Correcting for instrument response using the *Response Assistant* in *ISIS*

Paul Luckas

November, 2016

Abstract

The application of accurate instrument and atmospheric correction is critical for the large spectral range profiles produced by low resolution instruments such as the *Shelyak Alpy 600* spectrograph. This paper provides a brief analysis on the method and results of using the *Response Assistant* to *ISIS* to create and apply an instrument response profile to a target spectrum.

1 Basic steps

1. Acquire spectra of a bright type-B or type-A reference star[1]

2. Process the reference star in *ISIS* and then create a response profile using the *response assistant*.

3. Apply the response curve to the target spectrum and compare to the database standard.

2 Target acquisition and basic processing

The Miles standard HD17081, a 4th magnitude type-B7 star in the constellation of Cetus was targetted using the *Alpy 600* spectrogaph. 10 x 5s exposures (producing a maximum ADU less than 50,000) were acquired of the target situated at approximately 48° above the eastern horizon. The all important master flat field was created from 10 x 3s flat exposures acquired immediately prior to the target spectra using the Alpy's internal tungsten lamp. Library bias, dark and flat field masters were applied as part of the automated image acquisition process in *MaxIM DL* before the spectral images were imported into *ISIS*.

The 'first run' processing (R=530@5852Å) shows excellent wavelength correlation to the Miles standard with a wavelength solution derived using the 'mixed mode' method in *ISIS* (Figure 1).

---

[1]Stars that exhibit a generally 'featureless' profile consisting largely of a spectral continuum. Reference stars with published standard spectral profiles are preferred. The most commonly used examples can be found in the *Miles* catalogue.
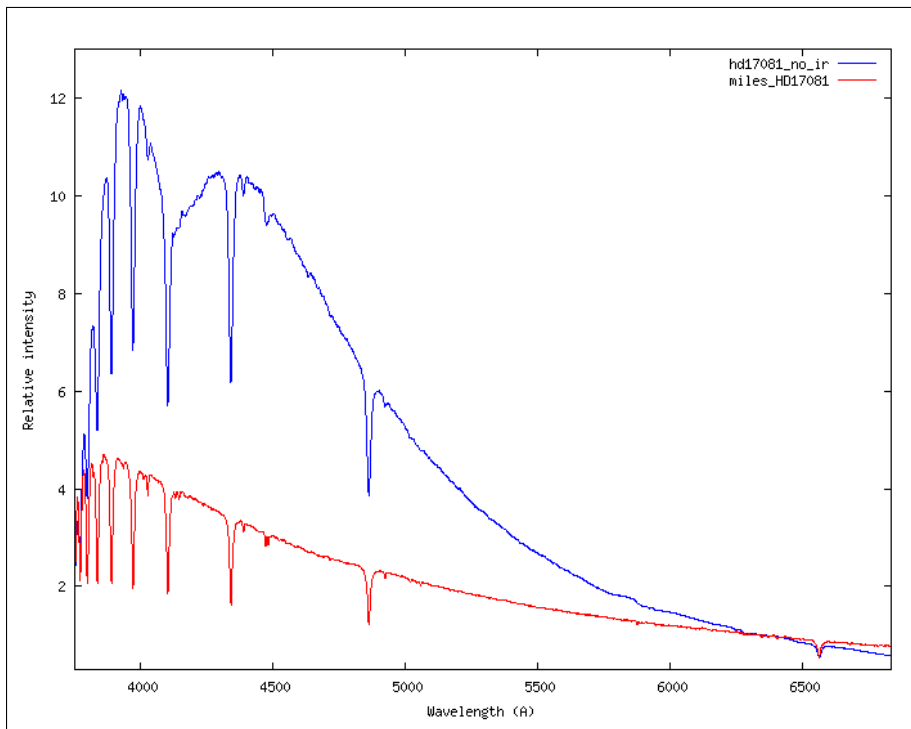
Figure 1: The non instrument response corrected spectrum of HD17081 (blue) compared to the Miles database standard (red). Both spectra have been normalised to unity over a small range centred on 6355Å.
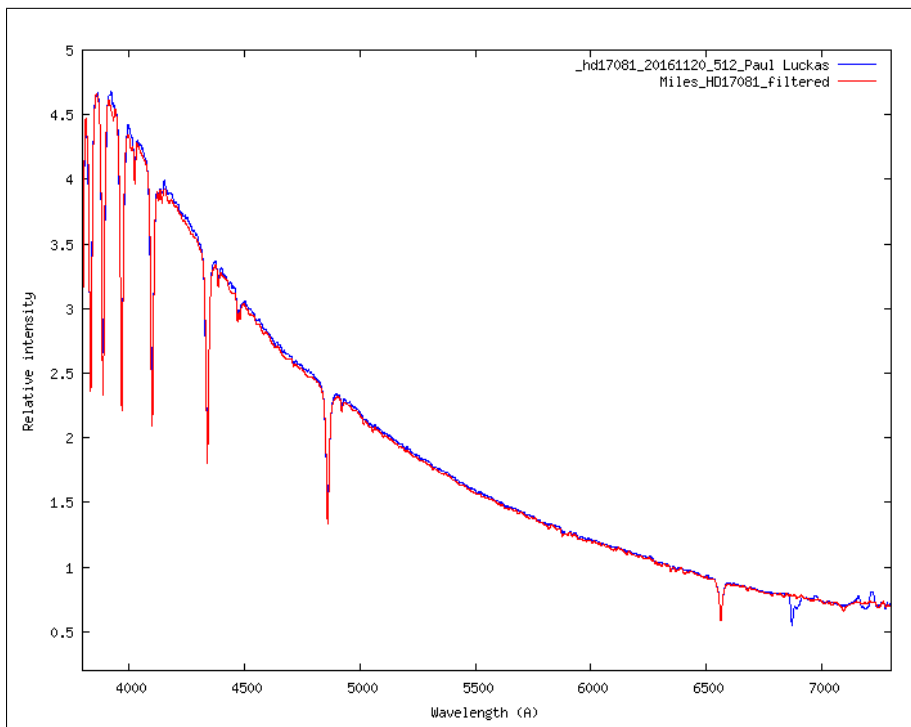

Figure 2: Instrument and and atmospheric corrected spectrum using the 'standard method' in *ISIS*. The solution (blue) shows excellent correlation with the Miles standard (red)

2

3 Using the *Response Assistant*

The *Response Assistant* appears as a tool on the calibration tab in *ISIS* when either the *Shelyak LISA* or *Alpy 600* spectrographs are specified under settings. The process makes use of a master flat field image to create a 'synthetic' response curve and as such, requires a high quality master flat field preferably created from flat field exposures acquired adjacent to the spectral imaging sequence. The *Response Assistant* dialogue includes a means to create this master flat field from a group of flat field exposures, or a pre-created master flat field can be specified directly in the tool dialogue.

Use of the *Response Assistant* includes a number of steps:

- Creating and/or specifying the master flat field.

- Selecting a reference spectrum from one of the databases in *ISIS*.

- Specifying a 'smoothing value'.

- Executing the response assistant.

- Inspecting the result.

- Re-adusting the smoothing value and repeating if necessary.

See Figure 3 for additional information on the response assistant dialogue.

3.1 The smooth coefficient

The *response assistant* automatically creates a 'smoothed' response curve, effectively removing the obvious emission and absorption features of a spectral profile to better represent the broad instrument response characteristics of the spectrograph. For a typical type-A star, these might include the hydrogen-balmer absorption lines. The degree of this 'smoothness' can be adjusted with the *smooth coefficient*. The resulting curve is then compared to a pre-smoothed response profile in order to 'eye ball' the solution. This intermediate profile with the file name **@.fit** remains as a temporary file for the duration that the current process is active, and can be displayed using the *compare* tool as part of iterative testing (Figure 5).
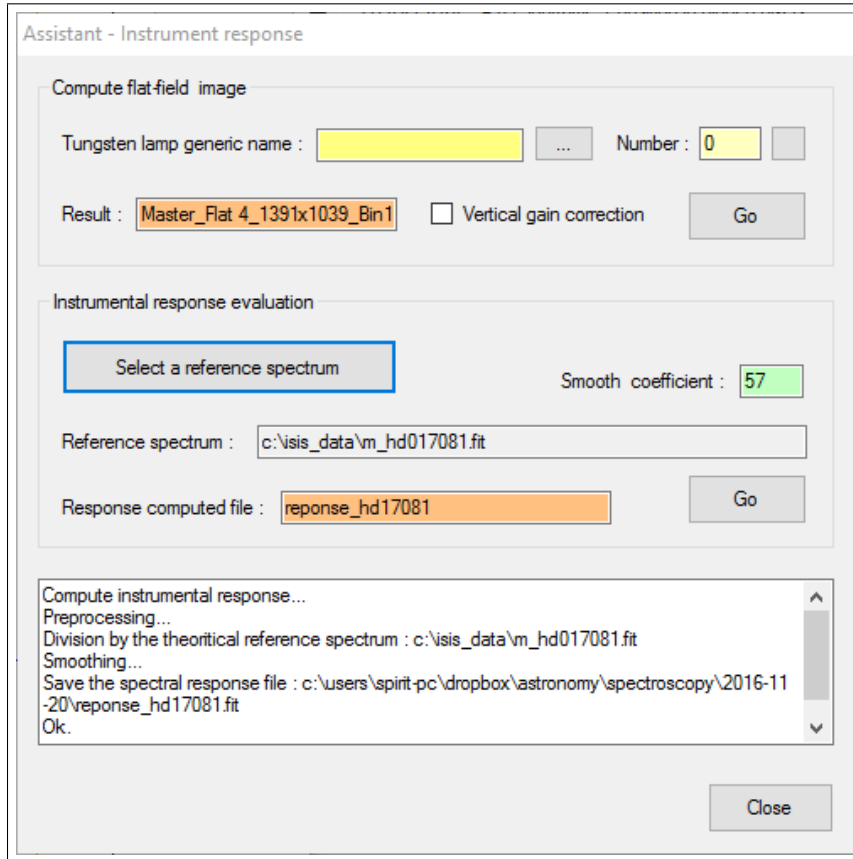
Figure 3: The *Response Assistant* dialogue in *ISIS*. The upper section provides the optional means to create a master flat field from a set of individual flat field exposures (nominally acquired using the spectrograph's integrated tungsten lamp). Alternatively, a pre-made master flat stored in the current working directory can be specified directly in the result field.

The bottom section is used to load and specify a reference spectrum selected from the internal *ISIS* database. Selecting **Go** creates a synthetic response curve based on the *smooth coefficent* also specified by the user.
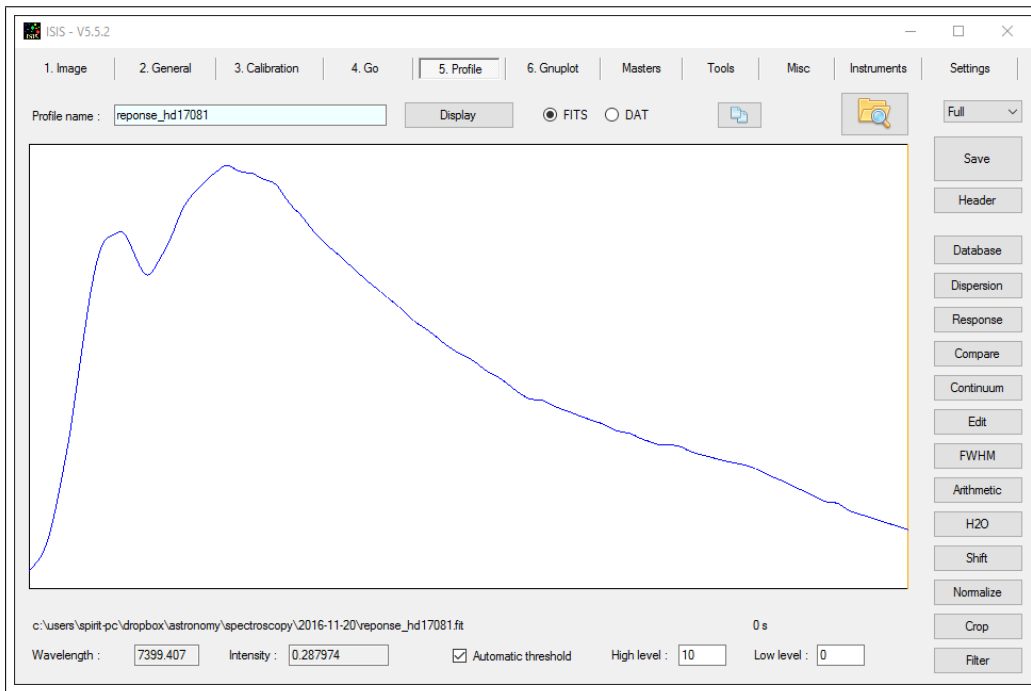
Figure 4: A synthentically generated response curve as it appears on the profile tab immediately after executing the response assistant.
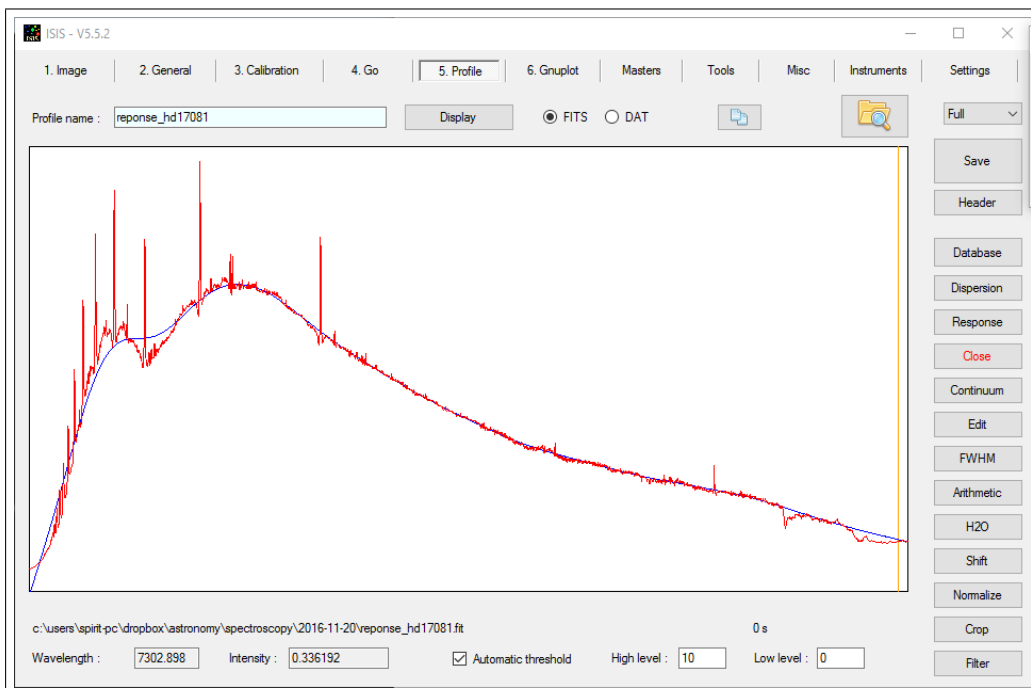

Figure 5: Using the compare tool to view a generated curve (blue) together with the intermediate profile (red). This poor fit, showing unsatisfactory correlation at the blue end of the spectrum, is the result of specifying an excessively large smooth value.

4 Results

The following section highlights the effect of changing the smooth coefficient.

4.1 Test 1

Test 1 shows the response assistant output (blue curve) when using a comparatively small or 'fine' smoothing coefficient. While the resulting response curve shows removal of the major features from the standard (grey profile), numerous fine residual spectral features remain.
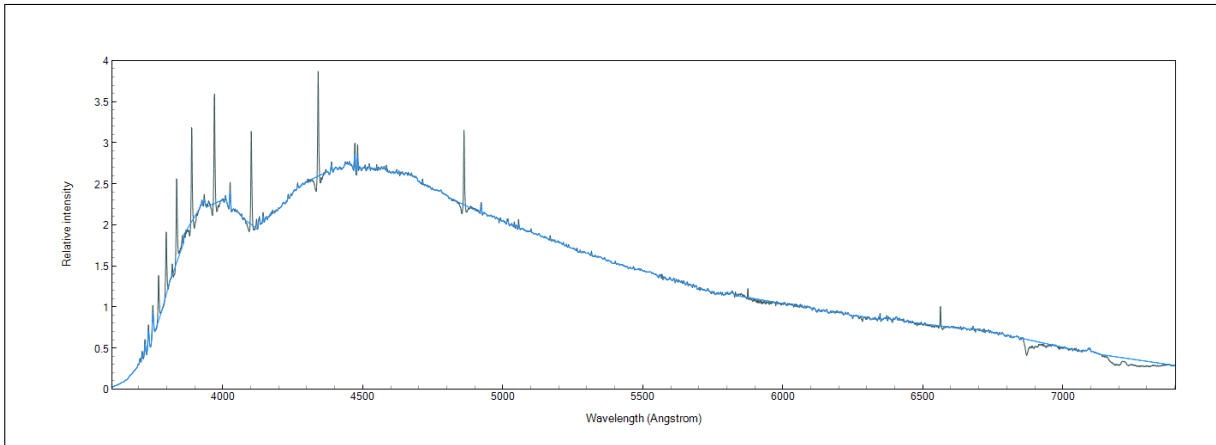

Figure 6: Insufficient smoothing evident when using a very small coefficient.

Applying this response curve to the target spectrum produces excellent black body correlation, but introduces a significant number of artefacts– effectively, spectral features from the Miles standard, not present in the original data (see Figure 7).
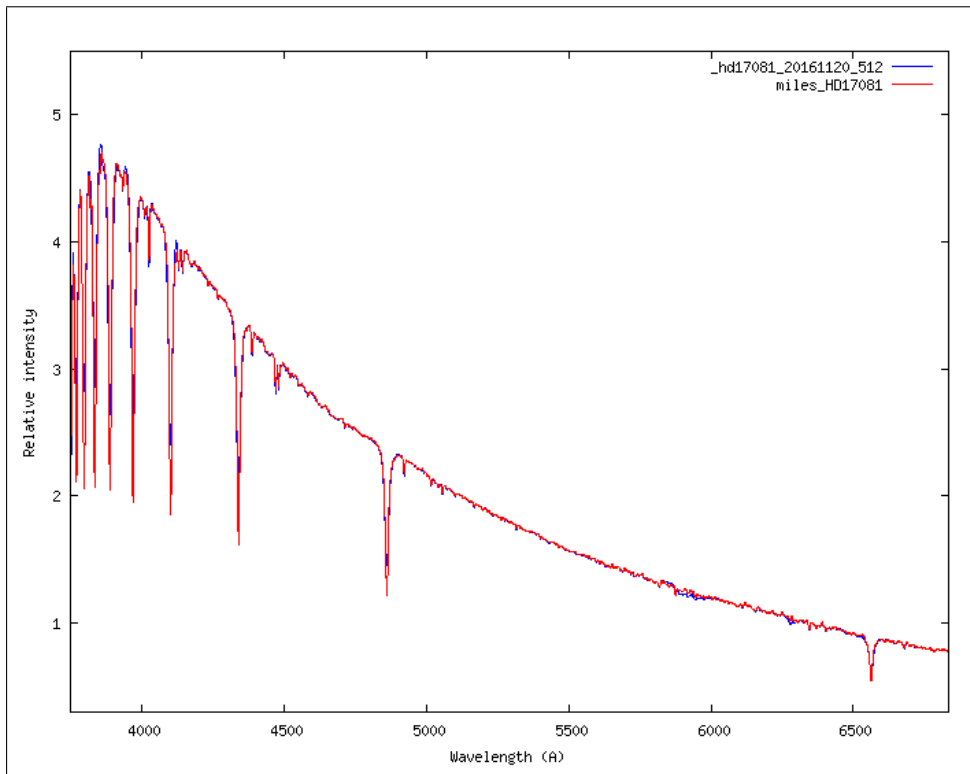
Figure 7: Comparison with the Miles standard shows a processed spectrum of HD17081 too good to be true! This is a very suspicious result caused by the application of a response curve that has a poorly chosen, and far too small smoothing coefficient.

4.2   Test 2

Test 2 shows the response assistant output (blue curve) when using a large or 'coarse' smoothing coefficient. The output produces a very smooth response curve, but poor correlation to the standard is evident in a large range centred around 4000Å.
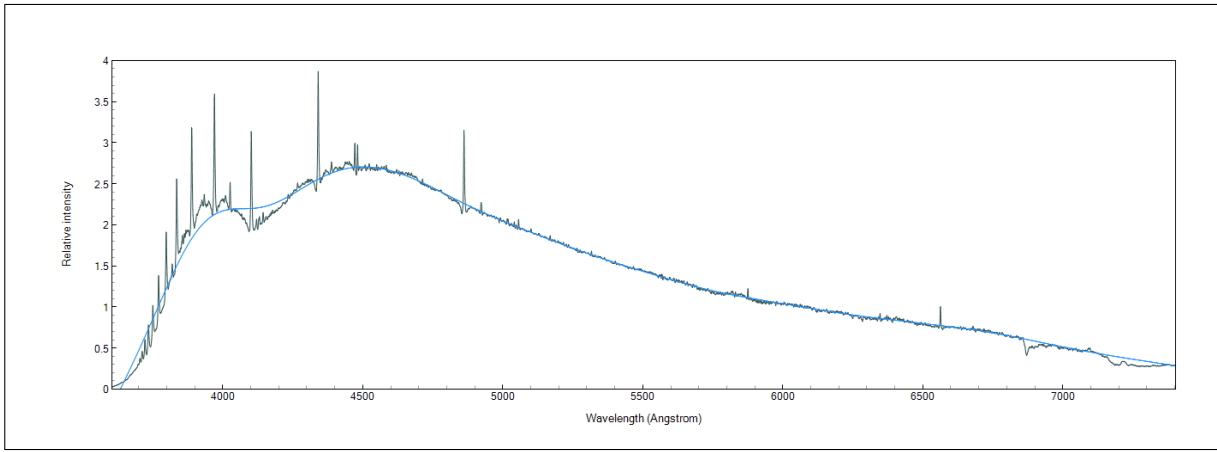
Figure 8: An 'over-smoothed' response curve produced when using a coefficient which is too large.

Though no spectral artefacts are introduced when applied to the target, the result shows a poorly corrected spectrum up to 4800Å.
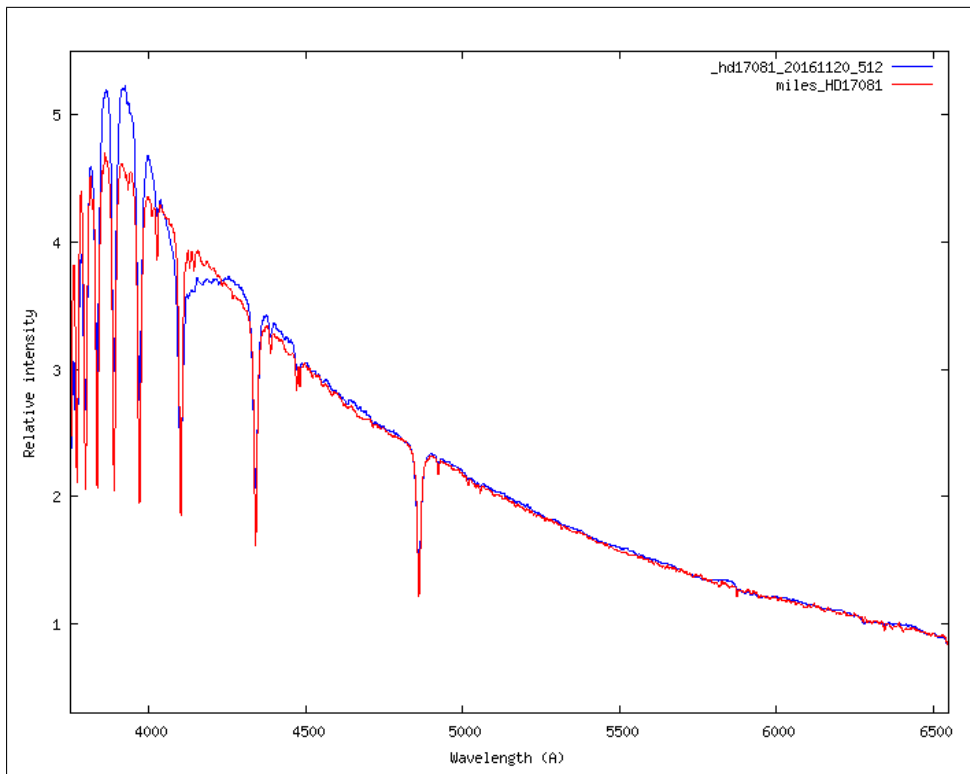

Figure 9: Comparison with the Miles standard shows a poorly corrected spectrum– the result of using an 'over-smoothed' response curve.

4.3   Test 3

Test 3 is an attempt to specify a coefficient that strikes the best balance between curve fitting and avoiding the addition of artefacts.
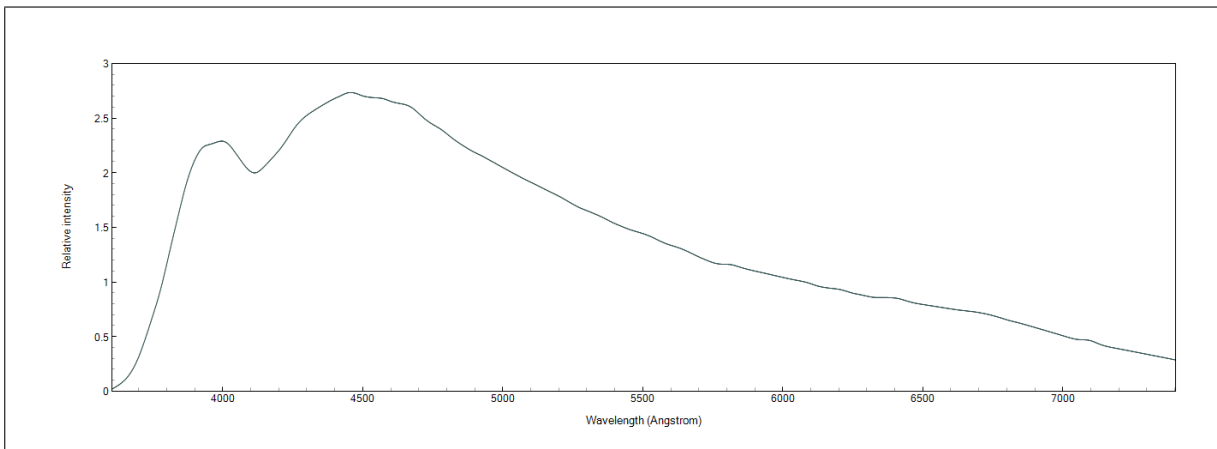

Figure 10: A sythetically produced curve from a more carefully specified smooth coefficient.

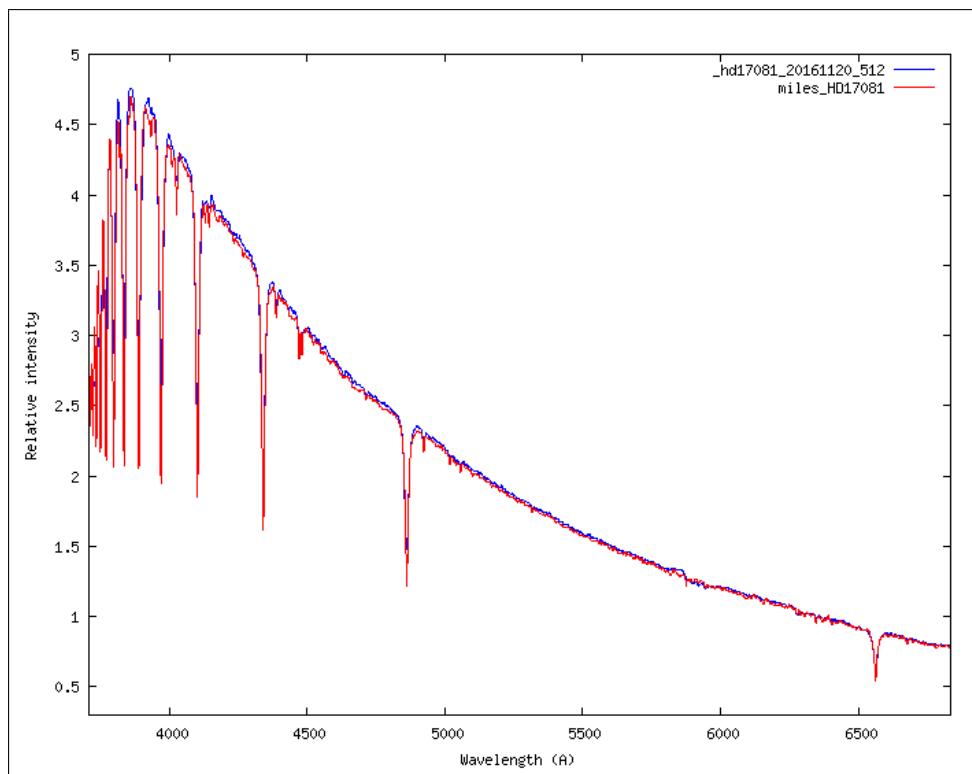When applied to the target spectrum, the result shows very good correction and no artefacts.

Figure 11: Comparison with the Miles standard shows a very well corrected spectrum with no added artefacts.

5 Summary

Tests using the *response assistant* have shown it to be an interesting tool for creating instrument response curves from a high quality master flat field and a database standard. Further tests on a number of additional stars have been performed using Miles standards of the same type and, in comparison tests, these have yielded surprisingly good results. This, given the assumed lack of any atmospheric correction in the response assistant algorithm, provides a basis for further investigation.

Refining the smooth coefficient with later stellar types is problematic as the smoothing algorithm appears to suffer (or at least becomes increasingly sensitive) for cooler stars with complex spectral features.

As a general rule, lower (finer) smooth coefficients that do not overly average out large scale deviations produce better results. However, selecting too small a smoothing coefficient can introduce new spectral 'features' where none exist in the original data.

Further tests, particularly those that examine the effect of atmospheric attenuation, would be useful.

6 Appendices

6.1 Additional plots

6.1.1 HD4150, Type-A0IV.

A response profile created using the *response assistant* and the Miles standard HD31295 (type-A0V) and a smooth coefficient of 75.
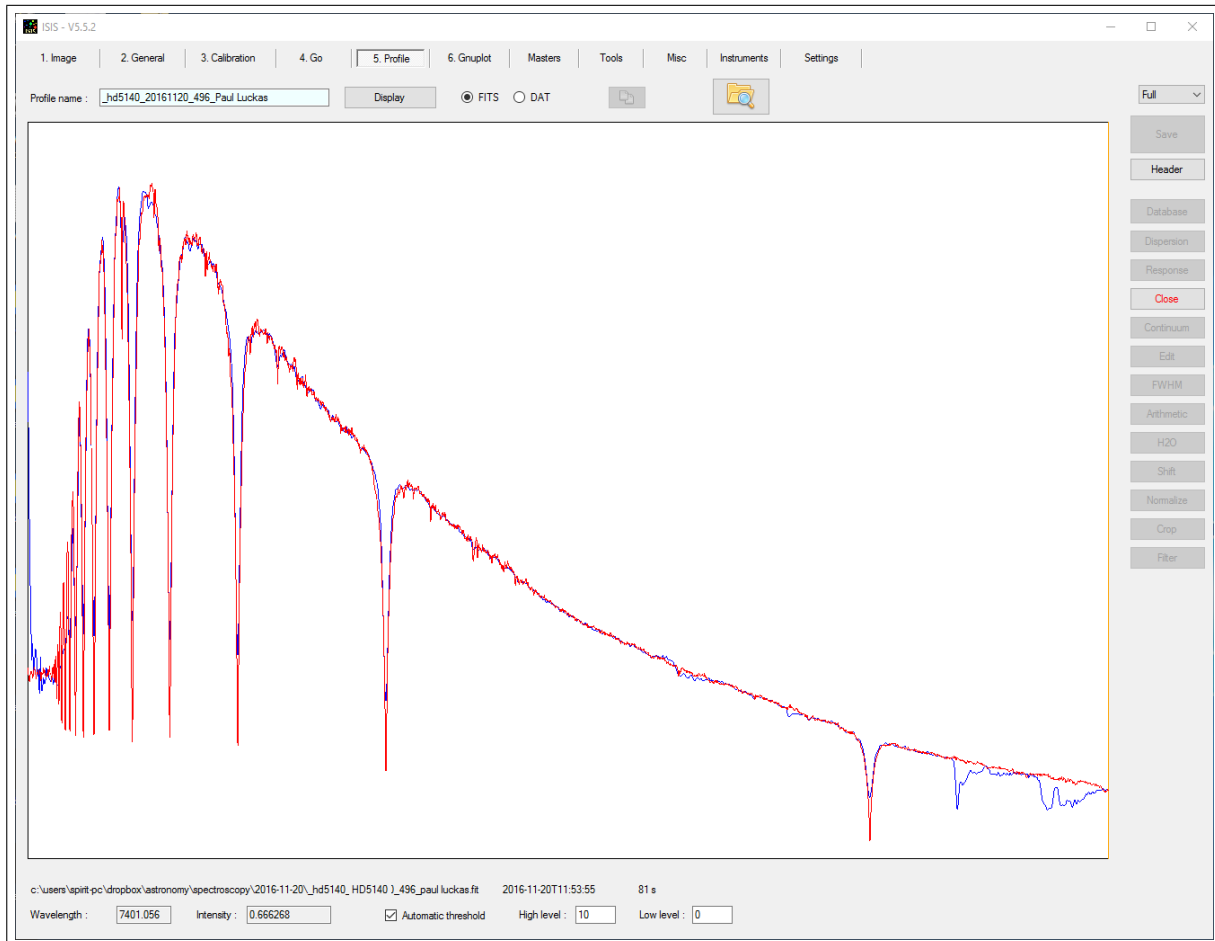

Figure 12: HD4150, Alpy 600, 10 x 5s (blue) compared with Miles HD31295 (red).

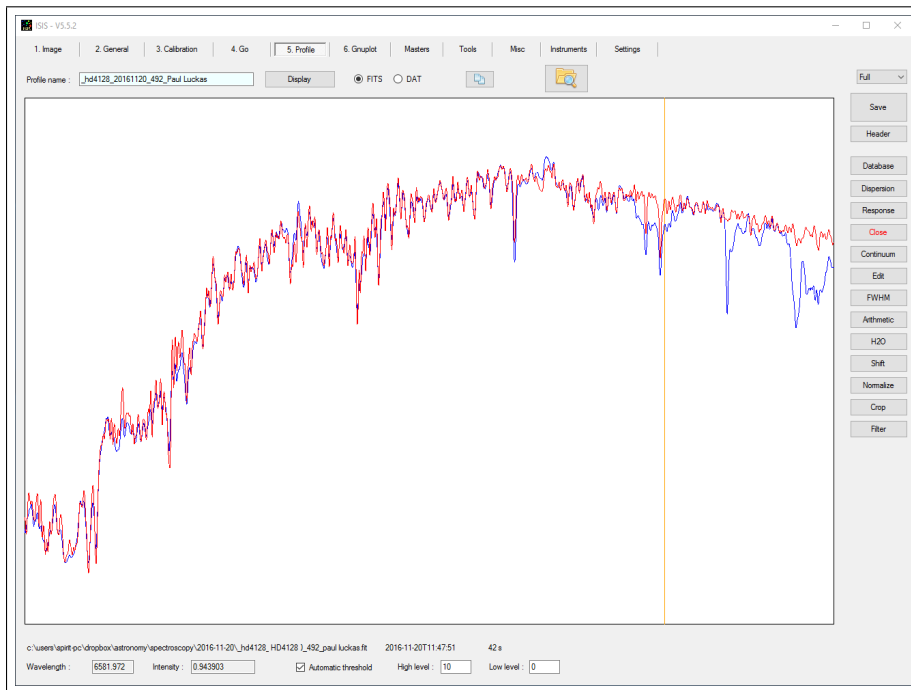### 6.1.2 HD4128 (Diphda), Type-K0III.

Figure 13: HD4128, Alpy 600, 10 x 1s (blue) compared with Miles HD6203 (red) which was also used as the response assistant standard. Smooth coefficient = 10,000.
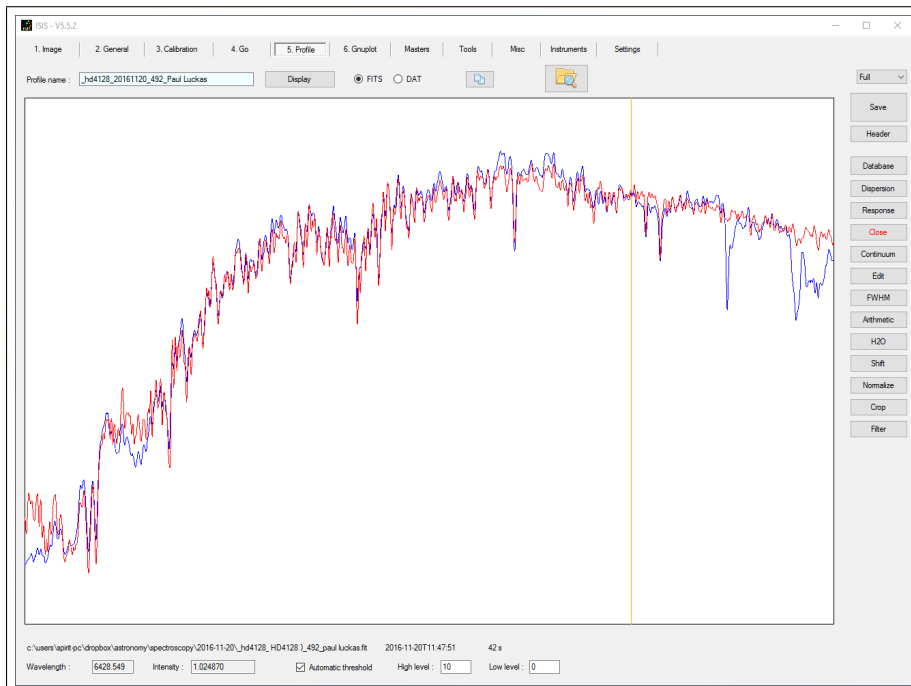

Figure 14: HD4128, Alpy 600, 10 x 1s (blue) compared with Miles HD6203 (red). Smooth coefficient = 15,000.

7 Acknowledgements

- *ISIS* software (Christian Buil)

- *Plot Spectra* software (Tim Lester)

- *ISIS* software (Christian Buil)

- *Plot Spectra* software (Tim Lester)