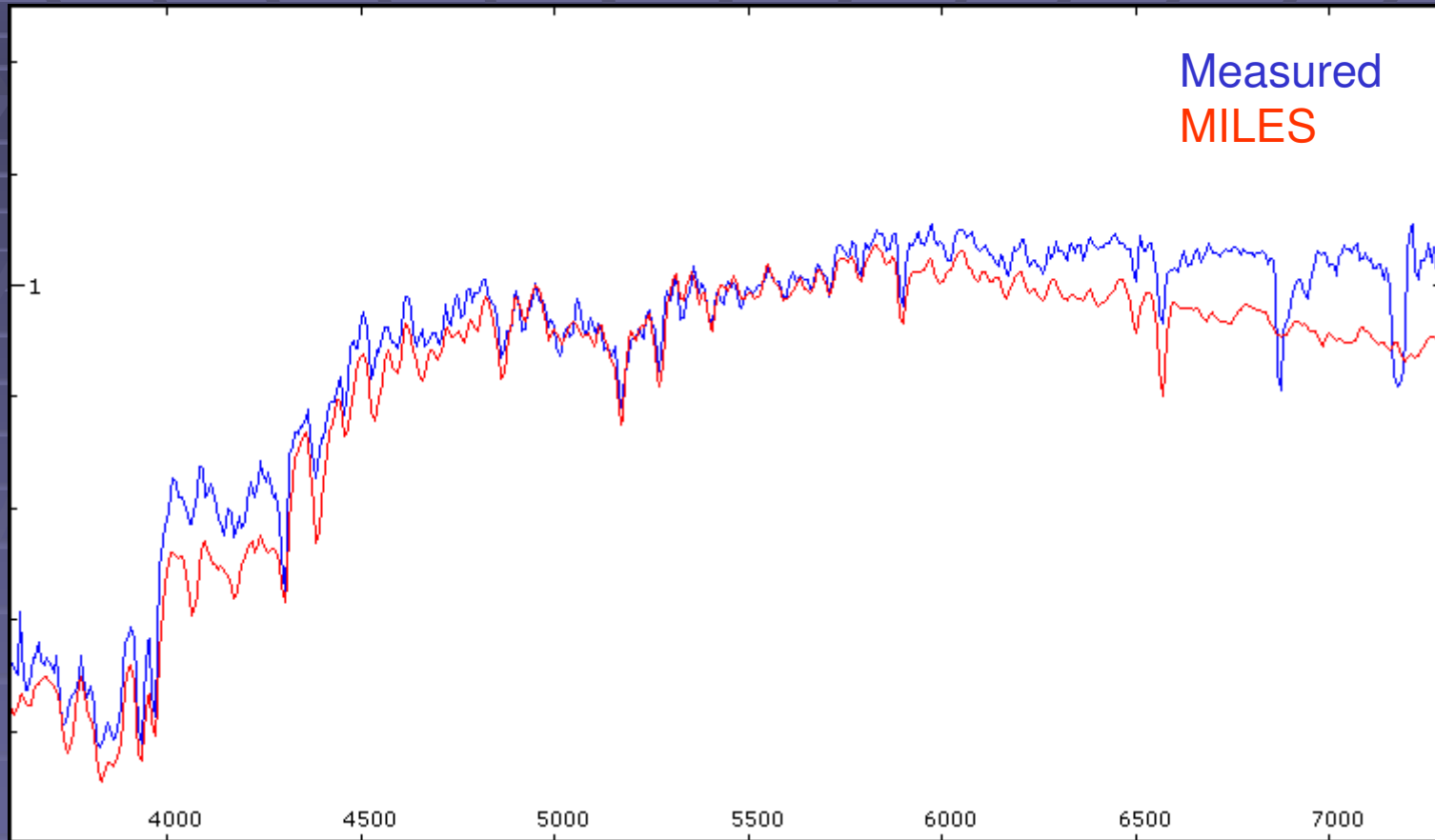
HD218031

K0iii



Small error in continuum (low air mass 1.2 v 1.6 ?)

HD218031      K0iii  
Refocused

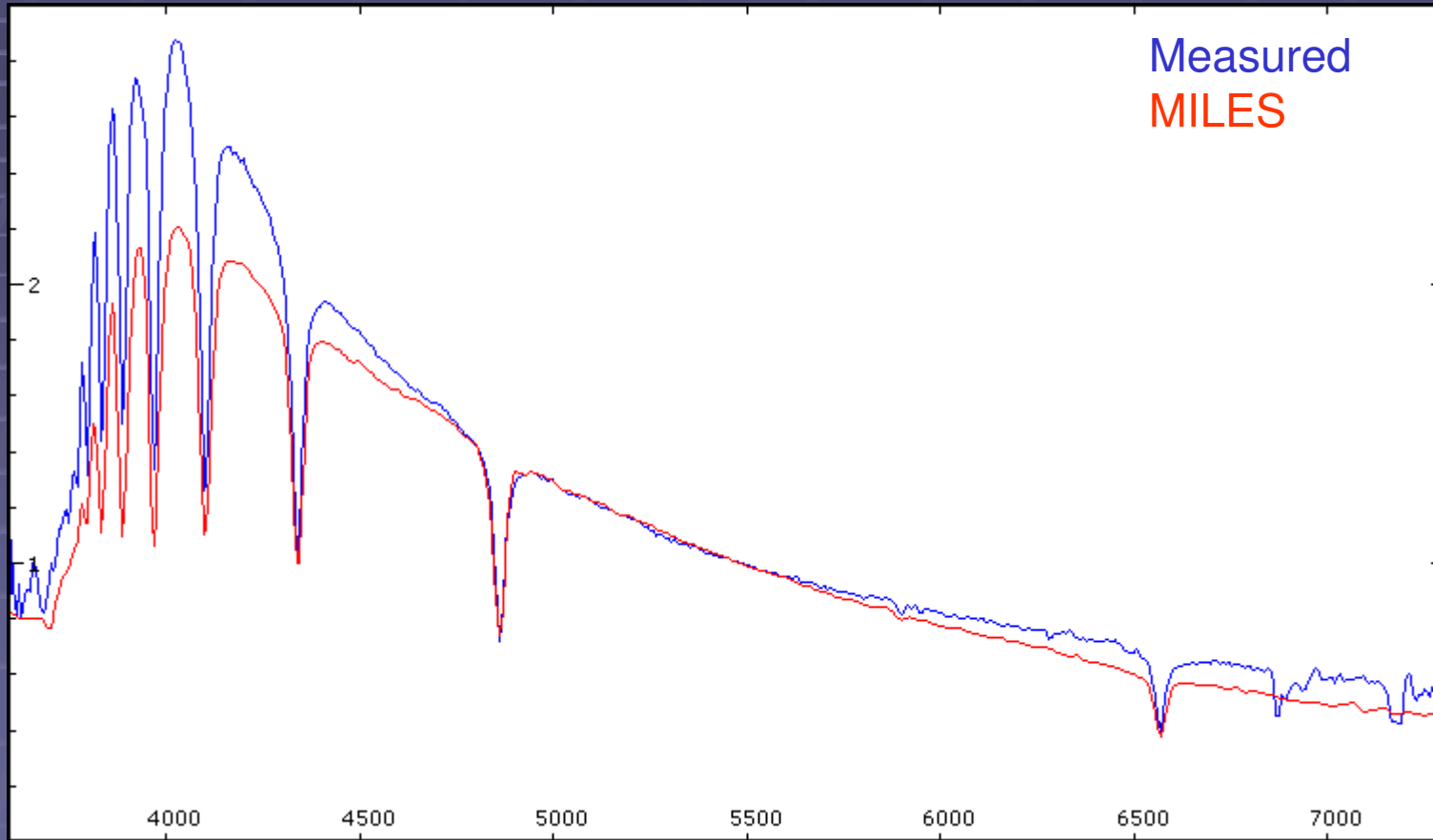


Note the significant change in continuum shape with focus change



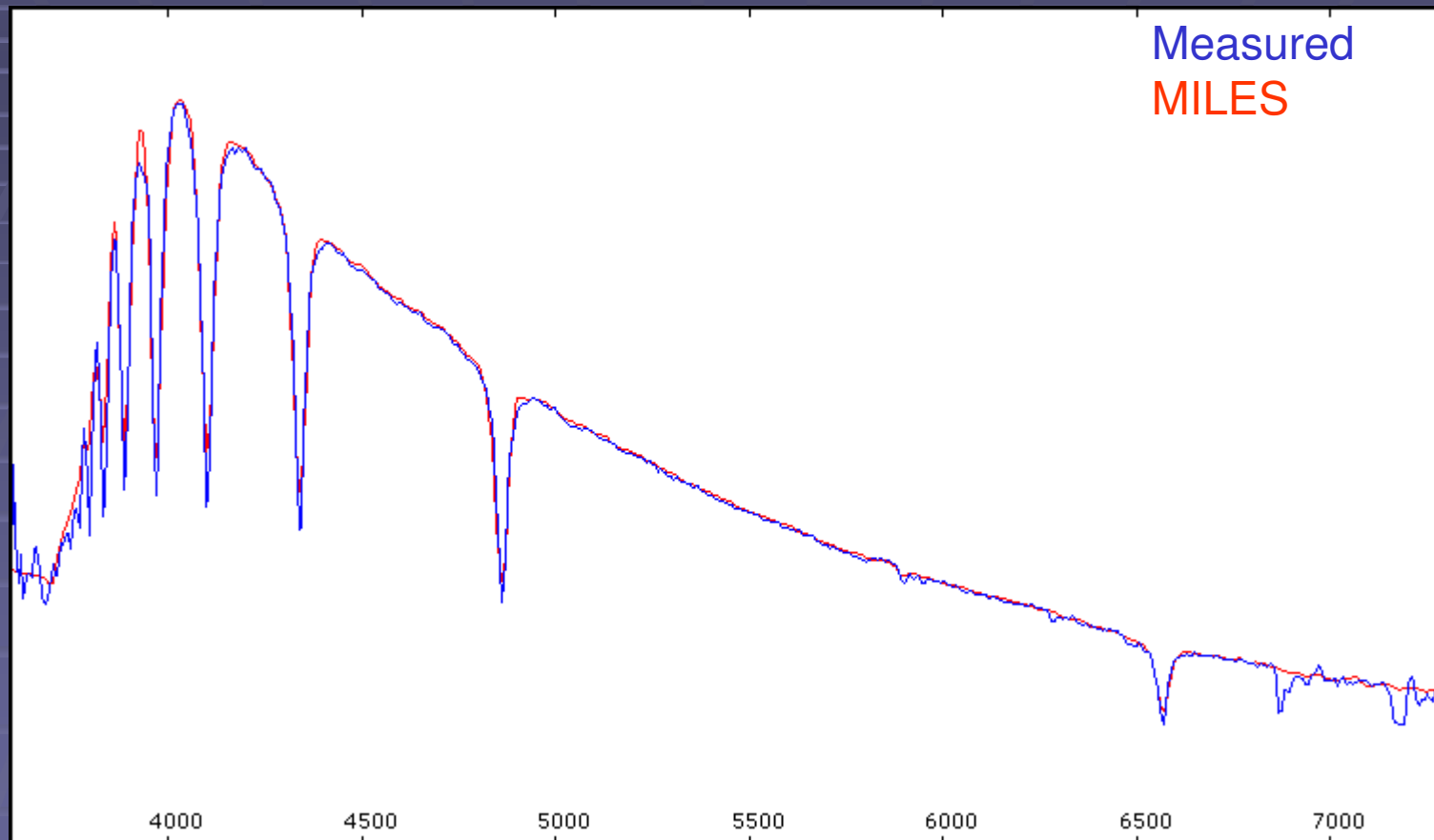
HD183324

A0v

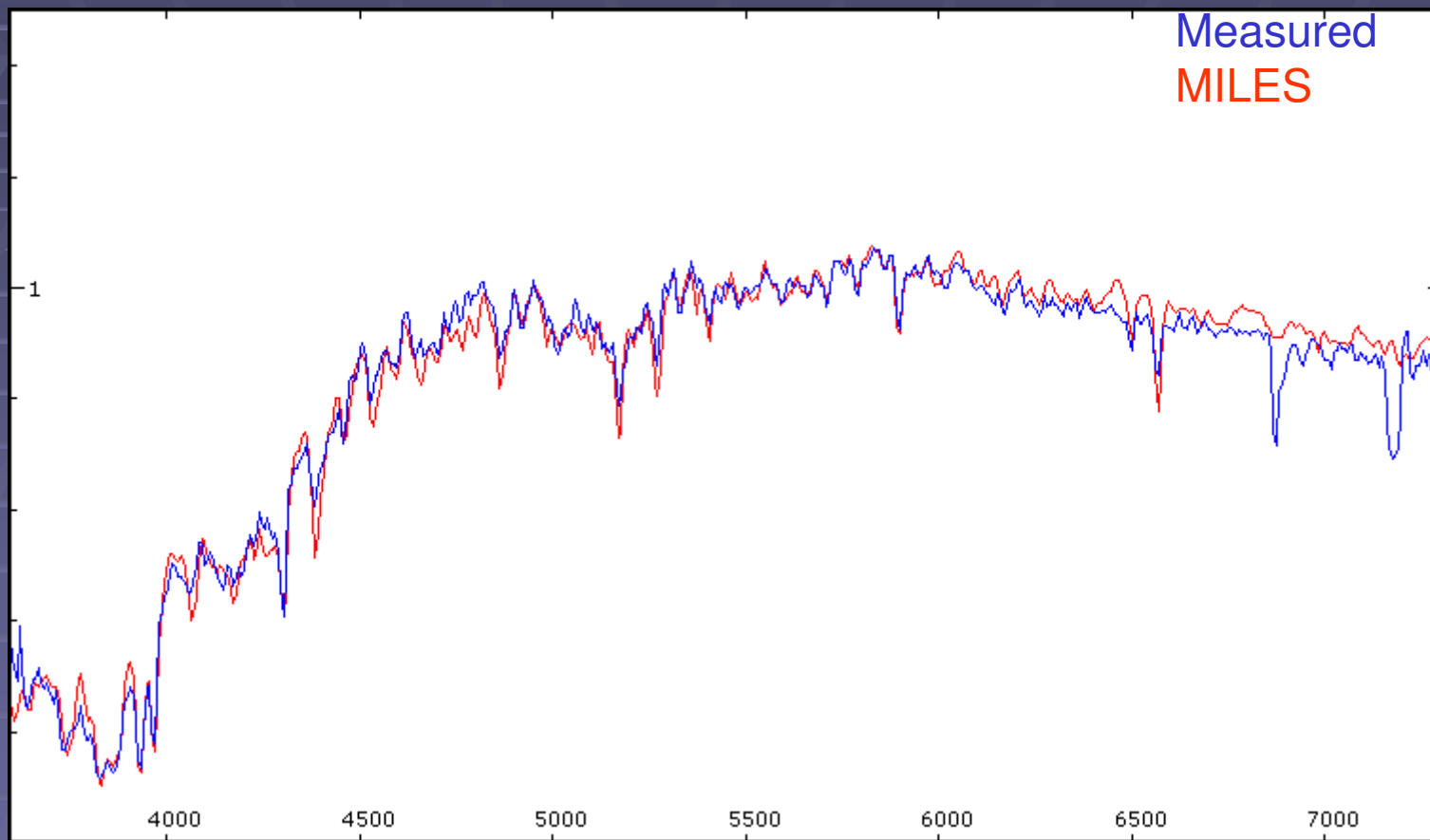


The error due to refocusing is clearly seen here too

HD183324 used to generate a new response



Refocused HD218031 spectrum corrected using new response



The continuum correction is now good

# Using a modified ALPY spectrograph for Supernova identification

Potential Supernovae, once discovered need spectroscopic follow up for confirmation and identification of type

With the increased use of automated surveys to detect transients, the emphasis for the amateur is shifting from discovery to follow up.

Except for a few bright examples, Supernova spectroscopy has proved tough for the typical amateur.

(To be useful, magnitudes fainter than mag 16 need to be reached)

Low resolution  $R \sim 100$  is sufficient to confirm and produce a preliminary classification so within range of the Star Analyser but getting results below  $\sim$ mag 15 has proved difficult

A potential alternative approach is to use a slit spectrograph designed for the minimum resolution required

An ALPY 600 spectrograph was therefore modified to reduce its resolution to  $\sim 130$

# MODIFYING THE ALPY SPECTROGRAPH (ALPY 200)



Removing the the Grism from  
the ALPY Core Module

Taking care that the collimator  
lens does not fall out!



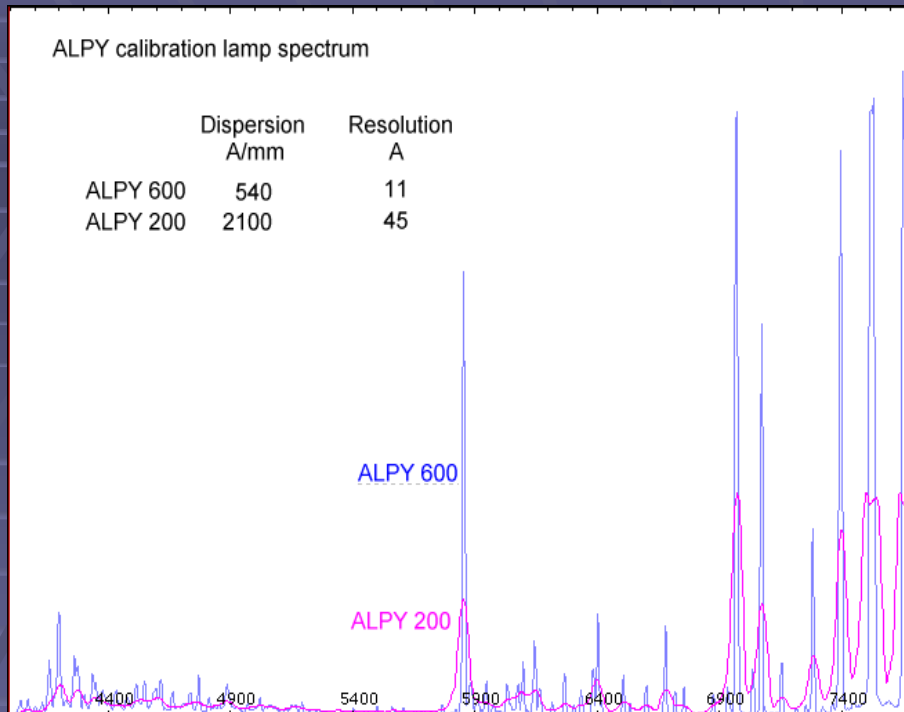
Standard  
600 l/mm  
Grism



Modified  
200 l/mm Grism  
(Made using the  
Star Analyser 200  
master grating)

# BENCH TESTS - ALPY 200 v 600

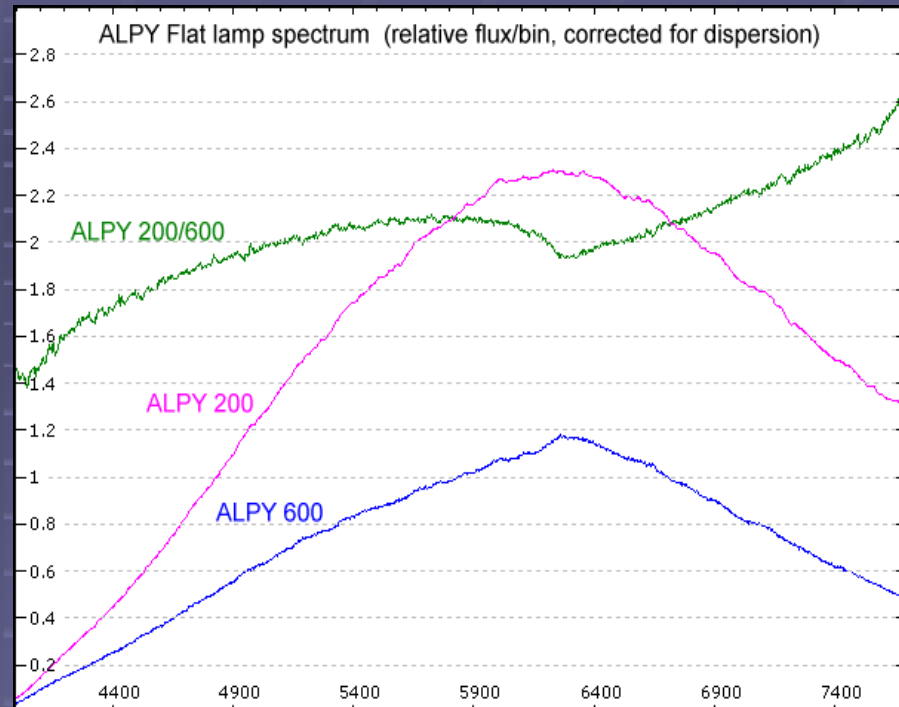
## Resolution



The dispersion and resolution of the ALPY200 are ~ 4 lower compared with the ALPY 600

**R = 130 at 6000 A** is sufficient for supernova identification for example

## Efficiency



The efficiency of the 200 l/mm grism is ~ 2x that of the 600 l/mm grism

Combining this with the 4x reduction in dispersion results in an **8x brighter spectrum**

# ADVANTAGES OF THE ALPY 200

## Compared with the Star Analyser

The slit reduces the sky background level by a factor of  $\sim 100$ , reducing sky noise and eliminating interference from field stars and their spectra.

The mirror slit guider allows longer individual exposures, reducing the total camera read noise contribution.

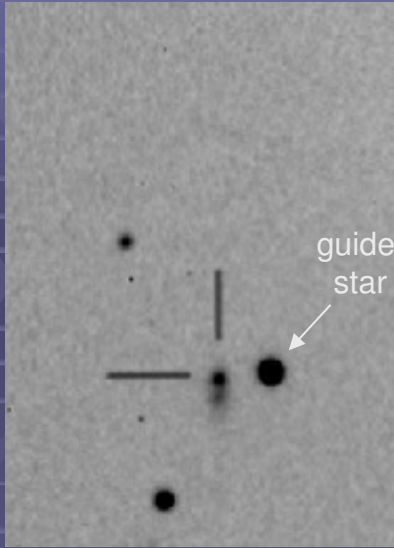
The fully collimated optics produce a sharp spectrum over the full wavelength range, allowing a lower dispersion to be used for the same resolution.

## Compared with the ALPY 600

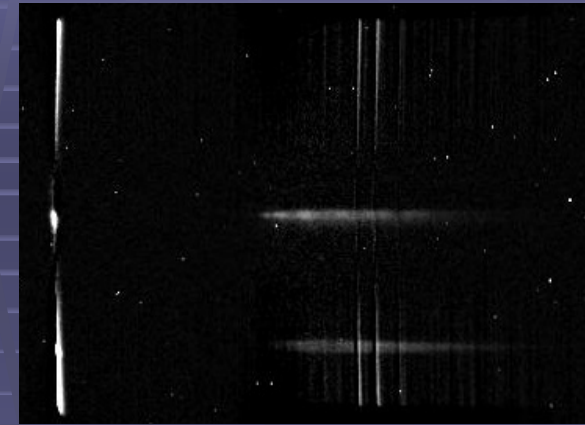
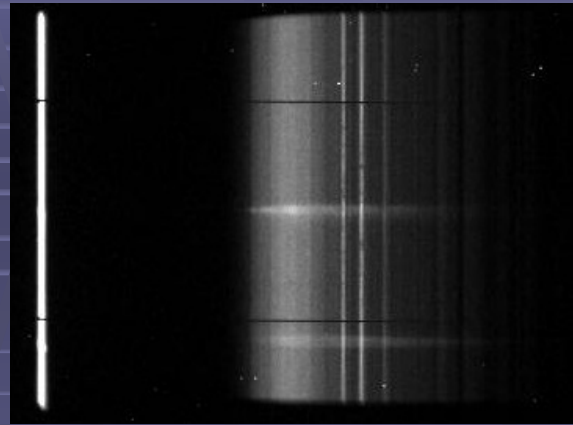
The higher efficiency of the 200 l/mm grism increases the flux in the spectrum.

The reduced dispersion minimises the camera thermal noise contribution compared with increasing the effective pixel size by in camera binning

PSNJ15024996+4847062\_20140521 in PGC 2325560 (mag ~16)  
 discovered amateurs R. Gagliano, J. Newton T. Puckett 2014-05-13



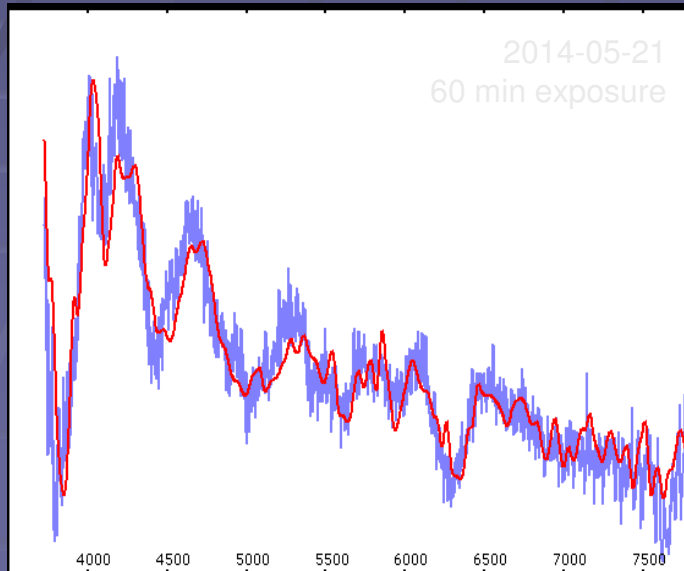
Discovery image



Spectrum image before and after sky subtraction

Spectrum of the supernova (centre).

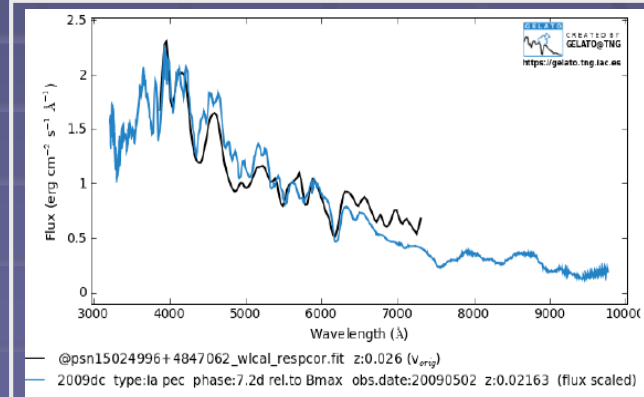
The lower spectrum is a field star caught in the slit



Reduced spectrum (red)

overlaid on professional spectrum (blue) taken 6 days earlier (ATel 6140)

The spectrum shows a strong Si II 6150 absorption feature redshifted to 6300 Å (characteristic of type Ia)

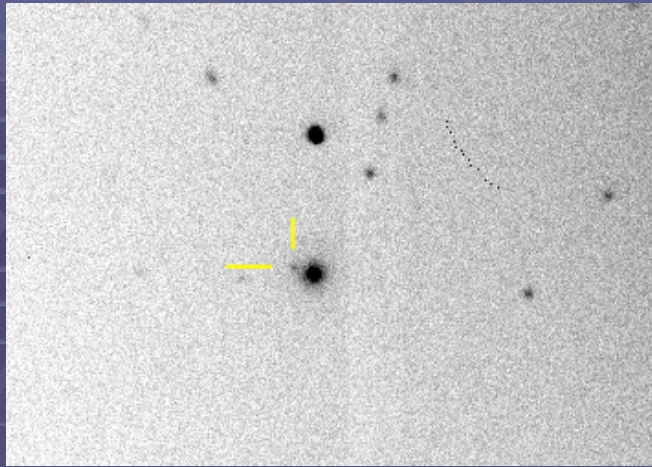


GELATO

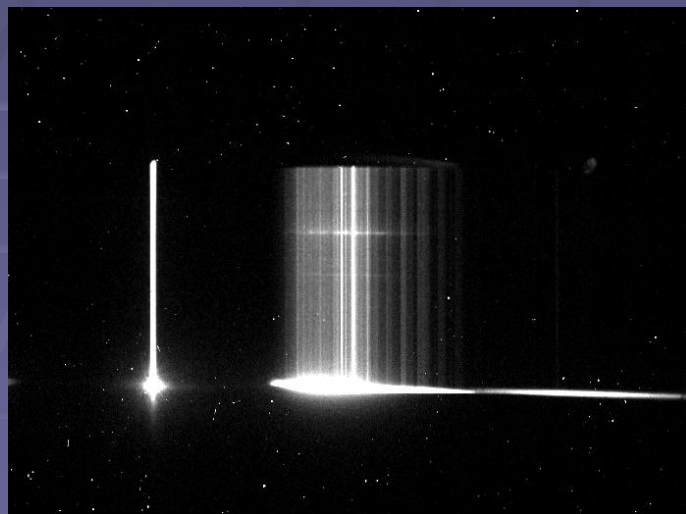
supernova identification program gives an excellent fit to type Ia a few days after maximum



# ASASSN 15fa in NGC 6319 29 days after discovery at mag ~17.5

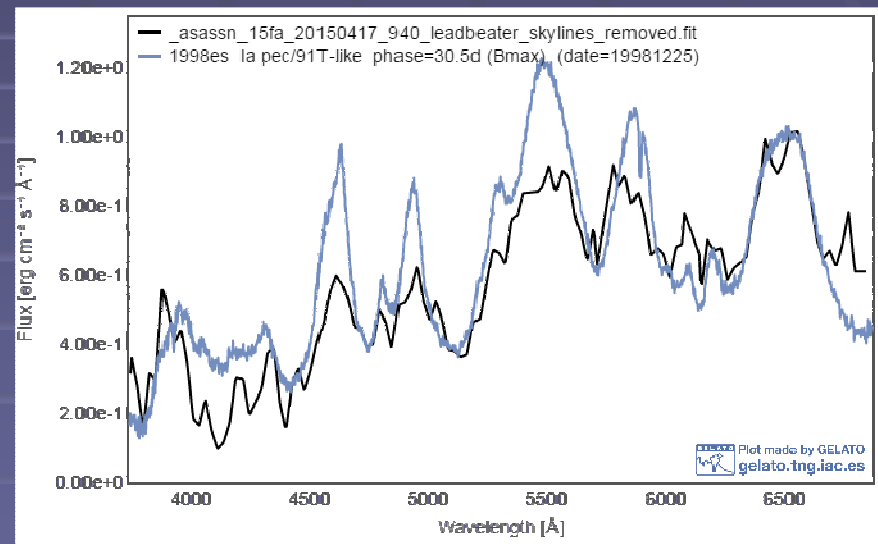


guider image (15x 20s)



raw spectrum  
(bright star below is mag 11)

ASASSN 15fa was discovered by the [All Sky Automated Survey for Supernovae](#) on 2015-03-17 ([ATel 7245](#)) and identified from a spectrum taken by the [Asiago Transient Classification Program](#) as a type 1a supernova ([ATel 7253](#)).



ALPY 200 spectrum (black) compared  
With best fit GELATO spectrum at 30 days